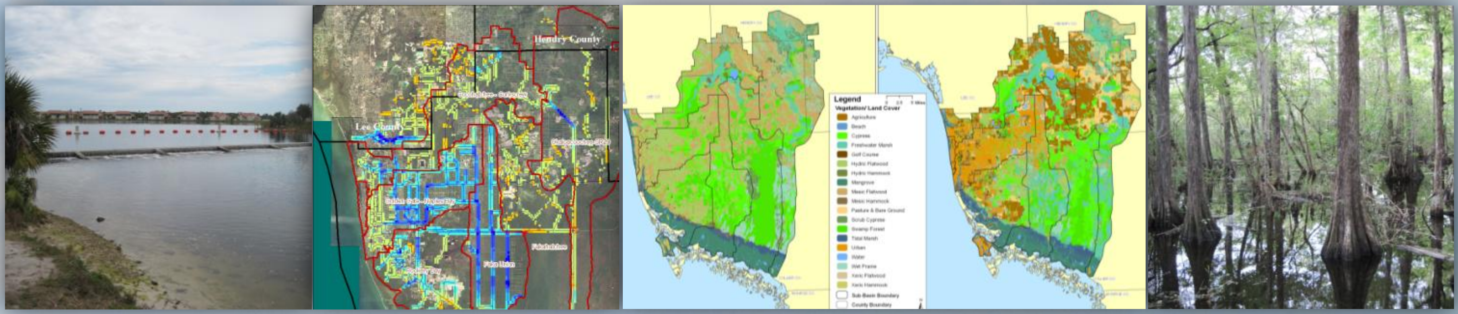
Collier County
Watershed Management Plan



Final Report
Volume 4A
Technical Report
Assessment of Existing Conditions and Performance Measures

Collier County

Prepared by ATKINS

November 2011

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FINAL REPORT

COLLIER COUNTY WATERSHED MANAGEMENT PLAN COLLIER COUNTY, FLORIDA

VOLUME 3: RECOMMENDED NON-STRUCTURAL INITIATIVES

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November 2011

Contents of Volume 4

Volume 4 is a compilation of the individual technical memoranda completed to describe results of the existing conditions analysis in the watersheds and estuaries of Collier County, as well as the performance measures utilized to assess the benefit of proposed structural projects. The technical memoranda are presented as individual chapters and sections in this document and address the following items in the project's scope of work:

- Literature Review
- Element 1: Assessment of Existing Conditions – Watersheds
- Element 2: Assessment of Existing Conditions – Estuaries
- Element 3: Development of Performance Measures

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Acronyms and Abbreviations

ACSC	Area of Critical State Concern
ACSC-ST	Area of Critical State Concern – Special Treatment
BCB	Big Cypress Basin
BCC	Board of County Commissioners
BCE	Black, Crow, and Eidsness
BCNP	Big Cypress National Preserve
BMAP	Basin Management Action Plan
BMP	Best Management Practices
BOD-5	5-Day Biochemical Oxygen Demand
CC	Cocohatchee-Corkscrew Watershed
CCME	Conservation Coastal Management Element
CCPC	Collier County Planning Commission
CCWMP	Collier County Watershed Management Plan
CDU	Community Development Unit
CERP	Comprehensive Everglades Restoration Plan
cfs	Cubic feet per second
CN	Curve Number
Cu	Copper
DCIA	Directly Connected Impervious Area
DEM	Digital Elevation Model
DO	Dissolved Oxygen
EAC	Environmental Advisory Council
ECM	Existing Conditions Model
EDDMapS	Early Detection and Distribution Mapping System
EMC	Event Mean Concentration
ENP	Everglades National Park
EPA	Environmental Protection Agency
ERD	Environmental Research and Design
ERP	Environmental Resource Permit
ERU	Equivalent Residential Unit
ET	Evapotranspiration
F.A.C.	Florida Administrative Code
FAS	Floridan Aquifer System
FCM	Future Conditions Model
FDEP	Florida Department of Environmental Protection
FDoH	Florida Department of Health
FLInv	Florida Invasive Plants Geodatabase
FLUCCS	Florida Land Use, Land Cover Classification System
FLUE	Future Land Use Element
FLUM	Future Land Use Map

FNAI	Florida Natural Areas Inventory
FPLOS	Flood Protection Level of Service
FRESP	Florida Ranchlands Environmental Services Project
FUFHOK	Faka Union, Fakahatchee, and Okaloacoochee-SR29 Watersheds
FWRI	Fish and Wildlife Research Institute
GGAMP	Golden Gate Area Master Plan
GGNB	Golden Gate-Naples Bay Watershed
GIS	Geographic Information Systems
GMP	Growth Management Plan
H&H	Hydraulic and Hydrologic
HOA	Homeowners Association
IAS	Intermediate Aquifer System
IWR	Impaired Waters Rule
JEI	Janicki Environmental Inc.
LASIP	Lely Area Stormwater Improvement Plan
LDC	Land Development Code
LID	Low Impact Development
LSI	Landscape Suitability Index
MAL	Minimum Aquifer Level
mg/l	milligrams/liter
MPN	Most Probable Number
MSL	Mean Sea Level
MSTU	Municipal Services Taxing Unit
NAVD	North American Vertical Datum
NEXRAD	High Resolution Radar
NGGE	Northern Golden Gates Estates
NGGEFRA	North Golden Gate Estates Flowway Restoration Area
NGGEFRP	North Golden Gate Estates Flowway Restoration Program
NGVD	National Geodetic Vertical Datum
NOx	Nitrate + Nitrite
NSG	Natural Systems Group
NSM	Natural Systems Model
OFW	Outstanding Florida Water
OL	Overland
Pb	Lead
PBS&J	Post Buckley Schuh and Jernigan
PCU	Platinum Cobalt Units
PDVM	Pre-Development Vegetation Map
PIR	Project Implementation Report
PSRP	Picayune Strand Restoration Project
PUD	Planned Unit Development
RB	Rookery Bay Watershed

RFMU	Rural Fringe Mixed Use
RIDS	Regional Irrigation Distribution System
RLSA	Rural Lands Stewardship Area
ROMA	Regional Offsite Mitigation Area
RSF	Residential Single Family
RWCA	Recyclable Water Containment Areas
SAS	Surficial Aquifer System
SCS	Soil Conservation Service
SFWMD	South Florida Water Management District
SGGE	Southern Golden Gate Estates
SOW	Scope of Work
S.R.	State Road
ST	Special Treatment
SWFFS	Southwest Florida Feasibility Study
SWIM	Surface Water Improvement and Management
SZ	Saturated Zone
TDR	Transfer of Development Rights
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TKN	Total Kjeldahl Nitrogen
TM	Technical Memorandum
TP	Total Phosphorus
TSS	Total Suspended Solids
TTI	Ten Thousand Islands
ug/l	micrograms/liter
UMAM	Uniform Mitigation Assessment Method
URF	Urban Residential Fringe
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geologic Survey
UZ	Unsaturated Zone
WBID	Water body Identification Number
WMD	Water Management District
WMPs	Watershed Management Plans
Zn	Zinc

INTRODUCTION

Collier County is developing Watershed Management Plans (WMPs) with the purpose of protecting the County's estuarine and wetland systems, consistent with Florida Statute (Subsection 163.3177 (5)(d)). Under the statute, a Conservation Element that addresses "the conservation, use, and protection of natural resources in the area, including air, water, water recharge areas, wetlands, water wells, estuarine marshes, soils, beaches, shores, flood plains, rivers, bays, lakes, harbors, forests, fisheries and wildlife, marine habitat, minerals, and other natural and environmental resources" is required as part of Local Government Comprehensive Plans.

This volume of the CCWMP provides a historical perspective and summary of previously completed studies. This volume also presents a detailed assessment of existing conditions in Collier County and performance measures that were used to evaluate the projects described in Volume 2.

DOCUMENT ORGANIZATION

This volume of the WMP describes the link between water quality, water quantity, and natural systems issues in Collier County watersheds and estuaries. This volume is presented in four (4) chapters, consistent with the work elements outlined in the County's Scope of Work.

Chapter 1: Literature Review and Preliminary Assessment Based on Review of Previously Developed Models. This section provides a historical perspective on water resource issues in Collier County. This chapter also describes other models previously applied for in BCB and compares model results in order to lay the groundwater necessary to fully understand the evaluation of existing conditions

Chapter 2: Assessment of Existing Conditions – Watersheds. Surface water, ground water, and natural systems conditions in the Cocohatchee-Corkscrew, Golden Gate, and Rookery Bay watersheds, and the rural Faka Union/Okaloacoochee/Fakahatchee basins combined are presented and assessed against performance measures to evaluate historical habitat loss.

Chapter 3: Assessment of Existing Conditions – Estuaries. Freshwater inflows, water quality of inflows and receiving waters, and coastal habitat conditions in Wiggins Pass, Naples Bay, Rookery Bay, and Ten Thousand Islands estuaries will be characterized and evaluated in terms of performance measures developed for the estuaries.

Chapter 4: Development of Performance Measures. Performance measures used for assessing watershed and estuary conditions are described in this chapter.

Chapter 5: References.

1.0 LITERATURE REVIEW AND PRELIMINARY ASSESSMENT BASED ON REVIEW OF PREVIOUSLY DEVELOPED MODELS

An initial task conducted as part of this project included a literature review and a comparison of simulation results of MIKE SHE computer models developed for the Big Cypress Basin Project Implementation Report (PIR). Three MIKE SHE models were developed for the PIR to evaluate the potential benefits of restoring the Southern Golden Gates Estates (SGGE) area of Collier County. This project is now referred to as the Picayune Strand Restoration Project (PSRP). The three models include an existing conditions model that is based on year 2000 land use, a future conditions models that is based on year 2050 land use, and a pre-development (or natural systems) model developed for the Southwest Florida Feasibility Study (SWFFS). Each of the PIR models was originally developed using the software version 2000 and were later updated to run with version 2003. For this analysis, each of the models was rerun using version 2009 of the software.

1.1 LITERATURE REVIEW

In order to adequately define future water management strategies, it is necessary to understand the history of water management in Collier County. For this task, more than 50 documents were reviewed. These are listed in the bibliography. This section summarizes 11 documents that were found to provide the most information in describing the historical hydrology and flow conditions in Collier County. It is noted that in many of the older documents, the Faka Union Canal Basin was referred to as the Fahka Union Basin. Following are summary descriptions of the relevant documents identified as part of this task.

Davis, John H. October 1943. The Natural Features of Southern Florida, Especially the Vegetation, and the Everglades. Florida Geological Survey Bulletin No. 25.

This bulletin describes some of the cultural history and the main physical and biological features of South Florida prior to major development and construction of the existing drainage network, although it does not provide quantified estimates about historic flows or water levels in Collier County. In this document, Collier County is described as consisting of three physiographic regions; the Flatlands, the Big Cypress Swamp, and the Southwest Coast and Ten Thousand Islands (Figure 1-1). Davis states that the county is 2,025.5 square miles in size, making it the largest land mass county east of the Mississippi River.

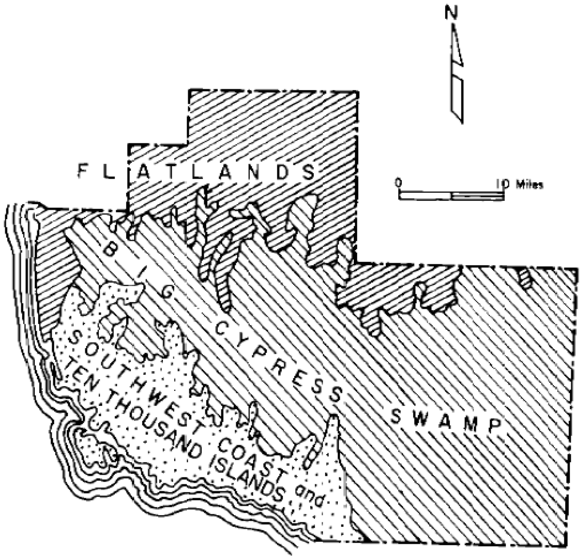


Figure 1-1
Physiographic Regions of Collier County, Florida (from Davis 1943)

The Flatlands region is described as consisting mainly of low, nearly flat to gently rolling land with some rivers dissecting the plains. There are many small ponds, sloughs and other depressions. The Collier County portion of the Flatlands regions is less well drained and of lower elevation than portions of the Flatlands region in Lee County and other counties to the north. Another feature of the Flatlands region is the great number of marsh, swamp, and open-water depressions including Lake Trafford and the Corkscrew marsh.

The Big Cypress Swamp region was described as covering about 1,200 square miles, most in Collier County with small areas in southeastern Hendry County and northern Monroe County. Davis describes the chief characteristics of the Big Cypress as "vegetational with an abundance of the cypress and mixed swamps of large trees, open elongated forest of cypress and medium sized trees, are large areas of scrubby stunted cypress trees growing in marsh-like seasonally wet prairies. The region is of low elevation, low relief and very confused drainage. Most of it lies between elevations of 5 and 20 feet. A number of sloughs drain the Big Cypress, some draining to the Gulf of Mexico, and others into the Everglades. Most of the west part drains toward the south through the Fakahatchee Swamp."

The Southwest Coast and Ten Thousand Islands regions is described as a very low-lying coastal region of small shoal-water islands, It is one of the most dissected coastal regions of Florida and one of the least accurately known due to dense mangrove swamps. These mangrove swamps and salt-water marshes are among the largest in the world. The tidal range is approximately two (2) feet, but combined with the flat topography causes the tidal inundation of large areas far inland and forces salt water far up the estuaries.

Kenner, W. E., 1966, "Runoff in Florida," Map Series No. 22, U.S. Geologic Survey.

In 1966, the United States Geologic Survey and W. E. Kenner produced Map Series No. 22 titled, "Runoff in Florida." This map suggests that the total runoff from the Collier County area at that time was between 0–10 inches annually.

Klein, H., W.J. Schneider, B.F. McPherson and T.J. Buchanan. May 1970. Some Hydrologic and Biologic Aspects of the Big Cypress Swamp Drainage Area, Southern Florida. United States Geologic Survey Open-file Report 70003.

In May 1970, the United States Geologic Survey and specifically, H. Klein, W.J. Schneider, B.F. McPherson and T.J. Buchanan published Open File Report 70003 entitled, "Some Hydrologic and Biologic Aspects of the Big Cypress Swamp Drainage Area, Southern Florida." The prime purpose of the report was to determine the importance of the Big Cypress in maintaining an adequate water supply for (1) the Everglades National Park, for (2) the expanding population of southwest Florida, and for (3) the adjacent estuaries, which constitute nurseries for fish.

For this report, the Big Cypress was divided into three subareas as shown in Figure 1-2. Each subarea has a reasonably distinct internal drainage determined largely by topographic configuration and man-made drainage. Subarea A lies northeast of a low ridge and drains southeastward into Conservation Area 3 of the Central and Southern Florida Flood Control District.

Subarea B includes approximately 550 square miles at the west edge of the Big Cypress. It is characterized by an extensive system of canals, which drain southward and westward into the Gulf Coast estuaries. This canal system includes primarily the Golden Gate Estates canal system.

Subarea C occupies the central part of the Big Cypress and drains toward the Everglades National Park. It consists of about 1,450 square miles.

Klein stated that during the rainy season, shallow depressions fill with water and, because of the poor drainage, water stands on the land until it evaporates or slowly drains off. Thus, as much as 90 percent of the undrained part of the Big Cypress is inundated to depths ranging from a few inches to more than three (3) feet at the height of the rainy season.

Klein stated that in southern Florida, land development usually began with the construction of canals to drain swampy land and to assure protection from high water during the rainy seasons. Significant development affecting the Big Cypress region began in the early 1920s, when two major roads were built. First was the north-south road (U.S. Highway 29) from Everglades City to Immokalee, completed in 1926. Second was the completion of the Tamiami Trail in 1928. Both were constructed of borrow material from continuous pits adjacent to the roads. The borrow pits became canals.

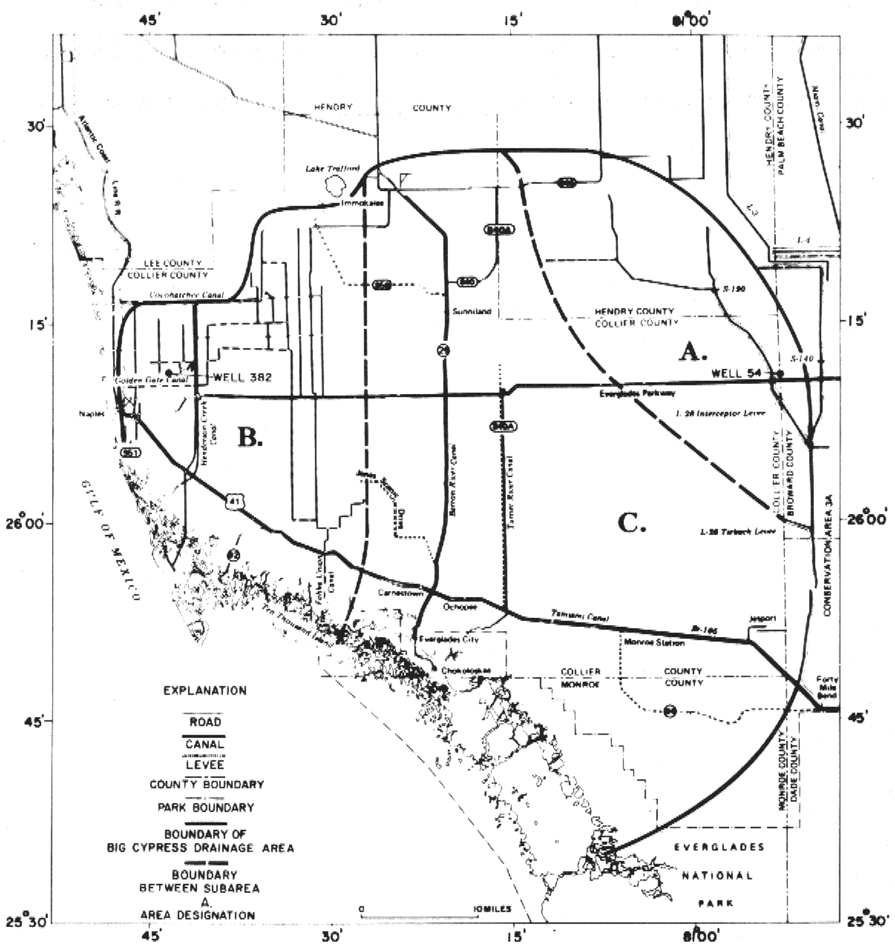


Figure 1-2
Map of the Big Cypress showing the delineation of the drainage area
and the subareas as defined by Klein (1970)

The Everglades Parkway (Alligator Alley) was completed in 1967. Numerous bridges along the parkway permit southward flow of water. Land development for housing in the 188-square-mile Golden Gate Estates area in western Collier County began in the 1960s. Drainage canals, most notably the Golden Gate Main Canal and the Cocohatchee River Canal were dug to drain the western part of the estates. The Fahka Union Canal (later called Faka Union) was completed to drain the southern portion in November 1969.

The Golden Gate Canal system is described as extending inland from the Gulf about 20 miles. The bottom of the canal is excavated to about five (5) feet below sea level near the coast and to 6–8 feet above sea level in the interior. The shallow depth of the canal and the distribution of weirs in the canal network limit the drainage of water from the shallow aquifer in inland areas. Prior to construction of the drainage network, the area inland from Naples was inundated each year during the rainy season.

In 1968, construction was started on the Fahka Union Canal. Klein reports that when completed, this canal will extend northward nearly to Lake Trafford. Weirs will be distributed throughout this canal system to limit the drainage of water from the shallow aquifer and to maintain water levels in conformance with the general slope of the land surface. Canals will connect the Fahka Union system with the Golden Gate system. This canal system was subsequently completed in the early 1970's.

Klein reported that of the various canals in Collier County, the Golden Gate Canal has been most frequently monitored and studied. Surface water has flowed continuously over the Golden Gate Canal outlet weir since its completion in August 1963. The northern most weirs in the system were completed between mid-1969 and mid-1970. Flow over the primary weir of the Golden Gate Canal (measured from 1965 through 1968) ranged from a high of 2,390 cubic feet per second (cfs) on July 1, 1966 to a low of 28 cfs on May 27, 1967. The average flow over the weir during the period was 350 cfs. Figure 1-3 shows hydrographs of discharge for the 1966 and 1968 water years.

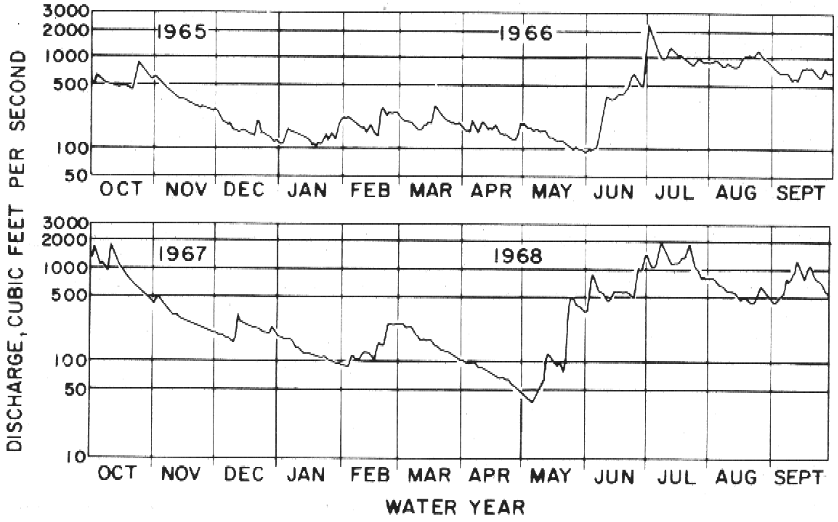


Figure 1-3
Hydrographs of Discharge for the Golden Gate Canal for the
1966 and 1968 Water Years (From Figure 18 of Klein, 1970)

McCoy, Jack. 1972. Hydrology of Western Collier County, Florida. State of Florida, Department of Natural Resources, Division of Interior Resources, Bureau of Geology Report of Investigations No. 63.

This project was a study of the Hydrology of Western Collier County and was completed at the request of the County. The driving issue was development of additional freshwater supplies to meet the demands of the rapidly growing population. McCoy states that although the water supply potential of western Collier County is large, water problems exist in that the 54 inches of annual rainfall are not evenly distributed throughout the year. In addition, salt-water intrusion threatens the Naples well field during prolonged dry periods, and contamination of existing and future ground water supplies is possible by man related activities.

The study focused on the areas drained by the Golden Gate and Faka Union Canal systems and included Henderson Creek. McCoy states that prior to construction of the canal system, much of Collier County was inundated each year during the rainy season. McCoy (1972) describes the canal system as follows:

- The Golden Gate Canal extends about 20 miles inland from the Gordon River. The bottom of the canal is 5 feet below mean sea level (msl) at its outlet to Gordon River and 6 to 8 feet above msl in the interior. The design plans for the Fahka Union Canal call for similar bottom elevations. Distributed throughout the canal system are about 30 weirs, with increase in elevation toward the interior. The elevations of the coastal weirs on the Golden Gate and Faka Union Canals are 3 and 2 feet above msl. The elevation of the highest interior weir (near Immokalee) is 17 feet above msl (it is assumed to mean NGVD29).

- The function of the canals is to lower annual peak water levels to prevent flooding during the rainy season. The function of the weirs is to control the canal flow and reduce the possibilities of over drainage. During the rainy season, when water levels in the interior are high, water moves from aquifer storage into the canals and downstream over the weirs. At the beginning of the dry season, flow over the inlandmost weirs ceases but continues over the downstream weirs. Flow over the weirs ceases in succession downstream, as the dry season continues, until flow occurs only at coastal weirs on the primary canals. By limiting drainage from aquifer storage, regional water levels near the coast are not lowered excessively, and therefore, the problem of sea-water intrusion is not magnified.

- The Golden Gate Canal is about 100 feet wide, less than 8 feet deep and has several fixed weirs throughout its reach of 26 miles; the Faka Union Canal is similar in width and depth and about 30 miles long; the Henderson Creek and Cocohatchee River Canals are 25 feet wide, less than 5 feet deep, and 7 to 13 miles in length respectively. The Henderson Creek Canal is uncontrolled except for a constriction at Alligator Alley which acts as a surface water divide most of the time. However, at the peak of the rainy season, the Henderson Creek Canal probably receives some flow from the Golden Gate Canal. The Cocohatchee River Canal has a control a short distance upstream from the gaging station. Farmers regulated the control according to irrigation needs. The Cocohatchee River Canal drains most of the area southwest of Lake Trafford, but it also helps drain the Golden Gate area during peak wet periods.

McCoy reports that during 1970, the average discharge at each of the four monitoring stations was: 250 cfs from the Golden Gate Canal, 270 cfs from the Faka Union Canal, 25 cfs from the Henderson Creek Canal, and 15 cfs from the Cocohatchee River Canal. It was further noted that during the dry season of 1971, discharge at the Golden Gate Canal outlet reached a record low of less than 20 cfs. This was approximately twice the average daily pumpage of the Naples water system in 1970.

Freiberger, H.J. 1972. Stream Flow Variation and Distribution in the Big Cypress Watershed during Wet and Dry Periods. Map Series 45. Bureau of Geology, Florida Dept. of Natural Resources, Tallahassee, FL.

In 1972, the Florida Bureau of Geology and Herbert Freiberger published Map Series No. 45 to present the Streamflow Variation and Distribution in the Big Cypress Watershed during wet and dry periods. This was based on measured flows from 1969 through 1971.

Figure 1-4 shows post-canal construction flow paths as estimated by Freiberger. This figure indicates that the overland sheet flow is reduced when compared to the natural system. The majority of flow is intercepted by the canal system and carried to tide via the Cocohatchee, Golden Gate, Henderson Creek, and Faka Union Canals. Figure 1-5 provides a comparison of average measured flows at the end of the rainy season in 1969 versus measured flows during the dry season of 1971.

Black, Crow, and Eidsness, Inc. 1974. Hydrologic Study of the G. A. C. Canal Network. Gainesville, FL. Project no. 449-73-53.

In 1974, Black, Crow, and Eidsness (BCE) completed a Hydrologic Study of the G. A. C. Canal Network. This study investigated the changes in the historical watersheds of Collier County and the resulting increase in wet season inflows through the Golden Gate Canal system into Naples Bay.

BCE presented a diagram of pre-canal construction basin boundaries of western Collier County. This diagram is shown in Figure 1-6. In the pre-canal time period, surface water in the Belle Meade Basin, which includes the existing Golden Gate basin, was integrated with the Corkscrew Swamp to the north and the Fakahatchee Strand to the east. Historical outlets from the Golden Gate Watershed were the Cocohatchee River, Gordon River (Naples Bay), Rock Creek, Henderson Creek, and the Fakahatchee Strand. Figure 1-7 shows the post-canal construction drainage basins as defined by BCE (1974).

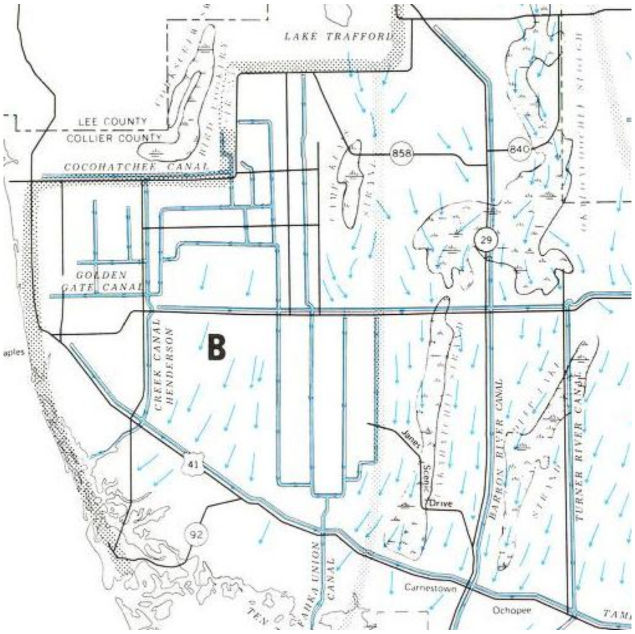
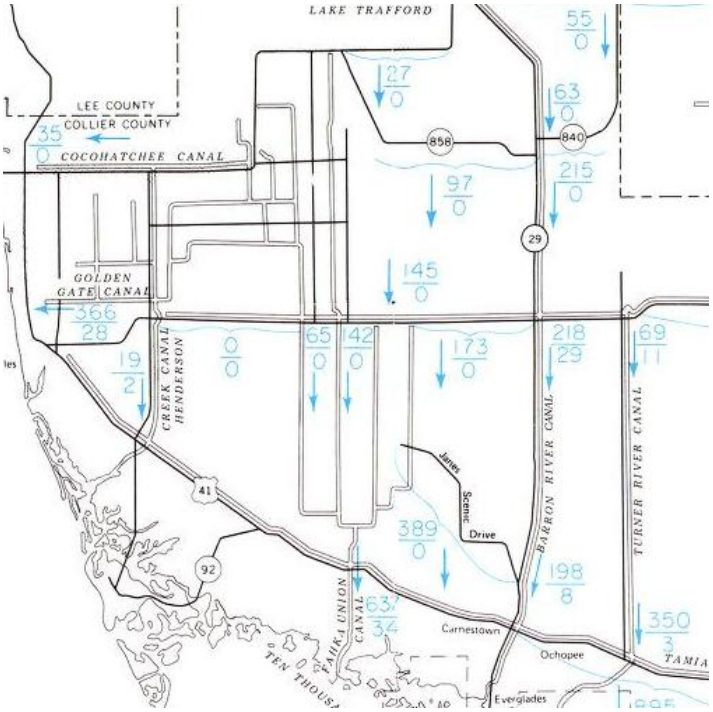


Figure 1-4
Map of the Big Cypress Basin Showing Direction of Overland Flow
for the Period November 18–20, 1969 (From Figure 1 in Freiberger 1972)



Top line = November 18–20, 1969 (cfs)
Bottom line = March 9, 1971 (cfs)

Figure 1-5
Average Measured Flow Data (From Freiberger 1972)

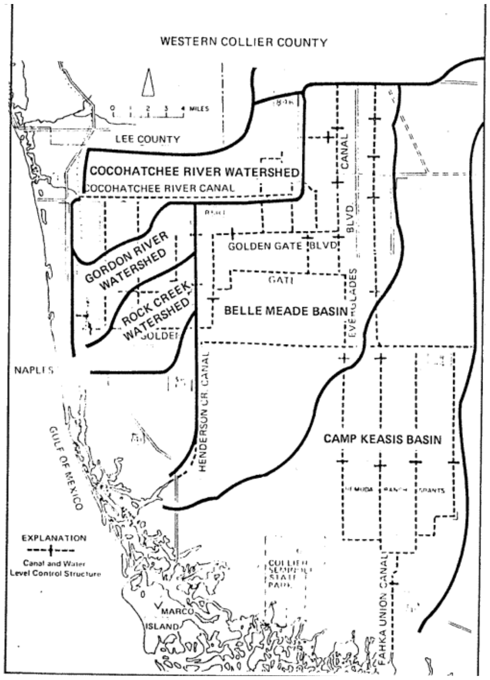


Figure 1-6
Pre-Canal Construction Basin Boundaries in Western Collier County
(From Figure 2.3 in BCE 1974)

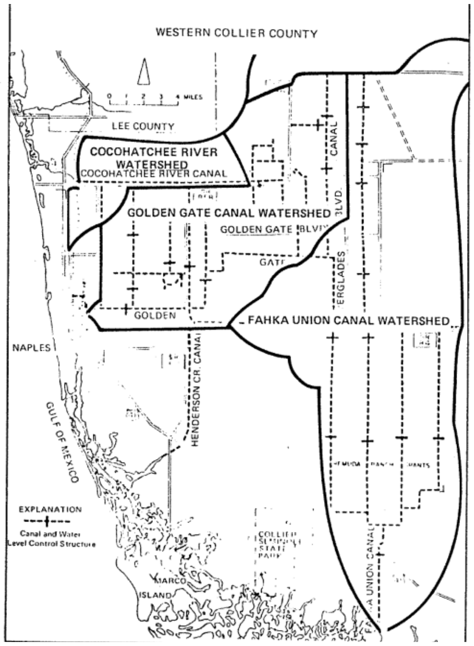


Figure 1-7
Post-Canal Construction Basin Boundaries in Western Collier County
(From Figure 2.2 in BCE 1974)

BCE presented the following conclusions concerning changes in the surface water drainage patterns which are attributed to construction of the canal network:

- The Cocohatchee River Watershed has been reduced in size. This is due to construction of a system of canals which drain the Southern portion of Corkscrew Swamp. The main flow from these canals is directed to the Golden Gate Canal system.
- The Gordon River Watershed has also been reduced in size from approximately 25 square miles to approximately 8 square miles. Flows from a major portion of this watershed are now directed to the Golden Gate Canal system.
- Substantial portions of the Rock Creek Watershed have been incorporated into the Golden Gate Canal Watershed.
- Most of the area north of Alligator Alley (State Route 84) and east of State Route 951, which was once tributary to the Henderson Creek estuary, is now part of the Golden Gate Canal system. This is the single most significant change from pre-construction conditions.
- The Faka Union Canal Watershed has increased in drainage area by a small amount.
- Observed mean annual runoff for the four outlets of the G.A.C. Canal Network is nearly 500,000 acre feet per year, which is equivalent to 24 inches of water. This is probably 2 to 3 times greater than the pre-construction runoff value.

Table 1-1 summarizes the general data related to the major drainage basins of western Collier County as defined by BCE in 1974. Each of these basins is monitored by the United States Geologic Survey and/or the South Florida Water Management District.

Table 1-1
General Data of Major Drainage Basins of Western Collier County[1]

Drainage Basin	Drainage Area sq. miles	Total Length of Canals (miles)	Number of Weirs	Drainage Density miles/sq. mile
Cocohatchee River	18.7	8	None	0.428
Golden Gate Canal	130	102	13	0.785
Henderson Creek Canal[2]	7.4	4	None	0.541
Faka Union Canal	234	88	12	0.376

[1] All values are based on the watershed defined by the location of the USGS stream gages.

[2] Also serves as an overflow outlet for Golden Gate Canal during periods of high flow. Effective drainage area and drainage density are actually indeterminate.

From this table, it appears that in 1974, the majority of flow in western Collier County was routed through the Golden Gate and Faka Union Canals as these basins incorporate more than 90 percent of the drainage area, all of the weir structures, and more than 90 percent of the constructed canals. Flow control structures have subsequently been installed on both the Cocohatchee and Henderson Creek Canals.

BCE reported that the Golden Gate Canal drains about one-third of the area served by the western Collier County drainage network, yet accounted for approximately 50 percent of the total runoff. This is shown in Table 1-2, which lists estimated annual runoff volumes from 1965 to 1973.

Table 1-2
Annual Runoff at Stream Gaging Stations

	Annual Runoff in acre-feet Water Year (Oct.–Sept.)			
Water Year	**Cocohatchee River**	**Golden Gate Canal**	**Henderson Creek Canal**	**Faka Union Canal**
1965	--	164,800	--	--
1966	--	302,400	--	--
1967	--	222,200	--	--
1968	--	323,600	--	--
1969	19,470	221,400	13,050	--
1970	25,540	278,000	23,400	--
1971	18,010	197,100	13,310	247,400
1972	22,460	239,900	16,230	177,000
1973	39,590	294,600	17,740	195,300
Mean Annual Runoff	25,014	249,333	16,746	206,600

To address potential reductions in discharge to the estuary system, BCE considered several alternatives, including:

- Fill the existing canal network.
- Enlarge the present canal system to create additional storage.
- Redistribute canal flows to natural areas and enlarge the canal network to create additional storage.

The final alternative suggested major enlargements to the existing canal system to allow a raising of the weirs to within 2 feet of the ground surface. Wet season flows in the Golden Gate Canal System would be redistributed to former historical patterns. The estimated cost was more than $18 million dollars for the Golden Gate Canal system alone. Comparable funds would be required for the Belle Meade and Faka Union Canal systems.

McPherson, B.F., G.Y. Hendrix, Howard Klein, and H.M. Tyus. 1976. The Environment of South Florida, A Summary Report. Geologic Survey Professional Paper 1011. Department of the Interior, Resource and Land Investigations Program.

This project was triggered by the planned construction of an international jetport in the Big Cypress Swamp by the Dade County Port Authority. This report summarizes the effort to develop the scientific information base required by land resource managers to make informed decisions affecting the economy and environment of south Florida.

Much of the information presented in this report is for areas located in the easternmost portions of Collier County and the western portions of Dade County. However, McPherson does reiterate that the purpose of the canal system in western Collier County was to lower groundwater levels, making the land suitable for urbanization, and reduce flooding.

McPherson states that "the Golden Gate Canal system and the Faka Union Canal system are cut into the highly permeable limestone of the shallow aquifer. Because of the high permeability, ground water drains rapidly to the canals and thereby lowers annual peak groundwater levels in the watershed. Where ever ponding occurs within those drainage areas during the rainy season, it is likely to be local and short lived. Thus, the pattern of slow prolonged southward sheet flow of freshwater through the west part of the Big Cypress to the Gulf estuaries was changed to one of accelerated and shortened-period runoff, primarily through the canal systems."

The report also states that water levels in the watershed were lowered approximately two (2) feet or more over a span of 4 or 5 years as a result of construction of the Golden Gate Canal network. Before the area was drained, it was inundated during most of the rainy season and for 2 or 3 months afterward. The Faka Union Canal network has also lowered water levels.

McPherson concluded that accelerated flow through the canal systems tends to increase the opportunity for transport of pollutants and water of poor quality to be discharged to the estuaries. It was suggested that the weir elevations in the Golden Gate and Faka Union Canal systems be raised by 1 to 2 feet. McPherson postulated that "the reduction in runoff would salvage for potential use a large part of the flow to the sea. The resulting rise in water levels would tend to reduce damage to the environment and the possibility of saltwater intrusion and would probably reinundate some of the sloughs that became dry as a result of drainage. The possibility of environmental changes in the Fakahatchee Strand, and in the Corkscrew Marsh northeast of Naples, would be reduced because diversion of freshwater toward canals would be reduced."

CH2M Hill. February 1980. Gordon River Watershed Study: Engineering Report. South Florida Water Management District.

In 1980, CH2M Hill completed a study of the existing conditions within the Gordon River Watershed. The study evaluated the flood hydrology of the basin during the 25- and 100-year storm events, determined the water surface profiles, and evaluated the economic impact of flooding on existing and potential development.

In the report, CH2M Hill stated that "Historically, the Gordon River Watershed was over 25 square miles in size, extending northeast from Naples Bay beyond the present intersection of S.R 551 and S. R. 846. With the development that has occurred in the area-specifically the construction of Airport Road (S. R. 31) and the Golden Gate Canal system, the watershed has been significantly reduced in size to about 8.5 square miles.

The main conclusions of the report are:

- Flooding in the watershed does not vary significantly between the 25- and 100-year storms.
- Flooding is generally limited to natural low-lying mangrove areas, golf courses, and portions of the area north of Pine Ridge Road (S.R. 896).
- Except for the area north of Pine Ridge Road, flooding is limited to areas which experience either no or moderate use. Economic impacts due to flooding south of Pine Ridge Road were considered negligible.
- Shallow flooding — up to one foot in depth — occurs over large portions of the area north of Pine Ridge Road. This flooding does affect buildings, equipment, and materials in the area.
- Economic impacts due to flooding in the industrial park area were estimated at $4,667 per year and possibly as much as $14,000 per year at full development
- Large improvements within the Gordon River Watershed consistent with the Master Plan for Water Management District No. 7 were recommended to benefit surface water management within the basin. These primarily consisted of culvert replacements.

Johnson Engineering, Inc. December 1981. Golden Gate Water Management Study. Big Cypress Basin Board, South Florida Water Management District.

This study (Golden Gate Water Management Study) was completed on behalf of the South Florida Water Management District. The goals were to determine the feasibility of diverting a portion of the normal outflow from the Golden Gate Canal into other areas for water conservation purposes and/or retaining increased amounts of surface water in the Golden Gate Canal system.

Johnson Engineering stated that, in the early 1900s, this watershed was basically a "sheet-flow type system." It was a large flat prairie-cypress area on which water stood much of the year. Johnson Engineering quoted a Naples Bay study completed in 1979 indicating that the greatest concern for Naples Bay was not the quality of water discharged from the Golden Gate Canal, but the increase in quantitative surges during the wet season.

Johnson Engineering considered several alternative approaches for this project, including:

- Diversion of water between basins to promote storage.
- Alteration of proposed land uses to promote wetland protection and groundwater recharge.
- Increased retention in the canal system.
- Increased operable flexibility in the canal system.
- Maintain the status quo.

Recommendations included increasing the operable flexibility and retention in the canal system. It was also suggested that purchasing low lying areas along the canal for retention and increasing the open space along major waterways would provide significant benefit to the environment and water quality.

United States Army Corps of Engineers – Jacksonville District. February 1986. Golden Gate Estates Collier County, Florida – Draft Feasibility Report.

In 1986, the United States Army Corps of Engineers completed a Draft Feasibility Study for Golden Gate Estates. The primary study objective was to assess the feasibility of modifying the existing, privately constructed water control works within the Faka Union basin of Golden Gates Estates for protection and enhancement of the basin's resources. This effort considers the restoration of the basin's wetland environmental values and other natural resources to the extent possible, while maintaining and protecting compatible human resources within the basin.

In describing flows within the canal network, the USACE states:

- Although weirs were placed within the canals to retard canal discharge and prevent overdrainage during periods of low flow, the canal system has more than doubled the pre-canal surface water runoff. The total mean annual surface run-off from the Golden Gate Estates Canal network is 497,693 acre-feet or 162,115 million gallons of water. Over 90 percent of the observed runoff is discharged through the Golden Gate Canal (50 percent) and the Faka Union Canal (42 percent).
- Under natural conditions, there was a lag of several months between peak rainfall and peak runoff and the magnitude of season variation in runoff was dampened by storage in the basin. The pattern of canal discharge more closely approximates the rainfall pattern by responding quickly to rainfall events.

An resource protective assessment of Faka Union Bay concluded that canal discharge affects abundance of some estuarine organisms by affecting salinity distributions.

After detailed review of six proposed management strategies for the Faka Union basin, including the proposal by BCE and proposals suggested by the Golden Gate Estates Study Committee, the USACE concluded that, "after review of current Federal policies and guidelines, there is no basis for Federal implementation of modifications to the Faka Union Basin portion of the existing Golden Gate Estates water control system." However, it was suggested that the conceptual information in the report could be used by State and local interests to determine long-term solutions to local water management problems within the basin.

South Florida Water Management District. January 2007. Naples Bay Surface Water Improvement and Management (SWIM) Plan.

This plan, prepared by the South Florida Water Management District focuses on strategies to improve the health and habitat of Naples Bay. Key strategies consider initiatives on water quality, stormwater quantity, watershed master planning, and implementation, and habitat assessment, restoration and improvement.

With regards to the flow and timing of discharges from the Golden Gate Estates Canal system, this report states that, "the results of 60 years of canal drainage and urban development activities have reduced water clarity, increased concentrations of contaminants and nutrients, increases in freshwater and reduced dissolved oxygen levels in the NBW. The Watershed now collects surface water input from approximately 120 square miles, over a ten-fold increase from the historic drainage condition. Extensive areas of mangroves and salt marsh have been replaced by canals, seawalls and bulkheads. Development activities in the watershed have altered the volume, quality, timing and mixing characteristics of freshwater flows reaching Naples Bay.

Natural tributaries, Gordon River, Rock Creek, and Haldeman Creek, have been altered by urban infrastructure which has significantly changed the historic flowways to Naples Bay and impacted its biology. Seasonal influxes of freshwater from the Golden Gate Canal system have altered the natural salinity regime of the Bay, resulting in declines in seagrass beds, and harmful impacts to all levels of flora and fauna in the aquatic ecosystem."

Summary and Conclusions

The literature review was unable to identify any flow monitoring data for the period prior to development of the canal system in Collier Canal. However, it has been estimated that flows from western Collier County were typically between 0–10 inches annually prior to construction of the canal network.

It has been documented that construction of the canal network has significantly changed the flow regime into the receiving water bodies. The combined current annual flow from the primary canals in western Collier County averages approximately 36 inches. This is approximately 3.5 times the maximum annual volume of runoff estimated by Kenner (1966). The percentage of rainfall that discharges to tide has increased from approximately 17 percent (10 inches of runoff/57 inches of rainfall) prior to construction of the canal network to more than 60 percent (36 inches of runoff/57 inches of rainfall) after construction of the canal network.

For Naples Bay it was estimated that the volume of freshwater discharge has increased by 20 to 40 percent which has significantly changed the salinity balance in the estuary. Historically, the Gordon and Rock Creek watersheds were the primary sources of inflow to Naples Bay. These two basins had a combined area of approximately 50 square miles. Now, the Golden Gate Canal watershed is the primary source of inflow to Naples Bay. This basin has an area of approximately 130–175 square miles.

1.2 PRELIMINARY ASSESSMENT OF EXISTING WATERSHED MODELS

The three MIKE SHE models that were developed for the Big Cypress Basin Project Implementation Report (PIR) in order to evaluate the methods and benefits of restoring the wetland system within the Southern Golden Gates Estates (SGGE) area of the Big Cypress Basin (BCB) were compared to conduct a preliminary assessment of discharge volumes from the Collier County watersheds. These models were received from the United States Army Corps of Engineers (USACE) for this analysis and represent the existing condition (year 2000 land use), the future condition (year 2050 land use), and the natural system (pre-development) condition.

The following three sections provide a description of the models and document the differences between the model input files. In addition, comparative results are presented to evaluate basin discharge to the estuary systems and to review predicted water budgets and hydro-periods.

1.2.1 Description of Computer Models

Three models, existing conditions, future conditions, and natural systems (pre-development), were received from the USACE. Each of these models is described below.

Existing Conditions Model

The original existing conditions MIKE SHE model developed for the Big Cypress Basin is documented in a report titled "Big Cypress Basin Integrated Hydrologic-Hydraulic Model" (DHI, 2002). The model received from the USACE was updated in 2006 and is documented in a reported titled "Southwest Florida Feasibility Study, Hydrologic Model Development, Scope of Work Modification IDC DACW17-01-D-0013, Big Cypress Basin, Final Report (CDM, 2006). This model is referred to as the Existing Conditions Model (ECM).

The ECM model is based on year 2000 land use conditions and was updated to the 1988 (NAVD) vertical datum from the 1929 (NGVD) vertical datum in 2006. In addition, the rules that determine structure operations were changed during the model update to reflect the operational guidance specified by the South Florida Water Management District (SFWMD). Figure 1-8 shows the model domain and canal network used in the ECM simulation.

This model was run using meteorological data for 1976–1986 in order evaluate the system under a range of hydrologic conditions. The USACE determined that this period of time included wet, dry, and average year conditions in the study area.

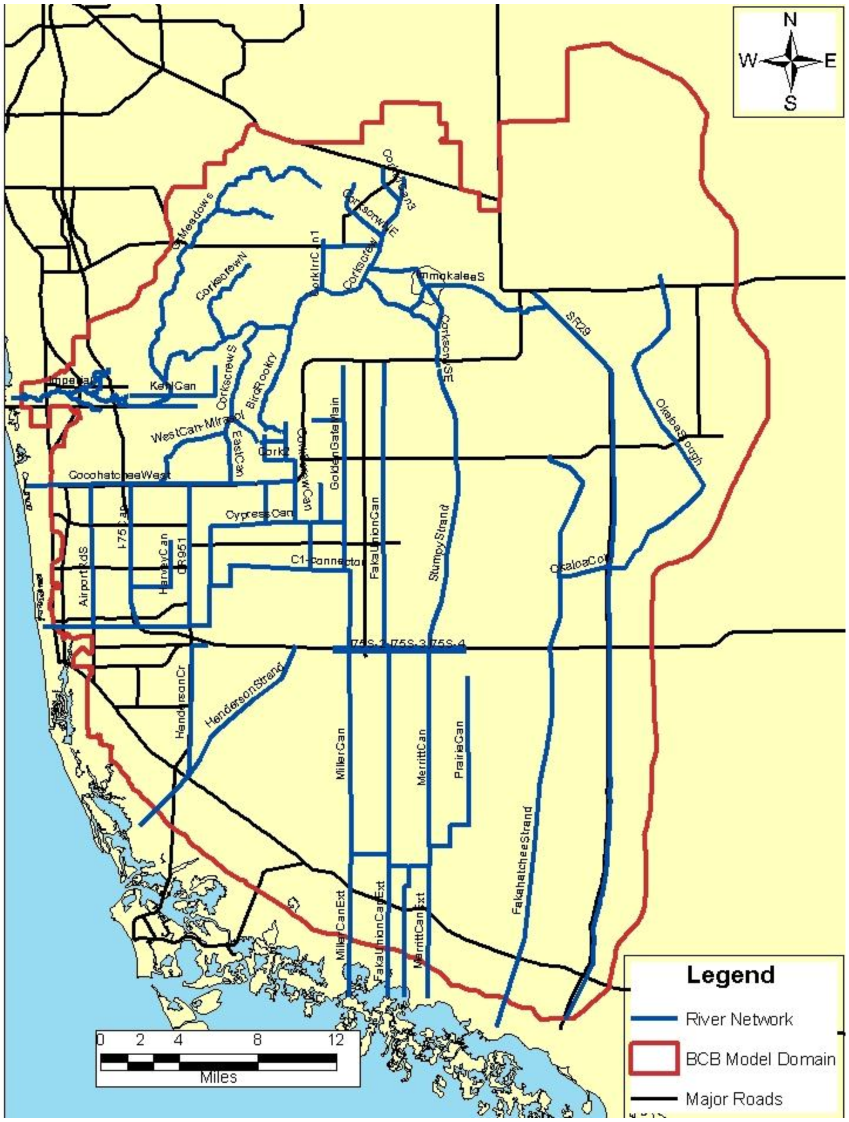


Figure 1-8
Modeled Canal Network for the BCB Existing Conditions Model

Future Conditions Model

The BCB Future Conditions Model (FCM) is based on a projected year 2050 land use map that was generated by the SFWMD. This model includes the canal network defined in the ECM as well as the pumps and spreader canals recommended for the proposed Picayune Strand Wetland Restoration Project (PSRP). Figure 1-9 shows the canal network for the BCB Future Conditions model. This project was formally known as the SGGE. The PSRP considers the installation of canal blocks in the Miller, Faka Union, Merritt and Prairie Canals south of I-75. In addition, it calls for construction of spreader swales and large pump stations to prevent flooding in the Northern Golden Gate Estates north of I-75.

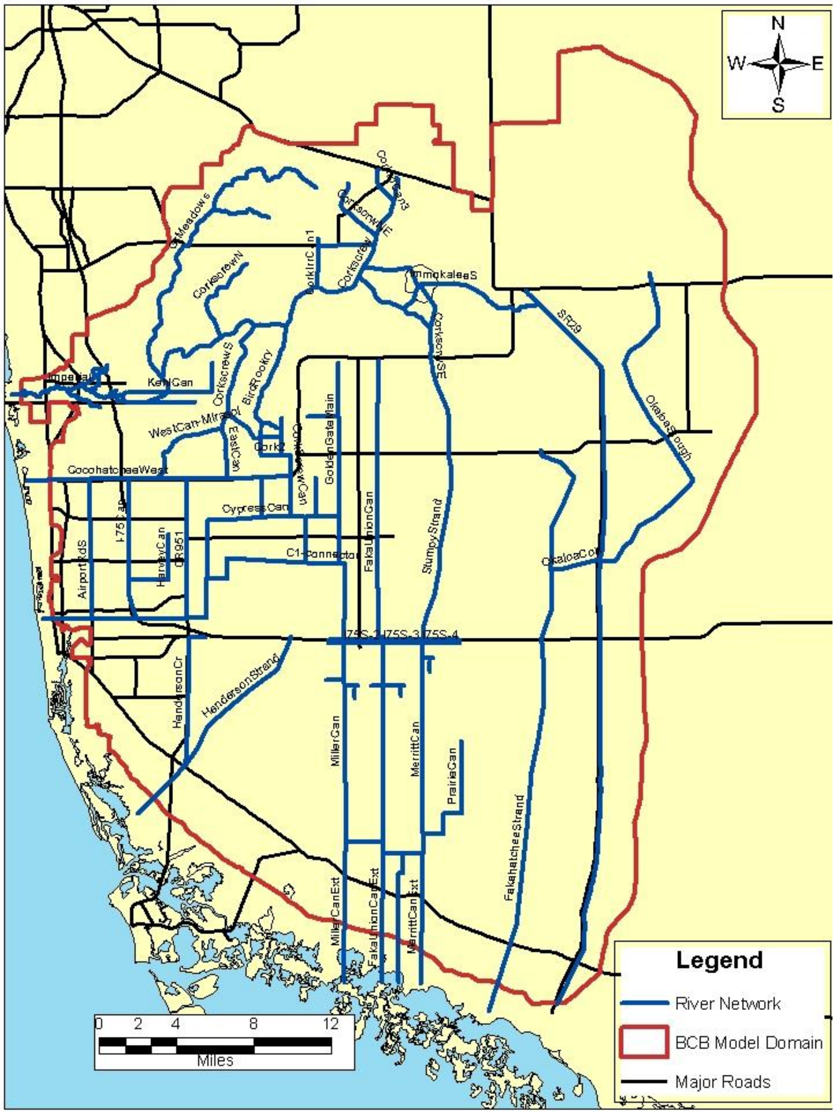


Figure 1-9
Modeled Canal Network for the BCB Future Conditions Model

Natural Systems Model

The Natural Systems, or pre-development, model was developed for the entire Southwest Florida Feasibility Study (SWFFS) area. A full description of the model can be found in the report titled "Final Report, Natural Systems Model (NSM) Scenario Southwest Florida Feasibility Study" (SDI, 2007). The model domain includes the BCB as well as the Caloosahatchee and Estero River Basins. The SWFFS and BCB model domains are shown in Figure 1-10. Figure 1-10 also shows the modeled natural systems river network. In the BCB model area, only the Imperial and Cocohatchee Rivers are explicitly modeled. In order to accurately compare the three models, the NSM model was rerun as part of this project using the same BCB model domain as was defined for the ECM and the FCM.

Groundwater results were extracted from the larger SWFFS NSM model and used to define a time varying boundary condition for the northern edge of the BCB NSM model.

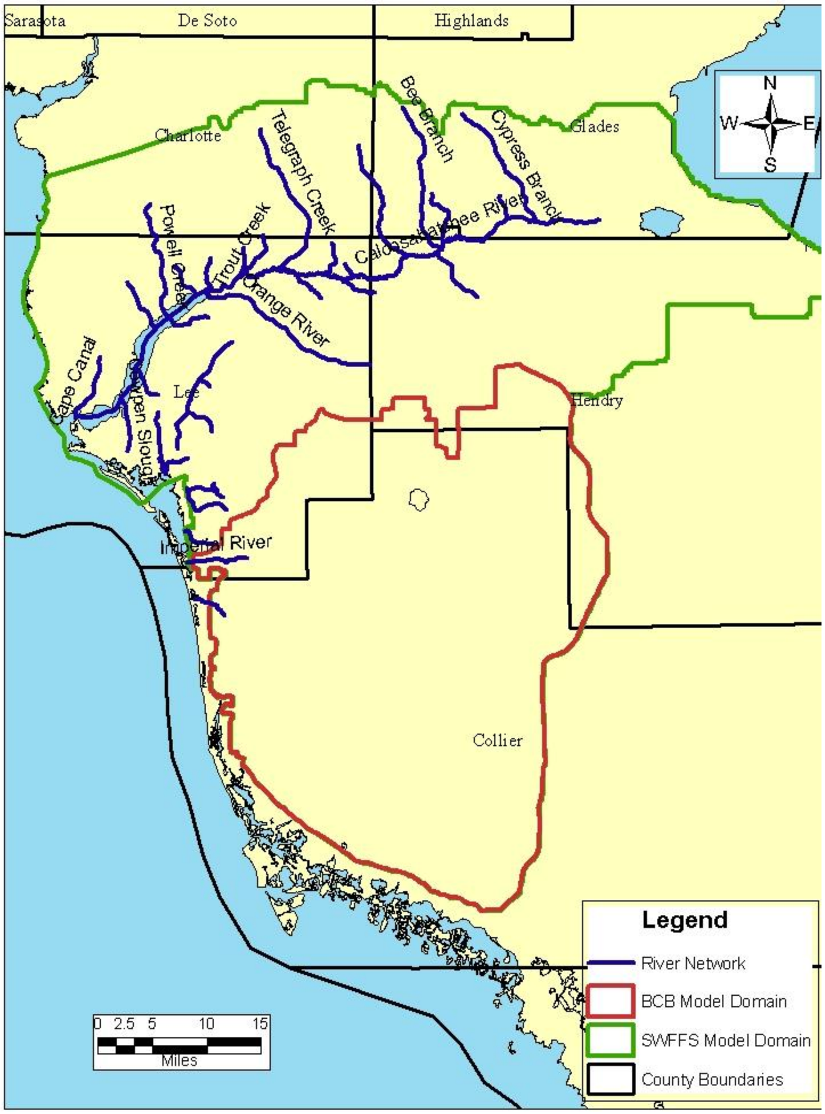


Figure 1-10
Model Domains and Canal Network for the Natural Systems Model

1.2.2 Comparison of Key Model Input Parameters

In this section, results of comparisons among several of the input parameters for the three MIKE SHE models are presented. The discussion focuses on model inputs related to overland flow and discharge to the estuarine system because the saturated components of the three models are equivalent.

River Network

As discussed above, the NSM includes only the Imperial and Cocohatchee Rivers within the Big Cypress Basin model domain. This representation assumes that no structures exist within the river network and is assumed to be representative of the pre-development time period. The model does not include the Gordon River or Henderson Creek, although both were present in the pre-development time.

The ECM and FCM river/canal networks include many of the canals and structures that have been constructed in Collier County since the 1960s. The models are set up using a 1,500-foot grid cell size where the river/canal network consists of the primary drainage canals and structures maintained by the SFWMD and do not explicitly represent the secondary canals maintained by Collier County or within private developments.

Topography

The ECM and FCM models utilize the same topographic input data file that is based on a 750-foot grid. The topographic data input file was prepared by the SFWMD and includes a mixture of data sources, including LiDAR and topographic survey maps. To define topographic characteristics within each of the 1,500-foot grid cells, the model calculates the average of four (4) 750-foot grid cells from the original data set to determine the value used in a single grid cell. The 1,500-foot grid cell topographic data file was used in the comparative analysis.

The NSM report did not clearly define the sources of information used to define the topographic input file used in the NSM. Therefore, it is difficult to determine the level of reliability for the data. The data set was provided to the modeling team by the SFWMD and is also based on a 1,500-foot grid. Therefore, it was possible to directly compare to the ECM and FCM topographic data files.

Plate 1 (Appendix 4-A) shows the topographic elevation for the ECM and NSM models. In addition, a map showing the difference for each cell between the ECM and NSM topographic maps is included in Plate 1. Positive values indicate that the ESM topographic elevation is higher than the NSM topographic elevation. Negative values, on the other hand, indicate that the NSM topographic elevation is higher.

As shown in Plate 1, there is a significant difference in ground surface elevation between the models. In the Okaloacoochee Slough and Faka Union Canal area south of I-75, the ECM and FCM topographic elevation is as much as three (3) feet higher than the NSM. In the Faka Union Canal area south of I-75, this may be reasonable and could be attributed to road building and other development activities. The Okaloacoochee Slough is a natural area that has little development; therefore, it seems that the difference in elevation would be much less three (3) feet. The elevation difference is likely due to the quality of data available when the models were developed.

The new LiDAR data that will be used to define the Collier County ECM should be an improvement over the current topographical data set. However, caution is advised when comparing results against the NSM model.

Detention Storage

In the MIKE SHE model, detention storage is used to define the volume of water (inches or millimeters) that will be stored in a grid cell before overland flow occurs. The values are typically related directly to land use characteristics. In natural areas, this value is indicative of the volume of storage available in local depressions or micro-topography. In urban areas, this value represents the volume of water stored in ponds or other storm water management features that are not explicitly modeled.

Plate 2 (see Appendix 4-A) shows the detention storage values used in each of the models. The FCM and NSM models used similar detention storage values for the same land uses throughout the model domain. However, the ECM used significantly higher values. The ECM will detain anywhere from 0.8 to 3.8 inches more water in each cell before overland flow will occur.

These differences significantly determine model results which may impact the validity of model comparisons. Potential effects would include (but not be limited to) changes in evapotranspiration, infiltration, overland flow and annual hydroperiod.

Overland Manning Values

In MIKE SHE, Manning n values are assigned to each grid cell and are typically associated with land use. These values influence the rate of overland flow from cell to cell. It is expected that natural areas will offer more resistance to overland flow; while urbanized areas would offer less resistance to overland flow.

Plate 3 (see Appendix 4-A) shows the Manning n values used in each grid of the models. These maps show inconsistency in the application of Manning values between the models, although the models all utilize the same land use categories. The range of values varies from 0–1 for the ECM, from 0.5–100 for the FCM, and from 0.04–0.59 for the NSM.

The Natural Systems Model documentation report (SDI, 2007) provides a table that documents the relationship between the land use classification and the assigned Manning value. The initial Big Cypress Basin Integrated Hydrologic-Hydraulic Model report (DHI, 2002) reported that a uniform value of n = 0.5 was specified for all land uses in the ECM. However, the 2006 modeling report (CDM) does not provide any information describing the basis of the revised Manning values used in the final ECM and FCM models.

Soils

For each soil type in the model, retention and conductivity curves are defined based upon soil moisture. In the unsaturated zone soils database, there is a slight difference in the definition of the Plantation soil type between the models. This soil type is observed primarily in the wetland areas of the model. The soils database used for the ECM and FCM models extends the conductivity and retention curves for the Plantation soil.

The curves defined for the NSM are not defined to the same extent as for the ECM and FCM. Therefore, the NSM generates a warning for most time steps indicating that calculated soil moisture values are outside the range of values provided for the conductivity curve. For each of those time steps, the conductivity value was subsequently set to zero (0). These warning are not generated for the ECM and FCM models.

It is likely that the NSM underestimated infiltration; however, it is not clear what the full effect of this warning had on the overall model results.

1.2.3 Comparison of Model Results

Table 1-3 provides a summary of average annual rainfall data across the entire model domain. The model input file uses a distributed rainfall pattern, meaning that different rainfall time series are associated with each grid cell in the model. The volume of rainfall applied to each grid cell varies widely across the model domain.

Table 1-3
Average Annual Rainfall Comparison

Year	Average Model Rainfall Basin-wide (inches)
1976	58.58
1977	55.23
1978	53.62
1979	58.18
1980	53.26
1981	44.29
1982	69.01
1983	76.18
1984	51.53
1985	50.74
1986	52.68

For comparison purposes, and based on the basin-wide average annual rainfall values, comparative model results were generated for the years 1981 (dry year), 1983 (wet year) and 1986 (average year). Model results are presented in the following sections. Because of the inconsistency among the models, these results and conclusions should be considered preliminary.

Basin Discharges

Table 1-4 provides a summary of discharge to the estuaries from the contributing basin during the simulation period. The values for the NSM model are taken from the total water budget for each basin, and represent the total overland flow out of each basin. The results for the ECM and FCM models were extracted from the results of the canal system portion of the model. These results represent the discharge from the canal system directly into the receiving estuary.

When reviewing results, it should be kept in mind that the Cocohatchee Basin discharges to the Cocohatchee Estuary, the Golden Gate Basin discharges to Naples Bay, the Henderson Creek Basin discharges primarily to Rookery Bay, and the Faka Union Basin discharges to the Ten Thousand Islands Estuary. It should also be noted that interbasin flow transfers occur during wet dry periods, which does not allow for a direct correlation between basin and estuary discharge; however, the overall conclusions are still valid.

Review of the results indicates that they are consistent with the historical discharges discussed in the Literature Review of this report. Discharge from the NSM model is generally consistent with the average annual discharge value of 10 inches estimated by Kenner (1966). The flow to Naples Bay from the Golden Gate Basin has increased significantly since construction the canal network. On average, the increase is about four (4) times the volume predicted by the NSM, although there were years where the increased flow predicted by the ECM and the FCM for the Golden Gate Basin was more than 10 times the volume predicted by the NSM. This is also generally true for flow to the 10,000 Islands estuary from the Faka Union Basin. Flow to Rookery Bay from Henderson Creek Basin in the ECM and the FCM is approximately double that predicted by the NSM.

The model results also indicate little difference in average annual discharge from the Cocohatchee Basin. This may be due to the fact that comparatively little development has occurred in Corkscrew Swamp that forms the headwaters of this basin. In addition, structural operations in the Cocohatchee Canal are able to route water south into the larger Golden Gate Canal system.

Hydroperiods

Calculated annual hydroperiod maps for the three modeled conditions are presented in Plates 4–6 (see Appendix 4-A). Hydroperiods were calculated by determining the number of days per year that the depth of water was greater than 0.1 inches above the ground surface.

Table 1-4. Annual Total Discharge per Basin

Year	Rainfall (In)	Cocohatchee			Golden Gate			Henderson Creek			Faka Union		
		NSM (In)	Existing (In)	Future (In)	NSM (In)	Existing (In)	Future (In)	NSM (In)	Existing (In)	Future (In)	NSM (In)	Existing (In)	Future (In)
1977	55.23	0.79	4.43	6.62	2.20	44.22	48.29	1.81	35.04	27.76	4.57	38.38	25.29
1978	53.62	0.75	3.26	5.79	2.09	37.95	48.15	4.29	31.10	27.40	5.24	31.04	26.19
1979	58.18	1.69	6.00	8.83	1.93	43.08	51.51	1.73	23.19	20.37	3.98	35.17	31.17
1980	53.26	4.25	6.43	10.27	4.69	51.15	57.28	3.07	27.02	23.81	5.47	40.86	35.63
1981	44.29	2.91	4.17	6.02	4.06	35.86	45.26	2.09	20.19	18.26	2.83	26.74	21.00
1982	69.01	6.54	8.68	11.26	12.80	55.98	64.44	14.45	39.48	36.18	13.27	59.70	57.74
1983	76.18	19.61	10.82	15.19	36.02	72.54	77.09	54.17	45.54	40.60	37.44	72.57	69.73
1984	51.53	16.06	6.76	10.81	27.01	53.25	59.66	37.44	21.34	18.05	23.74	35.75	31.02
1985	50.74	6.57	4.88	7.71	13.82	42.95	50.79	20.16	28.40	25.22	8.98	30.28	25.70
1986	52.67	3.86	2.81	5.60	9.37	38.90	48.46	12.56	19.71	17.40	6.61	30.96	26.62
Average	56.47	6.30	5.82	8.81	11.40	47.59	55.09	15.18	29.10	25.51	11.21	40.14	35.01

The hydroperiod results appear to be reasonable over most of the BCB model domain. In general, the hydroperiod predicted for the NSM is much longer than that predicted for the ECM and FCM. The maps also demonstrate the effect on the PSRP on the wetland areas south of I-75 between the ECM and the FCM.

However, in the Okaloacoochee Slough (northeast portion of the model domain) there appears to be a discrepancy. This is an area that has been kept in its natural state and one would expect that the hydroperiod would be very similar between all of the models. The model results indicate that the hydroperiod predicted by the ECM and FCM is longer than in the NSM in 1981 and 1986. This is unexpected given that the topographic elevation in this area is lower in the NSM than in the ECM or FCM.

The discrepancy may be a function of the boundary conditions used in the NSM or the effect of differences in model input parameters. This discrepancy will have to be evaluated if the NSM is to be used as a baseline for evaluating future projects.

Average Water Depth Above the Ground Surface

Average depth of water calculations were completed for the wet and dry seasons for each year of the simulation that was analyzed herein. The analysis was made consistent with the USACE definition of the wet season as being from May 1–October 15 of each year. Therefore, the dry season is from October 16–April 30. These time periods were used for the average season calculations.

The results of the average depth of water calculations for 1981, 1983, and 1986 wet and dry seasons are presented on Plates 7–12 (see Appendix 4-A). Results are consistent with the hydroperiod results described above.

Groundwater Levels

Plates 13–18 (see Appendix 4-A) present comparisons of annual groundwater elevations in the Water Table aquifer for 1981, 1983, and 1986. Each plate includes three (3) maps. The first map shows the average NSM groundwater elevation in the Water Table aquifer. The second map shows the average groundwater elevation in the Water Table aquifer associated with either the ECM or the FCM.

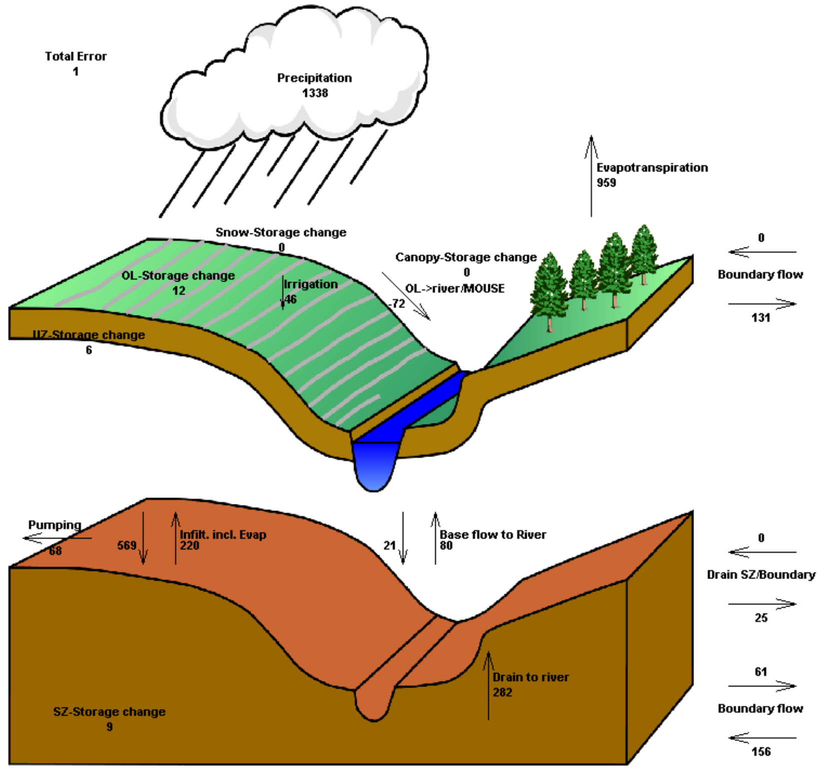
The third map on each plate presents the difference between the average elevations in the other two maps. A positive value means that the NSM groundwater elevation is higher than the ECM or FCM groundwater elevation. A negative value means that the ECM or FCM groundwater elevation is higher.

As with the Hydroperiod and Average Depth of Water results, the predicted groundwater elevations for each model appear to be reasonable over most of the model domain. The ECM and FCM model results show a depression in the water surface elevation of the Water Table aquifer consistent with the location of the Collier County well field. The difference represents the extent of the Water Table aquifer drawdown relative to the NSM model.

The groundwater results also show a significant difference in head elevation in the Okaloacoochee Slough area. The difference maps indicate that the average head elevation in Okaloacoochee Slough is as much as five (5) feet higher in the ECM and FCM than in the NSM. This result is consistent with the observed hydroperiod results and may be due to the groundwater boundary conditions defined in the NSM. This issue will have to be investigated if the NSM is to be used as a baseline for evaluating future projects.

Water Budgets

The MIKE SHE model provides many options for producing water budgets. Total water budgets can be produced in tabular or graphical format. In addition, detailed water budgets may be produced for each component (overland, groundwater, unsaturated zone, etc.) of the MIKE SHE model. Figure 1-11 shows the Total Water Budget graphical output produced for 1986 year meteorological conditions in the Future Conditions Model.



Accumulated waterbalance from 1/1/1986 to 12/31/1986. Data type : Storage depth [millimeter].
Flow Result File : C:\BigCypressBasin\BCB\BCB_2050_V2009.SHE - Result Files\BCB_2050_V2009
Title : BCB - 2050 Future Without Proiect Conditions 1976 to 1986 Text : 2050 FWO Proiect Conditions 1976 to 1986

Figure 1-11
Graphical Water Balance Output for 1986 of the FCM

Equation 1 (below) describes the components used to calculate the change in storage for the overland (OL) and unsaturated (UZ) components of the model. Equations 2 and 3 show the components used to calculate the change in storage for the saturated zone (SZ) and the water volume contributed to the MIKE 11 model, respectively.

OL+UZ Change in Storage = Prec – ET + Irr – OL to Riv + O/UZ In – O/UZ Out – GW Infil + GW Evap (1)

SZ Change in Storage = D/SZ in – D/SZ Out +SZ In – SZ Out + GW Infil – GW Evap – Pump – BF to Riv + BF from Riv – Dr to Riv – Dr to Ex (2)

Contribution to MIKE 11 = OL to Riv + BF to Riv – BF from Riv + Dr to River (3)

Where:

Prec = Precipitation
ET = Evapotranspiration
Irr = Irrigation
OL to Riv = Overland Flow to River
O/UZ in = Overland/UZ Boundary In
O/UZ Out = Overland/UZ Boundary Out
D/SZ In = Drain SZ/Boundary In
D/SZ Out = Drain SZ/Boundary Out
SZ In = SZ Boundary In
SZ Out = SZ Boundary Out
GW Infil = Infiltration to GW
GW Evap = Infiltration from GW
Pump = Pumping
BF to Riv = Baseflow to River
BF from Riv = Baseflow from River
Dr to Riv = Drain to River
Dr to Ex = Drain to External River

Water budgets for the MIKE SHE model were extracted from the results for the entire BCB model domain and for the Golden Gate, Cocohatchee, Henderson Creek and Faka Union Canal subcatchments (basins). Subcatchment locations are shown in Figure 1-12.

The water budget comparisons for the entire BCB model domain and the four subcatchments are shown in Tables 1-5 through 1-9. It is noted that the subcatchment water budgets only consider the hydrologic processes that occur within the subcatchment. They do not consider inflows from outside the subcatchment within the canal/river network.

Table 1-5. Total Water Budget Comparison for BCB Model Domain

BCB Model Domain									
Water Budget Component	1981			1983			1986		
	NSM (inches)	ECM (inches)	FCM (inches)	NSM (inches)	ECM (inches)	FCM (inches)	NSM (inches)	ECM (inches)	FCM (inches)
Precipitation	44.29	44.29	44.29	76.18	76.18	76.18	52.68	52.68	52.68
Evapotranspiration	50.35	36.77	36.69	51.18	38.78	38.98	50.39	37.76	37.76
Irrigation	0.00	3.07	2.99	0.00	0.94	0.94	0.00	1.85	1.81
Overland (OL) Flow to River	0.08	-4.17	-3.15	0.94	-1.10	0.08	0.08	3.94	-2.83
OL/UZ Boundary Flow In	0.55	0.00	0.00	0.16	0.00	0.00	0.43	0.00	0.00
OL/UZ Boundary Flow Out	4.41	3.86	4.84	18.58	5.47	9.80	5.67	3.90	5.16
Overland Storage Change	-4.69	-0.75	-0.75	6.34	1.38	1.10	-0.28	0.28	0.47
Unsaturated Zone (UZ) Storage Change	-0.39	-0.35	-0.31	0.08	0.47	0.31	0.00	0.35	0.24
Infiltration to GW	5.35	19.88	18.54	7.95	41.50	37.17	6.97	24.02	22.40
Evaporation from GW	10.24	7.76	8.54	8.70	9.33	10.31	9.69	7.80	8.66
GW Pumping	0.00	3.90	3.86	0.00	1.85	1.81	0.00	2.76	2.68
Drain to River	0.00	11.93	9.88	0.00	27.83	22.68	0.00	13.35	11.10
Baseflow to River	0.28	3.27	2.95	0.39	4.33	3.86	0.24	3.54	3.15
Baseflow from River	0.00	0.71	0.83	0.00	1.14	1.46	0.00	0.75	0.83
GW Boundary Flow In	3.46	6.46	6.38	3.54	5.98	5.98	3.54	6.22	6.14
GW Boundary Flow Out	0.75	2.01	2.05	0.94	3.07	3.27	0.79	2.40	2.40
Drain SZ/Boundary Flow Out	0.00	0.59	0.79	0.00	1.26	1.65	0.00	0.71	0.98
Saturated Zone (SZ) Storage Change	-2.40	-2.44	-2.28	1.46	0.98	0.94	-0.20	0.47	0.35
Total Error	0.00	0.08	0.08	0.00	0.04	0.04	0.00	0.04	0.04

Table 1-6. Total Water Budget Comparison for Golden Gate Basin

Golden Gate Basin									
Water Budget Component	1981			1983			1986		
	NSM (inches)	ECM (inches)	FCM (inches)	NSM (inches)	ECM (inches)	FCM (inches)	NSM (inches)	ECM (inches)	FCM (inches)
Precipitation	47.52	47.52	47.52	79.33	79.33	79.33	54.57	54.57	54.57
Evapotranspiration	54.29	27.99	24.88	53.11	32.60	30.87	51.57	30.67	28.31
Irrigation	0.00	1.38	1.18	0.00	0.55	0.47	0.00	0.79	0.67
Overland (OL) Flow to River	0.00	-1.30	7.13	0.00	-1.34	13.70	0.00	-0.91	7.36
OL/UZ Boundary Flow In	3.86	0.28	0.71	20.35	1.02	2.32	5.00	0.16	0.43
OL/UZ Boundary Flow Out	4.06	0.04	0.20	36.02	0.08	0.67	9.37	0.00	0.08
Overland Storage Change	-5.98	0.00	0.00	7.80	0.28	0.20	-1.89	0.04	0.00
Unsaturated Zone (UZ) Storage Change	-0.51	-1.22	-1.06	0.08	1.26	1.22	0.04	1.22	0.91
Infiltration to GW	6.93	24.06	18.46	6.61	48.66	35.71	6.02	24.80	19.09
Evaporation from GW	7.40	0.28	0.12	3.90	0.59	0.12	5.55	0.28	0.08
GW Pumping	0.00	5.00	4.84	0.00	4.37	4.33	0.00	4.57	4.45
Drain to River	0.00	19.02	9.88	0.00	38.03	20.08	0.00	17.01	8.70
Baseflow to River	0.00	6.89	9.37	0.00	10.79	15.20	0.00	8.19	10.31
Baseflow from River	0.00	3.46	2.09	0.00	2.72	1.65	0.00	2.95	1.73
GW Boundary Flow In	1.42	3.86	3.90	1.73	4.72	4.61	1.30	4.06	4.02
GW Boundary Flow Out	1.77	1.46	1.26	2.44	1.34	1.34	2.13	1.34	1.18
Drain SZ/Boundary Flow Out	0.00	0.04	0.00	0.00	0.12	0.08	0.00	0.04	0.04
Saturated Zone (SZ) Storage Change	-0.83	-1.34	-1.06	2.01	0.87	0.91	-0.31	0.39	0.08
Total Error	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00

Table 1-7. Total Water Budget Comparison for Cocohatchee Basin

Cocohatchee Basin									
Water Budget Component	1981			1983			1986		
	NSM (inches)	ECM (inches)	FCM (inches)	NSM (inches)	ECM (inches)	FCM (inches)	NSM (inches)	ECM (inches)	FCM (inches)
Precipitation	45.16	45.16	45.16	74.76	74.76	74.76	50.59	50.59	50.59
Evapotranspiration	50.39	39.45	38.46	50.35	39.37	38.46	48.94	38.35	37.32
Irrigation	0.00	6.18	5.94	0.00	2.20	2.09	0.00	3.98	3.78
Overland (OL) Flow to River	0.28	-32.48	-29.76	2.48	-34.61	-30.94	0.43	-33.54	-30.00
OL/UZ Boundary Flow In	0.55	0.47	0.16	5.51	0.87	0.43	0.63	0.59	0.20
OL/UZ Boundary Flow Out	2.60	0.20	0.51	17.09	0.75	1.61	3.39	0.20	0.43
Overland Storage Change	-5.59	-0.28	-0.28	6.02	0.63	0.63	-2.68	0.08	0.08
Unsaturated Zone (UZ) Storage Change	-1.06	-0.47	-0.47	0.47	0.55	0.51	0.16	0.39	0.28
Infiltration to GW	5.67	47.24	44.84	13.07	73.46	69.41	8.62	51.46	48.46
Evaporation from GW	6.54	1.77	1.93	9.25	2.24	2.32	7.64	1.69	1.93
GW Pumping	0.00	6.22	5.98	0.00	2.36	2.28	0.00	4.09	3.90
Drain to River	0.00	40.28	37.68	0.00	64.49	61.26	0.00	43.35	40.51
Baseflow to River	0.04	1.10	1.26	0.04	0.98	1.10	0.04	1.06	1.18
Baseflow from River	0.00	0.67	0.83	0.00	1.22	1.26	0.00	0.63	0.91
GW Boundary Flow In	1.06	4.02	3.82	1.65	3.35	3.46	1.22	3.39	3.19
GW Boundary Flow Out	1.97	4.65	4.41	3.66	6.73	6.02	2.72	5.59	5.28
Drain SZ/Boundary Flow Out	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saturated Zone (SZ) Storage Change	-1.81	-2.09	-1.81	1.77	1.14	1.14	-0.51	-0.28	-0.28
Total Error	0.00	0.12	0.12	0.04	0.08	0.04	0.00	0.12	0.04

Table 1-8. Total Water Budget Comparison for Henderson Creek Basin

Henderson Creek Basin									
Water Budget Component	1981			1983			1986		
	NSM (inches)	ECM (inches)	FCM (inches)	NSM (inches)	ECM (inches)	FCM (inches)	NSM (inches)	ECM (inches)	FCM (inches)
Precipitation	46.34	46.34	46.34	77.20	77.20	77.20	55.87	55.87	55.87
Evapotranspiration	55.43	32.20	31.89	53.39	34.49	34.33	53.19	33.43	33.23
Irrigation	0.00	0.16	0.12	0.00	0.08	0.94	0.00	0.08	0.04
Overland (OL) Flow to River	0.00	-3.11	-4.02	0.00	-2.87	0.83	0.00	-2.64	-1.22
OL/UZ Boundary Flow In	6.18	0.12	0.24	43.03	0.63	1.30	13.11	0.08	0.28
OL/UZ Boundary Flow Out	2.09	1.10	1.85	54.17	2.56	4.76	12.56	1.34	2.48
Overland Storage Change	-6.46	-0.04	-0.79	7.28	0.51	0.94	-0.87	0.35	0.31
Unsaturated Zone (UZ) Storage Change	-0.08	-1.30	-0.87	0.00	0.63	0.35	0.00	0.55	0.28
Infiltration to GW	10.51	20.00	22.20	8.03	46.10	42.52	8.58	24.96	24.61
Evaporation from GW	8.98	2.28	3.54	2.68	3.46	5.12	4.53	1.89	3.46
GW Pumping	0.00	2.44	2.48	0.00	2.32	2.32	0.00	2.32	2.36
Drain to River	0.00	12.48	11.97	0.00	31.81	25.51	0.00	13.86	11.10
Baseflow to River	0.00	0.51	1.30	0.00	0.63	1.69	0.00	0.63	1.42
Baseflow from River	0.00	1.93	1.65	0.00	1.57	1.57	0.00	1.69	1.42
GW Boundary Flow In	3.07	3.23	3.31	3.19	3.43	3.78	2.99	3.19	3.35
GW Boundary Flow Out	6.46	9.57	9.76	7.56	11.57	11.89	7.36	10.20	10.35
Drain SZ/Boundary Flow Out	0.00	0.04	0.16	0.00	0.24	0.67	0.00	0.08	0.28
Saturated Zone (SZ) Storage Change	-1.89	-2.17	-2.09	1.02	1.06	0.71	-0.31	0.91	0.43
Total Error	-0.04	0.00	0.08	0.00	0.04	0.08	0.00	0.04	0.04

Table 1-9, Total Water Budget Comparison for Faka Union Canal Basin

Faka Union Canal Basin									
Water Budget Component	1981			1983			1986		
	NSM (inches)	ECM (inches)	FCM (inches)	NSM (inches)	ECM (inches)	FCM (inches)	NSM (inches)	ECM (inches)	FCM (inches)
Precipitation	45.91	45.91	45.91	78.78	78.78	78.78	55.12	55.12	55.12
Evapotranspiration	53.58	32.28	35.67	52.09	35.04	37.56	52.32	33.82	36.54
Irrigation	0.00	1.77	1.61	0.00	0.51	0.47	0.00	1.02	0.91
Overland (OL) Flow to River	0.00	-2.44	-1.42	0.00	-2.17	14.88	0.00	-1.54	0.47
OL/UZ Boundary Flow In	1.50	1.22	1.50	20.91	9.41	11.22	3.90	2.52	2.68
OL/UZ Boundary Flow Out	2.83	-0.12	0.47	37.44	-0.28	2.80	6.61	-0.28	0.55
Overland Storage Change	-7.48	-0.12	-0.79	8.94	0.55	1.06	0.16	0.20	0.71
Unsaturated Zone (UZ) Storage Change	-0.28	-0.98	-0.59	0.08	0.91	0.43	0.00	0.87	0.31
Infiltration to GW	5.87	21.42	21.61	2.99	56.46	43.03	4.17	26.77	26.61
Evaporation from GW	7.17	1.18	5.94	1.85	1.81	9.29	4.29	1.18	6.46
GW Pumping	0.00	3.46	3.31	0.00	2.24	2.17	0.00	2.72	2.60
Drain to River	0.00	10.12	7.05	0.00	37.83	20.63	0.00	12.01	8.58
Baseflow to River	0.00	11.14	7.48	0.00	17.01	11.22	0.00	13.27	9.17
Baseflow from River	0.00	0.43	1.34	0.00	0.20	0.87	0.00	0.28	1.10
GW Boundary Flow In	0.94	3.50	1.34	0.87	4.29	1.93	0.91	3.94	1.38
GW Boundary Flow Out	0.98	1.26	1.93	1.02	1.14	1.73	0.98	1.18	1.93
Drain SZ/Boundary Flow Out	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saturated Zone (SZ) Storage Change	-1.38	-1.77	-1.42	0.98	0.94	0.75	-0.16	0.67	0.39
Total Error	-0.04	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00

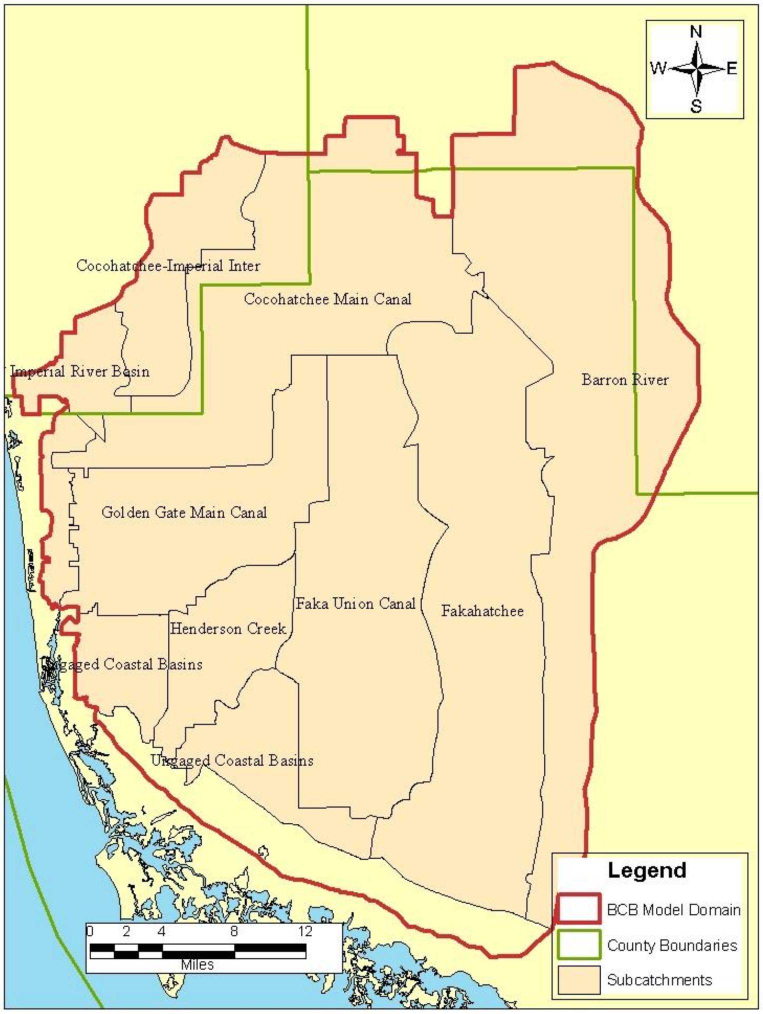


Figure 1-12
Defined Subcatchments (basins) in the Big Cypress Model Domain

The total contribution from the entire BCB model domain to the estuary system via overland flow can be calculated using the following equation:

BCB Flow to Estuaries = OL to Riv + O/UZ Out + Dr to Riv + BF to Riv – BF from Riv

Table 1-10 provides a summary of calculated total flow to the estuaries for each of the BCB models during the three rainfall years evaluated during this analysis. Results indicate that the discharge ratio compared to the NSM is largest during average years. During dry years, runoff and baseflow are limited which reduces discharges to the receiving water bodies. In addition, structures during those periods are operated such that flows are retained in the drainage system. During wet years, discharges from both natural and developed areas are large due to high groundwater elevation and soil saturation. It should be noted that values in Table 1-10 represent the total flow from the entire model domain and may differ significantly from discharge rates from individual sub-basins, as shown in Table 1-4.

Table 1-10
Total Runoff from the BCB MIKE SHE Models

Year	MIKE SHE Model		
	NSM	**ECM**	**FCM**
1981	4.76	14.17	13.70
1983	19.92	35.39	34.96
1986	5.98	23.98	15.75
Avg.	10.22	24.51	21.47

1.3 SUMMARY AND CONCLUSIONS

In this section, the MIKE SHE models used for the BCB PIR were reviewed and the discharge results were evaluated relative to values reported in the literature. The model review indicated that there appears to be inconsistency in how some parameters were defined in the MIKE SHE models. The Manning's "n" values and the detention storage values show the most variation between the models.

In general, the model predicted discharge results are consistent with the values identified in the literature. However, the review of the NSM model results raised some questions about input values used in the NSM model in the vicinity of Okaloacoochee Slough. The Okaloacoochee Slough area is mostly undeveloped; however, the NSM predicted groundwater levels and hydroperiod in this area are substantially different from the results predicted by the ECM and FCM models. These differences will have to be investigated if the NSM is to be used as a baseline for evaluating future projects.

The model results indicate that the average annual discharge from the NSM model is generally consistent with the average annual discharge value of 10 inches estimated by Kenner (1966).

The model comparison results (see Table 1-4) also indicate that the flow to Naples Bay from the Golden Gate basin and to the Ten Thousand Islands from the Faka Union basin has increased significantly since construction of the canal network. On average, the increase in flow in these basins is approximately four (4) times the volume predicted by the NSM over the simulation period. However, there were years where the increased flow predicted by the ECM and the FCM for these basins was estimated to be more than 10 times the volume predicted by the NSM. These values are also consistent with those reported by BCE (1974) and others as described in the literature review.

2.0 ASSESSMENT OF EXISTING CONDITIONS: WATERSHED

This chapter describes the results of the assessment of existing conditions in the study area in terms of surface water, ground water, and natural system conditions. The assessment included evaluations of the areal extent and functional quality of native wetland and upland communities, as well as a comparison of existing conditions with performance measures (described in Chapter 4) to identify watershed issues and potential opportunities for addressing those issues.

2.1 SURFACE WATER QUANTITY

This chapter section presents water budget results of the Collier County MIKE SHE/MIKE11 Existing Conditions Model (ECM), summarizes the predicted water budgets simulated by the ECM, and discusses potential issues identified through the water budgeting process. It addresses the following items:

- **Water Budget Components.** This section describes the components used to define the water budget in MIKE SHE.
- **Surface Water and Groundwater Budgets.** This section describes the overall surface water and groundwater budgets, and the water budgets developed for each watershed (**Figure 2-1**).
- **Baseflow and Structure Operations.** This section focuses on the distribution of baseflow contributions within the Golden Gate-Naples Bay Watershed. The section will also evaluate the potential effect of changes in structure operations.
- **Canal Capacity.** This section will identify locations at which water elevations in the canal are predicted to exceed the top of bank elevation during storm events. This is another factor that could help define potential changes in structure operations.
- **Conclusions.** This section presents the conclusions of these analyses.

Figure 2-1. Collier County Watersheds and Coastal WBIDs

2.1.1 Water Budget Components

A water budget analysis was conducted to understand the distribution of watershed inflows and outflows. **Figure 2-2** is a schematic of the water budget components. As shown, the primary sources of inflow to a watershed are precipitation and applied irrigation. This water accumulates on the ground surface as basin storage, runs off as overland flow or infiltrates into the ground. Overland flow can be evaporated, discharged into the canal, or flow across watershed boundaries. Water that infiltrates into the soils can be taken up by plants or percolate into the Water Table aquifer. This water can then be removed from the Water Table Aquifer by plant uptake, by moving laterally across the watershed boundary, by pumping to meet potable water and irrigation needs, or by percolation to underlying aquifers. Any residual water is stored in the aquifer. Similar processes occur in each of the deeper aquifers.

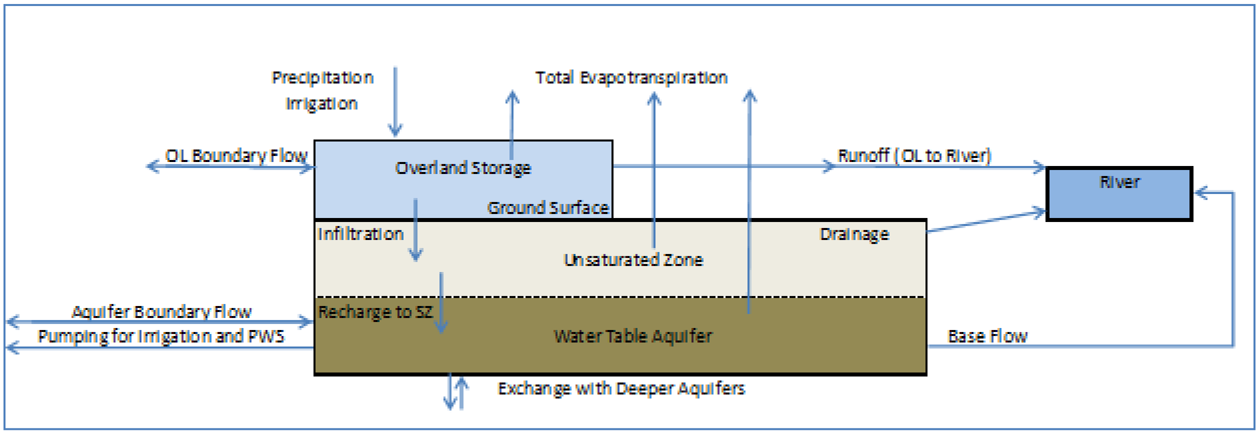


Figure 2-2. Schematic of MIKE SHE Water Budget

The components of the water budget are described in further detail below:

Inflows:

- **Precipitation:** This is water entering the watershed as rainfall. Some portion of precipitation is intercepted by the vegetative canopy. The rest is applied to the ground surface.
- **Irrigation:** This is the sum of all model predicted irrigation applied to the ground surface in the watershed. This consists of water pumped from the Water Table and Lower Tamiami aquifers and water applied from external sources such as reuse water provided by Collier County or the City of Naples.
- **Overland Boundary Inflow:** This is water that enters a watershed as sheet flow from adjacent watersheds. This typically occurs during large storm events in the wet season when water ponded on the ground surface crosses a watershed boundary.
- **Aquifer Boundary Inflow:** This is groundwater that enters a watershed via subsurface flow from adjacent watersheds. There are four aquifers in the model, so this component can be broken in inflows per aquifer layer.

Outflows:

- **Evapotranspiration (ET):** The ET represents the combined total of direct evaporation of water ponded on the ground surface or captured in the vegetative canopy and water transpired from the soils and Water Table aquifer by plant uptake.
- **Runoff:** This represents the model predicted amount of overland flow that discharges into the river and canal network. This component also includes stormwater runoff from secondary and tertiary urban and agricultural drainage networks that are not explicitly represented in the model.
- **Baseflow:** This component of the model represents groundwater inflows to the canal network.

- **Pumping for irrigation and potable water supply:** This item represents the total volume of water pumped out of the aquifer system. Some portion of this water is applied to the ground surface as irrigation. Water pumped for potable water supply is used as reuse irrigation water or is injected into deep aquifers.
- **Overland Boundary Outflow:** This is water that leaves a watershed as overland flow into adjacent watersheds or across the model boundary and typically occurs during large storm events.
- **Aquifer Boundary Inflow:** This is groundwater that exits a watershed or the model via subsurface flow. There are four aquifers in the model, so this component can be broken in outflows per aquifer layer.

Storage Change:

- This component represents the total change in watershed storage. This includes overland storage, storage in the unsaturated zone and storage in groundwater.

2.1.2 Water Budget Analysis

For the water budget analyses, data were extracted from the MIKE SHE/MIKE11 model results files using a pre-defined Total Water Budget tool in the program. The model results were then post processed to create water budgets for the entire model study area as well as for each of the watersheds, Cocohatchee-Corkscrew (CC), Golden Gate Naples Bay (GGNB), Rookery Bay (RB), and the combined Faka Union, Fakahatchee, and Okaloacoochee-SR29 (FUFHOK) watersheds. These watersheds are comprised of aggregated WBID areas.

Water budgets were generated for the model simulation period of January 1, 2002 through October 31, 2007. Budgets were developed for different time periods based on model simulation data availability. The time periods include:

- **Annual:** The water budget represents average conditions during the water year. The budget represents the period from November 1–October 31. For example, the 2003 water year is the period from November 1, 2002–October 31, 2003. Water year budgets were calculated for 2003 through 2007.
- **Wet Season:** The wet season is defined as July 1–October 31. Wet season water budgets were developed for the years 2002–2007. This period includes all the wet seasons incorporated in the model simulation period.
- **Dry Season:** The dry season is defined as the period from November 1–June 30. The 2003 dry season represents November 2002–June 2003. Dry season water budgets were developed for the years 2003–2007.

In this section, the results of the water budget analysis in terms of annual average, wet season and dry season are described. In addition, water budgets were prepared for a wet year and a dry year relative to the average annual conditions. Finally, seasonal water budgets were developed for each watershed.

2.1.3 Seasonal Water Budgets

Table 2-1 shows the annual water year and seasonal water budget components for the study area. **Figure 2-3** shows the average water year budget for the entire study area. **Figure 2-4 and Figure 2-5** show the corresponding average wet season and dry season water budgets. The data indicate that rainfall during the four (4) month wet season represents about 54 percent of the total annual amount and that most is lost through ET.

Table 2-1. Annual Water Year and Seasonal Water Budgets for Study Area

Period	Inflows (inches)		Outflows (inches)				Change in Storage
	Precipitation	Irrigation	Evapo Transpiration	Runoff	Baseflow to River	Pumping	
Dry Season Average							
2003	31.10	1.57	24.45	1.65	1.93	2.17	3.15
2004	24.72	1.81	25.55	1.26	2.28	2.44	-4.45
2005	35.79	1.81	25.08	3.31	2.24	2.44	4.41
2006	19.45	2.60	25.47	1.22	2.13	3.27	-9.57
2007	17.17	3.50	24.69	0.16	1.06	4.21	-7.99
Average	25.65	2.26	25.05	1.52	1.93	2.91	-2.89
Wet Season Average							
2002	21.14	0.31	16.22	1.38	1.85	0.63	1.14
2003	29.65	0.12	15.67	8.86	3.11	0.39	-0.35
2004	34.72	0.08	16.26	8.70	2.87	0.39	4.53
2005	33.86	0.08	17.36	10.16	3.50	0.39	-0.51
2006	30.59	0.43	17.17	5.31	2.80	0.71	3.62
2007	26.38	0.39	17.44	0.83	1.61	0.71	6.26
Average	29.39	0.24	16.69	5.87	2.62	0.54	2.45
Annual Average							
2003	60.75	1.69	40.12	10.51	5.04	2.56	2.80
2004	59.45	1.89	41.81	9.96	5.16	2.83	0.08
2005	69.65	1.89	42.44	13.46	5.75	2.83	3.90
2006	50.04	3.03	42.64	6.54	4.92	3.98	-5.94
2007	43.54	3.90	42.13	0.98	2.68	4.92	-1.73
Average	56.69	2.48	41.83	8.29	4.71	3.43	-0.18

Runoff and base flow are important components of the water budget as they represent about 15 and 8 percent of annual rainfall (8.3 and 4.7 inches, respectively). In other words, the volume of groundwater that enters the canal network as base flow is approximately 36 percent of the total fresh water discharged into the canal network. It is important to point out that base flow discharges are the result of the construction of the drainage canals that cut into the Water Table aquifer.

During the wet period, runoff is about 70 percent of the total contributions to the canal network. However, in the dry season, the runoff volume decreases to about 44 percent of the total contribution the canal network. Therefore, the majority of the dry season canal flow is baseflow. This is because runoff is highly sensitive to varying meteorological conditions, whereas baseflow is relatively stable. The ratio of average runoff to average rainfall ranges from 20 percent in the wet season to 6 percent in the dry season. On the other hand, baseflow (wet season = 2.62 inches and dry season = 1.93 inches) remains at about 8 percent of rainfall.

Figures 2-4 and 2-5 also illustrate the seasonal variations in pumping and irrigation. As expected, pumping and irrigation demand during the dry season represents about 85 percent of the annual water budget for these two items.

Finally, the water budget also includes watershed storage. As shown in **Figure 2-3**, change in storage as an annual average is negligible. **Figures 2-4 and 2-5** show that about 2.5 inches of storage is lost in the dry season, but that volume is recovered in the wet season. This indicates that, at least during the simulation period 2002–2007, hydrologic characteristics of the study area did not worsen, although no recovery is apparent.

To assess the system characteristics during critical conditions, water budgets were developed for both the driest dry season and the wettest wet season in the simulation period. **Figure 2-6** shows the results of the 2007 dry season (November 2006 through June 2007). Total precipitation during this period amounted to about 17 inches, which is about 33 percent less than the average dry season rainfall for the entire simulation period. **Figure 2-7** represents the extremely wet 2004 rainy season (July through October 2004) when Florida experienced three hurricanes in less than 45 days. Total rainfall accumulated during that season was almost 35 inches, which is about 20 percent more than the wet season average for the model simulation period.

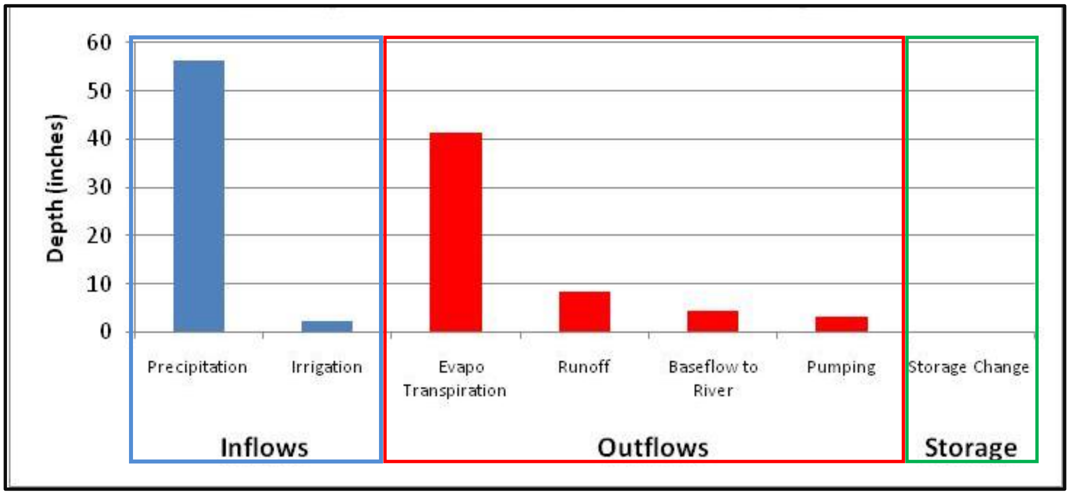


Figure 2-3. Average Water Year (2003–2007) Water Budget

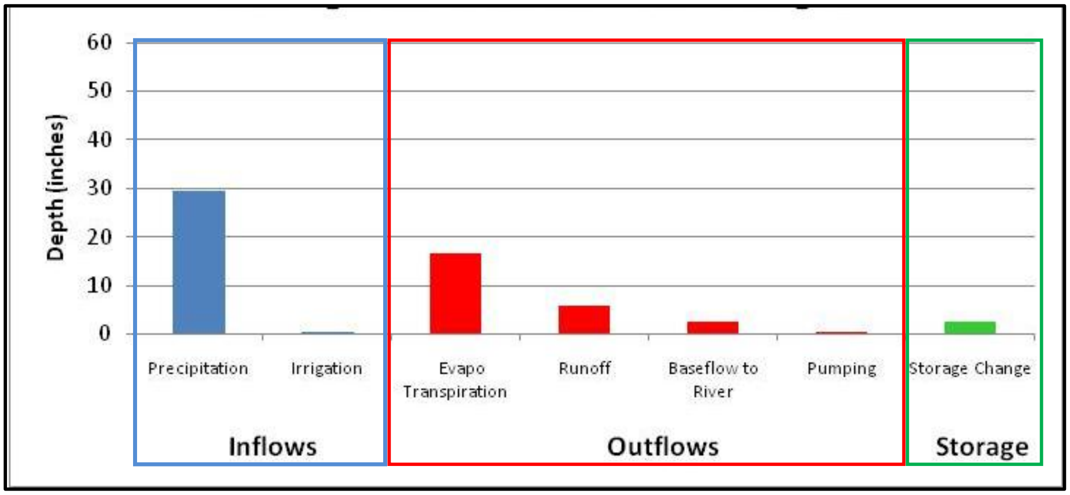


Figure 2-4. Average Wet Season (2002–2007) Water Budget

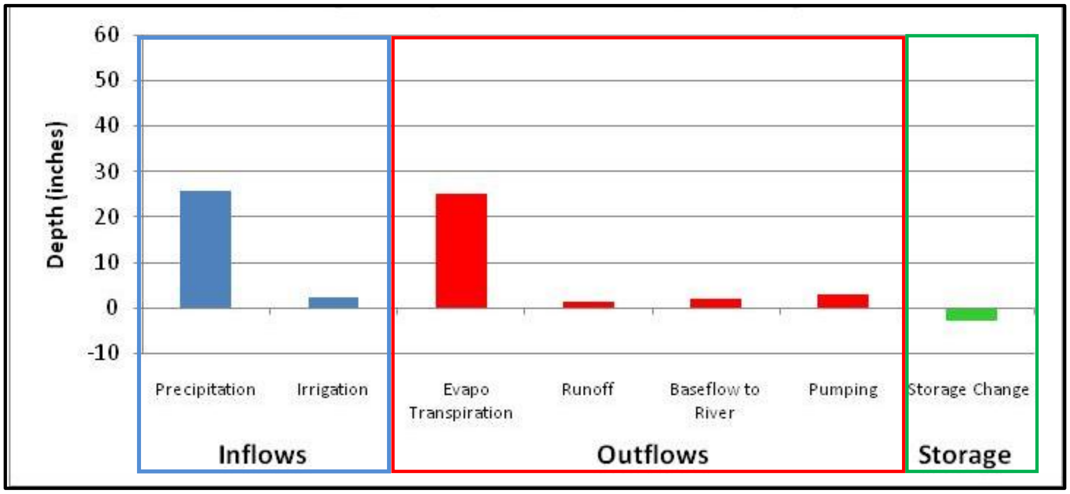


Figure 2-5. Average Dry Season (2003–2007) Water Budget

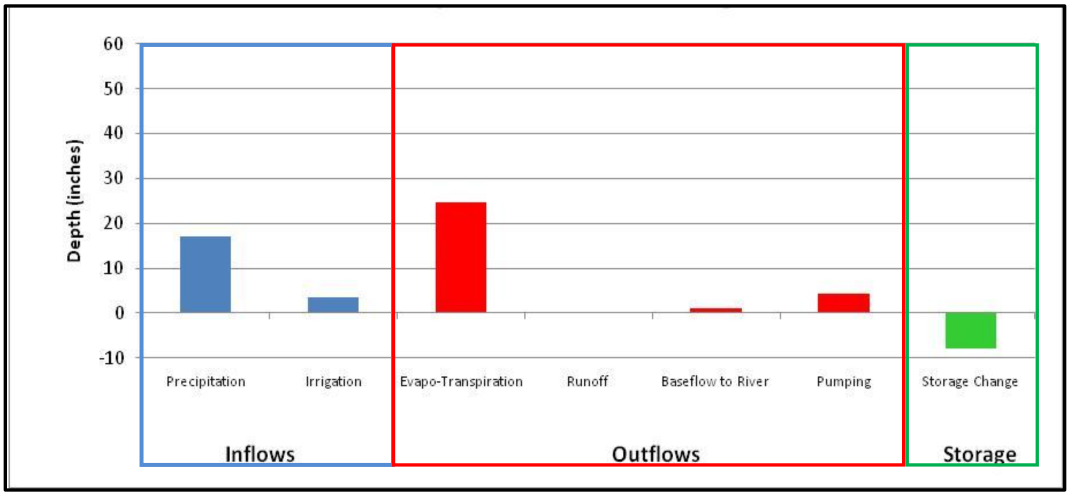


Figure 2-6. 2007–Driest Dry Season Water Budget

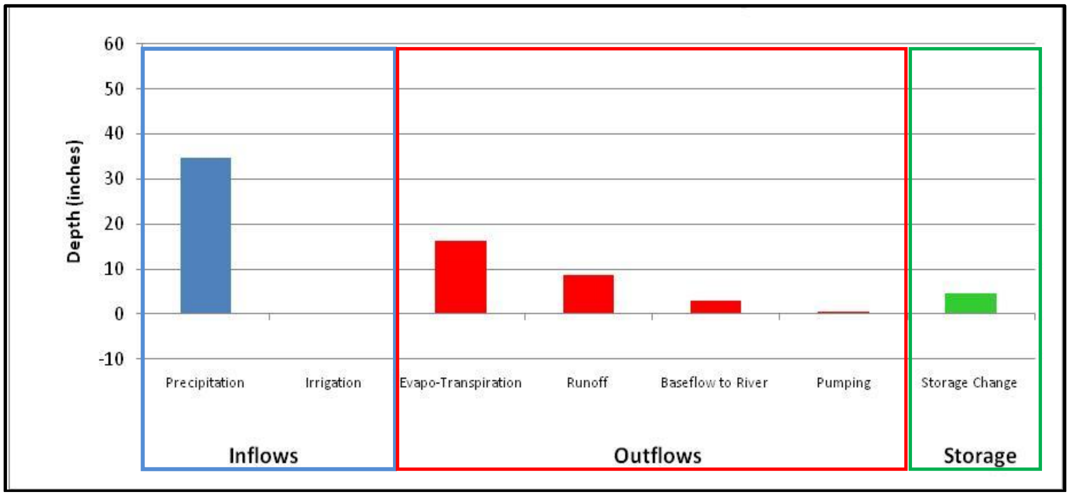


Figure 2-7. 2004–Wettest Wet Season Water Budget

Results of the analysis confirm that the change in runoff volume is much larger than the change in precipitation. During the 2007 dry season, a 33 percent reduction in precipitation from the period average resulted in an approximately 90 percent reduction in runoff volume. Similarly, the 20 percent increase in precipitation during the 2004 wet season resulted in an about 50 percent increase in runoff volume. As stated previously, baseflow is not affected as drastically as runoff volume. The change in baseflow contribution is small during extremely wet conditions as demonstrated by the 10 percent increase from average during the 2004 wet season. The impact is more severe during dry weather conditions when it was reduced by about 50 percent from average. It is important to point out that this also indicates that fresh water flows in the canal in the 2007 dry conditions was almost exclusively baseflow.

The results of the annual and seasonal water budgets indicate that the management of both runoff and base flow are key to reducing the volume of water discharged to the estuaries. During the dry season, the reduction of baseflow to the canal network appears to be the more critical issue. It should be noted that structure operations are important to managing both discharge and baseflow in the canal network.

During extreme dry weather, irrigation and pumping also increase substantially, accompanied by a substantial reduction in watershed storage. Similarly to the annual average analysis, irrigation and pumping are drastically reduced during extreme wet weather conditions and the watershed storage is quickly recovered.

2.1.4 Water Budgets by Watershed

Average water year and seasonal water budgets were also generated for each of the watersheds in Collier County. As described for the entire study area, the majority of the precipitation is lost to ET, which ranges between 50 and 60 percent in the wet season for all watersheds. During the dry season, ET losses equal precipitation in all watersheds except Golden Gate–Naples Bay, where ET is about 80 percent of precipitation. This is due to the high level of watershed urban development, as water is quickly routed to the drainage network.

Cocohatchee-Corkscrew Watershed. The budgets for the Cocohatchee-Corkscrew watershed are shown in **Figures 2-8 through 2-10** and in **Table 2-2.** Model results indicate that the annual average runoff volume is approximately 14 percent of rainfall. Most of the runoff comes from urban and agricultural development. As an example, in the 2003 wet season results indicate that runoff was more than nine (9) inches. Of that, 8.5 inches came from urban and agricultural development.

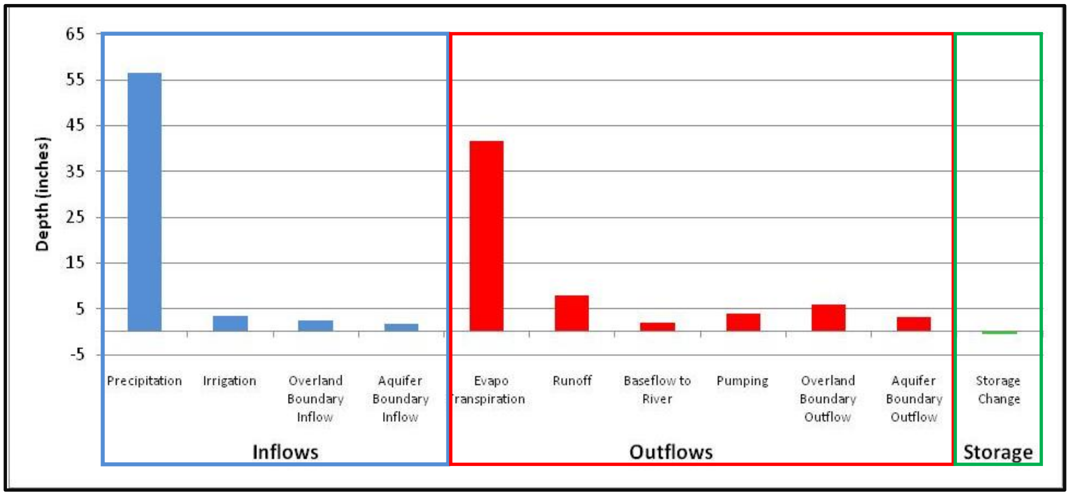


Figure 2-8. Average Water Year Budget – Cocohatchee-Corkscrew Watershed

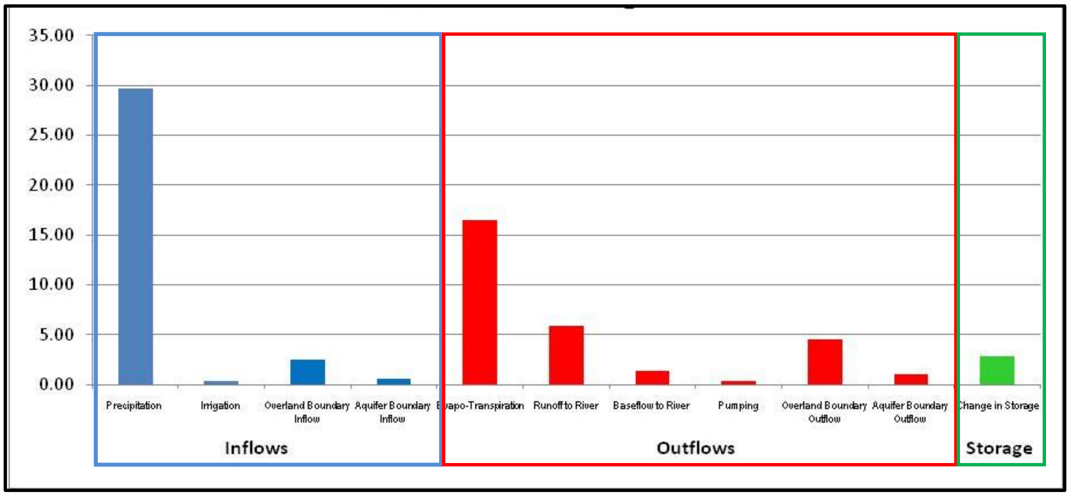


Figure 2-9. Average Wet Season Water Budget – Cocohatchee-Corkscrew Watershed

Table 2-2. Seasonal Water Budget for Cocohatchee-Corkscrew Watershed

Season	Inflows (inches)				Outflows (inches)						Storage (inches)
	Precipitation	Irrigation	Overland Boundary Inflow	Aquifer Boundary Inflow	Evapo-Transpiration	Runoff to River	Baseflow to River	Pumping	Overland Boundary Outflow	Aquifer Boundary Outflow	Storage Change
Wet 2002	23.14	0.34	0.25	0.59	15.99	2.46	1.01	0.43	0.64	0.81	2.88
Wet 2003	29.78	0.17	4.09	0.62	15.26	9.10	1.81	0.26	7.11	1.17	-0.67
Wet 2004	36.10	0.19	4.30	0.63	16.05	9.11	1.66	0.29	7.88	1.11	4.46
Wet 2005	33.54	0.11	4.72	0.62	17.36	9.14	1.91	0.22	8.61	1.25	-0.07
Wet 2006	29.79	0.55	1.35	0.67	17.11	4.89	1.33	0.65	2.76	0.98	4.33
Wet 2007	25.30	0.56	0.07	0.73	17.42	0.91	0.45	0.66	0.16	0.78	6.18
Average Wet	29.61	0.32	2.46	0.64	16.53	5.93	1.36	0.42	4.53	1.02	2.85
Dry 2003	33.32	2.31	0.56	0.97	24.43	2.80	1.09	2.51	1.08	1.72	3.37
Dry 2004	24.91	2.63	0.56	1.05	25.37	1.51	1.10	2.83	0.77	1.91	-4.40
Dry 2005	35.40	2.57	1.16	1.08	25.08	3.54	1.21	2.80	1.99	1.97	3.38
Dry 2006	19.83	3.62	1.26	1.10	25.69	1.18	1.06	3.85	1.82	1.94	-9.80
Dry 2007	15.15	5.03	0.25	1.13	24.08	-0.55	0.24	5.27	0.13	1.92	-9.52
Average Dry	25.72	3.23	0.76	1.07	24.93	1.70	0.94	3.45	1.16	1.89	-3.39

Table 2-3. Seasonal Water Budget for Golden Gate-Naples Bay Watershed

Season	Inflows (inches)				Outflows (inches)						Storage (inches)
	Precipitation	Irrigation	Overland Boundary Inflow	Aquifer Boundary Inflow	Evapo-Transpiration	Runoff to River	Baseflow to River	Pumping	Overland Boundary Outflow	Aquifer Boundary Outflow	Storage Change
Wet 2002	23.29	0.04	0.35	0.92	15.21	1.20	6.34	1.53	0.26	0.51	-0.47
Wet 2003	33.93	0.02	6.12	1.02	15.05	11.99	10.52	1.27	3.40	0.50	-1.76
Wet 2004	36.10	0.02	7.11	1.07	16.04	10.98	9.38	1.45	3.55	0.51	2.32
Wet 2005	37.47	0.01	7.82	1.25	17.08	13.32	10.74	1.56	4.12	0.59	-0.97
Wet 2006	34.29	0.06	2.39	1.05	16.36	6.69	9.23	1.37	1.34	0.59	2.13
Wet 2007	26.77	0.17	0.06	1.16	16.62	0.16	4.85	1.69	0.06	0.50	4.29
Average Wet	31.98	0.05	3.97	1.08	16.06	7.39	8.51	1.48	2.12	0.53	0.92
Dry 2003	32.81	0.89	0.75	1.83	21.24	1.52	5.01	3.70	0.35	0.84	3.59
Dry 2004	25.01	1.13	0.45	2.17	20.66	0.42	4.89	4.13	0.25	0.80	-2.40
Dry 2005	37.61	1.32	1.42	2.23	21.21	4.97	5.71	4.49	0.89	0.91	4.35
Dry 2006	19.86	1.79	1.58	2.37	19.43	0.94	5.02	4.93	0.92	0.95	-6.60
Dry 2007	14.35	2.55	0.12	2.20	19.00	-0.09	0.72	5.49	0.03	0.79	-6.71
Average Dry	25.93	1.54	0.86	2.16	20.31	1.55	4.27	4.55	0.49	0.86	-1.56

Table 2-4. Seasonal Water Budget for Rookery Bay Watershed

Season	Inflows (inches)				Outflows (inches)						Storage (inches)
	Precipitation	Irrigation	Overland Boundary Inflow	Aquifer Boundary Inflow	Evapo-Transpiration	Runoff to River	Baseflow to River	Pumping	Overland Boundary Outflow	Aquifer Boundary Outflow	Storage Change
Wet 2002	19.89	0.16	0.16	0.95	16.42	0.19	1.45	0.16	0.98	0.91	1.05
Wet 2003	33.15	0.02	0.92	0.80	16.13	9.52	3.38	0.02	4.66	1.48	-0.52
Wet 2004	30.46	0.09	0.67	1.02	16.94	4.76	3.23	0.09	2.51	1.31	3.19
Wet 2005	31.48	0.04	0.80	0.99	17.25	7.19	4.04	0.09	3.44	1.72	-0.69
Wet 2006	31.82	0.05	0.69	1.00	17.17	5.11	3.32	0.06	2.82	1.41	3.51
Wet 2007	26.51	0.17	0.22	1.15	17.41	0.43	1.15	0.17	1.00	1.01	6.83
Average Wet	28.88	0.09	0.58	0.99	16.89	4.53	2.76	0.10	2.57	1.31	2.23
Dry 2003	29.23	1.02	0.55	2.07	24.15	0.24	1.62	1.02	1.26	1.79	2.79
Dry 2004	23.84	0.84	0.56	2.17	25.13	0.03	2.19	0.84	0.88	2.07	-3.72
Dry 2005	35.71	1.08	0.82	2.39	24.10	3.22	2.15	1.13	2.62	2.17	4.56
Dry 2006	19.09	1.19	0.69	2.45	24.13	0.24	2.12	1.27	0.73	2.30	-7.40
Dry 2007	16.28	1.48	0.68	2.69	24.17	-0.10	0.89	1.48	0.58	1.79	-7.67
Average Dry	24.83	1.12	0.66	2.35	24.34	0.72	1.80	1.15	1.21	2.03	-2.29

Table 2-5. Seasonal Water Budget for Faka Union, Fakahatchee and Okaloacoochee-SR29 Watersheds

Season	Inflows (inches)				Outflows (inches)						Storage (inches)
	Precipitation	Irrigation	Overland Boundary Inflow	Aquifer Boundary Inflow	Evapo-Transpiration	Runoff to River	Baseflow to River	Pumping	Overland Boundary Outflow	Aquifer Boundary Outflow	Storage Change
Wet 2002	20.59	0.00	0.12	1.73	16.50	0.16	4.41	0.47	0.24	0.51	0.16
Wet 2003	29.37	0.00	6.57	1.81	15.98	8.31	8.66	0.43	3.07	1.06	0.31
Wet 2004	32.52	0.00	7.28	1.85	16.65	9.02	8.15	0.43	2.80	1.02	3.58
Wet 2005	33.19	0.00	9.45	1.69	17.17	12.32	11.02	0.55	3.70	1.30	-1.69
Wet 2006	32.17	0.00	4.21	1.73	17.05	7.05	8.07	0.59	2.36	1.02	2.01
Wet 2007	26.77	0.00	0.12	1.54	17.24	0.31	4.88	0.59	0.28	0.67	4.41
Average Wet	29.10	0.00	4.63	1.73	16.77	6.19	7.53	0.51	2.07	0.93	1.46
Dry 2003	27.44	0.08	0.08	3.86	23.70	0.00	3.31	1.14	0.24	0.98	2.05
Dry 2004	23.94	0.12	0.24	4.06	23.98	0.24	5.91	1.10	0.31	1.18	-4.37
Dry 2005	34.33	0.12	1.54	4.06	23.43	2.32	4.61	1.42	1.10	1.22	5.98
Dry 2006	19.88	0.16	0.59	4.21	23.19	0.39	4.92	1.57	0.24	1.14	-6.69
Dry 2007	19.13	0.20	0.04	3.90	23.39	-0.28	2.40	1.61	0.16	1.18	-5.20
Average Dry	24.94	0.13	0.50	4.02	23.54	0.54	4.23	1.37	0.41	1.14	-1.65

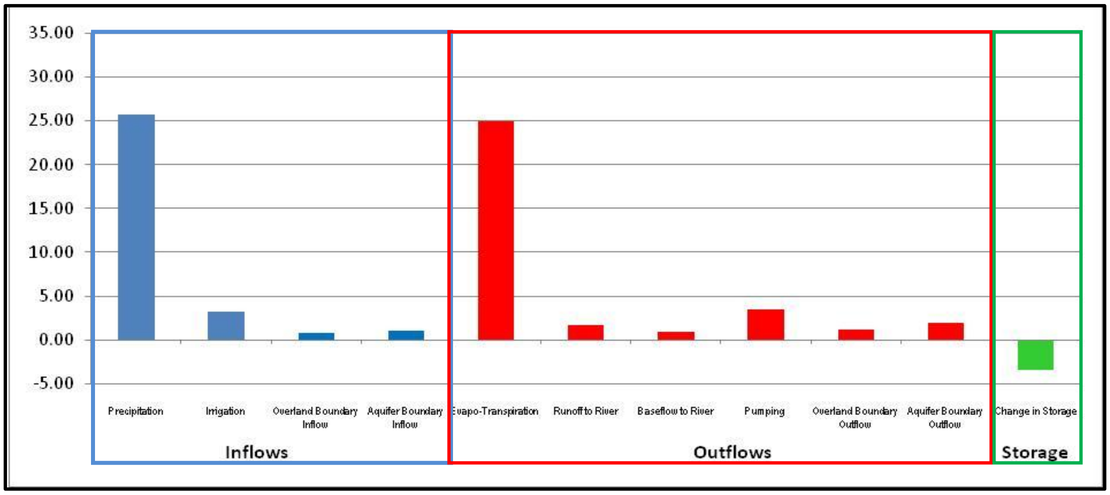


Figure 2-10. Average Dry Season Water Budget – Cocohatchee-Corkscrew Watershed

Runoff flow contributions from natural areas are small because the majority is stored in the Corkscrew Swamp. In addition, there is a large component of overland runoff flow that leaves the Cocohatchee-Corkscrew watershed and enters the Golden Gate–Naples Bay, Okaloacoochee-SR 29, Fakahatchee, and Faka Union watersheds during large rainfall events due to the little difference in elevation at the watershed ridges. In terms of baseflow, the amount relative to runoff is only half of that computed for the entire study area. This can be attributed to the low density of canals in the watershed.

Golden Gate-Naples Bay Watershed. The water budgets for the Golden Gate watershed are shown in **Figures 2-11 through 2-13** and in **Table 2-3**. The most important feature of this watershed is that baseflow is the primary source of water to the canal network. It often exceeds 70 percent of the canal flow during the dry season. This can be attributed to the density of canals throughout the drainage area. Reducing baseflow to the canal network could have a significant effect on the volume of water discharging to the Naples Bay Estuary.

Runoff exceeds 19 percent of rainfall and occurs primarily during the rainy season. As in the Cocohatchee–Corkscrew watershed, most of the runoff is from urban development close to the coast. The volume of water leaving the watershed via overland and aquifer flow is low and is directly influenced by the presence of the canal network that drains the Water Table Aquifer and directs water to the estuary systems.

Rookery Bay Watershed. The Rookery Bay watershed is diverse with urban development located west of the Henderson Creek Canal. The central portion of the watershed is mostly natural and consists of the Henderson Strand and portions of the Picayune Strand State Forest. The southeast portion of the watershed is agricultural. In general, the percentage of runoff relative to precipitation

(11 percent) is low compared to the other watersheds. The low runoff value is most likely associated to the lack of development in large parts of the watershed.

The seasonal water budget results shown in **Figures 2-14–16** and **Table 2-4** indicate that surface runoff makes up 60 percent of canal flow during the wet season. However, during the dry season, baseflow contributions often exceed 70 percent of canal flow. Wet season runoff occurs primarily from the urbanized and agricultural areas; while dry season baseflow contributions occur primarily in the Henderson Creek Canal.

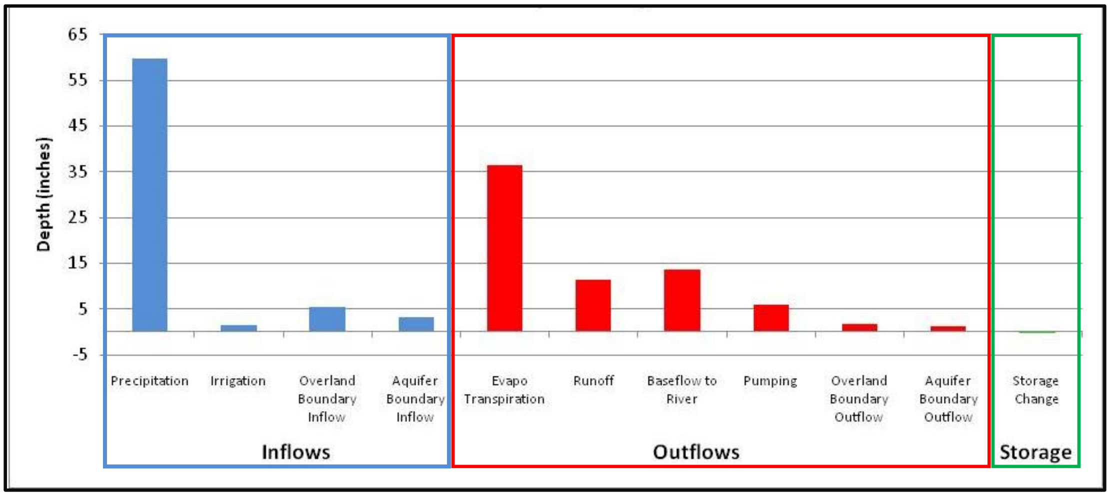


Figure 2-11. Average Water Year Budget–Golden Gate-Naples Bay Watershed

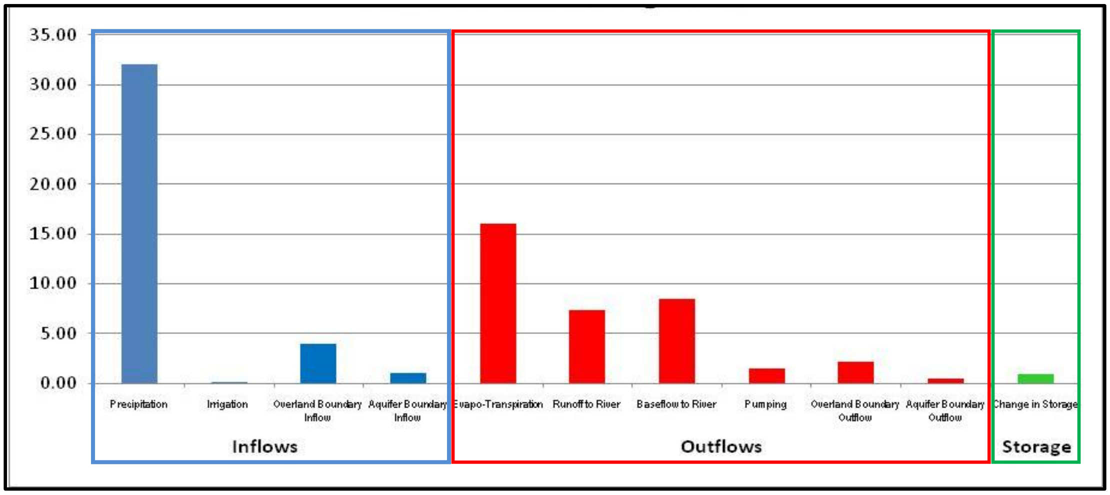


Figure 2-12. Average Wet Season Water Budget – Golden Gate-Naples Bay Watershed

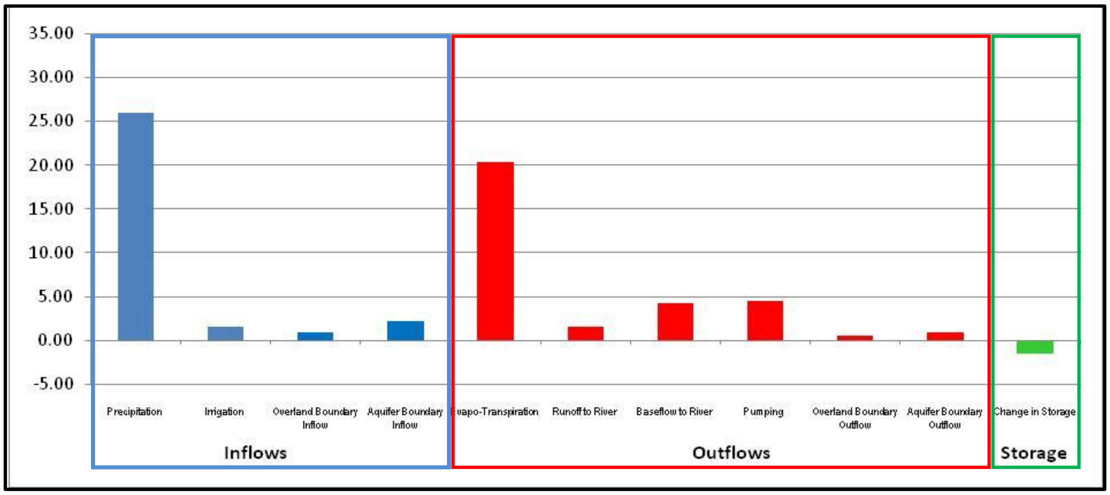


Figure 2-13. Average Dry Season Water Budget – Golden Gate-Naples Bay Watershed

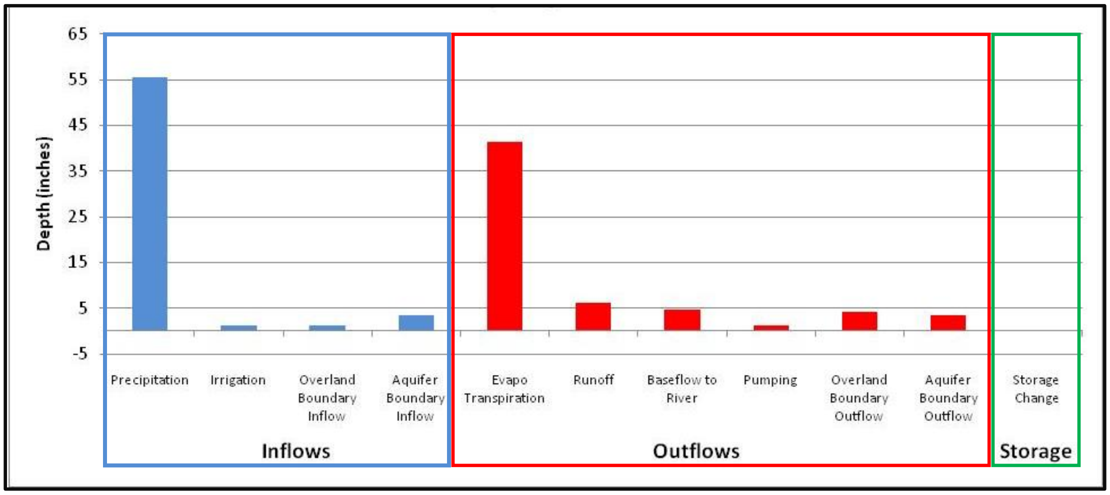


Figure 2-14. Average Annual Water Budget – Rookery Bay Watershed

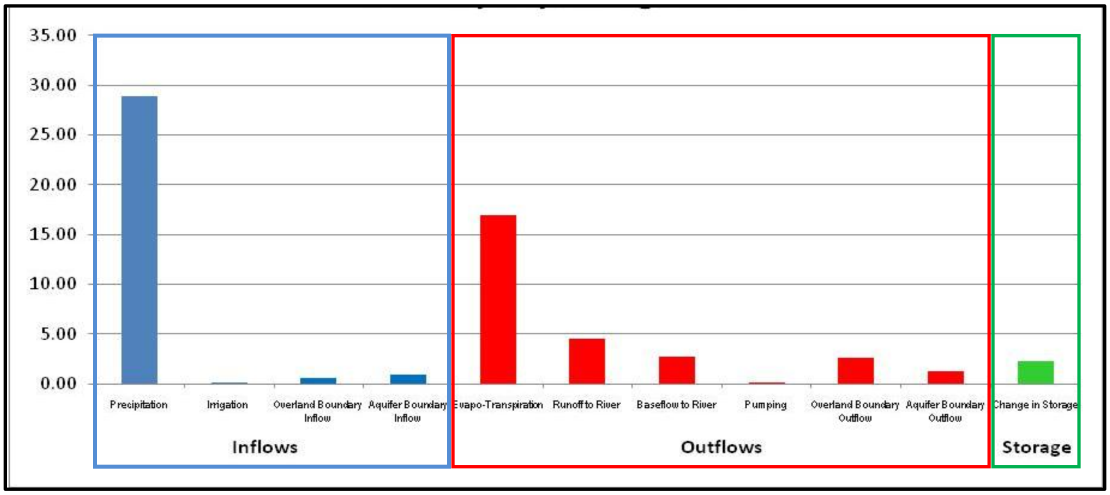


Figure 2-15. Average Wet Season Water Budget – Rookery Bay Watershed

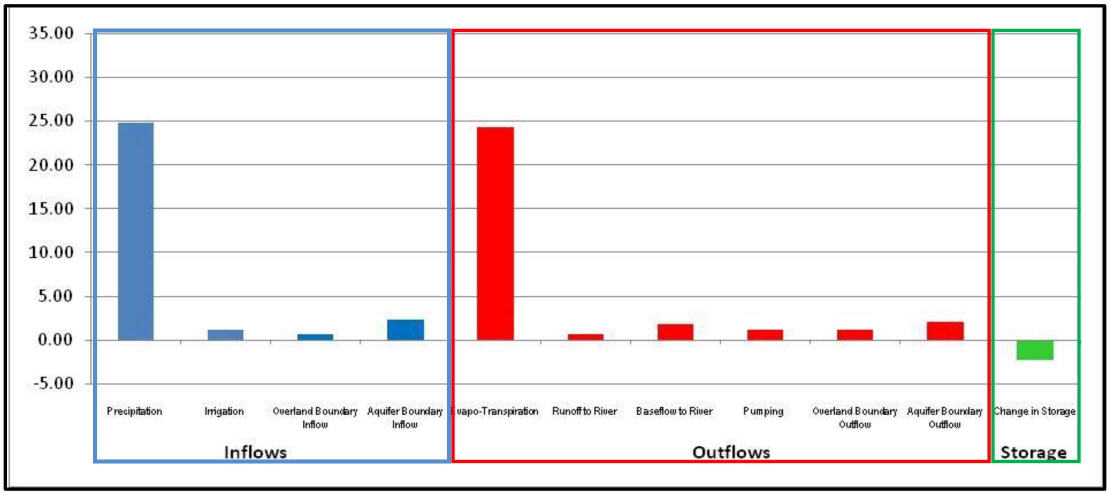


Figure 2-16. Average Dry Season Water Budget – Rookery Bay Watershed

Faka Union, Fakahatchee, and Okaloacoochee–SR29 Watersheds. The water year and seasonal water budgets for the Faka Union, Fakahatchee, and Okaloacoochee-SR29 watersheds are shown in **Figures 2-17–2-19** and in **Table 2-5.** There are a large percentage of agricultural lands in the northern portion of the Fakahatchee and Okaloacoochee-SR29 watersheds; whereas, the northern part of the Faka Union watershed includes rural residential areas. The remainder of the watershed consists of wetlands or other natural areas; however, portions of the Golden Gate Canal network drain large portions of the natural areas in the southern Faka Union watershed.

In the wet season, baseflow in these watersheds is equal to approximately 120 percent of runoff, but during the dry season, the volume of baseflow is more than 7.5 times that of runoff. The model results indicate that baseflow occurs primarily in the Faka Union watershed, although there are baseflow contributions to the State Road 29 Canal in the Okaloacoochee–SR29 watershed. It is Atkins opinion that the Picayune Strand Restoration Project will greatly reduce the volume of baseflow in these combined watersheds.

The water budget results indicate a slight loss in stored water over the model simulation period. The results suggest that this loss is most likely attributed to the high baseflow contributions to the canal network in the Faka Union watershed, although groundwater pumping for potable water supply and agricultural irrigation in the northern parts of the watershed may contribute to loss of water.

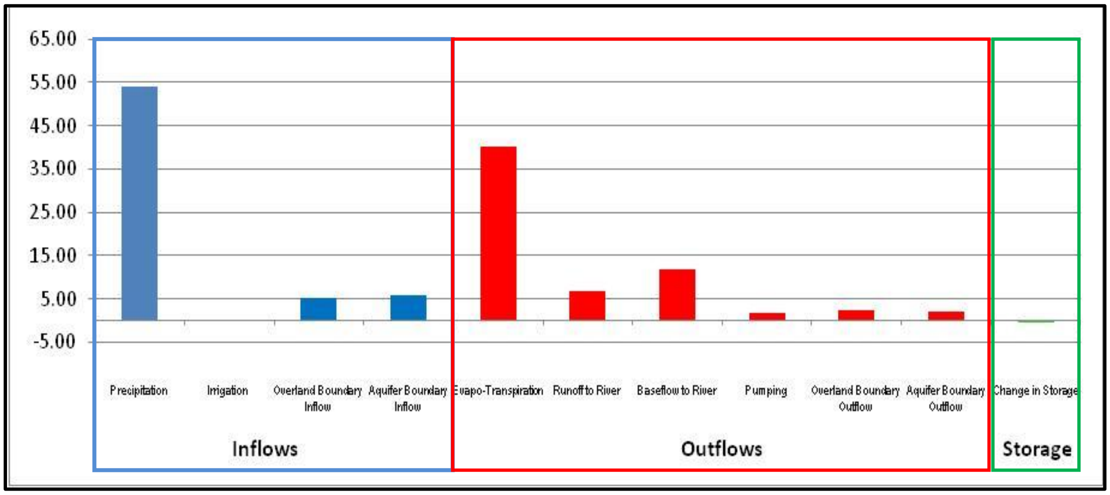


Figure 2-17. Average Water Year Budget – Faka Union, Fakahatchee, and Okaloacoochee-SR29 Watersheds

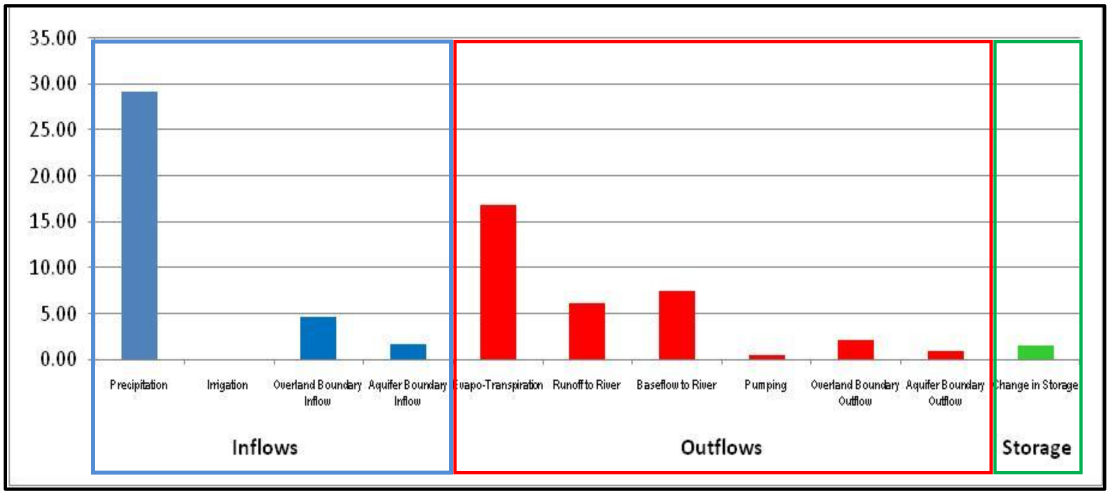


Figure 2-18. Average Wet Season Water Budget – Faka Union, Fakahatchee, and Okaloacoochee-SR29 Watersheds

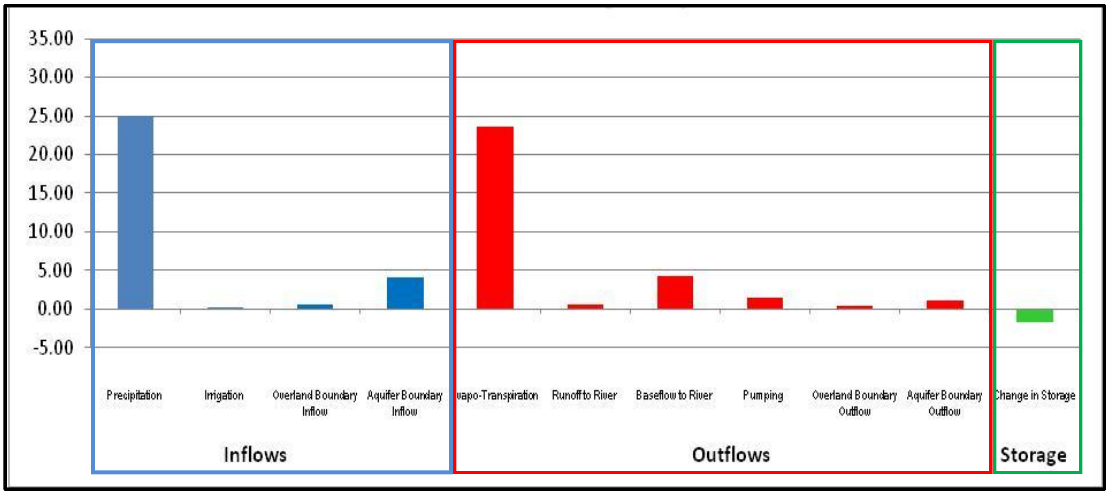


Figure 2-19. Average Dry Season Water Budget – Faka Union, Fakahatchee, and Okaloacoochee-SR29 Watersheds

2.1.5 Baseflow and Structure Operations

The water budget discussion indicated the relative importance of baseflow in the individual watersheds. **Figures 2-20 and 2-21** show the average baseflow contribution to the individual drainage features. The maps indicate that the wetland area in the Okaloacoochee Slough, Camp Keais Strand, and the Corkscrew Swamp provides groundwater recharge (negative baseflow) on a year round basis. The maps also indicate that significant baseflow contributions to the canal network occur especially in the Golden Gate and Faka Union watersheds. It is expected that completion of the Picayune Strand Restoration Project will greatly reduce the baseflow contributions in the Faka Union watershed; therefore, the remainder of this discussion will focus on baseflow and structure operations in the Golden Gate-Naples Bay Watershed.

A comparison of baseflow during the wet and dry seasons in the Golden Gate-Naples Bay Watershed indicates that substantially more baseflow occurs during the wet season than during the dry. The water budget analysis showed that 8.51 inches of baseflow occurs in the Golden Gate-Naples Bay Watershed during the wet season compared to 4.27 inches during the dry season.

Figure 2-22 and **Figure 2-23** show the average wet season and dry season baseflow contributions in the Golden Gate-Naples Bay Watershed. It is interesting to note that during the dry season, recharge (negative baseflow) is predicted to occur in several locations immediately upstream of operable gates, or near shallow potable water supply well fields. The greatest volume of dry season recharge occurs immediately north of the CR951-1 structure which includes a pump to divert water from the Golden Gate Main Canal into the CR951 Canal. The results shown in **Figure 2-23** suggest that water pumped into the CR951 Canal is returning to the Golden Gate Main Canal via baseflow. Groundwater recharge influenced by pumping for potable water supply is also observed in the dry season near the GG-4 structure.

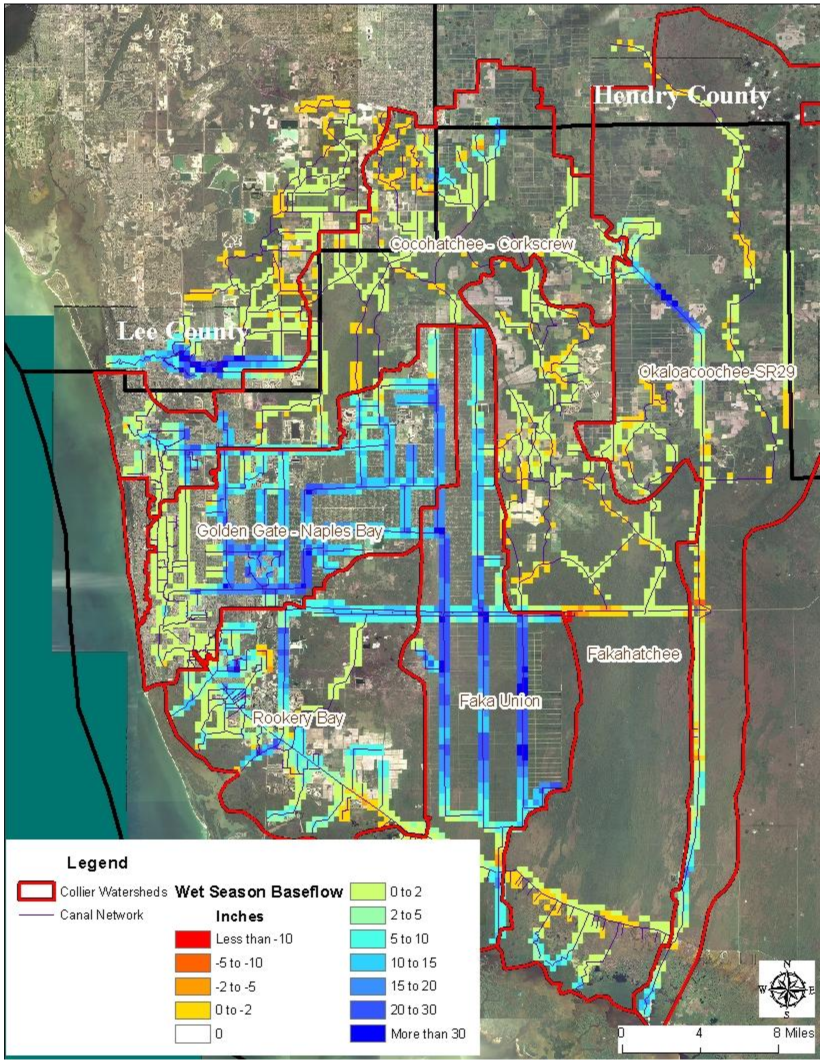


Figure 2-20. Average Wet Season Baseflow Contributions

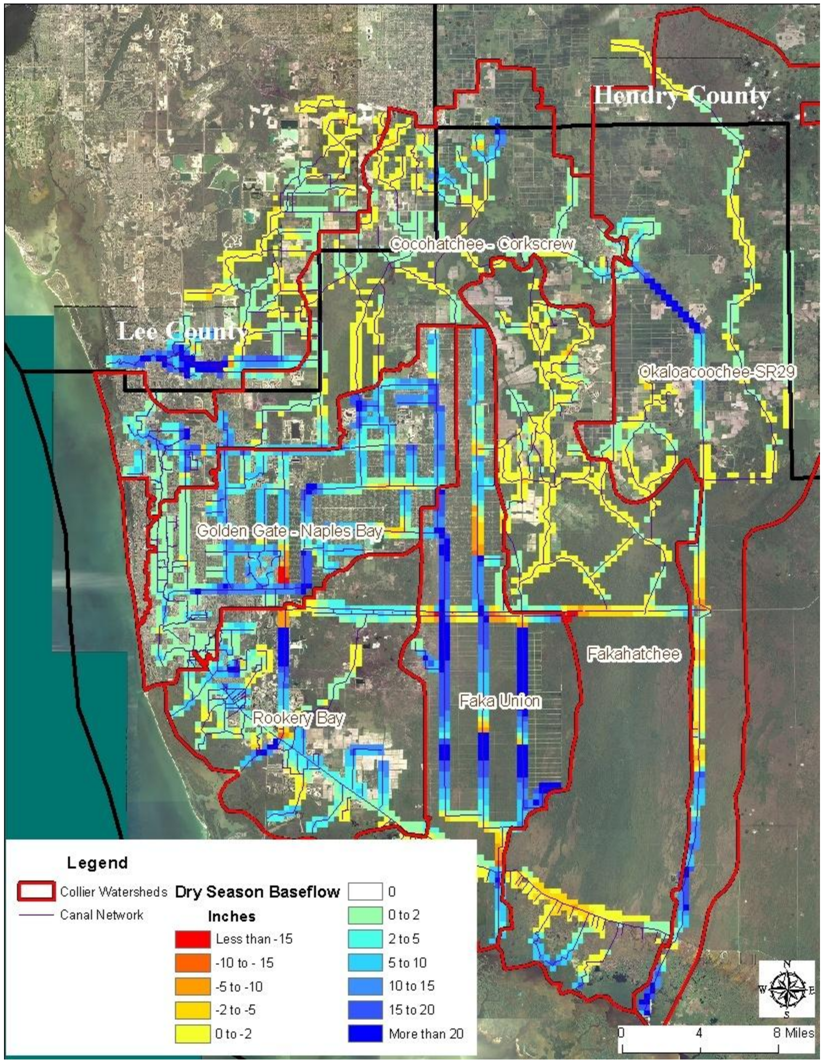


Figure 2-21. Average Dry Season Baseflow Contributions

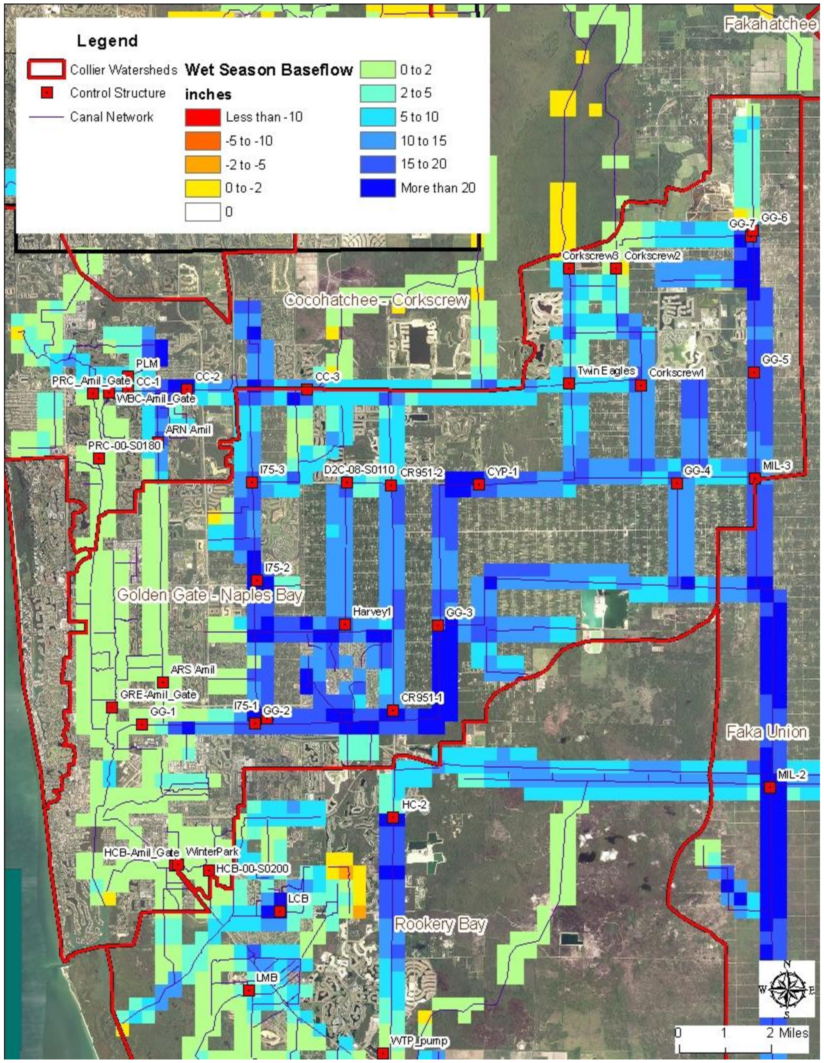


Figure 2-22. Average Wet Season Baseflow Contributions Golden Gate Watershed

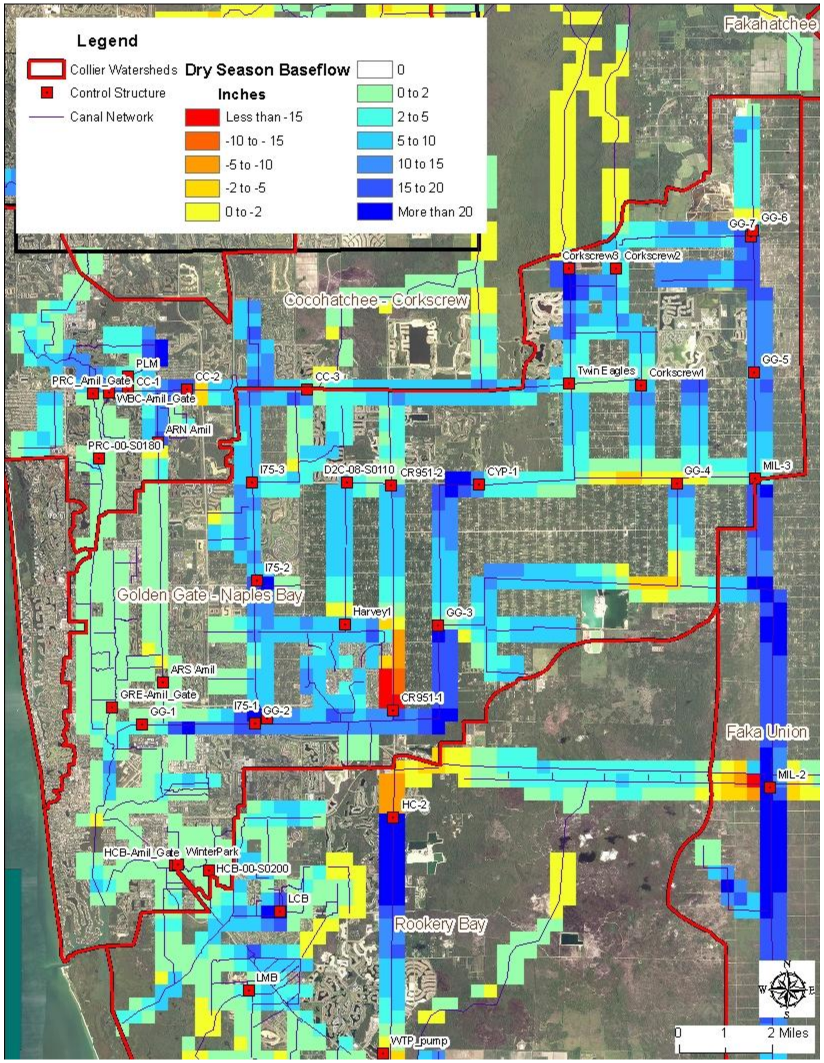


Figure 2-23. Average Dry Season Baseflow Contributions Golden Gate Watershed

The maps also show that the highest predicted baseflow values occur immediately downstream of the operable structures and that baseflow decreases along the canal toward the next downstream structure. This is most evident along the Cypress Canal segment between structures CYP-1 and GG-3. This pattern of baseflow along the length of a canal segment is the result of staging water at different elevations upstream of each structure.

It should be noted that the ECM was setup to replicate the standard operating rules defined by the SFWMD for each structure. These rules primarily rely upon the water levels upstream and downstream of the individual structures and are designed to stage water at different elevations for the wet and dry seasons and may contribute to the seasonal difference in baseflow. During the wet season, the structures are operated to stage the canals at an elevation that is approximately one foot (1 ft) lower than the dry season. The lower elevation, paired with higher groundwater elevations due to rainfall, leads to an increase in baseflow.

Figure 2-24 shows the typical relationship between baseflow and the difference in groundwater and canal water surface elevation in the Cypress Canal. The data clearly indicate that managing canal stage to match groundwater elevations is important to reducing the volume of baseflow entering the canal network. It is our understanding that the existing structures are physically limited in their ability to stage water at a higher elevation within the canal network. It is recommended that the design of new and replacement structures consider seasonal groundwater head elevation data. The ability to more closely match canal stage and the groundwater head elevation will have long-term benefits to reduce baseflow to the canal network.

2.1.6 Analysis of Canal Conveyance Capacity

Model simulation results using the SFWMD design storm events were conducted to assess the conveyance capacity of the existing canals. To evaluate canal capacity, the maximum predicted water surface elevation at each cross-section in the canal was compared to the top of bank elevation at those locations. The water level is defined as “Out of Bank” if the predicted elevation is higher than that at one or both of the canal banks.

An important simulation parameter is the establishment of the model’s initial conditions. For this analysis it was assumed that the water elevations in the canals prior to the beginning of the storm were those that occurred in September 4, 2004, after Hurricane Charley and prior to Hurricane Francis. That assumption is consistent with numerous recent H&H studies in Florida because it is representative of a historical period when large back-to-back precipitation events occurred.

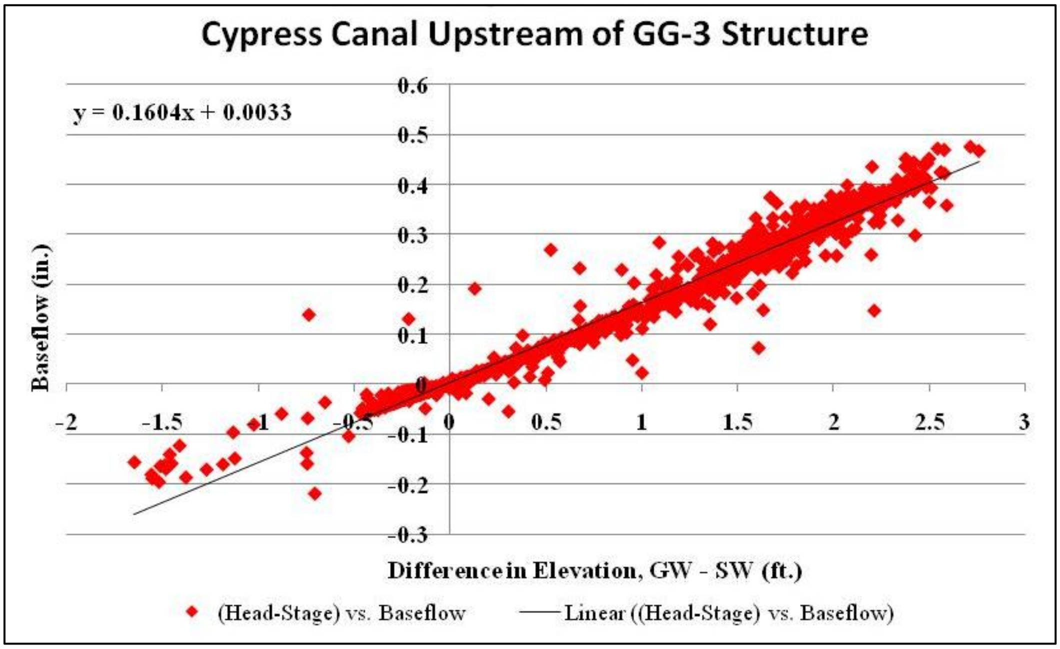


Figure 2-24. Relationship of Baseflow and (Head–Stage) Elevation Difference

The SFWMD has established emergency canal management protocols that require that the structures be opened and the water levels in the canal network be lowered prior to large storm events to provide additional canal conveyance to mitigate the risk of flooding. Therefore, for the design storm simulations, structure operations were modified to open all operable gates 72 hours prior to the storm event.

The next step was to determine the flow rate in the existing canal network just prior to the out of bank conditions. However, since flow conditions may change within a given canal due to inflows from other canals and structure operations, each canal was divided into smaller segments. The segments are defined by structure locations and junctions with other canals. For each segment, model results were reviewed to determine if out of bank conditions exist for each of the design storms. At the time step when out of bank conditions in the canal network occurred, the predicted flow was extracted from the model results.

Figure 2-25 shows the locations where overtopping is predicted to occur during the 5-year, 72-hour hour storm event. The results for the 10-, 25-, and 100-year storm events are very similar indicating that canal overtopping would occur at the low lying areas. Most of the overtopping occurs in wetland areas where inundation is expected to occur. However, the results also indicate areas along the Cocohatchee Canal and within the Golden Gate–Naples Bay and Rookery Bay watersheds that may be subject to flooding conditions due to limited canal conveyance capacity.

Table 2-6 specifies the predicted flow in each of the existing canal segments and identifies the smallest storm when out of bank conditions are predicted to occur. The results indicate that the canal networks that provide drainage to many areas of Collier County are at risk of flooding during the 5-yr/72-hour return period storm event. The overall results show that future development would worsen an already difficult condition unless management strategies are established to mitigate flooding risks.

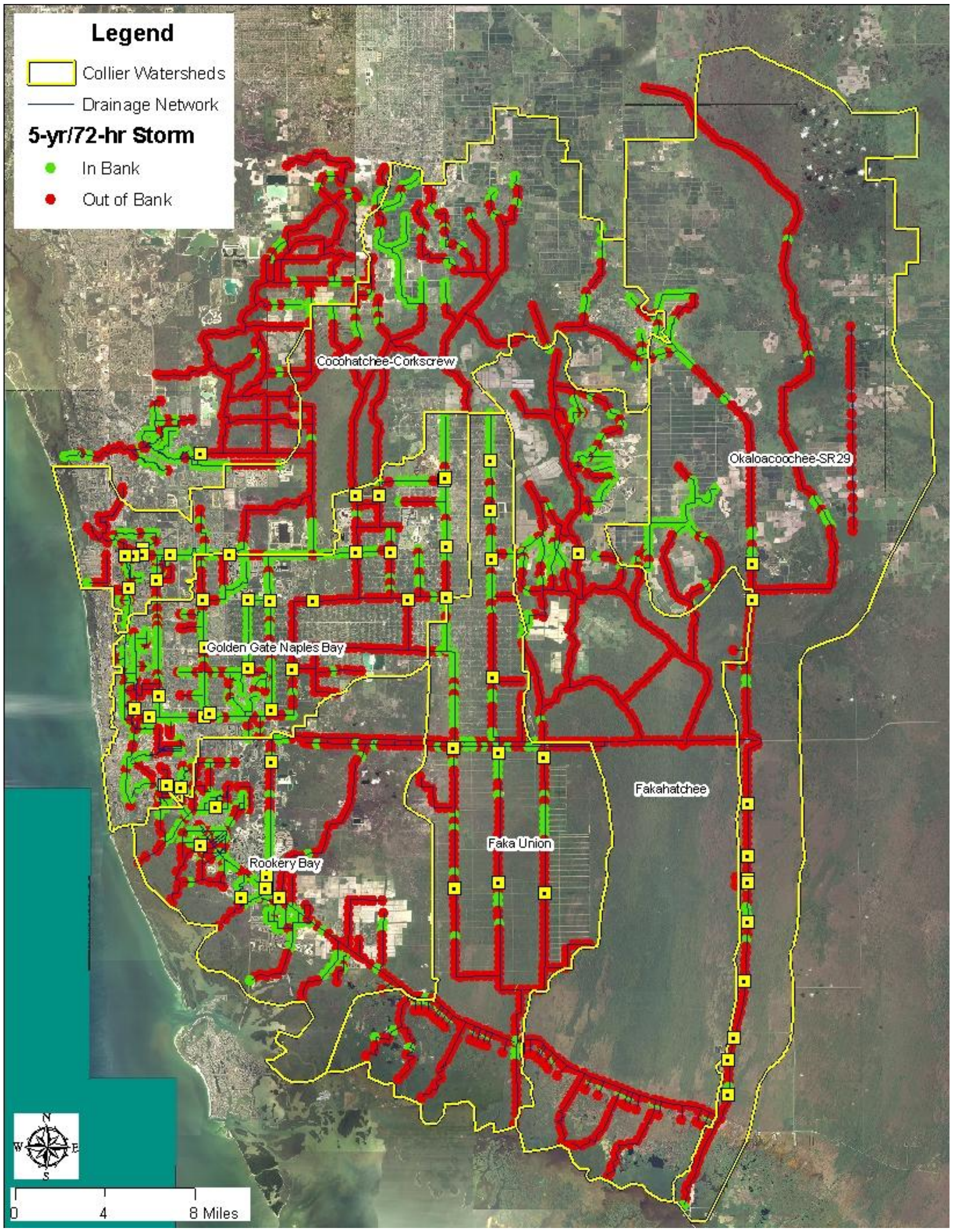


Figure 2-25. Bank Overtopping Locations for the 5-yr, 72-hr Storm Event

Table 2-6. Predicted Flow Just Prior to Canal Segment Failure

Storm Sub-Basin	Segment Name	Upstream End of Segment	Downstream End of Segment	Return Period Storm Causing Failure				Predicted 5-year Flow at Failure
				5-yr/ 72-hr	10-yr/ 72-hr	25-yr/ 72-hr	100-yr/ 72-hr	cfs
951 Canal Central	CR951	Control Structure CR951-2	Control Structure CR951-1	✓				496.34
951 Canal North	CR951	Junction with Cocohatchee Canal	Control Structure CR951-2	✓				123.42
Airport Road North Canal	Airport Road Canal-01	Junction with Airport Road Canal-02	Junction with AirportRdN	✓				21.75
Airport Road North Canal	AirportRdN	Control Structure ARN Amil	Junction with AirportRdS	✓				308.19
Airport Road North Canal	AirportRdN	Junction with Cocohatchee West	Control Structure ARN Amil	✓				323.77
Airport Road South Canal	AirportRdS	Junction with AirportRdN	Weir-Cross_Air1	✓				485.60
Airport Road South Canal	AirportRdS	Weir-Cross_Air1	Junction with AirportRdS	✓				695.89
Airport Road South Canal	AirportRdS	Junction with AirportRdS	Control Structure ARS_Amil	✓				681.51
Airport Road South Canal	AirportRdS	Control Structure ARS Amil	Junction with Golden Gate Main Canal	✓				1007.79
C-4	C-4_Canal-00	Weir C4C-00-S0170	Control Structure C4C-00-S0110_Eagle Creek Road	✓				326.70
Cocohatchee River Canal	Cocohatchee Canal-06	Upstream end of Branch	Junction with CocohatcheeWest	✓				355.22
Cocohatchee River Canal	CocohatcheeWest	Junction with Cocohatchee East	Junction with CocohatcheeWestN	✓				195.27
Cocohatchee River Canal	CocohatcheeWest	Junction with CR951	Control Structure CC-3	✓				268.11

Storm Sub-Basin	Segment Name	Upstream End of Segment	Downstream End of Segment	Return Period Storm Causing Failure				Predicted 5-year Flow at Failure
				5-yr/ 72-hr	10-yr/ 72-hr	25-yr/ 72-hr	100-yr/ 72-hr	cfs
Cocohatchee River Canal	CocohatcheeWest	Control Structure CC-3	Junction with I-75Can	✓				489.80
Cocohatchee River Canal	CocohatcheeWest	Junction with I-75 Canal	Control Structure CC-2	✓				1163.92
Cocohatchee River Canal	CocohatcheeWest	Control Structure CC-2	Junction with AirportRdN	✓				1298.25
Cocohatchee River Canal	CocohatcheeWest	Junction with AirportRdN	Control Structure CC-1	✓				1680.12
Cocohatchee River Canal	CocohatcheeWest	Control Structure CC-1	Junction with Palm River Canal	✓				1631.39
Corkscrew Canal	CocohatcheeEast	Junction with Corkscrew1	Control Structure Twin Eagles	✓				113.07
Corkscrew Canal	Cork2	Junction with CorkTribCan	Junction with Corkscrew Canal-01					
Corkscrew Canal	Corkscrew Canal-00	Upstream end of Branch	Junction with Corkscrew					
Corkscrew Canal	Corkscrew Canal-01	Junction with Cork2	Junction with Cocohatchee East	✓				203.43
Corkscrew Canal	CorkScrew Canal	Junction with Corkscrew	Control Structure Corkscrew2					
Corkscrew Canal	CorkScrew Canal	Control Structure Corkscrew2	Junction with Corkscrew Canal					
Corkscrew Canal	CorkScrew Canal	Junction with CorkTribCan	Junction with Cork2	✓				86.49
Corkscrew Canal	CorkScrew Canal	Junction with Cork2	Junction with Corkscrew Canal-02	✓				221.68
Corkscrew Canal	CorkScrew Canal	Junction with Corkscrew Canal-02	Control Structure Corkscrew1	✓				516.23
Corkscrew Canal	CorkScrew Canal	Control Structure Corkscrew1	Junction with Cypress Canal	✓				698.29

Storm Sub-Basin	Segment Name	Upstream End of Segment	Downstream End of Segment	Return Period Storm Causing Failure				Predicted 5-year Flow at Failure
				5-yr/ 72-hr	10-yr/ 72-hr	25-yr/ 72-hr	100-yr/ 72-hr	cfs
Corkscrew Canal	CorkTribCan	Control Structure Corkscrew3	Junction with CorkTribCanal	✓				
Corkscrew Canal	CorkTribCan	Junction with CorkscrewTribCan	Junction with Corkscrew Canal					
Cypress Canal	Curry Canal	Junction with CocohatcheeEast	Junction with Cypress Canal	✓				90.95
Cypress Canal	Cypress Canal	Junction with Golden Gate Main Canal	Junction with Corkscrew Canal	✓				623.32
Cypress Canal	Cypress Canal	Junction with Corkscrew Canal	Junction with Curry Canal	✓				47.22
Cypress Canal	Cypress Canal	Junction with Curry Canal	Control Structure CYP-1	✓				308.78
Cypress Canal	Cypress Canal	Control Structure CYP-1	Junction with Golden Gate Main Canal	✓				615.76
West Branch Cocohatchee	West Branch Cocohatchee River	Upstream end of Branch	Control Structure WBC-00-S0110	✓				50.03
Faka Union Canal	Faka Union Canal	Upstream end of Branch	Control Structure FU-7	✓				393.38
Faka Union Canal	Faka Union Canal	Control Structure FU-7	Control Structure FU-6	✓				806.48
Faka Union Canal	Faka Union Canal	Control Structure FU-6	Control Structure FU-5	✓				1208.51
Faka Union Canal	Faka Union Canal	Control Structure FU-5	Junction with Faka-Union Canal-04	✓				1159.90
Faka Union Canal	Faka Union Canal	Junction with Faka-Union_Canal-04	Control Structure FU-4	✓				1589.53
Faka Union Canal	Faka Union Canal	Control Structure FU-4	Control Structure FU-3	✓				1877.55
Gateway Triangle	GTB	Upstream end of Branch	Discharge to Naples Bay	✓				79.30

Storm Sub-Basin	Segment Name	Upstream End of Segment	Downstream End of Segment	Return Period Storm Causing Failure				Predicted 5-year Flow at Failure
				5-yr/ 72-hr	10-yr/ 72-hr	25-yr/ 72-hr	100-yr/ 72-hr	cfs
Gordon River Extension	Gordon River Extension_0	Upstream end of Branch	Junction with Gordon River Extention_0	✓				601.87
Gordon River Extension	Gordon River Extension_0	Junction with Gordon River Extention_0	Junction with Gordon River Extention_9	✓				183.27
Gordon River Extension	Gordon River Extension_9	Junction with Gordon River Extention_9	Control Structure GRE-00-S0100	✓				53.76
Gordon River Extension	Gordon River Extension_0	Control Structure GRE-00-S0100	Junction with Gordon River Extention_1	✓				748.28
Gordon River Extension	Gordon River Extension_0	Junction with Gordon River Extention_1	Junction with Golden Gate Main Canal	✓				123.65
Gordon River Extension	Gordon River Extension_1	Weir GRE-01-S0510	Weir GRE-01-S0480	✓				163.45
Gordon River Extension	Gordon River Extension_1	Weir GRE-01-S0480	Junction with Gordon River Extension__1	✓				63.00
Gordon River Extension	Gordon River Extension_1	Junction with Gordon River Extension_1	Junction with Gordon River Extension_3	✓				14.23
Gordon River Extension	Gordon River Extension_1	Junction with Gordon River Extension_3	Junction with Gordon River Extention_0	✓				0.68
Gordon River Extension	Gordon River Extension_0	Upstream end of Branch	Junction with Gordon River Extension_41	✓				25.80
Gordon River Extension	PRC Connection	Junction with Gordon River Extension_1	Junction with Pine Ridge Canal_00	✓				3.94
Green Canal	Green Canal	Upstream end of Branch	Junction with Sunshine Canal	✓				41.08
Green Canal	Green Canal	Junction with Sunshine Canal	Junction with Harvey Canal	✓				459.06
Green Canal	Harvey Canal	Weir Harvey1	Junction with Neptune Canal	✓				523.15

Storm Sub-Basin	Segment Name	Upstream End of Segment	Downstream End of Segment	Return Period Storm Causing Failure				Predicted 5-year Flow at Failure
				5-yr/ 72-hr	10-yr/ 72-hr	25-yr/ 72-hr	100-yr/ 72-hr	cfs
Green Canal	Harvey Canal	Junction with Neptune Canal	Junction with I-75 Canal	✓				175.59
Green Canal	Hunter Canal	Upstream end of Branch	Junction with Harvey Canal	✓				5.53
Green Canal	Sunshine Canal	Upstream end of Branch	Junction with Green Canal	✓				64.72
Haldeman Creek	Haldeman Creek-00	Junction with Lely Canal Branch-10	Control Structure HCB-00-S0200	✓				394.65
Haldeman Creek	Haldeman Creek-00	Control Structure HCB-00-S0200	Control Structure HCB-00-S0130	✓				466.59
Haldeman Creek	Haldeman Creek_01	Weir HCB-01-S0100	Junction with Lely Canal Branch-00_1	✓				9.83
Haldeman Creek	Haldeman Creek_01	Junction with Haldeman Creek-00	Weir ID HCB-01-S0100	✓				91.54
Haldeman Creek	Haldeman Creek_00	Control Structure HCB-00-S0130	Discharges to Naples Bay	✓				400.62
Haldeman Creek	Haldeman Creek_09	Upstream end of Branch	Junction with Haldeman Creek-00	✓				9.04
Harvey Canal	Harvey Canal-00	Control Structure D2C-08-S0110	Junction with Harvey Canal	✓				277.69
Harvey Canal	Harvey Canal	Junction with Harvey Canal	Control Structure Harvey1	✓				621.90
Henderson Creek	Henderson Creek Canal	Junction with I75-Block1	Control Structure HC-2	✓				240.68
Henderson Creek	Henderson Creek Canal	Control Structure HC-2	Control Structure HC-1	✓				491.32
I-75 Canal	I-75 Canal_06	Junction with CocohatcheeWest	Weir D2C-07-S0100	✓				74.47
I-75 Canal	I-75 Canal_06	Weir D2C-07-S0100	Junction with I-75Can	✓				157.00

Storm Sub-Basin	Segment Name	Upstream End of Segment	Downstream End of Segment	Return Period Storm Causing Failure				Predicted 5-year Flow at Failure
				5-yr/ 72-hr	10-yr/ 72-hr	25-yr/ 72-hr	100-yr/ 72-hr	cfs
I-75 Canal	I-75 Canal_04	Upstream end of Branch	Junction with I-75Can	✓				69.99
951 Canal North	I-75 Canal_08	Junction with CR951	Structure ID D2C-08-S0110	✓				145.35
I-75 Canal	I-75 Canal_09	Upstream end of Branch	Weir Discharge_to_I75Can					
I-75 Canal	I-75 Canal	Junction with CocohatcheeWest	Control Structure I75-3	✓				203.28
I-75 Canal	I-75 Canal	Control Structure I75-3	Junction with I-75 Canal_04	✓				481.11
I-75 Canal	I-75 Canal	Junction with I-75 Canal_04	Control Structure I75-2	✓				687.44
I-75 Canal	I-75 Canal	Control Structure I75-2	Junction with I-75 Canal_05	✓				991.97
I-75 Canal	I-75 Canal	Junction with I-75 Canal_05	Junction with I-75 Canal_03	✓				1472.26
I-75 Canal	I-75 Canal	Junction with I-75 Canal_03	Control Structure I75-1	✓				1056.90
Imperial Drainage Outlet	Imperial Drainage Outlet	Weir-like Feature in Canal	Junction with Cocohatchee West	✓				180.18
Island Walk (aka Harvey)	I-75 Canal_07	Upstream end of Branch	Inlet to Island Walk Pond System	✓				178.14
Island Walk (aka Harvey)	I-75 Canal_07	Inlet to Island Walk Pond System	Junction with I-75 Canal_06	✓				138.63
Lely Canal	Lely Canal Branch-00_1	Upstream end of Branch	Control Structure LCB-00-S0150	✓				150.25
Lely Canal	Lely Canal Branch-00_1	Control Structure LCB-00-S0150	Junction with Lely Canal Branch-01_1	✓				607.95
Lely Canal	Lely Canal Branch-00_1	Junction with Lely_Canal_Branch-01_1	Weir LCB-00-S0100	✓				1184.98

Storm Sub-Basin	Segment Name	Upstream End of Segment	Downstream End of Segment	Return Period Storm Causing Failure				Predicted 5-year Flow at Failure
				5-yr/ 72-hr	10-yr/ 72-hr	25-yr/ 72-hr	100-yr/ 72-hr	cfs
Lely Canal	Lely Canal Branch-01_1	Junction with Haldeman_Creek-00	Junction with Lely Canal Branch-00_1	✓				488.95
Lely Canal	Lely Canal Branch-01_2	Upstream end of Branch	Junction with Lely Canal Branch-09	✓				204.41
Lely Canal	Lely Canal Branch-01_2	Junction with Lely_Canal_Branch-09	Junction with Lely Canal Branch-10	✓				235.58
Lely Canal	Lely Canal Branch-02_1	Junction with Haldeman_Creek-00	Junction with Lely Canal Branch-00_1	✓				31.84
Lely Canal	Lely Canal Branch-09	Junction with Lely_Canal_Branch-01-2	Junction with Lely Canal Branch-10	✓				7.37
Lely Canal	Lely Canal Branch-10	Junction with Lely_Canal_Branch-09	Junction with Lely Canal Branch-01_1	✓				243.90
Lely Canal	Lely Canal Branch-11	Upstream end of Branch	Junction with Lely Canal Branch-00_1	✓				31.48
Lely Canal	Lely Canal Branch-15	Upstream end of Branch	Weir LCB-15-S0100	✓				165.21
Lely Manor Canal	C-4 Canal-01	Upstream end of Branch	Junction with C-4 Canal-02	✓				
Lely Manor Canal	C-4 Canal-02	Upstream end of Branch	Junction with C-4 Canal-03	✓				44.10
Lely Manor Canal	C-4 Canal-02	Junction with C-4_Canal-03	Junction with Lely Manor Canal-00	✓				3.65
Lely Manor Canal	Lely Manor Canal-00	Weir LMB-00-S0150	Junction with Lely Manor Canal-01-1	✓				147.09
Lely Manor Canal	Lely Manor Canal-00	Weir LMB-00-S0150	Junction with Lely Manor Canal-08	✓				13.68
Lely Manor Canal	Lely Manor Canal-01_2	Upstream end of Branch	Junction with Lely Manor Canal-03_1	✓				83.56

Storm Sub-Basin	Segment Name	Upstream End of Segment	Downstream End of Segment	Return Period Storm Causing Failure				Predicted 5-year Flow at Failure
				5-yr/ 72-hr	10-yr/ 72-hr	25-yr/ 72-hr	100-yr/ 72-hr	cfs
Lely Manor Canal	Lely Manor Canal-01_2	Junction with Lely Manor Canal-03_1	Junction with Lely Manor Canal-01-2	✓				288.83
Lely Manor Canal	Lely Manor Canal-03_1	Junction with Lely Manor Canal-08	Junction with Lely Manor Canal-01-2	✓				100.59
Lely Manor Canal	Lely Manor Canal-07_1A	Junction with Lely Manor Canal-08	Junction with Lely Manor Canal-11	✓				120.60
Lely Manor Canal	Lely Manor Canal-11	Upstream end of Branch	Junction with Lely Manor Canal-07_1A	✓				47.99
Lely Manor Canal	Lely Manor_Canal-11	Junction with Lely Manor Canal-07_1A	Junction with Lely Manor Canal-12_1	✓				24.95
Lely Manor Canal	Lely Manor Canal-12_1	Control Structure LMB-07-S0100	Discharges to Rookery Bay	✓				274.66
Lely Manor Canal	MCB-16	Upstream end of Branch	Junction with Lely Manor Canal-01-2	✓				4.02
Main Golden Gate Canal	C1 Connector Canal	Junction with Golden Gate Main Canal	Junction with Miller Canal	✓				48.67
Main Golden Gate Canal	Coronado Canal	Upstream end of Branch	Junction with Santa Barbara Canal	✓				19.55
Main Golden Gate Canal	Golden Gate Canal_09	Upstream end of Branch	Junction with Golden Gate Main Canal	✓				94.52
Main Golden Gate Canal	Golden Gate Canal _10	Upstream end of Branch	Junction with Golden Gate Canal_09	✓				145.65
Main Golden Gate Canal	Golden Gate Canal _12	Upstream end of Branch	Junction with Golden Gate Main Canal	✓				335.14
Main Golden Gate Canal	Golden Gate Canal _14	Upstream end of Branch	Weir MGG-14-S0100	✓				130.09
Main Golden Gate Canal	Golden Gate Canal _15	Upstream end of Branch	Junction with Golden Gate Main Canal	✓				62.82

Storm Sub-Basin	Segment Name	Upstream End of Segment	Downstream End of Segment	Return Period Storm Causing Failure				Predicted 5-year Flow at Failure
				5-yr/ 72-hr	10-yr/ 72-hr	25-yr/ 72-hr	100-yr/ 72-hr	cfs
Main Golden Gate Canal	Golden Gate Canal _16	Upstream end of Branch	Weir MGG-16-S0140	✓				112.68
Main Golden Gate Canal	Golden Gate Canal _16	Weir MGG-16-S0140	Junction with Golden Gate Main Canal	✓				61.82
Main Golden Gate Canal	Golden Gate Canal _18	Upstream end of Branch	Discharge to Naples Bay	✓				18.26
Main Golden Gate Canal	Golden Gate Branch	Upstream end of Branch	Control Structure GG-7	✓				414.44
Main Golden Gate Canal	Golden Gate Main Canal	Upstream end of Branch	Control Structure GG-6	✓				457.37
Main Golden Gate Canal	Golden Gate Main Canal	Control Structure GG-6	Junction with Golden Gate Canal_12	✓				1291.05
Main Golden Gate Canal	Golden Gate Main Canal	Junction with Golden Gate Canal_12	Control Structure GG-5	✓				1533.53
Main Golden Gate Canal	Golden Gate Main Canal	Control Structure GG-5	Junction with Miller Canal	✓				1827.24
Main Golden Gate Canal	Golden Gate Main Canal	Junction with Miller Can	Junction with Orange Tree Canal	✓				411.01
Main Golden Gate Canal	Golden Gate Main Canal	Junction with Orange Tree Canal	Control Structure GG-4	✓				788.53
Main Golden Gate Canal	Golden Gate Main Canal	Control Structure GG-4	Junction with C1-Connector	✓				936.60
Main Golden Gate Canal	Golden Gate Main Canal	Junction with C1-Connector	Junction with Golden Gate Canal_09	✓				845.06
Main Golden Gate Canal	Golden Gate Main Canal	Junction with Golden Gate Canal_09	Control Structure GG-3	✓				959.25
Main Golden Gate Canal	Golden Gate Main Canal	Control Structure GG-3	Junction with CR951	✓				504.22

Storm Sub-Basin	Segment Name	Upstream End of Segment	Downstream End of Segment	Return Period Storm Causing Failure				Predicted 5-year Flow at Failure
				5-yr/ 72-hr	10-yr/ 72-hr	25-yr/ 72-hr	100-yr/ 72-hr	cfs
Main Golden Gate Canal	Golden Gate Main Canal	Junction with CR951	Junction with Tropicana Canal	✓				670.27
Main Golden Gate Canal	Golden Gate Main Canal	Junction with Santa Barbara Canal	Junction with I-75Can	✓				1328.89
Main Golden Gate Canal	Golden Gate Main Canal	Junction with I-75Can	Control Structure GG-2	✓				3186.83
Main Golden Gate Canal	Golden Gate Main Canal	Control Structure GG-2	Junction with AirportRdS	✓				2480.48
Main Golden Gate Canal	Golden Gate Main Canal	Junction with AirportRdS	Control Structure GG-1	✓				4362.73
Main Golden Gate Canal	Golden Gate Main Canal	Control Structure GG-1	Discharges to Naples Bay	✓				3323.70
Main Golden Gate Canal	I-75_Canal_03	Upstream end of Branch	Junction with I-75Canal	✓				79.66
Main Golden Gate Canal	I75N-1	Weir I75N-Block1	Junction with Henderson Creek Canal	✓				41.64
Main Golden Gate Canal	Santa Barbara Canal	Junction with Coronado Canal	Junction with Tropicana Canal	✓				25.63
Main Golden Gate Canal	Tropicana Canal	Upstream end of Branch	Junction with Golden Gate Main Canal	✓				27.10
Miller Canal	Miller Canal	Control Structure MIL-3V notch	Junction with C1-Connector	✓				457.40
Miller Canal	Miller Canal	Junction with C1-Connector	Control Structure MIL-2	✓				823.19
Orange Tree Canal	Orange Tree Canal	Upstream end of Branch	Junction with Golden Gate Main Canal	✓				263.39
Palm River Canal	Palm River Canal	Junction with Imperial Drainage Outlet	Control Structure PLM-00-S0100	✓				197.39

Storm Sub-Basin	Segment Name	Upstream End of Segment	Downstream End of Segment	Return Period Storm Causing Failure				Predicted 5-year Flow at Failure
				5-yr/ 72-hr	10-yr/ 72-hr	25-yr/ 72-hr	100-yr/ 72-hr	cfs
Palm River Canal	Palm River Canal	Control Structure PLM-00-S0100	Junction with CocohatcheeWest	✓				195.35
Pine Ridge Canal	Pine Ridge Canal_00	Junction with PRC Connection	Control Structure PRC-00-S0180	✓				161.93
Pine Ridge Canal	Pine Ridge Canal_00	Control Structure PRC-00-S0180	Control Structure PRC-00-S0110	✓				316.93
Pine Ridge Canal	Pine Ridge Canal_00	Control Structure PRC-00-S0110	Junction with CocohatcheeWest	✓				13.69
Rock Creek	Rock Creek-00	Upstream end of Branch	Junction with Rock_Creek-01	✓				233.62
Rock Creek	Rock_Creek-00	Junction with Rock_Creek-01	Discharges to Naples Bay	✓				55.03
Rock Creek	Rock Creek-01	Upstream end of Branch	Junction with Rock_Creek-00	✓				152.73
Winter Park Outlet	Winter Park	Upstream end of Branch	Control Structure WP0-00-S0100	✓				95.47
Wiggins Pass Outlet	Wiggins Bay	Upstream end of Branch	Junction with CocohatcheeWest					
Upper Immokalee	Upper Immokalee Canal	Junction with Barron River Canal	Junction with SR29	✓				482.31
Baron River (North)	SR29	Junction with ImmokaleeS	Control Structure BRN-00-S0110	✓				166.20
Baron River (North)	SR29	Control Structure BRN-00-S0110	Control Structure BRC-00-C0345_Sunniland	✓				216.75

2.1.7 Conclusions

Several conclusions are drawn from the water budget analysis.

- Critical water budget processes are stormwater runoff and groundwater discharges to the canal network through baseflow.
- Annual and seasonal average stormwater runoff volumes are greatly influenced by the amount of precipitation. Relatively small variations in precipitation results in large changes in the volume of runoff.
- Baseflow contributions increase with canal density. Baseflow to the canal network in the Golden Gate and Faka Union watersheds make up approximately 55 percent of canal flow during the average year, and as much as 85 percent of canal flow during the dry season. Reducing baseflow would have a significant effect on the volume and timing of discharge to the estuary systems.
- The seasonal water budget analysis indicates a net balance in watershed storage over the simulation period. Annual losses in storage occur during the dry season and are associated with high baseflow contributions and with pumping from the Water Table and Lower Tamiami Aquifers to meet potable and irrigation water supply needs.
- Collier County and the SFWMD should consider seasonal groundwater elevations to establish updated seasonal controlled water levels in the canal network. Additional flexibility to raise the stage in the canals and reduce baseflow contributions should be considered when designing new or replacement control structures.
- Lowering the water surface in the canal network prior to large storm events is an important management tool to provide storage within the canal network and to mitigate flooding risks in Collier County.
- The existing conveyance capacity of the canal system is limited. Conditions would worsen in the future unless management actions are implemented to control for the impact of new development.

2.2 IN-STREAM SURFACE WATER QUALITY

This Chapter addresses Element 1, Task 1.2: In-Stream Water Quality.

2.2.1 Introduction and Objective

This section describes the water quality conditions of the Cocohatchee-Corkscrew, Golden Gate–Naples Bay, Rookery Bay, and the combined Faka Union, Okaloacoochee–SR29, Fakahatchee, watersheds. This effort focused on characterizing the water quality in Collier County's priority watersheds in the context of the Total Maximum Daily Load (TMDL) impairment conditions as described in the Florida Department of Environmental Protection's (FDEP) verified list of impaired waters.

The analysis conducted as part of this project included: 1) review of relevant reports from local, regional and state agencies related to water quality conditions, 2) review of relevant water quality data for Collier County's watersheds, 3) an assessment of locations where the water quality "impairment" may need to be further verified, 4) determination of the factor(s) likely to be responsible for impairment, 5) determination of factors likely to be responsible for phytoplankton growth, and 6) a conceptual overview of factor(s) that most strongly influence water quality in Collier County's priority watersheds.

The reports reviewed to identify impaired and potential waters of concern within Collier County included the water quality impairment analysis completed as part of the FDEP TMDL program implementation and the analysis of water quality conditions conducted by both the United States Army Corps of Engineers (USACE) as part of the Southwest Florida Feasibility Study (SWFFS) and more recently by Janicki Environmental, Inc. (JEI) at the request of Collier County. Results of analyses conducted as part of those studies are presented below.

2.2.2 The FDEP TMDL Impairment Analysis

For implementation of the statewide TMDL program, the FDEP divided the state into five groups. Each group is comprised of multiple basins and each basin is assigned a water body identification number (WBID). All water bodies within Collier County are in the Everglades West Coast Group 1 Basin. Per TMDL guidelines, every five years (cycle) each WBID is evaluated to determine whether available data indicate that water quality parameters exceed the limits defined by FDEP in the Impaired Waters Rule (IWR). After the compilation of all impaired WBIDs from Cycles 1 and 2, a total of fourteen impairments have been designated by FDEP in the freshwater portions of the study area. The freshwater WBIDs of concern in the study area are listed in **Table 2-7**. It must be noted that the FDEP analysis is based on available data. The County must continue working with the agency to identify the causes of the impairments and the corresponding courses of action.

The water quality impairment parameters include dissolved oxygen, nutrients, fecal coliform bacteria, iron, and un-ionized ammonia (**Figures 2-26 through 2-29**). The majority of impairments (9 of 14) are due to low dissolved oxygen concentrations, which was observed mostly in the Cocohatchee-Corkscrew watershed and also in the Golden Gate-Naples Bay and Okaloacooche-SR29 watersheds. Nutrients and un-ionized ammonia have been considered impairment parameters in WBID 3259W (Lake Trafford) within the Cocohatchee-Corkscrew watershed. Presently, large-scale restoration projects including sediment removal are underway to improve water quality in Lake Trafford. As such, the current water quality conditions may not reflect the impaired water quality status identified by FDEP. Lake Trafford will be re-evaluated during the next FDEP listing cycle. Only WBID 3278G (Fakahatchee Strand) was identified as impaired for fecal coliform concentrations. No water quality impairments were identified by the FDEP TMDL program in the freshwater portion of the Rookery Bay or Faka Union watersheds.

Table 2-7. List of FDEP Impaired Waters from Group 1 Cycles 1 and 2 for the freshwater discharge WBIDs of each watershed

WBID#	WBID Name	Impaired Parameter	Watershed
3259W	Lake Trafford	Dissolved Oxygen	Cocohatchee-Corkscrew
3259W	Lake Trafford	Nutrients	Cocohatchee-Corkscrew
3259W	Lake Trafford	Un-ionized Ammonia	Cocohatchee-Corkscrew
3278D	Cocohatchee Inland	Dissolved Oxygen	Cocohatchee-Corkscrew
3278F	Corkscrew Marsh	Dissolved Oxygen	Cocohatchee-Corkscrew
3278L	Immokalee Basin	Dissolved Oxygen	Cocohatchee-Corkscrew
3278K	Gordon River Extension	Dissolved Oxygen	Golden Gate–Naples Bay
3278S	North Golden Gate	Dissolved Oxygen	Golden Gate–Naples Bay
3278S	North Golden Gate	Iron	Golden Gate–Naples Bay
3278G	Fakahatchee Strand	Dissolved Oxygen	Fakahatchee
3278G	Fakahatchee Strand	Fecal Coliform	Fakahatchee
3261C	Barron River Canal	Iron	Okaloacooche-SR29
3278T	Okaloacoochee	Dissolved Oxygen	Okaloacooche-SR29
3278W	Silver Strand	Dissolved Oxygen	Okaloacooche-SR29

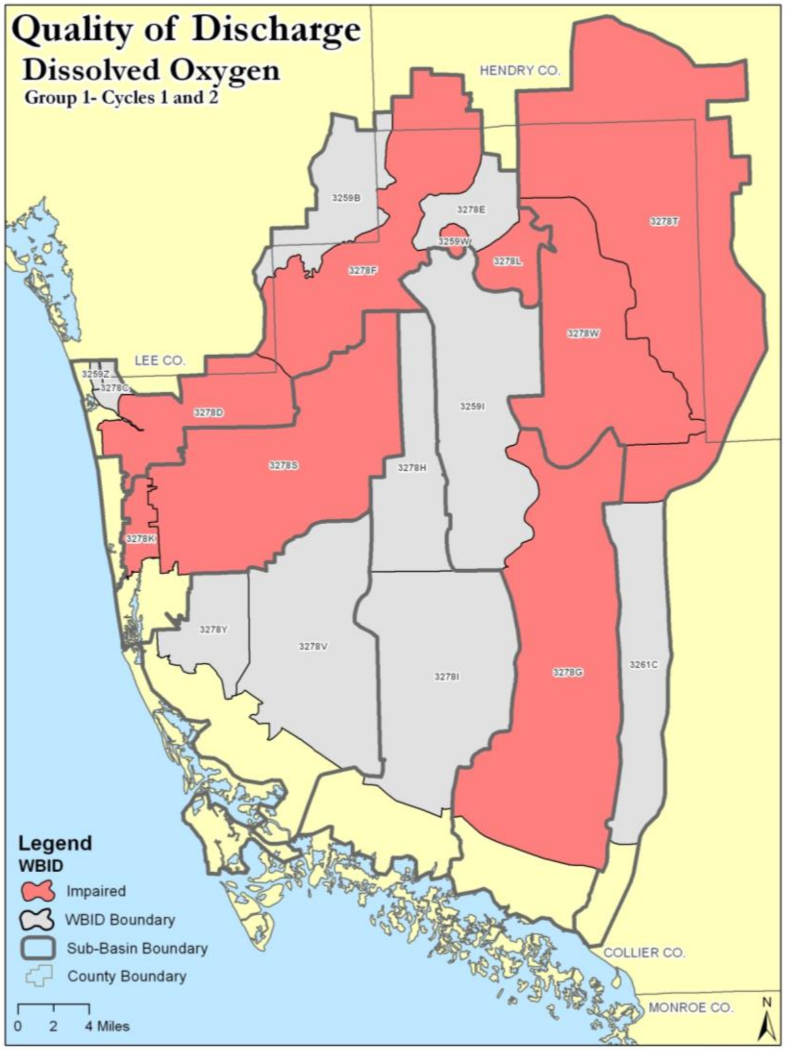


Figure 2-26. WBIDs within priority watersheds that were verified impaired for Dissolved Oxygen by FDEP

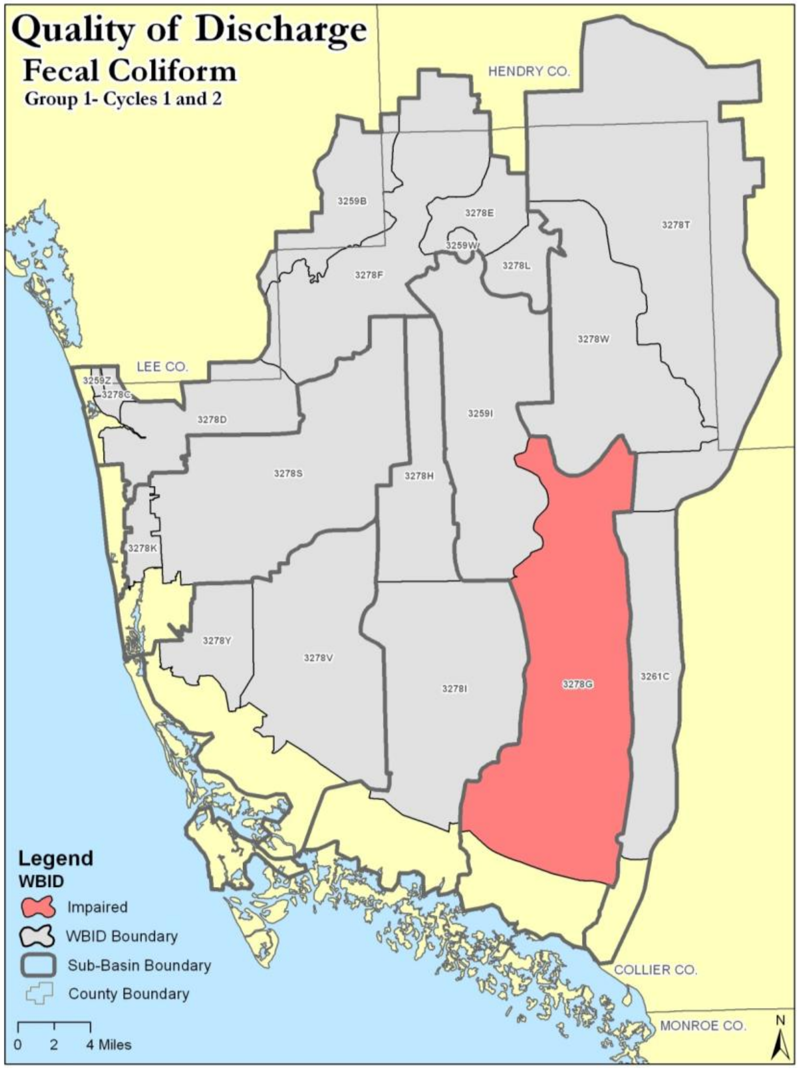


Figure 2-27. WBIDs within priority watersheds that were verified impaired for Fecal Coliform Bacteria by FDEP

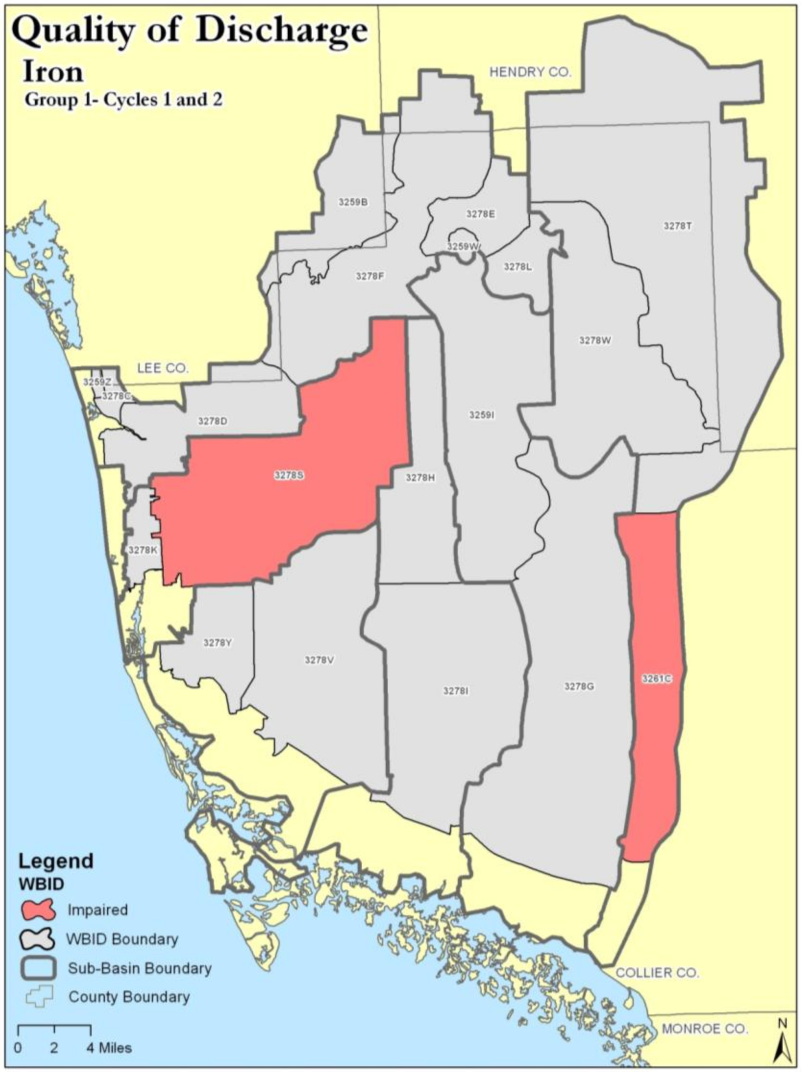


Figure 2-28. WBIDs within priority watersheds that were verified impaired for Iron by FDEP

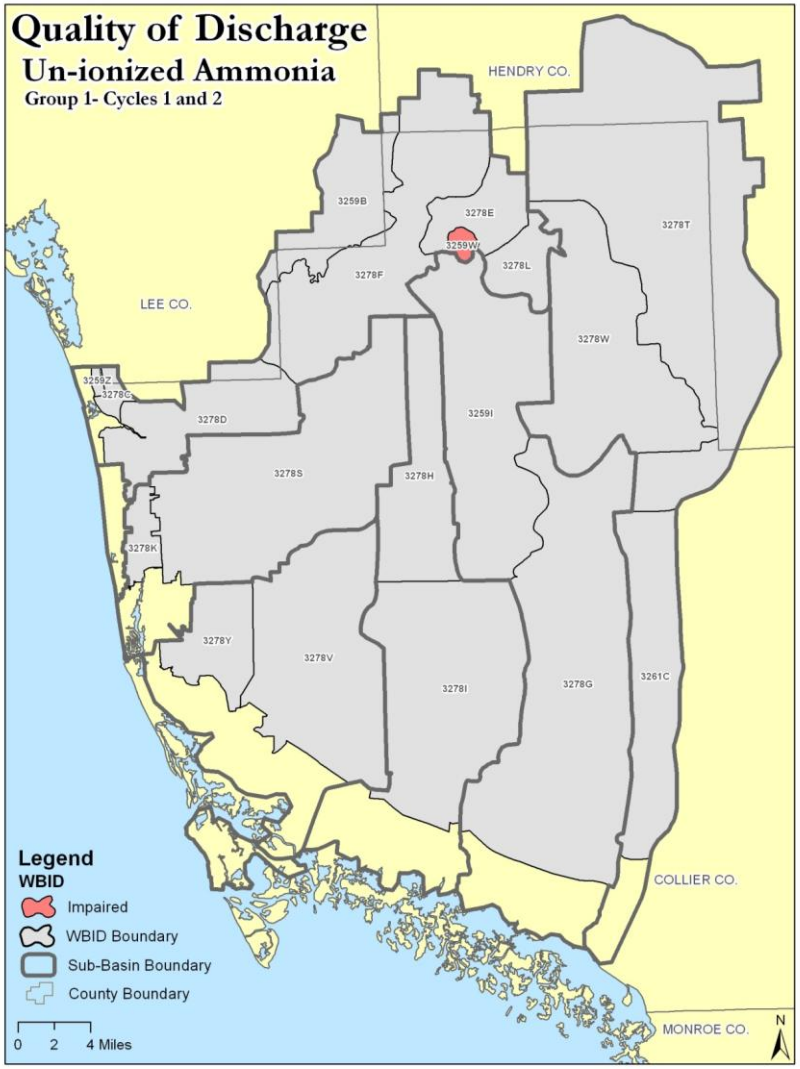


Figure 2-29. WBIDs within priority watersheds that were verified impaired for Nutrients and Un-ionized Ammonia by FDEP

2.2.3 Relevant Reports

The Southwest Florida Feasibility Study Water Quality Evaluation

The SWFFS water quality analysis was conducted in 2004 by Tetra Tech, Inc., and Janicki Environmental, Inc. The report was entitled "Compilation, Evaluation, and Archiving of Existing Water Quality Data for Southwest Florida" to the USACE. Task 7 of that report focused on the identification of waters of concern within the SWFFS area using a modification of the IWR. The boundaries of the watersheds reviewed for that report include the Collier County area included in the current study. WBID boundaries were not considered for their analysis.

The SWFFS identified a total of 318 parameter-specific waters of potential concern and 296 waters of verified concern. **Figures 2-30 through 2-34** show the location of potential waters of concern by parameter. Consistent with FDEP's evaluation, dissolved oxygen is the dominant parameter of concern. All of the priority watersheds in Collier County were identified as potential waters of concern for dissolved oxygen even those with limited urban development. Additionally, fecal coliform, un-ionized ammonia, and iron were reported as elevated in the majority of watersheds. Discrepancies were found between FDEP impairment analysis and SWFFS evaluation. Atkins believes the discrepancies are likely due to the variations in water quality databases, spatial scale of analysis (WBID vs. watershed) and the type of analysis (IWR vs. modifications to the IWR).

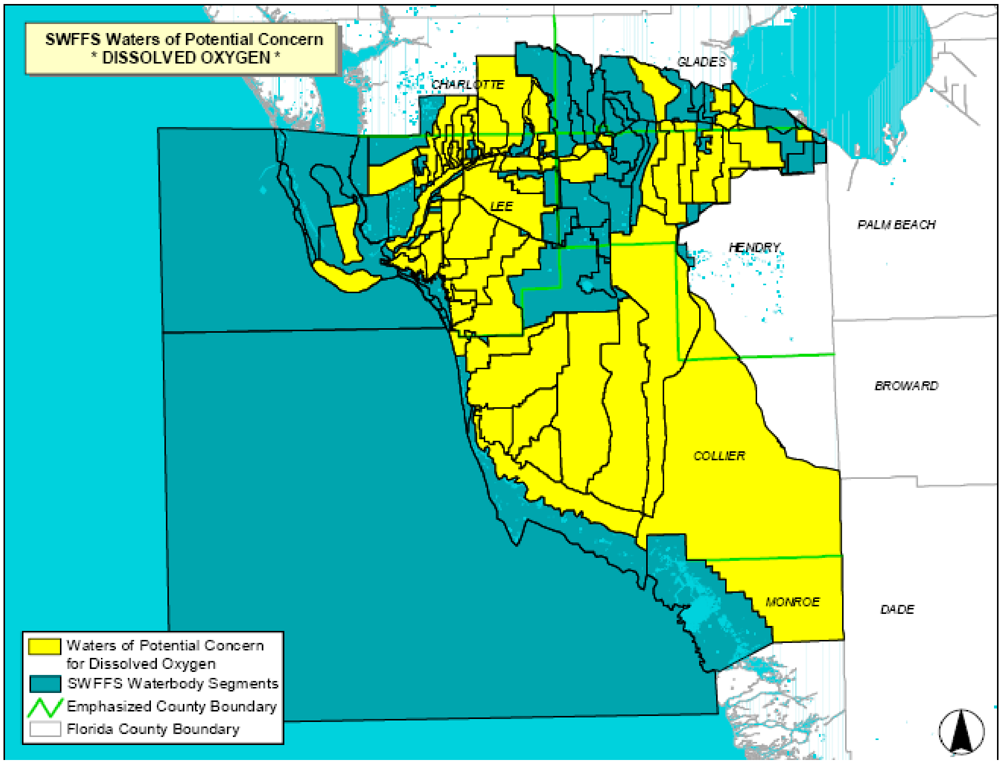


Figure 2-30. Potential Waters of Concern for Dissolved Oxygen as determined by Tetra Tech, Inc., and Janicki Environmental, Inc. (2004).

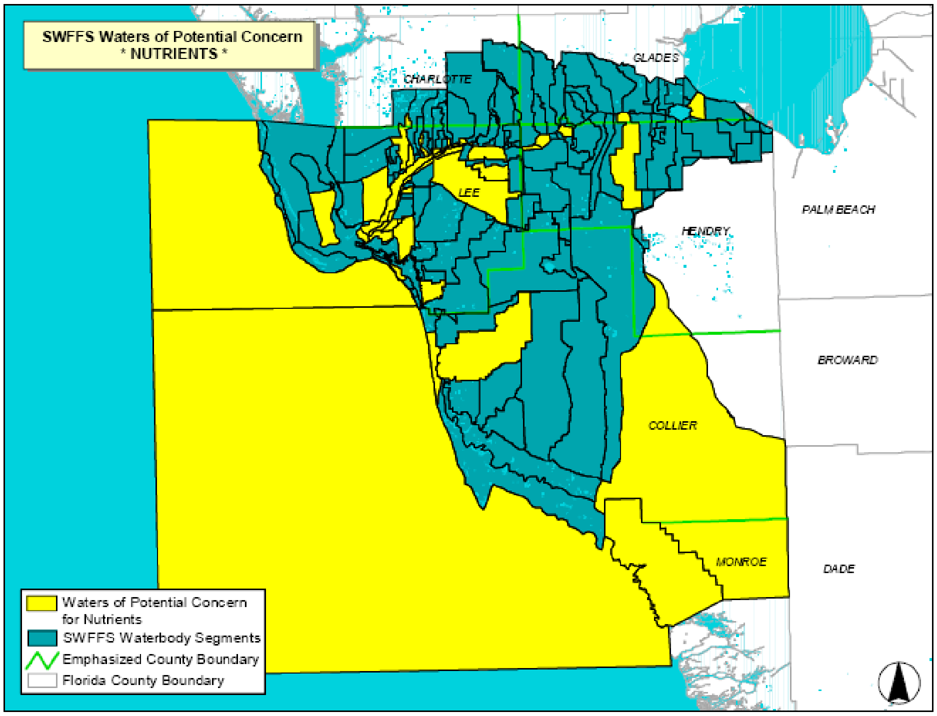


Figure 2-31. Waters of Potential Concern for Nutrients as determined by Tetra Tech, Inc., and Janicki Environmental, Inc. (2004).

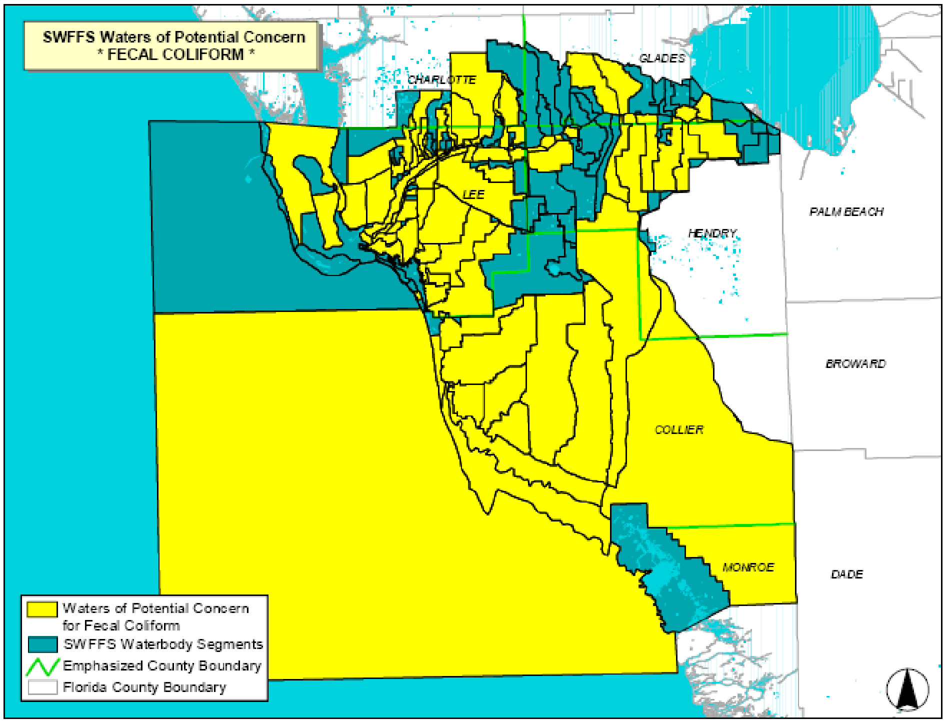


Figure 2-32. Potential Waters of Concern for Fecal Coliform as determined by Tetra Tech, Inc., and Janicki Environmental, Inc. (2004).

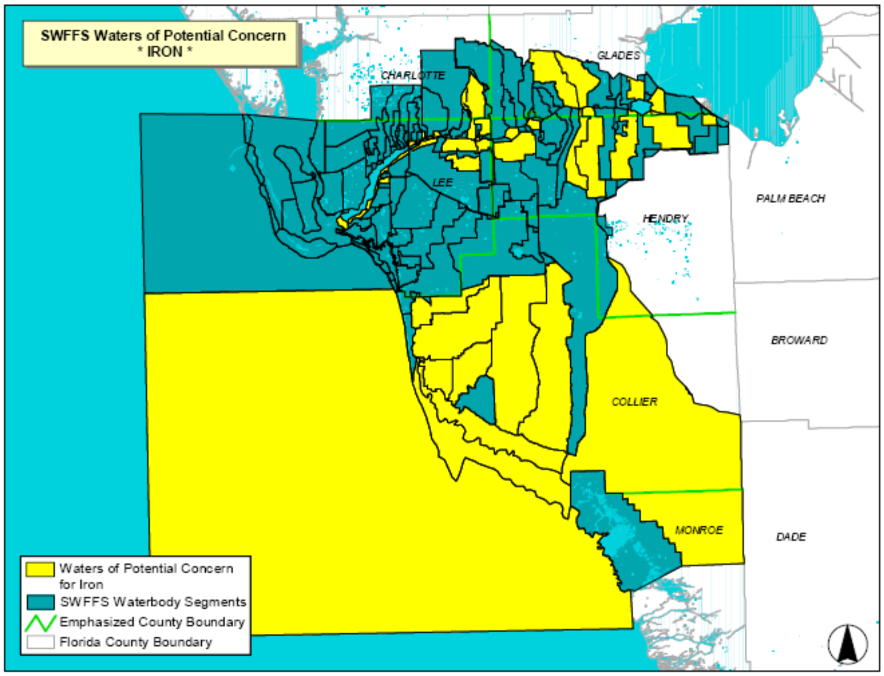


Figure 2-33. Potential Waters of Concern for Iron as determined by Tetra Tech, Inc., and Janicki Environmental, Inc. (2004).

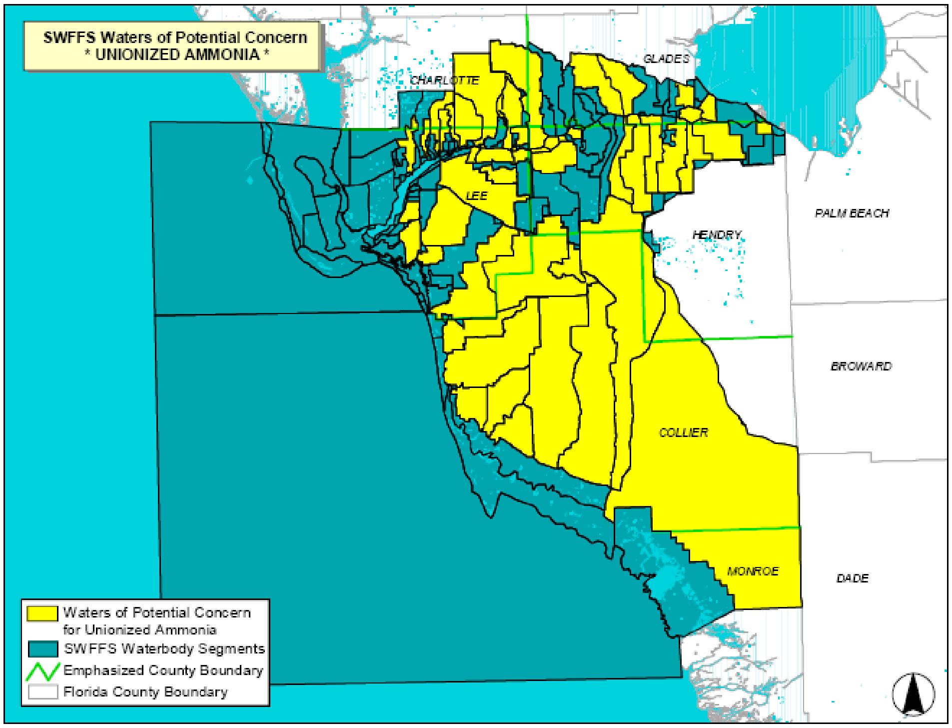


Figure 2-34. Potential Waters of Concern for Unionized Ammonia as determined by Tetra Tech, Inc., and Janicki Environmental, Inc. (2004).

The Collier County Surface Water Quality Annual Assessment and Trend Report (Janicki Environmental, Inc. 2010)

Collier County contracted Janicki Environmental, Inc. (JEI) to complete a review of water quality data from the County in the context of Florida's IWR (JEI 2010). The JEI review of annual chlorophyll *a* values six basins in the County indicated that all six exceeded the chlorophyll thresholds established by FDEP, compared with the single impairment (Lake Trafford) identified by FDEP for the watershed. The difference in results can be attributed to differences in classification of the water bodies (i.e. marine or freshwater systems) and the corresponding chlorophyll *a* threshold used to assign impairment. All the water bodies examined by JEI are considered freshwater systems by FDEP. JEI identified Barron River Canal, Camp Keais and Okaloacoochee Slough as freshwater basins, while Fakahatchee Strand, the Gordon River Extension, and Rookery Bay (Inland East) were identified as marine basins. Using the lower chlorophyll *a* threshold of 11 µg/L established for marine systems, the three basins designated as marine exceeded the chlorophyll threshold and were identified as potentially impaired by JEI. Exceedances were predominantly observed in 2007 and 2009 which was attributed to years of low rainfall (JEI 2010).

Table 2-8 lists the eight basins (and corresponding WBIDs) in Collier County identified as impaired or potentially impaired by FDEP, JEI, or Atkins. Lake Trafford is the only WBID identified as impaired for nutrients (chlorophyll *a)* by FDEP. Atkins identified two WBIDs (Cow Slough and Okaloacoochee Slough) which may be impaired in addition to the six potentially impaired WBIDs identified by JEI. The methods and results of the Atkins method are discussed in greater detail in further sections of this report.

Table 2-8. Impairment Status in Eight WBIDs in the Collier County Watersheds (Potential = Potentially Impaired)

WBID	WBID Name	Watershed	FDEP	Atkins	Janicki
3259W	Lake Trafford	Cocohatchee-Corkscrew	Impaired	Potential	Not Evaluated
3278E	Cow Slough	Cocohatchee-Corkscrew	Not Impaired	Potential	Not Evaluated
3259I	Camp Keais	Fakahatchee	Not Impaired	Not Impaired	Potential
3278G	Fakahatchee Strand	Fakahatchee	Not Impaired	Not Impaired	Potential
3278K	Gordon River Extension	Golden Gate Naples Bay	Not Impaired	Not Impaired	Potential
3261C	Barron River Canal	Okaloacoochee-SR29	Not Impaired	Not Impaired	Potential
3278T	Okaloacoochee Slough	Okaloacoochee-SR29	Not Impaired	Potential	Potential
3278V	Rookery Bay (Inland East Segment)	Rookery Bay	Not Impaired	Not Impaired	Potential

2.2.4 Stream Water Quality Analysis Method

The two methods used in this report to evaluate the potential waters of concern for each of the Collier County watersheds are described below:

- Watershed Analysis: A review of long-term water quality data was conducted to identify potential parameters of concern at the watershed level.
- Evaluation of WBID Impairment: A review of water quality data within each WBID was performed to compare results with FDEP impairment determinations.

The data used for the analyses included the IWR Run 39 data (supplied by FDEP), as well as data from Florida STORET, Collier County, City of Naples, and the Rookery Bay National Estuarine Research Reserve. This resulted in an updated and comprehensive database of water quality data. All analyses were conducted using the most recent 10-year time period (2000–2009) to minimize the effect of temporal variations. It should be noted that the majority of water quality data available was collected during this ten year period.

To eliminate potential errors due to duplicate data entry via multiple agencies uploading the same data, median values were calculated by station, date, and parameter. To allow for a direct comparison between lab parameters (i.e., nutrients) and field parameters (i.e., temperature, dissolved oxygen, samples were restricted to those collected from less than one meter depth. Since lab parameters are typically from surface grab samples, this ensures that comparisons between various parameters are from samples taken from the same general water depth.

Using GIS and the station descriptions, the locations of water quality stations were reviewed in order to identify locations where multiple stations were sampled. Data were merged when more than one water quality station was sampled at the same location and a unique merged station name was assigned to that location. **Appendix 4-B** lists all water quality stations and assigned merged station names. Each parameter in the database was screened to identify outliers or entry errors due to unit inconsistencies. Identified inconsistencies were reviewed and corrected. When Total Nitrogen (TN) species were not listed, TN was calculated as the sum of Total Kjeldahl Nitrogen (TKN) and Nitrate + Nitrite (NOx). To ensure consistency with IWR guidance, corrected chlorophyll *a* was preferentially used over uncorrected chlorophyll *a* for samples collected in 2006 and earlier. After 2006, IWR guidance from FDEP directs that only corrected chlorophyll *a* data should be used.

Watershed Analysis

This analysis was conducted using only data from the long-term water quality stations that were consistently sampled throughout the ten year time period 2000-2009. Summary statistics for all discharge water quality stations are found in **Appendix 4-C**. The use of long-term water quality stations accommodates variability in water quality due to irregular sampling and temporary monitoring efforts. The long-term data also provided a means of evaluating the watershed as a whole, rather than characterizing it using short-term “snapshots” of water quality from individual sub-basins. **Figure 2-35** shows the long-term freshwater discharge water quality sampling stations used for analysis.

Summary data for each watershed were compared to the Criteria for Surface Water Quality Classifications (F.A.C. 62-302.530) for water quality parameters based on their water body classification. **Table 2-9** lists the regulatory class for each watershed. Class is defined as the associated designated use of the water body provided by FDEP. All freshwater bodies examined here are classified as class III freshwater (3F). **Table 2-11** lists the regulatory standards for a Class 3F water body for selected parameters. Regulatory standards have been vetted by the scientific community and provide a biologically relevant basis for comparison.

The FAC Chapter 62-303: “Identification of Impaired Surface Waters,” provides a list of the minimum number of samples not meeting a water quality criterion for a range of sample sizes in order for the water to be included on the FDEP Verified list. The same criteria were used herein to classify a watershed as a “watershed of concern” when an appropriate regulatory standard was exceeded. In terms of chemical parameters, chlorophyll a, dissolved oxygen, iron, and fecal coliform are parameters used by FDEP to classify WBIDs as impaired water bodies. In contrast, color, total phosphorus, total nitrogen, and total suspended solids cannot be quantitatively assessed to identify impaired water bodies. Total nitrogen and total phosphorus are valuable parameters providing indicators of eutrophication. Both chlorophyll *a* and dissolved oxygen levels can be directly impacted by the nutrient loads. Color has the ability to affect chlorophyll *a* and dissolved oxygen concentrations. Additionally, total suspended solids provide an indication of sediment erosion, which occurs frequently in storm water run-off.

To further evaluate potential water quality impairments at the watershed level when no numeric state standards exist, such in the case of nutrients, data were compared to screening level standards, which can provide an indication of water quality concerns. Screening level standards are available for total nitrogen (TN) and total phosphorus (TP) based on the 70th percentile of all available data, a technique first used by Friedman and Hand (1989). Using IWR Run 39, a similar screening level was calculated by water body type for color and total suspended solids, in which the 70th percentile of all data available from 2000 to 2009 by water body type was calculated. **Table 2-12** lists the screening level standard for selected parameters by water body type (stream or lake).

As the focus of the watershed management plan is to protect, and if possible restore, the natural environment, the watershed analysis also considered the water quality characteristics of the natural systems. In addition, the analysis referred to the potential impact of groundwater discharges into the drainage system within each of the watersheds.

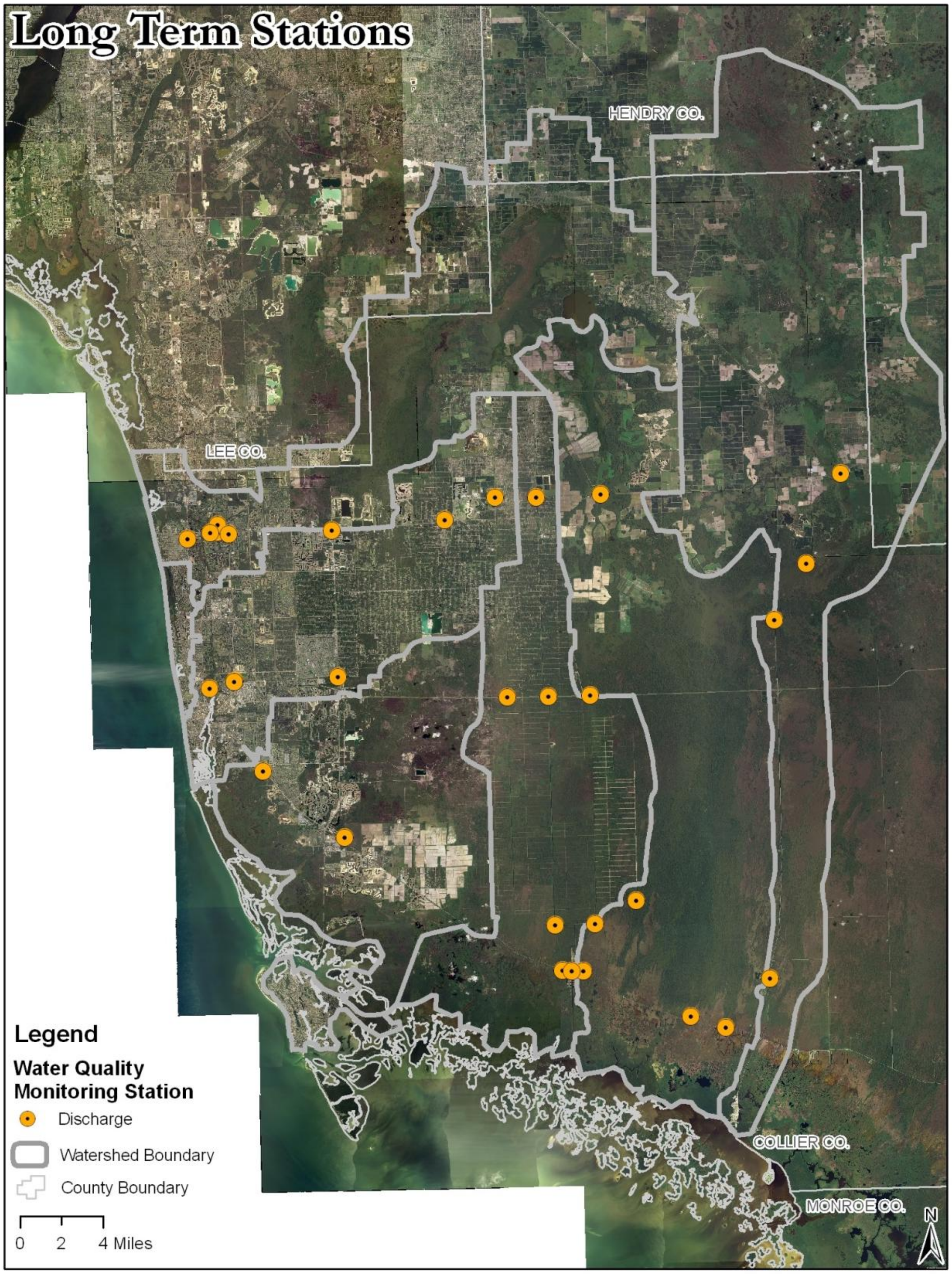


Figure 2-35. Long-term stations for watershed in-stream water quality analysis

Table 2-9. WBID name and corresponding watershed designation

WBID	Class*	Watershed	WBID Name
3259W	3F	Cocohatchee-Corkscrew	LAKE TRAFFORD
3259Z	3F	Cocohatchee-Corkscrew	LITTLE HICKORY BAY
3278D	3F	Cocohatchee-Corkscrew	COCOHATCHEE (INLAND SEGMENT)
3278C	3F	Cocohatchee-Corkscrew	COCOHATCHEE GOLF COURSE DISCHARGE
3278F	3F	Cocohatchee-Corkscrew	CORKSCREW MARSH
3278E	3F	Cocohatchee-Corkscrew	COW SLOUGH
3259B	3F	Cocohatchee-Corkscrew	DRAINAGE TO CORKSCREW
3278L	3F	Cocohatchee-Corkscrew	IMMOKALEE BASIN
3278H	3F	Faka Union	FAKA UNION (NORTH SEGMENT)
3278I	3F	Faka Union	FAKA UNION (SOUTH SEGMENT)
3278G	3F	Fakahatchee	FAKAHATCHEE STRAND
3259I	3F	Fakahatchee	CAMP KEAIS
3278K	3F	Golden Gate Naples Bay	GORDON RIVER EXTENSION
3278S	3F	Golden Gate Naples Bay	NORTH GOLDEN GATE
3261C	3F	Okaloacooche-SR29	BARRON RIVER CANAL
3278T	3F	Okaloacooche-SR29	OKALOACOOCHEE SLOUGH
3278W	3F	Okaloacooche-SR29	SILVER STRAND
3278V	3F	Rookery Bay	ROOKERY BAY (INLAND EAST SEGMENT)
3278Y	3F	Rookery Bay	ROOKERY BAY (INLAND WEST SEGMENT)

*3F: Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife (Predominantly Fresh Waters)

Table 2-10. List of Water Quality Parameters

Parameter	Unit	Parameter	Unit
Salinity	ppt	Conductivity	µmhos/cm
Total Nitrogen	mg/l	Nitrate-Nitrite	mg/l
Total Phosphorus	mg/l	Orthophosphate	mg/l
Total Kjeldahl Nitrogen	mg/l	Unionized Ammonia	mg/l
Chlorophyll a	µg/L	Fecal Coliform	#/100 mL
Color	PCU	Copper	µg/L
Total Suspended Solids	mg/l	Turbidity	NTU
Dissolved Oxygen	mg/l	Biochemical Oxygen Demand	mg/l
Iron	µg/L	Hardness	mg/l
Secchi Depth	m		

Table 2-11. List of regulatory standards for selected water quality parameters

Parameter	Classification*
	3F
Dissolved Oxygen (mg/l)	5
Iron (µg/L)	1000
Fecal Coliform (#/100 mL)	400
Chlorophyll a (µg/L)	20
Copper (µg/L)	e^(0.854[lnH]-1.702)
Un-ionized Ammonia (mg/l)	0.02

*3F: Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife (Predominantly Fresh Waters)

Evaluation of WBID Impairment

Using methods similar to IWR, Atkins analyzed the water quality data for each WBID in a watershed. As opposed to the watershed analysis that used data only for the long-term water quality stations, for this analysis it was decided that all data available for the period 2000–2009 would be used for consistency with FDEP's approach for impairment evaluation. Dissolved oxygen, iron, fecal coliform, un-ionized ammonia, and copper concentrations were compared to the appropriate state regulatory standard to determine impairment status (**Table 2-12**). It should be noted that a modification to the FDEP method for determining chlorophyll *a* impairments was used. Each chlorophyll *a* value was compared to the state regulatory standard and the percent exceedance was calculated. This approach is more conservative than the FDEP method by which an annual average is calculated using data from each yearly quarter for comparison with the regulatory standard. The results of Atkins analyses for each WBID within a watershed were compared to the FDEP impaired WBID list for those water bodies in the study area.

Table 2-12. List of screening levels for selected water quality parameters

Parameter	Lake	Stream
Color (PCU)	80	111.5
TSS (mg/l)	13	7
TN (mg/l)	1.7	1.6
TP (mg/l)	0.11	0.22

2.2.5 Results

This section presents the results of both the evaluation of watershed conditions and the review of impaired WBIDs for each of the priority watersheds. In general, using the methods described previously, five parameters were identified as parameters of concern, color, dissolved oxygen, TN, iron, and fecal coliform. Chlorophyll *a*, total phosphorus, and total suspended solids concentrations were within range of the regulatory standards and screening levels for all six watersheds. While un-ionized ammonia was identified by FDEP as a parameter of concern for WBID 3259W (Lake Trafford), elevated levels of un-ionized ammonia were not observed in other locations in the Cocohatchee-Corkscrew watershed.

Table 2-13 lists the parameters and the number of watersheds for which that parameter is of concern. The majority of watersheds frequently had low dissolved oxygen concentrations (**Figure 2-36**). Two of the six watersheds showed elevated fecal coliform bacteria levels: Fakahatchee and Cocohatchee-Corkscrew (**Figure 2-37**). The Okaloacoochee/SR29 watershed had elevated total nitrogen concentrations (**Figure 2-38**). Only the Rookery Bay watershed was not identified as having elevated color (**Figure 2-39).** Data from a number of watersheds indicated elevated iron concentrations (**Figure 2-40**).

A more-detailed description of results by watershed and WBID is provided in the following sections.

Table 2-13. Total number of Watersheds of Concern identified for each parameter

Parameter	Watersheds of Concern
Chlorophyll a	0
Color	5
Dissolved Oxygen	6
Fecal coliform	2
Iron	2
Total Nitrogen	1
Total Phosphorus	0
Total Suspended Solids	0
Un-ionized Ammonia	0

2.2.5.1 Cocohatchee-Corkscrew Watershed

A description of the results of the watershed analysis and WBID impairment condition are presented here. The summary water quality statistics for the Cocohatchee-Corkscrew watershed are provided in **Table 2-14**. Based upon the evaluation of the long term stations within the watershed, three potential parameters of concern were identified: color, dissolved oxygen, and fecal coliform bacteria. Chlorophyll *a* and nutrients were not found to be elevated in the Cocohatchee-Corkscrew watershed.

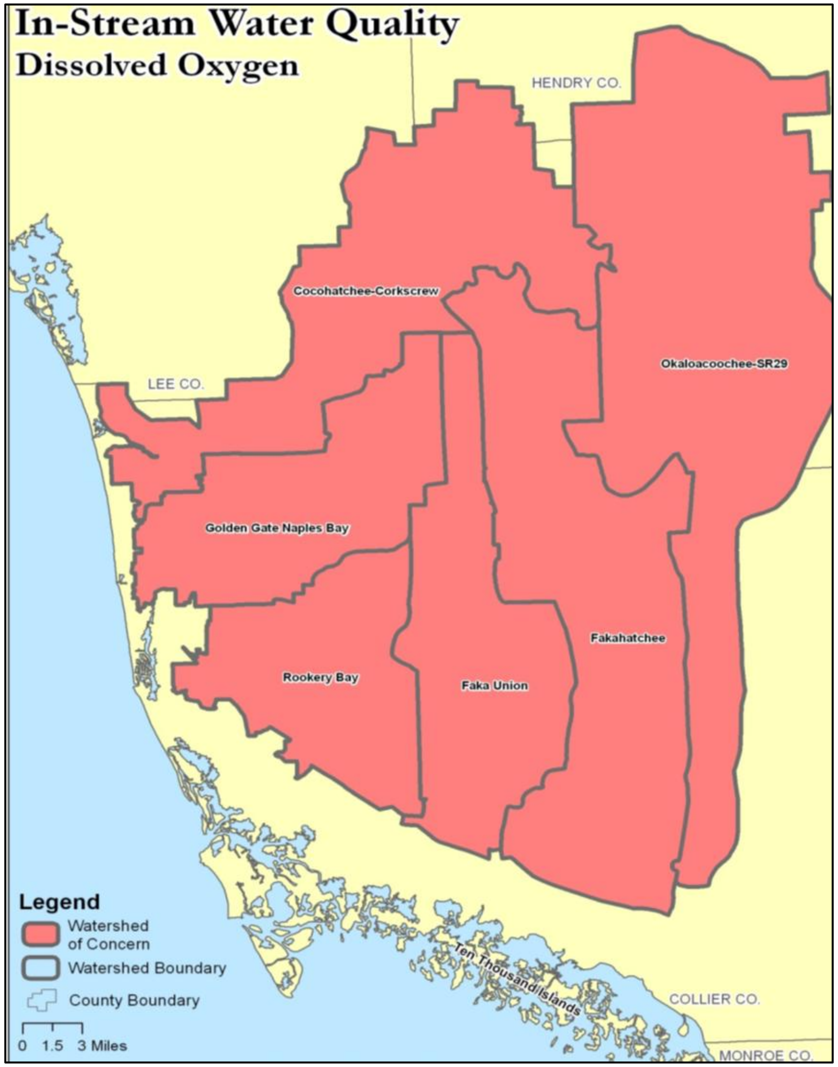


Figure 2-36. Watersheds of Concern for Dissolved Oxygen

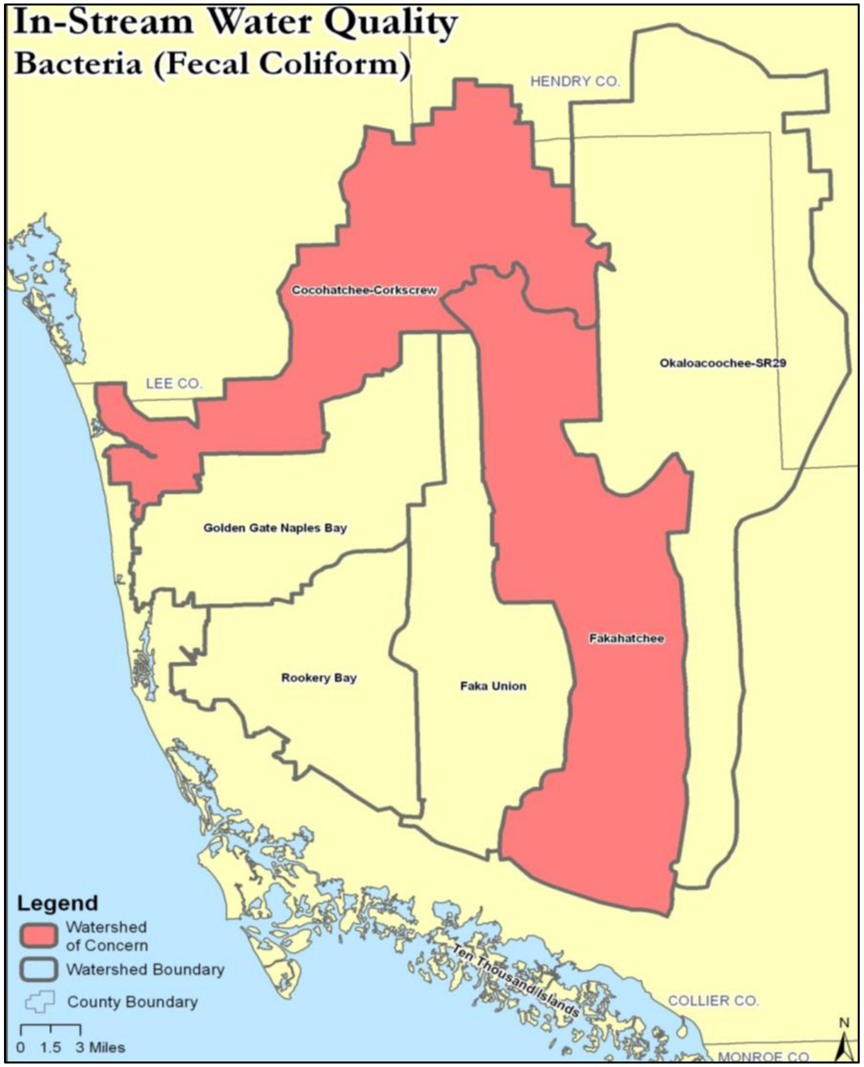


Figure 2-37. Watersheds of Concern for Fecal Coliform Bacteria

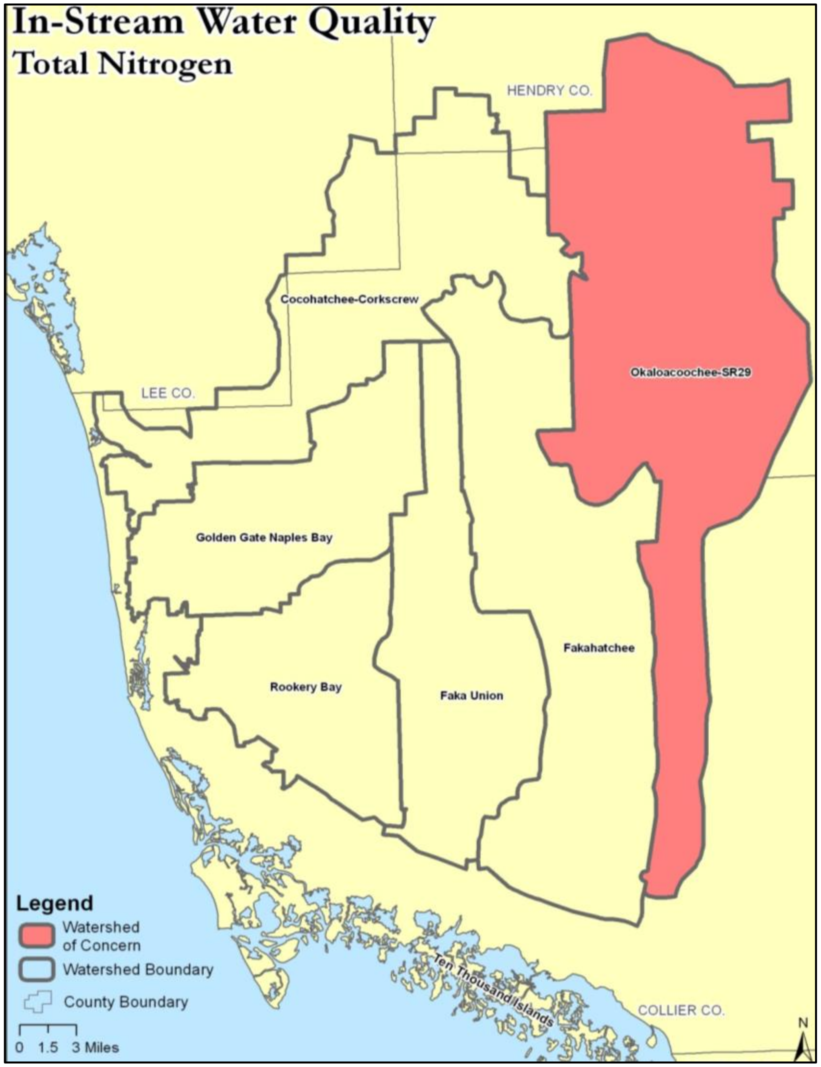


Figure 2-38. Watersheds of Concern for Total Nitrogen

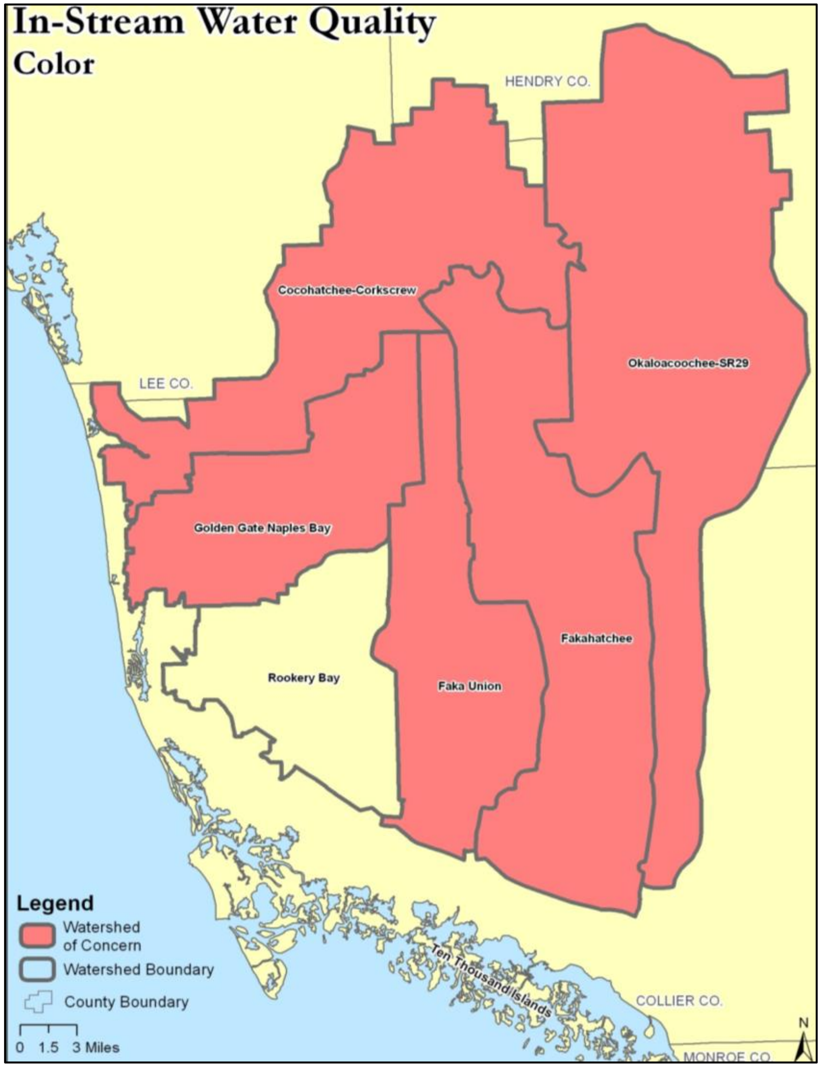


Figure 2-39. Watersheds of Concern for Color

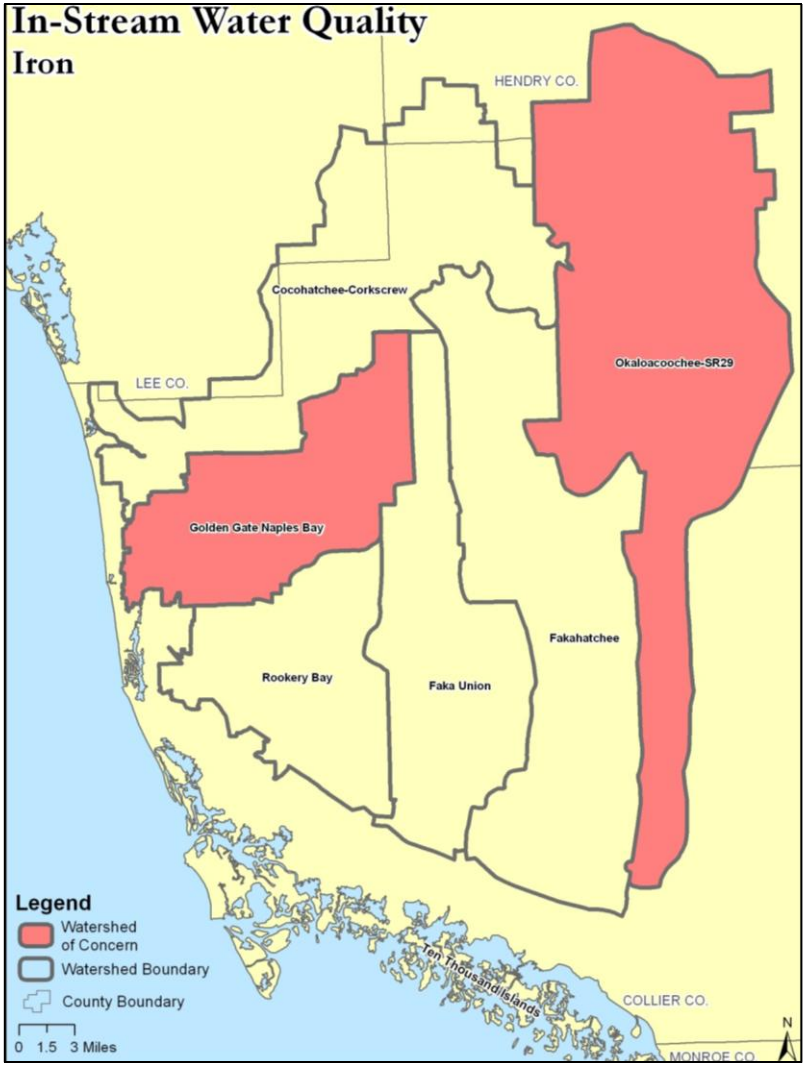


Figure 2-40. Watersheds of Concern for Iron

Table 2-14. Water Quality Summary Statistics for the Cocohatchee-Corkscrew Watershed indicating potential parameters of concern

Parameter	N	Min	Mean	Median	Max	Percent Exceed	Parameter of Concern
BOD, mg/l	125	1.6	2.4	2.0	6.8		
Chlorophyll-a, µg/L	449	3.0	9.1	4.3	246.3	9	N
Color, PCU	437	5	72	60	300	12	Y
Conductivity, umhos/cm	495	317	6718	1064	49624		
Copper, µg/L	153	0.30	5.28	2.25	178.00		
Dissolved Oxygen, mg/l	499	0.42	5.45	5.10	16.74	47	Y
Fecal Coliform, #/100 mL	442	1	259	88	4500	13	Y
Iron, µg/L	140	100.0	352.3	325.0	1100.0	1	N
Nitrate-Nitrite, mg/l	435	0.01	0.08	0.05	0.78		
Orthophosphate as P, mg/l	347	0.004	0.042	0.024	0.290		
Salinity, ppt	447	0.2	4.2	0.5	32.4		
Secchi Depth, m	471	0.10	1.16	1.10	2.50		
TKN, mg/l	394	0.05	0.86	0.83	4.30		
Total Nitrogen, mg/l	407	0.005	0.790	0.860	4.300	3	N
Total Phosphorus, mg/l	428	0.004	0.079	0.055	0.563	6	N
TSS, mg/l	365	1.3	4.5	2.0	102.0	8	N
Turbidity, NTU	276	0.4	2.4	1.8	24.0		
Unionized Ammonia, mg/l	266	0.0000	0.0013	0.0010	0.0082	0	N

Chlorophyll a and Nutrients

FDEP declared Lake Trafford (WBID 3259W) impaired for both chlorophyll *a* (nutrients) and un-ionized ammonia. However, elevated chlorophyll a and nutrient values were not observed on the watershed-scale. It is important to note that due to the poor water quality conditions observed in Lake Trafford by FDEP, Collier County, and the SFWMD, a large-scale restoration project has been implemented. Previous water quality conditions that existed during the timeframe used for the Lake Trafford TMDL report and that resulted in the identified impairment are complex. The Lake Trafford sediment removal project has been completed and observed water quality improvements have been documented (i.e., PBS&J 2009). Further water quality improvements are anticipated. Much of the data for Lake Trafford is from the period prior to implementation of the Lake Trafford sediment removal project and may not accurately represent post-project conditions. Atkins believes that the impairments indicated by FDEP (un-ionized ammonia and chlorophyll *a*) are likely not indicative of current water quality conditions in the Lake. The County should work with FDEP to re-evaluate Lake Trafford during the next assessment cycle.

Dissolved Oxygen

Dissolved oxygen concentrations in the Cocohatchee-Corkscrew watershed are consistently below the regulatory standard of 5.0 mg/L for freshwater water bodies. Wet and dry season median values amount to 4.3 and 2.1 mg/L, respectively. An evaluation of the cause for the low dissolved oxygen levels was completed to determine the factor(s) that may explain the depressed dissolved oxygen values. Three factors were identified: high nutrient concentrations, impact of wetland systems, and groundwater contributions to the drainage system. Boyer (2008) reported that "localized naturally low DO conditions are common due to stratification and inputs of large amounts of organic material from natural mangrove forests" (as cited in FDEP 2010).

The decomposition of detritus associated with color, and phytoplankton biomass associated with TN and TP, can affect levels of dissolved oxygen. Increased color and decreased dissolved oxygen values have also previously been documented from forested wetlands in Florida (PBSJ 2009). That study concluded that low dissolved oxygen concentrations due to high levels of color (aka. tannins) occurring in wetland systems can be an entirely natural phenomenon. It is possible that low dissolved oxygen concentrations are a function of natural seasonal fluctuations which occur in wetland environments. This is relevant because the majority of the Cocohatchee-Corkscrew watershed is comprised of natural areas (47%), which are located primarily in the headwater of the watershed associated with the Corkscrew Swamp.

In addition, low DO concentrations may result from elevated nutrient concentrations and can be indicative of anthropogenic pollution loads. Anthropogenic sources may include nutrients carried in stormwater runoff from urban and agricultural areas located in the watershed. Groundwater contributions may also be a factor affecting DO levels because groundwater concentrations are predicted to be less than 1.5 mg/L (Section 2.5).

Based on those considerations, it was important to conduct an analysis to statistically determine the most likely causative factor that explains the observed low dissolved oxygen concentrations in the watershed. Regression analyses were conducted between dissolved oxygen and TN, TP and color. For each regression the best-fit curve was selected when comparing exponential, linear, and power relationships.

Results shown in **Table 2-15** indicate that color is potentially a causative factor for the low dissolved oxygen discharge in the watershed. This finding indicates that low dissolved oxygen concentrations may be due to discharges from wetland systems in the Corkscrew Swamp. This applies to the Corkscrew marsh and potentially the area downstream from the marsh. However, even though color is the strongest predictor of dissolved oxygen in the Cocohatchee-Corkscrew watershed (compared to TN or TP) the low r^2 value of the DO vs. color relationship also illustrates that color alone cannot explain observed low DO values.

Table 2-15. Identification of causative factor in the Cocohatchee-Corkscrew watershed for low dissolved oxygen concentrations

Causative Factor	Method	p	r^2
Color	Exponential regression	0.000	0.08
TN	Power regression	0.008	0.02
TP	Power regression	0.000	0.07

In addition to wetland function, other factors are likely involved in the DO impairment. More than 50% of the watershed is developed for urban or agricultural uses. Runoff from these areas may contribute nutrients to the drainage network. Stormwater pollutant loading calculations are discussed in Sections 2.3 and 4.3 of this document. Those results indicate that water quality in the canal network in the area around Immokalee is likely impacted by urban and agricultural runoff. It is also possible that the canal network in the western portion of the watershed is affected by urban runoff. Additional monitoring is recommended to assess the nutrient contributions from these developed areas.

In terms of groundwater quality, there is no monitoring data for dissolved oxygen available in the watershed. However, an average DO concentration of 0.57 mg/L (Collier County, 2010) has been reported in groundwater measurements completed in the Gordon River Extension (WBID 3278K). Predicted DO concentrations in groundwater (described in Section 2.5) are less than 1.5 mg/L in the Cocohatchee – Corkscrew watershed. **Table 2-16** shows the water budget components for each of the WBIDs in the watershed per the hydrologic/hydraulic model results. That information indicates that baseflow represents almost 40 percent of the average annual canal flow in WBID 3278D and ranges between 30 percent in the wet season to 65 percent in the dry season. Therefore, groundwater contributions may have a significant effect on dissolved oxygen levels in the Cocohatchee Canal.

Table 2-16. Water budget contributions to the drainage network in the Cocohatchee-Corkscrew watershed

		Average Annual		Average Wet Season		Average Dry Season	
WBID	Name	Groundwater (inches)	Surface Runoff (inches)	Groundwater (inches)	Surface Runoff (inches)	Groundwater (inches)	Surface Runoff (inches)
3259B	Drainage to Corkscrew	1.00	4.75	0.76	4.41	0.24	0.34
3278D	Cocohatchee (Inland Segment)	5.84	9.26	3.53	8.05	2.32	1.21
3278E	Cow Slough	0.16	3.20	0.12	2.51	0.03	0.69
3278F	Corkscrew Marsh	0.70	8.67	0.40	6.34	0.30	2.33
3278L	Immokolee Basin	1.01	9.04	0.62	6.22	0.39	2.82

To further assess the low DO condition in the Cocohatchee-Corkscrew and the other watersheds in the study area, the measured DO concentrations at all stations were plotted based on day and month of occurrence in a calendar year, as shown in **Figure 2.41**. A monthly running average line was also added to the plot. Results show that the oxygen concentration varies with temperature as expected for systems that are not influenced by algae or vegetation that exerts oxygen during the day due to photosynthetic activity. This result suggests that algae, caused by excessive nutrient concentrations, are apparently not the cause of the low DO levels.

It is recognized that the urbanized areas of the watershed discharge nutrients and organic material that may contribute to DO concentrations being below water quality standards. However, results of the analysis also suggest the possibility that DO levels are a result of natural influences. It is recommended that the County implement additional monitoring studies to further assess the causes of the low DO concentrations.

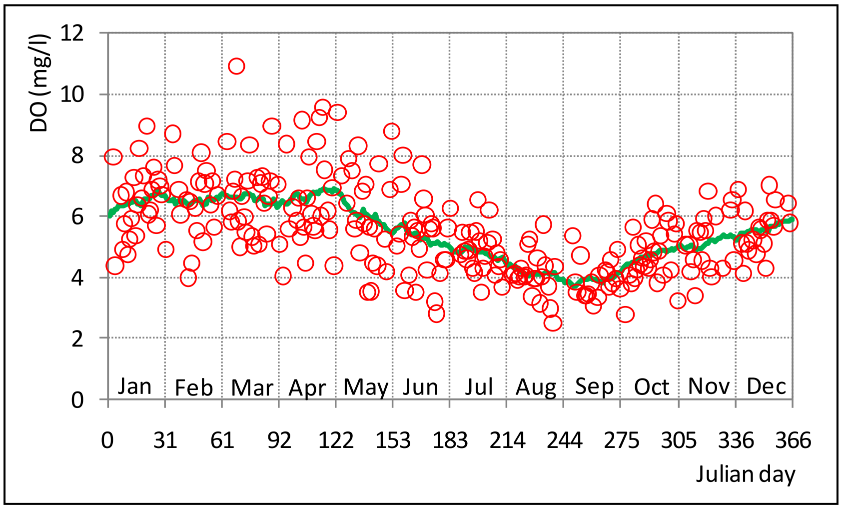


Figure 2-41. Measured Dissolved Oxygen Concentrations

Fecal Coliform Bacteria

The numeric criteria of fecal coliform bacteria concentrations for Class 3 waters as established by Rule 62-302, F.A.C., states that *"The Most Probable Number (MPN) shall not exceed a monthly average of 200, nor exceed 400 in 10% of the samples, nor exceed 800 on any one day."*

No WBIDs were identified as verified impaired for bacteria as evaluated by FDEP. In contrast, the Cocohatchee-Corkscrew watershed reported 13% of the 442 values exceeded the 400 #/100 mL criteria established for Class 3 waters. As such, the watershed was classified as a "watershed of concern" for bacteria based on the analysis of the long-term sampling stations.

Though values exceed the regulatory standard for Class 3 waters, fecal coliform bacteria may not be an appropriate indicator for pathogenic diseases in sub-tropical climates. In subtropical environments such as South Florida, the specificity of the fecal coliform test is compromised by the more constant and warmer ambient water temperatures of sampled water bodies. The inability to specifically identify humans as a source of bacteria using traditional indicator bacteria testing protocols has been noted by Fujioka (2001) and Fujioka et al. (1999) for various tropical locations. Further identification efforts are warranted to verify the source of impairment.

Evaluation of WBID Impairment

Using all of the available water quality data over the 10-year period for each WBID, Atkins evaluated the impairment status determined by FDEP in the watershed. **Table 2-17** shows the FDEP impairment as well as the results of the Atkins analysis. As shown all impairments were confirmed when compared to the State standards. Additionally, six potential impairments were identified in the Cow Slough, Corkscrew Marsh, Cocohatchee (Inland Segment) or the Drainage to Corkscrew water bodies that have not been identified by FDEP. As indicated previously, further site specific analyses may be necessary to determine whether the impairments and the potential impairments are caused by anthropogenic pollutant loads or are the reflection of natural conditions. It should be noted that the evaluation of the WBID impairment provided similar results to the long-term station watershed analysis.

Table 2-17. Impaired WBID comparison for Cocohatchee-Corkscrew watershed

WBID#	Water Segment Name	Impairment Parameter	PBSJ Analysis
3259W	Lake Trafford	Dissolved Oxygen	Confirm FDEP assessment
3259W	Lake Trafford	Nutrients	Confirm FDEP assessment
3259W	Lake Trafford	Un-ionized Ammonia	Confirm FDEP assessment
3278D	Cocohatchee Inland	Dissolved Oxygen	Confirm FDEP assessment
3278F	Corkscrew Marsh	Dissolved Oxygen	Confirm FDEP assessment
3278L	Immokalee Basin	Dissolved Oxygen	Confirm FDEP assessment
3278E	Cow Slough	Nutrients (Chlorophyll a)	Potential new impairment
3278E	Cow Slough	Dissolved Oxygen	Potential new impairment
3278F	Corkscrew Marsh	Fecal Coliform	Potential new impairment
3278D	Cocohatchee (Inland Segment)	Fecal Coliform	Potential new impairment
3259B	Drainage to Corkscrew	Dissolved Oxygen	Potential new impairment
3259B	Drainage to Corkscrew	Fecal Coliform	Potential new impairment

2.2.5.2 Golden Gate-Naples Bay Watershed

The results of the watershed analysis and WBID impairment condition in the Golden Gate-Naples Bay Watershed is presented here. The summary statistics for the Golden Gate-Naples Bay Watershed are provided in **Table 2-18**. Based upon the evaluation of the long term stations within the watershed, three parameters were identified as being of "potential concern"; dissolved oxygen, color, and iron. The canal network in the watershed was built to lower the water table and encourage development. Therefore, the majority of the watershed is comprised of urban development (61%), which suggests that anthropogenic modifications in the watershed may have resulted in a decline in water quality conditions.

Table 2-18. Water Quality Summary Statistics for the Golden Gate-Naples Bay Watershed indicating potential parameters of concern

Parameter	N	Min	Mean	Median	Max	Percent Exceed	Parameter of Concern
BOD, mg/l	119	0.7	2.0	2.0	5.7		
Chlorophyll-a, µg/L	558	1.0	5.4	3.0	83.0	3	N
Color, PCU	553	5	93	80	800	26	Y
Conductivity, umhos/cm	558	184	2348	616	40222		
Copper, µg/L	151	0.15	1.24	1.00	4.90		
Dissolved Oxygen, mg/l	570	0.17	5.30	5.27	16.10	45	Y
Fecal Coliform, #/100 mL	502	1	128	32	5400	6	N
Iron, µg/L	153	100.0	554.6	500.0	1500.0	14	Y
Nitrate-Nitrite, mg/l	545	0.00	0.05	0.04	0.33		
Orthophosphate as P, mg/l	450	0.004	0.015	0.007	0.222		
Salinity, ppt	443	0.0	1.7	0.3	25.6		
Secchi Depth, m	535	0.00	1.20	1.10	6.00		
TKN, mg/l	510	0.04	0.81	0.75	3.30		
Total Nitrogen, mg/l	518	0.005	0.750	0.770	3.330	4	N
Total Phosphorus, mg/l	525	0.006	0.034	0.025	0.270	0	N
TSS, mg/l	478	2.0	3.7	2.0	94.0	5	N
Turbidity, NTU	394	0.2	2.3	1.9	19.5		
Unionized Ammonia, mg/l	478	0.0000	0.0008	0.0006	0.0099	0	N

Dissolved Oxygen

Similar to the analysis for the Cocohatchee watershed, an evaluation was completed to determine a likely causative factor for the depressed dissolved oxygen concentrations. Regressions analysis between dissolved oxygen and TN, TP, and color were conducted. For each regression the best-fit curve was selected when comparing exponential, linear, and power relationships. Results indicated that TP is the parameter that better explains statistically the low dissolved oxygen discharge in the watershed (**Table 2-19**). However, it explains only 29 percent of the condition. In addition TP mean and median concentrations are less than 15 percent of the nutrient screening levels for Florida streams. Therefore, other parameters are also likely affecting the DO condition.

Table 2-19. Identification of causative factor in the Golden Gates Naples Bay watershed for low dissolved oxygen values

Causative Factor	Method	P	r^2
Color	Power regression	0.0000	0.062
TN	Exponential regression	0.0005	0.024
TP	Power regression	0.0000	0.29

A potential causative factor for low dissolved oxygen values is groundwater contributions to the drainage network. Predicted groundwater concentrations of DO in the Golden Gate watershed are discussed in Section 2.5, The highest measured DO concentration in the watershed is less than 3.5 mg/L and the average DO concentration is less than 1.5 mg/L.

Table 2-20 shows the predicted flows in the watershed's drainage network, per the H&H model results. The table indicates that groundwater represents 43 and 24 percent of the average annual flow in the Golden Gate North canal and the Gordon River Extension, respectively. During the dry season, the groundwater contribution at those same locations increases to 52 and 32 percent, respectively. This data suggests that the groundwater flow to the canal network is significant and that the DO concentration in groundwater could be a factor that strongly influences DO concentrations in the canal network.

Table 2-20. Water budget contributions to the drainage network in the Golden Gate-Naples Bay Watershed

WBID	Name	Average Annual		Average Wet Season		Average Dry Season	
		Groundwater (inches)	Surface Water (inches)	Groundwater (inches)	Surface Water (inches)	Groundwater (inches)	Surface Water (inches)
3278S	Golden Gate North (1)	16.08	21.16	11.06	16.53	5.02	4.63
3278K	Gordon River Extension	1.09	6.67	0.54	5.48	0.55	1.19
(1) Indicates total flow in the canal in WBID area in inches, including diversions from other areas,							

Another factor that impacts DO concentrations is the discharge of nutrients and organic matter from urbanized areas. That is particularly important in the Golden Gate watershed, although as indicated for the Cocohatchee-Corkscrew watershed, the monthly concentrations curve shows that DO varies with temperature as expected for systems not influenced by algal activity. Further water quality analyses may be needed to assess the cause of the low DO levels.

Iron

Iron concentrations in the Golden Gate-Naples Bay watershed are sufficiently elevated to classify the watershed as of "potential concern". Fourteen percent of the 153 surface water samples show concentrations greater than the 1,000 µg/L Class 3 regulatory standard. Similarly, FDEP identified

WBID 3278S (North Golden Gate) as impaired for iron. Potential sources include iron dissolved in baseflow to the canal network, mine drainage, sewage treatment plant outfalls, or landfill leachate from industrial scrap yards.

Table 2-21 provides a summary of iron data collected within the Golden Gate-Naples Bay watershed. In WBID 3278K (Gordon River Extension), the average surface water concentration for iron is approximately 18 percent of the groundwater concentration. As indicated previously, the predicted average groundwater contribution is approximately 14 percent of inflows to the drainage network. This suggests that the measured surface water concentration may be directly related to the dilution of groundwater flowing into the drainage network.

In WBID 3278S (North Golden Gate), the average surface water concentration of iron is approximately 21 percent of the predicted groundwater concentration (Section 2.5). However, the predicted groundwater inflow to WBID 3278S comprises approximately 43 percent of the total inflow. The measured iron concentration in the surface water system is approximately half of what would be expected based on a relationship between the measured groundwater analytic data and the predicted inflow data. The data also suggests that surface water concentrations may be related to dilution of groundwater flowing into the drainage network. Additional studies should be conducted to further determine the impact of groundwater on iron concentration.

Table 2-21. Measured iron concentrations in the
Golden Gate-Naples Bay Watershed

WBID	WBID Name	Measured Average Annual Concentration	
		Groundwater (µg/L)	Surface Water (µg/L)
3278S	North Golden Gate	2,805	604
3278K	Gordon River Extension	1,643	304

The iron impairment issue was also analyzed with a water quality model developed for the Golden Gate watershed. Model results confirm that groundwater is a large component of the surface water flow. During the year, the majority of the flow in numerous sections of the Golden Gate Main Canal network is from groundwater, and therefore has a high concentration of iron. **Figure 2-42** shows the average concentration of iron during April for the entire data analysis period. During the wet season, baseflow is approximately equal to stormwater runoff. However, during the dry season, baseflow contributes more than 70 percent of the surface water flow, indicating that the concentration of iron may be more pronounced during days when no stormwater runoff is present.

Evaluation of WBID Impairment

Using all of the water quality data for each WBID, Atkins confirmed the impairment status of all three FDEP impaired WBIDs (**Table 2-22**). An additional potentially impaired condition for fecal coliform in the Gordon River Extension was also identified. However, fecal coliform concentration was not identified as a parameter of concern at the watershed level using long-term station data. As mentioned previously, this is simply an evaluation of impairments based on a comparison of the measured data with State standards. Further source identification efforts are warranted.

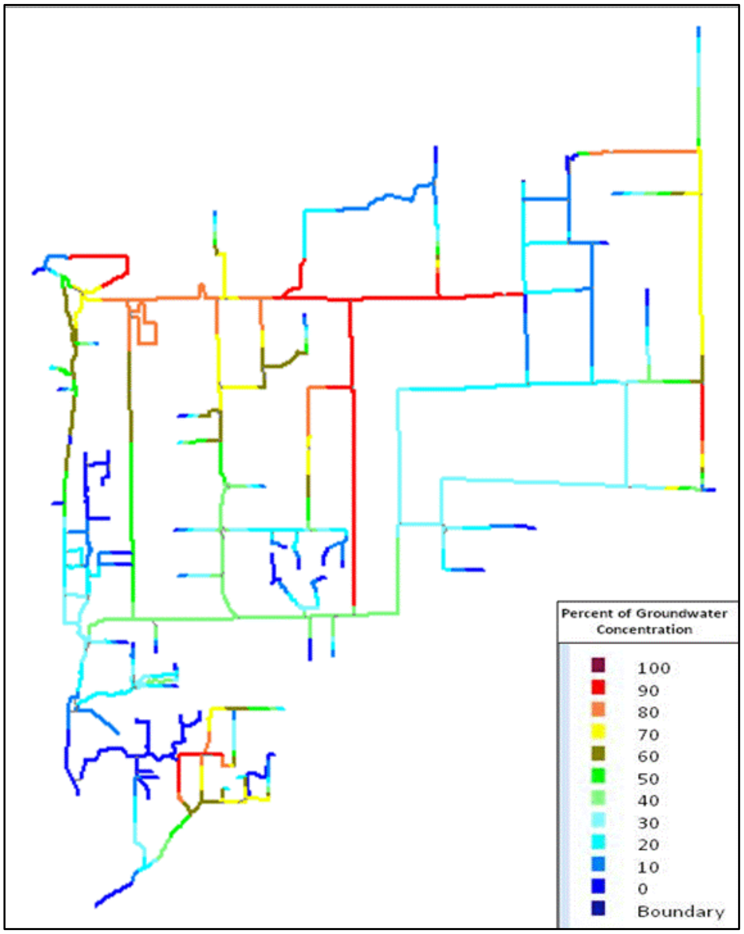


Figure 2-42. Percent of Iron Concentration in Canals Compared to Groundwater Concentration

Table 2-22. Impaired WBID comparison for
Golden Gate-Naples Bay watershed

WBID#	Water Segment Name	Impairment Parameter	PBSJ Analysis
3278K	Gordon River Extension	Dissolved Oxygen	Confirms FDEP assessment
3278S	North Golden Gate	Dissolved Oxygen	Confirms FDEP assessment
3278S	North Golden Gate	Iron	Confirms FDEP assessment
3278K	Gordon River Extension	Fecal Coliform	Potential new impairment

2.2.5.3 Rookery Bay Watershed

The summary statistics for the Rookery Bay watershed WBID impairment analysis are provided in **Table 2-23**. Based upon the evaluation of the long term stations within the watershed, one parameter (dissolved oxygen) was identified as being of "potential concern", although none of the WBIDs that comprised the Rookery Bay watershed were identified by FDEP as impaired waters for dissolved oxygen. Consistently elevated chlorophyll a and nutrient values were not observed in the watershed. Similar to the Cocohatchee-Corkscrew watershed, the majority of the Rookery Bay watershed is comprised of natural areas (69%) predominantly in the northern and central portions.

Table 2-23. Water Quality Summary Statistics for the Rookery Bay Watershed indicating potential parameters of concern

Parameter	N	Min	Mean	Median	Max	Percent Exceed	Parameter of Concern
BOD, mg/l	35	0.8	2.1	2.0	4.7		
Chlorophyll-a, µg/L	147	3.0	5.2	3.2	24.6	2	N
Color, PCU	144	20	58	50	240	8	N
Conductivity, umhos/cm	143	182	1565	810	24400		
Copper, µg/L	50	0.30	3.33	1.00	54.00		
Dissolved Oxygen, mg/l	147	1.41	5.59	5.69	11.42	39	Y
Fecal Coliform, #/100 mL	131	1	107	40	2600	6	N
Iron, µg/L	45	0.1	249.3	220.0	770.0	0	N
Nitrate-Nitrite, mg/l	139	0.00	0.04	0.02	0.25		
Orthophosphate as P, mg/l	120	0.004	0.008	0.005	0.067		
Salinity, ppt	137	0.1	0.8	0.4	14.7		
Secchi Depth, m	138	0.20	1.01	1.00	1.80		
TKN, mg/l	129	0.24	0.70	0.63	4.30		
Total Nitrogen, mg/l	132	0.010	0.631	0.645	4.300	2	N
Total Phosphorus, mg/l	129	0.007	0.029	0.022	0.220	0	N
TSS, mg/l	122	2.0	3.6	2.0	56.0	6	N
Turbidity, NTU	88	0.4	1.6	1.4	7.5		
Unionized Ammonia, mg/l	124	0.0000	0.0009	0.0006	0.0088	0	N

Dissolved Oxygen

As in the other watersheds within Collier County, an evaluation of potential causative factor(s) was completed to identify the reasons for the potential dissolved oxygen concentrations below the regulatory standard of 5.0 mg/l for fresh water bodies. Based upon regressions between dissolved oxygen and TN, TP and color, a potential causative factor for the low dissolved oxygen concentration in the watershed was identified as TP (**Table 2-24**). For each regression the best-fit curve was selected when comparing exponential, linear, and power relationships. While TP may be a causative factor, the low r^2 value (0.11) associated with the correlation between TP and dissolved oxygen concentrations suggests that multiple influences are contributing to dissolved oxygen fluctuations. The r^2 value can be interpreted as indicating that only 11 percent of the variation in levels of dissolved oxygen is explained by TP levels. In addition, the measured TP concentrations represent only about 10 percent of the screening level standard for Florida screens.

Table 2-24. Identification of causative factor in the Rookery Bay watershed for low dissolved oxygen values

Causative Factor	Method	p	r^2
Color	Power regression	0.0004	0.085
TN		>0.05	
TP	Power regression	0.0002	0.11

Factors influencing the depressed dissolved oxygen concentrations may include discharges from the forested landscape in the upstream portions of the watershed, groundwater contributions to the drainage network and anthropogenic pollutant loads.

As in the Cocohatchee watershed, a large percentage of the watershed consists of undeveloped wetland and forested landscapes within the Picayune Strand State Forest. It is likely that low dissolved oxygen concentrations in the upper portions of the watershed are a function of natural seasonal fluctuations which occur in these wetland environments.

In terms of groundwater, as shown in **Table 2-25,** computer model results indicate that the drainage network, particularly in the more developed western portion of the watershed, is strongly influenced by groundwater inflows. Approximately 68 percent of the total average annual flow and 85 percent of the dry season flow in the canal represents groundwater. There is little measured groundwater data for DO in the watershed; however, predicted groundwater concentrations of DO (Section 2.5) are less than 2.5 mg/L in the watershed. This information suggests that low DO levels in the canal network may be influenced by groundwater contributions. Groundwater monitoring within the watershed is recommended to verify the predicted groundwater concentrations.

Table 2-25. Water budget contributions to the drainage network in the Rookery Bay watershed

		Average Annual		Average Wet Season		Average Dry Season	
WBID	Name	Groundwater (inches)	Surface Water (inches)	Groundwater (inches)	Surface Water (inches)	Groundwater (inches)	Surface Water (inches)
3278V	Rookery Bay (Inland East)	3.34	6.09	2.15	5.48	1.19	0.61
3278Y	Rookery Bay (Inland West)	10.89	5.11	6.40	4.34	4.49	0.77

Anthropogenic impacts may be important particularly in the urban and agricultural areas of the watershed and their impact may be further assessed by local watershed assessments.

Evaluation of WBID Impairment

No impaired WBIDs have been identified by FDEP within the Rookery Bay watershed. However, Atkins identified two WBIDs with potential dissolved oxygen impairments (**Table 2-26**). As indicated previously, depressed dissolved oxygen concentrations may be influenced by natural conditions associated with the forested landscape in the upstream portions of the watershed. However, further studies are necessary to assess the cause of the impairment if in the future FDEP finds these areas impaired for DO.

Table 2-26. Impaired WBID comparison for Rookery Bay watershed

WBID#	Water Segment Name	Impairment Parameter	Atkins Analysis
3278V	Rookery Bay (Inland East Segment)	Dissolved Oxygen	Potential new impairment
3278Y	Rookery Bay (Inland West Segment)	Dissolved Oxygen	Potential new impairment

2.2.5.4 Faka Union Watershed

Summary statistics for the Faka-Union watershed WBID impairment analysis are provided in **Table 2-27**. Based upon the evaluation of the long term stations within the watershed, two parameters were identified as being of "potential concern"; color and dissolved oxygen. In terms of dissolved oxygen, concentrations were consistently below the regulatory standard of 5.0 mg/l for fresh water bodies.

An evaluation was completed to determine the causative factor likely responsible for the depressed dissolved oxygen concentrations. Regression analyses between dissolved oxygen and TN, TP and color indicated that the causative factor for the low dissolved oxygen discharge in the watershed may be color (**Table 2-28**). For each regression the best-fit curve was selected when comparing exponential, linear, and power relationships. As the vast majority (86%) of the Faka-Union watershed is comprised of natural areas, low dissolved oxygen concentrations in the watershed may be attributed to high color resulting from discharge from the adjacent natural landscape. However, the presence of areas where hydrologic processes have been altered (i.e., the Southern Golden Gate Estates drainage canals) suggests that further analysis are necessary to determine the actual cause of the observed low DO concentrations.

Table 2-27. Water Quality Summary Statistics for the Faka Union Watershed indicating potential parameters of concern

Parameter	N	Min	Mean	Median	Max	Percent Exceed	Parameter of Concern
BOD, mg/l	132	1.2	2.2	2.0	8.5		
Chlorophyll-a, µg/L	524	1.0	6.3	3.0	206.0	5	N
Color, PCU	509	5	62	50	240	12	Y
Conductivity, umhos/cm	528	211	2046	569	62047		
Copper, µg/L	166	0.15	1.37	1.00	17.70	0	N
Dissolved Oxygen, mg/l	542	1.02	6.02	5.96	14.54	37	Y
Fecal Coliform, #/100 mL	456	1	135	23	3850	8	N
Iron, µg/L	179	100.0	309.1	220.0	1390.0	2	N
Nitrate-Nitrite, mg/l	514	0.00	0.03	0.01	1.31		
Orthophosphate as P, mg/l	418	0.004	0.007	0.005	0.099		
Salinity, ppt	522	0.0	1.2	0.3	41.7		
Secchi Depth, m	319	0.30	1.19	1.20	2.50	34	Y
TKN, mg/l	463	0.04	0.60	0.52	4.90		
Total Nitrogen, mg/l	473	0.005	0.516	0.470	5.030	3	N
Total Phosphorus, mg/l	496	0.004	0.023	0.015	0.435	0	N
TSS, mg/l	441	2.0	3.1	2.0	62.0	6	N
Turbidity, NTU	331	0.1	1.8	1.3	7.1		
Unionized Ammonia, mg/l	449	0.0000	0.0006	0.0003	0.0127	0	N

Table 2-28. Identification of causative factor in the Faka Union watershed for low dissolved oxygen values

Causative Factor	Method	p	r^2
Color	Power regression	0.000	0.28
TN	Power regression	0.028	0.01
TP	Power regression	0.000	0.06

The impact of groundwater discharges into the drainage system was also evaluated based on results of the computer model. Model results shown in **Table 2-29** indicate that groundwater contributions are the primary source of inflows to the drainage network primarily during the dry season. In addition, measured and predicted groundwater concentrations of DO are less than 0.75 mg/L (Section 2.5). Groundwater contributions may also help explain the observed low dissolved oxygen concentrations.

Table 2-29. Water budget contributions to the drainage network in the Faka Union watershed

		Average Annual		Average Wet Season		Average Dry Season	
WBID	Name	Groundwater (inches)	Surface Water (inches)	Groundwater (inches)	Surface Water (inches)	Groundwater (inches)	Surface Water (inches)
3278H	Faka Union (North Segment)	11.71	7.81	7.70	6.91	4.00	0.90
3278I	Faka Union (South Segment)	14.67	3.94	9.41	3.66	5.26	0.28

Evaluation of WBID Impairment

No impaired WBIDs have been identified by FDEP within the Faka Union watershed. However, Atkins identified three potential impaired water bodies (**Table 2-30**). The Faka Union (South segment) had low dissolved oxygen values and elevated fecal coliform concentrations. Additionally, the north segment also was identified with low dissolved oxygen. If these impairments are verified by FDEP in the future, causative parameters and source identification work would be necessary.

Table 2-30. Impaired WBID comparison for Faka Union watershed

WBID#	Water Segment Name	Impairment Parameter	Atkins Analysis
3278I	Faka Union (South Segment)	Dissolved Oxygen	Potential new impairment
3278I	Faka Union (South Segment)	Fecal Coliform	Potential new impairment
3278H	Faka Union (North Segment)	Dissolved Oxygen	Potential new impairment

2.2.5.5 Fakahatchee Watershed

The vast majority of the Fakahatchee watershed is comprised of natural areas (85%). In fact, the Fakahatchee watershed has been identified by FDEP as a reference area due to the limited hydrologic impacts and absence of large-scale nutrient inputs. Therefore, water quality in this watershed is influenced by natural conditions.

The summary statistics for the Fakahatchee watershed are provided in **Table 2-31**. Based upon the evaluation of the long term stations within the watershed, three parameters were identified as being of "potential concern"; dissolved oxygen, fecal coliform and color. The Fakahatchee Strand (WBID 3278G) was declared verified impaired by FDEP for both dissolved oxygen and fecal coliform.

Table 2-31. Water Quality Summary Statistics for the Fakahatchee Watershed indicating potential waters of concern

Parameter	N	Min	Mean	Median	Max	Percent Exceed	Parameter of Concern
BOD, mg/l	107	1.5	2.3	2.0	9.8		
Chlorophyll-a, µg/l	435	3.0	9.3	3.0	404.5	9	N
Color, PCU	418	5	79	75	350	23	Y
Conductivity, umhos/cm	436	197	5599	604	72958		
Copper, µg/l	133	0.15	1.16	1.00	8.00		
Dissolved Oxygen, mg/l	448	0.24	3.80	3.34	12.77	75	Y
Fecal Coliform, #/100 mL	387	1	201	50	5450	12	Y
Iron, µg/l	147	0.1	213.8	150.0	1300.0	1	N
Nitrate-Nitrite, mg/l	428	0.00	0.02	0.01	0.22		
Orthophosphate as P, mg/l	351	0.004	0.020	0.006	0.368		
Salinity, ppt	441	0.0	3.4	0.3	50.3		
Secchi Depth, m	361	0.20	1.03	1.00	2.80		
TKN, mg/l	395	0.04	0.88	0.74	5.19		
Total Nitrogen, mg/l	393	0.005	0.716	0.650	5.320	7	N
Total Phosphorus, mg/l	407	0.004	0.047	0.020	1.180	3	N
TSS, mg/l	368	2.0	4.8	2.0	97.0	10	N
Turbidity, NTU	281	0.1	1.0	0.7	5.9		
Unionized Ammonia, mg/l	353	0.0000	0.0007	0.0003	0.0162	0	N

Dissolved Oxygen

Based upon the current regulatory criteria for the Fakahatchee watershed, dissolved oxygen levels were consistently below the regulatory threshold of 5.0 mg/l for fresh water bodies. An evaluation was completed to determine the causative factor likely responsible for the depressed dissolved oxygen concentrations. Based upon regressions between dissolved oxygen and TN, TP and color, the causative factor for the low dissolved oxygen discharge in the watershed was identified as color (**Table 2-32**). For each regression the best-fit curve was selected when comparing exponential, linear, and power relationships. The identification of color as the primary causative factor further supports the explanation of the tendency for low dissolved oxygen values in this mostly undeveloped landscape.

In terms of groundwater impacts, the Fakahatchee watershed is a recharge area. Model results show a net annual loss to groundwater from the surface water system. Therefore, groundwater is unlikely to have an impact on DO concentrations in the surface drainage system.

Table 2-32. Identification of causative factor in the Fakahatchee watershed for low dissolved oxygen values

Causative Factor	Method	p	r^2
Color	Power regression	0.000	0.17
TN	Linear regression	0.033	0.01
TP	Power regression	0.000	0.06

Fecal Coliform Bacteria

Fecal Coliform bacteria were identified as a potential parameter of concern in the Fakahatchee watershed based on the analysis of the long-term sampling stations. Twelve percent of the 387 values exceeded the 400 #/100 mL criteria established for Class 3 waters. WBID 3278G (Fakahatchee Strand) was identified as verified impaired for bacteria as evaluated by FDEP. As was previously discussed, fecal coliform are used as an indicator of pathogenic organisms and are currently used to identify potential health threats. Further source identification efforts are warranted.

Evaluation of WBID Impairment

Using all of the water quality data for each WBID, Atkins confirmed the FDEP impairment status of WBID 3278G, Fakahatchee Strand (**Table 2-33**). WBID 3289I (Camp Keais) was also identified as potentially impaired for dissolved oxygen. The lower DO concentrations are likely influenced by the natural characteristics of the watershed. However, nutrient loading from agricultural areas in the northern portions of the watershed may also contribute to low DO concentrations. Monitoring is recommended to identify any potential contribution from agricultural areas.

Table 2-33. Impaired WBID comparison for Fakahatchee watershed

WBID#	Water Segment Name	FDEP Impaired Parameter	PBSJ Analysis
3278G	Fakahatchee Strand	Dissolved Oxygen	Confirm FDEP assessment
3278G	Fakahatchee Strand	Fecal Coliform	Confirm FDEP assessment
3259I	Camp Keais	Dissolved Oxygen	Potential new impairment

2.2.5.6 Okaloacoochee–SR29 Watershed

About 60 percent of the Okaloacooche-SR29 watershed is comprised of natural areas. However, agricultural development exists in the upper portions of the watershed. Therefore it is possible that some impairments represent natural conditions, whereas others may be caused by anthropogenic impacts.

The summary statistics for the Okaloacoochee/SR29 watershed are provided in **Table 2-34**. Based upon the evaluation of the long term stations within the watershed, four parameters were identified as being of "potential concern"; dissolved oxygen, iron, total nitrogen, and color. Iron and dissolved oxygen were found to be impairment parameters by FDEP in this watershed.

Dissolved Oxygen

FDEP determined that WBIDs 3278T (Okaloacoochee) and 3278W (Silver Strand) are impaired for dissolved oxygen. Based upon the current dissolved oxygen criteria for the Okaloacooche-SR29 watershed, dissolved oxygen levels were consistently below the regulatory standard of 5.0 mg/l for fresh water bodies. Similar to the analyses conducted for the other watersheds, an evaluation was completed to determine the potential causative factor for the depressed dissolved oxygen concentration. Regression analyses between dissolved oxygen and TN, TP and color indicated that the most likely causative factor for the low dissolved oxygen level in the watershed was color (**Table 2-35**). For each regression the best-fit curve was selected when comparing exponential, linear, and power relationships. The identification of color as the causative factor is statistically significant, but it has a very low r^2 value, suggesting other factors may be influencing dissolved oxygen levels. For example, the data indicate that the 16 percent exceedence of TN occurs primarily in the upper portion of the watershed, which includes significant agricultural development.

Predicted groundwater concentrations (Section 2.5) and baseflow contributions may also be a contributing factor to low dissolved oxygen levels. **Table 2-36** shows the groundwater and surface water components of total flows in the drainage system from the associated WBIDs. Computer model results indicate that average annual groundwater contribution in the Barron River and Silver Strand canal amount to 20 and 38 percent, respectively. During the dry season, groundwater accounts for 39 and 77 percent of the total flow, respectively. Therefore, groundwater may be a significant factor explaining the DO levels, particularly in the Silver Strand canal, which has been found impaired for this parameter. Further site-specific analyses may be necessary to assess this finding.

Table 2-34. Water Quality Summary Statistics for the Okaloacoochee/SR29 Watershed indicating potential waters of concern

Parameter	N	Min	Mean	Median	Max	Percent Exceed	Parameter of Concern
BOD, mg/l	38	1.6	2.3	2.0	5.1		
Chlorophyll-a, µg/L	266	1.0	6.5	3.0	69.4	11	N
Color, PCU	255	5	90	80	450	31	Y
Conductivity, umhos/cm	297	103	491	502	905		
Copper, µg/L	73	0.15	1.35	1.10	6.29		
Dissolved Oxygen, mg/l	299	0.12	2.57	2.36	8.60	91	Y
Fecal Coliform, #/100 mL	243	1	112	33	3050	5	N
Iron, µg/L	49	0.1	478.2	250.0	1910.0	18	Y
Nitrate-Nitrite, mg/l	295	0.00	0.02	0.01	0.37		
Orthophosphate as P, mg/l	254	0.002	0.019	0.010	0.312		
Salinity, ppt	154	0.0	0.2	0.2	0.5		
Secchi Depth, m	262	0.10	1.28	1.25	2.60		
TKN, mg/l	282	0.04	1.23	0.90	35.35		
Total Nitrogen, mg/l	280	0.005	1.124	0.811	35.353	16	Y
Total Phosphorus, mg/l	290	0.006	0.049	0.026	0.470	2	N
TSS, mg/l	238	2.0	4.6	4.0	174.0	5	N
Turbidity, NTU	210	0.2	1.4	0.7	20.0		
Unionized Ammonia, mg/l	267	0.0000	0.0018	0.0003	0.3241	1	N

Table 2-35. Identification of causative factor in the Okaloacooche-SR29 watershed for low dissolved oxygen values

Causative Factor	Method	p	r^2
Color	Exponential regression	0.0001	0.06
TN		>0.05	
TP		>0.05	

Table 2-36. Water budget contributions to the drainage system in the Okaloacoochee-SR29 watershed

WBID	Name	Average Annual		Average Wet Season		Average Dry Season	
		Ground–water (inches)	Surface Water (inches)	Ground–water (inches)	Surface Water (inches)	Ground–water (inches)	Surface Water (inches)
3261C	Barron River Canal	2.88	11.36	1.50	9.16	1.38	2.20
3278T	Okaloacoochee Slough	0.04	3.22	0.03	2.51	0.01	0.70
3278W	Silver Strand (1)	3.04	5.04	1.40	4.56	1.64	0.48
(1) Flows are expressed in inches over the WBID area							

Iron

FDEP identified WBID 3261C (Barron River Canal) as impaired for iron. The Okaloacooche-SR29 watershed iron concentrations were sufficiently elevated to classify the entire watershed as of "potential concern" in regards to elevated iron concentrations. Analytical data show that nine (9) of the 49 samples had total iron concentrations higher than the 1,000 µg/L Class 3 regulatory standard. **Table 2-37** shows iron concentration statistics in the Barron River WBID both in the Water Table aquifer and the drainage network. The data seem to indicate that groundwater contributions from the WBID itself are not causing the elevated iron concentrations in the surface water system. However, the table also shows that groundwater iron concentrations in the WBID representing the Silver Strand, which discharges into the Barron River, are 180 percent higher than the regulatory standard. As indicated previously, groundwater contributions in the Silver Strand WBID represent 38 percent of the average annual flow and 77 percent of the dry season flow. The elevated groundwater concentrations in WBID 3278W, paired with the high percentage of baseflow suggest that iron concentrations in the downstream canal may be due to groundwater contributions from upstream.

As described previously in this report, sources of iron may also be of anthropogenic nature. The County may elect to conduct further analyses in this watershed to confirm the sources of the elevated iron concentrations in the Barron River.

Evaluation of WBID Impairment

Per the evaluation of the water quality data for each WBID, Atkins confirmed the impairment status of all three FDEP impaired WBIDs. As shown in **Table 2-38,** three additional potential impairment locations were also identified. Dissolved oxygen and iron were both identified as parameters of concern in the watershed analysis. However, the copper and chlorophyll *a* impairments resulted from the analysis of data for each WBID.

Table 2-37. Measured Iron concentrations in the Okaloacoochee-SR29 watershed

WBID	Name	Average Iron Concentration (ug/L)		Maximum Iron Concentration (ug/L)	
		Water Table Aquifer	Drainage Network	Water Table Aquifer	Drainage Network
3278W	Silver Strand	1817	No data	5880	No data
3261C	Barron River	309	663.2	510	1910

Table 2-38. Impaired WBID comparison for Okaloacoochee/SR29 watershed

WBID#	Water Segment Name	FDEP Impaired Parameter	PBSJ Analysis
3261C	Barron River Canal	Iron	Confirm FDEP assessment
3278T	Okaloacoochee	Dissolved Oxygen	Confirm FDEP assessment
3278W	Silver Strand	Dissolved Oxygen	Confirm FDEP assessment
3278W	Silver Strand	Copper	Potential new impairment
3278T	Okaloacoochee	Chlorophyll a	Potential new impairment
3261C	Barron River Canal	Dissolved Oxygen	Potential new impairment

In regards to the potential copper impairments for WBID 3278W (Silver Strand), four water quality locations provide data within the water body. However, all of the copper data were collected at a single location (station 21FLSFWMIMKBRN). It is recommended that the additional water quality samples be collected at other stations within the WBID to assess the extent of the problem. It is possible that water samples collected near boardwalks and pilings that are constructed from pressure-treated lumber show localized effects of copper leaching. It is also possible that the problem is generic to the WBID, in which case, action should be taken to eliminate anthropogenic sources.

In terms of Chlorophyll *a*, a review of the data analyzed for Okaloacoochee WBID (3278T) showed that five water quality stations exist in the WBID. However, 76 of the 78 chlorophyll *a* data points came from one station (Okala858). A preliminary investigation indicates that TP may be the causative factor resulting in elevated phytoplankton production at this location. However, a more detailed evaluation of the data and additional sampling from other water quality stations is recommended.

2.2.6 Conclusions

The FDEP has identified multiple impairments of individual WBIDs for several water quality parameters in Collier County. Results of water quality analyses at the watershed level suggest that

DO is the main parameter of concern in the context of FDEP's TMDL program. The data analyses for individual WBIDS conducted as part of this project are consistent with the FDEP findings, although additional potential water quality impairments are possible within some WBIDS. Following is a summary of the project findings.

- No discrepancies were found between FDEPs and Atkins impaired WBID designation. However, Atkins identified 16 new potential impairments. The difference is likely due to the incorporation of additional data with the IWR Run 39 dataset as well as differences in the analysis period.
- The most widespread "impairments" or "parameters of concern" appear to be those for dissolved oxygen. Causative factors include anthropogenic pollution loads, natural surface water discharges from forested landscapes, and groundwater inflows.
- Anthropogenic loads of nutrients and organic material are often the cause of low dissolved oxygen concentrations in urbanized areas. Discharge of pollution loads is generally best achieved by source control.
- High levels of color appear to be related to influences of high-tannin water from the extensive forested landscapes in areas such as the Corkscrew Swamp and the Fakahatchee Strand. In turn, increased tannin-rich waters during the wet season appear to result in depressed levels of dissolved oxygen.
- Groundwater discharges are significant in several watersheds. These discharges contribute to the observed low DO concentration conditions, particularly during the dry season.
- With the exception of Lake Trafford, freshwater water bodies in Collier County are not characterized by consistently high levels of TN or TP. The water quality benefits that seem to be occurring in response to the dredging project for Lake Trafford should be considered prior to implementing any water quality "fixes", as water quality may already be improved sufficiently that further activities are not needed.
- While many of the freshwater water bodies within the watersheds of Collier County are designated as "impaired" for fecal coliform bacteria, these indicator organisms do not specifically identify humans as a source of contamination (Fujioka 2001, and Fujioka et al. 1999). Additional efforts aimed at source identification are appropriate.

2.3 SURFACE WATER POLLUTANT LOADING

An approach that has been used by federal and state regulatory agencies to quantify the amount of pollutants discharged into a water body is to estimate the average annual pollutant loads. Land use based pollutant loading can serve as a useful accounting method for determining the relative contribution of various land use types to total pollutant load. In addition, establishing baseline and existing condition pollutant loads allows for a relative comparison as a performance of current pollutant loading to that resulting once improvement projects are implemented. The calculation of pollution loads for the management plans considered strictly anthropogenic loads as the focus of watershed protection and restoration is the mitigation of anthropogenic impacts.

2.3.1 Methods

Pollution loads discharged to the Collier County receiving water bodies were estimated using a Pollutant Loading and Removal Model. The model computes the loads using a variation of what is referred to as the USEPA Simple Method.

$$L_l = (0.227)(R)(EMC)(A)$$

where:
L_l = Annual pollutant load (lb/yr)
R = Annual average runoff (in/yr)
EMC = Event mean concentration of a pollutant (mg/l)
A = Catchment area (acres)

Runoff volume was determined using flow data from the MIKE SHE / MIKE 11 hydrologic & hydraulic (H&H) existing conditions computer model. The EMC is the mean concentration of a chemical parameter expected in the stormwater runoff discharged from a particular land use category during a typical (average) storm event. The area was considered that of each grid cell in the model domain, which amounts to approximately 51.6 acres.

Anthropogenic pollutant loads were estimated for the pollutants listed in **Table 2-39**. These are the same pollutants identified as parameters of concern in the SWFFS.

Table 2-39. List of Evaluated Pollutants

Conventional Pollutants	Heavy Metals
Total Suspended Solids (TSS) Total Nitrogen (TN) Total Phosphorus (TP) 5-Day Biological Oxygen Demand (BOD_5)	Copper (Cu) Zinc (Zn) Lead (Pb)

Iron is also a parameter of water quality concern in Collier County. However, pollutant loads were not calculated because EMCs for iron are usually not available. Anthropogenic iron pollution is either site specific or sources are of natural origin.

The pollution loads calculated as described above represent the loads generated in the watershed (gross pollutant load). The pollutant loads discharged into the County's drainage system are referred to as net loads and they consider the effects of runoff treatment provided by the existing Best Management Practices (BMPs). The method used to estimate the pollutant removal capacity of the BMPs is described later in the report. It should be noted that pollutant loads should be not be compared to in-stream water quality measurements, as the land use base loading does not account for fate, transport and degradation of pollutants, nor ambient in-stream conditions and processes. Comparisons to in-stream data should be done in combination with a water quality model that incorporates in-stream chemical processes.

Following are descriptions of the land use analysis performed for estimating pollutant loads, as well as a detailed description of the pollutant load calculation method.

2.3.1.1 Land Use Analysis

The land use distribution for this analysis was made consistent with both the H&H model and the SWFFS. Therefore, it represents 2007 land use conditions. The land use maps incorporated in the H&H model were converted to a GIS-compatible format. The land use within each cell (1,500 x 1,500 feet) within the model domain grid was set based on its dominant use. The land use categories are shown in **Table 2-40**.

2.3.1.2 Pollution Load Calculation Method

As indicated previously, pollutant load calculation is based on expected annual runoff volume, the stormwater event mean concentrations (EMC), and the area of each cell.

2.3.1.3 Expected Annual Runoff Volume

The H&H model results for the simulation period considered for the watershed analysis were used to generate water balance data for every model grid cell. Because the simulation period includes a variety of rainfall conditions, it is reasonable to assume that it provides a reasonable estimate of annual average runoff volume.

Table 2-40. Land Use Categories in the H&H Model

Land Use Code	MIKE SHE Land Use	Land Use Type
1	Citrus	Agriculture
2	Pasture	Agriculture
5	Truck Crops	Agriculture
6	Golf Course	Agriculture
7	Bare Ground	Natural
8	Mesic Flatwood	Natural
9	Mesic Hammock	Natural
12	Hydric Flatwood	Natural
13	Hydric Hammock	Natural
14	Wet Prairie	Natural
16	Marsh	Natural
17	Cypress	Natural
18	Swamp Forest	Natural
19	Mangrove	Natural
20	Water	Natural
41	Urban Low Density	Urban
42	Urban Medium Density	Urban
43	Urban High Density	Urban

The runoff volume discharged from each cell was determined based on the product of expected runoff depth and the area of each cell (2,250,000 ft^2). Runoff depth was calculated as:

Runoff Depth = Overland flow to canals and rivers + drainage from the unsaturated zone.

The overland flow to canals and rivers includes cell to river flow and cell to cell boundary flow. The drainage from the unsaturated zone includes water that was captured by stormwater management features and agricultural drains and eventually discharges to the canals and rivers.

Because the MIKE SHE / MIKE 11 model includes a larger number of components than the typical surface water hydrologic model, errors are introduced when determining the runoff depth from a single cell. These errors are due primarily to the regional nature of some of the modelling processes and their spatial variations. For example, in the event that a cell represents a low area and ponds water, a certain volume of rainfall would go to storage and the runoff estimate from the cell may show as negative. To reduce the effects of these spatial variations, the runoff volume from each cell was adjusted by a smoothing process that consisted of averaging the runoff using a 12-cell grid of neighbouring cells. This produced stable and satisfactory results for pollution load calculations.

2.3.1.4 Event Mean Concentrations (EMCs)

As indicated previously, the EMC is the mean concentration of a chemical parameter expected in the stormwater runoff discharged from a particular land use category during a typical (average) storm event. For consistency with previous work, the EMCs used in this analysis were obtained from the SWFFS Water Quality Model Development report. Because the focus of this analysis is on anthropogenic loads, the EMCs associated with the natural areas were assumed to be zero (0). **Table 2-41** lists the EMCs by land use category and chemical parameter.

2.3.1.5 Pollution Load Estimates By H&H Model Grid Cell

As described previously, gross pollutant loads were estimated for each cell in the model domain. Those loads were then modified to reflect the pollution removal effect of Best Management Practices (BMPs), such as detention ponds that exist throughout the County. The net loads are pollution loads that enter the drainage network, and therefore discharge into the estuary systems.

The method used to assess the extent of BMPs in the project area considered that current stormwater regulations in Florida came into effect in 1984. Therefore, development occurring since the mid to late 1980s includes treatment facilities that meet current regulatory standards.

To account for the presence of BMPs, a land use map from the 1980s was compared to the current land use map to identify the areas developed during the period. The SFWMD publishes land use data every number of years and the 1988 land use data base was determined to be the most appropriate for the analysis, as it was assumed that it would take a few years for the regulations to affect development. **Figure 2-43** illustrates the extent of urban development for the periods before and after 1988. Development from the period after 1988 was assumed to discharge stormwater runoff treated to current regulatory standards.

As the most commonly used BMP in Collier County is wet detention, net pollutant load calculations considered the typical pollutant reduction efficiency at this type of facility. They are listed in **Table 2-42**.

Table 2-41. Event Mean Concentrations (EMCs) by Land Use and Chemical Parameter

Land Use Code	H&H Model Land Use	SWFFS Land Use Category	Pollutant EMC's for Loading Analysis (mg/l)						
			TN	TP	BOD	TSS	CU	PB	ZN
1	Citrus	Agricultural/Pasture/Golf Course	3.18	0.64	4	13	0.004	0.005	0.023
2	Pasture	Agricultural/Pasture/Golf Course	3.18	0.64	4	13	0.004	0.005	0.023
5	Truck Crops	Agricultural/Pasture/Golf Course	3.18	0.64	4	13	0.004	0.005	0.023
6	Golf Course	Agricultural/Pasture/Golf Course	3.18	0.64	4	13	0.004	0.005	0.023
7	Bare Ground	Forest/Rural/Open	1.16	0.05	1	11	0.001	0.001	0
8	Mesic Flatwood	Forest/Rural/Open	0	0	0	0	0	0	0
9	Mesic Hammock	Forest/Rural/Open	0	0	0	0	0	0	0
12	Hydric Flatwood	Forest/Rural/Open	0	0	0	0	0	0	0
13	Hydric Hammock	Forest/Rural/Open	0	0	0	0	0	0	0
14	Wet Prairie	Water/Wetlands	0	0	0	0	0	0	0
16	Marsh	Water/Wetlands	0	0	0	0	0	0	0
17	Cypress	Water/Wetlands	0	0	0	0	0	0	0
18	Swamp Forest	Water/Wetlands	0	0	0	0	0	0	0
19	Mangrove	Water/Wetlands	0	0	0	0	0	0	0
20	Water	Water/Wetlands	0	0	0	0	0	0	0
41	Urban Low Density	Low Density Residential	2.02	0.39	13	27	0.012	0.016	0.051
42	Urban Medium Density	Medium Density Residential	2.34	0.39	9	59	0.023	0.016	0.073
43	Urban High Density	Urban and Built Up	2.45	0.37	8	72	0.031	0.015	0.065

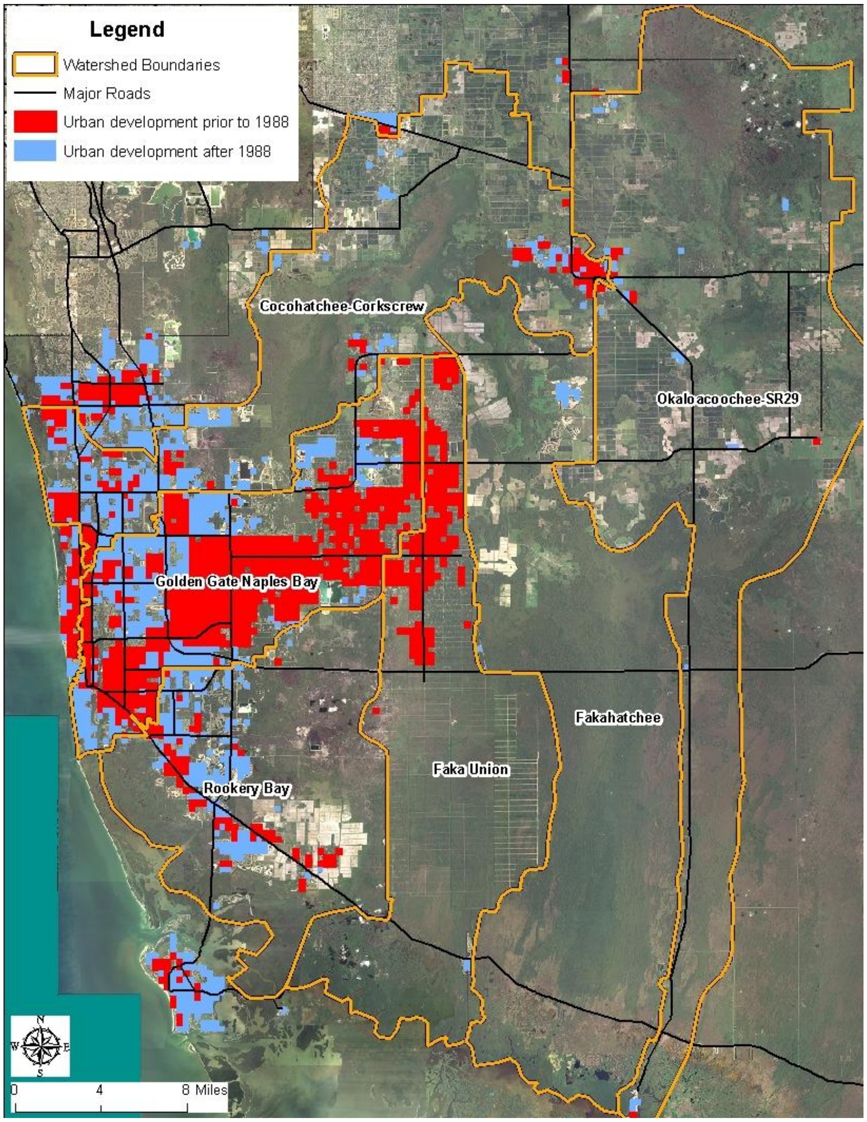


Figure 2-43, Areas of Development Before and After Current Stormwater Regulations Base Year for Analysis 1988

Table 2-42. Pollutant Removal Efficiency of Wet Detention Ponds

Chemical Parameter	Removal Efficiency (%)
Total Suspended Solids (TSS)	80
Total Nitrogen (TN)	30
Total Phosphorus (TP)	65
5-Day Biological Oxygen Demand (BOD-5)	80
Copper (Cu)	65
Lead (Pb)	80
Zinc (Zn)	80

2.3.2 Results

The estimated annual pollutant loads by cell were aggregated to reflect loads by WBID and watershed. They are shown in **Tables 2-43 through 2-49**. In addition, the tables show the load by unit area (lbs/acre/year) and the pollution load performance score to better reflect areas of concern. The scoring method is described in detail in section 4.3 of this volume. Results show that the WBIDs of most concern in terms of nutrient pollution loads are in the Cocohatchee–Corkscrew and the Golden Gate-Naples Bay Watersheds, particularly the coastal segment of Naples Bay and the Gordon River Extension. The Golden Gate-Naples Bay Watershed received the lowest average scores for the other pollutants because of the presence of areas of urban development with no treatment. It should be noted that the Lake Trafford WBID shows a pollution load of zero (0). That is because the WBID includes only the lake itself. The drainage area contributing to Lake Trafford includes WBIDs 3278E, Cow Slough, and 3278L, the Immokalee Basin.

Table 2-43. Total Suspended Solids Pollution Loads by WBID and Watershed

Watershed	WBID	WBID Name	Area (Acres)	Net Load (lbs/yr)	Net Load per Acre (lbs/ac/yr)	Performance Score
Cocohatchee - Corkscrew	3259A	COCOHATCHEE RIVER	3151	73414	23.3	8
	3259B	DRAINAGE TO CORKSCREW	21333	291250	13.7	9
	3259W	LAKE TRAFFORD	1395	0	0.0	10
	3259Z	LITTLE HICKORY BAY	620	25268	40.8	7
	3278C	COCOHATCHEE GOLF COURSE DISCHARGE	2066	47072	22.8	8
	3278D	COCOHATCHEE (INLAND SEGMENT)	25930	554807	21.4	9
	3278E	COW SLOUGH	11983	169129	14.1	9
	3278F	CORKSCREW MARSH	53461	431283	8.1	10
	3278L	IMMOKALEE BASIN	8368	215006	25.7	8
Total Watershed			128306	1807230	14.09	9
Golden Gate - Naples Bay	3278K	GORDON RIVER EXTENSION	5424	305600	56.3	5
	3278R	NAPLES BAY (COASTAL SEGMENT)	9246	1196629	129.4	0
	3278S	NORTH GOLDEN GATE	72624	1760485	24.2	8
Total Watershed			87293	3262713	37.38	7
Rookery Bay	3278U	ROOKERY BAY (COASTAL SEGMENT)	26033	144194	5.5	10
	3278V	ROOKERY BAY (INLAND EAST SEGMENT)	53719	444148	8.3	10
	3278Y	ROOKERY BAY (INLAND WEST SEGMENT)	14876	274768	18.5	9
Total Watershed			94628	863110	9.12	10
Faka Union - Fakahatchee - Okaloacoochee SR29	3278H	FAKA UNION (NORTH SEGMENT)	27221	214664	7.9	10
	3278I	FAKA UNION (SOUTH SEGMENT)	60227	1738	0.0	10
	3259I	CAMP KEAIS	55320	887706	16.0	9
	3278G	FAKAHATCHEE STRAND	94112	13370	0.1	10
	3261C	BARRON RIVER CANAL	33368	2622	0.1	10
	3278T	OKALOACOOCHEE SLOUGH	125413	1180126	9.4	10
	3278W	SILVER STRAND	54236	1537972	28.4	8
Total Watershed			449897	3838198	8.53	10

Table 2-44. Total Nitrogen Pollution Loads by WBID and Watershed

Watershed	WBID	WBID Name	Area (Acres)	Net Load (lbs/yr)	Net Load per Acre (lbs/ac/yr)	Performance Score
Cocohatchee - Corkscrew	3259A	COCOHATCHEE RIVER	3151	3973	1.26	8
	3259B	DRAINAGE TO CORKSCREW	21333	71326	3.34	3
	3259W	LAKE TRAFFORD	1395	0	0.00	10
	3259Z	LITTLE HICKORY BAY	620	1383	2.23	5
	3278C	COCOHATCHEE GOLF COURSE DISCHARGE	2066	4337	2.10	6
	3278D	COCOHATCHEE (INLAND SEGMENT)	25930	75503	2.91	4
	3278E	COW SLOUGH	11983	31528	2.63	5
	3278F	CORKSCREW MARSH	53461	100424	1.88	6
	3278L	IMMOKALEE BASIN	8368	32341	3.86	2
Total Watershed			128306	320814	2.50	5
Golden Gate - Naples Bay	3278K	GORDON RIVER EXTENSION	5424	20392	3.76	2
	3278R	NAPLES BAY (COASTAL SEGMENT)	9246	51998	5.62	0
	3278S	NORTH GOLDEN GATE	72624	167717	2.31	5
Total Watershed			87293	240107	2.75	4
Rookery Bay	3278U	ROOKERY BAY (COASTAL SEGMENT)	26033	17113	0.66	9
	3278V	ROOKERY BAY (INLAND EAST SEGMENT)	53719	94441	1.76	7
	3278Y	ROOKERY BAY (INLAND WEST SEGMENT)	14876	27643	1.86	6
Total Watershed			94628	139197	1.47	7
Faka Union - Fakahatchee - Okaloacoochee SR29	3278H	FAKA UNION (NORTH SEGMENT)	27221	26815	0.99	8
	3278I	FAKA UNION (SOUTH SEGMENT)	60227	130	0.00	10
	3259I	CAMP KEAIS	55320	215056	3.89	2
	3278G	FAKAHATCHEE STRAND	94112	3271	0.03	10
	3261C	BARRON RIVER CANAL	33368	312	0.01	10
	3278T	OKALOACOOCHEE SLOUGH	125413	287563	2.29	5
	3278W	SILVER STRAND	54236	370499	6.83	0
Total Watershed			449897	903646	2.01	6

Table 2-45. Total Phosphorus Pollution Loads by WBID and Watershed

Watershed	WBID	WBID Name	Area (Acres)	Net Load (lbs/yr)	Net Load per Acre (lbs/ac/yr)	Performance Score
Cocohatchee - Corkscrew	3259A	COCOHATCHEE RIVER	3151	520	0.17	8
	3259B	DRAINAGE TO CORKSCREW	21333	14225	0.67	1
	3259W	LAKE TRAFFORD	1395	0	0.00	10
	3259Z	LITTLE HICKORY BAY	620	204	0.33	6
	3278C	COCOHATCHEE GOLF COURSE DISCHARGE	2066	423	0.20	8
	3278D	COCOHATCHEE (INLAND SEGMENT)	25930	12003	0.46	4
	3278E	COW SLOUGH	11983	6083	0.51	4
	3278F	CORKSCREW MARSH	53461	19883	0.37	5
	3278L	IMMOKALEE BASIN	8368	6228	0.74	0
Total Watershed			128306	59569	0.46	4
Golden Gate - Naples Bay	3278K	GORDON RIVER EXTENSION	5424	3188	0.59	2
	3278R	NAPLES BAY (COASTAL SEGMENT)	9246	7628	0.83	0
	3278S	NORTH GOLDEN GATE	72624	26280	0.36	6
Total Watershed			87293	37096	0.42	5
Rookery Bay	3278U	ROOKERY BAY (COASTAL SEGMENT)	26033	3067	0.12	9
	3278V	ROOKERY BAY (INLAND EAST SEGMENT)	53719	18334	0.34	6
	3278Y	ROOKERY BAY (INLAND WEST SEGMENT)	14876	3652	0.25	7
Total Watershed			94628	25054	0.26	7
Faka Union - Fakahatchee - Okaloacoochee SR29	3278H	FAKA UNION (NORTH SEGMENT)	27221	3890	0.14	9
	3278I	FAKA UNION (SOUTH SEGMENT)	60227	25	0.00	10
	3259I	CAMP KEAIS	55320	42964	0.78	0
	3278G	FAKAHATCHEE STRAND	94112	658	0.01	10
	3261C	BARRON RIVER CANAL	33368	24	0.00	10
	3278T	OKALOACOOCHEE SLOUGH	125413	57779	0.46	4
	3278W	SILVER STRAND	54236	74376	1.37	0
Total Watershed			449897	179716	0.40	6

Table 2-46. Total BOD-5 Pollution Loads by WBID and Watershed

Watershed	WBID	WBID Name	Area (Acres)	Net Load (lbs/yr)	Net Load per Acre (lbs/ac/yr)	Performance Score
Cocohatchee - Corkscrew	3259A	COCOHATCHEE RIVER	3151	10674	3.4	8
	3259B	DRAINAGE TO CORKSCREW	21333	90438	4.2	8
	3259W	LAKE TRAFFORD	1395	0	0.0	10
	3259Z	LITTLE HICKORY BAY	620	4161	6.7	7
	3278C	COCOHATCHEE GOLF COURSE DISCHARGE	2066	6145	3.0	9
	3278D	COCOHATCHEE (INLAND SEGMENT)	25930	125610	4.8	8
	3278E	COW SLOUGH	11983	50622	4.2	8
	3278F	CORKSCREW MARSH	53461	140057	2.6	9
	3278L	IMMOKALEE BASIN	8368	47590	5.7	7
Total Watershed			128306	475295	3.70	8
Golden Gate - Naples Bay	3278K	GORDON RIVER EXTENSION	5424	48487	8.9	5
	3278R	NAPLES BAY (COASTAL SEGMENT)	9246	159348	17.2	0
	3278S	NORTH GOLDEN GATE	72624	587334	8.1	6
Total Watershed			87293	795169	9.11	5
Rookery Bay	3278U	ROOKERY BAY (COASTAL SEGMENT)	26033	29465	1.1	10
	3278V	ROOKERY BAY (INLAND EAST SEGMENT)	53719	130833	2.4	9
	3278Y	ROOKERY BAY (INLAND WEST SEGMENT)	14876	49438	3.3	9
Total Watershed			94628	209735	2.22	9
Faka Union - Fakahatchee - Okaloacoochee SR29	3278H	FAKA UNION (NORTH SEGMENT)	27221	101807	3.7	8
	3278I	FAKA UNION (SOUTH SEGMENT)	60227	837	0.0	10
	3259I	CAMP KEAIS	55320	270057	4.9	8
	3278G	FAKAHATCHEE STRAND	94112	4114	0.0	10
	3261C	BARRON RIVER CANAL	33368	291	0.0	10
	3278T	OKALOACOOCHEE SLOUGH	125413	362788	2.9	9
	3278W	SILVER STRAND	54236	467854	8.6	5
Total Watershed			449897	1207748	2.68	9

Table 2-47. Total Copper (Cu) Pollution Loads by WBID and Watershed

Watershed	WBID	WBID Name	Area (Acres)	Net Load (lbs/yr)	Net Load per Acre (lbs/ac/yr)	Performance Score
Cocohatchee - Corkscrew	3259A	COCOHATCHEE RIVER	3151	33	0.0	8
	3259B	DRAINAGE TO CORKSCREW	21333	92	0.0	8
	3259W	LAKE TRAFFORD	1395	0	0.0	10
	3259Z	LITTLE HICKORY BAY	620	11	0.0	7
	3278C	COCOHATCHEE GOLF COURSE DISCHARGE	2066	28	0.0	9
	3278D	COCOHATCHEE (INLAND SEGMENT)	25930	266	0.0	8
	3278E	COW SLOUGH	11983	62	0.0	8
	3278F	CORKSCREW MARSH	53461	142	0.0	9
	3278L	IMMOKALEE BASIN	8368	80	0.0	7
Total Watershed			128306	714	0.01	8
Golden Gate - Naples Bay	3278K	GORDON RIVER EXTENSION	5424	135	0.0	5
	3278R	NAPLES BAY (COASTAL SEGMENT)	9246	520	0.1	0
	3278S	NORTH GOLDEN GATE	72624	854	0.0	6
Total Watershed			87293	1510	0.02	5
Rookery Bay	3278U	ROOKERY BAY (COASTAL SEGMENT)	26033	61	0.0	10
	3278V	ROOKERY BAY (INLAND EAST SEGMENT)	53719	160	0.0	9
	3278Y	ROOKERY BAY (INLAND WEST SEGMENT)	14876	144	0.0	9
Total Watershed			94628	366	0.00	9
Faka Union - Fakahatchee - Okaloacoochee SR29	3278H	FAKA UNION (NORTH SEGMENT)	27221	112	0.0	8
	3278I	FAKA UNION (SOUTH SEGMENT)	60227	1	0.0	10
	3259I	CAMP KEAIS	55320	281	0.0	8
	3278G	FAKAHATCHEE STRAND	94112	4	0.0	10
	3261C	BARRON RIVER CANAL	33368	2	0.0	10
	3278T	OKALOACOOCHEE SLOUGH	125413	365	0.0	9
	3278W	SILVER STRAND	54236	480	0.0	5
Total Watershed			449897	1244	0.00	9

Table 2-48. Total Lead (Pb) Pollution Loads by WBID and Watershed

Watershed	WBID	WBID Name	Area (Acres)	Net Load (lbs/yr)	Net Load per Acre (lbs/ac/yr)	Performance Score
Cocohatchee - Corkscrew	3259A	COCOHATCHEE RIVER	3151	19	0.0	8
	3259B	DRAINAGE TO CORKSCREW	21333	113	0.0	9
	3259W	LAKE TRAFFORD	1395	0	0.0	10
	3259Z	LITTLE HICKORY BAY	620	7	0.0	7
	3278C	COCOHATCHEE GOLF COURSE DISCHARGE	2066	11	0.0	9
	3278D	COCOHATCHEE (INLAND SEGMENT)	25930	181	0.0	8
	3278E	COW SLOUGH	11983	66	0.0	9
	3278F	CORKSCREW MARSH	53461	175	0.0	9
	3278L	IMMOKALEE BASIN	8368	67	0.0	8
Total Watershed			128306	638	0.00	9
Golden Gate - Naples Bay	3278K	GORDON RIVER EXTENSION	5424	80	0.0	6
	3278R	NAPLES BAY (COASTAL SEGMENT)	9246	283	0.0	0
	3278S	NORTH GOLDEN GATE	72624	776	0.0	7
Total Watershed			87293	1139	0.01	6
Rookery Bay	3278U	ROOKERY BAY (COASTAL SEGMENT)	26033	43	0.0	10
	3278V	ROOKERY BAY (INLAND EAST SEGMENT)	53719	167	0.0	9
	3278Y	ROOKERY BAY (INLAND WEST SEGMENT)	14876	78	0.0	9
Total Watershed			94628	288	0.00	9
Faka Union - Fakahatchee - Okaloacoochee SR29	3278H	FAKA UNION (NORTH SEGMENT)	27221	125	0.0	9
	3278I	FAKA UNION (SOUTH SEGMENT)	60227	1	0.0	10
	3259I	CAMP KEAIS	55320	339	0.0	8
	3278G	FAKAHATCHEE STRAND	94112	5	0.0	10
	3261C	BARRON RIVER CANAL	33368	1	0.0	10
	3278T	OKALOACOOCHEE SLOUGH	125413	454	0.0	9
	3278W	SILVER STRAND	54236	587	0.0	7
Total Watershed			449897	1512	0.00	9

Table 2-49. Total Zinc (Zn) Pollution Loads by WBID and Watershed

Watershed	WBID	WBID Name	Area (Acres)	Net Load (lbs/yr)	Net Load per Acre (lbs/ac/yr)	Performance Score
Cocohatchee - Corkscrew	3259A	COCOHATCHEE RIVER	3151	86	0.0	9
	3259B	DRAINAGE TO CORKSCREW	21333	516	0.0	9
	3259W	LAKE TRAFFORD	1395	0	0.0	10
	3259Z	LITTLE HICKORY BAY	620	28	0.0	7
	3278C	COCOHATCHEE GOLF COURSE DISCHARGE	2066	49	0.0	9
	3278D	COCOHATCHEE (INLAND SEGMENT)	25930	766	0.0	8
	3278E	COW SLOUGH	11983	282	0.0	9
	3278F	CORKSCREW MARSH	53461	768	0.0	9
	3278L	IMMOKALEE BASIN	8368	303	0.0	8
Total Watershed			128306	2798	0.02	9
Golden Gate - Naples Bay	3278K	GORDON RIVER EXTENSION	5424	341	0.1	6
	3278R	NAPLES BAY (COASTAL SEGMENT)	9246	1231	0.1	1
	3278S	NORTH GOLDEN GATE	72624	2754	0.0	8
Total Watershed			87293	4325	0.05	7
Rookery Bay	3278U	ROOKERY BAY (COASTAL SEGMENT)	26033	186	0.0	10
	3278V	ROOKERY BAY (INLAND EAST SEGMENT)	53719	739	0.0	9
	3278Y	ROOKERY BAY (INLAND WEST SEGMENT)	14876	329	0.0	9
Total Watershed			94628	1254	0.01	9
Faka Union - Fakahatchee - Okaloacoochee SR29	3278H	FAKA UNION (NORTH SEGMENT)	27221	404	0.0	9
	3278I	FAKA UNION (SOUTH SEGMENT)	60227	3	0.0	10
	3259I	CAMP KEAIS	55320	1560	0.0	8
	3278G	FAKAHATCHEE STRAND	94112	24	0.0	10
	3261C	BARRON RIVER CANAL	33368	2	0.0	10
	3278T	OKALOACOOCHEE SLOUGH	125413	2085	0.0	9
	3278W	SILVER STRAND	54236	2697	0.0	7
Total Watershed			449897	6775	0.02	9

2.4 GROUND WATER QUANTITY

The purpose of this section is to present the results of the groundwater analyses completed using data extracted from the Collier County MIKE SHE/MIKE11 Existing Conditions Model (ECM). This section summarizes the predicted water budgets for each aquifer simulated by the ECM and discusses potential issues identified through the water budgeting process.

2.4.1 Ground Water Budgets

Three main aquifer systems have been identified in Collier County and Southwest Florida, the Surficial Aquifer System (SAS), the Intermediate Aquifer System (IAS), and the Floridan Aquifer System (FAS). Two aquifers are included in the SAS, the Water Table Aquifer and the Lower Tamiami Aquifer. A thin, semi-confining marl exists between the two aquifers (Weedman, 2002). The IAS also includes two aquifers, the Sandstone Aquifer and the Mid-Hawthorn Aquifer, which are separated by confining units. These two aquifer systems are simulated in the ECM. The Floridan Aquifer system is not represented in the ECM since it is isolated from the overlying aquifer and is not used as a source of drinking water. Atkins believes that the model is adequate to assess the conditions in Collier County; however, it is recognized that the groundwater calibration, primarily in the deeper aquifers, may be improved with additional effort. A detailed discussion of model limitations is presented in the Model Calibration Report.

The assessment of existing groundwater conditions involved detailed water budget calculations and spatial evaluations from ECM model results. Water budgets were set up to evaluate the lateral flow of water across model boundaries and internal basin delineation boundaries, and the vertical flow of water or exchange between aquifers.

The water budget analysis was conducted to understand the distribution of aquifer inflows and outflows. Data was extracted from the model result files using the water budget tool included in the software. The model results were then post processed to create water budgets for the entire model study area as well as for each of the watersheds, Cocohatchee-Corkscrew (CC), Golden Gate Naples Bay (GGNB), Rookery Bay (RB), and the combined Faka Union, Fakahatchee, and Okaloacoochee-SR29 (Eastern) watersheds.

Aquifer specific water budgets were generated for the model simulation period of January 1, 2002 through October 31, 2007. Budgets were developed for different time periods based on the availability of model simulation data. The time periods included:

- **Annual**: The annual water budget represents average conditions during each water year from 2003 to 2007. The budget represents the period from November 1–October 31. For example, the 2003 water year is the period from November 1, 2002–October 31, 2003.
- **Wet Season**: The wet season is defined as July 1–October 31. Wet season water budgets were developed for the years 2002–2007. This period includes all the wet seasons incorporated in the model simulation period.

- **Dry Season**: The dry season is defined as the period from November 1–June 30. For example, the 2003 dry season represents the period from November 2002–June 2003. Dry season water budgets were developed for the years 2003–2007.

Figure 2-44 is a schematic of the overall water budget components. As shown, the primary sources of inflow to a watershed are precipitation and applied irrigation. This water accumulates on the ground surface as basin storage, runs off as overland flow or infiltrates into the ground. Overland flow can be evaporated, discharged into the canal, or flow across watershed boundaries. Water budgets related to surface water runoff and baseflow are discussed in Technical Memorandum 1.1: Surface Water Quantity.

Water that infiltrates into the soils can be taken up by plants or percolate into the Water Table aquifer. This water can then be removed by plant uptake, lateral flows across the watershed boundary, pumping activities to meet potable water and irrigation needs, or by percolation to underlying aquifers. Any residual water is stored in the aquifer. Similar processes occur in each of the deeper aquifers.

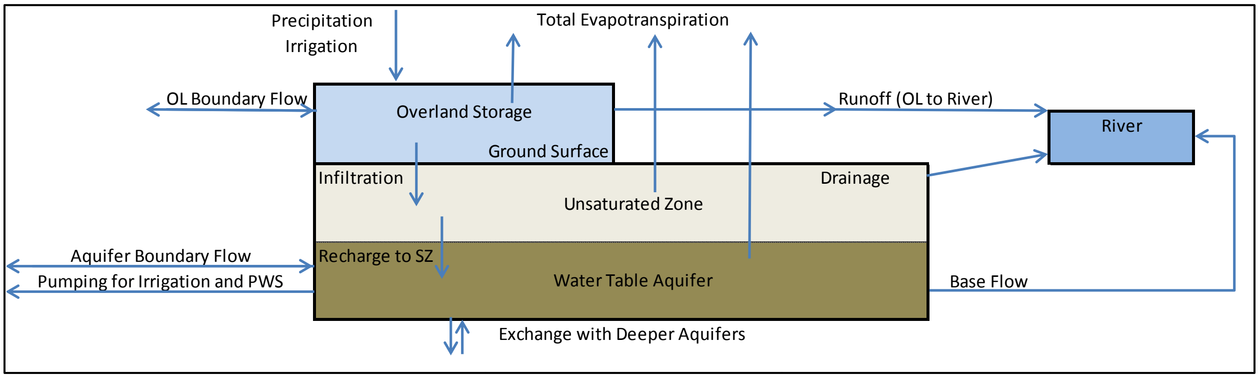


Figure 2-44. Components of Water Table Aquifer Budget

This section describes the results of the groundwater budget analysis in terms of annual average, wet season, and dry season. In addition, annual and seasonal groundwater budgets were developed for each watershed.

Groundwater Budget Analysis for the Water Table Aquifer

Table 2-50 and Figure 2-45 show the annual water year budget components for the study area. Tables 2-51 through 2-54 show the groundwater budgets for each watershed. Results indicate that approximately 93 percent of the water percolating downward from the unsaturated zone is lost due to evapotranspiration, baseflow, and pumping. The timing and volume of water percolating downward from the unsaturated zone is directly correlated to the timing of rainfall events. As an example, in the dry season of 2005, more than 10 inches of water infiltrated into the Water Table Aquifer. This volume exceeds most of the average wet season infiltration volumes and was caused by more than 18 inches of rainfall that occurred in June 2005.

Table 2-50. Water Table Aquifer, Annual Water Year and Seasonal Budgets for the Study Area

Period	Inflows (inches)				Outflows (inches)					Change in Storage (inches)
	Infiltration from Unsaturated Zone	Recharge from Canal Network	From Lower Tamiami	Boundary Inflow	Evapo-transpiration	Baseflow	To Lower Tamiami	Pumping	Boundary Outflow	
Average Water Year										
2003	16.69	0.31	8.23	0.16	10.39	4.21	7.99	0.28	0.83	1.69
2004	16.22	0.31	8.11	0.28	10.87	4.25	8.58	0.35	0.79	0.12
2005	18.58	0.35	7.99	0.31	10.94	4.84	9.21	0.35	0.75	1.18
2006	13.31	0.31	7.60	0.31	10.08	4.09	8.98	0.51	0.63	-2.72
2007	9.84	0.43	6.34	0.51	7.32	2.09	7.72	0.71	0.39	-1.06
Average	14.93	0.35	7.65	0.31	9.92	3.90	8.50	0.44	0.68	-0.16
Average Wet Season										
2002	6.50	0.04	2.48	0.08	3.50	1.54	2.60	0.04	0.20	1.14
2003	7.40	0.04	3.46	0.04	4.72	2.72	3.46	0.04	0.35	-0.28
2004	10.39	0.04	3.31	0.08	4.41	2.52	3.54	0.04	0.31	3.07
2005	8.62	0.04	3.43	0.08	4.80	3.03	3.94	0.00	0.35	0.04
2006	10.04	0.04	2.99	0.12	4.13	2.40	3.58	0.08	0.20	2.80
2007	9.37	0.08	2.48	0.20	2.87	1.34	2.99	0.08	0.12	4.72
Average	8.72	0.05	3.02	0.10	4.07	2.26	3.35	0.05	0.26	1.92
Average Dry Season										
2003	9.29	0.28	4.76	0.08	5.75	1.54	4.53	0.28	0.47	1.89
2004	5.83	0.28	4.80	0.16	6.50	1.77	5.00	0.31	0.47	-2.99
2005	10.35	0.31	4.61	0.24	6.18	1.81	5.31	0.35	0.39	1.46
2006	3.31	0.28	4.61	0.20	5.94	1.69	5.39	0.43	0.43	-5.51
2007	0.51	0.35	3.86	0.31	4.45	0.79	4.72	0.59	0.28	-5.79
Average	5.86	0.30	4.53	0.20	5.76	1.52	4.99	0.39	0.41	-2.19

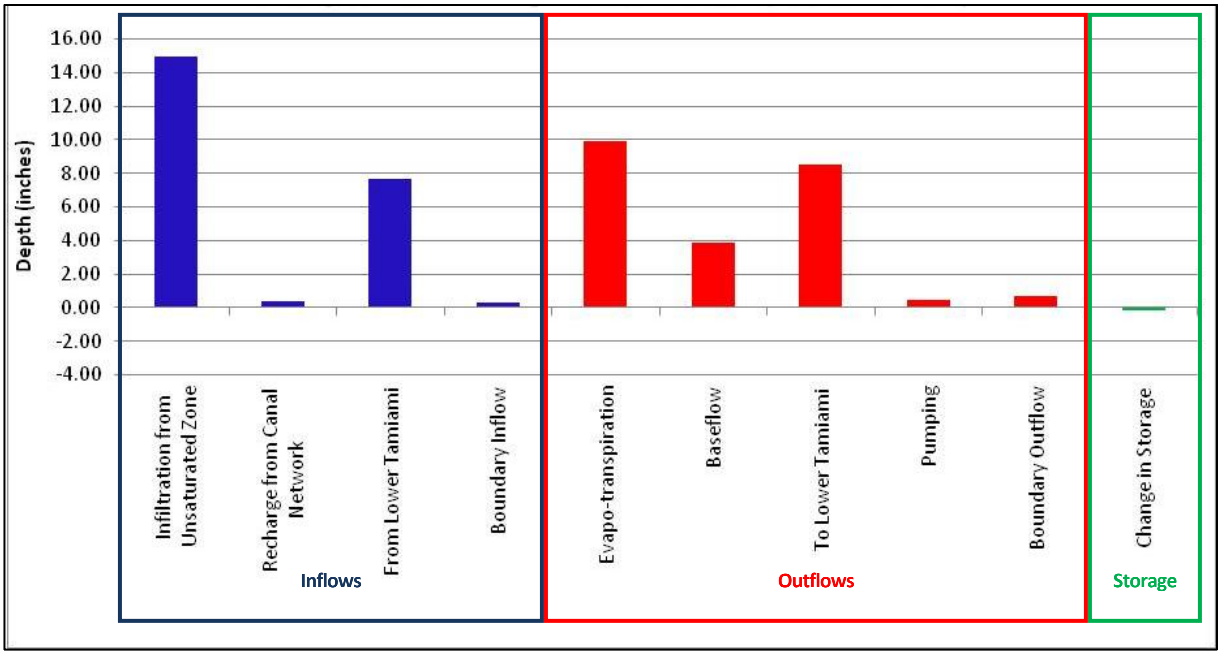


Figure 2-45. Water Table Aquifer, Average Annual Water Year Budget for the Study Area

Table 2-51. Water Table Aquifer, Annual Water Year and Seasonal Budgets for the Cocohatchee-Corkscrew Watershed

Period	Inflows (inches)				Outflows (inches)					Change in Storage (inches)
	Infiltration from Unsaturated Zone	Recharge from Canal Network	From Lower Tamiami	Boundary Inflow	Evapo-transpiration	Baseflow	To Lower Tamiami	Pumping	Boundary Outflow	
Annual Water Year Average										
2003	17.01	0.12	3.31	0.55	8.43	2.60	6.54	0.67	0.98	1.81
2004	16.46	0.16	3.50	0.63	9.17	2.52	7.05	0.83	0.98	0.16
2005	19.06	0.16	3.74	0.67	9.88	2.83	7.36	0.79	1.06	1.69
2006	12.64	0.20	3.03	0.67	7.95	2.20	7.40	1.22	0.91	-3.23
2007	8.74	0.20	1.77	0.59	3.74	0.75	6.73	1.57	0.79	-2.32
Average	14.78	0.17	3.07	0.62	7.83	2.18	7.02	1.02	0.94	-0.38
Wet Season Average										
2002	7.05	0.04	1.06	0.20	2.83	0.91	1.85	0.12	0.28	2.36
2003	6.89	0.04	1.77	0.24	4.49	1.57	2.52	0.04	0.43	-0.12
2004	10.00	0.04	1.73	0.28	4.45	1.50	2.52	0.08	0.39	3.15
2005	7.95	0.04	1.89	0.28	4.96	1.69	2.68	0.04	0.43	0.39
2006	9.29	0.04	1.38	0.31	3.70	1.18	2.40	0.16	0.31	3.27
2007	7.87	0.04	0.87	0.28	1.81	0.39	1.89	0.16	0.28	4.53
Average	8.18	0.04	1.45	0.26	3.71	1.21	2.31	0.10	0.35	2.26
Dry Season Average										
2003	10.20	0.08	1.54	0.31	3.98	1.02	4.02	0.63	0.59	1.93
2004	6.46	0.12	1.77	0.35	4.72	1.06	4.53	0.75	0.63	-2.99
2005	11.06	0.12	1.89	0.39	4.92	1.18	4.69	0.75	0.63	1.34
2006	3.31	0.16	1.65	0.35	4.25	1.02	5.00	1.06	0.59	-6.50
2007	0.87	0.16	0.91	0.35	1.93	0.35	4.84	1.50	0.51	-6.85
Average	6.38	0.13	1.55	0.35	3.96	0.93	4.61	0.94	0.59	-2.61

Table 2-52. Water Table Aquifer, Annual Water Year and Seasonal Budgets for the Golden Gate-Naples Bay Watershed

Period	Inflows (inches)				Outflows (inches)					Change in Storage (inches)
	Infiltration from Unsaturated Zone	Recharge from Canal Network	From Lower Tamiami	Boundary Inflow	Evapo-transpiration	Baseflow	To Lower Tamiami	Pumping	Boundary Outflow	
Annual Water Year Average										
2003	23.27	0.79	2.28	0.94	3.70	15.94	6.14	0.75	0.35	0.47
2004	21.61	0.71	2.40	1.06	3.62	14.53	6.34	0.94	0.39	0.00
2005	26.02	0.87	2.36	1.02	4.25	16.97	6.42	1.10	0.43	1.10
2006	20.51	0.71	2.40	0.98	3.35	14.49	6.42	1.38	0.43	-1.46
2007	11.22	1.30	1.65	0.91	1.57	6.69	5.51	1.93	0.35	-0.94
Average	20.53	0.87	2.22	0.98	3.30	13.72	6.17	1.22	0.39	-0.17
Wet Season Average										
2002	9.02	0.04	0.87	0.31	1.30	6.14	2.36	0.08	0.12	0.28
2003	13.15	0.04	1.14	0.39	2.32	10.28	2.40	0.04	0.12	-0.39
2004	13.46	0.04	1.06	0.39	2.24	9.21	2.40	0.08	0.16	0.87
2005	14.09	0.04	1.14	0.39	2.52	10.55	2.48	0.08	0.16	-0.08
2006	13.39	0.04	1.10	0.35	2.01	9.02	2.44	0.12	0.20	1.14
2007	9.45	0.20	0.75	0.35	0.87	4.92	2.17	0.16	0.12	2.48
Average	12.09	0.07	1.01	0.37	1.88	8.35	2.38	0.09	0.14	0.72
Dry Season Average										
2003	10.12	0.75	1.14	0.55	1.38	5.63	3.78	0.67	0.24	0.87
2004	8.11	0.67	1.34	0.67	1.38	5.31	3.94	0.87	0.20	-0.87
2005	11.93	0.83	1.22	0.63	1.73	6.42	3.94	1.10	0.28	1.18
2006	7.13	0.67	1.26	0.59	1.38	5.47	3.98	1.26	0.24	-2.60
2007	1.77	1.14	0.91	0.55	0.71	1.77	3.35	1.77	0.20	-3.39
Average	7.81	0.81	1.17	0.60	1.31	4.92	3.80	1.13	0.23	-0.96

Table 2-53. Water Table Aquifer, Annual Water Year and Seasonal Budgets for the Rookery Bay Watershed

Period	Inflows (inches)				Outflows (inches)					Change in Storage (inches)
	Infiltration from Unsaturated Zone	Recharge from Canal Network	From Lower Tamiami	Boundary Inflow	Evapo-transpiration	Baseflow	To Lower Tamiami	Pumping	Boundary Outflow	
Annual Water Year Average										
2003	16.42	0.28	7.09	0.47	8.98	4.21	8.78	0.12	1.18	0.94
2004	15.91	0.28	7.32	0.35	9.61	4.49	8.74	0.12	1.18	-0.24
2005	19.80	0.31	8.11	0.51	10.16	5.20	10.28	0.12	1.22	1.73
2006	14.76	0.31	7.28	0.35	9.61	4.53	9.06	0.16	1.22	-1.85
2007	9.17	0.43	5.55	0.51	6.77	1.85	6.14	0.20	0.91	-0.20
Average	15.21	0.32	7.07	0.44	9.02	4.06	8.60	0.14	1.14	0.08
Wet Season Average										
2002	5.59	0.08	2.01	0.28	3.07	1.22	2.68	0.04	0.28	0.71
2003	8.78	0.12	3.78	0.24	5.12	2.87	4.92	0.00	0.39	-0.43
2004	10.08	0.08	3.54	0.20	4.57	2.72	4.45	0.00	0.39	1.77
2005	10.04	0.08	4.09	0.24	5.24	3.43	5.39	0.00	0.47	-0.08
2006	10.63	0.08	3.46	0.24	4.76	2.80	4.57	0.00	0.43	1.85
2007	8.07	0.16	2.44	0.28	3.03	1.10	3.27	0.04	0.28	3.27
Average	8.86	0.10	3.22	0.24	4.30	2.36	4.21	0.01	0.37	1.18
Dry Season Average										
2003	7.64	0.20	3.31	0.20	3.86	1.34	3.86	0.12	0.79	1.38
2004	5.87	0.20	3.78	0.16	5.04	1.77	4.29	0.12	0.79	-2.01
2005	9.80	0.24	4.02	0.24	4.92	1.81	4.88	0.12	0.75	1.81
2006	4.13	0.24	3.82	0.12	4.84	1.77	4.49	0.16	0.79	-3.70
2007	1.10	0.28	3.11	0.24	3.70	0.79	2.87	0.20	0.63	-3.46
Average	5.71	0.23	3.61	0.19	4.47	1.50	4.08	0.14	0.75	-1.20

Table 2-54. Water Table Aquifer, Annual Water Year and Seasonal Budgets for the Eastern Watersheds

Period	Inflows (inches)				Outflows (inches)					Change in Storage (inches)
	Infiltration from Unsaturated Zone	Recharge from Canal Network	From Lower Tamiami	Boundary Inflow	Evapo-transpiration	Baseflow	To Lower Tamiami	Pumping	Boundary Outflow	
Annual Water Year Average										
2003	15.20	0.31	11.34	0.12	13.11	2.68	8.27	0.12	0.83	1.97
2004	15.12	0.31	11.30	0.28	13.58	2.99	9.25	0.12	0.83	0.20
2005	16.89	0.31	11.02	0.28	13.31	3.31	9.69	0.12	0.79	1.34
2006	11.42	0.31	10.63	0.31	12.68	2.76	9.33	0.20	0.63	-2.91
2007	10.24	0.39	9.25	0.47	10.20	1.65	8.35	0.24	0.43	-0.55
Average	13.77	0.33	10.71	0.29	12.57	2.68	8.98	0.16	0.70	0.01
Wet Season Average										
2002	5.79	0.08	3.39	0.04	4.29	0.91	2.95	0.04	0.24	0.87
2003	6.18	0.04	4.49	0.04	5.24	1.73	3.70	0.00	0.35	-0.28
2004	9.84	0.04	4.37	0.08	4.88	1.65	3.86	0.00	0.35	3.62
2005	7.32	0.04	4.49	0.08	5.28	2.17	4.21	0.00	0.35	-0.08
2006	9.13	0.04	4.02	0.12	4.76	1.57	3.74	0.04	0.20	3.07
2007	10.08	0.08	3.54	0.16	3.74	0.98	3.50	0.04	0.16	5.43
Average	8.06	0.05	4.05	0.09	4.70	1.50	3.66	0.02	0.28	2.11
Dry Season Average										
2003	9.02	0.31	6.85	0.08	7.87	0.94	4.57	0.12	0.51	2.24
2004	5.24	0.28	6.97	0.16	8.70	1.34	5.39	0.12	0.51	-3.46
2005	9.57	0.31	6.54	0.20	8.03	1.14	5.47	0.12	0.43	1.42
2006	2.28	0.31	6.61	0.16	7.95	1.14	5.59	0.16	0.47	-5.94
2007	0.16	0.31	5.71	0.28	6.46	0.67	4.84	0.20	0.28	-5.98
Average	5.25	0.31	6.54	0.17	7.80	1.05	5.17	0.14	0.44	-2.35

In the Water Table Aquifer, approximately 24 percent of the water infiltrating from the unsaturated zone is lost baseflow on average in the study area. However, in the Golden Gate-Naples Bay Watershed, the percentage of baseflow exceeds 60 percent as is shown in Table 2-52. The high percentage of baseflow losses is directly related to the canal density in the Golden Gate-Naples Bay Watershed and is discussed in more detail in Technical Memorandum 1.1: Surface Water Quantity. The other watersheds have a lower density of canals and as a result, the percentage of baseflow losses is much lower.

Results also indicate that there is a great deal of interaction between the Water Table and Lower Tamiami aquifers. On average approximately 7.65 inches of water moves upward from the Lower Tamiami aquifer into the Water Table Aquifer annually, and 8.50 inches moves downward. The net result is that approximately six (6) percent of the water entering the aquifer from the unsaturated zone percolates downward to recharge the Lower Tamiami Aquifer.

The seasonal annual water year results for the Water Table Aquifer indicate that percolation from the water table to the Lower Tamiami aquifer amounts to approximately four (4) percent of the water entering the unsaturated zone during the wet season and eight (8) percent during the dry season. This process is controlled by the characteristics of the confining unit that restricts downward movement. The result is that the storage in the Water Table aquifer increases by an average of 1.92 inches during the wet season.

During the dry season, the opposite occurs. With less rainfall, the amount of water percolating from the Water Table Aquifer to the Lower Tamiami Aquifer exceeds the amount that infiltrates into the Water Table Aquifer from the overlying soils. This activity, coupled with pumping for irrigation and water supply needs results in an average net loss of Water Table aquifer storage of approximately 2.19 inches during the dry season.

Computer model results also show that an average of 0.44 inch of water is pumped from the Water Table Aquifer annually. The majority of the pumping occurs during the dry season when demand to meet irrigation needs increase.

The results of the water budget analysis for each watershed indicate that the highest percentage of annual average percolation to the Lower Tamiami Aquifer occurs in the Cocohatchee-Corkscrew Watershed (Table 2-51). In this watershed, more than 25 percent of the water infiltrating into the aquifer from the unsaturated zone percolates into the Lower Tamiami Aquifer. In the Golden Gate–Naples Bay and Rookery Bay watersheds (Tables 2-52 and 2-53), the percentage of water percolating to the Lower Tamiami Aquifer is 19 and 10 percent, respectively.

The annual water budget results for the Faka Union, Fakahatchee, and Okaloacoochee–SR29 (Eastern) watersheds, shown in Table 2-54, indicate that there is a net gain in water migrating upward into the Water Table Aquifer System from the Lower Tamiami Aquifer. This appears to be the result of high levels of evapotranspiration from the natural areas in the watersheds. This is most evident in the dry season when evapotranspiration is approximately equal to the volume of water infiltrating into the aquifer from the unsaturated zone.

The groundwater budget for the Water Table Aquifer indicates that there is a net annual loss of stored water of approximately 0.16 inch across the study area. However, that watershed scale budgets show that the net loss only occurs in the Cocohatchee–Corkscrew and Golden Gate-Naples Bay Watersheds. In the Cocohatchee–Corkscrew watershed, the predicted average net loss of storage in the Water Table Aquifer is most likely associated with groundwater pumping and movement of water across watershed boundaries. In the Golden Gate-Naples Bay Watershed, the annual net loss is storage is related to baseflow losses to the canal network and groundwater pumping for potable water supply.

Groundwater Budget Analysis for the Lower Tamiami Aquifer

Table 2-55 shows the annual water year and seasonal water budget results for the Lower Tamiami Aquifer across the study area. Figure 2-46 shows the average annual water year water budget for the Lower Tamiami Aquifer. In addition to an annual average inflow from the Water Table Aquifer of 0.84 inch, the results indicate that the Lower Tamiami Aquifer also receives a net annual inflow from the underlying Sandstone Aquifer of 1.5 inches. This net inflow from the over- and underlying aquifers appears to be driven by the annual pumping activities conducted to meet potable water and irrigation demand. As expected, the majority of the inflow occurs during the dry season when pumping demand is at its peak.

The water budgets for the Lower Tamiami Aquifer include losses due to baseflow. This loss is associated with the canal networks that cut into this aquifer system. The watershed budgets indicate that baseflow to the canals from the Lower Tamiami Aquifer is low in the Cocohatchee-Corkscrew Watershed. The amount of baseflow increases in each watershed moving to the south and east, with the most baseflow occurring in the Rookery Bay and Eastern Watersheds. This pattern indicates that the Water Table Aquifer is less thin in the southern parts of the county.

In the Cocohatchee-Corkscrew watershed (Table 2-56), the water budget results indicate a net loss of water (1.9 inches) to the Sandstone Aquifer suggesting that this watershed is a primary source of recharge to the underlying aquifer system. On the other hand, the Golden Gate-Naples Bay (Table 2-57) and Rookery Bay (Table 2-58) watersheds have net gains from the Sandstone Aquifer of 0.14, and 0.78 inch, respectively. This net gain is likely the result of additional hydraulic head differences resulting from pumping activities.

Table 2-55. Lower Tamiami Aquifer, Annual Water Year and Seasonal Budgets for the Study Area

Period	Inflows (inches)				Outflows (inches)					Change in Storage (inches)
	Percolation from Water Table	From Sandstone	Recharge from Canal Network	Boundary Inflow	Baseflow	Percolation To Sandstone	To Water Table	Pumping	Boundary Outflow	
Annual Water Year Average										
2003	7.99	2.87	0.08	3.07	0.79	1.18	8.23	1.65	2.09	0.04
2004	8.58	2.91	0.08	2.64	0.91	1.18	8.11	1.85	2.17	0.00
2005	9.21	2.76	0.08	2.48	0.91	1.26	7.99	1.81	2.56	0.00
2006	8.98	2.87	0.08	2.60	0.83	1.38	7.60	2.44	2.24	-0.04
2007	7.72	2.64	0.08	2.48	0.55	1.57	6.34	2.87	1.57	-0.04
Average	8.50	2.81	0.08	2.65	0.80	1.31	7.65	2.13	2.13	-0.01
Wet Season Average										
2002	2.60	1.02	0.00	0.75	0.31	0.24	2.48	0.47	0.67	0.16
2003	3.46	1.02	0.04	0.98	0.39	0.31	3.46	0.31	0.98	0.04
2004	3.54	1.02	0.04	0.87	0.39	0.31	3.31	0.28	1.06	0.12
2005	3.94	0.98	0.00	0.79	0.47	0.35	3.43	0.28	1.22	0.00
2006	3.58	0.98	0.00	0.83	0.39	0.31	2.99	0.51	0.98	0.20
2007	2.99	0.87	0.04	0.79	0.28	0.28	2.48	0.43	0.59	0.55
Average	3.35	0.98	0.02	0.83	0.37	0.30	3.02	0.38	0.92	0.18
Dry Season Average										
2003	4.53	1.85	0.04	2.09	0.39	0.87	4.76	1.34	1.10	0.00
2004	5.00	1.89	0.04	1.77	0.51	0.87	4.80	1.57	1.10	-0.12
2005	5.31	1.77	0.08	1.69	0.43	0.91	4.61	1.54	1.34	0.00
2006	5.39	1.85	0.04	1.77	0.43	1.06	4.61	1.97	1.26	-0.24
2007	4.72	1.73	0.04	1.69	0.28	1.30	3.86	2.44	0.94	-0.59
Average	4.99	1.82	0.05	1.80	0.41	1.00	4.53	1.77	1.15	-0.19

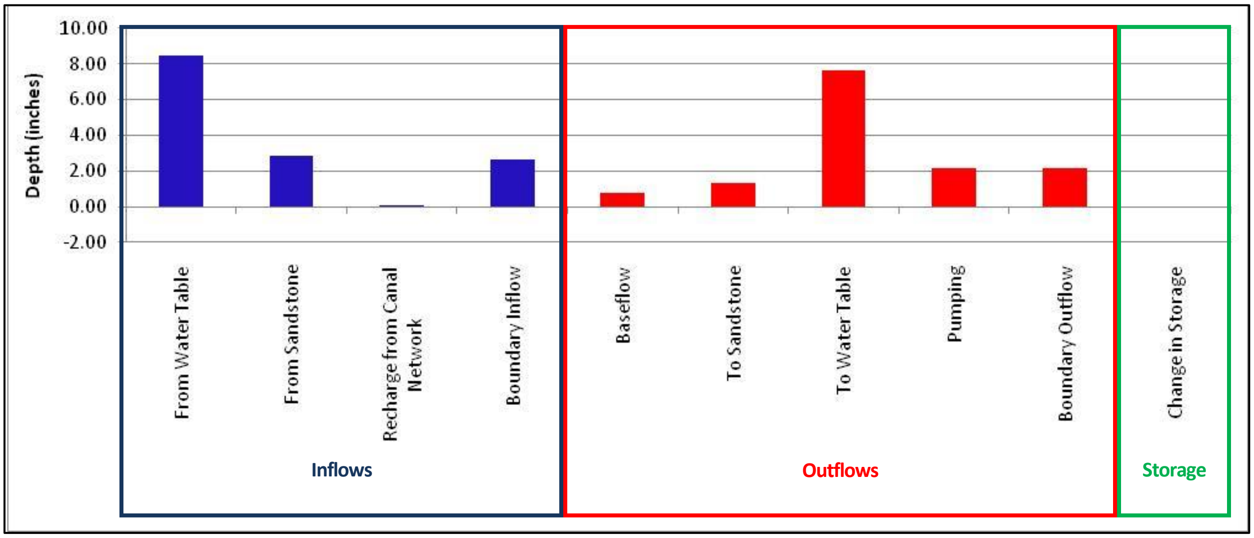


Figure 2-46. Lower Tamiami Aquifer, Average Annual Water Year Budget for the Study Area

Table 2-56. Lower Tamiami Aquifer, Annual Water Year and Seasonal Budgets for the Cocohatchee-Corkscrew Watershed

Period	Inflows (inches)				Outflows (inches)					Change in Storage (inches)
	Percolation from Water Table	From Sandstone	Recharge from Canal Network	Boundary Inflow	Baseflow	Percolation To Sandstone	To Water Table	Pumping	Boundary Outflow	
Annual Water Year Average										
2003	6.54	0.28	0.00	0.71	0.08	1.81	3.31	0.87	1.46	0.00
2004	7.05	0.31	0.00	0.75	0.08	1.93	3.50	1.02	1.54	0.00
2005	7.36	0.31	0.00	0.75	0.08	1.97	3.74	1.02	1.61	0.00
2006	7.40	0.28	0.00	0.83	0.08	2.44	3.03	1.57	1.42	0.00
2007	6.73	0.20	0.00	0.91	0.00	2.87	1.77	2.13	1.18	-0.12
Average	7.02	0.28	0.00	0.79	0.06	2.20	3.07	1.32	1.44	-0.02
Wet Season Average										
2002	1.85	0.12	0.00	0.24	0.04	0.35	1.06	0.16	0.39	0.20
2003	2.52	0.16	0.00	0.28	0.04	0.39	1.77	0.08	0.63	0.04
2004	2.52	0.16	0.00	0.28	0.04	0.39	1.73	0.08	0.59	0.08
2005	2.68	0.16	0.00	0.28	0.04	0.39	1.89	0.12	0.67	0.00
2006	2.40	0.12	0.00	0.28	0.04	0.51	1.38	0.20	0.51	0.16
2007	1.89	0.08	0.00	0.35	0.00	0.43	0.87	0.24	0.39	0.39
Average	2.31	0.13	0.00	0.28	0.03	0.41	1.45	0.14	0.53	0.14
Dry Season Average										
2003	4.02	0.12	0.00	0.43	0.04	1.42	1.54	0.79	0.83	0.00
2004	4.53	0.16	0.00	0.47	0.04	1.54	1.77	0.94	0.94	-0.08
2005	4.69	0.16	0.00	0.47	0.04	1.57	1.89	0.94	0.94	0.00
2006	5.00	0.16	0.00	0.51	0.04	1.93	1.65	1.34	0.91	-0.16
2007	4.84	0.12	0.00	0.55	0.00	2.44	0.91	1.85	0.83	-0.51
Average	4.61	0.14	0.00	0.49	0.03	1.78	1.55	1.17	0.89	-0.15

Table 2-57. Lower Tamiami Aquifer, Annual Water Year and Seasonal Budgets for the Golden Gate-Naples Bay Watershed

Period	Inflows (inches)				Outflows (inches)					Change in Storage (inches)
	Percolation from Water Table	From Sandstone	Recharge from Canal Network	Boundary Inflow	Baseflow	Percolation To Sandstone	To Water Table	Pumping	Boundary Outflow	
Annual Water Year Average										
2003	6.14	0.43	0.00	1.61	0.91	0.16	2.28	4.09	0.71	0.00
2004	6.34	0.51	0.00	1.81	0.87	0.16	2.40	4.53	0.71	0.00
2005	6.42	0.39	0.00	1.69	0.87	0.43	2.36	4.13	0.75	0.00
2006	6.42	0.43	0.00	1.73	0.83	0.43	2.40	4.13	0.83	0.00
2007	5.51	0.47	0.04	1.73	0.35	0.35	1.65	4.65	0.75	0.00
Average	6.17	0.45	0.01	1.72	0.76	0.31	2.22	4.31	0.75	0.00
Wet Season Average										
2002	2.36	0.16	0.00	0.55	0.35	0.08	0.87	1.42	0.28	0.04
2003	2.40	0.16	0.00	0.59	0.51	0.08	1.14	1.18	0.24	0.00
2004	2.40	0.16	0.00	0.59	0.43	0.08	1.06	1.34	0.24	0.04
2005	2.48	0.16	0.00	0.59	0.51	0.20	1.14	1.14	0.28	0.00
2006	2.44	0.16	0.00	0.55	0.43	0.08	1.10	1.14	0.31	0.04
2007	2.17	0.12	0.00	0.55	0.20	0.20	0.75	1.18	0.28	0.24
Average	2.38	0.15	0.00	0.57	0.41	0.12	1.01	1.23	0.27	0.06
Dry Season Average										
2003	3.78	0.28	0.00	1.02	0.39	0.12	1.14	2.91	0.47	0.00
2004	3.94	0.31	0.00	1.22	0.43	0.12	1.34	3.19	0.43	-0.04
2005	3.94	0.28	0.00	1.10	0.35	0.24	1.22	2.99	0.51	0.00
2006	3.98	0.28	0.00	1.18	0.35	0.31	1.26	2.99	0.51	-0.08
2007	3.35	0.35	0.04	1.18	0.16	0.16	0.91	3.46	0.47	-0.24
Average	3.80	0.30	0.01	1.14	0.34	0.19	1.17	3.11	0.48	-0.07

Table 2-58. Lower Tamiami Aquifer, Annual Water Year and Seasonal Budgets for the Rookery Bay Watershed

Period	Inflows (inches)				Outflows (inches)					Change in Storage (inches)
	Percolation from Water Table	From Sandstone	Recharge from Canal Network	Boundary Inflow	Baseflow	Percolation To Sandstone	To Water Table	Pumping	Boundary Outflow	
Annual Water Year Average										
2003	8.78	0.75	0.08	1.61	1.18	0.04	7.09	0.91	2.01	0.04
2004	8.74	1.02	0.08	1.61	1.30	0.04	7.32	0.79	2.05	0.00
2005	10.28	0.94	0.08	1.57	1.38	0.24	8.11	0.98	2.20	0.00
2006	9.06	0.94	0.08	1.77	1.26	0.20	7.28	1.06	2.05	0.00
2007	6.14	0.87	0.12	2.24	0.75	0.12	5.55	1.42	1.54	0.00
Average	8.60	0.91	0.09	1.76	1.17	0.13	7.07	1.03	1.97	0.01
Wet Season Average										
2002	2.68	0.28	0.04	0.39	0.35	0.00	2.01	0.12	0.63	0.28
2003	4.92	0.28	0.00	0.28	0.59	0.04	3.78	0.00	1.06	0.00
2004	4.45	0.39	0.00	0.39	0.63	0.00	3.54	0.08	0.87	0.12
2005	5.39	0.35	0.00	0.28	0.71	0.12	4.09	0.04	1.06	0.00
2006	4.57	0.35	0.00	0.35	0.63	0.04	3.46	0.04	0.91	0.24
2007	3.27	0.24	0.04	0.55	0.28	0.08	2.44	0.16	0.59	0.59
Average	4.21	0.31	0.01	0.37	0.53	0.05	3.22	0.07	0.85	0.20
Dry Season Average										
2003	3.86	0.47	0.08	1.34	0.55	0.00	3.31	0.91	0.94	0.04
2004	4.29	0.67	0.08	1.22	0.71	0.00	3.78	0.75	1.18	-0.12
2005	4.88	0.63	0.08	1.30	0.67	0.12	4.02	0.94	1.14	0.00
2006	4.49	0.59	0.08	1.46	0.67	0.16	3.82	1.02	1.14	-0.24
2007	2.87	0.63	0.08	1.69	0.47	0.04	3.11	1.30	0.94	-0.59
Average	4.08	0.60	0.08	1.40	0.61	0.06	3.61	0.98	1.07	-0.18

Table 2-59. Lower Tamiami Aquifer, Annual Water Year and Seasonal Budgets for the Eastern Watersheds

Period	Inflows (inches)				Outflows (inches)					Change in Storage (inches)
	Percolation from Water Table	From Sandstone	Recharge from Canal Network	Boundary Inflow	Baseflow	Percolation To Sandstone	To Water Table	Pumping	Boundary Outflow	
Annual Water Year Average										
2003	8.27	4.84	0.12	4.96	1.06	1.26	11.34	1.54	2.95	0.08
2004	9.25	4.84	0.12	4.53	1.22	1.18	11.30	1.77	3.23	0.00
2005	9.69	4.61	0.16	4.37	1.22	1.26	11.02	1.81	3.46	0.00
2006	9.33	4.80	0.08	4.53	1.14	1.26	10.63	2.83	2.91	-0.08
2007	8.35	4.41	0.12	4.09	0.83	1.38	9.25	3.31	2.28	-0.04
Average	8.98	4.70	0.12	4.50	1.09	1.27	10.71	2.25	2.97	-0.01
Wet Season Average										
2002	2.95	1.69	0.04	1.22	0.47	0.28	3.39	0.43	1.10	0.20
2003	3.70	1.69	0.04	1.69	0.51	0.39	4.49	0.24	1.42	0.04
2004	3.86	1.65	0.04	1.50	0.47	0.39	4.37	0.16	1.50	0.20
2005	4.21	1.65	0.04	1.54	0.63	0.43	4.49	0.20	1.69	0.00
2006	3.74	1.65	0.00	1.50	0.51	0.31	4.02	0.55	1.22	0.28
2007	3.50	1.50	0.04	1.34	0.39	0.28	3.54	0.43	0.98	0.75
Average	3.66	1.64	0.03	1.46	0.50	0.35	4.05	0.33	1.32	0.24
Dry Season Average										
2003	4.57	3.15	0.08	3.27	0.55	0.87	6.85	1.30	1.50	0.04
2004	5.39	3.19	0.08	3.03	0.71	0.79	6.97	1.61	1.73	-0.20
2005	5.47	2.95	0.12	2.87	0.59	0.83	6.54	1.61	1.81	0.00
2006	5.59	3.15	0.08	3.03	0.63	0.94	6.61	2.28	1.69	-0.31
2007	4.84	2.91	0.08	2.76	0.39	1.10	5.71	2.87	1.30	-0.79
Average	5.17	3.07	0.09	2.99	0.57	0.91	6.54	1.94	1.61	-0.25

In the Eastern watersheds, there is also a net loss of water to the Water Table Aquifer (Table 2-59). Hydraulic head differences in these watersheds results from the combination of evapotranspiration and irrigation pumping activities affecting the Water Table Aquifer.

Groundwater Budget Analysis for the Sandstone Aquifer

The average water year and seasonal water budgets for the study area within the Sandstone Aquifer are shown in Table 2-60. Figure 2-47 shows the annual water year budget for the Sandstone Aquifer. The results indicate that there is no change in storage on an annual basis meaning that the seasonal inflows and outflows are in equilibrium. The results indicate that there is a net loss of 1.5 inches water to the overlying Lower Tamiami Aquifer, and a net gain of 0.3 inch in water from the underlying Mid-Hawthorn Aquifer. In addition, there is a net annual loss of 0.76 inch of water due primarily to dry season pumping activities. Boundary inflows make up for the losses resulting in a no net change in aquifer storage.

The Sandstone aquifer system in the Cocohatchee-Corkscrew watershed (Table 2-61) has a net inflow of water from the Lower Tamiami aquifer of 1.93 inches annually, and a net loss to the Mid-Hawthorn Aquifer of 0.05 inch annually. In each of the other watersheds (Tables 2-62 through 2-64), there is a net loss of groundwater to the overlying Lower Tamiami Aquifer and a net gain from the underlying Mid-Hawthorn Aquifer. The inflows from the Mid-Hawthorn are less than one (1) inch annually, which is an indication of little interaction between the Sandstone and Mid-Hawthorn aquifer systems.

Table 2-60. Sandstone Aquifer, Annual Water Year and Seasonal Budgets for the Study Area

Period	Inflows (inches)			Outflow (inches)				Change in Storage (inches)
	Percolation from Lower Tamiami	From Mid-Hawthorne	Boundary Inflow	Percolation to Mid-Hawthorne	To Lower Tamiami	Pumping	Boundary Outflow	
Annual Water Year Average								
2003	1.18	0.28	2.36	0.08	2.87	0.55	0.28	0.00
2004	1.18	0.43	2.20	0.08	2.91	0.59	0.24	0.00
2005	1.26	0.43	2.01	0.12	2.76	0.51	0.28	0.00
2006	1.38	0.43	2.24	0.12	2.87	0.91	0.20	0.00
2007	1.57	0.39	2.17	0.08	2.64	1.26	0.20	0.00
Average	1.31	0.39	2.20	0.09	2.81	0.76	0.24	0.00
Wet Season Average								
2002	0.24	0.08	0.83	0.04	1.02	0.08	0.04	0.00
2003	0.31	0.08	0.75	0.04	1.02	0.04	0.04	0.00
2004	0.31	0.16	0.71	0.04	1.02	0.04	0.08	0.00
2005	0.35	0.12	0.67	0.04	0.98	0.04	0.08	0.00
2006	0.31	0.12	0.75	0.04	0.98	0.12	0.04	0.00
2007	0.28	0.08	0.75	0.04	0.87	0.12	0.04	0.00
Average	0.30	0.10	0.74	0.04	0.98	0.07	0.05	0.00
Dry Season Average								
2003	0.87	0.20	1.61	0.04	1.85	0.51	0.24	0.00
2004	0.87	0.28	1.50	0.04	1.89	0.51	0.16	0.00
2005	0.91	0.28	1.34	0.08	1.77	0.51	0.20	0.00
2006	1.06	0.28	1.50	0.08	1.85	0.79	0.12	0.00
2007	1.30	0.31	1.42	0.04	1.73	1.10	0.16	0.00
Average	1.00	0.27	1.47	0.06	1.82	0.69	0.17	0.00

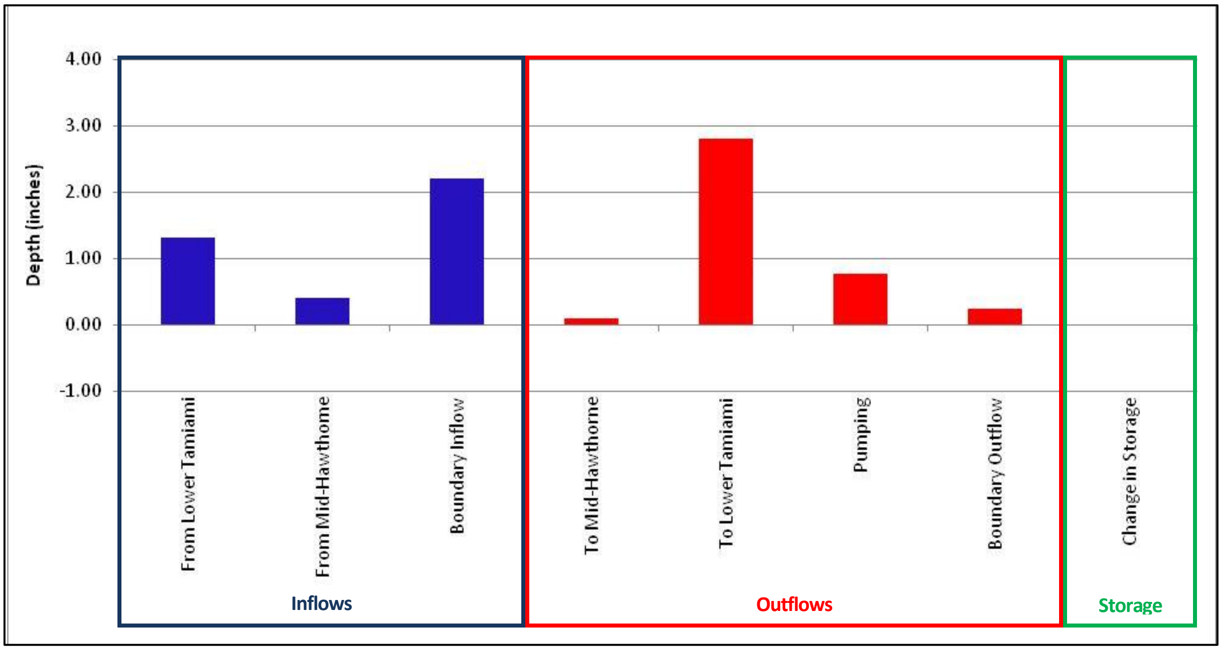


Figure 2-47. Sandstone Aquifer, Average Annual Water Year Budget for the Study Area

Table 2-61. Sandstone Aquifer, Annual Water Year and Seasonal Budgets for the Cocohatchee-Corkscrew Watershed

Period	Inflows (inches)			Outflow (inches)				Change in Storage (inches)
	Percolation from Lower Tamiami	From Mid-Hawthorne	Boundary Inflow	Percolation to Mid-Hawthorne	To Lower Tamiami	Pumping	Boundary Outflow	
Annual Water Year Average								
2003	1.81	0.08	0.28	0.12	0.28	1.26	0.47	0.00
2004	1.93	0.08	0.24	0.12	0.31	1.30	0.55	0.00
2005	1.97	0.08	0.24	0.12	0.31	1.22	0.59	0.00
2006	2.44	0.08	0.28	0.08	0.28	1.77	0.59	0.00
2007	2.87	0.08	0.35	0.20	0.20	2.28	0.63	0.00
Average	2.20	0.08	0.28	0.13	0.28	1.57	0.57	0.00
Wet Season Average								
2002	0.35	0.00	0.12	0.04	0.12	0.20	0.12	0.00
2003	0.39	0.04	0.08	0.04	0.16	0.12	0.16	0.00
2004	0.39	0.04	0.08	0.04	0.16	0.16	0.16	0.00
2005	0.39	0.04	0.08	0.04	0.16	0.12	0.20	0.00
2006	0.51	0.00	0.08	0.04	0.12	0.31	0.16	0.00
2007	0.43	0.04	0.12	0.04	0.08	0.28	0.12	0.04
Average	0.41	0.03	0.09	0.04	0.13	0.20	0.15	0.01
Dry Season Average								
2003	1.42	0.04	0.20	0.08	0.12	1.10	0.31	0.00
2004	1.54	0.08	0.16	0.08	0.16	1.14	0.39	0.00
2005	1.57	0.08	0.16	0.08	0.16	1.10	0.43	0.00
2006	1.93	0.08	0.20	0.12	0.16	1.46	0.43	0.00
2007	2.44	0.08	0.24	0.16	0.12	2.01	0.51	-0.04
Average	1.78	0.07	0.19	0.10	0.14	1.36	0.42	-0.01

Table 2-62. Sandstone Aquifer, Annual Water Year and Seasonal Budgets for the Golden Gate-Naples Bay Watershed

Period	Inflows (inches)			Outflow (inches)				Change in Storage (inches)
	Percolation from Lower Tamiami	From Mid-Hawthorne	Boundary Inflow	Percolation to Mid-Hawthorne	To Lower Tamiami	Pumping	Boundary Outflow	
Annual Water Year Average								
2003	0.16	0.24	0.08	0.04	0.43	0.00	0.04	0.00
2004	0.16	0.31	0.08	0.00	0.51	0.00	0.04	0.00
2005	0.43	0.24	0.08	0.28	0.39	0.00	0.04	0.00
2006	0.43	0.24	0.08	0.24	0.43	0.00	0.08	0.00
2007	0.35	0.28	0.08	0.16	0.47	0.00	0.08	0.00
Average	0.31	0.26	0.08	0.14	0.45	0.00	0.06	0.00
Wet Season Average								
2002	0.08	0.08	0.04	0.00	0.16	0.00	0.00	0.00
2003	0.08	0.08	0.04	0.00	0.16	0.00	0.00	0.00
2004	0.08	0.12	0.04	0.00	0.16	0.00	0.00	0.00
2005	0.20	0.08	0.04	0.12	0.16	0.00	0.00	0.00
2006	0.08	0.08	0.04	0.04	0.16	0.00	0.00	0.00
2007	0.20	0.08	0.04	0.12	0.12	0.00	0.00	0.00
Average	0.12	0.09	0.04	0.05	0.15	0.00	0.00	0.00
Dry Season Average								
2003	0.12	0.16	0.04	0.00	0.28	0.00	0.04	0.00
2004	0.12	0.20	0.04	0.00	0.31	0.00	0.04	0.00
2005	0.24	0.16	0.04	0.16	0.28	0.00	0.04	0.00
2006	0.31	0.16	0.04	0.20	0.28	0.00	0.04	0.00
2007	0.16	0.20	0.04	0.04	0.35	0.00	0.04	0.00
Average	0.19	0.17	0.04	0.08	0.30	0.00	0.04	0.00

Table 2-63. Sandstone Aquifer, Annual Water Year and Seasonal Budgets for the Rookery Bay Watershed

Period	Inflows (inches)			Outflow (inches)				Change in Storage (inches)
	Percolation from Lower Tamiami	From Mid-Hawthorne	Boundary Inflow	Percolation to Mid-Hawthorne	To Lower Tamiami	Pumping	Boundary Outflow	
Annual Water Year Average								
2003	0.04	0.51	0.24	0.00	0.75	0.00	0.04	0.00
2004	0.04	0.87	0.20	0.00	1.02	0.00	0.04	0.00
2005	0.24	0.79	0.16	0.20	0.94	0.00	0.04	0.00
2006	0.20	0.79	0.16	0.16	0.94	0.00	0.04	0.00
2007	0.12	0.75	0.12	0.08	0.87	0.00	0.04	0.00
Average	0.13	0.74	0.17	0.09	0.91	0.00	0.04	0.00
Wet Season Average								
2002	0.00	0.20	0.08	0.00	0.28	0.00	0.00	0.00
2003	0.04	0.16	0.08	0.00	0.28	0.00	0.00	0.00
2004	0.00	0.28	0.08	0.00	0.39	0.00	0.00	0.00
2005	0.12	0.24	0.08	0.08	0.35	0.00	0.00	0.00
2006	0.04	0.28	0.08	0.00	0.35	0.00	0.00	0.00
2007	0.08	0.16	0.08	0.08	0.24	0.00	0.00	0.00
Average	0.05	0.22	0.08	0.03	0.31	0.00	0.00	0.00
Dry Season Average								
2003	0.00	0.35	0.12	0.00	0.47	0.00	0.00	0.00
2004	0.00	0.55	0.08	0.00	0.67	0.00	0.00	0.00
2005	0.12	0.55	0.08	0.08	0.63	0.00	0.00	0.00
2006	0.16	0.51	0.08	0.16	0.59	0.00	0.04	0.00
2007	0.04	0.59	0.04	0.04	0.63	0.00	0.04	0.00
Average	0.06	0.51	0.08	0.06	0.60	0.00	0.02	0.00

Table 2-64. Sandstone Aquifer, Annual Water Year and Seasonal Budgets for the Eastern Watersheds

Period	Inflows (inches)			Outflow (inches)				Change in Storage (inches)
	Percolation from Lower Tamiami	From Mid-Hawthorne	Boundary Inflow	Percolation to Mid-Hawthorne	To Lower Tamiami	Pumping	Boundary Outflow	
Annual Water Year Average								
2003	1.26	0.28	4.13	0.08	4.84	0.35	0.39	0.00
2004	1.18	0.43	3.86	0.04	4.84	0.35	0.31	0.00
2005	1.26	0.47	3.62	0.04	4.61	0.31	0.35	0.00
2006	1.26	0.47	3.94	0.04	4.80	0.63	0.24	0.00
2007	1.38	0.43	3.78	0.04	4.41	0.87	0.24	0.00
Average	1.27	0.42	3.87	0.05	4.70	0.50	0.31	0.00
Wet Season Average								
2002	0.28	0.08	1.46	0.04	1.69	0.04	0.04	0.00
2003	0.39	0.08	1.34	0.04	1.69	0.00	0.08	0.00
2004	0.39	0.16	1.26	0.04	1.65	0.00	0.12	0.00
2005	0.43	0.16	1.22	0.04	1.65	0.00	0.12	0.00
2006	0.31	0.16	1.34	0.00	1.65	0.08	0.04	0.00
2007	0.28	0.08	1.26	0.04	1.50	0.04	0.04	0.00
Average	0.35	0.12	1.31	0.03	1.64	0.03	0.07	0.00
Dry Season Average								
2003	0.87	0.20	2.83	0.04	3.15	0.31	0.35	0.00
2004	0.79	0.31	2.64	0.04	3.19	0.31	0.20	0.00
2005	0.83	0.31	2.40	0.04	2.95	0.31	0.24	0.00
2006	0.94	0.31	2.60	0.04	3.15	0.55	0.16	0.00
2007	1.10	0.35	2.52	0.04	2.91	0.83	0.20	0.00
Average	0.91	0.30	2.60	0.04	3.07	0.46	0.23	0.00

Groundwater Budget Analysis for the Mid-Hawthorn Aquifer

The Mid-Hawthorn has little interaction with the overlying aquifer systems. The annual water year water budgets for the study area and each of the watersheds are shown in Tables 2-65 through 2-69. Figure 2-48 shows the annual average water budget for the Mid-Hawthorn Aquifer. The results indicate that less than 0.3 inch of water moves between the Sandstone in Mid-Hawthorn Aquifers across the study area.

The aquifer also experiences limited pumping withdrawals for potable water supply. The majority of the pumping occurs in the Golden Gate-Naples Bay Watershed at the Collier County wellfield. Smaller pumping withdrawals occur in the Rookery Bay and Cocohatchee-Corkscrew watersheds.

Table 2-65. Mid-Hawthorn Aquifer, Annual Water Year and Seasonal Budgets for the Study Area

Period	Inflows (inches)		Outflows (inches)			Change in Storage (inches)
	Percolation from Sandstone	Boundary Inflow	To Sandstone	Pumping	Boundary Outflow	
Annual Water Year Average						
2003	0.08	0.28	0.28	0.04	0.04	0.00
2004	0.08	0.47	0.43	0.08	0.04	0.00
2005	0.12	0.47	0.43	0.12	0.04	0.00
2006	0.12	0.47	0.43	0.12	0.04	0.00
2007	0.08	0.43	0.39	0.12	0.00	0.00
Average	0.09	0.43	0.39	0.09	0.03	0.00
Wet Season Average						
2002	0.04	0.08	0.08	0.00	0.00	0.00
2003	0.04	0.08	0.08	0.00	0.00	0.00
2004	0.04	0.16	0.16	0.00	0.00	0.00
2005	0.04	0.16	0.12	0.04	0.00	0.00
2006	0.04	0.16	0.12	0.04	0.00	0.00
2007	0.04	0.12	0.08	0.04	0.00	0.00
Average	0.04	0.12	0.10	0.02	0.00	0.00
Dry Season Average						
2003	0.04	0.20	0.20	0.04	0.00	0.00
2004	0.04	0.31	0.28	0.04	0.00	0.00
2005	0.08	0.31	0.28	0.08	0.00	0.00
2006	0.08	0.31	0.28	0.12	0.00	0.00
2007	0.04	0.31	0.31	0.08	0.00	0.00
Average	0.06	0.29	0.27	0.07	0.00	0.00

Table 2-66. Mid-Hawthorn Aquifer, Annual Water Year and Seasonal Budgets for the Cocohatchee-Corkscrew Watershed

Period	Inflows (inches)		Outflows (inches)			Change in Storage (inches)
	Percolation from Sandstone	Boundary Inflow	To Sandstone	Pumping	Boundary Outflow	
Annual Water Year Average						
2003	0.12	0.12	0.08	0.04	0.16	0.00
2004	0.12	0.16	0.08	0.04	0.16	0.00
2005	0.12	0.16	0.08	0.04	0.16	0.00
2006	0.16	0.16	0.08	0.08	0.16	0.00
2007	0.20	0.16	0.08	0.08	0.16	0.00
Average	0.14	0.15	0.08	0.06	0.16	0.00
Wet Season Average						
2002	0.04	0.04	0.00	0.00	0.04	0.00
2003	0.04	0.04	0.04	0.00	0.04	0.00
2004	0.04	0.04	0.04	0.00	0.04	0.00
2005	0.04	0.04	0.04	0.00	0.08	0.00
2006	0.04	0.04	0.00	0.00	0.04	0.00
2007	0.04	0.04	0.04	0.00	0.04	0.00
Average	0.04	0.04	0.03	0.00	0.05	0.00
Dry Season Average						
2003	0.08	0.08	0.04	0.04	0.08	0.00
2004	0.08	0.12	0.08	0.04	0.08	0.00
2005	0.08	0.12	0.08	0.04	0.08	0.00
2006	0.12	0.12	0.08	0.04	0.12	0.00
2007	0.16	0.12	0.08	0.08	0.12	0.00
Average	0.10	0.11	0.07	0.05	0.09	0.00

Table 2-67. Mid-Hawthorn Aquifer, Annual Water Year and Seasonal Budgets for the Golden Gate-Naples Bay Watershed

Period	Inflows (inches)		Outflows (inches)			Change in Storage (inches)
	Percolation from Sandstone	Boundary Inflow	To Sandstone	Pumping	Boundary Outflow	
Annual Water Year Average						
2003	0.04	0.28	0.24	0.00	0.08	0.00
2004	0.00	0.39	0.31	0.00	0.08	0.00
2005	0.28	0.75	0.24	0.67	0.16	0.00
2006	0.24	0.71	0.24	0.59	0.12	0.00
2007	0.16	0.59	0.28	0.39	0.12	0.00
Average	0.14	0.54	0.26	0.33	0.11	0.00
Wet Season Average						
2002	0.00	0.08	0.08	0.00	0.04	0.00
2003	0.00	0.08	0.08	0.00	0.00	0.00
2004	0.00	0.12	0.12	0.00	0.04	0.00
2005	0.12	0.28	0.08	0.31	0.04	0.00
2006	0.04	0.16	0.08	0.04	0.04	0.00
2007	0.12	0.24	0.08	0.24	0.04	0.00
Average	0.05	0.16	0.09	0.10	0.03	0.00
Dry Season Average						
2003	0.00	0.20	0.16	0.00	0.04	0.00
2004	0.00	0.24	0.20	0.00	0.04	0.00
2005	0.16	0.47	0.16	0.35	0.08	0.00
2006	0.20	0.55	0.16	0.51	0.12	0.00
2007	0.04	0.35	0.20	0.16	0.08	0.00
Average	0.08	0.36	0.17	0.20	0.07	0.00

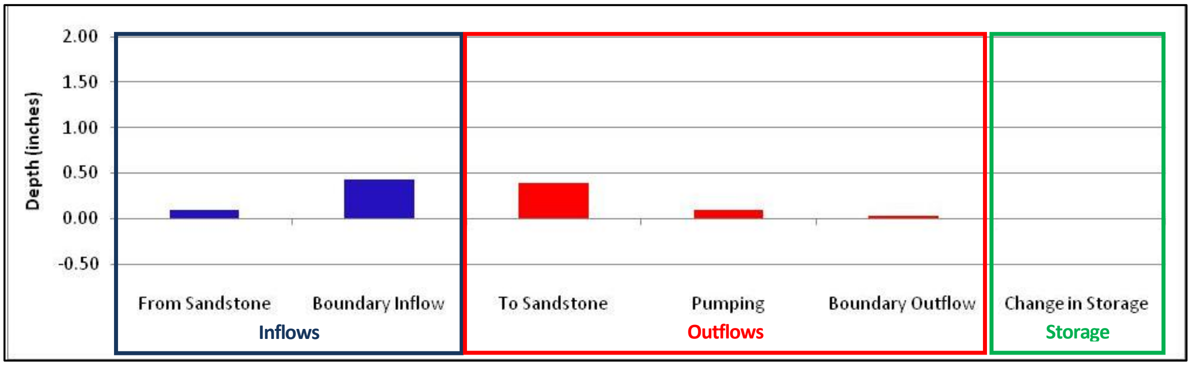
Table 2-68. Mid-Hawthorn Aquifer, Annual Water Year and Seasonal Budgets for the Rookery Bay Watershed

Period	Inflows (inches)		Outflows (inches)			Change in Storage (inches)
	Percolation from Sandstone	Boundary Inflow	To Sandstone	Pumping	Boundary Outflow	
Annual Water Year Average						
2003	0.00	0.59	0.51	0.00	0.08	0.00
2004	0.00	1.02	0.87	0.00	0.16	0.00
2005	0.20	1.18	0.79	0.12	0.47	0.00
2006	0.16	1.18	0.79	0.08	0.43	0.00
2007	0.08	0.98	0.75	0.00	0.35	0.00
Average	0.09	0.99	0.74	0.04	0.30	0.00
Wet Season Average						
2002	0.00	0.20	0.20	0.00	0.00	0.00
2003	0.00	0.20	0.16	0.00	0.00	0.00
2004	0.00	0.35	0.28	0.00	0.04	0.00
2005	0.08	0.39	0.24	0.04	0.20	0.00
2006	0.00	0.35	0.28	0.00	0.08	0.00
2007	0.08	0.24	0.16	0.00	0.16	0.00
Average	0.03	0.29	0.22	0.01	0.08	0.00
Dry Season Average						
2003	0.00	0.39	0.35	0.00	0.04	0.00
2004	0.00	0.67	0.55	0.00	0.12	0.00
2005	0.08	0.79	0.55	0.04	0.28	0.00
2006	0.16	0.83	0.51	0.08	0.35	0.00
2007	0.04	0.75	0.59	0.00	0.20	-0.04
Average	0.06	0.69	0.51	0.02	0.20	-0.01

Table 2-69. Mid-Hawthorn Aquifer, Annual Water Year and Seasonal Budgets for the Eastern Watersheds

Period	Inflows (inches)		Outflows (inches)			Change in Storage (inches)
	Percolation from Sandstone	Boundary Inflow	To Sandstone	Pumping	Boundary Outflow	
Annual Water Year Average						
2003	0.08	0.28	0.28	0.00	0.08	0.00
2004	0.04	0.47	0.43	0.00	0.08	0.00
2005	0.04	0.51	0.47	0.00	0.08	0.00
2006	0.04	0.51	0.47	0.00	0.08	0.00
2007	0.04	0.43	0.43	0.00	0.08	0.00
Average	0.05	0.44	0.42	0.00	0.08	0.00
Wet Season Average						
2002	0.04	0.08	0.08	0.00	0.04	0.00
2003	0.04	0.08	0.08	0.00	0.04	0.00
2004	0.04	0.16	0.16	0.00	0.04	0.00
2005	0.04	0.16	0.16	0.00	0.04	0.00
2006	0.00	0.16	0.16	0.00	0.04	0.00
2007	0.04	0.12	0.08	0.00	0.04	0.00
Average	0.03	0.12	0.12	0.00	0.04	0.00
Dry Season Average						
2003	0.04	0.20	0.20	0.00	0.04	0.00
2004	0.04	0.31	0.31	0.00	0.04	0.00
2005	0.04	0.35	0.31	0.00	0.04	0.00
2006	0.04	0.35	0.31	0.00	0.04	0.00
2007	0.04	0.35	0.35	0.00	0.04	0.00
Average	0.04	0.31	0.30	0.00	0.04	0.00

Figure 2-48. Mid-Hawthorn Aquifer, Average Annual Water Budget for the Study Area



Boundary inflows into the Mid-Hawthorn Aquifer match the losses due to transference to the Sandstone Aquifer and pumping. The result is a no net change in aquifer storage. This is also evident in each of the watershed specific budgets shown in Tables 2-66 through 2-69.

2.4.2 Water Uses

This section discusses groundwater withdrawals from each aquifer. Comparisons were made to the boundary inflows and aquifer exchanges to evaluate the general effects of pumping activities.

Potable Water Supply

Groundwater is the primary source of potable water in Collier County. Municipal water supply systems were represented in the ECM as individual wells that withdraw water from specific aquifers. The pumping rates for each well were defined using reported time series of groundwater withdrawal or established based on permitted pumping rates. The distribution of the municipal water supply wells in the ECM is shown in Figure 2-49. The figure also shows the extent of the wellhead protection areas. The majority of water supply wells are located in the Golden Gate-Naples Bay, Rookery Bay, and Faka Union watersheds. Figure 2-50 shows the extent of the County area served by the public water supply system. Table 2-70 shows the annual volume of water pumped for potable water supply in each watershed. The majority of municipal water supply is withdrawn from the Lower Tamiami Aquifer.

Most of the municipal water supply wells are located in the Golden Gate-Naples Bay Watershed and are screened in the Lower Tamiami Aquifer. As a result, the volume of water pumped from these municipal wells far exceeds the volumes pumped in the other watersheds or from the other aquifers. The water pumped from the public wells in the Golden Gate-Naples Bay Watershed is used to meet water supply needs throughout the county and is not limited to usage within the watershed.

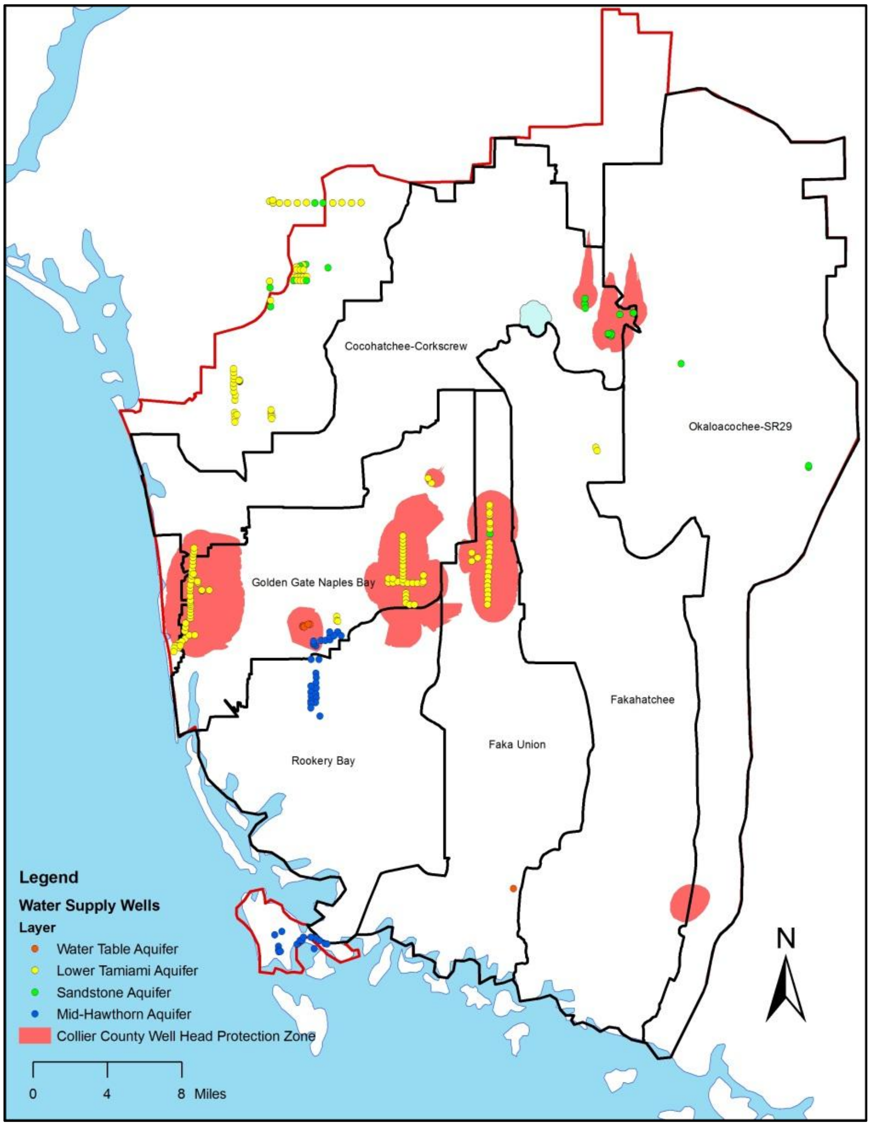


Figure 2-49. Municipal Water Supply Wells and Well Head Protection Zones

Onsite Private Wells

Throughout suburban areas in the county, private wells are used to provide water for domestic consumption and landscape irrigation. Currently there is no database identifying the location and number of the domestic self supply wells within Collier County. For modeling purposes, it was assumed that urban areas outside of water service areas use private wells. Figure 2-50 shows the areas in the County that were assumed to be served by private water wells.

Due to the lack of data, domestic self supply wells are not represented as individual wells in the model. The urban areas served by private wells were represented within the irrigation component of the model. This is reasonable because water used for domestic self supply is returned to the Water Table Aquifer through septic systems or as irrigation. It is assumed that the model applies an equal maximum pumping rate for domestic water supply for each cell within the defined area. It was further assumed that the private wells pump water from the Water Table Aquifer; however, it is noted that in some urban areas of the county, the Water Table Aquifer is very thin and these domestic self-supply wells are screened in the Lower Tamiami Aquifer.

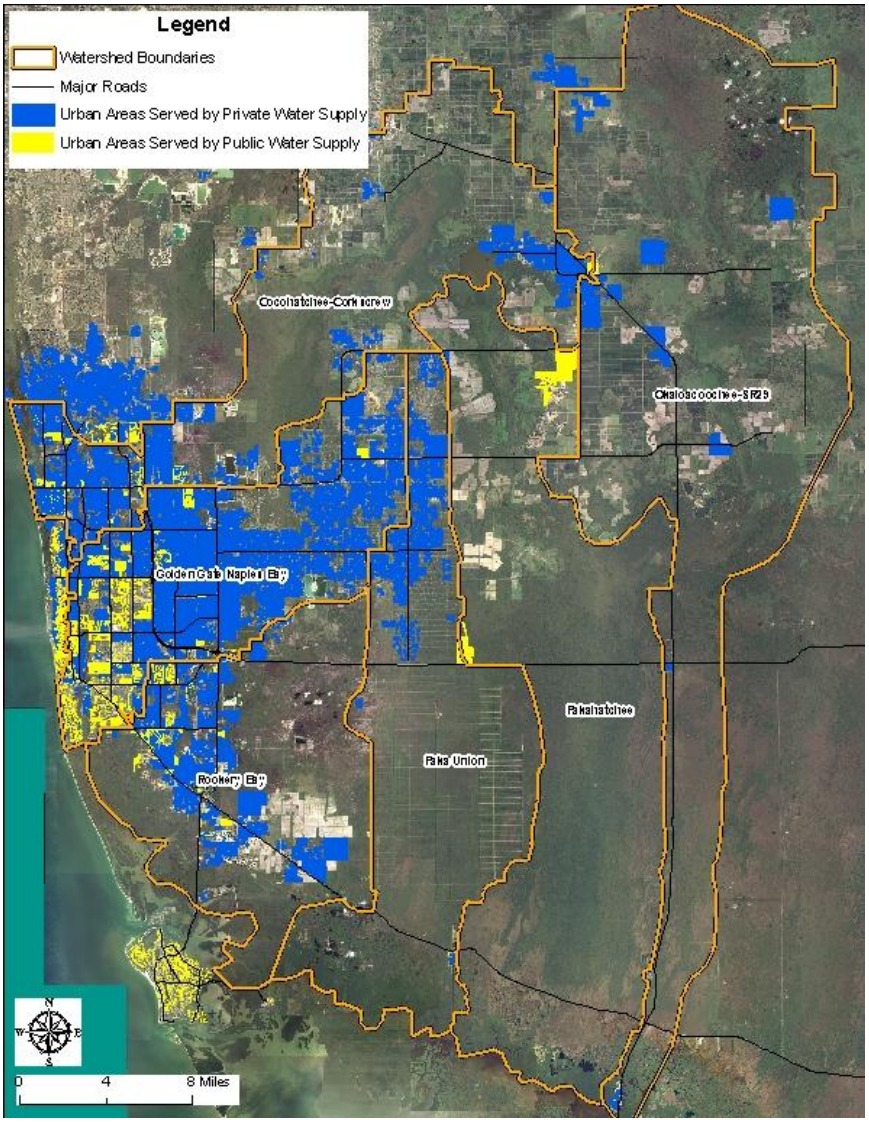


Figure 2-50. Urban Water Supply Distribution

Table 2-70 shows the predicted volume of water pumped by private wells annually in each watershed. The results indicate that demand from private wells exceeds demand from municipal wells only in Rookery Bay watershed where most of municipal water users are supplied from wells in other watersheds. Rookery Bay is also the only watershed where domestic self supply is taken primarily from the Lower Tamiami Aquifer.

Table 2-70. Annual and Seasonal Water Pumping Rates for
Public Water Supply and Domestic Self Supply

Period	Cocohatchee Corkscrew				Golden Gate			
	Water Table	Lower Tamiami	Sandstone	Mid-Hawthorne	Water Table	Lower Tamiami	Sandstone	Mid-Hawthorne
	Domestic Self Supply (inches)							
Average Wet Season	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Average Dry Season	0.12	0.00	0.00	0.00	0.61	0.07	0.00	0.00
Average Water Year	0.14	0.00	0.00	0.00	0.63	0.07	0.00	0.00
	Public Water Supply (inches)							
Average Wet Season	0.00	0.02	0.09	0.00	0.07	1.22	0.00	0.12
Average Dry Season	0.00	0.03	0.19	0.00	0.13	2.68	0.00	0.19
Average Water Year	0.00	0.05	0.28	0.00	0.20	3.90	0.00	0.31
Period	Rookery Bay				Faka Union, Fakahatchee, Okaloacoochee			
	Water Table	Lower Tamiami	Sandstone	Mid-Hawthorne	Water Table	Lower Tamiami	Sandstone	Mid-Hawthorne
	Domestic Self Supply (inches)							
Average Wet Season	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average Dry Season	0.02	0.04	0.00	0.00	0.03	0.00	0.00	0.00
Average Water Year	0.02	0.04	0.00	0.00	0.03	0.00	0.00	0.00
	Public Water Supply (inches)							
Average Wet Season	0.00	0.00	0.00	0.01	0.00	0.11	0.01	0.00
Average Dry Season	0.00	0.00	0.00	0.02	0.00	0.26	0.02	0.00
Average Water Year	0.00	0.00	0.00	0.04	0.00	0.37	0.02	0.00

Agricultural and Golf Course Irrigation

Agricultural and Golf Course irrigation is a significant amount of total water demand in Collier County. These areas are represented in the irrigation component of the model and pumping rates and well withdrawal information was defined by data obtained from permitted withdrawal information.

Figure 2-51 shows the distribution of irrigated agricultural lands and golf courses in the study area. This figure shows that the majority of the citrus areas are located in the Cocohatchee-Corkscrew and Okaloacoochee-SR29 watersheds. Truck or row crops are produced mostly in the northern portion of the Faka Union watershed and in the southeastern portion of the Rookery Bay watershed. The majority of the golf courses are located in the more urbanized areas near the coast in the Cocohatchee–Corkscrew, Golden Gate–Naples Bay, and Rookery Bay watersheds.

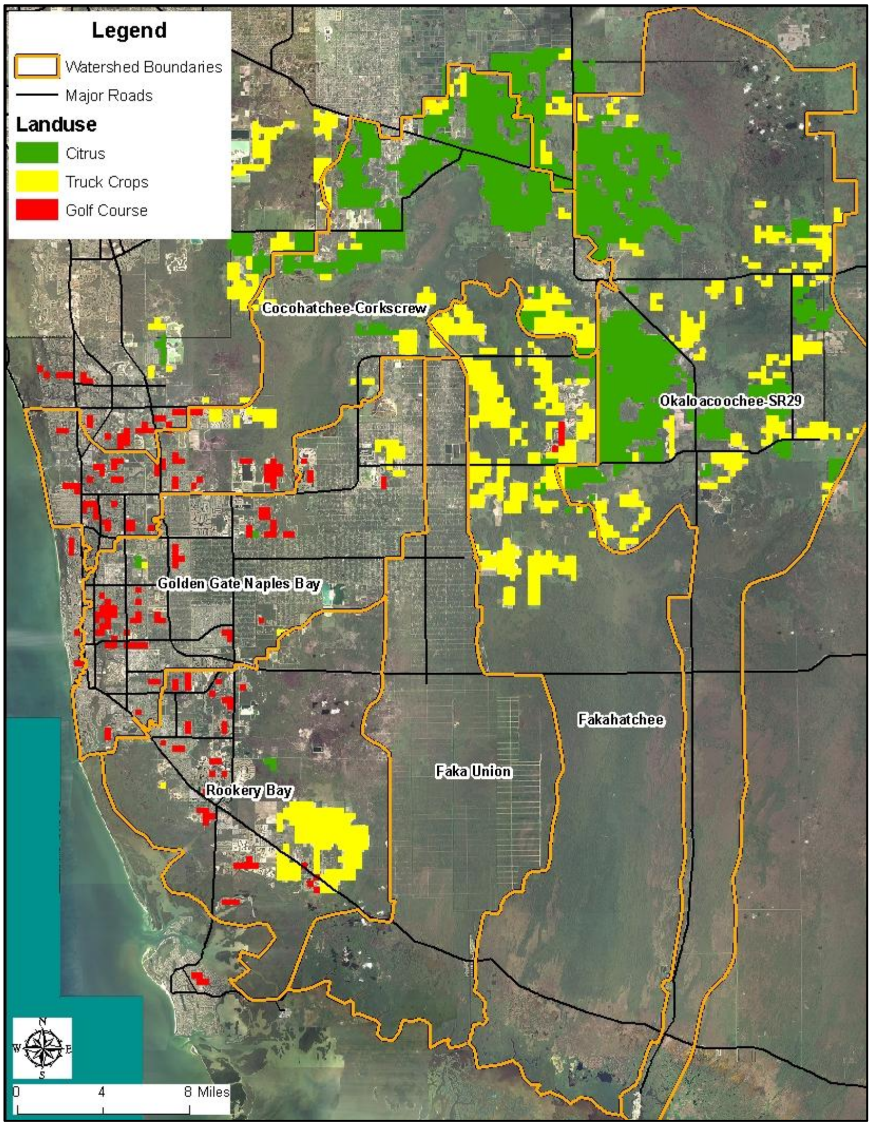


Figure 2-51. Agricultural and Golf Course Irrigated Areas

Table 2-71 shows predicted volumes of water applied to meet irrigation requirements in each watershed. For comparative purposes, the reported volumes for each specific land use classification were averaged across the entire area of the watershed. As an example, in the Cocohatchee–Corkscrew watershed, 8.9 inches of irrigation was applied to citrus during an average water year. This was average across the watershed to obtain the total of 1.5 inches reported in Table 2-71.

Table 2-71. Annual and Seasonal Water Pumping Rates for Agricultural and Golf Course Irrigation Needs

Period	Cocohatchee Corkscrew				Golden Gate			
	Surficial	Lower Tamiami	Sandstone	Mid-Hawthorne	Surficial	Lower Tamiami	Sandstone	Mid-Hawthorne
	Golf Courses (inches)							
Average Wet Season	0.002	0.003	0.000	0.000	0.007	0.003	0.000	0.000
Average Dry Season	0.026	0.030	0.000	0.000	0.129	0.068	0.000	0.000
Average Water Year	0.028	0.032	0.000	0.000	0.136	0.071	0.000	0.000
	Citrus (inches)							
Average Wet Season	0.008	0.014	0.057	0.003	0.000	0.000	0.000	0.000
Average Dry Season	0.180	0.409	0.792	0.038	0.004	0.001	0.000	0.000
Average Water Year	0.188	0.422	0.849	0.041	0.004	0.001	0.000	0.000
	Truck Crops (inches)							
Average Wet Season	0.030	0.061	0.020	0.000	0.000	0.005	0.000	0.000
Average Dry Season	0.148	0.268	0.093	0.000	0.000	0.023	0.000	0.000
Average Water Year	0.178	0.329	0.113	0.000	0.001	0.028	0.000	0.000
Period	Rookery Bay				Faka Union, Fakahatchee, Okaloacoochee			
	Surficial	Lower Tamiami	Sandstone	Mid-Hawthorne	Surficial	Lower Tamiami	Sandstone	Mid-Hawthorne
	Golf Courses (inches)							
Average Wet Season	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average Dry Season	0.016	0.028	0.000	0.000	0.000	0.007	0.000	0.000
Average Water Year	0.018	0.028	0.000	0.000	0.000	0.007	0.000	0.000
	Citrus (inches)							
Average Wet Season	0.000	0.000	0.000	0.000	0.000	0.002	0.007	0.000
Average Dry Season	0.000	0.006	0.000	0.000	0.006	0.134	0.233	0.000
Average Water Year	0.000	0.006	0.000	0.000	0.007	0.136	0.239	0.000
	Truck Crops (inches)							
Average Wet Season	0.007	0.051	0.000	0.000	0.007	0.102	0.003	0.000
Average Dry Season	0.055	0.520	0.000	0.000	0.041	0.506	0.012	0.000
Average Water Year	0.062	0.571	0.000	0.000	0.048	0.608	0.015	0.000

In the Cocohatchee-Corkscrew watershed, the total volume of water applied to meet irrigation demand (2.18 inches) slightly exceeds the demand for potable water supply (0.47 inch). Sixty-nine percent of the irrigation water is applied to citrus and 28 percent is applied to truck crops. Less than three (3) percent of irrigation water is applied to golf courses.

In the Golden Gate-Naples Bay watershed, total irrigation demand for groundwater at golf courses and in agricultural areas is predicted to be 0.24 inch annually compared to slightly more than 5 inches of demand to meet potable water supply needs. Irrigation at golf courses consists of 86 percent of the irrigation demand in the watershed.

Pumping for potable water supply needs is also less than the irrigation demand in the Rookery Bay watershed. The pumped volumes are 0.10 and 0.68 inch, respectively. Of the irrigation demand, truck crops utilize 92 percent of water used during the average water year.

Demand for irrigation supply exceeds potable water demand in the Faka Union, Fakahatchee, and Okaloacoochee-SR29 watersheds. Potable water usage averages 0.42 inches in the typical water year, while irrigation usage is predicted to equal 1.06 inches across the watersheds. More than 60 percent of the irrigation water was applied to truck crops; another 35 percent of the irrigation water was applied to citrus.

2.4.3 Aquifer Hydraulic Heads/Elevations

The following sections present information describing the average water year and average seasonal groundwater head (measured by elevation of water levels) in each aquifer. The model-predicted hydraulic heads will be used to identify areas of potential concern in terms of groundwater withdrawals. The hydraulic heads will also be used as the basis for determining a performance measure to assess impacts of proposed projects.

Water Table Aquifer

Figures 2-52 through 2-54 show the predicted average annual and average seasonal hydraulic heads in the Water Table Aquifer. The gradient of the average annual groundwater surface is approximately 0.8 feet per mile (0.016 percent) and trends from the northeastern part of the county, north of Immokalee, to the southwest. The water surface gradient generally follows the topographic slope of approximately 1.0 foot per mile (0.020 percent).

The seasonal average groundwater surface elevation maps for the Water Table Aquifer shown in Figures 2-53 and 2-54 show a shift in the isohyetal lines. This is most evident near the coast in Faka Union watershed where the 5- and 10-foot contour lines shift as much as five (5) miles further inland. In the Faka Union watershed, this shift may be attributed to the presence of the canal network and the high volume of baseflow in this watershed. As shown in Table 2-54, baseflow from the Water Table Aquifer in the eastern watersheds is more than 2.5 inches annually. The majority of that baseflow occurs in the Faka Union watershed. In the Cocohatchee–Corkscrew, Golden Gate–Naples Bay, and Rookery Bay watersheds, the isohyetal line shift is strongly influenced by increased groundwater pumping during the dry season and may be indicative of potential risks to water supply due to salt water intrusion.

There is an area of the Water Table Aquifer, north of Immokalee, where the water table is predicted to exceed 30 feet in elevation, This average annual groundwater elevation is not observed in the underlying Lower Tamiami Aquifer, except during the wet season (see Figure 2-57). This suggests that the aquitard in this location is less permeable than in other areas, and creates a perched water table.

Figure 2-55 shows the predicted annual fluctuation in the Water Table Aquifer. For this evaluation, fluctuation is defined as the difference between the average water year maximum groundwater head and the average water year minimum groundwater head and represents the change in groundwater head from wet season to dry season. Darker areas indicate greater fluctuation in the groundwater surface. These large fluctuations are attributed to groundwater pumping to meet potable water supply and irrigation demand during the dry season. The areas with greater differences in elevation are also influenced by the horizontal conductivity of the aquifers and the connectivity to other aquifers. Figure 2-55 also indicates that there are large differences in groundwater head near the boundary of the study area. These results are most likely due to differences in the established boundary conditions defined in the models.

Lower Tamiami Aquifer

The average annual, average seasonal, and annual fluctuation in groundwater surface elations for the Lower Tamiami Aquifer are shown in Figures 2-56 through 2-58. During the wet season, there is an area of higher potentiometric elevations north of Immokalee that is not observed in the average annual and average dry season maps. The results also indicate similar shifts in the 5- and 10-foot isohyets as was seen in the Water Table Aquifer system.

In the Faka Union, watershed, the shift is less than three (3) miles compared to the five (5) miles observed in the Water Table aquifer. The difference is due to less interaction with the canal network. Baseflow from the Lower Tamiami Aquifer is predicted to be approximately 1.25 inches annually (Table 2-59). This is less than half of what was predicted for the Water Table Aquifer.

The shift of the isohyetal lines near the coast in the Cocohatchee–Corkscrew, Golden Gate–Naples Bay, and Rookery Bay watershed are also similar to that observed in the Water Table Aquifer. This indicates that there is high connectivity between the aquifers.

The annual fluctuation in head elevation for the Lower Tamiami Aquifer, shown in Figure 2-59, indicates that there is a great demand placed on this aquifer during the dry season in the Fakahatchee and Okaloacoochee-SR29 watersheds. This is supported by the information presented in Table 2-59, which reports agricultural irrigation exceeds 1.29 inches from the Lower Tamiami Aquifer during the dry season. This volume is averaged over the watershed and approaches nine (9) inches of water applied directly to agricultural lands.

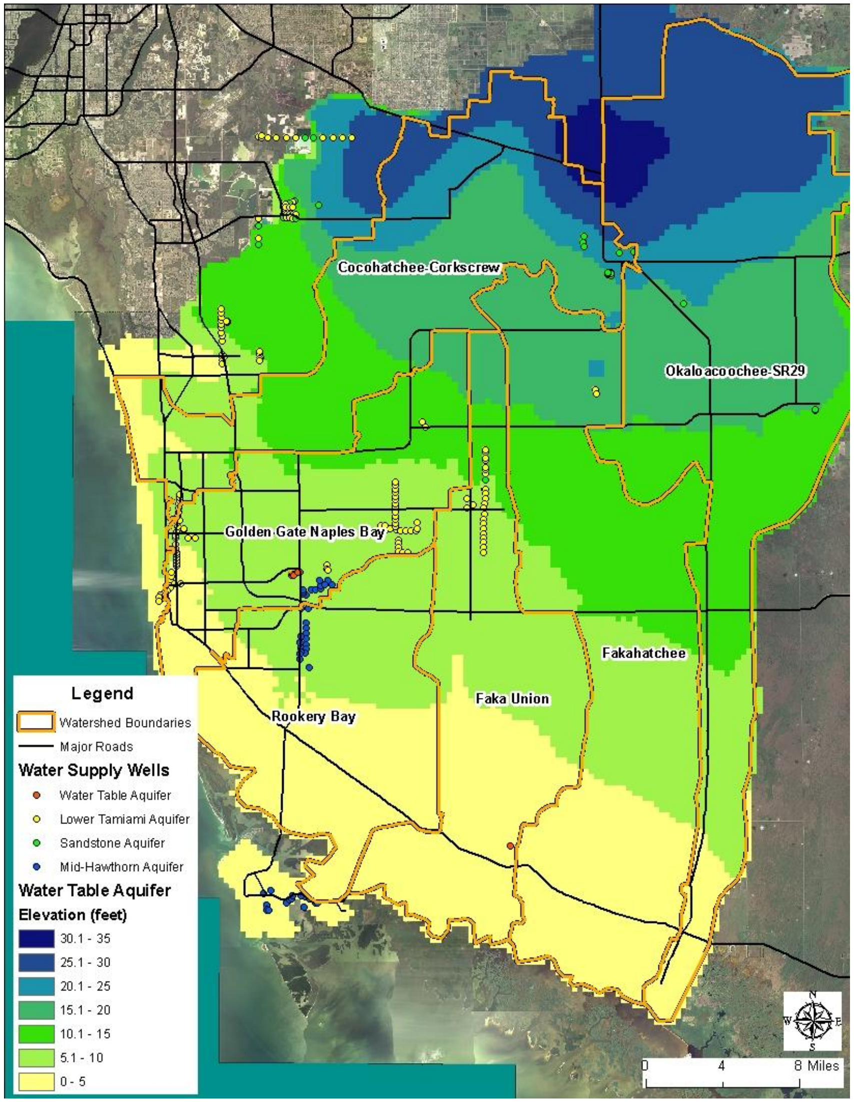


Figure 2-52. Water Table Aquifer Average Annual Elevation

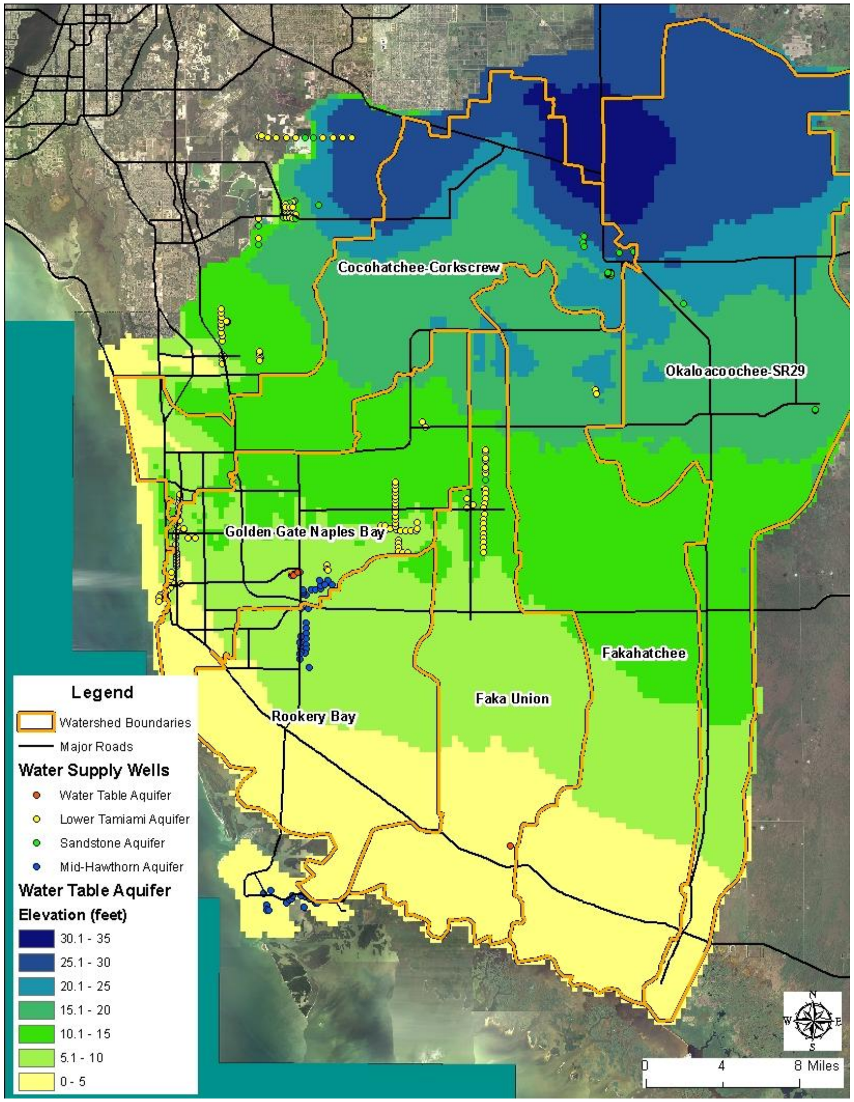


Figure 2-53. Water Table Aquifer Average Wet Season Elevation

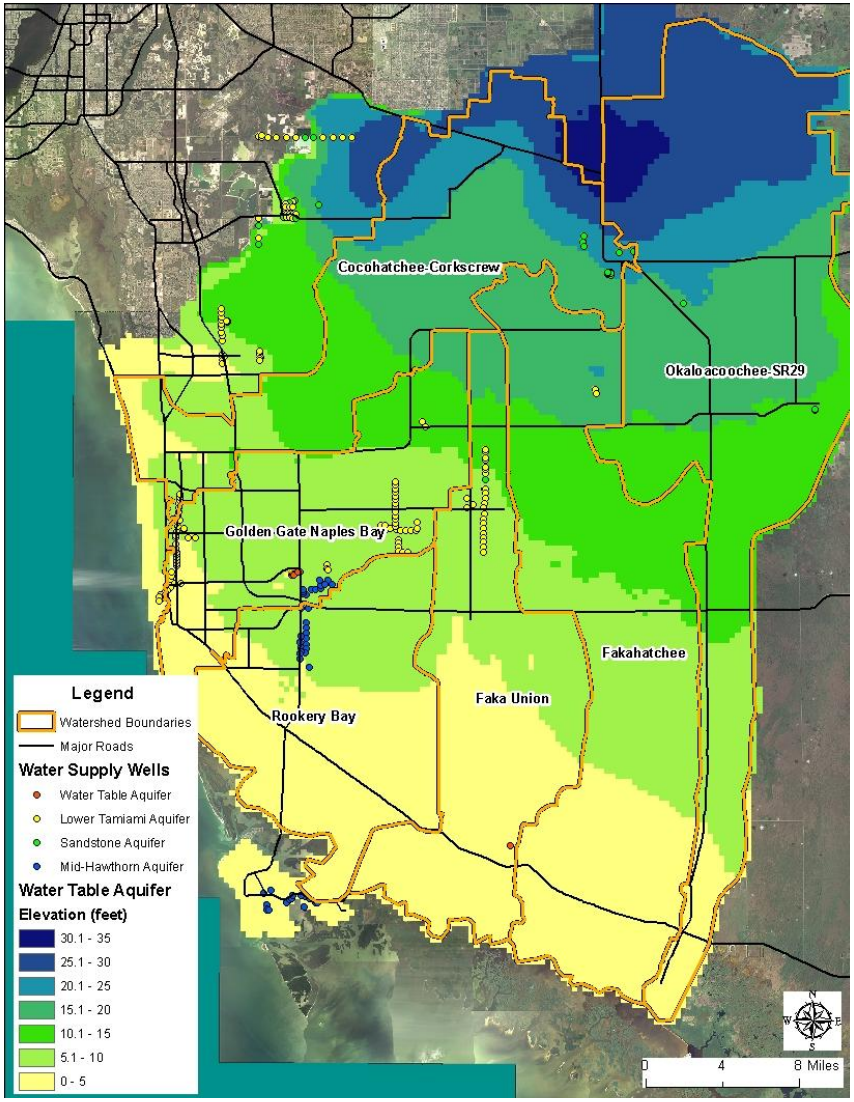


Figure 2-54. Water Table Aquifer Average Dry Season Elevation

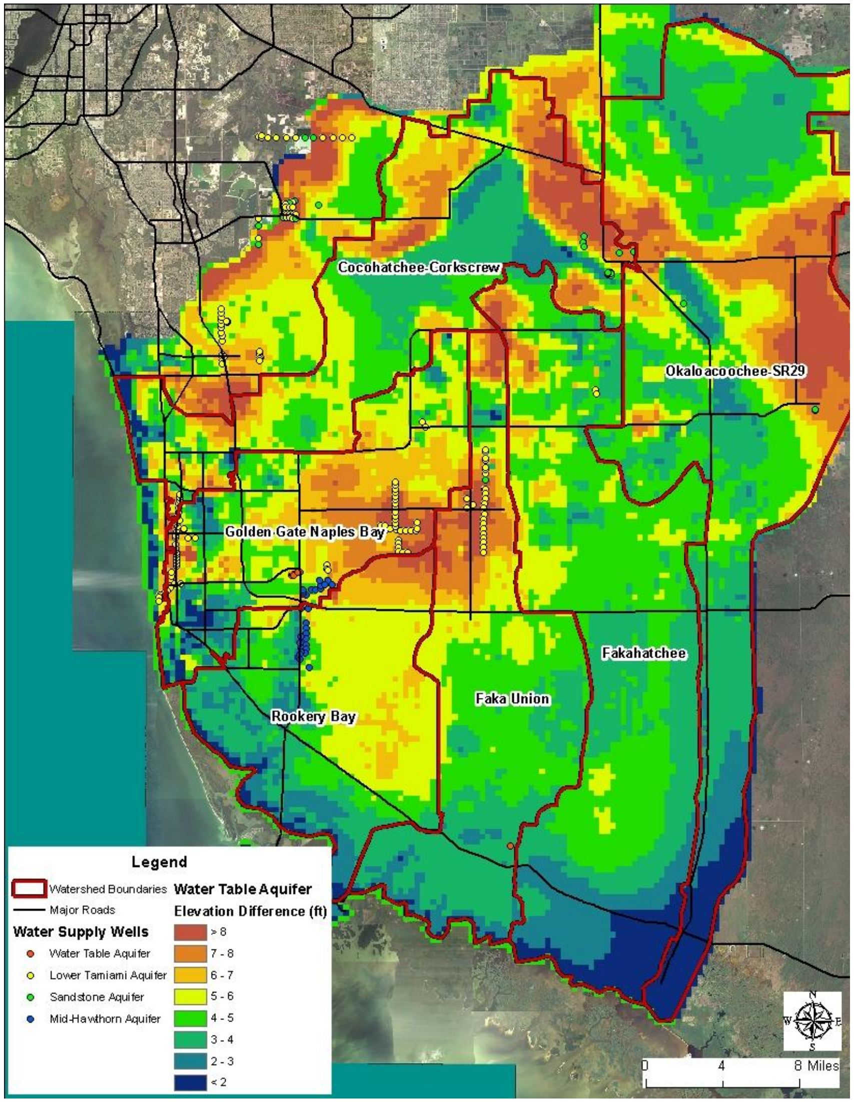


Figure 2-55. Water Table Aquifer Average Annual Groundwater Fluctuation

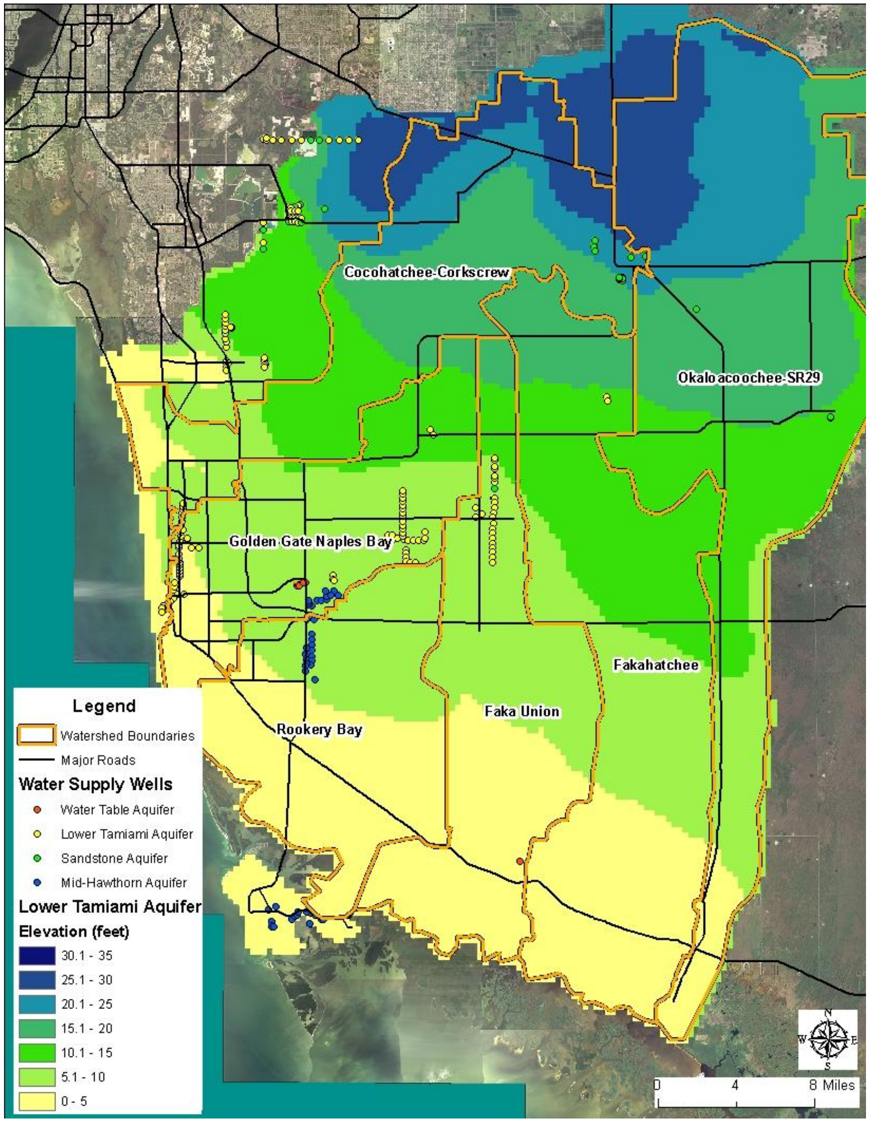


Figure 2-56. Lower Tamiami Aquifer Average Annual Elevation

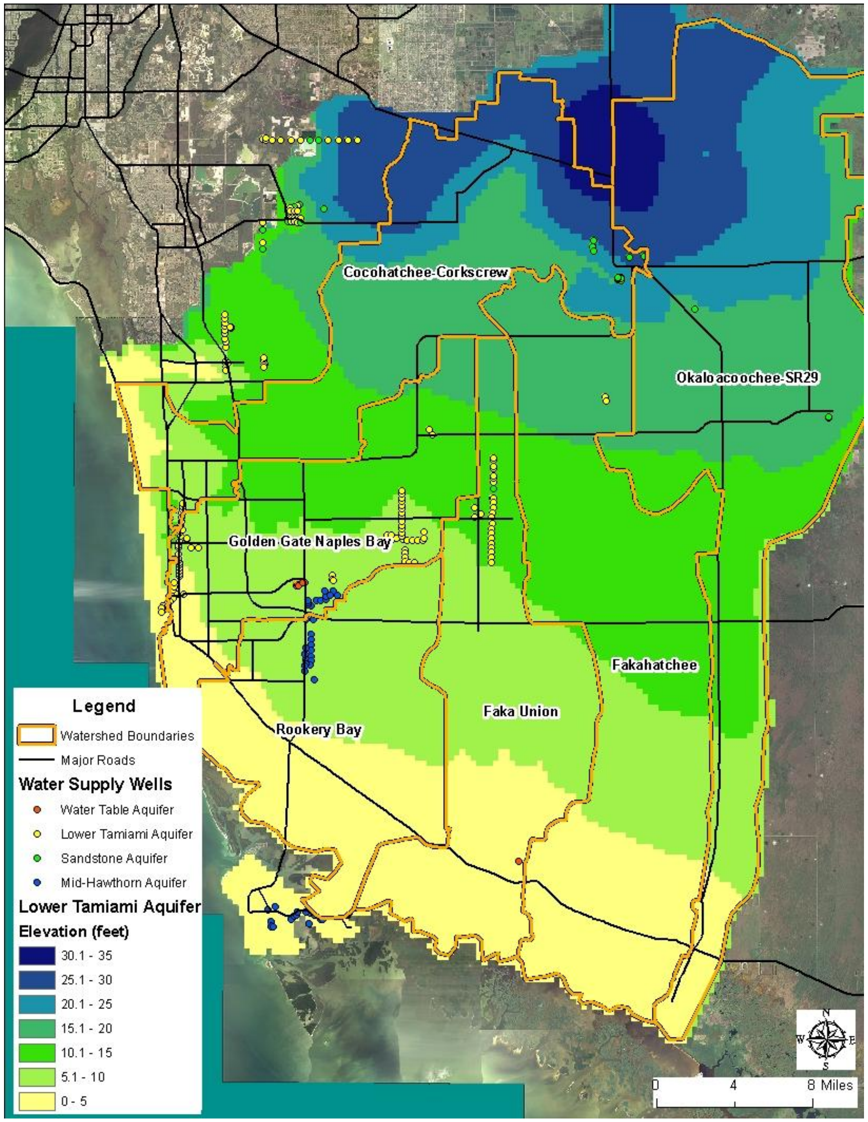


Figure 2-57. Lower Tamiami Aquifer Average Wet Season Elevation

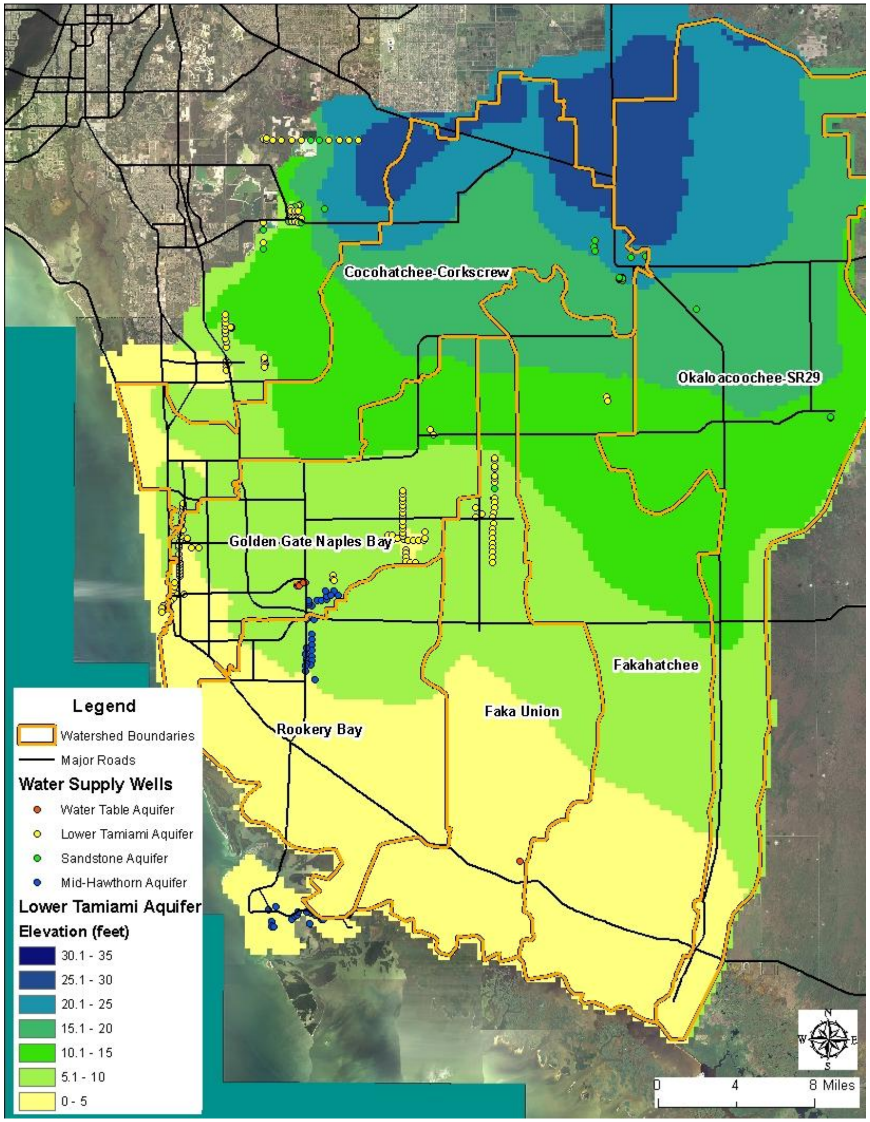


Figure 2-58. Lower Tamiami Aquifer Average Dry Season Elevation

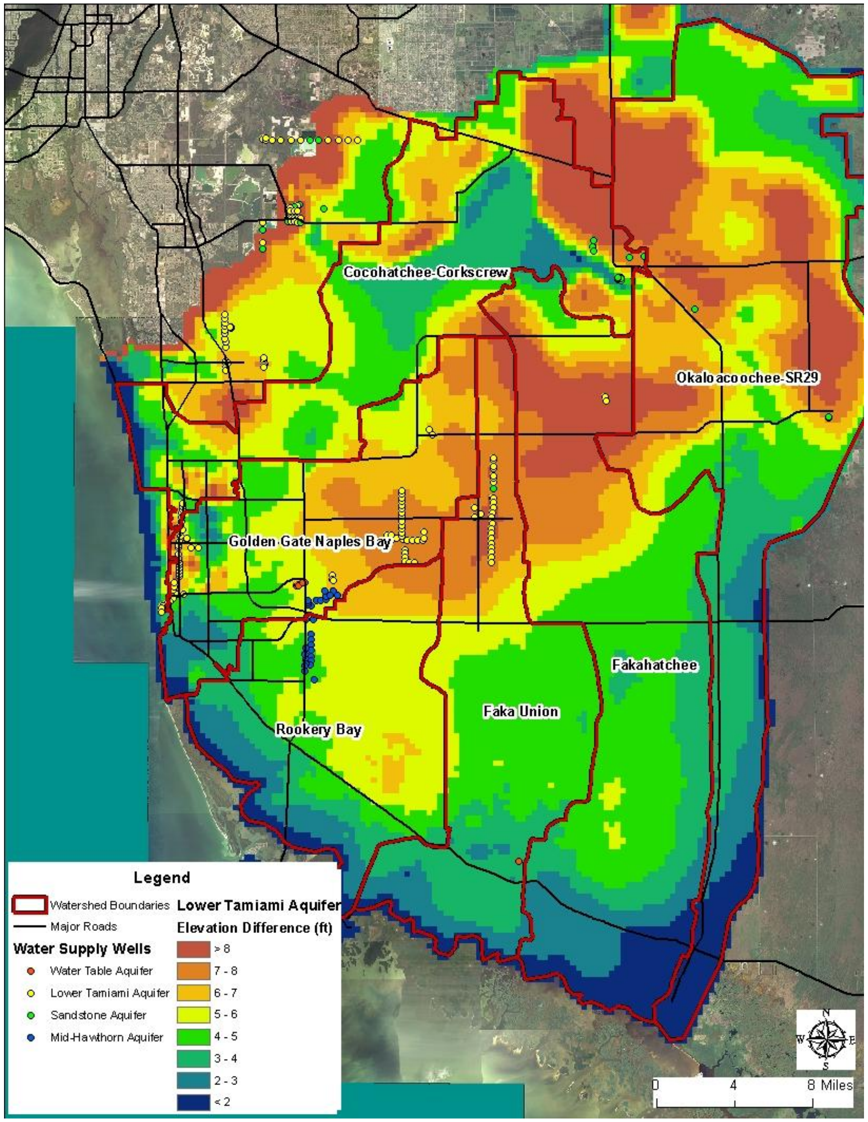


Figure 2-59. Lower Tamiami Aquifer Average Annual Groundwater Fluctuation

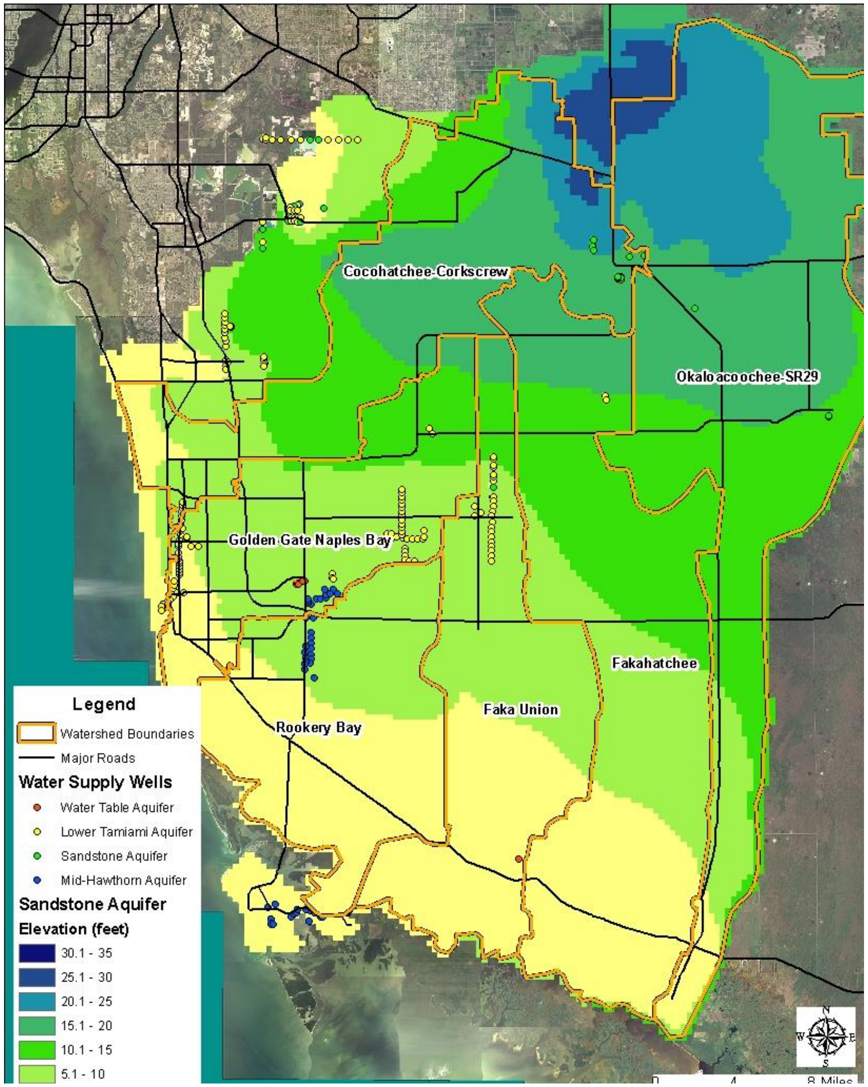


Figure 2-60. Sandstone Aquifer Average Annual Elevation

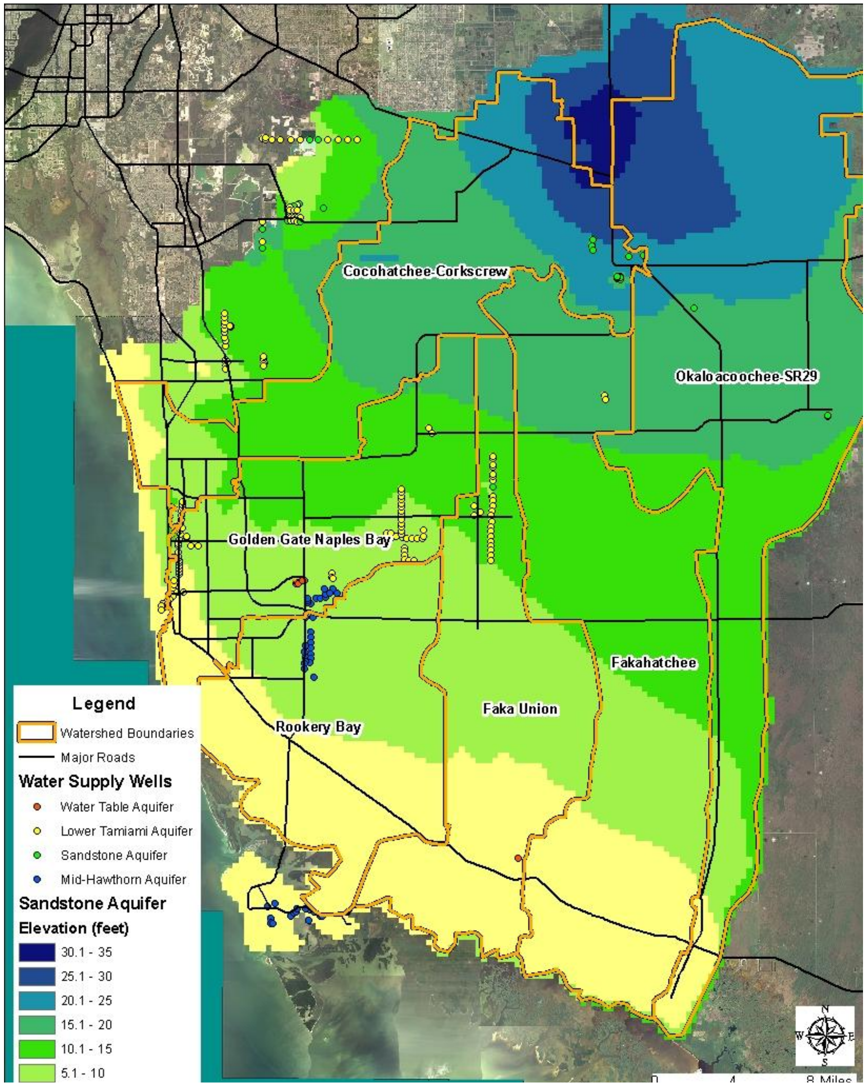


Figure 2-61. Sandstone Aquifer Average Wet Season Elevation

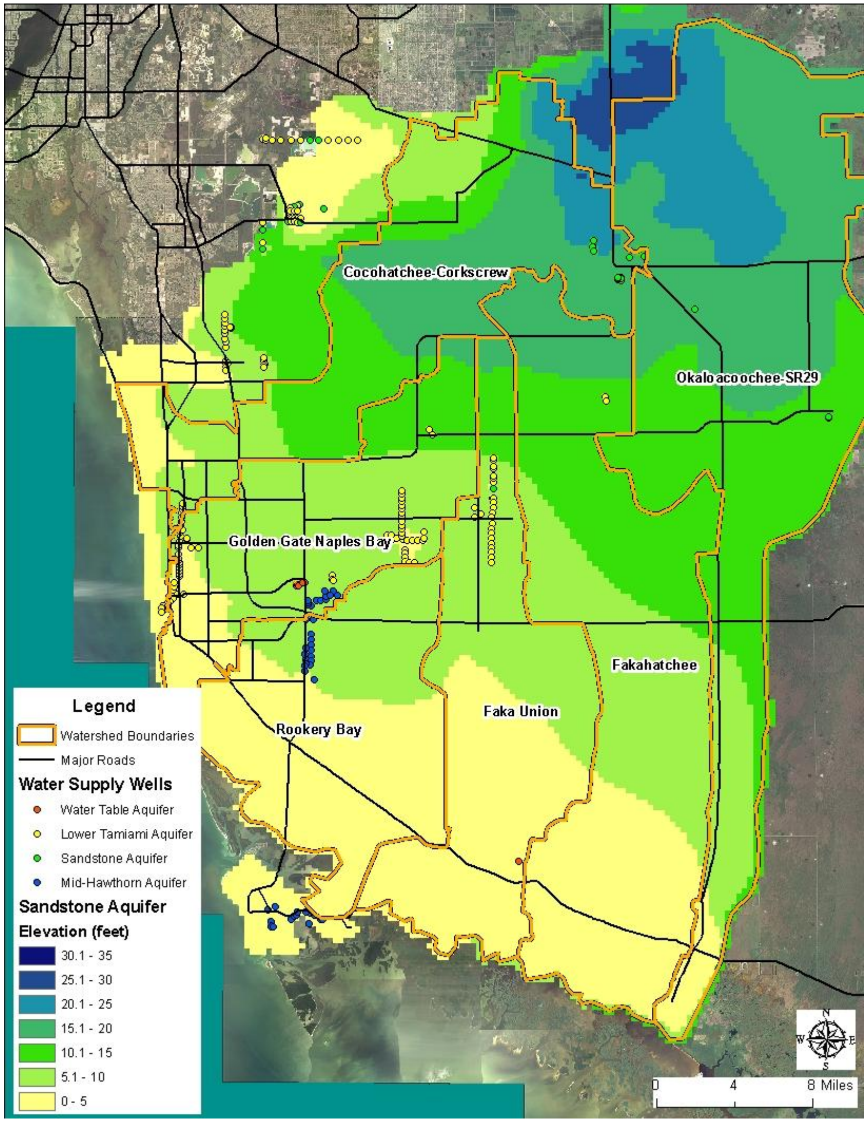


Figure 2-62. Sandstone Aquifer Average Dry Season Elevation

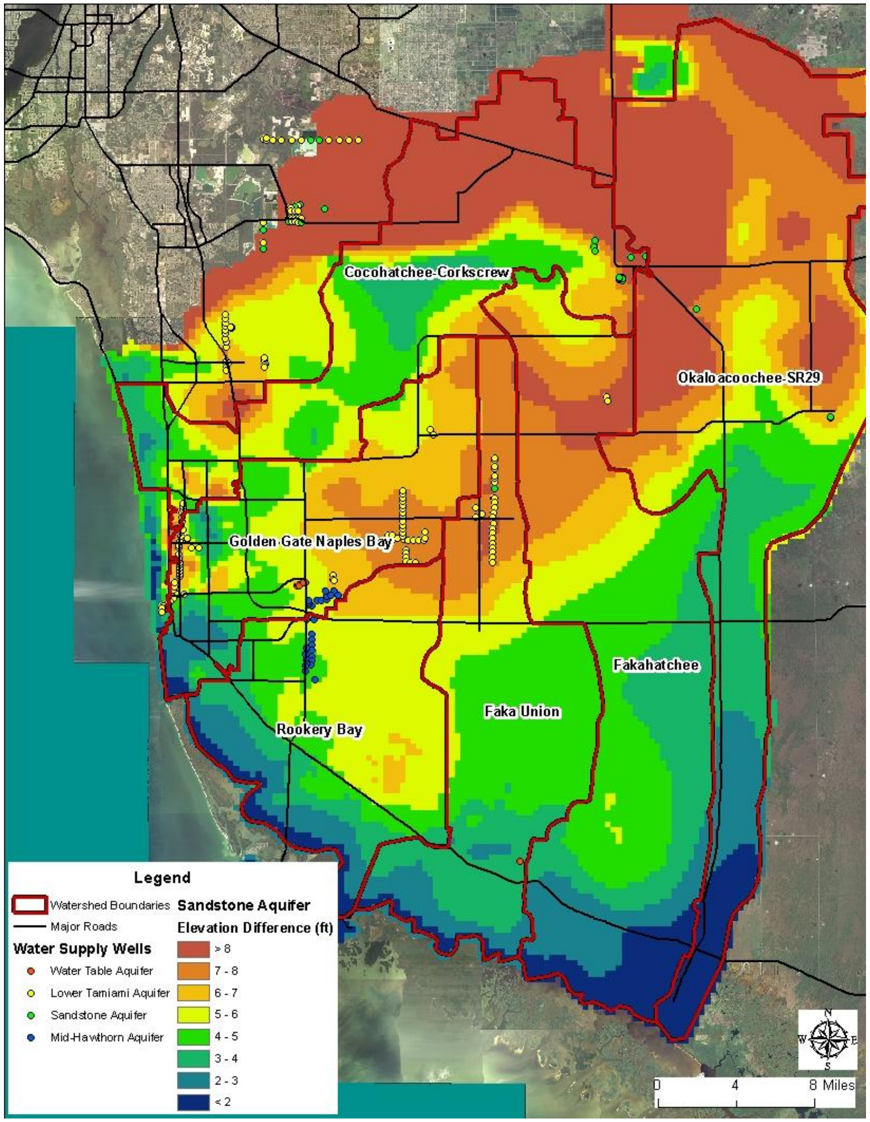


Figure 2-63. Sandstone Aquifer Average Annual Groundwater Fluctuation

Sandstone Aquifer

Figures 2-60 through 2-62 show the average annual and seasonal groundwater surface elevations for the Sandstone aquifer. As was observed in the Lower Tamiami Aquifer, there is an area of increased groundwater surface elevation north of Immokalee where the groundwater surface exceeds 30 feet in elevation. Similar elevations were not observed in the average annual and average dry season maps. The results also indicate similar shifts in the 5- and 10-foot isohyets as was seen in the Lower Tamiami Aquifer system.

In all of the watersheds, the shift in the isohyetal lines from the wet season (Figure 2-61) to the dry season (Figure 2-62) is almost identical to those observed in the Lower Tamiami Aquifer. This similarity indicates that there is high connectivity between the aquifers. The water budget discussion (Table 2-55) indicated that the Lower Tamiami Aquifer receives large volumes of inflow from the underlying Sandstone Aquifer, which supports the results of the mapped groundwater elevations.

Figure 2-63 shows the annual fluctuation in head elevation for the Sandstone Aquifer. As with the Lower Tamiami Aquifer, the figure indicates that there is great demand placed on this aquifer during the dry season. The Lee County wellfield draws from the Sandstone Aquifer and is the likely cause of the drawdown observed in the northern portion of the Cocohatchee-Corkscrew watershed. However, there is little pumping directly from the Sandstone Aquifer in the Faka Union and Okaloacoochee-SR29 watersheds as is shown in Table 2-64. This suggests that water is migrating from the Sandstone Aquifer into the Lower Tamiami Aquifer to meet irrigation demands. This is supported by the information presented in Table 2-59. More than 3 inches of groundwater migrates from the Sandstone to the Lower Tamiami Aquifer during the average dry season.

Mid-Hawthorn Aquifer

The Mid-Hawthorn Aquifer exhibits a noticeable depression in the potentiometric surface around the well field that straddles the boundary between the Golden Gate and Rookery Bay watersheds. This is seen in Figures 2-64 through 2-66. This well field draws from the Mid-Hawthorn Aquifer and is the likely source of drawdown. The wet season and dry season elevation maps indicate that the area influence by pumping shifts several miles to the north and east. This pattern of drawdown was not observed in the Sandstone Aquifer; indicating that there is little interaction between the Mid-Hawthorn Aquifer and the overlying Sandstone Aquifer.

Figure 2-67 shows extensive drawdown near the Collier County wellfield. The area of drawdown in the northern portion of the Cocohatchee-Corkscrew watershed is most likely a function of boundary conditions defined in the model. There are no known wells that draw from the Mid-Hawthorn Aquifer in that area.

2.4.4 Model Sensitivity to Increased Potable Water Supply Demand

In order to evaluate the sensitivity of the groundwater system to an increase in potable water supply demand, model sensitivity tests were conducted assuming a 10 percent increase in potable water demand. It was assumed that such an increase is realistic without having to develop new wellfields. The ECM pumping time series for all potable water supply pumping wells were modified to reflect the increased withdrawal rate.

It is expected that agricultural demand will decrease as development continues in the county. It is further expected that future development, and redevelopment of areas currently using private wells and septic systems, will be required to utilize municipal water and sewer systems. Therefore, no change was made to pumping rates for irrigation or domestic self supply wells.

A first model sensitivity test consisted of comparing the average annual minimum water level in each aquifer predicted by the ECM against the average annual minimum water level in each aquifer as predicted by the model with increased pumping. The results are shown in maps that define the change in drawdown resulting from the increased pumping in each aquifer. **Figures 2-68 through 2-71** show the increased drawdown in each aquifer.

A second sensitivity test considered the effect of increased pumping during a prolonged dry season. The dry season of 2007, which began on November 1, 2006 and continued through June 2007, followed a wet season with little rainfall. This average groundwater elevation calculated for the dry season 2007 was used to evaluate the effect of increased pumping during prolonged drought conditions. **Figures 2-72 through 2-75** show the extent of the increased drawdown during the extended dry period.

The area near where Immokalee Road turns to the north indicates a predicted difference in water surface elevation for the Water Table Aquifer that exceeds 0.5 feet during the driest dry season, although no potable water supply wells exist at this location. This result appears to be related to an unstable structure operation in the Cocohatchee Canal that occurs only during the driest dry season with the increased pumping.

In each of the aquifer systems, the extent of the predicted area influenced by pumping increases during extended drought conditions. The results show that the area of influence extends from the City of Naples wellfield into the northern portions of the Fakahatchee watershed and that individual areas of influence have merged into a single area of influence that encompasses almost the entire area of the Golden Gate-Naples Bay Watershed.

The results indicate that the availability of groundwater is limited to meet long-term water supply needs for Collier County. Increased pumping is predicted to increase the risk of salt water intrusion and potentially affect availability of water for domestic self supply from the Water Table and Lower Tamiami aquifer systems.

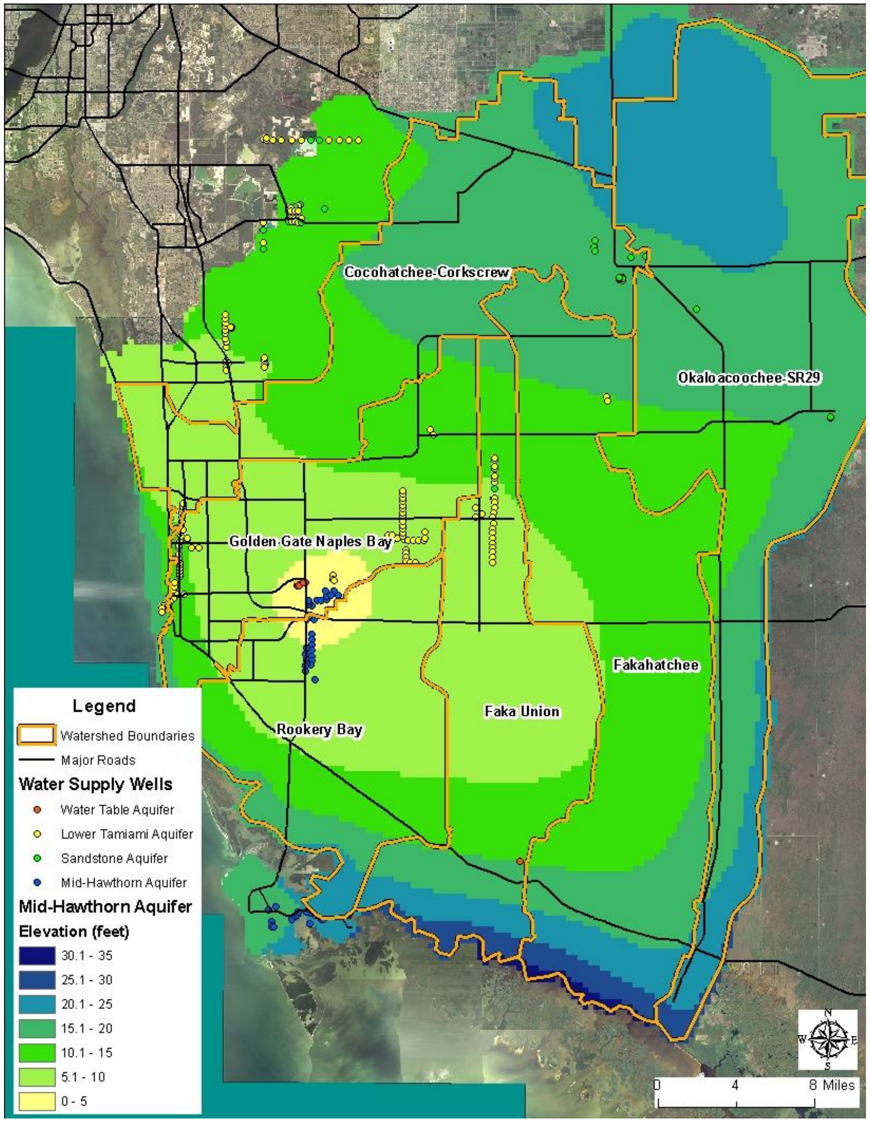


Figure 2-64. Mid-Hawthorn Aquifer Average Annual Elevation

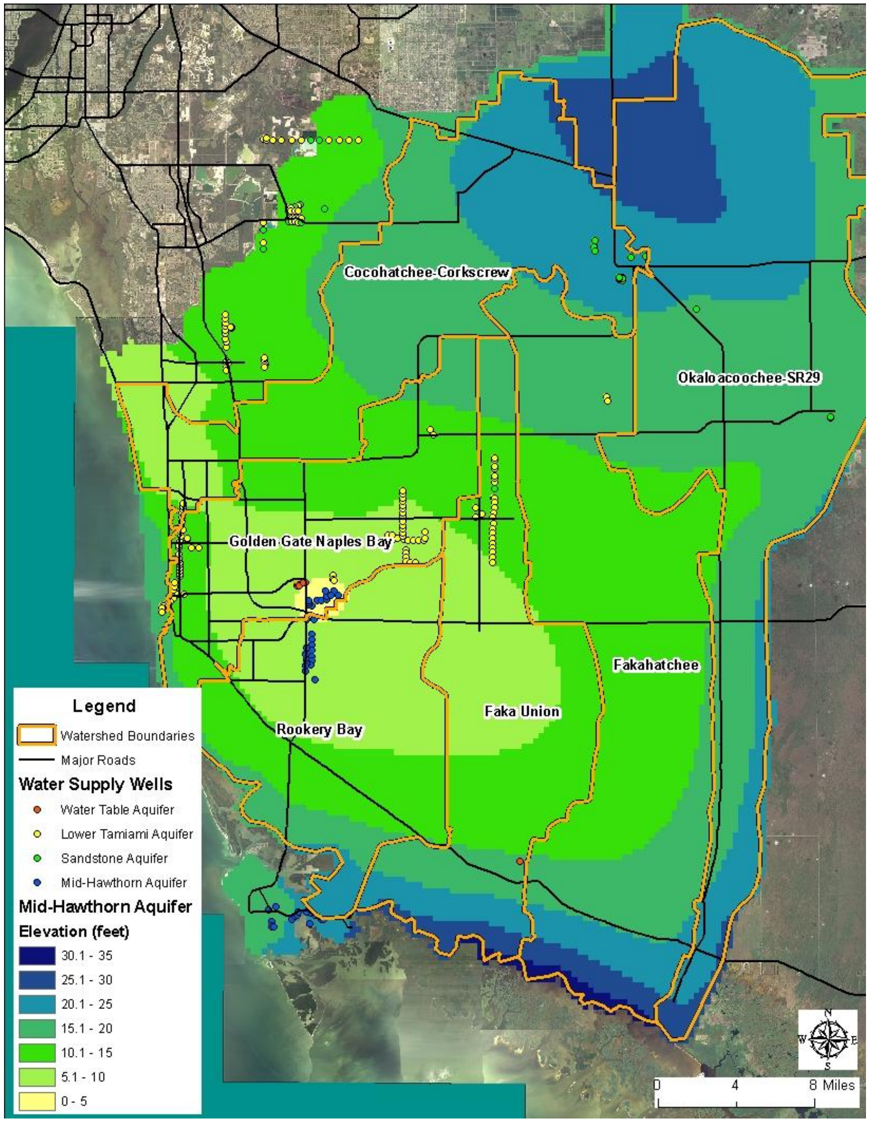


Figure 2-65. Mid-Hawthorn Aquifer Average Wet Season Elevation

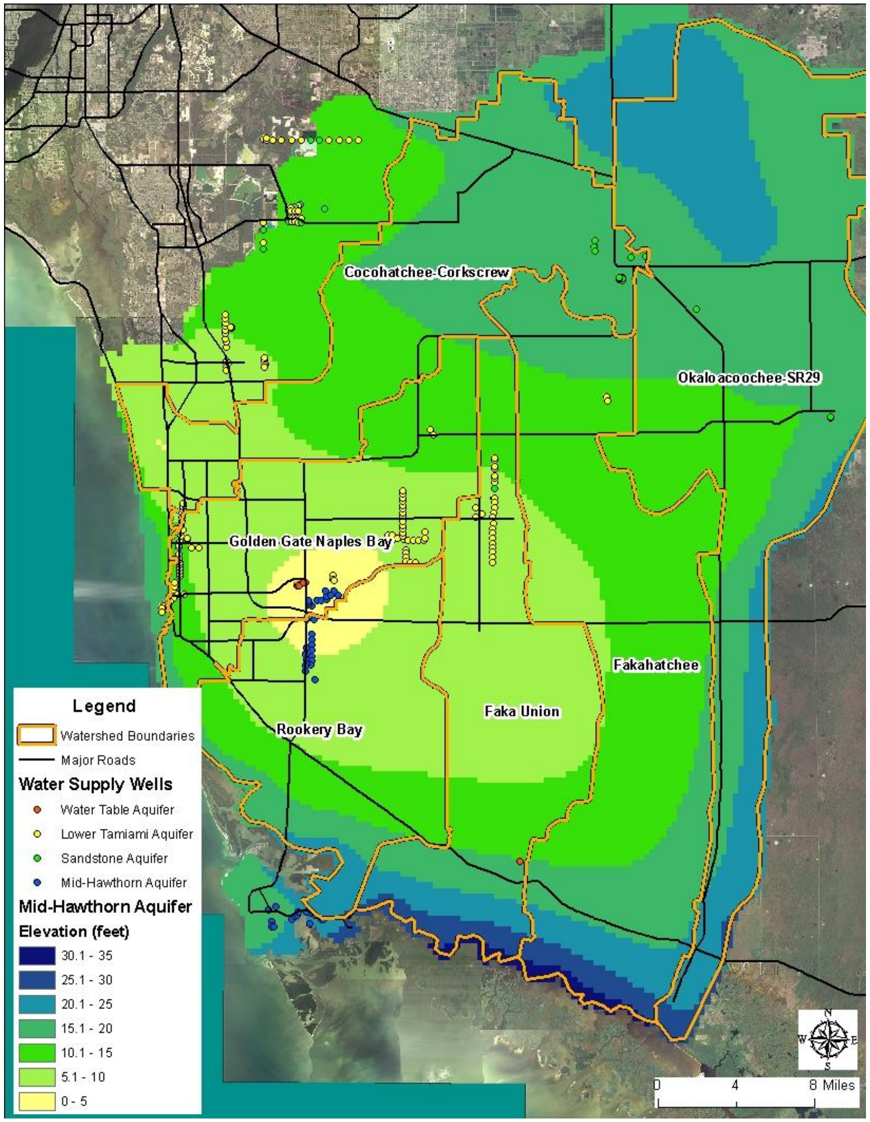


Figure 2-66. Mid-Hawthorn Aquifer Average Dry Season Elevation

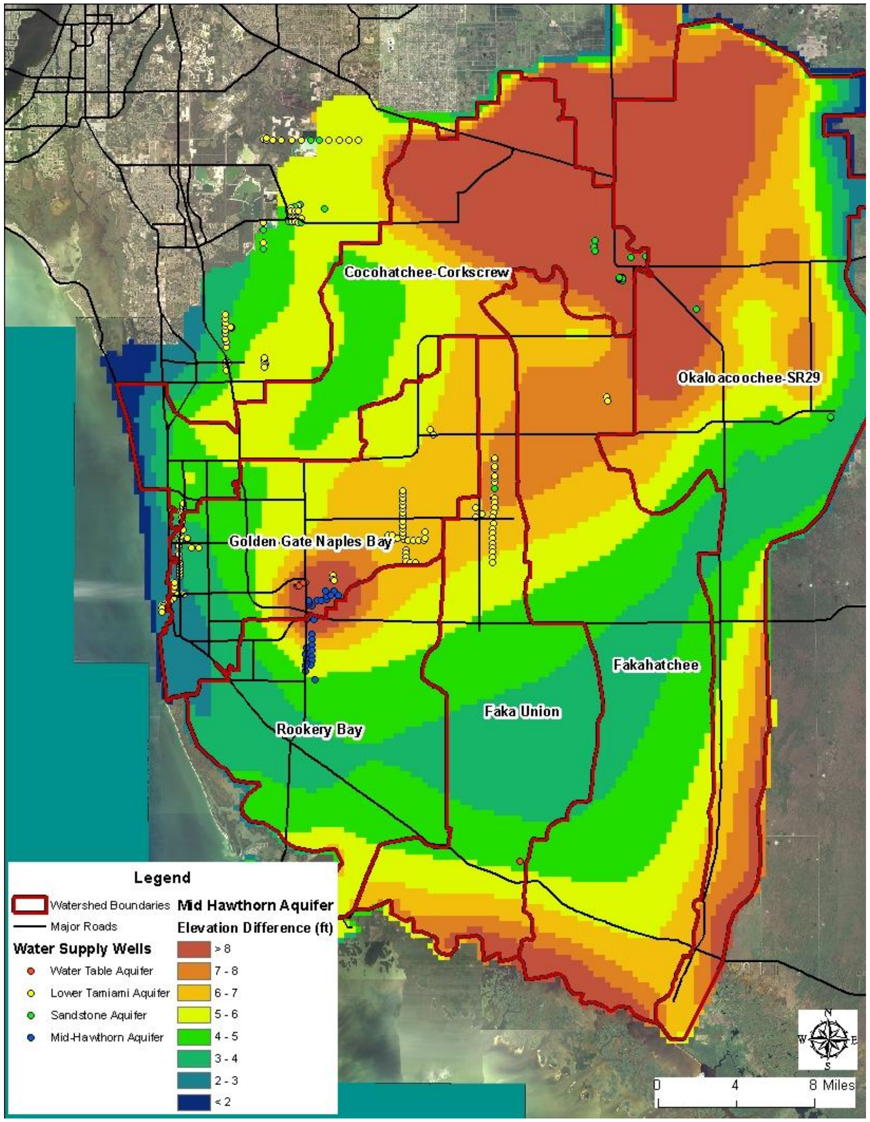


Figure 2-67. Mid-Hawthorn Aquifer Average Annual Groundwater Fluctuation

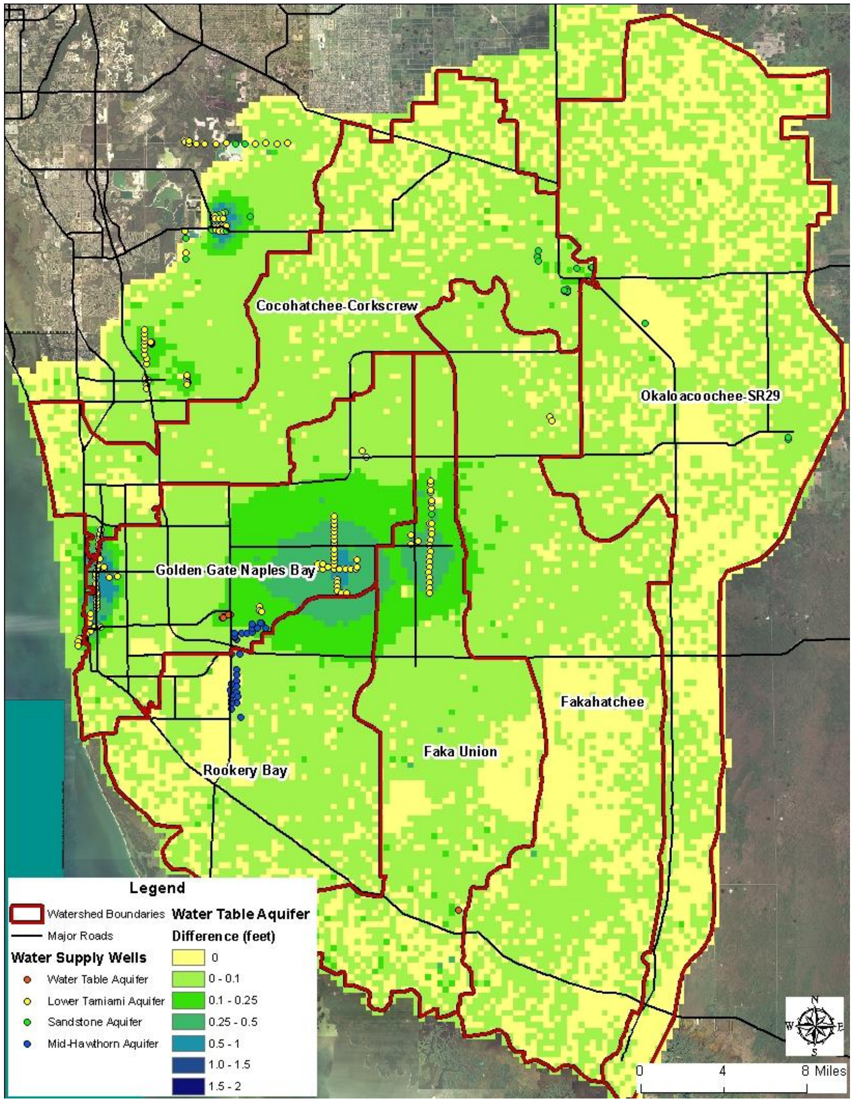


Figure 2-68. Water Table Aquifer Average Increase in Drawdown With 10% Increase in Groundwater Withdrawal

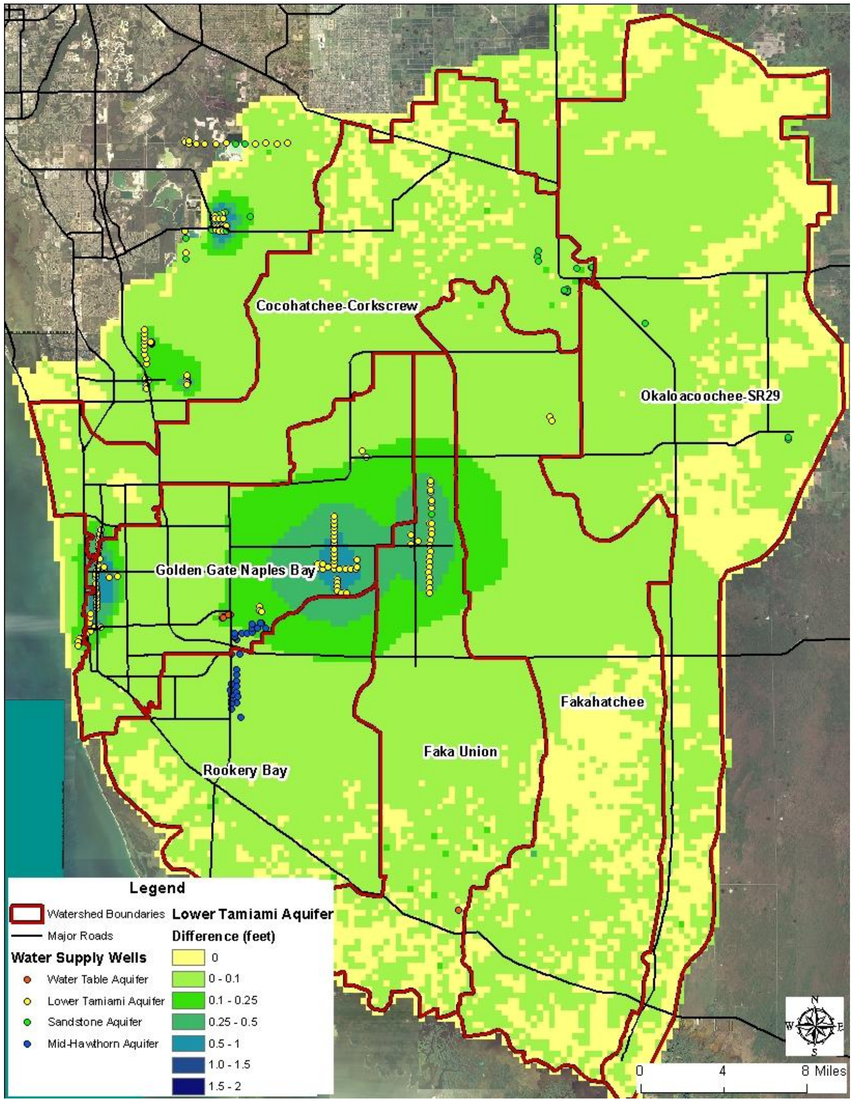


Figure 2-69. Lower Tamiami Aquifer Average Increase in Drawdown With 10% Increase in Groundwater Withdrawal

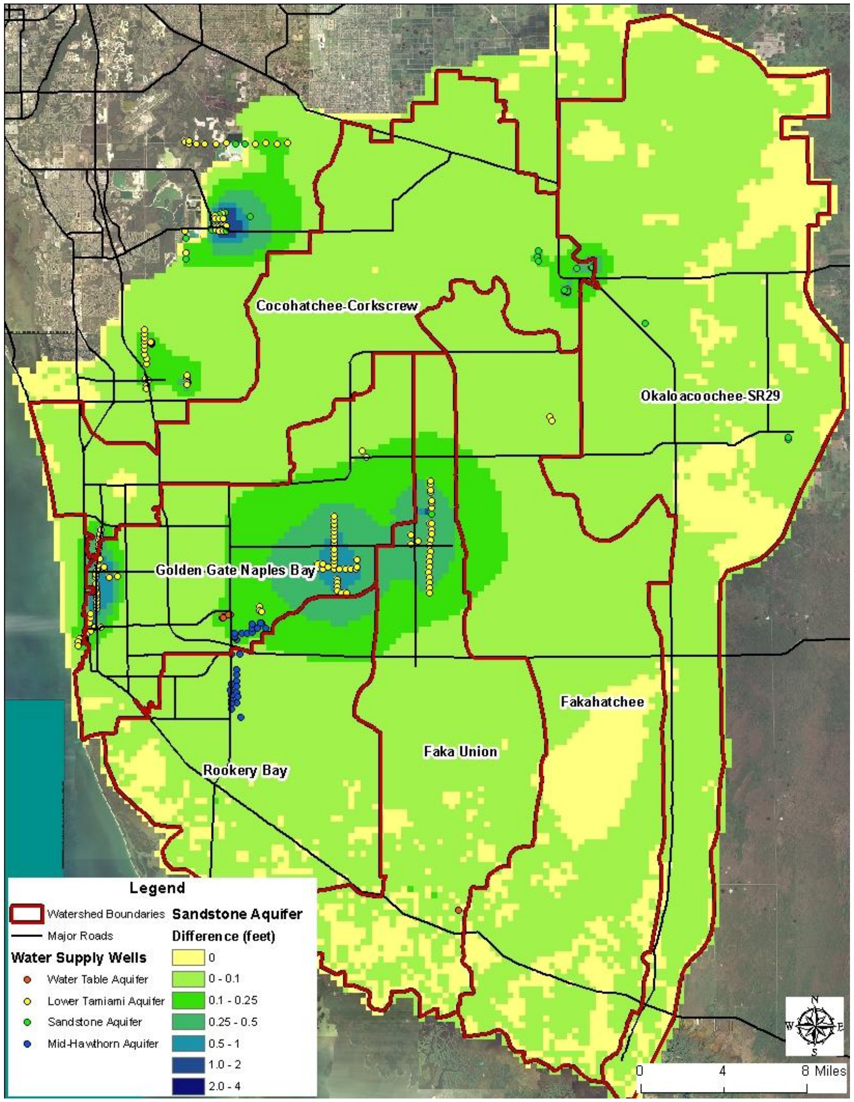


Figure 2-70. Sandstone Aquifer Average Increase in Drawdown With 10% Increase in Groundwater Withdrawal

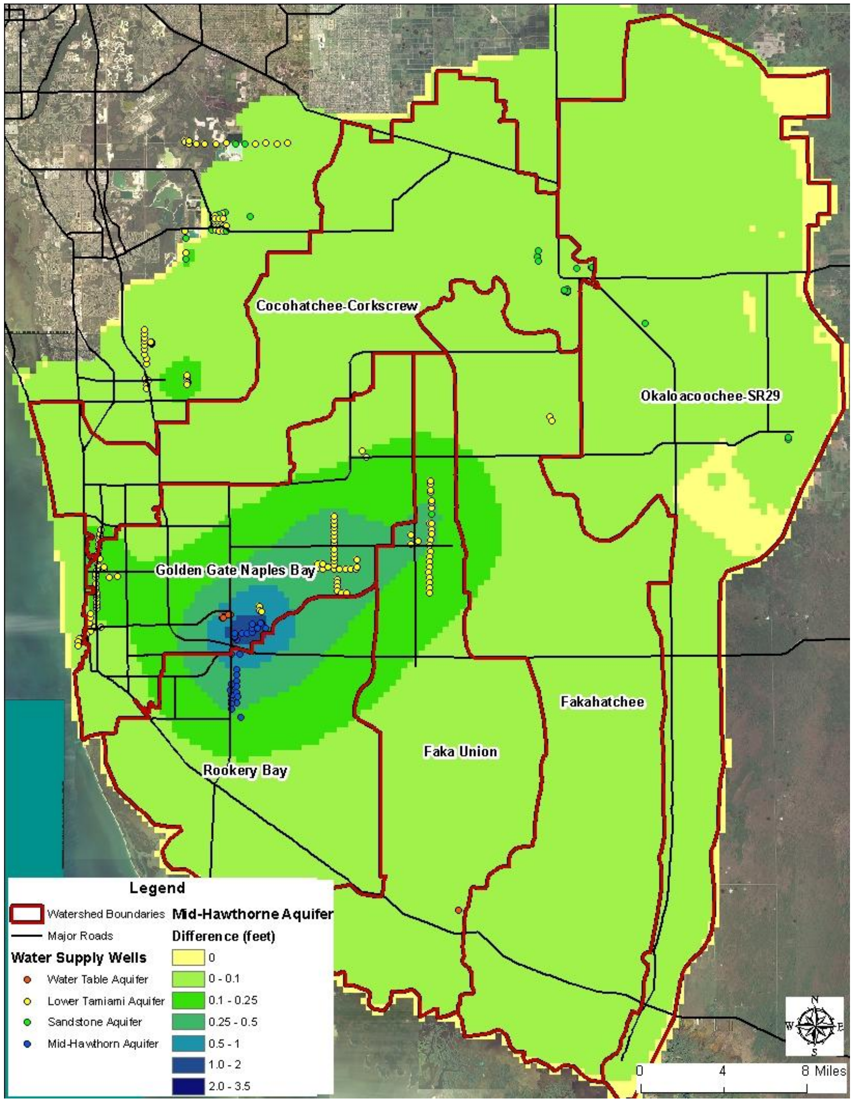


Figure 2-71. Mid-Hawthorn Aquifer Average Increase in Drawdown With 10% Increase in Groundwater Withdrawal

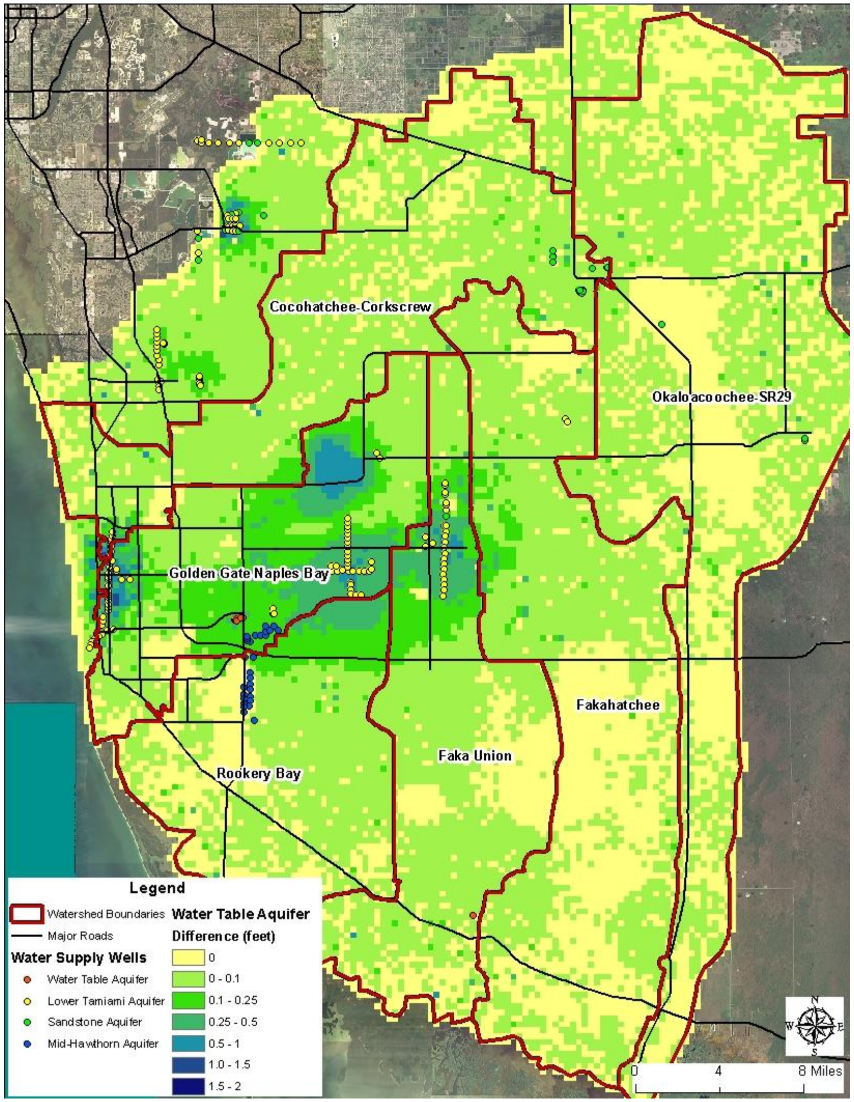


Figure 2-72. Water Table Aquifer Driest Dry Season Increase in Drawdown With 10% Increase in Groundwater Withdrawal

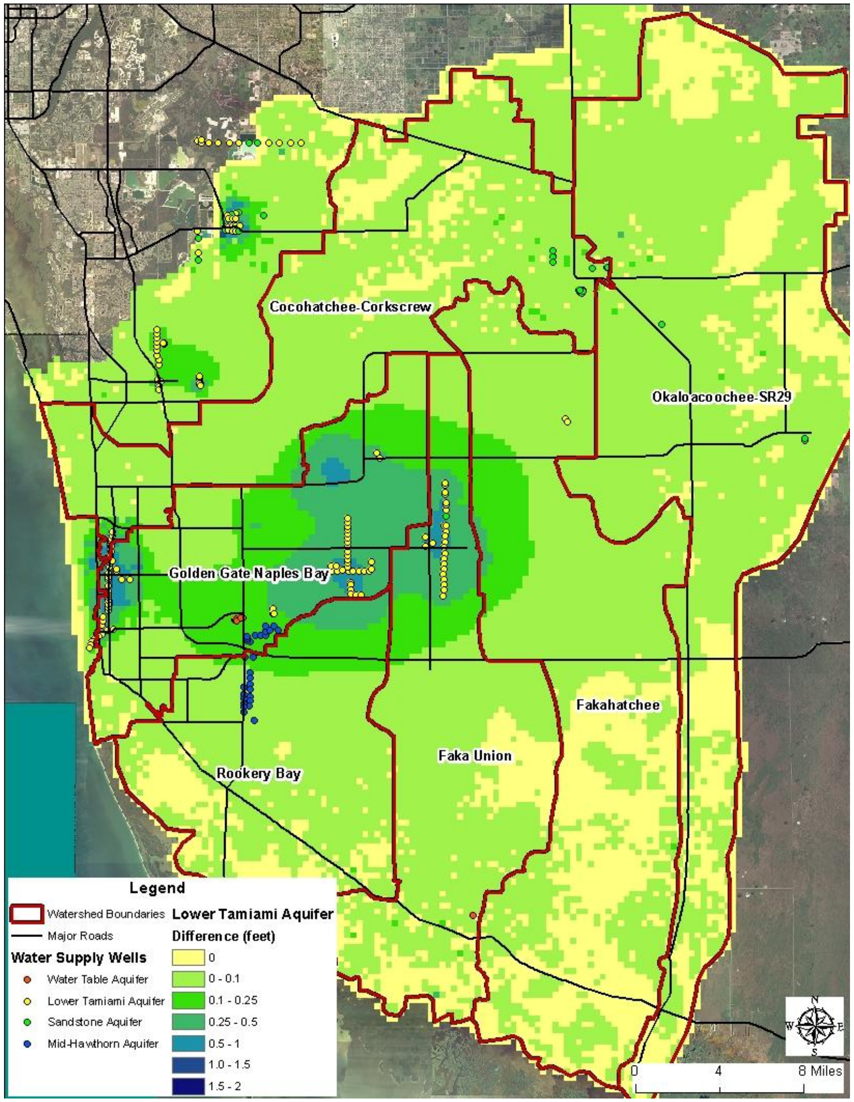


Figure 2-73. Lower Tamiami Aquifer Driest Dry Season Increase in Drawdown With 10% Increase in Groundwater Withdrawal

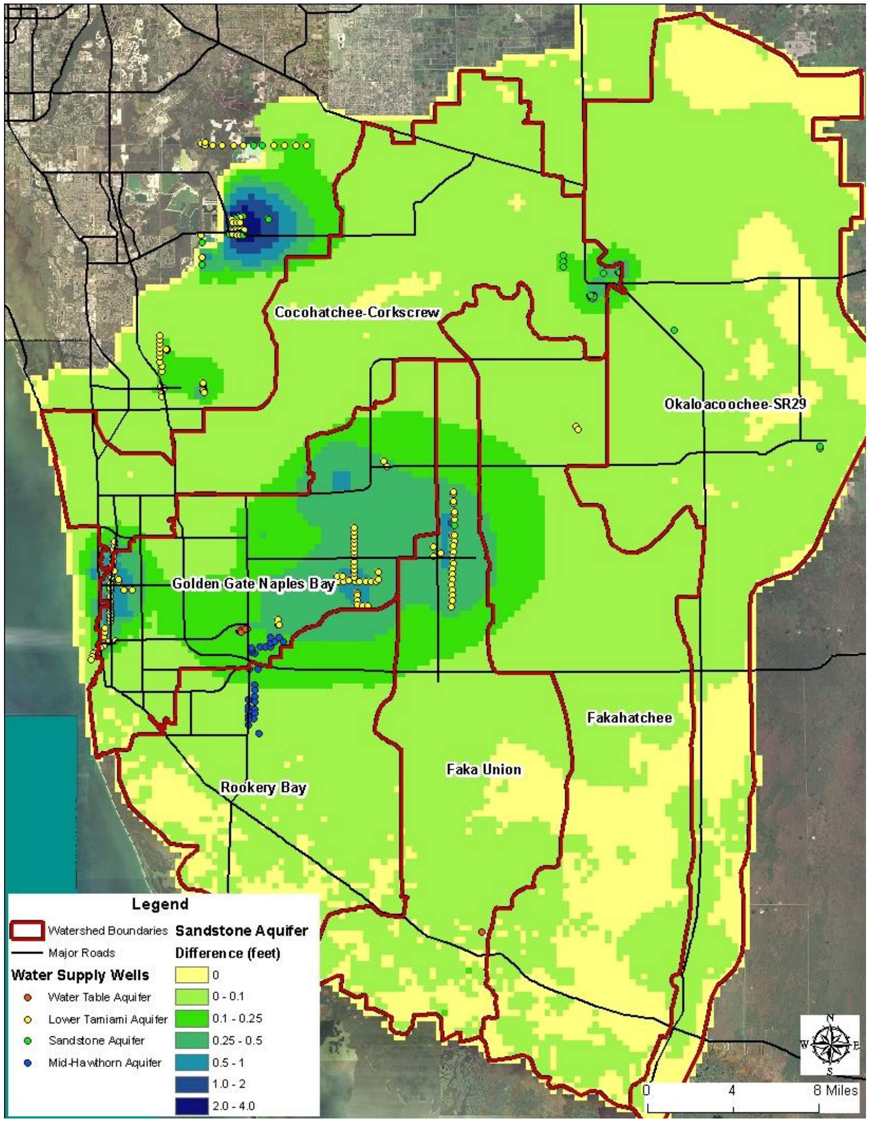


Figure 2-74. Sandstone Aquifer Driest Dry Season Increase in Drawdown With 10% Increase in Groundwater Withdrawal

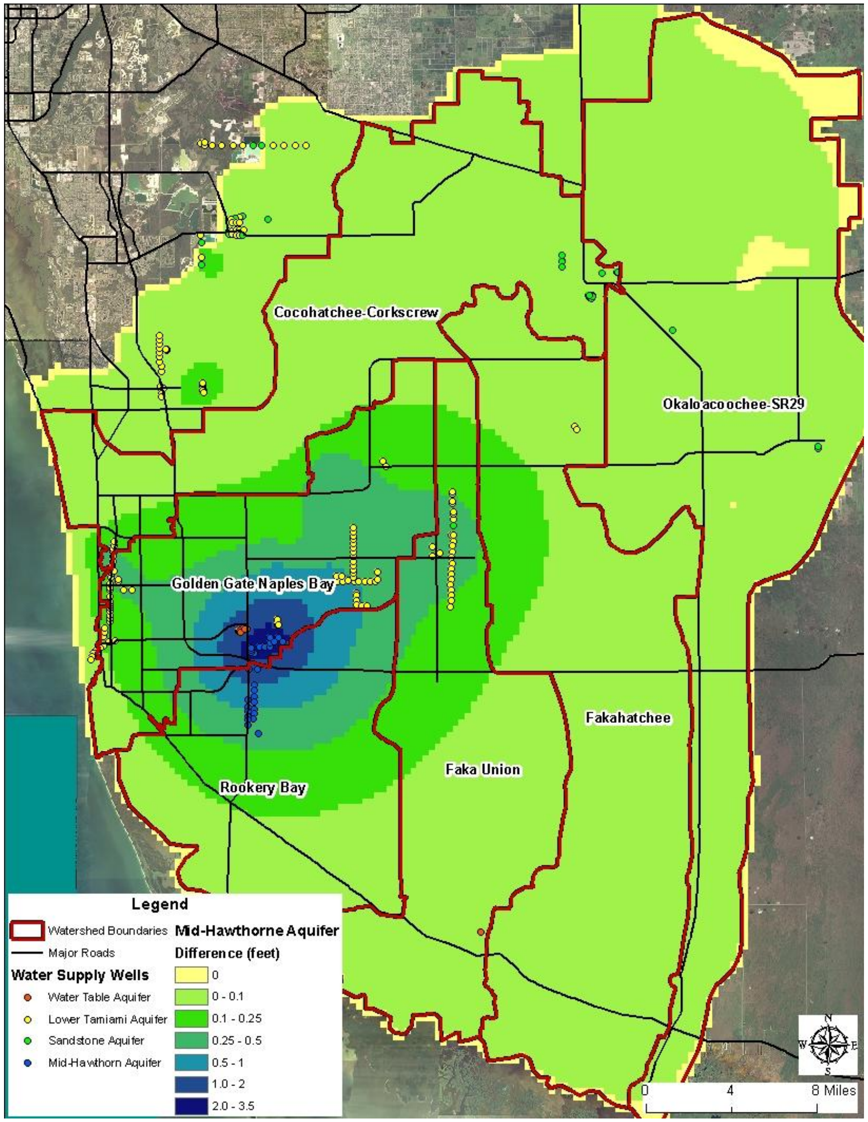


Figure 2-75. Mid-Hawthorn Aquifer Driest Dry Season Increase in Drawdown With 10% Increase in Groundwater Withdrawal

2.4.5 Conclusions

The groundwater system of Collier County is an integral part of the highly integrated hydrologic system of southwest Florida. The groundwater systems in Collier County act as regional reservoirs and exhibit seasonal variations in water storage. The use of groundwater to meet potable water supply and irrigation demand places extensive pressure on the aquifer systems to meet current and future needs. Several conclusions were drawn from this analysis.

- The water budget completed for the Water Table Aquifer indicates that wet season recharge may be insufficient to match dry season losses in the Cocohatchee-Corkscrew and Golden Gate-Naples Bay Watersheds. Losses are directly influenced by baseflow losses to the canal network and to pumping to meet water supply and irrigation demand.
- Conditions in the canal network influence groundwater elevations and contribute to long term changes in the water table elevation. Changes in structural operations in the Golden Gate Canal network will likely help mitigate groundwater losses and increase water availability.
- The water budget analysis indicates that current wet season recharge rates within the lower aquifers tend to match the current dry season withdrawals. However, additional pumping may lead to an annual loss of stored water within each aquifer.
- The groundwater performance measure evaluation indicated that locations with relatively low scores tend to correspond to areas with high groundwater demand to meet potable water supply and irrigation needs. Projects and policies that encourage additional recharge and reduce demand on the shallow aquifer systems would most likely lead to improved scores in these areas.
- Sensitivity tests related to groundwater pumping indicate that the availability of groundwater is limited to meet long-term water supply needs for Collier County and may increase the risk of salt water intrusion and potentially affect availability of water for domestic self supply from the Water Table and Lower Tamiami aquifer systems.

2.4.6 Performance Scores for Aquifer Conditions

The continued use of groundwater resources in Collier County has resulted in groundwater levels that fluctuate seasonally in response to the demand for withdrawals. During the wet season, sufficient rainfall and recharge typically result in higher aquifer storage and hydraulic heads. However, during the dry season, limited rainfall leads to additional groundwater pumping to meet seasonal population needs and increased demand for irrigation purposes.

In order to assess the relative yield or quantity of available water within each aquifer, the ECM-predicted hydraulic heads were compared to those obtained from the Natural Systems Model (NSM) that was developed for the SWFFS. The NSM was an approximation of the predevelopment hydrologic and hydrogeologic conditions of the region. The NSM did not include the Mid-Hawthorn Aquifer and so comparisons were completed for the Water Table, Lower Tamiami, and Sandstone aquifers.

The SFWMD has defined the Minimum Aquifer Level (MAL) for confined aquifers to be the structural top of each aquifer. The lower limit of the performance measure was therefore designated as the physical top of the aquifer unit. The upper limit of the Water Table Aquifer is defined by the simulated NSM results. For the water table, the lower limit was defined as the bottom of the aquifer.

A performance measure score (0 to 10) was calculated for the top three aquifers and each cell in the model grid. The NSM does not include the Mid-Hawthorn Aquifer so no performance score was been calculated for the Mid-Hawthorn. The score was defined as follows:

$$\text{Score} = ((\text{ECM Head Elevation} - \text{Structural Top of Aquifer}) / (\text{NSM Head Elevation} - \text{Structural Top of Aquifer})) \times 10$$

Figure 2-76 illustrates a theoretical aquifer condition representing performance scores for a confined aquifer system.

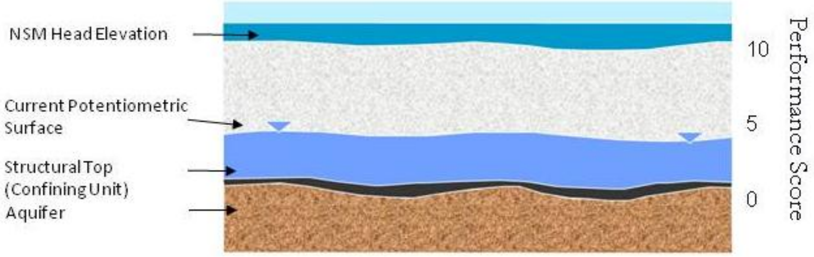


Figure 2-76. Theoretical Condition for Confined Aquifer Performance Score

Figures 2-77 through 2-79 show the difference between the average annual groundwater surface elevation for the NSM and ECM models for the Water Table, Lower Tamiami, and Sandstone aquifer systems. The results show that the most drawdown occurs near municipal wells fields and in areas where there is demand for irrigation or domestic self supply. These figures also indicate that boundary conditions can contribute to significant differences in predicted groundwater elevations. Negative values indicate that the ECM groundwater elevation is lower than the NSM groundwater elevation.

Aquifer performance measure scores were calculated for each aquifer on a cell-by-cell basis within the model area. The scores for each aquifer were then averaged within WBIDs and watersheds. Table 2-72 lists each WBID and the performance score for each aquifer. These scores are based on the average dry season water level for the ECM and the NSM. The relatively high performance scores averaged over WBID and watershed areas do not provide the resolution to evaluate local effects of groundwater drawdown. Figures 2-80 through 2-82 show the distribution of grid level performance scores within each watershed.

Figure 2-80 shows the cell by cell performance score in the Water Table Aquifer. The areas in green indicate high performance or relatively little change in dry season conditions from the NSM. Areas in red indicate locations where water demand to meet agricultural and potable water supply needs results in low performance scores relative to historic groundwater levels. Areas that score poorly tend to correspond to well field locations. This is most apparent in the Rookery Bay and Golden Gate watersheds.

Other areas that correspond to well field locations include the area near Immokalee and in the northern portion of the Faka Union watershed. Another area that scores poorly is in the Okaloacoochee watershed and corresponds with agricultural areas with significant irrigation demands. Projects and policies that encourage additional recharge and reduce demand on the shallow aquifer systems would most likely lead to improved scores in these areas.

A final area that scores poorly is in the southern Faka Union watershed. This poor score is likely attributable to the canal network that has effectively drained this historic wetland area. Similar results are observed in portions of the Golden Gate-Naples Bay Watershed. The high level of baseflow in these areas influences the groundwater elevation and contributes to lower water table elevations. Changes in structure operations could have a positive influence on groundwater elevation and availability in the watershed.

The results for the Lower Tamiami Aquifer (Figure 2-81) show that poor scores that correspond with similar locations in the Water Table Aquifer. This can be attributed to the significant interaction between the aquifer systems coupled with the high water demand.

Areas in red along the model boundaries in both the Water Table and Lower Tamiami Aquifers are likely not real and caused by the differences in defined boundary conditions between the ECM and NSM.

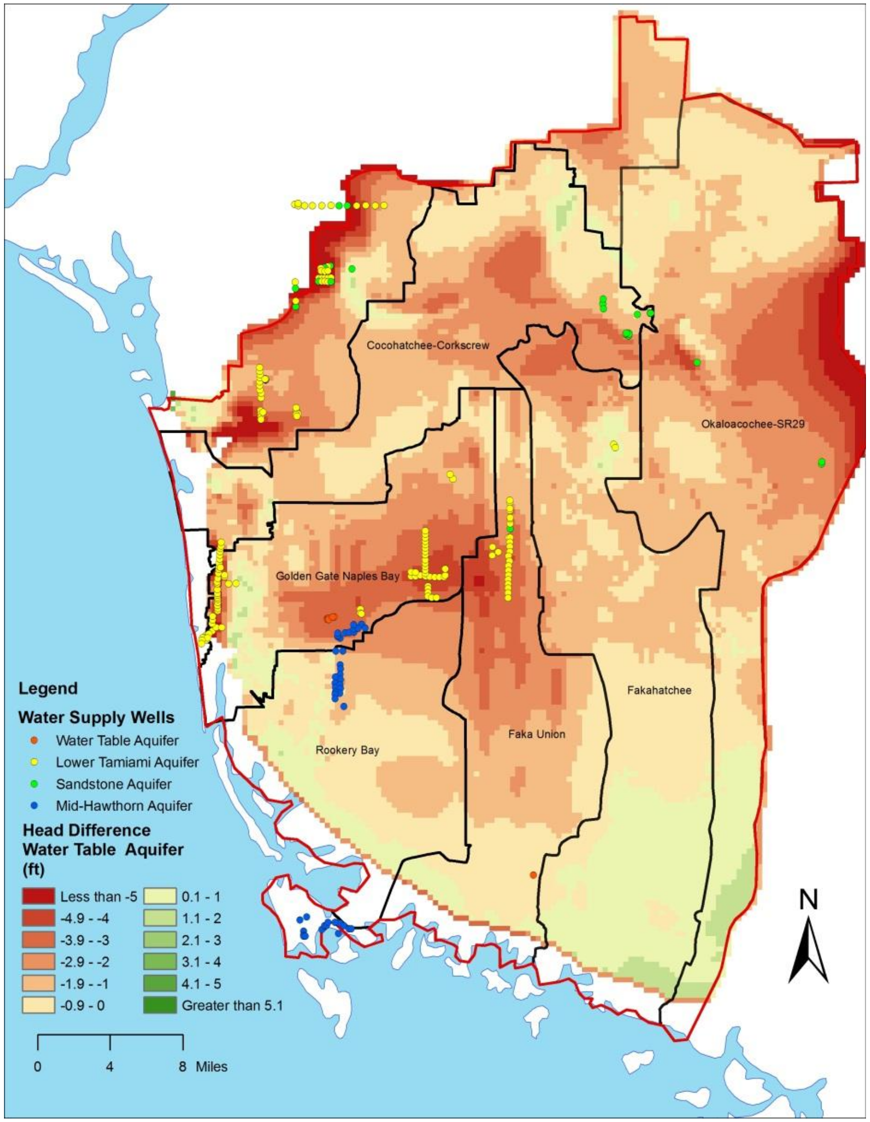


Figure 2-77. Water Table Aquifer, Average Annual Elevation Difference ECM–NSM

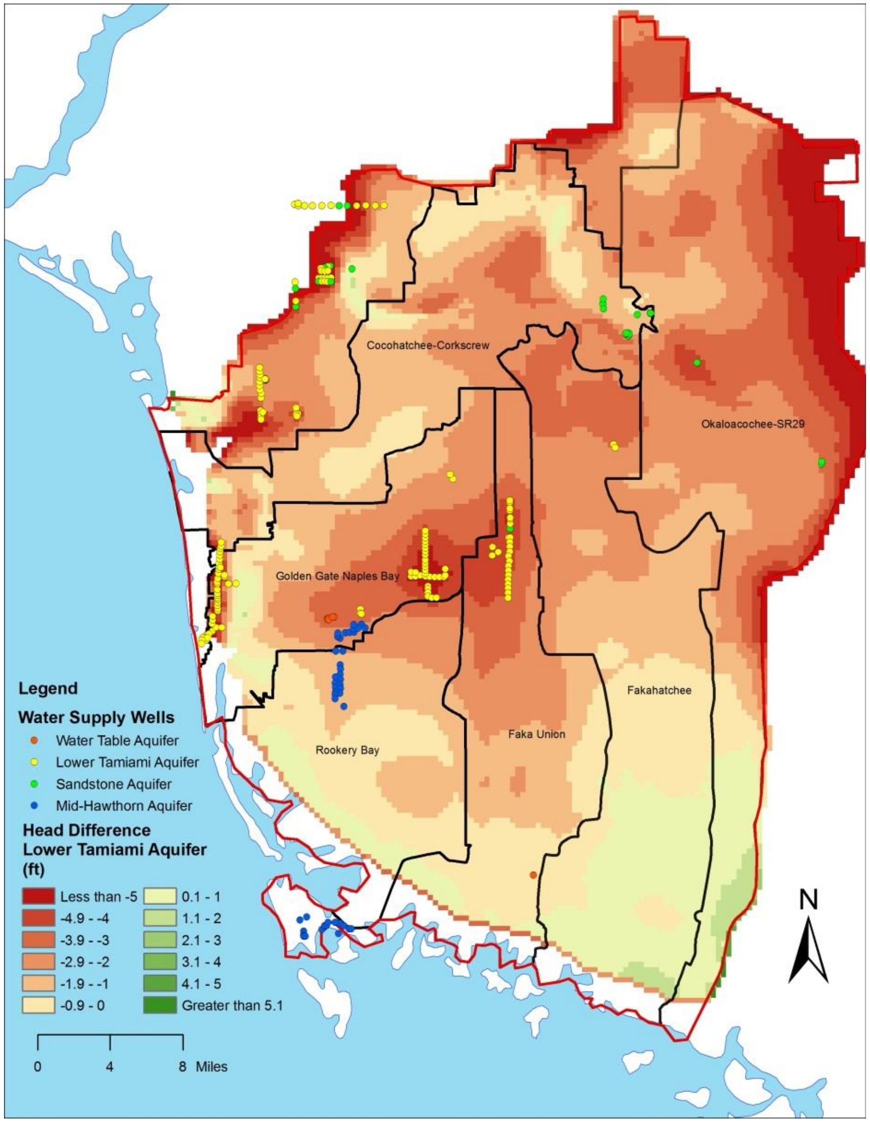


Figure 2-78. Lower Tamiami Aquifer, Average Annual Elevation Difference ECM–NSM

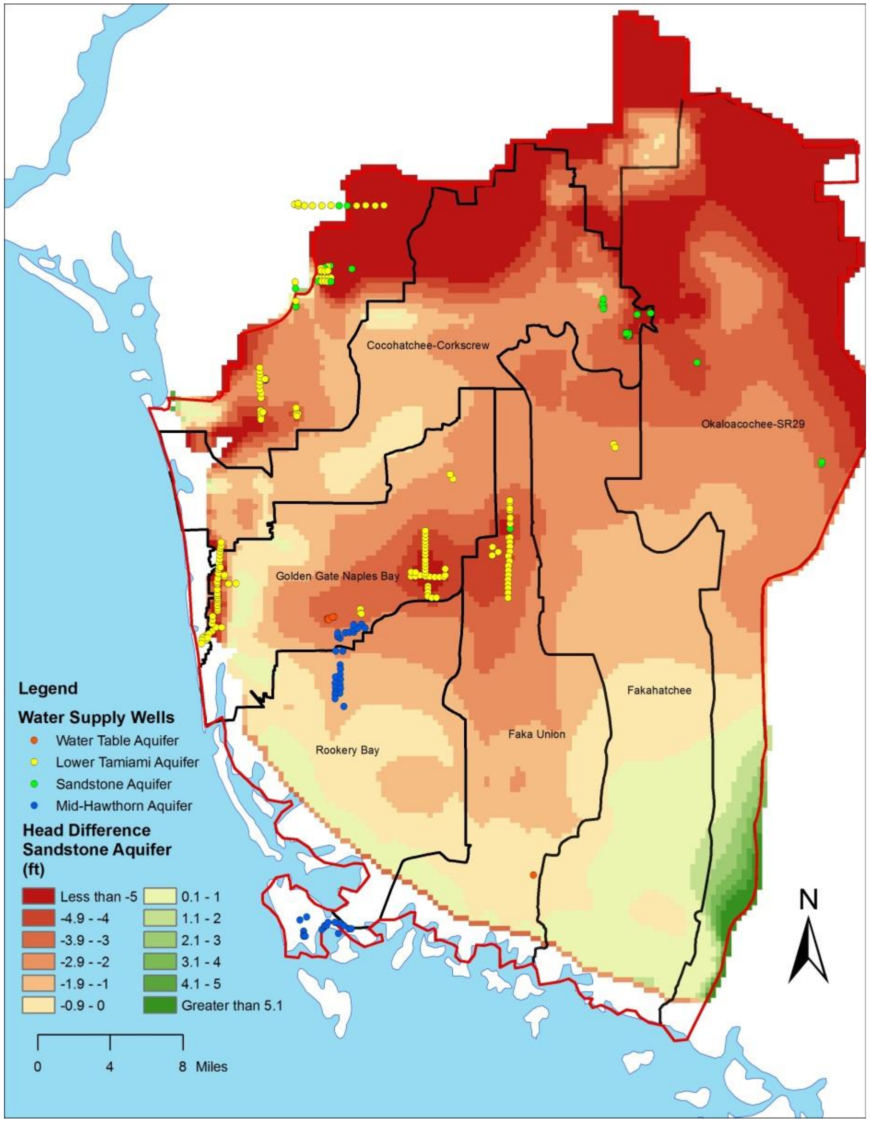


Figure 2-79. Sandstone Aquifer, Average Annual Elevation Difference ECM–NSM

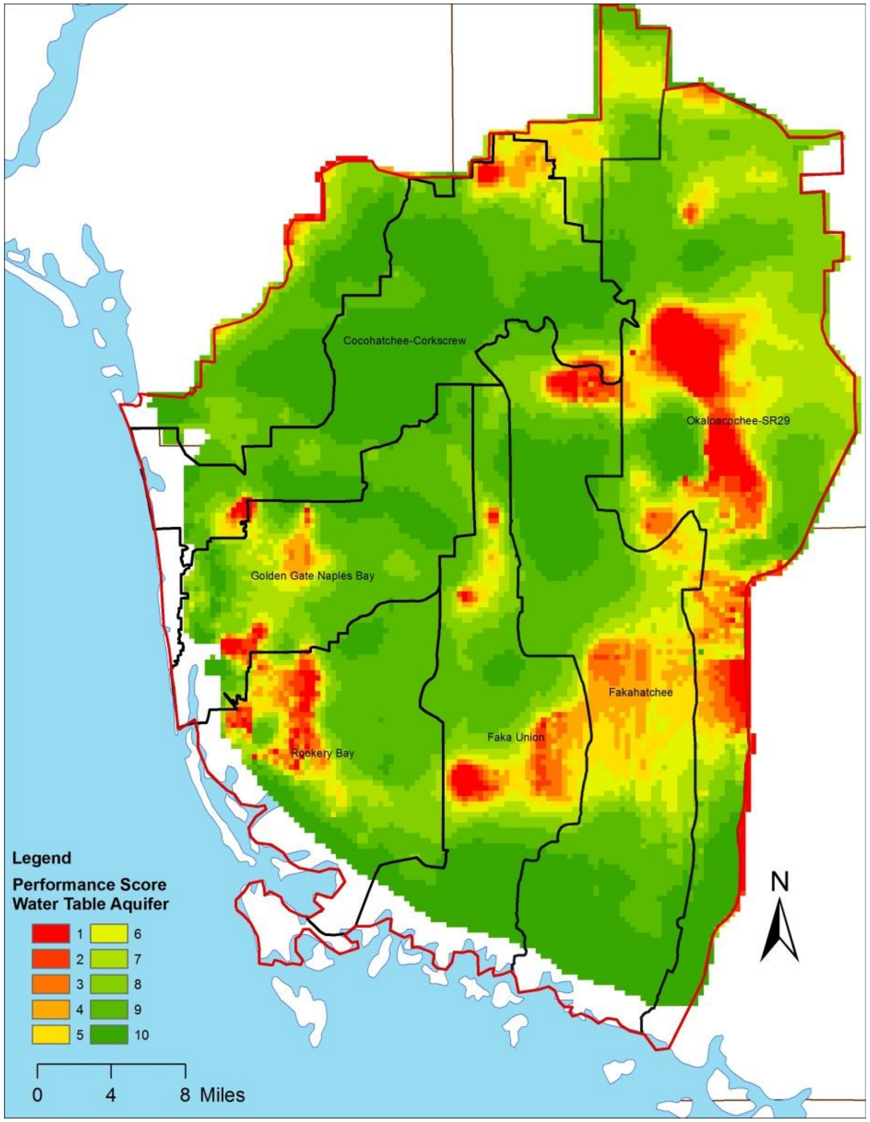


Figure 2-80. Water Table Aquifer, Average Dry Season Performance Score

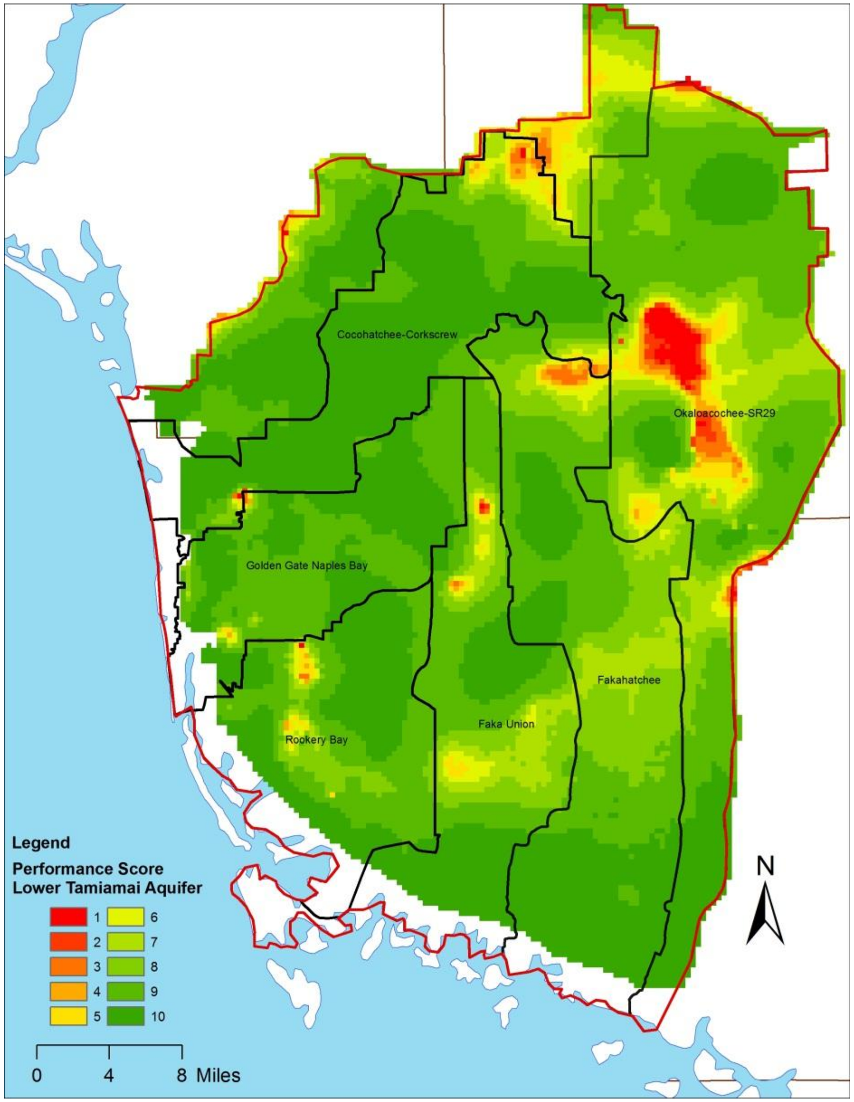


Figure 2-81. Lower Tamiami Aquifer, Average Dry Season Performance Score

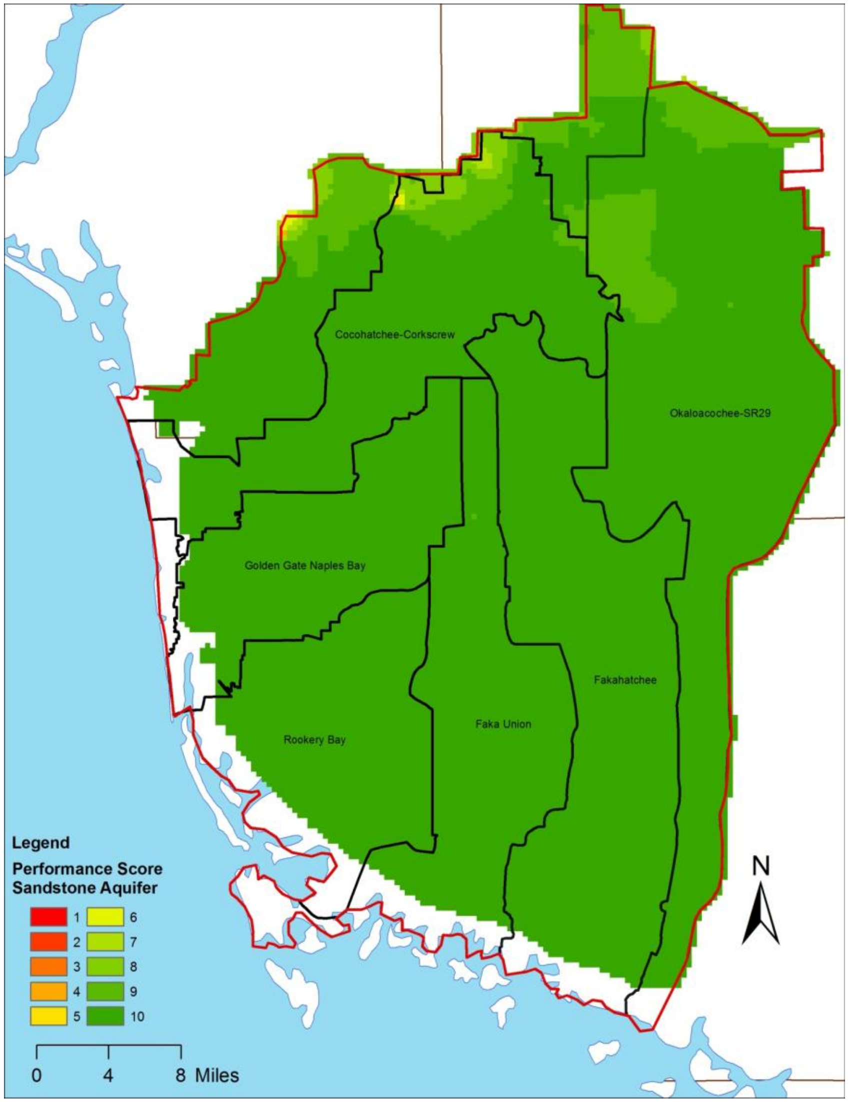


Figure 2-82. Sandstone Aquifer, Average Dry Season Performance Score

Table 2-72. Performance scores for each aquifer by WBID

Watershed	WBID	WBID Name	Water Table Aquifer	Lower Tamiami Aquifer	Sandstone Aquifer
Cocohatchee-Corkscrew	3278D	COCOHATCHEE (INLAND SEGMENT)	9.3	9.6	9.9
	3278C	COCOHATCHEE GOLF COURSE DISCHARGE	9.1	9.6	9.7
	3278F	CORKSCREW MARSH	9.4	9.4	9.6
	3278E	COW SLOUGH	9.5	9.4	9.5
	3259B	DRAINAGE TO CORKSCREW	9.5	9.6	9.5
	3278L	IMMOKALEE BASIN	9.1	9.2	9.5
	3259W	LAKE TRAFFORD	9.4	9.4	9.7
	3259Z	LITTLE HICKORY BAY	8.9	9.6	9.7
		Weighted Average	9.4	9.5	9.6
Golden Gate - Naples Bay	3278K	GORDON RIVER EXTENSION	9.3	9.5	9.8
	3278R	NAPLES BAY (COASTAL SEGMENT)	9.6	9.6	10.0
	3278S	NORTH GOLDEN GATE	8.9	9.3	9.8
		Weighted Average	9.0	9.3	9.8
Rookery Bay	3278U	ROOKERY BAY (COASTAL SEGMENT)	9.6	9.8	10.0
	3278V	ROOKERY BAY (INLAND EAST SEGMENT)	9.0	9.2	9.9
	3278Y	ROOKERY BAY (INLAND WEST SEGMENT)	7.2	9.1	9.9
		Weighted Average	8.7	9.3	9.9
Fakaunion	3278H	FAKA UNION (NORTH SEGMENT)	8.5	8.8	9.7
	3278I	FAKA UNION (SOUTH SEGMENT)	8.4	8.9	9.8
		Weighted Average	8.5	8.9	9.8
Fakahatchee	3259I	CAMP KEAIS	9.3	9.2	9.8
	3278G	FAKAHATCHEE STRAND	8.7	9.0	9.9
		Weighted Average	8.9	9.1	9.8
Okaloacochee-SR29	3261C	BARRON RIVER CANAL	8.4	8.8	10.0
	3278T	OKALOACOOCHEE SLOUGH	8.5	8.9	9.3
	3278W	SILVER STRAND	8.4	8.6	9.5
		Weighted Average	8.4	8.8	9.5

2.5 GROUND WATER QUALITY

2.5.1 Introduction and Objective

This Chapter addresses Element 1, Task 2.3: Groundwater Quality and Element 1, Task 2.4: Groundwater Pollutant Loading. The objective of this task is twofold, characterization of the groundwater quality conditions of the Cocohatchee-Corkscrew, Golden Gate–Naples Bay, Rookery Bay, Faka Union, Okaloacoochee–SR29, and Fakahatchee watersheds (**Figure 2-83**), and estimation of pollutant loads discharged from the Water Table and Tamiami aquifers into the surface water system in these watersheds.

This effort focused on characterizing the groundwater quality in the context of the water body impairment analysis, as discussed in the Chapter for Element 1, Task 1.2: In-Stream Water Quality.

The topics addressed in this document include the following: 1) data collection, 2) description of the applied analysis method, 3) groundwater concentrations of pollutants of concern, and 4) estimated groundwater pollutant loads. In addition, this document describes results of a preliminary analysis conducted to assess the potential impacts of septic tanks on the groundwater system.

2.5.2 Methods

Water quality in the County's drainage network is affected by groundwater quality. Data collection efforts, as well as the overall analysis, focused on the groundwater quality conditions in the Water Table and Lower Tamiami aquifer systems. The other aquifers are confined and have no known interaction with the surface water drainage system.

The groundwater quality data used for the analyses included data from Florida STORET, the South Florida Water Management District (SFWMD) DBYHDRO, the United States Geologic Survey (USGS), and Collier County. This resulted in an updated and comprehensive database of groundwater quality data. A total of 163 monitoring wells were identified within the model study area. Of those wells, 136 are located within the Water Table and Lower Tamiami aquifer systems.

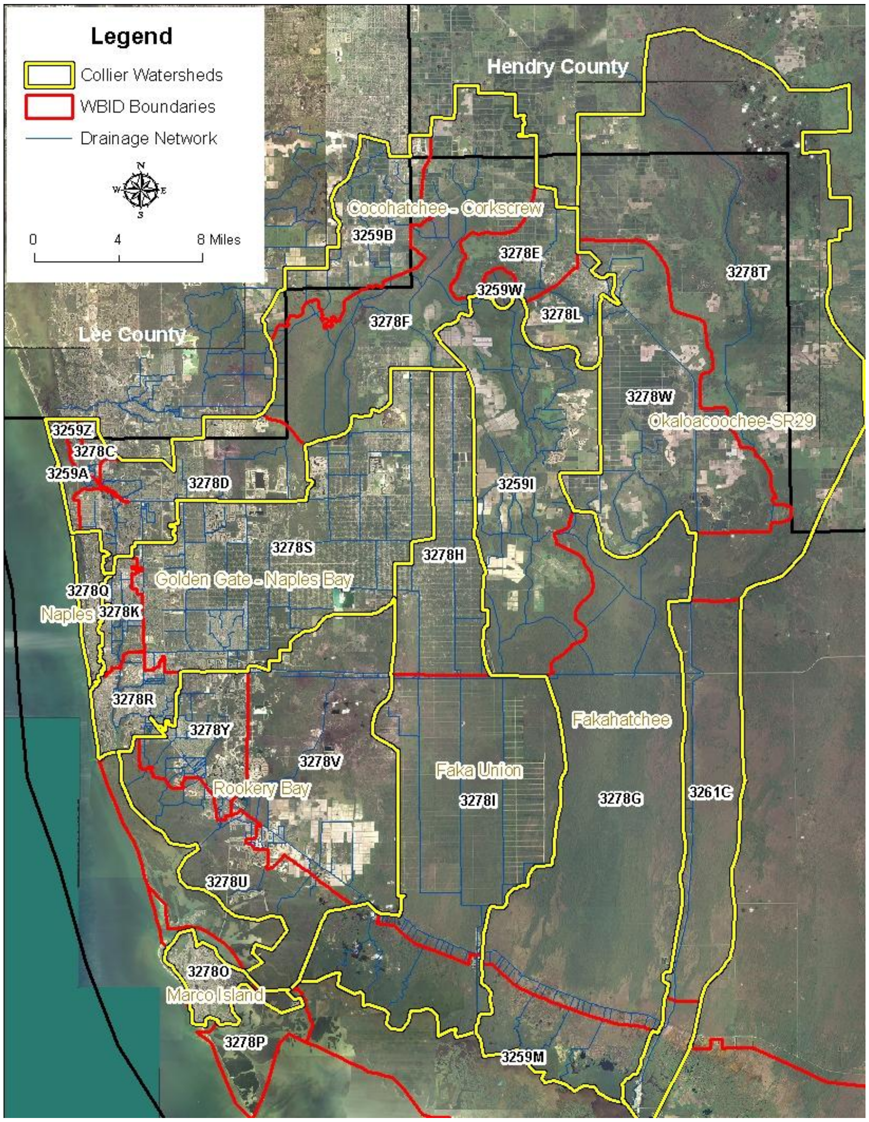


Figure 2-83. Collier County Watersheds

In terms of water quality parameters, the analysis focused on Dissolved Oxygen (DO), Total Nitrogen (TN), Total Phosphorus (TP), Copper (Cu), and Iron (Fe). It should be noted, that the DO data collected in the southern Golden Gate Estates area of the Faka Union watershed, as reported in DBHYDRO, was revised to correct for an apparent data entry error. Review of the data collection sheets indicated that the data was initially collected in units of percent saturation; however, the data was incorrectly reported in DBHYDRO as mg/L (Rhonda Watkins, personal communication). Therefore, the DO values incorrectly reported in DBHYDRO were converted to the correct units of mg/L using a methodology proposed by the University of Wisconsin (2006).

The analysis included calculation of groundwater quality concentrations of the parameters of interest throughout the study area, and subsequent estimates of pollutant loads discharged from the local aquifers into the surface water network that eventually would reach the receiving estuaries. Following is a brief description of the method applied for determining both concentrations and pollutant loads.

2.5.3 Results

Chemical Concentration Data Analysis and Kriging Interpolation. As indicated previously, data for 136 monitoring wells in the Water Table and Lower Tamiami aquifer systems were identified within the model study area. Because groundwater systems, as opposed to surface water, are regional in nature, the Kriging interpolation method was applied to create regional groundwater concentration maps for each constituent. For each well where data was available, median concentrations were calculated and groundwater concentration was predicted for each cell within the hydrologic/hydraulic model domain. This made the groundwater quality analysis consistent with the surface water modeling approach.

The results of the Kriging analysis for Dissolved Oxygen (DO), Total Nitrogen (TN), Total Phosphorus (TP), Copper, and Iron are shown in **Figures 2-84 through 2-88**. Each of the figures is colored such that orange, red, and brown represent areas where the predicted concentration of the constituent exceeds the corresponding surface water standard or screening levels described in the Chapter for Element 1, Task 1.2: In-Stream Water Quality. Each of these figures also includes the locations of wells included in the analysis for each specific parameter. Following is a description of the results by constituent.

2.5.3.1 Dissolved Oxygen Concentration

Dissolved oxygen concentration is not a parameter commonly monitored in groundwater. Therefore, the available data is limited. The majority of the data comes from wells located in the Gordon River and the Picayune Strand areas. No data are available for the Cocohatchee-Corkscrew, Fakahatchee, and Okaloacoochee–SR29 watersheds, or the eastern portion of the Golden Gate watershed. The data evaluation predicted that dissolved oxygen concentrations do not vary significantly across the study area and are less than 3.5 mg/L. Adamski (2001) states that DO concentrations in ground water generally decrease over time as the oxygen reacts with minerals and organic material; therefore, it is assumed that the results are appropriate to provide a preliminary assessment of groundwater quality. Additional groundwater monitoring for dissolved oxygen should be completed to verify this assumption.

The location of the wells and the results of the Kriging interpolation analysis are shown in **Figure 2-84.** Results indicate that predicted concentrations throughout the study area are less than the in-stream water quality standard of 5.0 mg/L. The highest concentrations are associated with two wells located adjacent to I-75 and the Golden Gate Main Canal. In 1994, a single measurement of DO was made in each well and the reported concentrations were between 2.5 and 3.0 mg/L. These data appear to be outdated and the wells should be re-sampled to verify the accuracy of the reported values.

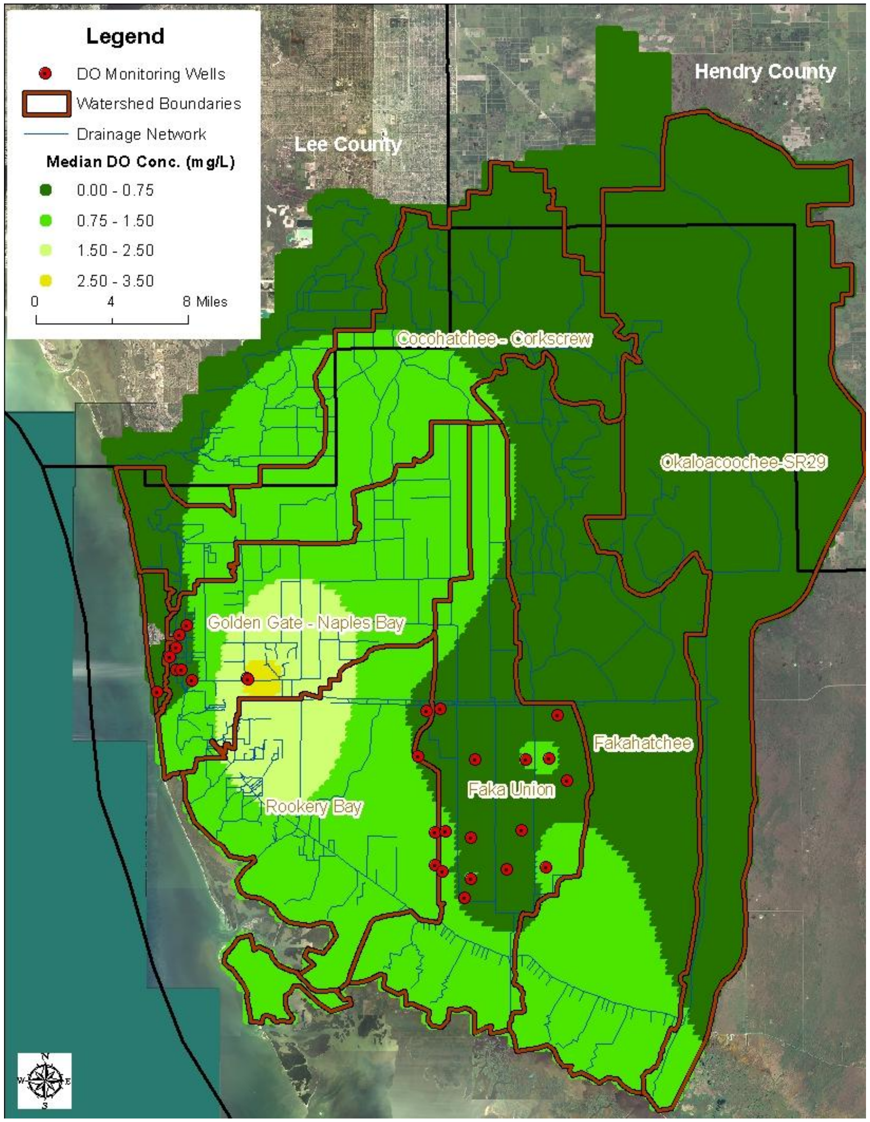


Figure 2-84. Estimated Dissolved Oxygen concentrations

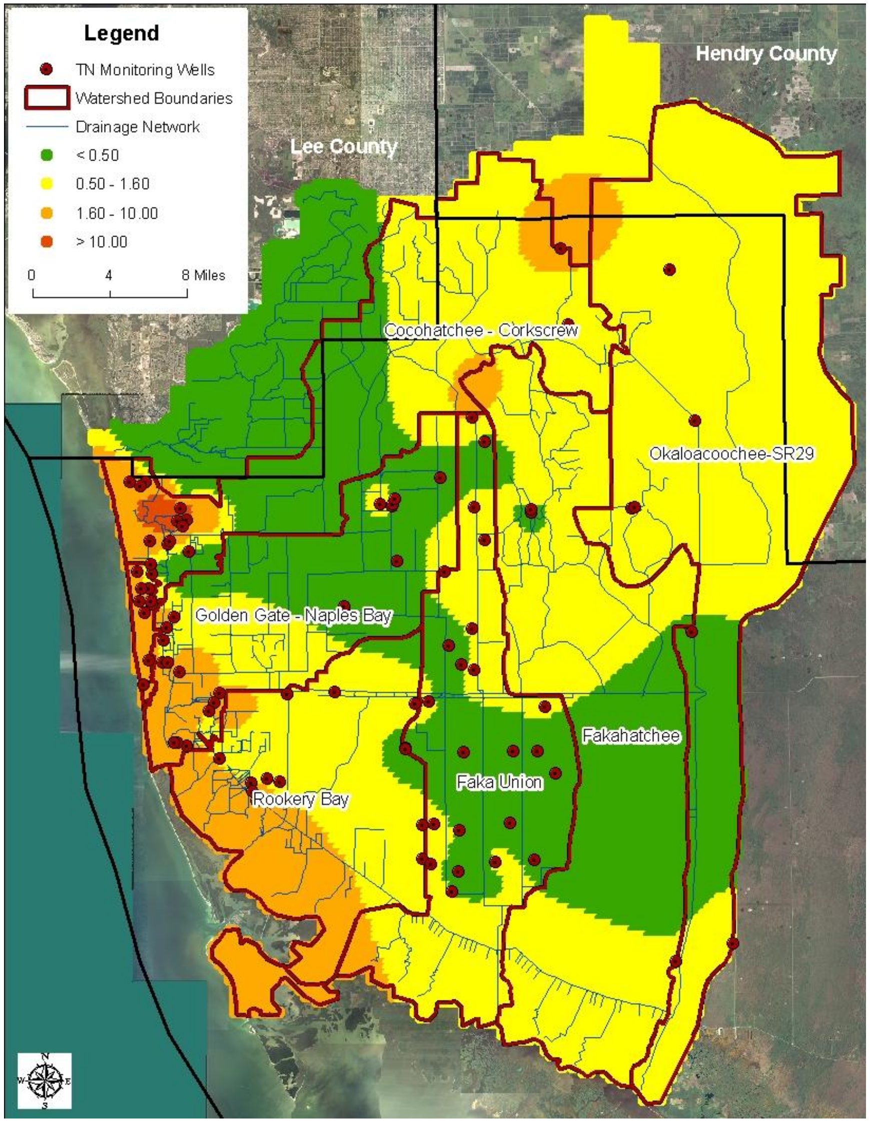


Figure 2-85. Estimated Total Nitrogen concentrations

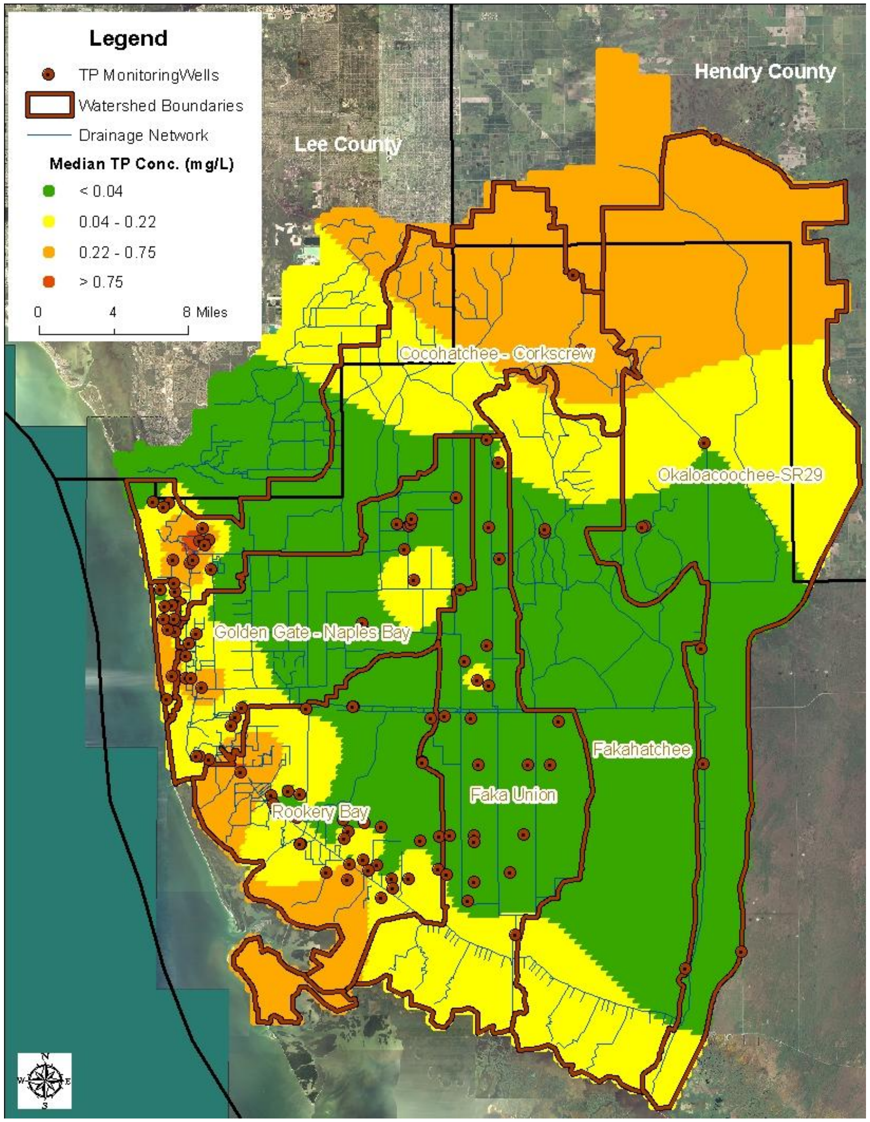


Figure 2-86. Estimated Total Phosphorus concentrations

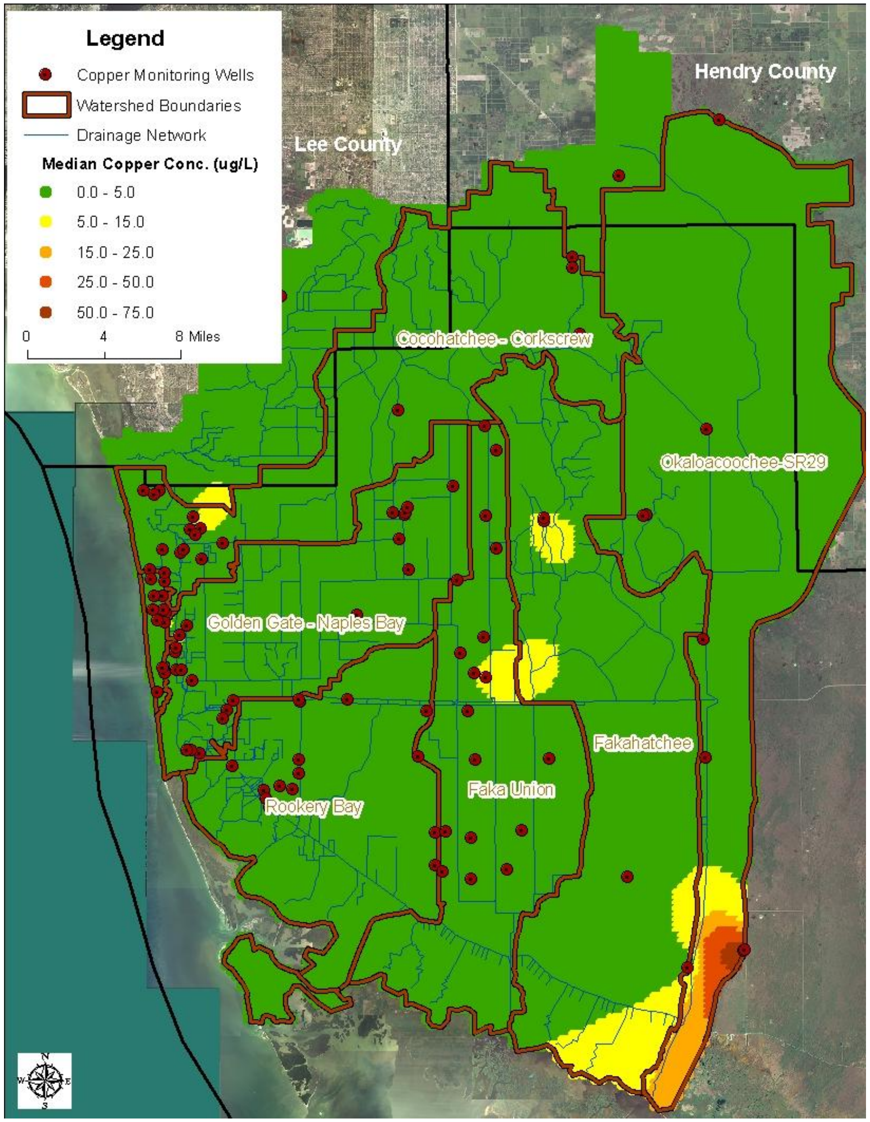


Figure 2-87. Estimated Copper concentrations

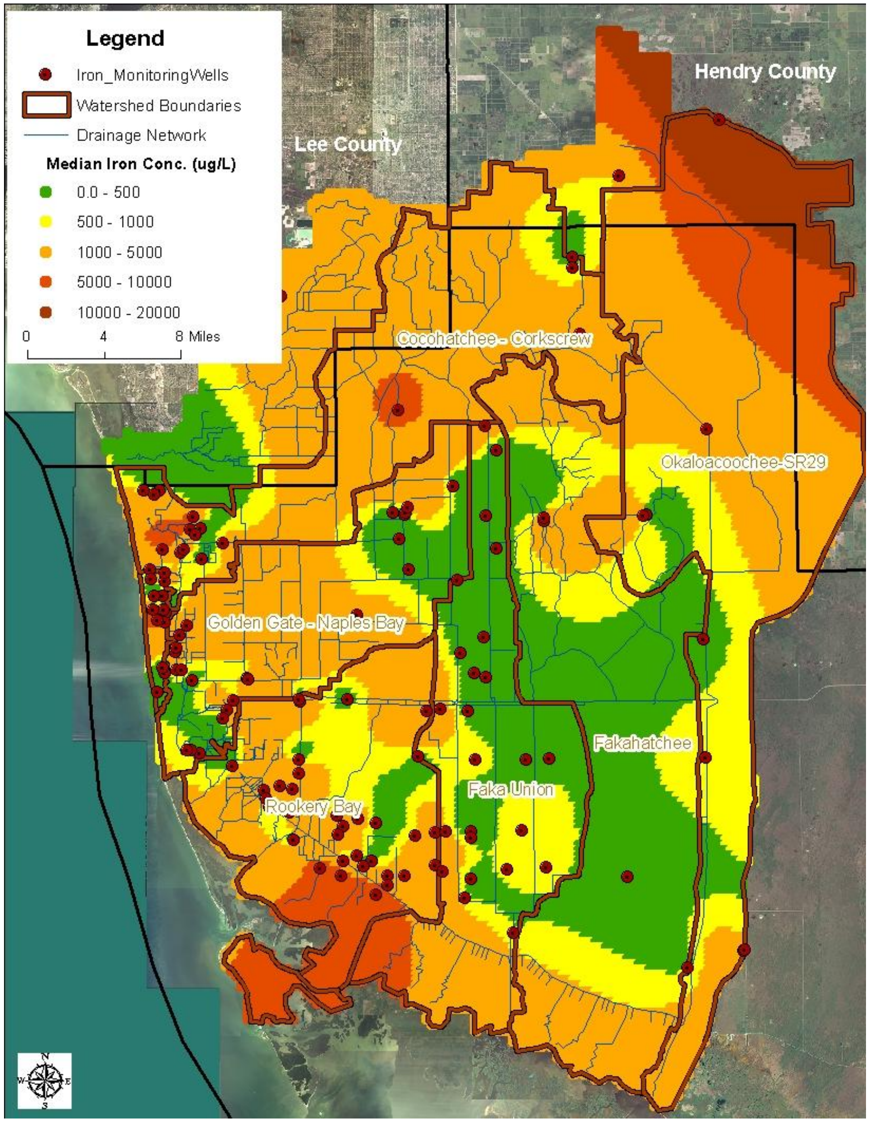


Figure 2-88. Estimated Iron concentrations

All other samples, measured in the Gordon River and Southern Golden Gate Estates area have reported concentrations between 0.5 mg/L and 1.5 mg/L. These data were collected between 2007 and 2009.

The water budget (Section 2.4) and groundwater quality analyses suggest that the low DO concentrations in the groundwater, coupled with the significant amount of base flow predicted in the main drainage canals contribute to the low measured DO concentrations in the canal network.

2.5.3.2 Total Nitrogen Concentration

Total nitrogen concentration data is available at 94 wells located throughout the study area. Well locations and Kriging interpolation results are shown in **Figure 2-85.**

A potential problem identified for this analysis was that a total of 47 wells exist along the coast from the Cocohatchee canal to Henderson Creek, but 38 of these wells are associated with the County's reuse monitoring program. It was considered possible that the reuse data may be biasing the results. To assess this condition, the measured TN concentrations at the reuse wells were compared to those at wells not associated with reuse. Results indicated that there is not a significant difference in measured concentrations for the majority of the wells, except for the area influenced by reuse monitoring wells CCN4 and CCN5, which are located near the coast north of the Cocohatchee Canal (**Figure 2-89**), and well CCS2 located near Rock Creek between Radio Road and Davis Blvd (**Figure 2-90**). These three wells are screened into the Water Table aquifer and concentrations amount to 21.52 mg/L, 31.96 mg/L, and 8.14 mg/L, respectively.

The fact that the areas of influence of wells CCN4, CCN5, and CCS2 are well defined by the Kriging interpolation and there is not a significant difference in concentrations between the other reuse wells and the non-reuse wells, it was considered that the analysis is providing adequate results. It is noted that the three wells showing high concentrations are located at golf courses irrigated by reuse water and it is unclear if groundwater concentrations are directly related to golf course land management practices or are influenced by other factors, including activities in the surrounding land uses.

Overall the analysis showed that areas with predicted TN groundwater concentrations that exceed the in-stream water quality screening levels are located primarily in the western portion of the County. FDEP's screening criteria for streams uses the 75th percentile of values in STORET. It amounts to 1.6 mg/L TN. FDEP has also developed a TMDL TN target of 0.74 mg/L for Hendry Creek in Lee County that is being used in this analysis as an alternative screening criterion.

Figure 2-89. Total Nitrogen (TN) Monitoring Wells in the Western Cocohatchee Watershed

Figure 2-90. Total Nitrogen Monitoring Wells in the Western Golden Gate-Naples Bay Watershed

In addition to the area influenced by wells CCN4, CCN5, results of the analysis show that groundwater concentrations in the Cocohatchee- Corkscrew watershed exceed the TN criteria in the area represented by WBIDs 3259A, 3259Z, 3278C, and the most western portion of WBID 3278D. These areas are located along the coast. Although none of these WBIDs have been found impaired for nutrients, they may be considered at risk due to the potential groundwater discharges. As shown in **Figure 2.85,** the rest of the watershed shows predicted groundwater TN concentrations less than the in stream screening level of 1.6 mg/L, except for a single well located near Immokalee, which has a mean reported concentration of 1.7 mg/L.

In the Golden Gate-Naples Bay Watershed, WBIDs 3278R (coastal segment of Naples Bay) and 3278K (Gordon River Extension) have predicted groundwater TN concentrations that exceed the screening criteria. As in the Cocohatchee-Corkscrew watershed, these WBIDs have not been found impaired for nutrients in the canal network. However, the baseflow contributions to the canal network (Section 2.4) are predicted to exceed 50 percent of the canal flow suggesting there is a risk of future nutrient impairment due to the potential groundwater discharges.

In Rookery Bay, Kriging interpolation analysis indicates that groundwater concentrations of TN along the coastal portion of the watershed (WBID 3278U) exceed the in-stream water quality screening level of 1.6 mg/L. This would appear to support the identified TMDL impairment for nutrients. However, it should be noted that monitoring wells with TN data in this area are all located in the Lely area. In the eastern portion of the watershed predicted concentrations result from the extrapolation of concentrations observed in two wells. The location of these wells, CCS16 and CCS17 are shown in **Figure 2-91**. Additional sampling is necessary in this area to verify the extrapolated results.

Groundwater TN concentration data in the Faka Union, Fakahatchee, and Okaloacoochee-SR29 watersheds includes data from the wells in Picayune Strand. TN concentrations at these locations were calculated by adding the reported Total Kjeldahl Nitrogen and Nitrate–Nitrite results. Nine of the other 14 sampling stations are located in the northern part of the Faka Union at single family residences. The average predicted concentration of TN is less than the in stream water quality screening level in the majority of the watershed area. The highest reported mean concentration in these watersheds was 2.96 mg/L in a sample taken from the well located in the headwaters of the Faka Union watershed. It is unclear what might be contributing to the elevated TN concentration in this well.

The Okaloacoochee-SR29 watershed was designated as a watershed of concern for TN; however, the lack of data makes it is difficult to accurately assess the potential contributions of TN from groundwater. Additional groundwater monitoring should be completed to evaluate the contribution of TN to the surface water drainage network.

Figure 2-91. Total Nitrogen Monitoring Wells in Rookery Bay Watershed

Table 2-73 shows the predicted TN median concentration in the groundwater by WBID. These were calculated by averaging the total load by grid cell. A total of six (6) WBIDs have predicted concentrations that equal or exceed the in stream screening level of 1.6 mg/L and all except five exceed the Hendry Creek TMDL screening value of 0.74 mg/L.

2.5.3.3 Total Phosphorus

TP concentration data is available at 117 wells located throughout the study area. Results of the Kriging interpolation analysis are shown in **Figure 2-86**. Similar to the TN analysis, the interpolated values were compared to the FDEP's screening criteria for streams (0.22 mg/L) and Hendry Creek TMDL (0.04 mg/L). However, as with TN, a potential identified problem is that 80 percent of the wells located along the coast from the Cocohatchee canal to Henderson Creek are associated with the County's reuse monitoring program. Since the reuse data may bias the results, the measured TP concentrations at the reuse wells were compared to those at wells not associated with reuse. Results indicated that there is not a significant difference in measured concentrations for the majority of the wells. Unfortunately, as opposed to the TN analysis, the reuse wells showing higher TP concentrations do not define specific problem areas, but are present at various locations along the coast.

Table 2-73. Groundwater Concentrations Predicted by Kriging Interpolation Analysis for Critical Parameters per WBID

WBID	Watershed	Name	Dissolved Oxygen	Total Nitrogen	Total Phosphorus	Copper	Iron
			mg/L			ug/L	
3259A	Cocohatchee - Corkscrew	COCOHATCHEE RIVER	0.56	6.22	0.10	0.99	2425
3259B		DRAINAGE TO CORKSCREW	0.72	0.59	0.22	1.90	3050
3259W		LAKE TRAFFORD	0.70	1.43	0.31	0.91	2136
3259Z		LITTLE HICKORY BAY	0.59	2.78	0.01	0.52	251
3278C		COCOHATCHEE GOLF COURSE DISCHARGE	0.63	5.05	0.11	0.74	1133
3278D		COCOHATCHEE (INLAND SEGMENT)	0.95	2.30	0.12	2.38	1514
3278E		COW SLOUGH	0.67	1.45	0.42	1.15	1667
3278F		CORKSCREW MARSH	0.76	0.96	0.23	1.40	2951
3278L		IMMOKALEE BASIN	0.66	1.14	0.29	0.95	1807
3278K	Golden Gate - Naples Bay	GORDON RIVER EXTENSION	0.61	1.60	0.15	1.84	1445
3278R		NAPLES BAY (COASTAL SEGMENT)	1.18	3.08	0.14	1.03	740
3278S		NORTH GOLDEN GATE	1.35	0.50	0.03	1.26	1552
3278U	Rookery Bay	ROOKERY BAY (COASTAL SEGMENT)	1.24	2.44	0.25	0.91	4180
3278V		ROOKERY BAY (INLAND EAST SEGMENT)	1.21	0.91	0.04	1.38	1527
3278Y		ROOKERY BAY (INLAND WEST SEGMENT)	1.82	1.49	0.24	0.62	1476
3259I	Fakahatchee	CAMP KEAIS	0.66	0.81	0.06	2.93	901
3278G		FAKAHATCHEE STRAND	0.68	0.48	0.02	2.56	474
3278H	Faka Union	FAKA UNION (NORTH SEGMENT)	0.73	0.61	0.02	1.96	348
3278I		FAKA UNION (SOUTH SEGMENT)	0.67	0.42	0.02	0.86	721
3261C	Okaloacoochee - SR29	BARRON RIVER CANAL	0.66	0.45	0.02	8.87	700
3278T		OKALOACOOCHEE SLOUGH	0.60	1.11	0.26	2.01	6222
3278W		SILVER STRAND	0.61	0.87	0.10	2.14	1332

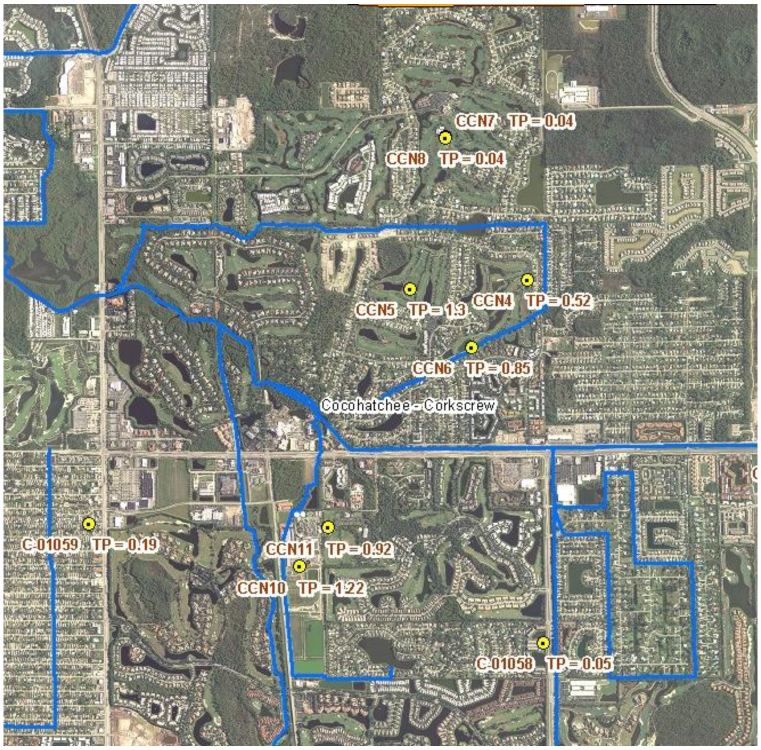


Figure 2-92. Total Phosphorus Median Concentrations
in the Western Cocohatchee-Corkscrew Watershed

One of the wells showing high TP concentrations is CCN5, which is located north of the Cocohatchee Canal (**Figure 2-92**). This well also shows high TN concentrations. A total of six samples were collected at this well from October 2006 through April 2009. The measured values range from a low of 0.171 mg/L in August 2007 to a maximum of 2.5 mg/L in April 2008. The measured values prior to September 2007 are all less than 0.22 mg/L, but are all higher than 2.20 mg/L after March 2008. This suggests that the increased concentrations may be associated with a change in land management practices, potentially including application of reuse water.

Other examples of wells with TP concentrations exceeding the screening criteria are CCN10, MW-9, and CCS20. Well CCN10 is located adjacent to a wastewater treatment facility, well MW-9 is located on a golf course adjacent to the Golden Gate Main Canal south of Golden Gate Parkway and west of Airport Pulling Road, and well CCS20 is located in the Lely Golf Estates near the Tamiami Trail.

As indicated above, the area of influence of some of the reuse wells showing high TP concentrations is not very well defined. However, there is not a clear criterion to select only a certain number of wells for the analysis without biasing the results. Therefore, it was decided that the best approach is to include all wells in the Kriging interpolation and recognize that the results probably err on the side of higher-than-actual concentrations.

Overall, results indicate that the areas where the predicted concentrations exceed the in stream water quality screening levels are located along the coast, as well on the northeastern portion of the study area. It is noted that the predicted concentration in northeast Collier County are based on sample results from only three wells. One of these wells is located in the City of Immokalee, one is located in an agricultural area near Immokalee, and the third is located near Keri Rd close to the study area boundary. There is insufficient data to determine whether land use activities contribute to the measured concentrations. However, no stream water quality impairments for TP have been identified in that area.

In the Cocohatchee-Corkscrew and Golden Gate-Naples Bay Watersheds the high TP concentrations along the coast seem to be the result of interpolation of the high concentrations at some of the reuse wells. In the Rookery Bay watershed the highest reported median TP concentrations are 0.71 mg/L and 0.76 mg/L in wells CCS20 and 021-67, respectively. These values far exceed the screening criteria. Well CCS20 is located in the Lely Golf Estates near the Tamiami Trail. TP concentrations exceed 1.0 mg/L in three (3) of the seven (7) collected samples. The data from well 021-67, which is located south of the Tamiami Trail in the agricultural lands east of Collier Blvd, was collected in 1997-1998. At this location, TP concentrations exceed 0.65 mg/L in three (3) of four (4) samples.

Finally, in the Faka Union, Fakahatchee and Okaloacoochee-SR 29 watersheds the highest reported mean concentration of 0.44 mg/L for TP was measured in well HE-852 located in Hendry County at the northern boundary of the Okaloacoochee-SR 29 watershed. The data from well HE-852 was collected in 1989 and 1990. All other monitoring wells in these watersheds have a median concentration of 0.07 mg/L or less.

A summary of the results indicates that the relatively high groundwater TP concentrations are not currently determining surface water quality conditions in terms of nutrients because only one WBID (3278U–Rookery Bay Coastal Segment) has been identified as impaired for nutrients. However, the relatively high groundwater TP concentrations in the groundwater at some of the reuse wells may indicate a risk of groundwater pollution loads. As shown in **Table 2-73**, the median TP concentration in five (5) of the WBIDs exceeds the stream screening criteria of 0.22 mg/L, whereas the Hendry Creek criteria of 0.04 mg/L is exceeded in 12 out of the 15 WBIDs in the Cocohatchee-Corkscrew, Golden Gate–Naples Bay, and Rookery Bay watersheds. Most of the WBIDs in the undeveloped areas of the County meet the 0.04 mg/L screening criteria.

2.5.3.4 Copper

The predicted results for copper (**Figure 2-87**) indicate that only one area is of concern for copper in groundwater. Well C-00495, which monitors the Lower Tamiami aquifer system, is located near the SR29 canal and has a median copper concentration in excess of 90 µg/L and a maximum concentration of 213 µg/L. As a comparison, the in-stream standard for copper in WBID 3261C is calculated to be 22.69 µg/L based on the average hardness value from the groundwater samples. Collier County is investigating potential sources of metals in the area around this well (Rhonda

Watkins, personal communication). There is no known activity in the area that would contribute to elevated copper concentrations. It is noted that no exceedance of water quality standards for copper has been reported in the SR29 canal.

2.5.3.5 Iron

The results of the Kriging interpolation analysis for iron concentrations in groundwater are shown in **Figure 2-88**. Results indicate that the groundwater concentration of iron in most of the study area exceed the in-stream water quality standard of 1,000 ug/L. As shown in **Table 2-73**, the calculated median concentration exceeds the in stream water quality standard in 68 percent (15 of 22) of the WBIDs. These results suggest that identified surface water iron impairments may be attributed to groundwater inflows.

In the Cocohatchee-Corkscrew watershed, all but one of the WBIDs exceed the screening criteria. Well C-492, located adjacent to the Corkscrew Swamp in the central portion of the watershed reported the highest mean concentration of iron. The reported median concentration is 8,100 µg/L.

In the Golden Gate-Naples Bay Watershed, reported mean concentrations of iron in the Water Table and Lower Tamiami aquifers range from 50 µg/L, in the north Golden Gate Estates to 5,060 µg/L near the Gordon River. Concentrations in two of the three WBIDs exceed the State water quality standard.

In the Rookery Bay watershed, the Kriging analysis indicated that groundwater iron concentrations exceed 5,000 µg/L in some parts of the watershed and median predicted concentrations exceed 1,400 µg/L. These concentrations are higher than those in the Cocohatchee–Corkscrew and Golden Gate–Naples Bay. However, there are limited groundwater contributions to overland flow in the Rookery Bay watershed, which may explain why there are no identified impairments for iron in the stream network.

2.6 GROUNDWATER POLLUTANT LOADING

2.6.1 Methods

Pollutant loads associated with groundwater discharges from the Water Table and Lower Tamiami aquifers to the surface water system were calculated based on a) water flows obtained for each cell from the H&H model simulation domain, and b) pollutant concentrations determined from the Kriging analysis described herein. Pollutant loads were calculated for TN, TP and copper. The analysis was limited to the parameters of concern that are also part of the NPDES list of pollutants included in the calculation of surface water loads. The pollutant load was assumed to be zero (0) in WBIDs where surface runoff in the drainage network is lost to the surface aquifers. Pollutant loads by cell were also aggregated to determine the load by WBID. Iron is not one of the NPDES parameters and no comparisons are possible with surface water loadings because event mean concentration data is not available.

2.6.2 Results

Table 2-74 shows the total estimated annual groundwater pollutant load by WBID and watershed. For comparison purposes, the table also shows the calculated surface water pollutant loads, as described in the corresponding chapter. The largest total predicted TN groundwater load in lbs / year is found in WBID 3278S (Northern Golden Gate). Naples Bay is listed as impaired for DO with the likely cause identified as nutrients. It is likely that baseflow in the canal network, which results from groundwater discharging into the surface water system, contributes to the low DO concentrations in the estuary; however nutrients entering the groundwater system and discharging to the canal network may also contribute to the impairment.

Results also show that in terms of nutrients, 74 and 88 percent of the total TN and TP load in the study area comes from surface water sources, respectively. However, Rookery Bay is the only watershed where the predicted groundwater load of TN is basically the same as the predicted surface water load and groundwater represents about 40 percent of the TP load. In other watersheds, the TN load from groundwater is less than 30 percent. As Rookery Bay is the only estuary found impaired for nutrients, results suggest that the control of nutrients entering the groundwater would be important to address the impairment condition.

Copper pollution seems to be originating primarily in the surface water system, which account for 76 percent of the total load.

It should be noted that as total pollution loads are determined by the extent of the watershed and the anticipated baseflow entering the surface water system, total loads do not provide a good representation of actual WBID conditions. A better indicator is the load per unit area. **Table 2-75** shows the pollutant load by WBID per unit area (acres). It also shows the mean unit area pollutant load by watershed. Rookery Bay shows by far the largest nutrient load / acre / year. Approximately 60 percent of the TN load per acre appears to be of groundwater origin.

Assessment of Pollution Loads from Septic Tanks. Septic tanks are common in parts of Collier County that are not served by sewer. They are also potential sources of nutrients discharges into the receiving water bodies by way of percolation into the Water Table aquifer. The objective of this analysis was to evaluate the potential effect of septic tanks on the groundwater concentrations of TN and TP. This was done by first estimating the number of septic tanks in each cell within the model domain and subsequently conducting a correlation analysis between septic tank density and constituent concentration in the groundwater.

The actual density of septic systems is unknown in most parts of the county. The Florida Department of Health (FDoH) is in the process of developing a comprehensive inventory of septic tanks in Florida; however, that inventory is not complete. In the interim, the FDoH has developed a GIS based shapefile that predicts the probability of a septic tank existing in any area within the State. This map was modified as part of this project to estimate the existing density of septic tanks within each grid cell that makes up the existing conditions H&H model (ECM). The process consisted of the following steps.

- The FDoH data was modified to represent only the probability of existing septic systems in Collier and Lee counties. If a polygon was located within an area currently served by sanitary sewer, the probability of a septic tank was set to zero (0). It is possible that some septic systems exist in sewered areas, but this decision eliminates the potential influence of outside sources when comparing septic system density and groundwater concentrations.
- The probability value was then converted to predicted number of septic tanks per parcel and summed within the area of a grid cell. **Figure 2-93** shows the predicted location and density of septic tanks per grid cell in Collier County.

Figures 2-94 and 2-95 are scatter diagrams of predicted septic tank density versus predicted concentrations of TN and TP. Concentrations were as determined from the Kriging interpolation analysis described previously. For illustration purposes, the line of best fit to the data was also included, along with the corresponding coefficient of determination.

Results of this analysis indicate that there is little correlation between TN and TP and septic tank density. Therefore, it can be concluded that septic tanks appear not to be a major countywide problem. Of course localized problems may exist.

Table 2-74. Predicted Pollution Loads from the Groundwater and Surface Water Systems

WBID	Watershed	Name	Groundwater Pollutant Load			Surface Water Pollutant Load		
			TN	TP	Cu	TN	TP	Cu
			lbs/yr	lbs/yr	lbs/yr	lbs/yr	lbs/yr	lbs/yr
3259A	Cocohatchee - Corkscrew	COCOHATCHEE RIVER	6,489	109	1	4,614	661	38
3259B		DRAINAGE TO CORKSCREW	3,152	1,202	10	83,815	16,768	110
3259W		LAKE TRAFFORD	0	0	0	0	0	0
3259Z		LITTLE HICKORY BAY	0	0	0	1,605	268	11
3278C		COCOHATCHEE GOLF COURSE DISCHARGE	2,623	58	0	4,807	614	39
3278D		COCOHATCHEE (INLAND SEGMENT)	82,284	4,291	85	77,840	13,398	253
3278E		COW SLOUGH	716	208	1	31,052	6,049	61
3278F		CORKSCREW MARSH	8,572	2,040	13	99,729	19,880	141
3278L		IMMOKALEE BASIN	2,551	656	2	31,806	6,148	82
Subtotal			**106,387**	**8,564**	**112**	**335,267**	**63,786**	**734**
3278K	Golden Gate - Naples Bay	GORDON RIVER EXTENSION	2,574	243	3	21,885	3,482	132
3278R		NAPLES BAY (COASTAL SEGMENT)	13,397	609	4	52,523	8,001	526
3278S		NORTH GOLDEN GATE	135,931	7,396	339	166,652	28,165	838
Subtotal			**151,901**	**8,247**	**346**	**241,060**	**39,648**	**1,497**
3278U	Rookery Bay	ROOKERY BAY (COASTAL SEGMENT)	46,964	4,760	17	23,551	4,315	77
3278V		ROOKERY BAY (INLAND EAST SEGMENT)	40,289	1,662	61	94,760	18,550	160
3278Y		ROOKERY BAY (INLAND WEST SEGMENT)	60,045	9,798	25	28,130	4,151	145
Subtotal			**147,298**	**16,220**	**104**	**146,442**	**27,015**	**382**
3259I	Fakahatchee	CAMP KEAIS	0	0	0	231,302	46,134	300
3278G		FAKAHATCHEE STRAND	0	0	0	5,532	1,113	7
3278H	Faka Union	FAKA UNION (NORTH SEGMENT)	48,412	1,705	155	36,092	6,312	2
3278I		FAKA UNION (SOUTH SEGMENT)	88,616	4,120	179	129	25	4
3261C	Okaloacoochee-SR29	BARRON RIVER CANAL	6,234	264	122	311	34	2
3278T		OKALOACOOCHEE SLOUGH	1,587	380	3	291,256	58,543	9
3278W		SILVER STRAND	33,443	3,690	82	379,120	76,110	541
Subtotal			**178,292**	**10,160**	**541**	**943,743**	**188,271**	**866**
Total	**All Watersheds**		**583,878**	**43,191**	**1,103**	**1,666,512**	**318,720**	**3,479**

Table 2-75. Predicted Pollution Loads by Unit Area from the Groundwater and Surface Water Systems

WBID	**Watershed**	**Name**	**Groundwater Pollutant Load**			**Surface Water Pollutant Load**		
			TN	TP	Cu	TN	TP	Cu
			lbs/ac/yr	lbs/ac/yr	lbs/ac/yr	lbs/ac/yr	lbs/ac/yr	lbs/ac/yr
3259A	Cocohatchee - Corkscrew	COCOHATCHEE RIVER	2.166	0.036	0.000	1.540	0.221	0.013
3259B		DRAINAGE TO CORKSCREW	0.147	0.056	0.000	3.910	0.782	0.005
3259W		LAKE TRAFFORD	0.000	0.000	0.000	0.000	0.000	0.000
3259Z		LITTLE HICKORY BAY	0.000	0.000	0.000	2.390	0.400	0.016
3278C		COCOHATCHEE GOLF COURSE DISCHARGE	1.238	0.028	0.000	2.270	0.290	0.018
3278D		COCOHATCHEE (INLAND SEGMENT)	3.192	0.166	0.003	3.020	0.520	0.010
3278E		COW SLOUGH	0.061	0.018	0.000	2.660	0.518	0.005
3278F		CORKSCREW MARSH	0.162	0.038	0.000	1.880	0.375	0.003
3278L		IMMOKALEE BASIN	0.287	0.074	0.000	3.580	0.692	0.009
Average			**0.831**	**0.067**	**0.001**	**2.618**	**0.498**	**0.006**
3278K	Golden Gate - Naples Bay	GORDON RIVER EXTENSION	0.484	0.046	0.001	4.114	0.655	0.025
3278R		NAPLES BAY (COASTAL SEGMENT)	1.457	0.066	0.000	5.713	0.870	0.057
3278S		NORTH GOLDEN GATE	1.853	0.101	0.005	2.272	0.384	0.011
Average			**1.729**	**0.094**	**0.004**	**2.744**	**0.451**	**0.017**
3278U	Rookery Bay	ROOKERY BAY (COASTAL SEGMENT)	1.699	0.172	0.001	0.852	0.156	0.003
3278V		ROOKERY BAY (INLAND EAST SEGMENT)	0.743	0.031	0.001	1.747	0.342	0.003
3278Y		ROOKERY BAY (INLAND WEST SEGMENT)	3.954	0.645	0.002	1.852	0.273	0.010
Average			**1.518**	**0.167**	**0.001**	**1.509**	**0.278**	**0.004**
3259I	Fakahatchee	CAMP KEAIS	0.000	0.000	0.000	4.154	0.829	0.005
3278G		FAKAHATCHEE STRAND	0.000	0.000	0.000	0.058	0.012	0.000
3278H	Faka Union	FAKA UNION (NORTH SEGMENT)	1.755	0.062	0.006	1.309	0.229	0.000
3278I		FAKA UNION (SOUTH SEGMENT)	1.505	0.070	0.003	0.002	0.000	0.000
3261C	Okaloacoochee-SR29	BARRON RIVER CANAL	0.195	0.008	0.004	0.010	0.001	0.000
3278T		OKALOACOOCHEE SLOUGH	0.013	0.003	0.000	2.372	0.477	0.000
3278W		SILVER STRAND	0.618	0.068	0.002	7.004	1.406	0.010
Average			**0.400**	**0.023**	**0.001**	**2.118**	**0.423**	**0.002**
Average	**All Watersheds**		**0.770**	**0.057**	**0.002**	**2.197**	**0.420**	**0.005**

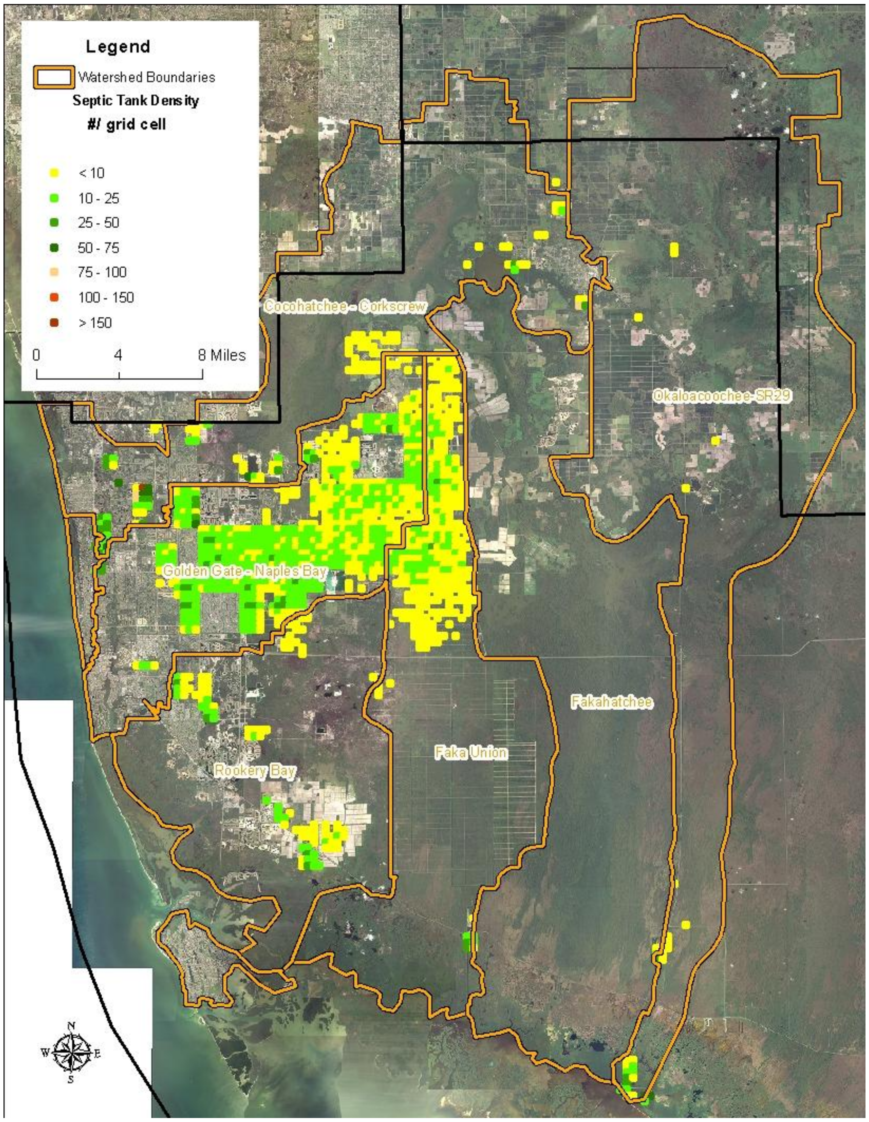


Figure 2-93. Estimated Septic Tank Density in Collier County

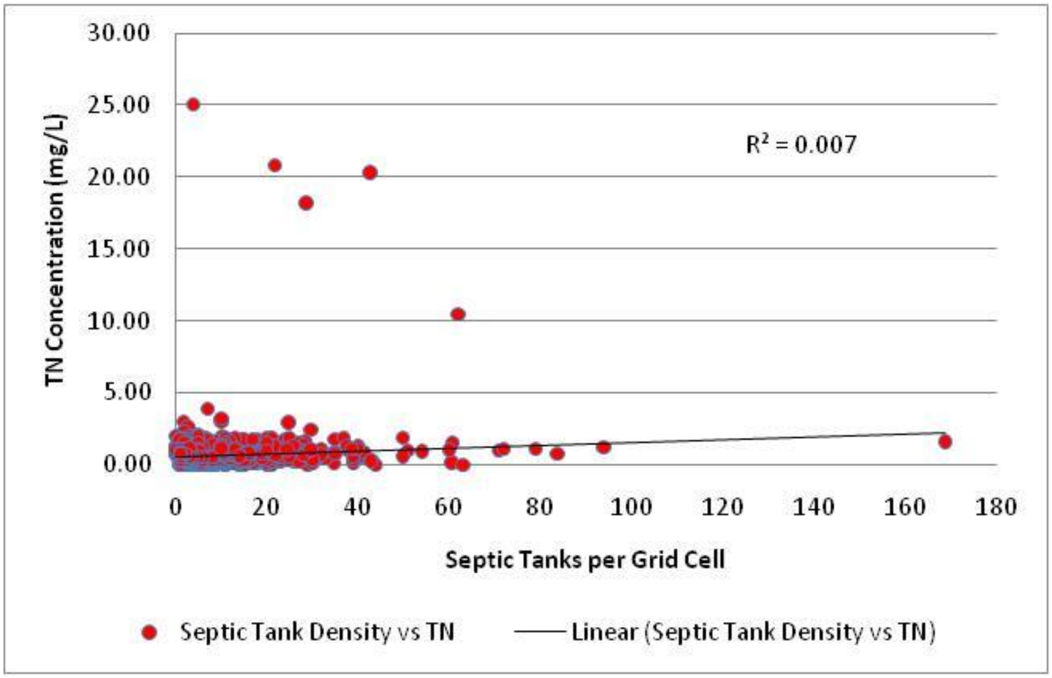


Figure 2-94. Scatter Diagram of Septic Tank Density vs. TN Concentration

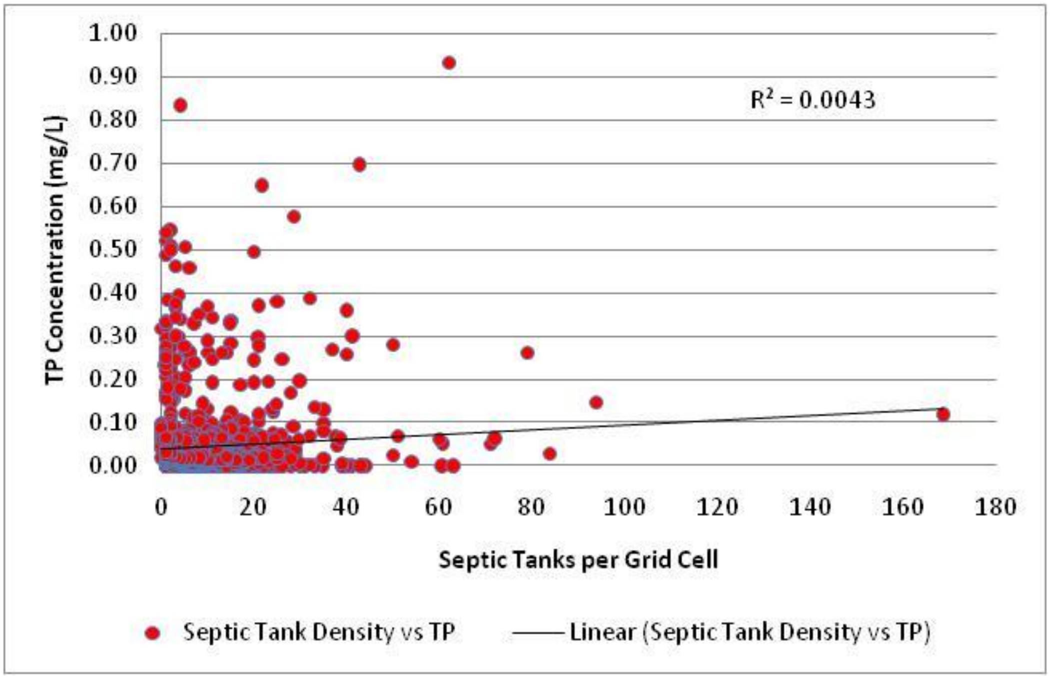


Figure 2-95. Scatter Diagram of Septic Tank Density vs. TP Concentration

2.6.3 Conclusions

The following conclusions can be drawn from the analysis:

- Dissolved oxygen concentration data is not commonly reported. Data for the Water Table and Tamiami aquifers was available only in the Gordon River and Picayune Strand. The collected data and the Kriging interpolation analysis indicate that dissolved oxygen concentrations in groundwater are less than 1.5 mg/L throughout most of Collier County. Groundwater inflows likely contribute to identified DO impairments in the canal network.
- A potential problem identified for this analysis was that many of the wells whose data was used to predict TN and TP loads are associated with the County's reuse monitoring program. It was considered possible that the reuse data may be biasing the results. To assess this condition, measured concentrations at the reuse wells were compared to those at wells not associated with reuse. Results indicated that there is not a significant difference in measured concentrations for the majority of the wells
- Results indicate that TN concentrations in groundwater exceed the corresponding screening criteria for surface water in a significant portion of the study area. TP concentrations exceed the criteria along the coast and in the northern portion of the area. The limited data available suggests that land practices in the immediate vicinity of the wells may contribute to the elevated groundwater concentrations. Additional sampling data that provides a better overview of existing conditions is necessary.
- Copper concentrations in groundwater are generally very low across Collier County suggesting that copper impairments in the canal network can be attributed to surface runoff. One well, located at the edge of the Big Cypress Preserve, shows elevated copper concentrations. Additional on-site assessments should be completed to identify the source of copper at this location.
- Iron concentrations in groundwater are elevated relative to the Class 3 surface water standard in many WBIDs within the study area. The areas of elevated iron concentrations in groundwater correspond with the locations of identified impairment in the canal network. Therefore, it is possible that groundwater inflows are a significant source of iron in the surface water system.
- Pollution load calculations indicate that groundwater is a potential contributor to the nutrient impairment in the Rookery Bay watershed. It is possible that human activities contribute to predicted nutrient concentrations in groundwater. Additional studies should be conducted to identify sources and verify groundwater contributions to the canal network.
- There is little correlation between TN and TP and septic tank density. While septic tanks may not be a countywide problem, localized problems may exist and should be resolved.

2.7 NATURAL SYSTEMS: REFERENCE PERIOD COMPARISON

The existing areal extent and functional quality of native wetland and upland communities in the three primary watersheds are presented in this section.

2.7.1 Introduction and Objective

This chapter addresses Element 1, Task 3.1. Under this task, pre-development and current conditions were compared and losses and conversions of native plant communities in Collier County watersheds over the past 50–60 years were estimated via a change analysis of land use cover data. The 1942 Collier County soils map provided additional data to characterize pre-development characteristics in the watersheds. The vegetation and soils data are reported and analyzed for the first three watersheds individually and the other three watersheds collectively.

Results of an analysis of changes in areal extent of natural communities and the causes of those changes are reported here and used to evaluate current watershed functions for Element 1 Task 3.2 (Functional Assessment). The pre-development data serve as the reference period, or baseline index against which to evaluate current vegetation data in determining resource protective function. This section of the chapter also presents a summary of soils characteristics from the 1942 soils survey data layer published in 2006, discovered in the course of preparing this section. These soils data do not appear to have been evaluated as part of the SWFFS and Natural Systems Model (NSM), but may be useful in calibrating other historical data collected through those and other efforts. The 1942 soils data is not directly comparable to current soils data due to changes in soils taxonomy, so was not evaluated to determine changes in soils or vegetation over time as part of this memorandum or the memorandum regarding functional assessment.

2.7.2 Methods

Vegetation changes were quantified as the change in number of acres in each vegetation community for each watershed, and further examined to determine losses due to conversion to specific types of development (i.e. change analysis). Changes were quantified from a simple comparison of pre-development and current vegetation data. Land use conversions were quantified using a GIS digital overlay process that generates a matrix of "from/to" changes in land use and cover (e.g. cypress swamp to urban).

Pre-development and current vegetation classifications vary among classification systems. Therefore, a "crosswalk" of natural communities was developed to compare pre- development and current conditions. The crosswalk was derived from the three sources:

- Pre-Development Vegetation Map (PDVM; Duever, 2004), which groups vegetation into 15 broad communities.

- Florida Land Use, Cover, and Forms Classification System (FLUCCS) maps in Collier County include over 300 land use and cover codes.
- Land use designations used in the MIKE SHE analysis for the Watershed Model Update include up to 23 land use/cover codes.

MIKE SHE-FLUCCS vegetation groupings were conducted as part of this project using a SWFFS-FLUCCS crosswalk table (http://crocdoc.ifas.ufl.edu/crosswalk/) and supplemented where necessary based on professional judgment of Atkins scientific staff. Eight additional MIKE SHE land use classes were further aggregated into four developed land uses (agriculture, golf course, pasture/bare ground, urban) since differences in these four developed land uses are of no consequence to the resource protective assessment.

Consequently, the 2004/2007 FLUCCS data were grouped into the 15 corresponding resource protective community descriptions used in the PDVM or one of the 8 additional agricultural and development land use/land cover types commonly used in the MIKE SHE model. Using the crosswalk, 19 “change analysis vegetation classes” or “crosswalk vegetation/ land cover classes” were designated and are listed in **Table 2-76**. These vegetation/ land cover classes were subsequently applied to pre-development and current mapping and data used to quantify the changes in vegetation from pre-development to current (2007) conditions and are referred to as “vegetation/land cover” changes in comparisons of pre-development vegetation with current land use/land cover in maps and tables.

Soils data from the 1942 survey (36 soil names) do not correspond to soil taxonomic classification standards developed circa 1950 (finalized in 1975 as the U.S. Department of Agriculture (USDA) and Soil Conservation Service (SCS) Soil Taxonomy). Neither is the extent of soils in the 1942 data directly comparable to the pre-development vegetation map, due in part to the difficulty of

Table 2-76. Land Use/Model Code/FLUCCS Crosswalk Vegetation Classes

PDVM and/or MIKE SHE Land Use Type	FLUCCS Code	Crosswalk Vegetation/ Land Cover
Citrus	221, 222, 223	Agriculture
Pasture	190, 191, 192, 193, 194, 211, 212, 213, 251, 260, 261, 8115, 832	Pasture/Bare Ground
Sugar Cane & Sod	2156, 242	Agriculture
Truck (Row) Crops	214, 215, 216	Agriculture
Golf Course	180, 182	Golf Course
Bare Ground	161, 162, 163, 164, 181, 231, 740, 743, 744, 835	Pasture/Bare Ground
Mesic Flatwood	310, 320, 321, 323, 330, 410, 411, 442	Mesic Flatwood
Mesic Hammock	420, 422, 427, 4271, 434, 437	Mesic Hammock
Xeric Flatwood	4120, 4130	Xeric Flatwood
Xeric Hammock	322	Xeric Hammock
Hydric Flatwood	624, 625, 626	Hydric Flatwood
Hydric Hammock	424, 428, 6111, 618	Hydric Hammock
Wet Prairie	643	Wet Prairie
Freshwater Marsh	6172, 641, 6411, 6412, 644,	Freshwater Marsh
Cypress	620, 621 (except 6211), 6215, 6216	Cypress
Dwarf/Scrub Cypress	6211	Dwarf/Scrub Cypress
Swamp Forest	615, 617, 6191, 630	Swamp Forest
Mangrove	612	Mangrove
Open Water	166, 184, 254, 511, 512, 520, 525, 530, 541, 543, 560, 572, 651, 836	Open Water
Tidal Marsh	642	Tidal Marsh
Beach	710,720	Beach
Urban Low Density	110, 111, 112, 113, 118, 119, 148, 185, 240, 241, 243, 250	Urban
Urban Medium Density	120, 121, 122, 123, 129, 176, 834	Urban
Urban High Density	130, 131, 132, 133, 134, 135, 139, 140, 1411, 1423, 146, 149, 154, 155, 156, 170, 171, 183, 187, 252, 810, 8110, 8113, 814, 820, 831, 833	Urban

associating soils with particular pre-development vegetation communities, and in part due to soils classification by runoff characteristics (i.e. the speed at which water flows across the soil surface as opposed to seeping into the soil) in the earlier data set rather than seasonal water table (the primary indicator of hydric soils). The soils data nonetheless provide a seamless GIS data layer of 1942 soils in Collier County and may be useful in the calibration of other historical data sets. Soils runoff characteristics (1942) are presented for each watershed and summarized in a narrative.

2.7.3 Data Sources

Several sources of data were for defining, analyzing and comparing reference conditions and current conditions. The primary source of vegetation reference conditions was the PDVM GIS layer developed by Mike Duever and the Natural Systems Group (NSG) at SFWMD. Existing vegetation characteristics were determined from a 2004 GIS data layer developed by SFWMD, and updated by Atkins for 2007. 1940s soils characteristics were identified from a data layer developed by the United States Geological Survey. These three data sources are described below.

Duever, M. 2004. Southwest Florida Pre-Development Vegetation Map. South Florida Water Management District.

The Pre-Development Vegetation Map (PDVM) is an ArcView data coverage representing pre-development vegetation communities in the five-county region (including Collier County) addressed by the SWFFS. The PDVM was developed over a period of two years using several GIS data sources, including 1940s soils (lands outside of Everglades National Park and Big Cypress National Preserve) and 1990s vegetation maps (lands within ENP and BCNP), as well as best professional judgment of pre-development vegetation by the author and NSG where necessary due to data gaps and altered conditions. The PDVM identifies 15 pre-development plant communities based on their hydrological characteristics (depth and duration of inundation). One of the NSG's guiding principles in developing this data layer was to provide sufficient detail for the development of a hydrological model with a resolution of 20 acres or larger. Changes in vegetation from the pre-development period to present conditions are attributed to a variety of causes, including conversion to agricultural or residential land uses, altered hydrologic and/or fire regimes, or invasion by exotic plants. Potential errors in the PDVM may occur due to different degrees of familiarity of those working on the map with the various geographic areas in southwest Florida, and the imprecise nature of soil–plant community relationships. The PDVM is widely recognized as a reasonably accurate source of seamless GIS coverage of pre-development vegetation communities (e.g., Zahina et al, 2007) in the SWFFS area.

South Florida Water Management District Land Cover/Land Use 2004-05 Mapping Project

GIS data from this SFWMD project was utilized to characterize existing land use and land cover conditions, with classification codes based on the Florida Land Use, Cover, and FLUCCS; Department of Transportation, State Topographic Bureau, Thematic Mapping Section; January 1999 Edition.

Atkins reviewed the 2007 aerial photography to identify areas that had changed to urban land uses between 2004 and 2007. This information was used to update the land use distribution to better represent the 2007 land use and land cover conditions. The majority of the changes occurred due to development of the Town of Ave Maria and nearby areas.

Jones, J.W. 2006. Creation of GIS-Compatible, Historic Detailed Soil Data Sets for Collier and Miami-Dade Counties of Florida. United States Geological Survey (Table 2-77).

This publication describes a GIS data layer developed by USGS in 2006 for which a single GIS data file was created for Collier County from eight individual 1942 soils maps (presumably from aerial photographs prior to 1942) and published in 1954 by the USDA/SCS, in cooperation with the Florida Agricultural Experiment Station. The USGS developed the data layer using a multi-step process that included scanning paper copies of surveys, geo-rectification, and selection of appropriate uniform colors and line types.

Table 2-77. 1942 Collier County Soil Names, Relief and Surface Runoff Characteristics (Data Source from Jones/USGS, 2006)

Soil Name	**First_RELI** (Relief)	**First_SURF** (Surface Runoff)
Arzell fine sand	Level to nearly or slightly depressional	Very shallow or ponded
Blanton fine sand	Level to gently undulating	Slow to medium
Broward Ochopee complex	Level nearly level or gently undulating	Slow
Coastal beach	Gently sloping	Medium
Copeland fine sand	Level or nearly level	Very slow
Copeland fine sand–Low phase	Level depressions	Very slow or ponded
Lakewood fine sand	Hummocky (dunes) to level	Very slow due to rapid infiltration
Mangrove swamp	Level below high tide	Water covered at high tide

2.7.4 Results

Results of the watershed assessment are reported below for each of the three primary watersheds, followed by an aggregated summary of the three remaining watersheds.

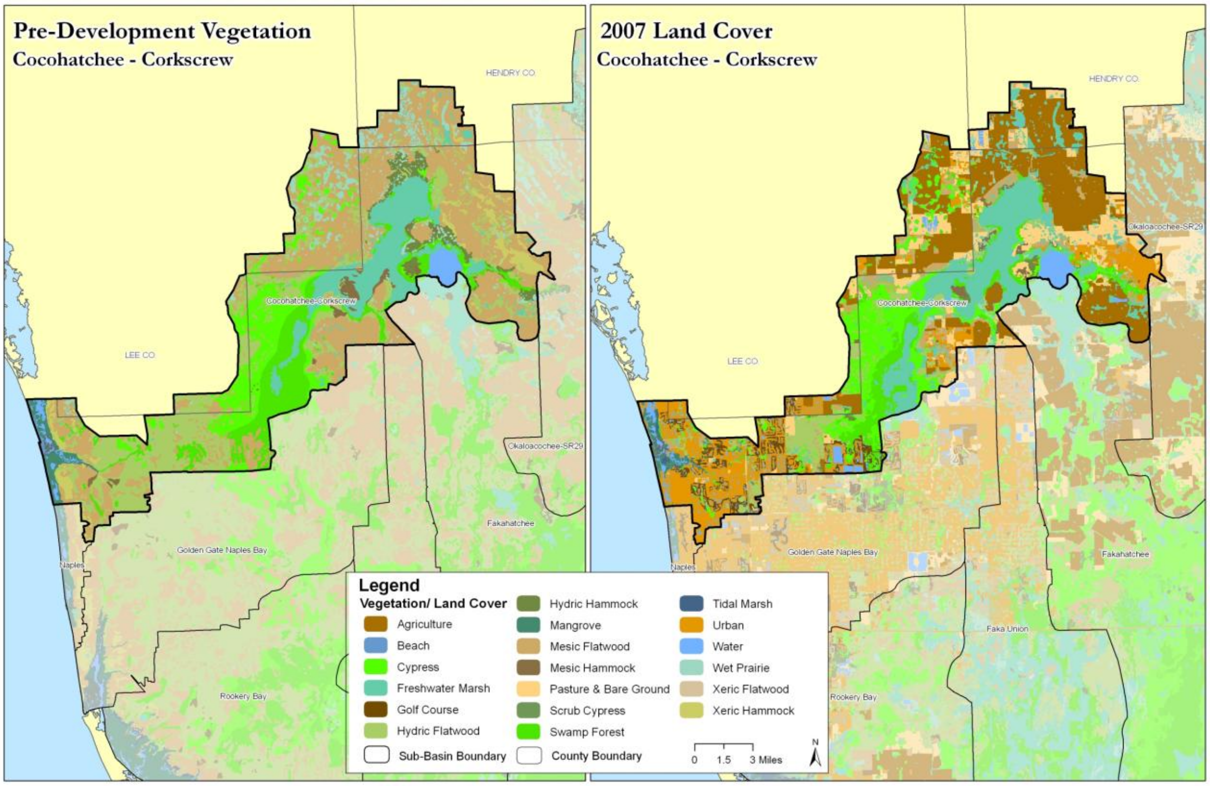
2.7.4.1 Cocohatchee-Corkscrew Watershed

The Cocohatchee-Corkscrew Watershed has experienced a loss of nearly 85 percent of pre-development upland communities and just over 30 percent of freshwater wetlands. The greatest loss of a natural upland community was due to conversion of natural uplands to agricultural land uses, while urban development accounted for the greatest loss of pre-development wetlands.

The Cocohatchee-Corkscrew PDVM included 13 of the 15 identified vegetation communities. Scrub cypress and tidal marsh were not present on the PDVM, presumably because the data used by SWFFS were not sufficient to determine whether or where these communities were historically present in the Cocohatchee-Corkscrew watershed. The 2007 land use and land cover map includes these thirteen PDVM communities, as well as tidal marsh and four agricultural/development cover types. Changes are mapped in **Figure 2-96** and listed in **Table 2-78**.

Table 2-78. Cocohatchee-Corkscrew Watershed Vegetation/ Land Cover
Changes from Pre-Development vs. 2007

Cocohatchee–Corkscrew Vegetation/ Land Cover	**Pre-Development Vegetation/ Land Cover**		**2007 Vegetation/Land Cover**	
	Acres	**Percent of Total**	**Acres**	**Percent of Total**
Agriculture	-	-	29,512	23
Freshwater Marsh	13,372	10	20,652	16
Urban	-	-	17,084	13
Cypress	11,334	9	12,931	10
Pasture & Bare Ground	-	-	11,869	9
Hydric Flatwood	25,911	20	7,969	6
Swamp Forest	12,167	9	7,353	6
Mesic Flatwood	46,501	36	7,094	6
Water	2,439	2	5,577	4
Golf Course	-	-	3,603	3
Mesic Hammock	1,463	1	1,109	1
Wet Prairie	5,969	5	1,101	1
Mangrove	1,731	1	1,056	1
Hydric Hammock	3,042	2	990	1
Tidal Marsh	-	-	195	0
Xeric Hammock	4,090	3	86	0
Beach	231	0	68	0
Xeric Flatwood	10	0	10	0
Total	128,260	100	128,260	100



Pre-Development Vegetation
Cocohatchee - Corkscrew

2007 Land Cover
Cocohatchee - Corkscrew

Figure 2-96. Cocohatchee-Corkscrew Watershed, Vegetation/Land Cover Changes from Pre-Development vs. 2007
(GIS Source Data from SFWMD)

Under pre-development conditions, the watershed (128,670 acres) included approximately 72,000 acres freshwater wetlands (56 percent), 52,000 acres undeveloped uplands (41 percent), and 4,400 acres (4 percent) open water and tidal systems. By 2007, over 62,000 acres (48 percent) of this watershed had been converted to agricultural and urban-related development. Approximately 44,000 acres (84 percent) of native uplands and 21,000 acres (29 percent) of freshwater wetlands (freshwater marsh, cypress, hydric flatwoods, swamp forest, wet prairie, hydric hammock) had been lost, while the acres of open water increased by over 3,000 acres. There were estimated increases in the extent of freshwater marsh and cypress of 7,300 acres and 1,600 acres, respectively. However, these apparent increases may have resulted from the inherent difficulties in determining which specific vegetation community is associated with a pre-development soil type, particular where, for instance, a given hydric soil is common to more than one type of freshwater wetland. For this reason, aggregation of the data among similar cover types would be more accurate than for an individual vegetation community. The Cocohatchee-Corkscrew watershed in 2007 included 8,300 acres of undeveloped uplands (16 percent of the pre-development acres) and 51,000 acres of freshwater wetlands (71 percent of the pre-development acres).

The net conversions (change in number of acres) of pre-development vegetation to the four development land use and land cover classes are summarized in **Table 2-79**. By far, the greatest conversion of natural lands to a developed land use is mesic flatwood to agriculture (approximately 22,000 acres), representing approximately 33 percent of the conversion of natural lands that occurred during this time period. The wetland community with the greatest loss during this time period was hydric flatwoods (nearly 18,000 acres lost; 69 percent of the pre-development total), due to conversions to urban development (5,700 acres; 31 percent of the loss), agriculture (4,000 acres; 23 percent of the loss), pasture and bare ground (2,500 acres; 14 percent of the loss), and golf course (2,000 acres; 11 percent of the loss).

The 1940s soils data, based on runoff characteristics listed in the USGS data (an attribute labeled as "First SURF" in the USGS spatial data), are mapped in **Figure 2-97** for soils data in the Cocohatchee-Corkscrew Watershed and Collier County (approximately 75 percent of the watershed). Of the 97,550 acres in this watershed within Collier County, approximately 41,000 acres in the USGS data are soils with runoff characteristics described as medium, medium/slow, slow, or slow due to rapid infiltration, which are most likely to occur in uplands. Another 37,000 acres are soils with runoff characteristics described as very slow/ponded or very shallow/ponded, which are most likely to occur in wetlands. Approximately 1,700 acres are categorized as covered at high tide (most likely representing tidal communities such as mangrove, tidal marsh and beach). About 2,500 acres are open water. The remaining 16,000 acres are categorized as very slow runoff, a description that may be characteristic of either wetlands or uplands (e.g., flatwoods) in Collier County.

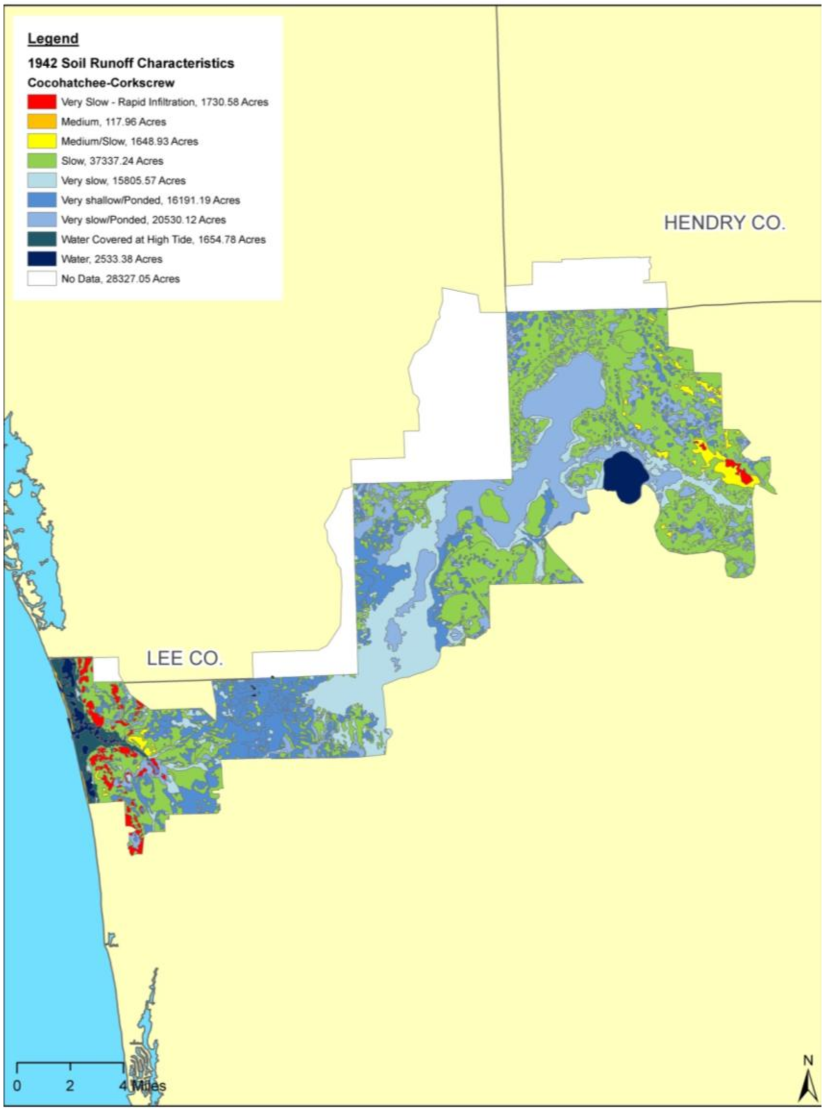


Figure 2-97. Cocohatchee-Corkscrew Watershed 1942 Soils Runoff Characteristics (Source Data from USGS)

Table 2-79. Cocohatchee-Corkscrew Watershed Vegetation/ Land Cover Conversions from Pre-Development to 2007 (Acres)

Pre-Development Vegetation/ Land Cover	Agriculture	Golf Course	Pasture & Bare Ground	Urban
Beach	0	0	0	39
Cypress	820	83	135	244
Freshwater Marsh	165	6	86	89
Hydric Flatwood	4,221	1,999	2,466	5,731
Hydric Hammock	715	0	561	191
Mangrove	0	2	0	432
Mesic Flatwood	21,562	1,149	7,188	7,504
Mesic Hammock	17	53	196	84
Scrub Cypress	0	0	0	0
Swamp Forest	8	215	34	394
Tidal Marsh	0	0	0	0
Water	0.00	0.04	1.3	52
Wet Prairie	1,054	8	726	166
Xeric Flatwood	0	0	0	7
Xeric Hammock	949	88	476	2,152

2.7.4.2 Golden Gate-Naples Bay Watershed

The Golden Gate-Naples Bay watershed had the greatest loss of pre-development vegetation communities of any of the watersheds analyzed for this study, with a loss of almost 70 percent of wetland acreage and over 80 percent of uplands. Urban development accounted for most of the loss. The PDVM for this watershed included eleven vegetation communities; xeric hammock, hydric hammock, scrub cypress and tidal marsh were not represented in the PDVM. The current land use map includes the same eleven PDVM vegetation communities, plus four agricultural/development land uses. **Figure 2-98** and **Table 2-80** present and summarize the pre-development and 2007 land use and land covers. The change analysis summarized below uses the current boundaries overlaid on the PDVM and current FLUCCS coverages, rather than the smaller historical watershed. This approach allows for direct comparison of land use and land cover acreages between the two time periods.

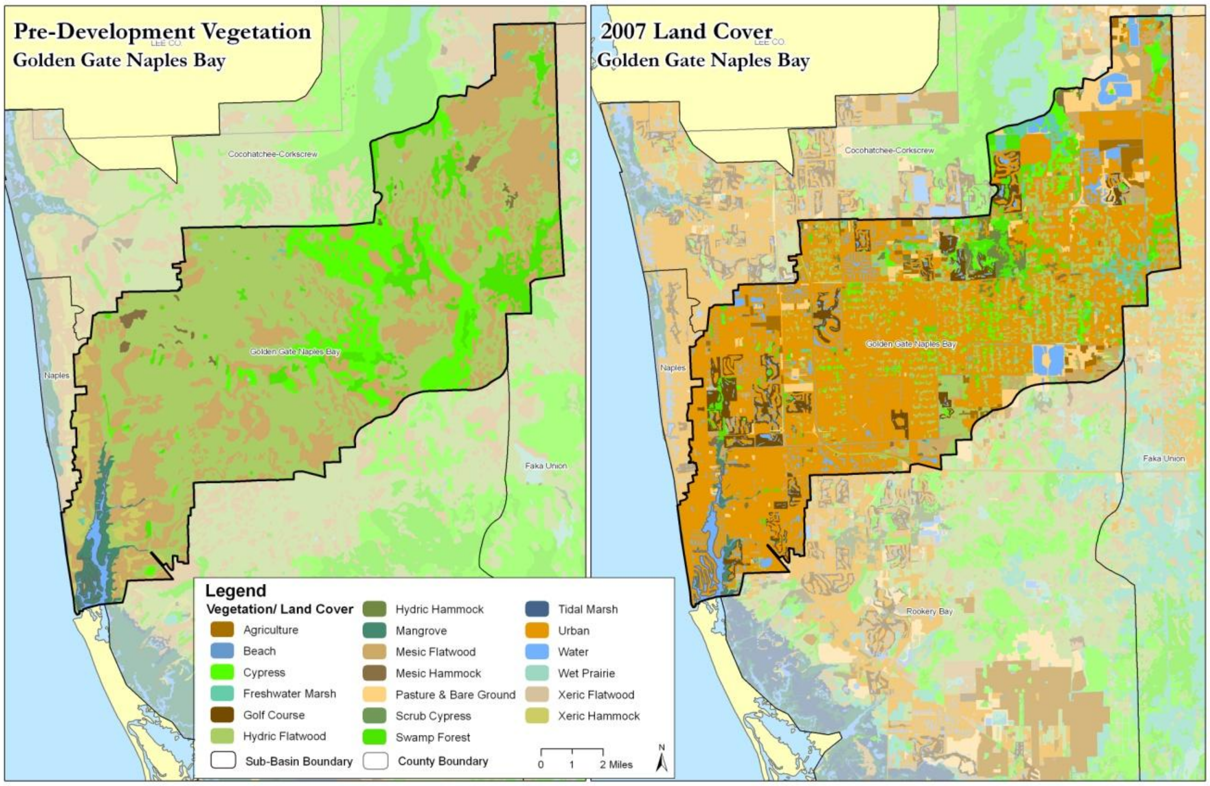


Figure 2-98. Golden Gate-Naples Bay Watershed, Vegetation/ Land Cover Changes from Pre-Development vs. 2007
(GIS Source Data from SFWMD)

Table 2-80. Golden Gate-Naples Bay Watershed Vegetation/Land Cover Changes from Pre-Development vs. 2007

Vegetation/Land Cover	**Pre-Development Vegetation/ Land Cover**		**2007 Vegetation/ Land Cover**	
	Acres	**Percent of Total**	**Acres**	**Percent of Total**
Urban	-	-	49,257	56
Hydric Flatwood	40,893	47	7,776	9
Water	777	1	5,986	7
Mesic Flatwood	27,545	31	4,545	5
Golf Course	-	-	4,216	5
Pasture & Bare Ground	-	-	3,941	5
Swamp Forest	5,279	6	2,922	3
Cypress	8,289	9	2,858	3
Freshwater Marsh	167	0	2,027	2
Agriculture	-	-	1,557	2
Hydric Hammock	-	-	1,254	1
Mesic Hammock	530	1	442	1
Mangrove	1,675	2	420	0
Wet Prairie	151	0	237	0
Beach	59	0	32	0
Xeric Flatwood	2,152	2	29	0
Tidal Marsh	-	-	20	0
Total	87,517	100	87,517	100

In the pre-development condition, this watershed (87,517 acres) was composed of approximately 55,000 acres freshwater wetlands (63 percent), 30,000 acres undeveloped uplands (35 percent), and 2,500 acres (3 percent) other natural land cover (open water and tidal systems). By 2007, 59,000 acres of this watershed (67 percent) had been converted to development. Nearly 37,000 acres of freshwater wetlands and over 25,000 acres of undeveloped uplands were lost by conversion to other land uses, while the acreage of open water increased by approximately 5,200 acres. There were also apparent increases in acreage in freshwater marsh (1,900-acre increase) and hydric hammock (1,300-acre increase). However, as with the other watersheds, these increases may in fact be due to the difficulty of correlating specific pre-development vegetation communities with soil data rather than actual changes in these communities; aggregate data for similar vegetation types is more accurate. The Golden Gate-Naples Bay watershed in 2007 retained just over 17,000 acres of wetlands (31 percent of the pre-development amount) and 25,000 acres of undeveloped uplands (17 percent of the pre-development amount).

The net conversion of each pre-development community type to the four categories of development is summarized in **Table 2-81**. Unlike the Cocohatchee-Corkscrew watershed, the largest conversion of lands in the Golden Gate-Naples Bay watershed occurred due to urban development, which replaced over 24,000 acres of mesic flatwoods, nearly 17,000 acres of hydric flatwoods, approximately 2,000 acres of xeric flatwoods, and 1,700 acres of swamp forest communities. The second highest conversion of natural lands occurred due to golf course development, which replaced over 2,500 acres of hydric flatwoods and almost 1,200 acres of mesic flatwoods.

Table 2-81. Golden Gate-Naples Bay Watershed Land Use and Land Cover Conversions from Pre-Development to 2007 (Acres)

Pre-Development Vegetation/ Land Cover	Agriculture	Golf Course	Pasture & Bare Ground	Urban
Beach	0	0	0	28
Cypress	161	383	514	3,124
Freshwater Marsh	1	0	5	81
Hydric Flatwood	634	2,514	1,511	24,348
Hydric Hammock	0	0	0	0
Mangrove	0	28	37	885
Mesic Flatwood	694	1,174	1,807	16,657
Mesic Hammock	18	15	46	298
Scrub Cypress	0	0	0	0
Swamp Forest	48	64	15	1,732
Tidal Marsh	0	0	0	0
Water	0	0	1	33
Wet Prairie	0	8	0	54
Xeric Flatwood	0	0	0	0
Xeric Hammock	0	30	6	2,017

Soils runoff characteristics are mapped **in Figure 2-99** for the Golden Gate-Naples Bay watershed. The USGS soils data cover all but 55 acres of this watershed. Of the 87,403 acres within the 1942 soils coverage, just over 27,000 acres are soils with runoff characterized as medium, medium/slow, slow or slow due to rapid infiltration, characteristic of uplands. Another 43,000 acres of soils had runoff characteristics described as very slow/ponded or very shallow/ponded, characteristic of wetlands. About 1,400 acres are categorized as covered at high tide, characteristic of estuarine tidal systems; and 900 acres are open water. The remaining 15,000 acres of soils had a runoff characteristic described as very slow runoff, which can occur in wetlands and uplands (e.g., flatwoods) in Collier County.

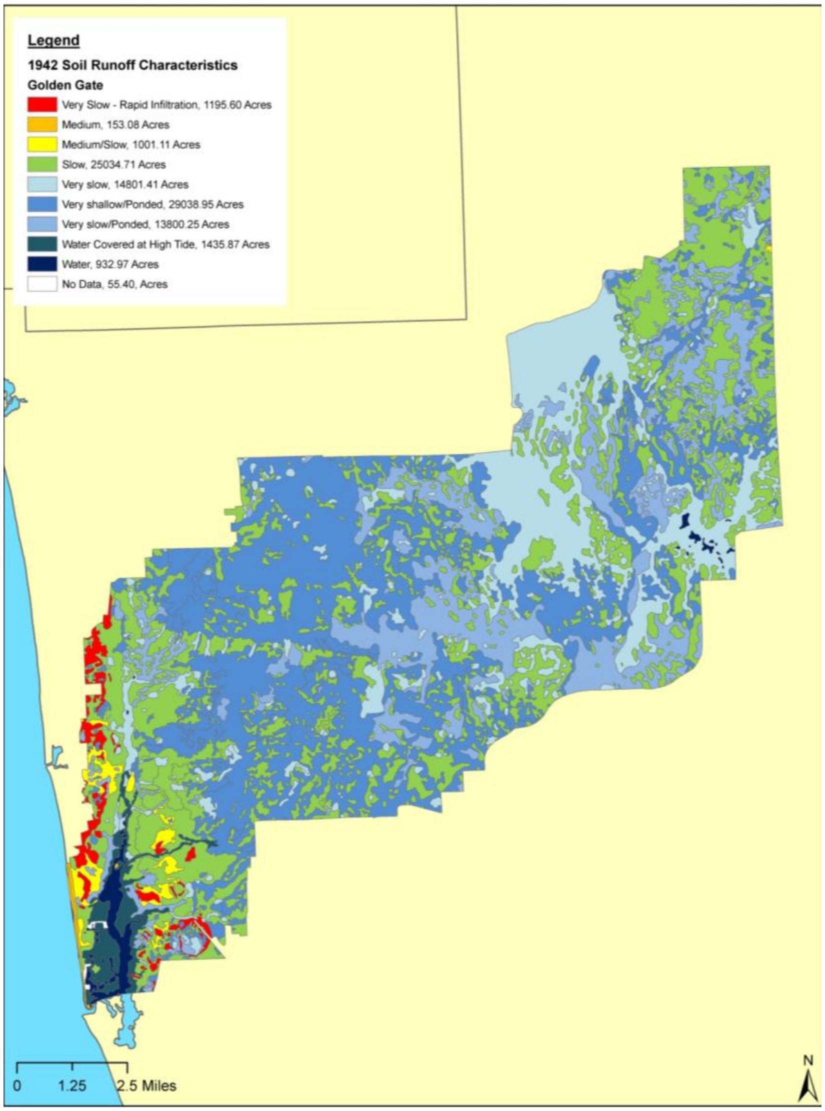


Figure 2-99. Golden Gate-Naples Bay Watershed 1942 Soils Runoff Characteristics
(Source Data from USGS)

2.7.4.3 Rookery Bay Watershed

The Rookery Bay Watershed exhibited the smallest loss of pre-development vegetation communities among the three priority watersheds, with a loss of approximately 30 percent of wetlands and less than 50 percent of uplands. The largest conversion of pre-development natural lands occurred due to urban development. The Rookery Bay PDVM included twelve vegetation/land cover classes: xeric hammock, hydric hammock, and tidal marsh were not represented in the PDVM for this watershed. The current vegetation/land cover map includes the same twelve classes, plus hydric hammock and four agricultural/development cover classes. Pre-development and 2007 vegetation/land cover classes in the watershed are mapped in **Figure 2-100** and listed in **Table 2-82**.

Table 2-82. Rookery Bay Watershed Vegetation/ Land Cover Changes
from Pre-Development vs. 2007

Vegetation/ Land Cover Class	Pre-Development Vegetation/ Land Cover		2007 Vegetation/ Land Cover	
	Acres	Percent of Total	Acres	Percent of Total
Hydric Flatwood	35,041	37	19,576	21
Urban	-	-	12,029	13
Mangrove	15,805	17	10,634	11
Cypress	9,562	10	9,422	10
Mesic Flatwood	13,575	14	7,703	8
Agriculture	-	-	6,753	7
Freshwater Marsh	183	0	6,062	6
Tidal Marsh	2,328	2	5,209	5
Water	1,792	2	4,323	5
Pasture & Bare Ground	-	-	3,664	4
Swamp Forest	13,789	14	3,330	3
Golf Course	-	-	2,838	3
Hydric Hammock	-	-	1,531	2
Wet Prairie	325	0	1,366	1
Mesic Hammock	2,202	2	707	1
Xeric Hammock	521	1	71	0
Scrub Cypress	97	0	-	-
Total	95,218	100	95,218	100

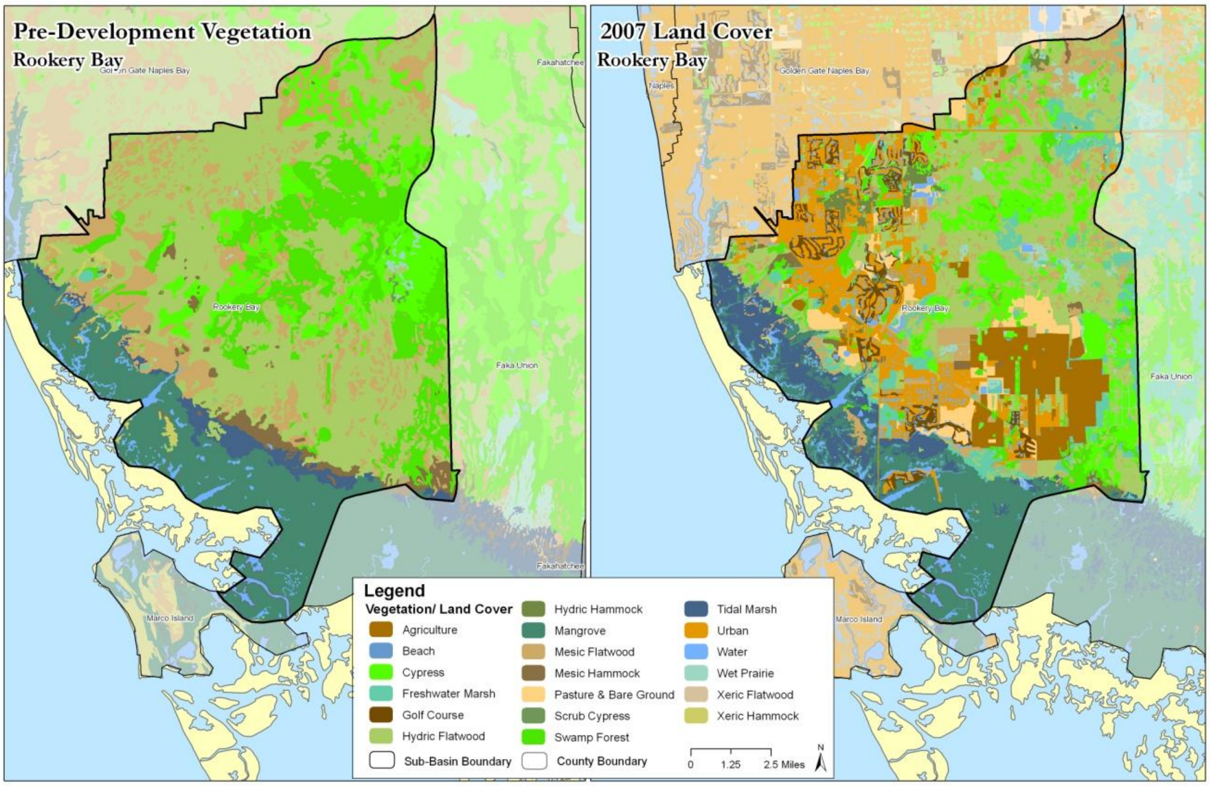


Figure 2-100. Rookery Bay Watershed, Vegetation/ Land Cover Changes from Pre-Development vs. 2007 (GIS Source Data from SFWMD)

Under the pre-development condition, this watershed (95,122 acres) included approximately 59,000 acres of freshwater wetlands (62 percent), 16,300 acres of undeveloped uplands (17 percent), 18,000 acres tidal systems (19 percent) and 1,800 acres open water (2 percent). By 2007, just over 25,000 acres (less than 27 percent) of this watershed had been converted to one of the four development-related land uses. There were 18,000 acres of freshwater wetlands, 8,000 acres of undeveloped uplands, and nearly 2,300 acres of tidal systems lost via conversion to other land uses, while acres of open water increased by over 2,500 acres. The cover of several natural resource protective communities appeared to increase during this time period, including freshwater marsh (by almost 6,000 acres), wet prairie (by over 1,000 acres), and tidal marsh (by nearly 3,000 acres). However, as mentioned previously, the data are more accurate when aggregated for similar ecosystems (e.g. freshwater wetlands) than for individual vegetation communities, due to the difficulty in determining specific pre-development vegetation from soils that occur in multiple similar systems. The Rookery Bay watershed in 2007 still included approximately 42,000 acres of wetlands (70 percent of the pre-development amount), 8,500 acres of undeveloped uplands (52 percent of the pre-development amount), and 16,000 acres of tidal systems (87 percent of the pre-development amount).

The net conversion of each pre-development community type to the four categories of development is summarized in **Table 2-83**. Similar to the Golden Gate-Naples Bay watershed, the largest conversion of lands in the Rookery Bay watershed occurred due to urban development, which replaced approximately 7,000 acres of hydric flatwoods and 3,000 acres of mesic flatwoods. The second highest conversion of natural lands occurred due to agriculture, which replaced nearly 5,000 acres of hydric flatwoods and 1,700 acres of mesic flatwoods. Not included in this analysis of loss to development is an apparent shift from a mangrove-dominated coastal estuary zone to one dominated by tidal marshes, as the acreage of mangroves decreased by nearly 5,000 acres, and tidal marshes increased by almost 3,000 acres. This may represent an actual shift due to a natural or artificially-induced successional/disturbance cycle (see Lewis and Streever, 2000), or be attributable to the difficulty in determining which of these two communities were associated with a soil type common to both for the PDVM.

The 1940s soils map, based on soil runoff characteristics (First_SUR) in the USGS data, is shown in **Figure 2-101** below. The USGS soils data covers all but 4 acres of this watershed. In this coverage, approximately 19,000 acres are soils characterized as medium, medium/slow, slow, or slow runoff due to rapid infiltration, typical of uplands in Collier County. Another 46,000 acres are soils with runoff characteristics described as very slow/ponded or very shallow/ponded, typical of freshwater wetlands. Almost 11,000 acres are categorized as covered at high tide, typical of tidal systems. About 1,700 acres are open water. The remaining 17,000 acres are soils described as having very slow runoff, which may occur in wetlands or uplands (e.g., flatwoods) in Collier County.

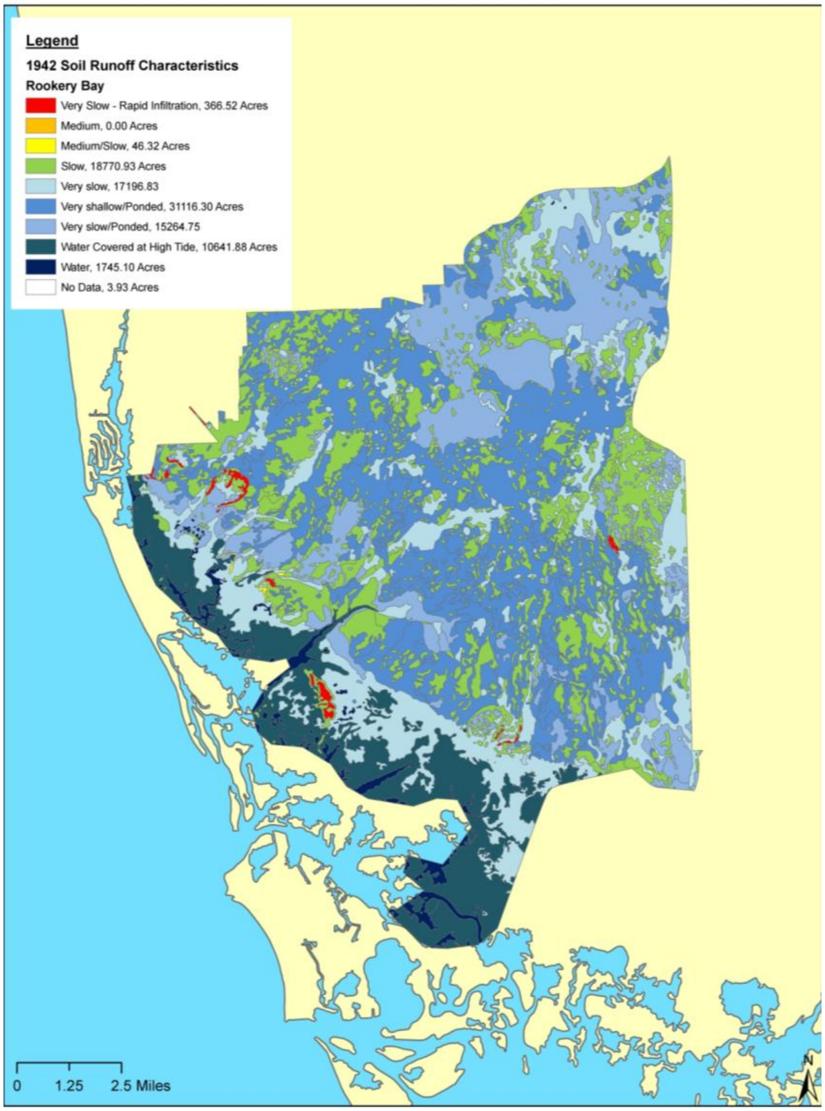


Figure 2-101. Rookery Bay Watershed 1942 Soils Runoff Characteristics
(Source Data from USGS)

Table 2-83. Rookery Bay Watershed Vegetation/ Land Cover Conversions from Pre-Development to 2007 (Acres)

Pre-Development Vegetation/ Land Cover	Agriculture	Golf Course	Pasture & Bare Ground	Urban
Beach	0	0	0	0
Cypress	274	173	589	911
Freshwater Marsh	1	0	0	1
Hydric Flatwood	4665	1606	1797	6924
Hydric Hammock	0	0	0	0
Mangrove	0	168	14	221
Mesic Flatwood	1731	508	918	3235
Mesic Hammock	33	272	231	191
Scrub Cypress	0	0	0	0
Swamp Forest	44	72	54	358
Tidal Marsh	0	32	50	99
Water	0	3	0	3
Wet Prairie	0	3	11	11
Xeric Flatwood	0	0	0	0
Xeric Hammock	4	0	1	74

2.7.4.4 Faka Union, Okaloacoochee/SR 29, and Fakahatchee Watersheds

The Faka Union, Okaloacoochee/SR 29, and Fakahatchee watersheds were analyzed as an aggregate, rather than individually, due to lower priority assigned to them (re: anticipated development, etc.) compared with the three priority watersheds analyzed above. These watersheds retain the highest percentage of pre-development wetlands (nearly 85 percent), but only 30 percent of the pre-development uplands. The largest losses occurred via conversion to agricultural land uses.

The pre-development vegetation/land cover map for these watersheds included 14 cover types; only xeric hammock was not represented in the PDVM. The current land use and land cover map includes the same fourteen, plus hydric hammock, and the four agricultural/development cover types. **Table 2-84** summarizes the pre-development and 2007 land use and land covers.

In the pre-development condition, this trio of watersheds (507,369 acres) was composed of approximately 335,000 acres freshwater wetlands (66 percent), 115,000 acres undeveloped uplands (23 percent), 54,000 acres tidal systems (11 percent) and 3,500 acres open water (1 percent). Similar to Rookery Bay watershed, as of 2007, just 135,000 acres of these watersheds

Table 2-84. Faka Union, Okaloacoochee/SR 29, Fakahatchee Watersheds
Vegetation/Land Cover Changes from Pre-Development vs. 2007
(GIS Source Data from SFWMD)

Faka Union, Okaloacoochee/SR 29, Fakahatchee Watersheds				
Vegetation/ Land Cover	**Pre-Development Vegetation/ Land Cover**		**2007 Vegetation/ Land Cover**	
	Acres	**Percent of Total**	**Acres**	**Percent of Total**
Freshwater Marsh	38,749	8	117,994	23
Cypress	39,302	8	63,101	12
Swamp Forest	106,601	21	61,437	12
Agriculture	-	-	59,028	12
Pasture & Bare Ground	-	-	52,347	10
Mangrove	43,579	9	33,885	7
Mesic Flatwood	107,183	21	28,293	6
Hydric Flatwood	67,832	13	26,568	5
Urban	-	-	22,626	4
Tidal Marsh	10,315	2	13,172	3
Wet Prairie	58,693	12	11,973	2
Water	3,541	1	8,097	2
Mesic Hammock	4,639	1	6,554	1
Hydric Hammock	10,662	2	1,593	0
Golf Course	-	-	527	0
Beach	262	0	152	0
Xeric Hammock	3,289	1	21	0
Scrub Cypress	12,720	3	-	-
	507,369	100	507,369	100

(27 percent) had been converted to development. In addition, 52,000 acres of freshwater wetlands, 80,000 acres of undeveloped uplands, and 7,000 acres of tidal systems were lost by conversion to development-related land uses, while the acreage of open water increased by almost 5,000 acres. As in other watersheds, the extent of several natural systems appeared to increase during this time period, including freshwater marsh (by 79,000 acres), cypress (by 24,000 acres), mesic hammock (by 2,000 acres) and tidal marsh (by 3,000 acres). It is likely that these reflect difficulties in determining specific pre-development resource protective communities from soil surveys, rather than actual changes. The accuracy of analysis of vegetation therefore increases with aggregation among similar vegetation communities. These watersheds in 2007 still included 283,000 acres of freshwater wetlands (84 percent of the pre-development amount), 35,000 acres of undeveloped

uplands (just 30 percent of the pre-development amount), and 47,000 acres of tidal systems (87 percent of the pre-development amount).

The net conversion of each pre-development community type to the four categories of development is summarized in **Table 2-85**. The largest conversion of lands in this set of watersheds occurred due to agriculture, which replaced more than 38,000 acres of mesic flatwoods and slightly less than 16,000 acres of hydric flatwoods. The second highest conversion of natural lands occurred due to conversion to pasture, which replaced 26,000 acres of mesic flatwoods, 12,000 acres of hydric flatwoods, and 5,000 acres of wet prairie.

Table 2-85. Faka Union, Okaloacoochee/SR 29, Fakahatchee Watersheds
Land Use and Land Cover Conversions from Pre-Development to 2007
(Acres)

Pre-Development Vegetation/ Land Cover	Agriculture	Pasture & Bare Ground	Urban
Beach	0	0	0
Cypress	433	876	1,367
Freshwater Marsh	525	2,247	87
Hydric Flatwood	15,923	12,162	4,359
Hydric Hammock	34	4,440	133
Mangrove	0	21	201
Mesic Flatwood	38,200	26,495	7,407
Mesic Hammock	1,050	872	58
Scrub Cypress	0	3	48
Swamp Forest	227	550	814
Tidal Marsh	0	8	95
Water	2	0	10
Wet Prairie	2,539	4,582	315
Xeric Flatwood	0	0	0
Xeric Hammock	90	14	125

The 1940s soils map, based on soil runoff characteristics in the USGS data, is shown in **Figure 2-102**. The USGS soils data does not cover 42,831 acres of these watersheds located in Hendry County. In this coverage, approximately 108,147 acres have soils with runoff characteristics described as medium, medium/slow, slow or slow due to rapid infiltration. Another 168,455 acres are soils with runoff characterized as very slow/ponded or very shallow/ponded and may be assumed to occur in wetlands. 14,759 acres of soils were described as covered at high tide; and 3,398 acres were open water. The remaining 151,440 acres have soils with a runoff characteristic described as very slow runoff.

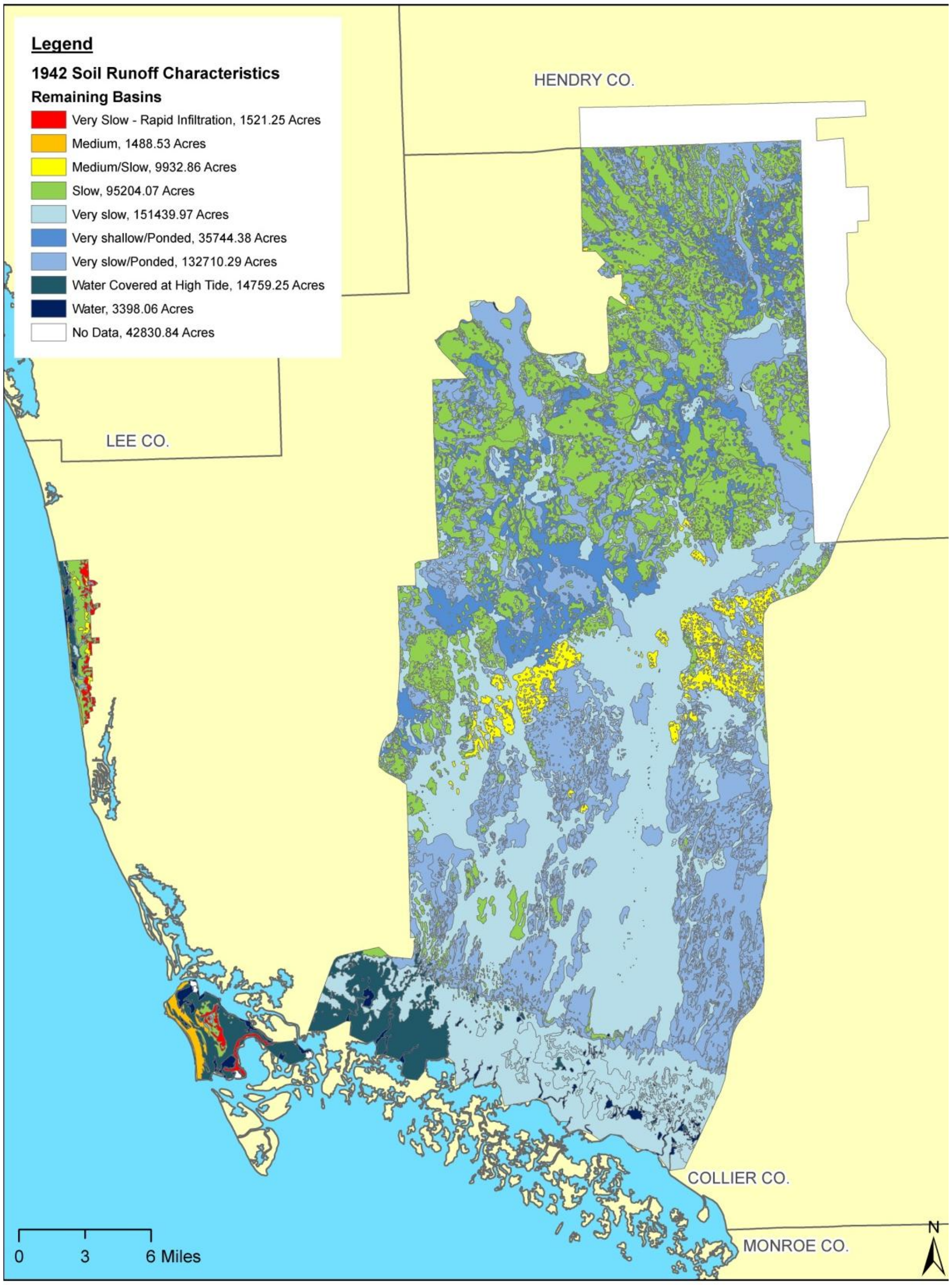


Figure 2-102. Faka Union, Okaloacoochee/SR 29, Fakahatchee Watersheds 1942 Soils (Source Data from USGS)

2.7.5 Conclusions

Vegetation and land cover changes from pre-development to current (2007) conditions were evaluated for the Cocohatchee-Corkscrew, Golden Gate-Naples Bay, Rookery Bay, Faka Union, Okaloacoochee/SR 29, and Fakahatchee watersheds. (**Figure 2-103**, **Tables 2-86 and 2-87)**. PDVM vegetation communities included approximately 520,000 acres (64 percent of the total area) of freshwater wetlands, 214,000 acres (26 percent of the total area) of uplands, 76,000 acres (9 percent of the total area) of estuarine tidal systems, and 8,500 acres (1 percent of the total area) of natural open water. By 2007, pre-development acres of freshwater wetlands had declined by 128,000 acres (25 percent) across these watersheds. The extent of native uplands had declined by 157,000 acres (73 percent) and estuarine tidal wetlands had declined by more than 11,000 acres (15 percent).

Declines were greatest for hydric and mesic flatwoods (70 percent loss) and increases were greatest for urban development (12 percent), agriculture (12 percent), and pasture/bare ground (9 percent). The largest conversion of one land cover/land use class to another was from mesic flatwoods to agricultural land use (over 62,000 acres), followed by conversion of hydric flatwoods to urban land use (over 37,000 acres).

The conversion of natural wetlands and uplands summarized in this memorandum represent a loss of nearly 273,000 acres (426 square miles) of wildlife habitat, natural water storage, filtration, and open recreational space in these six watersheds. Of the three primary watersheds, the greatest percentage loss has occurred due to urban development within the Golden Gate-Naples Bay watershed, with almost 60 percent of the watershed now categorized as urban. In contrast, just 23 percent of the lands within Rookery Bay watershed are categorized as any type of development. Of the 273,000 acres of natural lands converted to other land uses throughout these six basins, agriculture accounts for approximately 97,000 acres (12 percent of the watersheds' area).

Assessment of potential restoration opportunities includes recognition of limitations (e.g., land converted to urban development has far less restoration potential than agricultural lands or degraded natural areas), as well as opportunities (e.g., restoration of highly degraded areas may provide greater value, particularly if located contiguous with natural areas). The related analysis of wetland and upland functional values provides a more in-depth qualitative assessment, including the effect of the loss of natural lands and identification of areas with the greatest opportunity for recovery.

The results of this change analysis provide the basis for assessing the functional value of the natural systems in the watershed, evaluating the potential for restoration, and a comparison with performance measures, as further analyzed in the technical memorandum for Element 1, Task 3.2 (Functional Assessment).

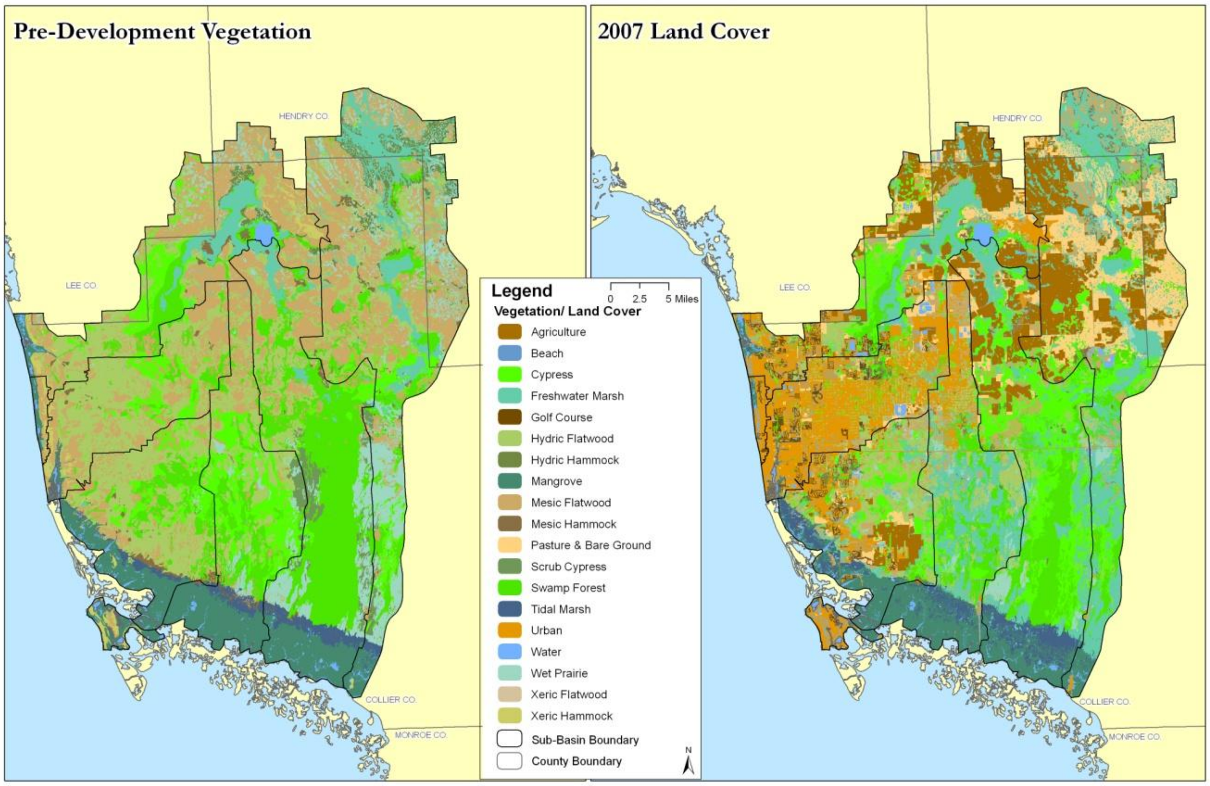


Figure 2-103. Model-Wide Overview, Land Use and Land Cover Changes from Pre-Development vs. 2007 (GIS Source Data from SFWMD)

Table 2-86. Collier County Watersheds Land Use and Land Cover Changes from Pre-Development vs. 2007

Cocohatchee-Corkscrew, Golden Gate-Naples Bay, Rookery Bay, Faka Union, Okaloacoochee/SR 29, and Fakahatchee Watersheds				
Vegetation/ Land Cover Class	**Pre-Development Vegetation/ Land Cover**		**2007 Vegetation/ Land Cover**	
	Acres	**Percent of Total**	**Acres**	**Percent of Total**
Agriculture	0	0%	96,849	12%
Beach	552	0%	251	0%
Cypress	68,487	8%	88,312	11%
Freshwater Marsh	52,471	6%	146,734	18%
Golf Course	0	0%	11,184	1%
Hydric Flatwood	169,677	21%	61,888	8%
Hydric Hammock	13,704	2%	5,367	1%
Mangrove	62,790	8%	45,995	6%
Mesic Flatwood	194,804	24%	47,635	6%
Mesic Hammock	8,833	1%	8,812	1%
Pasture & Bare Ground	0	0%	71,821	9%
Scrub Cypress	12,817	2%	0	0%
Swamp Forest	137,836	17%	75,042	9%
Tidal Marsh	12,643	2%	18,596	2%
Urban	0	0%	100,996	12%
Water	8,549	1%	23,983	3%
Wet Prairie	65,138	8%	14,678	2%
Xeric Flatwood	2,162	0%	40	0%
Xeric Hammock	7,901	1%	178	0%
Total	818,364	100%	818,364	100%

Table 2-87. Collier County Watersheds Land Use and Land Cover Conversions from Pre-Development to 2007 (Acres)

Pre-Development Vegetation/ Land Cover	Agriculture	Golf Course	Pasture/Bare Ground	Urban
Beach	0	0	0	66
Cypress	1,688	1,514	2,604	4,279
Freshwater Marsh	691	2,254	178	170
Hydric Flatwood	25,443	18,282	10,132	37,003
Hydric Hammock	749	4,440	694	191
Mangrove	0	219	251	1,539
Mesic Flatwood	62,187	29,326	17,320	27,396
Mesic Hammock	1,118	1,212	531	573
Scrub Cypress	0	3	48	0
Swamp Forest	328	901	917	2,484
Tidal Marsh	0	40	146	99
Water	2	3	12	88
Wet Prairie	3,593	4,601	1,052	231
Xeric Flatwood	0	0	0	7
Xeric Hammock	1,044	132	608	4,243
Total	96,843	62,928	34,492	78,370

2.8 NATURAL SYSTEMS: FUNCTIONAL ASSESSMENT

2.8.1 Introduction and Objective

This Chapter addresses Element 1, Task 3.2 *Functional Assessment*. The primary objective of this task was to develop and apply a method to assess the County's natural systems under existing conditions throughout the study area. The method is a landscape-level functional assessment of native wetland and upland communities. The assessment also provides the basis for the application of performance measures that are used to evaluate the potential impact of proposed restoration projects. Because the functional assessment is intended to target areas for resource protection and restoration, the analysis addressed only the non-urban portions of the watersheds, which are more likely to provide opportunities for restoration.

The functional assessment considered vegetation conditions, hydrologic conditions, and locations of the natural features. A scoring procedure was used to assess conditions compared to a reference time period.

In addition to the functional assessment analysis, this task also included two additional analyses that help estimate the resource protective capacity for additional water storage on undeveloped (non-urban) lands, and coverage (acres) of non-native invasive vegetation. These analyses, though not used directly for the functional assessment, provide information that may be used to further assess watershed conditions.

Results of the functional assessment were used first as a criterion to identify areas within each watershed where projects are most likely to improve or restore the functional value of the natural system. Also, development of the functional assessment is tied closely to the development of performance measures, which is the methodology used to assess the potential impact of proposed restoration actions.

2.8.2 Methods

The Uniform Mitigation Assessment Method (UMAM, Chapter 62-345 Florida Administrative Code) is widely accepted as a means of resource protection assessment. UMAM provided the template from which to develop the functional assessment for this project. Modifications were necessary to implement the functional assessment at the watershed level, rather than the site-specific level for which UMAM was designed. The overall concepts and design, however, are consistent with the development of UMAM.

Similar to UMAM, the optimal condition for this functional assessment is defined in terms of the landscape position, vegetation, and hydrology of the resource protective community in a targeted reference condition. Scores are assigned based on the degree of change between the existing condition of the natural communities and a reference condition.

This assessment relies exclusively on available GIS data to determine functional values at a watershed (and regional) level scale. The results presented herein should therefore be evaluated as a watershed-level assessment and cannot be used as a substitute for on-site analysis typically required for permitting purposes. Consistent with the level of detail incorporated in the hydrologic/hydraulic MIKE-SHE computer model developed as part of this project, the functional assessment methodology is applied using 1500 X 1500 foot cells whose land use characteristics are designated by the predominant land cover in each cell. For example, if a 1500 X 1500 foot cell is characterized by 80 percent cypress swamp, the entire cell is designated as cypress swamp.

An initial element of the functional assessment was establishing the reference conditions, similar to the Part I “frame of reference” prescribed in UMAM. Based on discussions with Collier County staff, other agencies, and not-for-profit conservation organizations, it was agreed that the data set which best defines the reference condition for this project area is the Pre Development Vegetation Model (PDVM). The PDVM is a 5-county map (including Collier County) with 15 vegetation associations defined by common vegetation composition and hydrological characteristics in the locations anticipated prior to development.

The functional assessment developed for this project included three (3) independent indices (scores), each of which includes a specific method for evaluating the current condition of a cell in comparison to its reference condition. The methods used to assign these indices (listed below) are presented in the following sections.

- Vegetation Score
- Hydrological Score
- Landscape Suitability Index (LSI)

2.8.2.1 Vegetation Scores

The vegetation score provides a means of comparing the resource protective functions of a cell (consisting of vegetation stratum (e.g., forested vs. herbaceous) and type of ecosystem (e.g., upland vs. wetland)) with the PDVM community that historically occupied the cell. UMAM provides a means of evaluating the set of characteristics to provide a parameter known as Community Structure. The change in vegetation characteristics is calculated by comparing 2007 FLUCCS data with the PDVM data. The land cover change analyses completed under Element 1 Task 3.1 (Reference Period Comparison) are incorporated into the vegetation scoring method for this project. The vegetation scoring method is described in greater detail below under Vegetation.

Vegetation scores generally represent the functional value of a cell in the landscape based on the degree to which the current cell retains natural vegetation (the PDVM conditions). A cell that has experienced a large change from pre-development vegetation (i.e., to a developed land use) would be characterized by low scores, while little or no change in vegetation cover (i.e., same as pre-development, or shift to another natural vegetation classification) would be characterized by a higher score. The vegetation scoring method is summarized in the following bullets and in **Table 2-88**. Vegetation scores are displayed in **Figure 2-104** and listed in **Table 2-91**.

- Polygons with existing FLUCCS designation that indicate the same dominant vegetation or natural water body as the PDVM (e.g., hydric flatwoods under pre-development and existing conditions) received a score of 10.
- Polygons that retained the same dominant stratum and ecosystem type (e.g., freshwater forested wetland to freshwater forested wetland) also received a score of 10.
- Polygons that shifted from one dominant stratum to another but retained the same ecosystem type (e.g., freshwater forested wetland to herbaceous freshwater wetland) received a score of 8.
- A shift from mesic to hydric flatwoods or vice-versa received a score of 8.
- Polygons in which vegetation shifted between natural ecosystem types and strata (e.g., herbaceous freshwater wetland to forested native upland or natural water body) received a score of 8.
- Polygons that were converted to an artificial water body received a score of 6.
- A natural system that was converted to a developed land use class was scored as listed in **Table 2-88**.

Table 2-88. Vegetation Score for Developed Lands

Model Land Use Type	MIKE SHE Model Code	FLUCCS Code	Vegetation Score
Citrus	1	221, 222, 223	4
Pasture	2	211, 212, 213, 251, 260, 261, 832	6
Pasture	2	190,192, 193 (urban abandoned)	1
Sugar Cane & Sod	3	2156, 242	4
Truck (Row) Crops	5	214, 215, 216	4
Golf Course	6	180, 182	1
Bare Ground	7	161, 162, 163, 164, 181, 231, 740, 743, 744, 8113, 8115, 835	0
Urban Low Density	41	110, 111, 112, 113, 119, 148, 185, 240, 241, 243, 250	1
Rural Residential Low Density	41	118	3
Urban Medium Density	42	120, 121, 122, 123, 129, 176, 834	1
Urban High Density	43	130, 131, 132, 133, 134, 135, 139, 140, 1411, 1423, 146, 149, 154, 155, 156, 170, 171, 183, 184, 187, 252, 810, 811, 814, 820, 831, 833	0

2.8.2.2 Hydrology Scores

The hydrology score is used to characterize the effects of depth and duration (hydroperiod) of inundation. Like the vegetation scoring, the hydrologic scoring method developed for this project assigns values by comparing existing modeled hydrology and PDVM conditions. Areas for which existing hydrological conditions are in the normal range of the pre-development conditions are designated with higher scores, while areas dryer (i.e. shorter duration or depth of inundation) than PDVM conditions are assigned lower scores.

Similar to the approach used for assessing the vegetation functional value, hydrology scoring represents the functional value of a parcel of land based on the degree to which the parcel retains the same hydrological characteristics as its pre-development reference condition. Pre-development hydrological conditions are estimated based on the typical range of depth and duration (hydroperiod) of inundation of the vegetation community present on the PDVM per **Table 2-89**. Current average depth and hydroperiod were determined from the MIKE SHE - MIKE 11 model developed for this project for 1500 x 1500 feet sized cells. For example:

- No change from pre-development would result in a score of 10.
- Total loss of hydrology (e.g., a cell dominated by a pre-development wetland or open water body but which now experiences no inundation) would result in a score of 0.

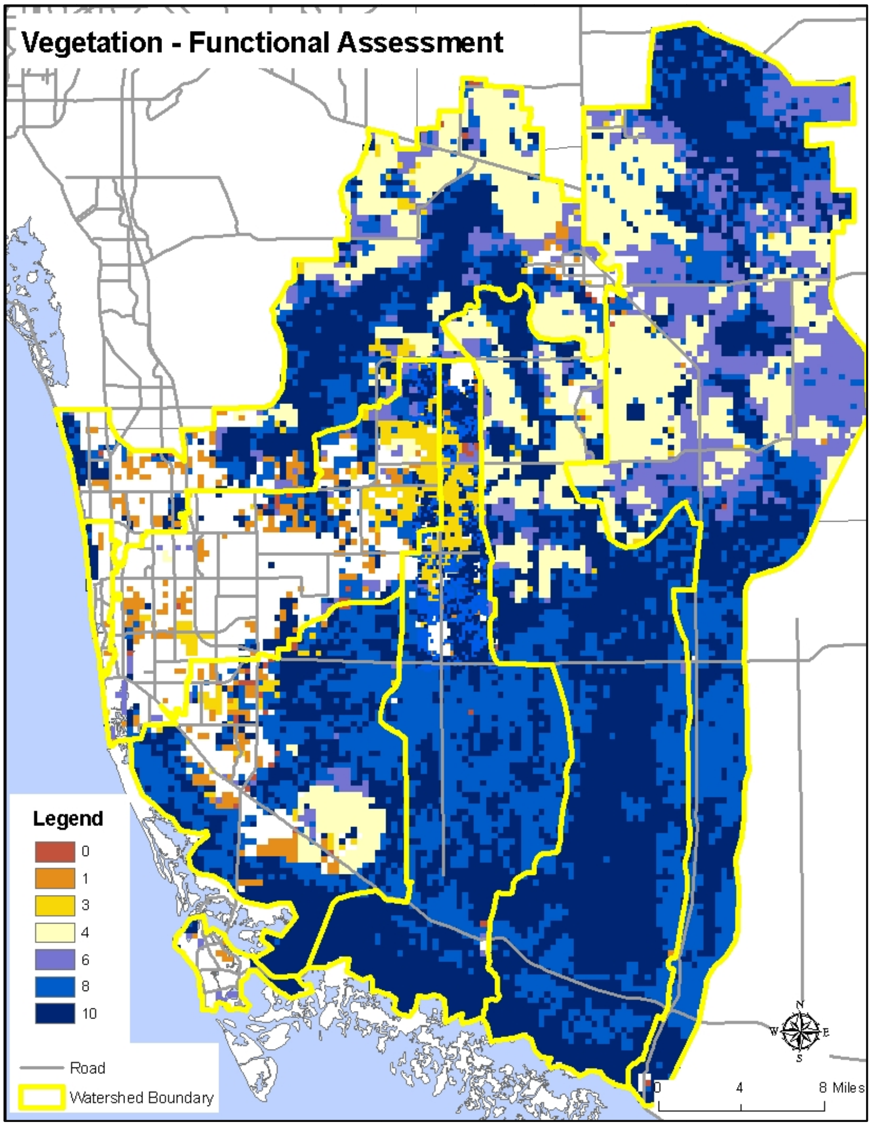


Figure 2-104. Vegetation Functional Assessment Values

The hydrology score for a cell was calculated as the average of the depth and duration scores of the current and reference (PDVM) conditions, adjusted to a scale of 0 to 10. For instance, a site with a reference (PDVM) average hydroperiod of 6 months and an average inundation of 12 inches, but which currently is inundated for only 2 months at an average depth of 4 inches has a quantifiable change of 1/3 ((6/12 + 2/4)/2 = 1/3). Therefore, the hydrology score for the cell is 3.3.

Table 2-89. Hydrologic Regimes of Major
Southwest Florida Plant Communities

Plant Community	Duration (months)	Seasonal Water Depth (inches)	
		Wet	Dry (1,10)*
Xeric Flatwood	0	≤-24	-60, -90
Xeric Hammock			
Mesic Flatwood	≤1	≤2	-46, -76
Mesic Hammock			
Hydric Flatwood	1–2	2–6	-30, -60
Hydric Hammock			
Wet Prairie	2–6	6–12	-24, -54
Dwarf Cypress			
Freshwater Marsh	6–10	12–24	-6, -46
Cypress	6–8	12–18	-16, -46
Swamp Forest	8–10	18–24	-6, -36
Open Water	>10	≥24	< 24, -6
Tidal Marsh	Tidal	Tidal	Tidal
Mangrove			
Beach			

* 1 = average year low water; 10 = 1 in 10 year drought, July 2002

The reference condition for hydrology scoring depends on whether the existing vegetation community remains in the same vegetation/hydrology class as in the PDVM, per **Table 2-89** (Mike Duever, personal communication).

The hydrology scoring allows for a single score to be developed for each cell. The hydrology score also serves as a performance measure for proposed project evaluations: it differentiates between the hydrologic “lift” associated with projects that could enhance a particular wetland type without altering the vegetation (e.g., hydric flatwoods that will become wetter through project implementation) versus projects that would likely change current vegetation to achieve the PDVM vegetation community (e.g. wet prairie that would be rehydrated to achieve pre-development freshwater marsh hydrology).

If the vegetation community currently characterizing a cell is different than it was in the PDVM, the hydrological reference condition is the minimum depth and hydroperiod typical of the PDVM plant community. In cells where the current vegetation class is the same as the PDVM, the hydrology reference condition is the maximum depth and hydroperiod typical of the plant community. These calculations are summarized below.

- If PDVM vegetation = FLUCCS vegetation, then Score = (Model Hydro/Max PDVM Hydro)*10
- If PDVM vegetation is not equal to FLUCCS vegetation, then Score = (Model Hydro/Min PDVM Hydro)*10
- Tidal marshes and mangroves = 8.
- Combined Hydrology Score = (depth score + duration score)/2
- Recognizing that a score of 10 represents target conditions, all scores greater than 10 were set to 10.

where*:*

- "Model Hydro" is a cell's average depth or hydroperiod in the MIKE SHE/MIKE 11 model;
- "Max PDVM Hydro" or "Min PDVM Hydro" is the top or bottom value, respectively, of the typical average range of depth or hydroperiod for a vegetation community, as estimated in **Table 2-89**.

Due to a wide range of hydroperiod and depth of inundation for mangroves and salt marshes, no specific hydroperiod conditions were established for these systems in **Table 2-89,** but a hydrology score of 8 was globally assigned. Results of the hydrology scoring are mapped in **Figure 2-105** and listed in **Table 2-91**.

2.8.2.3 Landscape Suitability Index (LSI)

The LSI, unlike the hydrology and vegetation scores, is a measure of the effects of adjacent lands on a site (cell) rather than conditions within the site itself. The LSI represents the degree to which adjacent lands provide or inhibit resource protective connectivity, buffers, and corridors. Higher scores characterize areas surrounded by natural lands or lands conducive to wildlife passage, while lower LSI scores are typical of areas surrounded by land uses that function as barriers. For instance, even a natural preserve area would receive a low LSI score if surrounded by commercial land uses, while a parcel with otherwise poor conditions could receive a high LSI score if surrounded by pasture or natural areas. The LSI is based on peer-reviewed work published by researchers at the University of Florida during the development of UMAM (Bardi et al. 2011, Reiss et al. 2009; Brown and Vivas. 2005).

Initially, each 1500 X 1500 foot cell was assigned a dominant vegetation FLUCCS code. Each FLUCCS code was then assigned an LSI score representing the degree to which that land use supports the resource protective functions of adjacent lands, per **Table 2-90**. In some instances, this required interpretation to determine which land use/land cover description in **Table 2-90** best matches a FLUCCS code.

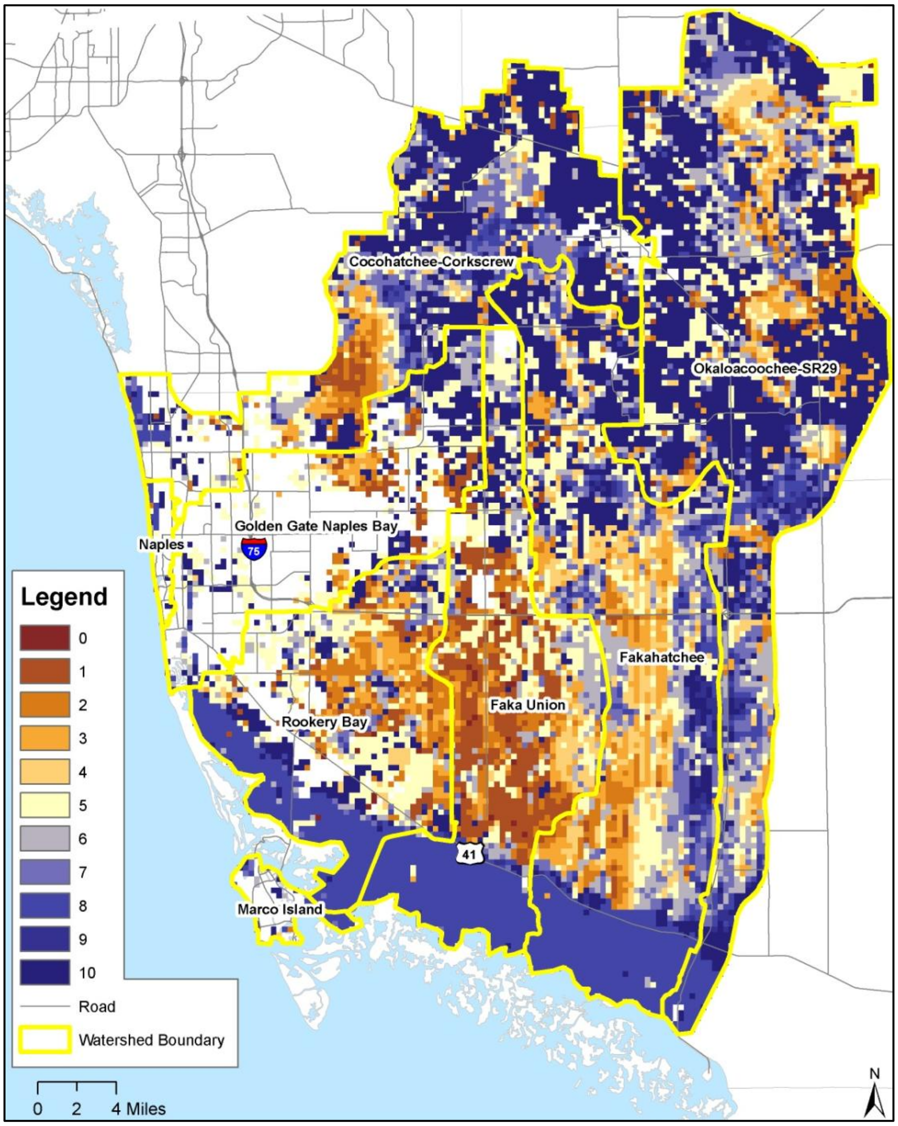


Figure 2-105. Hydrology Functional Assessment Values

Table 2-90. LSIs for Land Use/Land Cover Classes in Florida

Land Use/Land Cover Class	LSI
Natural System	10.00
Natural Open water	10.00
Pine Plantation	9.36
Recreational / Open Space (Low-intensity)	9.08
Woodland Pasture (with livestock)	8.87
Pasture (without livestock)	8.03
Low Intensity Pasture (with livestock)	7.32
Citrus	7.02
High Intensity Pasture (with livestock)	6.96
Row crops	6.07
Single Family Residential (Low-density)	3.57
Recreational / Open Space (High-intensity)	3.42
High Intensity Agriculture (Dairy farm)	3.33
Single Family Residential (Med-density)	2.81
Single Family Residential (High-density)	2.72
Mobile Home (Medium density)	2.56
Highway (2 lane)	2.43
Low Intensity Commercial	2.22
Institutional	2.14
Highway (4 lane)	1.91
Mobile Home (High density)	1.90
Industrial	1.87
Multi-family Residential (Low rise)	1.49
High Intensity Commercial	0.91
Multi-family Residential (High rise)	0.90
Central Business District (Average 2 stories)	0.64
Central Business District (Average 4 stories)	0.00

The LSI for each cell was calculated as the average LSI score of the eight adjoining cells. LSIs are mapped in **Figure 2-106** and summarized in **Table 2-91**. Due to the focus on identifying and evaluating potential projects, no LSI scores were generated for cells dominated by urban land uses.

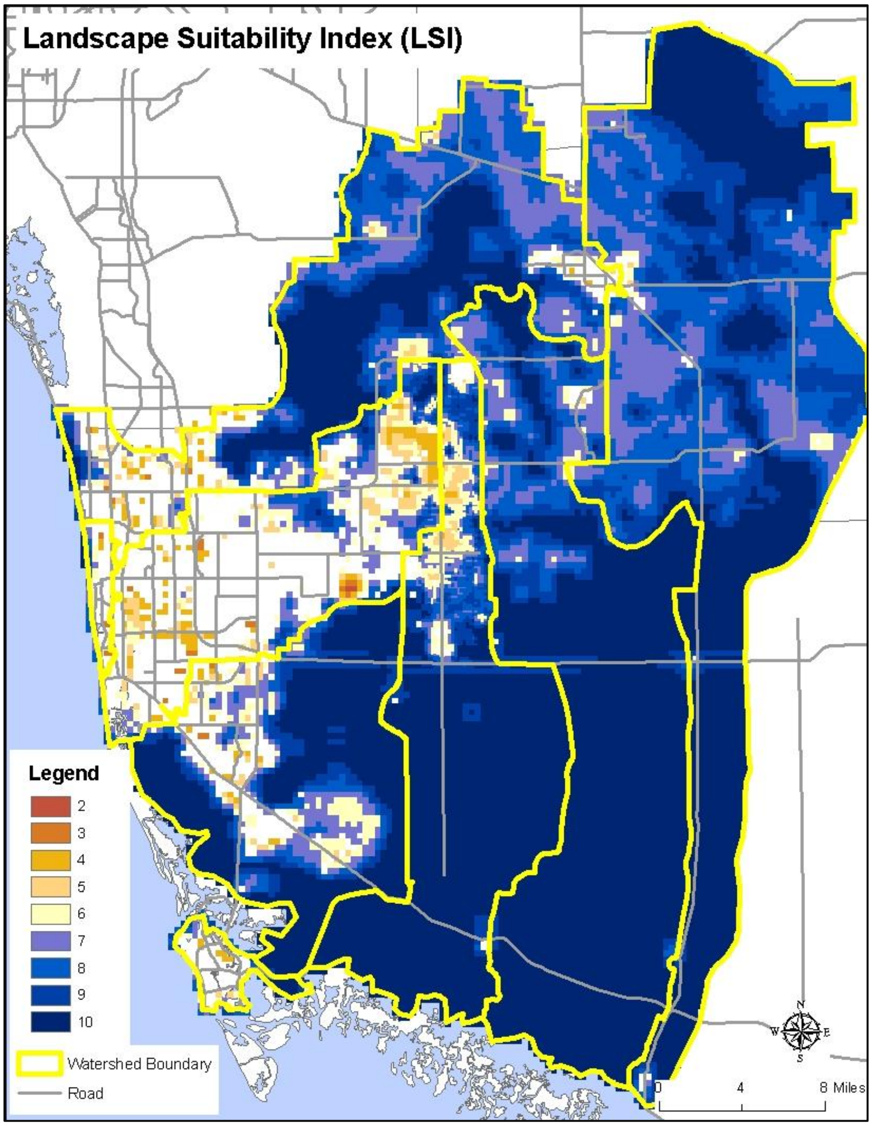


Figure 2-106. LSI Functional Assessment Values

2.8.3 Results

Watersheds with higher functional values reflect less development and urbanization impacts in the watershed. As expected, the highest resource protective values, as measured by the individual functional assessment scores for vegetation, hydrology and LSI, were found in the eastern Faka Union/Okaloacoochee SR29/Fakahatchee watersheds, followed by the Rookery Bay and Cocohatchee-Corkscrew watersheds (**Table 2-91**). The lowest functional values occurred in the Golden Gate-Naples watershed. Individual vegetation, hydrology and LSI scores are listed by watershed in **Tables 2-92 through 2-94.** Scores are also shown in **Figures 2-104 through 2-106.**

Table 2-91. Average Functional Values, by Parameter and Watershed, in Non-urban Areas of Collier County Watersheds

Watershed	Acres	Average Vegetation Score	Average Hydro Score	Average LSI Score
Cocohatchee-Corkscrew	111,250	7	7	8
Golden Gate-Naples	36,627	5	6	6
Rookery Bay	83,105	8	6	9
Faka Union/ Okaloacoochee SR29/ Fakahatchee	431,414	9	6	9

Water bodies in the state of Florida are each assigned a unique Water Body Identification number (WBID). WBID units include drainage basins, lakes, lake drainage areas, springs, rivers and streams, segments of rivers and streams, coastal, bay and estuarine waters in Florida. The WBIDs identify polygons that roughly delineate the drainage basins surrounding the water body and are used in FDEP's Total Maximum Daily Load (TMDL) program as well as other applications. Some water bodies in the watersheds examined are identified as impaired, pursuant to FDEP's Impaired Waters Rule (IWR), as approved by EPA. Functional values were calculated herein by WBID as well as watershed, so that projects offering opportunities for improved resource protective value can also be examined in the context of their impairment condition. **Tables 2-95 through 2-97** list corresponding functional scores by watershed and WBID.

2.8.3.1 Cocohatchee-Corkscrew Watershed

The functional assessment of the non-urban portions of the Cocohatchee-Corkscrew Watershed (**Figures 2-104 through 2-106**) reveals two distinct trends: the central part of the watershed just east of Corkscrew Swamp system maintains a high functional value for all three parameters, while the northern and eastern portions dominated by non-pasture agricultural lands retain relatively high hydrology and LSI scores and moderate vegetation scores. The LSI remains high (seven or greater) throughout the non-urban portion of the watershed due to natural and agricultural land uses. Vegetation and hydrology scores are somewhat lower due to conversion to agricultural uses.

Table 2-92. Detailed Vegetation Scores by Watershed

Vegetation Score	Cocohatchee-Corkscrew		Golden Gate/Naples Bay		Rookery Bay		Faka Union/SR29/Fakahatchee	
	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed
0	563	0.44	579	0.66	1,229	1.29	821	0.20
1	4,954	3.86	7,594	8.68	4,937	5.18	1,061	0.26
3	2,306	1.80	8,299	9.48	2,266	2.38	8,461	2.11
4	33,165	25.87	979	1.12	7,260	7.62	68,427	17.03
6	11,395	8.89	3,203	3.66	1,920	2.02	56,759	14.12
8	19,795	15.44	8,159	9.32	32,344	33.97	119,205	29.66
10	39,072	30.47	7,815	8.93	33,148	34.81	138,017	34.34
N/A - Urban	16,965	13.23	50,882	58.14	12,112	12.72	9,122	2.27
Total:	**128,215**	**100.00**	**87,509**	**100.00**	**95,218**	**100.00**	**401,873**	**100.00**

Table 2-93a. Detailed Hydroperiod Scores by Watershed

Hydroperiod Score	Cocohatchee-Corkscrew		Golden Gate/Naples Bay		Rookery Bay		Faka Union/SR29/Fakahatchee	
	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed
1	98	0.08	0	0.00	620	0.65	2,251	0.46
2	1,092	0.85	2,318	2.65	1,983	2.08	15,353	3.11
3	2,772	2.16	1,672	1.91	3,600	3.78	15,596	3.16
4	3,429	2.67	1,603	1.83	8,894	9.34	20,807	4.21
5	4,696	3.66	1,061	1.21	7,891	8.29	27,381	5.54
6	3,933	3.07	1,876	2.14	1,898	1.99	30,950	6.26
7	2,463	1.92	491	0.56	1,431	1.50	28,320	5.73
8	4,524	3.53	638	0.73	18,043	18.95	65,386	13.23
9	3,718	2.90	301	0.34	1,601	1.68	15,982	3.23
10	84,525	65.92	26,667	30.47	37,144	39.01	264,503	53.52
N/A - Urban	16,965	13.23	50,882	58.14	12,112	12.72	7,684	1.55
Total:	**128,215**	**100.00**	**87,509**	**100.00**	**95,218**	**100.00**	**494,212**	**100.00**

Table 2-93b. Water Depth Scores by Watershed

Water Depth Score	Cocohatchee-Corkscrew		Golden Gate/Naples Bay		Rookery Bay		Faka Union/SR29/Fakahatchee	
	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed
0	15,690	12.24	13,187	15.07	21,964	23.07	75,097	17.97
1	12,378	9.65	4,606	5.26	18,731	19.67	59,940	14.34
2	7,221	5.63	2,577	2.94	5,381	5.65	54,066	12.94
3	7,278	5.68	1,669	1.91	2,659	2.79	43,078	10.31
4	6,578	5.13	550	0.63	1,829	1.92	29,872	7.15
5	7,031	5.48	416	0.48	1,037	1.09	18,827	4.51
6	3,314	2.59	323	0.37	1,161	1.22	11,855	2.84
7	2,083	1.62	246	0.28	302	0.32	8,909	2.13
8	2,802	2.19	483	0.55	17,921	18.82	52,849	12.65
9	743	0.58	155	0.18	207	0.22	4,879	1.17
10	46,131	35.98	12,415	14.19	11,912	12.51	127,156	30.43
N/A - Urban	16,965	13.23	50,882	58.14	12,112	12.72	6,469	1.55
Total:	**128,215**	**100.00**	**87,509**	**100.00**	**95,218**	**100.00**	**417,901**	**100.00**

Table 2-93c. Combined Hydrology Scores by Watershed

Combined Hydrology Score	Cocohatchee-Corkscrew		Golden Gate/Naples Bay		Rookery Bay		Faka Union/SR29/Fakahatchee	
	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed
0	98	0.08	0	0.00	413	0.43	2,251	0.46
1	3,765	2.94	3,783	4.32	4,789	5.03	28,854	5.88
2	5,069	3.95	2,245	2.57	10,030	10.53	27,060	5.51
3	5,791	4.52	1,997	2.28	8,113	8.52	34,722	7.08
4	3,663	2.86	1,004	1.15	3,002	3.15	34,905	7.11
5	15,700	12.25	9,761	11.15	17,467	18.34	68,205	13.90
6	10,790	8.42	3,404	3.89	5,851	6.14	53,131	10.83
7	11,398	8.89	1,018	1.16	3,061	3.21	33,574	6.84
8	6,838	5.33	939	1.07	19,490	20.47	66,896	13.63
9	2,100	1.64	268	0.31	671	0.71	10,871	2.22
10	46,037	35.91	12,209	13.95	10,219	10.73	126,061	25.69
N/A - Urban	16,965	13.23	50,882	58.14	12,112	12.72	6,469	1.32
Total:	**128,215**	**100.00**	**87,509**	**100.00**	**95,218**	**99.57**	**490,747**	**100.00**

Table 2-94. LSI Scores by Watershed

LSI Score	Cocohatchee-Corkscrew		Golden Gate/Naples Bay		Rookery Bay		Faka Union/SR29/Fakahatchee	
	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed
2	0	0.00	103	0.12	0	0.00	0	0.00
3	258	0.20	732	0.84	155	0.16	0	0.00
4	1,664	1.30	4,605	5.26	930	0.98	250	0.05
5	2,067	1.61	5,916	6.76	1,623	1.70	2,964	0.60
6	4,943	3.86	7,403	8.46	6,119	6.43	6,475	1.31
7	23,987	18.71	8,426	9.63	9,369	9.84	41,479	8.39
8	28,443	22.18	5,399	6.17	6,755	7.09	79,878	16.16
9	16,547	12.91	3,331	3.81	10,678	11.21	66,977	13.55
10	33,341	26.00	713	0.81	47,477	49.86	288,504	58.38
N/A - Urban	16,965	13.23	50,882	58.14	12,112	12.72	7,684	1.55
Total:	**128,215**	**100.00**	**87,509**	**100.00**	**95,218**	**100.00**	**494,212**	**100.00**

Table 2-95. Vegetation Functional Assessment Values by Watershed and WBID

Veg. Score	Cocohatchee-Corkscrew																		Golden Gate-Naples					
	3259A		3259B		3259W		3259Z		3278C		3278D		3278E		3278F		3278L		3278K		3278R		3278S	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
0	43	1	44	0	0	0	0	0	63	3	103	0	0	0	207	0	103	1	33	1	19	0	527	1
1	16	1	0	0	0	0	52	8	52	2	4,008	16	753	6	0	0	73	1	1,154	21	401	4	6,039	8
3	0	0	923	4	7	0	0	0	16	1	231	1	200	2	878	2	52	1	103	2	41	0	8,154	11
4	0	0	9,623	45	0	0	0	0	0	0	833	3	3,099	26	15,544	29	4,066	47	0	0	0	0	979	1
6	109	4	4,440	21	0	0	0	0	0	0	847	3	3,162	27	2,123	4	714	8	0	0	723	8	2,480	3
8	413	13	3,934	18	94	6	22	3	475	22	2,804	11	1,985	17	8,868	17	1,200	14	258	5	229	2	7,672	11
10	1,787	58	2,500	12	1,388	93	16	2	110	5	6,000	23	1,582	13	24,984	47	703	8	203	4	455	5	7,157	10
Urban	720	23	112	1	0	0	545	86	1,438	67	11,012	43	996	8	309	1	1,832	21	3,660	68	7,446	80	39,776	55
Acres	3,088		21,576		1,490		635		2,155		25,837		11,777		52,914		8,745		5,412		9,313		72,784	

Veg. Score	Rookery Bay						Faka Union/Okaloacoochee SR 29/Fakahatchee															
	3278U		3278V		3278Y		3259I		3259M		3261C		3278G		3278H		3278I		3278T		3278W	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
0	45	0	814	2	371	2	103	0	52	0	0	0	18	0	310	1	137	0	0	0	155	0
1	1,724	7	1,024	2	2,189	15	59	0	0	0	0	0	52	0	744	3	0	0	52	0	155	0
3	139	1	1,074	2	1,054	7	636	1	0	0	0	0	14	0	7,103	26	6	0	300	0	399	1
4	314	1	6,895	13	51	0	19,823	36	0	0	0	0	343	0	123	0	0	0	24,254	19	24,227	45
6	52	0	1,662	3	207	1	4,331	8	52	0	110	0	148	0	639	2	93	0	35,745	28	15,789	29
8	8,953	34	21,410	40	1,981	13	10,896	20	8,611	20	22,450	67	26,550	28	7,483	27	37,680	63	25,539	20	6,071	11
10	13,074	50	17,947	33	2,128	14	19,266	35	34,726	79	10,447	31	67,371	71	7,295	27	21,463	36	38,875	31	5,834	11
Urban	1,872	7	3,166	6	7,075	47	591	1	497	1	358	1	0	0	3,752	14	69	0	1,215	1	1,201	2
Acres	26,171		53,991		15,055		55,706		43,938		33,365		94,494		27,449		59,450		125,980		53,830	

Table 2-96. Hydrology Functional Assessment Values by Watershed and WBID

Hydro Score	Cocohatchee-Corkscrew																		Golden Gate - Naples					
	3259A		3259B		3259W		3259Z		3278C		3278D		3278E		3278F		3278L		3278K		3278R		3278S	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
0	46	1	0	0	0	0	0	0	0	0	0	0	0	0	52	0	0	0	0	0	0	0	0	0
1	4	0	103	0	0	0	0	0	52	2	1,669	6	50	0	1,784	3	103	1	0	0	27	0	3,756	5
2	0	0	269	1	0	0	0	0	0	0	1,774	7	72	1	2,894	5	59	1	0	0	0	0	2,245	3
3	0	0	614	3	0	0	0	0	0	0	1,686	7	275	2	3,106	6	109	1	0	0	0	0	1,997	3
4	0	0	237	1	0	0	0	0	7	0	611	2	352	3	2,382	5	73	1	52	1	0	0	952	1
5	202	7	3,261	15	1	0	0	0	64	3	3,606	14	1,039	9	6,664	13	864	10	677	13	241	3	8,843	12
6	258	8	2,348	11	108	7	0	0	0	0	1,758	7	428	4	5,672	11	218	2	177	3	516	6	2,711	4
7	267	9	1,584	7	1,218	82	0	0	0	0	310	1	885	8	6,756	13	378	4	52	1	127	1	840	1
8	1,398	45	813	4	33	2	37	6	52	2	231	1	741	6	3,327	6	207	2	136	3	437	5	366	1
9	52	2	371	2	48	3	0	0	0	0	207	1	146	1	1,271	2	5	0	0	0	0	0	268	0
10	141	5	11,864	55	82	6	52	8	542	25	2,973	12	6,791	58	18,694	35	4,897	56	659	12	519	6	11,031	15
Urban	720	23	112	1	0	0	545	86	1,438	67	11,012	43	996	8	309	1	1,832	21	3,660	68	7,446	80	39,776	55
Acres	3,088		21,576		1,490		635		2,155		25,837		11,777		52,914		8,745		5,412		9,313		72,784	

Hydro Score	Rookery Bay						Faka Union/Okaloacoochee SR 29/Fakahatchee															
	3278U		3278V		3278Y		3259I		3259M		3261C		3278G		3278H		3278I		3278T		3278W	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
0	109	0	304	1	0	0	52	0	0	0	0	0	0	0	166	1	867	1	1,114	1	52	0
1	62	0	4,365	8	362	2	293	1	0	0	52	0	1,528	2	3,648	13	20,199	34	2,304	2	831	2
2	110	0	9,547	18	373	2	1,797	3	0	0	956	3	6,724	7	1,770	6	8,587	14	6,434	5	792	1
3	38	0	7,809	14	266	2	4,093	7	96	0	1,727	5	13,367	14	375	1	4,155	7	9,304	7	1,604	3
4	127	0	2,563	5	312	2	5,444	10	0	0	2,030	6	12,206	13	335	1	3,798	6	10,021	8	1,071	2
5	1,099	4	12,748	24	3,619	24	10,284	18	211	0	2,788	8	12,575	13	6,638	24	10,103	17	16,978	13	8,627	16
6	871	3	4,047	7	932	6	5,159	9	280	1	8,637	26	14,486	15	3,240	12	5,439	9	13,425	11	2,464	5
7	657	3	2,197	4	207	1	3,946	7	288	1	6,313	19	10,694	11	1,044	4	1,789	3	7,823	6	1,677	3
8	18,169	69	1,076	2	245	2	2,191	4	40,160	91	3,489	10	11,411	12	166	1	2,676	5	5,255	4	1,548	3
9	52	0	568	1	52	0	889	2	214	0	1,911	6	3,877	4	146	1	310	1	2,753	2	771	1
10	3,005	11	5,601	10	1,613	11	20,968	38	2,191	5	5,106	15	7,627	8	6,168	22	1,458	2	49,353	39	33,191	62
Urban	1,872	7	3,166	6	7,075	47	591	1	497	1	358	1	0	0	3,752	14	69	0	1,215	1	1,201	2
Acres	26,171		53,991		15,055		55,706		43,938		33,365		94,494		27,449		59,450		125,980		53,830	

Table 2-97. LSI Functional Values by Watershed and WBID

LSI	Cocohatchee-Corkscrew																		Golden Gate-Naples					
Score	**3259A**		**3259B**		**3259W**		**3259Z**		**3278C**		**3278D**		**3278E**		**3278F**		**3278L**		**3278K**		**3278R**		**3278S**	
	Acres	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	103	0
3	0	0	0	0	0	0	51	8	1	0	207	1	0	0	0	0	0	0	61	1	155	2	517	1
4	0	0	0	0	0	0	1	0	51	2	1,509	6	8	0	0	0	95	1	599	11	207	2	3,799	5
5	18	1	95	0	0	0	0	0	209	10	1,449	6	52	0	163	0	80	1	756	14	299	3	4,861	7
6	43	1	891	4	0	0	0	0	229	11	2,041	8	283	2	965	2	491	6	335	6	401	4	6,667	9
7	506	16	5,964	28	0	0	37	6	177	8	2,664	10	3,430	29	8,180	15	3,027	35	0	0	481	5	7,945	11
8	504	16	9,250	43	7	0	0	0	17	1	1,941	8	2,812	24	11,885	22	2,027	23	0	0	196	2	5,203	7
9	732	24	3,970	18	64	4	0	0	32	1	1,902	7	2,693	23	6,031	11	1,121	13	0	0	129	1	3,202	4
10	563	18	1,294	6	1,419	95	0	0	0	0	3,112	12	1,502	13	25,380	48	71	1	0	0	0	0	712	1
Urban	720	23	112	1	0	0	545	86	1,438	67	11,012	43	996	8	309	1	1,832	21	3,660	68	7,446	80	39,776	55
Acres	3,088		21,576		1,490		635		2,155		25,837		11,777		52,914		8,745		5,412		9,313		72,784	

LSI	Rookery Bay						Faka Union/Okaloacoochee SR 29/Fakahatchee															
Score	**3278U**		**3278V**		**3278Y**		**3259I**		**3259M**		**3261C**		**3278G**		**3278H**		**3278I**		**3278T**		**3278W**	
	Acres	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	155	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	116	0	78	0	736	5	0	0	0	0	0	0	0	0	250	1	0	0	0	0	0	0
5	231	1	422	1	969	6	78	0	0	0	0	0	0	0	2,708	10	0	0	0	0	178	0
6	431	2	3,822	7	1,867	12	1,644	3	0	0	0	0	0	0	3,197	12	0	0	591	0	1,043	2
7	1,359	5	6,011	11	2,000	13	9,789	18	52	0	38	0	13	0	4,160	15	0	0	12,257	10	15,171	28
8	2,093	8	3,933	7	728	5	13,991	25	428	1	261	1	430	0	6,407	23	14	0	36,921	29	21,427	40
9	2,535	10	7,533	14	610	4	13,433	24	969	2	1,455	4	2,712	3	4,967	18	3,271	6	29,406	23	10,764	20
10	17,534	67	29,027	54	916	6	16,180	29	41,991	96	31,253	94	91,340	97	2,007	7	56,096	94	45,591	36	4,046	8
Urban	1,872	7	3,166	6	7,075	47	591	1	497	1	358	1	0	0	3,752	14	69	0	1,215	1	1,201	2
Acres	26,171		53,991		15,055		55,706		43,938		33,365		94,494		27,449		59,450		125,980		53,830	

The distribution of vegetation scores (**Figure 2-104**) reflects conversion of natural landscape cover outside the Corkscrew Swamp. Just over 30 percent (over 36,000 acres) of this watershed has a vegetation score of 4 or less, resulting primarily from the loss of most of the mesic and hydric flatwoods (as documented under the Reference Period Comparison). WBID 3278F (Corkscrew Marsh) retains the highest vegetation scores, with nearly 65 percent (just under 34,000 acres) of total area of that WBID scoring 8 or higher. Just 5 percent of WBID 3259Z (Little Hickory Bay) is comprised of non-urban land with a vegetation score of 8 or higher (**Table 2-92**), and over 15 percent of WBID 3278D (Cocohatchee–Inland Slough) has a vegetation score of 3 or lower.

Hydrology scores in the Cocohatchee-Corkscrew Watershed reflect existing conditions similar to PDVM depth and duration throughout much of the agricultural lands, and dryer-than-PDVM conditions in the vicinity of Corkscrew Swamp. For example over 55 percent (nearly 5,000 acres) of WBID 3278L (Immokalee Basin) has a hydrology score of 10, while only 35 percent (just under 5,000 acres) of WBID 3278F scores that high (**Table 2-93**). The lowest hydrology scores occur in WBID 3278D, with nearly 65 percent (over 9,000 acres) of the non-urban portion of that WBID comprised of lands scoring 5 or less.

LSI scores (**Table 2-94**) reflect natural lands surrounding Corkscrew Marsh, Lake Trafford, and coastal mangroves. Nearly 80 percent (nearly 80,000 acres) of the non-urban portion of Cocohatchee-Corkscrew Watershed has an LSI of 8 or greater. The largest portion of this high-LSI area (over 40,000 acres) occurs in WBID 3278F (Corkscrew Marsh). The lowest-scoring area, WBID 3278L (Immokalee Basin), is dominated by agricultural lands with moderately-high LSI values, with over 3500 acres (approximately 40 percent) scoring 6 or 7, and most of the rest scoring higher.

Reviewing the results, the greatest opportunities for improvement of resource protective value occur within WBIDs 3278D and 3278F. These portions of the watershed contain over 10,000 acres with a hydrology score of 4 or lower, indicating significant potential for improvement due to hydrological restoration. WBID 3278F, with a relatively higher extent of compatible land uses based on LSI and vegetation scores, presents greater potential opportunity for resource protective benefits from hydrological restoration.

The western portion of this watershed was not evaluated for restoration potential, due to the prevalence of urban lands that restrict the feasibility of resource protective benefits from hydrological restoration projects.

2.8.3.2 Golden Gate-Naples Bay Watershed

Nearly 60 percent (over 50,000 acres) of the Golden Gate-Naples Bay watershed is urban land not suitable for resource protection (**Tables 2-92 through 2-94**). The analysis of current condition and restoration projects is focused on the remaining non-urban portion of this watershed. Overall, even the non-urban areas have relatively low resource protective value, with an average vegetation score of 5 and hydrology and LSI scores of 6 (**Table 2-91**).

The area with the highest functional value is WBID 3278S (Northern Golden Gate Estates). Reflecting the relatively less-developed land uses in this portion of the watershed, just over 20 percent of this WBID (approximately 15,000 acres) has vegetation scores of 8 or higher, 15 percent (11,000 acres) has a hydrology score of 10, and just over 25 percent (approximately 19,500 acres) has an LSI score between 5 and 7.

Overall, this watershed presents relatively few opportunities for large-scale improvement in resource protective value. Urban and suburban development throughout the watershed limits the degree to which restoration projects would improve functional values beyond the footprint of the project itself. In relation to other portions of the watershed, the eastern portion of WBID 3278S (Northern Golden Gate Estates) presents the greatest opportunity for resource protective restoration. The relatively less-developed land uses in this portion of the watershed may allow restoration projects to improve resource protective values on a wider scale.

2.8.3.3 Rookery Bay Watershed

The functional values calculated for this watershed are low in the portions of the watershed surrounding Belle Meade and Tamiami Trail, but functional values are relatively higher when compared with Cocohatchee-Corkscrew and Golden Gate watersheds. The watershed-wide average LSI score in Rookery Bay Watershed is nine (9) and the average vegetation score is eight (8) (**Table 2-91**). This is primarily because less than 30 percent of the watershed has been converted to urban or agricultural uses (refer to Reference Period Comparison). Within the watershed, the Belle Meade area scores the lowest, with low to moderate scores in all three parameters.

Vegetation score distribution (**Figure 2-104** and **Table 2-92**) reflects the relatively high proportion of undeveloped lands in this watershed other than the Belle Meade area and Tamiami Trail corridor. Over 65 percent (65,000 acres) of this watershed has a vegetation score of eight (8) or higher. Among WBIDs (**Table 2-92**), 3278Y (Rookery Bay—Inland West Slough) has the lowest vegetation score, with almost 25 percent (approximately 3,500 acres), scoring three (3) or lower. The highest-scoring area is WBID 3278U (Rookery Bay–Coastal Slough), with vegetation scores of eight (8) or higher for almost 85 percent (22,000 acres) of this WBID.

The overall hydrology scores (**Figure 2-105** and **Table 2-93**) indicate existing dryer conditions throughout the watershed in comparison to PDVM conditions. Comparing the PDVM to current FLUCCS data shown in the Technical Memorandum for Task 3.1 (Reference Period Comparison), large portions of the watershed once supported swamp forest but are now dominated by shorter-hydroperiod hydric flatwoods. As a result of this shift, over 40 percent (over 21,500 acres) of WBID 3278V (Rookery Bay–Inland East Slough) has a hydrology score of three (3) or lower.

LSI scores in the Rookery Bay Watershed (**Figure 2-106** and **Table 2-94**) reflect moderate resource protective value in the Belle Meade agricultural area, but otherwise high values throughout the watershed. The non-urban portion of WBID 3278Y includes approximately 5,000 acres of lands (30 percent of the WBID) with a moderate LSI score (between 5 and 7), and WBID 3278V contains approximately 10,200 acres (just under 20 percent) in that same scoring range. At the high end, over 75 percent (approximately 20,000 acres) of WBID 3278U have an LSI score of nine (9) or higher.

The large extent of undeveloped and agricultural lands in this watershed provides opportunities for restoration, while the functional values indicate opportunities for improvements via hydrological restoration throughout these lands.

2.8.3.4 Faka Union, Okaloacoochee/SR 29, and Fakahatchee Watersheds

These watersheds, individually and as a whole, retain relatively high functional value, with average Vegetation and LSI scores of nine (9), and hydrological score average of six (6) (**Table 2-91**). The mapped scores (**Figures 2-104 through** 2-**106**) indicate higher vegetation and LSI scores south of I-75 than north, and the opposite trend among the hydrology scores (i.e., higher hydrology scores in the north than in the south).

Vegetation scores (**Figures 2-104 and Table 2-92**) reflect the prevalence of agricultural lands in the northern portion of these watersheds, with highest scores in the preserved natural lands in the southern and eastern portions of the watersheds. WBID 3259M (Ten Thousand Islands [TTI]) has the highest vegetation score, with nearly 100 percent of this WBID scoring eight (8) or higher. WBID 3278H (Faka Union–North Segment) has the lowest vegetation value, with 30 percent (approximately 8,100 acres) of this WBID scoring three (3) or lower. The overall average vegetation score of nine (9) throughout these watersheds, however, indicates significant resource protective value including near the agricultural lands.

The modest hydrological scores throughout these watersheds (**Figure 2-105** and **Table 2-93**) reflect the effects of regional drainage canals, with the highest scores occurring in the northern and eastern portions of the Okaloacoochee-SR 29 Watershed and the lowest scores in the Faka Union Watershed. No primary drainage canals serve the northern Okaloacoochee-SR 29 Watershed, while the Faka Union is currently drained by several. Over 33,000 acres (over 60 percent) of WBID 3278W (Silver Strand) have a hydrology score of 10, in contrast to WBID 3278I (Faka Union–South Segment), of which nearly 30,000 acres (over 50 percent) have a hydrological score of two (2) or less.

Over 70 percent (325,000 acres) of the land in these watersheds has an LSI value of nine (9) or higher. The relatively lowest-LSI value WBID is 3278H (Faka Union North Segment), with just under 40 percent of that WBID having an LSI between five (5) and seven (7). These modest scores reflect low-density rural development north of Alligator Alley in the eastern portion of Golden Gate Estates. Each of the other WBIDs have LSI scores of 8 or higher for at least 65 percent of their area.

Based on the scores for these three watersheds, the greatest opportunity for measurable improvement in functional value would occur through hydrological restoration. The ongoing restoration of Picayune Strand, as an example, is well-positioned to deliver hydrological and resource protective benefits to the Faka Union Watershed.

2.8.4 Resource Protective Capacity for Additional Water Storage

The potential for hydrological storage provides information useful for evaluating watershed conditions and restoration opportunities. Restoration of an area that is currently an upland but was previously a wetland, for instance, would require development of storage capacity to a depth and duration typical of the pre-development wetland. Storing water in restored wetlands could also cleanse and attenuate freshwater flows to downstream estuaries, depending on the location and morphology of those wetlands. This section describes both the method and results of calculating potential water storage.

Hydrological storage capacity and coverage of non-native invasive species are summarized in **Figures 2-107 and 2-108** and **Tables 2-98 and 2-99**.

2.8.4.1 Methods

The difference between the existing depth and duration of inundation (based on FLUCCS vegetation type) and the pre-development depth and duration of inundation (based on PDVM vegetation type) may be considered as the resource protective capacity for additional water storage. Adding water beyond this amount would potentially exceed the hydrological tolerance of the pre-development vegetation community and result in a transition to a different type of wetland or open water system that was not previously present on that site. For example, adding too much water for too much time to a current upland site that was a wet prairie could result in creation of a deepwater marsh or unvegetated pond rather than restoration of the pre-development wet prairie. In Atkins' opinion, this scenario would be ecologically and logistically difficult to justify or accomplish.

For the purposes of this project, the change in depth of inundation is estimated in inches based on comparisons between the typical water levels of existing vegetation and PDVM vegetation. **Table 2-99** lists data used to calculate the available resource protective capacity for additional storage. The formula used is:

$$\text{Capacity for Additional Storage} = WSWL_{PDVM} - WSWL_{2007}$$

where:

WSWL is the long-range average wet season water level typical for the type of vegetative community.

Similarly, the change in duration of inundation between PDVM and current FLUCCS vegetation is calculated in months, based on the hydroperiod per **Table 2-90**.

2.8.4.2 Results

Due to the close relationship between vegetation community and hydrology, the results of the calculations for depth and duration of inundation are displayed and summarized together. **Table 2-100** summarizes the results of the calculations for each watershed.

A comparison of the hydrological characteristics of pre-development and 2007 vegetation communities (**Figure 2-107**) suggests areas for potential additional wet season water storage (**Figure 2-108**). Overall, approximately 44,000 acres of undeveloped lands (including over 10,000 acres in Rookery Bay watershed) have capacity for additional wet season storage of at least 0.5 feet up to over 2.5 feet (**Table 2-98**).

The largest opportunity for storage, based strictly on the difference in hydrological characteristics between pre-development and 2007 vegetation communities, is the portion of the Rookery Bay watershed north of Belle Meade. Restoration of hydrology in these areas could lead to large-scale improvements in both functional value and hydrological storage. Not included in this assessment is the potential benefit to downstream estuaries as a result of attenuating freshwater flows. To the extent that improved storage in northern Belle Meade would restore healthier salinity regimes in downstream estuaries, this would further contribute to the resource protective value of such projects.

Table 2-98. Resource Protective Capacity for Additional Storage

PDVM	Existing (2007) FLUCCS	Additional Storage Capacity
Open Water	Freshwater marsh, cypress, or swamp forest	≥ 1 foot
Open Water	Wet prairie, dwarf/scrub cypress	≥ 1.5 feet
Open Water	Hydric flatwood, hydric hammock	≥ 2 feet
Open Water	Mesic flatwood, mesic hammock	≥ 2.5 feet
Open Water	Xeric flatwood, xeric hammock	≥ 4 feet
Any	Developed	0
Freshwater Marsh, Cypress, or Swamp Forest	Wet prairie, dwarf cypress	0.5-1 foot
Freshwater Marsh, Cypress, or Swamp Forest	Hydric flatwood, hydric hammock	1-1.5 feet
Freshwater Marsh, Cypress, or Swamp Forest	Mesic flatwood, mesic hammock	1-2 feet
Freshwater Marsh, Cypress, or Swamp Forest	Xeric flatwood, xeric hammock	≥ 3 feet
Any natural system	Same system	0

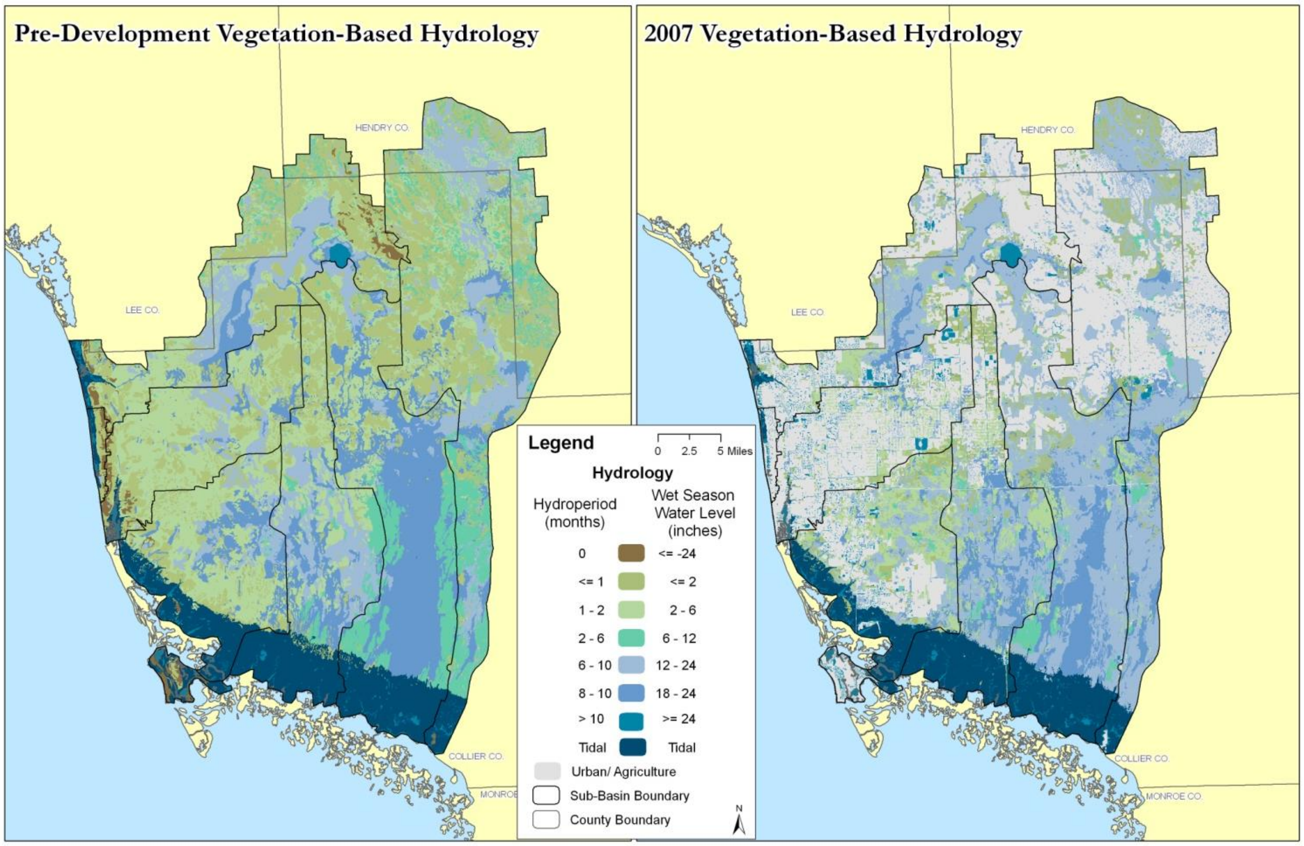


Figure 2-107. Hydrology of Pre-Development and 2007 Vegetation

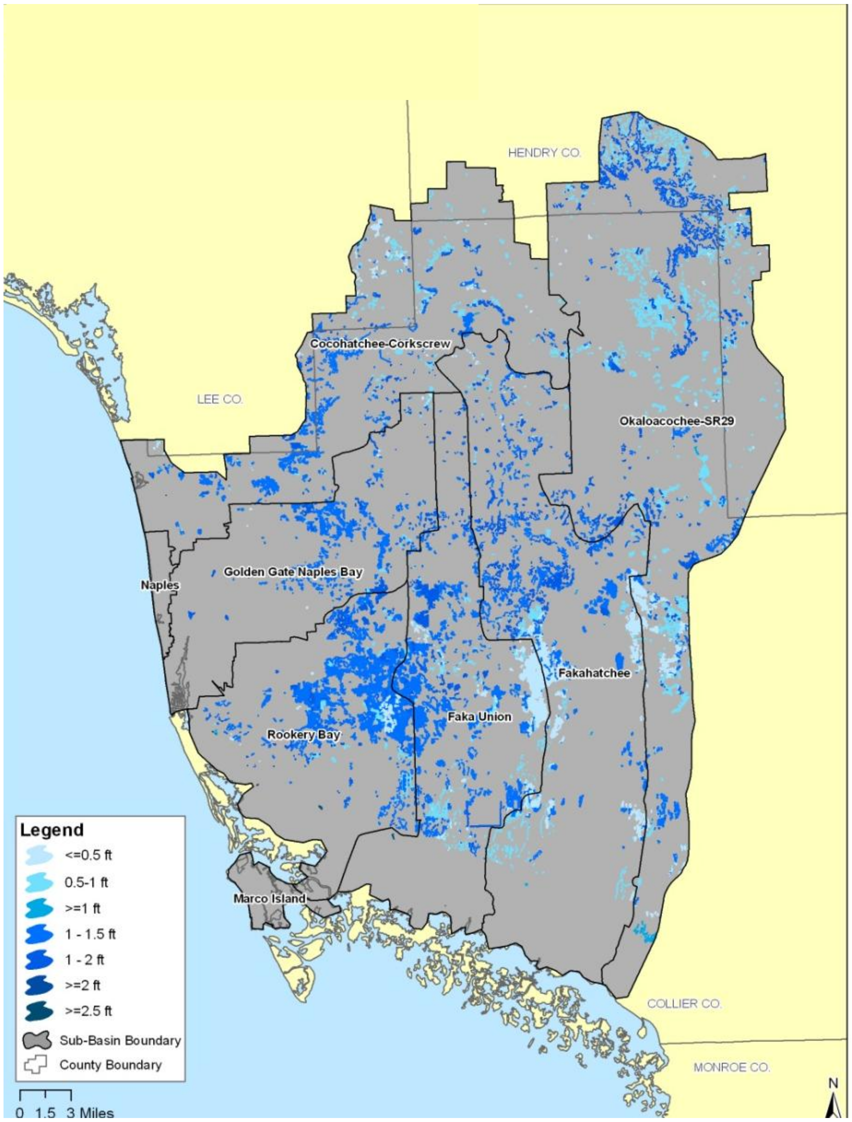


Figure 2-108. Resource Protective Systems' Wet Season Water Storage Potential

Table 2-99. Resource Protective Capacity for Additional Water Storage in Watersheds

Potential Additional Storage	Additional Acres, by Watershed				Total (acres)
	Cocohatchee Corkscrew	Golden Gate Naples Bay	Rookery Bay	Faka Union/ Okaloacoochee SR 29/ Fakahatchee	
0.5–1 foot	277	75	694	2,042	3,087
0.5-1 feet	285	7	42	1,919	2,254
0.5–1 feet	571	14	84	3,839	4,508
1–1.5 feet	2,071	2,026	7,673	8,612	20,381
1–2 feet	677	472	1,611	3,935	6,695
<=0.5 f00t	292	21	219	6,304	6,837
>=1 foot	7	2	5	80	94
>=2 feet	1	0	0	0	1
>=2.5 feet	0	1	5	3	10
n/a (urban)	50,200	55,029	21,619	74,047	209,030

2.8.5 Non-Native Invasive Vegetation

The presence of non-native invasive vegetation can significantly degrade wildlife habitat functions, as documented by many studies, including studies specific to southwestern Florida (e.g., Myers 1975). This section describes the extent of non-native vegetation in the study area.

2.8.5.1 Methods

Due to the potentially significant impact of non-native invasive species at a watershed level, several data sources, government agencies, and non-profit organizations were consulted to determine the availability of comprehensive, County-wide, accurate GIS coverages of non-native exotic vegetation. However, no GIS data layers were found that provide a sufficiently comprehensive and accurate coverage of the six watersheds to incorporate these into the functional assessment method. The two best sources of identified data are the Florida Natural Areas Inventory (FNAI) Florida Invasive Plants Geodatabase (FLInv) for public lands and the Early Detection and Distribution Mapping System (EDDMapS) for private lands. Due to the limited extent of both of these data layers, non-native invasive vegetation was not included in the calculation of watershed-wide functional values. Instead, data from these two sources are mapped and discussed separately from the functional assessment, as well as suggestions for obtaining additional GIS data for this purpose.

2.8.5.2 Results

The data presented in **Table 2-100** and **Figures 2-109 and 2-110** represent the most up-to-date and accurate GIS sources available at this time. Due to the lack of comprehensive non-native invasive species data on private lands, the most suitable use of these GIS data sources is to evaluate the effects of non-native invasive species on publicly managed lands, in combination with the other factors described earlier in this Chapter.

The public lands with the greatest extent of non-native invasive species on these maps are the Belle Meade and western Corkscrew Swamp areas. Comparing the non-native invasive species maps to the functional assessment and hydrological storage data for these two areas, the greatest opportunity for multi-function improvement on public lands occurs in northern Belle Meade. Projects in this area would achieve improvements in overall functional value (particularly if coupled with restoration of adjacent private lands), large potential improvements in hydrological storage, and improvements in natural vegetation communities.

A more thorough analysis and comparison that incorporates non-native invasive species coverage is only possible with the development of additional GIS data layers for private lands. The primary options include remote sensing via multi-spectral imagery coupled with unsupervised classification and a more detailed mapping via hyperspectral imagery, LiDAR, and supervised classification based on existing known non-native invasive vegetation data points. Multispectral imagery and unsupervised classifications can be expected to achieve overall accuracy of 60 to 70 percent. A more detailed and accurate mapping of non-native invasive vegetation can be accomplished using hyperspectral imagery, LiDAR and supervised classifications.

Table 2-100. Acres of Non-native Invasive Species
on Publicly Managed Lands

Watershed	Brazilian Pepper	Cogon Grass	Downy Rose-Myrtle	Melaleuca	Old World Climbing Fern
Cocohatchee-Corkscrew	16,052	3,041	3,747	13,246	11,942
Golden Gate-Naples Bay	985		37	828	829
Rookery Bay	1,674	1	166	8,438	421
Faka Union, Okaloacoochee-SR29, Fakahatchee	6,415	271	0	206	106
Total Area	25,125	3,313	3,950	22,719	13,298

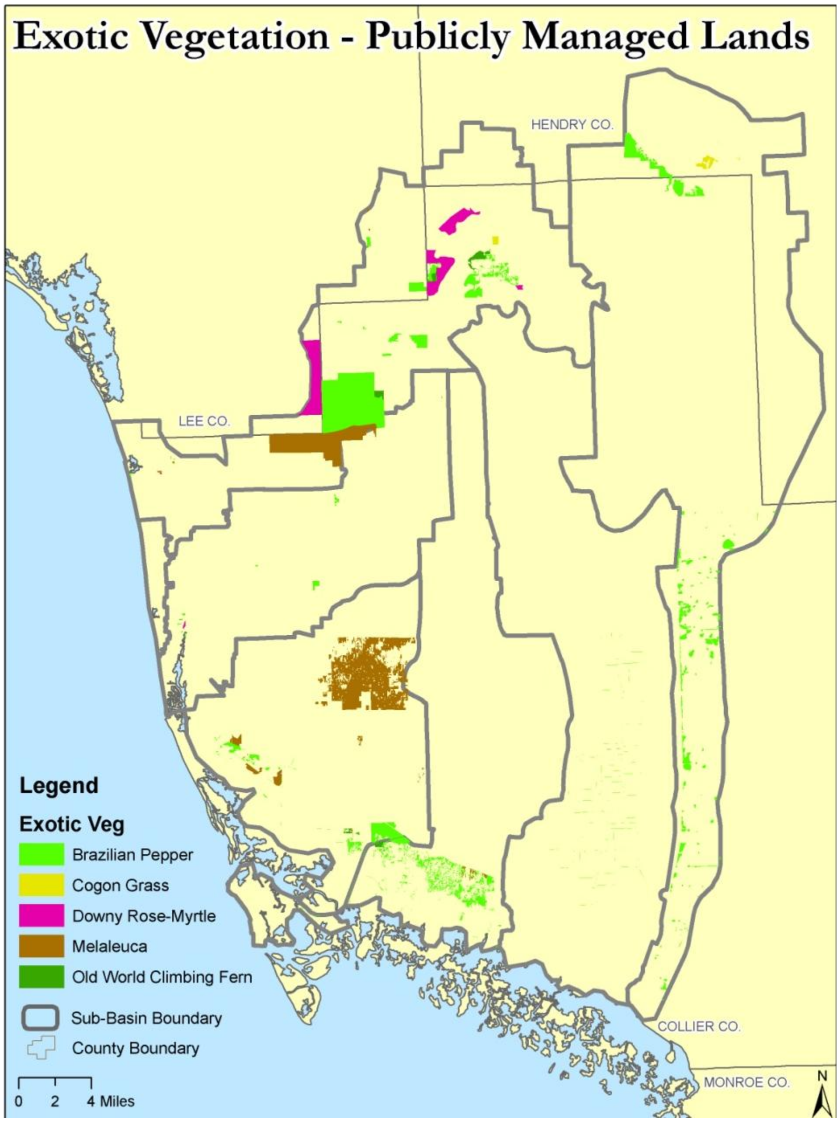


Figure 2-109. Non-native invasive Species on Public Lands
(Source: FNAI)

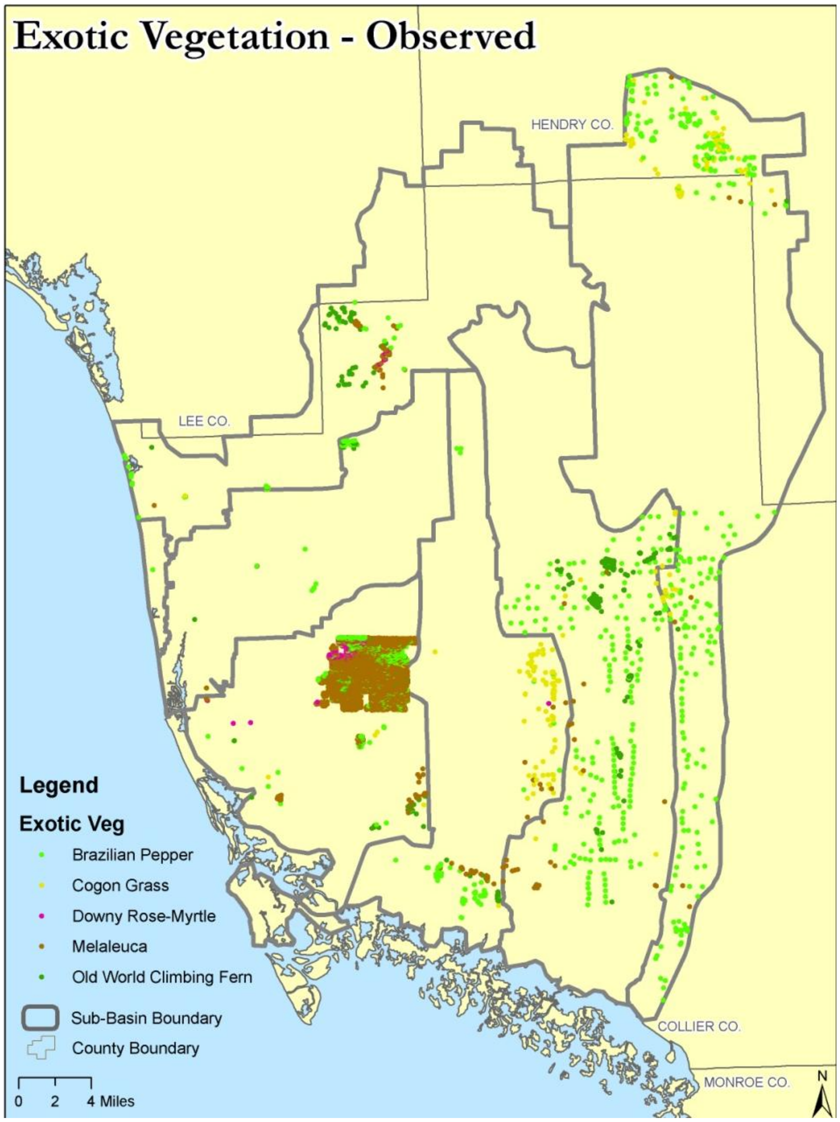


Figure 2-110. Non-native invasive Species Observation—Point Data (Source: EDDMapS)

2.8.6 Resource Protective Lands

The results of the functional assessment indicate declining resource protective scores in the Golden Gate-Naples Bay Watershed, as well as the western Cocohatchee-Corkscrew Watershed, and Belle Meade portion of Rookery Bay watershed. In these watersheds, the relatively lower functional value has resulted from conversions of natural lands to agricultural or other developed land uses. Reduced resource protective values in the Faka Union watershed, in contrast, are primarily related to impacts to the regional historical drainage patterns.

Resource protective and supportive lands were identified in the watersheds via consideration of LSI and vegetation scores. The hydrology score was not included in this analysis, due to focus on natural and passive land use management rather than identification of hydrological restoration projects. Three groups of LSI and vegetation scoring ranges designated, reflecting their degree of compatibility with preserved lands. All three categories support resource protective functions and are listed below.

- Natural areas with the highest resource protective value are those showing an LSI score of 10 and a vegetation score of 8 or higher. These areas are labeled “Resource Protective Lands” on **Figure 2-111** and **Figure 2-112**.
- Additional supportive agricultural lands, with a vegetation score of 6 to less than 8 and LSI score of 8 to less than 10, indicate pasture and similar passive land uses. These lands are identified as “Resource Supportive Lands” in **Figure 2-112**.
- Other agricultural lands, with a vegetation score of 4 to less than 6 and LSI score of 6 to less than 8, are identified as “Agricultural Supportive Lands” in **Figure 2-112.**

Collier County and the SFWMD have put in place programs to help preserve areas of high resource protective value. The functional assessment analysis conducted as part of this study provides a means of identifying lands in the three categories listed above, resource protective lands, resource supportive lands, and agricultural supportive lands that may not be included in the County’s or the SFWMD’s preserved/Sending lands and supportive agricultural lands programs. The process consisted of comparing the extent of currently protected areas through the County or State programs with the extent of each of the protective/supportive lands identified herein. **Figures 2-111 and 2-112** also show the areas under the Preserved and Sending lands programs.

Results of this analysis indicate that, although much of the preserved lands are in areas where the vegetation and relative location provide high-value resource protective functions, areas in and adjacent to the preserved lands also contain supportive land uses. Continued or improved management of passive land uses in these areas provides opportunities for additional resource protective improvement. Recommendations that would help contribute to the protection of the identified protective/supportive lands in Collier County. Recommendations are described in Volume 3.

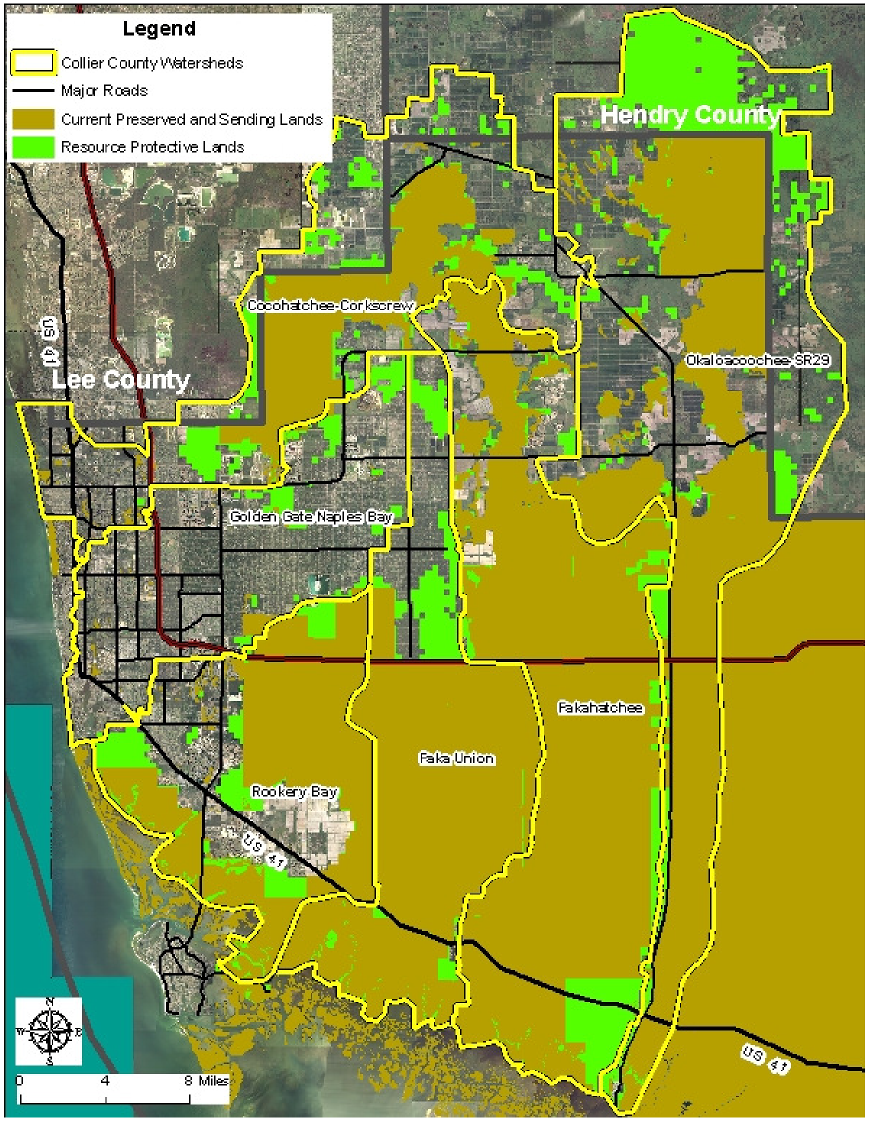


Figure 2-111. Resource Protective Lands (Based on Vegetation and LSI Scores)

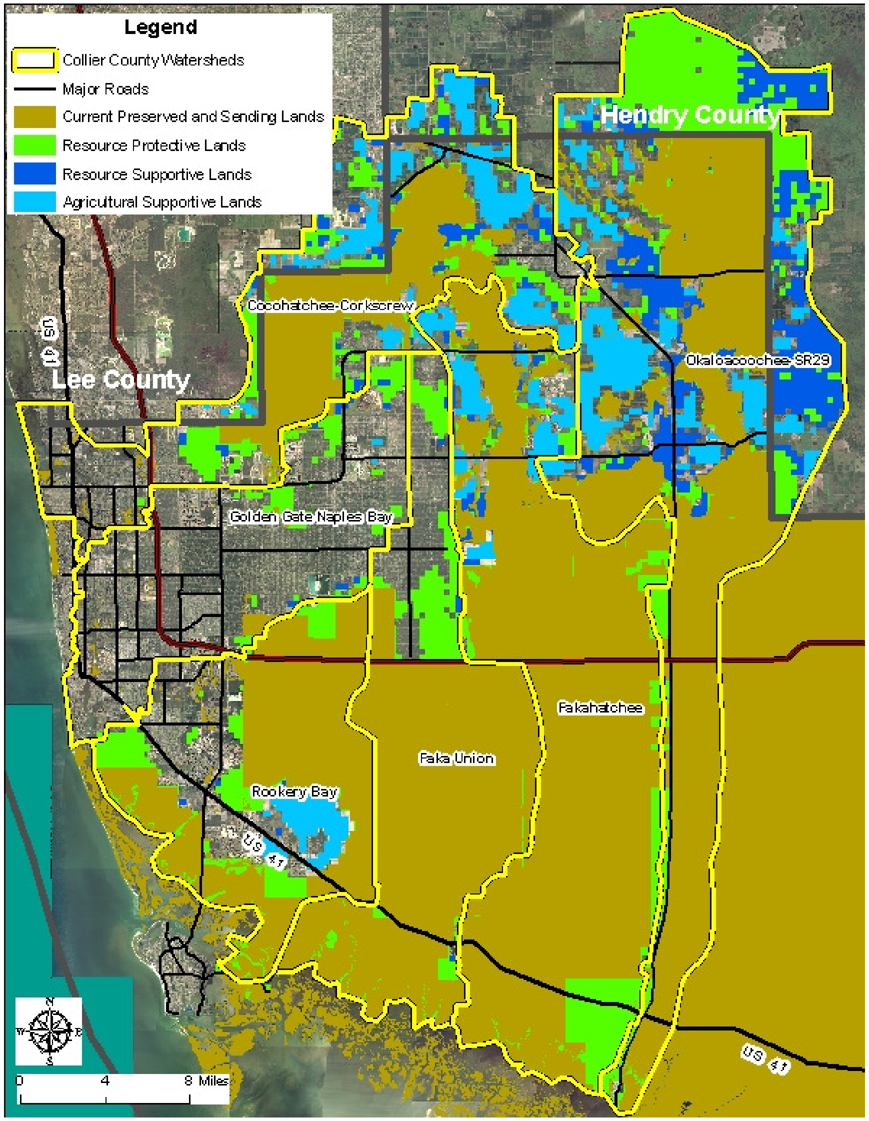
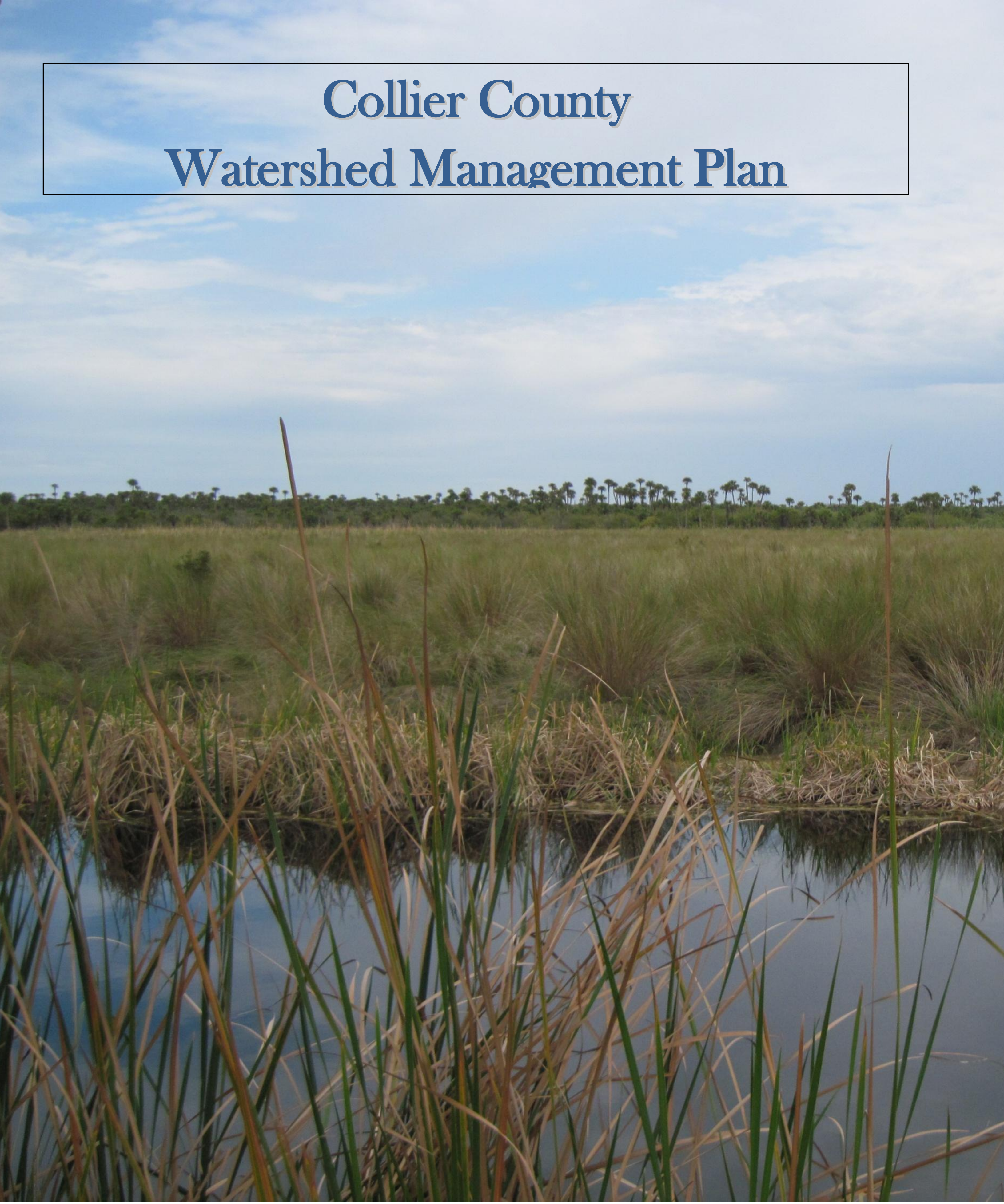


Figure 2-112. Resource Protective Lands and Resource Supportive Lands (Based on Vegetation and LSI Scores)

Collier County
Watershed Management Plan



Collier County

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