Final Post-Treatment Assessment for Aquatic Plant Control ERDC Demonstration Project Tonawanda Creek/Erie Canal 2018

Contract No. W912P4-16-D-0002

January 2019

US Army Corps of Engineers®
Buffalo District
BUILDING STRONG®

Prepared for:

UNITED STATES ARMY CORPS OF ENGINEERS
Buffalo District

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List of Abbreviations and Acronyms

Canal Corp.	New York State Canal Corporation
cfs	cubic feet per second
E & E	Ecology and Environment, Inc.
ERDC	Engineer Research and Development Center
ft/s	feet per second
GPS	Global Positioning System
Hydrilla	*Hydrilla verticillata*
NYPA	New York Power Authority
NYSDEC	New York State Department of Environmental Conservation
ppm	parts per million
Project	Tonawanda Creek/Erie Canal Hydrilla Demonstration Project
RM	river mile
SLM	SOLitude Lake Management, LLC
USACE	U.S. Army Corps of Engineers (Buffalo District)
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

1 Introduction

The Tonawanda Creek/Erie Canal[1] Hydrilla Demonstration Project (the Project) is a field-scale demonstration of a technology developed under the U.S. Army Corps of Engineers – Buffalo District's (USACE's) Aquatic Plant Control Research Program to manage monoecious hydrilla (*Hydrilla verticillata;* Hydrilla) in a flowing water system.

This report contributes to the Year 5 post-treatment monitoring and assessment of herbicide efficacy on Hydrilla by summarizing field conditions before, during, and after the treatment; summarizing herbicide treatment methodology and contact time; and identifying lessons learned to benefit future work.

1.1 Background

Hydrilla is a very aggressive, submerged aquatic plant. The U.S. Fish and Wildlife Service (USFWS) first discovered this invasive plant in the Tonawanda Creek section of the Erie Canal in September 2012. Hydrilla infestations have been documented from just upstream of the creek/canal's outlet at the Niagara River, in the cities of North Tonawanda and Tonawanda, and upstream to the Lockport area, approximately 15 miles to the east. Hydrilla was identified within a total area of approximately 359 acres when initially discovered, and USACE determined Hydrilla frequency to be at 31% in July 2014, prior to the initial large-scale herbicide application. Hydrilla beds were patchy and limited to the shallow shoreline areas outside of the main navigation channel. Based on USACE surveys of over 2,000 points within the canal conducted in 2015, 2016, and 2017, Hydrilla frequency was less than 1%.

There is significant concern regarding the potential spread of Hydrilla to other areas of New York State and the Great Lakes as a whole. Hydrilla could spread because fragments of Hydrilla within the creek/canal are easily transported via waterflow, the creek/canal is located directly adjacent to the Niagara River, and the canal has heavy boat traffic. These concerns provided the impetus for implementation of the Project.

This year, to control and eradicate Hydrilla, the USACE conducted a fifth year of treatment for the Project within an approximately 15-mile-long stretch of creek/canal that focused on application of the aquatic herbicide endothall

[1] The Erie Canal and Tonawanda Creek are separate waterbodies until they merge in Pendleton, New York, just downstream of the East Canal Road/New Road bridge. From the confluence, the canal then follows the modified former channel of Tonawanda Creek. This document refers to this channel as the creek/canal.

(Aquathol K™) and spot treatment with chelated copper (Komeen Crystal™) (see Figure 1-1). Prior to treatment application, Hydrilla populations were delineated and mapped by the USACE using point-intercept and hydro-acoustic surveys. The 2018 endothall treatment areas were designated as follows:

- **Western block treatment areas**: 3.8 miles between the Seymour Street Bridge in Tonawanda, New York, to the North Tonawanda Botanical Gardens in North Tonawanda, New York (Botanical Gardens). Of this area, 57 acres were directly treated with endothall and the remaining areas received secondary treatment from flow in the creek/canal; and
- **Eastern block treatment areas**: 8 miles between West Canal Park and the Pendleton Guard Gate in Pendleton, New York. This area received secondary treatment from flow in the canal.

The western block contains the majority of the Hydrilla beds, thus it continued to receive the majority of the direct herbicide application in Year 5.

Additionally, for the first time as part of the Year 5 treatment plan, spot treatment with chelated copper occurred in various locations within the 15-mile stretch to control small, persistent beds of Hydrilla (see Figure 1-1).

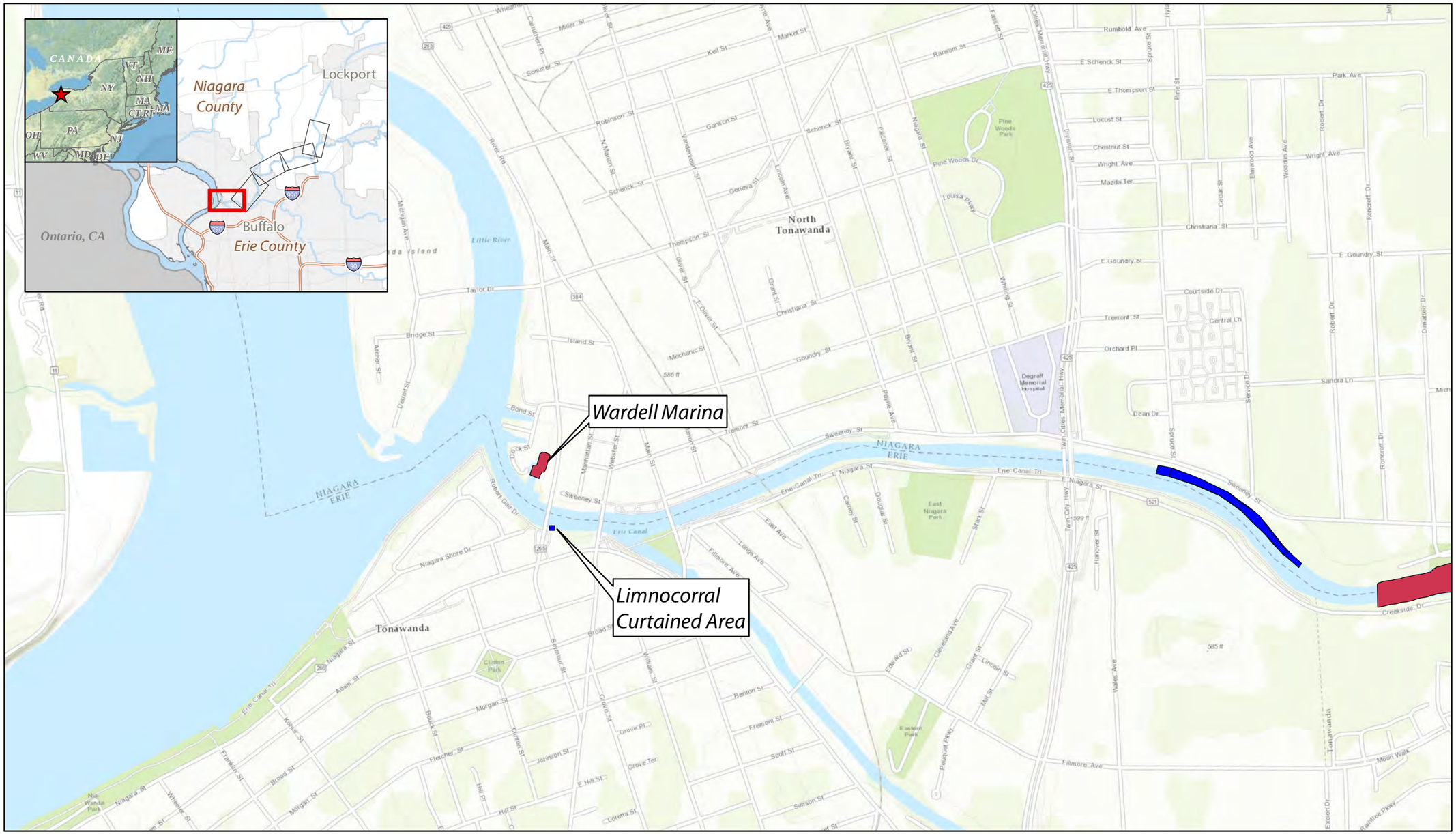
Implementation of the Project was a collaborative effort between the Engineer Research and Development Center (ERDC); USACE; Ecology and Environment, Inc. (E & E); New York State Canal Corporation (Canal Corp.); New York State Department of Environmental Conservation (NYSDEC); USFWS; and the applicator, SOLitude Lake Management, LLC (SLM).

1.2 Purpose and Scope

The purpose of the Project is to develop and implement selective control methods to manage Hydrilla in a flowing water system, while limiting impacts on native vegetation. Prior to the Year 1 implementation of the Project in 2014, management of monoecious Hydrilla using an aquatic herbicide in a flowing water system had not been tested. Therefore, the results of this continued field-scale Project will provide valuable information for developing future guidance on how to manage this species in other flowing water systems throughout the northeastern United States. In addition, this Project evaluates herbicide efficacy on a delineated stretch of Tonawanda Creek where Hydrilla is more problematic.

The ERDC will use the findings in this report to support continued post-treatment monitoring to determine the success of each successive treatment program. Post-treatment monitoring will also be used to determine whether additional creek/canal treatments will be needed in the future, and the most effective way to remove small satellite populations that survive treatment or re-sprout from the bank of subsurface tubers.

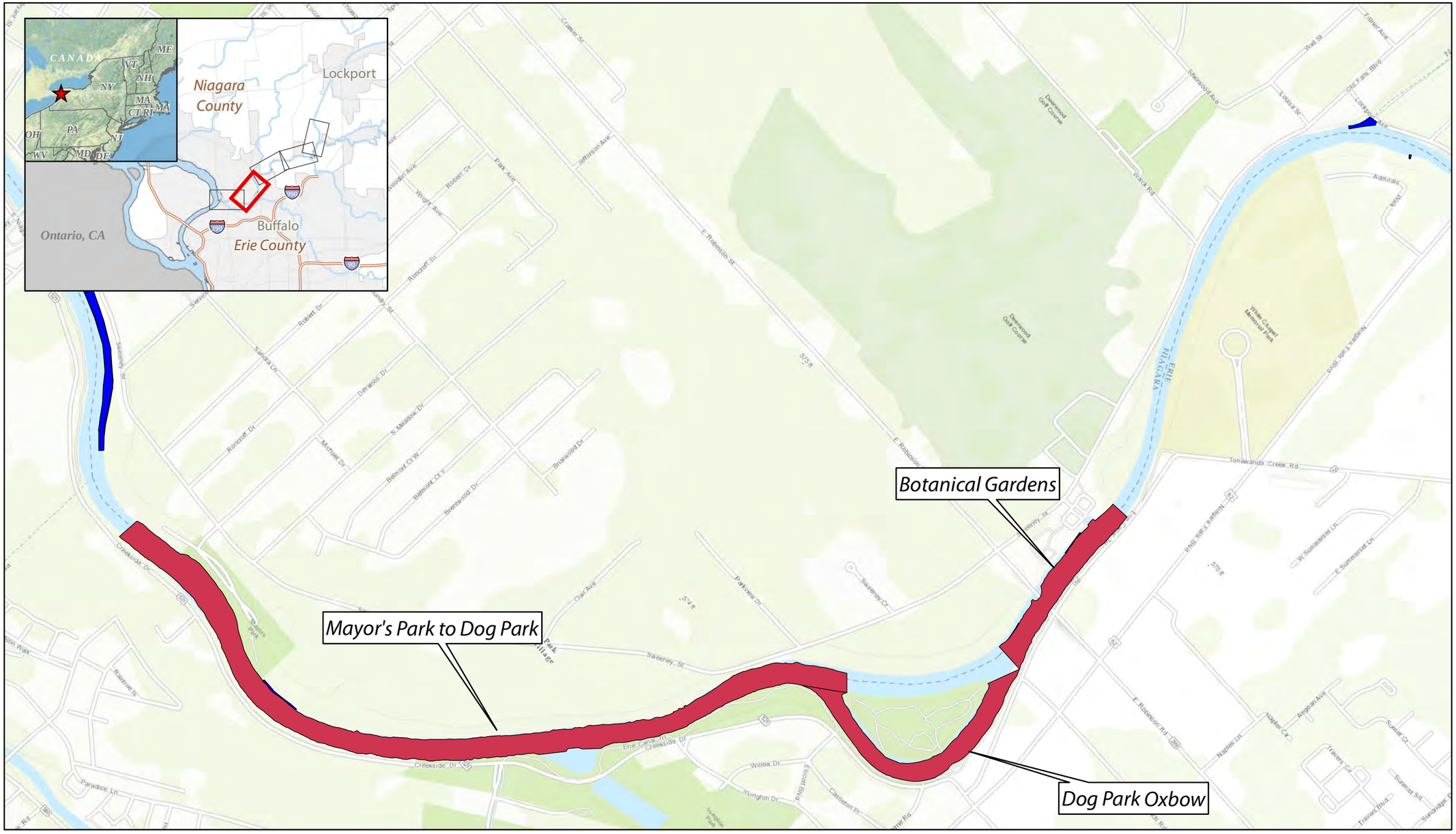
This post-treatment report includes a summary of the herbicide treatment methodology, including quantity of herbicides used and total acreage treated; a discussion of herbicide contact time and dispersion through the system; and a discussion of the flow management and monitoring that accompanied the herbicide application. Lastly, conclusions are provided, in the form of lessons learned, to help shape future treatment projects.



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 1-1a Hydrilla Treatment Areas for Summer 2018 in Tonawanda Creek/Erie Canal - Endothall and Copper Treatments

Tonawanda Creek, Erie and Niagara Counties, New York



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 1-1b Hydrilla Treatment Areas for Summer 2018 in Tonawanda Creek/Erie Canal - Endothall and Copper Treatments

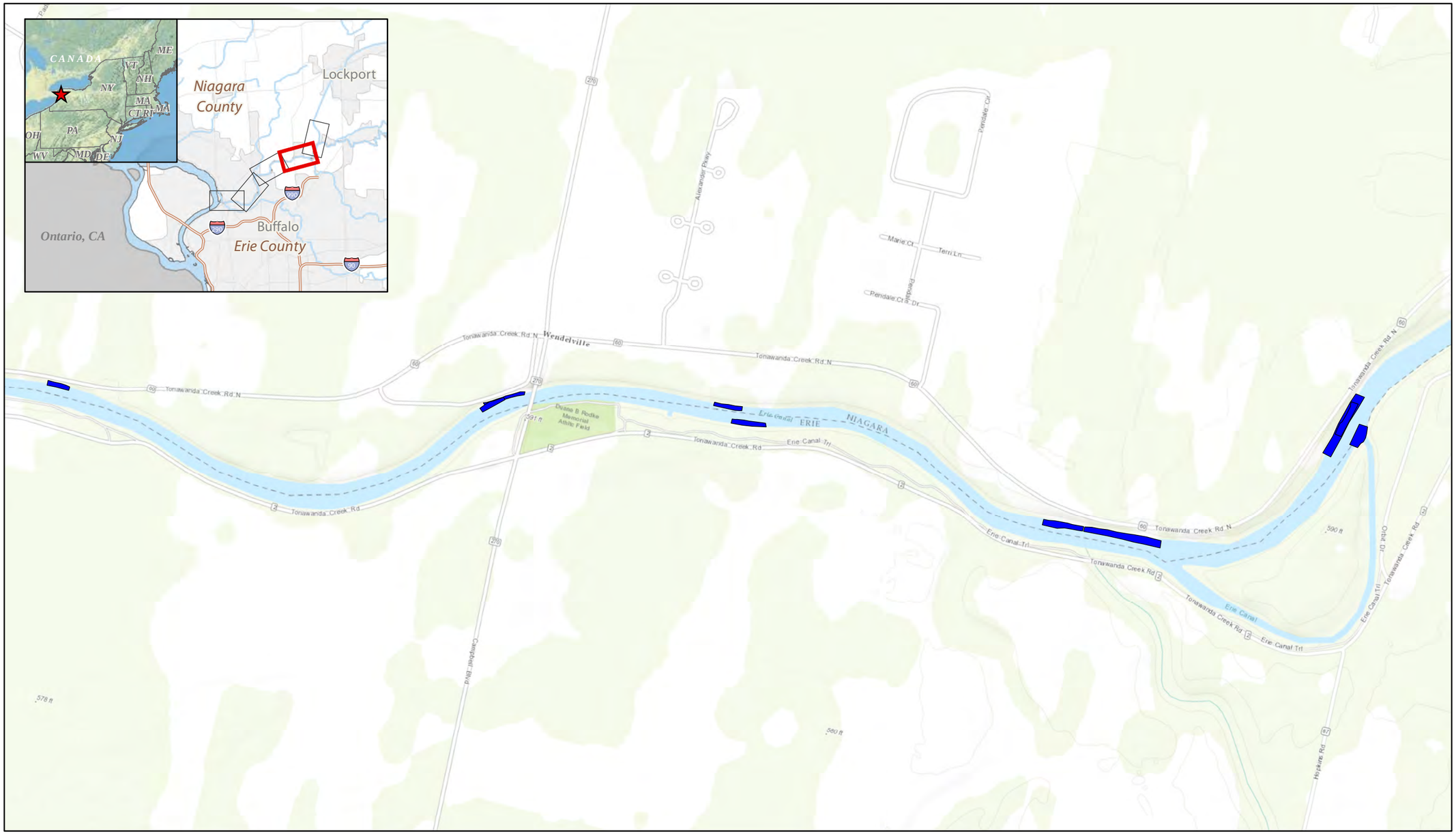
Tonawanda Creek, Erie and Niagara Counties, New York

Copper Spot Treatment Areas

SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 1-1c Hydrilla Treatment Areas for Summer 2018 in Tonawanda Creek/Erie Canal - Endothall and Copper Treatments

Tonawanda Creek, Erie and Niagara Counties, New York



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 1-1d Hydrilla Treatment Areas for Summer 2018 in Tonawanda Creek/Erie Canal - Endothall and Copper Treatments

Tonawanda Creek, Erie and Niagara Counties, New York

Copper Spot Treatment Areas

0 0.25 0.5 Miles

SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 1-1e Hydrilla Treatment Areas for Summer 2018 in Tonawanda Creek/Erie Canal - Endothall and Copper Treatments

Tonawanda Creek, Erie and Niagara Counties, New York

2 Overview of Herbicide Treatment

Treatment of Hydrilla for this Project focused on the application of the aquatic herbicides endothall and chelated copper within the creek/canal. During treatment, the Canal Corp. minimized water flow in the creek/canal utilizing flow control structures on the canal in Lockport, New York, for a period of 48 hours in order to achieve a maximum (or ideal) contact time at a target concentration. Minimizing water flow yielded greater contact time between the herbicide and Hydrilla. To minimize flow, a target flow rate of 50 cubic feet per second (cfs) or less to the east was identified.

The following sections outline the public notification that preceded treatment; field conditions before, during, and after treatment; herbicide treatment methodology; quantity of herbicide used, and its dispersion; and details of the flow management and monitoring.

2.1 Public Notification

Public awareness and understanding of the Project were important to its successful implementation. Although a State of New York Permit to Use a Pesticide for the Control or Elimination of Aquatic Vegetation (Article 1, Part 327) was not required for this Project, the notification requirements stipulated for the permit were adhered to (i.e., riparian owner and permitted user notification and use of warning signs). Five methods of public notification were used to announce the July 24 and 25, 2018, treatment:

1. Riparian (creekside) owners and permitted users were notified by E & E via U.S. certified mail approximately 21 days prior to the application and follow-up postcards were sent out with online links for herbicide labels;
2. Yellow warning signs were posted along the primary treatment areas at public access points;
3. Display advertisements were published in two local/regional newspapers, *Lockport Journal* and the *Niagara Gazette*, and *The Buffalo News* on July 21, 2018;
4. Agency notification letters were distributed by mail 19 days prior to the application; and
5. Project factsheets were distributed during Canal Fest (July 15 through 22, 2018) by NYSDEC staff.

Additionally, in an effort to notify the public regarding the August 23, 2018, spot treatment, riparian owners and users were again notified via certified mail; mailings were sent out on August 17, 2018.

2.2 Field Conditions

Field conditions prior to treatment (July 19 through July 23, 2018), during treatment (July 24 and 25, 2018), and immediately following the treatment (July 26 through July 30, 2018) are summarized in Table 2-1. As indicated in Table 2-1, a total of approximately 1.05 inches of rain fell in the three days immediately preceding treatment. During treatment, conditions were also wet with rain. The five days following treatment were generally dry.

Table 2-1 Field Conditions Preceding, During, and Following Herbicide Application

Date	Temperature Range (degrees Fahrenheit)	Precipitation (inches)	Other
July 19, 2018	Min: 57 Max: 83	0	No significant weather observed Average wind speed 7.2 mph with gusts up to 18 mph
July 20, 2018	Min: 64 Max: 90	0	No significant weather observed Average wind speed 11.1 mph with gusts up to 29 mph
July 21, 2018	Min: 59 Max: 84	0.15	Rain Average wind speed 12.6 mph with gusts up to 26 mph
July 22, 2018	Min: 60 Max: 79	0.88	Rain and mist Average wind speed 10.0 mph with gusts up to 30 mph
July 23, 2018	Min: 67 Max: 84	0.02	Light rain Average wind speed 8.1 mph with gusts up to 22 mph.
July 24, 2018 Treatment Day 1	Min: 73 Max: 87	0.03	Light rain Average wind speed 10.4 mph with gusts up to 25 mph
July 25, 2018 Treatment Day 2	Min: 70 Max: 79	0.71	Rain and mist Average wind speed 6.9 mph with gusts up to 20 mph
July 26, 2018	Min: 65 Max: 82	Trace	Mist and light rain Average wind speed 10.3 mph with gusts up to 31 mph
July 27, 2018	Min: 66 Max: 78	0	No significant weather observed Average wind speed 12.2 mph with gusts up to 31 mph
July 28, 2018	Min: 65 Max: 74	0.03	Light rain Average wind speed 11.6 mph with gusts up to 31 mph

Table 2-1 Field Conditions Preceding, During, and Following Herbicide Application

Date	Temperature Range (degrees Fahrenheit)	Precipitation (inches)	Other
July 29, 2018	Min: 58 Max: 80	0	No significant weather observed Average wind speed 5.9 mph with gusts up to 19 mph
July 30, 2018	Min: 59 Max: 78	0	No significant weather observed Average wind speed 5.8 mph with gusts up to 24 mph

Source: National Oceanic and Atmospheric Administration 2018

2.3 Herbicide Treatment Methodology

The aquatic herbicide endothall (Aquathol K™) was applied in designated sections of the creek/canal on July 24 and 25, 2018, and spot treatments using chelated copper (Komeen Crystal™) on July 24 and 25 and August 23, 2018 (see Figures 2-1 through 2-5). The herbicides were applied by SLM in accordance with the *Architect-Engineer Scope of Work (SOW) Aquatic Plant Control ERDC Demonstration Project Tonawanda Creek/Erie Canal* dated May 14, 2018 (USACE 2018).

Two boats were utilized during the July treatments: an 18-foot, shallow-draft aluminum work skiff powered by a 40-horsepower conventional four-stroke outboard motor, and a 20-foot aluminum, shallow-draft work skiff powered by a 50-horsepower conventional four-stroke outboard motor. A 24-foot, aluminum airboat with a small-block Chevy engine, was utilized on August 23, 2018, for the spot treatment.

2.3.1 Herbicide Transfer

An in-line herbicide injection system was used on the two conventional work skiffs. The skiffs were outfitted with a 100-gallon polyethylene tank. The airboat was outfitted with adjustable granular spreaders. The liquid herbicide was pumped from 250-gallon totes in the chemical delivery box truck located onshore into the polyethylene tanks via 1.5-inch-diameter tubing by electric- and gasoline-powered transfer pumps. Liquid herbicide was also delivered in 2.5-gallon jugs, which were triple rinsed and recycled after they were emptied. The empty totes were taken back by the herbicide distributor and were returned to the manufacturer for reloading and reuse. The granular herbicide was carried in company work trucks from the New York warehouse to the site in 20-pound bags. These bags were triple rinsed and then disposed of as solid waste. Personal protective equipment was worn by SLM staff and by the driver from the company that delivered the herbicide and assisted with the herbicide transfer to the skiffs.

2.3.2 Endothall Treatment

The work skiffs were outfitted with a 2-inch-diameter gasoline-powered water pump. Water was drawn from the creek/canal and sprayed out beneath the water's surface through a boom and subsurface hose assembly mounted to the stern of each boat. The storage tanks and hoses were fitted with ball valves that

could be closed to stop flow. Herbicide was drawn from the tanks in-line at a rate of approximately 8 gallons per minute. The tanks on the skiffs were filled at the designated loading area, at the City of North Tonawanda boat launch at Service Drive. Herbicide was applied from west to east along the creek/canal. Boat passes were made parallel to the shorelines. The herbicide was applied in water less than 12 feet deep, which was generally within 50 feet of the shoreline. The quantity of herbicide needed for each section was initially determined by the total acreage of the treatment areas. Each boat had a Global Positioning System (GPS) navigation system with all of the treatment sections preloaded.

As stated in Section 1.1, the Project area was divided into two blocks for endothall treatment: the western block encompassing approximately 3.8 miles between Seymour Street Bridge in Tonawanda and the North Tonawanda Botanical Gardens in North Tonawanda; and the eastern block encompassing approximately 8 miles between West Canal County Park in Niagara County and the Pendleton Guard Gate. The western block contains the vast majority of large Hydrilla beds and received direct herbicide application in four main sections of the canal (Wardell Marina, North Tonawanda Mayor's Park [Mayor's Park] to Amherst Ellicott Island Park [Dog Park], Dog Park Oxbow, and Botanical Gardens) which total approximately 2.4 miles (see Figures 2-1 through 2-4). Herbicide was applied in the littoral areas and allowed to disperse across the canal to bring herbicide concentrations to target levels. The non-treated eastern block of the Project area received exposure via the resumption of flow and direct spot treatment of large Hydrilla beds with endothall at the maximum label rate during the initial treatment.

In July 2018, the USACE ERDC conducted supplementary mapping and plant delineation and identified the four primary treatment areas discussed above (Wardell Marina, Mayor's Park to Dog Park, Dog Park Oxbow, and Botanical Gardens; see Figures 1a-1e, and 2-1 through 2-4). The Wardell Boat Yard Marina treatment area was isolated with a limnocorral (impermeable divider) and received direct endothall application along with the side channel marina.

2.3.3 Chelated Copper Treatment

Chelated copper was applied using both a calibrated Venturi system and granular spreaders. The Venturi system was utilized during the first two days of treatment, July 24 and 25, 2018. The granular spreaders were utilized during the August 23, 2018, spot treatment, from the airboat. Both application systems were calibrated by SLM before use to accurately apply the amount of product to each treatment area. Chelated copper was loaded onto the boats from the city of North Tonawanda boat launch at Service Drive. Boat passes were made parallel to shore in water that was less than 12 feet deep. These passes were generally made within 50 feet of the shoreline. The boats were outfitted with GPS systems, with the treatment zones preloaded on them, to ensure accuracy and record the amount of acreage that the boats covered.

The following paragraphs summarize the 2018 treatment activities, including both endothall and chelated copper.

July 24, 2018: Day 1

SLM staff arrived at the City of North Tonawanda boat launch at 700 Sweeney Street at the foot of Service Road at 0800 hours, launched both work skiffs, and began assembling the treatment systems. Following on-site meetings with staff from the USACE and NYSDEC, and confirmation with the Canal Corp that the creek/canal flow had slowed to the desired rate (50 cfs), SLM personnel began to transfer the herbicide at approximately 0900 hours. Two treatment crews were sent out, consisting of either a lead applicator or a lead applicator and an assistant/technician. Treatment began at approximately 1000 hours. One team was sent to the upper treatment sites (i.e., predominantly east of West Canal Park) to do the chelated copper application while the other treated the endothall treatment areas. Aside from brief breaks when the skiffs stopped to reload herbicide, the treatments continued uninterrupted until the operation was completed at approximately 1800 hours.

The following areas were treated with endothall on Day 1 (see Table 2-2 and Figures 2-1 through 2-4):

- Wardell Marina Treatment Area;
- Mayor's Park to Dog Park Treatment Area;
- Dog Park Oxbow Treatment Area; and
- Botanical Gardens Treatment Area.

Before treatment began, a limnocorral was installed in the Wardell Marina and the area was treated using a hand-held spray gun. This area was isolated with a 60-foot-long, floating limnocorral secured to the creek bottom with cinder blocks and to the shoreline on each end. The limnocorral extended from above the surface of the water to the creek/canal bed in order to isolate the Hydrilla bed from the surrounding flowing water. SLM noted on July 25, 2018, that the limnocorral had been cut away from the shore and was addressed in the field. The limnocorral then remained in place until SLM removed it on September 5, 2018.

The base of operations was moved upstream to the Amherst Veterans Canal Park launch towards the end of Day 1 of the treatment. At the City of North Tonawanda boat launch, the chemical delivery box truck was able to park adjacent to or on one side of the ramp, which still enabled each ramp to be used by other boaters, as necessary, during the herbicide transfer operations. Day 1 treatment efforts were completed at 1800 hours, resulting in a total treatment time of approximately 8 hours.

Additionally on Day 1, approximately 3.8 acres, comprised of seven different, treatment plots, were treated with chelated copper (see Table 2-2 and Figure 2-5a through 2-5e). As indicated above, treatment for the copper plots began in the uppermost plots and moved back toward the Niagara River. One SLM team did this while another team conducted the endothall treatment.

July 25, 2018: Day 2

SLM launched both work skiffs from the City of North Tonawanda boat launch at 700 Sweeney Street. The same herbicide transfer and application methods were used as Day 1. Treatment began at 0800 hours and was completed by 1500 hours for a total treatment time of approximately 7 hours. On Day 2, the Mayor's Park to Dog Park Treatment Area was retreated with endothall. Additionally, approximately 4.4 acres, comprised of nine treatment plots, were treated with chelated copper (see Table 2-2 and Figure 2-5a through 2-5e), including a curtained area on the southeast side of the Seymour Street bridge in Tonawanda.

August 23, 2018: Spot Treatment

Multiple plots were treated or re-treated with chelated copper on August 23, 2018, with the same herbicide transfer and application methods that were used on Days 1 and 2 (see Table 2-2 and Figure 2-6a through 2-6e). Approximately 50% of the copper treatment plots constituted repeat applications, and the other half represented new treatment plots. All treatment areas were determined by monitoring conducted by the USACE/ERDC. A total of 13.4 acres were spot treated.

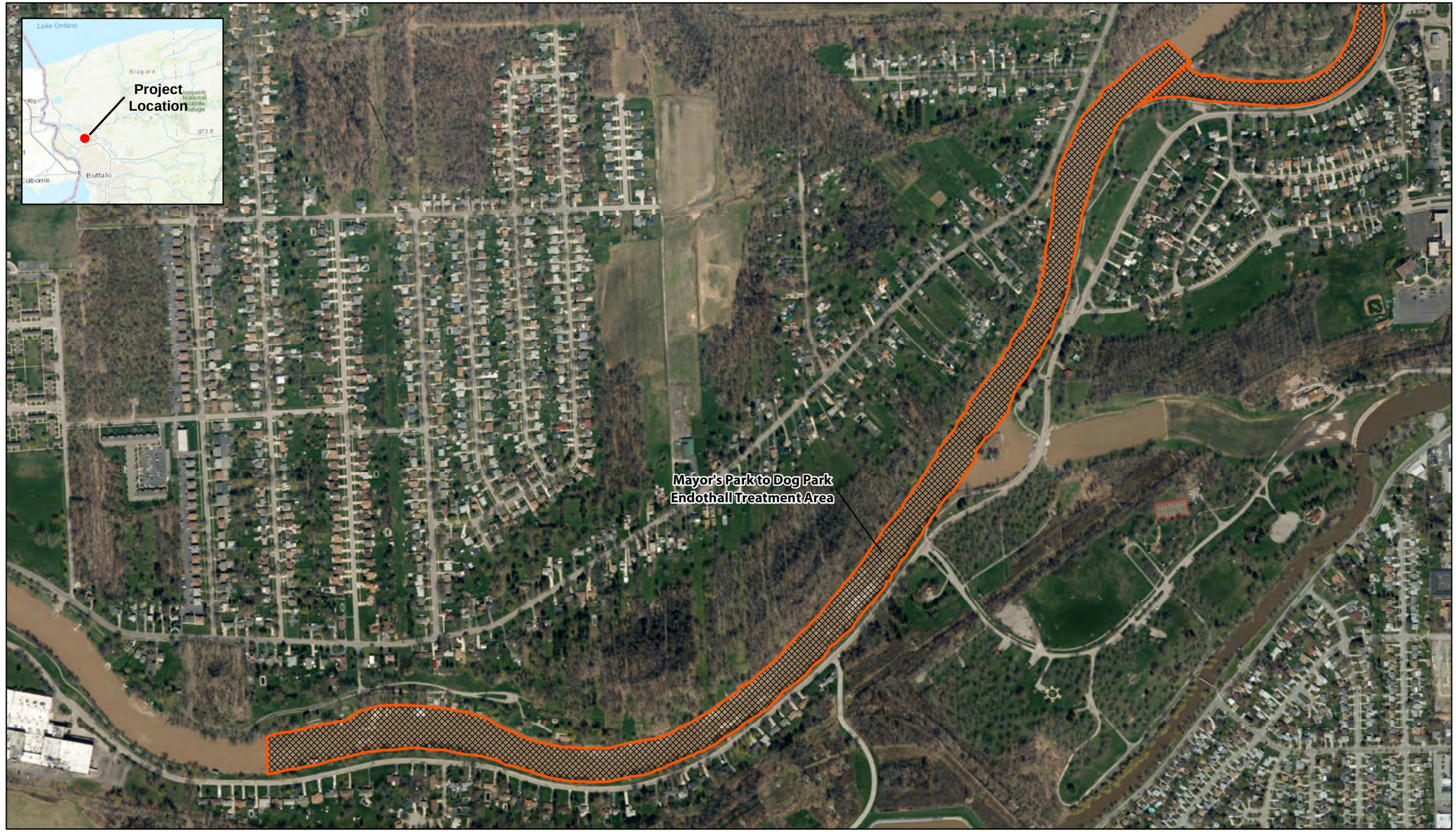
SLM launched the 24-foot aluminum airboat at the Amherst Veterans Memorial Park at 0800 hours. Chelated copper was applied to the treatment areas using calibrated granular spreaders. Application occurred parallel to the shore and all treatment areas indicated in Table 2-2 were treated twice during the day. Application concluded at 2030 hours for a total of 12.5 hours of work.

Before the treatment began, a 20-foot floating limnocorral was installed just downstream of the New Road/East Canal Road bridge in Pendleton around spot treatment plot 15 (see Figure 2-6e). This was a decision made in the field on August 23, 2018, by the USACE. It was secured to the bottom of the canal with cinder blocks, and to the shoreline on each end. The limnocorral extended from above the surface of the water to the creek/canal bed, in order to isolate the Hydrilla bed from the surrounding flowing water. The limnocorral was tampered with and was never found by SLM when they went back to retrieve it on September 5, 2018. The ropes were still attached onshore and appeared to have been cut. It is unknown how long the curtain remained in place before they were cut; however, the results of the chelated copper treatment should not have been substantially affected due to the granular nature of the herbicide.

SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-1 Wardell Marina Endothall Treatment Areas

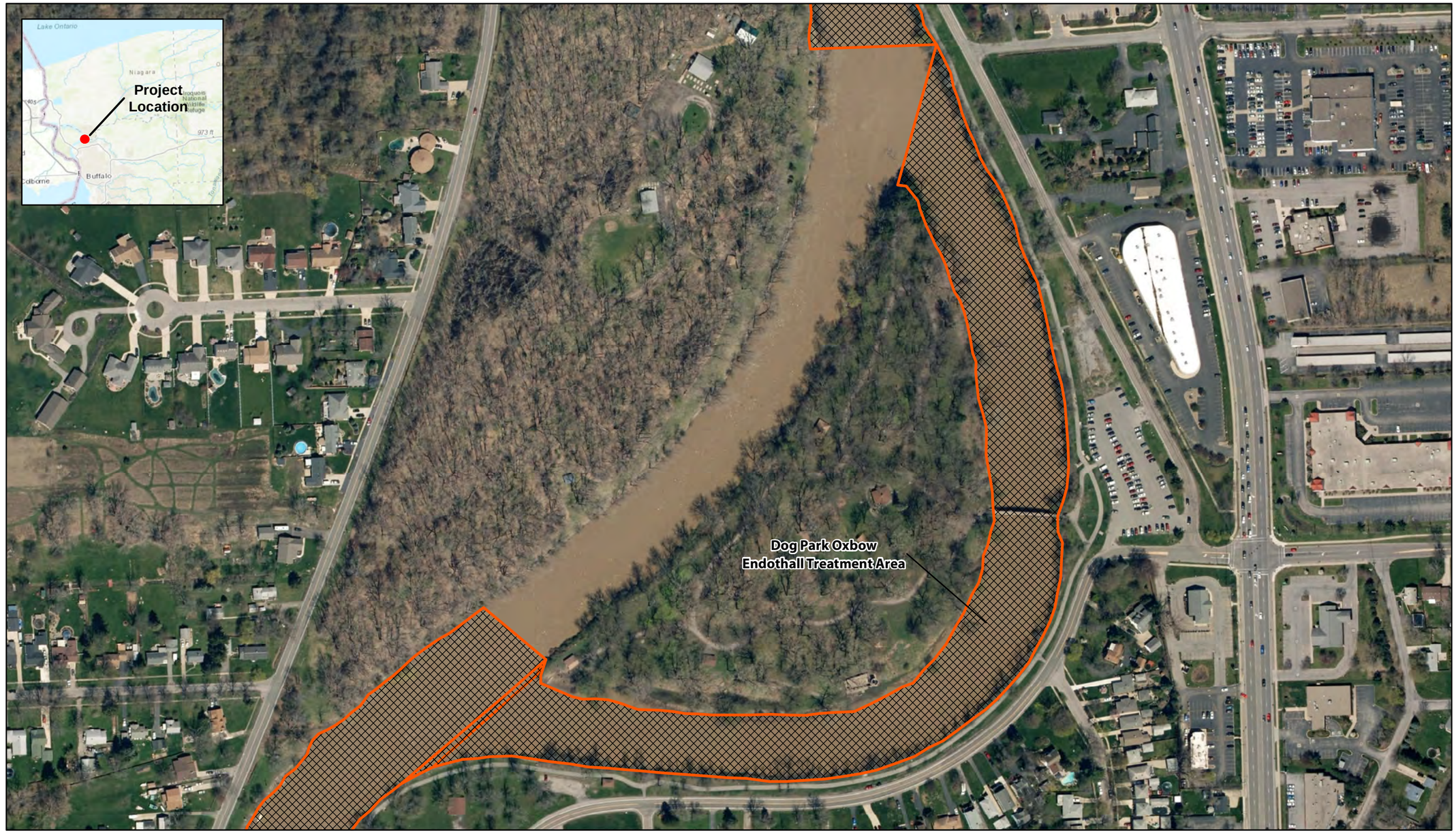
Tonawanda Creek, Erie and Niagara Counties, New York



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-2 Mayor's Park to Dog Park Endothall Treatment Area

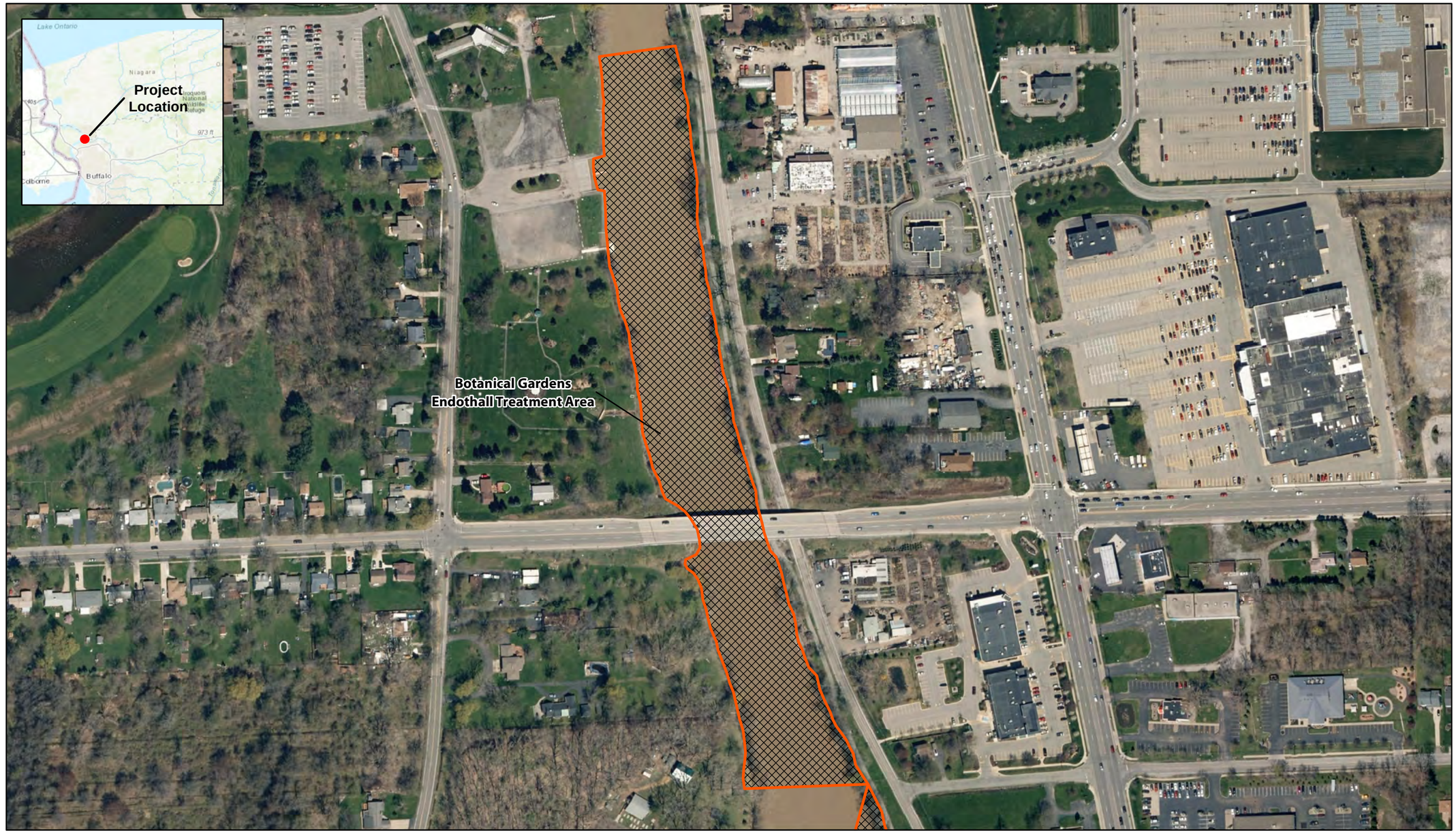
Tonawanda Creek, Erie and Niagara Counties, New York



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-3 Dog Park Oxbow Endothall Treatment Area

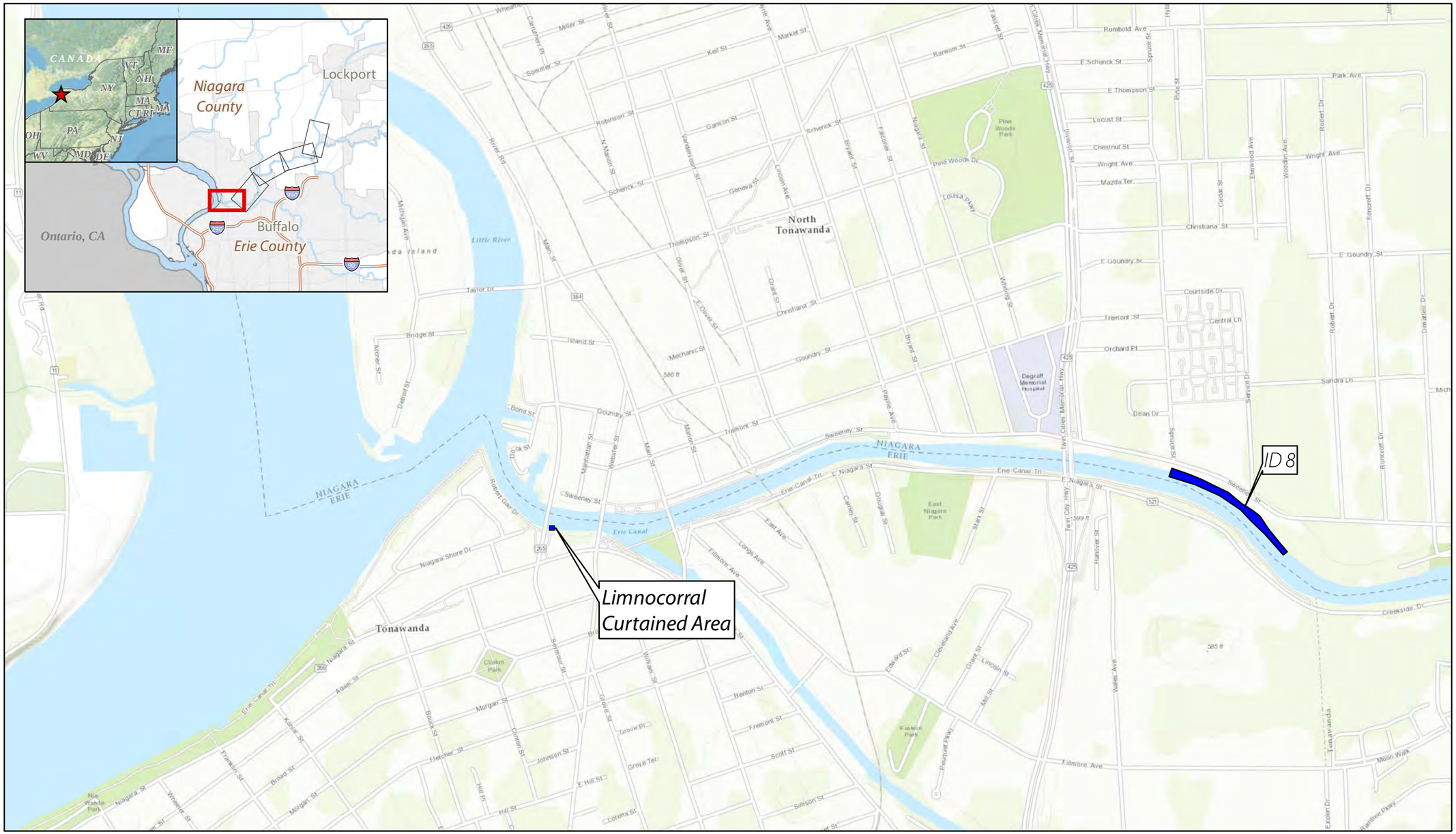
Tonawanda Creek, Erie and Niagara Counties, New York



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-4 Botanical Gardens Endothall Treatment Area

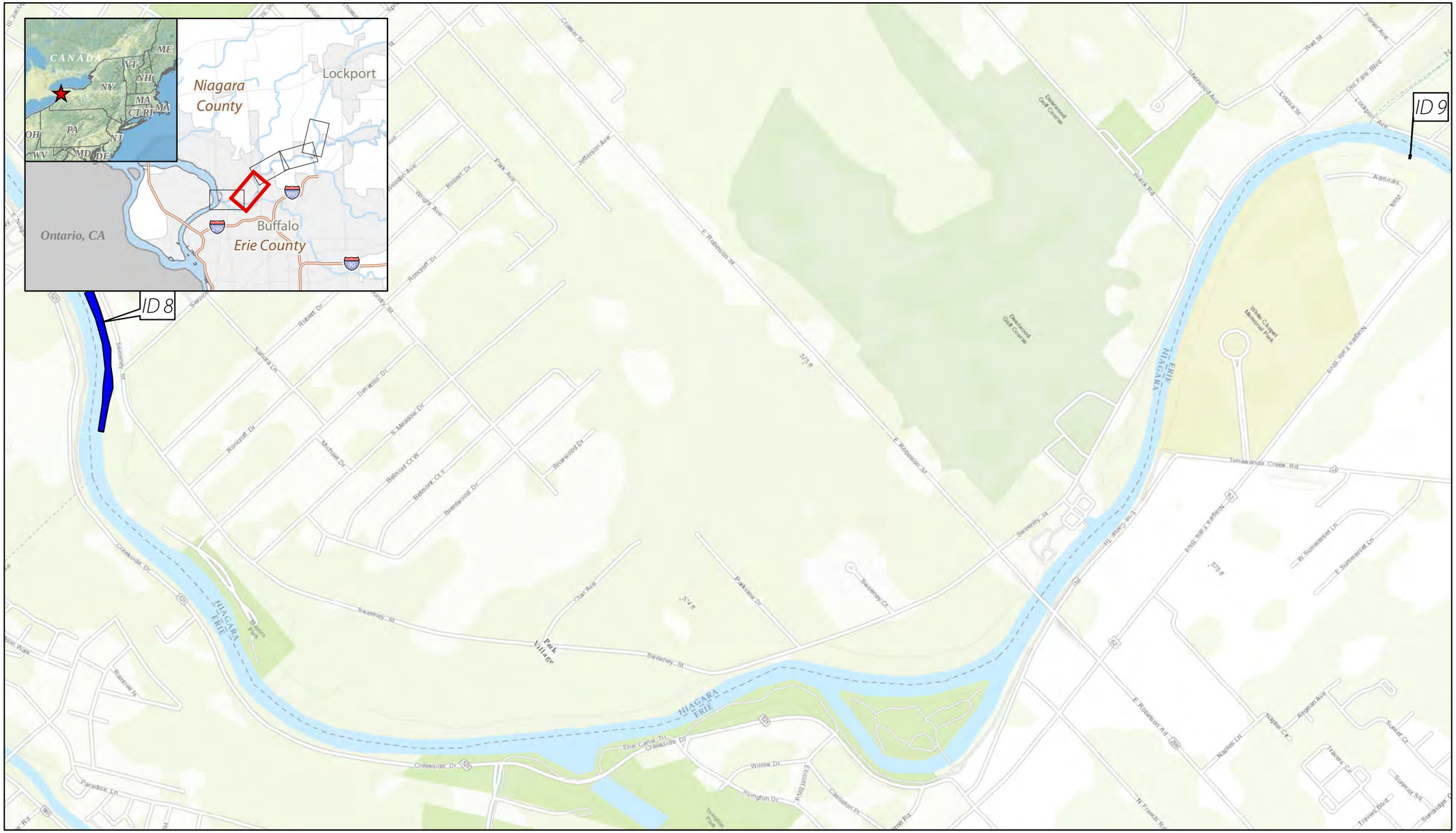
Tonawanda Creek, Erie and Niagara Counties, New York



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-5a July 2018 Copper Spot Treatments

Tonawanda Creek, Erie and Niagara Counties, New York



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-5b July 2018 Copper Spot Treatments

Tonawanda Creek, Erie and Niagara Counties, New York

Copper plots treated July 24, 2018

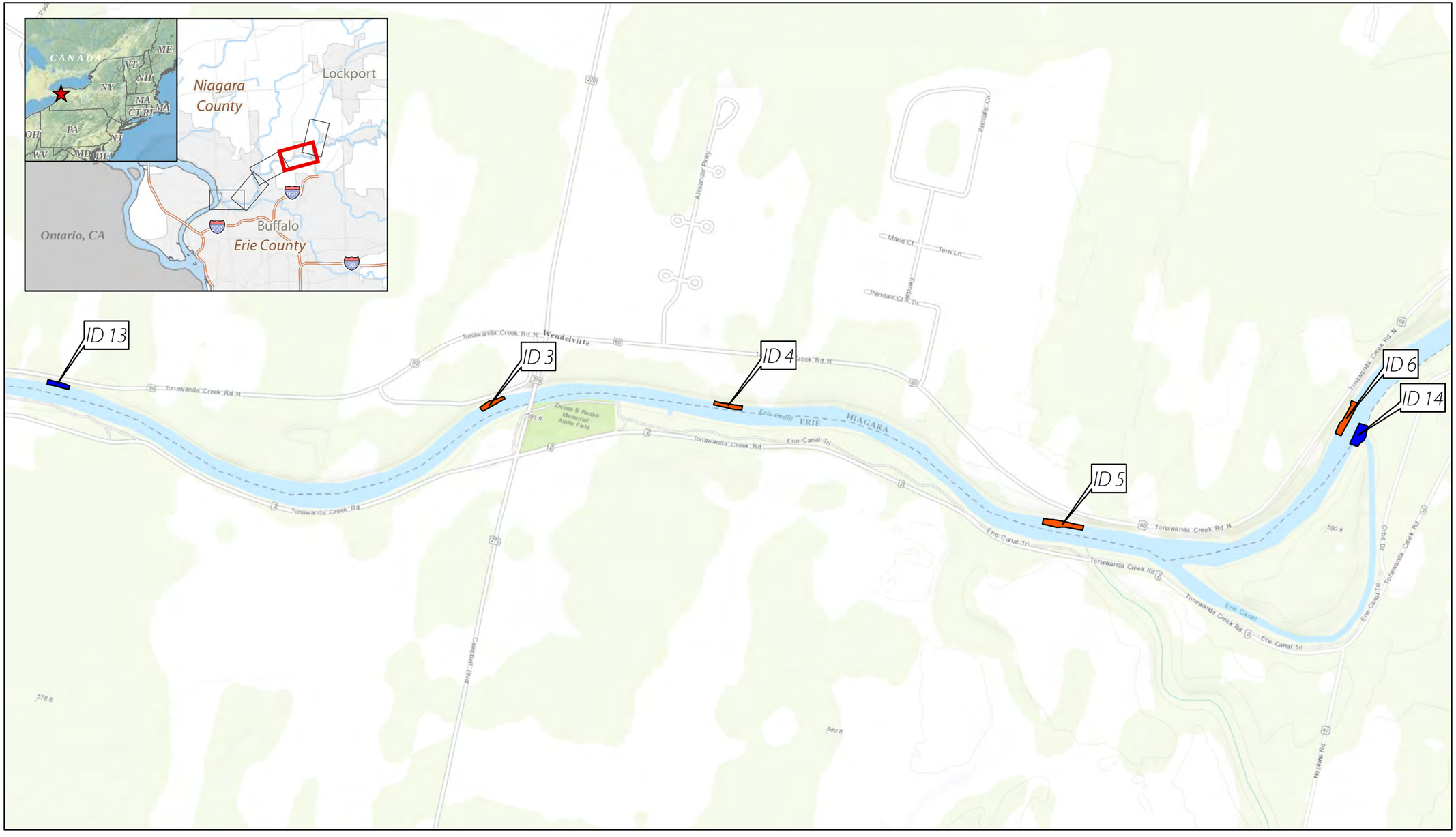
Copper plots treated July 25, 2018

0 0.25 0.5 Miles

SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-5c July 2018 Copper Spot Treatments

Tonawanda Creek, Erie and Niagara Counties, New York



SOURCE: ESRI 2018; USACE ERDC 2018.

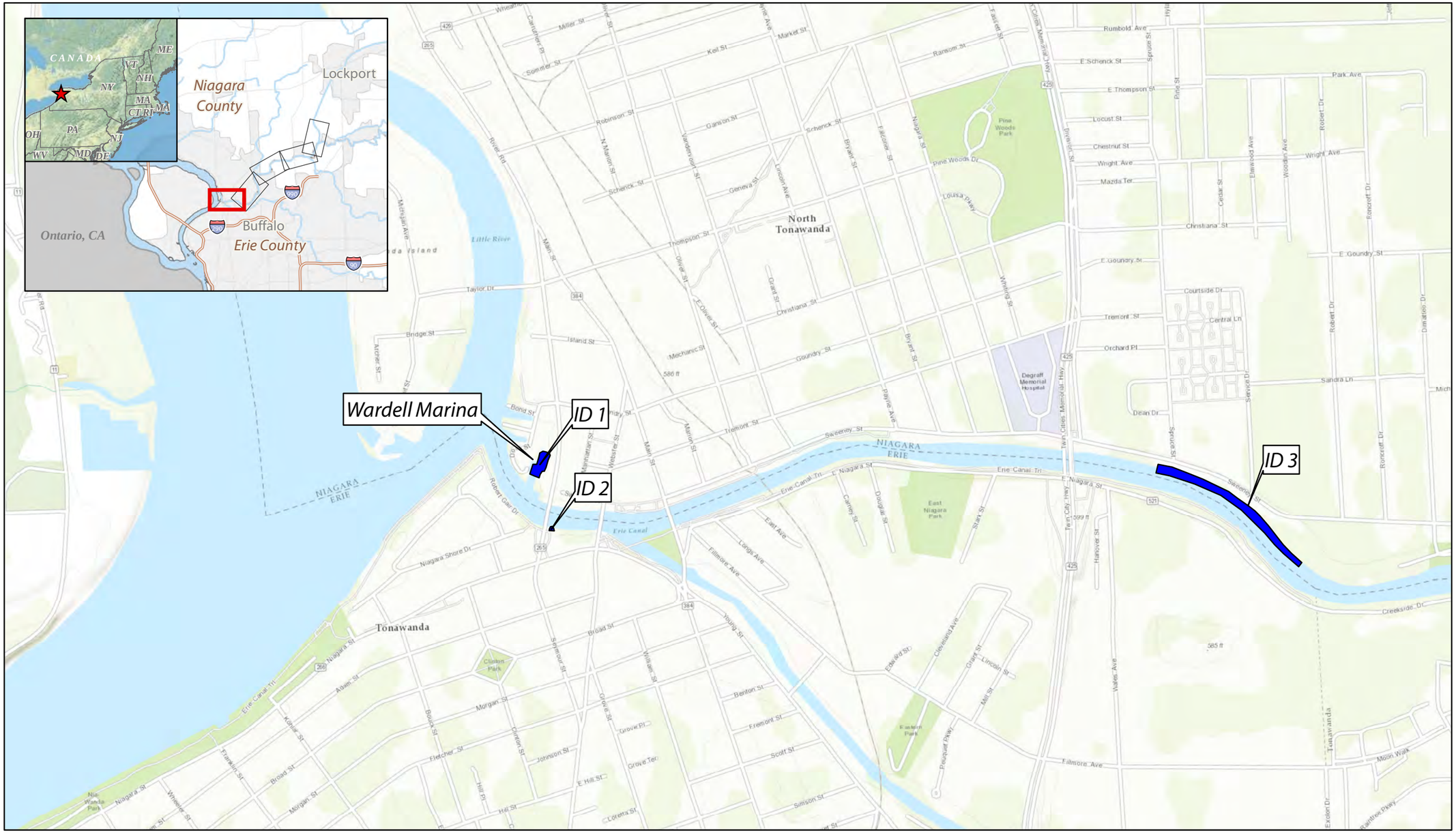
Figure 2-5d July 2018 Copper Spot Treatments

Tonawanda Creek, Erie and Niagara Counties, New York

SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-5e July 2018 Copper Spot Treatments

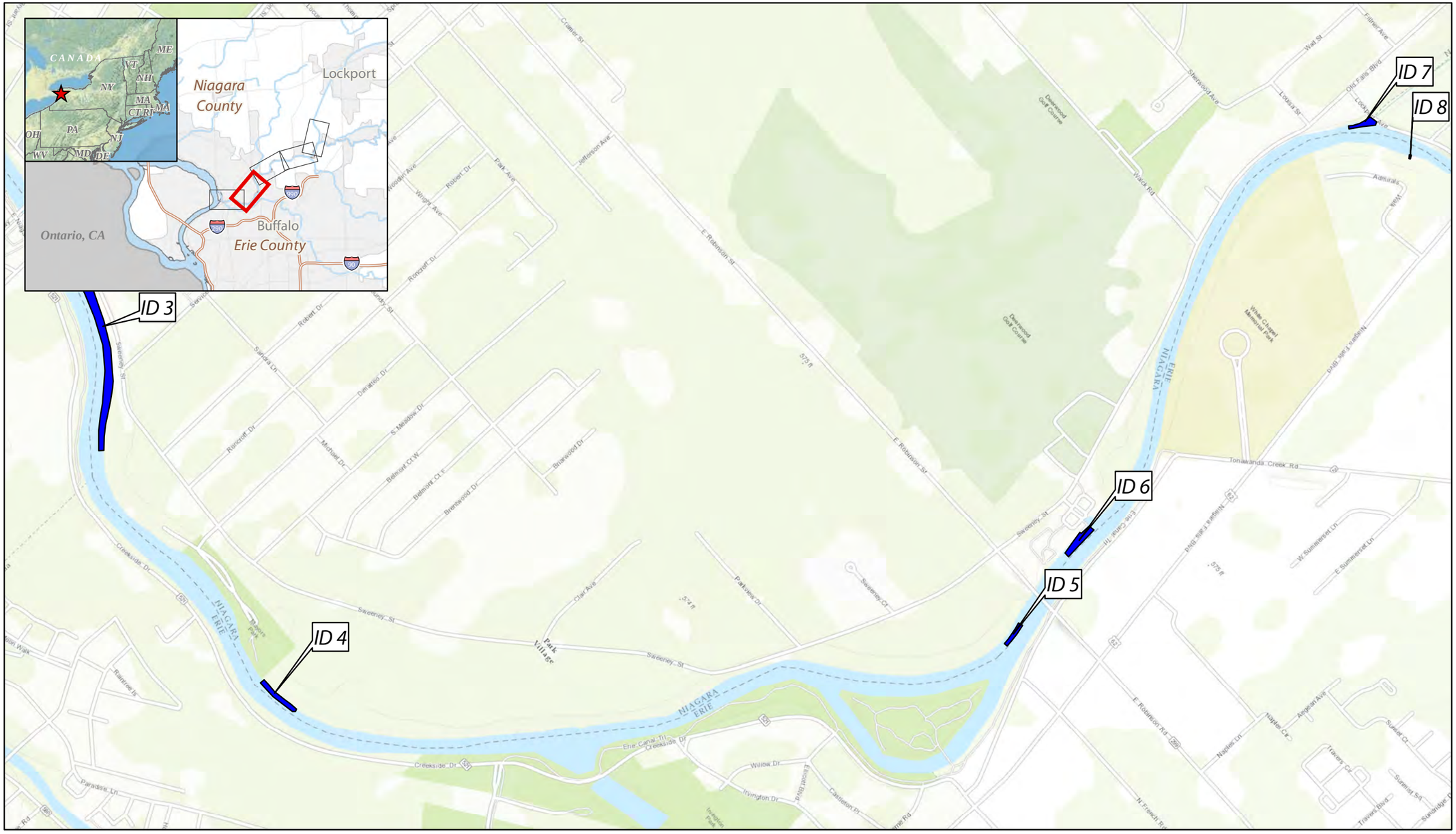
Tonawanda Creek, Erie and Niagara Counties, New York



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-6a August 2018 Copper Spot Treatments

Tonawanda Creek, Erie and Niagara Counties, New York



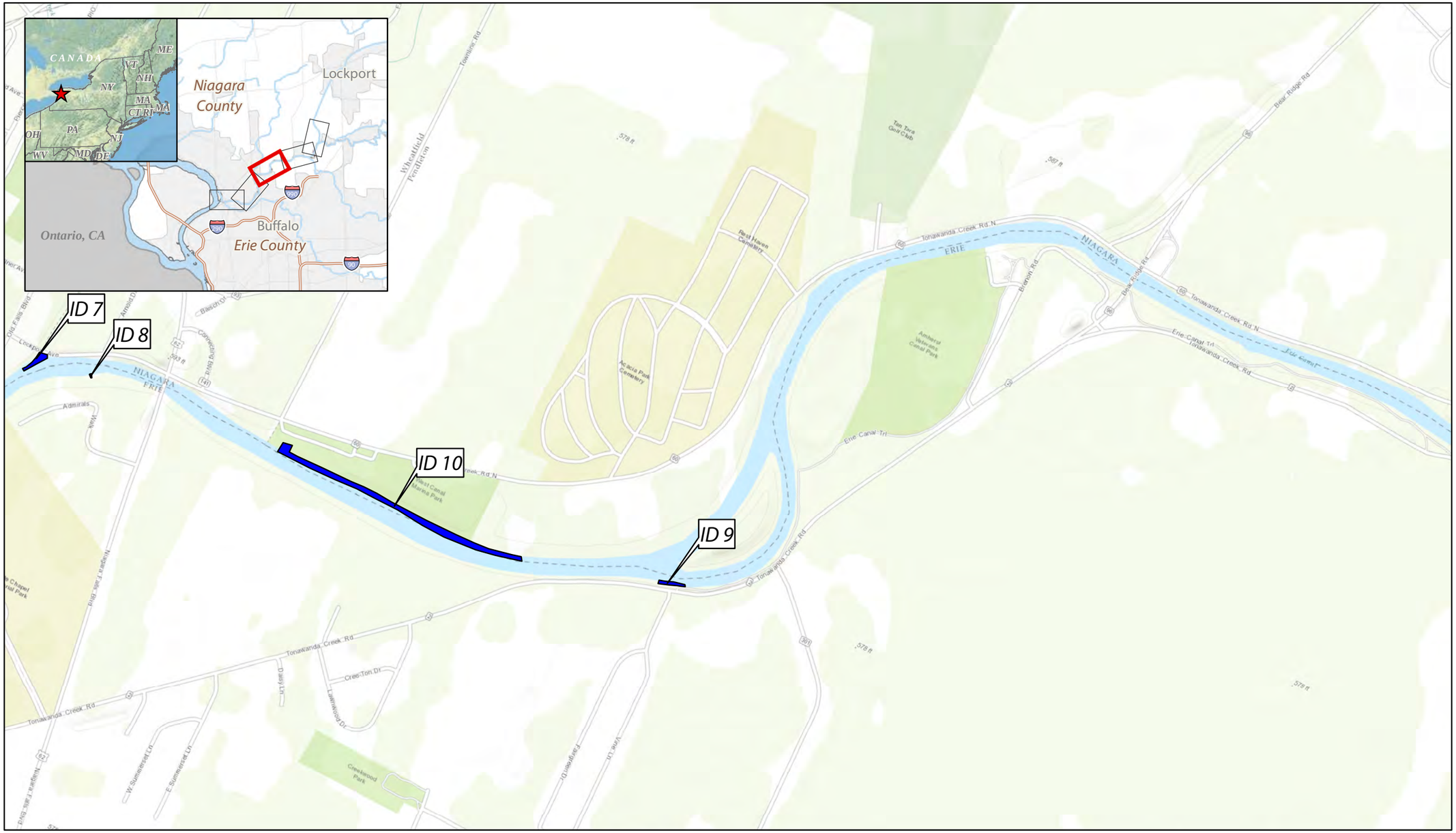
Copper Plots Treated August 2018

0 0.25 0.5 Miles

SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-6b August 2018 Copper Spot Treatments

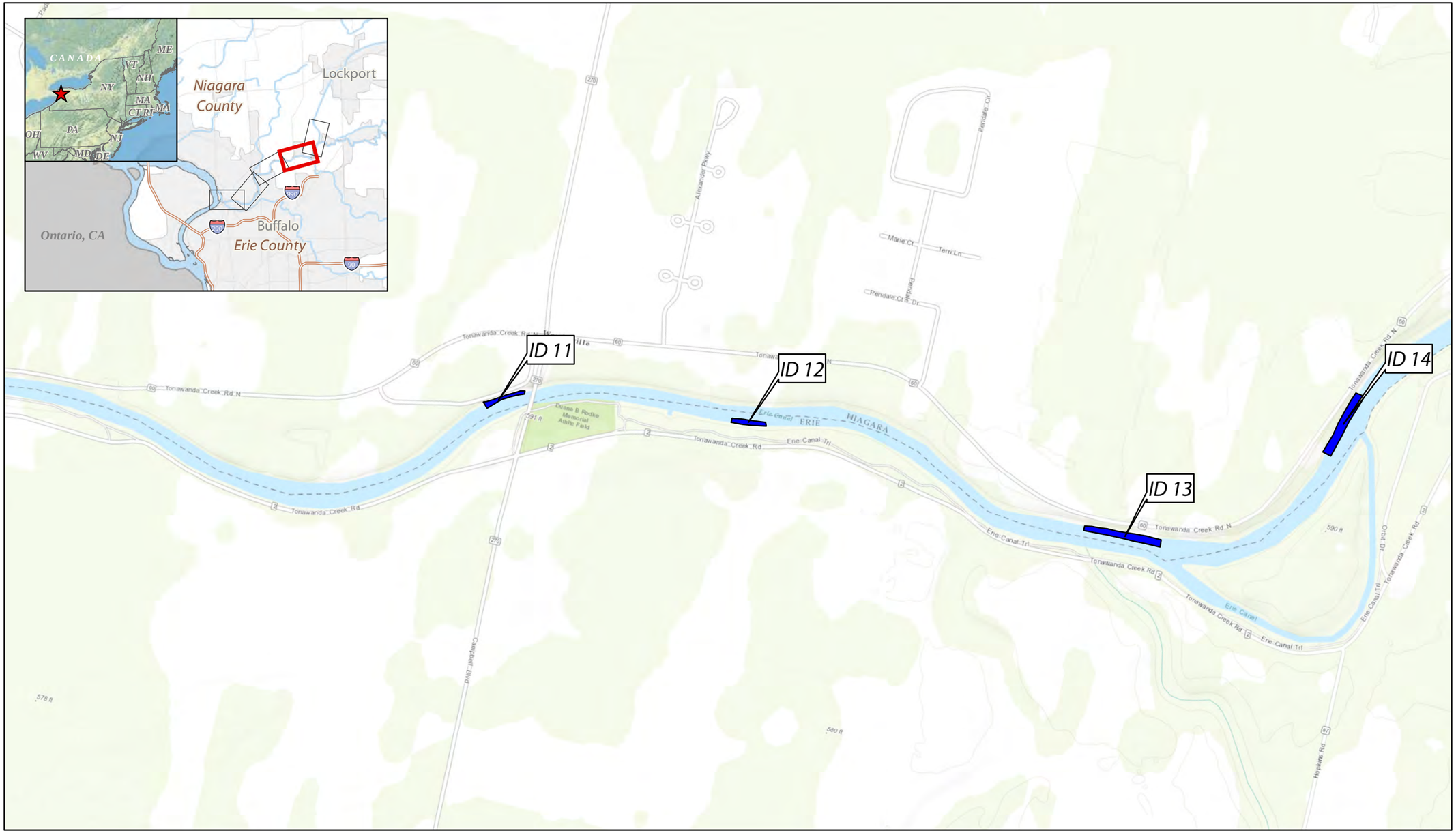
Tonawanda Creek, Erie and Niagara Counties, New York



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-6c August 2018 Copper Spot Treatments

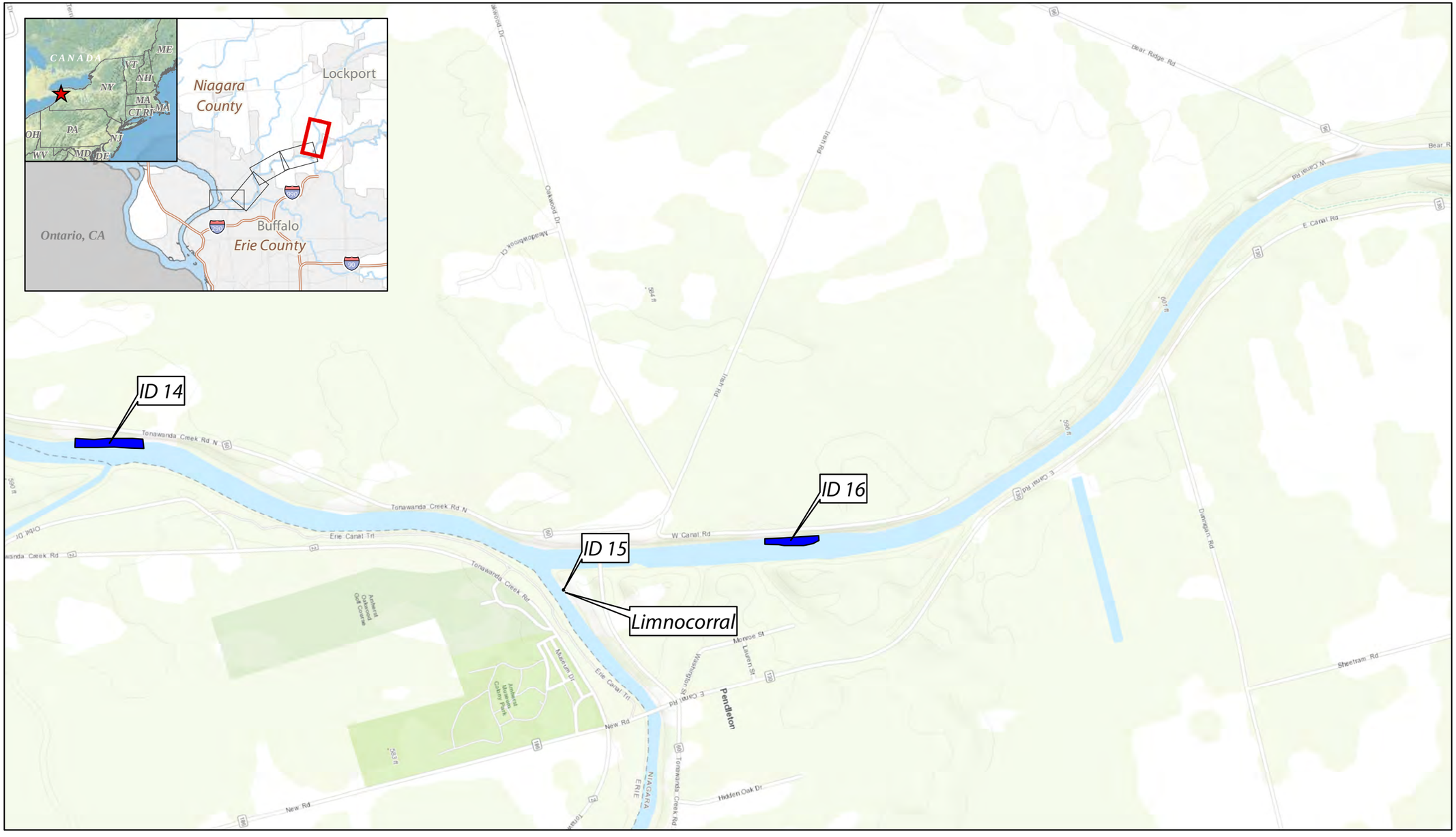
Tonawanda Creek, Erie and Niagara Counties, New York



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-6d August 2018 Copper Spot Treatments

Tonawanda Creek, Erie and Niagara Counties, New York



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-6e August 2018 Copper Spot Treatments

Tonawanda Creek, Erie and Niagara Counties, New York

2.4 Quantity of Herbicide Used and Total Area Treated

A summary of the herbicide quantities applied during the July and August 2018 treatment activities is provided in Table 2-2. The planned treatment areas were divided into distinct areas or plots using a geographic information system, the total amount of endothall or chelated copper to be applied to each area/plot was calculated, and the products were then applied as described in Section 2.3.

The dosing was predetermined and calculated by the ERDC based on the treatment area acreages and volumes. The target concentration of endothall for all of the treated areas in the main creek/canal channel was 1.5 milligrams per liter (mg/L or parts per million [ppm]) on Day 1 and 1.0 ppm on Day 2. This dose was calculated on the entire water volume of the creek/canal treated areas, but the herbicide was applied in the infested areas along the shoreline, resulting in higher concentrations at the time of application.

Table 2-2 summarizes herbicide application for each canal treatment area as depicted on Figures 2-1 through 2-6.

Table 2-2 Herbicide Application Summary, by Canal Treatment Area

Date	Treatment Area	Acres	Endothall Applied (gallons)	Targeted Concentration (ppm)	Chelated Copper Applied (pounds)	Targeted Concentration (ppm)
7/24/18	Wardell Marina	1.0	4	1.5	N/A	N/A
	Mayor's Park to Dog Park	38	345	1.5	N/A	N/A
	Dog Park Oxbow	9.0	14	1.5	N/A	N/A
	Botanical Gardens	9.0	75	1.5	N/A	N/A
	Copper treatment area 1	2.00	N/A	N/A	95.0	1.0
	Copper treatment area 2	0.24	N/A	N/A	8.5	1.0
	Copper treatment area 3	0.25	N/A	N/A	13.7	1.0
	Copper treatment area 4	0.25	N/A	N/A	9.8	1.0
	Copper treatment area 5	0.49	N/A	N/A	21.1	1.0
	Copper treatment area 6	0.50	N/A	N/A	17.8	1.0
	Copper treatment area 7	0.10	N/A	N/A	4.6	1.0
	Total		**438**		**170.5**	
7/25/18	Mayor's Park to Dog Park	38	230	1.0	N/A	N/A
	Copper treatment area 8	2.2	N/A	N/A	68	1.0
	Copper treatment area 9	0.01	N/A	N/A	0.09	1.0
	Copper treatment area 10	0.23	N/A	N/A	7.6	1.0
	Copper treatment area 11	0.51	N/A	N/A	14.9	1.0
	Copper treatment area 12	0.27	N/A	N/A	9.5	1.0
	Copper treatment area 13	0.22	N/A	N/A	10.9	1.0
	Copper treatment area 14	0.51	N/A	N/A	17.7	1.0
	Copper treatment area 15	0.26	N/A	N/A	10.6	1.0
	Copper treatment area 16	0.23	N/A	N/A	10.6	1.0
	Curtained area	0.03	N/A	N/A	1.39	1.0
	Total	**42.5**	**230**		**151.3**	

Table 2-2 Herbicide Application Summary, by Canal Treatment Area

Date	Treatment Area	Acres	Endothall Applied (gallons)	Targeted Concentration (ppm)	Chelated Copper Applied (pounds)	Targeted Concentration (ppm)
8/23/18	Copper treatment area 1	0.58	N/A	N/A	53.9	1.0
	Copper treatment area 2	0.03	N/A	N/A	1.2	1.0
	Copper treatment area 3	2.9	N/A	N/A	175.5	1.0
	Copper treatment area 4	0.46	N/A	N/A	28.5	1.0
	Copper treatment area 5	0.24	N/A	N/A	19.5	1.0
	Copper treatment area 6	0.53	N/A	N/A	34.7	1.0
	Copper treatment area 7	0.28	N/A	N/A	31.6	1.0
	Copper treatment area 8	0.01	N/A	N/A	0.31	1.0
	Copper treatment area 9	0.18	N/A	N/A	22.6	1.0
	Copper treatment area 10	3.2	N/A	N/A	245.5	1.0
	Copper treatment area 11	0.33	N/A	N/A	25.7	1.0
	Copper treatment area 12	0.34	N/A	N/A	28.2	1.0
	Copper treatment area 13	1.1	N/A	N/A	102	1.0
	Copper treatment area 14	1.3	N/A	N/A	83.4	1.0
	Copper treatment area 15	0.03	N/A	N/A	1.2	1.0
	Copper treatment area 16	0.85	N/A	N/A	75	1.0
	Total	**12.4**			**928.8**	
Total Quantity Applied:			**668 gallons**		**1,250.6 pounds**	

Key:
N/A = not applicable
ppm = parts per million

2.5 Herbicide Contact Time and Dispersion

Herbicide was applied to pre-determined areas of the creek/canal on July 24 and 25, 2018, and on August 23, 2018. ERDC and E & E performed water sampling after the July 24 and 25, 2018, applications to determine the endothall concentrations and dispersion of herbicide from the date of application through July 27.

2.5.1 Initial Sampling Results – First 48 Hours

ERDC performed endothall concentration sampling between approximately river mile (RM) 1.2 and RM 5.0 of the creek/canal area at varying spatial and temporal intervals on Days 1 and 2 (July 24 and 25, 2018) of treatment and dispersion. E & E performed endothall concentration sampling on the entire 15-mile creek/canal area at 1.0-mile intervals on Days 4 and 5. These sample locations and denotations are provided in Appendix A. E & E sampling locations were established along Tonawanda Creek/Erie Canal beginning at the confluence of the creek/canal at the Niagara River in Tonawanda, New York (RM 0) and ending at Lockport Road/Robinson Road in Lockport, New York, approximately 15 miles to the northeast.

The samples were analyzed using an enzyme-linked immunoassay procedure specific for endothall. The standard operating procedures for use of the RaPID

Assay® Endothall Test Kit were followed. The detection limit for this method is 7 micrograms per liter (or 0.007 ppm). Samples were analyzed at dilutions of 10:1 or 20:1 with detection limits of 0.07 ppm or 0.14 ppm, respectively, or as non-diluted samples with a detection limit of 0.007 ppm. The sampling results analyzed and reported by the ERDC indicate the concentrations of the active ingredient, dipotassium salt of endothall, in each sample. For every 10 samples, duplicate analyses were performed to determine the relative percent difference of endothall between samples and evaluate analytical precision. Each sample run incorporated the use of external standards at 0.5 and 1 ppm.

The analytical results for samples collected during the initial 48 hours following application during the reduced flow period suggest movement of endothall to the east as anticipated based on normal creek/canal flow. The additional endothall application in the Mayor's Park to Dog Park treatment area on July 25, 2018, was conducted prior to the sampling events on that same day. (The Mayor's Park to Dog Park treatment area is in the vicinity of RM 2 and 2.5 as illustrated in the figures in Appendix A.) It was conducted in order to maintain adequate herbicide concentrations (see Tables 2-2 and 2-3). This additional herbicide application resulted in increased endothall concentrations noted between the morning sample and the early afternoon sample on July 25, 2018, in the immediate area treated and eastward to approximately RM 3.2 that day. Of the three primary treatment areas within the canal proper – Mayor's Park to Dog Park, Dog Park Oxbow, and Botanical Gardens (generally RM 2 - 4) – target endothall concentrations were most consistently maintained at or above the target throughout the 48-hour application period in RM 2.7 to about 3.4. Endothall concentrations were generally the lowest during the 48-hour period at the upstream-most extent of the directly treated areas (near RM 4.1). The remaining areas within the directly treated area (RM 2 - 4) evidenced fluctuations in endothall concentrations, from non-detect up to over 3.0 ppm. Table 2-3 summarizes results obtained from July 24 through 27, 2018, and emphasizes distribution of the treatment in relation to the target zone and clearance of the herbicide from the system.

2.5.2 Water Sampling Results Following Flow Resumption

As discussed in detail in Section 2.6.2, flows were managed by the Canal Corp. during the 48-hour application period and immediately after. On July 24, 2018, at approximately 0800 hours, flow gates were closed within the canal system, and flow was minimized prior to herbicide application to 50 cfs. Canal Corp. resumed flows on July 26, 2018, at 1300 hours.

As stated above, following the initial sampling effort by ERDC, E & E obtained grab samples of water along Tonawanda Creek/Erie Canal on July 26 and 27, 2018 (see Table 2-3 for sampling results; Appendix B for photos). Sampling locations were spaced approximately 1 mile apart. In addition, samples were also collected in both channels where the flow is divided at the following four locations:

- East side of the small island along Creekside Drive (RM 2.8);
- East side of Ellicott Island Park (dog park) near Creekside Drive and Niagara Falls Boulevard (RM 3.5);
- East side of the island at Tonawanda Creek Road and Sweet Home Road (RM 6.3); and
- The side channel along Tonawanda Creek Road just west of Hopkins Road (RM 10.1).

All sampling locations are indicated on Figures A1 through A24 in Appendix A.

The samples obtained by E & E were collected by hand as grab samples from an approximate depth of 1 foot below the creek/canal surface using a hand-operated peristaltic pump. After each sample was collected, two drops of 31.45% hydrochloric acid were added to the bottle to preserve each sample. Each sample was labeled with a unique sample code and immediately placed into a cooler containing ice.

Google Earth was used to navigate to the predetermined sampling locations. At the time of collection, a Bad Elf GPS receiver was used to obtain the actual sampling location coordinates. The accuracy of this unit varied depending on availability of satellites but was typically between 5 and 10 feet.

Table 2-3 Summary of Post-treatment Canal/Creek Water Sample Results

River Mile	Location ID[2]	Endothall Concentrations in ppm[3] Sampling Dates[1]						
		7/24/18 afternoon (2 HAT)[4]	7/24/18 early evening (4 HAT)	7/25/18 morning (19 HAT)	7/25/18 early afternoon (23 HAT)	7/25/18 Late afternoon (26 HAT)	7/26/18	7/27/18
0.0	0.0 C						ND	ND
1.0	1.0 RB						ND	ND
1.13	20 NW	ND	ND	ND	0.11			
	20 C	0.02	0.04	0.02	ND			
	20 SE	0.19	ND	ND	ND			
1.54	19 NW	0.02	ND	ND	0.19			
	19 C	0.06	ND	ND	0.21			
1.55	19 SE	ND	0.03	0.04	0.07			
1.99	**18 SE**	**0.67**	**0.49**	**ND**	**1.54**	**1.06**		
2.0	**2.0 LB**						**0.64**	**ND**
	18 NW	**0.30**	**0.64**	**ND**	**1.80**	**1.04**		
	18 C	**0.17**	**0.52**	**ND**	**0.65**			
2.25	**17 NW**	**3.00**	**0.92**	**0.09**	**1.81**	**1.39**		
	17 C	**2.27**	**1.02**	**ND**	**1.54**	**1.09**		
2.26	**17 SE**	**3.24**	**1.90**	**ND**	**0.83**	**1.01**		

Table 2-3 Summary of Post-treatment Canal/Creek Water Sample Results

River Mile	Location ID[2]	Endothall Concentrations in ppm[3] Sampling Dates[1] 7/24/18 afternoon (2 HAT)[4]	7/24/18 early evening (4 HAT)	7/25/18 morning (19 HAT)	7/25/18 early afternoon (23 HAT)	7/25/18 Late afternoon (26 HAT)	7/26/18	7/27/18
2.7	24 NW	2.54	1.48	0.53	2.03	2.37		
	24 C	1.47	1.76	0.44	1.91			
	24 SE	2.71	1.39	0.54	1.49	1.38		
2.8	2.8 A						1.31	ND
3.0	3.0 C						1.26	0.03
3.16	16 NW	2.81	4.17	1.23	1.75	1.41		
3.17	16 C	3.79	1.77	1.09	1.66	1.52		
	16 SE	4.16	2.01	1.11	1.81	1.61		
3.41	15 C	3.71	0.80	1.25	0.77	1.10		
3.5	3.5 A						1.31	0.01
3.55	14 C	ND	0.45	0.89	1.05	1.05		
3.83	13 NW	ND	0.40	1.01	0.78	0.71		
	13 C	0.26	1.07	1.00	0.51	NS		
	13 SE	ND	3.81	1.22	0.68	0.57		
3.99	12 NW	0.05	0.06	0.83	0.53	0.52		
	12 C	ND	0.61	1.00	0.28	0.46		
	12 SE	0.48	2.25	1.08	ND	0.43		
4.0	4.0 RB						1.21	0.02
	4.0 LB						1.30	
4.11	11 SE	0.38	0.29	0.72	0.18	0.39		
4.12	11 C	0.25	0.53	0.72	0.21	NS		
4.13	11 NW	0.23	0.05	0.79	0.11	0.33		
4.44	10 NW	0.40	0.51	0.31	ND	0.19		
	10 C	1.30	0.59	0.38	0.04	NS		
	10 SE	0.37	0.33	0.51	0.11	0.34		
4.89	9 NW	0.03	ND	ND	ND	0.10		
	9 C	0.02	ND	0.02	ND	0.06		
4.9	9 SE	ND	ND	ND	0.09	0.19		
5.0	5.0 LB						0.51	0.12
	5.0 RB							0.31
6.0	6.0 C						ND	0.47
6.3	6.3 A						ND	0.45
7.0	7.0 RB						ND	0.05
8.0	8.0 LB						ND	0.469
9.0	9.0 C						ND	0.428
10.0	10.0 RB						ND	0.477
10.1	10.1 A						ND	ND
11.0	11.0 LB						ND	0.146
12.0	12.0 C						ND	0.038

Table 2-3 Summary of Post-treatment Canal/Creek Water Sample Results

River Mile	Location ID[2]	Endothall Concentrations in ppm[3] Sampling Dates[1] 7/24/18 afternoon (2 HAT)[4]	7/24/18 early evening (4 HAT)	7/25/18 morning (19 HAT)	7/25/18 early afternoon (23 HAT)	7/25/18 Late afternoon (26 HAT)	7/26/18	7/27/18
13.0	13.0 RB						ND	0.014
14.0	14.0 LB						ND	ND
15.0	15.0 C						ND	ND

[1] Application occurred on July 24 and 25, 2018. Samples collected on July 24 and 25 were by ERDC; all samples collected on July 26 and 27, 2018, were post-treatment, and collected by E & E.
[2] Location ID assigned by ERDC or E & E. Number indicates river mile of location and letter indicates location within creek.
[3] Endothall results provided by ERDC for all samples. River miles for ERDC samples were approximated by E & E.
[4] HAT is measured from the initial treatment on July 24, 2018.

Key:
HAT = hours after treatment
C = center of canal/creek
ND = Non-detect (detection limit of 0.07 ppm unless otherwise noted by footnote)
RB = Right bank of creek/canal (when heading toward the Niagara River)
LB = Left bank of creek/canal (when heading toward the Niagara River)
Blank cell = no sample collected
Bold text = samples taken within the main treatment areas

All samples collected by E & E on July 26 and 27, 2018, were shipped on ice to Mike Netherland for analysis. Samples arrived on the morning of July 28, 2018. All samples were analyzed using an enzyme-linked immunoassay procedure specific for endothall (RaPID Assay® Endothall Test Kit).

Quality control samples collected in the field by E & E consisted of normal/ duplicate pairs collected from the same location at the rate of approximately 5%. Two normal/duplicate pairs were collected over two days of sampling. The sample pair collected at location RM 4.0 along the right bank had positive values and a relative percent difference of less than 1.0%, showing good correlation, and the sample pair collected at location RM 5.0 along the right bank also had positive values and a relative percent difference of 3.5% also showing good correlation.

The purpose of E & E's sampling effort was to determine the movement and degradation of endothall following the resumption of flow in the canal after the initial 48-hour application period (refer to Section 2.6.2 for a discussion of how flows were managed). Sample results from July 26, 2018, indicated the presence of endothall from RM 2.0 through RM 5.0. Concentrations in this area ranged from 0.64 ppm to 1.31 ppm (see Table 2-3 and Figures A3 through A8 in Appendix A). On July 27, 2018, sample results indicated the presence of endothall from RM 3.0 to RM 13.0 (see Table 2-3). These concentrations clearly demonstrate the dispersion of endothall to the east after the resumption of normal flows in the creek/canal.

Lateral Dispersion

Samples were collected at various locations on both banks of the creek/canal and in the center. Based on the data in Table 2-3, there is disparity in when and where herbicide laterally dispersed. At the downstream-most end, south of the endothall treatment areas, and at the upstream-most end, north of the endothall treatment areas, lateral dispersion was evident across the creek/canal on both days of treatment. In several locations (e.g., RM 3.17 and 3.99), mixing still occurred on Day 1 (July 24, 2018) of treatment, and concentrations were more uniform on Day 2 (July 25, 2018), especially in the afternoon, indicating lateral dispersion. At RM 2.7, mixing was still evident throughout the day on the second day of treatment (see Table 2-3).

2.6 Flow Monitoring and Management

Flow monitoring and management were integral components of the Project. This section provides an overview of the flow monitoring methodology, management actions taken by Canal Corp., and general trends evident in the flow data collected during the monitoring period.

2.6.1 Flow Monitoring

E & E personnel programmed and installed flow meters prior to the application of the herbicide in order to help Canal Corp. manage the flows in the Erie Canal during the 48-hour treatment window. Prior to application, on July 11 and 12, 2018, E & E personnel set up a flow meter at each of the three following locations to test operations: North Tonawanda Botanical Gardens; near the East Canal Road/New Road Bridge in Pendleton; and near the Stevens Street bridge in Lockport (see Figure 2-7).

Flow in the creek/canal was measured prior to, during, and following herbicide application. Flow was calculated for each location as a function of the cross-sectional area and average cross-sectional velocity. Prior to deployment of flow sensors, on July 2 and 5, 2018, E & E obtained measurements of the creek/canal depth and instantaneous velocity in a cross section perpendicular to the flow direction. In general, depth measurements were recorded every 10 feet across the channel, and at each location velocity measurements were recorded 6 inches below the surface and at approximately 25%, 50%, and 75% of the total creek/canal depth, except where the creek/canal depth was too shallow to allow for four measurements. These data were used to create a depth profile and velocity profile at each location (see Appendix C). Velocity readings were measured using a Hach FH950 Handheld Flow Meter with electromagnetic sensor with a resolution of 0.01 foot per second (ft/s), an accuracy of ±2%, and a zero stability of 0.05 ft/s.

The velocity data were then contoured using the Surfer software package by Golden Software. The Kriging method of data interpolation was used to grid the data obtained in the field and resulting grid nodes outside of the measured stream channel were removed. Surfer was used to calculate univariate statistics for the interpolated dataset, including the mean cross-sectional velocity. The area within

the stream that represented the mean velocity ±20% was then highlighted to indicate areas within the stream where single, continuous velocity measurements could be obtained that would represent the approximate mean cross-sectional velocity (see Appendix C).

To continuously measure flow during the application period, single flow sensors were deployed at each monitoring location. Flow sensors were Hach Submerged AV, 1-megahertz acoustic Doppler flow sensors connected to a Hach FL900AV Flow Meter equipped with a Hach AV9000 Area-Velocity Analyzer Module. Each flow meter was equipped with a cellular modem to transmit data via Hach's Data Delivery Service for remote download and analysis. The flow sensors were positioned by E & E approximately 1 to 4 feet above the streambed using custom-made mounting systems. The sensors had a resolution of 0.01 ft/s, an accuracy of ±2%, a zero stability of 0.05 ft/s, and were capable of sensing both positive and negative velocities. They were oriented so that positive flow was recorded for the following conditions:

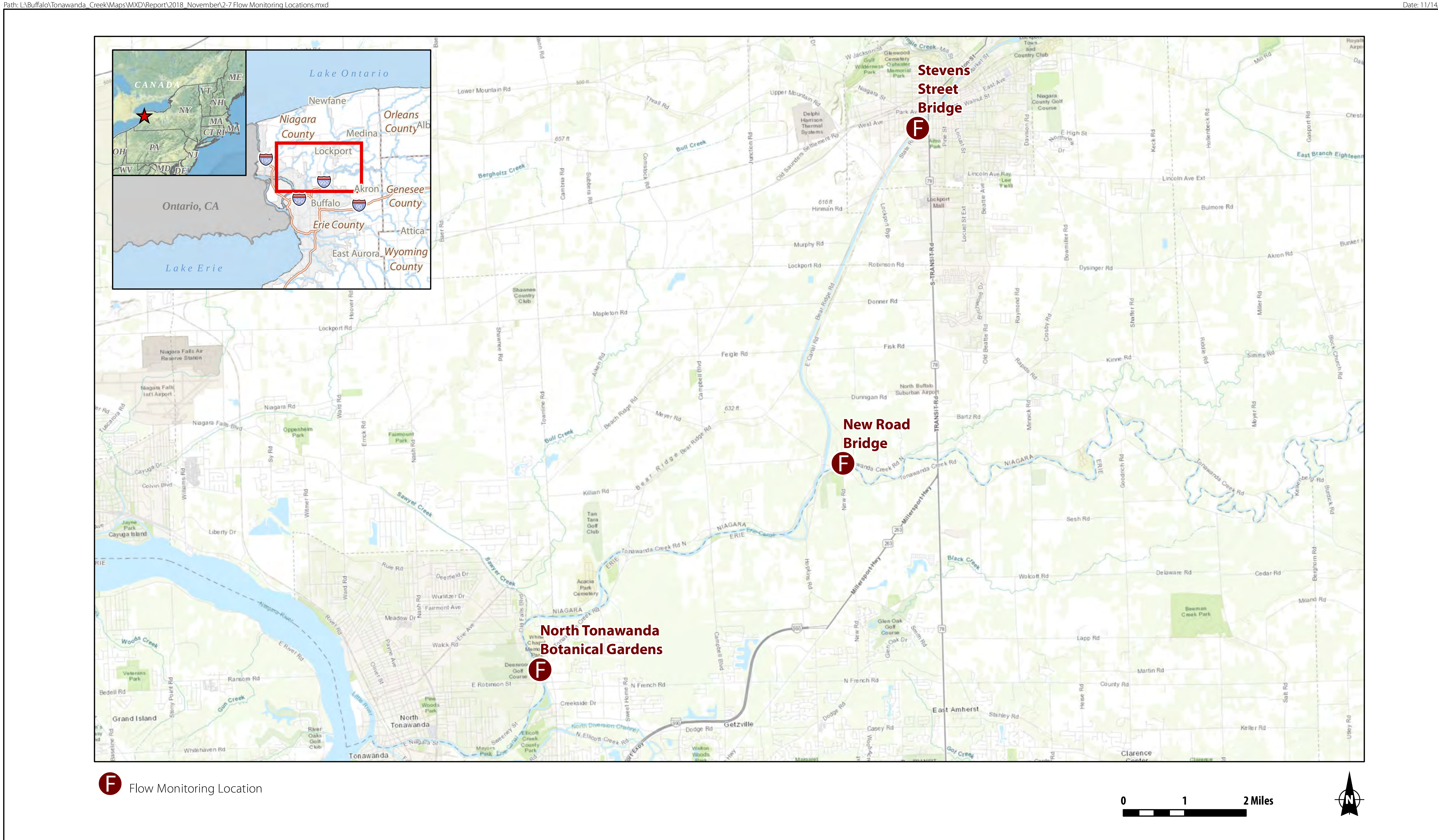
- South to north (away from the Niagara River) in Tonawanda Creek/Erie Canal at North Tonawanda Botanical Gardens;
- East to west (towards the canal) in Tonawanda Creek at New Road in Pendleton; and
- Northeast to southwest (towards the Niagara River) in the Erie Canal at Stevens Street in Lockport.

For each monitoring location, the cross-sectional area of the creek/canal was calculated using the depth measurements obtained prior to sensor deployment. The area of the stream below each sensor was calculated as a fixed area using Surfer software. The area above each sensor was calculated as a function of the water level (measured as height above the sensor) and stream bank geometry. Levels were measured using pressure transducers built into the flow sensors. The relationship between level above the sensor and cross-sectional area was determined using the depth measurements and a river profile area calculator provided by the equipment manufacturer. This calculator is based on simple trapezoidal sections of the river. The calculated areas were plotted against the levels and a line of linear interpolation was fit to the data using the basal area beneath the sensor as the intercept. The resulting formulas were used to calculate the total cross-sectional area based on the measured level. The relationships used for these calculations are depicted on the graphs in Appendix C.

Level and velocity measurements were recorded every 5 minutes. These data were saved in a spreadsheet format and the area was calculated as described herein. The product of the calculated area and measured velocity was then calculated to determine the average cross-sectional flow rate.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\2-7 Flow Monitoring Locations.mxd

Date: 11/14/2018



SOURCE: ESRI 2018; USACE ERDC 2018.

Figure 2-7 Flow Monitoring Locations

Tonawanda Creek, Erie and Niagara Counties, New York

All monitoring stations successfully recorded flow before, during, and after treatment. During treatment, flow at the all stations fluctuated as a function of water level, which was influenced by the Niagara River levels and New York Power Authority (NYPA) operations. Flow rate also responded to fluctuations in velocity. This is reflected in the flow, velocity, and level graphs in Appendix D.

Hourly updates were provided to USACE regarding flow conditions observed over the previous hour at each monitoring location between the hours of 8 a.m. and 6 p.m. For the overnight hours, hourly flow data was compiled and provided to USACE the following morning.

2.6.2 Flow Management

Water passes through Canal Corp. Locks 34/35 in three ways: 1) through the bypass tunnel, 2) through the miter gates of Locks 34/35, and 3) through the Flight of Five gates, which are associated with Old Locks 67 and 71 and located immediately north of Locks 34/35 (Manns 2014). During herbicide application, Canal Corp. closed the bypass tunnel and operations of Locks 34/35 were kept to a minimum, leaving water to be directed through the Flight of Five gates. In order for Canal Corp. to control the amount of flow through Locks 34/35, the Brookfield Power Plant was taken off-line. In addition, Canal Corp. controlled the water level between Lockport and the Genesee River by taking the RG&E Power Plant at Station 26 on the Genesee River off-line.

Prior to the 48-hour treatment period on July 24 and 25, 2018, Canal Corp. ceased flows out of Lockport by closing the bypass gate opening at approximately 0800 hours on July 24, 2018. As stated above, Canal Corp. reported that they were operating at 50 cfs. Canal Corp. minimized lock operations, which continued during the treatment period. Typically, when Locks 34/35 are filled, this causes a short-term increase in flow rate towards the locks at the Stevens Street Bridge (east) and a drop in water level. Several lock fills were observed in the level data obtained near the Stevens Street Bridge showing sudden decreases in level and flow direction towards the locks (away from the Niagara River) (see Appendix D). The bypass gate was reopened at approximately 1300 hours on July 26, 2018.

Canal Corp. stopped flow again at 1200 hours on August 22, 2018, for the spot treatment on August 23, 2018, and resumed flow at 0900 hours on August 24, 2018. No flow monitoring was conducted for the August spot treatment.

2.6.3 Flow Observations

As part of its relicensing studies, the NYPA reviewed natural and man-made factors affecting water levels in the upper and lower Niagara River (URS Corporation et al. 2005a). In the upper river, the NYPA found that regulation of the river level in the Chippawa-Grass Island Pool (downstream from the northern tip of Grand Island) has a more pronounced effect on river levels during the tourist season (April 1 to October 31). This is because the pool level is cycled more fully between day and nighttime to maintain the required flows at Niagara Falls. During non-tourist hours (nighttime), the pool is generally maintained at a

lower water level than during the day. However, the change in pool level is gradual, and on a typical day, the water level in the pool is at a maximum at 0700 hours; it is drawn down during the day for power production and is generally lowest at 2100 hours. During the tourist season, the daily median water level fluctuation at Tonawanda Island was recorded at 0.55 feet (versus 0.43 feet during the non-tourist season). Water levels were generally higher in the Niagara River during the spring and summer due to generally higher natural outflow from Lake Erie.

The effects of Niagara River water level fluctuations on tributaries were also studied (URS Corporation et al. 2005b). Fluctuations in Niagara River water levels affect Tonawanda Creek/Erie Canal throughout the entire length of the study area, which extended from the confluence with the Niagara River to 10,570 feet upstream (modeling beyond this distance was not performed in this study). Based on the analysis of the creek/canal profile, this study suggests that the influences from the median Niagara River level extend approximately 13.7 miles upstream in Tonawanda Creek to two riffle areas (rocky or shallow parts of a stream or river with rough water), which act as hydraulic controls limiting the river's upstream influence.

The effects of the drawdown of the Niagara River level by the NYPA were evident in the water level data obtained during this project (see Appendix D). The water level at North Tonawanda Botanical Gardens exhibited a cyclic behavior on an approximately daily cycle. Similar cyclic fluctuations in level were also observed at the Pendleton and Lockport monitoring locations; although the magnitude of the fluctuations was less than that observed in North Tonawanda and had other changes in level superimposed on the daily cycle. During 2017, the water level in the creek/canal near the Niagara River (Botanical Gardens flow monitoring location) was generally at its highest in the late morning/early afternoon (1100 to 1400 hours) and then decreased to a minimum between 2200 and 0600 hours, with a magnitude change of 0.4 to 0.6 feet. Measurements in 2018 showed the maximum water level generally occurring in the late morning/early afternoon (1000 to 1400 hours) with a few exceptions, likely due to rain events. Minimum water levels were generally observed overnight (2200 to 0600 hours), with a magnitude change between 0.5 and 0.7 feet. Anomalies in this pattern were likely due to heavy rains. Fluctuations in flow generally followed patterns of fluctuations in water level. At North Tonawanda Botanical Gardens, the flow rate was generally 1,500 cfs or less, primarily to the north (away from the river) with lower magnitude flow fluctuations to the south (toward the river) (see Appendix D).

At the Stevens Street monitoring station, flow rates were generally below 1000 cfs, averaging 250 cfs to the northwest (toward the locks) prior to the treatment period. During treatment, flows were the same with fewer high magnitude fluctuations directed to the west. Before and during treatment, there were a few instances of high flows towards the west (up to 1,670 cfs) likely due to boat traffic. Following resumption of flow at the locks and bypass gates on July 26,

2018, flow rates increased again to an average of 200 to 250 cfs to the west (see Appendix D).

Flows out of the natural channel of Tonawanda Creek (near East Canal/New Road) were generally measured between 0 and 100 cfs before and during treatment. Some fluctuations in flow direction were likely due to the backwater influence of the canal (resulting from changes in Niagara River level and changes in lock status in Lockport), creating westward flow. The typical flow is corroborated by the U.S. Geological Survey (USGS) gauging station data on Tonawanda Creek in Rapids, New York (USGS Station Number 04218000). Flow was highest on July 27, mirroring the peak flow at the USGS gage of 428 cfs (USGS 2018).

3 Study Improvements

The study improvements, summarized below, were based on lessons learned from previous years' endothall application efforts, coordination with the study partners during the 2018 treatment season, and activities conducted during the 2018 herbicide application.

3.1 Herbicide Application and Analysis

There have been no issues with herbicide handling since the Project's inception in 2014 at the public launch areas, and public access to the boat ramps continued to be uninterrupted while used by the applicators.

The immunoassay tests performed to determine endothall concentrations during the 2018 application were effective at detecting the herbicide and for tracking its movement and degradation.

3.2 Flow Monitoring and Management

Various improvements were implemented pertaining to flow monitoring and management as described below.

Flow Resolution and Fluctuation

Hach submerged AV, 1-megahertz acoustic Doppler flow sensors connected to Hach FL900AV flow meters equipped with Hach AV9000 area-velocity analyzer modules were deployed again in 2018, as they have been since 2015. The sensors had a resolution of 0.01 ft/s, an accuracy of ±2%, a zero stability of 0.05 ft/s, and were capable of sensing both positive and negative velocities. This sensitivity of instrumentation allowed for a better flow rate resolution. Issues with sensors tipping due to boat traffic observed in 2017 did not occur in 2018. No adjustments to the sensors or deployment will be required in 2019.

Canal Corp. Operations

After the initial demonstration in 2014, it was determined that one of the most important aspects to maximize herbicide contact time was to reduce operations of the Lockport locks and bypass gate flow to the maximum extent practicable. After eliminating flow to the east through the locks, the only significant input remaining is that from the natural channel of Tonawanda Creek entering the canal in Pendleton, New York. The flow rate of Tonawanda Creek averaged 90 cfs during the 2018 application period (USGS 2018, Rapids, NY stream gauge). This inflow rate can be matched at Lockport by operating the bypass gate at a

comparable flow rate. However, rainstorms experienced before the application period (on Sunday, July 22, 2018) and on the second day of the treatment (Wednesday, July 25, 2018) influenced flow during the 2018 application. It is recommended that flows be reduced to the 50 cfs rate 24 hours prior to the start of the herbicide application, in addition to the 48-hour period of application. Flow reductions at 24 hours preceding treatment would help with flow stabilization during the herbicide application; this is especially critical if there is rain preceding or during the treatment, as there was in 2018. There are additional flow inputs to the canal such as stormwater ditches and small tributaries, but these flows are typically insignificant based on direct observations made during sampling events. Fluctuations in the level of the Niagara River resulting from NYPA operations also affects flow within the canal; however, this cannot be controlled and flows within the canal should continue to be monitored during future application periods in order to inform decisions regarding changes in lock and bypass gate operation in Lockport to balance changes in flow.

Flow Monitoring Locations

No issues with meter tipping were noted at the three monitoring locations and ease of access existed. It is anticipated that the three locations used in 2018 will be repeated in 2019. However, the deployment location within each stream section should be evaluated for stability prior to subsequent deployments. The height of the sensor above the streambed must be known, so the structure used to secure the sensor must itself be stable and vertical within the water. Areas outside navigation channels and away from docks should continue be used to the extent practicable in order to minimize the effects of turbulence caused by boat traffic. Even if the same monitoring locations are used in the future, it is recommended to obtain new velocity and depth cross-sectional measurements at each monitoring location prior to application events. Both the cross-sectional area and locations representative of the average velocity may vary from year to year as a result of erosion, deposition, dredging, construction, etc.

Potential Discrepancies between Flow Monitoring Data and Visual Flow Observations

USACE Buffalo noted that there were instances in which flow rates reported through the monitoring efforts did not match what they saw on the water or what the herbicide monitoring showed. This could be due to local flow variations caused by flow contributed by tributaries, though as indicated above, these are typically considered insignificant inputs. To help to address these potential discrepancies in the future, written notes regarding flow observations should be made during such instances. Notes should include date/time/location of visual observations of potential flow discrepancies. This will allow field observations to be reviewed along with flow monitoring data and precipitation and wind data. Additionally, USACE could perform spot velocity measurements using an instantaneous velocity meter provided by E & E.

3.3 2018 Lessons Learned

Treatment Areas

As more spot-treatment areas will likely be involved in future work, these areas will probably be added and modified according to the ERDC survey work before application. Modifying or adding treatment areas in the field on the day of treatment will require the applicator to be prepared to upload new information into the GPS units that are used for navigation to ensure accurate herbicide placement.

Herbicide Type and Volumes

For future management with chelated copper, to facilitate optimal treatment efficiency, the applicator should ensure that the chelated copper crystals are appropriately sized for the distribution equipment to be used. Initially in 2018, the crystal size was too large for the granular spreader and a new formulation was obtained from SePRO.

If feasible, utilize bubble curtains in lieu of limnocorrals for future treatments. Bubble curtains have advantages over limnocorrals with respect to ease of use as well as the ability to achieve a deeper area below the water's surface for treatment. Additionally, with the use of a limnocorral, there is a risk that someone might cut the lines that secure it to the shore; that risk would be eliminated with the use of a bubble curtain.

Where limnocorrals/bubble curtains are used, verify that they are the correct size and that they fit the area where they are used. This was an issue during the 2018 treatments, as one of the USACE bubble curtains did not go all the way across the area to be treated. Lastly, in areas where dilution may play a greater factor, increase the chelated copper dosage in smaller treatment areas. This is especially important in open water areas where a lot of water is passing through them. Two examples of such areas are copper treatment plots 3 (near Mayor's Park) and 13 (just downstream of Threemile Island and the Dog Park) from the August 23, 2018 spot treatment (see Figures 2-6a and 2-6d).

Sampling Locations

In the 2017 post-treatment assessment report, it was recommended that dispersion of endothall along the length of the creek could be tracked by a few additional sample locations aligned with the "upstream" and "downstream" ends of the treatment areas. It was recommended that sampling locations be picked to coordinate with the treatment area locations and to establish longitudinal dispersion of endothall within the treatment areas. These recommendations were implemented in 2018 by ERDC during the 48-hour application period on July 24 and 25, 2018. Sampling points were concentrated within the delineated endothall treatment areas (see Appendix A). E & E sampling took a broader look by sampling up and downstream of the delineated endothall treatment areas, from RM 0 up to RM 15.

Communication

As the Project enters its maintenance phase, it is critical to maintain one point of contact for the client and each subcontractor and Project stakeholder for efficient communication of needs.

4 References

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A Water Quality Sampling Location Maps

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A1

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A2
Tonawanda Creek/Erie Canal
Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- USACE Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A3

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- USACE Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A4
Tonawanda Creek/Erie Canal
Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- USACE Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A5

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- USACE Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A6
Tonawanda Creek/Erie Canal
Erie and Niagara Counties, New York

11 NW (ppm)
2 HAT (7/24/18): 0.23
4 HAT (7/24/18): 0.05
19 HAT (7/25/18): 0.79
23 HAT (7/25/18): 0.11
26 HAT (7/25/18): 0.326

11 SE (ppm)
2 HAT (7/24/18): 0.38
4 HAT (7/24/18): 0.29
19 HAT (7/25/18): 0.72
23 HAT (7/25/18): 0.18
26 HAT (7/25/18): 0.392

11 CENTER (ppm)
2 HAT (7/24/18): 0.25
4 HAT (7/24/18): 0.53
19 HAT (7/25/18): 0.72
23 HAT (7/25/18): 0.21
26 HAT (7/25/18): ns

H04.0LB (ppm)
July 26, 2018: 1.30
July 27, 2018: ND

H04.0RB (ppm)
July 26, 2018: 1.21
July 27, 2018: 0.02

12 CENTER (ppm)
2 HAT (7/24/18): ND
4 HAT (7/24/18): 0.61
19 HAT (7/25/18): 1.00
23 HAT (7/25/18): 0.28
26 HAT (7/25/18): 0.456

12 SE (ppm)
2 HAT (7/24/18): 0.48
4 HAT (7/24/18): 2.25
19 HAT (7/25/18): 1.08
23 HAT (7/25/18): ND
26 HAT (7/25/18): 0.429

12 NW (ppm)
2 HAT (7/24/18): 0.05
4 HAT (7/24/18): 0.06
19 HAT (7/25/18): 0.83
23 HAT (7/25/18): 0.53
26 HAT (7/25/18): 0.515

13 CENTER (ppm)
2 HAT (7/24/18): 0.26
4 HAT (7/24/18): 1.07
19 HAT (7/25/18): 1.00
23 HAT (7/25/18): 0.51
26 HAT (7/25/18): ns

13 NW (ppm)
2 HAT (7/24/18): ND
4 HAT (7/24/18): 0.40
19 HAT (7/25/18): 1.01
23 HAT (7/25/18): 0.78
26 HAT (7/25/18): 0.711

13 SE (ppm)
2 HAT (7/24/18): ND
4 HAT (7/24/18): 3.81
19 HAT (7/25/18): 1.22
23 HAT (7/25/18): 0.68
26 HAT (7/25/18): 0.567

MP 4

Old Falls Blvd
Tonawanda Creek Rd
Summerset Ln
E Summerset Ln
Sweeney St
Niagara Falls Blvd
62
Erie County
Niagara County
Tonawanda Creek
E Robinson St
E Robinson Rd
Old Niagara Falls Blvd
N French Rd

Legend
- E&E Sample Location
- USACE Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

N

SCALE
0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A7
Tonawanda Creek/Erie Canal
Erie and Niagara Counties, New York

Legend

- USACE Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

SCALE

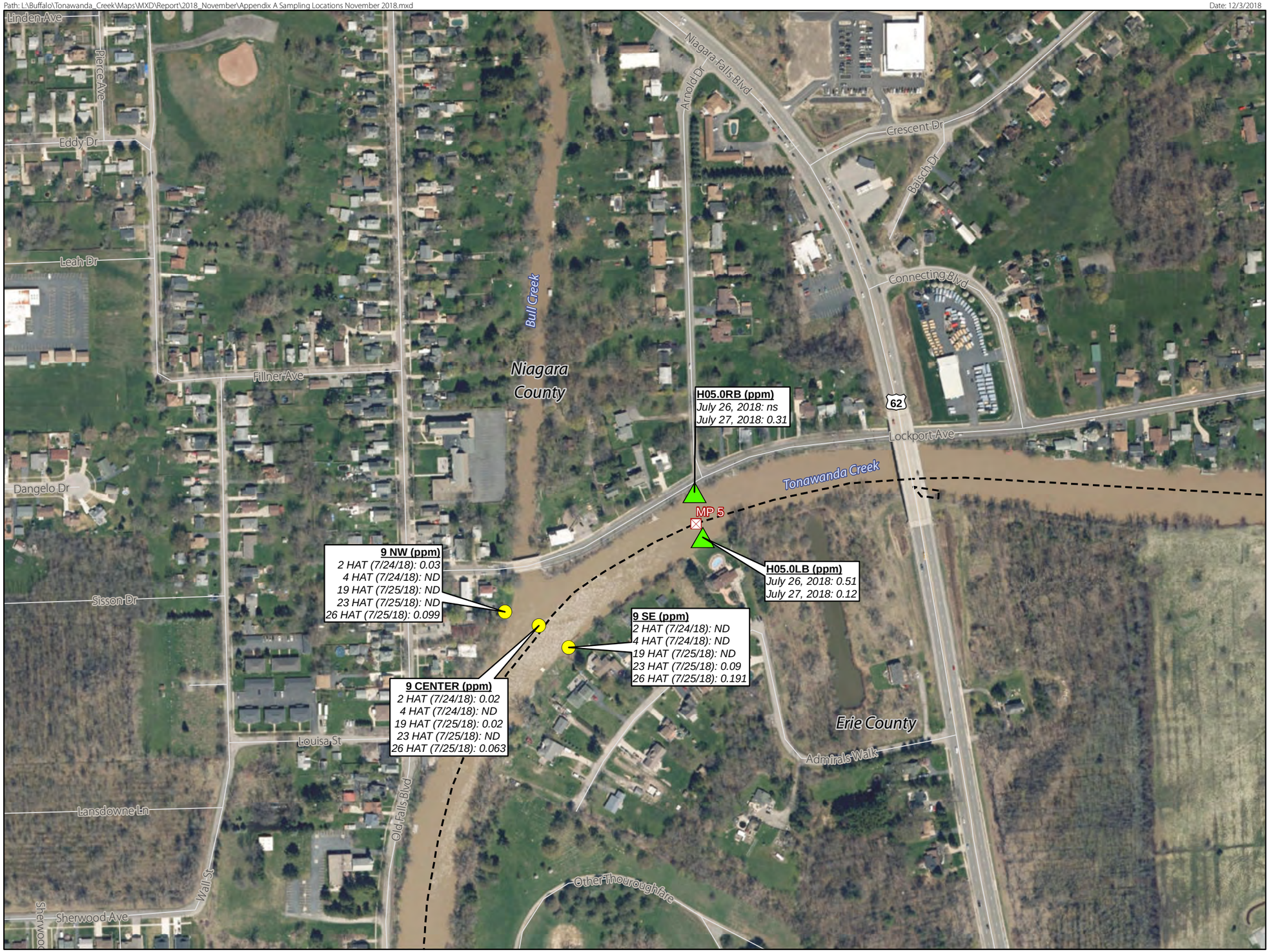
0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A8
Tonawanda Creek/Erie Canal
Erie and Niagara Counties, New York



Legend

- E&E Sample Location
- USACE Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

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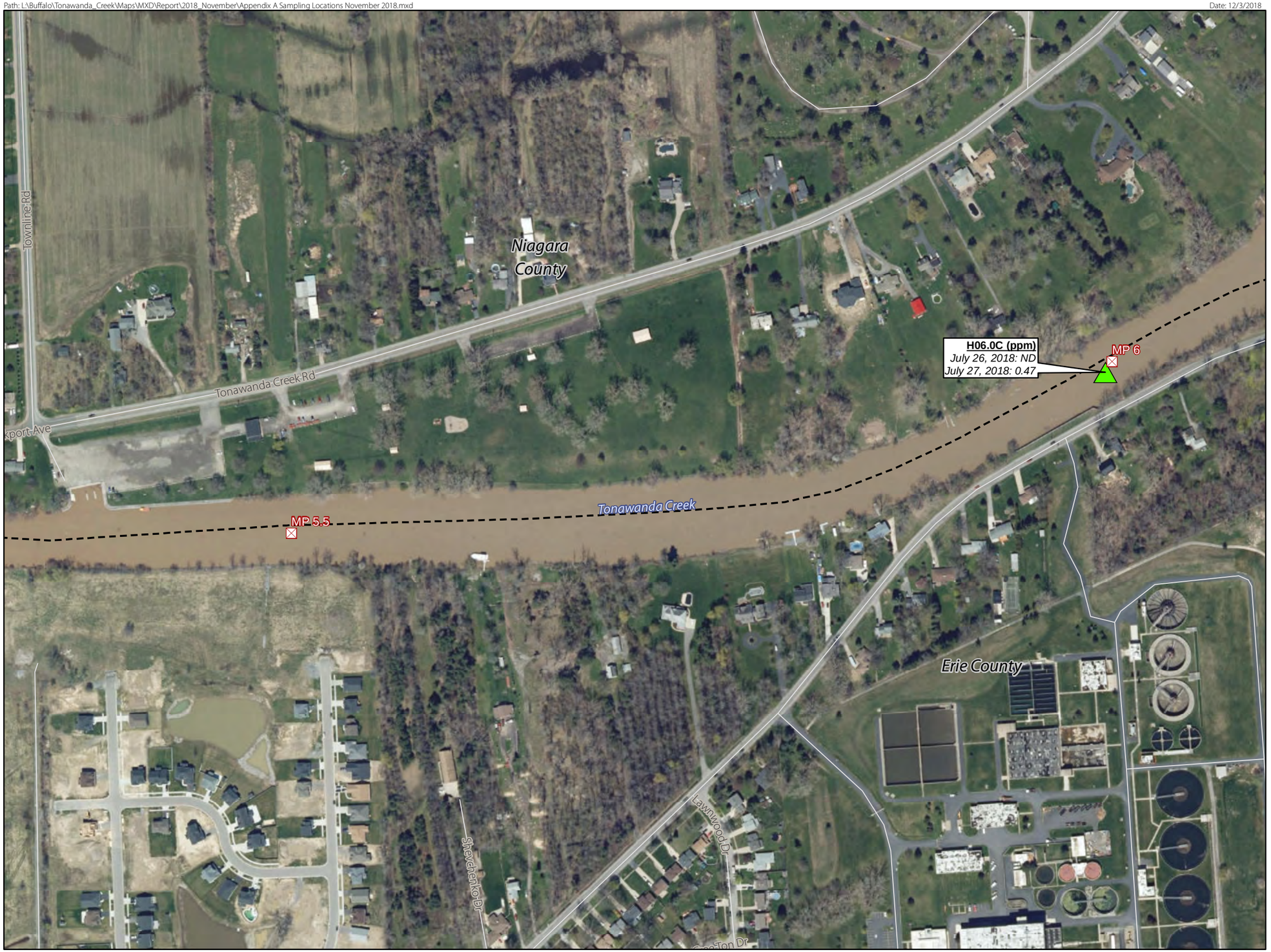

Water Sample Locations and Associated Herbicide Concentration Values
Figure A9

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A10
Tonawanda Creek/Erie Canal
Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A11

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018;
Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A12

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018;
Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

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Water Sample Locations and Associated Herbicide Concentration Values
Figure A13
Tonawanda Creek/Erie Canal
Erie and Niagara Counties, New York

Legend

- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Note: All sample locations are approximate.
ppb = parts per billion

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

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Water Sample Locations and Associated Herbicide Concentration Values
Figure A14

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

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Water Sample Locations and Associated Herbicide Concentration Values
Figure A15

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

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Water Sample Locations and Associated Herbicide Concentration Values
Figure A16

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Note: All sample locations are approximate.
ppb = parts per billion

N

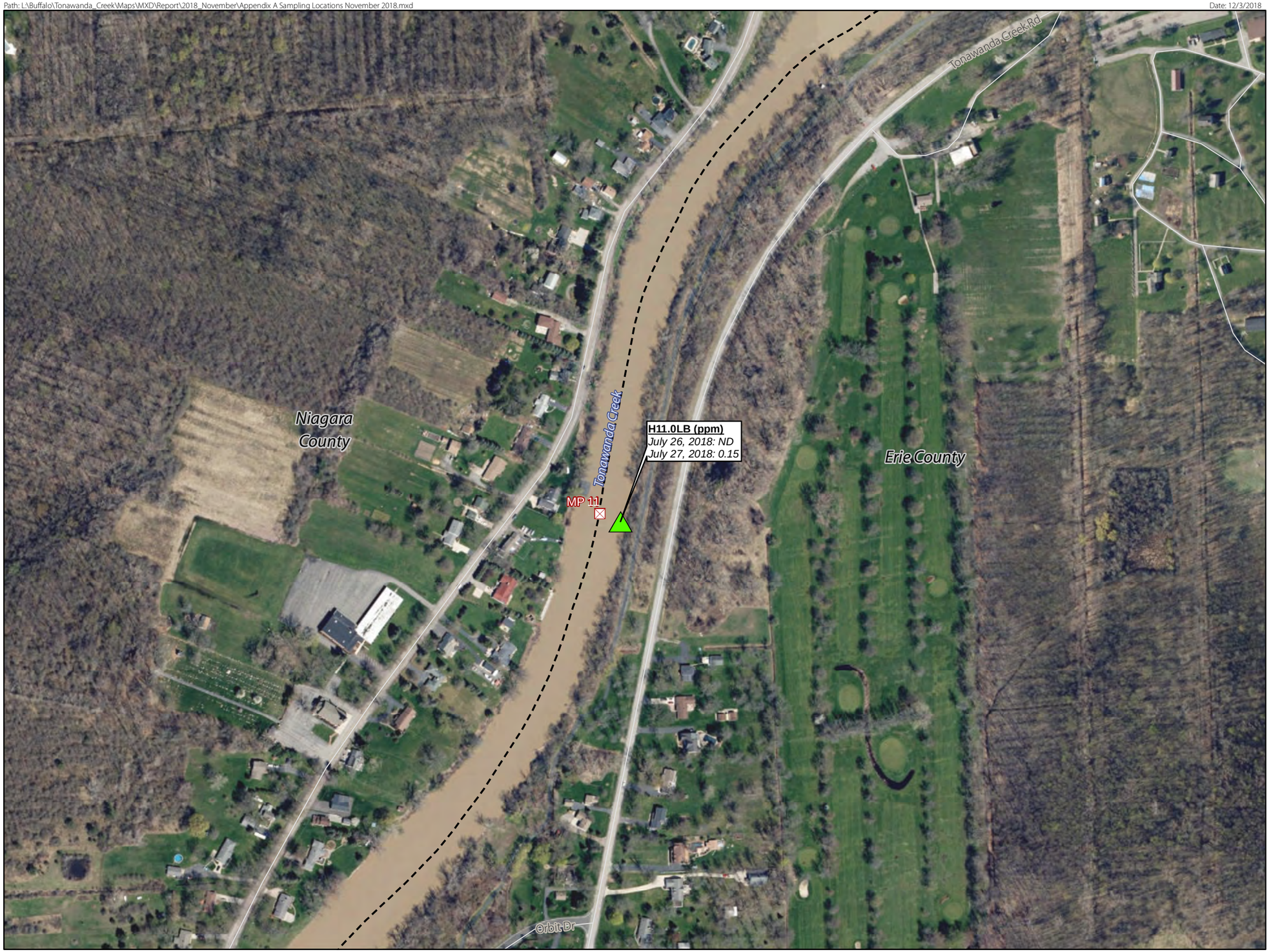
SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018;
Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018



Water Sample Locations and Associated Herbicide Concentration Values
Figure A17
Tonawanda Creek/Erie Canal
Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

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Water Sample Locations and Associated Herbicide Concentration Values
Figure A18
Tonawanda Creek/Erie Canal
Erie and Niagara Counties, New York

Legend

- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- County Boundary
- Roadway

*Note: All sample locations are approximate.
ppb = parts per billion

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018;
Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

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Water Sample Locations and Associated Herbicide Concentration Values
Figure A19
Tonawanda Creek/Erie Canal
Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

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Water Sample Locations and Associated Herbicide Concentration Values
Figure A20

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

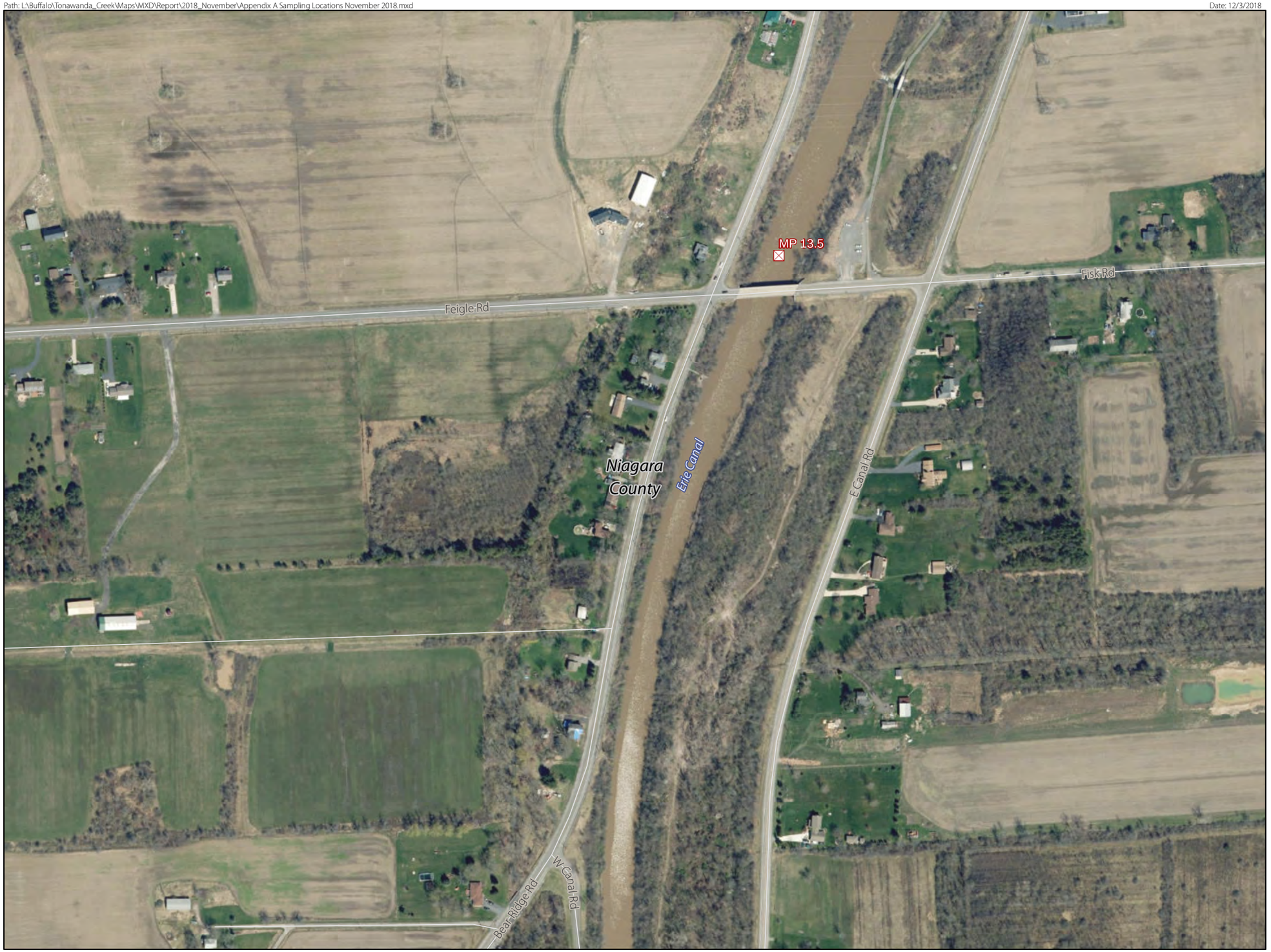
SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018;
Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018



Water Sample Locations and Associated Herbicide Concentration Values
Figure A21

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- Roadway

*Note: All sample locations are approximate.
ppb = parts per billion

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A22

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

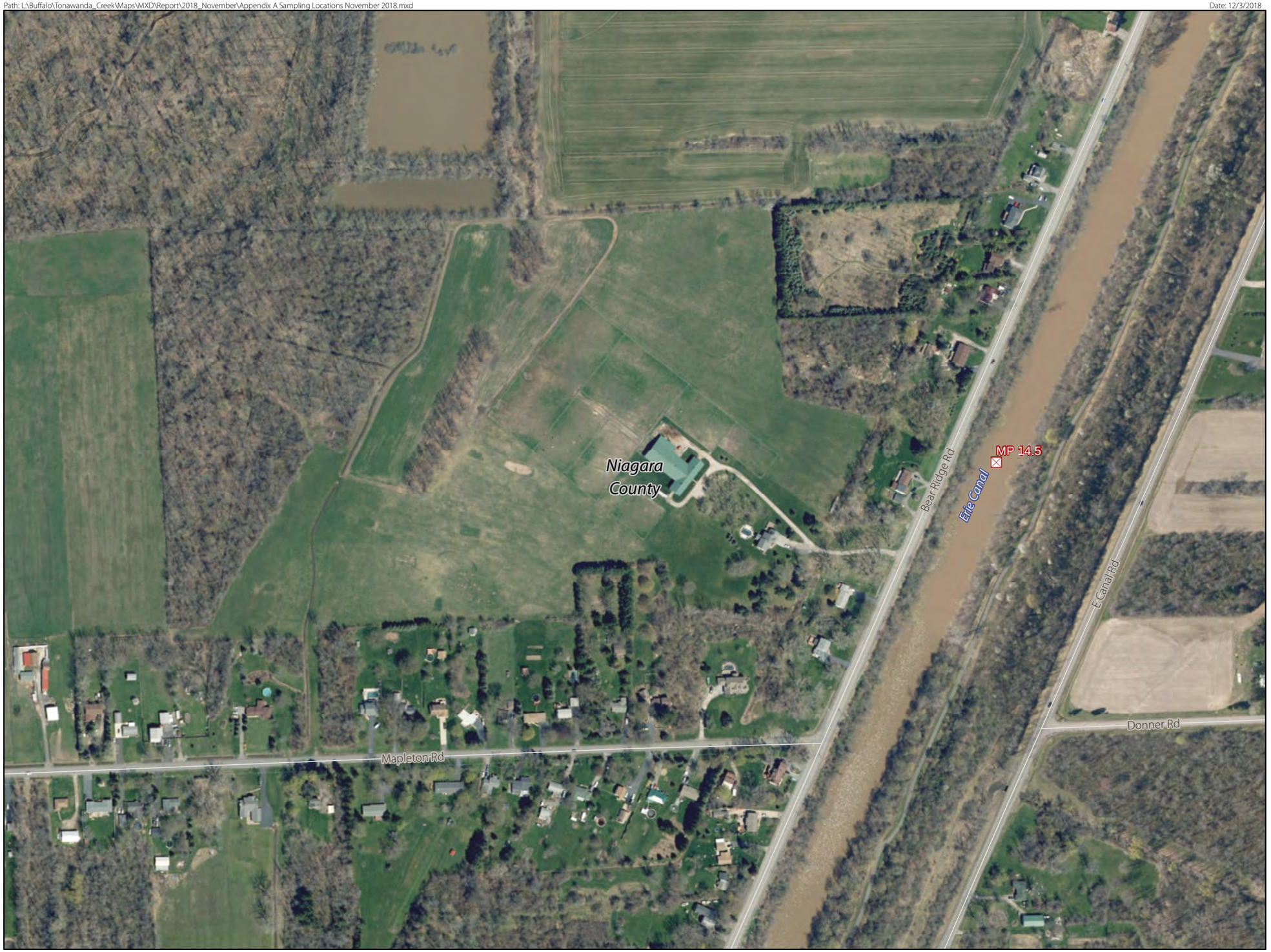
SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018; Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018



Water Sample Locations and Associated Herbicide Concentration Values
Figure A23

Tonawanda Creek/Erie Canal

Erie and Niagara Counties, New York

Legend

- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- Roadway

*Note: All sample locations are approximate.
ppb = parts per billion

N

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018;
Ecology and Environment, Inc. 2018; USACE ERDC 2018.

Path: L:\Buffalo\Tonawanda_Creek\Maps\MXD\Report\2018_November\Appendix A Sampling Locations November 2018.mxd

Date: 12/3/2018

Water Sample Locations and Associated Herbicide Concentration Values
Figure A24

Tonawanda Creek/Erie Canal
Erie and Niagara Counties, New York

Legend

- E&E Sample Location
- Milepost from Mouth of Creek/Canal
- Endothall Treatment Area
- Roadway

*Notes: All sample locations are approximate.
ppb = parts per billion
HAT = hours after treatment
nd = non-detect
ns = not sampled

SCALE

0 0.05 0.1 Miles

SOURCE: ESRI 2012; ESRI 2018;
Ecology and Environment, Inc. 2018; USACE ERDC 2018.

B Photo Log

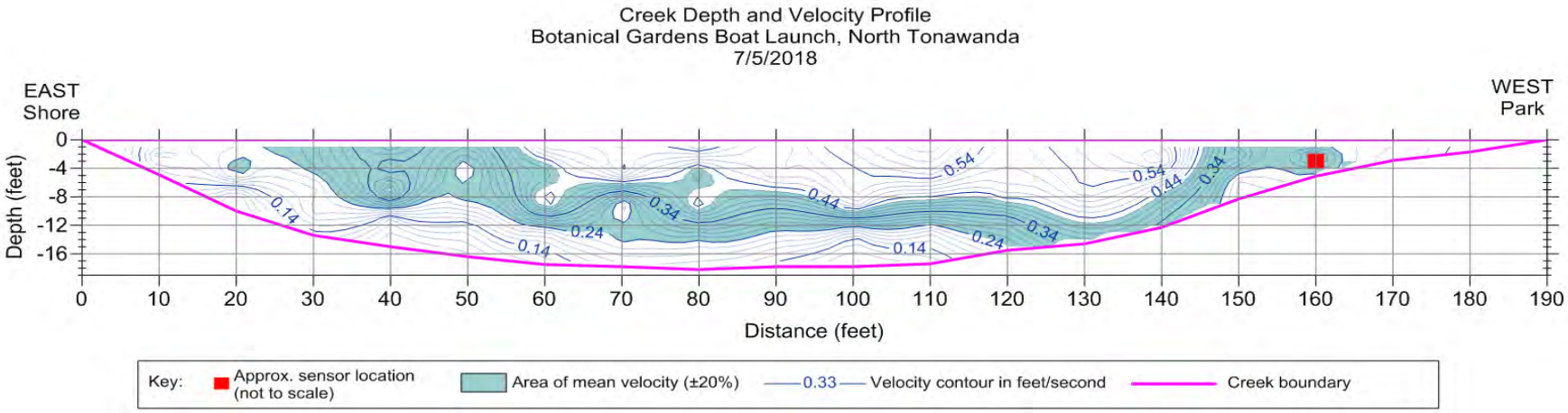
Photo 1 Velocity profiling, July 5, 2018.

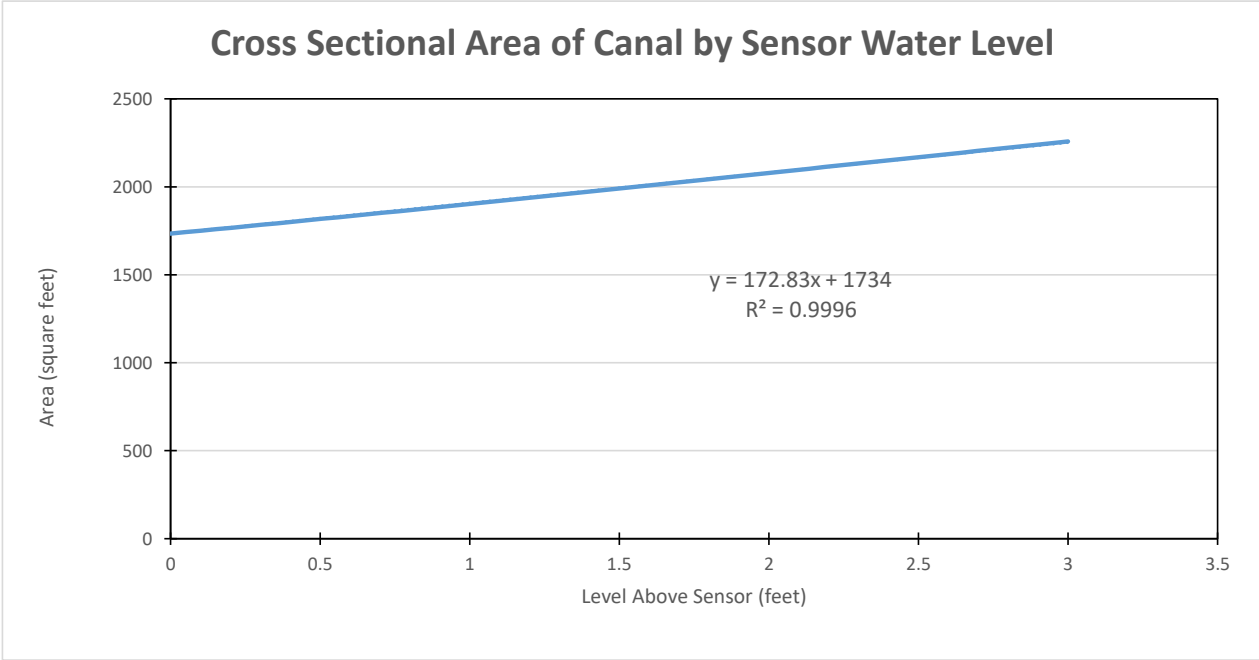
Photo 2 Velocity profiling, July 5, 2018.

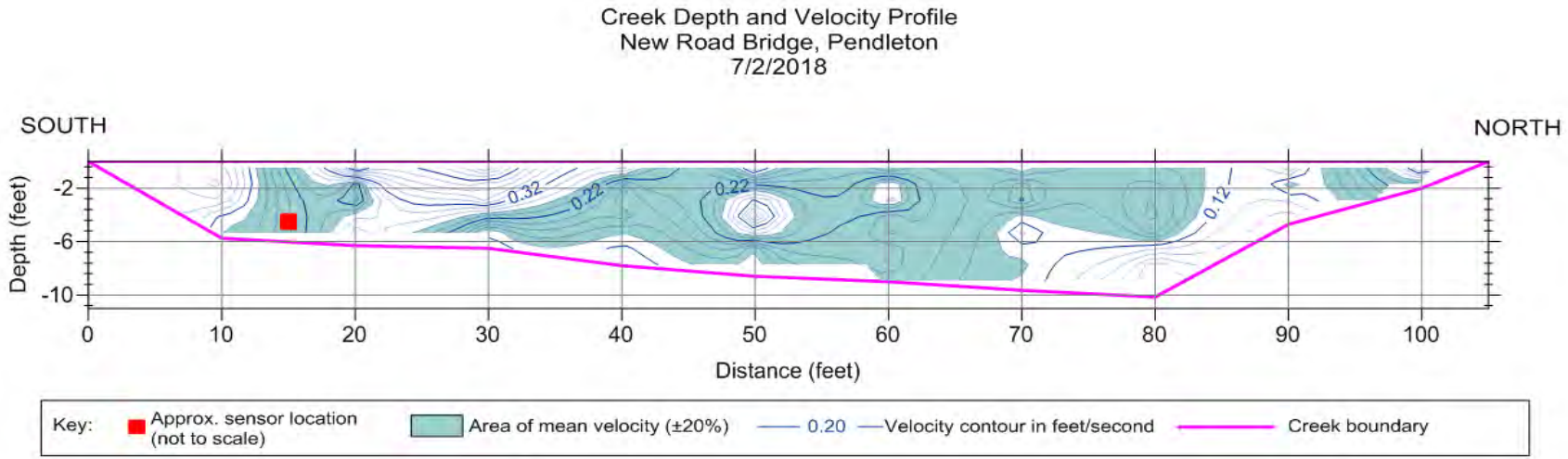
Photo 3 Water sampling July 28, 2018.

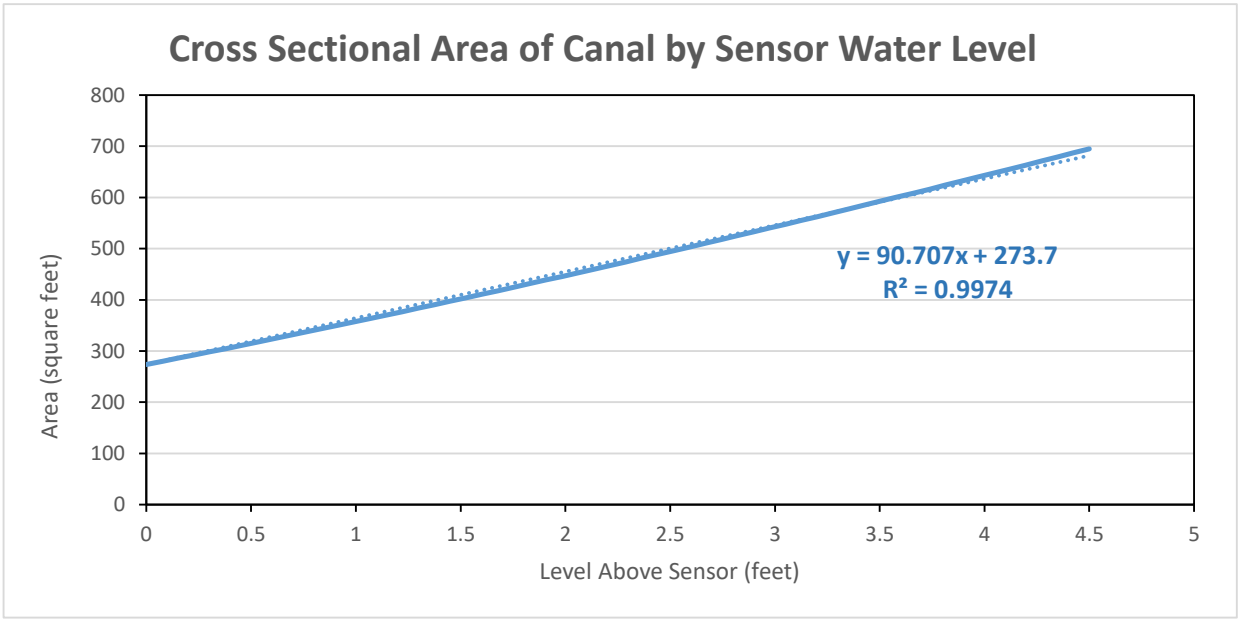
Photo 4 Water sampling near Wardell Marina, July 28, 2018.

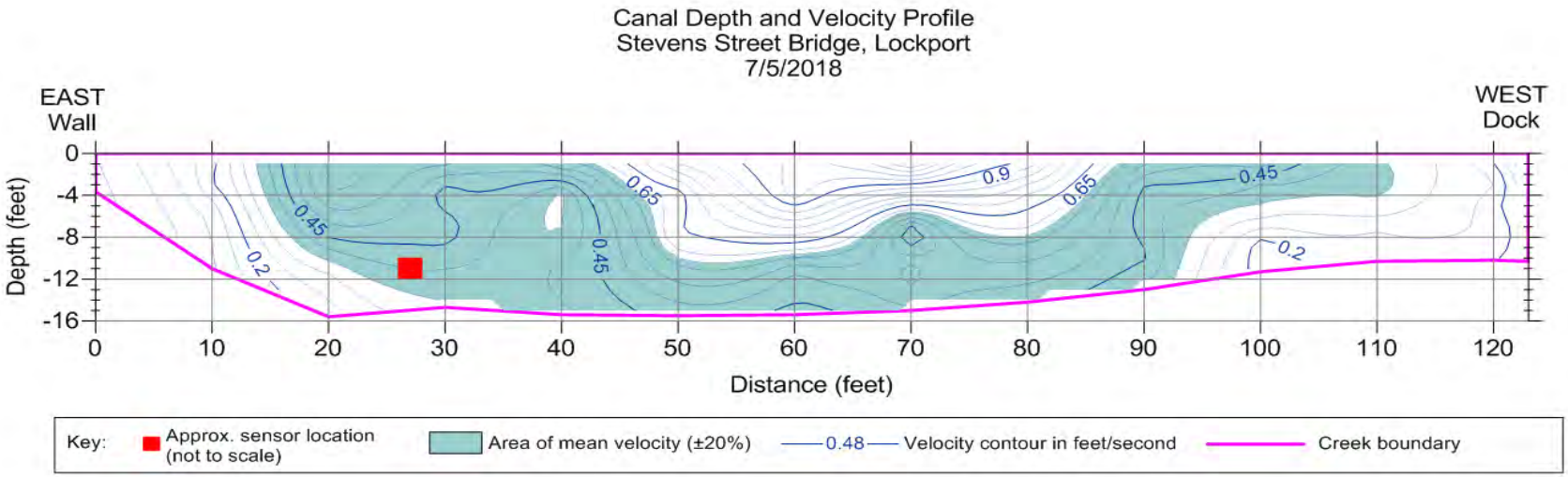
C Creek Cross Sections at Monitoring Locations

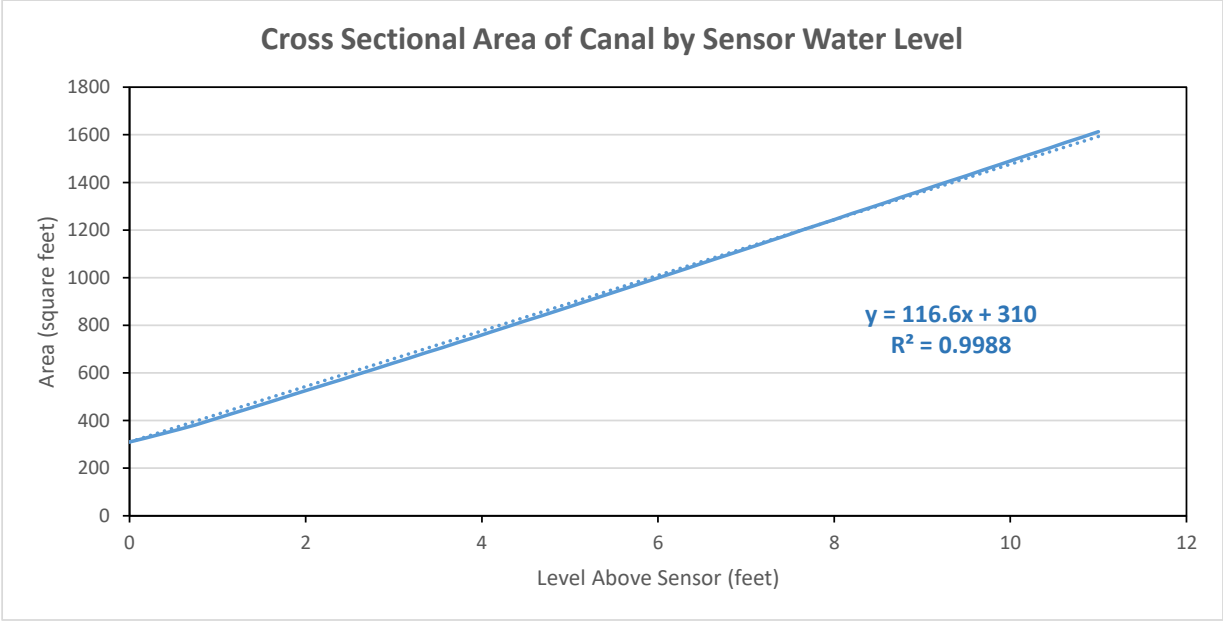

Creek Depth and Velocity Profile
Botanical Gardens Boat Launch, North Tonawanda
7/5/2018
EAST
Shore
WEST
Park
Depth (feet)
0
-4
-8
-12
-16
0.14
0.24
0.34
0.44
0.54
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190
Distance (feet)
Key:
Approx. sensor location (not to scale)
Area of mean velocity (±20%)
0.33
Velocity contour in feet/second
Creek boundary


Cross Sectional Area of Canal by Sensor Water Level
Area (square feet)
2500
2000
1500
1000
500
0
y = 172.83x + 1734
R² = 0.9996
0 0.5 1 1.5 2 2.5 3 3.5
Level Above Sensor (feet)


Creek Depth and Velocity Profile
New Road Bridge, Pendleton
7/2/2018
SOUTH
NORTH
Depth (feet)
-2
-6
-10
0
10
20
30
40
50
60
70
80
90
100
Distance (feet)
0.32
0.22
0.22
0.12
Key:
Approx. sensor location (not to scale)
Area of mean velocity (±20%)
0.20
Velocity contour in feet/second
Creek boundary

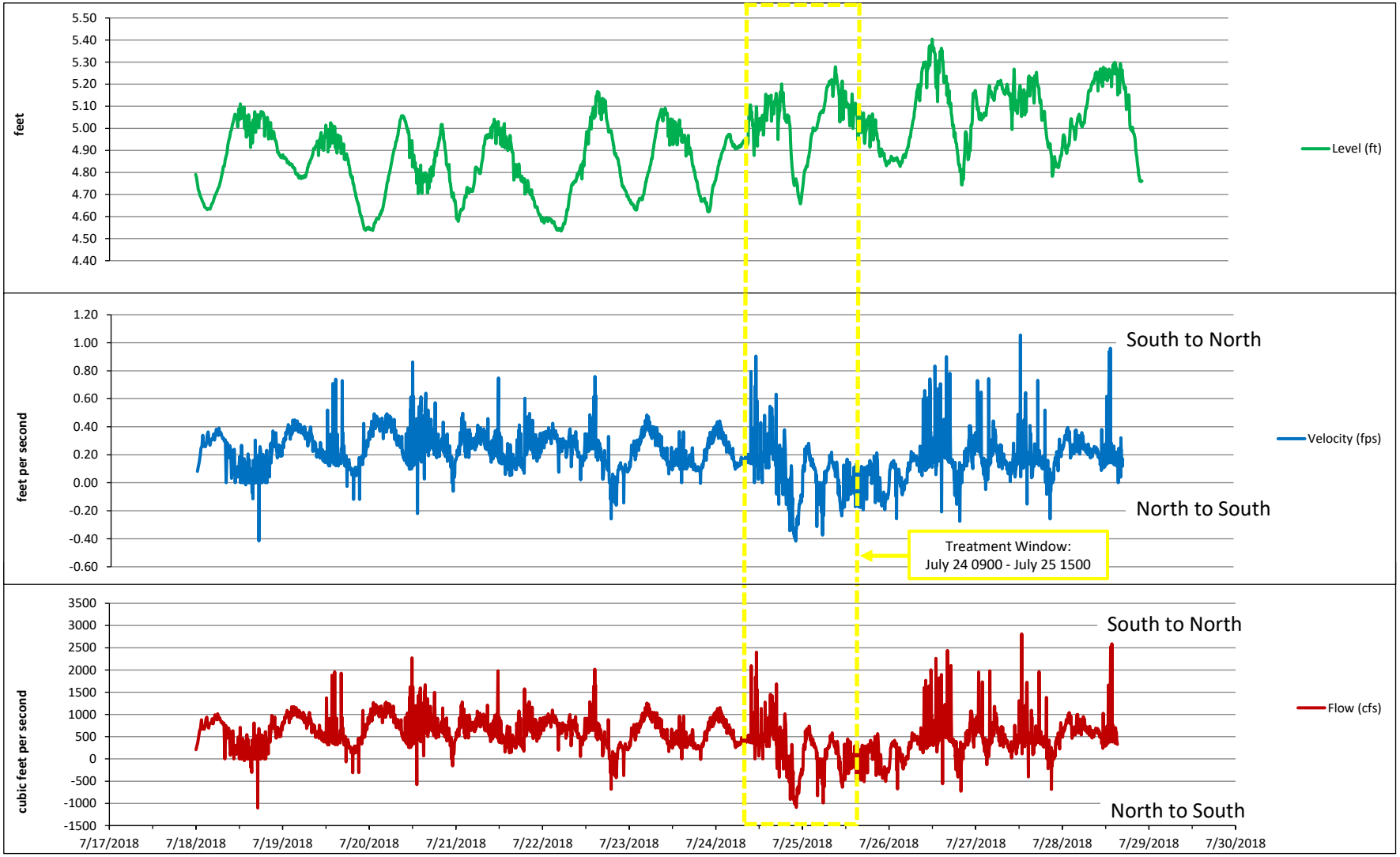

Cross Sectional Area of Canal by Sensor Water Level
Area (square feet)
800
700
600
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Level Above Sensor (feet)
y = 90.707x + 273.7
R² = 0.9974


Canal Depth and Velocity Profile
Stevens Street Bridge, Lockport
7/5/2018
EAST
Wall
WEST
Dock
Depth (feet)
0
-4
-8
-12
-16
0
10
20
30
40
50
60
70
80
90
100
110
120
Distance (feet)
0.2
0.45
0.65
0.9
Key:
Approx. sensor location (not to scale)
Area of mean velocity (±20%)
0.48
Velocity contour in feet/second
Creek boundary

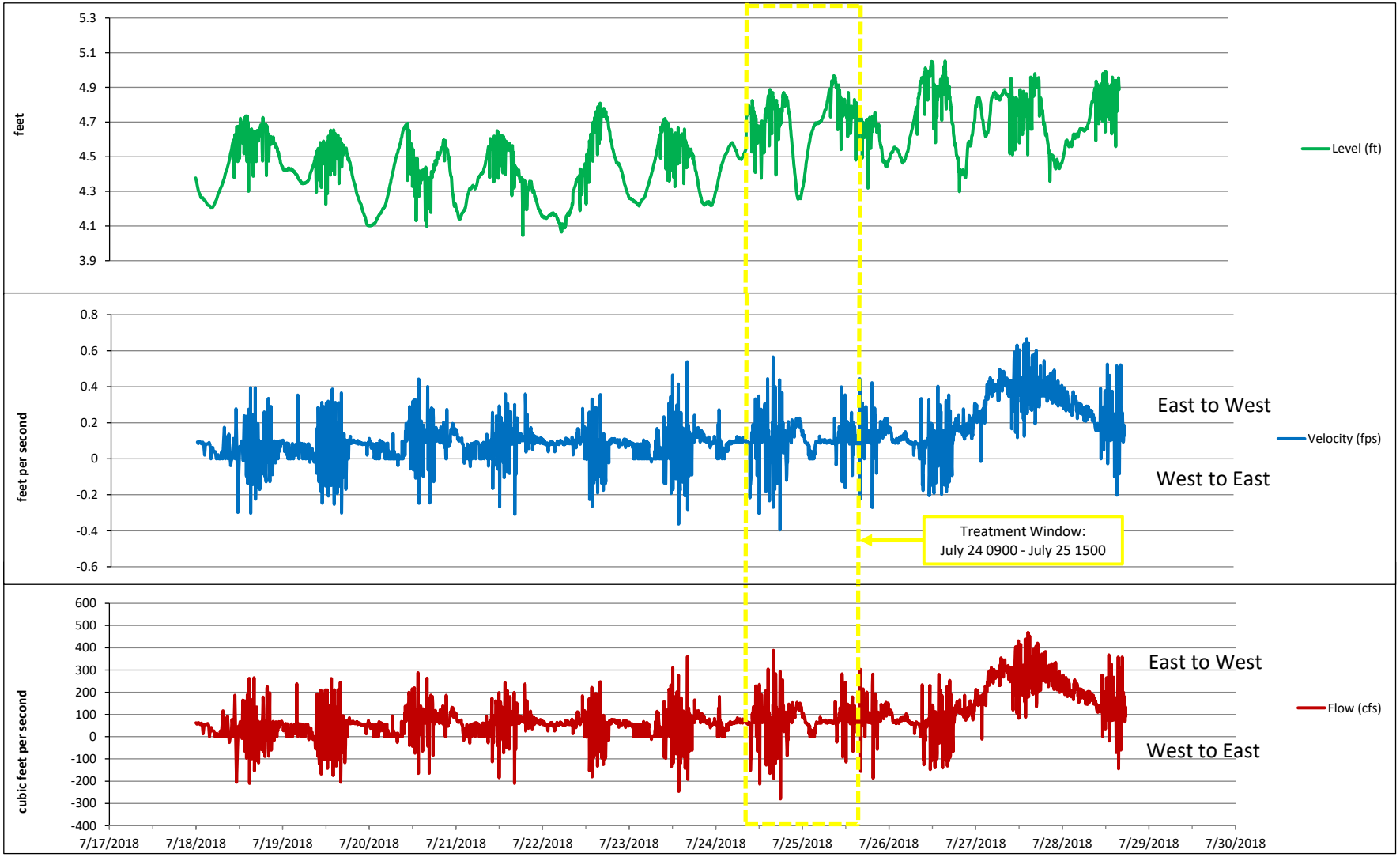

Cross Sectional Area of Canal by Sensor Water Level
Area (square feet)
1800
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
Level Above Sensor (feet)
y = 116.6x + 310
R² = 0.9988

D

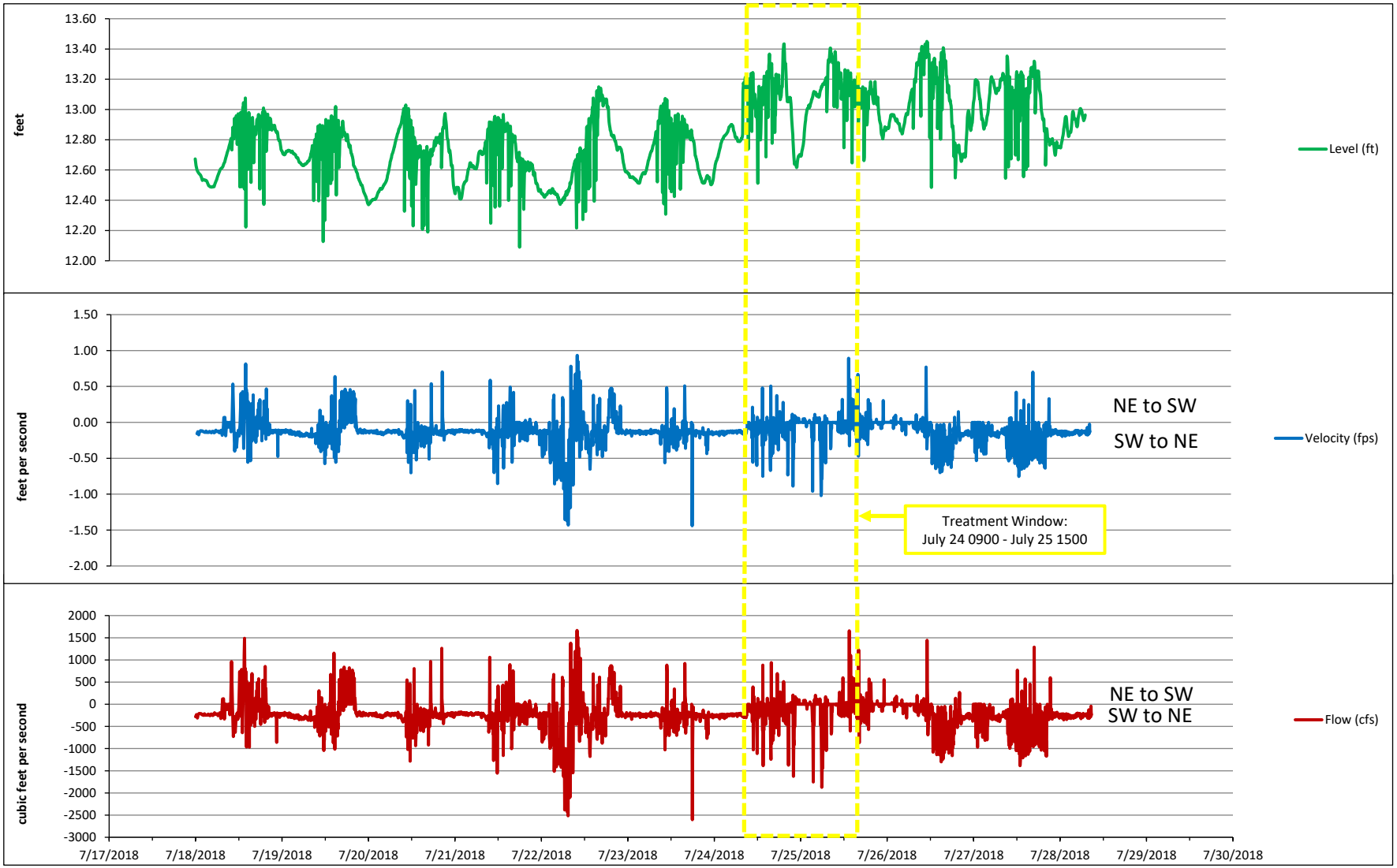
Flow Meter Data and Water Level Graphs



Summary of Flow Data and Water Levels for Tonawanda Creek at North Tonawanda Botanical Gardens (July 18th - July 28th, 2018)



Summary of Flow Data and Water Levels for Tonawanda Creek at New Road (July 18th - July 28th, 2018)



Summary of Flow Data and Water Levels for Tonawanda Creek at Stevens St (July 18th - July 28th, 2018)