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WOODBRIDGE RIVER FLOODPLAIN
BASELINE ECOLOGICAL MONITORING REPORT
Woodbridge Township
Middlesex County, New Jersey

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Cover Photograph:
View of the Woodbridge River and Floodplain Forest near Omar Avenue, Avenel

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1.0 INTRODUCTION AND BACKGROUND

Dense urbanization has significantly modified New Jersey's natural landscape, reducing the ecological and economic benefits it provides. Low-lying developed areas in close proximity to surface waters are particularly affected. During storms, these locations receive elevated stormwater inputs from upland areas and storm surge from overflowing riverbanks and marsh fringes. The resulting flooding severely jeopardizes health and human safety, compromises the integrity of development and infrastructure, and furthers environmental degradation through sediment and chemical pollutant deposition into adjacent ecosystems. Improving resiliency in urbanized coastal areas requires an integrated approach of shoreline retreat, ecological restoration, and green infrastructure construction, coupled with community education and acceptance of resilience strategies through tangible socioeconomic outcomes.

Woodbridge Township (~100,000 residents) is located within the *coastal shoreline county* of Middlesex, NJ, USA. It is a demonstrated environmentally conscious community and one of the first in New Jersey to receive silver certification from the Sustainable Jersey program. The Township covers ~24 mi^2 and is bounded by several major waterways, including the Rahway River to the north, the Arthur Kill to the east, and the Raritan River to the south (Figure 1). The eastern half of the Township is bisected by the Woodbridge River, which flows north to south and discharges to the Arthur Kill. Recent storms caused extensive damage to property and infrastructure (Hurricane Sandy alone resulted in an assessment reduction of >$1.2 million to residential properties) and threatened human safety. In response, the Township initiated a strategic plan to improve community resiliency against climate hazards, focusing first on shoreline retreat. The Township secured funds through the NJ Blue Acres Program to acquire properties located within the 100-yr floodplains of the surrounding water bodies. Through the Blue Acres initiative, residents voluntarily sell their properties to the State of New Jersey. These parcels then become permanently protected open space and are either aggregated into nearby state parks or managed by local government entities through a memorandum of understanding. By 2015, the Township had acquired ~190 lots located within five separate communities, including Avenel, Colonia, Port Reading, Sewaren and Watson-Crampton (Figure 1).

Following acquisition, the Township established an Open Space Conservation/Resiliency Zone (OSC/R) in and around the floodplains to help minimize the risk to residences, reduce the amount of flood damage sustained during future flood events, and enhance biodiversity. The OSC/R Zone ordinance codifies the design criteria associated with structures within this area as well as permitted uses, street arrangement, landscaping restrictions, buffer requirements, and required registration for all property owners within it. In addition, building design standards within the OSC/R are triggered at any proposed demolition, addition, reconstruction, renovation, or change in tenancy. The areas designated as within the Open Space Conservation/Resiliency Zone are located within Watson-Crampton, Sewaren and Port Reading neighborhoods of the Township.

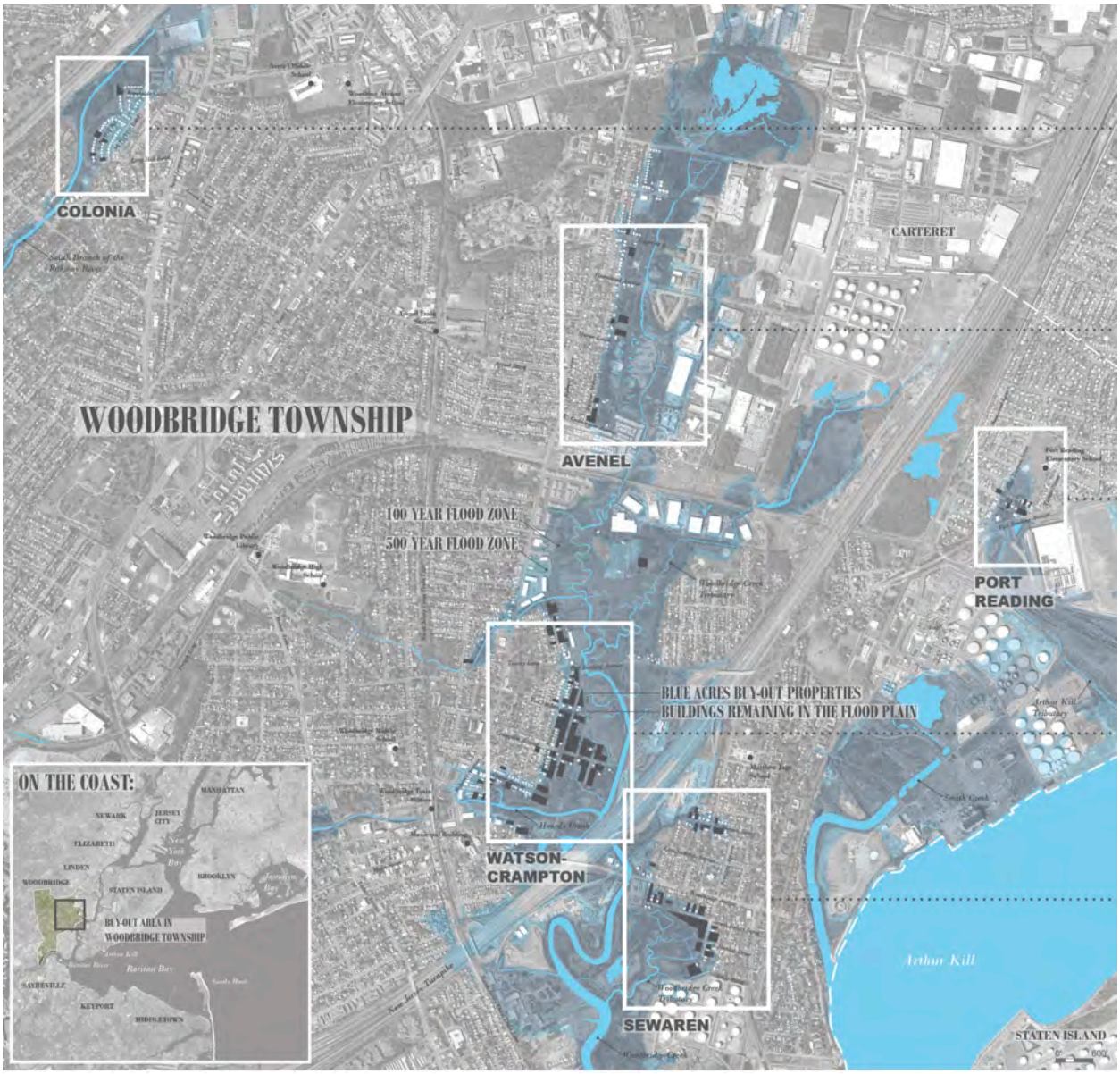

Figure 1: Blue Acres properties located in Woodbridge Township

The Township then partnered with Rutgers Cooperative Extension (RCE) to better understand opportunities for maximizing community resilience in these areas through ecologically centered land stewardship. In 2016, RCE completed the *Woodbridge Township Open Space and Flood Plain Restoration Plan*, which included recommendations for ecological restoration, stormwater management and flood storage, landscape buffer establishment, and increased public access. Roughly 87% of the properties (165 lots) are concentrated along the Woodbridge River floodplain within the neighborhoods of Avenel, Watson-Crampton and Sewaren.

The RCE received National Fish and Wildlife (NFWF) National Coastal Resilience funding to address resiliency of the communities adjacent to the Woodbridge River by examining the floodplain as a whole and creating comprehensive design solutions to restore ecological function, manage stormwater, and increase socioeconomic value. This report establishes a baseline understanding of the ecological, hydrologic, and water quality conditions of the Woodbridge River floodplain to determine pre-restoration conditions from which to design floodplain restoration and green infrastructure interventions.

2.0 EXISTING ECOLOGICAL CONDITIONS

2.1 Project Area

The Woodbridge River floodplain resiliency project covers an area totaling approximately 4,232 acres. The headwaters of the Woodbridge River begin at the Ernest L. Oros Wildlife Preserve, located on Omar Avenue, but the floodplain reaches north to the Rahway River (Figure 2; Appendix A – Map 1). From the Preserve, the river flows south parallel to Rahway Avenue. After flowing through the town of Avenel, the river forms the municipal border between Port Reading and Sewaren to the east, and Woodbridge Proper and Perth Amboy to the west, before emptying into the Arthur Kill.

Figure 2: Headwaters of the Woodbridge River in Ernest L. Oros Wildlife Preserve

2.2 Land Use

Single-family neighborhoods and multi-family/high density housing are dispersed along the center of the project area and then spread west, with commercial land use, parks and cemeteries located

throughout. Industrial land use dominates the northern end of the project area, as well as the northeastern and southeastern portions (Appendix A – Map 2). Open land including forest, shrubland, marsh, and water is centralized along the Woodbridge River running from north to south (Appendix A – Map 3).

The natural areas are dominated by a matrix of floodplain wetlands (~530 acres; Appendix A – Map 4). Wetlands in the southern portion of the project area consist of tidally influenced saline marsh, with large areas of *Phragmites*-dominated marsh stretching northward. This significant remnant habitat is unique to the project area.

2.3 Soils

Soils in the undeveloped landscapes bordering the Woodbridge River are characterized primarily by Manahawkin muck, Hasbrouck silt loam, Pawcatuck-Transquaking complex, and Psamments (Appendix A – Map 5). Manahawkin muck is found in floodplains and swamps. With a soil profile of muck from 0 to 47 inches over sand, the soil is poorly drained. The water table is 0 to 6 inches below the surface, and the slope ranges from 0 to 2 percent. The Hasbrouck silt loam soil profile begins with a layer of decomposed plant material that transitions to silt loam, sandy loam and finally loam at 62 inches below the surface. The soil is poorly drained with the water table at 0 to 6 inches below the surface and a slope of 0 to 3 percent. The Pawcatuck-Transquaking complex is typically found in tidal marshes with a soil profile of mucky peat from 0 to 45 inches and loamy sand/sand from 45 to 90 inches below the surface. The substrate of this complex is poorly drained with the water table existing at the surface and a slope of 0 to 1 percent. Psamments consists of fine sand from 0 to 6 inches over courser sand. The soil is well drained with a water table depth of 48 inches and a slope of 0 to 3 percent.

Residential areas in the project area are dominated by the Boonton-Urban land complex and Haledon-Urban land complex. Both complexes are found on ground moraines, with a combination of loamy basal till derived from basalt and areas covered by pavement, concrete, buildings and other structures. The soil profile for the Boonton-Urban land complex transitions from loam, silt loam, fine sandy loam, and loamy sand from 0 to 72 inches below the surface and has a slope of 0 to 8 percent. In areas devoid of impervious surfaces, the soil is well drained with a water table depth of more than 80 inches below the surface. The soil profile for the Haledon-Urban land complex transitions from silt loam, sandy loam, to gravelly sandy loam from 0 to 70 inches below the surface and has a slope of 0 to 3 percent. Natural areas are somewhat poorly drained with a water table depth between 6 to 18 inches below the surface.

Industrial and commercial sites are largely characterized by Urban Land, which consists of surfaces covered by pavement, concrete, buildings and other structures underlain by disturbed and natural soil material. Secondary soils in these areas contain Boonton loam and Psamments. The Boonton loam profile consists of decomposed plant material, which transitions to loam, silt loam, then sandy loam at 30 to 40 inches below the surface. The soil is well drained with a depth to the water table greater than 80 inches and a slope of 3 to 8 percent.

2.4 Vegetation

Natural Landscape

The Woodbridge River floodplain is a mosaic of moderate to highly disturbed habitats characteristic of the central New Jersey urban landscape (Figure 3). The vegetation species composition in these areas is typical of the freshwater floodplains of central New Jersey and support a variety of habitat types largely dependent upon local drainage patterns and landcover type. RCE conducted vegetation surveys throughout the project area and identified the following ecotypes:

Figure 3: Riparian zone consisting of native canopy trees and an understory dominated by invasive vegetation

Deciduous Woodland

The majority of upland habitats within the project area can be classified as either dense (>50% canopy cover) or sparse (<50% canopy cover) deciduous woodland. These forest patches are all adjacent to the Woodbridge River or the surrounding *Phragmites*-dominated wetlands and consist

of poorly drained soils. Maples (*Acer* spp.) and oaks (*Quercus* spp.) dominate the canopy, with elms (*Ulnus* spp.), sweet gum (*Liquidambar styraciflua*), black locust (*Robinia pseudoacacia*), and black cherry (*Prunus serontina*) also common. Remnant patches of river birch (*Betula nigra*) and paper birch (*B. papyrifera*) exist as well.

The subcanopy layers of the deciduous woodlands range from degraded to virtually absent, which is typical of disturbed habitats in urban areas (Figure 4). Common native shrubs and vines observed include greenbriar (*Smilax* spp.), wild raspberry (*Rubus occidentalis*), poison ivy (*Toxicodendron radicans*) and wild grape (*Vitis* spp.). Other less common native shrubs observed include arrowwood viburnum (*Viburnum dentatum*), serviceberry (*Amelanchier canidensis*), and winged sumac (*Rhus copallinum*).

Figure 4: Deciduous woodland with an absent understory, located in the Watson-Crampton neighborhood

The herbaceous layer is dominated by invasive plants, primarily mugwort (*Artemisia vulgaris*), mile-a-minute (*Polygonum perfoliatum*), Japanese stiltgrass (*Microstegium vimineum*), and Japanese knotweed (*Fallopia japonica*). Common reed (*Phragmites australis*) dominates the

forest understory along most of the forest/wetland interface. However, patches of native wildflowers exist in some areas. Milkweeds (*Asclepias* spp.), goldenrods (*Solidago* spp.), white snakeroot (*Ageratina altissima*), and late boneset (*Eupatorium serotinum*) dominate the remnant patches of herbaceous native plants.

Edge Habitat

Along riparian and woodland edges not dominated by *Phragmites*, edge habitats include a mix of deciduous trees and shrubs that are tolerant of both dry and wet conditions. Common species include green ash (*Fraxinus pennsylvanica*), silver maple (*Acer saccharinum*), pin oak (*Quercus palustris*), marsh elder (*Iva annua*), and groundsel bush (*Baccharis halimifolia*). In many of these transition areas, *Phragmites* is encroaching on existing vegetation.

The transition between residential zones to open space contains variable edge habitat. These areas host a diversity of extensively nonnative plants that are usually tolerant of both wet and dry conditions. Many of the mowed or developed edges of the forested areas are dominated by the invasive species, mugwort (*Artemisia vulgaris*) and Japanese honeysuckle (*Lonicera japonica*).

Phragmites-dominated Marsh:

A large percentage of the unmanaged portion of the project can be classified as a *Phragmites* monoculture (Figure 5). Within these zones exist some patches of remnant habitat, typically small stands of trees (maples, birches, etc.) that are producing enough shade to limit Phragmites growth. Bordering *Phragmites* monoculture zones are saline marsh, edge habitats, or deciduous woodlands, depending upon the surrounding topography.

Figure 5: *Phragmites*-dominated marsh along the Woodbridge River in Avenel

Saline Marsh:

Patches of relatively healthy saline marsh occurs the project area (Figure 6). Dominant vegetation includes salt marsh cordgrass (*Spartina alterniflora*) and salt-meadow grass (*Spartina patens*), indicating relatively normal tidal dynamics. Bordering the majority of the marsh edges are *Phragmites*-dominated marsh and edge habitats, likely resulting from elevation increases due to historic fill.

Figure 6: Intact saline marsh in Avenel

Invasive Plant Species

The majority of habitats within the project bounds have considerable coverage of various invasive plant species. *Phragmites* is the most abundant invasive plant, dominating a significant portion of the wetland and wetland transition zones (Figure 7). The extensive coverage of this species is typical of highly disturbed natural habitats, most often where hydrology has been altered.

Figure 7: *Phragmites*-dominated marsh near Port Reading Avenue in Woodbridge

Within wooded areas, mugwort (*Artemisia vulgaris*) appears to be the dominant invasive plant. RCE also observed several patches of Japanese knotweed (*Fallopia japonica*) along riparian fringes. Other woody invasive plants observed include tree-of-heaven (*Ailanthus altissima*), multiflora rose (*Rosa multiflora*), Japanese barberry (*Berberis thunbergii*), and Amur honeysuckle (*Lonicera maackii*), and other herbaceous invasive plants include mile-a-minute (*Polygonum perfoliatum;* Figure 8) and Japanese stiltgrass (*Microstegium vimineum*).

Figure 8: Degraded woodlot in the Watson-Crampton neighborhood dominated by invasive mile-a-minute (*Polygonum perfoliatum*)

Former Residential Properties

RCE documented vegetation remaining on former residential lots that are now under NJ Blue Acres jurisdiction (Figure 9). They consist of a mix of native and nonnative woody species typically found in suburban yards. In addition to ornamental trees and shrubs such as Japanese maple (*Acer palmatum*), callery pear (*Pyrus calleryana*), star magnolia (*Magnolia stellata*), apple (*Malus* spp.), cherry (*Prunus* spp.), arborvitae (*Thuja* spp.) and privet (*Ligustrum* spp.), there are several native trees that can and have been incorporated into planting plans including black walnut (*Juglans nigra*), silver maple (*Acer saccharinum*) and pin oak (*Quercus palustris*). The understory of these lots primarily consists of mowed lawn and *Phragmites,* which encroaches from adjacent wetlands.

Figure 9: Former residential lot in Sewaren with remaining landscape plantings and *Phragmites*-dominated marsh adjacent to the property

To date, RCE has performed restoration activities on 79 Blue Acres properties in Woodbridge Township, with the goal of incorporating many of these parcels into the surrounding natural landscape. The restored sites fall into three habitat categories: meadow, forest, and green-space. The meadows consist of native grasses and flowers that RCE either drill-seeded or planted plugs (Figure 10). The forests consist of native trees and shrubs, including black gum (*Nyssa sylvatica*), hackberry (*Celtis occientalis*), sweetgum, silky dogwood (*Cornus amomum*), and a variety of oaks (Figure 11). Green-space lots are located adjacent to remaining residential areas, and in some cases offer a buffer between existing homes and more natural habitats (Figure 12). These lots received 1.5”-caliper tree plantings spaced in a park-like setting and are actively mowed throughout the growing season. RCE conducts invasive species management on all 79 lots to encourage native plant establishment and decrease competition from invasive plants.

Figure 10: Restored meadow habitat in the Watson-Crampton neighborhood

Figure 11: Restored forest habitat in the Watson-Crampton neighborhood

Figure 12: Park-like green space in the Watson-Crampton neighborhood

3.0 WILDLIFE

3.1 Birds

RCE conducted point count bird surveys to establish a baseline avian species inventory along the Woodbridge River corridor. Surveys were also conducted at Cheesequake State Park (Matawan, NJ) to serve as a reference site. Point counts are the most widely used quantitative method to monitor bird populations (Ralph et al. 1995).

Prior to conducting point counts, RCE chose five permanent points representing the range of habitats available within each of the two sites (Table 1; Appendix B – Map 7 and Map 8). These habitats include meadow, *Phragmites*-dominated marsh, tidal river, woodland, and saltmarsh. RCE originally planned to conduct point counts at the two sites once in late May and once in early June (i.e. two visits to each site), and to schedule point counts at the two sites on consecutive days. We completed the Woodbridge surveys following this timeline, but there was a delay in obtaining access to Cheesequake State Park, Matawan, NJ, so the surveys were performed there in late June (Table 2).

Table 1: Point count site locations and habitat descriptions

Woodbridge River Corridor, Woodbridge		
Point Count Site	Location	Habitat Class
WB01	40.577844, -74.26575	Meadow
WB02	40.562303, -74.267882	*Phragmites* Marsh
WB03	40.557597, -74.270241	Tidal River (Woodbridge River)
WB04	40.549574, -74.264199	Woodland
WB05	40.586546, -74.262348	Saltmarsh
Cheesequake State Park, Matawan		
CQ01	40.43329, -74.26263	Meadow
CQ02	40.43638, -74.26906	*Phragmites* Marsh
CQ03	40.43908, -74.27299	Tidal River (Cheesequake Creek)
CQ04	40.43635, -74.26798	Woodland
CQ05	40.44221, -74.27183	Salt Marsh

Table 2: Avian monitoring schedule

Site	Survey 1	Survey 2
Woodbridge River Corridor	May 27, 2019	June 05, 2019
Cheesequake State Park	June 24, 2019	June 29, 2019

Point counts took place on mornings with fair conditions in the absence of rain or high wind (<10mph). The observer arrived at the first point count location within an hour after sunrise and visited points sequentially. Upon arriving at a point, the observer waited for 3 minutes to allow surrounding birds to acclimate and resume normal activity (Rosenstock et al. 2002). After the 3-minute waiting period, the observer started a timer and recorded all birds observed within a 10-minute period, including both the species and the number of individuals observed (Ralph et al. 1995). If the observer was unsure about the number of individuals seen due to potential individual movements between observations, he recorded the minimum number of individuals likely to have been observed during the 10-minute period.

Results

RCE documented 40 unique bird species during the point-count surveys; 26 species were observed along the Woodbridge River corridor, and 27 species were observed in Cheesequake State Park (Table 3). Red-winged blackbird was the most abundant species observed in Woodbridge (70 individuals), while marsh wren was the most abundant species observed at Cheesequake State Park (31 individuals; Appendix B – Avian Monitoring Photolog). When looking at the combined results from survey dates, the Woodbridge meadow habitat produced the highest species diversity with 15 species recorded. *Phragmites*-dominated marsh habitats at both sites supported the lowest species diversity, with 5 species documented in Woodbridge and 3 species documented in Cheesequake State Park.

RCE calculated the Shannon Diversity Index for each point count location and compared Woodbridge and Cheesequake habitat types, as well as both sites as a whole. Woodbridge scored a slightly higher diversity index for each habitat type, with the exception of salt marsh. This may have been due to the Woodbridge surveys occurring earlier in the breeding season, when many bird species are more active and vocal across the landscape. However, Cheesequake scored a slightly higher diversity index overall. In addition, two state-threatened species (black-crowned night heron and osprey) were documented in Cheesequake and not in Woodbridge. Overall, the *Phragmites*-dominated marsh habitats supported the lowest species diversity, while meadow and woodlot habitats supported the highest diversity.

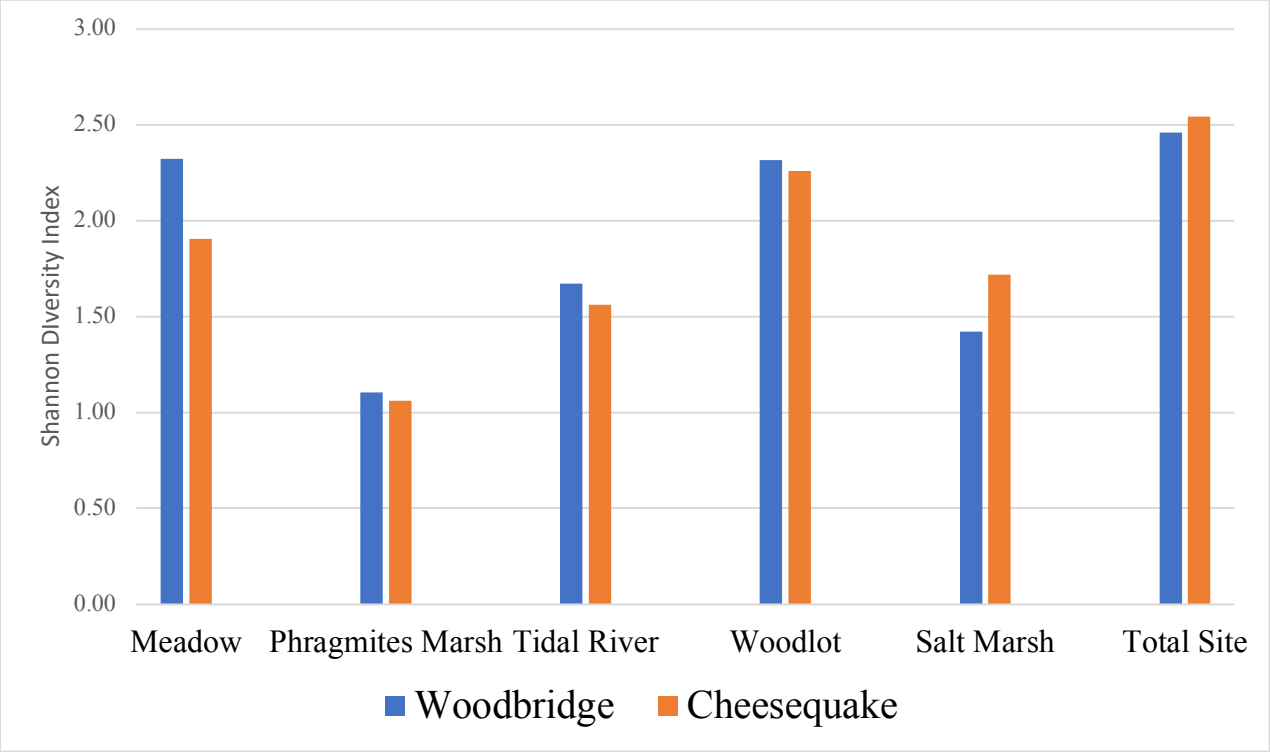

Figure 13: Shannon Diversity Indices of avian point counts along the Woodbridge River corridor and Cheesequake State Park (reference site)

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Table 3: Avian species observed during Woodbridge River and Cheesequake State Park surveys

Species Common Name	Species Latin Name	Woodbridge	Cheesequake
American goldfinch	*Spinus tristis*	■	■
American robin	*Turdus migratorius*	■	■
Baltimore oriole	*Icterus galbula*	■	■
barn swallow	*Hirundo rustica*	■	■
black-crowned night heron	*Nycticorax nycticorax*		■
blue jay	*Cyanocitta cristata*	■	■
brown-headed cowbird	*Molothrus ater*	■	
Carolina chickadee	*Poecile carolinensis*		■
Carolina wren	*Thryothorus ludovicianus*		■
cedar waxwing	*Bombycilla cedrorum*	■	■
chipping sparrow	*Spizella passerina*		■
clapper rail	*Rallus crepitans*		■
common grackle	*Quiscalus quiscula*	■	
common yellowthroat	*Geothlypis trichas*	■	■
downy woodpecker	*Picoides pubescens*	■	
eastern bluebird	*Sialia sialis*		■
European starling	*Sturnus vulgaris*	■	
gray catbird	*Dumetella carolinensis*	■	■
great egret	*Ardea alba*		■
great-blue heron	*Ardea herodias*		■
great-crested flycatcher	*Myiarchus crinitus*		■
green heron	*Butorides virescens*	■	
herring gull	*Larus argentatus*	■	
house wren	*Troglodytes aedon*	■	
mallard	*Anas platyrhynchos*	■	
marsh wren	*Cistothorus palustris*	■	■
mourning dove	*Zenaida macroura*	■	
northern flicker	*Colaptes auratus*	■	■
northern rough-winged swallow	*Stelgidopteryx serripennis*	■	
orchard oriole	*Icterus spurius*	■	
osprey	*Pandion haliaetus*		■
red-eyed vireo	*Vireo olivaceus*		■
red-winged blackbird	*Agelaius phoeniceus*	■	■
song sparrow	*Melospiza melodia*	■	■
tree swallow	*Tachycineta bicolor*	■	
white-breasted nuthatch	*Sitta carolinensis*		■
willet	*Tringa semipalmata*		■
willow flycatcher	*Empidonax traillii*	■	■
yellow warbler	*Setophaga petechia*	■	
yellow-billed cuckoo	*Coccyzus americanus*		■

Summary

RCE conducted two surveys at five point-count locations in both Woodbridge Township and Cheesequake State Park to provide a baselines avian species inventory for each site. Many common species were found present at both sites, including American robin, red-winged black bird, and song sparrow. While some species were documented only in Woodbridge or Cheesequake, this may be due to differences in sampling dates or natural variation. RCE did not document a significant difference in species diversity between Woodbridge and Cheesequake State park.

3.2 Amphibians

New Jersey is home to 14 species of frogs and toads (Gessner and Stile, 2001). Because amphibians, such as frogs and toads, require both terrestrial and aquatic habitats to complete their life stages, they are particularly sensitive to ecosystem stressors such as contamination, land-use change, hydrology and climate. Therefore, they are excellent indicators of habitat quality and provide a measure to assess ecological health (Smrekar and Byrne, 2015).

Frogs and toads can be easily identified by their unique breeding vocalizations. RCE performed frog and toad call monitoring along the Woodbridge River floodplain to determine a baseline species inventory and compared the results to those of the project reference site, Cheesequake State Park. RCE performed the monitoring in Woodbridge from April through June 2019, at 19 sites that were chosen along the floodplain (Figure 14; Appendix C – Map 9). Due to a delay in gaining access to Cheesequake State Park outside of regular park hours, RCE monitored from late March – June 2020 at 5 sites containing vernal pools in forested habitat (Figure 15; Appendix C – Map 10), with a gap in monitoring from April 7 to May 5 due to COVID-19 related park closures.

Results

RCE identified 3 species utilizing the Woodbridge River floodplain: American bullfrog (*Lithobates catesbeianus*; Figure 16), green frog (*Rana clamitans melanota*), and northern spring peeper (*Pseudacris crucifer crucifer*). The vast majority of positive detections were documented at the Ernest L. Oros Wildlife Preserve, which is a natural area at the headwaters of the Woodbridge River. These three species were also documented immediately south of the preserve near Piper Avenue and Morrisey Avenue, Avenel. Green frogs were detected in mid-June near Heards Brook, a tributary of the Woodbridge River located near Claire Avenue in the Watson-Crampton neighborhood. RCE identified two species utilizing Cheesequake State Park including green frog and northern spring peeper. These species were heard throughout the park.

Figure 14: Amphibian monitoring location within a wet meadow along Heards Brook, Woodbridge Township

Figure 15: Vernal pool at Cheesequake State Park, Matawan, NJ

Spring peepers breed from early March through May, and prefer habitat that includes trees and shrubs in water, such as swamps and vernal ponds. The American bullfrog is New Jersey's largest frog, and does well in permanent bodies of water such as lakes, bogs, ponds, and slower portions of streams. They breed from April through July. Green frogs breed from April through August, and can be found in any body of freshwater (Gessner and Stiles, 2001).

Both green frogs and American bullfrogs are common species throughout New Jersey. Unlike many amphibian species, which are only found in ephemeral wetlands that lack predatory fish, green frogs and bullfrogs can persist in permanent water bodies despite the presence of fish (Buxton and Sperry, 2016; Global Invasive Species Database, 2020). Both species are also opportunistic generalist foragers and will eat an assortment of prey items including insects, fish, other frogs, and plant matter.

Figure 16: American bullfrog observed in the Woodbridge River

Summary

RCE performed frog and toad call monitoring along the Woodbridge River floodplain and Cheesequake State Park to provide baseline species inventories for each site. While species richness was lower in Cheesequake State Park compared to Woodbridge Township, frogs could be heard throughout the park. In comparison, frog calls in Woodbridge Township were largely concentrated at the Ernie Oros Wildlife Preserve or directly south of it, and virtually absent in the more developed areas of the Woodbridge River. The three documented species are all common throughout New Jersey.

3.3 Benthic Macroinvertebrates

Benthic macroinvertebrates (BMI) include small aquatic animals and aquatic larval stages of insects that live on the bottom of waterbodies. Examples include dragonfly and stonefly larvae, snails, worms, and beetles. They are typically found on rocks, vegetation and logs, or are burrowed into bottom substrate. BMI are often used to indicate the biological condition of a waterbody because they spend all or the majority of their lives in water, and different species have predictable tolerances to pollution. If a waterbody is healthy, it should contain a wide variety of macroinvertebrate taxa, including those that are pollution intolerant (EPA, 2016).

Artificial substrate samplers are a common method for sampling BMI, especially in deep or fast-moving water such as the Woodbridge River, where traditional techniques like kick-sampling are not feasible. One type of artificial substrate sampler called the Hester-Dendy is a standard device, constructed of 14 round 0.3cm thick and 7.5cm diameter tempered hardboard plates, separated by 2.5cm spacers. The top 9 plates are divided by a single spacer while plate 10 is divided by 2 spacers, plates 11 and 12 are divided by 3 spacers, and plates 13 and 14 are divided by 4 spacers. These samplers mimic natural submerged substrate and attract colonies of macroinvertebrate communities, primarily immature aquatic insects, crustaceans, coelenterates, bryozoans, worms, gastropods and mollusks (Wildlife Supply Company, 2009).

Figure 17: Hester-Dendy macroinvertebrate samplers deployed in the Woodbridge River

RCE deployed Hester-Dendy samplers at 4 sites along the Woodbridge River and 3 sites along Cheesequake Creek (Appendix D – Map 11 and Map 12). At each site, RCE attached 3 Hester-Dendy samplers to a metal T-post using zip ties (Figure 17). The samplers were positioned in the euphotic zone (~0.3 m) and the T-posts were hammered into the substrate. Each T-post was secured to the river bank with a rope. After a 6-week deployment in late summer (July 16 - August 28, 2020), RCE collected the samplers from the sites. Each Hester-Dendy sampler was disassembled, and the contents of each individual hardboard were scraped into a collection cup, which was then filled with 95% ethanol to preserve the specimens. RCE sorted through each

sample at a Rutgers University laboratory and identified the specimens to family level when possible (Table 4).

Results

Table 4: Inventory of benthic macroinvertebrates in the Cheesequake Creek and Woodbridge River*

Common Name	Order	Family	CQ1	CQ2	CQ3	WB1	WB2	WB3	WB4	Tolerance Values
Aquatic fly	Diptera		1					2		n/a
Aquatic worm	Oligochaeta			5	3	1				8
Caddisfly	Trichoptera	Polycentropodidae		1				4		6
Crab	Decapoda	Brachyura	5	3	37		1	14	1	n/a
Crane fly	Diptera	Tipulidae		1						3
Dragonfly - Spotted Darner	Odonata	Aeshnidae				2				3
Fishfly	Megaloptera	Corydalidae							1	4
Flatworm	Turbellaria	Planariidae				6				1
Limpet	Crustacea	Patellidae		11	22			12	1	7
Mayfly	Ephemeroptera	Siphlonuridae				1				7
Non-biting Midge	Diptera	Chironomidae	3			63	12	17	6	6
Scud	Amphipoda	Gammaridae	3	20	1		232	255	31	4
Shrimp	Decapoda	Crangonidae	1			1				6
Tadpole	Anura					1				n/a
Water penny	Coleoptera	Psephenidae		4						4

*taxa with a n/a tolerance value were not included in FBI calculations

RCE used the Hilsenhoff Family Biotic Index (FBI) to evaluate water quality of the sample sites based on the benthic invertebrate community (Hilsenhoff, 1988). This method assigns individual taxa of benthic arthropods with a pollution-tolerance value. These values range from 0 to 10, with 0 describing taxa that are least tolerant to pollution, and 10 describing taxa that are most tolerant to pollution. The formula for calculating the FBI is:

$$FBI = \sum x_i t_i / n$$

x = number of individuals in a given taxa
t = tolerance value for that taxon
n = number of individuals in the sample that contributed to the calculated products

Table 5: Family Biotic Index scores and water quality evaluation ratings for the sites

Location	Site	Hilsenhoff Family Biotic Index Score	Water Quality Evaluation Rating
Cheesequake Creek	CQ1	5.14	Fair
	CQ2	5.29	Fair
	CQ3	7.00	Poor
Woodbridge River	WB1	5.55	Fair
	WB2	4.10	Very Good
	WB3	4.27	Good
	WB4	4.38	Good

Table 6: Evaluation of water quality using the family-level biotic index (Hilsenhoff, 1988)

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

The FBI for the Woodbridge River sites ranged from 4.38 to 5.55, indicating that the water quality is good (some organic pollution probable) to fair (fairly substantial pollution likely). The Cheesequake Creek samples ranged from 5.14 to 7.00, indicating the water quality is fair to poor (very substantial pollution likely; Table 5; Table 6).

Summary

RCE collected macroinvertebrate samples at 3 sites along Cheesequake Creek and 4 sites along the Woodbridge River from mid-July to late-August 2020, inventoried 15 distinct taxa from the samplers, and calculated the Hilsenhoff Family Biotic Index for each site. This inventory provides baseline data which will help RCE evaluate environmental changes at these sites. The results indicate that organic pollution within both waterways is probable. The large range in water quality evaluation ratings may be due to natural variation within the macroinvertebrate community, or that the samples may not be a true indicator of the water quality. These results can be corroborated using standard water quality testing, which was performed at the same sites along the Woodbridge River. This baseline water quality monitoring methods and results can be viewed on page 30. RCE did not perform water quality testing along the Cheesequake Creek.

3.4 State Endangered and Threatened Wildlife

RCE used existing landscape level GIS data from both the New Jersey Department of Environmental Protection (NJDEP) and the Rutgers Center for Remote Sensing and Spatial Analysis (CRSSA) to evaluate the habitat potential of the open space areas within the project bounds.

The NJDEP Landscape Project classifies approximately 31% of the project area as suitable habitat for endangered, threatened, or special concern wildlife species. The majority of suitable habitat is designated as Rank 1 and Rank 3 (Appendix A – Map 6). Rank 3 habitat, which is centralized around the Woodbridge River, contains one or more occurrences of state threatened species. State threatened species documented within the project area include black-crowned night heron (*Nycticorax nycticorax*), cattle egret (*Bubulcus ibis*) and osprey (*Pandion haliaetus*). Rank 1 habitat is found adjacent to the Rank 3 habitat and contains habitat-specific requirements for endangered, threatened or special concern wildlife species, but does not currently overlap any documented occurrences of these species.

Small patches designated as Rank 2, Rank 4, and Rank 5 exist within the project boundary. Habitat classified as Rank 2 is assigned to habitat containing one or more occurrences of special concern species, and can be found in the western section of the Ernest L. Oros Wildlife Preserve in Avenel. Species of special concern documented within the project area include glossy ibis (*Plegadis flacinellus*), little blue heron (*Egretta caerulea*), snowy egret (*Egretta thula*), and a non-breeding sighting of bobolink (*Dolichonyx oryzivorus*).

Habitat classified as Rank 4 is assigned to habitat that contains one or more occurrences of State endangered species and can be found at the northern edge of the project boundary, bordered by the Rahway River. State endangered species documented within the project area include bald eagle (*Haliaeetus leucocephalus*).

Habitat classified as Rank 5 is assigned to habitat containing one or more occurrences of wildlife listed as endangered and threatened under the Federal Endangered Species Act of 1973, can be found where the Woodbridge River empties into the Arthur Kill. Federally endangered species documented within this area include shortnose sturgeon (*Acipenser brevirostrum*).

Additional species documented inside the project area that are tracked by the Endangered and Nongame Species Program but are not state or federally listed include Virginia rail (*Rallus limicola*). Two state endangered species, the peregrine falcon (*Falco peregrinus*) and pied-billed grebe (*Podilymbus podiceps*) have been documented within the immediate vicinity of the project boundaries.

4.0 BASELINE WATER QUALITY

Rutgers Cooperative Extension (RCE) performed baseline surface water quality monitoring along the Woodbridge River from June through October 2019 at four established monitoring locations. The four sites feature various sections of the Woodbridge River, including locations where Blue Acres Properties exist in adjacent neighborhoods. From these monitoring results, RCE will be able to measure water quality improvements that may result from the future implementation of various green infrastructure projects throughout the project area. All surface water samples were processed and analyzed by the New Jersey Analytical Laboratories in Ewing, NJ.

Surface Water Quality Monitoring

Surface water quality samples were collected from four established sampling locations along the Woodbridge River (Table 7, Appendix E – Map 13). Surface water quality sampling was conducted to assess the current input of nutrients (i.e., total phosphorus, nitrate, and nitrite), total suspended solids, total solids, pH, and dissolved oxygen levels along the Woodbridge River. The sites are representative of various neighborhoods along the Woodbridge River where Blue Acres properties exist.

Table 7. Description of and basis for water quality monitoring locations

Location	Description	Coordinates	Basis for Sampling
Site 1	Woodbridge River south of Omar Ave	40°35'03.6" N 74°15'46.1" W	Site 1 was selected to represent the first quarter of the Woodbridge River coming from its origin, and the Avenel neighborhood
Site 2	Woodbridge River at Port Reading JCT/CSX Trenton Sub/ Manville Yard MP35.8 track crossing	40°34'17.2" N 74°15'58.9" W	Site 2 was selected to represent the second quarter of the Woodbridge River as it flows through a more developed area, and Port Reading neighborhood
Site 3	Woodbridge River immediately north of a NJ Turnpike overpass	40°33'25.8" N 74°16'03.1" W	Site 3 was selected to represent the third quarter of the Woodbridge River as it flows through a more developed area, and Watson/Crampton neighborhood
Site 4	Woodbridge River near Shell Oil holdings; off of Arbor St	40°32'57.5" N 74°15'52.9" W	Site 4 was selected to represent the fourth quarter of the Woodbridge River as it flows through an industrial/marshy area to meet the Arthur Kill, and Sewaren neighborhood

Site 1: The Woodbridge River south of Omar Avenue was selected to represent the first quarter of the river in close proximity to its headwaters at the Ernest L. Oros Wildlife Preserve. It also represents the Avenel neighborhood.

Site 2: The Woodbridge River at the Port Reading JCT/CSX Trenton Sub/ Manville Yard MP35.8 track crossing, was selected to represent the second quarter of the river as it flows through a more developed area. It also represents the Port Reading neighborhood.

Site 3: The Woodbridge River immediately north of a NJ Turnpike overpass, was selected to represent the third quarter of the river as it flows through a more developed area (similar to site 2). It also represents the Watson/Crampton neighborhood located in Woodbridge proper.

Site 4: The Woodbridge Creek near Shell Oil holdings off of Arbor Street, was selected to represent the fourth quarter of the river as it flows through a marsh bordered by industrial sites to where it meets the Arthur Kill. It also represents the Sewaren neighborhood.

Surface water quality samples were collected from all sampling locations, on the same day for each event twice a month, from June through October 2019 (8 events). *In situ* measurements of pH and dissolved oxygen were measured by Rutgers Cooperative Extension Wildlife Conservation and Management Program, and these measurements are provided for informational purposes only. Analyses for total phosphorus, nitrate, nitrite, total suspended solids and total solids were conducted by New Jersey Analytical Laboratories (NJDEP certified laboratory #11005).

Results

The tabulated water quality monitoring results from the 2019 sampling period are presented in Appendix E. Basic summary statistics (i.e., n, minimum, maximum, mean, standard deviation, and standard error) are provided with the tables.

To evaluate the health of the Woodbridge River area of the Arthur Kill Watershed, the monitoring results were compared to applicable surface water quality standards (SWQS). Water quality standards are developed according to the waterbody's designated uses (NJDEP, 2016). The Woodbridge River is classified as FW2-NT/SE3, or freshwater (FW) non-trout (NT)/ saline estuarine (SE). "FW2" refers to waterbodies that are used for primary and secondary contact recreation; industrial and agricultural water supply; maintenance, migration, and propagation of natural and established biota; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses. "NT" means those freshwaters that have not been designated for trout production or trout maintenance. NT waters are not suitable for trout due to physical, chemical, or biological characteristics, but can support other fish species. "SE3" refers to waterbodies that are used for secondary contact recreation, maintenance and migration of fish populations, migration of diadromous fish, maintenance of wildlife, and any other reasonable uses (NJDEP, 2016). The applicable surface water quality standards for this project are detailed in Table 8.

The percentage of samples that were in violation of the surface water quality standards (SWQS) or exceeded the criteria during the 2019 monitoring program is provided in Table 3. Almost all of the samples collected throughout the Woodbridge River exceeded the criteria for total phosphorus. For nitrate, Site 3 and Site 4 each had 1 sampling event that exceeded the SWQS. For total suspended solids, Site 2 violated the SWQS during the first 3 sampling events. No violations of nitrite, pH or dissolved oxygen criteria were observed in the Woodbridge River during the 2019 monitoring.

Table 8: Applicable Surface Water Quality Standards – NJAC 7:9B (*Re-adopted: October 17, 2016*; *Last Amended: January 18, 2011 43 N.J.R. 174(b)*)

Substance	Surface Water Classification	Criteria
pH (Standard Units)	FW2 and SE	6.5 – 8.5
Dissolved oxygen (mg/L)	FW2-NT	FW2-NT: 24-hour average not less than 5.0, but not less than 4.0 at any time
	SE	SE: Not less than 3.0 at any time
Total Phosphorus (mg/L)	FW2	Non-Tidal Streams: Concentrations of total P shall not exceed 0.1 in any stream, unless watershed specific translators are established pursuant to N.J.A.C. 7:9B-1.5(g)2 or if the Department determines that concentrations do not render the waters unsuitable in accordance with (d)4i. above.
Solids, Suspended (mg/L) (Non-filterable residue)	FW2-NT	FW2-NT: 40.0
	All SE	All SE: None of which would render the water unsuitable for the designated uses.
Nitrite	All Classifications	1.0mg/L
Nitrate	All Classifications	10.0mg/L
Total Solids		n/a

Table 9: Percentage of water samples that exceeded surface water quality criteria (SWQC)

Station	SWQC	Count	Minimum	Maximum	Mean	% not satisfying SWQC
Nitrates (mg/L)						
Site 1	10.0mg/L in any stream	1	0.25	1.20	0.37	0% (0/8)
Site 2		4	0.25	4.60	1.25	0% (0/8)
Site 3		4	0.25	44.00	7.09	1.25% (1/8)
Site 4		3	0.25	40.00	5.76	1.25% (1/8)
Total Phosphorus (mg/L)						
Site 1	0.1mg/L in any stream	8	0.110	0.340	0.205	100% (8/8)
Site 2		8	0.097	0.380	0.212	87.5% (7/8)
Site 3		8	0.083	0.270	0.180	87.5% (7/8)
Site 4		8	0.027	0.310	0.205	87.5% (7/8)
Total Suspended Solids (mg/L)						
Site 1	40.0 mg/L	8	5.00	28.00	13.88	0% (0/8)
Site 2		8	14.00	48.00	30.13	37.5% (3/8)
Site 3		8	9.500	34.00	21.30	0% (0/8)
Site 4		8	9.50	31.0	21.10	0% (0/8)

The NJDEP's Integrated Water Quality Monitoring and Assessment Methods indicates that if the frequency of water quality results exceeds the water quality criteria twice within a five-year period, then the waterway's quality may be compromised (NJDEP, 2015). Clearly the Woodbridge River water quality is compromised given the continual and persistent violations of the surface water quality criteria for total phosphorus. Nitrate and total suspended solids should be monitored. Nitrite, dissolved oxygen and pH do not appear to be parameters of concern based on the 2019 monitoring results. There is no SWQS for total solids, a measurement which includes both total suspended and total dissolved solids. However, it is important to note that the average amount of total solids increased dramatically at sites as they approached the Arthur Kill.

The 2019 monitoring results were plotted using the average concentrations relative to the surface water quality standards (Figures 18 – 24).

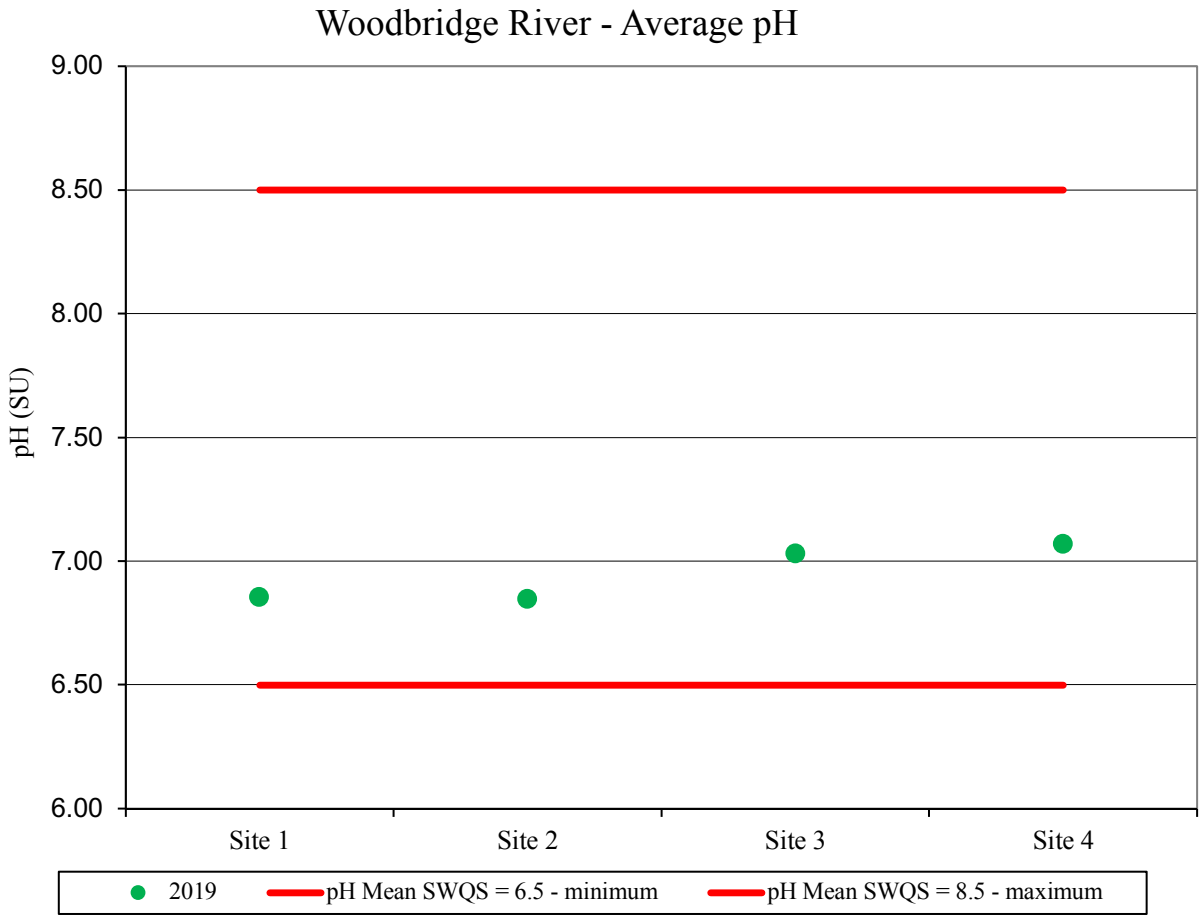

Figure 18: 2019 average pH (SU) at each sampling location with respect to the surface water quality standard (SWQS)

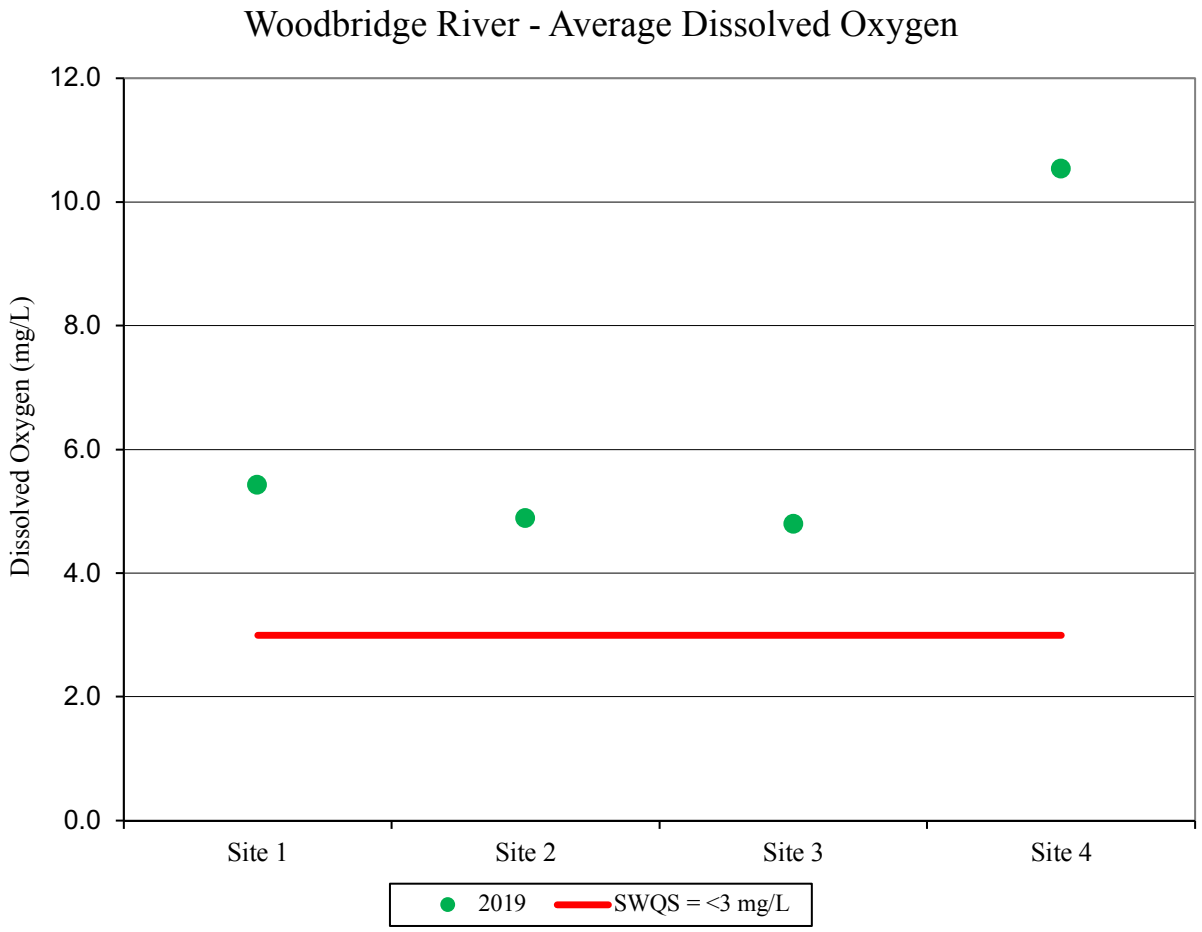

Figure 19: 2019 average dissolved oxygen concentration (mg/L) at each sampling location with respect to the surface water quality standard (SWQS)

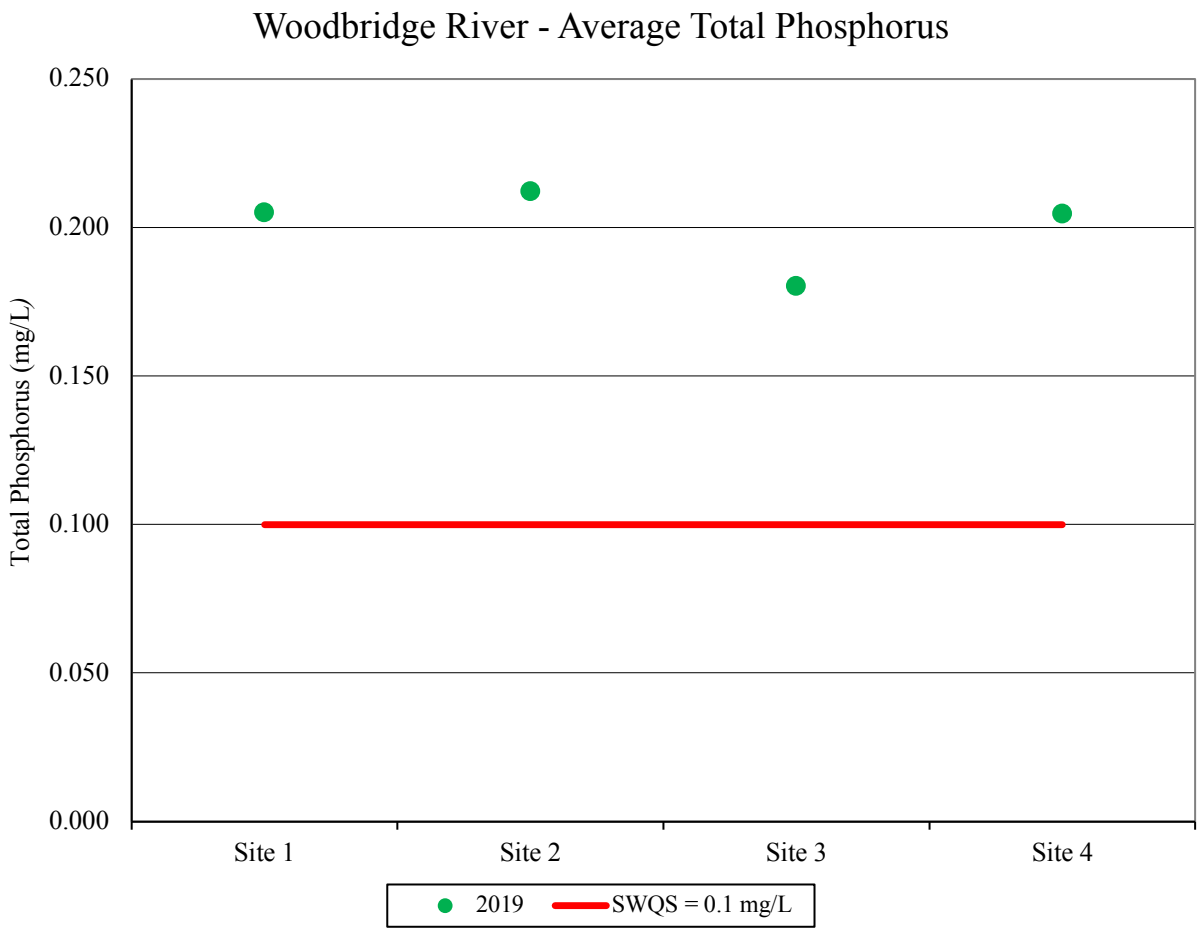

Figure 20: 2019 average total phosphorus concentration (mg/L) at each sampling location with respect to the surface water quality standard (SWQS)

Figure 21: 2019 average total suspended solids concentration (mg/L) at each sampling location with respect to the surface water quality standard (SWQS)

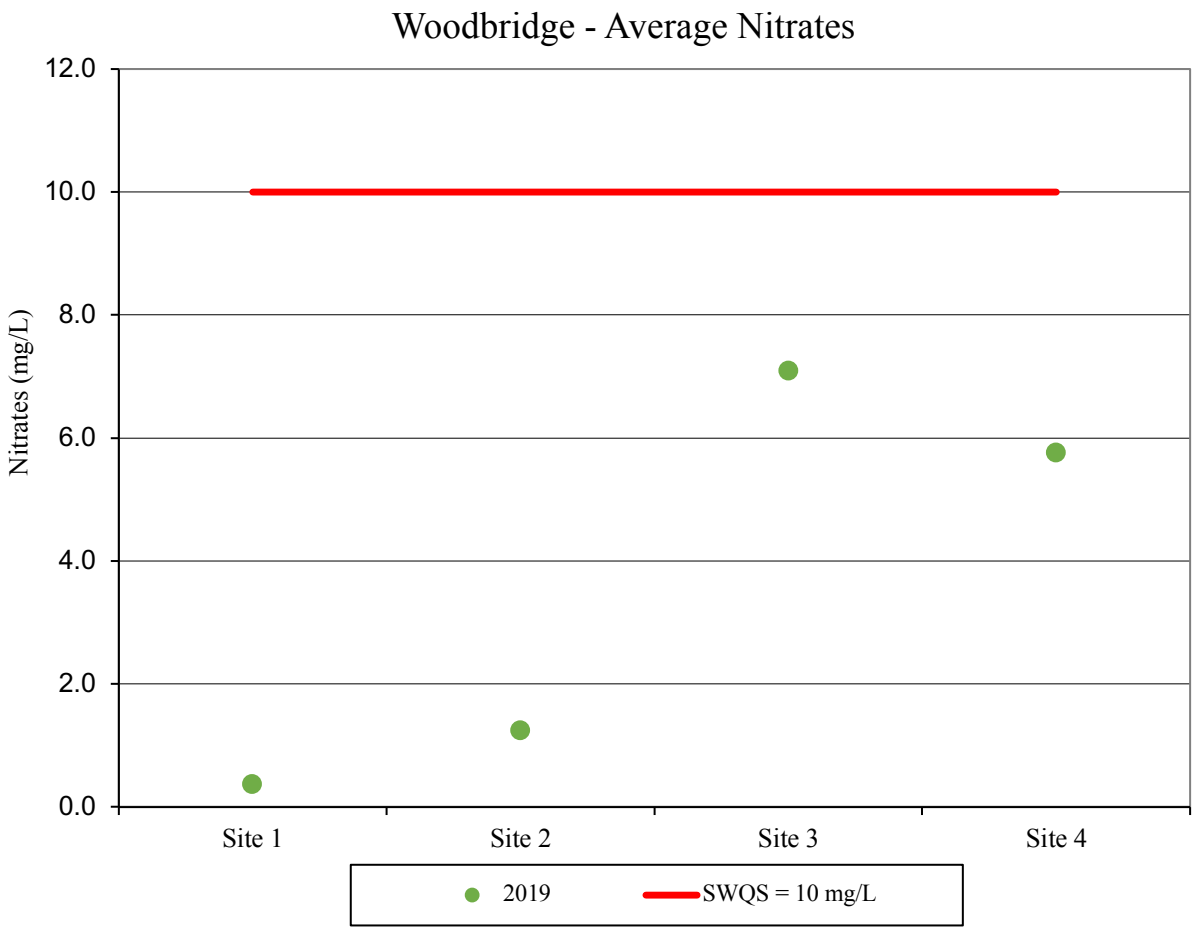

Figure 22: 2019 average nitrate concentration (mg/L) at each sampling location with respect to the surface water quality standard (SWQS)

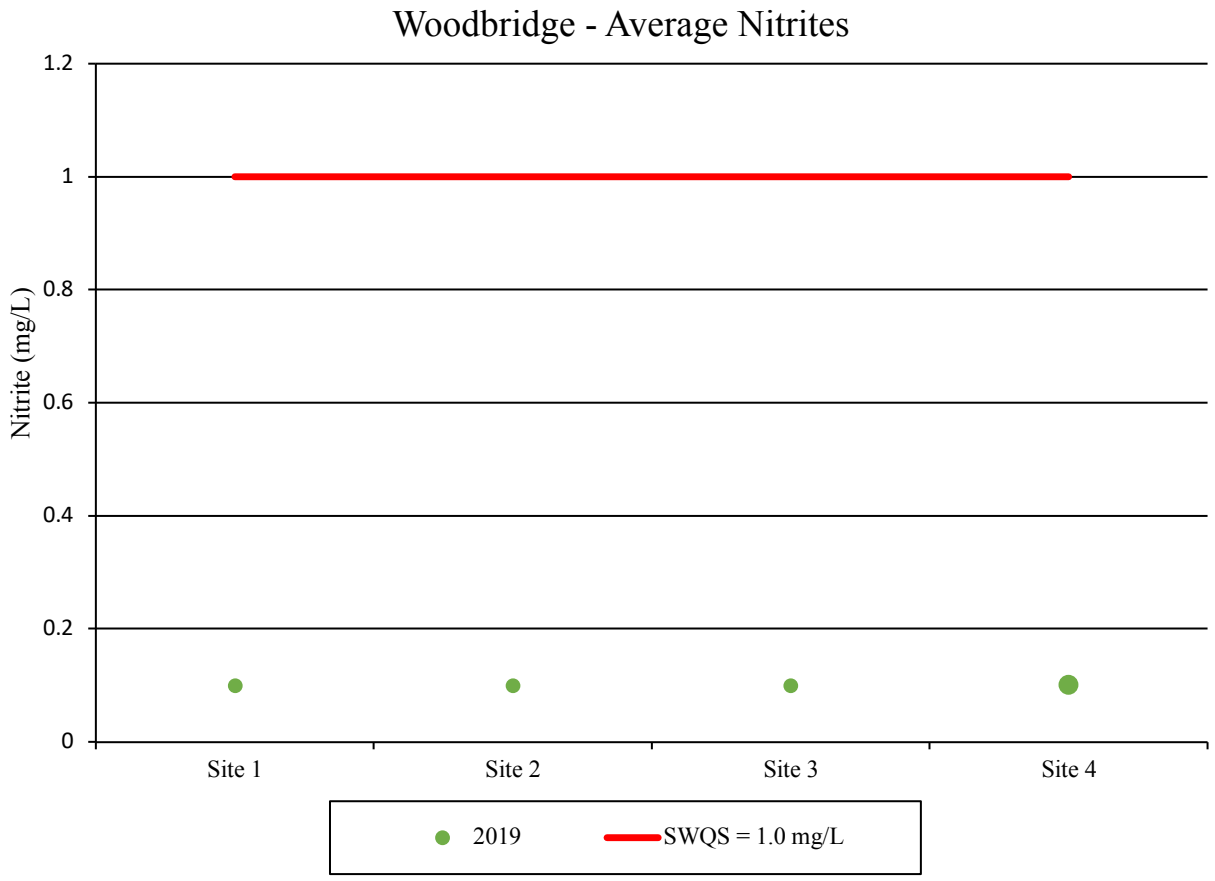

Figure 23: 2019 average nitrite concentration (mg/L) at each sampling location with respect to the surface water quality standard (SWQS)

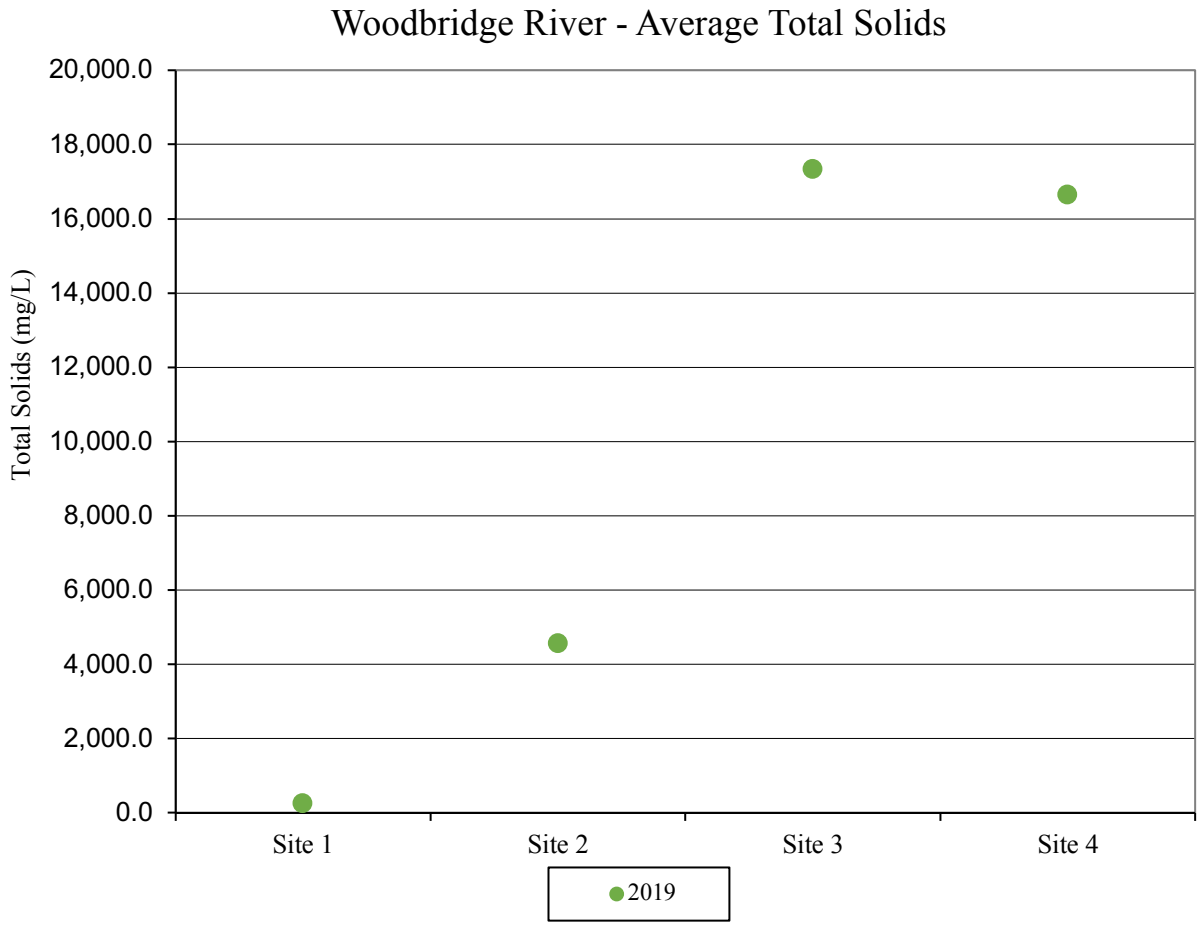

Figure 24: 2019 average total solids concentration (mg/L) at each sampling location

Summary

The surface water quality of the Woodbridge River area of the Arthur Kill Watershed appears to be compromised given the continual and persistent violations of the surface water quality criteria for total phosphorus, and occasional violations of nitrates and total suspended solids. Dissolved oxygen, pH and nitrite do not appear to be parameters of concern for the Woodbridge River.

5.0 SUMMARY AND CONCLUSIONS

RCE's baseline ecological monitoring of the Woodbridge River floodplain has identified several positive conditions. Despite the surrounding urban matrix, the floodplain contains many remnant pockets of native vegetation that support a diversity of species, including NJ state listed species or species of special concern. Although the water quality monitoring indicated that multiple metrics are below the New Jersey Surface Water Quality Standards, the waters did receive a 'fair' to 'good' water quality evaluation rating, based upon the composition of their benthic macroinvertebrate communities. Removal of impervious surfaces, as well as the promotion of stormwater infiltration in and around the floodplain, can help to alleviate some of the negative inputs to the Woodbridge River system.

Typical of much of urbanized New Jersey, the landscape is dominated by invasive vegetation, which severely inhibits the growth and sustainability of native ecosystems. However, where restoration activities have occurred (e.g., Watson-Crampton neighborhood), consistent invasive species management is allowing for the regeneration of native meadow and woodland habitat. These results demonstrate the promising nature of ecological restoration activities in enhancing the biodiversity and public appeal of this area.

The details provided in this baseline ecological monitoring report can serve as a reference from which to base future ecological restoration and green infrastructure goals for increasing the resiliency of the Woodbridge River floodplain and its surrounding areas.

6.0 REFERENCES

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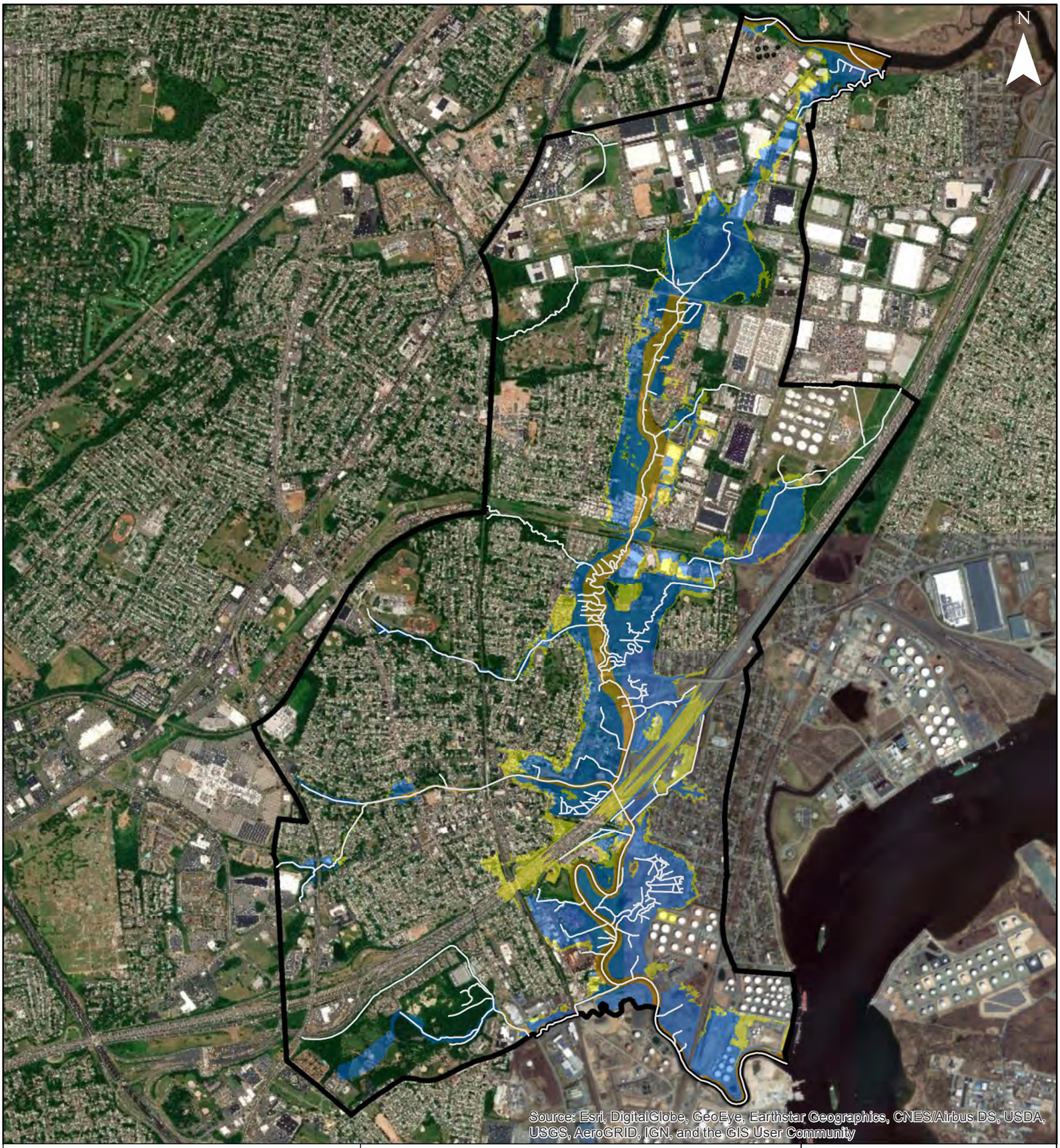
APPENDIX A

GIS Inventory and Resource Maps

- Map 1 – Woodbridge River Floodplain
- Map 2 – Woodbridge River Floodplain Land Use
- Map 3 – Woodbridge River Floodplain Land Cover
- Map 4 – Woodbridge River Floodplain Wetlands
- Map 5 – Woodbridge River Floodplain Soils
- Map 6 –Woodbridge River Floodplain Landscape Project



Legend

- Streams
- 100-Year Storm
- 500-Year Storm
- Floodway
- Boundary

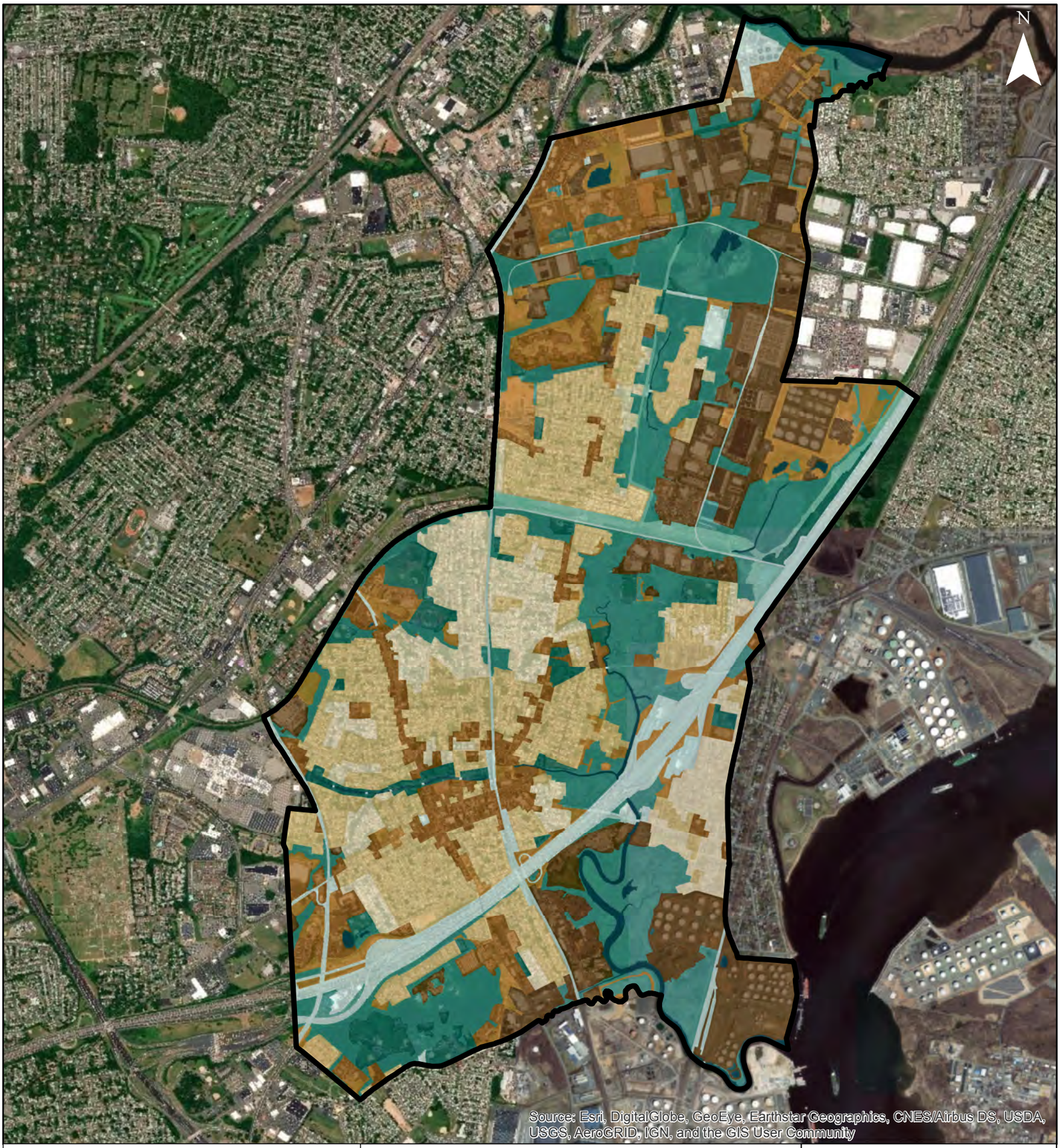
0 250 500 1,000 1,500 2,000 Meters

Map 1
Woodbridge River Floodplain

Climate Resiliency Plan
Woodbridge Township, NJ

Wildlife Conservation and Management

Composed by: Justin Martinez
Map Creation Date: April 3, 2020
Source: NJDEP, DOIT, BGIS
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
Coordinate System: GCS_North_American_1983



Legend

- Industrial
- Commercial
- Misc. Urban
- Residential - Multi-Family
- Residential - Single Family
- Transportation
- Rights-of-Way
- Open Land
- Parks and Cemeteries
- Water
- Boundary

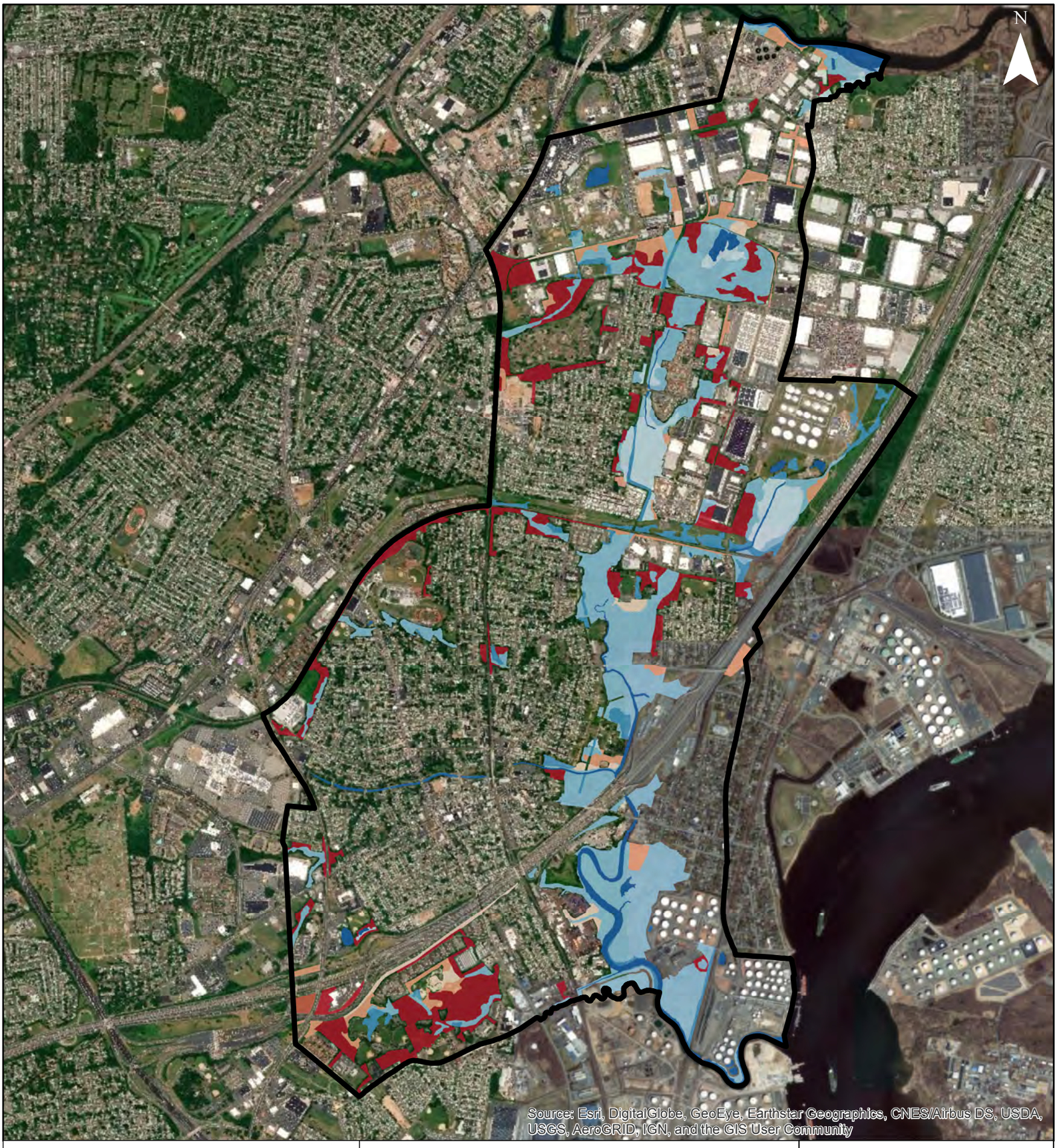
0 250 500 1,000 1,500 2,000 Meters

Map 2
Woodbridge River Land Use

Climate Resiliency Plan
Woodbridge Township, NJ

Wildlife Conservation and Management

Composed by: Justin Martinez
Map Creation Date: April 3, 2020
Source: NJDEP, DOIT, BGIS
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
Coordinate System: GCS_North_American_1983



Legend

- Deciduous Forest
- Coniferous Forest
- Brush/shrubland
- Old Field
- Phragmites-Dominant
- Saline Marsh
- Wetlands
- Water
- Boundary

0 250 500 1,000 1,500 2,000 Meters

Map 3
Woodbridge River Land Cover

Climate Resiliency Plan
Woodbridge Township, NJ

Wildlife Conservation and Management

Composed by: Justin Martinez
Map Creation Date: April 3, 2020
Source: NJDEP, DOIT, BGIS
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
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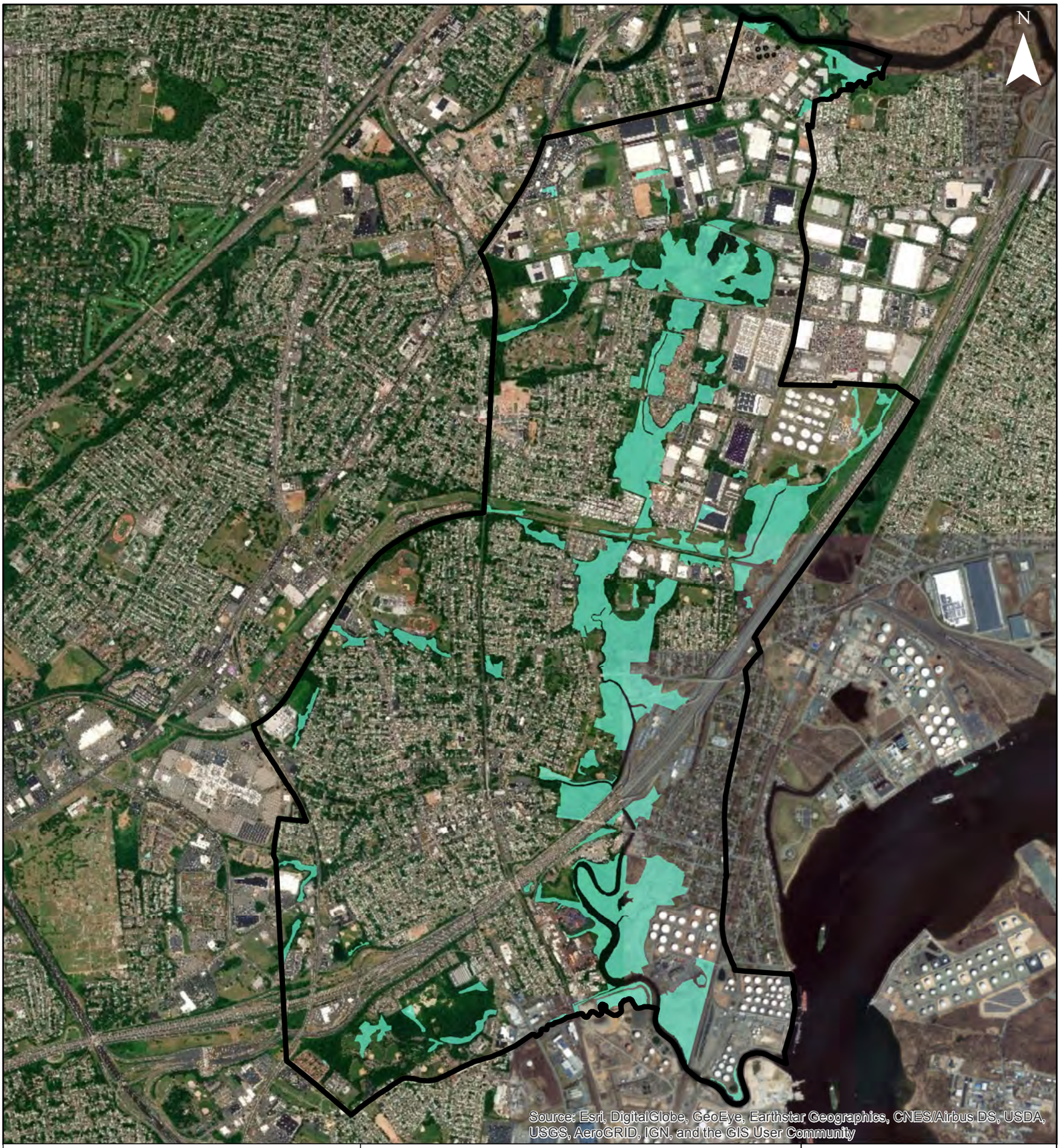


Legend

- Wetlands
- Boundary

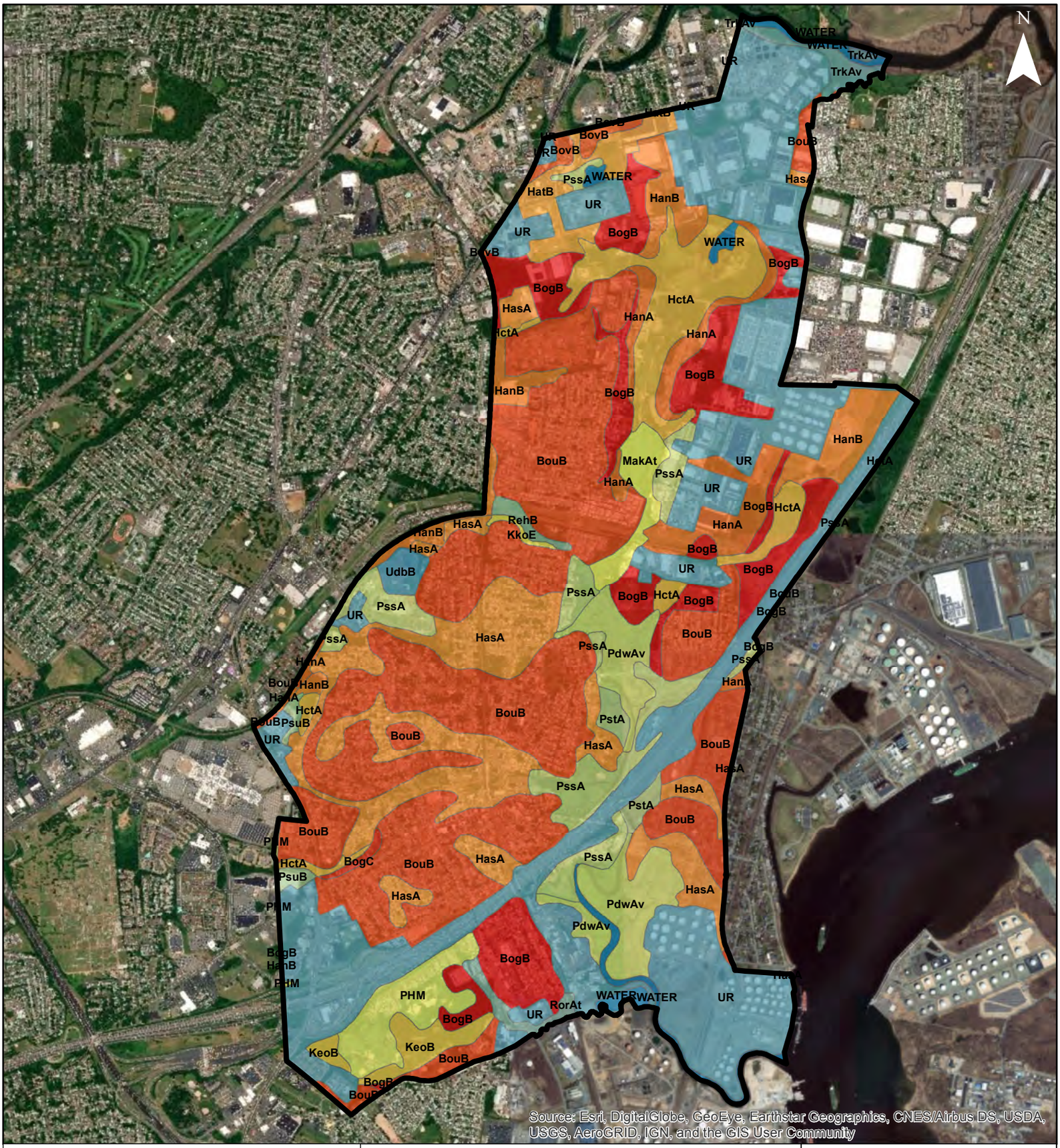
0 250 500 1,000 1,500 2,000 Meters

Map 4
Woodbridge River Floodplain Wetlands

Climate Resiliency Plan
Woodbridge Township, NJ

Wildlife Conservation and Management

Composed by: Justin Martinez
Map Creation Date: April 3, 2020
Source: NJDEP, DOIT, BGIS
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
Coordinate System: GCS_North_American_1983



Legend

BogB, BogC, BouB, BovB, HanA, HanB, HasA, HatB, HctA, KeoB, KkoE, MakAt, PHM, PdwAv, PssA, PstA, PsuB, RehB, RorAt, TrkAv, UR, UdbB, Water, Boundary

0 250 500 1,000 1,500 2,000 Meters

Map 5
Woodbridge River Floodplain Soil Survey

Climate Resiliency Plan

Woodbridge Township, NJ

Wildlife Conservation and Management

Composed by: Justin Martinez
Map Creation Date: April 3, 2020
Source: NJDEP, DOIT, BGIS
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
Coordinate System: GCS_North_American_1983

Legend

Species Based Habitat

- Rank 1 - Suitable
- Rank 2 - Special concern
- Rank 3 - State threatened
- Rank 4 - State endangered
- Rank 5 - Federally endangered/threatened
- Boundary

0 250 500 1,000 1,500 2,000 Meters

Map 6
Woodbridge River Floodplain Landscape Project

Climate Resiliency Plan
Woodbridge Township, NJ

Wildlife Conservation and Management

Composed by: Justin Martinez
Map Creation Date: April 3, 2020
Source: NJDEP, DOIT, BGIS
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
Coordinate System: GCS_North_American_1983

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APPENDIX B

Avian Monitoring Data

- Map 7 – Woodbridge River Avian Monitoring Locations
- Map 8 – Cheesequake State Park Avian Monitoring Locations
- Avian Monitoring Photolog
- Avian Monitoring Datasheets

Legend

★ Locations

Boundary

0 250 500 1,000 1,500 2,000 Meters

Map 7
Woodbridge River Avian Monitoring Locations

Climate Resiliency Plan

Woodbridge Township, NJ

Wildlife Conservation and Management

Composed by: Justin Martinez
Map Creation Date: April 10, 2020
Source: NJDEP, DOIT, BGIS
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
Coordinate System: GCS_North_American_1983

Legend

- ★ Locations
- Boundary

0 125 250 500 750 1,000 Meters

Map 8
Cheesequake State Park Avian Monitoring Locations

Climate Resiliency Plan
Old Bridge Township, NJ

Wildlife Conservation and Management

Composed by: Justin Martinez
Map Creation Date: April 10, 2020
Source: NJDEP, DOIT, BGIS
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
Coordinate System: GCS_North_American_1983

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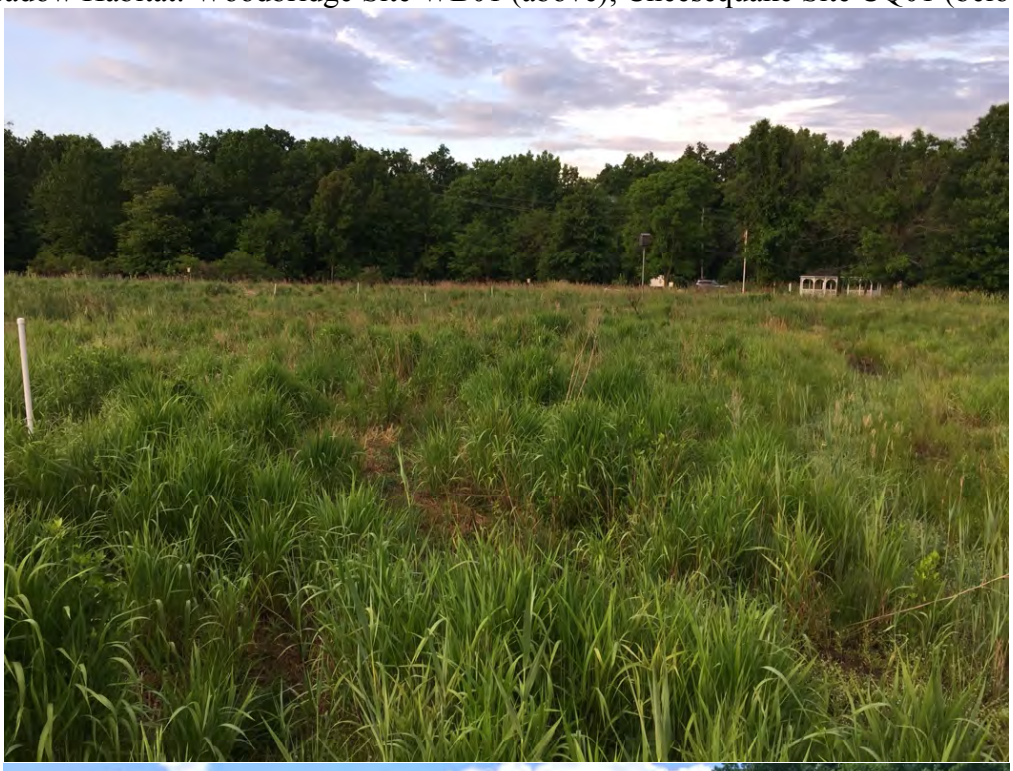
AVIAN MONITORING PHOTOLOG

Meadow Habitat: Woodbridge Site WB01 (above); Cheesequake Site CQ01 (below).



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Phragmites-dominated Marsh Habitat: Woodbridge Site WB02 (above); Cheesequake Site CQ03 (below).

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Tidal River Habitat: Woodbridge Site WB03 (above); Cheesequake Site CQ02 (below).

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Woodland Habitat: Woodbridge Site WB04 (above); Cheesequake Site CQ04 (below).

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Saltmarsh Habitat: Woodbridge Site WB05 (above); Cheesequake Site CQ05 (below).

Red-winged blackbirds (*Agelaius phoeniceus*) were commonly observed at both sites.

Yellow warblers (*Setophaga petechia*) were observed in the Woodbridge meadow habitat.

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Marsh wren (*Cistothorus palustris*) were commonly observed in tidal river and saltmarsh habitats at both sites.

Woodbridge / Cheesequake Avian Point Count Data Sheets

Date: 5/27 Observer: TC Site: Woodbridge

check all that apply

point	start time	species	number	sex			vocal.		interact				breeding					
				male	female	unknown	call	song	countersing	chase	flock	pair	copulation	food carry	fecal sac	feed young	juv. Seen	nest material
WB-01	6:02	RWBL	𝍸 II	X			X	X	X									
		YEWA	III	X				X	X									
		TRSW	𝍸 𝍸 I			X	X							X		X	X	
		NRWS	I			X												
		BHCO	𝍸 I	X			X											
		~~WAVI~~	~~III~~	X				X										
		SOSP	III	X				X	X									
		~~REVI~~	~~II~~	X				X										
		AMRO	IIII			X												
		~~GEOW~~	~~II~~			X	X											
		HOWI	I	X				X										
		GRHE	I			X												
		~~EHSW~~	~~II~~			X												
		~~NOFL~~	~~I~~			X												
		WIFL	I	X				X										
		~~BAOR~~	~~I~~	X			X	X										
		~~OSPR~~	~~I~~			X												
		MALL	III	X	X						X							
		OROR	I	X				X										

Woodbridge / Cheesequake Avian Point Count Data Sheets

Date: " Observer: " Site: "

check all that apply

point	start time	species	number	sex			vocal.		interact					breeding					
				male	female	unknown	call	song	countersing	chase	flock	pair	copulation	food carry	fecal sac	feed young	juv. Seen	nest material
WB02	6:32	COYE	1	X				X										
		RWBL	IIII	X				X	X									
		BARS	~~IIII~~			X	X											
		AMRO	1			X											X	
		WIFL	1	X				X										
WB03	7:01	MAWR	III	X	X		X	X	X			X						
		RWBL	~~IIII~~ ~~IIII~~ I	X	X			X		X								
		BARS	II															
		SOSP	1	X				X										
		HEGU	1			X												
		COGR	1			X												
WB04	7:20	HOWR	1	X				X						X				
		BHCO	IIII			X	X											
		AMRO	IIII	X				X										
		SOSP	1	X				X										
		NOFL	1			X												
		BAOR	1	X				X										
		EUST	IIII			X								X				
		AMGO	II	●		X	X											
		RWBL	II	X				X										
		DOWO	1	X			X							X			X	
		MODO	1			X												
WB05	7:44	COGR	~~IIII~~ I			X											X	
		MAWR	IIII	X			X	X	X									
		RWBL	~~IIII~~ ~~IIII~~ I	X			X	X	X									
		~~COYE~~	~~1~~	~~X~~				~~X~~										
		~~YEWA~~	~~1~~	~~X~~				~~X~~										

Woodbridge / Cheesequake Avian Point Count Data Sheets

Date: " Observer: " Site: "

check all that apply

point	start time	species	number	sex			vocal.		interact				breeding					
				male	female	unknown	call	song	countersing	chase	flock	pair	copulation	food carry	fecal sac	feed young	juv. Seen	nest material
		~~WIFL~~	~~1~~	~~X~~				~~X~~										
		BHCO	1	X				X										
		~~SOSP~~	~~1~~	~~X~~				~~X~~										
		BARS	1			X												
		EUST	11			X												

Woodbridge / Cheesequake Avian Point Count Data Sheets

Date: 6/5/19 Observer: TC Site: Woodbridge

check all that apply

point	start time	species	number	sex			vocal.		interact				breeding					
				male	female	unknown	call	song	countersing	chase	flock	pair	copulation	food carry	fecal sac	feed young	juv. Seen	nest material
WB01	6:03	AMRO	III			X								X				
~~RWBL~~		RWBL	𝍸 III	X			X	X		X								
		TRSW	III			X												
		OROR	I	X				X										
		WIFL	III	X				X	X									
		SOSP	III	X				X	X									
		YEWA	II	X				X	X									
		BAOR	I	X			X	X										
		HOWR	II	X				X	X									
		CEDW	II			X	X											
		AMGO	I	X														
WB02	6:20	BARS	𝍸			X											X	
		RWBL	𝍸 III	X	X		X	X	X									
WB03	6:42	WIFL	II	X				X										
		MAWR	II	X			X	X										
		COGR	II			X												
		RWBL	𝍸 III	X	X		X	X	X	X								
		GRCA	I			X												
		BARS	IIII			X												
		BHCO	I	X				X										
		SOSP	I			X												

Woodbridge / Cheesequake Avian Point Count Data Sheets

Date: 6/5/19 Observer: R Site: Woodbridge

check all that apply

point	start time	species	number	sex			vocal.		interact				breeding					
				male	female	unknown	call	song	countersing	chase	flock	pair	copulation	food carry	fecal sac	feed young	juv. Seen	nest material
WB04	6:58	SOSP	III	x				x										
		HOWR	II	x				x	x									
		BAOR	I			x	x											
		AMRO	IIII	x			x	x										
		EUST	II			x												
		BHCO	I	x				x										
		BLJA	II			x	x											
		RWBL	III			x	x											
WB05	7:16	MALL	● I		x													
		MAWR	IIII	x			x	x	x									
		RWBL	𝍸 III	x	x		x	x	x									
		COGR	II			x				x								

Woodbridge / Cheesequake Avian Point Count Data Sheets

Date: 6/24/19 Observer: TC Site: Cheesequake

check all that apply

point	start time	species	number	sex			vocal.		interact				breeding					
				male	female	unknown	call	song	countersing	chase	flock	pair	copulation	food carry	fecal sac	feed young	juv. Seen	nest material
CQ05	5:54	MAWR	IIII	X		X	X	X	X									
		CLRA	II			X	X											
		OSPR	II		X	X						X					X	
		WILL	III			X	X											
		RWBL	IIII	X	X		X	X						X				
		BAIS	I			X												
		BLNH	I			X												
CQ03	6:11	[redacted] MAWR	IIII I	X		X	X	X	X	X								
		CLRA	I			X	X											
		WILL	II			X	X											
		BAIS	II			X												
		RWBL	III	X				X										
		GREG	I			X												
CQ04	6:31	REVI	II	X				X										
		BLSA	II			X	X			X								
		GRCA	I	X				X										
		COYE	I			X	X											
		WBNU	I			X	X											
		CARW	I	X				X										
CQ02	6:44	COYE	III	X		X	X	X										
		RWBL	III	X		X	X	X										
		MAWR	IIII	X				X										
CQ01	7:02	EABL	I	X				X										
		GRCA	[redacted] III	X		X		X		X								
		CEDW	I			X	X											
		CHSP	I	X				X										
		BAOR	I			X	X											

page 1 of _____

Woodbridge / Cheesequake Avian Point Count Data Sheets

Date: 6/24/19 Observer: TC Site: Cheesequake

check all that apply

point	start time	species	number	sex: male	sex: female	sex: unknown	vocal.: call	vocal.: song	interact: countersing	interact: chase	interact: flock	interact: pair	breeding: copulation	breeding: food carry	breeding: fecal sac	breeding: feed young	breeding: juv. Seen	breeding: nest material
		AMGO	1	X			X											

page 2 of 2

Woodbridge / Cheesequake Avian Point Count Data Sheets

Date: 6/29 Observer: TL Site: Cheesequake

check all that apply

point	start time	species	number	sex: male	sex: female	sex: unknown	vocal.: call	vocal.: song	interact: countersing	interact: chase	interact: flock	interact: pair	breeding: copulation	breeding: food carry	breeding: fecal sac	breeding: feed young	breeding: juv. Seen	breeding: nest material
CQ05	5:47	MAWR	卌 I	X			X	X	X									
		RWBL	卌 III	X	X		X	X										
		WIFL	I	X														
		OSPR	II			X											X	
		CLRA	I			X	X											
		WILL	I			X	X											
		BARS	III			X												
CQ03	5:59	MARW	卌	X				X	X									
		RWBL	III	X	X		X	X	X									
		GREG	III			X												
		GBHE	II			X				X								
		BARS	I			X	X											
CQ04	6:42	CACH	III															
		AMRO	I			X	X											
		COYE	I	X				X										
		BLJA	II			X	X											
		GCFL	II			X	X											
		RWBL	II	X			X											
~~CQ02~~	~~6:55~~	~~RWBL~~	~~III~~	~~X~~	~~X~~		~~X~~	~~X~~	~~X~~									
		~~MAWR~~	~~I~~	~~X~~				~~X~~										
		YBCU	I	X				X										
		NOFL	I			X	X											
CQ02	6:55	RWBL	III	X	X		X	X	X									
		MAWR	I	X				X										
CQ01	7:11	GRCA	I	X				X										
		EABL	I	X			X	X										
		AMRO	I	X				X										
		SOSP	I	X				X										

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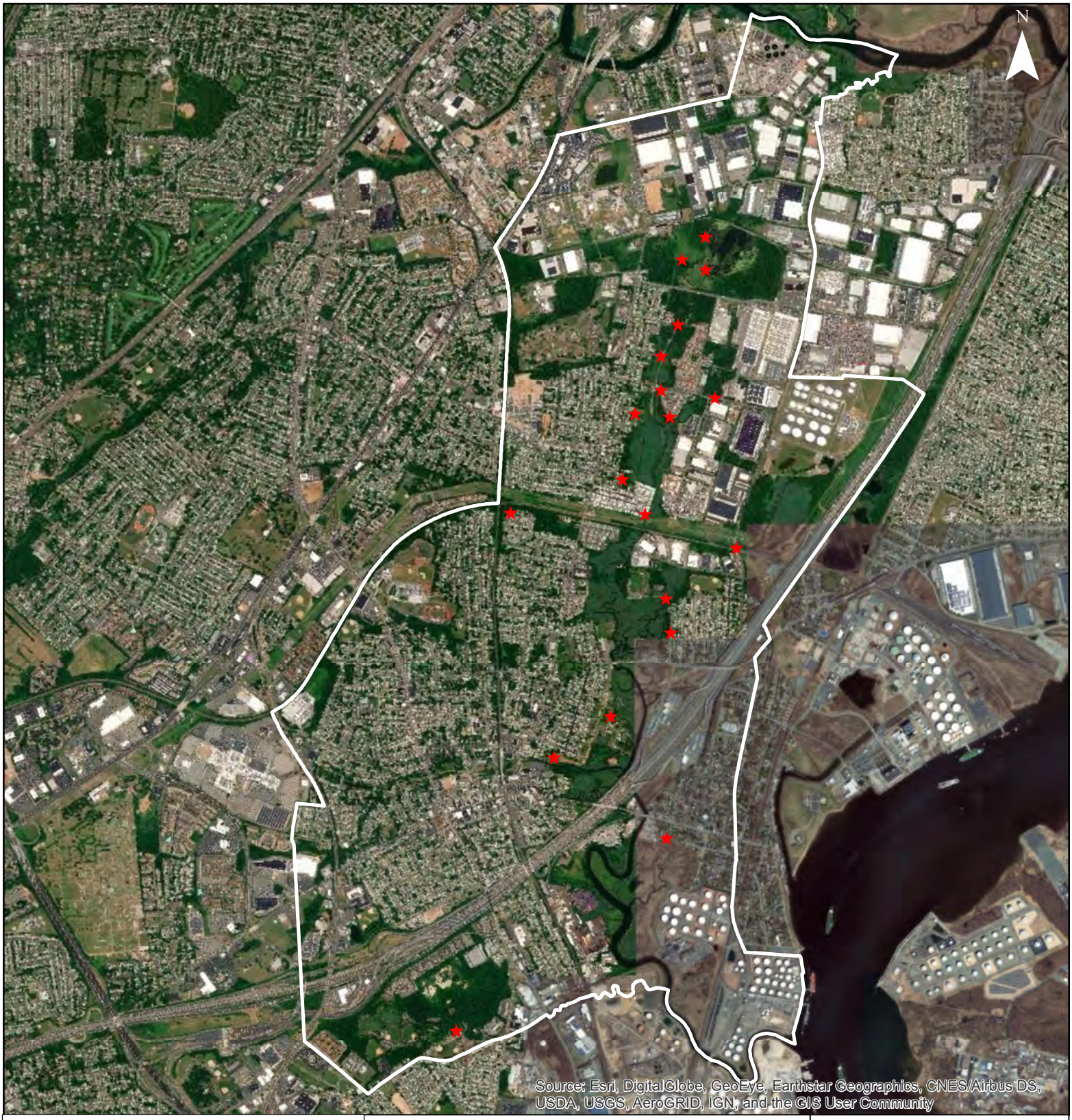
APPENDIX C

Amphibian Monitoring Data



Legend

- ★ Locations
- Boundary

0 250 500 1,000 1,500 2,000 Meters

Map 9
Woodbridge River Amphibian Monitoring Locations

Climate Resiliency Plan
Woodbridge Township, NJ

Wildlife Conservation and Management

Composed by: Justin Martinez
Map Creation Date: April 10, 2020
Source: NJDEP, DOIT, BGIS
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
Coordinate System: GCS_North_American_1983

Woodbridge River
Amphibian Survey 2019

Date	Oros N	Oros W	Oros S	267 Homestead Ave, Avenel	408 Evergreen Forest Blvd, Avenel	1001 Evergreen Evergreen Forest Blvd, Avenel	1489 Piper Ave, Avenel	120 Morrisey Ave, Avenel	1054 Blandford Ave, Avenel	971 Blandford Ave, Avenel	29 Alison Dr., Avenel	83 Lyons Ave, Woodbridge	185 Blair Rd, Port Reading	99 6th Ave, Port Reading	62 6th Ave, Port Reading	564 Heidelberg Ave, Woodbridge	52 Claire Ave, Woodbridge	27 Bridge St, Sewaren	1010 Florida Grove Rd, Perth Amboy
3/21/19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-
4/6/19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4/20/19	*	*	*	-	-	-	-	BUFR	-	-	-	-	-	-	-	-	-	-	-
5/4/19	BUFR	BUFR	BUFR SPPE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5/17/19	GRFR BUFR SPPE	GRFR SPPE	BUFR SPPE	-	-	-	SSPE	SPPE *	-	-	-	-	-	-	-	-	-	-	-
6/11/19	GRFR	BUFR GRFR	BUFR GRFR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6/17/19	BUFR GRFR	GRFR SPPE	BUFR GRFR	-	-	-	-	BUFR	-	-	-	-	-	-	-	-	GRFR	-	-

	Pickerel Frog	S. Leopard Frog	Wood Frog	Green Frog	Carpenter Frog	Bullfrog	Upland Chorus Frog	NJ Chorus Frog	Spring Peeper	N. Gray Treefrog	N. Cricket Frog	Fowler's Toad	American Toad	Eastern Spadefoot Toad
Code	PIFR	SOLF	WOFR	GRFR	CAFR	BUFR	UPCF	NJCF	SPPE	NGTF	NOCF	FOTO	AMTO	ESFT

5/17 * = GRFR HEARING? VISUAL CONFIRMATION OF GRFR OR BUFR

Legend

- ★ Locations
- Boundary

0 125 250 500 750 1,000 Meters

Map 10
Cheesequake State Park Amphibian Monitoring Locations

Climate Resiliency Plan
Old Bridge Township, NJ

Wildlife Conservation and Management

Composed by: Justin Martinez
Map Creation Date: April 10, 2020
Source: NJDEP, DOIT, BGIS
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
Coordinate System: GCS_North_American_1983

Cheesequake State Park
Amphibian Survey 2020

Date	Site 1: Green Trail	Site 2: Green Trail	Site 3: Museum Road	Site 4: Museum Road	Site 5: Museum Road	Notes
4/2/20	SPPE	SPPE	-	-	-	Windy night. Calls became unclear at moments due to strong winds.
4/7/20	SPPE	SPPE	SPPE	-	-	for site 4 and 5, I could hear SPPE in the background but not in the actual vicinity
5/5/20	SPPE, GRFR	SPPE, GRFR	GRFR	-	-	
5/23/20	SPPE, GRFR	SPPE, GRFR	-	GRFR	GRFR	
6/6/20	GRFR	GRFR	-	GRFG, SPPE	GRFR	
6/21/20	GRFR	GRFR	GRGR	GRFR	GRFR	
7/7/20	GRFR	GRFR	GRFR	GRFR	GRFR	

	Pickerel Frog	S. Leopard Frog	Wood Frog	Green Frog	Carpenter Frog	Bullfrog	Upland Chorus Frog	NJ Chorus Frog	Spring Peeper	N. Gray Treefrog	N. Cricket Frog	Fowler's Toad	American Toad	Eastern Spadefoot Toad
Code	PIFR	SOLF	WOFR	GRFR	CAFR	BUFR	UPCF	NJCF	SPPE	NGTF	NOCF	FOTO	AMTO	ESFT

Camper Gate Combo : 2 - 3 - 1 - 9

In case of emergies, call the 24 hour DEP Dispatch at 877-927-6337; be prepared to tell them your exact location within the park

Alwavs have the Permit and Letter of Permission with vou AT ALL TIMES and on the dashboard of EACH VEHICLE. AND HAVE YOUR RUTGERS ID WITH YOU.

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Experiment Station

APPENDIX D

Benthic Invertebrate Data

Map 11 – Woodbridge River Benthic Invertebrate Monitoring Locations

Map 12 – Cheesequake State Park Benthic Invertebrate Monitoring Locations

Legend

★ Locations

Boundary

0 250 500 1,000 1,500 2,000 Meters

Map 11
Woodbridge River
Benthic Macroinvertebrate Monitoring Locations

Climate Resiliency Plan
Woodbridge Township, NJ

Wildlife Conservation and Management

Composed by: Justin Martinez
Map Creation Date: April 10, 2020
Source: NJDEP, DOIT, BGIS
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
Coordinate System: GCS_North_American_1983

Legend

★ Locations

Boundary

0 125 250 500 750 1,000

Meters

Map 12
Cheesequake State Park
Benthic Macroinvertebrate Monitoring Locations

Climate Resiliency Plan

Old Bridge Township, NJ

Wildlife Conservation and Management

Composed by: Isabelle Zoccolo
Map Creation Date: 1/21/2021
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
Coordinate System: GCS_North_American_1983

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APPENDIX E

Water Quality Monitoring Data

Maps 13 – Water Quality Sampling Locations

Water Quality Monitoring Site Photo Log

Tabulated Water Quality Monitoring Results

Legend

- ★ Locations
- Boundary

0 250 500 1,000 1,500 2,000 Meters

Map 13
Woodbridge River Water Quality Monitoring Locations

Climate Resiliency Plan
Woodbridge Township, NJ

Wildlife Conservation and Management

Composed by: Justin Martinez
Map Creation Date: April 10, 2020
Source: NJDEP, DOIT, BGIS
Projection System: NAD_1983_StatePlane_NJ_FIPS_2900_Feet
Coordinate System: GCS_North_American_1983

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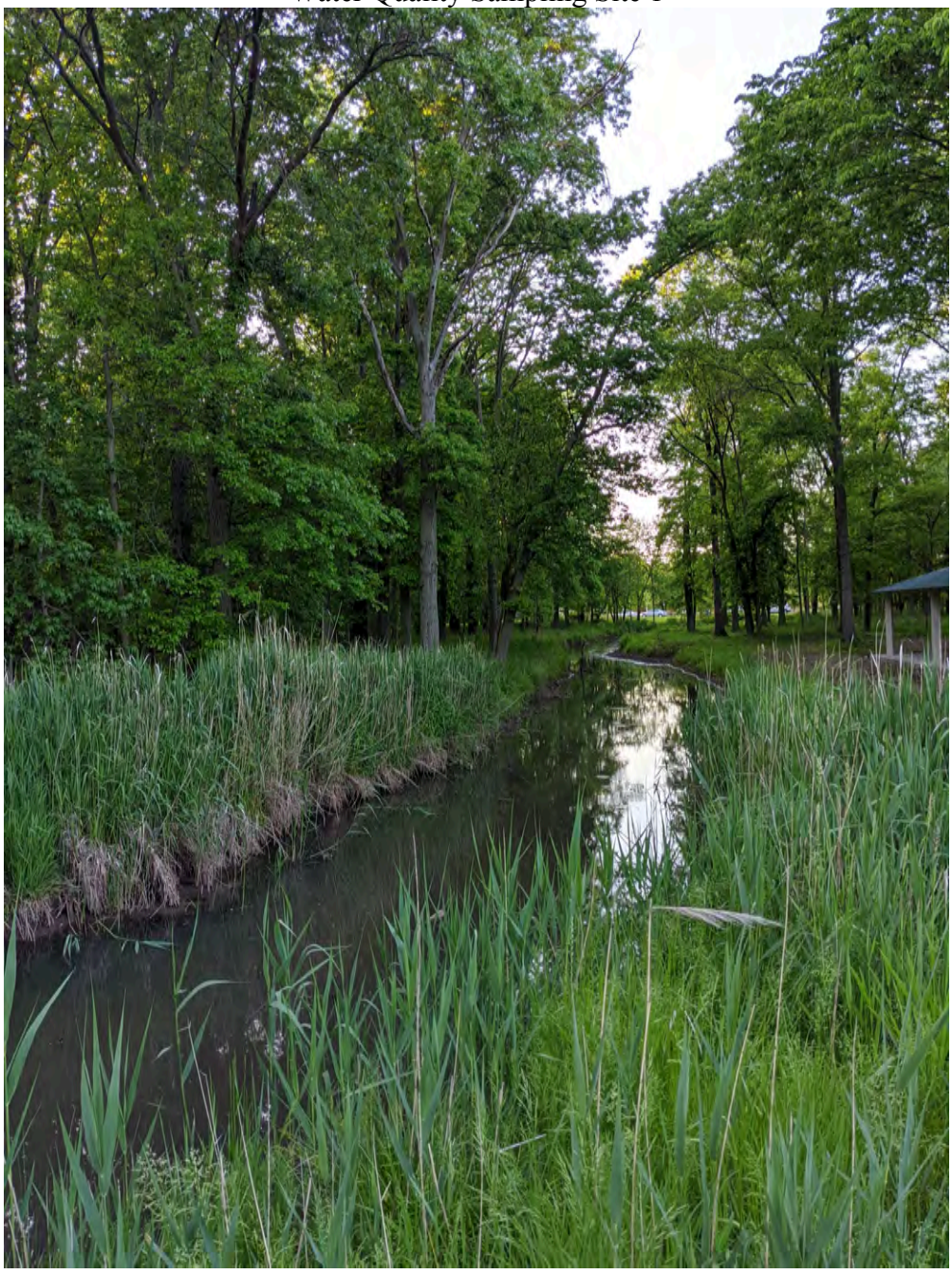
WATER QUALITY MONITORING SITE PHOTO LOG

Water Quality Sampling Site 1



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Water Quality Sampling Site 2

Water Quality Sampling Site 3

RUTGERS
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Experiment Station

Water Quality Sampling Site 4

Woodbridge River Surface Water Quality Monitoring - 2019

Location	Date Collected	48-hr Precipitation (inches)	pH (S.U.)	Dissolved Oxygen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Total Solids (mg/L)
Site 1	06/25/19	0.74	6.75	5.43	0.220	28.00	0.10 ND	0.25 ND	
Site 1	07/08/19	0.03	7.11	6.85	0.340	10.00	0.10 ND	0.25 ND	
Site 1	07/22/19	0.00	6.98	6.43	0.170	14.00	0.10 ND	0.25 ND	240.000
Site 1	08/05/19	0.73	6.70	4.71	0.320	16.00	0.10 ND	0.25 ND	260.000
Site 1	08/19/19	0.00	6.64	4.23	0.210	10.00	0.10 ND	0.25 ND	240.000
Site 1	09/07/19	0.32	6.92	6.04	0.150	5.00	0.10 ND	0.25 ND	250.000
Site 1	09/27/19	0.00	6.76	3.87	0.110	18.00	0.10 ND	0.25 ND	270.000
Site 1	10/20/20	0.00	7.47	5.81	0.120	10.00	0.10 ND	1.20	190.000
n			8	8	8	8	8	8	6
minimum			6.64	3.87	0.11	5.00	0.10	0.25	190.00
maximum			7.47	6.85	0.34	28.00	0.10	1.20	270.00
mean			6.86	5.42	0.21	13.88	0.10	0.37	241.67
std. dev.			7.18	1.06	0.09	7.02	0.00	0.34	27.87
std. error			2.54	0.38	0.03	2.48	0.00	0.12	11.38

Woodbridge River Surface Water Quality Monitoring - 2019

Location	Date Collected	48-hr Precipitation (inches)	pH (S.U.)	Dissolved Oxygen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Total Solids (mg/L)
Site 2	06/25/19	0.74	6.90	4.39	0.260	42.00	0.10 ND	0.25 ND	
Site 2	07/08/19	0.03	7.13	6.43	0.200	48.00	0.10 ND	4.60	
Site 2	07/22/19	0.00	6.85	3.43	0.380	42.00	0.10 ND	0.25 ND	330.000
Site 2	08/05/19	0.73	6.80	5.72	0.200	30.00	0.10 ND	2.30	5900.000
Site 2	08/19/19	0.00	6.97	4.30	0.240	26.00	0.10 ND	0.25 ND	980.000
Site 2	09/07/19	0.32	7.22	6.29	0.200	14.00	0.10 ND	0.76	880.000
Site 2	09/27/19	0.00	7.01	4.05	0.097	22.00	0.10 ND	0.25 ND	18000.000
Site 2	10/20/19	0.00	6.43	4.46	0.120	17.00	0.10 ND	1.30	1200.000
n			8	8	8	8	8	8	6
minimum			6.43	3.43	0.10	14.00	0.10	0.25	330.00
maximum			7.22	6.43	0.38	48.00	0.10	4.60	18000.00
mean			6.85	4.88	0.21	30.13	0.10	1.25	4548.33
std. dev.			7.01	1.11	0.09	12.63	0.00	1.54	6898.84
std. error			2.48	0.39	0.03	4.47	0.00	0.54	2816.44

Woodbridge River Surface Water Quality Monitoring - 2019

Location	Date Collected	48-hr Precipitation (inches)	pH (S.U.)	Dissolved Oxygen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Total Solids (mg/L)
Site 3	06/25/19	0.74	7.01	4.55	0.270	18.00	0.10 ND	0.75	
Site 3	07/08/19	0.03	7.03	5.51	0.130	34.00	0.10 ND	0.25 ND	
Site 3	07/22/19	0.00	7.02	3.89	0.210	16.00	0.10 ND	44.00	14000.000
Site 3	08/05/19	0.73	7.01	4.29	0.200	32.00	0.10 ND	0.25 ND	21000.000
Site 3	08/19/19	0.00	6.97	4.30	0.180	20.00	0.10 ND	0.25 ND	20000.000
Site 3	09/07/19	0.32	7.22	6.29	0.083	9.50	0.10 ND	4.80	10000.000
Site 3	09/27/19	0.00	7.01	4.09	0.170	27.00	0.10 ND	6.20	22000.000
Site 3	10/20/19	0.00	7.01	5.44	0.200	14.00	0.10 ND	0.25 ND	17000.000
n			8	8	8	8	8	8	6
minimum			6.97	3.89	0.083	9.5	0.10	0.25	10000.00
maximum			7.22	6.29	0.270	34.0	0.10	44.00	22000.00
mean			7.03	4.80	0.180	21.3	0.10	7.09	17333.33
std. dev.			7.85	0.85	0.056	8.8	0.00	15.10	4633.21
std. error			2.78	0.30	0.020	3.1	0.00	5.34	1891.50

Woodbridge River Surface Water Quality Monitoring - 2019

Location	Date Collected	48-hr Precipitation (inches)	pH (S.U.)	Dissolved Oxygen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Total Solids (mg/L)
Site 4	06/25/19	0.74	7.01	3.75	0.310	18.00	0.10 ND	2.30	
Site 4	07/08/19	0.03	7.22	5.31	0.150	28.00	0.10 ND	0.25 ND	
Site 4	07/22/19	0.00	7.10	5.29	0.280	15.00	0.10 ND	2.50	8800.000
Site 4	08/05/19	0.73	7.20	4.81	0.220	24.00	0.10 ND	0.25 ND	23000.000
Site 4	08/19/19	0.00	7.20	4.61	0.240	21.00	0.10 ND	0.25 ND	19000.000
Site 4	09/07/19	0.32	6.93	5.95	0.027	22.00	0.10 ND	0.25 ND	10000.000
Site 4	09/27/19	0.00	7.00	49.30	0.260	31.00	0.10 ND	40.00	21000.000
Site 4	10/20/19	0.00	6.99	5.23	0.150	9.50	0.10 ND	0.25 ND	18000.000
n			8	8	8	8	8	8	6
minimum			6.93	3.75	0.027	9.5	0.10	0.25	8800.00
maximum			7.22	49.30	0.310	31.0	0.10	40.00	23000.00
mean			7.07	10.53	0.205	21.1	0.10	5.76	16633.33
std. dev.			7.66	15.68	0.092	6.9	0.00	13.87	5872.53
std. error			2.71	5.54	0.032	2.5	0.00	4.90	2397.45

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= violation of surface water quality standard (SWQS)
ND = non-detect; 1/2 the Reporting Detection Limit applied

SWQS:

pH	6.5-8.5 SU
dissolved oxygen	<3.0 mg/L
total phosphorus	0.1 mg/L
total suspended solids	40.0 mg/L
nitrite	1.0 mg/L
nitrate	10.0 mg/L
total solids	n/a

Methods:

pH	SM 4500-H B-11
dissolved oxygen	SM 4500-O G-11
total phosphorus	SM 4500-P B5-11+E-11
total suspended solids	SM 2540 D-11
nitrite	EPA 300.0
nitrate	EPA 300.0
total solids	SM 2540 G (18th Ed.)

Weather Station:
www.wunderground.com