Florida Envirothon Study Packet
Aquatic Section

CONTENTS

WATER CYCLE FACTS

Most freshwater in Florida comes from rainfall within the state, recharging the vast Floridan aquifer system. This aquifer system plays a unique and valuable role in the cycle of our water resources.

THE HYDROLOGIC CYCLE

The phrase **hydrologic cycle** describes the circulation and distribution of water on the surface of the land, underground and in the air. There are five basic processes in the hydrologic cycle. These can occur at the same time and, except for rainfall, happen continuously:

- Condensation
- Precipitation
- Runoff
- Evapotranspiration
- Infiltration

Condensation

The first process is condensation, visible in the form of Florida's often spectacular cloud formations. Water vapor in the air condenses to form droplets that eventually merge and fall as rain.

Precipitation

Precipitation in Florida most often occurs in the form of rain. There is no "normal" amount of rain. In most years we get either more or less than we need. Florida's average rainfall lies between these two extremes at 54 inches, but even average rainfall fluctuates throughout the state. Because of large seasonal and annual variations, floods and droughts are common in this state. Future variations will probably be as unpredictable as those recorded in the past.

Rainfall varies in amount, as well as by season, geographic area and intensity (the quantity of rain that falls within a certain number of hours). Traditionally, 70% of the state's rain falls between May and October, with the remaining 30% between November and April. Most rain falls between July and September. North-central Florida may experience more total rainfall during the summer months, but recharge of the aquifer systems usually takes place during the winter. This is due to reduced evapotranspiration rates. Plants use less water because they are in a semi-dormant state and the sun's intensity is less, which reduces **evaporation**.

Runoff

The third process in the hydrologic cycle is runoff. **Runoff** is the water that does not soak into the ground or percolate into aquifers. When aquifers are not saturated, they can absorb rainfall either directly or through **sinkholes** or recharge areas. When the weather is wet, shallow aquifers are frequently saturated, causing much of the rainfall to run off into lakes and streams.

Florida's average yearly runoff is 14 inches out of our average rainfall total of 54 inches. It is useful to know how much water actually runs off in average, very wet or very dry seasons, and how much infiltrates the ground.

Evapotranspiration

The fourth process in the hydrologic cycle is **evapotranspiration**. Evaporation occurs when water is returned to the atmosphere in vapor form by the combined effects of solar radiation, the energy source, and wind. The evaporation process occurring in plant leaves is called transpiration, and together the processes are called evapotranspiration. Water that does not infiltrate or run off, evaporates.

Florida is a subtropical state with much rain. Plants have a high demand for water. High solar radiation levels means a high level of evapotranspiration activity. The quantity of water evaporated varies proportionately as **surface water** acreage varies. In south and central Florida, evapotranspiration exceeds rainfall during the dry season and the water is replaced during the wet season. A great variance exists between the dry and wet seasons in the need for agricultural irrigation water.

Infiltration

Water may be contained on the ground in ponds, lakes, rivers, streams or wetlands. Although the processes of evaporation and drainage occur continuously from these areas, water also percolates through the soil. The pores and channels of the soil determine its **permeability**, or the speed with which water can move through the soil. Different soils have different water-holding capacities and permeability rates, depending on the amount of sand, silt, clay and organic matter in the soil.

Florida's soils consist largely of sands that lie over less-permeable clays. These sands do not retain water very well. Sandy soils are different from the silty clay or loamy soils found in other parts of the country. If you have 20 inches of rain over loamy soils, you can grow a crop. In Florida, that same 20 inches over sandy soils would not be retained and the soil would be too dry for most crops.

Water has a high flow rate through sandy soils. Where a slowly permeable layer separates the surface soil from the limestone layer, the water flow rate is slower. An understanding of permeability and **porosity** of soils is important for understanding infiltration and groundwater movement. (See Soils Section.)

Rooting Zone. As water from rainfall or irrigation moves downward through the soil, it enters the rooting zone. This is the only area where plants can absorb water with their roots. In soils that do not retain water, excess rainfall or irrigation water moves or gravitates downward from the rooting zone. The rooting zone may be as deep as 6 feet in the well-drained sands typical of the central Florida region. In flatwood soils or pastureland, the rooting zone may extend from 2 to 3 feet deep. Rooting zones vary, depending on location, soil types and water tables.

AQUIFER FACTS

Below the land, there is a region in which all the pore spaces in the rock or soil are filled with water. This is an **aquifer**, which means "water bearing." An aquifer may be a few feet thick or hundreds of feet thick. It may be just beneath the surface or hundreds of feet down. It may underlie a few acres or thousands of square miles. The aquifers are the source of 90% of Florida's drinking water.

Aquifers function in two very important ways. First, they transmit **groundwater** from the point of entry to points of **discharge** (from where it goes in, to where it comes out). Second, they provide storage for large volumes of water. In a sense, they act as both pipes and storage tanks. Aquifers are classified as either unconfined or confined.

CLASSIFICATION

Unconfined Aquifers

Unconfined aquifers are those in which water is free to percolate through an unsaturated zone of soil or rock to the water table. (See Soils Section.)

Confined Aquifers

Confined aquifers have an impermeable layer or layers, such as clay, over the aquifer. These layers prevent the free movement of water. Thus the water is confined under pressure, as in a pipe system. Drilling a well into a confined aquifer is like puncturing a water pipe, with water under pressure gushing into the well, sometimes even rising to the surface and overflowing. These free-flowing wells are called **artesian wells**. The many springs of Florida are natural areas where the confined aquifer's water is pushed to the earth's surface.

RECHARGE

Recharge to an aquifer occurs when water flows through unconfined zones or leaks slowly through a confining layer. Water may enter an aquifer through **recharge areas** many miles from a spring or well. Generally, good recharge areas in Florida are areas where highly permeable sand overlies porous limestone such as rolling hills near Orlando or Gainesville, ridges of the Lake Wales area or the sandy forests of the Ocala National Forest. Recharge or infiltration of water into an aquifer system has been impacted by human development in recharge areas.

SHALLOW AQUIFER

The main source of freshwater for much of Florida comes from the unconfined shallow aquifers in the state. Rainfall reaches the shallow aquifer quickly by flowing through the sandy soil downward to an impermeable layer. Since the upper surface of the shallow aquifer is free to rise and fall, it is easily influenced by rainfall. Wells tapping the shallow aquifer are nonartesian because the water is not under pressure. Such wells need to be pumped.

The top of the shallow aquifer is called the **water table**. Above the water table, the pore spaces in the soil or rock are mostly filled with air. This area is called the zone of aeration. The water which is present in the zone of aeration is bound to plant roots or soil/rock particles. Below the water table is the zone of saturation where all the pore spaces are full of water.

The depth of the water table below the ground surface depends on various factors including climate, season of the year, volume of groundwater pumped or withdrawn, and topography. When the land surface and the water table intersect, water seeps onto the surface. This may result in the formation of a lake, wetland or spring or simply a discharge into a water body.

Since lakes, wetlands and other surface water areas can be part of the shallow aquifer system, depleting the state's water storage by draining these areas can impact the state's water supply and aquatic habitats.

DEEP AQUIFER

Underground limestone layers extend from Tallahassee to Key West. In some areas, the layers may be as much as 12,000 feet thick, down to the granite base of the continent. Porous limestone holds water much like a sponge. At some locations, the porous limestone outcrops at the surface and water moves easily into the aquifer. In other places, faults and natural sinkholes breach the overlying confining layers and allow water infiltration.

The aquifers are confined by relatively impermeable strata. A confined, artesian aquifer holds water under sufficient pressure to rise above the top of the confining layer when a tightly cased well taps the aquifer. Artesian wells are free-flowing, and most highyielding wells are supplied from the deep aquifer. Because water moves slowly through the deep aquifers, these storage areas may be slow to be recharged if they are overpumped.

MAJOR FLORIDA AQUIFERS

Florida has five major aquifers: the Floridan aquifer, the Biscayne aquifer, the sand-and-gravel aquifer, the surficial aquifer and an aquifer area with highly mineralized water. The Floridan aquifer actually extends to the southern tip of Florida, but the water in that southern portion is highly mineralized and not potable, that is, drinkable.

Floridan Aquifer

The thick porous limestone of this aquifer extends over much of the state. Except in outcrop areas, such as along the Suwannee River, it generally lies under several hundred feet of sedimentary strata. The Floridan aquifer is artesian. In areas such as eastern Duval County, the water level has been lowered because of heavy use. In other areas, water quality has been degraded by the intrusion of seawater or highly mineralized water. The water supply is replenished by rainfall in northern and central Florida and to some extent in southern Alabama and Georgia where the aquifer outcrops.

Biscayne Aquifer

This aquifer underlies an area of about 3,000 square miles in Dade and Broward counties and the southern part of Palm Beach County. It is nonartesian and gets most of its recharge from local rainfall and by canals from water conservation areas. The Biscayne aquifer is shielded from upward intrusion by the Floridan aquifer by relatively impermeable beds of clay and marl. Use of the Biscayne aquifer is limited because of **saltwater intrusion** due to extensive drainage during the past 50 years.

Nonartesian Sand-and-Gravel Aquifer

This type of aquifer is the major source of groundwater in extreme western Florida. The recharge source is mainly local rainfall, but the **potentiometric surface** inclines steeply, implying some recharge from Alabama.

Surficial Aquifer

The surficial aquifer is less than 100 feet deep and is present over much of Florida. In South Florida, the surficial aquifer is the major source of groundwater in Martin, Palm Beach, Hendry, Lee, Collier, Indian River, St. Lucie, Glades and Charlotte counties. Recharge comes mainly from local rainfall.

Highly Mineralized Aquifer

This aquifer underlies the extreme southwest portion of the state. The water is not considered usable. This area covers about half of Monroe and Collier counties and portions of Hendry, Palm Beach, Broward and Dade counties.

HUMAN IMPACTS

Florida is unique as a peninsula that juts into the ocean. The unique location of the state leads to the problem of salt water intruding into the groundwater supply. Salt water is more dense than freshwater and exerts a constant pressure to permeate the porous land mass. Salt water intrudes beneath the freshwater in estuaries and canals and in the aquifer. As long as freshwater levels are above the ocean level in the shallow and deep aquifers, the water pressure keeps salt water from moving inland and upward in the land.

South Florida’s coastal area canals, for example, flow at stages about 2 feet above sea level. The small resulting pressure in the permeable subsurface rock is enough to hold out the denser salt water. But during dry periods, canals without locks or dams fall to sea level or below; then the denser salt water moves upward in tidal canals and inland in the aquifer.

In some places, overpumping of wells can increase saltwater intrusion. As water is pumped at a rate faster than the aquifer is replenished, the pressure of freshwater over salt water in the land mass is decreased. This may cause the salt-fresh divide, or interface, to rise and cause degraded water. As coastal cities move their wells inland to escape saltwater intrusion, the effect may be to move this intrusion inland. This depends on management of the area between the wells and the coast.

Pumping water from an aquifer for industrial, irrigation or domestic use reduces an aquifer’s volume. Unless withdrawals are modified or recharge increased, the aquifer will eventually be depleted. A drained aquifer can collapse from the settling of the overlying lands. Collapsed underground aquifers no longer have as much capacity to accept and hold water. Recharge is difficult, volume is smaller, and yields are considerably reduced. Springs once fed from the water table also dry up.

MANAGEMENT TECHNIQUES

Saltwater intrusion can be prevented through water conservation techniques, alternative sources such as desalination, and careful siting of wellfields. Intrusion is caused by withdrawing too much water from an aquifer and reducing the water pressure that prevents salt water from intruding or invading the potable water supply.

RIVER SYSTEM FACTS

Many people, plants and wildlife either use, need or live on streams or rivers. Some people like to live near rivers for **aesthetic** reasons. Many communities developed near water for economic reasons — industry, power, transportation, etc. Some plants and wildlife depend on rivers for water and food. Most organisms require a nearby water source to survive.

When we change the physical, chemical or biological elements of an aquatic ecosystem, we change its ability to support species and provide the products and services we depend on. These services include controlling floods, purifying water, recharging aquifers, restoring soil fertility, supporting recreation, nurturing fisheries and supporting evolution. Once nature can no longer provide, we must either do without or find a substitute, usually less effective and at a much higher cost financially and environmentally.

In Florida, when water falls to the ground as precipitation, it begins a long journey to the Atlantic Ocean or the Gulf of Mexico. A single drop may run into a small creek, which may run into a stream. Streams eventually flow into rivers, which combine to form larger and larger rivers. Streams, creeks or rivers that flow into a larger water system are called **tributaries**. On maps you can see that all the creeks, streams and rivers look like a tree.

The land that is drained by the creeks, streams and rivers that flow into the single major river is called a **watershed**. Watersheds of major rivers can cover many thousands of square kilometers or miles. Human activity that takes place within a watershed and along its rivers can affect the condition of the watershed.

RIVER FEATURES

River Forms

Rivers or streams only conform to perfectly straight lines when human engineers build channels for them. All other rivers bend, twist and cut back on themselves. The momentum of rivers and their erosive nature makes them independent in shape as they cut around erosion-resistant rock.

The momentum of the moving water causes outside-curve cutting. In turn, loss of momentum causes the deposit of materials, which build up on the slower inside of a curve. In time, rivers develop a number of very recognizable characteristics or forms:

Island — land surrounded by two channels of the river
Oxbow — a meander that has been cut off
Floodplain — land that can be covered with water by a flood
Gravel and sand bars — deposits of sand and gravel in the river
Meander — an *S*-shaped curve in the river
Braid — a river that splits and then rejoins within its channel
Wetland — habitats flooded by shallow water for at least a part of the year. There are both federal and state legal definitions used by regulatory agencies.

Velocity and Discharge

The **velocity**, or speed, of a river and the discharge, or volume, vary greatly from season to season depending on runoff both locally and upriver or anywhere within the watershed of the river. Rain, feeder streams and control devices such as dams also affect seasonal flows.

While the Colorado River's headwaters are found at 14,000 feet above sea level, the headwaters of Florida's 310-mile-long St. Johns River are only 26 feet above sea level. Elevation changes along a river affect the velocity or discharge rates. More drastic elevation changes cause a river to run faster, more gradual elevation changes cause the river to flow slower.

The velocity of a river greatly affects the character of a river by sculpting banks, **scouring** bottom material and affecting the lives of in-stream and streambank plants and animals. The speed the river travels also affects the types of invertebrates living within it. Where the current is strong, large particles are kept in suspension and the substrate consists of larger particles where grasping invertebrates attach. A slow flow allows particles to settle out. Within the same general area, a river may commonly have alternating riffles or shoals (stony areas with fast-flowing water) in some locations and pools (muddy areas with slow-moving water) in others.

Riverbed Materials or Substrate

The roughness of the riverbed affects the river's current or speed. A silt or sand bed is smooth, while gravel or rocks increase friction and turbulence. The riverbed material is affected by the velocity of the river, determining what gets washed away or deposited, what's exposed or covered up. Bottom sediments are a good reflection of the geology of the river's origins or the material through which the river flows.

The types of materials and the size of the rocks on the river bottom will influence life found there. Silt is more suitable for burrowing types of invertebrates, while large rocks attract clinging invertebrates. (See Benthic Invertebrate Facts.) Soil carried by runoff waters is deposited in slower parts of the river, while areas with swift currents will have clean, coarse substrate. Substrate particles range from large boulders to fine silt and clay.

Bank Slope

The **slope** of the river bank reflects the interaction between discharge and velocity of the river and the nature of the material and geology of the area through which the river flows. The slope of the bank affects the riparian life and use by wildlife. It also affects use by humans.

Steep slopes are easier to undercut and more susceptible to erosion from runoff. Gentle slopes are more susceptible to flooding. The upper Suwannee River has steep slopes, while the lower Suwannee River has more gentle sloping banks. The lower Suwannee River floods and overflows its shallow banks each year, while the upper Suwannee River only floods out of its steeper banks periodically.

RIPARIAN HABITAT

Habitat is an area that provides food, water, shelter and space for an organism. **Riparian habitat** refers to the life-supporting area adjacent to rivers. The habitat for a particular organism varies in size depending on the needs of the organism. The **riparian zone** extends as far as the riparian vegetation grows and is limited by adjacent land uses, such as agriculture, roads, and houses.

Riparian areas act as buffers between upland and aquatic habitats. Some ecosystem functions of riparian areas include helping to prevent silt and contaminants such as animal waste, pesticides or fertilizers from entering the water. Changes to the riparian area affect both the instream habitat and habitat for land animals such as birds, deer and many other species. In addition to offering food, cover and water, this area also forms an undeveloped corridor that many animals use as a "highway" or "greenway" to safely go from one place to another.

River Habitat Features

The most distinctive feature of a river habitat is the constantly moving water. A river is home to many different types of plants and animals, each of which is specially adapted to life in this unique habitat. To survive in a river or stream, organisms must be able to:

1. Maintain their position in moving water and have adapted different lifestyles or physical features to allow them to remain in one place.
2. Absorb enough oxygen. Many aquatic organisms have gills to help them breathe and absorb dissolved oxygen.
3. Obtain enough food in spite of water carrying their food downstream.
4. Avoid **predators**.
5. Reproduce successfully.

OTHER AQUATIC HABITATS

In addition to rivers, Florida is blessed with other types of water bodies.

Ponds and Lakes

A lake or pond is probably one of the most familiar sources of water. It is merely a large amount of standing water with land on all sides. Some lakes are man-made, others are natural due to sinkholes, erosion or other causes. Florida has more lakes than other states.

Estuaries

Estuaries are found at the lower end of most rivers. They are the point where the river dumps into a larger body of salt water. A unique feature about estuaries is that they have a balance of fresh and salt water. Pollution, as well as the tides, affect these areas. Estuaries can slow the rate of pollution entering oceans by filtering it though various marsh / seagrass / wetland systems. Estuaries also serve as nurseries for many aquatic species, including many that are commercially important. Some well-known estuaries are in Apalachicola Bay, Tampa Bay, Biscayne Bay and the St. Johns River.

Springs

Springs dot the landscape in Florida. They are evidence of water returning to the surface after having been absorbed by the earth. Over time, the movement of the Earth's crust has caused cracks in the limestone. Acidic groundwater causes the cracks to enlarge, resulting in a network of tunnels and caverns. If one of these tunnels connects with the surface, a spring is formed. The water rises several hundred feet, depending upon the geology of the area. Most spring water is a clear blue color, and the water temperature fluctuates very little.

HUMAN IMPACTS

People use lakes, rivers and estuaries for recreational purposes such as fishing, swimming or canoeing. Impacts vary depending upon use. Impacts made on the river in one area can affect the water and life in other parts of the river, especially downriver. Often, limits must be placed on who or what may occupy a river site.

Human activities can reduce or increase the velocity of a river. These activities can greatly affect the character of the river and its environmental functions. For example, recreational activities can increase sediments carried by a river, eventually reducing the water-holding or transmission capacity of the river.

Riparian habitat, like any other part of a natural ecosystem, is constantly changing. Some of these changes are natural: trees may die and fall to the ground or the river may slowly erode the bank. However, some are caused by humans. Riparian areas provide pleasant areas for bicycling, horseback riding, walking and hiking. If an area is frequently used by people, there are signs of their use left behind. These signs could be litter, trampled vegetation, eroded paths, campsites or fire pits, etc.

Clearing or tilling land close to a stream or river disrupts groundcover and increases runoff, and the land dries out much more quickly. As the water table under the land drops, water eventually begins to seep out of the streambed back into the surrounding land. This decreases flow significantly during dry spells and results in streams drying out completely at times so that they are classified as having intermittent rather than continuous streamflow. This interruption in flow alters both aquatic and riparian ecosystems.

Investigation of the physical characteristics of river systems is carried out on a regular and ongoing basis by government, industry and the private sector, both nationally and statewide. Data gathered from these investigations help in planning for a river's management and protection or in identifying problems and solutions.

Traditionally, men have tried to constrain or alter the free-flowing nature of rivers to suit their needs. This was due to a belief that floods served no purpose and undeveloped rivers and their floodplains, wetlands and backwaters were wasted and unproductive.

A dynamic equilibrium exists between the biological and physical features of aquatic systems. Aquatic systems in Florida are adapted to “pulse” disturbances — events such as naturally occurring seasonal floods. The flood pulses help maintain the natural interactions between a river and its surrounding landscape. These floods make both the river and the landscape extremely productive and diverse.

Animals and plants are adapted to this regime. For example, many fish use the floodplain as a spawning ground and nursery; some consume and help distribute seeds, while others depend on the temporary abundance of food. Many plants use the flood period to germinate and absorb newly available dissolved nutrients. Migratory waterfowl rely on the flood period bounty also. Many soils need the regular addition of nutrients and organic matter to stay productive. The flood pulse is a natural part of the system which man frequently attempts to interrupt.

In addition to providing flood protection and prevention, man has fragmented the majority of river systems in the United States. **Fragmentation** takes place through the engineering of dams, reservoirs and structures, and through navigation and transportation. Altering the structure of a river brings about changes in the water depth, flow rate, temperature, sediment content, chemistry and oxygen concentration. These factors influence the composition and abundance of species. Many freshwater mussel species are extinct or threatened due to dams and other structures erected to control rivers. Man has also constructed canal systems that connect previously unconnected aquatic systems, thus allowing for the invasion of non-native species and sometimes for drastic changes to the natural systems.

In addition, industries, towns, houses and agricultural fields have been placed in the floodplain. The reduction of the natural floodplain reduces the capacity to store and filter flood waters. The loss of floodplains frequently aggravates or increases the length and severity of floods. Floodplains were designed by nature to hold excess waters during a flood until they can be released or slowly absorbed by the river system.

WATERSHED FACTS

All land on earth is a watershed. Humans and their activities play important and essential roles within them, yet few people understand watersheds. Still fewer know the dynamics and boundaries of the ones in which they live.

A watershed is the land area from which both surface water and groundwater, sediment and dissolved materials drain to a common watercourse or body of water. For each watershed, there is a drainage system that conveys rainfall to its outlet. A watershed may be the drainage area surrounding a lake that has no surface outlet, or a river basin as large as that of the St. Johns or Suwannee rivers or the Colorado River. Within a large watershed are many smaller watersheds that contribute to overall streamflow.

The point at which the boundaries of two watersheds come together or connect is called a **divide**. In Florida there are only small changes in land surface or topographic relief, and the divide between watersheds is subtle. A watershed is drained by a network of channels that increase in size as the amount of water and sediment they must carry increases or by overland sheet flow, which is harder to visualize.

Streams are dynamic, open-water systems that collect and convey surface runoff generated by rainfall, snowmelt, or groundwater discharge to estuaries and oceans. The shape and pattern of a stream are a result of the land it cuts and the sediments it carries, as well as the results of human alterations.

STREAM ORDERS

In most cases, a watershed system is almost entirely made of hillsides or, as in many areas of Florida, by slight elevation changes. Only about 1% of a watershed is stream channels. The smallest channels in a watershed have no tributaries and are called first-order streams. When two first-order streams join, they form a second-order stream. When two second-order channels join, a third-order stream is formed, and so on. First- and second-order channels are often small, steep or intermittent. Orders six or greater are larger rivers.

Channels change by erosion and deposition. Natural channels of rivers increase in size downstream as tributaries enter and add to the flow. A channel is neither straight nor uniform, yet its average size changes in a regular and progressive fashion. In upstream reaches, the channel tends to be steeper. Banks become lower as the width and depth increase in the lower reaches. More sand and silt are found downstream.

STREAMFLOW

Besides the ordering system previously described, streams may be classified by the period of time during which flow occurs.

Perennial flow indicates a nearly year-round flow (90% or more) in a well-defined channel. Most higher order streams are perennial.

Intermittent flow generally occurs only during the wet season (50% of the time or less). In Florida, some streams and creeks have surface water flows that sink beneath the ground due to fissures and cavities in the underlying limestone formations and then re-emerge some distance downstream. This is known as spatial intermittency.

Ephemeral flow generally occurs during and shortly after extreme precipitation or, in other areas of the world, during snowmelt conditions. Ephemeral channels are not well defined and are usually headwater or low-order (1–2) streams.

Natural groundwater discharge is the main contributor to streamflow during dry summer and fall months. Without groundwater discharge, many streams would dry up.

FACTORS AFFECTING WATERSHEDS

The physical, chemical and biological makeup of a stream relates to surrounding physical features of the watershed and geologic origin. By analyzing these features, we can better understand stream-watershed relationships and predict effects of human influences on different stream types.

Climate

Land and water are linked directly by the water cycle. Solar energy drives this and other cycles in the watershed. A region's source of water depends on its weather and climate. Water comes to a watershed in seasonal cycles, principally as rain or snow. In some areas, condensation and fogdrip contribute water. The seasonal patterns of precipitation and temperature variation control streamflow and water production.

Climate affects water loss from a watershed as well as provides water. In hot, dry or windy weather, evaporation loss from bare soil and from water surfaces is high. The same climatic influences that increase evaporation also increase transpiration from plants. Transpiration draws on soil moisture from a greater depth than evaporation because plant roots may reach into the available moisture supply. Transpiration is greatest during the growing season and least during cold weather when most plants are relatively dormant.

Area

The area of a watershed affects the amount of water produced. Generally, a large watershed receives more precipitation than a small one, although greater precipitation and runoff may occur on a smaller watershed in a moist climate than on a large watershed in an arid climate.

Shape and Slope

Shape and slope of a watershed and its drainage pattern influence surface runoff and seepage in the streams draining the watershed. The steeper the slope, the greater the possibility for rapid runoff and erosion. Plant cover is more difficult to establish, and infiltration of surface water is reduced on steep slopes. Soil depths and moisture-holding capacities are usually less on steep slopes, and plant growth rates are often slower.

Water moves downward, but not straight down — it follows the slope of the watershed. The water slowly filters through the sand, rocks and soil of an aquifer. It usually travels just a few inches each day. This slow movement keeps pollutants from being quickly dispersed and allows some of them to be intercepted and removed.

Orientation of the Land

Orientation of a watershed relative to the direction of storm movement also affects runoff and peak flows. A storm at the top of a watershed releases water which flows down the watershed. As the storm moves down through the watershed, rain continues to fall. The accumulation of upstream rain and continuing rain causes or increases flooding. A rainstorm moving up a watershed releases water so that runoff from the lower section passes its peak before runoff from the higher sections arrives. But the degree of flooding is also influenced by the size and geometry of the watershed and its physical features, such as pavement, wooded areas and wetlands.

Orientation of a watershed relative to sun position affects temperature, evaporation and transpiration. Soil moisture is more rapidly lost by evaporation and transpiration on steep slopes facing the sun. Watersheds sloping away from the sun are cooler, and evaporation and transpiration are less. Slopes exposed to the sun usually support different plants than those facing away from the sun. Orientation with regard to the prevailing winds acts in a similar fashion.

Soils and Geology

Soil is the outer, thinnest layer of the earth's crust. It is composed of mineral particles of all sizes and varying amounts of organic materials.

Soils are of two types. **Residual soils** are those developed in place from underlying rock formations and surface plant cover. Characteristics of residual soils are closely related to the parent material from which they were formed. **Transported soils** include those transported by gravity, wind or water. Florida's soils were transported from other areas and have been deposited over time to form its current, different soils.

Soil often determines which plants will establish a protective vegetative cover. Plants also modify and develop soil. Plant roots create soil spaces and extract water and minerals through their roots. Plant litter adds organic matter to soil. Plant litter slows surface runoff and protects the soil surface from rainfall's beating and the subsequent puddling effects.

Soil is the basic watershed resource. Careful management and protection are necessary to preserve its function and productivity.

Vegetative Cover

Grasses, forbs, shrubs and trees make up the major plant cover types which build up organic litter and affect soil development. They usually develop under differing climatic conditions and all are important to watershed management.

Plant cover benefits a watershed. The canopy intercepts rain and reduces the force with which it strikes the ground. The canopy and stems also reduce wind velocity.
When leaves and twigs fall, they produce litter, which decomposes and is eventually incorporated into the soil. Shade and mulch formed by plant litter reduce evaporation of soil moisture. Plant litter protects the soil surface, allows infiltration and slows down surface runoff.

Vegetation provides a physical barrier, slowing down the flow of runoff and providing more time for it to infiltrate the soil. Stems and roots lead water into the ground. Roots open up soil spaces for water retention and drainage and add organic materials to the soil. They also help bind or hold the soil in place.

Windbreaks of trees and shrubs protect crops and reduce moisture loss from evaporation. Grasses, trees and shrub stems along riverbanks trap sediments and floating debris during high-water flows. Roots bind and stabilize streambanks and slopes to reduce slides and slumps.

MANAGEMENT CONSIDERATIONS

Water quality is largely determined by the soils, vegetation and human activities in a watershed. Human activities include timber harvesting, livestock grazing, agriculture, recreation and urban or industrial development.

Timber

Timber harvesting opens the canopy cover and reduces plant cover density. Timber harvesting does not negatively affect a watershed if slope and soil are carefully considered and plant cover rapidly restored. Best management practices (BMPs) are followed in Florida to ensure consideration of soil and water resources during timber harvest. The Forestry Section will address BMPs.

Isolated wetlands are exempt from BMPs, and the bedding and ditching in some forestry areas have affected many watersheds. The forestry industry is exempt from most existing regulations based on the voluntary use of forestry BMPs.

Agriculture

Domestic livestock tend to concentrate in specific areas when grazing. Concentrated grazing impacts plant cover and soil. Grass cover is improved by removing some annual growth, but productivity of the pasture is greatly reduced if overgrazing occurs. Excessive trampling by grazing animals can contribute to soil compaction, accelerated runoff and erosion problems.

Management of livestock and grazing wildlife species can enhance watershed values but is limited by the carrying capacities of the land and the forage species it supports. Management must consider timing, density and duration of animal use to capitalize on the positive aspects of grazing. Generally, recovery does not occur if vegetation is thinned to less than 70% of the natural cover. Without management practices such as reseeding, degradation will continue.

Animal waste management should be used in all livestock practices. Any areas where animals concentrate require waste management techniques. Concentration of animals increases the waste found in an area. As an area is intensely used by livestock, the soil is compacted and the land's natural capacity to use the waste is reduced. The compacted soils accelerate runoff, which contains fecal material.

Crop production usually involves removing the original plant cover and tilling the soil for seedbed preparation. Crop cover is usually seasonal and less dense than natural cover, which affords less protection for the soil. Erosion by both wind and water may remove the finer and more fertile soil particles, reducing land productivity. Crop and grove production involves adding fertilizers and pesticides to crops which may run off into natural water systems. Agricultural operations based on careful appraisal of soil, slope and climatic conditions include erosion control and are compatible with watershed management.

BMPs have been developed for all agricultural practices. Some BMPs have been converted to urban stormwater use.

Exotic Plants

An exotic plant is anything that is not native to a region. Exotic plants have had severe impacts on both aquatic systems and land systems. An increase in exotic plants has, in part, caused decreased streamflows. Many exotics compete more successfully than other vegetation for available moisture. This reduces groundcover and may cause increased runoff and less infiltration to groundwater storage. In addition, some exotics have high transpiration rates that leave less water for stream runoff as summer progresses. Control of exotics is a major economic commitment within Florida. For detailed information on exotic plants, contact the Florida Exotic Pest Plant Council or the Florida Department of Environmental Protection.

Fire

Many of Florida's natural ecosystems are based on a "fire ecology." They are fire-dependent, meaning fire is used to maintain the vegetation necessary to the ecosystem. Fire triggers many plant species to reproduce or seed and eliminates pest or invasive species. Man uses fire as a conservation tool to maintain or restore altered ecosystems to a viable functioning system.

Fire can be beneficial to a watershed when it is carefully managed. It can reduce available fuel and prevent more-destructive fires which generally happen where fire has been suppressed for years. Fire thins understory seedlings that compete with larger trees for available moisture. Open-forest types, such as longleaf pine, are maintained by fire. Natural fires are beneficial if they do not burn too hot or if a large amount of fuel has not built up. Humans have suppressed natural fires in many areas, increasing the amount of fuel and the likelihood of “hot” fires burning out of control.

Fire is one of the most widespread agents affecting plant cover and can be either beneficial or destructive. Under certain conditions, fire can remove nearly all vegetation and organic litter and, in extreme cases, sterilize and change the chemistry of the surface soil. Burning converts organic materials in plant cover, litter and topsoil to gases, solubles and readily leached ashes that can make acid soils alkaline. Damage to soil varies, but it may take several seasons for soil conditions to return to normal.

Without a protective canopy and litter, the soil surface is rapidly puddled and sealed by the first rains. Infiltration is greatly reduced, making runoff and erosion more rapid. Debris-laden floods often occur within fire-denuded watersheds during only slightly abnormal rainfall. Most of the water falling on a burned landscape is lost by rapid runoff. Streams from burned watersheds at first carry a heavy load of salts dissolved from ashes, floating debris and sediments. Water quality soon returns to normal, except for sediment-laden high flows. These conditions may continue for several years until the plant cover becomes re-established on the watershed.

Beavers

Beavers can have both positive and negative effects on a watershed. Their actions change watershed hydrology as well as damage cover. A beaver dam changes energy flow in its immediate area by turning part of a stream environment into a pond or swamp. If high beaver populations coincide with heavy livestock use, the results can be devastating to streams. On the other hand, their dams can be beneficial as sediment traps and fish habitat. Water held behind a beaver dam is released more slowly over a longer period of time.

Mining

Mining requires opening the earth to remove mineral resources. It is done by stripping off the surface soil and rock layers or by drilling tunnels into the earth to reach minerals. With either method, quantities of waste material are left on the surrounding land. This waste material is subject to erosion and dissolution, adding to the dissolved sediment load of streams draining the mined area.

Surface changes include altered topography and drainage. Drainage from mined areas may contain toxic minerals or salts harmful to the aquatic habitat. Additives to extract the desired mineral — such as cyanide for gold — can enter the watershed if not properly managed. In Florida, phosphate, titanium and peat are mined; all of these types of mining produce waste materials. To prevent degradation of the watershed, waste material disposal must be carefully controlled and managed.

Development/Construction

Urban development involves

- Clearing, leveling and filling land surfaces
- Constructing buildings with impermeable roofs
- Paving roads and sidewalks with impervious materials
- Installing sewage disposal systems

Communication and transportation development includes roads, railroads, airports, power lines and pipelines. All of these involve disturbance of plant cover, soil and topography. Road and highway networks, with their impermeable paving and rapid drainage systems may radically change the runoff characteristics of their immediate area. They also require changing the natural topography and drainage and moving huge amounts of soil and rock. Often these networks are responsible for the discharge of sediments and may become the source of other water pollutants. Railroads and airports have similar effects. Power lines and pipelines require open paths through watersheds and access roads for construction and maintenance.

Human developments may greatly change infiltration and runoff, reduce recharge to underground water and increase runoff to produce rapidly fluctuating streamflows.

Air Pollution

Urban air pollution, especially photochemical smog caused by internal combustion gasoline engine emissions and industrial smokes, contributes to acid rain. This has an effect on vegetation, streams and lakes within watersheds, especially on the east coast and in Canada. The problem continues to grow, however, and no place is immune to the effects of acid rain.

Impoundments

Flood control structures, dams, lined stream channels, dikes and levees to restrict the spread of floodwaters and channel bed stabilization techniques are all installations that modify channel capacity as well as the rate and volume of streamflow. All are the consequence of human efforts to modify the watershed.

Many dams or water control structures are built and operated for multiple purposes:
- To control floods
- To store water for irrigation or other consumptive use
- To regulate flow for navigation
- To provide power generation

Effects on streamflow and aquatic habitat are similar regardless of purpose. Impoundments, if shallow, allow water to warm and, if deep, preserve cooler water. As streamflow peaks are reduced and low flows increased, streamflow generally becomes more regular from season to season and year to year regardless of climatic variations. These changes in streamflow may affect migratory, endangered and threatened species, increase exotic invasives and otherwise alter the natural habitat of the region.

In many cases, reservoirs have added water-based recreation and new fisheries, although their construction may destroy stream habitat used by fish and other aquatic organisms. A watershed under good management — where water storage occurs in the soils and riparian areas — lessens the need for reservoirs, particularly small headwater impoundments.

Water is often seasonally diverted from impoundments and streams for irrigation in agricultural areas. This reduces streamflows during the warm growing season. Some water is returned to the stream by drainage from the irrigated fields. These return flows are warmed and may contain soil salts, fertilizers and pesticides leached from the fields.

In the past, mosquito impoundments were constructed to concentrate the mosquito larvae and facilitate spraying. Many of the impoundments still exist and have altered the water patterns of local areas. Some impoundments are still sprayed on a regular basis during the warmer seasons which then makes them a potential source of pesticide pollution. Blanket spraying for mosquitoes, whether done at impoundments or throughout a region, can alter the natural food chain for an area. Most pesticides are not selective for just mosquitoes but also eliminate beneficial insects as well.

Management Techniques

The objective of managing a watershed is to maintain useful vegetative cover and soil characteristics beneficial for good water quality. When the non-renewable soil resource is protected and maintained in good condition, the dependent renewable resources, wildlife habitat and recreational opportunities, can be supported.

Timber, forage, minerals, food and wildlife represent important considerations. Problems arise when development and use of these resources conflict with the primary objective of regulating water yield and maintaining water quality and watershed integrity. These must be considered as part of watershed management. Their use and development must be integrated as part of a management system that produces and protects water supplies.

Land ownership is the principal institutional control of watersheds. A private individual or public management agency may be free to apply whatever measures are believed necessary or desirable on their own land. They may regulate access and prevent use and development of associated resources.

Ownership of most watersheds is mixed between public and private landowners. Most watersheds are used and developed to take advantage of all resources available. It is in these multiple-use, multi-owned watersheds that management faces the most serious conflicts and challenges.

It is necessary to attain balanced use and development with the least disruption of the water resource. Watershed users need to be aware that private actions have public consequences on water quality and quantity.

Legislation and government rules and policies also provide controls that can aid water resource management. These laws may include

- Land use planning
- Zoning
- Permitted and prohibited land uses or types of development
- Restrictions on water use
- Limitations and / or requirements on development
- Pollution control
  - Minimum flows and levels
  - Special designations such as Outstanding Florida Waters, Heritage River

SUMMARY

Rivers, hillsides, soils, forests and bottomlands are all part of one integrated system. Hillside shape and slope control the rate or energy of water flow. All biotic elements in the watershed interact with and modify the energy flow through the system. So it follows that the shape of the watershed is a function of what lives there. The combination of climatic conditions, soil types, topography, vegetative cover and drainage system define the particular character of each watershed.

Rivers do not stop at state lines. The effects of natural and human processes in a watershed are focused at its outlet, wherever that may be, even if it crosses another state's or country's borders. Each watershed is a part of a larger watershed whose downstream portion may suffer from upstream influences.

Impacts on water quality and quantity (from private actions) occur by either reducing or increasing the levels of chemical compounds and flow volume beyond the watershed's ability to absorb (in the case of increase) or meet its needs (in the case of reduction).

WETLAND FACTS

Wetlands are important because these areas have unique functions and values. Wetlands are found throughout the world: in dry (arid) regions and in wet (humid) regions; in cool, temperate and very hot (tropical) regions; in the middle of fields; and near rivers, lakes or oceans. Because wetlands are found in so many places, they are hard to describe, and even more difficult to define.

COMMON CHARACTERISTICS

Some wetlands are links between water bodies and land. They may be transitional areas because they bridge the gaps between land areas and water systems. Before the land ends and the water begins, we find “wetlands.” Wetlands receive water by rain, groundwater seepage, adjacent streams and, in the case of tidal wetlands, tides.

The soils and vegetation of wetlands are typically distinct from the surrounding areas. The soils in a wetland support a certain type of vegetation. The majority of plants, trees or shrubs that grow in a wetland are specially adapted to water — they are hydrophytic, or water-loving, plants. Plant roots need oxygen. In flooded soils, bacteria quickly use up the available oxygen, so wetland plants must have special adaptations to get oxygen to the roots.

You can recognize wetlands by looking for the following:

- Water on the surface or in the root zone. This water causes the flooding, ponding or spongy, saturated conditions that we associate with many types of wetlands.
- Hydric or wetland soils. Wetland soils usually hold water longer than other soils; that is, the soils drain poorly or are strongly influenced by water, and may lack oxygen.
- Wetland plant and animal species. The plants, trees or shrubs that grow in the wetlands — and wetland animals and microbes — are those that live only in water or are adapted to either wet or dry conditions.

Water levels, soils, and vegetation provide clues toward identifying wetlands. Each of these components interacts with, and influences, the other two. Along with the wetland microbial content — the many “critters” that live in the water, soil and air — these components create the conditions that determine the nature and functions of a particular wetland. Salinity, substrate and frequency of flooding determine the specific plant and animal life a wetland can support.

Water

An area is considered a wetland if it is saturated (soaked through) with water long enough to affect vegetation and soil. Wetlands can be found on hilltops or sides of slopes as well as low areas. Standing water may not always be present in some wetlands, but the root zone will be saturated during some portion of the growing season.

Soils

The USDA Natural Resource Conservation Service classifies soils in wetland areas as hydric soils. Hydric soils occur in areas with high water tables or where frequent, long-lasting flooding or ponding occurs. Wetland soils are either high in clay content (which slows water **percolation**) or sandy and may be wet due to low elevations or high water tables. (See Soils Section.)

Vegetation

Plants found in wetlands are usually **hydrophytes** (water-loving plants). Hydrophytes are particularly well adapted to growing in soils that are periodically or permanently saturated with water. Some wetland plants and trees cannot grow anywhere else. Over time, these plants influence the quality of water and soil resources. They also provide habitat for numerous wildlife species.

Typical wetland plants include reeds, sedges, rushes and some grasses; shrubs and trees such as willow, cypress, ash, red maple and tupelos; and other plants such as water lilies, smartweeds, pondweeds and cattails. The wetland plants found in a region vary with the climate and the type of wetland.

Types of Wetlands

There are many different types of wetlands. For example, coastal wetlands are distinct from freshwater types since the plants need to be adapted to growing in salty soils as well as saturated or flooded conditions.

- **Coastal wetlands** include salt marshes and mangrove wetlands found along the coastlines.
- **Freshwater wetlands** comprise most of the wetlands in North America.

Wetlands appear in many different landscapes and shapes. They are found in all parts of the world except Antarctica.

Wetland Classification Chart

Category	General Location	Wetland Type
Coastal Wetlands		
Marine (undiluted salt water)	Open coast	Shrub wetland, salt marsh, mangrove swamp; exposed to waves and currents from open ocean or Gulf of Mexico
Estuarine (saltwater /freshwater mix)	Estuaries (deltas, lagoons)	Brackish marsh, shrub wetland, salt marsh, mangrove swamp; usually partially enclosed by land
Freshwater Wetlands		
Riverine (associated with rivers and streams)	River channels and floodplains	Bottomlands, freshwater marsh, delta marsh
Lacustrine (associated with lakes and reservoirs)	Lakes and deltas	Freshwater marsh, shrub and forest wetlands
Palustrine (shallow ponds and miscellaneous freshwater wetlands)	Ponds, peatlands, uplands, groundwater seeps	Ephemeral ponds, tundra, peatland, groundwater spring oasis, bogs; dominated by trees, shrubs, persistent erect-rooted plants

COASTAL WETLANDS

Salt Marshes

Salt marshes occur in protected areas along the coastline of Florida. These areas are periodically flooded by salt water or **brackish** water due to tidal cycles. Plants and animals inhabiting salt marshes are adapted to the stressful environment of the marshes, including fluctuations in salinity, periodic and variable water inundation due to the tides, and extremes in temperature as tides rise and fall. Salt marshes are dominated by salt-tolerant plants called **halophytes**.

Salt marshes are one of the most productive ecosystems in the world. Tiny pieces of plant and animal matter called **detritus** form the basis of the salt marsh food chain. This material is consumed by other organisms such as plankton, clams, fiddler crabs, snails, insect larvae and some fish. Some of this decomposed organic matter may remain in the marsh, but much of it is exported into estuaries where it provides food for aquatic organisms. Salt marshes absorb much of the water from ocean surges during severe storms, and this helps to reduce damage from erosion and flooding.

The following excerpt on salt marshes is from *Turning the Tides*, summer 1995:

> Salt marshes are coastal wetlands rich in marine life. They are found in the intertidal zone along low-energy coastlines, forming along the margins of estuaries, where freshwater from the land mixes with seawater. The coastal area known as "Big Bend" has the greatest salt marsh acreage in Florida, extending from Apalachicola Bay to Cedar Key. South of Cedar Key mangroves replace salt marshes as the predominant intertidal plant. Salt marshes occur locally all along the Atlantic coast.
>
> Salt marshes are composed of a variety of plants including rushes, sedges and grasses. Florida's dominant salt marsh species include black needlerush *(Juncus roemerianus)*, the dark green rush occurring along higher marsh areas; saltmeadow cordgrass *(Spartina patens)*, growing in areas that are periodically inundated; smooth cordgrass *(Spartina alterniflora)*, found in the lowest areas that are frequently inundated; and sawgrass *(Cladium jamaicense)*, which is actually a freshwater plant that sometimes grows along the upper edges of salt marshes.
>
> People can benefit from natural salt marshes in several ways. Salt marshes provide protected nursery areas for juvenile fishes, shellfish, crabs and shrimp. These animals are savored as seafood delights when they grow larger and are caught by fishermen, thereby providing food and a source of income for people. Numerous commercially important fish species spend the early part of their lives in salt marshes. Salt marshes provide a home for other animals such as birds, small mammals and turtles. Many people visit salt marshes simply to watch birds and enjoy nature's beauty.
>
> The extensive root systems of salt marsh plants enable them to withstand strong winds, waves and flooding from storms, and act as natural buffers against storm damage to upland development. Salt marshes also act as filters. Tidal creeks meander through the marshes, transporting valuable nutrients to marsh and estuary inhabitants. Pollutants from upland activities flow through the marsh and may be trapped by marsh vegetation and sediments, reducing the pollutant load entering estuaries. Man benefits from the buffering and filtering capabilities of the marsh by having cleaner water. Clean water is good for the environment and helps maintain healthy populations of fish, shrimp, crabs and oysters.

Tidal Brackish Marshes

Low-lying wetlands along the coasts are likely to be affected by the pulse of tides. Salinity in marshes ranges from fresh to salt water. Tidal brackish wetlands are dominated by **herbaceous** (non-woody) vegetation and subjected to tidal flooding. These wetlands have a low marsh zone (flooded by every high tide) and a high marsh zone (flooded only by extremely high tides). Because of the combination of fresh and salt water, a wide diversity of plants can survive in this area.

Mangrove Swamps

Mangrove swamps are common in Florida along the Atlantic coast up to St. Augustine and along the Gulf of Mexico to Cedar Key. Mangrove swamps are one of the most important aquatic habitats in Florida. These wetlands are dominated by woody plants called mangroves that have multibranched, tangled, thick root systems emerging from the soil. Mangroves are among the few woody plants capable of tolerating the salinity of the open ocean.

Mangroves provide important habitat for birds and shelter for juvenile fish and a wide variety of invertebrates. They help hold the shoreline in place, their falling leaves contribute to the food web, and their roots even help filter impurities out of the water. In addition, there is increasing evidence that mangroves play an important role in moderating the interaction between freshwater and saltwater areas.

FRESHWATER WETLANDS

Freshwater Marshes

Freshwater marshes are wetlands dominated by herbaceous (nonwoody) plants which emerge above the water, float on the surface, or remain completely submerged. Water levels may fluctuate greatly. Surface water may be entirely absent during late summer or excessively dry periods. Marshes generally have sources of water other than direct precipitation, such as groundwater seeps or streams.

Marshes provide habitat for a variety of species because of their abundant food supply, vegetative cover and superior nesting habitat. Migratory waterfowl especially use marshes for nesting and wintering areas.

Wet Prairies

Wet prairies are a type of wetland dominated by grasses or sedges. Water saturates the soil at a depth of six inches or less but generally is not visible on the surface for the entire year.

Swamps

Swamps are wetlands dominated by woody trees or shrubs, which distinguish them from marshes. Swamps occur in isolated depressions or along the borders of lakes, ponds, rivers and streams. These wetlands are fed water through precipitation, groundwater discharge, or a combination of these sources, or through being flooded by water bodies such as lakes and rivers. Swamps may dry out completely during the dry season.

WETLAND FUNCTIONS AND VALUES

Wetlands have many different functions and values, including the following:

- Water-holding, absorbing capacity
- Sediment trapping, erosion control
- Filtering, water quality improvement
- Nesting, nursery, spawning and habitat areas for fish and wildlife
- Recreation
- Cultural values, attractiveness
- Atmospheric equilibrium

Wetlands serve as a temporary storage place for water. They empty slowly. It is this slow release that helps downstream communities plan for flood protection and management and keeps water flowing in times of drought.

By holding water temporarily, wetlands further protect the quality of the water because they also absorb some pollutants. Then, when the water is released, it carries fewer pollutants with it downstream. And finally, by slowing the velocity or speed of runoff, wetlands help curb streambank erosion.

In seasons of prolonged, heavy downpours, the storage capacity of wetlands can be filled. Wetlands do not have an unlimited or long-time water storage capacity to prevent flooding. However, without the wetlands, flooding would be more frequent and extensive.

The complex connections between groundwater and wetlands are not constant. Because the wetland may be in a low spot, it can be a common area for groundwater interactions, including discharge. Shallow groundwater can flow into a wetland, carrying nutrients that can be used by the wetland plants. When the flow of the water is from the wetlands to groundwater, the wetland may help prevent pollutants from entering groundwater.

Wetlands provide a home to many species which use wetlands for breeding, nesting and feeding, and even as escape routes. Some threatened and endangered species, such as the wood stork and whooping crane, live in wetlands or depend on them. The wildlife and plants that live in the wetlands are valuable parts of the wetland ecosystem — and a source of aesthetic and recreational pleasure. Many people hunt, fish, hike and enjoy watching birds and wildlife in wetlands.

Wetland plants produce oxygen through the process of **photosynthesis**. Excess nitrogen such as that contained in fertilizers is broken down in wetlands through a process known as **denitrification**.

Atmospheric levels of carbon and sulfur, both of which have increased dramatically as a result of fossil fuel and peat burning, are lowered by the ability of wetlands to act as sinks (natural catchment basins) and as environments capable of reducing these elements to harmless or inert forms.

HUMAN IMPACTS

In the past, wetlands were often considered mosquito-infested, mucky, dangerous and unhealthy places. Due to these prejudices and an overall ignorance of a wetlands' true function, much of the wetlands in Florida and the United States have been destroyed since the 1700s. They have been drained for agricultural activities, filled for housing developments and industrial complexes, and used as dumping sites for household and hazardous wastes. Despite the fact that scientists have discovered and documented the value of wetlands as ecosystems, their destruction continues worldwide.

Filling and dredging wetlands for houses, commercial buildings, ports, highways, airports, waste disposal sites and other construction projects takes place daily. Paving large areas with asphalt and concrete increases the likelihood of flooding. Developments can also cause fragmentation of large wetland systems. For example, road crossings disrupt the continuity of a system and adversely impact wildlife. Numerous small impacts to wetlands within a watershed can add up to a significant cumulative loss.

Some activities that affect wetlands are

- Agricultural activities — ditching, draining, grazing and clearing wetlands for farming.
- Pond and lake construction — diking, excavating, and flooding wetlands for water supply, flood protection, recreation and other purposes.
- Mining — for peat, coal, sand, gravel and other products.
- Natural threats — erosion, sea level rise, droughts, hurricanes and overgrazing by wildlife can impact wetlands especially if the wetlands natural functions and capacity have been diminished by human activities.
- Wetland degradation — pollution from pesticides, heavy metals, sediments, domestic sewage and fertilizers discharged from a variety of point sources or nonpoint sources degrade the quality of wetland waters. Wetlands are effective filters for some, though not all, potential water pollutants.

MANAGEMENT OPTIONS

Recreational impacts occur through the overuse or misuse of sensitive wetland areas. Soils and plants in wetlands are not meant to handle heavy foot or vehicle traffic. The wet conditions aggravate damage. Soils are compacted and vegetation destroyed by traffic through wetland areas.

Any use of wetlands must be structured to limit impacts and funnel intensive use into less-sensitive areas. Even though many wetland plants are tolerant of extreme weather conditions, they are not adapted to crushing or compaction.

Hunting can create many trails and pathways through wetlands when off-road vehicles are used. Vehicle hunting should be limited to less-sensitive sites already experiencing degradation. Walking hunts can be less destructive, but the number of hunters using an area can affect its environmental health.

Off-road bicycles, hiking and horseback riding can also create a variety of impacts in wetland areas. These activities can cause increased compaction, and as sediments are loosened from the soil, water quality is reduced.

STORMWATER FACTS

Stormwater runoff is the water flowing over the land during and immediately following a rainstorm. (See Water Cycle Facts.) Stormwater runoff is natural and takes place everywhere it rains. Several factors affect stormwater runoff and the way it flows through a watershed. Some of the most important are the soil, vegetation and slope of the watershed, the orientation of the land, and the pollution caused by human development, which results in alterations to the watershed.

SOIL

Soil permeability, which determines how long it takes for water and pollutants to flow through the soil, can slow pollutants or allow them to travel quickly through the soil. Soils rich in organic matter and microbes can slow the water, which allows microbes to trap and break down some pollutants. Sandy soils are more porous than clay soils and may not retain water. In addition, sandy soils have fewer microbes to help degrade pollutants.

VEGETATION

Vegetation on the land plays a major role in reducing the pollution that enters both ground and surface water. (See River System Facts.) Vegetation will slow the water so the soil is given more time to trap pollutants. In addition, vegetation will trap large pieces of trash or sediments before these pollutants can enter the surface water. Additionally, some vegetation has the ability to capture and process certain types of excess nutrients and convert them to biomass, which removes them from the water cycle.

SLOPE

The water that falls on higher elevations has the help of gravity to flow to lower ground levels. As this water rushes down the incline, it carries soil and pollutants with it. The presence of groundcover slows the water enough to minimize these soil losses and allow some pollutants to be trapped by vegetation, resulting in cleaner water.

ORIENTATION OF THE LAND

Water moves downward, but it follows the slope of the watershed. Water filters slowly through the sand, rocks and soil of an aquifer. It usually travels just a few inches each day. Slow movement keeps pollutants from being quickly diluted (or transported) and allows them to be intercepted and removed. In some areas of Florida, the movement can be very rapid due to the limestone underlying the surface, which contains cracks, crevices and tunnels. (See Watershed Facts.)

SOURCES OF POLLUTION

Pollution sources can be divided into two categories — point and nonpoint. The Clean Water Acts of the 1960s and ‘70s have greatly lessened point source impacts to our surface water bodies.

Point Source Pollution

Point source pollution flows from a specific discharge point. Common sources are discharges from factories and municipal sewage treatment plants or dairy waste being dumped into a river. These sources are usually easy to distinguish because they originate from one site. This pollution is relatively easy to collect and treat and is regulated through permitting processes.

Nonpoint Source Pollution

Nonpoint source pollution does not come from a specific location. This type of pollution is the result of water runoff in the form of storm water or snow melt that travels across the land. Nonpoint source pollution comes from a variety of sources such as agriculture, urban construction, residential developments, timber harvest, roadsides and parking lots. Sediment, fertilizers, petroleum, toxic materials and animal waste are major nonpoint source pollutants. The diffuse source and variety of these pollutants makes them more difficult to quantify and control than point source pollutants.

Nonpoint source pollution is really a new name for an old problem — runoff and sedimentation. Nonpoint source pollution runs off or seeps from broad land areas as a direct result of land use.

Nonpoint source pollution causes considerable water pollution problems. The impact of nonpoint source pollutants on water quality is variable. Some pollutants are potential health hazards or are harmful to fish and other aquatic organisms. Streams can absorb and dispose of limited amounts of pollutants, but these limits are often exceeded.

You will notice that both point and nonpoint pollution sources are found in urban as well as rural areas. In fact, urban areas can quickly become serious pollution sources. In the typical urban community, storm water washes down from rooftops and through gutters to spill onto driveways or parking lots. The sidewalks and roads are expressways taking pollutants to storm drains. In turn, the storm drains carry water and pollutants directly to larger natural bodies of water, like rivers.

Vast paved areas have replaced grass or vegetation — the type of environment that would slow and filter water. Construction equipment tears the earth trying to level and prepare a site, and the shape of the land is altered. As water washes over these sites, it picks up paint, pesticides, fertilizers and other contaminants. The fast movement of the water coupled with the loss of vegetation increases erosion and reduces filtration.

The worst pollution occurs during the "first flush." This is the first inch of rain water that flushes over the land. This first inch of rain washes the largest concentration, or approximately 80–90%, of pollutants off the land.

Rural areas have other problems with pollutants entering the water. While it is rare for a farmer to overfertilize a field (it's just too costly), farmers do use a variety of chemicals to help grow their produce. Farmers time fertilizer and pesticide applications with irrigation schedules and anticipated rainfall since too much water may wash the fertilizers and pesticides off the fields and into our water systems. In addition, some farmers till, or disturb, the land in order to close out one growing season and begin another. During the time the fields lie fallow, there is no plant cover on the land to slow the water as it washes over. Unfortunately, this allows the water to take some of the soil with it, along with residual fertilizers and pesticides.

TYPES OF POLLUTION

Organic Pollution

Organic pollution comes from the decomposition of living materials and their byproducts or fertilizers. Plant residue, human sewage and pet waste are all examples of organic materials. Any loading of organic material will lead to higher amounts of microorganisms, which drain the water of oxygen and may increase turbidity.

Phosphates and nitrates are common fertilizer ingredients — they help both land and aquatic plants grow. When washed into water bodies, plants and algae flourish, but when they die, the decomposition process uses up oxygen needed by other aquatic residents. These phosphates and nitrates can cause eutrophication, which is defined as the process where lakes and other water bodies accumulate decaying plant materials and begin to shrink in size. In addition, excessive nitrates in drinking water has been linked to metheglobenemia, a disease of infants that hinders the body's ability to transport oxygen. (See Water Quality Facts.)

Inorganic Pollution

Inorganic pollution consists of suspended and dissolved solids. This is usually seen as severe sedimentation and turbidity in the water. The sedimentation, caused by loose soil flowing into water bodies, can clog the gills of fish, causing them to suffocate. It may also bury and smother the eggs of fish and other aquatic organisms. Inorganic pollution increases the turbidity of a waterway and leads to increased temperatures.

Turbid, or cloudy, water is warmer, which results in a decrease in photosynthesis. Both conditions (turbidity and warmth) cause oxygen levels to fall. Turbid water can be caused by soil erosion, waste discharge, algal growth and fish or boat propellers stirring up the bottom. (See Water Quality Facts and River System Facts.)

Toxic Pollution

Heavy metals such as lead or mercury can affect people or wildlife. Some other common contaminants from urban areas include copper, zinc, chromium, nickel, silver, cadmium and arsenic. Industrial discharges contribute significant amounts of selenium, chromium, nickel, lead, copper and zinc. **Toxic pollution** is also caused by the spraying of pesticides, herbicides and insecticides. These chemical compounds bond with the soil and are easily washed into a water system. Toxics are difficult to test for, but research on bottom-dwelling organisms gives clues to their presence.

Thermal Pollution

Thermal pollution is known as "waste heat" and comes from industries that use water to cool or power generators. The heat is returned to waterways at a much higher temperature than when it left. Thermal heat is only a problem if the temperature rises enough that aquatic life is affected. In some areas, thermal pollution is seen as a benefit since warmer waters can provide better habitat for manatees and other aquatic species during winter months. Still, the original ecosystem of an area is altered by the change in water temperature.

MANAGEMENT ALTERNATIVES

Knowing and understanding the water cycle is important for stormwater management. The amount of water that runs off from a development or area is used to compute the size or capacity of retention / detention ponds. These ponds are designed to treat runoff before it reaches lakes, streams or other waterways by using the natural processes of infiltration and evaporation.

Retention / detention ponds must store water for a specific period of time. While being stored, part of the water infiltrates into the soil. This infiltration removes contaminants that become bound, or attached, to soil particles. When water is taken up by plant roots, pollutants remain behind or become a part of the plant. When the water is transpired, it is clean. Water that evaporates from the pond also is cleansed.

Best Management Practices

To protect water (and soil) from pollution, people practice BMPs, or best management practices. BMPs are developed by industry experts and are considered both economically and ecologically appropriate ways to improve poor or to maintain good quality water. BMPs range from encouraging home and store owners to plant trees, grass or shrubs, to helping farmers develop new farming techniques. Plants are one of nature's ways of slowing water and filtering out pollutants. Vegetative filters use natural methods to assist in improving water quality. Other BMPs include no-till farming, using cloth or hay bales on construction sites to slow runoff, or building berms to direct the water through grassy areas before it enters a storm drain.

Both rural and city dwellers can protect water from nonpoint source pollution by storing toxic products in the proper containers, using these products sparingly and only as directed, maintaining household septic systems, composting leaves and yard wastes and keeping up with vehicle maintenance (e.g., fixing oil leaks).

Some urban communities are developing their own methods of slowing the rate of stormwater runoff by using porous concrete, gravel or brick paths and constructing buildings that encourage water to drain off the roof onto grass or gardens. These urban communities are also developing ways to control the effects of the "first flush" through stormwater management.

Retention/Detention BMPs

One reason storm drains were developed was to prevent neighborhoods from flooding. The water was removed as quickly as possible. We now see that this may not be the best method. Retention BMPs hold water until it either soaks or infiltrates into the ground or evaporates. Retention ponds may be dry during certain parts of the year. One form of a retention BMP is a grassed swale. To most people, a swale is no more than a ditch. There are often culverts at both ends and grass planted where the water collects after a rain. Other retention devices include both large and small ponds.

In areas that are too wet or have water that requires more cleansing, detention ponds are often needed. Detention BMPs are storage areas that maintain a planned permanent level of water throughout the year. They hold stormwater for an extended time and act as treatment facilities. Some detention ponds are aesthetically appealing, with waterfalls and aquatic plants.

WATER QUALITY FACTS

Humans have done very well at leaving their mark on the world. We have invented powerful weapons that could destroy us, and we have developed numerous vaccines that can save us. In the process, we have tapped into natural resources. By doing so, we alter them — sometimes for the better, but sometimes for the worse. Each time we construct an office, grade a road, dig a ditch, brush our teeth or empty our trash, we are affecting our water quality. You would be hard pressed to name one activity that does not somehow impact water quality.

In order to understand how our actions impact water quality, we need to be able to measure water quality. Scientists use a variety of tests and assessments to monitor water quality. Some of the most common water quality tests measure dissolved oxygen, fecal coliform, pH, biochemical oxygen demand, temperature, nutrients (phosphates and nitrates), total solids and turbidity.

DISSOLVED OXYGEN

Although our atmosphere contains 21% oxygen, not all organisms get their oxygen directly from the air. Aquatic plants, invertebrates and **aerobic** bacteria require oxygen for respiration. Most aquatic organisms depend on oxygen dissolved in water. Even if water is saturated with oxygen (to saturate a thing is to fill it completely so that no more can be added), it may contain less than 1% dissolved oxygen (DO).

DO reaches water through the atmosphere. DO is increased by water movement. Waves, swiftly moving rivers and waterfalls allow atmospheric oxygen to mix with the water. This mixing increases the opportunity for oxygen to dissolve in the water. Generally, standing, or stagnant, water contains less DO than turbulent, or moving, water.

Many factors affect the oxygen content of water. These include turbulence, temperature, photosynthesis and organic content. The absence of DO can signal polluted water that is frequently unable to support aerobic life.

Photosynthesis

DO levels can fluctuate significantly during a 24-hour period. Levels rise from morning through late afternoon as a result of photosynthesis. Algae and rooted aquatic plants provide oxygen through photosynthesis. DO levels reach a peak in late afternoon, then fall as photosynthesis stops for the night, even though plants and animals continue to respire. Sunlight plays an active role in assisting plant photosynthesis and its contribution to DO.

In northern waters, dead aquatic vegetation causes serious problems in winter as it decomposes under a layer of ice. This decomposition increases the biological oxygen demand, but there is little chance to restore oxygen levels as they are depleted. The ice barrier separates the water from the air, preventing atmospheric oxygen from reaching and dissolving into the water. The barrier created by the ice also blocks or diffuses what little light there is, reducing photosynthetic oxygen production and DO replenishment.

Temperature

In addition to the sun's DO role, water temperature and the volume of water impact DO levels. Oxygen is a gas and, like all gasses, it dissolves easily in cold water. As water runs through a cool, shaded area, its capacity to hold oxygen increases. But in an open area warmed by the sun, its oxygen-holding capacity decreases.

The volume of water is important because in times of low water levels, flow is reduced and the water temperature is typically higher (warmer). Both low flow and higher temperatures adversely affect DO levels.

The source of water in a stream determines its upstream temperature. For example, water coming from a glacier or underground spring may be cold. However, water coming from very deep within the earth from an aquifer may be warm. In such cases, the deeper the aquifer, the warmer the water that emerges. Hot springs are good examples.

Many factors along a watercourse can change the water temperature. Natural warming occurs when the air temperature is high. Direct sunlight also has a warming effect. A number of human activities can also raise water temperatures. The removal or destruction of riparian vegetation exposes the otherwise shaded streams to the extremes of the sun. Water slowed by dams or weirs warms near the surface as it sits in a reservoir, pond or lake, though deep sections remain very cold. Industrial use raises water temperature if the water is used for cooling equipment and then returned to the stream without a cooling process to return the water to its original temperature.

Organic Matter

Decomposition of organic matter by microorganisms such as bacteria and fungi requires oxygen. Therefore, water with a high organic content uses up available oxygen quickly.

Biochemical oxygen demand measures the amount of oxygen needed to decompose organic matter in a sample of water. High biochemical oxygen demand causes oxygen levels to become so low they are unable to sustain some aquatic organisms.

The quantity of organic matter (anything that was once part of a plant or animal) in the water also affects the amount of DO. In a natural environment (an ecosystem) that is not disturbed by humans, the organic matter present in a river originates from dead aquatic plants, leaves shed from riparian vegetation, or animals that defecate or die in the area.

Other sources of organic matter in water usually result from human activity. These sources include logging debris, pulp mill effluent, municipal sewage effluent, leaking septic tanks, farm runoff (particularly animal waste) and stormwater runoff from urban centers. As these products decompose, they use up oxygen.

Species Variety

Low levels of DO may cause a change in the variety of species living in the particular environment. Some species, such as mayfly and stonefly nymphs and caddisfly and beetle larvae, will not survive in waters with low levels of DO. Thus, they are replaced with worms and fly larvae that can tolerate lower oxygen levels when conditions reduce DO levels. Algae and anaerobic organisms may become abundant in water with low DO levels. (See Benthic Invertebrates Facts.)

Invertebrates which live in the water absorb oxygen through their **integuments** or, like fish, have specialized organs called gills. As water flows past the delicate finger-like projections of fibers which make up the gills, the blood flowing through the fibers absorb oxygen from the water and distributes it to the body's cells. Organisms from areas with low DO (slow-running and warm water) have relatively large gills. Those that live in colder, faster-moving waters tend to have smaller gills.

Quick Study Notes

Definition: The amount of oxygen that is dissolved in a particular water column. DO measurements are made as either the percent atmosphere saturation or as concentration. Major shifts in DO will cause certain organisms to be replaced by those that can tolerate the change.

Sources:

Atmosphere — the main source; by contact with water. The amount of action in the water body affects the amount of DO in the water; the more that water is stirred (think of shoals, rapids and waterfalls), the more oxygen gets into contact with water molecules and so dissolves into the water.

Plants: algae and rooted aquatic plants, through photosynthesis.

Physical influences — temperature and discharge rate:
High temperatures and low discharge rates, or flow, result in low DO.
Low temperatures and high discharge rates, or flow, result in high DO.

Factors affecting capacity to hold oxygen:
Dissolved minerals
High salinity lowers potential for DO
High temperature lowers potential for DO

Human-caused changes that affect DO:
The buildup of organic wastes — these can be anything originating from a living plant or animal. They can enter a system by many ways such as sewage, agricultural runoff and commercial discharge. The decomposition of organic matter consumes DO, therefore potentially reducing the amount available.

If DO decreases:
Invertebrate diversity decreases
Species richness decreases
Pollution-tolerant species increase (red midges, Oligochaetes)
Fish kills ensue

Sampling procedures are very important and can be misleading if tests are not performed at the same time of day. Because the location and depth of the sample can also affect the DO, it is important to keep track of location and depth.

BIOCHEMICAL OXYGEN DEMAND

After any living thing dies or any part of it is removed (like leaves or waste), it begins to decompose. As it decomposes, the organic matter breaks down and combines with oxygen. Biochemical oxygen demand (BOD) is the measure of the oxygen needed by microorganisms as they feed on or decompose organic matter; it also takes into account the amount of oxygen respired by these organisms. As the organic matter is broken down, nutrients are released which stimulate the growth of plants.

The decomposition of large quantities of organic matter can require more DO than the system can provide without a reduction in DO or can cause high BOD levels. Some large point sources of this kind include pulp and paper mills, meat packing plants, food processing plants and wastewater treatment plants. Some nonpoint sources are agricultural or urban runoff, melting snow and fertilized yard clippings.

High BOD levels indicate that aquatic organisms are being robbed of available oxygen. Organisms that are intolerant of high BOD levels disappear. Things such as caddisfly larvae and mayfly and stonefly nymphs will be among the first to die or leave an area. Carp, midge larvae and sewage worms that can tolerate low available oxygen levels flourish. As a result, the diversity of organisms decreases. Most popular sportfish species are also intolerant of low DO or high BOD levels.

As more nutrients are fed into a system, the microorganisms needed to decompose the matter use up more oxygen. This leads to high BOD and low DO, which increases organisms that can tolerate low DO.

FECAL COLIFORM

Fecal coliform are a group of bacteria naturally found in the lower intestines of humans and other warm-blooded animals. The most common species, from the large intestine in humans, is *Escherichia coli (E. coli*). The human host provides a consistent environment for this bacteria, and they aid the host in breaking down digestive wastes. These organisms are not usually pathogenic (disease-causing). Billions of fecal coliforms pass out of the body each day with the feces from each individual.

Pathogenic organisms include some bacteria, viruses and protists which cause diseases such as tetanus, typhoid fever, cholera, infectious hepatitis, gastroenteritis and dysentery. Feces from an infected person contain pathogens which are released with the feces and may enter a river as effluent from a sewage treatment plant or by **leaching** through the soil from cesspools.

Pathogenic bacteria are difficult to detect in water quality tests because of their low survival rate. Pathogens are expensive and time-consuming to monitor. Instead, testing for fecal coliform is done and a correlation established to determine if there is a likelihood of contamination by pathogens. In most cases, sanitary wastes are treated and do not pose a problem. Animal wastes pose a different problem because they are usually untreated.

When sampling, all equipment must be sterilized and the samples should be tested within one hour of collection. The samples can also be placed in ice for up to six hours if more time is needed.

pH

pH is a measure of the hydrogen ion concentration in liquids. The scale ranges from 0 (most acid) to 14 (most basic); 7 is neutral. pH is a logarithmic value, which means that for every one-unit change, the actual hydrogen ion concentration change in the sample is ten-fold. To give a general picture of the range, consider that battery acid has a pH of 0.5, lemon juice 2.0, cola about 3.5, orange juice 4.5, seawater 8.0, ammonia 11.0 and bleach 12.7.

Changes in pH can greatly affect aquatic species. These changes can be caused by humans through emissions from automobiles and coal-fired power plants that contribute to acid rain, or by a natural process due to soils and vegetation. In general, the best range for most organisms is between 6.5 and 8.2. At more basic levels, chemical changes in the water can indirectly affect fish. At the other extreme, highly acidic water affects bottom dwellers first. They begin to die and allow a buildup of detritus or decaying material. Insects are the next species usually affected, followed by fish and frogs. pH may have a direct influence by interfering with the physiology of individuals or an indirect influence by interfering with the food web.

At pH 6.0, the microorganisms which decompose organic matter begin to die. The plankton (microscopic plants and animals) which form the base of the food chain also begin to decline drastically. Between pH 6.0 and 5.5, the number of aquatic invertebrate species declines, most fish species lose the ability to reproduce and algal mats form along the shoreline. At stronger acid levels, toxic metals such as aluminum, mercury, lead and cadmium dissolve more readily and so are more easily absorbed by fish and other aquatic animals.

How pH affects aquatic life is indicated in the following ranges:

3.0–3.5	Some plants and invertebrates affected
3.5–4.0	Known to be lethal to salmonids
4.0–4.5	All fish, most frogs and insects absent
4.5–5.0	Mayfly and other insects absent; some fish eggs will not hatch
5.0–5.5	Bottom dwelling bacteria die; leaf litter and detritus accumulate; snails and clams absent; fungi replace bacteria; metals which can be toxic to fish released from sediments
5.5–6.5	Shrimp (freshwater) gone
6.5–8.2	*Optimal range for most organisms*
8.2–9.0	Can cause chemical changes in water
9.0–10.5	Harmful to perch and salmonid
10.5–11.0	Lethal to perch and carp
11.0–11.5	Lethal to all species of fish

TEMPERATURE

Most people do not consider temperature a water quality condition except when swimming. However, it is a very important water quality indicator. Many physical, chemical and biological traits of a river are directly related to water temperature. Temperature influences the amount of oxygen dissolved in the water, the photosynthetic rate of aquatic plants, the metabolic rates of aquatic organisms and the sensitivity of organisms to toxic waste, parasites and other physical stressors.

Cool water more easily dissolves gases; therefore, cool water can hold more oxygen than warm water. As water temperature rises, so does the photosynthetic and growth rates of plants. More plants grow and die. The dead plants are consumed by oxygen consuming bacteria. This creates a greater need for free oxygen (BOD), but warmer water temperatures hold less oxygen.

Aquatic organisms are also affected by temperature increases. As the water warms, the metabolic rate of organisms rises. This rise in turn creates increasing temperatures. The life cycles of aquatic insects accelerate in warmer water. This can affect migratory birds that depend upon insects emerging at key sites and times during their migratory flights.

Most aquatic organisms are adapted to a particular range of water temperature. If that temperature varies greatly, the organism becomes stressed. This stress exposes an organism to a variety of stress-induced factors or makes it less able to fend off other stresses such as disease, pollution or decreased oxygen levels. Fish larvae and eggs tend to require a narrower temperature range, so they feel the effects first.

Changes in temperature may be the result of natural factors such as seasonal changes and nightfall. Drastic temperature changes are usually linked to man but may be due to volcanic activity.

Thermal pollution is adding warm water to a water body. Many industries use water for cooling generators and processing plants and discharge warmer water back into our water systems. The life cycles of aquatic insects speed up under increased water temperature conditions. This alters the balance of the organisms that rely on certain insects during specific times of the year.

Another human activity that can change water temperature is cutting down shade trees along waterways. The shade keeps the water at a cooler temperature throughout the year. When trees are removed, the sun will warm the water to a higher temperature. Thermal pollution may also be the result of stormwater running off hot paved surfaces.

NUTRIENTS

Phosphorus

Phosphorus is needed for life and is usually a limiting factor in the growth of plants. Phosphorus is found in many forms, including orthophosphates, polyphosphates and organically bound phosphates. Orthophosphates primarily concern water quality analysts because these are the phosphates found in fertilizers and the form which plants most easily use during growth. Phosphates are a natural occurrence in water.

The problem with phosphorus comes from its attraction to organic matter and soil particles. Available phosphorus is rapidly taken up by algae and larger aquatic plants. Because algae require only small amounts of phosphorus to live, it grows quickly, causing algal blooms. This is eutrophication.

Some significant sources of phosphorus include human, animal and industrial wastes, as well as the human activities that disturb the land and its vegetation. Draining swamps or wetlands for buildings releases this nutrient and removes the filtering effect of soil and vegetation. Soil erosion has the same effect.

Nitrogen

Nitrogen is more naturally available than phosphorus and is also needed by all living things. It can be found in many forms in aquatic ecosystems.

The main source of nitrates is from sewage discharged into rivers. Septic tanks located too close to the water table or a river allow raw sewage or dissolved nutrients to percolate into the water system. Nitrates can also be introduced by animal waste and fertilizers. Another source of nitrates is from acid rain.

The decomposing bacteria (those that consume dead organic matter) break down protein molecules from the organic matter into ammonia. It then combines with oxygen to form nitrates and nitrites.

It is the ammonia and nitrates that cause concern for water quality. They are plant nutrients and can lead to eutrophication. This in turn promotes more plant growth and thus plant death, which causes an increase in BOD.

When nutrients increase, invertebrate diversity and fish production increase. In excess, however, invertebrate diversity decreases and some fish species production decreases. Very low levels can also be a problem by limiting the growth of aquatic life. Some species, like phytoplankton, must have the nitrates and phosphates that are dissolved in water.

TOTAL SOLIDS

Total solids are divided into two basic categories — dissolved and suspended in water. Total dissolved solids are the material that is left in a water sample after it has been filtered. Dissolved solids include inorganic materials such as calcium, bicarbonate, iron and sulfur, phosphorus and nitrogen. Suspended solids are found in the form of silt, plankton and sewage. The biggest factor affecting total solids is the type rocks and soils that make up the landscape near the water body.

Total suspended solids are those pieces trapped by a filter. They would be things like leaves, tree bark, soil particles and decaying organic matter. High levels of total solids can be a problem because they can create a laxative effect or give a mineral taste to drinking water. In addition, they reduce water clarity, decrease photosynthesis and can increase water temperature by absorbing more sunlight. On the other hand, a low concentration of solids can limit the growth of aquatic life.

The main sources of solids are urban runoff and wastewater treatment discharge.

Both high and low concentrations can have adverse effects on aquatic life. High amounts of solids will cause an imbalance for the aquatic organisms in the water medium; low concentration of solids can limit the growth of aquatic life.

TURBIDITY

Turbidity is the measure of the clarity of the water — the higher the turbidity, the cloudier the water. It is caused by suspended material that scatters light coming into the water.

Excessive turbidity hinders the water's ability to support a diverse aquatic population. The water becomes warmer and photosynthesis decreases because the particles absorb the sunlight. This causes oxygen levels to fall. Aquatic plant production decreases, certain forms of invertebrates decrease and **benthic** algal production decreases.

The particles that create this turbid condition clog fish gills, smother eggs and make aquatic life more susceptible to disease. Gills of aquatic organisms are very delicate organs and are easily damaged by excess **suspended particulate matter** or sediments such as silt or sand in the water. This matter clogs the gills directly or irritates them enough to cause a mucous secretion. If the irritation of the gills is severe enough, the mucous prevents the gill from functioning and the organism dies.

Turbidity is caused by soil erosion, waste discharge, runoff and aquatic creatures that stir up the river bottom (e.g., catfish) or algal growth. The water changes color and becomes a dark muddy red-brown or green.

Many of Florida's waterways are normally dark in color due to the tannins that are naturally abundant. This tea color is not caused by turbidity but may affect the clarity of the water or the depth that light can penetrate the water. This affects plant phytosynthesis or the depth at which many aquatic plants can grow. Florida's dark water systems are adjusted for a high level of tannins but can still be affected by increased turbidity or water clarity changes.

PROPERTIES OF WATER

Physical Properties

Stratification — layering of water due to temperature. Many ponds, rivers and lakes develop distinct layers of water because the water density varies with water temperature. In other words, the cooler water is “heavier” and settles down.

Stratified water bodies typically have a warm upper layer (epilimnion) of uniform temperature, a cooler bottom layer (hypolimnion) and a separating layer (metalimnion) with a temperature gradient (thermocline).

These zones serve as physical barriers to some organisms and chemical processes, not unlike the layering effect of oil and water. Stratification is common in water bodies protected from wind, deep open-water lakes and in some large, low-gradient stream and river systems.

Turnover — another temperature-related characteristic of some ponds and lakes. Turnover is the complete mixing of the water, often triggered by temperature changes and wind action. It occurs commonly in fall and again in spring in the northern temperate regions. When a water body turns over, stratification is destroyed, resulting temporarily in a water body of homogeneous temperature.

Turbidity — the decreased ability of water to transmit light. It is caused by suspended particulate matter that is either living (e.g., plankton) or nonliving (e.g., soil particles).

Other physical properties strongly influence the behavior of pollutants in a water body. Water is a universal solvent and is capable of dissolving many compounds.

Chemical Properties

Nutrient composition, pH (acidity and alkalinity) and chemicals affect the chemistry of water. Changes can be caused by both land and water activities, either natural or man-made.

Man-induced factors include land use and management practices in the watershed. The chemical properties of a water body can be affected by things such as chemicals in runoff, waste dumped into a river, atmospheric conditions (e.g., acid rain) and even seasonal changes.

Biological Properties

The biological properties of an aquatic system are composed of organisms and their life functions. Organisms found in aquatic environments can be microscopic like bacteria, viruses and protozoans or creatures like algae, invertebrates and vertebrates. Each biological group supports and is supported by another portion of this delicate system. Life functions, such as photosynthesis, decomposition, respiration and metabolism, also play a major role in impacting water quality due to biochemical oxygen demand, dissolved oxygen and nutrient levels.

Benthic Invertebrate Facts

The term "benthos" refers to organisms that live in the bottom substrata of wetlands, lakes, ponds, streams and rivers. These bottom-dwelling organisms play an important role in an aquatic community. Aquatic invertebrates are involved in the recycling of organic matter in the water. They also make up an important component of the food web. Many benthic insects and their larval forms are the major food source for small fishes.

The aquatic invertebrates that are found, or not found, in particular aquatic environments are known as indicator species. Some species are tolerant of low oxygen or high nutrients, others are not. These creatures tell us about environmental conditions of aquatic systems and are used to compile a biotic index that relates water quality to invertebrate communities. Biologists find benthic invertebrates very useful in pollution studies for the following reasons:

1. Benthic invertebrates are in close contact with water and directly affected by changes in water quality.
2. Benthic invertebrates are relatively immobile or sedentary and so cannot escape immediate changes in the environment; this helps in identifying precise locations of pollution sources.
3. Some of these organisms which are sensitive to changes in their environment have relatively long life cycles, making it easy to study the changes over time.
4. Benthic invertebrates are relatively easy to sample.

Most people think first of fish when discussing the life in a stream. It is difficult to study fish populations in relation to habitat or water quality, however. Therefore, the presence or absence of certain other organisms is often used to measure water quality. Such organisms include insects and other invertebrate species lower than fish in the food chain. Benthic organisms live on the bottom where they can cling, burrow or cluster to withstand the current. These types of organisms are more easily measured, collected and monitored than fish, yet their survival is closely linked to the survival of higher species and they reflect the quality of the aquatic ecosystem where they live.

Organisms Monitored

Three general groups of benthic organisms are often examined: those tolerant of poor water quality, those somewhat tolerant and those intolerant. General descriptions are given of five major types of organisms found in Florida. Additional organisms found in Florida are illustrated on the chart at the end of this section.

Benthic invertebrate data provide information on water quality conditions because the community composition differs with water quality. However, one must be careful in associating differences in benthic invertebrate composition with differences in water quality. For example, sampling may be carried out in areas which have only recently become covered with water and which benthic invertebrates have not yet had sufficient time to invade. Some factors other than water quality that can cause changes in communities include:

- Differences in the substrata. Invertebrates living in fast-moving water will be different from invertebrates living in silty gravel banks in slow-moving water, even though the water quality may not be different.
- Variation in sampling depth.
- Variation in current velocity.
- Food sources. Some organisms feed on dead leaves and are therefore found in areas with trees. All organisms are most abundant in areas where food sources are nearby.
- Life cycle. Many stoneflies, mayflies and caddisflies actively grow during the winter and emerge as adults in the spring. In the summer, their offspring avoid high temperatures by remaining as unhatched eggs.
- Season. Spring runoff and flood conditions decrease the normal density of a population in several ways. For example, excess water may sweep away many organisms, leaving only those with efficient holdfast mechanisms.

Stoneflies and Mayflies

The pollution-sensitive stoneflies and mayflies spend the juvenile portion of their lives as aquatic nymphs. Winged adults emerge from the water to reproduce. Although the immature stoneflies and mayflies resemble each other, there are differences between them:

Stonefly	Mayfly
Two claws on legs	One claw on legs
Two filamentous tails	Three filamentous tails

Caddisflies

Caddisfly adults are also aerial, but the larvae is aquatic. Caddisfly larvae are known for their portable cases. Each species constructs its own unique version from vegetation or sand. Instead of long filamentous tails (like stoneflies and mayflies), caddisflies possess a small abdominal proleg bearing a claw. Most caddisflies are tolerant of moderate pollution.

Midges

Midges are also found as aquatic larvae. Only two pairs of short prolegs are present: one pair in the front segment and one pair on the last segment. Most midges are tolerant of poor water quality and may become extremely abundant.

Segmented Worms

The most pollution-tolerant group is the segmented worms or oligochaetes. Aquatic oligochaetes have the same basic structure as common terrestrial worms. The majority of species are found in the mud of the bottom substrata. They range from 1 to 30 millimeters in length and are very delicate, with a thin body wall through which gas exchange readily occurs. Other characteristics and habits, such as specialized blood pigment and waving action of the posterior end, allow for even greater oxygen uptake. These adaptations are needed in the low dissolved oxygen conditions in which these worms often live.

MANAGEMENT TECHNIQUES

Benthic invertebrate monitoring is a technique used by scientists and water managers to give indications of the water quality of water systems. A variety of sampling techniques can be used.

A biotic index reflects the current knowledge of the specific water quality requirements of invertebrates in a particular geographic area. A biotic index developed for one particular area may not be applicable to another area.

If a large sample of organisms is taken from a natural habitat, one would discover that the number of individuals belonging to each species varies greatly. A community of organisms that is under stress will probably have fewer total number of species. At the same time, those species that are present will be represented by more individuals than normal. In order to estimate the intensity of environmental stress, community diversity can be measured using a diversity index. Diversity is characterized by two factors, species richness and equitability. Species richness means the number of different species present; equitability means the relative abundance of each species.

Water that is home to a variety of aquatic species usually indicates an environment that is able to support aquatic life. Pollution typically reduces the ability of many plants and animals to adapt to certain conditions. Occasionally, the total number of living organisms will actually increase as a result of pollution, but the variety or diversity goes down. In other words, there may be lots of one species, but few of another species.

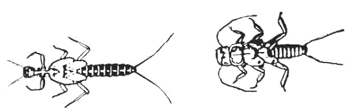
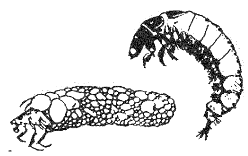
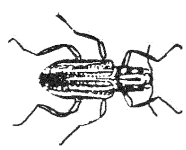
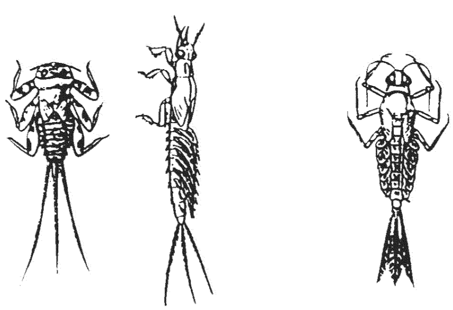
Some conditions that will affect the types of aquatic invertebrates found are the pH and the temperature of the water and the amount of dissolved oxygen in the water (refer back to these sections for review if needed). Each of these elements help comprise the specific environment or habitat that aquatic invertebrates call home. In order to use some of these animals as indicators of water quality, you must be sure of their habitat.

Some habitats are much more supportive of aquatic invertebrates. Places such as woody "snags" with tree stumps and branches, areas of aquatic vegetation and places with an accumulation of leaf and wood debris frequently host a variety of aquatic species. Sandy and muddy habitats are less desirable for aquatic species.

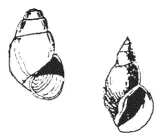
Some of the activities carried out by man can greatly affect the habitat and therefore decrease the variety of aquatic invertebrates. One example is the dredging of stream channels. This dredging leaves steep, often sandy, banks that are difficult for some species to adapt to. Consider the importance of there being a suitable habitat for aquatic invertebrates, not only in terms of water quality, but physical factors as well.

The following chart outlines several aquatic insects and crustaceans that are key indicators to water quality.

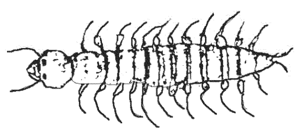
Found in GOOD quality water — pollution-sensitive

Taxonomic Order	Size	Physical Features
Plecoptera 	1/2 to 1 1/2 inch	6 legs with hooked tips, **2 hairlike tails**, smooth lower body
Trichoptera 	Generally less than 1 inch	6 hooked legs on upper body, 2 hooks at back end; may have fluffy gills on lower half; most build a case of leaves or twigs
Coleoptera 	1/4 inch	Oval body covered with tiny hairs, 6 legs with hooks on the end, antennae; walks underwater clinging to objects; does not swim
Ephemeroptera 	1/4 to1 inch	Brown, leaflike gills on sides of lower body, 6 hooked legs, antennae, usually **3 long hairlike tails** (may be webbed together)

Common Name	Taxonomic Order	Size	Physical Features
Gilled snail	Class Gastropoda	Less than 1/4 inch to 3 inches	Shell opening covered by thin plate (operculum); shell usually opens on right

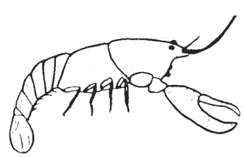


Dobsonfly	Megaloptera	3/4 to 4 inches	Dark brown or black colored; 6 legs, large pinching jaws, 8 pairs of threadlike gills on lower body, short antennae, 2 tails and 2 pairs of hooks at back end

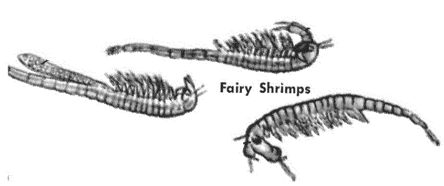


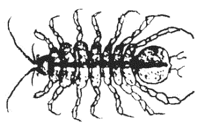
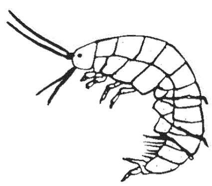
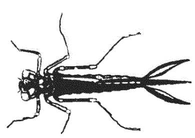
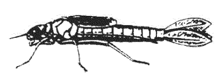
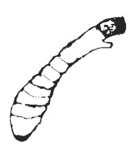
Found in GOOD TO FAIR quality water — somewhat pollution-tolerant

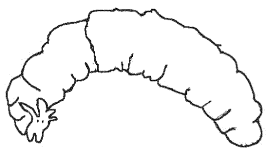
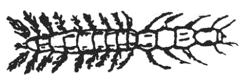
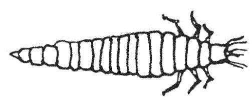
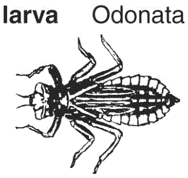
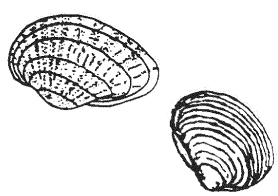
Crayfish		Up to 6 inches	2 large claws, 8 legs; looks like small lobster (also known as craw-fish)

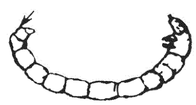
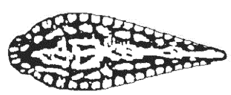
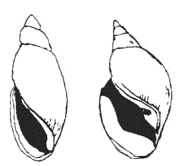
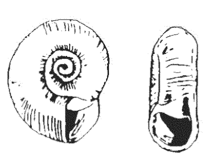


Freshwater shrimp	Decapoda	1 to 2 inches	Clear, transparent color; 10 legs, first pair with small pinchers; "grass shrimp"

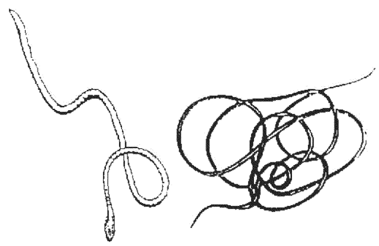


Common Name	Taxonomic Order	Size	Physical Features
Sowbug 	Isopoda	1/4 to 3/4 inch	Grey, oblong body wider than it is high; more than 6 legs; long antennae
Scud 	Amphipoda	1/4 inch	White to grey color, body taller than wide; swims sideways; more than 6 legs; like small shrimp
Damselfly  	Odonata	1/2 to 1 inch	Large eyes; 6 thin, hooked legs; 3 broad, oar-shaped or leaflike tails; no gills on sides of lower body
Blackfly larva 	Diptera	1/4 inch or less	Medium to dark brown; “bowling pin” shaped with small tufts on head for filtering food

Common Name	Taxonomic Order	Size	Physical Features
Crane fly 	Diptera	1/3 to 2 inches	Milky green or brown color; looks like plump caterpillar with segmented body; 4 lobes at back end
Beetle larva  	Coleoptera	1/4 to 1 inch	Light colored; 6 legs on upper body; feelers and antennae; may have threadlike or feathery gills running down side of abdomen
Dragonfly larva 	Odonata	1/2 to 3 inches	Large eyes, hooked legs,wide oval/round abdomen
Clam 	Class bivalve		Hinged “clam” shell with concentric shaped grooves; may have dark brown or black coating

Common Name	Taxonomic Order	Size	Physical Features
Found in FAIR TO POOR quality water — pollution-tolerant			
Midge fly larva	Diptera	Up to 1/4 inch	Dark head, wormlike segmented body, 2 tiny legs on each side just behind head
			
Leech	Class Hirudinea	1/4 to 2 inches	Brown, slimy body; suction pads on end
			
Pouch snail and pond snail	Class Gastropoda		No operculum; breathes air; shell usually opens on left
			
Other snails	Class Gastropoda		No operculum; breathes air; shells coil in one plane, flat
			

Common Name	Taxonomic Order	Size	Physical Features
Aquatic worm	Class Oligochaeta a	1/4 to 2 inchess	Can be very tiny; thin, wormlike body



Adapted from Izaak Walton League of America, Save Our Streams

MARINE/COASTAL FACTS

The coast is the place where the sea meets the land. Many kinds of marine organisms and plants are found in coastal areas. They all have ways to survive in the changing, sometimes harsh conditions present in coastal areas.

COASTAL AREAS

Rocky Coast

On most rocky coastlines, distinct color bands (some white, some black, some brownish-green) are seen when the rocks are exposed at low tide. Each of these bands represents a particular zone where certain animals and plants live.

The uppermost zone on the rocks, the splash zone, usually has a black color. This is due to the presence of two types of microscopic organisms living on the rocks: blue-green algae and lichens. Small snails called periwinkles also live in the splash zone and feed on the algae and lichen.

The next color zone, the intertidal zone, is often white. This is due to the presence of barnacles. Barnacles are any marine crustacean of the subclass Cirripedia, usually having a calcareous shell. Each individual barnacle produces a cone-shaped shell around itself, which is attached to the rocks by powerful glue. This glue and cone shape help the barnacles resist the force of the waves pounding on them. Barnacles sweep the water with their appendages (legs) to trap plankton.

Below the zone of barnacles, or sometimes intermingled with them, is a bluish-blackish colored zone of mussels. Mussels and barnacles feed on plankton at high tide (when they are covered with water). Mussels filter water through their gills to trap plankton — the filtering helps to clean the water of any impurities or pollution.

In the lower intertidal or subtidal zone, a brown or green zone dominated by some type of algae is usually found. Most algae do not tolerate drying out and so they are found in subtidal areas, where they are wet most of the time.

Organisms must be able to tolerate being both underwater and exposed to air in order to live in the intertidal zone. At low tide, the intertidal zone is exposed to the air. Organisms that can tolerate a longer exposure to the air are able to live where they are exposed more often. Organisms less tolerant live in the lower intertidal or the subtidal zone where they are not exposed to the air. Biological conditions such as predation and competition for food and space also limit organisms to certain zones or restrict their growth and abundance.

Sandy Coast

On rocky coasts, the communities of organisms are easily visible and the patterns of zonation are clearly seen. Zonation is present on sandy coasts as well, but it is not easily seen because most of the organisms live under the surface of the sediment (the soft mud or sand). Few animals live on the sediment surfaces, which are easily shifted by waves. Particular plant communities are found on some sandy coasts.

There are basically two types of sandy coastlines, high-energy beaches and low-energy beaches. Each type of sandy coast supports different communities of plants and animals. This is due to differences in the size and strength of the waves that occur on each type of coast and variations in the kinds of sediments on each beach.

High-Energy Beach. These beaches are usually found on coasts facing the open sea, such as those which face the Atlantic Ocean on the east coast of the United States. On these coasts, large, heavy waves regularly pound the shore. Sediments on these beaches are usually coarse sand or pebbles.

A typical feature of high-energy beaches is sand dunes. Sand dunes are formed by the action of wind. Certain types of grasses (such as sea oats and panicum) grow on the dunes and accumulate sand by trapping it among their roots and stems. These grasses are important in maintaining a healthy coastal system. Dunes are important because they protect the coastal communities (both natural and man-made) during severe storms and they provide habitat for many animals.

Sand dunes are not designed by nature to remain a constant width, height or form. With the action of waves and storms, they are constantly changing and developing. When reduced in size, they need many years to redevelop or rebuild their structure. Sand dunes are an important part of the beach ecology, but they can be easily damaged by human activity. Construction and development in coastal communities should be done in a way to protect the vital dune systems and their fluid nature.

Low-Energy Beach. These beaches are found in sheltered locations such as bays, sounds and estuaries. On these coasts, the waves are not usually as large and powerful as those that occur on high-energy coasts. Usually the sediments on these shores are finer and muddier. Sand dunes are usually not found on low-energy beaches since these coasts do not have the strong winds that form and shape the sand dunes. It is common to find salt marshes or seagrass beds in or near low-energy coastlines.

Zonation does occur on low-energy coastlines and is influenced by tides, salinity and sediment type. A biological factor affecting zonation is predation.

SEAWATER

Seawater contains salt. Most of the salt came from the land after the oceans were formed millions of years ago. The major salt dissolved in seawater is sodium chloride, the same salt as table salt. The other types of chemical compounds called “salts” found in seawater include magnesium chloride, sodium sulfate, calcium chloride and potassium chloride.

Salinity is the term used to describe the total amount of salt present in seawater. It is measured in parts per thousand (ppt). The Atlantic Ocean is the saltiest of the world’s oceans, with an average salinity of 36 ppt. Salinity is important because some marine organisms only tolerate water at a specific salinity, while others tolerate a broad range of salinity. Salinity is also important because one of the salts found in seawater contains calcium. Calcium is used by many marine organisms to build their shells and skeletons.

ESTUARIES

Estuaries are places where rivers meet the ocean. They are semi-enclosed bodies of water. Dense salt water from the ocean or the Gulf is carried by tides into the estuaries, where it mixes with less-dense freshwater that flows downstream from the rivers. Estuaries act as spawning and nursery grounds for most forms of seafood. When it rains, the nutrients and pollutants which run off the land travel down the river to the **estuary**, which serves as a buffer zone capturing nutrients and slowly releasing them to the open sea. These nutrients are essential to the whole chain of life in the estuary because all plants require these nutrients, both rooted and non-rooted, or microscopic, plants (phytoplankton).

Sunlight is an important factor in an estuary. Sunlight must be able to penetrate the water to depths which allow rooted plants and phytoplankton to grow. Sediments carried in the water can affect an estuary’s ability to function.

In the grass flats, rooted plants such as shoal grass and turtle grass are found along with colonial animals that look like plants. Nutrients, organic detritus and organisms move readily in and out of this community and the intertidal flat community with each tidal cycle.

The barren looking mud flats contain a number of microscopic producers. Red, blue-green, and green algae and diatoms are found on the surface of the sediments. In the mud, worms with their round air hole and waste pile may be found, and trails left by a variety of clams and mussels may be seen. On top of the mud flats, horseshoe crabs plow the surface, oysters attach to hard stationary objects and hermit crabs occupy empty shells. These primary consumers provide an energy source for bottomfeeders like crabs, pistol shrimp, pig fish, spots and drum. They support a large population of wading and shore birds.

The abundant plant life in an estuary attracts an endless variety of animals because of the food and shelter available. The amount of plant material produced in an estuary exceeds that of even our cultivated corn fields.

In some estuaries, the freshwater flows out in a distinct layer on top of the salt water. The upper layers of water in this type of estuary have a low salinity (salt content), and the bottom layers have a high salinity. There is little mixing between the two layers. A sharp change in salinity, called a halocline, occurs where the two layers meet. The saltwater layer at the bottom is sometimes called a salt wedge because of its shape. A salt wedge tends to form in estuaries where the outgoing river is much stronger than the incoming saltwater tidal current.

The circulation pattern in an estuary traps nutrients. This creates a highly productive environment which serves as a nursery, spawning and migration area for many marine animals. Tides can affect the mixing in an estuary.

SALT MARSHES

Salt marshes are found in areas protected by barrier islands or associated with shallow, low-energy coasts. Salt marshes act as filters for land runoff. The grasses remove sediments and pollutants. They also control floodwater, recharge groundwater and provide habitat for waterfowl and wildlife. They are breeding and nursery grounds for fisheries, they provide sanctuary for rare and endangered species, and they have educational, recreational and aesthetic value.

Salt marshes exhibit characteristics of both terrestrial and marine ecosystems. A distinct watershed and a network of drainage creeks is often present. Salt marsh sediments, under the influence of colonizing plants and animals, begin to develop layered soil horizons similar to those of terrestrial soils.

At times of flooding, however, the marsh surface becomes an extension of the continuum of coastal marine benthic sediments. Intertidal marsh sediments, despite their similarity to terrestrial soils, are largely anaerobic and are similar to marine benthic sediments.

The salt marsh is a delicate ecosystem that myriad forms of life call home. Florida's dominate salt marsh species include black needle rush, salt meadow cordgrass, smooth cordgrass and sawgrass. All are tolerant of the salt in sea spray. As salt marsh plants die and decompose, they create organic detritus, another food source for many marsh dwellers. Salt marshes are important because they create the base of the food chain — the detritus. All of the wild animals large and small, plus man, are primary consumers of the bounties provided by this habitat.

With increased residential development around coastal areas, coastal water quality is increasingly affected by fertilizers, pesticides and the leaching of septic waste. The degree of this impact depends in part on the filtering capacity of the salt marsh system.

Along with tidal currents, marsh vegetation is a critical factor in determining how various substances are transported, diluted and deposited within the marsh. Because vegetation is an obstruction, it enhances the diffusion of substances in the water.

Differences Among Florida Salt Marshes

Salt marshes vary considerably around the state owing to a combination of latitudinal change and geographic differences in tidal range, local relief or topography, and wave energy. These differences can be divided into four parts of the state: northeast Florida, northwest Florida, the Indian River Lagoon and south Florida.

North of Tampa on the west coast and Merritt Island on the east coast, non-woody vegetation dominates the intertidal zone. Isolated mangrove trees occur as far north as St. Augustine and throughout the northwest coast of Florida, but winter freezes have reduced the pockets of mangrove ecosystems.

Northeast Florida salt marshes from the Georgia border to Marineland are similar in vegetation, hydrology and climate to the well-studied marshes of Georgia. This type of marsh accounts for approximately 20% of the total area of non-woody salt marsh in Florida. These marshes contain large expanses of smooth cordgrass and are flooded and drained twice daily by the tides.

Half of the salt marsh area in Florida occurs from Tampa Bay north and west to the Alabama border. These marshes are irregularly flooded by a combination of lunar and windblown tides and a seasonal rise in sea level. About 60% of northwest Florida's salt marshes are covered with nonspecific stands of black needlerush. These expansive stands often grow nearly to the water's edge. Smooth cordgrass is not as prevalent as it is in the northeast Florida salt marshes.

About 10% of the non-woody salt marshes of Florida occur along the Indian River Lagoon. Like northwest Florida salt marshes, these are above mean high water and are naturally flooded only by windblown tides and a seasonal rise in sea level. Unlike northwest Florida, nearly all of the Indian River high marsh has been diked and semipermanently flooded in attempts to control the salt marsh mosquitoes that once bred there.

In south Florida, mangroves have developed and non-woody vegetation is confined to the seaward and landward intertidal fringes. A narrow strip of smooth cordgrass occurs seaward of some red mangrove forests, with narrow strips to extensive zones of black needlerush landward.

MANGROVES

The word mangrove comes from a combination of the Portuguese word for tree (mangue) and the English word for a stand of trees (grove). Three species of mangrove are found in Florida: red, black and white.

Mangroves are essentially tropical trees that usually do not occur in regions where the annual average temperature is much lower than 19ºC. While Florida mangroves can grow quite well in freshwater, mangrove ecosystems do not prosper well in strictly freshwater environments, apparently because of competition from freshwater plant species. Therefore, salt water plays a key role in mangrove ecosystem development by excluding potential competing species.

Mangroves flourish in low-wave-energy environments. High-wave energy prevents establishment of propagules, destroys the relatively shallow root system and prevents accumulation of fine anaerobic sediments. As in salt marshes, salt water, fluctuating water levels and waterlogged anaerobic sediments appear to combine to exclude most competing plants from the mangrove environment.

Mangroves have solved the problem of successful reproduction in the marine environment with two special adaptations: vivipary and dispersal of propagules by means of water. Vivipary means that the embryo initiates germination and begins developing while still on the tree. This continuous development without intermediate resting stages makes the word *seed* inappropriate for mangroves — the term *propagule* is used instead.

Mangrove Characteristics and Differences

	Red Mangrove	**Black Mangrove**	**White Mangrove**
Classification	Taxonomically, the term mangrove is only used for the red mangrove; ecologically used to refer to red, black and white	Taxonomically, not a mangrove, but classified in the family Avicenniaceae	Taxonomically, not a mangrove, but classified in the family Laguncularia
Location	Forefront of mangrove swamp	Behind red mangroves	Landward of other two species of mangroves
Flowers	Produced all year	Appear all year; give rich nectar	Produced all year; small, greenish-white in clusters on narrow spikes
Fruit	Leathery brown fruit that germinates on tree, producing seedling 10–12 inches long. Propagule floats until establishes roots in mud	Ripen all year; fuzzy, lima bean-like	Mature year-round; a downy green-brown about 3/4-inch long; may germinate while still on tree
Identifying features	Prop roots (see below)	Leaves are dark green above with pale downy undersides	Smaller in size, broad, flattened, succulent; oval leaves are 1–3 inches opposite
Root system	Complex network of "prop roots" that come from the trunk and aerial roots that drop from branches to shallowly penetrate the soil to anchor the tree	System of shallow "cable" roots that radiate out from tree and have fingerlike projections that extend above the soil. These are pneumatophores and often form an extensive carpet under the tree	Dense network of roots that bind the soil

In general, mangrove species in the higher part of the intertidal zone (white and black) have small propagules and those in the lower part (red) have large propagules. Propagules of all three mangrove species in Florida float and remain viable for extended periods of time. Red mangrove propagules that were floating for more than 12 months were found to be still viable.

Many mangrove ecosystems, like many tidal wetlands, probably tend to act as sinks (net accumulators) for a variety of elements, including nitrogen, trace elements and heavy metals. Although mangrove ecosystems tend to accumulate nutrients, they also have a continual loss through export of gaseous, dissolved and particulate forms through processes such as denitrification and flushing by heavy rains and tidal action. The major nutrient inputs for mangroves come from upland, terrestrial sources. Many of the most productive and luxuriant mangrove forests in Florida occur in riverine locations or adjacent to significant upland drainage.

Litter fall is one of the major energy inputs from mangrove ecosystems. Litter is defined as leaves, wood (twigs and small branches), leaf scales, propagules, bracts, flowers and insect frass (excrement) that fall from the tree. Litter fall in mangrove swamps is continuous throughout the year. This litter fall contributes to the detritus-based food webs in coastal waters.

Mangrove ecosystems provide a variety of services that are valuable to humans. They are able to stabilize intertidal sediments where no strong erosional forces exist. This function allows them to provide shoreline protection and to be used to stabilize dredge spoil in suitable locations.

Mangrove systems provide valuable habitat for a wide range of animals, including seven species and four subspecies of endangered animals. Mangroves are important nursery areas for sport and for commercial fishes and invertebrates, such as the spiny lobster, pink shrimp and mangrove snapper. The critical value of mangrove systems as nursery habitats for fishes and invertebrates is well established. Both sport and commercial fisheries decline when mangrove systems are destroyed.

MARINE AND COASTAL IMPACTS

The use of the marine environment by humans has many different effects on the systems. The animals and plants living in the oceans are influenced by biological conditions such as salinity, temperature and tides and by biological conditions such as predation and competition. People can also influence the animals and plants of the marine environment. The most serious threats to marine areas today are the effects of man-made pollution and the destruction of habitats.

Water Pollution. There are two main types of water pollution: point source and nonpoint source. Both types of pollution affect our marine and coastal systems. Oil, gas and diesel fuel are spilled into our waterways at an alarming rate. Dumping of boat sewage into the water instead if using proper pumpout facilities can release harmful nutrients and fecal matter in our waterways.

Habitat Destruction. Many acres of valuable marine habitat, including coastal marshes, mangrove swamps and grassbeds, are lost to dredge and fill, both for developments and for recreational facilities such as docks and marinas. These habitats serve as nurseries for the young of many species of fish and shellfish caught by people for food and sport. Declines in numbers of species caught is linked directly to destruction of the nursery habitat. Seagrass beds and reef areas are also vulnerable to destruction by boat propellers and anchors cutting across their systems.

Habitat destruction of the dune systems can occur from foot or vehicular traffic. As the dunes are eroded by paths, they become vulnerable to destruction by wind and water.

Mangroves are especially vulnerable to pollutants that clog their modified root systems. Petroleum and its byproducts pose a particularly serious threat to mangroves. Crude oil kills mangroves by coating and clogging their root systems. Mangroves are also highly susceptible to herbicides. Although mangroves are not negatively affected by highly eutrophic waters, they can be killed by heavy suspended loads of fine sediments or material. These can come from untreated sugar cane wastes, pulp mill effluent, and ground bauxite and other ore wastes.

SUPPLEMENTAL FACTS SECTION

The following excerpt on sea grasses is from *Marine Times* 19(13), May–June 1995:

> Sea grasses serve as a good indicator of water quality because they are so sensitive to change and they are so visible. “Light penetration into estuarine waters is critical to sea grasses,” said Bob Day, program scientist at the Indian River Lagoon National Estuary Program (IRLNEP). “Algal growth due to high nutrient levels in the water, turbidity, and colored water from freshwater flows all lessen the amount of light that reaches the grasses and therefore impact their growth.”
>
> Some of the activities responsible for the decreased water quality include dredge and fill projects; nonpoint source pollution from road runoff, septic systems and agricultural practices; and turbidity from boat propellers. Losses during the past few decades have been as high as 100% in some areas, according to Day.

In the Tampa Bay National Estuary Program (TBNEP), sea grasses are the primary indicator of water quality. “Sea grasses provide critical habitat for many estuarine species, including fish, crabs and shrimp,” said Holly Greening, program scientist at the TBNEP. “Small fish use the grasses as a nursery and adults feed in them, while crabs, shrimp, mollusks and other marine creatures attach themselves to the grasses to feed or hide,” explained Greening.

Between 1870 and 1950, seagrass acreage declined from more than 76,000 acres to about 40,000 acres. From 1950 to 1980, the decline continued, to a low point of about 21,000 acres.

“Since 1980, we have seen an increase of about 2,000 acres, probably due at least in part to decreases in nitrogen levels in the water, which leads to decreases in algal growth and, ultimately, to clearer water,” explained Greening. “We know that algal levels have decreased dramatically since 1985, and when 20–25% of the ‘incident light’ hitting the surface of the water penetrates to the bottom, sea grasses can grow again.”

Restoration of 15,000 acres during the next 20 years is a goal of the TBNEP. “If the sea grasses are returning and, more importantly, functioning as habitat for many marine creatures, then we know that the overall health of the water must be good. The sea grasses themselves tell us about nitrogen levels, and the marine creatures tell us about other issues, such as dissolved oxygen and pesticides.”

WATER CONSERVATION FACTS

BACKGROUND

Florida is blessed with an abundant supply of water in comparison to other states and countries. But this supply is neither uniform nor consistent statewide. Florida's hot, humid climate causes large amounts of water to be lost to the atmosphere. Because Florida gets large amounts of rain and has many rivers, lakes and swamps, residents and visitors often tend to take water for granted. As a result, some areas of Florida are beginning to experience inadequate supplies of freshwater, although other areas still seem to have more than enough.

Water is becoming an important national and international issue as droughts occur and water supplies dwindle. Typically, the United States uses two to four times as much water per person as the countries of Europe, and that is certainly true in most of Florida. Farms and cities, countries and provinces, and states and counties must compete for limited or decreasing water supplies. Population growth, unequal distribution or access to water supplies, and depletion or degradation of our water resources increase the potential for conflict.

Historically, rivers or water bodies have been used as political boundaries that separate counties, states and countries. Thus they have been used to politically divide a region. Ecologically, rivers join, not divide. Water does not recognize boundaries and a river or water body is usually the center of a watershed or ecosystem, joining two politically separate regions into one interwoven natural system.

Experts like Sandra Postel, WorldWatch, agree that "cooperation is essential not only to prevent conflict but to protect the natural systems. Water requires an ethic of sharing — both with nature and each other." Postel believes that priorities should be placed on ensuring that both people and ecosystems receive a minimum amount of good quality water to maintain their health and functions.

WATER MANAGEMENT DISTRICTS

The boundaries of Florida's water management districts were created to allow management of the state's waters based on watersheds, not politics. Each water management district must consider the needs of the ecosystem when developing its water management plans. Districts are required to determine how much water and what quality water is needed to maintain Florida's ecosystems in good working order.

This is a difficult task, since a variety of factors influence the minimum amounts needed by these systems. Some factors are seasons, habitat requirements, the system's sediments and salts, and the value local residents place on fisheries and recreation.

Water management districts use water conservation and alternative sources as management tools for protecting, extending and developing our water resources. Conservation, recycling and increased efficiency are the most economical ways to balance water budgets and are usually less expensive than developing new sources of water.

Legally, when evaluating and permitting new sources of water use, water management districts and the Florida Department of Environmental Protection must consider the following factors:

1. Reasonable demand. Are the water withdrawals necessary to supply a certain reasonable need or demand?
2. Sources of water. Sources of withdrawals must be identified.
3. Lowest quality sources. Consideration must be given to the availability of the lowest quality of water acceptable for the intended use. For example, if reclaimed wastewater is readily available, it should be used in place of higher quality water for purposes such as citrus or golf course irrigation, unless it is shown to be harmful to the environment or economically or technically unfeasible.

CONSERVATION

Water conservation is the practice of using water resources efficiently and protecting them from pollution. Energy savings, resource protection and economic benefits are several of the main benefits of practicing good water conservation habits.

Reasons for Saving Water

Economy. With today's costs for water distribution, usage and wastewater treatment rising, it is advantageous to reduce the amount of water we use. Using less water saves money. With less water usage, fewer chemicals are needed for purification, operating costs are lower for both water distribution systems and sewage treatment plants, and expansions of plants to provide distribution and treatment are needed less frequently.

Pollution Reduction. Water used in homes and businesses eventually makes its way to wastewater treatment plants. Reduction of water use automatically reduces the volume of wastewater reaching the treatment plant or your septic tank. In turn, this reduces the possibility of streams and lakes being polluted by spills from overloaded facilities.

Energy Savings. Large amounts of energy are required to heat residential and commercial water. Heating water is second only to the cost of home heating on your utilities bill. Large amounts of energy also are required to operate pumps to move water from place to place, to extract groundwater, to pressurize distribution systems and to pump and treat wastewater.

Many publications are available from your local water management district, extension service, and utilities and water suppliers that give ways to conserve water in your home, school or business.

Efficiency

We can reduce our water consumption rates by increasing the efficiency of the systems, or infrastructure, that deliver water to our households, industries and farms. Also, laws have been passed to mandate the use of water-saving fixtures within our homes. Today, the average United States resident uses an estimated 150 gallons per day in the home. Within 30 years, this figure is expected to be reduced by 50% as more-efficient fixtures replace existing ones.

Agriculture accounts for two-thirds of total water use worldwide, so even slight improvements in irrigation efficiency can mean large water savings. Many techniques already have been developed to reduce agricultural water use.

Pricing Structure

In some cases, the more water you use, the less you pay. For instance, many utility companies offer price reductions for their larger-volume water users. If this pricing structure were inverted so that rates increased in conjunction with higher use, consumers would have a greater incentive to reduce their water consumption and waste. Revising the pricing structure for water use also encourages the treatment and reuse of wastewater for irrigation and conservation.

Creative pricing could also include water marketing or trading. Instead of developing new water sources, cities and farmers could purchase supplies from others willing to sell, trade or lease their water or water rights. For example, in the South American country of Chile, urban water companies frequently buy small portions of water rights from farmers, most of whom have gained their surpluses through increased efficiency.

Through water markets, organizations and government agencies could purchase existing water rights and dedicate them to restoring the aquatic environment.

ALTERNATIVE SOURCES

Desalination

Like other states and nations surrounded by salt water, Florida uses the process of desalination to create alternative water supplies. Florida currently leads the nation in the number of desalination facilities.

Desalination is defined as any water treatment process that removes salts from water. Reverse osmosis in one type of desalination process. Other types include electro-dialysis, de-ionization, evaporation and distillation.

Sources of salt water have either been brackish water (e.g., wells that have experienced saltwater intrusion) or ocean or gulf water. Seawater has not been extensively developed but is being considered as an ideal source of water. This source has a limitless potential for supply even in times of drought.

Although desalination can be an expensive process, new technology is quickly closing the gap between the costs of desalination and other alternative water sources. Relatively high energy costs associated with desalination plants can be reduced by building co-generation plants that desalinate the water and then use it for energy production.

Another challenge facing those who promote desalination is what to do with the salt or brine byproduct created by the process. The amount of byproduct produced is determined by the kind of water and the processes used. As a general rule, the higher the salt content in the water, the more byproduct will be produced. Currently, there is no commercial market for this byproduct and dumping the salt in one area can be extremely harmful to the marine environment. These salty byproducts must be diluted before they are returned to the ocean or the Gulf, and researchers are now studying methods of offshore, near-shore and inland disposal.

Reuse

Many communities in Florida, the United States and the world are now recycling their wastewater. The city of St. Petersburg has been recycling water for almost a decade to augment its public supply. By using reclaimed water, the city saves an estimated seven million gallons per day of potable water.

What are some benefits of recycling wastewater? Reuse can stretch water supplies, reduce wastewater disposal costs, reduce water costs, save energy, improve water quality and reduce the discharge of pollutants to receiving waters. Reclaimed or recycled water is used for landscape and agricultural irrigation.

Urban wastewater contains nitrogen and phosphorus, which are beneficial nutrients when applied to farmland or golf courses, although they may act as pollutants when released to lakes and rivers. Reclaimed wastewater may be used for rehydration of impacted wetlands.

With urban water use predicted to double by 2025, wastewater can be an expanding and fairly reliable source. As long as the wastewater stream is kept free of heavy metals and harmful chemicals and is adequately treated against disease, it can be a vital supply for agricultural and landscape use.

With additional treatment, reclaimed wastewater eventually may be used for human consumption. Wastewater can be treated so that it meets all the health standards for drinking water. However, negative perceptions about drinking treated wastewater must be overcome before the idea will gain widespread public acceptance.

Offshore Freshwater Springs

Offshore freshwater springs have recently come under consideration as another potential alternative water source. By using some type of surface or subsurface structure, freshwater could be captured as it wells up from these springs. It would then be transported to shore by either an underground pipeline in the bottom of the Gulf or the ocean or by an overland pipeline constructed within existing railroad or other rights-of-way. The water would then be sold to utilities which would treat and resell the water to its customers.

Before such steps are taken, however, studies must be conducted to ensure that no natural communities associated with offshore springs would be affected by the decrease in freshwater flow. Springs located in or near estuaries that depend on a balance of salt water and freshwater for their health and productivity should be protected.

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GLOSSARY

Aerobic. Requiring oxygen.

Aesthetic. Appealing to the senses; pertaining to art and beauty.

Aquifer. An underground layer of porous or fractured rock or soil that carries or holds water. Limestone bedrock is the main geologic formation in Florida aquifers.

Artesian (aquifer or well). Created when a well is drilled into a confined aquifer whose pressure is large enough to force the water onto the land surface.

Benthic. Bottom dwelling.

Brackish. Mixed fresh and salt waters.

Coastal wetlands. Wetlands found along the coastline containing salt or brackish water.

Confined aquifer. Subsurface water which is restricted to a particular rock unit by an impermeable rock or soil layer above it.

Denitrification. Reduction of nitrate ion to nitrogen oxide or di-nitrogen gas through several intermediate steps.

Detritus. Tiny pieces of decomposing plant or animal matter.

Discharge. The amount of water flowing past a given point in a stream or river, measured in cubic meters per second.

Divide. The point where two watersheds connect or come together.

Ephemeral. Lasting a very short time; flow generally occurs during or shortly after extreme precipitation or snowmelt conditions.

Estuary. A surface area where fresh and salt waters mix; for example, where a river joins the ocean.

Evaporation. The process whereby water from land areas, bodies of water, and all other “moist” surfaces is absorbed into the atmosphere as a vapor.

Evapotranspiration. The combined processes of evaporation and transpiration. It can be defined as the sum of water used by vegetation and water lost by evaporation.

Floodplain. An area of land along a river that floods.

Fragmentation. Broken into small parts or incomplete areas.

Groundwater. All water beneath the surface of the ground (whether in defined channels or not).

Habitat. The place where a plant or animal naturally grows or lives. Habitat must contain four elements: food, water, shelter and space.

Halophytes. Salt-tolerant plants.

Herbaceous. Non-woody.

Hydrologic cycle. Movement or exchange of water between the atmosphere and the earth.

Hydrophytes. Water-loving plants.

Infiltration. Movement of water into the soil. The infiltration rate is the quantity of water (usually measured in inches) that will enter a particular soil per unit of time (usually one hour).

Inorganic pollution. Consists of suspended or dissolved solids.

Integuments. The natural outer covering of an animal or plant, for example, skin, seed coat, shell.

Intermittent. Not continuous, coming and going at intervals; flow generally occurs only during the wet season.

Leaching. Movement of dissolved particles through soil by water.

Nonpoint source pollution. Pollution sources that can not be traced to specific source or point of entry.

Organic pollution. Comes from the decomposition of living materials and their byproducts or fertilizers. Plant residue, human sewage and pet waste are all examples of organic wastes.

Perennial. Year-round; indicates a year-round flow in a well-defined channel.

Permeability. Generally used to refer to the ability of rock or soil to transmit water**.**

Percolation. The slow seepage of water into and through the ground.

Photosynthesis. A process by which plants use energy from the sun to make food and oxygen.

Point source pollution. Pollution that can be traced to a particular source or point of entry.

Porosity. Refers to the spaces between the rock or soil particles which can hold air or water. Porosity is expressed in a percentage of the total volume.

Potentiometric water level or surface. The level to which water will rise, in cased wells or other cased excavations into aquifers, measured as feet above mean sea level. For example, if some point on the surface of the ground was 10 feet above mean sea level and the potentiometric surface was 6 feet, water would rise to within 4 feet of the surface in a well dug at this point. If the potentiometric surface was 20 feet (i.e., anything above 10 feet) at this point, the well would be free-flowing or artesian. Where the potentiometric surface is higher than the land surface, swampy areas can result.

Predator. An organism that feeds on other organisms.

Recharge. Generally, the inflow to an aquifer and/or groundwater.

Recharge area. Generally, an area that is connected with the underground aquifer(s) by a highly porous soil or rock layer. Water entering a recharge area may travel for miles underground.

Residual soils. Soils developed in one place from underlying rock formations and surface plant cover. Characteristics of residual soils are closely related to the parent material from which they formed.

Riparian habitat. The natural vegetation adjacent to a river or the portion of the riparian zone that provides an organism with its food, water, shelter and space requirements.

Riparian zone. The area along the entire length of both sides of a river that is affected by the river. It serves as habitat for both wildlife and vegetation.

Runoff. Water which drains from the surface of the land into a body of water.

Saltwater intrusion. Occurs when freshwater is withdrawn allowing salt water to move into the underground storage areas (aquifers). Salt water underlies freshwater in Florida's coastal areas. As the freshwater volume is reduced, salt water moves upward. The salt-freshwater interface along the coast is affected by intrusion through water channels where the channel bottom is below sea level (and particularly when freshwater levels are low).

Scouring. Gradual or rapid erosion of particles from the channel walls or bed caused by a concentration of current.

Sinkhole. An area where the surface of the land has subsided or collapsed as a result of the underlying limestone being dissolved.

Slope. Degree of deviation from the horizontal. Slope is usually described as a percent or fraction. The higher the fraction or percentage, the greater or steeper the slope.

Surface water. All water on the surface of the ground, including water in natural and man-made boundaries as well as diffused water.

Suspended particulate matter. Fine soil or mineral particles that are prevented from settling out by the movement of the water; they create turbidity.

Thermal pollution. Known as “waste heat,” it is when water temperature is raised above its naturally occuring temperature.

Toxic pollution. Pollution containing hazardous wastes or heavy metals.

Transpiration. The process whereby water vapor is emitted or passes through plant leaf surfaces and is diffused into the atmosphere; more simply, plants give up moisture through their leaves.

Transported soils. Soils transported by gravity, wind or air.

Tributary. Stream, creek or river that flows into a larger water system.

Unconfined aquifer. Subsurface water which is not restricted from flowing into other rock units. In this type of aquifer, the water table is under atmospheric pressure.

Velocity. Rate of stream flow measured in meters per second.

Vernal. Spring, fresh or new.

Water table. The water level (or surface) above an impermeable layer of soil or rock (through which water cannot move). This level can be very near the surface of the ground or many feet below it.

Watershed. The whole area which drains into a particular lake or river.

Wetlands. Swamps, marshes, bogs, wet meadows, and tidal water stands on the ground surface.