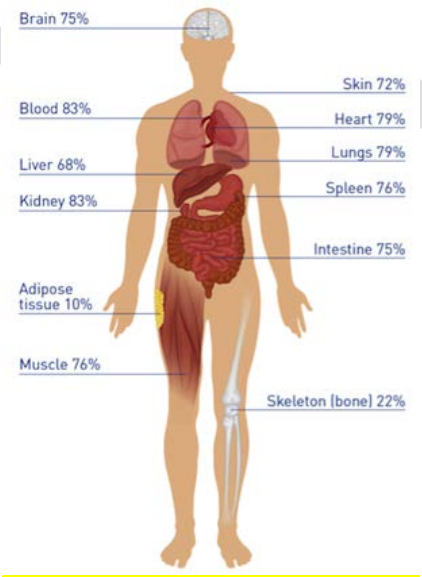
WATER RESOURCES

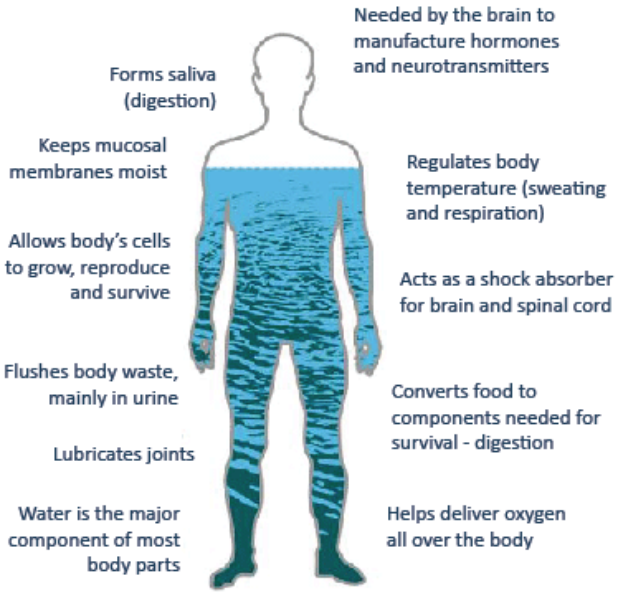
IMPORTANCE OF WATER

Water is a foundational building block that supports all life on Earth. Wherever there is water, life has been found. Whether it is in a freshwater lake, the ocean, or even the desert, life has adapted to even the most severe conditions as long as there is water. Water is often called the "universal solvent" because it is capable of dissolving more substances than any other liquid. This attribute is important to every living organism because it allows water to carry valuable chemicals, minerals and nutrients wherever it goes, whether through the air, the ground, or even our bodies.

All terrestrial plants and animals need a steady supply of water to maintain cell structure, support bodily functions, and provide habitat. Water can be the most important component for the world's terrestrial ecosystems because it often determines where certain organisms can live and others cannot based on precipitation patterns, soil moisture or water levels. Organisms that live in water, such as fish or other aquatic species, depend on water to provide habitat, dissolved oxygen and other gases, dissolved minerals, and organic matter.

The majority of the human body, along with the bodies of other living animals, is made up of water. In humans, up to 60% of the body is composed of water depending on a person's age and gender 7. Bodies use this water in all of its cells, organs, and tissues to aid in respiration, regulate temperature, transport oxygen and nutrients, remove toxins, and maintain other bodily functions. Because the human body regularly loses water through breathing, perspiration, and bodily wastes, the body's water needs to be constantly recharged to maintain health.





Water is also necessary for economic development since people are not likely to invest in homes or businesses without access to water. Human uses of water include agricultural, residential, industrial, environmental, and recreational. Water uses can be for direct or indirect purposes. Direct purposes may include drinking, bathing, cooking or washing. Indirect purposes may include processing wood for paper products or producing steel for automobiles. Maintaining access to safe, clean and reliable water supplies and providing healthy sanitation systems are primary functions of municipalities in the U.S. While economic development is important, communities need to ensure the demand for water does not exceed the sustainable yield of water supplies. Pollution that can result from development activities must also be controlled to prevent contamination of their water resources.

WATER CYCLE

The Earth has an abundance of water which is why it is sometimes referred to as the "blue planet". Approximately 71% of the Earth's surface is covered with water 3. Most of this water is salt water located in its oceans. Only about 2.5 percent of all the water on the planet consists of fresh water which is what people and over 100,000 other animal species need for survival 16. The majority of fresh water is locked up in glaciers or ice caps and is inaccessible. While groundwater accounts for a large portion of the worlds freshwater, and is the main source of drinking water for people in the world, most groundwater is not suitable for consumption or is not economically viable to retrieve. The remaining small percentage of water is split between ice and permafrost, lakes, soil moisture, the atmosphere, wetlands, rivers, and living organisms 4. Therefore, although the Earth has a lot of water, only a small fraction of it is freshwater that can be used by people. According to the World Health Organization only 1% of the worlds freshwater, or 0.007% of all water in the world, is readily available for human use 5.

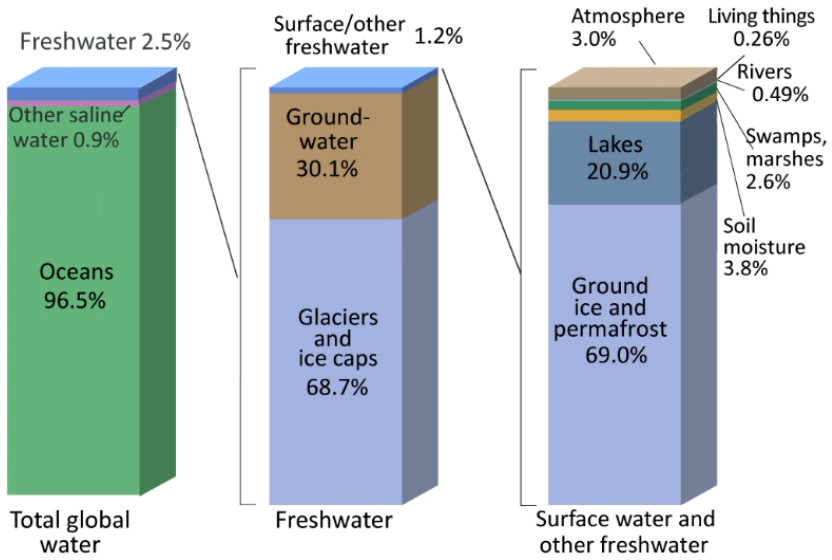


Figure ???:Graphic showing the distribution of the Earth's fresh water resources 17.

All the water on earth today, is all the water that has ever been on the planet. For all practical purposes, the amount of water on Earth remains the same and is constantly being recycled in a continuous loop through a process known as the water cycle. Water is the only common substance that can exist as a gas, liquid, or solid at the relatively small range of temperatures found on the Earth's surface. The water cycle is driven by the sun's energy that warms the surface of land and water, causing liquid water or solid ice to evaporate into a gas. The gas moves into the atmosphere in the form of water vapor. Over a period of time, typically days or weeks, the water vapor in the atmosphere condenses into clouds and eventually falls back to the ground as precipitation in the form of rain, snow, or hail.

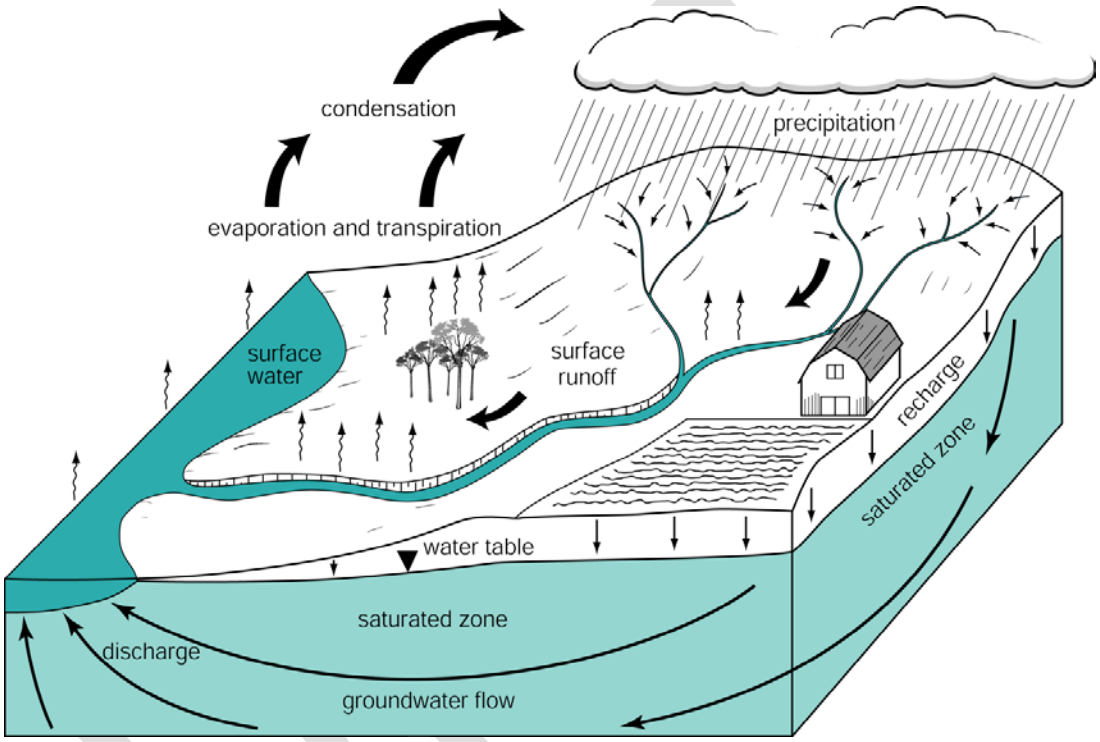


Figure ???: Illustration depicting how the hydrologic cycle involves the continuous circulation of water from the ground, to the atmosphere, and back again. Water remains in motion as it shifts between liquid, gas, and solid forms.

Most precipitation that reaches the land surface will either become groundwater or surface water. Rain or snowmelt that seeps through the soil and into the ground becomes groundwater that can recharge groundwater aquifers. Rainfall or snowmelt that does not infiltrate into the ground may flow over the surface as stormwater runoff. The stormwater runoff flows overland into water bodies (e.g. lakes, rivers, streams, wetlands) and becomes surface water. Exposed to the sun and air, surface water can evaporate and begin the water cycle over again. Some of the water in the upper levels of the soil can also be taken up and used by plants. Most of the water taken up by the plants will be released to the atmosphere as a gas through a process called transpiration.

Groundwater not only moves downward through soil and rock but also slowly moves sideways where it seeps into lakes, rivers, streams, and wetlands. In shallow groundwater systems it can take days, months, years, decades or centuries for groundwater to return to the surface. In deep aquifers, it can be millennia before the groundwater reaches the surface. After returning to the surface however, groundwater can evaporate and once again become part of the continuous water cycle.

On natural undisturbed ground, most precipitation infiltrates into the soil or returns to the atmosphere through evapotranspiration, only a small percentage flows overland as runoff. However, this balance is reversed when modern development practices convert natural ground to turfgrass and impervious surfaces such as streets, roofs, parking lots, walkways, etc. Impervious surfaces typically include asphalt, concrete, or other hardscape materials. These impervious surfaces prevent water from infiltrating into the ground, thereby decreasing groundwater recharge and increasing the volume of stormwater runoff that flows overland before discharging into surface waters. The greater volumes of stormwater that rapidly flow into water bodies contributes to increased potential for flooding. The increased runoff also degrades water quality because the stormwater that flows over the hardscape surfaces picks up pollutants such as oil and grease, heavy metals, sediment and debris.

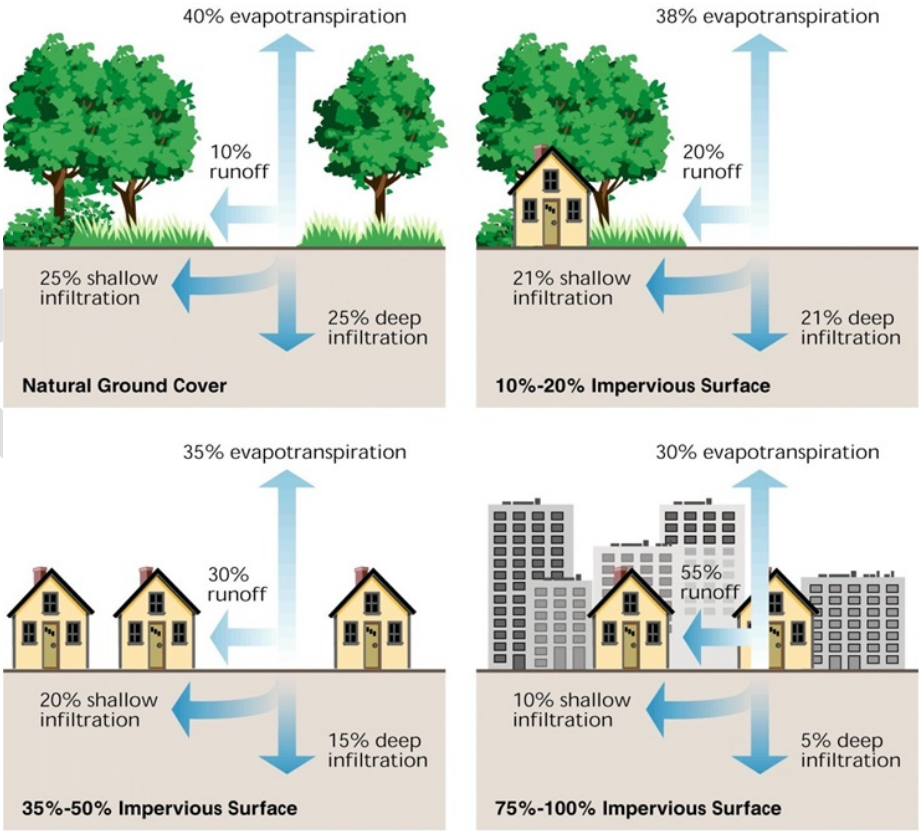


Figure ???: On land with natural groundcover, most precipitation infiltrates into the ground and only a small amount of runoff is produced. As land is developed with turfgrass and impervious surfaces the percentage of runoff increases because water can no longer infiltrate into the ground.

Key elements of the water cycle include:

- Evaporation – Natural process of converting liquid water into a gas (water vapor)
- Transpiration – Natural process of plants converting liquid water into a gas
- Evapotranspiration – Sum of evaporation from land surfaces and transpiration from plants
- Sublimation – Conversion of solid ice to gas
- Condensation – Conversion of water vapor to liquid water which forms clouds
- Precipitation – Release of water from clouds in form of rain, snow or hail
- Infiltration – Process of rain or snowmelt seeping through the ground surface into soil and rock
- Runoff – Rain or snowmelt that flows overland into water bodies (lakes, rivers, streams, wetlands)
- Groundwater – Water that accumulates underground in soil or rock
- Surface Water – Water that accumulates on the ground surface (lakes, rivers, streams, wetlands)

WATER RESOURCES

The Chicago Region, including McHenry County, has an abundance of water resources. These resources support rich habitat for wildlife, drinking water for millions of residents, economic prosperity for businesses, and a multitude of recreational opportunities. For the water resources to continue providing benefits at the same level, they need to be managed sustainably. Whether or not the water resources are managed sustainably depends largely on how the resources are understood and appreciated by those who use them. Water resources in the region generally include the following elements:

- Surface Water
    - Natural Lakes, Man-Made Lakes, and Ponds
    - Rivers, Creeks, and Streams
    - Headwaters
    - Wetlands
- Groundwater
- Watersheds
- Nature-Based Solutions

Surface Water – Surface waters are areas where water accumulates above ground and includes lakes, rivers, streams, wetlands, and ponds. Since these water bodies are often prominent features on the landscape, surface waters may be the most recognizable form in the water cycle.

The worlds surface waters account for less than one thousandth of a percent of all the world's water, but serve critical functions for the environment and for human life. Fresh surface waters sustain ecological systems and provide habitat for many plant and animal species. They also support a vast array of human uses including drinking water, irrigation, wastewater treatment, livestock, industrial uses, power, and recreation. As part of the water cycle, surface-water bodies are thought of as renewable resources. However, they are highly dependent on other parts of the water cycle for replenishment (e.g. precipitation, baseflow from groundwater) and can be altered by natural or man-made forces. Pollution, channelization, and drainage are examples of man-made disturbances that can permanently alter of damage surface waters. Each form of surface water provides different benefits and face distinct challenges:

- **Natural Lakes, Man-Made Lakes and Ponds:** These water bodies usually occur in low areas where surface runoff and groundwater seepage accumulate. They consist predominantly of still water as opposed to the flowing water found in rivers. Natural lakes are typically recognized as water bodies with no dam or where the lake would exist even without a dam. Dams are often added to natural lakes to raise or control water levels. Manmade lakes (also referred to as impoundments) are usually constructed by damming a stream and flooding the surrounding low land area. Some impoundments may also be excavated, but their size is usually constrained by the high costs of earthmoving. Impoundments are typically constructed to serve a specific purpose such as drinking water supplies, flood control, agricultural irrigation, fisheries or recreation. Ponds are usually thought of as small lakes and may be constructed by excavating depressions in areas with shallow water tables, such as wetland. However, some limnologists who study these water bodies distinguish lakes from ponds based on the depth of water, with ponds being shallow enough for light to reach the bottom and sustain plant life across the entire surface.

  Lakes, impoundments and ponds are highly valued for their recreational, aesthetic, or scenic qualities. Impoundments are sometimes constructed specifically to provide a source of drinking water in areas with limited options. These water bodies also provide important habitat for a diverse array of fish, aquatic species, wildlife, and vegetation. In their natural state, the shores of lakes and other water bodies usually consist of wetland habitat that helps stabilize the shoreline and provide wildlife habitat. The ecosystems of lakes and impoundments can be fragile and can undergo rapid degradation if not properly managed.

  *** Photo of a Lake ***

- **Rivers, Streams and Creeks:** These are all names for linear water bodies that flow across the land surface, moving from higher elevations to lower elevations. The terms are often used to differentiate between sizes of the linear water bodies, with rivers being the largest and creeks representing medium to small water bodies. The term stream is commonly used in more generic terms to refer to any linear water body that flows. Streams typically increase in size as they flow downstream and intersect with other water sources. Small creeks initially form by precipitation on the land surface or groundwater that discharges to the surface. As the small creeks flow downhill they merge into progressively larger streams and then rivers. Rivers merge into larger rivers that ultimately flow into the oceans.

  Each of these waterways can provide important habitat for fish and aquatic species. They are also important to people and may be valued for their aesthetic qualities, recreation, shipping or transportation, and sometimes as a source of drinking water. They are also used to move waste downstream. Wastewater treatment plants are typically situated close to streams where the treated waste is discharged. In some streams the wastewater effluent has become a primary source of baseflow to support the aquatic habitat. In the past these waterways were frequently used as sewers for human and industrial waste. Such discharges of waste have had detrimental impacts to the environment, water quality, and health. However, there are currently Federal and state laws that regulate the discharge of illicit wastes and reduce damage to public health and aquatic resources. There is also growing awareness about pollution from stormwater runoff and improved regulations, innovations and practices are being implemented nationwide to prevent pollution from stormwater.

  *** Photo of a river ***

- **Headwaters:** The areas upstream of creeks and rivers are known as headwaters (or river sources) and are often composed of small streams. While headwater streams are the smallest parts of river and stream networks, they collectively make up the majority of river miles in the U.S. and are the primary source of water for the larger stream and river systems 9. Therefore, the physical and biological quality of larger streams is also directly correlated to that of the headwater streams. Headwaters provide important functions such as trapping floodwater, recharging groundwater supplies, removing pollution, providing habitat for fish and wildlife, and sustaining the health of downstream rivers. First or second order streams are considered headwater streams (see Figure ???). The headwater streams may be perennial with flowing water all year or they may be intermittent with water drying up in warmer months. Because many headwater streams have small, intermittent drainage areas, they may not receive proper protection. When headwater streams are degraded or destroyed the larger water bodies downstream are also impacted.

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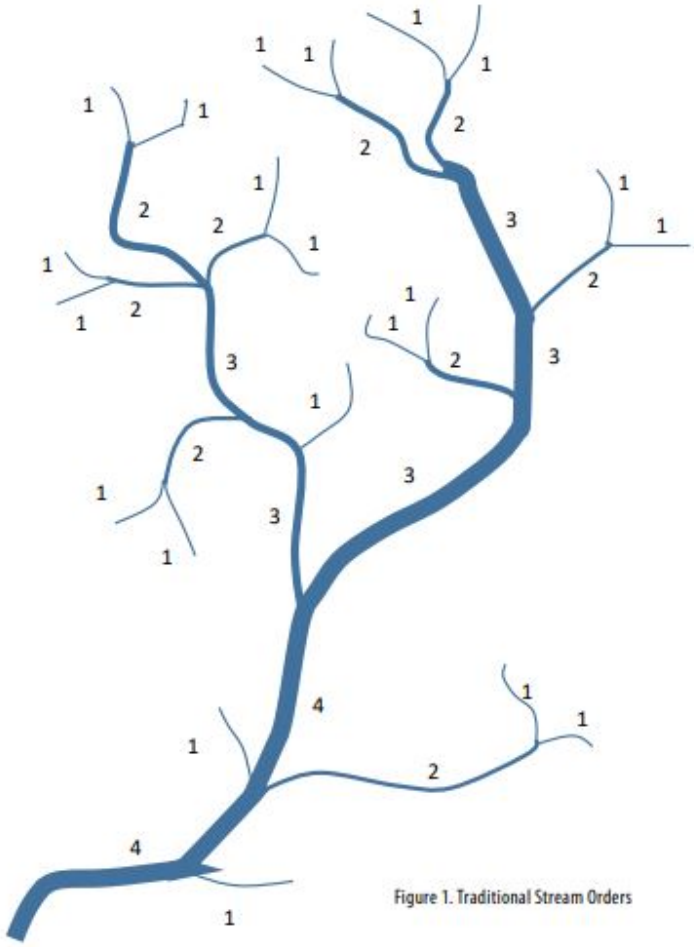

Figure ???: Illustration showing the concept of stream order that uses numerical designations to indicate where a stream segment is located in the watershed. First or second order streams are considered headwater streams. As smaller streams flow together, larger (higher order) streams are formed. Courtesy of the McHenry County Conservation District.

- **Wetlands:** In general terms, wetlands can be thought of as wet areas between dry ground and open water. More specifically, the EPA defines wetlands as "*areas where water covers the soil, or is present either at or near the surface of the soil all year or for varying periods of time during the year, including during the growing season*" 18. Wetlands are characterized by the presence of three parameters – evidence of water, hydric soils (soils that lack oxygen), and hydrophytic vegetation (plants that grow in water or saturated soil). Soils that are saturated by water for extended periods of time undergo physical and chemical changes thereby forming hydric soils. The presence of hydric soils and the degree of saturation by water are largely responsible for determining the types of plants or animals that can live in various wetland areas. There are a wide variety of wetland types based on variations in the plant communities, soil conditions, water flow, water chemistry, and climate.

The two general categories of wetlands are coastal/tidal wetlands and inland/non-tidal wetlands. As the name suggests, coastal/tidal wetlands are found along the oceans coasts and are adapted to salt water and the fluctuating water levels of the oceans tides. Inland/non-tidal wetlands are the category of wetland found in mid-western states. These wetlands can be found on floodplains along rivers and streams, in isolated depressions surrounded by dry land, along the margins of lakes and ponds, and in other low-lying areas with shallow water tables or where precipitation accumulates or saturates the soil. Inland wetlands include marshes and wet meadows dominated by herbaceous plants, swamps dominated by shrubs, wooded swamps dominated by trees, and riparian habitat that borders streams. Many of these wetlands are also seasonal and may only be dry for one or more seasons of the year (e.g. vernal pools that capture and hold spring snowmelt and rainfall).

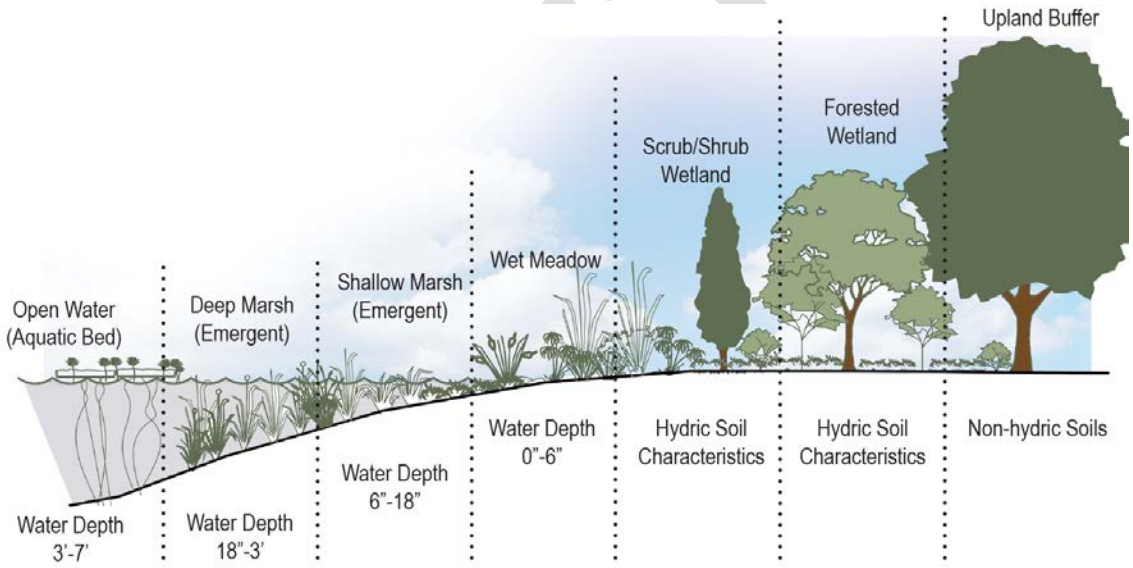

Figure ???: Illustration showing a variety of common types of wetland based on water levels and plant communities.

Wetlands are among the most productive ecosystems in the world, comparable to rain forests and coral reefs. The combination of shallow water, high levels of nutrients, and vegetative growth is ideal for the development of organisms that form the base of the food web and feed many species of fish, amphibians, shellfish and insects. Wetlands provide vital food and shelter in the life cycle of up to 90 percent of recreational fish caught in the U.S. 19. Many species of birds and mammals rely on wetlands for food, water and shelter, especially during migration and breeding. More than one-third of the United States' threatened and endangered species live only in wetlands, and nearly half use wetlands at some point in their lifecycle 20.

Wetlands also provide valuable benefits for people and their built communities such as flood reduction and water quality treatment. Wetlands function as natural sponges that trap and slowly release rain, snowmelt, groundwater and floodwaters. The absorption, storage, and slow release of water by wetlands lowers flood heights and reduces erosion. Wetlands vegetation, soils and the organisms that live in wetlands act as filtering systems, removing sediment, nutrients and pollutants from water. Wetlands help to moderate global climate conditions by physically storing carbon within their plant communities and soil instead of releasing it to the atmosphere as carbon dioxide. However, wetlands capacity to absorb floodwater, nutrients or other elements is not limitless and excess loading of any of these can degrade and damage a wetland ecosystem. Even when wetlands are not directly impacted from development, natural wetlands are often overloaded with excess water, nutrients, or pollutants that degrades the wetland habitat and their ability to provide benefits. Wetlands and other aquatic habitats can also be damaged or destroyed when buffers of undeveloped land are not maintained along their borders.

*** Provide photos side-by-side of different wetland types in McHenry Co. ***

Although wetlands provide valuable services for people and wildlife, they are under constant threat from destruction and degradation. Historically the benefits of wetlands were not well understood or recognized so they were routinely drained or filled to convert land for agricultural use or urban development. For example, between the 1950's and 1970's more than a half million acres of wetland were being lost every year, and by the 1980' the U.S. had lost over half its original wetlands 21. In Illinois, almost 90 percent of the original wetlands have been lost 22.

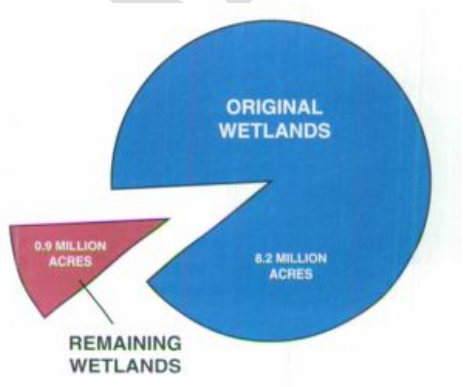

Figure ???: Pie chart from the Illinois Department of Natural Resources (IDNR) illustrating the amount of original wetlands lost compared to the amount of wetland remaining in Illinois.

Federal wetland protections under Section 404 of the Clean Water Act have slowed the destruction of wetland in the U.S. Under Section 404, permits from the U.S. Army Corps of Engineers may be required to fill wetland. Compensatory mitigation (replacing impacted wetland) may also be required to offset wetland losses. However, these protections are limited and significant wetland losses have continued 21. Wetland protections under Section 404 continue to be relaxed and Supreme Court rulings (Solid Waste Agency of Northern Cook County (SWANK) v. Army Corps of Engineers, and Rapanos v. United States) opened up so called "isolated wetlands" (wetlands not directly connected to a navigable waterway) to development and destruction. To compensate for the reduced Federal protection, and prevent the increased flooding that occurs when wetlands are filled, many counties in Northeast Illinois (including Lake, McHenry Cook, DuPage, Kane and Will Counties) have established countywide stormwater regulations that include protection of "isolated wetlands".

Watersheds – No matter where a person is, they are in a watershed. Watersheds are areas of land that drain the rainfall, snowmelt and streams to a common body of water such as a lake, river, creek or wetland. A watershed includes both the water (aquatic) and land (terrestrial) components within its boundaries. The landforms in a watershed determine the movement and quality of water that flows through. Watersheds are typically defined by the surrounding higher ground, such as ridges and hills, which direct water flow downhill to water bodies at lower elevations. The hills and ridges that separate watersheds are called drainage divides or watershed boundaries. Watersheds can be large or small depending on the regions' landscape. Larger watersheds may have many sub-watersheds that help direct flow to the common water body that forms the larger watershed. For instance the drainage area of a local creek may represent a sub-watershed that serves as a tributary to the larger watershed and river. Much of the precipitation or snowmelt in a watershed soaks into the ground, and instead of flowing to a stream, infiltrates through the soil to recharge groundwater aquifers. Therefore, watersheds play a major role in the recharge of groundwater aquifers, the direction of flow for shallow groundwater, and how groundwater provides baseflows to surface water bodies.

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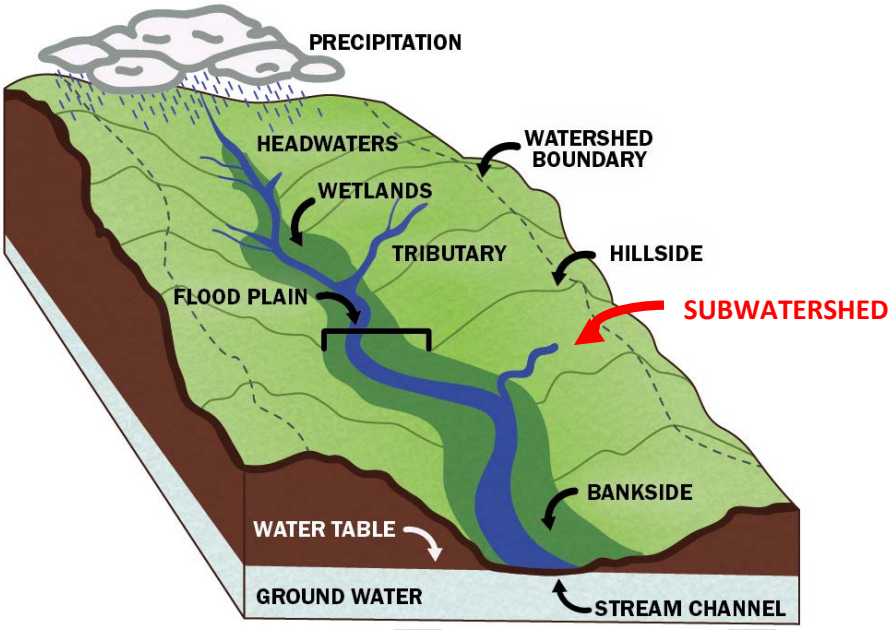

Figure ???: Cross-Section illustrating a watershed and its various components.

Healthy intact watersheds provide many ecosystem services that are necessary to maintain the social, environmental, and economic well-being of communities. Ecosystem services refer to the direct and indirect contribution of natural ecosystems to people and the built environment. These services include water filtration, flood mitigation, groundwater recharge, air purification, carbon storage, nutrient cycling, soil formation, recreation, food and timber. The healthier the watershed, the greater the ecosystem services that can be provided. However, the monetary value for many of these ecosystem services is not widely recognized and therefore the economic contributions of healthy intact watersheds are often under-valued when making land use decisions. Ecosystem services provided by healthy watersheds can be difficult and expensive to replace using engineered systems. Additionally, engineered systems may only replace a fraction of the services that the intact ecosystem provided. Therefore, watershed protection is usually the most economical option to maintain benefits to communities. The benefits healthy watersheds can provide include:

- Filter runoff and improve quality of surface water or groundwater
- Recharge groundwater aquifers
- Reduce drinking water treatment costs
- Store runoff and reduce flooding
- Sustain recreation and tourism revenue
- Support critical ecosystems services at lower costs than engineered systems
- Provide a sustainable environment and economy for future generations

Stormwater runoff and pollution increases as urban development expands within a watershed. As water moves downhill across impermeable surfaces any pollutants on the ground can be absorbed, carried, concentrated or deposited throughout the watershed. Pollution can cause health problems, destroy habitat, impair water supplies, impede recreation, and cause other damages. Water pollution is often broken down into two main categories:

- Point Source Pollution – Comes from a single point such as a factory or sewage treatment plant.
- Non-Point Source Pollution – Comes from stormwater runoff in urban and suburban areas that absorbs or collects pollutants as the water flows across the land surface.

Increased stormwater runoff from impervious surfaces results in larger volumes of stormwater that can rapidly flow into lakes, rivers, streams, and wetlands. Runoff that comes in contact with pollutants becomes a source of non-point source pollution that can degrade water quality. The sudden rush of large volumes of water can also lead to heavy flooding in areas that were not historically prone to flooding. Such flooding can cause damage to people, property, and infrastructure. In urbanized areas, where steady baseflows of groundwater to water bodies have been replaced by surface runoff, flooding may be followed by drought conditions after the spike in runoff has moved downstream. The rapid shift between extremes of flooding and drought can further degrade habitat.

Because watersheds have well-defined boundaries and encompass so many aspects of a regions hydrology, they represent a logical framework to approach water resources planning and management. Additionally, since water flow does not recognize political boundaries, most water related issues can best be addressed on a watershed level. Watershed planning and management comprise an approach to protecting water quality and quantity that focuses on the entire watershed. This approach is necessary to help identify and address water-related issues such as water quality, non-point source pollution, erosion, drinking water supplies, flooding, wildlife habitat, and economic development.

A watershed management plan (WMP) is an important tool for water resource protection. A WMP provides a structured approach to identify water-related problems in the watershed, propose solutions to address the problems, create a strategy to implement the solutions, and establish monitoring criteria to measure success. The WMP's should include an overview of the watersheds current conditions including physical, chemical and biological characteristics of water resources, as well as current land uses and potential sources of impairment.

***Sidebar on Nippersink Creek Watershed Management Plan ***

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To assist communities, organizations, agencies and others, the U.S. Environmental Protection Agency (EPA) prepared the "*Handbook for Developing Watershed Plans to Restore and Protect Our Waters*". https://www.epa.gov/nps/handbook-developing-watershed-plans-restore-and-protect-our-waters
The Handbook identifies Six Steps to Watershed Planning. These are general steps the EPA recommends watershed planners take to achieve most types of watershed goals. For each step in the planning process the EPA emphasizes the importance of "building partnerships" to accomplish lasting change. The six steps to watershed planning includes:

1) Build partnerships
2) Characterize your watershed
3) Finalize goals and identify solutions
4) Design an implementation program
5) Implement the watershed plan
6) Measure progress and make adjustments

The EPA's Handbook and their Section 319 Non-Point Source Clean Water Act grant guidelines also refers to "9 minimum elements" of successful watershed projects. These nine elements are watershed planning components the EPA considers critical to preparing effective watershed plans. The nine elements are required to be included in all watershed plans that are developed and implemented with Section 319 funds. The EPA's nine minimum elements for watershed planning include:

a) Identify causes and sources of pollution
b) Estimate load reductions expected
c) Describe management measures and targeted critical areas
d) Estimate technical and financial assistance needed
e) Develop an information and education component
f) Develop a project schedule
g) Describe interim, measurable milestones
h) Identify indicators to measure progress
i) Develop a monitoring component

One of the most important parts to include in any watershed plan are specific projects that can correct water resource problems identified during the planning process. The watershed projects typically address problems related to non-point source pollution, water quality, flooding, erosion, or habitat.

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Identification of specific projects throughout a watershed empowers stakeholders to champion projects in their community or that correspond with their organizations goals. This also improves watershed planners' ability to obtain funding for these projects through grants or other means. One of the most common types of project used to address non-point source pollution (and other water resource issues) involve the installation of best management practices to help restore natural hydrology and offset problems associated with increased impervious surfaces and urbanization.

Nature-Based Solutions - New design practices that emulate nature are increasingly being used to restore natural hydrology and manage stormwater runoff. These nature-based solutions help promote infiltration and groundwater recharge, improve water quality, and reduce flooding in urban and suburban landscapes. The design practices are called Low Impact Development (LID) and they replicate natural systems such as wetland, prairie, or forest that had been in place prior to development. The LID practices are sometimes also referred to as green infrastructure or stormwater best management practices (BMPs). The LID practices include pervious pavement, raingardens, bioswales, street trees, landscaping with native vegetation, and stormwater detention basins with native vegetation. These LID practices can be incorporated into any type of land use whether it is residential, commercial or industrial and can be retrofitted into existing communities. Refer to Chapter ??? on Green Infrastructure for more detailed information on LID practices.

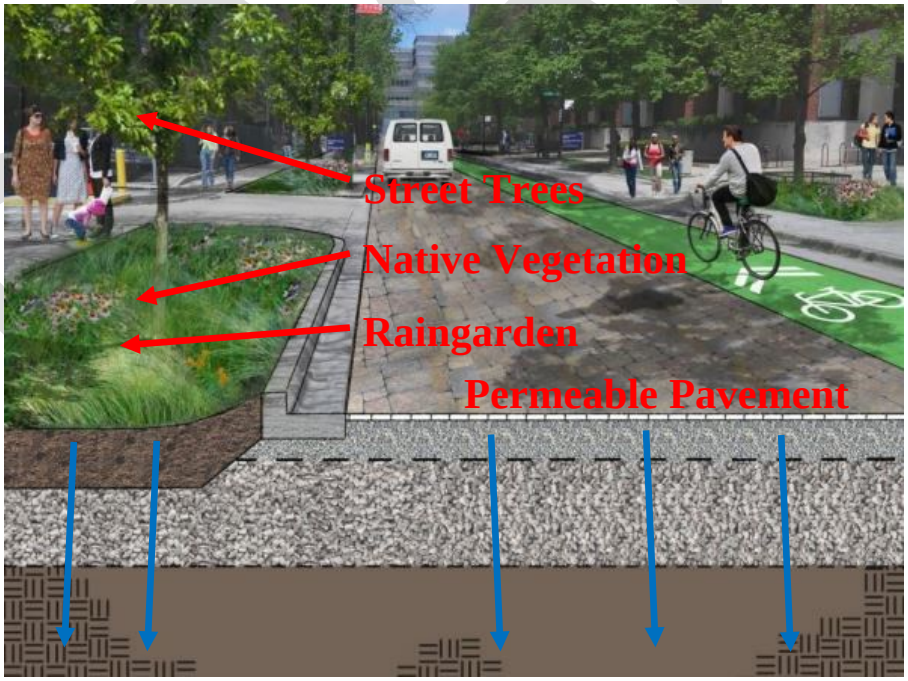

Figure ???: Cross-Section view of a streetscape with several Low Impact Development (LID) practices. The LID practices help reduce the volume of stormwater runoff by promoting infiltration into the ground. The LID practices also help improve water quality, reduce flooding, reduce urban heat island impacts, and provide habitat (image, courtesy of Environmental Consulting and Technology).

Groundwater – Groundwater is water found in the pore spaces and cracks of underground aquifers. An aquifer is a geologic formation that can hold useable amounts of groundwater and can provide the water to wells, springs, lakes, or streams.

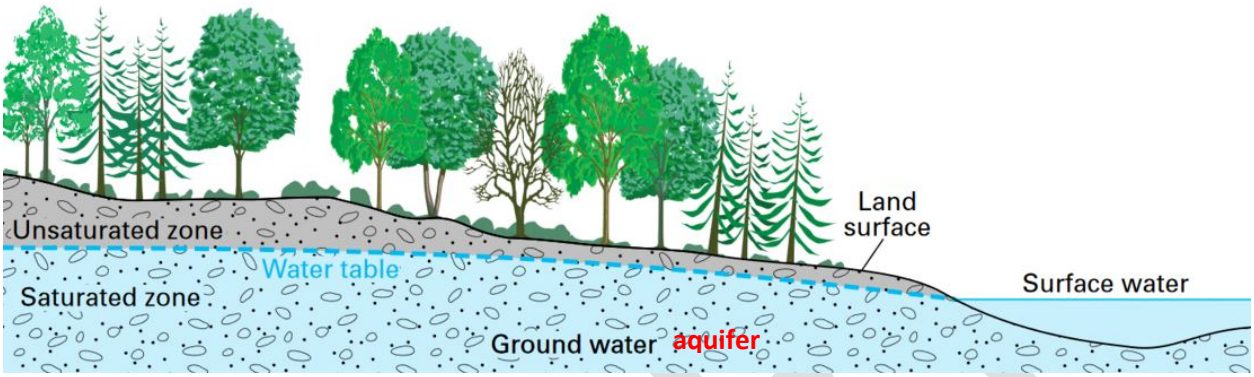

Figure ???: Cross-Section view showing the water table of a groundwater aquifer; the saturated zone where pore spaces are filled with water; and the relationship between the groundwater aquifer and the surface water (e.g. lake, river, stream, or wetland).

Aquifers are typically made up of sand, gravel, porous rock such as sandstone, or fractured rock such as limestone. Groundwater moves through the aquifers, flowing between the interconnected pore spaces and cracks in the geological material. The ability of geologic material to hold or transport water is based on the materials' porosity and permeability. "Porosity" refers to the amount of water a particular aquifer material can hold. Groundwater is held in the empty space (pore space) between the grains of minerals. For instance, a material like gravel with large grains and pore spaces can hold a larger volume of water (porous) than silts and clays that have extremely small pore spaces (non-porous). The "permeability" of an aquifer material refers to the ability of water to pass through the pore spaces. Permeability rates are based on the interconnectedness of the pore spaces. Pore spaces can be lined up so water can pass easily between them (permeable). Pore spaces can also be off-set or obstructed by smaller particles, thereby obstructing the movement of water (non-permeable).

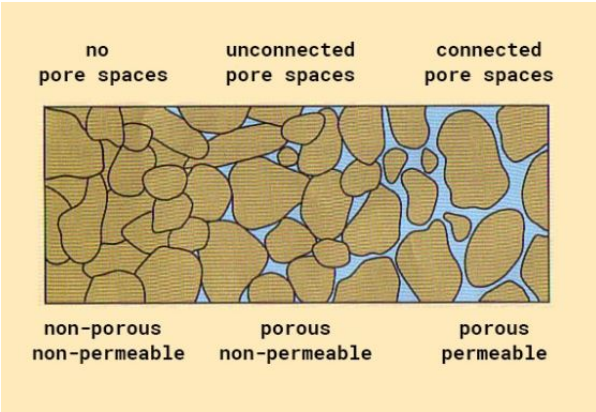

Figure ???: In most aquifers, water fills the pore spaces between the grains of sediment such as sand and gravel or sandstone. The size, shape, and composition of the sediment grains determine the **porosity** of the material. The **permeability** of the sediment is a measure of how the inter-connections between the pore spaces allow water to move sediment. Although low porosity usually results in low permeability, high porosity does not guarantee high permeability. It is possible to have highly porous sediment or rock that has little or no interconnected pore spaces, thereby resulting in low permeability.

In bedrock aquifers composed of hard rock, such as the shallow bedrock carbonate aquifers (mostly limestone and dolomite) underlying parts of Northern Illinois, the rock itself is not non-porous and non-permeable so groundwater is stored in fractures and cracks in the rock. These bedrock aquifers can only occur in areas with fractures and cracks large enough to hold significant volumes of water. The fractures and cracks also need to be properly aligned to allow water to flow readily (permeable), and be located below sand and gravel aquifers that can continually replenish the groundwater. Because solid bedrock aquifers depend on such specific conditions for recharge, they can be particularly susceptible to drawdown if pumping exceeds the natural recharge rate.

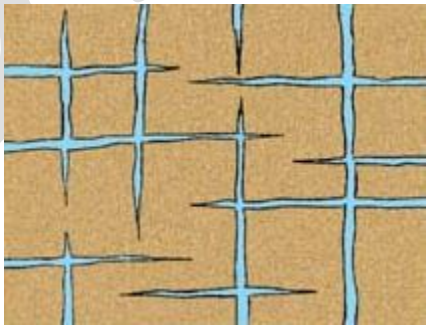

Figure ???: Some aquifers can be found in areas composed of solid rock where water fills fractures and cracks in the rock. The ability of rock aquifers to store water is a based largely on the size, number, alignment, and interconnection of fractures and cracks. Without sufficient interconnection between the fractures and cracks, water will not be able to move rapidly enough to refill and recharge the voids when water is pumped.

Groundwater in aquifers is replenished, or recharged, from rain or snowmelt that seeps down from the land surface into the aquifers. Water will continue to seep down until an impermeable surface (aquiclude) or minimally permeable surface (aquitard) is reached, causing water to rise, saturate the pore spaces, and create a water table. The elevation of the water table will rise and fall depending on factors such as the amount of rainfall, the porosity of the geologic material, and how much water is being pumped from the ground. The area below the water table is called the saturation zone and has pore spaces filled with water. The area above the water table is called the unsaturated zone, or zone of aeration, and has pore spaces filled with air, or a combination of air and water.

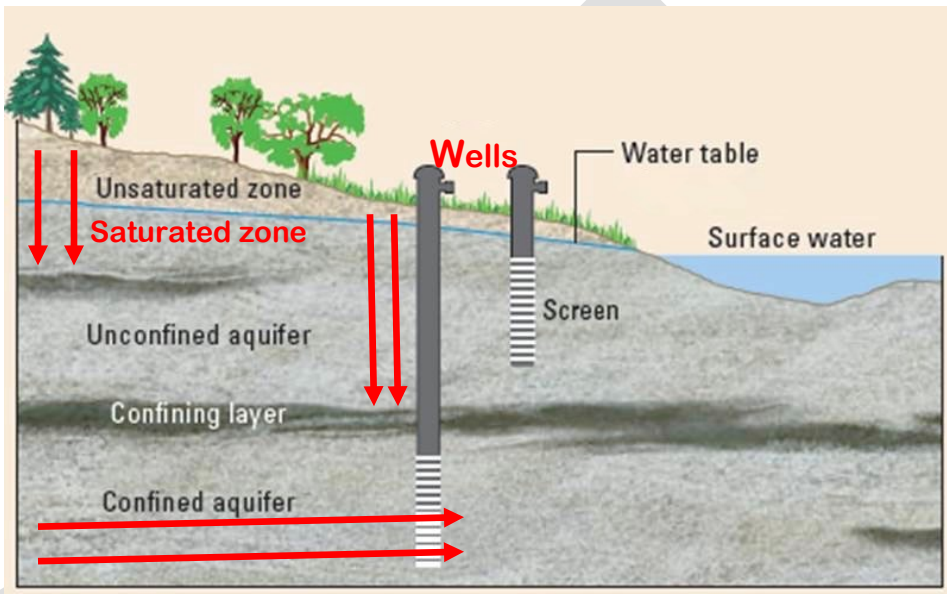

Figure ???: Cross section view illustrating the location of water tables, aquifers and wells

The impermeable surface below the water table is referred to as a confining layer. Confining layers often consist of impermeable, or less permeable, materials such as clay, rock, or shale that prevent, or slow, water from continuing to infiltrate downward. Aquifers can be located above and below confining layers. Aquifers above any confining layer are called unconfined aquifers (or water table aquifers) while aquifers below confining layers are called confined aquifers:

- Unconfined aquifers – Under atmospheric pressure because it is open to the ground surface. Water table can freely rise and fall.
- Confined aquifers – Under the weight and pressure of the ground bearing down on it. Water in wells is under pressure and rises above the aquifer. The height of water in wells is based on the amount of pressure, called head pressure, in the aquifer. As water levels drop, so does the head pressure.

Since unconfined aquifers are open to the land surface, they may be particularly vulnerable to contamination from pollutants infiltrating downward. The porosity and permeability of the geologic material plays a role in how readily water, and pollutants, can infiltrate and how susceptible wells may be to pollutants. When water infiltrates through sand and gravel or sandstone, many forms of pollutants will get filtered out as they move through the narrow pore spaces. Therefore, deeper wells may be less susceptible to many pollutants than shallow wells. In solid bedrock aquifers, where water flows through cracks and fissures, pollutants can travel farther and faster than aquifers with small pore spaces. Confined aquifers on the other hand may be somewhat protected from pollution because the impermeable (or less permeable) surface above them prevents pollutants from moving down into the aquifer. However, confined aquifers may also have slower recharge rates and therefore be more vulnerable to drawdown from over-pumping.

Groundwater aquifers provide drinking water to over 50 percent of the people in the United States, and is often the sole source of water available in rural areas. To access the water, wells are drilled down below the water table so groundwater can be pumped to the surface. Groundwater wells include high capacity wells capable of pumping large volumes of water for municipalities, industries and agriculture or low capacity wells suitable for private residences or businesses.

In addition to providing water for people to use, groundwater is also vital to maintaining hydrology to surface waters. Groundwater is in constant motion, not only infiltrating downward, but also moving laterally to provide a consistent baseflow of groundwater to lakes, rivers, streams and wetlands. Since groundwater moves slowly (e.g years, centuries, millennia), groundwater can continue providing baseflow to surface waters even during summer months or droughts. This baseflow of cool, filtered water is necessary to maintain high quality aquatic habitat in many types of water bodies.

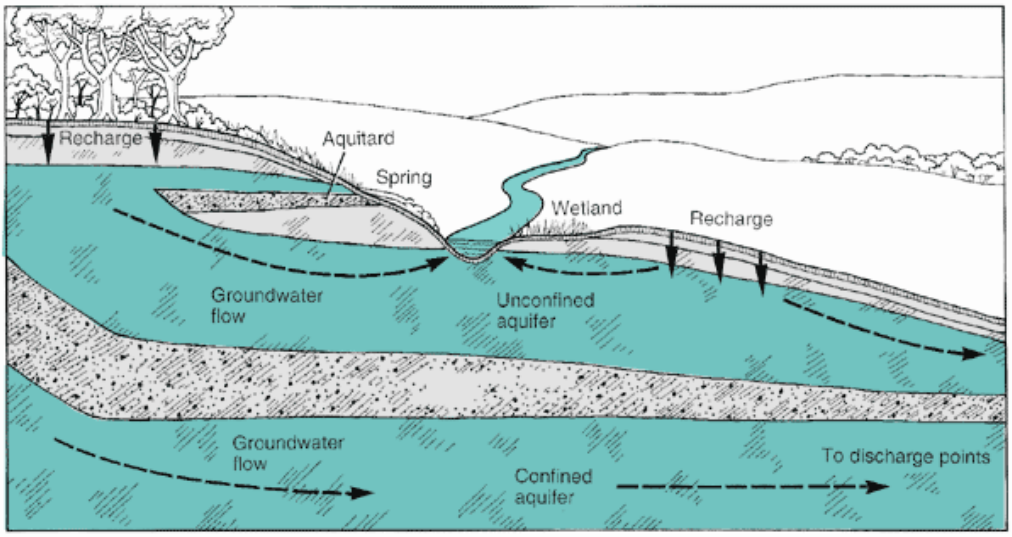

Figure ???: Cross section view showing groundwater flow in confined and unconfined aquifers. Groundwater is recharged by precipitation that infiltrates down from the land surface and discharges into water body (e.g. lakes, rivers, streams, wetlands)

Excessive pumping can adversly impact aquifers, as well as the people and resources that depend on them. When water is pumped from a well, the water table around the well is lowered. The artificially lowered water table creates a cone shaped area of desaturated soil that extends from the ground surface and down around the well. This zone of desaturated soil is called the “cone of depression”. The cone of depression will get larger and deeper as greater volumes of water are pumped out. As the cone of depression increases, neighboring wells can run dry if the water table drops below the depth of their wells. The affected well owners may have to pay to have deeper wells installed. This type of aquifer drawdown can happen on residential scales or even regional scales. For instance, the deep bedrock aquifer around Joliet, Illinois has been lowered by over 800 feet, potentially impacting water suplplies throughout northeast Illinois.

Excessive pumping can also reduce the volume of groundwater that provides baseflow to surface waters including lakes, rivers, streams, seeps and wetlands. Under natural conditions, precipitation infiltrates into the soil and slowly migrates underground until eventually flowing into a water body. If excessive amounts of water are being pumped, the cone of depression from a pumping well may lower the water tables in nearby lakes, rivers, streams, or wetlands. As a result, the water body begins to lose water to the adjacent groundwater aquifer by the well. This is known as induced recharge. Aquatic habitats have been damaged, and streams and wetlands have been completely dried up by induced recharge from well pumping 23. Induced recharge also has the potential to contaminate aquifers since any pollutants in the affected water body could also be pulled into the aquifer.

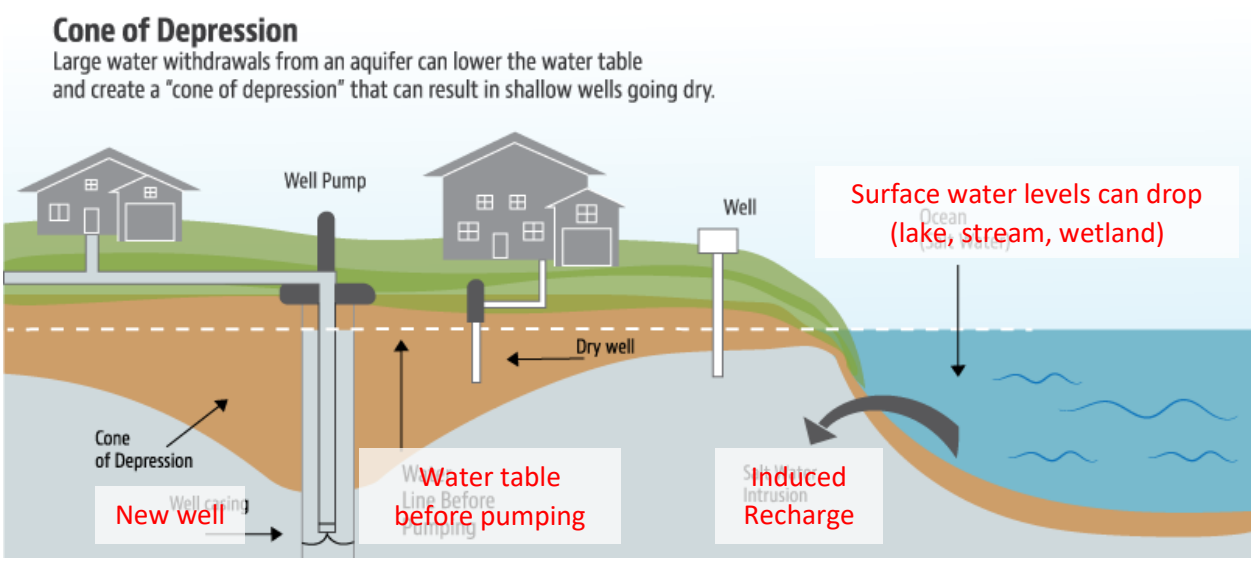

Figure ???: profile view showing how heavy pumping can create cones of depression, dry out neighboring shallow wells, lower water tables, pull water into aquifers, and dry out water bodies.

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