Natural Groundwater Quality and Human-Induced Changes
Indicator #7100

This indicator report was last updated in 2005.

Overall Assessment

Status: **Not Assessed**
Trend: **Not Assessed**
Note: This indicator report uses data from the Grand River watershed only and may not be representative of groundwater conditions throughout the Great Lakes basin.

Lake-by-Lake Assessment

Separate lake assessments were not included in the last update of this report.

Purpose
- To measure groundwater quality as determined by the natural chemistry of the bedrock and overburden deposits, as well as any changes in quality due to anthropogenic activities
- To address groundwater quality impairments, whether they are natural or human induced in order to ensure a safe and clean supply of groundwater for human consumption and ecosystem functioning

Ecosystem Objective
The ecosystem objective for this indicator is to ensure that groundwater quality remains at or approaches natural conditions.

State of the Ecosystem
Background
Natural groundwater quality issues and human induced changes in groundwater quality both have the potential to affect our ability to use groundwater safely. Some constituents found naturally in groundwater renders some groundwater reserves inappropriate for certain uses. Growing urban populations, along with historical and present industrial and agricultural activity, have caused significant harm to groundwater quality, thereby obstructing the use of the resource and damaging the environment. Understanding natural groundwater quality provides a baseline from which to compare, while monitoring anthropogenic changes can allow identification of temporal trends and assess any improvements or further degradation in quality.

Natural Groundwater Quality
The Grand River watershed can generally be divided into three distinct geological areas; the northern till plain, the central region of moraines with complex sequences of glacial, glaciofluvial and glaciolacustrine deposits, and the southern clay plain. These surficial overburden deposits are underlain by fractured carbonate rock (predominantly dolostone). The groundwater resources of the watershed include regional-scale unconfined and confined overburden and bedrock aquifers as well as discontinuous local-scale deposits which contain sufficient groundwater to meet smaller users' needs. In some areas of the watershed (e.g. Whitemans Creek basin) the presence of high permeability sands at ground surface and or a high water table leads to unconfined aquifers which are highly susceptible to degradation from surface contaminant sources.

The natural quality of groundwater in the watershed for the most part is very good. The groundwater chemistry in both the overburden and bedrock aquifers is generally high in dissolved inorganic constituents (predominantly calcium, magnesium, sodium, chloride and sulphate). Measurements of total dissolved solids (TDS) suggest relatively "hard" water throughout the watershed. For example, City of Guelph production wells yield water with hardness measured from 249 mg/l to 579 mg/l, which far exceeds the aesthetic Ontario Drinking Water Objective of 80 mg/l to 100 mg/l. Elevated concentrations of trace metals (iron and manganese) have also been identified as ambient quality issues with the groundwater resource.

Figures 1 and 2 illustrate water quality problems observed in bedrock and overburden wells, respectively. These figures are based on a qualitative assessment of well water at the time of drilling as noted on the Ontario Ministry of Environment's water well record form. The majority of these wells were installed for domestic or livestock uses. Overall, between 1940 and 2000, less than 1% (approximately 1131 wells) of all the wells drilled in the watershed reported having a water quality problem. Of the wells

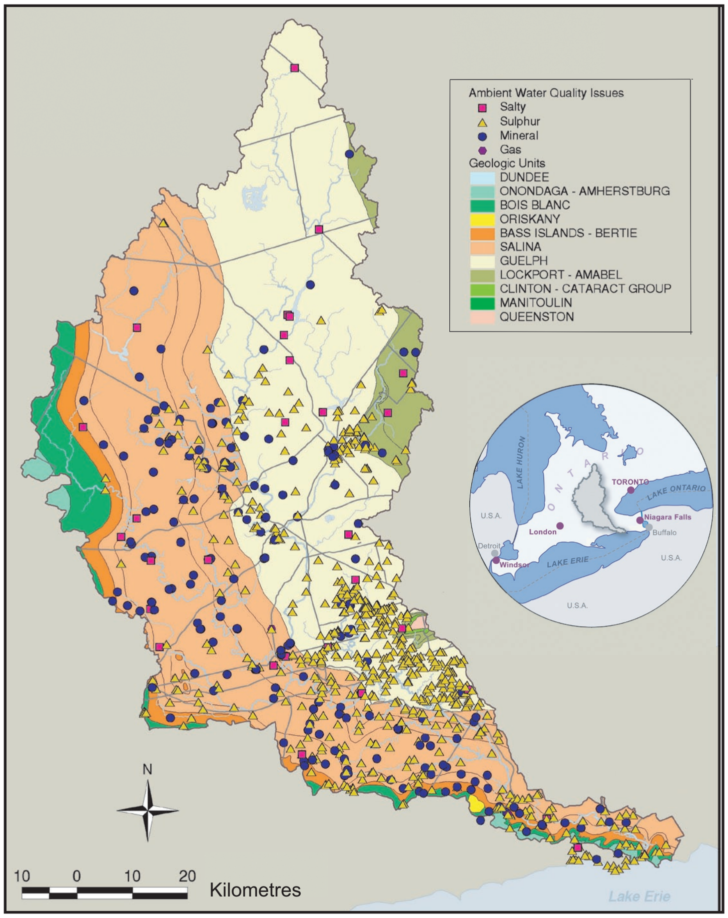

Figure 1. Bedrock wells with natural quality issues in the Grand River watershed.
Source: Grand River Conservation Authority

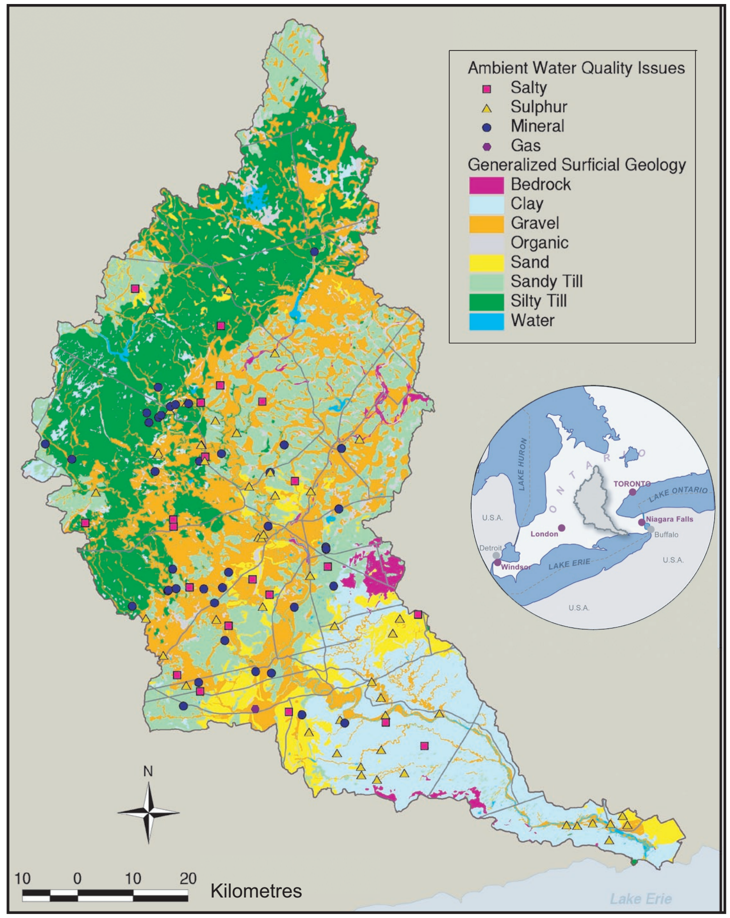

Figure 2. Overburden wells with natural quality issues in the Grand River watershed.
Source: Grand River Conservation Authority

exhibiting a natural groundwater problem about 90% were bedrock wells while the other 10% were completed in the overburden. The most frequently noted quality problem associated with bedrock wells was high sulphur content (76% of bedrock wells with quality problems). This is not surprising, as sulphur is easy to detect due to its distinctive and objectionable odor. Generally, three bedrock formations commonly intersected within the watershed contain most of the sulphur wells: the Guelph Formation, the Salina Formation, and the Onondaga-Amherstburg Formation. The Salina Formation forms the shallow bedrock under the west side of the watershed while the Guelph underlies the east side of the watershed.

Additional quality concerns noted in the water well records include high mineral content and salt. About 20% of the reported quality concerns in bedrock wells were high mineral content while 4% reported salty water. Similar concerns were noted in overburden wells where reported problems were sulphur (42%), mineral (34%), and salt (23%).

Human Induced Changes to Groundwater Quality

Changes to the quality of groundwater from anthropogenic activities associated with urban sprawl, agriculture and industrial operations have been noted throughout the watershed. Urban areas within the Grand River watershed have been experiencing considerable growth over the past few decades. The groundwater quality issues associated with human activity in the watershed include: chloride, industrial chemicals (e.g. trichloroethylene (TCE)), and agricultural impacts (nitrate, bacteria, and pesticides). These contaminants vary in their extent from very local impact (e.g. bacteria) to widespread impact (e.g. chloride). Industrial contaminants tend to be point sources, which generally require very little concentration to impact significant groundwater resources.

Chloride

Increasing chloride concentrations in groundwater have been observed in most municipal wells in the urban portions of the watershed. This increase has been attributed to winter de-icing of roads with sodium chloride (salt). Detailed studies carried out by the Regional Municipality of Waterloo have illustrated the impact of road salting associated with increased urban development to groundwater captured by two municipal well fields. Figure 3 shows the temporal changes in chloride concentration for the two well fields investigated in this study. Wells A, B, and C, are from the first well field while wells D and E are from the second well field. In 1967 land use within the capture zone of the first field was 51% rural and 49% urban, while in the second well field capture zone the land use was 94% rural and 6% urban. By 1998, the area within the first well field capture zone had been completely converted to urban land while in the second well field capture zone 60% of the land remained rural.

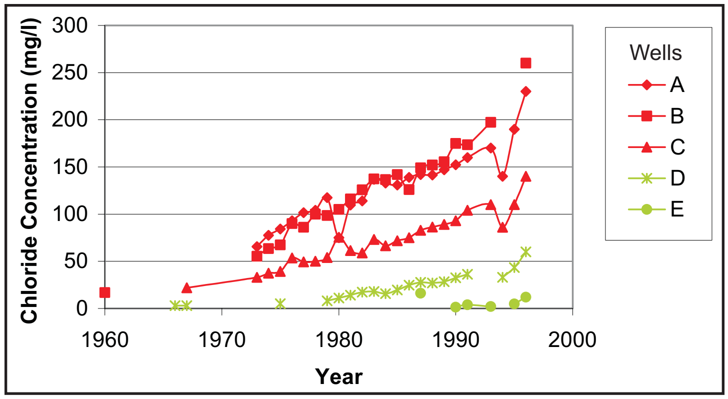

Figure 3. Chloride levels in selected groundwater wells in the Regional Municipality of Waterloo.

Red indicates wells from one area/well field. Green indicates wells from a different area/well field.

Source: Stanley Consulting (1998)

Although wells from both well fields show increased chloride levels, wells A, B, and C in the heavily urbanized capture zone show a greater increase in chloride concentrations than do wells D and E in the predominantly rural capture zone. For example, well B showed a change in chloride concentration from 16.8 mg/L in 1960, to 260 mg/L in 1996, where as well D showed a change from 3 mg/l in 1966, to 60 mg/l in 1996. This indicates that chloride levels in groundwater can be linked to urban growth and its associated land uses (i.e. denser road network). The Ontario Drinking Water Objective for chloride had been established at 250 mg/L, although this guideline is predominantly for aesthetic reasons, the issue of increasing chloride levels should be addressed.

Industrial Contaminants

Groundwater resources in both the overburden and bedrock deposits within the Grand River watershed have been impacted by contamination of aqueous and non-aqueous contaminants which have entered the groundwater as a result of industrial spills or discharges, landfill leachates, leaky storage containers, and poor disposal practices. A significant number of these chemicals are volatile organic compounds (VOCs). Contamination by VOCs such as TCE, have impacted municipal groundwater supplies in several communities in the watershed. For example, by the year 1998, five of the City of Guelph's 24 wells were taken out of service due to low-level VOC contamination. These wells have a combined capacity of 10,000 to 12,000 m^3/day and represent about 15% of the City's permitted water-taking capacity. As a second example, contamination of both a shallow aquifer and a deeper municipal aquifer with a variety of industrial chemicals (including toluene, chlorobenzene, 2,4-D, 2,4,5-T) emanating from a chemical plant in the Region of Waterloo led to the removal of municipal wells from the water system in the town of Elmira.

Agricultural and Rural Impacts

Groundwater quality in agricultural areas is affected by activities such as pesticide application, fertilizer and manure applications on fields, storage and disposal of animal wastes and the improper disposal and spills of chemicals. The groundwater contaminants from these activities can be divided into three main groups: nitrate, bacteria and pesticides. For example, the application of excessive quantities of nutrients to agricultural land may impact the quality of the groundwater. Excess nitrogen applied to the soil to sustain crop production is converted to nitrate with infiltrating water and hence transported to the water table. Seventy-six percent of the total land area in the Grand River watershed is used for agricultural purposes and thus potential and historical contamination of the groundwater due to these activities is a concern.

Land use and nitrate levels measured in surface water from two sub-watersheds, the Eramosa River and Whitemans Creek, are used to illustrate the effects of agricultural activities on groundwater quality and the quality of surface water.

In the Whitemans Creek sub-watershed, approximately 78% of the land classified as groundwater recharge area is covered with agricultural uses, and only 20% is forested. In the Eramosa subwatershed about 60% of the significant recharge land is used for agricultural purposes with approximately 34% of the land being covered with forest (Figure 4). Both of these tributary streams are considered predominantly groundwater-fed streams, meaning that the majority of flow within them is received directly from

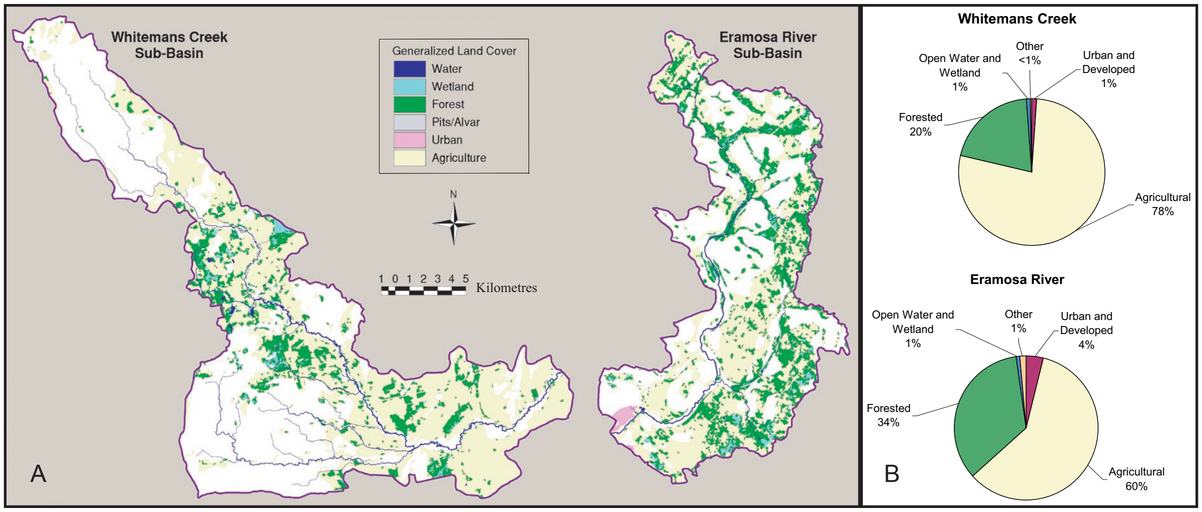

Figure 4. Land cover on moraine systems and areas that facilitate high to very high groundwater recharge of the Whitemans Creek and Eramosa River sub-watersheds: (a) Spatial distribution and (b) Percent distribution of classified land use.
Source: Grand River Conservation Authority

groundwater discharge.

Average annual concentrations of nitrate measured in the Eramosa River and Whitemans Creek from 1997 to 2003 are shown in Figure 5. Average annual concentration of nitrate measured in Whitemans Creek between 1997 and 2003 were 2.5 to 8 times higher than those measured in the Eramosa River. The higher nitrate levels measured in Whitemans Creek illustrate the linkage between increased agricultural activity and groundwater contamination and its impact on surface water quality. In addition to the agricultural practices in the Whitemans Creek subwatershed, the observed nitrate concentrations may also be linked to rural communities with a high density of septic systems that leach nutrients to the subsurface.

Manure spreading on fields, runoff from waste disposal sites, and septic systems may all provide a source of bacteria to groundwater. Bacterial contamination in wells in agricultural areas is common; however, this is often due to poor well construction allowing surface water to enter the well and not indicative of widespread aquifer contamination. Shallow wells are particularly vulnerable to bacterial contamination.

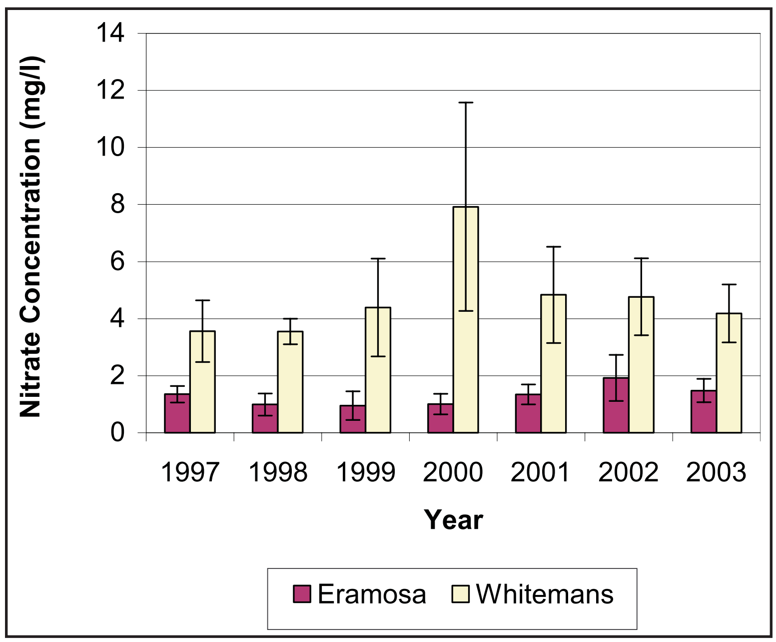

Figure 5. Average annual concentrations of nitrate measured in the Eramosa River and Whitemans Creek from 1997 to 2003. (Also shown on the bar graphs is the standard error of measurement.)
Source: Ontario Provincial Water Quality Monitoring Network (2003)

Pressures

The population within the Grand River watershed is expected to increase by over 300,000 people in the next 20 years. The urban sprawl and industrial development associated with this population growth, if not managed appropriately, will increase the chance for contamination of groundwater resources. Intensification of agriculture will lead to increased potential for pollution caused by nutrients, pathogens and pesticides to enter the groundwater supply and eventually surface water resources. While largely unknown at this time, the effects of climate change may lead to decreased groundwater resources, which may concentrate existing contaminant sources.

Management Implications
Protecting groundwater resources generally requires multifaceted strategies including regulation, land use planning, water resources management, voluntary adoption of best management practices and public education. Programs to reduce the amount of road salt used for de-icing will lead to reductions in chloride contamination in groundwater. For example, the Regional of Waterloo (the largest urban community in the watershed) in cooperation with road maintenance departments has been able to decrease the amount of road salt applied to Regional roads by 27% in just one winter season.

Comments from the author(s)
While there is a large quantity of groundwater quality data available for the various aquifers in the watershed, this data has not been consolidated and evaluated in a comprehensive or systematic way. Work is needed to bring together this data and incorporate ongoing groundwater monitoring programs. An assessment of the groundwater quality across Ontario is currently being undertaken through sampling and analysis of groundwater from the provincial groundwater-monitoring network (PGMN) wells (includes monitoring stations in the Grand River watershed). Numerous watershed municipalities also have had ongoing monitoring programs, which examine the quality of groundwater as a source of drinking water in place for a number of years. Integrating this data along with data contained in various site investigations will allow for a more comprehensive picture of groundwater quality in the watershed.

Acknowledgments
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Sources
Braun Consulting Engineers, Gartner Lee Limited, and Jagger Hims Limited Consulting Engineers. 1999. *City of Guelph Water System Study Resource Evaluation Summary.* Report prepared for the City of Guelph.

Crowe, A.S., Schaefer, K.A., Kohut, A., Shikaze, S.G., and Ptacek, C.J. 2003. *Groundwater quality.* Canadian Council of Ministers of the Environment, Winnipeg, Manitoba. Canadian

Council of Ministers of the Environment (CCME), Linking Water Science to Policy Workshop Series. Report No. 2, 52pp. Holysh, S., Pitcher, J., and Boyd, D. 2001. *Grand River regional groundwater study.* Grand River Conservation Authority, Cambridge, ON, 78pp+ appendices.

Ontario Provincial Water Quality Monitoring Network. 2003. Grand River Conservation Authority Water Quality Stations. Region of Waterloo. Official Municipal Website. http://www.region.waterloo.on.ca.

Stanley Consulting. 1998. *Chloride Impact Assessment Parkway and Strasburg Creek Well Fields Final Report*. Prepared for the Regional Municipality of Waterloo.

Whiffin, R.B., and Rush, R.J. 1989. Development and demonstration of an integrated approach to aquifer remediation at an organic chemical plant. In *Proceedings of the FOCUS Conference on Eastern Regional Ground Water Issues*, October 17-19, 1989, Kitchener, ON, Canada, pp. 273-288.

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