SWIL v5 Task 2 Update

Final Draft Memorandum

DATA EVALUATION FOR THE SUBSURFACE FLOW MODEL COMPONENT

PREPARED FOR:

PREPARED BY:

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Introduction

The goal of the Spatial Watershed Iterative Loading (SWIL) model is to use input parameters derived from water quality data to create the spatial and temporal representations of nutrient loads and volumes. The nutrients estimated in the SWIL model include total nitrogen (TN) and total phosphorus (TP). As stated in the Task 1 memorandum, the direct runoff module will be Direct Runoff Event Mean Concentration (EMC)-based, which is the same concept as the original SWIL model. Values are driven by rainfall amounts and Direct Runoff Coefficients (ROCs) for each land use and soil type to predict volumes. Those volumes are then associated with EMCs for each land use category to produce loads.

While the focus for Task 1 was to update static model inputs including land use / land cover, Environmental Resource Permit treatments, and soils, in addition to dynamic inputs including rainfall, evapotranspiration, direct runoff EMCs, and direct ROCs, the update for Task 2 examines other inputs that predict nutrient concentrations into the Indian River Lagoon (IRL). Specifically, Task 2 focuses on the subsurface component of the model and includes spatially and temporally refining EMCs associated with TN and TP as they relate to groundwater.

Fresh groundwater discharge and surface runoff from gauged and ungauged areas are the primary and secondary freshwater contributors to the IRL according to the water balance calculation for the IRL (Kim, 2003). The volumes of freshwater associated with runoff and groundwater seepage, in addition to precipitation, evaporation, and residual water exchanges between ocean water inflows and lagoon water outflows, all contribute to the overall water quality of the IRL (Kim, 2003). Therefore, in addition to the surficial runoff component calculated in Task 1, a subsurface component of the SWIL model is imperative to build a truly representative model that measures nutrient loading and to gain a better understanding both spatially and temporally of the nutrient loads affecting the IRL.

To complete this task, Applied Ecology Inc. (AEI) received best available data from various IRL stakeholders (see Table 1) and evaluated those data with literature-based data. Data received included groundwater quality datasets from monitoring well data, which provide a snapshot of TN and TP levels at the time of sample collection. The quality of these data is dependent upon sampling methods, frequency of sampling, and spatial representation of sampling locations. In addition, long-term continuous flow gauged station data were assessed in conjunction with surface water quality station data. These data were segregated into baseflow-specific and direct runoff-specific conditions to understand nutrient concentrations (e.g., EMCs) associated with subsurface flow volumes that are entering the IRL. Only the segregated baseflow data were retained for this study.

The purpose of this Task 2 memorandum is to compare the findings of groundwater quality concentration data from various monitoring well locations throughout the IRL with baseflow-specific water quality concentration data obtained from a combination of gauges to propose a science - driven approach for the refinement of subsurface EMCs. There are anticipated differences between both data, with likely higher measured nutrient concentrations associated with groundwater source data versus the likely attenuated measured concentrations in tributaries and canals. Both sources of subsurface flow data (wells or gauged data) are compared to the historically used uniform EMC concentrations for TN and TP for groundwater. This report provides the information to make an informed decision regarding the best direction for the Subsurface Flow Module Update of SWIL.

Model Relevance	Data Type	Source	Received Data Format	Spatial Coverage	Meets Acceptance Criteria	Processing Requirememts	Level of Effort	Recommendation	Comments
Subsurface Flow Model Update	Surficial Groundwater Well Information	SFWMD	SHP and Tabular	Yes	No	None	N/A	One is not surficial well, not enough readings to be used in model	Tested Specific conductance, chloride, pH, Temperature, and depth. 2 sample dates each (in 2014 and 2019) for 4 wells in Martin and St Lucie Counties
		SFWMD	SHP and Tabular	Yes	No	None	N/A	Might be useful to obtain water table information - average depth. Might be useful for septic component	Tested Depth, 38 Wells covering dates between 2016 and 2016 in Martin and St Lucie Counties
		SJRWMD	SHP	SJRWMD Basins	Yes	None	Minimal	Environmental Data Retreval Station and Water Resource Information Station	Surface Water and Ground Water
	Ground Water Quality	FDEP (FDOH)	Tabular / Literature	No	Yes	Reference data	N/A	Reference with county septic locations. Double check if only Phosphorus concentrations provided	Data reference dated 1993. Nutrient concentrations for monitor well sites IRL basin (FDOH septic justifications)
		IRC - FDEP	SHP	Yes	Yes	Update with treatment data, calculate statistics etc	High	Is this one time sampling? The mean? Etc	2015 data, 18 Wells testing Nitrogen, Phosphorus, Ammonia, and Nitrates
		IRC	Tabular/SHP	No	Yes	Yes - Reference data	Combine with other IRC well data	Can be used for qualitative analysis	Dated 6/28/2016 and 6/29/2016. Ground water quality data measuring Chloride, Ammonia, Nitrogen, Phosphorus, Boron, and Sucralose in 10 wells in IRC
		IRC	Tabular/SHP	Yes	Yes	Update with treatment data, calculate statistics etc	High	Convert coordinates to SHP with locations to characterize the wells. Are they in septic locations, concentrations appear low	Includes Monitor Wells and WWTF Discharges, 2020 and 2021 quarterly TN and TP concentrations
	WWTP19 Service Areas	IRC	SHP	Yes	No	Yes	Intermediate	Shapefile of reclaim water main in Indian River County	Can use to assume reclaim services if needed
		COM	SHP	Yes	Yes	None		Shapefile of Reclaim service ares in Melbourne	Can use as reference
		COVB	SHP	Yes	No	None	None - minimal data	Shapefile of Reuse Area in Vero Beach	Can use as reference
	WWTP Permitted and Mean Discharge Info	IRC	Tabular	No	Yes	Compare with WQ and stream flow data	Intermediate	Need WWTP service areas to apply concentrations by area	Dates October 2013 to September 2020, Lists Monthly average flows (MGD), TN and TP concentrations
	Septic inventory - current	IRC	SHP	Yes	Yes	Minimal	None	IRC Parcels depicting sewer service or septic designation	Only covers Indian River County
		IRC	Literature	No	No	Minimal	Reference Data	ArcNLET model estimating Nitrogen Load from septic systems to IRL (Main-South canal in IRC)	Model inputs include septic tank locations, water body locations, DEM, Hydrogeological and transport parameters including smooting factor, hydraulic conductivity, porosity, dispersivity, decay coefficinet of denitrification, souce load and concentration
		Brevard County	SHP	Brevard County	Yes	Minimal		All septic and reclaimed locations and associated parcels in Brevard County	Covers Brevard County

GROUNDWATER DATA

Groundwater data for the IRL were provided predominantly by Brevard County with additional data from Indian River County and the Florida Department of Environmental Protection (DEP). Data were received spatially as shapefiles as well as tables and pdf documents that contained additional parameters. Groundwater monitor wells in Brevard County were sourced from wells owned by the Brevard County Natural Resource Department and are used in part for nutrient monitoring for the Save Our Indian River Lagoon program (Brevard County, 2022) and septic-to-sewer projects implemented within the county. Groundwater monitor wells in Indian River County were sourced from wells associated with the county's Reuse Water program, and from DEP installed surficial groundwater wells as part of their effort to use the ArcGIS-Based Nitrate Load Estimation Toolkit (ArcNLET) model for loading to the South Relief Canal, as well as a later effort to determine septic system contributions to the St. Sebastian River. In addition, data from DEP's Generalized Well Information System (GWIS) were included (DEP, 2016). These well locations were supplemented by water quality information semi-regularly sampled at each well site by the St. Johns River Water Management District (SJRWMD) (2021). Although the GWIS database is large and contains water quality data as far back as the 1980s, once filtered for relative data including TN and TP quantities, updated for the timespan associated with the current SWIL model (2010–2020), and fit within the SWIL model boundary, only a few wells from this database were selected for this update.

All groundwater quality data from monitoring wells were aggregated and combined into a single database, which focused on a few key parameters (see Figure 1). Those parameters include the geometric means of all sampling events for each well for TN (see Figure 2) and TP (see Figure 3), collection frequency of TN and TP, treatment type associated with each well, type of land use surrounding the well within a 200-foot buffer (see Figure 4), date ranges of sample collection events for each well, dry or wet season conditions apparent at the time of sample collection, and depth of the wells. However, the quality of data and value of parameters mentioned varied between sources.

Brevard County data were the most extensive in nature. All data were attributed with the appropriate treatment types, and collection frequencies varied between 18 to 38 sample collection events between June 2018 and November 2021. Brevard County supplied data from 49 wells. Indian River County data were attributed with the appropriate treatment types and collection frequencies varied between one to four sample collection events. Wells associated with the county's Reuse Water program were sampled between October 2020 and September 2021. Wells associated with DEP's projects in Indian River County contained one sample event in 2015 and another in June 2016. Indian River County supplied data from 41 wells. To retain as much data from DEP GWIS wells as possible, sample dates from April 2006 through December 2015 were used with collection frequencies ranging between one to three sampling events. No treatment types were associated with any well. Nine additional wells were included from DEP's GWIS database for a total of 99 groundwater monitoring wells evaluated for Task 2.

Analyzing the statistics of total groundwater nutrient loads by treatment type yielded interesting results. For all well EMCs, average TN concentrations in septic and reclaimed treatments were three times higher than in areas treated with sewers and the natural or control areas (see Figure 5). Average TP concentrations on the other hand, were five times higher in septic treatment areas alone compared to natural and sewer treatment areas, and three times higher compared to reclaimed treatment areas (see Figure 6). Brevard County groundwater quality data had similar trends for TN to those described for the complete dataset. TN concentrations were three times higher in reclaimed and septic treatment areas (see Figure 7). However, for TP, concentrations within septic treatment areas are between three to eight times greater than those for all other treatments (reclaimed, sewer), or control areas depending on the sampling date (see Figure 8). For comparison, a breakdown of the geometric means of all wells by treatment type can be found in Figure 9.

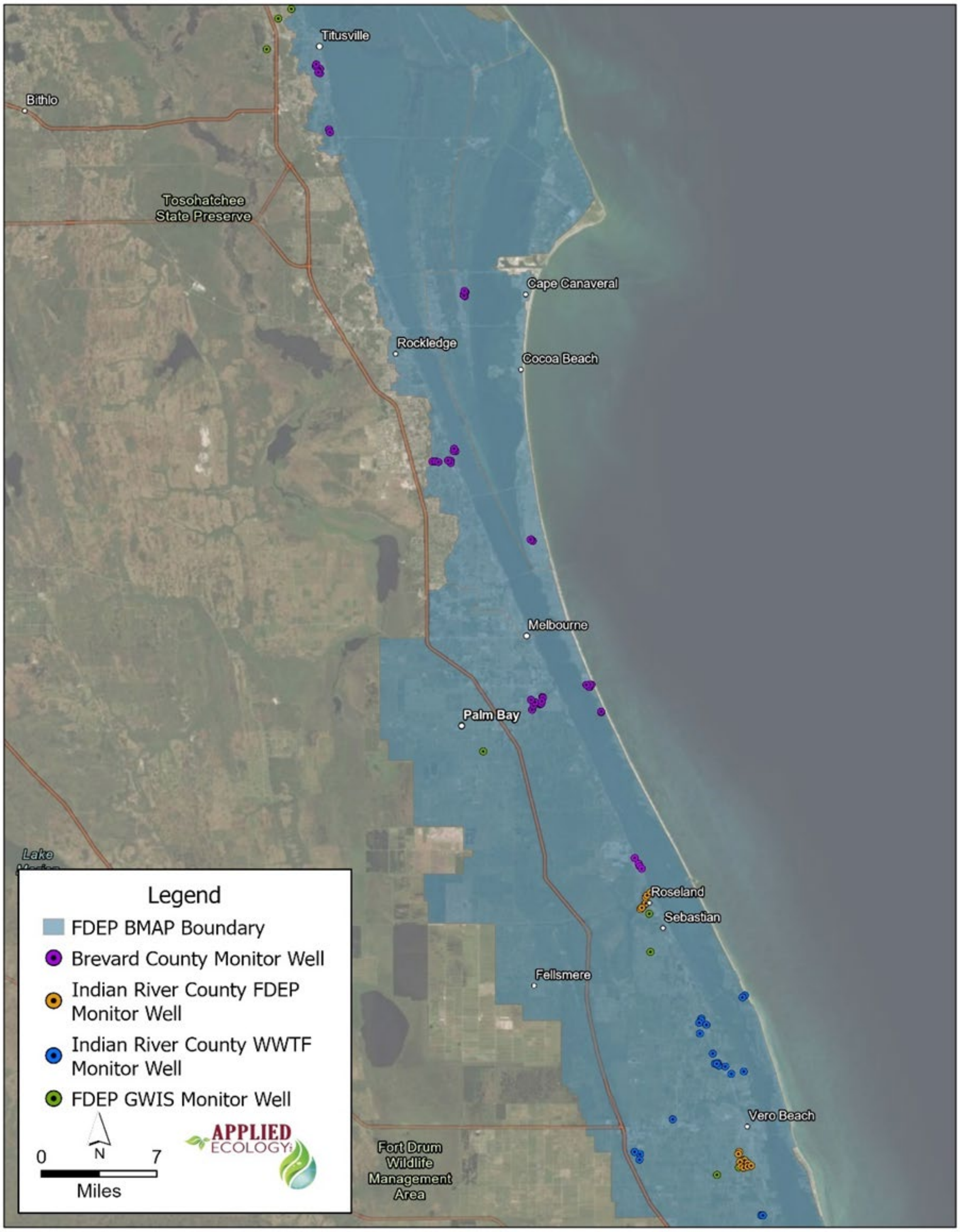


Figure 1: Groundwater wells used for the Task 2 SWIL model update

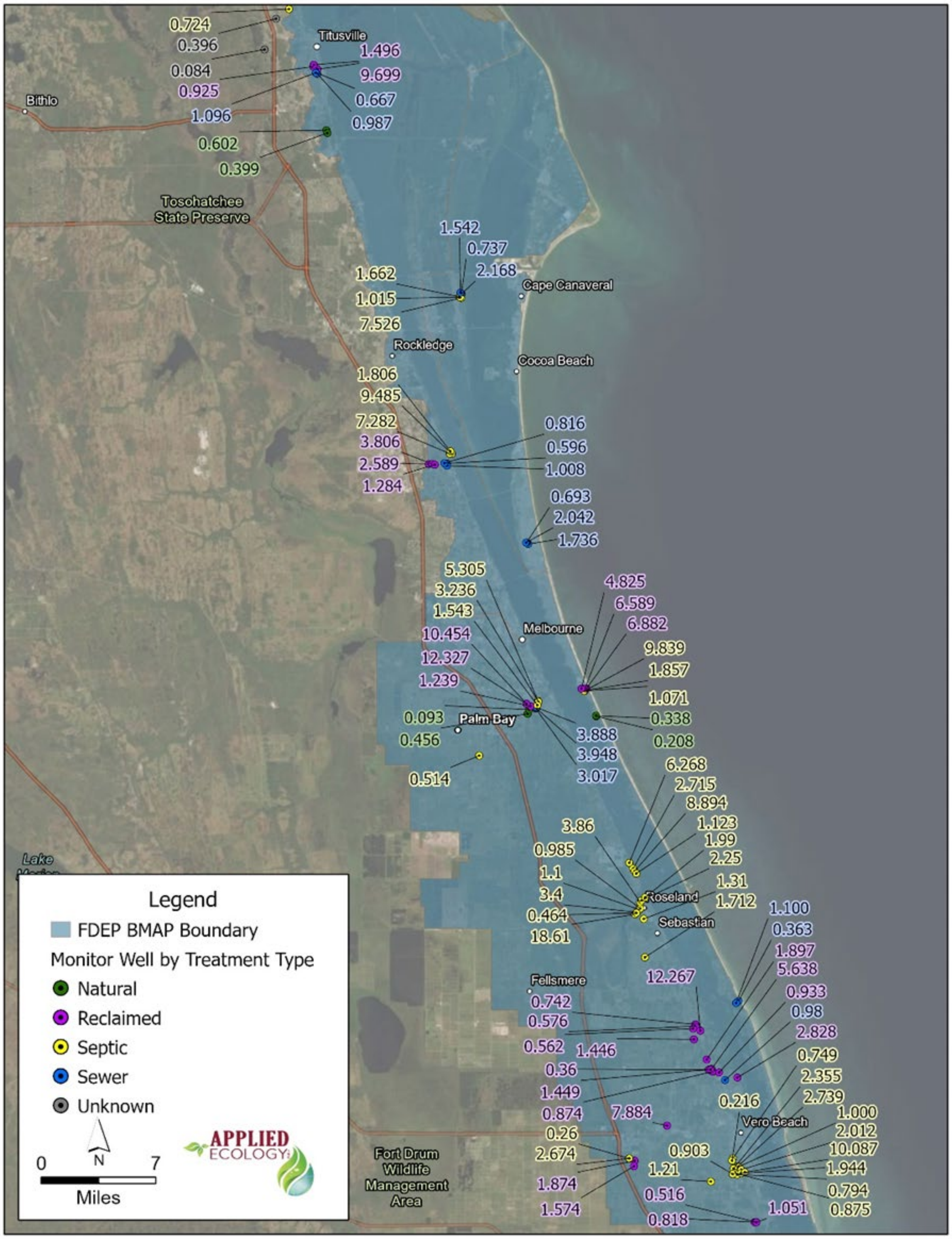


Figure 2: Geometric means to TN for each groundwater monitoring well

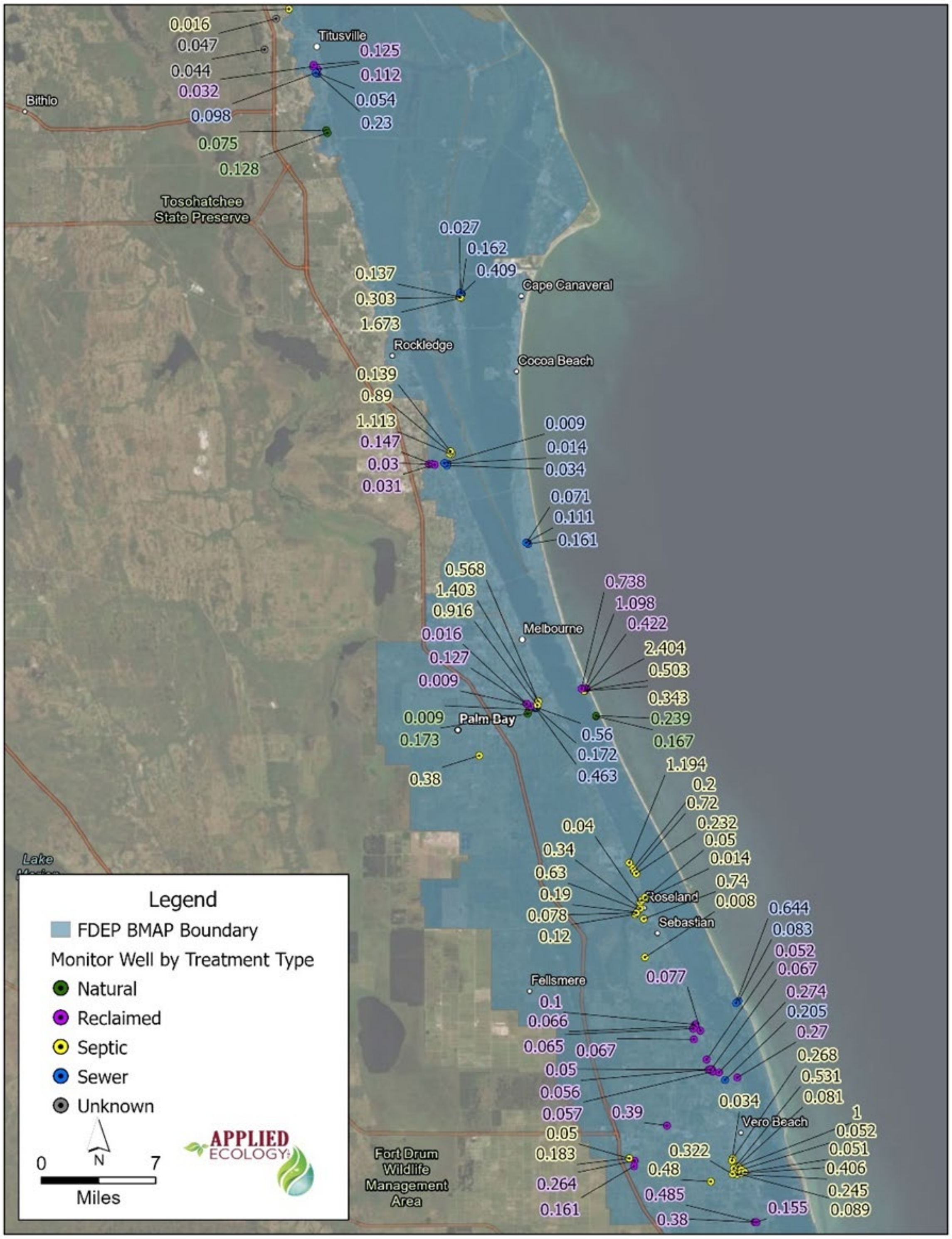


Figure 3: Geometric means to TP for each groundwater monitoring well

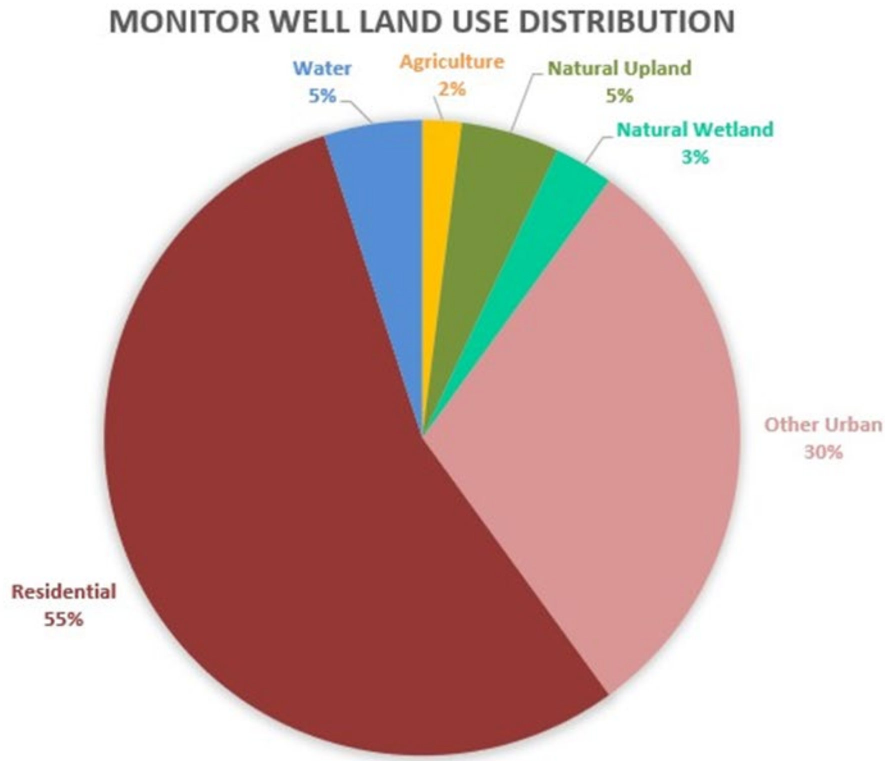


Figure 4: Land use distribution within a 200-foot buffer surrounding the groundwater monitoring wells

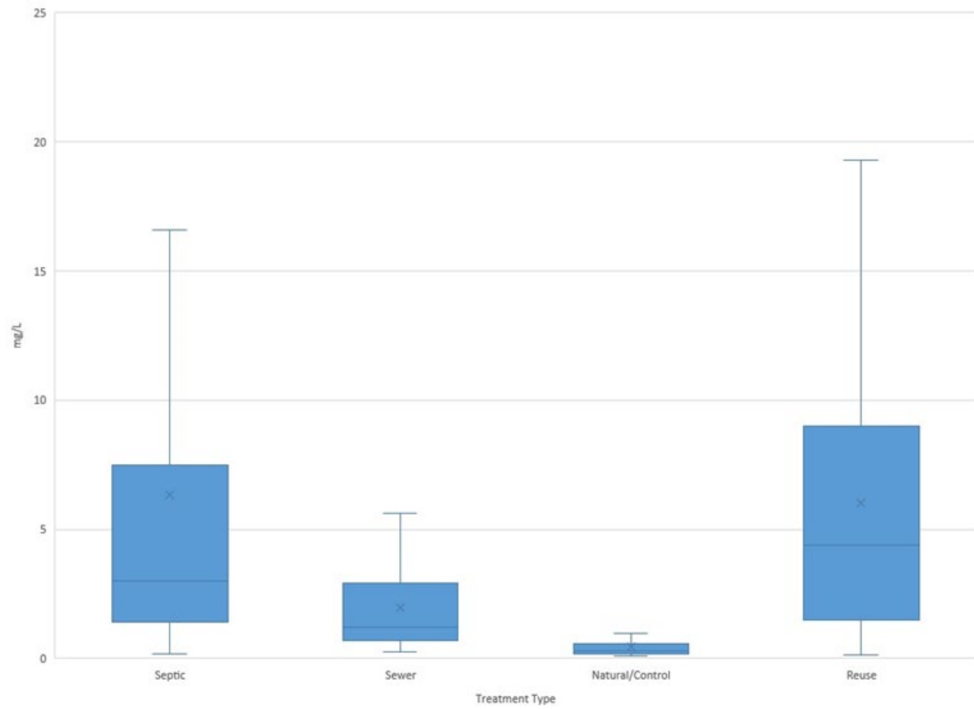


Figure 5: Groundwater quality concentrations of TN by treatment type for all wells (statistical outliers removed for visibility)

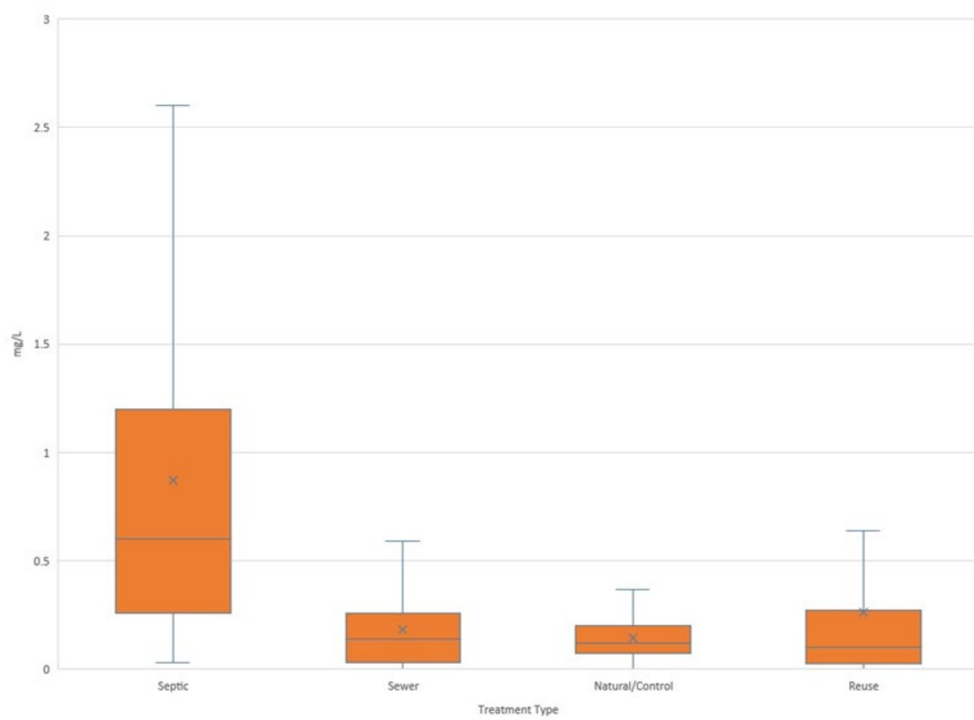


Figure 6: Groundwater quality concentrations of TP by treatment type for all wells (statistical outliers removed for visibility)

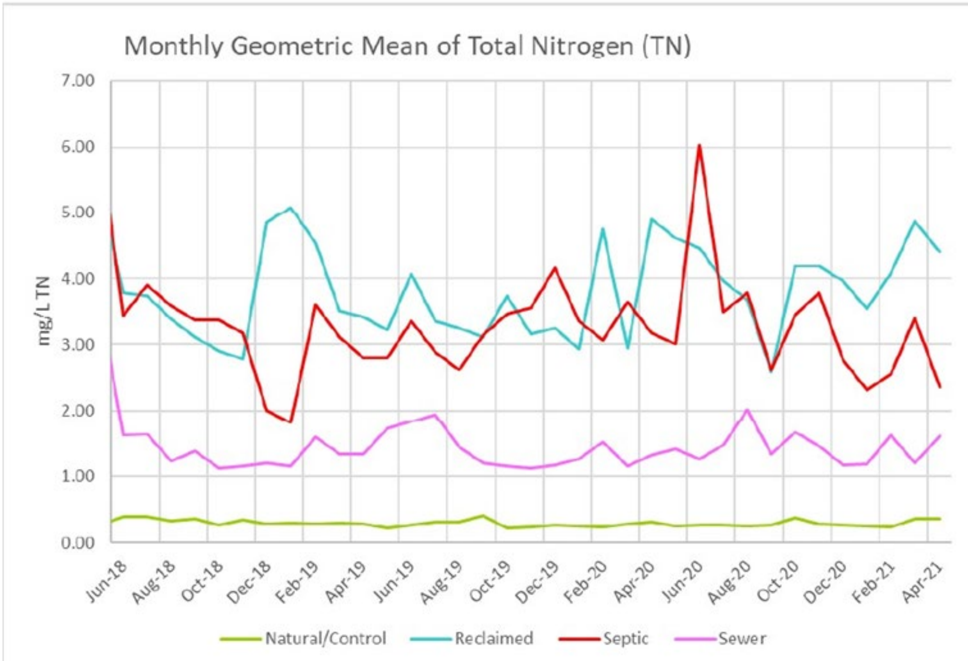


Figure 7: Monthly geometric mean concentrations of TN for Brevard County wells

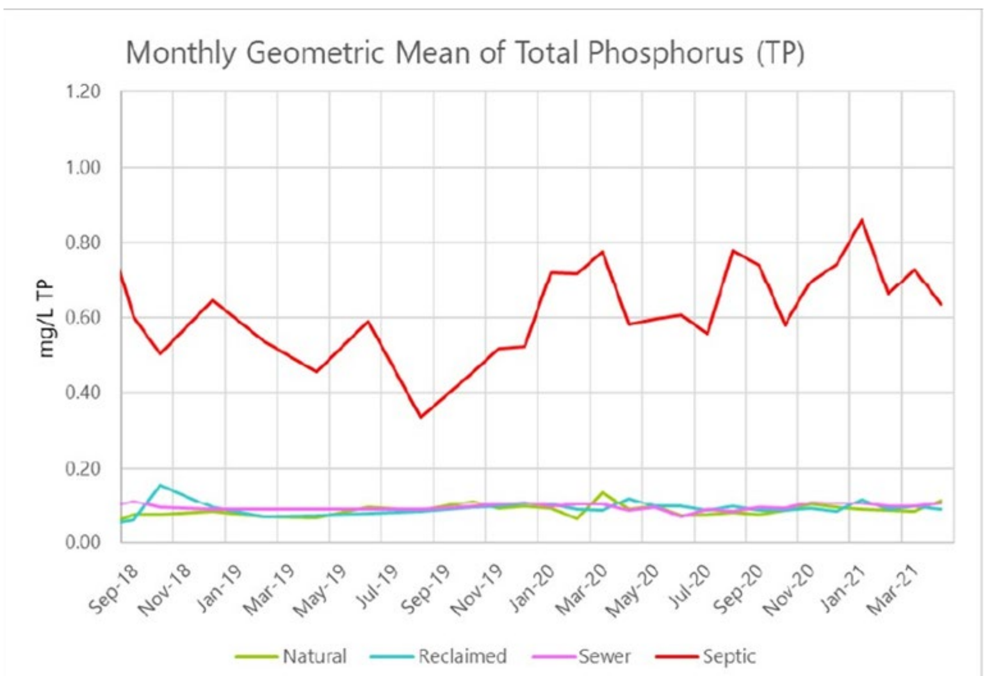


Figure 8: Monthly geometric mean concentrations of TP for Brevard County wells

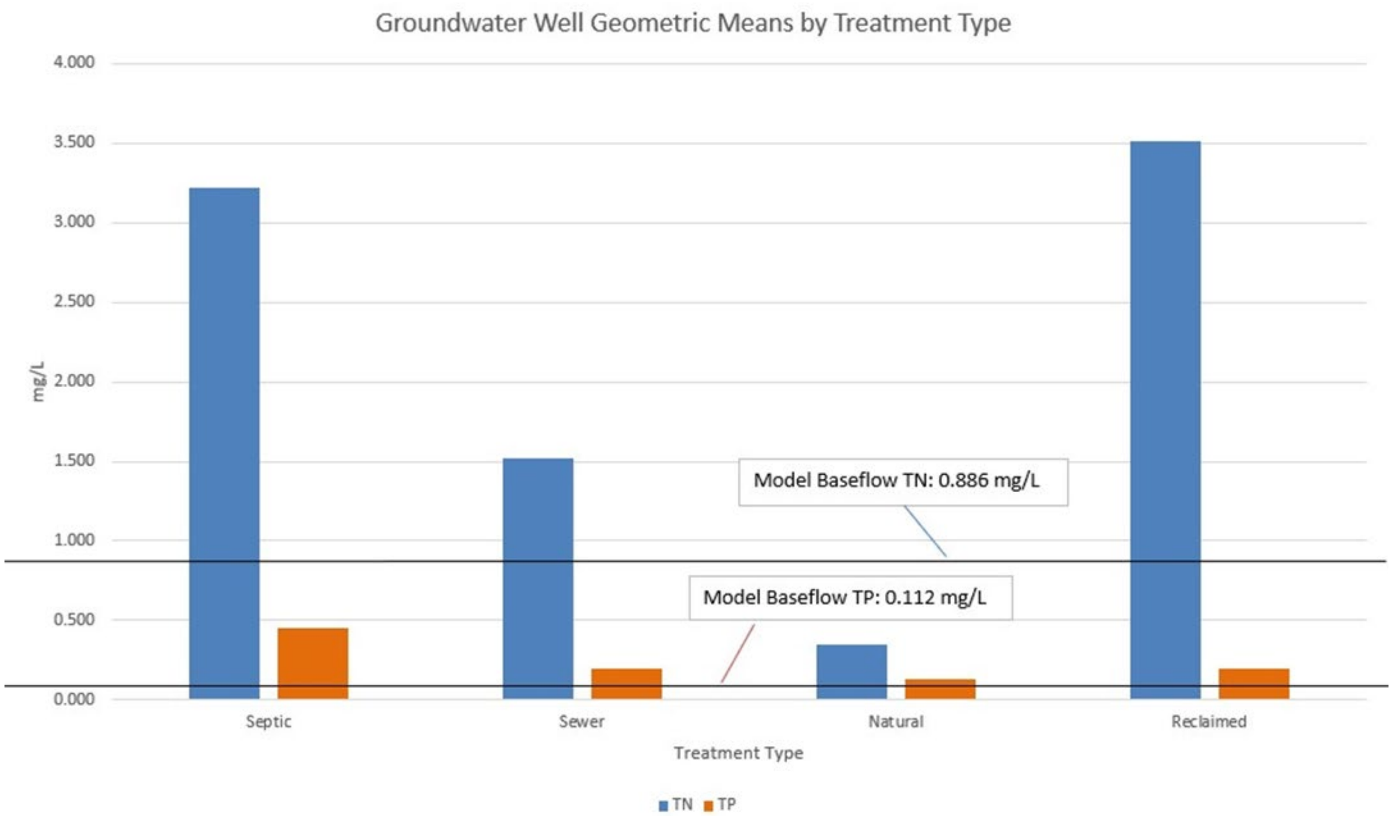


Figure 9: Geometric means of all groundwater monitor wells by treatment type
Note: Current SWIL TN and TP values for subsurface flow are labeled.

BASIN SELECTION

Specific subbasins (based on SJRWMD delineations) were used to determine baseflow and direct runoff from streamflow data. The selection of the SWIL model subbasins required that they had both water quality and quantity measurements from a location in a tributary where there were well defined basin boundaries. Additionally, the basins needed to represent a variety of land use types to be representative of the IRL watershed. Accurate land use representation produces a more comprehensive model indictive of the true conditions influencing water quality in the IRL and will be more closely aligned with land use types associated with the surface runoff component outlined in Task 1. The original SWIL basins (Harper and Baker, 2016) of Crane Creek, Sebastian North Prong, Sebastian South Prong, and Fellsmere Canal were included in this effort. To enhance the geospatial representation of the basins and provide additional representation of land use combinations, the Big Flounder Creek, Eau Gallie River, and Vero Beach South Canal were included (see Figure 10). The Harper and Baker (2016) SWIL Crane Creek basin was a subdivision of the Crane Creek subbasin into the Hickory Street and Washington-Crane SWIL subbasins. This was due to the introduction of U.S. Geological Survey (USGS) station 02249500 in 2003 farther upstream from the SJRWMD managed Hickory Street gauge station 09402102. While Harper and Baker (2016) used both the SJRWMD Hickory Street and USGS Washington-Crane basins, this SWIL model effort uses only the Washington-Crane SWIL subbasin and USGS station 02249500.

For the SWIL model update, the Crane Creek subbasin and Eau Gallie Creek subbasin had two different water quality stations that met the above-mentioned criteria. In the Crane Creek subbasin, those stations were IRLCCU and CC03. In the Eau Gallie Creek subbasin, those stations were IRLEGU and IRLUPEGWR. However, after an analysis of the data, more sample dates from the water quality sampling events matched baseflow specific event dates for more occurrences in one water quality station versus the other. This held true for both the Eau Gallie Creek and Crane Creek subbasins. Therefore, the water quality stations that had more matched data were selected to represent the TN and TP concentrations for their respective basin. For the Crane Creek basin, that station was IRLCCU and for Eau Gallie, that station was IRLUPEGWR. All other basins had one water quality station that matched the criteria needed for accurate analysis. The Fellsmere subbasin used station IRLUSPFW, Sebastian North Prong subbasin used station IRLSEBNP, Sebastian South Prong subbasin used station IRLSIR003, Vero Beach South Canal subbasin used station IRLVSC, and Big Flounder Creek subbasin used station IRLBFRR (see Figures 11–17).

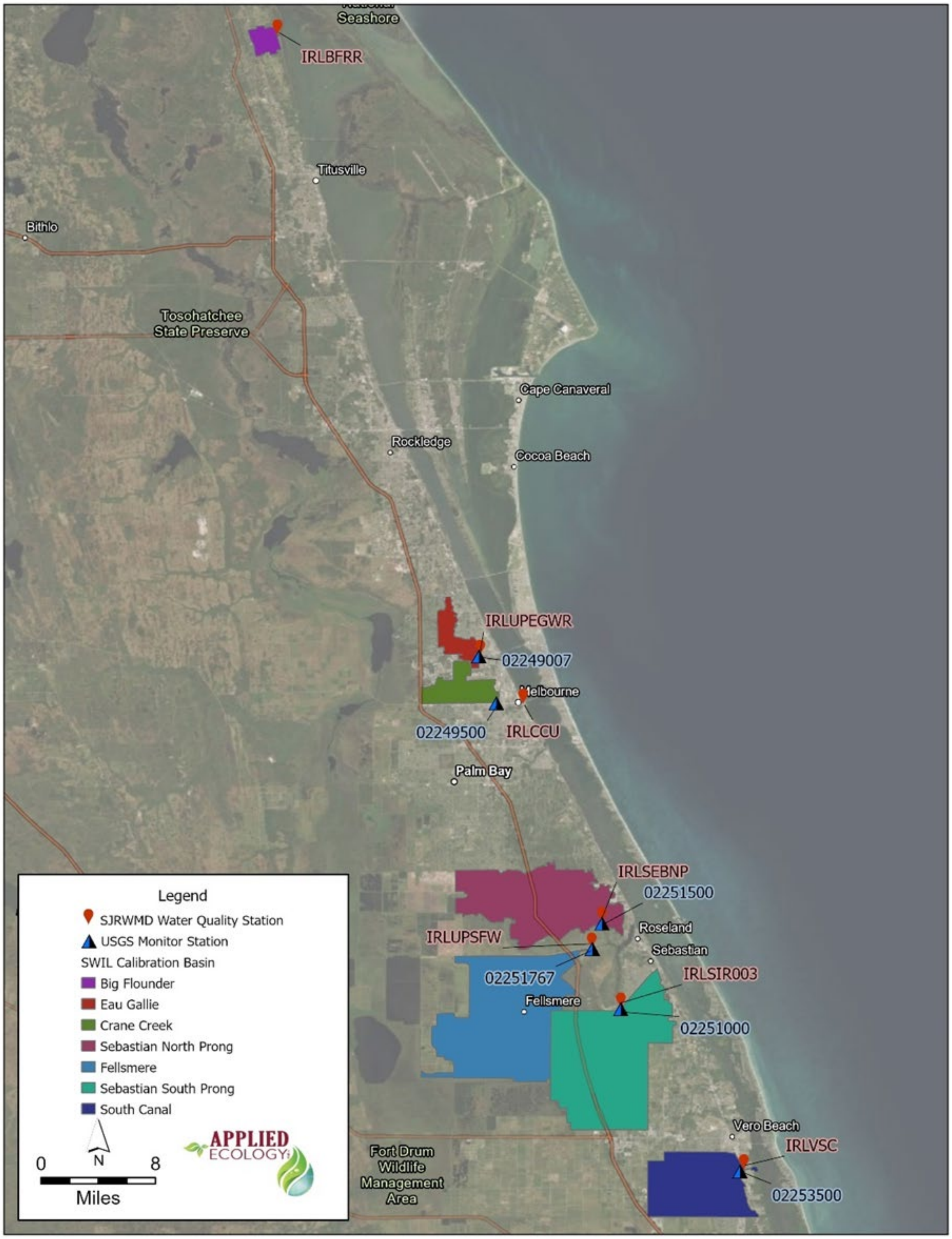


Figure 10: SJRWMD basins, water quality stations, and streamflow gage stations used in Task 2

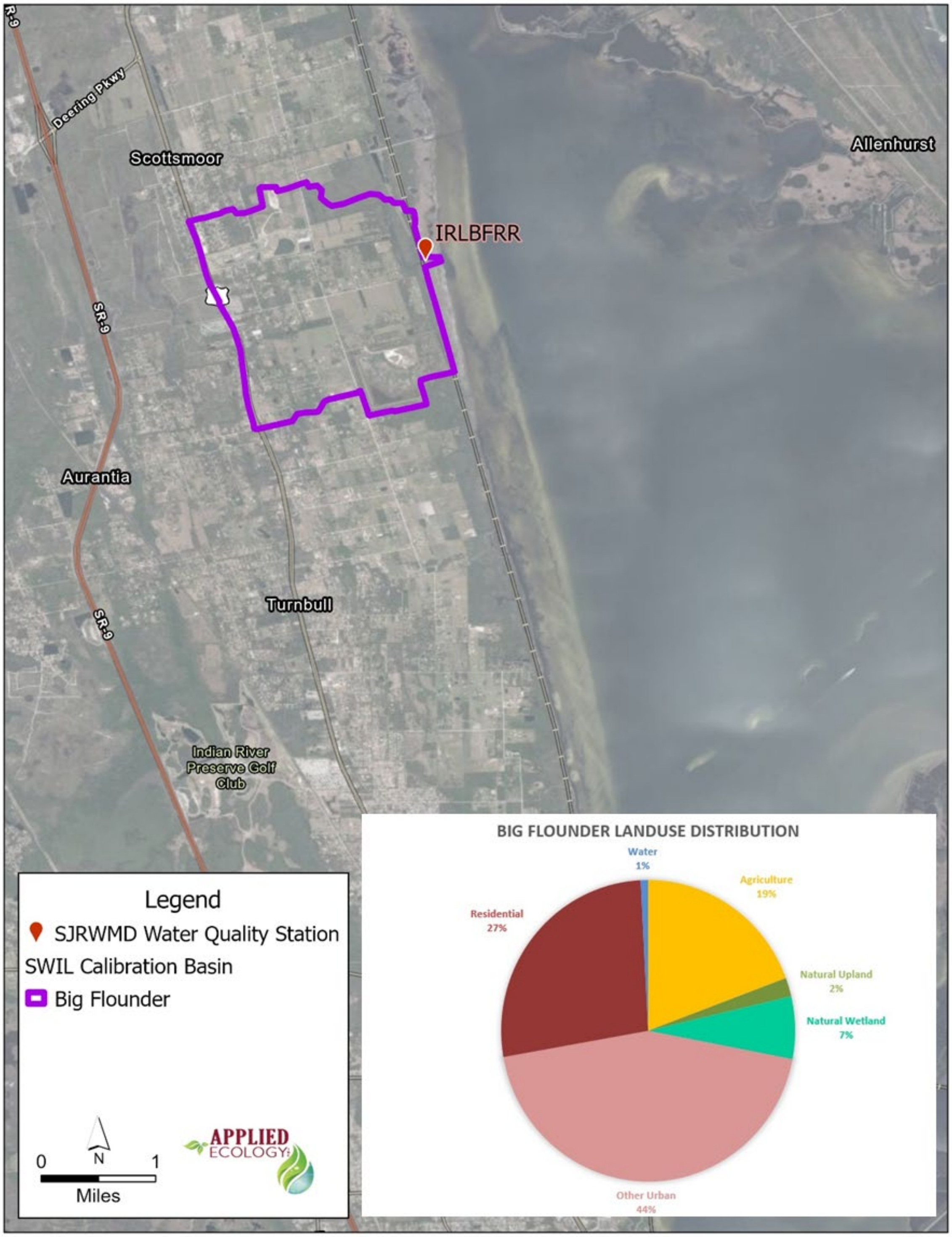


Figure 11: Big Flounder Creek basin

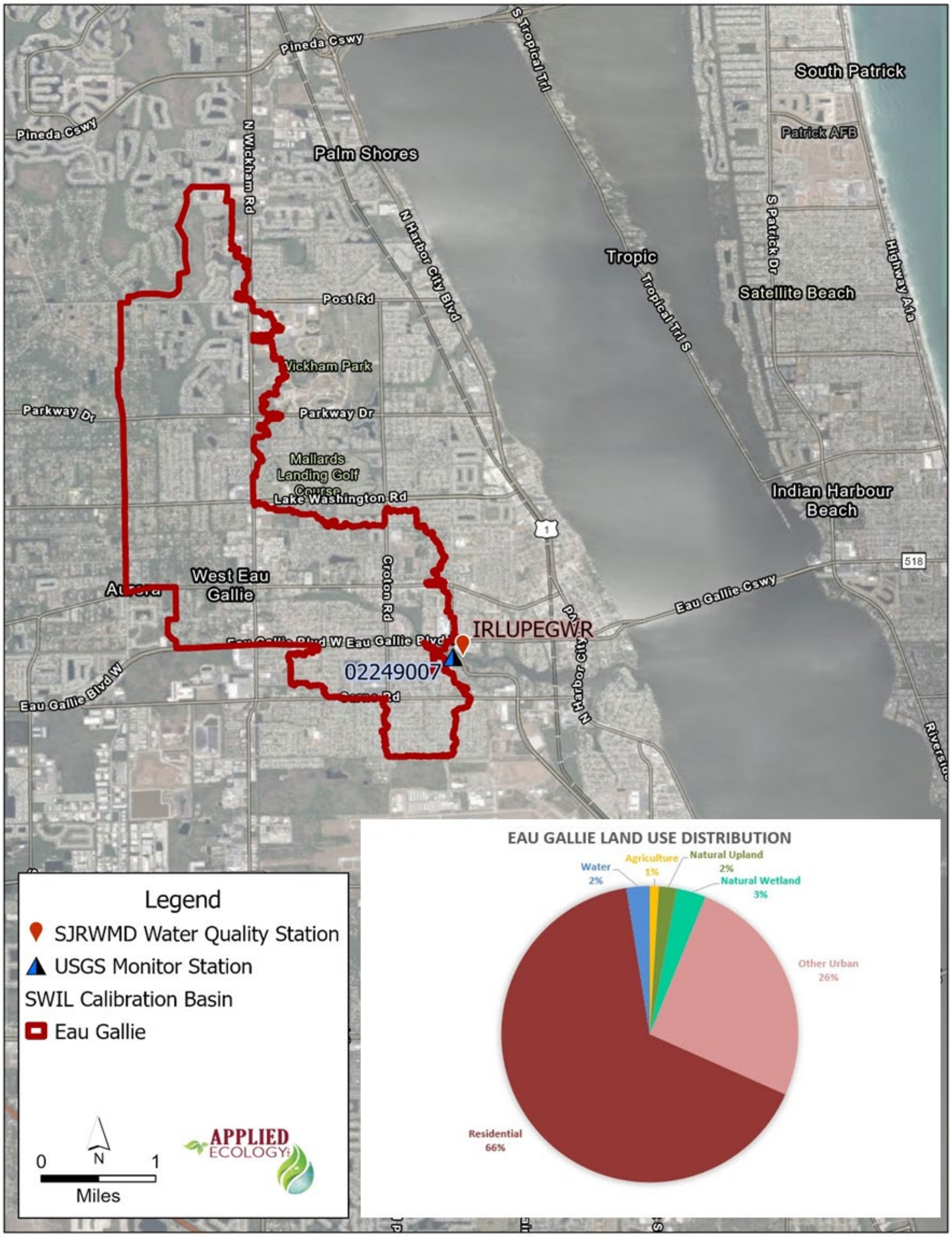


Figure 12: Eau Gallie basin

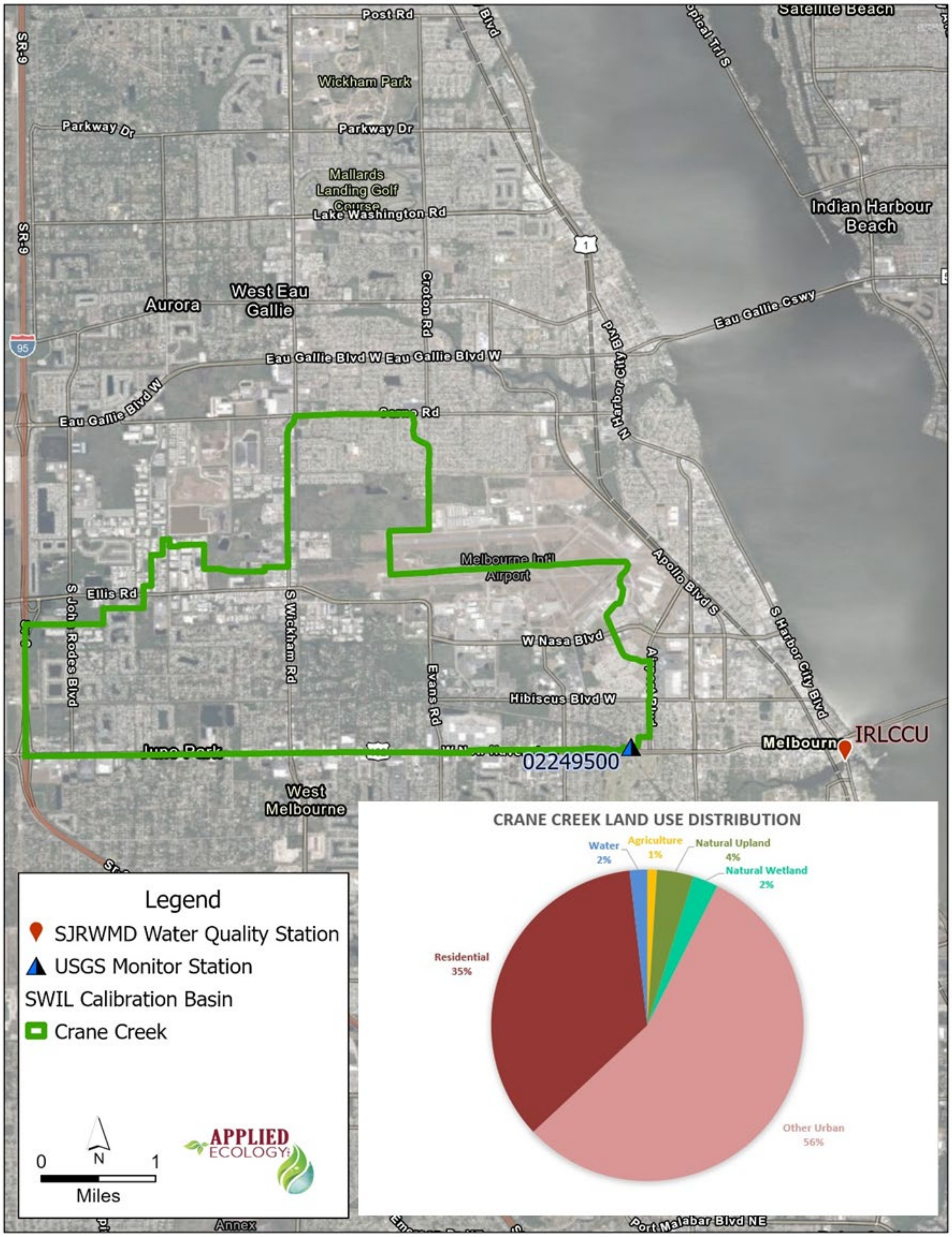


Figure 13: Crane Creek basin

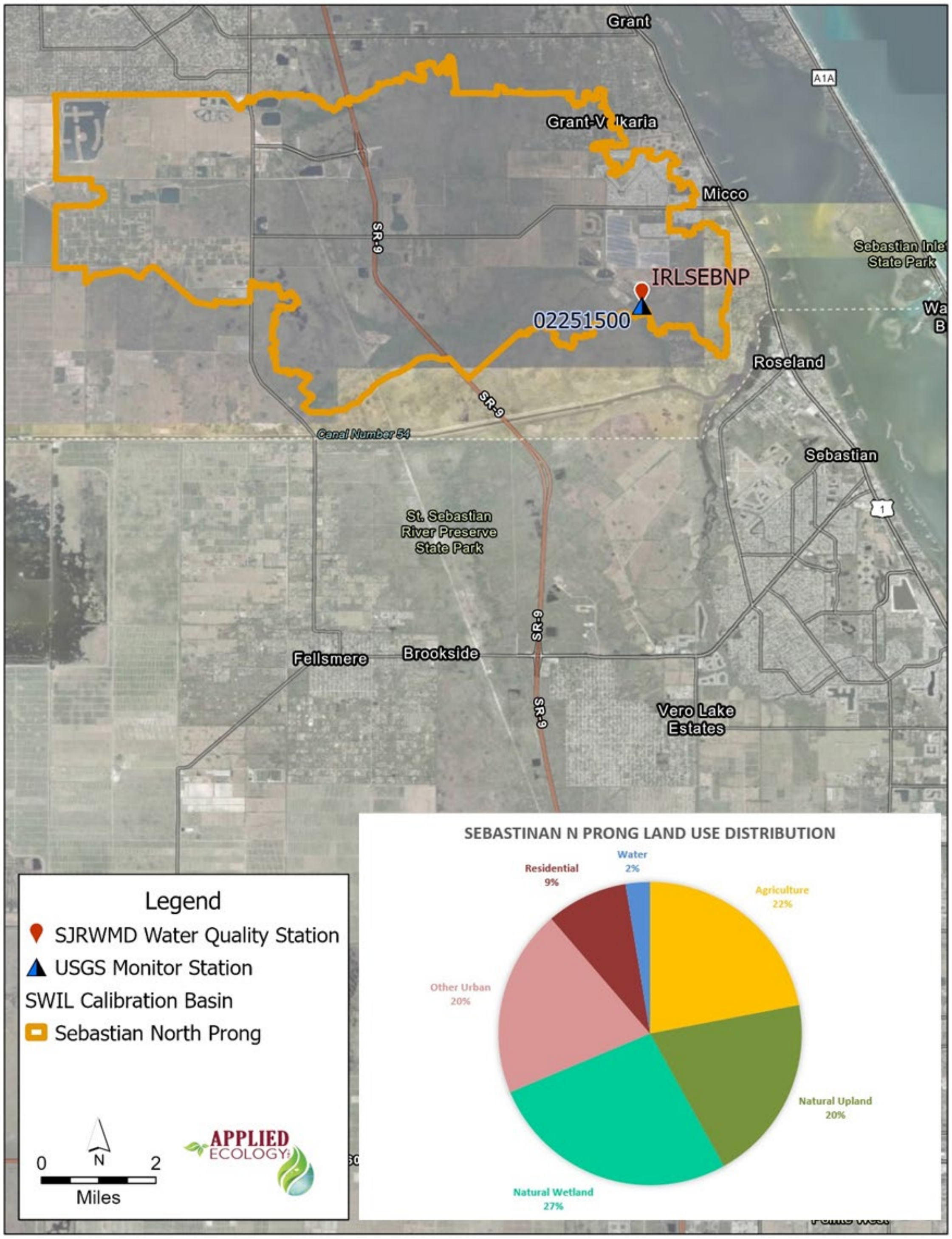


Figure 14: Sebastian North Prong basin

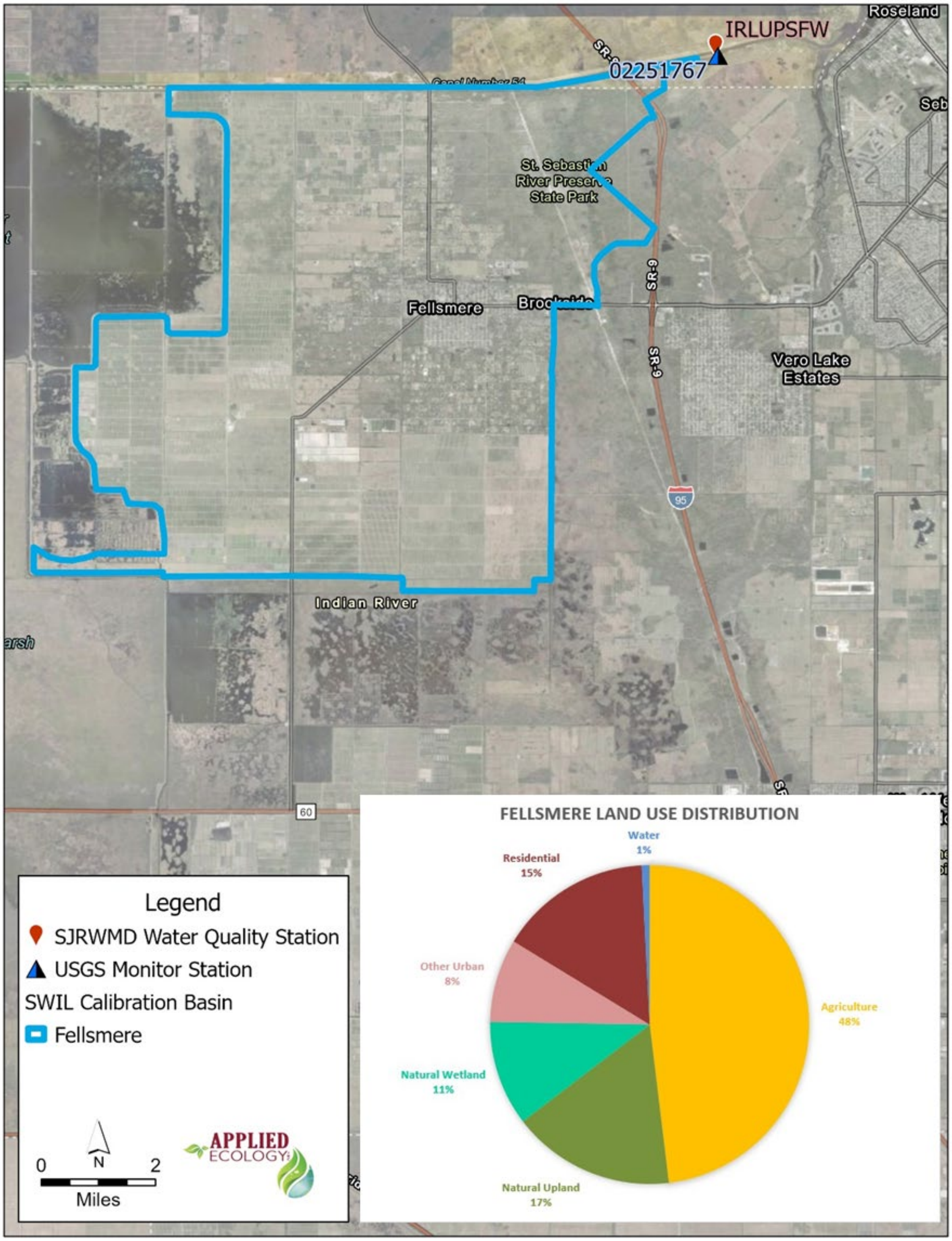


Figure 15: Fellsmere basin

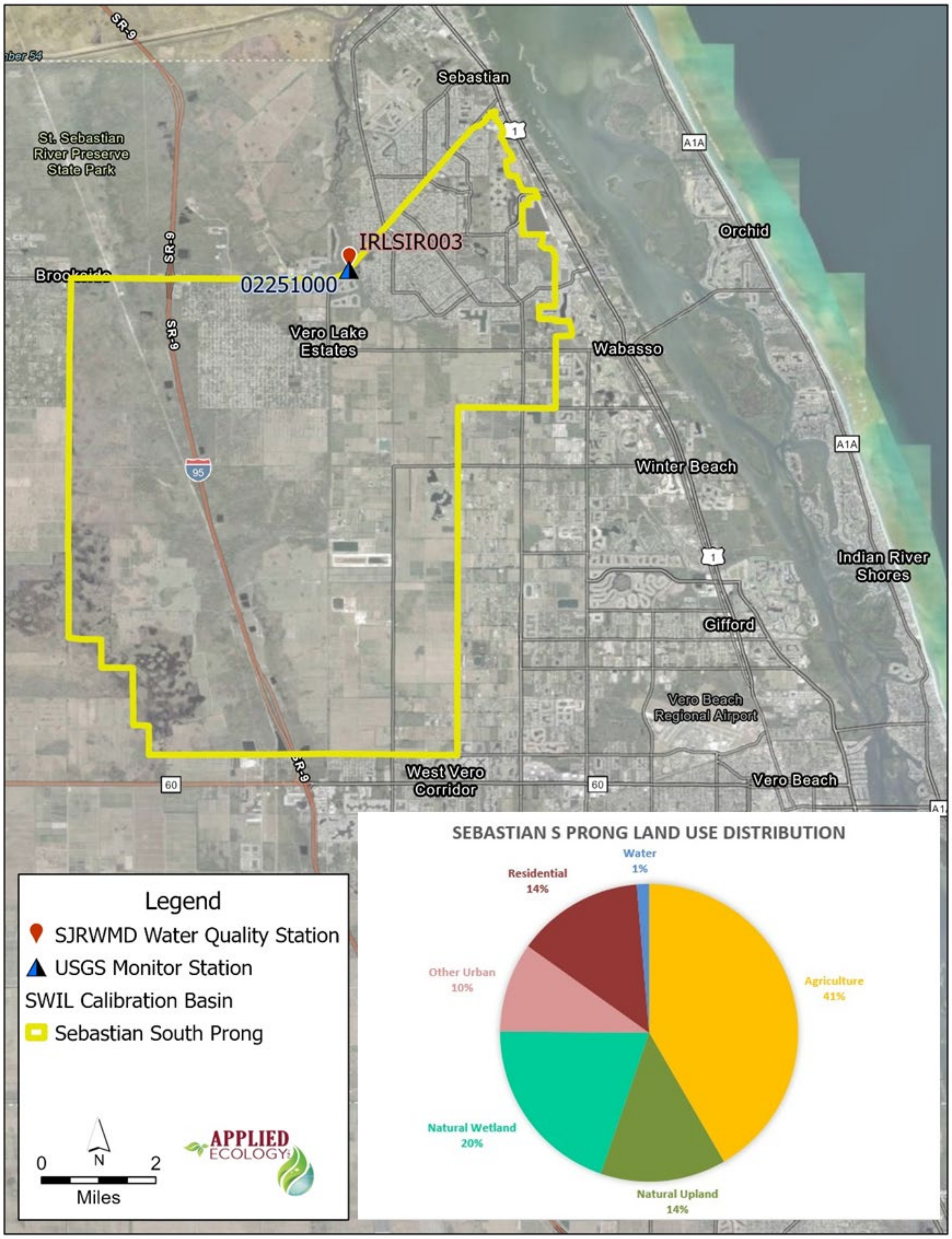


Figure 16: Sebastian South Prong basin

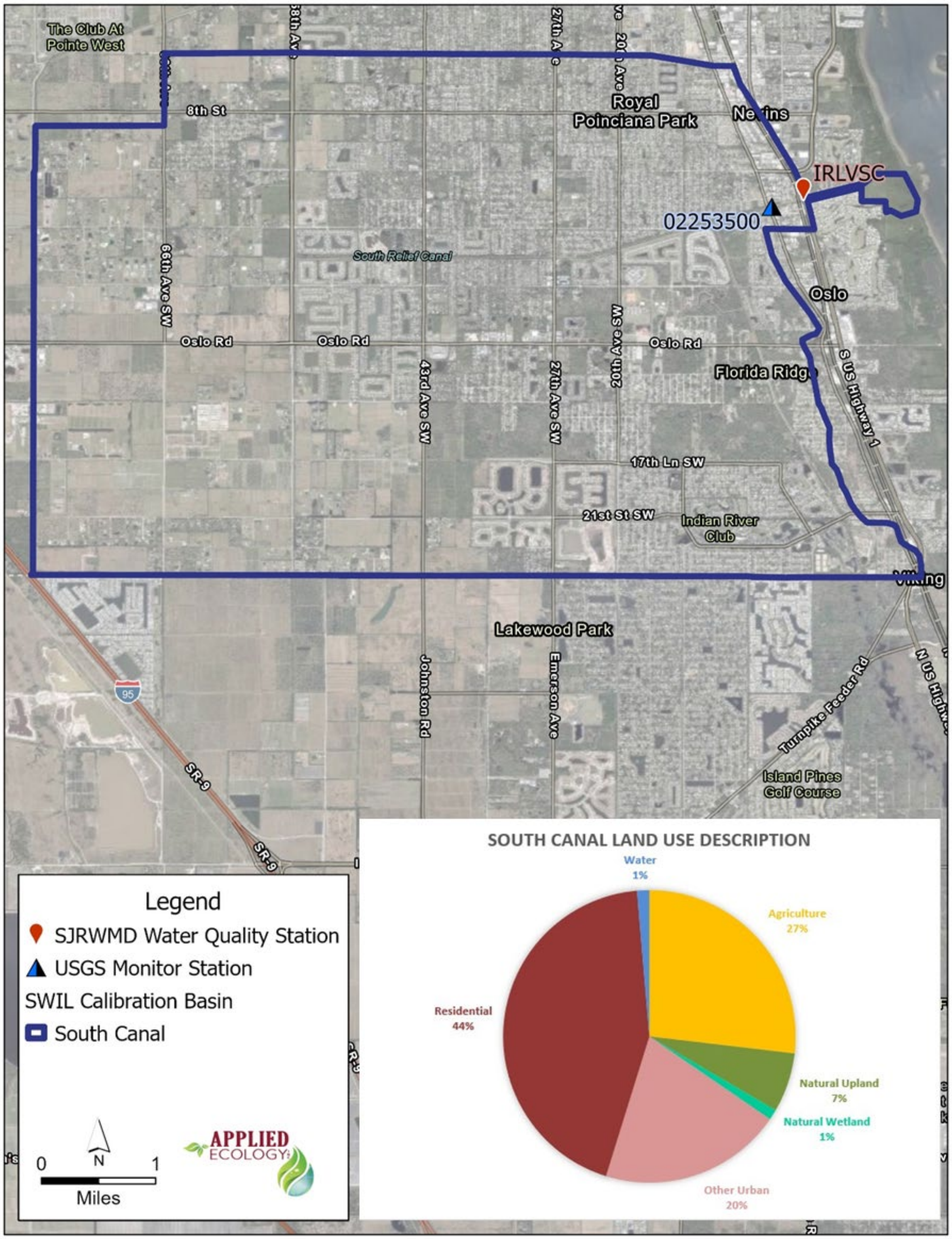


Figure 17: Vero Beach South Canal basin

BASIN CHARACTERIZATION

The Eau Gallie River, Sebastian North Prong, and Sebastian South Prong boundaries were updated using a Brevard County 2019 revision of their drainage basins. This review was based on the 2007 Florida Department of Emergency Management Light Detection and Ranging (LiDAR) and Brevard County Natural Resources Stormwater Management data. The original Eau Gallie River SWIL model sub-basin included areas that were downstream of the USGS gauging station and SJRWMD water quality monitoring stations. Using the Brevard County drainage basin revision, the Eau Gallie sub-basin was significantly adjusted to reflect the stakeholder input. The Sebastian North and South Prongs were adjusted to a lesser extent and largely were the result of more updated hydrologic basins of unincorporated areas and municipalities between the original sub-basin delineation and Brevard County review.

Each basin outlined above contained the necessary water quality monitoring station (SJRWMD, 2021) and stream flow gage station (USGS, 2022) with the exception of the Big Flounder Creek basin. To compensate for this shortcoming, supplemental rainfall data were obtained from the National Oceanic and Atmospheric Administration and National Weather Service jointly operated Next Generation Weather Radar (NEXRAD) system supplied to and used by SJRWMD (National Atmospheric and Oceanic Administration, 2021). Using a technique demonstrated by Graves et al. (2004), rainfall data were used in place of streamflow gage data to segregate direct runoff conditions from baseflow by establishing when "qualified rain events, defined as one preceded by at least 72 hours of no rain and in which the amount of rain in inches was between the 25th and 75th percentile of historic rainfall amounts for the basin" took place. For the purposes of their study, Graves et al. determined rainfall criteria "to be a rain event that delivered between 18 and 38 mm (0.70 and 1.50 in) of rain in a widespread pattern across most of the basin" (2004). For the purposes of the SWIL model, once qualified rain events were determined from the rainfall data for the Big Flounder Creek basin, baseflow conditions were assumed in water quality data sample dates if those dates were not within 72 hours of a qualified rain event and rainfall data were less than 0.7 inches.

As mentioned in the preceding paragraphs, the basins selected depict an accurate representation of land use distributions within the IRL (see Figure 18). Basins such as Fellsmere and Sebastian South Prong are dominated by agriculture, South Canal and Eau Gallie are dominated by residential, and Crane Creek and Big Flounder Creek are dominated by other urban areas including commercial land use. In addition, Sebastian North prong provides a depiction of the natural areas of the IRL, with almost 50% of its land use in natural wetlands and natural upland environments.

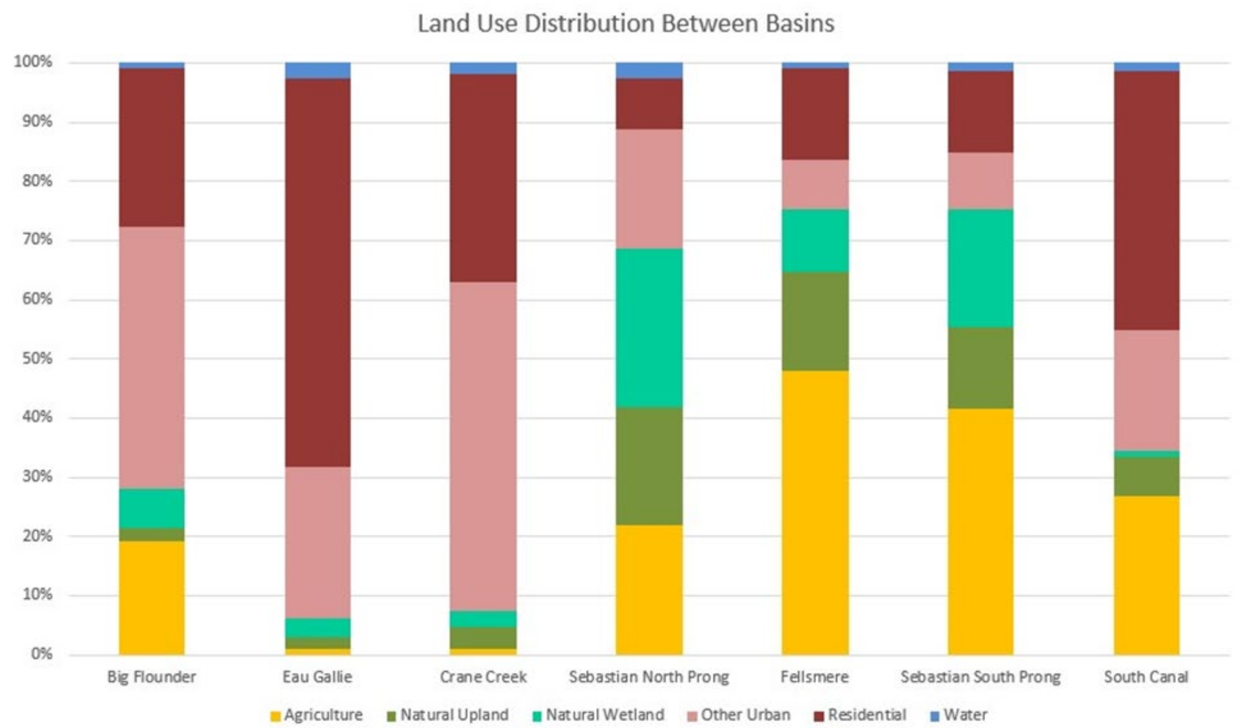


Figure 18: Comparison of land use distribution between the different basins

BASEFLOW SEGREGATION

In addition to groundwater quality data from monitoring wells throughout the IRL watershed, baseflow, or water that seeps into the IRL horizontally from groundwater (USGS, 2018), was measured. The purpose of this step was to analyze TN and TP levels in baseflow in comparison to nutrient EMCs from the groundwater monitoring wells. The methodology followed Harvey Harper and David Baker's (2016) steps of analyzing water quality data downloaded from SJRWMD Environmental Data Retrieval Tool (SJRWMD, 2021) (see Figures 19 and 20). and streamflow data downloaded from the USGS National Water Dashboard (USGS, 2022) (see Figure 21).

Following Harper and Baker (2016), the Web-based Hydrograph Analysis Tool (WHAT) system, developed at Purdue University (Lim and Engel, 2004), was used to segregate downloaded streamflow data into direct runoff and baseflow. "WHAT is a web-based hydrograph separation tool hosted by Purdue University that can separate baseflow using three separation methods. The two-parameter method (Eckhardt, 2005) was selected for the hydrograph separations because it has been shown to most closely match manual baseflow separations" (Harper and Baker 2016).

Once the data were segregated, a threshold of "75% was selected after reviewing the available baseflow and runoff data resulting from percentages ranging from 75–90%. The use of a selection criterion greater than 75% virtually eliminated the runoff-dominated samples since baseflow is such a significant and constant input" (Harper and Baker, 2016). If discharge from the tributary attributed to baseflow was 75% or more, that collected sample from the hydrograph was determined to be a baseflow sample (Harper and Baker, 2016). If discharge from the tributary attributed to direct runoff was 75% or more, that collected sample from the hydrograph was determined to be a direct runoff sample (Harper and Baker, 2016) and was not used for the purposes of this task. In addition, any sample that fell in between these two parameters was considered a mixture of baseflow and direct runoff and was not used for the purposes of the analysis included in this task.

The dates associated with sample collection events attributed solely to baseflow were then compared to collection dates for water quality from associated SJRWMD water quality monitoring sites on the same stream. If the dates matched, those EMCs were selected as pertaining to baseflow for the purposes of the subsurface flow EMC update (see Figure 22).

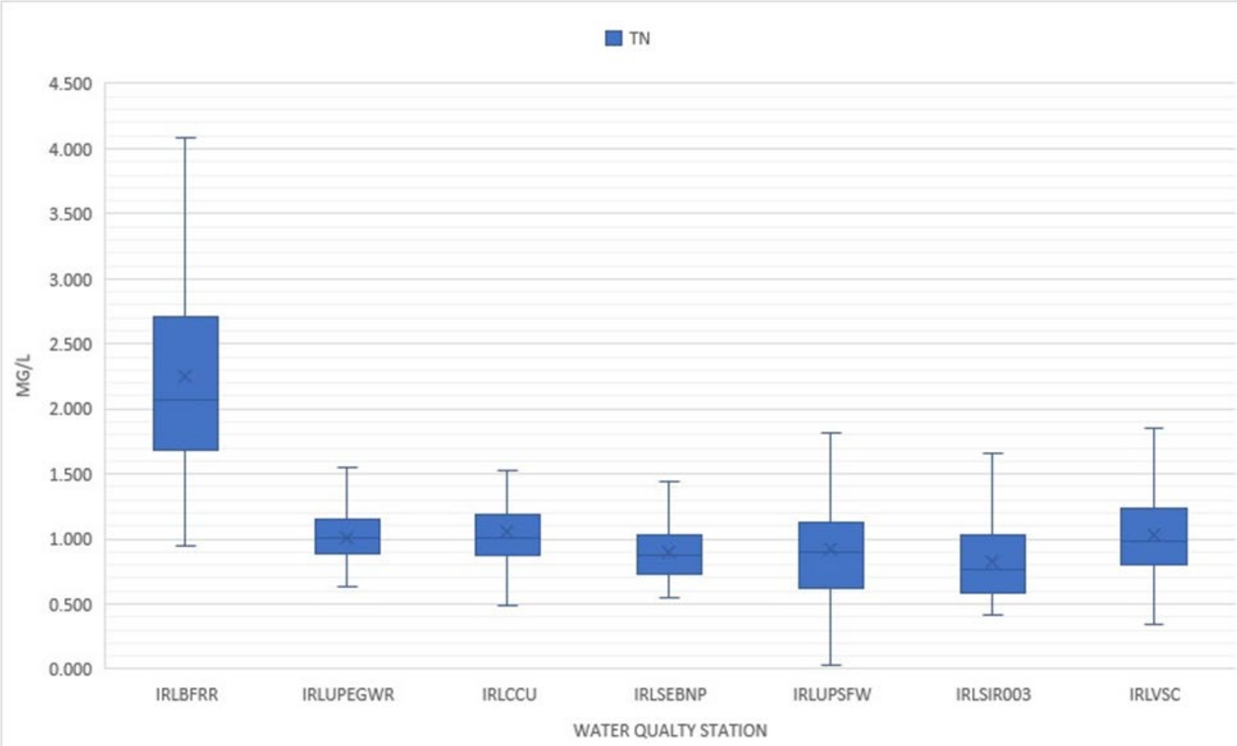


Figure 19: Overall water quality statistics for TN concentrations for years 2010 to 2020

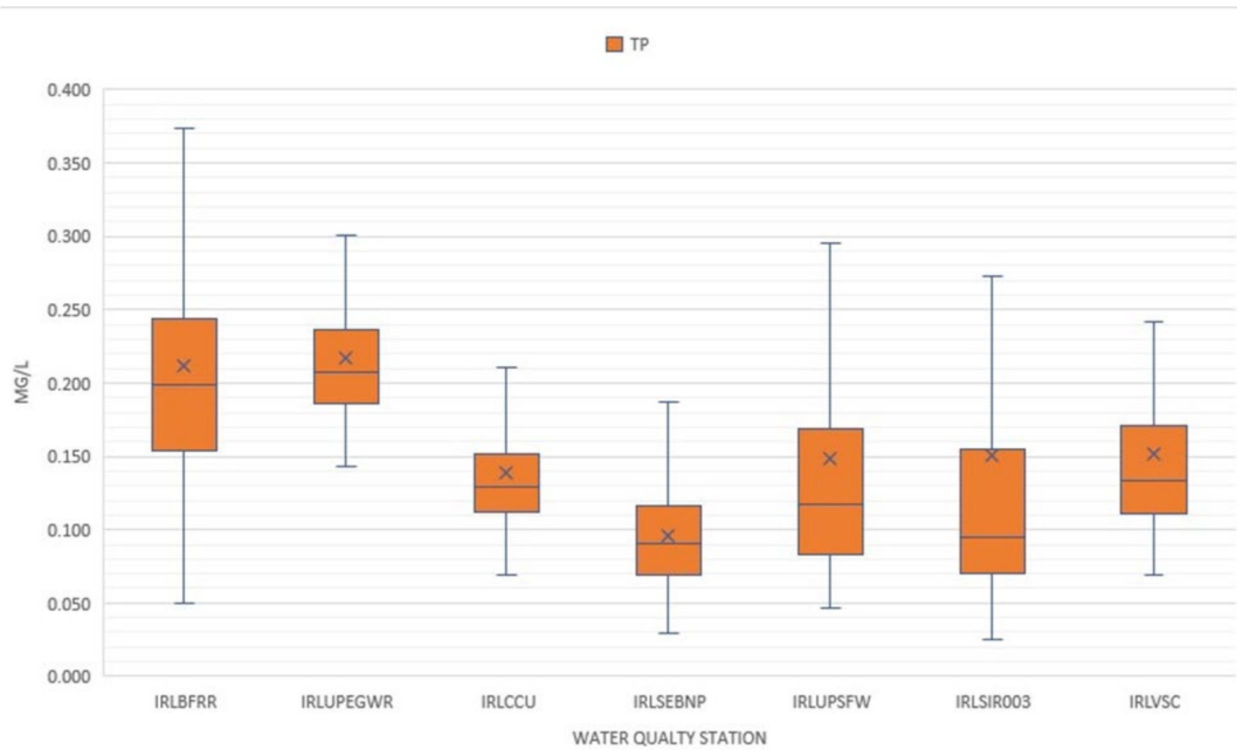


Figure 20: Overall water quality statistics for TP concentrations for years 2010 to 2020

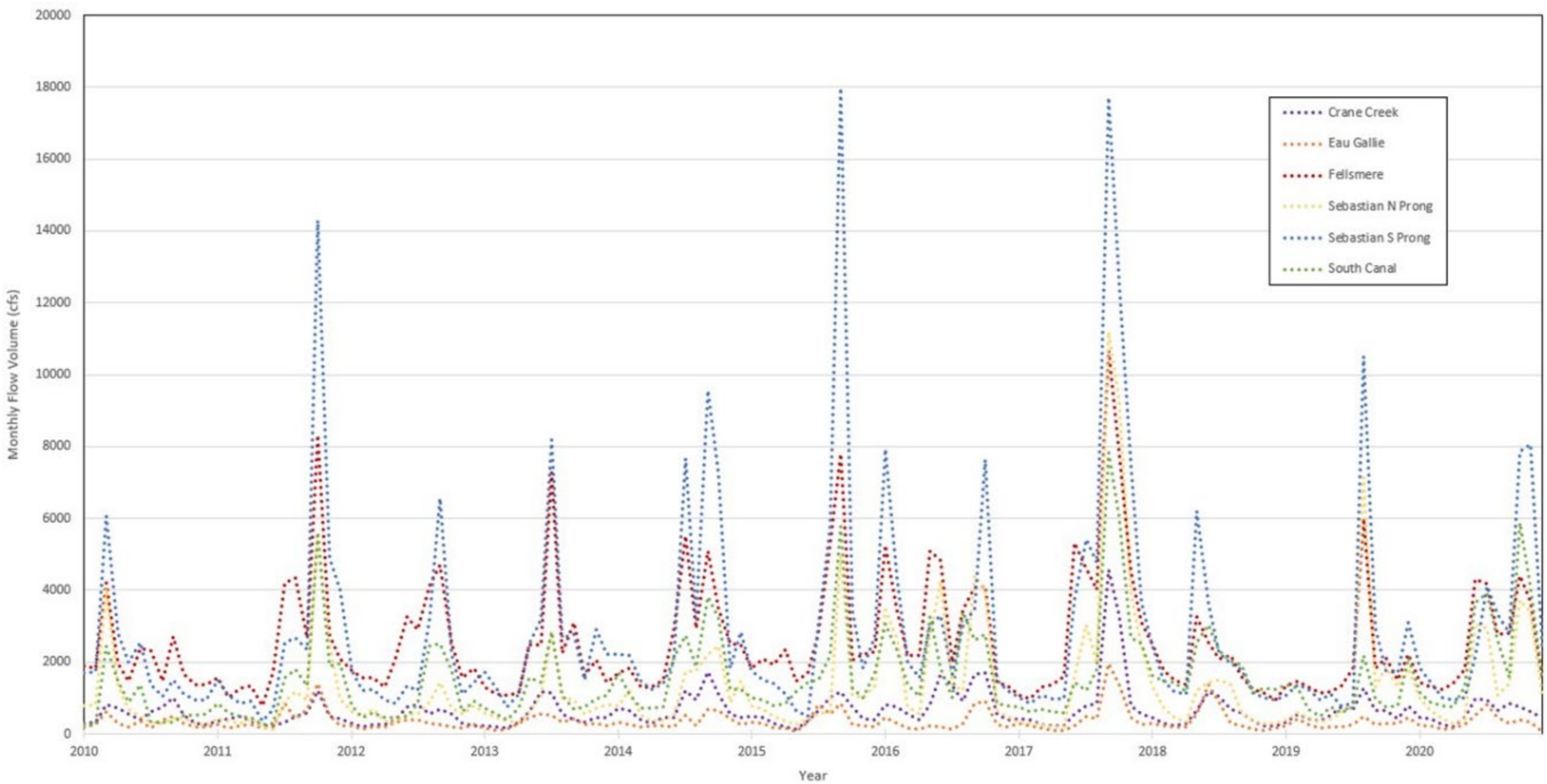


Figure 21: Total monthly stream flow for each gage station between 2010 and 2020

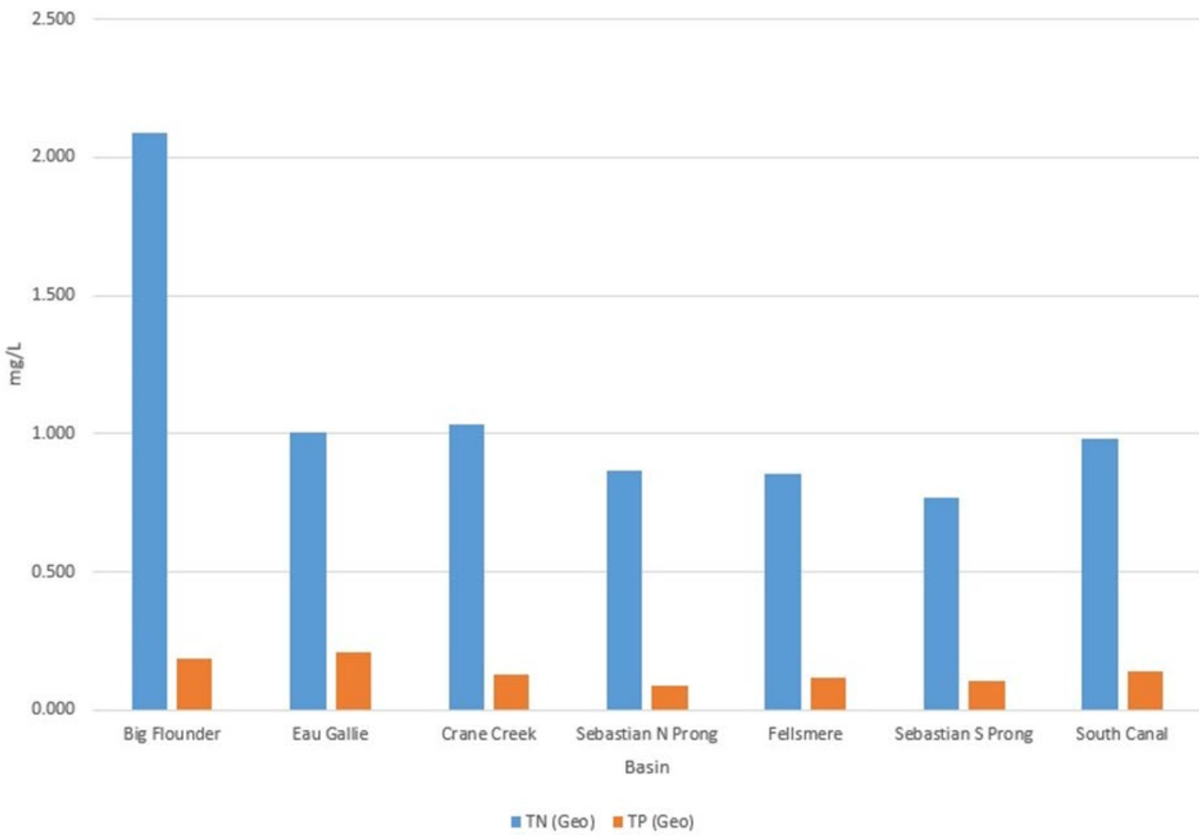


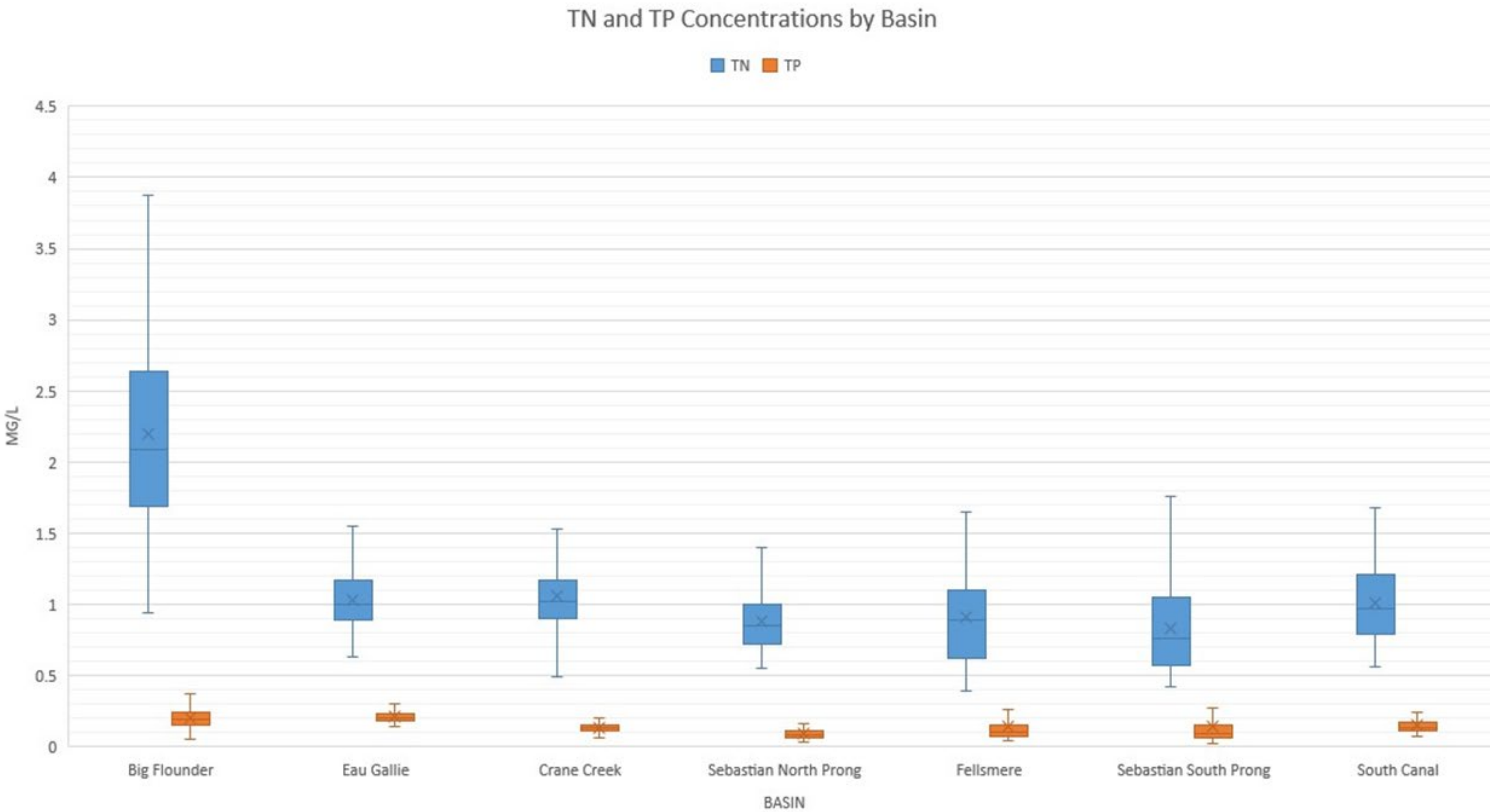
Figure 22: Geometric means of TN and TP concentrations attributed for each basin for baseflow events

Groundwater and Segregated Flow Comparison

Comparisons between the EMCs produced from groundwater monitoring wells and baseflow suggest nutrient concentrations accumulated in wells are much higher than those entering the lagoon from baseflow. Differences in the nutrient concentrations may be attributed to differences in sampling locations, frequency of samples collected, and sampling methodology. Groundwater wells provide a snapshot of the locations at the given moment a sample is collected. Water quality measured in combination with streamflow to capture nutrient concentrations related to baseflow provide an alternative and more consistent picture of the water quality entering the IRL.

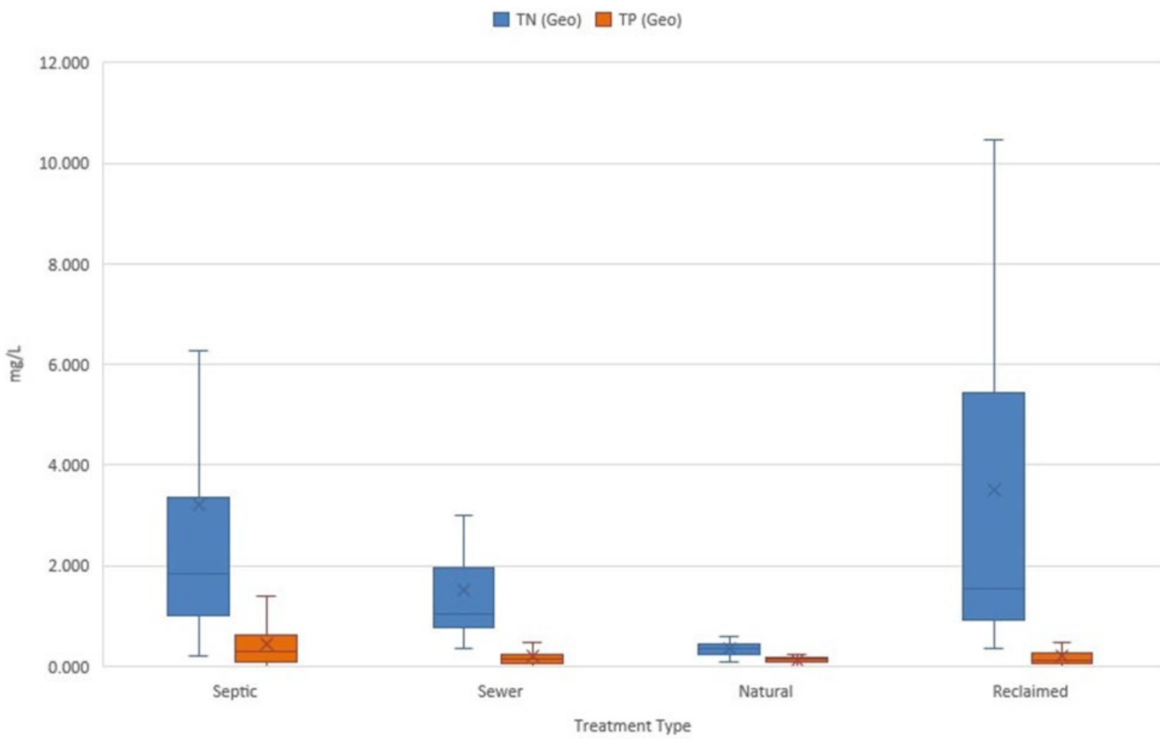
In the baseflow-specific data, TN concentrations in the Big Flounder Creek basin were more than double the concentration of all the other basins (see Figure 23). TP concentrations across the basins were more consistent, ranging between 0.08 milligrams per liter (mg/L) in the Sebastian North Prong basin to 0.20 mg/L in the Eau Gallie Creek basin. An analysis of groundwater wells by treatment type found abnormally high TP concentrations in septic system treatment areas compared to other treatment areas. In septic system treatment areas, TP concentrations were five times higher than in sewer and natural/control areas, and three times higher than reclaimed treatment areas. Septic and reclaimed areas also had three times the amount of TN compared to sewer and natural/control areas (see Figure 24).

The differences in water quality from groundwater wells and baseflow data are consistent with results seen in other studies that measure nutrient concentrations in groundwater versus stream flow. Oberdorfer et al. (1990) found "inorganic nitrogen and phosphorus species the concentrations are generally greater in groundwater… where they can exceed stream concentrations by an order of magnitude." The importance of measuring baseflow as a component of organic and inorganic nutrient concentrations in coastal environments is further confirmed by McKenzie et al. (2019) where "total groundwater dissolved nutrient fluxes were significantly greater than those sourced from stream surface runoff" in a study to measure nutrient concentrations in three urban streams in Kāne'ohe Watershed, Hawai'i. As outlined earlier, subsurface flows into the IRL account for most of the freshwater discharges (Kim, 2003). Further analysis is needed to understand spatially why some groundwater wells contain vastly higher concentrations of nutrients compared to others. In addition, further investigations into the differences in basins that account for different concentrations of nutrients are needed.



	Big Flounder		Eau Gallie		Crane Creek		Sebastian North Prong		Fellsmere		Sebastian South Prong		South Canal	
	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP
Min	0.945	0.050	0.439	0.032	0.493	0.004	0.555	0.039	0.391	0.046	0.420	0.025	0.567	0.071
Q1	1.691	0.152	0.896	0.184	0.900	0.110	0.721	0.067	0.626	0.078	0.568	0.061	0.791	0.109
Med	2.085	0.195	1.006	0.208	1.025	0.130	0.856	0.088	0.893	0.107	0.764	0.095	0.975	0.130
Q3	2.637	0.242	1.176	0.235	1.175	0.150	1.005	0.110	1.098	0.154	1.055	0.156	1.214	0.172
Max	4.089	0.649	1.645	0.415	2.861	0.309	1.579	0.245	2.110	0.791	1.760	1.030	1.685	0.464
Geomean	2.086	0.188	1.004	0.208	1.035	0.128	0.864	0.085	0.855	0.116	0.770	0.108	0.982	0.139

Figure 23: TN and TP concentrations by basin specifically for baseflow events (statistical outliers removed for visibility)



	Septic		Sewer		Natural		Reclaim	
	TN	TP	TN	TP	TN	TP	TN	TP
Min	0.216	0.008	0.363	0.009	0.093	0.009	0.360	0.009
Q1	1.004	0.083	0.757	0.058	0.240	0.088	0.927	0.056
Med	1.831	0.286	1.052	0.136	0.369	0.148	1.535	0.106
Q3	3.359	0.614	1.965	0.224	0.442	0.171	5.435	0.268
Max	18.610	2.404	3.948	0.644	0.602	0.239	12.327	1.098
Average	3.223	0.456	1.521	0.195	0.349	0.132	3.513	0.197

Figure 24: TN and TP concentrations of groundwater monitoring wells by treatment type (statistical outliers removed for visibility). Averages reflect averages of geometric means.

EMC RECOMMENDATION

It is clear from the data that high levels of TN and TP are entering the IRL. The data also show a distinction between TN and TP concentrations averaged through the second decade of the 21st century in selected subbasins compared to EMCs selected in the previous SWIL model (see Figure 25). This is in addition to the higher concentrations of TN and TP sampled in groundwater wells during the same decade compared to the previous SWIL model EMCs (see Figure 26).

Averaging the geometric means from the selected basins between 2010 and 2020 yields a TN value of 1.085 mg/L and a TP value of 0.139 mg/L. That amounts to about a 22% increase in TN compared to the previous model value of 0.886 mg/L, and a 24% increase in TP compared to the previous model value of 0.112 mg/L. TN concentrations in the groundwater monitoring wells are 363% higher in areas treated by septic systems and 396% higher in areas treated with reclaimed water, and 72% higher in areas treated with sewer systems compared to the previous model value. TP concentrations in groundwater monitor wells are 300% higher in areas treated with septic systems, and 175% higher in areas treated with reclaimed water and sewer systems compared to the previous model value. However, groundwater concentration data from wells in the watershed are anticipated to be higher than the concentration seeping into the Lagoon via subsurface flow, due to attenuation during transport.

A trend highlighted during the baseflow segregation analysis is the distinctly higher concentrations of TN in the Big Flounder Creek basin compared to the other basins. Although the study did not include any other basins within the North IRL or Banana River Lagoon, additional analysis is needed within those locations to see if the same trends captured in the Big Flounder Creek basin persist in other basins. Without any justification to remove it as an outlier, the geometric TN and TP means of this basin, the only basin representing the North IRL, was included in the average baseflow values recommended to be used in the SWIL model update.

The results of this memorandum recommend applying the average of geometric means for TN and TP from baseflow values derived from the selected basins to all anthropogenic (developed) lands. After evaluating the distinctly lower TN groundwater concentration values measured in natural lands via wells placed in non-developed areas, we recommend using these lower values in appropriate locations throughout the watershed. Therefore, while TN and TP groundwater concentrations values applied to anthropogenic lands will be 1.085 mg/L and 0.139 mg/L respectively, those applied to undeveloped or natural lands will be 0.349 mg/L and 0.132 mg/L respectively. For reference, the current model's land use distribution is 9.7% agriculture, 9.98% natural upland, 12.8% natural wetland, 27.56% residential, 17.75% other urban, and 22.22% water. Lower concentration values will be applied to about 22.8% of the model's watershed.

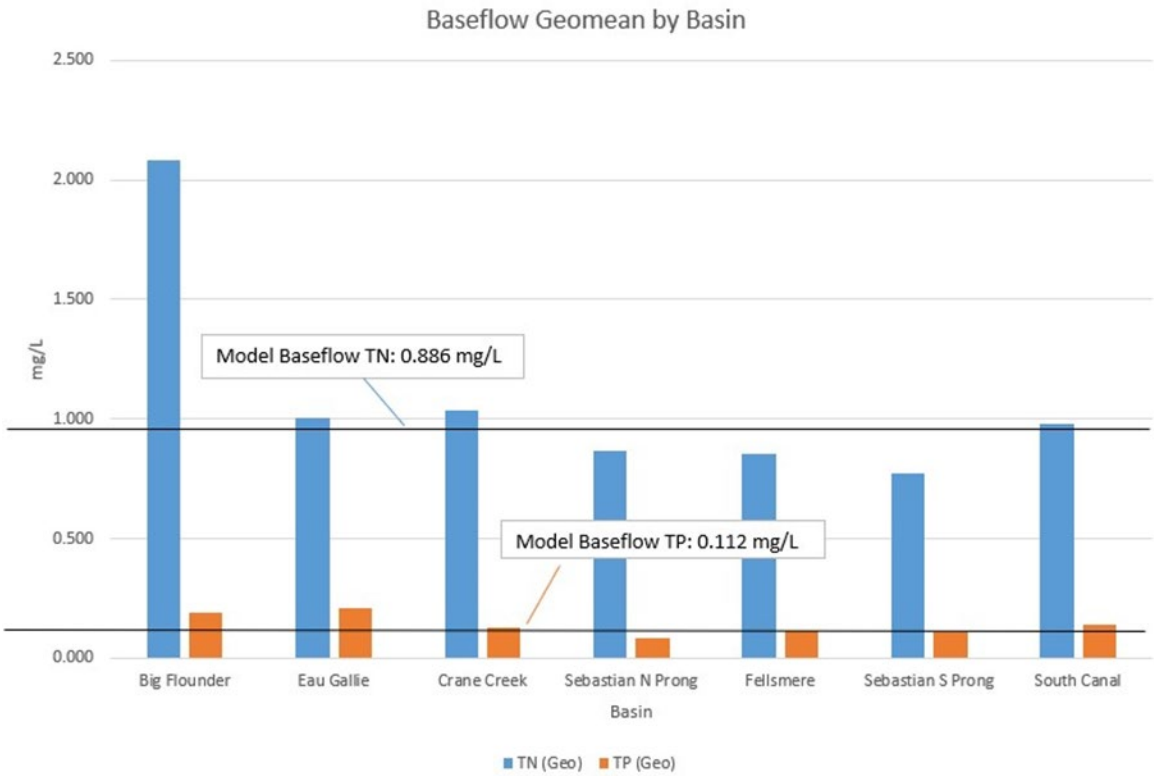


Figure 25: Overall baseflow geomeans of TN and TP by basin

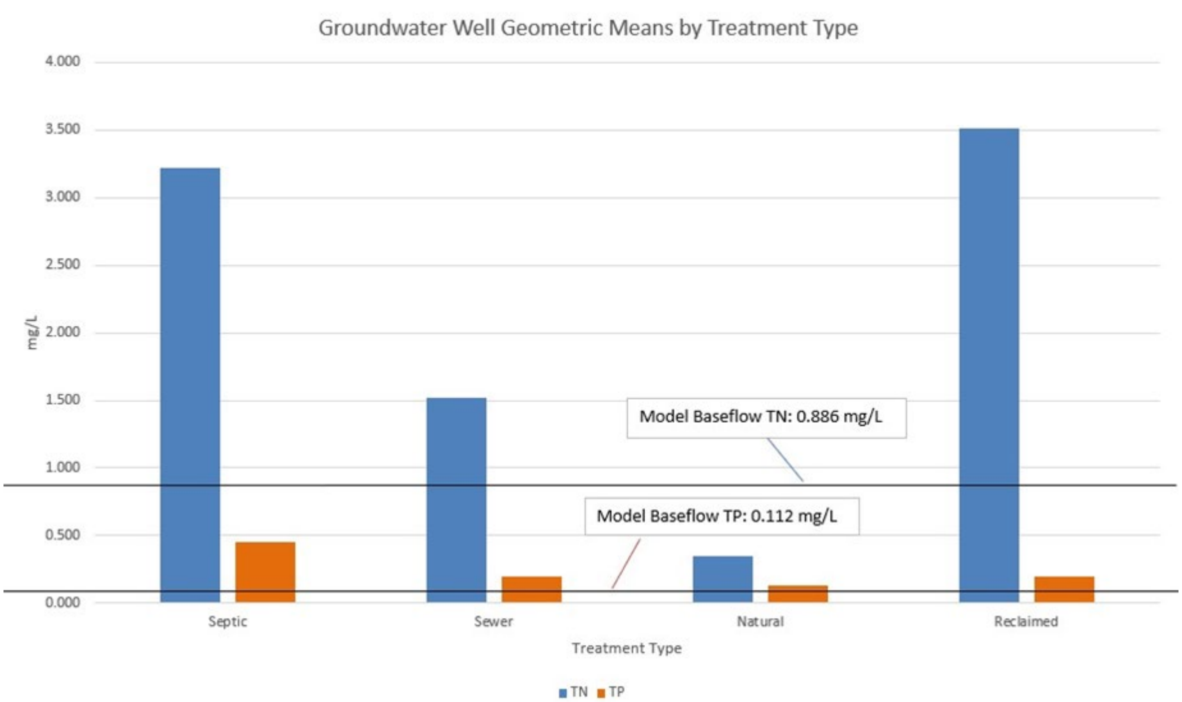


Figure 26: Overall groundwater geomeans of TN and TP by treatment type

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