Study of Select Lakes for Wastewater Inputs

Watershed Monitoring Section

Division of Environmental Assessment and Restoration

Florida Department of Environmental Protection

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Executive Summary

The Florida Department of Environmental Protection (DEP) performed a study to evaluate potential wastewater sources for 20 Florida lakes having histories of high concentrations of the wastewater indicator sucralose relative to statewide probabilistic surveys of Florida Lakes conducted in 2012, 2015 and 2017. The 20 lakes were resampled for the wastewater indicators sucralose, acesulfame potassium, acetaminophen, carbamazepine, and primidone during 2020. Of the 20 lakes resampled, sucralose was detected in all lakes, with the exception of lake Lenore, and at least one other wastewater indicator was detected in 13 of the 19 lakes having sucralose detections. While all wastewater indicator detections were relatively low, six lakes had sucralose values greater than 1 µg/L and had at least one other wastewater tracer detected: lakes Alice, Ann, Juniper, Sampson, Seminole and Little Lake Wilson. For context, a previous study done by the DEP Laboratory showed wastewater effluent values for sucralose ranged between 1 and 40 µg/L. Lake Juniper, Lake Sampson, and Little Lake Wilson had the highest densities of septic wastewater sources found within a 200-meter buffered area of the lake. All of these lakes had consistent detections of either, or combinations of, primidone, carbamazepine, and acesulfame potassium throughout 2020 further reinforcing the likely impact of wastewater to these lakes via surface and groundwater. Lake Alice has an effluent to reuse site and a wastewater treatment facility adjacent to the lake and within a 200-meter buffer and had detections of carbamazepine and sucralose.

Of the remaining 14 lakes, Lake Seminole, which is the largest lake included in this study and had a near shore sample location adjacent to septic wastewater sites, produced detections of sucralose, primidone and carbamazepine. Several lakes had lower wastewater source intensity and few or no detections of a wastewater indicators. Lake Lenore had no detections of the sucralose; whereas Lakes Apthorpe, Dot, and Myakka had at least one detection of sucralose and of one of the other wastewater indicators which typically signals wastewater impact. This may be due to sources located outside these buffered areas which are connected to rivers, streams, or canals feeding the lake or via groundwater base flows. In prior probabilistic surveys rivers and streams produced higher detection frequencies, and concentrations of acetaminophen, carbamazepine and primidone compared to the lake and confined groundwater resources sampled. While the presence of acetaminophen was not detected for lakes sampled in the prior probabilistic surveys, a resampling of Lake Dot, Lake George and Lake Jackson produced low level nanogram per liter (ng/L) detectable levels of acetaminophen, the one indicator which is effectively removed by conventional wastewater treatment.

Introduction and Study Design

The Florida Department of Environmental Protection conducts annual statewide probabilistic sample surveys of large and small lakes sampling as part of their Status Monitoring Network (FDEP 2020). Sucralose and other wastewater indicators were incorporated into these sample surveys during 2012, 2015, and 2017. A number of the sampled lakes showed detections of sucralose greater than 1 microgram per Liter (µg/L). As a frame of reference, measured detectable levels of sucralose in final effluent samples ranged from 1 to 40 µg/L in a DEP lab study of Florida domestic wastewater facility discharges. During 2020, 20 of the lakes (23 total site locations for lakes) providing previously measured sucralose concentrations > 0.5 µg/L were resampled for the wastewater indicators sucralose, acesulfame K, acetaminophen, carbamazepine, and primidone. These lakes include Lake Alice, Lake Amoret, Lake Ann, Lake Apthorpe, Buck Lake, Cherry Lake, Lake Dot, Lake George, Lake Hancock, Lake Harvey, Lake Jackson, Lake Juniper, Lake Leonore, Lake Myakka, Lake Sampson, Lake Seminole, Starvation Lake, Lake Weohyakapka, Lake Wimico, and Little Lake Wilson (Table 1).

Sucralose and acesulfame K (acesulfame potassium) are artificial sweeteners. Both sweeteners do not occur naturally, have low toxicity, are highly soluble and therefore mobile in water, have low sorption potential to soil and organic matter, have low bioaccumulation potential and persist in the environment with environmental half-lives of months (acesulfame K) to greater than a year (sucralose) (Belton et al. 2020, Oppenheimer et al. 2011; Tollefsen et al. 2012). Neither sweetener is effectively removed through standard wastewater treatment (Belton et al. 2020, Soh et al. 2011).

Acetaminophen, carbamazepine, and primidone are pharmaceuticals. Acetaminophen is an analgesic, while carbamazepine and primidone are anti-convulsant drugs. These pharmaceuticals have relatively short environmental half-lives in surface waters, days to perhaps as long as a few weeks. Half-lives for the sweeteners are months for acesulfame K and over a year for sucralose (Bu et al. 2016; Grice and Goldsmith 2000). Acetaminophen is effectively removed by standard wastewater treatment, whereas carbamazepine and primidone are not (Drewes et al. 2002; Kostich et al. 2014; Rounds et al. 2009).

Here we present a comparison of the results of the 2020 wastewater indicator sampling to known wastewater impacts found within one-mile and 200-meters of the boundaries of these lakes.

Methods

The field sampling protocols used for this study are identified in DEP's Surface Water Sampling Standard Operating Procedures document (FDEP, 2017). Samples were collected as either direct grabs into the sample container or using an intermediate collection device. All analyses were run at the DEP Jerry E. Brooks Environmental Laboratory in Tallahassee, Florida. High Performance Liquid Chromatography/Tandem Mass Spectrometer machinery utilizing either direct injection (sucralose and acesulfame K) or solid phase extraction (acetaminophen, carbamazepine, primidone) methods were used following US EPA method 8321B.

The locations of the wastewater treatment facilities, land application sites, effluent to reuse sites, and effluent to injection wells were loaded into an ArcGIS Pro project by incorporation of data from the Division of Water Resource Management's Wastewater Facility Regulation (WAFR) database and the septic system permits coverage from the Florida Department of Health (DOH) Onsite Sewage Treatment and Disposal System (OSTDS) database. The septic parcels layer from the Florida Water Management Inventory database managed by the DOH was also loaded into the project. Maps of each of the lakes with detected wastewater indicators and wastewater sources were created for visualization.. Mapping focused on those lakes having sucralose and additional wastewater tracer detections. Thirteen maps were produced showing 1) the site locations and number of water quality sample visits along with the maximum values and number of detections of any wastewater indicators which were detected, and 2) the densities of permitted septic tanks, locations of wastewater treatment facilities, land application sites, effluent to reuse, and effluent to injection wells within a mile buffered area of the boundary of each lake showing a sucralose detection over 0.5 µg/L and detections of at least one other wastewater indicator. An additional review included identifying rivers, streams, and canals within a one-mile buffer distance from the lake body and identifying parcels containing confirmed or likely septic sites within a 200-meter buffer distance from the lake body. This review was performed to help identify sources of wastewater entering the lake from surface and groundwaters. These maps are located in the Appendix following the text of this document.

Results and Discussion

Of the 20 lakes resampled in 2020, sucralose was detected at all sites, with the exception of lake Lenore, and at least one other wastewater indicator was detected at thirteen sites (Table 1, Figures 1 and 2). It should be noted that the detection limits for the pharmaceuticals and sucralose were one to two orders of magnitude lower than that for acesulfame K. For this study, the detection limits provided by the DEP lab for acesulfame K was 0.1 µg/L, whereas those for acetaminophen and carbamazepine were 0.0008 µg/L, primidone was 0.0004 µg/L, and sucralose was 0.01 µg/L. Sucralose detections ranged from 0.012 µg/L to 1.5 µg/L (Lake Alice). As a frame of reference, measured detectable levels of sucralose in final effluent samples ranged from 1 to 40 µg/L in a DEP lab study of Florida domestic wastewater facility discharges.

Of the thirteen lakes that had detections of wastewater indicators other than sucralose, eight of those lakes had detections of carbamazepine in concentration range of 0.0008 to 0.0035 µg/L (Lake Seminole). Five lakes had detections of Primidone in concentration range of 0.004 to 0.019 µg/L (Little Lake Wilson Center). Three lakes had acetaminophen detections ranging from 0.0086 µg/L to 0.2 µg/L (Lake George). Two lakes had acesulfame K detections ranging from 0.2 to 0.4 µg/L (Little Lake Wilson) and most of this parameter was detected at Little Lake Wilson.

For a frame of reference, sucralose, acetaminophen, carbamazepine, and primidone samples were collected during the 2015 Status Monitoring sample surveys of small and large lakes, canals, rivers, streams and unconfined and confined aquifers. The summary tables for sucralose and the pharmaceuticals as presented in Silvanima et al. 2018 are provided below as Tables 2 and 3. During the 2015 probabilistic study 168 lake sites were sampled. Eighteen of the 168 lake sites had detectable levels of carbamazepine, three lakes had detectable primidone, and none of them had detectable acetaminophen.

Table 1. Number of detections of wastewater indicators at lake sites, out of five visits per site in 2020. Empty cells indicate that the indicator was not detected. Numbers in parentheses indicate detections between the method detection limit and the practical quantitation limit ("I" qualified).

Lake Site	County	Acesulfame K #detections	Acetaminophen #detections	Carbamazepine #detections	Primidone #detections	Sucralose #detections
Lake Alice Center	Alachua			2 (2)		5
Lake Amoret	Polk					4
Lake Ann	Seminole			1 (1)		5
Lake Apthorpe	Highlands				2 (2)	4
Buck Lake	Highlands					1 (1)
Cherry Lake	Madison					4 (3)
Lake Dot	Orange		1 (1)	2 (2)		4
Lake George	Volusia		1			2
Lake Hancock	Polk			1 (1)	2 (2)	2
Lake Harvey	Hillsborough	1(1)				1
Lake Jackson Fords Arm	Leon		1 (1)			7 (1)
Lake Jackson Megginnis Arm Off Crowder Landing	Leon					8
Lake Jackson Megginnis Arm Off Fuller Rd Ramp	Leon					3 (1)
Lake Juniper	Walton			4 (4)	4 (4)	6
Lake Leonore	Polk					
Lake Myakka	Sarasota			1 (1)		4 (1)
Lake Sampson Center	Bradford			2 (2)		2

Lake Site	County	Acesulfame K #detections	Acetaminophe n #detections	Carbamazepine #detections	Primidone #detections	Sucralose #detections
Lake Sampson Near E Shore	Bradford			1 (1)		1
Lake Seminole	Jackson			1	1 (1)	1
Starvation Lake	Hillsborough					3
Lake Weohyakapka	Polk					3 (2)
Lake Wimico	Gulf					2
Little Lake Wilson	Hillsborough	6 (5)			6 (4)	6

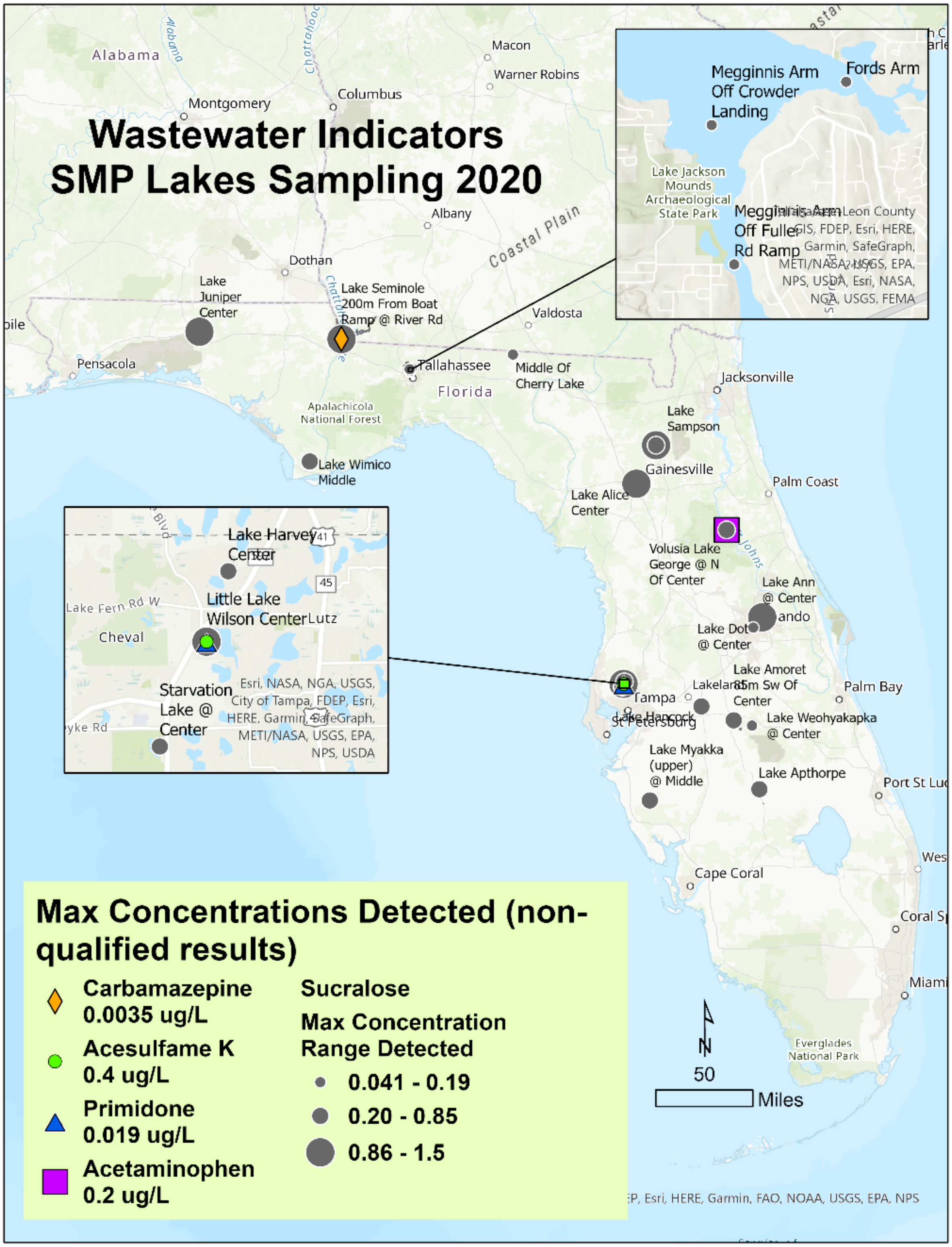

Figure 1. Locations of the lakes and the maximum concentrations of any wastewater indicators detected.

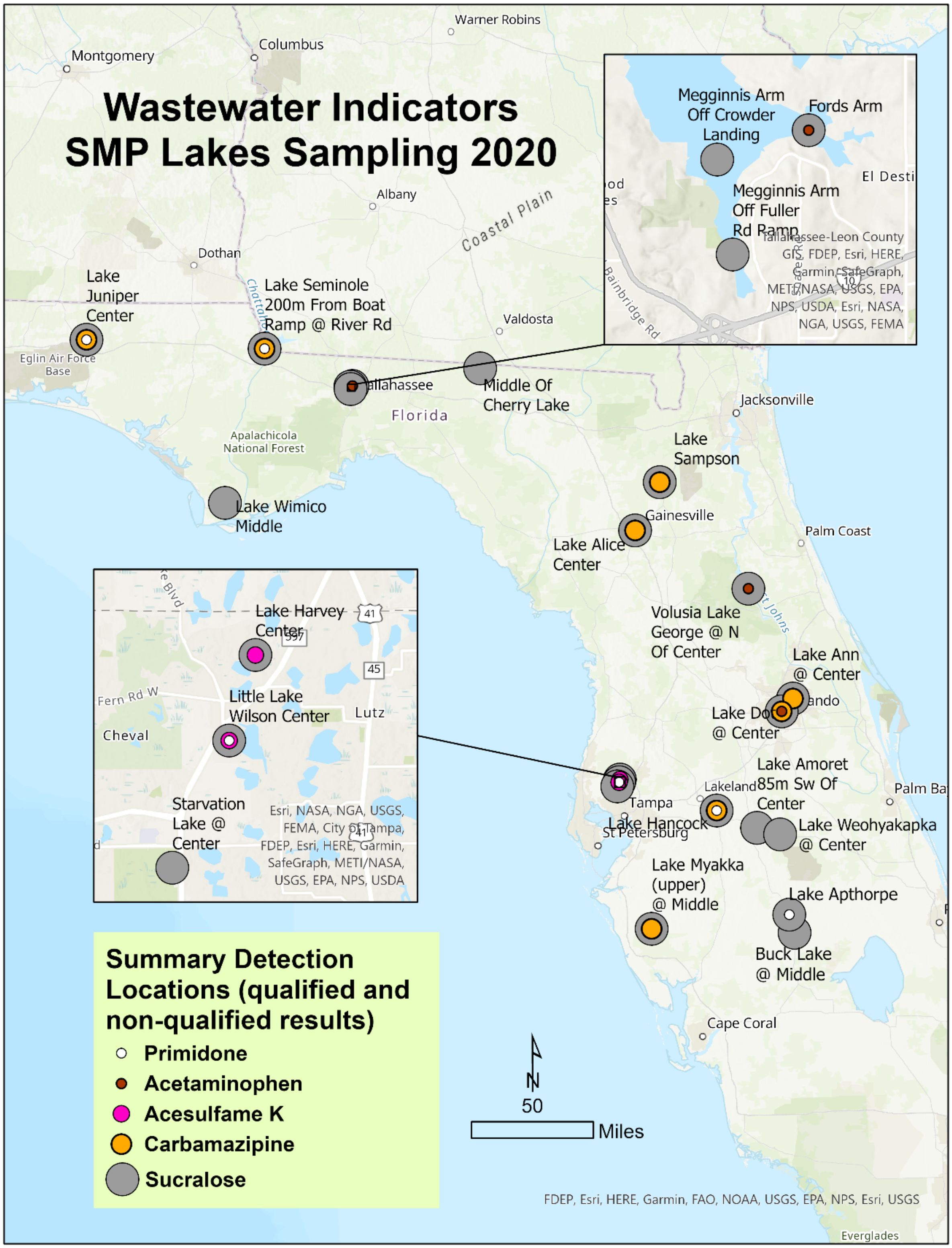

Figure 2. Locations of the lakes and the specific wastewater indicators detected at each lake.

Table 2. Sucralose Detections in the Status Monitoring Network (2015). Number and percentage of sites having detections, range of detected values, and number of sites having quantifiable values for each water resource and for all resources. [a] I = value detected but not quantifiable by the analysis method.

Resource	Sites Having Sucralose Detections	Total Sites Sampled	Percent Detected	Sucralose Concentration Range (µg/L)	Sites Having Quantified Values
Canal	35	60	58.3	0.014 I [a] – 1.7	25
Stream	53	90	60	0.012 I – 0.96	28
River	72	90	80	0.017 I – 27	54
Large lake	68	90	75.5	0.012 I – 1.4	53
Small lake	35	78	44.8	0.014 I – 1.4	20
Unconfined aquifers	28	120	23.3	0.012 I – 3.7	17
All Resources	292	528	55.3	0.012 I – 27	197

Table 3. Pharmaceutical Detections in the Status Monitoring Network (2015). Number and percentage of sites having detections, and range of detected values for each of the pharmaceuticals for each water resource and for all water resources, and the number sites having quantified values for each pharmaceutical for all resources. [a] I = value detected but not quantifiable by the analysis method. [b] na = not applicable.

Resource	Acetaminophen		Carbamazepine		Primidone	
	Sites Having Detections	Range (µg/L)	Sites Having Detections	Range (µg/L)	Sites Having Detections	Range (µg/L)
Canal	1 (1.7%)	0.003.1 I [a]	7 (11.7%)	0.0025 I – 0.024	2 (3.3%)	0.012 I – 0.026
Stream	5 (5.6%)	0.002 I – 0.0058 I	23 (25.6%)	0.00044 I – 0.022	0	na [b]
River	3 (3.3%)	0.0021 I – 0.011	25 (27.8%)	0.00042 I – 0.068	3 (3.3%)	0.0084 I – 0.088
Large lake	0	na	11 (12.2%)	0.0022 I – 0.019	2 (2.2%)	0.0058 I – 0.0061
Small lake	0	na	7 (9.0%)	0.00049 I – 0.0029	1 (1.3%)	0.030 I
Unconfined aquifers	0	na	9 (7.5%)	0.0007 I – 0.0092	3 (2.5%)	0.0097 I – 0.021 I

Resource	Acetaminophen		Carbamazepine		Primidone	
	Sites Having Detections	Range (µg/L)	Sites Having Detections	Range (µg/L)	Sites Having Detections	Range (µg/L)
All Resources	9 (1.7%)	0.0020 I – 0.011	82 (15.5%)	0.00042 I – 0.068	11 (2.1%)	0.0058 I – 0.088
Quantified Values	1 (< 0.5%)	0.011	22 (4.2%)	0.002 – 0.068	2 (0.4%)	0.026 – 0.088

Wastewater sources at the thirteen lakes evaluated within a one-mile buffered region from the boundary of the lakes consisted of low septic permit intensity (Lake Alice, Lake Apthorpe, Lake Dot, Lake Myakka, Lake Seminole, and Lake Sampson) to high septic permit intensity coverages surrounding the lake body (Lake George, Little Lake Wilson and Lake Juniper). Little Lake Wilson and Lake Juniper had higher frequency of carbamazepine and primidone detections. Lakes with potential sources of wastewater inputs in addition to septic systems identified within the one-mile buffered zone around the lakes included Lake Alice (effluent to reuse, land application, effluent to injection well location, and two wastewater treatment facilities [WWTFs]), Lake George (effluent to injection well location and one WWTF), Lake Seminole (effluent to injection well location, land application site, and one WWTF facility with an outfall found just outside the buffered area for the lake) and Lake Hancock (one effluent to reuse facility). Lake Dot is in a primarily urban setting in Orlando, Florida and was found in the lowest intensity area for septic use; however it had acetaminophen and carbamazepine detections. No additional wastewater sources were found in this review for Lake Dot. This lake is contrasted with Lake Jackson, a much larger lake in a medium to light residential setting, which had a high intensity of permitted septic tank coverage. Lake Jackson had an acetaminophen detection but did not have any carbamazepine detected during the sampling events at the lake. Lake Juniper had high septic use intensity and effluent to reuse nearby the lake body. This lake had both primidone and carbamazepine detections.

The higher concentration of acetaminophen detected in Lake George may be related to increased throughput due its receiving water from the St. Johns River. Pine Island WWTF does have a nearby effluent to injection well located at the boundary of the lake. Injection wells are Class I wells typically at greater depths than the lake bodies near them and therefore unlikely to be a direct source of wastewater input to the lake. Reuse areas however do consist of areas such as rapid infiltration ponds, golf courses, residential irrigation, or others where the effluent is sprayed with direct contact to the ground. Lakes that were impacted by wastewater indicators other than sucralose and had at least one reuse or land application facility within the one-mile buffered area of the lake are Lake Alice, Lake Hancock, Lake Juniper, Lake George, Little Lake Wilson, and Lake Seminole.

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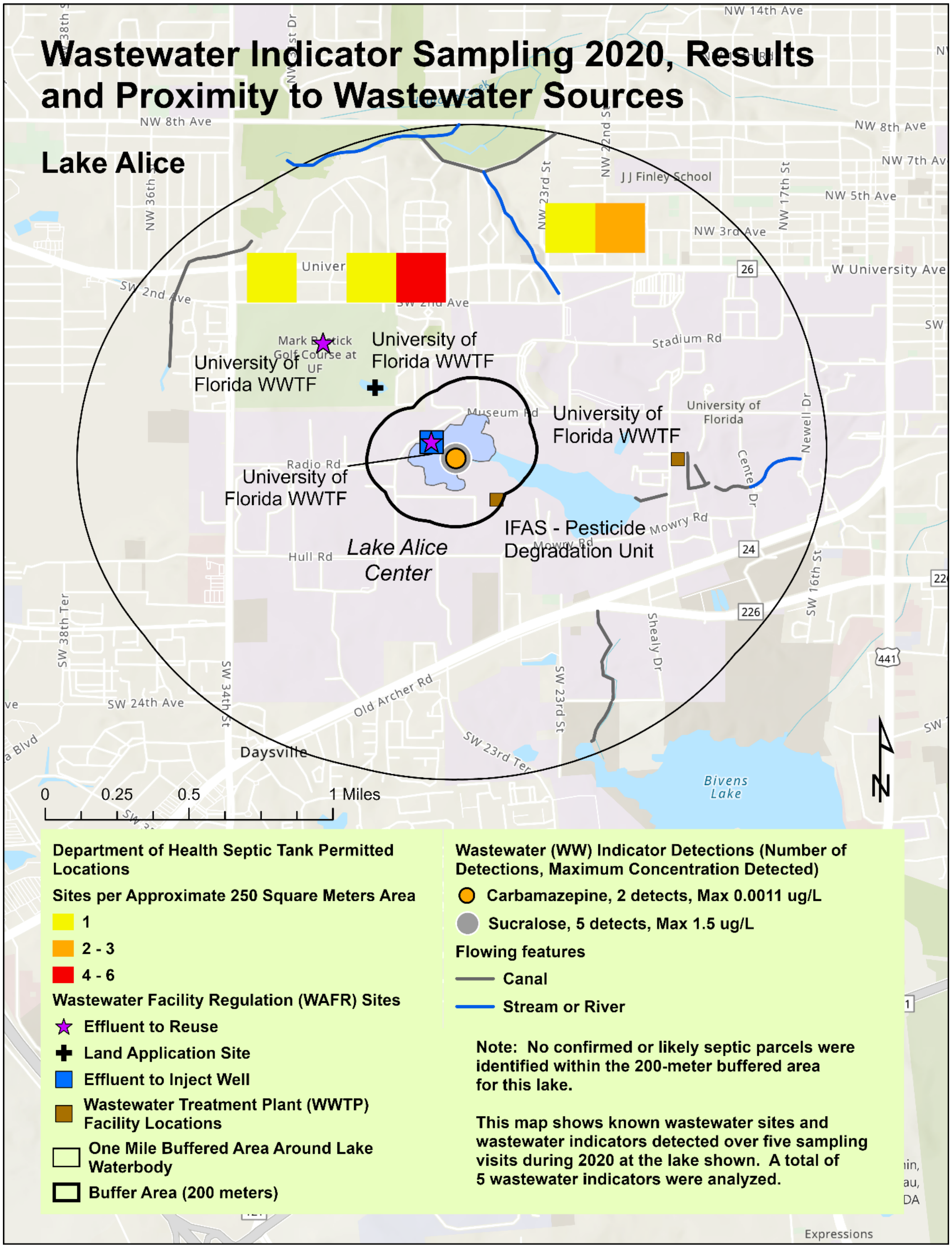
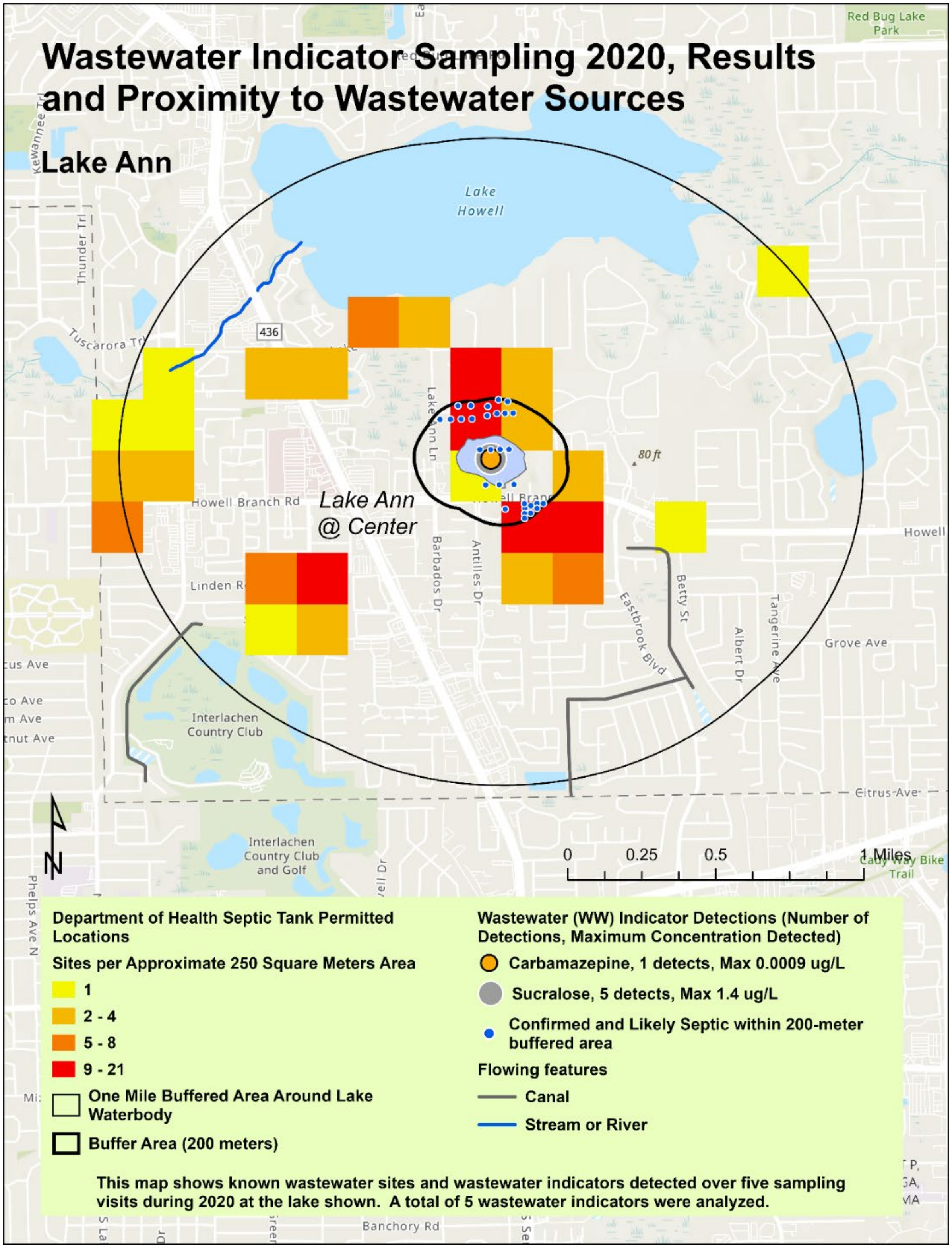
Appendix of Maps. Lakes listed in Alphabetical Order.

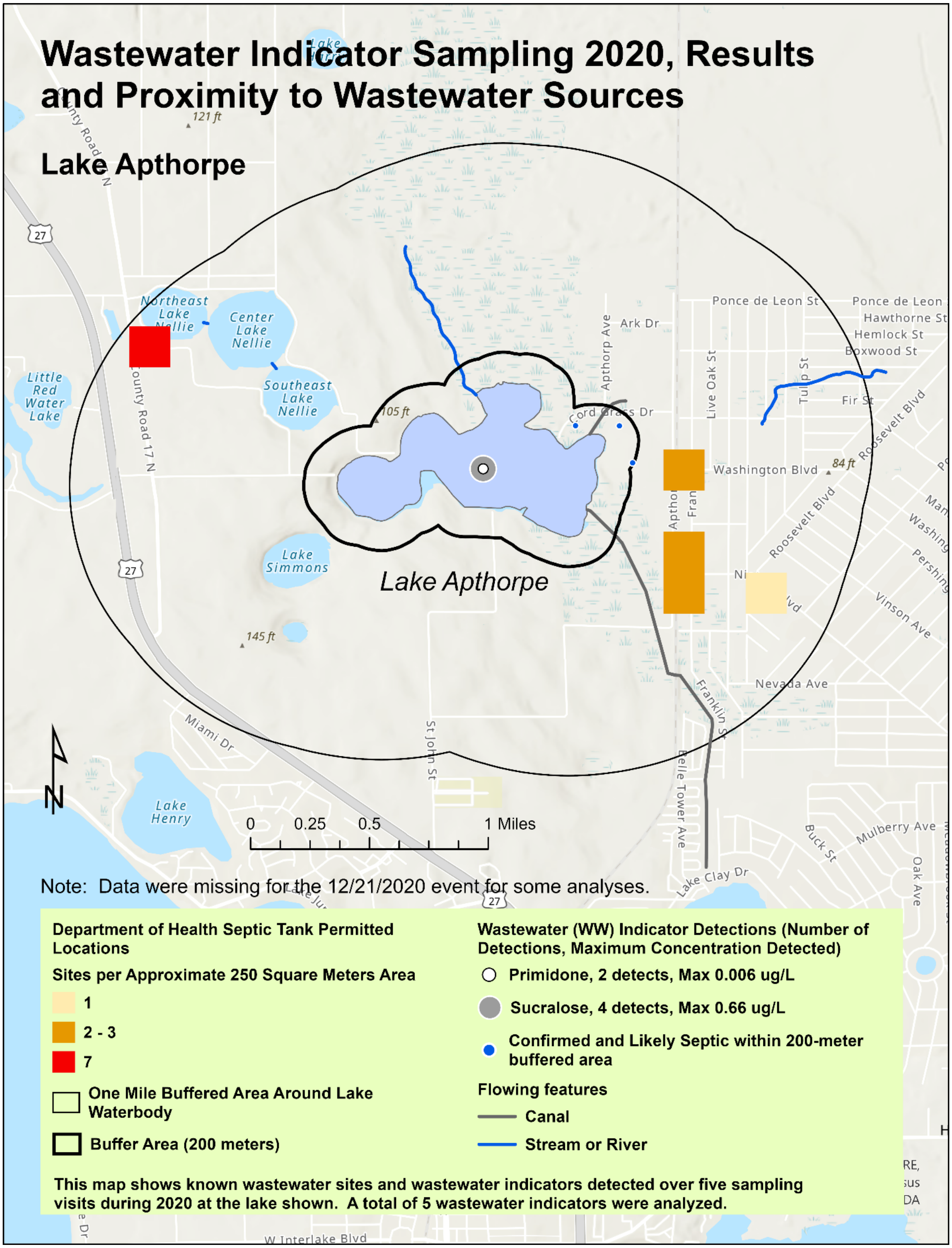
Lake Alice



Lake Ann


Wastewater Indicator Sampling 2020, Results and Proximity to Wastewater Sources
Lake Ann
Lake Howell
Lake Ann @ Center
Howell Branch Rd
Interlachen Country Club
Interlachen Country Club and Golf
0 0.25 0.5 1 Miles
N
Department of Health Septic Tank Permitted Locations
Sites per Approximate 250 Square Meters Area
1
2 - 4
5 - 8
9 - 21
One Mile Buffered Area Around Lake Waterbody
Buffer Area (200 meters)
Wastewater (WW) Indicator Detections (Number of Detections, Maximum Concentration Detected)
Carbamazepine, 1 detects, Max 0.0009 ug/L
Sucralose, 5 detects, Max 1.4 ug/L
Confirmed and Likely Septic within 200-meter buffered area
Flowing features
Canal
Stream or River
This map shows known wastewater sites and wastewater indicators detected over five sampling visits during 2020 at the lake shown. A total of 5 wastewater indicators were analyzed.

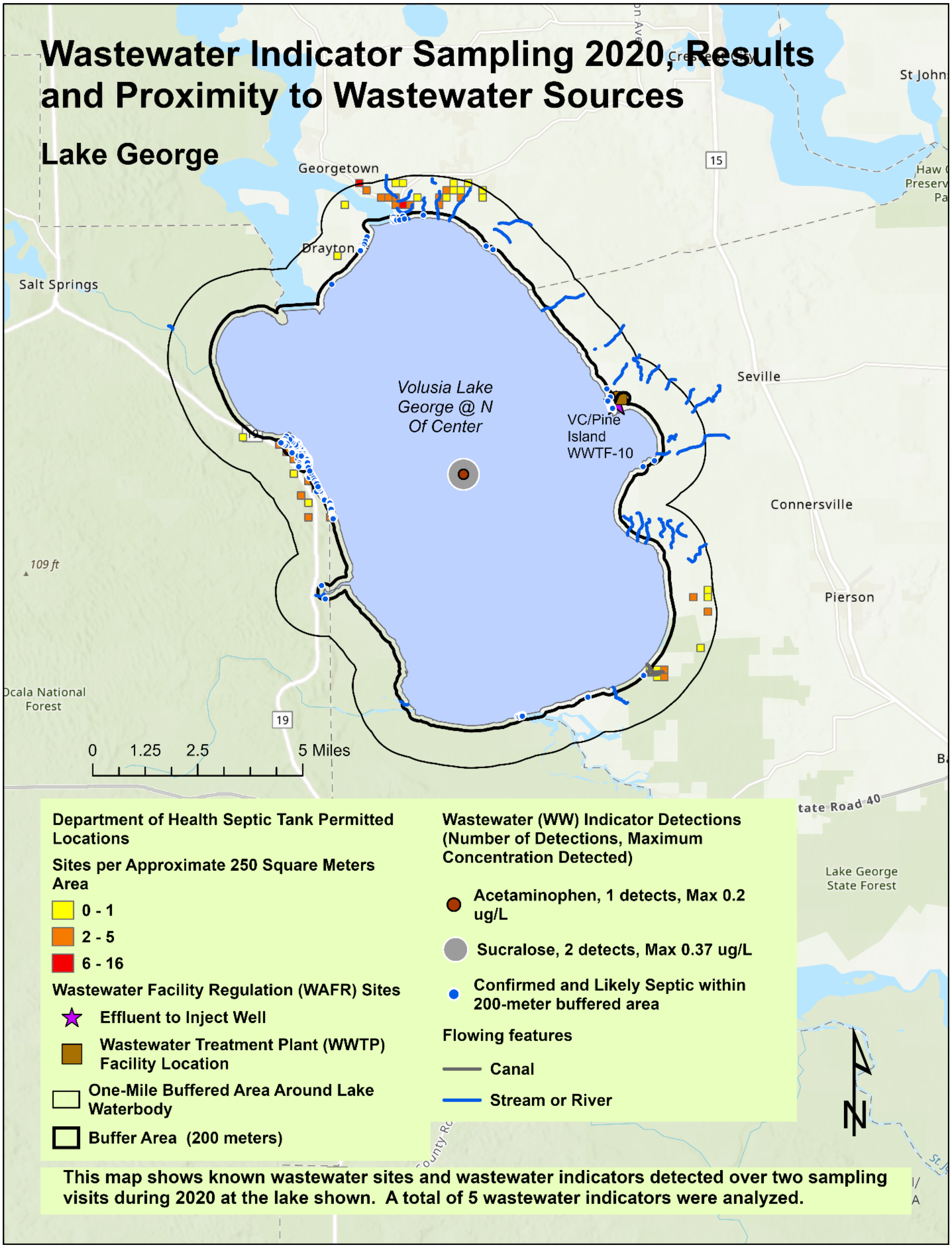
Lake Apthorpe



Lake Dot

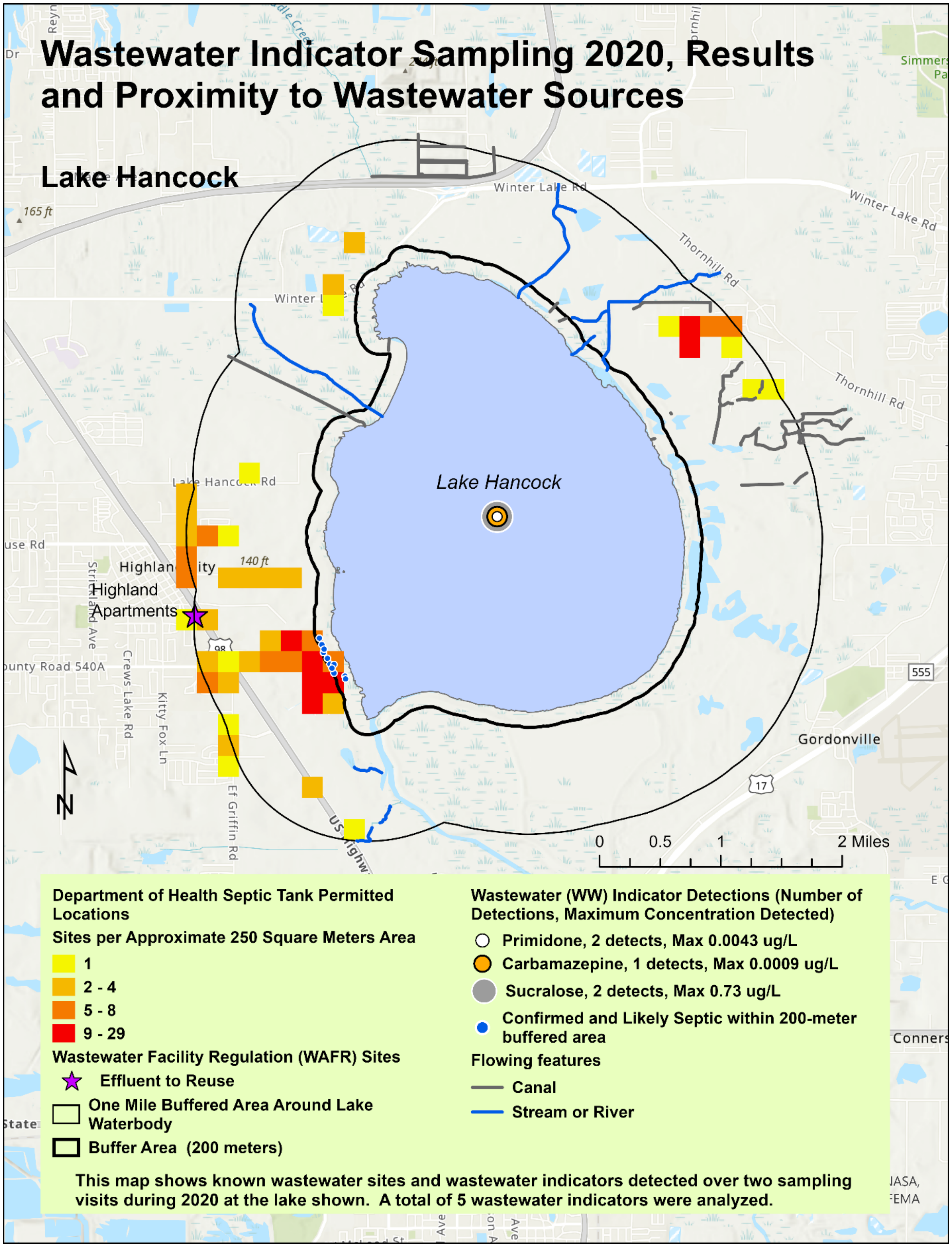

Wastewater Indicator Sampling 2020, Results and Proximity to Wastewater Sources
Lake Dot
Lake Dot @ Center
Lake Ivanhoe Park
Lake Ivanhoe
Mark O'mera Family Sports Complex
Lake Formosa
Lake Highland
Lake Adair Park
Spring Lake
Lake Concord
Country Club of Orlando
Rock Lake
Lake Eola Park
Orlando
0
0.5
1 Miles
Department of Health Septic Tank Permitted Locations
Sites per Approximate 250 Square Meters Area
1
2
One Mile Buffered Area Around Lake Waterbody
Buffer Area 200m
Wastewater (WW) Indicator Detections (Number of Detections, Maximum Concentration Detected)
Acetaminophen, 1 detects, Max 0.02 ug/L
Carbamazepine, 2 detects, Max 0.0013 ug/L
Sucralose, 4 detects, Max 0.15 ug/L
Flowing features
Canal
Stream or River
Note: No confirmed or likely septic parcels were identified within the 200-meter buffered area for this lake.
This map shows known wastewater sites and wastewater indicators detected over four sampling visits during 2020 at the lake shown. A total of 5 wastewater indicators were analyzed.

Lake George

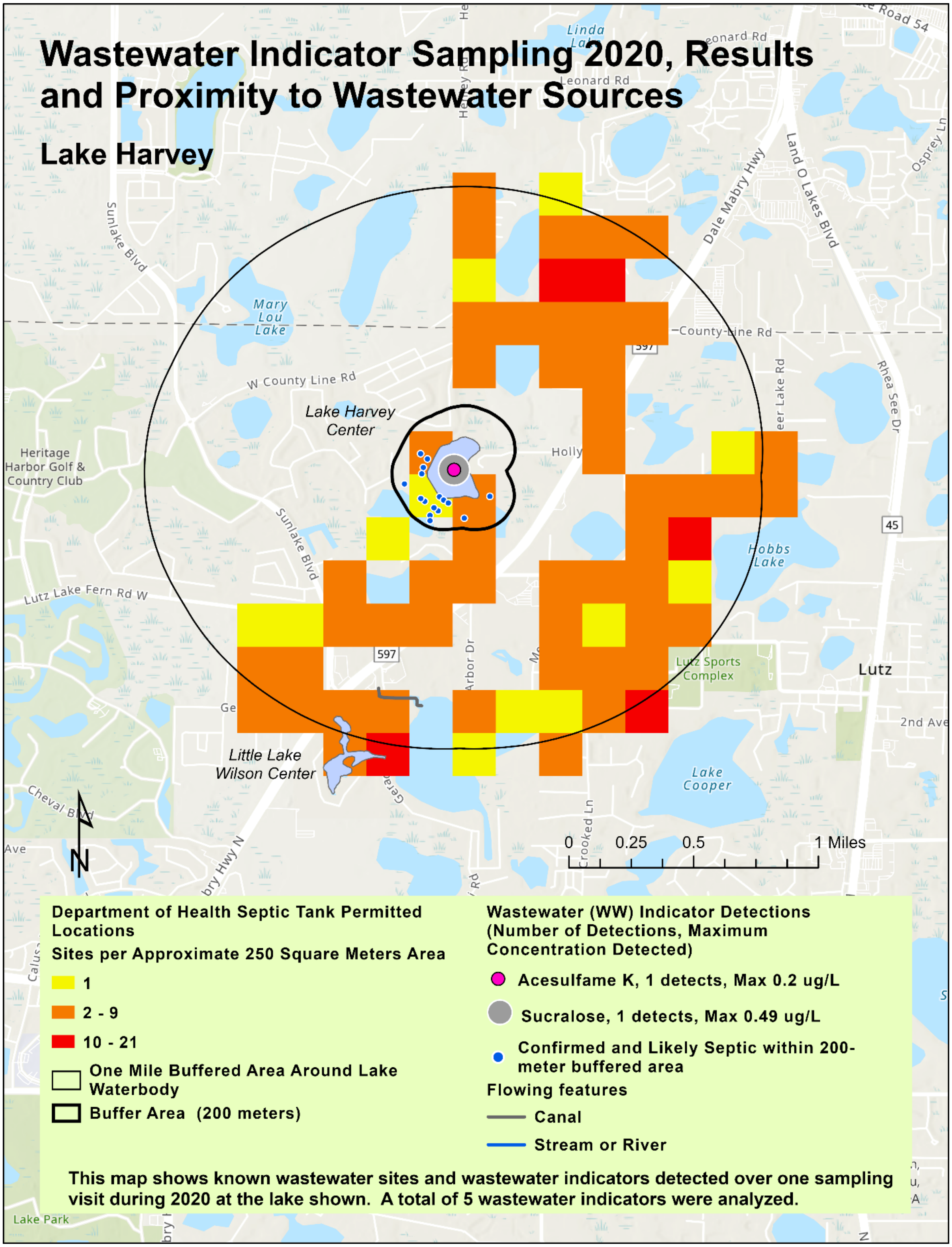


Wastewater Indicator Sampling 2020, Results and Proximity to Wastewater Sources
Lake George
Georgetown
Crescent City
St Johns
Drayton
Salt Springs
Seville
Connersville
Pierson
Volusia Lake George @ N Of Center
VC/Pine Island WWTF-10
Ocala National Forest
Lake George State Forest
State Road 40
109 ft
15
19
0
1.25
2.5
5 Miles
Department of Health Septic Tank Permitted Locations
Sites per Approximate 250 Square Meters Area
0 - 1
2 - 5
6 - 16
Wastewater Facility Regulation (WAFR) Sites
Effluent to Inject Well
Wastewater Treatment Plant (WWTP) Facility Location
One-Mile Buffered Area Around Lake Waterbody
Buffer Area (200 meters)
Wastewater (WW) Indicator Detections (Number of Detections, Maximum Concentration Detected)
Acetaminophen, 1 detects, Max 0.2 ug/L
Sucralose, 2 detects, Max 0.37 ug/L
Confirmed and Likely Septic within 200-meter buffered area
Flowing features
Canal
Stream or River
N
This map shows known wastewater sites and wastewater indicators detected over two sampling visits during 2020 at the lake shown. A total of 5 wastewater indicators were analyzed.

Lake Hancock

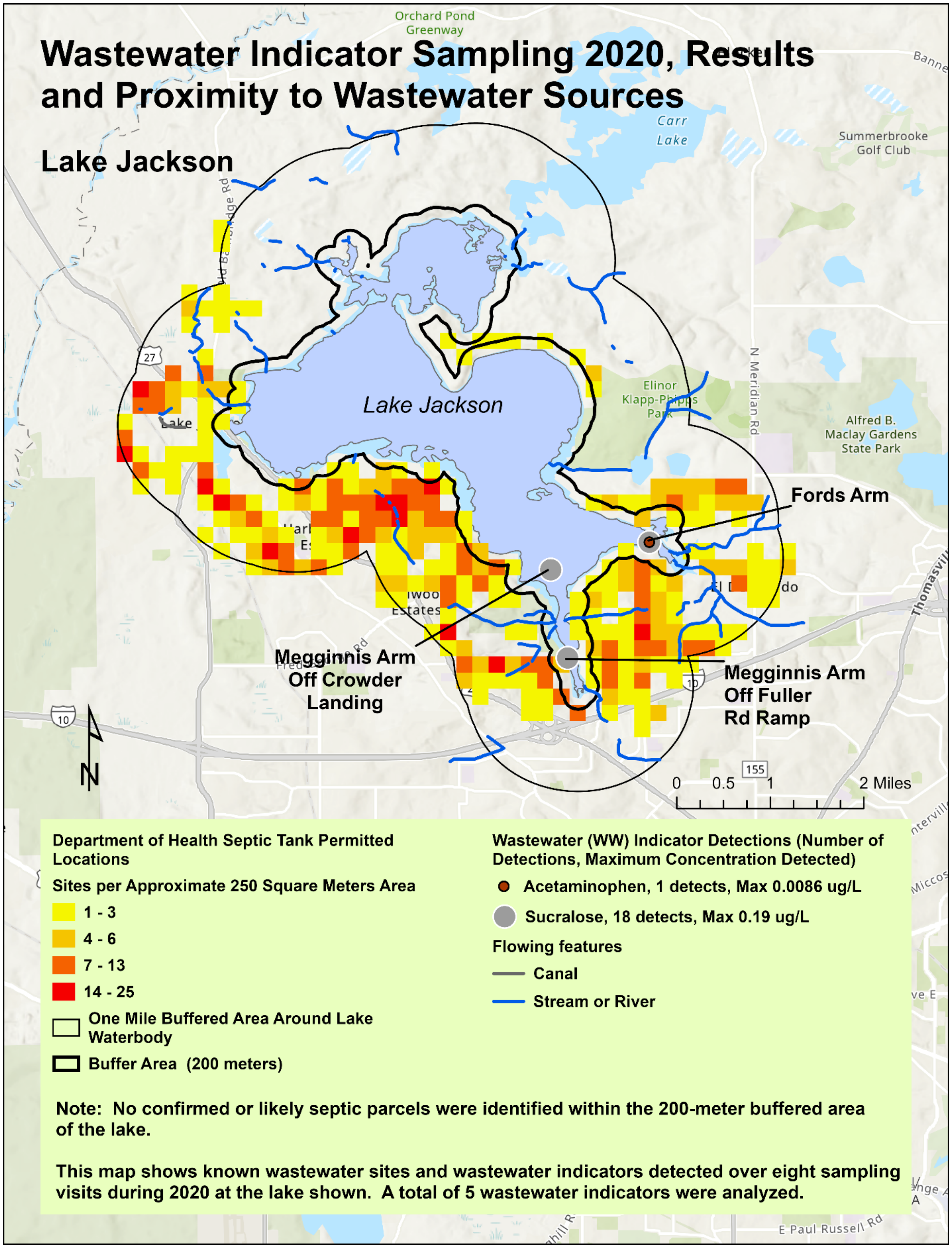


Lake Harvey

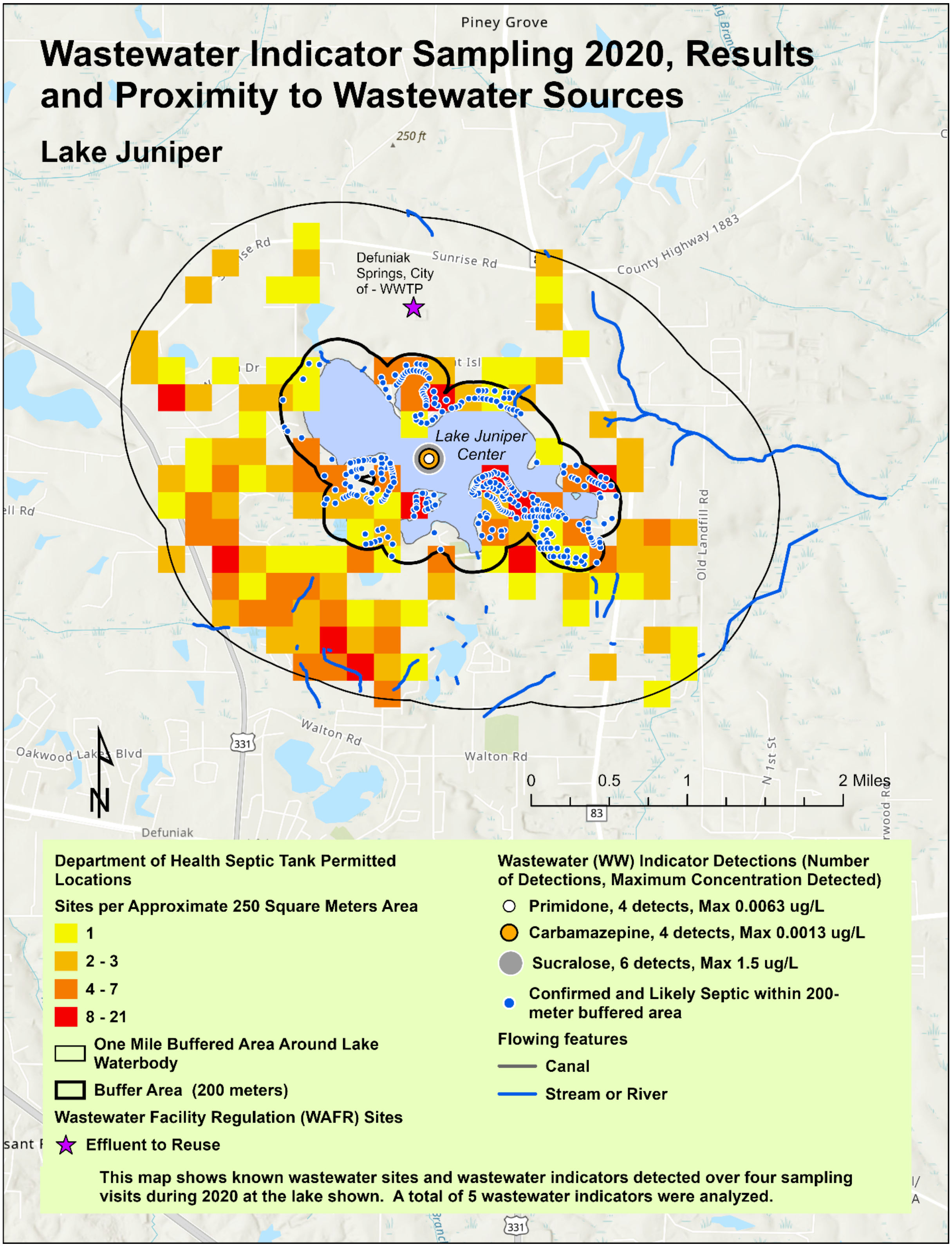


Wastewater Indicator Sampling 2020, Results and Proximity to Wastewater Sources
Lake Harvey
Lake Harvey Center
Little Lake Wilson Center
Mary Lou Lake
Hobbs Lake
Lake Cooper
Lutz
Lutz Sports Complex
Heritage Harbor Golf & Country Club
County Line Rd
W County Line Rd
Lutz Lake Fern Rd W
Sunlake Blvd
Dale Mabry Hwy
Land O Lakes Blvd
Leonard Rd
Rhea See Dr
2nd Ave
597
45
0 0.25 0.5 1 Miles
N
Department of Health Septic Tank Permitted Locations
Sites per Approximate 250 Square Meters Area
1
2 - 9
10 - 21
One Mile Buffered Area Around Lake Waterbody
Buffer Area (200 meters)
Wastewater (WW) Indicator Detections (Number of Detections, Maximum Concentration Detected)
Acesulfame K, 1 detects, Max 0.2 ug/L
Sucralose, 1 detects, Max 0.49 ug/L
Confirmed and Likely Septic within 200-meter buffered area
Flowing features
Canal
Stream or River
This map shows known wastewater sites and wastewater indicators detected over one sampling visit during 2020 at the lake shown. A total of 5 wastewater indicators were analyzed.

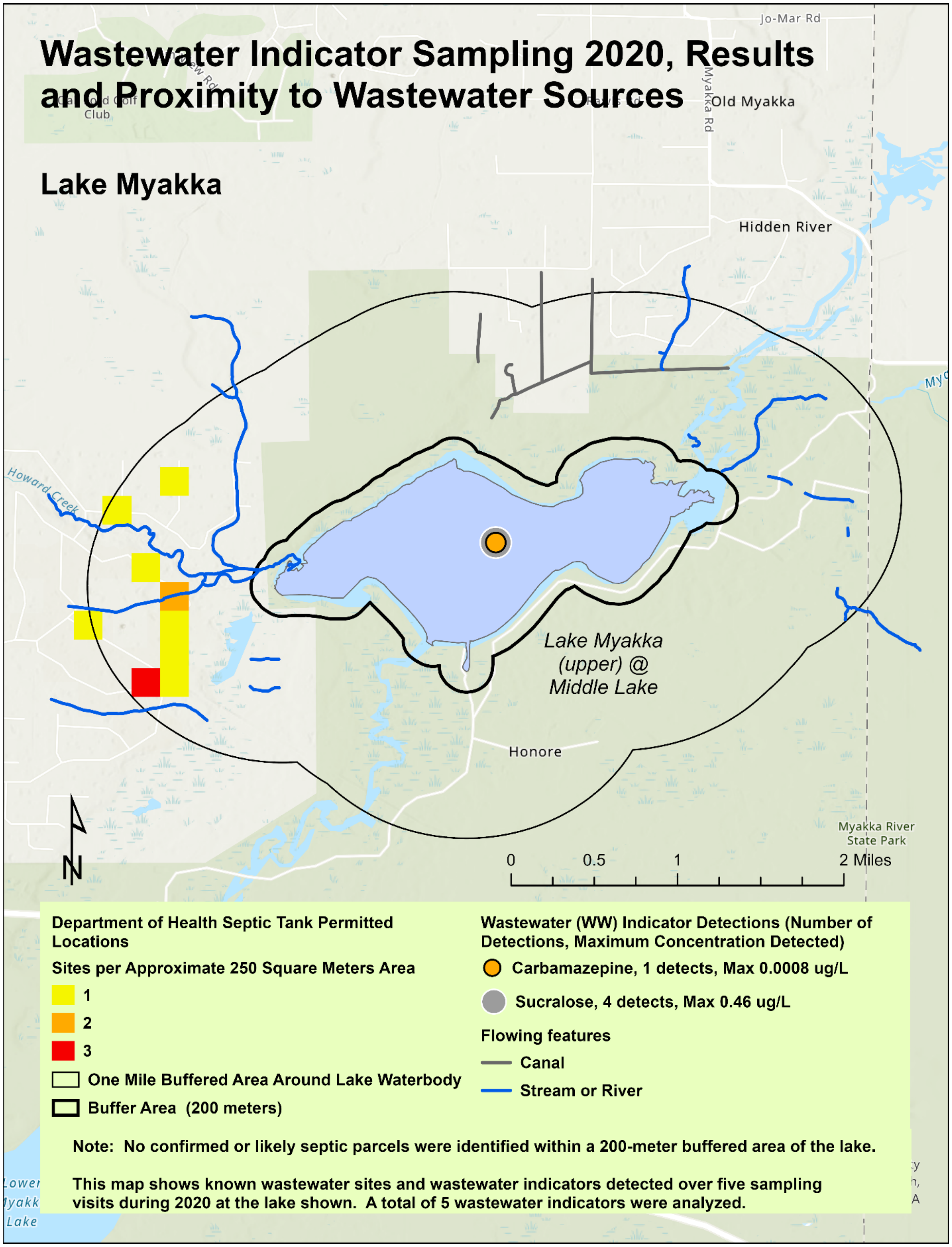
Lake Jackson



Lake Juniper

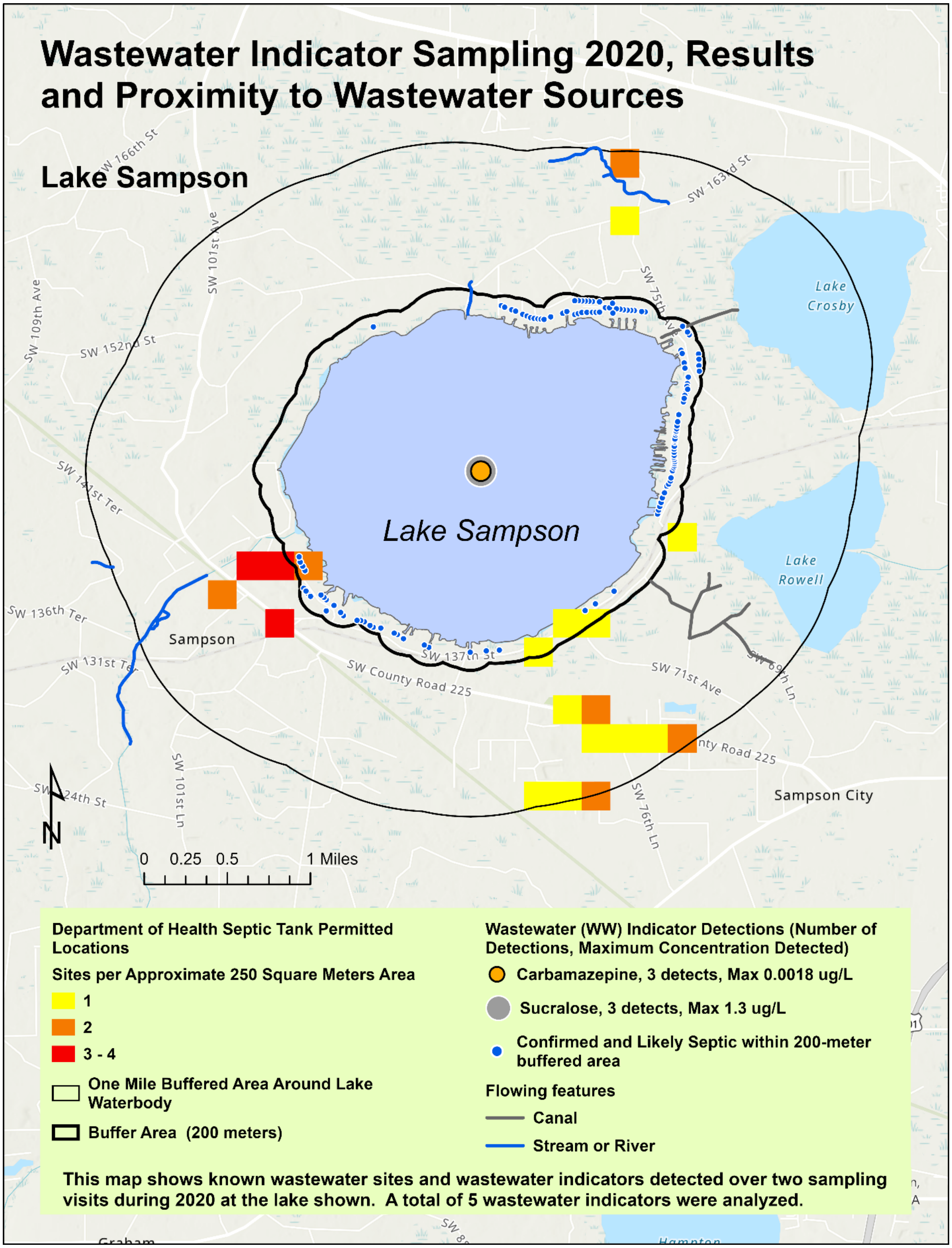


Lake Myakka

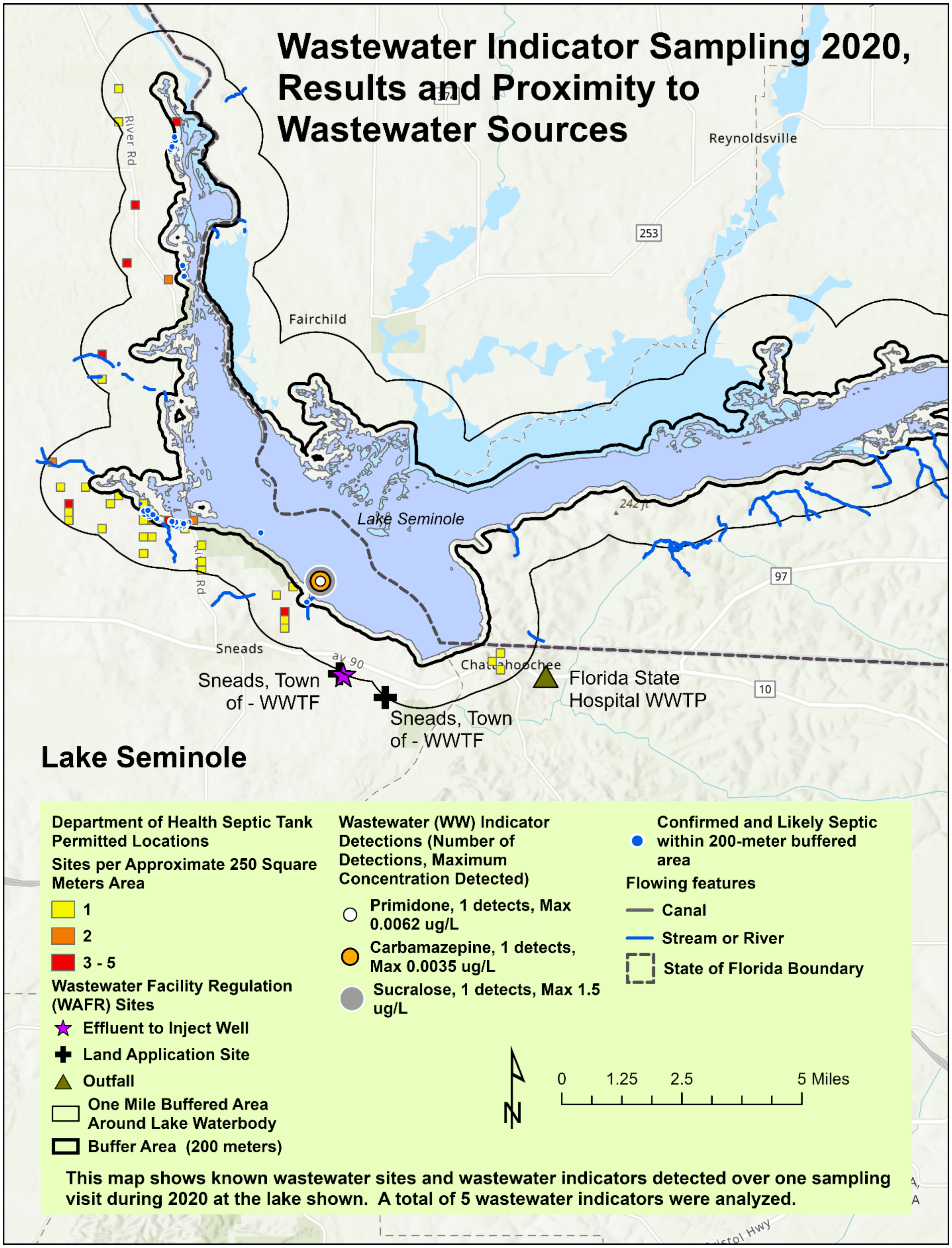


Wastewater Indicator Sampling 2020, Results and Proximity to Wastewater Sources
Lake Myakka
Jo-Mar Rd
Myakka Rd
Old Myakka
Club
Hidden River
Howard Creek
Lake Myakka (upper) @ Middle Lake
Honore
Myakka River State Park
0
0.5
1
2 Miles
N
Department of Health Septic Tank Permitted Locations
Sites per Approximate 250 Square Meters Area
1
2
3
One Mile Buffered Area Around Lake Waterbody
Buffer Area (200 meters)
Wastewater (WW) Indicator Detections (Number of Detections, Maximum Concentration Detected)
Carbamazepine, 1 detects, Max 0.0008 ug/L
Sucralose, 4 detects, Max 0.46 ug/L
Flowing features
Canal
Stream or River
Note: No confirmed or likely septic parcels were identified within a 200-meter buffered area of the lake.
This map shows known wastewater sites and wastewater indicators detected over five sampling visits during 2020 at the lake shown. A total of 5 wastewater indicators were analyzed.

Lake Sampson



Lake Seminole



Little Lake Wilson