2.0 Watershed Stressors and Key Indicators of Change

Combined, Chapters 3 and 4 of the Peace River Cumulative Impact Study (CIS) provide assessments of individual basin and cumulative watershed impacts resulting from natural and anthropogenic stressors with respect to historical changes in stream flow, ambient water quality, and selected ecological indicators. The CIS identifies watershed changes associated with both differences in long-term rainfall patterns, as well as the more direct impacts from anthropogenic stressors, including increasing urban development, expanding phosphate mining, and changes resulting from more intense agricultural uses.

The primary objective of Chapter 2 is to provide an overview and description of these identified stressors and summarize the potential adverse impacts identified in other studies. The goal is therefore to provide a context in which to evaluate changes in hydrologic indicators including stream flow, water quality, and ground water levels, and assess the impacts of losses of native upland, wetland, and stream habitat. The following descriptions of major watershed stressors identified by the CIS and associated impacts are summarized from previous studies from both within and outside the Peace River watershed. Consequently, not all the identified potential stressor effects presented in this general overview are specifically described in either Chapter 3 or Chapter 4, where the discussions of stressor impacts are limited to the scope of the information developed for the Peace River CIS.

The CIS presents comparisons of land use changes between the 1940s, 1979, and 1999 that indicate the expansion of urban development, phosphate mining, and more intense agriculture activities. These land use changes have altered natural drainage patterns, affected surface water runoff and infiltration rates, lowered ground water levels in the upper watershed, and complicated the analyses of the effects of long-term rainfall patterns. Some of the potential impacts of changes in rainfall patterns and land use on hydrology, water quality, and natural habitats are summarized below.

2.1 Natural Long-term Climatic Variability

Natural, long-term seasonal rainfall patterns and associated hydrologic (ground water and surface water) changes are potential watershed stressors in addition to those anthropogenic sources previously discussed. Southwest peninsular Florida is characterized by a summer wet season that accounts for approximately 59 percent of the 52 inches of total average annual precipitation. The four month wet season extends from June through September, while the three driest consecutive months are November through January (three driest months are November, April, and May), and streams, wetlands, and surficial ground water levels are typically at their lowest during May just prior to the beginning of the four month summer wet season. Conversely, during September and October, at the end of the summer wet season, hydrologic systems are usually near or at their annual peaks. Seasonal influences of rainfall on watershed hydrology are therefore directly linked to preceding hydrologic conditions.

At the beginning of the wet season, a large proportion of rainfall is incorporated into surface and ground water storage, while later in the wet season, soil moisture content is highest, ground water levels are near the surface, wetlands and lakes are full, and a large proportion of rainfall contributes directly to runoff. While these conditions are typical, there is a wide degree of both seasonal and annual variability in patterns of both rainfall and resulting river flow. Intense El Niño/Southern Oscillation (ENSO) events can result in atypical, extended periods of heavy rainfall during the usually drier winter/spring months and dramatically alter the annual watershed hydroperiod. While short term extremes of high and low flows influence the watershed budget over periods of years, larger cyclic periods may cover a number of decades.

Climate researchers have suggested that natural climate cycles or phases can persist over multiple decades. One of these cycles, the Atlantic Multidecadal Oscillation (AMO) refers to long-term cool and warm phase differences of only about 1°F (0.6°C) in North Atlantic average sea surface temperatures.

During warm AMOs, there is a higher frequency and duration of major tropical cyclones in the Gulf of Mexico and Atlantic and Caribbean Basins. These tropical systems can produce extremely high rainfall events as they move near (or across) Florida and a single storm event can account for as much as a third of the typical wet season rainfall. Since these storm events are more frequent toward the end of the summer wet season in August and September, soils in the watershed may be saturated, rivers and lakes are often at high flows and/or levels, and the hurricane associated rainfall events can dramatically influence annual flows and patterns in the watershed.

While annual rainfall has not significantly changed over the last century, the decades between the 1930s and 1960s were wetter than recent periods. Mean and median rainfall in the Peace River watershed indicated average declines of 4.5 and 5.5 inches/year between the two 30-year periods 1936-1965 and 1966-1995. Changes in wet season rainfall, primarily linked to the AMO, accounted for approximately 80 percent of the observed differences between the two periods.

A total of 47 documented tropical cyclones (subtropical systems, depressions, tropical storms, and hurricanes) impacted the Peace River watershed during the period 1930-2001. During the warmer AMO phase (1930-1969), 33 tropical cyclone events affected the watershed. During the cooler 1970-1994 AMO period, only 10 tropical systems impacted the watershed.

Analyses of Long-term Variations in Watershed Rainfall Patterns

A series of statistical and graphical analyses were conducted as part of the Peace River Cumulative Impacts Study to assess potential long-term changes in rainfall patterns in the Peace River watershed. Major findings of these analyses are presented below. Analyses of both yearly and cumulative total deviations from the long-term annual average rainfall supported the observations that historic rainfall patterns generally followed the intervals of the proposed AMO theory. Averaged over the watershed, annual rainfall totals were generally above average from the early 1920s through the early 1960s and then below average until the early/mid 1990s. Annual rainfall in the watershed prior to the 1960s averaged about 54 inches per year, compared with about 50 inches per year from the 1960s to the early/mid 1990s, and about 53 inches per year since the mid 1990s. The analyses indicated that decadal differences were primarily due to historically higher wet season rainfall during the earlier period.

2.2 Urban Development

In general, the greater the amount of impervious surface in a watershed, the greater the stream impacts, including reduced stream stability, habitat, water quality, and biological diversity.

Effects of Urban Development on Hydrology

Watershed development can dramatically alter the hydrologic regime of a basin or watershed as a result of increases in impervious surfaces. The replacement of natural surfaces with impervious surfaces, vegetation removal, soil displacement, and site grading eliminates much of the natural storage capacity and increases stormwater runoff. Construction of rooftops, roads, parking lots, sidewalks, and driveways increase the impervious area, decrease rainfall percolation into the ground, and subsequently increase the runoff volume, which may then require culverts, curbs, gutters, storm sewers, or lined channels to convey excess runoff away from the site. Total impervious surface of medium density residential areas typically ranges from 25 to nearly 60 percent, and runoff volumes are larger and are transported more quickly away from these areas.

The greatest changes in a stream channel due to increased stormwater flows are channel scour and widening and channel width can increase two to four times without effective runoff controls. Elevations in the floodplain may be raised to accommodate development and higher peak discharges, expanding the floodplain, and placing property and structures to flooding risk. Trees that previously stabilized the banks are exposed at the roots, and are more likely to be wind thrown, triggering even more bank erosion. Finally, increased sediment loads from eroded stream banks and uplands often form sandbars and other deposits before being transported downstream as bed load.

The expansion of urbanization increases demands on the development of potable supplies, which historically have been provided by either ground water and/or surface water withdrawals. Depending on the underlying geology, in areas without distinct confining layers between the surficial and deep aquifers, ground water withdrawals have caused localized and more regional drawdowns in both lakes and wetlands. Surface water withdrawals from lakes, reservoirs and streams have reduced water levels and available aquatic habitat, altered natural hydroperiods, and seasonally altered the salinity gradient of estuaries.

Effects of Urban Development on Water Quality

Stormwater runoff increases pollutant loads and discharges, and stormwater collection and conveyance systems can rapidly wash pollutants to downstream receiving waters and adversely impact water quality. Pollution from nonpoint sources accounts for most of the water quality problems in the State of Florida. Typically, nonpoint source pollution is associated with stormwater runoff from residential, urban, and agricultural activities and the associated transport of sediments, nutrients, pathogens and pesticides.

Conventional pollutants, metals, and dissolved oxygen can be used to measure the health of surface water bodies. Typical examples of conventional pollutants include chlorides, fecal coliform, nitrates, phosphorus, and total suspended solids. Metals in stormwater runoff may include arsenic, aluminum, copper, iron, lead, and mercury. The State of Florida has developed an impaired waters list and criteria used to assess whether a certain pollutant or metal level restricts the water body from meeting its designated use. Urban land uses and activities can also degrade ground water quality and contaminate wells in ground water supply aquifer areas if storm water with high pollutant loads is directed into the soil without adequate treatment.

Prior to the enactment of Clean Water Act and amendments to the Act in the early 1970s, wastewater discharges to flowing waters were largely unregulated and streams were used to dilute and transport wastes from their sources. While environmental regulations have resulted in substantial improvements in wastewater treatment, wastewater discharges still contribute to increased stream flows and pollutant concentrations in water bodies.

Effects of Urban Development on Natural Systems

The aquatic ecosystems in urban headwater streams are particularly susceptible to impacts of urbanization. Habitat and ecological impacts may include:

- A shift from external (leaf matter) to internal (algal organic matter) stream production
- Reduction in the diversity, richness, and abundance of the stream community (aquatic insects, fish, amphibians)
- Destruction of freshwater wetlands, riparian buffers, and springs
- Creation of barriers to fish migration
- Adverse impacts to health and reproduction of fish and other species

Impacts of urban stormwater runoff on biological communities are primarily the result of habitat destruction and long-term exposures to contaminants, while effects of acute exposures of toxins in the water column are rare. Some studies have shown important aquatic life impacts for streams in watersheds that are less than ten percent urbanized.

Ecological responses to watershed changes may take between five and 10 years to equilibrate and studies conducted soon after disturbances, therefore, may not accurately reflect the long-term conditions. The first changes caused by urbanization are to stream and ground water hydrology, followed by fluvial morphology, then water quality, and finally the aquatic ecosystem. The effects of large discharges of relatively uncontaminated sediment on aquatic environments include, but are not limited to:

- Shifts in fish communities toward more sediment tolerant species
- Reduced light penetration that causes reduced plankton and aquatic plant growth
- Adverse impacts to aquatic insects which are the base of the food chain
- Physical smothering of benthic aquatic insect community
- Reduced survival rates for fish eggs and destruction of fish spawning areas
- Imbedded stream bottom reduces fish and macroinvertebrate habitat value
- Increase in sediment oxygen demand in lakes or streams
- Significant contributing factor in the alarming decline of freshwater mussels

Urban stormwater runoff has also been shown to adversely impact wetlands, lakes, and estuaries (Table 2.1). Development alters the physical, geochemical, and biological characteristics of lakes, ponds, and wetlands. Estuaries experience increased sedimentation and pollutant loads, and more extreme salinity swings due to increased runoff and reduced base flow.

Table 2.1. Effects of Urbanization on Wetlands, Lakes, and Estuaries

Habitat	Impacts
Wetlands	• Changes in hydrology and hydrogeology • Increased nutrient and other contaminant loads • Compaction and destruction of wetland soil • Changes in wetland vegetation • Changes in or loss of habitat • Changes in the community (diversity, richness, and abundance) of organisms • Loss of particular biota • Permanent loss of wetlands
Lakes and Ponds	• Impacts to biota on the lake bottom due to sedimentation • Contamination of lake sediments • Water column turbidity • Aesthetic impairment due to floatables and trash • Increased algal blooms and depleted oxygen levels due to nutrient enrichment, resulting in an aquatic environment with decreased diversity • Contaminated drinking water supplies
Estuaries	• Sedimentation in estuariane streams and submerged aquatic vegetation (SAV) beds • Altered hydroperiod of tidal wetlands due to larger, more frequent pulses of fresh water and longer exposure to saline waters because of reduced base flow • Hypoxia • Turbidity • Bio-accumulation • Loss of SAV due to nutrient enrichment • Scour of tidal wetlands and SAV • Short-term salinity swings in small estuaries caused by increased runoff volume that can impact important productivity areas for aquatic organisms

Source: Adapted from WEF and ASCE

2.2 Phosphate Mining

Phosphate mining and associated beneficiation and fertilizer manufacturing operations make up approximately 10 percent of the area in the Peace River watershed and include actively mined lands, formerly mined lands not reclaimed and converted to another land use, and areas associated with ore beneficiation and fertilizer manufacturing. Lands in active mine operations include mine cuts and clay settling areas (CSAs) beneficiation facilities and fertilizer manufacturing facilities and associated gypsum stacks.

Effects of Mining on Hydrology

In active mining areas, clay settling areas, mine cuts, and ditch and berm systems can alter the hydrology of mined and proximate areas by acting as holding ponds, decreasing flows to stream channels, replacing uplands that may act as recharge areas, or replacing wetlands. Mining generally disturbs soils located to a depth of 30 and 45 feet below land surface and re-combined soils can change the rainfall-runoff relationships during wet periods, as well as the contribution of base flow from surrounding upland areas during dry periods. Presently, CSAs include approximately 100,000 acres of the phosphate mining lands in Florida and can occupy up to 30 percent of mining areas. It can take years for the clays in the CSAs to “crust over” and become useful for quality wildlife habitat and/or agriculture.

Phosphate mining reclamation activities can also alter surface and ground water hydrology by changing soil and land surface composition and structure, and subsequently alter the way the water flows over and through the land. Consequently, many phosphate mining reclamation activities can affect the relationship of rainfall to stream flow.

Historically, phosphate mining/beneficiation relied heavily on ground water use, which led to both localized and regional declines in the potentiometric surface of the Upper Floridan aquifer. Since the late 1970s, the industry has relied more heavily on recycling and storing surface runoff. These practices have markedly reduced industry ground water consumption, although ground water is still required and use is higher during seasonal and extended dry periods. The storage of surface water can also seasonally alter dry season hydroperiods.

Potential Effects of Mining on Water Quality

The impacts of phosphate mining on water quality can be associated with permitted and anticipated discharges from mining, beneficiation or fertilizer manufacturing activities, or with accidental and/or unanticipated discharges (e.g. spills). The magnitude of the impacts depends on whether the discharges are from mining, beneficiation, or fertilizer manufacturing operations.

Waters used in mining, beneficiation, and fertilizer manufacturing are normally recycled many times over, and therefore discharges are associated with periods of excess rainfall where the additional water generated through rainfall exceeds water storage capacity. Under normal rainfall conditions, discharges can be controlled through NPDES permitting and are relatively minor (on a watershed scale). Discharges from phosphate mining and beneficiation activities typically consist of excess stormwater runoff.

The process water contained in phosphogypsum stacks and cooling ponds at fertilizer manufacturing plants, however, has a low pH (about 1 to 2) and contains a dilute mixture of phosphoric, sulfuric, and fluorosilic acids. It is saturated with calcium sulfate and contains numerous other ions found in the phosphate rock used as a raw material as well as ammonia from the solid fertilizer manufacturing process. Process water has pH values far below that found in Florida surface waters and is much higher mineral content. The typical conductivity value for process water (22,100 µmhos/cm) corresponds to approximately 13 ppt, a salinity value similar to those found in the mesohaline, tidal portions of the lower Peace River. Dissolved portions of water samples are often orders of magnitude higher than the same parameter from the average Florida stream. In terms of nutrient availability, process water has nitrogen and phosphorus levels that are at least two orders of magnitude higher than in a typical Florida stream. Large volumes of rainfall due to tropical storms, hurricanes, or El Niño events can preclude adequate management of process water discharged offsite.

A single spill of process water from a fertilizer manufacturing plant can approximate an entire year of typical phosphorus loads to the Peace River at Arcadia. A spill from a clay settling area associated with mining and beneficiation operations can transport millions of pounds of sediments to receiving waters. Spills into the Peace and Alafia Rivers from phosphate mining and beneficiation activities have occurred at least five times since the 1960s. More recently, process water from fertilizer manufacturing plants was spilled into the Alafia River in 1997 and into Tampa Bay during 2004.

Effects of Mining on Natural Habitat

Active mining disturbs and/or eliminates natural habitats when lands are cleared of vegetation in preparation for mining. However, due to the conversion of natural marshes, lakes, and swamps to agriculture and residential uses, a number of birds, mammals, reptiles, amphibians, and fish species use some mined areas such as reclaimed lands, mine pits, clay settling areas as alternative habitat. Although some voluntary land reclamation occurred from the 1940s to the 1960s, Florida law now requires reclamation of lands mined after July 1, 1975. This law also created the Nonmandatory Land Reclamation Trust Fund to support reclamation efforts for lands disturbed prior to July 1, 1975. The Mandatory and Nonmandatory programs allow for reclamation to beneficial societal uses or rudimentary wildlife habitat.

Importantly, "reclamation" does not necessarily mean that disturbed land is restored to its pre-disturbance condition. Although restoration is now required for wetlands, uplands can be reclaimed to conditions suitable for agriculture, industry, or housing. Of the 166,722 acres of Florida lands mined for phosphate between 1975 and 2002, 63 percent (104,386 acres) were designated as reclaimed. Of these 104,386 acres, 51,628 acres have been reclaimed and released from regulatory oversight and 52,678 acres have been reclaimed through initial revegetation or converted to industrial land uses.

In cases where habitat restoration is the goal, there is debate on the equity of functions of these restored areas. Significant differences in soil characteristics, vegetation composition, and the abundance and diversity of vertebrate species have been documented between unmined reference sites and reclaimed mined sites. The need to connect restored habitats via wildlife corridors and better integrate restoration efforts for upland and wetland area was also identified.

2.4 Agriculture

Conversions of undeveloped land uses such as native uplands and wetlands to agricultural land uses increase both annual surface water runoff and stream base flows, although there are exceptions. Conversions to developed land uses often include deforestation of native uplands, filling of wetlands, and channeling natural streams. In addition to increased water quantities, nitrogen concentrations are usually higher in runoff from agricultural land uses, and depending on the type of agriculture, area-normalized nitrogen loads may be 100 to 500 percent higher when compared with undeveloped uplands. In contrast, phosphorus concentrations in storm water are more variable.

Effects of Agriculture on Hydrology

Agricultural practices lead to changes in vegetation in floodplains, subsequently altering hydraulic characteristics that, in turn, may lead to changes in the flood regime. Different crop types can also alter the water budget of the catchment and affect flow rates during periods of low flow. The direction and magnitude of a hydrologic response to agricultural practices is also a function of both prior and existing land uses.

Results from pollutant loading models developed for the Charlotte Harbor watershed indicate that changes in watershed level hydrologic yields depend upon the type of land use modification and soil. Model results indicate that a conversion from forested uplands to commercial land use would result in the largest proportional increase in runoff, particularly in poorly drained soils. The second and third largest proportional increases in runoff (assuming an original landscape of forested uplands) would be conversions to row crops and groves, respectively. Converting forested uplands to a medium density residential landscape would increase runoff slightly more when compared with a change to groves. Conversions of forested uplands to rangeland and pastureland would increase runoff, but less so when compared to previously described conversions.

Conversion of forested uplands to rangeland and/or pasture land results in a smaller increase in runoff when compared with a conversion to medium density residential land use, and the conversion of forested uplands to groves or row crops results in a substantial increase in predicted runoff. This increase is second only to that expected from a conversion to commercial land uses. Therefore, a conversion of lands from groves and/or row crops to medium density residential would be expected to result in decreased runoff.

In addition to altering hydrologic yields on an annual basis, information from both the Peace and Myakka rivers suggests that various agricultural land uses can have effects on stream base flow that exceed that which occurs naturally on an annual basis. For example, tree mortality in Flatford Swamp (located in the headwaters of the Myakka River) was attributed to a combination of higher seasonal water elevations and longer periods of seasonal flooding. Anthropogenic increases in base flow were proposed as the basis for this hydrologic stress, due mostly to conversion of large portions of the contributing watershed from upland forests and rangeland/pastureland to a combination of row crops and groves that require intense irrigation. Similar base flow supplementation has been reported for portions of the Peace River. Yearly ninety percent exceedance flows over the period of 1951 to 1996 indicated that for Joshua Creek in particular, agricultural irrigation waters pumped from the Floridan aquifer supplement the surficial aquifer and result in greater base flow and runoff volumes.

The conversion of undeveloped lands to agricultural land uses can increase annual flow, base flow, and runoff as a result of increased soil water in the surficial aquifer due to the introduction of deep ground water from a well-confined aquifer. Agricultural practices rely on ground water, primarily the Floridan aquifers, more so than on surface water, for irrigation supplies. The 2002 Southwest Florida Water Management District Estimated Water Use Report indicates ground water withdrawals for agriculture were more than ten times the amount of surface water withdrawals and irrigation withdrawals could account for a large portion of the 20-50 feet of historic Floridan aquifer water decline.

Effects of Agricultural Land Uses on Water Quality

Available information suggests that conversions from forested uplands to agricultural land use types (e.g. improved pasture and intense agriculture) increase surface water hydrologic yields. Consequently, even in the absence of differences in the stormwater runoff pollutant concentrations, pollutant loadings would increase since they are a function of both concentrations and flow. Most studies of the agricultural land use effects on pollutant loads have identified greater concentrations of nitrogen, phosphorus, and total suspended solids in stormwater runoff when compared to forested upland landscapes. A common approach to estimating the watershed level pollutant load potential of land uses is to combine estimates of stormwater runoff with estimates of pollutant concentrations in that runoff.

Conversion of forested upland landscapes to agricultural land uses typically increases concentrations of both nitrogen and phosphorus in stormwater runoff, although conversion of forested uplands to rangeland would result in a decrease in estimated phosphorus loads. The greatest anticipated increase in stormwater related phosphorus loads would be a conversion of forested uplands to intense agriculture, e.g. row crops. The second greatest increase in stormwater related phosphorus loads would be expected with a conversion from forested uplands to improved pasture.

Estimates of phosphorus loads to the watershed are probably compromised by the high variability in mean concentration values for phosphorus, which in turn may be due to the variability in phosphorus content in surface soils. However, Charlotte Harbor is a nitrogen limited system, and unexplained variability in phosphorus load estimates is probably not an issue when compared with unexplained variability in nitrogen loads.

Effects of Agricultural Land Uses on Habitat

Impacts of agriculture on habitat include soil erosion, wetlands loss, deforestation, habitat fragmentation, and environmental problems associated with chemical use and agricultural fertilizers, and subsequent reductions in plant and wildlife diversity and abundance. While these impacts are not limited to agriculture, agricultural land uses, including improved pasture and intense agriculture, make up the largest proportion (43 percent) of the watershed when compared with other land use classes.