ENGG*6820 Measurement of Water Quantity and Quality

TERM PAPER

CLIMATE CHANGE IMPACT ON CANADA

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Abstract

Water scarcity is a serious matter in the world but here in Canada water shortage is not a present concern. Although, the inability to manage water may restrain future social and financial advancement and may arise concerns about water scarcity in this nation. Climate change and geographical factors affect the distribution of water in Canada. Also, water resources are stressed by contamination, increasing population. This paper aims to assess the impacts of climate change on Canada's groundwater resources. This paper would also give a literature review on the history of climate change impacts groundwater resources within Canada and on the groundwater resources worldwide. The climate varies with the time, if we look at earth’s climate billions of years ago, it was dramatically different from today. Also, the amount of water on earth is distributed in the form of Glaciers (69.40%), Groundwater (30.28%), Surface water (0.31%) Since we know the water in form of Glaciers is not accessible and thus all of the world population rely on groundwater and surface water. In Canada, most of the people use groundwater to complete their daily needs. So, it is important to see how climate change affecting water resources. This study discusses the precipitation and temperature-related consequence of climate change in Canada. This paper began with the introduction of water resources and the amount of water available on earth and in Canada, the discussion is based on historical data available. Then the use of groundwater and surface water would be discussed for different purposes which indicates that most of the Canadian population depend on groundwater resources because of many reasons including lack of infrastructure to sustain the surface water and from the economic aspect. Precipitation and temperature effects the groundwater resources in the form of recharge and evapotranspiration. The results would give the idea of how climate change affecting the groundwater resources in Canada.

Keywords. Climate change, precipitation, temperature, groundwater resources, evapotranspiration, recharge.

INTRODUCTION

Canada is considered a water-rich country. But the problem is the magnitude and extent of the accelerating demand for water and the impact of climate change on water resources is growing. This paper discusses the various aspects of water-related to climate change. Groundwater is not a separate resource, it is linked with surface water, it can be influenced via land use, human activities, pollution, over-exploitation and Climate change (Rivera, Introduction, 2013). “The climate is a realm of variation” (Abott, 2012). Environmental change happens at about each historic and geologic time scale inspected. In the event If we look at environmental change on a few scales, for instance, billions of years, millions of years, hundreds of years, tens of years and a couple of years, the atmosphere is changing constantly and is influencing everything on earth. Climate change as:

- Seas bowls open and continents drift
- Earth's circle around the sun changes
- Volcanism pumps ash and gas up into the stratosphere
- the sun consumes more sizzling or colder
- Worldwide ocean level ascents or falls
- People burn enormous volumes of wood, oil, gas, and coal (Abott, 2012).

Water resources are highly influenced by climate change. This paper first discusses the amount of water available on earth and in Canada. It is important to address the use of water if we are going to study the changes in water So, this paper represents the water resources on the global level and in Canada and then the withdrawal of freshwater by the Canadians and by the world population. Evapotranspiration affects the amount of groundwater and surface water runoff.

1.Amount of groundwater in the World and Canada

Assessment of the amount of water on earth is questionable. The most precise proposal is credited to Russian researchers, who have bent over backward to set up and refine the measure of water on earth (Rivera, Introduction, 2013). The table is giving information about the amount of water on the Planet.

Table1. EVALUATIONS OF TOTAL WATER VOLUME ON EARTH

(FROM THE WORLD RESOURCES INSTITUTE,1990)

	VOLUME	% OF TOTAL
Oceans	1,350,000,000	97.1
Glaciers	27,500,000	1.984
Groundwater	8,200,000	0.592
Inland Seas	105,000	0.00758
Freshwater Lakes	100,000	0.00722
Humidity in soils	70,000	0.00505
Humidity on air	13,000	0.00094
Rivers	1,700	0.00012
Water in living cells	1,100	0.00008

(Rivera, Introduction, 2013)

It can be observed from the table that a massive amount of water is in the form of Oceans and Glaciers which shows the critical situation about the limited amount of water. Water in the form of Ocean is unfit for drinking purposes and 27,500,000amount of water is not accessible which is in the form of glaciers. As a consequence, we are left with a very limited amount of water which is useable**.**

Canada. The world has a huge amount of water in different forms but here we are talking about Canada's water resources. Table 2 showing the results of the estimation of the available average amount of surface water and groundwater in Canada. The original annual supply will change from year to year (Rivera, Introduction, 2013).

Table 2. AMOUNT OF SURFACE WATER AND GROUNDWATER IN CANADA (AVERAGE VALUES FOR DIFFERENT YEARS)

NAME	SURFACE WATER ($KM^{3/}Y$)	GROUNDWATER ($KM^{3/}Y$)	TOTAL
CANADA	2,901	380	3,281
USA	2,662	1,300	3,992
MEXICO	361	139	500

(Rivera, Introduction, 2013)

2.Availability and Use of Renewable Freshwater

Amount of freshwater available plays a key role in the process of estimating the dangers to water resources, there are mainly two sources of available freshwater in the form of yearly surface water runoff and groundwater recharge. Another important factor to consider is the actual use of freshwater.

Available Freshwater. Figure 1. displays a graphical representation of the world's renewable freshwater in each continent from the report published by "The Pacific Institute for Studies in Development, Environment, and Society in the year 2004". The data in the report introduces both renewable fresh surface water and groundwater in each continent (Rivera, Groundwater Sustainable Development in Canada — Emerging Issues, 2008).

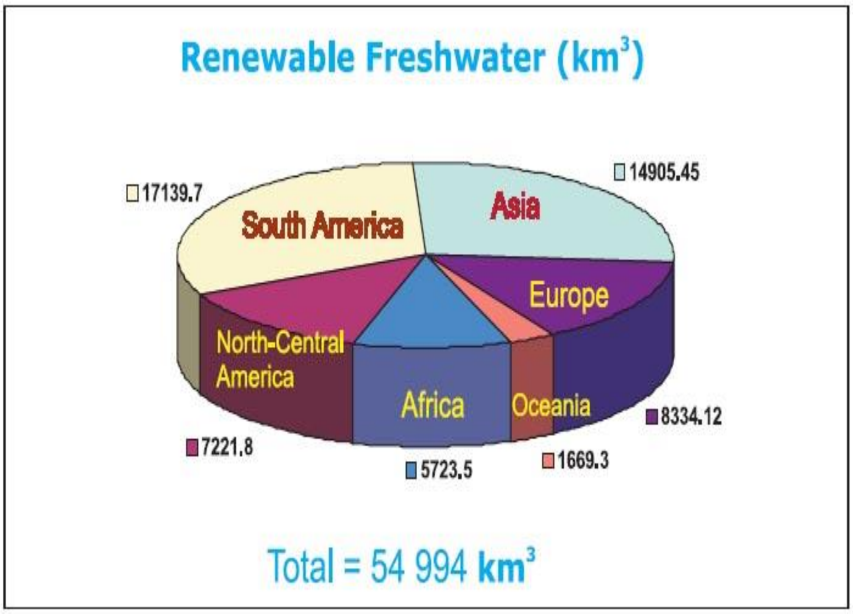

Figure 1. Total renewable freshwater supply by continent (Rivera, Groundwater Sustainable Development in Canada — Emerging Issues, 2008)

According to the report (2004) world have total 54,994 km^3 amount of available freshwater, which is the sum of surface water and groundwater.

Use of Freshwater worldwide.

Figure 2. shows the graphical representation of the world's total freshwater withdrawal for each region from the Institute's 2004 report. Table 3. Illustrates the amount of water used by world population for domestic, industrial and agricultural sectors in the 20th century. We can see the increased use of water over the hundred years period (Rivera, Groundwater Sustainable Development in Canada — Emerging Issues, 2008). It is clear from table 3 that World withdrawals of total freshwater are between 3,500km^3 to 5,500km^3 per year. Which is not the issue because the amount of water extracted is far less than the available renewable freshwater. But as mentioned above the use of water is increasing dramatically which can create problems in future.

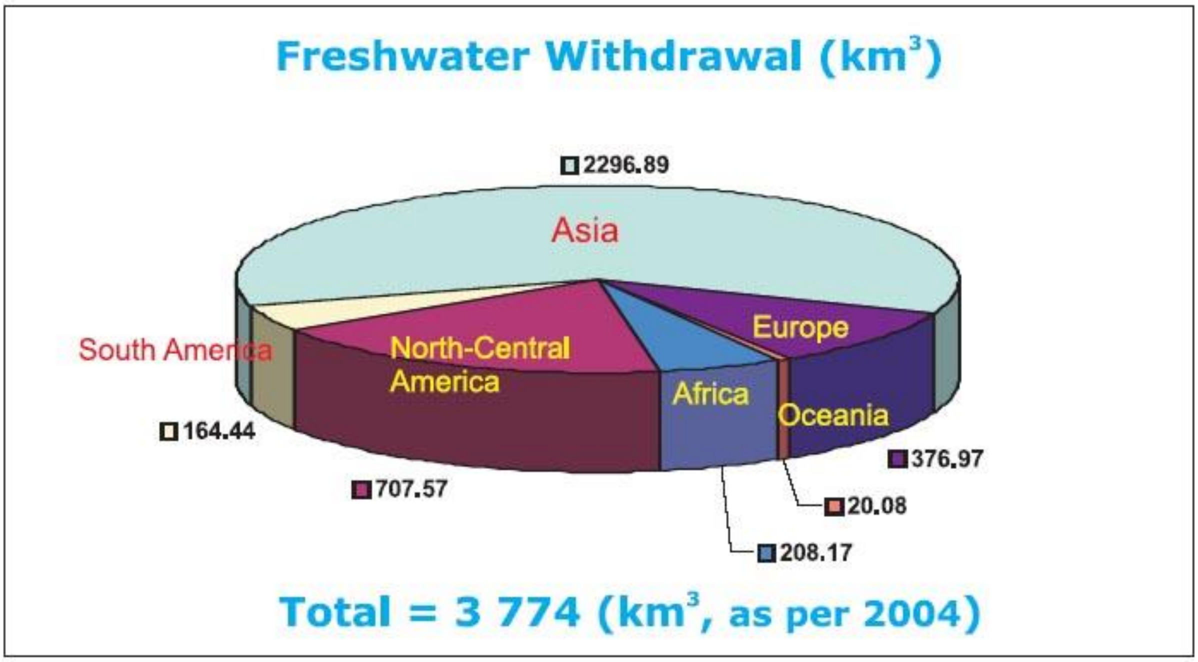

Figure.2. Total freshwater withdrawal by continent (Rivera, Groundwater Sustainable Development in Canada — Emerging Issues, 2008).

Table 3. WATER CONSUMPTION IN THE WORLD DURING THE 20TH CENTURY.

SECTOR	1900	1850	1990	2000	% (IN 2000)
Agriculture	525	1,130	2,680	3,250	63
Industry	37	178	937	1,280	25
Domestic	16	58	470	661	12
Totals	578	1,366	4,123	5,191	

Use of Freshwater in Canada.

The amount of water taken from the source is used for industrial, domestic, and agricultural sectors (Figure 3).

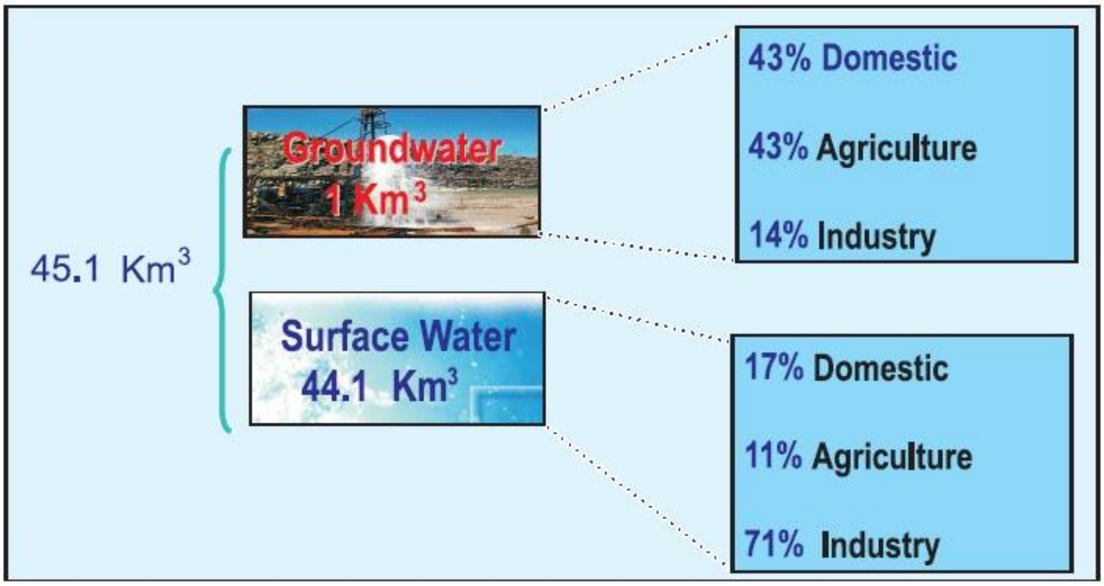

Figure.3. Freshwater withdrawals in Canada for 1996 (Rivera, Groundwater Sustainable Development in Canada — Emerging Issues, 2008)

Why groundwater has been a Primary source for water use in Canada.

There is no recent compilation of groundwater use in Canada. Because groundwater use varies according to the resource regulation in each province and territories and groundwater use is not always reported.

- Based on 1996, statistics data, Environment Canada reports that 30% of Canada's population relies on groundwater for municipal, domestic and rural use.
- If we consider the 2010, population which was 33.7million, Environment report implies that 10.2 million Canada's population depend on groundwater.
- 2/3 of Canada's population lives in rural areas where people rely on wells for a water supply because of the more reliable and less expensive water source.
- The population depend on groundwater in Canada varies from 21% in Alberta to 100% in Prince Edward Island (Figure.4).
- Remaining 33% population lives in small municipalities, people there also consider groundwater as their primary source of water.
- Canada does not have installed capacity to sustain all of the available surface water that is why the use of groundwater for domestic purposes increased dramatically, from 10% in the late 1960s to 30% in the late 1990s (Kohut, Wei, Allen, & Nowlan, 2013).(shown in Figure.5). Most of the withdrawn groundwater in Canada is used for domestic and agricultural purposes as shown in Figure.3. Nearly 30% of the Canadian population depends on groundwater for drinking purpose (Rivera, Groundwater Basics, 2013)

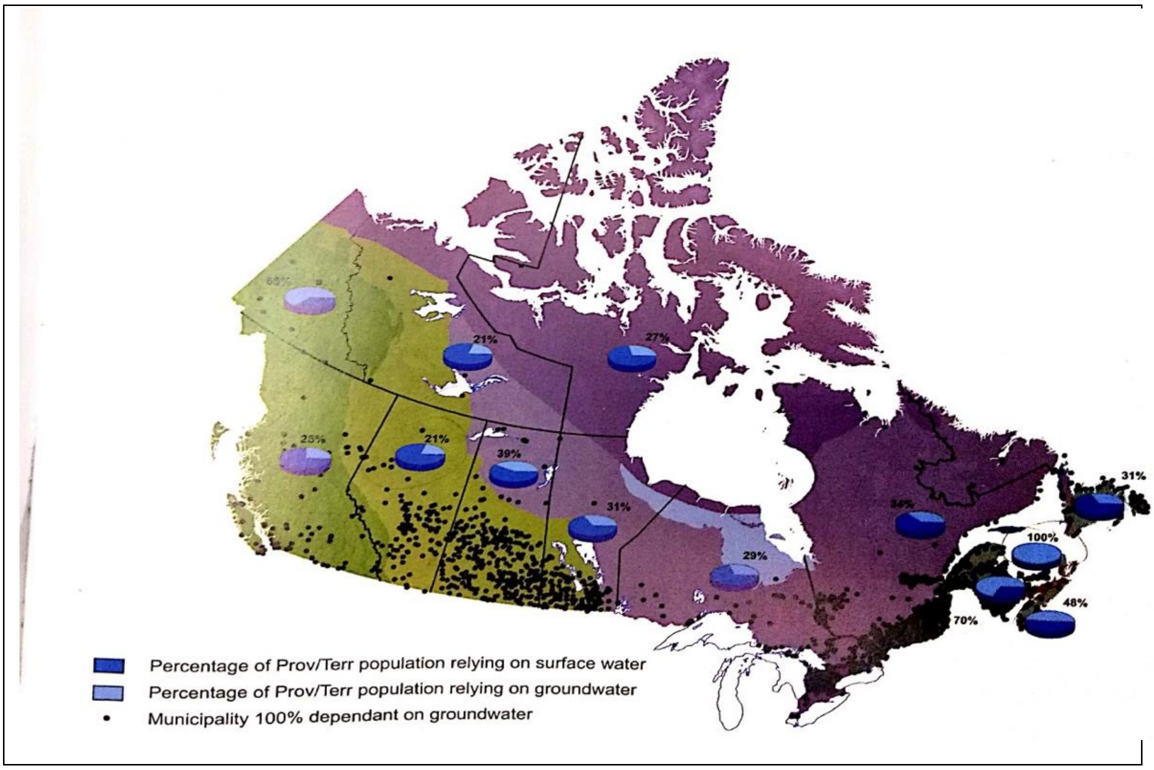

Figure.4. Groundwater use in each province and territory (Kohut, Wei, Allen, & Nowlan, 2013).

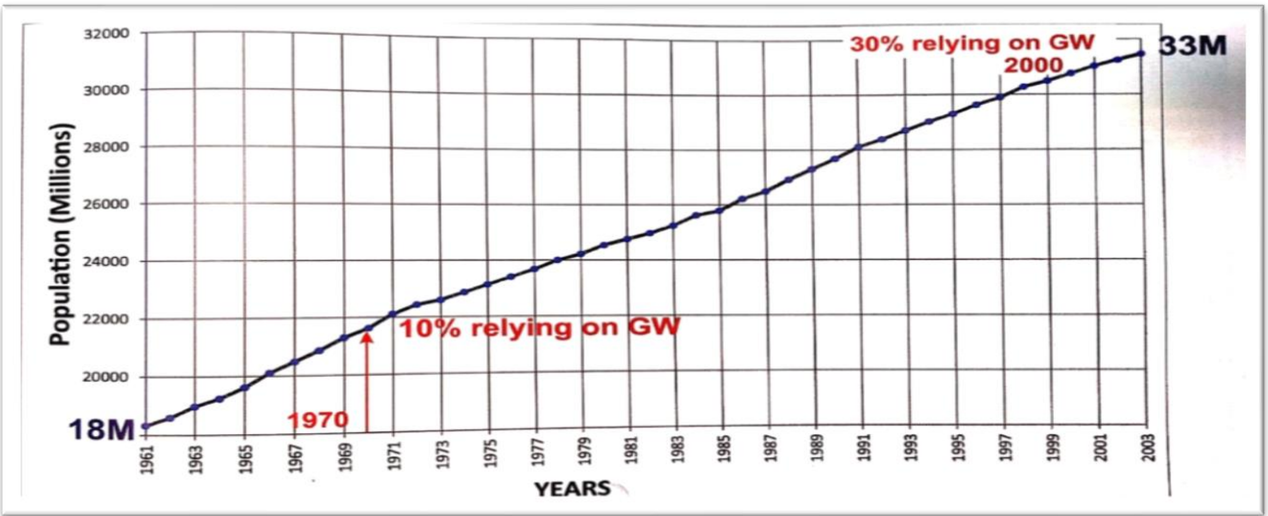

Figure.4. Groundwater use in Canada since the 1960s (Kohut, Wei, Allen, & Nowlan, 2013).

3.Climate change impacts on water resources

The climate of the region plays a significant part in groundwater recharge. It is mostly described in terms of precipitation and temperature. Groundwater is water that infiltrates into the ground, filling the pores, cracks, voids, and fractures of soils and rocks and essential part of the hydrological cycle. Most of the precipitation falls on the ground’s surface is redirected to the atmosphere as direct evaporation, or as transpiration from vegetation in whole called evapotranspiration.

Infiltration. 13% of total precipitation infiltrates into the soils and rocks at the ground surface. Deeper infiltration of water into the ground represents the recharge to the groundwater.

Surface runoff. This overland flow eventually from rivers depends on the soil type and rain intensity and representing on average 24% of precipitation.

Evapotranspiration. It is the most important flux of the water cycle, which represents 63% of annual precipitation on average (Rivera, Introduction, 2013). Evapotranspiration is closely related to both precipitation and temperature.

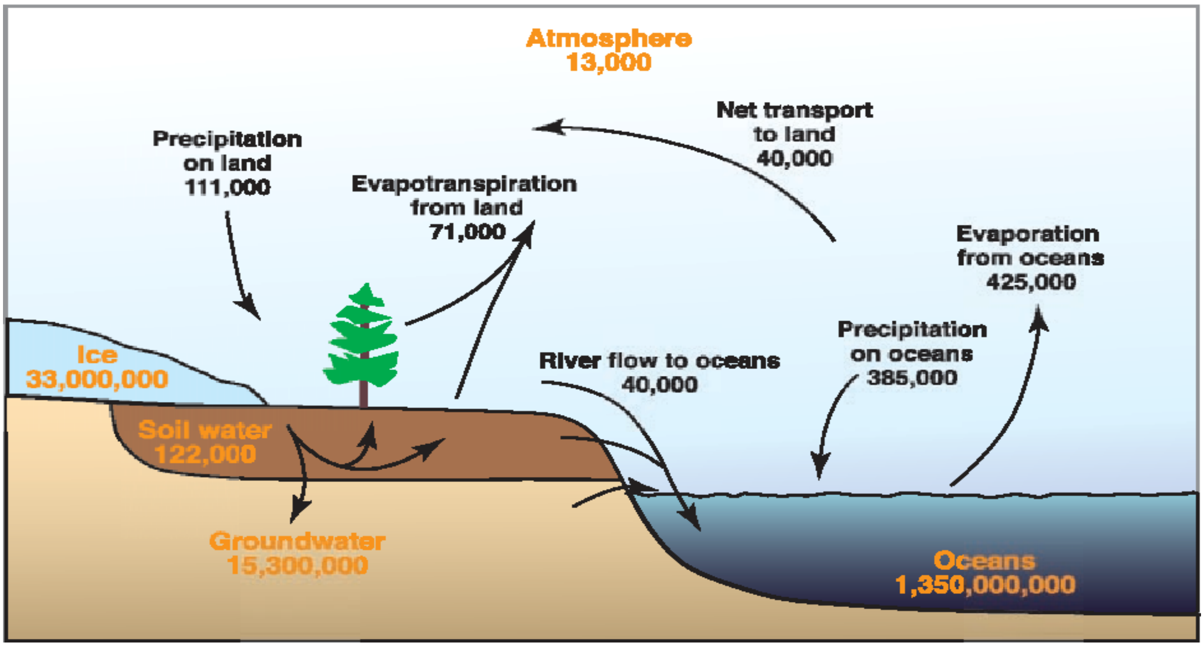

Figure 4. Global pools and fluxes of water on earth(reported in 1997) (Rivera, Groundwater Basics, 2013).

Table 4. Global Evapotranspiration and Precipitation Values

Parameter	Volume
Evaporation on oceans	425,000 km^3/year
Evaporation on continents	71,000 km^3/year
Precipitation on oceans	385,000 km^3/year
Precipitation on continents	111,000 km^3/year

(Rivera, Groundwater Sustainable Development in Canada — Emerging Issues, 2008)

Table 5. Water Fluxes from continents to Oceans

	Volume
The Flow rate of rivers	27,000 km^3/year
Baseflow from aquifers to rivers and oceans	10,500 km^3/year
Input from glaciers to oceans	2,500 km^3/year
Total	111,000 km^3/year

(Rivera, Groundwater Sustainable Development in Canada — Emerging Issues, 2008)

(A)Precipitation Impact on water resources. Precipitation is a major segment of the hydrologic cycle, and the most important climate variable regulating groundwater recharge. Precipitation reaches the Earth's surface in many forms, including rain, snow, freezing rain, sleet, and hail. Canada' s land does not receive uniform precipitation. The annual precipitation distribution is described below.

- West coast = 2500 - 4,000 millimetres

- East coast = 1,000- 1,250 millimetres
- Prairies = 250- 500 millimetres
- Extreme north =120-150 millimetres (as snow)

Figure.5. Showing the mean annual precipitation across Canada (mm/year) based on Canada precipitation map, Department of Energy, Mines and Resources, Forestry,1991.

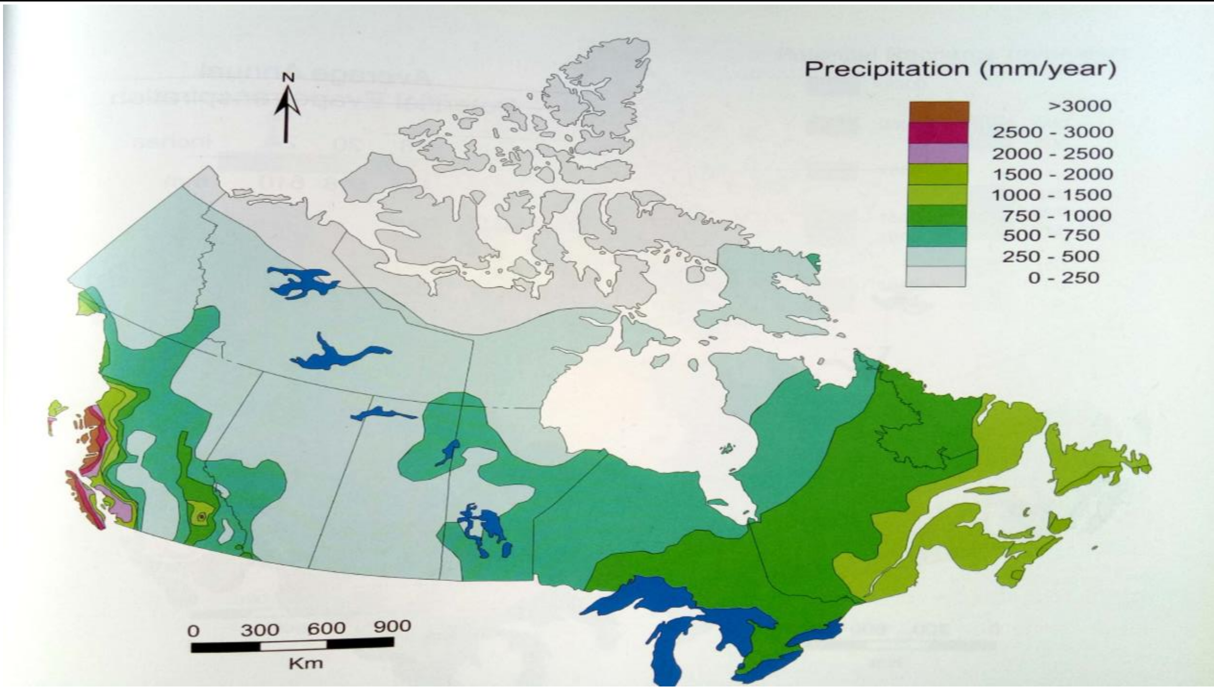

Figure.5.Variation in mean and annual precipitation on Canada (Allen, 2013).

Precipitation mainly affects the groundwater resources in the form of recharge.

Recharge. It is the process by which groundwater is replenished. which indicates that the total volume of available freshwater depends on recharge. To protect the groundwater resources recharge is crucial. Recharge is controlled by the following factors:

- Climate
- land cover/land use

- Topography
- Characteristics of the soil
- Geologic substrate (Allen, 2013).

Some of these factors may vary with time such as climate, thus significant to analyze the impacts of climate on recharge.

- Potential recharge. Potential recharge is the difference between the precipitation and the evapotranspiration which represents the amount of water available for groundwater recharge (shown in Figure.7)

The recharge is assembled into two types.

- **Direct recharge**. water infiltrates the ground directly from rainfall or snowmelt
- **Indirect recharge**. water penetrates ground indirectly from streams and rivers.

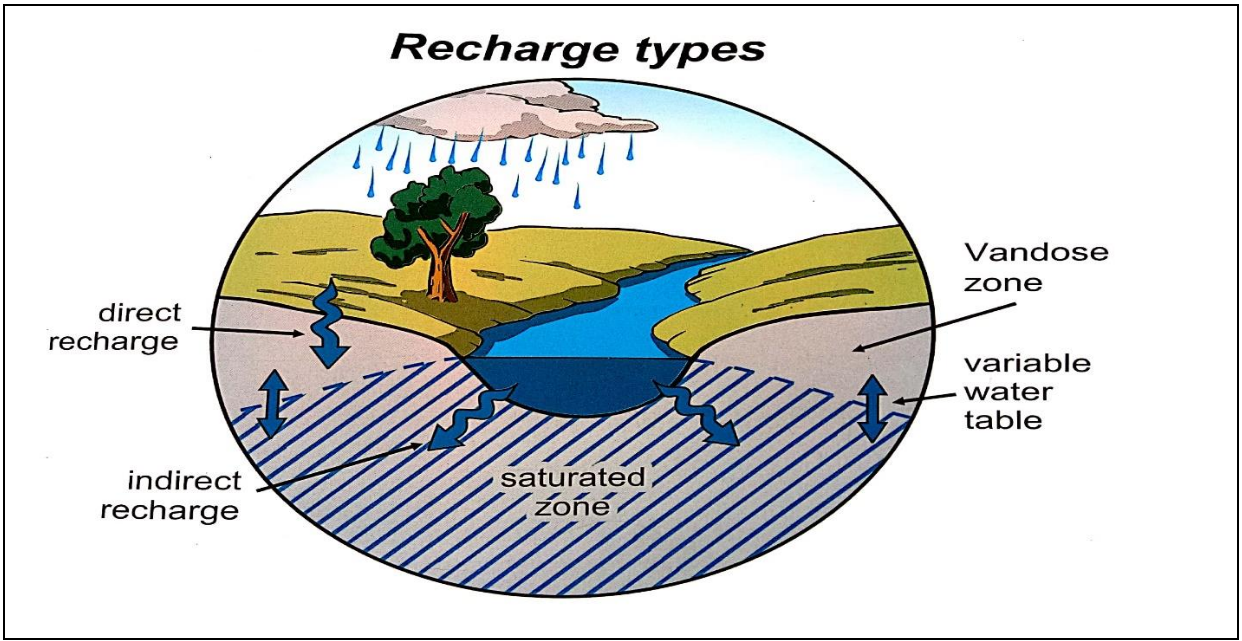

Figure.6. Recharge types.

Here the focus in on direct recharge because of the concern climate impact on groundwater.

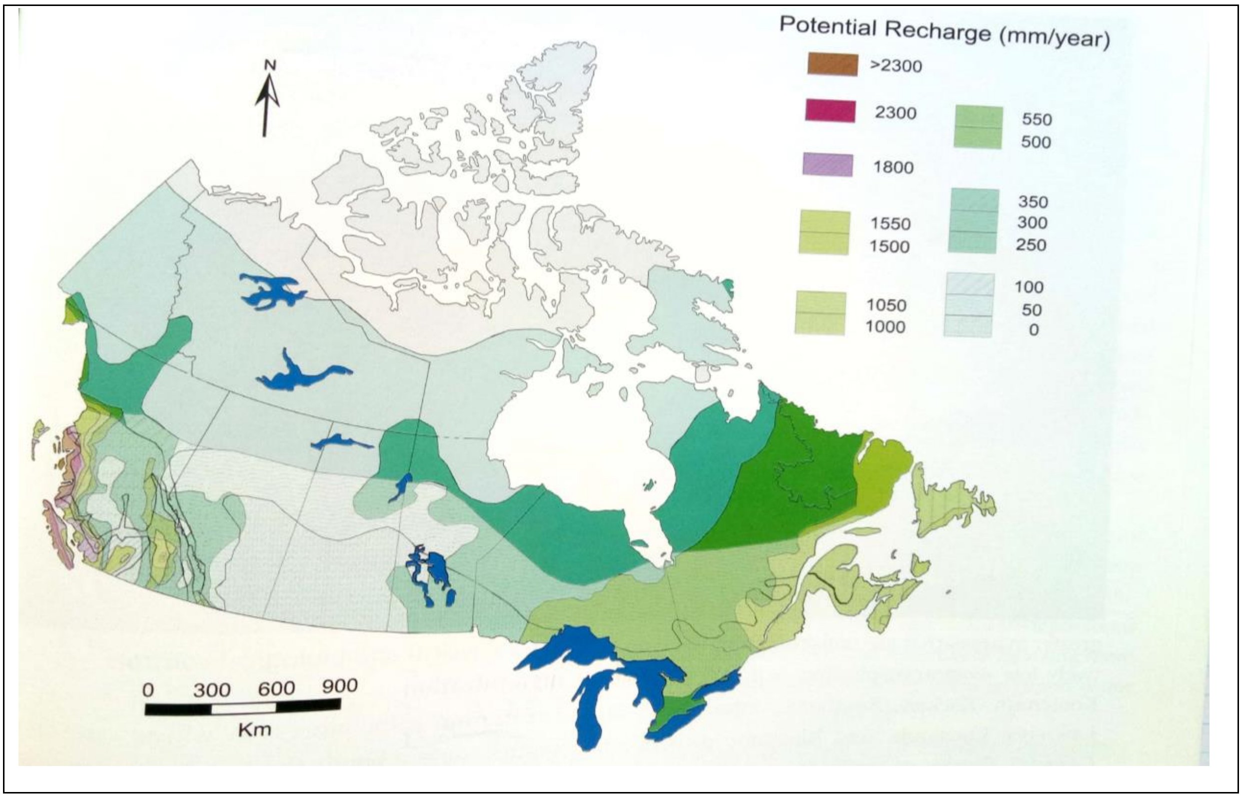

Figure.7. Annual potential recharge across Canada (Allen, 2013)**.**

There are mainly two groundwater sources confined and Unconfined aquifers.

Confined Aquifers.

Confined aquifers normally occur at the bottom, and maybe recharged at some distance from a point of extraction and, in some cases, very deep aquifers may be revived in remote mountain ranges. This groundwater is older and also furthermore more mineralized because of its more drawn out contact with rocks and sediments. Confined aquifers in complex geological formations may be partly exposed at the land surface, or the low permeable confining layer may be breached, allowing direct recharge from infiltrating precipitation. Confined springs in complex geographical developments might be mostly uncovered at the land surface, or the low permeable layer might be ruptured, permitting direct revive from penetrating precipitation (Allen, 2013).In figure 7.

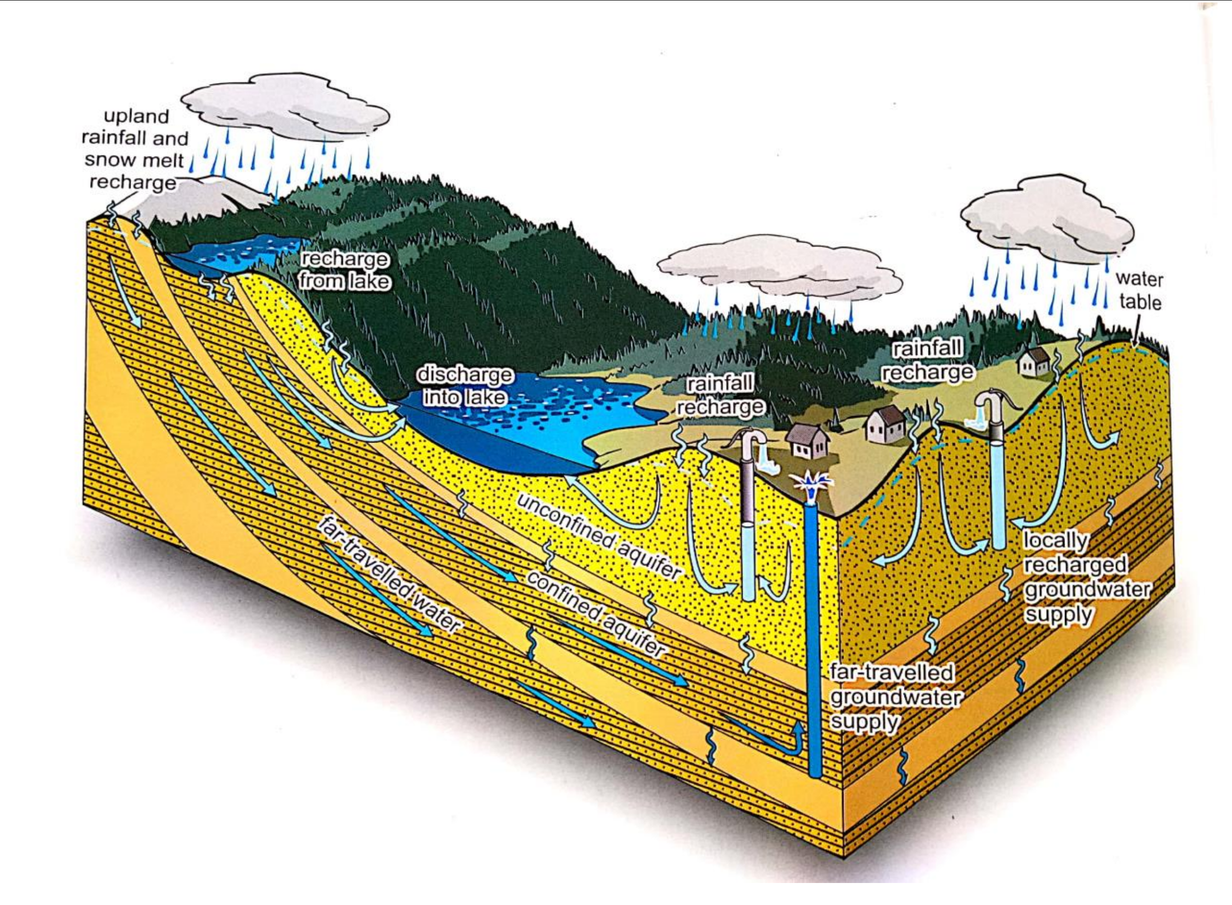

Figure.8 Groundwater in Confined and Unconfined Aquifers.

Unconfined Aquifers.

The direct and indirect recharge in the unconfined aquifer is shown in figure 6. In which water directly penetrating the groundwater through Vadose zone and via influent stream. In this case, precipitation moves downward to the water table Shown in figure7.

(B)Temperature impact on water resources.

Temperature also varies according to the location but not the same as precipitation. During the summer season, ground infiltration helps from the close surface supply of water needed for evaporation and transpiration. However, in cooler seasons, water infiltrates deeper into the ground and revive groundwater (Rivera, Groundwater Basics, 2013). The effect of temperature on the groundwater is mainly in the form of evapotranspiration. Momentary increases of groundwater to shallow springs might be separated by evapotranspiration without adding to spring recharging. For instance, in the southern piece of the Prairie territories, the driest district in Canada, the lateral progression of snowmelt and tempest storm runoff moves water into geographically closed depressions, causing depression-centred groundwater to revive (Allen, 2013).

The rate of direct recharge is very small because evapotranspiration demands often exceed available precipitation (Allen, 2013). This direct effect of temperature in the form of evapotranspiration on water resources helps in the discharge of groundwater.

Evapotranspiration and potential recharge

Evapotranspiration is the sum of evaporation and plant transpiration. Which varies according to change in both location and season. It is the movement of water in the form of vapours to the atmosphere which affects runoff, water cycle, groundwater recharge and discharge (Allen, 2013).

Potential evapotranspiration. Which means the ability of the atmosphere to remove water through evaporation and transpiration.

Actual Evapotranspiration (AET). The amount of water removed from the surface due to evaporation and transpiration is known as AET.

Both PET and AET affects the amount of water available on earth figure 8.

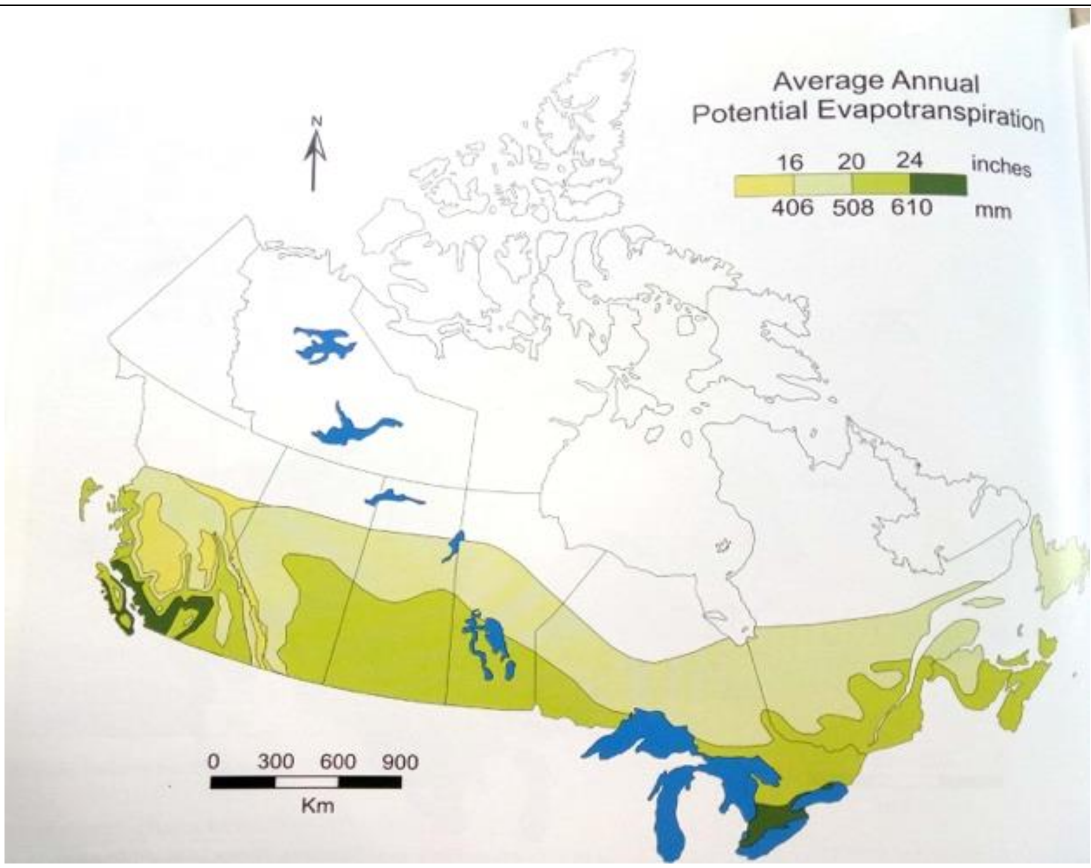

Figure.8. Average annual potential Evapotranspiration.

4. Results and Discussion

- We can see the expanded utilization of water over the hundred years. If we compare the amount of available freshwater from table 5, We have approximately 40,000 km3/year. If 27,000 km3/year of water cannot be contained by the capacity of the world’s dam then only 10,500 km3 of baseflow is left.
- This shows that in the year 2000, the total water withdrawal in the world was 5,191 km3 which was half of the volume of the accessible freshwater.
- Canadian dams have a limit of 846km3 to support surface water.
- This implies that the problem is not a shortage of water, however the divergence between the populace requirements and the water resource location.
- Canada's use of freshwater indeed seems negligible as compared to the world. Nevertheless, we should be careful when assuming this because of diversity in geography, population, and climate.
- Evapotranspiration affects the amount of recharge to the groundwater.

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