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Economic implications of increasing nitrate in groundwater due to climate change, Prince Edward Island, Canada

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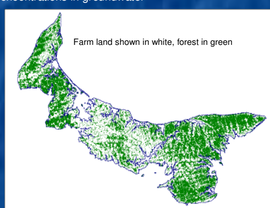
Drinking Water Supply in Prince Edward Island:

General Setting

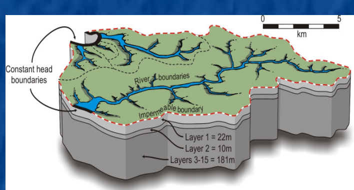
- Located in the Gulf of St. Lawrence, Eastern Canada
- Land area 5684 km2 , Population of 140,000
- Climate: humid – continental,
  - Mean annual precipitation =1153 mm (73% rain, 27% snow)
  - Mean annual temperature = 5.3° C,
    - max mean monthly temperature = +18.5°C (July)
    - min mean monthly temperature = -7.9°C (January)
- Economy based on Agriculture, followed by Tourism and Fisheries.
  - Agricultural land use accounts for 40% of land use
  - Row crop production (potatoes) dominates agricultural production
  - Natural groundwater quality is excellent and generally requires no treatment other than disinfection (municipal supplies)
  - Large leaching losses of N, particularly from potato production systems believed to be single largest contributor to elevated nitrate concentrations in groundwater



Aquifer characteristics

- Groundwater is sourced entirely from a fractured red-bed sandstone formation, overlain be a thin veneer of permeable glacial till.
- Geometry of groundwater flow systems defined by topography, and generally coincides with surface watershed boundaries
- The aquifer is highly productive
  - Recharge rates ~30% to 35% of annual precipitation (mm/yr)
  - Individual well yields range from
    - 0.023 – 0.46 m3/min (domestic)
    - 0.455 to 2.273 m3/min (municipal / industrial)
- The aquifer is un-confined, responds rapidly to recharge and vulnerable to contamination.

Conceptual model of typical groundwater flow system



Water supply Infrastructure

- 50% of the population is rural and depends on private wells for potable water supply (estimated 20,000 wells), the remaining population serviced by groundwater sourced municipal water systems.
- All wells are of "open-hole" construction, with current standards requiring minimum casing lengths of 12 m, grouted to the surface. Domestic wells vary from municipal and industrial wells only be diameter and depth.
- "book value" of water supply infrastructure estimated at $100 million (1/3 for domestic wells, 2/3 for industrial and municipal supplies)
- Replacement costs of water supply infrastructure estimated at 2 to 3 times "book value.
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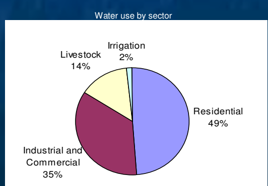
Water Use

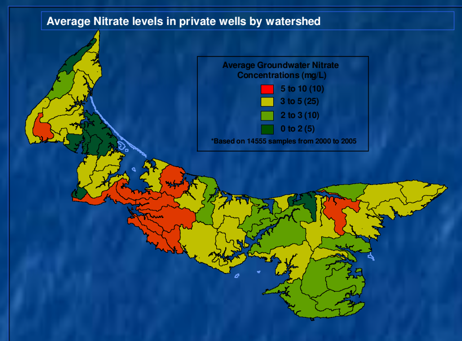
- 100% of potable water is sourced from groundwater.
- The vast majority of industrial and commercial water use also depends on groundwater sources.
- Total water use estimated at 24,462,542 m3/yr
- Domestic water use represents nearly 50% of total water use.

Water use by sector



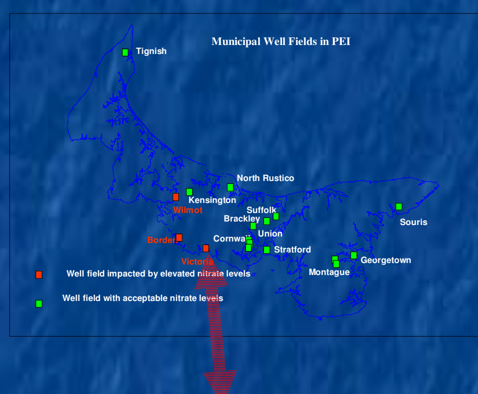
Current state of nitrate contamination of drinking water supplies:

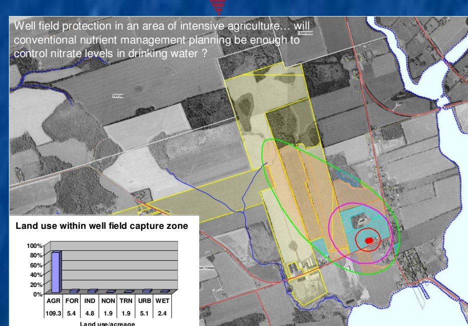
Nitrate contamination of private wells



- On a province-wide basis, water from 4% to 5% of private wells tested have NO_3-N > 10 mg/L
- In intensively cultivated regions as many as 10% to20% of wells may exceed 10 mg/L
- Well owners with elevated nitrate levels there typically are two options for remediation:
  - New well or well reconstruction ~ $3,000 – may only provide temporary relief
  - Water treatment ~ $1,500 – plus on-going maintenance costs

Nitrate contamination of municipal water supply wells

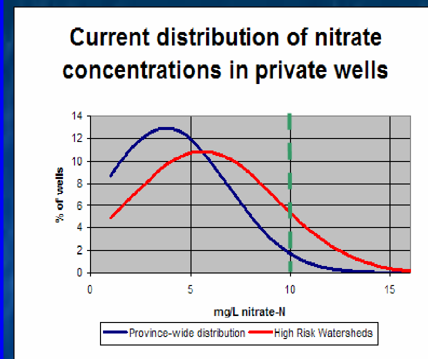




Example - Village of Victoria

- Water utility supplies a total of only 76 properties
- Original well field constructed in 1987 to replace private wells
- Municipal supply wells constructed to a depth of 75 m with 12 m of casing, and NO_3-N concentrations of 3.9 and 4.2 mg/L respectively
- Wells replaced in 2002 because of elevated nitrate levels… new wells constructed with 30 and 36 m of casing at cost of ~$20,000, nitrate levels dropped to ~ 6 mg/L
- Currently (2008), with nitrate levels continuing to rise, (concentrations as high as 13.3 mg/L in one well) the water utility is considering designing a water treatment plant at anticipated cost of ~ $50,000
- Well field protection measures, including nutrient management plans within capture zone of the supply wells, may provide some relief from nitrate contamination in the long term, but also have associated "opportunity costs" that may require compensation of local land owners by the water utility.

Current Economic Impact of Elevated Nitrate Concentrations



Current Situation

Private wells

If corrective action was taken for all cases of unacceptable nitrate levels, annual expenditures would range from:

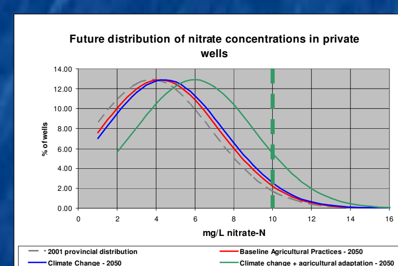
- ~$200,000 (water treatment), to
- ~$400,000 (well reconstruction)

Municipal Supplies:

- Over the past decade, 3 of 13 municipal water utilities have had to re-locate or reconstruct water supply wells due to elevated nitrate levels… to date water treatment for nitrate removal has not been necessary, although one small utility is currently considering treatment for nitrate removal.

Expected Future Economic Impact of Nitrate Contamination on Drinking Water Supplies:

Predicted* future situation for private wells



*Based on predictions for mean NO3-N concentrations under different CC scenarios in "*Numerical Modelling and isotopes underline climate impacts on groundwater nitrate in temperate agricultural settings*", M.M. Savard *et al.* (poster #546, this volume)

Private wells

- A continuation of current agricultural practices can be expected to result in an 11% increase in mean nitrate concentrations and a 20% increase in the number of wells exceeding drinking water standards by the year 2050.
- By 2050, if we include the impact of climate change (as a result of lower precipitation) we can expect mean nitrate concentrations to increase by 17% and the number of wells exceeding 10 mg/L NO_3-N to increase by 30%.
- If the agricultural sector adapts to climate change (longer growing season, warmer temperatures) as predicted, by 2050, mean nitrate concentrations will increase 32% over 2001 levels, and the number of wells exceeding drinking water standards will increase by nearly 70%.

Municipal wells

- Treatment for nitrate removal would require significant investment in additional plant facilities:
  - For a large well field (4500 m3/day) costs could be in the range of $500,000 to $1,500,000.
  - For a small system (1000 m3/day)costs could be in the range of $150,000.
- These additional expenses essentially double the cost producing potable water for distribution.

Conclusions

- Significant changes in agricultural practices are necessary to avoid substantially increased costs to the water supply sector
- The manner in which the agricultural sector adapts to future climatic conditions will be more significant than climate change alone.

Key reference: "Consequences of climatic changes on contamination of drinking water by nitrate on Prince Edward Island", Report to NRCan, Climate Change Action Fund : Impacts and Adaptation Agreement A881/A843, 142 p. http://adaptation.nrcan.gc.ca/projdb/pdf/109_e.pdf

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Natural Resources Canada Ressources naturelles Canada