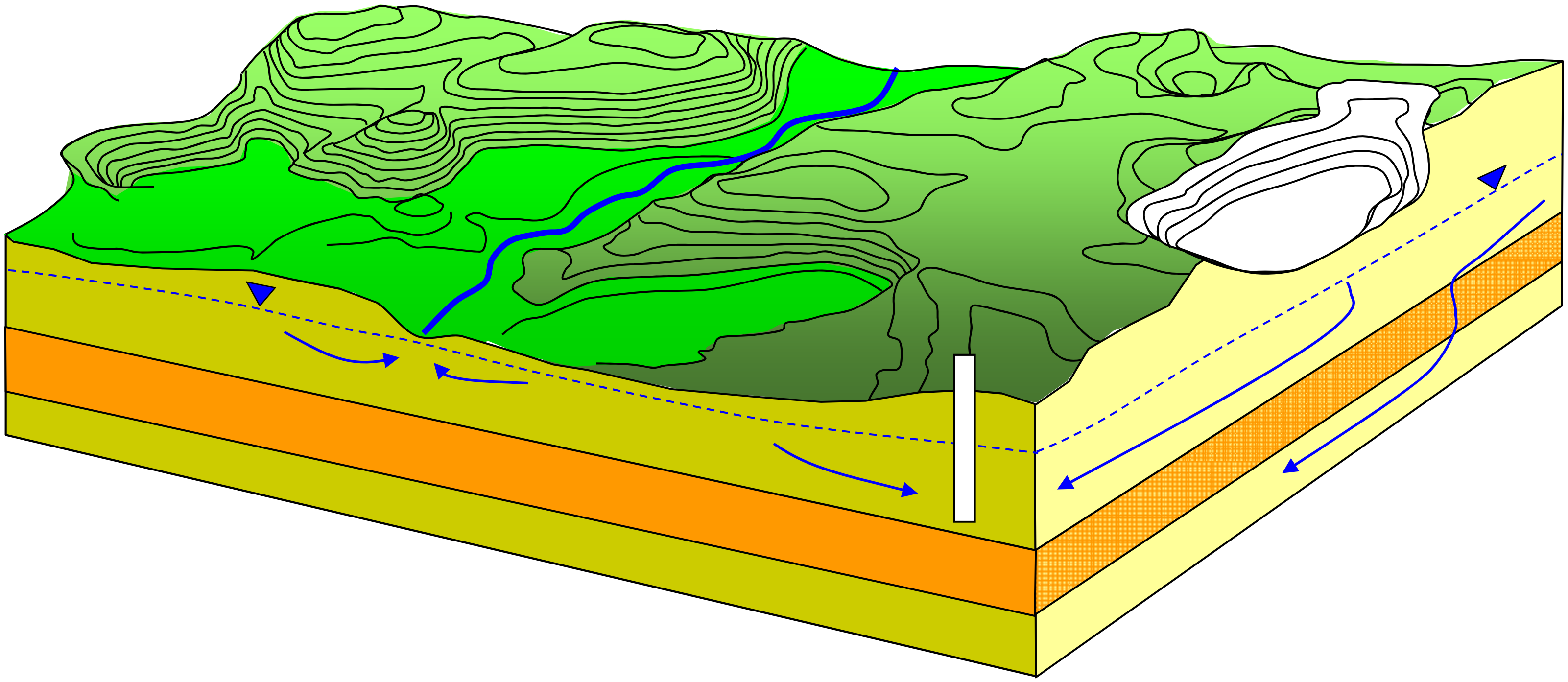

Ontario Stone Sand & Gravel Association

The Effect of Aggregate Extraction on Groundwater Quality

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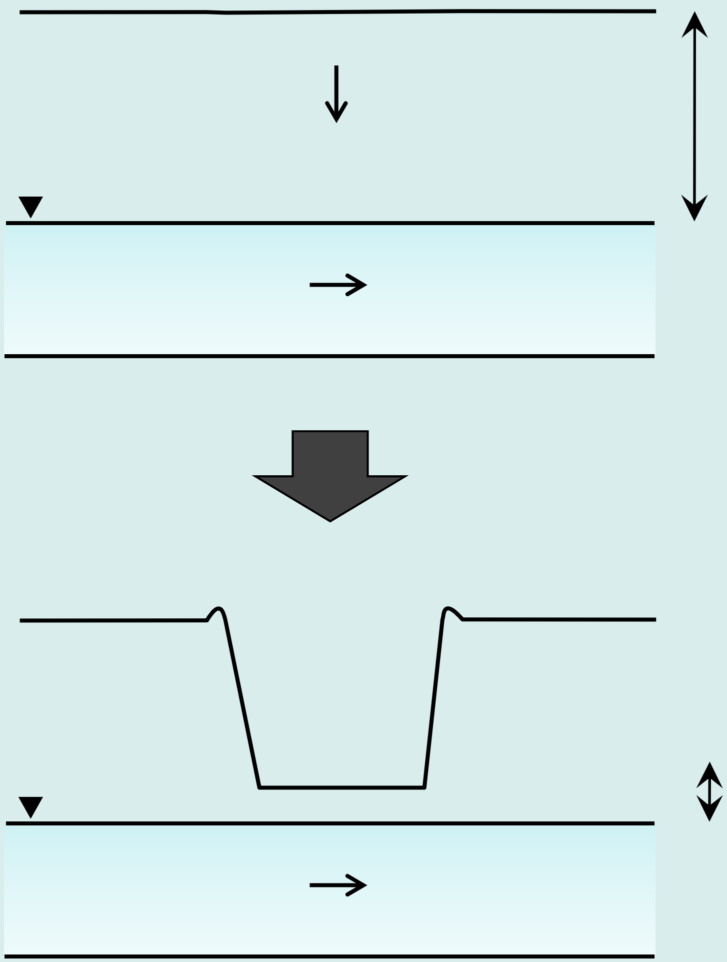
Perceived Concerns with Aggregate Extraction



1. Groundwater is of pristine quality
2. Soil above the water table provides a natural “filtration” capacity for contaminants
3. Aggregate extraction reduces the thickness of soil above the water table
4. Therefore, aggregate extraction degrades groundwater quality over the long term

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Does This Make Sense?

- Need to think of this in terms of “Attenuation Capacity” - the ability to lower contaminant concentrations along aquifer flowpaths (Chapelle and Bradley, USGS)
  - **Dilution** – reduction in contaminant concentration through mixing processes
  - **Attenuation** – contaminant degradation through natural chemical or biological processes over time (^{226}Ra=1,062 years, glycol= 4 days)
  - **Storage** – retaining contaminant mass until the storage capacity is exhausted
- <u>Strictly Speaking</u>: Aggregate removal decreases contaminant **storage** and **residence time** above the water table, therefore some increased potential for adverse groundwater quality impacts

What Do We Know About Aggregates Sites, Aquifer Vulnerability, and Assessing Impacts?

- No known instances of groundwater contamination associated with aggregate extraction (Blackport and Golder, 2006), but possible scenarios include:
  - importation of contaminated soil during rehabilitation
  - illegal waste disposal
  - drainage of contaminated stormwater from an adjacent location
  - petroleum hydrocarbon releases from equipment/tanks
- Widely-used methods of evaluating regional aquifer vulnerability to contamination, which depend on unsaturated zone thickness and permeability (sand/gravel sites are intrinsically vulnerable)
- Widely-accepted methods for modeling the contaminant transport in groundwater and assessing the exposure risks to potential receptors
- What kinds of contaminant releases?

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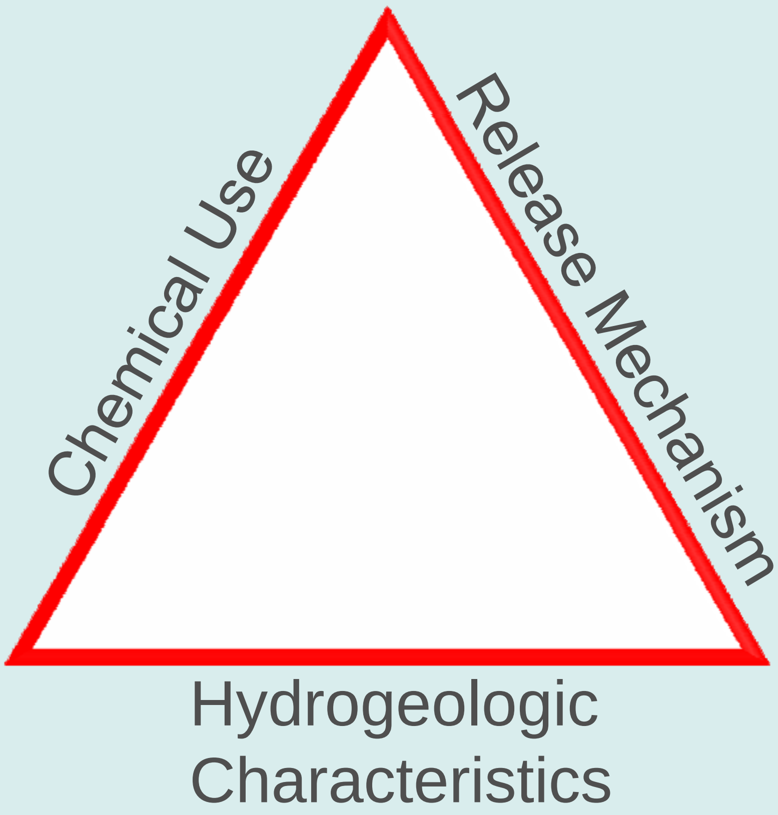
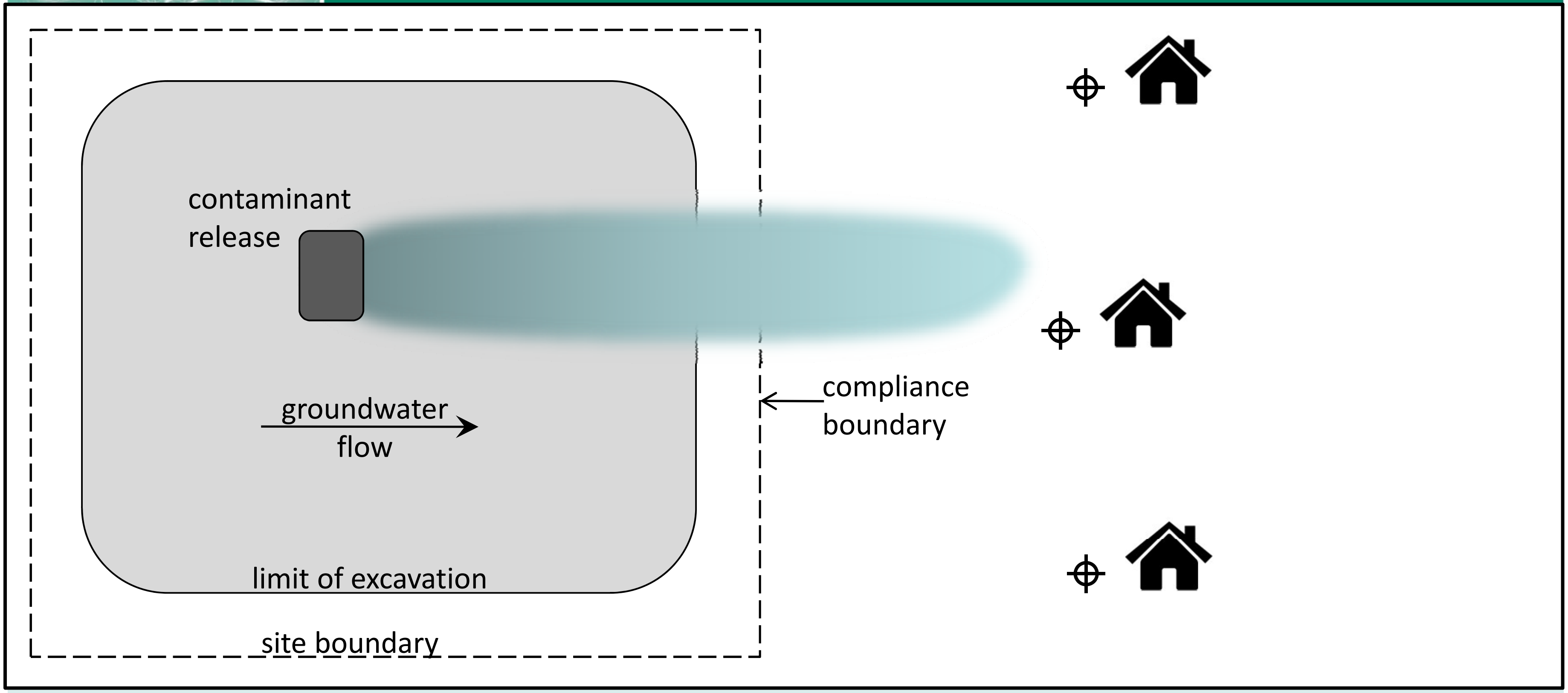
Key Factors Leading to Groundwater Contamination



- The conventional approach to contaminated sites is to consider what kinds of releases might have occurred
- Endless combinations of possible chemical uses (quantity and toxicity) and possible release mechanisms resulting in a release to the subsurface

Hydrogeologic Characteristics



- Potential for adverse impacts will depend on the contaminant, characteristics of the release, groundwater velocity, travel distance, and contaminant attenuation processes

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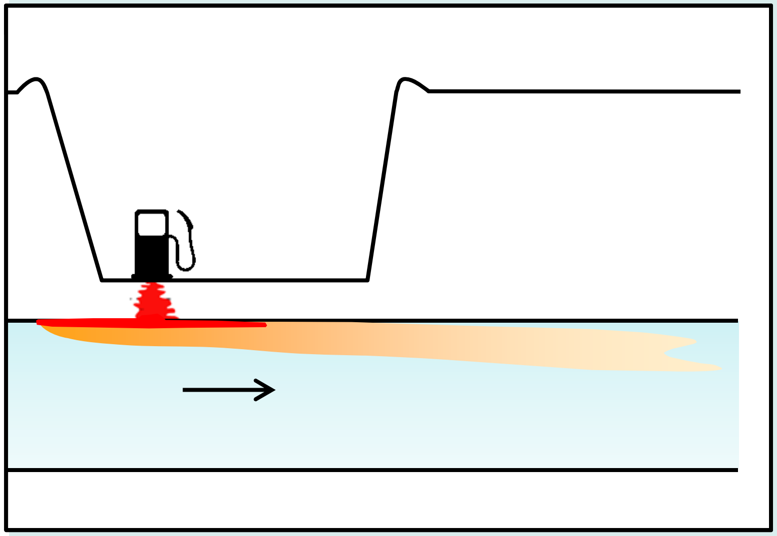
Its Not Just a Technical Issue

- Critics want to consider all possible potential impacts to water quality and only attenuation capacity above the water table
- What's wrong with this?
  - Some potential impacts are already closely managed under existing regulatory processes (e.g., fuel spills during the extraction period);
  - Under the existing land development process, there are relatively few realistic release scenarios
  - Places emphasis on aggregate sites as having some unique or sensitive characteristics that somehow distinguishes them from surrounding land uses
  - Does not consider attenuation processes that occur below the water table

Potential Groundwater Impacts During Aggregate Extraction



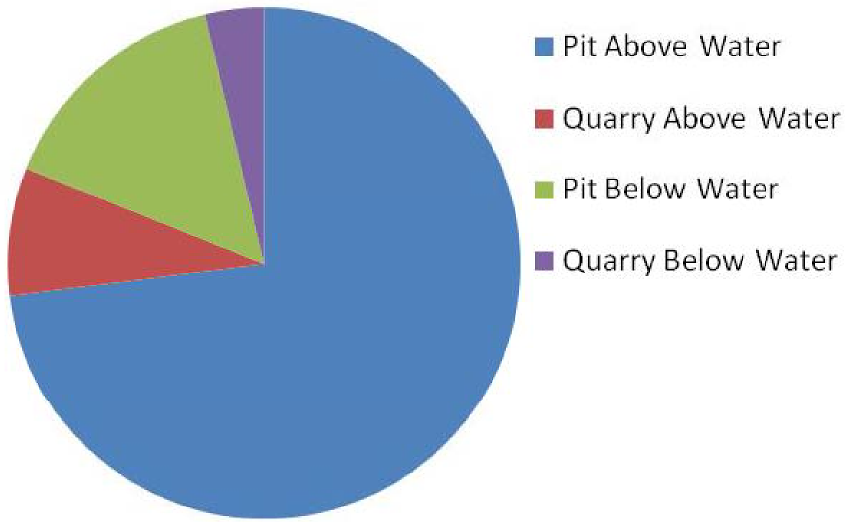
- Most likely contaminants are petroleum hydrocarbons (diesel or gasoline) released from equipment or aboveground storage tanks
- Existing risks of impacts already mitigated:

1. Regulatory - O.Reg 153/04 *Record of Site Condition*, including stringent monitoring, reporting & cleanup standards; spills reporting; plus TSSA requirements for storage tanks
2. Civil – potential liability associated with impacts to downstream property owners
3. Financial – insurers, purchasers and lending institutions want to understand the cost of cleanup under O.Reg 153/04 – drives due diligence efforts

How Did We Approach This Problem?

- Focus on a broader & more holistic perspective on the issue that recognizes the reality of former aggregate sites
- Develop a better understanding of
  1. The long-term impacts of aggregate extraction (i.e., what happens to these sites after closure?)
  2. The patterns of redevelopment to better understand how aggregate sites might increase the potential for groundwater contamination *in the context of the surrounding land uses*
  3. Use the literature to assess the attenuation capacity for the relevant contaminants

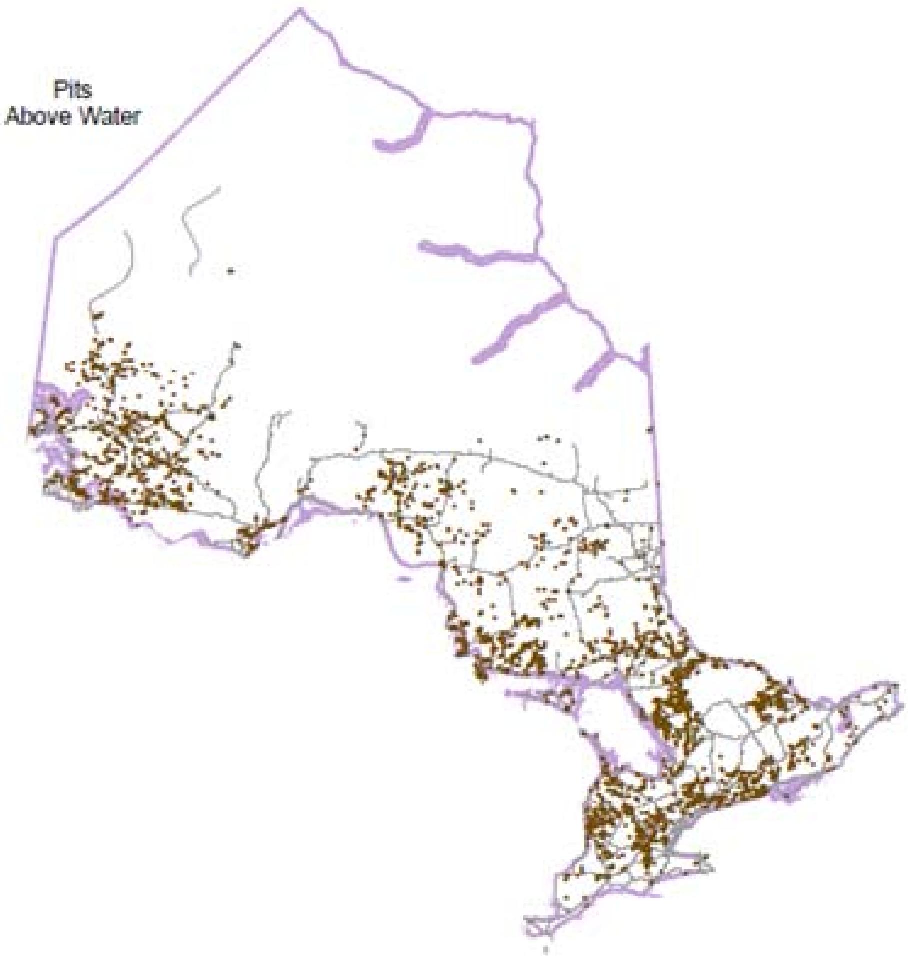
License Types

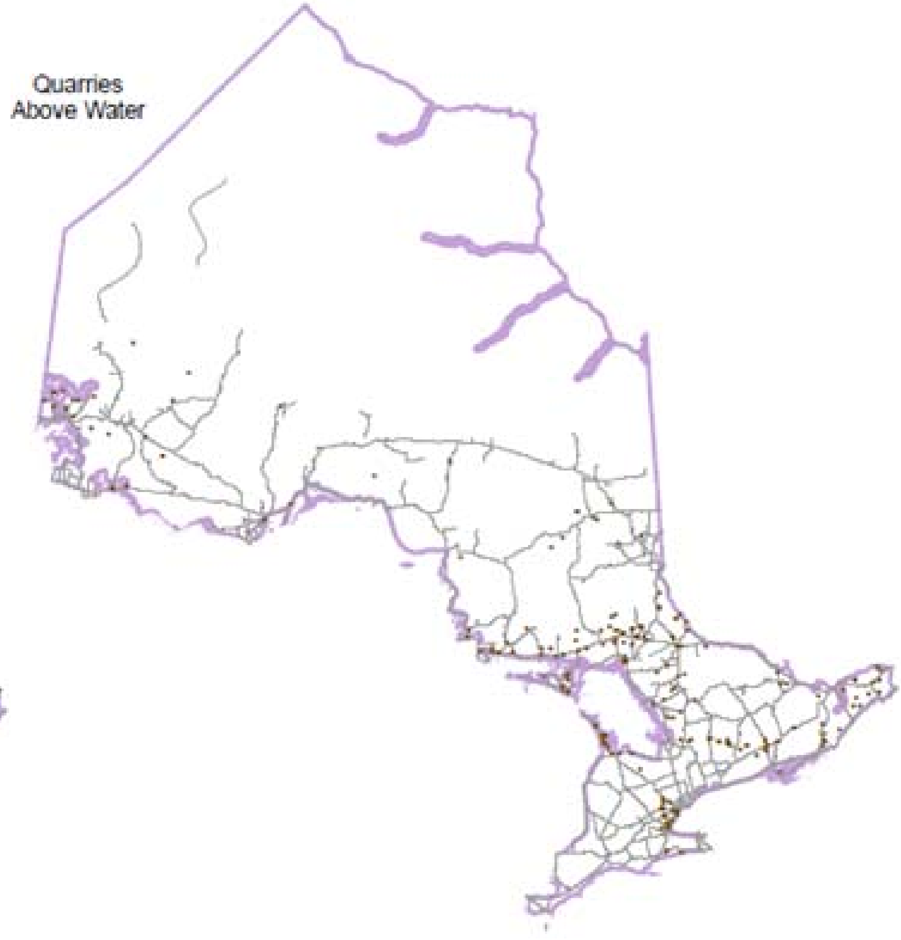


**license/permit types (2008 ALPS data set)*

- ~20% of pits and quarries are completed below water table; likely to become open body of water after closure with limited development potential
- Predominant license type is for pits completed above the water table

Aggregate Sites In Ontario (ALPs data, 2008)





Surrounding Land Uses

Landuse	Area (ha)	%Area
Naturalized	1,613,590	56
Agriculture	1,156,127	40
Tailing, Quarries, Outcrops	47,041	2
Settlement	49,755	2
Other	1,914	0.1

**distribution of land uses within a 1,000 metre buffer zone surrounding all aggregate license/permit types (2008 ALPS data set)*

- Predominantly naturalized and agricultural lands uses with only 2% settlement and other developed lands.
- Reflects the overwhelmingly rural nature of aggregate sites
- Aggregate extraction an "interim land use" (2005 Provincial Policy Statement); redevelopment land uses to be consistent with surrounding land uses
- Agricultural land uses most significant potential impact from a groundwater perspective

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Groundwater Quality in Rural Southwestern Ontario

- Closed sites that pose a minimal risk to groundwater quality include:
  - Sites excavated below the water table that become open bodies of water that cannot be restored to other land uses
  - Site rehabilitated to a naturalized land use (wetlands, species at risk habitats, conservation areas, park lands)
- Critical Land Use: Agricultural, which may involve the use and storage of nutrients, chemicals and/or fuels
- Land application of chemical fertilizers, animal wastes and pesticides is a wide-spread practice that represents a significant potential for groundwater contamination

Existing Rural Groundwater Quality

- Numerous surveys of groundwater quality in agricultural areas, including studies specific to Ontario, other Canadian provinces and the US
- Consistent result - the widespread presence of nitrate and bacterial contamination
- **Key Conclusions** Goss et al. (1998) ~1,300 drinking water wells in rural southwestern Ontario
  - 40% of the tested wells did not meet provincial standards for drinking water (either nitrate and/or bacteria)
  - Contamination from pesticides is infrequent, no detections of petroleum hydrocarbons compounds (BTEX)
  - Expect 10–20% of wells exceed standards for nitrate, 20–30% to exceed standards for bacterial contamination

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Pesticides and Petroleum Hydrocarbons in Soil and Groundwater

Pesticides

- mostly frequently detected in rural groundwater include alachlor*, atrazine, cyanazine*, metribuzin and metolachlor*
- taken up by crops, adsorbed to soil or degraded in soil and groundwater
- Rapid degradation - half lives 5–276 days (PAN Pesticide Database, 2009)

Petroleum Hydrocarbons

- Complex hydrocarbon mixtures, most significant compounds of concerns include benzene, toluene, ethylbenzene and xylene (BTEX)
- Rapid degradation in soil and groundwater - half lives 2-8 days (Suarez and Rifai, 1998)

Nitrate in Soil and Groundwater

urea

"ammoniafication" ↓ hydrolysis

ammonium

"nitrification" ↓ aerobic biodegradation

nitrate

"denitrification" ↓ anerobic biodegradation

nitrogen gas

- Sources include chemical fertilizers and animal wastes used as fertilizers, containing urea [$(NH_2)_2CO$], ammonium nitrate (NH_4NO_3), or nitrate (NO_3)
- Nitrogen fertilizers are rapidly converted to nitrate, which can be further biodegraded N_2, incorporated into plant biomass, or infiltrate into groundwater
- Nitrate will not biodegrade under aerobic conditions (limited above the water table)
- Nitrate will not biodegrade in many groundwater systems due to lack of organic carbon (Wilhelm et al., 1994)

Bacteria in Soil and Groundwater

- Emphasis is on the many pathogenic organisms that can result in disease (e.g., *Cryptosporidia*) although the analytical techniques for these are limited; use bacterial indicator species (e.g., total coliforms, faecal coliforms)
- Filtration (physical removal by attachment to soil particles) is a significant removal mechanisms
  - Highly variable, but a reasonable rule of thumb is 10X concentration reduction per metre of travel (e.g., Harvey et al., 1995)
- Spontaneous Inactivation – pathogen death in response to challenging environmental conditions or predation by other microorganisms
  - Typical half lives 3-15 days (Keswick et al., 1982; John and Rose, 2005; Azadpour-Keeley and Ward, 2005)

Conclusions

1. Aggregate sites are a rural land use, with redevelopment to natural or agricultural land uses that consistent with the surrounding land uses
2. Agricultural production in rural Ontario commonly results in groundwater contamination by nitrate and bacteria
3. Nitrate attenuation is not impacted by the depth of overburden material and often does not degrade in groundwater
4. Bacteria, pesticides and petroleum hydrocarbons are unlikely to result in adverse groundwater quality impacts except within and immediately down-gradient of releases of these contaminants
5. The potential impacts to groundwater quality at former aggregate sites are likely of similar nature to those associated with surrounding land uses (e.g., nitrate and bacteria)

Recommendations

1. Storm Water Management - ensure that focused storm water recharge to the excavated area does not contribute contaminants from adjacent land uses into the excavated area
2. Security – control inadvertent or illicit introduction of contaminants
3. “Intensive” Land Uses – Consider completing site-specific studies to ensure that intensive agriculture (i.e., feedlots, stockyards, some crops) or other land uses associated with the potential for groundwater impacts do not adversely impact groundwater quality
4. Agricultural BMPs – Use nutrient management practices that minimize the land application of chemical fertilizers and animal wastes