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:

- Located in the Gulf of St. Lawrence, Eastern Canada
- Land area 58,000 km². Population of 140,000
- Climate: humid - continental
- Mean annual precipitation = 1152 mm (72% rain, 28% snow)
- Mean annual temperature: ~5°C
- Mean monthly temperature = ~18°C (July)
- Mean monthly temperature = ~7°C (January)
- Exposed to Agriculture, tourism, and fisheries
- Agricultural land use: 40% of land use
- Most extensive production is seen in the potato production systems
- Large losses of nitrate, particularly from potato production systems

Aquifer Characteristics:
- Groundwater is sourced entirely from the fractured bed-limestone formation
- Water source is perennially fresh
- Geometry of groundwater flow systems defined by topography, and generally coincides with surface water extraction
- The aquifer is highly productive
- Recharge rates: 30% to 35% of annual precipitation (mm/year)
- Individual well yields range from ~1000 to ~4000 m³/month
- Water quality: depends rapidly to recharge and vulnerable to contamination

Water Supply Infrastructure:
- 10% of the population is rural and depends on private wells for potable water supply (estimated 20,000 wells)
- Operating population served by groundwater sources municipal water systems
- About 70% of houses with new/old standards, requiring water intake of 12 m, glazed to the surface
- Groundwater yield varies from municipal and industrial wells only determined by depth and distance
- Book vision: 30% of water supply infrastructure estimated at ~100 million m³ (of domestic and industrial supply of water)
- Replenishment costs of water supply infrastructure estimated at 0 to 3 times book value
- Groundwater is sourced entirely from a fractured bed-limestone formation
- Groundwater flow is a minor version of perennial fluvial glue
- The aquifer is highly productive
- Recharge rates: 30% to 35% of annual precipitation (mm/year)
- Individual well yields range from ~1000 to ~4000 m³/month
- 0.45 to 2.73 m³/min (municipal/industrial)
- The aquifer is unconfined, responds rapidly to recharge and vulnerable to contamination

Water Use:
- Important: water is sourced from groundwater
- The uses mostly of industrial and commercial water use also depend on groundwater sources
- Total water use estimated at 0.4 to 0.24 m³/m²/year
- Commercial, industrial and public use mostly of total water use.

Wells:
- Water supply infrastructure is provided to a depth of 75 m with 12 m of casing, and NO concentrations of 3.9 and 4.2 mg/L respectively
- Wells replaced in 2006 because of elevated nitrate levels. New wells constructed with 30 and 36 m of casing at cost of ~$200,000, nitrate levels dropped to ~6 mg/L
- Water utility is considering upgrading all water treatment plant at widespread cost of ~$500,000
- Water well management, including nutrient management plans within capture zone of the supply wells, can provide some relief from nitrate contamination over the long term, but also have widespread economically costs that may require compensation of local land owners by the water utility.


Current Economic Impact of Elevated Nitrate Concentrations

Current state of nitrate contamination of drinking water supplies:

- On a province-wide basis, water from 4% to 5% of private wells tested have NO₃ > 10 mg/L
- Steadily increasing numbers as many as 6% of wells may exceed 10 mg/L
- 1 in 10 wells with elevated nitrate levels may have two options for remediation:
  - New well or well rehabilitation: ~$3,000 - may only provide temporary relief
  - Water treatment: ~$1,500 - plus, on-going maintenance costs

Nitrate contamination of municipal water supply wells:

- Municipal well fields in PEI
- Well field impacted by elevated nitrate levels
- Well field with acceptable nitrate levels
- Municipal well field in PEI

Example - Village of Victoria
- Water utility supplies a total of 76 properties.
- Original well field constructed in 1987 to replace private wells
- Municipal well supply constructed to a depth of 75 m with 12 m of casing and NO₃ concentrations of 3.9 and 4.2 mg/L respectively
- Wells replaced in 2006 because of elevated nitrate levels. New wells constructed with 30 and 36 m of casing at cost of ~$200,000, nitrate levels dropped to ~6 mg/L
- Currently (2016), with nitrate levels continuing to rise, concentrations as high as 13.3 mg/L in one well. The water utility is considering upgrading all water treatment plant at widespread cost of ~$500,000
- Water well management, including nutrient management plans within capture zone of the supply wells, can provide some relief from nitrate contamination over the long term, but also have widespread economically costs that may require compensation of local land owners by the water utility.

Current distribution of nitrate concentrations in private wells

Future distribution of nitrate concentrations in private wells

Due to climate change + agricultural adaptation - 2050
- % of wells exceeding drinking water standards by the year 2050.
- Current state of nitrate contamination of drinking water supplies
- New well or well rehabilitation: ~$3,000 - may only provide temporary relief
- Water treatment: ~$1,500 - plus, on-going maintenance costs
- Municipal well field in PEI
- Well field impacted by elevated nitrate levels
- Well field with acceptable nitrate levels

Future distribution of nitrate concentrations in private wells

*Based on predictions for mean NO₃-N concentrations under different CC scenarios in "Impacts of energy, water, and agricultural climate change on public water utilities in a high energy, water, and agricultural climate change on" (J. Hydrol. 2006).