ASSESSING BENEFICIAL MANAGEMENT PRACTICES TO REDUCE PHOSPHORUS IN A SMALL WATERSHED

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Phosphorus (P)
Rural Non-Point Sources
On-site Wastewater Systems (OWS) in Nova Scotia
OWS Disposal Field

- House
- Disposal Field
- Septic Tank
- Water Course
OWS Disposal Field

- House
- Septic Tank
- Gravel Distribution Trench
- Biomat
- Sand
- Water Course
- Groundwater Table; Bedrock; Impermeable Soil
OWS Disposal Field

- House
- Septic Tank
- Water Course
- Groundwater Table; Bedrock; Impermeable Soil
Soil Subsurface Plume

House

Septic Tank

Soil Subsurface Plume

Water Course
Disposal Field Surface Failure

House

Septic Tank

Water Course
Watershed Management

• Beneficial management practices (BMPs)
  – Biophysical monitoring studies
  – Hydrological-water quality computer models

• Develop and test a watershed-scale computer modeling framework for simulating P loads from agricultural land uses and lateral flow OWS designs
The Modeling Framework

• Develop and test a model to simulate P loading from OWS
• Use OWS P loading model in conjunction with a watershed-scale hydrological-water quality model
• Evaluate ability of modeling framework to represent P loading from both agricultural crops and residential OWS
Phosphorus On-Site Wastewater Simulator (POWSIM)

Input Parameters
• % failure rate
• # years until full failure

House(s) → Septic Tank → Disposal Field Surface Failure → Water Course

Groundwater Table; Bedrock; Impermeable Soil
Phosphorus On-Site Wastewater Simulator (POWSIM)

- House(s)
- Septic Tank
- Disposal Field
- Water Course
- Groundwater Table; Bedrock; Impermeable Soil

Design:
- Slope
- Soil hydraulic conductivity
- Depth to bedrock/groundwater table
Phosphorus On-Site Wastewater Simulator (POWSIM)

- House(s)
- Septic Tank
- Disposal Field
- Water Course
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P Treatment Processes
• 2-part piecewise linear

Monthly Time Step
Phosphorus On-Site Wastewater Simulator (POWSIM)

- Design
  - Longitudinal and horizontal dispersion (Appelo & Postma, 2005)
  - Distance to water course
  - Soil hydraulic conductivity
  - Slope

House(s)

Septic Tank

Soil Subsurface Plume

Distance to water course

Soil hydraulic conductivity

Slope

Groundwater Table; Bedrock; Impermeable Soil

Water Course

Longitudinal and horizontal dispersion (Appelo & Postma, 2005)
Soil & Water Assessment Tool (SWAT) version 2009

- Agricultural land uses
- Thomas Brook Watershed (Ahmad et al., 2011; Goulden et al., 2013)
- POWSIM results input as point source discharges
• Monitoring Program
  ▪ Agricultural and Agri-Food Canada
  ▪ Watershed Evaluation of Beneficial Management Practices (WEBs) project
    ▪ Flow
    ▪ Sediment
    ▪ Total Phosphorus
    ▪ Land Use
    ▪ Crop Rotations
• OWS Mail-in Survey
  ▪ Length of operation
  ▪ OWS failure
SWAT Model Calibration & Validation

• Calibration - 2004 to 2006
• Validation – 2007 to 2008
• Flow
  ▪ Daily
• Sediment
  ▪ Monthly
• Total Phosphorus
  ▪ Monthly
Outcome

- Modeling framework able to simulate agricultural and residential OWS P loads at the watershed-scale
  - Flow, and sediment and TP loads in Thomas Brook
  - Better baseflow TP loads
  - OWS vs. agricultural TP loads
Research Objective

- Simulate and evaluate different development and BMP scenarios for agricultural crops and OWS
  - Use modeling framework to simulate 50 year time period and evaluate at the Thomas Brook Watershed outlet
  - Compare TP loads and in-stream TP concentrations
Agricultural Crop Development

- Corn-based crops replace pasture

- Corn-based crops replace hay
Residential Development
• 25% residential population increase

• 50% residential population increase
Agricultural Crop BMPs

- Hay replaces corn and rotational crops
- Pasture replaces corn and rotational crops
- Rangeland replaces corn and rotational crops
- No-till corn

Legend:
- Residences
- Monitoring Stations
- Stream Network

Landuse:
- New Pasture
- Pasture

Legend:
- Residences
- Monitoring Stations
- Stream Network

Legend:
- New Pasture
- Pasture

Legend:
- Residences
- Monitoring Stations
- Stream Network

Legend:
- New Pasture
- Pasture
Residential BMPs

- OWS failure rate reduced to 10% and 5%
- Increase OWS set-back to 50 m
- Replace disposal field filter media every 25 yrs
- High P sorption disposal field filter media
Agricultural Crop BMPs
Cumulative TP Load

- Reference
- Pastures Replace Corn and Rotational Crops
- Rangelands Replace Corn and Rotational Crops
- Hay Replaces Corn and Rotational Crops
- No-Till Corn
Residential OWS BMPs Cumulative TP Load
TP In-Stream Concentrations Development Scenarios

Reference

Corn-based Crops Replace Hay

50% Residential Population Increase

Time Period

Percent

Oligotrophic (<0.01 mg P L\(^{-1}\))

Eutrophic (0.035 - <0.1 mg P L\(^{-1}\))

Mesotrophic (0.01 - <0.035 mg P L\(^{-1}\))

Hyper-Eutrophic (≥ 0.1 mg P L\(^{-1}\))
• Pasture replaces corn and rotational crops
• High P sorption filter media
• Reduce OWS failure rate to 5%
Outcomes

- Simulated development and BMP scenarios for agricultural land uses and residential OWS
  - Cumulative TP loads
    - Replacing corn and rotational crops
  - In-stream TP concentrations
    - Residential OWS
  - Identified best combination BMP scenario
Recommendations

• Biophysical OWS BMP studies at field- and watershed-scales
• Biophysical studies involving both OWS and agricultural BMPs
Conclusions

• Relative contribution of OWS P loads in rural watersheds are potentially being under-estimated

• Identification of P water quality issue prior to developing a watershed management plan is very important
  – In-stream P concentration -> OWS
  – Downstream P load -> agricultural crops
Acknowledgements
Average Annual TP Load (kg)

Stn 3
- Forest: 20.4 kg (35%)
- Agricultural Crops: 2.2 kg (4%)
- Roads: 1.6 kg (3%)
- Residential Land-Use: 28.7 kg (48%)

Stn 4
- Forest: 146.5 kg (52%)
- Agricultural Crops: 6.6 kg (11%)
- Roads: 3.7 kg (1%)
- Residential Land-Use: 9.6 kg (3%)
- OWS: 111.0 kg (39%)