

Groundwater and Land: Use and Intensity

Indicator #7101

Overall Assessment

Status: **Not Assessed**

Trend: **Not Assessed**

Rationale: **Land use and water use and intensity, and the characteristics of the groundwater resources of the basin are interrelated.**

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

Each lake was categorized with a not assessed status and an undetermined trend, indicating that assessments were not made on an individual lake basis.

Purpose

- To measure water use and intensity and land use and intensity;
- To infer the potential impact of land and water use on the quantity and quality of groundwater resources as well as evaluate groundwater supply and demand; and
- To track the main influences on groundwater quantity and quality such as land and water use to ensure sustainable high quality groundwater supplies.

Ecosystem Objective

The ecosystem objective for this indicator is to ensure that land and water use does not negatively impact groundwater supplies/resources.

State of the Ecosystem

Background

Land use and intensity has the potential to affect both groundwater quality and quantity. Similarly, water use and intensity (i.e. demand) can impact the sustainability of groundwater supplies. In addition, groundwater use and intensity can impact streams and creeks, which depend on groundwater for base flows to sustain aquatic plant and animal communities.

Land use and intensity

An allegory for land use and water use intensity in the Great Lakes basin is the Grand River watershed of Ontario. The Grand River watershed can generally be divided into three distinct geological areas; the northern till plain, central 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. Whiteman's 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 contamination from surface contaminant sources.

Agricultural and rural land uses predominate in the Grand River watershed. Approximately 76% of the watershed land area is used for agriculture (Figure 1). Urban development covers about 5% of the watershed area while forests cover about 17%. The largest urban centers, including Kitchener, Waterloo, Cambridge and Guelph, are located in the central portion of the watershed and are situated on or in close proximity to many of the complex moraine systems that stretch across the watershed (Figure 1). The moraines and associated glacial outwash area in the watershed form a complex system of sand and gravel layers separated by less permeable till layers. Together with the sand plain in the southwest portion of the watershed these units provide significant groundwater resources. The majority of the groundwater recharge in the watershed is concentrated in a land area that covers approximately 38% of the watershed. Figure 2 illustrates the land cover associated with those areas that have high recharge potential.

Land use on these moraines and significant recharge areas can have major influence on both groundwater quantity and quality (Figure 2). Intensive cropping practices with repeated manure and fertilizer applications have the potential to impact groundwater quality while urban development can interrupt groundwater recharge and impact groundwater quantity. About 67% of the significant recharge areas are in agricultural production while 23% and 8% of the recharge areas are covered with forests and urban development respectively. Since the moraine systems and recharge areas in the Grand River watershed provide important ecological, sociological and economical services to the watershed, they are important watershed features that must be maintained to ensure sustainable groundwater supplies.

Land use directly influences the ability of precipitation to recharge shallow aquifers. Urban development such as the paving of roads and building of structures intercepts precipitation and facilitates the movement of water off the land in surface runoff, which subsequently reduces groundwater recharge of shallow aquifers. A significant portion (62%) of the urban area in the Grand River watershed tends to be concentrated in the highly sensitive groundwater recharge areas (Figure 3). Development is continuing in these sensitive areas. For example, of the total kilometers of new roads built between 2000 and 2004 in the Region of Waterloo, about half of them were situated in the more sensitive areas.

Land uses that protect groundwater recharge such as some agricultural land use and forested areas need to be protected to ensure groundwater recharge. About 34% and 51% of the watershed's agricultural and forested land cover is located in the significant recharge areas. Strategic development is needed to protect these recharge areas to protect groundwater recharging function in the watershed.

Groundwater use and intensity

Groundwater in the Grand River watershed is used for a range of activities including domestic, municipal, public, agricultural, and industrial/commercial supplies. It is estimated that approximately 80% of the 875,000 watershed residents use groundwater as their primary source of potable water.

Between 1940 and 2003, over 37,000 wells were constructed in the Grand River watershed. Approximately 79% of these wells (or 29,683 wells) are, or were, used for domestic water supplies (Figure 4). However, this represents only 3% of the total annual groundwater takings in the watershed (Figure 5). The largest users of groundwater in the watershed are municipalities (30%) who use the water to provide potable water to their residents. Industries, commercial developments, aggregate washing, dewatering and remediation also withdraw significant amounts of groundwater (43%, combined). Aquaculture is a significant user of groundwater at approximately 13% of the total annual groundwater takings in the watershed.

Even though total annual groundwater withdrawals identify municipal takings as the most significant use of groundwater, seasonal demands in selected areas can be significant. Irrigation becomes the second largest use of water in July in the Grand River watershed. Approximately 60% of all irrigation is done with groundwater. Therefore, this seasonal demand can have a significant impact on local groundwater fed streams and the aquatic life that inhabits them. Although the irrigated land in the Grand River watershed is less than 1% of the total land area, increasing trends in irrigation (Figure 6) places added stress on these local groundwater-dependant ecosystems.

Climatic factors and population growth can also impact the demand for groundwater resources. The number of new wells drilled since 1980 grew steadily until 1989 (Figure 7). The number of new wells drilled peaked between 1987 and 1989, which coincides with a period of lower flow in the river. The average annual river flows illustrated in Figure 7 represents conditions where average, below average and above average streamflow were measured. The 1987 to 1989 period had below average streamflow suggesting it was dryer than normal and that watershed residents were searching for new groundwater supplies. The same occurrence is illustrated again in 1998-1999. The cumulative impact of both climate effects and increased population growth (Figure 8) likely contributes to greater demand for groundwater supplies.

Pressures

Urbanization and associated development on sensitive watershed landscapes that facilitate groundwater recharge is a significant threat to groundwater resources in the Grand River watershed. Eliminating this important watershed function will directly impact the quantity of groundwater supplies for watershed residents. Therefore, it is essential that municipalities and watershed residents protect the moraine systems and significant recharge areas to ensure future groundwater supplies.

Population growth with continued urban development and agricultural intensification are the biggest threats to groundwater supplies in the Grand River watershed. It is estimated that the population of the watershed will increase by approximately 300,000 people in the next 20 years (Figure 8). The biggest single users of groundwater are municipalities for municipal drinking water supplies, although industrial users, including aggregate and dewatering operations, use a significant amount of groundwater. Municipalities, watershed residents and industries will need to increase their efforts in water conservation as well as continue to seek out new or alternate supplies.

Climate influence on groundwater resources in the Grand River watershed cannot be underestimated. It is evident that during times with below average precipitation, there is increased demand for groundwater resources for both the natural environment and human uses. In addition, climate change will likely redistribute precipitation patterns throughout the year, which will likely impact groundwater resources in the watershed.

Management Implications

Land use and development has a direct effect on groundwater quantity and quality. Therefore, land use planning must consider watershed functions such as groundwater recharge when directing future growth. Municipal growth strategies should direct growth and development away from sensitive watershed landscapes such as those areas that facilitate groundwater recharge. Efforts in recent years have focused on delineating wellhead protection zones, assessing the threats and understanding the regional hydrogeology. Through the planning process, municipalities such as the Region of Waterloo, City of Guelph and the County of Wellington have recognized the importance of protecting recharge to maintain groundwater resources and have been taking steps to protect this watershed function. These initiatives include limiting the amount of impervious cover in sensitive areas and capturing precipitation with rooftop collection systems. By permitting development that facilitates groundwater recharge or redirecting development to landscapes that are not as sensitive, important watershed functions can be protected to ensure future

groundwater supplies.

Water conservation measures should be actively promoted and adopted in all sectors of society. Urban communities must actively reduce consumption while rural communities require management plans to strategically irrigate using high efficiency methods and appropriate timing.

Comments from the author(s)

Understanding the impact of water use on the groundwater resources in the watershed will require understanding the availability of water to allow sustainable human use while still maintaining healthy ecosystems. Assessing groundwater availability and use at appropriate scales is an important aspect of water balance calculations in the watershed. In other words, assessing water and land use at the larger watershed scale masks more local issues such as the impact of extensive irrigation.

Consistent and improved monitoring and data collection are required to accurately estimate groundwater demand as well as determine long-term trends in land use. For example, linking groundwater permits to actual well log identification numbers will assist with understanding the spatial distribution of groundwater takings. Furthermore, groundwater permit holders should be required to report actual water use as opposed to permitted use. This will help estimate actual water use and therefore the true impact on the groundwater system.

Assessing Data Quality

Insert “x” under the statement that best corresponds with each data characteristic

Data Characteristics	Strongly Agree	Agree	Neutral or Unknown	Disagree	Strongly Disagree	Not Applicable
1. Data are documented, validated, or quality-assured by a recognized agency or organization	X					
2. Data are traceable to original sources	X					
3. The source of the data is a known, reliable and respected generator of data	X					
4. Geographic coverage and scale of data are appropriate to the Great Lakes basin		X				
5. Data obtained from sources within the U.S. are comparable to those from Canada			X			
6. Uncertainty and variability in the data are documented and within acceptable limits for this indicator report		X				
Clarifying Notes:						

Acknowledgments

Authors: (2006)

Alan Sawyer, Grand River Conservation Authority, Cambridge, ON;
 Sandra Cooke, Grand River Conservation Authority, Cambridge, ON;
 Jeff Pitcher Grand River Conservation Authority, Cambridge, ON; and
 Pat Lapcevic, Grand River Conservation Authority, Cambridge, ON.

Alan Sawyer's position was partially funded through a grant from Environment Canada's Science Horizons internship program. The assistance of Samuel Bellamy of the Grand River Conservation Authority, as well as Harvey Shear, Nancy Stadler-Salt and Andrew Piggott of Environment Canada is gratefully acknowledged.

Sources

Bellamy, S., and Boyd, D. 2004. *Water use in the Grand River watershed*. Grand River Conservation Authority, Cambridge, ON.

Dorfman, M.L., and Planner Inc. 1997. *Grand River Watershed Profile*. Prepared for the Grand River Conservation Authority.

Grand River Conservation Authority (GRCA). 2003. *Watershed Report*. Grand River Conservation Authority, Cambridge, ON.

Holysh, S., Pitcher, J., and Boyd, D. 2001. *Grand River Regional Groundwater Study*. Grand River Conservation Authority, Cambridge, ON.

Ontario Ministry of the Environment. 2003. *Water Well Information System Database*. Ministry of Environment, Toronto, ON.

Region of Waterloo. Official Municipal Website. <http://www.region.waterloo.on.ca>.

Statistics Canada. Census of Agriculture. 1986, 1991, 1996. Statistics Canada, Ottawa, ON.

List of Figures

Figure 1. Land cover in the Grand River watershed: (a) Spatial distribution and (b) Percent distribution of classified land use.

Source: Grand River Conservation Authority

Figure 2. Land cover on moraine systems and areas that facilitate high or very high groundwater recharge of the Grand River watershed: (a) Spatial distribution and (b) Percent distribution of classified land use.

Source: Grand River Conservation Authority

Figure 3. Percentage of land use type in significant recharge areas in the Grand River watershed.

Source: Grand River Conservation Authority

Figure 4. Distribution of groundwater wells by primary use in the Grand River watershed.

Source: Ontario Ministry of the Environment Water Well Database (2003)

Figure 5. Percentage of total annual groundwater takings in the Grand River watershed from designated uses.

Source: Modified from Bellamy and Boyd (2004)

Figure 6. Changes in amount of irrigated land in the Grand River watershed (percentage of total watershed area irrigated).

Source: Statistics Canada data for 1986, 1991, and 1996

Figure 7. Number of new wells drilled each year (bars). Annual average stream flow (as a percentage on long term average) in the Grand River watershed illustrating below average, and average climatic conditions (green line).
 Source: Ontario Ministry of the Environment Water Well Database (2003)

Figure 8. Estimated population in the Grand River watershed including future projections (burgundy bar).
 Source: Dorfman (1997) and Grand River Conservation Authority (2003)

Last Updated

State of the Lakes Ecosystem Conference (SOLEC) 2008

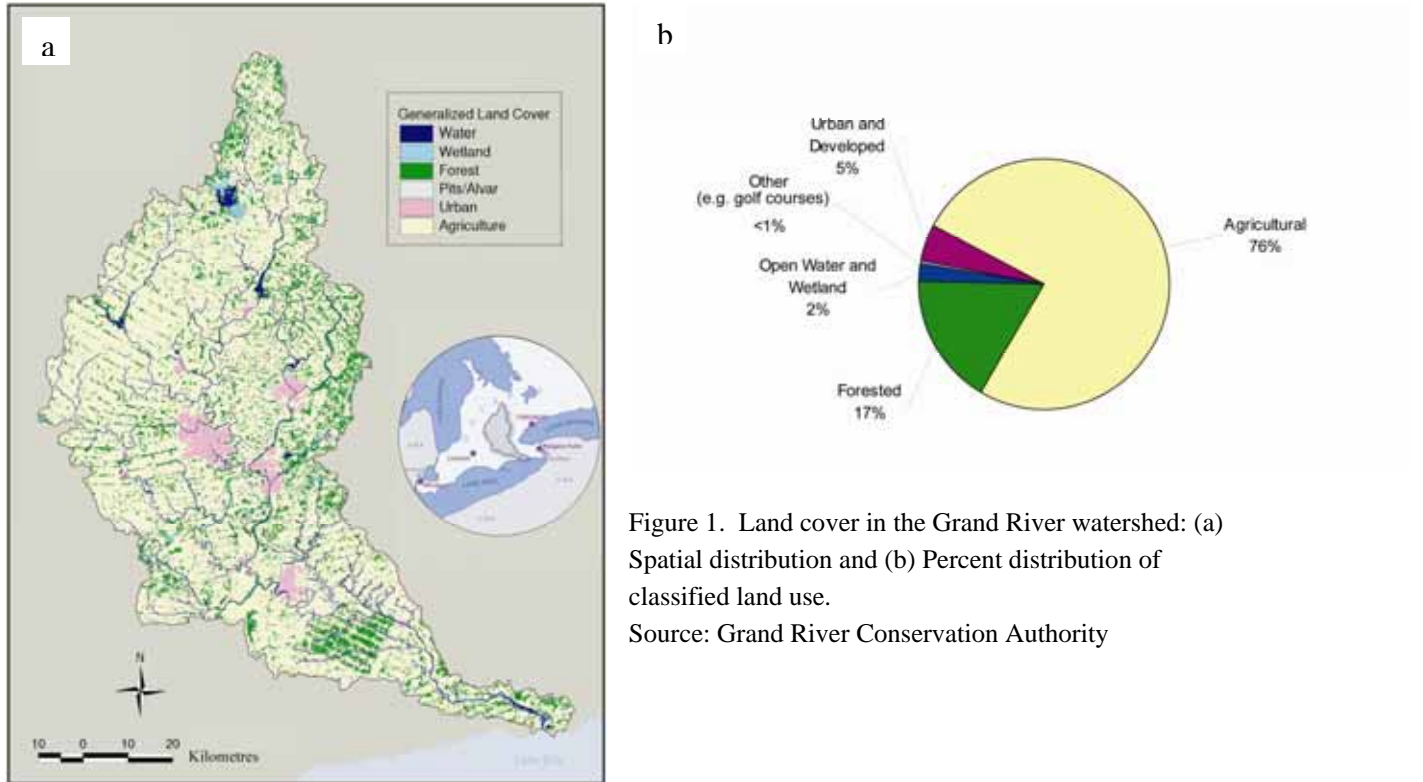


Figure 1. Land cover in the Grand River watershed: (a) Spatial distribution and (b) Percent distribution of classified land use.

Source: Grand River Conservation Authority

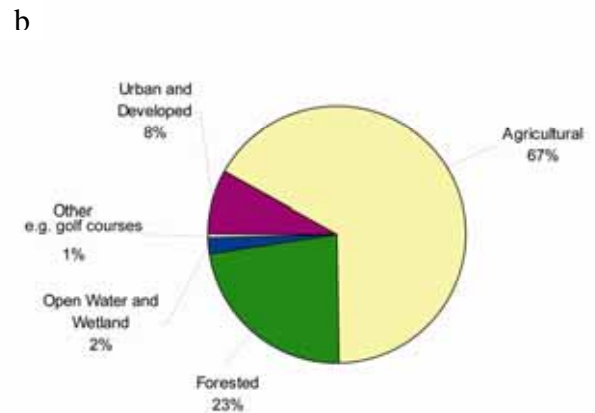
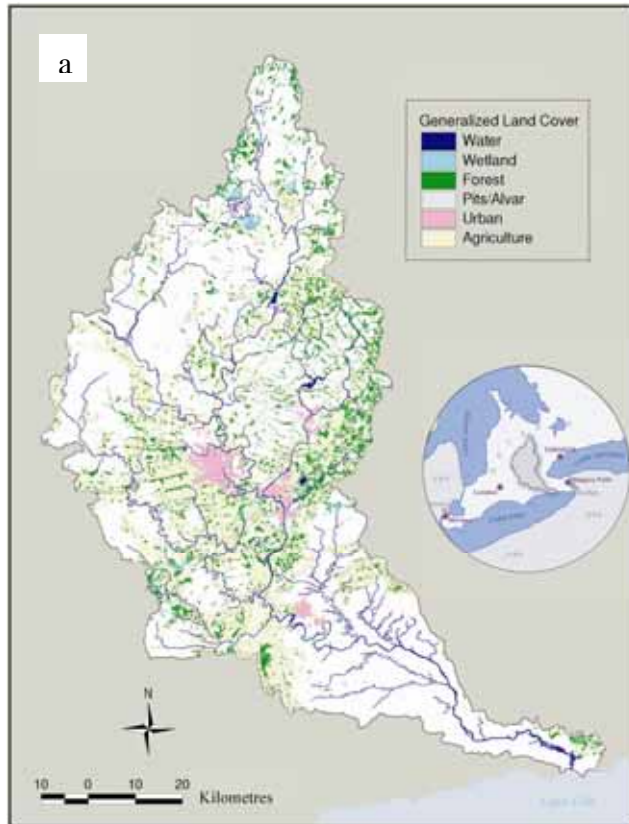


Figure 2. Land cover on moraine systems and areas that facilitate high or very high groundwater recharge of the Grand River watershed: (a) Spatial distribution and (b) Percent distribution of classified land use. Source: Grand River Conservation Authority

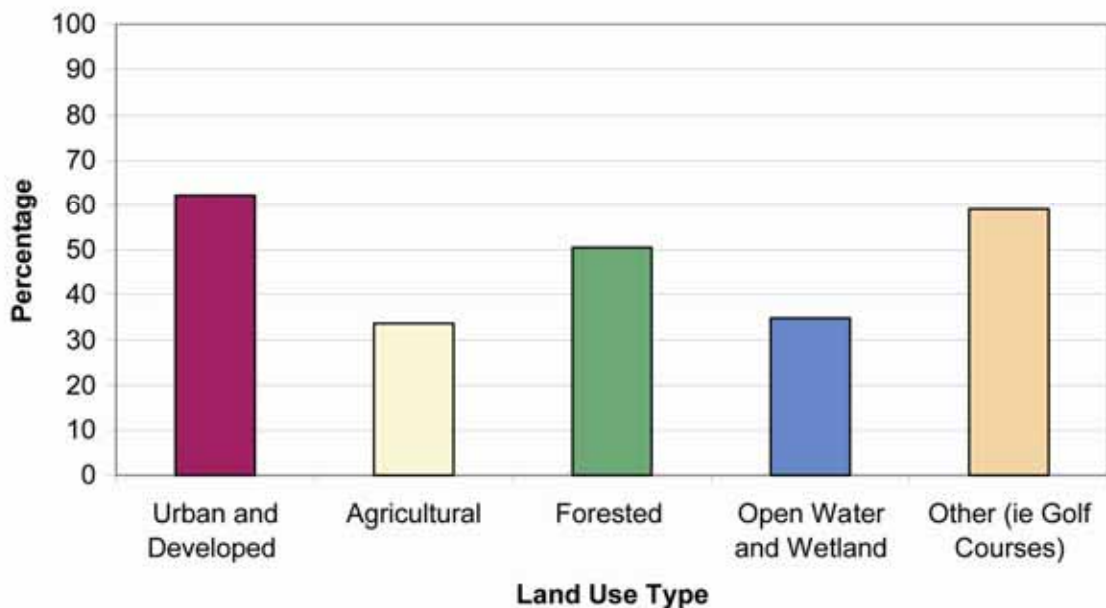


Figure 3. Percentage of land use type in significant recharge areas in the Grand River watershed. Source: Grand River Conservation Authority

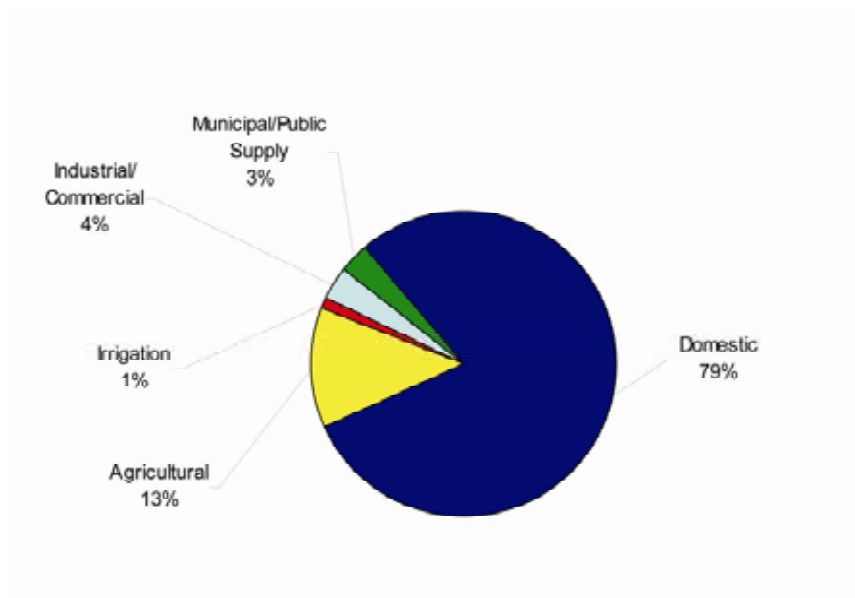


Figure 4. Distribution of groundwater wells by primary use in the Grand River watershed.
Source: Ontario Ministry of the Environment Water Well Database (2003)

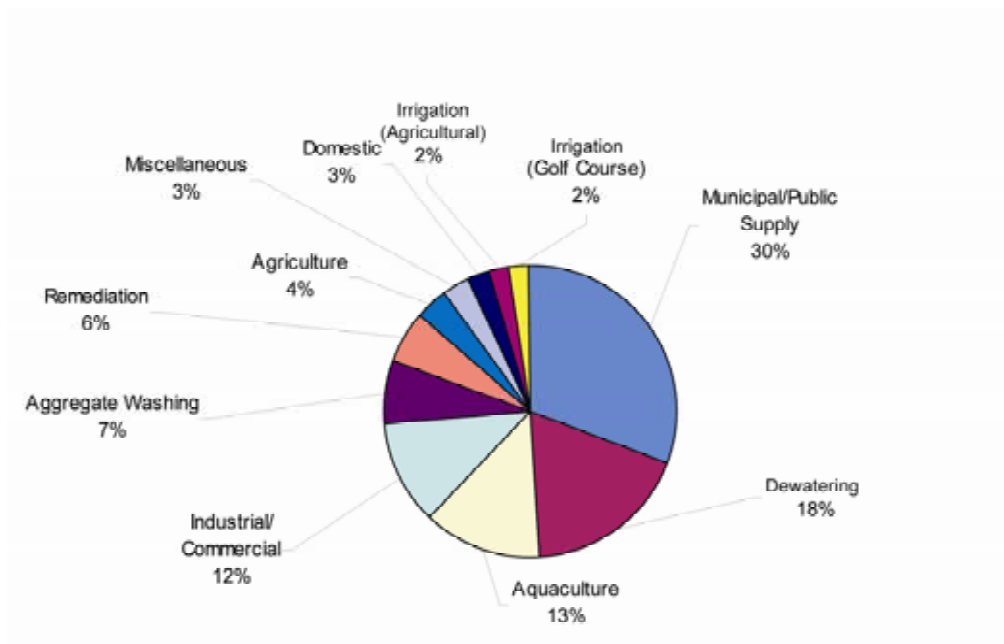


Figure 5. Percentage of total annual groundwater takings in the Grand River watershed from designated uses.
Source: Modified from Bellamy and Boyd (2004)

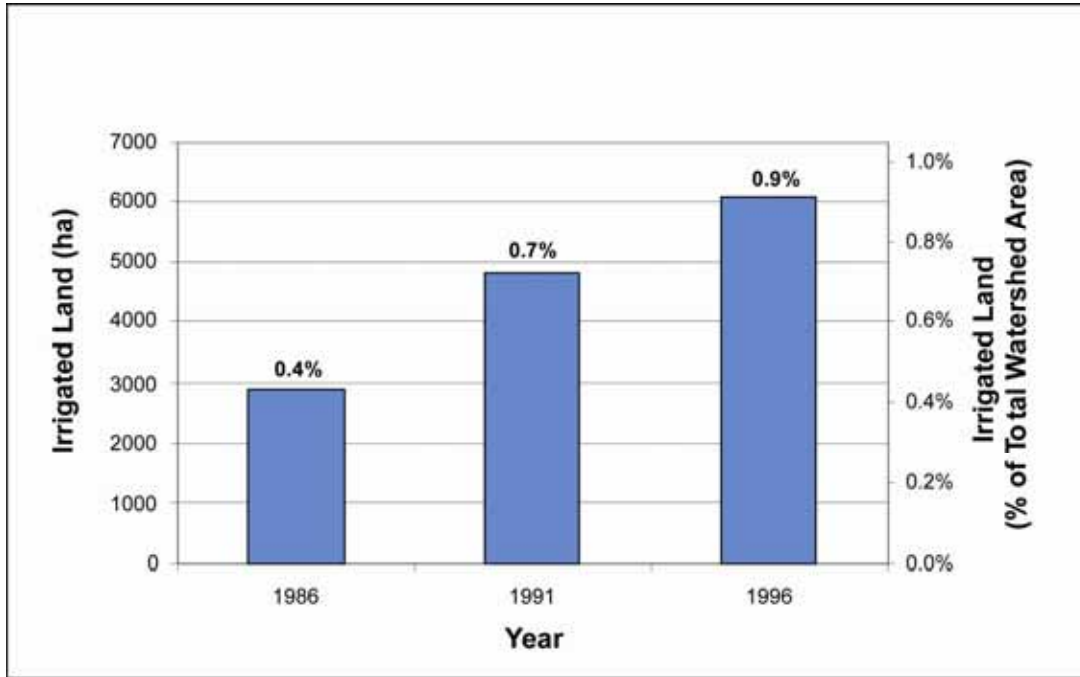


Figure 6. Changes in amount of irrigated land in the Grand River watershed (percentage of total watershed area irrigated).

Source: Statistics Canada data for 1986, 1991, and 1996

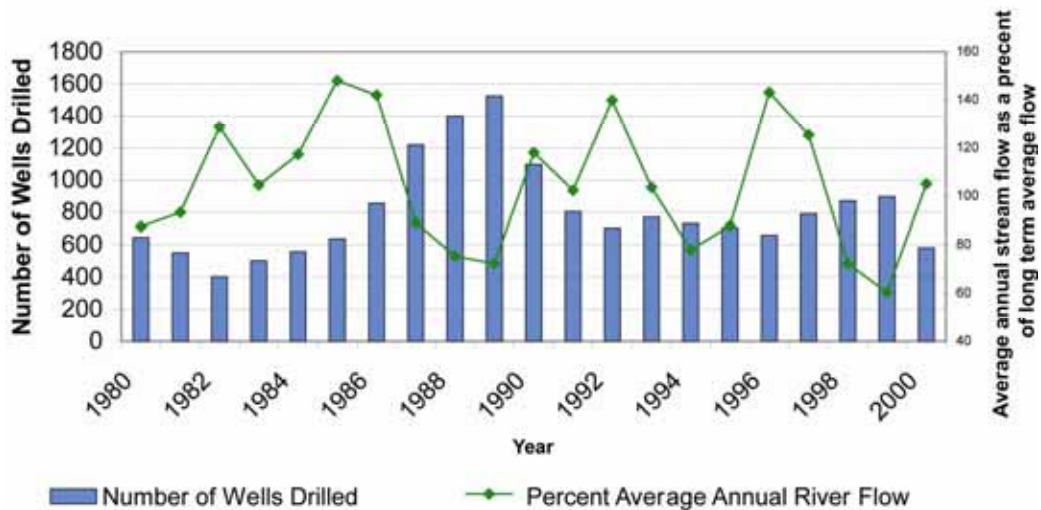


Figure 7. Number of new wells drilled each year (bars). Annual average stream flow (as a percentage on long term average) in the Grand River watershed illustrating below average, and average climatic conditions (green line).

Source: Ontario Ministry of the Environment Water Well Database (2003)

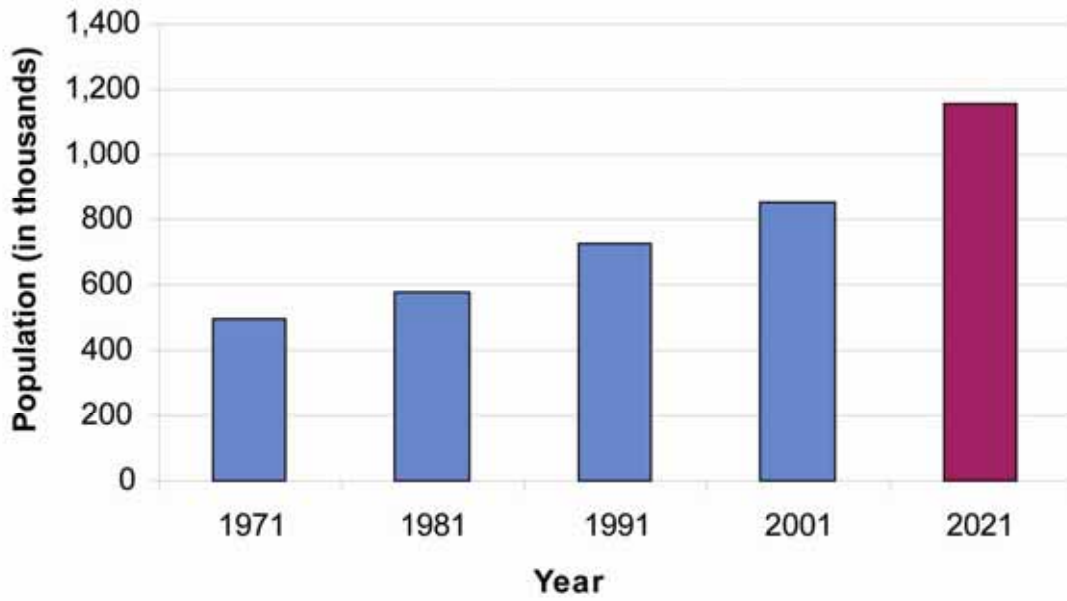


Figure 8. Estimated population in the Grand River watershed including future projections (burgundy bar).
Source: Dorfman (1997) and Grand River Conservation Authority (2003)