Surface Water

Rivers, lakes, and wetlands are an integral part of the physical and human landscape. They are important for their resources, in addition to their relation to settlement, industry, navigation, and agriculture. Flow and form of rivers and lakes and adjacent wetlands vary spatially and temporally in response to both natural and human factors. Understanding these variations is essential for a variety of concerns, including flood control, engineering structure design, water supply, biotic habitat, navigation, hydroelectric power, and recreation.

Drainage Systems in Florida

A drainage basin is an area on the land surface from which water flows to a stream or lake. Drainage basins are separated from adjacent basins by topographic divides. Portions of drainage basins of several large rivers in Florida are in Alabama and Georgia. Local topography controls the drainage direction and patterns. For management purposes the state has been divided into five surface water regions: the Northwest, Suwannee River, St. Johns River, Southwest, and Kissimmee-Everglades, generally corresponding to directions of surface water flow.

Geology as well as topography influences drainage systems and surface waters. Surficial sediments in Florida are both clastic (derived from weathering of rocks) and carbonate (derived from precipitation of carbonate minerals in solution and biologic processes). Where carbonate sediments are at or near the surface, karst topography typically develops. The landscape is characterized by sinkholes, caves, and underground drainage formed by dissolution of the carbonate sediments. Drainage patterns of karst landscapes are often characterized as disjointed, because rivers and creeks are not always continuous on the land surface and may disappear underground in local sinks or depressions. Karst areas generally have fewer large streams and tributaries than non-karst areas, but better developed underground drainage, such as caves and other underground conduits. Karst areas of Florida have more streams than karst areas elsewhere, partly because of high water tables, low topographic relief, and proximity to sea level. Geology also influences the subsurface drainage, and the groundwater basin contributing to a stream may be quite different from the topographic basin.

Some portions of Florida are poorly drained; that is, there are few or no channels, even though water flows across the surface. Extensive marsh or swamp areas, where the surface is almost flat, have poorly defined drainage. In Florida poorly defined drainage and disjointed drainage are commonly mixed and cannot be separated on a statewide map.

Soil type affects many aspects of drainage. Soil type is strongly influenced by geology, and different materials have differing drainage characteristics. Soils of the Central Ridge and Western Highlands are generally well drained, whereas soils of the Flatwoods and Coastal Lands and those of organic and recent limestone origin are somewhat poorly to very poorly drained, which causes differences in storage potential and the amount of ponding.

Climatic factors, especially inputs of precipitation and losses to evapotranspiration, are the most important influences on spatial and temporal variations in surface hydrology. Precipitation is strongly dominated by rainfall in Florida and contributes to flow in a stream through several pathways. Rainfall can be intercepted by vegetation and buildings, puddle, flow overland as a thin sheet of water, infiltrate the soil, or fall onto the surface of lakes and streams. A substantial proportion of precipitation is evapotranspired in Florida, especially in areas with dense vegetation. Water storage in puddles or depressions is generally temporary, as it ultimately evaporates or infiltrates the soil. Overland flow occurs when the soil is saturated or when the precipitation rate exceeds the infiltration rate. It usually lasts for a brief period during and following rainfall events, unless the ground surface is not very permeable. Soil permeability also influences percolation, or downward movement toward the water table. In permeable parts of the unsaturated zone, water moves downward, but in less permeable parts, infiltrated water will move horizontally, a process known as interflow.

Rainfall is generally abundant in Florida, but varies annually and seasonally. The details of these variations are discussed in the climate chapter. The statewide annual average is approximately 53 inches, and specific locations average from 40 inches in Key West to 69 inches at Wewahitchka in the panhandle. Seasonal distribution also varies, with the northern portion of the state having proportionately more winter precipitation associated with fronts and the southern part having proportionately more summer precipitation associated with thunderstorms.

Two ways in which the flow in streams is measured are discharge and runoff. Discharge is the volume of water pass ally measured in cubic feet or meters per second. Discharge is most often used to distinguish the size of rivers and to characterize temporal variations in flow. The stream flow is comprised of different sources: overland flow, interflow, and groundwater contributions or baseflow. Overland flow tends to produce a fairly rapid influence on stream flow, because water runs across the surface more quickly than though the ground. If the basin is small, rain falling on the basin surface might reach a stream via overland flow in minutes to hours. It could take days in a larger basin. Interflow has an intermediate response time, compared to overland flow and baseflow, because it generally has an intermediate length or pathway, with the response time being dependent upon the basin size, geology, and other factors. The baseflow or groundwater contributions tends to take longer to influence stream flow and is a relatively consistent source of water that allows streams to flow through extended periods of low rainfall. In rivers in karst terrain, groundwater is often contributed to streams via springs of varying sizes. In times of high river flow, springs may become sinks, drawing stream flow into the ground.

Runoff is depth of water uniformly distributed over a drainage basin, computed as the discharge divided by the drainage area. Runoff quantities and rates are influenced by climatic elements, slope, geology, land use, and other factors. Flat, poorly drained lands retain water and allow for more evapotranspiration and infiltration, thus yielding a low runoff per unit area. Permeability, soil moisture content, and the distribution of precipitation and evaporation also affect runoff. Long-term stream flow records show that local average annual runoff varies across the state, ranging from less than 10 to more than 30 inches (Hughes 1978).

Rivers and Their Classification

From a regional perspective, several rivers in Florida are moderate to large in terms of their discharge and drainage area. The largest rivers, as measured by discharge, are the Apalachicola, Suwannee, and St. Johns. Even the largest rivers in Florida have only a fraction of the flow of the continent's and world's largest rivers. Average runoff computations show regional variations throughout the state, with the northwest rivers having the highest discharge per unit of drainage area.

Planners, environmental scientists, and engineers require an understanding of the long-term and annual hydrology to be able to predict the likelihood of floods and droughts and their potential impact on humans and development. Long-term estimates of the seasonal variation in stream flow show considerable variation from the northern to southern part of the state. In the northernmost parts of the state, stream flow is highest in the winter and early spring months. In the southern part of the state, stream flow is highest in the summer and fall.

Several systems, developed primarily by ecologists, have been used for categorizing Florida rivers (Nordlie 1990). The most commonly used classification of Florida waterways, developed by Beck (1965), includes five categories: sand-bottomed streams, calcareous streams, swamp-and-bog streams, large rivers, and canals. Because of problems of mixing criteria, such as materials with size, setting, and human modification, this chapter characterizes Florida natural waterways as predominantly alluvial or predominantly karst. Canals and modified waterways are described separately. Yet this description is also general, as not all rivers in Florida are comprised exclusively of alluvium or carbonate bedrock. Some are transitional and have both materials.

Rivers are three-dimensional, but are typically displayed from various two-dimensional perspectives. Maps show a planform perspective, or comparison of width across the channel with distance along the valley or channel. A cross-section compares elevation (generally bed) with width or distance across the channel. Longitudinal profiles show the elevation of the water or bed surface with distance downstream. From the planform perspective, it is obvious that rivers have differing forms, varying in their sinuosity (ratio of channel length to valley length) and the number of channels.

Alluvial rivers occur in valleys surrounded by their own sedimentary materials and adjust their morphology according to discharges and the sediment sizes and loads present. Alluvial rivers typically develop features, such as meanders, channel bars, and islands, that are uncharacteristic of rivers exclusively in bedrock. Most alluvial rivers in sand and gravel have a series of alternating deeps (pools) and shallows (riffles), with pool-to-pool spacing averaging six times the channel width. They typically are dominated by suspended load transport, especially in low gradient settings as Florida, and experience erosion and deposition along the channel, especially during and following floods. Alluvial rivers are common in the panhandle of Florida, traversing the geologic units comprised of clastic sediments. Some of the larger alluvial rivers in Florida include the Escambia, Choctawhatchee, Apalachicola, and Ochlockonee.

In Florida, alluvial rivers typically have meandering or anastomosing patterns, with multiple channels that are separated by densely vegetated islands. Because elevations in low gradients and thus low energy. Most profiles are concave upward, with steeper headwaters that decrease in gradient approaching the bays or gulf, with local knickpoints associated with changes in geology. Some tributary stream profiles are locally quite pronounced, forming linear valleys with large gradients termed steepheads where some drainage networks have formed by groundwater seeping in highly permeable sands (Schumm et al. 1995).

Overland flow is generally very important in alluvial rivers and the stream hydrographs are relatively flashy (Escambia, Choctawhatchee, and Apalachicola). Even in large rivers, the crest occurs a few days following the precipitation event. Because of the limited delay caused by overland flow contributing much of the discharge during storm events, requests for evacuation in the event of flooding must be heeded immediately.

The stream hydrograph for karst rivers (for example, the Suwannee) is much flatter than those for alluvial rivers. Rivers in karst terrain typically have sinks and springs, and may disappear underground and reemerge for short or long distances. Groundwater input or baseflow contributes appreciably to stream flow, and the material load is dominated by dissolved materials rather than suspended sediments. Surface water-groundwater interactions are often bidirectional, as the river recharges the aquifer during floods, and the aquifer supplies the river during droughts. In rivers in karst terrain, groundwater input or baseflow contributes appreciably to stream flow. Because there is less direct runoff, it may take several weeks and even months for a flood to rise and fall, generally allowing ample time for evacuation. However, the flows are also slow to recede, preventing floodplain residents from returning to their homes for weeks to months during periods of high water. Hydrology and valley evolution are strongly dependent upon subsurface voids and relative sea level changes. The larger karst rivers of the panhandle include the Chipola River and Holmes Creek. In peninsular Florida, karst rivers are best developed in the north and include the Suwannee, Alapaha, Withlacoochee, their tributaries, and a number of smaller rivers.

Sinks and springs of varying sizes, largely associated with the presence of carbonate rocks, are numerous along river corridors. Bed surface irregularities associated with springs and sinks occur on large rivers, such as the Suwannee River (U.S. Army Engineer District-Jacksonville 1974, Mossa and Konwinski 1998). Some rivers, such as the Silver and Ichetucknee, are predominantly spring-fed. Others, such as the the river to disappear underground and springs that cause it to reemerge some distance downstream for all or part of the year. On the Santa Fe the underground channel is connected with wetland lakes between these points (Ellins et al. 1991). Some rivers, including the St. Johns and Kissimmee, have large lakes or large depressions along their courses.

Consequently, the hydrology of such rivers is highly varied along the river course and is sometimes more characteristic of a lake than a river. Channel offsets are a drainage feature which are in part created and maintained by karst processes. The St. Johns River has an offset course where the river initially turns to the west to reach a valley cut in older, higher terrain, then flows northward for a long distance, possibly in an ancestral valley, and then jogs back to the east to traverse a younger, lower surface (Pirkle 1971).

The hydrology of the St. Johns River is highly varied. Upstream at Melrose, the flow is unidirectional and generally not influenced by tides, with notable seasonal variation. Midstream at DeLand, flow is dominantly unidirectional. Since the late 1950s both locations seem to have smaller maxima and means, and DeLand has had more negative flows. Downstream at Jacksonville, flow is bidirectional with a strong daily variation associated with tides.

Lakes

Florida has thousands of large and small lakes. Of the named lakes exceeding one acre in size, the great majority are less than 50 acres. Most of Florida's lakes average between 7 and 20 feet in depth, although a few sinkhole lakes are hundreds of feet deep (Heath and Conover 1981). About 35 percent of the lakes in Florida are concentrated in four counties of central Florida (Osceola, Orange, Lake, and Polk). Schiffer (1998) characterizes the hydrology and issues regarding lakes in these counties. In addition to Lake Okeechobee, one-fourth of all lakes in Florida are in the Kissimmee River drainage.

Most of the lakes are natural in origin, formed by solution processes where groundwater dissolves carbonate sediments to form cavities which collapse to form depressions. Some solution lakes are nearly circular at the surface and conical in cross section, others are somewhat irregular from several coalescing sinkholes, and others are elongated if formed in a valley where the sinkhole becomes plugged. Many of the solution lakes are enclosed by topographic divides, and drainage into them either evaporates or percolates downward to the groundwater system where it may emerge in an adjacent drainage basin. Lakes also originate from relict sea bottom depressions and erosion and sedimentation processes in rivers (Edminston and Myers 1983).

Some Florida lakes have been formed through the emplacement of dams or impoundments to form reservoirs. Other human-made lakes or ponds include rock pits, sand pits, and cooling ponds for large power plants.

Natural lakes vary appreciably in their hydrology, depending on whether they only have subsurface connection, whether streams flow through them, whether streams only flow from the lakes, or whether streams flow into the lake. Lake levels change in response to direct precipitation, runoff, evaporation, and the exchange between the lake and groundwater. In Florida, the more important influences include seepage by groundwater and, secondly, surface drainage. Most Florida lakes are seepage lakes, and some estimates suggest that as many as 70 percent of the lakes lack overland flows (Palmer 1984).

Fluctuations in lakes dominated by seepage correlate with changes in the water table. Fluctuations in lakes that are dominated by drainage, with streams flowing through them, correlate with changes in stream flow. Lakes that are regulated show fairly consistent lake levels except for occasional breakages and stormwater inputs.

Lakes generally show variability annually and seasonally. During periods of below normal rainfall, lake levels begin to drop. They may do so for several years, causing concern for local residents with docks and lakeside businesses. Given time, lake levels generally rebound, and some lakeside residents may complain about too much water. Orange Lake has been through such cycles in recent years. Lake level is not actively regulated, but is influenced by a fixed crest weir on the outlet as there is no outflow, except from evaporation or seepage through the bottom when stages fall below 57.5 feet (Shuman, personal communication). Because slopes are gentle in Florida, vertical changes in water level of a few feet imply horizontal changes in water level of a few hundred feet. The St. Johns River flows through Lake Monroe and several other lakes. Lake levels within the river chain show seasonal fluctuations, related to stream flow variability.

Lakes that are regulated, or impounded for dams, show fairly consistent lake levels, especially in comparison with natural lakes. Variations are mostly associated with occasional breakages, stormwater inputs, and controlled management changes; for example, there was a breakage on Lake Talquin, a reservoir on the Ochlockonee River, in 1959.

Wetlands

Wetlands are the largest component of the state’s surface waters in terms of total area. In wetlands, high water tables determine the nature of soil development and the types of plant and animal communities living in the soil and on the surface. The water table is at, near, or above the land surface for a significant part of most years. These ecosystems are complex transitional systems between aquatic and terrestrial environments. Wetlands are often classified as swamps or marshes, depending on whether the vegetation is dominated by trees (swamps) or by grasses (marshes).

Wetlands occur near the ocean and gulf, adjacent to rivers and lakes, in areas of poor soil drainage, and in relict lake valleys or river channels. River and lacustrine (lake) floodplains are periodically inundated and often remain partly wet because of their low topographic position in the proximity of high water tables. In karst areas, the valleys and lakes may become dry because of water-table changes associated with sea level changes, climate, vertical adjustments in the earth’s crust, and cavern development. Specific examples reported include features associated with the Suwannee valley (White 1970) and a dry spring-fed tributary to the Santa Fe near High Springs (Edwards 1948). Paynes Prairie, a 19,000-acre wetland near Gainesville, is a relict lake bed.

Wetlands, like lakes, may be sites of internal drainage, exporting water only by infiltration and evapotranspiration, or they may be connected with streams along the stream corridor, transporting runoff as well. The dense vegetation and flat topography of bottomland wetlands in floodplains attenuates the flood peaks and provides greater detention storage (U.S. Environmental Protection Agency 1983).

Evapotranspiration in wetlands approximates the evaporation from open water bodies (Visher and Hughes 1975). Thus, changes in wetlands, usually a decrease in area from a reduction in hydroperiod, reduce the amount of water lost directly to the atmosphere. Some wetlands play a role in recharge, but most are situated in low-lying areas that are discharge areas of the groundwater system. Recharge results from the vertical movement of water through the soil. However, this vertical movement is often restricted because wetlands are often underlain by virtually impermeable clay and organic layers that severely restrict groundwater recharge.

Wetlands are extensive and are found nearly everywhere in the state. Prior to development, wetlands, including open waters and seasonally flooded areas, covered about half the state's area. Based upon satellite imagery from the early 1970s, wetlands and their associated open-water areas accounted for almost a third of the total land area of the state (Hampson 1984).

Over one-third of the wetlands had been drained for agriculture, flood control, and residential development, but many floodplain wetlands and coastal marshes are still largely undeveloped but are threatened by urban and agricultural land uses.

In southern Florida, extensive areas of wetlands include the Everglades and Big Cypress Swamp, where historically most surface flow moved slowly either as sheet flow through marshes or through broad sloughs. Extensive wetland areas in central Florida include the Green Swamp and parts of the Kissimmee basin. The Okeefenokee is an extensive swamp in the upper Suwannee Basin of northern peninsular Florida.

Human Modifications of Surface Waters

Humans created and modified waterways in Florida for a number of centuries, if not millennia, although the impacts, both indirect and direct, have been particularly severe within this past century. Most indirect changes are associated with human activities and land use changes within the basin, especially close to the channel and floodplain. Deforestation, agriculture, land drainage or flood protection, and urbanization have a number of effects on waterways. These activities typically increase the magnitude of peak flow and decrease the lag time, generally aggravating flooding. To minimize such impacts many communities in Florida have built retention and detention ponds in conjunction with development to increase the local storage and allow flood waters to behave more as they would under predevelopment conditions.

Direct modifications along the channel and floodplain are typically built to manipulate the spatial and temporal variations in surface waters. Structures such as dams and weirs, bridges and pipeline crossings, and activities such as channelization, dredging, and floodplain and in-channel mining are more direct impacts. Direct modifications have a long history, as building canals and modifying waterways dates well before European settlement (Leur 1989). Further changes have occurred in this century, when sections of waterways have been straightened and new artificial channels intertwine with the former natural one, especially along the Kissimmee. Some channels have been deepened or widened locally for navigation by dredging, and others have artificial cutoffs or shortcuts across meander bends. Blount Island on the St. Johns River is one of the larger artificial cutoffs, and several occur on the Caloosahatchee River and Upper St. Johns River as well.

Canals have been constructed in a number of places throughout peninsular Florida, especially the lowlands of south Florida in areas of urban and agricultural development. They have been constructed for a multitude of reasons, including flood control, water supply, navigation, wetlands drainage, and for control of water flow directions and elevations. Canalization results in either the straightening, widening, and/or deepening of an existing waterway or in the construction of a new waterway. Examples of canalization are so numerous that canals are included in Beck's (1965) classification of Florida's waterways. Eight major waterways, including the Caloosahatchee and Kissimmee rivers, and the Tamiami, Miami, North New River, Hillsboro, West Palm Beach, and St. Lucie canals are classified as such. Furthermore, there is an extensive set of numbered rather than named canals. This extensive network of canals built for flood control and water supply has led Palmer (1984) to characterize south Florida as the "quintessence of surface water manipulation."

Two areas of considerable modification in Florida include the partially completed Cross Florida Barge Canal (St. Johns to southern Withlacoochee) and the Kissimmee River basin. The Cross Florida Barge Canal was to have connected the east and west coast via the Withlacoochee, Ocklawaha, and St. Johns rivers, resulting in the modification of a number of Florida waterways. Predecessors to this aborted project were first initiated in 1850. Construction on the canal was first halted in 1862 because of the Civil War, but resumed for a short time in 1935 and 1936. Later, work recommenced in the 1960s with construction of major dams and locks on the Ocklawaha and Withlacoochee rivers (Southeastern Geological Society 1970). More recently, construction was halted in 1971, largely because of environmental opposition. Considerable controversy exists as to whether the modified system should be retained, whether the original conditions should be restored as much as possible, or whether a compromise involving partial restoration should be attempted. The Rodman Dam on the Ocklawaha River represents part of this controversy (Shuman 1995). Both the St. Johns River Water Management District (1994) and the Florida Department of Environmental Protection (1998) have conducted studies documenting problems resulting from the Rodman Dam. The Florida Defenders of the Environment (1998) have called for removal of the dam and restoration of the Ocklawaha, and the U.S. Fish and Wildlife Service (1997) has also issued a Biological Opinion in favor of restoration.

Construction of the project initially resulted in destruction of much bottomland forest. By changing the hydrology, the dam reduces productivity in the St. Johns River. The dam also is harmful to migratory aquatic species, especially manatees, because structures block passage and reduce habitat of these and other species. In warm and nutrient-rich waters of the reservoir, aquatic weeds and algae have flourished, requiring the use of mechanical and chemical treatments to control undesirable water plants. Additionally, maintaining the structure has an annual cost which over a period of years exceeds the one-time cost of destruction. However, many local fishermen, supported by a powerful legislator, want it left in place because it has become a favorite spot for bass, and the fish and bird populations now accustomed to the dam would undergo a period of adjustment. Should the dam be removed, much planning and environmental assessment will be needed to minimize potential problems associated with sediments, channel instability, and ecological changes.

The Kissimmee River is in south-central peninsular Florida. The Lower Kissimmee flows about 100 miles from Lake Kissimmee to Lake Okeechobee. Congress authorized the Kissimmee River Flood Control Project in 1954 to facilitate the passage of floodwater, and it was constructed between 1962 and 1971 at a cost of $32 million. The project diverted flow from the 103 miles of meandering river channel and a 0.9- to 1.9-mile-wide floodplain to an excavated 56-mile-long, 210- to 345-foot-wide, 29.5-foot-deep canal named C-38. Included in the project were six water flow control structures with tieback levees and navigation locks designed to allow passage of small boats. These maintain stable water levels in five stair-step impoundments or “pools” along the canal’s length. Although remnants of the former river channel remain on either side of the canal, the flowing river ecosystem has essentially been replaced by a series of relatively stagnant reservoirs with a central deep canal (Toth et al. 1993).

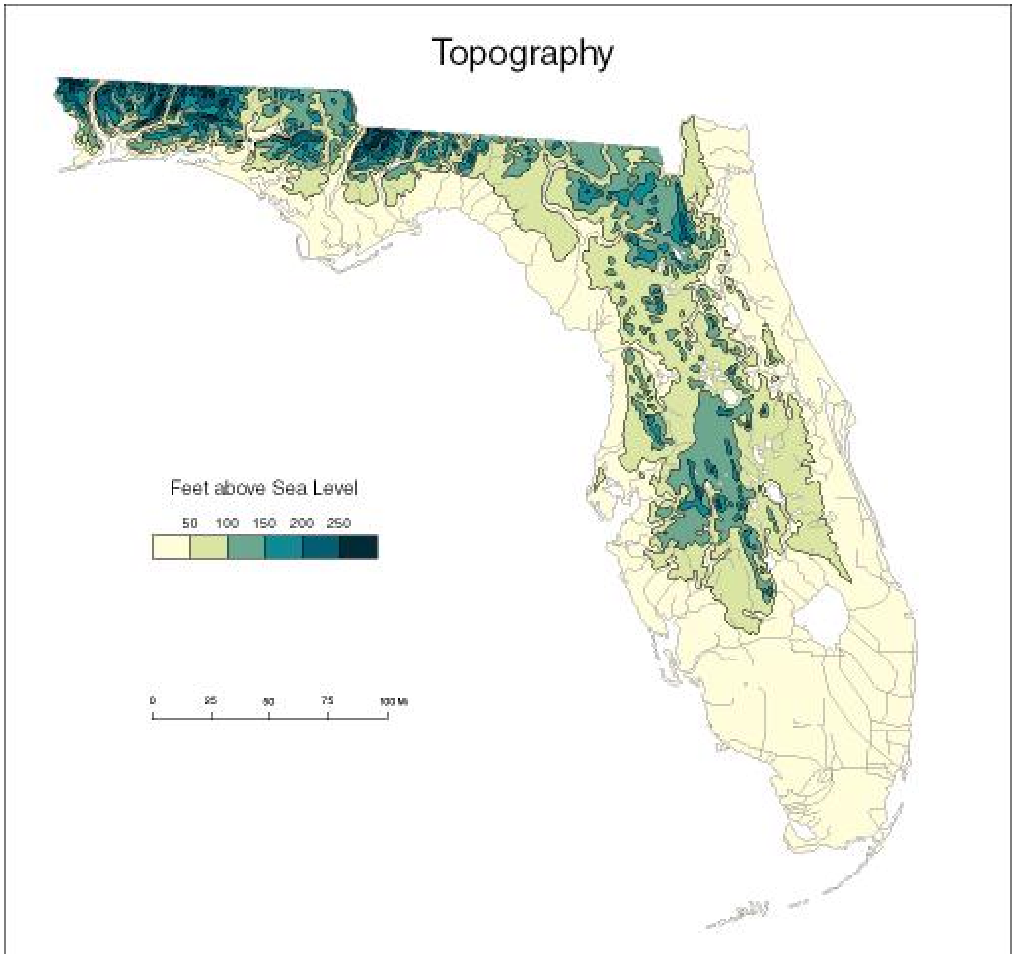
Inflows to C-38 occur through the uppermost structure and are regulated by a flood control operation schedule that was implemented in the Kissimmee’s headwater lakes.

Loss of wetlands and water-quality problems were anticipated, but the project went ahead anyway (Pilkey and Dixon 1996).

The drainage of 200,000 acres of floodplain wetlands caused a decline in water quality, water birds, commercially valuable fish species, and wildlife habitat. In the absence of flow, thick deposits of organic matter accumulated on the bottom of the remaining river channel and reduced depth and substrate diversity within these stagnant, remnant river courses (Toth 1993, Toth et al. 1993).

One year after the canal’s completion, there was much opposition calling for river restoration. In 1991, under a congressional mandate, the corps began restoring about one-third of C-38, which will cost over $400 million, more than ten times the cost of the entire original project (Pilkey and Dixon 1996).

Little is known about appropriate strategies for river restoration since such efforts have only been attempted quite recently, so it is unknown how successful these efforts will be. To avoid repeating such mistakes, an increasing number of individuals are interested in seeking alternatives to river modification, such as land acquisition and other approaches.


Topography
Feet above Sea Level
50 100 150 200 250
0 25 50 75 100 Mi


Wetlands Prior to Development
Wetlands

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Study Questions

1. The State of Florida is a flat land topographically with large amounts of slow-moving surface water. This type of land surface would not normally be conducive to hydroelectric power but there are several places in Florida that have water generators. Do a little research and answer the following questions:

1a. Are there any hydroelectric generating plants in your area of the state?
Where are most of the generators found geographically in Florida?

1b. How much electricity can they generate and do they function as a supplemental or a primary source of power?

2. Define a drainage basin?

3. What is a karst area? What are the characteristics of a karst area in Florida?

4. In Florida, what is the difference between the soils of the Central Ridge or Western Highlands and the soils of the Flatlands and Coastal Lands?

5. What are the two ways in which the flow in streams is measured? Define each type?

6. What are three largest rivers in terms of discharge in the State of Florida?

7. Define the following terms:
   a. alluvial river
   b. anastomosing
   c. sinuosity

8. What is the difference between an alluvial river and a karst river?

9. In a river what is the difference between a unidirectional and a bi-directional flow? What would cause a bi-directional flow?

10. What is a wetland? What is the difference between a swamp and a marsh?