R E P O R T

WATERSHED HYDROLOGIC WATER QUALITY MODEL CALIBRATION FOR KLOSTERMAN BAYOU

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Division of Resource Management
Watershed Assessment Section
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Table of Contents

Tables

Figures

Appendices

The Florida Department of Environmental Protection (FDEP) is developing a Total Maximum Daily Load (TMDL) for the Klosterman Bayou. URS and its team member Dynamic Solutions, Inc. are developing a watershed pollutant loading model and receiving water hydrodynamic and water quality model for the Klosterman Bayou watershed for use in TMDL development. The model is intended to provide a tool for establishing the load reductions necessary to restore water quality and support the development of Basin Management Action Plan (BMAP) for Klosterman Bayou.

The tidal segment of Klosterman Bayou (WBID 1508) in Pinellas County is impaired for both dissolved oxygen and nutrients. A freshwater reach upstream and to the east-southeast of the tidal portion of Klosterman Bayou, identified as WBID 1508A, drains into the tidal section of the bayou and must, therefore, be considered in the modeling analysis. Inclusion is necessitated both by the “watershed approach” suggested by the Environmental Protection Agency (USEPA) (USEPA, 2004) and adopted by the FDEP and by the physical processes affecting the DO, BOD and chlorophyll in Klosterman Bayou.

A data summary and a model evaluation have previously been completed for the Klosterman Bayou TMDL model development (URS, 2007a, 2007b). The modeling analysis will consist of a combination of a hydrologic model Hydrologic Simulation Program FORTRAN (HSPF) and a receiving water model Environmental Fluid Dynamic Code (EFDC). The receiving water model EFDC will simulate conditions in the tidal portion of Klosterman Bayou and the adjacent offshore region. The watershed model will simulate conditions in the entire watershed, including the representation of major streams, rivers and drainage features. The watershed model will provide discharges and water quality loads representative of stream discharges via tributaries and direct overland sheetflow discharges into the estuary.

This report documents the configuration, calibration and production simulations for the HSPF model for flow and water quality. The simulated discharges and water quality loads obtained from the HSPF model during the production runs have been provided to Dynamic Solutions, Inc. for the calibration and application in the EFDC model. The documentation of the calibration and application of the EFDC model is provided in a separate report.

The HSPF model has been calibrated to daily flow data collected during the period of August through December of 2006. The model has been calibrated to monthly water quality data collected during the period from 1999 to 2006. The water quality calibration period correlates to the period of record for which water quality data was used to determine the impaired status of the Klosterman Bayou Watershed. The water quality constituents simulated in the HSPF model are dissolved oxygen (DO), biologic oxygen demand (BOD), total ammonia, nitrate+nitrite, ortho-phosphorus, phytoplankton as chlorophyll-A (corrected), organic nitrogen and organic phosphorus.

2.1 SITE LOCATION

The Klosterman Bayou Watershed is a 3.22 square mile (2,072 acres) watershed located in the central-west coast of Florida. The entire watershed lies within the jurisdiction of the FDEP's southwest regulatory district, Southwest Florida Water Management District (SWFWMD) and within Pinellas County. The majority of the watershed lies within unincorporated Pinellas County, with northern segments reaching into the jurisdiction of the City of Tarpon Springs. The Klosterman Bayou Watershed is in FDEP's Springs Coast Basin, which is a Group 5 basin. The watershed's eastern boundary is bordered by the Tampa Bay Basin (Group 1 Basin), and northern and southern boundaries are the Gulf of Mexico (WBID# 1479), Spring Bayou (WBID# 1440A), and Health Spring (WBID# 1512).

The Klosterman Bayou contains a tidally-influenced, marine segment (WBID 1508) and freshwater segment (WBID 1508A) (See Figure 2-1). The tidal segment begins at the entrance to Klosterman Bayou from the Gulf of Mexico. The bayou is considered a lagoonal embayment due to the presence of headlands both to the north and south. The headland to the north is known as Klosterman Point and the headland to the south is Danenman Point. The headland feature directly south of the Klosterman Bayou entrance was created during dredge and fill operations associated with the construction of the Klosterman Bayou finger channels and the surrounding entrance channel.

A freshwater stream section of the watershed (WBID#1508A) connects to the bayou in the vicinity of the former Seaboard Coast Railroad, which has been converted into recreational trail. Klosterman Bayou Watershed can be sub-divided into five general regions: Klosterman Bayou, North Residential, Commercial, Innisbrook, and East Residential. Figure 2-2 illustrates the location of the five general regions and defines the areal extent of each region. The demarcation of each region is geographically based and delineated by roads, property or utility easements, and land uses. Klosterman Bayou Region includes areas south of Klosterman Road and west of Alternate Highway 19. The North Residential region is split between Alternate 19, but for the most part areas north of Klosterman Road are considered as north residential. Property surrounding Alternate 19 is Commercial Region due to the presence of small businesses and the William E. Dunn Water Reclamation Facility (WED WRF). Innisbrook region incorporates the 72-hole golf course east of Alternate Highway 19, south of Klosterman Road and West of utility easements. Lastly, East Residential Region includes area east and south of the Innisbrook region.

2.2 HISTORY

Pinellas County is the most densely-populated county in Florida, but the Watershed escaped most of the residential booms experienced with the exception of the Twenty-First century, as the development of Pinellas started south and worked its way north. Figure 2-3 is a comparison of a 1947 photo of the Bayou prior to the post-war land boom of the fifties to 2006 recent development. Even though Tarpon Springs was the first incorporated town in Pinellas County, development south of the city was limited to agriculture and water-front development. In Figure 2-3, the 1947 photograph shows various dredge cuts to connect the freshwater segment to the Tidal segment. These cuts were made to aid the drainage of agriculture of upland areas to the east.

Orange groves were the predominant agriculture of the region. Most of the groves were located in the north and southeast portion of the Watershed and not adjacent to the Bayou itself. Furthermore, forestation and non-salt tolerant scrub growth of the Bayou was limited due to the tidal influences. Klosterman Bayou is a barrier lagoon which lacks protection from coastal barrier islands found to the south. The exposure to the open Gulf, low-lying nature of the Estuary, and funneling of the incoming tide by the presence of the headlands increased the probability of tidal influences further inland than normal. This interaction prohibited non-salt tolerant growth of aerated species where mangroves dominated inside the Bayou portion of the Watershed. Some mangrove species are still present today in the southern natural canal. Cypress swamps are located all around the basin prior to development and were located to the north and southeast in significant amounts. Some deforestation occurred due to the need of the timber during World War II and development.

The residential development of Klosterman Bayou began in the 1960s with the construction of a network of finger canals. Today, this area is known locally as Baywood Village, an active community concerned with the Watershed's welfare. The access channel for Baywood Village homeowners is sited north of the Bayou's entrance (See Figure 2-3). This channel is essential for recreational traffic to access the Bayou without harming the continuous shallow water turtle grasses found along the outer boundaries of the Watershed. Even with the dredged channel, access to the Gulf or to the Bayou is limited at low tides. The entry channel from the Gulf waters is directly west of Klosterman Bayou entrance, but the channel's southwest to northeast track puts the access point of the channel north of the Bayou's entrance.

After a major freeze in 1962, citrus production of the area was dramatically reduced and the urbanization of the area began. In 1970, the construction of the Innisbrook Gulf Resort began. It was completed in the early 1980's. Directly west of the course is the William E. Dunn Water Reclamation Facility (WED WRF). The WED WRF collects and treats effluent for northern Pinellas County with the exception of Tarpon Springs. Commercial activity remains limited along Alternate Highway 19 and Highway 19.

2.3 TOPOGRAPHY

The topographic coverage used for the basin modeling was the Digital Elevation Model (DEM) attained from the United States Geological Survey (USGS) obtained for the third party vendor GIS Data Depot. (http://www.gisdatadepot.com). The DEM consisted of 7.5 minute tiled data (30- x 30-meter data spacing). The data was converted to a three-dimensional raster image and is illustrated in Figure 2-4. The topography contains the northern limits of the Pinellas Ridge, where the highest segments of the Bayou exist (95 feet NGVD). Not considering the Pinellas Ridge, land surface altitudes in the Klosterman Watershed typically range between sea level and 25 feet, but the elevations are less than ten feet in the Bayou itself.

2.4 SOILS

The United States Department of Agriculture produced generalized soil maps for Pinellas County in 1972. The study indicated there are five different soil associations within the Watershed. The majority of the basin is composed of Astatula-St. Lucie association (Hydro Group A), which is nearly level and gently sloping, excessively drained, acidic, and deep sandy soils. Surrounding the Bayou, Myakka-Immokalee-Pomello association (Hydro Group C) is found. This soil is described as poorly-draining to moderately well-draining sandy soils that are weakly cemented with organic matter to depths of 40 inches or less. Surrounding the Bayou is reclaimed dredge and fill land (Hydro Group C), which is nearly level, altered soils. There are sparse Astor-association soils (Hydro Group D or B/D), which are level, very poorly-draining sandy soils that have a thick surface layer high in organic matter. These soils are located in areas with abundant cypress swamps. At the Pinellas Ridge, the soils are classified as Astatula-Adamsville association (Hydro Group A), which are nearly level and gently sloping, deep sandy soils.

The distribution of hydrologic groups in the Klosterman Bayou watershed is shown in Figure 2-5. This grouping defines a soils capability to absorb, hold, or repel surface and groundwater, based on the dominant soil type. The acreage for each of the five hydrological soil groups is listed in Table 2-1. Over 70% of the Watershed's soils are comprised of hydrologic soil group A.

Table 2-1: Area per Hydrological Soil Group

Hydrologic Group	Area (Acres)	Percentage
A	1430	70
B/D	251	12
C	138	7
D	187	9
W	65	2
Total	2072	100

2.5 GEOLOGY

Klosterman Bayou Watershed is categorized as Gulf Coastal Lowlands which drain into the Gulf Coastal Lagoon. The area has always drained the hilly upland areas of the southeast, north, and northeast into the open Gulf. Gulf coastal lowlands are typically blanketed by relict shorelines of the Pleistocene age known as terraces. These terraces are defined as a narrow coastal strips formed of deposited material, sloping gently seaward. The terrace material left behind in the Watershed basin is Pamilco, Penholoway, and Wicomico Terraces. The identification of the terraces is elevation-dependent. Therefore, the majority of the watershed is comprised of Pamilco terraces, the youngest of the terraces. Pinellas Ridge has segments of Penholoway and Wicomico Terraces. The higher terraces are comprised of coarser sand. Lower terrace deposits are finer and contain more clay and carbonate materials.

The geology of the Watershed is overlaying three hydrogeologic units: Hawthorn Formation, Tampa Limestone, and Suwannee Limestone. The Tampa Limestone dominates the basin geological framework with a thin veneer of Hawthorn Formation on top. Tampa limestone is generally a hard, sandy limestone and its color varies from white to tan. It contains a presence of small cavities caused by shelly material being dissolved out of the rock. This feature allows drainage of surface areas to underground solution channels. For the majority of the basin, the location of the Florida Aquifer is within Tampa Limestone formation. The subsurface salinity boundary layer is between 0 to 100 feet in depth from north to south. The salinity boundary layer deepens at the Pinellas Ridge, where the salinity boundary is between 200 and 300 feet.

2.6 LAND USE

Land use data is available from the SWFWMD GIS database for the years 1999, 2004 and 2005 (See Figure 2-6). The 2005 data is summarized in Table 2-2. The golf course and residential areas represent the dominant land uses in the watershed, representing 25% and 42% of the total respectively. A mixture of waterbodies and wetlands, other urban landuses, and forests comprise the remaining area with 8 %, 12% and 13% of the total respectively.

Table 2-2: Land Use in the Klosterman Bayou Watershed

Level II	Land Use Designation	2005 Land Use (acres)
11	Residential Med Density 2->5 Dwelling Unit	109.1
12	Residential Low Density < 2 Dwelling Units	90.6
13	Residential High Density	671.9
14	Commercial And Services	74.5
15	Industrial	16.3
17	Institutional	3.3
18	Golf Courses	518.0
18	Recreational	40.2
19	Open Land	19.6
32	Shrub And Brush land	3.4
43	Hardwood Conifer Mixed	151.3
52	Lakes	46.9
53	Reservoirs	40.4
54	Bays And Estuaries	27.3
57	Gulf of Mexico	0.5
62	Cypress	79.0
63	Wetland Forested Mixed	33.3
64	Freshwater Marshes	43.8
64	Saltwater Marshes	1.6
64	Wet Prairies	6.0
65	Intermittent Ponds	7.7
81	Transportation	17.2
83	Utilities	70.3
	Total	2072.1

2.7 HYDROLOGY

The Klosterman Bayou receives freshwater from streams draining upland areas. The primary freshwater stream is known as the Innisbrook Canal, which flows in a northwesterly direction. This stream drains a series of storage areas, freshwater ponds and tributaries into the southeast portion of the bayou. This reach of the bayou connects to three other finger canals and one natural channel. The general flow of the canal system is westerly.

The western end of Klosterman Bayou connects to the St. Joseph Sound which is within the Pinellas County Aquatic Preserve (See Figure 2-1). The preserve at the Watershed's outflow is comprised of dense shallow water seagrasses. The seagrasses dominate the Basin's entrance because of the good to adequate flushing associated with the break of the continuous barrier islands to the west. Even though Three Rocker Bar is directly west of the entrance to Klosterman Bayou, it has only evolved in the last thirty years.

The Florida Department of Transportation (FDOT) and Pinellas County were contacted to indicate known flood-prone areas in the Watershed. FDOT did not indicate there were any flooding problems. Pinellas County noted the natural area south of the Bayou tends to experience minor flooding. For the most part flooding is not an issue. In 1981, HDR conducted a study of the Klosterman Bayou watershed (HDR, 1981). The results of the study indicate that flooding occasionally occurs in areas north of the Bayou and to the southwest. However, since the study was conducted, a detention basin has been constructed in the flood prone area. This basin has essentially eliminated flooding problems.

The rest of this section indentifies surface waterbodies and structures within the Estuary, and then discusses subbasin delineation.

2.7.1 Surface Waterbodies

There were 122 surface waterbodies identified within the Klosterman Bayou Estuary, covering a total area of 321 acres. The surface waterbodies within the watershed have been subdivided into six categories: Storage Areas, Stormwater Management Facilities (SWMFs), SWMFs-Ditch, Ponds, Bayou, and Streams. Each category was digitized in Arcmap using information from the HDR study (HDR, 1981), field observations, and the SWFWMD 2006 aerials. Table 2-3 shows the number of each waterbody type and the total acres.

Table 2-3: Identified Surface Waterbodies

Surface Waterbody Type	Description	Number of Waterbodies	Total Area (Acres)
Storage Area	Natural flooding areas for water storage during storm events. These areas are usually covered with water for 3 to 9 months.	32	195
SWMF	Stormwater Management Facilities (SWMFs) which are man-made to detain or retain excess surface water for stormwater management.	21	23
SWMF-Ditch	Man-made trapezoidal impervious or pervious open channel conveyance system to transport water during storm events.	15	4.1
Pond	Natural areas for year round water storage.	36	65
Bayou	Finger Canal system of Klosterman Bayou	1	29
Stream	Natural or man-made conveyances consistently saturated	17	4.7

2.7.2 Structures

There have been 71 control structures identified within Klosterman Bayou watershed that regulate the discharges. These structures are identified in Figure 2-7 and Figure 2-8. These structures were divided into two categories, those that were installed to regulate flow (i.e. culverts and weirs) and those that were installed for other purposes but may impact flow (i.e. bridges, fences) Of the 71 structures, 36 did not have a significant impact on the flow. The remaining structures were divided into three categories in order to guide the model configuration. The three types are: Type 1 outfalls which regulated stormwater directly at the Bayou banks, Type 2 structures which regulated flow into streams, ditches and ponds leading into the Bayou, and Type 3 structures which regulated flow into a storage area that eventually would drain to the Bayou via a Type 2 or 1 structure.

One of the most notable flow restrictions was a chain link fence found in the Innisbrook Canal. Even though it was porous, debris collected on the upstream side of the fence and constricted the flow. Two weirs were found in the watershed, but only one was operational, A8. The other is U-34. This weir has subsided and tilted so that one end is always below MSL.

2.7.3 Subbasin Characteristics

The five general regions demarcated earlier in Section 2.1 are subdivided into twenty subbasins (See Figure 2-9). These subbasins delineate the flowpaths within the watershed. Subbasin boundaries were defined based on field investigation, stormwater maps, topography, and historical information. Table 2-4 lists each subbasin with its acreage and storage capacity. The storage capacity designation (high, medium and low) are based on land use and aerial photography data and are used to guide the model configuration. Each subbasin is described in detail in the following sections.

Table 2-4: Subbasin Boundaries

Region Name	Subbasin Name	Subbasin Id	Area (Acres)	Storage Capacity
Klosterman Bayou	Baywood Village Sector04	Sub_21	33.5	Medium
	Baywood Village Sector05	Sub_20	79.2	Medium
	Baywood Village Sector02	Sub_19	32.6	High
	Baywood Village Sector01	Sub_18	32.1	Low
	Tarpon Breeze Estates	Sub_17	56.0	Low
	Eastern Stem	Sub_16	21.3	Low
	Western Stem	Sub_01	52.1	Low
	Klosterman Bayou	Sub_02*	-	n/a
North Residential	Trentwood Manor	Sub_15	75.9	Medium
	Golf Course	Sub_14	203.0	High
	East Klosterman Road	Sub_11	85.3	Medium
Commercial	Warehouse	Sub_13	60.8	Medium

Region Name	Subbasin Name	Subbasin Id	Area (Acres)	Storage Capacity
	Alternate Highway 19	Sub_12	7.4	Low
	William E Dunn WRF	Sub_10	58.4	High
Innisbrook	Innisbrook - Island Course	Sub_09	140.7	High
	Innisbrook - Highlands Course	Sub_08	272.2	High
	Innisbrook - S. Copperhead	Sub_07	135.9	High
	Innisbrook - Admin	Sub_06	58.1	High
	Innisbrook - Clubhouse	Sub_05	230.6	High
East Residential	Post Road	Sub_04	85.9	Medium
	Aldeman Rd	Sub_03	350.9	High

* Sub_02 represents the receiving water body and is not used explicitly in the HSPF model.

The Watershed boundary provided by the FDEP covered 2,063 acres. Following field investigations, the acreage increased to 2,072 acres by the addition of nine acres shown to drain into the Klosterman Bayou Watershed. The additional area is northeast of the Bayou, located at Alternate Highway 19 (Alt. 19). The watershed boundary at this location is the western edge of pavement of Alternate Highway 19. A series of ditches on the east side of Alt. 19 (Anclote River Bayou Complex (WBID #1440A)) drains into a SWMF (See Figure 2-10). The water is collected and then conveyed through an 18" corrugated metal pipe across Alt. 19 to a SWMF in Klosterman Bayou.

2.7.3.1 Klosterman Bayou Region

Klosterman Bayou region has an area of 305 acres with 30 acres dedicated to surface water and 29.3 acres containing the Bayou itself. The remaining acreage is comprised of residential and open land. The Klosterman Bayou region was sub-divided into seven subbasins to better delineate flow into the Bayou (See Table 2-4).

Western Stem Subbasin (Sub_01) contains 15.6 acres of the tidal segment of the bayou and 36.5 acres of residential land. Most surface water runoff flows directly into the Bayou as sheet flow. The subbasin has no storage capacity.

Baywood Village Sector 1 Subbasin (Sub_18) was the first area to be constructed along the Klosterman finger canals. This subbasin lies adjacent to the estuary and is comprised of a 2.5 acre finger canal and over 30 acres of residential land. At the western end of the finger canal, sedimentation is a frequent problem. Similar to Subbasin 1, Subbasin 18 drainage is considered rapid due to its limited storage capacity.

Baywood Village Sector 2 Subbasin (Sub_19) is located landward of Subbasin 18 and drains directly into the Bayou. Subbasin 19 contains a 2.0 acre finger canal with two dog-leg right canals. The rest of the basin is residential land use. Subbasin 19 extends into the North Residential region because of stormwater pipe connecting a natural surface waterbody to the Bayou. Most but not all excess surface water generated in this subbasin is directed towards the Bayou with little or no storage or soil infiltration.

Tarpon Breeze Estates Subbasin (Sub_17) does not border the Klosterman Bayou, but stormwater generated in the area eventually empties into the Bayou. The subbasin has an area of 32.6 acres with 9.8 acres dedicated to surface water conveyance or storage capacity. One basin outfall collects excess surface water from Trentwood Manor and Klosterman Road and drains stormwater through a series of conveyances discharging into a 7.7 acre SWMF (Detention Basin). At high water level, water is conveyed directly into the bayou. Subbasin 17 has medium storage capacity, due to its water retention facility and storage capacity.

The Eastern Stem Subbasin (Sub_16) has an area of 21.3 acres including 6.6 acres of Klosterman Bayou. Surrounding Subbasins 15, 12, and 21 discharge their excess water into Subbasin 16. The Bayou' depth in Subbasin 16 is extremely shallow and access is limited at low tide. The area is predominately flood prone similar to lower portions of Subbasin 17. The finger canal structure existed prior to urbanization of the area. Subbasin 16 has little or no storage as it is connected directly to Bayou.

Baywood Village Sector 4 Subbasin (Sub_21) covers 33.5 acres with 8.9 acres dedicated to surface water conveyance or storage capacity. Surface water is routed through a series of interconnected lakes that eventually drain into canal section of the Bayou.

Baywood Sector 5 (Sub_20) has maintained the original natural canal feature with mangrove swamps bordering the channel's western boundary. Subbasin 20 has 79.2 acres with 12.5 acres dedicated to surface water conveyance or storage capacity. Sixteen acres is comprised of single-family dwellings which leaves 50.7 acres of forested wetlands. Subbasin 20 adds little or no flow to the bayou due to its high storage capacity.

Klosterman Bayou Subbasin (Sub_02) is the receiving water body segment modeled by EFDC. The description of the subbasin is provided in a separate report.

2.7.3.2 North Residential Region

North Residential region has three subbasins including two subbasins that drain directly into the Bayou. The region has a total area of 320 acres with 42.8 acres dedicated to surface water conveyance or storage capacity.

The Trentwood Manor Subbasin (Sub_15) predominantly drains surface water from residences north of Klosterman Road. Originally, the area north of Klosterman Road was an orange grove, but following the 1962 freeze, the area was converted to single-family dwellings beginning in the 1970's. The total area of Subbasin 15 is 76 acres with 12.4 acres dedicated to surface water conveyance or storage capacity. Most of the area is comprised of single-family residences with excess stormwater conveyed through a series of three retention facilities which discharge directly into the Bayou. The surface water generated from Klosterman Road is mainly sheet-flow to a series of pervious-trapezoidal ditches on both sides of the road. The ditch system then conveys the excess surface run-off to the bayou.

The East Klosterman Road Subbasin (Sub_11) is comprised of commercial and residential properties. This subbasin has an area of 85 acres with 5.8 acres dedicated to surface water conveyance or storage capacity. The single-family dwellings north or Klosterman Road are older and have a high density of septic tanks. East of Alt 19 is included in the basin because of the presence of a 1.9 acre retention basin, which discharges into Bayou's eastern boundary.

The Golf Course Subbasin (Sub_14) has an area of 203 acres, dominated by 80 acres of surface water conveyance or storage. The north side of the subbasin contains 15 acres of commercial business bordered by a 74-acre golf course. To the south of the golf course, a 71 acre cypress swamp offers abundant surface water storage. Based on the swamp and surface water storage of the golf course, Subbasin 14 is considered a high storage area.

2.7.3.3 Commercial Region

The commercial region of the Bayou consists of 127 acres oriented along Alternate Highway 19. Of the total acreage, 4.1 acres is dedicated to surface water conveyance or storage capacity. Two of the commercial subbasins direct excess surface-water flow into the Bayou or Innisbrook Canal.

The Alternate Highway 19 Subbasin (Sub_12) is the smallest of the twenty subbasins. Excess stormwater generated from Alternate Highway 19 collects in pervious trapezoidal ditches and then is conveyed directly to the bayou. Subbasin 12 has virtually no storage capacity.

South of Sub_12 basin is the **Warehouse Subbasin (Sub_13)**. Subbasin 13 has 60.8 acres with four acres dedicated to surface water conveyance or storage capacity. This subbasin contains a small meandering channel which is the transition between the marine estuary and freshwater channel portion of Klosterman Bayou. .

The **William E. Dunn Water Reclamation Facility (Sub_10**) is a 9.0 MGD 5-stage Bardenpho Advanced Wastewater Treatment Water Reclamation Facility. This entire facility is contained within its own subbasin. The subbasin covers 58 acres, but the collection area for the facility is 36,200 acres covering the Northern Pinellas County, excluding Tarpon Springs. This facility was originally constructed in 1973 to treat 3.0 MGD, but the operation expanded with the closing of several similar facilities in the area. After waste water is treated the facility distributes reclaimed water for irrigation purposes. The recycled water is pumped to various new residential developments and at least three million gallons of treated water a day is routed to Innisbrook Gulf Resort through its five pumping stations (See Figure 2-11). The WED WRF subbasin is classified as high storage.

2.7.3.4 Innisbrook Gulf Resort Region

Innisbrook region has five subbasins, covering 837.7 acres. Surface water conveyance or storage capacity accounts for 117 acres of the subbasin. The majority of the flow in the region is through the Innisbrook Canal. This canal interconnects 21 ponds and 34 storage areas through a series of streams, culverts, and canals. Flow data was available for the stream for the period August 22, 2006 through December 31, 2006. A comparison of the flow data with local rainfall data indicates that there is a poor correlation between the flow and rainfall. The location of the flow monitoring station is shown in Figure 2-12 and the locations of local rainfall gauges are shown in Figure 2-13. These stations all have similar rainfall patterns. The rainfall records for one station are compared to the flow data in Figure 2-14. The poor correlation between the flow and rainfall data is due to the high storage capacity and water management practices in the subbasin.

Not all of Innisbrook Golf Resort is contained within the bounds of Klosterman Bayou watershed. The northern Copperhead Course, on the eastern portion of the watershed, is in the

Lake Tarpon Outlet watershed (WBID# 1486). Innisbrook pumps the water from the northern Copperhead course into their Highlands North Course, when the area floods. Innisbrook officials indicated this is rare and occurs at the most twice annually.

Innisbrook – Highlands Course (Sub_08) is located at the northern section of the Innisbrook area. The total area of the subbasin is 272 acres with 45.8 acres associated with surface water conveyance or storage capacity. Subbasin 8 is bordered by the Northern Copperhead Course to the east. Flow from this subbasin is not stream-defined in the north because it is either stored or runs off as sheet flow to various ponds or streams. This section does contain an older residential development to the west which conveys excess surface water to the south into a cypress swamp that borders the Innisbrook canal. At the southern boundary of the subbasin is the Innisbrook Canal. The last pond of the canal contains two tidal-flap gates to prevent flow from entering into Innisbrook. During the field investigation, one gate was permanently left open. Upstream from the flap gates is a failed weir. Innisbrook officials indicated that plans to construct a new weir are currently being investigated by their Board of Directors.

The Innisbrook – Island Course Subbasin (Sub_09) is immediately south of Subbasin 8. This subbasin contains the location of the flow gauge used to calibrate the model's flow data. The collection site is located upstream of Structure A-8 identified in Figure 2-9. A-8 is a weir downstream of 1,200 foot long-narrow trapezoidal pervious stream segment which drains five subbasins downstream of Subbasin 9. The 1,200-foot long-narrow stream is heavily vegetated with aqueous and aerial plant species. The channel's embankments are composed of various grasses and shrubs, but the weir's flanks are fortified with rip-rap. There is one pond located in this subbasin, which acts much like a stream due to its narrow width and limited area. At the southern end of the subbasin lies the Wildlife Preserve within Innisbrook. The northern border of the preserve is the Innisbrook Canal, but essentially the preserve is a large cypress swamp which collects water from two subbasins and empties into the Innisbrook Canal.

The Innisbrook – South Copperhead Subbasin (Sub_07) has an area of 135.9 acres with 5 acres associated with surface water conveyance or storage capacity. The eastern residential region contains numerous retention areas which cannot be demarcated accurately with the data currently available. Furthermore, this densely-populated segment is comprised mostly of multi-family dwellings and some single-family residences. Most of the flow from the eastern residential area is probably subterranean. Most surface flow in this basin is minimal and contained with the subbasin with the exception of flow generated by impervious surfaces around the administrative and sales office. Surface water flow is directed into the Wildlife Preserve by a 12" PVC culvert pipe.

Innisbrook – Administration Subbasin (Sub_06) has 58 acres with 4.7 acres dedicated to surface water conveyance or storage capacity. Two surface stream flows met prior to being conveyed to the wildlife preserve to the west. The first stream flows southward and interconnects the upper portion of the basin to the second stream. An 18" reinforced concrete pipe conveys water across Olde Post Road and into a collection area to be conveyed to the second stream. The second stream connects larger ponds to the south and then discharges into the Wildlife Preserve. The subbasin's area is the smallest in Innisbrook because of topography and manipulation of land to control water flow.

The Innisbrook – Administration Subbasin (Sub_05) total area is 230.6 acres with 51.8 acres dedicated to surface water conveyance or storage capacity. This is the highest percentage of surface water area to total subbasin area in the Klosterman Bayou Watershed. The majority of the low flow results from the flow gauge are probably the result of this area's capability to store water or infiltrate excess water. Like all subbasins in Innisbrook, this area is mostly comprised of golf courses with the exception of the southeastern portion of the subbasin. This part is comprised of sparsely-populated residences, where excess flow is directed to a pervious-trapezoidal ditch along the Innisbrook golf course boundary.

2.7.3.5 East Residential Region

Most of the urbanization of this area began after freezes in 1983 and 1985, which wiped out the remaining agriculture in the watershed. There is a series of pervious-trapezoidal ditches that outline the eastern end of the Innisbrook property line, but for the most part surface water flow is minimal because of the presence of various stormwater management facilities. Furthermore, the location of cypress swamps at the corners of the two subbasins divide the East Residential area.

Post Road Subbasin (Sub_04) is located directly east of Subbasin 6. Of the 86 acres in Subbasin 4, 29.4 acres are multi-family dwellings, 25.5 acres of single-family dwellings and 2.4 acres associated with surface water conveyance or storage capacity. Due to urbanization, stormwater runoff is rapid and storage capacity is low in this subbasin. The majority of flow from this subbasin is conveyed through a series of canals and culverts which discharge through a north-south trending, pervious-trapezoidal ditch into a cypress swamp in Subbasin 3.

Aldeman Road Subbasin (Sub_03) contains a mixture of commercial, multi- and single-family residences and wetlands. This basin also contains the only segment of the Pinellas Ridge within the watershed. The excess water generated by impervious surfaces is either moved to stormwater management facilities or the cypress swamp that borders to Subbasin 4. However, the excess water is more than likely infiltrated in the soil and recharged to the Floridian aquifer at the Pinellas Ridge. Storage capacity is high for the subbasin, due to absorption into the cypress swamp and infiltration into the aquifer.

2.8 CLIMATE

The climate of the basin is found to be marine subtropical with mild winters and long, hot and humid summers. The humid summers typically start in May and taper off in Mid-October. The average annual temperature is 71.8 degrees Fahrenheit. The average high is 81.3 degrees Fahrenheit. In the summer months, the temperatures range from the low 70s in the morning and climb to the high 90s by mid-afternoon. The average low is 62.1 degrees Fahrenheit. In the winter months, the normal daily fluctuation in temperatures can be up to 20 degrees ranging from the low 50s to the low 70s. The area has been rarely exposed to freezes.

The area is exposed to winter storms, tropical storms, and summer thunderstorms. The most recent winter storm occurred on March 13, 1993, and can be referred to as the "Storm of the Century "or "No-Name Storm of 93". This stormed caused seawalls to be overtopped with flood waters. Furthermore, many homeowners on the front of Klosterman Bayou had flooding damaged to their property. Other winter storms, such as those occurring in 1962, 1983 and 1985, dipped below the freezing mark for 3.5 days. Tropical storms impacting the area were the following: Tarpon Springs Hurricane (1921), Hurricane Easy (1950), Hurricane Gladys (1968), Hurricane Elena (1985), and Hurricane Frances and Jeanne (2004). During the summer months, the area is blanketed with afternoon thunderstorms with an average of 85.1 thunderstorms a year.

The basin receives a high annual rainfall. SWFWMD has summarized the historical rainfall amounts annually for each of the CWM basins since 1951. The annual rainfall for their Tampa Bay/Anclote River watershed during a 91-year period is 54.81 inches. 1959 recorded the maximum amount of rainfall at 83.07 inches. 1956 experienced the lowest annual rainfall of 32.95 inches. Between 1999 and 2006, the average rainfall recorded was 50.27 inches with the maximum amount of 67.04 inches recorded in 2004. Figures 2-15 (a and b) show the annual average rainfall for the two gauges and the seasonal variations in rainfall. The two sites correlate well and show a reasonable range of annual rainfall over the period of interest. The seasonal average is based on the eight years of data and indicates a distinct wet and dry season, with the wet season occurring from June through September and the dry season occurring from October through May.

2.9 WATER QUALITY

A review of the water quality data available in the Klosterman Bayou Watershed did not reveal any data in the freshwater portions of the stream nor in any freshwater surface water bodies. However, there are two marine stations location just downstream of the Innisbrook Canal. The station locations are shown in Figure 2-12. The water quality data consists of monthly samples for the period of 1/27/1999 to 12/3/2002 for station 21FPDEMAMB02-02 and 1/14/2003 to 6/20/2006 for station 21FLPDEM02-07 for nutrients, BOD, temperature, turbidity, salinity and conductivity (As well as other constituents). The two stations are located relatively close to one another, and when the data from each station is aggregated, they cover the period from 1999 through 2006. A review of the salinity data indicates that the water was predominantly fresh during most of the sampling periods. Of the approximately 80 samples collected over the 7 year period, the salinity was 5 ppt or lower during 63 of the sampling events. These “freshwater” samples are the only data available for characterizing the freshwater water quality. Furthermore, the data only represents water quality upstream of the sampling stations, which is predominately the Innisbrook Golf Course. Time series and seasonal characteristics of the aggregated data are shown in Figure 2-16. A summary of the constituent concentrations is provided in Table 2-5. The most notable characteristics of the time series data are the decreasing trend in the total phosphorus and orthophosphate. The levels of total phosphorus and ortho-phosphorus, which have mean values of 1.08 and 0.9 mg/L, are considered very high. The dissolved oxygen data show a seasonal variation with higher monthly averages occurring in November through February and the lowest values occurring in June. Some of the variation in dissolved oxygen can be explained by seasonal variations in temperature, which affect the solubility of oxygen in water. However, the lower dissolved oxygen levels do not completely correlate with the high temperature data, indicating that the low dissolved oxygen values are occurring due to BOD and nutrient effects.

Table 2-5: Summary Water Quality Constituent Concentrations for Estuary Monitoring Station

DATE	BOD (mg/L)	Chlorophyll-A (ug/L)	Dissolved Oxygen (mg/L)	Total Ammonia (mg/L)	TKN (mg/L)	NOX (mg/L)	Total Nitrogen (mg/L)	OPO (mg/L)	TPO (mg/L)	Turbidity NTU
Average	4.35	43.86	6.60	0.11	1.77	0.27	2.06	0.90	1.08	6.97
Median	4.00	41.90	6.54	0.09	1.73	0.11	1.98	0.86	1.03	5.84
Maximum	7.00	94.80	11.41	0.49	4.36	2.30	4.45	2.64	3.58	53.00
Minimum	1.00	1.00	2.37	0.01	0.94	0.01	0.96	0.26	0.28	2.10

Effluent water quality data is available for the William E. Dunn Facility effluent discharges to the Innisbrook golf course. The data, representing the fiscal years 2001-2002 through 2005-2006 are summarized in Table 2-6. The most notable characteristic of the data is the high levels of phosphorus, for which the median value is 1.9 mg/L.

Table 2-6: Summary Water Quality Constituent Concentrations at the Dunn Facility

Percentile	CBOD	TSS	CL2	TKN	NH3	NO3	Total P	Turbidity
90	2.0	1.0	5.00	3.52	4.82	1.35	3.61	1.33
75	2.0	1.0	4.50	1.88	1.12	0.94	2.79	1.16
50	1.0	1.0	3.78	0.98	0.62	0.45	1.91	0.90
25	1.0	1.0	3.10	0.83	0.06	0.13	1.32	0.80
10	1.0	1.0	3.00	0.78	0.02	0.02	0.98	0.68

3.1 MODELING APPROACH

The primary purpose of the HSPF model implementation is to provide estimates of daily discharges and water quality loads to the EFDC model. As described in Section 2.0, there is limited flow and water quality data for use in calibrating the model. Furthermore, the flow data is poorly-correlated with local rainfall data, indicating local water management (for which there is no documentation) and a relatively large storage capacity upstream of the flow gauge. Additionally, the flow data is only representative of one primary land use, recreational golf course, and other significant land uses in the watershed, such as residential and natural lands, are not gauged. A similar situation exists for the water quality data available for calibration. Calibration data is available at one location, which is primarily representative drainage from the golf course.

The review of the basin characteristics in Section 2.0 indicates that the soils, geology and topographic features are fairly consistent throughout the watershed. The most notable difference between the various subbasins is the amount of local storage. For instance, aerial photographs of the Innisbrook Golf Course, the flow data collected on the Innisbrook canal, information obtained during a field reconnaissance and the pumping characteristics of the William E. Dunn Facility indicate that the area represented by the Innisbrook Golf Course has a large storage capacity. A review of aerials of the residential areas, as well as the identification of drainage features obtained during the field reconnaissance, indicate that the residential areas adjacent to the bayou drain quickly with little or no storage. Alternately, there is evidence of natural storage and some retention facilities in the watershed which offer a moderate level of storage.

Due to the limited flow calibration data, the general approach for the flow calibration was designed to capitalize on the similarities in hydrology across the watershed, and then use estimates of the storage and structures to differentiate the drainage characteristics of the un-gauged subbasins. Thus, the model parameters for the areas upstream of the flow gauge were calibrated to the flow data and the hydrologic parameters obtained via the calibration were used to represent all other subbasin's hydrologic parameters in the model. However, the model parameters representing storage and drainage for each subbasin were set separately, based on the detailed knowledge of the subbasins discussed in Section 2.0. Due to the short period of flow data, only a model calibration was possible, and no model validation was conducted for flow.

Likewise, the water quality data available for calibration and validation also represented a portion of the entire watershed. Therefore, model parameters affecting water quality loads from subbasins upstream of the measurement station were calibrated to the measured data. The calibration included parameters representing surface runoff concentrations, as well as nutrient cycling and dissolved oxygen processes in the storage and drainage model components. For the configuration of the subbasins that were not represented in the measured data, the surface runoff concentrations were calibrated to mean concentrations associated with the land use categories within the subbasin. Typical values for nutrients, BOD and TSS for specific land uses were adopted from Harper (1992, 1994) and ERD (2003). The same in-stream model parameters, which control the nutrient, BOD and dissolved oxygen dynamics in the storage and drainage features obtained for the calibrated subbasins, were applied to the storage and drainage features in all of the other model subbasins. The eight-year time period of the water quality data were divided into two four-year periods, the first (1999 through 2002) for calibration and the second (2003 through 2006) for validation.

The calibration was conducted for the hydrodynamics first, then temperature and then the remaining water quality constituents. This order was used because changes in the hydrodynamic calibration can have significant effect on the water quality loads simulated with the build-up and washoff algorithms. The water temperature followed because it can be done independent of the other water quality parameters and influences the runoff concentrations of dissolved oxygen.

WinHSPF version 12.1, as available in Basin 4.0 (USEPA 2003) interface, was used for all modeling analysis.

3.2 MODEL CONFIGURATION

The basic model configuration consists of designating 20 subbasins which correspond to the 20 subbasins identified in Section 2.0. The land use, soils type and elevation data was projected into NAD_1983_UTM_Zone_17N, and then, slopes were mapped onto each HSPF model PERLND/IMPLND segment (i.e. subbasin) using the WinHSPF configuration tools A subbasin delineation was created specifically for representing the subbasins identified in Figure 2-9 and all of the data were used to configure the HSPF subbasins. The HSPF model representation of the subbasins and their connectivity is shown in Figure 3-1, along with the flow and water quality calibration points. The segment 2 was used to collect all of the segment discharges, but was not explicitly used for output from the model. The delivery points for the EFDC model are the 11 connections to segment 21. The land use designation for each of the 20 model subbasin is shown in Table 3-1.

Table 3-1: Land Use Designation for Each Model Subbasin

Reach ID	Subbasin ID	Urban-Impervious	Urban-Pervious	Open Land	Forest Land	Wetlands/ Water	Golf Course/ Recreation	Range Land	Total (acres)
Reach 21	Sub21	9	9	12		3			33
Reach 20	Sub20	10	10		33	7	15	3	78
Reach 19	Sub19	11	1		8	3			23
Reach 18	Sub18	15	15		1	2			33
Reach 17	Sub17	24	24			9			57
Reach 16	Sub16	8	8			5			21
Reach 15	Sub15	33	33			9			75
Reach 14	Sub14	22	22		14	73	73		204
Reach 13	Sub13	17	17		26				60
Reach 12	Sub12	4	4						8
Reach 11	Sub11	40	40		4	1			85
Reach 10	Sub10	18	18			21	1		58
Reach 9	Sub9	17	17		15	92			141
Reach 8	Sub8	25	25	3	47	19	153		272
Reach 7	Sub7	29	29			2	75		135
Reach 6	Sub6	7	7			9	35		58
Reach 5	Sub5	31	31		7	54	107		230

Reach ID	Subbasin ID	Urban-Impervious	Urban-Pervious	Open Land	Forest Land	Wetlands/ Water	Golf Course/ Recreation	Range Land	Total (acres)
Reach 4	Sub4	35	35			13	3		86
Reach 3	Sub3	154	154	4	10	29			351
Reach 1	Sub1	17	17			13	4		51

Each HSPF model subbasin has a reach/reservoir (RCHRES) associated with it that includes physical parameters describing its width and length and an F-Table which describes the discharge-volume-stage relationship. Initial estimates for each reach/reservoir element was obtained using the WinHSPF configuration tool with a shapefile containing the stream/canal delineations. FDEP provided the original polyline shapefile, NHDFlowline, for stream delineation, which is based on data from the National Hydrography Dataset (NHD). The initial estimates for the reach/reservoir parameters are shown in Table 3-2.

The 2006 aerial photography was used to obtain the channel width and depth. Slopes and minimum and maximum elevation were estimated from the topographic data. The initial reach/reservoir length and width were modified during the calibration processes to account for the additional storage in some subbasins, which is not represented in the stream/canal delineation.

Table 3-2: Reach/Reservoir Parameter Values

Reach ID #	Subbasin Id. #	Downstream Id. #	Stream Length (m)	Minimum Elevation (m)	Maximum Elevation (m)	Slope Percentage (%)	Channel Width (m)	Channel Depth (m)
Sub07	7	13	767.	1.0	1.5	0.065	25	1.2
Sub12	12	6	236.	0.0	1.0	0.423	2	0.75
Sub15	15	6	369	0.0	1.7	0.455	2	0.75
Sub17	17	6	934	0.0	2.0	0.214	2	0.75
Sub13	13	20	188	-1.0	-0.5	0.265	10	2.0
Sub10	10	14	255	0.0	0.5	0.196	50	2.0
Sub16	16	20	851	-1.0	0.0	0.117	15	2.4
Sub19	19	20	192	-2.0	-1.5	0.260	3	0.75
Sub20	20	20	355	-2.0	-1.0	0.281	20	2.4
Sub18	18	20	215	-2.0	-1.0	0.465	2	0.75
Innis_obs	9	14	1235	0.0	0.5	0.040	5	1.5
Innis_out	8	9	712	-0.5	0.0	0.100	7	2.0
Sub21	21	20	30	-1.0	-0.5	1.670	2	0.75
Klust_out	1	0	1860	-2.4	-1.0	0.100	20	2.4
Sub03	3	17	210	1.5	1.7	0.100	450	1.0
Sub05	5	13	1506	0.5	1.5	0.067	75	2.0
Sub14	14	11	127	1.0	1.5	0.393	2	0.5
Sub04	4	19	741	1.7	2.0	0.040	25	1.5
Sub11	11	6	514	0.0	1.0	0.388	2	0.75
Sub06	6	13	510	0.5	1.0	0.100	50	1.5

The F-Tables for each reach/reservoir were set during the model flow calibration.

There were no parameters required to configure the water quality model simulation in HSPF. For surface and groundwater discharges, the build-up wash-off algorithm represented by the PQAUL/IQUAL modules was used. In the reach/reservoirs, the RQUAL block was used to represent in-stream (or in-reservoir) bio-chemical processes. The model parameters used for these blocks is discussed in the calibration section.

3.3 MODEL FORCING DATA

Hourly weather records required by the model include: (precipitation [PREC], potential evapotranspiration [PEVT], evaporation [EVAP], temperature [ATEM], windspeed [WIND], solar radiation [SOLR], dewpoint temperature [DEWP], and cloud cover [CLOU]. Basic weather data was obtained from the National Oceanic Atmospheric Administration (NOAA) National Climatic Data Center (NCDC). Tampa International Airport (TPA) was the nearest weather station which contained hourly weather data for the period of impairment. TPA is located approximately20 miles from Klosterman Bayou. This location is sufficient for most weather data, however, since daily rainfall can have a large spatial gradient, local rainfall data was required in the modeling analysis.

3.3.1 Rainfall

Hourly rainfall data was provided from SWFWMD,WED WRF, and FDEP NEXRAD, for the period 1996 through 2006. The NEXRAD data is available for four-by-four kilometer grid cells throughout Florida. Figure 3-2 shows the NEXRAD grid network overlaying the Klosterman Bayou watershed. Due to the direct proximity to the watershed, the NEXRAD data sets for the associated cells was the preferred data set. However, the NEXRAD data set only covered the period from 1997 though 2005. In order to provide rainfall data for the 2006 period, data from surrounding gauges was used. The gauge locations and the spatial distribution of the annual average rainfall for the period of impairment are shown in Figure 2-13. Annual and seasonal average rainfall comparisons for the NEXRAD data and the data from the WED WRF are presented in Figure 3-3. The data compare well indicating that the WED WRF data is consistent with the NEXRAD data.

The William E. Dunn Reclamation Facility provides approximately 3 mgd of water to the Innisbrook Golf Course daily. This water is introduced into the ponds and then used for irrigation on the gold course. In order to represent this extra source of water, a second rainfall time series was created which consisted of the original rainfall data set plus a constant value of 0.006 inches/hour. This rate corresponds to the Dunn Facility rate of discharge divided by the total acres representing the golf course. It is equivalent to approximately 53 inches of rainfall, which is about the same amount as the naturally occurring rainfall. Figure 3-4 illustrates the elevated rainfall values used to account for the irrigation of golf course land uses.

3.3.2 Temperature and Dew Point

Air temperature is used in the model to determine soil and water temperature. Dew point is used for heat balance in the Watershed. Hourly air temperature and dew point values were collected at TPA. Figure 3-5 shows the monthly averages within the 1999-2006 period.

3.3.3 Solar Radiation

Total Solar Radiation is another input parameter used in the HSPF model. Solar radiation promotes algae growth through photosynthesis and by increasing water temperature. It also can assist in evapotranspiration. Solar Radiation decreases the amount of water in the drainage systems of each the basin, which inversely increases potential algae growth by a decrease in flow, a limitation in gate operations, and a resultant increase in water temperature due to the decrease in volume. The data used in the model was downloaded from the National Solar Radiation Database developed by US Department of Energy. The data covered the common measurements of solar radiation (i.e., global horizontal, direct normal, and diffuse horizontal) in watts per square meter (W/m^2). Global horizontal data was selected because the calculation covers the total amount of direct and diffuse solar radiation (modeled) received on a horizontal surface at hourly intervals. The period of record for solar radiation data is 1991 to 2005. The 2006 data was not available. To provide data for simulating the 2006 period, the average for each day of the year based on the data from 1991 through 2005 was used for 2006. Figure 3-6 shows the monthly averages for solar radiation within the simulation period.

3.3.4 Cloud Cover

As for dew point, cloud cover is used in the model for heat balance in the surface water. Cloud cover affects the long-wave radiation balance and decreases photolyzing radiation. Cloud cover values used in the model are in tenths of a percent coverage. Cloud cover data was not directly available, but was attained using cloud ceiling and sky cover data provided in the NCDC data set. An index table was used to convert the 8^{th} scale units used in cloud ceiling data to percentages of cloud cover. Using the converted data and criteria of less than 40% cloud cover, the average number of sunny days was 241 days. The highest number of sunny days in a single year was 266, in 2004.

3.3.5 Wind Speed

Wind speed is used in HSPF to model the heat balance between air and water and re-aeration of oxygen. Wind direction is not considered. The hourly values were attained from the NCDC data set from TPA. The maximum hourly winds (43 mph) received in the basin occurred on September 26, 2004 at 10:00 am and 5:00 pm. This is the same day the maximum daily average of 31 mph occurred. This coincides with the time when Hurricane Jeanne was crossing the state. March through May were the windiest months for the basin, with an average wind speed of 8-mph. Figure 3-7 shows the monthly averages of wind speed within the 1999-2006 period.

3.3.6 Evaporation

Evaporation data was not available in the NCDC data set, nor from other sources. The HSPF option for using the Penman method was therefore used to generate the hourly evaporation. This approach requires maximum and minimum air temperature, dewpoint, wind speed, and solar radiation. Figure 3-8 shows the monthly averages of calculated evaporation within the 1999-2006 period.

3.3.7 Evapotranspiration

Potential Evapotranspiration data available from the SWFWMD Lake Como site. This measurement site is approximately 15 miles from the basin. The Lake Como site (Station ID: 20) is located in medium density residential setting. The site was established on 10/15/1999 but was missing pan evaporation data for a 15-day period from mid-June of 2005 to the end of June 2005. A linear interpolation scheme was used to supply the missing data. The seasonal characteristics of the data area shown in Figure 3-9.

3.4 MODEL HYDRODYNAMIC CALIBRATION

The flow calibration consisted of a comparison of simulated and measured daily flows at the gauge location for the period for which measured flow data was available (August 22, 2006 through December 31, 2006). In the HSPF model, the discharge from RCHRES segment 9 simulates the discharge from the area upstream of the gauge. This discharge point includes runoff and discharges from upstream subbasins 3, 4, 5, 6, 7 and 9. The calibration comparison was made using a variety of metrics, including time series and cumulative discharge.

The field reconnaissance of the site indicated that the area represented by subbasin 3 did not generally produce any discharge and that most of the water was stored and either evaporated or percolated. In order to simulate these conditions, the RCHRES dimensions were adjusted to effectively increase the surface area of the RCHRES and the DEEPFR parameter was increased. The large surface area allowed the runoff that was accumulated in the RCHRES to evaporate and reduce discharges. The increase in the DEEPFR parameter decreased the groundwater discharge to the RCHRES by routing the infiltrated water to the underlying aquifer, rather than storing it in the water table. The effective groundwater storage was reduced, and consequently the groundwater discharge was reduced.

As discussed in Section 2.0, the measured flow and rainfall data did not correlate well at the gauge location. The poor correlation can be attributed to the highly permeable soils, a large natural and man-made storage capacity, control structures and water management practices on the golf course. In order to simulate the discharge characteristics both the RCHRES and F-Table characteristics were modified. The flow hydrograph (see Figure 2-14) indicates that the area can typically absorb individual rainfall amounts of up to 1 or more inches without producing discharges. However, for sequential events, occurring over many days, the system does exhibit some discharge. There also appears to be relatively persistent base flow which is attributed to the 3 mgd discharge from the William E. Dunn Facility. To obtain the model calibration, the hydrological parameters in the PQUAL and IQUAL modules were set with default values associated with the land use and soil types in the area upstream of the gauge. Then a similar approach, such as that used for Subbasin 3, was used to control the discharge. For the RESRCHs in subbasins 4, 5, 6, 7 and 9, the surface area was increased until it approximately equaled the local storage as indicated by the pond and natural area storage areas. The RESRCH area was effectively represented in each F-Table. This allowed for evaporation to reduce the storage and for accommodation of additional rainfall events with discharge. The F-Table discharge-stage relationships were also carefully constructed to provide for the proper discharge characteristics. The F-Table was divided into two regions. Below the stage of 6.95 feet, the discharge was set at a value representing baseflow conditions. Above this value, the discharge increase rapidly with stage. A typical scenario using this RESRCH and F-Table configuration would be low and decreasing flow during periods of no rainfall. The stage would decrease, so that for a subsequent individual rainfall event, all of the event discharge could be stored without significantly increasing the discharge, since in this region of the F-Table, increases in stage still produce small discharges. When consecutive or very large rainfall events occur, the runoff to the RESRCH will increase the storage volume faster than the evaporation and low discharge can drain the RESRCH and the stage will increase significantly. As the stage increases above 6.95 feet, the discharge rate will increase rapidly, due to the F-Table settings, to produce the occasional significant discharge events that are seen in the measured data.

The final calibrated discharge and its comparison to the measured data is shown as a time series and as a cumulative discharge plot in Figure 3-10. The final RESRCH area at the critical stage of 6.95 feet for subbasins 3, 4, 5, 6, 7 and 9 are shown in Table 3-3 and the F-Table values for RESRCH 9 is shown in Table 3-4.

Table 3-3: Final Reach Length and Width Parameter Values

RCHRES	ACRES
3	50
4	4.6
5	102
6	11
7	25
9	27

Table 3-4: Final Calibrated F-Table Values for Reach 9

Depth (ft)	Area (Acres)	Volumes (Acre/ft)	Outflow1 (ft3/s)
0	1.83	0	0
3.65	10.95	23.32	0
4.65	18.25	37.92	0.05
5.75	18.5	58.14	0.3
6.95	27.25	85.59	2.25
7	30.25	87.02	100
8.21	84.99	156.74	1000
410	159	49173.11	7.20E+06

The PQUAL and IQUAL model parameters used in the final calibration are shown in Tables 3-5 and 3-6 for each land use. These values are essentially the default values provided by WinHSPF based on land use and were not significantly adjusted during the calibration process.

Table 3-5a: Group 2 Calibrated Pervious Land Model Parameter Values

Land Use Code	Landuse	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
101	Urban	14	0.5	500	0.003726	5	0.99
102	Open Land	14	0.5	500	0.003726	5	0.99
103	Forest Land	14	0.5	500	0.003726	5	0.99
104	Wetlands/ Water	14	0.5	500	0.003726	5	0.99
105	Golf Course/ Recreation	14	0.75	400	0.007541	5	0.99
106	Range Land	14	0.5	500	0.002001	5	0.99

Table 3-5b: Group 3 Calibrated Pervious Land Model Parameter Values

Land Use Code	Landuse	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
101	Urban	2	2	0.5	0.2	0.2
102	Open Land	2	2	0.5	0.2	0.2
103	Forest Land	2	2	0.5	0.2	0.2
104	Wetlands/ Water	2	2	0.5	0.2	0.2
105	Golf Course/ Recreation	2	2	0.5	0.2	0.2
106	Range Land	2	2	0.5	0.2	0.2

Table 3-5c: Group 4 Calibrated Pervious Land Model Parameter Values

Land Use Code	Landuse	CEPSC	UXSN	NSUR	INTFW	IRC
101	Urban	0.1	1.25	0.5	10	0.85
102	Open Land	0.1	1.25	0.5	10	0.85
103	Forest Land	0.1	1.25	0.5	10	0.85
104	Wetlands/ Water	0.1	1.25	0.5	10	0.85
105	Golf Course/ Recreation	0.1	1.25	0.5	10	0.85
106	Range Land	0.1	1.25	0.5	10	0.85

Table 3-5d: Group 1 Calibrated Pervious Land Model Parameter Values

Land Use Code	Landuse	CSNOFG	RTOPFG	VRSFG	VNNFG	RTLIFG
101	Urban	0	0	0	0	0

Table 3-6a: Group 2 Calibrated Impervious Land Model Parameter Values

Land Use Code	Landuse	LSUR	SLSUR	NSUR	RETSC
101	Urban	500	0.003726	0.2	0.1

Table 3-6b: Group 3 Calibrated Impervious Land Model Parameter Values

Land Use Code	Landuse	PETMAX	PETMIN
101	Urban	40	35

The calibrated parameters obtained for the basins upstream of the calibration point were applied to the other subbasins in the watershed model. The only adjustments made for the other subbasins were the amount of local storage, which was accomplished by adjusting the RCHRES size based on estimates of storage from aerial photographs and land use data.

The water budgets, based on the eight-year simulation period, for each subbasin is shown in Table 3-7.

Table 3-7: Water Budget for Each Subbasin

SUBBASIN	ACRES	PREC (inches)	Surface Runoff (inches)	Interflow Runoff (inches)	Ground water Discharges (inches)	Evapo-transpiration (inches)	Loss to Aquifer (inches)	% Discharge
1	49	50.1	13.4	0.2	1.5	29.3	5.5	30.4
3	351	50.1	16.8	0.3	1.6	26.4	5.0	37.3
4	86	52.4	15.8	0.5	2.1	28.1	6.0	34.9
5	238	53.0	8.4	0.9	2.7	22.0	19.0	22.7
6	58	14.9	0.8	0.7	1.9	8.4	3.1	22.7
7	135	33.4	3.2	1.6	4.1	17.7	6.9	26.5
8	272	87.4	9.2	2.7	7.2	41.0	27.3	21.8
9	141	93.3	10.6	2.4	6.6	38.8	35.0	20.9
10	58	51.2	12.0	0.3	1.6	31.7	5.5	27.3
11	85	50.1	8.3	0.3	1.8	33.1	6.6	20.8
12	8	50.1	19.4	0.3	1.6	23.6	5.2	42.4
13	60	50.1	7.4	2.0	5.6	32.4	2.6	30.0
14	204	73.8	4.2	0.3	1.9	36.6	30.8	8.6
15	75	50.1	17.1	0.2	1.5	26.0	5.2	37.5

SUBBASIN	ACRES	PREC (inches)	Surface Runoff (inches)	Interflow Runoff (inches)	Ground water Discharges (inches)	Evapo-transpiration (inches)	Loss to Aquifer (inches)	% Discharge
16	21	50.1	14.8	0.2	1.4	28.5	5.2	32.8
17	57	50.1	16.3	0.2	1.5	26.8	5.2	36.0
18	33	50.1	17.6	0.2	1.5	25.4	5.2	38.7
19	33	50.1	12.9	0.2	1.5	30.0	5.4	29.2
20	78	62.8	5.0	0.2	1.8	36.2	19.5	11.2
21	33	50.1	10.6	0.3	2.1	29.9	7.1	25.9

3.5 MODEL WATER QUALITY CALIBRATION

The water quality calibration and validation were conducted for the 1999-2002 and 2003-2006 periods using the aggregated data from the two water quality stations to guide the calibration. The build-up/wash-up algorithm in PQUAL and IQUAL were used to simulate the runoff concentrations of Ortho-P, organic phosphorus, organic nitrogen, total ammonia, nitrate/nitrite and BOD. Temperature of the surface runoff was simulated with PWTGAS and IWTGAS algorithms, which also provided simulation of the dissolved oxygen in the runoff. Temperature in the RCHRES was simulated using the HTRCH algorithm. In each RCHRES, the water quality was simulated using the RQUAL set of algorithms which include OXRX, NUTRX and PLANK.

The water temperature calibration was completed first using parameters in the PWTGAS and IWTGAS to control the runoff temperature. The value of BSLT scales the soil to air temperature and was used to adjust the simulated water temperature of the surface runoff. In each RCHRES, the PWTGAS algorithm was used. Here, the fraction of solar radiation reaching the water surface, CFSAEX, was used also to calibrate the water temperature.

The general approach for calibrating the nutrients, BOD and dissolved oxygen was to adjust the runoff concentrations of the nutrients and BOD using the SQOLIM, ACQOP and WSQOP parameters, and then adjust the in-stream process coefficients to further refine the calibration of dissolved oxygen and chlorophyll. However, since the in-stream simulations also affected the nutrient concentrations, there was some need to iteratively adjust both the runoff parameters and the in-stream parameters to obtain the final calibration. Aside from the build-up/washoff parameters, the adjustments were made to the ammonia oxidation rate, (KTAM20), the algal respiration rate (ALR20) and the algal growth rate (MALGR) to obtain the calibration. The final calibrated parameter values are listed in the tables in Appendix A for each subbasin and RCHRES used in the model.

The results of the calibration and the validation are shown in Figures 3-11 and 3-12. The results for the temperature calibration are good. The seasonal variations are simulated and the full range represented. The results for the dissolved oxygen calibration indicate that the general seasonal pattern and distribution of dissolved oxygen are well represented. The median simulated dissolved oxygen value of 7 mg/L is almost identical to the measured value. The results for the ortho-phosphorus and organic phosphorus are good also. The general levels of both constituents are simulated. Both simulations produced some spurious high values that skew the frequency distribution plots. However, with those removed, the simulated distributions typically match the distributions of the measured data. The ortho-phosphorus appears to be slightly under-predicted.

The results for the nitrogen species calibration (Figure 3-11) indicate that the simulated values have the same distributional shape, although individual species are either over-predicted or under-predicted. The Nitrate/Nitrate values are reasonably represented, but total ammonia is over predicted. Total nitrogen and TKN are under-predicted. For all simulated quantities, spurious values appear occasionally. The simulated algal mass, as indicated by chlorophyll concentrations shows a stronger seasonal variation than the measured data, with lower values than the measured data occurring in the colder months. The simulated BOD values appear to synchronize with the algal growth, a result of the death and subsequent oxygen demand created by the algae in the model dynamics. However, they do not agree well with the measured data, which tends to fall in a narrower range without any seasonal variation.

The validation simulated results for each simulated constituent are shown in the same sequence of plots in Figure 3-12. Overall, the level of agreement between the simulated and measured data is about the same as for the calibration. The most noticeable difference between the calibrated and validated results is for phosphorus, resulting from a decreasing trend in phosphorus in the measured data. The cause of this decreasing trend is not known at this time and therefore was not well represented in the model simulation. Agreement of the results of the validation with the calibration generally indicate that the calibration is robust.

There was no additional data available to calibrate the water quality for other subbasins and reach segments. However, the high nutrient levels, primarily phosphorus, representative of the measured data are most likely unique to the golf course subbasins and therefore a direct application of the calibrated parameter values for other subbasins and reaches is not likely appropriate. Therefore a different approach was adopted to set the model parameters for the un-gauged subbasins. Representative nutrient levels were obtained from the literature Harper (1992, 1994) and ERD (2003) and used to guide the selection of parameter values for those basins. The general idea is that the nutrient levels in the discharges from these basins are different than those represented in the measured data. The build-up/washoff parameters were adjusted so that the nutrient levels in the discharges for the un-gauged subbasins were representative of the literature values. The nutrient and BOD target values for each land use are listed in Table 3-8.

Table 3-8: Target Value for Nutrients and BOD for Land Uses in Un-gauged Subbasins

Land Use	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	BOD (mg/L)
Urban	2.18	0.33	7.4
Forest	1.09	0.046	1.23
Wetlands	1.09	0.046	1.23

The median values for the nutrients and BOD for the discharge points obtained in the simulations is shown in Table 3-9. The median levels are in agreement with the adopted target values.

Table 3-9: Simulated Nutrient and BOD Average Values for the Un-gauged Basins Discharges

Reach	Dominant Land Use	BOD (mg/L)	TN (mg/L)	TP (mg/L)
1	Urban	6.2	1.8	.21
11	Urban	5.5	1.9	.22
12	Urban	3.0	2.1	.24
13*	Golf Course	2.5	1.2	.8
15	Urban	4.0	2.1	.27
16	Urban/Wetlands	1.5	1.4	.09
17	Urban	3.3	2.1	.22
18	Urban	4.1	2.0	.21
19	Urban/Forrest	1.3	1.3	.10
20	Urban/Forrest	1.2	1.7	.11
21	Urban/Open	2.0	1.6	.12
*gauged basin values included for comparison				

The calibrated HSPF model was used to simulate flows and water quality discharges at the 11 discharge points identified in Figure 3-1. RCHES 2 is the receiving waterbody segment for the 11 discharge points and is not used explicitly in the HSPF model. The period of simulation was from 1/1/1999 through 12/31/2006. The simulated flows and water quality constituents were recorded and then provided to Dynamic Solutions, LLC, as boundary conditions for an EFDC model of the Klosterman Bayou.

Annual average loads have been estimated using the model outputs for surface flows and base flow. Additional estimates were made for septic systems, municipal discharges and atmospheric deposition for total nitrogen, total phosphorus and BOD.

Atmospheric deposition for the Klosterman basin was estimated from rates established in previous studies and at sites in the general region. Three studies provide estimates of total nitrogen deposition rates: (1) an intensive two-year study for the Tampa Bay (Pribble et al., 1999), (2) sampling at two sites from the National Atmospheric Deposition Program (NADP) and (3) a study by Hendry and Brezonik (1981). The Tampa Bay study provides measurements of wet and dry TN deposition and Wet P deposition for the period August 1996 through July 1999. The wet-N value is 380 $kg/km^2/yr$, the total-N deposition is 754 $kg/km^2/yr$ and the wet-P deposition rate is 5.87 $kg/km^2/yr$. Data at two NADP sites, station FL05 and station FL41 also provide an estimate of total-N deposition for the general area, based on measurements from 1999 through 2006. The average total-N deposition rate for the 1999 through 2006 period is 552 $kg/km^2/yr$. The Hendry and Brezonik study provides data at a number of sites throughout Florida. The closest to Klosterman Bayou is located just south of Tampa Bay. A total-N deposition rate of 720 $kg/km^2/yr$ is reported for this site. Data from this study provides an estimate of total-P deposition of 27 $kg/km^2/yr$. To provide estimates of total N and P deposition rates for the Klosterman Bayou area, the three values for total-N were averaged, yielding 675 $kg/km^2/yr$. The total-P deposition rate of 27 kg/km2/yr was used for phosphorus.

Estimates of nitrogen and phosphorus inputs from septic-tank effluent were calculated by multiplying the number of septic tanks in each sub-basin permitted in 1990 (Bureau of the Census, 1993a,b) by the estimated average concentration of total nitrogen (45 mg/L) and total phosphorus (13 mg/L) in septic-tank leachate and then by an average effluent volume of 510 liters per day (Tchobanoglous, 1991).

Estimates of TN, TP and BOD loads for the Dunn Facility are based on monthly average data from the period 2001 through 2006.

Annual average surface and base flow estimates for each sub-basin and land-use were derived from the calibrated model simulations for the 1999-2005 period. The base flow was set to the total of the interflow and active groundwater outflow. The surface flow was then set to the total total discharge minus the base flow.

Annual average loads for total nitrogen, total phosphorus and BOD were also derived from the calibrated model simulations. The daily loads from each sub-basin and for each land use were calculated for each day in the simulation output. The daily averages were then converted to annual averages.

The results of the load calculations are provided in Tables 4-1 through 4-6. Table 4-1 shows the surface and base flows for each discharge point into the Klosterman Bayou (see Figure 2-9). Tables 4-2 through 4-4 show the annual average loads for TN, TP and BOD for each basin. The sub-basin RCH_13 includes all upland basins that drain through it to the bayou and RES_11 includes drainage from RES_14.

The loads by aggregate land use are shown in Table 4-5 and the loads for the gauged and un-gauged regions of the basin are shown in Table 4-6 through 4-8.

Table 4-1: Annual Average Flows

Reach	Area (Acres)	Total Discharge (cfs)	Total Discharge (acre-ft/yr)	Surface Discharge (acre-ft/yr)	Base Flow (acre-ft/yr)
RCH_13	1399	1.51	1099.	755.	341.
RCH_12	8	0.017	12.8	11.7	1.12
RCH_11	289	0.14	105.9	75.6	30.2
RCH_15	75	0.11	85.4	77.9	7.44
RCH_17	57	0.088	63.8	57.1	6.27
RCH_19	33	0.047	34.4	30.5	3.92
RCH_18	33	0.065	47.4	42.7	4.63
RCH_20	78	0.016	12.2	7.61	4.58
RCH_21	33	0.042	30.6	25.0	5.45
RCH_16	21	0.035	25.7	23.1	2.5
RCH_1	49	0.076	55.4	49.3	6.02

Table 4-2: Annual Average Loads for Total Nitrogen

Reach	Area (Acres)	TN Surface Flow Load (Mtons/yr)	TN Base Flow Load (Mtons/yr)	TN Septic tanks (Mtons/yr)	TN Dunn Facility (Mtons/yr)	TN* Atmospheric Deposition (Mtons/yr)
RCH_13	1399	2.23	0.235	0.1	3.089	3.81
RCH_12	8	0.0191	0.0012	0	0	0.0218
RCH_11	289	0.0747	0.018	0.17	0	0.788
RCH_15	75	0.0696	0.0030	0.01	0	0.204
RCH_17	57	0.0546	0.00344	0	0	0.155
RCH_19	33	0.0430	0.00180	0	0	0.090
RCH_18	33	0.0651	0.00240	0	0	0.090
RCH_20	78	0.0176	0.00400	0.02	0	0.212
RCH_21	33	0.0260	0.00596	0	0	0.090
RCH_16	21	0.0392	0.00203	0	0	0.0573
RCH_1	49	0.0964	0.00471	0	0	0.133

*based on 2.72 kg/acre/yr

**based on 0.109 Kg/acre/yr

Table 4-3: Annual Average Loads for Total Phosphorus

Reach	Area (Acres)	TP Surface Flow Load (Mtons/yr)	TP Base Flow Load (Mtons/yr)	TP Septic tanks (Mtons/yr)	TP Dunn Facility (Mtons/yr)	TP* Atmospheric Deposition (Mtons/yr)
RCH_13	1399	0.928	0.347	0.02	2.707	0.152
RCH_12	8	0.0024	0.000125	0	0	0.000872
RCH_11	289	0.0080	0.000794	0.04	0	0.0315
RCH_15	75	0.0059	8.83E-05	0	0	0.00817
RCH_17	57	0.00479	0.000182	0	0	0.00621
RCH_19	33	0.0042	8.89E-05	0	0	0.00359
RCH_18	33	0.00611	0.00013	0	0	0.00359
RCH_20	78	0.0024	5.07E-05	0	0	0.00850
RCH_21	33	0.0027	0.000568	0	0	0.00359
RCH_16	21	0.00404	0.000161	0	0	0.00228
RCH_1	49	0.0084	0.000334	0	0	0.00534
*based on 0.109 Kg/acre/yr						

Table 4-4: Annual Average Loads for BOD

Reach	Area (Acres)	BOD Surface Flow Load (Mtons/yr)	BOD Base Flow Load (Mtons/yr)	BOD Dunn Facility (Mtons/yr)
RCH_13	1399	7.54	0	1.86
RCH_12	8	0.059	0	0
RCH_11	289	0.29	0	0
RCH_15	75	0.20	0	0
RCH_17	57	0.15	0	0
RCH_19	33	0.13	0	0
RCH_18	33	0.21	0	0
RCH_20	78	0.15	0	0
RCH_21	33	0.082	0	0
RCH_16	21	0.13	0	0
RCH_1	49	0.33	0	0

Table 4-5: Nutrient and BOD Loads for Each Land Use

Land Use Designation	TN (Mtons/yr)	TP(Mtons/yr)	BOD (Mtons/yr)
Residential Med Density 2->5 Dwelling Unit	143.7	46.4	546.8
Residential Low Density < 2 Dwelling Units	95.3	21.5	275.4
Residential High Density	1075.3	352.8	4891.8
Commercial And Services	93.5	27.5	342.9
Industrial	20.1	6.2	75.6
Institutional	4.1	1.3	15.5
Golf Courses	1056.9	760.3	1956.3
Recreational	65.6	38.8	140.0
Open Land	13.4	2.9	72.7
Shrub And Brush land	1.1	0.1	5.8
Hardwood Conifer Mixed	91.2	7.4	123.2
Lakes/Reservoirs	129.6	9.3	136.9
Cypress	33.7	5.5	98.4
Wetland Forested Mixed	23.9	4.6	68.2
Freshwater Marshes	17.1	1.8	42.6
Saltwater Marshes	0.2	0.0	1.9
Wet Prairies	4.6	0.9	13.3
Intermittent Ponds	6.0	1.2	17.3
Transportation	29.4	7.9	97.8
Utilities	120.0	32.2	399.6

Table 4-6: Annual Average Loads for Total Nitrogen (gauged and un-gauged areas)

Reach	Area (Acres)	TN Surface Flow Load (Mtons/yr)	TN Base Flow Load (Mtons/yr)	TN Septic tanks (Mtons/yr)	TN Dunn Facility (Mtons/yr)	TN* Atmospheric Deposition (Mtons/yr)
gaged	1399	2.23	0.235	0.1	3.089	3.81
ungaged	676	0.505	0.0473	0.2	0	1.84

Table 4-7: Annual Average Loads for Total Phosphorus (gauged and un-gauged areas)

Reach	Area (Acres)	TP Surface Flow Load (Mtons/yr)	TP Base Flow Load (Mtons/yr)	TP Septic tanks (Mtons/yr)	TP Dunn Facility (Mtons/yr)	TP** Atmospheric Deposition (Mtons/yr)
gauged	1399	0.928	0.347	0.02	2.707	0.152
Un-gauged	676	0.049	0.00252	0.04	0	0.0736

Table 4-8: Annual Average Loads for BOD (gauged and un-gauged areas)

Reach	Area (Acres)	BOD Surface Flow Load (Mtons/yr)	BOD Base Flow Load (Mtons/yr)	BOD Dunn Facility (Mtons/yr)
gauged	1399	7.54	0	1.86
Un-gauged	676	1.77	0	0

A sensitivity analysis was performed on four HSPF parameters to discern the sensitivity of the HSPF model results to the parameters. The four parameters chosen were key parameters in the water quality calibration. The first is ACQOP. This parameter controls the rate of accumulation of the nutrients and BOD on the land surface. An increase in this parameter generally causes an increase on the runoff concentration. Note that this does not necessarily result in an increase in the discharge concentration, as sometimes the effect on the nutrient cycling can yield a net reduction. The second parameter tested is the rate of algal respiration. The third parameter is the BOD oxidation rate and the fourth is the algal maximum growth rate.

A baseline simulation was established using the calibrated model outputs. Values at RESRCH 9, which is the calibration point for the model, were used for comparison. Four simulations were conducted for each parameter, representing a 10% and 20% increase in the parameter value and a 10% and 20% decrease in the parameter value. The results of the tests are shown in Tables 5-1 through 5-4. Each table shows the median value of DO, BOD, TN and TP for each simulation as well as the percent change in the median value when compared to the baseline value.

Table 5-1: Sensitivity to Accumulate Rate

	-20%	-10%	Baseline	10%	20%
	Median Concentration (mg/L)				
DO	5.80	5.79	5.89	5.87	5.80
BOD	2.35	2.33	2.35	2.36	2.42
TN	1.02	1.03	1.02	1.03	1.03
TP	1.02	1.02	1.02	1.02	1.02
	Percent Change (%)				
DO	-1.44	-1.61	0.00	-0.25	0.00
BOD	0.26	-0.68	0.00	0.68	3.06
TN	0.05	0.29	0.00	0.39	0.58
TP	-0.27	-0.13	0.00	0.00	0.09

Table 5-2: Sensitivity to Algal Respiration Rate

	-20%	-10%	Baseline	10%	20%
	Median Concentration (mg/L)				
DO	6.64	6.31	5.89	5.58	5.35
BOD	2.31	2.42	2.35	2.83	2.60
TN	0.86	0.96	1.03	1.08	1.11
TP	0.97	0.99	1.03	1.09	1.17
	Percent Change (%)				
DO	12.7	7.05	0.00	-5.26	-9.25
BOD	-1.79	2.81	0.00	20.5	10.7
TN	-16.7	-6.92	0.00	5.50	8.09
TP	-5.37	-3.61	0.00	6.28	14.1

Table 5-3: Sensitivity to BOD Oxidation Rate

	-20%	-10%	baseline	10%	20%
	Median Concentration (mg/L)				
DO	5.92	5.89	5.89	5.87	5.85
BOD	2.44	2.332	2.35	2.274	2.35
TN	1.01	1.01	1.02	1.02	1.03
TP	1.01	1.02	1.02	1.02	1.03
	Percent Change (%)				
DO	0.59	0	0	-0.33	-0.67
BOD	3.8	-0.76	0	-3.23	0.25
TN	-0.68	-0.826	0	-0.04	0.77
TP	-0.83	-0.44	0	0.28	0.38

Table 5-4: Sensitivity to Algae Growth Rate

	-20%	-10%	baseline	10%	20%
	Median Concentration (mg/L)				
DO	6.09	6.00	5.89	6.05	6.19
BOD	2.37	2.73	2.35	2.61	2.70
TN	1.13	1.07	1.03	0.98	0.93
TP	1.16	1.09	1.03	1.00	0.99
	Percent Change (%)				
DO	3.40	1.87	0.00	2.63	5.09
BOD	0.68	16.26	0.00	11.23	14.81
TN	10.28	3.75	0.00	-4.63	-9.16
TP	13.44	6.19	0.00	-2.49	-4.01

In general, the results indicate a minor to moderate level of sensitivity. For most cases the percent change in the result is less than the corresponding percent change in the parameter value. In many cases, the changes are not intuitive. For instance, for both an increase and decrease in the accumulation rate of the nitrogen species, the median value of TN decreases. This is a result of the relatively small changes in the parameter values and the highly non-linear interactions associated with nutrient, DO and algal dynamics.

The HSPF model has been calibrated and validated for the Klosterman Bayou watershed and model outputs have been used as inputs to a receiving water body model. The configuration, calibration and validation process have revealed a number of data needs that could improve future modeling analysis and the general understanding of flow and water quality dynamics of the system.

There is limited flow data, from both a temporal and spatial perspective. Only 6 months of data was available from one site. Furthermore, the flow characteristics at the site indicated a large upland storage capacity and poor correlation with rainfall. Due to the unique characteristics of the basin drainage, continued data collection at the existing gauge location is warranted. Flow data collection at an additional site is also warranted, preferably on the northern end of the basin, where the upland basin storage characteristics moderate to low.

There are numerous ponds and detention/retention basins in the watershed, and monitoring the water level in one or two of the larger ponds would help verify the hydrological model. The modeling analysis indicated significant subsurface drainage, and therefore, a surface-table groundwater monitoring plan should be considered.

Another affect of the large to moderate storage is the residence time of water prior to discharge. The role of nutrient cycling and DO and algal dynamics has a significant effect on the water quality discharged during the high flow events, due to the extended residence time. However, there is virtually no freshwater monitoring station in the streams or any of the ponds or detention/retention basins. It is suggested that at least two and preferable three monitoring stations be established. One should be upstream of the salinity/freshwater boundary in the Innisbrook canal and the other two would be established in a pond and detention/retention basin. Two-weekly or at minimum monthly sampling of water quality should be established at these sites.

To summarize, recommended data collection include:

1) Continued flow data collected at the existing gauge location
2) Flow measurements at a site on the north side of the bayou
3) Stage monitoring in the ponds or detention/retention basis
4) On-site groundwater stage monitoring (water table only)
5) Water quality monitoring at two to three new sites:
    i) Freshwater section of the Innisbrook canal
    ii) Natural pond
    iii) Detention/retention pond

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Appendix A

Calibrated Water Quality Parameters

Table A-1. Buildup Wash-off Calibrated Parameter Values for the Perland Module

TAM		SQO	POTFW	POTFS	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
101	Urban or Built-up La	0.001	0	0	0.001	0.002	0.7	0.0002	0.00001
102	Open Land	0.001	0	0	0.001	0.001	0.7	0.0001	0.00001
103	Forest Land	0.001	0	0	0.001	0.001	0.7	0.0001	0.00001
104	Wetlands/Water	0.001	0	0	0.001	0.001	0.7	0.0001	0.00001
105	Golf course or Recrea	0.003	0	0	0.002	0.09	0.7	0.0004	0.00002
106	Range Land	0.001	0	0	0.001	0.001	0.7	0.0001	0.00001
NO3		SQO	POTFW	POTFS	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
101	Urban or Built-up La	0.2	0	0	0.001	0.003	0.5	0.0001	0.00001
102	Open Land	0.2	0	0	0.001	0.001	0.7	0.0001	0.00001
103	Forest Land	0.2	0	0	0.001	0.001	0.7	0.0001	0.00001
104	Wetlands/Water	0.2	0	0	0.001	0.001	0.7	0.0001	0.00001
105	Golf course or Recrea	0.2	0	0	0.001	0.09	0.7	0.0013	0.00003
106	Range Land	0.2	0	0	0.001	0.001	0.7	0.0001	0.00001
Ortho_P		SQO	POTFW	POTFS	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
101	Urban or Built-up La	0.01	0	0	0.0001	0.002	0.6	0.00002	0.000001
102	Open Land	0.01	0	0	0.0001	0.0002	0.7	0.00001	0.000001
103	Forest Land	0.01	0	0	0.0001	0.0002	0.7	0.00001	0.000001
104	Wetlands/Water	0.01	0	0	0.0001	0.0002	0.7	0.00001	0.000001
105	Golf course or Recrea	0.03	0	0	0.0001	0.06	0.7	0.0004	0.000002
106	Range Land	0.01	0	0	0.0001	0.0002	0.7	0.00001	0.000001
BOD		SQO	POTFW	POTFS	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
101	Urban or Built-up La	0.05	0	0	0.0001	0.03	0.7	0.0002	0.0001
102	Open Land	0.01	0	0	0.0001	0.005	0.5	0.0001	0.000011
103	Forest Land	0.01	0	0	0.0001	0.005	0.5	0.0001	0.000011
104	Wetlands/Water	0.01	0	0	0.0001	0.005	0.7	0.0001	0.000011
105	Golf course or Recrea	0.01	0	0	0.0001	0.005	0.5	0.0001	0.0001
106	Range Land	0.01	0	0	0.0001	0.005	0.5	0.0001	0.0001

Table A-2. Buildup Washoff Calibrated Parameter Values for the IMPland Module

TAM		SQO	POTFW	ACQOP	SQOLIM	WSQOP
101	Urban or Built-up La	0.0297	0	0.002	0.002	0.5
NO3		SQO	POTFW	ACQOP	SQOLIM	WSQOP
101	Urban or Built-up La	0.4	0	0.001	0.003	0.5
Ortho_p		SQO	POTFW	ACQOP	SQOLIM	WSQOP
101	Urban or Built-up La	0.05	0	0.0001	0.001	0.5
BOD		SQO	POTFW	ACQOP	SQOLIM	WSQOP
101	Urban or Built-up La	0.81	0	0.0001	0.03	0.5

Table A-3. Calibrated Values for NUT_NITDENIT Parameter Set

	KTAM20	**KNO220**	**TCNIT**	**KNO320**	**TCDEN**	**DENOXT**
RCH1	0.015	0.002	1.07	0.002	1.04	5
RCH3	0.001	0.002	1.07	0.002	1.04	5
RCH4	0.001	0.002	1.07	0.002	1.04	5
RCH5	0.015	0.002	1.07	0.005	1.04	5
RCH6	0.001	0.002	1.07	0.002	1.04	5
RCH7	0.001	0.002	1.07	0.002	1.04	5
RCH8	0.001	0.002	1.07	0.002	1.04	5
RCH9	0.015	0.002	1.07	0.005	1.04	5
RCH10	0.001	0.002	1.07	0.002	1.04	5
RCH11	0.02	0.002	1.07	0.002	1.04	5
RCH12	0.015	0.002	1.07	0.002	1.04	5
RCH13	0.015	0.002	1.07	0.002	1.04	5
RCH14	0.015	0.002	1.07	0.002	1.04	5
RCH15	0.015	0.002	1.07	0.002	1.04	5
RCH16	0.015	0.002	1.07	0.002	1.04	5
RCH17	0.015	0.002	1.07	0.002	1.04	5
RCH18	0.015	0.002	1.07	0.002	1.04	5
RCH19	0.015	0.002	1.07	0.002	1.04	5
RCH20	0.015	0.002	1.07	0.002	1.04	5
RCH21	0.015	0.002	1.07	0.002	1.04	5

Table A-4. Calibrated Values for PLNK-PARM1 Parameter Set

	RATCLP	NONREF	LITSED	ALNPR	EXTB	MALGR
RCH1	0.68	0.5	0	0.25	0.3	0.085
RCH3	0.68	0.5	0	0.25	0.3	0.15
RCH4	0.68	0.5	0	0.25	0.3	0.15
RCH5	0.68	0.5	0	0.25	0.3	0.1
RCH6	0.68	0.5	0	0.25	0.3	0.008
RCH7	0.68	0.5	0	0.25	0.3	0.15
RCH8	0.68	0.5	0	0.25	0.3	0.15
RCH9	0.68	0.5	0	0.25	0.3	0.1
RCH10	0.68	0.5	0	0.25	0.3	0.008
RCH11	0.68	0.5	0	0.25	0.3	0.085
RCH12	0.68	0.5	0	0.25	0.3	0.085
RCH13	0.68	0.5	0	0.25	0.3	0.085
RCH14	0.68	0.5	0	0.25	0.3	0.008
RCH15	0.68	0.5	0	0.25	0.3	0.085
RCH16	0.68	0.5	0	0.25	0.3	0.085
RCH17	0.68	0.5	0	0.25	0.3	0.085
RCH18	0.68	0.5	0	0.25	0.3	0.085
RCH19	0.68	0.5	0	0.25	0.3	0.085
RCH20	0.68	0.5	0	0.25	0.3	0.085
RCH21	0.68	0.5	0	0.25	0.3	0.085

Table A-5. Calibrated Values for PLNK-PARM2 Parameter Set

	CMMLT	CMMN	CMMNP	CMMP	TALGRH	TALGRL	TALGRM
RCH1	0.01	0.025	0.0001	0.005	95	-20	50
RCH3	0.01	0.025	0.0001	0.005	95	-20	50
RCH4	0.01	0.025	0.0001	0.005	95	-20	50
RCH5	0.01	0.025	0.0001	0.005	95	-20	50
RCH6	0.01	0.025	0.0001	0.005	95	-20	50
RCH7	0.01	0.025	0.0001	0.005	95	-20	50
RCH8	0.01	0.025	0.0001	0.005	95	-20	50
RCH9	0.01	0.025	0.0001	0.005	95	-20	50
RCH10	0.01	0.025	0.0001	0.005	95	-20	50
RCH11	0.01	0.025	0.0001	0.005	95	-20	50
RCH12	0.01	0.025	0.0001	0.005	95	-20	50
RCH13	0.01	0.025	0.0001	0.005	95	-20	50
RCH14	0.01	0.025	0.0001	0.005	95	-20	50
RCH15	0.01	0.025	0.0001	0.005	95	-20	50
RCH16	0.01	0.025	0.0001	0.005	95	-20	50
RCH17	0.01	0.025	0.0001	0.005	95	-20	50
RCH18	0.01	0.025	0.0001	0.005	95	-20	50
RCH19	0.01	0.025	0.0001	0.005	95	-20	50
RCH20	0.01	0.025	0.0001	0.005	95	-20	50
RCH21	0.01	0.025	0.0001	0.005	95	-20	50

Table A-6. Calibrated Values for PLNK-PARM3 Parameter Set

	ALR20	ALDH	ALDH	OXALD	NALDH	PALDH
RCH1	0.005	0.02	0.001	0.03	0.01	0.002
RCH3	0.01	0.02	0.001	0.03	0.01	0.002
RCH4	0.03	0.02	0.001	0.03	0.01	0.002
RCH5	0.015	0.02	0.001	0.03	0.01	0.002
RCH6	0.005	0.02	0.001	0.03	0.01	0.002
RCH7	0.03	0.02	0.001	0.03	0.01	0.002
RCH8	0.03	0.02	0.001	0.03	0.01	0.002
RCH9	0.03	0.02	0.001	0.03	0.01	0.002
RCH10	0.005	0.02	0.001	0.03	0.01	0.002
RCH11	0.005	0.02	0.001	0.03	0.01	0.002
RCH12	0.005	0.02	0.001	0.03	0.01	0.002
RCH13	0.03	0.02	0.001	0.03	0.01	0.002
RCH14	0.005	0.02	0.001	0.03	0.01	0.002
RCH15	0.005	0.02	0.001	0.03	0.01	0.002
RCH16	0.005	0.02	0.001	0.03	0.01	0.002
RCH17	0.005	0.02	0.001	0.03	0.01	0.002
RCH18	0.005	0.02	0.001	0.03	0.01	0.002
RCH19	0.005	0.02	0.001	0.03	0.01	0.002
RCH20	0.005	0.02	0.001	0.03	0.01	0.002
RCH21	0.005	0.02	0.001	0.03	0.01	0.002

Table A-7. Calibrated Values for PHYTO-PARM Parameter Set

	SEED	MXSTAY	OREF	CLALDH	PHYSET	REFSET
RCH1	10	35	100	55	0.002	0.025
RCH3	10	35	100	55	0.002	0.025
RCH4	10	35	100	55	0.002	0.025
RCH5	10	35	100	55	0.002	0.025
RCH6	10	35	100	55	0.002	0.025
RCH7	10	35	100	55	0.002	0.025
RCH8	10	35	100	55	0.002	0.025
RCH9	10	35	100	55	0.002	0.025
RCH10	10	35	100	55	0.002	0.025
RCH11	10	35	100	55	0.002	0.025
RCH12	10	35	100	55	0.002	0.025
RCH13	10	35	100	55	0.002	0.025
RCH14	10	35	100	55	0.002	0.025
RCH15	10	35	100	55	0.002	0.025
RCH16	10	35	100	55	0.002	0.025
RCH17	10	35	100	55	0.002	0.025
RCH18	10	35	100	55	0.002	0.025
RCH19	10	35	100	55	0.002	0.025
RCH20	10	35	100	55	0.002	0.025
RCH21	10	35	100	55	0.002	0.025

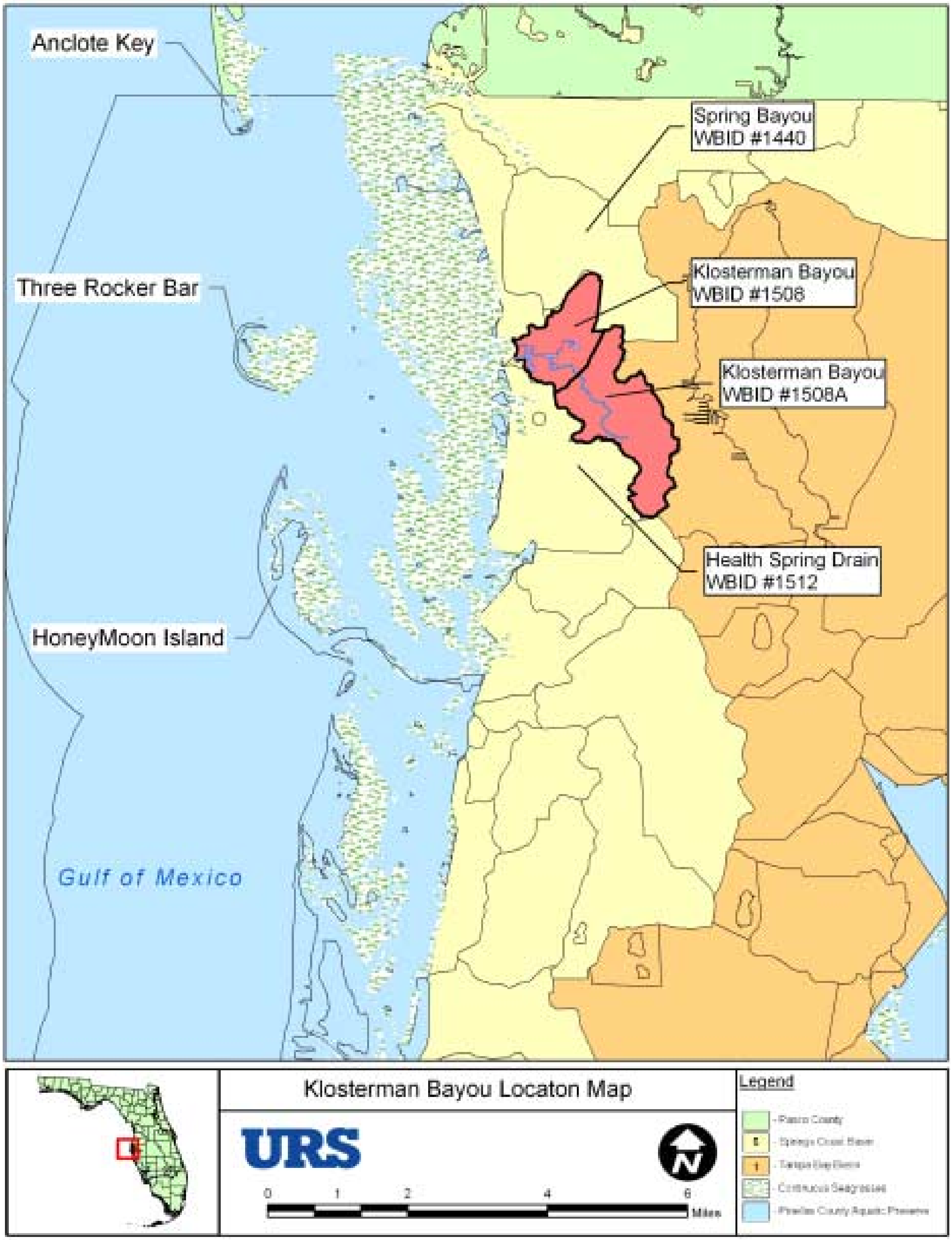


Figure 2-1. Klosterman Bayou Location and surrounding Water Bodies.

Figure 2-2. Klosterman Bayou Model Domain and Geographic Regions within the model with areal extents.

Figure 2-3. Aerial Photographs from 1947 and 2006 showing the development of the Klosterman Bayou area.

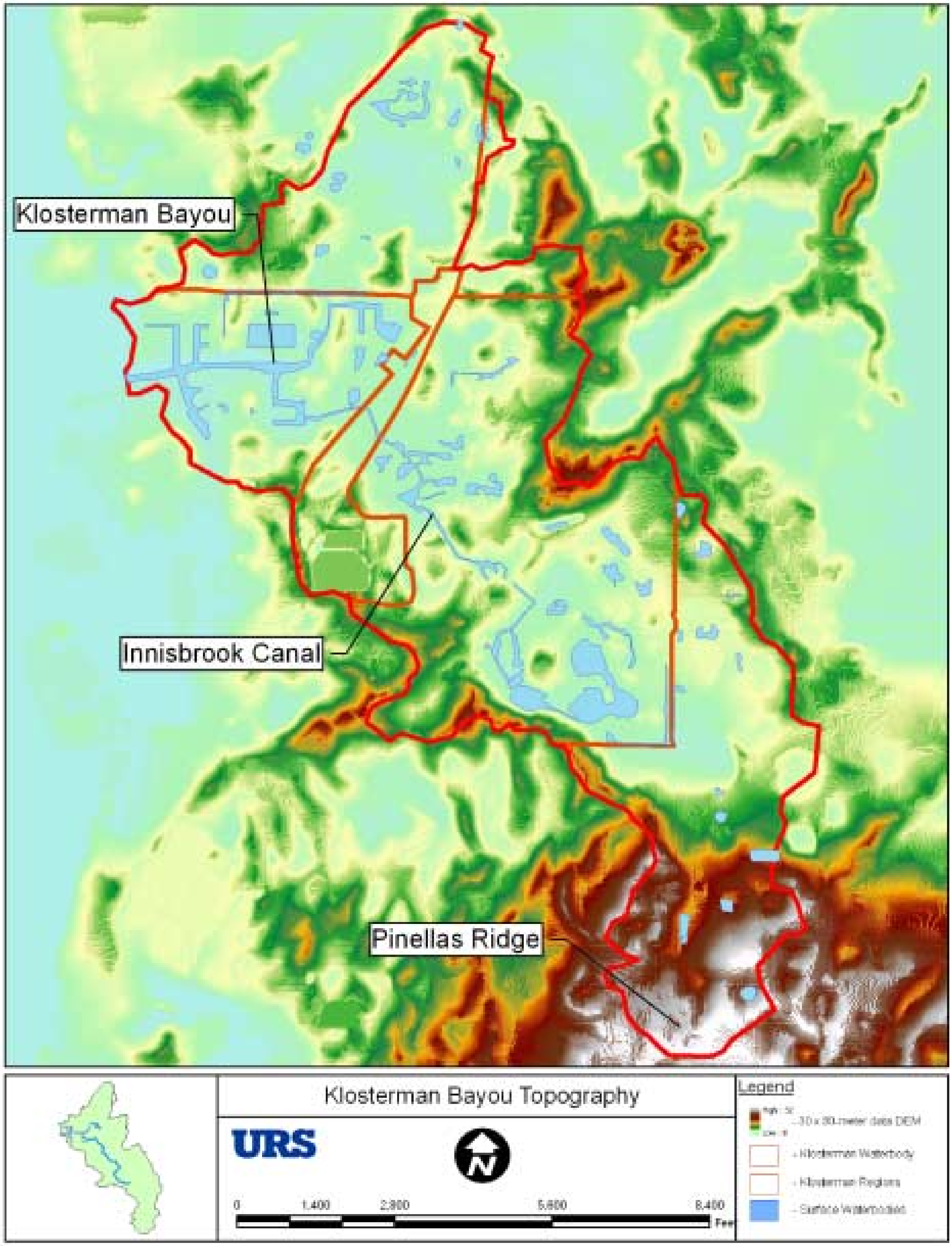


Figure 2-4. Topography of the Klosterman Bayou Watershed.

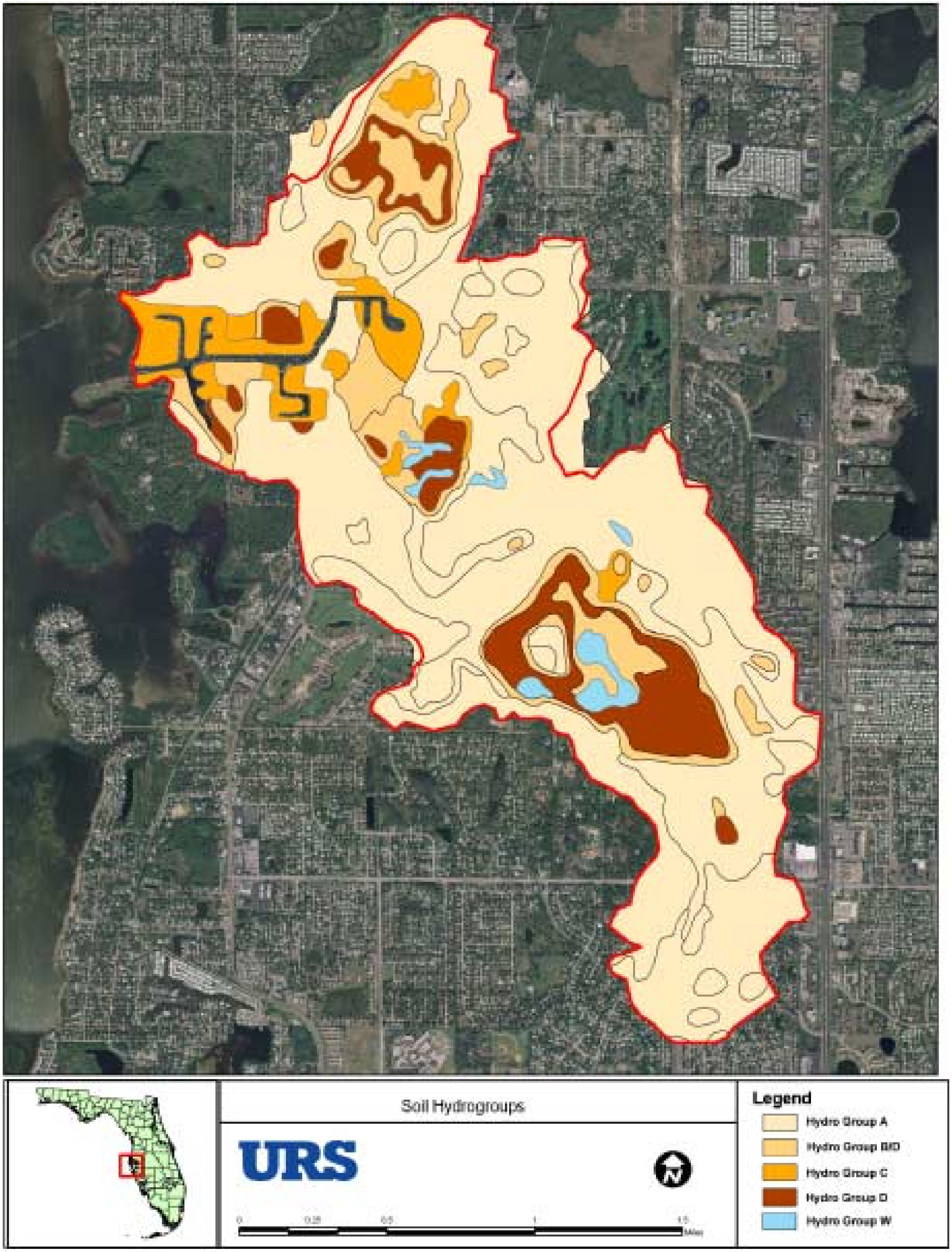


Figure 2-5. Hydrologic Group Soils classification within the model domain.

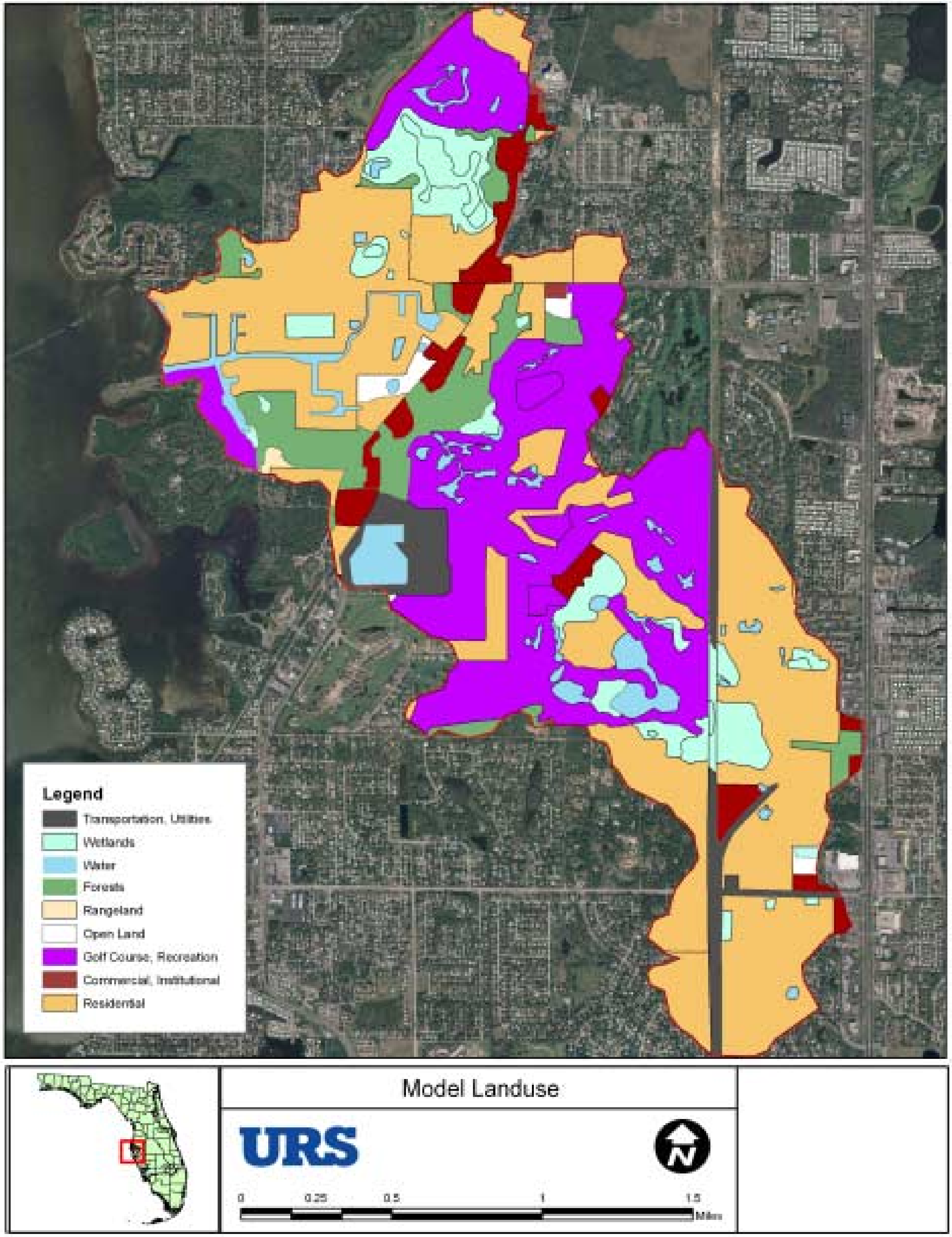


Figure 2-6. 2005 land use for Klosterman Bayou Model Domain.

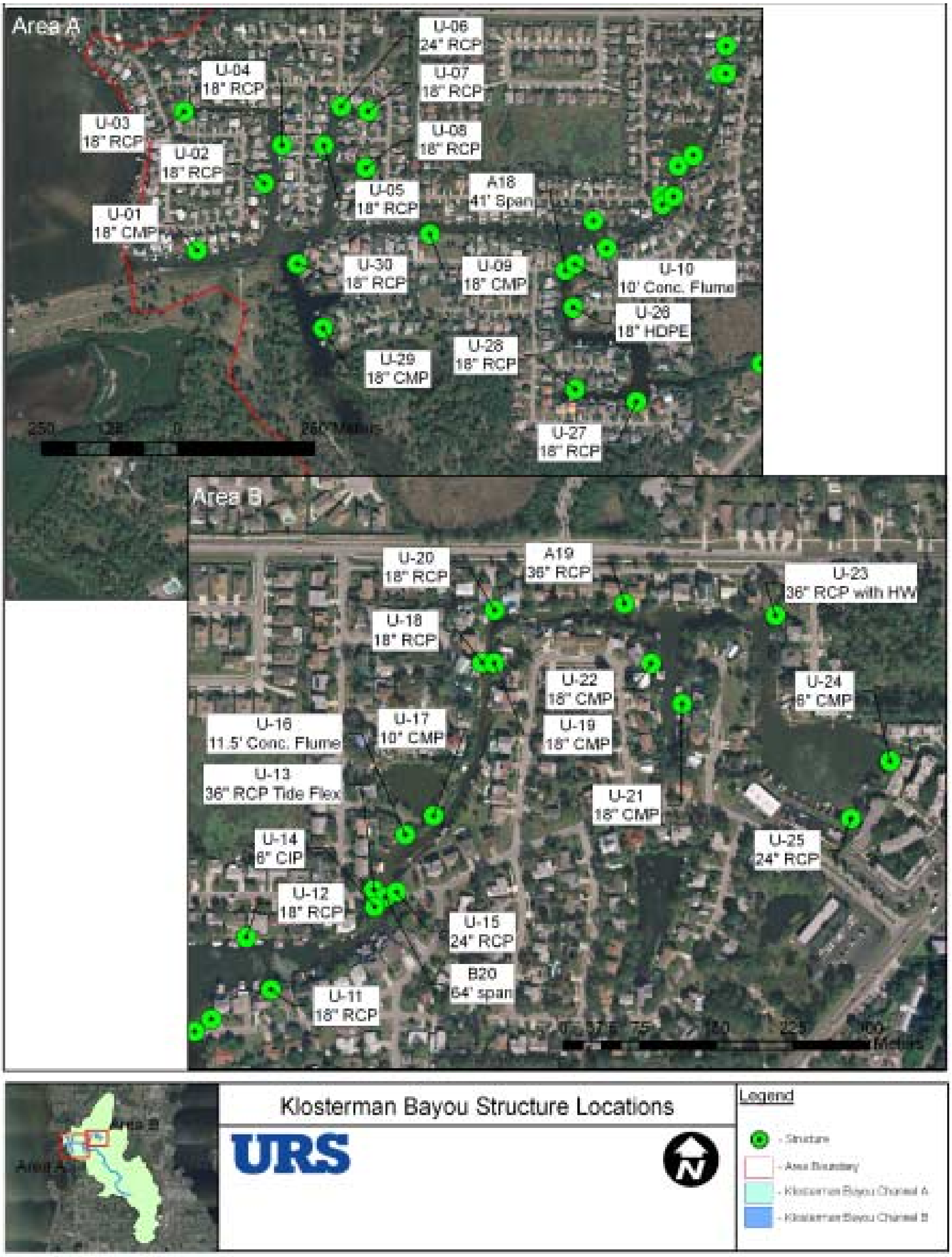


Figure 2-7. Structures in Areas A and B of Klosterman Bayou Watershed.

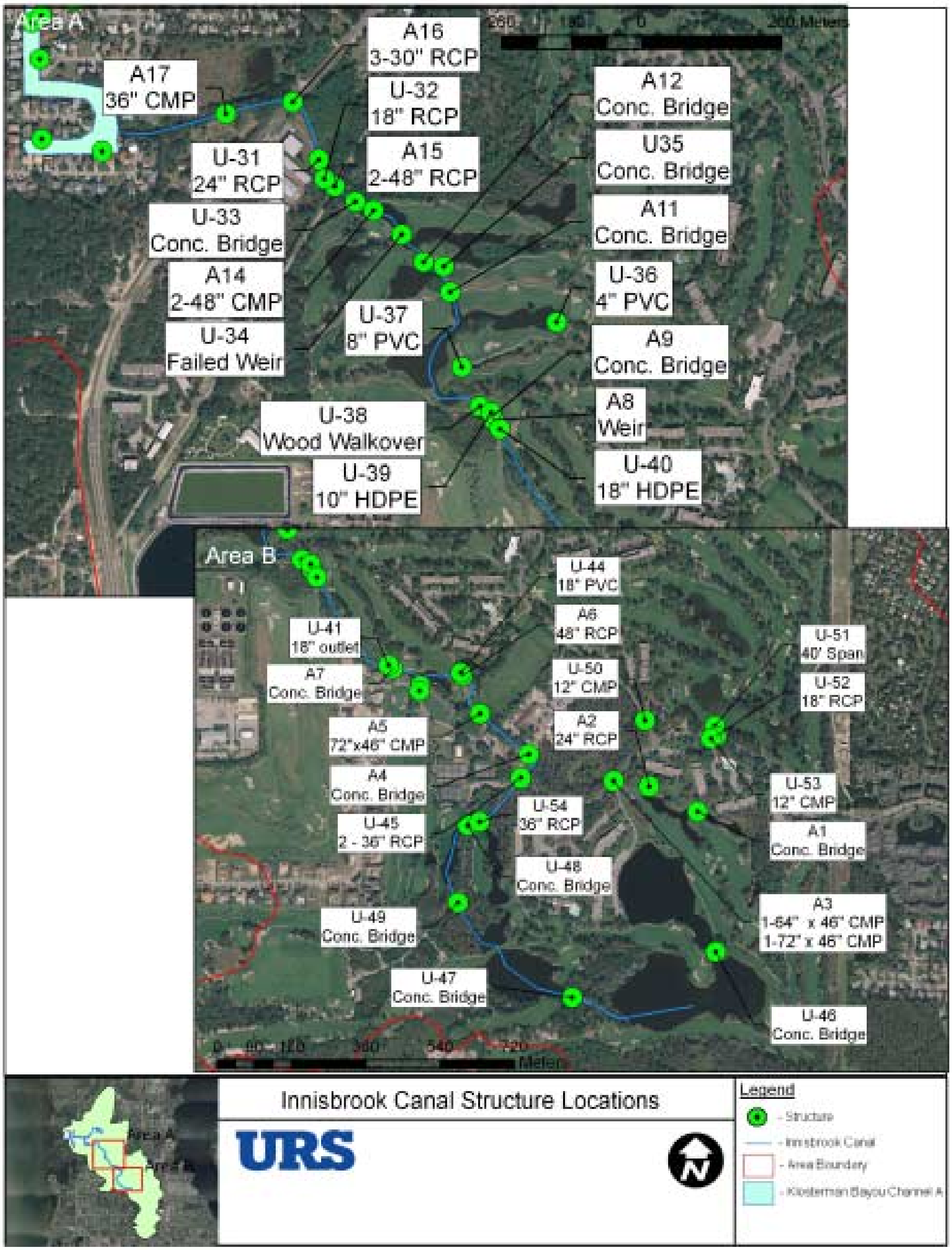


Figure 2-8. Structures in Areas C and D of Klosterman Bayou Watershed.

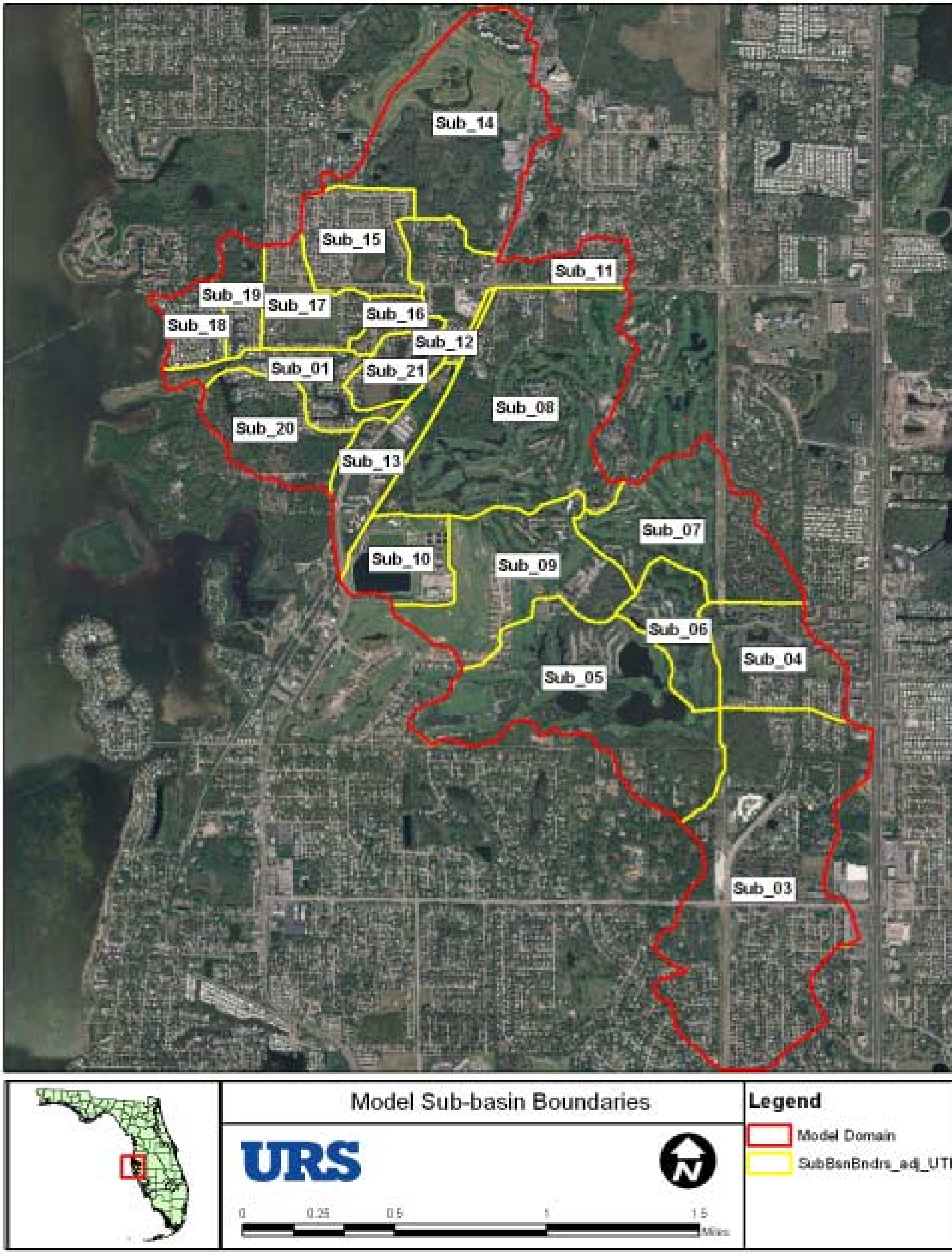


Figure 2-9. Klosterman Bayou model subbasin boundaries.

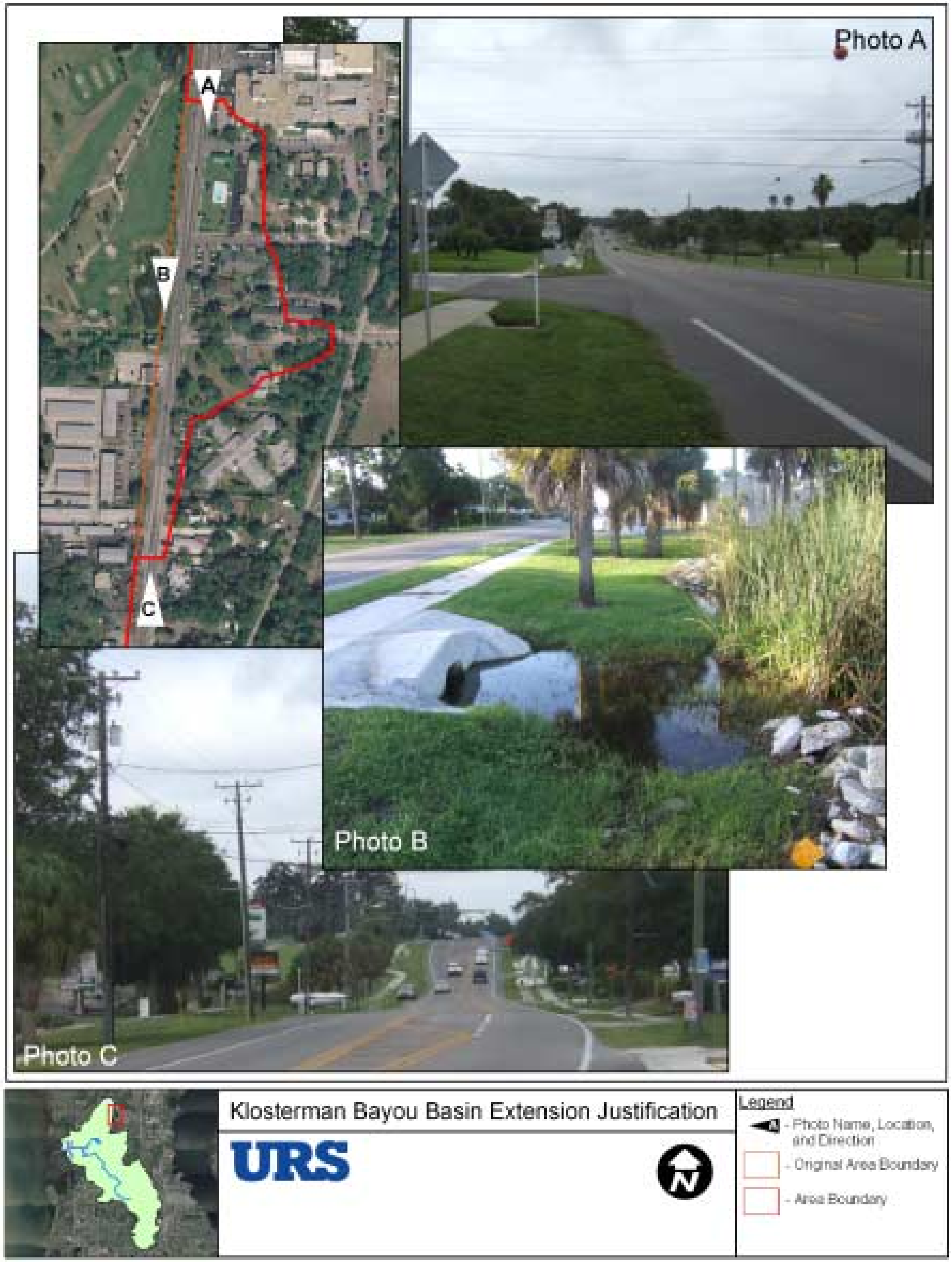


Figure 2-10. Ditch systems on the East side of Alternate 19.

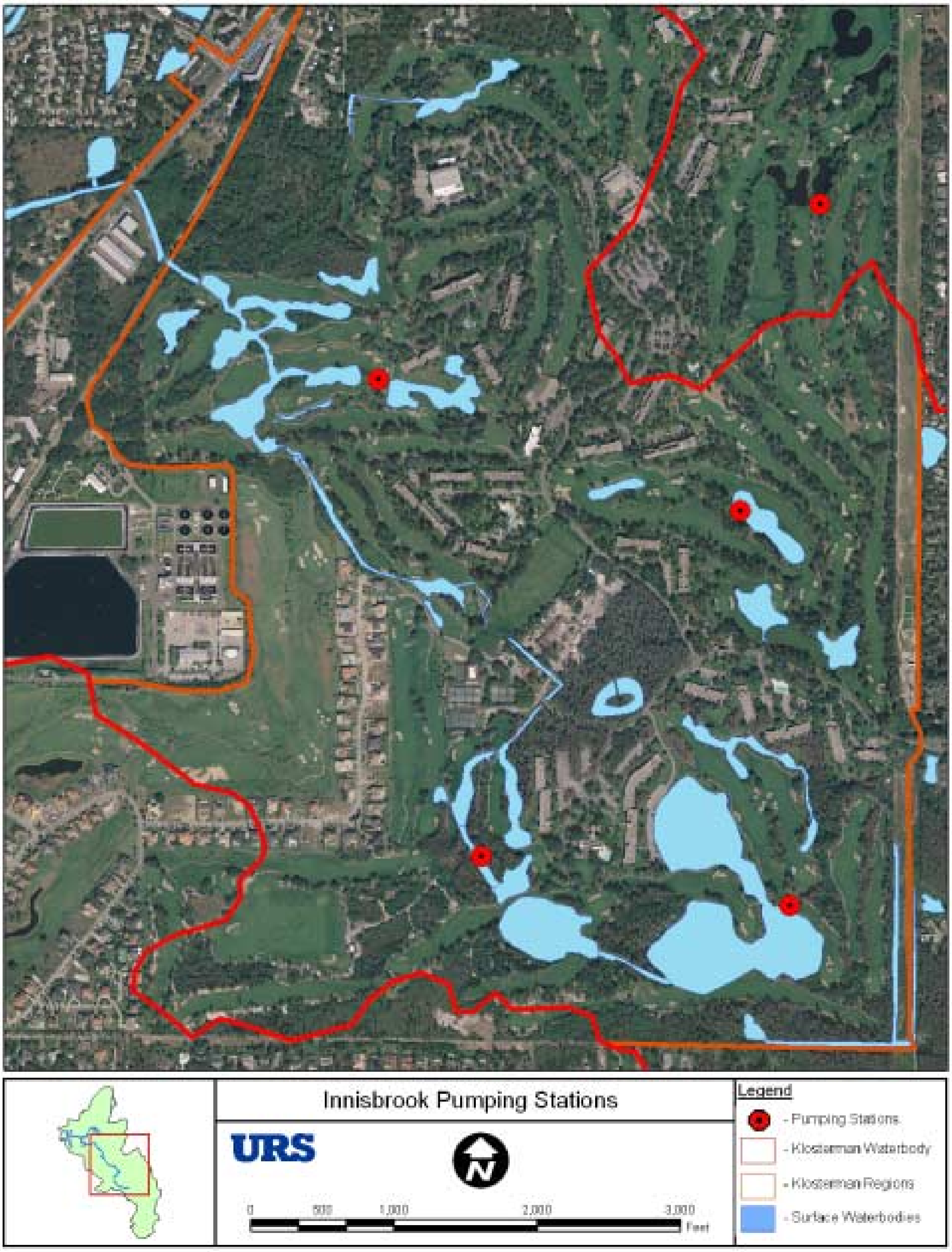


Figure 2-11. Innisbrook Pumping Stations.

Figure 2-12. Flow and Water Quality Monitoring Station Locations.

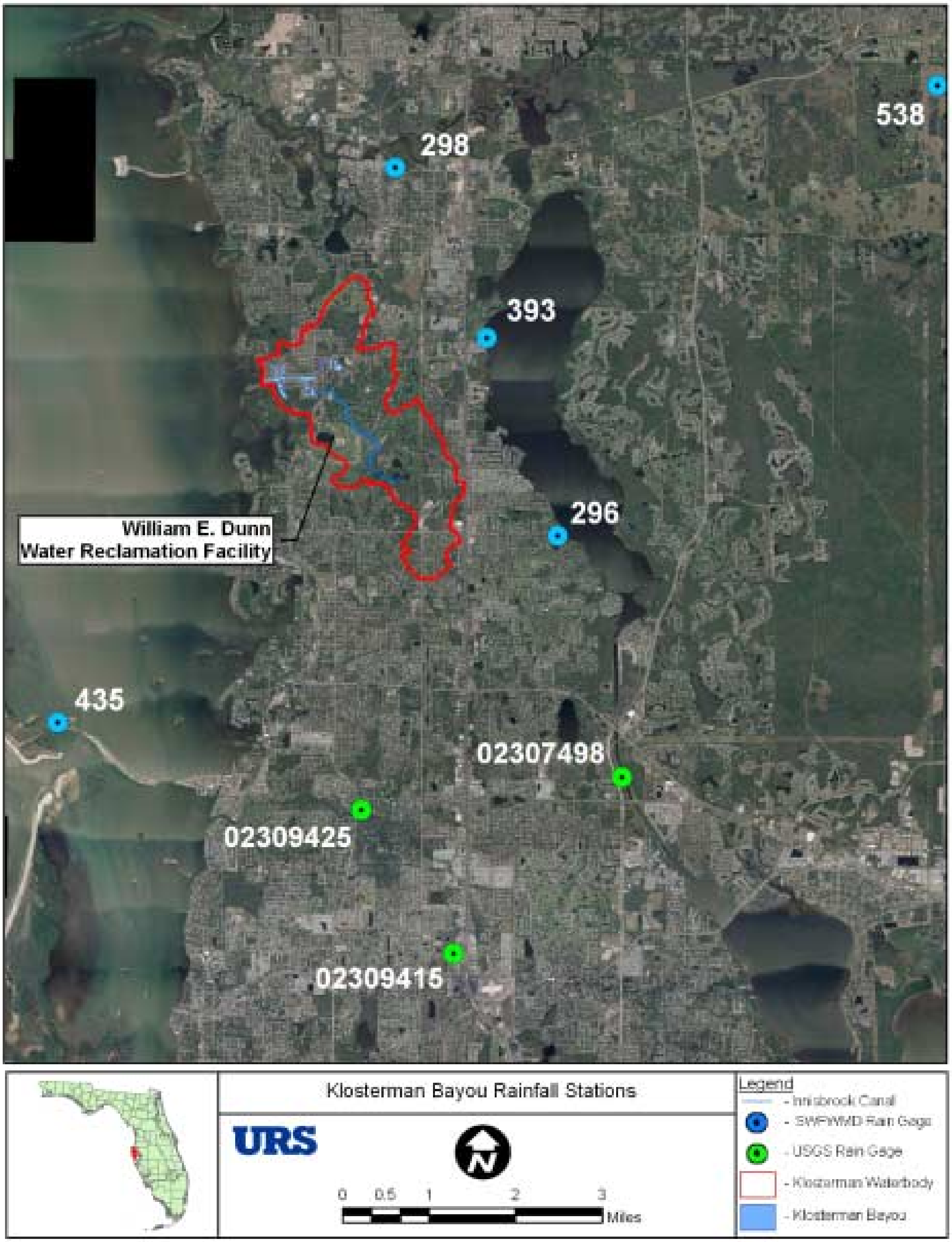


Figure 2-13. Rainfall Stations in Klosterman Bayou study area.

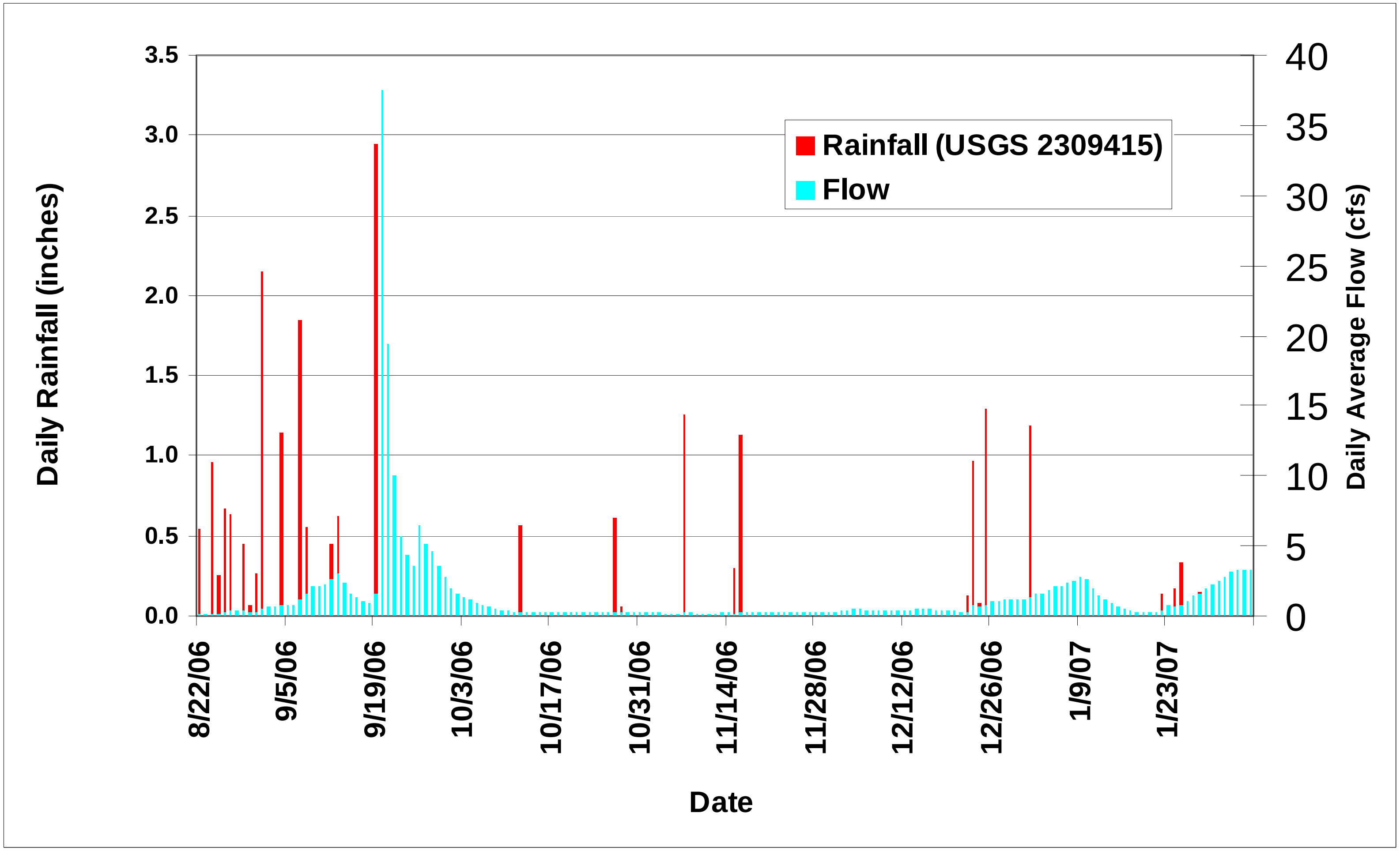


Figure 2-14. Correlation of Rainfall and Flow in Klosterman Bayou Watershed.

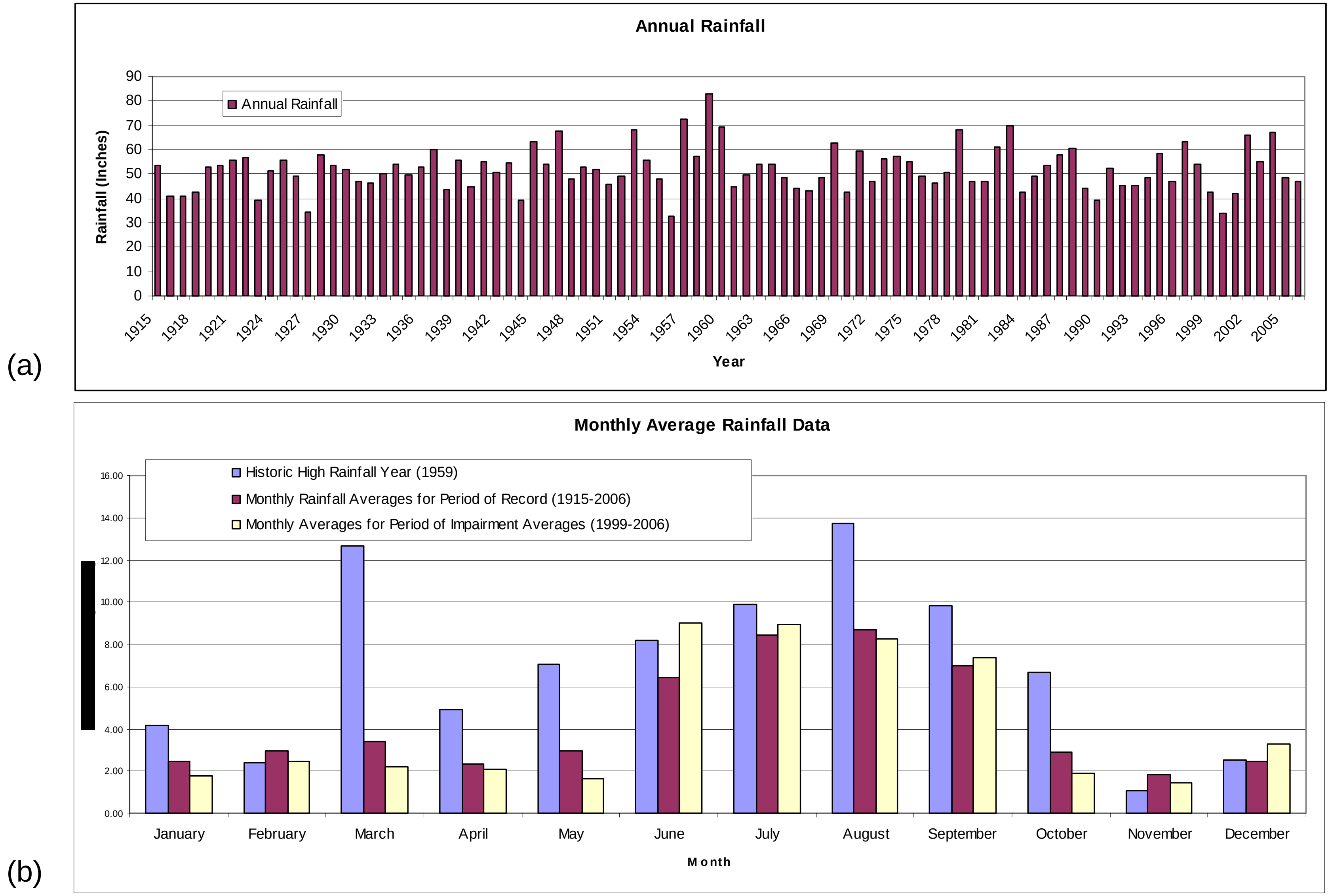


Figure 2-15. Rainfall data from CWM compiled by SFWMD. (a) Annual rainfall for period of record. (b) Seasonal averages for entire period of record from 1915-2006, period of impairment from 1999-2006, and for peak rainfall year 1959.

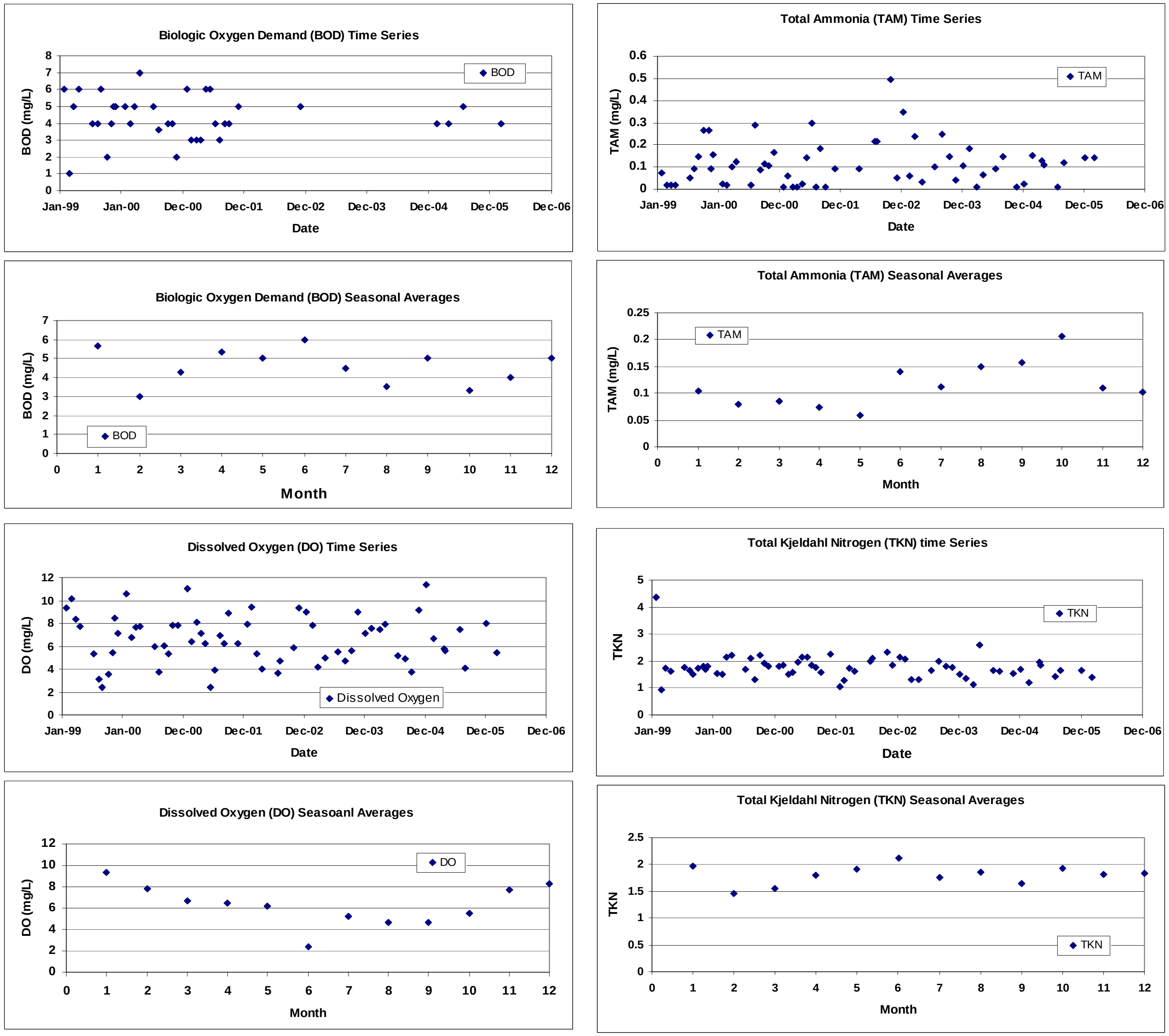


Figure 2-16. Water Quality Data from Stations 02-02 and 02-07 - Time Series and Seasonal Averages.

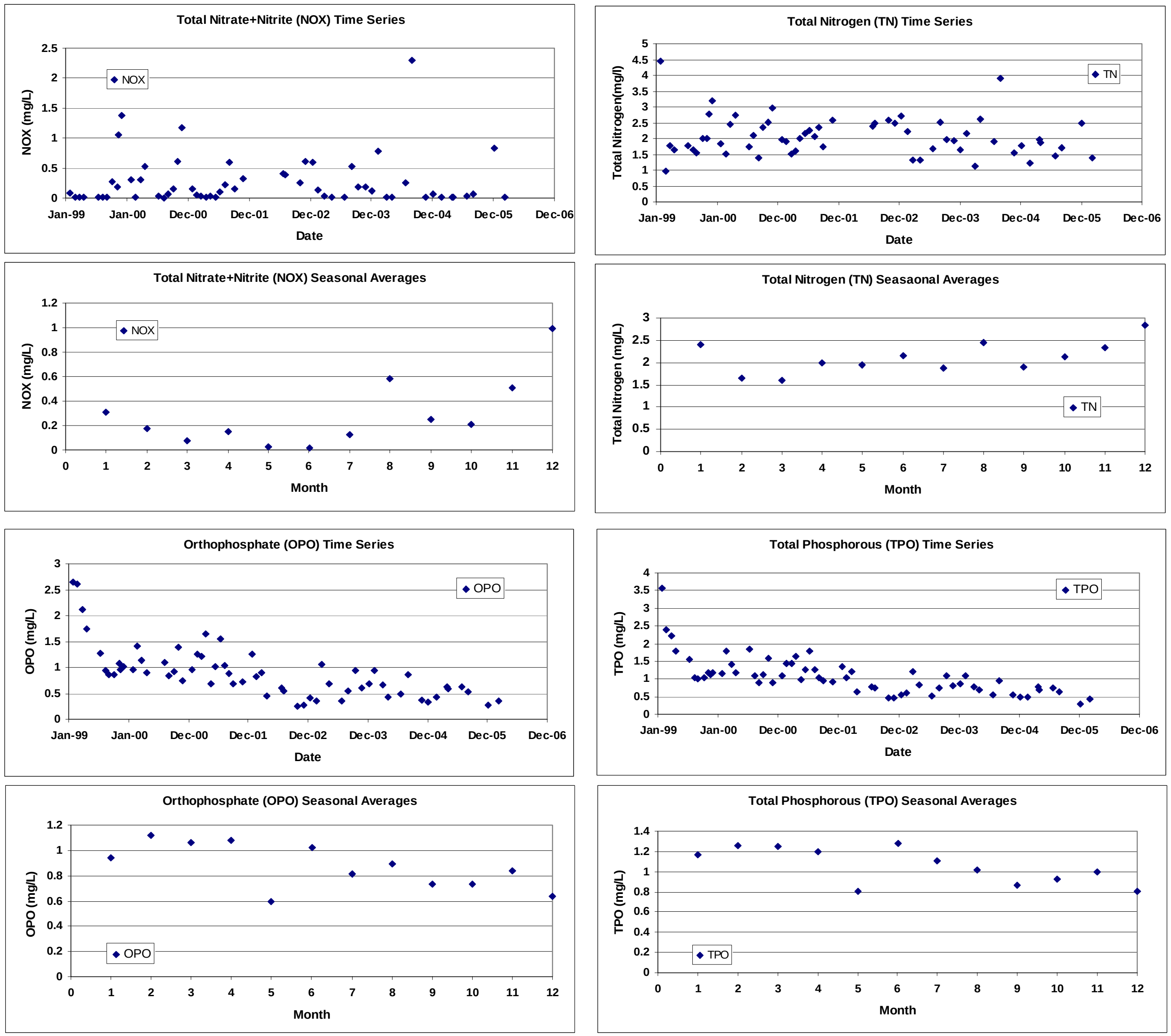


Figure 2-16. Water Quality Data from Stations 02-02 and 02-07 - Time Series and Seasonal Averages. (cont'd)

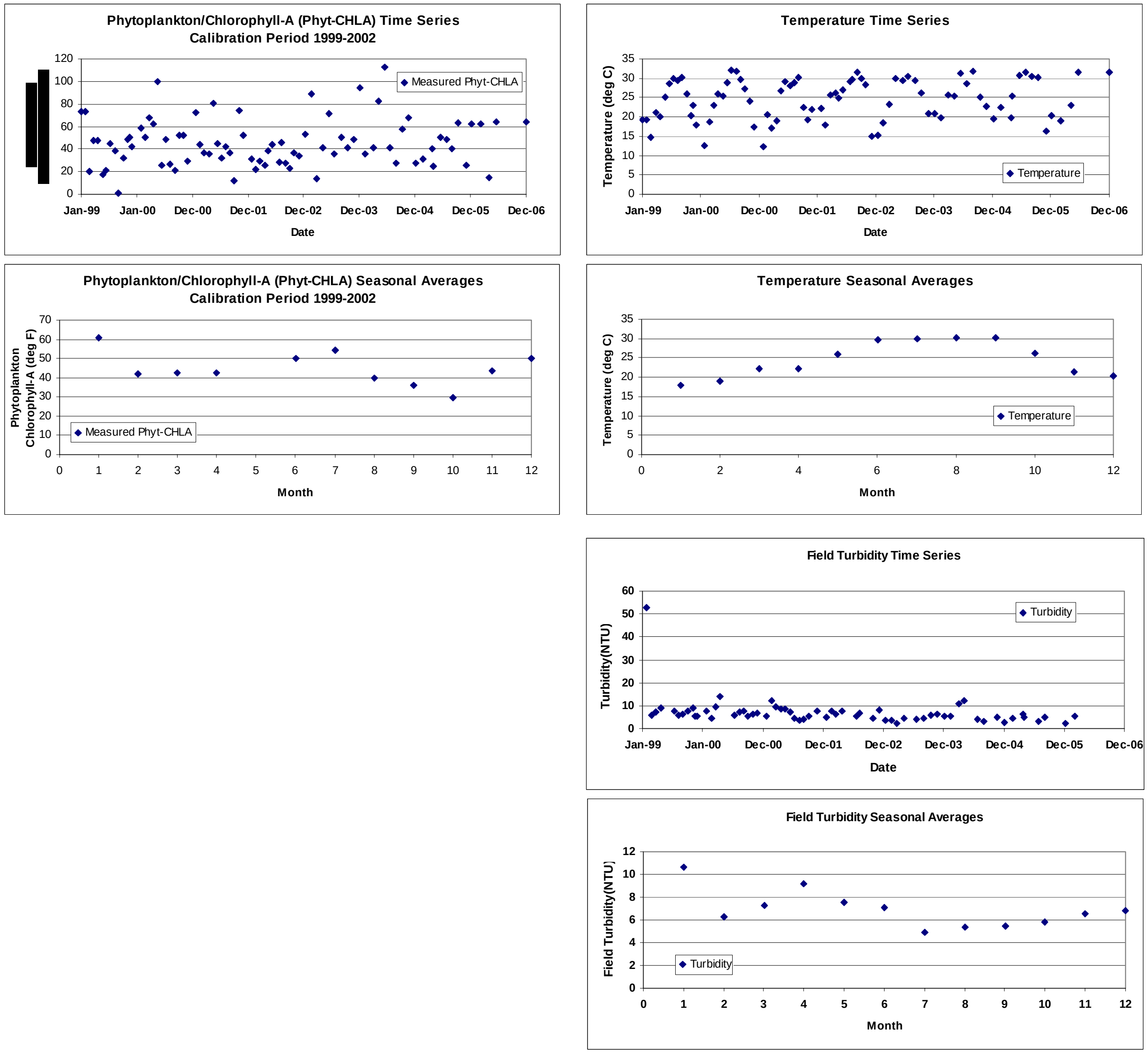


Figure 2-16. Water Quality Data from Stations 02-02 and 02-07 - Time Series and Seasonal Averages. (cont'd)

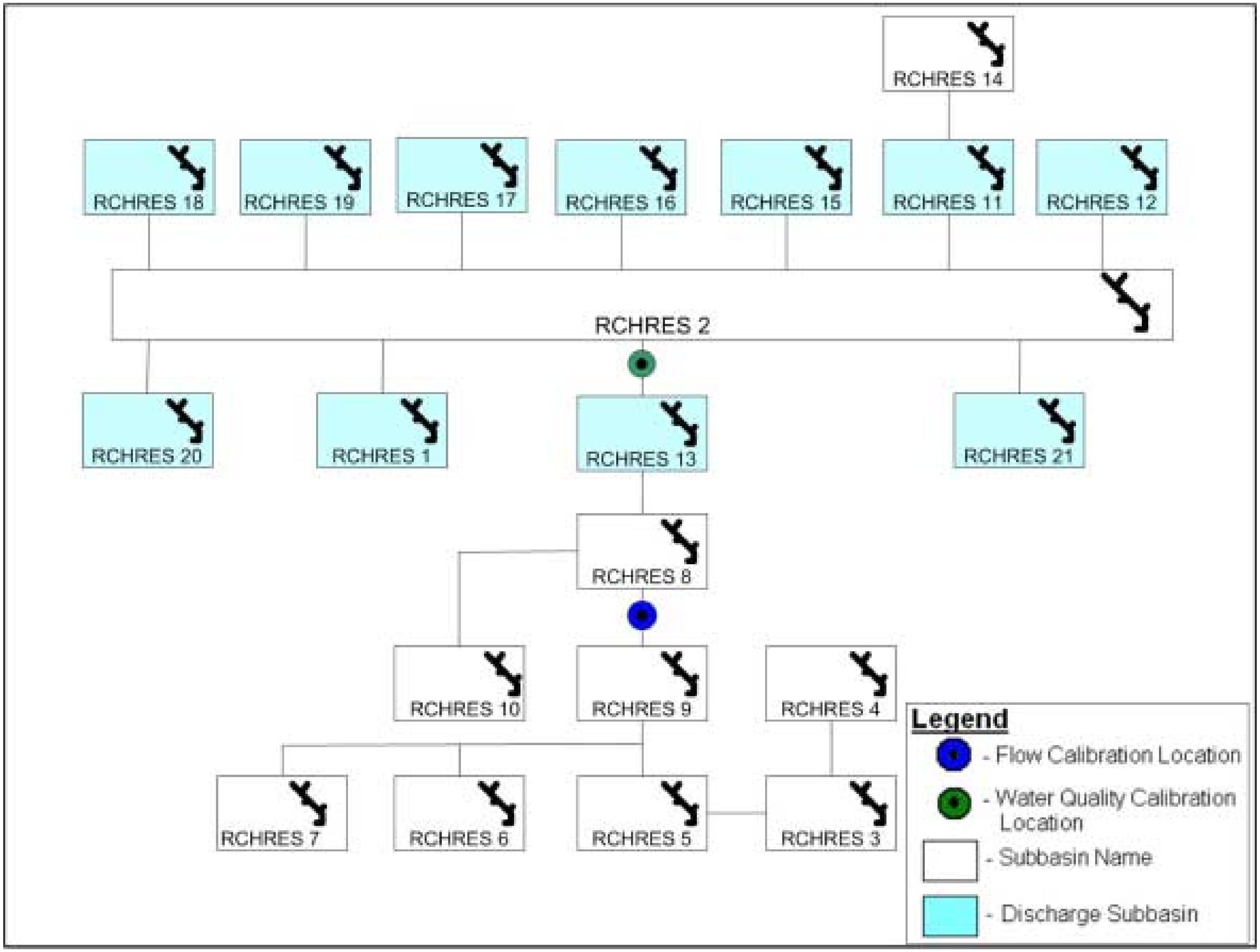


Figure 3-1. HSPF model subbasin configuration.

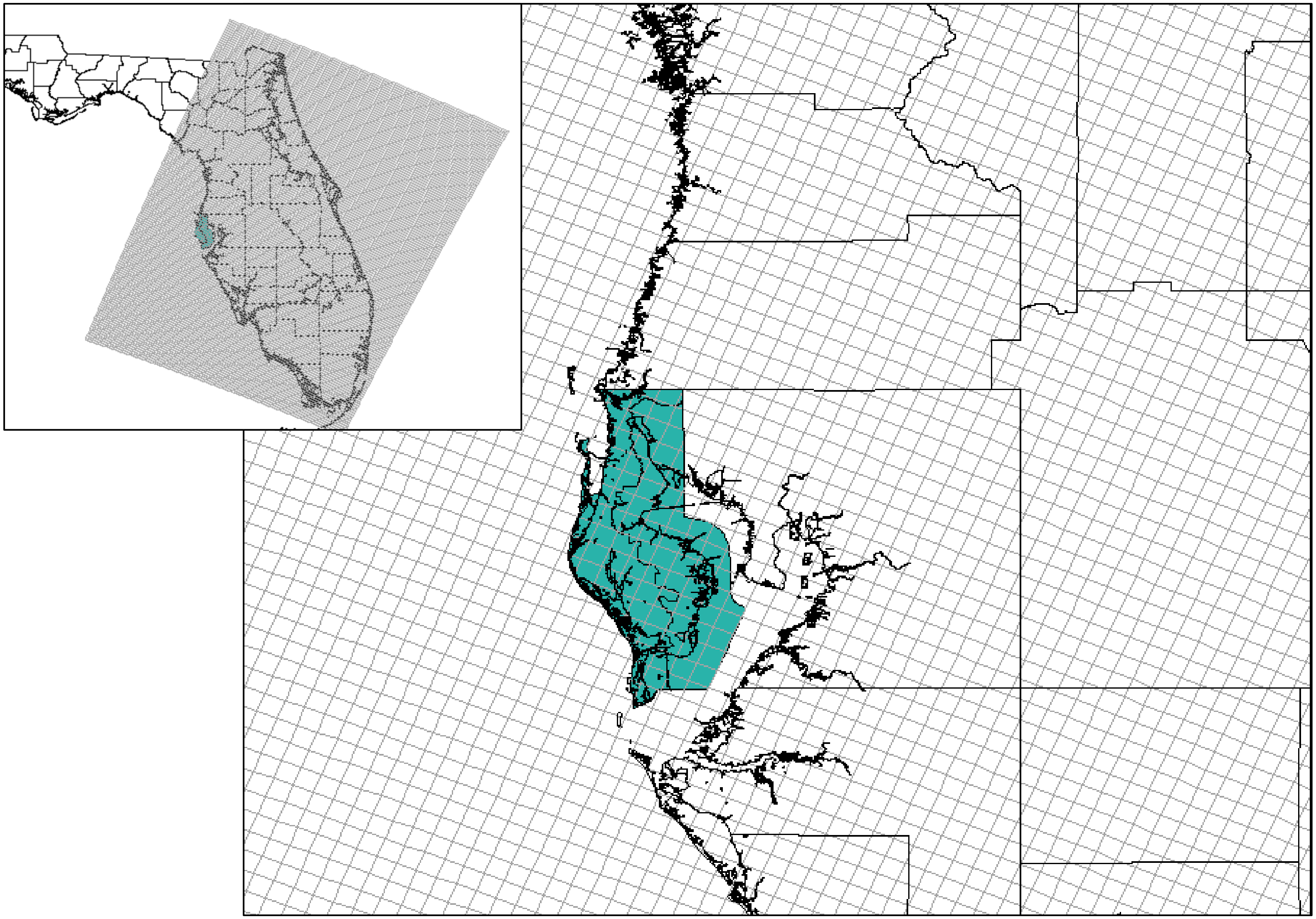
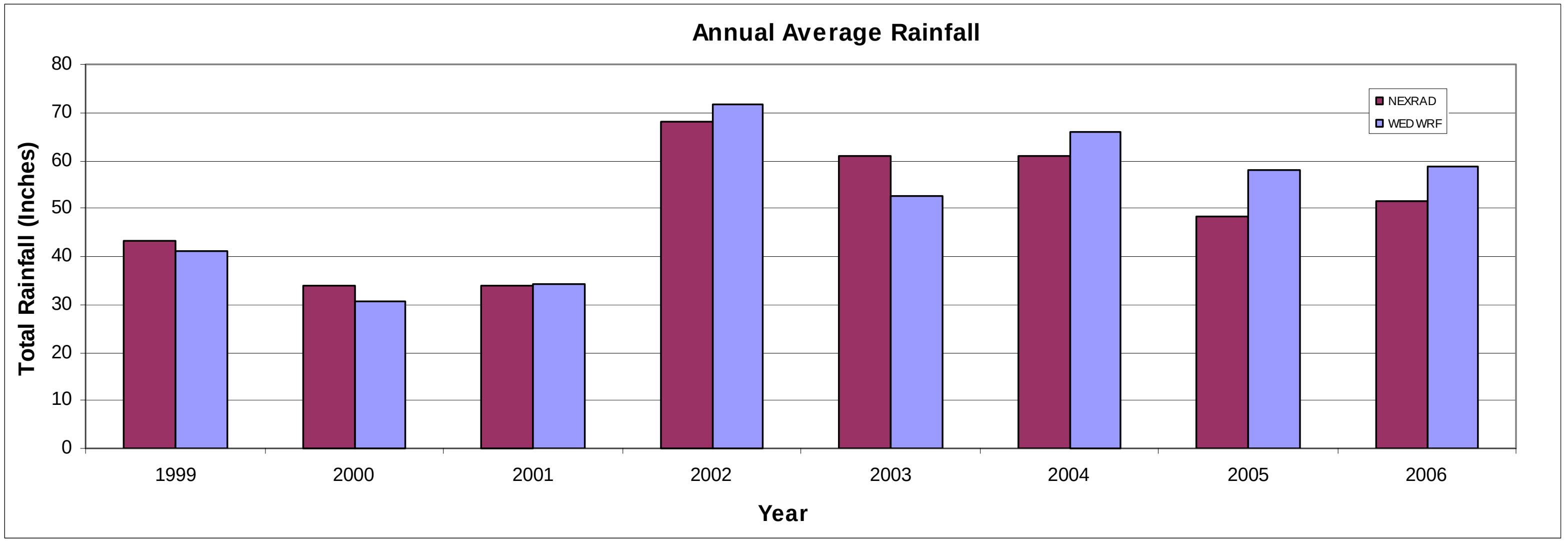


Figure 3-2. NEXRAD Grid in Klosterman Bayou Area.

(a)



(b)

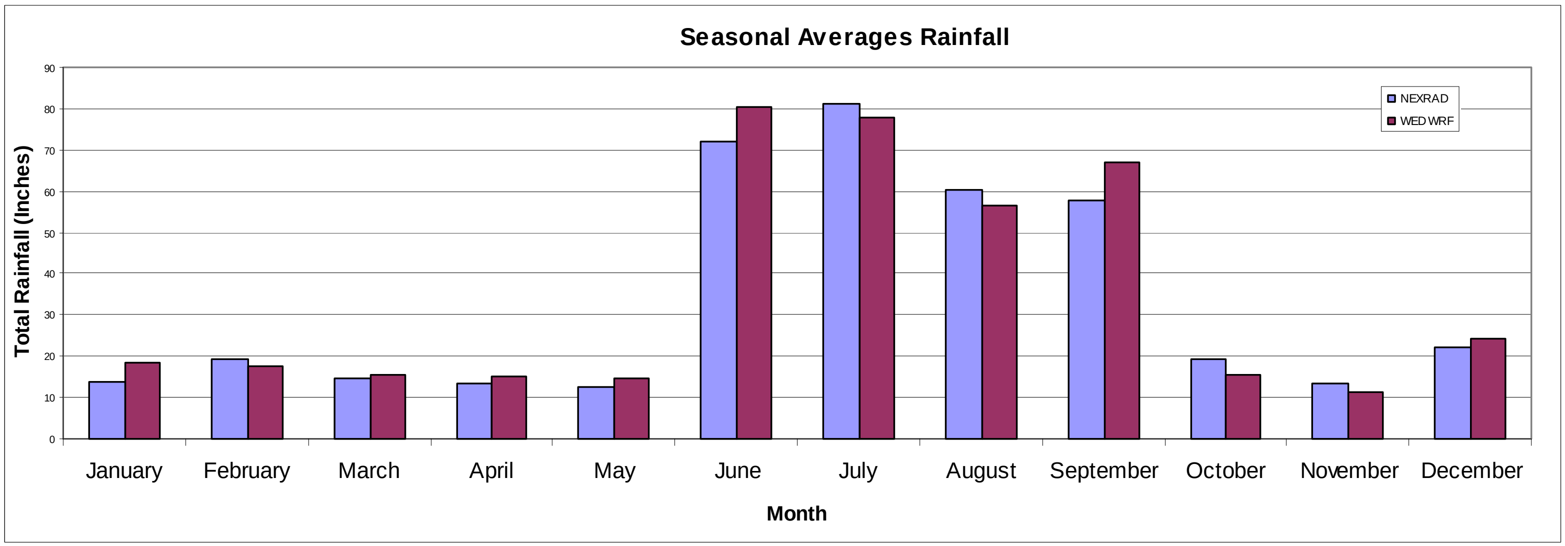


Figure 3-3. NEXRAD Doppler radar rainfall data compared to measured rainfall from William E. Dunn Water Reclamation Facility (WED).(a) Annual average rainfall comparison (b) Seasonal average rainfall.

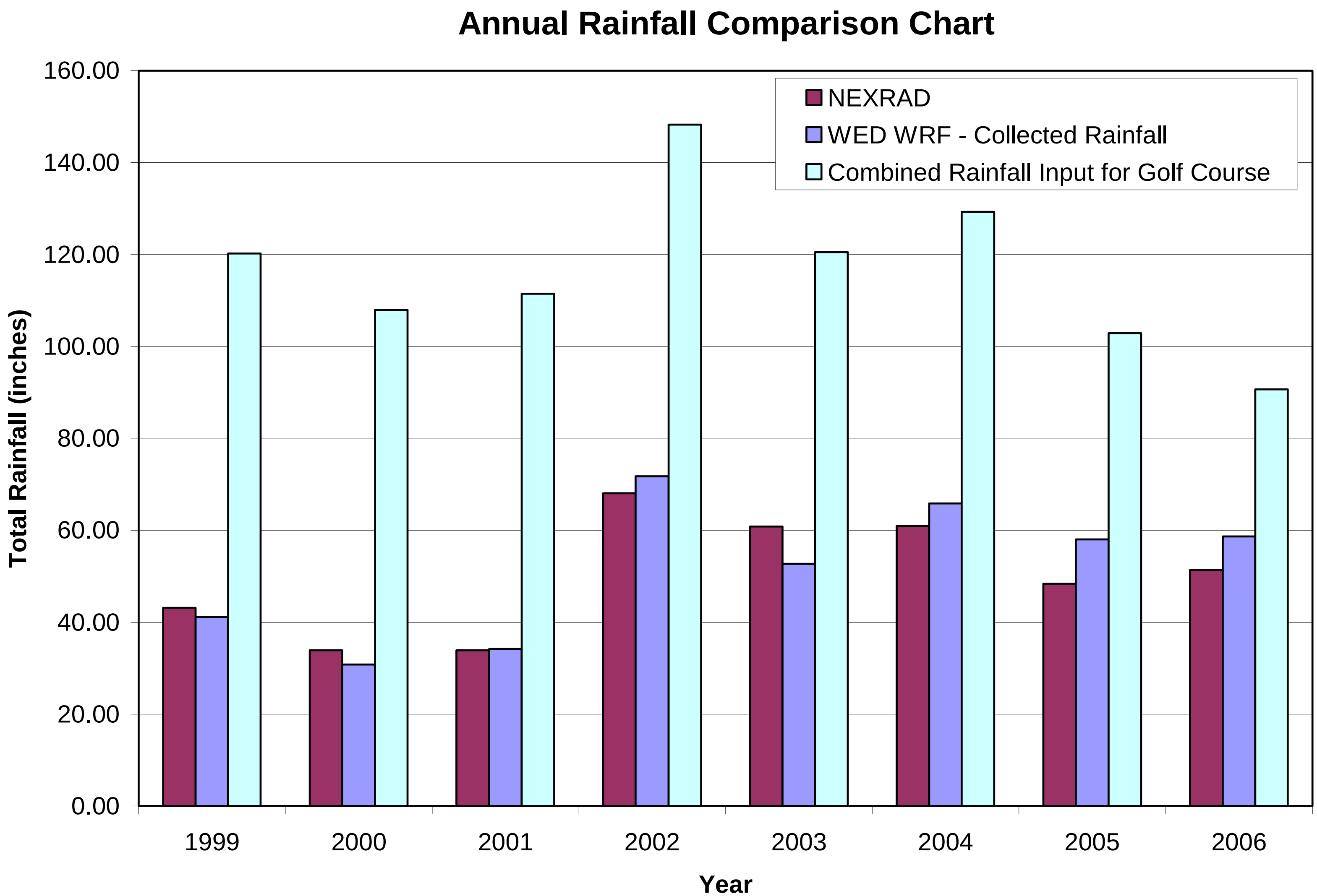


Figure 3-4. Comparison of NEXRAD rainfall, monthly measured rainfall at the Dunn Facility, and rainfall model input for the Golf Course which combines NEXRAD data with calculated water reclamation volumes.

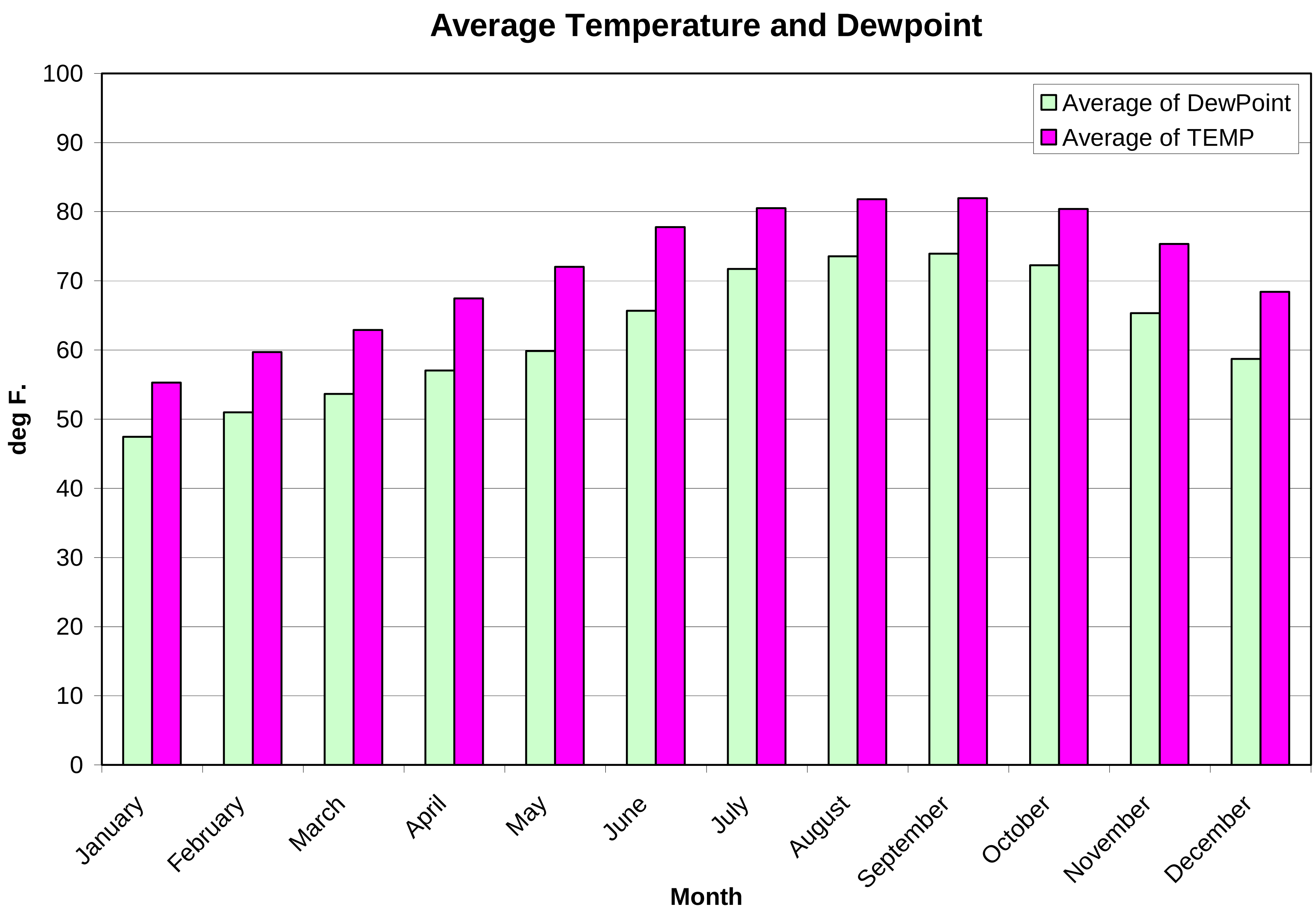


Figure 3-5. Average air temperature and dew point model forcing data.

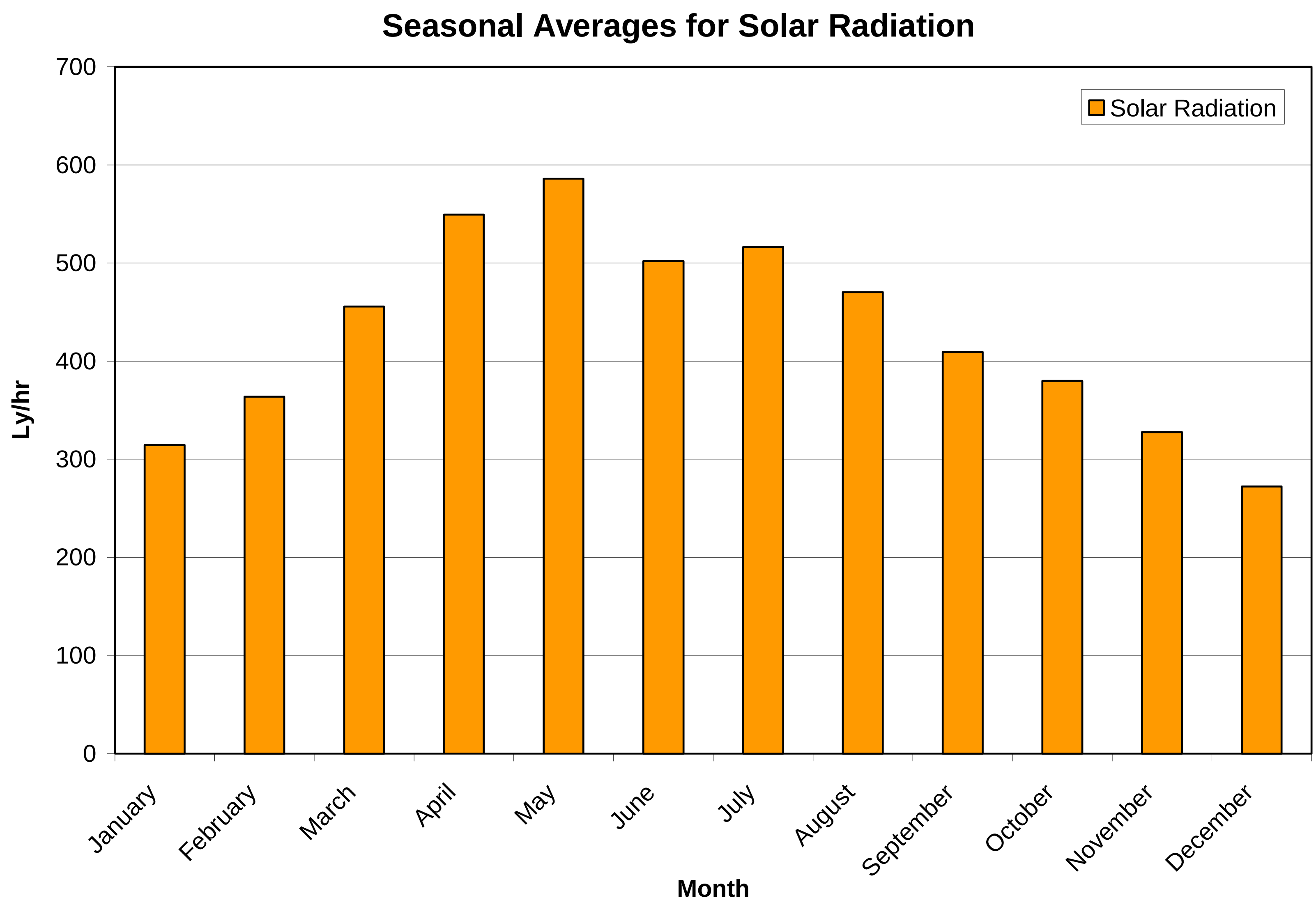


Figure 3-6. Solar Radiation from TPA Station for calibration period 1999-2006.

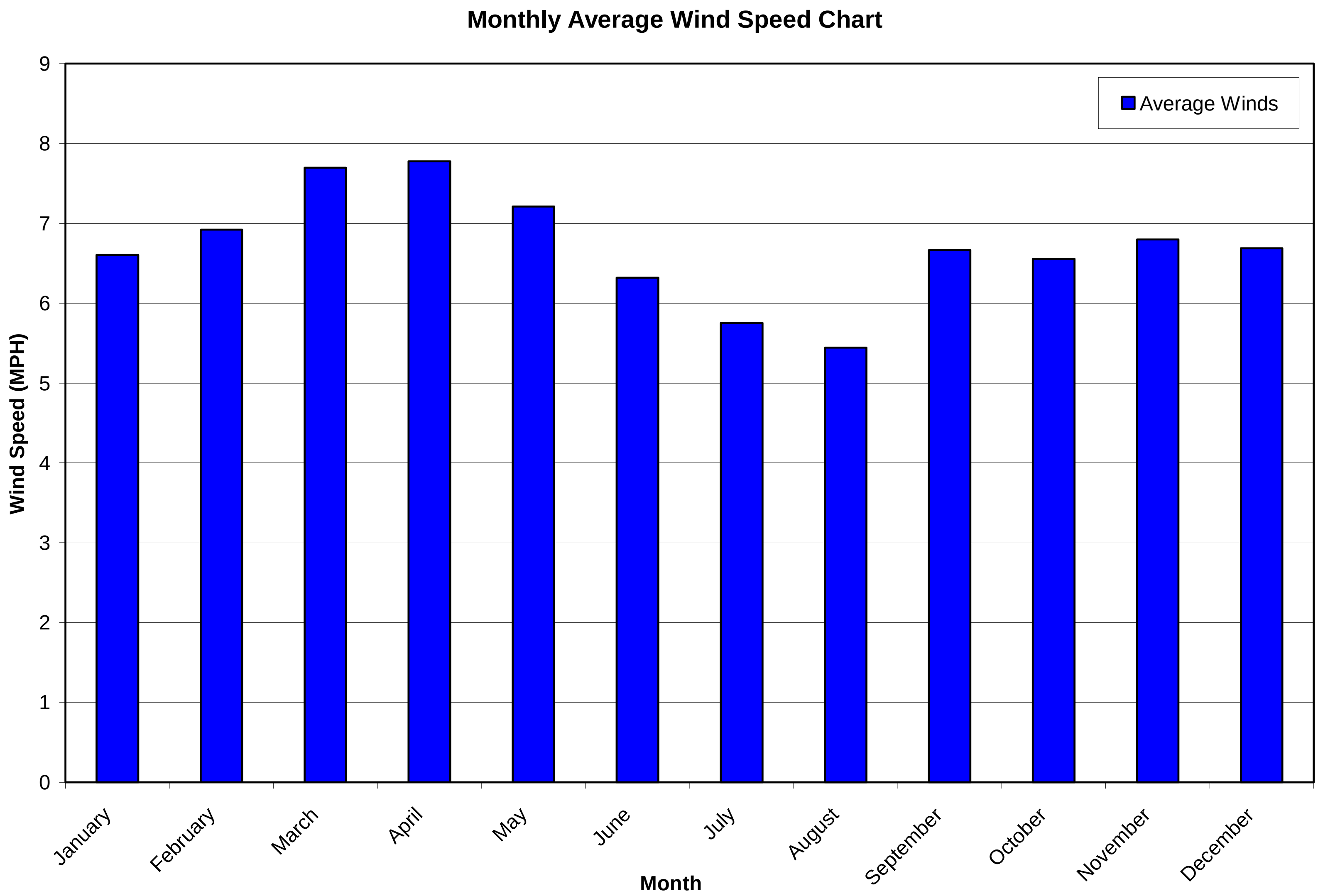


Figure 3-7. Monthly average Wind Speed data during calibration period of 1999-2006.

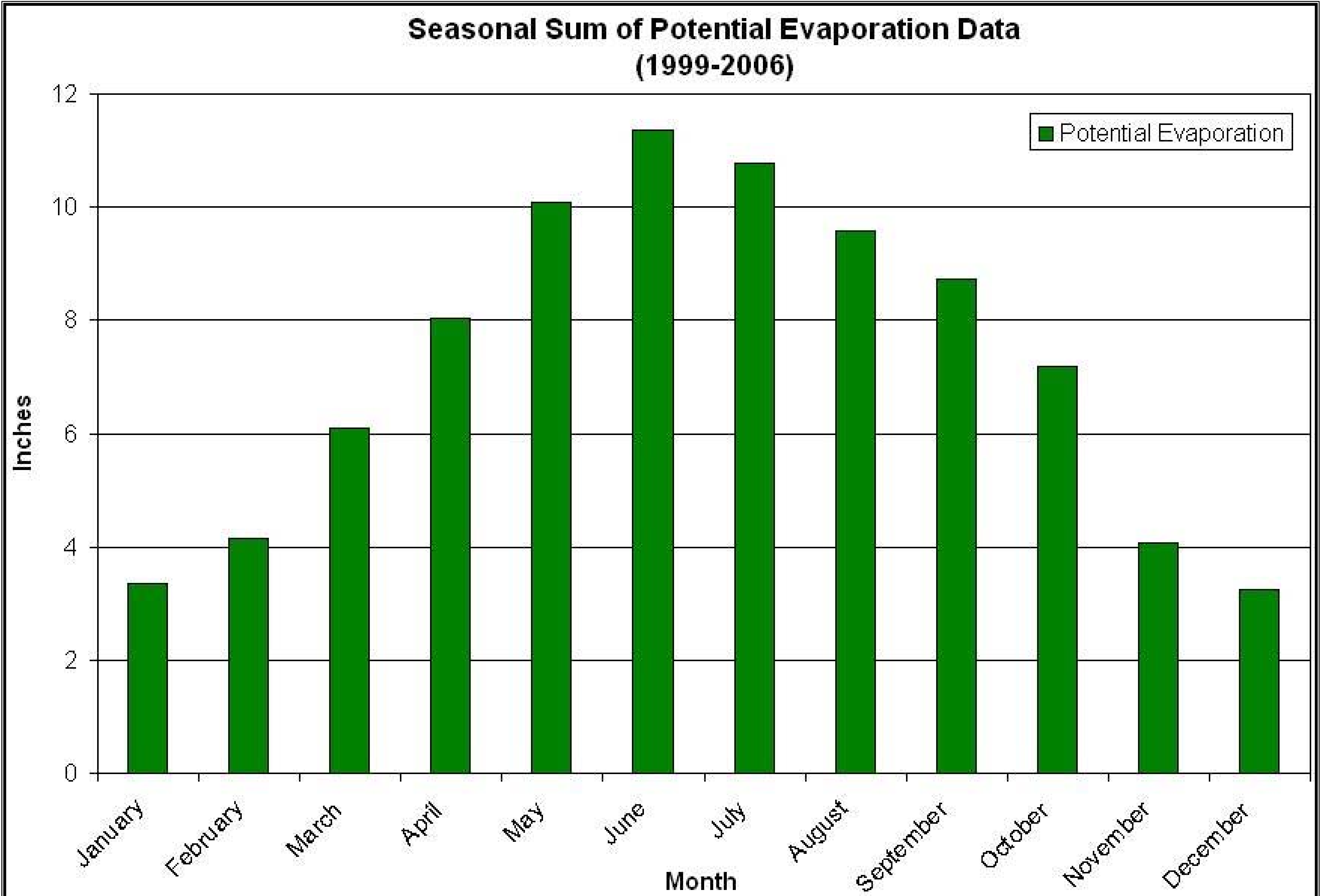


Figure 3-8. Calculated evaporation from climatic data collected at TPA for calibration period1999-2006.

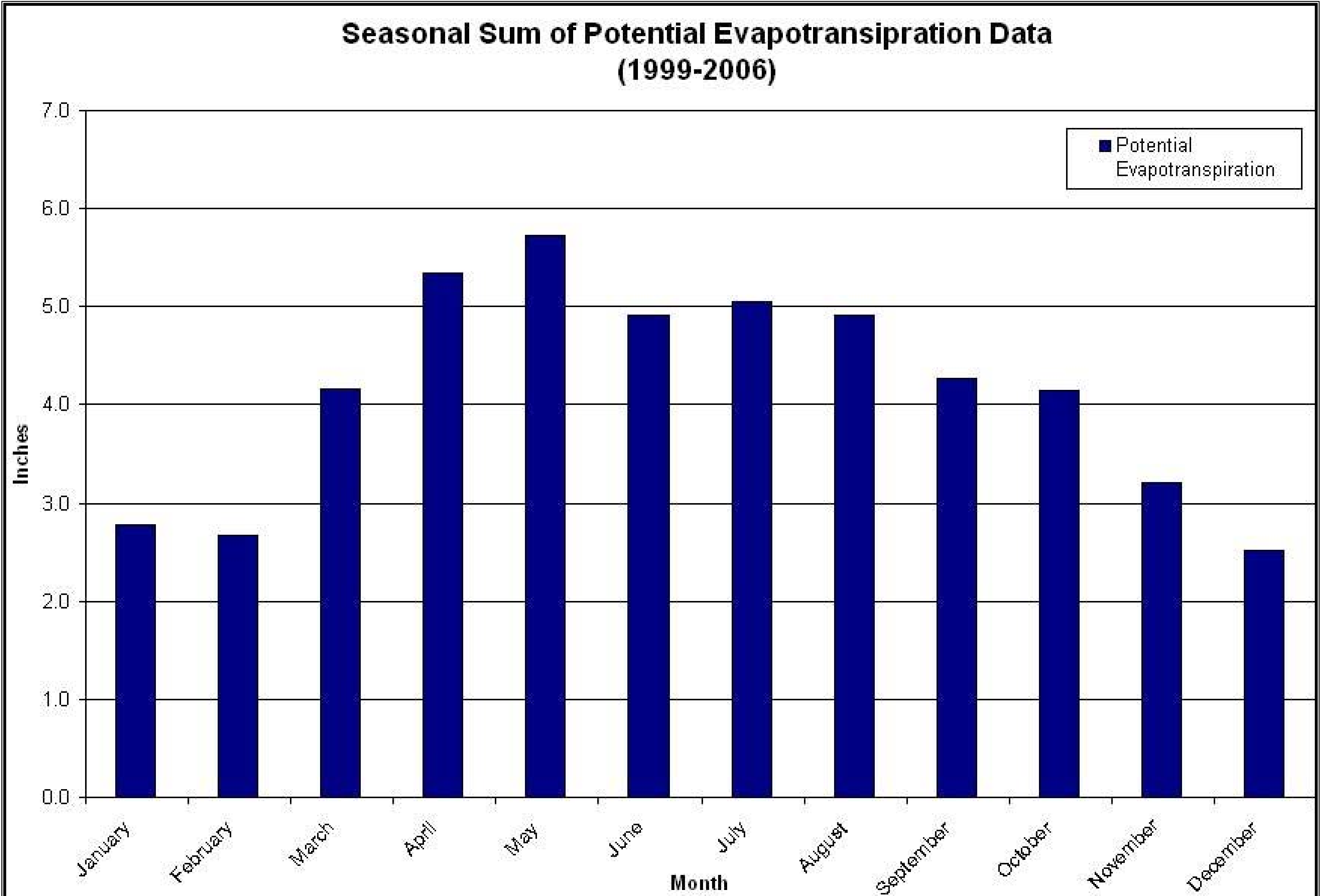


Figure 3-9. Potential Evapotranspiration data from Lake Como station (Station ID: 20) for calibration period 1999-2006.

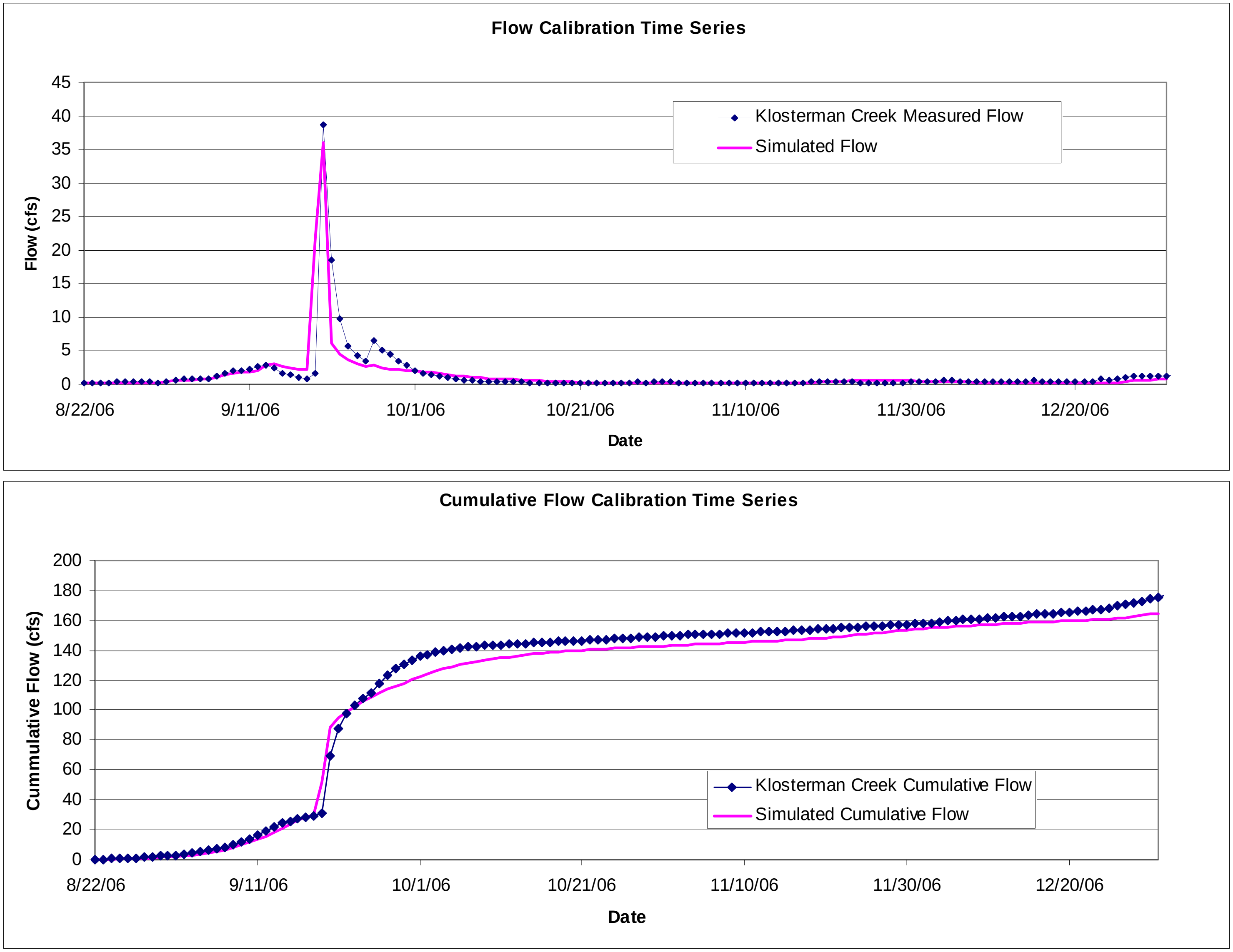


Figure 3-10. Flow Calibration Time Series and Cumulative Flow Calibration Time Series plots of measured flow and simulated flow.

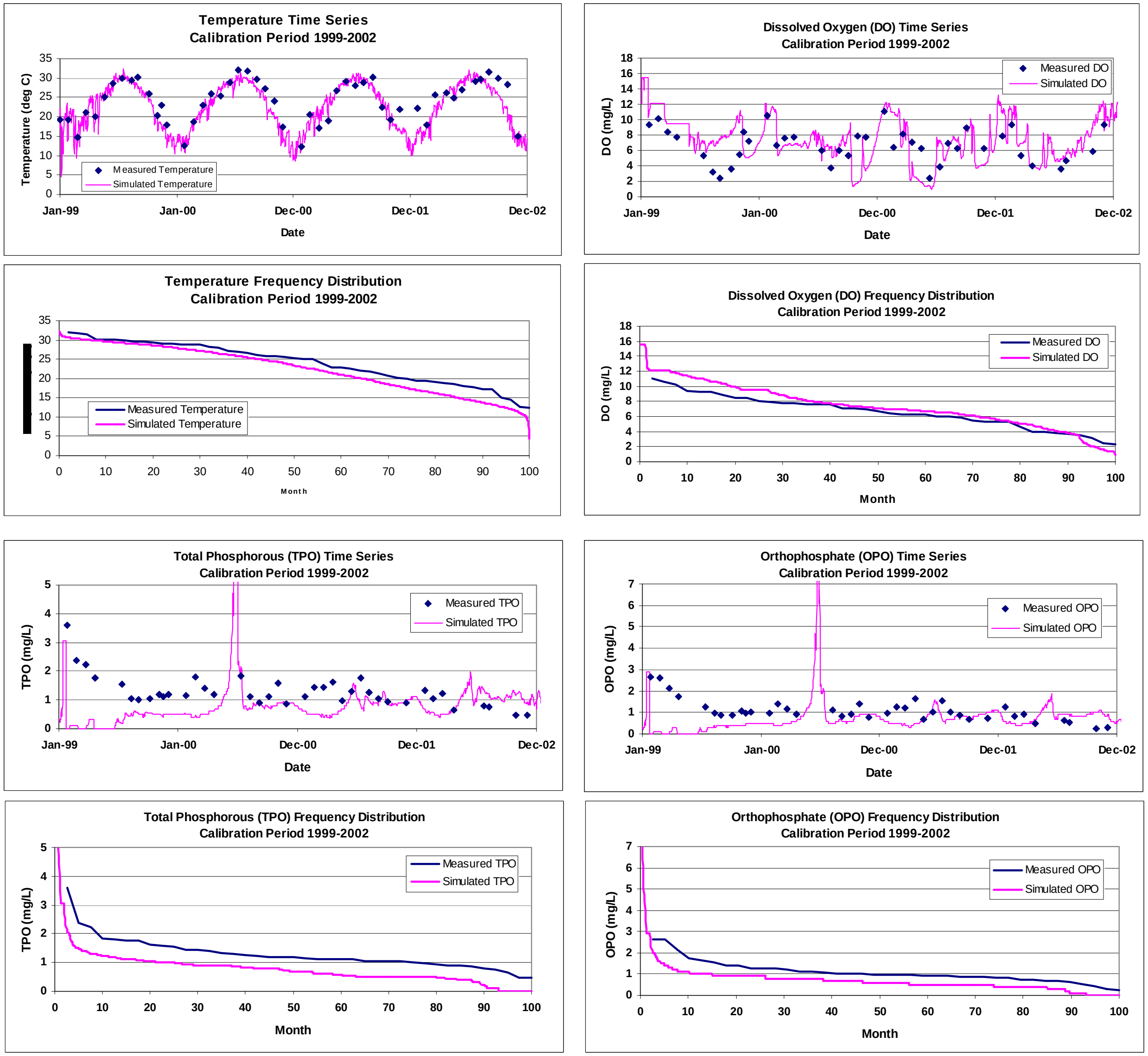


Figure 3-11. Time Series and Frequency Distribution plots for Water Quality parameters for Calibration Period of 1/1/1999 through 12/31/2002.

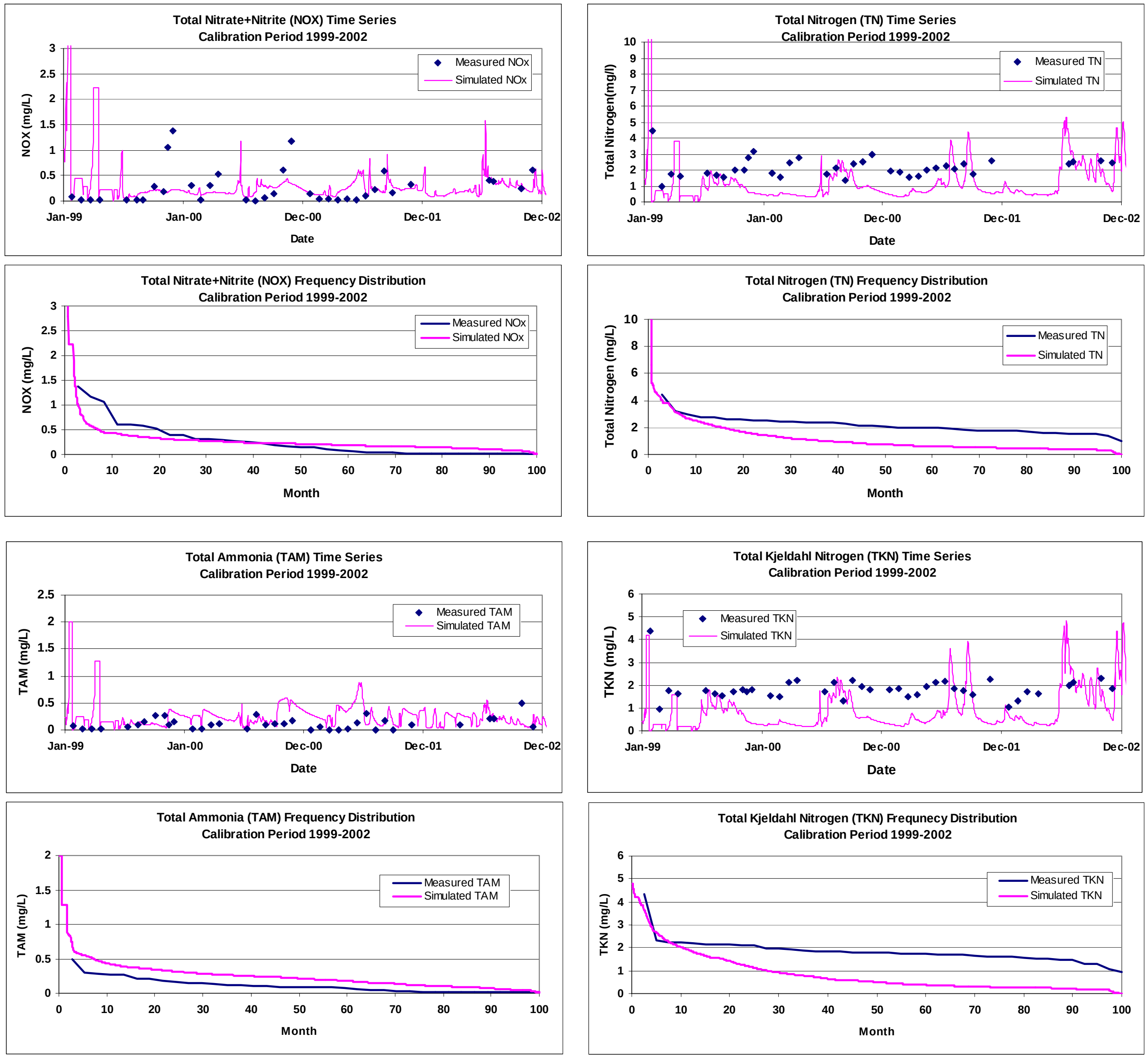


Figure 3-11. Time Series and Frequency Distribution plots for Water Quality parameters for Calibration Period of 1/1/1999 through 12/31/2002. (cont'd)

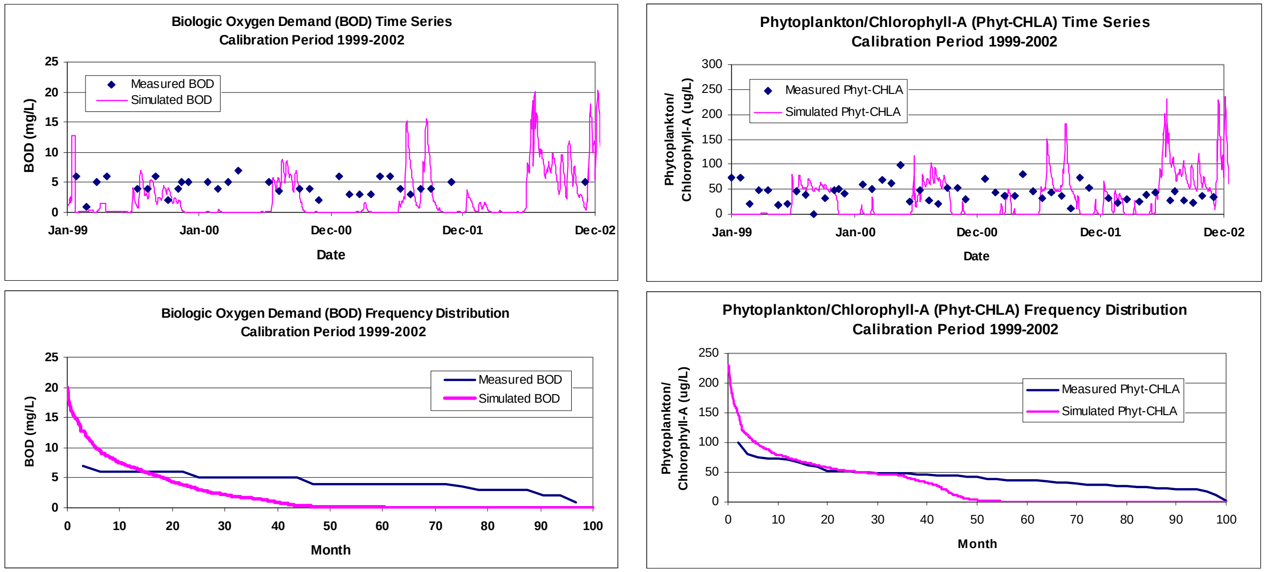


Figure 3-11. Time Series and Frequency Distribution plots for Water Quality parameters for Calibration Period of 1/1/1999 through 12/31/2002. (cont'd)

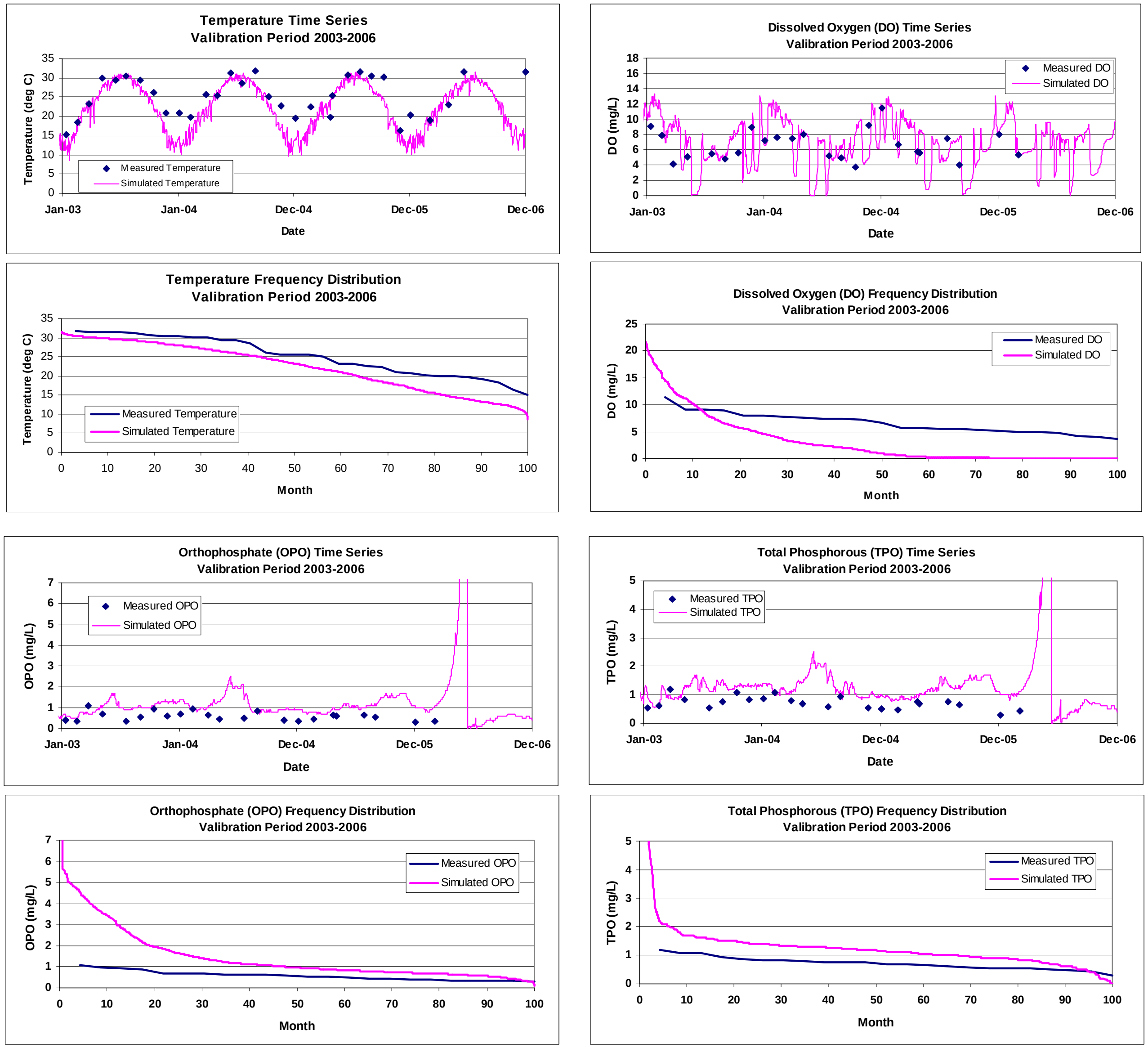


Figure 3-12. Time Series and Frequency Distribution plots for Water Quality parameters for Validation Period of 1/1/2003 through 12/31/2006.

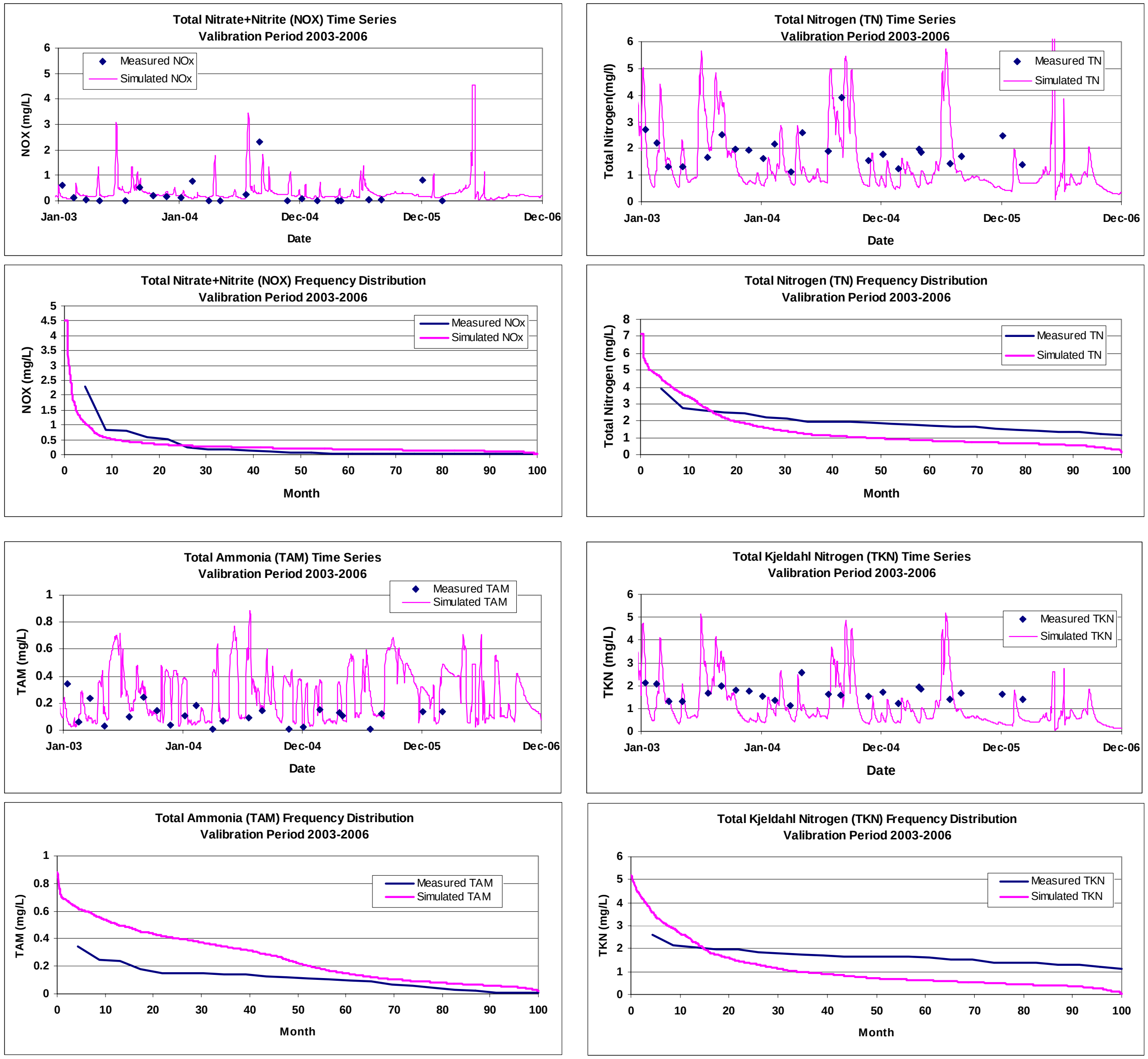


Figure 3-12. Time Series and Frequency Distribution plots for Water Quality parameters for Validation Period of 1/1/2003 through 12/31/2006. (cont'd)

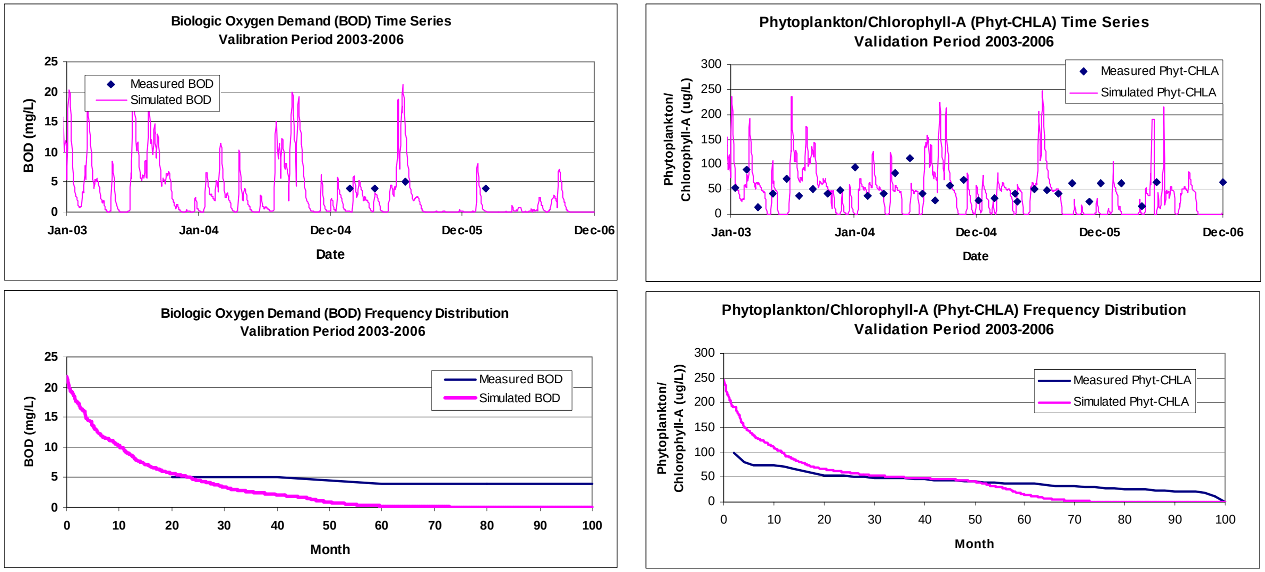


Figure 3-12. Time Series and Frequency Distribution plots for Water Quality parameters for Validation Period of 1/1/2003 through 12/31/2006. (cont'd)