ALLOCATION AND NATURAL BACKGROUND SWIL 5.0 MODEL SIMULATION RESULTS

DRAFT MEMORANDUM

TASK 8 (ALLOCATION SIMULATION) AND TASK 9 (NATURAL BACKGROUND CONDITION) OF THE SPATIAL WATERSHED ITERATIVE LOADING MODEL UPDATE

PREPARED FOR:

Florida Department of Environmental Protection

PREPARED BY:

Applied Ecology Inc.

July 12, 2024

EXECUTIVE SUMMARY

The goal of the Spatial Watershed Iterative Loading (SWIL) model is to use input parameters derived from observed datasets to create a spatial and temporal representation of nutrient loads and volumes for the Indian River Lagoon (IRL) watershed. The SWIL model estimates the volume of water, total nitrogen (TN), and total phosphorus (TP) loads discharged by segmenting the hydrological and nutrient contributions of subsurface flow (SSF) and direct rainfall runoff (DRO). The SWIL model was developed originally in 2011-2014 as part of the Brevard County IRL Total Maximum Daily Load (TMDL) refinement effort and recently adopted by the Florida Department of Environmental Protection (DEP) for estimating nutrient baseloads for stakeholders in the North IRL, Central IRL, and Banana River Lagoon (BRL). The contributions of portions of a basin are determined by land use, soil type, precipitation, evapotranspiration (ET), peer-reviewed event mean concentrations (EMCs), and runoff coefficients (ROCs). The SWIL model is designed to be consistently updated with more current data so that it can be a foundation for the Basin Management Action Plan (BMAP) process.

This memorandum is the fourth in a series summarizing an effort to update and evaluate SWIL 5.0. The first memorandum outlined the process and results of updating the static model inputs (e.g., land use, soils, and stormwater treatment systems) and dynamic inputs (e.g., rainfall, evapotranspiration, DRO EMCs, and direct ROCs) to reflect the IRL conditions between 2010 to 2020. The second memorandum examined the TN and TP EMCs for SSF and DRO. The third memorandum synthetized the methods used to develop the appropriate hydrological and water quality calibration factors that produce the best fit with available measured hydrological and water quality data from 2010 to 2020. Under the current Tasks 8 and 9, Applied Ecology Inc. (AEI) was contracted to complete the following:

- Update the SWIL for the BRL, North IRL and Central IRL BMAPs to produce calibrated outputs for load allocations, based on 2020 land use conditions, to guide the 2025 BMAP updates.
- Provide a natural background condition simulation for the BRL, North IRL and Central IRL BMAPs, based on 1943 best available land use conditions.

The purpose of this memorandum is to provide a summary of Land Use Land Cover (LULC) of the IRL from 1943 and 2020 data, as well as summarize the modeled outputs from the SWIL 5.0 update. Load estimations were performed on a 1943 LULC layer to simulate historical baseline conditions and then performed on 2020 data to create an updated IRL nutrient loading estimate. The SWIL 5.0 load estimations were calculated utilizing calibrated ROCs and EMCs provided in the third memorandum. Lastly, the SWIL 5.0 model results were then compared to the previous SWIL 4.0 model results.

The SWIL 5.0 natural background condition simulation based on 1943 data determined that undeveloped land accounts for 88% of the land use, agriculture accounts for 10%, high intensity development accounts for 2%, and low intensity development accounts for 1% of land within the IRL watershed. The Central IRL had the highest runoff volumes of 465,998,252 cubic meters per year (m^3/year), as well as the highest TN and TP loading contributions of 754,580 pounds per year (lbs/year) and 66,694 lbs/year, respectively. The BRL had the lowest volumes of 39,223,094 m^3/year, as well as the lowest TN and TP loading contributions of 56,141 lbs/year and 2,696 lbs/year, respectively.

The SWIL 5.0 2020 simulation estimated that undeveloped land accounts for 66% of the land use, high intensity development accounts for 16%, and both agriculture and low intensity development accounts for 9% each, within the IRL watershed. Undeveloped LULC decreased from historical data, while both high and low intensity development increased. Total volume and nutrient loadings also increased from 1943 data. Similar to the natural background condition simulation, the Central IRL had the highest volume and nutrient loading. The Central IRL had volumes of 586,265,515 m^3/year, and TN and TP loading contributions of 1,209,702 lbs/year and 161,493 lbs/year, respectively. The BRL had the lowest volumes of 51,355,305 m^3/year, as well as the lowest TN and TP loading contributions of 98,555 lbs/year and 10,847 lbs/year, respectively.

Compared to the SWIL 4.0, the newer SWIL 5.0 iteration estimated considerably lower volume and nutrient loading due to certain variables. The change in classification of LULC between SWIL 4.0 and SWIL 5.0 had an impact on loading throughout the IRL, after a more refined approach for LULC updates and thousands of acres being reclassified. Additionally, the updated SWIL model included a new hydrological calibration and the implementation of an EMC calibration for TN and TP, in which the DRO EMC calibration process resulted in decreases in TN and TP for all development types and significant decreases for some natural upland land uses (i.e. scrub, upland flatwoods, etc.). The combination of LULC updates and EMC calibration resulted in lower, calibrated loading estimations for the SWIL 5.0.

AEI has delivered this memorandum to fulfill Tasks 8 and 9 out of 12 tasks under this scope of work. The overall results from 2020 SWIL 5.0 indicate that LULC and loadings have increased from 1943 but are lower than the SWIL 4.0 estimations. The results presented within this memorandum can assist the DEP in developing updated allocations associated with the BRL, North IRL, and Central IRL BMAP updates. These will also be used by stakeholders to prioritize areas of concern and identify appropriate BMPs.

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AEI	Applied Ecology, Inc.
API	Aerial photointerpretation
BMAP	Basin Management Action Plan
BMPs	Best management practices
BRL	Banana River Lagoon
CCSFS	Cape Canaveral Space Force Station
DRO	Direct runoff
EMC	Event mean concentration
ET	Evapotranspiration
FDACS	Florida Department of Agriculture and Consumer Services
DEP	Florida Department of Environmental Protection
FLUCCS	Florida Land Use and Cover Classification System
IDW	Inverse distance weighting
IRL	Indian River Lagoon
JPL	Jet Propulsion Laboratory
lbs/year	Pounds per year
LET	Load Estimation Tool
LULC	Land Use Land Cover
m^3/year	Cubic meters per year
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NEXRAD	Next Generation Weather Radar
NRCS	Natural Resources Conservation Service
NSE	Nash-Sutcliffe Efficiency
NTSG	Numerical terradynamic simulation group
PAO	Property appraisers' office
PBIAS	Percent Bias
POR	Period of record
PSFB	Patrick Space Force Base
ROC	Runoff coefficients
SFWMD	South Florida Water Management District
SJRWMD	St. Johns River Water Management District
SNP	Sebastian North Prong
SSF	Subsurface Flow
SSP	Sebastian South Prong
SWIL	Spatial Watershed Iterative Loading
TMDL	Total Maximum Daily Load
TN	Total nitrogen
TP	Total phosphorus
USDA	United Stated Department of Agriculture
USGS	United States Geological Survey
WHAT	Web-based hydrograph analysis tool
WMD	Water management district
WSS	Web Soil Survey

1 INTRODUCTION

The goal of the SWIL model is to use input parameters derived from observed datasets to create a spatial and temporal representation of nutrient loads and volumes for the IRL watershed. The SWIL model estimates the volume of water and TN and TP loads discharged by segmenting the hydrological and nutrient contributions of SSF and DRO. The SWIL model was developed originally in 2011-2014 as part of the Brevard County IRL TMDL refinement effort and recently adopted by the DEP for estimating nutrient baseloads for stakeholders in the North IRL, Central IRL, and BRL. The contributions of portions of a basin are determined by land use, soil type, precipitation, ET, peer-reviewed EMCs, and ROCs. The SWIL model is designed to be consistently updated with more current data so that it can be a foundation for the BMAP process.

This memorandum is the fourth in a series summarizing an effort to update and evaluate SWIL 5.0. The first memorandum outlined the process and results of updating the static model inputs (e.g., land use, soils, and stormwater treatment systems) and dynamic inputs (e.g., rainfall, evapotranspiration, DRO EMCs, and direct ROCs) to reflect the IRL conditions between 2010 to 2020. The second memorandum examined the TN and TP EMCs for SSF and DRO. The third memorandum synthetized the methods used to develop the appropriate hydrological and water quality calibration factors that produce the best fit with available measured hydrological and water quality data from 2010 to 2020.

1.1 PURPOSE AND OBJECTIVES

The purpose of this memorandum is to produce and synthetize LULC of the IRL from 1943 and 2020 data, as well as use these inputs to estimate volume and nutrient loading (TN and TP) into the IRL. Load estimations included both a 1943, or "Natural background condition" simulation to replicate historical baseline conditions, as well as the most updated loadings from 2020 data. The load estimations are produced using the most up-to-date calibrated SWIL 5.0 model. The SWIL 5.0 model results are included in a general IRL-wide comparison to the SWIL 4.0 model results.

Under the current tasks, AEI was contracted to update the SWIL for the BRL, North IRL, and Central IRL to produce outputs for load allocations for the 2025 IRL BMAP update. This report presents the results from the most recent model iteration, SWIL 5.0 and compares it to the previous SWIL 4.0 iteration.

2 PROJECT METHODS

This section covers the general methodologies of both model input layer development and model calibration, as well as overall methodologies used to produce the SWIL 5.0 model iteration. Detailed methodologies for the calibration can be found in the previous Task 6 and 7 memorandum (AEI, 2023). The major inputs used in the SWIL model include LULC, soil hydrologic data, precipitation, ROCs, EMCs ET, and treatments. **Figure 1** presents the SWIL 5.0 model approach, outlining the input layers used to produce the most accurate loading estimations.

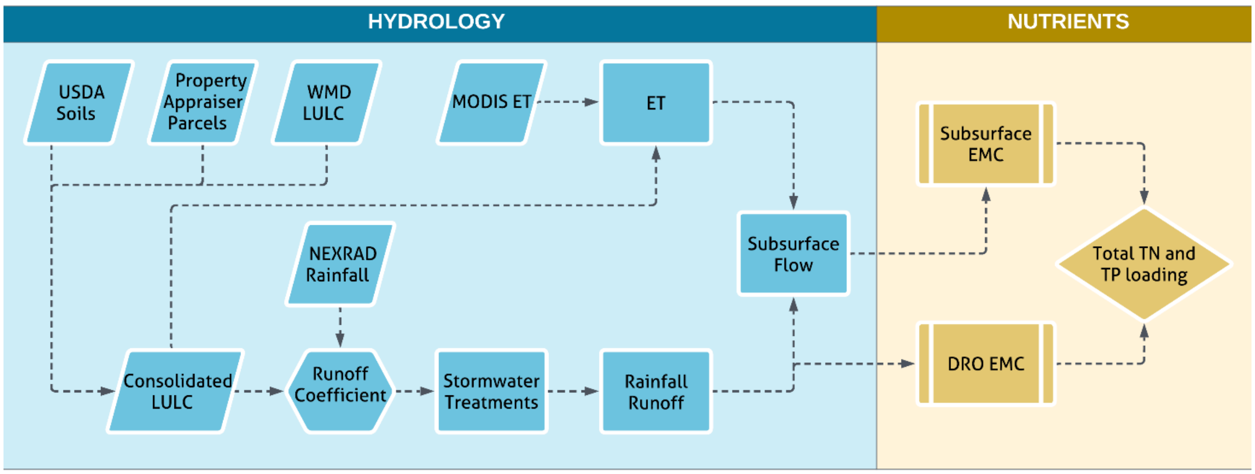

Figure 1. Spatial Watershed Iterative Loading (SWIL) Model Data Processing Diagram

As there were large-scale land use changes in the IRL watershed since the original calibration and changes in the SSF and DRO components of the model based on newly available data, calibration factors were regenerated for SWIL 5.0 model.

The main objectives are to produce loading results from two model simulations from the SWIL 5.0 iteration. The model simulations include the 1943 natural background condition simulation, as well as the 2020 simulation. Information for each of the simulations, methodologies for model inputs, and calibration requirements are described in the following sections.

2.1 NATURAL BACKGRUND CONDITION SIMULATION

The natural background condition simulation using the SWIL 5.0 model is based on 1943 conditions. The 1943 natural loading is considered a baseline or "background" loading. Data for 1943 conditions was sourced from St. Johns Water Management District (SJRWMD) and then validated against available aerial photography from around 1943. The natural background condition simulation was performed due to the assumption that natural loads may be independent from loading influenced by anthropogenic factors.

2.2 2020 SIMULATION

The 2020 simulation using the SWIL 5.0 model iteration produces the volumes and nutrient loadings in its current state. AEI extensively reviewed existing data and evaluated all input required for the newest model iteration. The updated load allocations are used to prioritize watershed areas for management and identify appropriate best management practices (BMPs).

2.3 NUTRIENT LOADING ALLOCATION

The approach used in the SWIL 5.0 update was the same as the previous SWIL 4.0 BMAP update. To produce the baseload layers to allow estimating baseloads (and subsequently load reductions) from small BMPs, such as swales, relatively small input grid cells (50 X 50 meter) were used as input basins for a custom allocation model simulation. AEI used a previously developed polygon grid layer that covers the entire BRL, North IRL, and Central IRL BMAP areas and adapted it to the currently approved watershed model area.

Like the SWIL 4.0 loading allocation, only the most recent land use layer was used. The 2020 land use created in Task 1 was selected as it would provide the stakeholders with the most current conditions to plan for. A set of monthly mean rainfall and ET rasters were generated from the entire approved model temporal and spatial extent, then resampled to a 10 X 10-meter cell size. This allowed the allocation model simulation to only include one year of watershed loads, using representative period of record (POR) rainfall means and the latest available previously developed land use cover.

POR means and standard deviations were calculated for the annual and dry season (January – May) results. One standard deviation was added to the mean annual volumes and loads and this total was normalized by each individual grid cell area. Normalizing is calculated by converting the SWIL estimated loading from pounds per meter to pounds per acre. Seasonal mean volumes and loads were independently normalized by grid cell area as well. Grid cells excluded from the normal simulation due to being marginally inside the watershed model domain were assigned appropriate volumes and loads based on the normalized area within the model domain. Normalized values were associated with their corresponding grid layer; annual SSF and direct runoff values created the annual mean baseload product, and dry season SSF and direct runoff values were associated with a separate dry season baseload product. Summary inputs by sublagoon for total volumes and nitrogen and phosphorus loads are provided in this report.

2.4 SWIL INPUTS

2.4.1 LAND USE LAND COVER (LULC)

The LULC layers developed during Task 1 were used for model calibration (AEI, 2022a). The general methodology implemented involved the following series of steps: 1) obtain property appraiser's office (PAO) Tax Parcel data, 2) convert county land use types to Florida Land Use and Cover Classification System (FLUCCS) codes using look-up comparison tables, 3) remove any non-urban land use types (i.e., types which were not residential, commercial, industrial, institutional, or recreational), and 4) substitute water management district (WMD) data for non-urban land use types (i.e., agriculture, natural lands, and other use types). Additional rules for certain parcel types as well as Florida Department of Agriculture and Consumer Services (FDACS) agricultural lands were also performed throughout the process. Additional aerial photointerpretation (API) of the LULC was performed to ensure the appropriate LULC designations were assigned.

2.4.2 TREATMENTS

Treatment layers in the SWIL 5.0 model update followed the same patterns of implementation as the previous model (AEI, 2022a), as well as the current calibration effort. In brief, county-specific PAO data from the LULC layer was used to identify treatment areas which were assigned various attributes, including treatment type (e.g., residential, commercial, etc.), year (based on year built), and classification (wet or dry) for each property. Layers were created for each respective land use layer (2010, 2015, and 2020), and additional API of the treatments were performed within each calibration basin.

2.4.3 SOIL HYDROLOGIC DATA

The soil hydrologic layers developed during Task 1 were used for model calibration (AEI, 2022a). Soil data were retrieved through United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey (WSS); specifically, to retrieve the hydrologic soil group which is associated with infiltration. The version used in SWIL 5.0 was published in 2020.

2.4.4 PRECIPITATION

Rainfall data were obtained from the National Weather Service Next Generation Weather Radar (NEXRAD) system supplied to the firm OneRain (www.OneRain.com) for the creation of radar rainfall estimates. OneRain utilizes the SJRWMD and South Florida Water Management District (SFWMD) rain gauge network to correct and validate the radar rainfall estimates across the IRL (Hoblit et al., 2003). The data were obtained from SJRWMD and summarized in monthly and annual rainfall averages (AEI, 2022a).

2.4.5 WEB-BASED HYDROGRAPH ANALYSIS TOOL (WHAT)

DRO and SSF data throughout the IRL watershed were retrieved from the SJRWMD Environmental Data Retrieval Tool (SJRWMD, 2021) and streamflow data downloaded from the United States Geological Survey (USGS) National Water Dashboard (USGS, n.d) and processed using the methodology as described in AEI 2022a. The Web-based Hydrograph Analysis Tool (WHAT) system (Lim and Engel, 2004) was used to segregate daily streamflow data into DRO and SSF via the two-parameter method (Eckhardt, 2005). After segregation, discharges events were classified (i.e., SSF, DRO, or mixed) utilizing previously established threshold criteria (AEI, 2022a). These data were then combined with the SJRWMD surface water sampling for TN and TP to generate estimates of the monthly mass of the nutrients entering the IRL.

2.4.6 DIRECT RUNOFF COEFFICIENTS (ROCS)

The SWIL 4.0 model's Soil Conservation Curve Number Method was retained for use in the SWIL 5.0 model update, including the calibration effort. Monthly values were calculated by land use and hydrologic soil type. It was assumed that hydrologic characteristics are similar between the EMC categories; therefore, new sub-segmented land use categories were assigned the same ROCs from existing categories. The resulting consolidated land ROCs use were kept and then used in the calibration effort. The ROC calibration effort compared the volume of modeled runoff against the WHAT estimated portion of runoff estimated at the USGS gauging stations. A calibration factor was generated for each ROC category to improve the accuracy of the model to estimate the volume of runoff.

2.4.7 EVAPOTRANSPIRATION (ET)

The calculation of ET for the SWIL model update followed Harper and Baker's 2016 interpolation method and was previously described in the Task 1 Memorandum (AEI, 2022a). The SWIL model estimates the total ET through the sum of the undeveloped pervious, developed pervious, and developed impervious area. Undeveloped pervious was derived from a satellite-based ET estimate, developed pervious by applying an empirically determined ET rate, and developed impervious was estimated by assuming that 0.1 inches of rain would evaporate per rain event. Calibration factors for all three types of ET were then generated by comparing the modeled estimate of ET against the SJRWMD rainfall and the USGS measured discharge.

The National Aeronautics and Space Administration (NASA) Moderate Resolution Imaging Spectroradiometer (MODIS) 8-day net satellite data were used as the starting point for creating the undeveloped pervious ET raster. The data gaps in "urban" areas were then filled in by a 0.1" ET abstraction and any other gaps were filled in by using Inverse Distance Weighing (IDW) Interpolation (ESRI, 2021).

2.4.8 DRO EVENT MEAN CONCENTRATIONS

Updates to the SWIL model DRO EMC values described in the Task 2 Memorandum (AEI, 2022b) were used for the calibration process. Original EMC values were evaluated for relation and appropriateness of representation for IRL conditions. Many studies contained within the database were conducted on basins in the IRL watershed, especially those focusing on agricultural land uses.

Specific changes were within agriculture, the "Pasture" category was changed to the more specific categories of "Improved Pasture" and "Unimproved Pasture" (or Rangeland). "Field Crops" was an additional category added. Finally, the "Agriculture" category is now referred to as "Other Agriculture" to better represent all EMC data which encompasses agricultural data that do not have their own category within the model. The TN and TP loading estimated by the model was then compared to the USGS and SJRWMD estimated loadings and used to generate calibration factors for each EMC.

2.5 CALIBRATION METHODS

2.5.1 CALIBRATION

For hydrological calibration, previously developed calibration factors used in SWIL 4.0 were initially used as inputs and compared to measured tributary/canal volume data for a basin. As water quality was not previously calibrated within SWIL, the model estimated TN and TP loadings were compared against long-term surface water monitoring in the selected basins to develop water quality calibration factors. The Microsoft Excel Solver add-in was utilized to perform the selection of optimal calibration factors.

The SWIL 5.0 recalibration effort first evaluated the performance of SWIL 4.0 in modeling TN, TP, and hydrology between 2010-2020 for the selected calibration basins. Performance was evaluated based on the Nash-Sutcliffe Efficiency (NSE) coefficient and Percent Bias (PBIAS). The NSE is a measure of how well the model fits the observed data, with satisfactory performance being above 0.50. The PBIAS characterizes the tendency of the model to over or underestimate in comparison to the observed data, with satisfactory performance being between -25.0% to +25.0%. These NSE and PBIAS criteria ranges were used in the previous model calibration. For more details about the calibration process refer to AEI (2024).

2.5.2 CALIBRATION BASIN SELECTION

SWIL model subbasins for calibration required both water quality and quantity measurements from a location in a tributary where there were well-defined basin boundaries. Additionally, the calibration basins needed to represent a variety of land use types to be representative of the IRL watershed.

The original SWIL basins of Crane Creek, Sebastian North Prong (SNP), Sebastian South Prong (SSP), and Fellsmere Canal were included in this effort. Also included were Eau Gallie River, and the Vero Beach South Canal, making a total of seven basins within the IRL watershed selected for the SWIL model calibration.

2.5.3 CALIBRATION OUTCOME

The recalibration of SWIL 4.0 into SWIL 5.0 resulted in improved model performance in both hydrology and water quality (**Table 1**). These new calibration factors resulted in an unchanged total flow monthly average NSE of 0.53 but an improvement in PBIAS from 26.2% to 5.8%. TN had an NSE improvement from 0.42 to 0.49 and PBIAS decreased from 7.6% to 5.8%. Lastly, TP had the largest improvements in both NSE from -0.01 to 0.28 and PBIAS from 46% to 16.7%. The new calibration factors for ET, DRO, SSF lag, and TN EMCs were all within performance goals. While the calibrated TP for independent SSF and DRO estimation did not meet the performance objectives, the total flow TP was closely within the range and is appropriate for estimating TP watershed loads.

Table 1. Average monthly Nash-Sutcliffe Efficiency (NSE) values and Percent Bias (PBIAS) of the calibrated SWIL 5.0 for the total flow of water and loading of nitrogen and phosphorus.

Model Output	Avg. Monthly NSE		Avg. Monthly PBIAS	
	SWIL 4.0	SWIL 5.0	SWIL 4.0	SWIL 5.0
Total Volume	0.53	0.53	26.2%	5.8%
Total Nitrogen	0.42	0.49	7.6%	4.3%
Total Phosphorus	-0.01	0.28	46.0%	16.7%

3 SUMMARY OF RESULTS

This section presents the summary of LULC and the calibrated SWIL 5.0 model simulation volume and loading results from both 1943 data inputs and 2020 data inputs. Results are presented for both the full year and for the dry season (January through May). The LULC and model results cover the BRL, North IRL, and Central IRL basins of the IRL. Additionally, a comparison between the SWIL 4.0 results and updated SWIL 5.0 results is presented within the section.

3.1 1943 NATURAL BACKGROUND CONDITION SIMULATION

3.1.1 1943 LAND USE LAND COVER

LULC results from 1943 are presented in **Table 2** and **Figure 2**. As anticipated, in 1943, the IRL was comprised of mostly undeveloped land, which also includes water (**Table 2**), with 590,934 acres out of 672,931 acres undeveloped. Based on the acreage, undeveloped land accounts for 88% of the land use, agriculture for 10%, high intensity development for 2%, and low intensity development for 1%. Undeveloped land comprised 97% of the land use in the BRL in 1943 (**Figure 2**), indicating that the land in the BRL was nearly untouched from development and agriculture. Similarly, undeveloped lands were the primary land use type in the North IRL and Central IRL, making up 91% and 83% of the basins, respectively. In the North and Central IRL basins, agriculture was the second highest land use type, making up 6% and 14% of the land use, respectively. BRL consisted of roughly 1% of agricultural land in 1943, only 1,078 acres, and had 1,528 acres of high intensity development.

Table 2. Land Use Land Cover (acres) in 1943.

LULC Type	BRL	NIRL	CIRL	Total
Agriculture	1,078	13,240	50,788	**65,106**
High Intensity Development	1,528	4,732	7,218	**13,477**
Low Intensity Development	309	1,171	1,934	**3,414**
Undeveloped	94,995	198,417	297,522	**590,934**
Total	**97,910**	**217,558**	**357,462**	**672,931**

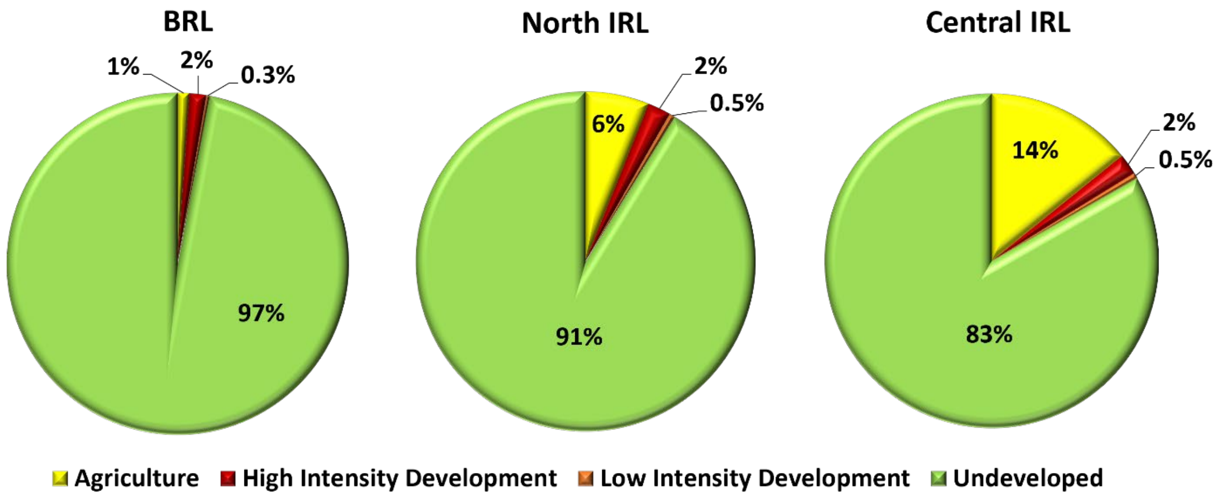

Figure 2. Land Use Land Cover in the IRL in 1943.

Figure 3, **Figure 4**, and **Figure 5** show the spatial distribution of the land use types for the BRL, North IRL, and Central IRL in 1943. In the BRL (**Figure 3**), the LULC was primarily undeveloped with isolated areas of agriculture and low intensity development. North of Satellite Beach, the Banana River Naval Air Station, now Patrick Space Force Base (PSFB), was established in the early 1940s and is the most notable high intensity development area in the BRL in 1943.

In the North IRL (**Figure 4**), land was primarily undeveloped in 1943, with agricultural lands occurring along the coastlines in Titusville, Cocoa, and Merritt Island, as well as other isolated areas of the basin. High intensity development was beginning to occur in the Titusville, Cocoa/Rockledge, Eau Gallie, and Melbourne areas.

In the Central IRL (**Figure 5**), land was primarily undeveloped in 1943, although agricultural lands were scattered throughout the region, including beachside areas of Vero Beach. The most notable high intensity development was occurring in Melbourne, Vero Beach, and Fellsmere.

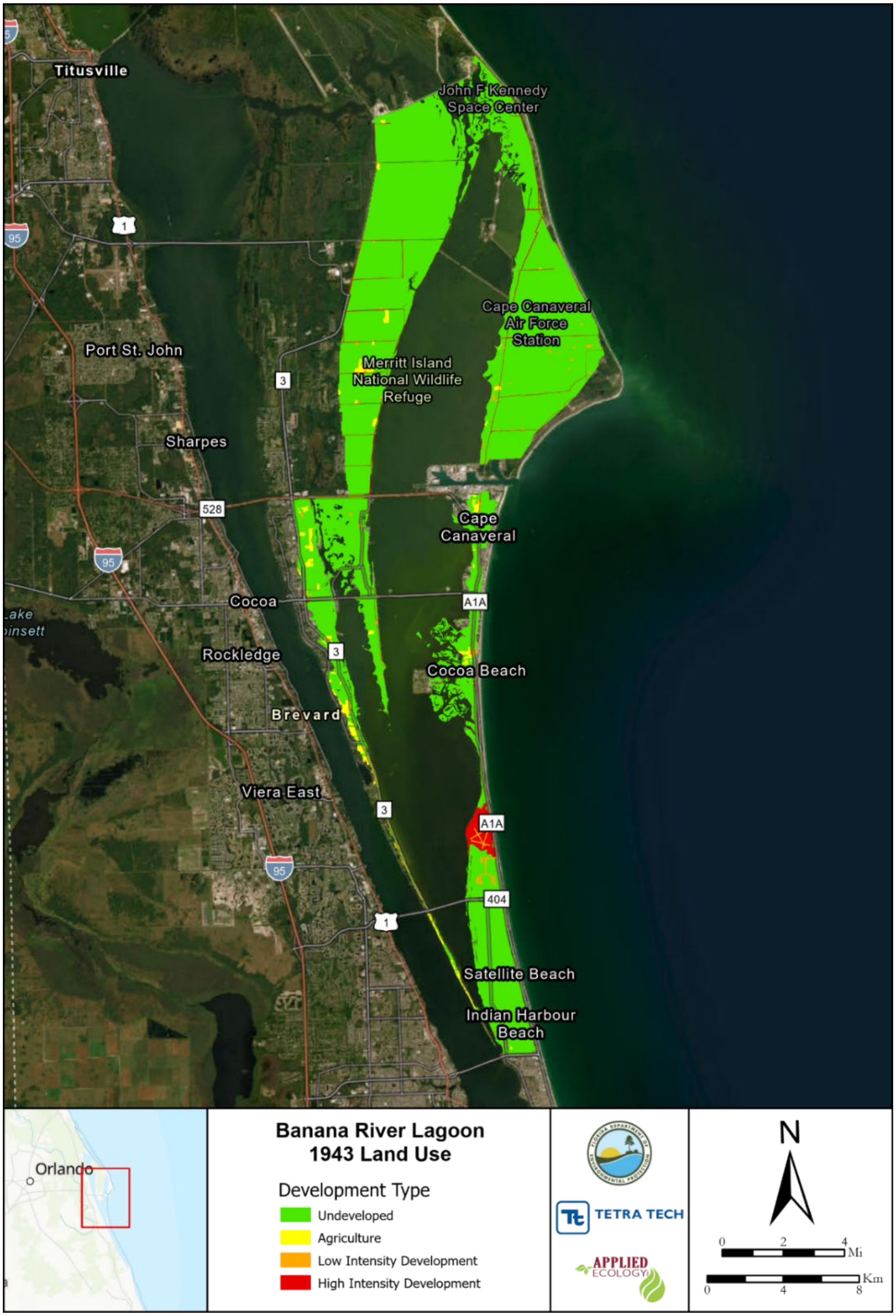

Figure 3. Land Use of the Banana River Lagoon in 1943.

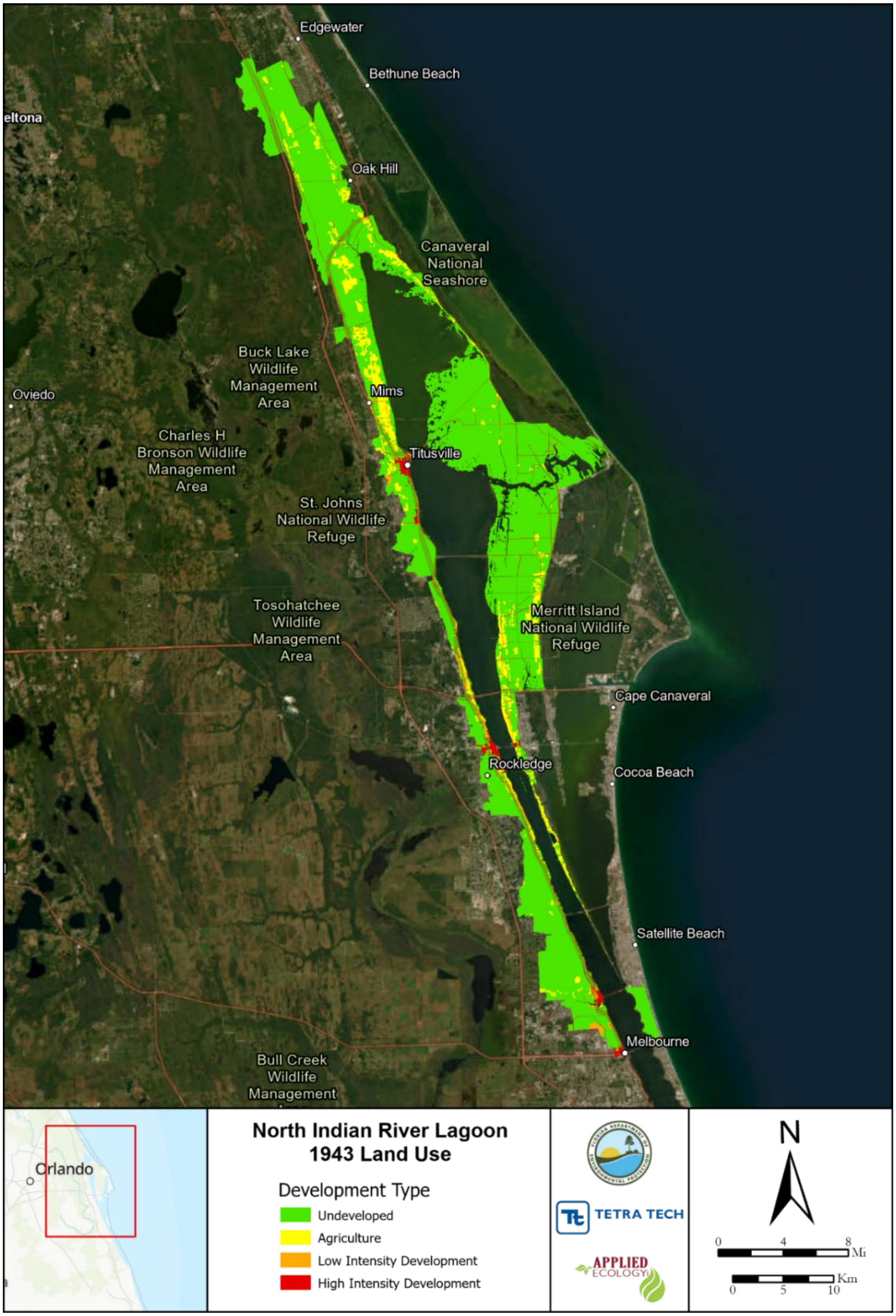

Figure 4. Land Use of the North Indian River Lagoon in 1943.

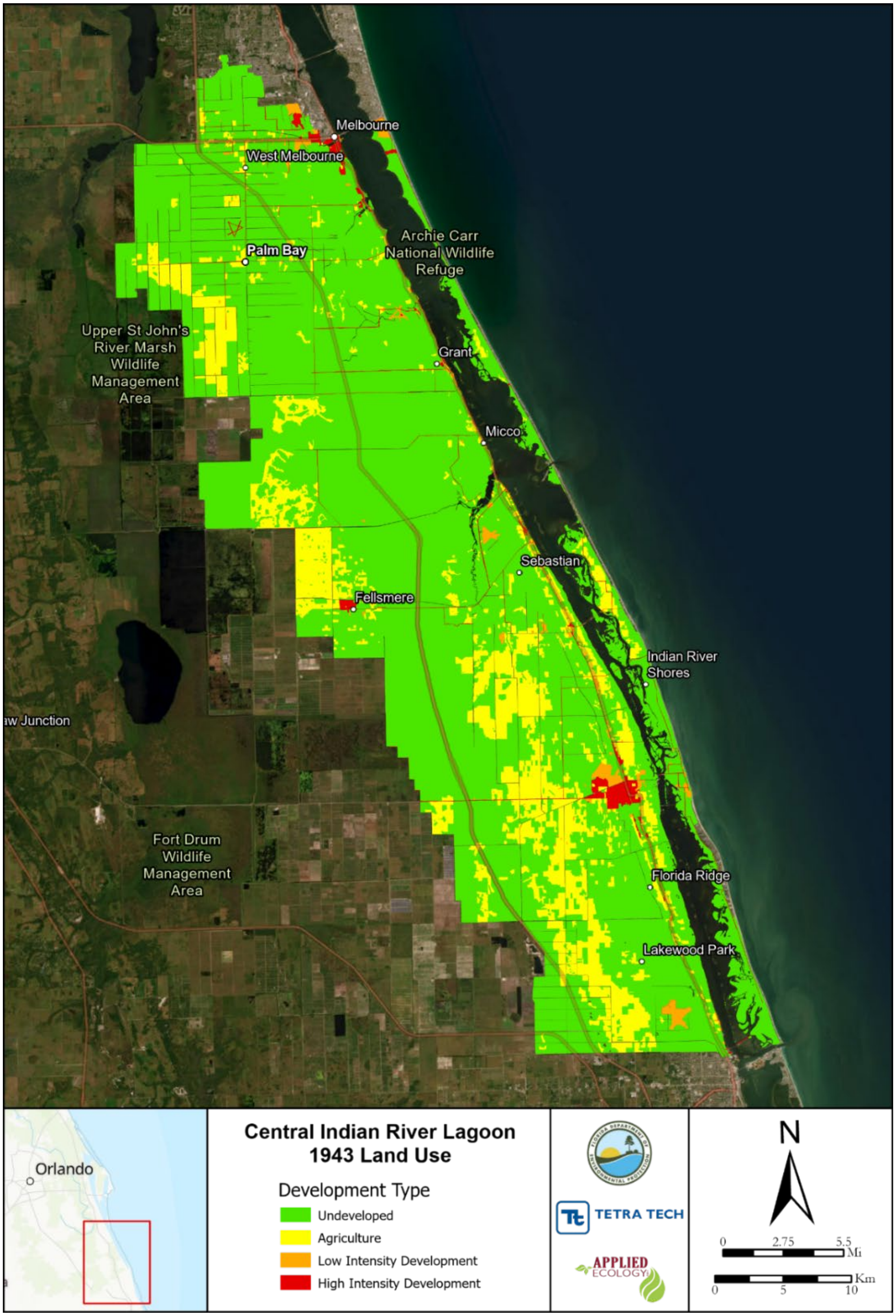

Figure 5. Land Use of the Central Indian River Lagoon in 1943.

3.1.2 1943 SWIL VOLUME AND LOADING

The combined volume of runoff and subsurface water in m^3/year and TN and TP loads in lbs/year for the 1943 SWIL model results are presented in **Table 3**. The Central IRL had the highest volumes as well as the highest TN and TP loading contributions, likely due to the large watershed size. The BRL had the lowest volumes and TN and TP loading of the three basins. Total volumes are 39,223,094 m^3/year in the BRL, 156,473,955 m^3/year in the North IRL, and 465,998,252 m^3/year in the Central IRL. TN loads are 56,141 lbs/year in the BRL, 229,059 lbs/year in the North IRL, and 754,580 lbs/year in the Central IRL. TP loads are 2,696 lbs/year in the BRL, 13,918 lbs/year in the North IRL, and 66,694 lbs/year in the Central IRL.

Table 3. Volume and nutrient loads simulated from the 1943 SWIL natural background condition simulation.

Parameter	Basin	Direct Runoff	Subsurface Flow	Total
Volume (m^3/year)	BRL	15,394,345	23,828,749	**39,223,094**
	North IRL	75,092,549	81,381,406	**156,473,955**
	Central IRL	214,723,095	251,275,157	**465,998,252**
Total Nitrogen (lbs/year)	BRL	17,008	39,133	**56,141**
	North IRL	87,094	141,964	**229,059**
	Central IRL	285,212	469,368	**754,580**
Total Phosphorus (lbs/year)	BRL	248	2,448	**2,696**
	North IRL	2,460	11,458	**13,918**
	Central IRL	18,825	47,869	**66,694**

The 1943 SWIL 5.0 volume and loading results are presented as stacked bar charts in **Figure 6**, **Figure 7**, and **Figure 8** as a visual representation of the allocation of direct runoff and SSF to total loads. SSF makes up the majority of volume and loads into the IRL. SSF makes up 61% of the total volume in the BRL, 52% in the North IRL, and 54% in the Central IRL (**Figure 6**). TN and TP loads are also mostly driven by SSF. SSF accounts for 70% of the TN loading in the BRL, 62% in the North IRL, and 62% in the Central IRL (**Figure 7**). SSF accounts for 91% of the TP loading in the BRL, 82% in the North IRL, and 72% in the Central IRL (**Figure 8**).

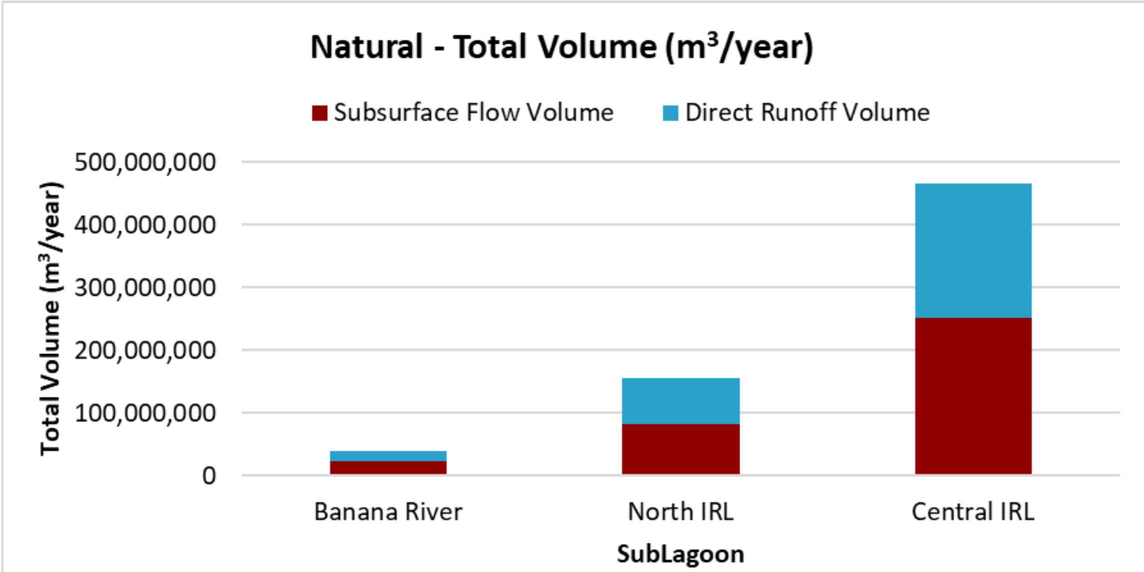

Figure 6. Total volume of baseloads (m³/year) into the IRL in 1943.

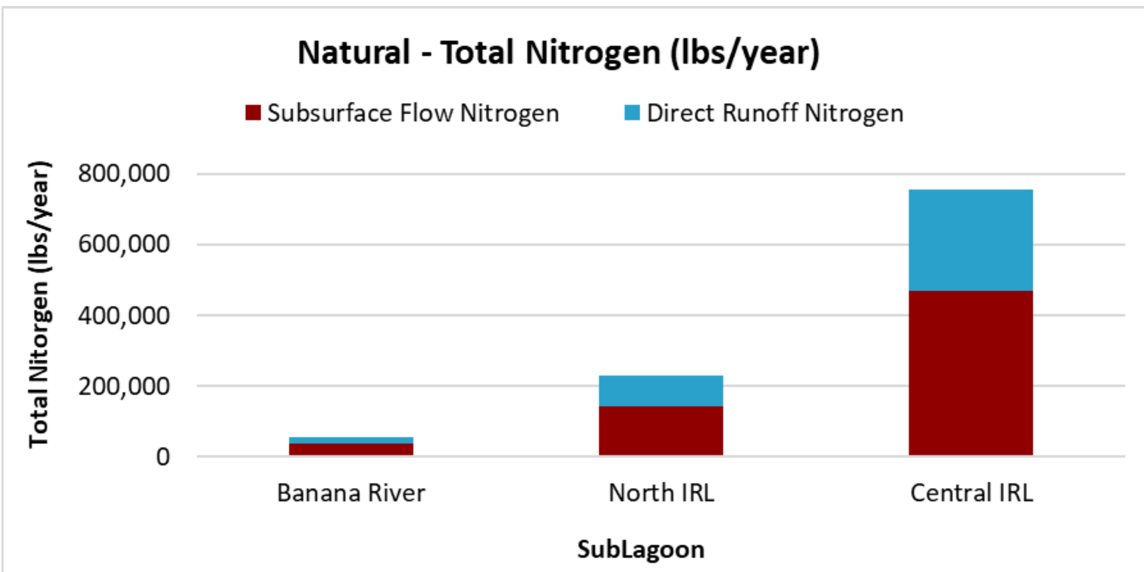

Figure 7. Total nitrogen baseloads (lbs/year) into the IRL in 1943.

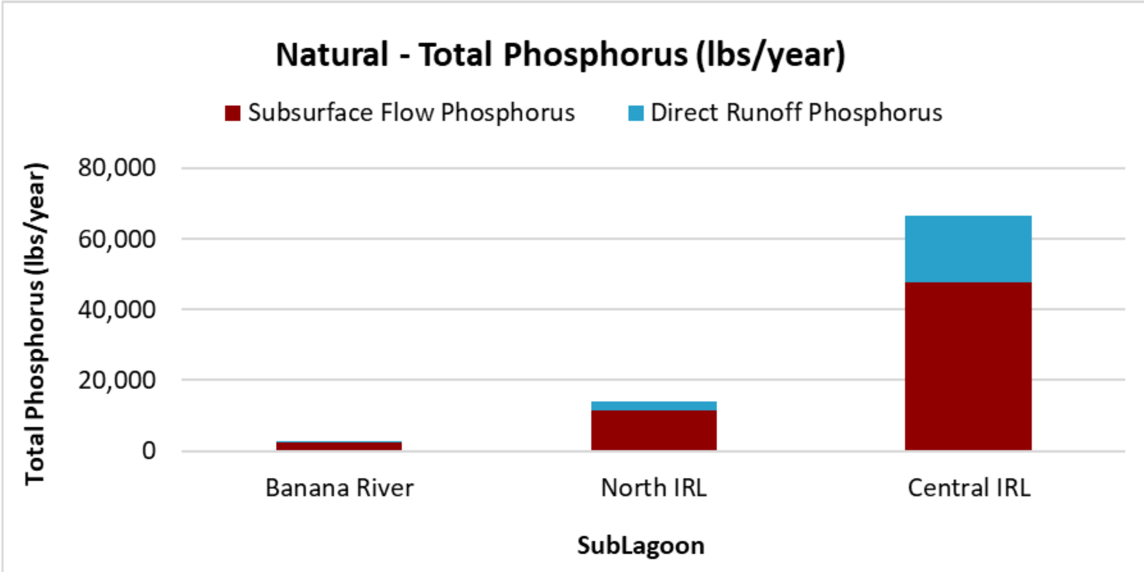

Figure 8. Total phosphorus baseloads (lbs/year) into the IRL in 1943.

Figure 9 through **Figure 14** present spatial interpretations of TN and TP loading across the IRL watershed based on the natural background condition simulation (1943). The highest TN loads are depicted in red, ranging from 2.70 lbs/year to 6.27 lbs/year and the highest TP loads range from 0.99 lbs/year to 1.73 lbs/year. In the BRL, the highest TN loads are concentrated around portions of the Merritt Island and Satellite Beach regions (**Figure 9**). TP loads in the BRL are generally low compared to other basins (**Figure 10**), with isolated hotspots as the total loads are less than 3,000 lbs/year (**Table 3**).

In the North IRL, notably high TN loads were found along the coastlines of Merritt Island, Titusville, Cocoa, and north Eau Gallie areas (**Figure 11**). Highest loads for TP are found along the Titusville and Cocoa coastal areas (**Figure 12**).

The Central IRL shows unique patterns of loads, with highest loading sourced from both coastal and western regions of the basin. High TN loads are associated with regions of Palm Bay and Fellsmere, as well as scattered inland hotspots stretching from north Vero Beach to Fort Pierce (**Figure 13**). TP hotspot regions in the Central IRL are less prominent than TN, with the highest loading areas located in west Palm Bay and northwest Vero Beach regions (**Figure 14**).

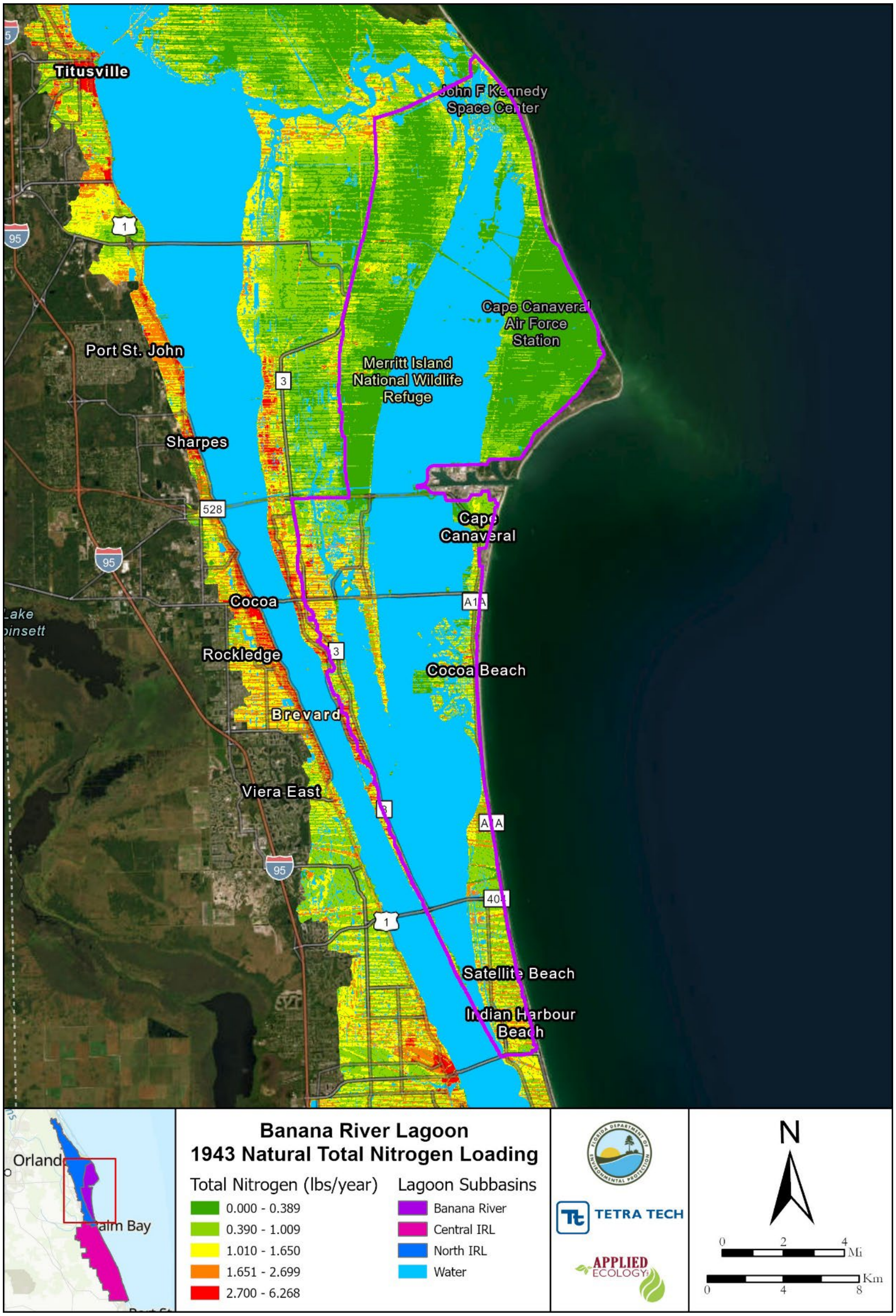

Figure 9. Natural background condition total nitrogen loading per cell into the Banana River Lagoon in 1943.

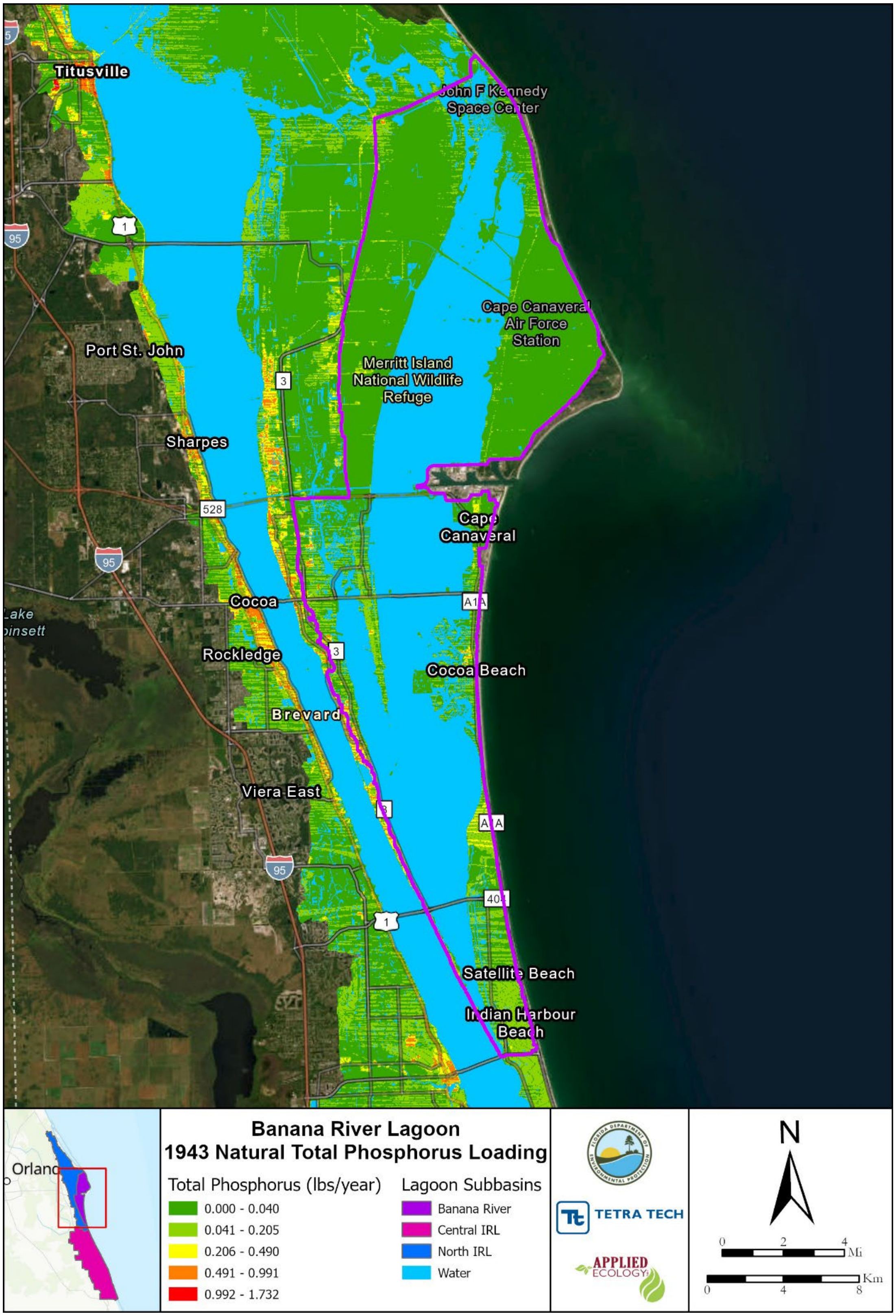

Figure 10. Natural background condition total phosphorus loading per cell into the Banana River Lagoon in 1943.

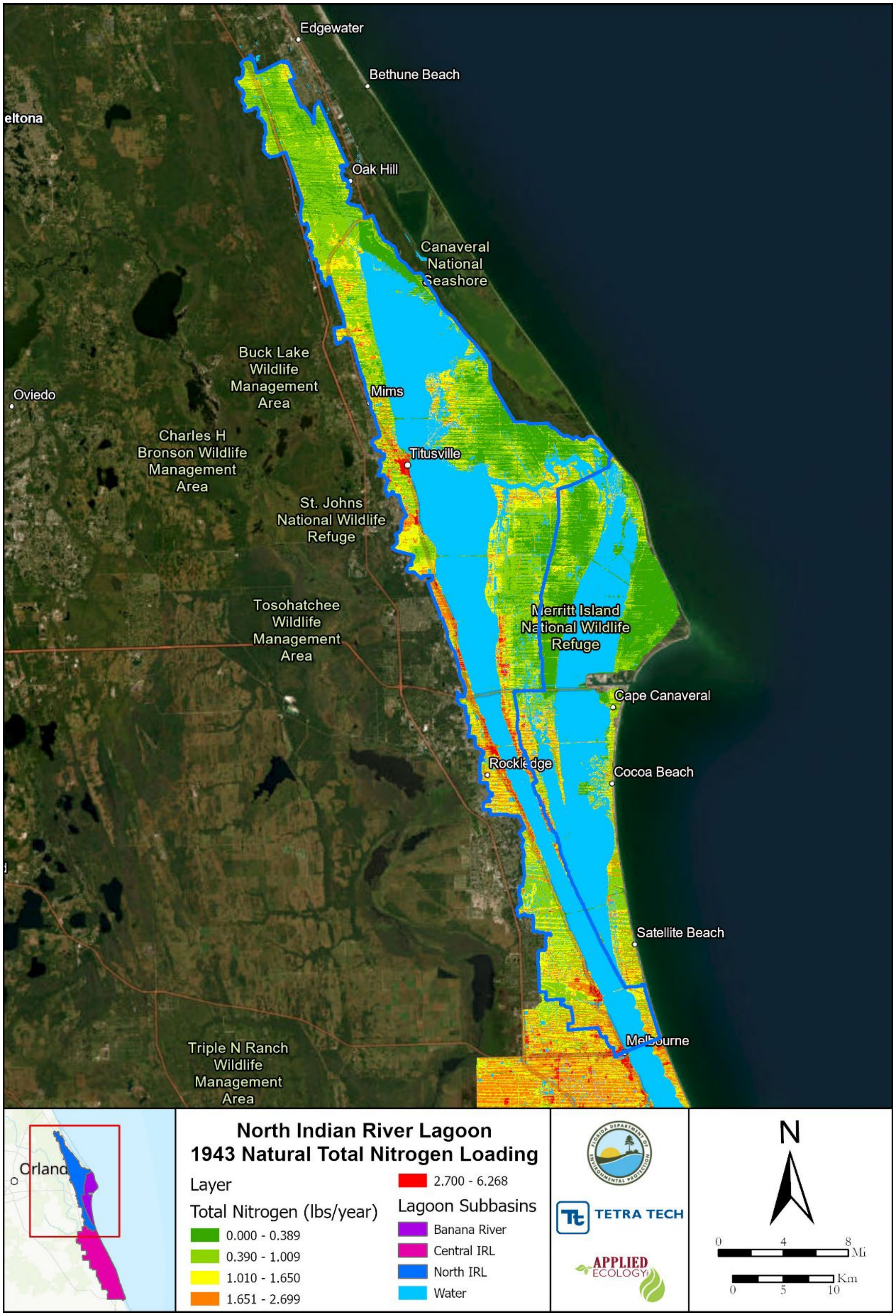

Figure 11. Natural background condition total nitrogen loading per cell into the North Indian River Lagoon in 1943.

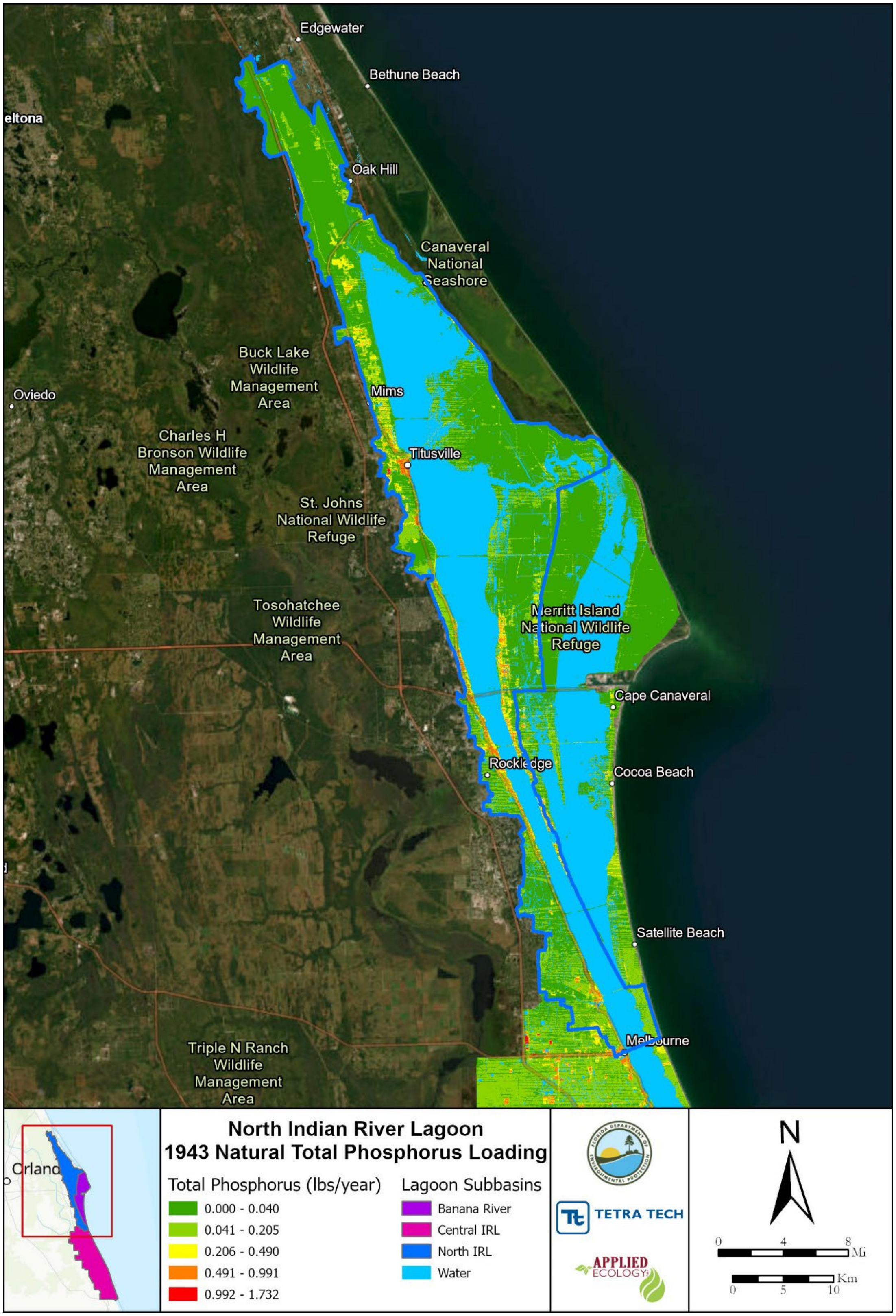

Figure 12. Natural background condition total phosphorus loading per cell into the North Indian River Lagoon in 1943.

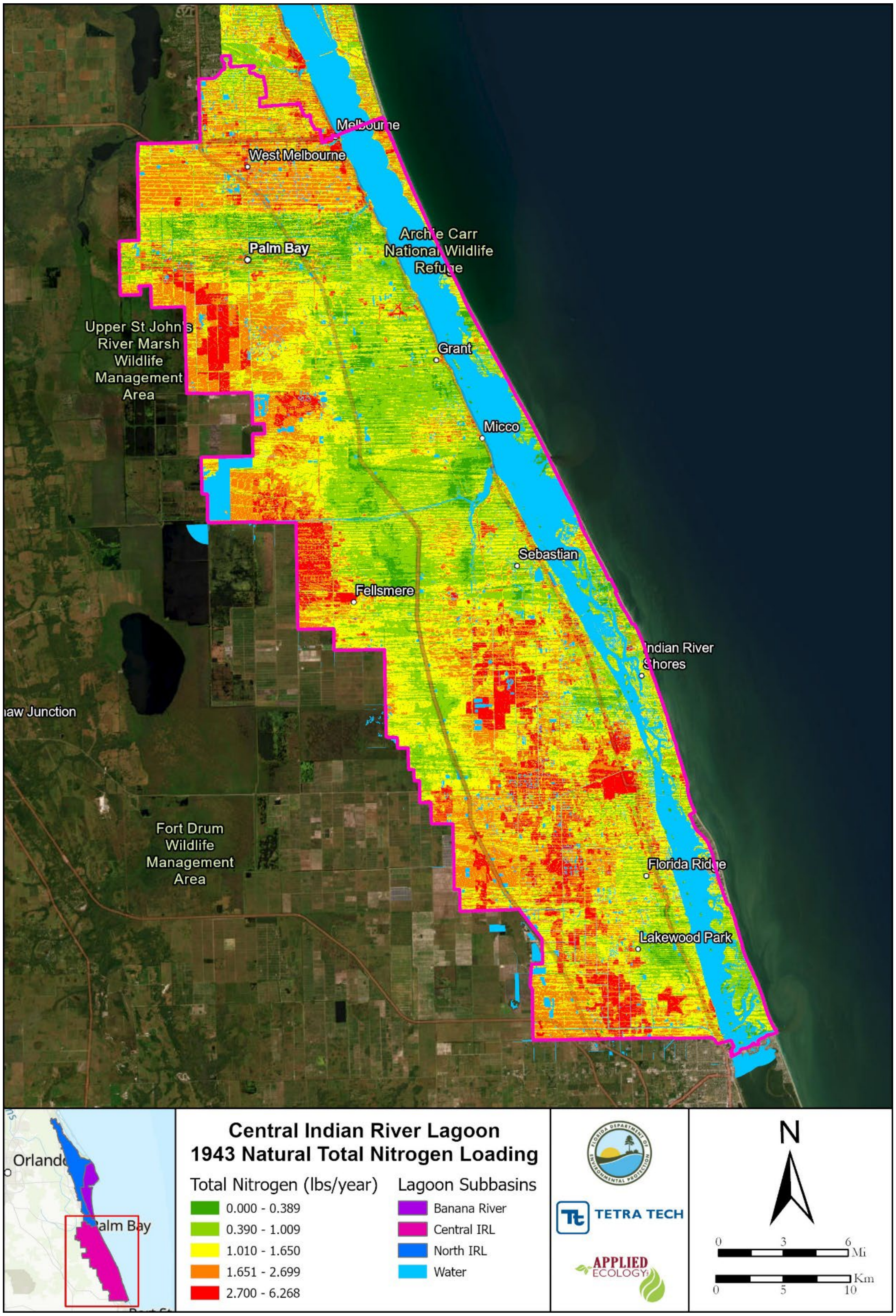

Figure 13. Natural background condition total nitrogen loading per cell into the Central Indian River Lagoon in 1943.

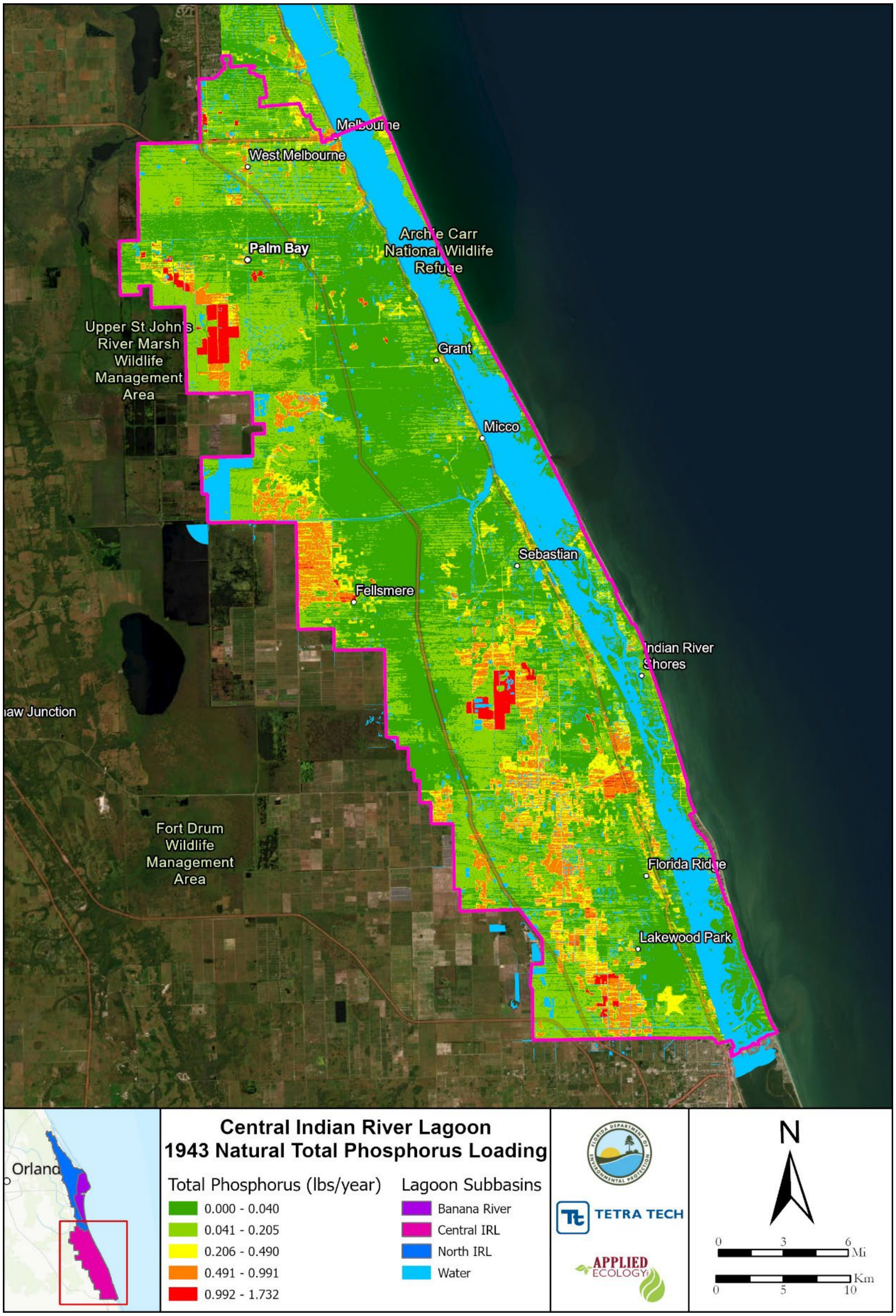

Figure 14. Natural background condition total phosphorus loading per cell into the Central Indian River Lagoon in 1943.

3.1.2.1 1943 Natural Background Condition Seasonal Results

Loading results were analyzed from January to May to represent the dry season. **Table 4** presents the dry season loading results for the IRL basins. As expected, the volumes and nutrient loads are lower than the corresponding results for the full year simulations, with 73-74% of the volumes and loads produced during the wet months of the year.

Total volumes are 11,392,143 m^3/year in the BRL, 43,011,318 m^3/year in the North IRL, and 104,523,301 m^3/year in the Central IRL. TN loads are 16,873 lbs/year in the BRL, 65,141 lbs/year in the North IRL, and 173,783 lbs/year in the Central IRL. TP loads are 814 lbs/year in the BRL, 3,890 lbs/year in the North IRL, and 15,723 lbs/year in the Central IRL.

Table 4. Seasonal loading results from the 1943 Natural background condition SWIL 5.0 results.

Parameter	Basin	Direct Runoff	Subsurface Flow	Total
Volume (m^3/year)	BRL	2,761,407	8,630,737	**11,392,143**
	North IRL	13,511,466	29,499,853	**43,011,318**
	Central IRL	35,410,445	69,112,856	**104,523,301**
Total Nitrogen (lbs/year)	BRL	3,026	13,847	**16,873**
	North IRL	15,716	49,426	**65,141**
	Central IRL	48,008	125,775	**173,783**
Total Phosphorus (lbs/year)	BRL	48	766	**814**
	North IRL	483	3,408	**3,890**
	Central IRL	3,816	11,907	**15,723**

3.2 2020 SIMULATION

3.2.1 2020 LAND USE LAND COVER

LULC results from 2020 data are presented in **Table 5** and **Figure 15**. The IRL was comprised of mostly undeveloped land in 2020, which also includes water (**Table 5**), with roughly 66% of the acreage as undeveloped, 16% as high intensity development, and 9% each for agriculture and low intensity development. Undeveloped land comprised 82% of the land use in the BRL in 2020, 78% in the North IRL, and 54% in the Central IRL (**Figure 15**). High intensity development was the second highest land use type in each of the basins. Low intensity development had also increased for each of the basins compared to historical data. Unlike other basins, agriculture in the Central IRL increased from 1943 to 2020 (**Figure 15**).

Table 5. Land Use Land Cover (acres) in 2020.

LULC Type	BRL	NIRL	CIRL	Total
Agriculture	98	5,533	56,196	**61,827**
High Intensity Development	10,754	26,645	71,600	**108,999**
Low Intensity Development	6,482	15,715	35,990	**58,187**
Undeveloped	80,575	169,642	193,650	**443,868**
Total	**97,910**	**217,535**	**357,436**	**672,881**

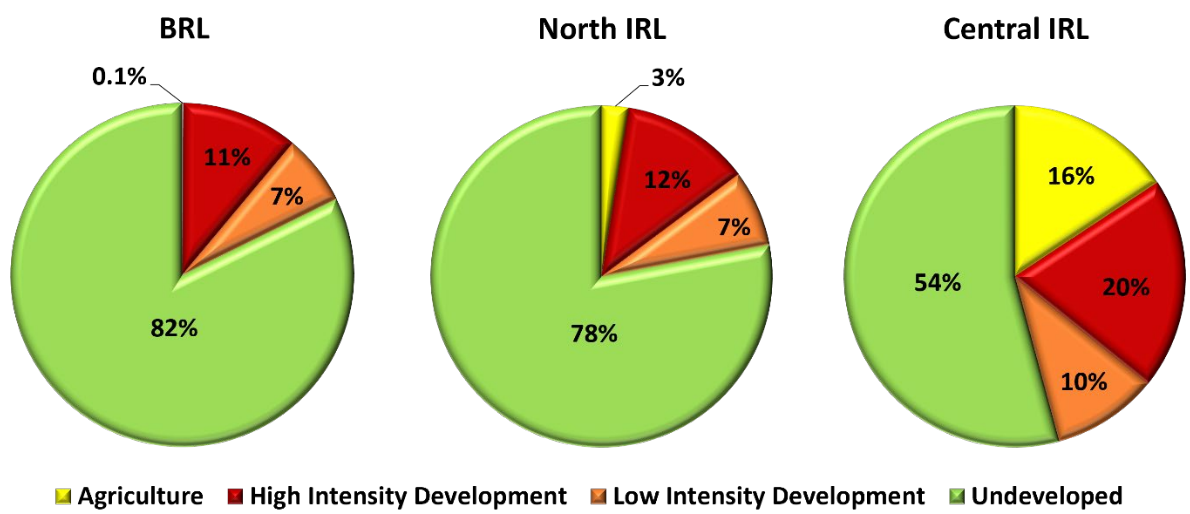

Figure 15. Land Use Land Cover in the IRL in 2020.

Figure 16, **Figure 17**, and **Figure 18** present the spatial distribution of the 2020 land use. In the BRL (**Figure 16**), high intensity development had visibly increased from historical data. High Intensity development occupies most of the beachside communities, except for Cape Canaveral Space Force Station (CCSFS) which remains mostly undeveloped with isolated low intensity development pockets. Additionally, high intensity development now occupies a large portion of Merritt Island south of Florida State Road 528, while land use north of Florida State Road 528 remains mostly undeveloped, as the Merritt Island National Wildlife Refuge was established in 1963.

In the North IRL (**Figure 17**), high and low intensity development occupy most of the coastline beginning in Titusville and stretching south to Melbourne. The most notably undeveloped lands are the Merritt Island National Wildlife Refuge and lands reaching further north to Mosquito Lagoon, as well as the most northern region of the basin surrounding Oak Hill.

The Central IRL (**Figure 18**) has each type of land use distributed throughout the basin. What was once mostly agriculture, undeveloped lands, and small isolated areas of high intensity development in 1943, is now more consistently developed areas throughout the basin. The isolated high density developed in the Vero Beach and Melbourne areas expanded further, and the Palm Bay and Sebastian areas rapidly expanded with new high intensity development that was not historically present in 1943. The Central IRL is still 54% undeveloped lands, and agriculture occupies the most western regions of the basin. There is a notably large area between Fellsmere and Palm Bay that remains agricultural lands or undeveloped, mostly due to the presence of the St. Sebastian River Preserve State Park.

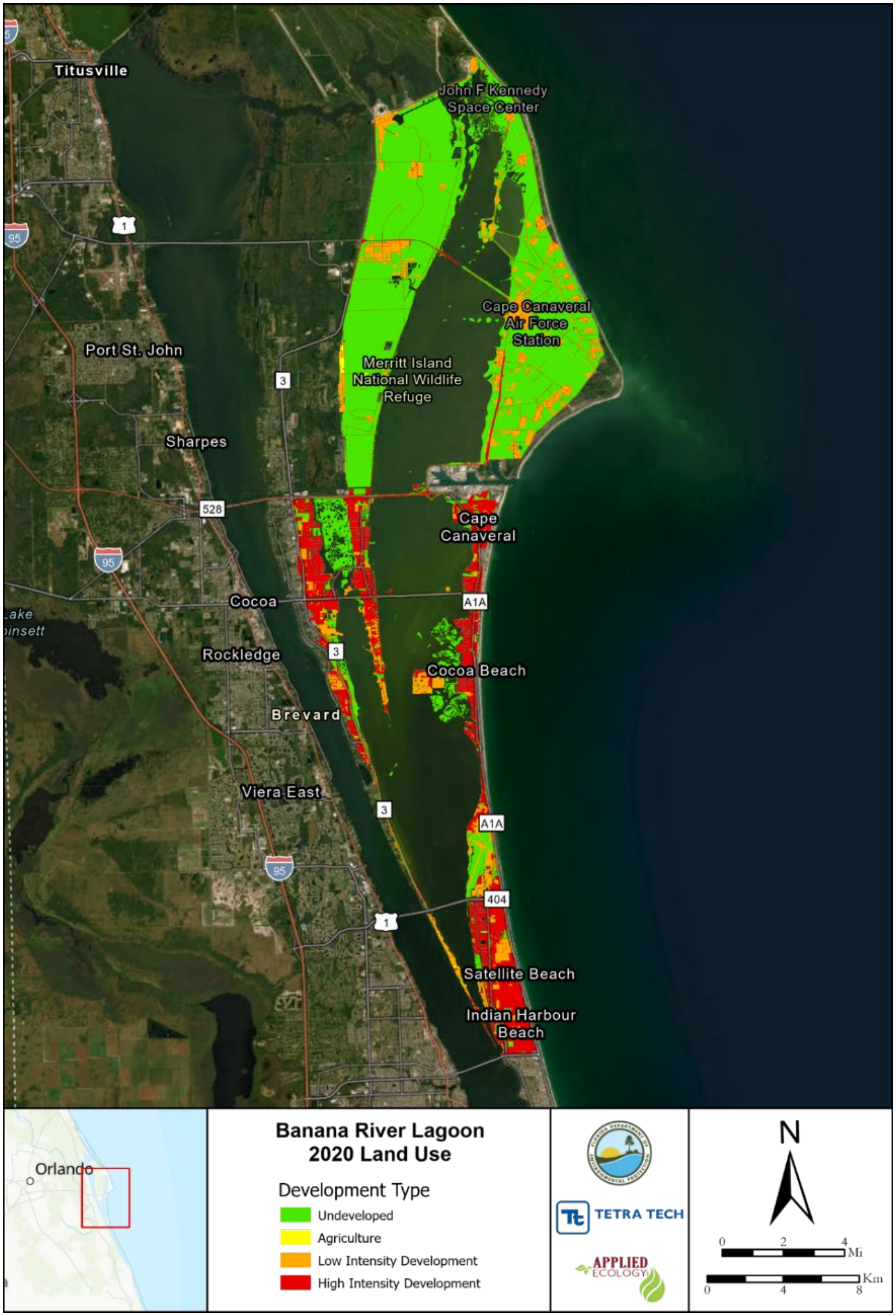

Figure 16. Land Use of the Banana River Lagoon in 2020.

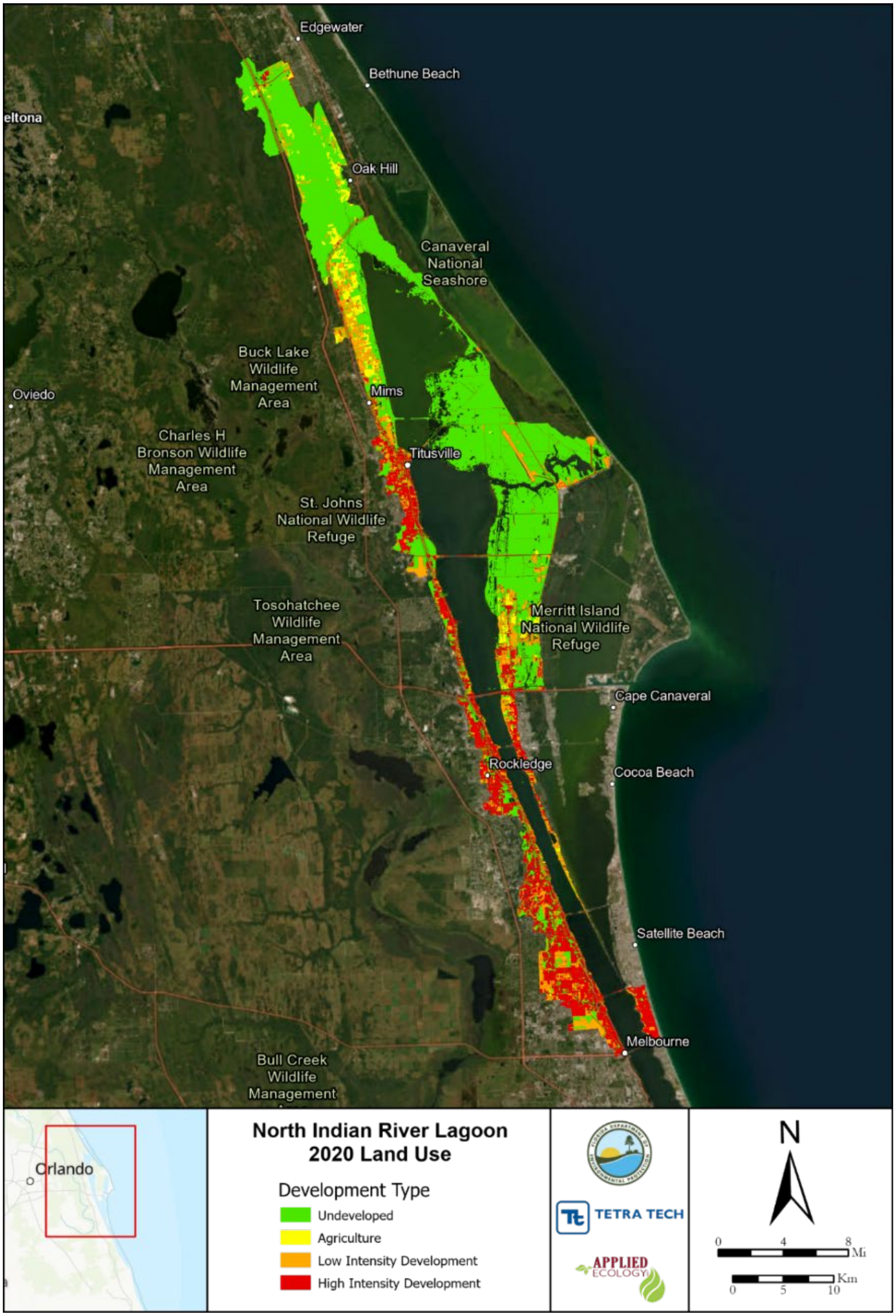

Figure 17. Land Use of the North Indian River Lagoon in 2020.

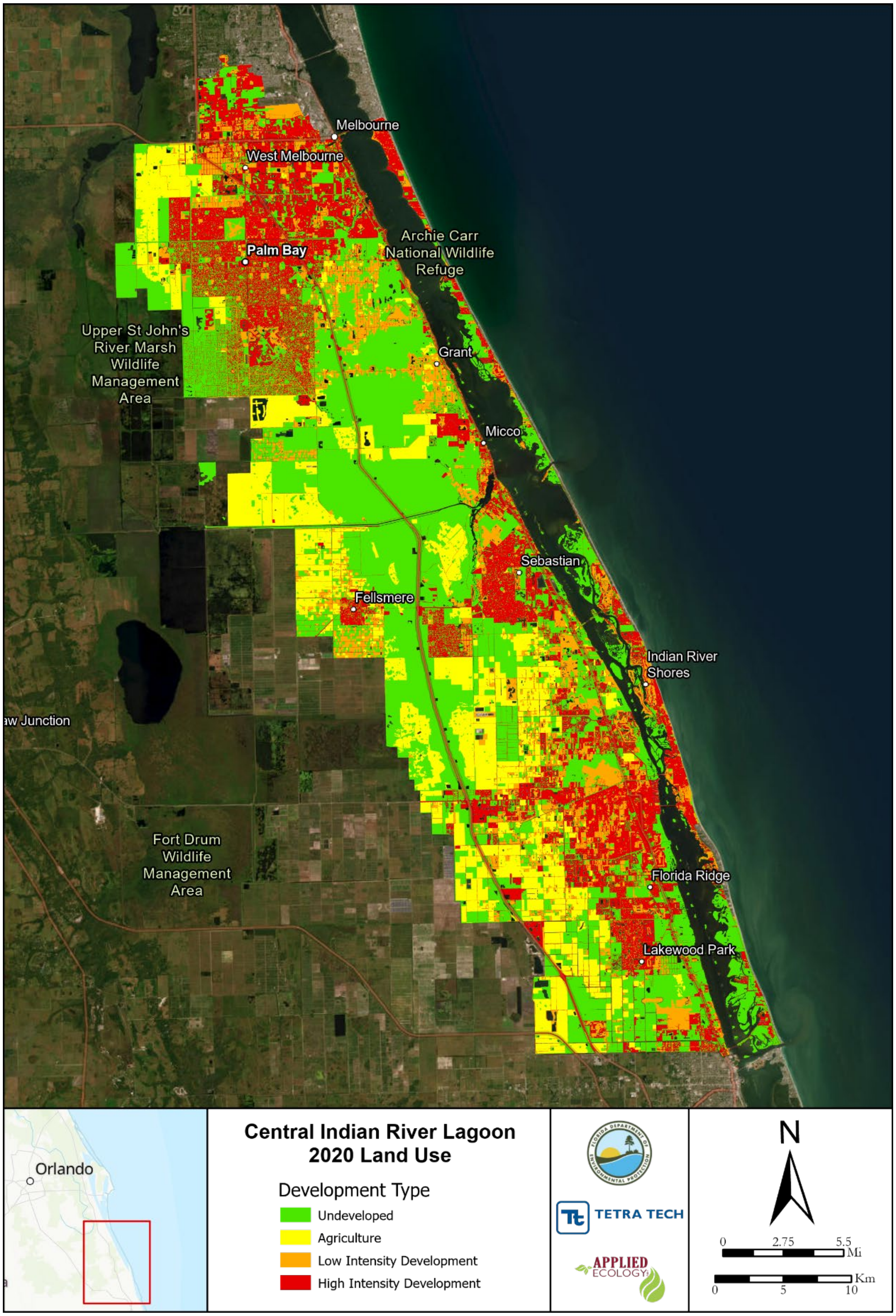

Figure 18. Land Use of the Central Indian River Lagoon in 2020.

3.2.1.1 Comparison to SWIL 4.0 Land Use Land Cover

LULC data from the SWIL 4.0 model iteration is presented in **Table 6**. The SWIL 4.0 iteration had more acres within the IRL watershed compared to the SWIL 5.0, which should result in higher volumes and loads. The SWIL 4.0 model includes 689,595 acres and the SWIL 5.0 uses 672,881 acres, an overall 16,714-acre reduction (2.4% reduction). The SWIL 5.0 update included the adjustment of two drainage basins based on stakeholder input, which resulted in a total reduction of 18,700.5 acres. The remaining difference of 1,986 acres was the result of the grid generation process.

Table 6. Land Use Land Cover (acres) from the SWIL 4.0 model iteration.

LULC Type	BRL	NIRL	CIRL	Total
Agriculture	104	6,932	69,253	**76,289**
High Intensity Development	12,073	36,360	99,332	**147,765**
Low Intensity Development	6,721	10,653	38,880	**56,254**
Undeveloped	79,036	163,141	167,110	**409,287**
Total	**97,934**	**217,086**	**374,575**	**689,595**

Overall, both SWIL iterations have similar patterns, in which undeveloped land is the highest LULC. In the SWIL 4.0, undeveloped land accounts for 58% of the land use, high intensity development accounts for 21%, agriculture accounts for 11%, and low intensity development accounts for 8%. In the SWIL 5.0 iteration, undeveloped land has a higher percentage of LULC, while high density development and agriculture slightly decrease.

The Eau Gallie River basin was the only basin to be expanded past the SWIL 4.0 boundary, adding an additional 631.5 acres (**Table 7**, **Figure 19**). This adjustment was based on updated stormwater drainage basin delineations provided by Brevard County. As the result of this expansion and the LULC update, the basin's overall LULC composition shifted towards low intensity development and undeveloped.

Table 7. Change in the acreage by development type in the Eau Gallie River basin between SWIL 4.0 and SWIL 5.0.

LULC Type	Change in Acres	Percent Change in Basin Composition
Agriculture	-89.4	-0.7%
High Intensity Development	-590.4	-6.8%
Low Intensity Development	335.5	1.9%
Undeveloped	975.9	5.6%
Total	**631.5**	

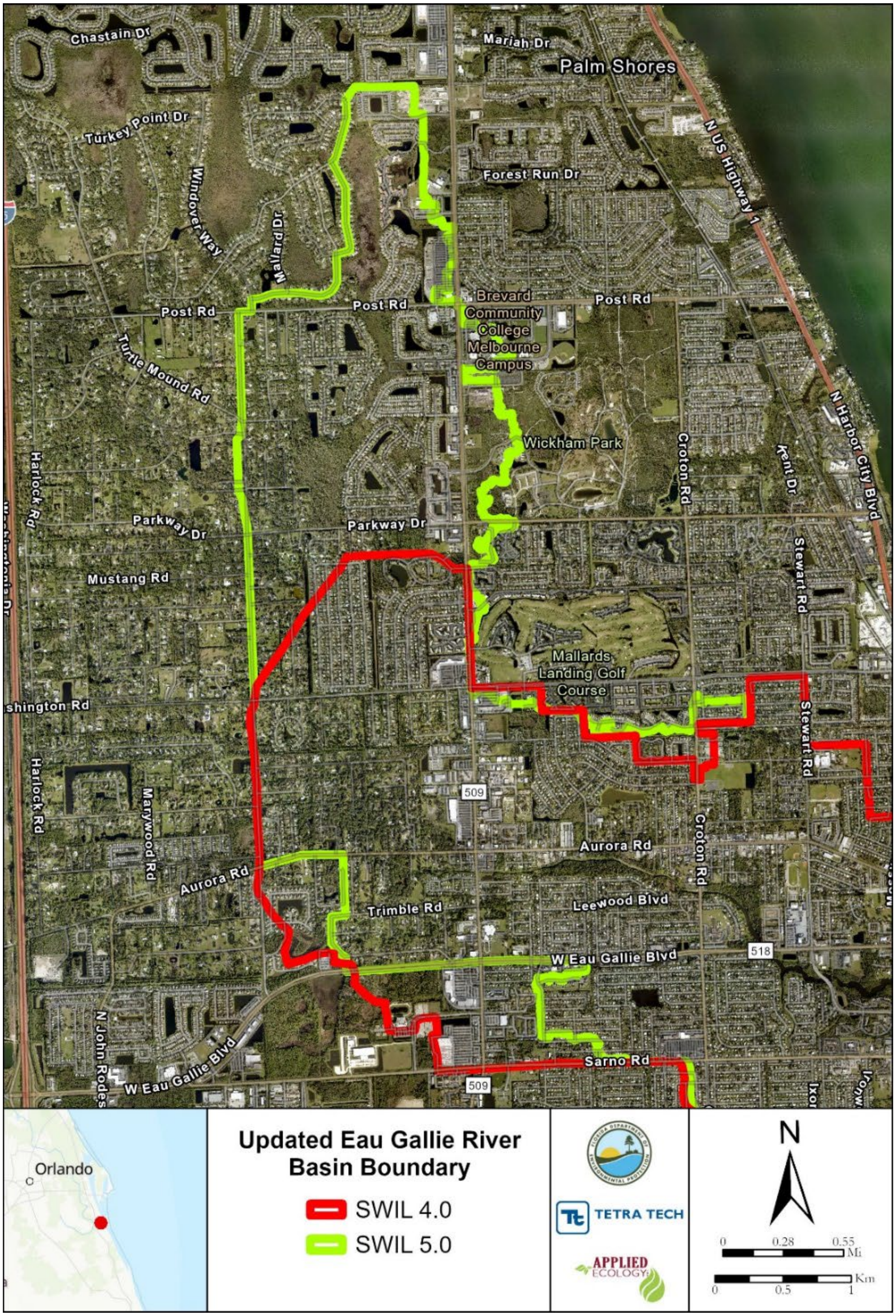

Figure 19. Map of the increase in the Eau Gallie River basin boundary between SWIL 4.0 and 5.0.

The Fellsmere basin was the only basin reduced (**Table 8, Figure 20**) and approximately 19,332 acres were removed. This adjustment was based on information regarding the SJRWMD Upper St. Johns River Basin project, which redirected the water from the removed area to the St. Johns River. Much of the land removed from the basin was agricultural LULC and resulted in the basin's overall LULC composition shifting towards low intensity development and undeveloped LULC.

Table 8. Change in the acreage by development type in the Fellsmere basin between SWIL 4.0 and SWIL 5.0.

LULC Type	Change in Acres	Percent Change in Basin Composition
Agriculture	-16,652.3	-29.8%
High Intensity Development	-2,438.1	-2.6%
Low Intensity Development	1,553.4	10.9%
Undeveloped	-1,795.0	21.5%
Total	**-19,332.0**	

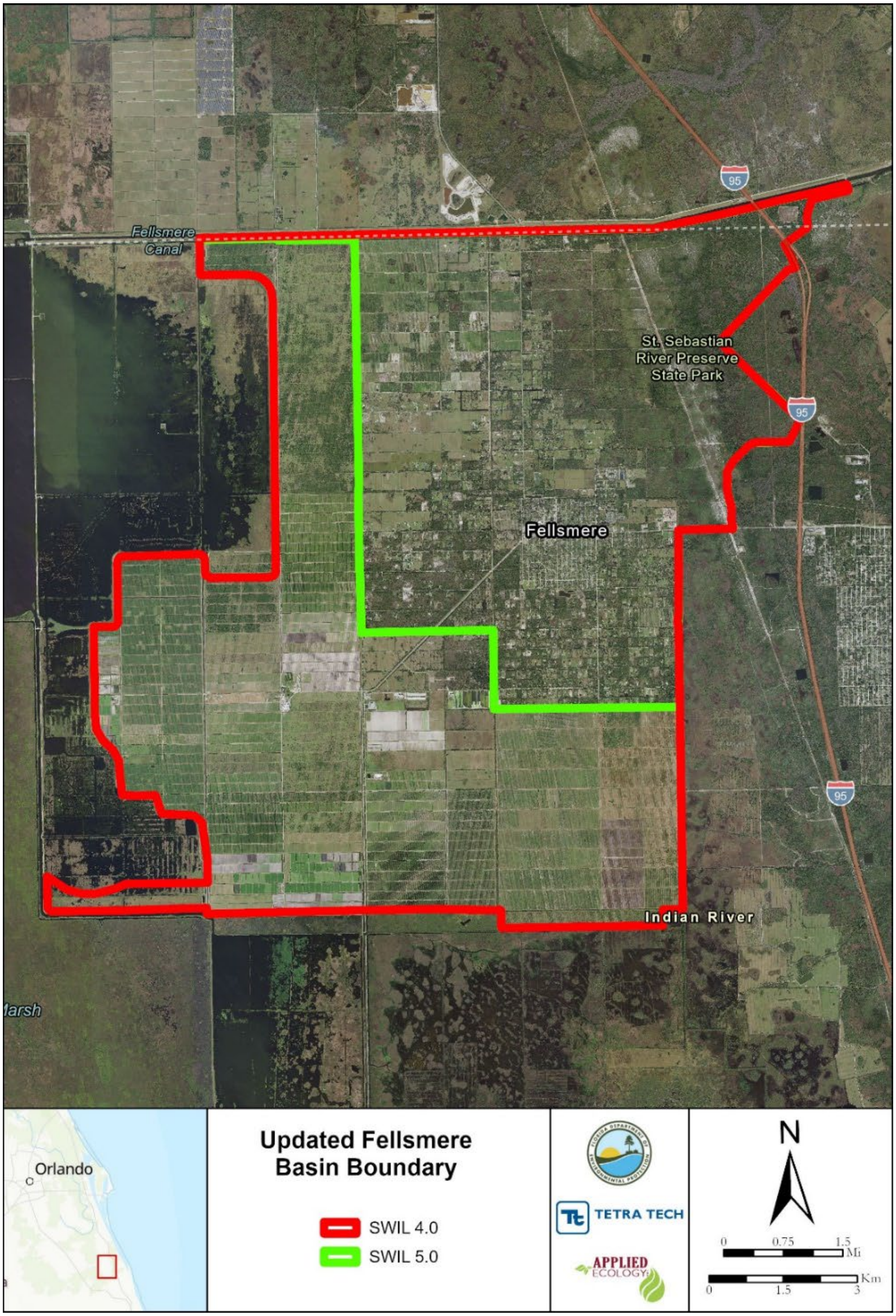

Figure 20. Map of the decrease in the Fellsmere basin boundary between SWIL 4.0 and 5.0.

3.2.1.1.1 Land Use Land Cover Update

The previous Load Estimation Toolkit (LET) was based on the output from the SWIL 4.0 model, which had used the available 2015 LULC generated by the WMD and parcel information from the county PAOs. The update to the SWIL 5.0 model in turn utilized data available for 2020, however due to a lack of LULC from the SJRWMD a more involved process was required to generate the final 2020 LULC.

The change in classification of LULC between SWIL 4.0 and SWIL 5.0 had an impact on loading throughout the IRL. This was the result of how the LULC type was assigned to the parcel as well as further refinement of the parcel's boundaries. The identification and separation of open or forested portions of developed parcels resulted in thousands of acres being reclassified (**Table 9**). Within the Central IRL alone, approximately 33,527.6 acres were reclassified as open which represents 10.7% of the total basin area.

Table 9. Change in the acreage of open and developed LULC between SWIL 4.0 and SWIL 5.0.

LULC Type	Model	BRL	NIRL	CIRL
Open	SWIL 4.0	394.4	1,447.5	5,501.7
	SWIL 5.0	1,623.2	6,450.9	39,029.3
	Change	**1,228.9**	**5,003.4**	**33,527.6**
Developed	SWIL 4.0	18,898.0	53,944.8	207,465.0
	SWIL 5.0	17,334.9	47,892.8	163,786.1
	Change	**-1,563.1**	**-6,052.1**	**-43,678.9**

The example provided in **Figure 21**, highlights the amount of undeveloped space which was previously classified as high intensity development. Other instances identified were commercial or industrial parcels which had development on a quarter or less of the total parcel or natural areas which the WMDs had identified but were considered as urban parcels by the PAO.

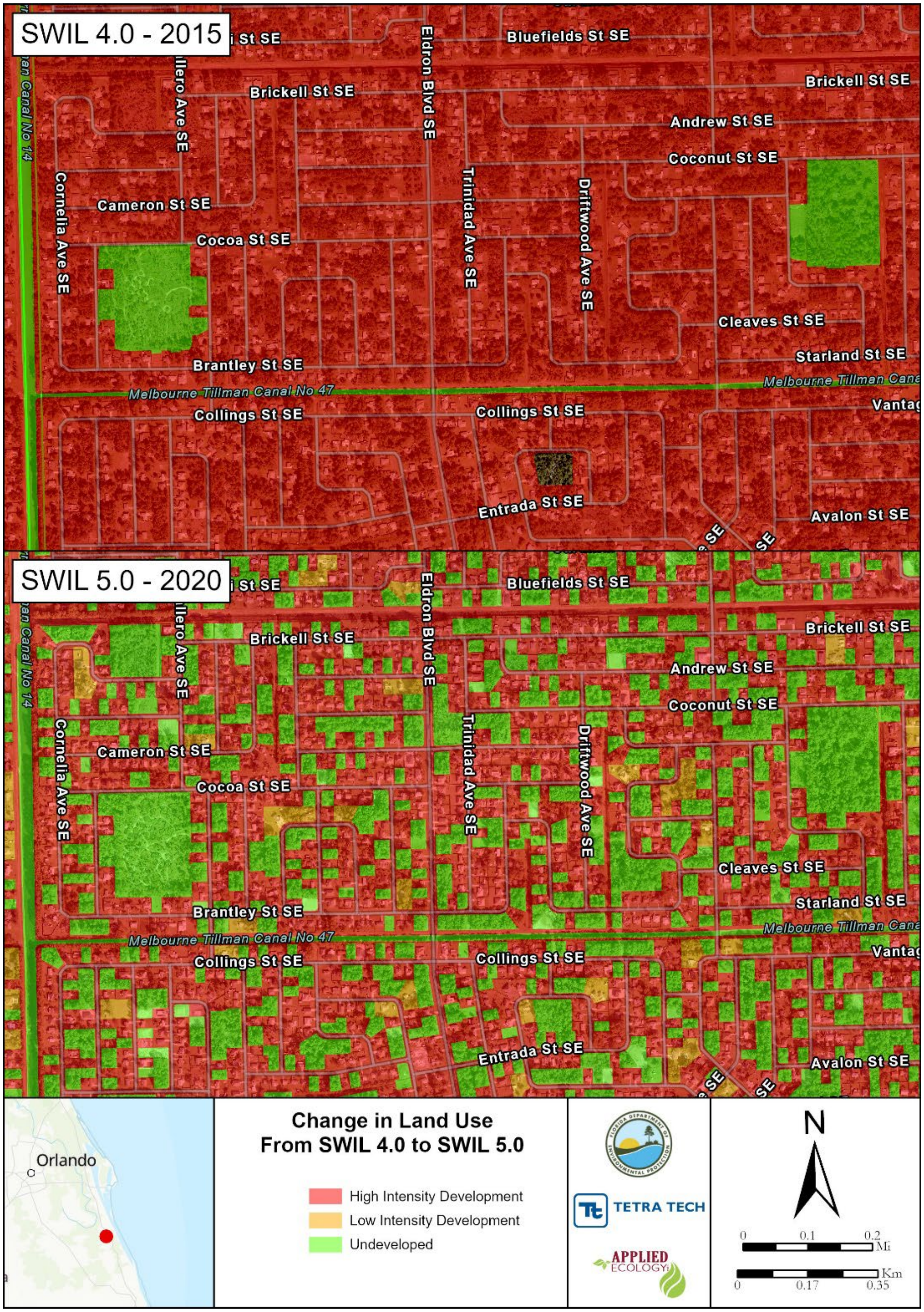

Figure 21. Change in development intensity between SWIL 4.0 and SWIL 5.0.

Another impact of the reclassification process was a reclassification of high and medium density residential parcels to low density residential and transportation (i.e. roads). Not accounting for new development or redevelopment, the medium density residential class was the most reclassified LULC category across the IRL (**Table 10**). As the density of residential parcels was assigned by the number of housing units per acre, some of the changes were the result of changes in the parcel boundary itself or an updated housing unit type (i.e. duplex becoming single housing unit).

Table 10. Percent change in total acreage as residential or transportation LULC by basin between SWIL 4.0 and SWIL 5.0

LULC Type	North IRL	Banana River Lagoon	Central IRL
High Density Residential	0.2%	0.8%	-0.4%
Medium Density Residential	-5.7%	-3.8%	-9.6%
Low Density Residential	3.4%	1.2%	4.3%
Transportation	2.3%	1.9%	4.7%

Other instances were due to API of suspect parcels and the implementation of a road buffer. The suspect parcels were identified based on the LULC assigned by the POAs and how they compared to the parcel size and WMD LULC assignment. An example of this is provided in **Figure 22** where residential parcels were identified to be undeveloped lots or the incorrect housing unit type. The road buffer was generated from the United States Census Bureau's TIGER/Line road data and was used to assign the transportation LULC to roads which due to parcel delineations were included in other LULC.

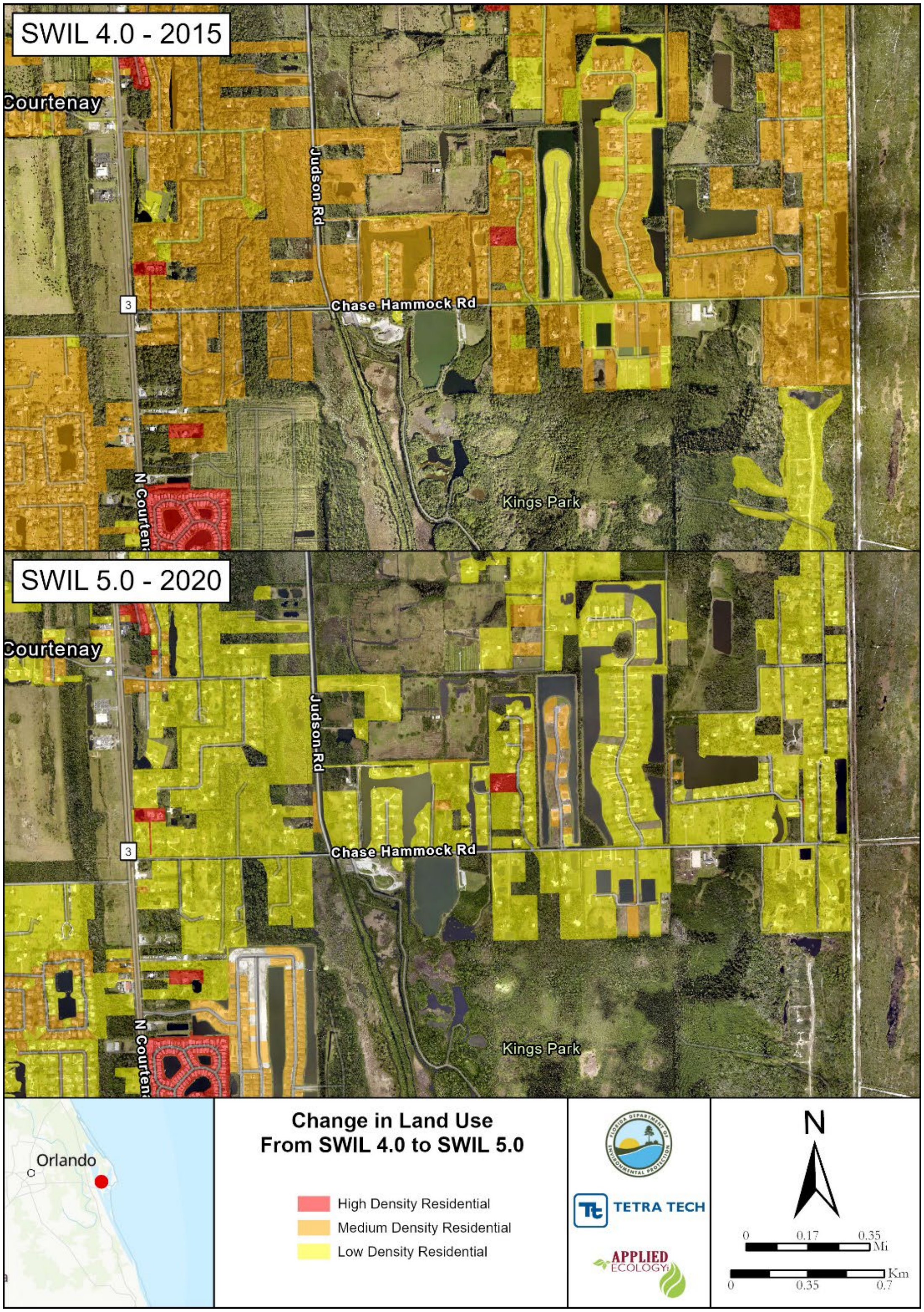

Figure 22. Change in residential LULC between SWIL 4.0 and SWIL 5.0.

3.2.2 2020 SWIL VOLUME AND LOADING

The total volume in m^3/year, TN in lbs/year, and TP in lbs/year, for the 2020 SWIL model results are presented in **Table 11**. Overall, total volumes and nutrient loadings have increased since the 1943 natural background condition simulation. Like the natural background condition simulation, the Central IRL had the highest volumes and TN and TP loading. The BRL had the lowest volumes and TN and TP loads of the three basins. Total estimated volumes are 51,355,305 m^3/year in the BRL, 185,708,423 m^3/year in the North IRL, and 586,265,515 m^3/year in the Central IRL. Estimated TN loads are 98,555 lbs/year in the BRL, 352,103 lbs/year in the North IRL, and 1,209,702 lbs/year in the Central IRL. TP loads are 10,847 lbs/year in the BRL, 39,234 lbs/year in the North IRL, and 161,493 lbs/year in the Central IRL.

Table 11. Volume and nutrient loads simulated by the 2020 SWIL 5.0.

Parameter	Basin	Direct Runoff	Subsurface Flow	Total
Volume (m^3/year)	BRL	14,919,418	36,435,887	**51,355,305**
	North IRL	46,646,636	139,061,787	**185,708,423**
	Central IRL	184,208,618	402,056,897	**586,265,515**
Total Nitrogen (lbs/year)	BRL	26,707	71,848	**98,555**
	North IRL	73,258	278,845	**352,103**
	Central IRL	329,886	879,815	**1,209,702**
Total Phosphorus (lbs/year)	BRL	3,479	7,367	**10,847**
	North IRL	9,309	29,925	**39,234**
	Central IRL	45,552	115,942	**161,493**

The 2020 SWIL 5.0 volume and loads are presented as stacked bar charts in **Figure 23, Figure 24**, and **Figure 25** as a visual representation of the allocation of direct runoff and SSF to total loads. SSF makes up most volume and loads into the IRL. SSF makes up 71% of the total volume in the BRL, 75% in the North IRL, and 69% in the Central IRL (**Figure 23**). Additionally, SSF accounts for 73-79% of the TN loads in the IRL basins (**Figure 24**), and 68-76% of the TP loads in the IRL basins (**Figure 25**).

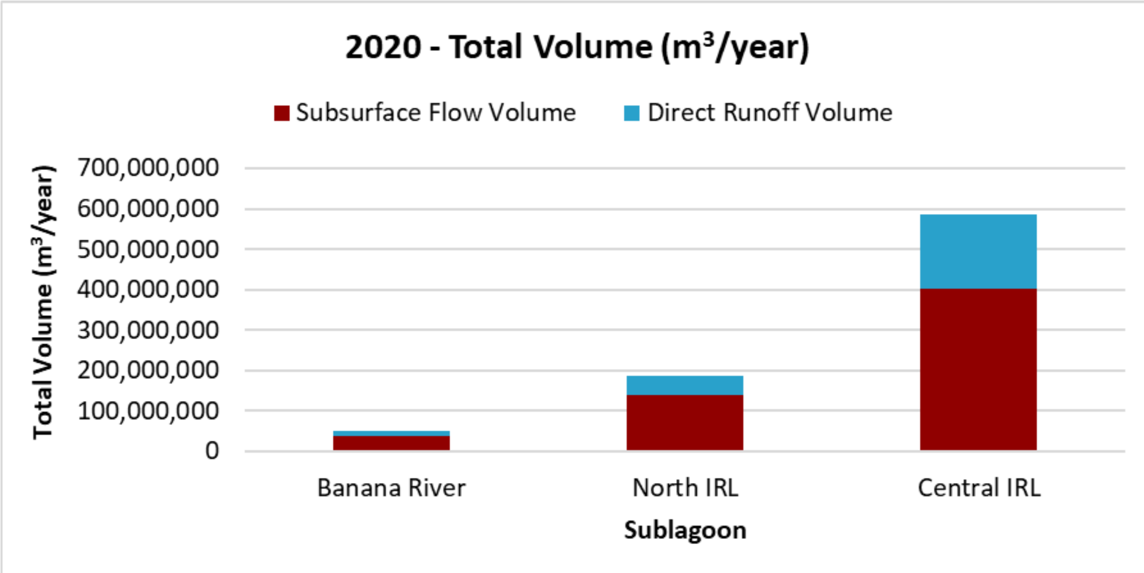

Figure 23. Total volume of baseloads (m³/year) into the IRL in 2020.

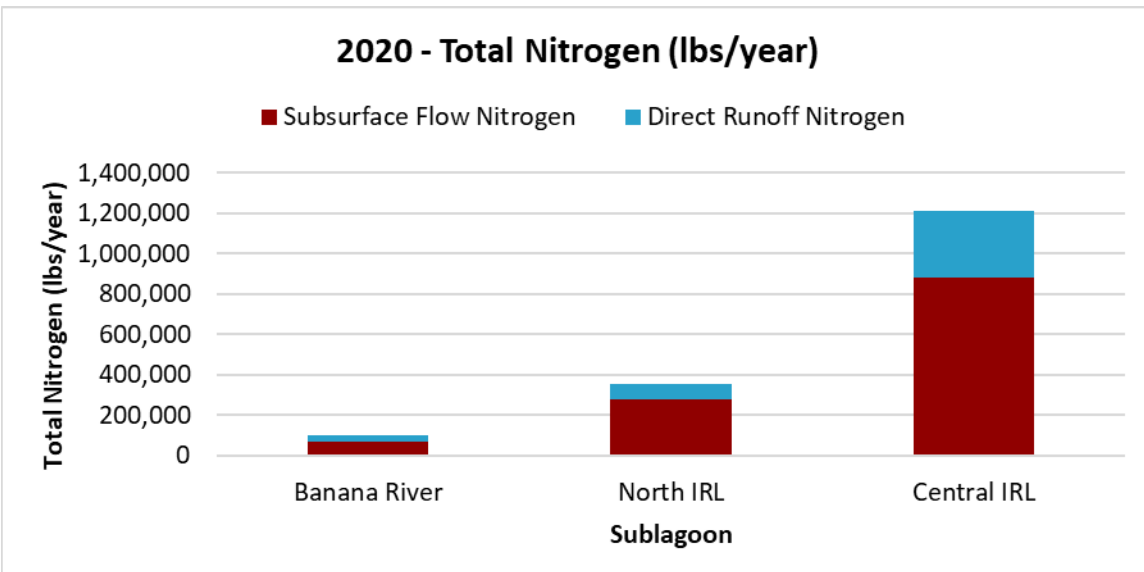

Figure 24. Total nitrogen baseloads (lbs/year) into the IRL in 2020.

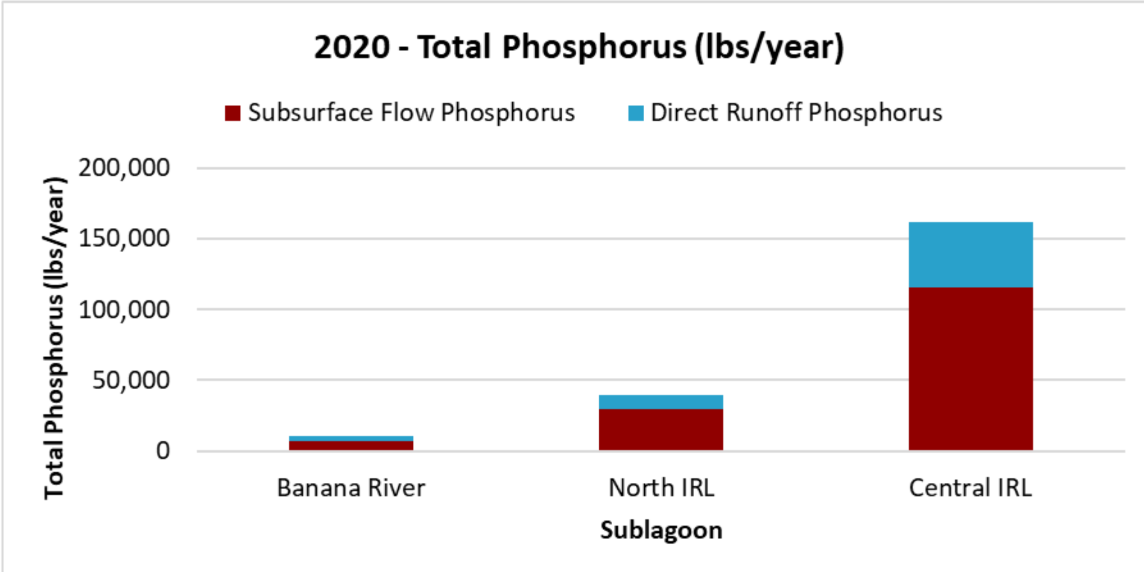

Figure 25. Total phosphorus baseloads (lbs/year) into the IRL in 2020.

Figure 26 through **Figure 31** present spatial interpretations of TN and TP loading into the IRL in 2020. The highest TN loads are depicted in red, ranging from 3.98 lbs/year to 8.34 lbs/year, and highest TP loads range from 0.81 lbs/year to 4.18 lbs/year. Loads are visibly higher in 2020 than historically in 1943. In the BRL, there are high estimated loads located throughout Merritt Island and beachside communities, with exceptions of CCSFS and PSFB which present, in general, lower nutrient loads. There is a TN hotspot located near the industrial area of the Kennedy Space Center region (**Figure 26**). TP loads in the BRL are most notable in the Merrit Island and residential beachside communities (**Figure 27**).

In the North IRL, notably high TN loads are visible along the coastlines, with the high loadings in the Titusville, Cocoa, and Melbourne/Eau Gallie areas (**Figure 28**). Similarly, the highest TP loads are centered around the Titusville and Eau Gallie coastline areas (**Figure 29**).

The Central IRL shows high TN loads throughout the basin, with highest TN and TP loads associated with regions of Palm Bay and Vero Beach (**Figure 30** and **Figure 31**).

Figure 26. Total nitrogen loading per cell into the Banana River Lagoon in 2020.

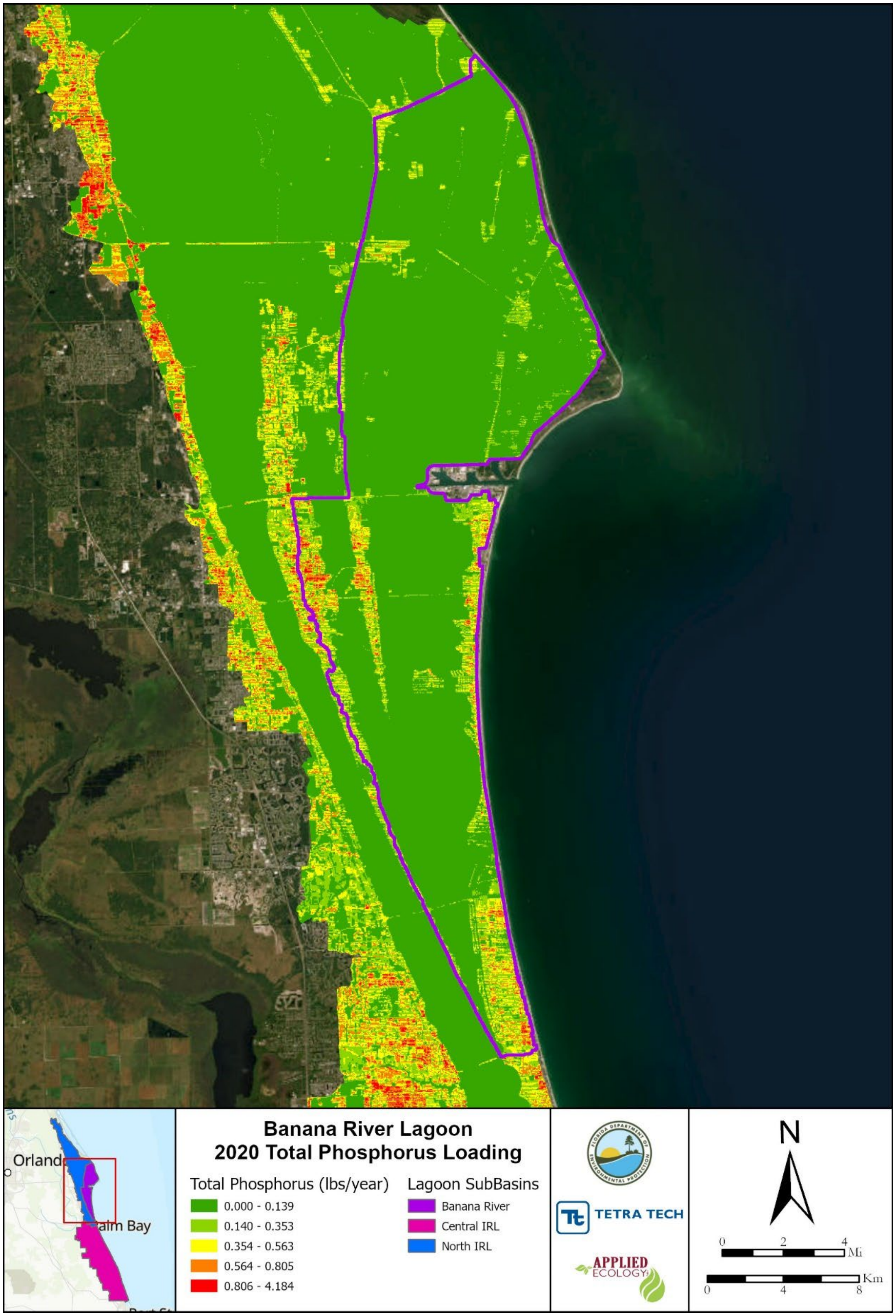

Figure 27. Total phosphorus loading per cell into the Banana River Lagoon in 2020.

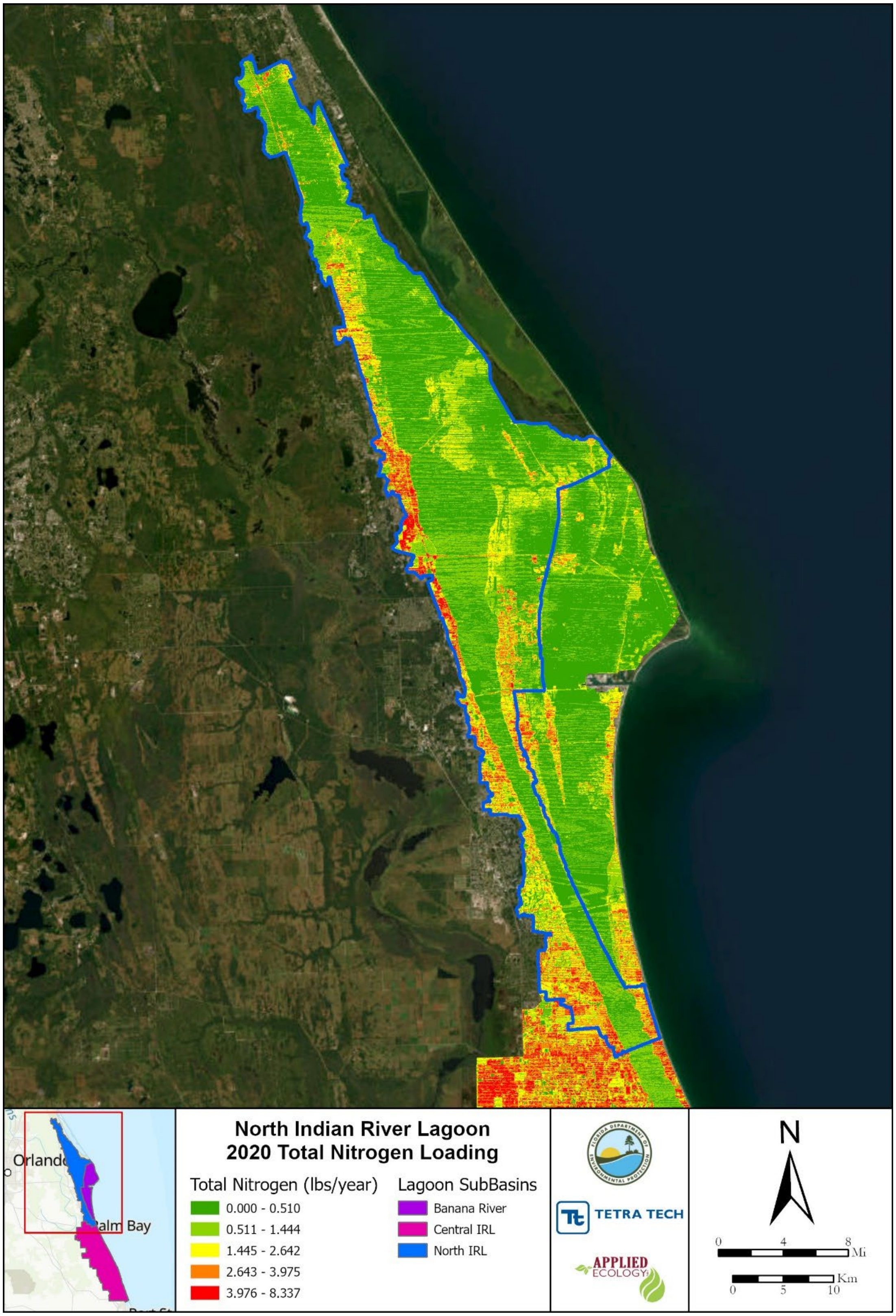

Figure 28. Total nitrogen loading per cell into the North Indian River Lagoon in 2020.

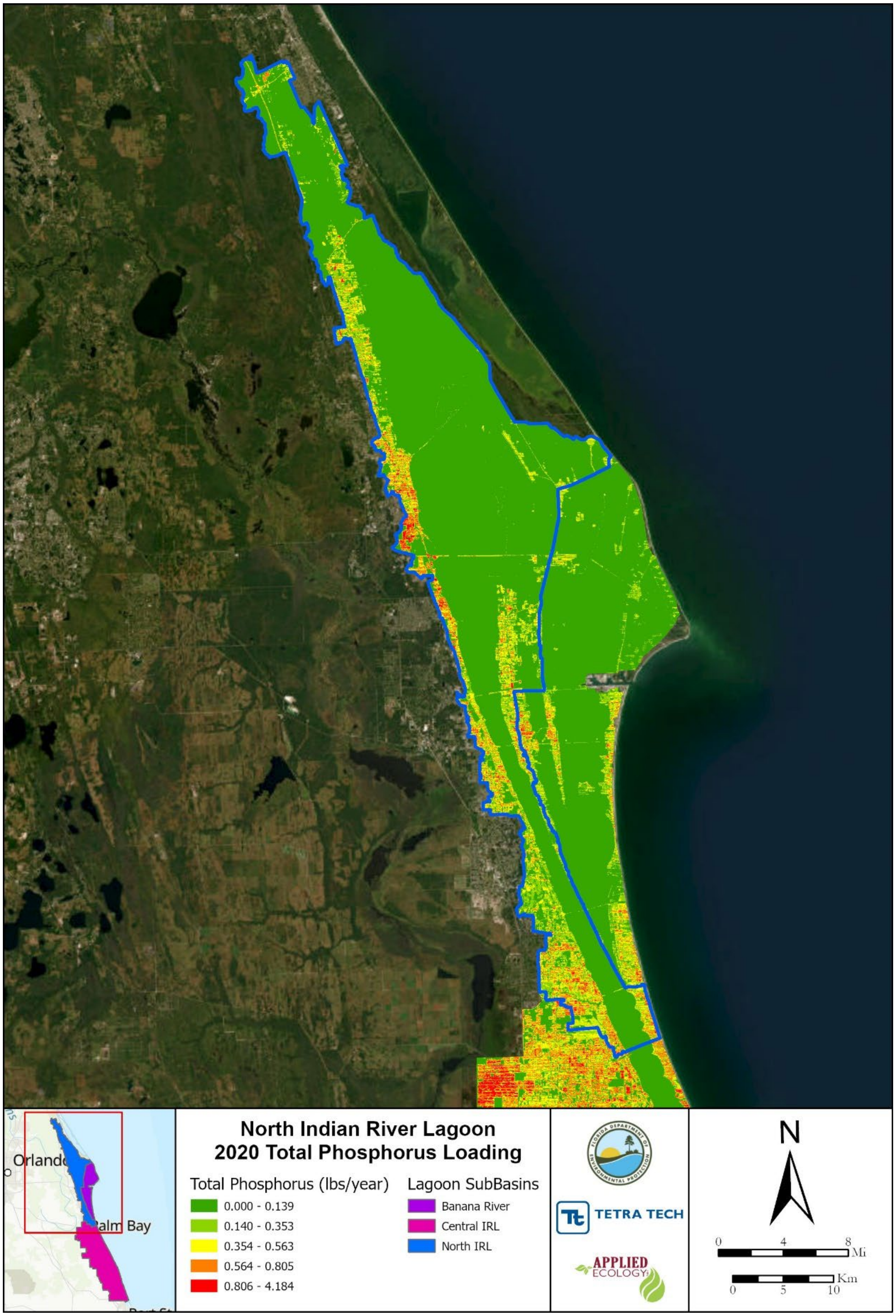

Figure 29. Total phosphorus loading per cell into the North Indian River Lagoon in 2020.

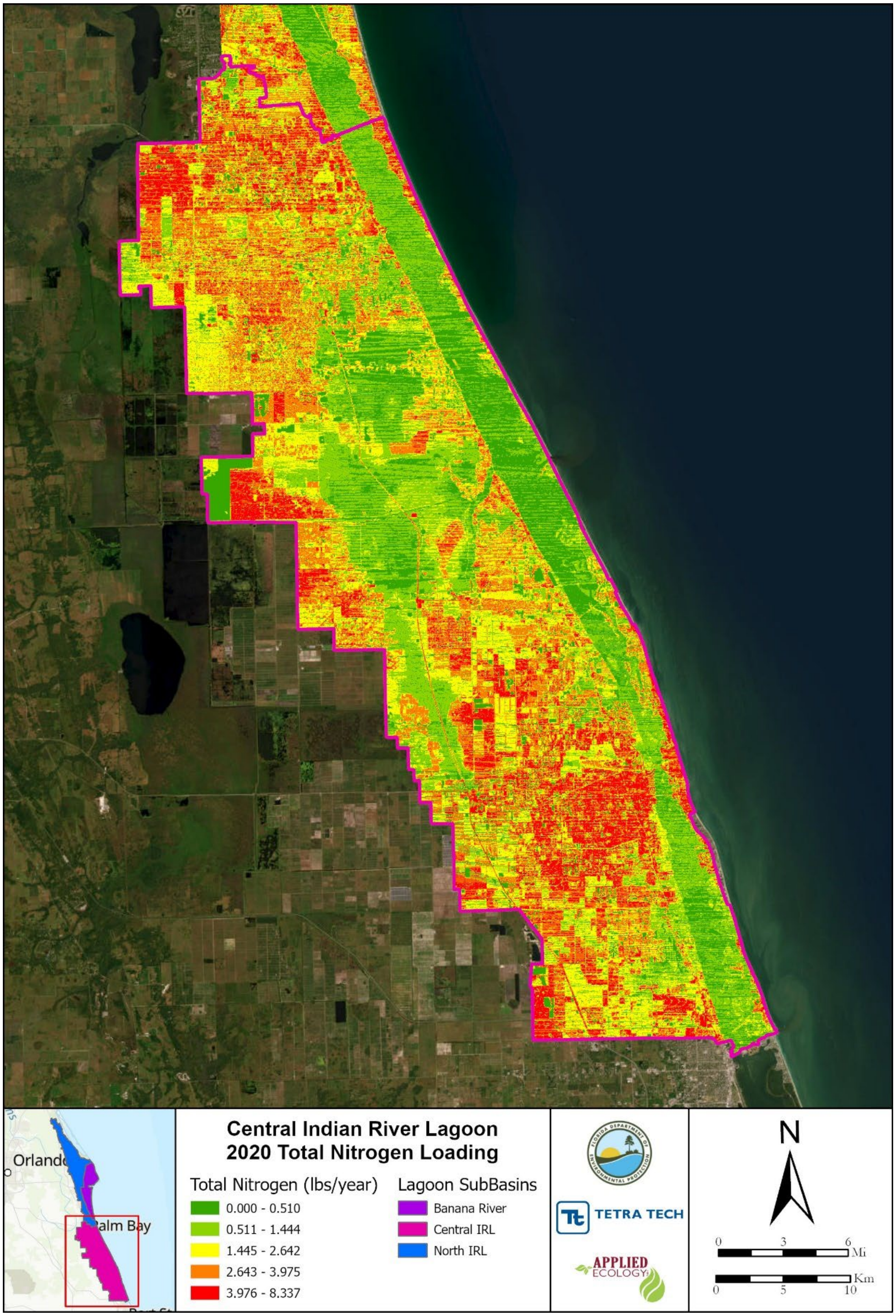

Figure 30. Total nitrogen loading per cell into the Central Indian River Lagoon in 2020.

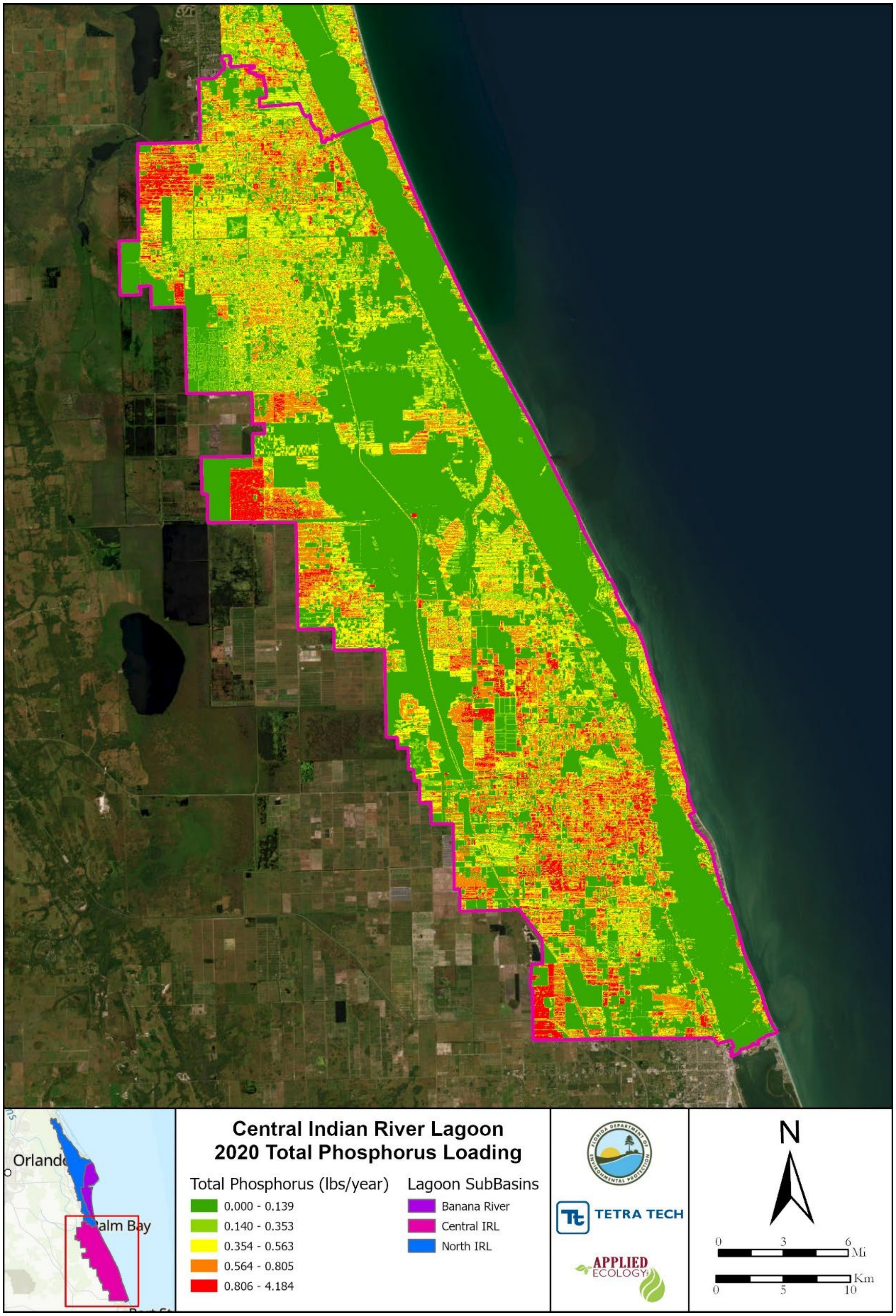

Figure 31. Total phosphorus loading per cell into the Central Indian River Lagoon in 2020.

3.2.2.1 2020 Seasonal Results

Estimated volumes and nutrient loads were analyzed from January to May to represent the dry season. **Table 12** presents the dry season loading results for the IRL basins. As expected, the volume and nutrient loads are lower than the full year of loading, with the wet season totals producing the 69-73% of the loads.

Total dry season volumes were estimated at 17,323,174 m^3/year in the BRL, 59,237,777 m^3/year in the North IRL, and 163,111,021 m^3/year in the Central IRL. Estimated TN loads are 31,354 lbs/year in the BRL, 105,539 lbs/year in the North IRL, and 328,279 lbs/year in the Central IRL. TP loads are 3,036 lbs/year in the BRL, 10,390 lbs/year in the North IRL, and 43,379 lbs/year in the Central IRL.

Table 12. Seasonal loading results from the 2020 SWIL 5.0 results.

Parameter	Basin	Direct Runoff	Subsurface Flow	Total
Volume (m^3/year)	BRL	4,098,815	13,224,360	**17,323,174**
	North IRL	12,249,101	46,988,676	**59,237,777**
	Central IRL	44,967,639	118,143,382	**163,111,021**
Total Nitrogen (lbs/year)	BRL	7,195	24,160	**31,354**
	North IRL	17,978	87,561	**105,539**
	Central IRL	72,698	255,581	**328,279**
Total Phosphorus (lbs/year)	BRL	957	2,079	**3,036**
	North IRL	2,355	8,035	**10,390**
	Central IRL	9,944	33,435	**43,379**

3.2.2.2 Comparison of SWIL 4.0 Loading Results

Total volumes and loading from the SWIL 4.0 model iteration is presented in **Table 13**. The SWIL 4.0 estimated much higher total volume and nutrient loads compared to the current SWIL 5.0 model (**Table 11**), with the largest differences associated with the total volumes. Due to the decrease of the IRL watershed used for SWIL 5.0, the estimated volumes and loads were normalized and presented in m^3/year/acre and lbs/years/acre for a more appropriate comparison.

Overall, the SWIL 4.0 model estimated 5,930 m^3/acre/year volume into the BRL, while the SWIL 5.0 estimates 525 m^3/acre/year. For the North IRL, the SWIL 4.0 model estimates 7,092 m^3/acre/year of volume, while the SWIL 5.0 estimates 854 m^3/acre/year. For the Central IRL, the SWIL 4.0 model estimates 11,388 m^3/acre/year of volume, while the SWIL 5.0 estimates 1,640 m^3/acre/year.

For TN, the SWIL 4.0 model estimates 2.78 lbs/acre/year TN loading into the BRL, while the SWIL 5.0 estimates 1.01 lbs/acre/year. For the North IRL, the SWIL 4.0 model estimates 3.50 lbs/acre/year of TN, while the SWIL 5.0 estimates 1.62 lbs/acre/year. For the Central IRL, the SWIL 4.0 model estimates 6.69 lbs/acre/year of TN, while the SWIL 5.0 estimates 3.38 lbs/acre/year.

For TP, the SWIL 4.0 model estimates 0.37 lbs/acre/year TP loading into the BRL, while the SWIL 5.0 estimates 0.11 lbs/acre/year. For the North IRL, the SWIL 4.0 model estimates 0.44 lbs/acre/year of TP, while the SWIL 5.0 estimates 0.18 lbs/acre/year. For the Central IRL, the SWIL 4.0 model estimates 0.90 lbs/acre/year of TP, while the SWIL 5.0 estimates 0.45 lbs/acre/year.

Table 13. Total volumes and loading comparisons of the SWIL 4.0 and 5.0 model iterations as normalized by the total acres of each basin.

Parameter	Basin	SWIL 4.0	SWIL 5.0
Volume (m^3/acre/year)	BRL	5,930	525
	North IRL	7,092	854
	Central IRL	11,388	1,640
Total Nitrogen (lbs/acre/year)	BRL	2.78	1.01
	North IRL	3.50	1.62
	Central IRL	6.69	3.38
Total Phosphorus (lbs/acre/year)	BRL	0.37	0.11
	North IRL	0.44	0.18
	Central IRL	0.90	0.45

3.2.2.2.1 Change in Event Mean Concentrations

The SWIL 5.0 model also included a new hydrological calibration and the implementation of an EMC calibration for TN and TP. This section of the memo provides several explanations and examples for the change in the estimated TN and TP loads between the prior model simulation and the current one.

The DRO EMCs were calibrated against the estimated monthly DRO nutrient loading as determined by the SJRWMD monthly surface water sample TN and TP concentration multiplied by the portion of the monthly flow as DRO. The DRO EMC calibration process resulted in decreases in TN and TP for all development types (**Table 14**). The largest decreases for TN and TP occurred in the undeveloped LULC types, with a 69.6% decrease in TN and 98.2% decrease in TP. Basins dominated by undeveloped LULC would have the greatest declines in estimated TN and especially TP loads (e.g., BRL). Additional details about the final EMCs can be found in AEI's Calibration Memorandum (AEI, 2023).

Table 14. Comparisons of the average Direct Runoff (DRO) Event Mean Concentrations by development type between the SWIL 4.0 and SWIL 5.0 models.

LULC Type	TN EMC (mg/L)		TP EMC (mg/L)	
	SWIL 4.0	SWIL 5.0	SWIL 4.0	SWIL 5.0
Agriculture	2.58	1.24	0.35	0.23
High Intensity Development	1.64	0.86	0.28	0.12
Low Intensity Development	1.52	0.84	0.20	0.05
Undeveloped	1.06	0.32	0.59	0.01

The SSF EMCs were calibrated using the same method as with the DRO EMCs. As the SSF represents most of the flow and nutrient contribution to the IRL, the decrease in the EMC values has a substantial impact. The SWIL 4.0 model had only developed and undeveloped SSF EMCs, whereas SWIL 5.0 further divides the developed category. The TN EMCs for all the development types were increased, with agriculture and low intensity development having the largest increases of 1.01 mg/L and 0.89 mg/L, respectively (**Table 15**). With the TP EMCs, only the undeveloped LULC types decreased from 0.13 mg/L to 0.03 mg/L while agriculture had the largest increase from 0.13 mg/L to 0.29 mg/L.

Table 15. Comparisons of the average subsurface flow Event Mean Concentrations (EMC) by development type between the SWIL 4.0 and SWIL 5.0 models.

LULC Type	TN EMC (mg/L)		TP EMC (mg/L)	
	SWIL 4.0	SWIL 5.0	SWIL 4.0	SWIL 5.0
Agriculture	0.35	1.36	0.13	0.29
High Intensity Development	1.09	1.17	0.14	0.20
Low Intensity Development	0.35	1.24	0.13	0.17
Undeveloped	0.35	0.70	0.13	0.03

Of note from the SWIL 5.0 calibration process, was the decrease in the DRO EMCs for the wetland and upland LULC types. The recalibrated DRO TN EMC for wetlands and uplands were approximately 74% lower and the TP EMC 98% lower (**Table 16**). As the IRL watershed has large swaths of natural areas, approximately 30.9% of the watershed, the sizable reduction of wetland and upland EMC values was a substantial part of the decrease in overall loading.

Table 16. Comparison of the average Direct Runoff (DRO) Event Mean Concentration (EMC) values for wetland and upland LULC types between the SWIL 4.0 and SWIL 5.0 models.

EMC Nutrient (mg/L)	Wetlands		Uplands	
	SWIL 4.0	SWIL 5.0	SWIL 4.0	SWIL 5.0
TN	1.19	0.27	1.13	0.33
TP	0.90	0.01	0.21	0.00

4 CONCLUSIONS

This memorandum summarizes the results from the updated SWIL 5.0 model simulations for 1943 and 2020 data. LULC was evaluated as well as volumes, TN loads, and TP loads for the BRL, North IRL, and Central IRL basins. Additionally, the LULC and loading results were compared to the previous SWIL 4.0 model. The major findings are as follows:

- The IRL LULC in 1943 consisted of 88% undeveloped, 10% agriculture, 2% high intensity development, and 1% low intensity development. The Central IRL had the highest volumes of 465,998,252 m^3/year, as well as the highest TN and TP loading contributions of 754,580 lbs/year and 66,694 lbs/year, respectively. The BRL had the lowest volumes of 39,223,094 m^3/year, as well as the lowest TN and TP loading contributions of 56,141lbs/year and 66,694 lbs/year, respectively.

- The SWIL 5.0 2020 simulation estimated that undeveloped land accounts for 66% of the land use, high intensity development accounts for 16%, and both agriculture and low intensity development accounts for 9% each within the IRL basin. Undeveloped LULC decreased from historical data, while both high and low intensity development increased. Total volume and nutrient loadings also increased from 1943 data. Similar to the natural background condition simulation, the Central IRL had the highest volume and nutrient loading. The Central IRL had volumes of 586,265,515 m^3/year, and TN and TP loading contributions of 1,209,702 lbs/year and 161,493 lbs/year, respectively. The BRL had the lowest volumes of 51,355,305 m^3/year, as well as the lowest TN and TP loading contributions of 98,555 lbs/year and 10,847 lbs/year, respectively.

- Compared to the SWIL 4.0, the newer SWIL 5.0 iteration estimated considerably lower volume and nutrient loads due to certain variables. The change in classification of LULC between SWIL 4.0 and SWIL 5.0 had an impact on loading throughout the IRL, after a more involved approach for LULC updates and thousands of acres being reclassified. Additionally, the updated SWIL model included a new hydrological calibration and the implementation of an EMC calibration for TN and TP, in which the DRO EMC calibration process resulted in decreases in TN and TP for all development types. The combination of LULC updates and EMC calibration resulted in much lower loading estimations for the SWIL 5.0.

AEI has delivered this memorandum to fulfill Task 8 and Optional Task 9 out of 12 tasks under this scope of work. The overall results from 2020 SWIL 5.0 indicate that LULC and loads have increased from 1943, but are lower than the SWIL 4.0 estimations. The results presented within this memorandum can assist the DEP in developing the load allocations associated with the BRL, North IRL, and Central IRL BMAPs.

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APPENDIX A

APPENDIX A: SUMMARY OF CONSOLIDATED LAND USE FOR BANANA RIVER LAGOON, NORTH INDIAN RIVER LAGOON, AND CENTRAL INDIAN RIVER LAGOON

Table A-1. Banana River Lagoon consolidated land use in acres for 1943, 2015, and 2020 SWIL simulations.

Land Use Consolidation	Land Use Area (Acres)			Percent of Total Land Use (%)		
	1943	2015	2020	1943	2015	2020
Citrus	929.9	75.9	33.0	0.95%	0.08%	0.03%
Commercial	0.0	1,533.2	1,399.8	0.00%	1.57%	1.43%
Dry Prairie	0.0	3,060.2	2,796.5	0.00%	3.12%	2.86%
Field Crop	0.0	0.0	0.0	0.00%	0.00%	0.00%
High Density Residential	16.7	1,733.4	2,510.6	0.02%	1.77%	2.56%
Hydric Hammock	0.0	380.5	372.1	0.00%	0.39%	0.38%
Improved Pasture	99.4	18.0	14.6	0.10%	0.02%	0.01%
Industrial	622.7	350.2	264.0	0.64%	0.36%	0.27%
Institutional	0.0	6,194.1	4,402.8	0.00%	6.32%	4.50%
Low Density Residential	309.2	196.8	1,337.0	0.32%	0.20%	1.37%
Medium Density Residential	43.2	7,249.4	3,545.6	0.04%	7.40%	3.62%
Mesic Flatwoods	0.0	15.6	17.0	0.00%	0.02%	0.02%
Mining	0.0	0.0	0.0	0.00%	0.00%	0.00%
Open	999.6	394.4	1,623.2	1.02%	0.40%	1.66%
Other Agriculture	13.5	5.6	8.7	0.01%	0.01%	0.01%
Rangeland	35.5	4.9	41.9	0.04%	0.01%	0.04%
Recreational 1	0.0	251.5	683.2	0.00%	0.26%	0.70%
Recreational 2	0.0	78.6	59.5	0.00%	0.08%	0.06%
Row Crops	0.0	0.0	0.0	0.00%	0.00%	0.00%
Ruderal	0.0	42.7	28.0	0.00%	0.04%	0.03%
Scrub	7,650.7	9,154.8	10,201.5	7.81%	9.35%	10.42%
Transportation	845.5	1,206.3	3,034.4	0.86%	1.23%	3.10%
Upland Flatwoods	23,264.7	3,379.9	1,622.5	23.76%	3.45%	1.66%
Upland Mixed	188.1	130.5	0.0	0.19%	0.13%	0.00%
Water	50,030.0	49,031.1	49,884.6	51.10%	50.07%	50.95%
Wet Flatwoods	0.0	292.3	213.9	0.00%	0.30%	0.22%
Wet Prairies	0.0	369.3	335.0	0.00%	0.38%	0.34%
Wetland	12,861.7	9,417.1	9,236.4	13.14%	9.62%	9.43%
Xeric Hammock	0.0	3,367.5	4,244.7	0.00%	3.44%	4.34%

Table A-2. North Indian River Lagoon consolidated land use in acres for 1943, 2015, and 2020 SWIL simulations.

Land Use Consolidation	Land Use Area (Acres)			Percent of Total Land Use (%)		
	1943	2015	2020	1943	2015	2020
Citrus	12,245.3	2,945.4	2,164.3	5.64%	1.36%	0.99%
Commercial	137.8	7,078.2	4,379.9	0.06%	3.26%	2.01%
Dry Prairie	812.4	2,755.4	1,855.8	0.37%	1.27%	0.85%
Field Crop	44.4	119.7	60.6	0.02%	0.06%	0.03%
High Density Residential	481.5	5,814.3	6,304.0	0.22%	2.68%	2.90%
Hydric Hammock	0.0	3,515.9	3,424.2	0.00%	1.62%	1.57%
Improved Pasture	470.3	3,347.4	2,023.1	0.22%	1.54%	0.93%
Industrial	0.0	1,275.4	1,026.1	0.00%	0.59%	0.47%
Institutional	0.0	7,734.7	4,496.3	0.00%	3.56%	2.07%
Low Density Residential	1,002.8	1,857.1	9,340.6	0.46%	0.86%	4.29%
Medium Density Residential	811.2	19,887.8	7,536.4	0.37%	9.16%	3.46%
Mesic Flatwoods	0.0	207.4	171.7	0.00%	0.10%	0.08%
Mining	0.0	202.1	33.2	0.00%	0.09%	0.02%
Open	1,761.9	1,447.5	6,450.9	0.81%	0.67%	2.97%
Other Agriculture	0.0	193.4	380.9	0.00%	0.09%	0.18%
Rangeland	0.0	324.3	850.5	0.00%	0.15%	0.39%
Recreational 1	167.9	768.3	1,735.5	0.08%	0.35%	0.80%
Recreational 2	0.0	90.4	109.0	0.00%	0.04%	0.05%
Row Crops	56.2	1.6	53.8	0.03%	0.00%	0.02%
Ruderal	0.0	1,104.1	1,849.9	0.00%	0.51%	0.85%
Scrub	13,036.2	12,213.0	12,212.9	6.00%	5.63%	5.61%
Transportation	3,300.9	2,304.6	7,398.4	1.52%	1.06%	3.40%
Upland Flatwoods	47,848.5	6,708.0	6,969.9	22.04%	3.09%	3.20%
Upland Mixed	1,930.7	20.2	7.0	0.89%	0.01%	0.00%
Water	78,461.9	82,171.7	84,073.3	36.14%	37.85%	38.65%
Wet Flatwoods	0.0	3,506.4	2,738.3	0.00%	1.62%	1.26%
Wet Prairies	0.0	1,136.8	845.0	0.00%	0.52%	0.39%
Wetland	54,565.1	47,218.2	48,250.5	25.13%	21.75%	22.18%
Xeric Hammock	0.0	1,136.8	793.1	0.00%	0.52%	0.36%

Table A-3. Central Indian River Lagoon consolidated land use in acres for 1943, 2015, and 2020 SWIL simulations.

Land Use Consolidation	Land Use Area (Acres)			Percent of Total Land Use (%)		
	1943	2015	2020	1943	2015	2020
Citrus	24,327.1	33,685.0	8,900.7	6.81%	8.99%	2.49%
Commercial	176.8	9,954.1	7,204.4	0.05%	2.66%	2.02%
Dry Prairie	21,874.6	24,377.7	8,654.6	6.12%	6.51%	2.42%
Field Crop	5,323.4	852.9	267.1	1.49%	0.23%	0.07%
High Density Residential	1,168.5	13,327.0	11,214.9	0.33%	3.56%	3.14%
Hydric Hammock	0.0	809.1	893.0	0.00%	0.22%	0.25%
Improved Pasture	7,387.8	25,740.8	29,493.3	2.07%	6.87%	8.25%
Industrial	425.0	4,921.5	2,833.3	0.12%	1.31%	0.79%
Institutional	0.0	26,254.1	6,736.9	0.00%	7.01%	1.88%
Low Density Residential	1,560.7	7,575.2	22,622.3	0.44%	2.02%	6.33%
Medium Density Residential	817.9	67,744.4	30,160.4	0.23%	18.09%	8.44%
Mesic Flatwoods	353.5	3,009.6	3,565.3	0.10%	0.80%	1.00%
Mining	0.0	910.5	347.6	0.00%	0.24%	0.10%
Open	5,560.0	5,501.7	39,029.3	1.56%	1.47%	10.92%
Other Agriculture	7.9	2,358.6	3,127.8	0.00%	0.63%	0.88%
Rangeland	13,012.3	3,631.4	10,111.2	3.64%	0.97%	2.83%
Recreational 1	373.4	3,863.6	5,621.8	0.10%	1.03%	1.57%
Recreational 2	0.0	276.9	661.6	0.00%	0.07%	0.19%
Row Crops	729.6	2,984.5	4,295.7	0.20%	0.80%	1.20%
Ruderal	0.0	4,685.1	5,528.8	0.00%	1.25%	1.55%
Scrub	61,938.8	22,343.4	21,182.7	17.33%	5.97%	5.93%
Transportation	4,629.6	3,384.7	20,187.1	1.30%	0.90%	5.65%
Upland Flatwoods	95,849.8	9,318.1	9,262.9	26.81%	2.49%	2.59%
Upland Mixed	1,500.5	41.4	1.8	0.42%	0.01%	0.00%
Water	45,884.0	45,376.1	54,792.0	12.84%	12.11%	15.33%
Wet Flatwoods	0.0	22,214.8	19,373.1	0.00%	5.93%	5.42%
Wet Prairies	0.0	6,964.5	3,122.6	0.00%	1.86%	0.87%
Wetland	64,561.2	21,753.4	27,517.2	18.06%	5.81%	7.70%
Xeric Hammock	0.0	714.8	726.4	0.00%	0.19%	0.20%