VERO BEACH UTILITIES COMMISSION MEETING
TUESDAY, OCTOBER 13, 2020 - 9:00 A.M.
CITY HALL, COUNCIL CHAMBERS, VERO BEACH, FLORIDA

A G E N D A

1. **CALL TO ORDER**

2. **APPROVAL OF MINUTES**

   A) **July 14, 2020**

3. **PUBLIC COMMENT**

4. **NEW BUSINESS**

5. **OLD BUSINESS**

6. **CHAIRMAN'S MATTERS**

7. **MEMBER'S MATTERS**

   A) **Basin Management Action Plan (BMAP) Video - Requested by Mrs. Judy Orcutt**
   B) **ArcNLET Nitrogen Modeling Study – Requested by Mrs. Judy Orcutt**
   C) **Progress on Main Canal Project that will Create a Pipeline to John's Island and its Effect on Lagoon Water Quality – Requested by Mr. John Cotugno**
   D) **New Wastewater Treatment Plant Design Update and its Effect on Lagoon Water Quality – Requested by Mr. John Cotugno**
   E) **Any other Stormwater Mitigation Projects being Considered that will Effect Lagoon Water Quality – Requested by Mr. John Cotugno**
   F) **Effect of State's Unfunded Mandates on Vero Beach's Approach to a Stormwater Utility - – Requested by Mr. John Cotugno**
   G) **Progress on New Wastewater Treatment Funding – Requested by Mr. John Cotugno**

8. **ADJOURNMENT**

This is a Public Meeting. Should any interested party seek to appeal any decision made by the Commission with respect to any matter considered at such meeting or hearing, he will need a record of the proceedings and that, for such purpose he may need to ensure that a record of the proceedings is made, which record includes the testimony and evidence upon which the appeal is to be based. Anyone who needs a special accommodation for this meeting may contact the City's Americans with Disabilities Act (ADA) Coordinator at 978-4920 at least 48 hours in advance of the meeting.

VERO BEACH UTILITIES COMMISSION MINUTES
TUESDAY, JULY 14, 2020 - 9:00 A.M.
CITY HALL, COUNCIL CHAMBERS, VERO BEACH, FLORIDA

PRESENT: Chairman, Jane Burton; Vice Chairman and Indian River Shores Representative, Bob Auwaerter; Members: Judy Orcutt, Mark Mucher, John Cotugno, and Bob McCabe **Also Present:** City Attorney, John Turner; Water and Sewer Director, Rob Bolton and Deputy City Clerk, Sherri Philo

Excused Absence: John Sanders

1. CALL TO ORDER

Today's meeting was called to order at 9:00 a.m.

2. APPROVAL OF MINUTES

A) March 10, 2020

Mr. McCabe made a motion to approve the minutes of the March 10, 2020 Utilities Commission meeting. Mr. Mucher seconded the motion and it passed unanimously.

3. PUBLIC COMMENT

None

4. NEW BUSINESS

A) Senate Bill 712 and House Bill 1091 – Mr. Rob Bolton, Water and Sewer Director

Mr. Rob Bolton, Water and Sewer Director, gave a Power Point presentation on Senate Bill 712 Environmental Resource Management Clean Waterways Act (attached to the original minutes).

Mr. Auwaerter referred to, Section 17 – Advance Water Treatment (AWT) required for discharges to Indian River Lagoon (IRL), item 3, *Annual expenditure dedicated to pipe assessment*. He asked how would they go about assessing the pipes.

Mr. Bolton said they are looking at hiring new employees and doing inspections and smoke testing.

Mr. Bolton did not give a presentation on House Bill 1091.

Mrs. Orcutt referred to Section 11 – Discharge Contingency Plan for Vessels, *increase penalty to $7,500 from $5,000* of the backup information on House Bill 1091 (on file in the

City Clerk's office). She asked if that applies to the City. She said currently the City is in the process of putting out signs and was not sure if the signs included the penalty.

Mr. Bolton said that he didn't think the sign has the amount of the penalty listed.

At this time, Mr. Bolton gave a Power Point presentation on the effect of the "Clean Waterway Act" on the City's Water and Sewer Customers (attached to the original minutes).

Mrs. Orcutt asked does smoke testing identify a broken pipe.

Mr. Bolton said sometimes it would if it is close enough to the surface and is not underwater.

Mrs. Orcutt said then that is not the way to find a broken pipe.

Mr. Bolton answered no. That is found by inspection.

Mr. Mucher referred to the slide, what is in the budget to address the new Clean Waterways Act. He said it states that this year's operating budget includes four (4) new employees to do tv and smoke testing. He asked are they year-round, year to year type of activities.

Mr. Bolton answered yes.

Mr. Mucher said so it is not something they could contract out.

Mr. Bolton said the problem with contracting is that every utility in the State of Florida now has to do this and there are only a few private contracting firms that does this and it is hard to get them to come and do a small segment of pipe, let alone the entire system.

B) FY 20/21 Budget – Mr. Rob Bolton, Water and Sewer Director

*Please note that questions and discussion took place throughout the presentation.

Mr. Bolton went over the FY 20-21 Proposed Water and Sewer Utility budget with the Commission members (on file in the City Clerk's office).

Mr. Auwaerter referred to the Water and Sewer Fund – Operating Expenses. He said they are projecting a 2.9% jump in revenues. He questioned rate increases.

Mr. Bolton said the rates would have to be determined when they go through the rate analysis. The revenue increases they are seeing is from meter sales, etc.

Mr. Auwaerter said that he placed a few handouts in front of the Commission member's seats (attached to the original minutes). He said that he wanted to discuss under the General Fund, the Administrative Chargeback. He said in 2017/2018 there was $732,000 and in

2018/2019 it jumped 29%. He said that he and Mr. Bolton had a discussion about that and he (Mr. Bolton) made a comment that he thought it would be a one (1) time thing. Mr. Auwaerter said instead it went up another 16.6%. Therefore, over two (2) years it has gone up 71%. This year it is flat, but it is up substantially from 2016/2017. He is concerned that this is a bit of a piggybank for the General Fund to take water and sewers customers to pay for the General Fund. He said in last year's budget book it shows that 40% of the City Clerk's office was allocated back to the Water and Sewer Fund, which was a big jump from previous years. He said that he has a concern that these costs are being dumped on the Water and Sewer Fund.

Ms. Cindy Lawson, Finance Director, explained that generally the administrative charges is calculated by the individual departments that are in the General Fund that provides support to Water and Sewer Department because they do not have those functions. It is for things like finance, cashiering, the City Clerk's office, the City Council, the City Manager's office, etc. Those functions do not exist within the Utility so they pay their proportionate share of those shared services. She said that she does not have this information with her and she can provide them, but wherever possible she likes to tie the general administrative charges from an individual department to something specific. In the transition from having an Electric Utility to not having an Electric Utility, there was a rise for all the Enterprise Funds because their proportionate share of the number of the employee population went up as the total employee population went down by the 85 or 90 employees that worked for the Electric Utility. That transition happened and now they see that this has leveled off. She said that she would be happy to provide more detail on the individual departments and how the allocations are calculated.

Mr. Auwaerter said still, in reality the cost went up 71%. He said the Electric Utility was a big chunk of this government before it was sold and you are telling me that you couldn't take any reductions in staff or reductions in other costs, that they just all stayed the same and caused it to go up 71%.

Ms. Lawson said some of them went down. She said there are four (4) people in the Human Resource's Department and you can't have a half of a person go. She said there is a certain level of fixed costs to operate the government.

Mr. Auwaerter said that he had a conversation with Mr. James O'Connor, former City Manager, about the City Clerk's office and at that time 50% was attributed to the Electric Utility and Mr. O'Connor stated that they were dealing with a lot of issues with electric.

Mr. Mucher said that he is trying to figure out how 40% of the City Clerk's office goes to Water and Sewer Utilities.

Ms. Lawson said that she does not have that information with her, but she can provide it to the Commission members.

Mr. Auwaerter said in the last fiscal year, $217,739 of the City Clerk's costs were attributed to Water and Sewer. The total was $537,551 so in dividing those two (2), you get approximately 40%.

Mr. Auwaerter referred to the Town of Indian River Shores and the City of Vero Beach Water, Wastewater, and Reuse Water Franchise Agreement that he provided the Commission members (attached to the original minutes). He said Section 14 – Capital Improvement Plan states in part, *Vero Beach shall annually provide the draft of its detailed Five (5) year capital improvement plan, specific to the water, wastewater, and reuse water utility systems within the Service Area to the Indian River Shores Town Manager ...* He asked Mr. Bolton if he has a breakdown on this.

Mr. Bolton answered no. He explained that he does not have this broken down by specific projects and a lot of times they don't list out every single project because it becomes cumbersome so they list it all as one (1) number and it is under rehab of the sewer system. He said one (1) of the first generators they put in will be at Lift Station 69, which is right by Town Hall, and all the flow from Indian River Shores goes through that Lift Station. He said that he can send Mr. Auwaerter the entire Capital Plan.

Mr. Auwaerter said that he is not an attorney and doesn't know if the City is adhering to that provision or not. But, they haven't been getting anything.

5. OLD BUSINESS

None

6. CHAIRMAN'S MATTERS

Mrs. Burton reported that in February or March, the Commission was asked by the City Council to comment on the pros and cons for teaming up with the County regarding the Wastewater Utility rather than building a new facility for the City. She said at that time, they were aware that the State was having the regulations that they just discussed and the consensus of the Commission was that it would be prudent on the City's part to provide their own wastewater facility.

7. MEMBER'S MATTERS

Mrs. Orcutt reported that she submitted a video that explains the Basin Management Action Plan (BMAP) history and process. She asked that they view the video at the next Utilities Commission meeting.

Mrs. Burton agreed to put this on their next agenda.

Mr. Mucher asked if they could watch the video in advance of their meeting.

Mrs. Burton said the Commission members could view the video prior to the meeting and they will watch it again and then have discussion. She asked the Deputy City Clerk to send the Commission members the link to the video.

8. ADJOURNMENT

Today's meeting adjourned at 10:14 am.

/sp

TETRA TECH

MEMO

To:	Matthew T. Mitts, P.E.
Cc:	Robert J. Bolton, P.E.
From:	Matt Shelton
Date:	October 28, 2019
Subject:	Calibration for Ammonia and Update to the Live Oak STEP Basin ArcNLET Model

The City of Vero Beach (City) has begun collection of groundwater and nitrogen concentration samples at three monitoring wells in the Live Oak Septic Tank Effluent Pumping (STEP) basin. To date four quarterly samples were collected at these wells. A refined ArcGIS-Based Nitrate Load Estimation Toolkit (ArcNLET) model was developed for the area to take advantage of these measurements. Table 1-1 summarizes the sampling results. Both Nitrite/Nitrate and Ammonia were simulated with the refined model. Below is a description of the model's set-up, calibration and results.

A total of 317 septic tanks are located in and around the Live Oak STEP Basin. An additional 30 STEP-converted septic tanks were used to estimate nitrogen load reductions. The locations of these septic tanks are shown on Figure 1-1.

The City of Vero Beach provided Tetra Tech with a detailed, 1.5 feet x 1.5 feet Digital Elevation Model (DEM) coverage of the City. This dataset was projected to the NAD83 UTM17N Meter projection with a resolution of 5-meter x 5 meter. The elevation values were converted from feet. to meter. A 5-meter x 5-meter DEM was chosen to preserve more detail for the smaller modeling area. This dataset was used to calibrate the groundwater particle tracking part of the refined ArcNLET model. A smoothing factor of 160 was used in the calibrated model. Results or the hydrological calibration are shown in Figure 1-2 and the refined groundwater particle paths on Figure 1-3.

The vadose zone model (VZMOD) utility of ArcNLET was used to estimate the initial concentrations of nitrite/nitrate and ammonia at the water table for each septic tank. Resulting concentrations are summarized in Table 1-2. These concentrations vary by septic tank but are generally about 12 mg/L for NO_x, and 28 mg/L for NH_4. Higher ammonia concentrations are due to the proximity of the water table to the septic drain fields, and lack of time for completion of the nitrification process.

After the VZMOD simulation, ArcNLET nitrogen transport model was calibrated by trial and error while attempting to match the model as closely as possible to the measured values. The calibrated parameters are summarized in Table 1-2. The resulting concentrations of ammonia and nitrite/nitrate and their comparison to measured values are shown in Figures 1-4 and 1-5. The concentration plumes are shown in Figures 1-6 and 1-7. The model performs well at simulation concentrations at MW-1 and MW-2, but underestimates both the ammonia and nitrite/nitrate concentration at MW-2. A reason for this behavior can be seen on the particle path figure (Figure 1-3) – there is only one septic tank particle paths running close to the monitoring well, and the concentrations of ammonia and nitrite/nitrate is low by the time the path nears the well. This could be attributed by a discrepancy in the shape of the water table as compared to the smoothed DEM. We can see the group of septic tanks just to the north of MW-2 is generally flowing southeast, possibly the actual paths flow further south. Additionally, the measured concentrations might be attributed to another source of nitrogen, background concentrations, or a leaking sewer line.

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The updated summary of surface water nitrogen load estimates for the Live Oak basin is shown in Table 1-3. The model estimated the 317 septic tanks contribute a load of 1,953.34 pounds of ammonia and 1,054.43 pounds of nitrite/nitrate per year to the surface waterbodies. Approximately 99% of this load is directed to the Indian River Lagoon (Waterbody ID 154). The average nitrogen load per septic tank is 9.49 pounds per year.

In order to estimate the nitrogen removal due to conversion of septic systems to STEP, an additional run of the ArcNLET model was set-up using all 347 (active and converted) septic systems. The model shows that the conversion of 30 septic systems to STEP reduced the nitrogen load by 293.49 pounds per year, or 8.89% of the load. The summary of the loads and removals are shown in Table 1-4. Simulated ammonia and nitrite/nitrate plumes from all septic systems is shown on Figures 1-8 and 1-9.

Figure 1-1 Overview of the Refined Model Area

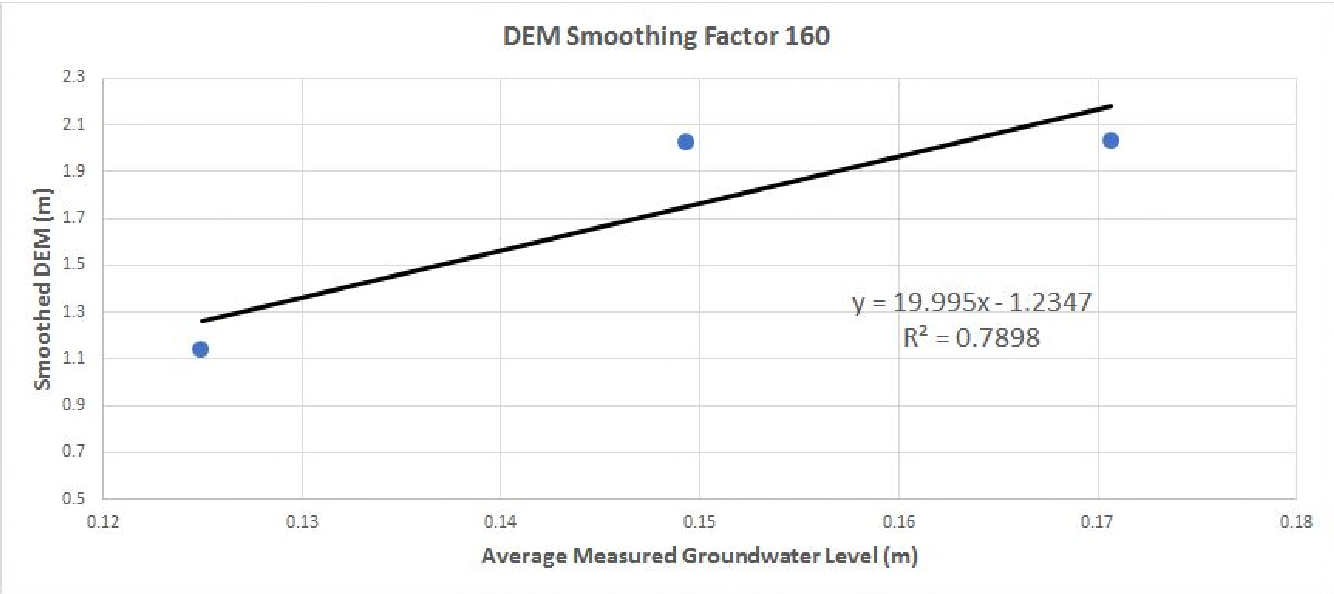

Figure 1-2 Smoothed DEM Relationship with the Measured Water Level

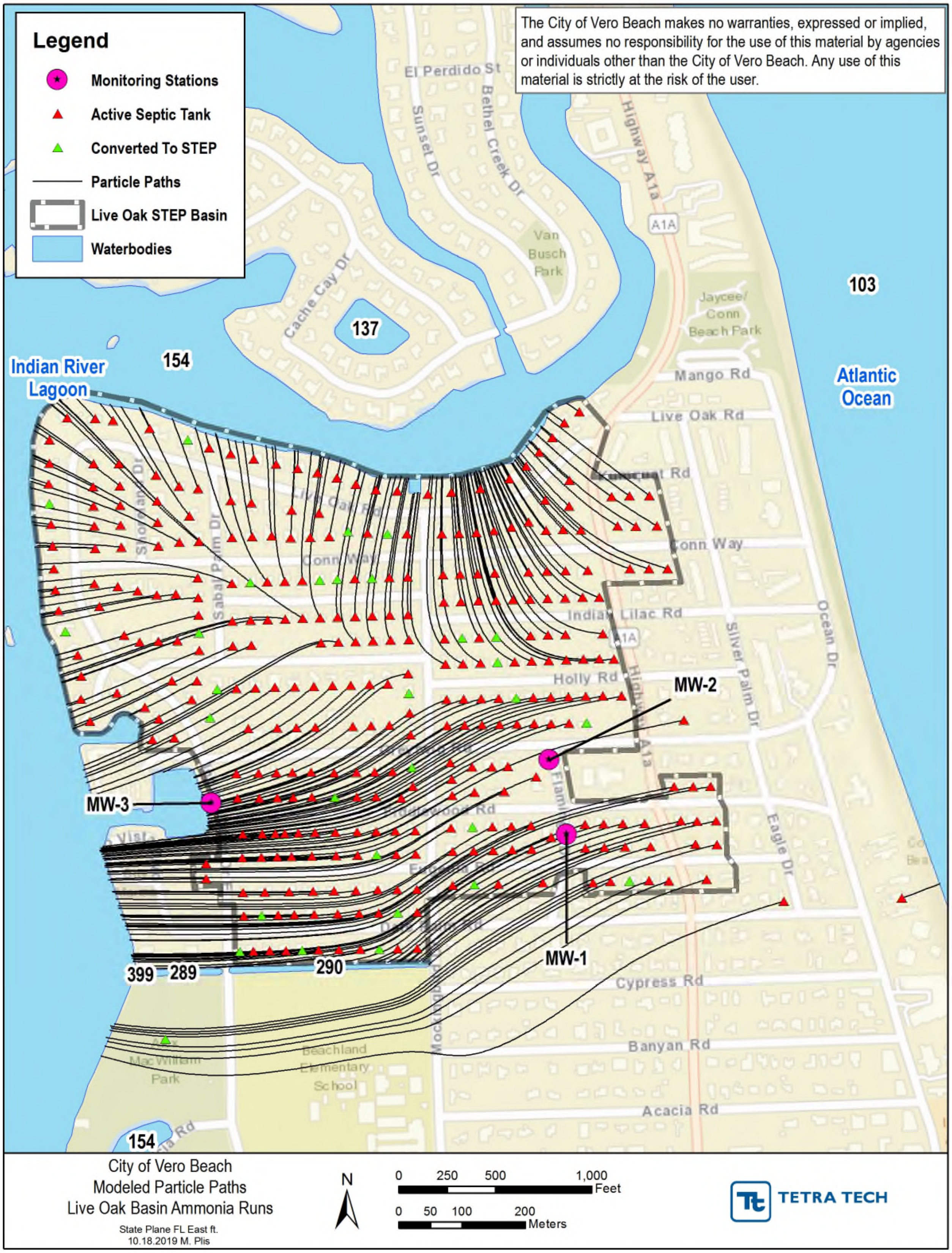

Figure 1-3 Refined Modeled Particle Paths

Table 1-1 Measured Ammonia and NOx Values

Station	Water Elevation	Min NH4	Average NH4	Max NH4	Min NO2/3	Average NO2/3	Max NO2/3
MW-1	0.49	0.18	0.23	0.26	< 0.03	1.10	4.30
MW-2	0.56	0.18	0.24	0.34	< 0.03	2.50	9.90
MW-3	0.41	0.25	0.79	1.30	< 0.03	2.38	9.40

Table 1-2 Initial and Calibrated ArcNLET Parameter Values

Parameter	Initial Value	Calibrated Value
Smoothing Factor	100	160
Source Plane NO3 Concentration (mg/L)	40	~12 (Varies)
Source Plane NH4 Concentration (mg/L)	N/A	~28 (Varies)
Longitudinal Dispersivity (m)	10	10
Horizontal Transverse Dispersivity (m)	1	2
First-Order Decay Coefficient of Denitrification	0.00055	0.005
Coefficient of Nitrification	N/A	0.00078

Table 1-3 Estimated Nitrogen Loading to Groundwater and Surface Waterbodies from 317 Septic Systems Located in the Live Oak Area

	Ammonia	NOx	Total
Loading to groundwater (kg/day)	4.51	2.53	7.03
Loading to Surface Waterbodies (kg/day)	2.43	1.31	3.74
Loading to Surface Waterbodies (lb/year)	1,953.34	1,054.43	3,007.77
Percentage of Loading to Waterbodies (%)	64.94%	35.06%	100.00%
Loading to Surface Waterbodies per Septic Tank (lb/year)	6.16	3.33	9.49
Percentage of Nitrogen Removal in Groundwater (%)	46.12%	48.15%	46.85%

Table 1-4 Estimated Reduction of Nitrogen Loading with STEP Conversion

	Ammonia	NOx	Total
Active Septic Loading to Surface Waterbodies (lb/year)	1,953.34	1,054.43	3,007.77
All Septic Loading to Surface Waterbodies (lb/year)	2,147.74	1,153.52	3,301.25
STEP Conversion Reduction of Loads (lb/year)	194.40	99.09	293.49
STEP Conversion Reduction of Loads per Septic Tank (lb/year)	6.48	0.34	6.82
Current Percentage of Nitrogen Reduction due to STEP Conversion	9.05%	8.59%	8.89%

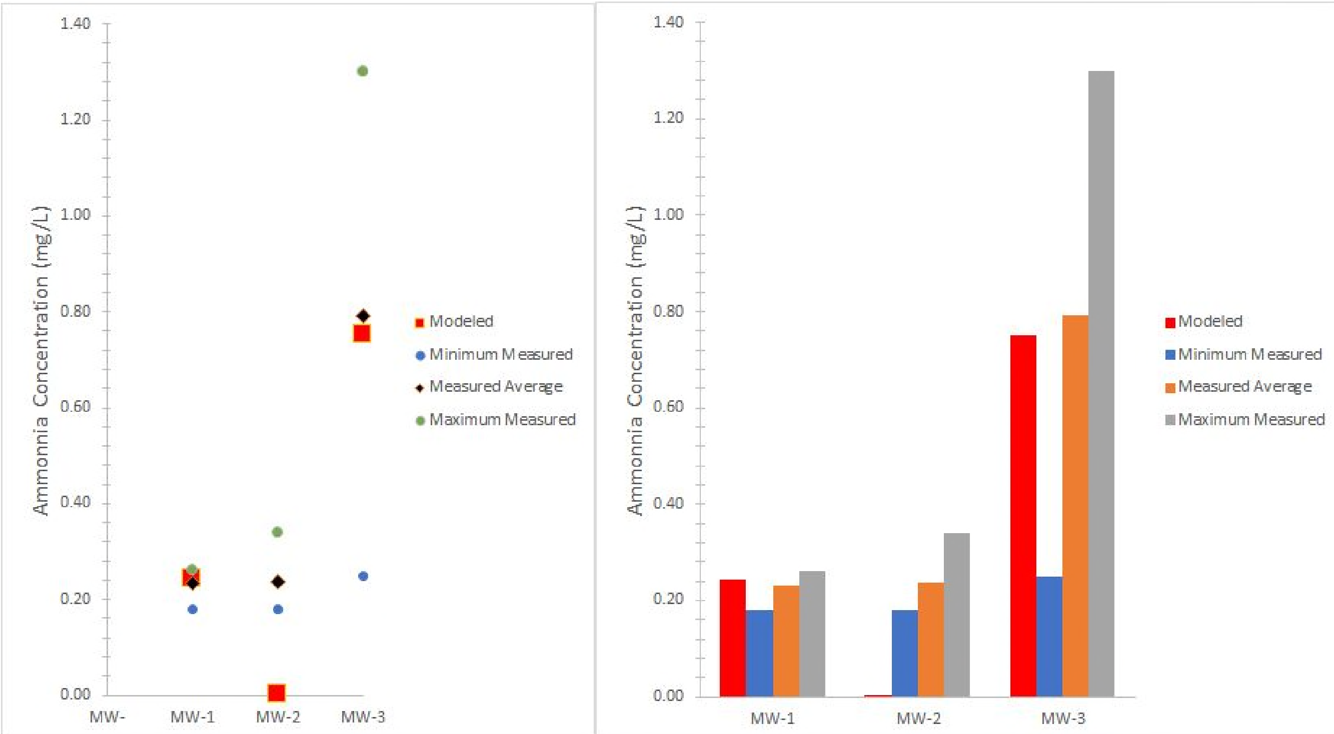

Figure 1-4 Modeled and Measured Ammonia Values

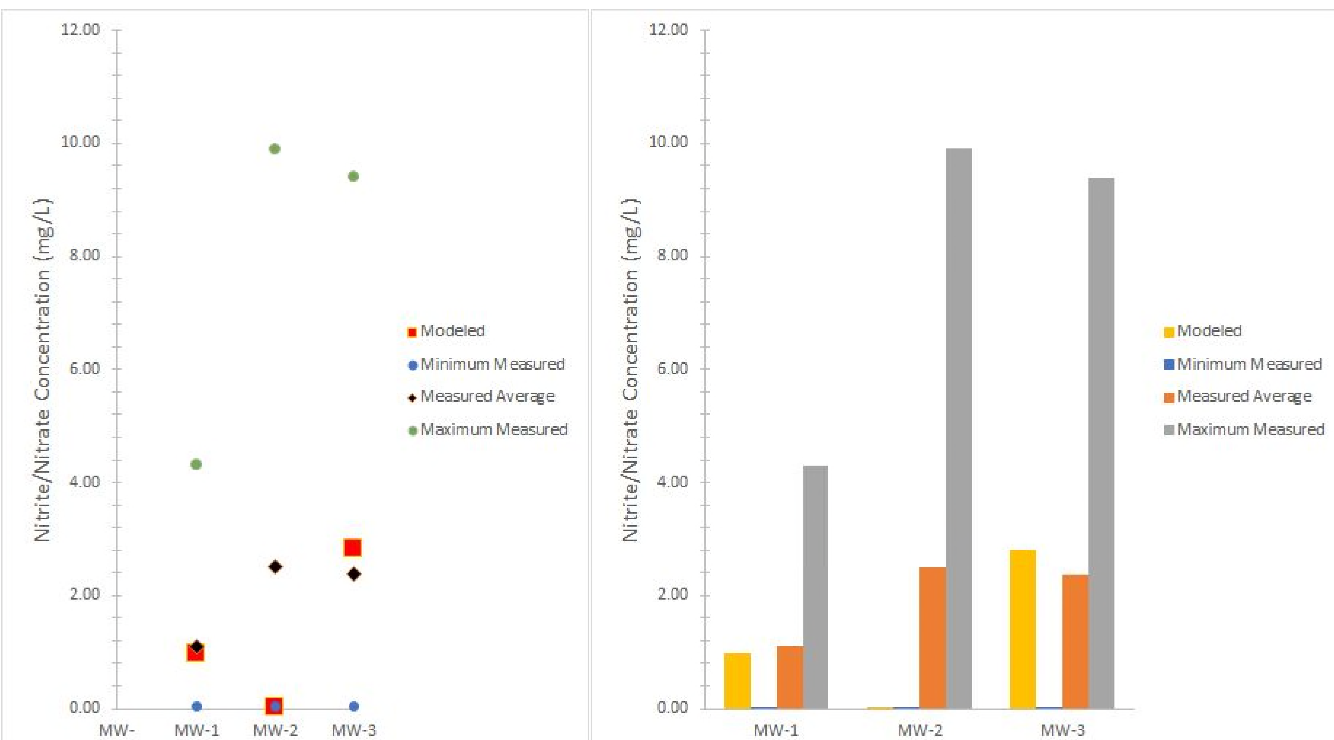

Figure 1-5 Modeled and Measured Nitrite/Nitrate Values

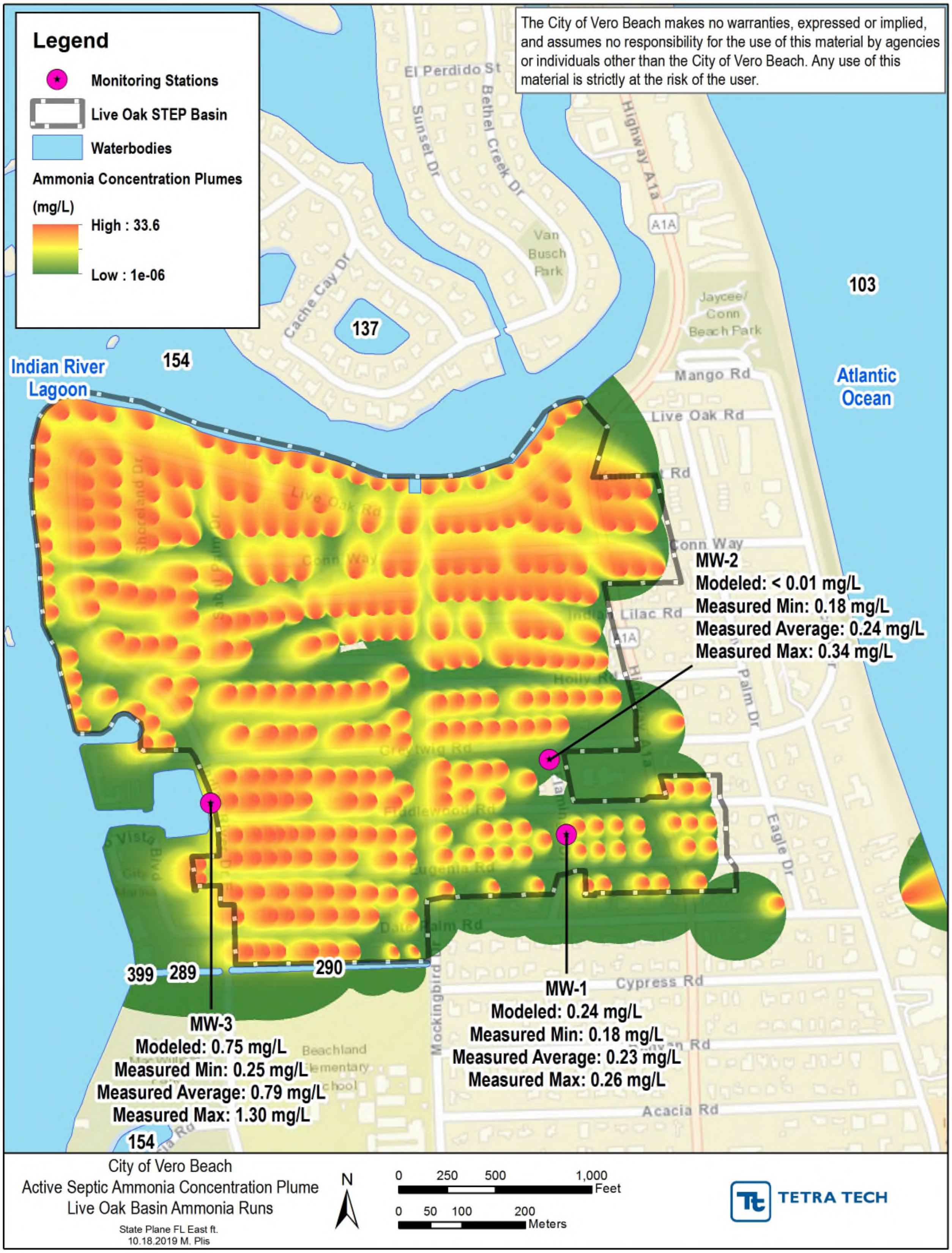

Figure 1-6 Modeled Ammonia Concentration Plumes (Active Septic)

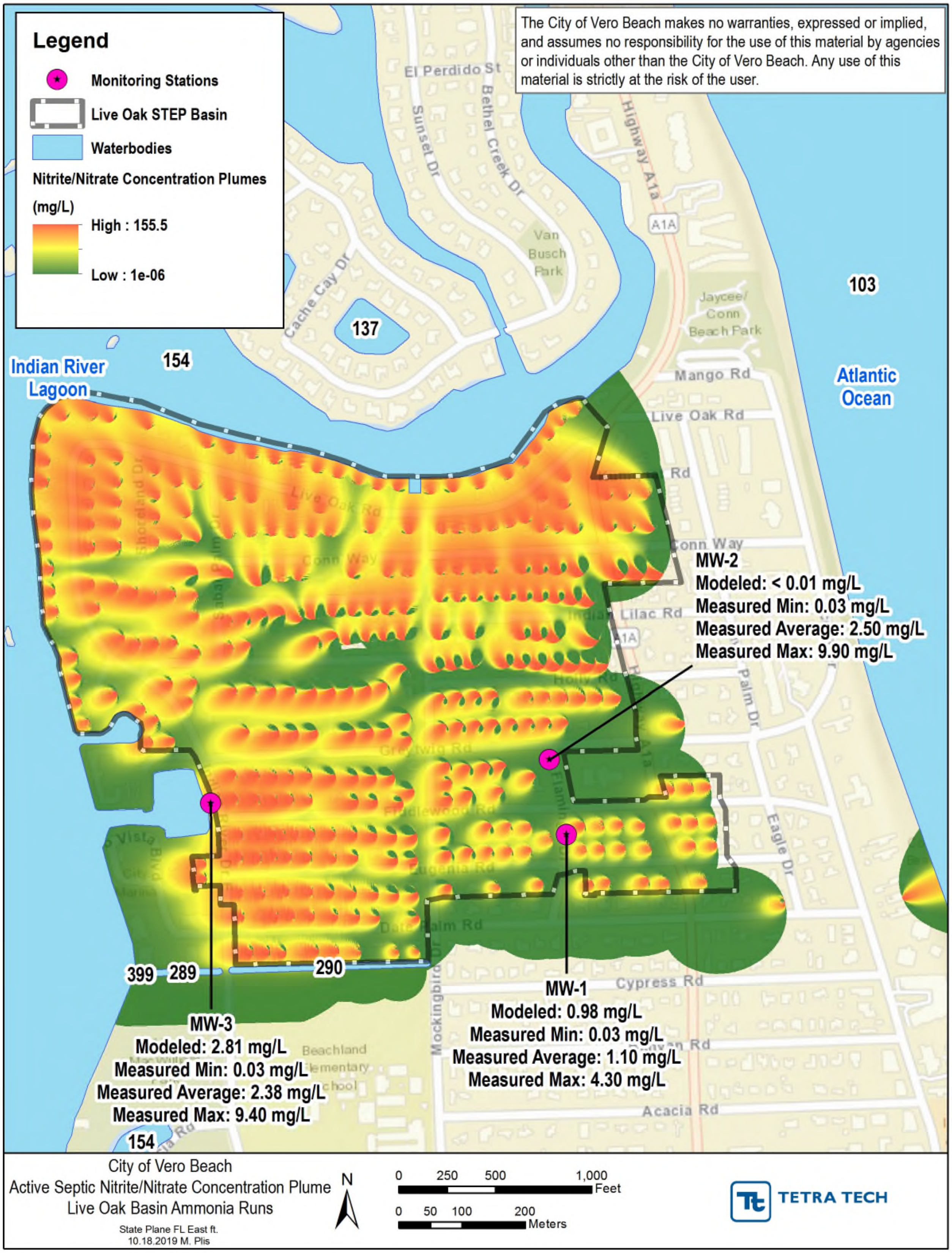

Figure 1-7 Modeled NOx Concentration Plumes (Active Septic)

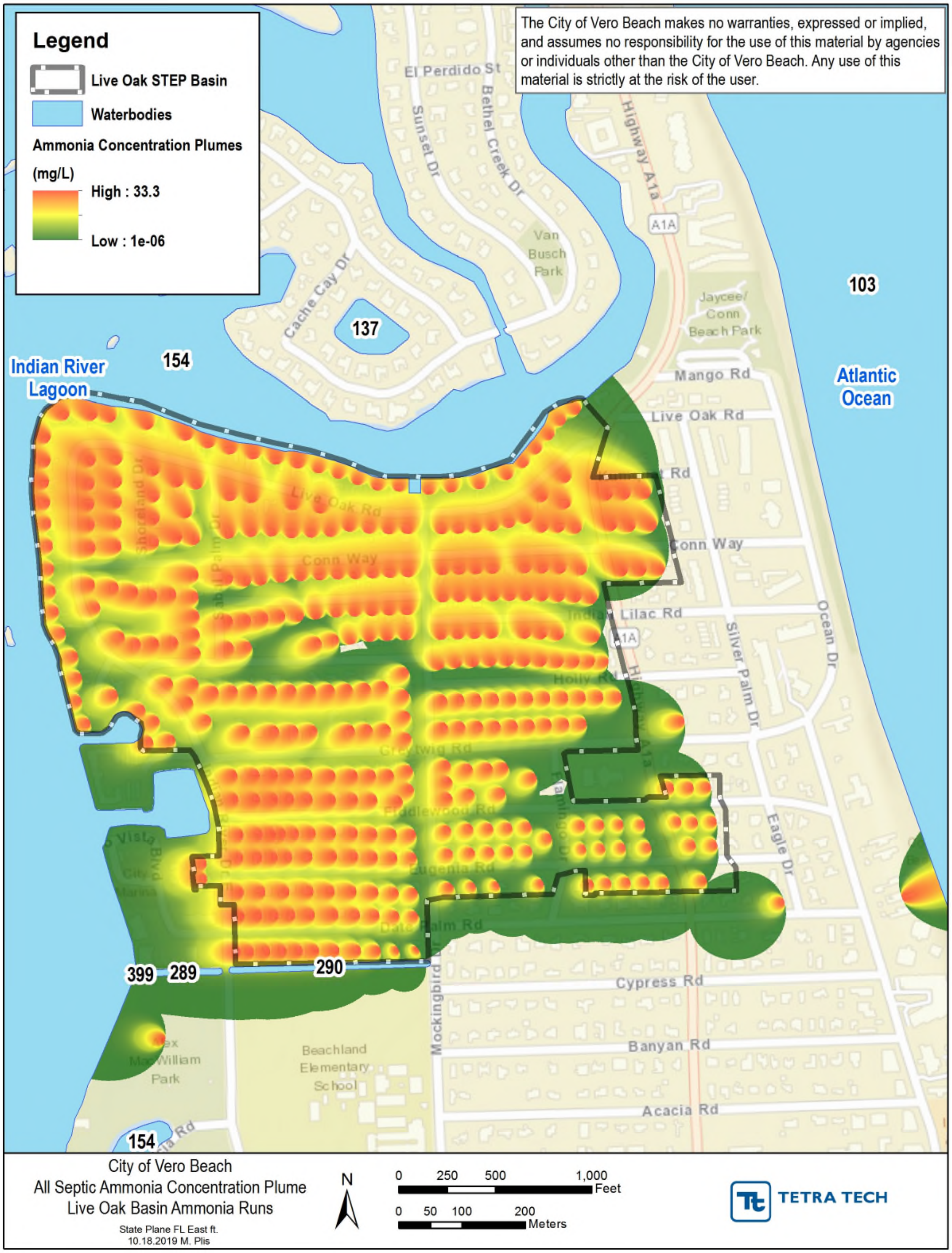

Figure 1-8 Modeled Ammonia Concentration Plumes (All Septic)

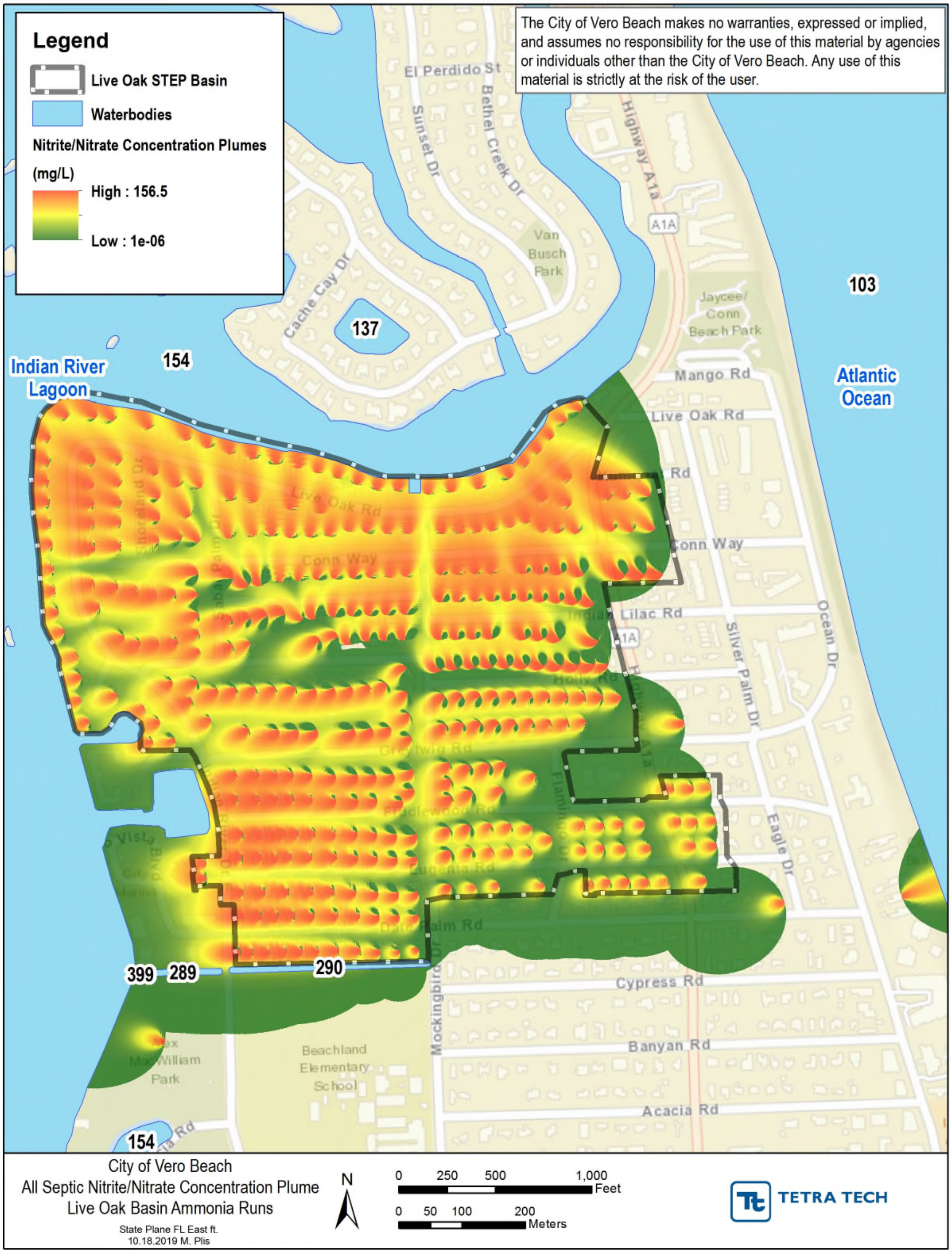

Figure 1-9 Modeled NOx Concentration Plumes (All Septic)

ArcGIS-Based Nitrate Load Estimation Toolkit (ArcNLET) Model Development and Septic System Loading Evaluation in City of Vero Beach, Florida

September 2018

PREPARED FOR

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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
ArcNLET	ArcGIS-Based Nitrate Load Estimation Toolkit
BMAP	Basin Management Action Plan
CDF	Cumulative Distribution Function
City	City of Vero Beach
DEM	Digital Elevation Model
DEP	Florida Department of Environmental Protection
FDOH	Florida Department of Health
GIS	Geographic Information System
IRL	Indian River Lagoon
lbs/yr	Pounds Per Year
mg/L	Milligrams Per Liter
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
SSURGO	Soil Survey Geographic Database
STEP	Septic Tank Effluent Pumping (system)
UTM17N	Universal Transverse Mercator Zone 17N

EXECUTIVE SUMMARY

The City of Vero Beach (City) has 1,473 homes on septic systems, and as of the time of this report, they have converted 101 of these homes to septic tank effluent pumping (STEP) systems to connect them to the sewer system. The City is evaluating additional areas to convert to STEP systems. The City requested that Tetra Tech develop an ArcGIS-Based Nitrate Load Estimation Toolkit (ArcNLET) model to quantify the water quality benefits of converting the existing septic systems to STEP systems.

Septic systems are one of the significant sources of nitrogen in groundwater and surface water, posing serious threats to human health and the environment. The ArcNLET model has been used to simulate nitrogen transport and estimate nitrogen loading from septic systems to surface waterbodies through the surficial aquifer. It is based on a simplified conceptual model of groundwater flow and nitrogen transport. The purpose of this study is to estimate the nitrogen load from the 1,372 active septic systems and 101 septic systems converted to STEP systems to the Indian River Lagoon (IRL) and other surface waterbodies in and around the City. This study found that all the waterbodies in and around the City (437 total), including the IRL, have been receiving a total nitrogen load of 6,560 pounds per year (lbs/yr). This load was reduced by 511 lbs/yr to 6,049 lbs/yr by converting the 101 septic systems to STEP systems. The IRL directly receives 68.2% (4,126 lbs/yr) of the total load, and the Atlantic Ocean directly receives an additional 14.2% (860.5 lbs/yr) of the total load. The summary of calibrated and current load estimates is shown in the table below:

STEP Basin	Calibrated Model - All Septic Systems		STEP Scenario (Current Conditions) - STEP System Converted to Septic Systems			
	# of Septic Systems	Total Load (lbs/yr)	# of Septic Systems Converted to STEP	Total Load (lbs/yr)	Current Load Reduction (lbs/yr)	Current Load Per Septic System (lbs/yr)
14th St	272	445.0	5	444.1	0.9	1.66
Airport	8	15.6	0	15.6	0.0	1.95
Atlantic Blvd	136	16.2	3	16.2	0.0	0.12
Bethel Creek	141	1,162.2	33	975.8	186.4	9.04
Country Club	81	28.8	1	28.8	0.0	0.36
Downtown	53	243.3	2	225.3	18.0	4.42
Live Oak	343	1,876.4	29	1,737.4	138.9	5.53
Riomar	115	539.1	9	486.0	53.1	4.58
South Beach	244	1,830.0	18	1,722.9	107.1	7.62
Total in STEP Basins	**1,393**	**6,156.5**	**100**	**5,652.1**	**504.4**	**4.37**
Outside of STEP	80	403.8	1	396.8	7.0	5.02
Total in City	**1,473**	**6,560.3**	**101**	**6,048.9**	**511.4**	**4.41**

Tetra Tech is currently working with the City to install groundwater monitoring wells in one of the City's basins. The information gathered through the groundwater monitoring will be used to refine the ArcNLET model. Therefore, the modeling results may change when these new data are available to improve model calibration.

1.0 INTRODUCTION

Nutrients, including nitrogen, are essential for plant and animal growth and nourishment, but excessive amounts of nitrogen in water can cause many adverse health and ecological effects. High nitrogen concentrations in surface waters can lead to overstimulation of growth of aquatic plants and algae, which can block light to deeper waters and lead to fish kills, hypoxia and, eutrophication.

Conventional septic tank and drainfield systems treat wastewater by settling solids and partly digesting the organic matter, allowing liquid effluent to be discharged into the soil beneath the drainfield. Septic systems are significant sources of nitrogen especially in urban areas (U.S. Environmental Protection Agency 2002). In the state of Florida, nearly one-third of households use septic systems (Hazen and Sawyer 2009). The City of Vero Beach (City) has 1,473 homes on septic systems, and they have converted 101 of these systems to septic tank effluent pumping (STEP) systems to connect them to the sewer system. The City is evaluating additional areas to convert to STEP systems (**Figure 1-1**). Understanding the magnitude of nitrogen loading from the septic systems to the surface waterbodies via groundwater discharge is important for restoration and planning purposes. A recent study by the Florida Department of Health (FDOH) showed that septic systems installed before 1983 potentially provide little to no treatment of septic system effluent because of the possible lack of separation from the water table for septic systems installed before modern requirements (FDOH 2015). Some barrier island residents within the City have begun to experience septic system failures over the past 18 months, brought on, in part, by high groundwater levels during extreme high tides. The City's hybrid STEP system project diverts septic system waste that seeps into groundwater via drainfields to a central sewage treatment plant for a higher level of nutrient treatment.

An ArcGIS-Based Nitrate Load Estimation Toolkit (ArcNLET) model was developed for the Florida Department of Environmental Protection (DEP) by Florida State University. The model focuses on nitrate transport and loads at a small scale with septic systems as point sources. ArcNLET includes a simple conceptual groundwater model to estimate the groundwater hydrologic process and uses analytical equations to describe nitrate transport with site-specific septic systems. This model has been used to estimate nitrate load from thousands of septic systems to surface waterbodies in the City of Jacksonville; City of Port St. Lucie, City of Stuart, and Martin County (Ye et al. 2013); and in the Indian River Lagoon (IRL) (Sayemuzzaman et al. 2015). With the above-mentioned advantages, ArcNLET is suited to estimate nitrogen loads from septic systems within the City.

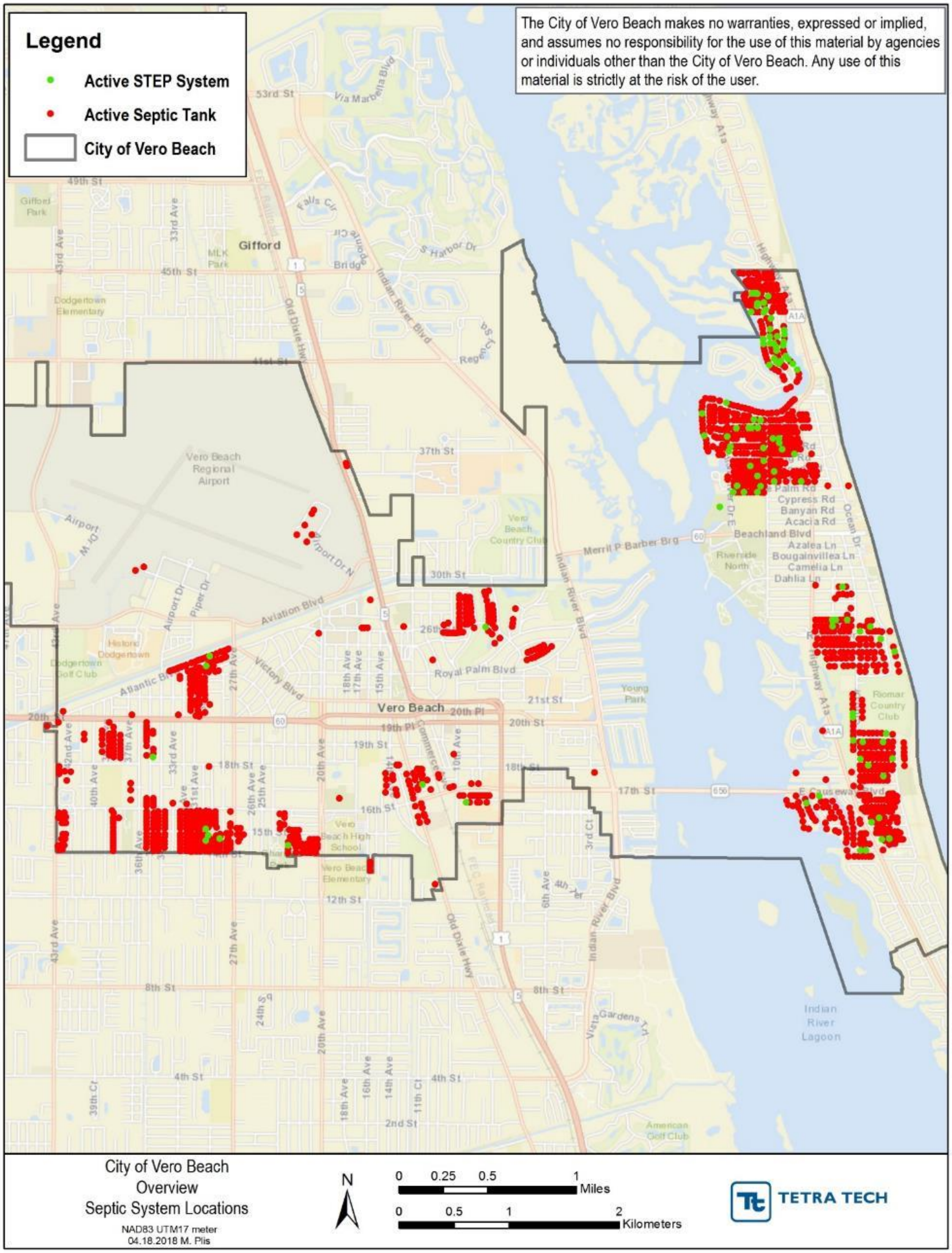

Figure 1-1. Location of the septic systems and STEP systems in the City of Vero Beach

2.0 MODEL DESCRIPTION

The ArcNLET model is intended to model the fate and transport of nitrate in surficial groundwater, originating from septic systems (Rios et al. 2011). The main ArcNLET model consists of four modules: (1) Groundwater Flow, (2) Particle Tracking, (3) Transport, and (4) Load Estimation. The model requires a basic set of geographic information system (GIS) inputs including a digital elevation model (DEM) surface elevation raster, saturated hydraulic soil conductivity raster, soil porosity raster, polygon shapefile representing the waterbodies inside the modeling extent, and point shapefile of the septic system locations. All spatial datasets must be in the same units and projections, and geodatabases are not supported. Individual model modules can be executed independently, making calibration easier and more time efficient.

2.1 GROUNDWATER FLOW

Groundwater Flow is the first module required to build the model. This module uses the DEM, soil conductivity, soil porosity raster, and waterbody shapefile. This module approximates the water table using the topography data, and it is built on the assumption that the hydraulic head of the surficial aquifer is a subsurface replica of the overlying topography. The model accomplishes this task by smoothing the DEM to a calibrated value, and then uses the ArcGIS Spatial Analysis and associated Groundwater Tools to compute the seepage velocity magnitude and direction rasters. Optional outputs include the smoothed DEM, which is very important in the calibration process, and a hydraulic gradient raster. In this module the user can control the parameters related to DEM smoothing including the smoothing factor and the number of cells used for smoothing. The user can also fill sinks or pits in the DEM, if the user find that flow lines calculated in the next module to become trapped. An additional included parameter is the Z-Factor. DEM elevation data often have differing horizontal and vertical units (i.e. the DEM raster is in a meter projection, but the elevation values are in feet) and the Z-Factor allows the conversion of the differing vertical units to the common horizontal unit.

2.2 PARTICLE TRACKING

The Particle Tracking module uses the point source shapefile with septic system locations, waterbody shapefile, soil porosity raster, and seepage velocity magnitude and direction rasters computed in the Groundwater Module to determine the flow path of an imaginary particle placed at the point where effluent enters the surficial aquifer. The output of this module is a polyline shapefile containing a set of flow paths from the septic system location along the gradient of the water table. These paths are then used by the Transport module.

2.3 TRANSPORT

The Transport module inputs are the septic system locations, particle paths polylines, and waterbody shapefile. The outputs are either a single nitrate plume raster containing concentration distributions of the calculated plumes, or separate nitrate and ammonia concentration rasters. The raster output is supplemented by a source point shapefile, whose attributes contain additional plume information, including calculated mass input/outputs, denitrification values, and plume termination waterbody identification. The technical details for this module can be found in the ArcNLET user manual (Rios et al. 2011). The user can control the following nitrate parameters: solution type (with and without denitrification), source plane concentration and dimensions, input mass rate, plume cell size, longitudinal and horizontal transverse dispersivities, and first-order decay constant. The module has additional plume shaping, warping, and post-processing controls.

2.4 LOAD ESTIMATION

This module uses the supplemental source point shapefile from the Transport module output to calculate the loads to individual waterbodies. The output is a list of nitrate load estimates for waterbodies that intersect a flow path.

3.0 DATA AVAILABILITY AND DESCRIPTION

3.1 DEM ELEVATION

The City of Vero Beach provided Tetra Tech with a detailed 1.5-foot x 1.5-foot DEM coverage of the City (**Figure 3-1**). This dataset was projected to the North American Datum 1983 (NAD83) Universal Transverse Mercator Zone 17N (UTM17N) projection with a resolution of 10 meters x 10 meters. The elevation values were converted from feet to meters (**Figure 3-2**).

3.2 SEPTIC SYSTEM LOCATIONS

The City provided a parcel polygon shapefile that contained septic system attributes and a coverage of seven separate STEP basins with STEP eligibility and connection status. Parcels inside the city limits were selected out of this dataset and parcel centroids were calculated and used as the septic drainfield locations. This resulted in 1,372 active septic systems and 101 converted STEP systems. All 1,473 septic systems (881 on the barrier island and 592 on the mainland) were used in the model calibration and uncertainty analysis. The spatial distribution of these parcels and the STEP system basins are presented in **Figure 3-3** and **Figure 3-4**.

3.3 WATERBODIES

The City of Vero Beach provided Tetra Tech with a waterbody polygon shapefile and a polyline shapefile with upland channel drainage lines. The polyline shapefile contained canals, major and minor ditches, and swales. Upon reviewing these data, Tetra Tech converted the polylines to polygons using reasonable buffers of ten meters for the major canals and five meters for the ditches. The swales were not converted and not used in the modeling.

While building the model, Tetra Tech found that due to the drainage line shapefiles being limited by the City boundaries, some of the septic system particle flow paths were flowing outside the City and were not being accounted for in the model. Therefore, the waterbody shapefile was supplemented with National Hydrography Dataset Plus v2 data. The flowline shapefiles were converted to polygons and added around the modeling extent as a “catch-all.” Visualization of these waterbodies and their sources are shown in **Figure 3-5.**

3.4 SOIL POROSITY AND SATURATED HYDRAULIC CONDUCTIVITY

The City provided soil polygons; however, the polygons did not contain porosity or conductivity values. Therefore, Tetra Tech acquired the Soil Survey Geographic Database (SSURGO) for Indian River County, Florida from the U.S. Department of Agriculture Web Soil Survey website. Values of hydraulic conductivity and porosity, bulk density, particle density, horizon depths, and component key were extracted from the horizon attribute table in SSURGO. These data were exported to Excel and the component with the lowest horizon and its attributes were kept. Component key, map unit key, major component flag, and the component percentages were extracted from the SSURGO component table. These data were filtered to only include major components. A series of Excel pivot and lookup tables were used to aggregate the hydraulic conductivity and soil porosity from the horizon level to the component level. Weighted averages were used for values where a map unit contained more than one component. Hydraulic conductivity values were converted to meters per day and missing porosity values were calculated from bulk and particle densities. The resulting values were joined to the soil shapefile in ArcGIS. Some map units still did not have conductivity and/or porosity values, and these were assigned manually based on the surrounding values (**Figure 3-6**).

The resulting soil polygons were converted to conductivity and porosity rasters. Resolution of these rasters matched the DEM raster at 10 meters x 10 meters. The hydraulic conductivity raster is presented in **Figure 3-7.** and the porosity is shown in **Figure 3-8.**

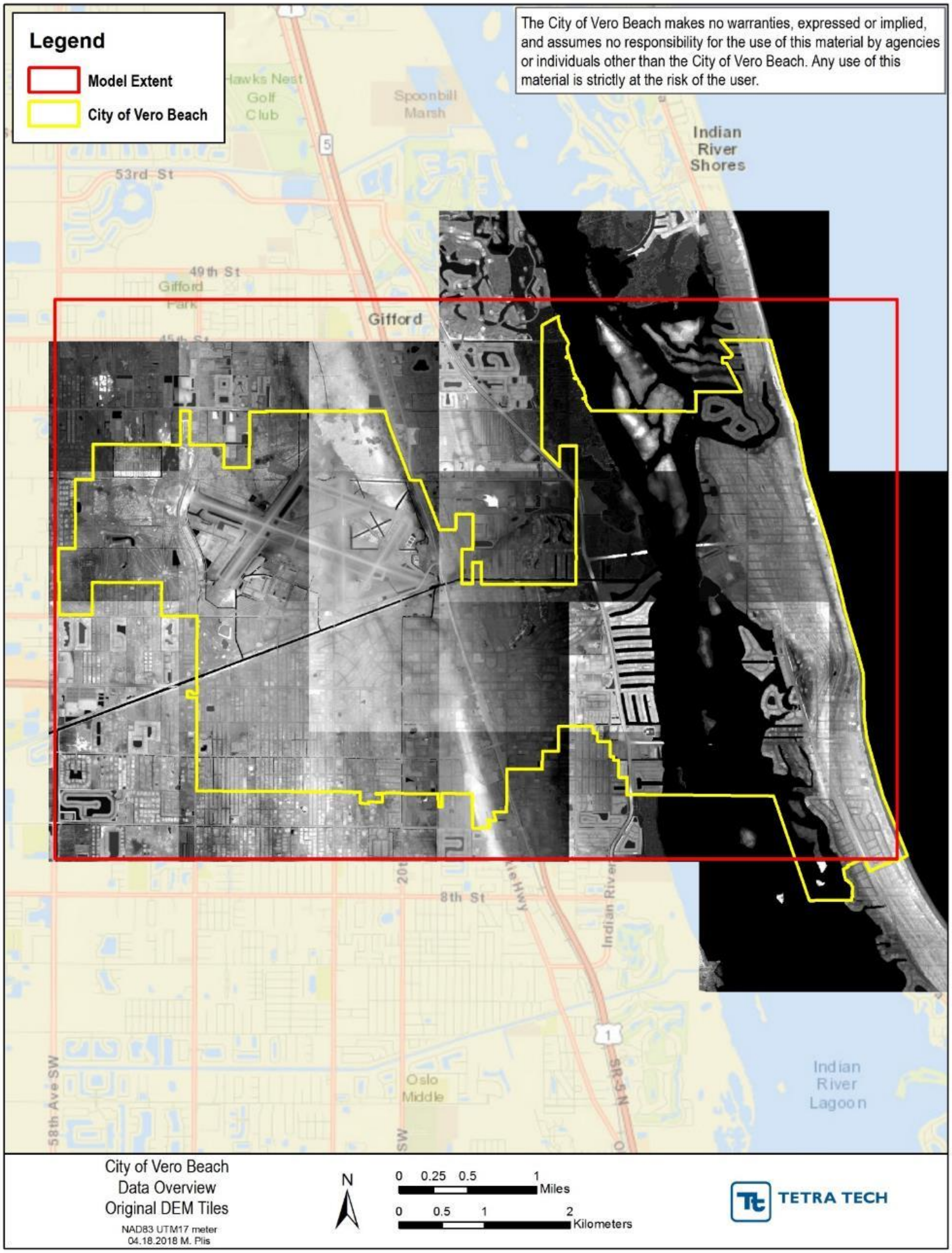

Figure 3-1. City 1.5 feet x 1.5 feet DEM

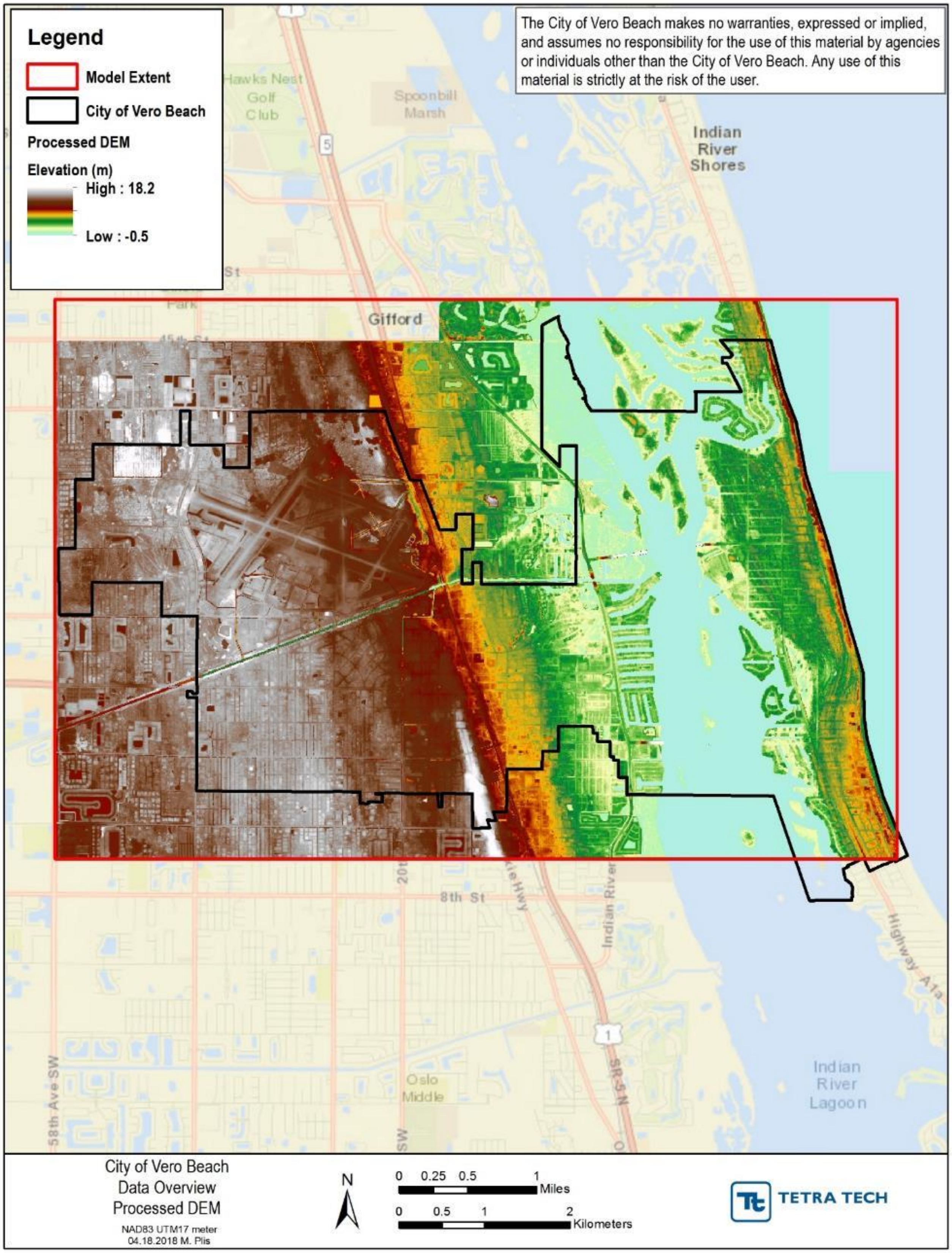

Figure 3-2. Processed and clipped DEM

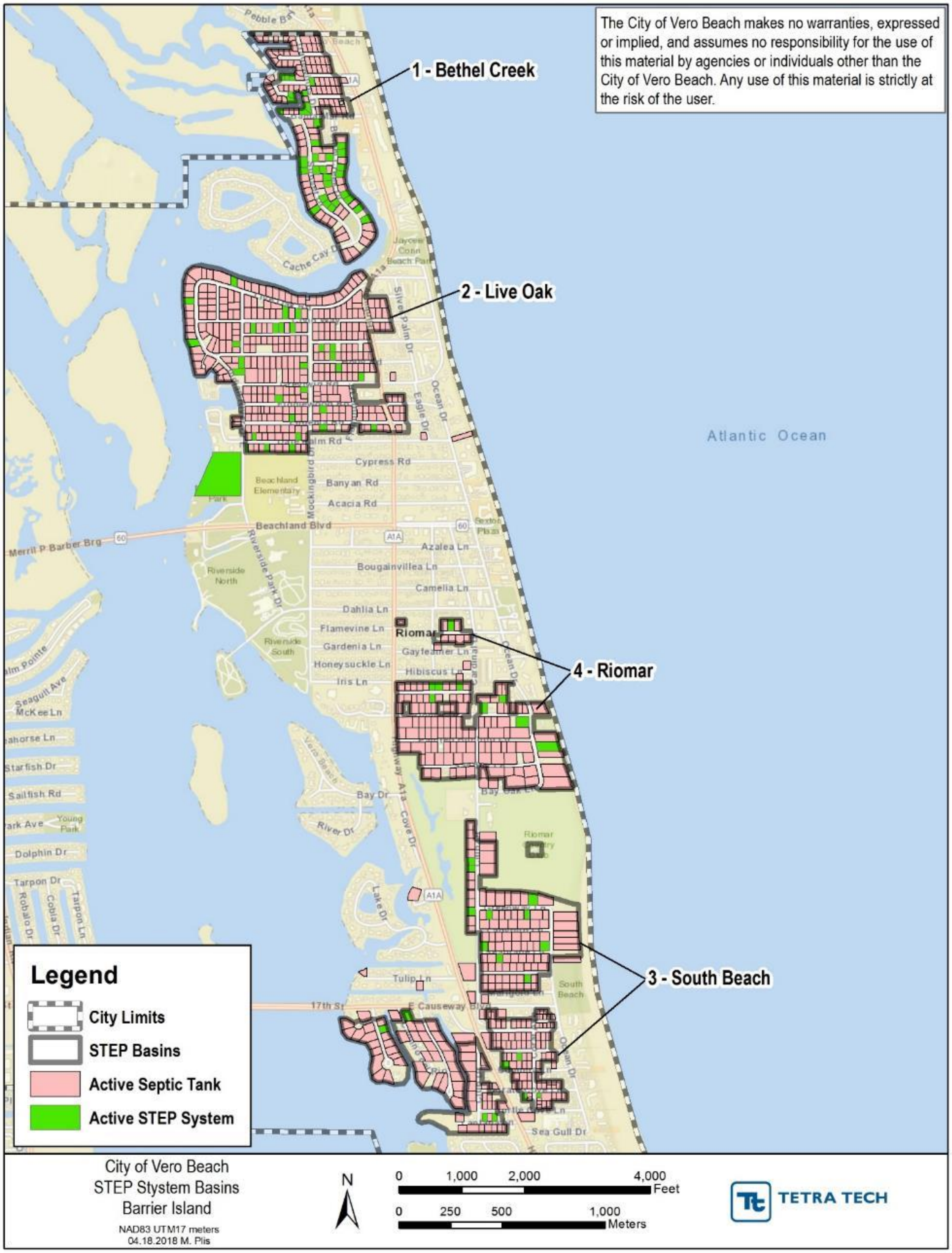

Figure 3-3. Barrier island septic system parcels and STEP system converted parcels

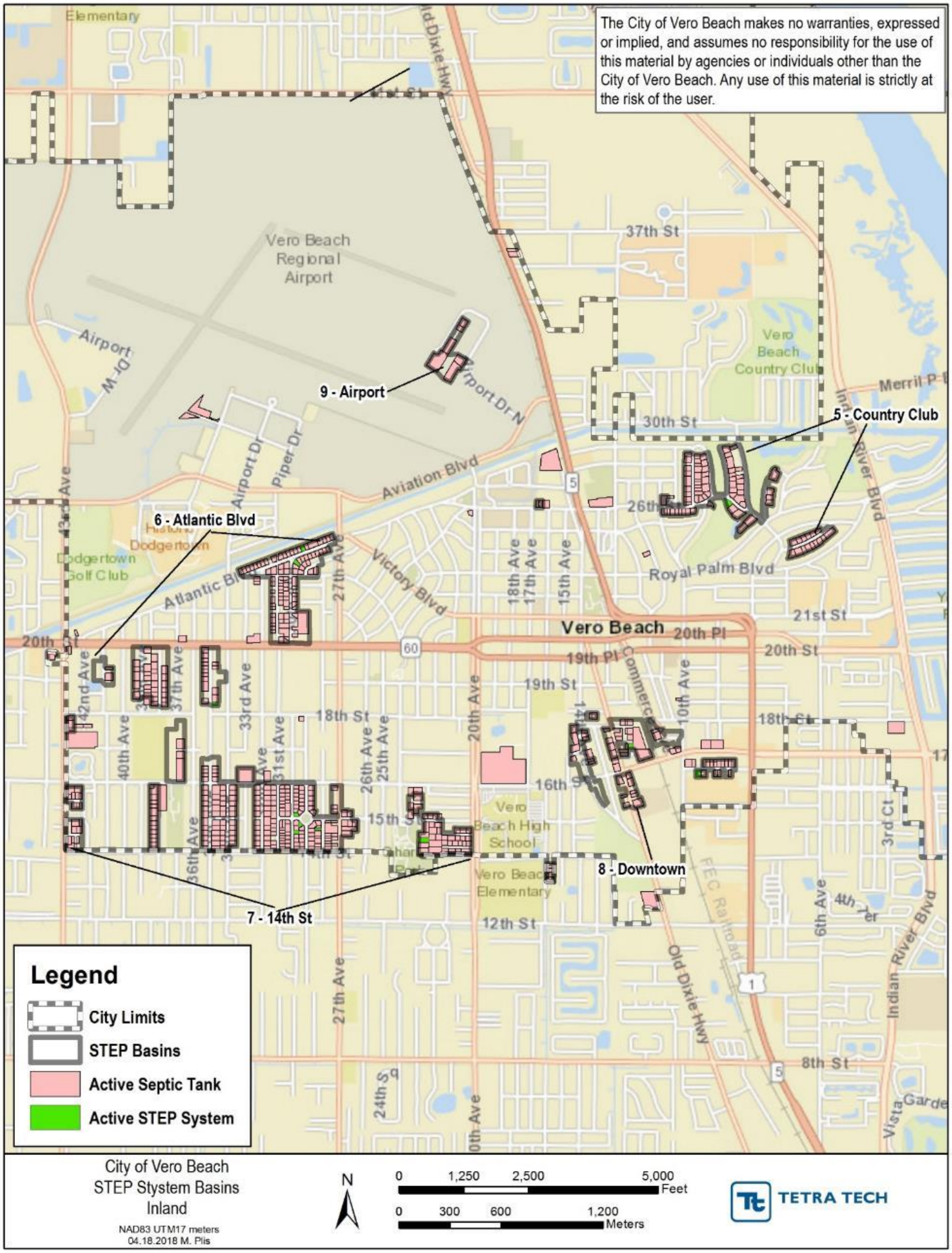

Figure 3-4. Mainland septic system parcels and STEP system converted parcels

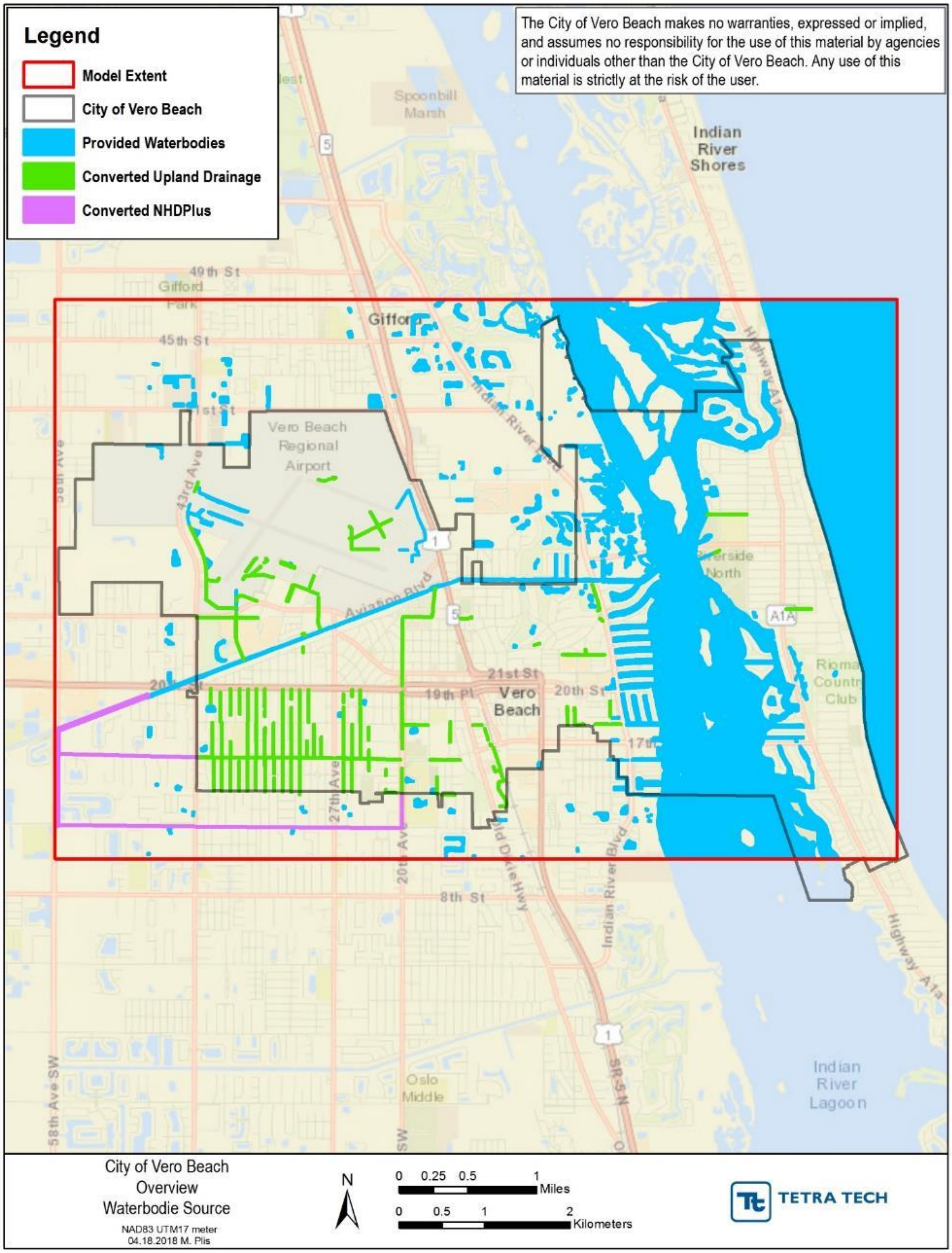

Figure 3-5. Waterbody coverage sources

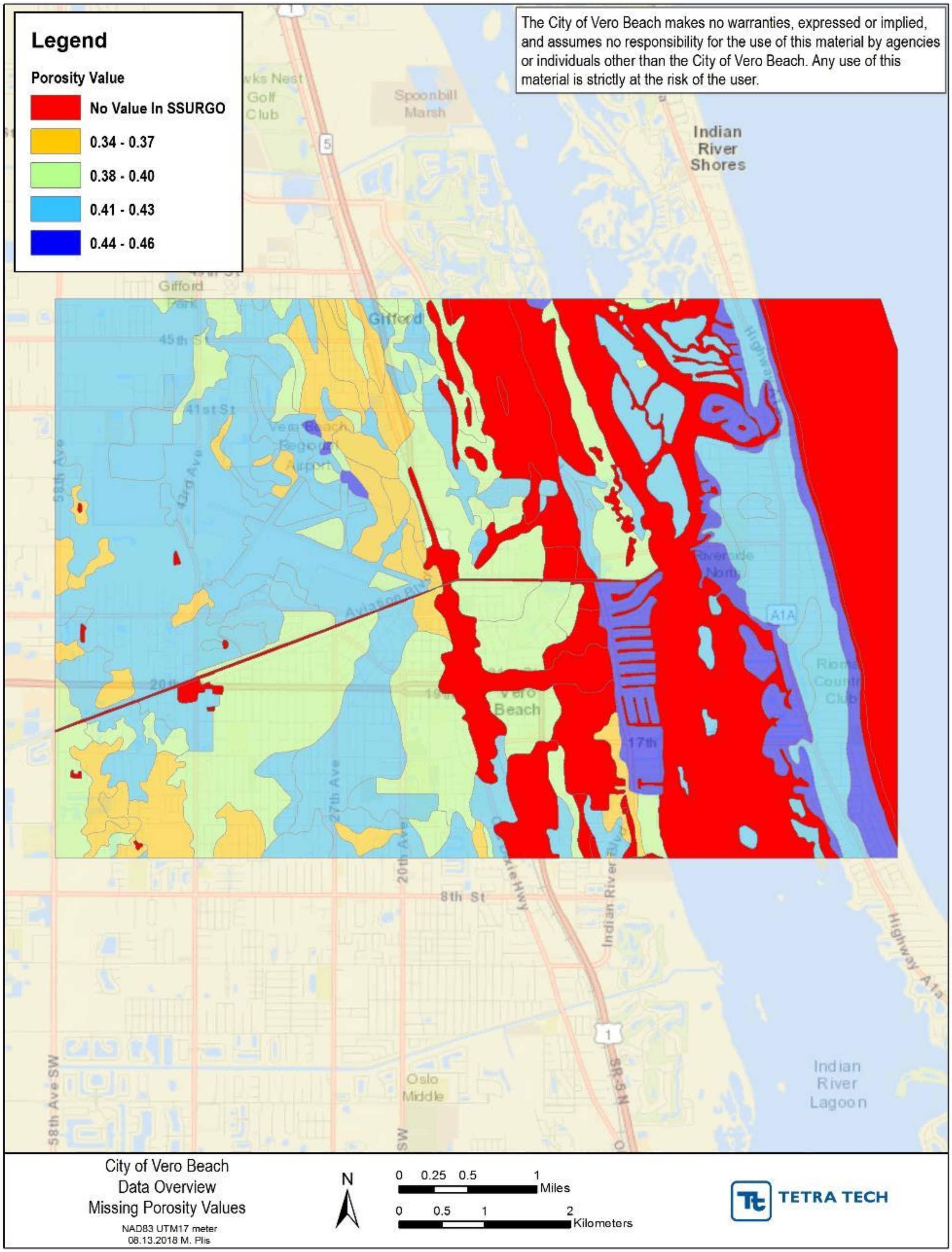

Figure 3-6. 2017 SSURGO soils with missing data

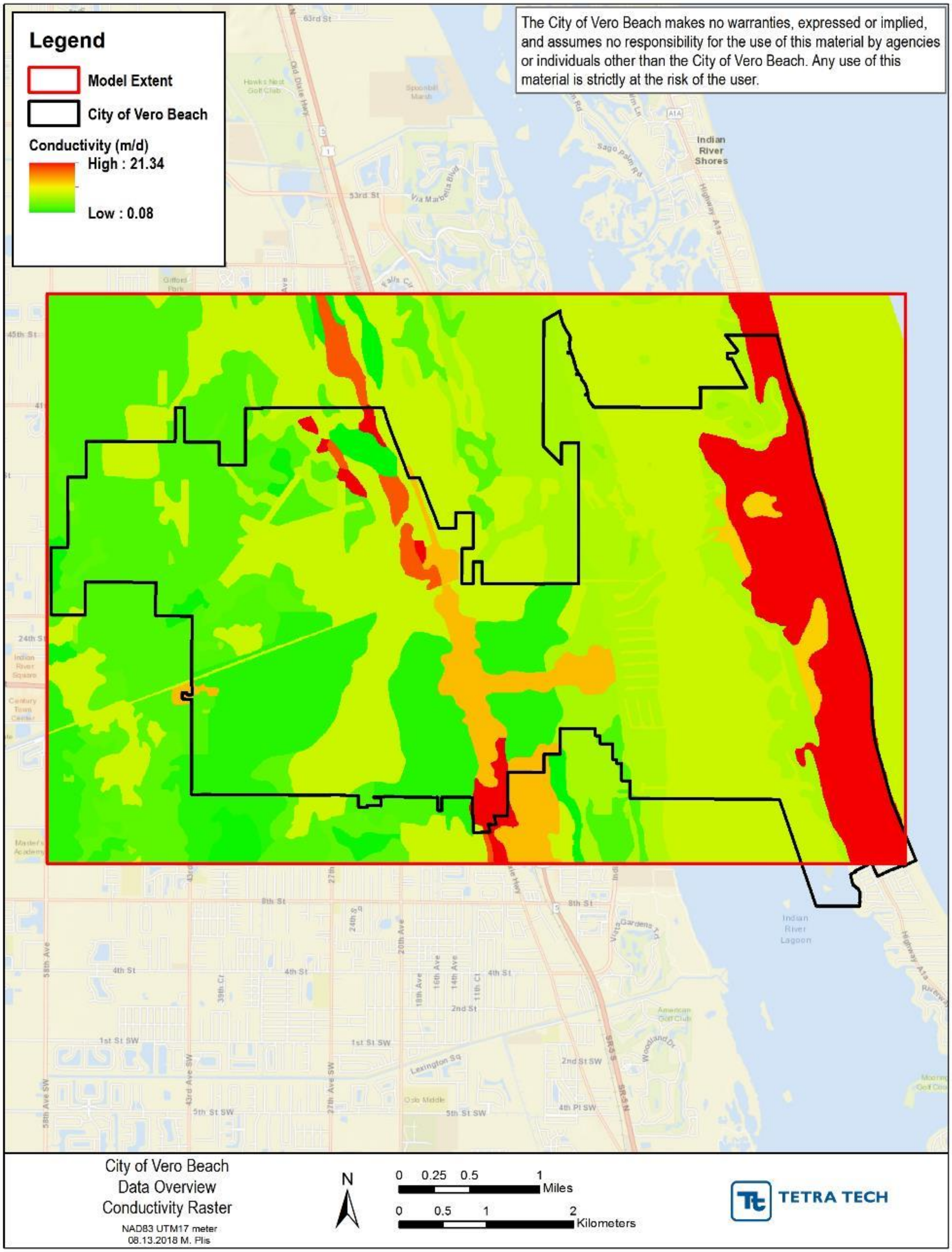

Figure 3-7. Modeled soil hydraulic conductivity

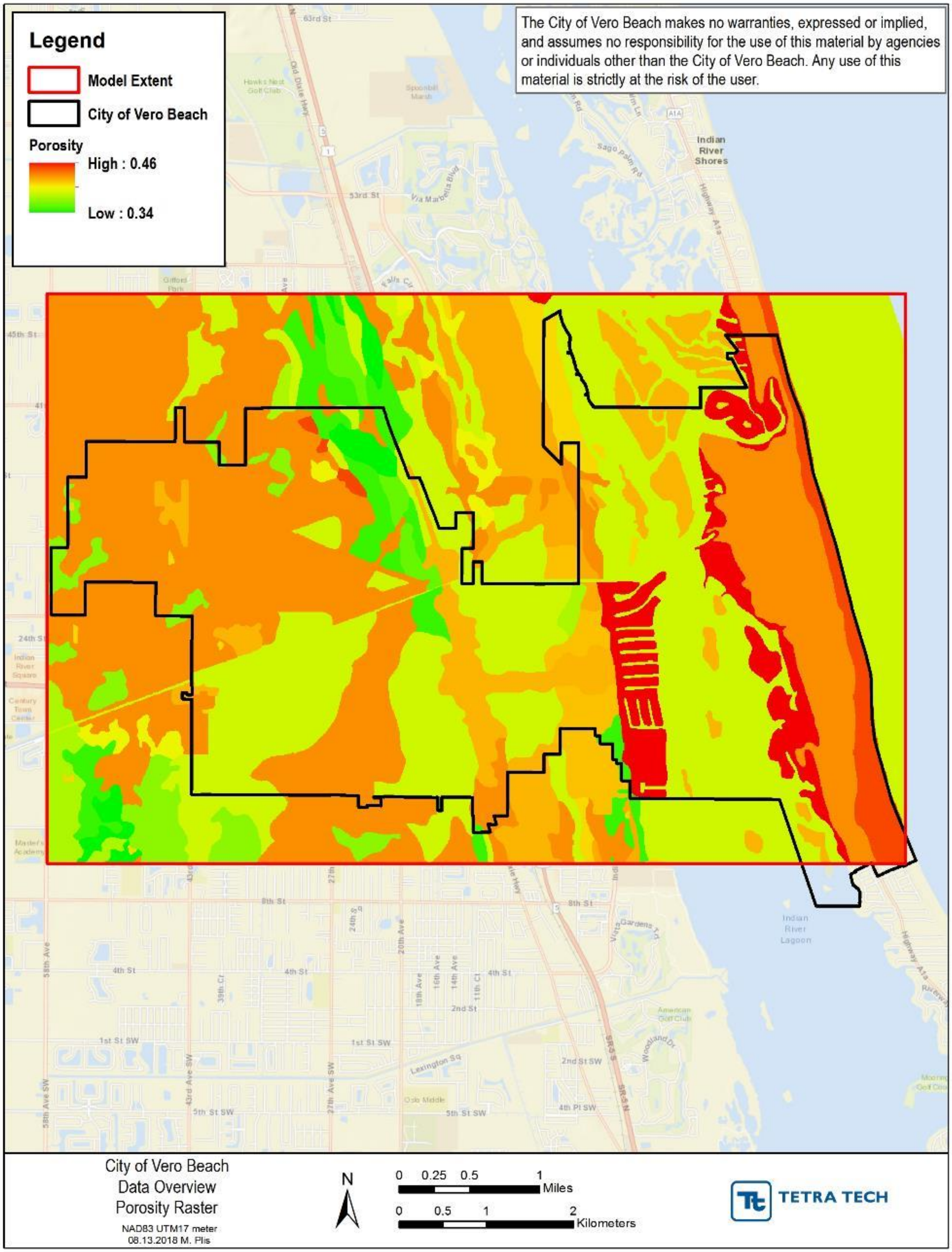

Figure 3-8. Modeled soil porosity

3.5 GROUNDWATER MEASUREMENTS

A search for available groundwater monitoring locations was conducted. Three wells with measured hydraulic head were acquired from the St. Johns River Water Management District website: currently active wells IR0114 and IR0993 and historic well IR0277 (**Figure 3-9**). The data for all wells were converted to meters, and the data from well IR0277 were also converted from National Geodetic Vertical Datum of 1929 (NGVD29) to North American Vertical Datum of 1988 (NAVD88). These three well data sets represent different periods of time; however, the overlapping timeframes show similar trends. The values of observed hydraulic head were averaged and compared to the smoothed DEM. Graphs of the measured values are shown in **Figure 3-10** through **Figure 3-12**.

3.6 GROUNDWATER NITROGEN MEASUREMENTS

No groundwater nitrogen measurements were found within the City.

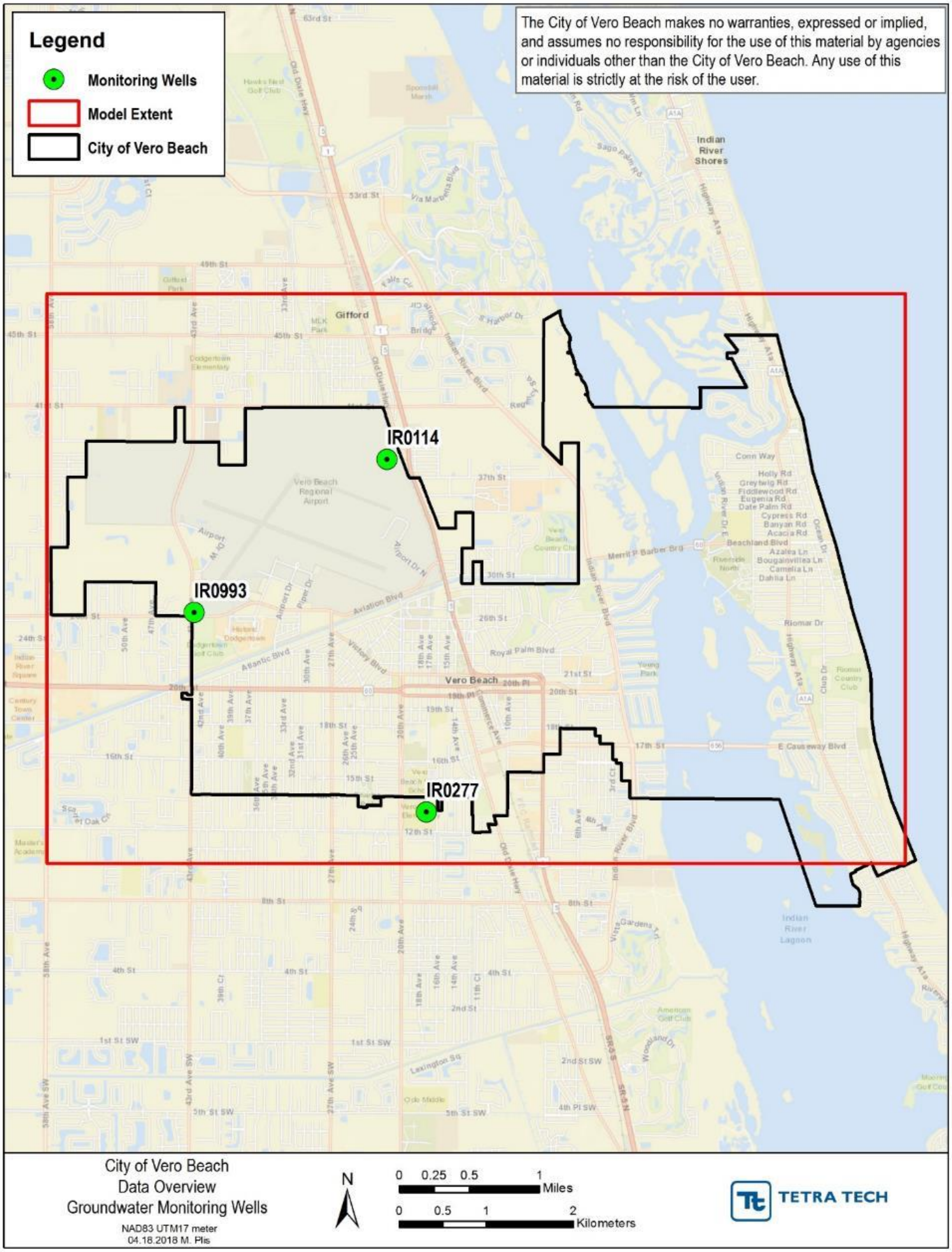

Figure 3-9. Groundwater monitoring well locations

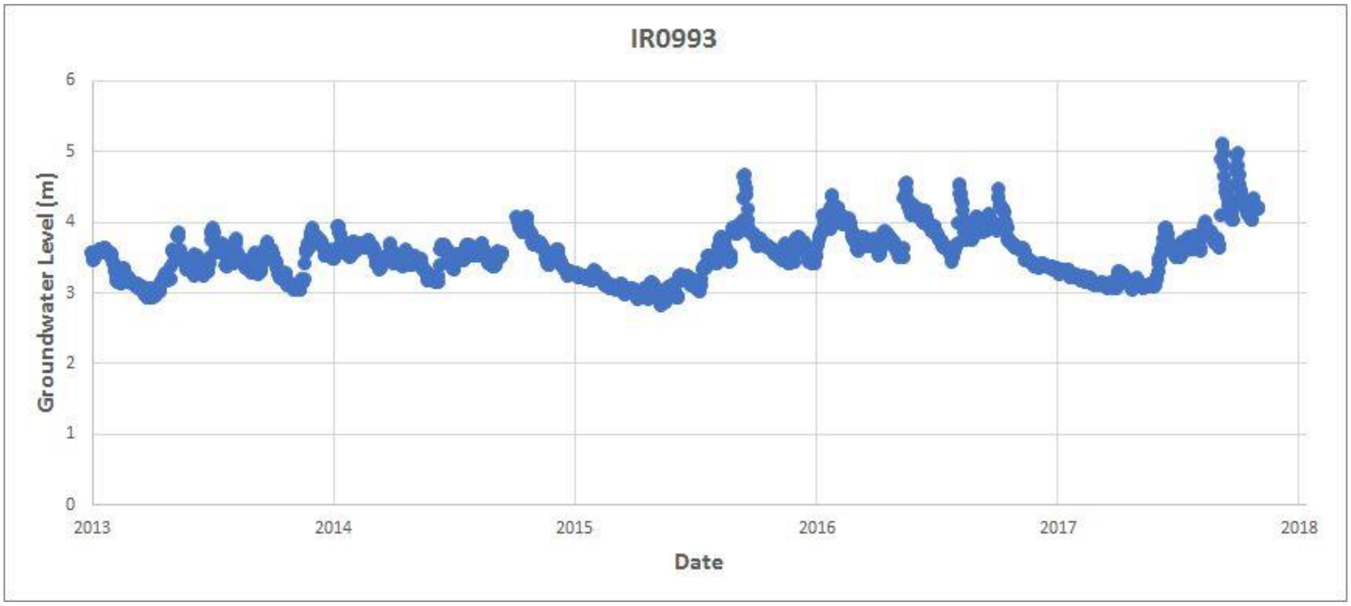

Figure 3-10. Observed groundwater level at IR0993

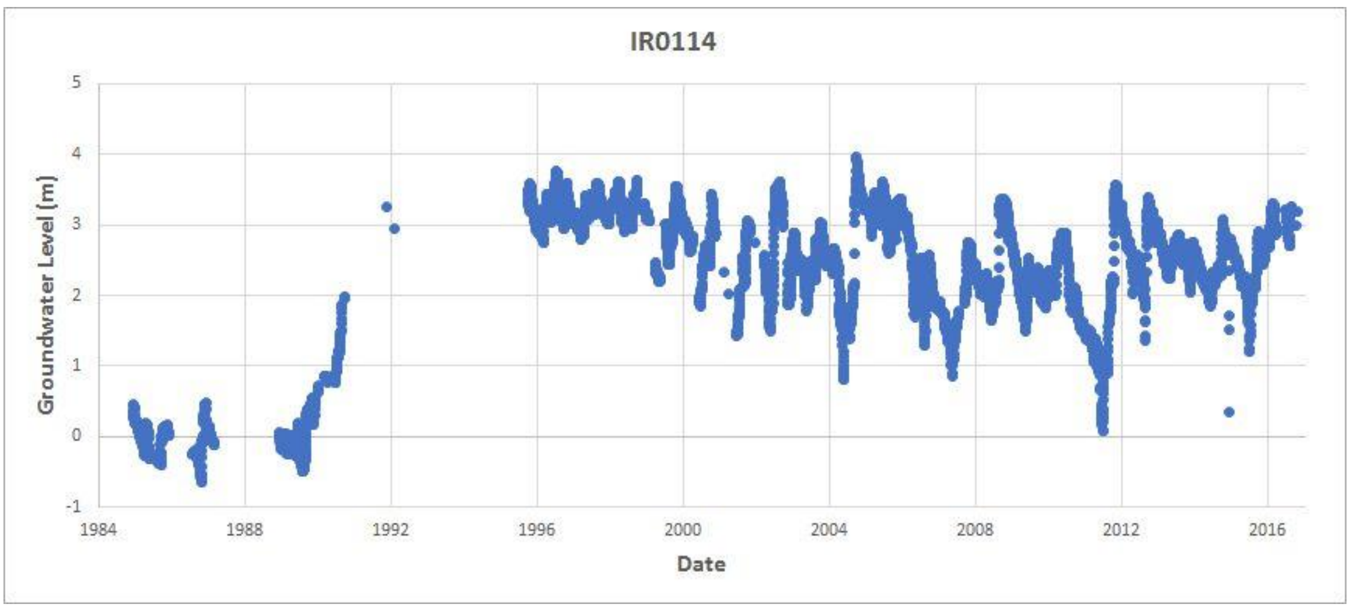

Figure 3-11. Observed groundwater level at IR0114

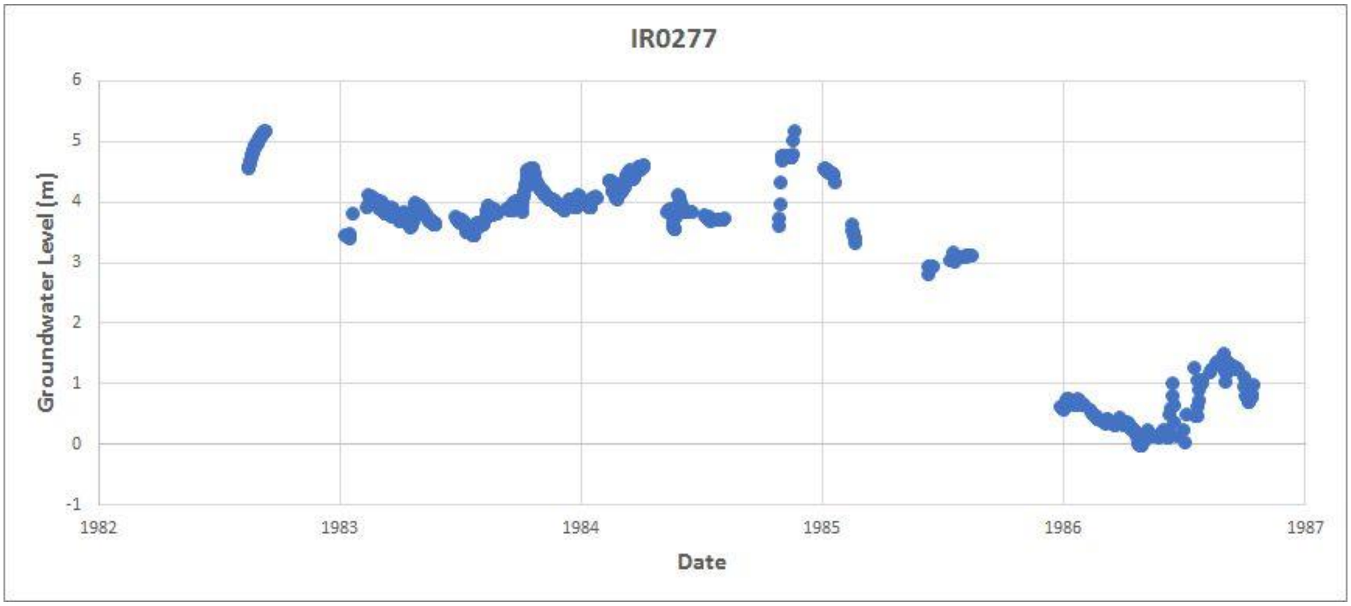

Figure 3-12. Observed groundwater level at IR0277

4.0 MODEL CALIBRATION AND RESULTS

ArcNLET model calibration consists of adjusting modeling parameters to match observed values as closely as possible. In this case there are two major components of the calibration: (1) groundwater flow calibration, and (2) nitrogen concentration calibration. The calibrated model parameters are the smoothing factor, source plane concentration, longitudinal dispersivity, horizontal transverse dispersivity, and first-order decay coefficient of denitrification. **Table 4-1** lists the initial and calibrated values of these parameters. Initial values (taken from Sayemuzzaman et al. 2015) were adjusted to match the available data in the City.

The differences in the parameters used for the City's model, as compared to the above referenced study, can be attributed to a difference in model input data. For instance, the DEM smoothing factor of 65 resulted in the flow paths exhibiting unexpected behavior, such as very closely following ridge lines in the elevation data. This was most likely caused by a much greater resolution of the elevation dataset provided by the City. A smoothing factor of 100 was found to work better in this model and created a smoothed DEM that agreed well with the available measured data (**Figure 4-1**). Source plane concentrations and first-order decay coefficients were not changed because of a lack of measured nitrogen concentrations for comparison. The longitudinal dispersity was increased to its default value to provide a more reasonable distribution of the plumes. The calibrated model particle paths are shown in **Figure 4-2**, and the calibrated nitrogen plume concentrations are show in **Figure 4-3**.

The estimated nitrogen loading results were summarized by each of the STEP basins. The model showed that most of the estimated loads are coming from the barrier island STEP basins – Live Oak, South Beach, and Bethel Creek. While all the nitrogen load ultimately reaches the IRL and Atlantic Ocean, the model showed that more than 83% of the City's modeled septic systems terminate directly into the IRL and Atlantic Ocean. The largest load per septic system is in Bethel Creek (8.24 pounds per year [lbs/yr] per septic system), followed by South Beach (7.50 lbs/yr per septic), and Live Oak (5.47 lbs/yr per septic). These results suggest that focusing on the barrier island STEP basins would yield the greatest load reductions. Interestingly, the Country Club STEP basin, which has a relatively large septic system concentration, does not seem to be contributing much nitrogen load. This is most likely due to a low soil hydraulic conductivity in the area, which allows the nitrogen time to denitrify instead of flowing directly to a waterbody.

Figure 4-4 through **Figure 4-7** show in more detail the modeled nitrogen plume concentrations in the individual STEP basins. **Figure 4-8.** Top ten waterbodies with the highest loads**,** and **Figure 4-9.** Top 20 waterbodies with the highest loads

show the ten waterbodies with the highest estimated loads and the relationship with the entire City's estimated loading. **Figure 4-9** shows the location of the top 20 waterbodies with the highest load. **Figure 4-10** and **Table 4-3** summarize estimated loadings by STEP basing and detail individual septic system load estimates.

Table 4-1. Initial and calibrated ArcNLET parameters

Parameter	Initial Value	Calibrated Value
Smoothing Factor	65	100
Source Plane Concentration (mg/L)	40	40
Longitudinal Dispersivity (m)	1	10
Horizontal Transverse Dispersivity (m)	0.1	1
First-Order Decay Coefficient of Denitrification	0.00055	0.00055

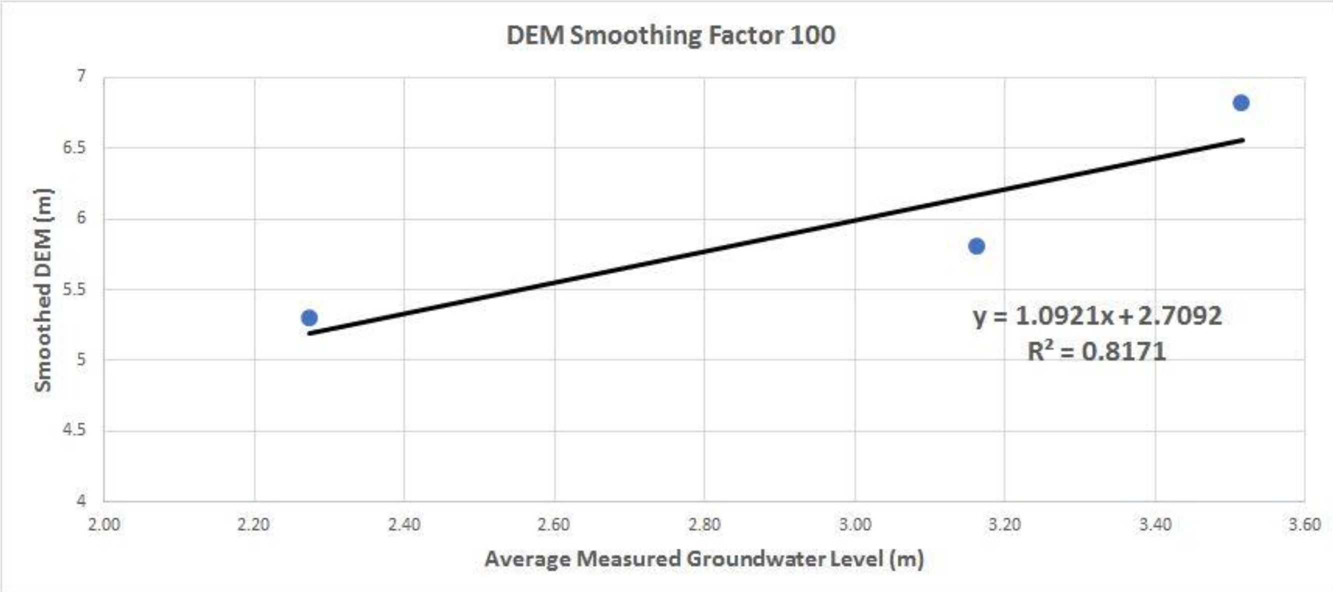

Figure 4-1. Smoothed DEM relationship with the measured water level

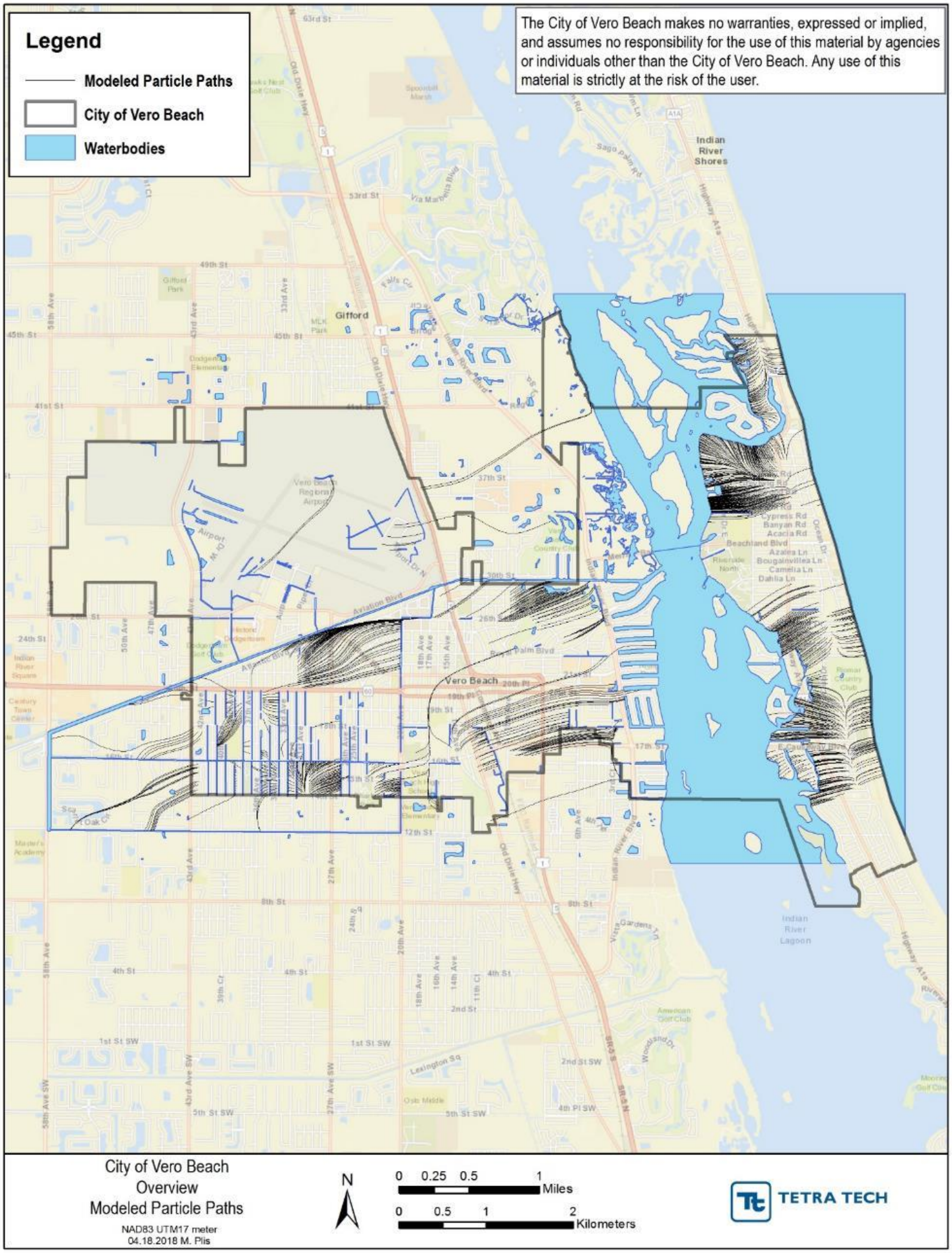

Figure 4-2. Modeled particle paths

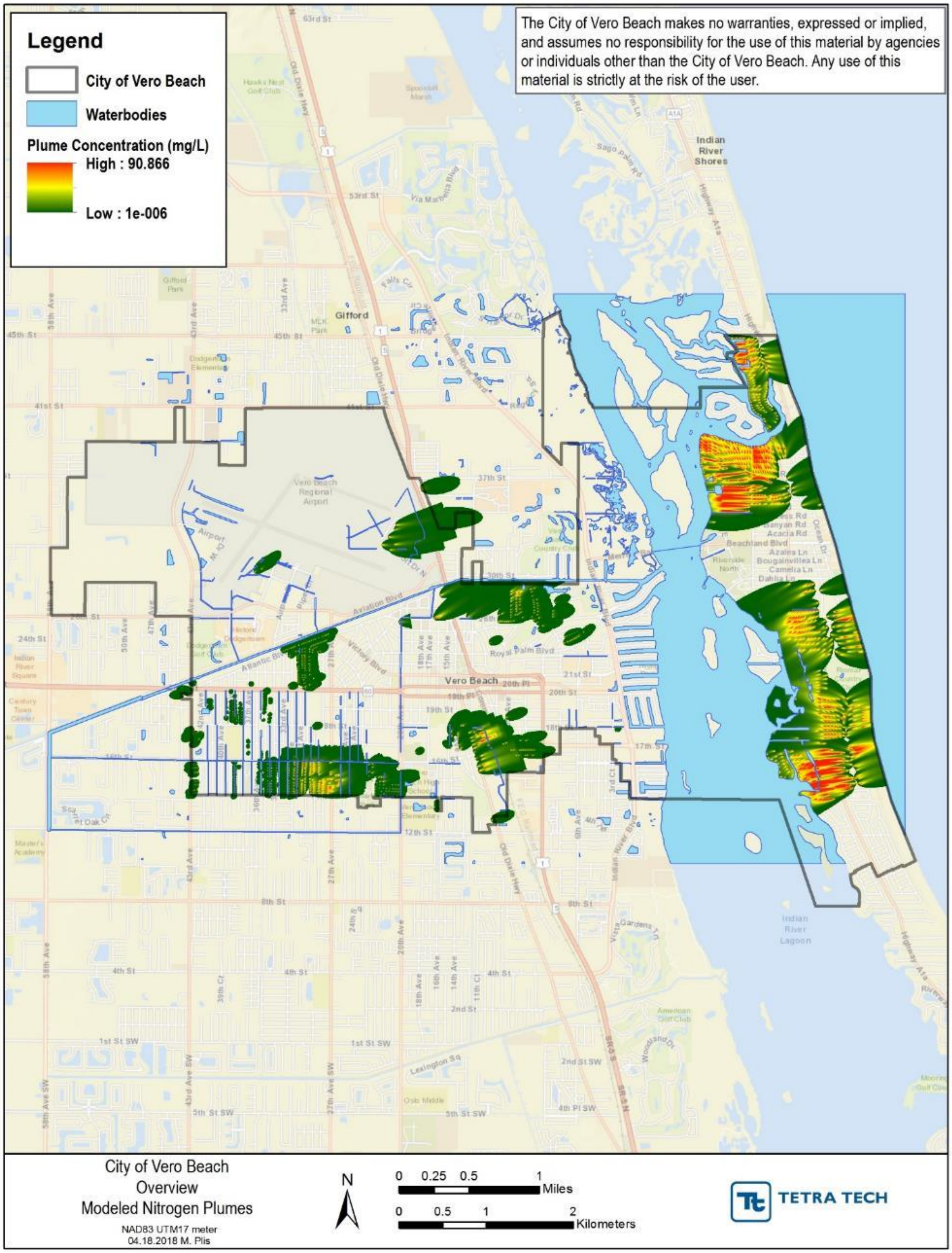

Figure 4-3. Modeled nitrogen plumes

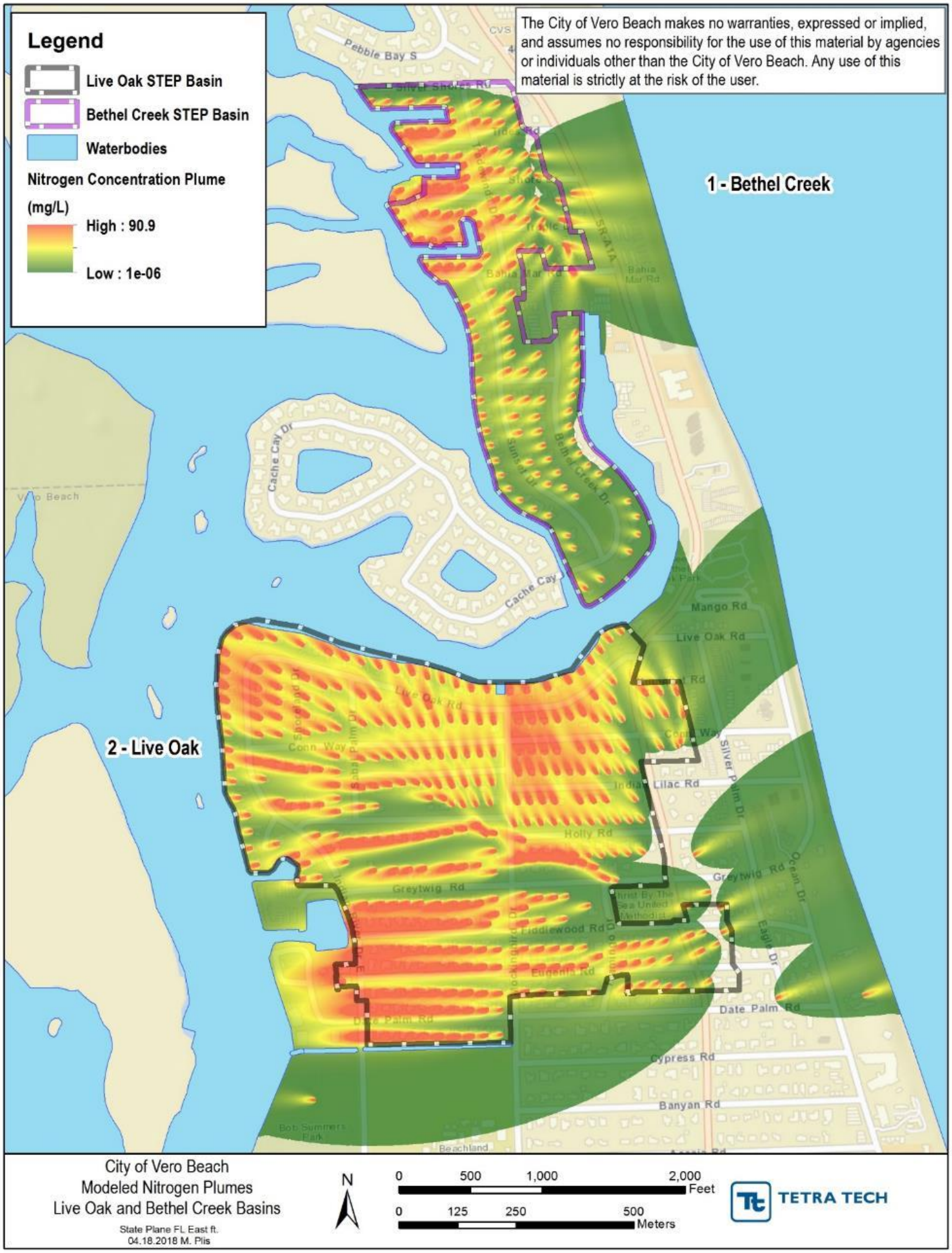

Figure 4-4. Bethel Creek and Live Oak modeled nitrogen concentrations

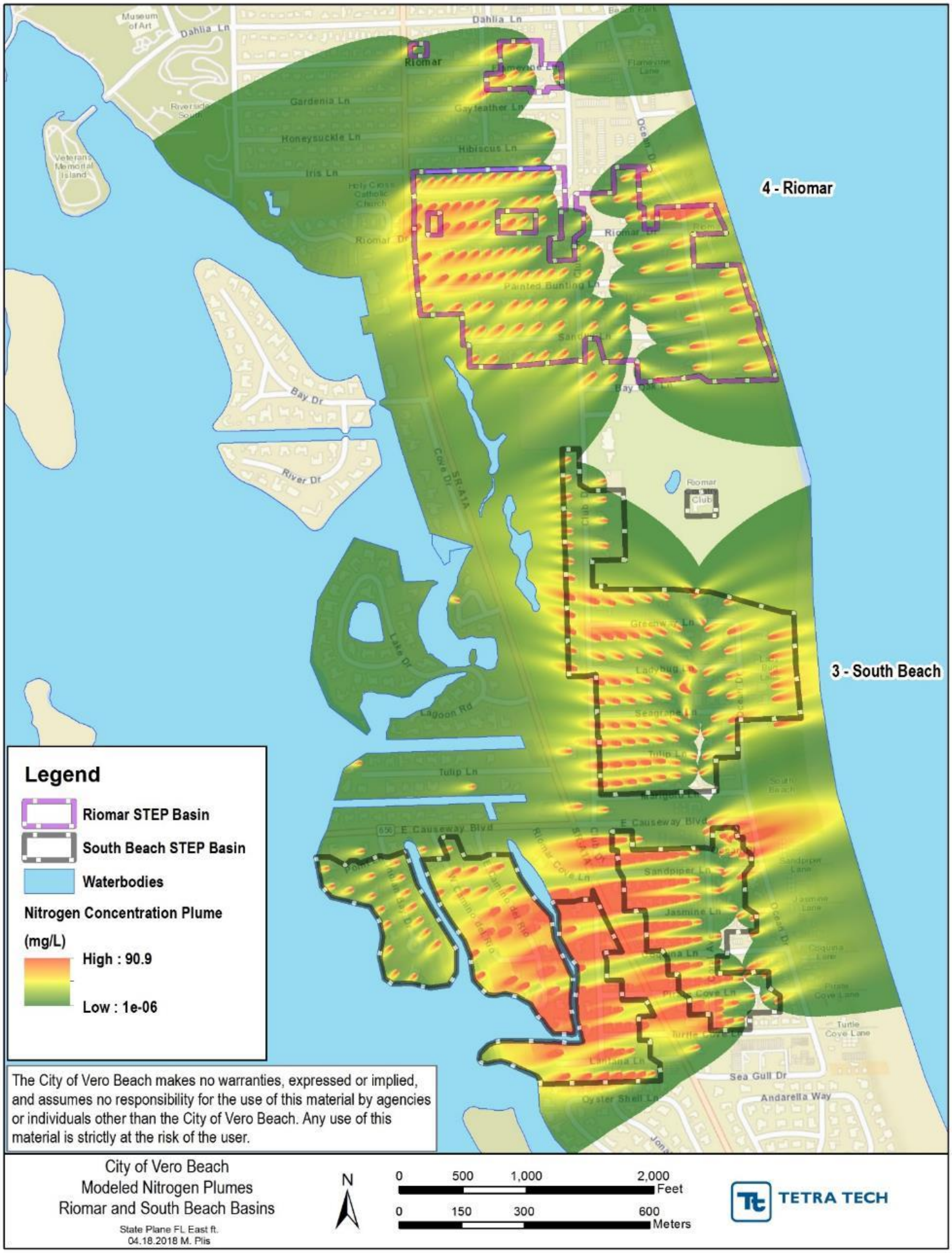

Figure 4-5. South Beach and Riomar modeled nitrogen concentrations

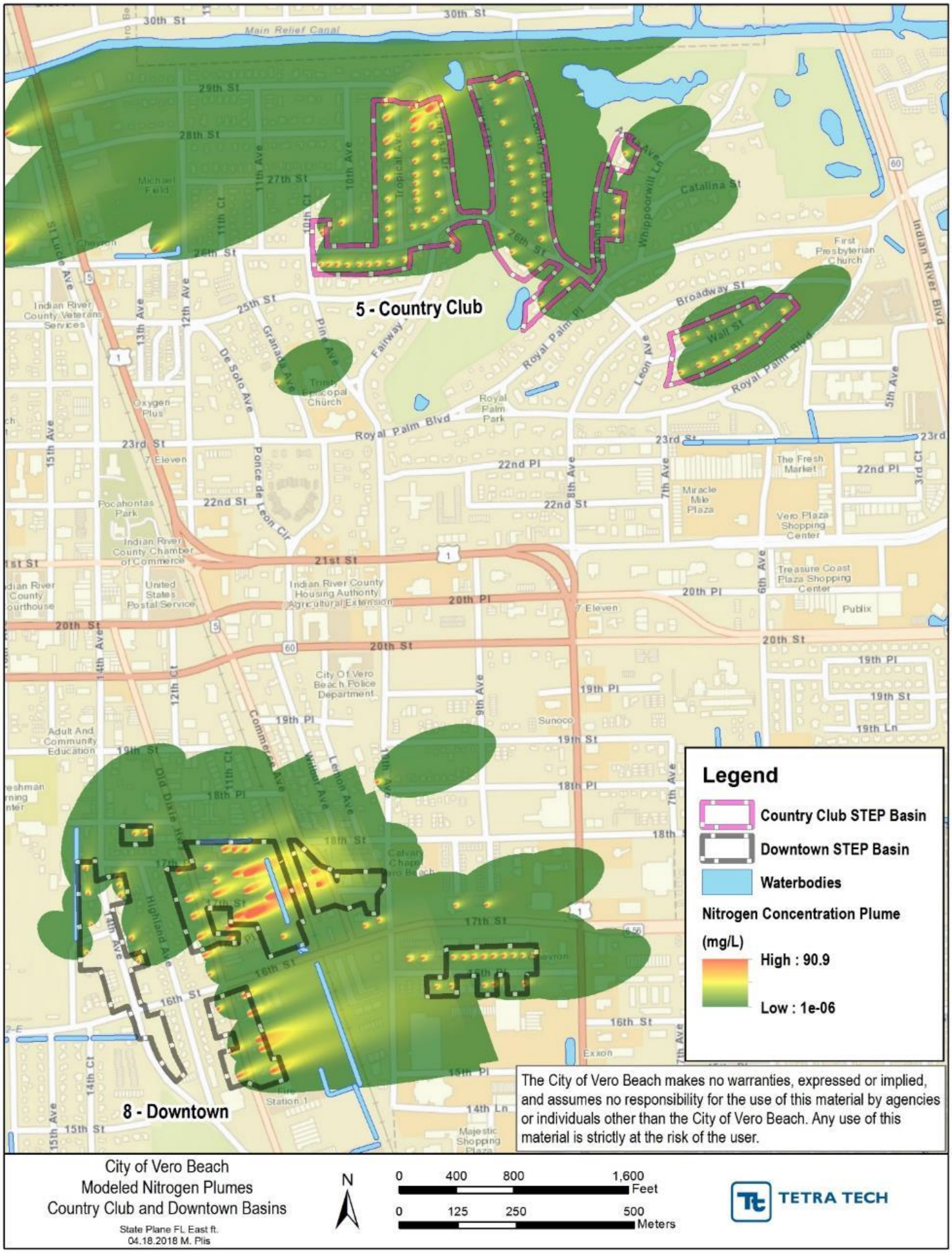

Figure 4-6. Country Club and Downtown modeled nitrogen concentrations

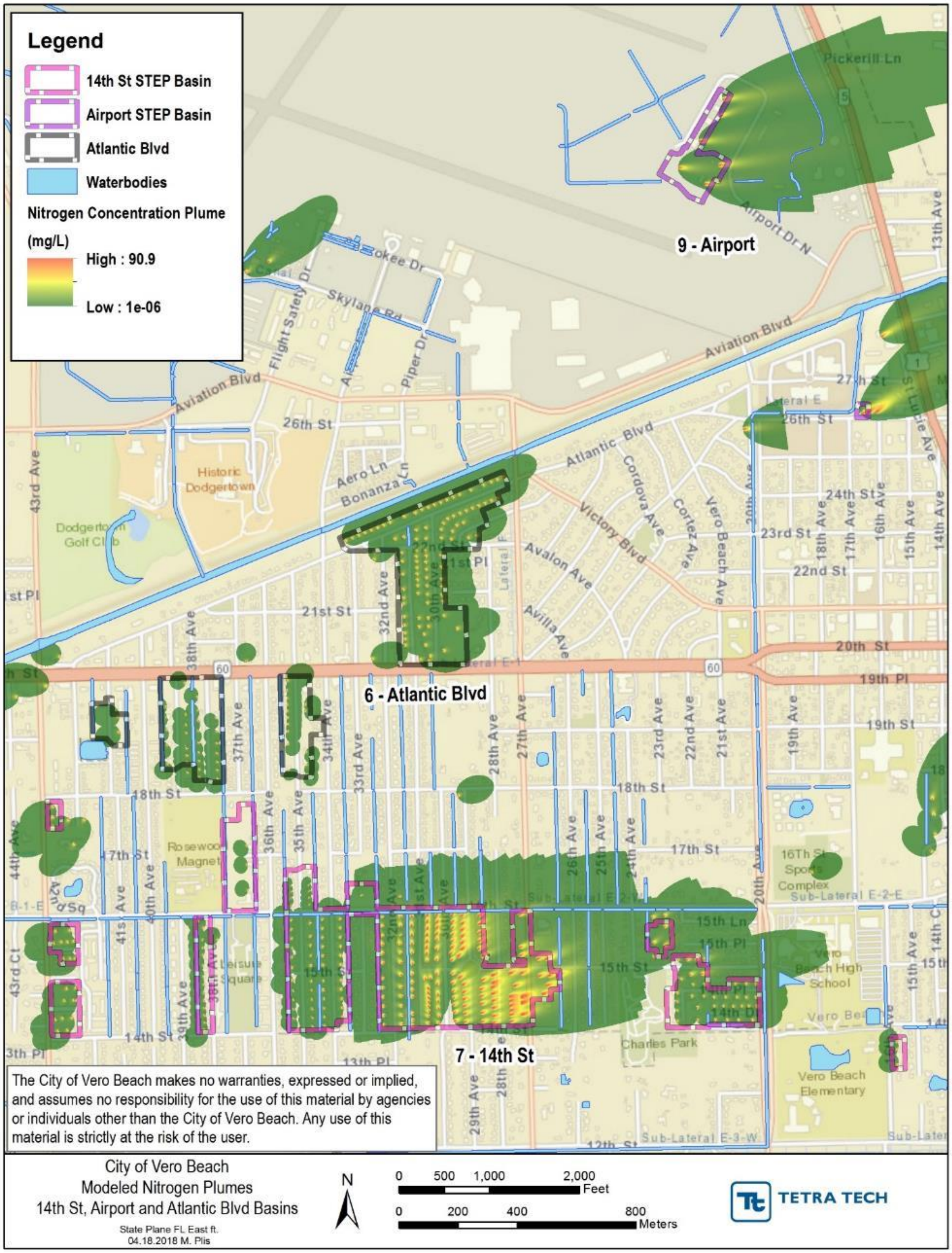

Figure 4-7. Atlantic Boulevard, 14th Street, and Airport modeled nitrogen concentrations

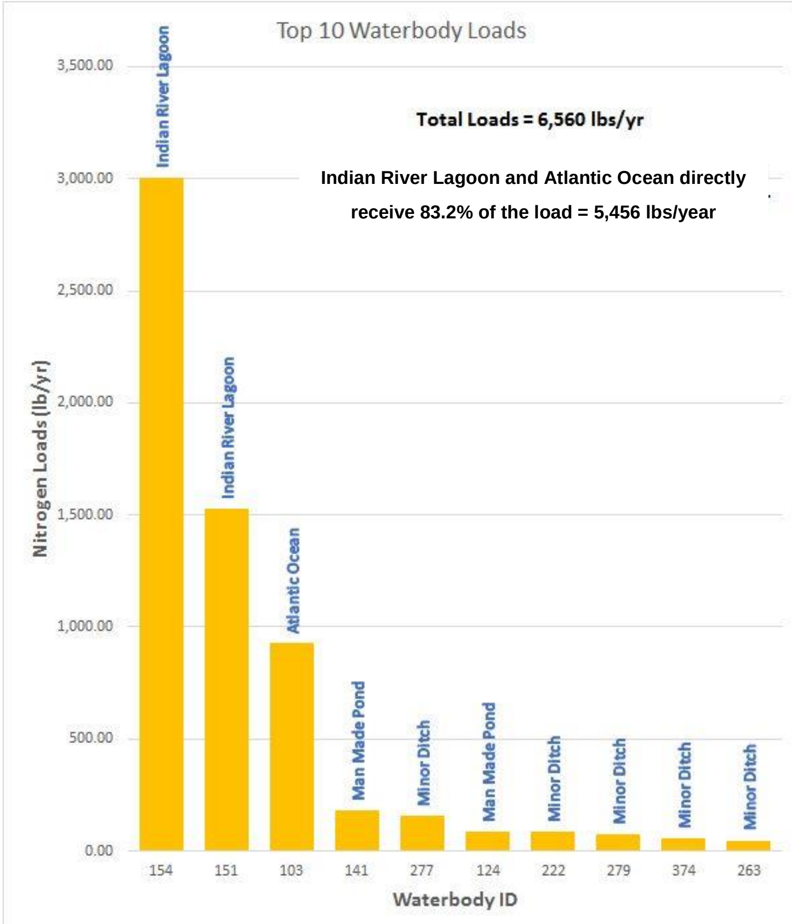

Figure 4-8. Top ten waterbodies with the highest loads

Table 4-2. Detailed loads for top ten waterbodies

Waterbody Name/Type	Waterbody ID	Contributing STEP Basins	Load (lbs/yr)	% of Total Load
IRL	154	Live Oak, Bethel Creek	3,004	45.79%
IRL	151	South Beach, Riomar	1,525	23.25%
Atlantic Ocean	103	Live Oak, Bethel Creek, South Beach, Riomar	928	14.14%
Man Made Pond	141	South Beach	181	2.76%
Minor Ditch	277	Downtown	155	2.36%
Man Made Pond	124	Riomar	86	1.31%
Minor Ditch	222	Downtown	85	1.30%
Minor Ditch	279	14^{th} Street	75	1.14%
Minor Ditch	374	14^{th} Street	57	0.86%
Minor Ditch	263	14^{th} Street	48	0.73%
Total in Top 10			**6,144**	**93.64%**

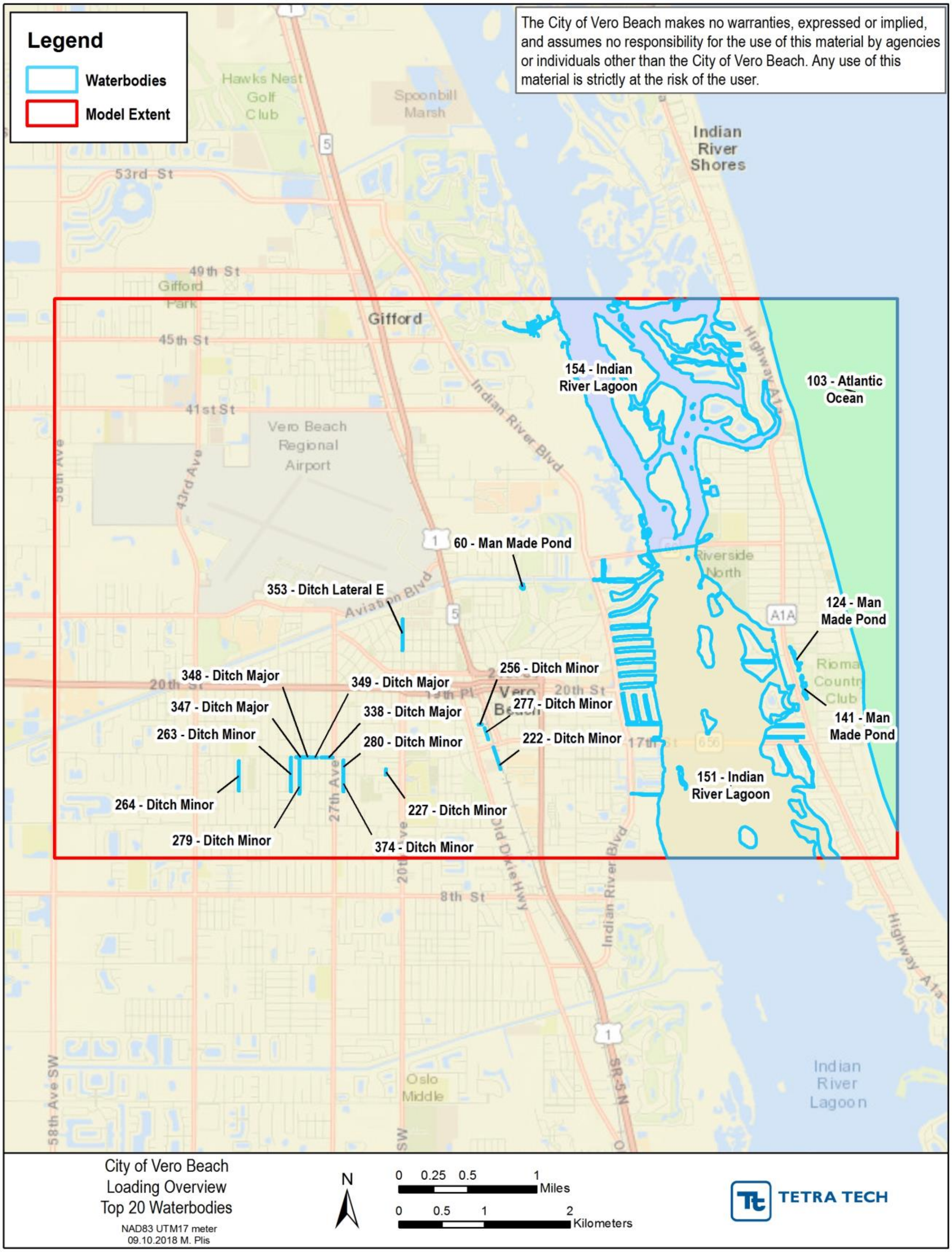

Figure 4-9. Top 20 waterbodies with the highest loads

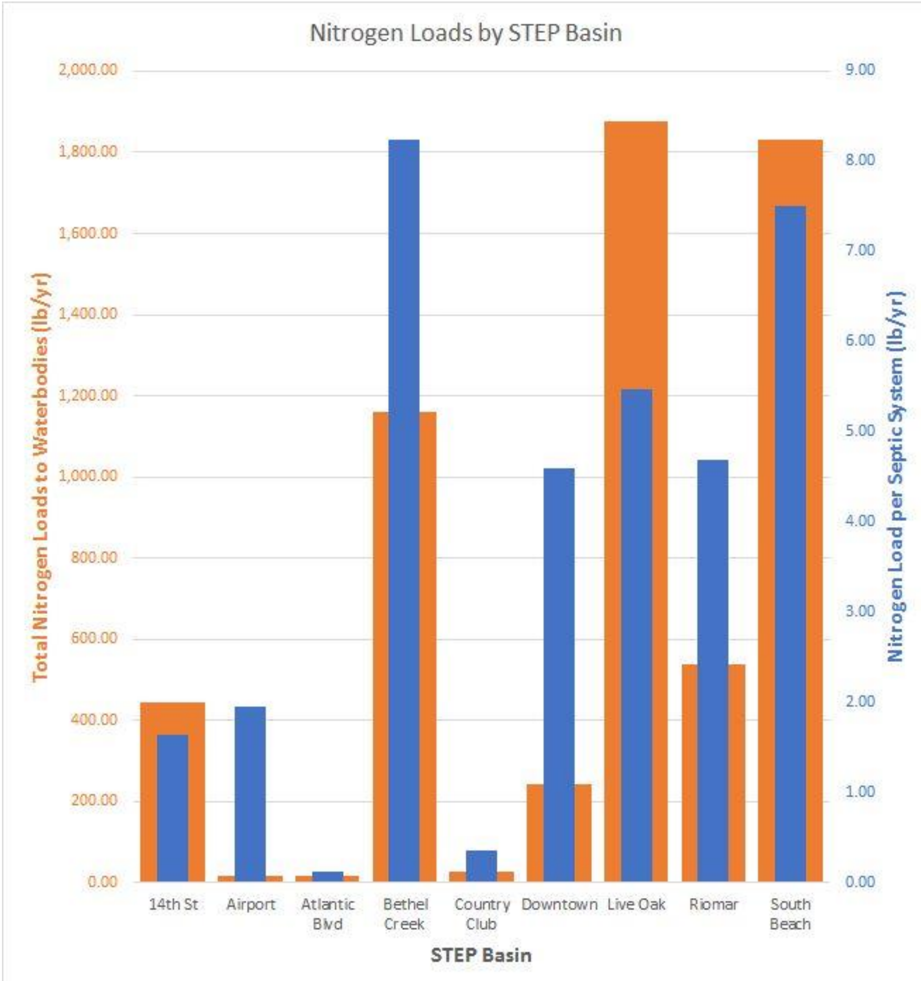

Figure 4-10. Estimated nitrogen loads by STEP basin

Table 4-3. Estimated nitrogen loads by STEP basin detail

STEP Basin	Total Load to Waterbodies	Number of Septic Systems	Load per System	% of Total Load
14th Street	445	272	1.64	6.78%
Airport	16	8	1.95	0.24%
Atlantic Boulevard	16	136	0.12	0.25%
Bethel Creek	1,162	141	8.24	17.72%
Country Club	29	81	0.36	0.44%
Downtown	243	53	4.59	3.71%
Live Oak	1,876	343	5.47	28.60%
Riomar	539	115	4.69	8.22%
South Beach	1,830	244	7.50	27.89%
Total in STEP Basins	**6,156**	**1,393**	**4.42**	**93.84%**

5.0 STEP SYSTEM CONVERSION NITROGEN LOAD REDUCTIONS

As of the time of this report, the City of Vero Beach have converted 101 of its 1,473 homes on septic systems to STEP systems and connected them to the sewer system. To estimate the nitrogen load reductions resulting from these conversions a separate current condition scenario of the model was developed and executed (STEP Scenario). This section discusses the current conditions scenario and findings.

5.1 STEP SCENARIO MODEL INPUT

The DEM, waterbodies, soil porosity, and saturated hydraulic conductivity value inputs to the current condition scenario model remained the same as the calibrated model. Septic system locations were updated to remove the 101 septic systems that were converted to STEP systems. Refer to Beach for the locations of the septic systems converted to STEP.

5.2 STEP SCENARIO MODEL RESULTS

The current condition model particle paths are shown in **Figure 5-1**,and the calibrated nitrogen plume concentrations are show in **Figure 5-2**. **Figure 5-3** through **Figure 5-6** show in more detail the modeled nitrogen plume concentrations in the individual STEP basins**. Figure 5-7** and **Table 5-1**Figure 4-9. Top 20 waterbodies with the highest loads

show the ten waterbodies with the highest estimated loads and the relationship with the entire City's estimated loading. **Figure 5-8** and **Table 5-2** show the estimated loads by STEP basin and detail individual septic system load estimates.

5.3 STEP SCENARIO MODEL LOAD REDUCTIONS

The STEP Scenario results in a 511 lbs/yr reduction in nitrogen loading to the surrounding waterbodies, which is a reduction of 7.9% in the total nitrogen loading. The average reduction per septic system converted to a STEP system is 5.1 lbs/yr of nitrogen. The STEP basins with the largest nitrogen load reductions are Bethel Creek with 186 lbs/yr, Live Oak with 139 lbs/yr, and South Beach with 107 lbs/yr.

Figure 5-9 through **Figure 5-12** show the per-STEP basin reduction in nitrogen concentrations of the modeled nitrogen plumes. **Figure 5-13** and **Table 5-3** show the five waterbodies with the highest estimated load reductions. The largest nitrogen load reductions occur to the IRL and Atlantic Ocean, which account for 471 lbs/yr (approximately 92%) of the total load reductions. **Figure 5-14** and **Table 5-4** show the nitrogen load reductions by STEP basin.

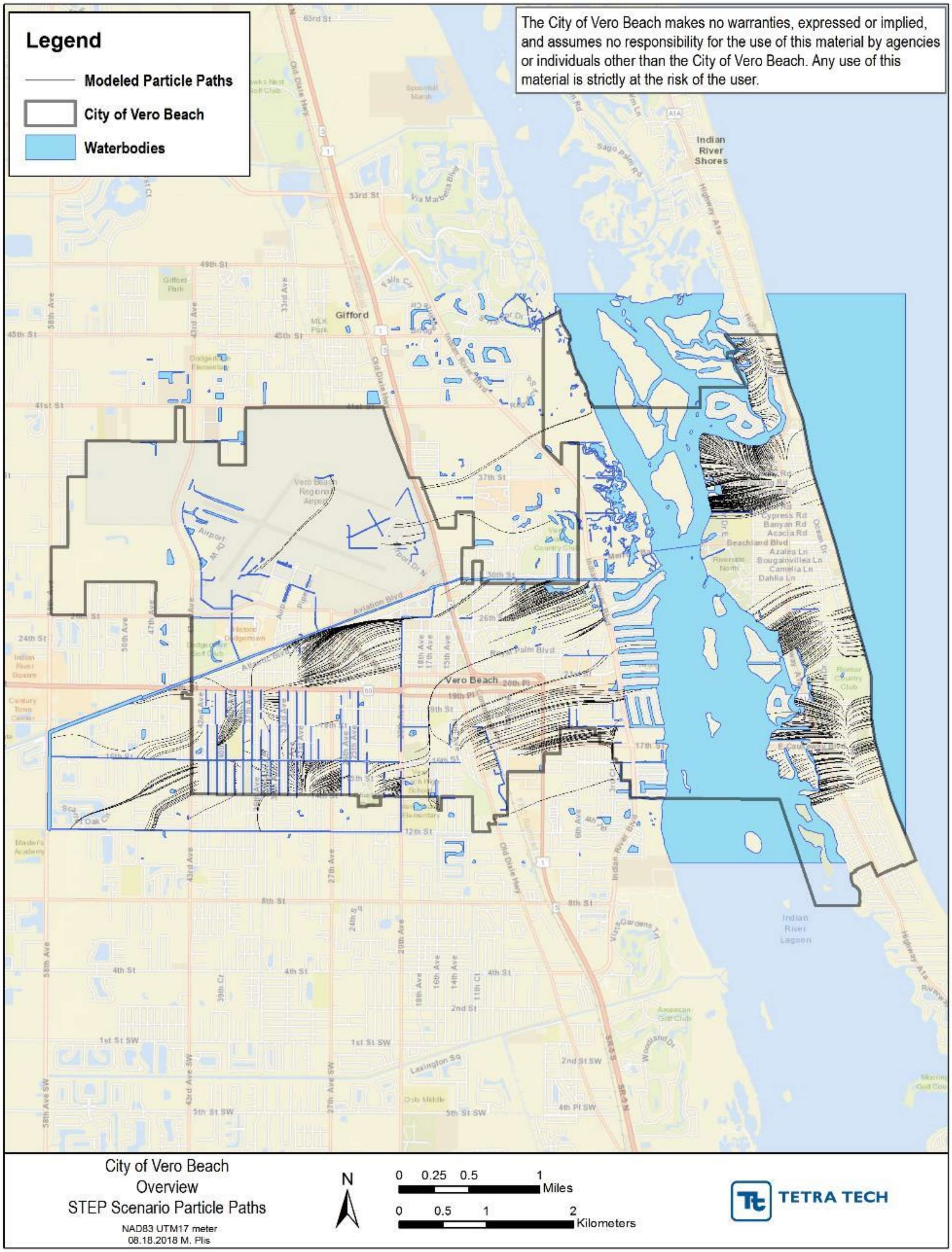

Figure 5-1. STEP Scenario modeled particle paths

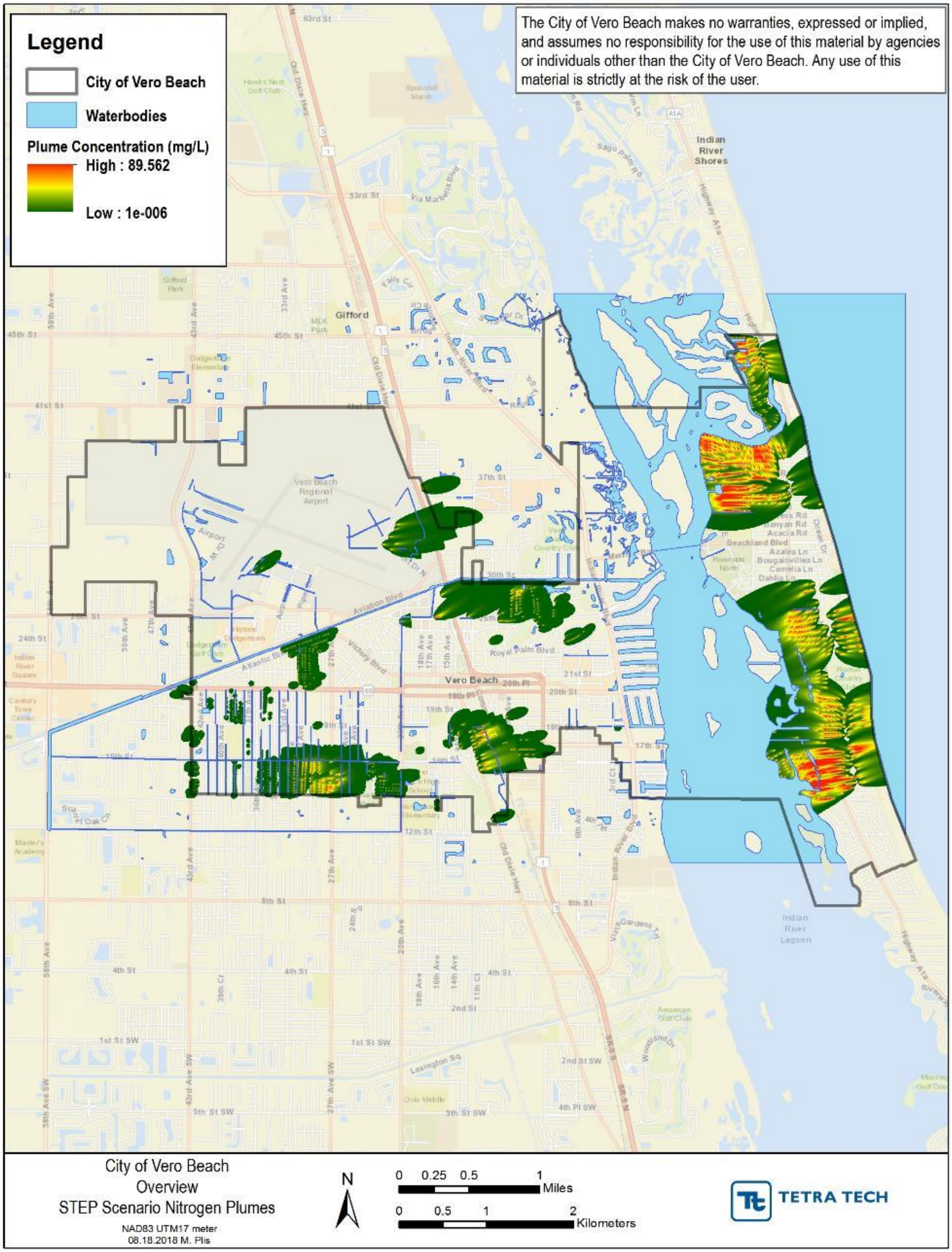

Figure 5-2. STEP Scenario modeled nitrogen plumes

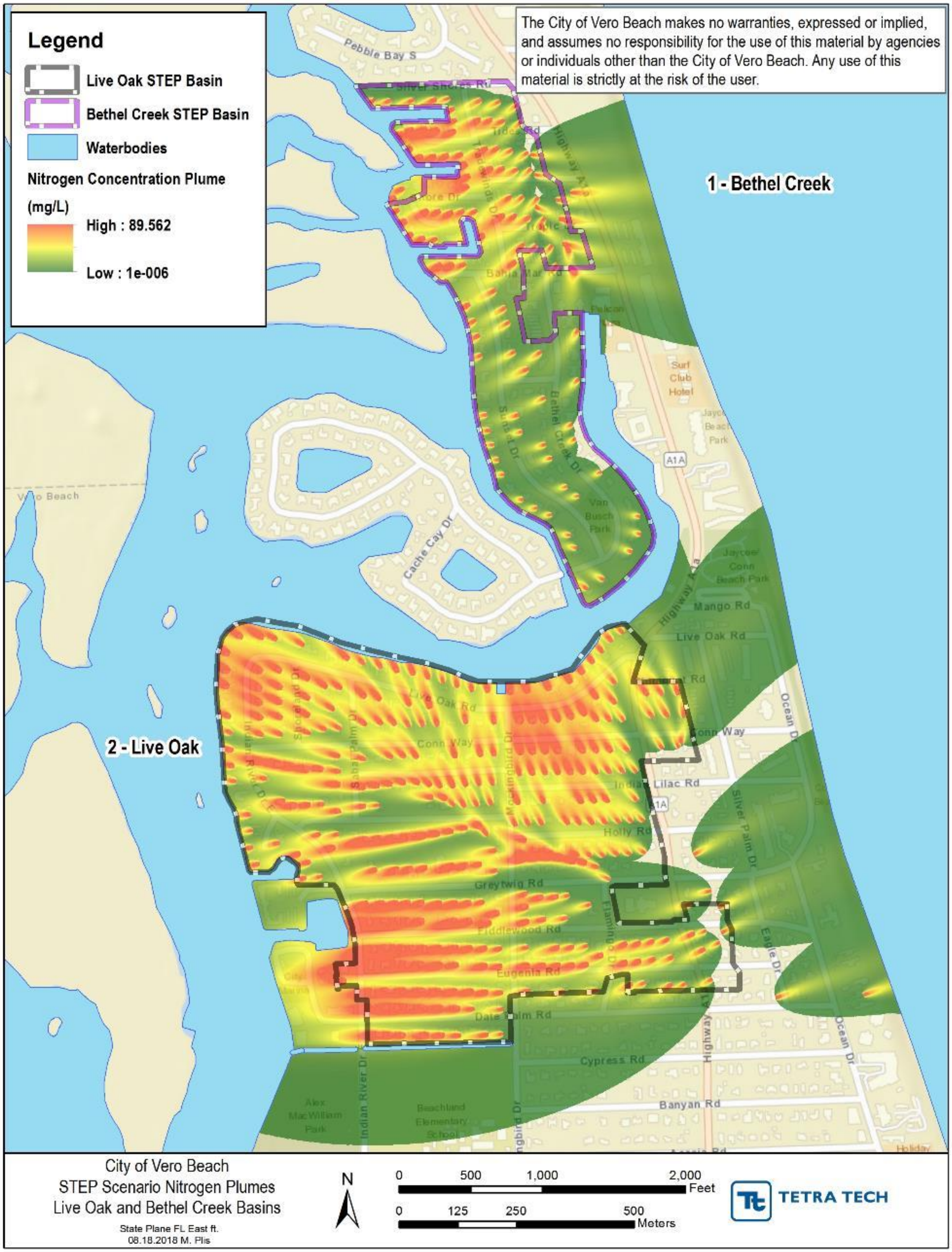

Figure 5-3. STEP Scenario Bethel Creek and Live Oak modeled nitrogen concentrations

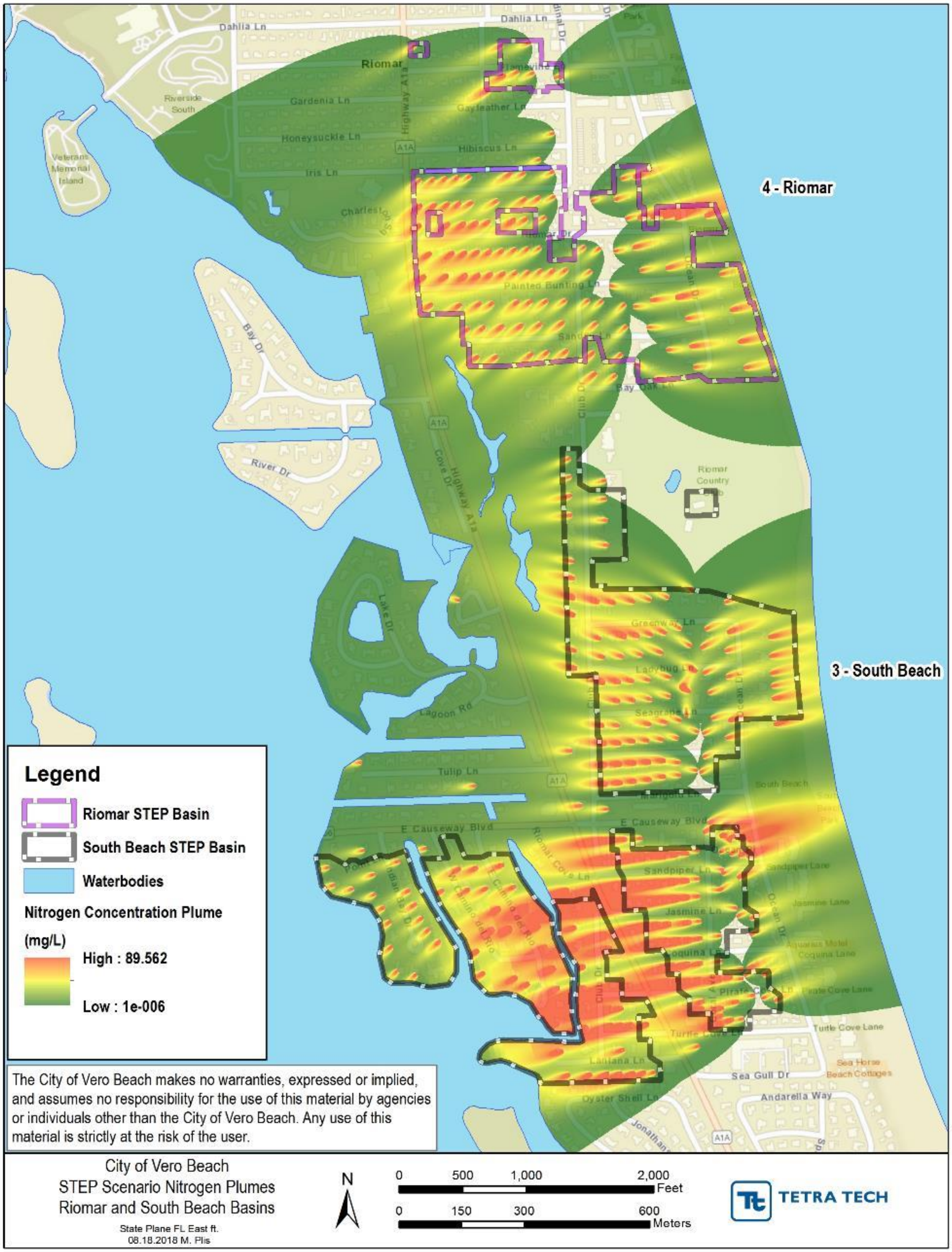

Figure 5-4. STEP Scenario South Beach and Riomar modeled nitrogen concentrations

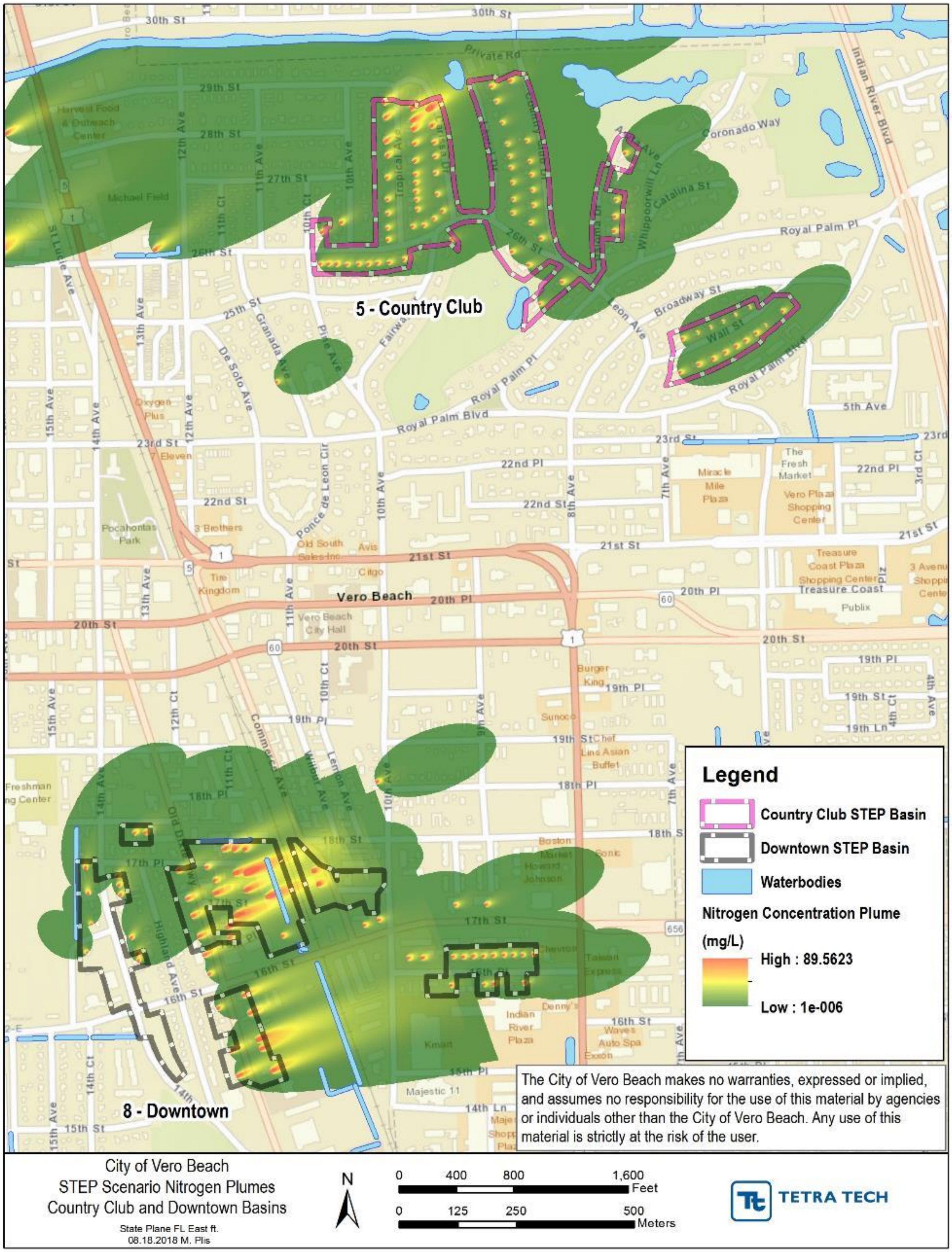

Figure 5-5. STEP Scenario Country Club and Downtown modeled nitrogen concentrations

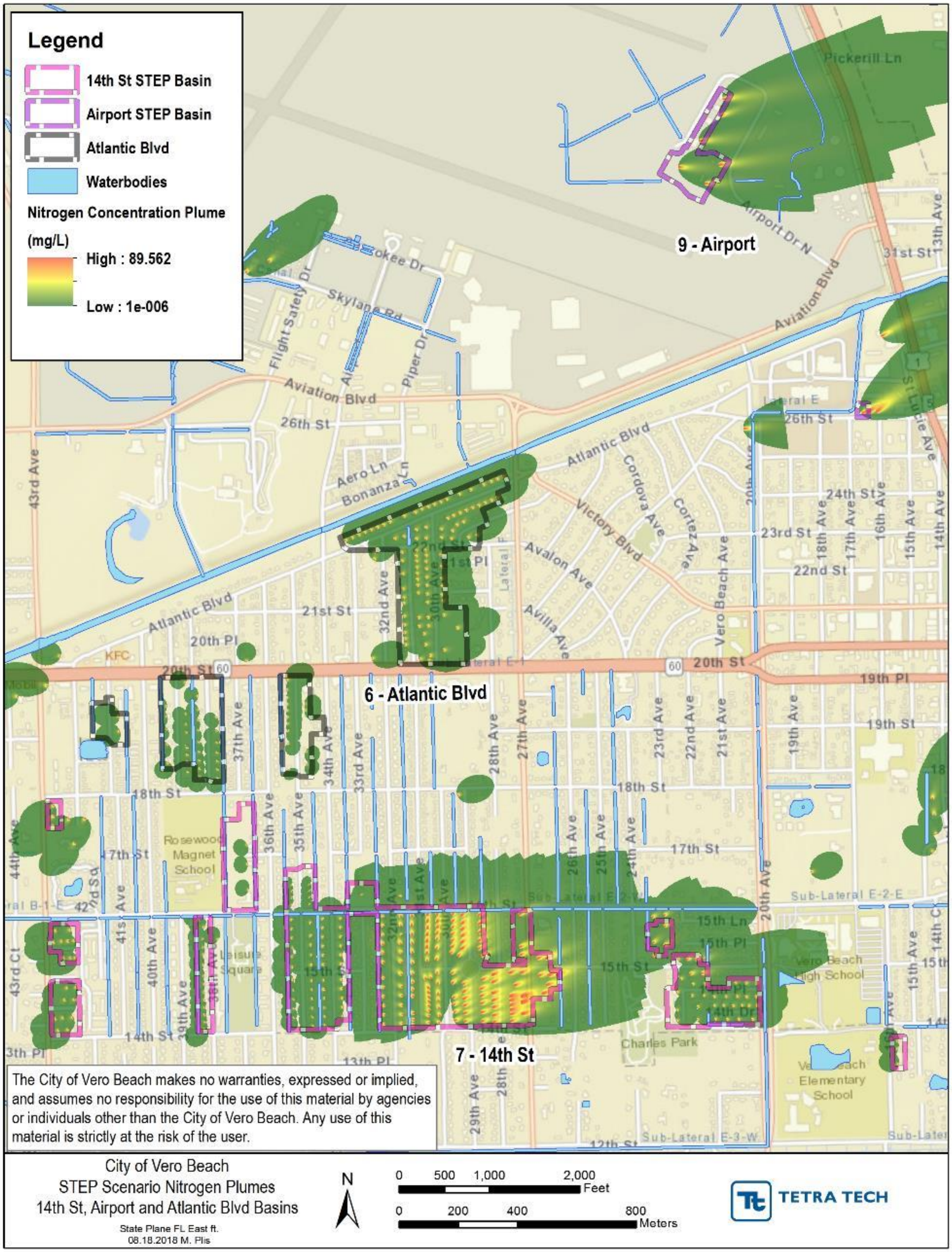

Figure 5-6. STEP Scenario Atlantic Boulevard, 14th Street, and Airport modeled nitrogen concentrations

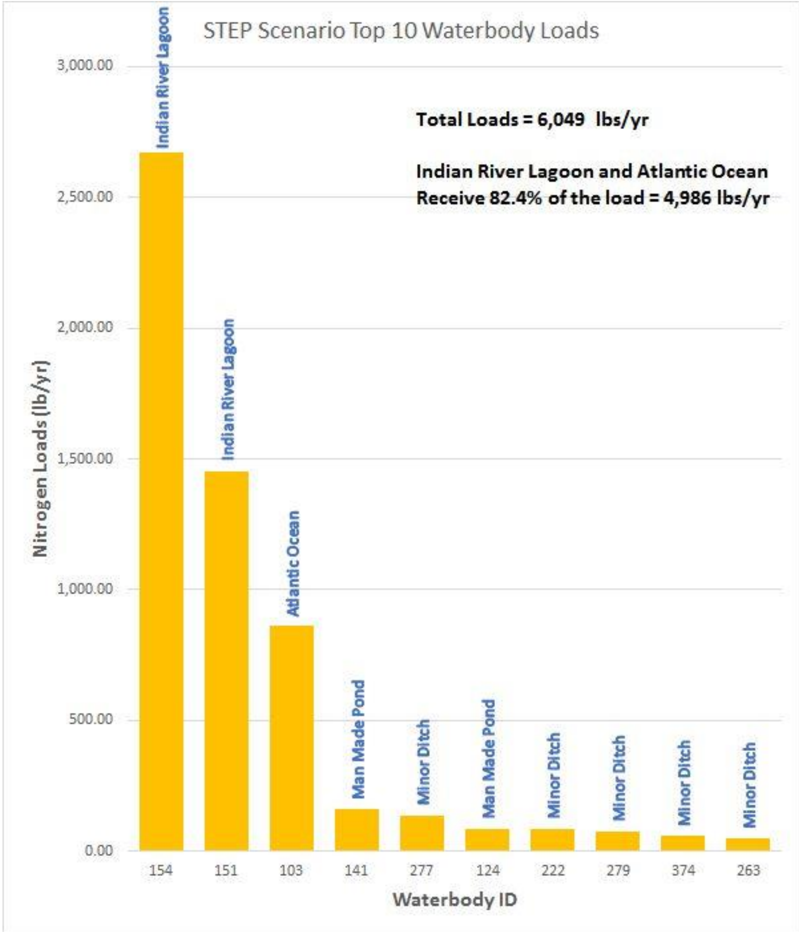

Figure 5-7. STEP Scenario top ten waterbodies with the highest estimated loads

Table 5-1. STEP Scenario top ten waterbodies with the highest estimated loads details

Waterbody Name/Type	Waterbody ID	Contributing STEP Basins	Load (lbs/yr)	% of Total Load
IRL	154	Live Oak, Bethel Creek	2,672	44.17%
IRL	151	South Beach, Riomar	1,454	24.03%
Atlantic Ocean	103	Live Oak, Bethel Creek, South Beach, Riomar	861	14.23%
Man Made Pond	141	South Beach	160	2.64%
Minor Ditch	277	Downtown	137	2.26%
Man Made Pond	124	Riomar	86	1.43%
Minor Ditch	222	Downtown	85	1.41%
Minor Ditch	279	14^{th} Street	75	1.24%
Minor Ditch	374	14^{th} Street	57	0.93%
Minor Ditch	263	14^{th} Street	48	0.79%
Total in Top 10			**5,633**	**93.12%**

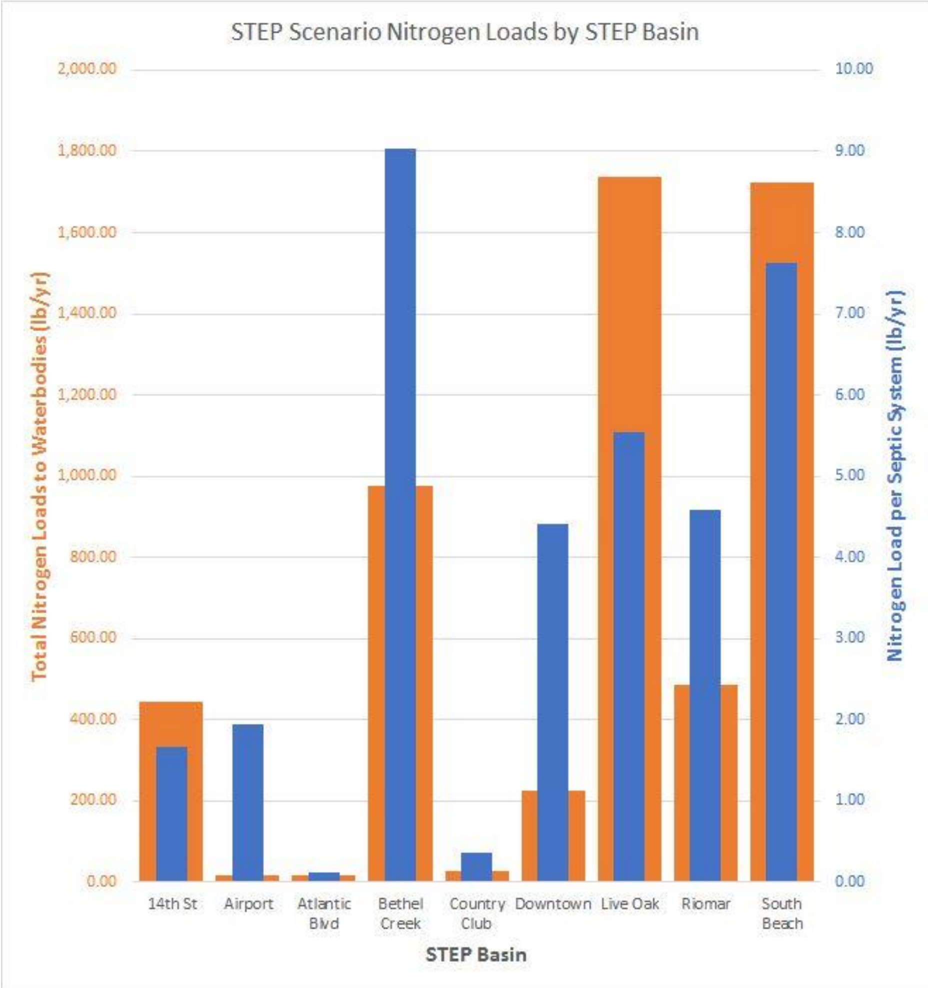

Figure 5-8. STEP Scenario estimated nitrogen loads by STEP basin

Table 5-2. STEP Scenario estimated nitrogen loads by STEP basin detail

STEP Basin	Total Load to Waterbodies	Number of Septic Systems	Load per System	% of Total Load
14th Street	444	267	1.66	7.34%
Airport	16	8	1.95	0.26%
Atlantic Boulevard	16	133	0.12	0.27%
Bethel Creek	976	108	9.04	16.13%
Country Club	29	80	0.36	0.48%
Downtown	225	51	4.42	3.72%
Live Oak	1,737	314	5.53	28.72%
Riomar	486	106	4.58	8.03%
South Beach	1,723	226	7.62	28.48%
Total in STEP Basins	**5,652**	**1,293**	**4.37**	**93.44%**

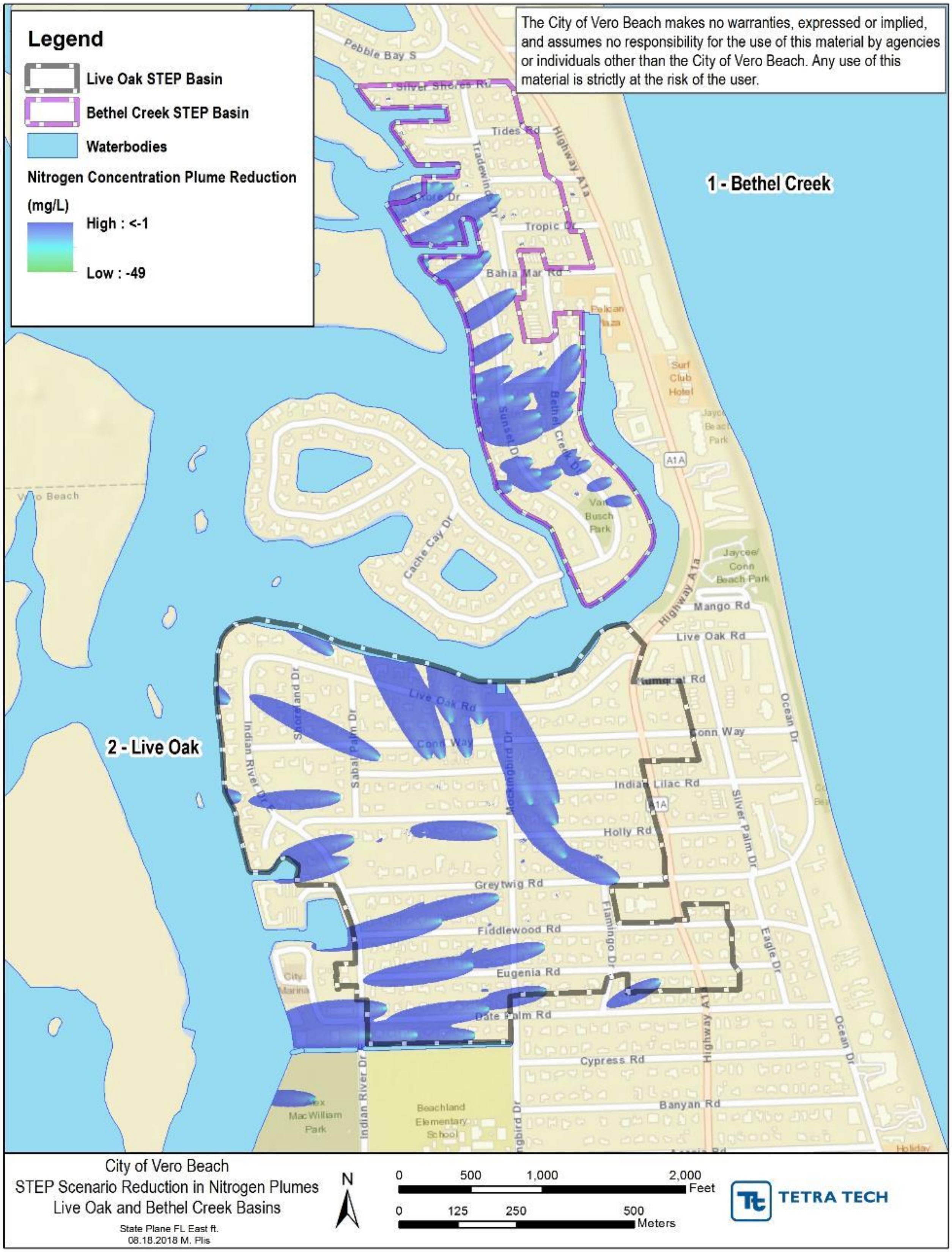

Figure 5-9. Bethel Creek and Live Oak modeled nitrogen concentration reductions

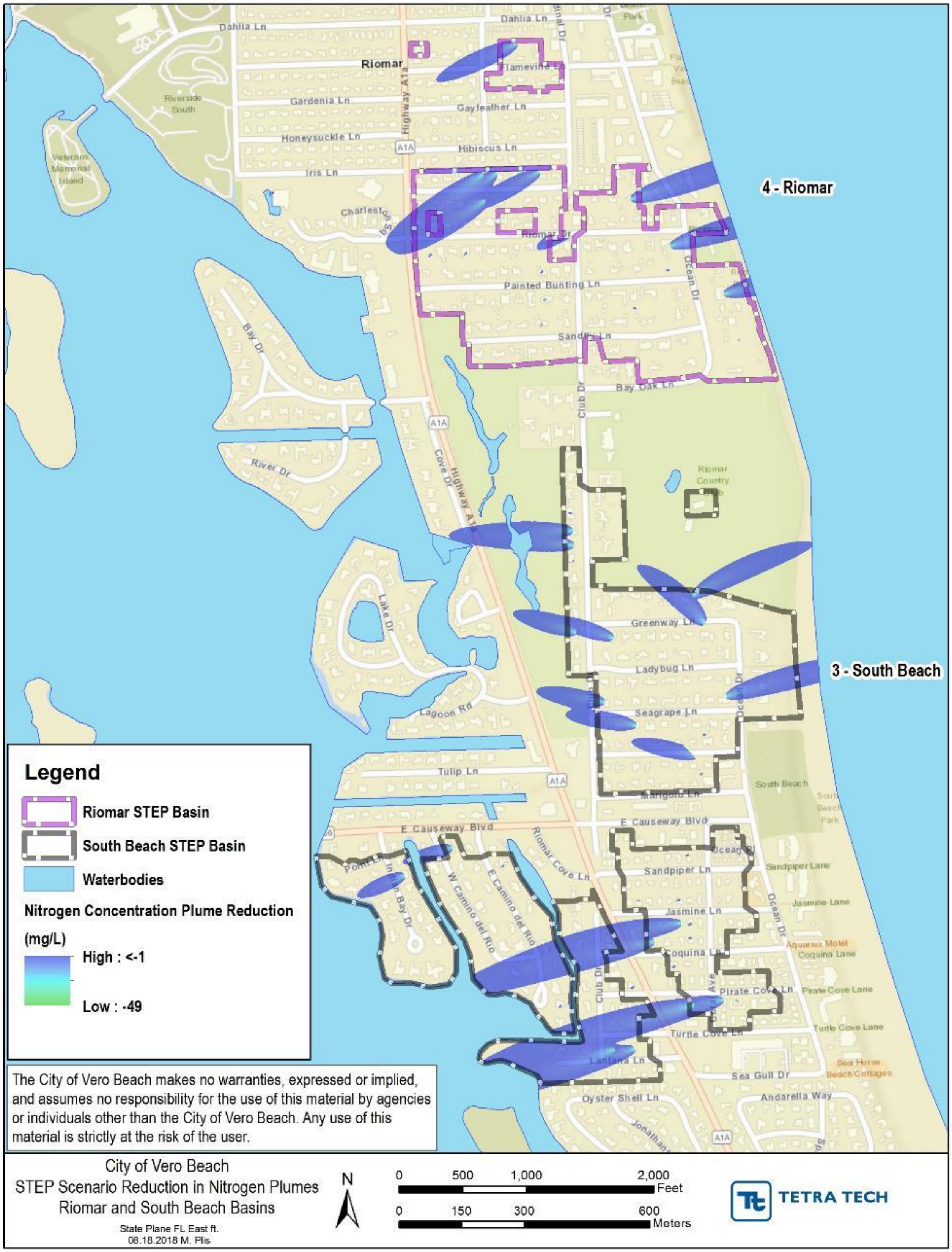

Figure 5-10. South Beach and Riomar modeled nitrogen concentration reductions

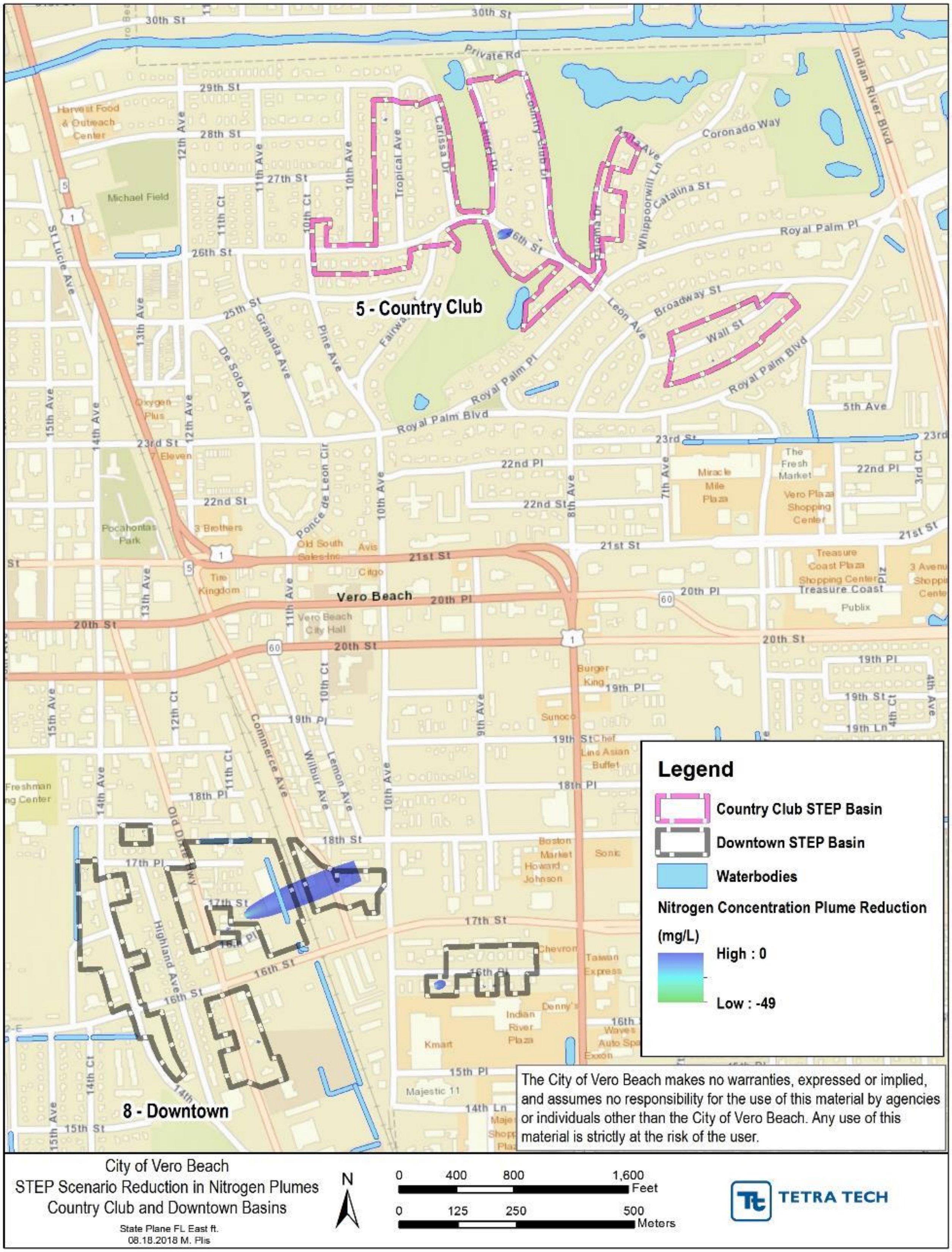

Figure 5-11. Country Club and Downtown modeled nitrogen concentration reductions

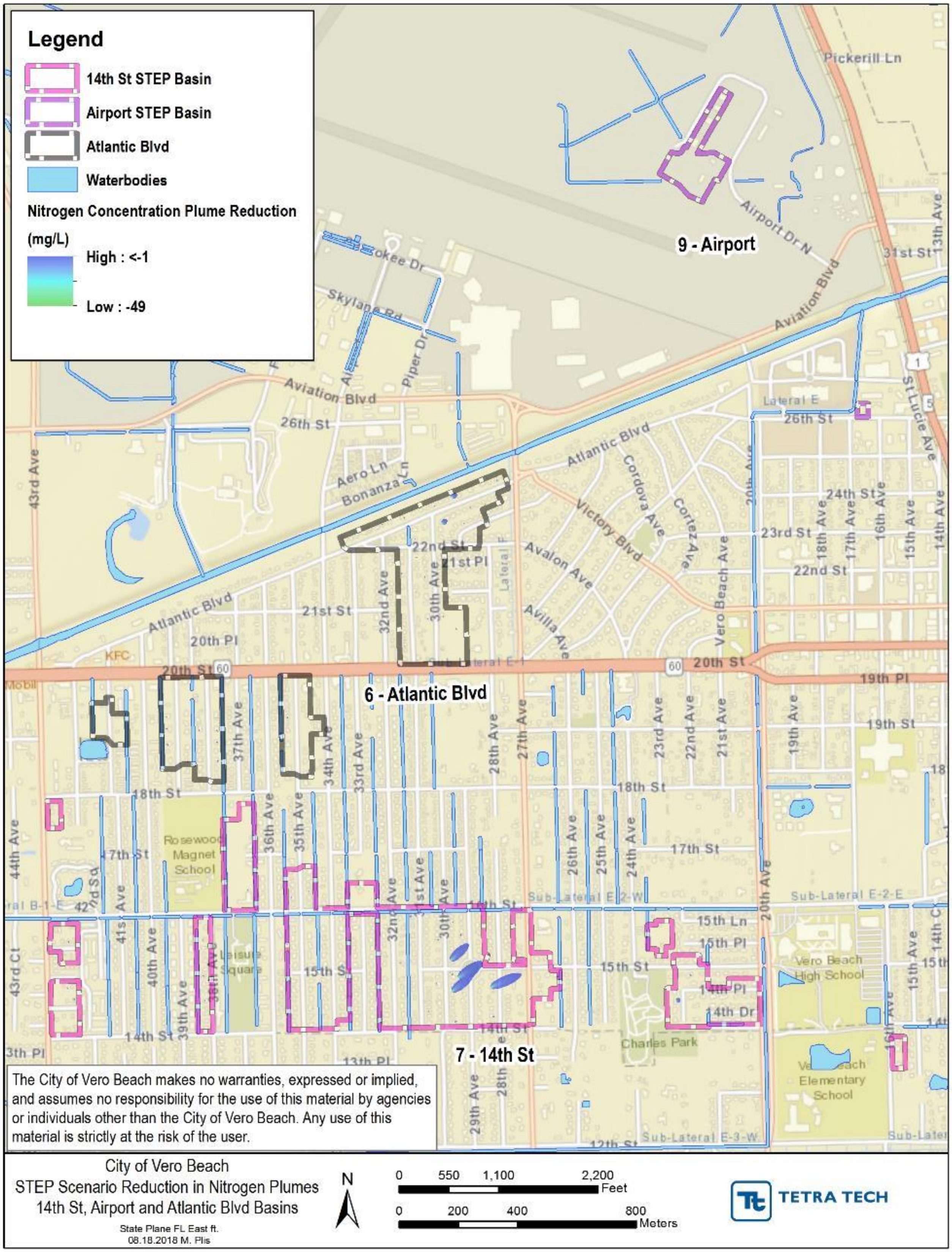

Figure 5-12. Atlantic Boulevard 14th Street, and Airport modeled nitrogen concentration reductions

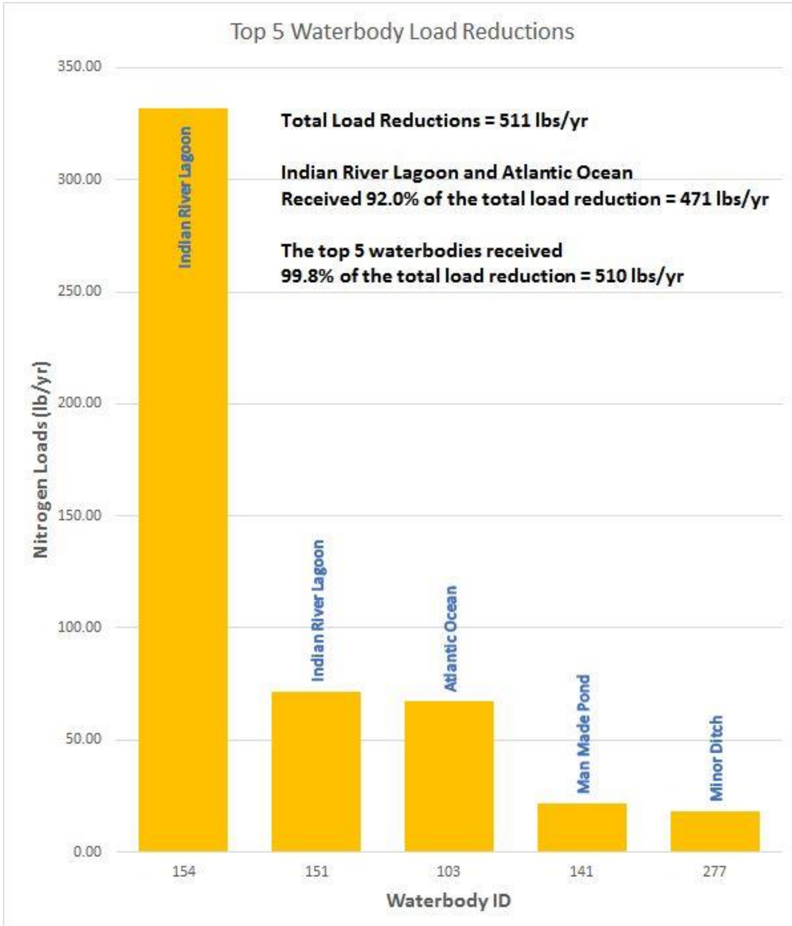

Figure 5-13. Top five waterbodies with the highest load reductions

Table 5-3. Top five waterbodies with the highest load reductions detail

Waterbody Name/Type	Waterbody ID	Contributing STEP Basins	Load Reductions (lbs/yr)	% of Total Load Reduction
IRL	154	Live Oak, Bethel Creek	332	64.94%
IRL	151	South Beach, Riomar	71	13.96%
Atlantic Ocean	103	Live Oak, Bethel Creek, South Beach, Riomar	67	13.17%
Man Made Pond	141	South Beach	21	4.19%
Minor Ditch	277	Downtown	18	3.52%
Total in Top 5			**510**	**99.78%**

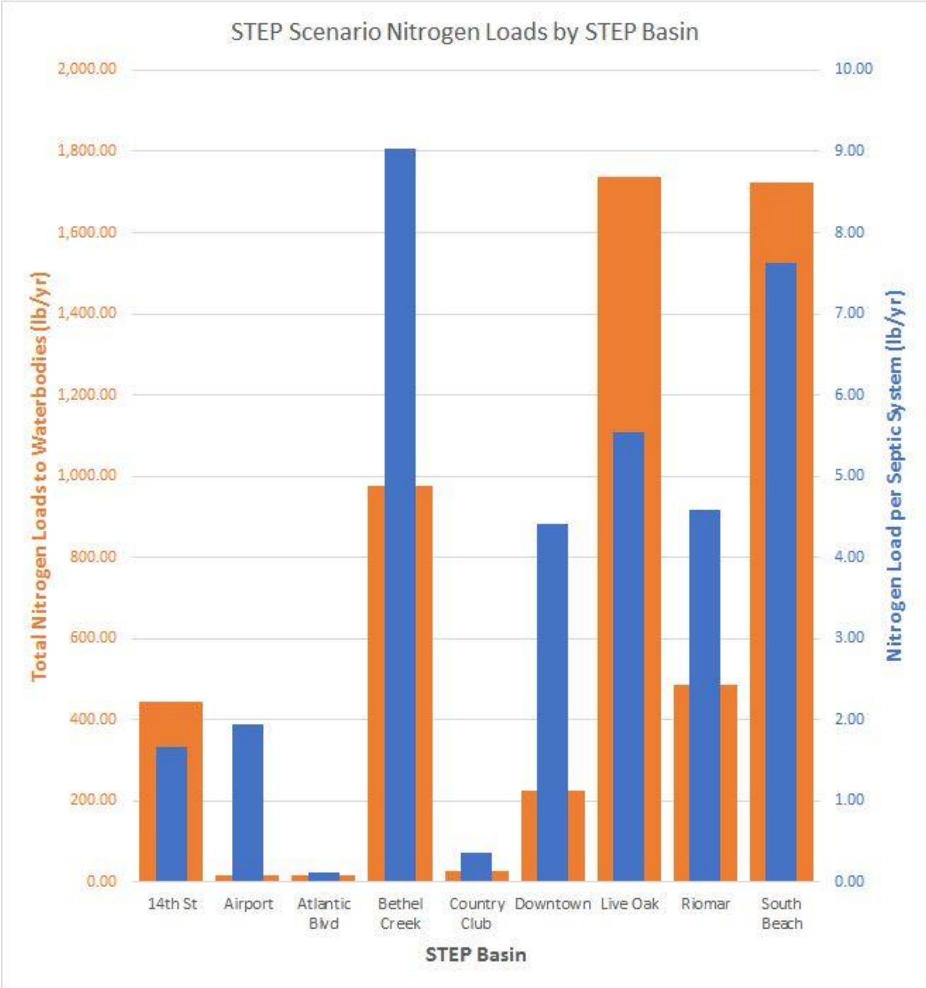

Figure 5-14. Estimated nitrogen load reductions by STEP basin

Table 5-4. Estimated nitrogen load reductions by STEP basin detail

STEP Basin	Reduction in Total Load (lbs/yr)	Number of STEP Conversions	Adjusted Load per System	% of Total Load Reduction
14th Street	1	5	1.66	0.17%
Airport	0	0	1.95	0.00%
Atlantic Boulevard	0	3	0.12	0.00%
Bethel Creek	186	33	9.04	36.47%
Country Club	0	1	0.36	0.00%
Downtown	18	2	4.42	3.52%
Live Oak	139	29	5.53	27.19%
Riomar	53	9	4.58	10.39%
South Beach	107	18	7.62	20.95%
Total in STEP Basins	**504**	**100**	**3.92**	**98.70%**

6.0 MODEL UNCERTAINTY IN LOAD ESTIMATES

A general lack of observations of model parameters including longitudinal dispersivity, source plane concentrations, and first-order decay coefficients, in addition to a very limited number of measured soil parameters (porosity, hydraulic conductivity) and nitrogen concentrations makes the ArcNLET model inherently uncertain. To help with quantifying this uncertainty, ArcNLET includes a Monte Carlo simulation function.

The Monte Carlo simulation function generates samples of random parameter values using the Latin Hypercube Method and based on user specified probability distributions. This function can address uncertainty in seven model parameters including smoothing factor, longitudinal dispersivity, horizontal transverse dispersivity, first-order decay coefficient of denitrification, hydraulic conductivity, porosity, and source plane concentration.

Running these simulations for a large area can be computer intensive; therefore, Tetra Tech conducted the uncertainty analysis for the City's model using a portion of the model area. STEP basins Live Oak and Bethel Creek were chosen to conduct the uncertainty analysis. These two basins are located on the barrier island and they represent a substantial portion of the overall loads, have similar soil compositions, and are the only basins directly discharging to waterbody 154 (the IRL). To conduct the nitrogen concentration uncertainty analysis, a monitoring point was selected within the largest barrier island soil group. The particle paths from this point do not cross any other soils before terminating at the IRL. **Figure 6-1** shows the uncertainly analysis sub-model extent and the monitoring point selected for the analysis.

The Monte Carlo Simulation model was set up to generate 1,000 random parameter samples. The parameters selected for the uncertainty analysis, range of values, and probability distributions of those parameters are presented in **Table 6-1** and the distribution histograms are shown in **Figure 6-2** through **Figure 6-5**.

Figure 6-6 and **Figure 6-7** show that the mean and standard deviations of the simulated nitrogen concentrations at the monitoring point and the estimated nitrogen loads to waterbody 154 converge after approximately 300 runs. This suggests that 1,000 simulations are sufficient to evaluate the uncertainty. Based on the 1,000 simulations, **Figure 6-8** and **Figure 6-9** show the histograms and cumulative distribution function (CDF) of the simulated nitrogen at the monitoring point and the estimated load to waterbody 154. The shape of the loading histogram follows a lognormal distribution, which suggests the most influential parameter for load is the first-order decay coefficient of denitrification. The calibrated estimated load to waterbody 154 is 3,004 lbs/yr, and comparing that to the load CDF plot, there is a 20% chance of a higher load. The calibrated model concentration at the monitoring point is 30.06 milligrams per liter (mg/L) and comparing that value to the concentration CDF plot suggests that this is on the high side of the concentration estimate.

The relationship between the estimated load to waterbody 154 and concentration at the monitoring point is shown on **Figure 6-10**. In general, higher concentrations result in higher loads, but a concentration between 25-40 mg/L can vary dramatically in the amount of loading.

Figure 6-11 through **Figure 6-14** show the relationship between individual model parameters and the resulting simulated concentrations and loads. The only parameter that has a major impact on nitrogen concentrations and loads is the first-order decay coefficient of denitrification.

Figure 6-15 shows the estimated load result of 1,000 Monte Carlo simulations with the calibrated load estimate. The load results varied from 218 lbs/yr to 8,402 lbs/yr. Most of the higher loads resulted from a lower coefficient of denitrification. Additional measured groundwater nitrogen concentrations would help to refine the model and narrow this uncertainty gap.

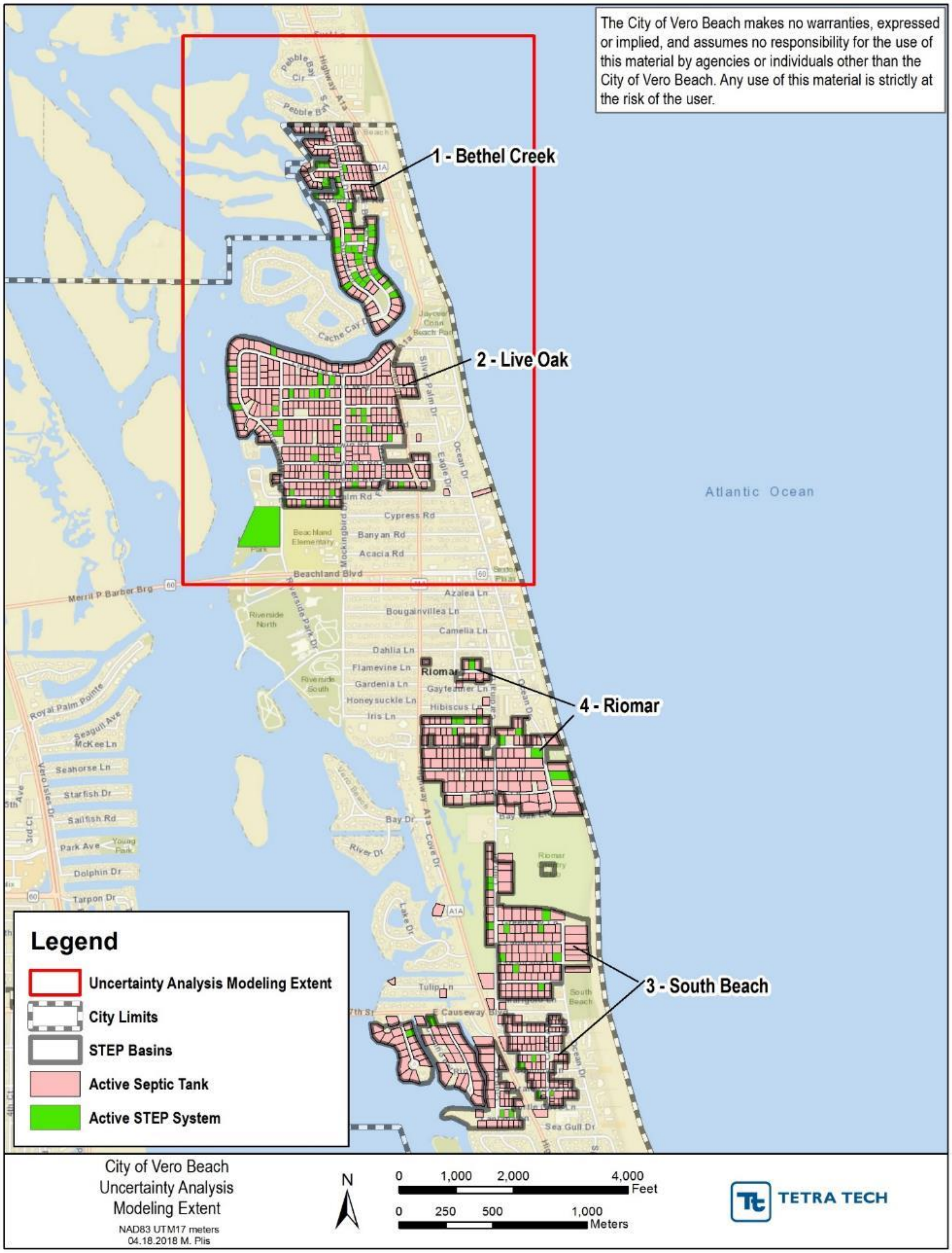

Figure 6-1. Monte Carlo simulation model area

Table 6-1. Probability distributions and value ranges for parameters selected for uncertainty analysis

Model Parameter	Distribution	Minimum	Mode	Max
Smoothing Factor	Uniform	20	N/A	120
Longitudinal Dispersivity	Normal	0.21	N/A	21.34
Decay Coefficient	Lognormal	0.0001	N/A	0.0360
Hydraulic Conductivity	Triangular	12.46	21.34	30.50

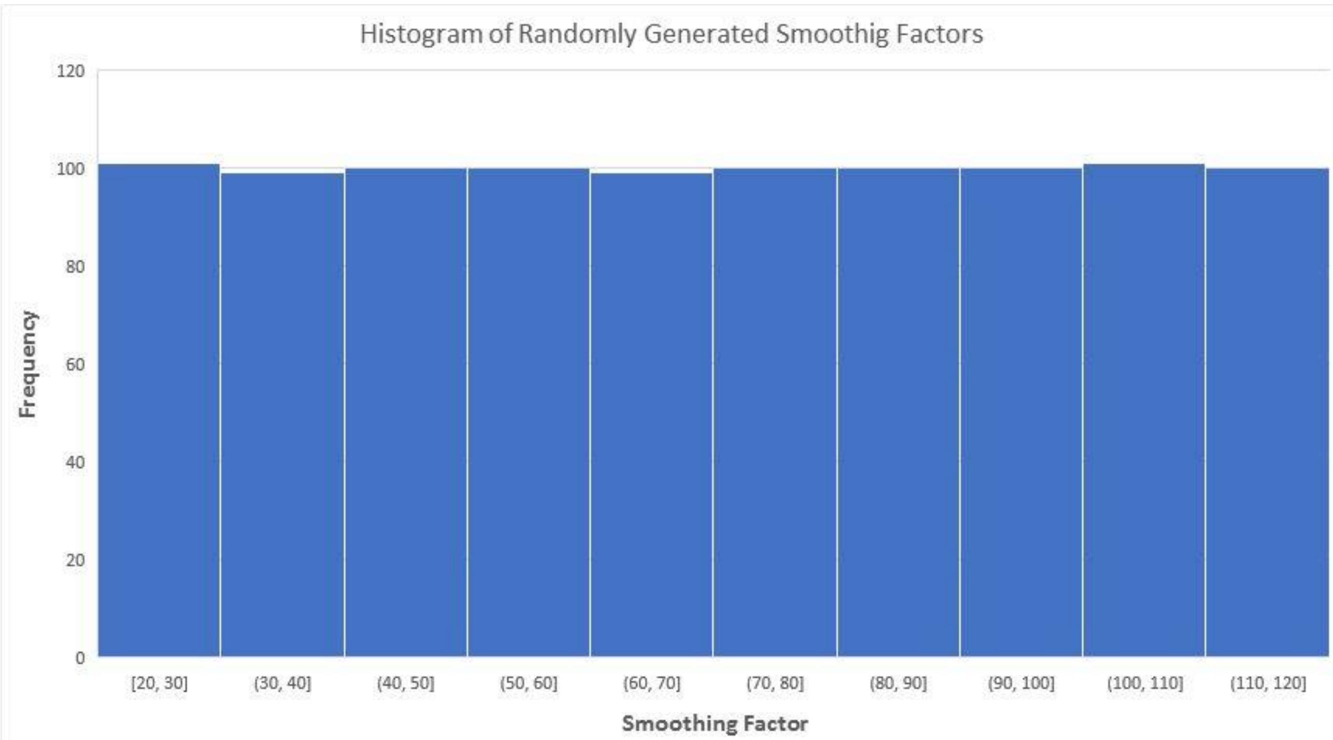

Figure 6-2. Histogram of 1,000 randomly generated smoothing factors

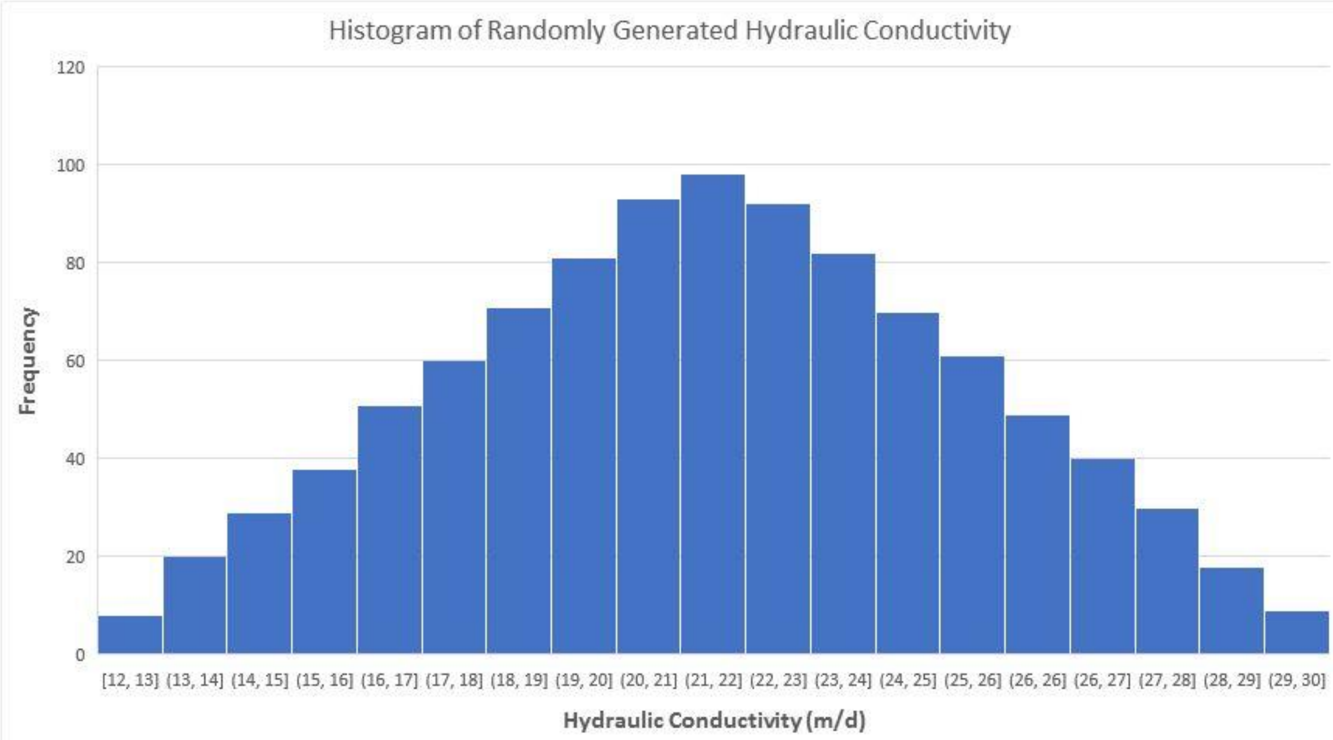

Figure 6-3. Histogram of 1,000 randomly generated values of hydraulic conductivity

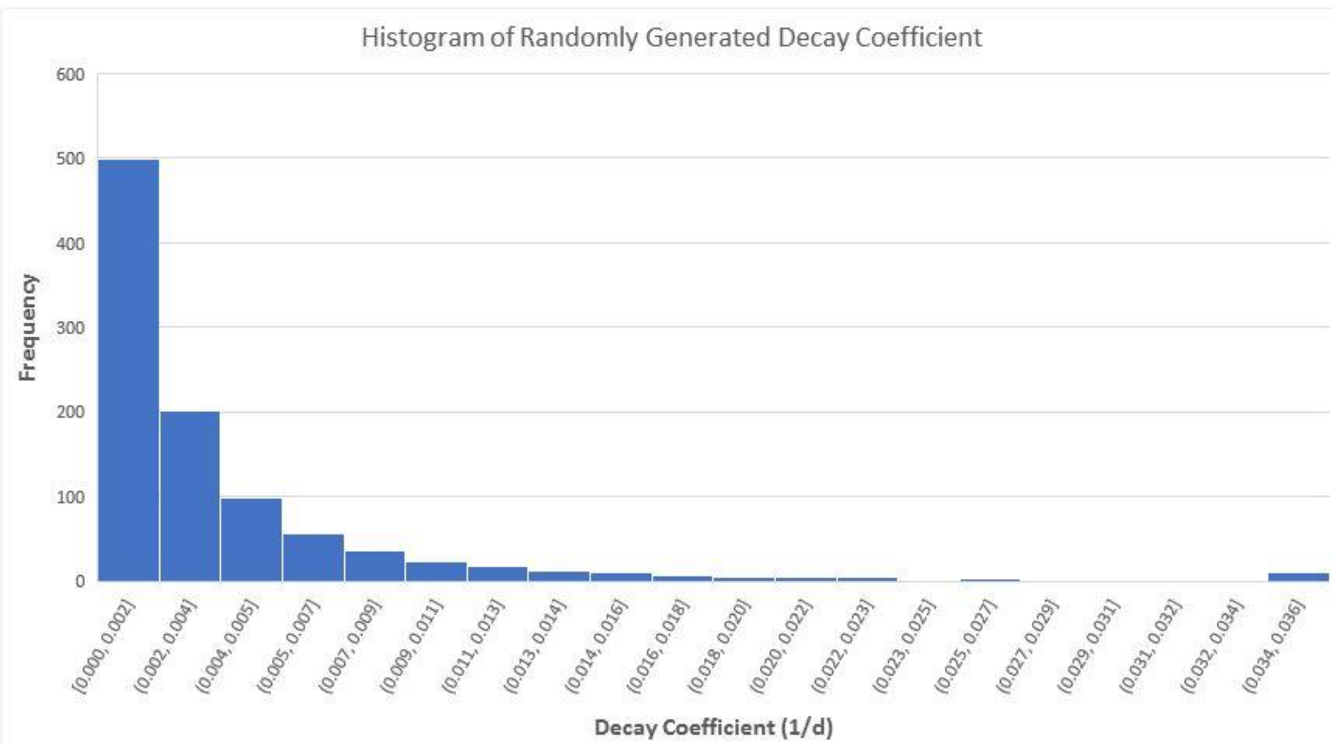

Figure 6-4. Histogram of 1,000 randomly generated values of first-order decay coefficient

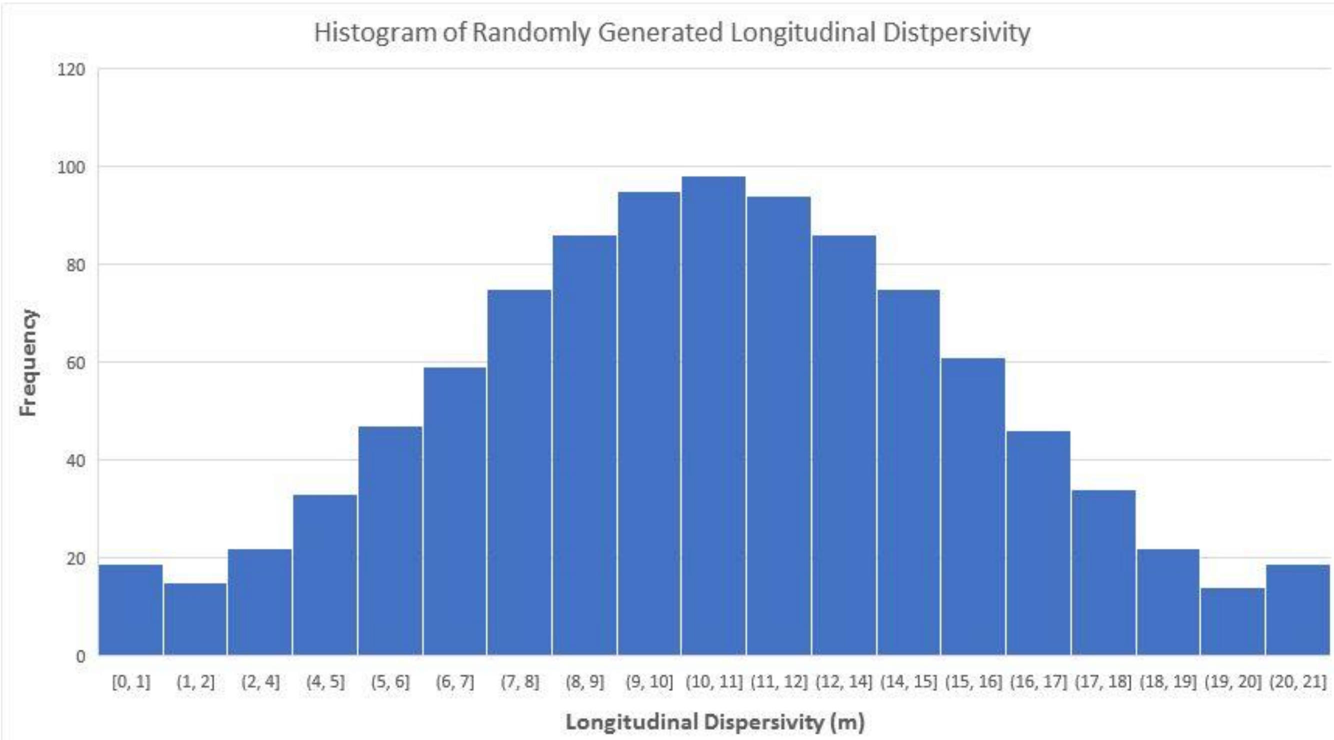

Figure 6-5. Histogram of 1,000 randomly generated values of longitudinal dispersivity

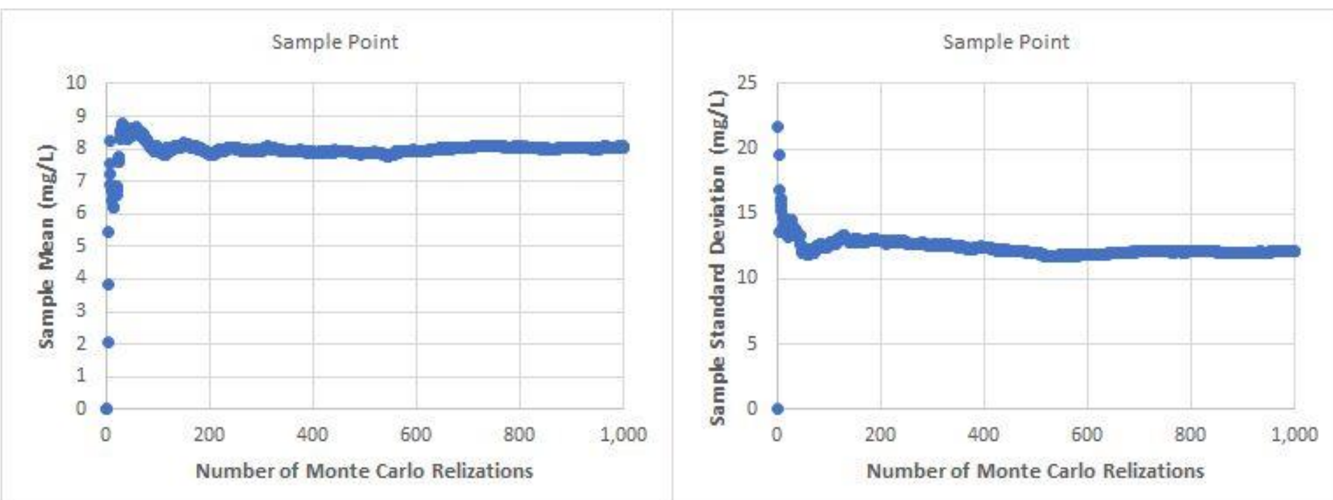

Figure 6-6. Sample mean (left) and standard deviation (right) of simulated nitrogen concentrations

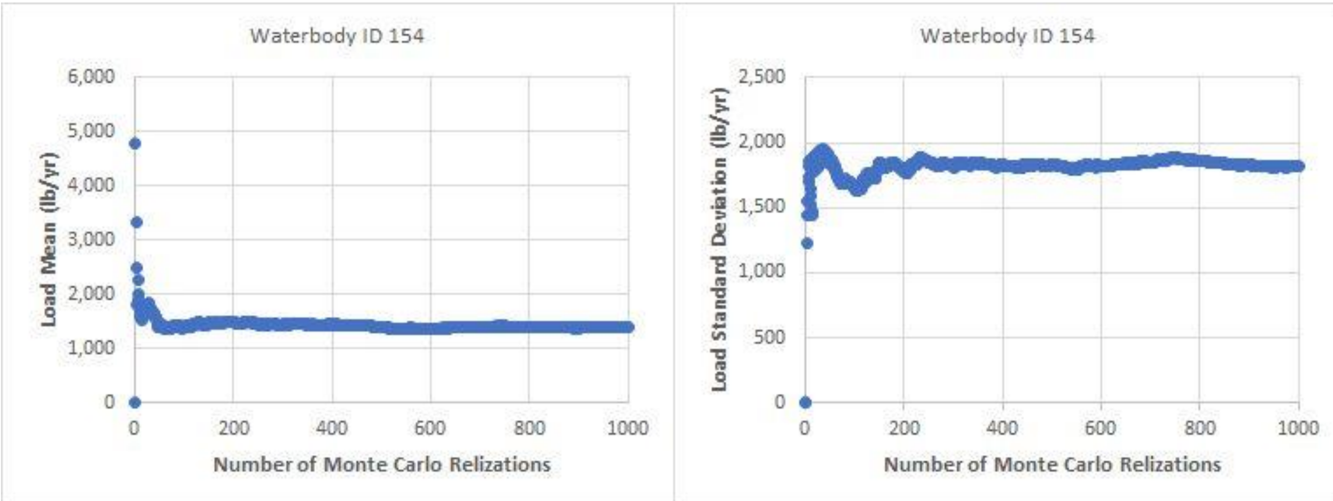

Figure 6-7. Waterbody 154 (IRL) mean (left) and standard deviation (right) of simulated nitrogen loads

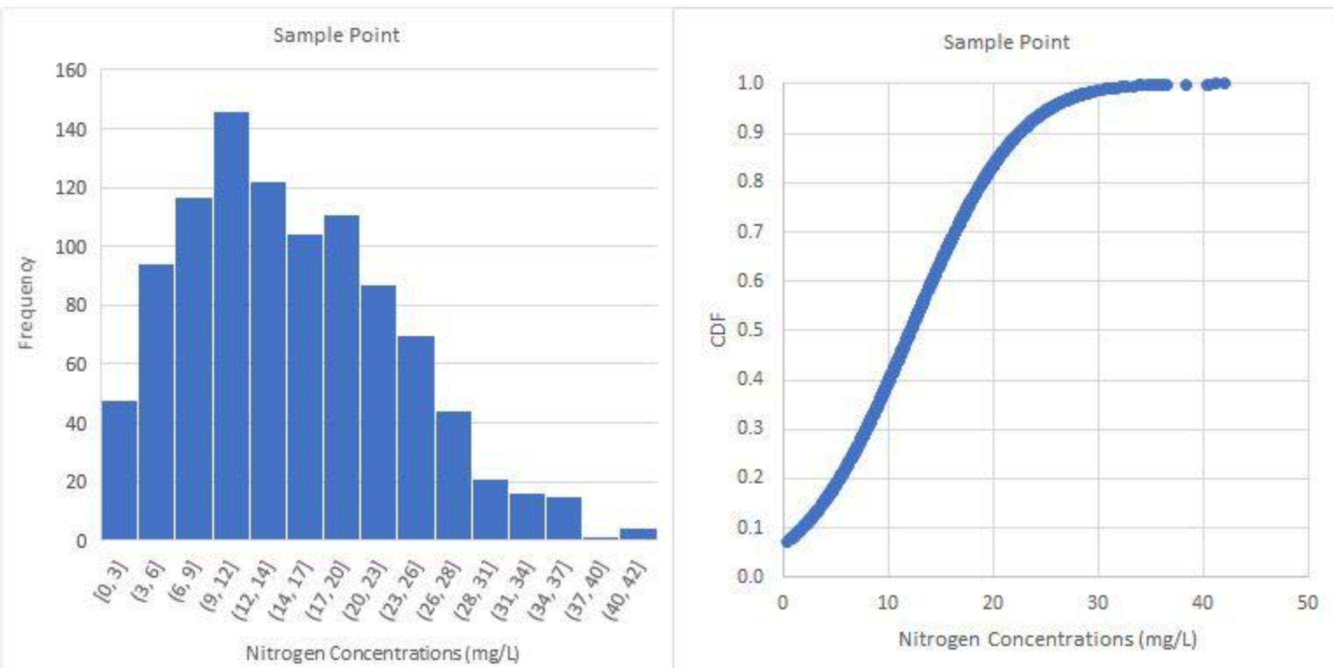

Figure 6-8. Histogram (left) and cumulative distribution function (right) of 1,000 simulations of nitrogen concentrations at the monitoring point

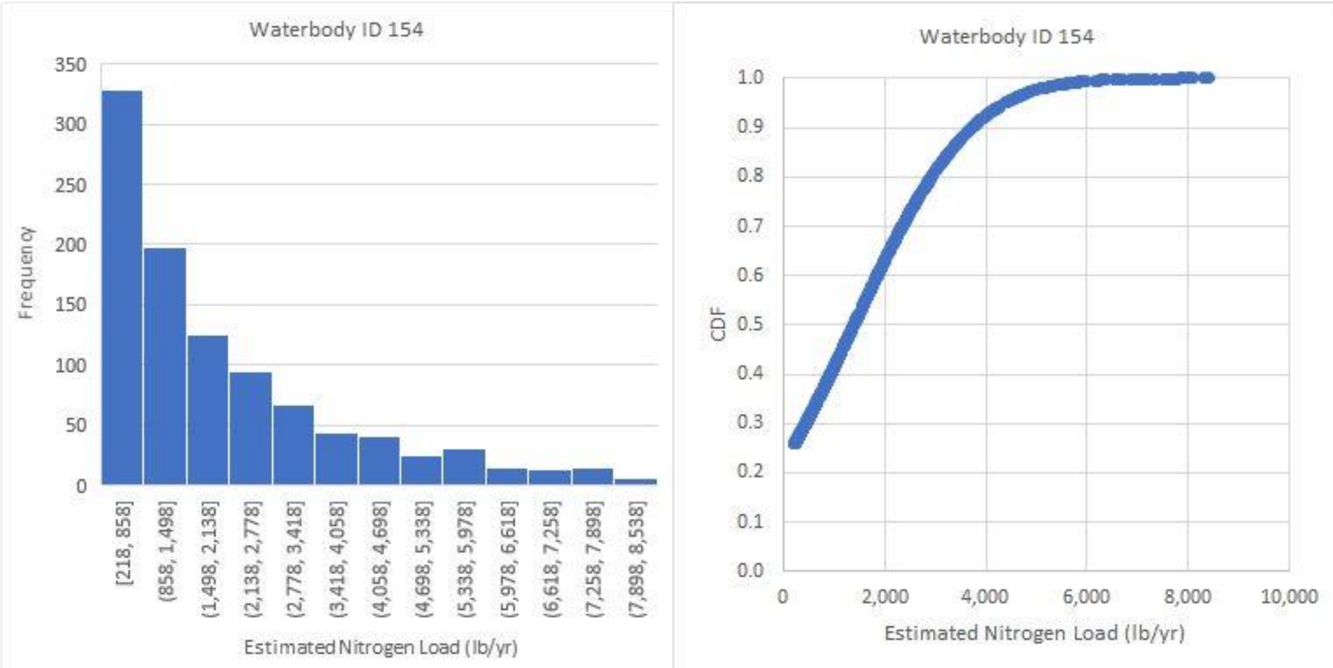

Figure 6-9. Histogram (left) and cumulative distribution function (right) of 1,000 simulations of nitrogen load to waterbody 154 (IRL)

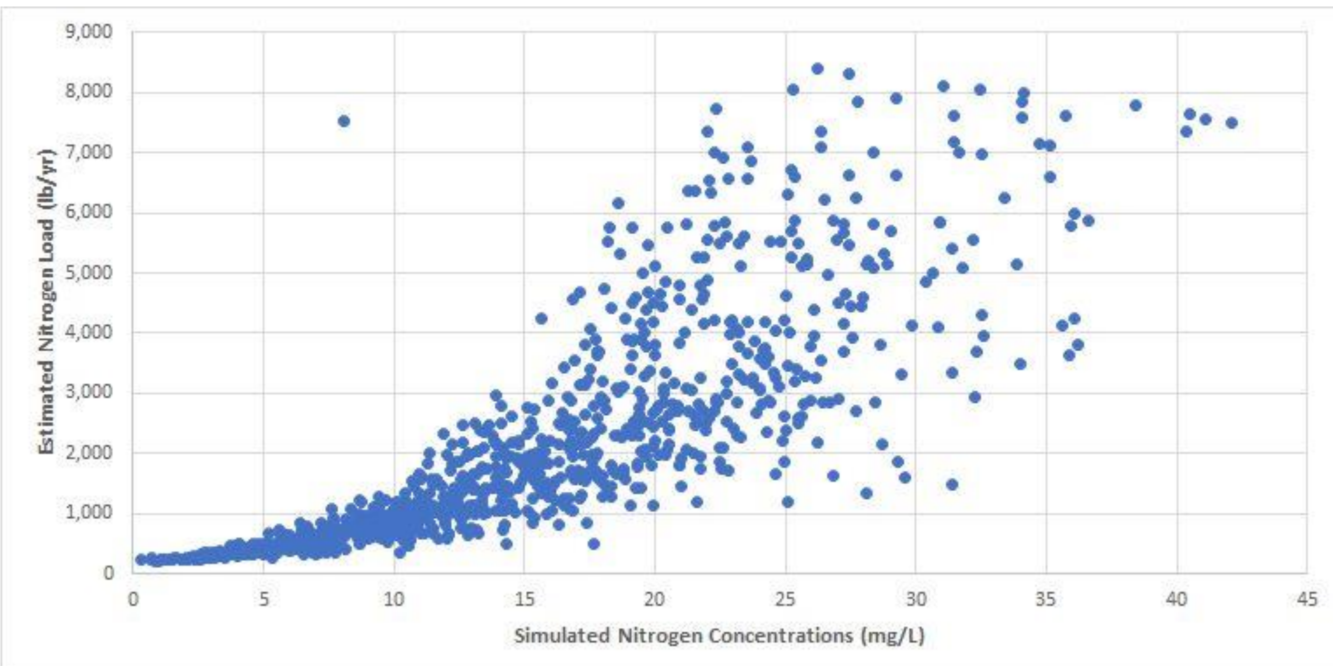

Figure 6-10. Relationship between the nitrogen load estimate and concentration at the monitoring point

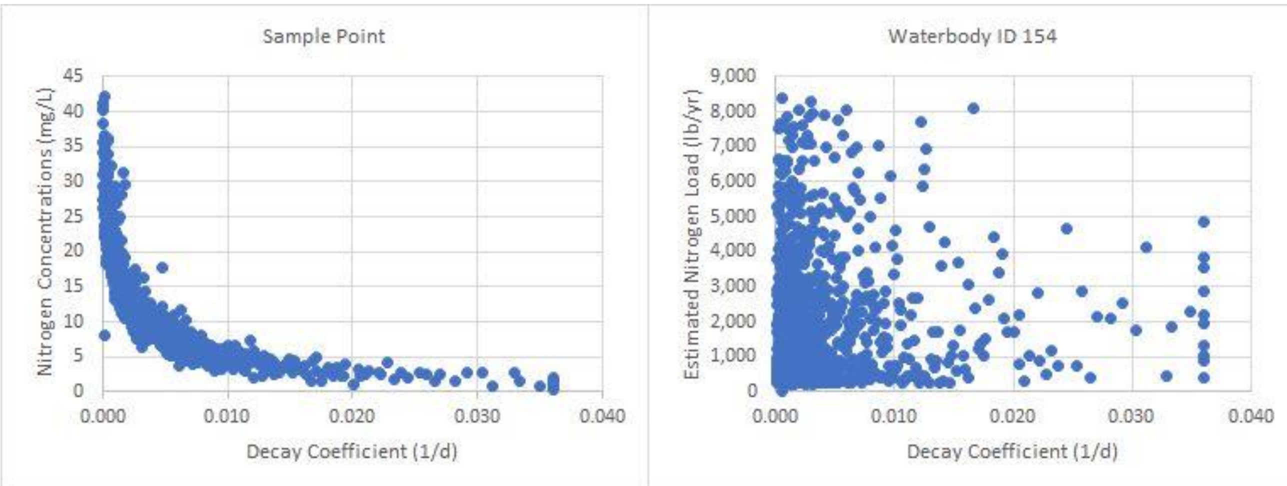

Figure 6-11. Scatterplots for the first-order decay coefficient of denitrification and simulated concentration (left) and load (right)

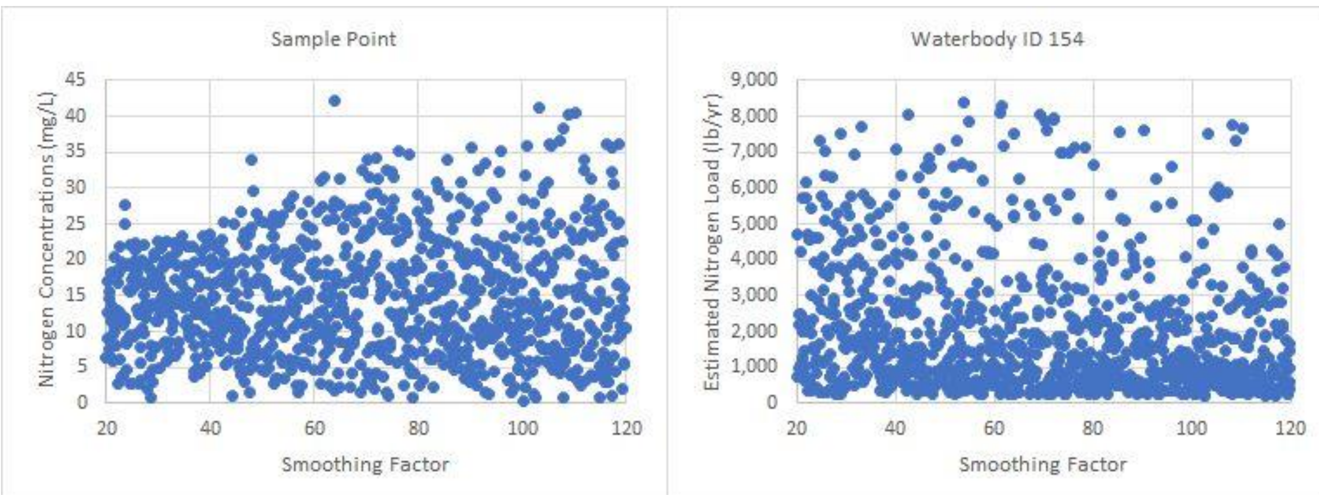

Figure 6-12. Scatterplots for the smoothing factor and simulated concentration (left) and load (right)

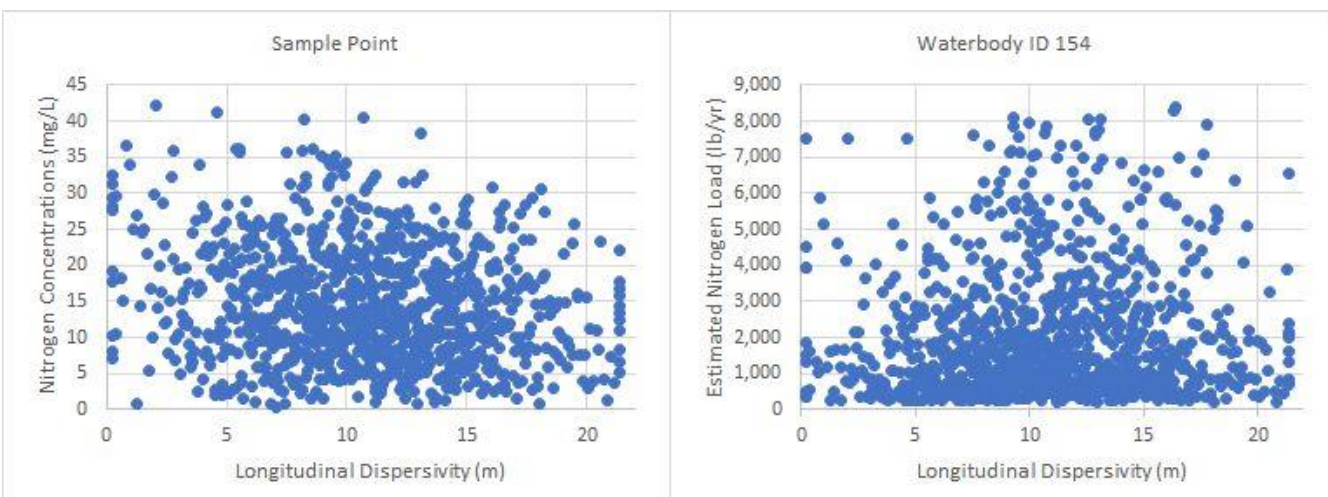

Figure 6-13. Scatterplots for the longitudinal dispersivity and simulated concentration (left) and load (right)

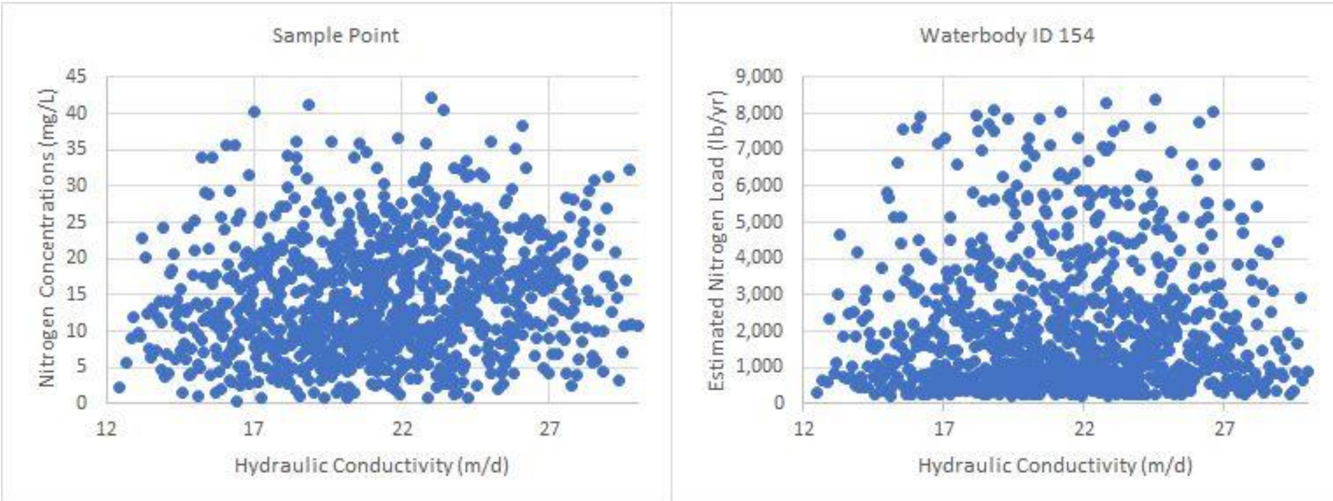

Figure 6-14*.* Scatterplots for the hydraulic conductivity and simulated concentration (left) and load (right)

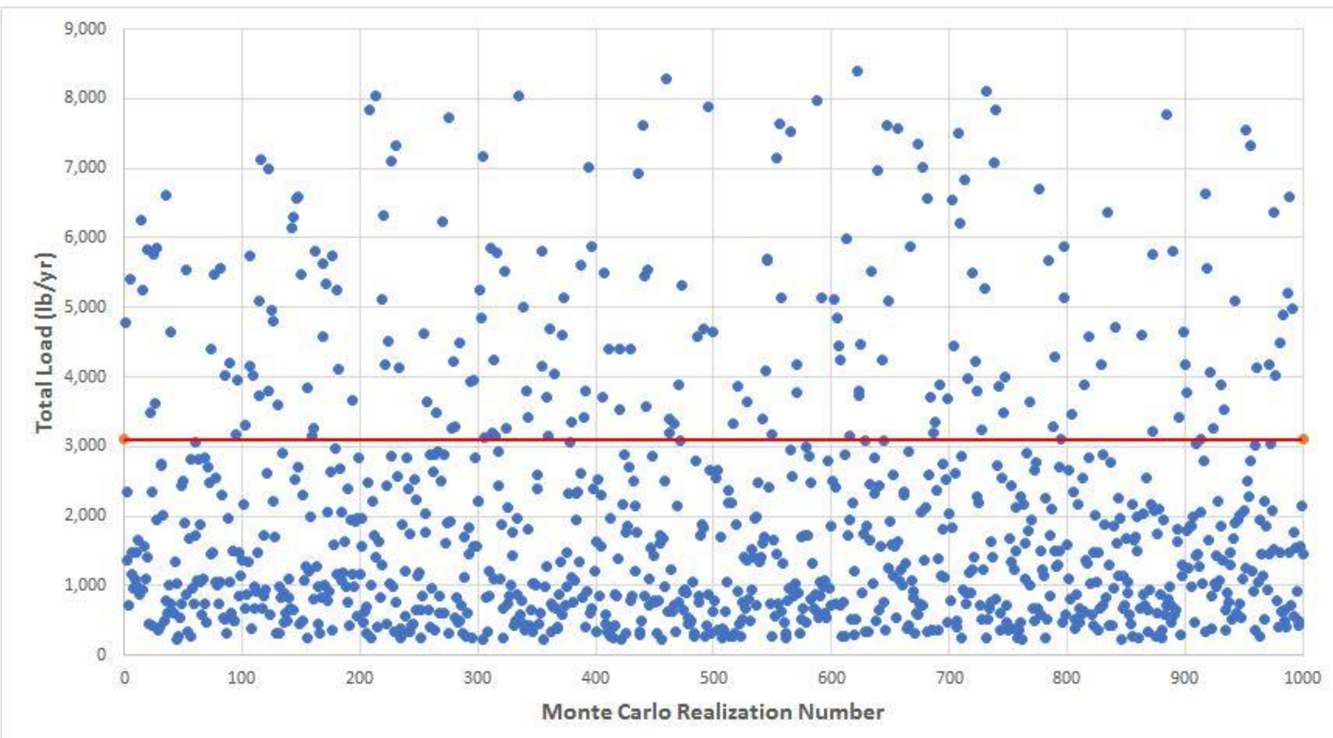

Figure 6-15. Scatterplots for the 1,000-simulated load estimates and calibrated values

7.0 NEXT STEPS

Add information on new monitoring wells and how data will be used to update model

The City of Vero Beach is stakeholder in the Central IRL Basin Management Action Plan (BMAP) that was adopted by DEP in 2013. The stakeholders in the BMAP are required to implement projects to reduce nutrients to improve water quality within the IRL to restore seagrass. As the City connects additional homes to STEP systems, the ArcNLET model can be used to determine the associated nutrient load reduction credit associated with those connections. Additional scenarios, like the STEP Scenario described in **Section 5.0**, can be run to estimate the nitrogen reductions from the STEP system projects each year. By comparing the scenario with the new STEP system connections to the previous scenario, the amount of nitrogen load that was reduced can be calculated and submitted to DEP for BMAP credit. The results from the ArcNLET modeling should also be submitted to DEP to support the City's new BMAP credits. The City can provide updated credit information to DEP on an annual basis as part of the statewide annual report process, which tracks progress towards BMAP targets.

8.0 REFERENCES

FDOH. 2015. Florida Onsite Sewage Nitrogen Reduction Strategies Study, Final Report, 2008-2015.

Hazen and Sawyer. 2009. Literature Review of Nitrogen Reduction Technologies for Onsite Sewage Treatment Systems. Report to the Florida Department of Health.

Rios, J.F., M. Ye, L. Wang, and P. Lee. 2011. ArcNLET: An ArcGIS-Based Nitrate Load Estimation Toolkit, User's Manual, Florida State University, Tallahassee, FL., available online at http://people.sc.fsu.edu/~mye/ArcNLET/users_manual.pdf.

Sayemuzzaman, M. and M. Ye. 2015. Estimation of Nitrogen Load from Septic Systems to Surface Water Bodies in the Indian River Lagoon (Main-South Canal drainage basin). Prepared for the Florida Department of Environmental Protection. Tallahassee, Florida.

United States Environmental Protection Agency. 2002. Onsite Wastewater Treatment Manual. EPA 625/R-00/008. National Risk Management Research Laboratory, Office of Water, U.S. Environmental Protection Agency. Washington, DC.

Ye, M. and H. Sun. 2013. Estimation of Nitrogen Load from Removed Septic Systems to Surface Water Bodies in the City of Port St. Lucie, the City of Stuart, and Martin County. Prepared for the Florida Department of Environmental Protection. Tallahassee, Florida.