

A satellite-style map of the Sarasota Bay Estuary Program area. The map shows the coastline of Sarasota Bay on the left, with various colored overlays: a red area in the upper left, a large green area in the center, a purple area to the right, and a blue area in the lower right. Major roads are marked with shields: a blue and red shield for Interstate 75 (I-75) running vertically on the right, a white shield for State Road 301 (SR 301) running vertically in the center, and a white shield for State Road 41 (SR 41) running horizontally near the bottom. The text is overlaid on the map in white.

Sarasota Bay Estuary Program Water Quality Assessment and Pollutant Loading Model Update

Report to the Sarasota Bay Estuary
Program
Final Report

Submitted By:
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Executive Summary

Several Sarasota Bay Estuary Program (SBEP) open bay estuarine segments (Bays) are likely to be deemed “Impaired” by the Florida Department of Environmental Protection (DEP) in the autumn of 2021 based on exceedances of existing water quality standards. The SBEP has received verbal and written confirmation of this preliminary assessment status and an official assessment is expected to be announced later this year (between September and December 2021). In addition, the SBEP and its partners have observed a recent degradation of several indicators of estuarine health with increasing 20 year trends in water column total nitrogen throughout the bays and tributaries, seagrass acreage declines in several segments, and a recent increase in the frequency of occurrence of nuisance macroalgae and harmful algal blooms.

The SBEP initiated a scientific study to support the development of a water quality protection and restoration strategy in order to be proactive in addressing adverse effects observed in the estuarine indicators and to prepare for a pending regulatory finding and the subsequent regulatory mandates associated with an impairment listing. The SBEP issued a scope of work (2020SBEP03) to collate and synthesize available data related to water quality and biological responses in SBEP bay segments and refine and existing pollutant loading model to estimate nutrient loads to these systems between 1995 and 2019. The goals of the study were to: assemble the most current and best available information on the pollutant loads and estuarine responses; be proactive in identifying potential remediative actions to reduce loads to the Bays, and organize and prepare for impending regulatory assessments by engaging local stakeholders and facilitating solutions oriented approaches to reduce and reverse adverse effects to these systems.

An evaluation of the updated estuarine indicator data collected to date confirmed that chlorophyll concentrations have recently exceeded their regulatory standards, trends in total nitrogen have increased significantly between 1998 and 2019 and, in several areas, seagrass acreage is decreasing and the frequency of occurrence of nuisance macroalgae and harmful algal blooms is increasing. Together, these results provide several lines of evidence that management actions should be considered to reduce nutrient loadings to the Bays to reverse observed adverse effects in these waters.

An important step in identifying potential management actions to reduce nutrients is to understand the source of nutrient loads to these estuarine water bodies. To that end an existing pollutant loading model was updated and refined to reflect the best currently available information on loading sources within these watersheds and model runs were

conducted to generate a continuous record of monthly pollutant loads between 1995 and 2019 for all watersheds of the SBEP using a consistent methodology that has been accepted by DEP for other recent projects. The model results suggest that while runoff and baseflow dominate nutrient loadings to the system, other sources closely tied to management activities in the watershed can result in significant effects on the overall pollutant load to these systems. Using total nitrogen loads as an example, the model documented significant reductions in point source and septic loads over time in some segments as well as increases in reclaimed water loads in some segments. While the reclaimed load contributes generally less than 10% to the total nitrogen load to the Bays, they represent an increasing fraction of the total inorganic nitrogen load in all segments and now make up over 15% of the estimated total inorganic load to Palma Sola and Sarasota Bay. While atmospheric deposition, runoff and baseflow nutrient loads are generated principally as a function of variation in rainfall and the natural and anthropogenic nutrients associated with those sources, other sources [septics, point sources, reclaimed irrigation, accidental releases (spills)] represent anthropogenic loads actively managed or at least regulated as a public service. The model estimates suggest that spills account for a small percentage of the overall nutrient loads at the watershed scale; however, at smaller spatial scales these loads can represent the majority of the total pollutant load to smaller catchments over short temporal windows and therefore should not be completely discounted. Importantly, while the loads summarized in this report represent watershed scale evaluations, the model was developed to operate at much smaller spatial scales allowing for natural resource managers to “drill down” evaluations to specific areas of interest to investigate management implementation options.

This study has provided a foundation from which the SBEP and its partners can work to evaluate potential management actions to address water quality and associated issues with biological response endpoints in the Bays. This proactive approach by SBEP is also intended to facilitate a locally driven, collaborative, and timely approach in response to impending regulatory impairments. The typical regulatory paradigm implemented by DEP after verifying waterbodies as impaired is to develop a total maximum daily load (TMDL) which is often lengthy process generally outside of local control; however, the proactive approach taken by SBEP allows for alternative regulatory pathways to be considered including a developing a Category 4B Plan, also known as a Reasonable Assurance Plan (RAP) which is a stakeholder-led effort, or developing a Category 4E Plan which is similar to a RAP but would not remove the Bays from the potential of a DEP TMDL. Ultimately, these decisions rely on the regulated local stakeholders in coordination with DEP to determine the best course of action to protect and restore the estuarine segments of the SBEP.

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1 Background

The estuarine waterbodies (Bays) of the Sarasota Bay Estuary Program (SBEP) have recently exhibited increasing trends in nitrogen and chlorophyll concentrations and indications are that these waterbodies are likely to be deemed “Impaired” by the State of Florida Department of Environmental Protection (DEP) for nutrient pollution in the near future. The SBEP and its partners are interested in initiating efforts to better understand the underlying causes of the observed degradation of water quality and associated biological responses endpoints in their estuarine waterbodies. Identifying drivers of these observed nutrient and chlorophyll increases and their relationship to the assimilative capacity of these systems are important first steps understanding the source and potential management actions required to address these issues.

The boundaries of the SBEP lie within Sarasota and Manatee Counties and include five bay segments (Figure 1):

- Palma Sola Bay,
- Sarasota Bay,
- Roberts Bay,
- Little Sarasota Bay, and
- Blackburn Bay.

The Sarasota and Roberts Bay watersheds are the largest watersheds (39,872 and 40,942 acres, respectively) and Sarasota Bay open water area is substantially larger than any other bay segment (Table 1). The watersheds for these Bays include the City of Bradenton, the City of Sarasota, Town of Longboat Key, Phillippi Creek, Osprey, and Nokomis as well as the barrier islands. The DEP Waterbody Identifiers (WBIDs) are outlined by blue lines in Figure 1.

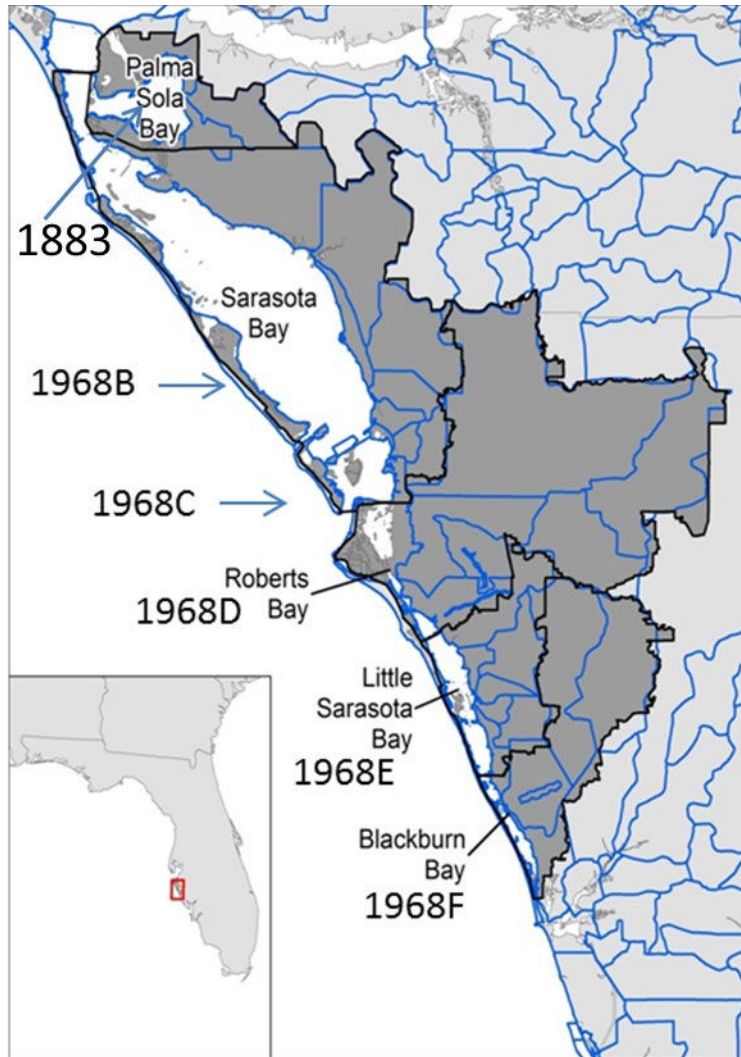


Figure 1. Location of bay segments and WBIDs (blue lines) in the Sarasota Bay Estuary Program (SBEP).

Table 1. Watershed acreage of the SBEP broken into the land based and open water size.

Watershed	Open Water (acres)	Watershed (acres)
Palma Sola Bay	3,215	6,587
Sarasota Bay	10,489	39,872
Roberts Bay	1,224	40,942
Little Sarasota Bay	1,948	8,580
Blackburn Bay	725	14,572

1.1 Goals and Objectives

The primary goal for this project was to synthesize available information on water quality and update an existing watershed pollutant loading model to support

stakeholder decisions on how to proceed in identifying and quantifying principal sources of nutrient loadings to the Bays, evaluate trends in loadings over time, and provide stakeholders information they can use to identify options for remedial actions if necessary in the face of potential regulatory impairments in the Bays. The specific objectives were to collect and synthesize available data, evaluate status and trends in estuarine indicators, update a nutrient loading model, and present this information to local stakeholders and natural resource managers as part of a newly formed Water Quality Consortium.

1.2 Scope of Services

Janicki Environmental, Inc. was contracted to complete a scope of work that focuses on providing several scientific investigations that are required to develop science-based informed decisions on how to proceed. The scope of services includes:

- identifying stakeholders and initiating collaboration among stakeholders,
- acquiring and synthesizing datasets relevant to identifying aquatic and ecological goals;
- updating pollutant loading models for the five Bay segments including both Manatee and Sarasota counties, and
- establishing a path forward for remedial action, if necessary, to ensure protection of these critical resources.

A major component of this effort was updating an existing pollutant loading model for analysis. The Spatially Integrated Model for Pollutant Loading Estimates (SIMPLE) was originally developed and implemented by Jones Edmunds to fulfill an NPDES MS4 permit requirement for Sarasota County (JEA 2005). That version of the model, SIMPLE-Seasonal, provided seasonal and annual loads based on annual rainfall estimates. In order to align the model outputs to the counties water quality monitoring programs, the SIMPLE model was upgraded to provide monthly estimates from spatially explicit rainfall with the addition of Next-Generation Radar (NEXRAD) rainfall estimates. The deliverables from that effort included the SIMPLE-Monthly model development and design report (JEA 2009a) and calibration report (JEA 2009b). SIMPLE-Monthly model (subsequently referred to herein as SIMPLE) was used to develop the Sarasota County watershed management plans for Roberts Bay (JEA and Janicki 2010), Little Sarasota and Blackburn Bays (JEA and Janicki 2012a) and Sarasota Bay (JEA and Janicki 2012b) and other Sarasota waterbodies outside of the SBEP boundaries. SIMPLE was also expanded into that portion of Manatee County that drains to Sarasota Bay and Palma Sola Bay to support development of nutrient targets and thresholds for SBEP estuarine

waters (Janicki Environmental 2010). A major component of this project was to update the Manatee and Sarasota County model input data to a common period of record, review model parameterizations, and employ the SIMPLE for both that portion of Manatee County that drains to SBEP waters and all of the Sarasota County watersheds that drain to SBEP waters using a common, updated, and unified model architecture.

Since its initial development for Sarasota County in 2005, SIMPLE has been used to support the development of several Sarasota County's watershed management plans as well as other watershed plans throughout Florida including Curlew Creek, the City of Dunedin, and the City of West Palm Beach. The model was also used in Walton County to evaluate loadings to the rare coastal dune lakes located there (JEA, 2018) and, most pertinent to this project, SIMPLE was recently accepted by DEP and the EPA as a valid model to estimate nutrient loadings for the Mosquito Lagoon Reasonable Assurance Plan (JEA and Janicki 2019).

The SIMPLE model is spatially explicit and temporally dynamic such that loading estimates can be aggregated over different spatial and temporal scales. SIMPLE includes a seasonal component to capture monthly variation in pollutant loads and is date-stamped to allow for the inclusion of management actions such as best management practices (BMPs) and expansion of reclaimed water service areas. The model is capable of estimating total forms of nutrients (i.e., total nitrogen and total phosphorus) as well as inorganic nutrients, suspended solids, dissolved solids, biochemical oxygen demand, and some metal contaminants. The loads are partitioned by source including direct runoff, base flow (aka surficial groundwater), point sources, septic, irrigation, and atmospheric deposition.

A schematic of the model architecture is provided in Figure 2 showing how the individual model "modules" are aggregated to generate total pollutant loadings. Briefly, a hydrologic engine uses daily NEXRAD precipitation data and spatially explicit land use and soils information to generate runoff and baseflow volumes at a monthly time step. Evapotranspiration and other losses are accounted for. Then, a table of coefficients including event mean concentrations for runoff and base flow concentrations are used to generate the runoff and baseflow loads, respectively. In an additive process, point sources (including spills) and atmospheric deposition (for open waters) are added to the runoff loads and estimates from septic systems and reclaimed water irrigation are added to the baseflow component to generate the total load at the sub basin level. The loads can then be aggregated over various spatial and temporal extents.

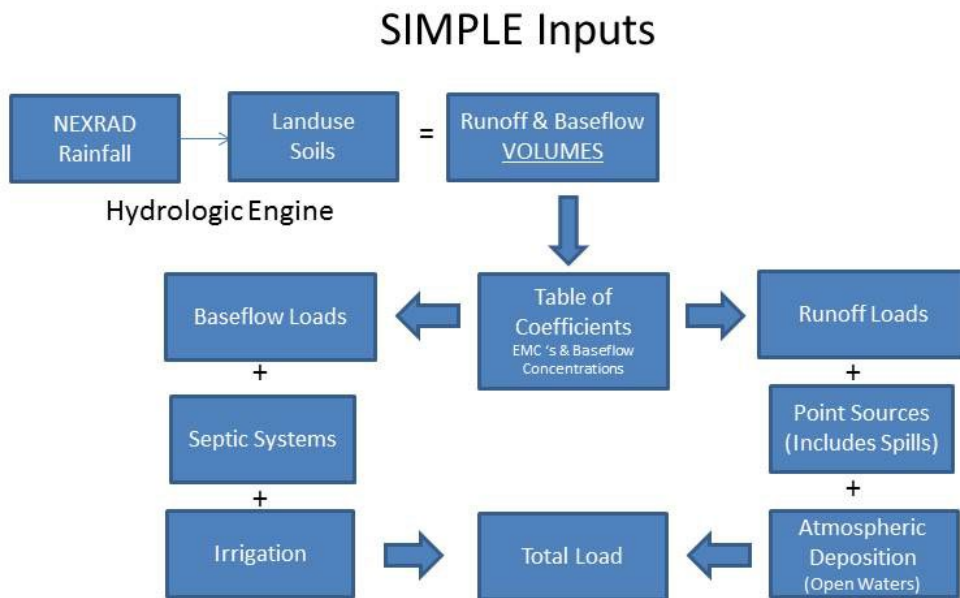


Figure 2. Schematic of SIMPLE model architecture.

The following chapters detail efforts to update the pollutant loading model and available data on estuarine water quality and biological response endpoints within the SBEP and describe results of analysis to describe the current status and trends in water quality, pollutant loading, and estuarine responses.

2 Data Acquisition and Synthesis

This chapter summarizes the data acquisition and synthesis tasks as well as the methods used to That technical memorandum is summarized in the following paragraphs.

2.1 Water Quality and Rainfall

Water quality data were acquired from the DEP Impaired Waters Rule database (Run 58). Since this project is related to regulatory actions, the IWR database was considered the principal data source for the project. However, Run 58 did not have data from 2018 or 2019 for Manatee County and only partial data for 2019 in Sarasota County. Therefore, the IWR database was supplemented using data directly from the counties or from the Sarasota County Water Atlas which is the standard repository of the Sarasota County ambient water quality monitoring data. The primary water quality parameters include nutrients, chlorophyll *a*, *in situ* parameters (dissolved oxygen, salinity, and temperature) and fecal indicator bacteria.

Rainfall data (i.e. NEXRAD) were downloaded from the Southwest Florida Water Management District (SWFWMD) website for the period of record available (1995-2019). The NEXRAD data offers the advantage of providing spatial and temporal measurements in much higher resolution than rain gage measurements can offer. Each NEXRAD measurement is based on a 2km by 2km cell, or pixel, and reported at 15 minute intervals. These values can be summed to produce daily, monthly, and annual rainfall totals. The NEXRAD pixels were spatially joined to the Sarasota Bay Estuary Program basins shapefile in GIS to create an area weighted rainfall total for each basin on daily, monthly, and annual timescales. For example, the overall average total NEXRAD rainfall amount for the Sarasota Bay watershed was 46.3 inches and each year varied around that average with deviations as much as 12 inches below “normal” during the 2000 drought (Figure 3). Rainfall overall grand annual averages ranged from 44 inches (Longboat Key) to 51 inches (Phillippi Creek). For most basins, the period between 1998 and 2000 and the period between 2007 and 2010 represented drought conditions while the period between 2001 and 2005 and the period of 2016-2019 represented either slightly above average or surplus conditions. These data are used to generate hydrologic loads in the pollutant loading model as well to assess relationships between meteorological conditions and water quality.

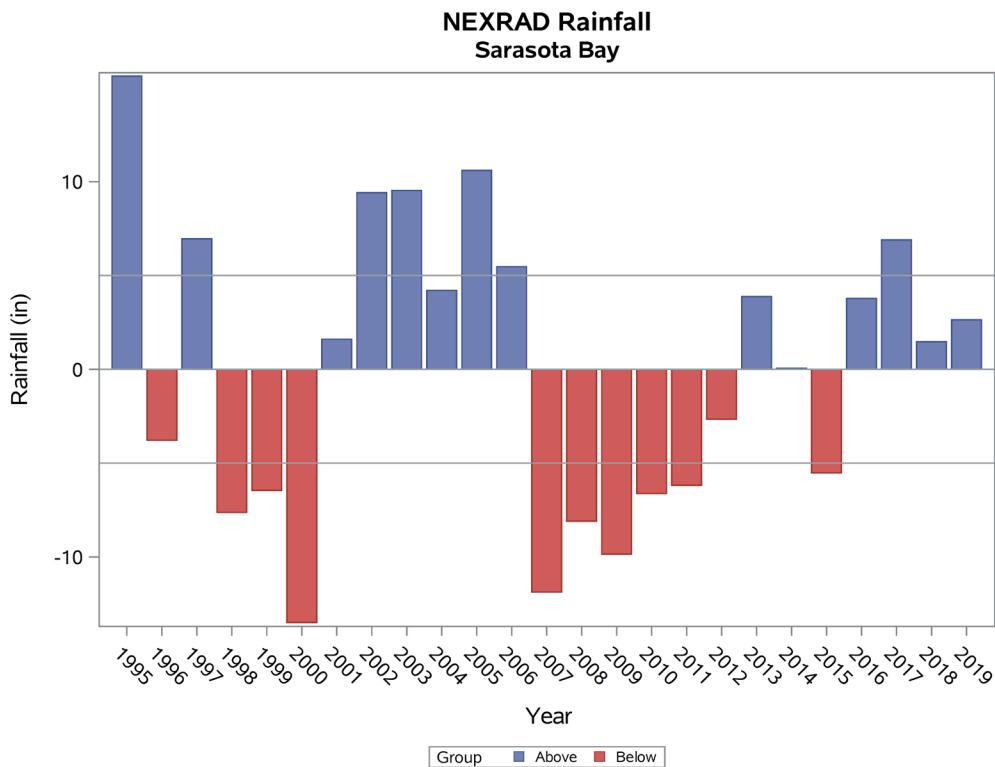


Figure 3. Annual rainfall deviations from long term annual average conditions in Sarasota Bay watershed. Reference lines indicate a 5 inch positive or negative deviation from the long term average.

2.2 Biological Data

2.2.1 Seagrass

Two seagrass monitoring efforts routinely evaluate Sarasota County seagrasses. First, the SWFWMD conducts biennial aerial surveys designed to calculate areal extents of seagrass within the SWFWMD jurisdictional boundaries. Second, Sarasota County staff has conducted field seagrass surveys since 2006 to compliment the SWFWMD surveys and provide additional information on seagrass species composition, drift and attached macroalgae prevalence and abundance, and epiphyte load at ca. 40 fixed and 120 random sampling locations annually. The exact sampling frequency and timing of the surveys has varied over time since the program has been initiated.

2.2.2 Nekton

Nekton (fish and crustacean) data were provided by the Florida Fish and Wildlife Conservation Commission (FWC) Fisheries-Independent Monitoring (FIM) Program. The program has routinely sampled the open bay estuaries of the SBEP every other month since 2009 using a multi-gear approach. A detailed description of methodologies employed in Sarasota Bay may be found in the Task 2 technical memorandum as well as MacDonald *et al.* 2015 or the FIM Procedure Manual (FWC-FWRI 2012).

2.2.3 *Karenia brevis*

The Bays experienced a significant "Red Tide" (*Karenia brevis*) harmful algal bloom between November of 2017 and February of 2019. Mote Marine Laboratory has analyzed samples collected as part of Sarasota County's routine water quality monitoring program for *K. brevis* since 2006. The effort to identify *K. brevis* in routine water quality samples by Mote Marine Laboratory was voluntary and there are some small gaps in the available data; however, the data are publicly available and were obtained for analysis from the Sarasota County Water Atlas ([data link](#)).

2.3 Pollutant Loading Model Data and Updates

The SIMPLE model has evolved over time and a number of enhancements have been made to improve efficiency of the calculations within the model architecture and to include more information as it has become available. In fact, the major advantage of this model relative to other pollutant loading models is the ease to update the source code and the lookup tables as new information becomes available.

This project began with a version of the Sarasota SIMPLE model last enhanced in 2019 using data collected through 2016. These data were updated through 2019 as available

including rainfall, atmospheric deposition, land use, septics, irrigation, point source discharges, accidental releases (spills) and BMP layers used to identify recent stormwater improvement projects throughout the Sarasota County watershed. In addition, the SBEP Manatee County portion of the watershed was last updated in 2008 and for this project was updated through 2019. The following sections provide an overview of each of the modules of the current version of SIMPLE which include: the hydrologic engine, direct runoff, base flow, point sources, spills, septic systems, reclaimed water irrigation, and atmospheric deposition. Detailed information regarding SIMPLE can be found in (JEA, 2009). The paragraphs below describe the model inputs for each module and a description of modifications, if any, to each module since the 2019 effort (JEA 2019).

2.3.1 Model Data and Spatial Extent

2.3.1.1 Model Data

The principal data used by SIMPLE which were updated for this model version include:

- NEXRAD Rainfall – NEXRAD (Next Generation Rainfall) data from 1995 through 2019 were provided by SWFWMD.
- Landuse – Landuse data between 1995 and 2019 were provided by the District
- Soils - The soils data used in this project were obtained from the 2018 National Resources Conservation Service soils layer.
- Geographic segmentation layers provided by Sarasota and Manatee Counties as well as the SBEP
- BMP layers updated through review of District ERP permits and aerial photography
- Point Source Discharge information obtained through DEP and Sarasota County discharge monitoring reports
- Accidental Releases (Spills) obtained from DEP Pollution Notice website
- Septic System locations were updated based on information obtained from Sarasota and Manatee Counties
- Reclaimed water irrigation volumes and concentrations were obtained from Sarasota and Manatee Counties as well as the City of Sarasota
- Atmospheric Deposition data from the Verna Wellfield site in Sarasota County were obtained from the National Atmospheric Deposition Program

2.3.1.2 Spatial Extents

The SIMPLE model incorporates features with varying spatial extents. For example, the NEXRAD data rely on ca. 2x2 km pixels while the landuse and soils coverages are polygons of varying sizes. In addition, hydrologic boundaries of watersheds are defined for estimating loadings to the Bay segments. All of these spatial features are intersected in SIMPLE to provide spatially explicit watershed, rainfall, landuse and soil derived loading estimates. An example of the overlay is provided in Figure 4 where the NEXRAD pixels are overlaid on the 2017 District landuse layer and the geographic watershed boundaries for the 5 SBEP Bay segments. Hydrologic and pollutant loadings for this project were generated at the “Basin” and “Watershed” scales (Figure 5) since the objective of this project was to estimate the watershed loadings for each Bay segment.

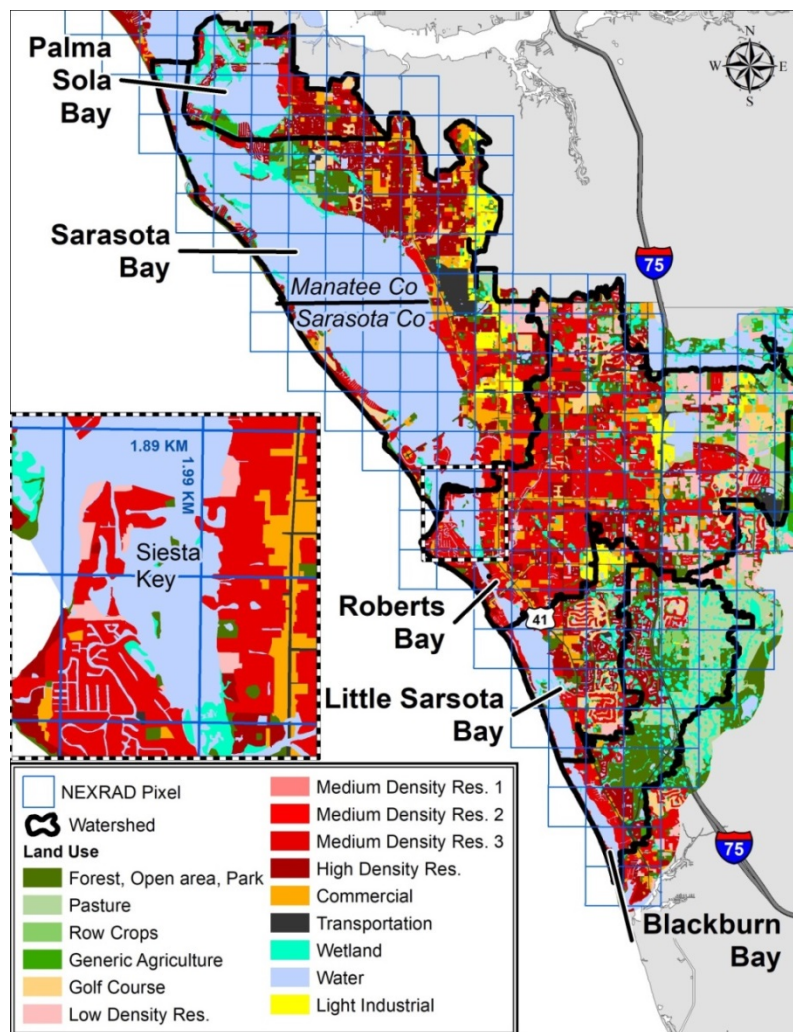


Figure 4. Spatial extent of project with overlays for NEXRAD rainfall, Landuse and watershed boundaries.

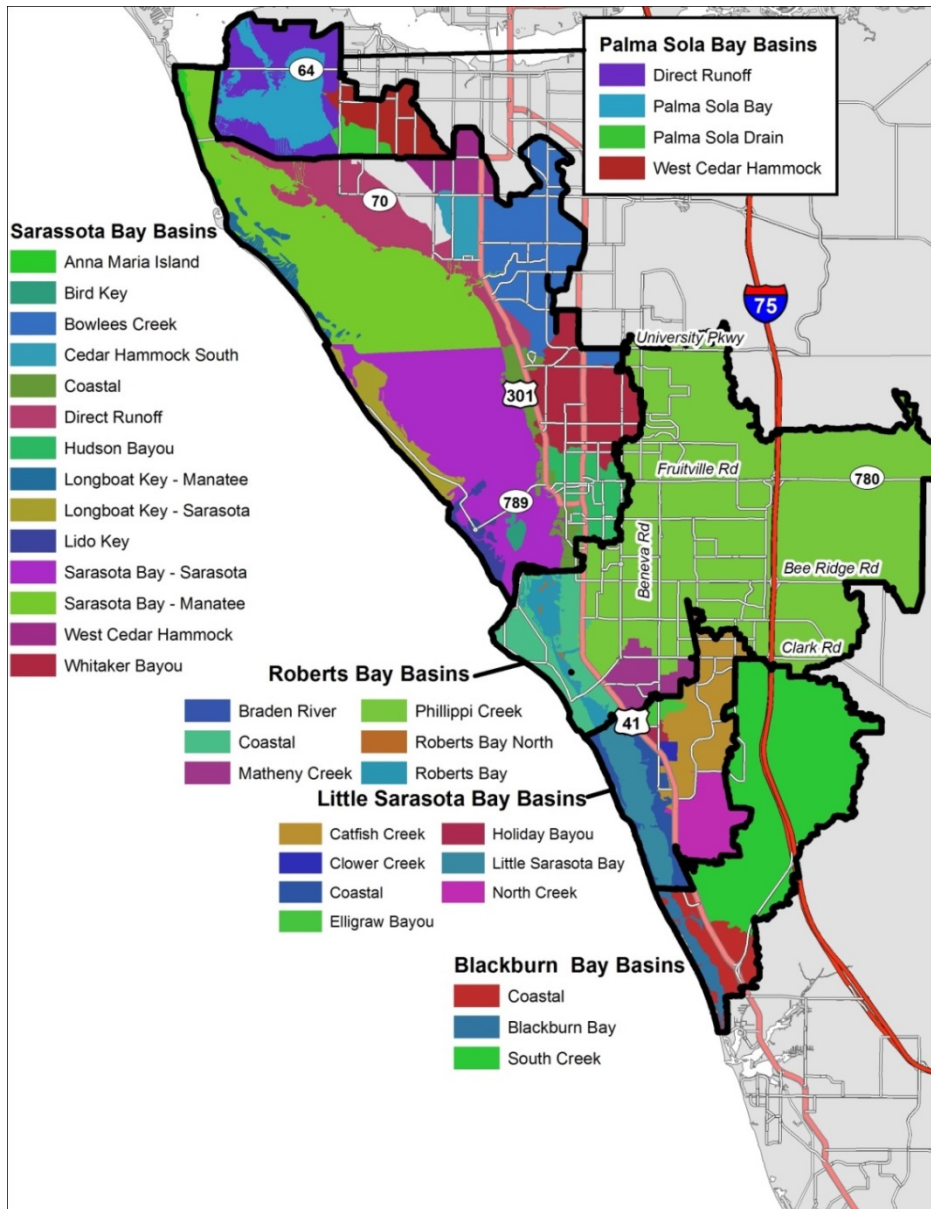


Figure 5. Basins used within the SIMPLE model.

2.3.2 Hydrologic Engine

The principal driver of pollutant loadings is the hydrologic load generated from rainfall. The SIMPLE model uses a hydrologic engine for estimating the runoff and baseflow hydrologic loads. NEXRAD rainfall data provided SWFWMD, along with evapotranspiration from the USGS are used to simulate the interaction between infiltration, evapotranspiration, and groundwater flow and leakage from the surficial aquifer to evaluate the water budget of a watershed on a daily time-step. A plot of the mean annual rainfall calculated from NEXRAD rainfall between 1995 and 2019 (Figure

6: Left) which portrays the average difference in annual rainfall within the SBEP watersheds and suggests that the inland areas receive, on average, higher annual total rainfall totals than the coastal segments.

The hydrologic engine calculates the daily runoff and baseflow hydrologic volumes for each intersection of rainfall, landuse, and soil type combination. An example of the layers used for this assessment is provided in the three panel plot of Figure 6. Changes in landuse over time are incorporated using date stamped changes in land use features. For example, an area once forested could be cleared for pasture, which could then be further developed into a medium density residential development and the model would track the loadings from those changes over time. An example land use layer (i.e., 2017) depicting the 16 major landuse categories is provided in Figure 6 (middle). The model relies on the hydrologic soil groups for various loading modules including runoff, baseflow and septic tanks and drainfields (Figure 6: Right). These layers are intersected such that each landuse within a pixel is assigned a rainfall estimate and the table of coefficients is used to generate a hydrologic loading estimate which is then summed by the geographic boundary. The hydrologic lookup table has a runoff and baseflow coefficient for each land use, and soil combination. The methodology for determining the direct runoff volumes follows a modified NRCS TR-55 methodology which incorporates a separate value for directly connected impervious areas. For baseflow, or surficial aquifer flow, the model uses the Forcheimer equation found in the Stormwater Management Model (Huber and Dickinson, 1992).

In Sarasota County, a catchment file was available to define the smallest geographic boundary which could be aggregated to basin and watershed areas; however, in Manatee County, only a larger "basin" file was available. These files were combined into a basin layer for analysis.

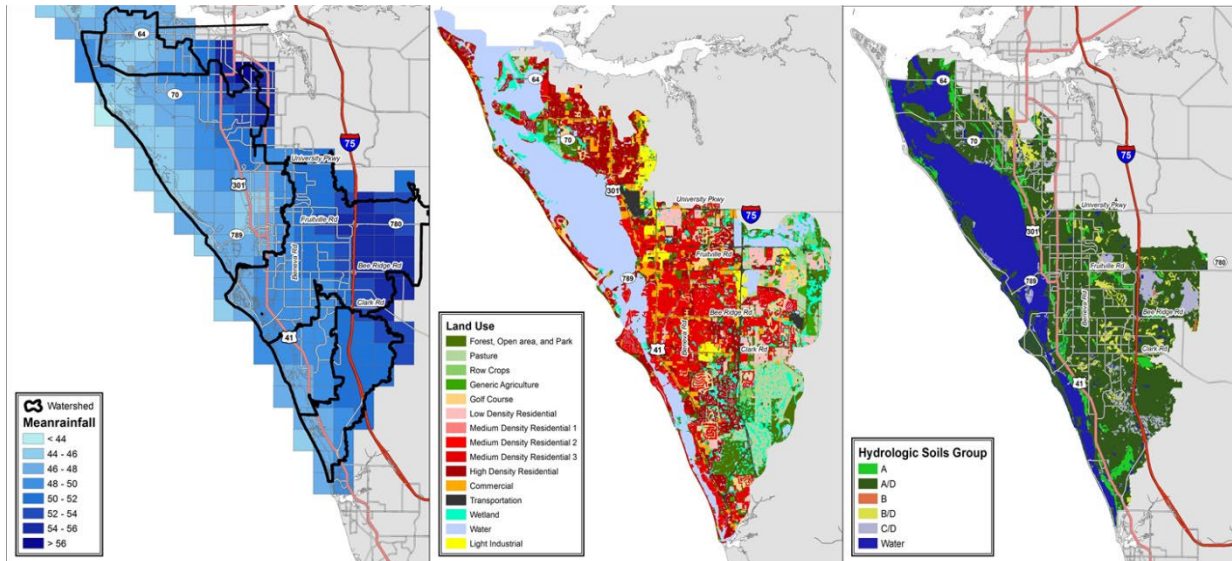


Figure 6. Mean annual rainfall derived from NEXRAD estimates 1995-2019 (left), 2017 District landuse (middle), and USGS soils layers used in the SIMPLE model.

2.3.3 Runoff/Baseflow Pollutant Loads

The methodology for calculating pollutant loading estimates mirrors that of the hydrologic loadings in that the table of coefficients is used to generate a pollutant load based on the hydrologic load, as well as the basin, soils, time-stamped land use, and structural best management practices (BMPs) feature classes. For this effort, all input layers were updated for the study area through 2019. The hydrologic loads from the hydrologic engine are combined with the appropriate landuse event mean concentrations (Table 2) and baseflow concentrations (Table 3) to calculate the runoff and baseflow pollutant loads. As described in the model report (Jones Edmunds and Associates, 2005) for runoff loads, EMC lookup tables are predominantly based on those used in Watershed Management Model (Camp Dresser & McKee, 1993) and were supplemented as needed with EMCs for pollutant runoff from wetlands taken from the Lemon Bay Model (ERD, 2003) (for BOD, TSS, TP, and TN).

Table 2 Event mean concentrations for direct runoff loading estimation.

Description	TP (mg/L)	DP (mg/L)	TKN (mg/L)	NO ₂ +NO ₃ (mg/L)	NH ₃ (mg/L)	TN (mg/L)
Forest, Open Area, and Parks	0.055	0.02	0.92	0.23	0.22	1.15
Pasture	0.616	0.23	2.79	0.68	0.67	3.47
Row Crops	0.593	0.22	2.12	0.53	0.51	2.65
Generic Agriculture	0.431	0.16	2.23	0.56	0.54	2.79
Golf Course	1.13	0.42	2.99	0.75	0.72	3.74
Low Density	0.191	0.08	1.29	0.32	0.31	1.61
Med. Density Residential	0.327	0.13	1.66	0.41	0.4	2.07
High Density Residential	0.52	0.25	1.86	0.46	0.45	2.32
Commercial	0.345	0.23	2.16	0.24	0.52	2.4
Transportation	0.22	0.15	1.47	0.17	0.35	1.64
Wetland	0.09	0.06	0.73	0.71	0.18	1.44
Water	0.17	0.12	0.5	0.48	0.12	0.98
Bay	0	0	0	0	0	0
Light Industrial	0.26	0.17	1.08	0.12	0.26	1.2

Table 3. Baseflow loading concentrations.

TP (mg/L)	DP (mg/L)	TKN (mg/L)	NO ₃₂ (mg/L)	NH ₃ (mg/L)	TN (mg/L)
0.2	0.05	0.7	0.05	0.1	0.75

A feature class that identifies BMPs by type and location was updated through 2019 (Figure 7). Each BMP type has a specific percent pollutant load removal efficiency (Table 4). These efficiencies assume the BMPs are maintained and operated as designed and are commonly used throughout around the state of Florida. The majority of the BMPs exist as stormwater detention ponds (either wet or dry) with wet detention having a much higher removal efficiency than dry detention. Retention BMPs have removal efficiencies of at least 90% across all parameters because they reduce the volume of water delivered; however, they are less common in the watersheds. Retention facilities that discharge to Outstanding Florida Waters have the highest removal efficiency of 99% across all parameters.

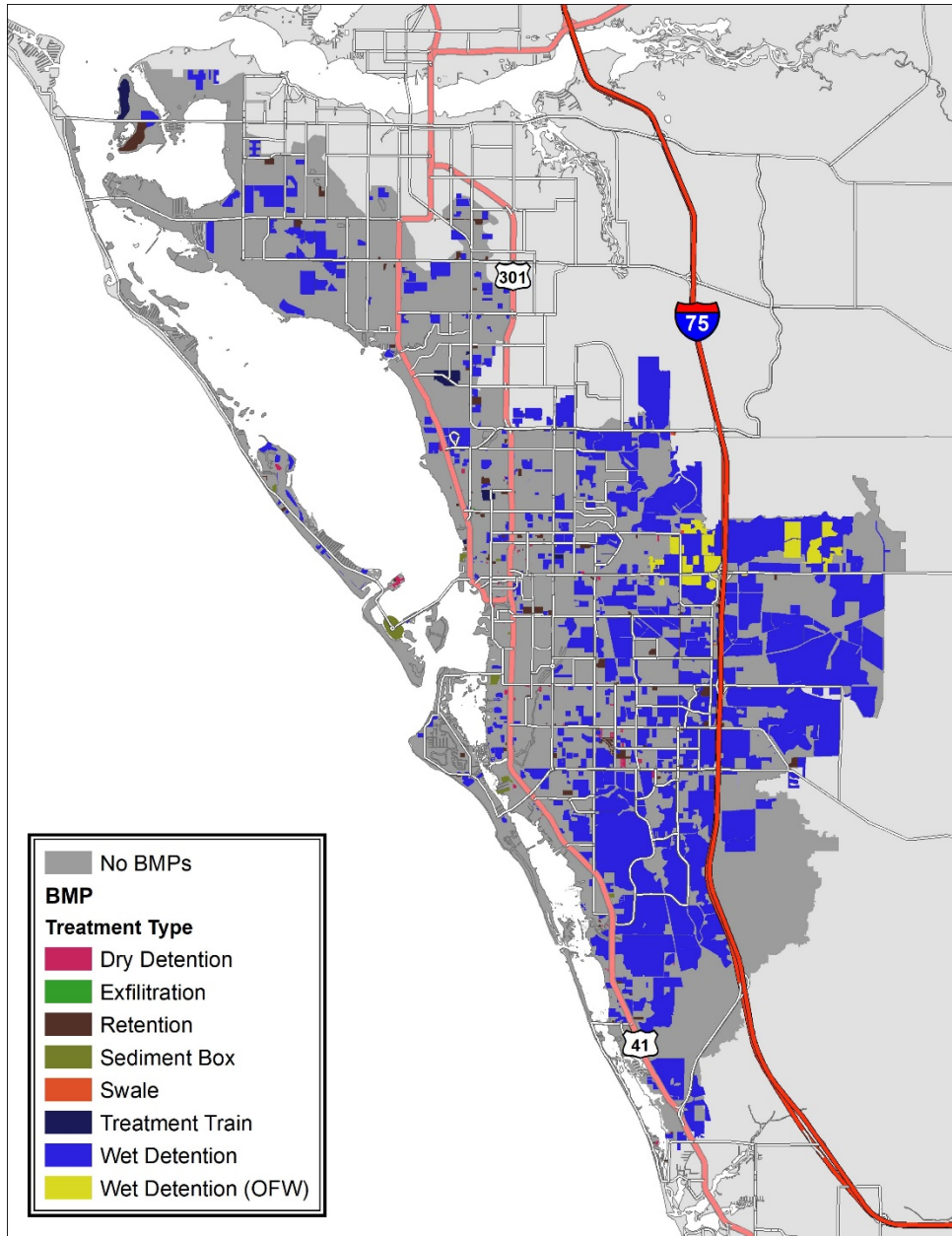


Figure 7. BMP layer for the study area.

Table 4. Pollutant removal efficiencies used within the SIMPLE model as percent reductions.

BMP Type	TP	DP	TKN	NO₂+NO₃	NH₃	TN
Retention OFW	99	99	99	99	99	99
Retention	90	90	90	90	90	90
Exfiltration	90	90	90	90	90	90
Wet Detention OFW	70	80	35	80	75	40
Wet Detention	60	70	30	70	70	35
Dry Detention	25	25	15	15	15	15
Baffle Box	30	30	10	10	10	10
Swale	35	35	25	25	25	25

For baseflow loads, the infiltrated volume (from the vadose zone) become part of the saturated groundwater module (Jones Edmunds and Associates, 2005). The Dupuit-Forcheimer equation was chosen because it has wide application in predicting surficial aquifer groundwater flow. This equation is one of the options used in the Stormwater Management Model (CDM, 1993) and is well documented.

2.3.4 Point Sources

Point source loads include any permitted discharges from wastewater treatment facilities (WTF) as well as any accidental spills reported to DEP. For accidental releases, the reported location and date of a release is used to attribute the load to the proper basin and month/year. The input data from monthly discharge monitoring reports provided to DEP were used to define point source inputs for this project. Where data are missing, either permitted values or long-term means were used. Each record includes a monthly time-stamp to track loads temporally. The point source module requires the basin, point source and spills feature classes, as well as lookup tables of flows and concentrations. Figure 8 presents the location of point sources within the study area as well as location of known septic tanks used for this project (next section).

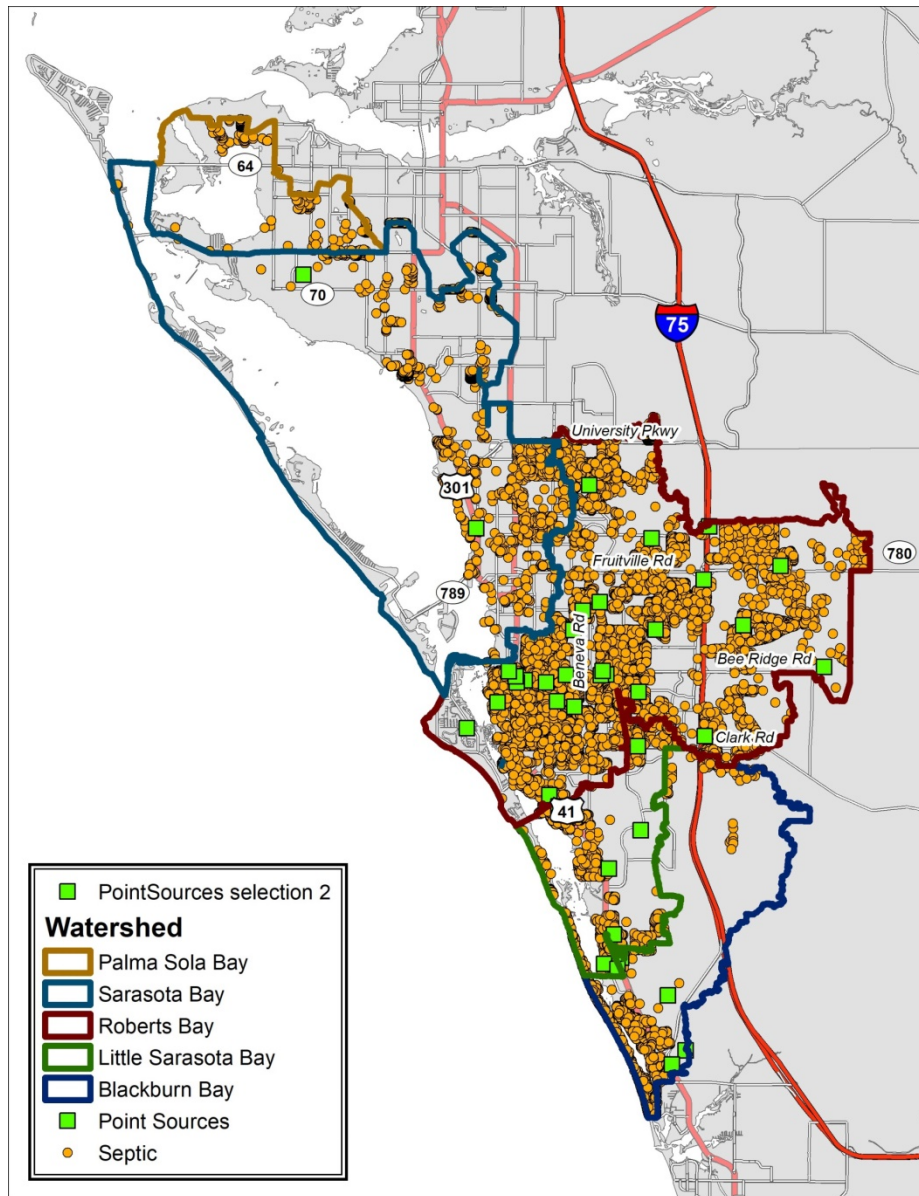


Figure 8. Map of the point sources and septic systems within the study area.

2.3.5 Septic Systems

During the initial development of SIMPLE, the septic module probably garnered the most attention as Sarasota County was beginning an aggressive septic-to-sewer replacement program in the Phillippi Creek basin to alleviate a bacteria impairment. The module begins with the location of the tanks. The Florida Department of Health manages the permitting of septic systems in Florida. The septic feature class was developed based on permit applications and the presumption that any parcel not connected to the wastewater system is presumed to have a septic system (Figure 8). As with other layers, the septic feature class records have a year built field that activates the calculation of a load from that location as well as a field to stop load

calculations in the case a parcel is converted to central sewer. With an aggressive septic to sewer conversion program, these time-stamp features are key to tracking this loading source.

The septic module assumes 100 gallons per person per day are produced and that 2.5 persons are served by each residential system. Other factors that affect the loads are the date the systems went in service, the distance from a waterbody and whether the flow path of the surficial groundwater may be intercepted by a BMP such as a wet detention pond.

2.3.6 Atmospheric Deposition

Atmospheric deposition, (i.e., wet+dry fall) represents the direct load to waterbodies. Only total nitrogen and total phosphorus are calculated through this module and loads are only generated for the open bay segments (i.e., direct deposition to the water surface). The nitrogen load is based on information from National Atmospheric Deposition Program site at the Verna Wellfield (FL41) located in eastern Sarasota County. Based on the relationships between nitrogen and phosphorus loads as determined for Tampa Bay (Poor 2002), atmospheric phosphorus loads are also estimated.

2.3.7 Reclaimed Water Irrigation

The reclaimed water irrigation module was developed to more accurately represent the distribution of reclaimed water nutrient loadings in a spatially-explicit manner. Since the inception of SIMPLE, additional information has become available regarding the location, quantity and quality of reclaimed water being applied throughout the County. The areas currently serviced by reclaimed water are provided in (Figure 9). The utility providers monitor the volume of reclaimed water delivered to customers through meter billing records. These records were used to provide better estimates of the volumes of reclaimed water distributed within each basin. This use of empirical data was a major upgrade to previous versions of the model which relied on published application rates and the assumption of advanced wastewater treatment effluent concentrations. The irrigation module requires the basin, irrigation feature classes and the reclaimed water lookup table. The module assumes an 85 percent attenuation rate to represent the retention due to such processes as plant uptake, soil absorption, and denitrification.

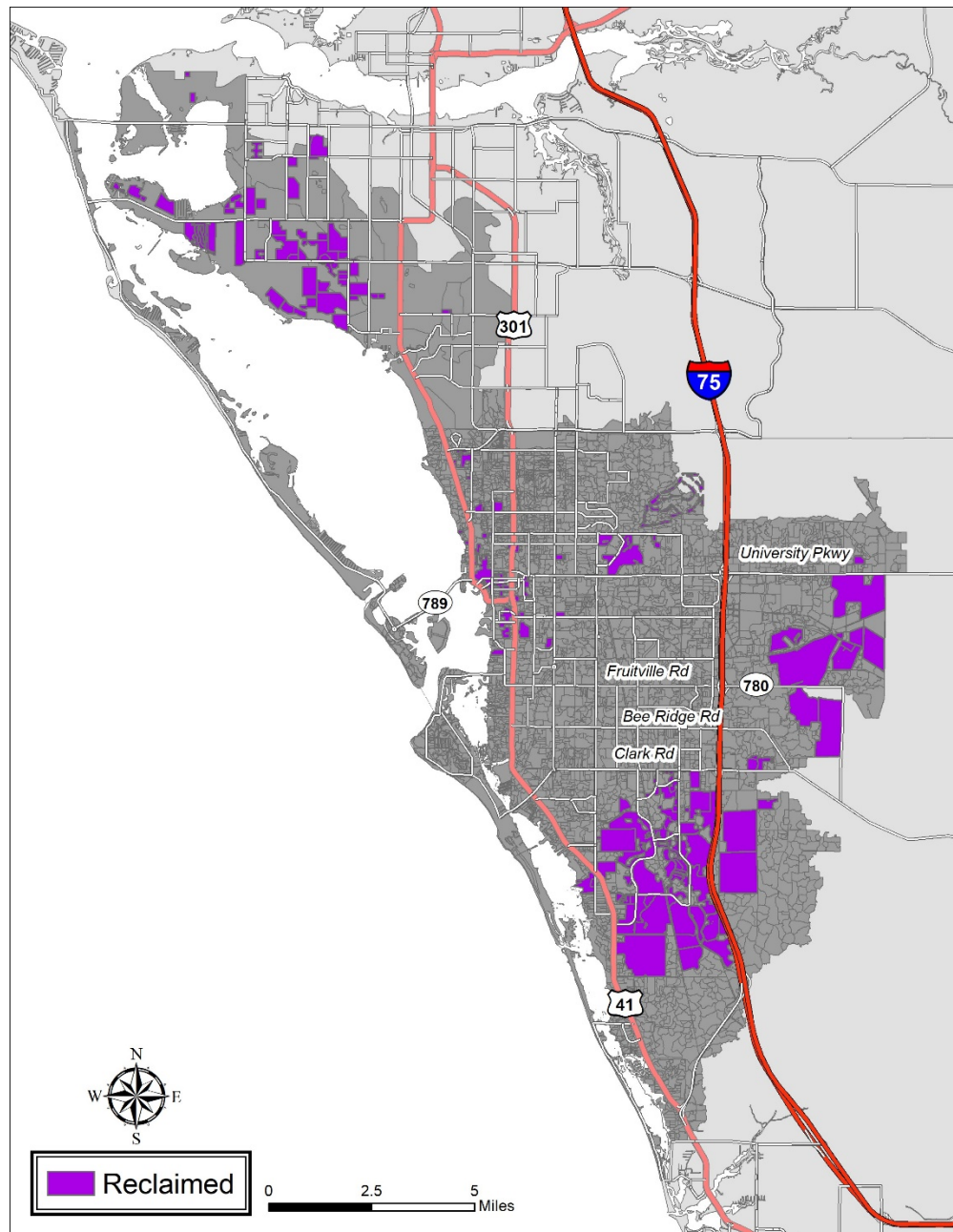


Figure 9. Current reclaimed water service area in Sarasota County.

3 Current Estuarine Indicator Status and Trends

The current regulatory status of the Bays was described in a recent letter from DEP to Mark Alderson, Director of the SBEP (Kevin O’ Donnell, pers. comm.) which is provided as Appendix A to this document. Currently, Palma Sola Bay is impaired for fecal coliform, Sarasota Bay (WBID 1968B) is impaired for bacteria, and Blackburn Bay is impaired for nutrients. These impairments were based on data collected through 2015.

DEP also provided a preliminary assessment of new listings that would be expected to result from an assessment that will occur based on data reported as of June 2020. The results indicate that all for southern WBIDs (1968 C, D, E, and F) are expected to be placed on the verified list for both nutrients and chlorophyll. This designation is typically followed by a requirement to develop a total maximum daily load (TMDL) for these waterbodies which includes a prescribed nutrient load reduction to meet the TMDL.

The following sections describe an independent investigation on the current status and recent history of water quality in the Bay segments of the SBEP with particular insights on how recent data collected since 2012 compare to the first 15 years of data routinely collected in these segments.

3.1 Water Quality Status and Trends

To evaluate the current WQ status and trends in Bay segment data, the DEP IWR Run 58 database was queried for the Bay segments. The database was found to contain an incomplete record of known water quality data for 2019 in Sarasota County and was also missing data collected in Manatee County after 2017. Therefore, we updated the Run 58 dataset with those found data through 2019 and conducted an independent assessment of the current status relative to their Bay segment specific standards. The following plots use color coding to highlight recent trends to a reference period of 1998-2012.

Updating the data on chlorophyll *a* confirmed DEP assessments that WBIDs 1968C, D, E, and F have exceeded the chlorophyll *a* standards in at least 3 of the last 5 years (Figure 10). Palma Sola Bay (WBID 1883) has not exceeded its respective chlorophyll *a* standard, while chlorophyll *a* concentrations in WBID 1968B exceeded in 2016 and 2018, indicating that this WBID may also be listed once the 2018 data are incorporated into the assessment. Total nitrogen AGM concentrations (Figure 11) appear to have been increasing over time in the southern bay segments but have remained largely below the NNC threshold values in all segments except in 2016 (and 2018 in Blackburn Bay which is already listed according to DEP). Similar to the result for chlorophyll *a*, no TN exceedances were observed in Palma Sola Bay throughout the time period.

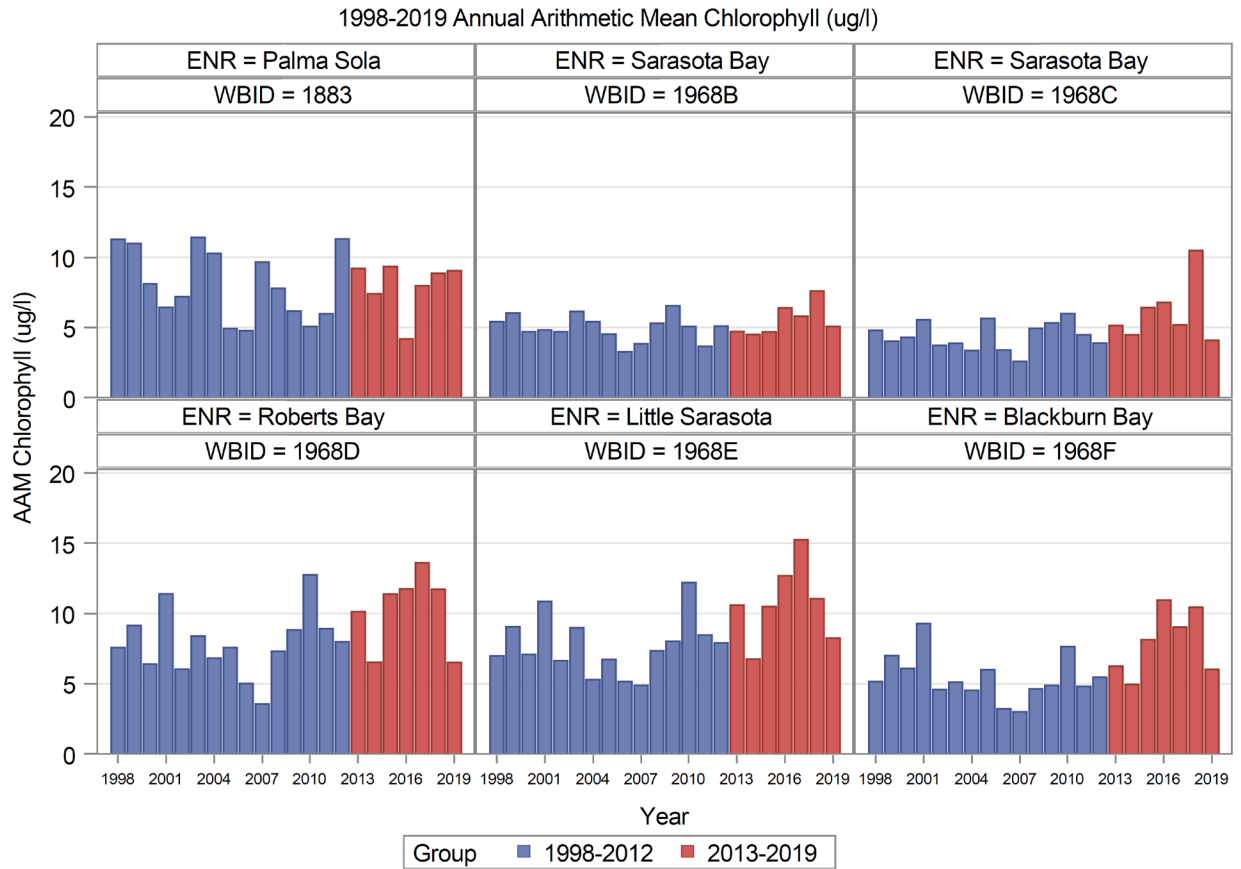


Figure 10. Annual arithmetic mean chlorophyll *a* concentrations in the Bay segments of the SBEP.

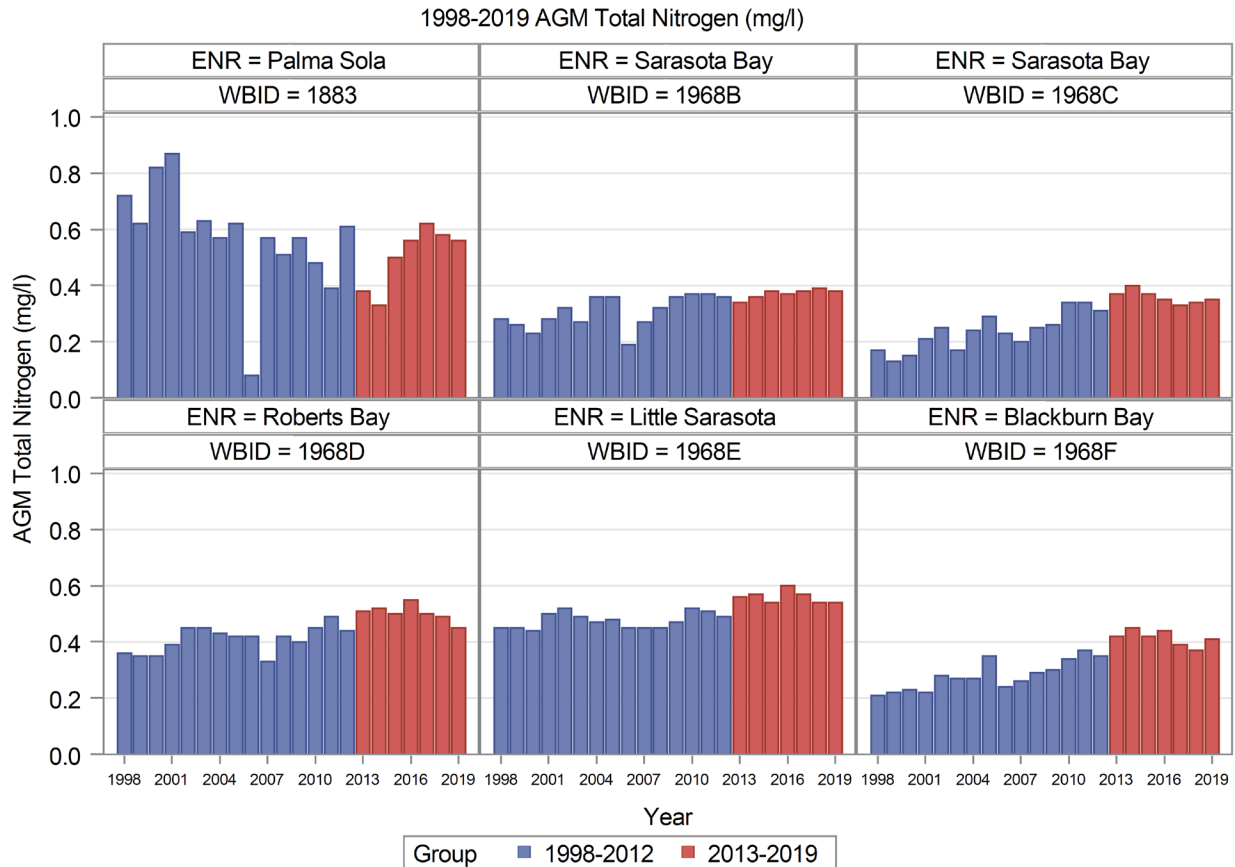


Figure 11. Annual geometric mean total nitrogen concentrations in the Bay segments of the SBEP.

It is important to note that, historically, AGM nutrient concentrations in the 1980's and 1990's were typically larger in magnitude than concentrations observed since 1998 as exemplified by the plot of TN AGMs for WBID 1968B in Sarasota Bay. This long term trend reflects improvements in wastewater practices that were implemented, for example, by the City of Sarasota, as well as upgrades to Manatee County's Southwest Regional Plant's wet weather disposal practices, and the retirement of percolation ponds from facilities such as Atlantic Utilities, on Philippi Creek (Figure 12). Full timeseries plots for all bay segments can be found in Appendix B.

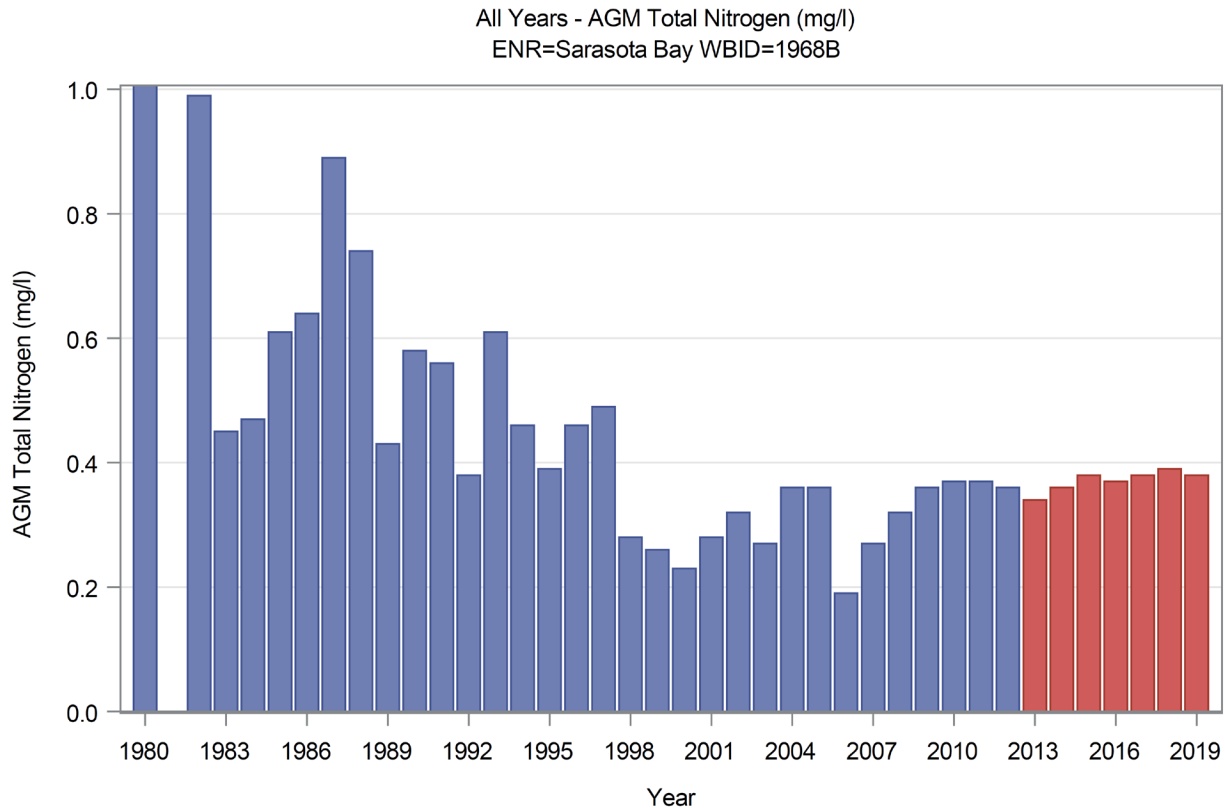


Figure 12. Annual geometric mean total nitrogen concentrations in Sarasota Bay WBID 1968B since 1980. The red bars represent the recent time period of 2013-2019.

3.2 Water Quality Time Series Trends

Times series trend analysis for water quality data collected in the Sarasota County is now routinely performed by the Sarasota County Water Atlas under contract for Sarasota County (hyperlink = [Trends](#)). These tests are performed using the Seasonal Kendall Tau test for trend (SKT) based on monthly data and an example result for total nitrogen for the period of record (1998-2019) in the bays is provided in Figure 13. The results for total nitrogen are striking in reporting consistently increasing trends throughout the estuarine segments. Trends conducted over the last 10 years (2010-2019) suggest largely stable trends over that time period as can be seen in the plots of AGMs in Figure 4 above, though the magnitude of the concentrations over the last 10 years is larger on average than the reference period for all segments other than Palma Sola Bay.

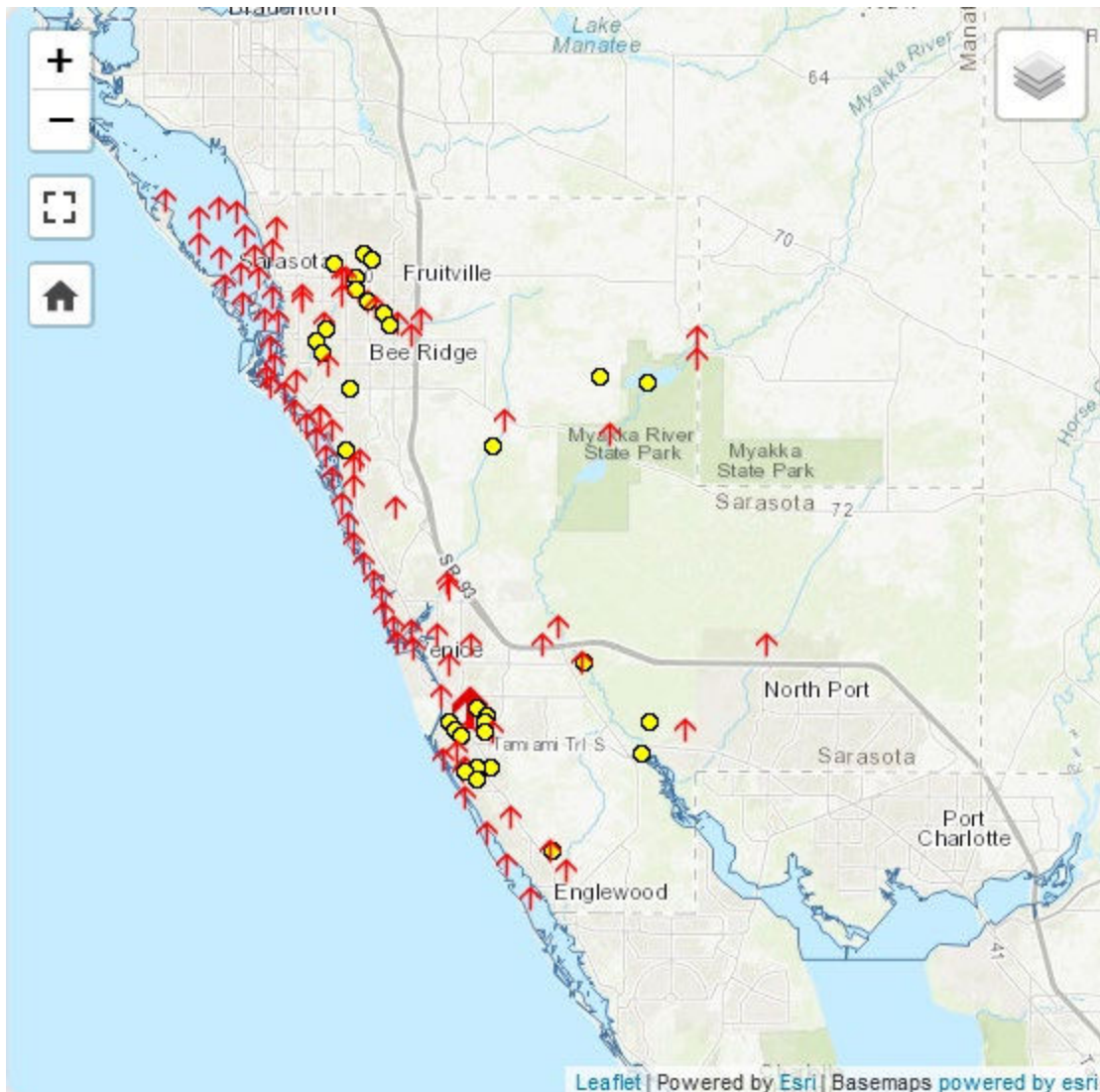


Figure 13. Water Atlas trend test results for total nitrogen for the period of record 1998-2019.

FDEP has recently implemented a statistical routine (Mann Kendall trend test: Helsel and Hirsh 2002) to evaluate trends in water quality data based on annual geometric means (AGM: the statistic used to evaluate nutrient impairments). The Mann Kendall trend test is a more simplistic variant of the Seasonal Kendall Tau trend test. The Mann Kendall trend test was used to evaluate the results of a FDEP type assessment of trends in SBEP Bay segments. Mann Kendall trend tests were conducted by WBID within ENR to approximate the assessment as it would be performed by FDEP. The results for total nitrogen support the results reported by the Water Atlas that total nitrogen concentrations in Sarasota County have increased over the period of record since 1998

(Table 5) but have remained stable over the most recent time period. Results conducted using only data over what would be considered the most recent assessment period (2012-2019) suggest an increasing trend in Sarasota Bay WBID 19698 B and no trend in total nitrogen for any other Bay segment, although values over the past 8 years are consistently higher than the prior 15 years (see Figure 11 above).

Table 5. Results of Mann Kendall test for trend on annual geometric mean total nitrogen (mg/l) concentrations by WBID.

ENR	WBID	Kendall Tau 1998-2019	Kendall Tau 2012-2019	P Value 1998-2019	P Value 2012-2019
Palma Sola	1883	-0.449	0.255	0.006	0.383
Sarasota Bay	1968B	0.574	0.694	0.001	0.021
Sarasota Bay	1968C	0.686	-0.148	<.0001	0.615
Roberts Bay	1968D	0.569	-0.182	<0.001	0.533
Little Sarasota	1968E	0.549	0.077	0.001	0.797
Blackburn Bay	1968F	0.737	-0.109	<.0001	0.708

Annual geometric mean chlorophyll concentrations were increasing over the period of record in the lower segments (WBIDs 1968C, 1968D, 1968E, and 1968F) while over the assessment period no trends were detected (Table 7).

Table 6. Results of Mann Kendall test for trend on annual geometric mean corrected chlorophyll concentrations (µg/l).

ENR	WBID	Kendall Tau 1998-2019	Kendall Tau 2012-2019	P Value 1998-2019	P Value 2012-2019
Palma Sola	1883	-0.360	-0.357	0.027	0.216
Sarasota Bay	1968B	0.034	0.182	0.832	0.533
Sarasota Bay	1968C	0.381	0.286	0.017	0.322
Roberts Bay	1968D	0.446	0.182	0.005	0.533
Little Sarasota	1968E	0.317	0.071	0.046	0.805
Blackburn Bay	1968F	0.358	0.357	0.024	0.216

Total phosphorus (TP) concentrations were not evaluated due to a known change in analytical method in 2008 which shifted the baseline concentrations of reported TP in subsequent years.

Results from this independent evaluation of water quality status and trends suggest:

- The independent analysis agrees with FDEP assessment that WBIDs 1968C, D, E, and F have exceeded the established chlorophyll *a* standards more than once in a three year period which violates current standards.
- 1968B might also be considered impaired for chlorophyll *a* once the Manatee County portion of 1968B is updated to include data from 2018.
- TN concentrations have not exceeded their respective water quality standards more than once in any 3-year period except in Blackburn Bay (WBID 1968F) though they are consistently higher in the southern bay segments since 2013 relative to the first 15 years of data collection.
- Timeseries trends for TN have been increasing over the 1998-2019 period of record for segments over than Palma Sola Bay which has decreased over the period of record.
- Chlorophyll *a* concentrations have significantly decreased in Palma Sola Bay and significantly increased in the southern Bays (WBIDs 1968C,D,E, and F)
- When timeseries analysis was conducted over the last 7.5 year "Assessment Period" (i.e. 2012-2019), most results suggested that water quality was stable with the exception of increasing TN in WBID 1968B

3.3 Seagrass Status and Trends

Seagrass acreage has been used as a keystone indicator of estuarine health since the inception of the SBEP (SBEP 1992). Table 8 presents the seagrass acreage estimates based on photo-interpreted aerial imagery surveys conducted by the Southwest Florida Water Management District between 1988 and 2018. Seagrass acreage has generally been stable or increasing over the period of record with Sarasota Bay dominating in acreage and average rate of increase (ca. 5%) over time. Seagrass acreages expanded substantially in Sarasota Bay and Little Sarasota Bay since 2006. In the year 2016, total seagrass coverage was 37% higher than in 2006. However, recent surveys have shown declines in seagrass acreage with baywide seagrass coverage in 2018 5% lower than in the prior mapping event. For the combined systems of Little Sarasota and Blackburn Bays, seagrass coverage declined by 33% between 2014 and 2018, a loss of 446 acres and are now below their observed 1988 acreage .

At the time this document was produced, the 2020 seagrass acreage estimates remain provisional but suggest additional losses, particularly in Sarasota Bay. Combined, these recent events suggest that the seagrass acreage targets for the SBEP bay segments should be revisited.

Table 7. SBEP seagrass aerial coverage estimates and targets (acres).

Year	Palma Sola	Sarasota	Roberts	Little Sarasota	Blackburn	Total
1988	1,111	6,323	334	533	411	8,712
1994	1,089	6,910	347	592	411	9,349
1999	1,025	6,750	332	770	374	9,251
2001	1,046	6,862	273	699	301	9,181
2004	1,002	6,646	371	763	468	9,250
2006	1,028	7,436	325	640	425	9,854
2008	1,164	9,997	302	837	346	12,646
2010	1,177	9,917	329	891	382	12,696
2012	1,185	9,797	306	902	399	12,589
2014	1,238	10,377	325	929	422	13,291
2016	1,258	10,659	361	806	390	13,473
2018	1,278	10,326	349	610	295	12,858

3.4 *Karenia brevis* Status and Trends

As described above, chlorophyll *a* concentrations have exceeded their respective criterion values in recent years in the southern Bay segments of the SBEP. However, this evaluation is complicated by the fact that the estuarine waters of the SBEP have been impacted by recent harmful algal bloom events. The most recent harmful algal bloom was a protracted event occurring in 2018 but Mote Marine Laboratory *K. Brevis* data suggested several other occasions when *K. brevis* may have been above background conditions in some parts of the Bay segments (Figure 14) including 2006, late 2012, early 2013, late 2015, early 2016. Some data gaps exist in this timeseries including fall of 2015, late spring through summer of 2016, and August and September of 2019. Despite these gaps, we wanted to investigate the potential for episodic *K. brevis* blooms to affect the chlorophyll concentration estimates and therefore exploratory data analysis was conducted to assess the potential for *K. brevis* blooms to effect the observed chlorophyll *a* concentration estimates used in the regulatory evaluation for the Bay segments.

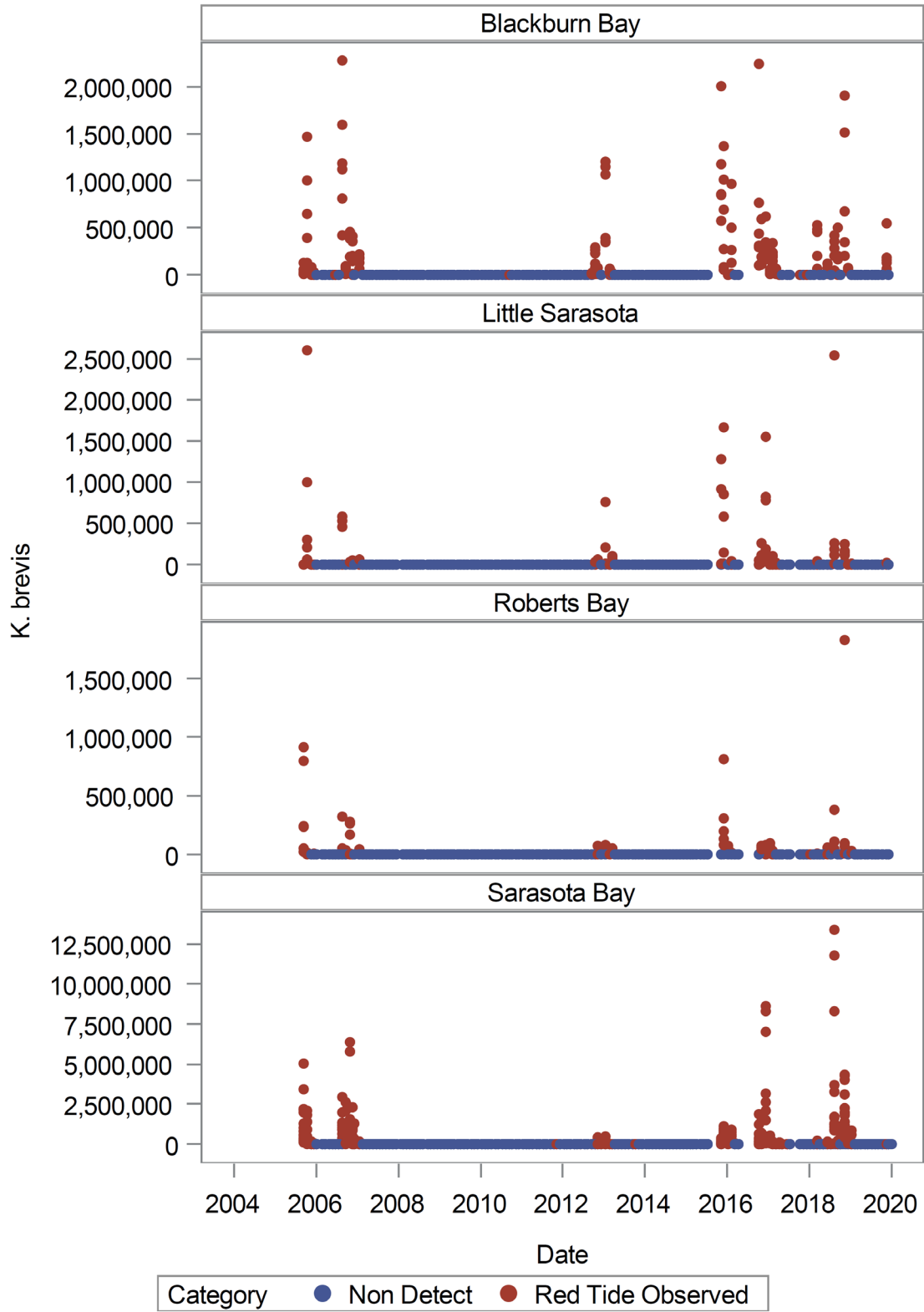


Figure 14. Red tide (*Karenia brevis*) observations in the SBEP Bay Segments.

A count of 250,000 was used to define an event and data were grouped according to whether or not the water quality sample collected was associated with an "event". Water quality parameters including chlorophyll a, nutrient concentrations and light attenuation parameters were then compared for data with and without events. For example, there were 228 observations when *K. brevis* counts were 250,000 or higher which is considered a "bloom" condition. The mean of the distribution of chlorophyll values was 11.5 µg/l in the bloom category while the mean was 6.5 µg/l in the group of observations (n=4823) with counts less than bloom condition. The distribution of values is highly skewed and the number of observations between groups highly unbalanced and therefore a permutation test was used to test for significant difference between these groups. The difference was highly statistically significant ($p < 0.001$).

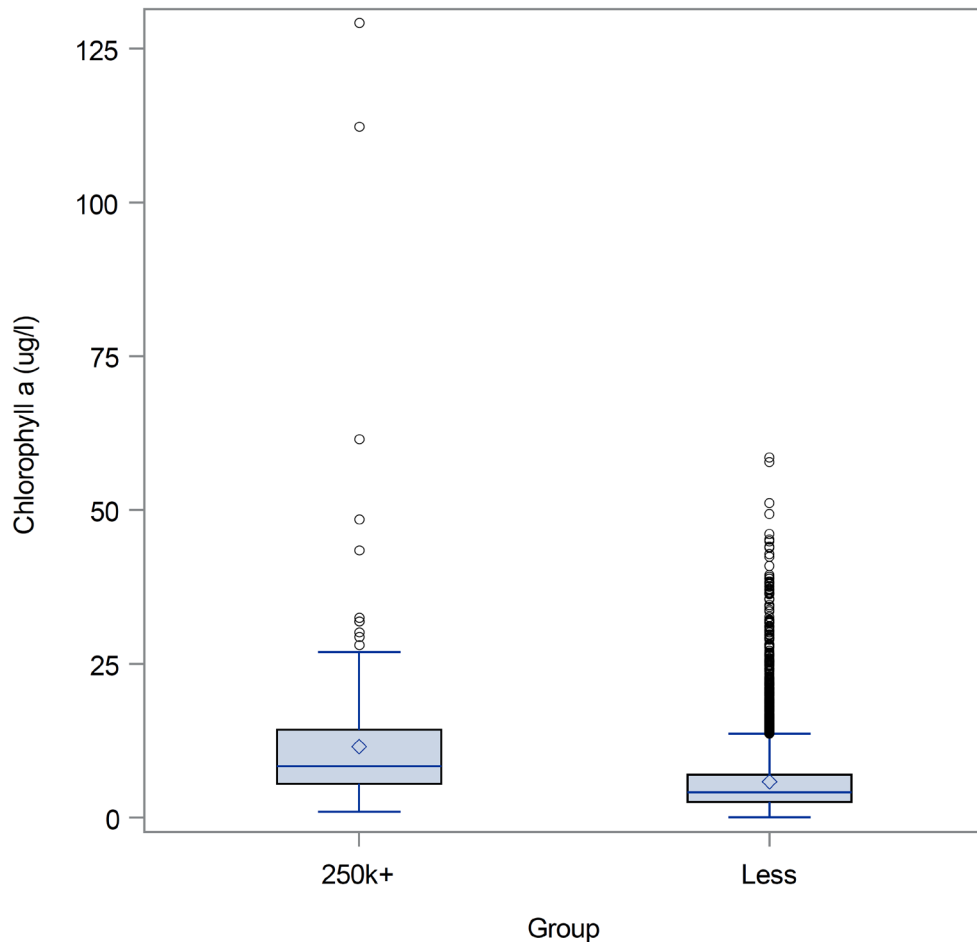


Figure 15. Distribution of chlorophyll a (µg/l) when *K. brevis* counts were 250,000+ compared to when *K. brevis* counts were less than 250,000.

Timeseries plots of chlorophyll a concentrations grouped by whether or not they exceeded two cutpoints (250,000: Left and 50,000: right) are provided in Figure 16.

These results also suggest some association between higher chlorophyll concentrations and *K. brevis* bloom conditions; more prominently in the more saline Blackburn and Sarasota Bays than in Roberts and Little Sarasota Bay. To quantify the potential effects of *K. brevis* on chlorophyll concentrations, regressions were developed using chlorophyll as the dependent variable and total nitrogen and salinity as the independent terms. The regression relationship was developed using data when *K. brevis* was at non-detect level which was defined as counts less than 1001 (multiple detection levels were reported including 1000, 500, and 0)). The regressions were then used to predict chlorophyll concentrations for data when *K. brevis* was above 1000 and the residuals used to evaluate the potential effects of *K. brevis* on the nitrogen chlorophyll relationship. The residuals were biased (positively) suggesting that the expected relationship between TN salinity and chlorophyll concentrations in the absence of red tide under-predicts the observed chlorophyll concentrations in the presence of *K. brevis* (Figure 17).

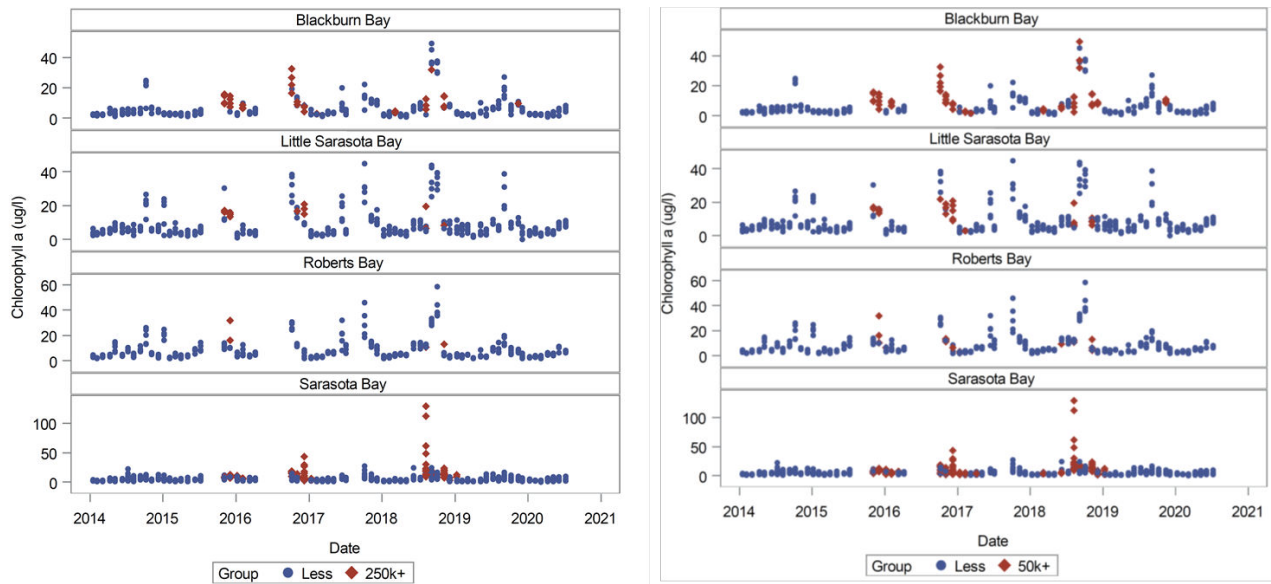


Figure 16. Timeseries distribution of chlorophyll a samples with data grouped by *K. brevis* count cutpoints (250,000: Left) and 50,000: right).

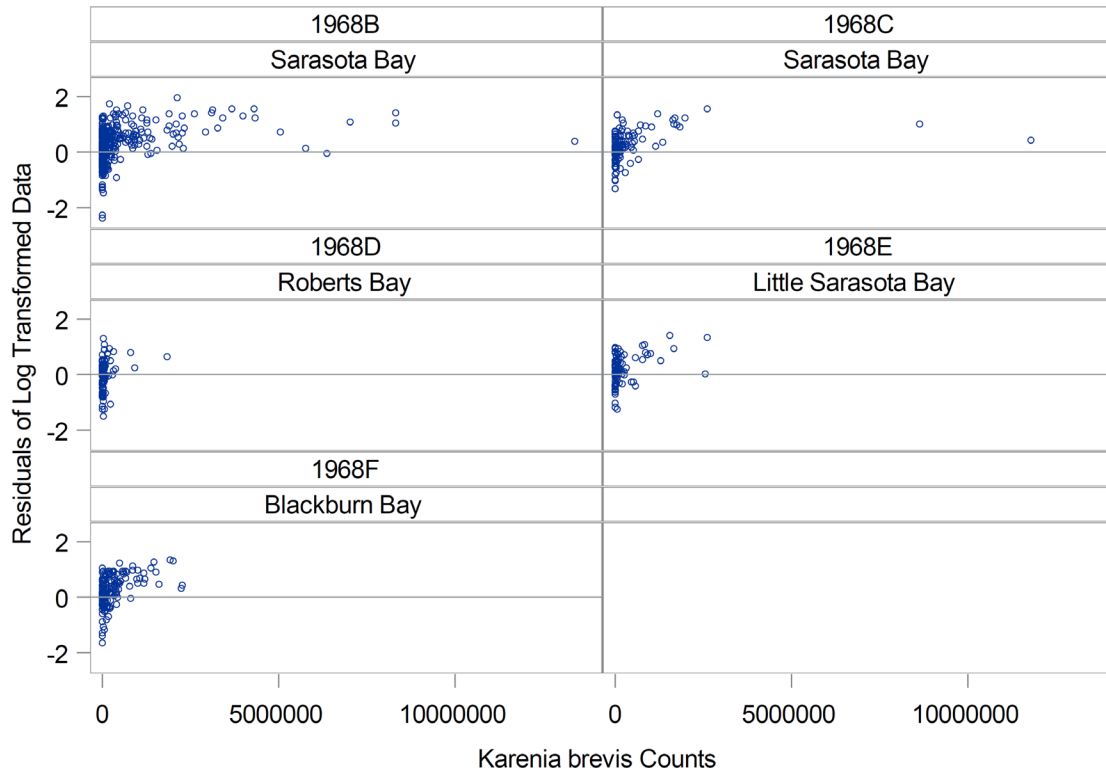


Figure 17. Residual plots against observed *Karenia brevis* counts for WBID specific regressions.

The degree to which *K. brevis* effects the annual geometric average chlorophyll concentrations used in regulatory compliance is currently unknown. There are several methods that could be used in an attempt to estimate what the annual geometric average chlorophyll concentration may have been in the absence of *K. brevis* but each method should be more carefully thought out to avoid biasing the results. For example, simply deleting observations where *K. brevis* was present may lead to biased seasonal distributions of the data and since chlorophyll concentrations are highly seasonal, this could bias the annual geometric average. Similarly, we don't know what the *K. brevis* concentrations were for missing samples in 2016 when the data gap coincides with an apparent wide spread *K. brevis* bloom. It should also be noted that Little Sarasota Bay and Roberts Bay, both of which have exceeded their chlorophyll concentrations in several recent years, did not seem to have the same frequency of bloom conditions as the higher salinity waters with more direct exchange with the Gulf of Mexico (Sarasota bay and Blackburn Bay). The effect of red tide blooms on chlorophyll concentrations (as well as other indicators of estuarine health), and the implications of this on DEP regulatory assessments warrant further research and should be more carefully considered as part of future water quality analysis and interactions with the SBEP Water Quality Consortium.

3.5 Macroalgae

The presence and quantity of macroalgae is recorded as ancillary information associated with two routine sampling programs in the Bay segments of the SBEP. The Sarasota County seagrass monitoring program records the presence and quantity of both drift and attached (rooted) macroalgae as part of its annual surveys which include both fixed and probabilistically selected (“Random”) sites. The quantities are recorded as ordinal values on a scale of 1 to 4 with 1 representing 1-25% cover, 2=26-50% cover, etc., Occasionally a ordinal category of 5 is used to represent the thickness of the algal biomass. The FIM program also records the presence and quantity of drift algae in their fish sampling and the presence as well as percent cover of rooted macroalgae as part of their characterization of bottom vegetation type for gear types where the bottom is visible. Both of these datasets were evaluated to characterize changes in macroalgal frequency of occurrence and abundance over time.

The County seagrass sampling frequency for each of the SBEP Bay segments is provided in Table 9 with sampling characterized by whether it occurred between November and March (“Winter”) or during other months of the year. The sampling frequency has changed over time as the program has been refined and the seasonal timing of those samples varies throughout the period of record. In some years, sampling was conducted in both Winter and other months of the year (e.g., 2010-2012) while in other years (2013-2017) sampling was conducted in only one of the defined seasons but not always the same season.

When evaluating the data grouped annually irrespective of what season the sample was collected, the overall frequency of occurrence of macroalgal observations appears to be increasing in some segments, particularly in Blackburn Bay in both the fixed and random surveys (Figure 18).

Table 8. Sampling frequency for Sarasota County seagrass survey between 2006 and 2020. Season is defined as Winter (November through March) and "Other" as the remaining months.

ENR	Season	Year														
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Blackburn Bay	Other	0	30	47	30	21	20	20	20	0	0	20	0	0	11	0
	Winter	41	48	0	4	21	20	20	0	20	20	0	20	1	20	20
Little Sarasota Bay	Other	0	41	37	16	24	20	20	3	0	0	20	0	0	8	0
	Winter	7	0	73	14	36	20	20	17	20	20	0	20	11	20	20
Roberts Bay	Other	0	28	37	15	25	20	20	0	0	0	20	0	0	5	0
	Winter	19	0	36	26	35	20	20	20	20	20	0	20	5	20	20
Sarasota Bay	Other	0	109	150	66	93	67	68	0	0	0	23	0	0	21	0
	Winter	11	0	68	123	77	64	67	68	67	66	37	61	33	58	58

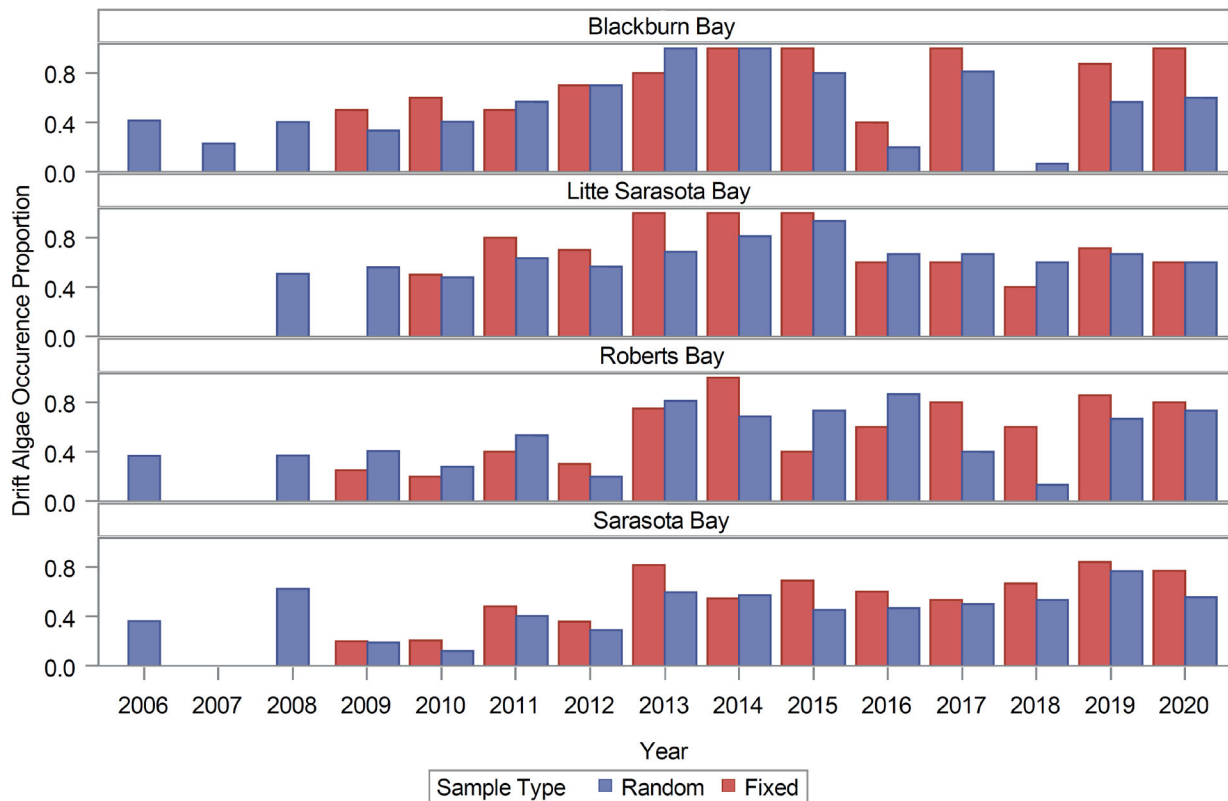


Figure 18. Proportion of samples with observed drift macroalgae for fixed and random samples by Bay segment.

The Cochran Armitage test (Zar 1994) was used to test for a linear trend over time among the binary outcome (presence –absence) and all Bay segments resulted in highly statistically significant result suggesting an increasing trend in the presence of drift algae over time. However, given the differences in timing of the sampling, the effect of seasonality on this relationship was investigated. The data between 2010 and 2012 were used since the sampling frequency among seasons was relatively consistent in those years. In these years, Winter samples had a higher frequency of occurrence (52%) than samples taken in other months (22%) (Table 10). The difference is highly statistically significant ($\chi^2=78.73$; $p<0.001$) suggesting seasonality is an important factor to consider when evaluating trends in drift macroalgae over time. Therefore, changes in sampling frequency over time, as well as the timing of those samples within a year, complicate analysis of trends over time.

The FIM program data was evaluated as an additional line of evidence to investigate both seasonality and trends over time in macroalgal occurrence.

Table 9. Percent occurrence of drift macroalgae by season using data between 2010-2012 (all segments combined).

Drift Algae	Season		
	Other	Winter	Total
Absent	324 77.51	201 47.86	525
Present	94 22.49	219 52.14	313
Total	418	420	838

The FIM program has been routinely sampling the Bay segments since 2009. This evaluation uses data collected by FIM between 2009 and 2018. The nonparametric Cochran Armitage test for trend was used to evaluate potential trends in the frequency of occurrence of drift algae bycatch in the FIM data using the "AM" code signifying mixed algae collected as part of the sample. The results of the trend test suggest increasing frequency of occurrence in areas sampled by small offshore seines (water depths ≤ 1.5 meters) in Palma Sola Bay Sarasota Bay and Roberts Bay Table 11. Analysis of other gear types (large seine gear and trawls) suggested only in Sarasota Bay was there and increasing frequency of algal bycatch over time between 2009 and 2018. The quantity of bycatch also increased over time in Sarasota Bay (all gear types) and Roberts Bay (small and large seine gears: Table 11).

Table 10. Results of Cochran Armitage test for trend by FIM gear type and Bay segment.

Gear	Zone	P Value
Small Seine	Palma Sola	0.0149*
	Sarasota	<0.001***
	Roberts	<0.001***
	Little Sarasota	0.3164
	Blackburn	0.1380
Large Seine	Palma Sola	0.4223
	Sarasota	0.0259*
	Roberts	0.1781
	Little Sarasota	0.4268
	Blackburn	0.1877
Trawl	Palma Sola	0.2736
	Sarasota	<0.001***
	Roberts	0.2118
	Little Sarasota	0.1129
	Blackburn	0.1728

Table 11. Mann Kendall trend test for the quantity of “AM” bycatch by FIM gear and Bay segment.

Gear	Zone	Kendall Tau B	P Value
Small Seine	Palma Sola	0.11770	0.2036
	Sarasota	0.16914	0.0095**
	Roberts	0.41265	<.0001***
	Little Sarasota	0.10013	0.2595
	Blackburn	-0.01097	0.9051
Large Seine	Palma Sola	0.02862	0.7716
	Sarasota	0.19836	0.0095**
	Roberts	0.20383	0.0302*
	Little Sarasota	0.01759	0.8547
	Blackburn	-0.10443	0.2746
Trawl	Palma Sola	0.11005	0.2962
	Sarasota	0.23175	0.0013**
	Roberts	0.16705	0.0984
	Little Sarasota	0.11430	0.2307
	Blackburn	0.11044	0.2642

Seasonality was evident in the frequency of occurrence of the “AM” bycatch with a highly statistically significant ($p < 0.001$) increased observed percentage of samples in Winter months compared to samples collected in other months (Table 13).

Table 12. Results of Chi Square test for seasonality in the frequency of occurrence of bycatch coded as "AM" in FIM samples across gear types and zones.

Algal Presence # and column percent)	Season		
	Other	Winter	Total
Absent	3140 82.41	1300 74.71	4440
Present	670 17.59	440 25.29	1110
Total	3810	1740	5550

Chi Square test: Chisq = 44.28 , DF=1, P <0.001

The status and trends of estuarine indicators described above provide context to detail the evaluation of the results of pollutant loading model analysis described in the next section.

4 Pollutant Loading Model Assessment

In this section, pollutant loads are presented at various spatial and temporal resolutions. First, an overview of the pollutant loading estimates is provided for the watersheds of the SBEP across the full period of record (1995-2019) to describe source apportionment and general comparisons of the loads between watersheds. This is followed by a breakdown of the loading sources for each watershed. Intra annual statistics are then presented to evaluate the relative contribution of sources within a year. Next, the loads are partitioned into 5 year blocks and the percent contributions of the total load for each source are provided. Finally, a comparison of inorganic versus organic nutrient loads is provided to evaluate differences in these constituents among sources and over time.

Total nitrogen results are used to illustrate the summary of the pollutant loading model because the Bay segments are nitrogen limited and therefore nitrogen is of most interest in stormwater management to limit production in these estuarine systems. However, the form of nitrogen is important for biological processes and the summary of organic versus inorganic loading is provided to elucidate potential sources that may be more influential in effecting the observed recent adverse trends in water quality and seagrass acreage. Other pollutant model output includes total phosphorus, all forms of

nitrogen, as well as biological and chemical oxygen demand, fecal coliform, and total suspended solids are provided in Appendix C.

To provide a general overview of the distribution of loads throughout the SBEP, the percent distribution of the hydrologic and TN loads over the full time period (1995-2019) are presented in (Figure 19). Sarasota Bay has the highest hydrologic load of the bay segments due to the extent of the open bay segment which capture direct deposition of rainfall. The highest TN loads occur in Roberts Bay which delivers ca. 44% of the total TN load to the SBEP estuaries while the Sarasota Bay watershed delivers ca. 30% of the total TN load to the watershed.

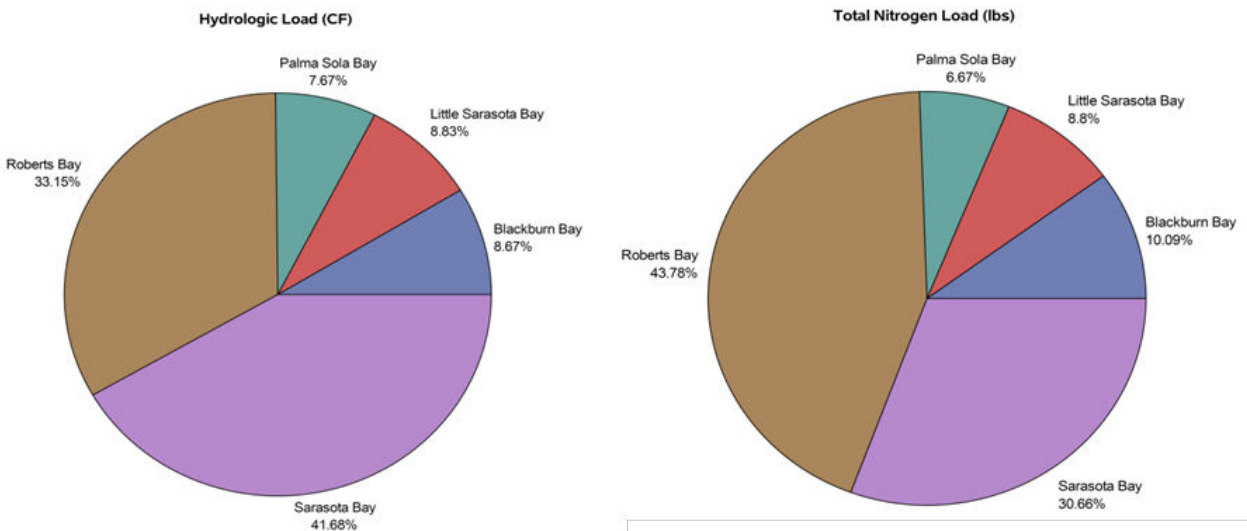


Figure 19. Pie charts showing percent contribution to the total nitrogen load over the 1995 – 2019 model period for each watershed (top) and source across watersheds (bottom).

4.1 Total Nutrient Loads Over Time

Timeseries plots of the TN load by segment are provided in Figure 20. The segments displayed a consistent temporal pattern over time suggesting that the variation in loads is principally a function of the rainfall and the subsequent hydrologic load generated in

the watershed. Other pollutant loads, including TP, displayed similar consistent trends over time (see Appendix C) lending credence for focusing on TN loads in this chapter to describe variations in pollutant loads over time and by source and for the remainder of the pollutant loading information to be described in the Appendix.

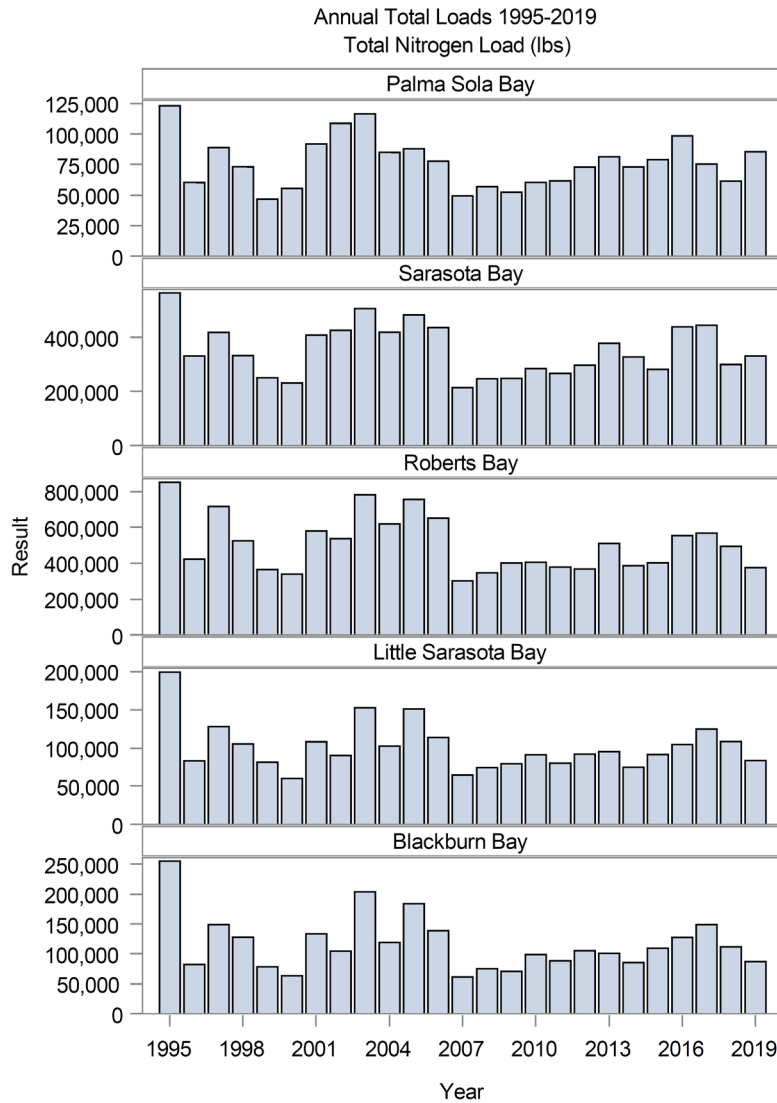


Figure 20. Segment specific annual total nitrogen loads.

4.2 Total Nutrient Loads by Source

Runoff accounted for between 61% and 74% of the total TN load while baseflow contributed between 15% and 20% (Table 14). Septics contributed a larger percentage to the total load in Roberts and Little Sarasota Bays than other bay segments.

Atmospheric deposition contributed the highest percentage to the total load in Sarasota Bay and Palma Sola which have the largest open water areas. Reclaimed loads were less than 5% of the total load to all segments over the full period of record. However, the relative contribution of these sources did change over time as described in section 4.3 and some nutrient sources may be more important drivers of estuarine responses than others as described in section 4.4.

Table 13. Percent of the total nitrogen loads for each SBEP bay segment by source.

Total Nitrogen Segment	Source (Percent of Segment Total)						
	AD	Baseflow	Point	Reclaimed	Runoff	Septic	Spills
Palma Sola Bay	8	17	.	5	67	2	.
Sarasota Bay	12	15	5	4	62	2	0
Roberts Bay	<1	19	5	1	61	12	1
Little Sarasota Bay	3	20	0	4	64	8	0
Blackburn Bay	1	19	0	2	74	3	0

4.3 Total Nutrient Loads by Source over Time

To illustrate the changes in relative source load contribution over time, the full model period of record was divided into 5 year blocks and percentages of the total load calculated (Table 15). The major contributing TN loading sources (baseflow and runoff) were remarkably consistent over time, generally comprising at least 65% of the total load for all segments in any 5 year time period. However, Point Source load contributions have declined over time in Sarasota and Robert’s Bays. Differences in the relative contribution of reclaimed and septic loads were also observed over time with a decrease percent contribution from septics in the Roberts Bay watershed as a function of septic to sewer conversion implementation, and an increase in Reclaimed loads in all but Roberts Bay as the volume of reclaimed water distributed to customers in these watersheds increased, particularly since 2008. Reclaimed and septic nitrogen loads are almost entirely inorganic and the relative contribution of organic versus inorganic nitrogen loads is explored in more detail in section 4.4.

Table 14. Percent distribution for total nitrogen loads by source for 5 year blocks within the model period of record.

Total Nitrogen %		Source						
Segment	Period	AD	Baseflow	Point	Reclaimed	Runoff	Septic	Spills
Palma Sola Bay	1995-1999	8	19	0	1	69	2	0
	2000-2004	8	16	0	2	72	2	0
	2005-2009	10	19	0	4	64	3	0
	2010-2014	8	17	0	9	64	2	0
	2015-2019	7	16	0	9	65	2	0
Sarasota Bay	1995-1999	12	16	9	1	59	2	0
	2000-2004	12	14	6	2	65	2	0
	2005-2009	14	15	6	2	60	2	0
	2010-2014	13	16	3	6	61	2	0
	2015-2019	11	15	1	8	62	2	0
Roberts Bay	1995-1999	0	19	5	1	61	14	.
	2000-2004	0	17	6	1	62	15	0
	2005-2009	0	19	6	1	60	13	0
	2010-2014	0	22	4	2	62	10	0
	2015-2019	0	21	3	2	62	8	3
Little Sarasota Bay	1995-1999	3	20	0	2	68	7	0
	2000-2004	3	20	0	3	66	8	0
	2005-2009	4	20	0	4	64	8	0
	2010-2014	4	22	0	6	59	9	0
	2015-2019	3	21	0	5	63	8	0
Blackburn Bay	1995-1999	1	18	0	0	78	2	0
	2000-2004	1	18	0	1	77	3	0
	2005-2009	1	19	0	3	73	3	0
	2010-2014	1	22	0	4	69	4	0
	2015-2019	1	20	0	4	72	3	0

Note: A zero represents a less than 0.5% contribution to the total load.

4.4 Inorganic versus Organic Nutrient Loads

Inorganic nitrogen loads are generated as part of SIMPLE's runoff and baseflow modules using EMC's or conversion factors. The Point Source module also includes

inorganic and organic nitrogen fractions. Septic loads are output as NH₃, NO_x or TKN but are almost entirely generated as NH₃. The AD module reports TN but the data suggest the TN load is almost entirely NH₄ and NO_x. However, reclaimed loads are simply generated as TN as the focus of SIMPLE historically has been to estimate TN loads. Therefore, some simplifying assumptions were used to generate inorganic fractions for the Reclaimed module to include all sources. Using empirical data reported by Sarasota County for the principal waste water treatment plant supplying reclaimed water within the SBEP bay segments (i.e. Bee Ridge), the average percentage of the inorganic load (NO_x) to the total TN load was 90%. This fraction was used to generate an estimated inorganic fraction of the total TN load for the reclaimed module. In addition, all septic loads were considered NH₃ meaning all septic loads were considered inorganic and all AD loads were also considered inorganic. Implementing these assumptions meant that inorganic loads would be available for all sources and the fraction of organic versus inorganic loads could be computed for comparisons. The following paragraphs describe the relative organic and inorganic loads over time and by source over time.

The inorganic fraction of the total nitrogen load was typically ca. 40% of the total load for all bay segments and did not trend much over time in any segment (Figure 21). The most variable ratios were observed for Sarasota Bay and Roberts Bay where the inorganic portion ranged between ca. 40% to ca. 50% of the total load. In Roberts Bay, the inorganic fraction decreased slightly over time as point source and septic loads were reduced, more than offsetting slight increases in reclaimed loads and loads from spills between 2016 and 2019 (Figure 22). It should be noted that these plots represent watershed totals and that at smaller spatial scales, contributions from sources like spills can make up a large fraction of the total nutrient load in any given event, season, or even longer temporal window. While point source loads and septic loads were also reduced in Sarasota Bay, the increase in reclaimed loads offset those reductions in inorganic loads from other sources.

Increased reclaimed loads over time were observed in most segments resulting in increases in the inorganic nitrogen load where other sources were not being reduced (Table 16). Since 2010 reclaimed loads represent more than 10% of the total inorganic nitrogen load to Palma Sola, Sarasota, and Little Sarasota Bays while remaining less than 10% of the inorganic load in Roberts and Blackburn Bays.

Timeseries of % Total Organic and Inorganic Nitrogen Loads

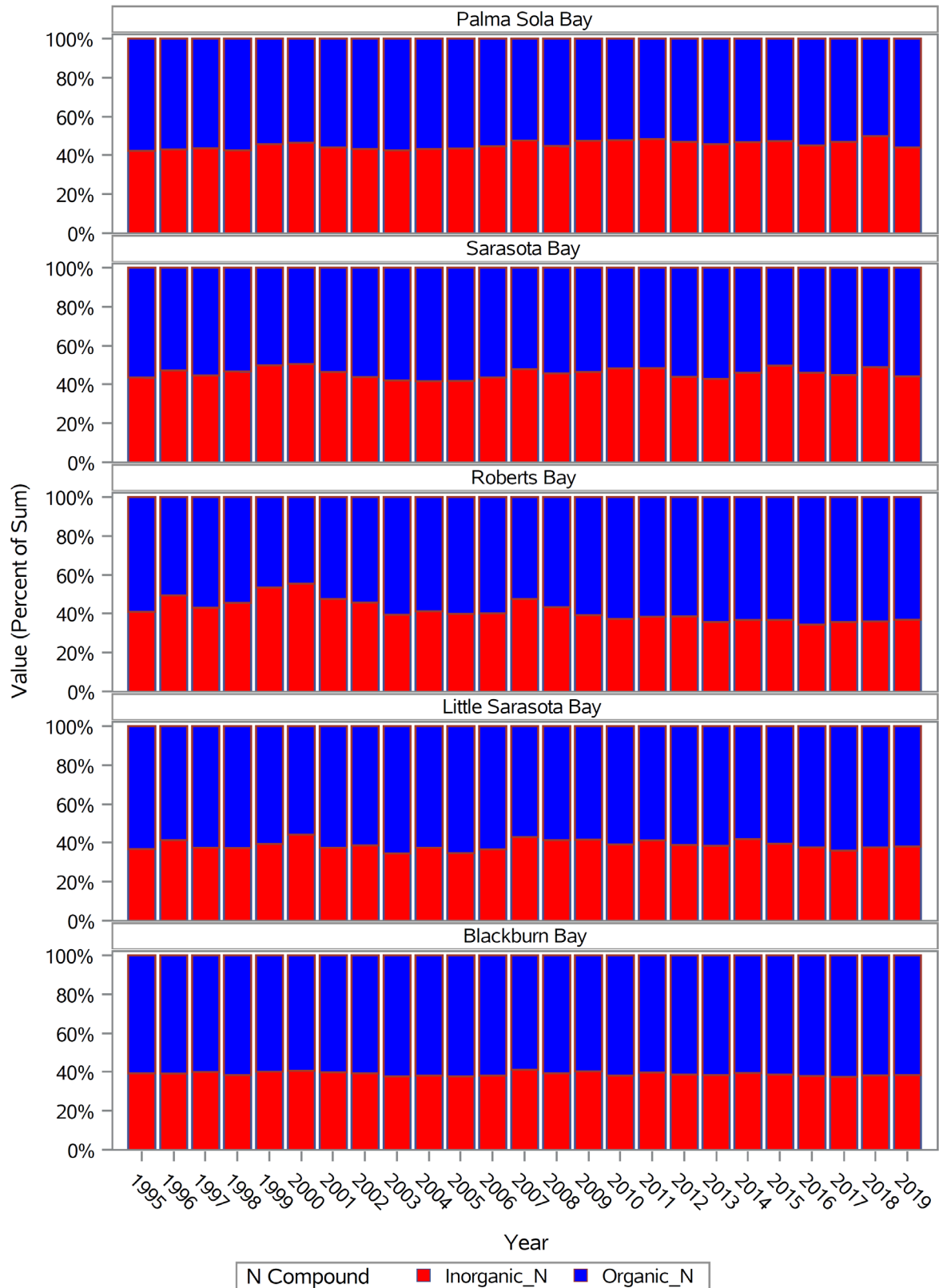


Figure 21. Annual percent inorganic and organic nitrogen for each model year.

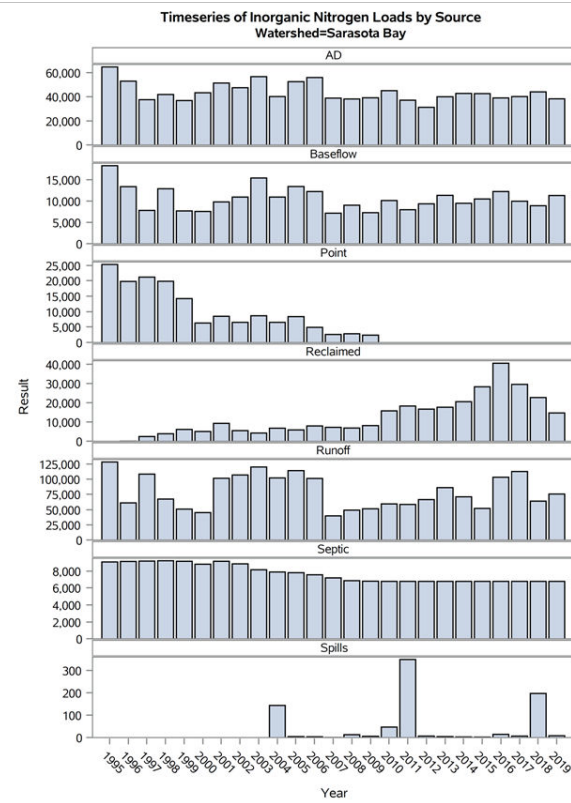
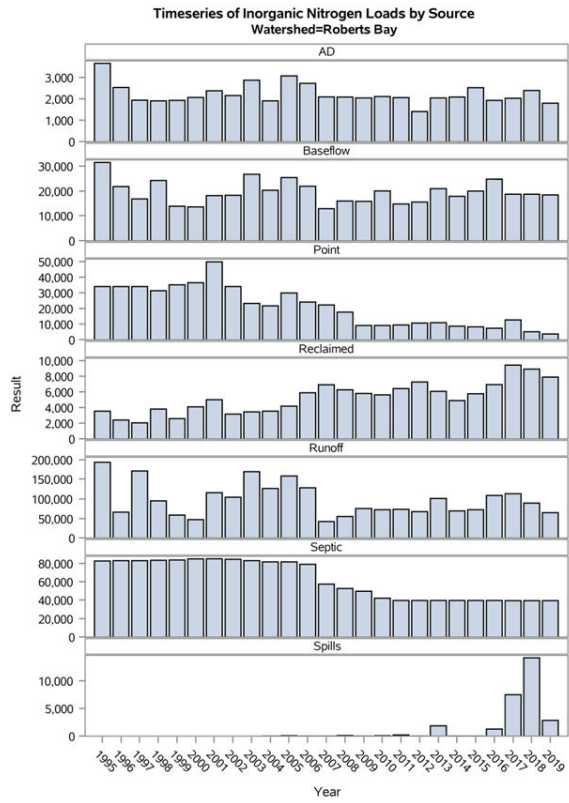


Figure 22. Timeseries of inorganic loads by source for Roberts Bay (left) and Sarasota Bay (right).

Table 15. Percent distribution for inorganic nitrogen loads by source for 5 year blocks within the model period of record.

Inorganic Nitrogen %		Source						
		AD	Baseflow	Point	Reclaimed	Runoff	Septic	Spills
Palma Sola Bay	1995-1999	19	9	0	3	64	5	0
	2000-2004	17	7	0	5	66	4	0
	2005-2009	21	8	0	9	56	6	0
	2010-2014	17	7	0	16	54	5	0
	2015-2019	16	7	0	17	55	5	0
Sarasota Bay	1995-1999	27	7	12	1	48	5	0
	2000-2004	27	6	4	4	54	5	0
	2005-2009	31	7	3	5	49	5	0
	2010-2014	28	7	0	13	48	5	0
	2015-2019	24	6	0	16	49	4	0
Roberts Bay	1995-1999	1	8	13	1	45	32	0
	2000-2004	1	8	13	2	44	33	0
	2005-2009	1	9	10	3	45	32	0
	2010-2014	1	12	6	4	50	26	0
	2015-2019	1	12	4	5	52	23	3
Little Sarasota Bay	1995-1999	8	10	0	5	59	17	0
	2000-2004	9	10	0	7	52	21	0
	2005-2009	9	10	1	10	48	21	0
	2010-2014	9	11	1	14	43	23	0
	2015-2019	9	11	0	12	47	20	0
Blackburn Bay	1995-1999	2	9	0	1	81	6	0
	2000-2004	3	9	0	2	78	7	0
	2005-2009	3	10	1	7	71	8	0
	2010-2014	3	11	1	9	67	9	0
	2015-2019	3	11	0	9	69	8	0

Note: A zero represents a less than 0.5% contribution to the total load.

5 Summary and Next Steps

The FDEP is likely to declare water quality conditions in the SBEP bay segments “Impaired” based on chlorophyll *a* exceedances. In addition, total nitrogen concentrations suggest increases in the bay segments in recent years relative to conditions used to establish previous management targets and thresholds. Evaluation of the estuarine indicators used to assess the ecosystem health of the SBEP bay segments suggest that seagrasses are decreasing and the presence of macroalgae are increasing in some bay segments, and the provisional 2020 seagrass acreage estimates for Sarasota Bay suggest a significant loss of seagrass in that segment which contains the majority of seagrass found throughout the SBEP. Together, these results provide several lines of evidence that management actions should be considered to reduce nutrient loadings to the bay segments in an effort to reverse observed adverse effects in these waters.

An important first step in identifying potential management actions to reduce nutrients is to understand the source of nutrient loads to these estuarine segments. The development of the latest version of the SIMPLE model described in this report fulfills that important knowledge gap. While no model is perfect in identifying all sources and mass balances associated with pollutant loading, this model serves as the best currently available estimates of nutrient loads throughout the SBEP watersheds and is structured in a manner that can be easily updated and refined as the science and understanding of the system improves. The SIMPLE model results suggest that runoff and baseflow dominate nutrient loadings to the system. These sources are derived from rainfall, landuse and soil features within the watersheds and variation in these loads are largely driven by rainfall. Point source loads have been decreasing over time as management actions to reduce point source loads to estuaries have been successfully implemented. Similarly, septic to sewer conversion programs have been implemented in several watersheds which have reduced the impacts from those sources. However, loads from reclaimed irrigation have been increasing as the customer base expands and the volumes processed have increased over time. In the majority of these watersheds, the reclaimed water is not treated to advanced wastewater treatment standards and yields at least 10 mg/l of total nitrogen. Reclaimed loads have increased as a percentage of the total nitrogen load in all segments. While the reclaimed load contributes generally less than 10% to the total nitrogen load to the bay segments, reclaimed loads now make up over 15% of the total inorganic load to Palma Sola and Sarasota Bay, and represent an increasing fraction of the total inorganic nitrogen load in all segments. In Roberts Bay the increased fraction of inorganic nitrogen loads was offset by point

source and septic reductions but in other watersheds, the offsets were not as evident. Spills account for a small percentage of the overall nutrient loads but at smaller spatial scales can represent the majority of the total nitrogen load to a catchment over short temporal windows. Importantly, while the loads summarized in this report represent watershed scale evaluations, the model was developed to operate at much smaller spatial scales allowing for natural resource managers to “drill down” evaluations to specific areas of interest as the management implementation becomes more refined.

The SIMPLE model, like all models, does rely on some assumptions. For example, event mean concentrations are used to calculate the runoff pollutant load based on the hydrologic load and this version of SIMPLE utilizes generally accepted EMC values that are currently used by Sarasota County in NPDES reporting and other management implementations. Likewise, attenuation rates for reclaimed and septic systems represent estimates of the total irrigated (or produced) load that makes it to a surface waterbody. While these rates are standard practice in recent modeling efforts for Sarasota County, adjusting these rates can have substantial impacts on estimating the total nutrient loads to these systems. Estimating the inorganic fraction of the total nitrogen (and phosphorus) loads required making assumptions about the proportion of the total nitrogen loads estimated by the model that were inorganic. Empirical data were used to support these assumptions to estimate the total inorganic nutrient loads to the system.

The typical regulatory paradigm implemented by FDEP after verifying waterbodies as impaired is to develop a total maximum daily load (TMDL). The TMDL process requires estimates of watershed nutrient loads under current conditions and often, a model simulation of a “natural background” state to derive a nutrient load reduction requirement for the impaired waterbody. This regulatory driven process is lengthy, often taking 5 years to implement, onerous and generally outside of local control. The SBEP has been proactive in supporting the development of a pollutant loading model that can benefit local natural resource managers pursuing management actions to reduce nutrients in a more timely manner and incorporate the extensive knowledge of the local scientific and natural resource management community. The DEP regulatory process does have alternative pathways to the TMDL to restoration for impaired waterbodies including developing a Category 4B Plan, also known as a Reasonable Assurance Plan (RAP) which is a stakeholder-led effort or developing a Category 4E Plan which is similar to a RAP but would not remove the Bays from the potential of a DEP TMDL. Ultimately, these decisions rely on local stakeholders in coordination with DEP to

determine the best course of action to protect and restore the estuarine segments of the SBEP.

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