Science Curriculum Resource

The Water Cycle on Prince Edward Island

Introduction

- Water is an essential component of the environment. It affects our health, and many aspects of our daily lives. It plays an important role in shaping the very nature of the surroundings we live in.

The Hydrosphere

- Water exists in many places in the environment, which collectively can be referred to as the *hydrosphere* or *watersphere*
- It includes all the earth's water that is found in streams, lakes, the soil, groundwater, and in the air.

- Water is constantly on the move from one part of the hydrosphere to another. These links are important in our understanding and use of water, and can be described using the concept of the *Water Cycle*.

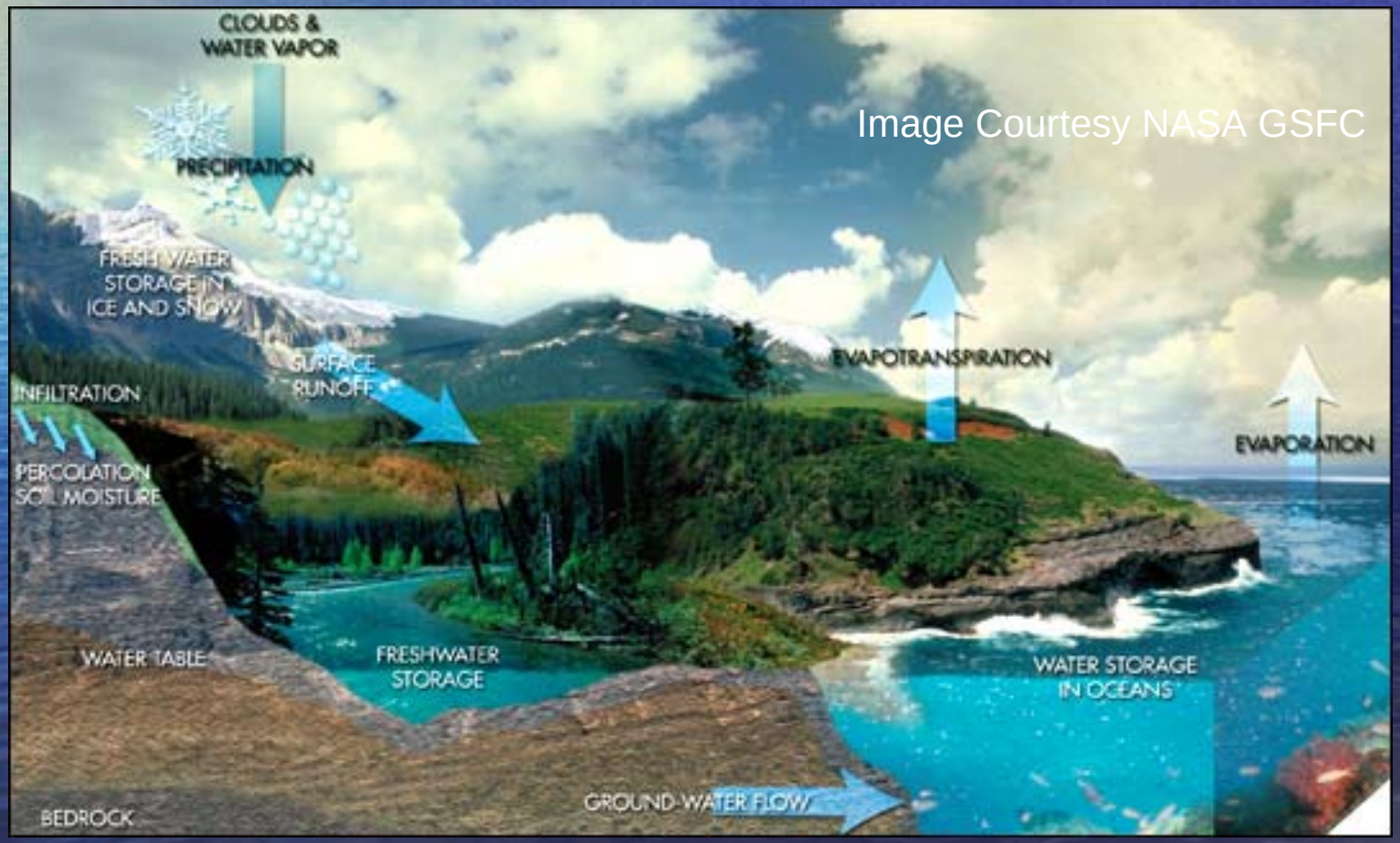


Image Courtesy NASA GSFC

Water's *Place* in the Environment

- Water exists in three physical states in the environment:

Gaseous State
(water vapor)

Liquid State
(liquid water)

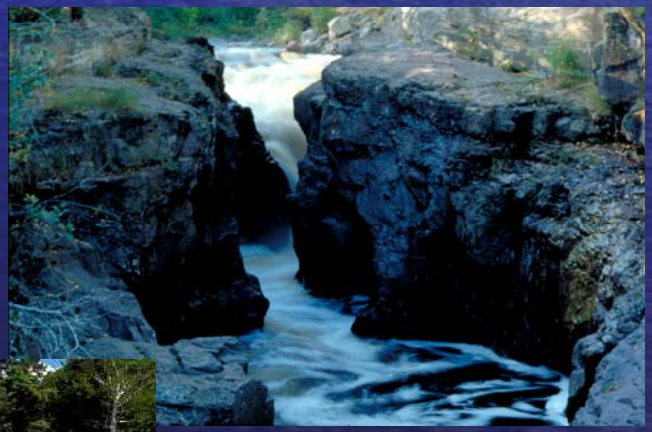
Solid State
(ice or snow)

Water Storage

Water is stored in a number of *reservoirs* in the environment

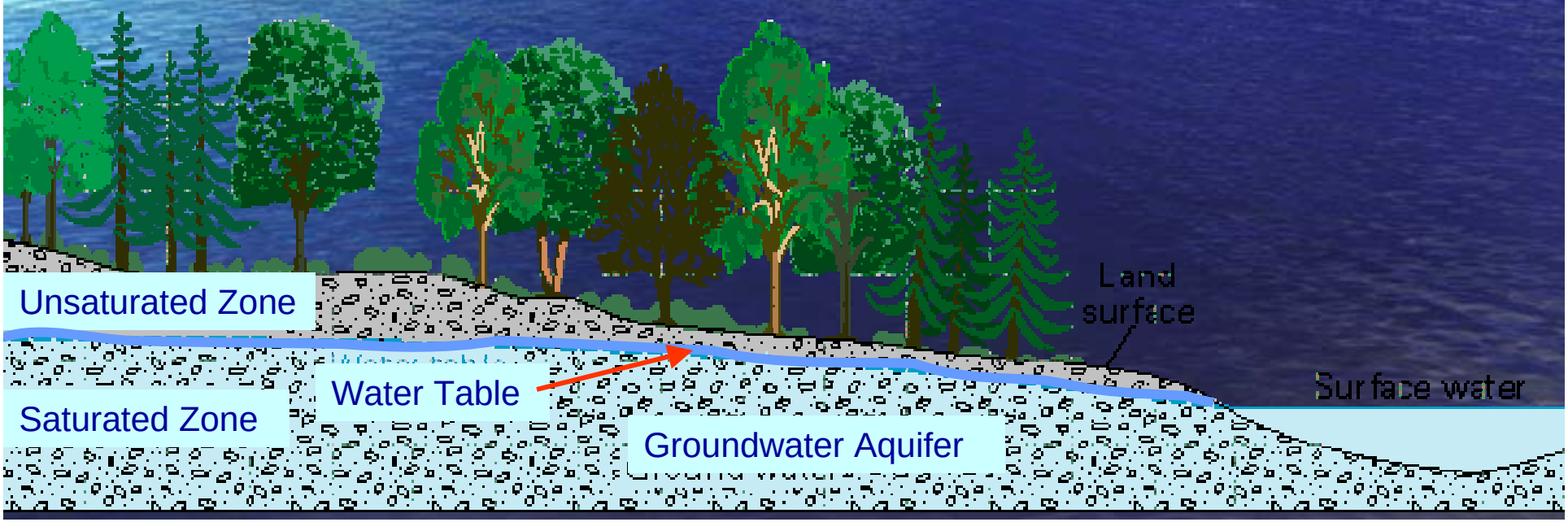
- in the atmosphere as a vapour and as a liquid (clouds, humidity)

- on the earth's surface as a liquid…
  - *Surface water such as oceans, ponds, lakes and rivers*
  - *Snow and ice including glaciers and permafrost*



Photos Courtesy Natural Resources Canada

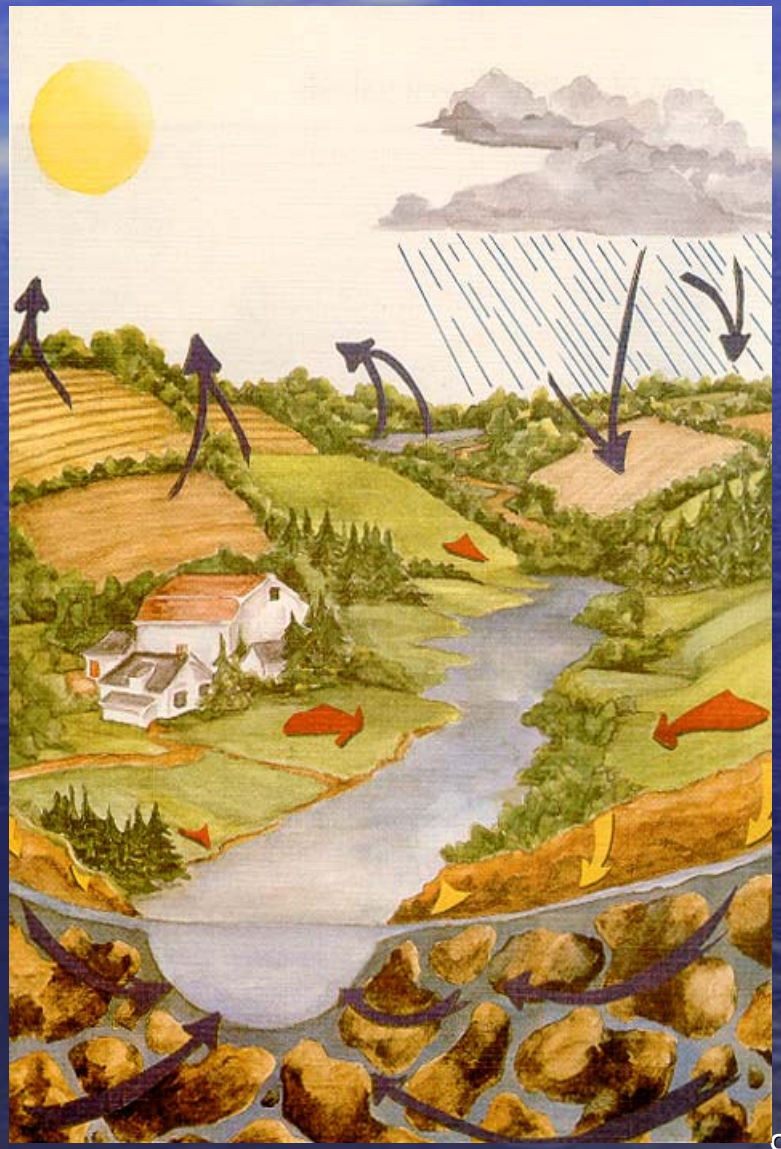
- in the ground as soil moisture, or stored as groundwater in reservoirs called *aquifers*



Water moves from one state to another and from one location to another through a number of processes:

Solar Energy

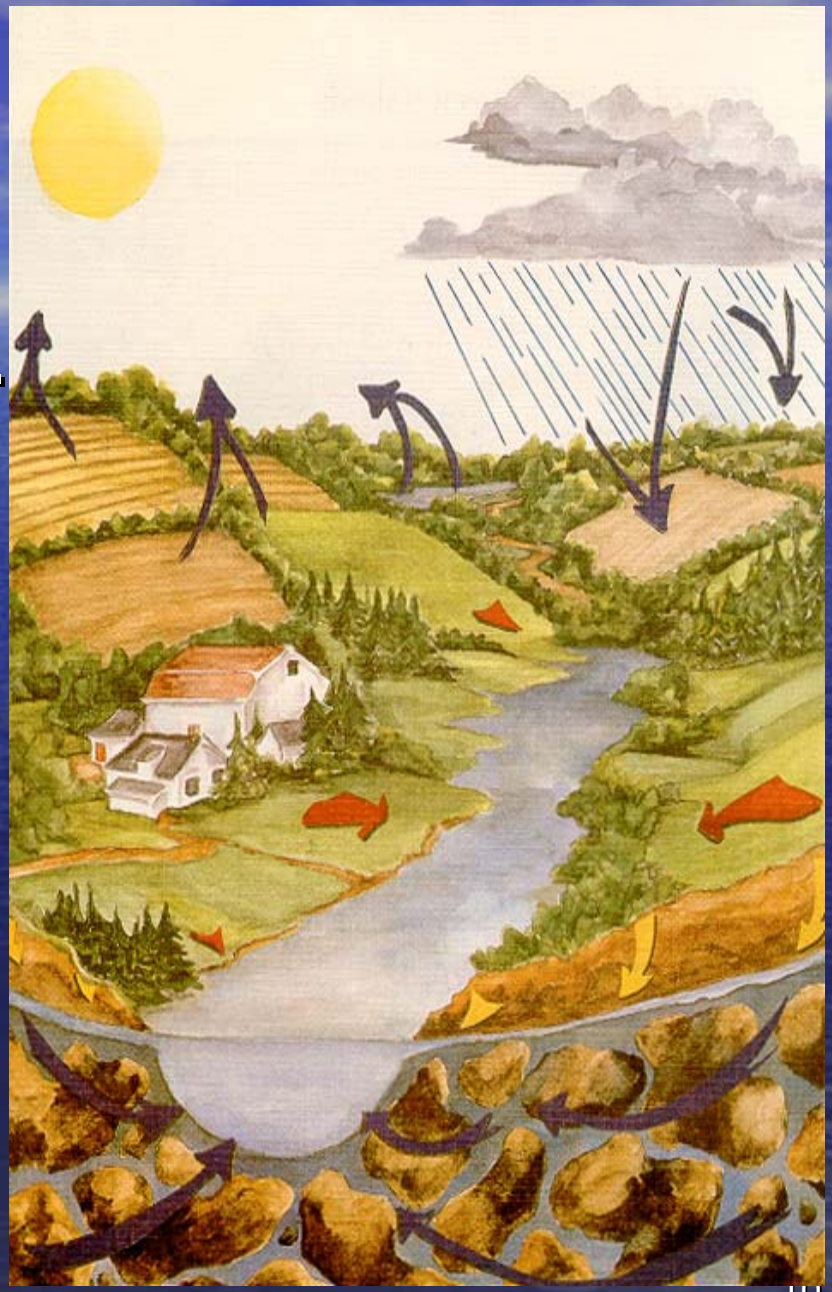
- Energy from the sun moves water from the earth's surface to the atmosphere in two ways:
- Evaporation - *water is evaporated to form water vapor (gas).*
- Transpiration - *water used by plants is also released through the leaves to the atmosphere as a vapor*



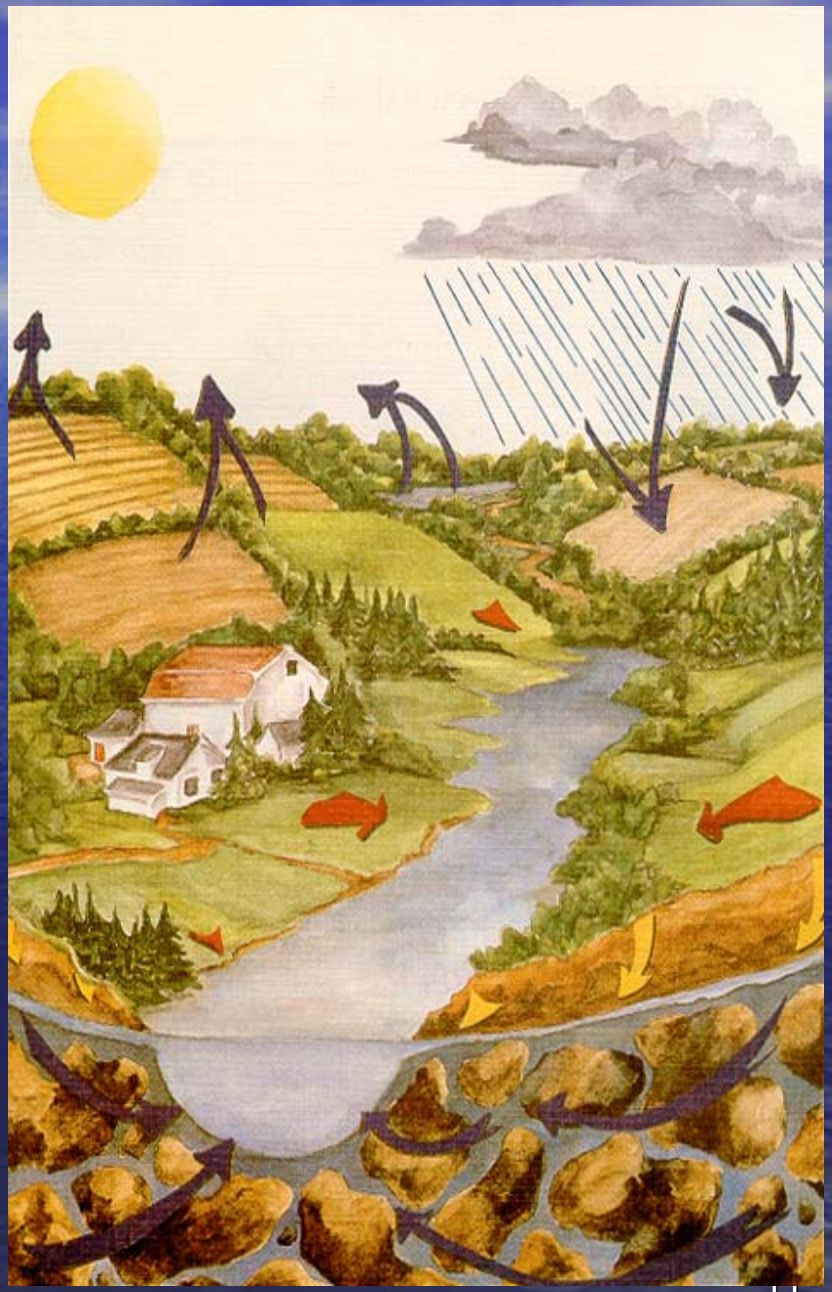
Gravity

Gravity is responsible for water movement at and below the Earth's surface.

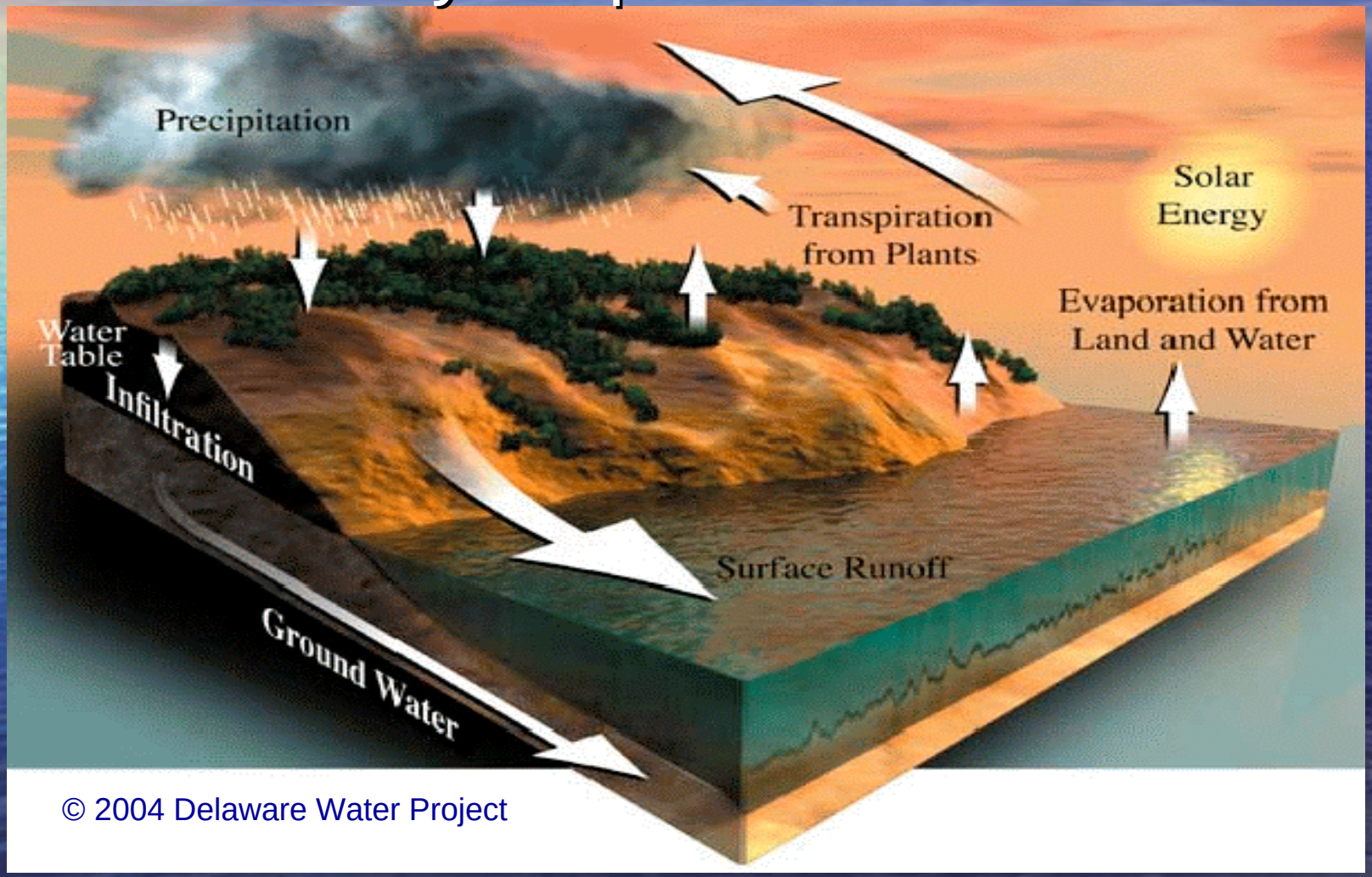
- Precipitation - *water vapour condenses to form rain or snow, and falls to the earth's surface.*
- Run-off - *precipitation and melting snow and ice run-off to lakes and streams*



- Infiltration - precipitation and melting snow and ice seep through the soil to be stored as groundwater
- Groundwater flow - groundwater flows underground through the rocks and soil and is eventually discharged to the surface into lakes and streams.



The Water Cycle can be used to describe the movement of water in and between different portions of the Hydrosphere

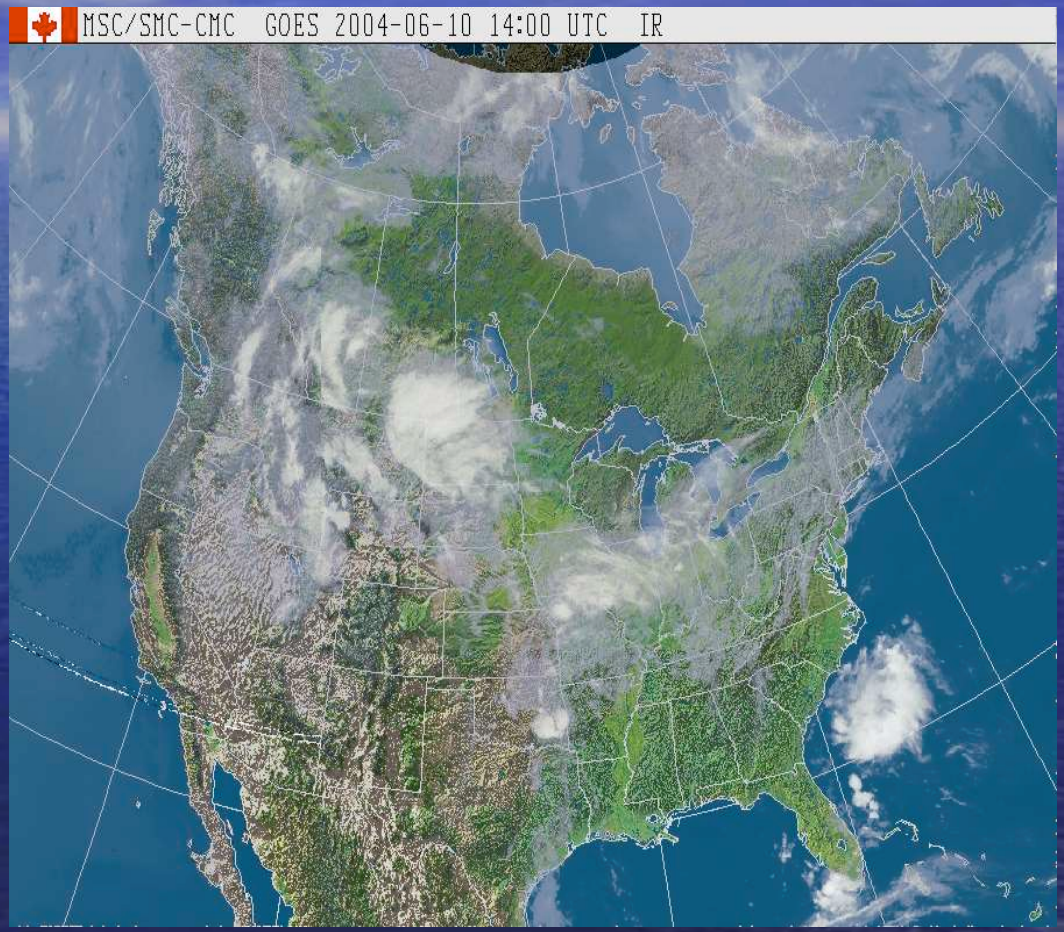


© 2004 Delaware Water Project

Water in the Atmosphere

- The air that makes up the atmosphere always contains some water, either in the form of clouds, or simply as humidity.
- While this accounts for a small amount of the world's fresh water, the atmosphere plays a very important role in carrying water from one place to another around the globe.
- The movement of water vapor through the atmosphere is a major influence on local climate.

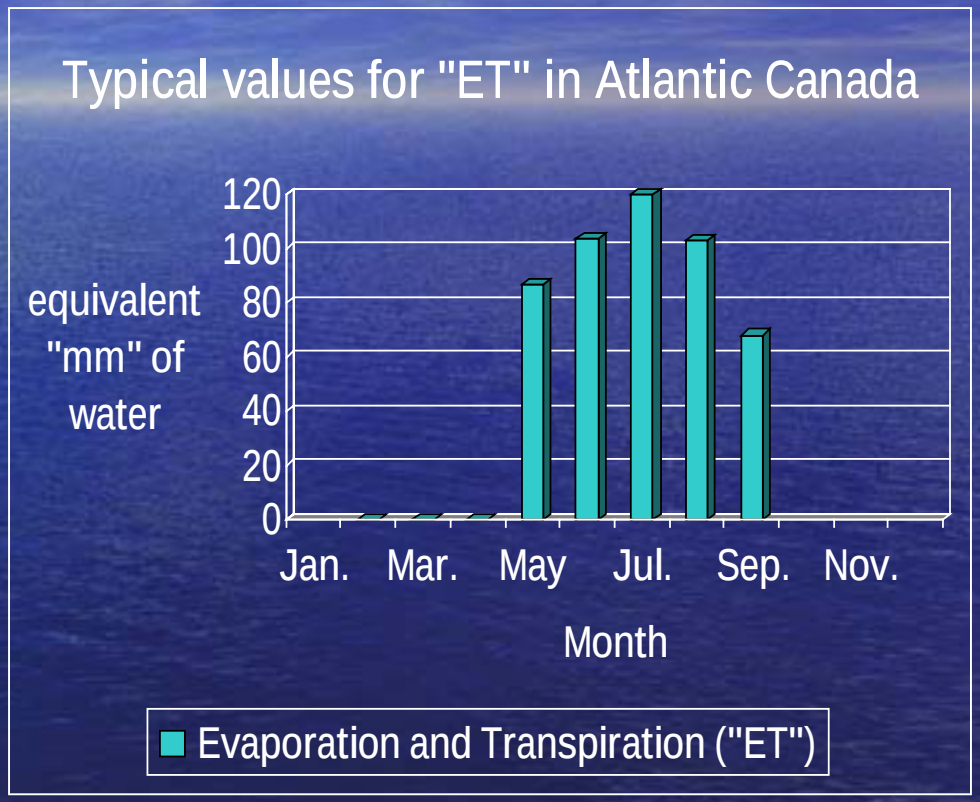
- In PEI, much of the moisture in the atmosphere is “imported” by weather systems traveling west across the continent, or from the south west along the eastern seaboard – this is what gives us our (comparatively) wet weather.



Evaporation and Transpiration

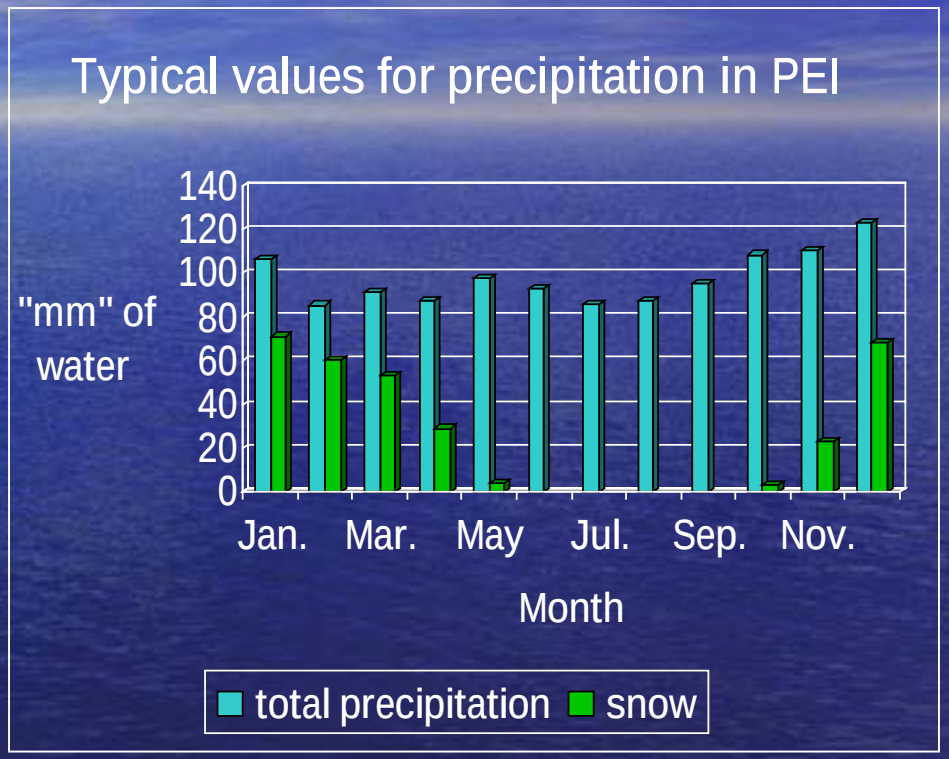
(evapotranspiration – ET)

- Evaporation and transpiration of moisture into the atmosphere require relatively warm temperatures; significant effects on PEI are normally limited to the period from late spring to early fall.



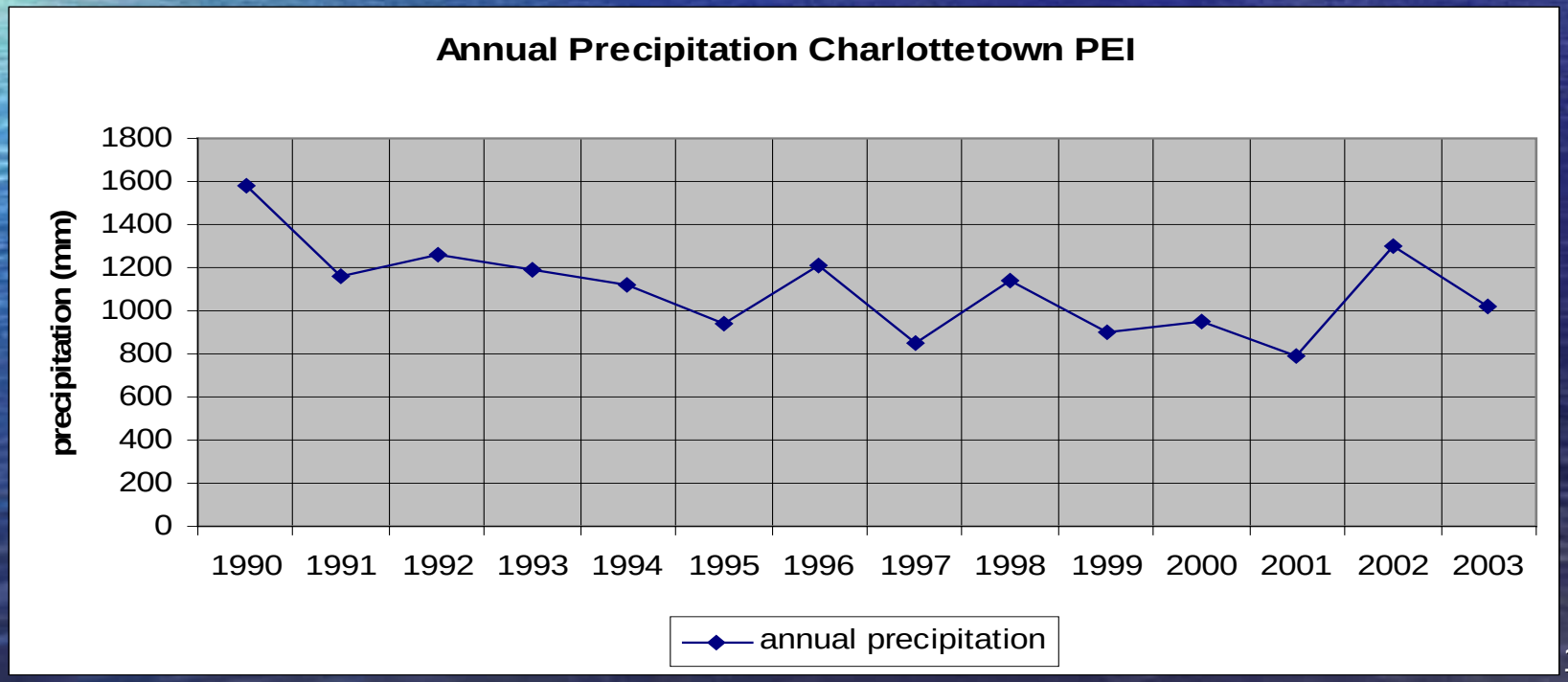
Precipitation

- Water is “precipitated” from the atmosphere as rain or snow. In an average year, about 1,100 mm of precipitation falls on Prince Edward Island. About 25% of total precipitation falls as snow.



* In the graph above, snowfall has been converted to its liquid equivalent. 1 cm of snow represents about 1 mm of water.

- While the month to month amount of precipitation is relatively consistent, the total amount of annual precipitation can vary substantially from year to year.
- A comparison of annual precipitation for 1990 and 2001 helps to illustrate this point, with rainfall in 1990 being about double the amount in 2001.



Investigation: Precipitation Data, Charlottetown PEI

Listed in the table below is the data used to prepare the graph on the previous page. The data has been collected from the Charlottetown weather station over the last 53 years.

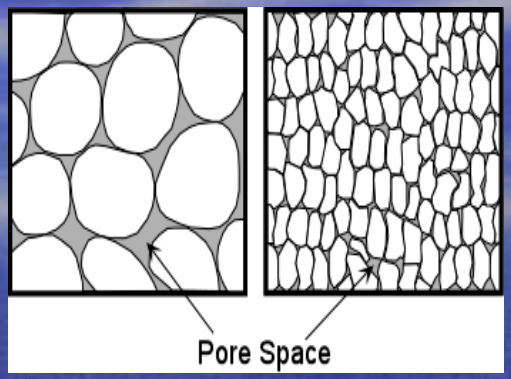
- Select any ten year period from the table below and plot it on graph paper.
- What is the average annual amount of precipitation for the ten year period you selected?
- Describe any trend that your data suggests about precipitation rates.

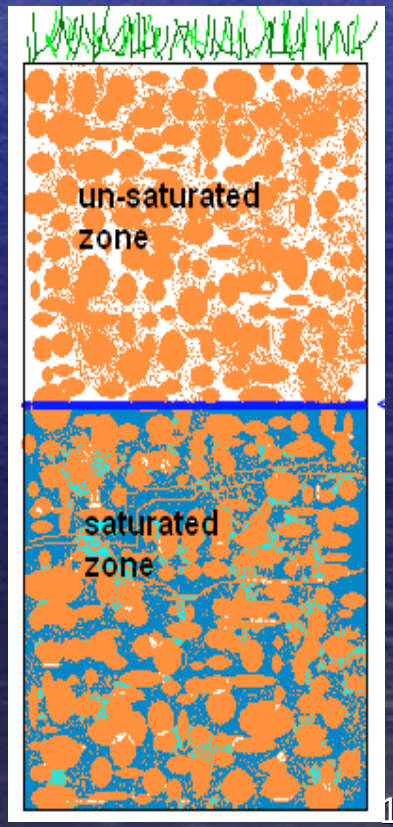
Annual Precipitation (mm/year)

year	precipitation	year	precipitation	year	precipitation	year	precipitation	year	precipitation	year	precipitation
1950	953	1960	849	1970	1188	1980	1093	1990	1579	2000	953
1951	1267	1961	1051	1971	1101	1981	1407	1991	1159	2001	787
1952	1056	1962	1382	1972	1335	1982	1237	1992	1255	2002	1297
1953	1159	1963	1328	1973	1137	1983	1169	1993	1189	2003	1024
1954	1282	1964	1131	1974	1166	1984	1299	1994	1120		
1955	1097	1965	832	1975	1050	1985	948	1995	937		
1956	1141	1966	998	1976	1276	1986	1055	1996	1209		
1957	1180	1967	1430	1977	1332	1987	1188	1997	848		
1958	1194	1968	1253	1978	1162	1988	1254	1998	1140		
1959	1048	1969	1108	1979	1343	1989	1153	1999	901		

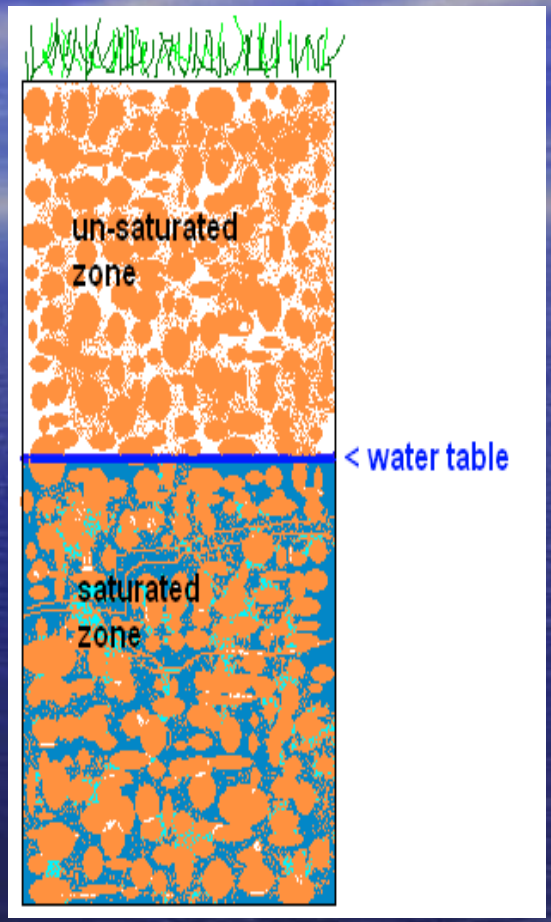
Groundwater: What is It?

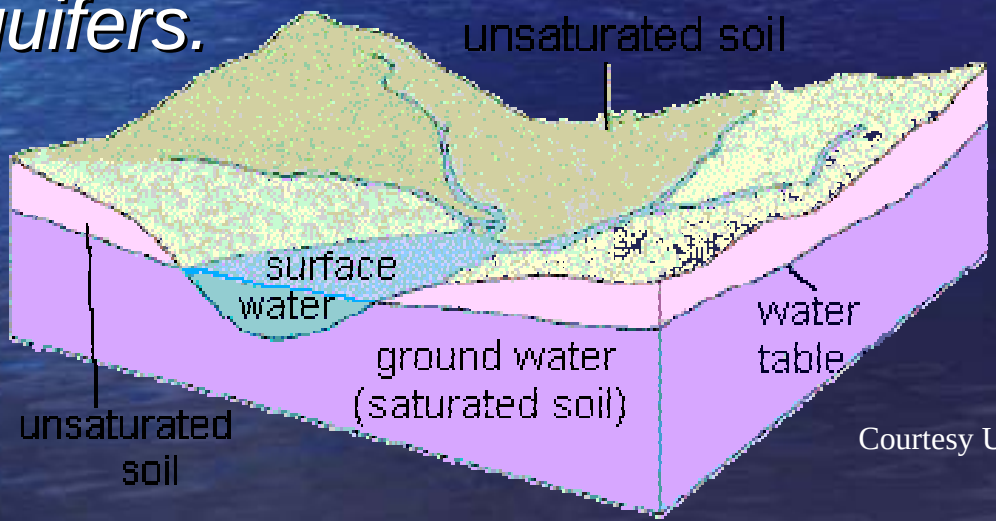
- Groundwater is water stored in the ground in the tiny pore spaces in the soil and rock below us. When we pump water from a well, we are pumping groundwater.
- The area below the ground surface can be divided into two zones:
  - Saturated zone where these void spaces are completely filled with water.
  - Un-saturated zone where pore spaces and fractures in rocks and soil are partially filled with air, and partially filled with water.





- The *water table* is the boundary between the un-saturated and saturated zones.
- Some parts of the saturated zone hold large quantities of groundwater that can be pumped to the surface. These geological formations are called *aquifers.*

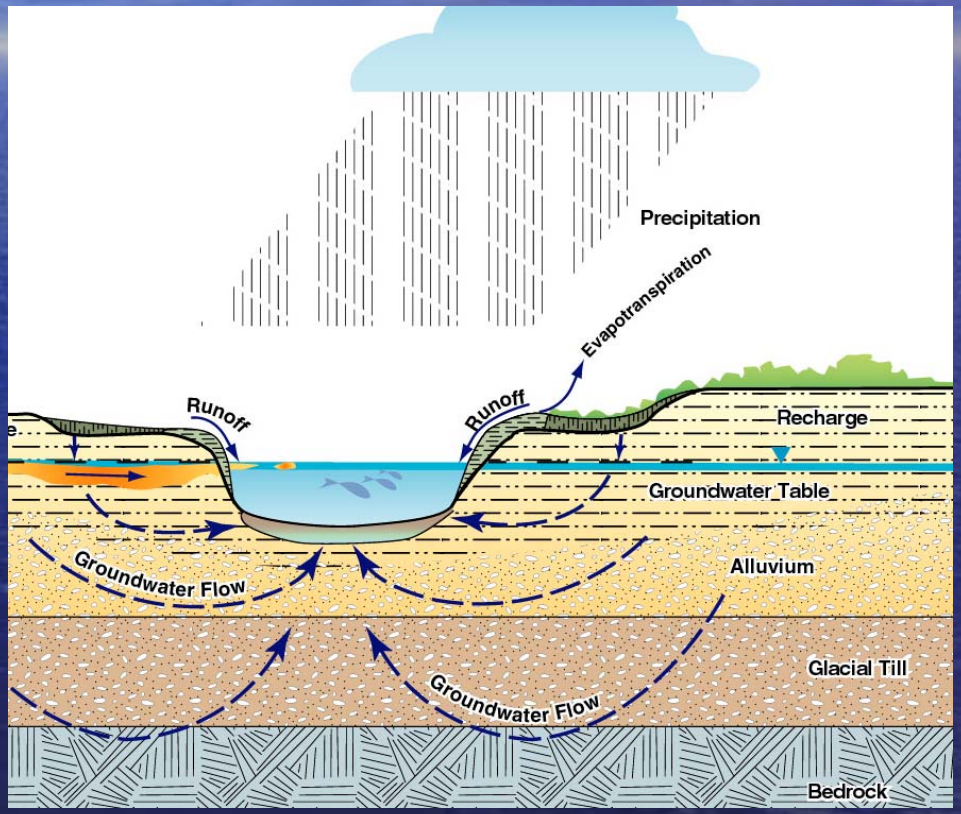




Courtesy USGS

The Groundwater Cycle

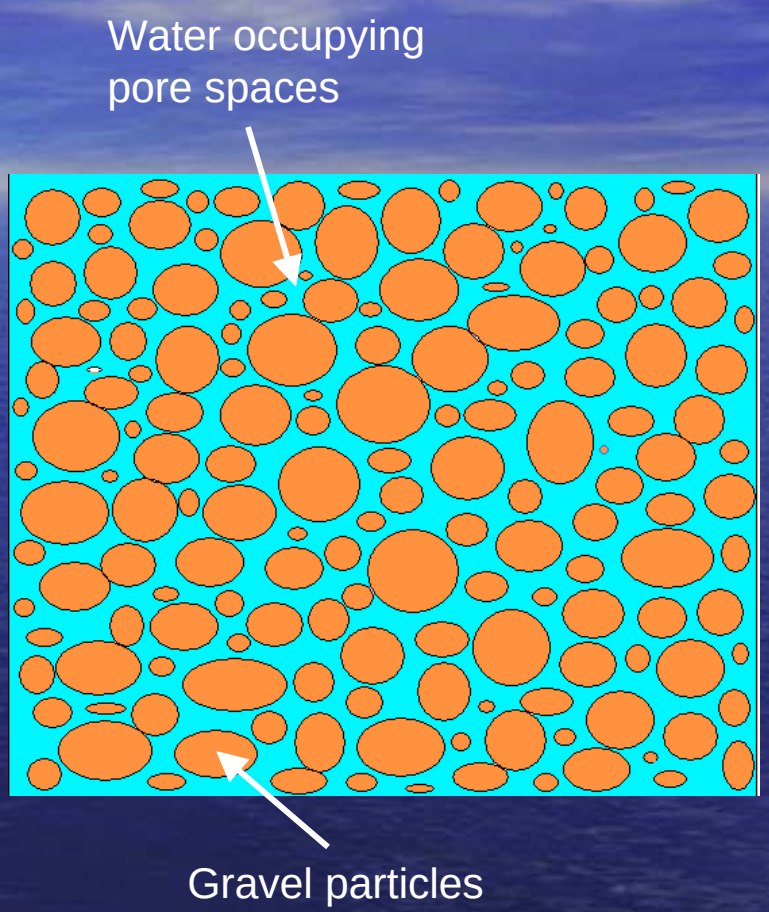
- While surface water flows quite rapidly, groundwater flows very slowly, often only a few metres to tens of metres per day.
- The process by which water seeps through the soil and reaches the water table is called *recharge*.
- Once water reaches the water table it moves away from areas of higher elevation, called *recharge areas*, toward areas of lower elevation called *discharge areas*.



Environmental Protection Agency

Aquifers: Reservoirs of Fresh Water

- Aquifers can store vast amounts of water. The aquifer underlying PEI is a good example.
- While the sandstone bedrock below us looks pretty solid, it is actually filled with many tiny *pore spaces* and fractures. The area occupied by these void spaces is referred to as *porosity.*



- On Prince Edward Island these spaces make up about 15% of the total volume of the rock, and we would say that the porosity of the rock is 15%.

Investigation : Measuring Porosity

- **Materials**
  - Container of coloured water
  - Large clear glass beakers or measuring cups
  - Fine grained, white gravel (the gravel used in the bottom of aquariums is ideal) sufficient to fill the beaker

Investigation : Measuring Porosity

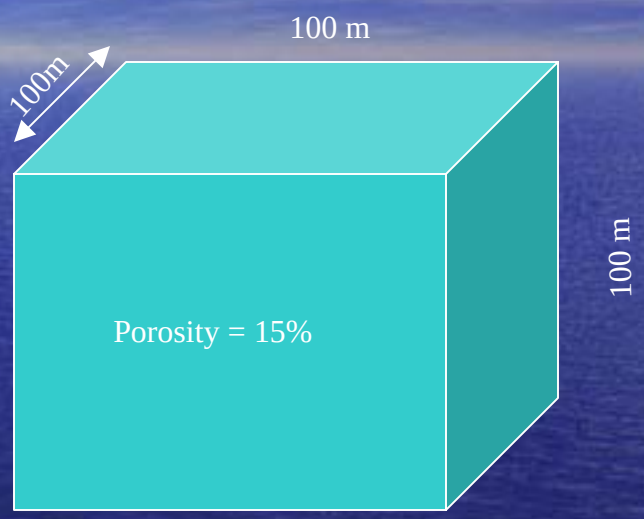
Procedure

- Fill one of the measuring cups to the top (1,000 ml) with white gravel and add water just to the top of the gravel.
- Drain the water from this mixture into the other cup.
- Record the volume of water. What percentage of the mixture is water? This value represents the *porosity* of the gravel.

Investigation : Porosity and Groundwater Storage

Consider a portion of *sandstone aquifer* (the type we have on PEI) having the dimensions of

100 m x 100 m in area, and extending 100 m in depth. Assume that the sandstone has a porosity of 15% and that the aquifer is completely saturated with water.



- calculate how many cubic metres of water (volume) is stored in the block of the aquifer.
- A cubic meter is equivalent to approximately 220 imperial gallons. How many gallons are stored in the block?

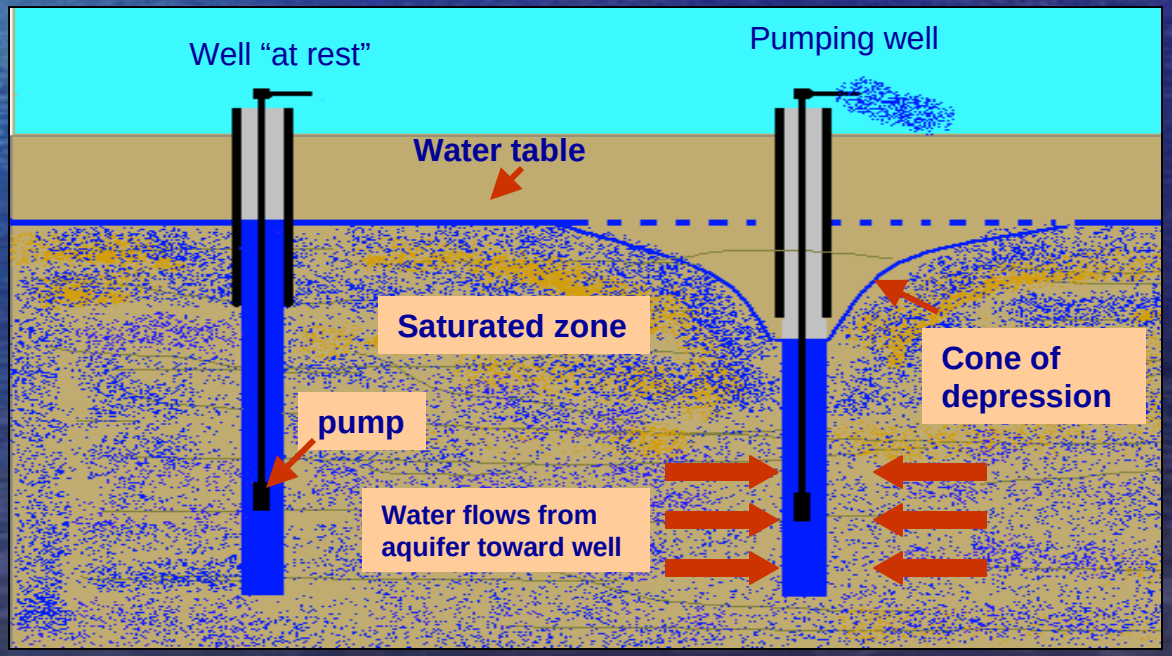
Answer: 150,000 cubic M
(33,000,000 gallons)

- Because groundwater is hidden out of sight, it is often taken for granted, however groundwater is one of the most important sources of fresh water in the world.
- Groundwater is vitally important to PEI. It is our only source of drinking water and is also used for many other commercial and industrial purposes.
- We access groundwater by digging wells.

Water tower being constructed in the Town of Cornwall – the water is pumped from a series of "well fields" to the water tower for distribution throughout the community.

Using Wells to Access Groundwater

- Wells provide a means of tapping groundwater stored in the "saturated zone" or "aquifer". When a well is not pumping, the water level in the well is the same as the water table elevation.
- When a well is pumping, the water level in and immediately around the well drops, forming what is called a "cone of depression. As water is pumped, water flows from the aquifer into the well.
- When a well is located near a stream, heavy pumping may draw water from the stream into the well.



Investigation: Wells

Materials

- Clear glass or plastic container filled with aquarium gravel
- 1 piece of rigid plastic tubing about 15 cm in length
- pump apparatus from a common spray bottle

Procedure

- Add water to the container until it's about ½ full
- Insert the rigid plastic tube through the gravel and down into the water. This represents the *well casing* which is usually made of metal or PVC. The bottom part of it has slots cut into it to allow water to enter. This is known as the *well screen*.

Procedure Continued:

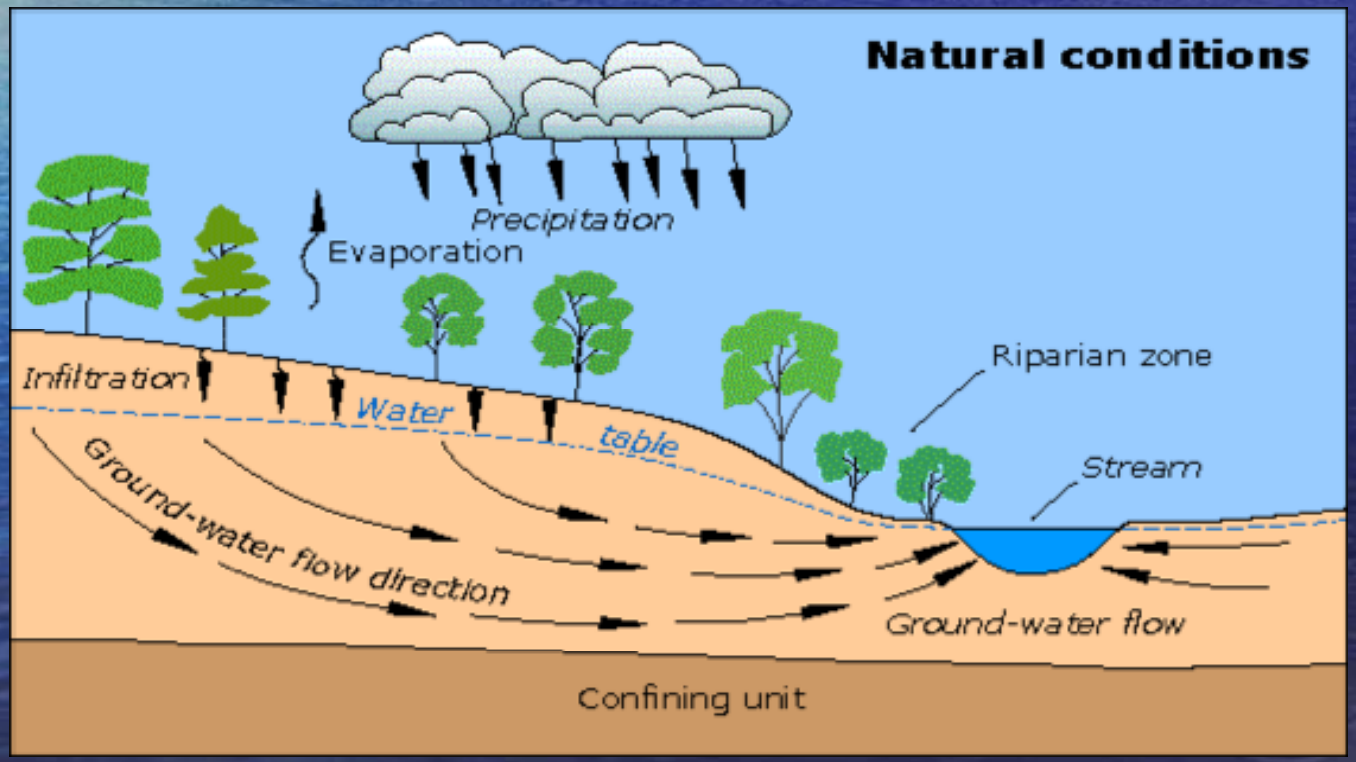
Insert the pump from the spray bottle in the straw, and begin pumping.

As you are pumping the water level in the plastic tube will drop immediately just as the water level drops in a well when it is pumped.

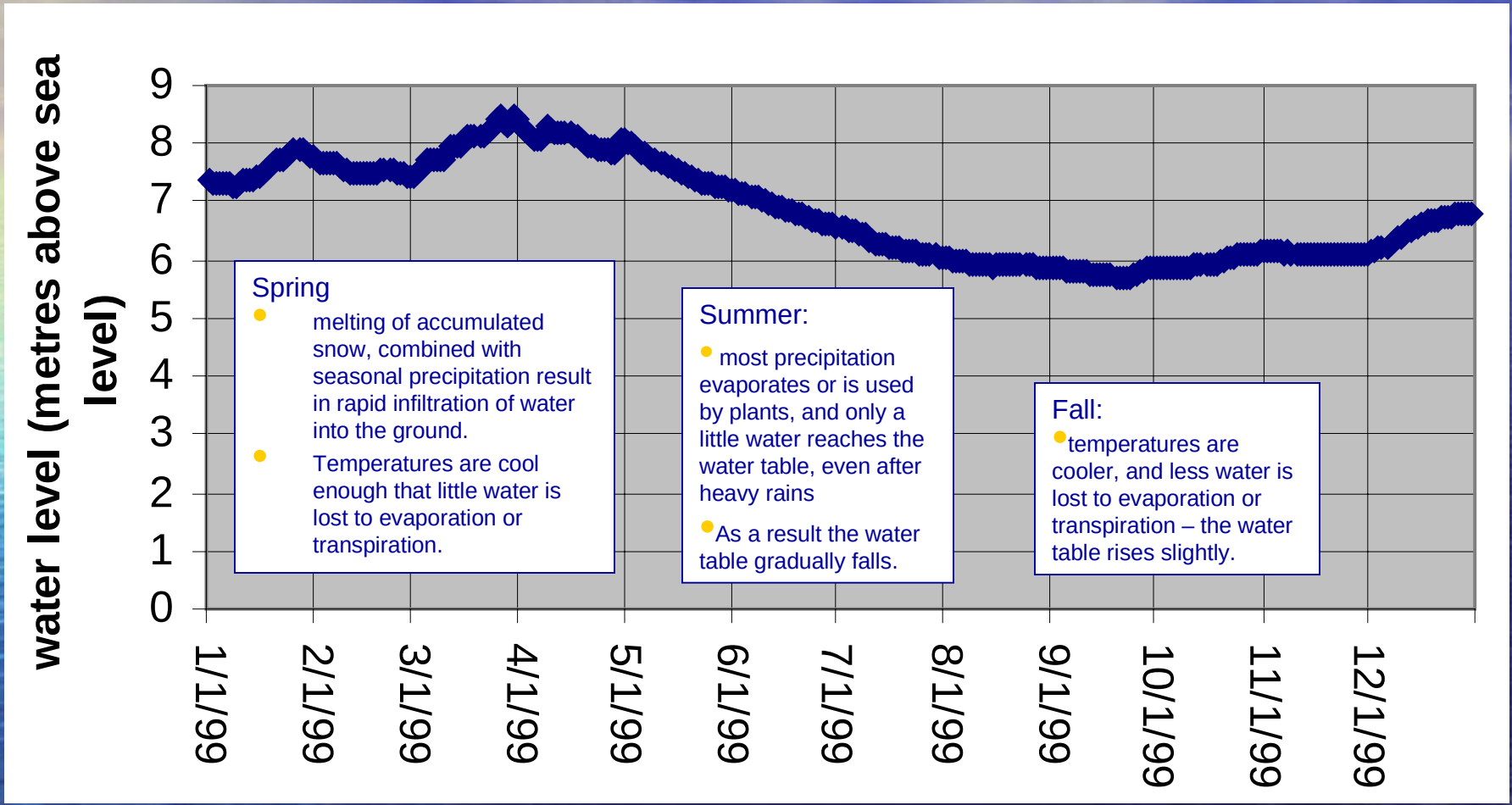
When you stop pumping, the water level should return to the same level as the water table.

Seasonal Trends in the Water Table

- The elevation of the water table rises and falls throughout the year depending on the rate at which groundwater is *recharged* and *discharged*.

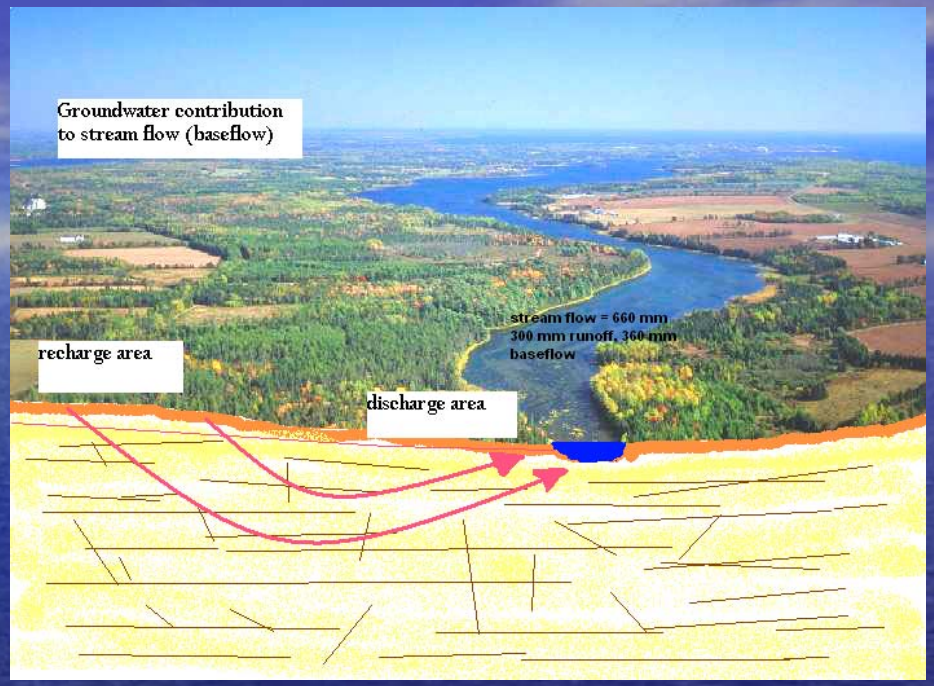


Water Table Elevation, Sleepy Hollow Well 1999



Groundwater: An Important Contributor to Stream Flow

- Groundwater which is *discharged* through springs and *seeps* to rivers or the shore is often called "base-flow"
- Base-flow accounts for 55-65% of the average annual stream flow.
- In dry summer months when there is little direct precipitation run-off, almost all the water we see in Island streams is groundwater discharge.



Spring discharging groundwater to a small stream. This is a fairly unusual example, and most springs are barely noticeable to the casual observer.

Surface Water: What is it?

- Surface water includes the water we see in ponds, lakes, rivers and the ocean. It is very important to the Island's environment and economy because of the role it plays in supporting fisheries and other wildlife, its use in agriculture and aquaculture, and its contribution to the recreational and tourism sectors.

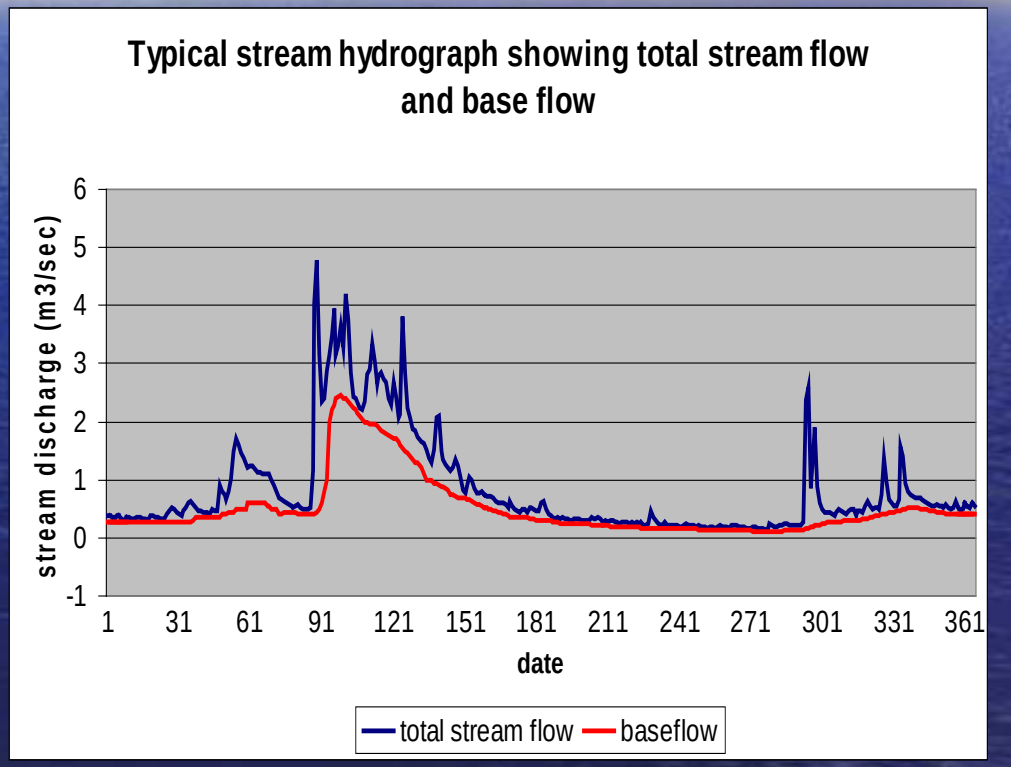
Bonshaw River

Winter River
(Gary Fournier)

- On PEI we have many small rivers and streams but relatively few lakes or natural ponds.
- Our rivers tend to be short, and a good portion of their length contains *brackish* water - a mixture of fresh water and salt water from the ocean. These areas of mixed fresh and salt water are called *estuaries*. They are highly productive areas for shell fish and fin-fish.

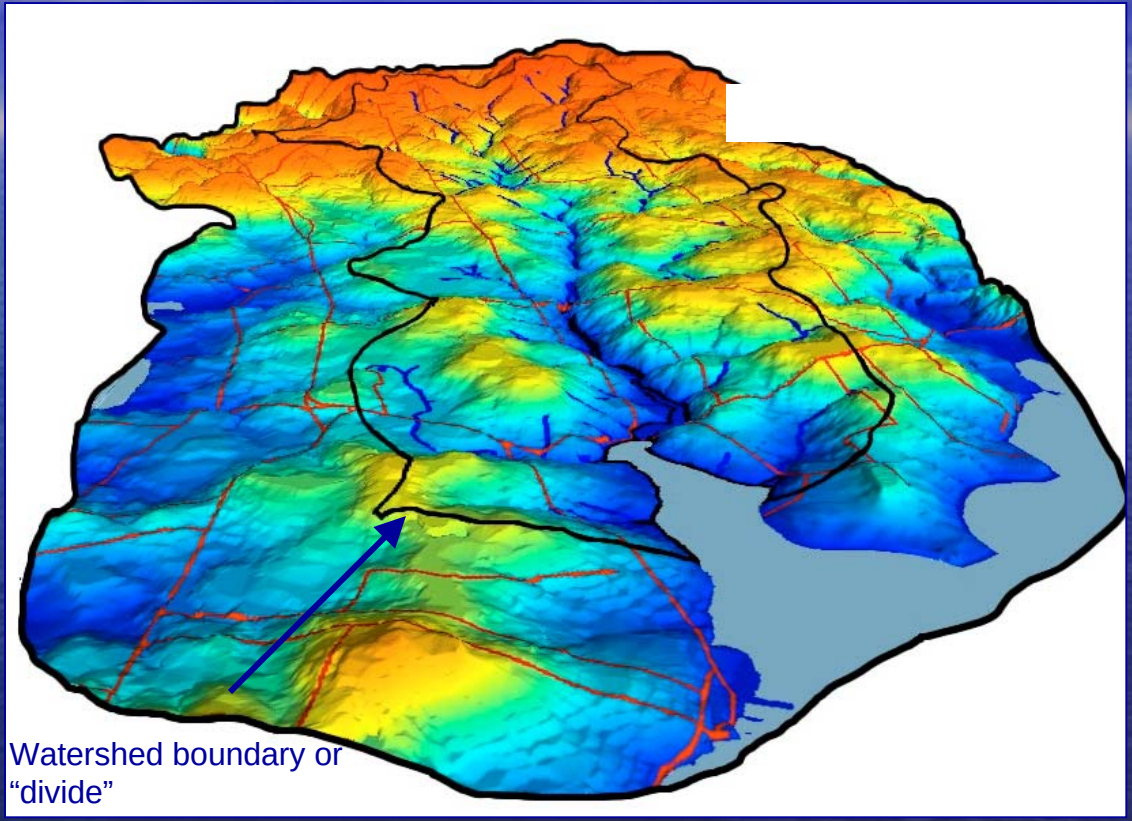
Fresh Water Flow in Island Streams

- The surface water we see in fresh water streams comes from two sources:
  - Water that runs over the ground surface to streams such as after a rain storm or snow melt, and
  - Groundwater discharge from springs.



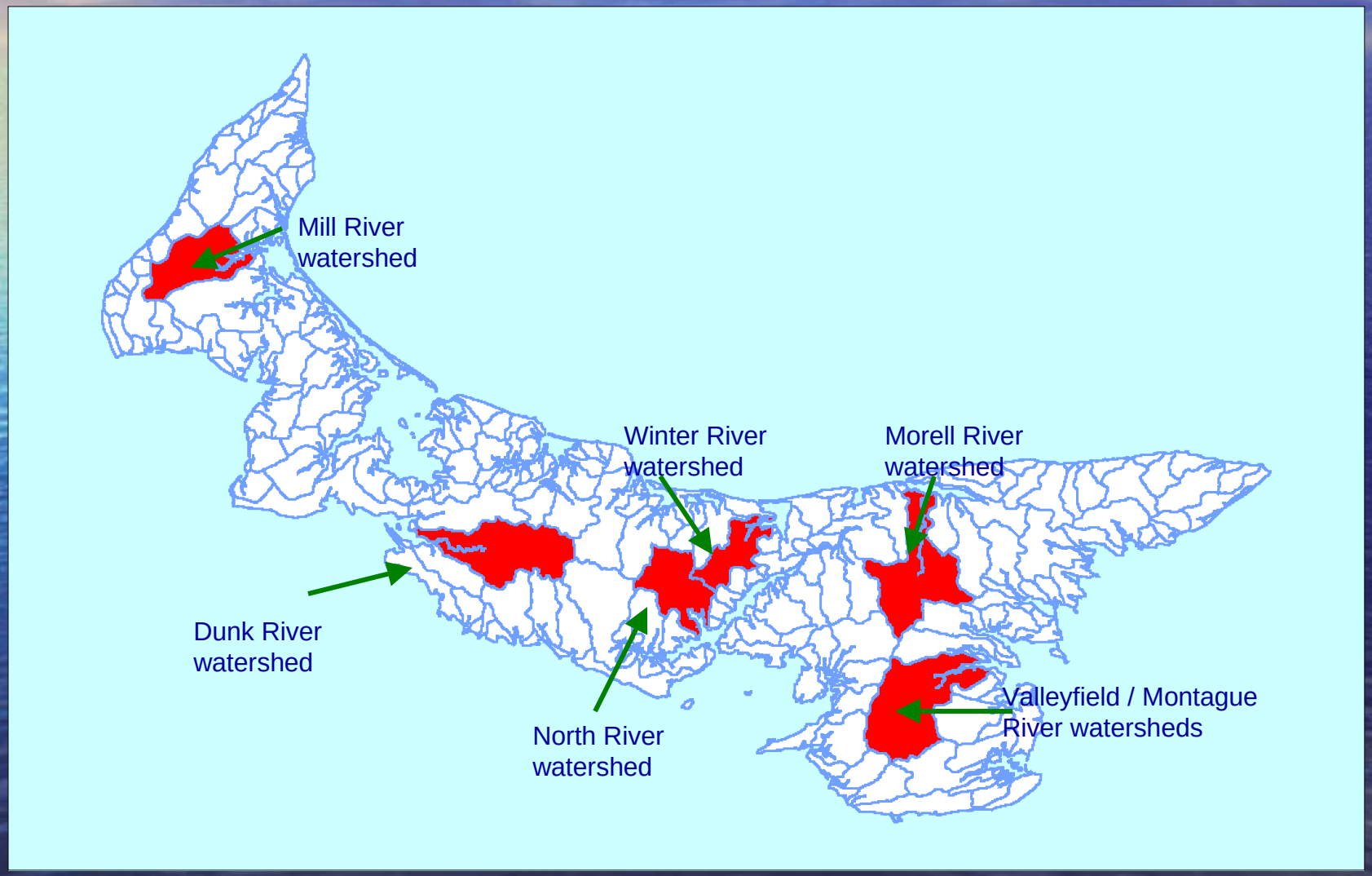
Watersheds: A Useful Tool in the Study of Water

- A *watershed* is the area of land over or under which water flows toward a stream, river or the ocean. Regardless of where you are, you're in a watershed!
- For many issues relating to water, we use watersheds to define the physical boundaries of the area of interest.

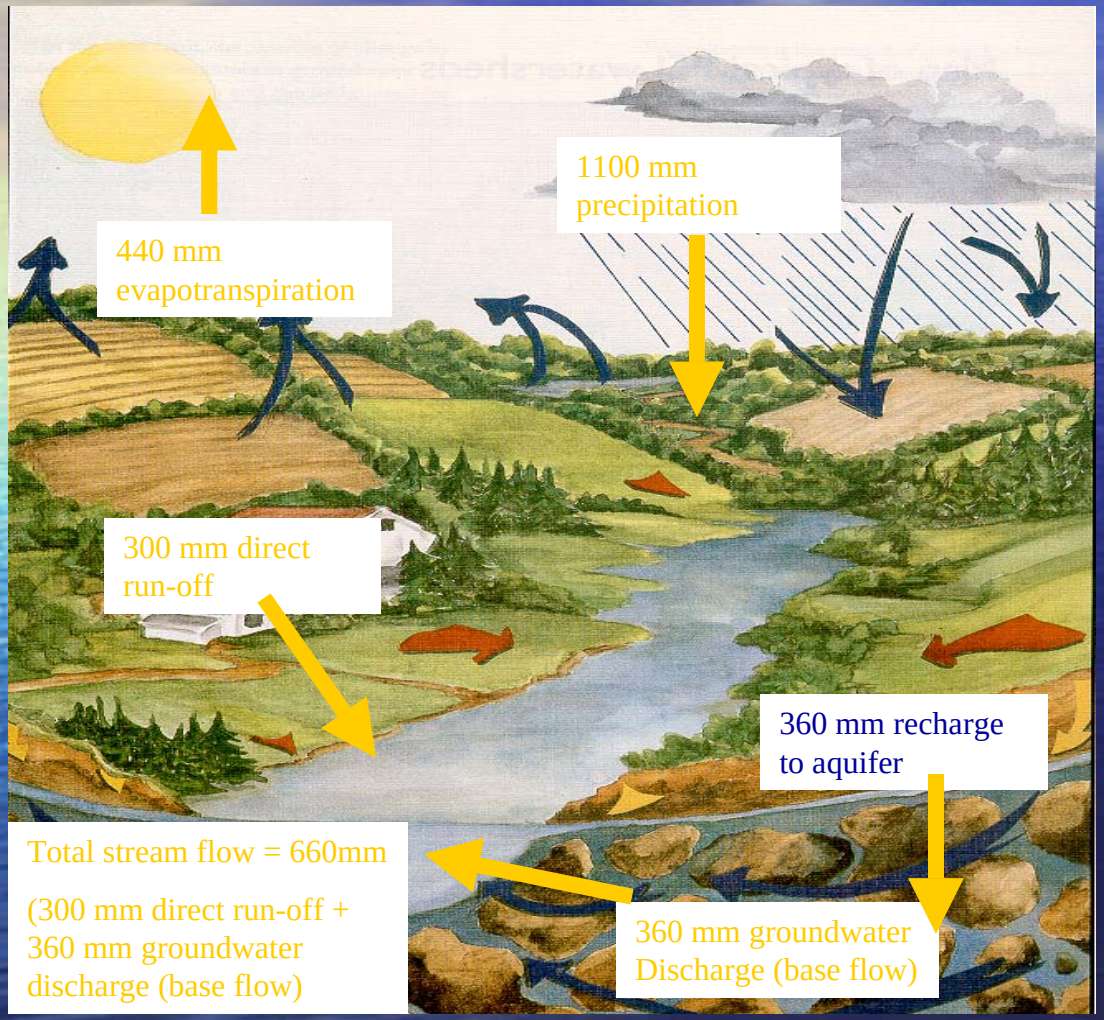


Watersheds on PEI

- On PEI there are about 240 watersheds, ranging in size from a few square kilometers (km^2) to a maximum size of about 150 km^2 . Some of the larger watersheds are outlined on the map below.



Putting it all together: An annual "water budget" for a typical PEI watershed



- Just like we can use a budget to account for money going into or out of a bank account, we can use a "water budget" to account for the movement of water into and out of various components of the water cycle.

Resources

Environment Canada

- **A Primer on Fresh Water: Questions and Answers**
  http://www.ec.gc.ca/water/en/info/pubs/primer/e_contnt.htm

- **Let's Not Take Water For Granted – A Resource Guide**
  http://www.ec.gc.ca/water/en/info/pubs/lntwfg/e_contnt.htm

- **Water Fact Sheets**
  http://www.ec.gc.ca/water/en/info/pubs/FS/e_contnt.htm

- **The Nature of Water**
  http://www.ec.gc.ca/water/en/nature/e_nature.htm

United States Geological Survey (USGS)

- Water Science for Schools
  http://water.usgs.gov.edu/

NASA

- NASA's Observatorium Hydrologic Cycle
  http://observe.arc.nasa.gov/nasa/earth/hydrocycle/hydro1.html

Acknowledgements

- The Water Cycle on Prince Edward Island is a joint project of the Prince Edward Island Department of Environment and Energy and the Department of Education. It has been developed as a resource to support the PEI/APEF Science Curriculum. For more information contact:
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  - Craig Ramsay – Science Consultant, Department of Education (French Programs) cxramsay@edu.pe.ca