Technical Memorandum

To: Mac Hatcher, PM Collier County

From: Moris Cabezas, PBS&J
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Date: August 11, 2009

Re: Watershed Model Update and Plan Development
Contract 08-5122, PO 4500106318
Element 1, Task 4: Initial Model Comparison and Estimate of Flow to Estuaries

1.0 Introduction

The purpose of this technical memorandum is to provide a preliminary assessment of historical fresh water discharges from the County watersheds into the receiving estuaries. It addresses two major topics, a literature review and a comparison of simulation results of MIKE SHE computer models developed for the Big Cypress Basin Project Implementation Report (PIR).

The 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, PBS&J ran each of the models using version 2009 of the software.

2.0 Literature Review

In order to adequately define future water management strategies, it is necessary to understand the history of water management in Collier County. Task 1 of Element 1 of the Collier County Watershed Model Update and Plan Development is to complete a review of literature related to flows and discharges from Collier County watersheds. For this task, PBS&J reviewed more than 50 documents that 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 is referred to as the Fahka Union Basin

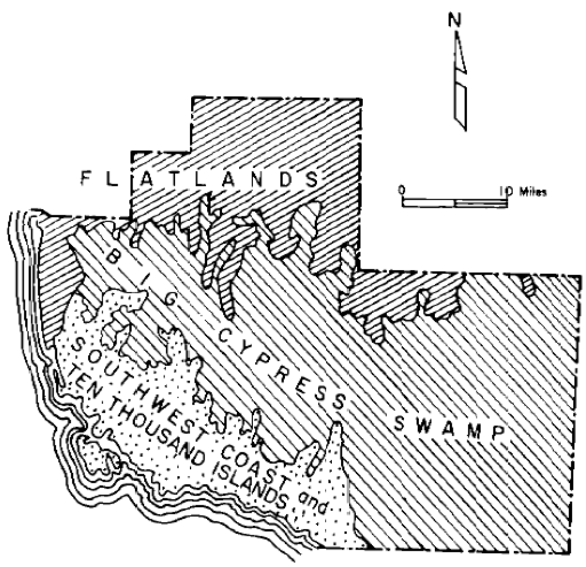
2.1 Summary of Relevant Literature

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 2-1**). 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 2-1
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 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 Fathahatchee 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 relatively high tidal range 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.

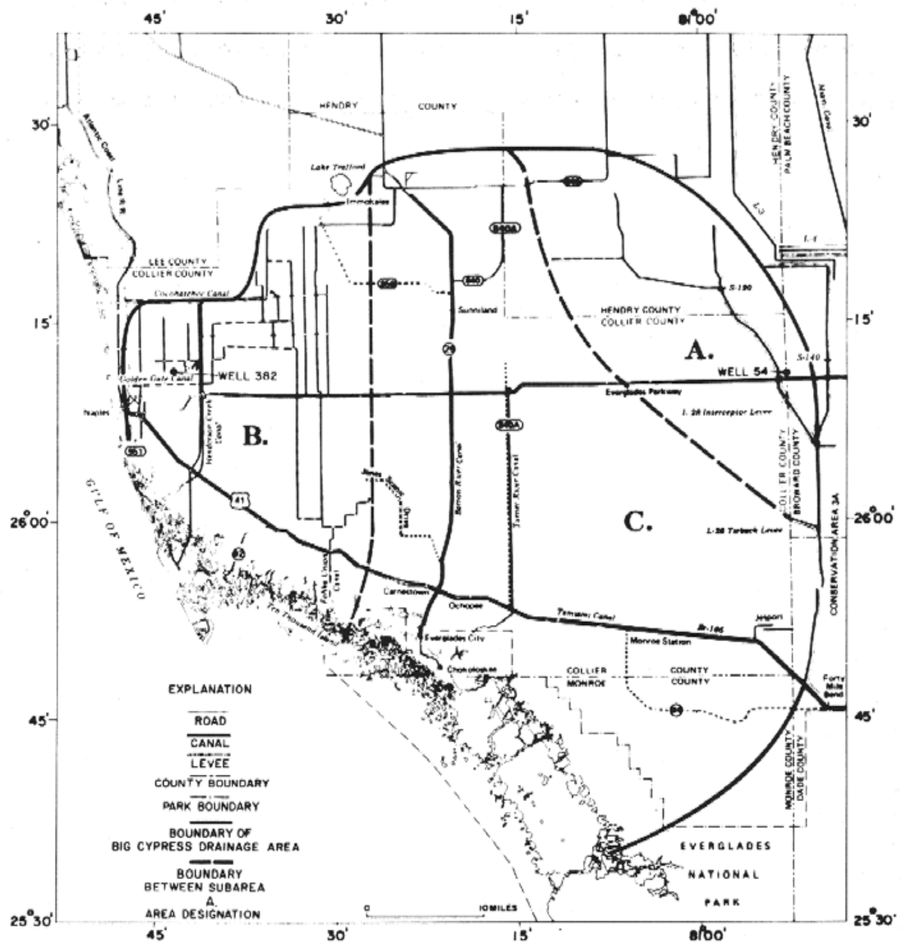
Klein, H., W.J. Schneider, B.F. McPherson and T.J. Buchanan. May 1970. Some Hydrologic and Biologic Aspects of the Big Cypress Swamp Drainage Area, Southern Florida. United States Geologic Survey Open-file Report 70003.

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 2-2**. 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 mile 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.

Figure 2-2
Map of the Big Cypress showing the delineation of the drainage area and the subareas as defined by Klein 91070)



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.

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

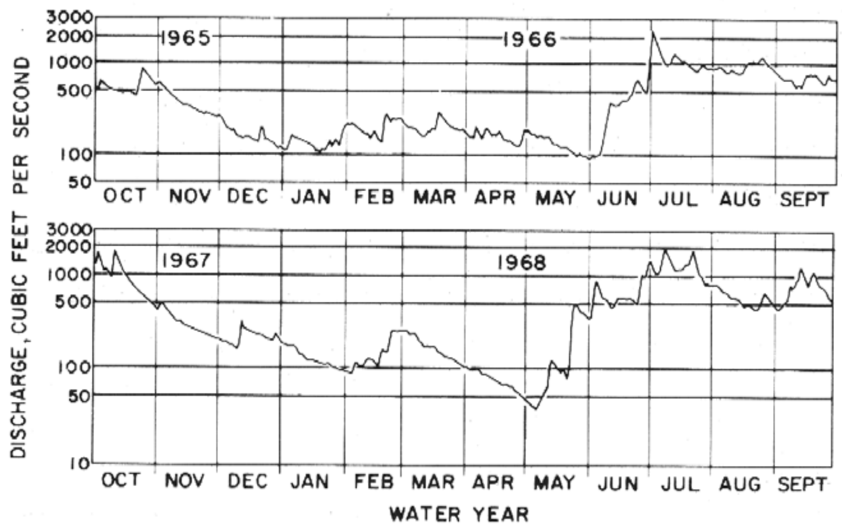
188-square mile Golden Gate Estates area in western Collier County began in the 1960s. Drainage canals, most notably the Golden Gate Main Canal and the Cocohatchee River Canal were dug to drain the western part of the estates. The Fahka Union Canal was completed to drain the southern portion in November 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 2-3** shows hydrographs of discharge for the 1966 and 1968 water years.

Figure 2-3
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 Fahka 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 Fahka 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 Fahka 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 Frieberger 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 2-4 shows post-canal construction flow paths as estimated by Frieberger. 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 Fahka Union Canals. **Figure 2-5** 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.

Figure 2-4
Map of the Big Cypress Basin Showing Direction of Overland Flow for the Period November 18 – 20, 1969 (From Figure 1 in Frieberger 1972)

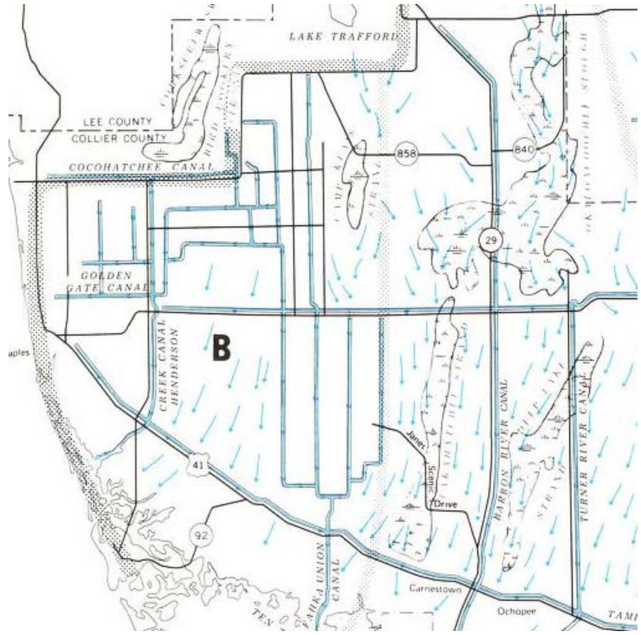
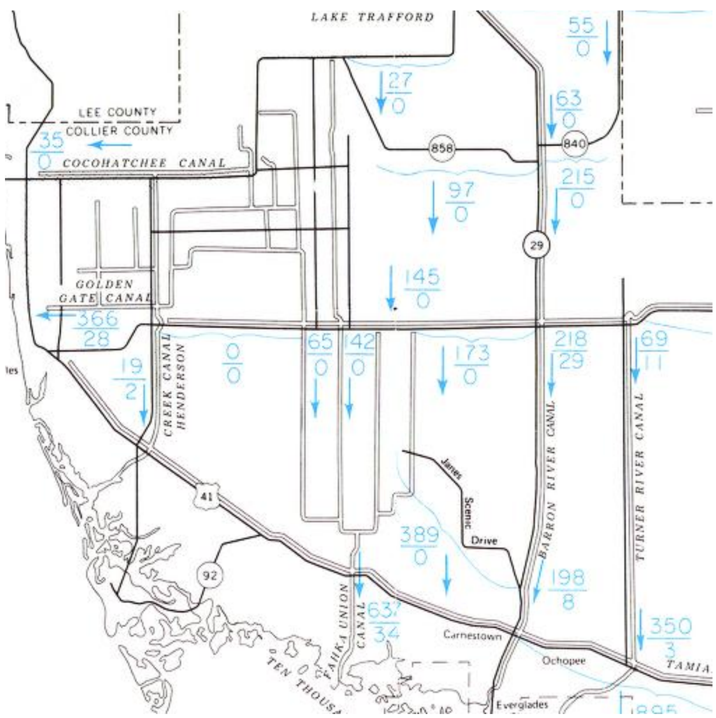


Figure 2-5
Average Measured Flow Data (From Frieberger 1972)



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

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 2-6**. 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 2-7** shows the post-canal construction drainage basins as defined by BCE (1974).

Figure 2-6
Pre-Canal Construction Basin Boundaries in Western Collier County
(From Figure 2.3 in BCE 1974)

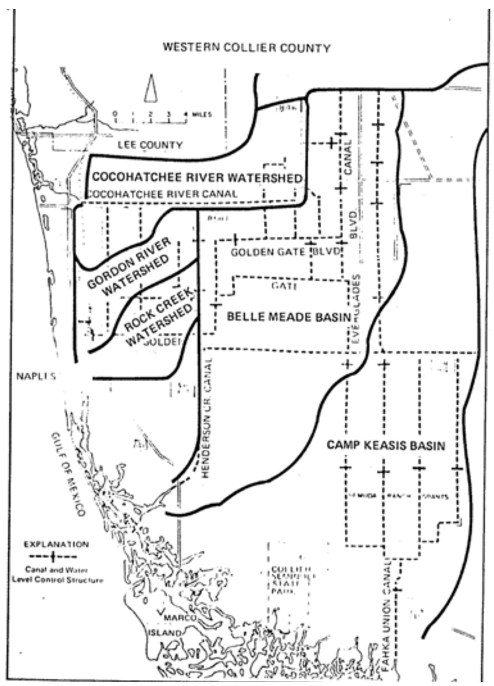
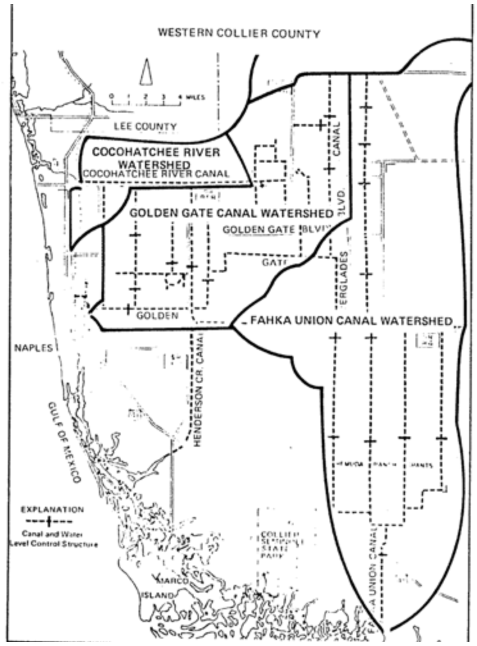


Figure 2-7
Post-Canal Construction Basin Boundaries in Western Collier County
(From Figure 2.2 in BCE 1974)



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 2-1 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 2-1.
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 1/3 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 2-2**, which lists estimated annual runoff volumes from 1965 to 1973.

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.

Table 2-2.
Annual Runoff at Stream Gaging Stations

Water Year	Annual Runoff in acre-feet Water Year (Oct. – Sept.)			
	Cochatchee 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

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 1900's, 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 ecological 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."

2.2 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.

3.0 Comparison of Computer Models and Model Results

As described in the introduction, 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. MIKE SHE models

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.

3.1 Computer Model Descriptions

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

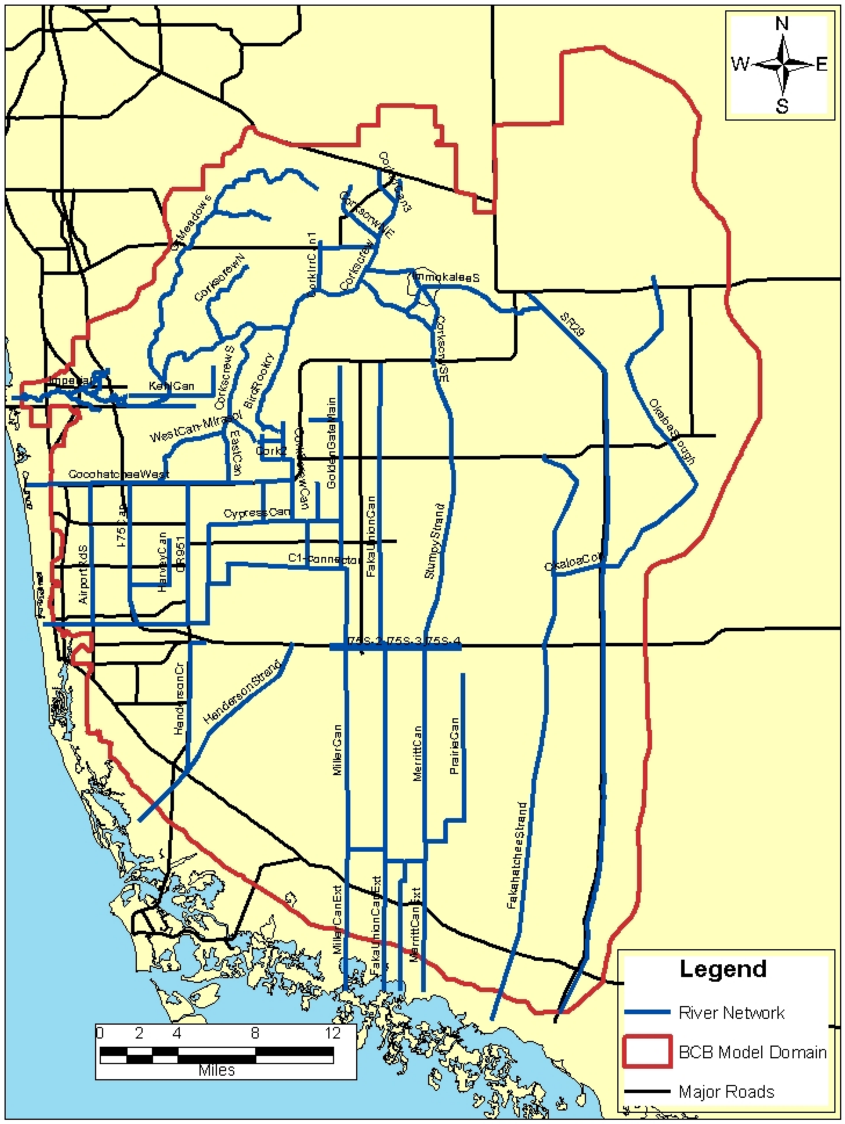
3.1.1 Existing Conditions Model

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 3-1** 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 3-1
Modeled Canal Network for the BCB Existing Conditions Model

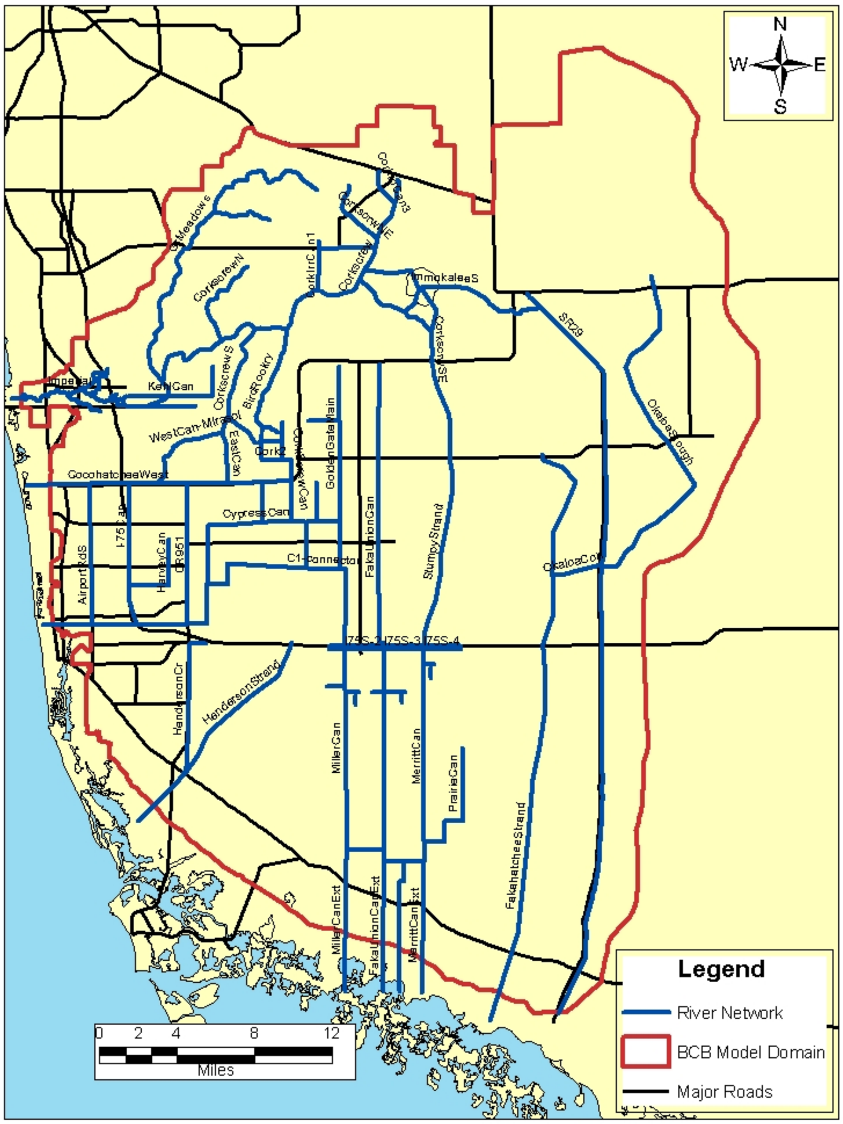


3.1.2 Future Conditions Model

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 3-2** 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.

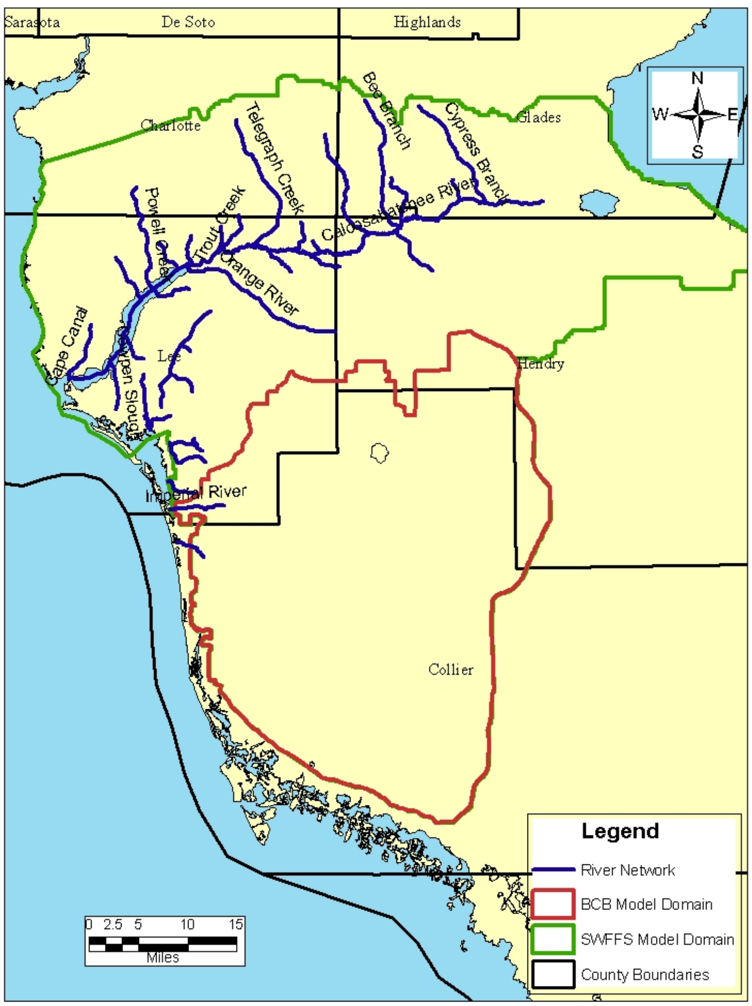
Figure 3-2
Modeled Canal Network for the BCB Future Conditions Model



3.1.3 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 3-3. Figure 3-3** 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 3-3
Model Domains and Canal Network for the Natural Systems Model



3.2 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.

3.2.1 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 1500-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.

3.2.2 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 1500-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 1500-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 based also based on a 1500-foot grid. Therefore, it was possible to directly compare to the ECM and FCM topographic data files.

Plate 1 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.

3.2.3 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 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.

3.2.4 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 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.

3.2.5 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.

3.3 Comparison of Model Results

Table 3-1 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 3-1.
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.

3.3.1 Basin Discharges

Table 3-2 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.

Table 3-2.
Annual Total Discharge per Basin

Year	Rainfall	Cocohatchee			Golden Gate			Henderson Creek			Faka Union		
	(In)	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

3.3.2 Hydroperiods

Calculated annual hydroperiod maps for the three modeled conditions are presented in Plates 4 – 6. 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.

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.

3.3.3 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. Results are consistent with the hydroperiod results described above.
`

3.3.4 Groundwater Levels

Plates 13 – 18 present comparisons of annual groundwater elevations in the surficial aquifer for 1981, 1983, and 1986. Each plate includes three (3) maps. The first map shows the average NSM groundwater elevation in the surficial aquifer. The second map shows the average groundwater elevation in the surficial 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.

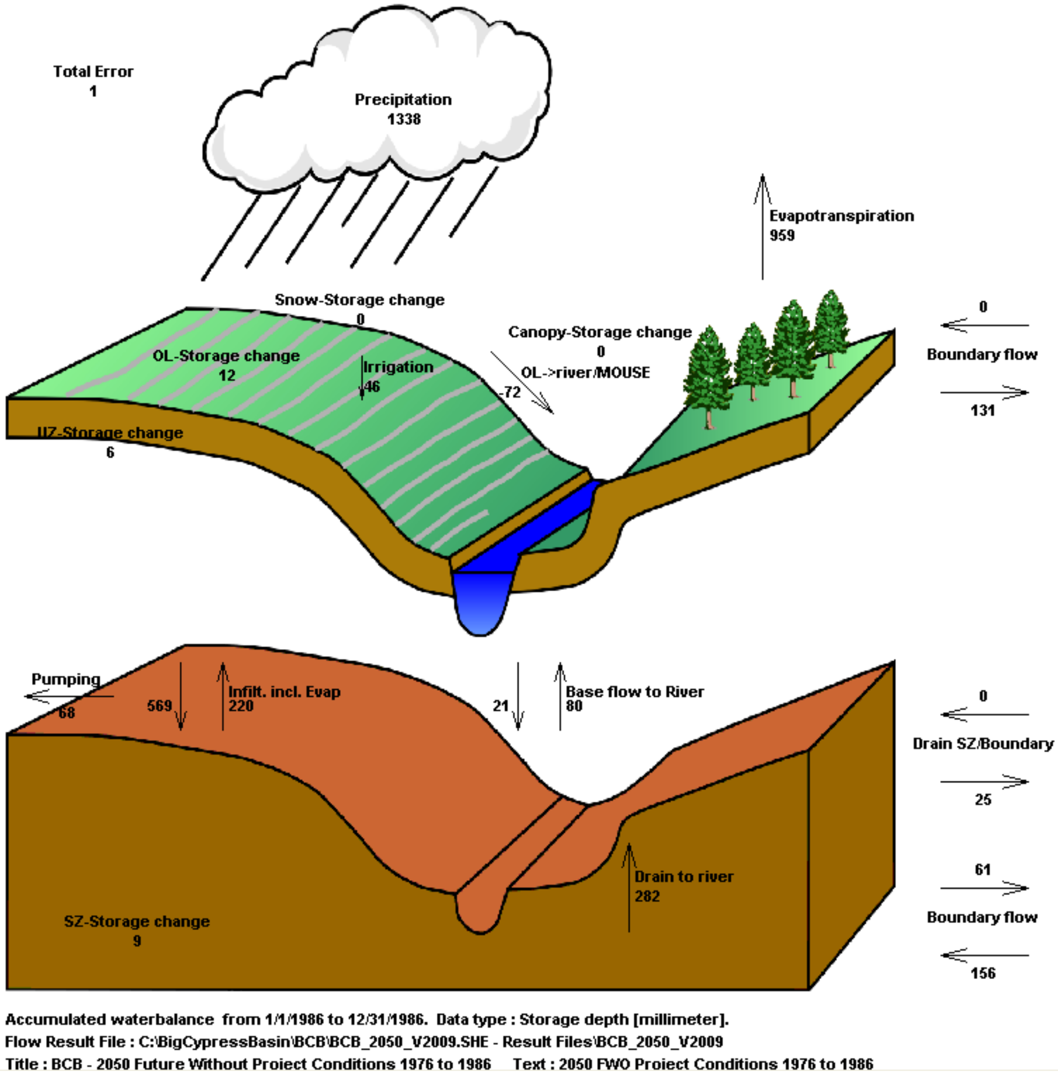
As with the Hydroperiod and Average Depth of Water results, the predicted groundwater elevations for each model appear to be reasonable over most of the model domain. The ECM and FCM model results show a depression in the water surface elevation of the surficial aquifer consistent with the location of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

3.3.5 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 3-4** shows the Total Water Budget graphical output produced for 1986 year meteorological conditions in the Future Conditions Model.

Figure 3-4
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 FakaUnion Canal subcatchments (basins). Subcatchment locations are shown in **Figure 3-5**.

The water budget comparisons for the entire BCB model domain and the four subcatchments are shown in **Tables 3-3 through 3-7**. 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.

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 3.8 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 3-8** represent the total flow from the entire model domain and may differ significantly from discharge rates from individual sub-basins, as shown in **Table 3-2**.

Figure 3-5
Defined Subcatchments (basins) in the Big Cypress Model Domain

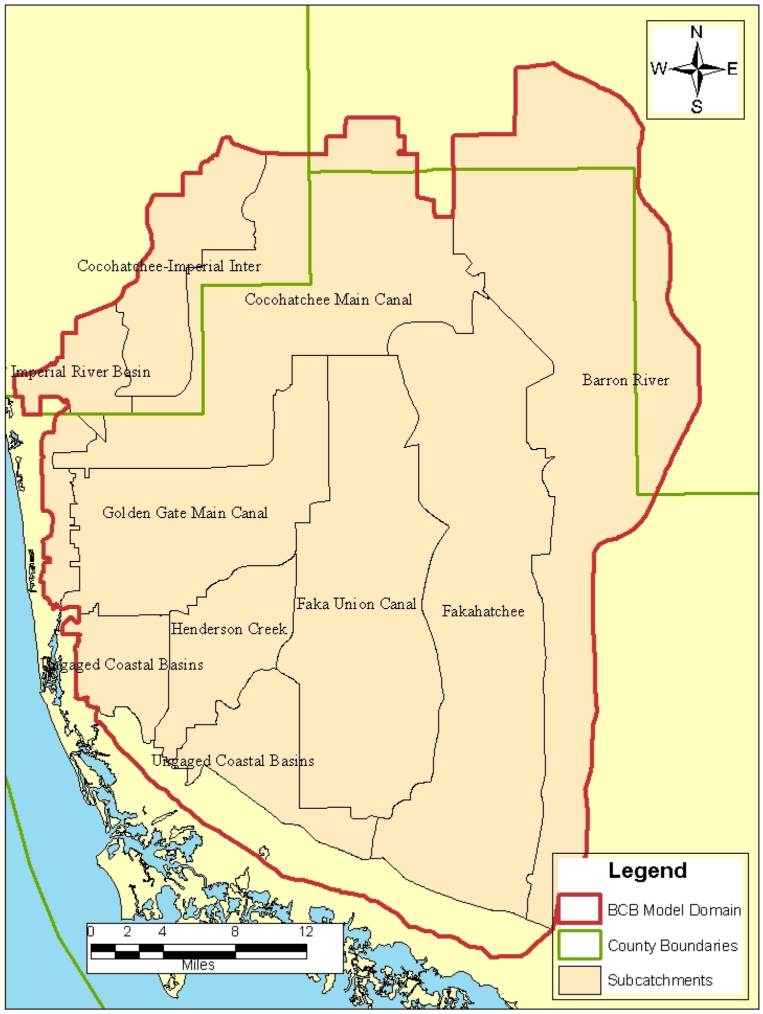


Table 3-8.
Total Runoff from the BCB MIKE SHE Models

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

Table 3-3.
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 3-4.
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 3-5.
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 3-6.
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 3-7.
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

4.0 Summary and Conclusions

In this report, 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 3-2**) 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. The model comparisons of individual rainfall years indicate that the discharge ratio compared to the NSM is largest during average years.

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