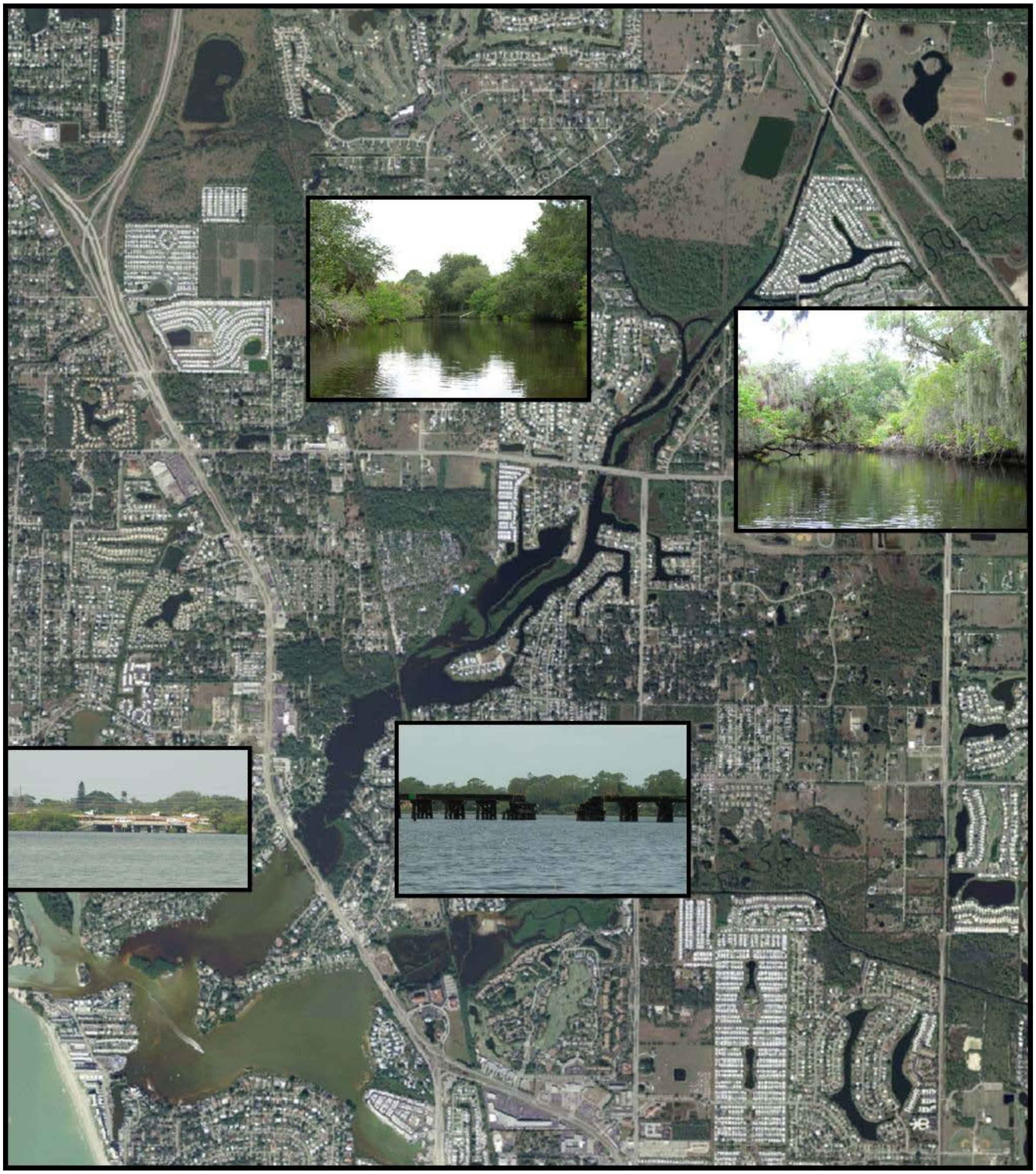
Proposed Minimum Flows and Levels for Dona Bay/Shakett Creek below Cow Pen Slough



Southwest Florida Water Management District

August 31, 2009

Proposed Minimum Flows and Levels for Dona Bay/Shakett Creek below Cow Pen Slough

Prepared Pursuant to 373.042 F.S.

August 2009
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Resource Projects Department
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Acknowledgement

This report was produced in collaboration with the staff of Janicki Environmental, Inc.(JEI) under contract to the Southwest Florida Water Management District (SWFWMD). The staff of JEI (Keith Hackett in particular) and their subcontractor (ATM, Inc) prepared the bulk of the estuarine analysis and report writing. I would also like to thank the many District contractors that contributed to this report. Patrick Tara (Intera, Inc.) provided the ungauged flow estimates. Ernst Peebles (and his staff and students at USF) and Tim MacDonald and his colleagues at Florida Fish and Wildlife Conservation Commission collected and analyzed the fish and invertebrate data. Ernie Estevez (Mote Marine Lab) provided the mollusk data and Jim Culter (Mote Marine Lab) contributed the benthic invertebrate results. The cost of outside support is approximately $407,600, which was provided by the Manasota Basin Board and the District Governing Board.

I would like to thank my colleagues for their contributions and useful suggestions. In particular, I would like to acknowledge Michelle Dachsteiner, Courtney James, Margaret Gilchrist and Mike Lee for their field efforts and to Barbara Matrone for her assistance in document production. Doug Leeper provided a much appreciated review of the initial draft document.

MGH

Executive Summary

The Southwest Florida Water Management District, by virtue of its responsibility to permit the consumptive use of water and a legislative mandate to protect water resources from “significant harm", has been directed to establish minimum flows and levels (MFLs) for streams and rivers within its boundaries (Section 373.042, Florida Statutes). As currently defined by statute, "the minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." In this report, minimum flows are proposed for Dona Bay/Shakett Creek, downstream of Cow Pen Slough.

The Dona Bay watershed has undergone significant physical and hydrologic alterations that have resulted in changes to the quantity of freshwater that flows into the system as well as changes to the salinity regime. There are currently no negative impacts to Dona Bay or Shakett Creek resulting from water withdrawals. Rather, negative environmental impacts due to excessively high flows during the wet season have been identified. These excessive flows are the result of the construction of the Cow Pen Slough and Blackburn Canals which have diverted additional freshwater from the Myakka River watershed to Dona Bay/Shakett Creek and Roberts Bay, the estuarine embayments that collectively comprise the Dona and Roberts Bay (DARB) system. In addition to the construction of these drainage features in the upper watershed, numerous physical alterations have been made to the Dona and Roberts Bay system itself including construction of the Venice Inlet, the Gulf Intracoastal Waterway, and several bridges, as well as substantial dredge and fill activities. In accordance with state law, these physical alterations must be considered when developing minimum flows and levels for Dona Bay/Shakett Creek. While it may be possible to mitigate some of these impacts through operational changes to the Cow Pen Slough Canal, the statutory MFL mandate is to determine the point at which <u>less</u> water becomes ecologically damaging rather than to define the point at which too much water becomes damaging. Furthermore, an MFL should not be equated to an optimal flow or a return to historical flows. In order to establish an MFL, a baseline flow must be defined.

Current flows are excessive for the estuary and as such, the District chose not to include these as baseline. Rather the District attempted to estimate the flows that existed prior to the major structural alterations (Cow Pen Slough Canal and Blackburn Canal) and use these as the baseline. While at first inspection, this would appear to be a return to historical pre-channelized flows, it is not. The difference is that the historical pre-channelized flow is the basis for determining the point at which further withdrawals would cause significant harm. By definition, the MFL flow will be something less than the historical flow of the original watershed.

The watershed area defined for the baseline condition included the historical Fox, Salt, and Shakett Creek basins prior to connection to the Cow Pen Slough channel. The Dona Bay minimum flow study area encompasses the portion of Dona Bay from the Intracoastal Waterway to the downstream Cow Pen Slough Structure. This portion of

Dona Bay is relatively shallow (less than 2 m). The lower portion of Dona Bay, downstream of the U.S. 41 bridge, is broader and is hardened. Moving upstream from the U.S. 41 bridge, the system narrows and has large areas of mangrove along the shoreline.

The District applied the percent-of-flow method to determine proposed minimum flows for Dona Bay/Shakett Creek. The percent-of-flow method allows water users to take a percentage of streamflow at the time of the withdrawal. The percent-of-flow method has been used for the regulation of water use permits issued by the District since 1989, when it was first applied to withdrawals from the lower Peace River. The method has been used to establish minimum flows for numerous systems in the District. The percent-of-flow method insures that the natural flow regime of the system is maintained, albeit with some allowable flow reduction for water supply.

Seasonal blocks corresponding to periods of low, medium, and high flows, previously defined for the development of minimum flows in the upper Myakka River, were used to establish minimum flows for Dona Bay/Shakett Creek. Short-term minimum flow compliance standards for the sum of the flows from Fox and Salt Creeks were developed for each of these seasonal periods using a "building block" approach. The concept of defining “building blocks” to establish MFLs is to get the “right flow at the right time.” The compliance standards include prescribed flow reductions based on limiting potential changes in aquatic and wetland habitat availability that may be associated with seasonal changes in flow.

The criterion used for MFL development in Dona Bay/Shakett Creek was the available habitat (quantified in terms of volume, bottom area, and shoreline length) less than 10, 15, or 20 ppt. A hydrodynamic model was developed to predict salinity in the DARB system as a function of flow and other pertinent variables. The hydrodynamic model was used to estimate available habitat in the study area for the baseline scenario and various flow reduction scenarios for a three-year period.

The amount of available habitat was determined for each scenario for the three-year modeling period for each of the three blocks. The threshold used to determine the MFL was a 15% reduction in available habitat compared to the baseline. For each block, the most conservative criterion was selected amongst the habitat metrics discussed above for the entire study area. The reduction in baseline flow resulting in a 15% loss of habitat are as follows:

- Block 1 (April 20 to June 25) = 3% reduction
- Block 2 (October 27 to April 19) = 3% reduction
- Block 3 (June 26 to October 26) = 10% reduction

These findings were submitted to an independent peer review panel who noted that the District’s data collection efforts were directed to Dona / Robert’s Bays and Shackett Creek, but did not extend into Salt and Fox Creeks. The panel recommended that the District follow the Precautionary Principle and establish the initial MFLs with little or no withdrawals from Fox and Salt Creek until more scientific information can be collected in these. The Panel went on to recommend the District revisit the topic periodically when new data becomes available. The peer review report and the District's response are included as Appendices A and B.

In light of these comments, the recommended MFL is zero withdrawals downstream of the CPS-2 structure. All flows above the baseline condition, which are at times considerable, are excessive and available for withdrawal and/or restoration. It is ecologically desirable to remove some or all of these excess flows from the system in order to re-establish a more natural hydroperiod. The District is committed to continuing the evaluation and to re-evaluate the MFL as required by Statute.

1 PURPOSE AND BACKGROUND OF MINIMUM FLOWS AND LEVELS

1.1 Overview

The Southwest Florida Water Management District (District) is responsible for permitting the consumptive use of water within the District's boundaries. With respect to this regulatory authority, State Law (Section 373.042, Florida Statutes; hereafter F.S.) mandates that the District establish minimum flows for streams and rivers within its boundaries to prevent "significant harm" to these resources or the ecology of the area that may be associated with excessive water use. In response to this legislative directive, the District has incorporated minimum flows for several flowing water bodies into its Water Levels and Rates of Flow Rule (Chapter 40D-8, Florida Administrative Code; hereafter F.A.C.). Recovery or prevention strategies for water bodies where flows are below or during the next twenty years expected to be below applicable minimum flows have also been developed and incorporated into District Recovery and Prevention Strategies for Minimum Flows and Levels (MFL) Rule (Chapter 40D-80, F.A.C), as required by State Law (Section 373.0421(2), F.S.)

In this report, the District documents the scientific and technical data and methods that were used to develop proposed minimum flows for the Dona Bay and Shakett Creek system (Dona Bay/Shakett Creek) in Sarasota County, Florida. The report is expected to serve as the basis for the voluntary (on the part of the District), independent scientific peer review of the data and analyses used to develop the recommended minimum flows. As necessary, results from the peer review will be used to revise the recommended flows. Rule amendments pertaining to the minimum flows will subsequently be presented to the District Governing Board for incorporation into Chapter 40D-8, F.A.C.

This introductory chapter provides an overview of how the District applied legislative and water management directives in the determination of proposed minimum flows for Dona Bay/Shakett Creek. The rationale and basic components of the District approach are also summarized. Greater details regarding the District's technical approach, including data collection efforts and analyses used to determine the proposed minimum flows, are provided in subsequent chapters.

1.2 Legislative and Water Management Directives and Relevance to Dona Bay/Shakett Creek

Florida law requires the state water management districts or the Florida Department of Environmental Protection to establish minimum flows and levels for surface waters and aquifers within their jurisdictions (Section 373.042(1), F.S.). As currently defined by statute, the minimum flow for a given watercourse "shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area", and the minimum level of an aquifer or surface water body is "the level of groundwater in the aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area". Minimum flows and levels are established and used by the District for water resource planning, as one of the criteria used for evaluating water use permit applications, and for the design, construction and use of surface water management systems.

According to state law, minimum flows and levels are to be established based upon the "…best available information…" and shall be developed with consideration of "...changes and structural alterations to watersheds, surface waters and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer... (Section 373.0421, F.S.). Each water management district must also consider the protection of non-consumptive uses in the establishment of minimum flows and levels (Section 373.042, F.S.).

While the legislature has explicitly identified the need to consider physical changes to watersheds, existing water withdrawals are not to be overlooked or necessarily accepted when developing minimum flows and levels. To adhere to this directive, a baseline hydrologic condition or regime for the water resource in question must be identified through consideration of hydrologic effects associated with changes and structural alterations to the watershed and through evaluation of and accounting for the hydrologic effects associated with existing water use. The baseline condition or hydrologic regime is intended to approximate conditions in the absence of withdrawal impacts and serves as a benchmark for development of criteria that can be used to evaluate potential changes and significant harm to the resources that may result from water use.

The Florida Water Resources Implementation Rule (Chapter 62-40.473, F.A.C.) of the Department of Environmental Protection provides additional guidance for the establishment of minimum flows and levels, requiring that "consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows, and environmental values associated with coastal, estuarine, aquatic and wetland ecology, including: a) recreation in and on the water; b) fish and wildlife habitats and the passage of fish; c) estuarine resources; d) transfer of detrital material; e) maintenance of freshwater storage and supply; f) aesthetic and scenic attributes; g) filtration and absorption of nutrients and other pollutants; h) sediment loads; i) water quality; and j) navigation." The Water Resource Implementation Rule also indicates that "minimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area".

Development of a minimum flow or level does not in itself protect a water body from significant harm; however, resource protection, recovery and regulatory compliance can be supported once the flow or level standards are established. State law governing implementation of minimum flows and levels (Chapter 373.0421, F.S.) requires development of a recovery or prevention strategy for water bodies if the "existing flow or level in a water body is below, or is projected to fall within 20 years below, the applicable minimum flow or level". Recovery or prevention strategies are developed to: "(a) achieve recovery to the established minimum flow or level as soon as practicable; or (b) prevent the existing flow or level from falling below the established minimum flow or level." Periodic re-evaluation and as necessary, revision of established minimum flows and levels are also required by state law.

Given the above considerations, the basic function of minimum flows and levels development and implementation is to ensure that the hydrologic requirements of natural systems associated with lakes, streams, rivers, estuaries and groundwater systems are met and not jeopardized by excessive withdrawals. Establishing minimum flows and levels is also important for water supply planning, because the flows or levels help identify how much water is available for consumptive use. Mere adoption of minimum flows and levels does not protect a water body from significant harm nor regulate water availability. It is the use of minimum flows and levels in planning and regulatory processes which ensures that the hydrologic requirements of natural systems are met.

As will be further developed within this report, there are currently no negative impacts to Dona Bay or Shakett Creek resulting from water withdrawals. Rather, negative environmental impacts due to excessively high flows during the wet season have been identified (Lincer 1975, Jones 2003 and 2005, Kimley-Horn and Associates *et al.* 2007). These excessive flows are the result of the construction of the Cow Pen Slough and Blackburn Canals which have diverted additional freshwater from the Myakka River watershed to Dona Bay/Shakett Creek and Roberts Bay, the estuarine embayments that collectively comprise the Dona and Roberts Bay system, which is referred to in this report as the DARB system. In addition to the construction of these drainage features in the upper watershed, numerous physical alterations have been made to the DARB system itself. These alterations include construction of the Venice Inlet, the Gulf Intracoastal Waterway, and several bridges, as well as substantial dredge and fill activities that have altered the morphology of the estuarine basin.

Construction of the Cow Pen Slough and Blackburn Canals has led to an increase in the volume of freshwater entering the DARB system and has also altered the timing of freshwater inflows. Construction of the Gulf Intracoastal Waterway and the Venice Inlet has influenced horizontal (longitudinal) and vertical (water column) salinity gradients in the DARB system. The construction of bridges over Dona Bay and Roberts Bay has also altered salinity patterns by restricting longitudinal exchange of water within the estuary.

In accordance with state law, these physical alterations must be considered when developing minimum flows and levels for Dona Bay/Shakett Creek. While it may be possible to mitigate some of these impacts through operational changes to the Cow Pen Slough Canal, the statutory MFL mandate is to determine the point at which <u>less</u> water becomes ecologically damaging rather than to define the point at which too much water becomes damaging. Furthermore, an MFL should not be equated to an optimal flow or a return to historical flows. Yet in order to establish an MFL, a baseline flow must be defined. Current flows are excessive for the estuary and as such, the District chose not to define these as baseline. Rather the District attempted to estimate the flows that existed prior to the major structural alterations and use these as baseline. While at first inspection, this would appear to be a return to historical flows, in fact it is not, but admittedly the difference is subtle. The difference is that the historical flow is the basis for determining the point at which further withdrawals would cause significant harm. By definition then the MFL flow will be something less than the historical flow.

1.3 Conceptual Approach to Establishing Minimum Flows

The District applied the percent-of-flow method to determine proposed minimum flows for Dona Bay/Shakett Creek. The percent-of-flow method allows water users to take a percentage of streamflow at the time of the withdrawal. The percent-of-flow method has been used for the regulation of water use permits issued by the District since 1989, when it was first applied to withdrawals from the lower Peace River. The method has also been used to establish minimum flows for freshwater segments of the Alafia, Braden, Hillsborough, Myakka and Peace rivers within the District (SWFWMD 2002, 2005b, 2005c, 2005d, 2007b, 2007c) and will be used to develop minimum flows for several estuarine systems, including the lower segments of the Alafia, Anclote, Little Manatee, Myakka and Peace rivers and Shell Creek.

A goal of the percent-of-flow method is that the natural flow regime of the system be maintained, albeit with some allowable flow reduction for water supply. Natural flow regimes have short-term and seasonal variations in the timing and volume of streamflow that reflect drainage basin characteristics and regional climate. In recent years, there has been considerable progress in the field of freshwater stream ecology and flow management in identifying the physical and biological processes that are linked to and dependent upon natural flow regimes (Longley 1994, Poff *et al.* 1997, Instream Flow Council 2002, Postel and Richter 2003). Physical processes that have been identified include sediment transport and channel maintenance, and biological processes include fish passage, the inundation of instream and floodplain habitats, and maintenance of adequate water levels and velocities to provide habitat suitable for the growth and reproduction of fishes and invertebrates.

Management issues regarding freshwater inflows to estuaries have also received considerable attention in recent decades. A national symposium on inflows to estuaries was held in 1980 (Cross and Williams 1981), and a special issue of the journal *Estuaries* devoted to freshwater inflows was produced by the Estuarine Research Federation in 2002 (Montagna *et al.* 2002), which included the paper by Flannery *et al.* (2002) that described the District's percent-of-flow method for establishing estuarine minimum flows. The District's percent-of-flow method has received accolades as a progressive method for estuarine flow management in the national technical literature (Alber 2002, Postel and Richter 2003, and National Research Council 2005) and its use for water supply planning and regulation has been established regionally in District documents (SWFWMD 1992, 2001, 2006).

1.4 Content of Remaining Chapters

In subsequent chapters of this report, the technical information used to develop proposed minimum flows for Dona Bay/Shakett Creek is described. Physical and hydrological characteristics of the Dona Bay and Roberts Bay watershed are described in Chapter 2 and the physical characteristics of the estuarine portion of the watershed, *i.e.*, the DARB system, are discussed in Chapter 3. In Chapter 4 the spatial and temporal variation in physical and water quality characteristics of the DARB system as well as the relationships between flow and water quality constituents are discussed. Chapter 5 contains a description of the biological communities found in the DARB system. In Chapter 6 modeling tools used to relate freshwater inflow to salinity are presented. The technical approach used in development of the MFL is described in Chapter 7. Major conclusions of this study along with the District's minimum flow recommendations for the DARB are presented in Chapter 8. Literature sources cited in the report are presented in Chapter 9.

2 THE GREATER DONA BAY AND ROBERTS BAY WATERSHED

A brief description of the greater Dona Bay and Roberts Bay watershed is presented in this chapter. Physical characteristics of the system as it exists today are provided along with a summary of the hydrologic modifications that have been made to the watershed.

2.1 Physical Characteristics of the Current Dona Bay and Roberts Bay Watershed

The greater Dona Bay and Roberts Bay watershed currently encompasses an area of approximately 62,000 acres on the southwest coast of Florida (Figure 2-1). The Dona Bay watershed represents the majority of the greater watershed (approximately 48,000 acres), and the Roberts Bay watershed extends over approximately 7,000 acres. Land that drains to Lyons Bay, the Gulf Intracoastal Waterway and the Gulf of Mexico comprises the remaining 7,000 acres of the greater watershed. For analyses and discussion presented in this report, an estuarine portion of the greater Dona Bay and Roberts Bay watershed, specifically the Dona Bay and Shakett Creek system (Dona Bay/Shakett Creek) from the Venice Inlet upstream to the CPS2 water control structure on the Cow Pen Slough Canal, and Roberts Bay, from a point approximately 0.4 km due south of Bird Island to the mouth of Curry Creek, is referred to as the DARB system. The DARB system is described in detail in Section 3.

Dona Bay has three main tributaries, Fox Creek, the Cow Pen Slough Canal, and Salt Creek, which converge in Shakett Creek at the upstream end of Dona Bay. Roberts Bay has two main tributaries, Blackburn Canal/Curry Creek and Hatchett Creek. The Blackburn Canal drains to Curry Creek, which is connected to the eastern end of Roberts Bay. The Blackburn Canal was constructed in the 1950s to provide relief from periodic flooding of the Blackburn property east of the Myakka River. The Blackburn Canal connects Roberts Bay to the Myakka River. Hatchett Creek flows into the Gulf Intracoastal Waterway at the southern end of Roberts Bay.

Since the early 1900s, substantial physical and hydrologic alterations have been made to the greater Dona Bay and Roberts Bay watershed. These alterations include the construction of the Venice Inlet, the construction of the Gulf Intracoastal Waterway, excavation of the Cow Pen Slough Canal connecting Cow Pen Slough to Shakett Creek/Dona Bay, and excavation of the Blackburn Canal connecting the Myakka River to Curry Creek and ultimately Roberts Bay. A detailed discussion of these physical and hydrologic alterations is presented in Section 2.1.3.1.

Figure 2-1. **Map of the current greater Dona Bay and Roberts Bay watershed.**

2.1.1 Geology and Soils

In the Dona Bay watershed, a confining bed ranging from 350 to 400 feet thick separates the surficial aquifer from the Floridan aquifer. Surficial sediments in the watershed are made up of several marine terraces that were laid down by ocean waters during the Pleistocene Age (United States Department of Agriculture 1985). At 25 feet and below, the surficial terraces are dominated by sands and marl. Below the surficial deposits and the surficial aquifer are Miocene and Holocene beds of clay, sandy clay and marl (United States Department of Agriculture 1985) which cause a high water table and inhibit drainage. The most prominent of these is the Miocene Hawthorn formation, which is comprised mainly of phosphatic clays and poorly indurated limestone and dolomite lenses (United States Department of Agriculture 1985).

Soils within the Dona Bay watershed (Figure 2-2) are primarily classified as having a very slow or moderate infiltration rate. Three soil associations are dominant in the Dona Bay watershed. The largest association consists of soils of the Immokalee, Myakka, and Pomello series. The second largest association in the Dona Bay watershed consists of soils of the Pineda, Bradenton, and Boca series. The last of the dominant soil associations consists of soils of the Holopaw, Malabar, and Floridana series (United States Department of Agriculture 1985). Under natural conditions, all three soil associations in the Dona Bay watershed have severe drainage limitations due to high water table which affects their suitability for septic tank absorption fields, roads, and building site development (United States Department of Agriculture 1985). This combination of a high water table and poor drainage is the reason for the existence of Cow Pen Slough. Efforts to drain Cow Pen Slough and convert it to useable land are described in Section 2.1.3.1.

2.1.2 Land use

Land use characteristics of the greater Dona Bay and Roberts Bay watershed were summarized by Jones (2007) based on 2004 land use data obtained from the District (Table 2-1). The watershed is heavily influenced by human development (34% developed and 23% agriculture). However, over 40% of the watershed consists of relatively unaltered land cover including wetlands (18%), uplands (22%), and open water (3%). Though the coastal areas are highly developed, overall, the greater Dona Bay and Roberts Bay watershed is the second least developed watershed in Sarasota County following the Myakka River (Jones 2007).

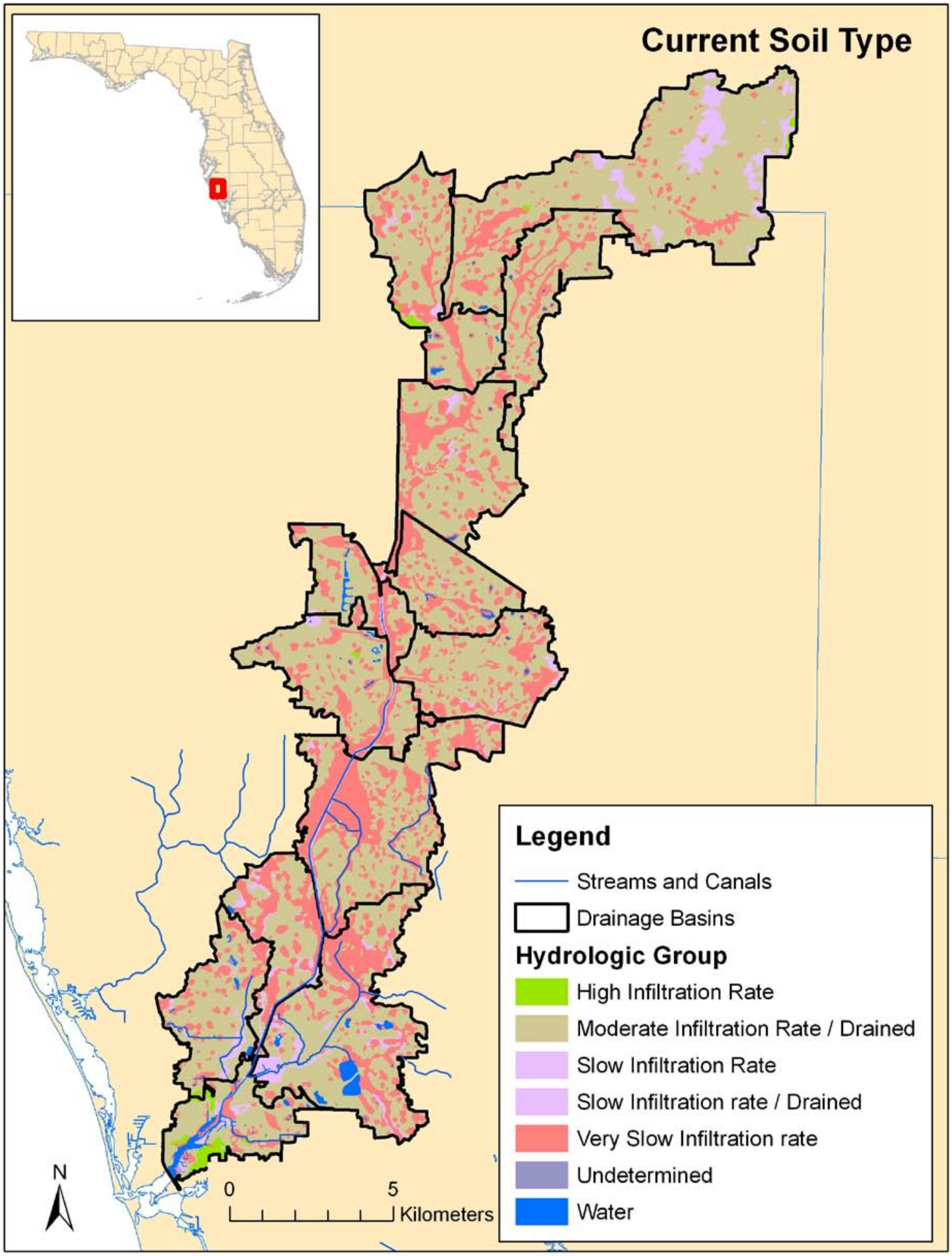

Figure 2-2. **Soil types and drainage basins in the Dona Bay watershed (Source: United States Department of Agriculture 2000).**

Table 2-1. Summary of landuse classifications of greater Dona Bay and Roberts Bay watershed from Jones (2007) based on District 2004 landuse/coverage.

Classification	Area in Hectares (acres)	Percent
Developed	8,272 (20,443)	34%
Wetland	4,654 (11,501)	18%
Uplands	5,604 (13,848)	22%
Agriculture	5,922 (14,634)	23%
Open Water	783 (1,935)	3%
Total	**25,237 (62,361)**	**100%**

Land use characteristics of the Dona Bay watershed are presented in Figure 2-3. In comparison to the greater Dona Bay and Roberts Bay watershed, the Dona Bay watershed has a lower percentage of developed land (21% for Dona Bay vs. 34% for entire watershed). The majority of the wetlands, uplands, and agriculture in the greater Dona Bay and Roberts Bay watershed are located in the Dona Bay watershed. In comparison to the Dona Bay watershed, the Roberts Bay watershed is mostly developed.

Table 2-2. Summary of land use classifications of the Dona Bay watershed based on District 2004 landuse coverage.

Classification	Area in Hectares (acres)	Percent
Developed	3,999 (9,882)	21%
Wetland	3,772 (9,321)	20%
Uplands	5,129 (12,674)	26%
Agriculture	5,726 (14,150)	30%
Open Water	624 (1,543)	3%
Total	**19,251 (47,570)**	**100%**

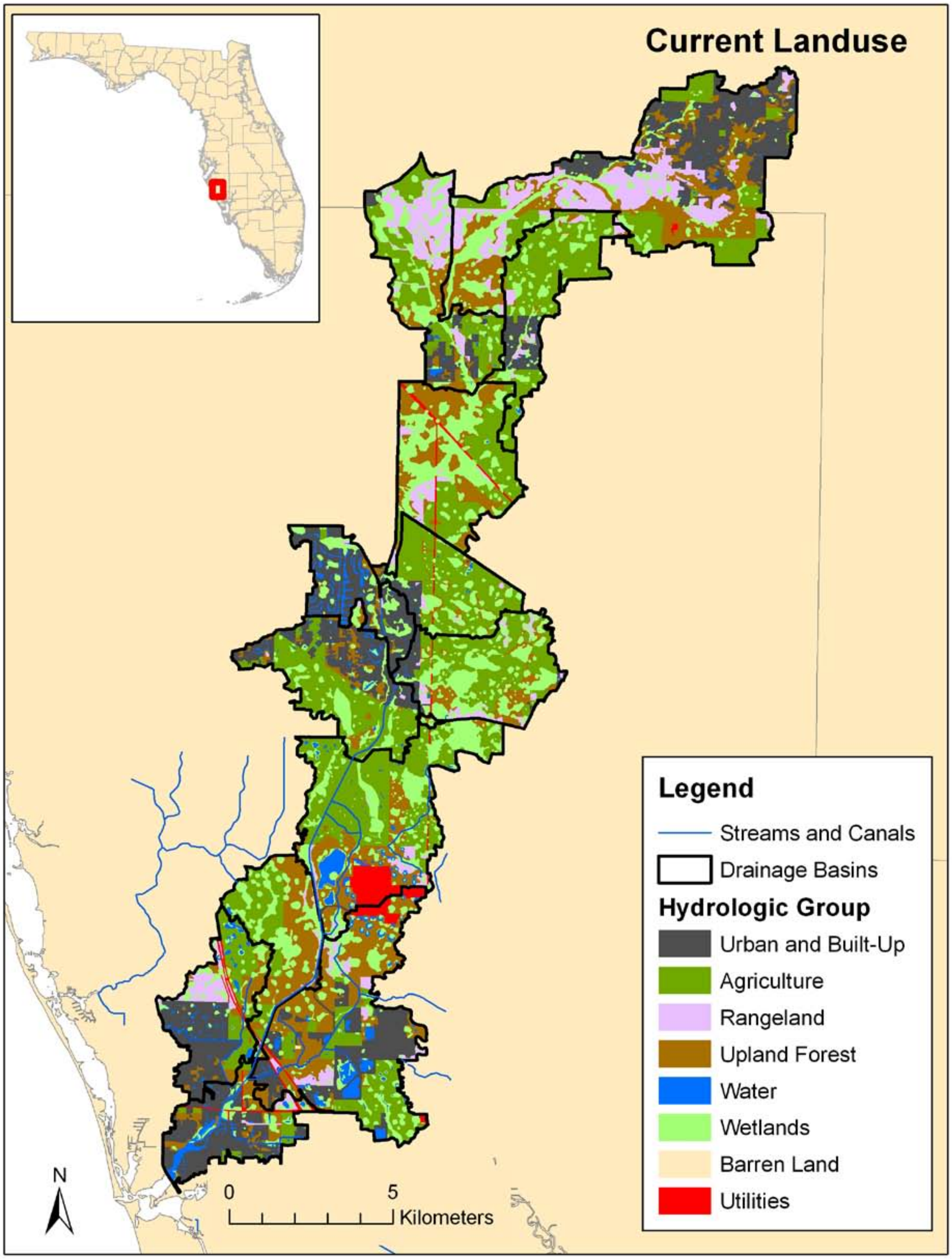

Figure 2-3. **Land use in 2004 in the Dona Bay watershed (Source: SWFWMD 2005e).**

2.1.3 Hydrology

Beginning in the early 1900s, significant hydrologic alterations have been made to the greater Dona Bay and Roberts Bay watershed. In addition, the land use characteristics of the watershed have changed over time. Together, these modifications have resulted in an increase in the amount of freshwater inflow to the estuarine portion of the watershed, *i.e.*, the DARB system.

2.1.3.1 Physical and Hydrologic Modifications to the greater Dona Bay and Roberts Bay Watershed

Analysis of the 1847 survey of Sarasota County (Figure 2-4) reveals a large slough, known as Cow Pen Slough, in western Sarasota County that flowed from north to south and eventually turned east toward the Myakka River (Kimley-Horn and Associates *et al.* 2007). According to the 1847 survey, Cow Pen Slough was part of the Myakka River watershed and the Dona Bay watershed was significantly smaller than its current size (Figure 2-4). The historical Dona Bay watershed, *i.e.*, the pre-channelization watershed, encompassed an area of 4,070 hectares (10,060 acres) compared to the current Dona Bay watershed which covers an area of 19,251 hectares (47,570 acres).

Between 1916 and 1920 a drainage ditch was excavated through Cow Pen Slough to connect Cow Pen Slough to Salt Creek, presumably for mosquito control and pasture conversion (Kimley-Horn and Associates *et al.* 2007). Runoff or flow that used to drain to the Myakka River was thereby diverted to Dona Bay, since Salt Creek drains to Shakett Creek, which empties into Dona Bay. As a result of this drainage alteration, an area of approximately 15,176 hectares (37,500 acres) was diverted from the Myakka River watershed to the Dona Bay watershed (Kimley-Horn and Associates *et al.* 2007). Despite these early attempts to drain the land, flooding problems continued. During periods of high rainfall, water pooled on pasture and range lands for periods of 20 to 30 days (United States Department of Agriculture 1985). Analysis of 1948 aerial photography of the Cow Pen Slough watershed reveals the extent to which canals had been excavated in an effort to alleviate flooding (Figure 2-5). Around 1950, a 12 km (7.5 mile) channel was excavated through the downstream reaches of Cow Pen Slough by local ranchers with technical assistance from the Soil Conservation Service (Kimley-Horn and Associates *et al.*2007).

Sarasota Soil Conservation District *et al.* (1961) documented flooding problems in the Phillippi Creek and Cow Pen Slough Basins. Cow Pen Slough starts at the south edge of Manatee County and flows south for approximately 48 km (30 miles) to Shakett Creek/Dona Bay. A man-made dike separates the Sarasota – Fruitville Drainage District from the area drained by Cow Pen Slough (Sarasota Soil Conservation District *et al.* 1961). In response to flooding problems in the Cow Pen Slough basin, ranchers along the lower and middle reaches of Cow Pen Slough enlarged the channel. However, the effectiveness of the ranchers' efforts was reduced by the intensive channel developments in the headwaters of Cow Pen Slough. Damage to pastures included loss of stands, reduction in grazing time, and the reversion of improved pastures to a less productive state (Sarasota Soil Conservation District *et al.* 1961).

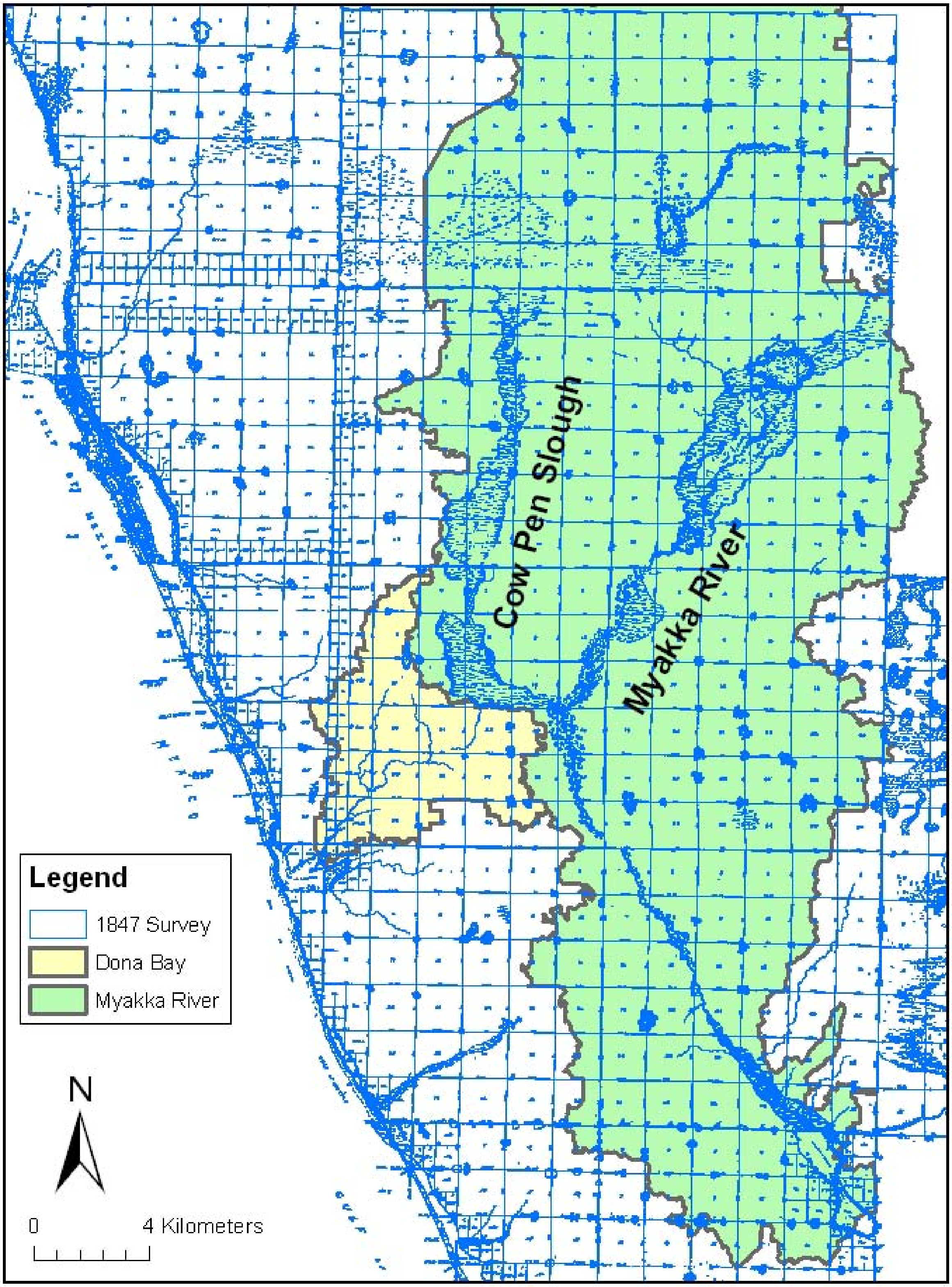

Figure 2-4. **1847 Survey of Sarasota County including the historical watershed boundaries of Dona Bay (yellow) and Myakka River (green).**

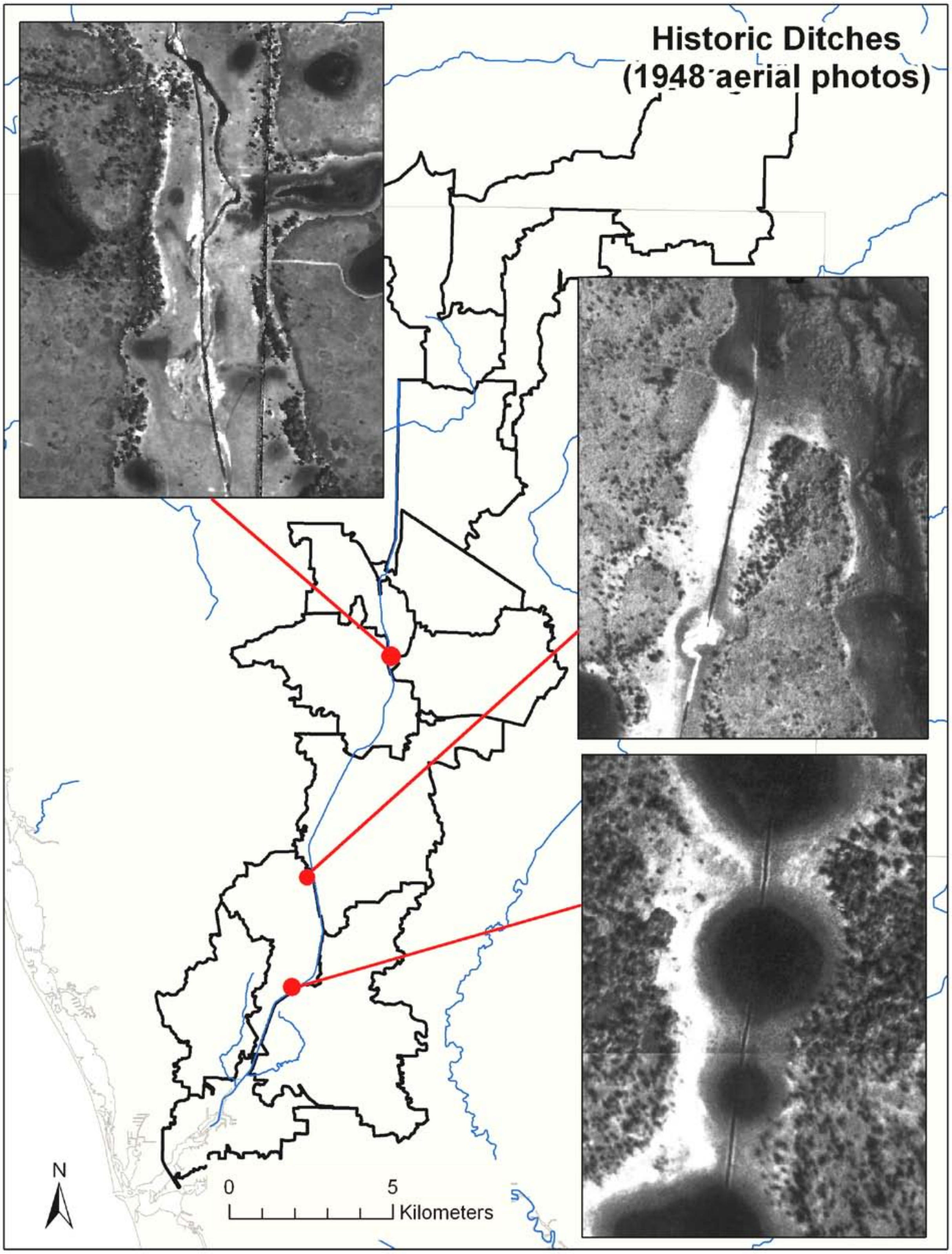

Figure 2-5. **1948 Aerial photographs of historical drainage features in the Cow Pen Slough watershed and location within the current watershed.**

In order to address flooding problems in the Cow Pen Slough watershed, the Soil Conservation Service provided assistance in developing watershed protection plans under the authority of the Watershed Protection and Flood Prevention Act (Public Law 566). In March 1961, the watershed work plan was prepared by the Sarasota Soil Conservation District, the Sarasota County Board of County Commissioners, and the Manatee River Soil Conservation District with assistance from the United States Department of Agriculture Soil Conservation Service. The watershed work plan was approved in June 1961 and construction began in 1962. The objective of the watershed work plan was to alleviate flooding associated with a 10-year frequency storm event (United States Department of Agriculture 1985).

As part of the work plan, the Cow Pen Slough Canal was excavated through Cow Pen Slough and connected directly to Shakett Creek (Kimley-Horn and Associates *et al.* 2007). The excavation resulted in approximately 22.5 km (14 miles) of improved channel with several gravity drains to allow water to enter the sides of the canal. When the project terminated three of the nine planned flood control structures were constructed (Figure 2-6). Structure 3 (CPS3) is 4 km (2.5 miles) north of State Road 72 and the drainage basin upstream of the structure is approximately 21,000 acres. Structure 1 (CPS1) is approximately 2 km south of State Road 72, and it's drainage area comprises 29,000 acres. Structure 2 (CPS2) is the furthest south, located just north of Laurel Road. The cumulative drainage area above CPS2 is 37,000 acres. The excavation began at Laurel Road in the southern end of the Cow Pen Slough watershed and was originally planned to continue to the Manatee County line in the northern portion of the watershed. However, construction was terminated approximately 300 m (1000 feet) north of CPS3 (United States Department of 1985). CPS3 failed in August 1967 resulting in a gully that bypassed the structure and the CPS3 structure has never been repaired.

In the 1950s, Roberts Bay was connected to the Myakka River in order to relieve periodic flooding at the Blackburn property, east of the Myakka River. This constructed drainage feature is known as the Blackburn Canal. The canal follows the route of an old drainage ditch that emptied into Curry Creek which is connected to the eastern portion of Roberts Bay (DeLeuw, Cather and Brill 1959).

The modifications of Cow Pen Slough have resulted in an increase in the size of the Dona Bay watershed and an increase in the amount of freshwater entering Dona Bay. In Roberts Bay, the excavation of the canal which connects the Myakka River to Roberts Bay has resulted in an increase in the amount of freshwater entering Roberts Bay.

At the same time that modifications were occurring in the upstream portions of the greater Dona Bay and Roberts Bay watershed, downstream areas were also being altered. Development of the current Gulf Intracoastal Waterway, a 9-foot-deep by 100-foot-wide channel connecting Tampa Bay to Charlotte Harbor, was initiated in 1896 and completed in 1967 (Antonini *et al.* 1999). During this time, dredging activities progressed in a sporadic manner (Antonini *et al.* 1999). Within the vicinity of the DARB system specifically, dredging of a 3-foot-deep by 75-foot-wide channel from Sarasota to

Venice was begun in 1896 and required more than 10 years to be completed. In 1945 the U.S. Congress authorized and funded the deepening and widening of the Gulf Intracoastal Waterway. In 1960, dredging was initiated to connect Lemon Bay in the south to Roberts Bay (Antonini *et al.* 1999), and this segment of the waterway, which is located south of the DARB system, was completed in 1967. A comparison of the DARB system and nearby areas pre-development and post construction of the Gulf Intracoastal Waterway is presented in Figure 2-7.

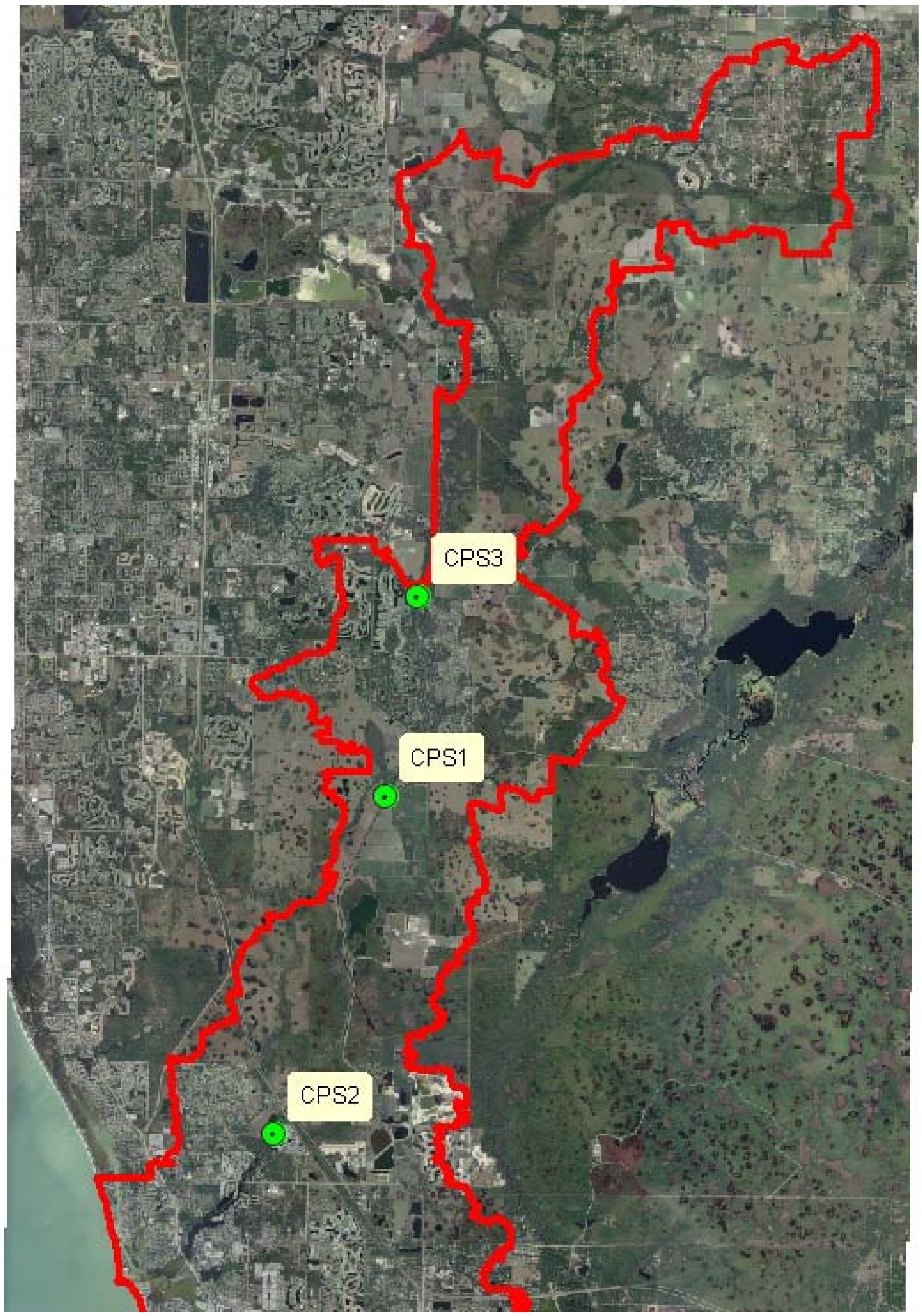

Figure 2-6. Aerial photograph of the Cow Pen Slough Canal in 2004 showing the location of existing flood control structures.

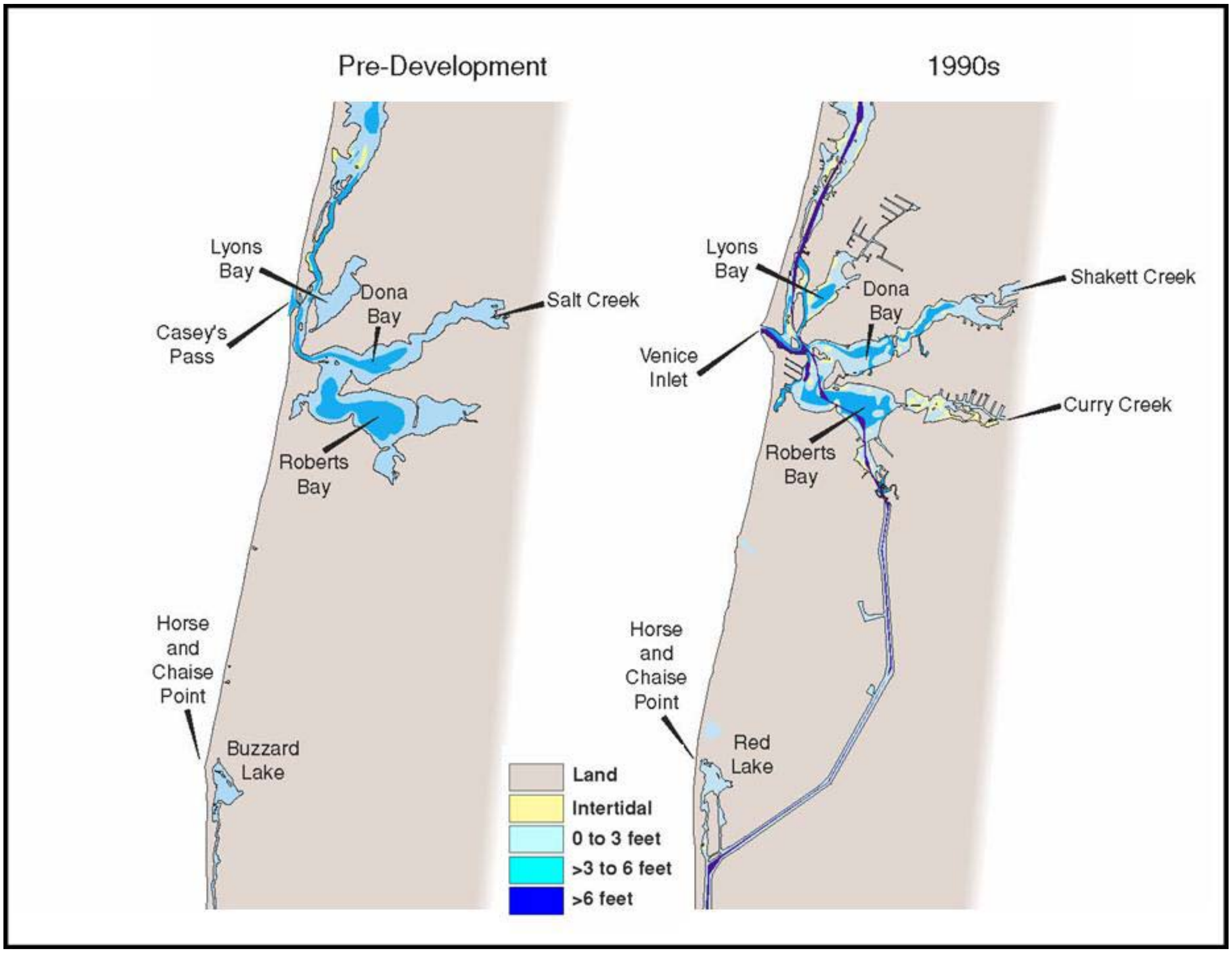

Figure 2-7. **Map of the DARB system and nearby areas prior to and after regional development, including completion of the Gulf Intracoastal Waterway (from Antonini *et al.* 1999).**

Construction of the segment of the Gulf Intracoastal Waterway between Sarasota and Venice provided an all-weather inland water route connecting Sarasota to Venice (Antonini *et al.* 1999). After the completion of this segment of the waterway, Casey's Pass (at the site of the current Venice Inlet) was dredged in 1925 to assure access to the Gulf of Mexico. However, this proved a temporary solution, and the jettied Venice Inlet was completed in 1938 (Antonini *et al.* 1999).

Other development, including bridge construction, has impacted the DARB system (Figure 2-8). In 1912 the Seminole Gulf railroad was extended from Fruitville to Venice, resulting in railroad bridges across Dona Bay and Roberts Bay (Antonini *et al.* 1999). In 1921, U.S. 41 was extended through Venice resulting in additional bridges being built over the two bays (Figure 2-8). The U.S. 41 bridge was widened to four lanes in 1950 (Antonini *et al.* 1999). Building of these bridges was associated with construction of foundations and causeways that constrict or reduce upstream/downstream exchange of water. In addition to the bridge construction, extensive dredge and fill activities and hardening of the shoreline have occurred throughout the DARB system (Figure 2-8).

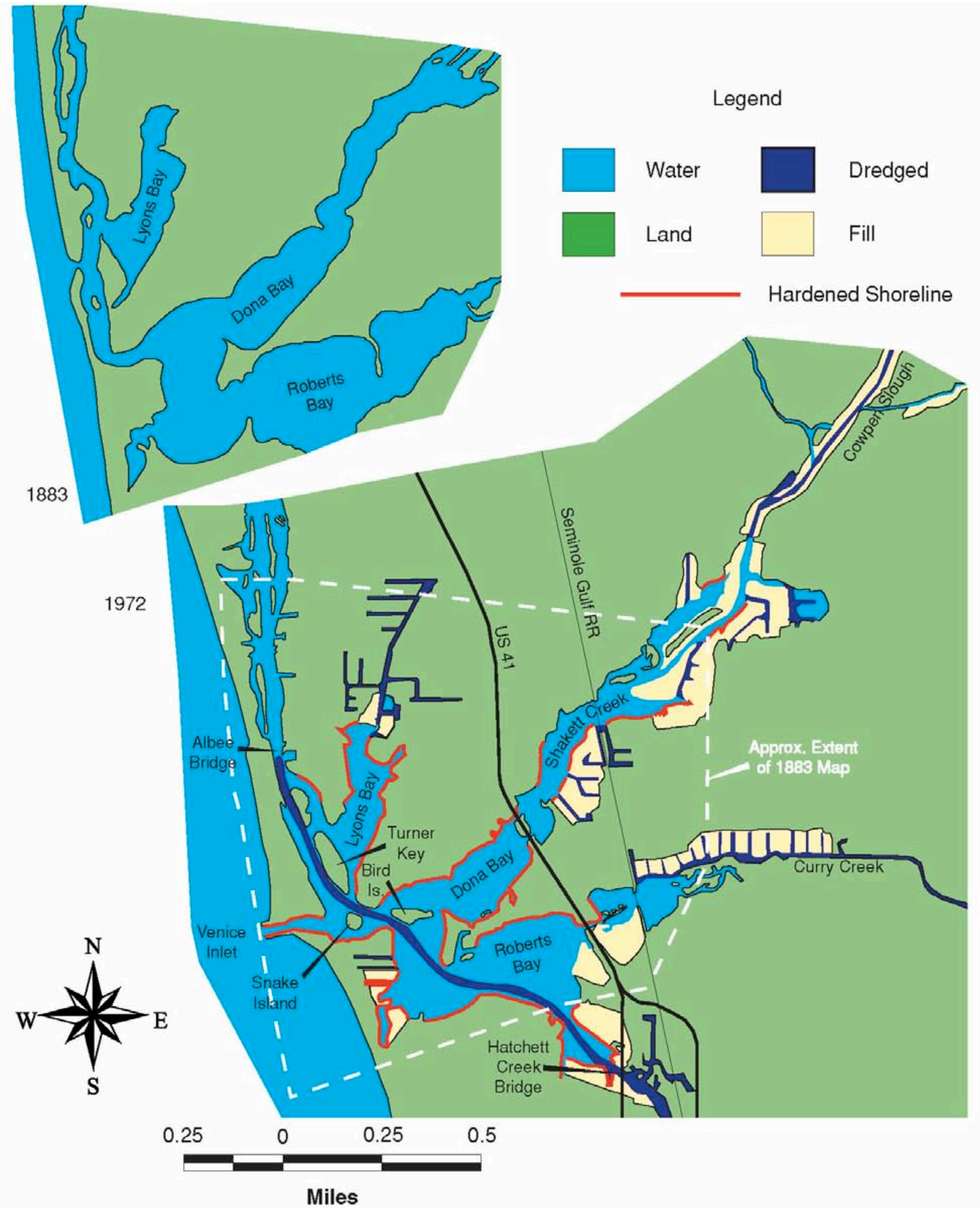

Figure 2-8. **Map of the estuarine portion of the DARB system in 1883 and 1972 illustrating physical alterations to the system (from Antonini *et al.* 1999).**

2.1.4 Rainfall

In peninsular Florida, there is typically a June through September high rainfall season. Superimposed on this seasonal cycle are the effects of less frequent events, notably the El Niño-Southern Oscillation and the Atlantic Multidecadal Oscillation (SWFWMD 2004). Typically El Niño years are wetter than La Niña years in peninsular Florida (Schmidt and Luther 2002). However, El Niño effects during the summer wet season are somewhat attenuated by the seasonal occurrence of thunderstorms. Mean monthly rainfall at the National Weather Service Venice gauge exhibits the typical June-September rainfall peak with lower values during the remainder of the year (Figure 2-9). Long-term trends for rainfall in the basin are shown (for the period from 1956 through 2006) in Figure 2-10. The total annual rainfall at Venice has ranged from 29 to 80 inches, while the mean and median were 50.4 and 48.3 inches, respectively.

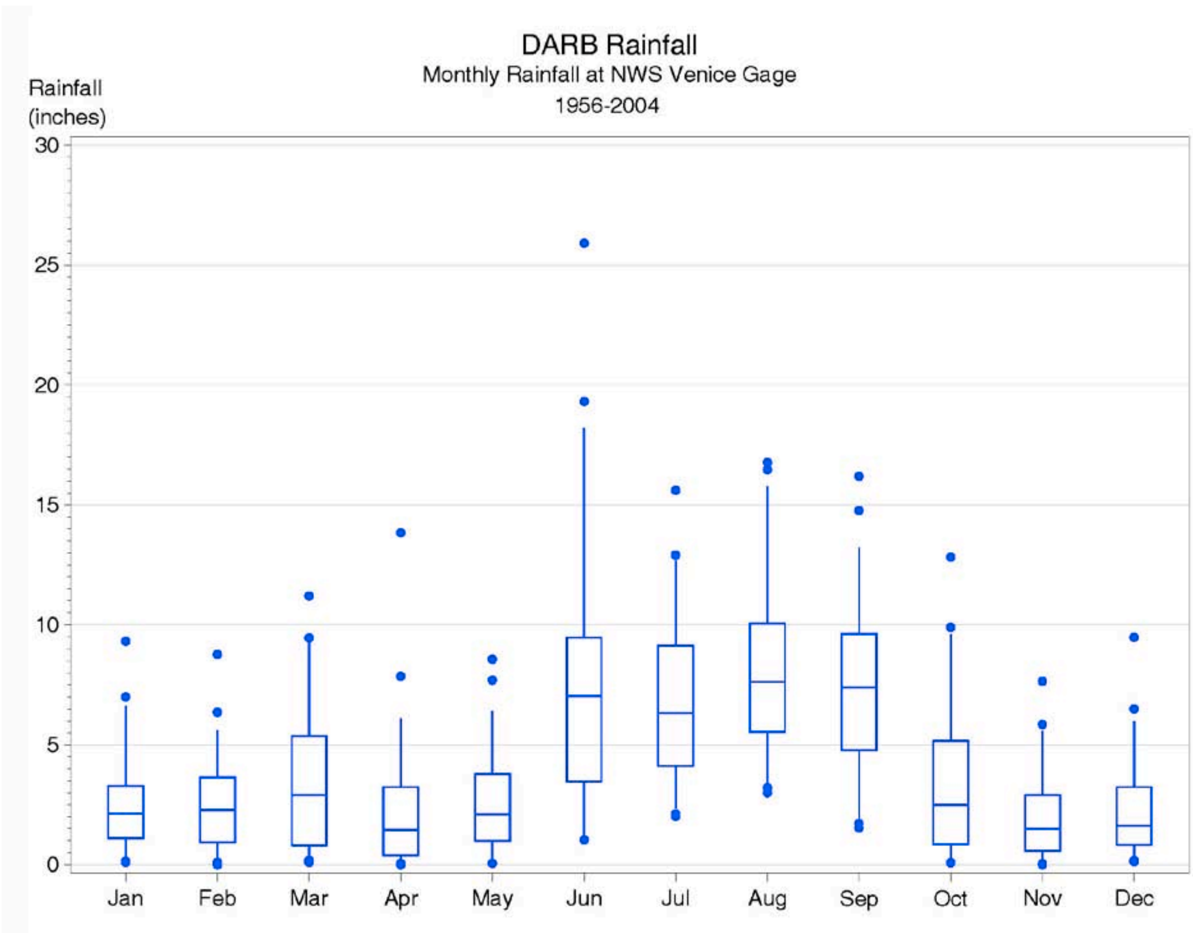

Figure 2-9. Box and whisker of monthly rainfall (total inches) at the National Weather Service Venice gauge (1956-2004). Whiskers represent the 5th and 95th percentile monthly rainfall.

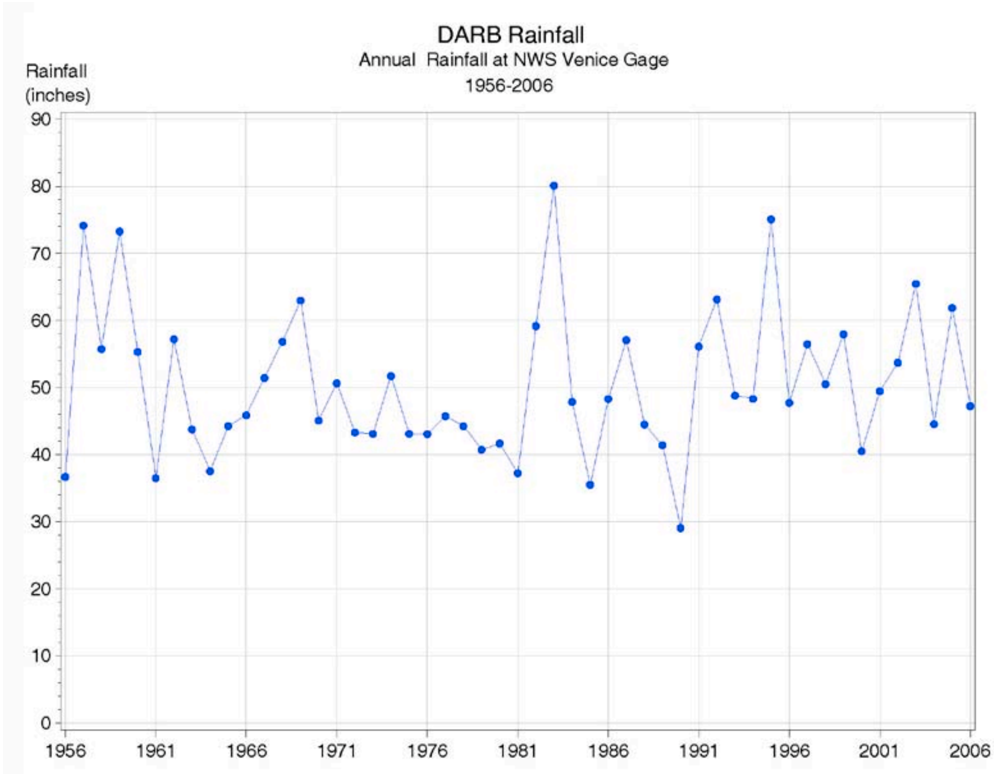

Figure 2-10. Annual rainfall (inches) at the National Weather Service Venice gauge (1956-2006).

2.1.5 Freshwater Flows

Streamflow represents the sum of the contributions of groundwater, runoff, direct rainfall, and anthropogenic discharges, *e.g.*, wastewater, minus the volume of water that is lost due to evapotranspiration, leakance, and withdrawals. Long-term alteration of inflow characteristics can produce changes in physical and chemical properties of aquatic ecosystems. Because the structure and function of biological communities associated with aquatic ecosystems depend in large part on the hydrologic regime (Poff and Ward 1989, 1990), biological processes may also be affected by flow alterations. In estuaries, for example, changes in water residence time, which is a function of freshwater inflow, can have significant effect on the biota. Streamflow into the DARB system has increased as a result of structural alterations that have improved drainage and altered the size of the contributing watershed.

There have been two USGS gauges that recorded flows that enter DARB, Cow Pen Slough near Bee Ridge FL (USGS gauge 02299700) and Blackburn Canal near Venice FL (USGS gauge 02299692) as well as one gauge operated by Sarasota County, Cow Pen Slough structure 2 (CPS2). The Cow Pen Slough near Bee Ridge gauge was located at the intersection of Cow Pen Slough and State Road 72 (Figure 2-11), approximately 13 km (8 miles) north of CPS2. The CPS2 gauge is located just upstream of the confluence of Salt Creek and Shakett Creek. The Blackburn Canal near Venice FL gauge is located on Blackburn Canal at North Jackson Road (Figure 2-11), approximately 8 km (5 miles) east of Roberts Bay.

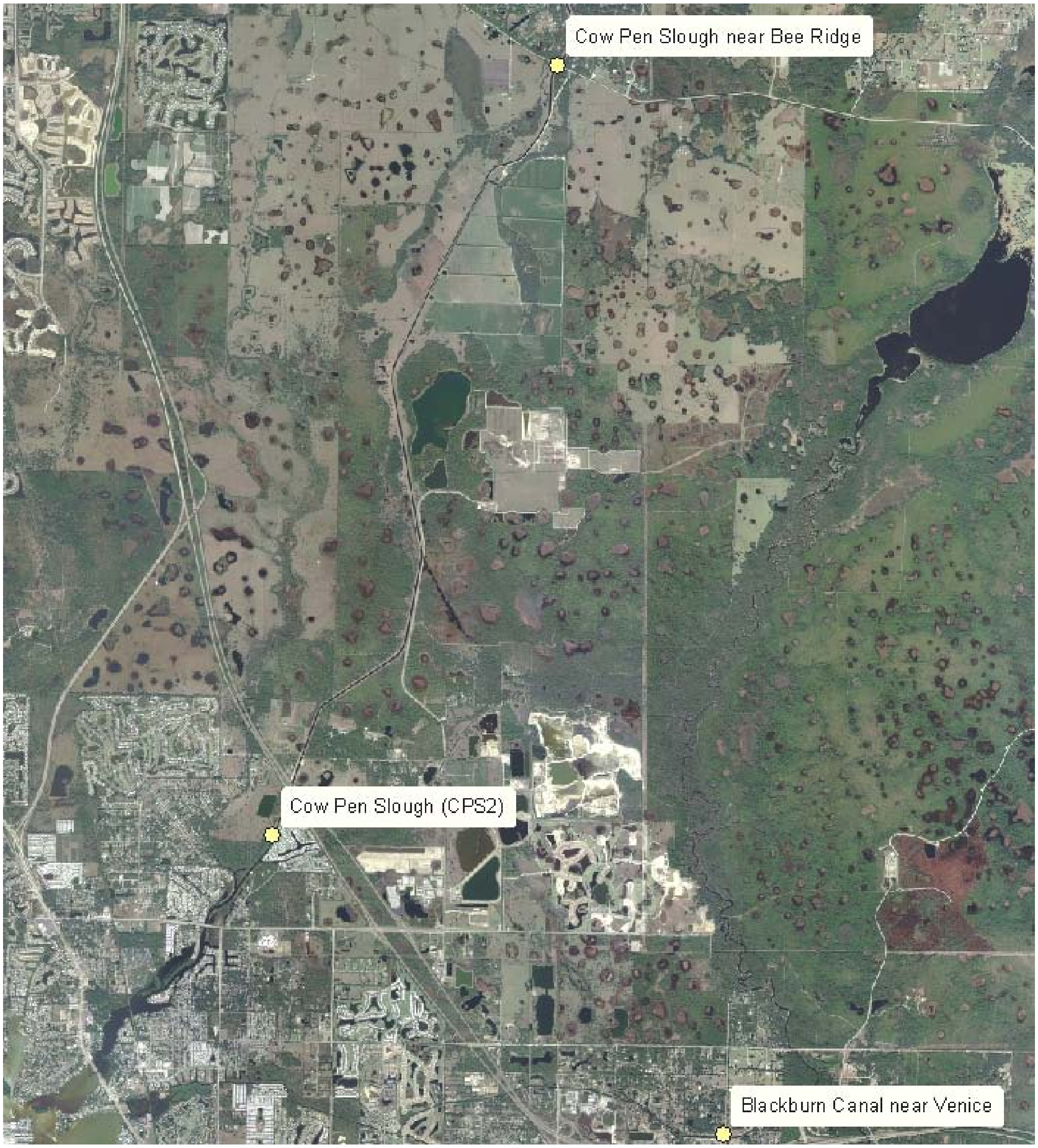

Figure 2-11. **Map of current and former streamflow gauge locations in the Dona Bay and Roberts Bay watersheds.**

Streamflow was measured at the Cow Pen Slough near Bee Ridge gauge between February 1, 1963 and June 30, 1966. Daily flows for this period ranged from 0 to 2,800 cubic feet per second (cfs) (Figure 2-12). Higher flows occurred from June to September and lower flows were evident from October to May (Figure 2-13). A flow duration curve of measured daily flows at the gauge site yielded 25^{th}, 50^{th} (median), and 75^{th} percentile flows of one, four, and 30 cfs, respectively (Figure 2-14).

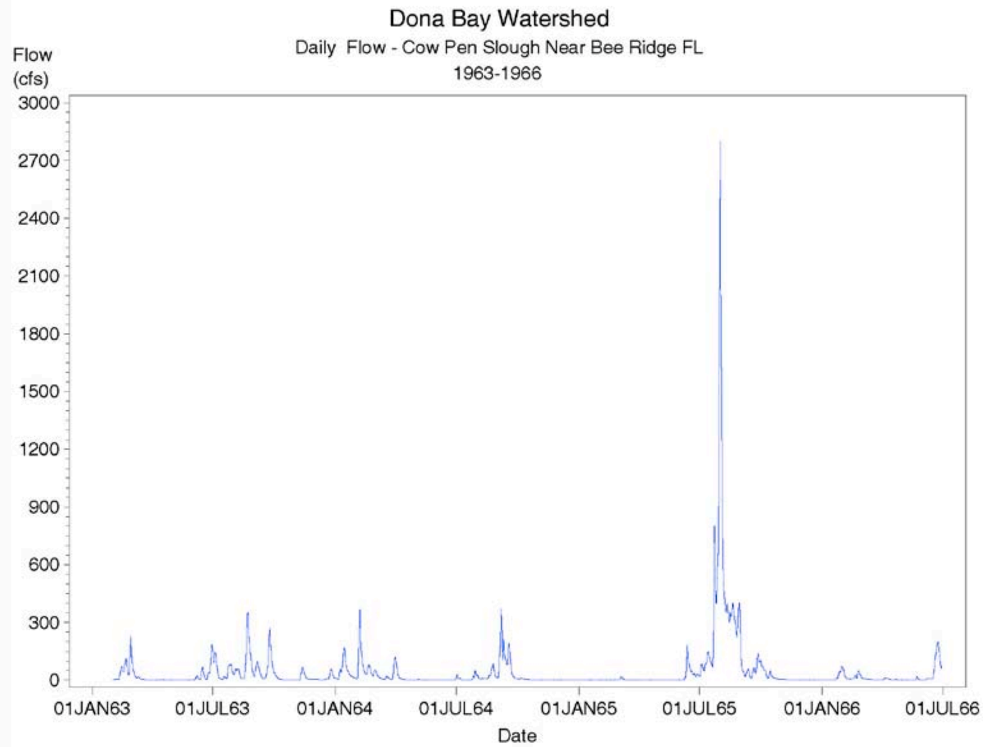

Figure 2-12. Time series of measured daily flows (cfs) at the Cow Pen Slough near Bee Ridge gauge (USGS 02299700) for the period from 1963 through 1966.

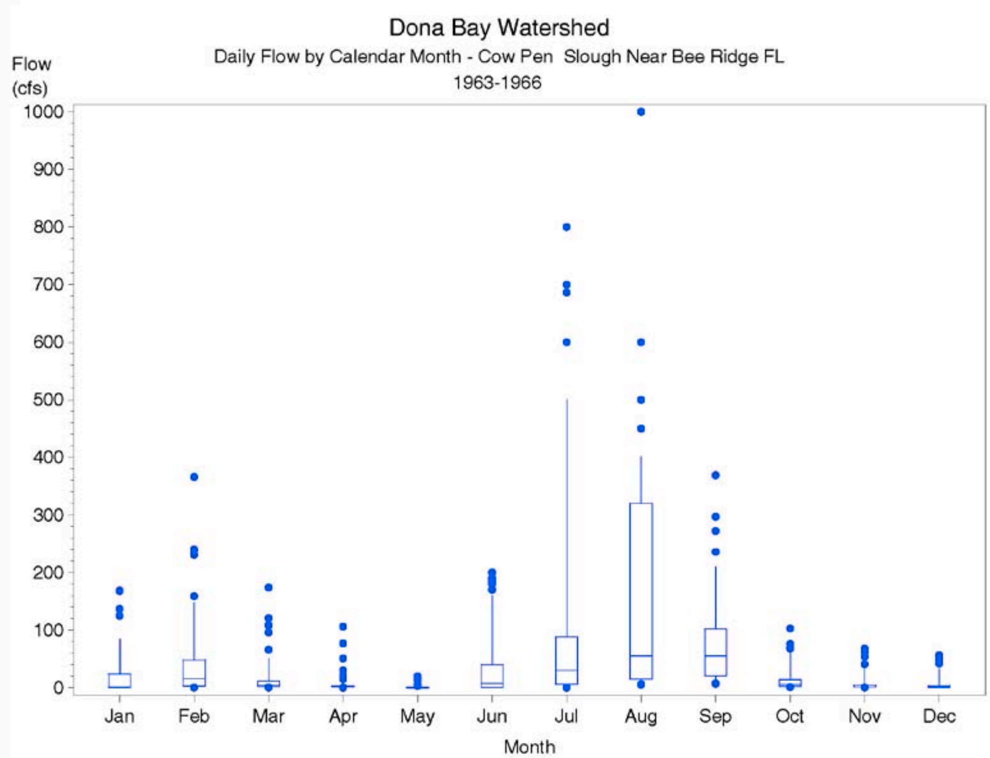

Figure 2-13. Box and whisker of measured daily flows (cfs) by calendar month at the Cow Pen Slough near Bee Ridge gauge (USGS 02299700) for the period from 1963 to1966.

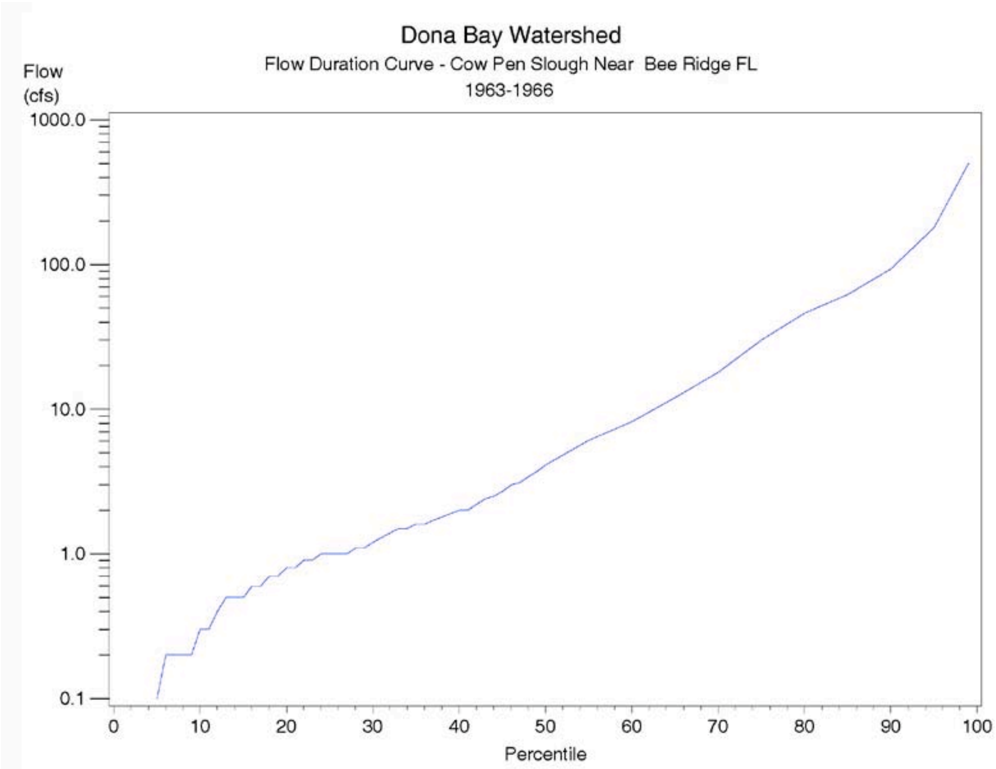

Figure 2-14. Flow duration curve of measured daily flows (cfs) at the Cow Pen Slough near Bee Ridge gauge (USGS 02299700) for the period 1963 to 1966.

The CPS2 gauge is currently used to measure stream stage and flow in the Cow Pen Slough Canal. Flow records based on stage measurements are available from 2003 to the present. The gates of the CPS2 structure are operated to mitigate flooding during the wet season and retain water during the dry season. Historically the gates are opened on about June 1 and closed on November 1 every year. When the gates are closed, water is able to flow over the top of the gates when the water level in the canal overtops the gates. As can be seen in Figure 2-16, it is not uncommon for the water level in the canal to overtop the gates, resulting in flows when the gates are in the closed position. Daily flows for the entire record ranged from 0 to 1,315 cfs (Figure 2-15). As was the case for the flows in the 1960s that were measured at the Cow Pen Slough near Bee Ridge gauge, a seasonal pattern of higher flows from June to September and lower flows from October to May is evident at the CPS2 structure (Figure 2-16). The 25th percentile, 50th percentile (median), and 75th percentile flows for the period of record were two, eleven, and 49 cfs, respectively (see Figure 2-17 for a flow duration curve for the gauge site).

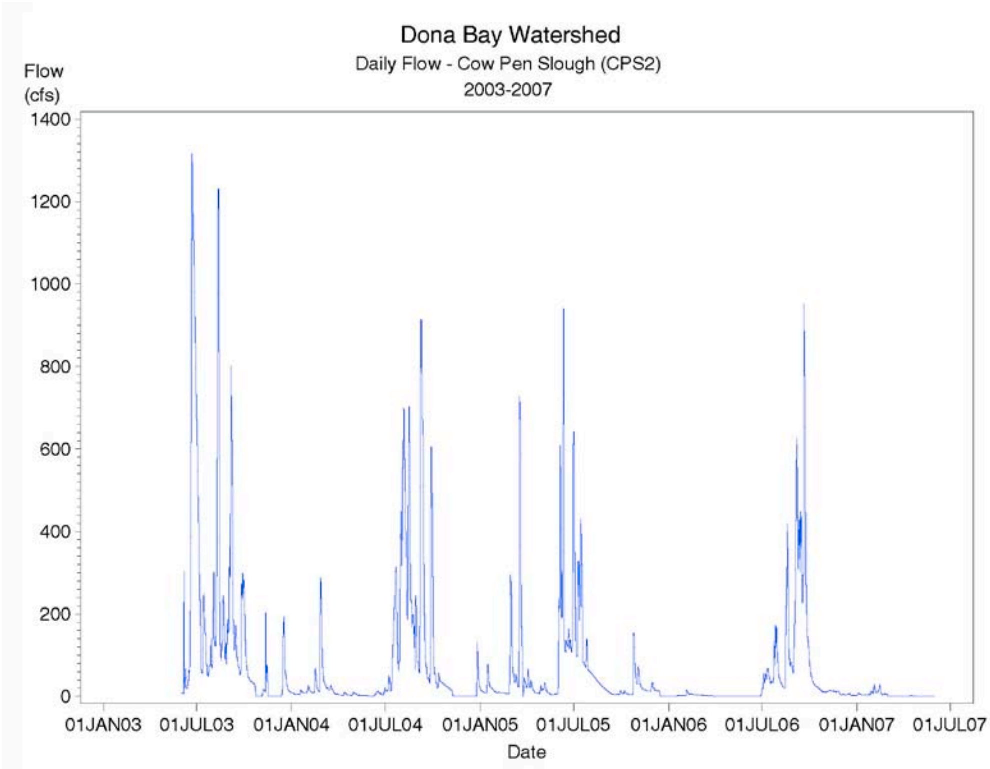

Figure 2-15. **Time series of measured daily flows (cfs) at the Cow Pen Slough (CPS2) gauge for the period from 2003 to 2007.**

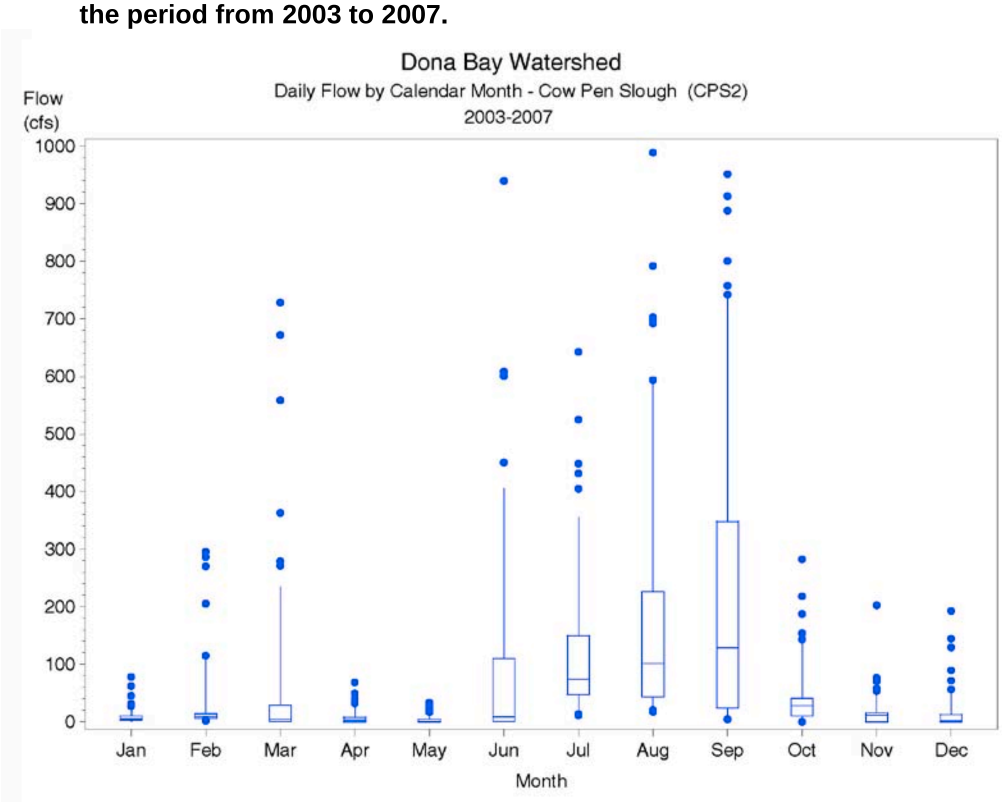

Figure 2-16. **Box and whisker of measured daily flows (cfs) by calendar month at the Cow Pen Slough (CPS2) gauge for the period from 2003 to 2007.**

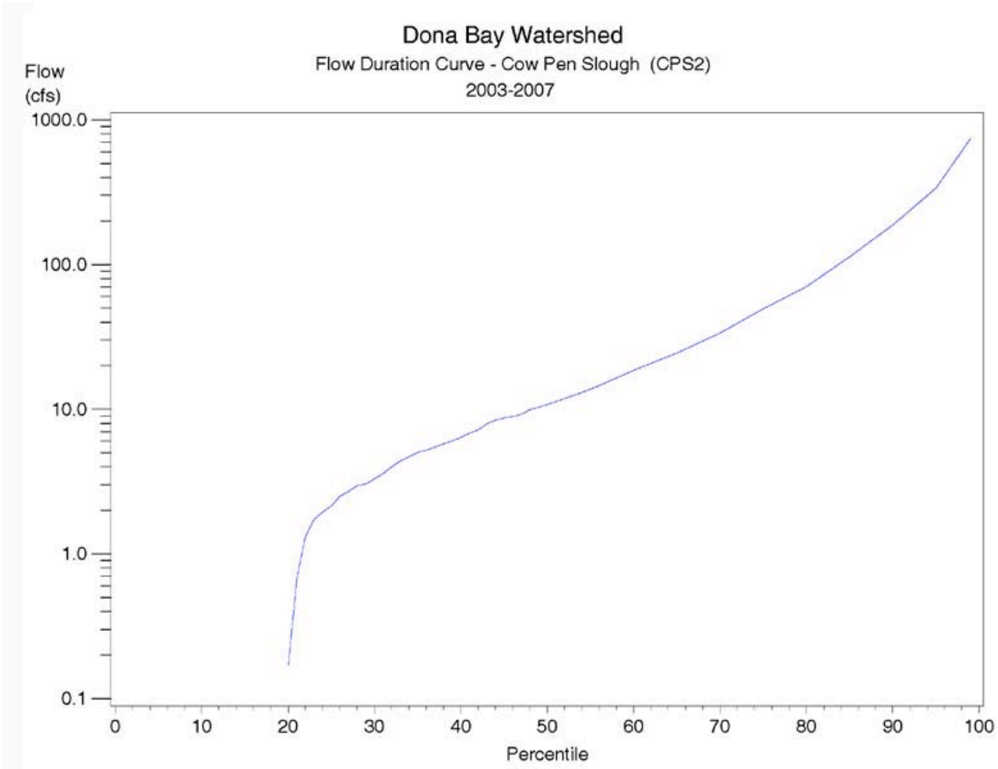

Figure 2-17. Flow duration curve of measured daily flows (cfs) at the Cow Pen Slough (CPS2) gauge for the period 2003 to 2007.

Data collection at the Blackburn Canal near Venice gauge was initiated in March 2004 and continues through the present. The gauge site is tidally influenced and negative flows (*i.e*., flows from Roberts Bay to the Myakka River) occur periodically. To calculate net daily flows for the site, a tidal filter is applied. Measured daily flows have ranged from a minimum of -80 cfs to a maximum of 507 cfs (Figure 2-18). A box and whisker plot of the daily flow from the Blackburn Canal near Venice gauge by calendar month from March 2004 through June 2006 is presented in Figure 2-19. The seasonal pattern of higher flows from June to September and lower flows from October to May observed for the gauging stations in the Cow Pen Slough system is also evident at the Blackburn Canal near Venice gauge site (Figure 2-19). The 25th percentile, 50th percentile (median), and 75th percentile flows for the available period of record were four, nine, and 29 cfs, respectively (see Figure 2-20 for a flow duration curve for the gauge site).

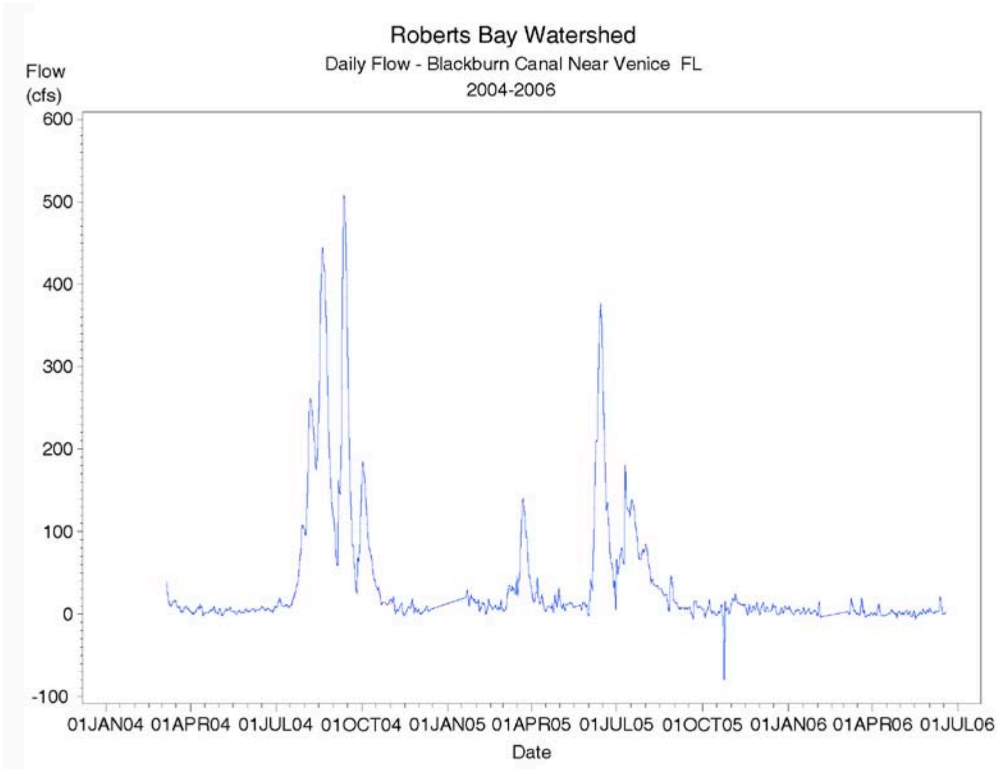

Figure 2-18. **Time series of measured daily flows (cfs) at the Blackburn Canal near Venice gauge (USGS 02299692) for the period 2004 to 2006.**

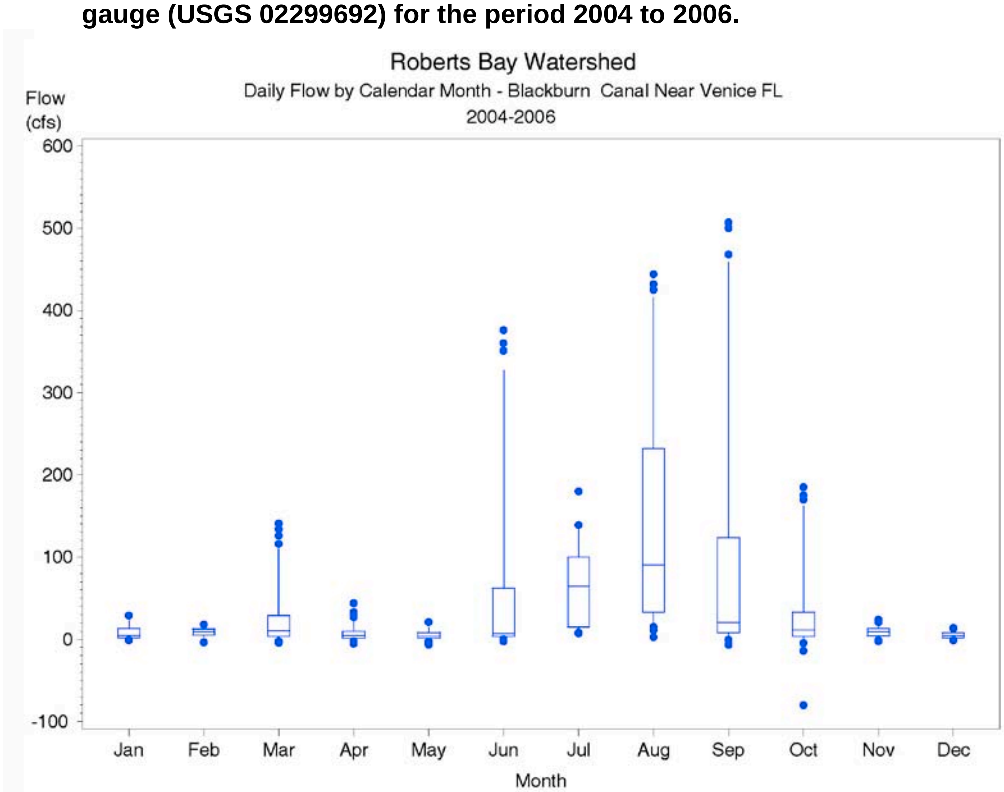

Figure 2-19. **Box and whisker of measured daily flows (cfs) by calendar month at the Blackburn Canal near Venice gauge (USGS 02299692) for the period 2004 to 2006.**

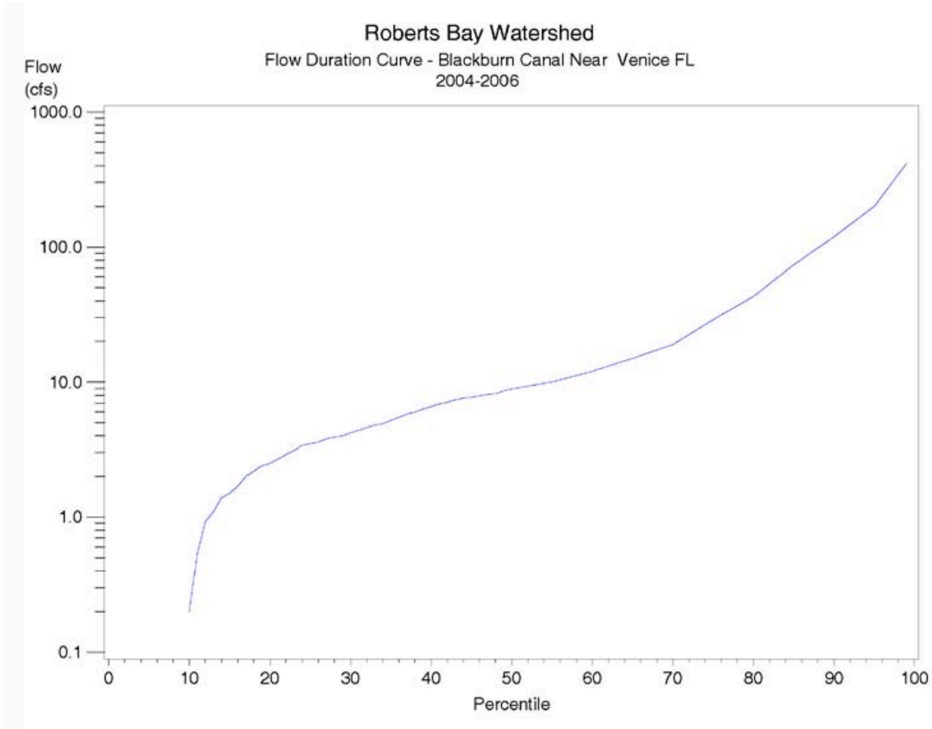

Figure 2-20. Flow duration curve of measured daily flows (cfs) at the Blackburn Canal near Venice gauge (USGS 02299692) for the period 2004 to 2006.

Because long-term records of freshwater inflows to the DARB system do not exist, a mechanistic model (Hydrological Simulation Program – FORTRAN [HSPF]) was developed to predict freshwater inflows to Dona Bay and an empirical model was developed to predict flows at the Blackburn Canal near Venice gauge (Intera 2007). The HSPF model was used to predict runoff from all sub-basins that drain to Dona Bay (Figure 2-21; basins 001 to 013) for a historical period, 1985 through 2005, based on rainfall records for the period. The empirical model was used to predict flows at the Blackburn Canal near Venice gauge for the same historical period. A complete description of these two models, including calibration of the models and hydrologic modeling of both systems, is presented in Appendix 2-1.

Daily freshwater inflow to Dona Bay based on existing structural alterations to the watershed, was predicted for the period January 1, 1985 through December 31, 2005 using the HSPF model developed by Intera (2007). The inflow to Dona Bay includes flows from the subbasins downstream of the CPS2 structure, specifically Fox, Salt, and Shakett creeks. The mean annual flow to Dona Bay ranged from 21 to 120 cfs, while the median annual flow ranged from 0 to 65 cfs (Figure 2-22). A seasonal pattern of higher flows from June to October and lower flows from November to May is apparent in a box and whisker plot of the predicted daily flows for the modeled period grouped by calendar month (Figure 2-23). Predicted daily flows ranged from zero cfs to 1,873 cfs. The 25th percentile, 50th percentile (median), and 75th percentile predicted flows for the modeled period were one, 17, and 91 cfs, respectively (Figure 2-24). No flow occurred at the site approximately 20 percent of the time for the modeled period and flows less than 10 cfs occurred 44 percent of the time (Figure 2-24).

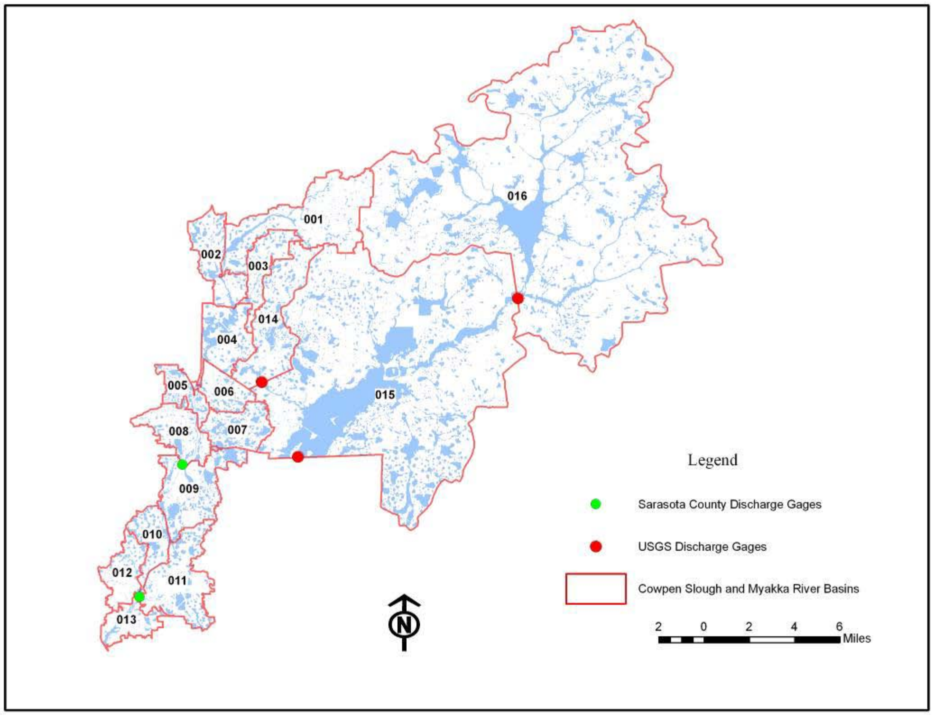

Figure 2-21. **Delineation of Dona Bay sub-basins (001-013) used in HSPF modeling to predict freshwater inflows to Dona Bay (From: Intera 2007).**

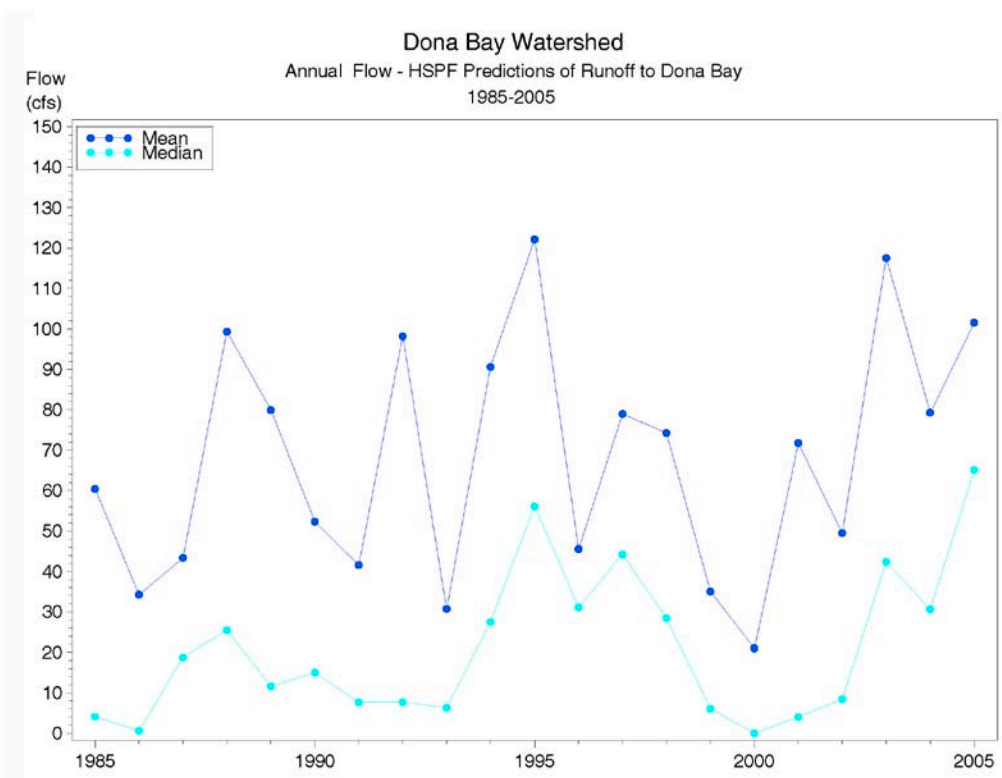

Figure 2-22. **Time series of predicted annual flows (cfs) to Dona Bay (1985 through 2005) based on use of a HSPF model developed by Intera (2007).**

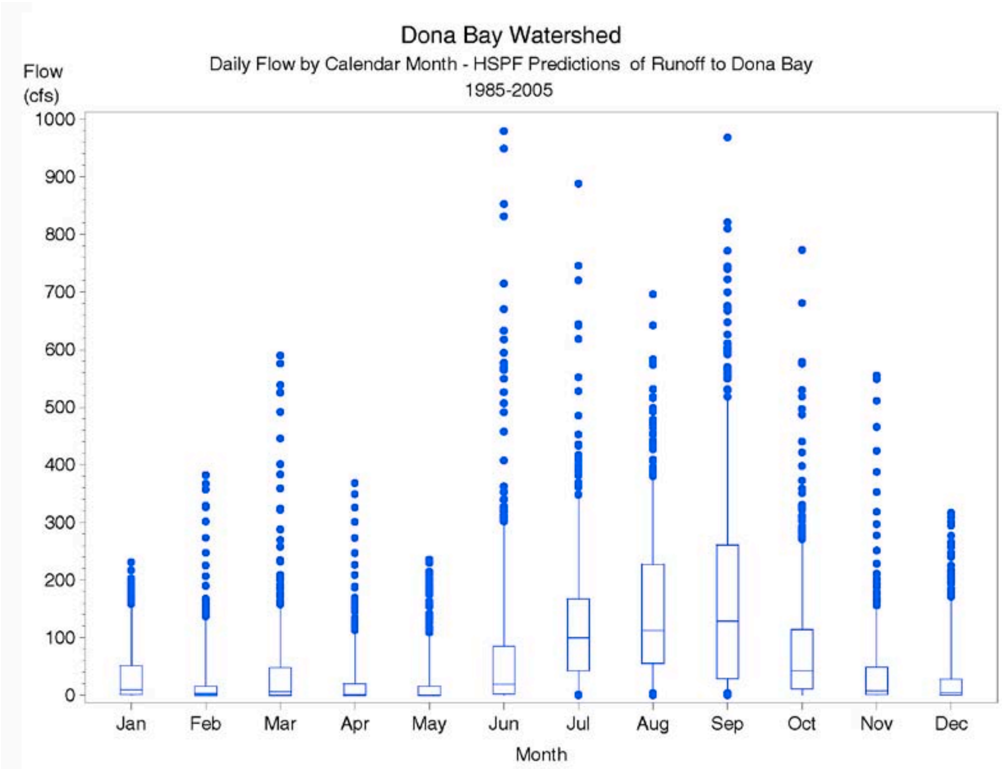

Figure 2-23. **Box and whisker of predicted daily flows (cfs) by calendar month to Dona Bay (1985 through 2005) based on use of a HSPF model developed by Intera (2007).**

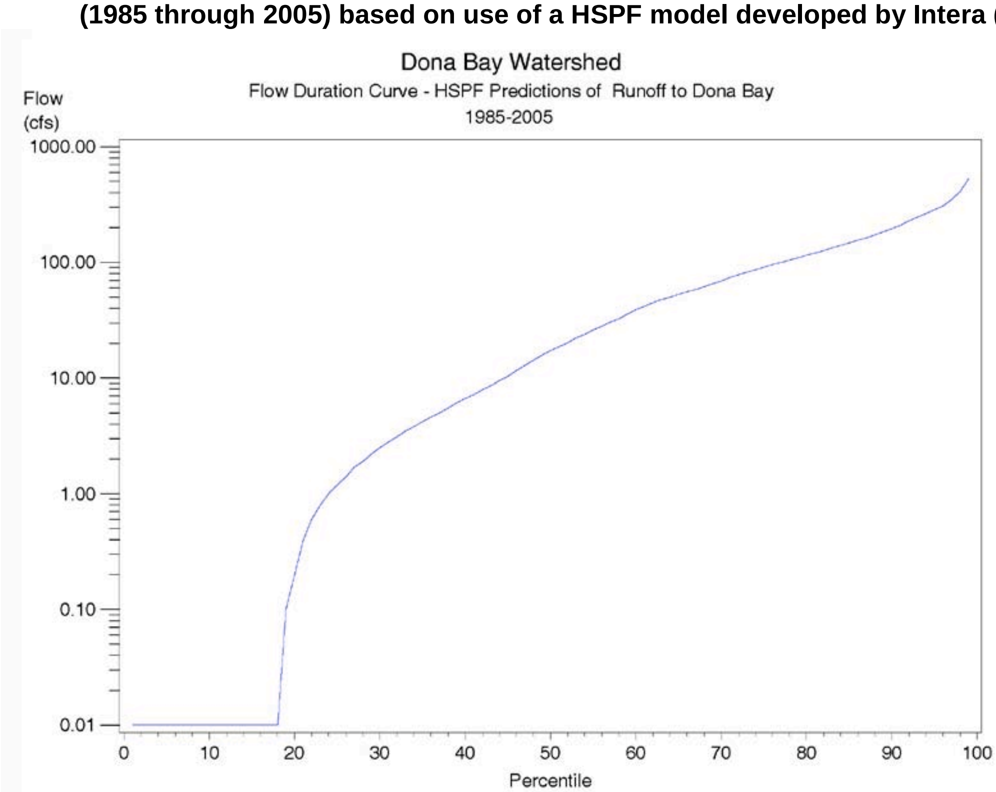

Figure 2-24. **Flow duration curve of predicted daily flows (cfs) to Dona Bay (1985 through 2005) based on use of a HSPF model developed by Intera (2007).**

The daily flow at the Blackburn Canal near Venice gauge was predicted for the period January 1, 1985 through December 31, 2005 using an empirical model developed by Intera (2007) which accounted for existing structural alterations. Based on modeled results, the mean annual flow at the gauge site ranged from 12 to 61 cfs, while the median annual flow ranged from six to 18 cfs (Figure 2-25). The typical seasonal pattern of higher flows from June to October and lower flows from November to May was evident in daily flows when grouped by calendar month (Figure 2-26). Predicted daily flows ranged from a minimum of -5 cfs to a maximum of 763 cfs. Predicted 25th percentile, 50th percentile (median), and 75th percentile flows for the 21-year modeled period were eight, 14, and 19 cfs, respectively (Figure 2-27).

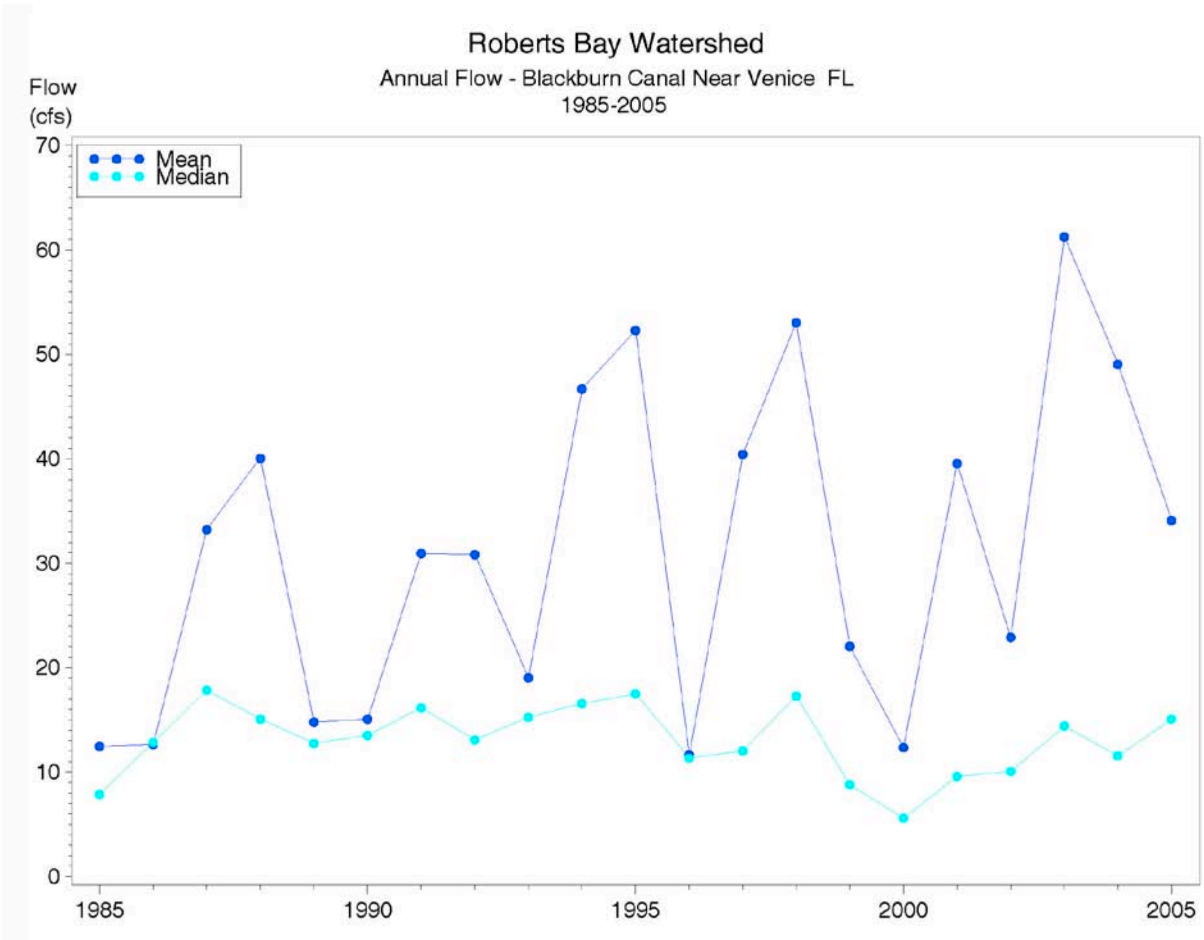

Figure 2-25. Time series of predicted annual flows (cfs) from the Blackburn Canal near Venice gauge (1985 through 2005) based on use of an empirical model developed by Intera (2007).

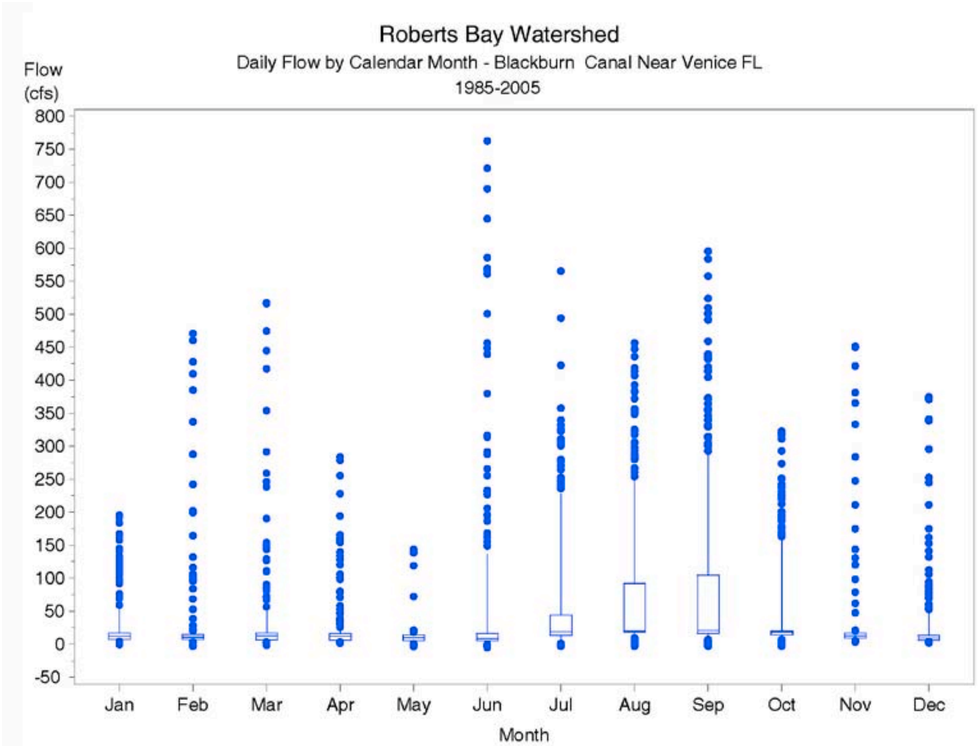

Figure 2-26. Box and whisker of predicted daily flows (cfs) by calendar month from the Blackburn Canal near Venice gauge (1985 through 2005) based on use of an empirical model developed by Intera (2007).

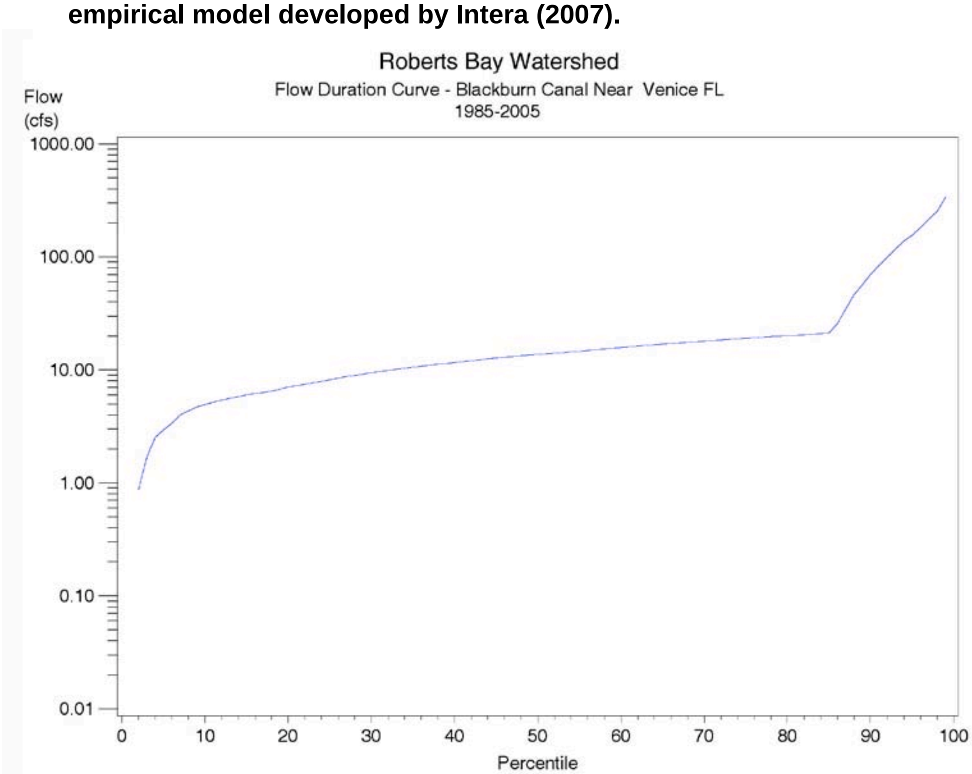

Figure 2-27. Flow duration curve of predicted daily flows (cfs) from the Blackburn Canal near Venice gauge (1985 through 2005) based on use of an empirical model developed by Intera (2007).

The main sources of freshwater to the DARB system are the channelized flows coming from the Cow Pen Slough Canal and Blackburn Canal. The flows from these two gauged canals have been described above. As mentioned, the CPS2 structure is operated by opening the gates on June 1 to avoid flooding during the wet season and closing the gates on November 1 to retain water during the dry season. The Blackburn Canal does not have a flow control structure. The Blackburn Canal provides a direct connection between the Myakka River and Roberts Bay and it has been estimated that 7% of the freshwater flowing in the lower Myakka River is diverted to Roberts Bay via the Blackburn Canal (Kimley-Horn and Associates *et al.* 2007). To quantitatively analyze the relative contribution of freshwater to the DARB system from the Blackburn Canal, a box-and-whisker plot comparing the percent contribution of predicted Blackburn Canal flows to the predicted Cow Pen Slough Canal flows to the DARB system was plotted by month (Figure 2-28). Monthly percentages were calculated as follows:

$$Percent_{Blackburn} = \frac{Flow_{Blackburn}}{Flow_{Blackburn} + Flow_{CPS2}} \text{ X } 100 \text{ ;}$$

where $Flow_{Blackburn}$ and $Flow_{CPS2}$ represent monthly total flows from the Blackburn Canal and from Cow Pen Slough Canal at the CPS2 gauge site derived from daily flows predicted using the HSPF or empirical models developed by Intera (2007).

During the dry season, when the gates on the Cow Pen Slough structures are closed (November 1 to June 1), the majority of the freshwater entering the DARB system typically comes from the Blackburn Canal. During the wet season, when the CPS2 structure is opened (June 1 to November 1), the influence of Blackburn flows is typically diminished as CPS2 flows are higher during these months.

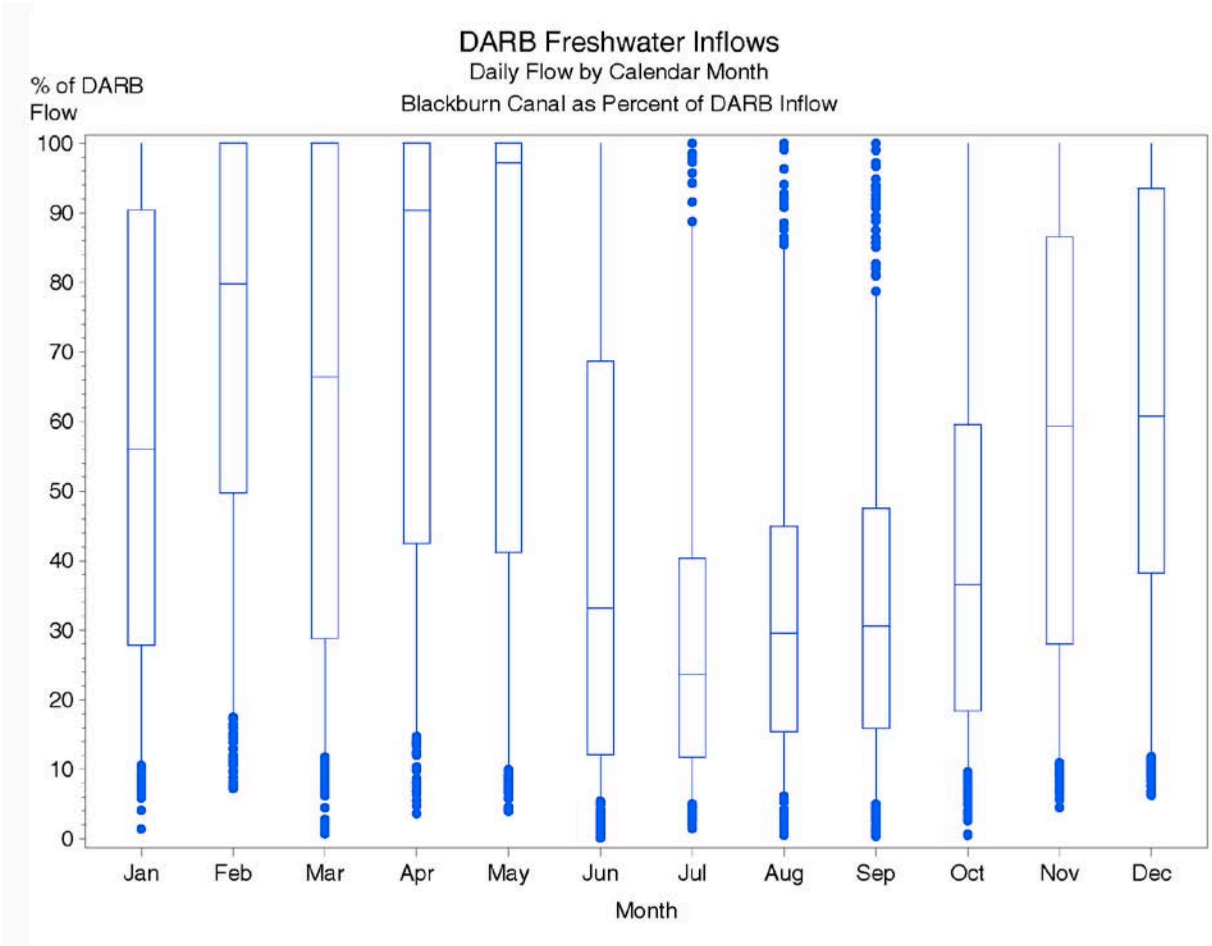

Figure 2-28. Blackburn Canal flows as a percentage of monthly DARB system inflows, based on daily flows predicted for the period from 1985 through 2005 (Intera 2007).

3 THE DONA BAY AND ROBERTS BAY ESTUARY

The estuarine portion of the DARB system is described in this section, including bathymetry, morphometry, bottom type, and shoreline features. The DARB watershed and hydrology have been described in Chapter 2. Shakett Creek (Cow Pen Slough), Salt Creek and Fox Creek are the major tributaries to Dona Bay (Figure 3-1 through 3-3); Curry Creek (Blackburn Canal) and Hatchett Creek flow into Roberts Bay (Figure 3-1). The Intracoastal Waterway also connects Roberts Bay with Lemon Bay to the south (Figures 3-1 and 3-4). An aerial photograph (2004) of the system is provided in Figure 3-5, showing that much of the shoreline has been urbanized and hardened. The surface area of the DARB estuary is 421 acres. As mentioned in Section 2, the area of the DARB watershed is approximately 62,000 acres. Therefore, the estuary to watershed ratio of DARB is 1:147.

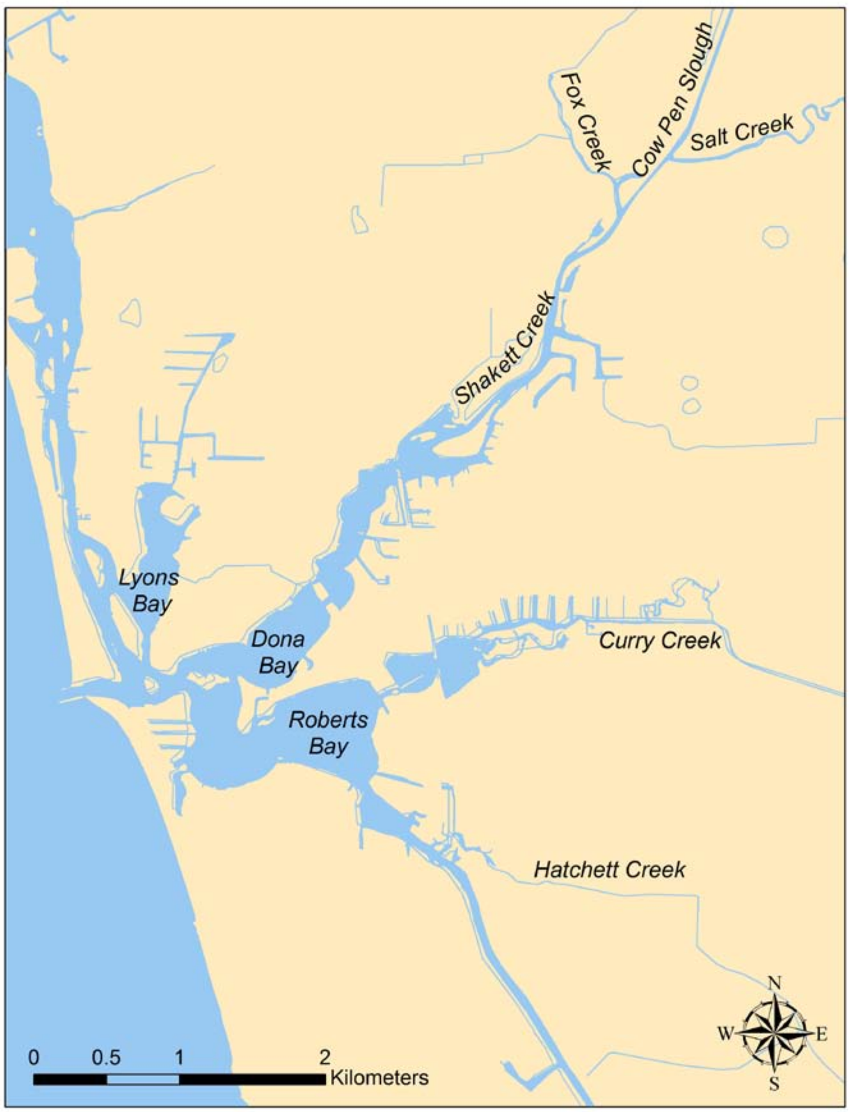

Figure 3-1. DARB estuary and its major tributaries.

Figure 3-2. **Photograph of Shakett Creek facing north, south of Laurel Road, taken on June 21, 2007.**

Figure 3-3. **Photograph of Dona Bay, facing upstream toward the U.S. 41 bridge, taken on June 21, 2007.**

Figure 3-4. **Photograph of Roberts Bay, facing south toward the Intracoastal Waterway, taken on June 21, 2007.**

Figure 3-5. **Aerial photograph of DARB (Source: SWFWMD 2004).**

3.1 Bathymetry and Morphometry

Physical dimensions of estuarine systems and other water bodies can affect water circulation patterns, temperature, salinity and residence time, and influence sediment characteristics and the distribution of biota. Bathymetric and morphometric information, including water depth, volume, bottom area and shoreline length were, therefore, obtained for the DARB system to support development of minimum flow recommendations.

A river kilometer system was developed for the District (Wang 2004) to aid in the description and analysis of the DARB system (Figure 3-6). The Dona Bay/Shakett Creek system extends 6.5 km from the mouth of Venice Inlet to the CPS2 structure (Figure 3-6) and all data and references to river kilometer in this report have been normalized to this system.

Bathymetric data for the DARB system were collected for the District by Wang (2004) and are shown in Figure 3-7. The greatest depths occur in the Intracoastal Waterway and Venice Inlet, which are dredged to facilitate navigation. Construction of the jettied Venice Inlet was completed in 1938 (Antonini *et al.* 1999). The majority of the system has depths less than two meters (relative to NGVD), with the exception of greater depths in the dredged areas (Figure 3-7).

The bathymetry was normalized to mean tide level and the volume and bottom area of DARB were calculated for the District by Berryman and Henigar (2006). In order to quantify the amount of habitat in terms of the volume and bottom area for DARB, each branch of the system was divided into 500-meter segments. In addition to volume and bottom area, shoreline length was calculated using GIS software. The relationship between river kilometer and bottom area in Dona Bay/Shakett Creek and Roberts Bay is presented in Figures 3-8 and 3-9, respectively. There is a greater proportion of bottom area in the Dona Bay/Shakett Creek system downstream of rkm 3.5, where the estuary widens and there are fewer islands (Figures 3-7 and 3-8). In Roberts Bay, there is a greater proportion of bottom area downstream of rkm 2.5, which is the widest portion of the bay (Figures 3-7 and 3-9). As with bottom area in the two bays, the volume of water is greatest in the downstream portions (Figure 3-10 and 3-11). Unlike bottom area and volume, the proportion of habitat in terms of shoreline length is similar or greater in the upstream portions of each bay, relative to the downstream areas (Figures 3-12 and 3-13). Islands in the upstream portions of each bay account for the greater upstream shoreline lengths.

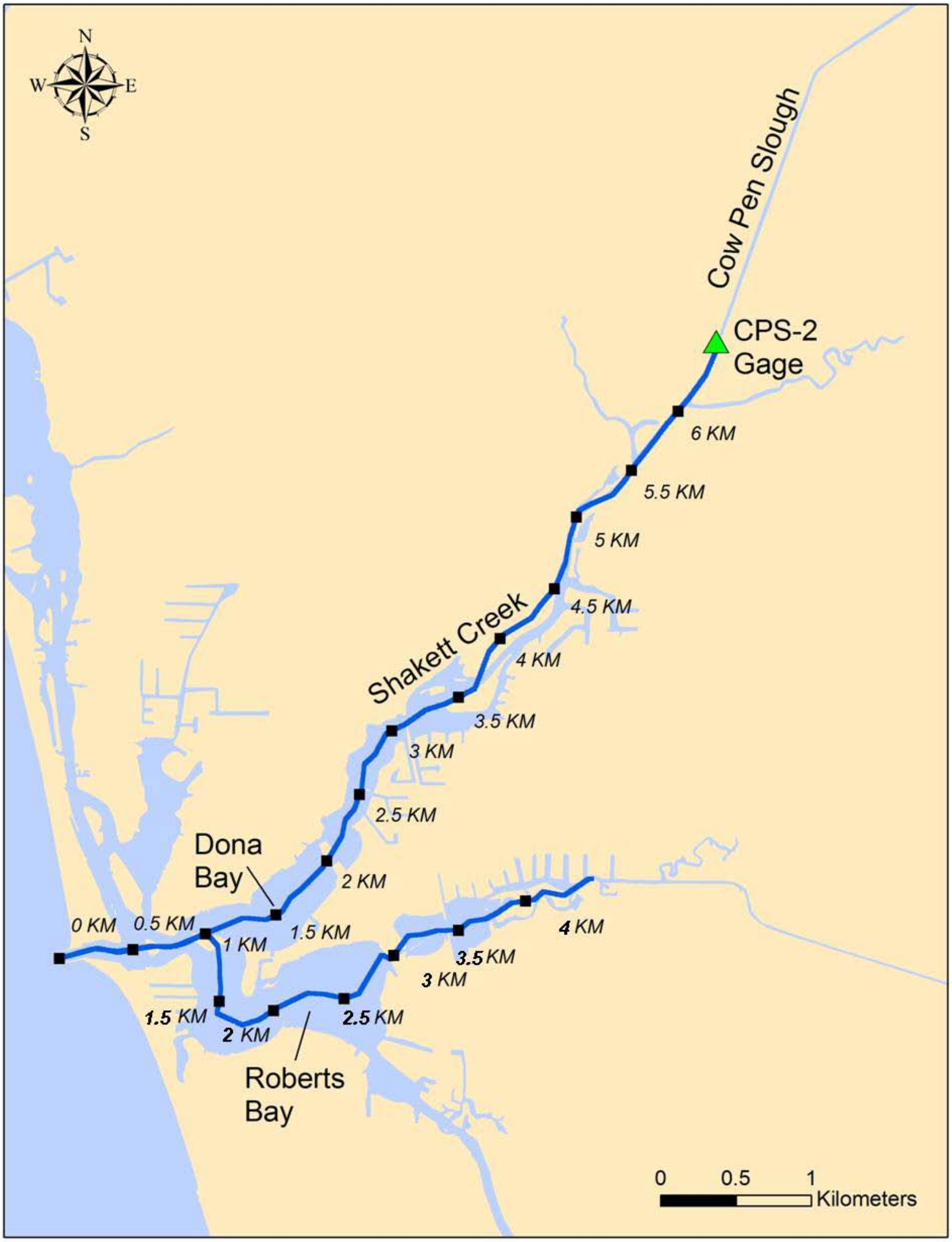

Figure 3-6. **DARB river kilometer system.**

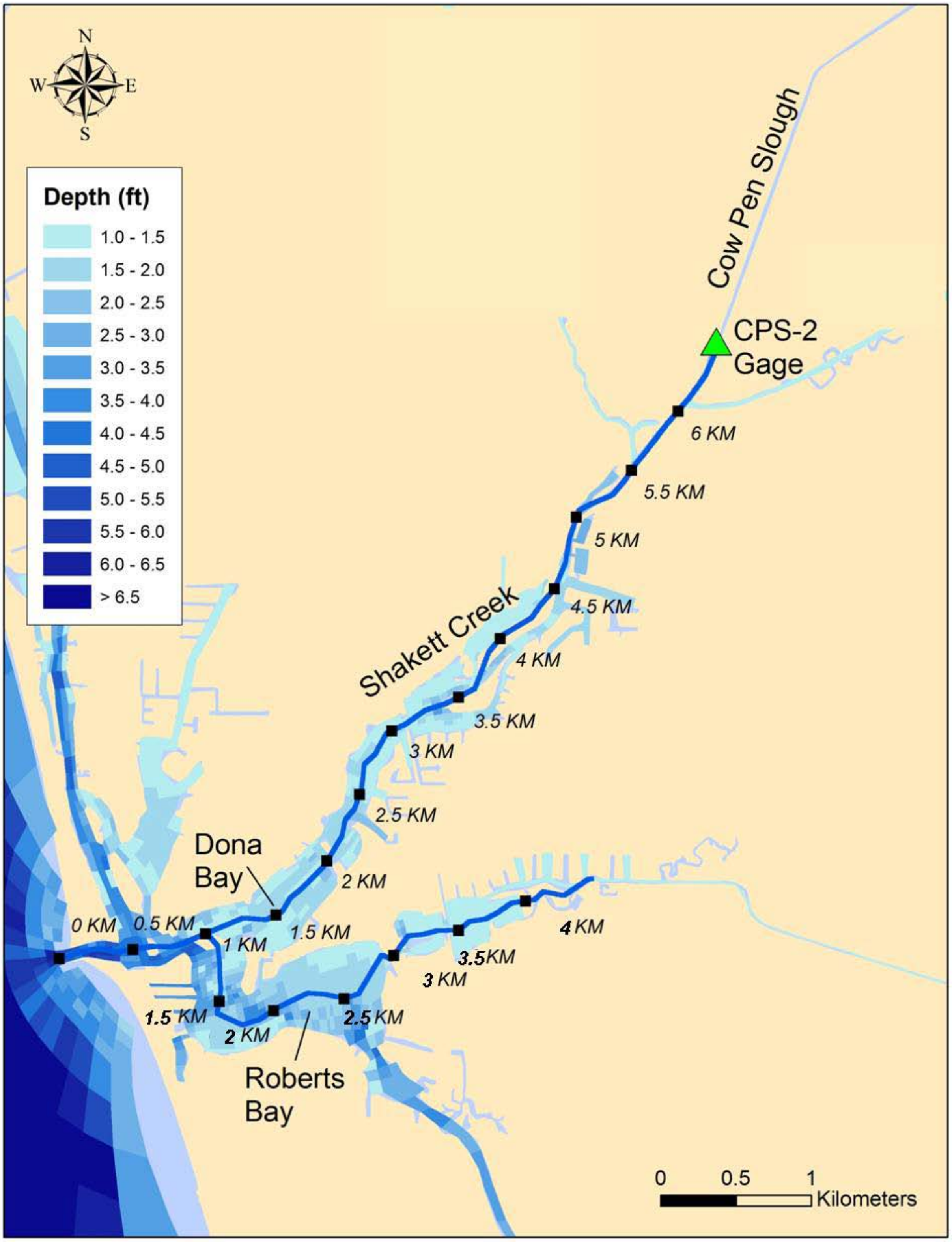

Figure 3-7. **Bathymetric map and river kilometer system used for describing the DARB estuarine system (relative to NGVD).**

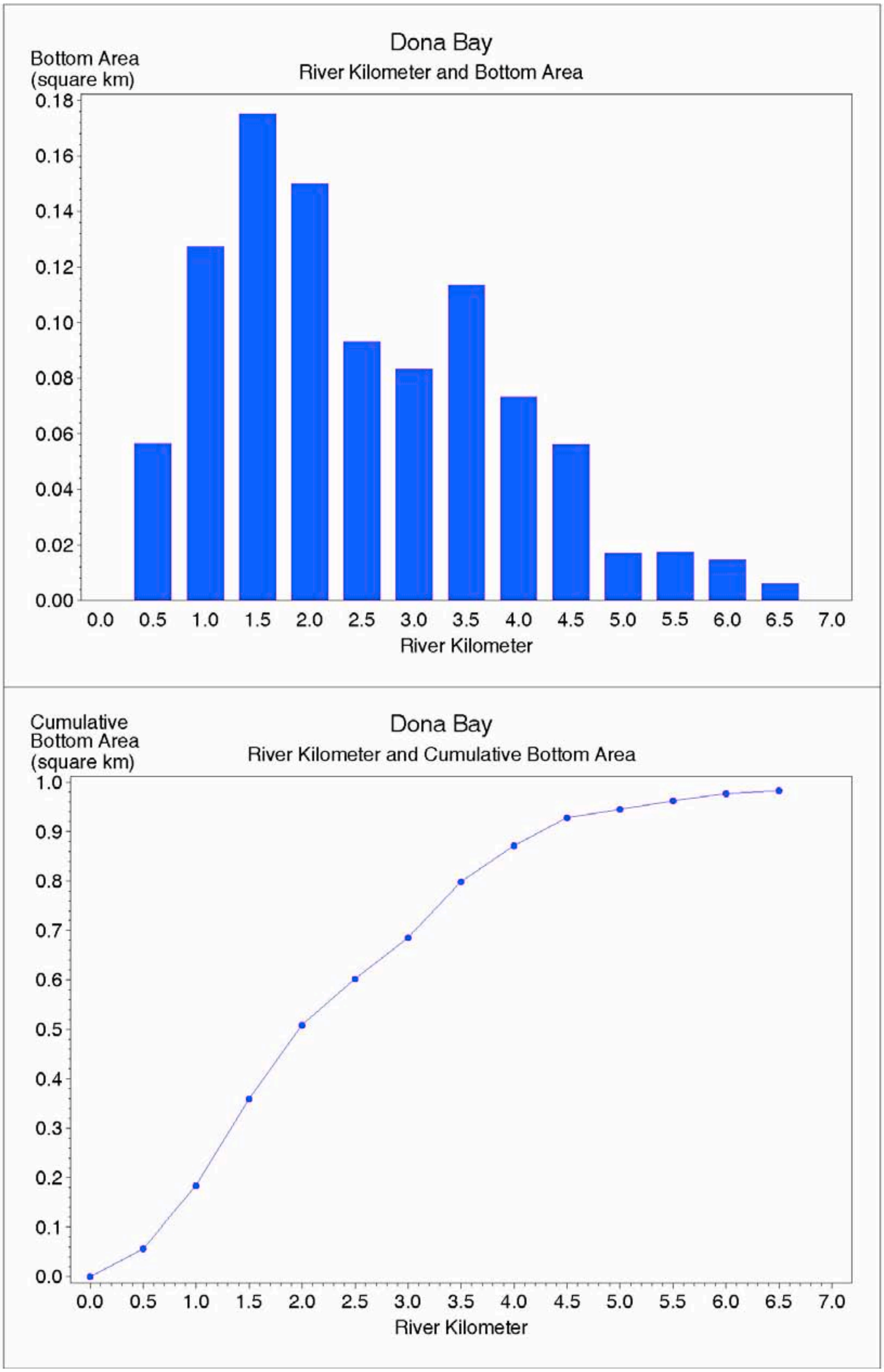

Figure 3-8. Relationship between river kilometer and bottom area in Dona Bay/Shakett Creek.

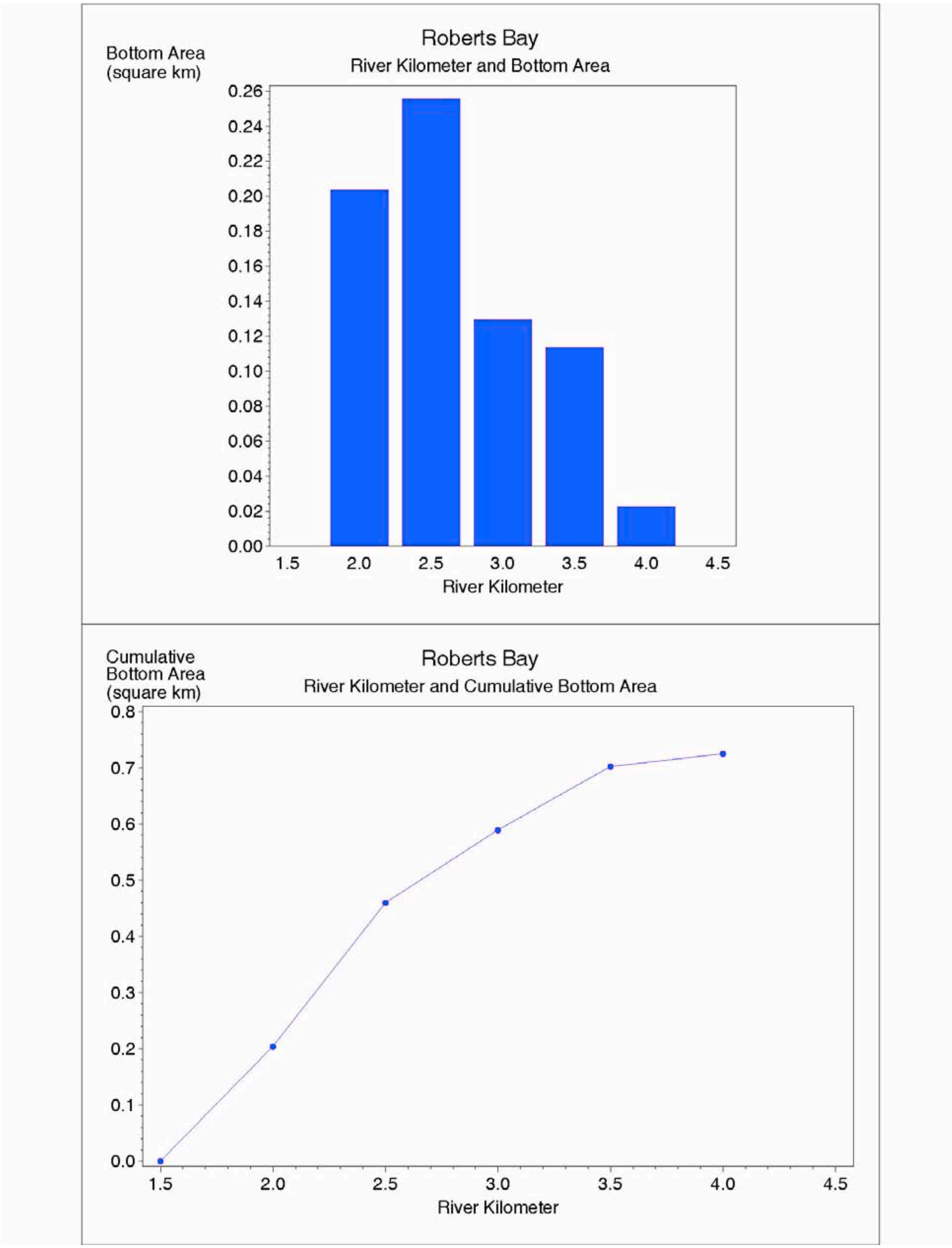

Figure 3-9. Relationship between river kilometer and bottom area in Roberts Bay.

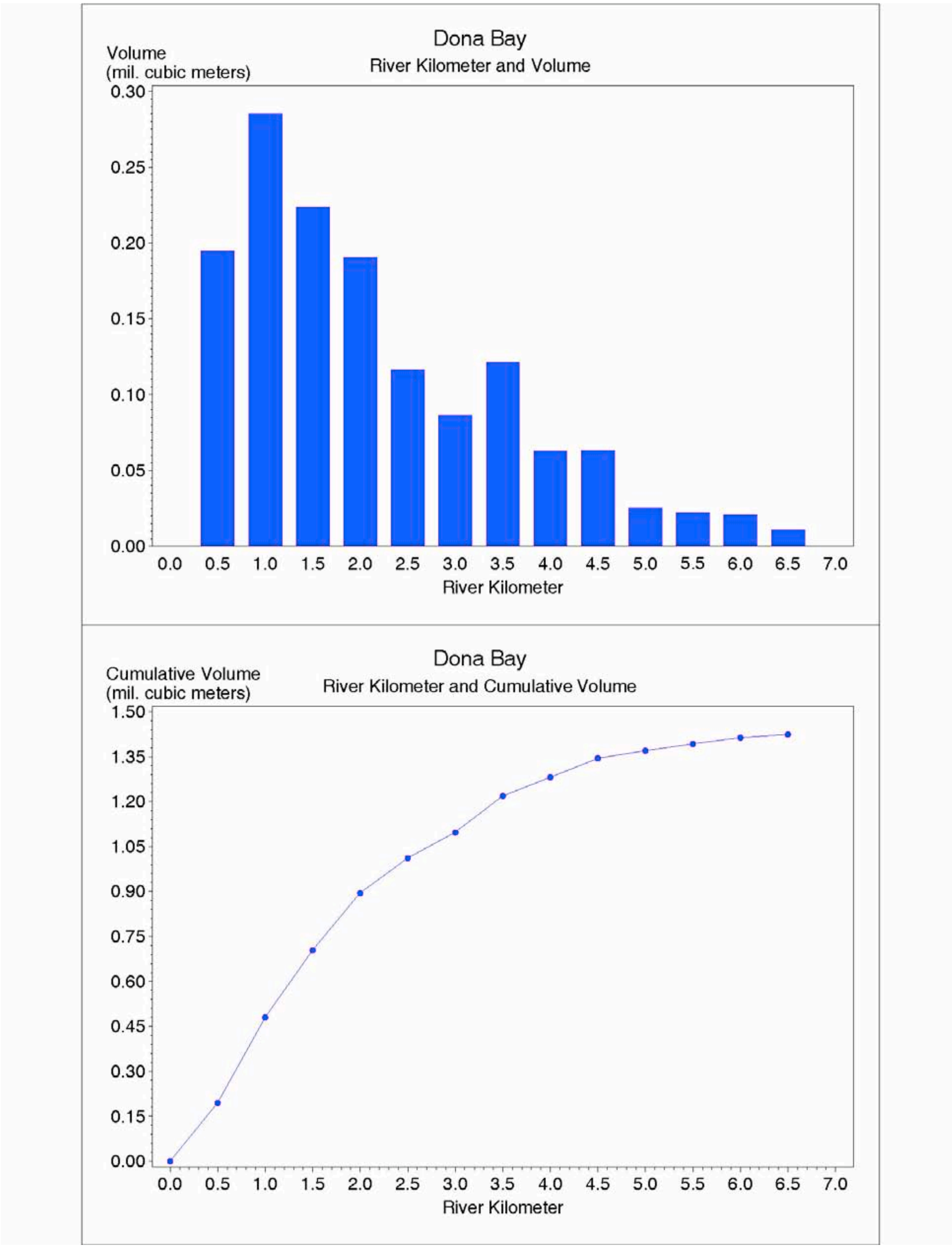

Figure 3-10. Relationship between river kilometer and volume in Dona Bay/Shakett Creek.

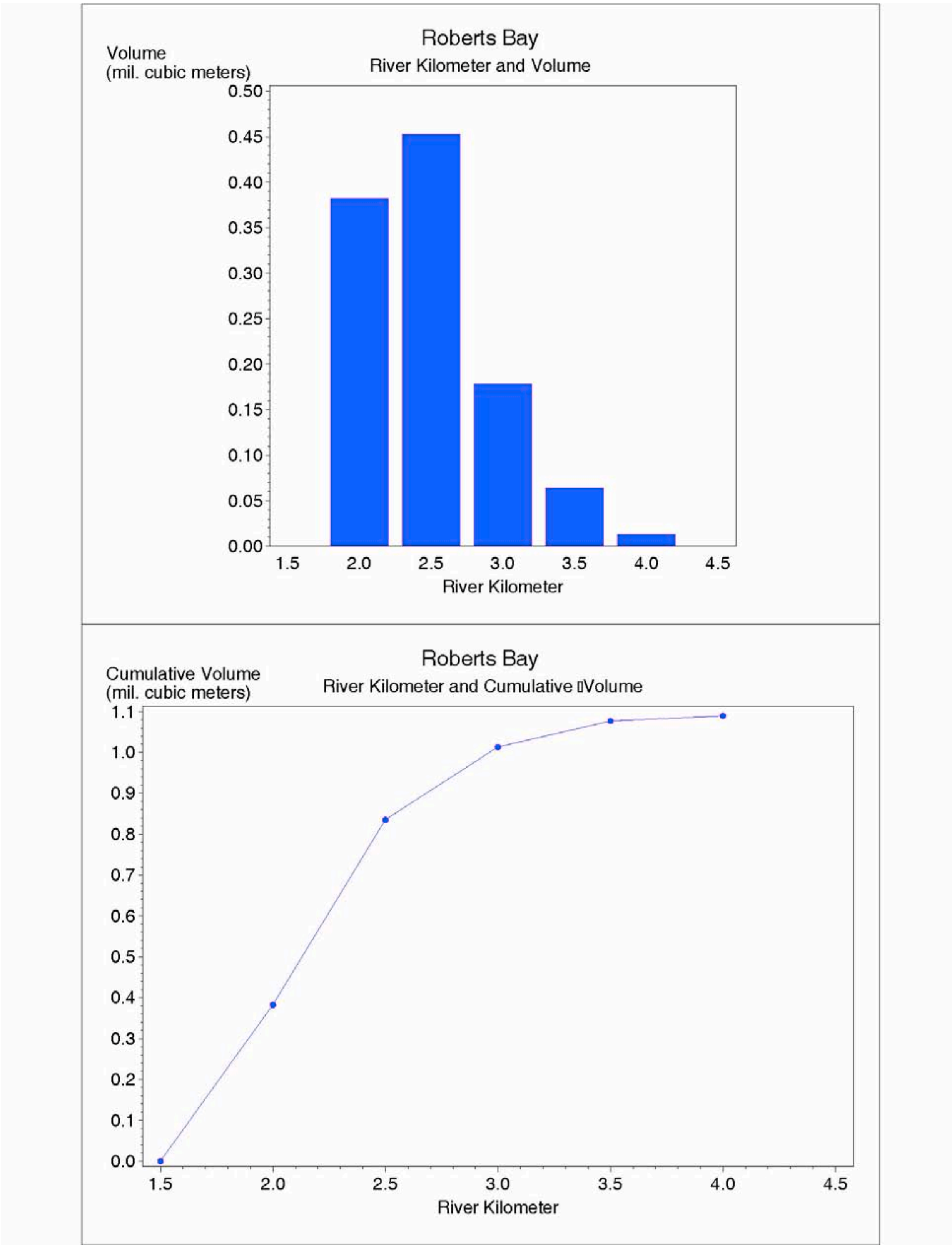

Figure 3-11. **Relationship between river kilometer and volume in Roberts Bay.**

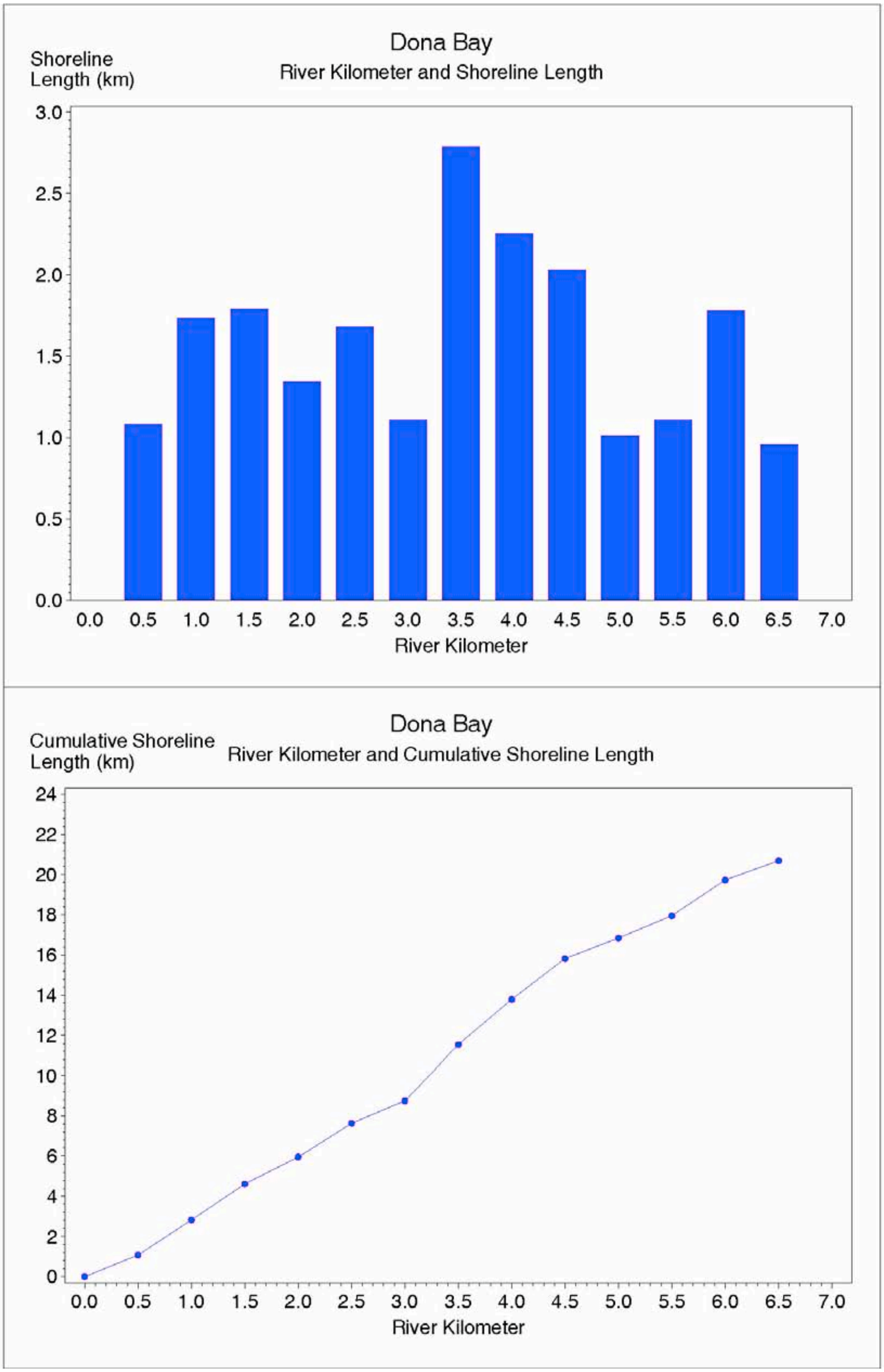

Figure 3-12. Relationship between river kilometer and shoreline length in Dona Bay/Shakett Creek.

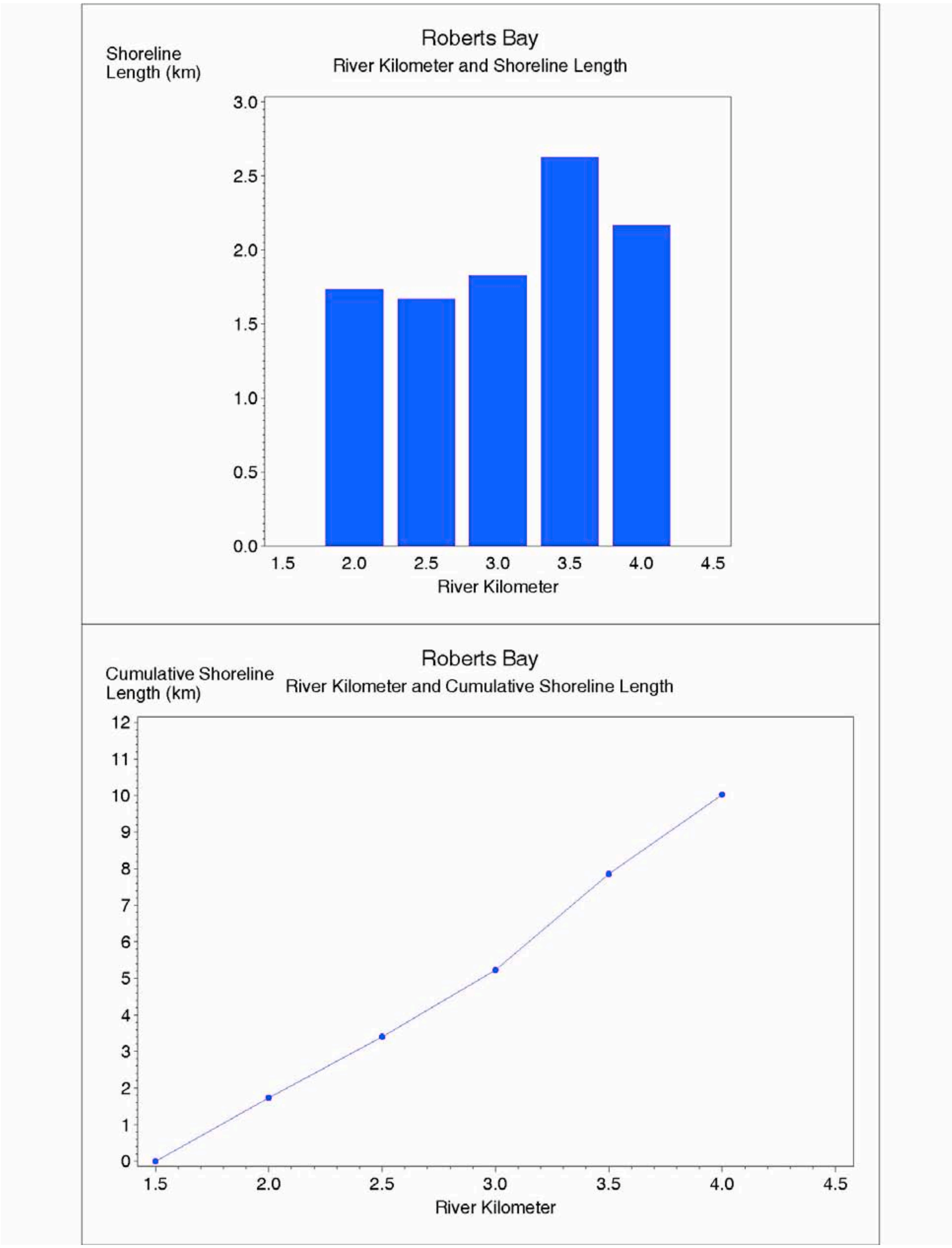

Figure 3-13. Relationship between river kilometer and shoreline length in Roberts Bay.

3.1.1 Bottom Type

The bottom types found within an estuary form through a combination of physical and chemical processes. These processes include inflows of freshwater and associated sediments, tides, circulation, geology, dredging, chemical reactions between freshwater sediment particles and sea water, among others. Understanding these processes is important since bottom type influences the nature of the biota that inhabit a particular system, or different portions of the same system. Many benthic invertebrates have preferences for a specific bottom type, such as sand, silt, or hard substrate. Some fish species also have bottom type preferences due to either prey availability or reproductive needs.

Sediments in the DARB system are typical of estuaries along the west coast of Florida, being dominated by medium quartz sands with low levels of organic matter. Sites sampled by Mote Marine Laboratory in Dona Bay/Shakett Creek in 2004 (Figure 3-14) ranged from 59-93% percent sand, and percent organic content of the sediments ranged from 1-4.4% (Table 3-1) (Cutler 2006). Carbonate as shell material had a patchy distribution, and was found mainly near oyster bars or around roots of mangroves colonized by oysters. In general, samples from deeper sites within the estuary contained higher percentages of silt and clay, and less sand, than shallow stations.

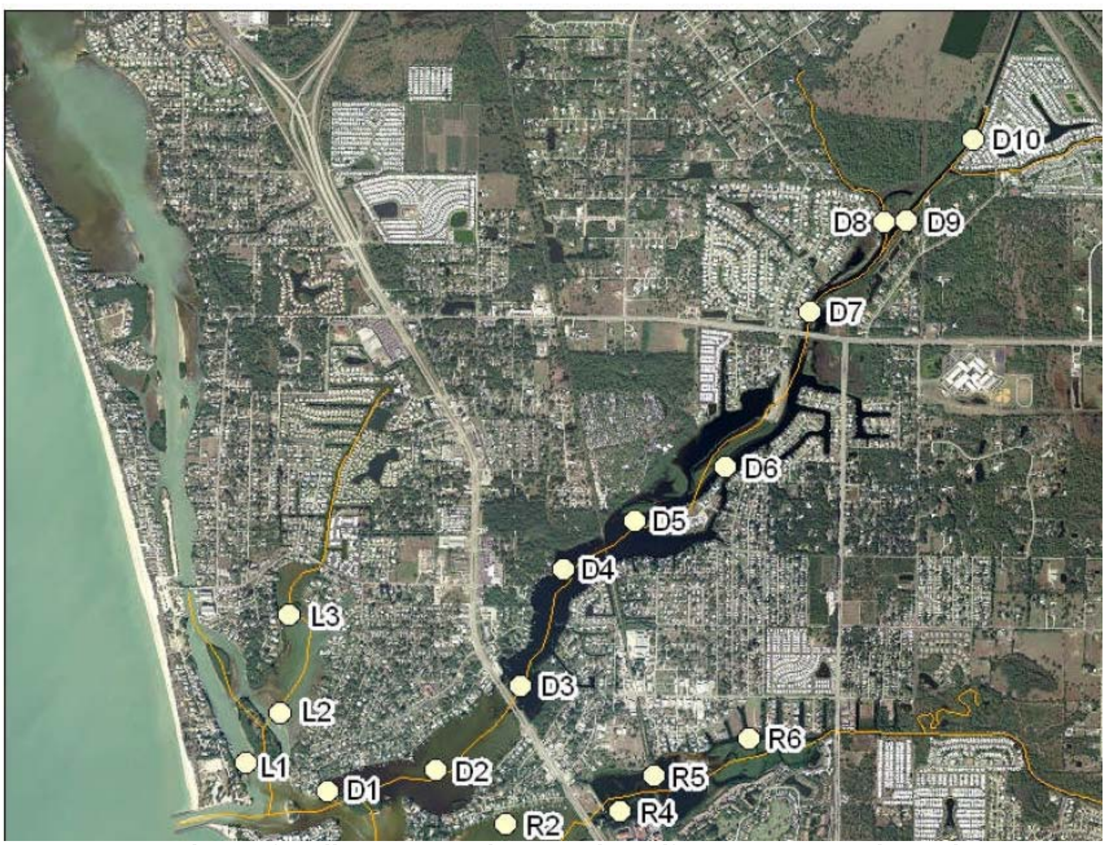

Figure 3-14. Locations of sediment sampling locations (from Culter 2006). Stations D1-D10 are located in Dona Bay/Shakett Creek.

Table 3-1. Sediment characteristics of Dona Bay/Shakett Creek (after Culter 2006).

Station	Rkm	Shallow (S), Deep(D)	Percent Organic	Percent Sand	Percent Silt	Percent Clay
D1	0.8	S	1.0	88.1	9.2	2.7
		D	1.5	87.9	9.6	2.5
D2	1.5	S	1.5	84.4	12.6	3.0
		D	4.4	67.4	28.1	4.6
D3	2.1	S	2.3	59.3	36.8	3.8
		D	2.0	79.0	16.2	4.8
D4	2.8	S	1.3	73.6	23.4	3.0
		D	4.3	69.3	26.9	3.8
D5	3.3	S	0.9	92.1	6.7	1.3
		D	3.0	70.7	23.9	5.4
D6	3.9	S	1.8	88.4	9.7	2.0
		D	2.4	88.7	9.6	1.7
D7	4.9	S	1.6	85.0	12.8	2.2
		D	1.9	92.8	6.1	1.1
D8	5.6	S	2.2	82.6	15.1	2.4
		D	1.0	92.6	6.5	1.0
D9	5.7	S	1.8	85.1	12.7	2.3
		D	3.5	66.2	29.8	4.0
D10	6.3	S	2.4	88.9	9.1	2.0
		D	3.4	70.1	27.5	2.4

3.2 Shoreline Features

Anthropogenic alteration to a coastal system can be assessed by quantifying the extent of shoreline hardening. Natural shorelines include beaches and tidal wetlands that consist of mangroves and emergent or submersed vegetation. Natural shorelines are ecologically valuable as habitat for aquatic organisms, and they facilitate natural water-column mixing and energy dissipation. Modified shoreline often includes seawalls and other structures (*e.g.*, rip-rap) that harden the shoreline and may reduce its ecological value.

As part of Sarasota County's Dona Bay Watershed Management Plan (Kimley-Horn and Associates *et al.* 2007), dominant shoreline features in the DARB system and nearby areas in 2004 were classified and mapped. Identified shoreline features included:

- beach,
- cleared land,
- deep fringing wetlands,
- patchy fringing wetlands,
- exposed banks,
- rip-rap,
- seawalls, and
- upland shorelines.

Based on the shoreline features noted in 2004, in the areas closest to Venice Inlet, the dominant shoreline is either seawall or rip-rap (Figure 3-15). Seawalls dominate the shoreline in residential areas, while rip-rap dominates the inlet itself, and along the Intracoastal Waterway. The majority of natural shorelines in DARB are "fringing deep wetlands", which describes wetland areas composed mostly of mangroves or a combination of mangroves and *Spartina* (Kimley-Horn and Associates *et al.* 2007) (Figure 3-16). The majority of the fringing wetlands were found east of U.S. 41 in upper Dona Bay and Roberts Bay, as well as in Shakett Creek and Curry Creek (Kimley-Horn and Associates *et al.* 2007) (Figure 3-16). Additionally, a shoreline features map was created from the 1948 data and superimposed on the 2004 aerial of the DARB system (Figure 3-17). In 1948, broad fringing wetlands extending toward uplands were the dominant shoreline feature. Rip rap is found near the Venice Inlet; however, the area now dominated by residential neighborhoods was dominated in 1948 by either deep or patchy fringing wetlands. The changes in shoreline features are shown in Figure 3-18.

Figure 3-15. Photo of Venice Inlet (Photo by Greg Wahl).

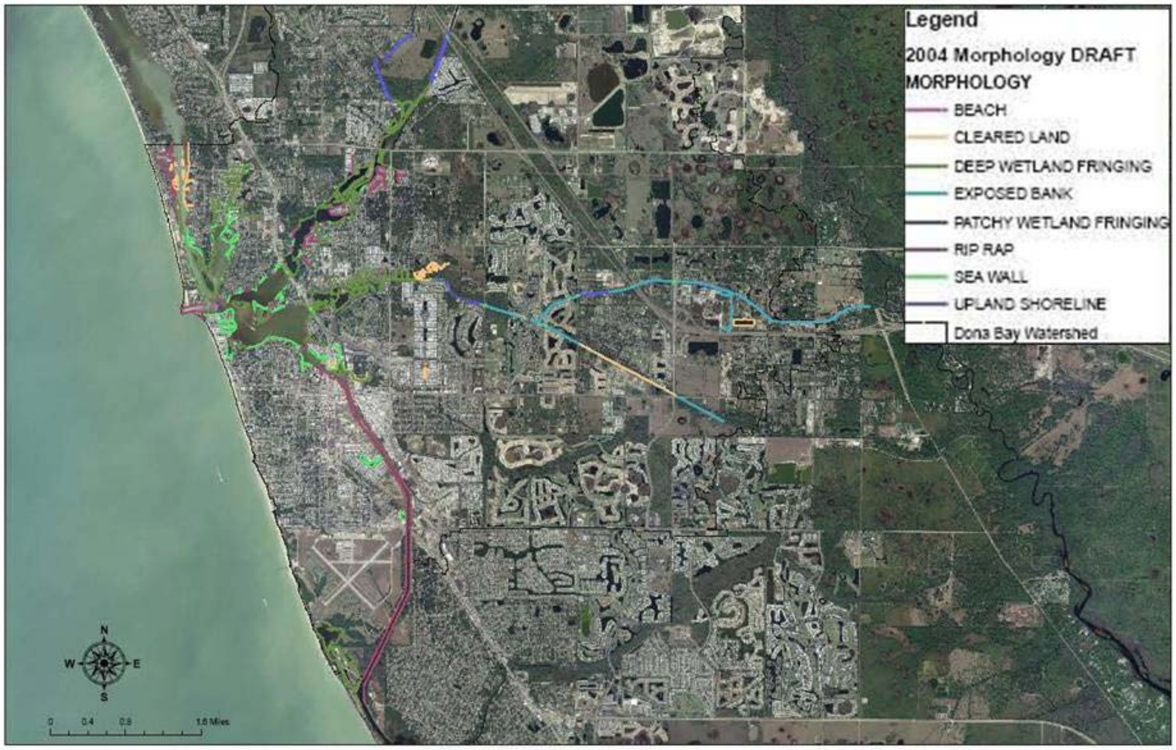

Figure 3-16. Aerial photograph of shoreline features in the DARB system, 2004 (Source: Kimley-Horn and Associates *et al.* 2007)

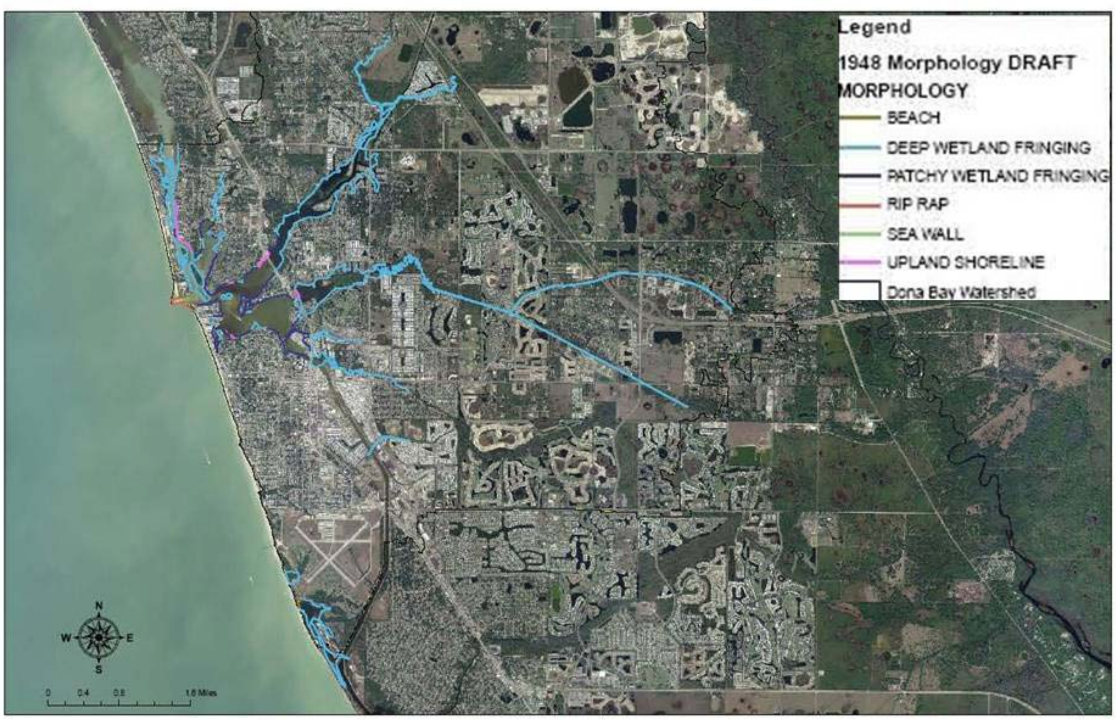

Figure 3-17. Shoreline features of 1948 in the DARB system superimposed on a 2004 aerial photograph (Source: Kimley-Horn and Associates *et al.* 2007).

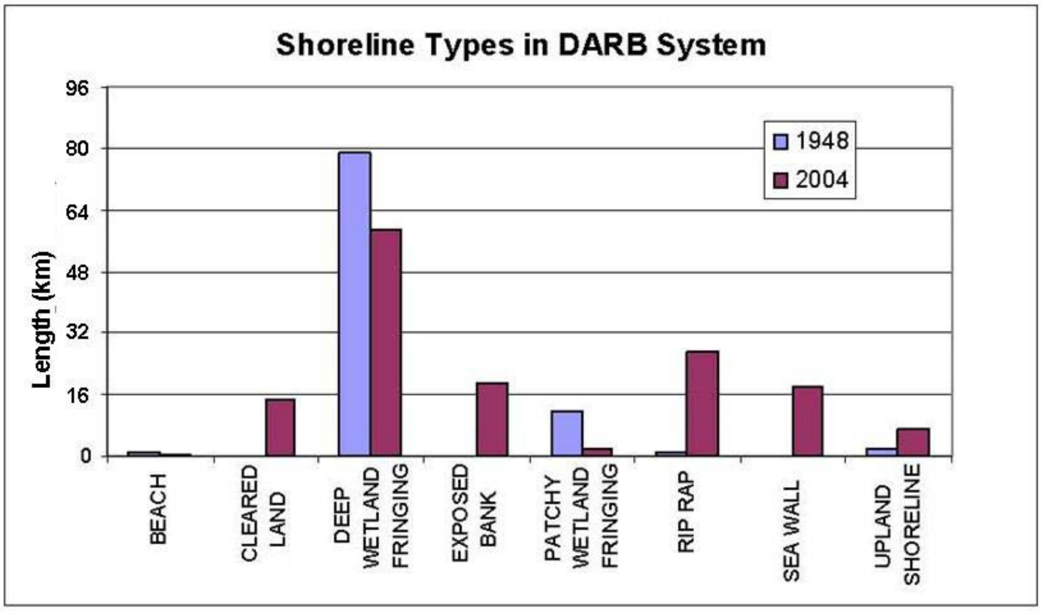

Figure 3-18. Comparison of shoreline types in the DARB system for 1948 and 2004 (Source: Kimley-Horn and Associates *et al.* 2007).

The length of shoreline in the DARB system has increased from 96 km in 1948 to 148 km in 2004 (Kimley-Horn and Associates *et al.* 2007). This increase is largely related to construction of canals and other drainage modifications. Most of the increased shoreline is either rip-rap or seawall (Figure 3-18). Fringing deep and patchy wetlands showed the greatest decreases between 1948 and 2004. Therefore, while the overall shoreline of the DARB system has increased as a result of man-made modifications during the past 50-60 years, there has been a decrease in ecologically important wetland habitat.

4 SALINITY AND WATER QUALITY CONSTITUENTS

Water quality constituents and physical water parameters measured in the field are described in this section, including the temporal and spatial patterns in the water quality constituents of DARB. The effects of freshwater flow on salinity, dissolved oxygen (DO), color and chlorophyll *a* are also described largely for the purpose of characterizing the system and the relationship of water quality parameters. Parameters chosen for evaluation are those most likely to affect significant biological resources within the system.

A description of the data sources used to investigate the patterns and relationships among the water quality parameters follows.

4.1 Data Sources

The District and Sarasota County supplied the water chemistry data used in this investigation. District data included discrete field measurement of selected physical parameters and results from laboratory analysis of field-collected grab samples. Sarasota County provided data from continuous recording *in situ* data loggers and from laboratory analyses of discrete grab samples. Flow estimates used for the analyses of spatial and temporal water chemistry parameters consisted of the flow at CPS2 plus the estimated flows from the sub-basins of the Dona Bay watershed downstream of the CPS2 structure (Intera 2007). The District cooperates with the USGS to maintain four continuous *in situ* data recorders in DARB.

4.1.1 Southwest Florida Water Management District Data

The District conducted a total of 30 field sampling events for the characterization of water quality in the DARB system. Sampling was conducted monthly from August, 2003 through January, 2006, except the period May through October of 2004 when samples were collected every two weeks. Twelve stations were sampled in the Dona Bay/Shakett Creek system and 7 stations were sampled in Roberts Bay (Table 4.1, Figure 4-1). To aid in the description of water quality information, Dona Bay/Shakett Creek and Roberts Bay were segmented into reaches containing water quality sampling stations. Dona Bay/Shakett Creek was divided into three reaches (Figure 4-1) based on the variability of the salinity regimes within and among these reaches.

- The lower reach of the Dona Bay/Shakett Creek includes those stations between the Venice Inlet and rkm 2.0, below the U.S. 41 bridge (stations DB3, DB5, DB16, DB17 and DB18).

- The middle reach of Dona Bay/Shakett Creek includes those stations above the U.S. 41 bridge up to rkm 3.7 (stations DB19, DB20 and DB21).

- The upper reach of the Dona Bay/Shakett Creek includes those stations in Shakett Creek, between rkm 3.7 and the CPS2 structure (stations DB22 through DB25).

Roberts Bay was divided into two segments based on the variability of the salinity regimes within and among these reaches.

- The lower reach of Roberts Bay is considered to be those waters west of the U.S. 41 bridge, up to rkm 1.5. The lower reach includes stations RB07, RB08, RB09, RB10, RB13.

- The upper reach of Roberts Bay is considered to be those waters east of the U.S. 41 bridge (above rkm 1.5), and includes stations RB14 and RB15.

4.1.1.1 Hydrolab

During each sampling event, Hydrolab Data Sondes were used to measure physical and chemical parameters, including dissolved oxygen (DO), conductivity, hydrogen ions (pH), salinity (ppt), and temperature (degrees C). Measurements were made 0.3 meters below the water surface (surface), 0.3 m above the bottom substrate (bottom) and at one meter intervals through the water column at each station. The deepest station, DB3, at the Venice Inlet, had a maximum depth of 5.3 m at the time of sampling.

4.1.1.2 Water Quality

Samples were collected to measure water quality constituents, using Nisken bottle grab samples. Standard USEPA protocols for sample processing and preservation were followed, and samples were delivered to the District's Lab for analysis. Water quality samples were analyzed for chlorophyll *a*, total and dissolved phosphorus and nitrogen constituents, total and dissolved organic carbon, total and volatile suspended solids, color, and turbidity. Grab samples were collected for lab analysis at four of the twelve stations (DB3, DB18, DB21 and DB24) in Dona Bay and two of the seven stations (RB9 and RB14) in Roberts Bay.

Table 4-1. River kilometer (rkm) for DARB system water-quality stations sampled by the District.

Station	Reach	rkm	Landmark
Dona Bay/Shakett Creek			
DB03	Lower	0.3	Venice Inlet
DB05	Lower	0.8	West of U.S. 41 Bridge
DB16	Lower	1.2	West of U.S. 41 Bridge
DB17	Lower	1.4	West of U.S. 41 Bridge
DB18	Lower	1.8	West of U.S. 41 Bridge
DB19	Middle	2.1	East of U.S. 41 Bridge
DB20	Middle	2.7	East of U.S. 41 Bridge
DB21	Middle	3.3	East of U.S. 41
DB22	Upper	4.2	Shakett Creek
DB23	Upper	5.1	Shakett Creek
DB24	Upper	5.8	Shakett Creek
DB25	Upper	6.3	Shakett Creek near CPS2 Structure
Roberts Bay			
RB07	Lower	1.7	West of U.S. 41 Bridge
RB08	Lower	1.9	West of U.S. 41 Bridge
RB09	Lower	2.2	West of U.S. 41 Bridge
RB10	Lower	2.5	West of U.S. 41 Bridge
RB13	Lower	2.7	West of U.S. 41 Bridge
RB14	Upper	3.3	East of U.S. 41 Bridge
RB15	Upper	3.5	East of U.S. 41 Bridge

4.1.2 Sarasota County Data

The Sarasota County Environmental Services staff (SCES) monitors water quality in DARB for purposes of watershed management. This includes deploying continuous recording data loggers to monitor physical water quality parameters, as well as collecting grab samples for nutrient parameters.

4.1.2.1 Data Sondes

The type of data logger deployed by the SCES staff to monitor physical water quality parameters is a YSI 6600 extended deployment data sonde (Jones 2003). Each sonde is deployed at the bottom of the water column for short periods of a week per deployment several times each season. Several stations in each Bay are visited each season. The station locations are listed in Table 4-2. Only one sonde is deployed at a time, so longitudinal studies of salinity versus rkm on any particular day are not possible.

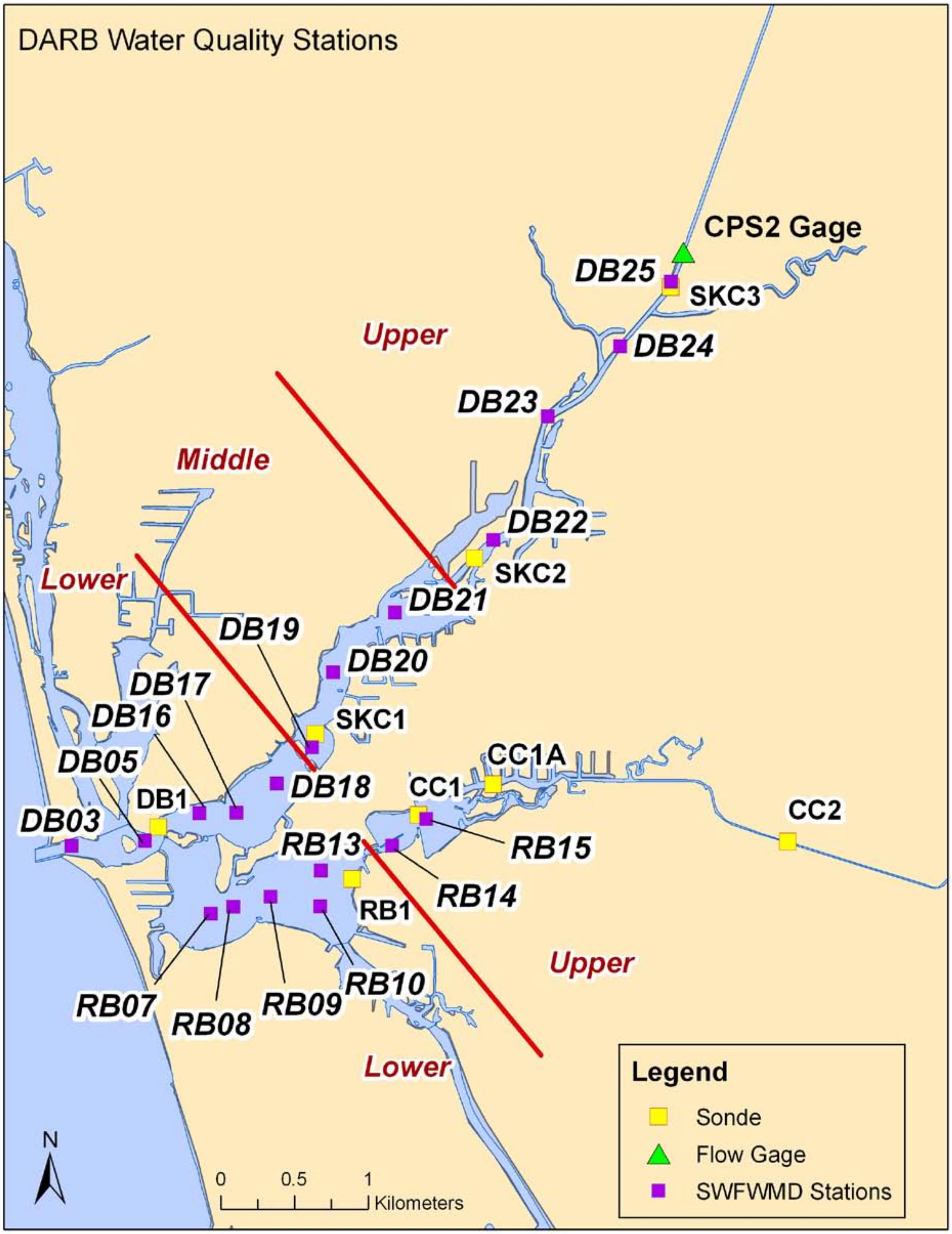

Figure 4-1. **District (purple squares) and Sarasota County (yellow squares) water quality sampling stations in the DARB system. Reaches are delineated by red lines.**

Table 4-2. **River km for water-quality stations sampled by Sarasota County Environmental Services using a continuous recording data sonde. Grab samples for laboratory analysis of water quality constituents were also collected from the stations.**

Station	Reach	rkm	Landmark
Dona Bay/Shakett Creek			
DB1	Lower	0.8	West of U.S. 41 Bridge
SKC1	Middle	2.2	East of U.S. 41 Bridge
SKC2	Upper	4.0	Upper Dona Bay
SKC3	Upper	6.3	Shakett Creek Near CPS2 Structure
Roberts Bay			
RB1	Lower	2.8	Lower Bay West of U.S. 41 Bridge
CC1	Upper	3.4	Upper Bay East of U.S. 41 Bridge
CC1a	Upper	4.0	Upper Bay East of U.S. 41 Bridge
CC2	Upper	6.2	Curry Creek

4.1.2.2 Water Quality

The SCES staff uses the data sonde to measure physical parameters in the DARB system including dissolved oxygen (DO), specific conductance, hydrogen ions (pH), salinity (ppt), temperature, chlorophyll a, and turbidity. Grab samples are collected and analyzed for chlorophyll *a*, turbidity, suspended solids, dissolved nitrate plus nitrite, total nitrate plus nitrite, dissolved inorganic nitrogen, dissolved orthophosphate, pH, salinity, color, dissolved oxygen percent saturation, biological oxygen demand 5-day (BOD5), total Kjeldahl nitrogen, total nitrogen, dissolved ammonium nitrogen, and total phosphorus (Jones 2003).

Investigation of the relationship between salinity and daily flow during this study showed that there is a lag effect of flow on salinity, which is discussed in detail in section 4.2.3. For this reason, the three-day average of flow has been used in the investigation of flow on all water quality parameters in this study.

4.2 Spatial and Temporal Variability in Salinity

Spatial and temporal patterns in salinity are described in this section for the DARB system. Based on the limited number of available salinity measurements for the system, inferences about the effects of flow on salinity were based on plots and descriptive statistics rather the modeled statistical relationships. Flow values used for the analyses included 3-day average flows that were derived using flows recorded at the CPS2 Structure site for Dona Bay/Shakett Creek and the Blackburn Creek gauge site for Roberts Bay. Three-day average flows rather than daily flows were used to minimize variability in salinity/flow relationships.

4.2.1 Spatial Variability in Salinity

Stations monitored by the District and SCES are illustrated on the map in Figure 4-1.

4.2.1.1 Vertical Variability in Salinity

Dona Bay/Shakett Creek

Water depth at the water quality parameter stations sampled by the District in Dona Bay/Shakett Creek ranged from 5 m at the Venice Inlet (Station DB03), to less than 2 m at the station (DB25) closest to the CPS2 structure. Vertical or water-column salinity profiles of the estuary varied considerably depending on the total inflow.

During periods of very low or no flow, as occurred on 23 November, 2004, when the 3-day average flow was 0 cfs, the water column remained well mixed throughout Dona Bay/Shakett Creek, with high salinity (*e.g.*, >28 ppt) measured all the way up to the CPS2 structure (Figure 4-2). Low to moderate flow rates, resulted in salinity stratification in upstream portions (low flow periods) or throughout (medium flow periods) Dona Bay/Shakett Creek (figures 4-3 and 4-4). Three-day flows in this range (up to ~80 cfs) were not, however sufficient to flush-out the salt wedge located at depth in the water column. For example, during the sampling event of November 12, 2003 (Figure 4-4), a 3-day average flow rate of 79 cfs resulted in significant salinity reductions at the surface of the water column, while a wedge of high salinity with a concentration range of ~22-25 ppt extended along the bottom of the estuary up to the CPS2 structure. This situation was caused by a relatively high flow rate on the sampling date that significantly exceeded the 3-day average flow rate of 79 cfs, and which peaked at 204 cfs.

During periods of high flow, the water column was completely flushed with freshwater as far downstream as Station DB17 (rkm 1.4), which is located west of the U.S. 41 bridge (data not shown). On 11 August, 2003, when the 3-day average flow was 462 cfs, the bay was flushed with freshwater downstream to Station DB21, rkm 3.0, while stations DB5 through DB20 remained stratified, and Station DB3 was mixed with salinities exceeding 24 ppt (Figure 4-5).

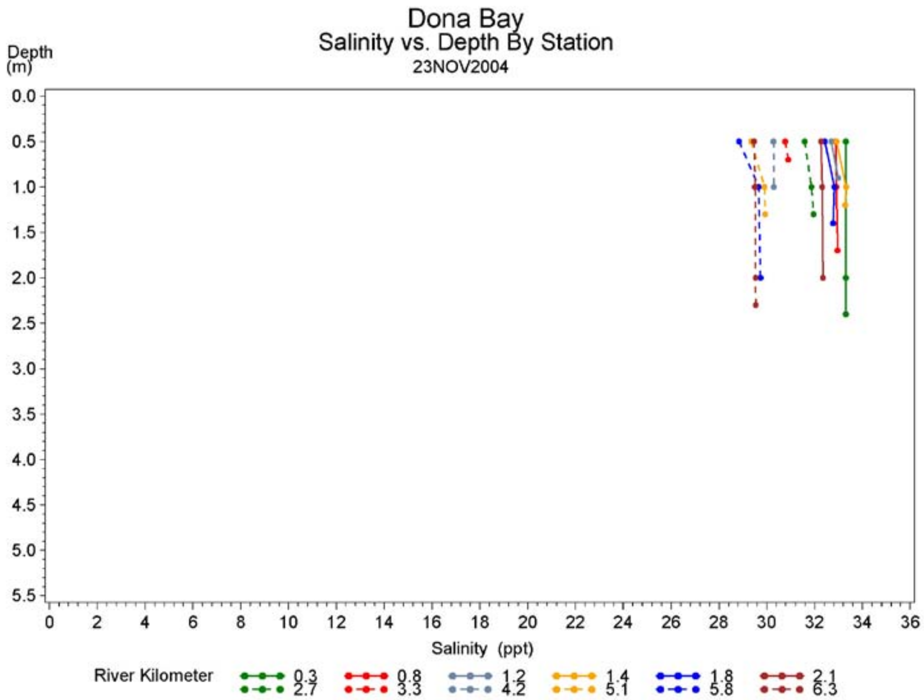

Figure 4-2. **Salinity versus water depth for twelve stations (identified by river kilometer) in Dona Bay/Shakett Creek on November 23, 2004, when the 3-day average flow into the estuary was 0 cfs.**

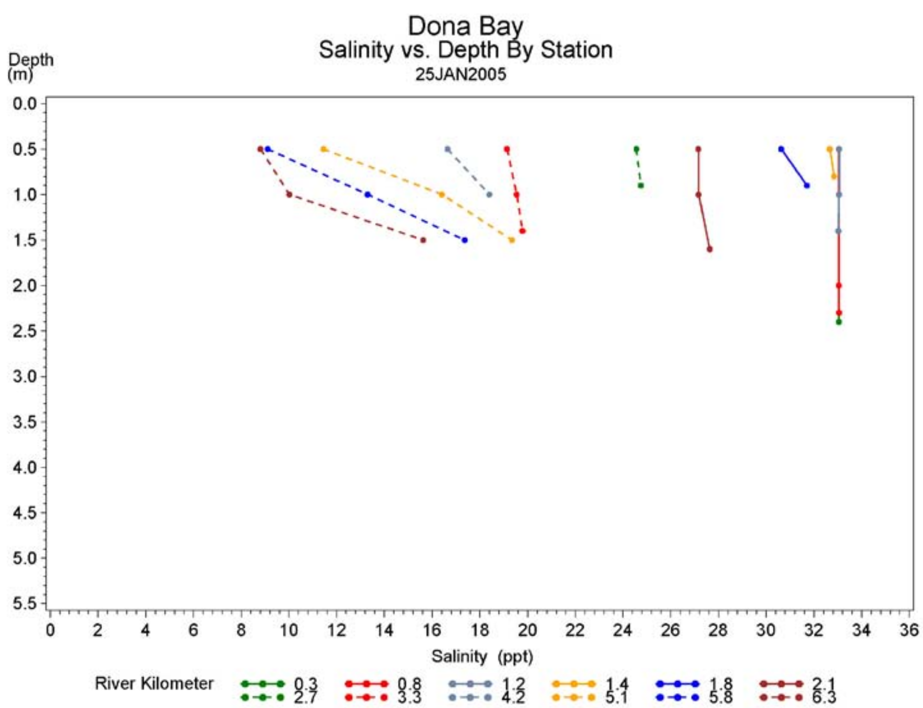

Figure 4-3. **Salinity versus water depth for twelve stations (identified by river kilometer) in Dona Bay/Shakett Creek on January 25, 2005, when the 3-day average flow into the estuary was 28 cfs.**

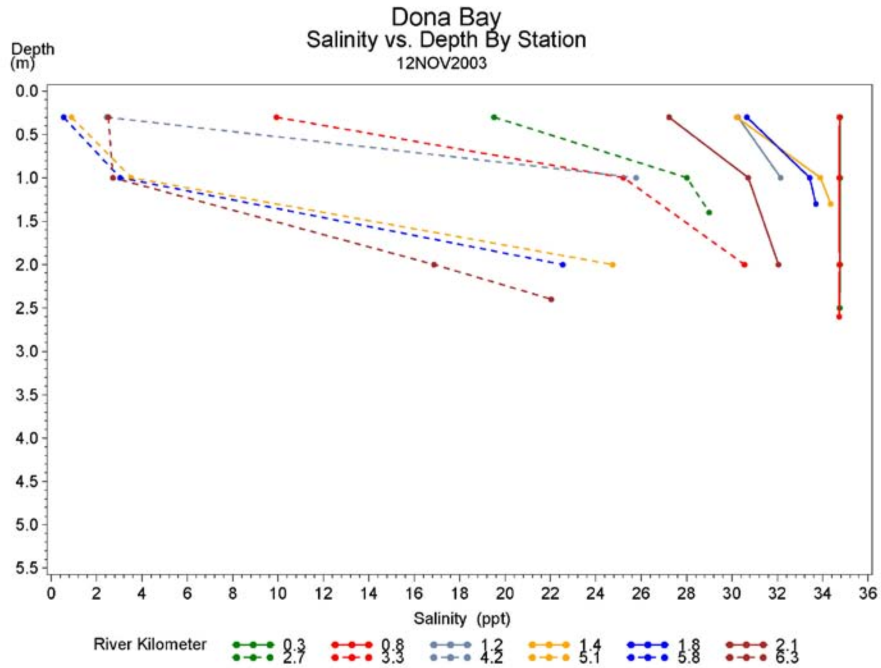

Figure 4-4. **Salinity versus water depth for twelve stations (identified by river kilometer) in Dona Bay/Shakett Creek on November 22, 2003, when the 3-day average flow into the estuary was 79 cfs. The sampling event occurred during a flow surge; the flow rate was 204 cfs on the day of sampling.**

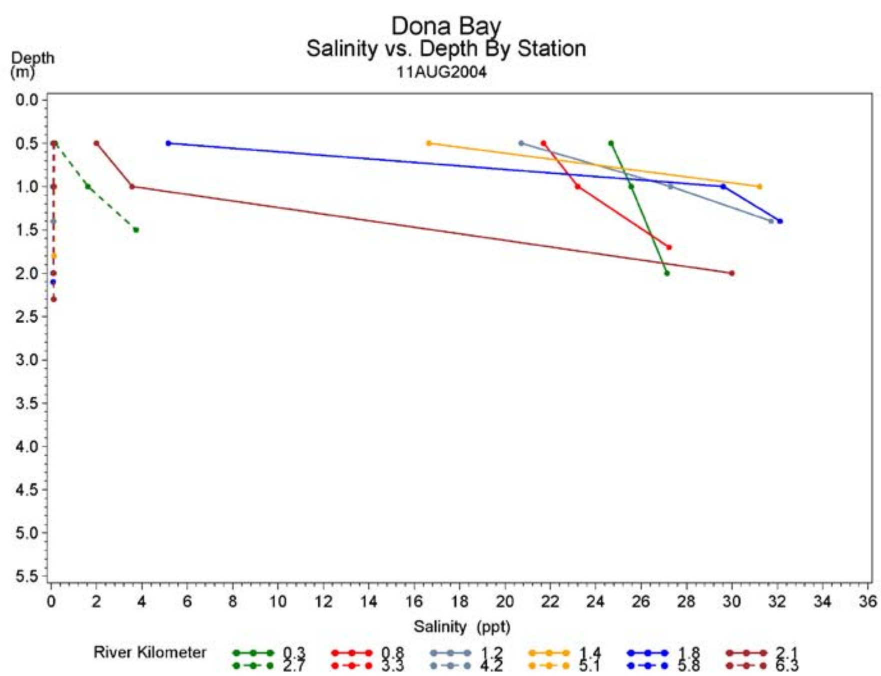

Figure 4-5. **Salinity versus water depth for twelve stations (identified by river kilometer) in Dona Bay/Shakett Creek on August 11, 2004, when the 3-day average flow into the estuary was 462 cfs.**

4.2.1.2 Longitudinal Variability in Salinity

Dona Bay/Shakett Creek

The Dona Bay/Shakett Creek estuary is ~6.5 km in length from the mouth of the bay at the Venice Inlet upstream to the CPS2 structure. When there is no flow into the system from any of its tributaries or Cow Pen Slough Canal, the estuary remains well mixed with high salinity throughout the water column. Salinity ranges from approximately 33 ppt at the Venice Inlet to 29 ppt near the CPS2 structure. This is illustrated by conditions during the sampling event of 23 November, 2004 (Figures 4-6 and 4-2).

As expected in an estuarine system, there was significant variation in the effect of flow on salinity in Dona Bay/Shakett Creek due to confounding factors such as tides, antecedent moisture conditions, and constrictions caused by bridges and causeways. During some periods of no or very low inflow, there was little variation in salinity over the entire length of the estuary, as illustrated for November 23, 2004, when the 3-day flow was 0 cfs (Figure 4-6). At other times, *e.g.*, on May 13, 2004, a 3-day average combined inflow rate of three cfs resulted in a 7 ppt gradient in surface water salinity from the inlet to the CPS2 structure (see Appendix 4-1). Periods without inflow to Dona Bay have resulted in salinities as high as 31 to 32 ppt throughout the Bay and Shakett Creek up to the CPS2 structure, such as occurred on 10 June, 2004 (Appendix 4-1).

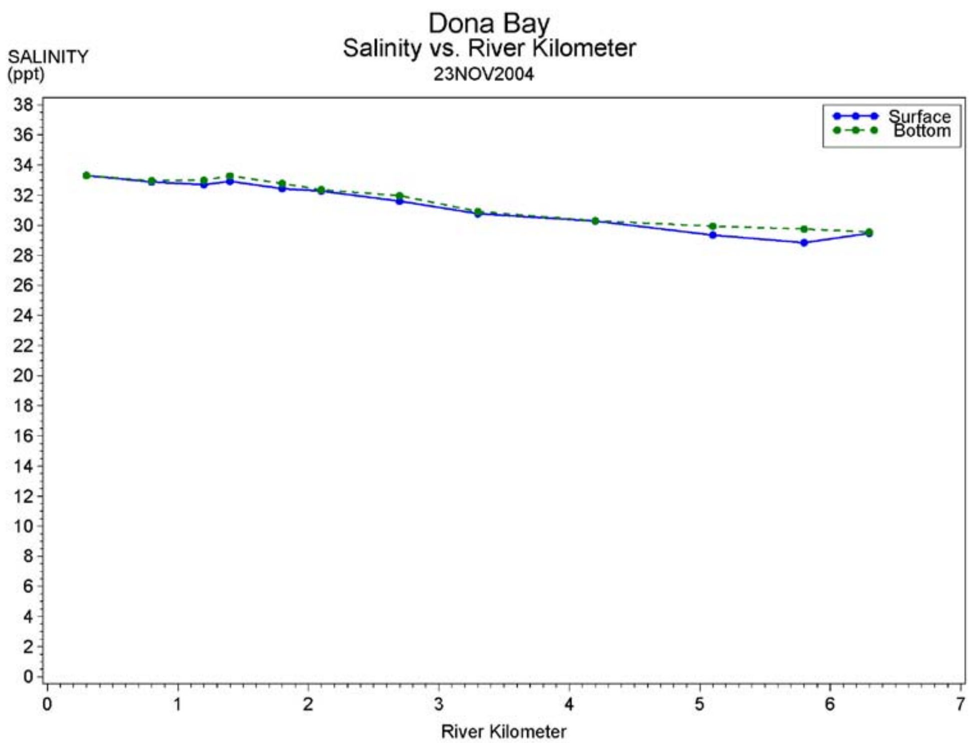

Figure 4-6. Surface and bottom salinity versus river kilometer for twelve stations in Dona Bay/Shakett Creek on November 23, 2004, when the 3-day average flow into the estuary was 0 cfs.

During periods of low to moderate inflow, decreases in salinity were observed in the upstream portion of Dona Bay/Shakett Creek, with surface water salinity ranging from <1 ppt near the CPS2 structure to 32 ppt at the Venice Inlet. Salinity of water near the bottom sediments also responded to low to moderate flows, but longitudinal salinity variation in this portion of the water column was not as pronounced as that of the surface waters.

An example of the longitudinal effect of low inflow on salinity is illustrated in Figures 4-7 and 4-3 (25 January, 2005), when the 3-day average flow was 28 cfs and surface and bottom salinities were reduced to ~20 ppt down to rkm 3.3. On this date, surface salinity was as low as 8 ppt near the CPS2 structure, while bottom water salinity was 16 ppt.

While low flows result in minor stratification, there is a large range of flows that result in significant stratification throughout Dona Bay/Shakett Creek, with a difference greater than 10 ppt between the surface and bottom layer. Flow rates in the range of 40 to as high as 200 cfs have occurred while moderate levels of salinity still remained in the bottom layer near the dam. During the sampling event of November 12, 2003 (Figures 4-8 and 4-4), a 3-day average inflow of 79 cfs resulted in substantial flushing of surface waters, with salinities less than 10 ppt extending down to rkm 3.3, while a wedge of moderate to high salinity (~22 ppt) water remained at depth up to the CPS2 structure.

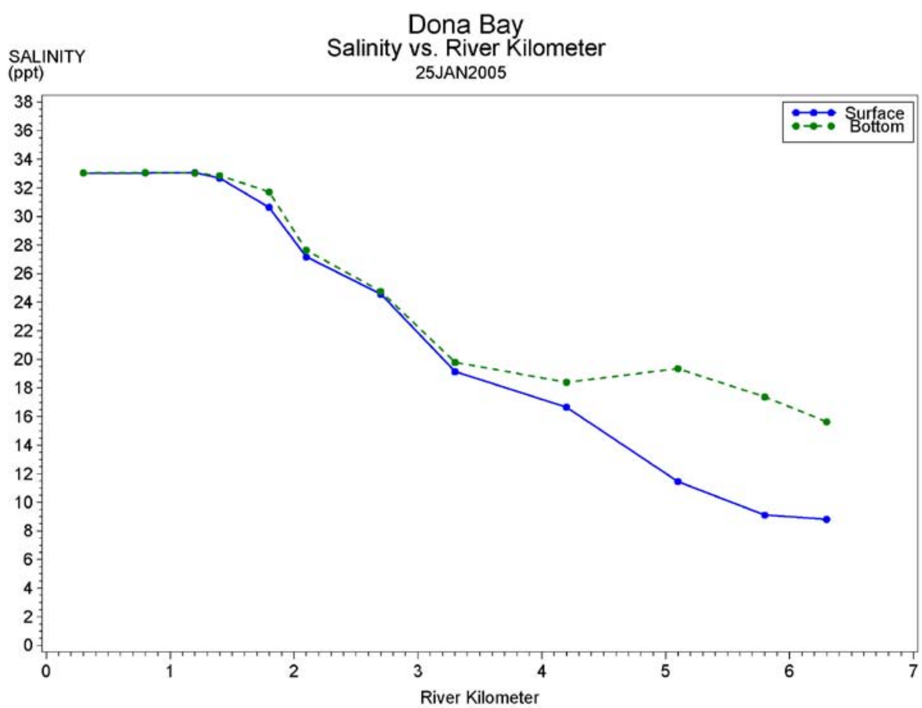

Figure 4-7. Surface and bottom salinity versus river kilometer for twelve stations in Dona Bay/Shakett Creek on January 25, 2005, when the 3-day average flow into the estuary was 28 cfs.

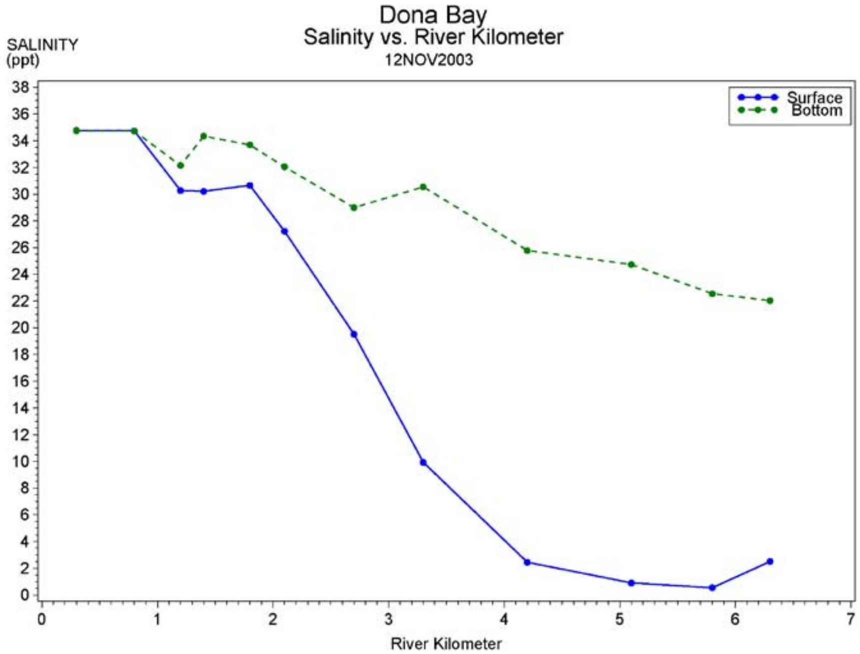

Figure 4-8. Surface and bottom salinity versus river kilometer for twelve stations in Dona Bay/Shakett Creek on November 12, 2003, when the 3-day average flow into the estuary was 79 cfs. The sampling event occurred during a flow surge; the flow rate was 204 cfs on the day of sampling.

Three-day average flows of 155 cfs and higher have caused varying lengths of the estuary to be completely flushed with freshwater from the surface to the bottom layer. Moderately high flow rates have caused flushing of the water column with freshwater above rkm 5. But flow rates as high as 1,358 cfs have occurred in the Bay that caused complete mixing of freshwater down to station 18 (rkm 1.8), just below the U.S. 41 bridge, such as seen on 12 August, 2003 (Appendix 4-1). An example of a longitudinal profile of salinity change by rkm under conditions of high flow rate is presented in Figure 4-9, when a 3-day average flow rate of 462 cfs preceded the sampling event of 11 August, 2004. The storm event caused a complete flushing of freshwater down to rkm 3.3. The full set of longitudinal plots for 26 sampling dates is presented in the Appendix 4-1.

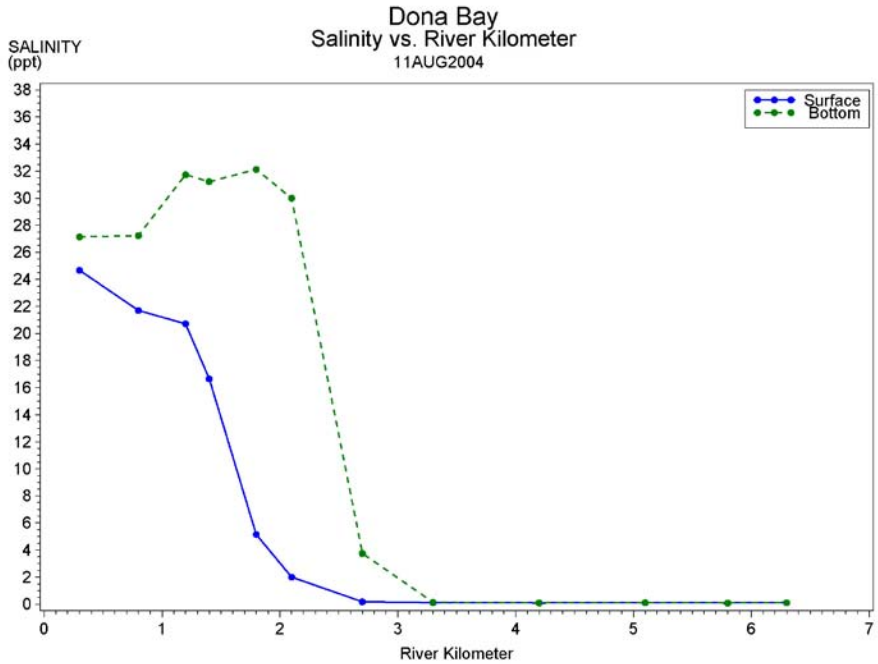

Figure 4-9. **Surface and bottom salinity versus river kilometer for twelve stations in Dona Bay/Shakett Creek on August 11, 2004, when the 3-day average flow into the estuary was 462 cfs.**

4.2.2 Temporal Variability in Salinity

Short term variability in salinity in the DARB system is associated with tidal cycles, with salinity in the bottom layer fluctuating from less then 1 ppt up to 30 ppt in a single day in the middle reach of each bay. Seasonal patterns in salinity gradients occur in response to annual rainfall patterns and longer-term cycles spanning years or decades may be associated with rainfall differences related to climatic cycles such as the Atlantic Multidecal Oscillation. Data illustrating short-term (tidal) and seasonal variability are presented in this section; empirical information on longer-term salinity patterns is not available because of a paucity of data.

4.2.2.1 Seasonal Variability in Salinity

The District defined three seasonal blocks for evaluating flow records and establishing proposed minimum flows for Dona Bay/Shakett Creek based on blocks developed for the upper segment of the Myakka River. Block 1 (the low flow period) is defined as the period from April 20 through June 25. The high flow period, Block 3, is defined as the period June 26 through October 26. The moderate flow period, Block 2, extends from October 27 through April 19.

Block-specific salinities for surface and bottom water of Dona Bay/Shakett Creek and Roberts Bay are described in this section to illustrate seasonal relationships between flow and salinity. The observed patterns support the use of seasonal flow blocks for developing minimum flow standards for the estuary.

Dona Bay

During Block 1, the spring low-inflow period, salinity in the surface waters of Dona Bay/Shakett Creek remained consistently high, based on sampling conducted from August 2003 through January 2006. The median surface salinity in Block 1 for the ~2.5 year sampling period ranged from 33.4 ppt in the lower bay to 26.1 ppt in the upper reach (Figure 4-10). Median surface salinity ranged from 28.3 ppt in the lower reach of the system to 2.4 ppt in the upper reach during Block 3, the period of higher flows associated with summer rainfall. Variability in salinity in the surface layer as measured by the interquartile range (difference between the 25th and 75th percentile of salinity) was greatest during Block 3 in the middle reach of the estuary. Moderate amounts of rainfall during the autumn and winter period of medium flows, Block 2, generally produce low to moderate inflow to Dona Bay/Shakett Creek. The median surface salinity during Block 2 ranged from 32.7 ppt in the lower Bay to 15.9 ppt in the upper portion of the estuary for the period from August 2003 though January 2006.

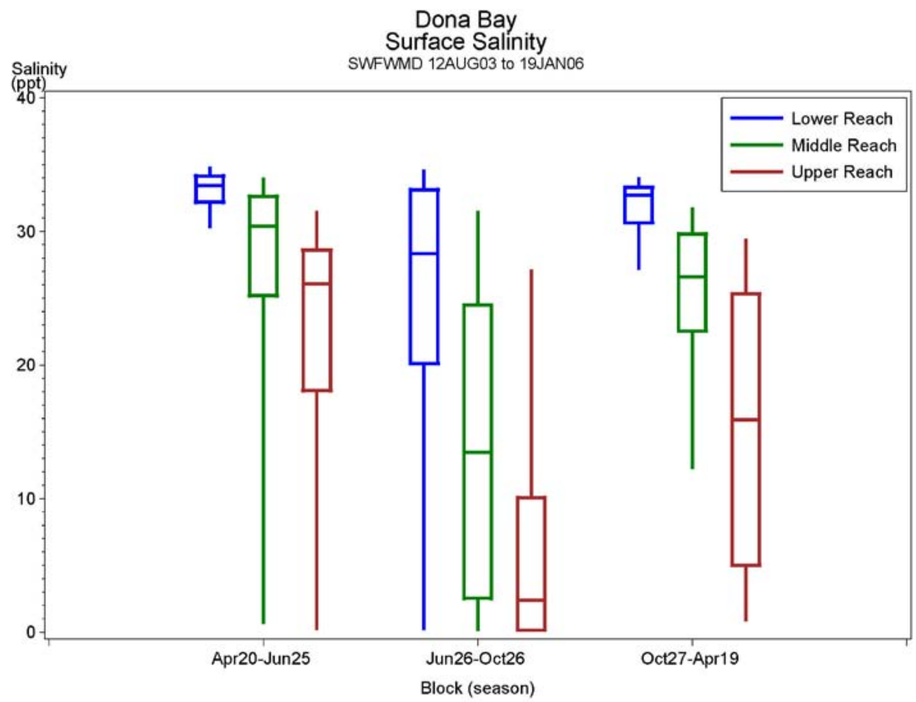

Figure 4-10. Surface water salinity by block-specific flow period in the lower, middle and upper reaches of Dona Bay/Shakett Creek from August 2003 through January 2006.

Salinity in the bottom layer of Dona Bay remained consistently high during Block 1, with median values similar to those for each respective portion of the system (Figure 4-11). Median bottom salinity for Block 1 for the sampling period ranged from 33.9 ppt in the lower reach to 27 ppt in the upper reach. Salinities in the bottom layer during Block 3 (the high flow period) and Block 2 (the moderate flow period) were higher than the surface layer salinities in the middle and upper reaches of the estuary during the respective blocks. During Block 3, the median bottom salinity ranged from 33.1 ppt in the lower segment of the estuary to 11.5 ppt in the upper portion. The median bottom salinity for Block 2 ranged from 33.1 ppt in the lower reach to 22.3 ppt in the upper reach. Variability in salinity in the bottom layer was greatest during Block 3 in the upper reach of Dona Bay/Shakett Creek, as measured by the interquartile range.

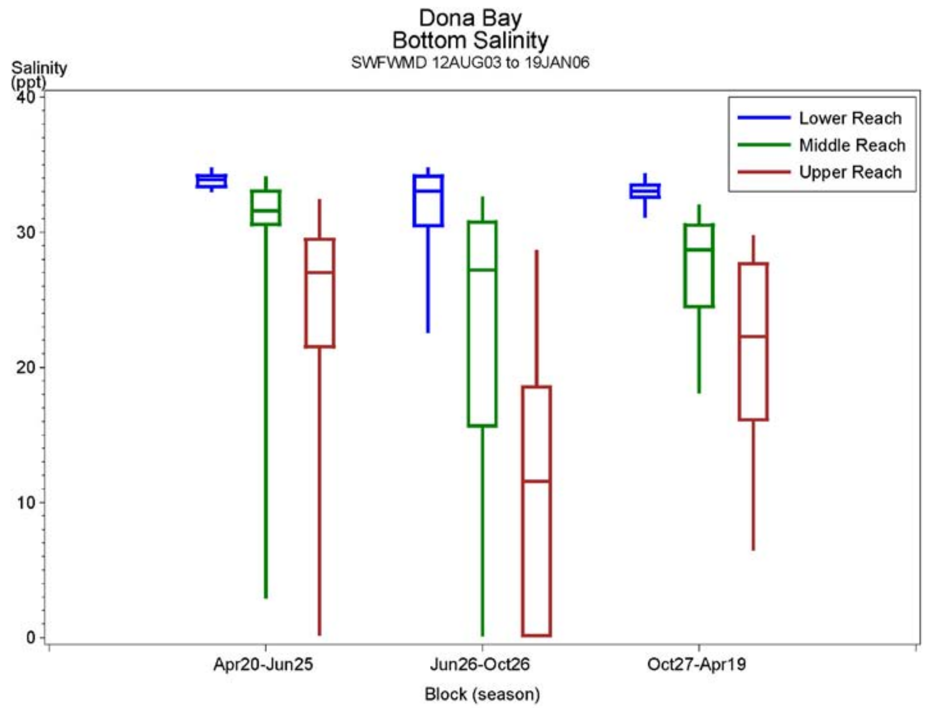

Figure 4-11. Bottom water salinity by block-specific flow period in the lower, middle and upper reaches of Dona Bay/Shakett Creek from August 2003 through January 2006.

Roberts Bay

Salinity patterns in Roberts Bay from August 2003 through January 2006 during the low (Block1) and high (Block 3) flow periods (Figures 4-12 and 4-13) were similar to those observed in Dona Bay/Shakett Creek. Median salinity values in the moderate flow block, Block 2, were, however, generally higher in Roberts Bay relative to those in Dona Bay/Shakett Creek.

Median surface salinity in Roberts Bay during Block 1 ranged from 33.1 ppt in the lower reach to 31.8 ppt in the upper reach. Median surface salinity during Block 3 ranged from 28.3 ppt in the lower reach to 6.5 ppt in the upper reach and median surface salinity during Block 2 ranged from 31.5 ppt in the lower reach to 28.9 ppt in the upper reach of the bay. Median salinity in the bottom waters of Roberts Bay ranged from 33.7 ppt to 31.9 ppt, 32.9 to 20.5 ppt and 32.9 to 29.8 ppt, in the upper and lower reaches of the bay respectively, during Blocks 1, 3 and 2.

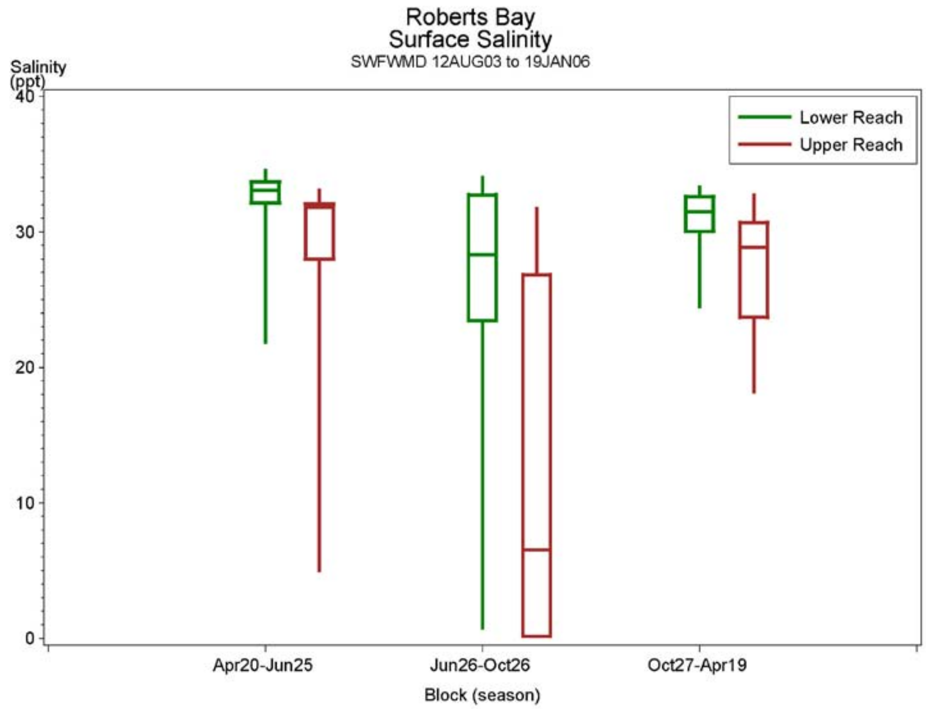

Figure 4-12. **Surface water salinity by block-specific flow period in the lower and upper reaches of Roberts Bay from August 2003 through January 2006.**

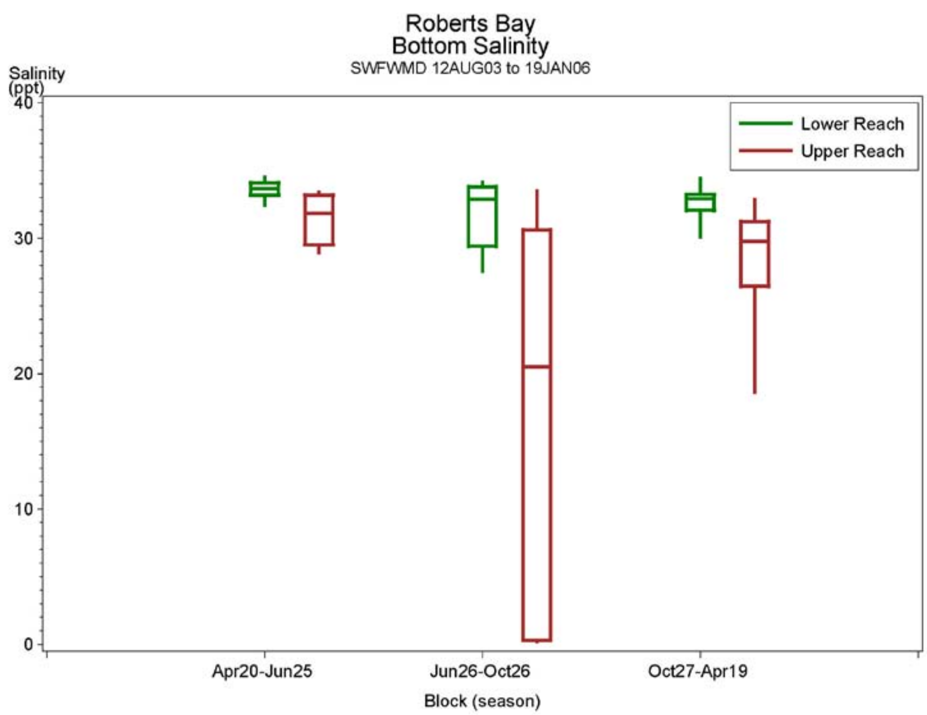

Figure 4-13. **Bottom water salinity by block-specific flow period in the lower and upper reach of Roberts Bay from August 2003 through January 2006.**

4.2.2.2 Short-Term Variability in Salinity

The continuous recording data sondes deployed in the bottom layer of the DARB system provided salinity records every 15 minutes for one or two week periods in each deployment. These records provided a high resolution record to illustrate daily salinity fluctuations on a scale perceptible to oysters. Sarasota County Government (SCG) seeks to re-establish habitat suitable for re-population of oyster communities.

The SCES station, SKC2, at rkm 4.0 is located one km below the northern-most limit of the historic range of oyster populations in Dona Bay. This is located in Shakett Creek, in the upper reach of Dona Bay. SCG staff deployed the sonde data logger at SKC2 on 23 April, 2004; 27 May, 2004; 4 August, 2004; and 21 October, 2004, providing data for two periods in the dry spring season and two periods in the wet summer season.

During the April 23rd deployment, fluctuations of approximately 3 ppt occurred at the SKC2 station with a length of the period observed to be greater than one day (Figure 4-14). Salinity at this station during the 13-day deployment ranged from 21 to 30 ppt. The flow measured at CPS2 during this period ranged from 2.3 to 10.9 cfs.

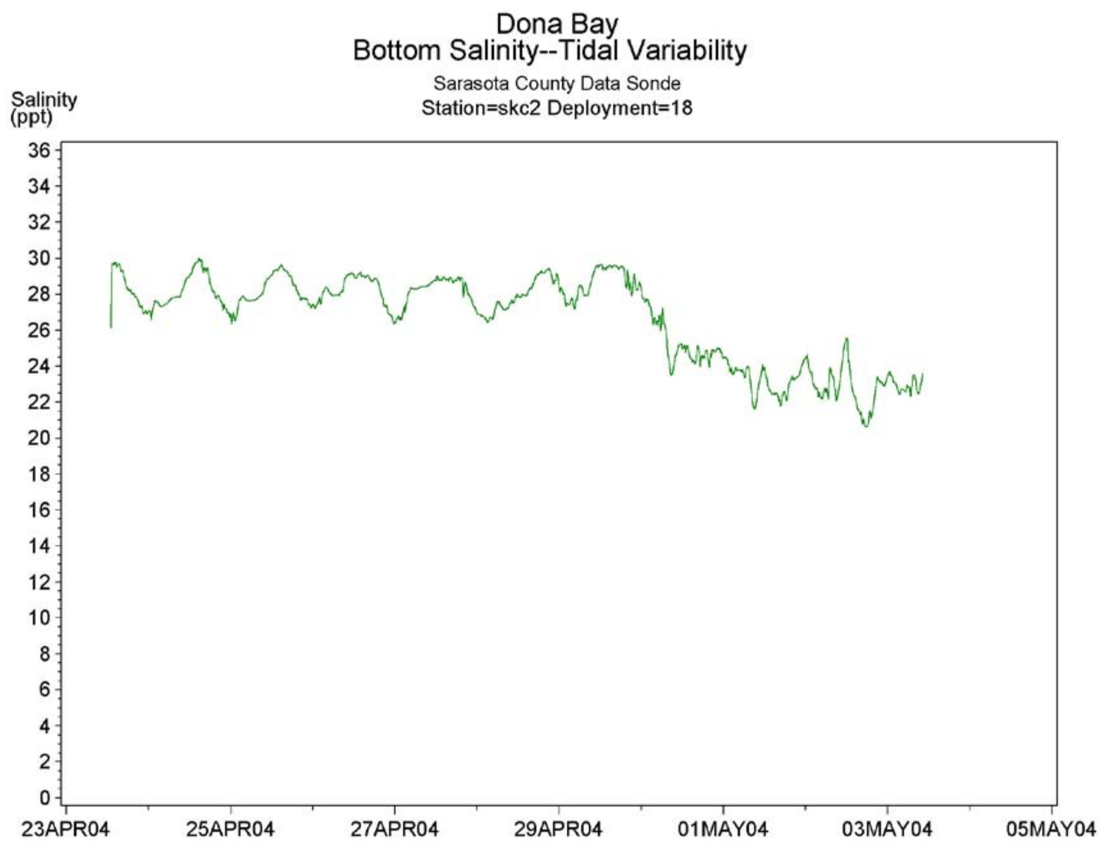

Figure 4-14. Salinity measured every 15 minutes at station SKC2, rkm = 4.0, on April 23, 2004, in the upper reach of Dona Bay. Flow during this period ranged from 2.3 to 10.9 cfs.

Salinity at the SKC2 station during the May 27th deployment remained above 30 ppt during the entire six-day deployment. For several days during this deployment, the salinity reached above 32 ppt (Figure 4-15). The flow measured at CPS2 during this period ranged from 0.5 to 1.4 cfs.

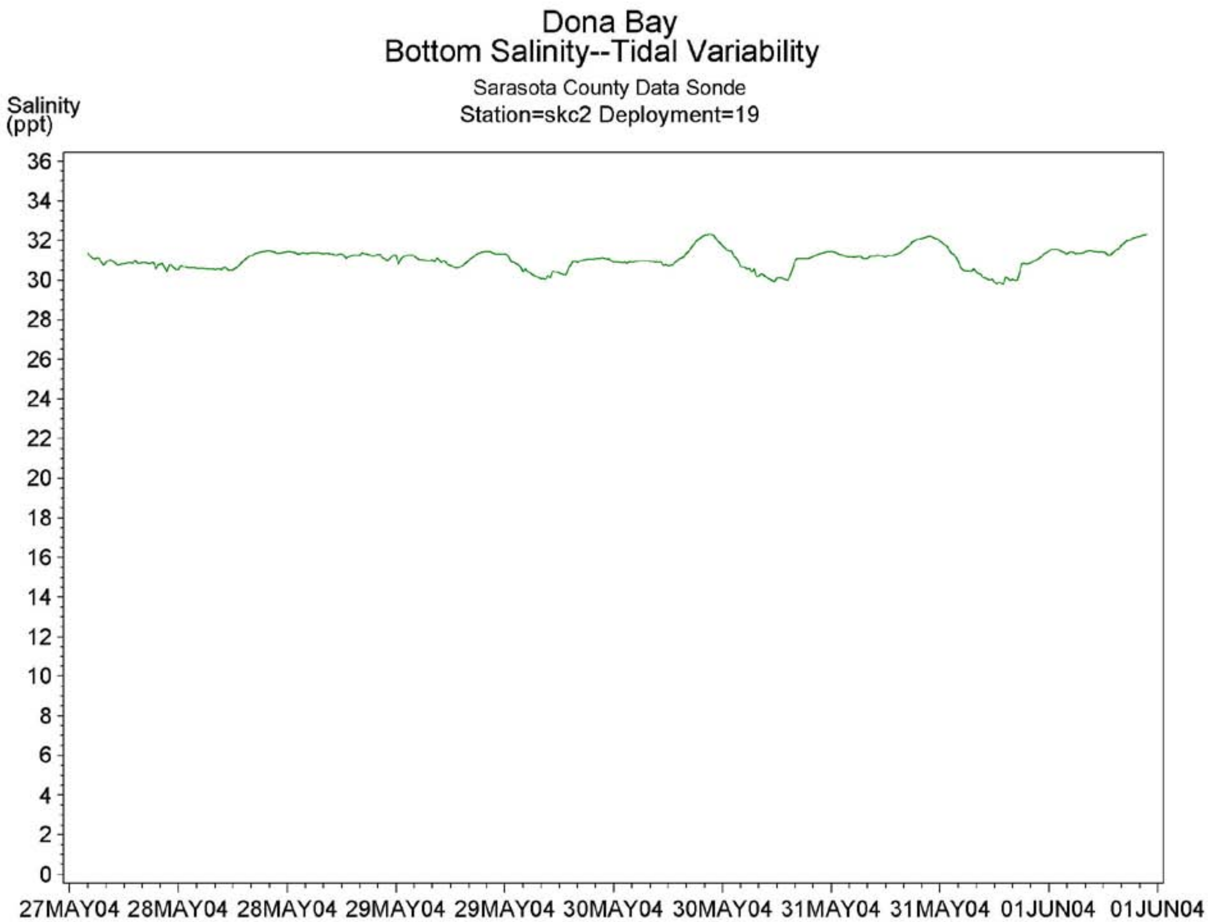

Figure 4-15. **Salinity measured every 15 minutes at station SKC2 (rkm = 4.0), on May 27, 2004, in the upper reach of Dona Bay. Flow during this period ranged from 0.5 to 1.4 cfs.**

Salinity at the SKC2 station during the August 4th deployment event was less than 1 ppt during then entire six-day sampling period (Figure 4-16). The flow measured at CPS2 during this period ranged from 421 to 699 cfs.

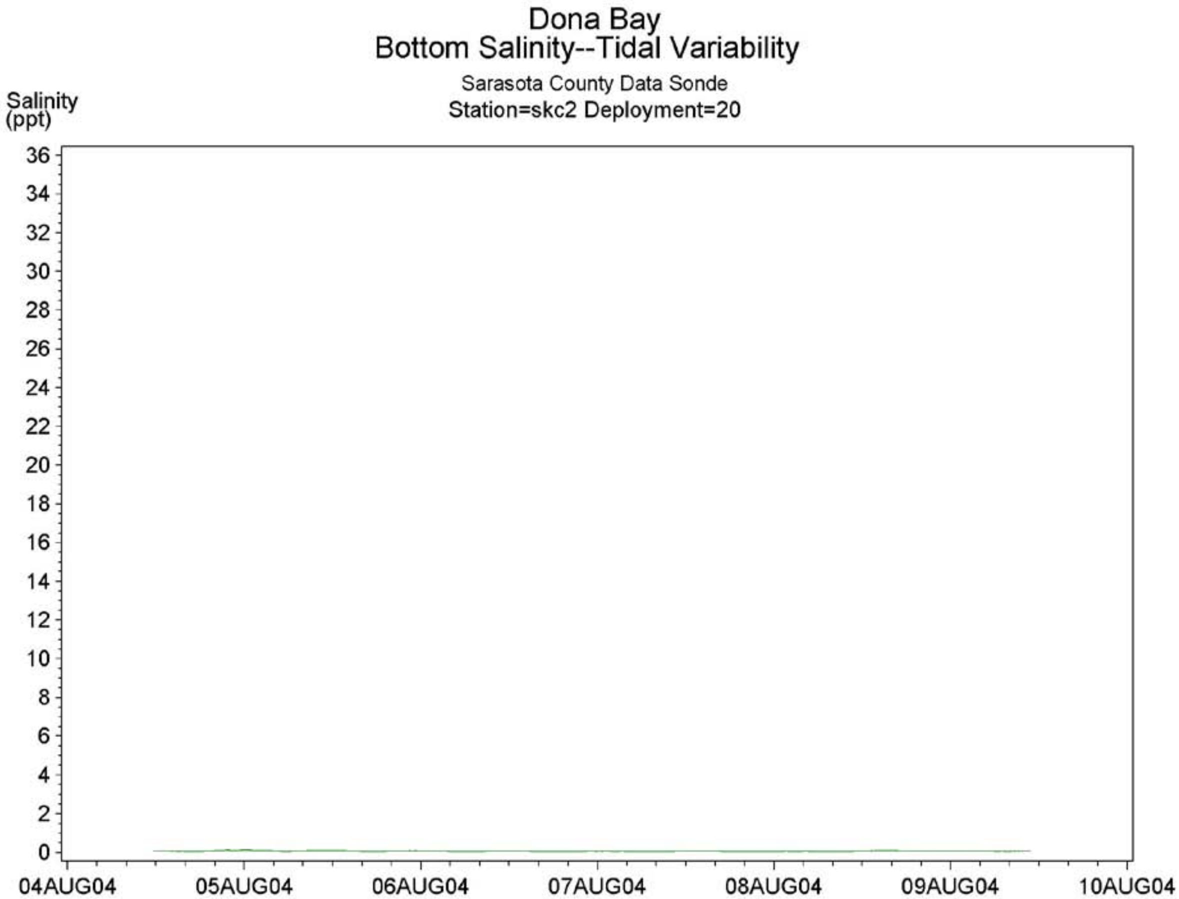

Figure 4-16. Salinity measured every 15 minutes at station SKC2, rkm = 4.0, on Aug.4, 2004, in the upper reach of Dona Bay. Flow during this period ranged from 421 to 699 cfs.

4.2.3 Salinity – Flow Relationships

Dona Bay

Discharge to Dona Bay/Shakett Creek, as measured at the CPS2 structure ranged from zero to over 1,300 cfs for the period (2003 to 2006) that coincided with the water quality/chemistry sampling effort. When salinity values were plotted against daily flow, a great deal of variability in the salinity versus flow relationship was observed. To investigate a potential lag effect of flow on salinity, three-day averages of flow were calculated and plotted against the measured salinity values. Plots of three-day average flows versus salinity yielded fewer outliers than the plots of daily flows versus salinity and are included in Appendix 4-2.

A selection of the plots of salinity versus three-day average flow rate in Dona Bay/Shakett Creek is presented in this section to further illustrate longitudinal and vertical relationships between salinity and inflow to the estuary. To better visualize salinity values associated with low and moderate flows, the x-axis in the plots was limited to 600 cfs, resulting in exclusion of salinity values that were measured on August 12, 2003, when the three-day average flow was 1,193 cfs. Inflow on that day caused total flushing of Dona Bay/Shakett Creek with freshwater down to rkm 1.8.

Surface salinity was inversely related to flow throughout much of the estuary, with effects evident downstream to rkm 1.8 (Figures 4-17 through 4-19). Bottom salinities in the upper segment of the estuary also exhibited an inverse relationship with flow, although the effect was not evident in the lower portion of the estuary (Figures 4-17 through 4-19).

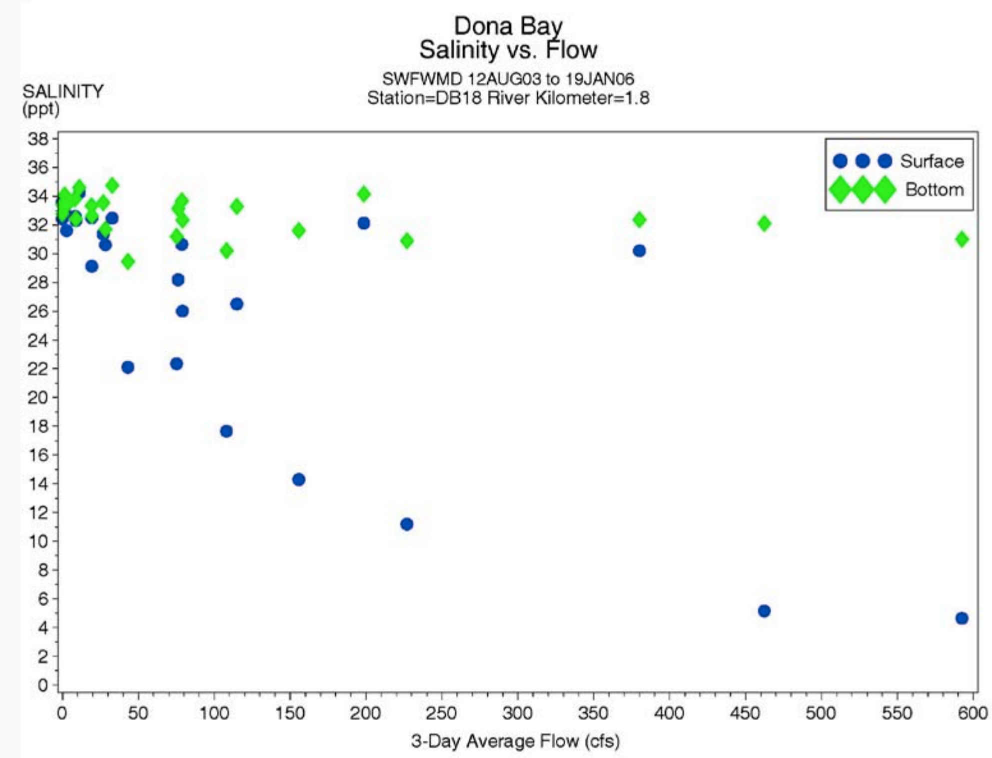

Figure 4-17. **Surface and bottom salinity at Station DB18 (river km 1.8) in Dona Bay/Shakett Creek versus 3-day average flow into the estuary.**

Roberts Bay

Discharge to Roberts Bay from the Curry Creek/Blackburn Canal ranged from 0 to 500 cfs for the three year period (2003 through 2006). Relationships between salinity and flow were less obvious for Roberts Bay than for Dona Bay/Shakett Creek. Salinity at station RB-09 in the lower reach of Roberts Bay was not greatly affected by Blackburn Canal flows (Figure 4-20). In the upper reach of Roberts Bay, at station RB-14, surface salinity was inversely related to flow, but bottom salinity was highly variable at flows above 70 cfs (Figure 4-21). Connections between Roberts Bay and the Intracoastal Waterway and the Gulf of Mexico may account for some of the complexity in the observed salinity/flow relationships.

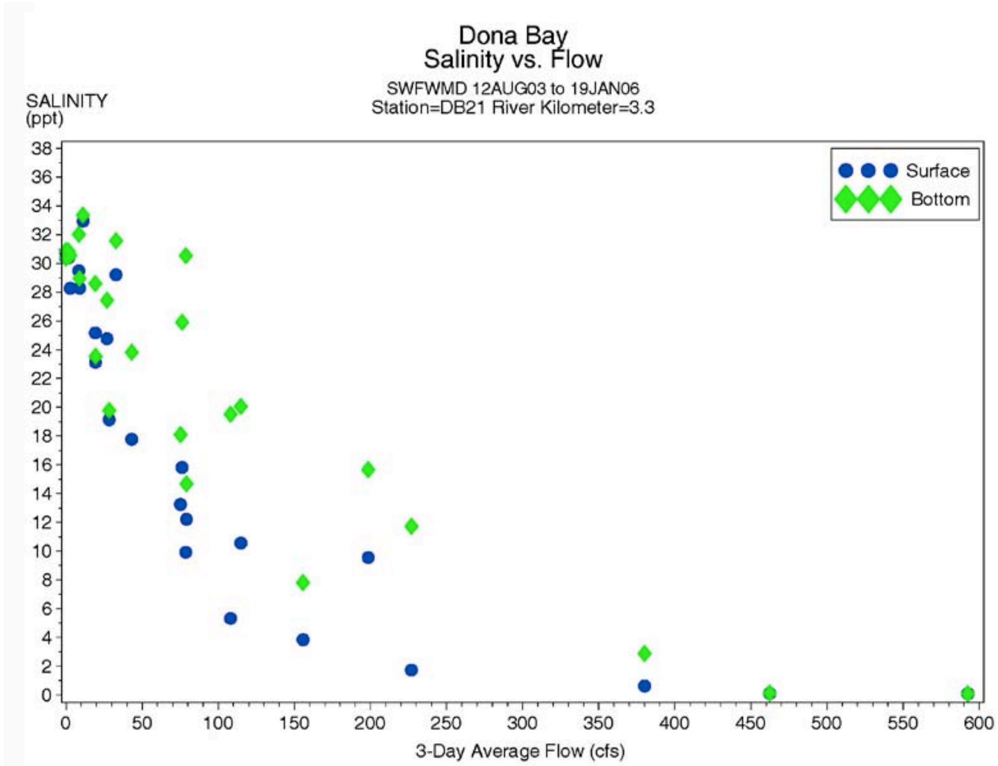

Figure 4-18. **Surface and bottom salinity at Station DB21 (river km 3.3) in Dona Bay/Shakett Creek versus 3-day average flow into the estuary.**

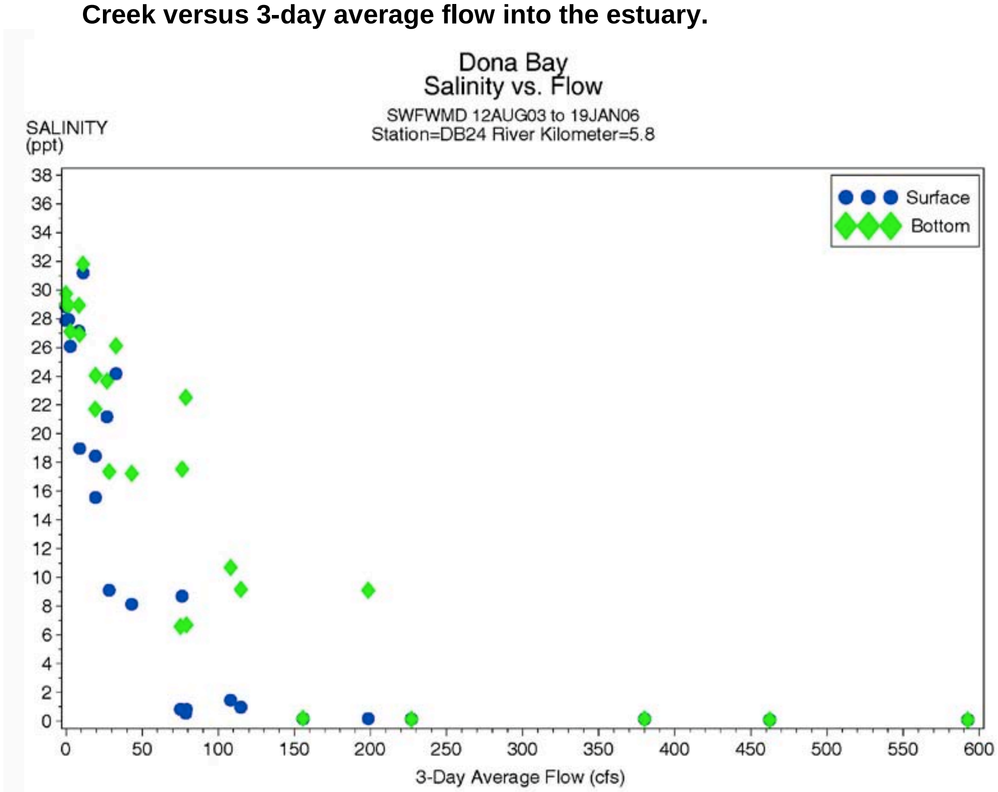

Figure 4-19. **Surface and bottom salinity at Station DB24 (river km 5.8) in Dona Bay/Shakett Creek versus 3-day average flow into the estuary.**

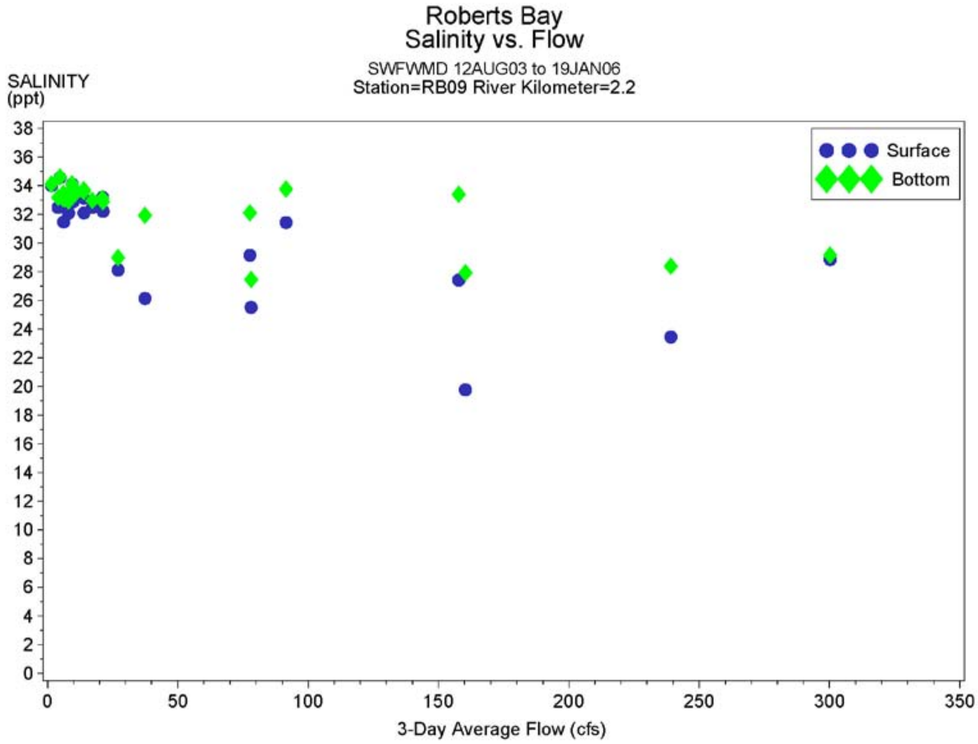

Figure 4-20. **Surface and bottom salinity at Station R09 (river km 2.2) in Roberts Bay versus 3-day average flow into the bay.**

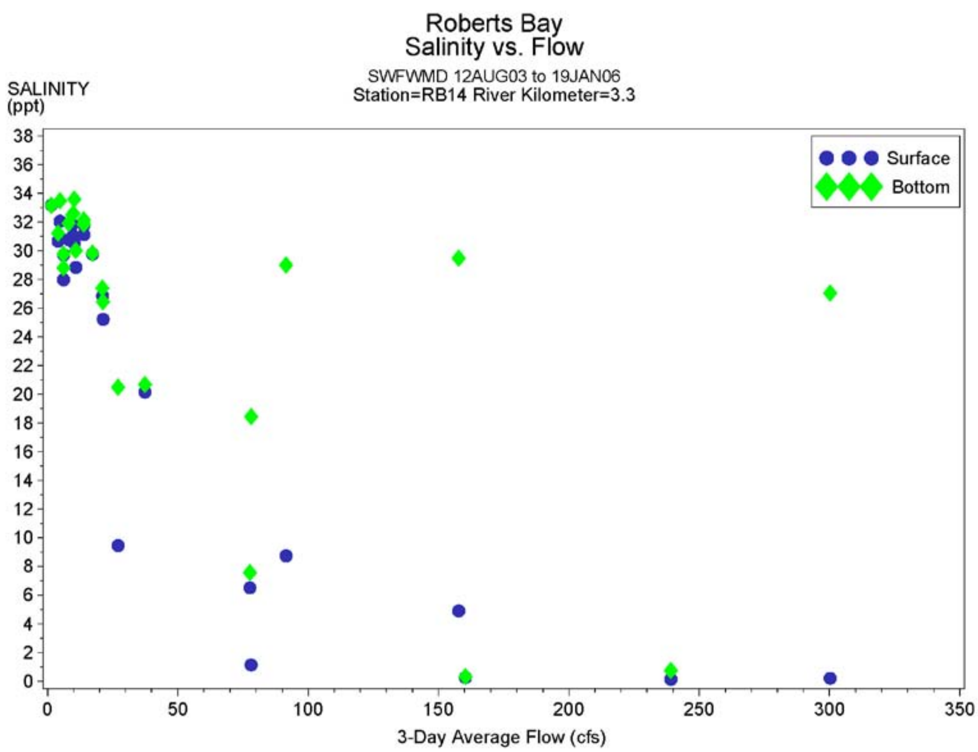

Figure 4-21. **Surface and bottom salinity at Station R14 (river km 3.3) in Roberts Bay versus 3-day average flow into the bay.**

4.3 Spatial and Temporal Variability in Color, Chlorophyll *a*, and Dissolved Oxygen

This section includes descriptive statistics and plots of water color, which is an indicator of the amount of dissolved organic matter in the water column, chlorophyll *a,* which is a measure of the concentration of phytoplankton; and dissolved oxygen, which is essential to support vertebrate and invertebrate organisms in estuarine systems. These parameters are discussed based on their importance to biological communities and processes occurring within the DARB system.

4.3.1 Color

As in many freshwater systems in Florida, the Cow Pen Slough canal drains a watershed that releases high levels of tannins, humic acids and other organic compounds from decaying leaf litter and other vegetative matter, resulting in dark, tea-colored water that is commonly referred to as "black water". Such water is the color of dark tea, and is at a low pH (acidic) because of the humic acids. The brown color is correlated with a high concentration of dissolved organic carbon (Wetzel and Likens 1991). In the United States, water color, which is primarily a function of dissolved organic matter content, is quantified in platinum color units (pcu), by comparing water samples to a series of platinum and cobalt containing solutions. The tannic and humic acids in large freshwater surges that increase water color in the DARB system during the wet summer months may also result in decreased dissolved oxygen concentrations as bacteria decompose these organic compounds. The high concentrations of color also inhibit penetration of light necessary to support seagrasses.

4.3.1.1 Spatial and Temporal Variability in Color

Color in the DARB system (Figures 4-22 and 4-23) from August 2003 through September 2006 ranged from 0 to 500 pcu, and was consistently lowest at DB03 (rkm 0.3), the most downstream of the sampled stations. Color tended to increase in Dona Bay/Shakett Creek from downstream to upstream stations during seasonal periods of low (Block 1) and medium (Block 2) flows, but with the exception of low values at station DB03, showed little spatial variation during the high flow (Block 3) period, when color values were highest (Figure 4-22). In Roberts Bay, color was also highest during the high flow period, and predictable spatial differences in color (*i.e.*, increasing color at more upstream stations) were only evident during the medium flow (Block 2) period (Figure 4-23).

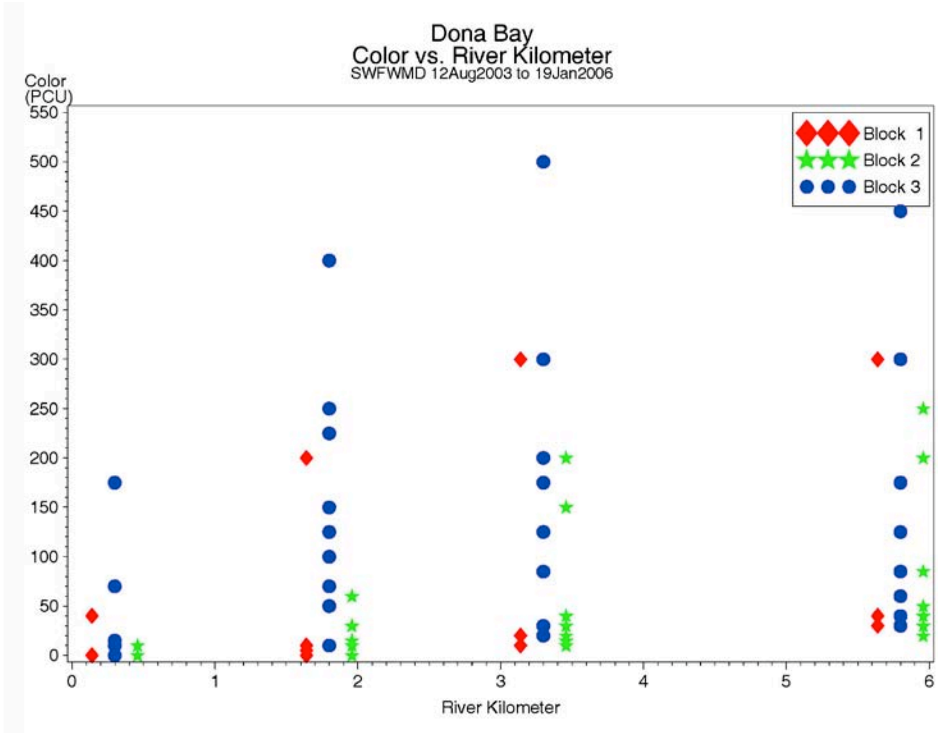

Figure 4-22. **Dona Bay/Shakett Creek color versus river km, by seasonal block (Block 1 = April 20 to June 25; Block 3 = June 26 to October 26; Block 2 = October 27 to April 19).**

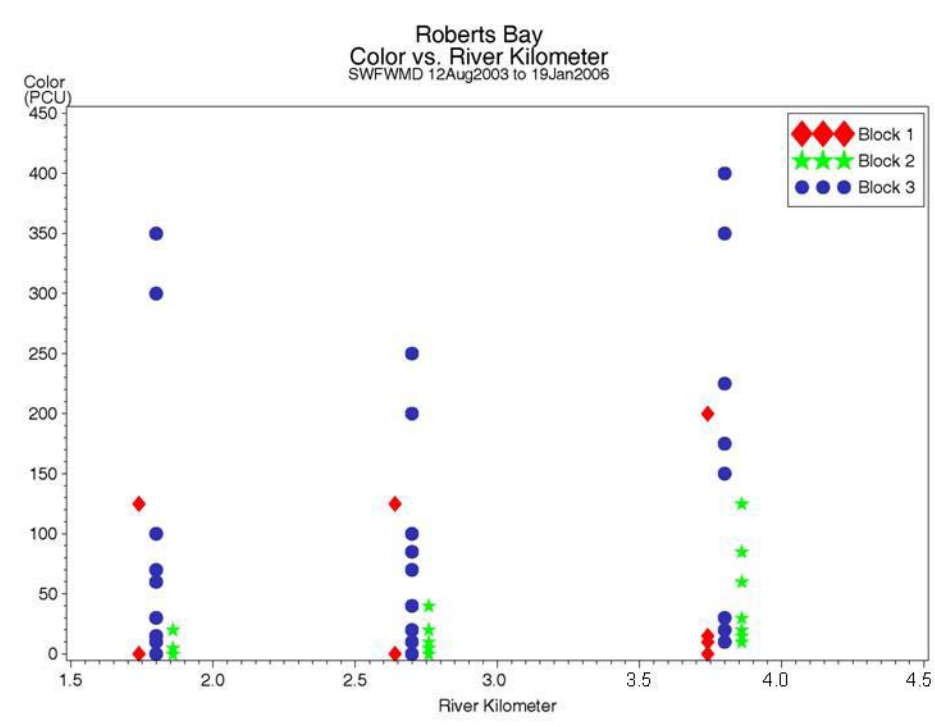

Figure 4-23. **Roberts Bay color versus river km by seasonal block (Block 1 = April 20 to June 25; Block 3 = June 26 to October 26; Block 2 = October 27 to April 19).**

4.3.1.2 Relationship Between Water Color and Flow

In Dona Bay/Shakett Creek, color increased proportionately with increasing 3-day average flows up to approximately 150 cfs and tended to level-off at higher flows (Figures 4-24 and 4-25). Color at more upstream stations tended to be higher, presumably due to greater proportion of freshwater near the CPS2 structure. Similar patterns in the relationship between color and flows were also apparent in Roberts Bay.

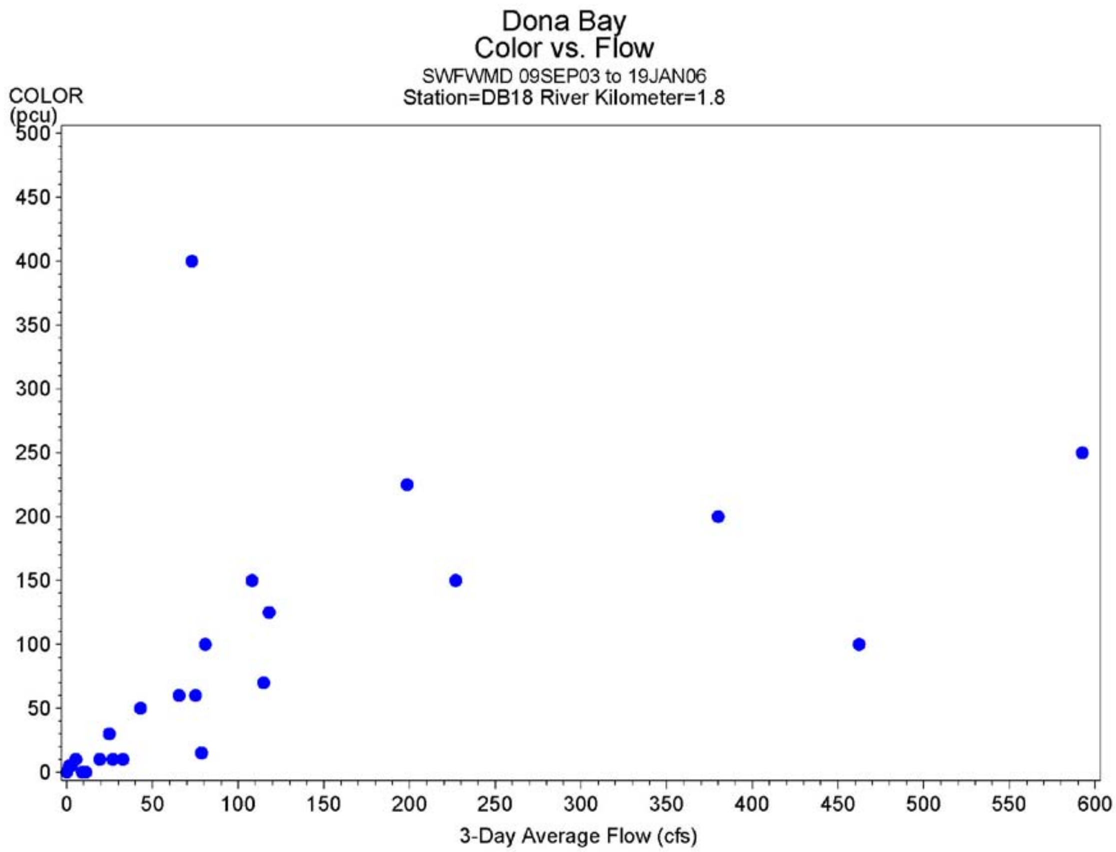

Figure 4-24. Dona Bay/Shakett Creek color versus flow, Station DB18, river km 1.8.

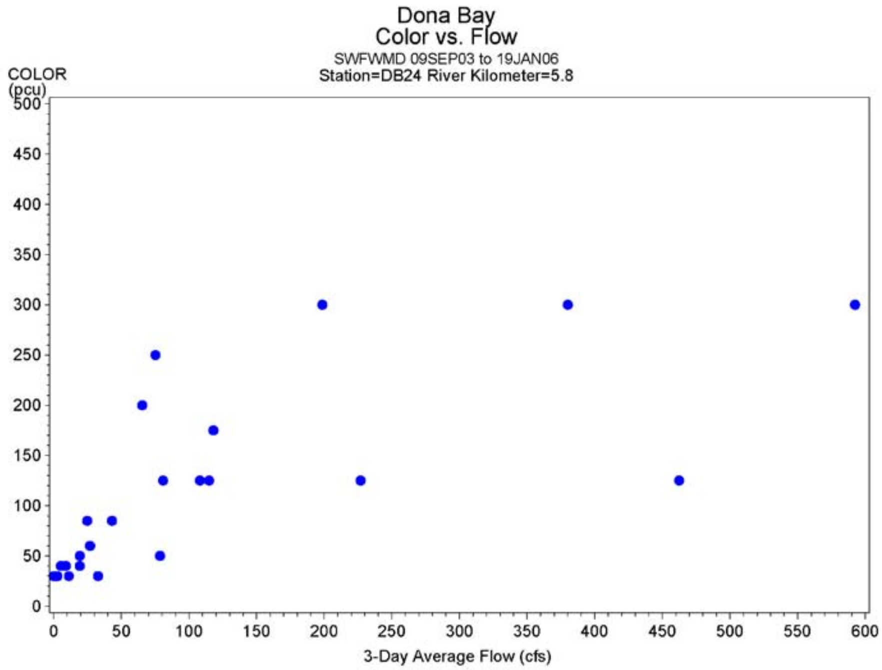

Figure 4-25. Dona Bay/Shakett Creek color versus flow, Station DB24, river km 5.8.

4.3.2 Chlorophyll *a*

High nutrient concentrations can fuel growth of phytoplankton, which can shade seagrass beds and reduce the distribution and diversity of seagrass species. Some species of phytoplankton may also physically attach to seagrass, further limiting light from reaching the photosynthetic portions of seagrass. A shift from a seagrass community to a phytoplankton-based system can lead to a loss of habitat for many benthic species and for larval and juvenile fishes. Seagrass beds also provide protection from predators as well as foraging habitat for numerous species.

4.3.2.1 Spatial and Temporal Variability in Chlorophyll *a*

Spatial or temporal, *i.e.*, seasonal, trends in chlorophyll *a* concentration were not observed in Dona Bay/Shakett Creek or Roberts Bay based on sampling conducted from August 2003 through January 2006 (Figures 4-26 and 4-27). For comparison, the 25^{th}, median and 75^{th} percentile values for Florida estuaries are 4.5, 8.5 and 15.8 ug/l respectively (Freidmen and Hand 1989).

4.3.2.2 Relationship Between Chlorophyll *a* and Flow

Trends in chlorophyll *a* concentration and flow were not observed for Dona Bay/Shakett Creek or Roberts Bay (Figures 4-28 and 4-29) during the September 2003 to August 2006 sampling period. The level of chlorophyll a observed at Station DB18 (rkm 1.8) was never greater than 15 μg/l. The concentration of chlorophyll *a* observed at Station DB24 during the study period was generally less than 15 μg/l, with three exceptions.

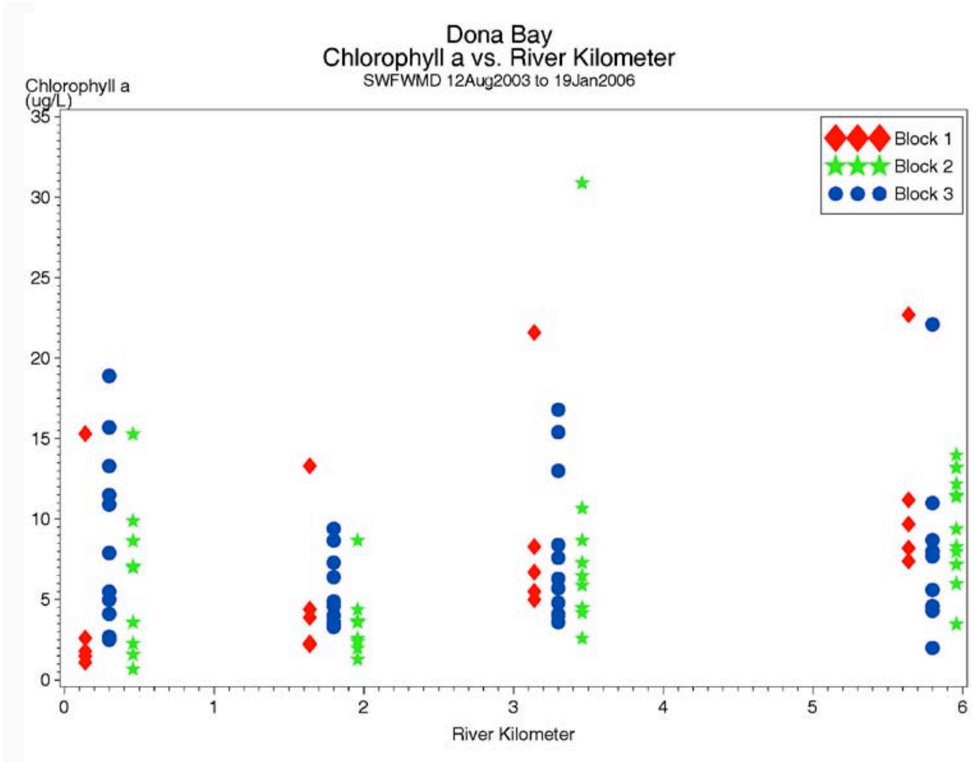

Figure 4-26. Dona Bay/Shakett Creek chlorophyll *a* versus river km by seasonal block (Block 1 = April 20 to June 25; Block 3 = June 26 to October 26; Block 2 = October 27 to April 19).

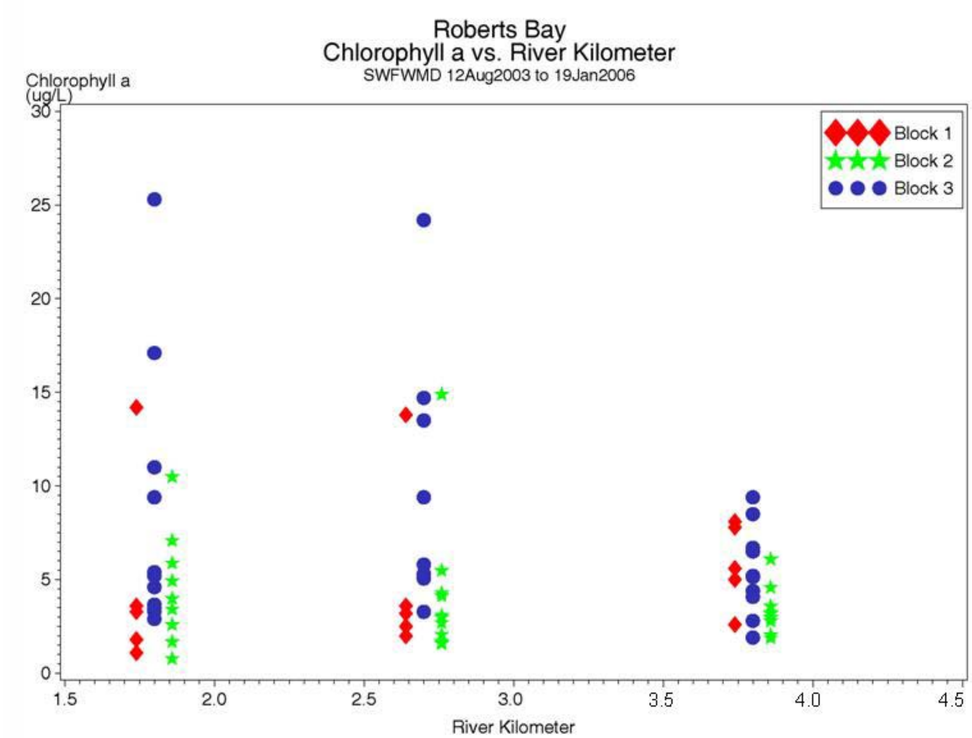

Figure 4-27. Roberts Bay chlorophyll *a* versus river km by seasonal block (Block 1 = April 20 to June 25; Block 3 = June 26 to October 26; Block 2 = October 27 to April 19).

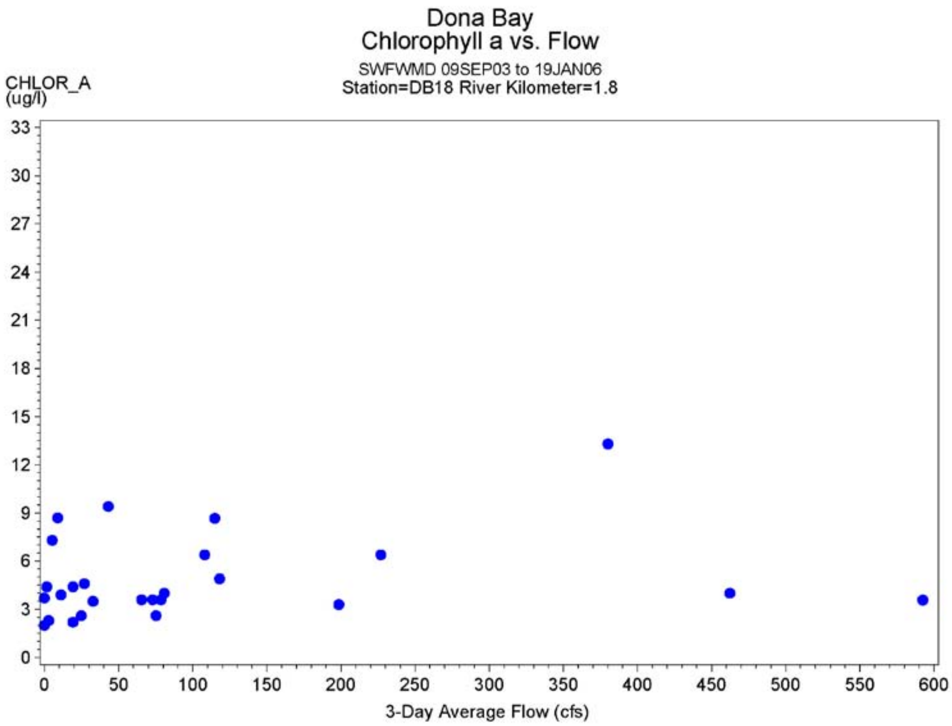

Figure 4-28. Dona Bay/Shakett Creek chlorophyll *a* versus flow, Station DB18, river km 1.8.

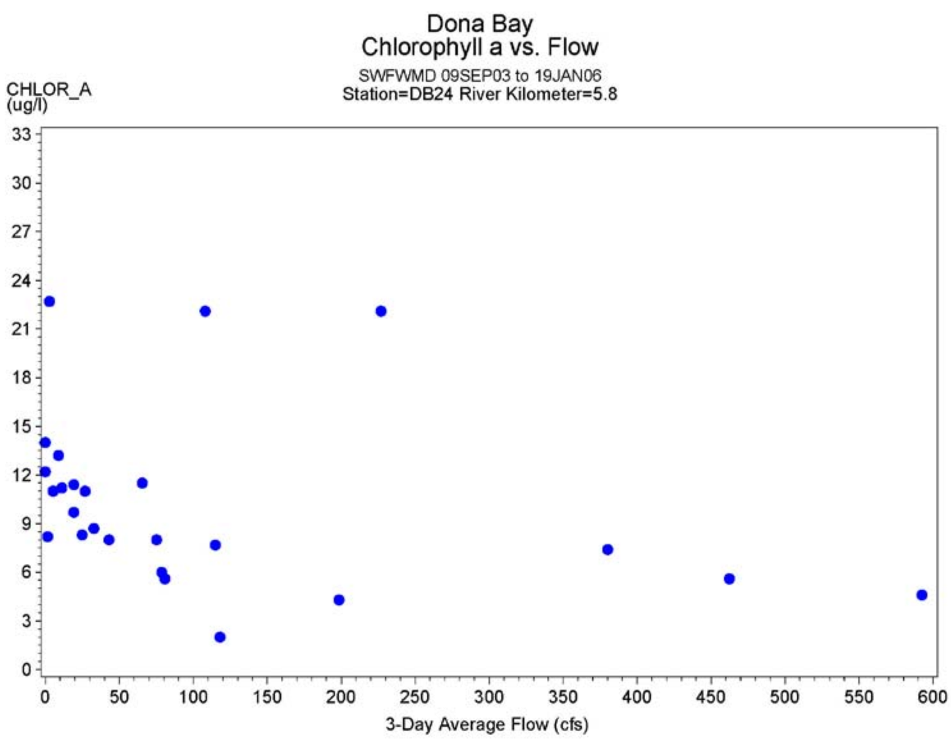

Figure 4-29. Dona Bay/Shakett Creek chlorophyll *a* versus flow, Station DB24, river km 5.8.

4.3.3 Dissolved Oxygen

The DARB system is classified as a Class III predominantly marine water body by the Florida Department of Environmental Protection (Rule 62-302.400, F.A.C.). Designated uses of Class III predominantly marine water bodies are defined as recreation and propagation and maintenance of a healthy, well-balanced population of fish and wildlife. Specific dissolved oxygen criteria (Rule 62-302.530 (31), F.A.C.) for Class III predominately marine water bodies are:

- 4.0 mg/l minimum instantaneous dissolved oxygen concentration;
- 5.0 mg/l as a 24-hour average; and
- Maintenance of normal daily and seasonal fluctuations in dissolved oxygen concentrations.

In addition to the specific dissolved oxygen criteria for Class III predominantly marine waterbodies defined above, hypoxia is traditionally defined as a dissolved oxygen concentration of less than 2 mg/l.

4.3.3.1 Spatial and Temporal Variability in Dissolved Oxygen

Block 1 appears to have a decreasing trend of bottom DO concentration moving upstream (Figure 4-30), although the range of variability was not consistent between the stations. The median values of DO measured in the bottom layer (indicated by the horizontal line through the mid-section of each box) appear to decrease with increasing distance from the Venice Inlet upstream in Dona Bay, especially between upper-most and lowest stations.

No association between DO concentration and rkm was observed during Block 2 (Figure 4-31), except for a slight decrease in median DO upstream of station DB22 (rkm 4.2). The lowest median DO during Block 2 was observed at station 25 (rkm 6.3), near the CPS2 structure.

The observations of DO made during Block 3 did not show any spatial association with rkm in Dona Bay (Figure 4-32). However, most of the median DO concentrations were depressed relative to median DO in the other blocks. None of the median DO concentrations were above 6 mg/l, but bottom hypoxia is generally absent throughout Dona Bay.

DO concentrations in the lower reach of Roberts Bay generally did not drop below 4 mg/l. However, the upper reach of Roberts Bay experienced DO concentrations below 4 mg/l in Blocks 1 and 3, but not in Block 2 (Figures 4-33 to 4-35).

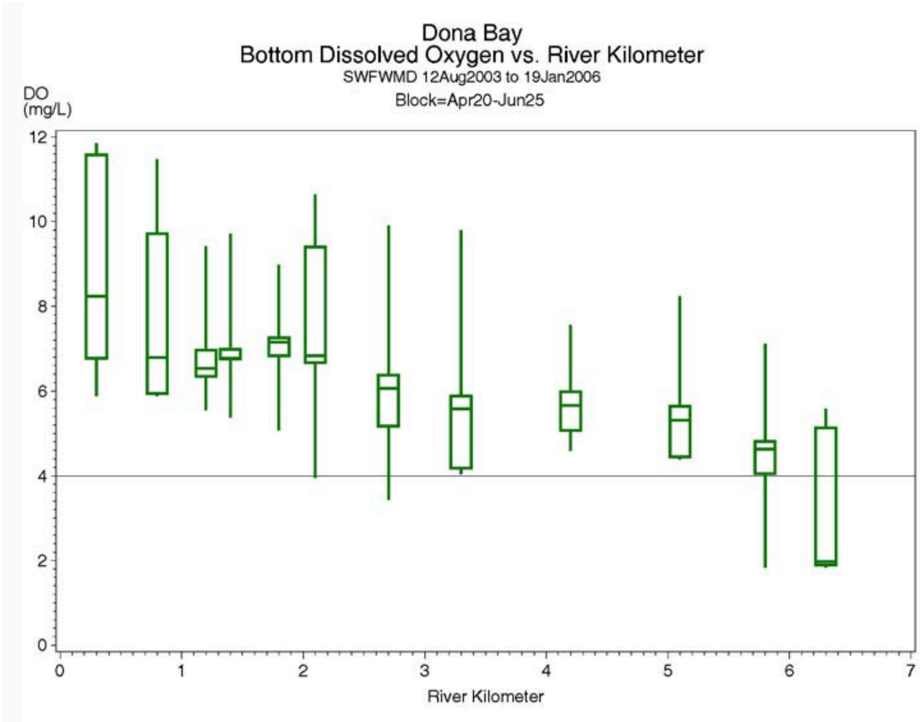

Figure 4-30. **Dona Bay/Shakett Creek dissolved oxygen concentration versus river km, Block 1 (April 20 through June 25).**

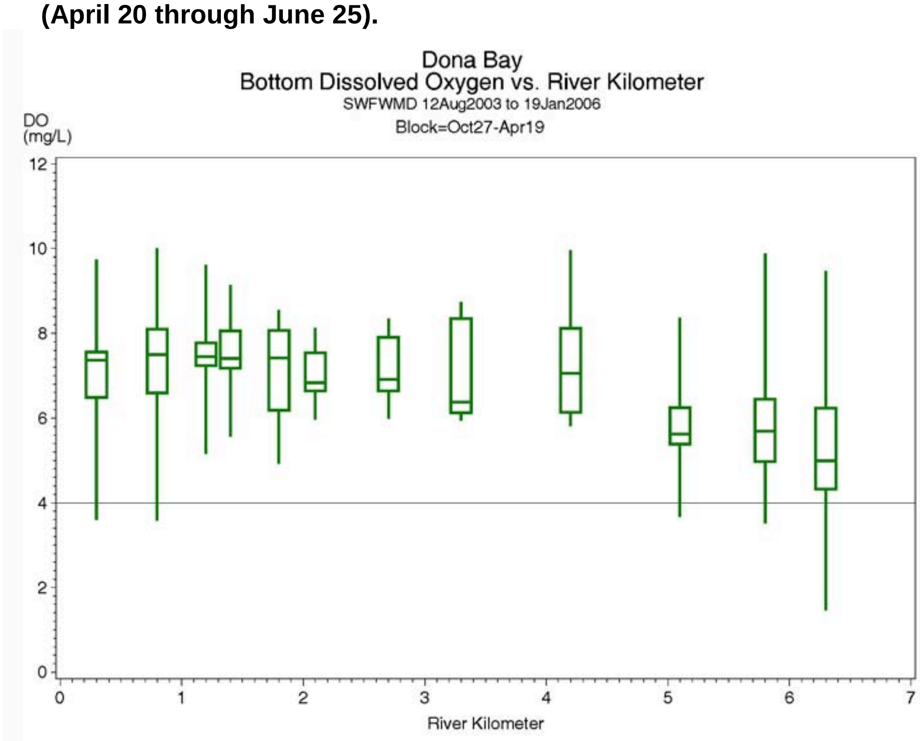

Figure 4-31. **Dona Bay/Shakett Creek dissolved oxygen concentration versus river km, Block 2 (October 27 through April 19).**

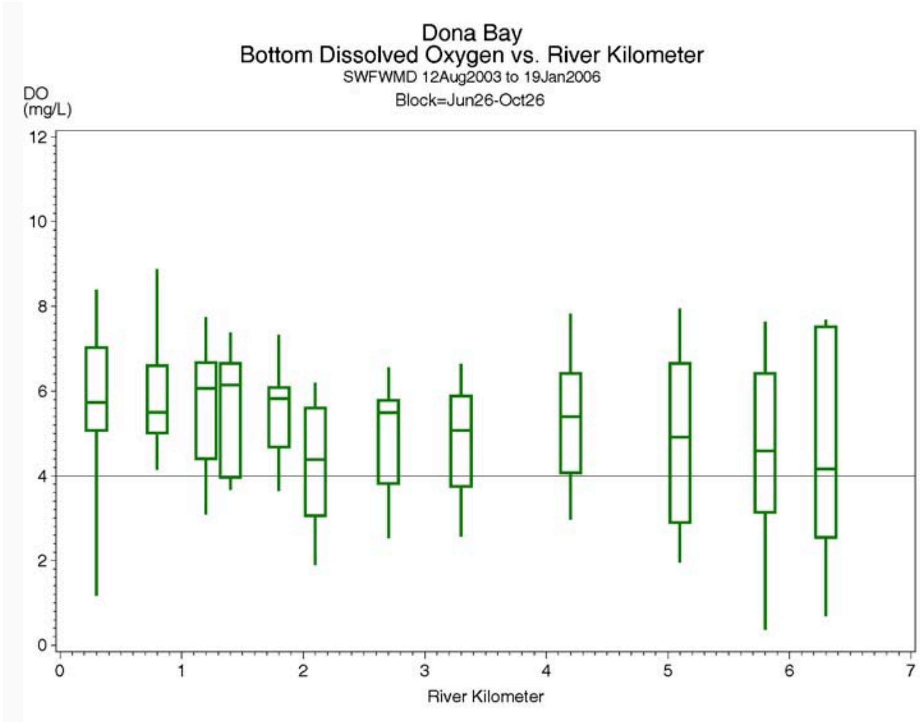

Figure 4-32. **Dona Bay/Shakett Creek dissolved oxygen concentration versus river km, Block 3 (June 26 through October 26).**

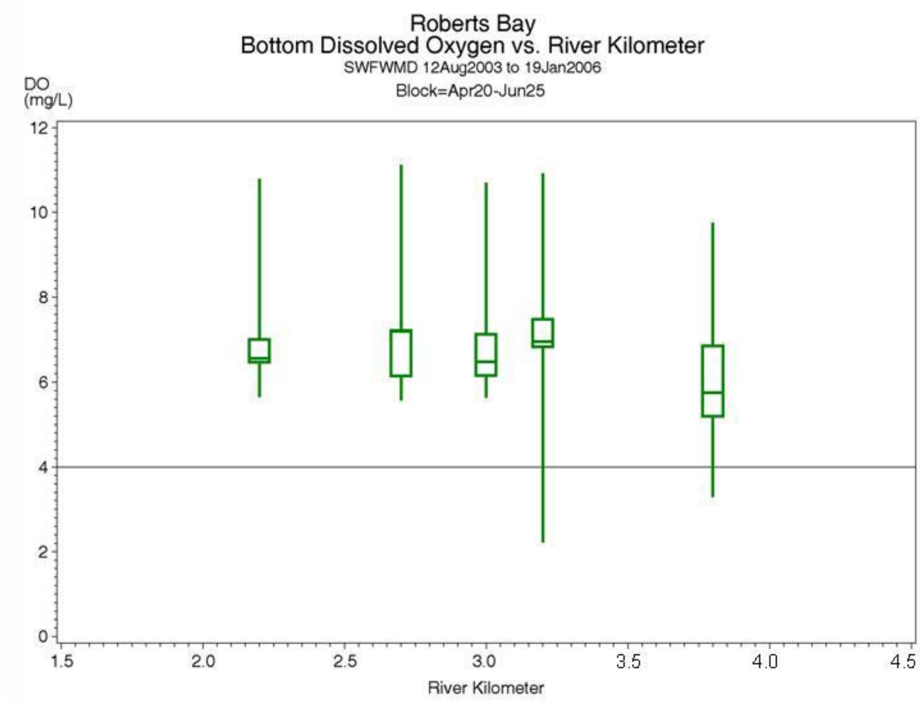

Figure 4-33. **Roberts Bay dissolved oxygen concentration versus river km, Block 1 (April 20 through June 25).**

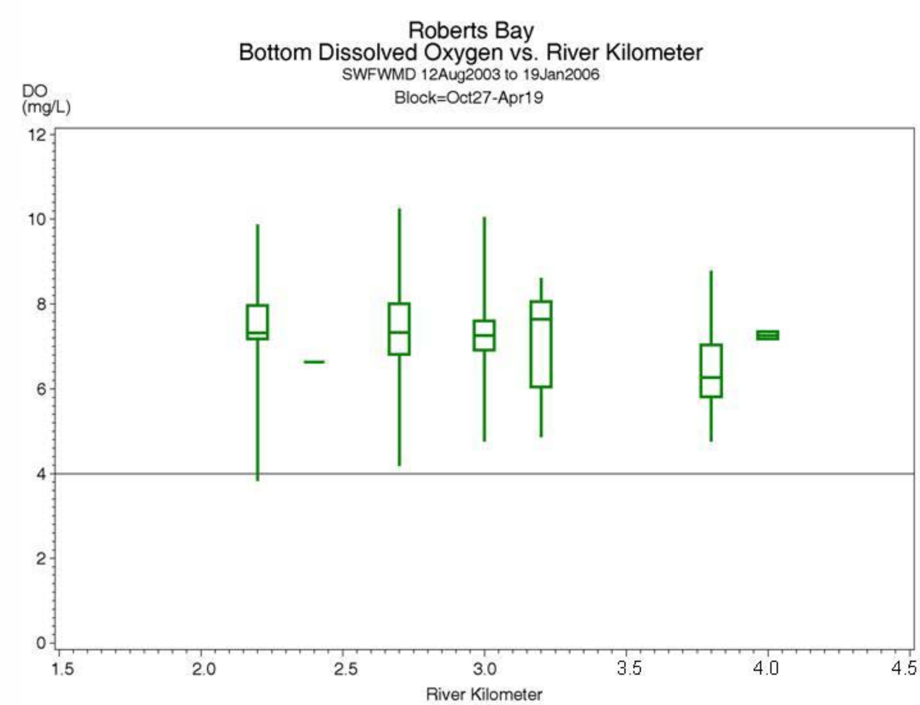

Figure 4-34. **Roberts Bay dissolved oxygen concentration versus river Km, Block 2 (October 27 through April 19).**

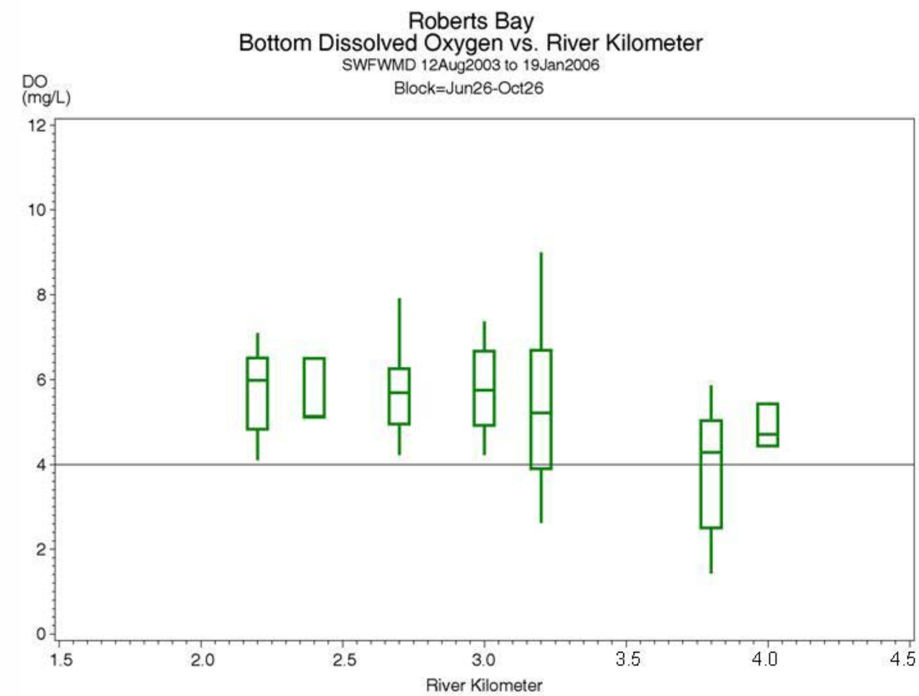

Figure 4-35. **Roberts Bay dissolved oxygen concentration versus river km, Block 3 (June 26 through October 26).**

4.3.3.2 Relationship Between Dissolved Oxygen and Flow

For flows between 50 cfs and 200 cfs, the upper limit of DO concentrations in the bottom layer declined at many of the stations. At higher levels of flow, the level of DO remained at a consistent low level. In the bottom layer, DO concentrations were in the range of 4 to 6 mg/l for stations DB5, DB16, DB17, DB18 when flows were between 150 and 400 cfs (Figure 4-36). For stations DB19, DB20 and DB21, bottom DO concentrations dropped to a range of 2 to 4 mg/l for flows ranging from 150 to 400 cfs (Figure 4-37).

The trend in bottom DO versus flow at stations DB22 and DB23 is similar to that in stations DB19 to DB21, but there was greater variability. The decreasing trend in DO versus flow did not hold at stations DB24 and DB25, as there were DO concentrations ranging from <1 mg/l up to 8 mg/l throughout the range of flow from 0 to 200 cfs. However, the lowest values of DO were measured at stations DB24 and DB25, where several bottom dissolved oxygen measurements below 2 mg/l were made (Figure 4-38). As discussed in section 4.3.3, these measurements would be defined as hypoxic. The field crew observed values of DO below 2 mg/l at no other stations besides these two.

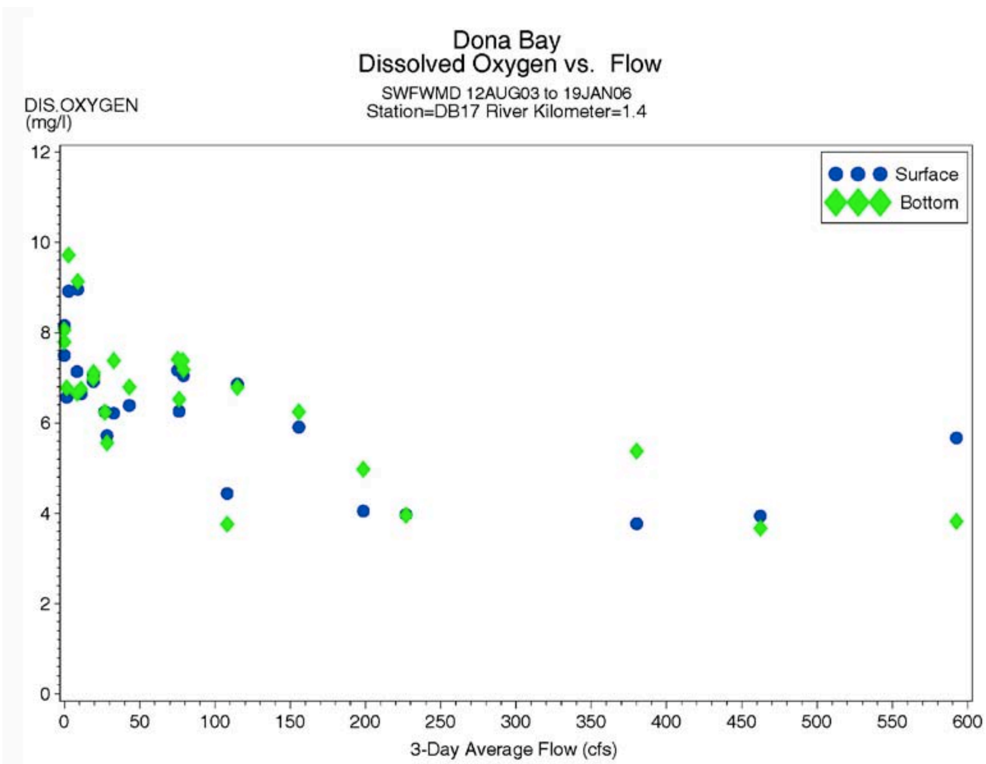

Figure 4-36. Dona Bay/Shakett Creek dissolved oxygen concentration versus flow, Station DB17, river km 1.4.

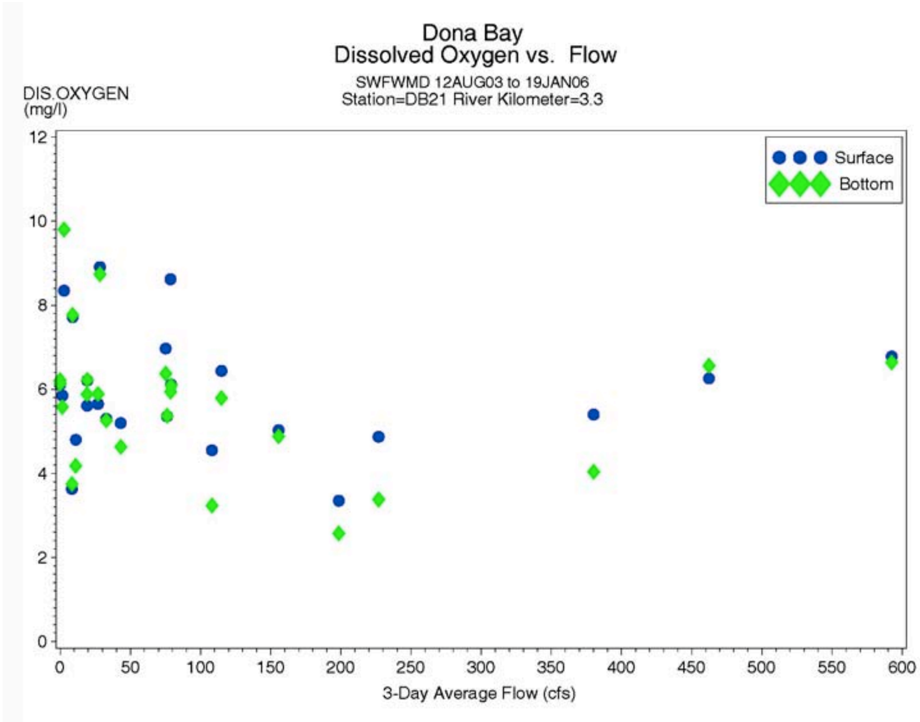

Figure 4-37. **Dona Bay/Shakett Creek dissolved oxygen concentration versus flow, Station DB21, river km 3.3.**

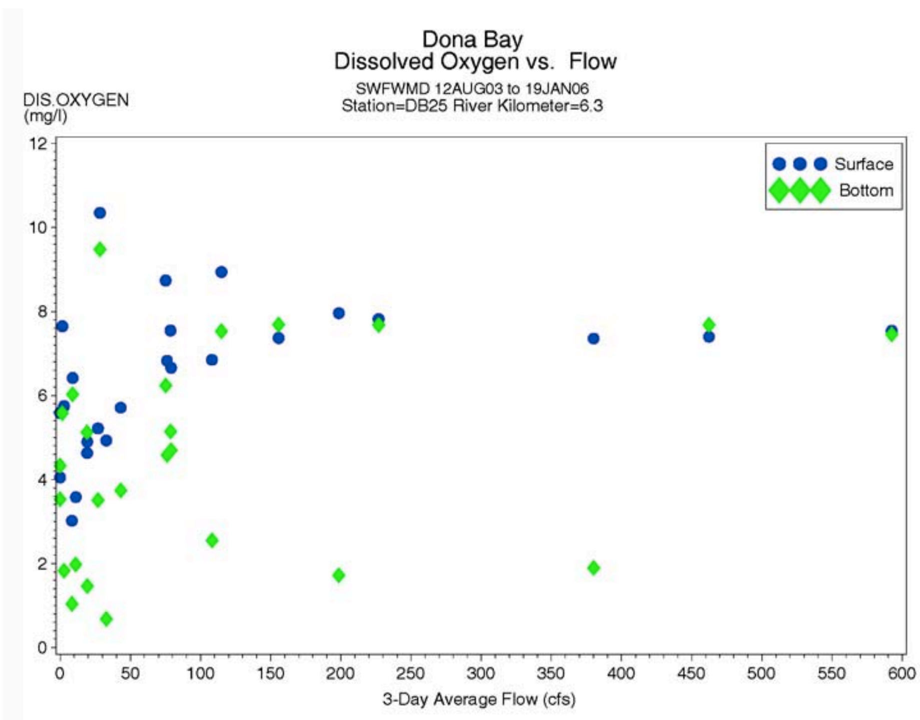

Figure 4-38. **Dona Bay/Shakett Creek dissolved oxygen concentration versus flow, Station DB25, river km 6.3.**

5 BIOLOGICAL CHARACTERISTICS

In this chapter the biological characteristics of the DARB system are described. Specifically, the extent and nature of seagrasses, macroinvertebrates, including oysters, and fish are presented. Temporal changes in populations or assemblages of these taxa in the DARB system and possible relationships between their presence or abundance as a function of freshwater inflow and salinity are discussed to provide a basis for developing criteria used to establish minimum flows for Dona Bay/Shakett Creek.

5.1 Seagrasses

Seagrasses are flowering vascular plants that complete their entire lifecycle in seawater, occupying shallow portions of oceans, estuaries, and lagoons (Rey and Rutledge 2001). Seagrass is an important component of estuarine ecosystems. Commercially important estuarine and marine fauna depend on seagrass habitat for all or part of their lifecycles. Seagrass beds serve as nursery and foraging areas for local sport fish, including adult red drum, spotted seatrout, silver perch, sheepshead, snook, shrimp and the bay scallop (Zieman and Zieman 1989). In addition to commercial and recreationally important species, other taxa, such as the West Indian manatee (*Trichechus manatus*), depend on seagrass as an essential food source. Seagrasses also provide ecologic functions, such as improving water quality by increasing oxygen and cycling nutrients in the water column. Additionally, seagrass beds help slow erosion by providing a buffer against wave energy and by stabilizing sediments with their root systems.

Seagrass growth and establishment are often limited by the amount of light that reaches the bottom of the estuary (Morris *et al.* 2002, Morris *et al.* 2000). Light attenuation in the water column is influenced by turbidity, phytoplankton and dissolved organic matter. In addition to light, salinity often determines which species are present in which locations, and at what depths, based on species-specific salinity tolerances and preferences. Seagrass coverage has been shown to increase in drought years and decrease in abnormally wet years, perhaps in response to changes in salinity or other chemical or physical parameters (Jones 2005). Increased seagrass coverage has also been associated with reductions in nutrient loading (Greening and Janicki 2006).

Currently, the primary seagrass species in the DARB system is shoal grass (*Halodule wrightii)* (Figure 5-1) (Jones 2003, Jones 2005). This species is well-adapted to the widely varying salinity conditions found in most estuaries and lagoons. Shoal grass occurs in intertidal habitats as well as deep water areas, and can occur closer to the beach than other seagrass species. *H. wrightii* occupies sediments ranging from silty mud to course sand with varying amounts of mud. The optimal salinity range for shoal grass is reported to be between 22 ppt and 34 ppt, and the tolerance range between 1 ppt and 45 ppt (Woodward-Clyde 1994). Shoal grass is, however, able to withstand salinities at the low end of this range for only a short time period. *Halodule wrightii* is thought to be an early successional species in seagrass beds because it is able to persist under relatively extreme conditions, tolerating both frequent and prolonged exposure at low tide, as well as surviving at the deepwater edge of beds (Environmental Protection Commission of Hillsborough County 2007).

Another seagrass species, turtle grass (*Thalassia testudinum)* has been observed recently in the mouth of Lyons Bay, but did not occur in transects where quantitative data were collected in the DARB system and Lyons Bay (Figure 5-1) (Jones 2003, 2005). The optimal salinity range for *T. testudium* is 24-35 ppt (Phillips 1960, McMillan and Moseley 1967, Zieman 1975). The overall salinity tolerance range for this species is between 3.5 (Sculthorpe 1967) and 60 ppt (McMillan and Moseley 1967), but the extremes of this salinity range may only be tolerated by *T. testudium* for short periods of time. Leaf loss occurs when salinities are below 20 ppt and photosynthetic activity is reduced linearly with reduced salinities (Zieman 1982).

Seagrasses have been used as indicators of water quality conditions in a number of estuarine systems, due to salinity and light requirements for individual species. Because seagrass beds are ecologically important aquatic habitat and have been identified as "Priority Habitat Targets" by Beck *et al.* (2000), they were included as one of several indicators in the development of Minimum Flows and Levels for the Lower Suwannee River and Estuary (WRA 2005). Seagrasses were also included in the development of Minimum Flows and Levels for the Caloosahatchee River and Estuary (SFWMD 2003)

Anecdotal evidence indicates that historically seagrass beds in the DARB system extended over a much greater area than they do currently (Jones 2005). Seagrass beds were already considerably reduced when the first seagrass survey of the area was conducted in 1986. Sarasota County has initiated an annual monitoring program of oyster populations and seagrass beds.

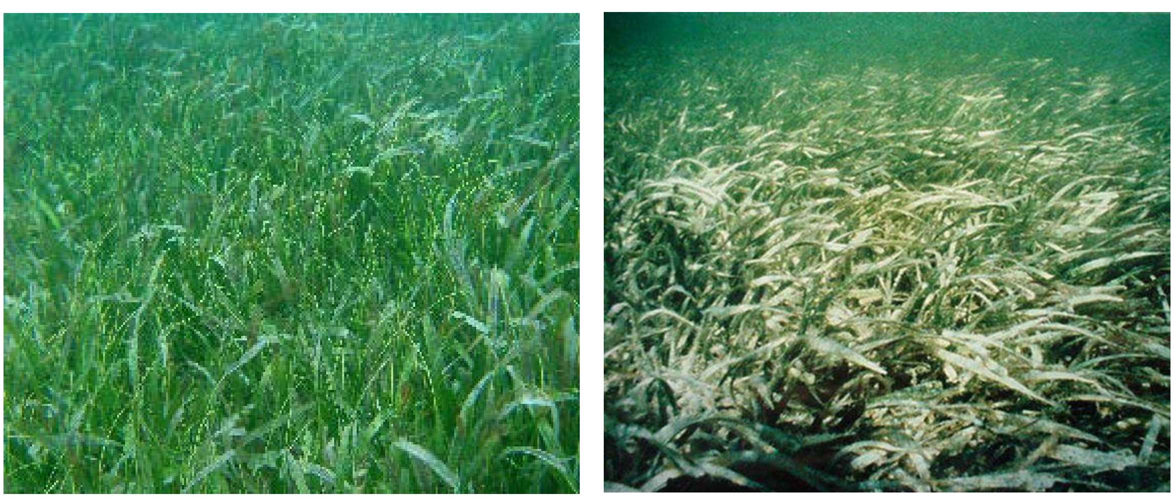

Figure 5-1. Beds of turtle grass *(Thalassia testudinum)* (left) and shoal grass *(Halodule wrightii)* (right).

5.1.1 Estimates of Seagrass Coverage

The extent of seagrass coverage in the DARB system has previously been estimated as part of two regional programs: the District's Aerial Mapping Program and Sarasota County Government's Seagrass Monitoring Program. A brief overview of these programs and available results of program activities are described in this section.

5.1.1.1 District Aerial Mapping Program

Aerial seagrass mapping has been conducted by the District for coastal counties every other year since 1986 (Kaufman 2007). Seagrass coverage is interpolated from aerial photographs that are obtained at the end of the growing season and converted to polygons in Geographic Information data sets. Individual polygons are then characterized as having patchy or continuous seagrass coverage and used for evaluating temporal changes in coverage. In addition to the recent coverage data sets, historical seagrass coverage in the DARB system and nearby areas has been mapped using 1948 aerial photographs.

5.1.1.2 Sarasota County's Seagrass Monitoring Program

In 2003, Sarasota County conducted ground-truthing of the seagrass beds delineated in the DARB system and nearby areas in 2001 by the District Aerial Mapping Program. County staff determined that actual seagrass bed locations were consistent with seagrass polygons mapped by the District using aerial photointerpretation techniques and established four seagrass transects (LYB1 and LYB2 in Lyons Bay, DB1 in Dona Bay and RB1 in Roberts Bay) in what appeared to be four stable grass beds (Jones 2003) (Figure 5-2).

Transects began at the shallow end of the bed and terminate at the deep edge. The Braun Blanquet method was used to classify seagrass percent coverage along each transect in 2003 and 2004. This method classifies coverage into categories based on percentages (i.e., category 1 is < 5% cover) and is the method used by the FDEP to monitor seagrass beds in Charlotte Harbor, Lemon Bay, and Sarasota Bay (Jones 2005). In addition to percent cover, several other parameters are recorded including species composition, shoot density, sediment type, and epiphyte density. In 2003, data were collected at the beginning, middle and end of the seagrass bed. In 2004, for each transect less than 50 meters, data were recorded at 10 meter intervals. In 2003 and 2004, for each transect with seagrass beds longer than 150 meters, data were collected at 50 meter intervals (Jones 2005, 2003).

Figure 5-2. Map of Sarasota County Seagrass Monitoring Program transect locations and 2001 District Aerial Mapping Program seagrass bed delineation for the DARB system and nearby areas including Lyons Bay (Source: Jones 2003).

5.1.1.3 Seagrass Monitoring Results

In 1948 seagrass beds occurred in most shallow areas in Lyons, Dona, and Roberts bays (Figure 5-3, Jones 2003). At that time, there were approximately 123 acres of seagrasses in the DARB system and Lyons Bay (Jones 2003). This estimate may be considered representative of the extent of seagrass beds in the area prior to the structural alterations that led to diversion of additional freshwater into the DARB system.

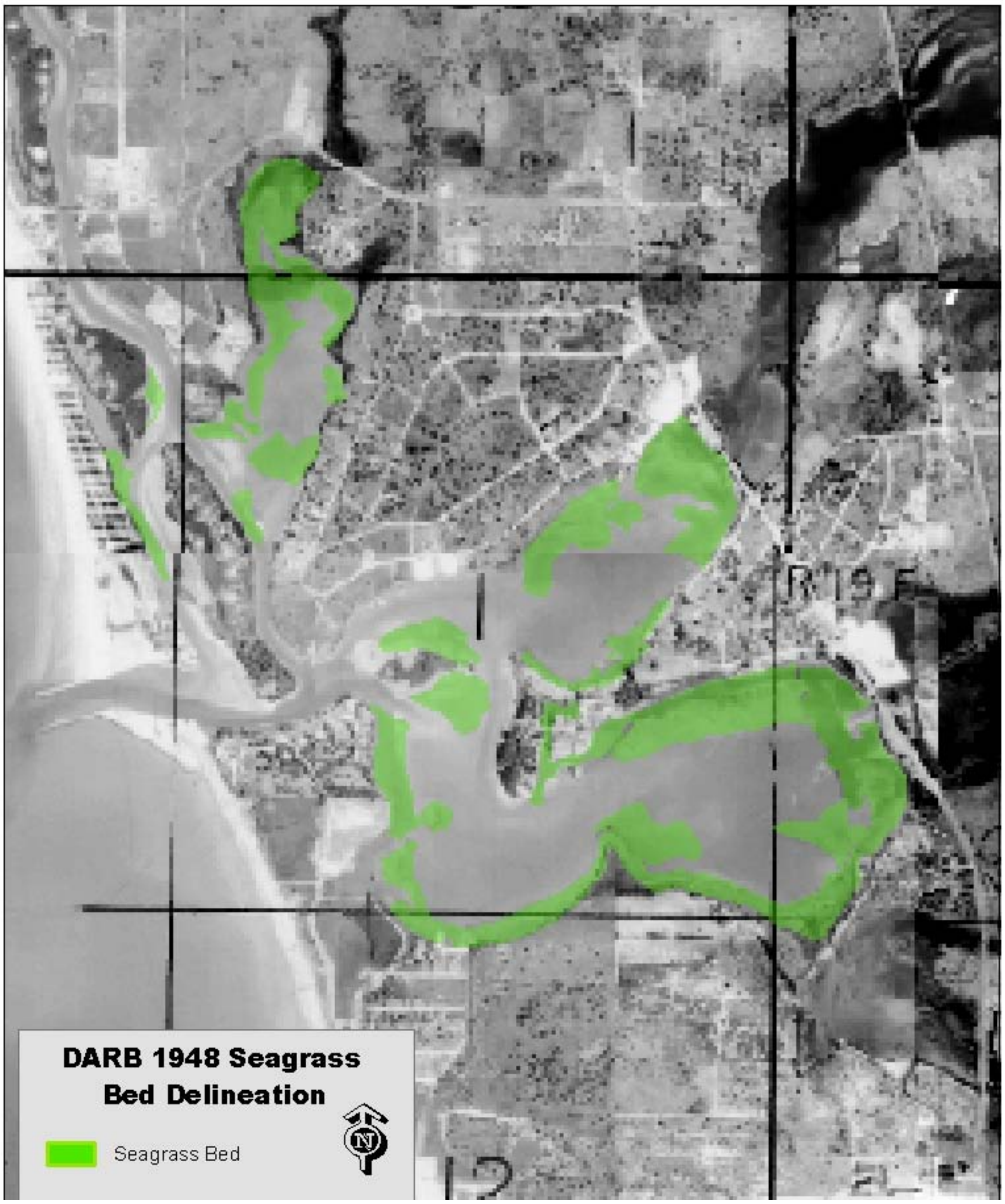

Figure 5-3. 1948 Sarasota County seagrass bed delineation in the DARB system and nearby areas, including Lyons Bay (Source: Jones 2003).

Overall, present seagrass coverage in the DARB system is sparse, lacking the continuous beds found in other estuaries of the west coast of Florida. Seagrass coverage in transects evaluated by the Sarasota Seagrass Monitoring Program in the DARB system was less than 5% (Table 5-1, Figure 5-4). Seagrass coverage in Lyons Bay is a mix of patchy and continuous beds. Seagrass coverage in Dona Bay is restricted to patchy meadows in the portion of the bay closest to Venice Inlet, despite having significant amounts of shallow water habitat in the eastern portion of the bay (Figure 5-5) (Kimley-Horn and Associates *et al.* 2007). Seagrass coverage in Roberts Bay extends upstream to the U.S. 41 bridge.

Table 5-1. Seagrass abundance, mean blade length and bed length at seagrass bed transects in Lyons Bay, Dona Bay, and Roberts Bay (Source: Jones 2005).

	Mean Braun Blanquet Abundance			Mean Blade Length (cm)			Bed Length (m)			Photosynthetically Active Radiation (% at deep edge)		
Date	LYB1	DB1	RB1	LYB1	DB1	RB1	LYB1	DB1	RB1	LYB1	DB1	RB1
10/3/2003	0.5	1	0.75	4.3	5.27	3.3	8	39	44	NO	METER	
1/12/2004	0.8	0.4		6.29	6.07		40	20		68.92	Too Shallow	47.2
4/7/2004	0.4	0.4	0.67	11.3	6.7	7.67	30	25	76	61	91.9	31.45
7/16/2004	1	2.13	2.67	10.48	7.85	17.27	37	30	63	25.68	85.95	21.42
10/6/2004		1	0.1		4.9	3.6	0	30	40	25.78	Too Shallow	16.52

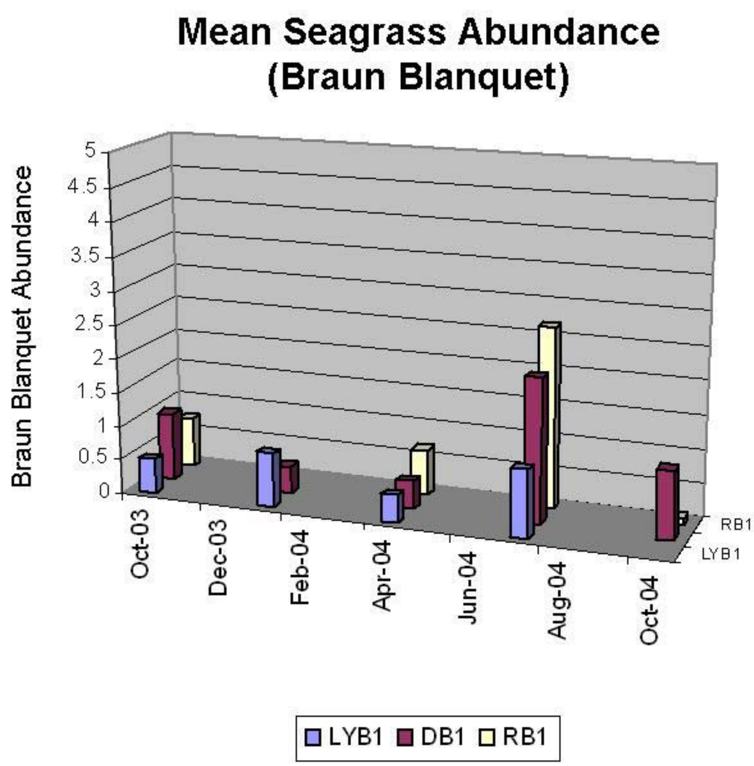

Figure 5-4. Trends in seagrass abundance, as measured by the Braun Blanquet method at three transects (one each in Lyons Bay, Dona Bay and Roberts Bay from October 2003 through October 2004 (Source: Jones 2005).

Inter-annual variation in seagrass coverage in the DARB system is evident based on comparison of mapped beds for 1948, 2001, 2003 and 2006. Aerial photographs from 2001 show a reduced presence of seagrass beds as compared to photographs from 2003, with less change observed in Lyons Bay (Figures 5-2 and 5-5). Dona Bay and Roberts Bay each have several tributaries contributing freshwater inflow, whereas Lyons Bay does not. Seagrass coverage in 2006 (Figure 5-6) was similar to that in 2003, with a small increase in the extent of patch seagrass beds in the upper portion of Roberts Bay (Figure 5-6). Comparison of seagrass beds mapped for recent years relative to the beds that existed in 1948, illustrates the decline of seagrass coverage in much of the estuarine system.

Field observation and transect data showed sparse seagrass coverage in DARB during October 2003 (Jones 2005). Additional quantitative monitoring of the three seagrass transects took place in January, April, July and October of 2004 (Jones 2005). The results showed seasonal variation at all transects (Table 5-1). Seagrass was not present at RB1 in January 2004 or at LYB1 in October 2004. While both *Halodule wrightii* and *Thalassia testudinum* (Figure 5-1) were observed in the mouth of Lyons Bay, only *Halodule wrightii* was observed along the transects (Jones 2003, 2005).

Using the Braun Blanquet method, the three transects monitored in 2004 fell below category 1, indicating that seagrass cover at each stations was < 5% (Table 5-1) (Jones 2005). One exception occurred in July 2004 in DARB which scored a “2” (indicating 5-25% cover). Blade length was generally < 8 cm (mean value) throughout the study area, except in July 2004 when mean blade length was 12 cm (Table 5-1). The Lyons Bay transect had the lowest recorded bed lengths, 8 meters and 0 meters (no seagrass observed), occurring in October 2003 and October 2004 (Jones 2005).

The current lack of seagrass beds in the shallow water habitats of Dona Bay suggests that conditions for seagrasses are most stressful in this portion of the DARB system (Kimley-Horn and Associates *et al.* 2007). Wessel *et al.* (2007) analyzed the consistency of seagrass coverage across years using District Aerial Mapping Program data from 1988, 1994, 1996, 1999, 2001 and 2004. Seagrass mapping data from 1990 and 1992 were incomplete for the DARB system and were not included in the comparison. Dona Bay had the least consistent seagrass coverage, with only a few areas near Venice Inlet having coverage across all years examined (Figure 5-7). With respect to seagrass bed persistence, conditions in Roberts Bay appear to be intermediate, relative to Dona Bay and Lyons Bay. While other factors could contribute to the observed distributional patterns, it has been suggested that the biggest impact to seagrass beds in Dona Bay is a combination of the effects of reduced salinities, increased variation in salinity, and reduced water clarity due to excess freshwater inflow from Cow Pen Slough (Kimley-Horn and Associates *et al.* 2007).

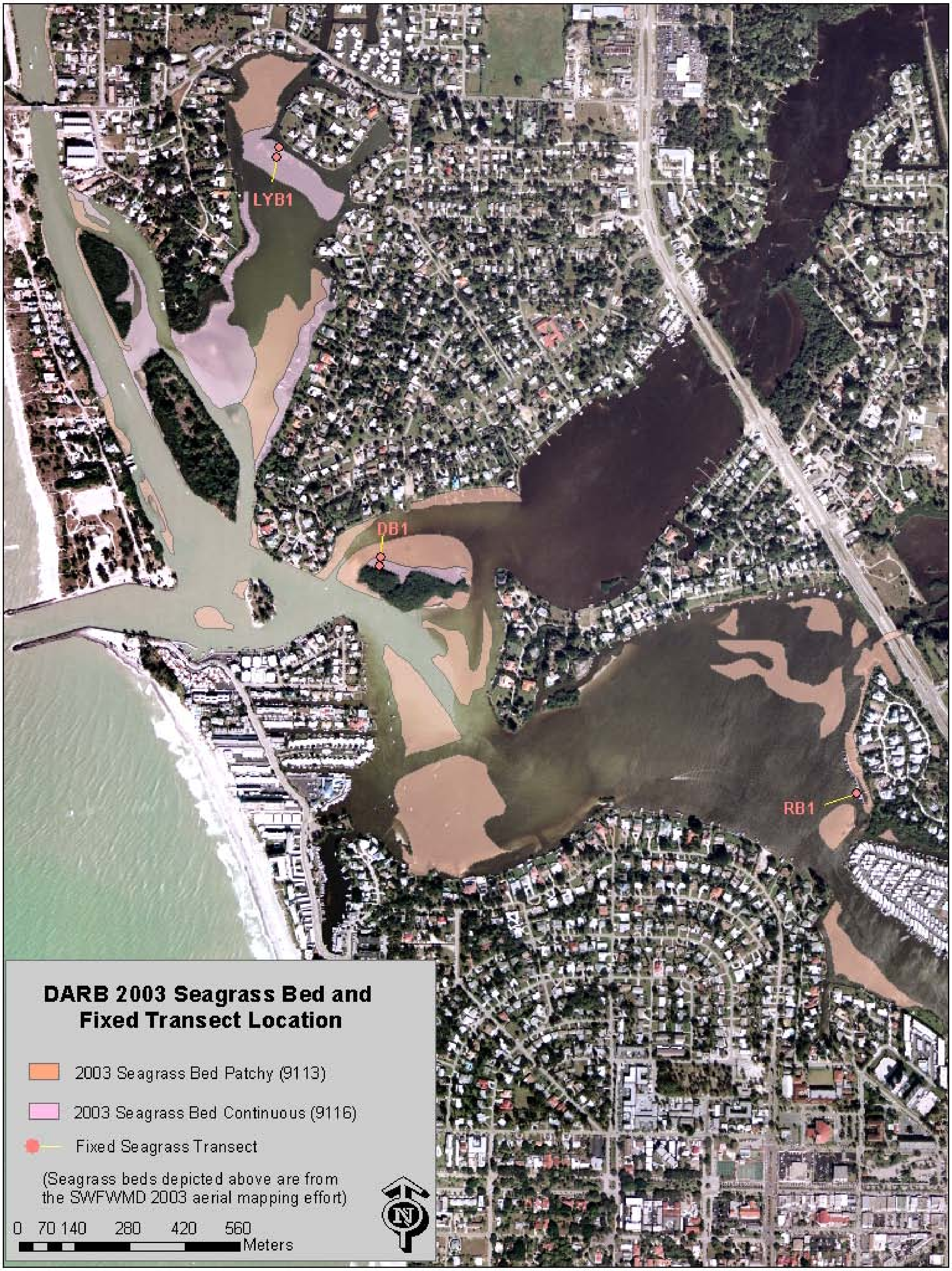

Figure 5-5. **2003 SWFWMD seagrass bed delineation in the DARB system and nearby areas, including Lyons Bay (Source: Jones 2005).**

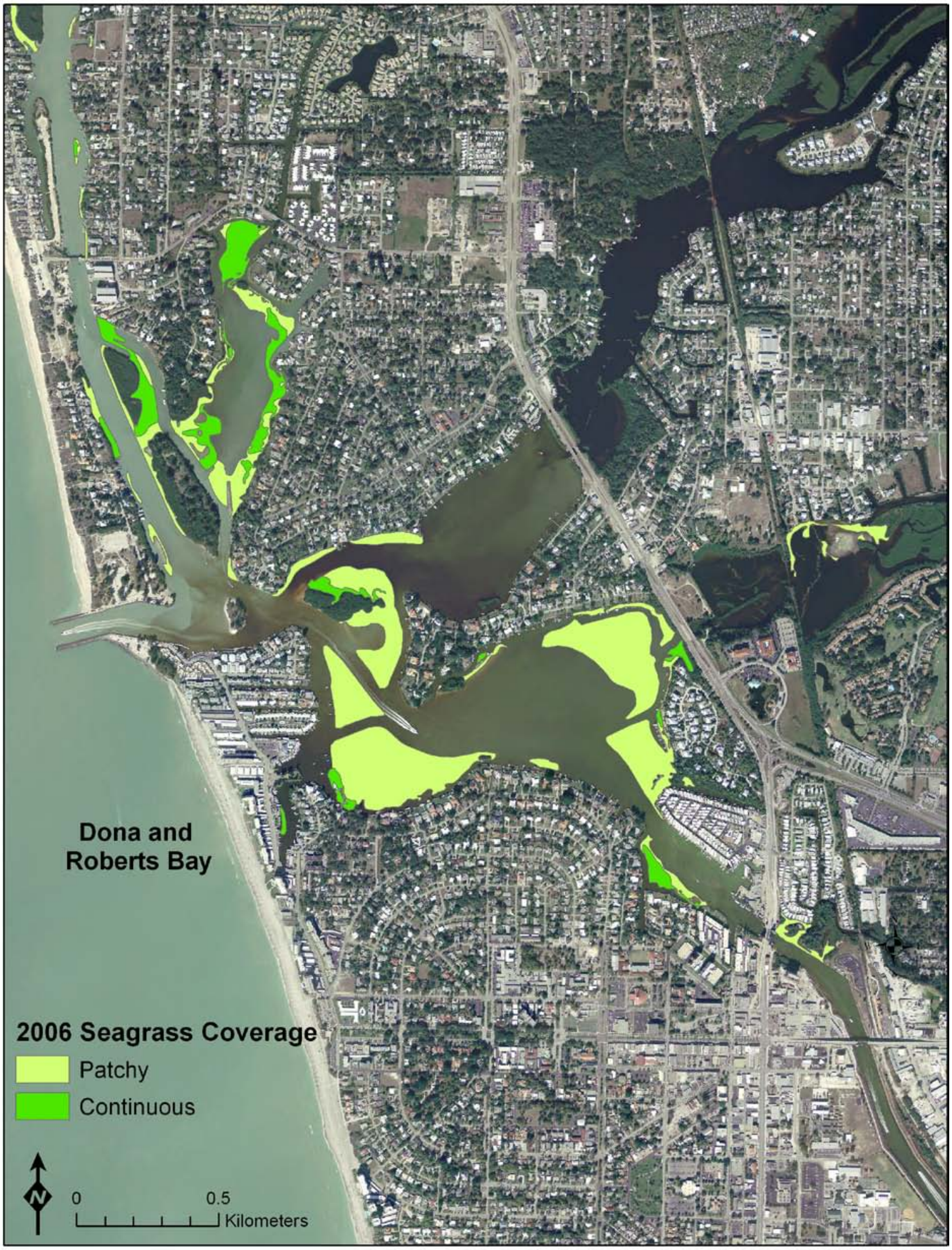

Figure 5-6. 2006 SWFWMD seagrass bed delineation in the DARB system and nearby areas, including Lyons Bay.

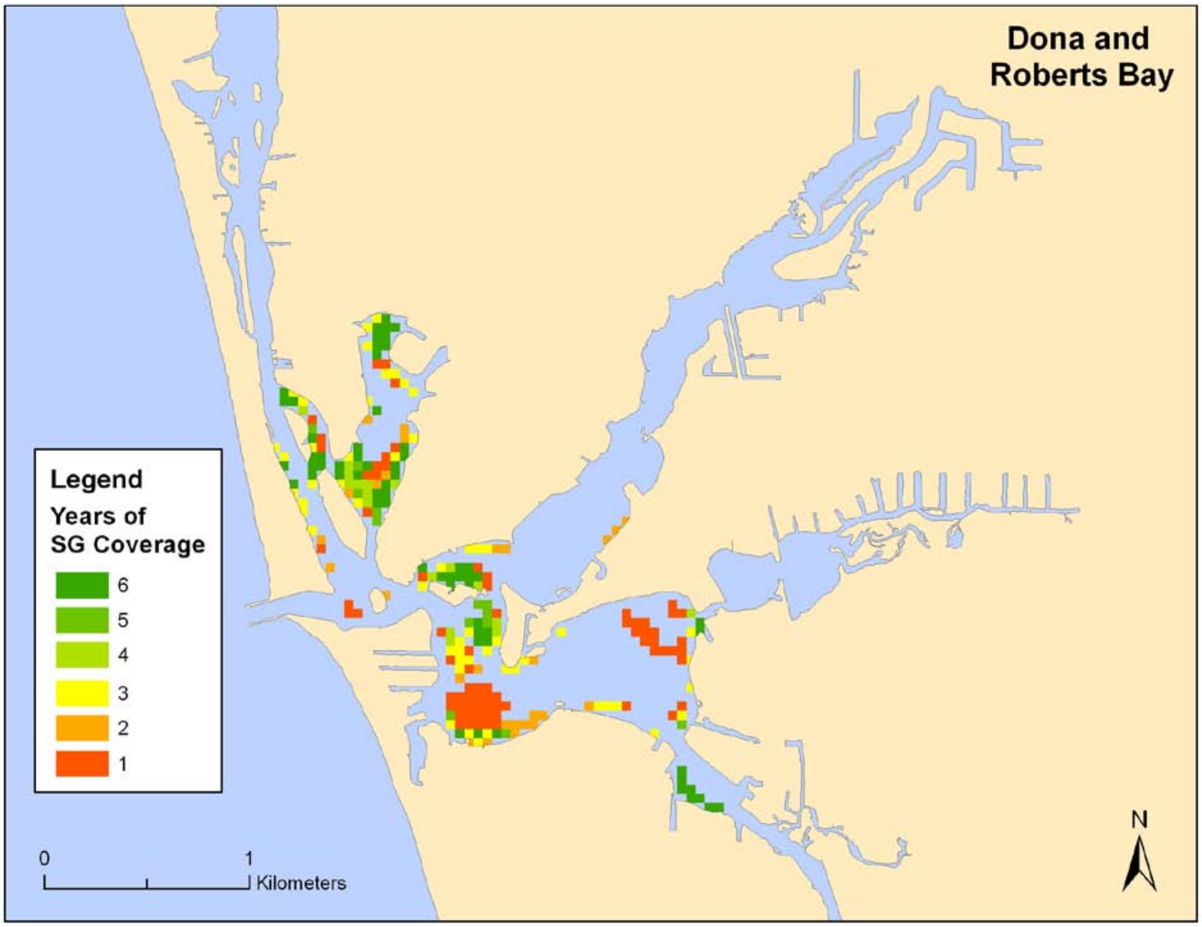

Figure 5-7. **Consistency in the presence of seagrass coverage throughout Lyons, Dona, and Roberts bays, based on data for 1988, 1994, 1996, 1999, 2001 and 2004.**

5.1.2 Conclusions

- Current seagrass coverage in DARB is sparse compared to the more continuous seagrass beds found in estuaries to the north (Sarasota Bay) and south (Charlotte Harbor). Based on aerial photography from 1948, seagrass beds historically occurred in most of the shallow water areas of the DARB system.

- Due to diversion of freshwater via the Cow Pen Slough Canal, the DARB system is highly colored, and reduced light penetration through the water column may influence seagrass coverage. Additionally, because of the increase in freshwater flow during certain times of the year, the system experiences a high degree of salinity variation which may limit seagrass growth and prohibit species less tolerant than *Halodule wrightii* from becoming established.

5.2 Benthos

Benthic organisms (also referred to as the benthos) are the plants, animals and other organisms that live in or on the bottom substrates of rivers, estuaries and other aquatic habitats. Benthic macroinvertebrates, a subset of the benthos, are benthic animals without backbones that are visible with the naked eye, and include organisms such as aquatic insects, worms, snails, clams, and shrimp (Figure 5-8). Many benthic macroinvertebrates are sessile, although some species may undergo migrations into the water column (*e.g.,* amphipod crustaceans) or produce planktonic larvae (*e.g.,* polychaete worms). As a group, however, benthic macroinvertebrates are relatively sedentary and are considered to be effective integrators of a variety of environmental factors, including salinity (Boesch and Rosenberg 1981, United States Environmental Protection Agency 1999). The sensitivity of benthic macroinvertebrate communities to changes in salinity and streamflow has been used to establish minimum flows in several estuarine systems along the Florida Gulf Coast (Janicki Environmental 2005 and 2006, Water Resources Associates 2006).

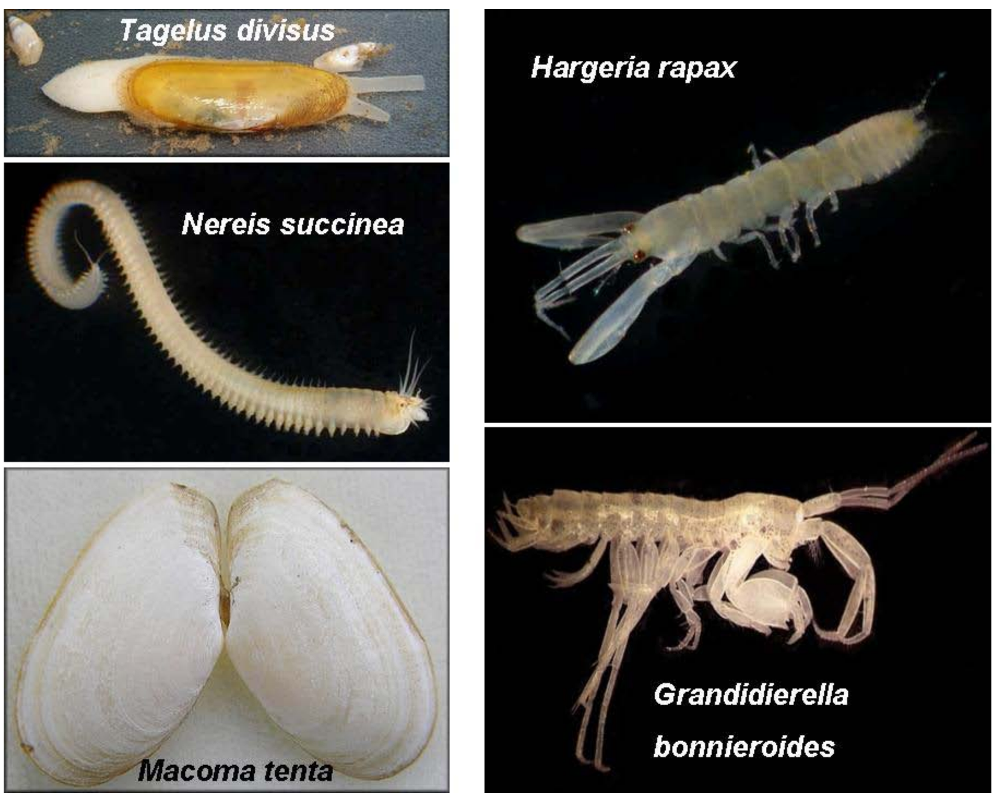

Figure 5-8. Examples of benthic organisms identified from Shakett Creek, Dona Bay, and Roberts Bay. Photos: *Tagelus divisus* (Source: http://www.jaxshells.org/1204b.jpg); *Nereis succinea* (http://www.dnr.sc.gov/marine/sertc/images/photo%20galleryNereis %20succinea.jpg); Macoma tenta (http://www.jaxshells.org/telf.jpg); *Hargeria rapax* (http://www.dnr.sc.gov/marine/sertc/images/photo%20gallery/Hargeria%20rapax.jp g); *Grandidierella bonnieroides* (Christina Holden, EPCHC).

Benthic organisms form an essential link in the transfer of energy to secondary consumers including other benthic organisms (Fauchald and Jumars 1979), finfish (Llanso *et al.* 1998), and avifauna. Tubiculous and fossorial benthic invertebrates may fulfill an important role in reworking sediments. In this role as bioturbators, they may bring suspended sediments into contact with the water column thereby translocating nutrients and pollutants and oxygenating sediments.

The composition and structure of the benthic macroinvertebrate community in the estuarine waters of the DARB system are expected to respond to the timing and volume of freshwater released from Cow Pen Slough and discharged into the estuary from the Blackburn Canal. In this section available data on the macroinvertebrate infauna, *i.e.*, the benthic macroinvertebrates living in the soft sediments of the DARB system, are reviewed with respect to the effects of salinity on their occurrence. Composition of the infaunal community of the DARB system is compared to that of Charlotte Harbor, a nearby estuarine system for which adequate benthic data exist. Based on the ecological significance of the eastern oyster (*Crassostrea virginica*) and the oyster beds created by this species, this benthic macroinvertebrate is discussed separately in section 5.3.

5.2.1 Sources of Macroinvertebrate Data

Mote Marine Laboratory (MML) has completed two investigations of macroinvertebrates in the estuarine receiving waters of Cow Pen Slough (Lincer 1975; Culter, 2006). The 1975 study was designed to describe the “present ecological status” of the DARB system with respect to Cow Pen Slough flows (Lincer 1975). The 2004 study was undertaken to “address natural resource management issues” for both the District and Sarasota County (Culter 2006). Sampling methods differed between the two studies, but were not so different as to preclude comparison of the results. Methods used for the two investigations are summarized in Appendix 5-1.

A total of eight stations were sampled in DARB as part of the 1975 study. A total of 16 stations were sampled in DARB as part of the 2004 study, including all eight sampling stations from the 1975 study. For the 1975 study, the benthos were sampled during May, July, and December 1974, and April 1975. The July 1974 samples were collected shortly after the June release of water from Cow Pen Slough through the CPS2 structure (Lincer 1975). For the 2004 study, samples were collected during May and June 2004, prior to the release of water from Cow Pen Slough (Culter 2006). Salinities in the DARB system were typically within the euhaline range (30 to 40 ppt), except following the June 1974 release of water from Cow Pen Slough, when salinities in the oligohaline (0.5 to 5 ppt) and mesohaline (5 to 18 ppt) ranges were measured in Shakett Creek and Dona Bay. Abiotic data associated with the benthic collections in the DARB system are summarized in Appendices 5-2 (salinity), 5-3 (dissolved oxygen), and 5-4 (sediments).

Comparative information on the macroinvertebrates of Charlotte Harbor is available from the Florida Marine Research Institute (FMRI) (unpublished data) and MML (2007). FMRI sampled the estuary in July 2002; MML collected samples in May 2004.

5.2.2 Summary Results for Macroinvertebrate Infauna Composition and Salinity Preference Information

This section summarizes and compares the findings of investigations of the soft-sediment benthos of the DARB system conducted by Lincer (1975) and Culter (2006).

5.2.2.1 Taxonomic Composition

More than 200 distinct infaunal macroinvertebrate taxa were identified from the DARB system based on sampling conducted in 1974/1975 (Lincer 1975) and 2004 (Culter 2006) (Appendix 5-5 and 5-6). Notable differences in the most abundant taxa were observed between the two surveys – differences that are not necessarily attributable to differences in sampling gear.

Numbers of taxa tended to decrease upstream from Dona Bay to Shakett Creek. In the 1974-1975 sampling period, the lowest numbers of taxa occurred after the release of freshwater from the CPS2 structure into Shakett Creek/Dona Bay during the July 1974 sampling. The highest number of taxa was observed in April 1975, towards the end of the dry season when the CPS2 structure was closed. In addition to the decrease in the number of taxa after the release of water from CPS2 in June, the number of individuals was also lower in Shakett Creek/Dona Bay after the release of water from CPS2. The flow increase and concomitant decrease in salinity during the July 1974 sampling resulted in reduced diversity and abundance in Shakett Creek/Dona Bay.

Bivalves, especially *Tagelus divisus* and to a lesser extent, *Macoma tenta*, were relatively abundant in Dona Bay/Shakett Creek in the 1974-1975 survey as was the polychaete *Onuphis* sp. (Table 5-2). Bivalves were relatively rare in the May-June 2004 samples. Amphipods, including *Grandidierella bonnieroides* and unidentified corophiids were relatively abundant in 2004.

Table 5-2. Most abundant taxa, by sampling period, in the DARB system, 1974-1975 (adapted from Lincer 1975) and 2004 (adapted from Culter 2006).

Study Area	May 1974	July 1974	December 1974	April 1975	May-June 2004
Shakett Creek-Dona Bay	*Tagelus divisus* *Macoma tenta* *Abra aequalis*	*Corbula barattiana* *Onuphis sp.* *Tellina texana*	*Tagelus divisus* *Chione cancellata* *Abra aequalis*	*Tagelus divisus* *Brachidontes exustus* *Adontia sp.*	*Fabriciola sp.* *Corophiidae* *Grandidierella bonnieroides*
Roberts Bay	*Terebellides stroemi* *Abra aequalis* *Tagelus divisus*	*Onuphis sp.* *Macoma tenta* *Corbula barattiana*	*Tellina texana* *Tagelus sp.* *Abra aequalis*	*Tellina texana* *Tagelus sp.* *Tellina versicolor*	*Corophiidae* *Monticellina cf. dorsobranchialis* *Grandidierella bonnieroides*

Tagelus divisus and *Onuphis* sp. were also relatively abundant in Roberts Bay in 1974-1975 and were not common in the bay in the 2004 survey. The terebellid polychaete, *Terebellides stroemi* was dominant in 1974. The cirratulid polychaete, *Monticellina cf. dorsobranchialis*, corophiids, and aorids (*Grandidierella bonnieroides*), not identified in the 1974 dredge samples from the bay, were common in 2004.

Tagelus divisus is a common inhabitant of the lower intertidal zone in bays and protected beaches (Fraser 1967, Britton and Morton 1989, de Arruda and Amaral 2003). *Grandidierella* is one of the most widespread and abundant amphipods in Florida Gulf Coast tidal rivers, particularly in mesohaline salinities. *Monticellina* has a preference for polyhaline and euhaline salinities. Bivalves, amphipods, and polychaetes are all important prey for fishes and birds.

Similarity indices were used to compare May 1974 (Lincer 1975) and May-June 2004 (Culter 2006) sampling results to evaluate temporal differences in macroinvertebrate infauna in the DARB system. These analyses confirmed that the DARB system macroinvertebrate infauna differed considerably between 1974 and 2004.

Although few of the species collected from the DARB system in 1974-1975 were found to be abundant in Charlotte Harbor in 2002 and 2004 surveys, more species were common to the two systems when 2004 sampling results for the DARB system were compared to the Charlotte Harbor survey data (Table 5-3).

Many of the abundant macroinvertebrate infauna in the DARB system are typical of tidal rivers in the region. *Macoma tenta, Monticellina cf. dorsobranchialis, Grandidierella bonnieroides*, as well as the corophiid *Apocorophium louisianum* were dominants in polyhaline (18 to 20 ppt) and euhaline (30 to 40 ppt) salinity class waters of other Florida Gulf Coast tidal rivers (Janicki Environmental 2007). *Grandidierella bonnieroides* is one of the most widespread and abundant amphipods in Florida Gulf Coast tidal rivers, particularly in areas of mesohaline (5 to 18 ppt) salinities. *Monticellina dorsobranchialis* has a preference for polyhaline and euhaline salinities.

Table 5-3. Abundant benthic organisms in Charlotte Harbor, July 2002 (FWRI unpublished data) and May 2004 (Mote Marine Laboratory 2007) compared to DARB studies in 1974-1975 and 2004 (Adapted from Lincer 1975 and Culter 2006). X=Present; NR=Not reported.

Taxa		DARB 1974-1975	DARB 2004
Rank	**IMAP Charlotte Harbor**		
1	*Amygdalum sagittatum*	NR	NR
2	Tubificidae	NR	X
3	*Cyclaspis varians*	NR	X
4	*Exogone rolani*	NR	NR
5	*Cerapus benthophilus*	NR	NR
6	*Streblospio gynobranchiata*	NR	X
7	*Paraprionospio pinnata*	NR	X
8	*Glottidia pyramidata*	NR	NR
9	*Mediomastus sp.*	NR	X
10	*Fabricinuda trilobata*	NR	NR
Rank	**Charlotte Harbor-Intertidal Sands**		
1	*Americhelidium americanum*	NR	NR
2	*Ampelisca agassizi*	NR	X
3	*Laeonereis culveri*	NR	X
4	*Acanthohaustorius uncinus*	NR	NR
5	Oligochaeta	NR	X
Rank	**Charlotte Harbor-Subtidal Sands**		
1	*Acanthohaustorius uncinus*	NR	NR
2	*Oxyurostylis smithi*	NR	X
3	*Mellita tenuis*	NR	NR
4	*Americhelidium americanum*	NR	NR
5	*Amakusanthura magnifica*	NR	X
Rank	**Charlotte Harbor-Intertidal Muds**		
1	*Laeonereis culveri*	NR	X
2	*Leitoscoloplos robustus*	NR	X
3	*Almyracuma nr. proximoculi*	NR	X
4	*Hargeria rapax*	NR	X
5	*Parastarte triquetra*	NR	NR
Rank	**Charlotte Harbor-Subtidal Muds**		
1	*Monticellina dorsobranchialis*	NR	X
2	*Spiochaetopterus oculatus*	X	NR
3	*Tellina sp.*	X	X
4	*Ampelisca holmesi*	NR	X
5	*Bittiolum varium*	NR	X

Some taxa that were abundant in the DARB system during some sampling events, including *Tagelus divisus, Fabriciola sp., Onuphis* sp, and *Terebellides stroemi,* have not been shown to be abundant or common in other regional estuaries. *Tagelus divisus* is a common inhabitant of the lower intertidal zone in bays and protected beaches (Fraser 1967, Britton and Morton 1989, de Arruda and Amaral 2003).

5.2.3 Conclusions

- The benthos of DARB was dominated by species that are successful in relatively high salinity environments.

- The taxon composition of DARB is generally similar to that found in Charlotte Harbor.

- Flow increases and concomitant decreases in salinity during the June 1974 sampling resulted in reduced diversity and abundance in Shakett Creek/Dona Bay.

5.3 Oysters

The eastern oyster *(Crassostrea virginica)* (Figure 5-9) is an ecologically and commercially important benthic macroinvertebrate that occurs throughout the Gulf of Mexico. Oyster beds (or reefs) provide habitat for a variety of marine fauna, including species such as oyster drills, conch, mud crab and several specialized fish that exhibit specific adaptations to oyster beds (Bahr and Lanier 1981, Wells 1961). Improved water quality conditions have been documented downstream from oyster beds (Jones 2005) and may be attributed to the high filter feeding activity of individual oysters, which can filter up to 40 liters of water per day (Volety *et al.* 2003) . Oyster beds also help stabilize the shoreline, thereby contributing to water quality improvement. In parts of the Gulf, oysters are harvested for human consumption.

Figure 5-9. Photograph of an exposed oyster reef and the shell of the eastern oyster *(Crassostrea virginica).*

Water chemistry, in particular salinity, can affect the health of oyster beds. Adult oysters are sessile and live in clumps referred to as reefs or beds (Stanley and Sellers 1986, Bahr and Lanier 1981, Wells 1961). The location of oyster beds (or reefs) is dependent on where larvae settle and on the subsequent survival of the spat, *i.e.*, the juvenile oysters. Larvae establishment is related to substrate characteristics and salinity (Stanley and Sellers 1986). Eastern oysters have specific environmental requirements, including an optimal salinity range of 15-25 ppt (Kennedy *et al.* 1996) and are tolerant of salinity ranging from 2 to 40 ppt (Gunter 1955). Oyster reproduction is, however, limited at salinities below 10 ppt and mortality of most spat will occur if salinity falls below 3 ppt. Most adult oysters will die if exposed for more than a month to water with salinity less than 2 ppt (Kennedy *et al.* 1996). Salinity greater than 30 ppt slows the growth rate of oysters and increases their susceptibility to predation, parasitism and disease (Stanley and Sellers 1986).

Because oysters are ecologically important, sessile as adults, and have specific salinity and substrate requirements, they are often used as ecological indicators in programs established to monitor ecosystem change. For example, a Habitat Suitability Index was developed for the eastern oyster by Mazzotti *et al.* (2006) as part of the Southwest Florida Feasibility Study, which is a component of the Comprehensive Everglades Restoration Plan. Oysters have also been used as indicators for development of Minimum Flows and Levels for the Lower Suwannee River and Estuary (Water Resources Associates 2005) and the Tampa Bypass Canal (SWFWMD 2005a).

Salinity levels in the DARB system prior to construction of Cow Pen Slough and the Blackburn Canal were high enough to support healthy populations of oysters and seagrasses well upstream of the Venice Inlet. Surveys of live oysters and dead shell material indicate that the historic distribution of oysters in Dona Bay was approximately double the range of current populations. Estevez (2005) concluded that the historical range of the oyster population in Dona Bay/Shakett Creek was between rkm 0.5 and rkm 6.0. Currently, the oyster population in this portion of the DARB sytem is distributed between rkm 1.5 and rkm 4.0. In Roberts Bay, Estevez (2005) notes that oyster populations historically reached the eastern side of the railroad bridge, at the District's station RB15.

5.3.1 Estimates of Oysters Coverage

Sarasota County developed an oyster monitoring program to be used as a tool in assessing the success of the County's watershed management practices. Oysters grow near the mouths of most of the tidal creeks in Sarasota County. Because of their immobility, importance as habitat, ability to improve water quality, and responsiveness to environmental fluctuations, oysters are an important indicator of estuarine health and they are relatively easy to monitor (Jones 2005). The status and health of oyster colonies can aid in determining water management problems at the landscape level. Sarasota County established a target of 70% live oysters on oyster reefs.

Oyster beds were delineated in the field using a Trimble GPS and locations were correlated with pixel signatures derived from 2001 aerial photographs of the area (Jones

2005). Approximately 30% of the oyster reefs delineated from the aerial photographs were verified in the field to support aerial photointerpretation of oyster bed coverage, (Jones 2005). The verified aerial photointerpretation method was then used to estimate the historic extent of oyster beds based on 1948 aerial photography. Due to the limited quality of the 1948 photographs, historical oyster beds could only be delineated for areas in the DARB system east of the current U.S. 41 bridges (Jones 2005).

Quantitative monitoring of oysters in DARB system and Lyons Bay by Sarasota County was initiated in October 2003 and the most recent data were collected in September 2006. Six stations were initially established for oyster sampling: one in each of the three bays (Dona-DB1, Lyons-LYB1 and Roberts's Bays-RB1), two stations from Shakett Creek (SKC1 and SKC2), and one from Curry Creek (CC1) (Figure 5-10) (Jones 2007). In 2005, two additional sites were added (one upstream site in Shakett Creek (SKC3) and one upstream site in Curry Creek (CC2)).

Oysters were monitored at the end of the dry season and the end of the wet season. At each sampling station, oysters were collected from within three randomly placed quarter-meter square quadrats. All oysters within the sample quadrats were counted and the number of live, dead and juvenile oysters was recorded. Sample counts were converted to abundances (individuals per m^2) and percentages of live oysters.

5.3.1.1 Summary of Results

Based on a comparison of the 1948 and 2001 aerials, an approximate loss of two acres of oyster coverage occurred between the two time periods (Jones 2003). The historical comparison was limited to areas east of U.S. 41 due to the quality of the 1948 aerial. In this area, approximately 10 acres of oyster bed habitat existed in 1948, compared to 8 acres delineated in 2001 (Jones 2003). Much of the acreage lost can be explained by the filling of a large portion of Roberts Bay (Jones 2003) between the two sets of photographs.

In recent years, oyster abundance and percentage of live oysters have exhibited considerable spatial and inter-annual variation within the DARB system, with less variation evident in Lyons Bay (Figures 5-11 through 5-13 and Tables 5-4 and 5-5). The most upstream sites in Shakett Creek and Curry Creek consistently contained the lowest number of live oysters and typically contained the lowest percentage of live oysters (Tables 5-4 and 5-5). Relatively high numbers of oysters and percentages of live individuals were consistently observed in Lyons Bay (Table 5-5). Stability of the Lyons Bay population could be a function of the relatively stable salinity of the bay, relative to Dona Bay/Shakett Creek and Roberts Bay.

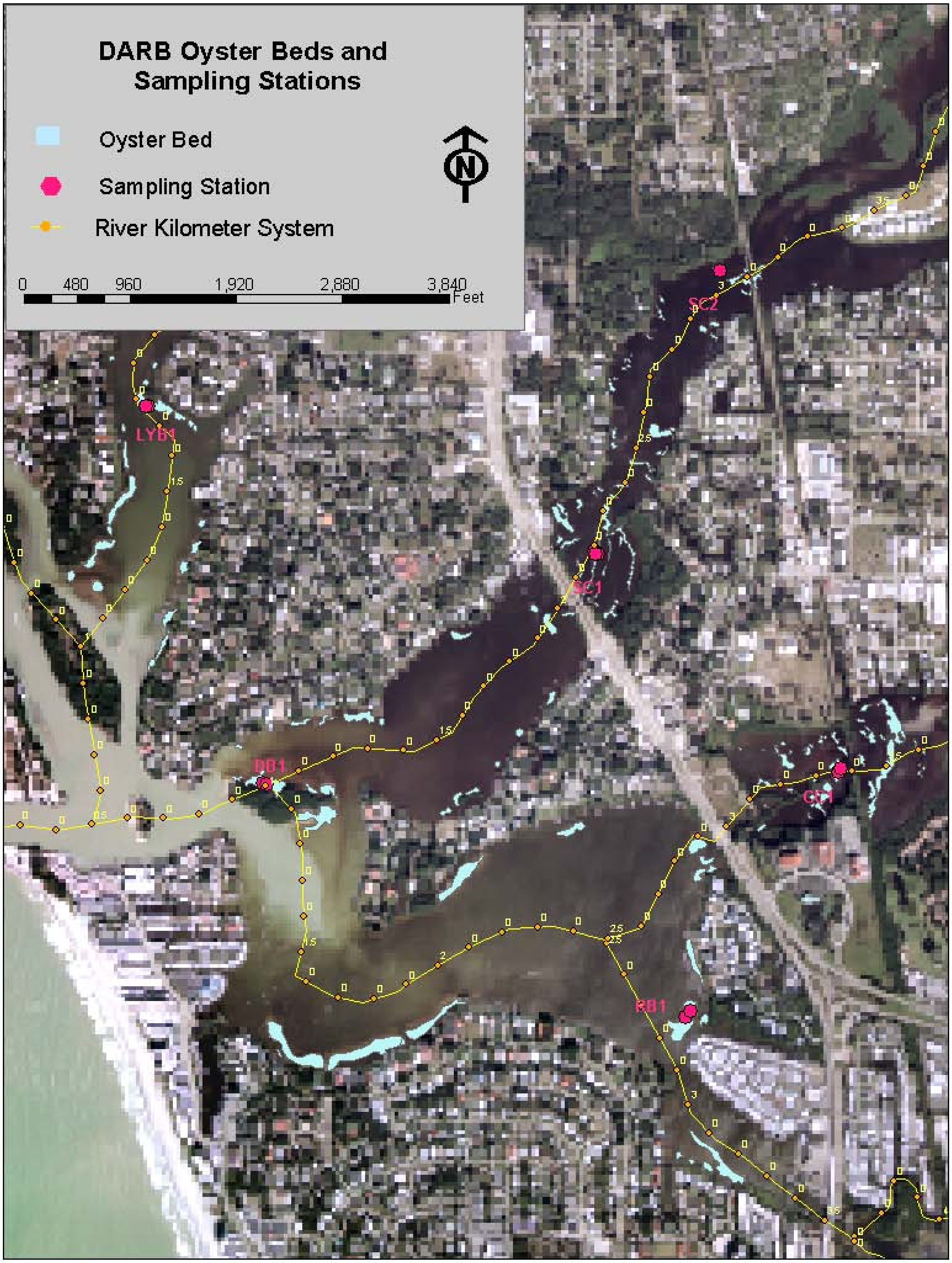

Figure 5-10. Oyster beds and sampling locations in the DARB study area (Source: Jones 2005).

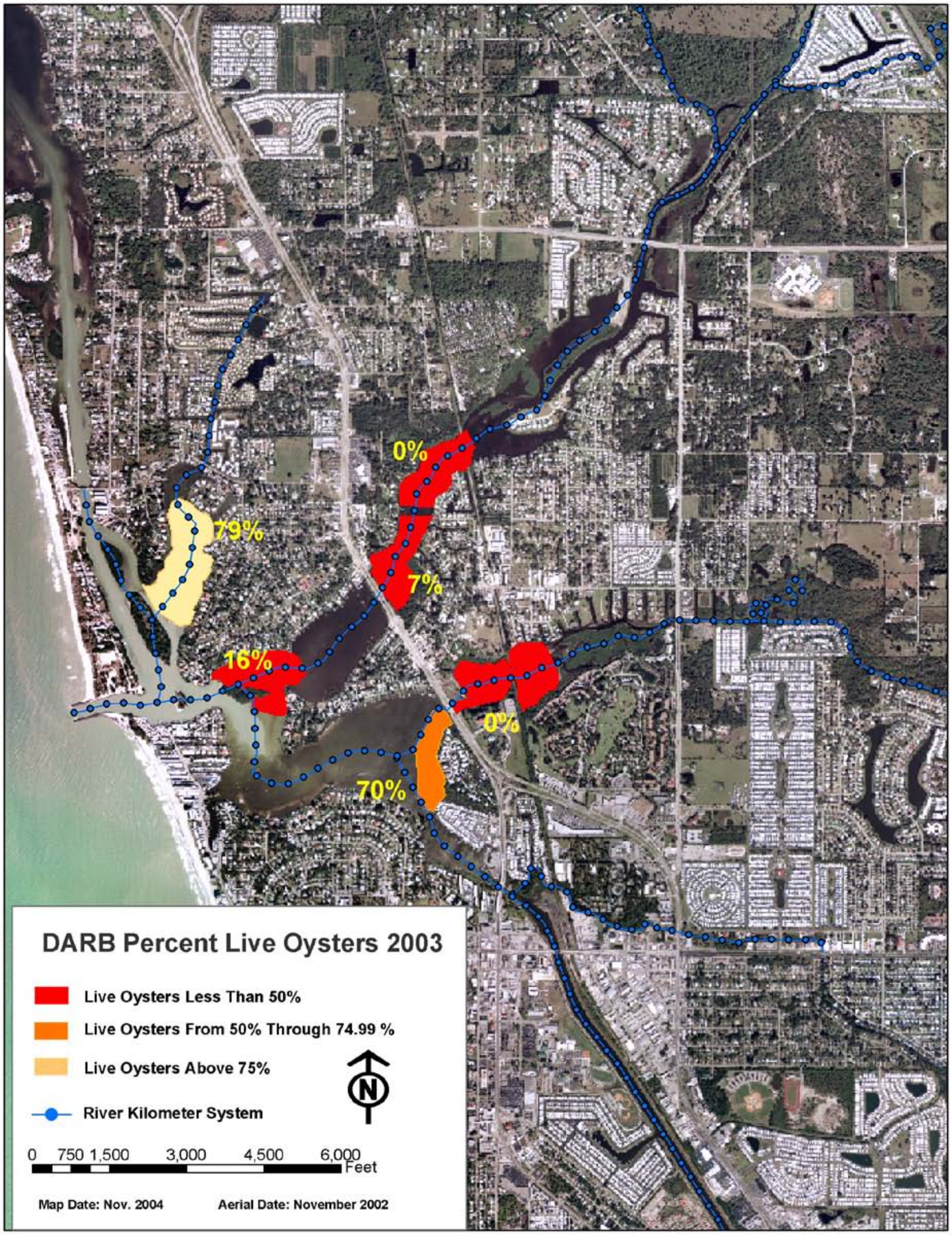

Figure 5-11. **Percent live oysters in oyster beds in the DARB system and Lyons Bay in 2003 (Source: Jones 2005).**

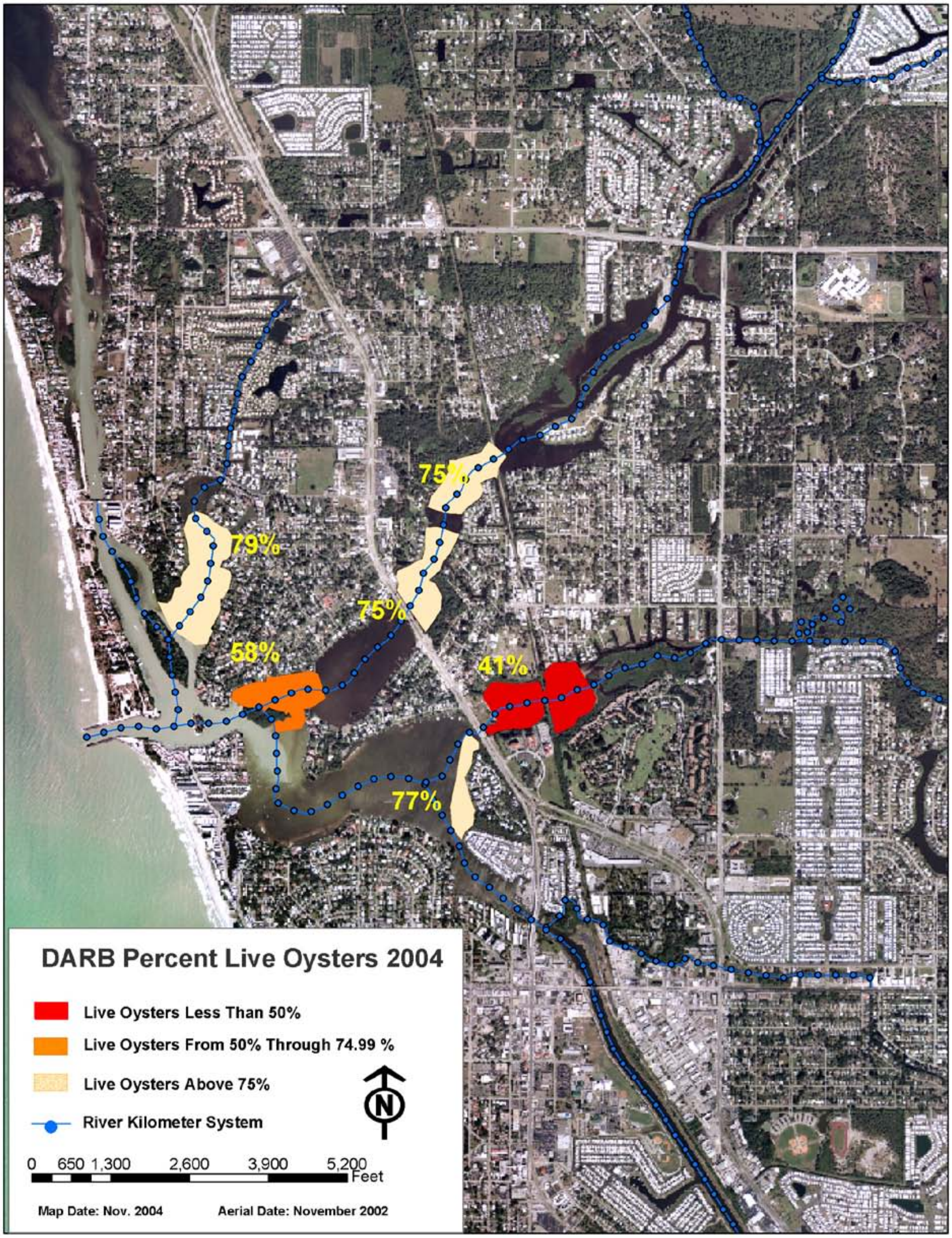

Figure 5-12. **Percent live oysters in oyster beds in the DARB system and Lyons Bay in 2004 (Source: Jones 2005).**

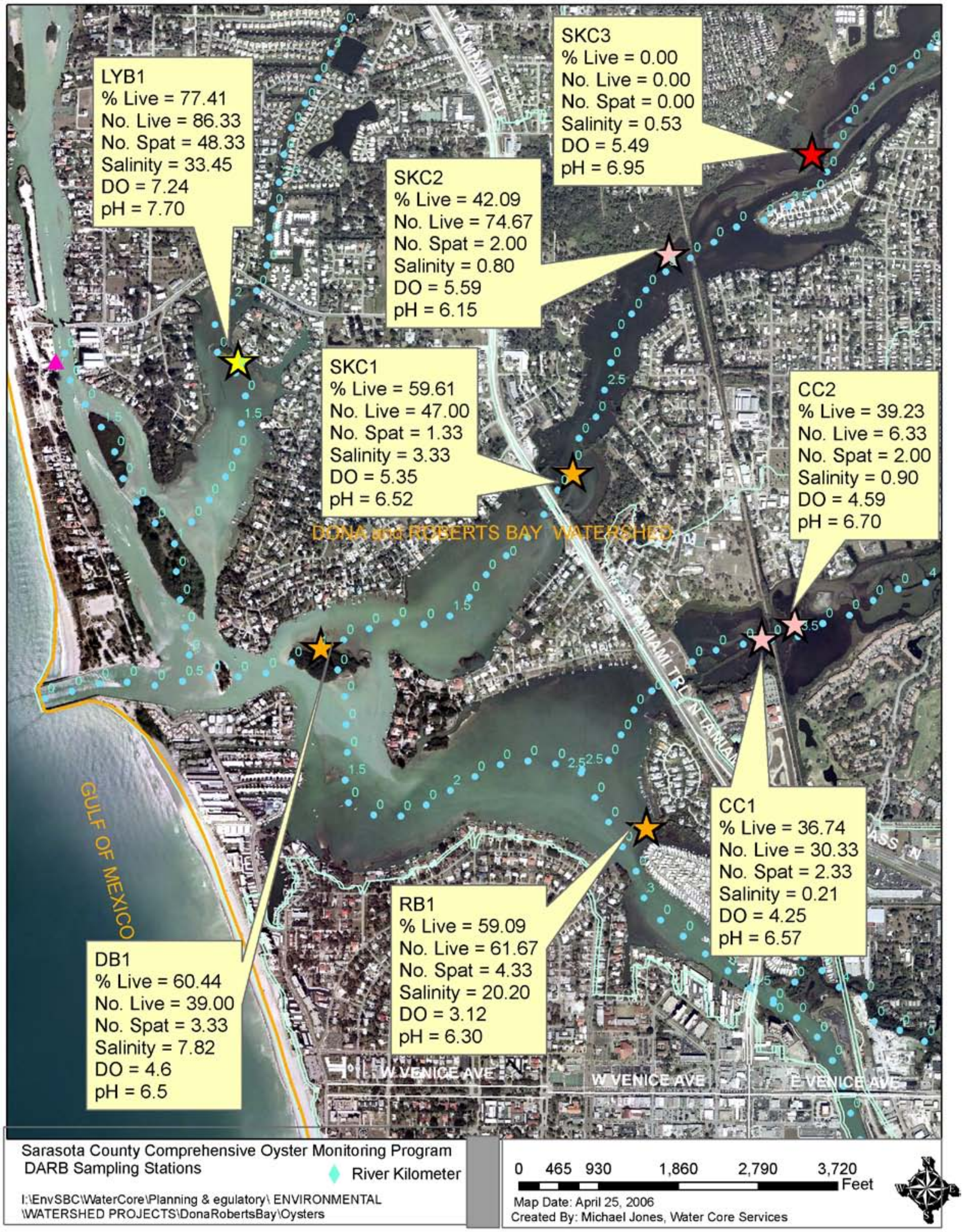

Figure 5-13. DARB System and Lyons Bay Oyster Monitoring Site Locations and 2006 Results (Source: Jones 2007). The percentage of live oysters (% Live) is listed for each station for comparison with results for 2003 and 2004 presented in Figures 5-12 and 5-13.

Table 5-4. Number of live oysters (individuals per quarter-m^2) at 8 stations (LYB1, DB1, etc.) sampled from October 2003 trough September 2006 and mean station abundance values (Source: Jones 2007). Sites SKC3 and CC2 were not sample prior to April 2005.

	LYB1	DB1	SKC1	SKC2	SKC3	RB1	CC1	CC2
Oct-03	109	14	7	0		38	0	
Apr-04	92	51	80	81		30	43	
Oct-04	113	81	126	113		94	41	
Apr-05	141	50	73	113	12	136	69	4
Sep-05	132	65	116	9	1	119	22	0
Apr-06	111	434	75	81	33	112	93	13
Sep-06	86.	39	47	75	0	68	30	6
AVG.	**112**	**49**	**75**	**67**	**11**	**85**	**43**	**6**

Table 5-5. Percentage of live oysters at 8 stations (LYB1, DB1, etc.) sampled from October 2003 trough September 2006 and mean station percentage values (Source: Jones 2007). Sites SKC3 and CC2 were not sample prior to April 2005.

	LYB1	DB1	SKC1	SKC2	SKC3	RB1	CC1	CC2
Oct-03	79	16	7	0		70	0	
Apr-04	74	51	80	70		76	39	
Oct-04	83	65	71	80		79	44	
Apr-05	82	81	90	93	68	78	73	16
Sep-05	78	74	86	10	4	68	35	0
Apr-06	74	68	78	83	79	83	75	57
Sep-06	77	60	60	42	0	59	37	39
AVG	**78**	**59**	**67**	**54**	**38**	**73**	**43**	**28**

Comparison of numbers and percentages of live individuals from 2003 through 2004 illustrates the dynamic nature of oyster populations in the DARB system. In 2003, sampled oyster beds in Dona Bay contained 0 to 16 % live oysters (Jones 2003). In the lower portion of Roberts Bay in 2003, oyster beds were reported to include 70% live oysters, but no live oysters were observed at the site upstream of the U.S. 41 bridge (Jones 2003). In 2004, oyster beds in Dona Bay made dramatic improvements, ranging from 51 to 80% live oysters at the three sampled sites. Oyster beds in the lower portion of Roberts Bay increased from 70 up to 79% live oysters from 2003 to 2004, while the oyster beds in the upper portion of Roberts Bay increased from 0 up to 43% live oysters. In both 2003 and 2004, oyster health in Lyons Bay remained consistent at 79-83% live oysters (Jones 2005).

Changes in oyster abundance and percentage of live individuals also occurred in portions of the DARB system from 2004 through 2006. For example, numbers of individuals and live percentages in Shakett Creek and the upper portion of Roberts Bay declined sharply from April to September in 2005 and 2006. Seasonal changes during these two years were less pronounced in Dona Bay and the lower portion of Roberts Bay and even less substantial in Lyons Bay.

Previous studies have also documented highly variable oyster populations in the DARB system. A 1982 survey conducted by Sarasota County found no live oysters in Curry Creek, Shakett Creek or Dona Bay. In the following year, however, Sauers (1983) noted the occurrence of live oysters throughout DARB system. An oyster relocation project conducted in Shakett Creek documented an increasing trend in abundance and a mid-study peak in abundance (Ed Barber and Associates 2003).

While oyster mapping from 2003 and 2004 showed an increase in the percentage of live oysters in Dona and Roberts Bay, the 2006 monitoring data showed an overall decline. In all years, Lyons Bay has remained relatively consistent in terms of oyster beds and percent live oysters.

5.3.2 Conclusions

- The percent of live oysters in the DARB system varies considerably from year to year. Comparison of oyster abundance from 1948 and 2001, indicated that recent oyster coverage in the estuary has been reduced by approximately two acres in Roberts Bay. In 2003, sampled oyster beds in both Dona Bay and Roberts Bay contained relatively few live individuals with percentages of live individuals ranging from 0 to 70%. In 2004 the percentage of live oysters increased to between 30-80% in the DARB system. Differences in oyster population parameters were also observed from 2004 through 2006, with the greatest changes observed for Shakett Creek and upstream portions of Roberts Bay.

- Lyons Bay had the most consistent oyster coverage throughout the monitoring period. Stability of the Lyons Bay oyster population could be a function of the relatively low freshwater input to the bay, relative to Dona Bay/Shakett Creek and Roberts Bay.

5.4 Fish

Fisheries yields around the world have been positively correlated with freshwater discharge near the coast (Drinkwater 1986). Freshwater inflow influences the salinity of an estuarine system. The physiological challenges and stresses associated with variable salinity environments affect the presence, absence, and range of fish species. Osmotic limitations restrict the ability of many freshwater species from using habitat in downstream portions that are tidally influenced. Marine species also face osmotic problems, which restrict access to upstream freshwater habitats that are low in salinity. However, numerous euryhaline species exist that have adaptations that allow them to live within a wide range of salinity conditions. Many species, including estuarine-dependent fish, rely on different habitats/salinity zones, during different life stages.

While the distribution of a given fish species within an estuary is determined in large part by salinity, species able to tolerate saline conditions may still be affected by salinity-related stressors. Species typically have an optimal salinity that is somewhere within the range of salinity that they may be able to tolerate. The salinity in which the eggs, larval, or juvenile forms of certain species develop may impact their growth and survival rates. It will also affect the availability of prey and where adults of the species congregate and forage. The composition of the fish community in a tidal system is likely to change based on the salinity regime.

Freshwater flow influences a large number of other physical/chemical parameters that may affect estuarine fish. Decreased freshwater inflow may be associated with decreased dissolved oxygen concentrations resulting from increased water residence time and stratification of the water-column. Increased freshwater inflow may also be associated with decreased oxygen levels as a result of increased nutrient and sediment loading and increased water color and turbidity. Changes in flow may also directly impact fish by increasing or decreasing the amount of available habitat or resources used for feeding, cover or reproductive activities.

Other physical factors influenced by flow include depth, velocity, substratum, and residence time. Water depth influences two physical factors relevant to fish, habitat availability and structure, and dissolved oxygen. Available habitat expands as water levels increase and additional areas adjacent to the edge of the river become inundated. Accessibility to these habitats also changes with water depth, as increasing depth allows larger sized fish to enter into areas typically restricted only to the smallest fish. As water depth increases, the volume of certain habitats increases as well. Dissolved oxygen also changes with depth. Typically dissolved oxygen is lower in bottom waters than in surface waters due to influx from the atmosphere and possible lack of mixing and stratification in the bottom waters.

The magnitude and timing of freshwater inflows affects the amount of nutrients and organic matter that enters a waterway, such that increased productivity may occur some time after a period of increased flows (Kalke and Montagna 1989, Bate *et al.* 2002). Sediment loads to a water body are also increased during high flows. Loadings of contaminants, including metals and organic compounds that bind to smaller particles are often associated with increased sediment loads.

Residence time affects the ability of phytoplankton to uptake nutrients, as well as the ability for secondary producers to consume phytoplankton. This extends to other consumers as well. Higher flows are associated with increased nutrient loading. Low flow also allows a longer residence time for chlorophyll and nutrients. During high flow conditions, flushing is more rapid and residence time is reduced (Jassby *et al.* 1995, Flannery *et al.* 2002).

5.4.1 Fish Study Design

To support development of minimum flows for Dona Bay/Shakett Creek, the District funded a study of patterns of fish habitat use and abundance under variable freshwater inflow conditions in the DARB system and Lyons Bay by the University of South Florida and the Florida Fish and Wildlife Research Institute (Peebles *et al.* 2006). The study involved extensive field sampling with the goal of developing explanatory regression models relating inflow/salinity to fish population parameters. Data collection efforts also yielded information on selected invertebrates, including commercially important species and important prey for juvenile estuarine-dependent and estuarine-resident fishes. Data derived from the study were intended to serve as a descriptive baseline against which future ecological change may be measured. The baseline data were also developed to provide a record of seasonality associated with the presence of dominant taxa within the estuary and thereby aid in identification of times of the year when the potential risk of adverse impacts would be greatest for specific organisms (Peebles *et al.* 2006).

For the study, five collection zones were identified in the DARB system and Lyons Bay, with the zones in Dona Bay and Roberts Bay delineated using the river kilometer system described previously (Table 5-6; Figure 5-14). Sampling was initiated in March 2004 and continued through June 2005. Sampling included two seine hauls and two trawl deployments conducted during daylight under variable tide conditions on a monthly basis in each zone. Shallow areas were sampled with a bag seine and deeper (channel) areas were sampled with an otter trawl. Plankton-net tows were conducted monthly at night during high tide periods in each zone, except for Zone 1 in Dona Bay, where three tows were conducted monthly. Locations for seine and trawl tows within each zone were selected randomly; plankton-net samples were collected at fixed locations.

Table 5-6. Summary of distribution of sampling effort in the DARB study area; zone positions relative to river mouth (Source: Tables 2.2.1 in Peebles *et al.* 2006).

Location	Plankton	Seine	Trawl
Lyons Bay	16	32	16
Roberts Bay	32	32	16
0.1-3.0 km Dona Bay	48	32	16
3.0-5.0 km Dona Bay	32	32	16
5.0-6.4 km Dona Bay	32	32	16
Totals	160	160	80

Salinity, water temperature, dissolved oxygen, and pH measurements were recorded at 1-meter intervals from the surface to the bottom of the water column during each net (plankton-net, seine or trawl) deployment. These data were used to evaluate distributional and abundance patterns of sampled taxa within the estuary as a function of freshwater inflow as measured at the CPS2 structure gauging station or the Blackburn Canal near Venice gauging station. Distributional responses were evaluated by examining linear relationships between the center of abundance (km_u, based on the river kilometer system for the DARB system) for individual taxa or pseudo-species (*i.e.*, taxa subdivided by appropriate size classes) and inflow for seines and trawls. Linear relationships between total abundances of taxa in plankton-net, seine and trawl samples were also examined.

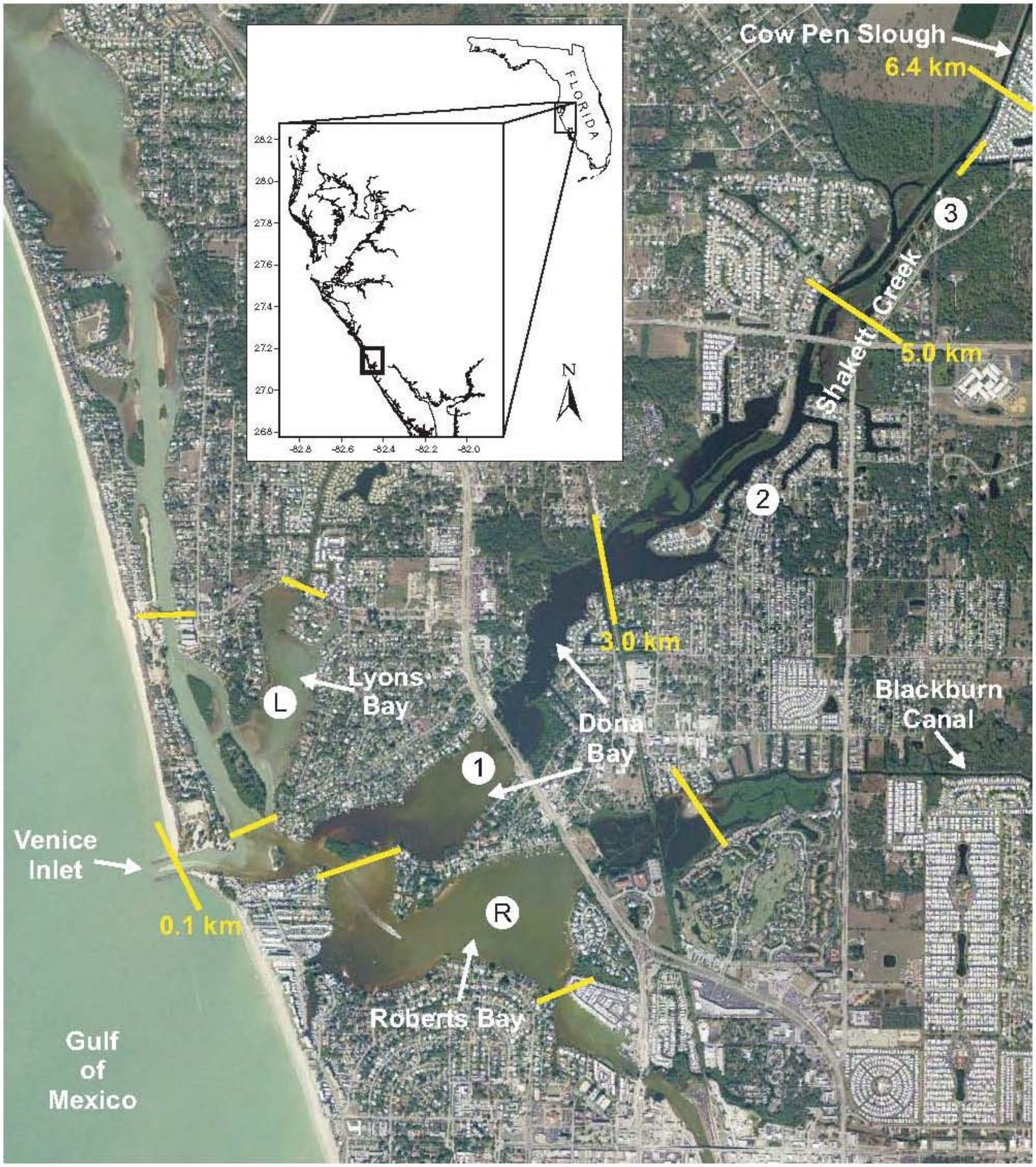

Figure 5-14. **Location of fish study collection zones in the DARB system and Lyons Bay (Source: Peebles *et al.* 2006).**

5.4.2 Fish Study Results

5.4.2.1 Dominant Fish Catch

The plankton-net larval fish catch was dominated by larval gobies (with the genus *Gobiosoma* being more dominant than *Microgobius*) and anchovies (dominated by bay anchovy, *Anchoa mitchilli*) (Peebles *et al.* 2006). Other common fish in the plankton-net samples included scaled sardine *(Harengula jaguana*), mojarras *(Eucinostomus spp.)*, freshwater shads *(Dorosoma spp.)* and sand seatrout *(Cynoscion arenarius)*. The gobies, anchovies and other common species represented over 95% of the plankton-net fish catch, if fish eggs were excluded from the abundance total.

The seine-net fish catch was dominated by the bay anchovy (*Anchoa mitchilli*), mojarras (*Eucinostomus spp*.), scaled sardine (*Harengula jaguana*), Spanish sardine (*Sardinella aurita*), silversides (*Menidia spp*.), Cuban anchovy (*A. cubana*), pinfish (*Lagodon rhomboides*), silver jenny (*Euncinostomus gula*), and tidewater mojarra (*Eucinostomus harengulus*). These species comprised 94% of the total seine catch.

The trawl fish catch was dominated by mojarras (*Eucinostomus spp.*), pinfish (*Lagodon rhomboides*), silver jenny (*Eucinostomus gula*), and Cuban anchovy (*A. cubana*). These species represented over 94% of the total trawl fish catch.

5.4.2.2 Dominant Invertebrate Catch

Invertebrates in the plankton-net samples were dominated by larval crabs (decapod zoeae), the mysid *Americamysis almyra*, gammaridean amphipods, the planktonic copepods *Acartia tonsa* and *Labidocera aestiva*, the planktonic shrimp *Lucifer faxoni*, chaetognaths and the larvacean *Oikopleura dioica* (Peebles *et al.* 2006). These taxa comprised 80% of the invertebrate plankton-net catch.

The seine net invertebrate catch was dominated by daggerblade grass shrimp (*Palaemonetes pugio*), pink shrimp (*Farfantepenaeus duorarum*), and blue crab (*Callinectes sapidus*). These species represented 94% of the seine invertebrate catch.

The trawl invertebrate catch was dominated by pink shrimp, longtail grass shrimp (*Periclimenes longicaudatus*), and blue crab. These species represented over 85% of the total invertebrate trawl catch.

5.4.2.3 Use of the DARB system as Spawning Habitat

The presence of fish eggs and newly hatched larvae indicate the DARB system is used as spawning habitat (Peebles *et al.* 2006). Eggs of the following species were found in the study area, specifically in Roberts Bay and Venice Inlet: unidentified herrings (clupeids), the scaled sardine (*Harengula jaguana*), the Atlantic thread herring (*Opisthonema oglinum*), the bay anchovy (*Anchoa mitchilli*), the striped anchovy (*A. hepsetus*), and unidentified sciaenid fishes. The following sciaenid fishes are thought to spawn within the sampled area due to the abundance of early larvae, *i.e.* young or small larval stages: the silver perch (*Bairdiella chrysoura),* seatrouts (*Cynoscion arenarius* and *C. nebulosus*) and kingfishes (*Menticirrhus spp*.). Early larvae were most abundant in Roberts Bay and near Venice Inlet. Blennies (blenniids) and the hogchoker (*Trinectes maculatus*) spawned near Venice Inlet and potentially in other seaward parts of the sampled area. Skilletfish (*Gobiesox strumosus*) and gobies (*Bathygobius soporator, Gobiosoma spp.,* and *Microgobius spp*.) spawned within upper Dona Bay and Shakett Creek. Small juveniles of the live-bearing gulf pipefish (*Syngnathus scovelli*), chain pipefish (*S. louisianae)* and lined seahorse (*Hippocampus erectus*) were collected repeatedly, indicating that these species reproduce within or near the study area (Peebles *et al.* 2006).

5.4.2.4 Use of the DARB as Nursery Habitat

A number of estuarine-dependent nearshore or offshore-spawning fish and invertebrate taxa used the study area as nursery grounds (Peebles *et al.* 2006). Seven of the ten most abundant taxa collected with the seine, which was used to sample shallow nearshore habitat, could be considered estuarine-dependent. Six of the ten most abundant taxa in the trawl nets, which were used to sample deeper, offshore habitat, could be considered estuarine-dependent. The identified estuarine-dependent taxa include those of ecological importance due to high abundance (*i.e.*, pinfish, mojarras, tidewater mojarra, and silver jenny) and those of commercial importance (*i.e.*, blue crab and pink shrimp). The non-estuarine-dependent taxa were either estuarine spawners or tidal river residents.

5.4.2.5 Seasonality

Species richness based on taxa sampled with the plankton-net was greater in the warmer months than during the winter (Figure 5-15) (Peebles *et al.* 2006). Diversity was higher near the seaward ends of coastal embayments due to the presence of marine species, and also at upstream areas due to the occurrence of freshwater species. Overall, the middle reaches had the lowest diversity. Variations in the flow regime could cause species richness to vary longitudinally within the sampled areas.

The analysis of plankton-net data and flow data indicated that alteration of flows would have the lowest potential impact for many taxa from November through February, which is the time period when the fewest taxa are present (Figure 5-16) (Peebles *et al.* 2006). June through October represents the time period of greatest potential impact for many species, based on their presence in the estuary. Many species collected with the plankton-net displayed seasonal spawning and recruitment patterns, whereas others, such as the bay anchovy, were present throughout the year.

Few clear seasonal patterns of taxa richness were evident in the DARB system or Lyons Bay based on the seine or trawl catches (Figure 5-17) (Peebles *et al.* 2006). Monthly taxa richness, based on the seine collections, was highly variable with no consistent patterns during the study period (Figure 5-17). Monthly taxa richness based on the trawl data showed higher taxon richness between November and February. Overall fish abundances (Figure 5-18) and the abundance of new recruits (Figure 5-19) indicate that the study area is used extensively during all months. Fish abundance peaked for tidal-river residents in late spring/early summer (Figure 5-18). Abundance peaked for estuarine and nearshore spawners (seine net) in the summer, while the abundance of offshore spawners (trawl net) peaked in winter and late spring (Figure 5-18). For new recruits, peak recruitment periods exhibited variation between life-history stages: estuarine spawners recruitment peaks were in spring and summer, resident recruitment peaks were in late spring and winter, offshore spawners tended to recruit in winter and late summer, while nearshore spawners peak in summer and winter (Figure 5-19).

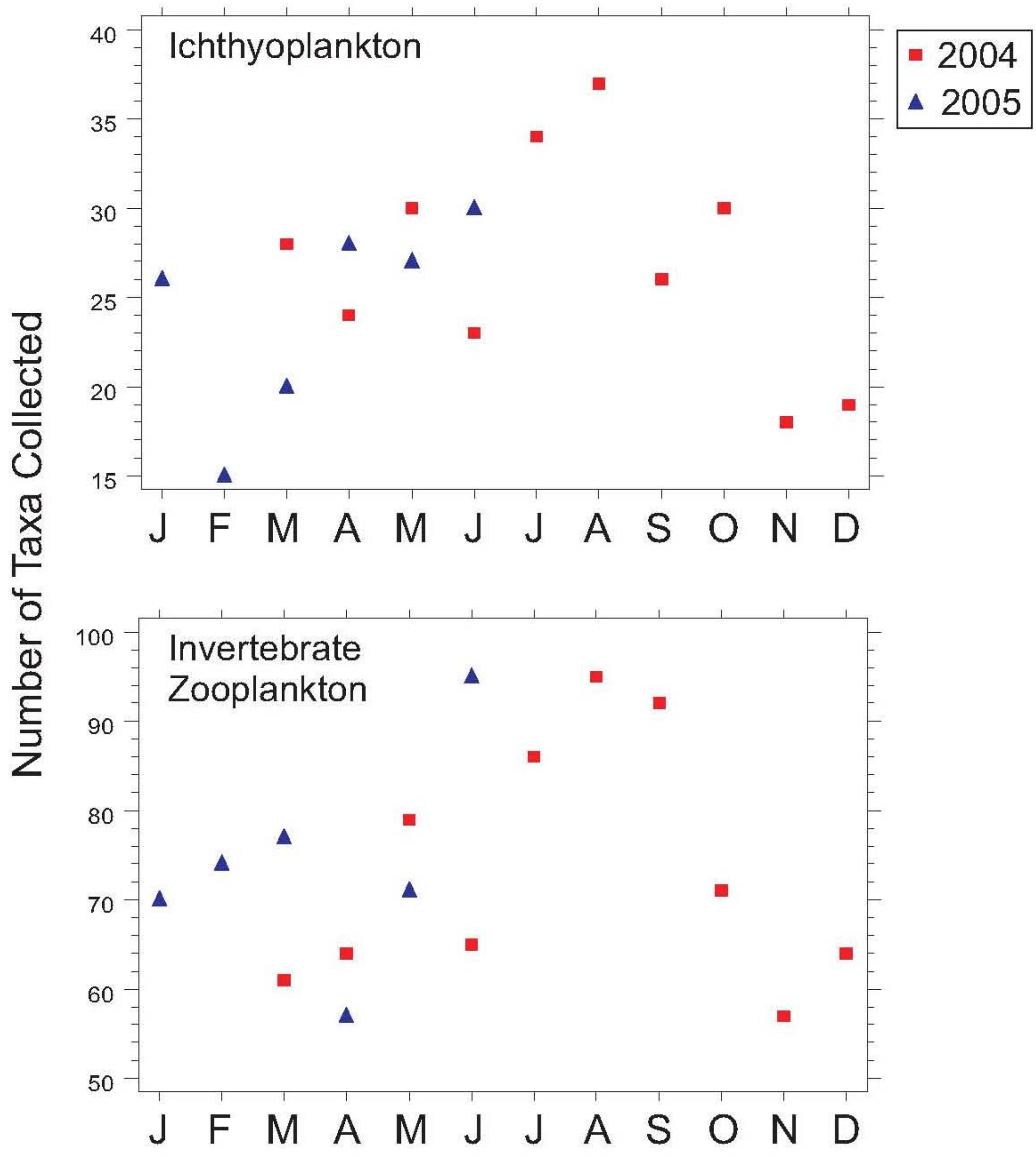

Figure 5-15. Number of taxa collected by plankton net per month in the DARB system (Source: Peebles *et al.* 2006).

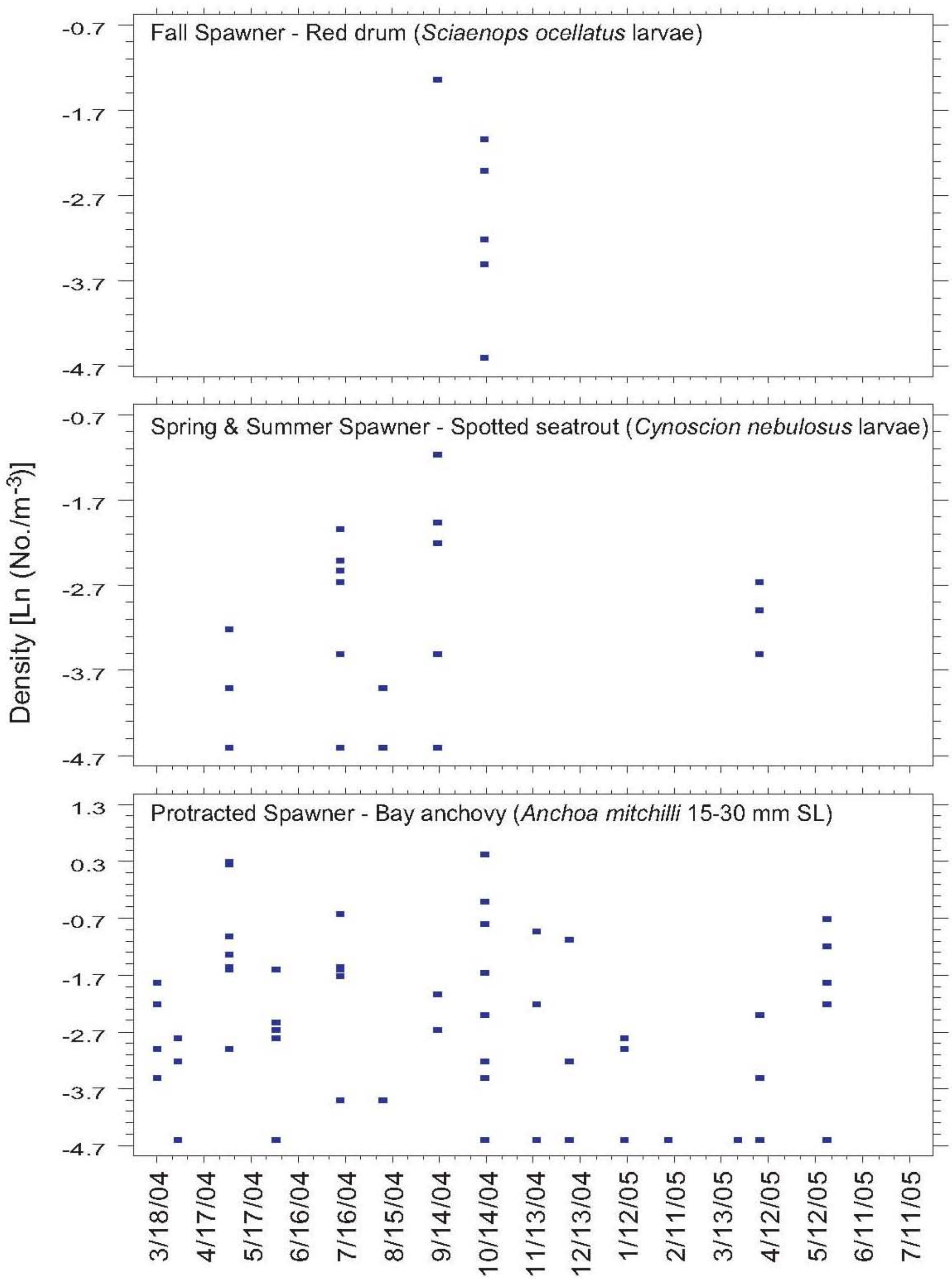

Figure 5-16. **Examples of species specific seasonal abundance based on plankton net samples (Source: Peebles *et al.* 2006).**

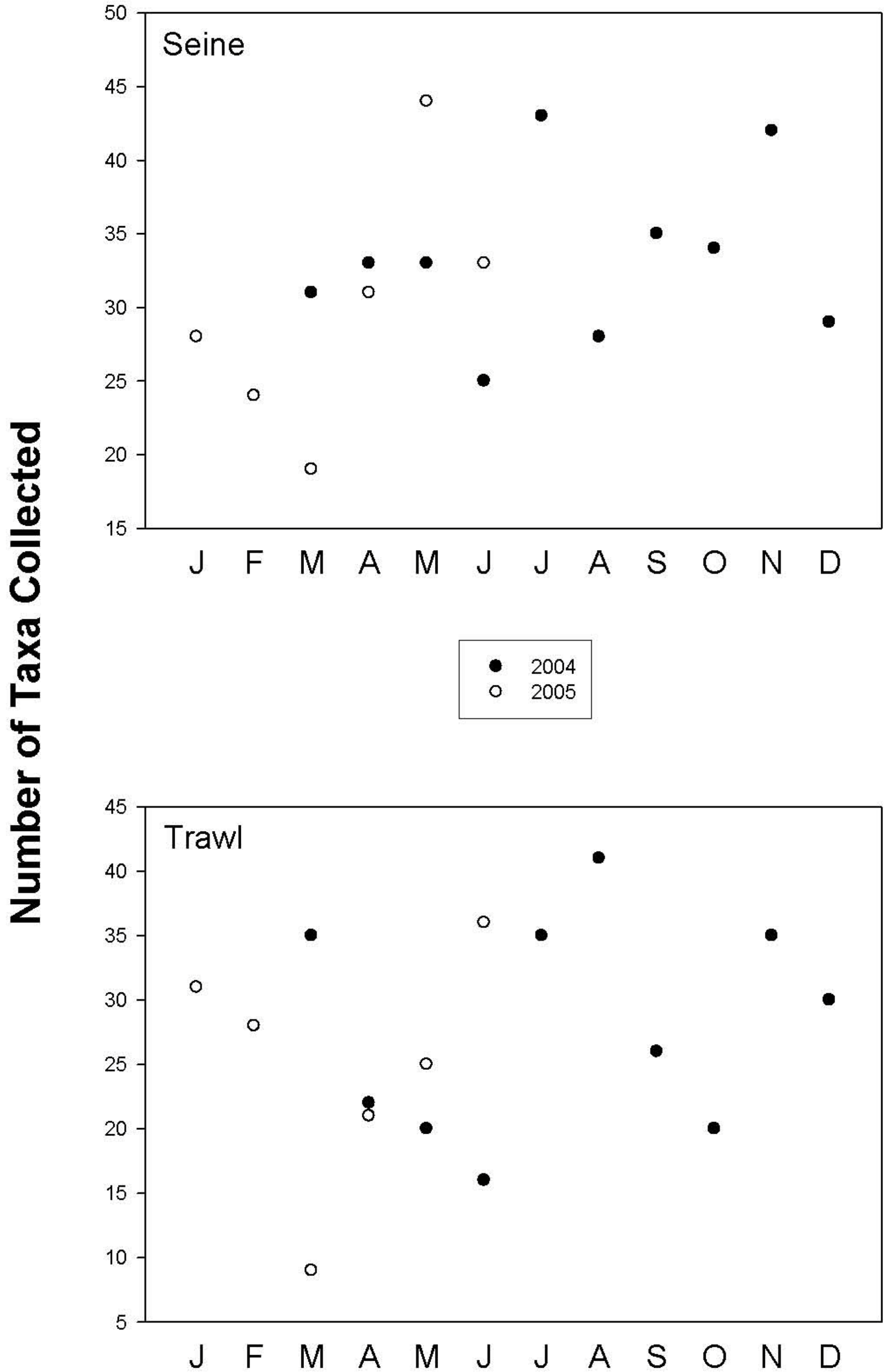

Figure 5-17. **Number of seine and trawl taxa collected by month in the DARB system (Source: Peebles *et al.* 2006).**

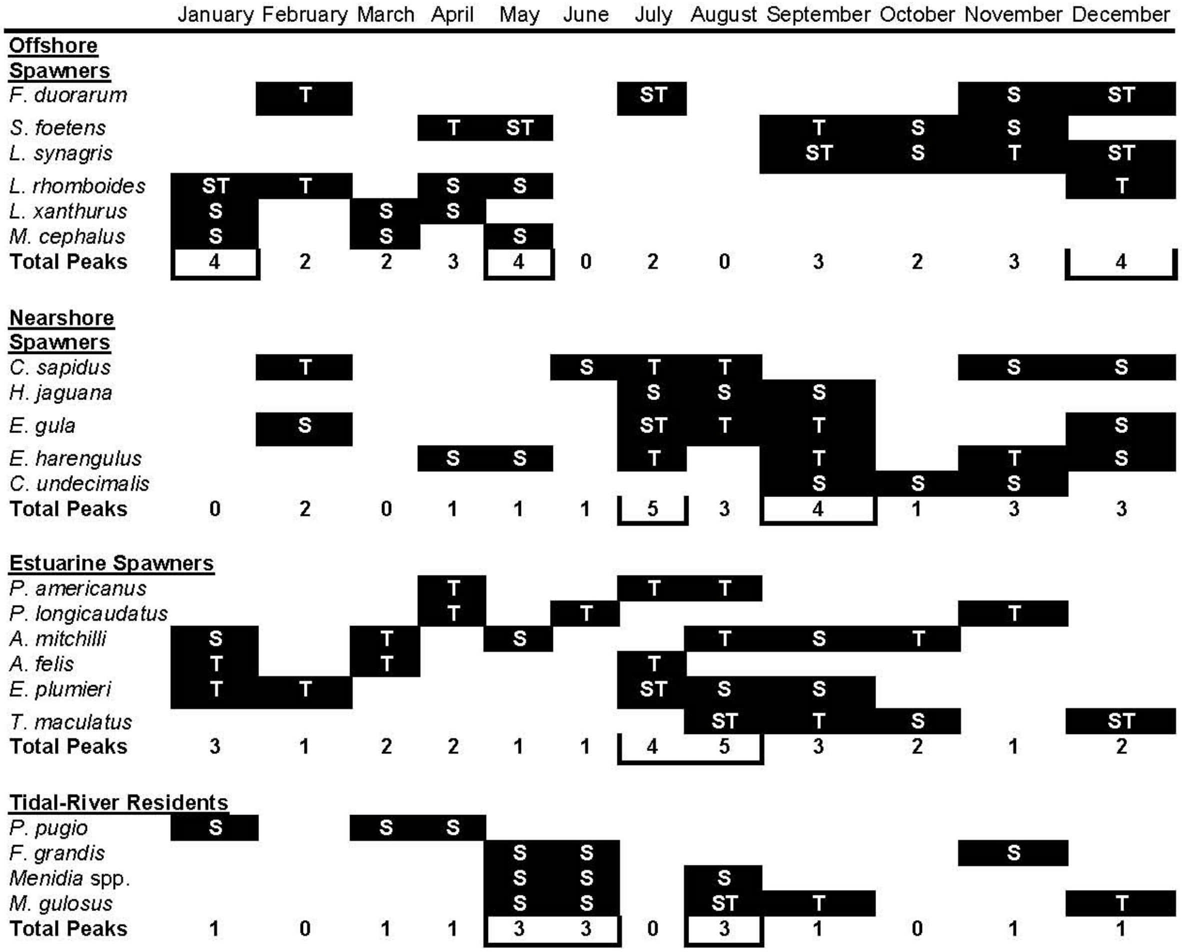

Figure 5-18. Top months of relative abundance for all individuals (fish and invertebrates) collected in seines (S) and trawls (T). Note that spawning location is uncertain for some species, and may shift between nearshore and estuarine areas depending on local conditions. Bracketed total peak values indicate months of peak abundance. (Source: Peebles *et al.* 2006).

5.4.2.6 Distributional Responses to Flow

Nearly 50% of the plankton-net taxa (28 out of 57 taxa) evaluated for distributional responses to freshwater flow (as discharge from CPS2) had significant responses (Table 5-7) (Peebles *et al.* 2006). All responses were negative, meaning animals moved upstream as flow decreased. Variable time lags were associated with the distributional responses, but most taxa adjusted to flow changes within days or weeks. Significant responses had r^2 values, adjusted as percentages, ranging from 24-89%; nearly half of the significant responses had r^2 values >50%. Taxa that were strong responders were generally estuarine, rather than freshwater taxa (Peebles *et al.* 2006).

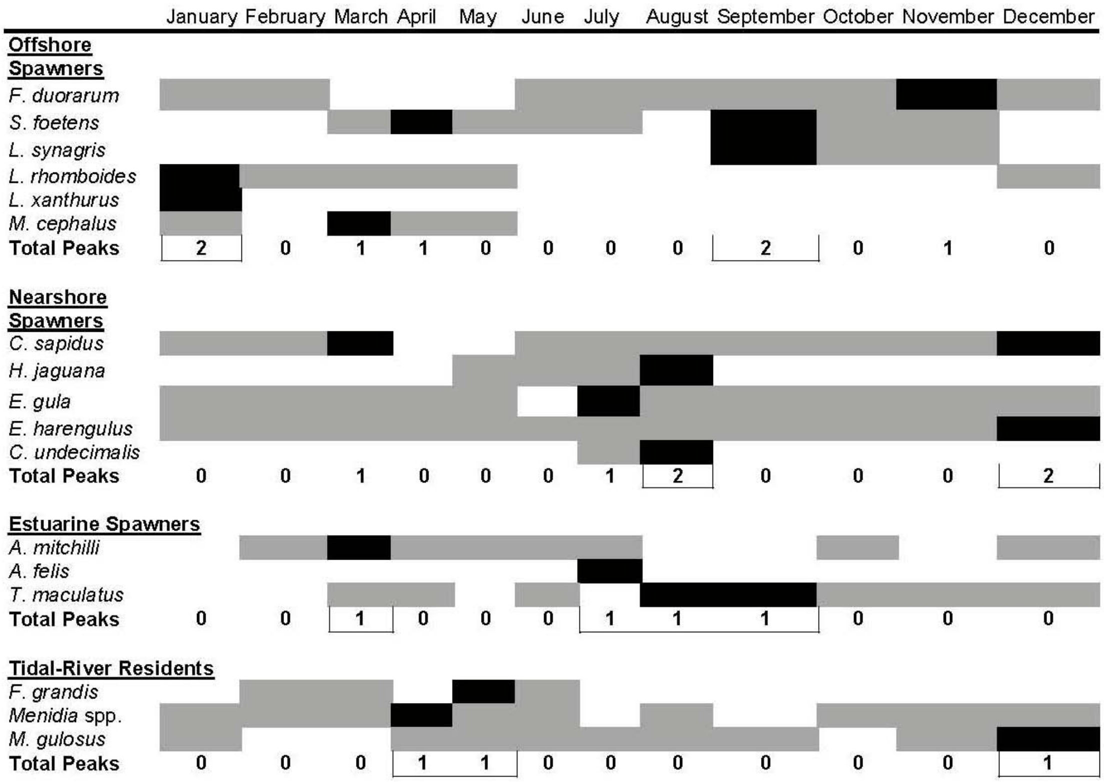

Figure 5-19. Months of occurrence (gray) and peak abundance (black) for new recruits collected by seine and trawl. Note that spawning location is uncertain for some taxa, and may shift between nearshore and estuarine areas depending on local conditions. Brackets indicate months of peak abundance. (Source: Peebles *et al.* 2006).

Based on the seine and trawl data, nearly 60% of the 19 pseudo-species/gear combinations (referred to as “pseudo-species”) evaluated for distributional responses to flow had a significant response to at least one lagged flow period (Table 5-8, Figure 5-20) (Peebles *et al.* 2006). In general, the longer lag periods were associated with the best models. Just under half (45%) of the significant responses were negative (animals moved upstream as flow decreased). This result differs from observations made in other studies, where the vast majority of significant responses were negative (Peebles 2002, Greenwood *et al.* 2004, MacDonald *et al.* 2005). Generally during periods of high flow, organisms move downstream, as areas of suitable salinity or food resources shift. In this study, the majority of sampling events occurred at below average flows. Peebles *et al.* (2006) hypothesized that because inflows were so low during the study, that the relatively small quantities of freshwater flow may have had the effect of attracting many animals upstream towards freshwater resources rather than downstream into higher salinity areas.

Table 5-7. Plankton-net organism distribution (km_u) responses to mean freshwater inflow (Ln*F*+1), ranked by linear regression slope. Other regression statistics are sample size (*n*), intercept (*int.*), slope probability (*P*) and fit (adjusted r^2 as %). *DW* identifies where serial correlation is possible (x indicates $p<0.05$ for Durbin-Watson statistic). *D* is the number of daily inflow values used to calculate mean freshwater inflow. (Source: Peebles *et al.* 2006).

Description	*Common Name*	*n*	*Int.*	*Slope*	*P*	r^2	*DW*	*D*
Lucifer faxoni juveniles and adults	shrimp	16	0.392	-0.049	0.030	24		1
Hippolyte zostericola postlarvae	zostera shrimp	16	0.535	-0.075	0.032	24		99
chaetognaths, sagittid	arrow worms	16	0.921	-0.159	0.000	67		1
Sarsiella zostericola	ostracod, seed shrimp	11	1.484	-0.233	0.040	32		6
Cassidinidea ovalis	isopod	15	4.660	-0.300	0.005	43		1
decapod mysis	shrimp larvae	16	3.224	-0.398	0.034	23	x	6
amphipods, gammaridean	amphipods	16	4.375	-0.403	0.000	61		8
alphaeid postlarvae	snapping shrimps	13	2.090	-0.423	0.042	26		28
cumaceans	cumaceans	16	2.586	-0.430	0.019	29		120
blenniid preflexion larvae	blennies	11	2.816	-0.440	0.019	41		1
branchiurans, Argulus spp.	fish lice	15	3.373	-0.464	0.013	35		63
Microgobius spp. postflexion larvae	gobies	13	5.833	-0.524	0.023	33		5
decapod zoeae	crab larvae	16	3.766	-0.530	0.004	42		5
dipteran, Chaoborus punctipennis	phanton midge	13	6.843	-0.537	0.000	89		9
Taphromysis bowmani	mysid, opossum shrimp	12	5.625	-0.539	0.017	39		3
Anchoa mitchilli juveniles	bay anchovy	15	5.776	-0.548	0.013	34		21
Edotea triloba	isopod	16	5.814	-0.559	0.000	72		9
unidentified Americamysis juveniles	mysid, opossum shrimp	16	5.687	-0.564	0.000	73		10
Americamysis almyra	mysid, opossum shrimp	16	6.061	-0.590	0.000	63		11
gobiid preflexion larvae	gobies	16	5.054	-0.600	0.002	49		9
Microgobius spp. flexion larvae	gobies	14	5.555	-0.608	0.002	52		7
Bowmaniella dissimilis	mysid, opossum shrimp	15	4.156	-0.642	0.000	61		11
Palaemonetes spp. postlarvae	grass shrimps	16	5.359	-0.659	0.000	61		9
Sphaeroma terebrans	isopod	16	6.361	-0.685	0.001	56		84
Gobiosoma spp. postflexion larvae	gobies	15	5.967	-0.708	0.002	51		8
Palaemonetes pugio juveniles	daggerblade grass shrimp	13	5.855	-0.722	0.005	49		56
cymothoid sp. a (Lironeca) juveniles	isopod	12	4.064	-0.723	0.005	53		56
gobiid flexion larvae	gobies	16	5.779	-0.740	0.000	64		8

5.4.2.7 Abundance Responses to Freshwater Flow

Twenty-eight percent (16 out of 57) of the plankton-net taxa showed significant responses for abundance relationships with freshwater flow (Table 5-9) (Peebles *et al.* 2006). Of the sixteen significant responses, six were positive and ten were negative. Nine out of the ten negative responses exhibited significant movement downstream in response to flow, suggesting their reductions in abundance might be associated with movement into the Gulf or lateral bays. Four of the six taxa with positive responses were insect larvae that are primarily freshwater species. These taxa were introduced to the study area by freshwater inflow and this may account for the positive response. Two estuarine taxa, preflexion anchovy larvae and the tanaid *Hargeria rapax*, had positive responses to flow. Anchovy larvae had the highest significance at lags of four days, but were also significant for lags up to several weeks in duration.

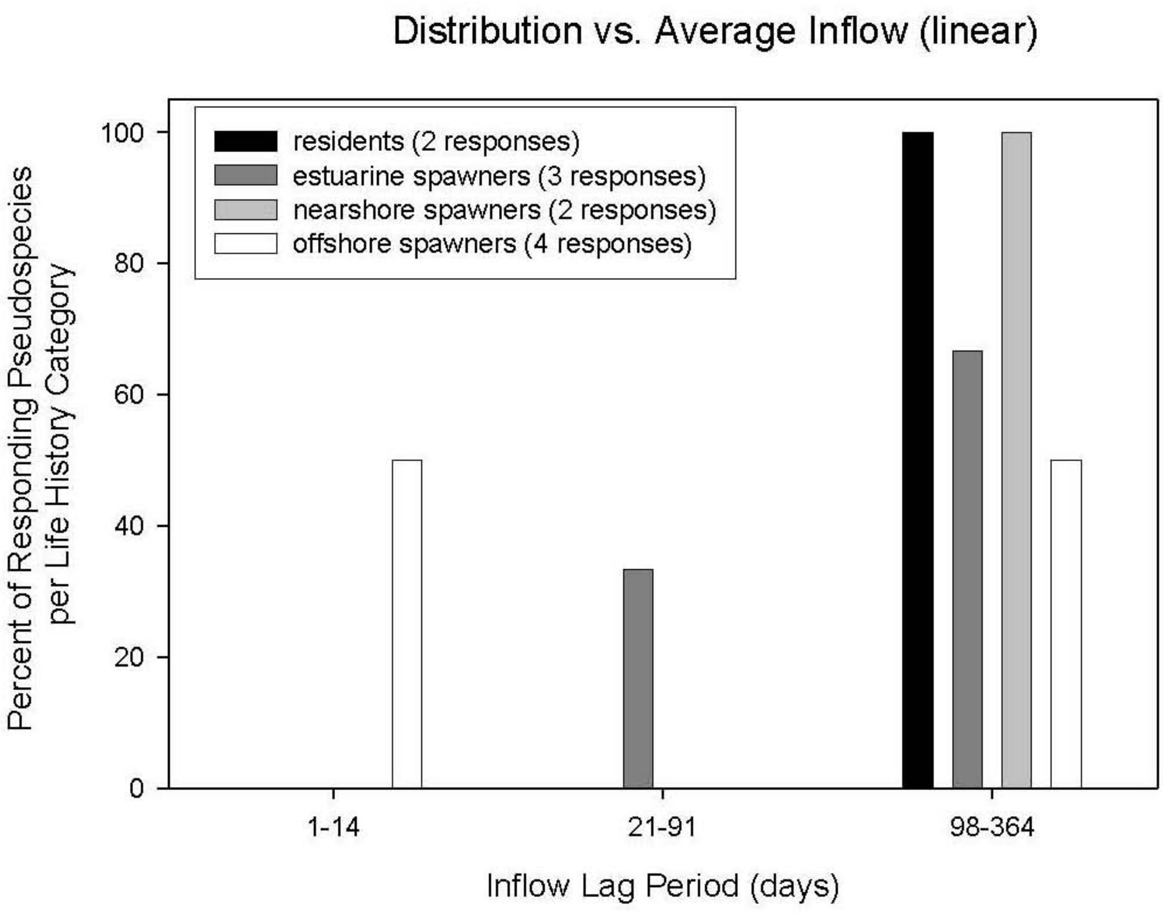

Figure 5-20. Summary of linear regression results assessing distribution (km_u) in relation to inflow to Dona Bay/Shakett Creek as measured at the CPS2 structure and lag period (Source: Peebles *et al.* 2006).

Table 5-8. Best fit seine and trawl-based pseudo-species distributional response to continuously-lagged mean freshwater inflow [Ln (*km_u*) vs. Ln(inflow)] for the DARB estuary. Degrees of freedom (*df*), intercept, slope, probability that the slope is significant (*P*), and fit (Adj-r^2) are provided. The number of days in the continuously=lagged mean inflow is represented by *D*. An "x" in *DW* indicates that the Durbin-Watson statistic was significant (*p*<0.05), a possible indication that serial correlation was present. (Source: Peebles *et al.* 2006).

Species	*Common name*	*Gear*	*Size*	*Period*	*df*	*Intercept*	*Linear coef.*	*Linear P*	*Adj-r^2*	*DW*	*D*
Farfantepenaeus duorarum	Pink shrimp	seine	<=10	Jan. to Dec.	9	1.8358	-0.1834	0.0048	60.59		1
Farfantepenaeus duorarum	Pink shrimp	seine	>=11	Jan. to Dec.	5	-13.1008	3.3796	0.0019	87.69	x	350
Callinectes sapidus	Blue crab	seine	<=30	Jan. to Dec.	12	0.1816	0.3371	0.0119	42.21		147
Callinectes sapidus	Blue crab	trawl	<=30	Jan. to Dec.	8	0.8851	0.1221	0.0019	71.92		7
Anchoa mitchilli	Bay anchovy	seine	<=25	Jan. to Dec.	4	2.7528	-0.2865	0.0486	66.29		238
Anchoa mitchilli	Bay anchovy	seine	26 to 35	Jan. to Dec.	4	3.694	-0.486	0.0311	72.63		266
Anchoa mitchilli	Bay anchovy	seine	>=36	Jan. to Dec.	5	0.4147	0.29	0.0009	90.73		84
Eucinostomus harengulus	Tidewater mojarra	seine	>=40	Jan. to Dec.	14	2.1615	-0.1442	0.0357	27.85		203
Eucinostomus harengulus	Tidewater mojarra	trawl	>=40	Jan. to Dec.	6	2.8232	-0.3476	0.0042	77.05		161
Microgobius gulosus	Clown goby	seine	All sizes	Jan. to Dec.	14	1.3693	0.102	0.0031	47.58		189
Microgobius gulosus	Clown goby	trawl	All sizes	Jan. to Dec.	6	-2.8947	1.0427	0.0013	84.3	x	308

Table 5-9. Plankton-net organism abundance responses to mean freshwater inflow from Cow Pen Slough (Ln *F*+1), ranked by linear regression slope. Other regression statistics are sample size (*n*), intercept (*Int.*), slope probability (*P*) and fit (adjusted r^2 as %). *DW* identifies where serial correlation is possible (x indicates *p*<0.05) for Durbin-Watson statistic). *D* is the number of daily inflow values used to calculate mean freshwater inflow. (Source: Peebles *et al.* 2006).

Description	*Common Name*	*n*	*Int.*	*Slope*	*P*	*r^2*	*DW*	*D*
dipterans, pupae	flies, mosquitos	12	6.930	1.112	0.0080	47		6
Hargeria rapax	tanaid	15	6.782	1.001	0.0333	25	x	67
Anchoa spp. preflexion larvae	anchovies	12	9.688	0.886	0.0049	52		4
dipteran, Chaoborus punctipennis	phantom midge	13	9.984	0.799	0.0067	46		6
trichopteran larvae	caddisflies	10	7.115	0.669	0.0058	59		9
dipterans, chironomid larvae	midges	14	8.427	0.649	0.0006	61		8
blenniid preflexion larvae	blennies	11	11.109	-0.275	0.0377	33		16
branchiurans, Argulus spp.	fish lice	15	11.707	-0.296	0.0384	24		2
decapod mysis	shrimp larvae	16	17.044	-0.641	0.0344	23		120
chaetognaths, sagittid	arrow worms	16	17.043	-0.673	0.0005	56	x	11
cymothoid sp. a (Lironeca) juveniles	isopod	12	13.290	-0.719	0.0028	57		49
Bowmaniella dissimilis	mysid, opossum shrimp	15	15.131	-0.786	0.0055	42		51
Temora turbinata	copepod	10	13.774	-0.908	0.0039	63	x	106
alphaeid postlarvae	snapping shrimp	13	15.166	-0.976	0.0173	36		120
Microgobius spp. flexion larvae	gobies	14	16.005	-1.280	0.0130	37		120
cumaceans	cumaceans	16	19.535	-1.602	0.0001	64	x	120

Over 70% of the 27 pseudo-species from seine and trawl nets had significant relationships between abundance and average flows (Table 5-10) (Peebles *et al.* 2006). A mix of linear and quadratic models were used and the best fitting regression models were those that incorporated medium or longer flow lags. The best models for residents ranged from 28 to 259 day lags, for estuarine spawners 1 to 238 day lags, and for nearshore and offshore spawners 1 to 364 day lags (Figure 5-21). A mix of negative (abundance increased with decreasing flow), intermediate-maxima (highest abundance at intermediate flows), intermediate minima (lowest abundance at intermediate flows) and positive (abundance increased at higher flows) were found (Figure 5-22). Of the ten strongest abundance-flow relationships (r^2>50%), nine were from trawl data collected in channel habitat (Peebles *et al.* 2006).

5.4.2.8 Community Structure

Peebles *et al.* (2006) found that salinity was negatively related to freshwater inflow, increasing until reaching an asymptote at 100 cfs, and that this observation had relevance to the observed community structure responses to flow (Figure 5-23). However, few data points exist above 100 cfs to base this conclusion on.

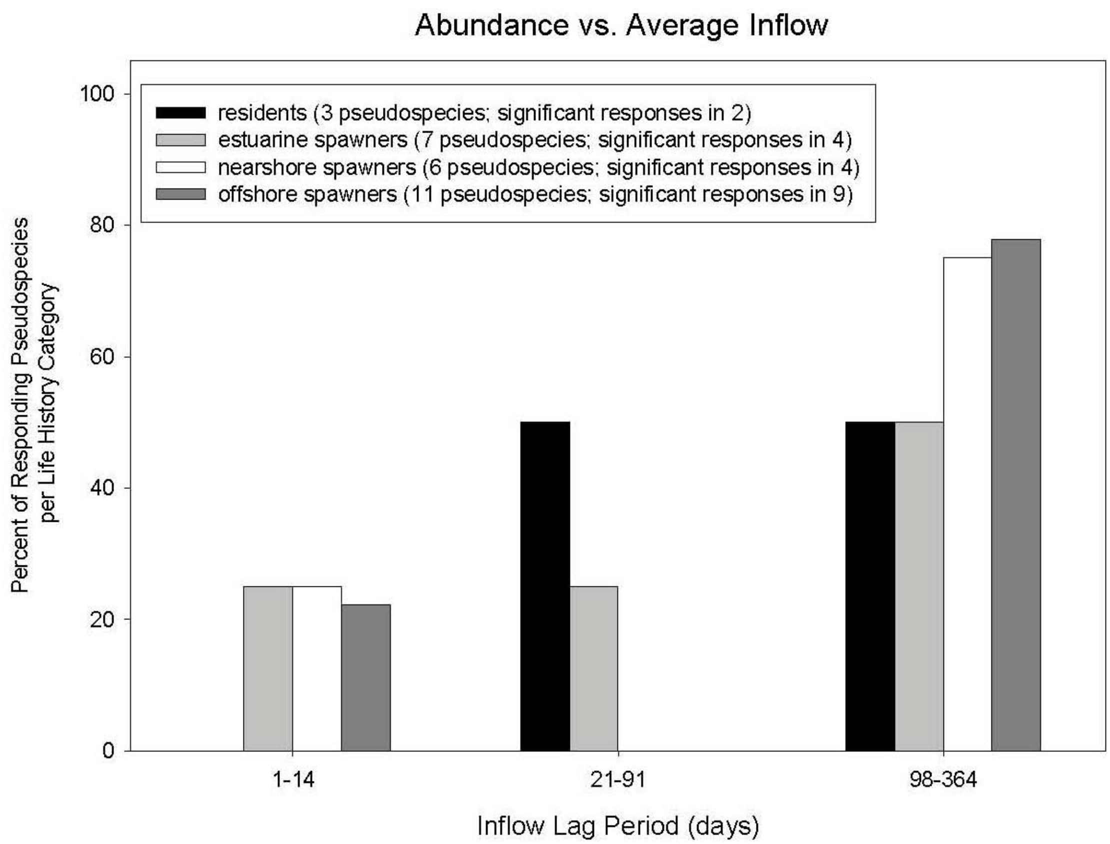

Figure 5-21. Summary of regression results assessing abundance (N) in relation to inflow and lag period (Source: Peebles *et al.* 2006).

Table 5-10. **Best fit seine and trawl-based pseudo-species abundance (*N*) response to continuously-lagged mean freshwater inflow [LN(cpue) vs. Ln(flow)]) for the DARB estuary. The type of response is either quadratic (Q) or linear (L). Degrees of freedom (*df*), intercept, slope (*Linear coef.*), probability that the slope is significant (*Linear P*), quadratic coefficient (*Quad. coef.*), probability that the quadratic coefficient is significant (*Quad. P*) and fit (r^2) are provided. The number of days in the continuously-lagged mean inflow is represented by *D.* An "x" in *DW* indicates that the Durbin-Watson statistic was significant (p<0.05), a possible indication that serial correlation was present. (Source: Peebles *et al.* 2006).**

Species	*Common name*	*Gear*	*Size*	*Period*	*Response*	*df*	*Intercept*	*Linear coef.*	*Linear P*	*Quad. Coef.*	*Quad. P*	*Adj-r^2*	*DW*	*D*
Farfantepenaeus duorarum	Pink shrimp	seine	<=10	Jun. to Mar.	Q	9	24.9745	-12.8432	0.0025	1.6525	0.0022	67.15		168
Farfantepenaeus duorarum	Pink shrimp	seine	>=11	Jun. to Mar.	L	10	1.3805	-0.2701	0.0017	.	.	64.4	x	1
Farfantepenaeus duorarum	Pink shrimp	trawl	<=10	Jun. to Mar.	Q	8	16.5038	-7.6512	0.0319	0.9001	0.0476	81.16		280
Farfantepenaeus duorarum	Pink shrimp	trawl	>=11	Jun. to Mar.	Q	7	574.5863	-258.3373	0.0012	29.0284	0.0013	89.88		364
Periclimenes americanus	American grass shrimp	trawl	All sizes	Dec. to Aug.	Q	10	2.0008	-1.0893	0	0.1457	0	84.9		119
Callinectes sapidus	Blue crab	seine	<=30	Jan. to Dec.	Q	13	1.8106	-0.8446	0.0161	0.1466	0.015	38.02		1
Callinectes sapidus	Blue crab	trawl	<=30	Jan. to Dec.	Q	9	139.9573	-63.2239	0.0018	7.1422	0.002	80.49		357
Anchoa mitchilli	Bay anchovy	seine	<=25	Dec. to Oct.	Q	12	-46.8116	26.7227	0.0006	-3.5889	0.0005	68.47	x	238
Anchoa mitchilli	Bay anchovy	seine	26 to 35	Dec. to Oct.	Q	12	5.5183	-2.7702	0.0019	0.3652	0.0065	60.15	x	1
Anchoa mitchilli	Bay anchovy	seine	>=36	Dec. to Oct.	L	13	3.5541	-0.5985	0.1947	.	.	12.57		84
Eucinostomus gula	Silver jenny	seine	40 to 70	Jan. to Dec.	Q	13	21.0857	-10.2962	0.0188	1.2636	0.0231	41.39		189
Eucinostomus gula	Silver jenny	trawl	40 to 70	Jan. to Dec.	Q	9	201.2805	-89.8794	0.0184	10.032	0.0215	80.14		350
Eucinostomus harengulus	Tidewater mojarra	seine	>=40	Jan. to Dec.	L	14	3.3141	-0.3331	0.0116	.	.	37.53	x	1
Eucinostomus harengulus	Tidewater mojarra	trawl	>=40	Jan. to Dec.	Q	9	206.648	-92.9807	0.0242	10.4577	0.0261	68.18		364
Lagodon rhomboides	Pinfish	seine	>=31	Jan. to Aug.	Q	9	-26.4046	15.7406	0.015	-2.1195	0.0132	53.61		245
Lagodon rhomboides	Pinfish	trawl	<=30	Dec. to Jun.	Q	8	1.5461	-0.9122	0.0008	0.1337	0.0003	91.28	x	126
Leiostomus xanthurus	Spot	trawl	All sizes	Jan. to Apr.	Q	3	-23.0567	10.6294	0.0177	-1.2188	0.0177	88.29		245
Microgobius gulosus	Clown goby	seine	All sizes	Jan. to Dec.	Q	12	-30.0672	17.4733	0.0016	-2.3064	0.0015	58.12		259
Microgobius gulosus	Clown goby	trawl	All sizes	Jan. to Dec.	Q	13	0.9441	-0.5856	0.0001	0.0875	0.0001	68.95		28

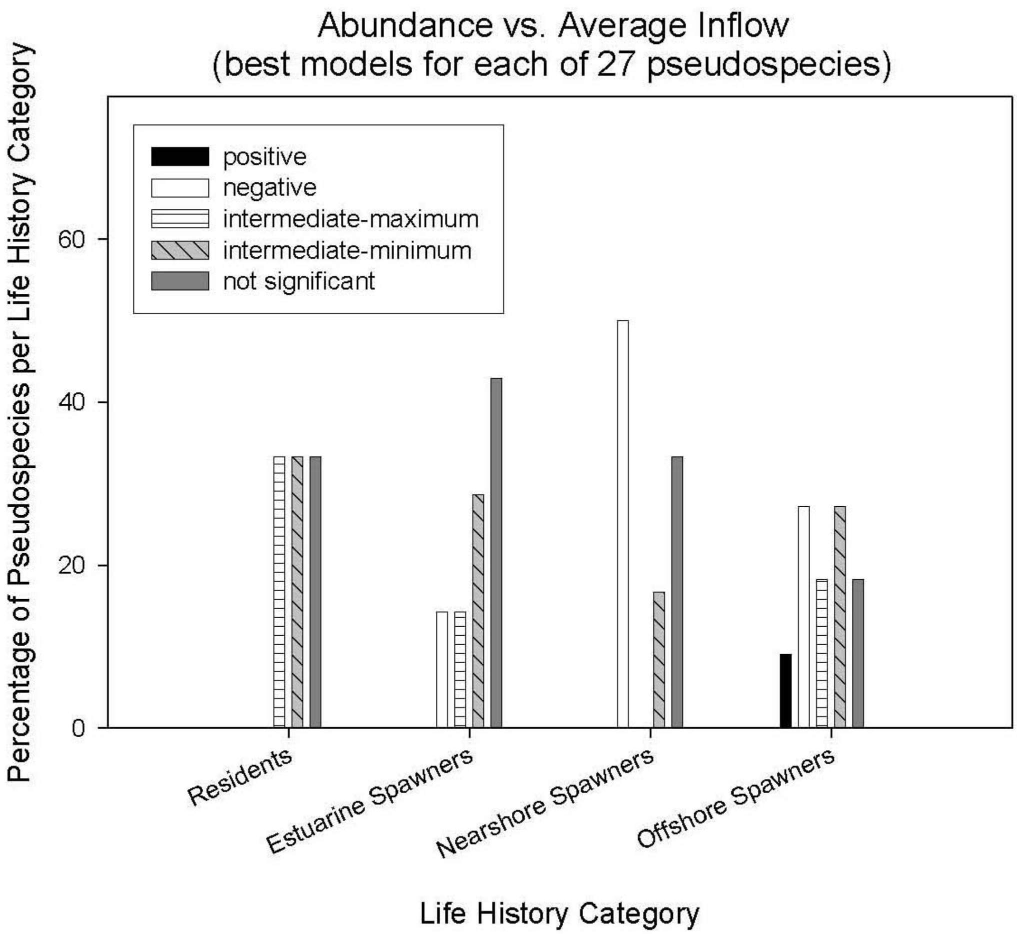

Figure 5-22. **Summary of regression results assessing abundance (N) in relation to inflow. Positive and negative indicate increase and decrease in abundance with increasing inflow, respectively, while intermediate indicates maximum or minimum abundance at intermediate inflows. (Source: Peebles *et al.* 2006).**

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5.4.2.9 Plankton Catch Community Analyses

Invertebrate community (i.e., zooplankton) structure in the DARB system based on the plankton-net samples was the most spatially consistent and homogenous when flows were less than 100 cfs, and was the most spatially variable and heterogeneous when flows exceeded 100 cfs (Peebles *et al.* 2006). A gradient in community structure was evident from the Venice Inlet, through Dona Bay and into Shakett Creek Community structure in the two upstream zones (3.0-5.0 and 5.0-6.4 km) were significantly different than in the downstream zone (1.0-3.0 km) and the two lateral bays (Roberts Bay and Lyons Bay) (see Appendix 5-7). Invertebrate zooplankton community structure was more strongly influenced by inflow than icthyoplankton community structure. Mysid shrimp and amphipods were more common in the upstream zones, while copepods were more abundant in the downstream zones (see Appendix 5-7). Mysids and amphipods are important prey items for juvenile estuarine-dependent fish, while copepods are important prey for fish larvae and adult zooplanktivorous fish (*e.g.*, anchovies, sardines, and herring).

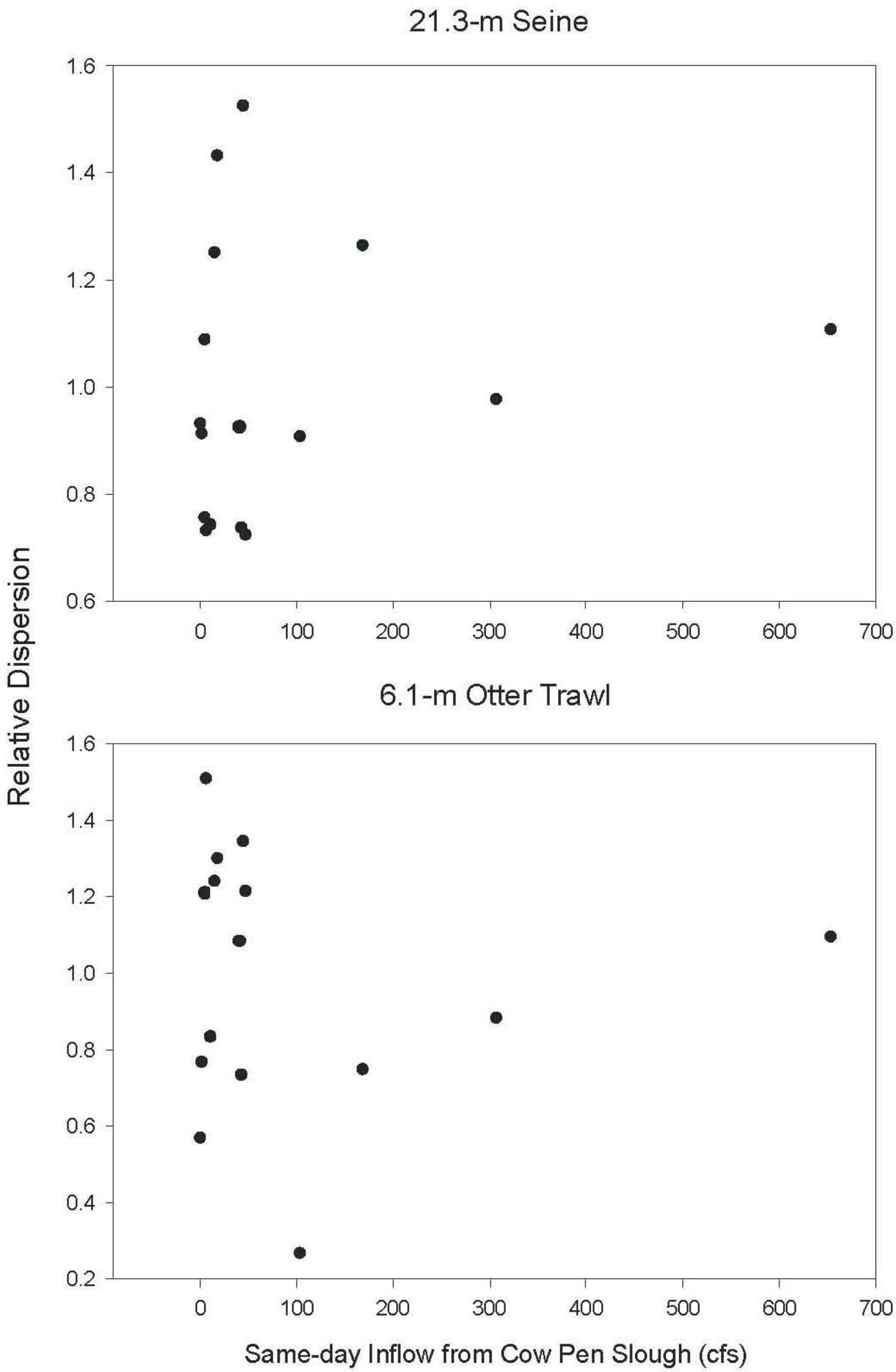

Figure 5-23. **Relationships between Cow Pen Slough inflow and nekton community variability (measured using an index of multivariate dispersion, *i.e.*, relative dispersion) based on seine and trawl samples collected in the Dona Bay/Shakett Creek portion of the DARB system. (Source: Peebles *et al.* 2006)**.

5.4.2.10 Seine and Trawl Community Analyses

Comparison of nekton community similarity between Lyons and Roberts Bay, showed that shallow water species (sampled with the seine) declined in similarity as inflow from Blackburn Canal increased (Figure 5-24). No effect of increased inflow on nekton similarity between the two bays was, however, evident in trawl samples. Lyons Bay receives no major freshwater inflow and is therefore relatively stable in terms of physiochemical conditions. However, Roberts Bay receives freshwater inflow from Blackburn Canal and ambient conditions fluctuate with inflow.

Multivariate analyses of the effects of inflow on the nekton assemblage throughout the DARB system and Lyons Bay highlighted differences in community structure associated with a low flow year (2004) and a high flow year (2005). Community differences were attributed to increased abundance of low-salinity nekton taxa in the high flow year (Figure 5-25). Spatial variability in nekton community structure within the study area was consistent with taxa salinity preferences. The upper portion (5.0-6.4 km) of Shakett Creek, with relatively high abundances of taxa that prefer low salinity conditions and low abundances of taxa typically associated with higher salinities, was substantially different from Lyons and Roberts Bays, i.e., it plotted substantially apart from the Lyons Bay and Roberts Bay in multidimensional space. Only minor differences in community structure were observed between Lyons Bay, Roberts Bay, and the lower (0.1-3.0 km) portion of Dona Bay/Shakett Creek (Peebles *et al.* 2006).

5.4.2.11 Conclusions and Discussion

- Estuarine fish displayed an affinity, in terms of both community structure and the distribution of individual species, for the two sources of freshwater inflow (Cow Pen Slough and Blackburn Canal).

- Fewer successful models of abundance responses to inflow were developed during this study compared to similar studies. The authors suggest that could be due to several factors: the short duration of the study period, atypically low inflow levels, and/or a high degree of spatial irregularity in the effects of inflow.

- In the DARB estuary, distributional responses to inflow were somewhat anomalous. Some typical responses were seen, such as organisms moving upstream with decreasing flow. However, the opposite response was also seen with seine and trawl taxa moving upstream during elevated flows. The same response was not seen in plankton taxa, suggesting the pattern observed in seine and trawl taxa was an active behavior rather than passive advection.

- Because the flow regime was somewhat erratic, the expected trophic benefits of increased inflow may not have occurred or occurred inefficiently and were not expressed in the data as clearly as in other studies. However, freshwater inflows in the DARB estuary still attracted estuarine fish and crustaceans. A study under a less erratic inflow regime may yield results more similar to previous studies.

- Though the empirical relationships developed by Peebles *et al.* (2006) showed some promise, they used the flow at CPS2 as the inflow for their regressions and did not consider the ungauged inflows downstream of the CPS2 structure. As will be discussed in Section 8.4, the baseline condition for this study does not include flows from upstream of the CPS2 structure. Therefore, the flow used to develop their regressions, CPS2, is not included in the MFL scenarios that were evaluated and these regressions can not be applied to the MFL scenarios.

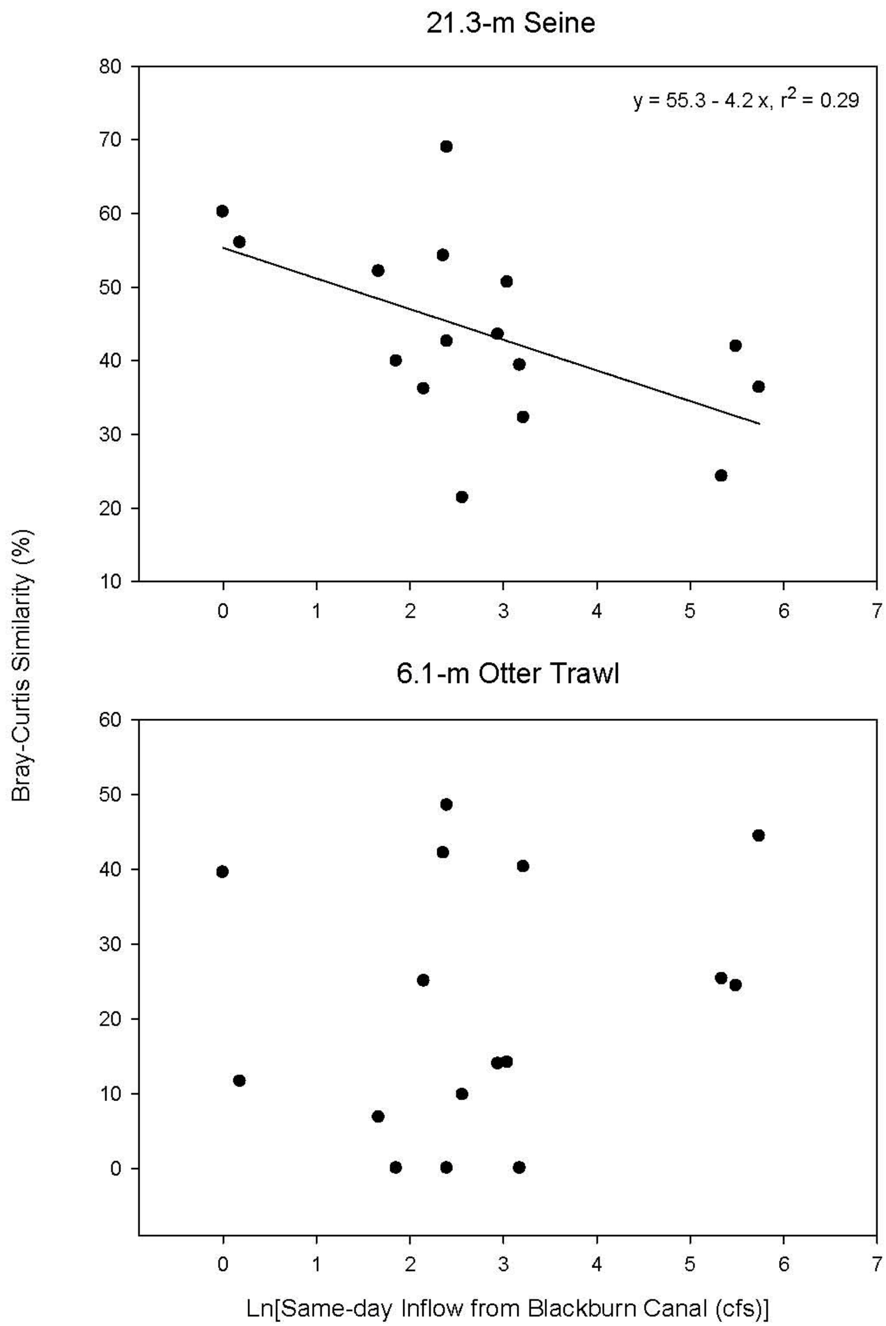

Figure 5-24. **Relationship between Blackburn Canal inflow and similarity (Bray-Curtis similarity) of nekton communities in Lyons Bay and Roberts Bay based on monthly seine and trawl samples. (Source: Peebles *et al.* 2006).**

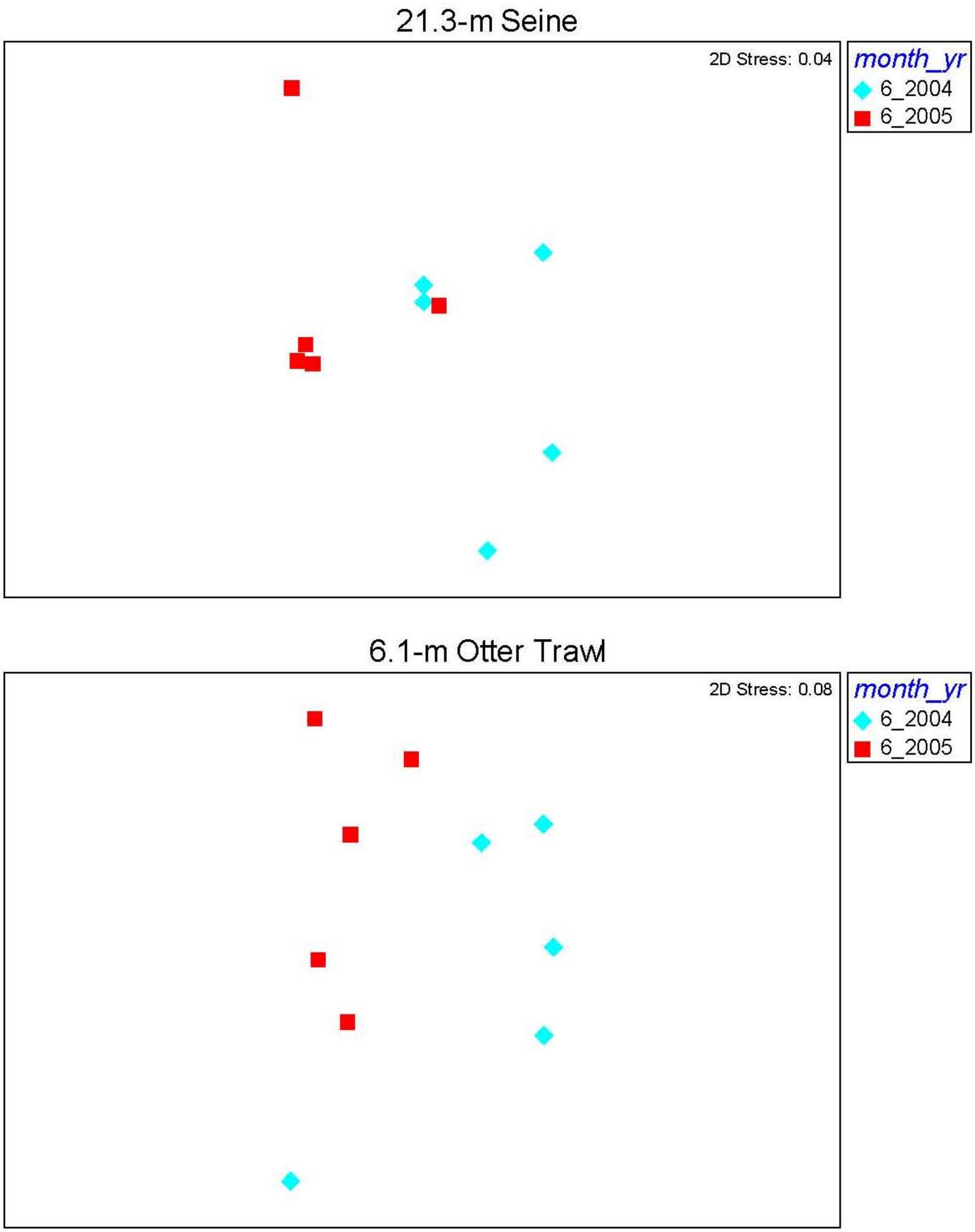

Figure 5-25. Nonmetric Multidimensional Scaling (MDS) ordination plot of nekton community structure in the DARB system and Lyons Bay on June 16, 2004 (mean Cow Pen Slough inflow was 11 cfs) and June 9, 2005 (mean Cow Pen Slough inflow was 331 cfs). (Source: Peebles *et al.* 2006).

6 Development of Modeling Tools that Relate Freshwater Inflows to Salinity in the DARB system

In this section, elements of the modeling tools that were used to establish proposed minimum flows for the Dona Bay/Shakett Creek portion of the DARB system are presented. Seasonally-specific periods for evaluation of flow scenarios are introduced. The development of historical, benchmark flows to Dona Bay/Shakett Creek is outlined and baseline and alternative flow scenarios used for evaluating salinity regimes and establishing minimum flow criteria are identified.

6.1 DARB Baseline Period and Corresponding Watershed

As discussed in Section 2, the DARB watershed has undergone significant modifications since the early 1900s. In 1966, the Cow Pen Slough canal (Figure 2-6) was completed, connecting Cow Pen Slough directly to Shakett Creek (Kimley-Horn and Associates *et al.* 2007). These modifications have resulted in an increase in freshwater inflows and the timing of delivery of water to Shakett Creek and subsequently Dona Bay. These flow alterations have resulted in negative impacts to seagrasses, oysters, and water quality (Lincer 1975, Jones 2003 and 2005). In recognition of the fact the system is presently receiving more water than it did historically and that there are currently no withdrawals, a pre-channelization watershed was chosen to represent the 'baseline' condition.

Return to a more natural flow regime would be expected to result in a more natural estuarine environment in the DARB system. With this goal in mind, the configuration or state of the Dona Bay/Shakett Creek watershed in 1948 was used to model a historical benchmark flow record for the Dona Bay/Shakett Creek portion of the DARB system and was also used to estimate historical benchmark inflows for other portions of the DARB system. Development of historical benchmark flows from the Blackburn Canal into Roberts Bay was a simple process; flows from the canal were not considered to be a component of the historical benchmark inflows because the canal was not constructed until the 1950s.

The delineated 1948 Dona Bay/Shakett Creek watershed (Figure 6-1) was used to develop historical benchmark flows because it pre-dated construction of the current Cow Pen Slough Canal, and a comprehensive set of geo-rectified aerial photographs was available from which land use/cover could be determined for modeling purposes. The delineated 1948 watershed included the Fox Creek, Salt Creek and Shakett Creek sub-basins and was much smaller than the current watershed. While the current Dona Bay landuse (Figure 2-3, Table 2-2) is approximately 50% natural (wetlands, uplands, open water) and 50% developed (urban and agriculture), the historical Dona Bay watershed which consists of the Fox Creek, Salt Creek, and Shakett Creek sub-basins is greater than 90% natural (shrub/pastureland and wetlands) and less than 10% developed (urban and agriculture).

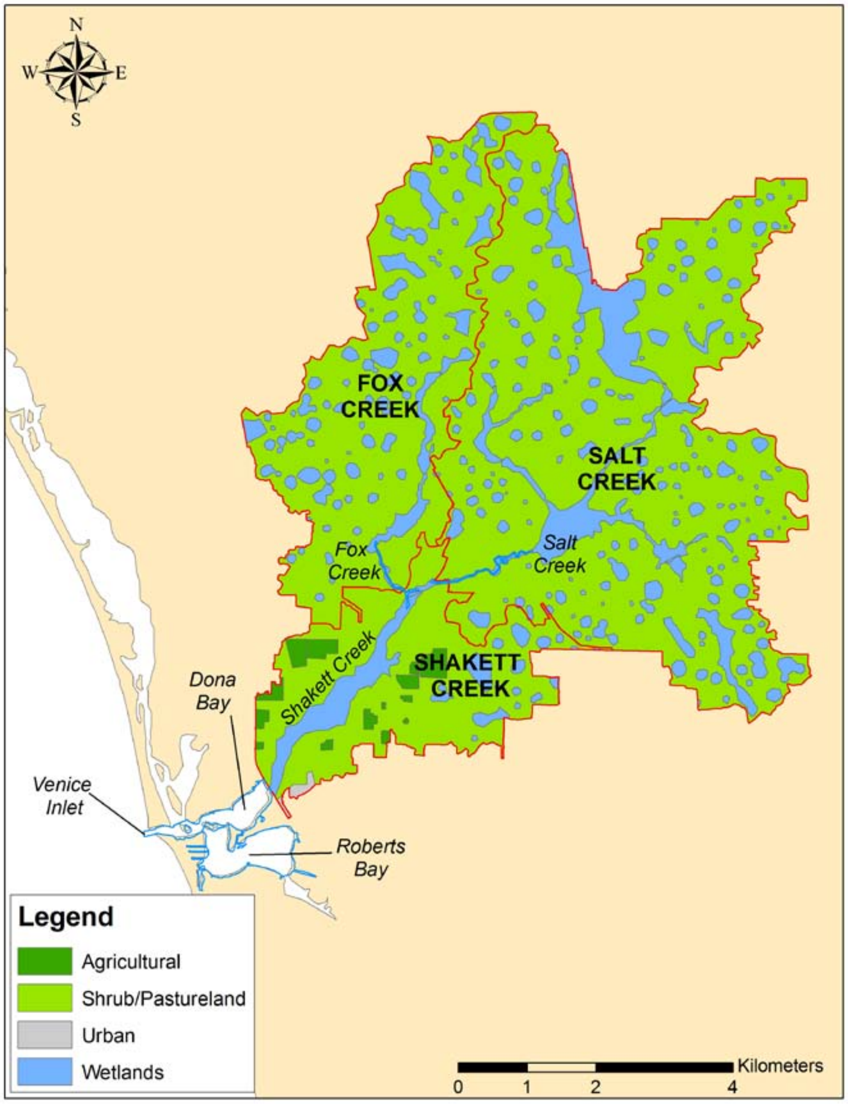

Figure 6-1. **Map of the historical Dona Bay watershed (Fox Creek, Salt Creek, and Shakett Creek subbasins) including land use circa 1948.**

6.2 Seasonally-Specific Assessment Periods

Methods used for establishing minimum flows over the full range of flow conditions must consider seasonal flow variation. The peer-review report on proposed minimum flows for the upper segment of the Peace River (Gore *et al.* 2002) identified a "building block" approach as "a way to more closely mirror original hydrologic and hydroperiodic conditions in the basin". Development of regulatory flow requirements using this type of approach typically involves description of the natural flow regime, identification of building blocks associated with flow needs for ecosystem specific functions, biological assemblages or populations, and assembly of the blocks to form a flow prescription (Postel and Richter 2003). As noted by the panelists comprising the upper Peace River minimum flows review panel, "assumptions behind building block techniques are based upon simple ecological theory; that organisms and communities occupying that river have evolved and adapted their life cycles to flow conditions over a long period of pre-development history (Stanford *et al.* 1996). Thus, with limited biological knowledge of flow requirements, the best alternative is to recreate the hydrographic conditions under which communities have existed prior to disturbance of the flow regime." Although in most cases, the District does not expect to recreate pre-disturbance hydrographic conditions through development and implementation of minimum flows, the building block approach is viewed as a reasonable means for ensuring the maintenance of similar, although dampened**,** natural hydrographic conditions (SWFWMD 2005b).

Conceptually, the approach used by the District for development of minimum flows for the upper Peace River (SWFWMD 2002) was consistent with the building block approach. Available flow records were summarized and used to describe flow regimes for specific historical periods. For development of minimum flows for the middle segment of the Peace River, the District explicitly identified three building blocks in its approach (SWFWMD 2005c). The blocks corresponded to seasonal periods of low, medium and high flows that were evident in hydrographs of median daily river flows. These seasonal blocks were also used to develop recommended minimum flows for the lower Peace River and Shell Creek (SWFWMD 2007a).

Watershed-specific flow records could not be used to develop seasonal blocks for the DARB system due to the lack of available long-term flow records. Seasonal blocks previously developed for the upper segment of the Myakka River (SWFWMD 2005d) were however, available and considered appropriate for analyzing DARB system flows. Blocks developed for the Myakka River (Figure 6-2) were considered appropriate based on the proximity of the DARB watershed to the river and the expectation of similar rainfall and natural flow regimes for the two systems. The low flow period (Block 1), is a 67-day period that extends from April 20 through June 25 (Julian day 110 through 176). Highest flows occur during Block 3 (June 26 through October 26; Julian day 177 through 299), the 123-day period that immediately follows the dry season. The remaining 175 days (October 27 through April 19; Julian day 300 through 365 and 1 through 109) constitute an intermediate or medium flow period, referred to as Block 2.

6.3 Definition of Biologically-Relevant Salinities

Clearly, establishment of an MFL requires identification of a critical biologically-relevant variable that can be defensibly and quantitatively related to variation in freshwater flows. Based on the results presented in Section 4, salinity has the most quantifiable and defensible relationship to variation in freshwater flow. Therefore, a critical step in the establishment of an MFL is the definition of biologically-relevant salinities to provide a focus to the analysis of the effect of freshwater flow on the DARB system. As discussed in Section 2, the DARB system has undergone significant physical and hydrologic alterations that have led to increases in the volume of freshwater to the system and the timing of the delivery of freshwater to the system. Lincer (1975) and Jones (2003, 2005) documented the negative effects of this excess freshwater on seagrass and oyster populations in the DARB system. As documented in Section 6-4, the historical salinity regime in Dona Bay was more mesohaline in nature.

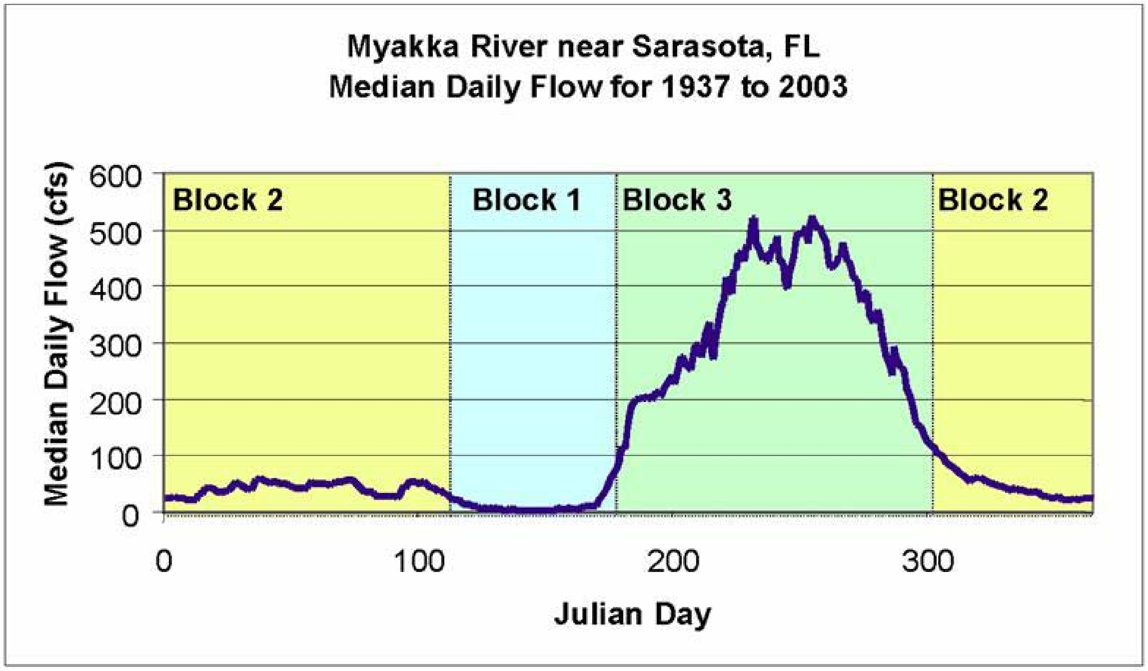

Figure 6-2. **Building blocks developed for a building block approach to the development of minimum flows. Blocks corresponding to low (Block 1), medium (Block 2) and high (Block 3) flows are shown along with period of record median daily flows for the USGS Myakka River near Sarasota gauge (from: SWFWMD 2005c).**

Therefore, the following biologically-relevant salinities were used in minimum flow development for DARB based on the several important species:

- 10 ppt is the bottom of the optimal range for larval oysters, the bottom of the tolerance for adult oysters, and needed for spawning of bay anchovies;
- 15 ppt is near the peak of spawning for bay anchovies, and the bottom of the optimum range of adult oysters;
- 20 ppt is in the peak range for oyster larvae and in the optimum range for adult oysters and sand seatrout.

6.4 Definition of Baseline Flow

As discussed in Section 2, an HSPF model was developed to predict runoff to Dona Bay for the current land use, hydrography, and rainfall (Intera 2007). This model was used to predict daily runoff to Dona Bay for the period 1985 to 2005. To estimate runoff to Dona Bay under the baseline period, the 1948 aerial photographs were used to delineate the Dona Bay watershed, as well as the landuse coverage for the baseline period (Figure 6-1). The Blackburn Canal / Curry Creek connection with the Myakka was not included in the model to recreate pre-channelization conditions. The HSPF model was then employed to predict the flows to Dona Bay for the baseline period (i.e., 1948 watershed delineation and landuse) using the current rainfall record (1985-2005). Thus, a 21-year record of inflows to Dona Bay was created for the baseline period.

The historical benchmark flows were expected to more closely approximate a more natural estuarine environment than currently exists in Dona Bay/Shakett Creek, especially with respect to salinity. A comparison of the current and baseline inflows to Dona Bay in presented in Figure 6-3. As expected, the current inflows are substantially greater than the baseline inflows because of the increased watershed area and change in landuse. The difference between the two lines in Figure 6-3 represents the excess water that is available currently when compared to the baseline inflows.

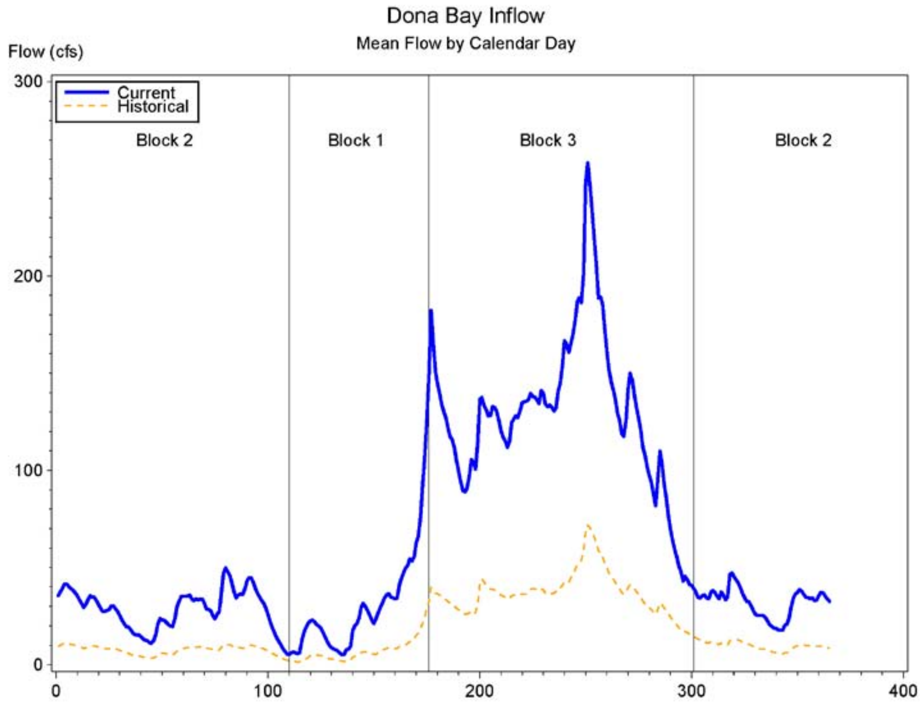

Figure 6-3. **Mean flow by calendar day for the 21-year period of model simulations to predict inflows to Dona Bay under the current and baseline scenarios.**

Historical benchmark flows for other portions of the DARB system were developed based on known drainage alterations and comparisons of historical land use within DARB system drainage basins. Historical benchmark flows into Roberts Bay through the Blackburn Canal were determined to be nonexistent because the canal was not constructed until sometime in the 1950s. Historical benchmark flows for Lyons Bay, Roberts Bay (Curry Creek and Hatchett Creek) were estimated based on comparisons between land use in these drainage basins (as determined from 1948 aerial photography) and land use in drainage basins in the delineated 1948 Dona Bay/Shakett Creek watershed. Unit areal runoff values for individual drainage basins (Fox Creek, Salt Creek and Shakett Creek) in the delineated 1948 Dona Bay/Shakett Creek watershed were used for the Lyons Bay, Curry Creek and Hatchett Creek based on similarity of land use in the respective basins. For example, land use in Lyons Bay was determined to be most similar to that of Shakett Creek, so unit area runoff values for the 1948 Shakett Creek watershed were multiplied by the area of the Lyons Bay watershed to estimate historical benchmark flows for Lyons Bay.

6.5 Definition of Baseline Salinities

The occurrence of historical benchmark flows into the DARB system with currently existing structural alterations would not likely result in the historical salinity regime because of the physical alterations that have been made to downstream areas, specifically the dredging and maintenance of the Gulf Intracoastal Waterway and Venice Inlet and construction of several bridges and causeways. To understand and characterize the salinity regime that would be associated with historical benchmark flows into the current DARB system, a method for predicting salinities based on flow records was needed. A hydrodynamic model, Environmental Fluid Dynamics Code (EFDC), was developed (ATM, 2007) to predict salinity, temperature, and water surface elevation for the DARB system and is described in Appendix 6-1. The model was originally developed to evaluated re-opening Midnight Pass in Sarasota Bay. The model boundaries were expanded to include the DARB system. The domain of the EFDC model extends from upper Sarasota Bay 46 km to the north and southerly 12 km to upper Lemon Bay and extends inland to CPS2. Gulf boundaries extend 4 km offshore of New Pass, 4 km offshore of Big Pass and 8 km offshore of Venice Jetties.

The EFDC model was used to predict baseline salinities for the Shakett Creek/Dona Bay portion of the DARB system based on a three-year subset of the historical benchmark flow records, given the existing downstream structural changes that have been made to the system. The EFDC model was also used to predict alternate salinities for several modified historical benchmark flow scenarios to identify acceptable flow reductions for Dona Bay/Shakett Creek.

The modeled baseline scenario for DARB system incorporated predicted daily runoff (baseline flows) for Fox, Salt, and Shakett Creeks in Dona Bay/Shakett Creek as well as the sub-basins of Lyons Bay, Roberts Bay and Sarasota Bay for the three-year baseline period. Baseline flows for Dona Bay/Shakett Creek consisted of the three-year (1986 through 1988) record of baseline flows based on the delineated 1948 watershed. Baseline flows for Lyons Bay, Roberts Bay and Sarasota Bay were derived using the baseline flow record as described in the previous section of this chapter.

To obtain a better understanding of the historical salinity regime, predicted salinities were analyzed for the baseline period and corresponding watershed (described in Section 6.1) at four locations in Shakett Creek/Dona Bay (Figure 6-4). The sites selected range from the middle of Dona Bay at rkm 1.5 (Location 4) to the upper portion of Shakett Creek at rkm 5 (Location 1). The most upstream location, Location 1, is downstream of the confluences of the major tributaries, Salt Creek and Fox Creek.

Time series plots of the daily average surface and bottom salinity at locations 1 through 4 in Dona Bay/Shakett Creek are presented in Figures 6-5 to 6-8. Summaries of the daily average surface and bottom salinities by block for all four locations are presented in Tables 6-1 to 6-3.

With the exception of Block 3 (the high flow block), the median salinities are greater than 30 ppt at all four locations for the surface and bottom. For this reason, the biologically-relevant salinities for Dona Bay are mesohaline in nature.

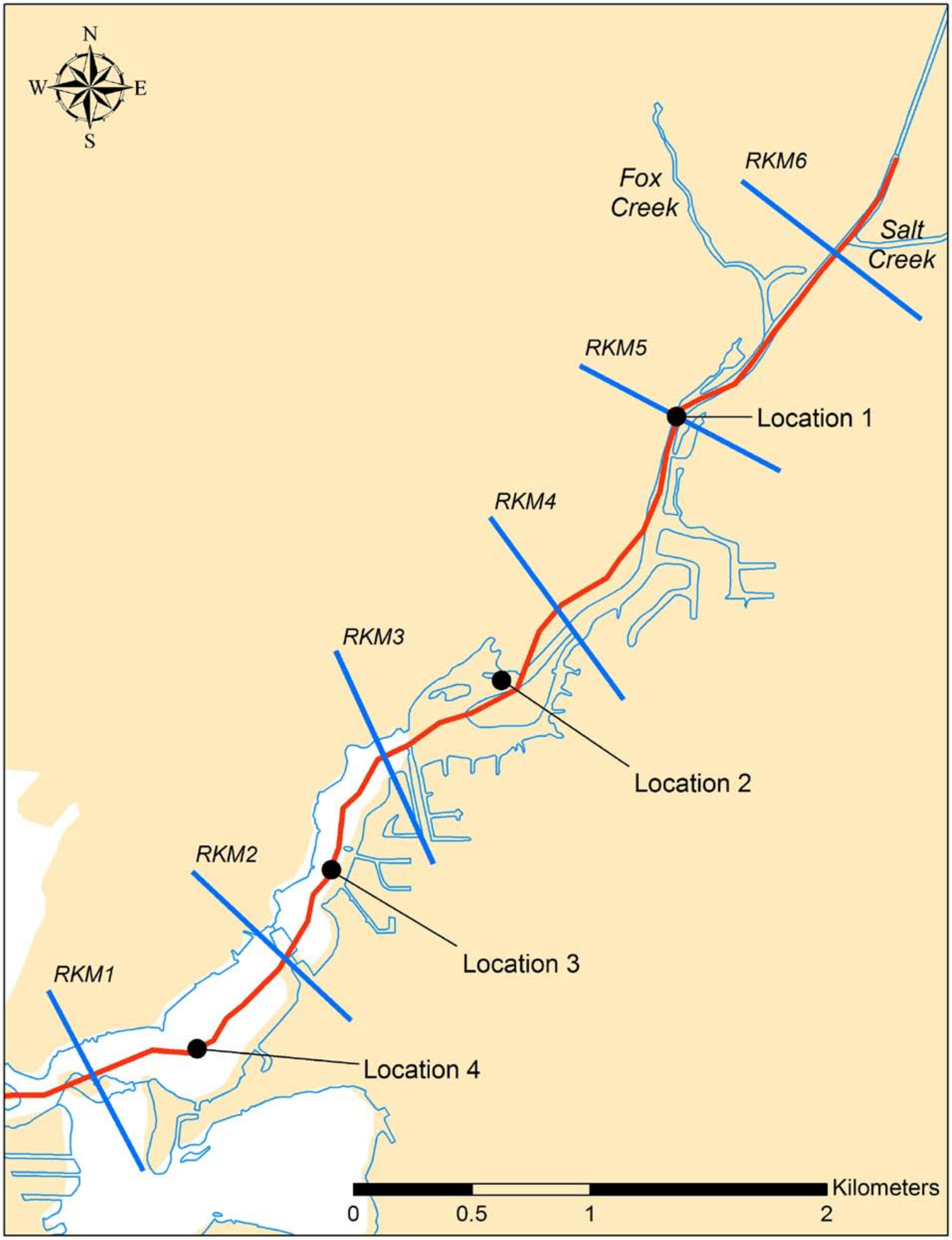

Figure 6-4. Map of study locations used to analyze historical salinity regime in Dona Bay/Shakett Creek.

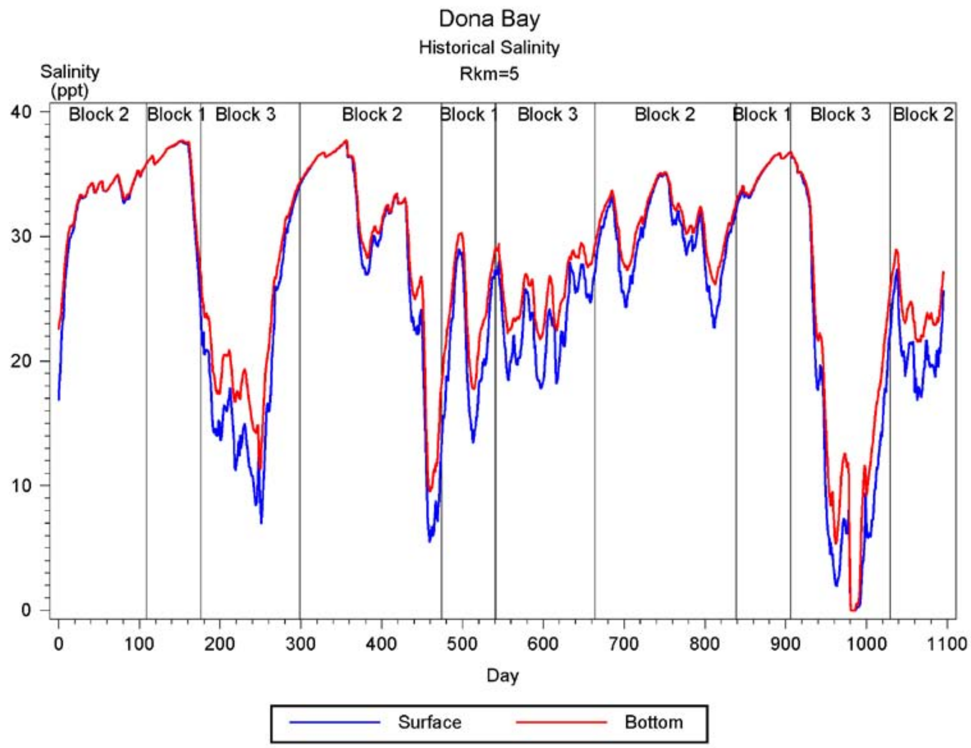

Figure 6-5. **Predicted average daily surface and bottom salinity for the three-year baseline period at rkm 5 (Location 1).**

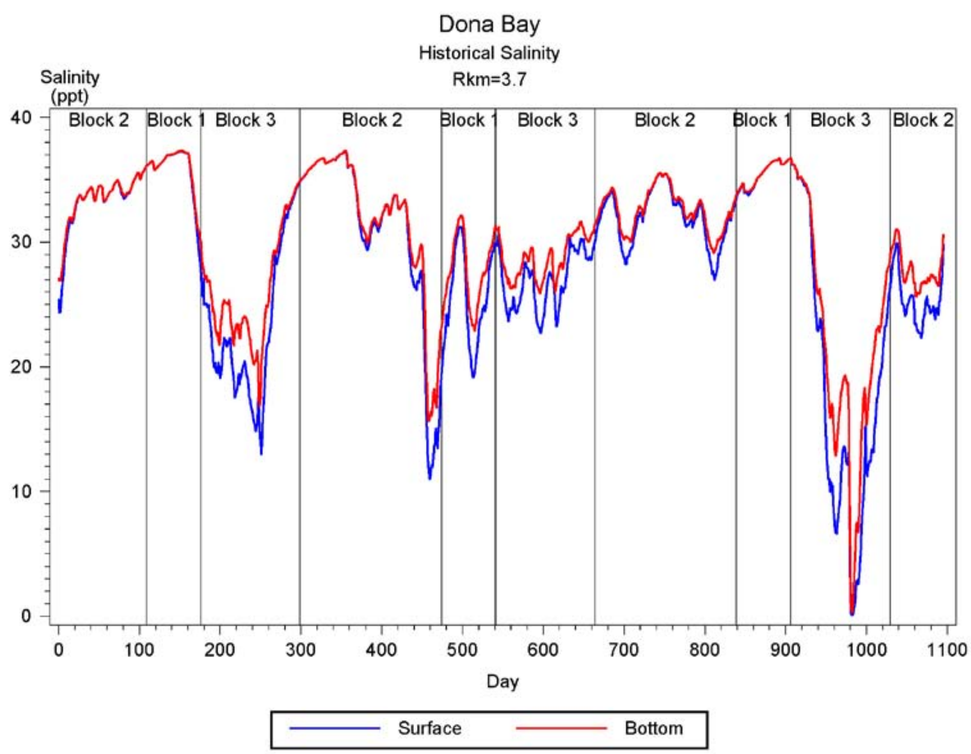

Figure 6-6. **Predicted average daily surface and bottom salinity for the three-year baseline period at rkm 3.7 (Location 2).**

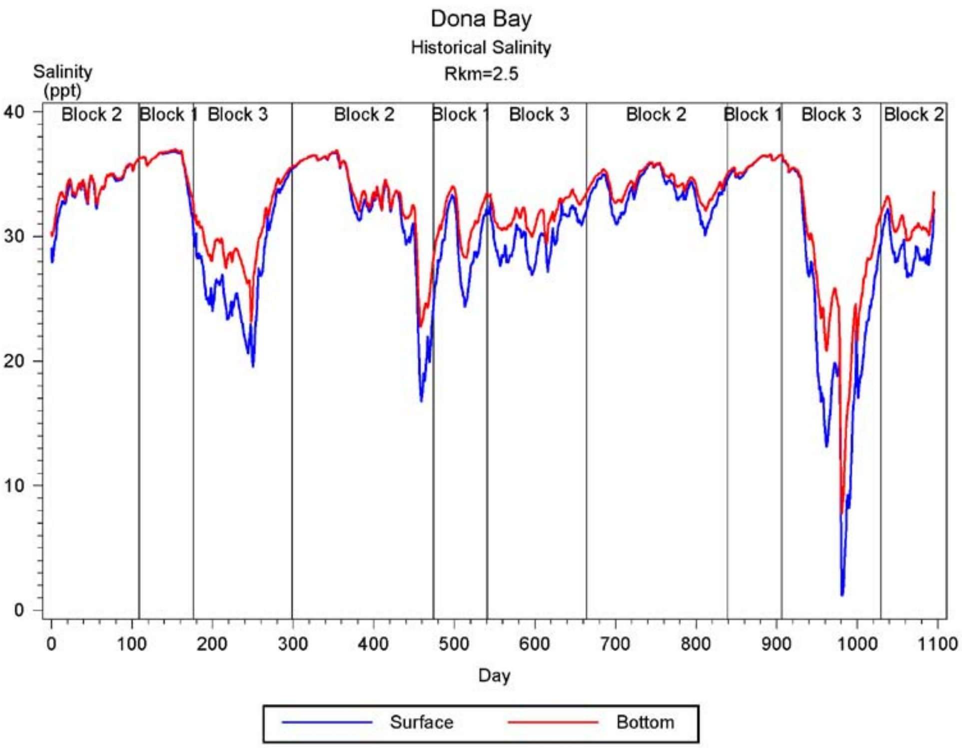

Figure 6-7. Predicted average daily surface and bottom salinity for the three-year baseline period at rkm 2.5 (Location 3).

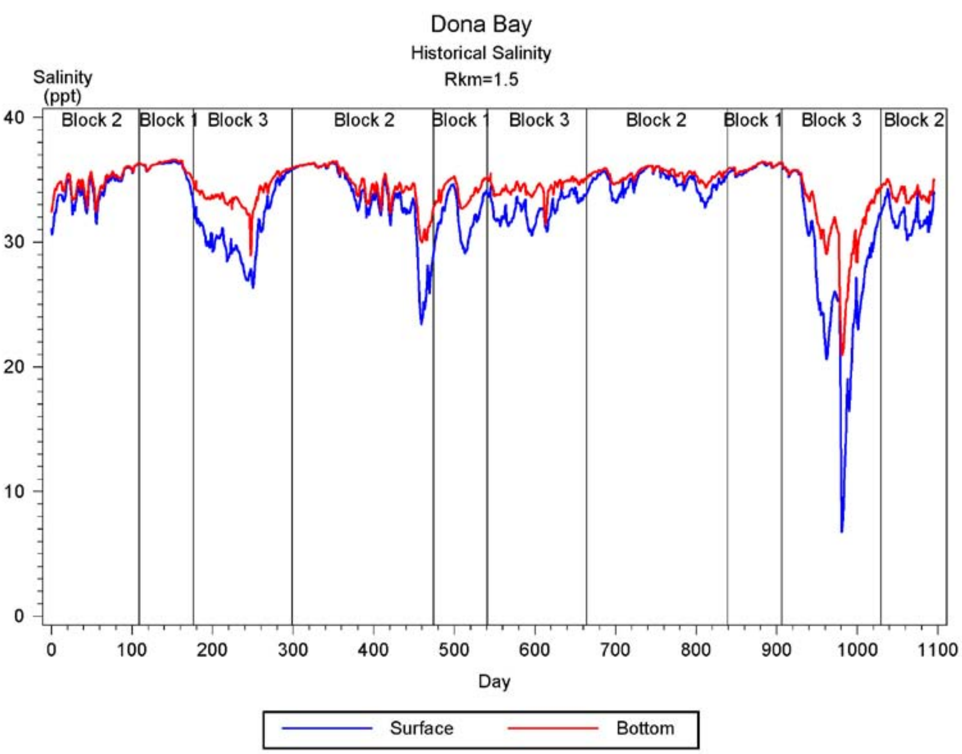

Figure 6-8. Predicted average daily surface and bottom salinity for the three-year baseline period at rkm 1.5 (Location 4).

Table 6-1. Summary of predicted surface and bottom salinities by location for Block 1 (April 20 to June 25).

Location	Layer	Mean Daily Salinity				
		10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
1	Surface	18.4	25.6	34.1	36.4	37.2
	Bottom	21.5	27.5	34.3	36.5	37.3
2	Surface	23.3	28.7	34.8	36.5	37.0
	Bottom	25.8	30.1	34.8	36.5	37.0
3	Surface	27.7	31.5	35.4	36.4	36.7
	Bottom	30.2	32.8	35.5	36.4	36.8
4	Surface	31.2	33.7	35.7	36.3	36.3
	Bottom	33.3	34.8	35.9	36.3	36.4

Table 6-2. Summary of predicted surface and bottom salinities by location for Block 2 (October 27 to April 19).

Location	Layer	Mean Daily Salinity				
		10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
1	Surface	19.9	25.6	30.9	34.0	35.7
	Bottom	23.4	27.9	31.8	34.1	35.8
2	Surface	24.9	29.2	32.5	34.3	36.0
	Bottom	27.1	30.3	32.8	34.4	36.0
3	Surface	28.4	31.5	33.4	34.8	36.0
	Bottom	30.7	32.7	33.9	35.1	36.1
4	Surface	31.6	33.0	34.3	35.4	36.1
	Bottom	33.4	34.2	35.1	35.7	36.1

Table 6-3. Summary of predicted surface and bottom salinities by location for Block 3 (June 26 to October 26).

Location	Layer	Mean Daily Salinity				
		10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
1	Surface	5.9	12.6	19.7	25.5	31.2
	Bottom	10.8	17.3	23.0	27.7	32.0
2	Surface	11.8	18.7	24.4	28.7	32.7
	Bottom	17.3	22.8	26.9	30.1	33.0
3	Surface	18.3	24.0	28.1	31.1	33.8
	Bottom	24.1	28.2	30.7	32.7	34.6
4	Surface	24.6	29.1	31.6	33.4	35.1
	Bottom	30.7	33.0	34.0	34.8	35.8

6.6 DARB Study Area

The portion of the EFDC model domain that was used for MFL development is presented in Figure 6.9. This area is comprised of Dona Bay upstream of the Intracoastal Waterway and Shakett Creek.

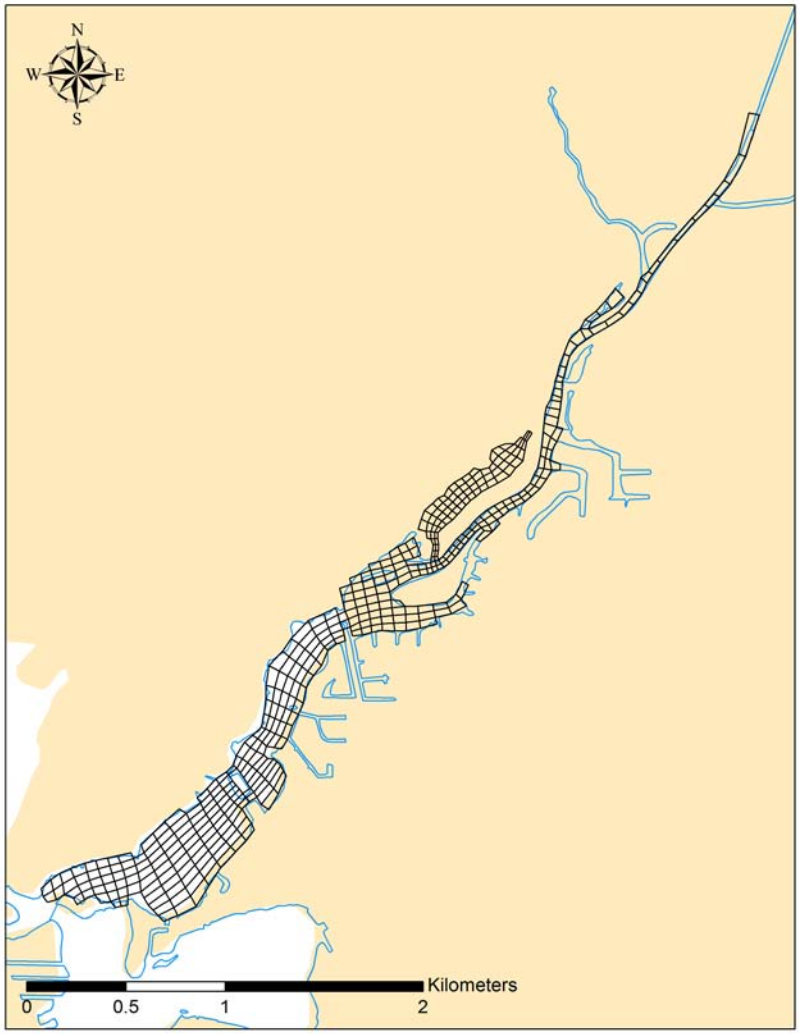

Figure 6-9. Study area for DARB hydrodynamic model.

6.7 Definition of Habitat Assessment Metrics

In order to estimate the amount of available habitat that meets the biologically-relevant salinities discussed above under various flow conditions, the following metrics were used:

- the volume of water in the system less than a given salinity, since fishes generally utilize the entire water column,
- the bottom area in the system less than a given salinity since the benthic macroinvertebrates and SAV inhabit the bottom substrate, and
- the natural shoreline length (i.e., seawall is not included) in the system less than a given salinity, since this metric best defines the amount of shoreline vegetation habitat available in the system.

6.8 DARB Modeling Period

It is impractical to run a complex hydrodynamic model for the entire 21-year (1985 through 2005) baseline period. Therefore, a three-year period was selected that is most representative of the 21-year baseline period. The modeling period was selected by comparing the flow duration curves for the entire 21-year period to each three-year period (year 1 to 3, year 2 to 4,…, year 19 to 21) by block (Appendix 6-2). The difference between the flow duration curve for the 21-year period and each three-year period was plotted by block. The three-year period that most closely mimicked the flow duration curves for the entire 21-year period for all blocks was 1986 through 1988 (years 2 through 4, Figure 6-10). For Blocks 1 and 2, the flow duration curves for years 2 to 4 was the same as the flow duration curves for the 21-year period between the 1st and 95th percentiles. This was the best agreement between any of the three-year periods as compared to the 21-year period.

6.9 Definition of Baseline and Model Scenarios for DARB

The Baseline Scenario for DARB consisted of the predicted daily runoff for Fox, Salt, and Shakett Creeks in Dona Bay as well as the subbasins of Roberts Bay, Lyons Bay, and Sarasota Bay for the three-year modeling period. The baseline modeling included existing physical alterations (ICW, bridges, Venice Jetties) but did not include the Blackburn Canal connection to the Myakka River. Additional model runs were made based on a series of percent reductions from the baseline. For these percent flow reduction scenarios, Fox and Salt Creek flows were reduced, flows from all other subbasins were the same as under the Baseline Scenario. The series of percent flow reductions that defined the percent flow reduction modeling scenarios were:

- 5% reduction of Fox and Salt Creek flows,
- 7.5% reduction of Fox and Salt Creek flows,
- 10% reduction of Fox and Salt Creek flows,
- 15% reduction of Fox and Salt Creek flows,
- 20% reduction of Fox and Salt Creek flows,
- 25% reduction of Fox and Salt Creek flows, and
- 30% reduction of Fox and Salt Creek flows.

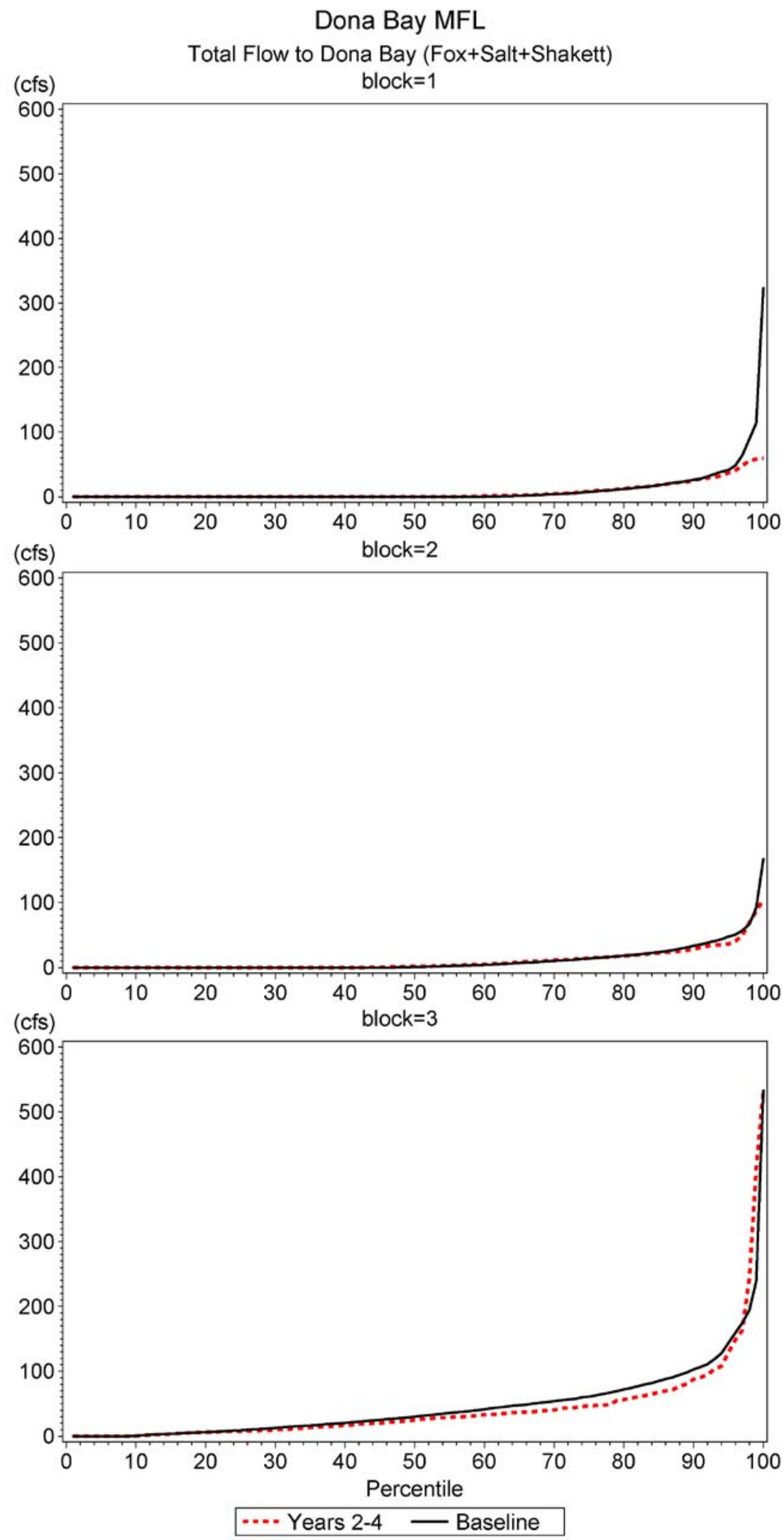

Figure 6-10. Flow duration curve for the 21-year period and years 2 to 4 by block.

During the seasonal low (Block 1) and medium (Block 2) flow periods, surface and bottom baseline salinities were typically within the polyhaline (18 to 30 ppt) and euhaline (30 to 40 ppt) ranges throughout Dona Bay/Shakett Creek. Median salinities for the two blocks exceeded 30 ppt. During the high flow period (Block 3), baseline salinities were more variable within the estuary. Median surface salinities for the baseline period ranged from 20 to 32 ppt from the upstream to downstream site. Median bottom salinities ranged from 23 to 34 ppt. Based on the increased volume of freshwater in the upper portion of the estuary, salinities during Block 3 typically ranged from mesohaline (5 to 18 ppt) to euhaline.

Modeled baseline scenario results indicate that consideration of salinities in the mesohaline to polyhaline range may be appropriate for developing minimum flows for Dona Bay/Shakett Creek. The baseline scenario approximates expected salinities based on freshwater inflow to Dona Bay/Shakett Creek that would be expected in the estuary given existing downstream alterations (*e.g.*, dredging, bridge construction) and drainage that could have been expected from the upper watershed, prior to completion of the Cow Pen Slough Canal.

7 Application of Modeling Tools for Quantification of Estuarine Habitat in the DARB System and Development of Minimum Flow Criteria

In this section, elements used for application of a salinity/inflow modeling approach to identify minimum flow criteria for the Dona Bay/Shakett Creek portion of the DARB system are presented. Biologically-relevant salinities and habitat measures or metrics used to quantify habitat change associated with change in flow/salinity are defined. Use of cumulative distribution function plots for quantifying spatial and temporal habitat availability as a function of flow is presented and the specific criterion used to identify acceptable percent of flow reduction used to establish minimum flows for the system are discussed.

7.1 Approach to the Quantification of Habitat Availability as a Function of Inflows to DARB

Habitat availability is best quantified in terms of space and time. For developing minimum flow recommendations for the Dona Bay/Shakett Creek portion of the DARB system, temporal persistence and the amount of habitat meeting biologically relevant salinities for baseline and alternate flow reduction scenarios were quantified using cumulative distribution function (CDF) plots. The plots provide a visual representation of the amount of time and spatial extent of the habitat availability defined by the identified biologically-relevant salinities (10, 15 and 20 ppt) and habitat assessment metrics (water volume, bottom area and shoreline length). The plots were developed to quantify habitat availability by seasonal flow-block, using model output from EFDC model runs for the three year baseline period.

An explanation of a CDF plot is aided by examination of Figures 7-1 through 7-3. An overview of a CDF plot is provided in Figure 7-1. Here, the horizontal axis is reversed from what is normally seen, with the percent of time increasing to the left. In this plot space, the upper left hand portion represents more habitat availability for a greater proportion of the time, the upper right hand portion represents more habitat availability for a lower proportion of the time, the lower left portion represents less habitat availability for a greater proportion of the time, and the lower right portion represents less habitat availability for a lower proportion of the time. Therefore, the end point along the hypothetical cumulative frequency distribution line in the upper right portion of the figure indicates that the entire habitat is available the least amount of time while lesser amounts of habitat are available for increasing amounts of time. Example curves for two different scenarios are shown in Figure 7-2, with the habitat value of 15 units found 58% of the time in the example scenario represented by Curve 1, and only 18% of the time in the example scenario represented by Curve 2. The same two curves are shown in Figure 7-3, illustrating differences in the amount of habitat that is available for the same percentage of the time, with 20 units available 36% of the time in the example scenario represented by Curve 1, and only 3 units available 36% of the time in the example scenario represented by Curve 2.

Habitat availability [in terms of a) volume, b) bottom area and c) shoreline length] is characterized as those waters that meet the following biologically-relevant salinities:

- less than 10 ppt,
- less than 15 ppt, and
- less than 20 ppt.

The evidence that supports the choice of the three biologically-relevant salinities was discussed in Section 6.

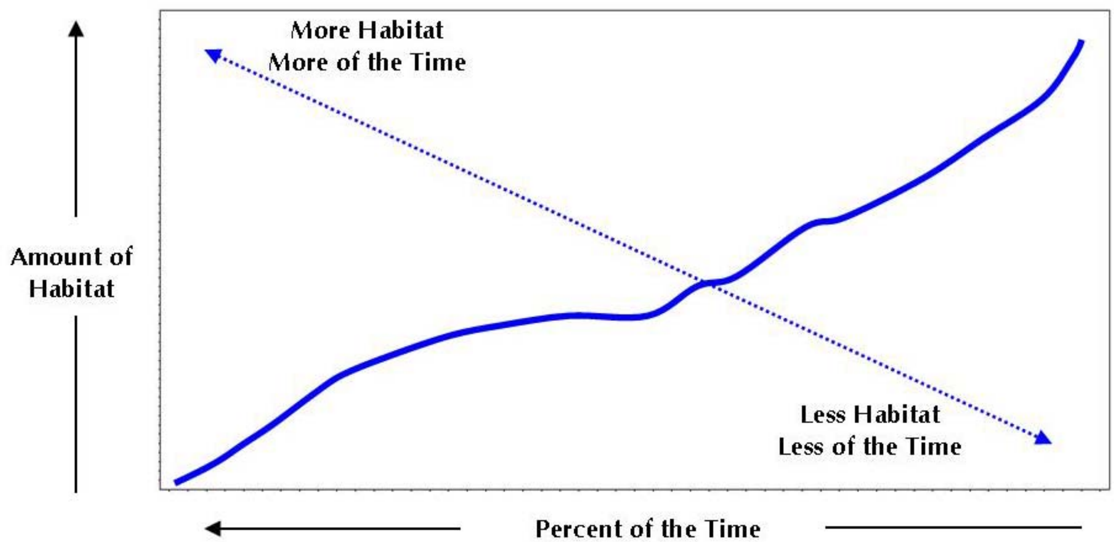

Figure 7-1. Flow Example of a CDF plot of habitat occurrence.

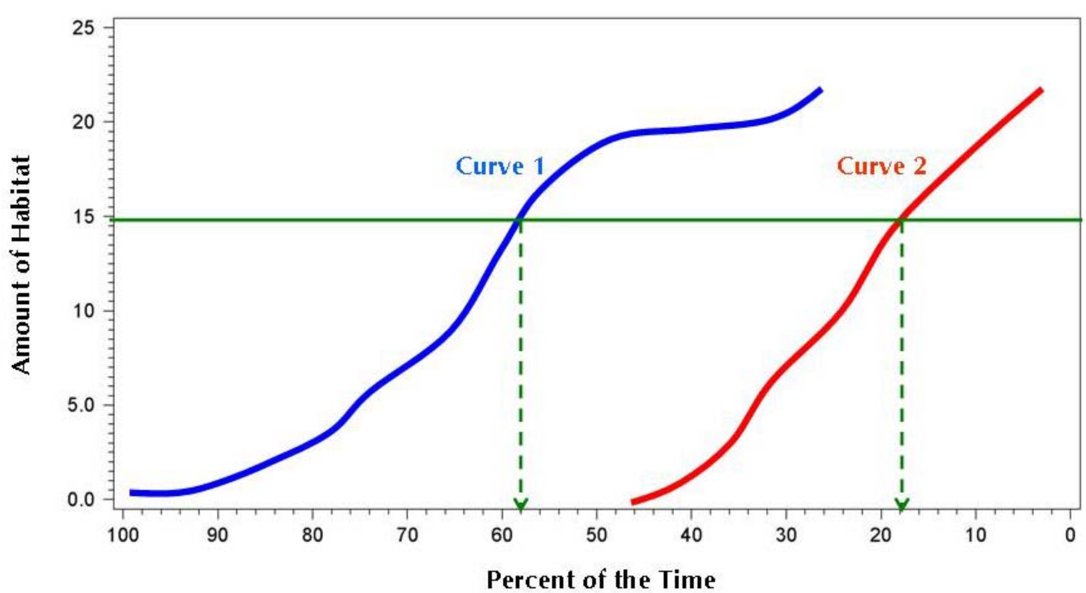

Figure 7-2. Example of a CDF plot of habitat availability with the same habitat value found at different percentages of time for the two example scenario curves.

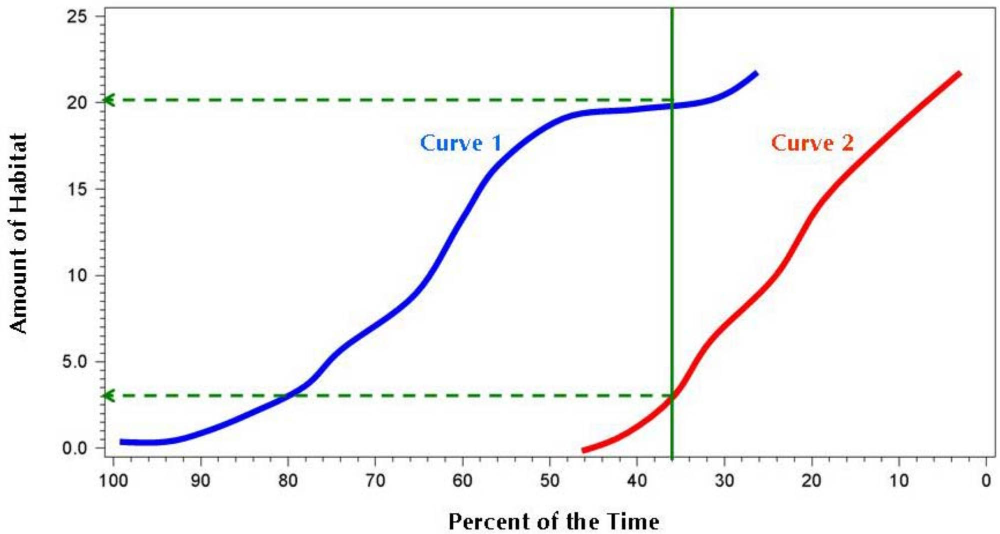

Figure 7-3. **Example of a CDF plot of habitat availability, with the same percentage of time value found at different habitat values for the two example scenario curves.**

As discussed above, three habitat metrics are assessed to estimate the MFL in DARB:

- volume of water,
- bottom area, and
- shoreline length.

Also as discussed above, the MFL for each of three distinct flow periods (blocks) are estimated. These blocks include:

- Block 1 (low flow) from April 20 through June 25,
- Block 2 (moderate flow) from October 27 through April 19, and
- Block 3 (high flow) from June 26 through October 26.

7.2 Results of the Quantification of Habitat Availability as a Function of Inflow in DARB

The hydrodynamic model, as described in Section 6, was run for a three-year period, and was used to simulate the salinity responses in the DARB system to a series of flow scenarios, including:

- Baseline condition,
- 5% flow reduction,
- 7.5% flow reduction,
- 10% flow reduction,
- 15% flow reduction,
- 20% flow reduction,
- 25% flow reduction, and
- 30% flow reduction.

The volume, bottom area, and shoreline length for a given salinity criteria are analyzed for each of these scenarios. CDF plots of mean daily volume, bottom area, and shoreline length for the stated salinity criteria are presented for the DARB minimum flow study area. For reference the following are the totals for the DARB system estimated for each habitat metric:

- volume = 1.8 million m^3,
- bottom area = 91.2 ha, and
- natural shoreline length = 12.4 km.

7.2.1 Salinity Criterion: Less than 10 ppt.

CDF plots of the mean daily volume of water less than 10 ppt in the DARB minimum flow study area are presented in Figure 7-4 for each Block. Examination of this figure reveals the following:

- Under the baseline scenario, and thus under all flow reduction scenarios as well, there was no volume of less than 10 ppt water in the system during Block 1.
- In all scenarios during Block 2, less than 10 ppt water was only available for 3% of the time or less. Under a 30% flow reduction, the greatest volume of less than 10 ppt water was 0.05 million m^3, and under the baseline it was 0.20 million m^3.
- During Block 3, less than 10 ppt water was available a maximum of 28% of the time, with a maximum volume of 1.1 million m^3.

From the CDF plots of mean daily bottom area less than 10 ppt in the DARB minimum flow study area (Figure 7-5), the following conclusions can be drawn:

- There was no bottom area less than 10 ppt in any scenario.
- During Block 2, less than 5 ha of bottom area less than 10 ppt existed, and only occurred 3% of the time or less.
- During Block 3, bottom area less than 10 ppt occurred 16% of the time or less, and maximum bottom area less than 10 ppt was about 45 ha.

CDF plots of mean daily shoreline length less than 10 ppt in the DARB minimum flow study area are presented in Figure 7-6. From these plots, the following observations can be made:

- There was no shoreline length less than 10 ppt in any scenario.
- During Block 2, very little shoreline length less than 10 ppt existed (<5 km), and what was there only occurred a very small percentage (<3%) of the time.
- During Block 3, shoreline length less than 10 ppt occurred 28% of the time or less, and maximum shoreline length less than 10 ppt was about 12 km.

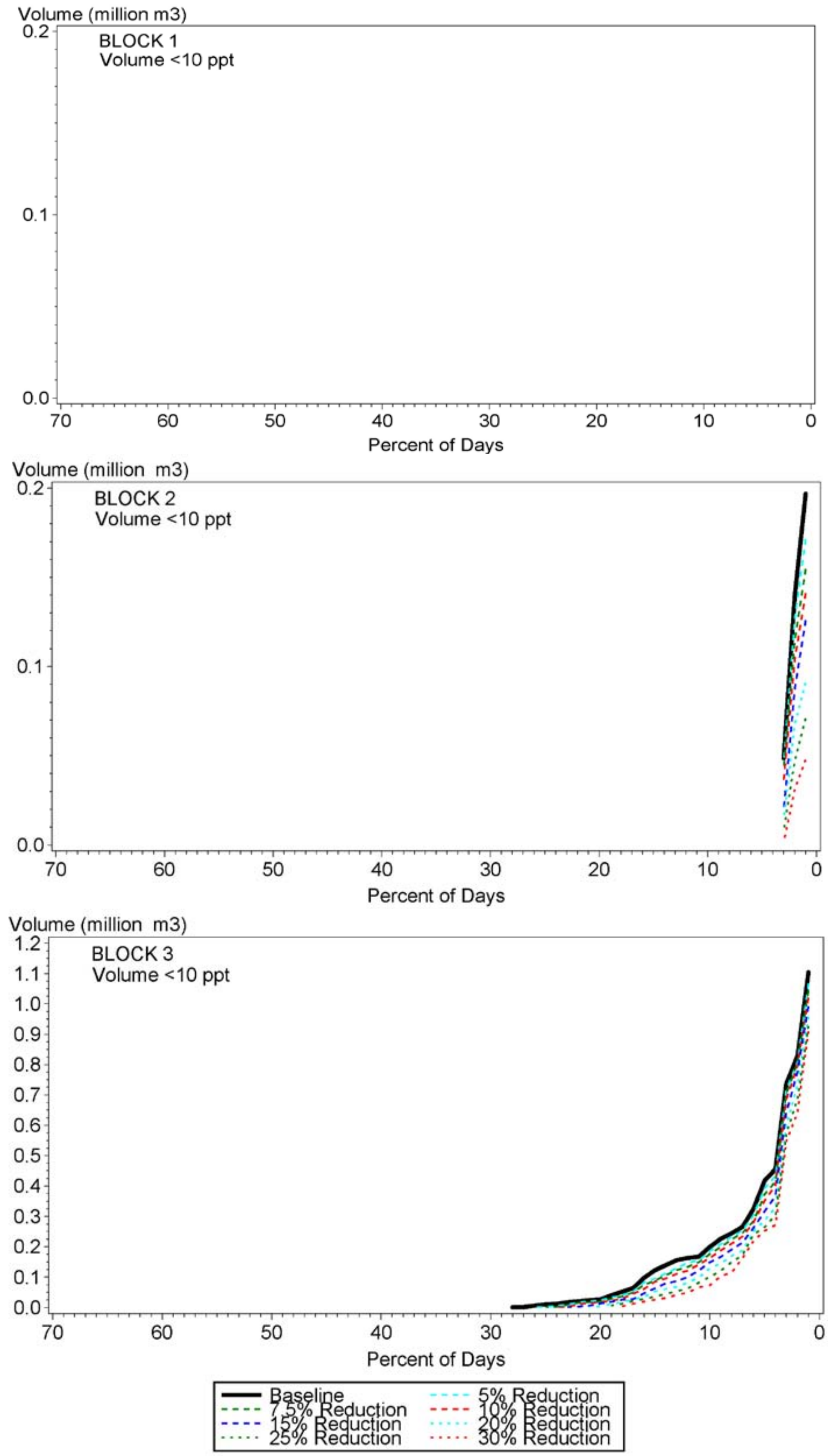

Figure 7-4. Cumulative distribution function plots of water volume with salinity less than 10 ppt by time for eight modeled flow scenarios during three seasonal blocks. Water with salinity less than 10 ppt during did not occur for any flow scenario Block 1.

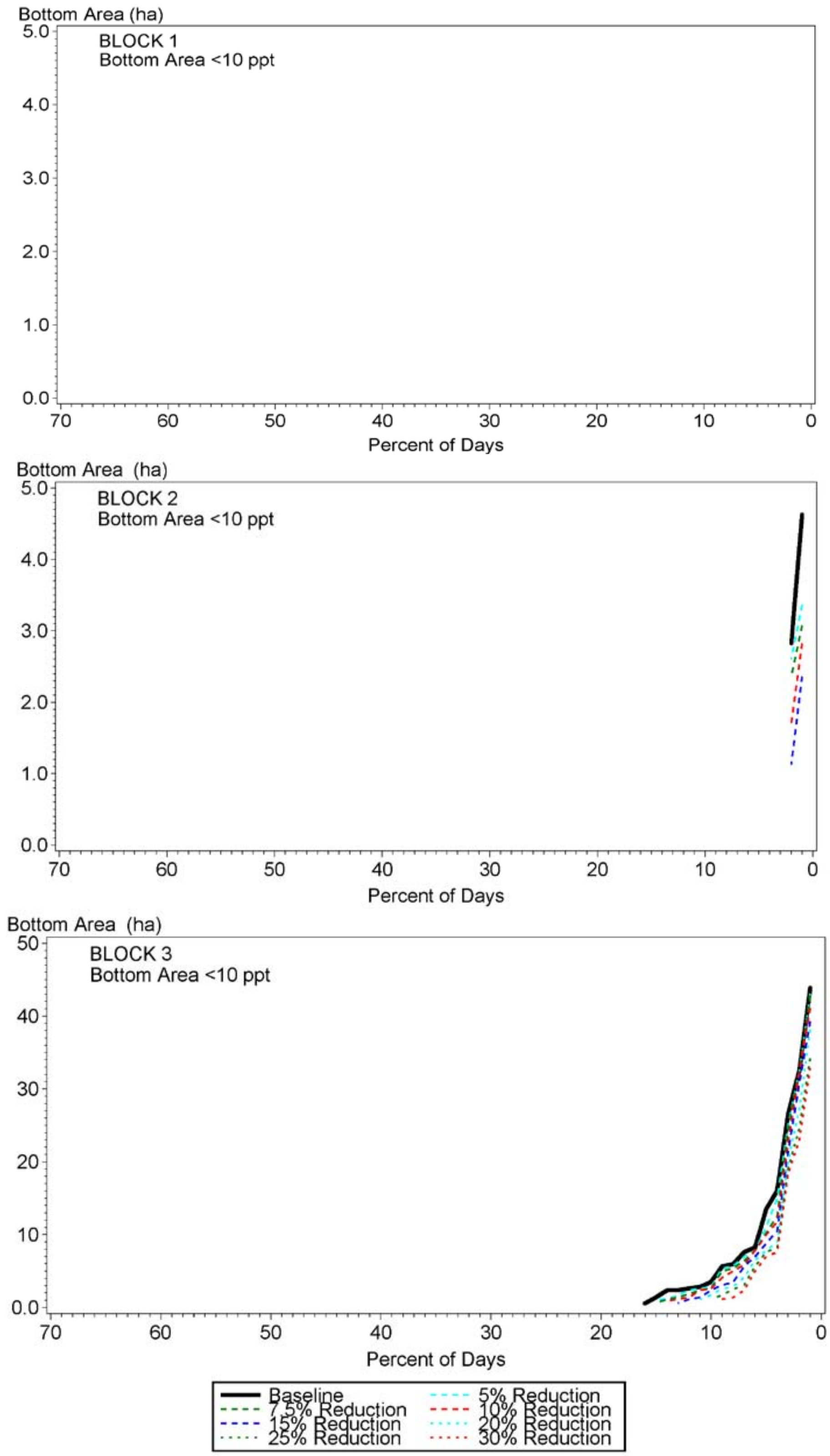

Figure 7-5. **Cumulative distribution function plots of bottom area underlying water with salinity less than 10 ppt by time for eight modeled flow scenarios during three seasonal blocks.**

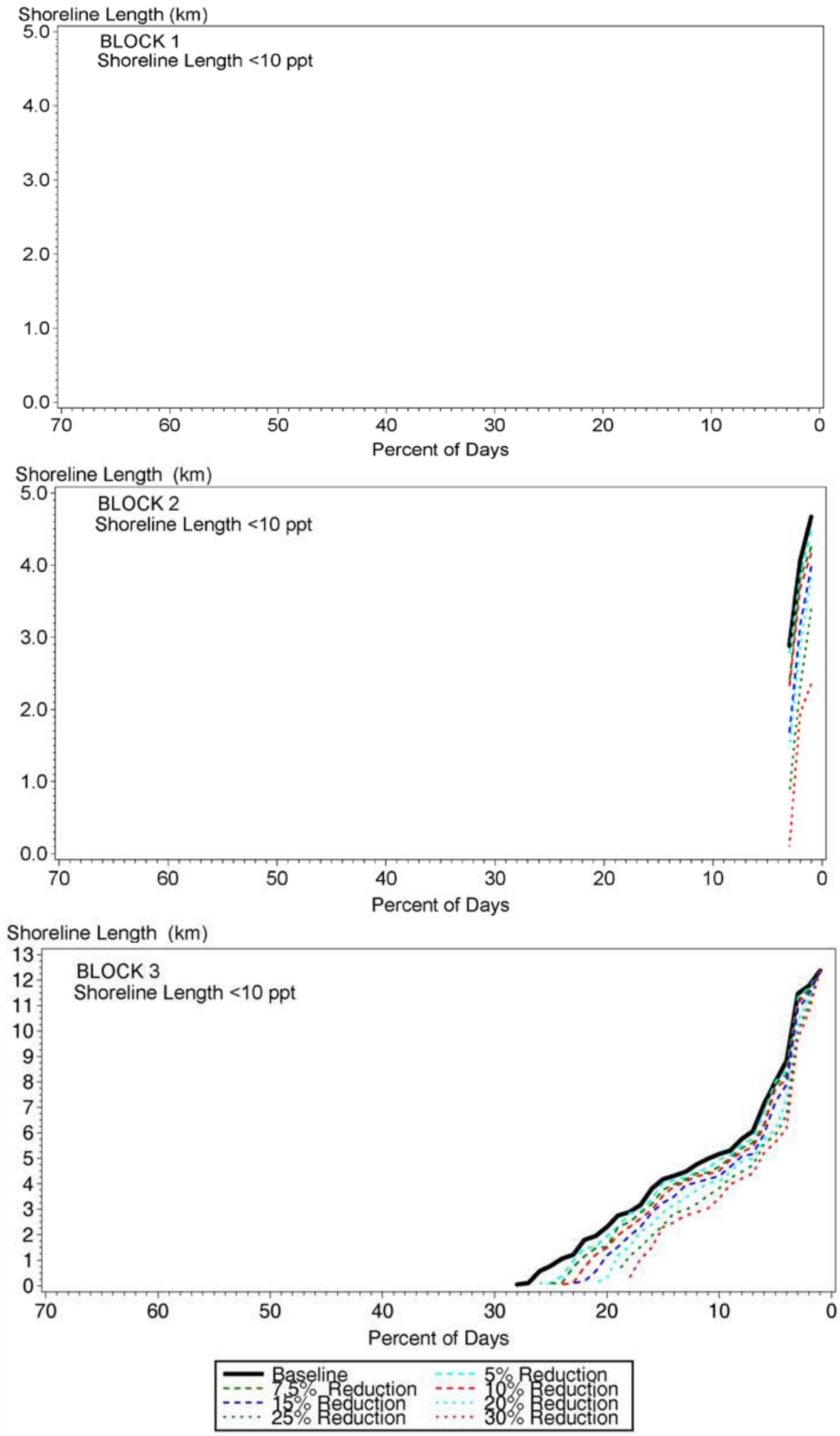

Figure 7-6. **Cumulative distribution function plots of shoreline length where water with salinity less than 10 ppt by time for eight modeled flow scenarios during three seasonal blocks.**

7.2.2 Salinity Criterion: Less than 15 ppt.

CDF plots of mean daily volume less than 15 ppt in the DARB minimum flow study area are presented in Figure 7-7. From this figure, the following observations can be made:

- During Blocks 1 and 2, the less than 15 ppt volume was available for a maximum of 11% of the time in the Baseline Scenario, with a maximum volume of less than 0.09 million m^3 in Block 1 and 0.45 million m^3 in Block 2 in the Baseline Scenario.

- During Block 3, some volume of less than 15 ppt water was available at least 33% of the time, even under the greatest flow reduction scenario. In Block 3, the maximum volume of less than 15 ppt was 1.4 million m^3 in all the Scenarios.

- Under all flow scenarios, some volume of less than 15 ppt water was available.

CDF plots of the mean daily bottom area of water less than 15 ppt in the DARB minimum flow study area are presented in Figure 7-8. Examination of this figure reveals the following:

- During Block 1, only the Baseline Scenario had any bottom area of less than 15 ppt.

- During Blocks 1 and 2, the less than 15 ppt bottom area was available for a maximum of 3% of the time in the Baseline Scenario, with a maximum area of only 1.1 ha in Block 1 and 16 ha in Block 2 in the Baseline Scenario.

- During Block 3, some bottom area less than 15 ppt was available at least 18% of the time, even under the greatest flow reduction scenario. In Block 3 for the Baseline Scenario, maximum bottom area of less than 15 ppt was about 52 ha.

From the CDF plots of mean daily shoreline length less than 15 ppt in the DARB minimum flow study area (Figure 7-9), the following conclusions can be drawn:

- During Blocks 1 and 2, the less than 15 ppt shoreline length was available for a maximum of 11% of the time in the Baseline Scenario, with a maximum length of 3.7 km in Block 1 and 8.6 km in Block 2 in the Baseline Scenario.

- During Block 3, some shoreline length less than 15 ppt was available at least 33% of the time, even under the greatest flow reduction scenario. In Block 3, maximum shoreline length of less than 15 ppt was about 12 km in the Baseline Scenario.

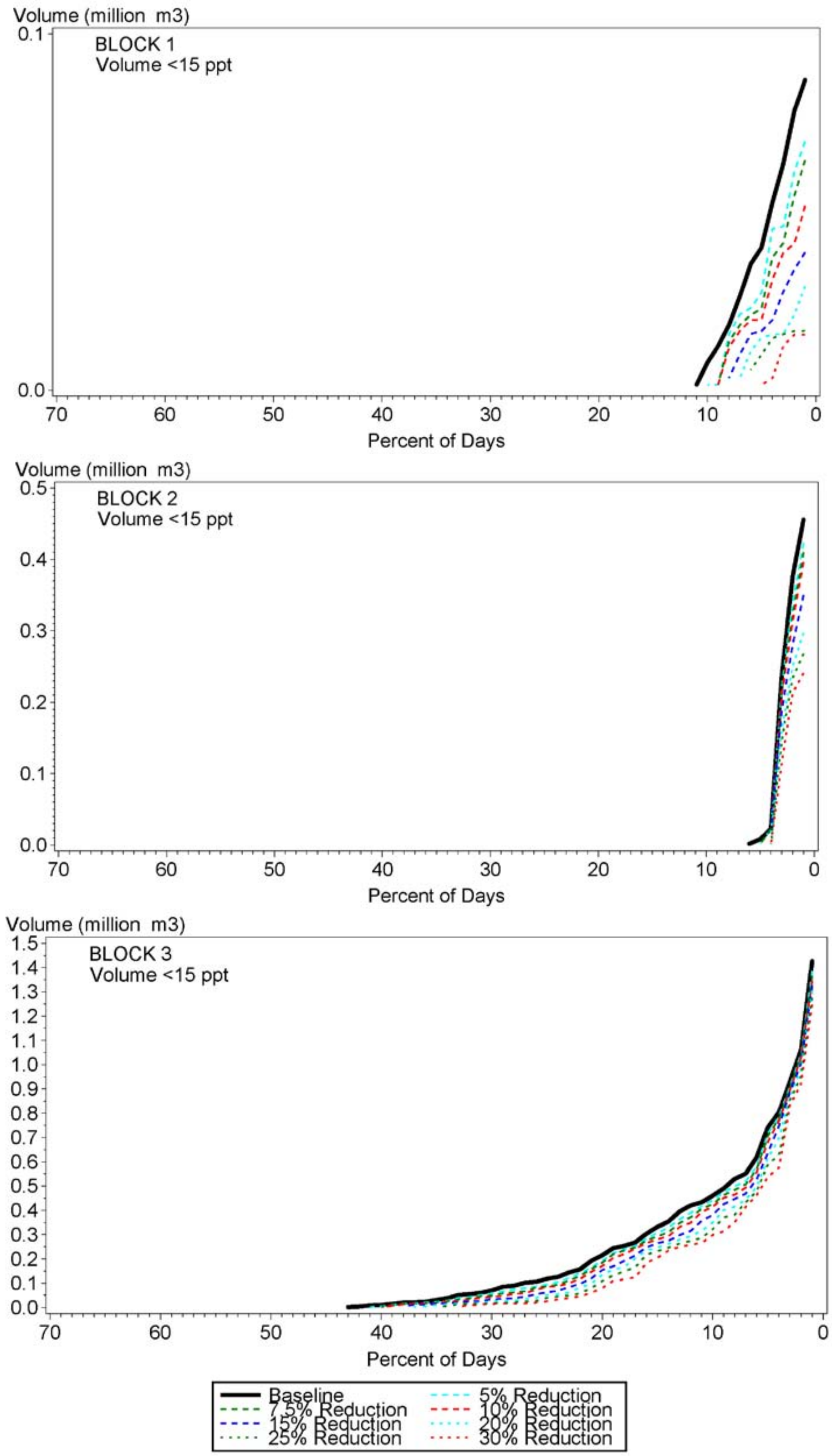

Figure 7-7. Cumulative distribution function plots of water volume in Dona Bay/Shakett Creek with salinity less than 15 ppt by time for eight modeled flow scenarios during three seasonal blocks.

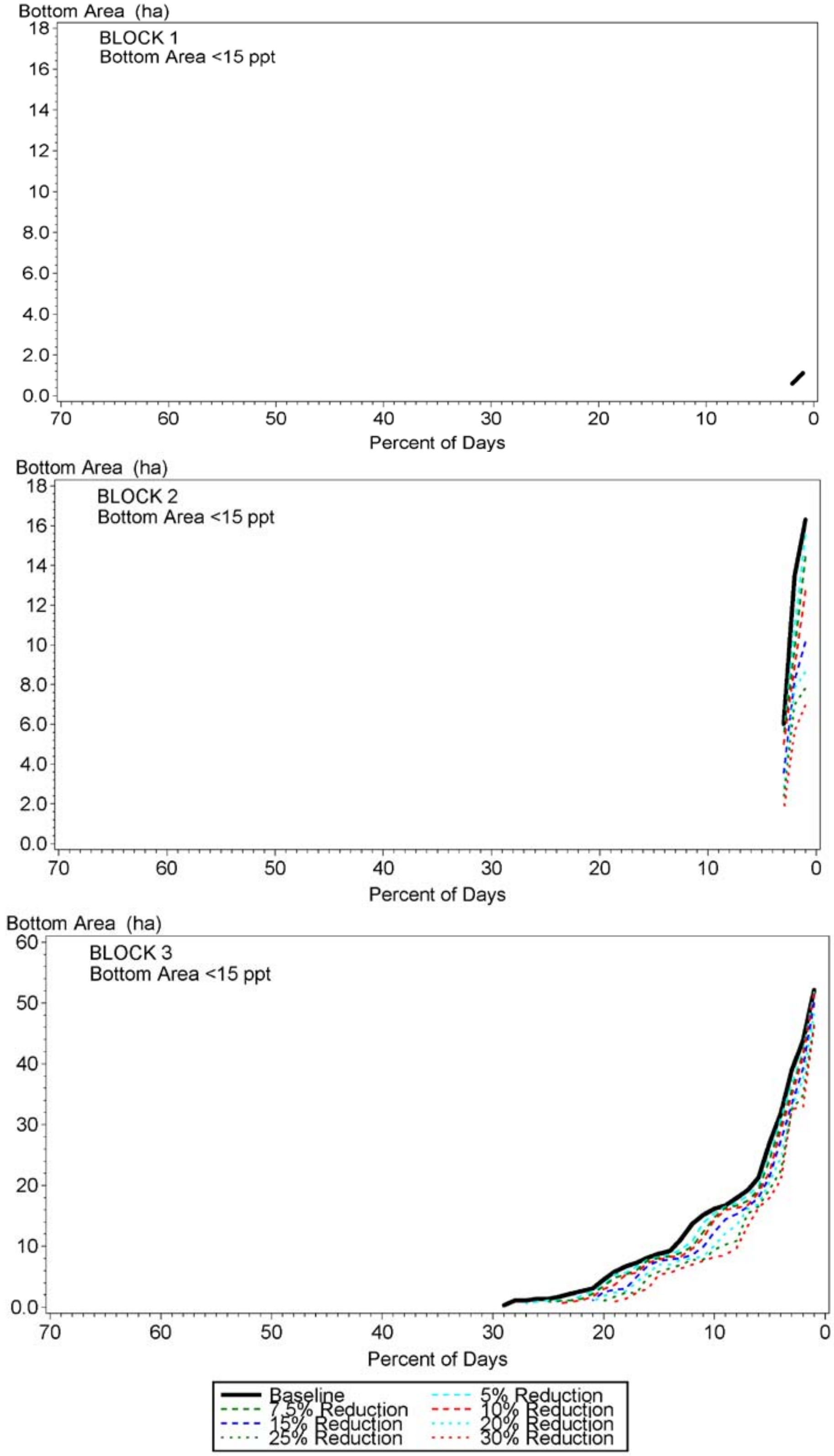

Figure 7-8. **Cumulative distribution function plots of bottom area in Dona Bay/Shakett Creek underlying water with salinity less than 15 ppt by time for eight modeled flow scenarios during three seasonal blocks.**

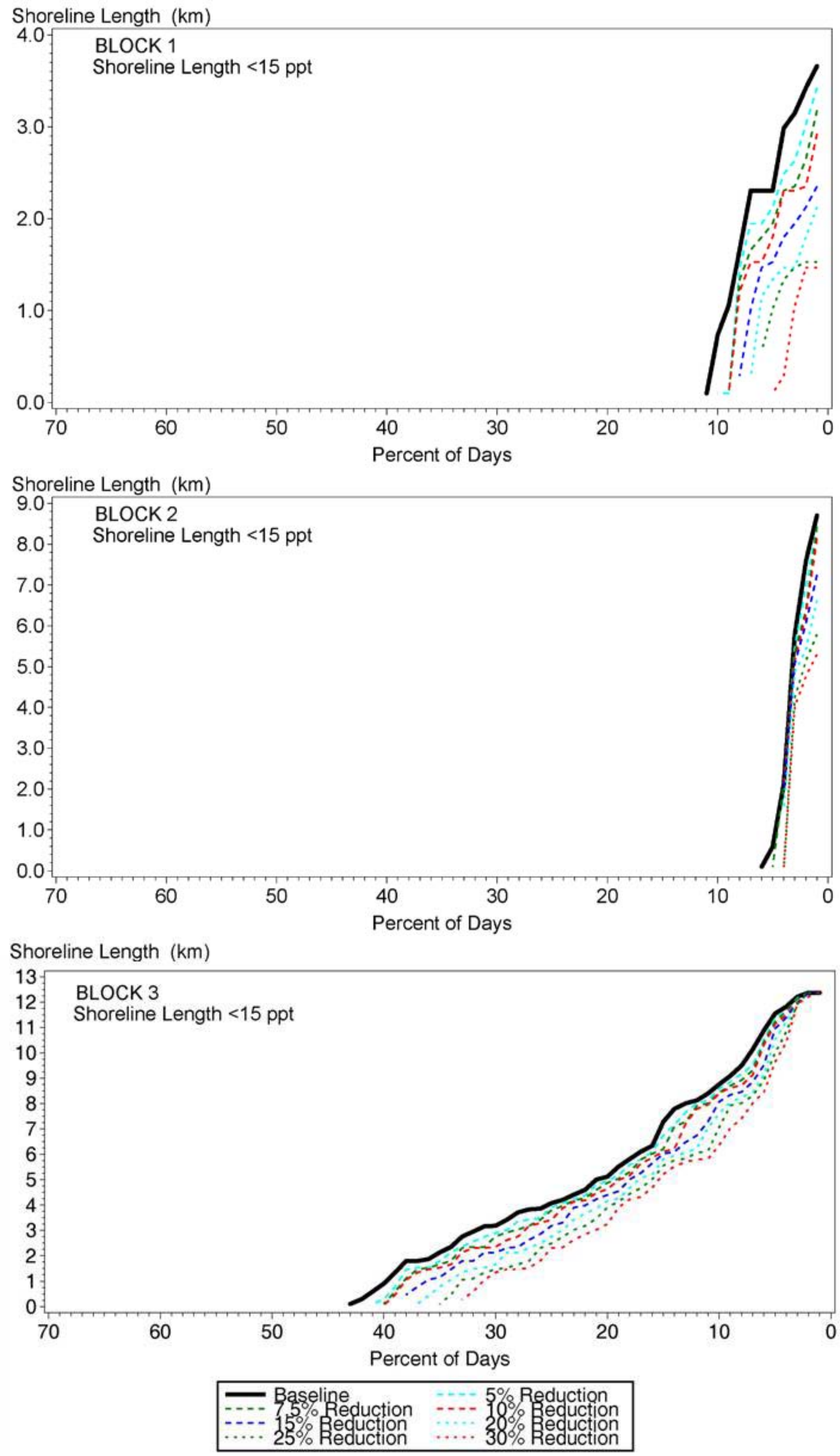

Figure 7-9. Cumulative distribution function plots of shoreline length in Dona Bay/Shakett Creek where water with salinity less than 15 ppt by time for eight modeled flow scenarios during three seasonal blocks.

7.2.3 Salinity Criterion: Less than 20 ppt.

CDF plots of mean daily volume less than 20 ppt in the DARB minimum flow study area are presented in Figure 7-10. From this figure, the following observations can be made:

- During Blocks 1 and 2, the less than 20 ppt volume was available for a maximum of 20% of the time in the Baseline Scenario, with maximum volumes of only 0.3 million m^3 in Block 1 and 0.8 million m^3 in Block 2 for the Baseline Scenario.

- During Block 3, some volume of less than 20 ppt water was available at least 50% of the time, even under the greatest flow reduction scenario. In Block 3 under all scenarios, maximum volume of less than 20 ppt was 1.7 million m^3.

CDF plots of the mean daily bottom area of water less than 20 ppt in the DARB minimum flow study area are presented in Figure 7-11. Examination of this figure reveals the following:

- During Blocks 1 and 2, the less than 20 ppt bottom area was available for a maximum of 12% of the time in the Baseline Scenario, with a maximum bottom area of 9 ha in Block 1 and 33 ha in Block 2 for the Baseline Scenario.

- During Block 3, some bottom area of less than 20 ppt water was available at least 35% of the time, even under the greatest flow reduction scenario. In Block 3 under all scenarios, maximum bottom area of less than 20 ppt was greater than 50 ha for all scenarios.

From the CDF plots of mean daily shoreline length less than 20 ppt in the DARB minimum flow study area (Figure 7-12), the following conclusions can be drawn:

- During Blocks 1 and 2, the less than 20 ppt shoreline length was available for a maximum of 20% of the time in the Baseline Scenario, with a maximum shoreline length of only 6.5 km in Block 1 and 11.5 km in Block 2 in the Baseline Scenario.

- During Block 3, some shoreline length less than 20 ppt was available at least 51% of the time, even under the greatest flow reduction scenario. In Block 3 under all scenarios, maximum shoreline length of less than 20 ppt was 12.4 km.

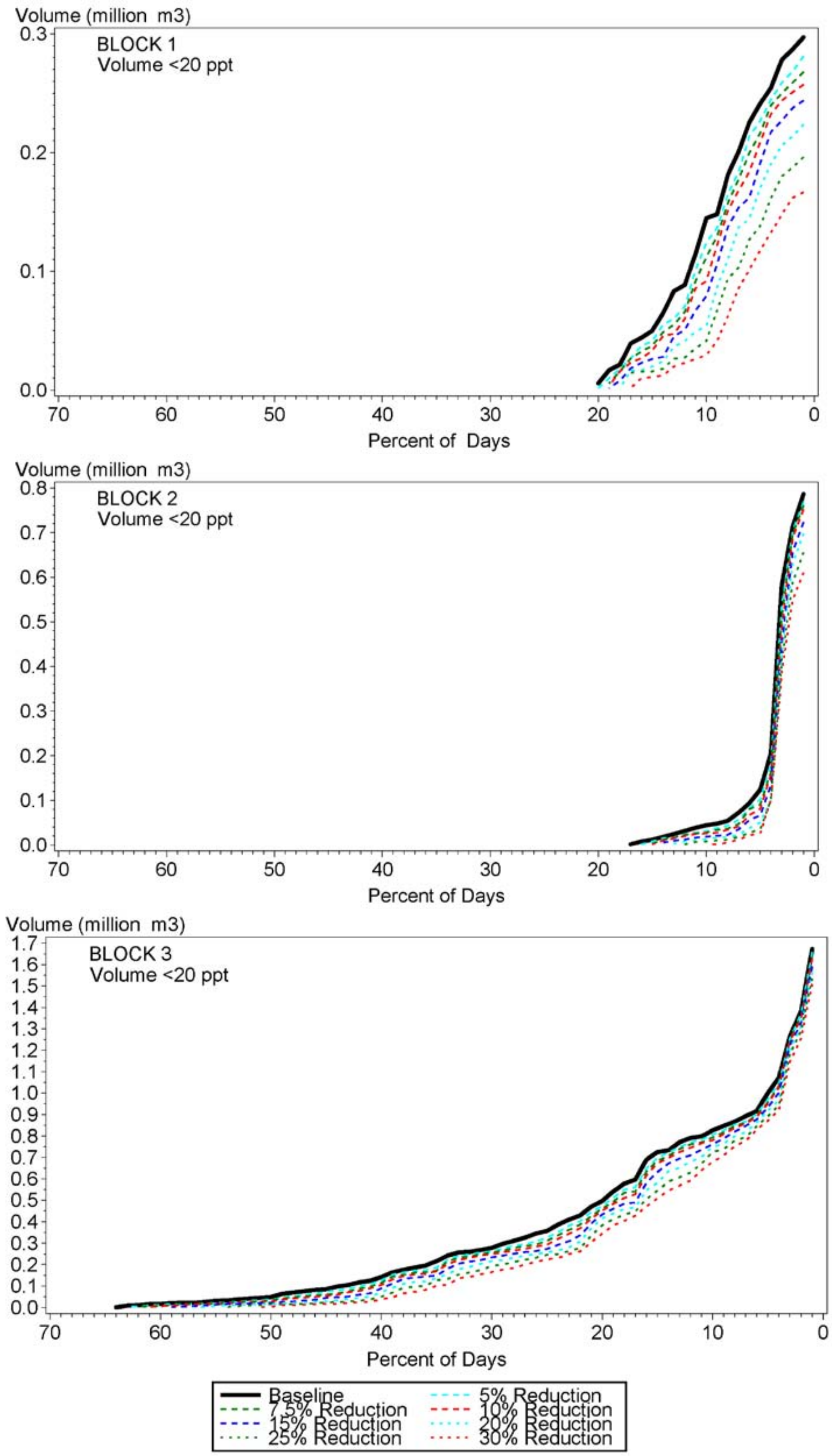

Figure 7-10. Cumulative distribution function plots of water volume in Dona Bay/Shakett Creek with salinity less than 20 ppt by time for eight modeled flow scenarios during three seasonal blocks.

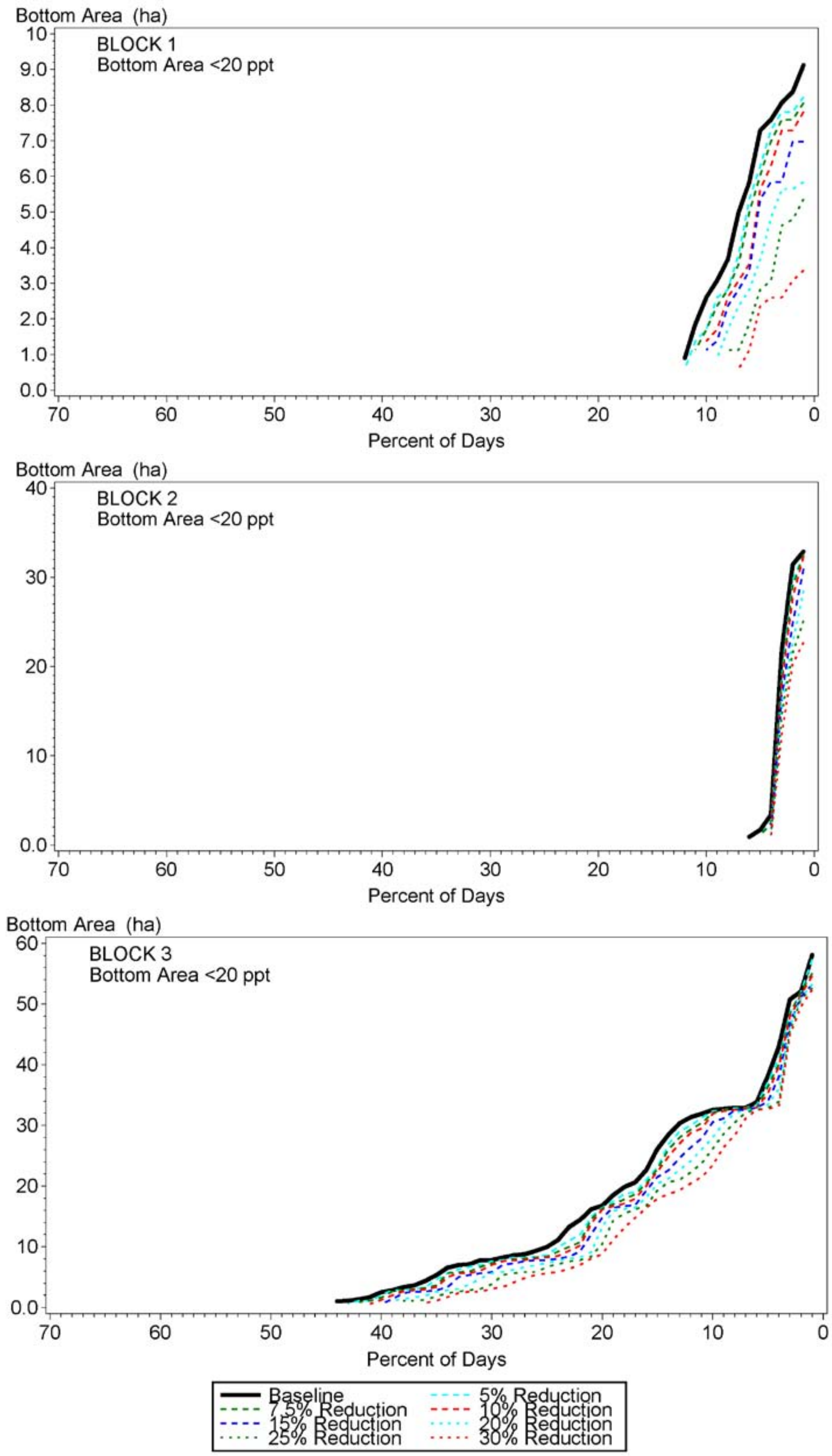

Figure 7-11. Cumulative distribution function plots of bottom area in Dona Bay/Shakett Creek underlying water with salinity less than 20 ppt by time for eight modeled flow scenarios during three seasonal blocks.

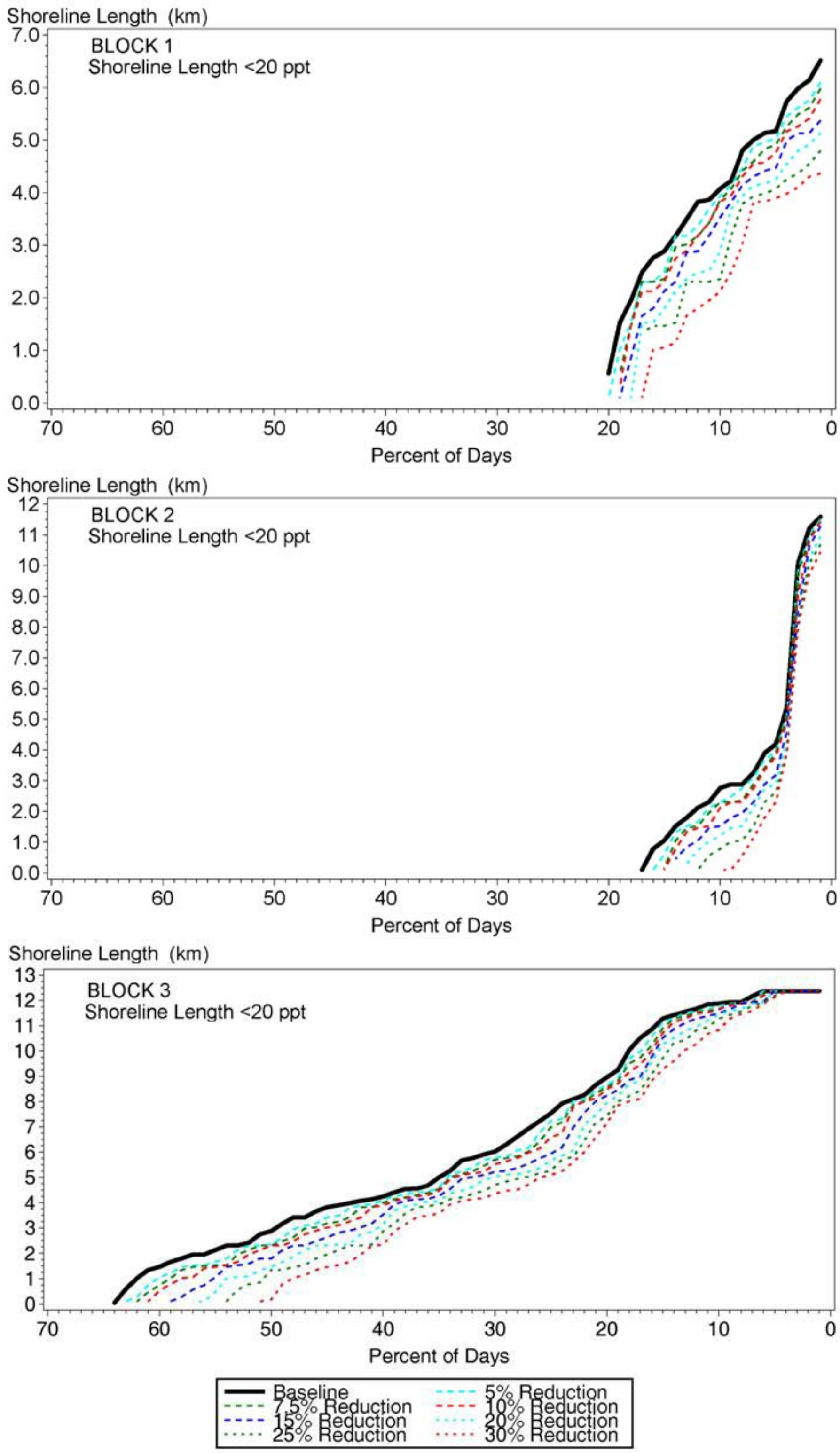

Figure 7-12. **Cumulative distribution function plots of shoreline length in Dona Bay/Shakett Creek where water with salinity less than 20 ppt by time for eight modeled flow scenarios during three seasonal blocks.**

8 DISTRICT RECOMMENDATION FOR DARB MINIMUM FLOWS

The objectives of this section are:

1. to define the minimum flow criterion to be used in estimating the minimum flows for DARB,
2. to define the method to be used to establish the minimum flows for DARB,
3. to apply the method to results of the analytical tools that relate flow to salinity in DARB,
4. to recommend minimum flows for DARB, and
5. to describe the influence of the proposed minimum flows on other water quality constituents and ecological components in DARB.

8.1 Minimum Flow Criterion

Section 373.042, F. S. defines the minimum flow for a surface watercourse as “the limit at which further withdrawals would be significantly harmful to water resources or ecology of the area”. The District currently uses a percent-of-flow approach for identifying significant harm thresholds used to establish and implement minimum flows. The percent-of-flow method allows water users to take a percentage of streamflow at the time of the withdrawal. The method has been used for the regulation of water use permits since 1989, when it was first applied to withdrawals from the lower Peace River. A goal of the percent-of flow approach is the approximation of the natural hydrologic regime, albeit with some dampening for water use, to promote the range of flows necessary to maintain habitat that are required for aquatic and wetland species and chemical/physical processes.

As part of the percent-of-flow approach to establishing minimum flows, “significant” harm has been operationally defined as a 15% loss of available habitat. This definition of significant harm has been used in minimum flow studies for the middle Peace River (SWFWMD 2005c), upper Alafia River (SWFWMD 2005b), upper Myakka River (SWFWMD 2005d), Braden River (SWFWMD 2007b), upper Hillsborough River (SWFWMD 2007c), and lower Peace River and Shell Creek (SWFWMD 2007a). Use of this criterion, in the form of limiting changes in habitat availability to no more than a 15% decrease relative to the habitat available under the baseline condition was employed for development of proposed minimum flows for the Dona Bay/Shakett Creek portion of the DARB system.

As discussed in Section 2, DARB has undergone significant physical and hydrologic alterations. These alterations include the following:

- Construction of the Cow Pen Slough Canal which connected Cow Pen Slough to Shakett Creek/Dona Bay.
- Construction of the Blackburn Canal which connects the Myakka River to Curry Creek/Roberts Bay.

- Excavation of the Intracoastal Waterway which connected Sarasota Bay in the north to Lemon Bay in the south.
- Excavation and maintenance of the Venice Inlet which provides a direct connection between DARB and the Gulf of Mexico.
- Construction of bridges over Dona Bay and Roberts Bay.

The construction of the Cow Pen Slough and Blackburn canals has led to an increase in the volume of freshwater entering DARB as well as modifying the timing of the freshwater inflows to the system. As discussed in Section 2, the construction of the Cow Pen Slough Canal diverted an area of approximately 37,000 acres that previously drained to the Myakka River to Shakett Creek/Dona Bay. This significant increase in the size of the Dona Bay watershed resulted in an increase in the amount of freshwater that enters Dona Bay. Additionally, there are two structures on the Cow Pen Slough Canal which are used to conserve water during the drier portion of the year (historically November 1 to May 31) and drain the land to avoid flooding during the wetter portion of the year (June 1 – October 31). Therefore, the construction of the Cow Pen Slough Canal has modified the amount and timing of freshwater delivered to Dona Bay. The construction of the Blackburn Canal provides a direct connection between the Myakka River and Curry Creek/Roberts Bay. This connection diverts a portion of the Myakka River flow to Roberts Bay. Unlike the Cow Pen Slough Canal, there are no structures on the Blackburn Canal that control flow. While the Cow Pen Slough and Blackburn canals have led to additional freshwater entering the DARB system upstream, several alterations have led to increased saltwater in the DARB system downstream.

The excavation of the ICW and the construction of the Venice Inlet have influenced the longitudinal and vertical distribution of salinity in the DARB system. The dredging of the Venice Inlet has resulted in a shortened, straightened passage which provides a direct connection between the Gulf of Mexico and DARB. This tide-dominated inlet increases the mixing of salt water from the Gulf of Mexico and the waters of DARB. Additionally, the Intracoastal Waterway has led to an increase in water volume in the system due to the dredging and maintenance of the navigation channel.

The construction of bridges over Dona Bay and Roberts Bay has accentuated the longitudinal differences in salinity in the DARB system by restricting longitudinal exchange at the constrictions formed by the bridge construction. During periods of high freshwater inflow, the freshwater is held back upstream of the bridges, and saltier water is restrained from moving upstream as rapidly during incoming tides, so that the region upstream of the constrictions is fresher and that downstream of the constrictions is more saline than would be expected if the constrictions did not exist. During periods of low freshwater inflows, more saline water which reaches upstream of the constrictions does not move out of the upstream region as easily as it would in the absence of the constrictions.

As discussed in Section 1, the legislature recognizes that restoration to historical hydrologic conditions is not always technically or economically feasible. For the DARB system, removal of the Venice Inlet, the ICW, or the bridges over Dona Bay and

Roberts Bay are not actions that could be considered economically feasible. Therefore these alterations are considered as un-alterable physical elements of the DARB system and were included in the development of the baseline flow regime. However, the baseline flow condition does not include flows which presently enter Shakett Creek and Dona Bay from the channelized CPS nor does it include the Myakka flows which presently enter Roberts Bay. ***The proposed minimum flow criterion for DARB is the flow that results in no more than a 15% reduction in available habitat relative to the baseline flow condition*** recognizing that even a complete restoration of the historical flow regime will not result in restoration of the historical salinity regime in Dona Bay that existed prior to the aforementioned physical alterations. To this end, results from Section 7 were summarized in order to define seasonal minimum flows for Dona Bay.

The recommended minimum flows have been defined as an allowable percent reduction in flow to Dona Bay. Therefore, the proposed minimum flow is the seasonally-specific percent flow reduction that maintains at least 85% of the habitat that is available under Baseline Scenario conditions. As the minimum flow is quantified as an allowable percent reduction in flow from Salt Creek and Fox Creek, implementation of the minimum flow will require some estimate of flows from both creeks.

8.2 Method to Define Minimum Flow

As discussed in Section 3.1, the District typically applies a percent-of-flow method to determine minimum flows. The percent-of-flow method allows water users to take a percentage of streamflow at the time of the withdrawal. The percent-of-flow method has been used for the regulation of water use permits since 1989, when it was first applied to withdrawals from the Lower Peace River.

Habitat availability can be quantified in terms of both space and time. The tool used to evaluate temporal persistence and spatial extent of habitat meeting a biologically-relevant salinity is a cumulative distribution function (CDF) plot, described in Section 7. CDF plots are an ideal tool as they incorporate the spatial extent and the temporal persistence that a given salinity is met. Plots are drawn of the various scenarios that have been run and comparisons can be made among scenarios.

The method used to compare alternative scenarios to the baseline condition is presented in Figure 8-1. The habitat available for a given scenario is estimated by calculating the area under the curve from the CDF plots in Section 7. Simply, the amount of available habitat increases as the area under the curve increases. In Figure 8-1a, the blue-hatched area (area under the curve) is the estimate of the habitat available under the Baseline condition (HA_B) for the baseline period. The habitat available under an alternative scenario, Scenario 1 (HA_{S1}), is presented in Figure 8-1b. To compare the two scenarios, the area between the two curves can be calculated (Figure 8-1c). This difference is the habitat loss from the baseline scenario under Scenario 1.

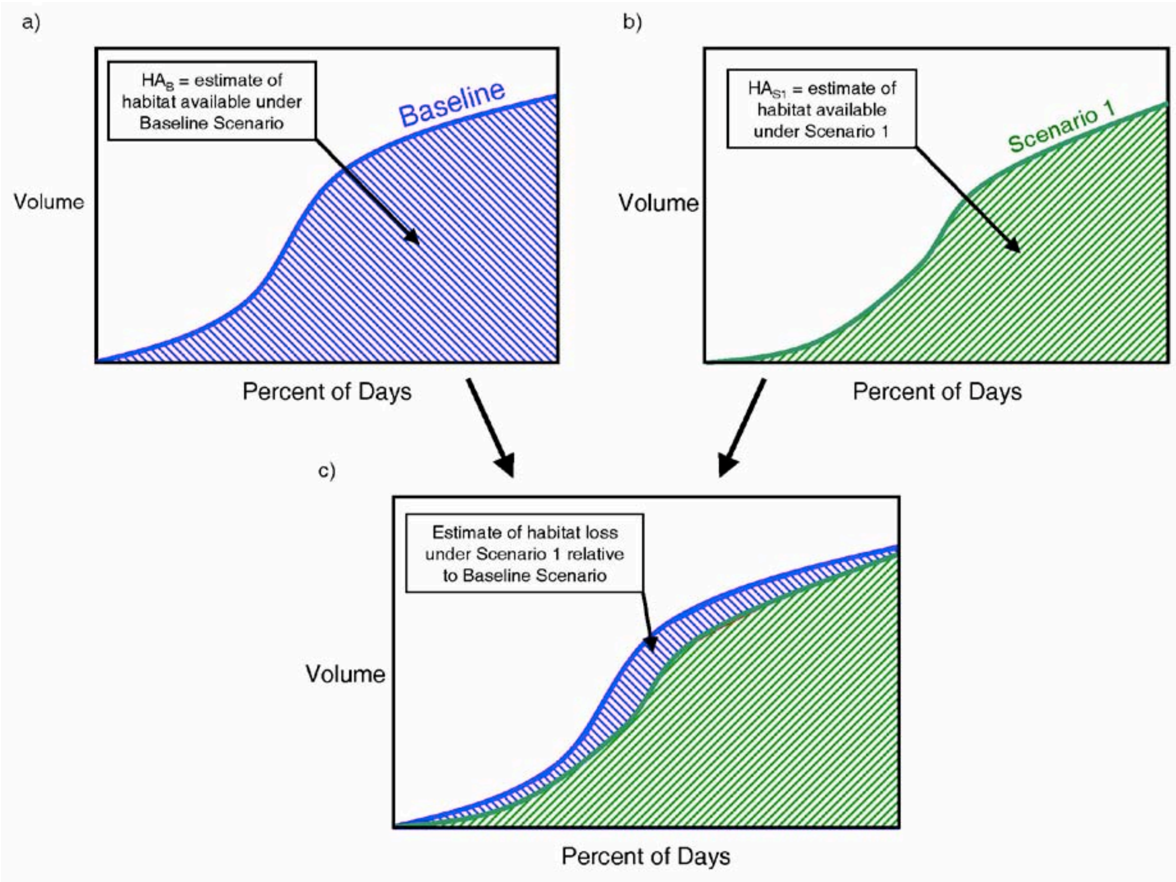

Figure 8-1. Examples of the available habitat, or areas under curves calculated from cumulative distribution function plots. Panel (a) represents the available habitat (*HA_B*) for the baseline condition. Panel (b) represents the available habitat for an alternative condition (*HA_{S1}*). Panel (c) illustrates the difference in available habitat for the baseline and scenario 1.

The proposed minimum flow is defined as the flow that maintains at least 85% of the habitat that is available under the Baseline Scenario. In order to determine which alternative scenario results in no more than a 15% reduction in available habitat relative to the Baseline Scenario (i.e., maintains 85% of habitat available in the Baseline Scenario), the normalized area under the curve (NAUC) has been calculated for each alternative scenario relative to the Baseline Scenario. The formula to calculate the NAUC for a scenario (e.g., Scenario 1) is:

$$NAUC = \frac{(HA)_{S1}}{(HA)_B}$$

By plotting the NAUC for all alternative scenarios for each block, the scenario that results in a 15% reduction in available habitat can be identified. A conceptual plot of NAUC for several alternative scenarios is presented in Figure 8-2. The scenarios are plotted on the x-axis while the NAUC for each scenario is on the y-axis. The reference line on the y-axis at 0.85 represents a 15% loss in habitat. From Figure 8-3, it can be seen that the flow which results in a 15% reduction in available habitat is between Scenario A and Scenario B.

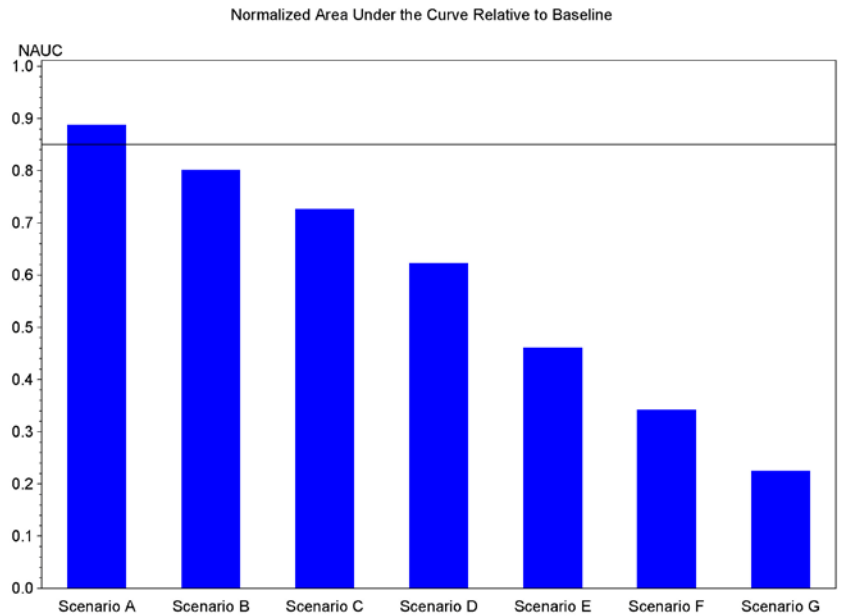

Figure 8-2. **Example plot of normalized areas from cumulative distribution function plots of habitat for seven flow scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario.**

8.3 Application of Method to Define Minimum Flows

The method described in Section 8.2 was applied to all combinations of metrics and biologically-relevant salinities for all blocks. The results of these analyses for Dona Bay are presented for each salinity criterion in the following subsections.

8.3.1 Salinity Criteria

Plots of the NAUC by block for the volume of water, bottom area, and shoreline length less than 10 ppt are presented in Figures 8-3 to 8-4, Figures 8-5 to 8-6, and Figures 8-7 to 8-8, respectively. As discussed in Section 7, under the flow reduction scenarios, there was no water in the system less than 10 ppt during Block 1. Therefore, comparisons can not be made for Block 1 when salinity is less than 10 ppt.

NAUC plots by block for the volume of water, bottom area, and shoreline length less than 15 ppt are presented in Figures 8-9 to 8-11, Figures 8-12 to 8-13, and Figures 8-14 to 8-16, respectively. As discussed in Section 7, under the baseline and flow reduction scenarios, there was no bottom area in the system less than 15 ppt during Block 1. Therefore, comparisons can not be made for bottom area during Block 1 when salinity is less than 15 ppt.

Plots of the NAUC by block for the volume of water, bottom area, and shoreline length less than 15 ppt are presented in Figures 8-17 to 8-19, Figures 8-20 to 8-22, and Figures 8-23 to 8-25, respectively.

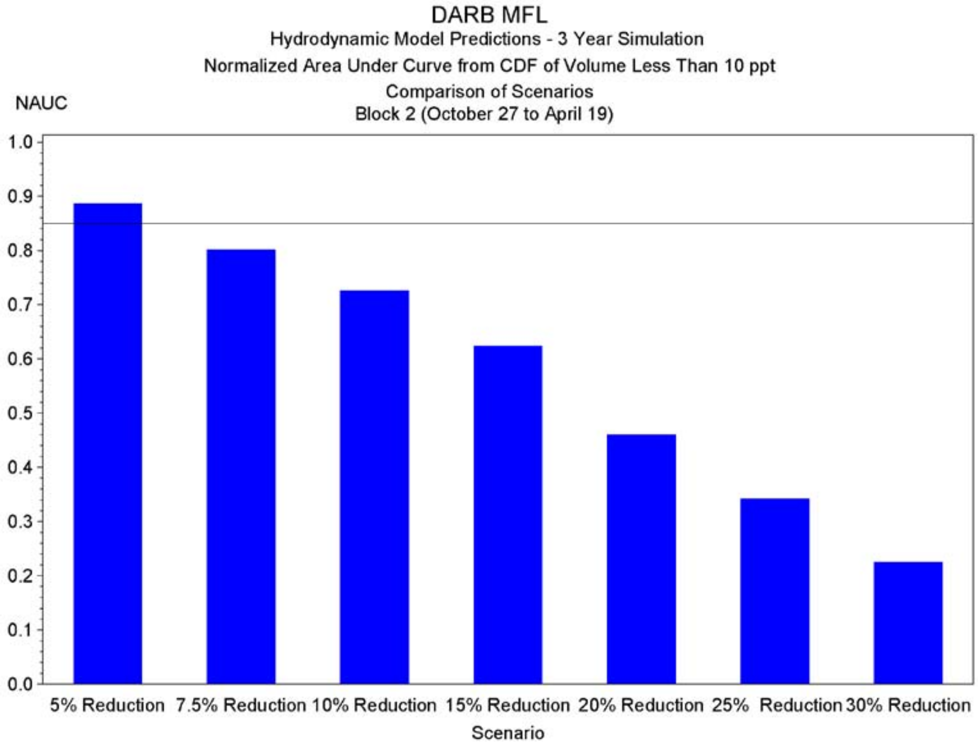

Figure 8-3. **Normalized areas from cumulative distribution function plots of water volume in Dona Bay/Shakett Creek with salinity less than 10 ppt during Block 2 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 2.**

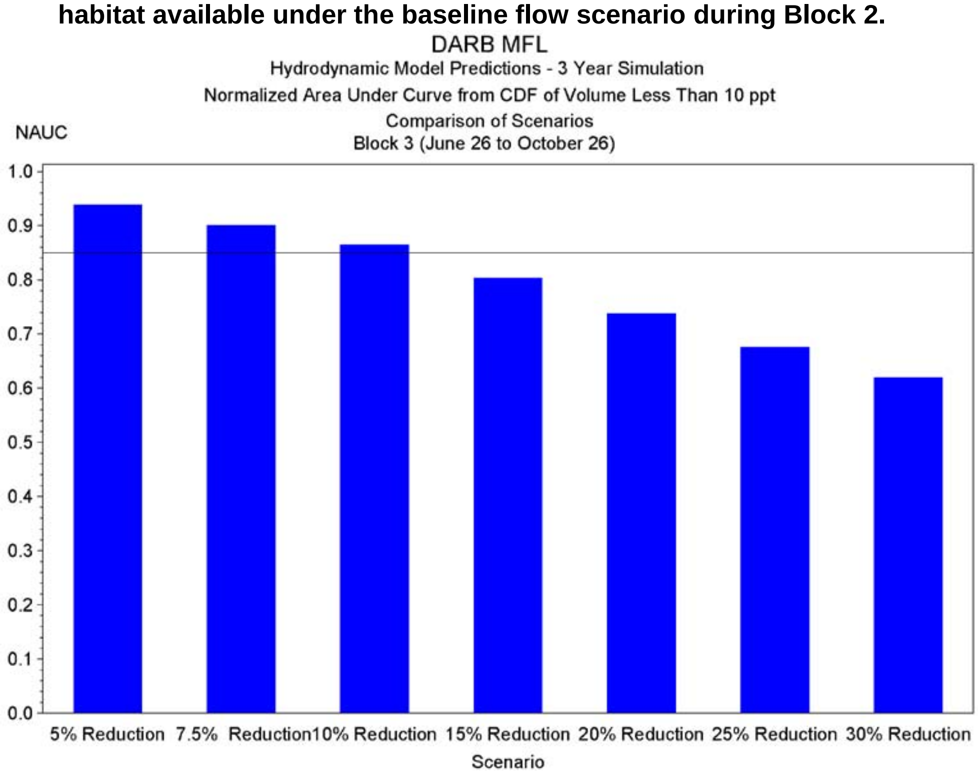

Figure 8-4. **Normalized areas from cumulative distribution function plots of water volume in Dona Bay/Shakett Creek with salinity less than 10 ppt during Block 3 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 3.**

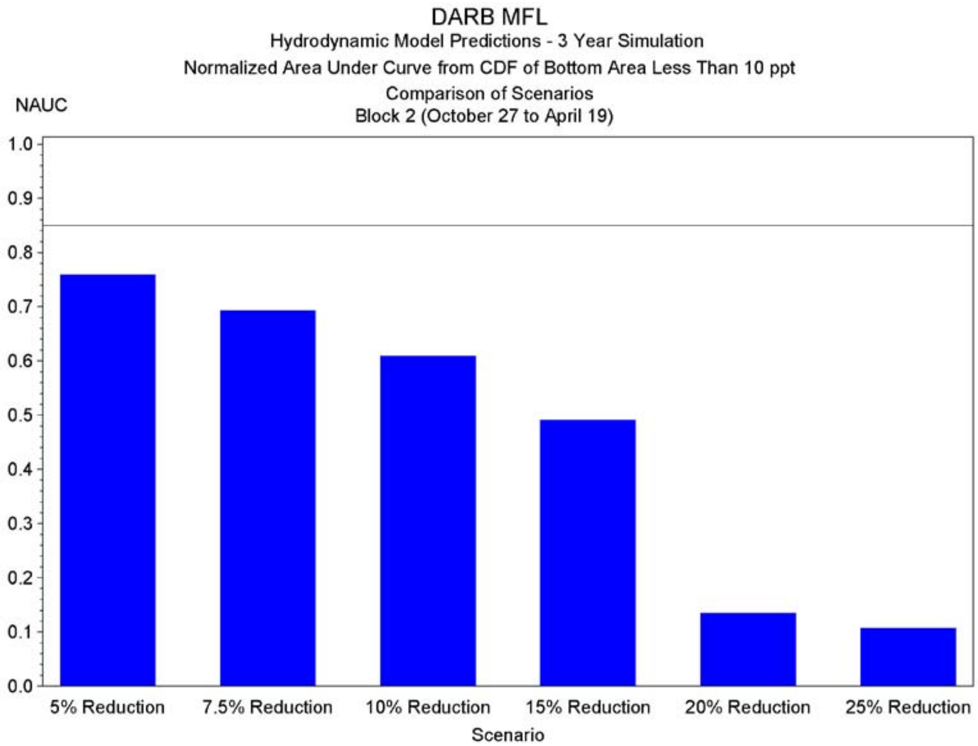

Figure 8-5. **Normalized areas from cumulative distribution function plots of bottom area in Dona Bay/Shakett Creek with salinity less than 10 ppt during Block 2 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 2.**

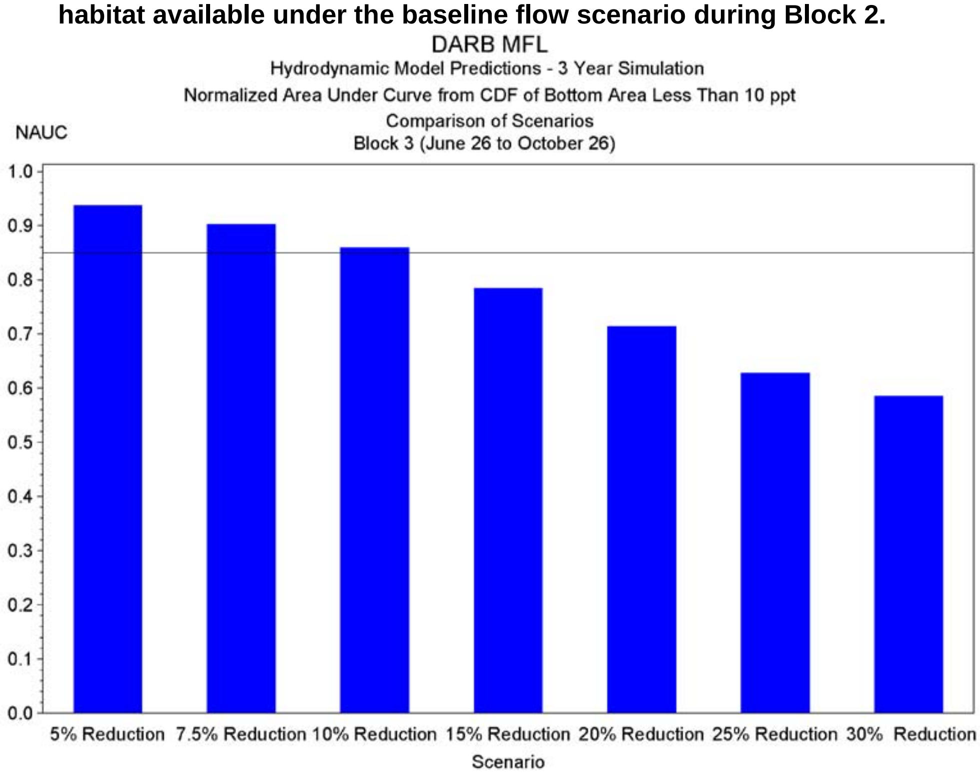

Figure 8-6. **Normalized areas from cumulative distribution function plots of bottom are in Dona Bay/Shakett Creek with salinity less than 10 ppt during Block 3 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 3.**

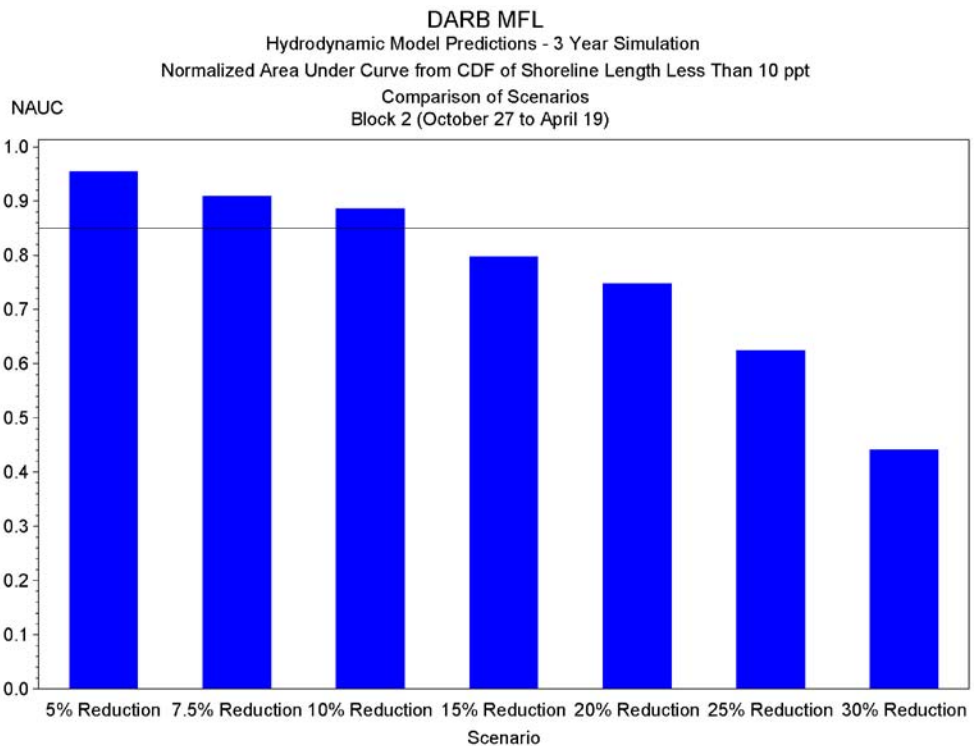

Figure 8-7. **Normalized areas from cumulative distribution function plots of shoreline length Dona Bay/Shakett Creek with salinity less than 10 ppt during Block 2 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 2.**

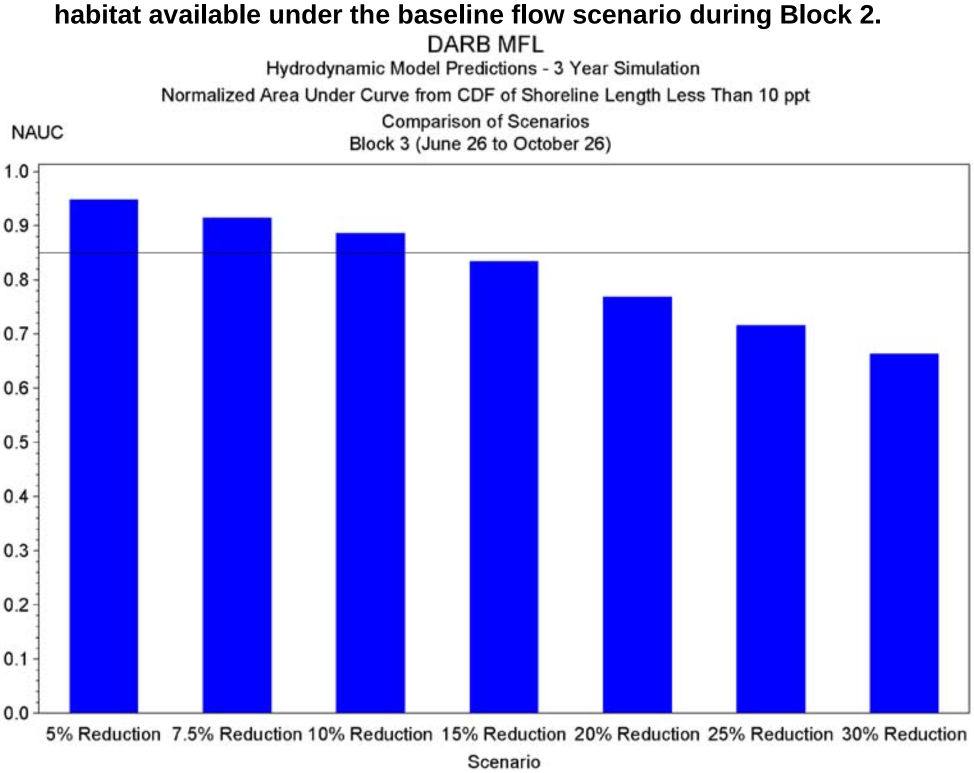

Figure 8-8. **Normalized areas from cumulative distribution function plots of shoreline length in Dona Bay/Shakett Creek with salinity less than 10 ppt during Block 3 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario Block 3.**

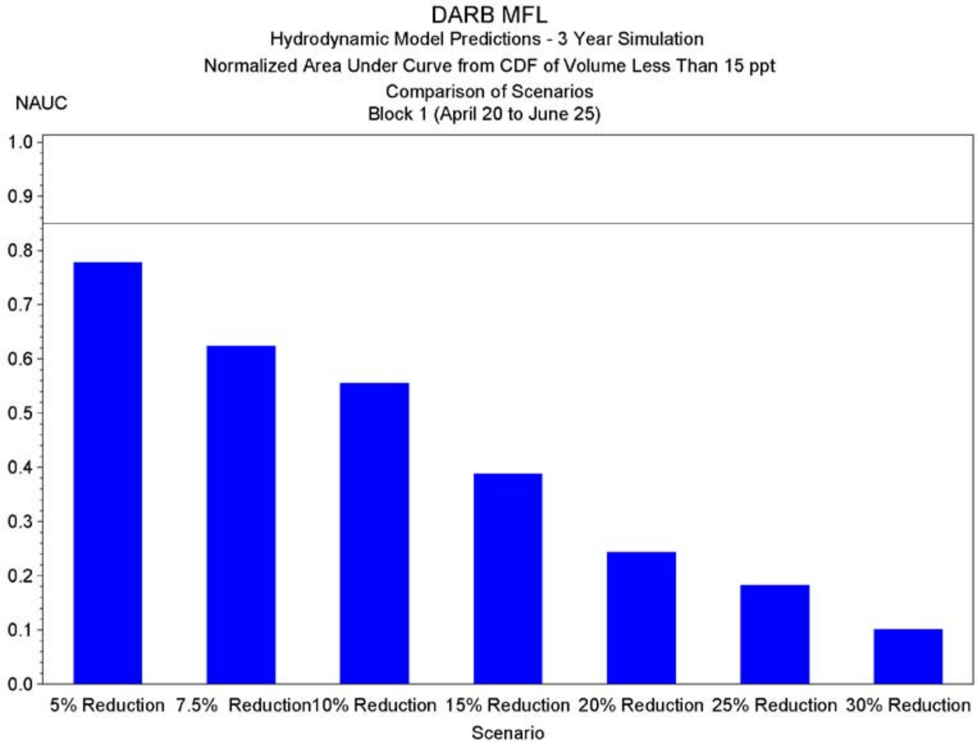

Figure 8-9. Normalized areas from cumulative distribution function plots of water volume in Dona Bay/Shakett Creek with salinity less than 15 ppt during Block 1 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 1.

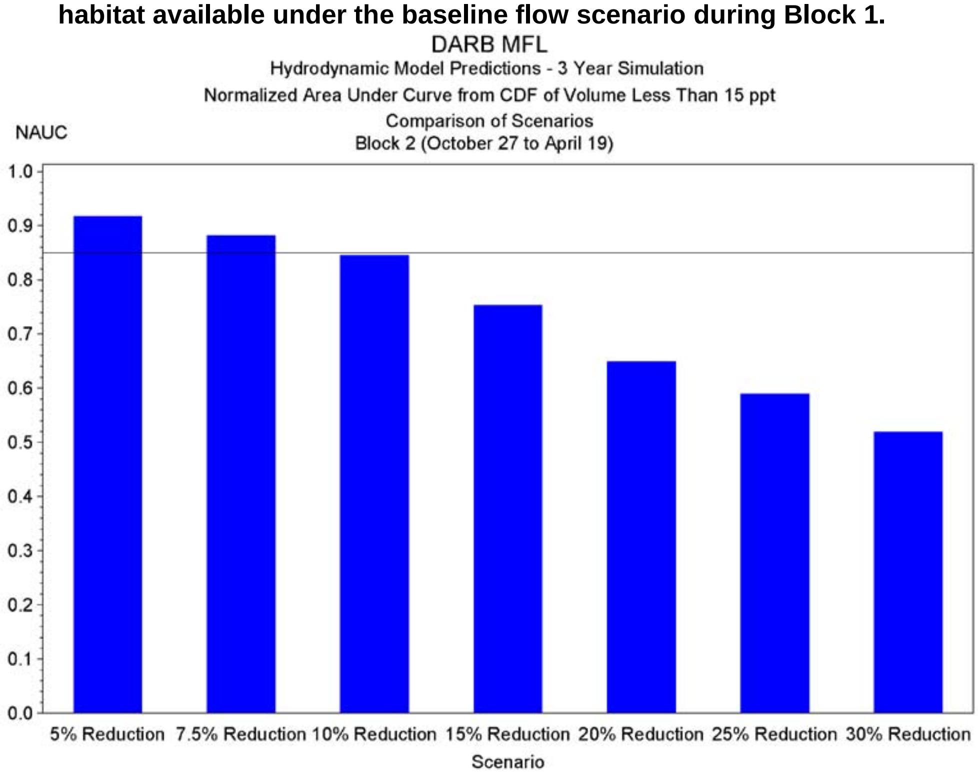

Figure 8-10. Normalized areas from cumulative distribution function plots of water volume in Dona Bay/Shakett Creek with salinity less than 15 ppt during Block 2 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 2.

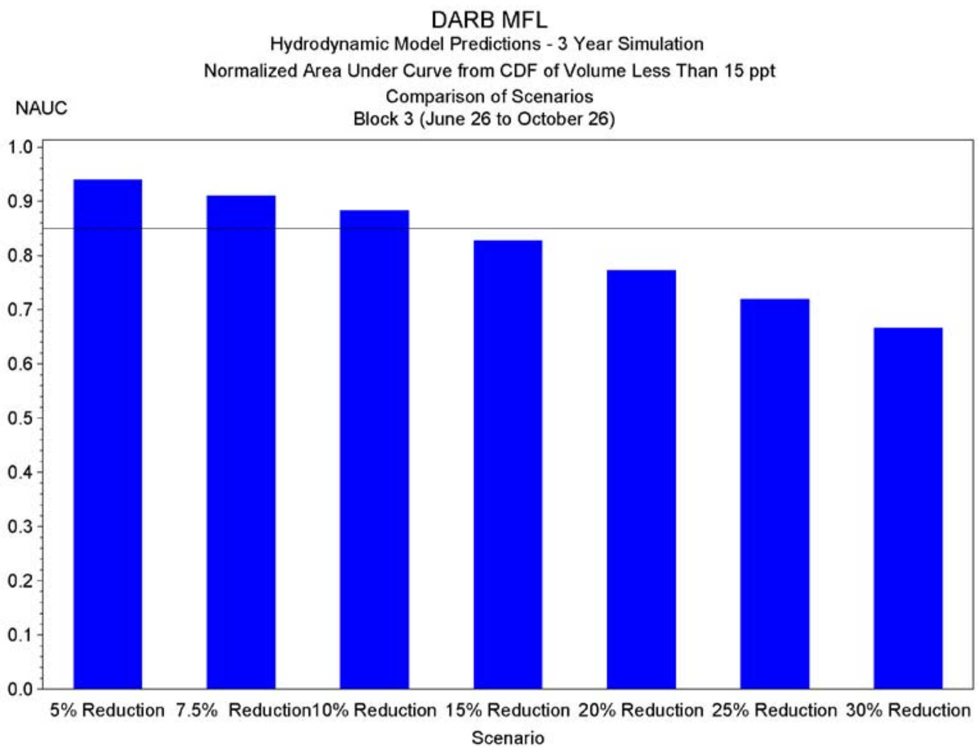

Figure 8-11. **Normalized areas from cumulative distribution function plots of water volume in Dona Bay/Shakett Creek with salinity less than 15 ppt during Block 3 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 3.**

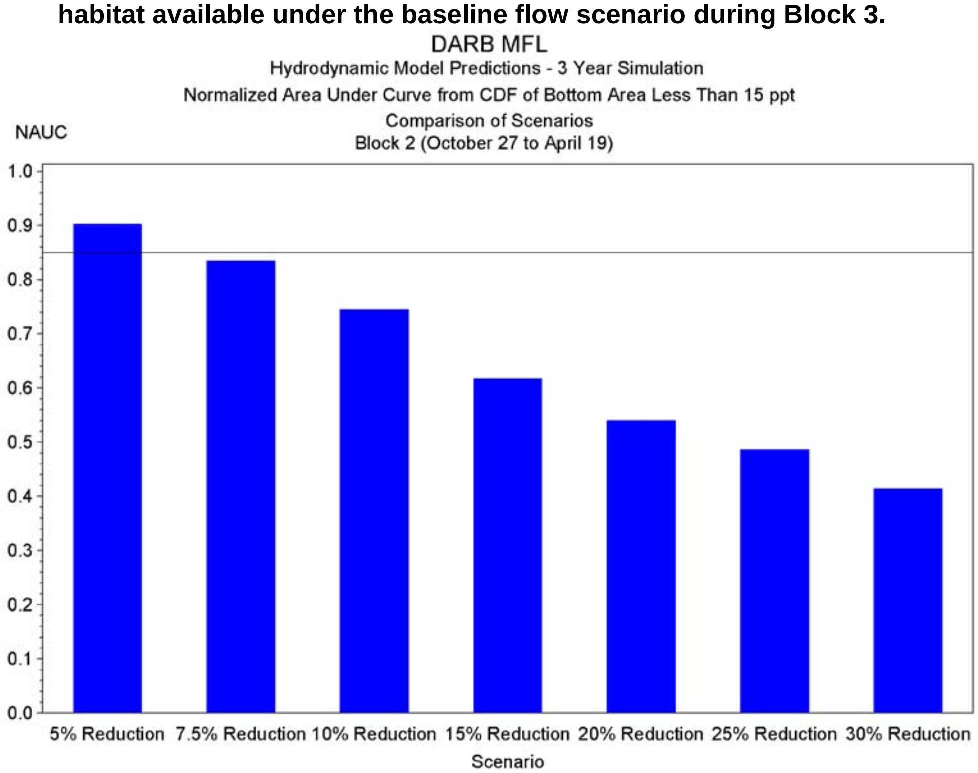

Figure 8-12. **Normalized areas from cumulative distribution function plots of bottom area in the Dona Bay/Shakett Creek with salinity less than 15 ppt during Block 2 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 2.**

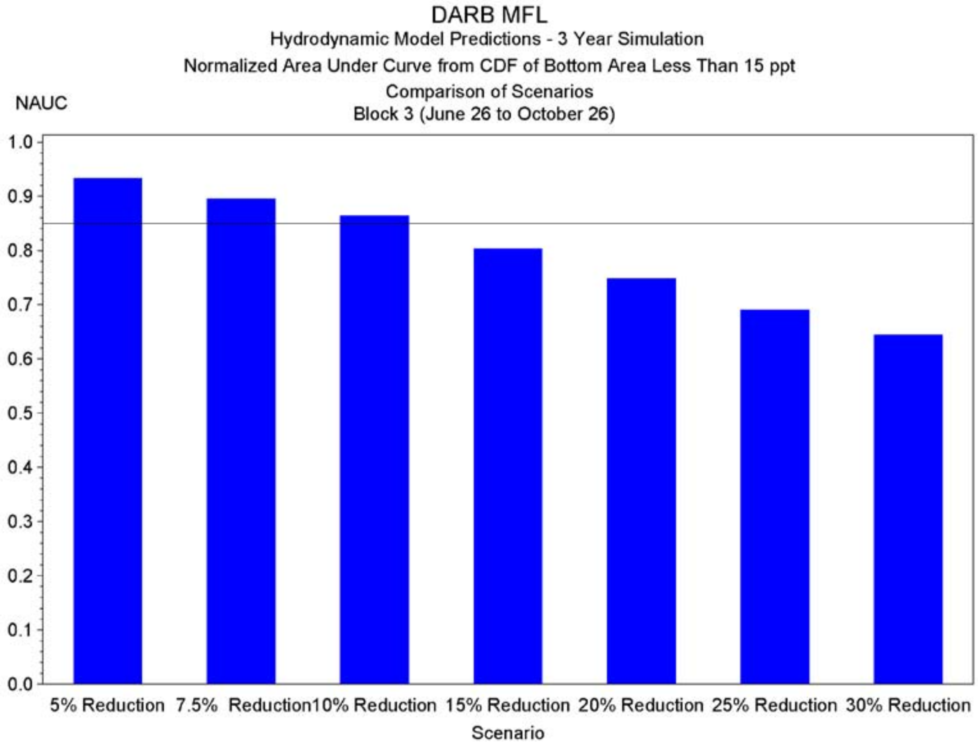

Figure 8-13. Normalized areas from cumulative distribution function plots of bottom area in the Dona Bay/Shakett Creek with salinity less than 15 ppt during Block 3 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 3.

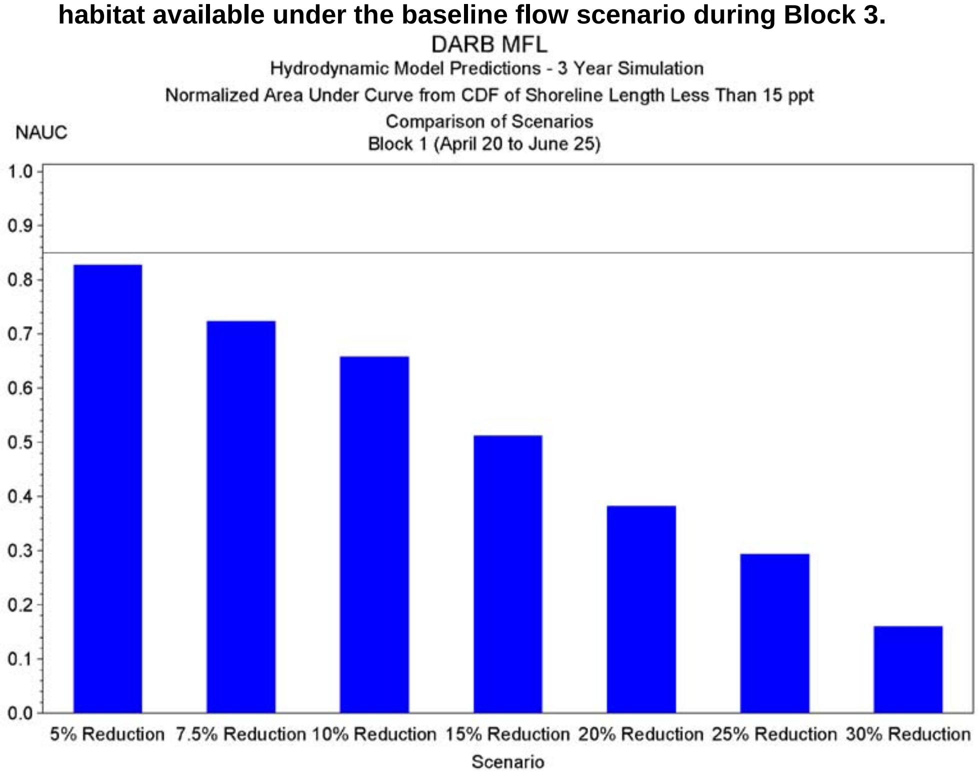

Figure 8-14. Normalized areas from cumulative distribution function plots of shoreline length in Dona Bay/Shakett Creek with salinity less than 15 ppt during Block 1 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 1.

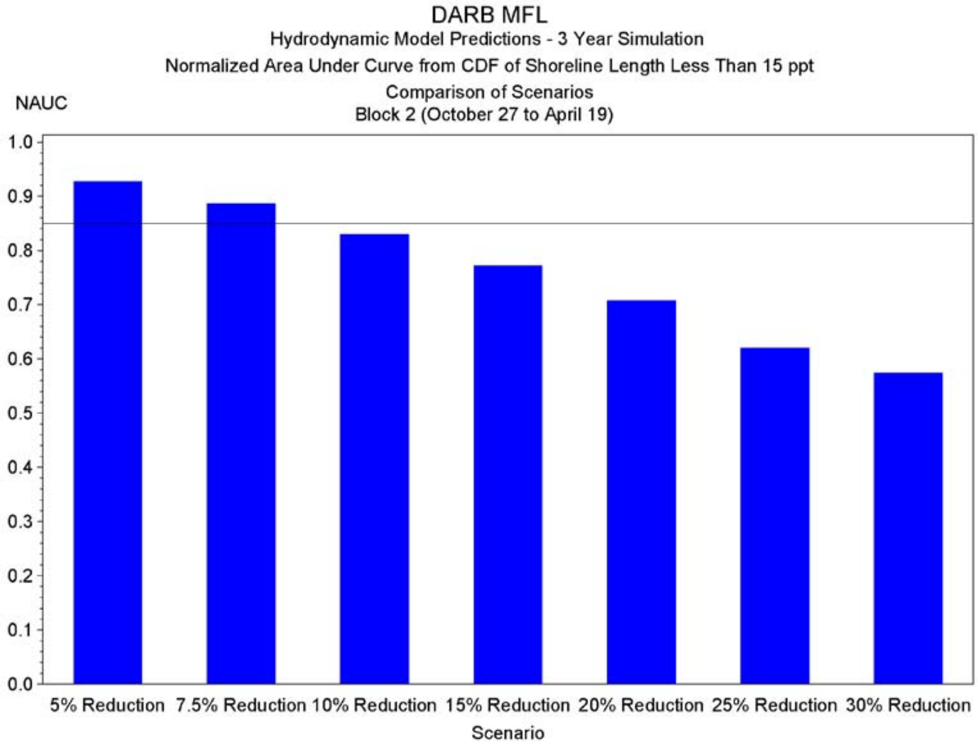

Figure 8-15. Normalized areas from cumulative distribution function plots of shoreline length in Dona Bay/Shakett Creek with salinity less than 15 ppt during Block 2 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 2.

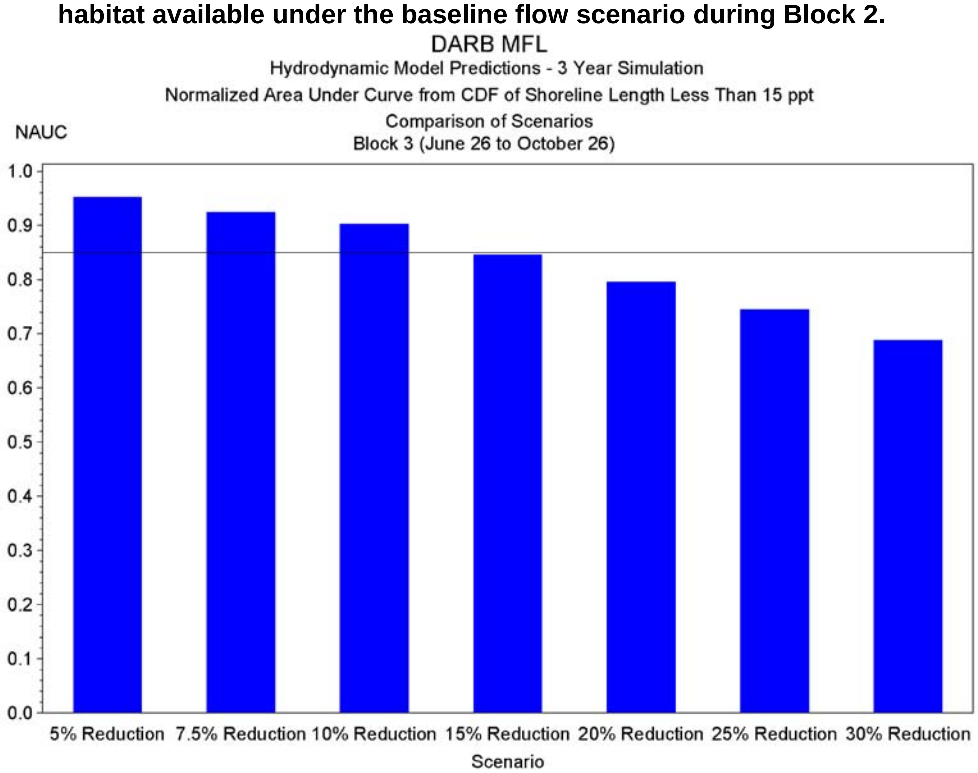

Figure 8-16. Normalized areas from cumulative distribution function plots of shoreline length in Dona Bay/Shakett Creek with salinity less than 15 ppt during Block 3 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 3.

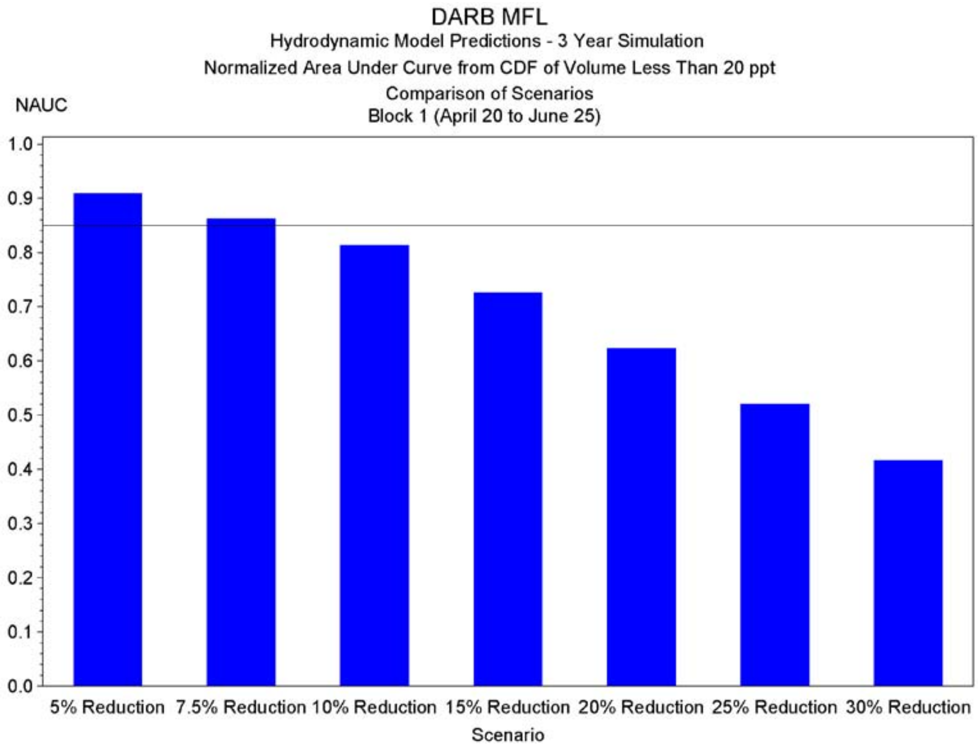

Figure 8-17. **Normalized areas from cumulative distribution function plots of water volume in Dona Bay/Shakett Creek with salinity less than 20 ppt during Block 1 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 1.**

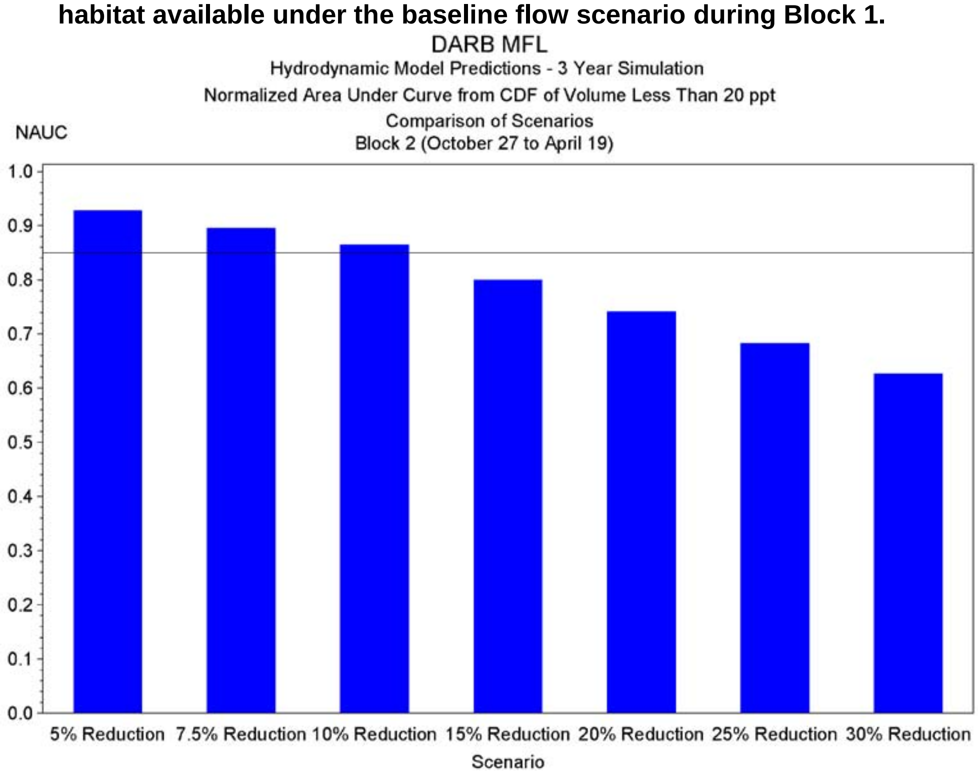

Figure 8-18. **Normalized areas from cumulative distribution function plots of water volume in Dona Bay/Shakett Creek with salinity less than 20 ppt during Block 2 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 2**

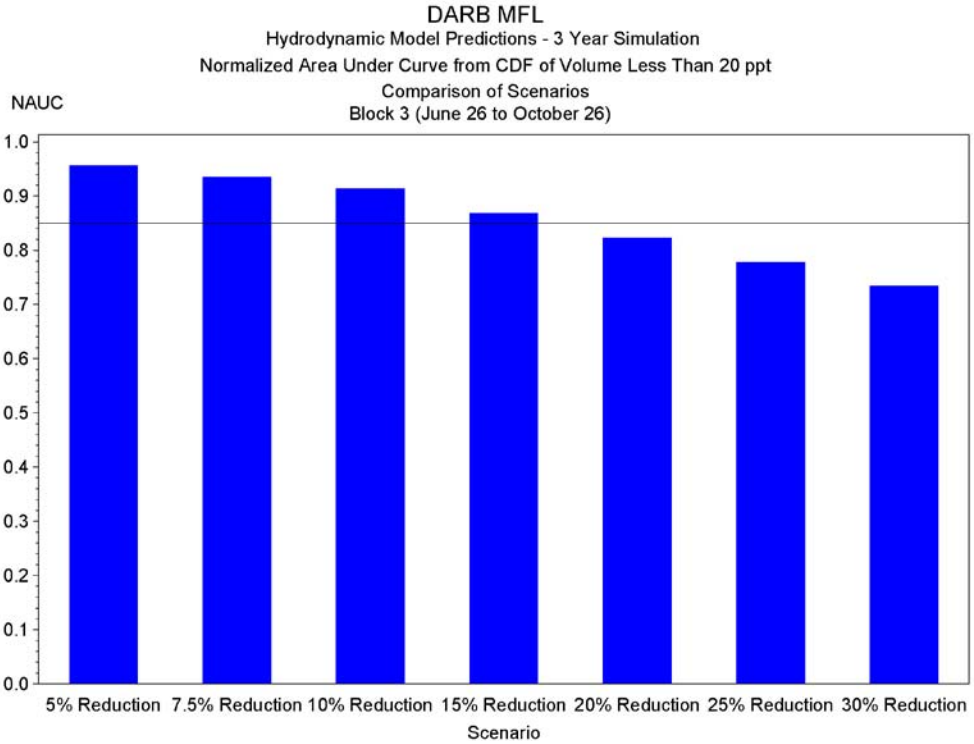

Figure 8-19. **Normalized areas from cumulative distribution function plots of water volume in Dona Bay/Shakett Creek with salinity less than 20 ppt during Block 3 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 3.**

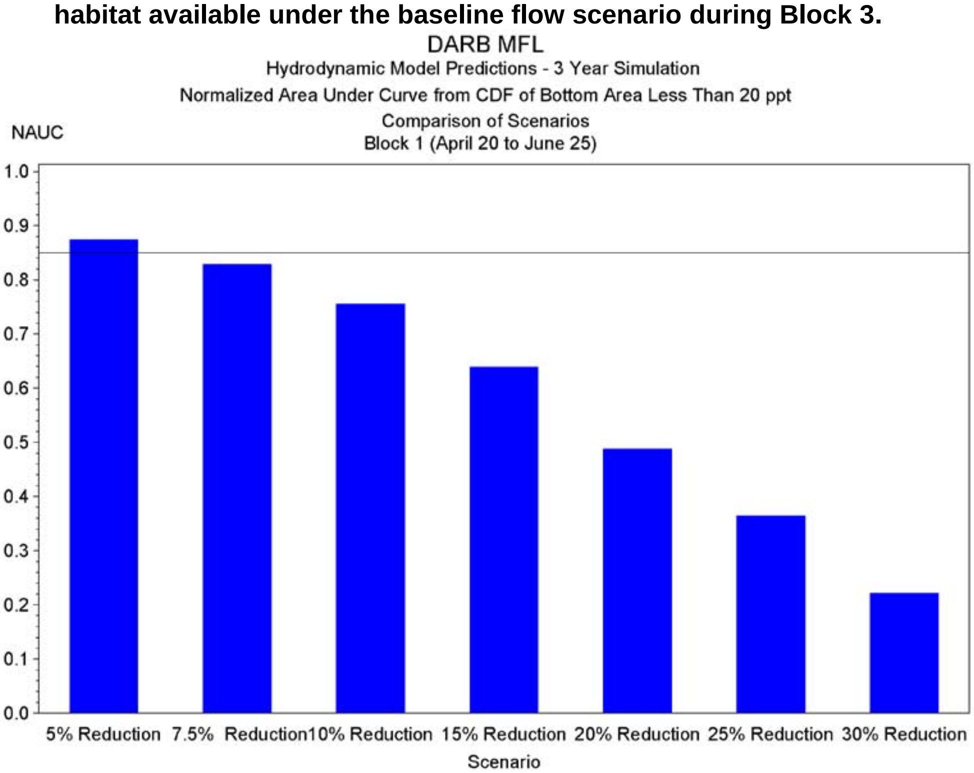

Figure 8-20. **Normalized areas from cumulative distribution function plots of bottom area in the Dona Bay/Shakett Creek with salinity less than 20 ppt during Block 1 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 1.**

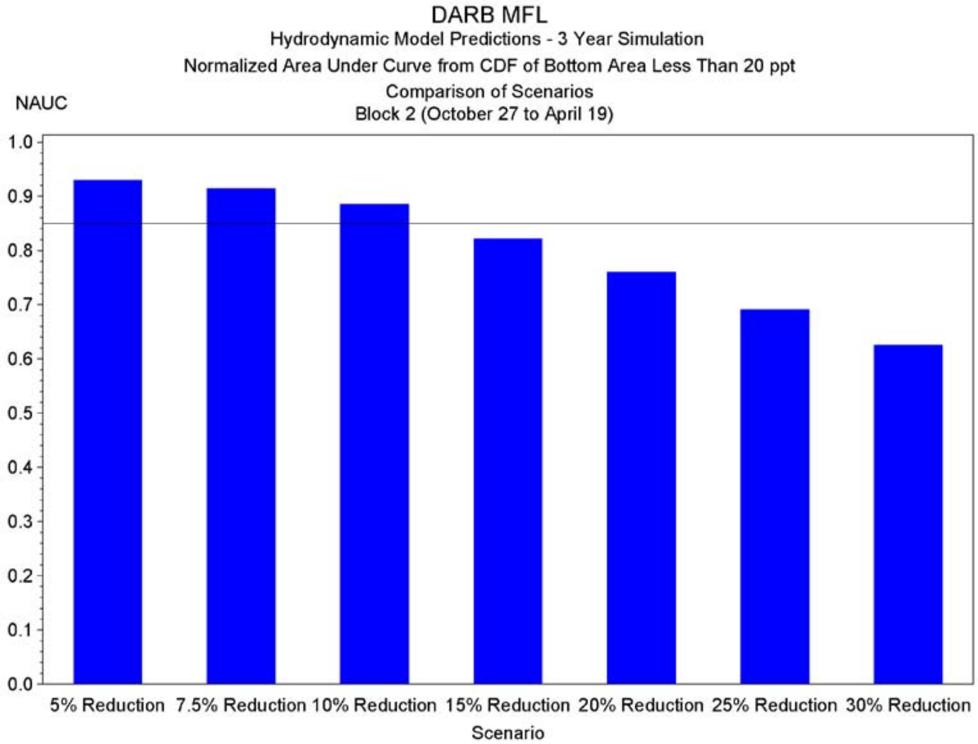

Figure 8-21. **Normalized areas from cumulative distribution function plots of bottom area in the Dona Bay/Shakett Creek with salinity less than 20 ppt during Block 2 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 2.**

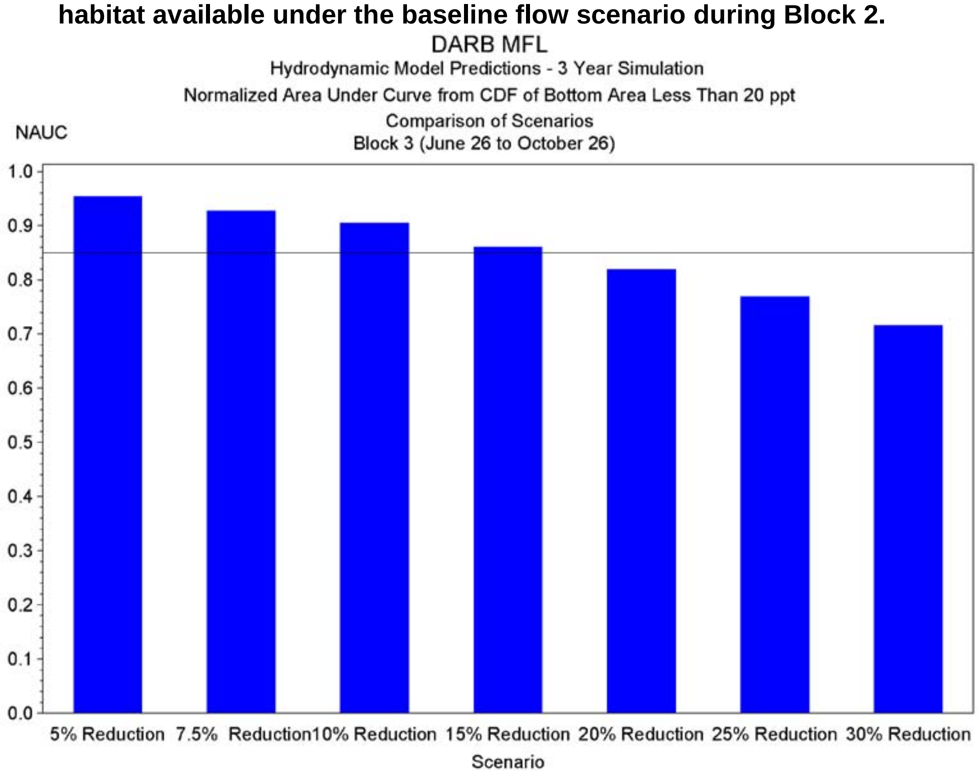

Figure 8-22. **Normalized areas from cumulative distribution function plots of bottom area in the Dona Bay/Shakett Creek with salinity less than 20 ppt during Block 3 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 3.**

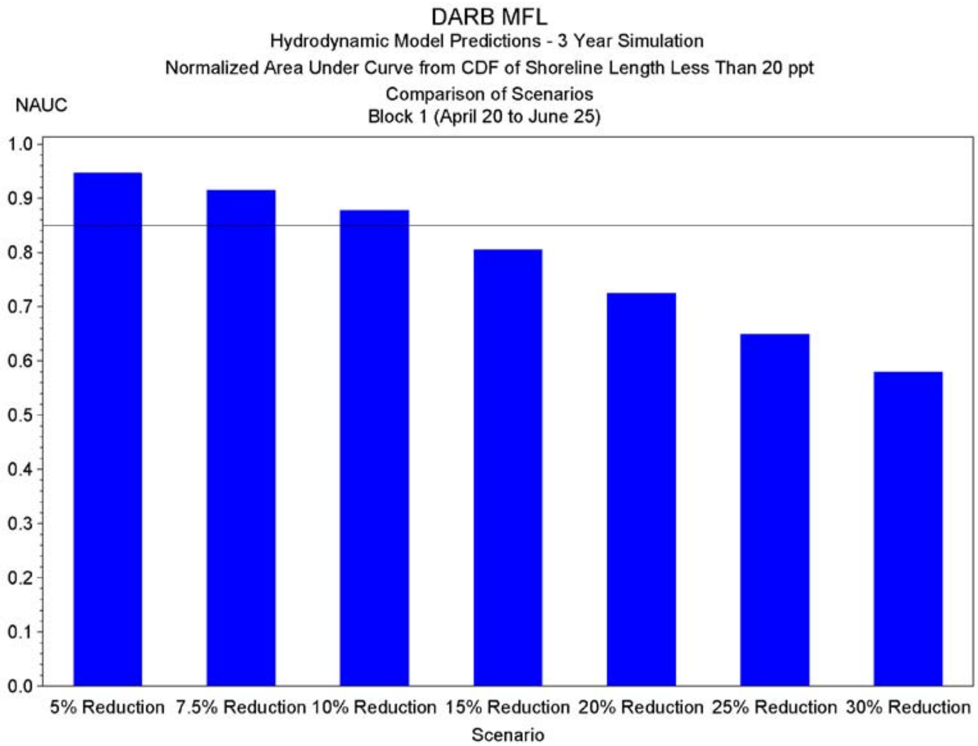

Figure 8-23. **Normalized areas from cumulative distribution function plots of shoreline length in Dona Bay/Shakett Creek with salinity less than 20 ppt during Block 1 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario o during Block 1.**

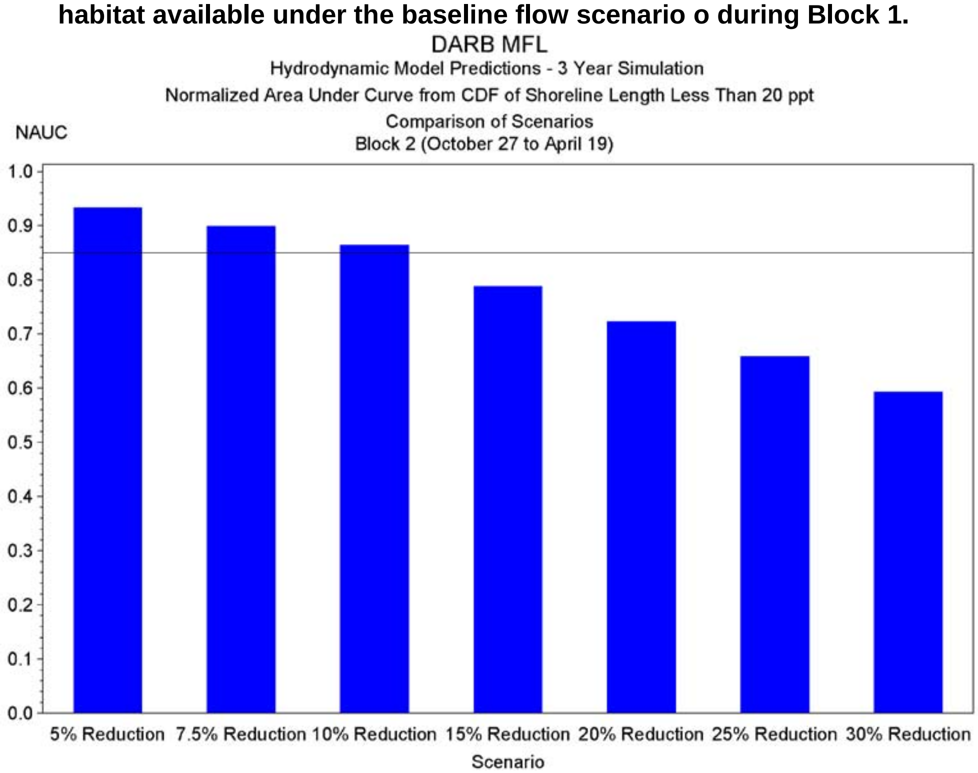

Figure 8-24. **Normalized areas from cumulative distribution function plots of shoreline length in Dona Bay/Shakett Creek with salinity less than 20 ppt during Block 2 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 2.**

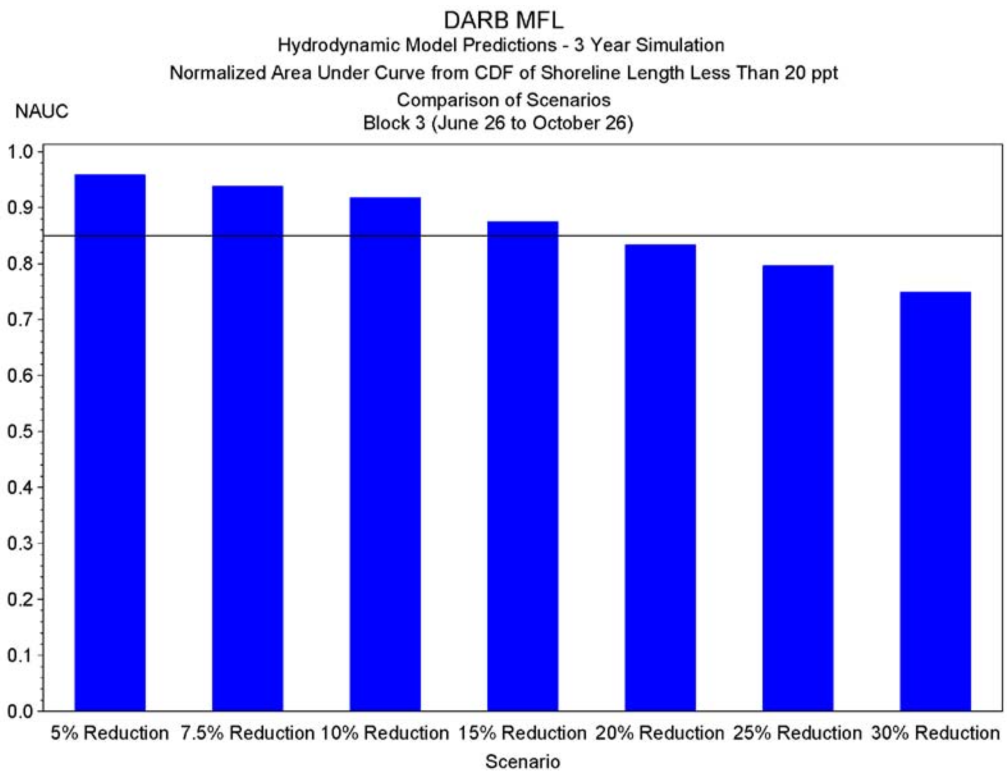

Figure 8-25. Normalized areas from cumulative distribution function plots of shoreline length in Dona Bay/Shakett Creek with salinity less than 20 ppt during Block 3 for seven flow reduction scenarios. The horizontal line indicates a 15% reduction in the habitat available under the baseline flow scenario during Block 3.

Percent flow reductions by seasonal block based on the volume of water, bottom area, and shoreline length where the biologically relevant 10, 15, and 20 ppt salinity criteria in the Dona Bay/Shakett Creek portion of the DARB system that would be expected to result in no more than a 15% reduction in normalized area under the curve for respective cumulative distribution functions, *i.e.*, more than a 15% reduction in the area under the respective baseline flow cumulative distribution function are presented in Table 8-1. For Block 1, the low flow period that extends from April 20 through June 25, flow reductions that met the fifteen-percent reduction limit for the respective habitat metric-salinity criteria ranged from 3 to 11% of baseline flows. The most limiting, i.e., lowest, flow reduction, was identified for potential change in water volume where salinity was less than 15 ppt. For Block 2, the period of medium flows that extends from October 27 through April 19 acceptable flow reductions for the specific habitat metric-salinity criteria ranged from 3 to 12%. Change in bottom area underlying water with salinity less than 10 ppt was the most sensitive factor. Allowable flow reductions for Block 3, the high flow period that extends from June 26 to October 26, ranged from 10 to 18%, with change in bottom area underlying water less than 10 ppt being the most sensitive of the examined habitat metric-salinity criteria.

Table 8-1. Summary of percent flow reductions by seasonal flow block for Dona Bay/Shakett Creek that would result in no more than a 15% decrease in the normalized area associated with the criterion-specific cumulative distribution function derived for the baseline flow scenario.

Criterion	Allowable Percent Reduction in Flow Under:		
	Block 1	**Block 2**	**Block 3**
Volume < 10 ppt	-	6%	11%
Bottom Area < 10 ppt	-	3%	10%
Shoreline Length < 10 ppt	-	12%	13%
Volume < 15 ppt	3%	10%	12%
Bottom Area < 15 ppt	-	7%	11%
Shoreline Length < 15 ppt	4%	10%	14%
Volume < 20 ppt	8%	11%	16%
Bottom Area < 20 ppt	7%	12%	16%
Shoreline Length < 20 ppt	11%	11%	18%

8.4 Influence of MFL on Water Quality Constituents and Other Ecological Parameters

As mentioned in Section 4, attempts were made to develop empirical models that relate flow to water quality constituents for DARB. No defensible quantitative relationships were found between flow and water quality constituents in DARB. A series of regressions were developed by Peebles *et al.* (2006) that relate inflows to center of abundance and inflows to catch-per-unit-effort. However, Peebles *et al.* (2006) used the flow at CPS2 as the inflow for their regressions and did not consider the ungauged inflows downstream of the CPS2 structure. Given that the baseline in this study does not include flows from upstream of the CPS2 structure (i.e., the CPS2 flows Peebles *et al.* used to develop their regressions), these regressions can not be applied to the baseline and recommended minimum flow scenarios. Therefore, no empirical relationships between flow and water quality constituents or between flow and ecological parameters were established for DARB.

8.5 Summary of MFL Recommendations

As discussed previously, the Dona Bay watershed has undergone significant physical and hydrologic alterations that have resulted in changes to the quantity of freshwater that flows into the system as well as changes to the salinity regime. The watershed area defined for the baseline and flow reduction scenarios included the historical Fox, Salt, and Shakett Creek basins (Figure 6-2). The Dona Bay minimum flow study area encompasses the portion of Dona Bay from rkm 0.9 to the CPS2 structure at rkm 6.5 (Figure 6-4). This portion of Dona Bay is relatively shallow (less than 2 m). The lower portion of Dona Bay, downstream of the U.S. 41 bridge, is broader and is hardened. Moving upstream from the U.S. 41 bridge, the system narrows and has large areas of mangrove along the shoreline. There are two major tributaries that flow into Shakett Creek, Fox Creek and Salt Creek. Shakett Creek then flows into Dona Bay.

There are no permitted surface water withdrawals from or NPDES discharges to Shakett Creek/Dona Bay.

The criterion used for MFL development in Dona Bay was the available habitat less than 10, 15, or 20 ppt. A hydrodynamic model was developed to predict salinity in the DARB system as a function of flow and other pertinent variables. The hydrodynamic model was used to estimate available habitat in the study area (rkm 0.9 to rkm 6.5) for the baseline scenario and various flow reduction scenarios for a three-year period. For the flow reduction scenarios, the flows from Fox Creek and Salt Creek were reduced, the runoff from Shakett Creek was not reduced.

The amount of available habitat was determined for each scenario for the three-year modeling period for each of the three blocks. The threshold used to determine the MFL was a 15% reduction in available habitat compared to the baseline. For each block, the most conservative criterion was selected amongst the metrics discussed above for the entire study area.

The MFLs which meet these criteria, expressed as an allowable percentage reduction in the combined natural flows for Dona Bay, Shakett Creek, Salt, Creek and Fox Creek are:

- Block 1 (April 20 to June 25) = 3% reduction
- Block 2 (October 27 to April 19) = 3% reduction
- Block 3 (June 26 to October 26) = 10% reduction

As stated in Section 1, the goal of the percent-of-flow method is to maintain the natural flow regime, albeit with some dampening allowed due to withdrawals. The hydrographs of the Dona Bay median daily inflows for the current, baseline, and flow remaining after the maximum allowable withdrawals were taken is presented in Figure 8-26 for the period 1985 to 2005. As mentioned in section 6.4, the difference between the current and baseline inflows represents excess water that will be available under the proposed minimum flow. In Figure 8-27, a plot of the cumulative median flow by calendar day for the period 1985 to 2005 is shown. As anticipated, the maximum divergence between the baseline and the minimum flow is seen during Block 3, the high flow block which has the highest allowable reduction out of the three blocks.

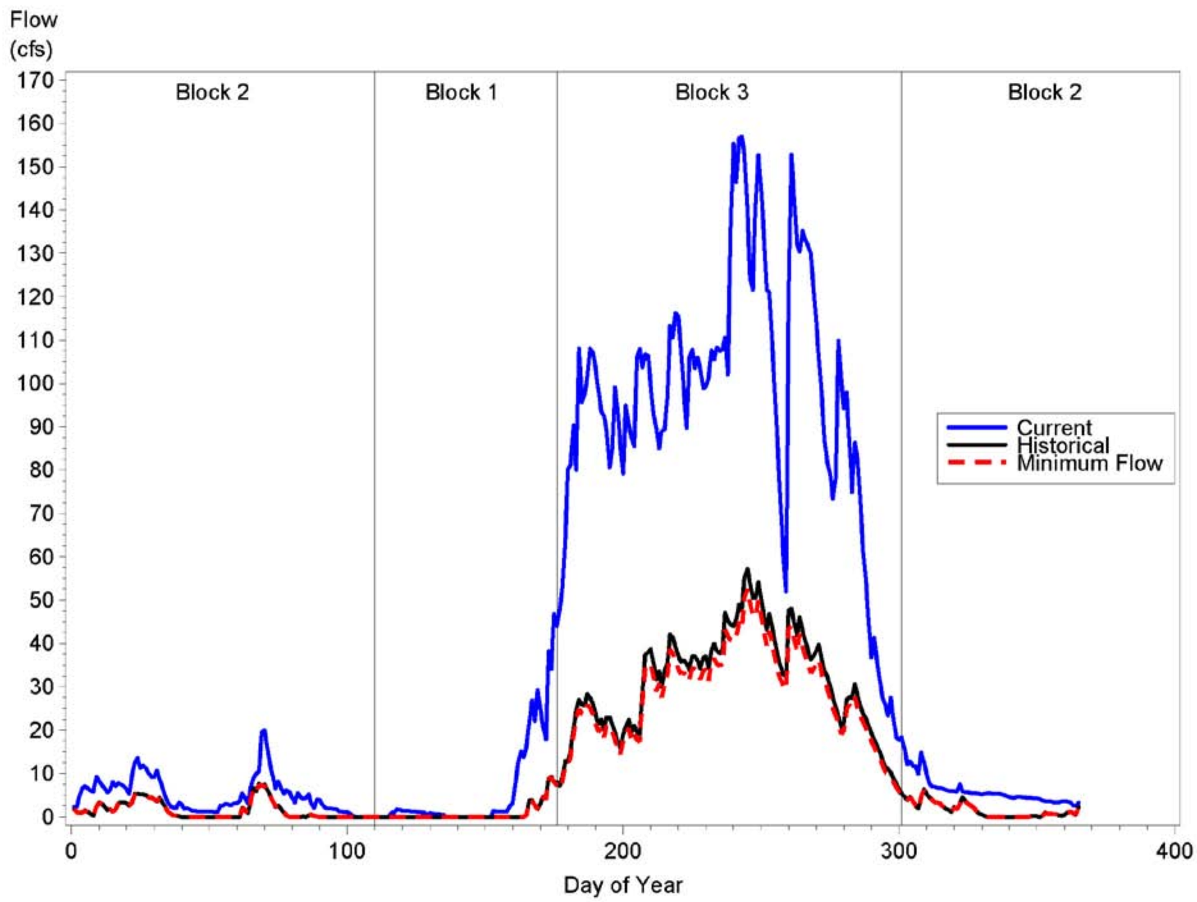

Figure 8-26. **Median daily inflow to Dona Bay/Shakett Creek based on the current flow record (blue line), historical benchmark flow record (black line), and a modified historical flow record derived by removing the maximum allowable withdrawals defined by the proposed minimum flows (red dashed- line) for 1985 through 2005.**

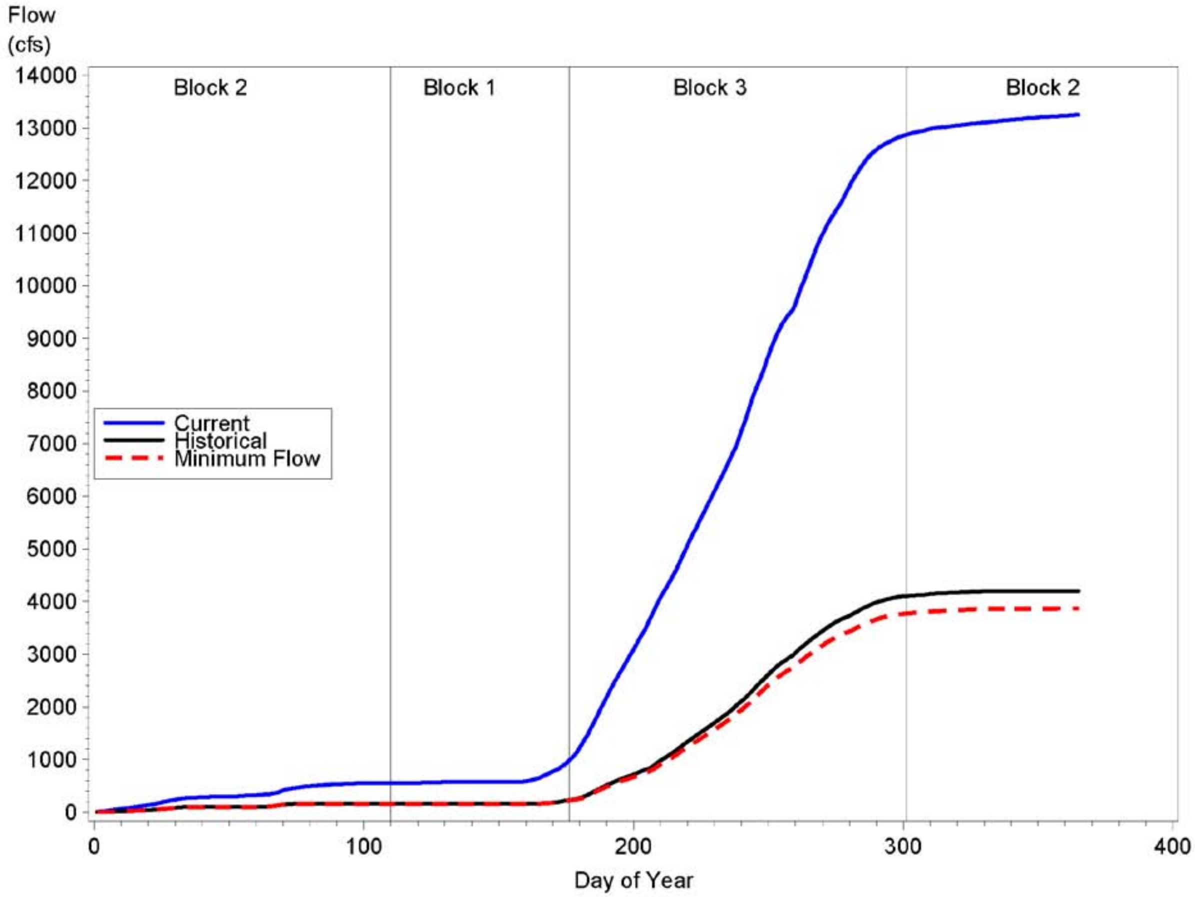

Figure 8-27. **Cumulative median daily inflow to Dona Bay/Shakett Creek based on the current flow record (blue line), historical benchmark flow record (black line), and a modified historical flow record derived by removing the maximum allowable withdrawals defined by the proposed minimum flows (red dashed- line) for 1985 through 2005.**

These findings were submitted to an independent peer review panel who noted that the District's data collection efforts were directed to Dona / Robert's Bay and Shakett Creek but did not extend into Salt and Fox Creeks. The panel recommended that the District follow the Precautionary Principle and establish the initial MFL with little or no withdrawals from Salt and Fox Creeks until more scientific information can be collected in these tributaries. The Panel went on to recommend that the District revisit the MFL periodically when new data becomes available.

In light of these comments, the recommended MFL is zero withdrawals downstream of the CPS-2 structure. All flows above the natural baseline condition, which are at times considerable, are excessive and available for withdrawal and/or restoration. It is ecologically desirable to remove some, or all of these excess flows from the system in order to re-establish a more natural hydroperiod in Shakett Creek / Dona Bay. The District is committed to continuing the evaluation and to re-evaluate the MFL as required by Statute.

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APPENDIX A

SCIENTIFIC REVIEW OF PROPOSED MINIMUM FLOWS AND LEVELS FOR DONA BAY/SHAKETT CREEK BELOW COW PEN SLOUGH

SCIENTIFIC REVIEW OF PROPOSED MINIMUM FLOWS AND LEVELS FOR DONA BAY/SHAKETT CREEK BELOW COW PEN SLOUGH

Scientific Peer Review Report

March 20, 2009

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Scientific Peer Review of Proposed Minimum Flows and Levels for Dona Bay/Shakett Creek below Cow Pen Slough, Florida

EXECUTIVE SUMMARY

These studies were conducted by the Southwest Florida Water Management District (the District) because Florida Statutes (§373.042) mandate the District's evaluation of minimum flows and levels (MFLs) for the purpose of protecting the water resources and the ecology of Shakett Creek and the Donna Bay estuary from "significant harm" that might result from potential future freshwater diversions from the contributing watersheds. With appropriate water management, including science-based MFL rules for environmentally safe operation of water supply impoundments and diversions, the District can ensure that Shakett Creek, Dona Bay and their associated tidal (estuarine) marshes and brackish wetlands will continue to provide essential food and cover for the myriad of marine and estuarine-dependent fish and wildlife that need them for survival, growth and reproduction.

Historically, the Dona Bay watershed included approximately 10,000 acres, consisting primarily of native upland habitats such as pine flatwoods, cabbage palm hammocks and wetlands. Most significantly, the original Cow Pen Slough was, primarily, a wetland drainage that conveyed runoff to the Myakka River. It consisted of large, slow flowing marshes that ultimately discharged into the Myakka River.

Conversion of the historical watershed included excavation of Cow Pen Slough by a series of deeply incised canals that more efficiently drained and significantly altered the character, function and values of the natural wetlands. Furthermore, the construction of the Intracoastal Waterway and Venice Inlet has resulted in an increased reach of Gulf marine waters into the Dona and Roberts Bay (DARB) estuarine region. The more efficient connection to the Gulf of Mexico has influenced water levels and circulation, sedimentation, salinity, and the numbers and kinds of plants and animals inhabiting the study area.

On the other hand, the diversion of Cow Pen Slough from the Myakka River watershed into Shakett Creek and the Dona Bay watershed, the connection of Curry Creek and Roberts Bay to the Myakka River via the Blackburn Canal, and the transformation of the region's natural land cover to agricultural uses (e.g., improved pastures, citrus and row crops) have increased freshwater inflows tremendously, especially during the "wet" season. Taken together, the combination of increased inflows and marine influences has created a strong salinity gradient over a relatively short distance in the DARB area, resulting in rapid, high-amplitude salinity oscillations that are not well tolerated by much of the marine life of interest here.

In the Dona Bay estuary, the major features include the most downstream control structure (i.e., the CPS2 dam) on Cow Pen Slough, the channelized reach of upper Shakett Creek, the emergence of the Shakett Creek into a broader and more natural lower creek east of US 41, the highway bridge at US 41, the upper, middle and lower Dona Bay system, and the ICW-Venice Inlet area. Major features in the Roberts Bay estuary involve the channelized reach of the Blackburn Canal, remnants of the historic Curry Creek, the emergence of Curry Creek into a broader and more natural lower creek east of US 41, the highway bridge at US 41, the upper, middle and lower Roberts Bay system, and the ICW-Venice Inlet area. The entire region is tidally affected, with the effect increasing closer to the Venice Inlet near the Gulf of Mexico.

The District's researchers found that Dona Bay and Shakett Creek appear to be depressed in both number of benthic (bottom dwelling) species and abundance when compared to the other nearby bays, such as Lyons Bay. The Lyons Bay watershed has not been altered to the same extent as the adjacent Dona Bay watershed. As a result, the oyster and seagrass populations of Lyons Bay have been found to be generally healthier than those of Dona Bay. In addition, salinity has been found to be consistently higher and less variable in Lyons Bay than in Dona Bay. Thus, it is widely accepted by the District and others in Sarasota County that the implementation of plans to restore the watershed and its hydrologic condition will have a high probability of improving water quality, oyster populations, and seagrass communities in the DARB system.

The District's approach for setting the MFL was to determine inflows to Dona and Roberts Bay without the flows from the two diversions. This means that the baseline condition for the system does not include this large interbasin transfer of water and, consequently, the proposed MFL is only for the two original tributaries to the DARB system (Fox and Salt Creeks). Baseline flows, as well as various inflow reduction scenarios, were used in association with a hydrodynamic model to predict estuarine salinity. The model was used to evaluate the amount of available habitat in the estuary during three different portions of the year (seasonal blocks) for each flow reduction scenario. Habitat was defined in terms of the volume, bottom area, and length of shoreline exposed to water of different salinity ranges (< 10, < 15, or < 20). The MFL was designed so that reduced flows from Fox and Salt Creeks would never result in more than a 15% decrease in available habitat (either as volume, bottom area, or shoreline length) when compared to the baseline condition.

The Scientific Review Panel (the Panel) finds that the District's hydrological analyses are more or less adequate, as are the numerical simulations. Although the Panel has numerous suggestions for improvement, if the District's exclusion of the majority of freshwater inflows to the DARB system is accepted, then it appears to the Panel that the model applications have the accuracy and resolution to simulate circulation and salinity patterns in enough detail for use in decision-making.

The Panel also supports the District's finding that changes in the shallow-water distribution of estuarine-dependent fishes and shellfish is related to freshwater inflow and salinity regimes. Freshwater discharges attract these organisms, particularly the young-of-the-year, into areas that provide habitat (i.e., food and cover) in which they can survive and grow. Such is the case in the DARB system, especially during low flow periods. Nevertheless, District researchers indicate that this is happening without providing the usual trophic (food-chain) benefits, suggesting that a less erratic inflow regime may result in more efficient production of estuarine fish and crustaceans. Theoretically, the District's proposed MFL should help mitigate any negative impacts on the exposed young of these estuarine-dependent species from natural drought during their peak seasonal utilization of estuarine nursery habitats in the springtime. But with the complete exclusion of flows from Cow Pen Slough and Blackburn canals, it is not certain that the District's MFL will provide sufficient protection all the time.

The District is to be commended for voluntarily committing to independent scientific peer review of its MFLs determinations. The Panel finds that the District's goals, data, methods and conclusions, as developed and explained in the MFL report, are generally reasonable and appropriate. One exception might be the District's policy decision to exclude all inflows from the long-standing Cow Pen Slough and Blackburn canals, and any related water quality or biological analyses and relationships, from the determination of the MFL. Excluding these flows means there are NO (emphasis added) empirical relationships between freshwater flow and water quality constituents, benthos, fishes or other important ecological components used in the District's MFL determination. This leaves little existing physical, chemical and biological information upon which to base the MFL determination. The Panel believes that the environmental consequences of changing inflows to Cow Pen Slough should be evaluated in relation to current conditions in order to better understand impacts of the proposed MFL and its net benefits to the ecosystem. Another Panel concern arises from indications that the baseline conditions used in the report are saltier than historic conditions.

Given the lack of data for Fox and Salt Creeks, the normal uncertainties inherent in the HSPF and EFDC model predictions for baseline conditions, and the fact that there has not been an analysis of the consequences of changing inflows to Cow Pen Slough, the Panel does not believe there is enough scientific information available to allow withdrawals from Fox and Salt Creeks at present, particularly during low flow seasons (Blocks 1 and 2). Therefore, the Panel recommends that the District follow the Precautionary Principle and establish initial MFLs with little or no withdrawals from Fox and Salt Creeks until adequate scientific information can be collected and evaluated to determine with more confidence how changes in inflow will affect the DARB system. The Panel urges continued monitoring in the future to verify that any MFL is having its intended effect of protecting the ecological health and productivity of the DARB system.

INTRODUCTION

The Southwest Florida Water Management District (the District) is mandated by Florida statutes to establish minimum flows and levels (MFLs) for state surface waters and aquifers within its boundaries for the purpose of protecting the water resources and the ecology of the area from "significant harm" (Florida Statutes, 1972 as amended, Chapter 373, §373.042). The District implements the statute directives by annually updating a list of priority water bodies for which MFLs are to be established and identifying which of these will undergo a voluntarily independent scientific review. Under the statutes, MFLs are defined as follows:

1. A minimum flow is the flow of a watercourse below which further water withdrawals will cause significant harm to the water resources or ecology of the area; and
2. A minimum level is the level of water in an aquifer or surface water body at which further water withdrawals will cause significant harm to the water resources of the area.

Revised in 1997, the Statutes also provide for the MFLs to be established using the "best available information," for the MFLs "to reflect seasonal variations," and for the District's Board, at its discretion, to provide for "the protection of nonconsumptive uses." In addition, §373.0421 of the Florida Statutes states that the District's Board "shall consider changes and structural alterations to watersheds, surface waters and aquifers, and the effects such changes or alterations have had, and the constraints such changes or alterations have placed on the hydrology of the affected watershed, surface water, or aquifer…." As a result, the District generally identifies a baseline condition that realistically considers the changes and structural alterations in the hydrologic system when determining MFLs. While this is always important, it is especially important in the DARB system where ~77 % of freshwaters that have been flowing into the area for the past half century may be eliminated, in part to restore the watershed's original drainage patterns, as well as to provide supplies for the region's growing water needs.

Current state water policy, as expressed by the State Water Resources Implementation Rule (Chapter 62-40.473, Florida Administrative Code) contains additional guidance for the establishment of MFLs, providing that "…consideration shall be given to the protection of water resources, natural seasonal fluctuations, in water flows or levels, and environmental values associated with coastal, estuarine, aquatic and wetlands ecology, including:

1. Recreation in and on the water;
2. Fish and wildlife habitats and the passage of fish;
3. Estuarine resources;
4. Transfer of detrital material;
5. Maintenance of freshwater storage and supply;
6. Aesthetic and scenic attributes;
7. Filtration and absorption of nutrients and other pollutants;
8. Sediment loads;
9. Water quality; and
10. Navigation."

After a site visit on September 16, 2008 to perform a reconnaissance survey of the Dona and Roberts Bay system, including their tributaries, the Panel discussed the scope of the review and subsequently prepared their independent scientific reviews of the draft report and associated study documents. The reviews were compiled by the Panel Chair and edited by all Panel Members into the consensus report presented herein.

BACKGROUND

The quantity, quality and timing of freshwater input are characteristics that define an estuary. Freshwater inflows affect estuarine (tidal) areas at all levels; that is, with physical, chemical and biological effects that create a vast and complicated network of ecological relationships (Longley 1994). The effects of changes in inflows to estuaries are also described in Sklar and Browder (1998) and reviewed in Alber (2002). This scientific literature describes and illustrates how changing freshwater inflows can have a profound impact on estuarine conditions: circulation and salinity patterns, stratification and mixing, transit and residence times, the size and shape of the estuary, and the distribution of dissolved and particulate material may all be altered in ways that negatively effect the ecological health and productivity of coastal bays and estuaries.

Inflow-related changes in estuarine conditions consequently will affect living estuarine resources, both directly and indirectly. Many estuarine organisms are directly linked to salinity: the distribution of plants, benthic organisms and fishery species can shift in response to changes in salinity (Drinkwater and Frank 1994, Ardisson and Bourget 1997). If the distributions become uncoupled, estuarine biota may be restricted to areas that are no longer suitable habitat for their survival, growth and reproduction. Potential effects of human activities, particularly freshwater impoundment and diversion, on the adult and larval stages of fish and invertebrates include impacts on migration patterns, spawning and nursery habitats, species diversity, and distribution and production of lower trophic level (food) organisms (Drinkwater and Frank 1994, Longley 1994). Changes in inflow will also affect the delivery of nutrients, organic matter and sediments, which in turn can affect estuarine productivity rates and trophic structure (Longley 1994).

There are a number of approaches for setting the freshwater inflow requirements of an estuary. The District has selected to use a “percent-withdrawal” method that sets upstream limits on water supply diversions as a proportion of river flow. This links daily withdrawals to daily inflows, thereby preserving natural streamflow variations to a large extent. This type of inflow-based policy is very much in keeping with the approach that is often advocated for river management, where flow is considered a master variable because it is correlated with many other factors in the ecosystem (Poff et al. 1997; Richter et al. 1997). In this case, the emphasis is on maintaining the natural flow regime while skimming off flows along the way to meet water supply needs. Normally, regulations are designed to prevent impacts to estuarine resources during sensitive low-inflow periods and to allow water supplies to become gradually more available as inflow increases. The rationale for the District's MFL, along with some of the underlying biological studies that support the percent-of-flow approach, is detailed in Flannery et al. (2002).

REVIEW

Developing minimum flow rules requires several steps: (1) setting appropriate management goals; (2) identifying indicators to measure characteristics that can be mechanistically linked to the management goals; (3) reviewing existing data and collecting new data on the indicators; and (4) assembling conceptual, qualitative, and quantitative models to predict behavior of the indicators under varying flow regimes. The first two steps above represent the overall approach to setting the minimum flow rule.

The District's management goal for Dona Bay and Shakett Creek below Cow Pen Slough was developed to limit potential changes in aquatic and wetland habitat availability associated with reductions in seasonal blocks of freshwater inflows (SWFWMD 2008). A hydrodynamic model was employed to estimate selected salinity habitat availabilities under a baseline inflow condition versus various flow reduction scenarios. A criteria of no more than a 15% change in habitat availability, as compared to the estuary's baseline condition, was used as the threshold for "significant harm." While the use of 15% as a threshold is a management decision, the Panel agrees that this is a reasonable approach for avoiding the most serious negative impacts on the ecosystem. The remainder of this report is focused on review of the data, methods and analyses used as a basis for the District's recommended MFL.

Specifically, the District's proposed MFL was determined based on the following procedure:

1. A 1948 pre-channelization watershed was defined for the bay and estuary complex that excludes a large amount (~78.9%) of the system's current watershed (Figure 1). This was done to remove artificial inflows (i.e., interbasin transfers) from the Cow Pen Slough canal, completed in 1966, and the Blackburn canal, which was constructed in the 1950s. Both of these dredged canals were part of watershed protection plans and were built to alleviate flooding on the nearby Myakka River. Excluding their unnatural contributions to the estuary's inflows in the "baseline condition" was seen by the District as a return to a more natural flow regime and environment for the Shakett Creek estuary and the Dona Bay System (Figure 2).

   Since long-term freshwater inflow records do not exist, a mechanistic model (i.e., the Hydrological Simulation Program--Fortran or HSPF model) was used for simulation of rainfall runoff to Dona Bay from the lesser watershed of the baseline condition (Intera 2007). This lesser watershed included only the original Fox, Salt and Shakett Creek drainage basins. A historical period of 21 years (1985-2005) was used in the development of the ungaged inflow estimates. Seasonal intervals of similar flow levels were blocked out to represent low (Block 1), medium (Block 2) and high (Block 3) inflows. The low flow block extends from April 20 through June 25, the high flow block runs from June 26 through October 26, and the rest of the year (i.e., before Block 1 and after Block 3) is assumed to represent an intermediate or medium flow block of time.

Figure 1. Existing greater watershed of the Dona and Roberts Bay System.

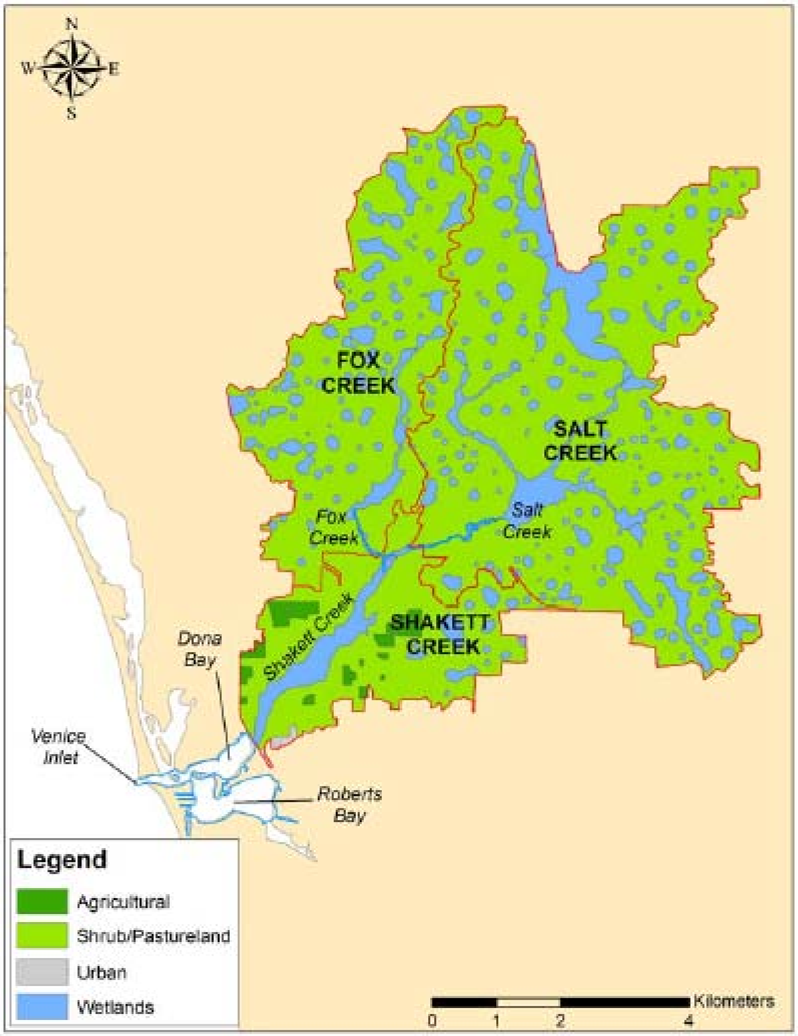

Figure 2. Historical lesser watershed of the Dona Bay System with major tributaries and land use circa 1948.

2. A hydrodynamic (circulation) and conservative mass (salinity) transport model (i.e., the Environmental Fluid Dynamics Code or EFDC) was applied to the baseline condition of the DARB system to estimate the length, area and volume of selected salinity habitats over a representative three-year (1986-1988) simulation period (ATM 2007). The model was also used to predict salinities at four locations along the salinity gradient (Figure 3) under various reduced inflow scenarios in order to identify minimum flows needed by the estuary. Percent flow reductions evaluated ranged from -5% to -30%.

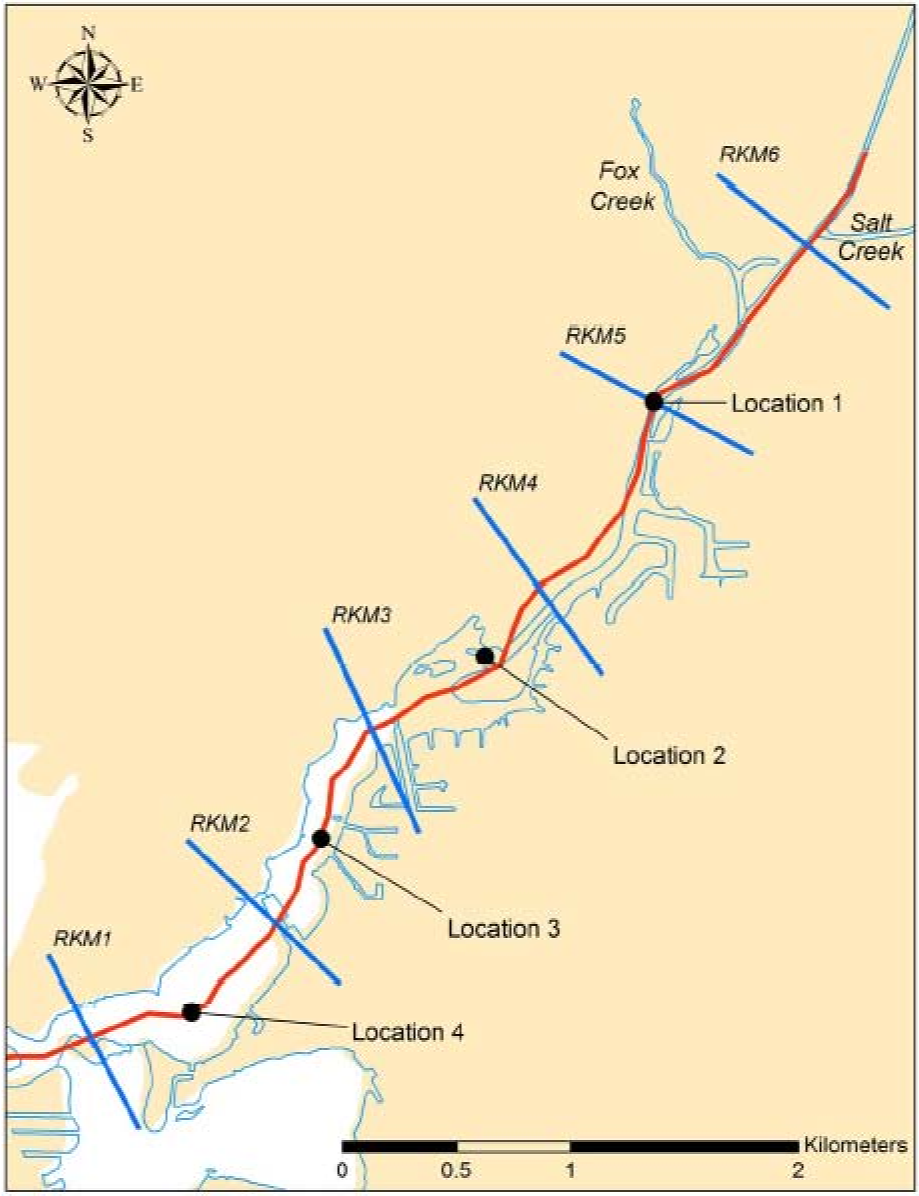

Figure 3. Map of river reach locations and their river kilometer boundaries used to analyze salinity regimes in Dona Bay/Shakett Creek under various freshwater inflow scenarios.

3. Habitat assessment metrics were developed in order to estimate the amount of available habitat that meets biologically-relevant salinity criteria. These included the length of natural shoreline for shoreline vegetation, the area of bottom habitat for benthos and submerged aquatic vegetation, and the volume of water for fishes over various salinity ranges.

4. Biologically-relevant salinities used in the MFL determination were based on (a) the 10 ppt bottom of the optimal range for larval oysters, the bottom of the tolerance range for adult oysters and the minimum spawning needs of bay anchovies; (b) the 15 ppt bottom of the optimum ranges for adult oysters and sand seatrout, and near the spawning peak of bay anchovies; and (c) the 20 ppt peak range for oyster larvae, which is also within the optimum ranges of adult oysters and sand seatrout.

5. Predicted salinity habitat lengths, areas and volumes were used to construct cumulative distribution function (CDF) plots for each of the three salinity criteria (i.e., <10 ppt, <15 ppt, and <20 ppt). The predicted CDFs were compared to CDFs under baseline conditions to determine the percent change under each reduced inflow scenario. A criteria of no more than a 15% change in any habitat availability as compared to baseline was used as the threshold for "significant harm."

6. The District's proposed MFL is defined as the flow that maintains at least 85% of the biologically-relevant salinity habitats in the estuarine system under the baseline scenario. Resulting inflow reductions from the baseline condition varied from 3-11% during Block 1 (low flow season), 3-12% during Block 2 (intermediate or medium flow season), and 10-18% during Block 3 (high flow season). The most limiting (i.e., lowest) flow reduction allowed under Block 1 was 3% for water volumes less than 15 ppt, 3% for bottom areas less than 10 ppt under Block 2, and 10% for bottom areas less than 10 ppt under Block 3. Thus, the District recommended an MFL for Fox and Salt Creeks with allowable flow reductions of only 3% in Block 1, 3% in Block 2, and 10% in Block 3.

DARB Hydrologic and Hydrodynamic Simulations

The MFL analysis of the DARB system is based upon results from two numerical models; namely, the HSPF hydrologic (rainfall runoff) model and the EFDC hydrodynamic and salinity model. Panel comments given below relate to those models and their applications.

In the MFL determination, a baseline flow period must be established. The baseline flow for the DARB MFL analysis was taken to be the predicted flow from an HSPF model simulation for the period of 1985 – 2005 (Intera 2007). Although rainfall from 1985 – 2005 was employed in the simulation, the area's land use and watershed boundaries were taken to be those that existed in 1948. Existing flows from the Cow Pen Slough and Blackburn canals were assumed to be zero, since those flows were not in the DARB system in 1948. The District has explained the reasoning behind adopting this baseline flow in the MFL report, as well as in separate correspondence with the Panel.

For calibration purposes, an HSPF application was first made using actual rainfall from 1985 - 2005. This application used the existing Dona Bay watershed of about 47,000 acres and current land use. The baseline application also used rainfall from 1985-2005, but it used the 1948 watershed area and historic land use. The baseline computed significantly lower flows into Dona Bay because a much smaller watershed of about 10,000 acres was assumed to exist in 1948, and because only about 10% of the watershed was urban in 1948 as compared to about 50% at present.

The MFL analysis utilized three seasonal flow blocks. Block 1 represents low flows, with Blocks 2 and 3 representing medium and high flows, respectively. An inspection of Figure 6.2 in the modeling report (Intera 2007) reveals that the average daily baseline flows for Blocks 1 and 2 are about 1/3 of existing flows, whereas for Block 3 the baseline flows are perhaps only 1/5 of the existing flows. The maximum baseline flows are also much less than existing maximum flows from the Cow Pen Slough and Blackburn canals.

HSPF model application--In developing the pervious land segments in the HSPF model, it appears that only the land use grid was used. No discussion of the soil textures or their variability within the watershed was mentioned in Appendix 2, although soil variability is discussed in the body of the ungaged flow report (Intera 2007). The assumption of a uniform infiltration rate of 1.31 in/hr over all the land segments implies that the soil texture was assumed to be uniform throughout the watershed in the HSPF model. With a variable soil texture, a composite map should be constructed whereby the land use and the soil texture are cross referenced, with each pervious land segment having a unique land use and soil texture classification within a particular sub-basin.

The statement is made that *"Dividing the basins into land segments practically eliminates the parameter lumping typically found in hydrologic models"* (Intera 2007). While discretizing the pervious land segments is an improvement over assuming a constant parameter for the whole sub-basin, the HSPF is still a lumped-parameter model. There does not appear to be any routing between land segments. Hence the overland flows are assumed to be placed (lumped) within the channel system without any consideration being given to additional infiltration as water flows across multiple pervious land segments.

The Intera (2007) report gives the following statistical (coefficient of determination = R^2) measures of the HSPF model's performance at the daily level:

Location	**R^2**
Howard Creek	0.4125
Myakka River near Myakka City	0.4791
Myakka River near Sarasota	0.3302
Cow Pen Slough 1 Dam	0.5748
Cow Pen Slough 2 Dam	0.5020

Based on published HSPF applications, Munson (1998) finds that a "good" calibration has an R^2 > 0.9 at the annual level, > 0.8 at the seasonal level, and > 0.6 at the daily level.

From the results given above for the Dona Bay area, the model does not seem to capture the watershed variability very well.

EFDC Model --Unfortunately, the MFL analysis of the DARB system has to rely almost totally on results from a three-dimensional (3-D) numerical hydrodynamic (circulation) and conservative mass (salinity) transport model known as the Environmental Fluid Dynamics Code (EFDC). This is because the previously developed regression equations relating freshwater inflows to various biota and habitats in the estuary used flows from Cow Pen Slough, which are not included in the baseline flow defined by the District.

The EFDC code is well known in the scientific community and is supported by the EPA. The grid employed by EFDC is an orthogonal curvilinear grid in the horizontal plane and a sigma stretched grid in the vertical. The vertical sigma grid allows for a more accurate representation of the bottom of the water body, but errors can occur when computing long-term stratification in channels with adjacent shallow areas if the horizontal resolution is insufficient.

The grand domain of EFDC model application covered a large area ranging from Big Sarasota Bay in the north, on through the Gulf Intracoastal Waterway (ICW) to Lemon Bay in the south; however, the District's MFL analysis only used results from that portion of the computational grid covering Dona Bay and Shakett Creek (Figure 4). The depths over most of Dona Bay and Shakett Creek are around 2 m, without a definable deeper channel. The number of horizontal grid cells across the bay range from about 10 or so in the lower bay to only one in upper Shakett Creek, with the average cell size across the bay being 40 m. From Figure 2.3 in Appendix 6, it can be seen that the impact of the US 41 highway bridge is modeled by blocking much of the flow with zero-depth cells. The grid extends offshore into the Gulf of Mexico far enough to minimize the influence of freshwater inflows on the Gulf salinity boundary condition.

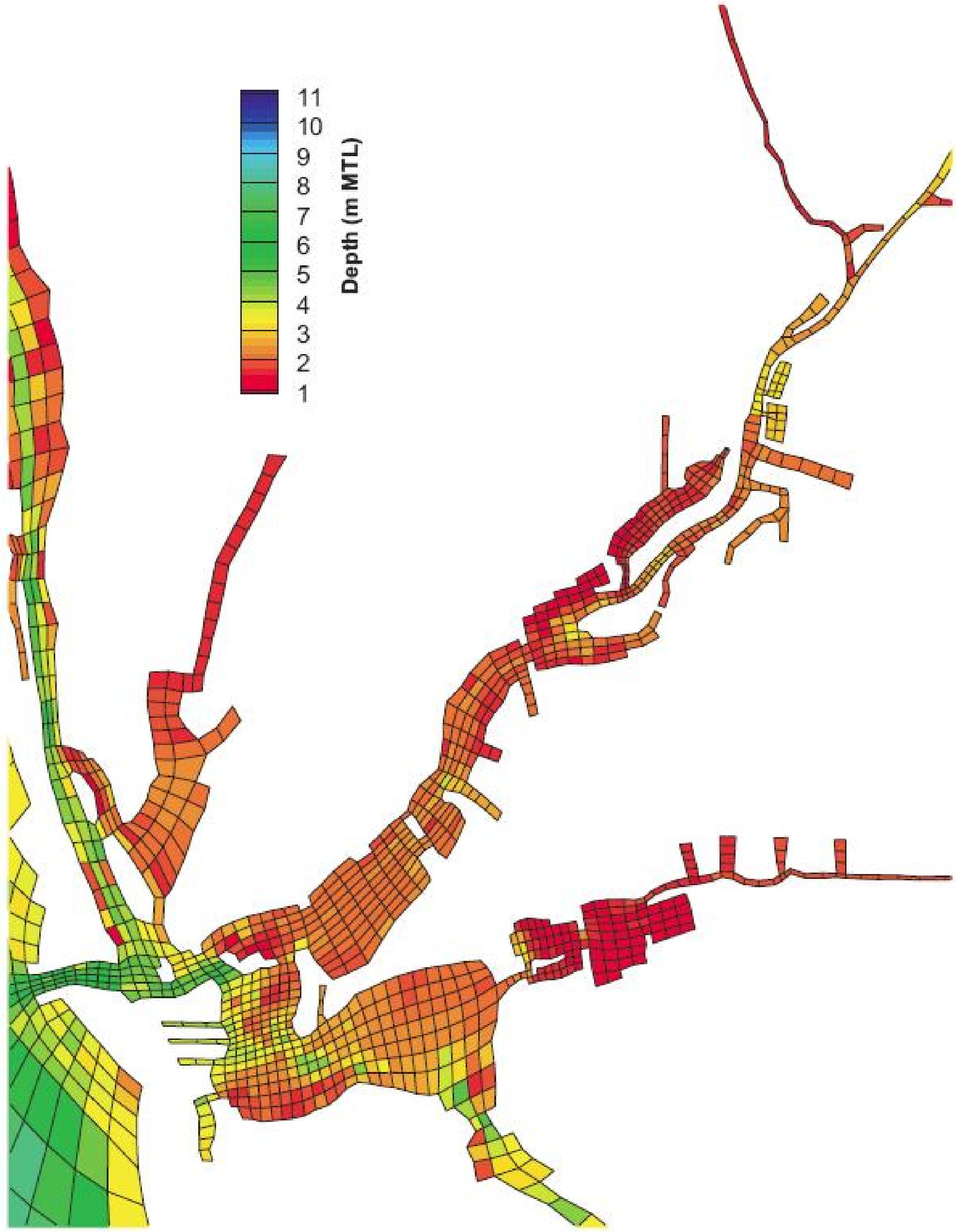

Figure 4. DARB model grid and bathymetry.

The EFDC model was calibrated using data from May 2004 to September 2004. Model validation was conducted by simulating conditions from May 2003 to September 2004. Inflow boundary conditions for model calibration consisted of observed flows from Cow Pen Slough and Blackburn Canal; predicted flows for Salt, Fox and Shakett Creek from the HSPF simulations, and predicted flows at several other locations using estimated flows from Fox and Shakett Creeks multiplied by a ratio of watershed areas. A point source inflow was prescribed at the Venice Reverse Osmosis Treatment Plant. The prescribed salinity boundary conditions were set to be a constant 34 ppt on the open Gulf boundary and monthly values recorded in northern Lemon Bay at the southern ICW boundary. Water surface elevations on the Gulf portion of the grid were measured values at the USGS Venice gage, but were adjusted to match computed values to the observed values at Venice. Water surface elevations at the southern ICW boundary were taken to be the observed values at the USGS Shakett gage. Obviously, this isn't exactly correct, but the boundary is far enough removed from Dona Bay to have little impact on salinity computations in Dona Bay and Shakett Creek. Rainfall and wind data were specified at the water surface. The wind data came from the Sarasota Airport, with the rainfall data coming from the NOAA gage at Venice. The boundary conditions specified appear to be reasonable.

As noted previously, a longer simulation was conducted during the model validation phase. The inflows were as prescribed above, although the first year of the Blackburn Canal data was estimated because observed data weren't available. The salinity, wind and rainfall data were also as prescribed above; however, the USGS Venice gage did not have tide data for the entire period. Thus, predicted tides for a station at Bradenton Beach were employed for setting the offshore boundary. The dampening that occurred between the offshore water surface elevations and the southern ICW boundary during the calibration period was applied to the predicted offshore water surface elevations in the model to specify conditions at the ICW southern boundary for model validation.

For both model calibration and validation, there were three USGS continuous-recording data stations and an additional 25 sampling stations in Dona Bay, Shakett Creek, and Roberts Bay where monthly salinity data were collected. Salinity data were collected near the surface, near the bottom, and at one-meter intervals in the water column of the monthly sampling stations. At the USGS stations, only near surface and near bottom salinities were collected.

An inspection of the calibration results for the period of May 2004 to September 2004 (Appendix 6) shows that the computed water surface elevations compare well with the recorded values at the three USGS stations, but this is the easiest part of the modeling. Given the rather severe restriction at the US 41 Bridge, more dampening of the tidal signal at the Shakett Creek gage would be expected; however, neither the recorded data nor the computed values show much dampening.

Near surface and near bottom salinities were compared with recorded values at the USGS Venice, Dona Bay and Shakett Creek gages. The model responds quite well to freshwater inflows, with salinity values at Shakett Creek ranging from zero to 30 ppt. Generally, the computed and recorded salinities compare reasonably, especially during periods of low freshwater inflow, but the model seems to under predict water column stratification at times. Therefore, the Panel questioned how many “sigma” layers were used in the model, since this information isn’t given in the report (ATM 2007). During the simulation period, the large stratification that can occur in the system (see Figure 4.8 in SWFWMD 2008) doesn’t show up in either the recorded data or in the model results.

As noted above, the validation exercise covered the period of May 2003 to September 2004. Thus, the validation period started one year earlier than the calibration period and continued through the calibration period. Salinity results aren’t presented for the Venice gage. At the USGS Dona Bay gage, the computed results don’t compare very well with the recorded data for the first three months or so; however, once low inflows occur, the results improve significantly. During this period the Blackburn Canal flows weren’t measured values, but rather were estimated values. This could be a reason for the poor early comparison or perhaps the initial salinity conditions were still having an effect on the simulation.

Model salinities were also compared with the monthly salinities collected at the 25 stations in Dona Bay, Shakett Creek and Roberts Bay. During low flow periods the comparison of model salinities with the observed data was quite good, since they aren’t changing much. On the other hand, the comparison wasn’t as good during higher flow periods. Comparing data collected only once a month is not ideal because the measured salinity may change significantly from hour-to-hour and day-to-day, which is why modelers universally desire continuous-recording instrument data for calibrating and validating model simulations of tidal elevations, freshwater inflows and salinities.

EFDC Model Application --For the purposes of MFL determination, the EFDC model was applied for the three years of 1986-1988 (ATM 2007). These three years were selected from the base period of 1985-2005 because they most closely mimicked the flow duration curves for the entire 21 years for all blocks. The model was first applied using estimated inflows from the 1948 watershed simulation with the HSPF model to create baseline results for bottom area, water volume, and shoreline length for salinities less than 20, 15, and 10 ppt. Simulations were then made assuming reductions ranging from 5 to 30% in the estimated freshwater inflows from the Salt and Fox Creeks. These results were presented as Cumulative Distribution Function (CDF) plots for each of the three seasonal blocks in order to visually represent the amount of time and spatial extent of habitat availability defined by salinity levels of 10, 15 and 20 ppt, where the habitat assessment metrics were shoreline length, bottom area and water volume. By computing the difference in area under the habitat value – time curve between the baseline and a particular flow reduction scenario for each block, the impact of the flow reduction was estimated. As in all recent District's MFL studies, a habitat reduction no greater than 15% was considered to be the maximum acceptable limit.

The greatest response for each of the salinity levels and flow reductions was for Block 3 (high flow). In addition, the habitat showing the greatest response was the shoreline length because surface salinity is most responsive to flow reductions, and the length of shoreline habitat is dependent on the surface salinity in this MFL determination.

Based on all of the CDF plots generated from the EFDC model's computed salinity, it was concluded that a 3% reduction in Salt and Fox Creeks flows could be allowed for Blocks 1 and 2, with a 10% reduction allowed for Block 3 flows.

In summary, the EFDC model developed for the MFL determination of the DARB system appears to be adequate as far as grid resolution, model calibration and model validation. Its application to the three year (1986-1988) period and the generation of the CDF plots to determine appropriate levels of acceptable flow reduction are also reasonable given what the District is left to work with in the MFL determination. However, the accuracy of the predicted HSPF flows that drive the EFDC computations are open to question. Nevertheless, since the MFL analysis is based on differences in habitat values between the baseline condition and a flow reduction simulation, rather than absolute values, the issue of the accuracy of the HSPF flow prediction is minimized to some extent.

Bottom Habitats

In May/June of 2004 (the dry season), Mote Marine Laboratory personnel collected bottom samples for benthic macroinvertebrates and sediment analysis within Dona, Roberts and Lyons Bays (Cutler 2006). A total of 3,720 macroinvertebrates representing 199 taxa were collected from 19 sample sites. Total taxa collected were Roberts Bay 137 taxa, Lyons Bay 105 taxa and Dona Bay 90 taxa. Perhaps the most notable features of this study was the lack of any freshwater zones. Indeed, the salinity regime at the time of sampling would probably be more accurately described as marine rather than estuarine, since most of the observations were above 30 ppt.   As a result, there was a total lack of oligohaline fauna. Small crustaceans (e.g., Tanaids, amphipods and Mysids) were the principal groups represented in the benthos, particularly at the most upstream stations. These organisms are known to be well adapted for exploitation of areas that undergo significant tidal salinity variations, and most can readily colonize much lower salinity waters.

Cutler (2006) found that faunal similarity analysis indicated that the three bays maintain different species composition and abundance characteristics. In particular, Dona Bay and Shakett Creek appear to be depressed in both number of species and abundance when compared to the other nearby bays. He hypothesized that this benthic community depression is related to inordinately high flows during the wet season in Shakett Creek.

The Lyons Bay watershed has not been altered to the same extent as the nearby Dona Bay watershed. As a result, the oyster and seagrass populations of Lyons Bay have been found to be generally healthier than those of Dona Bay (Estevez 2006, Jones 2004, 2005, 2007). Also, salinity has been found to be consistently higher and less variable in Lyons Bay than in Dona Bay. Thus, it is widely accepted by the District and others in Sarasota County that the implementation of watershed/hydrologic restoration activities will have a high probability of improving water quality, oyster populations, and seagrass communities in Dona Bay.

In a recently completed Dona Bay Watershed Management Plan (Kimley-Horn and Associates, Inc. 2007), the authors found that conditions in Dona Bay are more stressful than those in Roberts Bay, and considerably more stressful than in the contiguous estuary of Lyons Bay. The Plan concludes that large influxes of freshwater inflow from the expanded watershed are associated with reductions in salinity, increases in the variability of salinity, decreases in average oxygen conditions, decreases in the minimum dissolved oxygen values, and a significant increase in loads of nitrogen, phosphorus and total suspended solids to Dona Bay. The combination of these impacts is most probably responsible for the reduced abundance and health of various estuarine habitats in DARB. Especially impacted are the benthic communities (e.g., seagrass, oysters and clams) that are unable to migrate away from stressful conditions. For this reason, the Plan identifies these ecological communities as useful “bio-indicators” of the estuary’s health.

Submerged aquatic vegetation (SAV, primarily seagrasses), the hard clam *Mercenaria campechiensis*, and the American oyster, *Crassostrea virginica* are all considered valued ecosystem components in the region (Kimley-Horn and Associates, Inc. 2007). Aerial photography indicates that only 36% of Dona Bay’s total surface area has seagrass; however, Roberts Bay has approximately 43% seagrass and Lyons Bay is estimated to have 75% of its area covered by seagrass (Estevez 2006). Major seagrass losses, such as those in the DARB system, typically cause large decreases in the productivity of fisheries within the affected areas (Livingston 1987).

Live hard clams occur in Lyons Bay but only dead clams were collected from either Dona Bay or Roberts Bay (Estevez 2005). This may not be surprising considering that larval and juvenile clams are more susceptible to low salinities; adult *Mercenaria* can tolerate long exposures to lowered salinities by tightly closing their thick valves. On the other hand, sudden increases in salinity exceeding 8 ppt are also lethal to hard clams. Shell growth is lowest in summer (wet season) when temperatures are highest and salinities are lowest, both stresses on the physiology of the clams. Eversole (1987) describes the hard clam as only moderately euryhaline (read: not broadly salt tolerant) and concludes that optimum salinities for egg development, larval growth and survival, and adult growth are in a fairly narrow range of 24 to 28 ppt. As a result of this and other information, Estevez (2006) recommended a bottom salinity of 20 ppt as the lowest average salinity genuinely suitable for hard clams in the DARB system.

Adult oysters can briefly tolerate lower salinities, but salinities less than 6 ppt are not tolerated for longer than 2 weeks, nor are salinities lower than 2 ppt tolerated for more than a week without significant mortality in the population. To protect recruitment, Estevez (2006) states that salinity during local spawning seasons should be above 10 ppt, while optimal survival and growth of oyster larvae and spat in a natural setting are only observed in salinities between 12.5 and 20 ppt, which limits many marine predators, parasites and disease organisms. Salinities in DARB areas where oyster reefs are desired can have large fluctuations between 10 ppt and 28 ppt, and they will do best in hard-bottom areas with good circulation and mixing to facilitate their filter-feeding life style (Estevez 2006).

In conclusion, all reported measures of oyster abundance and condition indicate that the DARB system and its tributaries experience intermittent conditions that severely limit oyster survival, growth and reproduction (Estevez 2006, Jones 2004, Jones 2005, Jones 2007). While it is obvious that oysters have the potential to grow and reproduce in Dona

Bay and Shakett Creek, they are clearly killed off on a fairly regular basis here, as well as in Roberts Bay and Curry Creek, by large freshwater pulses that basically “sterilize” the area of most marine and estuarine species.

Ichthyoplankton and Fishes

Three gear types were used to monitor organism distributions in the DARB system: a plankton net deployed during nighttime flood tides and a bag seine and otter trawl deployed during the day under variable tide stages (Peebles et al. 2006). The study area was divided into five collection zones and monthly sampling began in March 2004 and ended in June 2005. The two summer rainy seasons and high inflows during the spring of 2005 created a broad salinity regime within the DARB system.

Peebles et al. (2006) identified the eggs of herrings (clupeids), scaled sardine (*Harengula jaguana*), Atlantic thread herring (*Opisthonema oglinum*), bay anchovy (*Anchoa mitchilli*), striped anchovy (*A. hepsetus*) and several sciaenid fishes in the collections. If the abundance of early larvae is considered to be more or less proportionate to the abundance of eggs, then the researchers also suggested that silver perch (*Bairdiella chrysoura*), seatrouts (*Cynoscion arenarius* and *C. nebulosus*) and kingfishes (*Menticirrhus* spp.) are the sciaenids that are spawning in the area. Also spawning in the area are blennies, the hogchoker (*Trinectes maculatus*), skilletfish (*Gobiesox strumosus*) and gobies (*Bathygobius soporator*, *Gobiosoma* spp. and *Microgobius* spp.). Further, the repeated collection of small juveniles of live-bearing gulf pipefish (*Syngnathus scovelli*), chain pipefish (*S. louisianae*) and the lined seahorse (*Hippocampus erectus*) was viewed as an indication that these species are also reproducing near or within the area.

Prey availability, retention and transport are influenced by freshwater inflows; therefore, alteration of flows would appear to have the lowest potential for impacting many taxa during the period from November through February, which is the period when the fewest taxa were present (Peebles et al. 2006). The highest potential to impact many species would appear to be from June through October. Few clear seasonal patterns of taxon richness were evident in the DARB system, which may be attributed to both the relatively short duration of nekton sampling and the unusual hydrological (relatively low flow) conditions encountered during the study. Peak recruitment tended to occur in winter and summer for offshore spawners, spring and summer for estuarine spawners, and late spring and winter for resident species.

Of the 57 plankton net taxa, 49% exhibited significant responses to freshwater inflows to the DARB system. Similarly, about 70% of the 27 pseudo-species from seine and trawl samples were significantly related to freshwater inflows. Furthermore, approximately half of the significant responses had R^2 values > 50%, and these strong responders were dominated by estuarine, rather than freshwater, taxa. Most of the relationships were negative, indicating that the taxa exhibited significant downstream movement in response to inflow, which suggested to the researchers that the reductions in abundance were caused by their movement into the Gulf or lateral bays (Peebles et al. 2006).

According to the researchers, the estuarine fauna demonstrated a distributional affinity for the two point sources of freshwater inflow (i.e., Cow Pen Slough and Blackburn canals), which were flowing uncharacteristically low during their study. This finding was evident both in the community structure and in the distributions of individual species. In conclusion, Peebles et al. (2006) found that freshwater inflows appear to be serving as an attractant to estuarine fish and crustaceans in the DARB estuary during low flow periods, but perhaps without providing the usual trophic benefits, suggesting that a less erratic inflow regime may result in more efficient production of estuarine fish and crustaceans. However, since the researchers used observed inflows to the estuary, including those from Cow Pen Slough, the District opted to discard these results when making the MFL determination.

Spotted seatrout (*Cynoscion nebulosus*), snook (*Centropomus undecimalis*), and red drum (*Sciaenops ocellatus*) are common residents of the tidal (estuarine) waters of the DARB system (Estevez 2006). They are affected by salinities in variable ways and at different life stages, thus, a single salinity regime is not suitable for all estuarine-dependent species. Additionally, these three fish species need a rich and diverse invertebrate and fish-based food chain for their growth. Large and abrupt salinity changes have been observed to cause either mass migrations from, or mortalities of, adult seatrout in Florida estuaries (Tabb 1966). Large pulses of freshwater into Shakett Creek probably do not compromise the osmoregulatory abilities of common estuarine-dependent fishes, but increased flows can wash weakly motile juveniles and their prey from their preferred lower salinity habitats near the freshwater sources.

Based on a review of seatrout, snook and red drum salinity requirements (Estevez 2006), salinities outside a more or less seasonally appropriate level within the nursery grounds and spawning areas are not conducive for successful production of these three species. When red drum and seatrout larvae are present, a larval tolerance range of 15 -35 ppt will help reduce metabolic stress and mortality (Holt and Banks 1989). On the other hand, juvenile snook must have access to freshwater nursery areas, such as those that exist in the upper reaches of Shakett and Curry Creeks. Salt-water encroachment in these areas will decrease availability of prey species consumed by juvenile snook. In addition, the existing flood control structures (i.e., the CPS2 dam) may block juvenile snook from a large part of their favored nursery habitat in this watershed.

The increasing salinities bring with them more marine conditions, including the invasion of marine predators, parasites and disease organisms (Overstreet 1978 and Overstreet and Howse 1977). Theoretically, the District's proposed MFL should help mitigate any negative impacts on the young of these estuarine-dependent fish species from natural drought during their peak seasonal utilization of estuarine nursery habitats in the springtime. However, with the complete exclusion of flows from Cow Pen Slough and Blackburn canals, it is not certain that the District's MFL will provide sufficient protection at all times.

Other Panel Comments and Concerns

The District is to be commended for their thorough response to the questions raised by the Panel Members after the initial reading of the District's draft report. As the District moves forward to plan and supply water in the future to the people, their economy and their environment, the Panel strongly recommends that the District continue to monitor the DARB system for the purpose of verifying that the MFL is having its intended effect of maintaining ecological health and productivity. The verification monitoring should include streamflows, tidal flows, basic water quality, salinity, DO, chlorophyll, seagrasses, benthos and fisheries, particularly during the dry season, which coincides with the spring peak utilization of nursery habitats by estuarine-dependent organisms.

The Panel recognizes that the policy decision to include or exclude existing flows from Cow Pen Slough and the Blackburn Canal is up to the District. Whether one agrees or disagrees with that decision, the Panel feels the MFL report would be strengthened and made more understandable if the following issues are addressed in the final MFL report:

1. An evaluation of the consequences of changing inflows to Cow Pen Slough in relation to current conditions.

   Rationale: It is the Panel's understanding that altered flows are not necessarily required to be returned to their original conditions if such recovery could cause adverse environmental or hydrologic impacts (it is noted that several examples where this has been the case exist in previous MFL reports from the District). Cow Pen Slough and Blackburn Canal have been in place for more than 50 years, during which time the plants and animals in the system have presumably shifted in response to the altered flow. The report presents relationships between flow at the CPS2 dam structure and current conditions in the estuary (e.g., water quality and biotic resources) that could be used to evaluate the effects of decreasing flow. This analysis is also important in the context of evaluating the effects of potential future withdrawals for regional water use.

Of particular relevance to this point are the results of a recent effort to develop a Dona Bay Watershed Management Plan (Kimley-Horn and Associates, Inc. 2007). The Plan was prepared with funding assistance from the District and is referenced in the District's MFL report. It addressed the following general objectives:

a) Provide a more natural freshwater/saltwater regime in the tidal portions of Dona Bay.
b) Provide a more natural freshwater flow regime pattern for the Dona Bay Watershed.
c) Protect existing and future property owners from flood damage.
d) Protect existing water quality.
e) Develop potential alternative surface water supply options that are consistent with and support other plan objectives.

The Watershed Management Plan recognizes that the diversion of a significant portion of the Myakka River watershed into the Dona Bay watershed via the Cow Pen Slough canal has dramatically increased freshwater inflows to Dona Bay in a sporadic manner (Figure 5). The Watershed Management Plan makes an effort to consider a number of watershed restoration scenarios that could potentially "re-balance" and create a more natural water budget. Under the Plan, the re-balanced hydrology would more closely reflect pre-diversion conditions and restore more natural seasonal salinity regimes in the estuary. Also, a draft Dona Bay Monitoring Plan was developed to allow benefits to the estuary, its water quality and its living resources to be quantified from future implementation of the Watershed Management Plan.

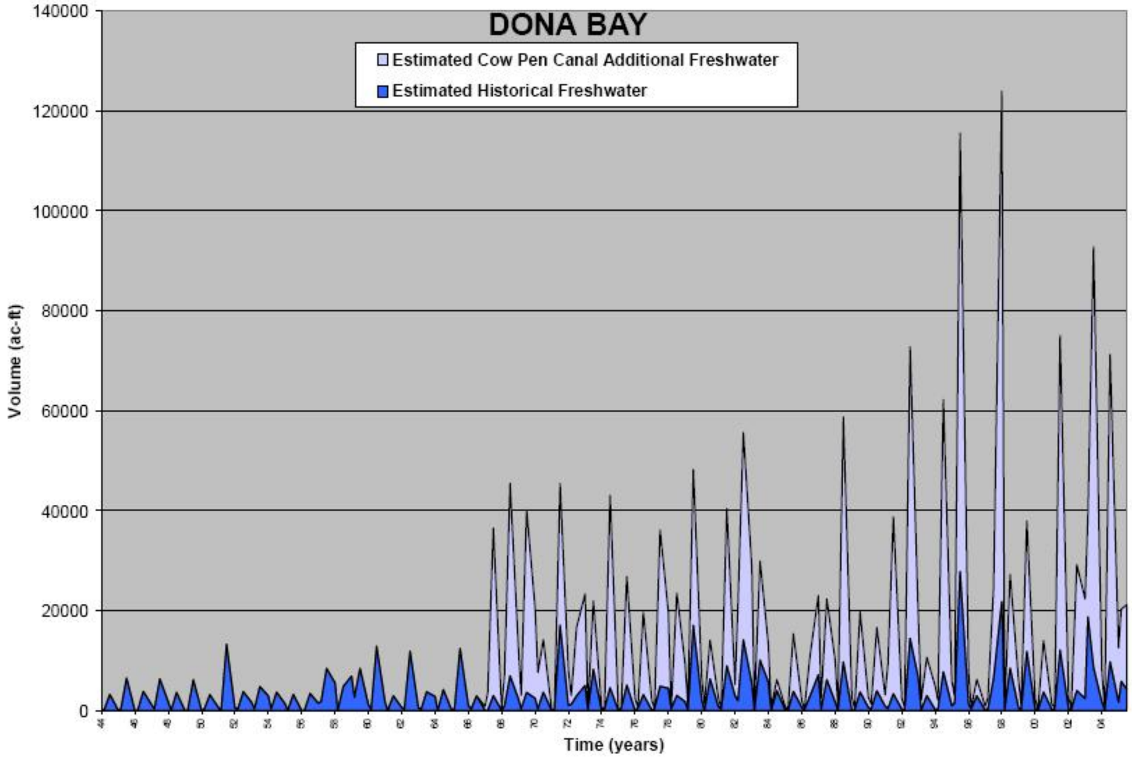

Figure 5. Estimated Historical and Potentially Excess Freshwater Inflows to Dona Bay (1944-2005).

In the end, the Watershed Management Plan concludes that the implementation of a 15 mgd water supply withdrawal would reduce over 40% of the excess freshwater diverted by the Cow Pen Slough canal without doing any real harm to the estuarine ecosystem and its living resources, and potentially creating several ecological benefits, such as a concurrent reduction in pollutant loads delivered to Shakett Creek and Dona Bay. However, inflows to Roberts Bay through the Blackburn Canal were not included in this analysis either (Figure 6).

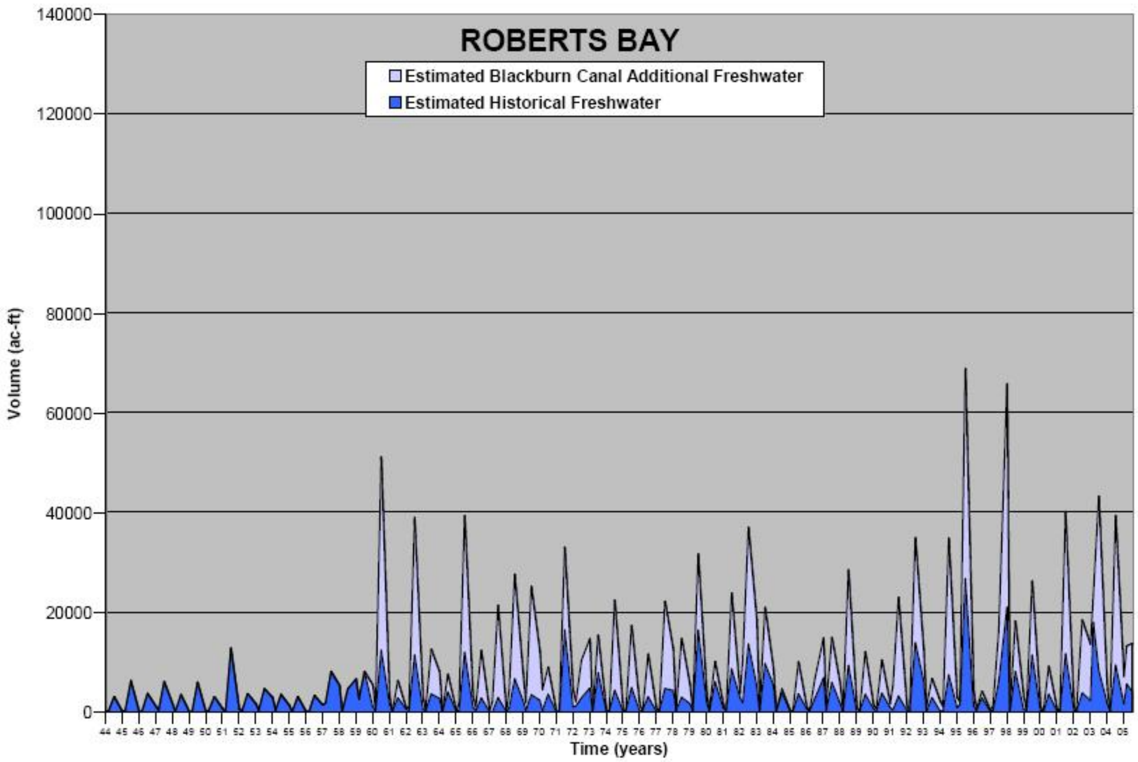

Figure 6. Estimated Historical and Potentially Excess Freshwater Inflows to Roberts Bay (1944-2005).

As mentioned before, these inflows are excluded by the District as a policy matter. However, there are a number of unspecified scientific assumptions that underlie this policy decision. Primarily, the District must be assuming that the ecological changes that will occur in affected habitats that have adapted to these higher freshwater inflows over the past half century, will not produce any unacceptable "net" harm to living resources of interest (e.g., wetlands and fisheries) when they are excluded in the MFL analysis and eventually removed from the system. In order to bring more confidence and certainty to its MFL determination, the District should consider making a similar analysis to that in the Plan with even higher reductions (e.g., up to 100%) of inflows from the Cow Pen Slough and Blackburn canals.

2. A comparison of how the habitat (volume, bottom area, length of shoreline) under baseline conditions compares to current conditions.

Rationale: The baseline conditions used in the report are dramatically different from current conditions, but these are never directly compared. The Panel suspects that the low-salinity habitat (defined as < 10 ppt) would be extremely reduced given that during the Block 3 (high inflow) season, surface salinity currently averages 2.4 ppt in the upper reach of Dona Bay and 6.5 ppt in the upper reach of Roberts Bay (Figures 4-10 and 4-12 in SWFWMD 2008); whereas such low-salinity water was available for a maximum of only 28% of the time during baseline conditions. If a more stable, saltier environment is desirable (i.e., for seagrass expansion) and the low-salinity habitat is not important, then this case should be made explicitly along with a clear characterization of the expected changes.

3. A reconsideration of baseline in light of historic conditions.

Rationale: The baseline condition is not only saltier than existing conditions, but also saltier than historic conditions due to the fact that the structural alterations that have occurred (e.g., Venice Inlet) are ones that increase the amount of Gulf water that enters the mouth of the Bay. This means that the starting condition (before removing water to set the MFL) is already saltier than the Bay has ever experienced. It would be useful to understand the extent to which the effect of dredging and other physical alterations that influence tidal flows from the Gulf are mitigated by the increased freshwater inflows from the canals. The Panel believes that the numerical EFDC model could be used to address the impact of the structural changes by making a "hindcast" application using the existing computation grid with bathymetric changes where appropriate. The Panel is not suggesting that the structural alterations that have occurred can be reversed, but rather that a more appropriate baseline condition may be one that corresponds to the historic salinity regime of the estuary rather than just the approximated historic inflows.

4. Additional data collection for Fox and Salt Creeks prior to allowing withdrawals.

Rationale: Fox and Salt Creeks are the focus of the MFL determination but there is not a lot of data for these two creeks presented in the District's report (SWFWMD 2008). Neither are gauged, there was no salinity or other water quality data collected in these areas, and it is unclear whether there were stations sampled for biological characteristics (e.g., macroinvertebrates and fish). Although neither creek has a substantial influence on the current salinity regime of the DARB system, this would potentially change under the assumed baseline conditions. The Panel notes that during the site visit provided by the District it appeared that Fox Creek had some of the best intertidal habitat and an indication that there is currently fresh water reaching the area, based on the Panel's visual identification of the presence of the black needle rush, *Juncus roemarianus*, along the shoreline.

Given the lack of data for Fox and Salt Creeks, the normal uncertainties inherent in the HSPF and EFDC model predictions for baseline conditions, and the potentially large ecological shifts that may occur in response to removing water from the interbasin diversions, the Panel does not believe there is enough scientific information available to allow any withdrawals from these two creeks, particularly during low flow seasons (Blocks 1 and 2). Therefore, the Panel recommends that the District follow the Precautionary Principle and establish the initial MFLs with little or no withdrawals from Fox and Salt Creeks until more scientific information can be collected and evaluated to determine with more confidence how changes in inflow will affect the DARB area. Further, the Principle of Adaptive Management suggests that it would be useful for the District to revisit this topic periodically when enough new data becomes available for a more and better analysis than that presented here.

ERRATA and EDITORIAL COMMENTS

Page	Paragraph	Line	Comment
All			While the report uses English units in accordance with the Governor's requirement for simplicity in writing, in many cases metric units still are used rather than common English units. The Panel notes a couple of exceptions − distance, expressed in kilometers, and water depth, expressed in meters. Some readers would probably say these are the wrong exceptions, finding river miles and depth in feet much more readily understandable by the public. Metric units should probably be reserved for chemical concentrations and related water quality parameters that are not familiar to the general public anyway.
xv	3		The distinction between baseline and historical flows is confusing. The report suggests that flows that existed prior to major structural alterations were considered "baseline" but that this is somehow not historical. Later (pp. 1-4) the report states that the MFL will be less than the historic flow, but the MFL would presumably always be less than the flow to which it is being compared.
xvi	5	4	Does "the metrics discussed above" mean volume, bottom area, and shoreline length?
2-4			The two purple areas in the legend for Figure 2-2 are not distinct.
2-10	2		Are the drainage areas provided for the different control structures cumulative?
2-15	1	3	The Panel is not familiar with the use of the term "leakance." Do you mean leakage? Presumably, this refers to channel losses due to infiltration of surface waters into the water bearing strata of the underlying water table/groundwater formation (aquifer).
2-16 Thru 2-18			A table showing 25th, 50th and 75th percentiles for the different gage predictions (and also the observed flows at Blackburn vs. predictions) would be useful. Also, can the runoff model results for CPS2 be extracted and quantified?
2-23 And 2-25			The HSPF model results for inflows to Dona Bay (Figure 2-22) and empirical model results for Roberts Bay (Figure 2-25) are indicative of extreme episodic events. The effects of large non-normal data distributions are illustrated in these graphs by differences up to 300% between measures of central tendency (mean average and median flows) in the same month.
2-27	1		Why not also compare runoff to observations in 2004-2006 when both gages were operating? That might be better than relying entirely on the models with their potential errors.

Page	Paragraph	Line	Comment
3-4	4	10	The greatest bottom area is shown at rkm 2.5 and doesn't extend to rkm 1.0 (Figure 3-9). Thus, the sentence that begins "In Roberts Bay…" needs to be corrected.
3-14	2		It is not clear exactly what "deep fringing wetlands" means and how it contrasts with "patchy fringing wetlands." Perhaps "deep" refers not to water depth, but to the width of the fringing vegetation. Does this mean that deep fringing wetlands are more or less continuous, while patchy fringing wetlands are spotty?
3-16			Figures 3-16 and 3-17 are difficult to see. They should either be expanded to full page or deleted.
4-5	1	3	The word "turbidity" is repeated twice.
4-5	1	6	The word "color" is repeated twice.
4-6	3		The fact that a 3-day average flow of 79 cfs, with a high flow of 204 cfs on the sampling date, was not sufficient to flush out the salt wedge suggests that the 3-day average may not be all that useful as a way to represent what is occurring. The point is that at a flow of 204 cfs the system is stratified (see Figure 4-8). Also, the example in the next paragraph again shows that the system remains stratified even at much higher (462 cfs) 3-day average flows, though the greatest stratification has moved downstream a couple of kilometers (see Figure 4-9).
4-16	1	4	What are the "benthic organisms of interest to the Sarasota County government?"
4-18	1		The justification provided for why flows were averaged over 3 days in this salinity analysis is that plots yielded fewer outliers than daily (same day?) flows. Were other averaging periods tested as well, such as 2-day or 5-day flows antecedent to the lagged salinity sampling day? Or was the 3-day average just a lucky guess?
4-25 Thru 4-27			How does chlorophyll observed in Dona Bay compare to other nearby bay and estuary systems? Mean and standard deviations might also be useful in better understanding this system.
4-28	3		Both sentences in the paragraph beginning "Block 1…" need revision as they are somewhat confusing. Also, while the location of the sampling stations shown in Figure 4-1 is generally informative, the reader might be better served by referring in the text to their river kilometer position instead since that's what's shown in Figures 4-30 through 4-35.
5-6			Figure 5-4 may be unnecessary as it just repeats a portion of what is already given in Table 5-1.
5-14	3		Where are the data on the similarity indices that were used?
5-16			The conclusion that the benthic taxa in the DARB are similar to that found in Charlotte Harbor is not well-supported. The point that the benthos is dominated by high salinity species also is not made clearly.

Page	Paragraph	Line	Comment
5-18	4 and 5		This shows that the change in oysters is not a function of change in flow but rather filling (habitat loss), particularly in Roberts Bay. The observation that live oysters were found in Lyons Bay could be due to multiple factors—just because it's correlated with salinity doesn't mean that's the cause. For example, it could be due to differences in pollutant levels or in the abundance of predators, parasites and disease organisms.
5-25			This discussion is more detailed than what was presented in other sections of the report, and most of it is not about fish *per se*.
5-26			The fact that the rkm ranges given in Table 5-6 are in Dona Bay is not noted but should be.
5-29	5	6-10	Shouldn't the discussion about "new recruits" and "peak abundances" be referenced to Figure 5-19 instead of 5-18?
5-34	1	10	If fish were attracted upstream due to the lower-than-normal flows experienced during this study, wouldn't that also happen under the flows being considered as historical or baseline?
5-37			The finding (shown in Table 5-8) that pink shrimp of one size class (< 10 mm) have such a different relationship with flow to that of another (> 11 mm), to the point where the sign of the slope changes, deserves some discussion and explanation. Same thing applies to bay anchovies (26-35 mm vs. > 36 mm).
5-42	1	2	The evidence that salinity becomes more variable at higher flows is not evident here. Higher flows generally shorten the salinity gradient; while lower flows generally elongate the salinity gradient; however, making a site-specific salinity more variable normally requires the flow itself (either high or low) to become more variable over time.
6-4	1		Why is sand seatrout included in the "biologically-relevant salinities?" It is not included in Appendices C, D, E, F, G, H or I. Indeed, their larvae are only mentioned once on page 5-28 as being caught in the plankton-net. Is there any evidence this species is important in this estuary?
6-6	1		There is no citation to the ATM 2007 hydrodynamic modeling report here or in the references at the end of the MFL document on page 9-1.
6-10	1	2	The text says the EFDC model's domain comprised the area of Dona Bay "upstream of the Intracoastal Waterway and Shakett Creek." However, the referenced Figure 6.9 shows a computational grid that includes Shakett Creek and Cow Pen Slough.

Page	Paragraph	Line	Comment
7-1			The District should consider providing an illustration of average surface and bottom salinity in each reach during each seasonal block of the baseline period, which the reader can then compare with the current condition salinities shown on pages 4-13 and 4-14. This should be done before moving on to the CDFs.
7-9			When presenting model results, a map would be useful to see how far upstream salinities are changed under the baseline scenario.

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APPENDIX B

DISTRICT RESPONSE TO SCIENTIFIC PEER REVIEW FINDINGS

Resource Management Committee
July 28, 2009

Submit & File Report
Response to Peer Review Panel Report of the Proposed Minimum Flows and Levels for the Dona Bay/Shakett Creek System below Cow Pen Slough (B115)

Purpose
To respond to the peer review of the Proposed Minimum Flows and Levels (MFL) for the Dona Bay/Shakett Creek System.

Background/History
Staff completed a draft report recommending minimum flows for the Dona Bay/Shakett Creek System below Cow Pen Slough (CPS) that was presented to the Governing Board at its July 2008 meeting. This report was then submitted to an independent scientific review panel for voluntary peer review. The panel was composed of three scientists who have extensive experience in hydrology, ecology, and freshwater inflow relationships. The panel's charge was to review the validity of the technical approach used by the District to determine the proposed minimum flows. In doing so, the panel considered how well the conclusions in the report are supported by data, procedures, and analyses that are presented.

Dona Bay/Shakett Creek is the four-mile stretch of estuary between Venice Jetties and the downstream control structure of the channelized CPS. Historically this estuary received only local runoff from the surrounding 16-square miles (mi^2) watershed and the 59-mi^2 CPS watershed drained to the Myakka River. Between 1962 and 1971, the Soil Conservation Service constructed 14 miles of channel and re-directed CPS to Dona Bay/Shakett Creek, thereby increasing the natural watershed by a factor of 3.7. In addition, during the 1950's local residents constructed the Blackburn Canal to divert Myakka River flood flows to Roberts Bay, which joins with Dona Bay approximately 0.3 miles upstream from Venice Jetties. The combination of the CPS and Blackburn Canal projects results in significantly more freshwater entering Shakett Creek and Dona Bay than would have occurred historically. The District chose to use the smaller pre-channelization watershed and associated hydrology as the baseline condition for the MFL determination based on the knowledge that Sarasota County and the Peace River/Manasota Regional Water Supply Authority have identified the excess water for alternative water supply projects. Thus, while the CPS channelization is a significant hydrologic alteration, staff anticipates that some of the detrimental effects of excess water can be ameliorated by future water supply projects. The panel acknowledged that it is a District policy ***to include, or exclude existing flows. . .*** from the baseline evaluation.

The panel did make four specific suggestions for further evaluation of the impact of removing all of the channelized CPS flows, which are presented along with staff response.

1) **An *evaluation of the consequences of changing inflows to [from] Cow Pen Slough in relation to current condition*.** Staff intends to complete additional modeling efforts to compare and contrast the pre-channelized salinity, the present salinity, and the expected salinity under the proposed MFL. These results will be used to guide permitting of withdrawals from CPS.

2) ***A comparison of how the habitat (volume, bottom area, length of shoreline) under baseline conditions compares to current conditions***. The additional model evaluations

identified under recommendation number one will be post-processed to quantify and compare the metrics recommended by the peer review panel.

3) ***A reconsideration of baseline in light of historic conditions. . . . It would be useful to understand the extent to which the effect of dredging and other physical alterations that influence tidal flows from the Gulf are mitigated by the increased freshwater inflows from the canals.*** Staff intends to complete a computer simulation of existing flows, but without the physical influences of the Intracoastal Waterway, the flow constrictions of the US 41 bridge and the railroad bridge, and with a natural pass instead of the dredged Venice Jetties. The results will be evaluated with respect to the current conditions and the conditions expected under the proposed MFL.

4) ***Additional data collection for Fox and Salt Creeks prior to allowing withdrawals…the panel recommends that the District…establish the initial MFLs with little or no withdrawals from Fox and Salt Creeks until more scientific information can be collected and evaluated…***Staff concurs with the panel recommendation regarding Fox and Salt Creek. Staff anticipated that withdrawals would be taken from the channelized CPS upstream of the control structure (and Fox and Salt Creeks). While the MFL evaluation concluded that small amounts of water (3-10 percent) could be taken from below the structure, the magnitude of those volumes is much, much smaller than the amount of water that could be removed from CPS proper upstream of Shakett Creek.

The panel further recommended that the District continue monitoring and adopt an adaptive management approach to removal of the CPS flows. Staff agrees with this recommendation and is committed to re-evaluating all minimum flow and level determinations in light of additional scientific data or after withdrawals increased.

<u>Staff Recommendation</u>:

This item is presented for the Committee's information only; no action is required.

<u>Presenter</u>: Michael G. Heyl, Chief Environmental Scientist
Resource Projects Department

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6/22/2009 2:36 PM
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