MaineDOT

Final Reports

Roadside Vegetation Management of Invasive Plants

To Benefit Biodiversity and MaineDOT Management Programs

Roadside Bumblebee and Butterfly Survey

August 2018

TABLE OF CONTENTS

FINAL REPORT

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Roadside Vegetation Management of Invasive Plants to Benefit Biodiversity and MaineDOT Management Programs

Surveying for invasive and native plants along the roadside, 2016.

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Maine Department of Agriculture, Conservation and Forestry

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Executive summary

Roadside vegetation management is a complex challenge in which multiple objectives must be considered. Safety is of course paramount, but additional considerations include controlling aggressive invasive plants and fostering native plant biodiversity to support a variety of pollinators. To better understand how Maine Department of Transportation (MaineDOT) can maximize benefits in these areas, a research project was conducted by the Maine Natural Areas Program (MNAP) to investigate invasive plant and native plant diversity along the roadsides. A pollinator census project was conducted by Dr. Frank Drummond of the University of Maine.

Surveys were conducted along MaineDOT Priority 1 Road Corridors in the summers of 2016 (vegetation) and 2017 (vegetation and pollinators). Forty-four vegetation sites and 10 pollinator sites were sampled, representing all MaineDOT Regions and all but four Maine counties. At the same time, a separate project (Wild Seed native plants manual) was underway to identify native plants suitable for use in roadside restoration plantings. This report presents the results of the MNAP vegetation sampling, and a synthesis of this work with the Wild Seed manual and the pollinator results.

A total of 33 invasive plant species were found across the 44 sites. Invasive plants were found at every site except one, with 50% of sites having at least one larger area of mapped infestation. This report suggests "trigger points" for targeted invasive plant management, including small/new infestations and infestations of not-yet-widespread ("Early Management") species. These represent an excellent return on investment to manage invasive plants, since success is more likely when infestations are small or species are not yet widespread. The identification of Special Management Areas for invasive plants is also suggested – these are areas of adjacency with special natural habitats where invasive plant management could be prioritized in order to protect the special natural features bordering the MaineDOT right of way.

Dominant plants found via vegetation survey included beneficial, pollinator-supporting native plants (goldenrods, asters, white meadowsweet) and numerous non-native grass species. This report compares the dominant plants found with the Wild Seed manual and notes several species or species groups already flourishing along the roadsides which could be used as potential seed sources, and/or managed differently (e.g., less frequent mowing, mowing around identified patches of desirable species) to encourage their spread and persistence.

Pollinators were found foraging on a variety of native and non-native flowering plants, as summarized in Dr. Drummond's separate report. Drummond found that pollinator diversity was positively correlated with flowering plant diversity. Although pollinators may forage for nectar or pollen resources on exotic plants, this represents only a single phase of the insect life cycle. Native plants are known to provide a more complete set of resources (e.g., oviposition sites, overwintering sites, leaf tissue for larval food source). Despite opportunistic use of exotic plant flowers by pollinators, native plants are recommended for roadside restoration and planting projects.

Introduction and Objectives

Roadside vegetation management is an important and complex responsibility for state Departments of Transportation. In addition to maintaining safety along travel corridors, other goals of vegetation management may include protection of habitat for rare and/or beneficial species such as pollinators and native plants, and reduction of invasive plants. Invasive plants can grow over infrastructure, obscure sight lines, interfere with routine maintenance, and negatively impact ecological values of roadside habitats.

In this project, the Maine Natural Areas Program (MNAP), in the Maine Department of Agriculture, Conservation and Forestry, received research funding from the Maine Department of Transportation (MaineDOT) to conduct a study of invasive and native plants along Priority 1 road corridors. The project also included a separate, contracted insect survey of a subset of the vegetation sampling sites, conducted by Dr. Frank Drummond of the University of Maine. At the same time, a separate research award was made to the Wild Seed Project (WSP) to develop a guide to Maine native plants useful for roadside restoration. MNAP, WSP, and Dr. Drummond collaborated to share key information to benefit both projects. These projects together represent a significant investment in understanding the current composition and potential of vegetation along the roadsides.

Key objectives of the MNAP project included:

- Better understanding of the status of invasive, non-native, and native plants along the roadways.
- Upload of all invasive plant data to the centralized database *i*MapInvasives, to improve our understanding of statewide invasive plant distribution.
- Invasive plant management recommendations given the observed status of invasive plants, including Best Management Practices for preventing the spread of invasive plants along roadways.
- Recommendations for ways to support native plant populations, given the native plants found along the roadways and how these can benefit pollinators.
- Support for the preparation of a *Maine Invasive Plants Field Guide* (this MNAP project was already underway with the support of multiple additional partners).
- Census of butterfly and bumblebee populations at selected vegetation sites and analysis of these results in the context of butterfly and bumblebee conservation needs (via contracted entomologist).

Methods

Vegetation surveys

Vegetation survey sites along the Priority 1 road corridors were selected in two ways. First, the GIS layer of Priority 1 roads was intersected with MNAP Focus Areas of Statewide Significance. (Focus Areas of Statewide Significance represent modeled areas of potential rare species abundance, and are therefore of higher priority for survey and potential habitat improvement and protection.) Intersecting areas of roadway were highlighted and saved. The same procedure was conducted using the Inland Wading Bird and Waterfowl Habitat layer (IWWH) produced by the Maine Department of Inland Fisheries and Wildlife. These data represent important wetland areas used by wildlife, including but not limited to waterbirds. Finally, the road network was intersected with the MNAP Conserved Lands data layer, which represents lands under formal protection from development by fee ownership and/or conservation easement. In all three analyses, a buffer of 100 meters was first applied to the roads to account for the actual width of interstate roads. Intersections of these areas represented MNAP priorities for vegetation survey, given the many miles of Priority 1 roads statewide and the desire to survey and therefore inform management of the more ecologically important areas of roadside. From these intersected areas, ~25 sites were selected with the goals of a) spreading the surveys geographically over as much of the Priority 1 road network as possible, and b) including many sites along 295/95 (more potential for backslope habitat of interest). Second, an additional 25 sites were generated by using a random number generator to generate a direction and starting distance (within 4 miles) from existing sites. Randomly generated sites were all one mile in length, whereas the MNAP-selected sites varied in length from 0.5-5 miles. Within the longer sites, a subsample was selected based on evaluation of aerial imagery (e.g., to maximize survey in areas adjacent to wetlands or other non-forested areas), safety factors, or location of overlap between adjacency to Conserved Land, Focus Area, and/or mapped rare habitats (from previous MNAP data).

Vegetation surveys were conducted at 44 sites along Priority 1 roads in 2016 and 2017 (Figure 1). At each site, the survey proceeded in 0.2 mile increments ("segments"). Within each segment, surveyors noted up to ten most dominant native and non-native plants, mapped invasive plants (more detail below), noted adjacent habitat type, and estimated total percent cover of invasive plants.

Invasive plants were mapped using either points or shapes, depending on infestation severity. For herbaceous plants, a 15 meter minimum separation distance was used – i.e., plants within 15 meters of each other were not mapped independently. For shrubs and trees, a 25 meter separation distance was used. The threshold for mapping using shapes (polygons) as opposed to points was determined by density and continuousness of the infestation, at the discretion of the survey team. When infestations were mapped as polygons, additional information was collected: percent cover class, plant maturity, and plant density/distribution.

Field sites were located on the ground using Garmin Oregon GPS units, loaded with GIS shapefiles. The start and end of each segment was recorded as a point and a track of the survey path was recorded. The same two people (Nancy Olmstead and Mary Yurlina) sampled each vegetation site, and every effort was made to cover the entire inslope, backslope, and adjacent habitat edge. Surveyors wore standard fluorescent safety vests and hats, the survey vehicle was parked off the pavement at every restricted access highway site, and surveys were coordinated with MaineDOT regional staff to provide safety signage and support at restricted access sites.

Development of Best Management Practices (BMPs)

BMPs from four other states were reviewed (three New England states + California), and personnel from four New England states were interviewed by Nancy Olmstead on the phone in October and November 2017. See Appendix 1 for questions used and a list of interviewees. Note the questions were a guide and not all questions were asked to all interviewees. Internet research was conducted to locate other key materials such as federal executive orders, best educational resources and research on this issue.

Insect survey

Please see the report "Roadside Bumblebee and Butterfly Survey – Final Report to the Maine Department of Transportation" for methods and results of the insect survey

Invasive Plant Field Guide preparation

Several additional species which would not otherwise have been included in MNAP's *Maine Invasive Plants Field Guide* were researched and prepared thanks to support from this project funding. These include white sweet clover (*Melilotus albus*), wild parsnip (*Pastinaca sativa*), wild chervil (*Anthriscus sylvestris*), and giant hogweed (*Heracleum mantegazzianum*). Identification and control information was gathered from published sources such as scientific literature, white papers, and well-referenced fact sheets.

Results

Invasive plants

Thirty-three species of invasive plants were observed along the roadsides (Table 1). This included herbs, grasses, shrubs, vines, and trees. All but one site contained invasive plants, and twenty-two sites (50% of sites) had at least one mapped assessment (larger area of infestation) (Table 2). Seven sites had fewer than 10 invasive plants records. Average percent cover class midpoint ranged from 0 – 24% cover and invasive plant species richness ranged from 0 – 7 (Table 3).

The four sites along Route 9 in eastern Maine were the consistently least-invaded sites. In general, sites along I-95 and I-295 were some of the worst-invaded (high numbers of observations and assessments), but sites north of Old Town had fewer records than other I-95/I-295 sites. However, some routed road sites were just as infested as interstate sites.

Morrow's honeysuckle (*Lonicera morrowii*) was by far the most frequently observed invasive plant. The next-most observed plants (relatively similar levels) were: multiflora rose (*Rosa multiflora*), purple loosestrife (*Lythrum salicaria*), Asiatic bittersweet (*Celastrus orbiculatus*), autumn olive (*Elaeagnus umbellata*), Canada thistle (*Cirsium arvense*), and glossy buckthorn (*Frangula alnus*).

Please see Appendix 2 for maps of each site including point records of invasive plants and infested area assessments. Species-specific georeferenced invasive plant data will be provided with this report in the form of ArcGIS geodatabases for observations (points) and assessments (larger polygon areas of infestation).

Dominant plants (MNAP survey)

Five of the top 10 most dominant plants found along the roadsides were native species (Table 4). Of the top 52 most dominant species/groups (noted as dominant at High, Medium, or Low level in ≥5% of segments), 30 were native. The most dominant genus by far (twice as frequently dominant as the next-most dominant plant) was the goldenrod genus (*Solidago* spp.). White meadowsweet (*Spiraea alba*) was the next-most dominant plant. Not surprisingly, non-native grasses frequently dominated the areas surveyed. Dominant non-native grass species included: reed canary grass (*Phalaris arundinaceae*), redtop bentgrass (*Agrostis gigantea*), wild rye (*Elymus repens*), Kentucky blue grass (*Poa pratensis*), and smooth brome (*Bromis inermis*). A handful of non-native herbs such as crown vetch (*Securigera varia*), purple vetch (*Vicia cracca*), and smooth bedstraw (*Gallium mollugo*) were also frequently dominant.

Comprehensive list of all plants observed

While MNAP surveyed to record *dominant* plants, Dr. Drummond recorded plants *in flower* at the time(s) of his surveys. Hence, it is not surprising that the plant lists differed. MNAP recorded 382 dominant plant species or species groups (those noted as dominant in at least one segment; please see Excel file of Linear Transect Data provided with this report). Dr. Drummond recorded 231 plant species or species groups in flower. Of Drummond's species, 87 were not included in the MNAP list. In addition, 33 invasive plant species were found by MNAP, 11 of which were not dominant and which were therefore not included in the dominant plant list. After adding species from Dr. Drummond's list and the additional invasive species not recorded as dominant, a grand total of 480 species/species groups were recorded over the entire project (Appendix 3, note shaded species are additions from Drummond plant list).

Discussion and take-home messages

Invasive plants found along the Priority 1 roadsides

Of the top 10 most commonly observed invasive plants in this project (Table 1), six of them are bird-dispersed: Morrow's honeysuckle (*Lonicera morrowii*), multiflora rose (*Rosa multiflora*), Asiatic bittersweet (*Celastrus orbiculatus*), autumn olive (*Elaeagnus umbellata*), glossy false buckthorn (*Frangula alnus*), and common buckthorn (*Rhamnus cathartica*). These five shrubs and one vine can spread along the roadways and from the roadside into adjacent habitats as birds consume fruits and transport the seeds. Many of these infestations were found in backslope areas and forest edges where birds could realistically be expected to forage for fruits. Unfortunately, our results confirm that roadsides host large populations of invasive plants which can be "source" populations for invasion of interior forests, wetlands, other natural areas, and productive farmlands.

It is notable that the dominant invasive plants observed do not include some common invasive plants which have horticultural origins such as Japanese barberry and burning bush. These two species were observed, but at much lower frequencies. This could perhaps reflect a different composition of invasive plants along roadways compared to young forests, old fields, and other areas closer to human habitation.

Five of the top ten most commonly observed invasive plants were shrubs, with one vine, one tree, and three herbs (Table 1). Trees such as black locust and Norway maple may be more likely to be managed since trees encroaching on the safety clear zone, and large trees in some areas of backslopes, are likely viewed as a safety hazard. Therefore, invasive shrubs, herbs, and vines may more frequently escape vegetation management.

A few "Early Management" invasive plant species were found – these are species MNAP regards as not yet widespread in the state and therefore of higher priority to manage. Ornamental jewelweed (*Impatiens glandulifera*), false spiraea (*Sorbaria sorbifolia*), wild parsnip (*Pastinaca sativa*), and white poplar (*Populus alba*) all fall into this category and are recommended for management action. Ornamental jewelweed is an annual herb which favors wet areas and riparian zones. It spreads aggressively along waterways and forms dense monocultures. It can be controlled with mowing, weed-whacking, or pulling. Cut stems will re-sprout and can flower, so more than one treatment per season will likely be required to prevent seed production. Herbicides can also be used before seed set, though aquatic formulations and a licensed applicator would be required. False spiraea has been planted as an ornamental and can spread from plantings to colonize adjacent forests and open areas. Although its ability to spread by seed is somewhat unclear, due to its documented ability to persist and spread from plantings, MNAP recommends control of this species. Wild parsnip is a threat to open natural areas, productive hayfields and pastures, and contains a phytophototoxin which causes a painful rash if a person is exposed; for this last reason it might be considered a top priority to control. Field crews should wear protective gear around this plant, and use caution not to get plant juices on exposed skin. Pulling, weed-whacking or mowing, or herbicide can be used for control. White poplar has been planted as an ornamental and can spread by seed and suckering. It is an aggressive colonizer of open and edge habitats, and is a much larger problem in states to our south. Therefore, we recommend nipping it in the bud where found to avoid potential spread.

Mowing equipment may be playing a role in the spread of several of the herbaceous invasive plants (e.g., knapweeds, thistles, largeleaf lupine). If mowing occurs later in the season, these species may have already gone to seed and can therefore be spread on mowing equipment between and within sites. Local and long-distance travel of seeds may be possible. There are many factors to take into consideration when deciding on time of mowing, but it is good to recognize that later mowing can spread invasive plant seeds. Treatment of these species by spot herbicide application earlier in the season, to prevent seed production, should be encouraged when possible.

Mowing equipment may also inadvertently spread species which can propagate via fragments – the most notable of these is Japanese knotweed. We recommend *not mowing Japanese knotweed populations* unless this is done on purpose as part of a management strategy, separate from general roadside mowing, with provisions made for cleaning of equipment immediately following mowing.

Suggested "trigger points" for invasive plant management

There are not enough resources to control every invasive plant along the roadsides. Therefore, we suggest a targeted program of controlling: 1) not yet widespread species, 2) new/small infestations, and 3) infestations located in Special Management Areas. A clear set of decision-making criteria could go a long way toward reducing the spread of invasive plants into natural areas, and provide an opportunity for MaineDOT to demonstrate leadership on this issue.

Not yet widespread invasive plants are currently in limited distribution within the state. In the forthcoming *Maine Invasive Plants Field Guide*, MNAP has characterized 42 species as either widespread, not yet widespread, or not yet detected in the state, based on published distributions in references such as *i*MapInvasives, the online flora GoBotany, and knowledge of MNAP staff. Aggressively controlling invasive plants which are not yet widespread is a way to get ahead of future invasive plant problems and reduce future spending on large, aggressive infestations which could block sight lines, be a nuisance and hazard in maintenance, harm workers via phytophototoxins, and spread aggressively into neighboring natural areas. Not yet widespread species such as ornamental jewelweed (*Impatiens glandulifera*) and wild parsnip (*Pastinaca sativa*) were infrequently found in our surveys and should not pose an undue burden to control. Field crews could be trained to recognize, report, and spot-control these species. MaineDOT could reap an immediate benefit of community support and appreciation by undertaking targeted control projects on a select set of invasive plants.

Small or new infestations of common invasive plants should also be targeted for rapid control. Treating small infestations of common species such as Japanese knotweed (*Fallopia japonica*), common reed (*Phragmites australis*), and others can prevent future safety problems, save valuable resources, and demonstrate MaineDOT leadership on this topic.

To achieve control of not yet widespread species and small/new infestations of common species, field vegetation crews need some level of training and support to recognize, document, control, and monitor the infestations. Please see the Potential Next Steps section below for suggestions.

Finally, we suggest the identification of Special Management Areas, within which MaineDOT could consider additional management of invasive plants. Special Management Areas could be designated based on proximity of MaineDOT roads to high-value habitats such as existing Conserved Lands, areas identified by the Dept. of Inland Fisheries and Wildlife as Inland Wading Bird and Waterfowl Habitats (typically large wetland complexes), and Exemplary or Rare Plants and Natural Communities as identified by MNAP. See the Potential Next Steps section for more detail on the Special Management Areas idea.

Dominant plants found along the roadsides and comparison with Wild Seed manual

Of the top 52 most-frequently dominant plant species (or species groups), 13 are included in the Wild Seed manual (Table 4). An additional 17 of the most-dominant plants are native species which are not included in the Wild Seed manual. It is encouraging that ~60% of dominant plant species found along the roadsides are native. Several of the most-dominant native plants (goldenrods, asters, and white meadowsweet) are noted in the Wild Seed manual as Workhorse species, able to be propagated relatively easily. These species should be good candidates for encouragement along the roadsides where they already exist, and can serve as potential restoration planting species. Whenever possible, avoid mowing areas of thriving native plant species, so they can complete their life cycles, set seed, and support beneficial native insects. Another native plant found to be dominant in many segments was sweetfern (*Comptonia peregrina*), a small, aromatic shrub which can tolerate dry, open sites since it can fix nitrogen; this species may be an excellent restoration candidate for open, full-sun sites where soils are well-drained and nutrient poor.

Some of the most dominant non-native plants found include grass species which have likely been purposely planted in seed mixes (e.g., *Agrostis gigantea*, *Elymus repens*, *Bromus inermis).* Although they may provide soil stabilization, these species likely provide minimal habitat for pollinators and other wildlife. Likewise, dominant herbs such as crown vetch and purple vetch (*Securigera varia*, *Viccia cracca*) may be visited for floral resources, but do not provide food or pupation sites for other life stages of native insects (e.g., caterpillars), and therefore are less desirable than native plants which could provide floral resources *and* larval food and development sites (Tallamy, 2018).

Plant use by pollinators

The majority of butterflies were caught in flight or on non-nectar plant sources (together > 63% of captures). That said, butterflies were collected more frequently than would be expected on exotic flowering plant species compared to native flowering plant species

(Drummond report, page 13). This is somewhat discouraging as it may mean that native plants are not receiving pollination services from butterflies compared to exotic plants.

Bumblebees were noted to forage on a variety of exotic and native plant species. Dr. Drummond wrote in his report, "This is not surprising since bumblebees are considered generalist foragers that while having preferences also visit a wide range of taxa for pollen and nectar." One wonders whether bumblebees would have opportunistically visited native flowering plants instead of exotics and invasive plants, if native plants had been available.

It is important to note that nectar and pollen are only one resource necessary to maintain pollinator health. Larval stages (e.g., butterfly and moth caterpillars) need other food resources such as the leaves and other tissue of specific native plant hosts. Most insects are specialized herbivores which have evolved to consume the tissues of particular plant genera or species. When invasive or exotic plants displace natives, overall native insect diversity can be expected to decline (Tallamy, 2018). Dr. Drummond notes in his report that as overall floral species richness increased, total pollinator richness (butterflies and bumblebees) increased. We suggest that all attempts to augment flowering plant species richness utilize native plants, since these provide both floral and non-floral resources necessary for the complete life cycles of native insects.

Potential next steps

Special Management Areas

There are numerous places along the Priority 1 roadways where Conserved Lands, mapped MNAP features (Rare Plant or Rare or Exemplary Natural Community), Inland Wading Bird and Waterfowl Habitat, MNAP Focus Areas, or other special natural habitats abut the MaineDOT right of way. These areas could be considered Special Management Areas (SMAs), where invasive plant management may rise to a higher level of priority in order to protect the conservation values of the adjacent habitats. Some of these SMAs abut public or private Conservation Lands which would benefit from partnership between MaineDOT and the local land manager(s).

Two sites which abut numerous kinds of natural areas and which could therefore be considered SMAs are Sites 1 and 23 from this project (Table 2). Detailed maps of these two sites show invasive plant species present and adjacency to the natural habitats (Figures 2 & 3). Site 1, located in T1 R6 WELS, abuts Conserved Land, Inland Wading Bird and Waterfowl Habitat, and an MNAP feature. Site 23, in Fryeburg along the Saco River, abuts all these kinds of features plus an MNAP Focus Area.

While this project took the initial step of mapping invasive plants in a fraction of the locations where potential SMAs exist, a future collaboration could conduct a more exhaustive GIS analysis to locate areas of adjacency between special natural features and MaineDOT Priority 1 road corridors. Such an analysis could determine the areas of highest density of special natural features, and prioritize these for consideration as SMAs, where invasive plant management could be prioritized (to include mapping, control, and monitoring).

Proposed training opportunities for MaineDOT field staff

To enable field staff to recognize invasive plants, we propose annual invasive plant training, with a field component, during the growing season. Ideally this training would be rotated through the Regions at different times of the year so that over the course of several years each Region's staff would be exposed to training at different times across the growing season. This would allow staff to learn the phenology of the top invasive plant species, which greatly impacts their detection. For example, the easiest time to spot (and learn!) multiflora rose is in mid-late June when it is in bloom. By rotating the training time each year, each Region would eventually receive a training at multiple times during the growing season.

The invasive plant training could be combined with native plant identification training focused on the suite of dominant native plant species found along the roadsides. Now that we have a short list of the most-frequent native plants found along the roadsides, the training can be focused on this set of species.

At the same time, field staff could be trained on the iMapInvasives online reporting tool. This would allow for quick, easy, centralized reporting via smartphone when small or new populations of target invasive plants are found. The iMap App is a simple and free tool for reporting and MNAP staff could easily provide a hands-on training as part of the annual training. Vegetation managers could set up customized iMap email alerts to receive notification when field staff report infestations.

References

Tallamy, D., PhD. Professor of Entomology, University of Delaware. Presentation 7/2018 in Rockport, ME on the topic of how native plants support biodiversity.

Table 1. *i*MapInvasives invasive plant data collected statewide. 33 species observed.

Species	# Observations	# Assessments
Morrow's Honeysuckle	305	23
Multiflora Rose	124	6
Purple Loosestrife	118	2
Asiatic Bittersweet	113	5
Autumn Olive	108	5
Canada Thistle	108	1
Glossy False Buckthorn	94	16
Black Locust	77	5
Japanese Knotweed	67	6
Buckthorn	52	2
Bull Thistle	50	0
Climbing Nightshade	46	0
Largeleaf Lupine	39	0
White Sweet-clover	36	0
Norway Maple	32	1
Colt's-foot	26	0
Common Reed	23	2
Japanese Barberry	21	0
Wild Parsnip	19	2
Spotted Knapweed	9	2
Rugosa Rose	7	0
Black Knapweed	4	0
Bishop's Goutweed	3	0
Privet (species unknown)	3	0
Knapweed (species unknown)	3	0
Burning Bush; Winged Euonymus	2	0
False Spiraea	2	0
Honeysuckle Shrub (species unknown)	2	0
Bristly Locust	1	0
Brown Knapweed	1	0
Dame's Rocket	1	0
Ornamental Jewelweed, Himalaya Touch-me-not	1	0
White Poplar	1	0
sum	**1498**	**78**

Table 2. Sites detail – location, adjacent Natural Areas, abundance of invasive plants. Numbers give a broad sense of site-level invasive plant infestations.

Site	**Town**	**Road**	**Kind(s) of Natural Area Adjacent†**	**Inv. Obs**	**Inv. Assmts**	**Acres Assmts**
1	T1 R6 WELS	I-95 SB	Conserved Lands, MNAP Feature, IWWH	28		
2	Herseytown	I-95 SB	None	17	3	2.7
3*	Monticello/Littleton	Route 1	None	29	1	5.6
4*	Monticello	Route 1	None	38	1	0.3
5	Poland/New Gloucester	Route 26	Conserved Lands, IWWH	95		
6	Gray	Route 26	None	20		
7	Searsmont	Route 3	Conserved Lands, IWWH	25		
8	Belmont	Route 3	None	54	9	1.0
9	Sydney	I-95 SB	IWWH	70		
10	Augusta	I-95 SB	None	79	2	0.6
11*	Plymouth	I-95	IWWH	29	8	3.5
12*	Plymouth/Etna	I-95 NB	None	18	3	0.3
13	Bar Harbor	Route 3	Focus Area, MNAP Features	39		
14	Trenton	Route 3	None	7		
15	Brunswick	Route 1 NB	Conserved Lands, Focus Area	31	7	1.8
16	Brunswick	I-295 SB on-ramp	None	11		
17	Kennebunk	Route 1	Conserved Lands, Focus Area	42	6	1.4
18	Wells/Ogunquit	Route 1	Focus Area, MNAP Feature	29		
19	Scarborough	Route 1	Focus Area, MNAP Feature, Conserved Lands	37	4	0.9
20	Scarborough	Route 701	Focus Area	52		
21	Newcastle	Route 1	Conserved Lands, Focus Area	24	1	0.1
22	Nobleboro	Route 1	IWWH	3		

23	Fryeburg	Route 302	Conserved Lands, MNAP Features, Focus Area, IWWH	20	1	0.2
24	Bridgton	Route 302	None	10		
25	Sanford	Route 109	Focus Area, MNAP Feature, Conserved Lands	14		
26	Alfred/Lyman	Route 111	Conserved Lands, Focus Area	34	1	0.1
27N*	Old Town/Orono	I-95 SB	Conserved Land, Focus Area	21	2	3.6
27S	Bangor	I-95 SB	Conserved Land, Focus Area	31	4	0.5
28*	Old Town	I-95 SB	IWWH	10		
29	Amherst	Route 9	Conserved Land, Focus Area	4		
30	Clifton	Route 9	None	6		
31	Crawford	Route 9	Conserved Land, Focus Area	4		
32	Wesley	Route 9	IWWH, Conserved Lands	0		
33	Presque Isle	Route 1	None	8		
34	Presque Isle	Route 1	None	11		
35*	Gilead	Route 2	Conserved Lands	18		
36*	Bethel	Route 2	None	10		
37	Hampden	I-95 NB	IWWH, Conserved Lands	31	3	2.8
38	Bangor	I-95 NB	None	59	4	6.2
39*	Richmond	I-295	IWWH	75	3	5.8
40*	Bowdoinham	I-295 SB	None	71	5	2.5
41	Carmel	I-95 SB	IWWH	13	2	2.2
42	Skowhegan	Route 2	Conserved Lands, MNAP Features	35	5	6.5
43	Norridgewock	Route 2	None	41	3	0.5

*Pollinator sampling site.

† IWWH = Inland Wading Bird and Waterfowl Habitat; MNAP Feature = mapped rare plant, or rare or high-quality natural community; Conserved Lands = lands held in fee or easement for conservation purposes; Focus Area = Focus Area of Statewide Ecological Significance = area identified in statewide analysis as having exemplary biological diversity potential, potential high conservation value.

Table 3. Detailed invasive plant data by site.

Site	Average* midpoint of % Cover class of invasive plants	Average* invasive plant spp. richness
1	1.0	2.4
2	2.2	2.8
3	1.0	2.2
4	1.5	4.8
5	1.6	3.9
6	1.6	2.8
7	0.7	1.3
8	7.3	7.0
9	2.3	3.3
10	15.0	6.2
11	24.2	3.2
12	2.2	1.8
13	1.0	3.2
14	0.8	1.0
15	4.0	4.0
16	1.0	4.3
17	13.2	4.0
18	6.0	5.3
19	11.5	4.3
20	2.2	6.0
21	2.0	4.0
22	1.0	4.0

23	0.8	1.2
24	0.5	1.5
25	0.4	0.8
26	1.5	3.3
27N	3.0	2.8
27S	7.0	4.7
28	0.8	1.5
29	0.4	0.6
30	0.6	0.6
31	0.2	0.2
32	0.0	0.0
33	0.8	0.8
34	0.8	1.0
35	1.0	1.8
36	0.8	1.0
37	4.2	3.2
38	11.5	6.0
39	4.0	4.8
40	12.0	7.0
41	5.4	3.8
42	2.2	4.2
43	3.0	5.3

*Averages of segment scores. Each site had between 3-7 segments (commonly 5-6).

Table 4. Dominant plants found in MNAP survey. Green denotes native species; dark green are in Wild Seed manual.

Species name	Habit	High	Medium	Low	# segments in which dominant at any level	Wild Seed manual?	Wild Seed notes
Solidago spp.	Herbs	14	57	44	115	YES (this genus)	Workhorse
Spiraea alba	Shrub	5	28	36	69	YES	Workhorse
Phalaris arundinacea	Graminoid	11	27	26	64	Non native genotype likely in roadsides	
Pteridium aquilinum	Fern	1	27	27	55	Native but not in manual	
Aster spp.	Herbs	1	24	25	50	YES (this genus)	Workhorse
Agrostis gigantea	Graminoid	4	21	25	50	Not native	
Elymus repens	Graminoid	6	14	29	49	Not native	
Poa pratensis	Graminoid	8	29	10	47	Not native	
Bromus inermis	Graminoid	5	14	26	45	Not native	
Calamagrostis canadensis	Graminoid	2	15	22	39	Native but not in manual	
Securigera varia	Herb	6	21	11	38	Not native	
Anthoxanthum odoratum	Graminoid	5	11	20	36	Not native	
Vicia cracca	Herb		11	23	34	Not native	
Galium mollugo	Herb	2	10	18	30	Not native	
Comptonia peregrina	Shrub		12	17	29	YES	Dioecious
Carex spp.	Graminoid	3	11	15	29	Native but not in manual	
Daucus carota	Herb		10	17	27	Not native	
Schizachyrium scoparium	Graminoid	2	11	12	25	YES	Workhorse
Vaccinium angustifolium	Sub-shrub		10	15	25	YES	
Rubus spp.	Shrubs		10	14	24	YES (this genus)	Workhorse
Trifolium pratense	Herb		9	15	24	Not native	
Graminoids	Graminoids	12	8	3	23	Not species specific	
Toxicodendron radicans	Shrub	1	6	12	19	Native but not in manual	
Dactylis glomerata	Graminoid	3	5	10	18	Not native	
Digitaria spp.	Graminoid	2	9	7	18	Not native	

Rubus idaeus	Shrub		9	9	18	Native but not in manual	
Asclepias syriaca	Herb		7	10	17	YES	Workhorse
Lawn grasses	Graminoids	8	7	2	17	Not species specific	
Onoclea sensibilis	Fern		4	13	17	Native but not in manual	
Agrostis sp.	Graminoid	4	5	7	16	Not species specific	
Lotus corniculatus	Herb		9	7	16	Not native	
Schedonorus arundinaceous	Graminoid	6	6	4	16	Not native	
Apocynum androsaemifolium	Herb		5	11	16	Native but not in manual	
Symphyotrichum spp.	Herbs			15	15	YES (this genus)	Workhorse
Schedonorus pratensis	Graminoid	6	5	4	15	Not native	
Poa palustris	Graminoid	1	5	8	14	Native but not in manual	
Parthenocissus quinquefolia	Vine		3	10	13	YES	Workhorse
Solidago canadensis	Herb		3	9	12	YES (this genus)	Workhorse
Acer rubrum	Tree		3	9	12	Native but not in manual	
Achillea millefolium	Herb		4	8	12	Native but not in manual	
Dicanthelium clandestinum	Graminoid		5	7	12	Native but not in manual	
Quercus rubra	Tree		5	7	12	Native but not in manual	
Rhus hirta	Shrub		5	6	11	YES	Workhorse
Artemisia vulgaris	Herb		2	9	11	Not native	
Gaultheria procumbens	Sub-shrub	1	4	6	11	Native but not in manual	
Pinus strobus	Tree		3	8	11	Native but not in manual	
Potentilla simplex	Herb		1	10	11	Native but not in manual	
Alnus incana	Shrub	1	5	4	10	YES	Workhorse
Phleum pratense	Graminoid		1	9	10	Not native	
Turf grass	Graminoids	6	4		10	Not native	
Aralia nudicaulis	Herb	1	2	7	10	Native but not in manual	
Danthonia spicata	Graminoid	3	4	3	10	Native but not in manual	

Figure 1. Map of sampling sites.

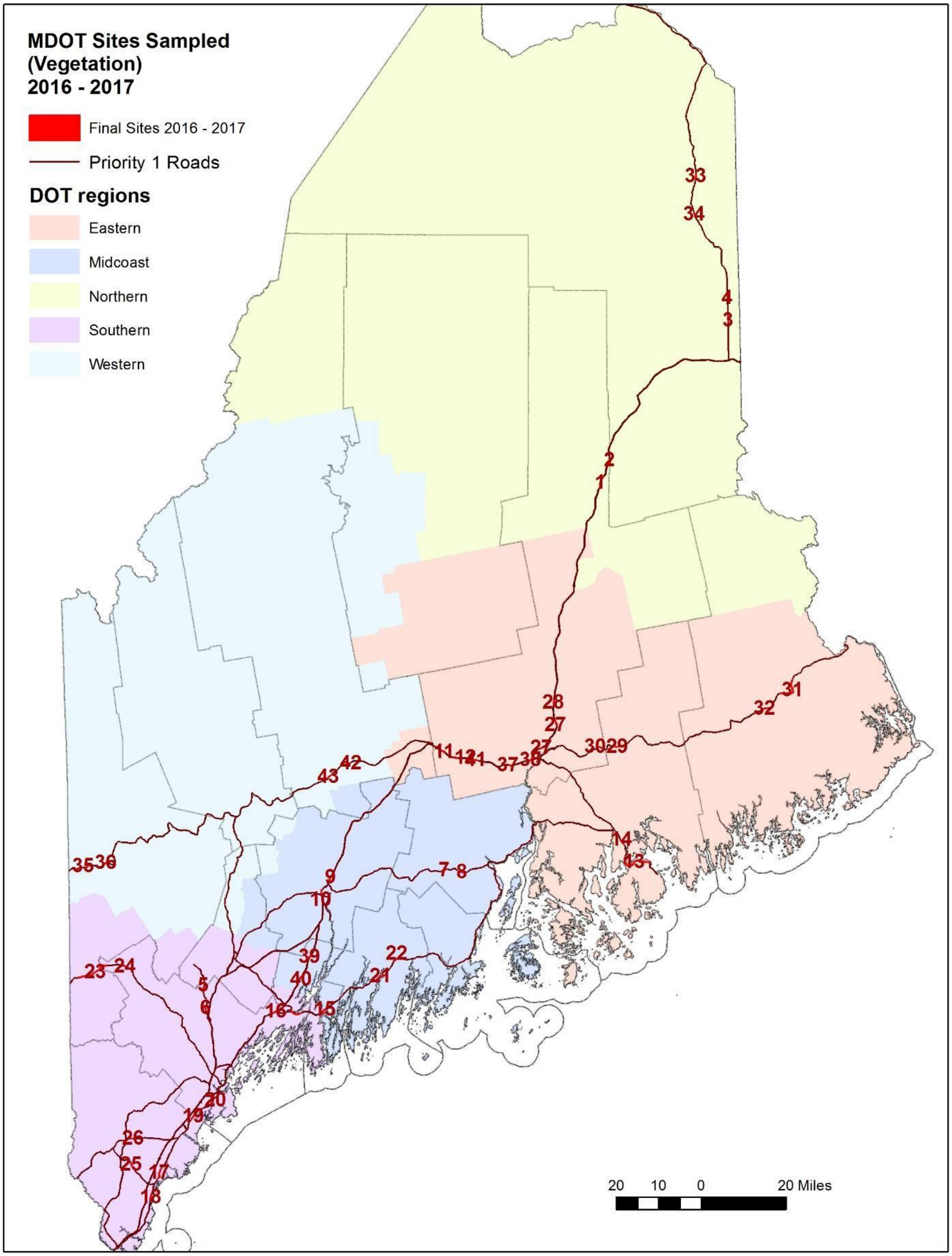


Figure 2. Map of Site 1, along I-95 in T1 R6 WELS, an example of a potential Special Management Area for invasive plants. Note the high density of overlapping natural resource features adjacent to the MaineDOT right of way.

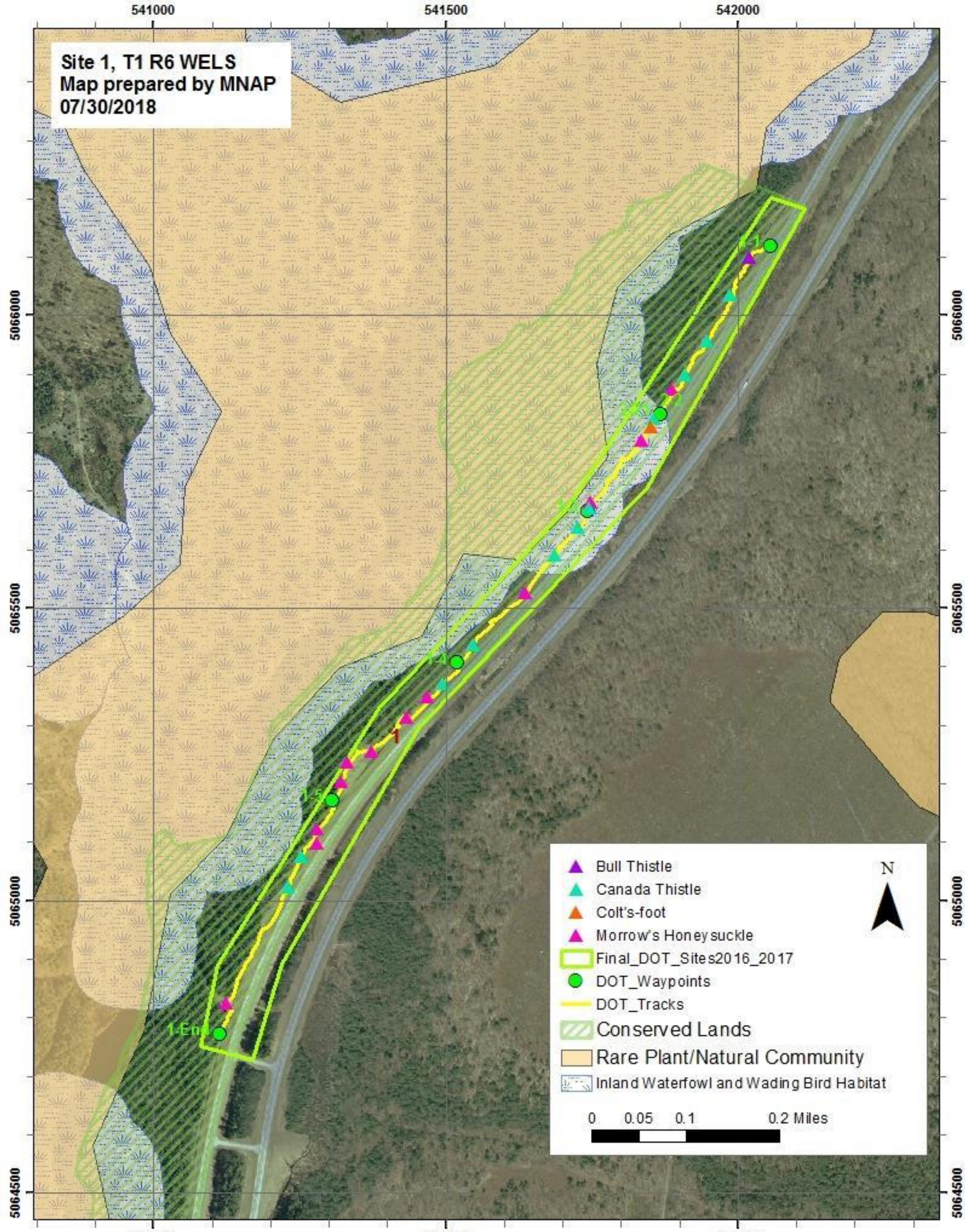
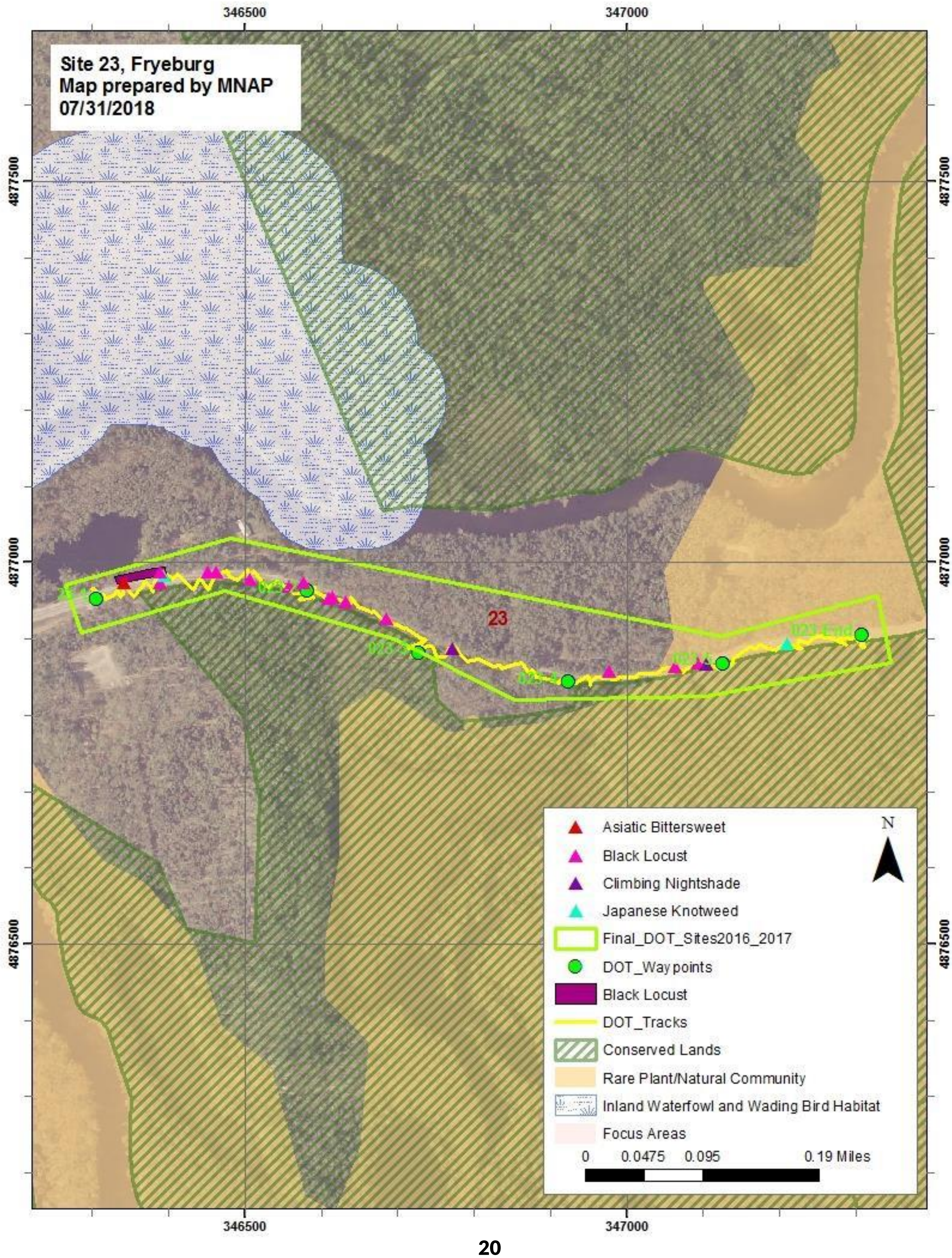


Figure 3. Map of Site 23, along Route 302 in Fryeburg, an example of a potential Special Management Area for invasive plants. Note the high density of overlapping natural resource features adjacent to the MaineDOT right of way.



Appendix 1

QUESTIONS FOR OTHER NEW ENGLAND DOTS RE INVASIVE PLANT BMPS FOR ROADSIDE WORK

1. Does your dept. have formalized BMPs for addressing invasive plants during DOT operations? IF SO, CONTINUE, IF NOT, SEE QUESTIONS AT BOTTOM.

2. What was the motivation/genesis of the BMPs? What was the process to develop them?

3. Are the BMPs considered mandatory or voluntary? Do you use any systems for tracking efforts such as project management software, checklists or sign-off procedures?

4. Once the BMPs were adopted, how are staff and contractors trained? What education strategies have been the most successful in helping workers learn to identify the plants and practice the BMPs?

5. What have been the biggest success stories in implementing the BMPs, or the most impactful of the BMPs?

6. What have been the biggest challenges in implementing the BMPs? Are there other practices that you wish the BMPs had addressed?

7. Anything else you wish to share about how your department has addressed invasive plants in your work?

[+ 1-2 specific questions on that state's BMPs as needed]

IF NO FORMALIZED BMPS

What are some of the practices your dept. uses to address roadside invasive plants in your operations? These might relate to control or suppression, preventing transport of seeds and fragments, dealing with ditching and culvert clean-out material, etc.

How are staff and contractors trained in invasive plant identification and issues such as avoiding accidental transport and how to avoid spreading invasive plants during construction projects?

Do your staff/contractors target invasive plants with herbicide and if so, can you tell me about those efforts? [If not, can you explain why not?] If so, do they target all invasive plants, or a subset?

Appendix 1

PERSONS INTERVIEWED BY N. OLMSTEAD FALL 2017

Marc Laurin, NH DOT Bureau if Environment

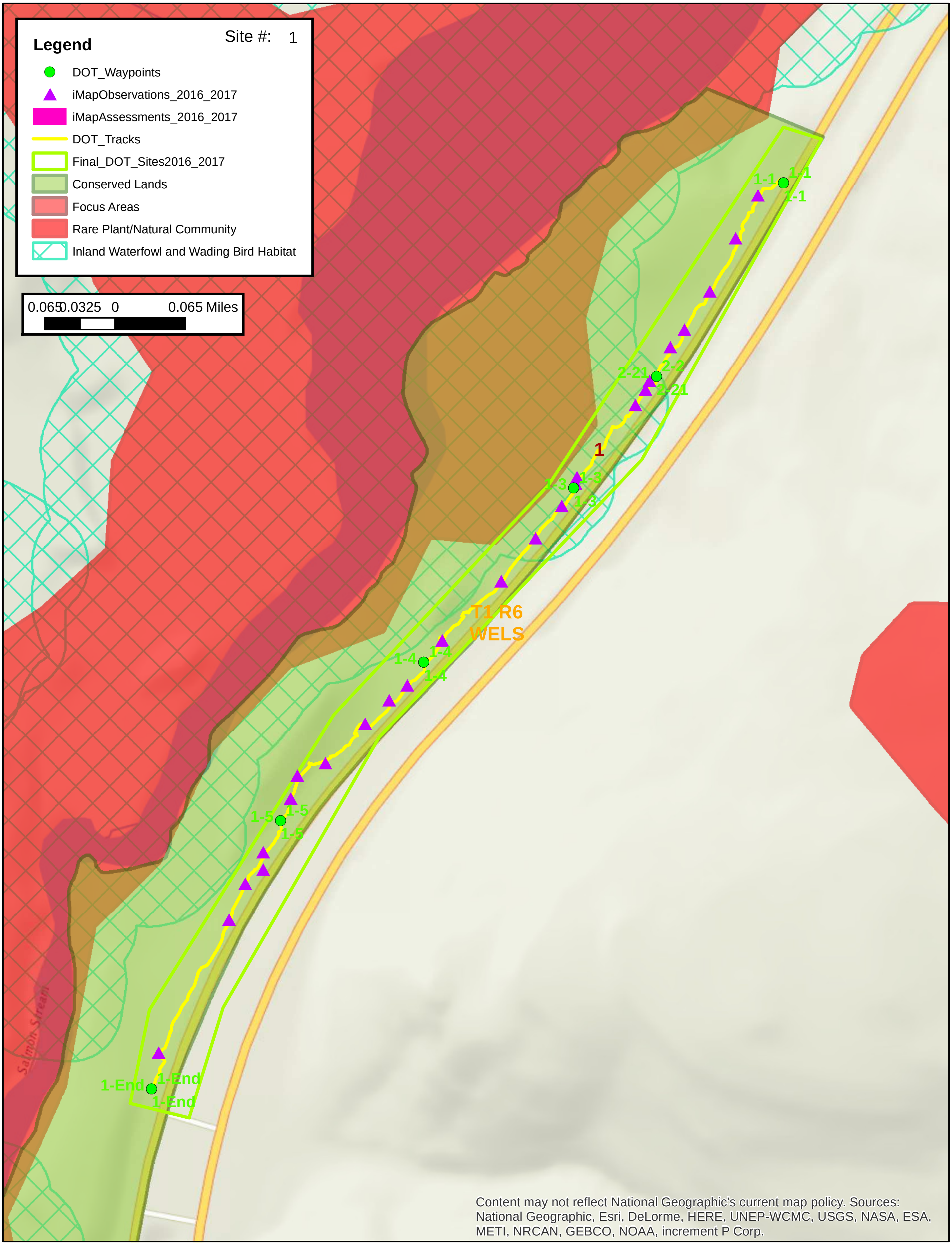
Loey Pushee, NH DOT, Maintenance Bureau

Craig DiGiammarino, VTrans Environmental Program Manager for Maintenance and Operations

George Batchelor, Mass DOT Landscape Design

Ed Frantz, NY DOT

Appendix 2 - Maps of All Study Areas (Areas 1 through 43)



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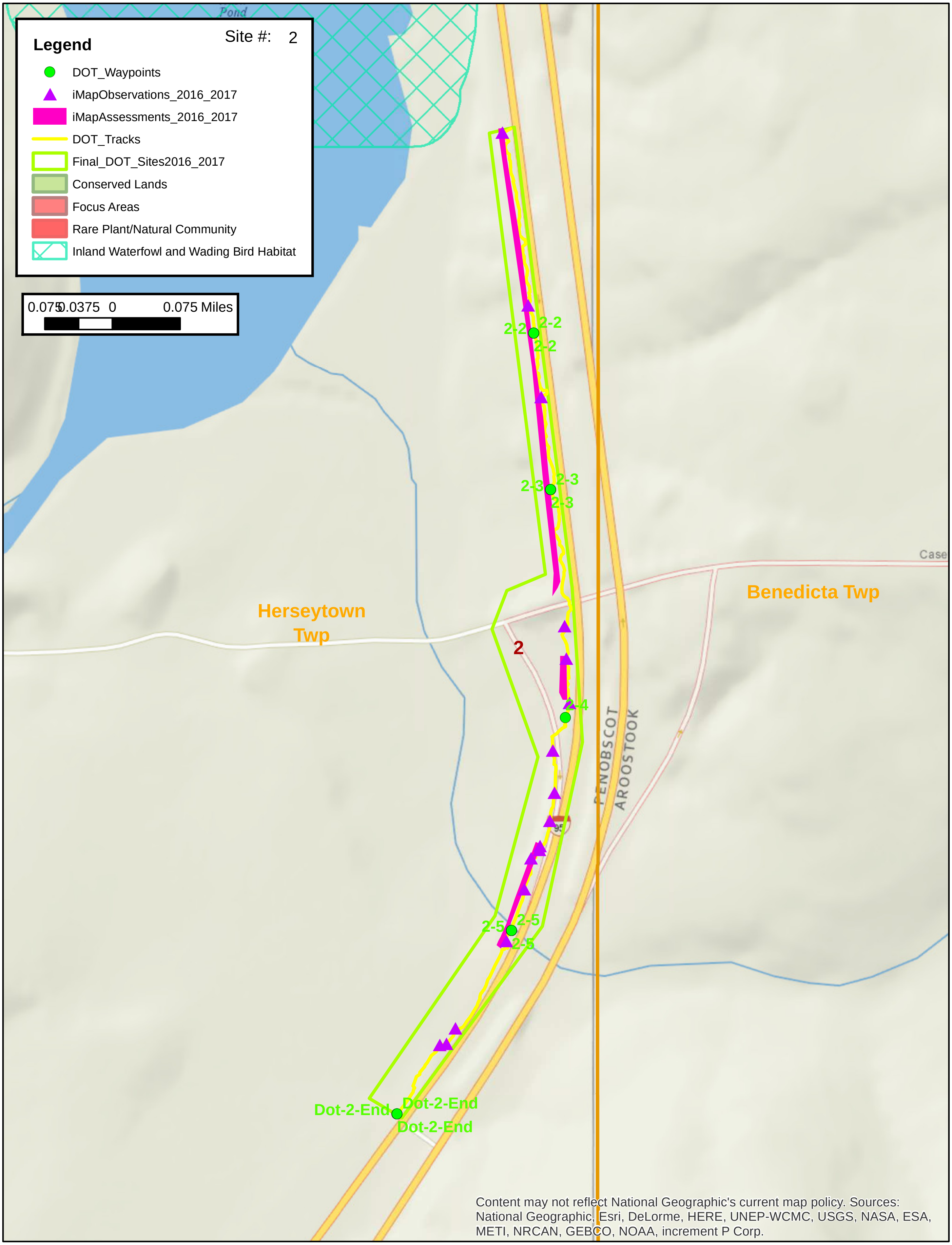
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.065 0.0325 0 0.065 Miles
1-1
2-21
2-2
1
1-3
T1 R6
WELS
1-4
1-5
1-End
Salmon Stream
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.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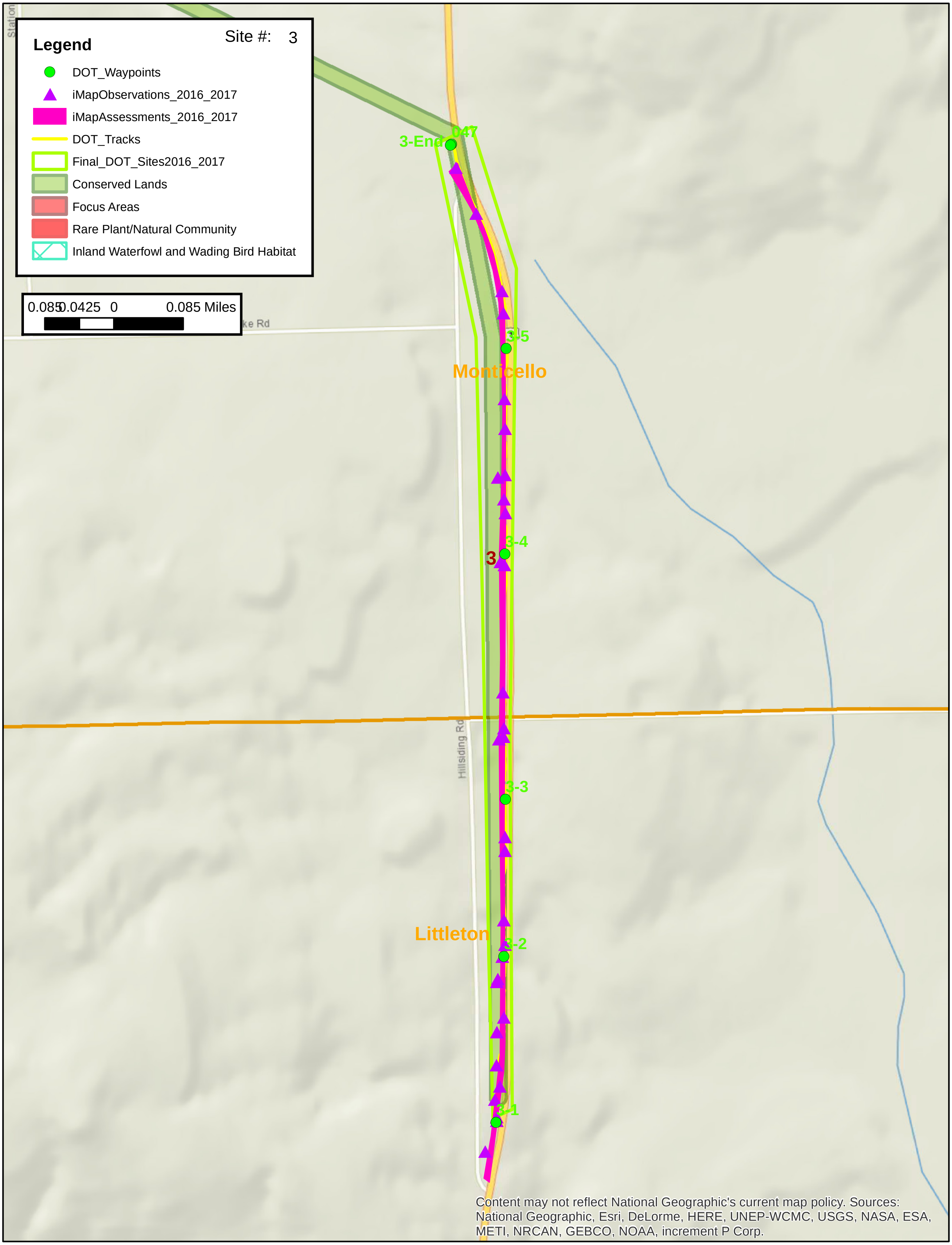
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.075 0.0375 0 0.075 Miles
Pond
2-2
2-3
2-4
2-5
Dot-2-End
2
Herseytown Twp
Benedicta Twp
Case
PENOBSCOT
AROOSTOOK
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.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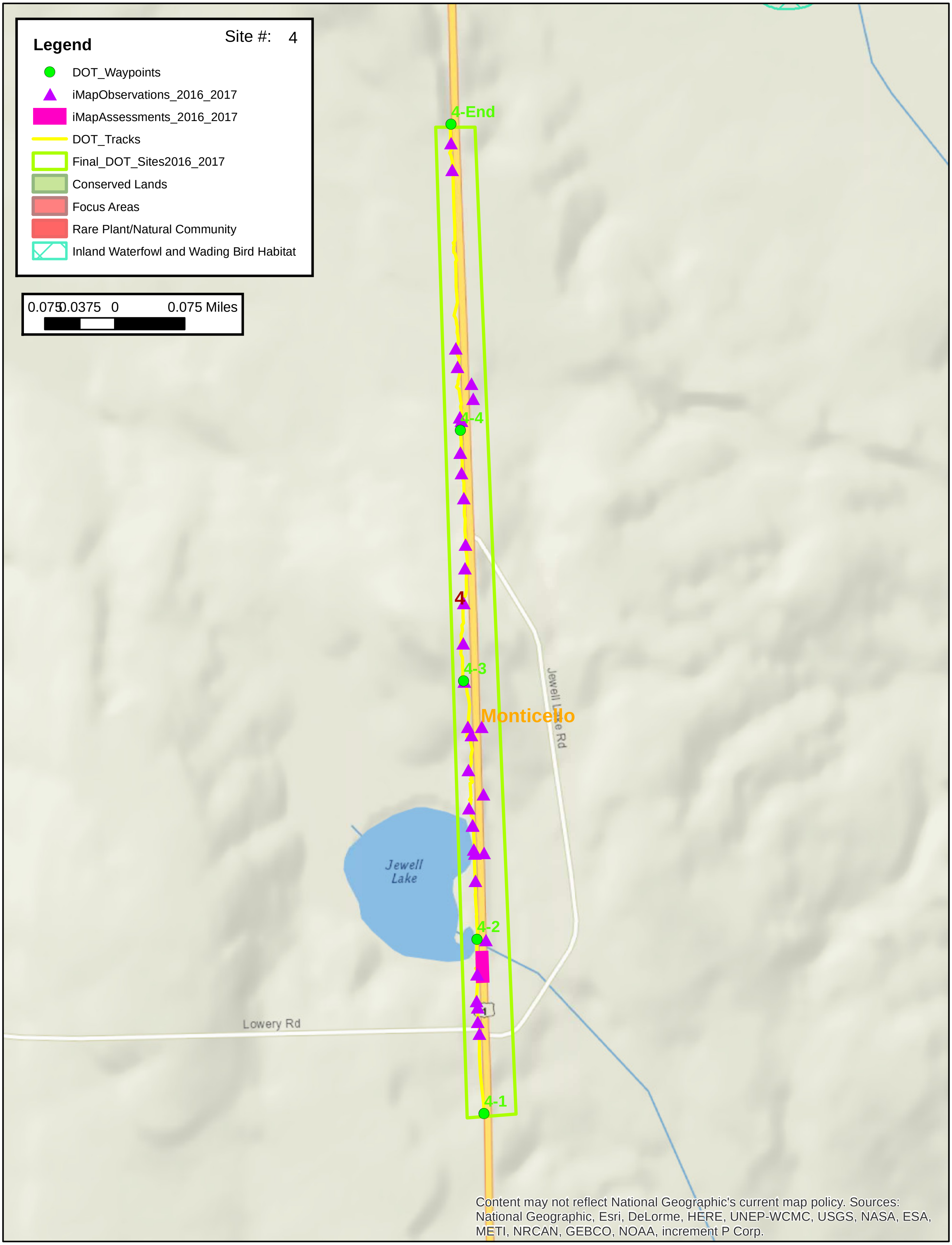
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.085 0.0425 0 0.085 Miles
3-End
3-5
Monticello
3-4
3
Hillsiding Rd
3-3
Littleton
3-2
3-1
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.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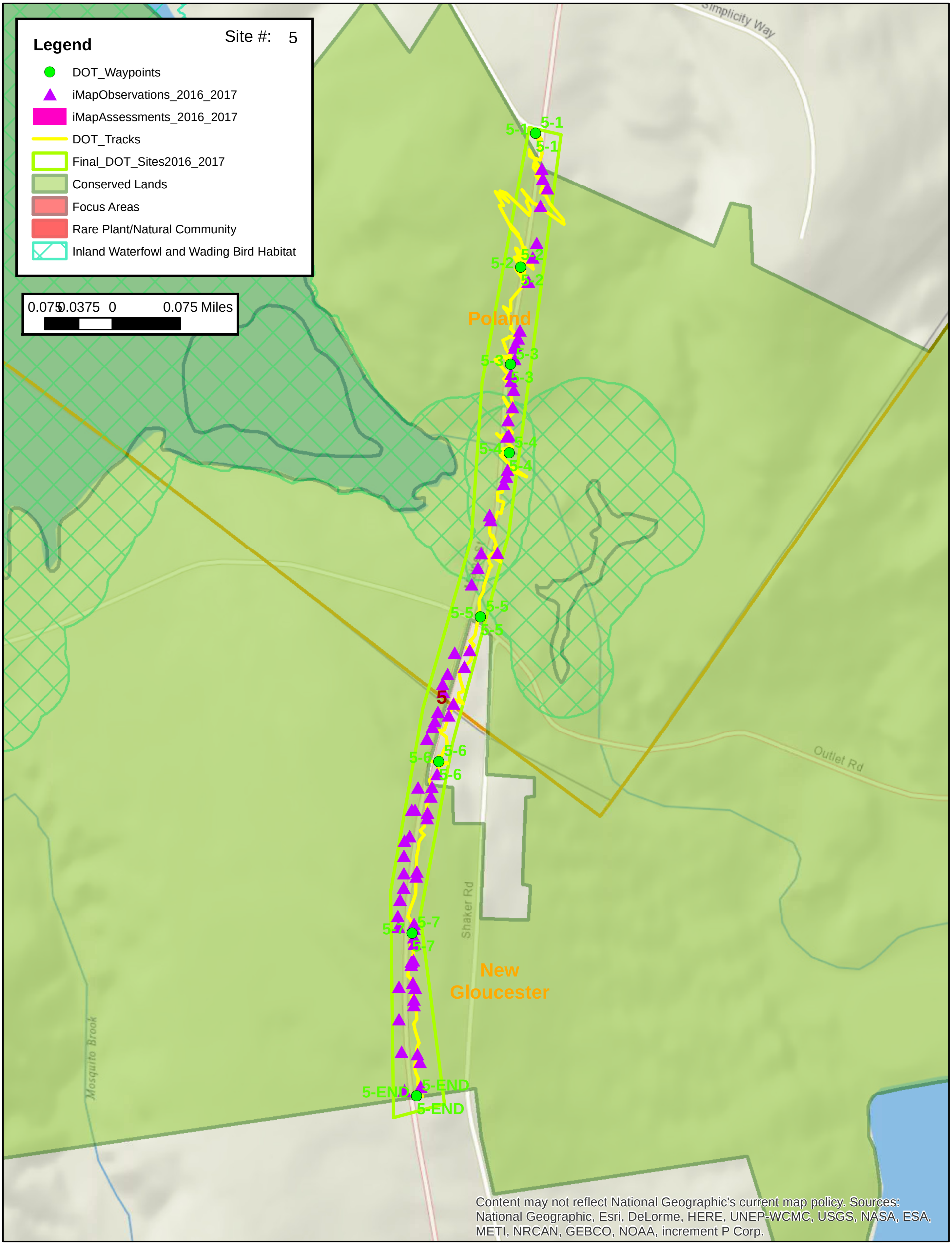
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.075 0.0375 0 0.075 Miles
4-End
4-4
4
4-3
Monticello
Jewell Lake Rd
Jewell Lake
4-2
Lowery Rd
4-1
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.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iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.075 0.0375 0 0.075 Miles
Simplicity Way
Poland
New Gloucester
Outlet Rd
Shaker Rd
Mosquito Brook
5-1
5-2
5-3
5-4
5-5
5-6
5-7
5-END
5
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.


Legend
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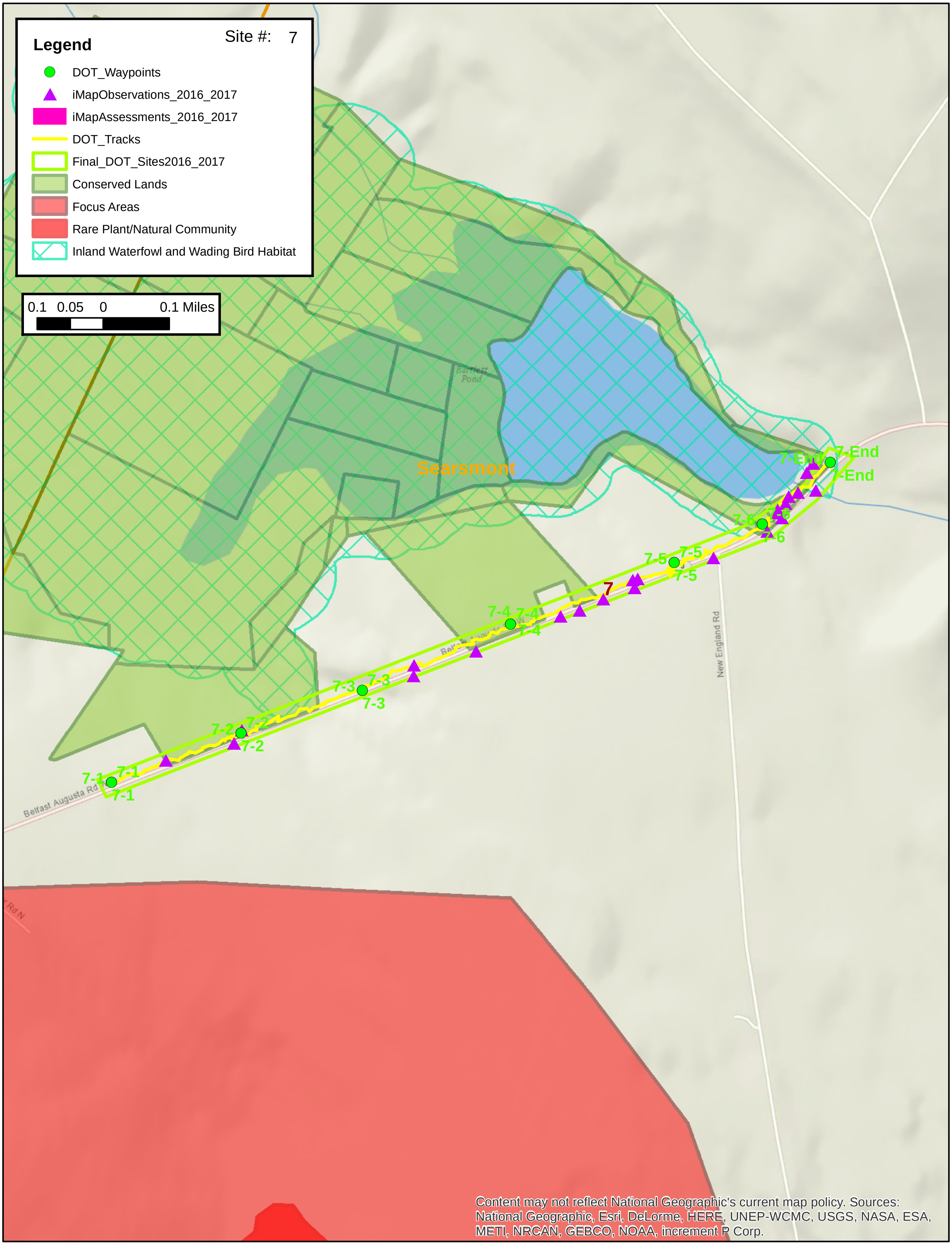
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.07 0.035 0 0.07 Miles
Mayberry Rd
Crystal Lake
Charlonate Dr
Game Farm Rd
Gray
Shaker Rd
Spiro Ave
Pine Cove Rd
Marie St
Marion Ave
Preble Way
Shaw Brook Ln
6-1
6-2
6-3
6-4
6-5
6-End
6
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.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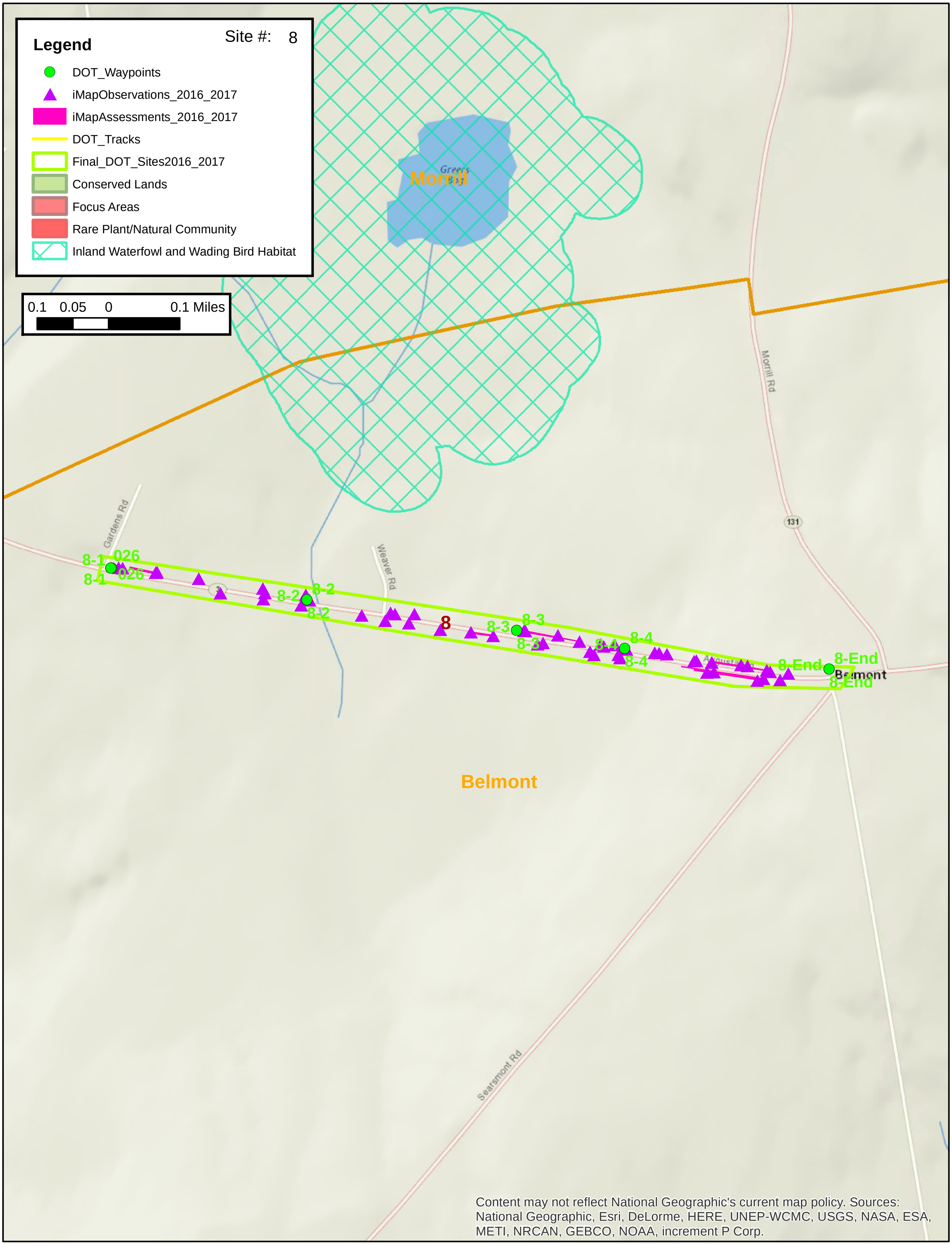
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.1 0.05 0 0.1 Miles
Searsmont
Bartlett Pond
Belfast Augusta Rd
New England Rd
7-1
7-2
7-3
7-4
7-5
7-6
7
7-End
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.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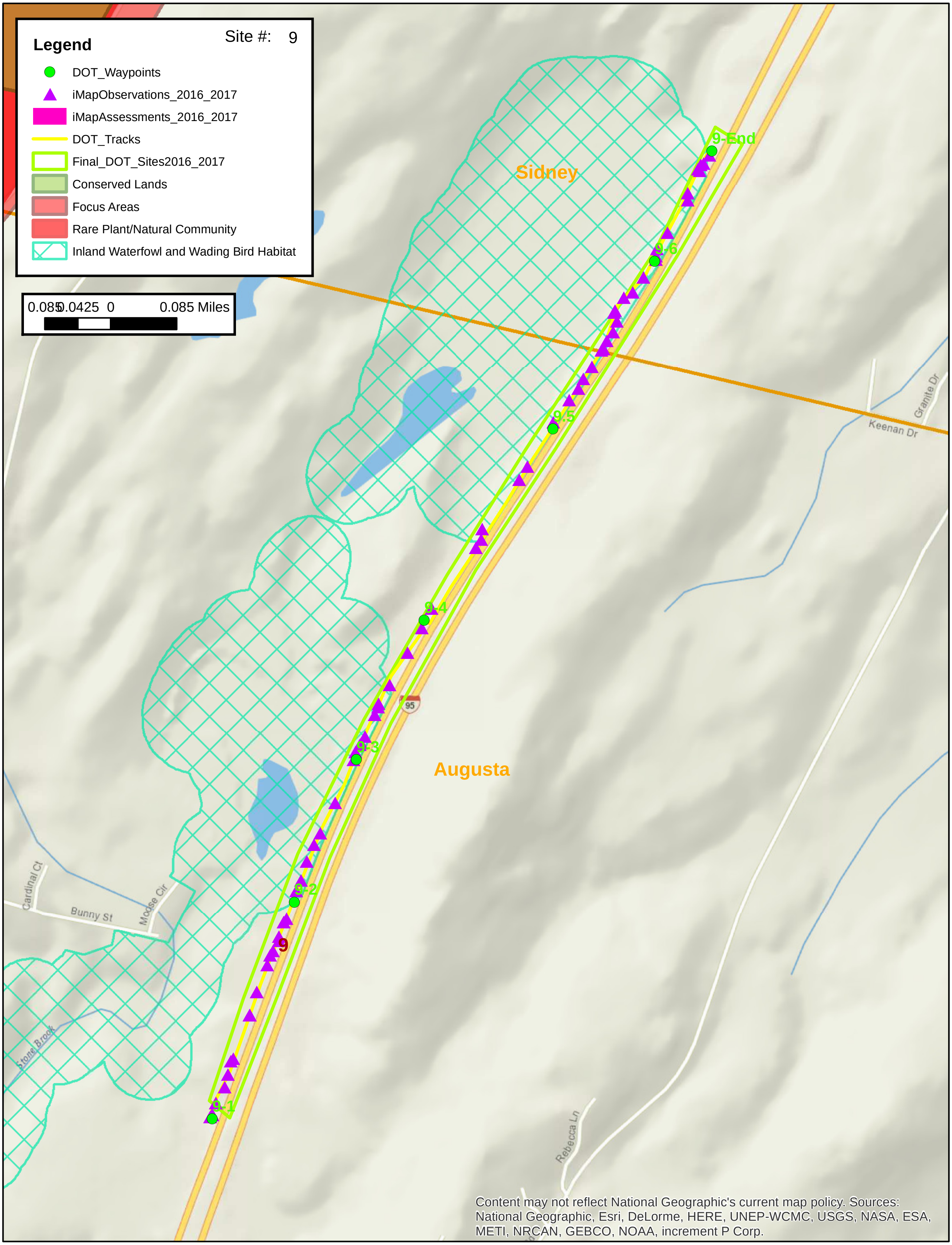
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.1 0.05 0 0.1 Miles
Morrill
Belmont
Morrill Rd
Gardens Rd
Weaver Rd
Searsmont Rd
131
8-1
026
8-2
8-3
8-4
8-End
8
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.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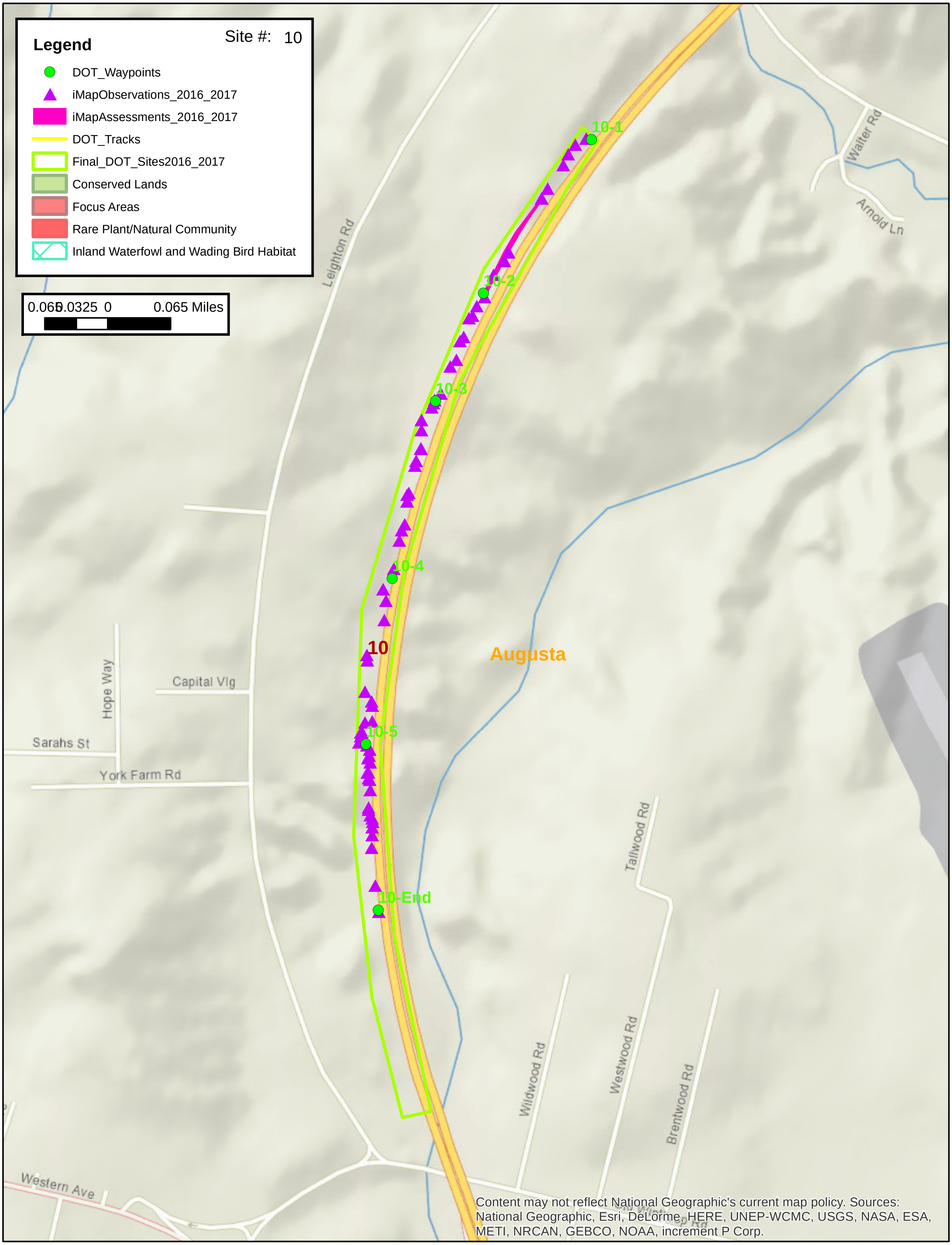
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.085 0.0425 0 0.085 Miles
9-End
Sidney
9-6
9-5
9-4
9-3
9-2
9-1
9
Augusta
95
Keenan Dr
Granite Dr
Cardinal Ct
Bunny St
Moose Cir
Stone Brook
Rebecca Ln
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.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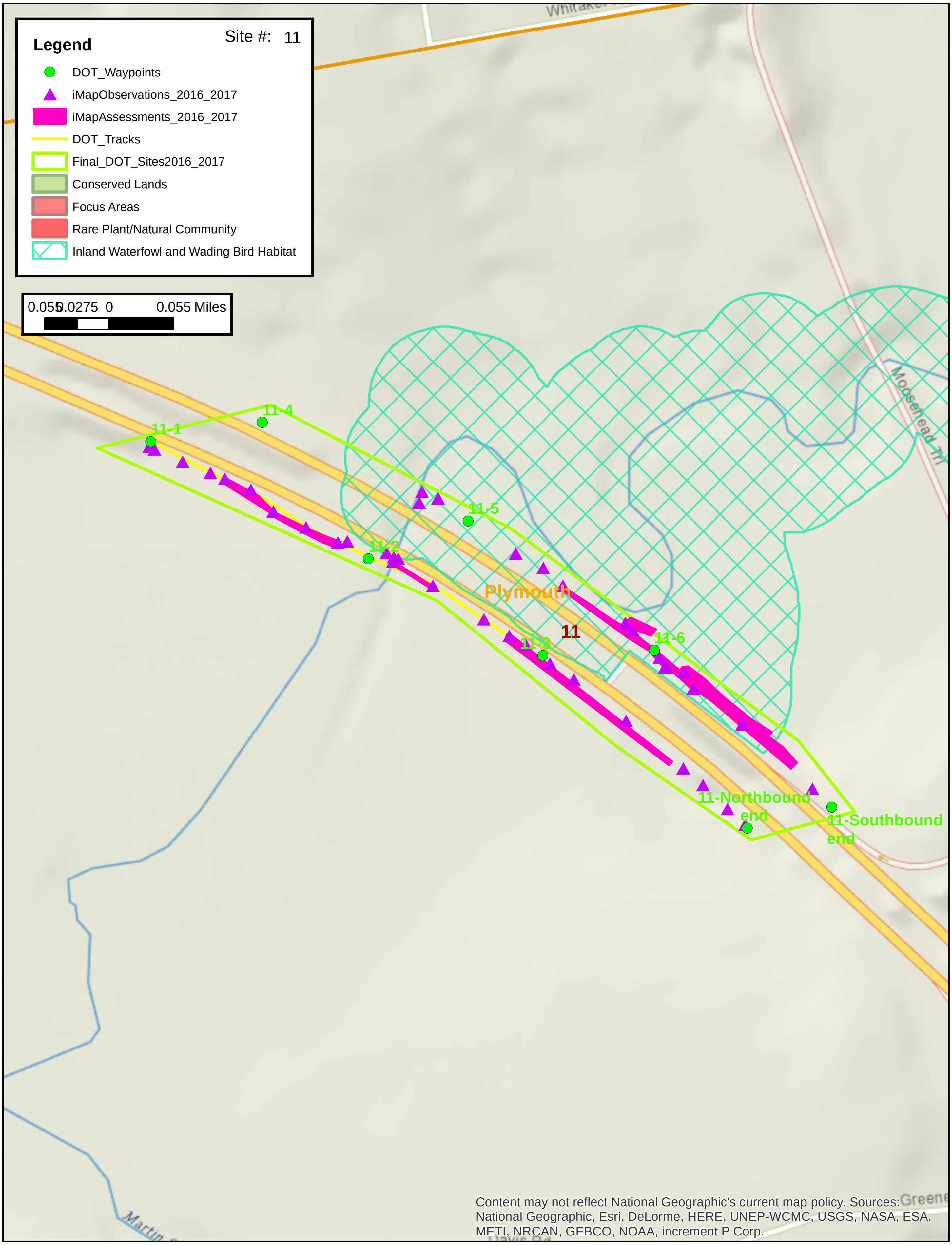
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.065 0.0325 0 0.065 Miles
10-1
10-2
10-3
10-4
10
10-5
10-End
Augusta
Leighton Rd
Walter Rd
Arnold Ln
Hope Way
Capital Vlg
Sarahs St
York Farm Rd
Tallwood Rd
Wildwood Rd
Westwood Rd
Brentwood Rd
Western Ave
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.



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DOT_Tracks
Final_DOT_Sites2016_2017
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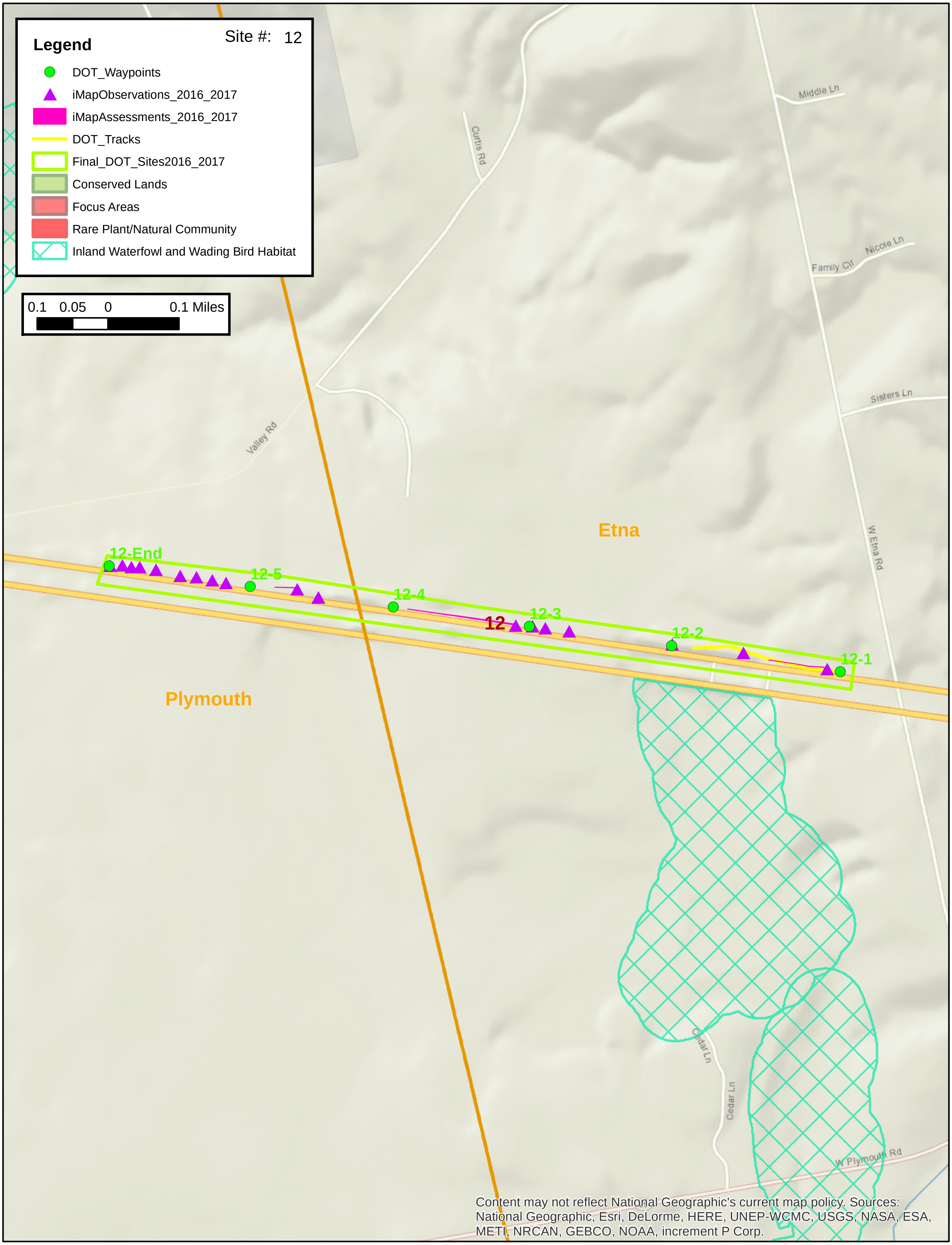
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.055 0.0275 0 0.055 Miles
11-1
11-4
11-5
11-2
Plymouth
11
11-3
11-6
11-Northbound end
11-Southbound end
Moosehead Trl
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.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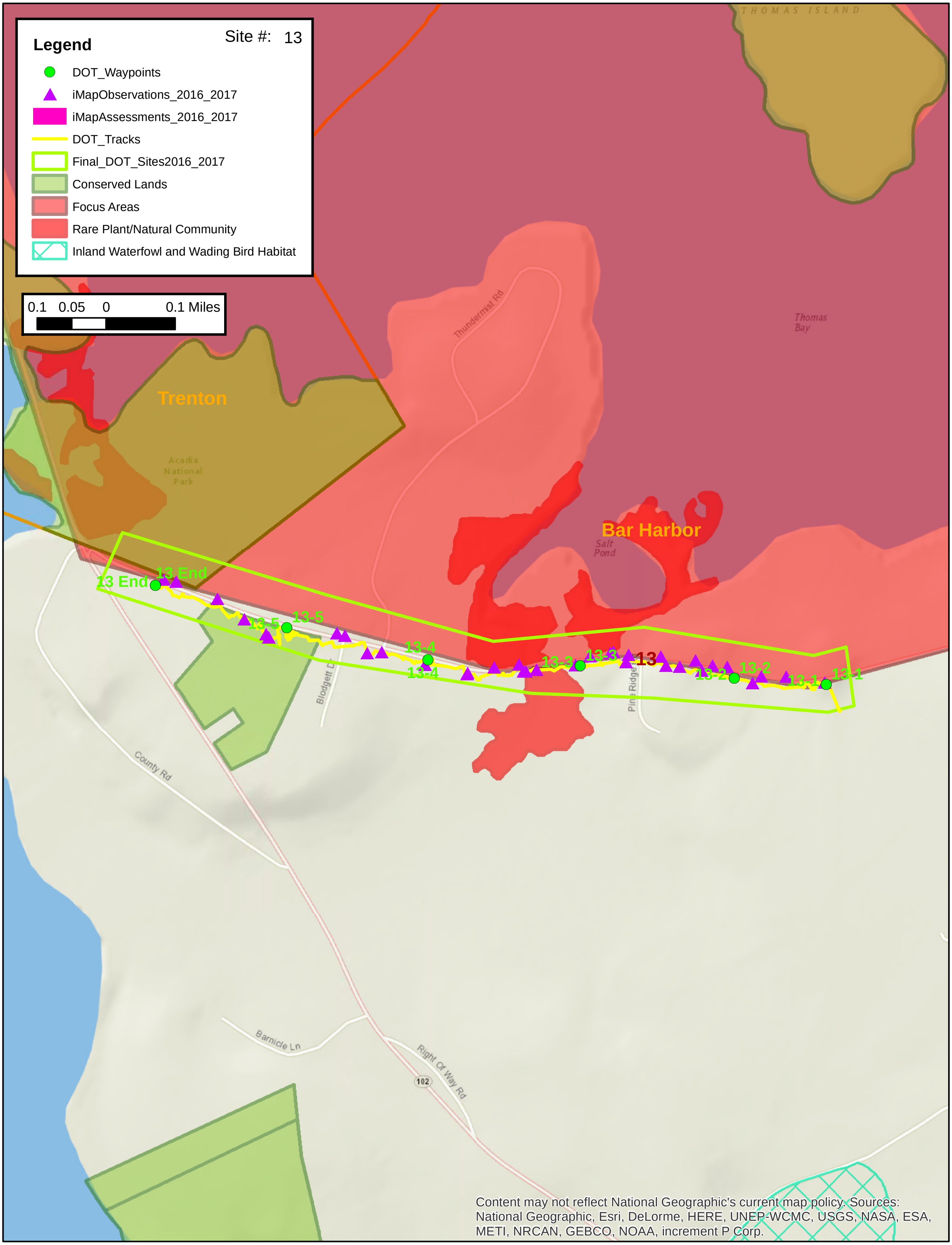
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.1 0.05 0 0.1 Miles
Middle Ln
Curtis Rd
Nicole Ln
Family Cir
Sisters Ln
Valley Rd
Etna
W Etna Rd
12-End
12-5
12-4
12
12-3
12-2
12-1
Plymouth
Cedar Ln
Cedar Ln
W Plymouth Rd
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.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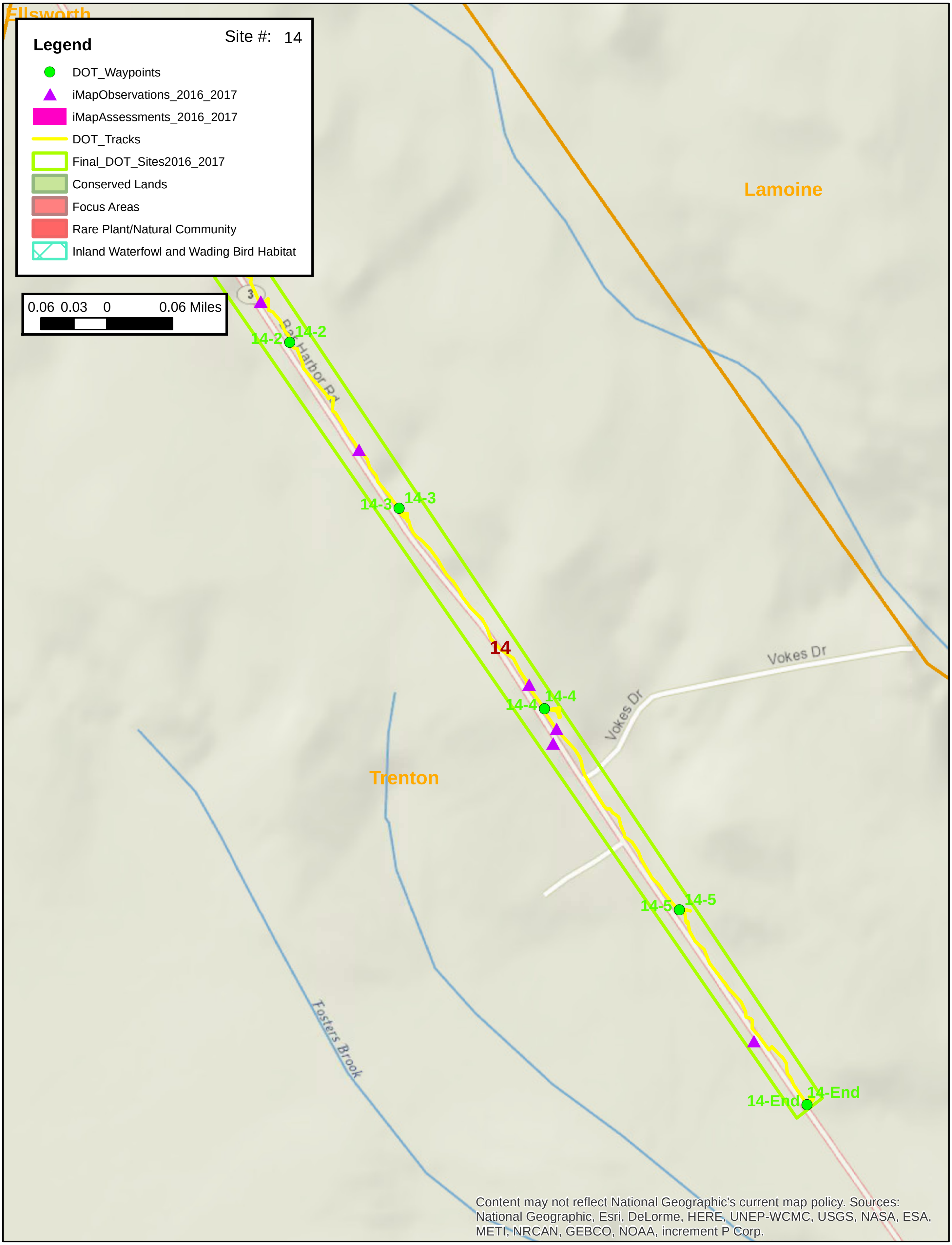
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.1 0.05 0 0.1 Miles
THOMAS ISLAND
Thomas Bay
Trenton
Acadia National Park
Bar Harbor
Salt Pond
Thundermist Rd
13 End
13-5
13-4
13-3
13
13-2
13-1
Blodgett Dr
Pine Ridge
County Rd
Barnicle Ln
Right Of Way Rd
102
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.



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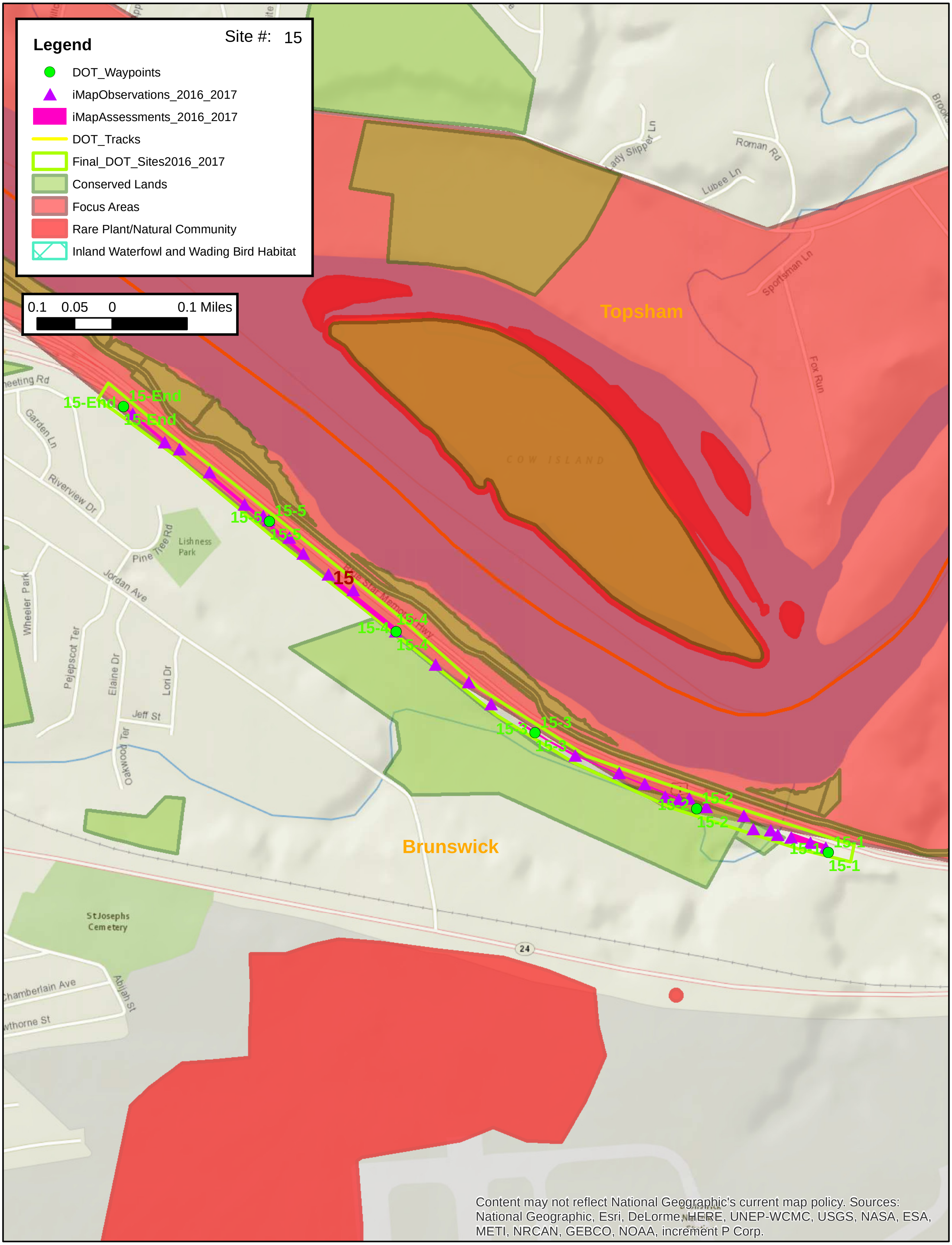
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.06 0.03 0 0.06 Miles
Ellsworth
Lamoine
Trenton
14
14-2
14-3
14-4
14-5
14-End
Vokes Dr
Fosters Brook
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.



Legend
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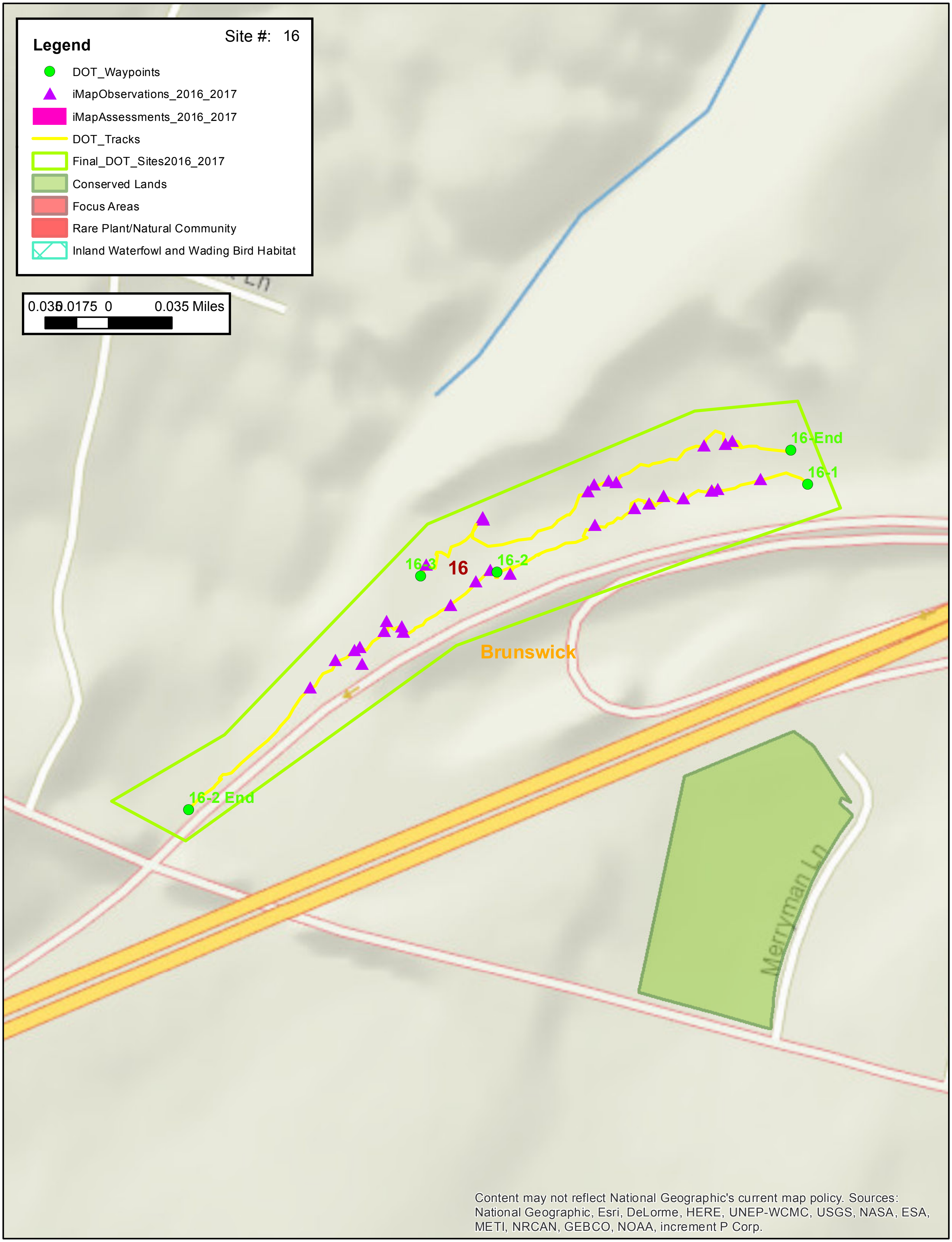
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.1 0.05 0 0.1 Miles
Topsham
Brunswick
COW ISLAND
15
15-End
15-5
15-4
15-3
15-2
15-1
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.



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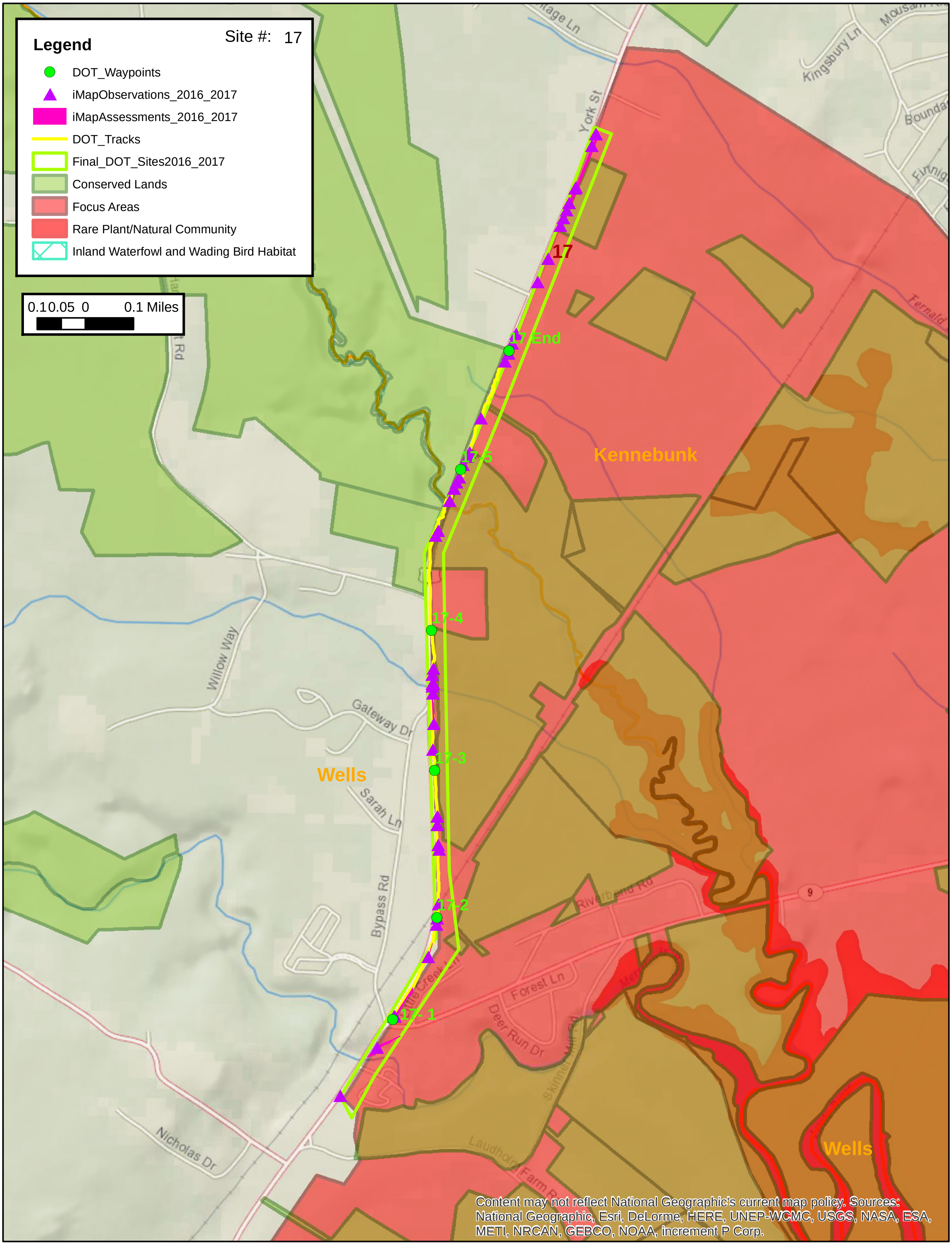
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.035 0.0175 0 0.035 Miles
16-End
16-1
16-3
16
16-2
Brunswick
16-2 End
Merryman Ln
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.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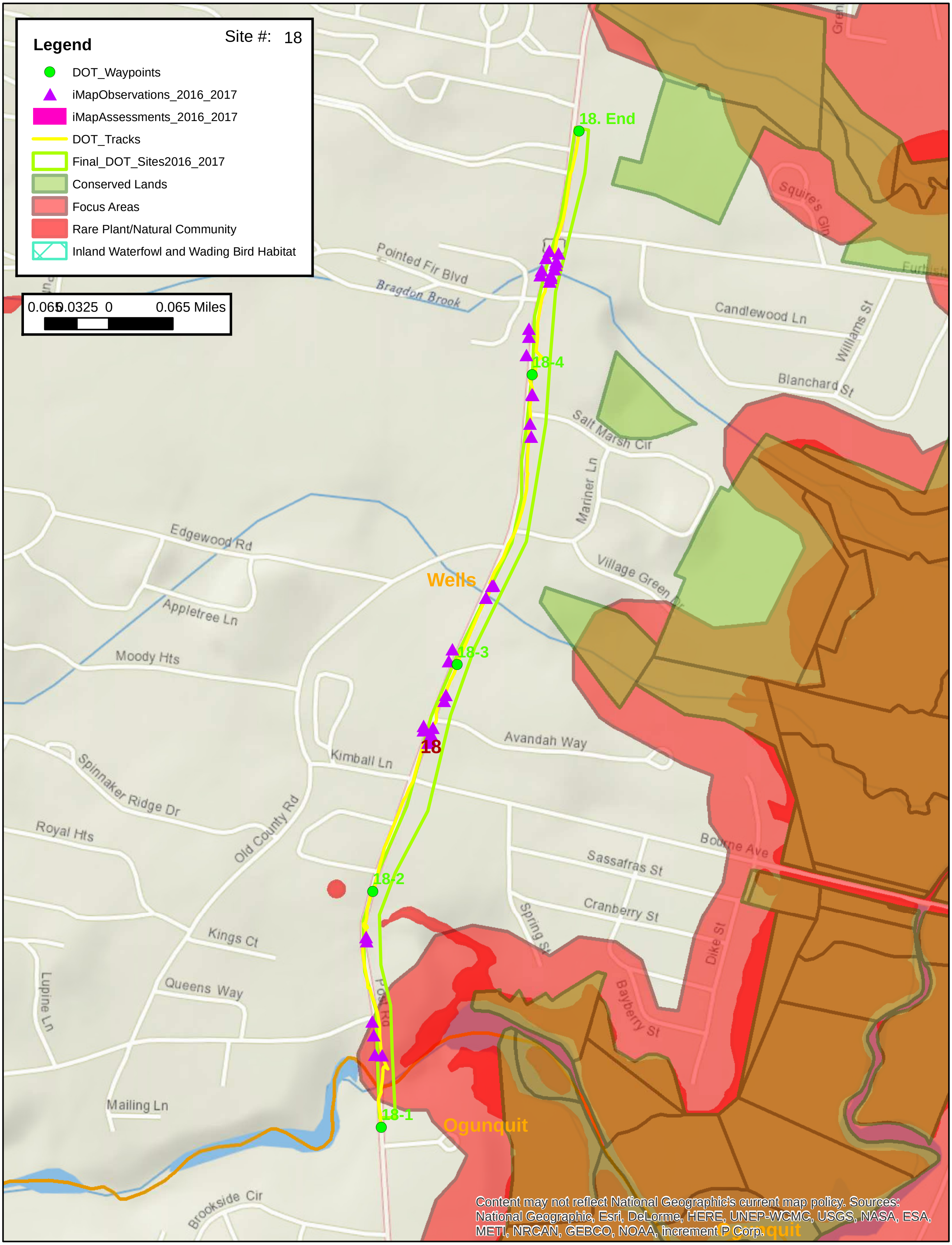
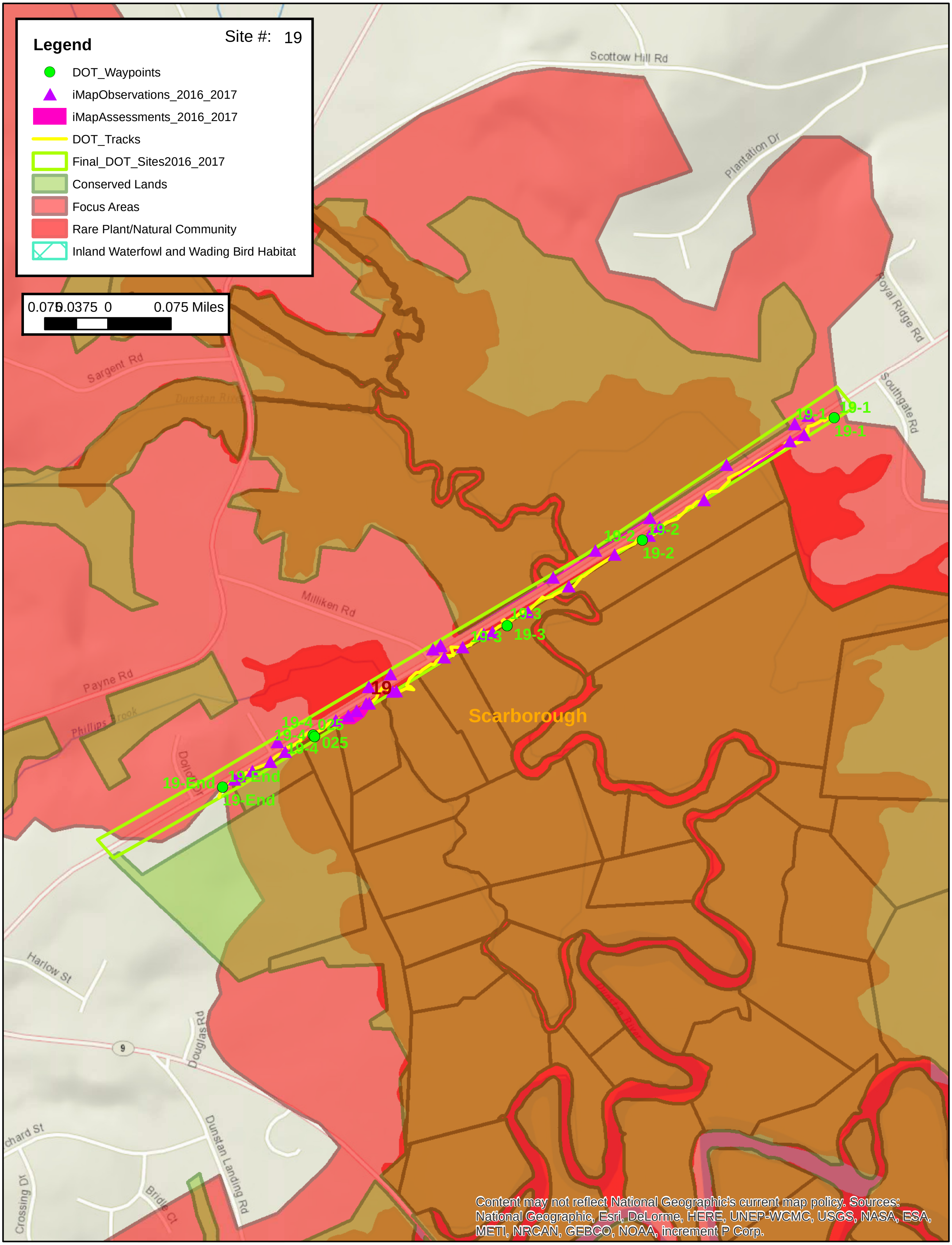
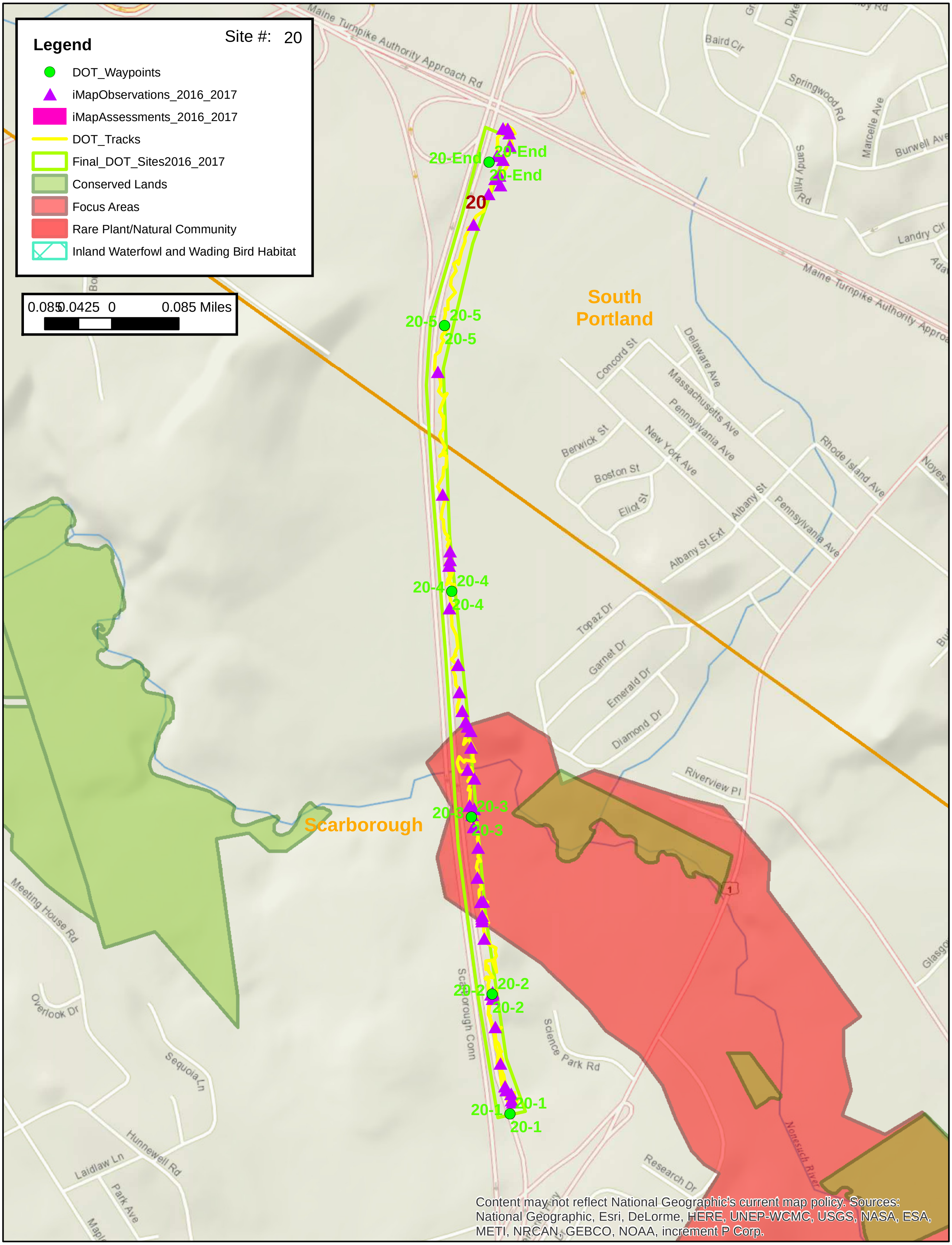
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.10.05 0 0.1 Miles
17
17-End
17-5
17-4
17-3
17-2
17-1
Kennebunk
Wells
Wells
York St
Willow Way
Gateway Dr
Sarah Ln
Bypass Rd
Riverbend Rd
Forest Ln
Deer Run Dr
Nicholas Dr
Kingsbury Ln
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.



Legend
Site #: 18
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.065 0.0325 0 0.065 Miles
18. End
18-4
18-3
18
18-2
18-1
Wells
Ogunquit
Pointed Fir Blvd
Bragdon Brook
Candlewood Ln
Williams St
Blanchard St
Squire's Gln
Salt Marsh Cir
Mariner Ln
Village Green
Edgewood Rd
Appletree Ln
Moody Hts
Avandah Way
Kimball Ln
Spinnaker Ridge Dr
Royal Hts
Old County Rd
Bourne Ave
Sassafras St
Cranberry St
Spring St
Dike St
Bayberry St
Kings Ct
Queens Way
Lupine Ln
Mailing Ln
Brookside Cir
Post Rd
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.


Legend
Site #: 19
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.075 0.0375 0 0.075 Miles
Scottow Hill Rd
Plantation Dr
Royal Ridge Rd
Southgate Rd
Sargent Rd
Milliken Rd
Payne Rd
Phillips Brook
Harlow St
Douglas Rd
Dunstan Landing Rd
Bridle Ct
Scarborough
19-1
19-2
19-3
19-4
025
19
19-End
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.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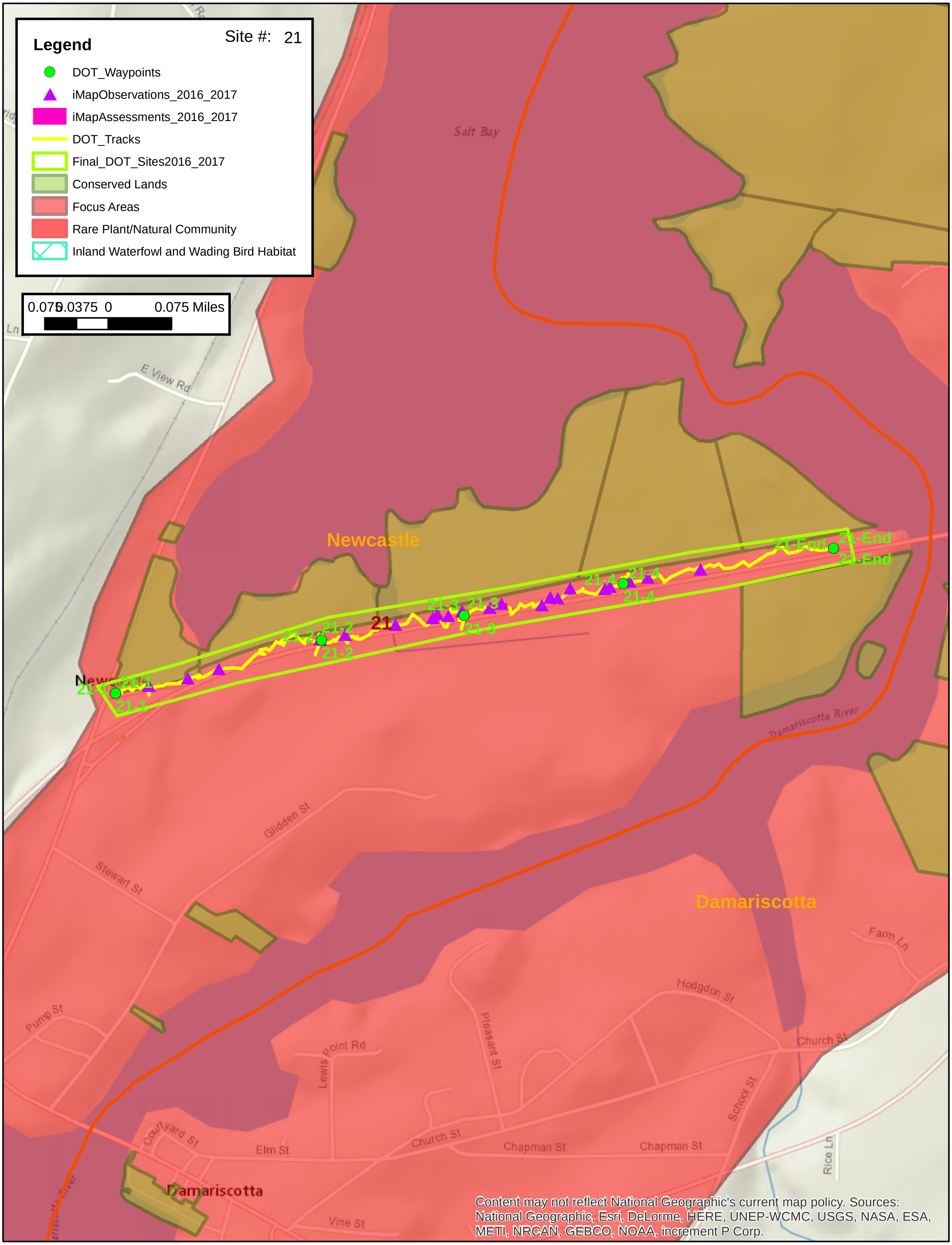
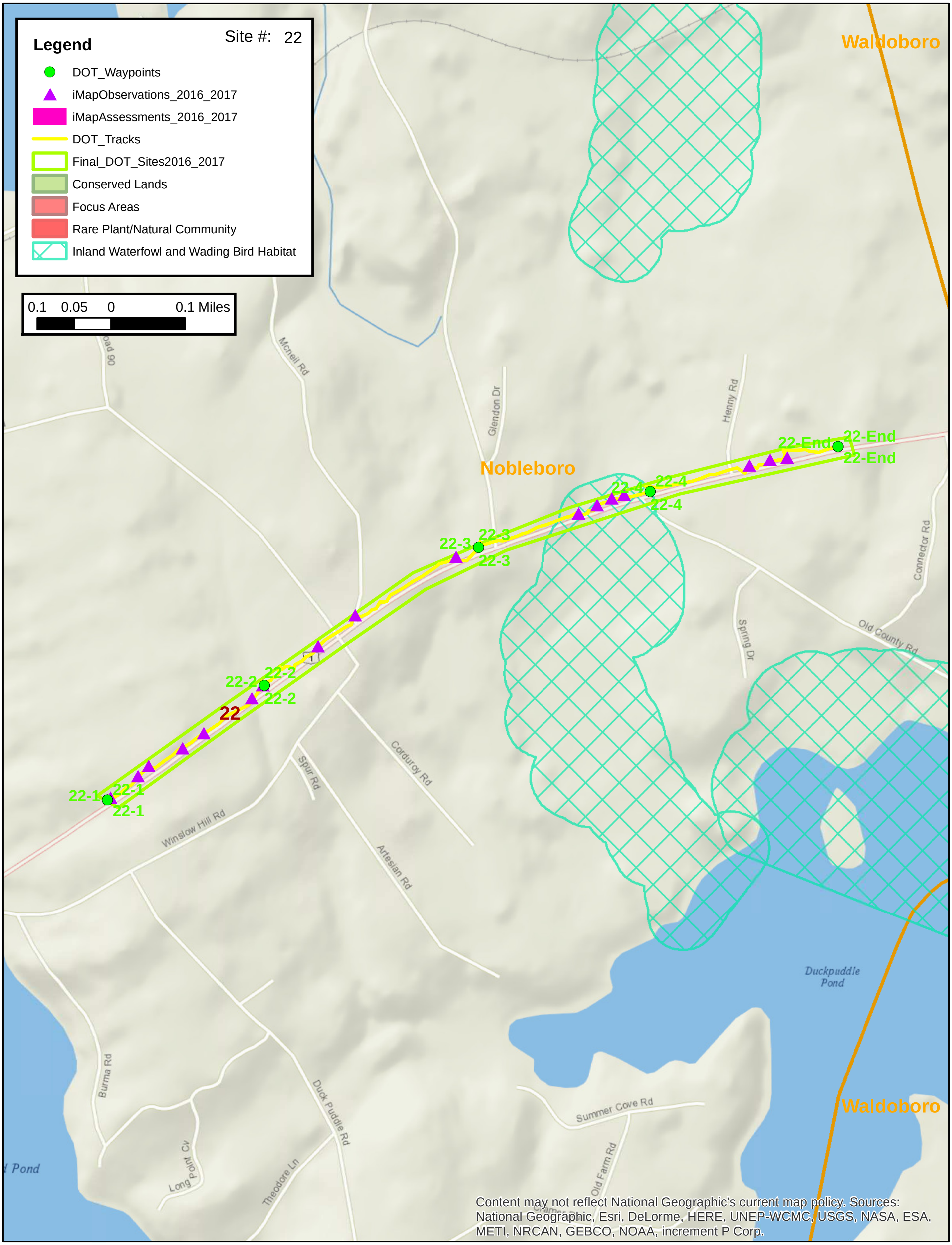
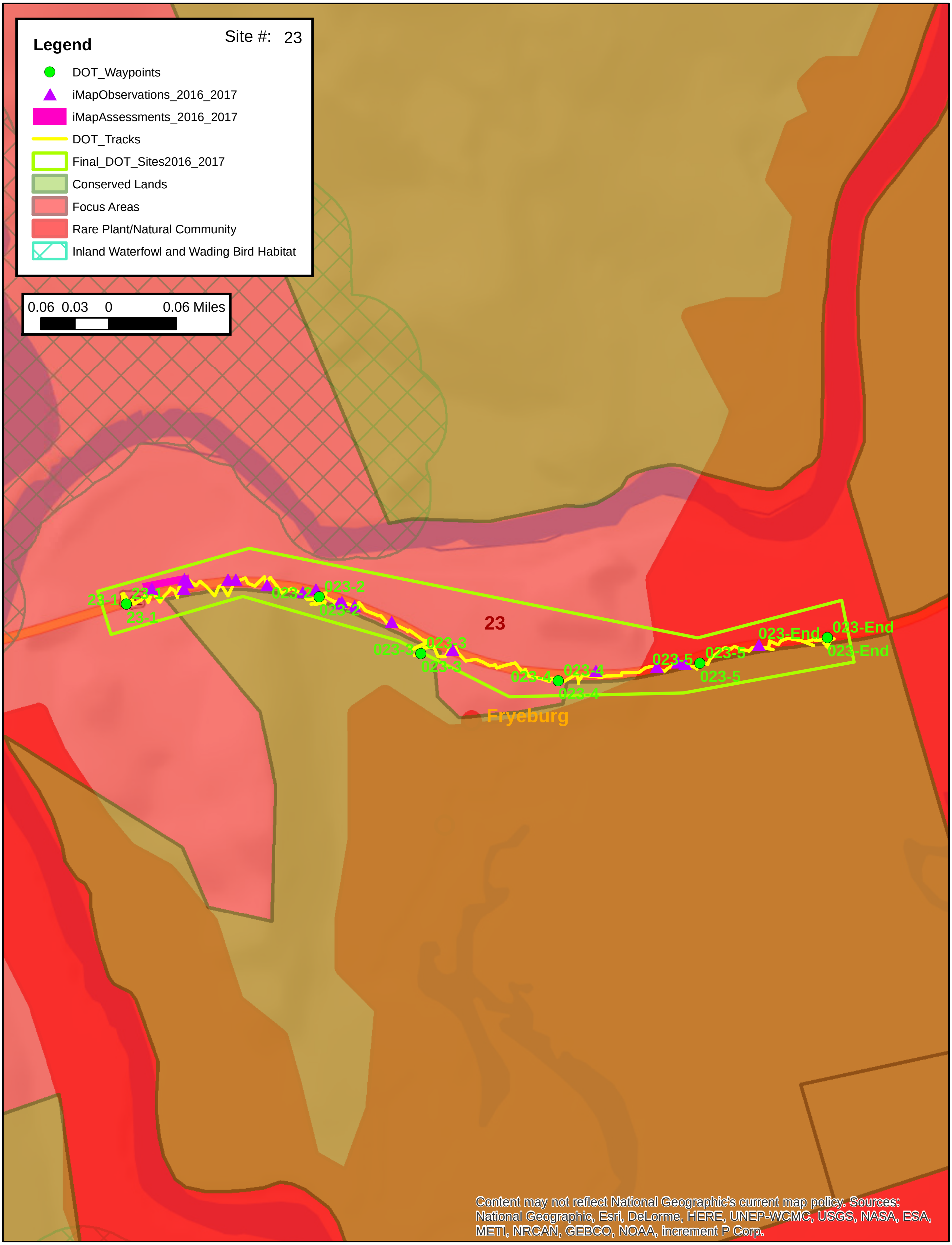
Site #: 20
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.085 0.0425 0 0.085 Miles
South Portland
Scarborough
20
20-End
20-5
20-4
20-3
20-2
20-1
Maine Turnpike Authority Approach Rd
Baird Cir
Springwood Rd
Sandy Hill Rd
Marcelle Ave
Burwell Ave
Landry Cir
Concord St
Delaware Ave
Massachusetts Ave
Pennsylvania Ave
New York Ave
Berwick St
Boston St
Eliot St
Albany St
Albany St Ext
Rhode Island Ave
Topaz Dr
Garnet Dr
Emerald Dr
Diamond Dr
Riverview Pl
Meeting House Rd
Overlook Dr
Sequoia Ln
Hunnewell Rd
Laidlaw Ln
Park Ave
Science Park Rd
Research Dr
Nonesuch River
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

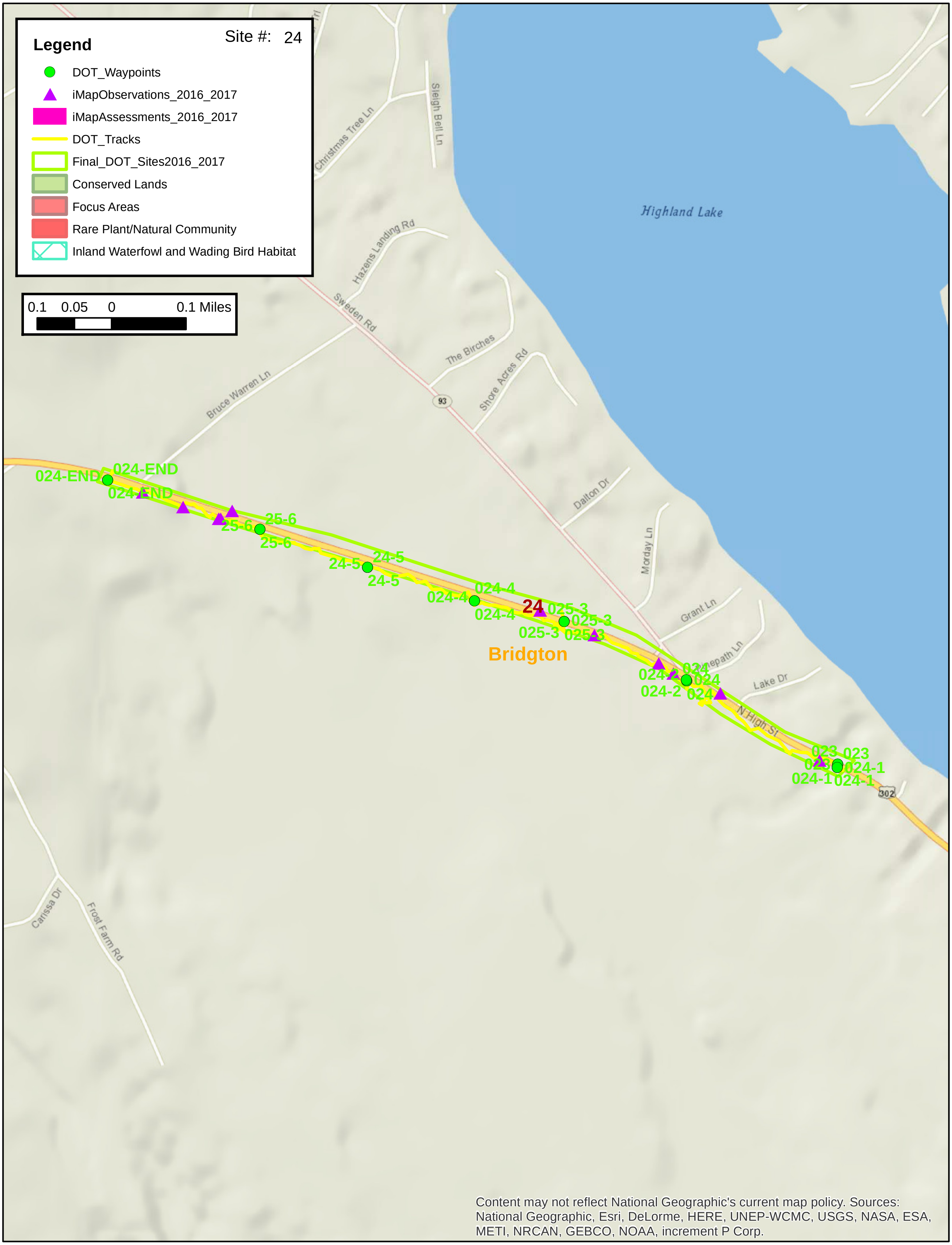

Legend
Site #: 21
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.075 0.0375 0 0.075 Miles
Salt Bay
E View Rd
Newcastle
21
21-1
21-2
21-3
21-4
21-End
Damariscotta River
Glidden St
Stewart St
Damariscotta
Farm Ln
Hodgdon St
Pump St
Point Rd
Lewis
Pleasant St
Church St
School St
Courtyard St
Elm St
Chapman St
Rice Ln
Vine St
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

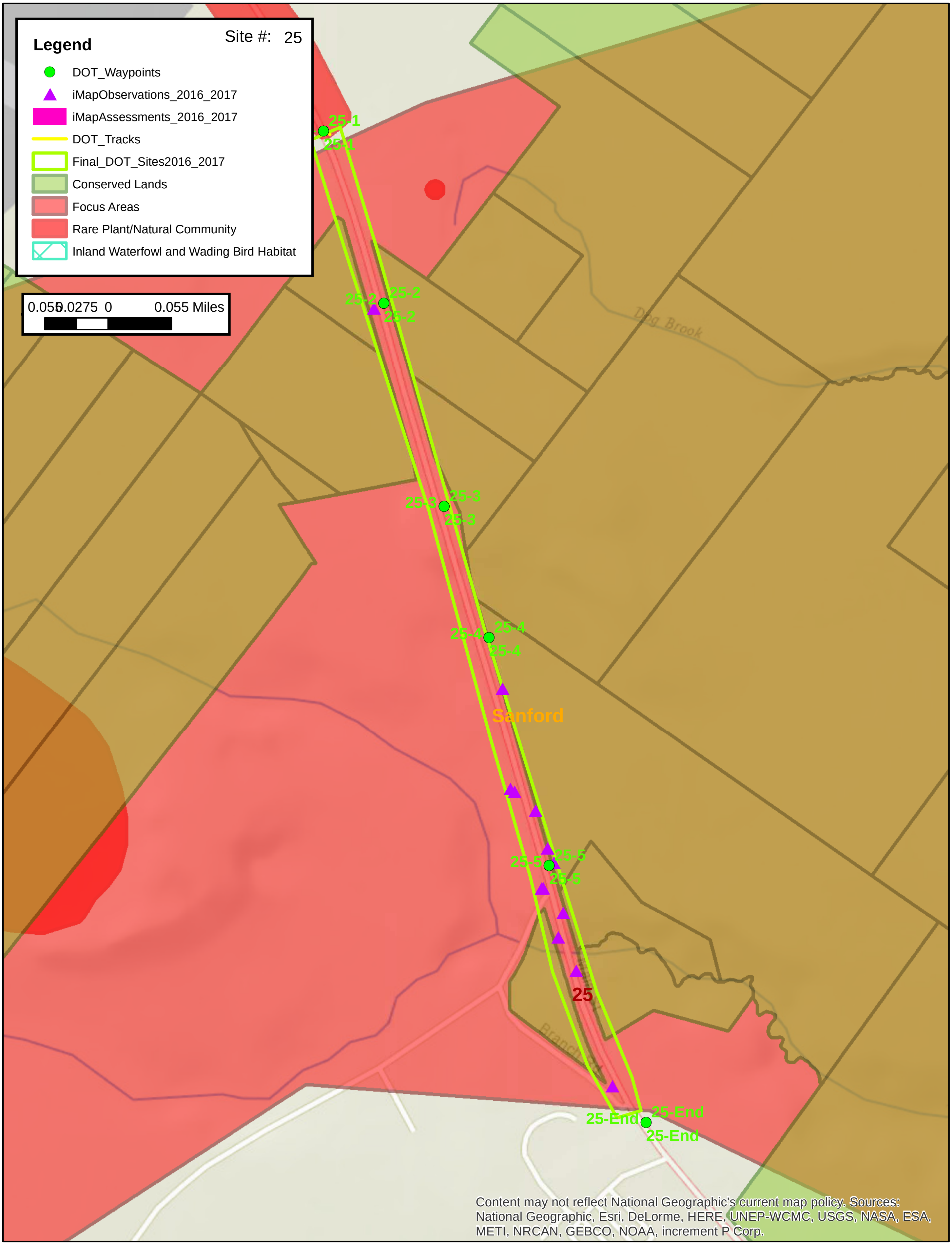


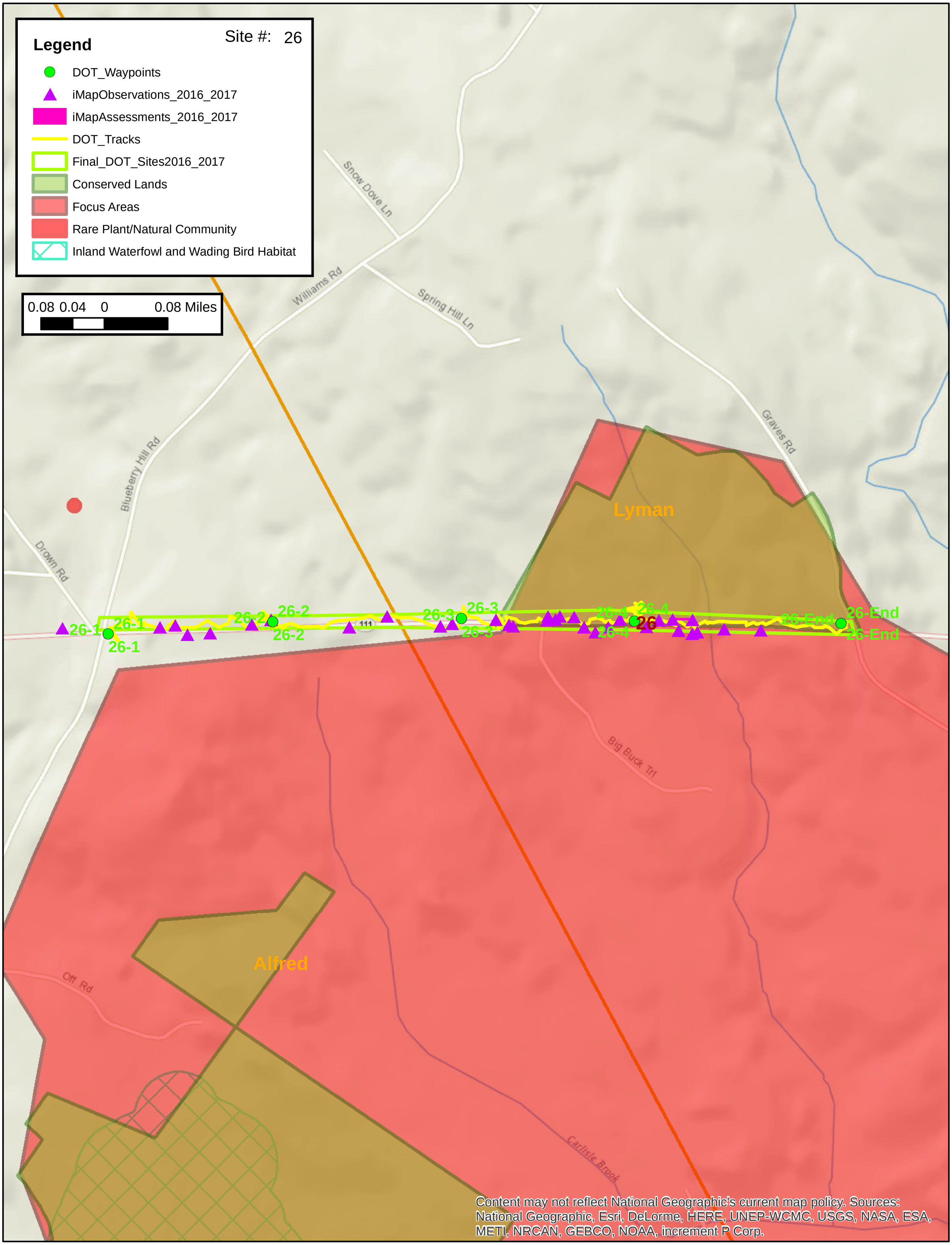
Legend
Site #: 22
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.1 0.05 0 0.1 Miles
Waldoboro
Nobleboro
Mcneil Rd
Glendon Dr
Henny Rd
Connector Rd
Old County Rd
Spring Dr
Corduroy Rd
Spur Rd
Artesian Rd
Winslow Hill Rd
Duckpuddle Pond
Burma Rd
Duck Puddle Rd
Theodore Ln
Summer Cove Rd
Old Farm Rd
22-1
22-2
22-3
22-4
22-End
22
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

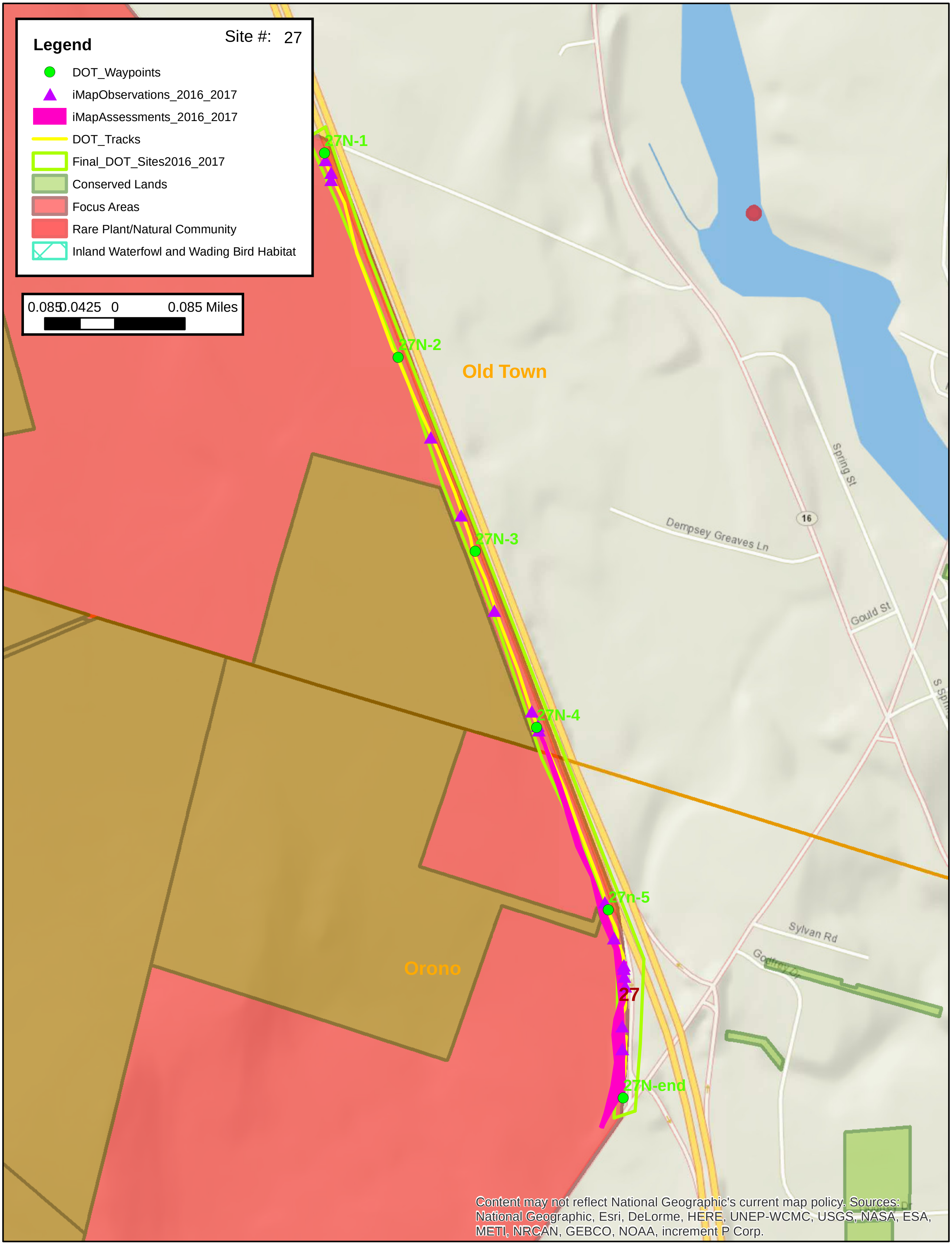


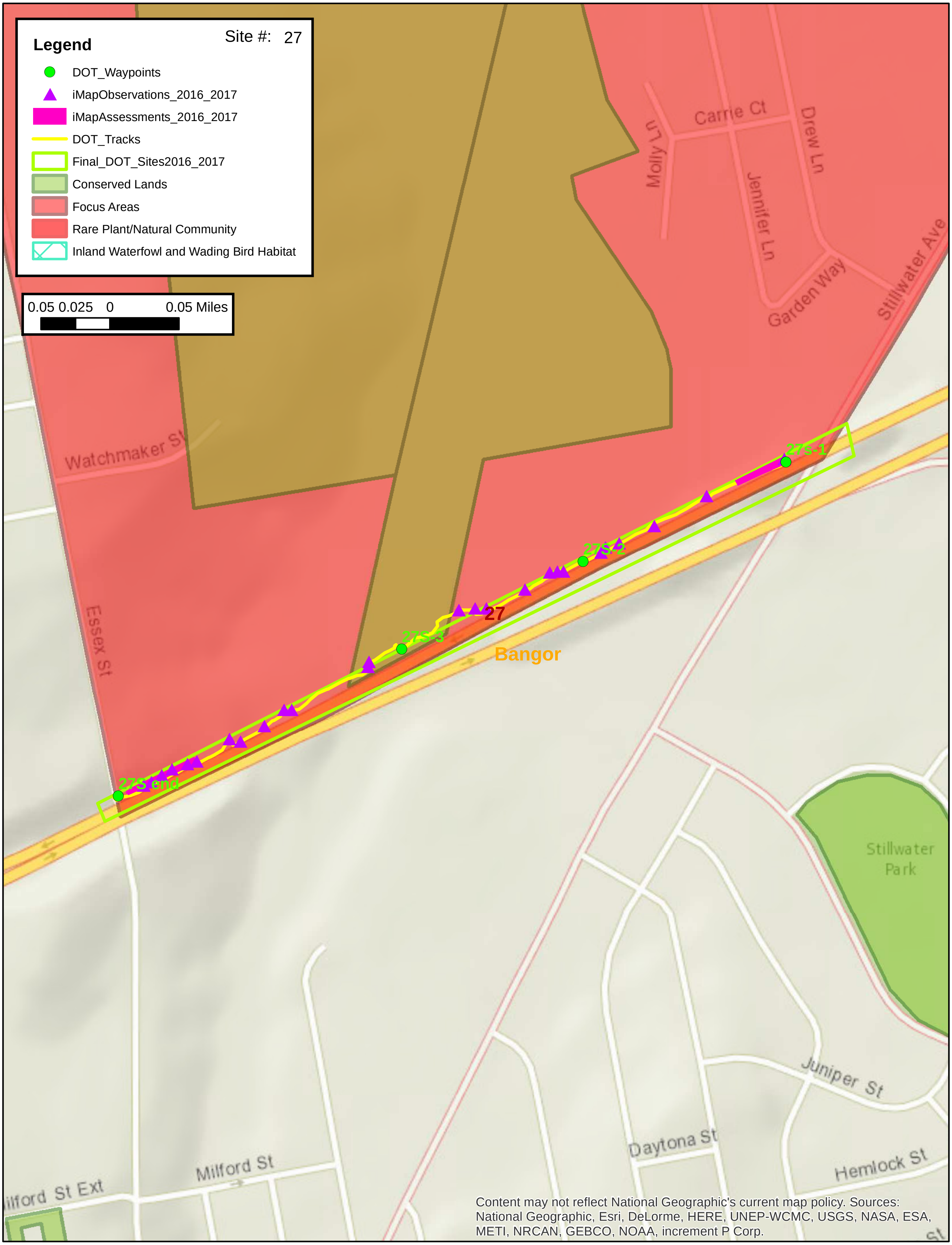
Legend
Site #: 23
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.06 0.03 0 0.06 Miles
23-1
023-2
023-3
023-4
023-5
023-End
23
Fryeburg
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

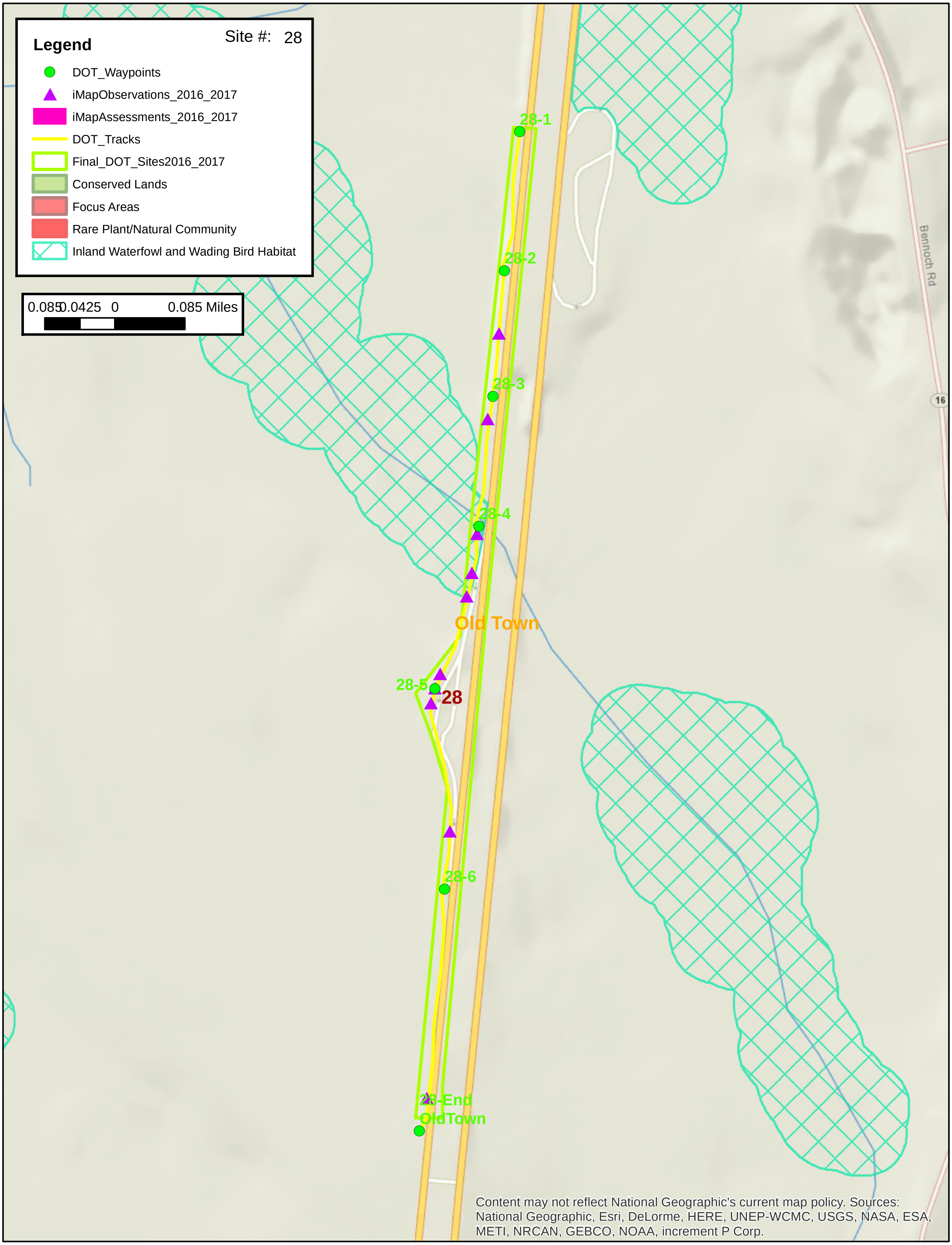

Legend
Site #: 24
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.1 0.05 0 0.1 Miles
Highland Lake
Christmas Tree Ln
Sleigh Bell Ln
Hazens Landing Rd
Sweden Rd
The Birches
Shore Acres Rd
Bruce Warren Ln
93
Dalton Dr
Morday Ln
Grant Ln
Lake Dr
N High St
302
Carissa Dr
Frost Farm Rd
Bridgton
24
024-END
25-6
24-5
024-4
025-3
024-2
024
023
024-1
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

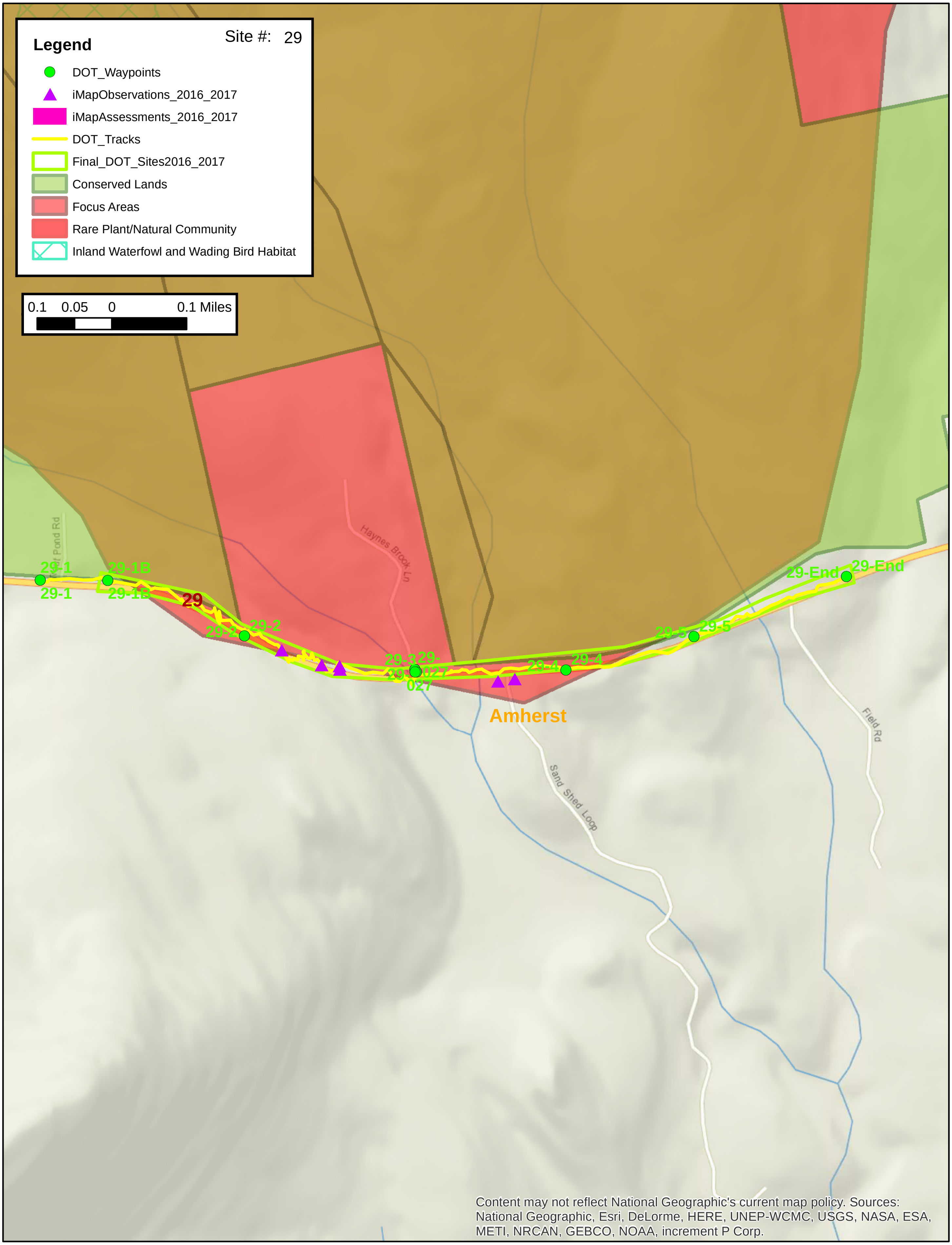

Legend
Site #: 25
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.055 0.0275 0 0.055 Miles
25-1
25-2
25-3
25-4
Sanford
25-5
25
25-End
Dug Brook
Branch Brook
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.


Legend
Site #: 26
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.08 0.04 0 0.08 Miles
Snow Dove Ln
Williams Rd
Spring Hill Ln
Graves Rd
Blueberry Hill Rd
Drown Rd
Lyman
26-1
26-2
26-3
26-4
26
26-End
111
Big Buck Trl
Alfred
Off Rd
Carlisle Brook
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.


Legend
Site #: 27
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.085 0.0425 0 0.085 Miles
27N-1
27N-2
27N-3
27N-4
27n-5
27N-end
27
Old Town
Orono
Spring St
Dempsey Greaves Ln
16
Gould St
Sylvan Rd
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

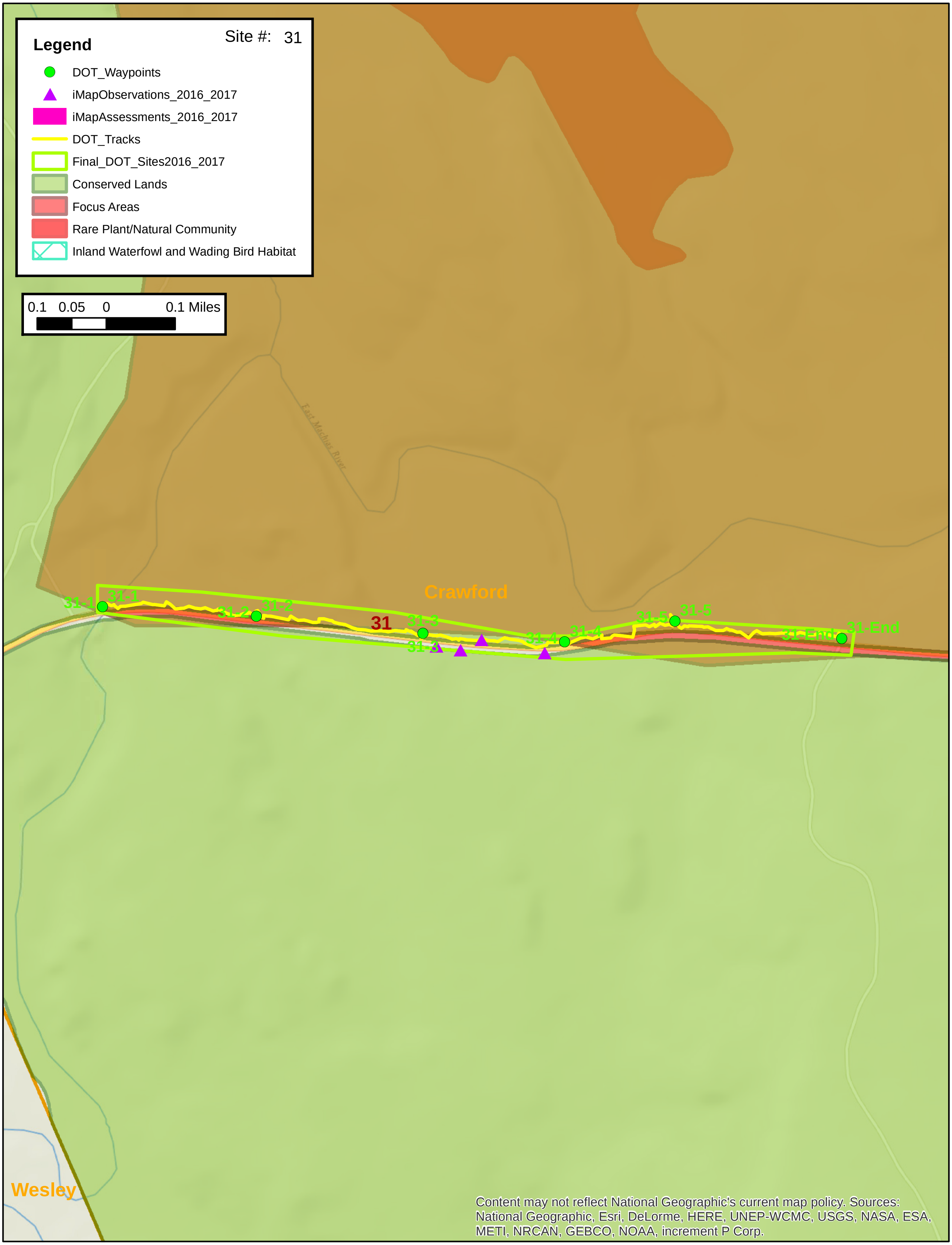

Legend
Site #: 27
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.05 0.025 0 0.05 Miles
Watchmaker St
Molly Ln
Carrie Ct
Drew Ln
Jennifer Ln
Garden Way
Stillwater Ave
Essex St
27S-1
27S-2
27S-3
27S end
27
Bangor
Stillwater Park
Juniper St
Daytona St
Hemlock St
Milford St
ilford St Ext
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

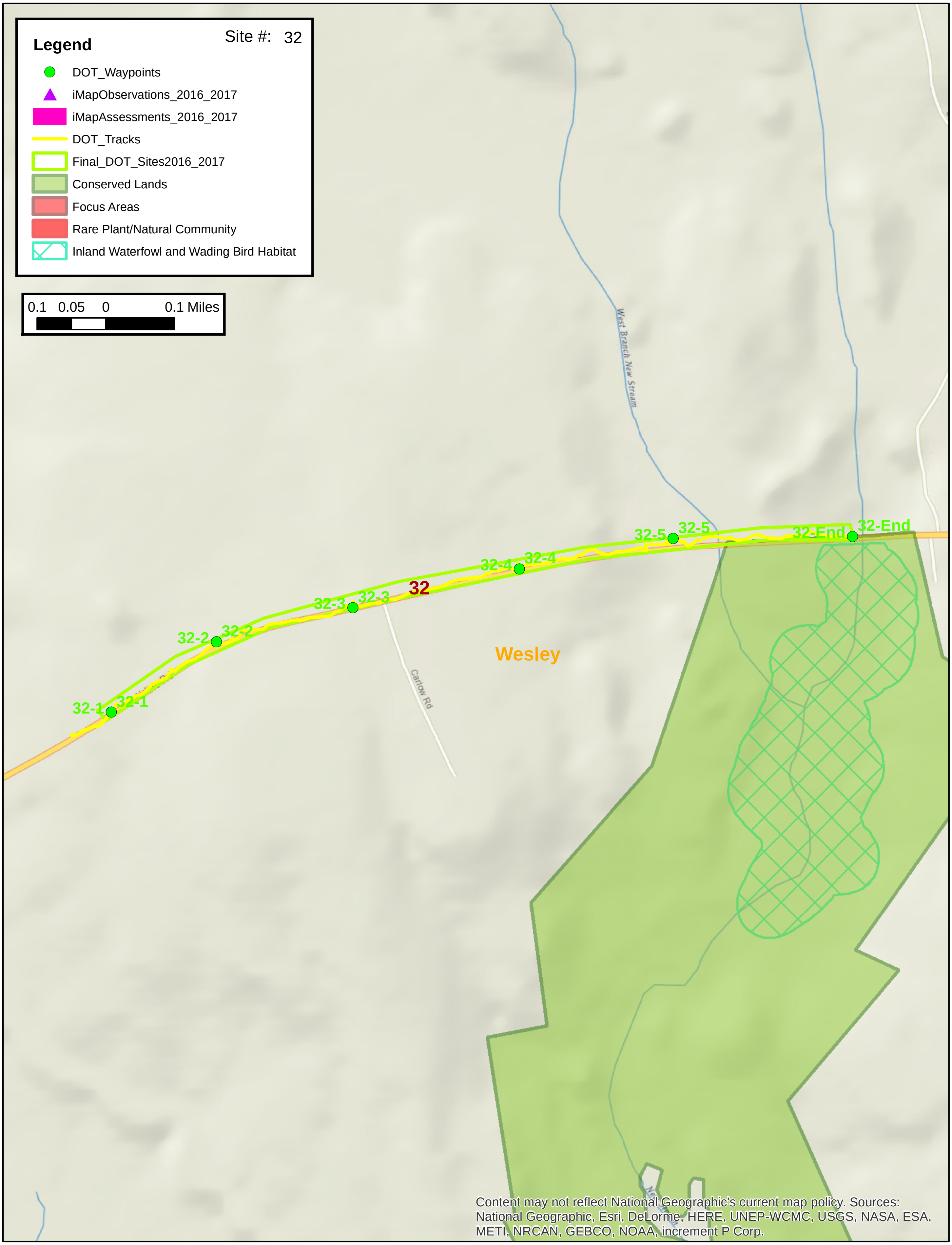

Legend
Site #: 28
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.085 0.0425 0 0.085 Miles
28-1
28-2
28-3
28-4
Old Town
28-5
28
28-6
28-End
OldTown
Bennoch Rd
16
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

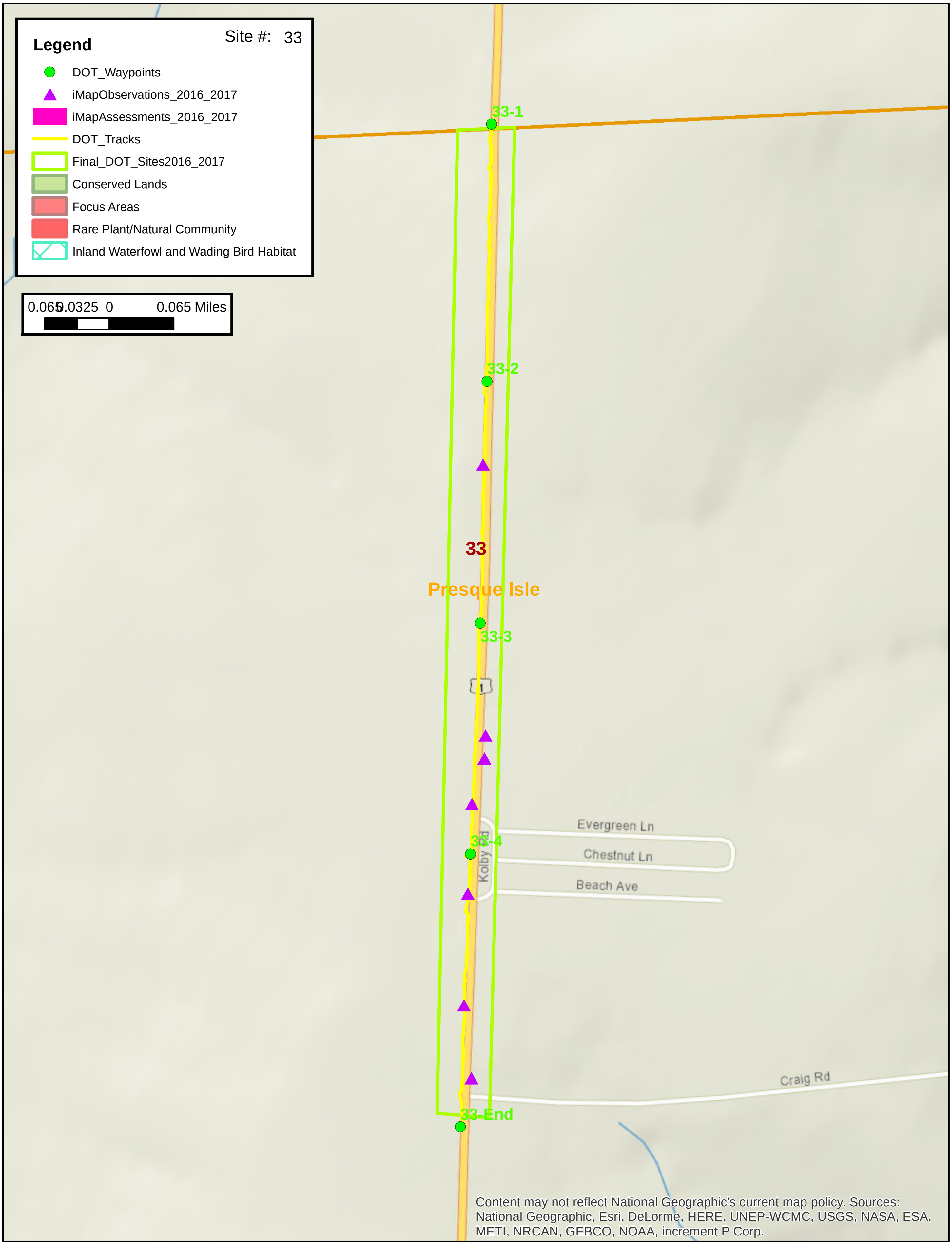


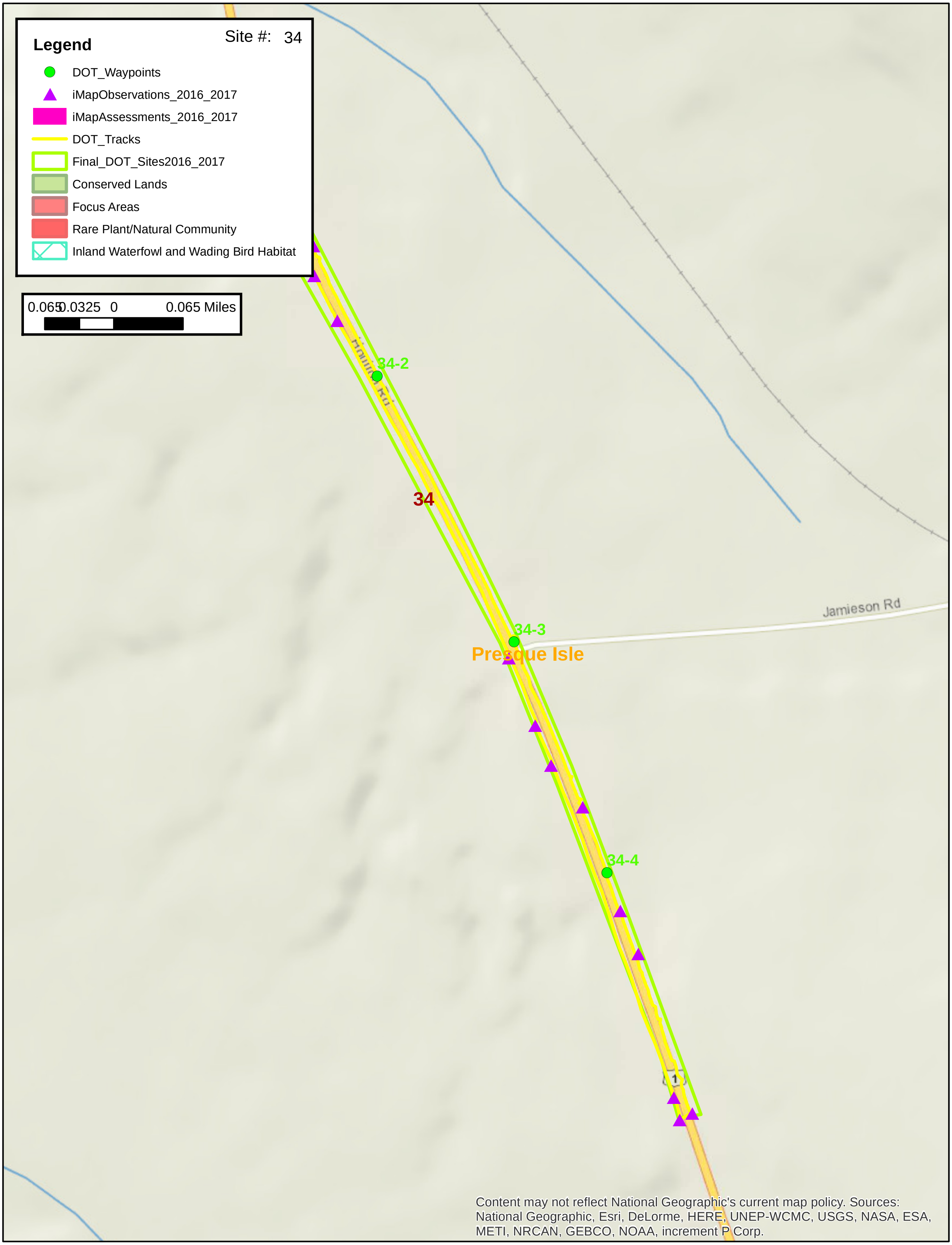
Legend
Site #: 29
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.1 0.05 0 0.1 Miles
29-1
29-1B
29
29-2
29-3
29-4
29-5
29-End
Haynes Brook Ln
Amherst
Sand Shed Loop
Field Rd
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.


Legend
Site #: 30
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.075 0.0375 0 0.075 Miles
Bradbury Brook Rd
Bradbury Brook
Chick Hill Rd
Erickson Ln
Stage Coach Rd
30
30-5
30-5
30-4
30-4
Clifton
30-End
30-End
30-3
30-3
30-2
30-2
Country Ln
Bobho Ln
30-1
30-1
Campbell Ln
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

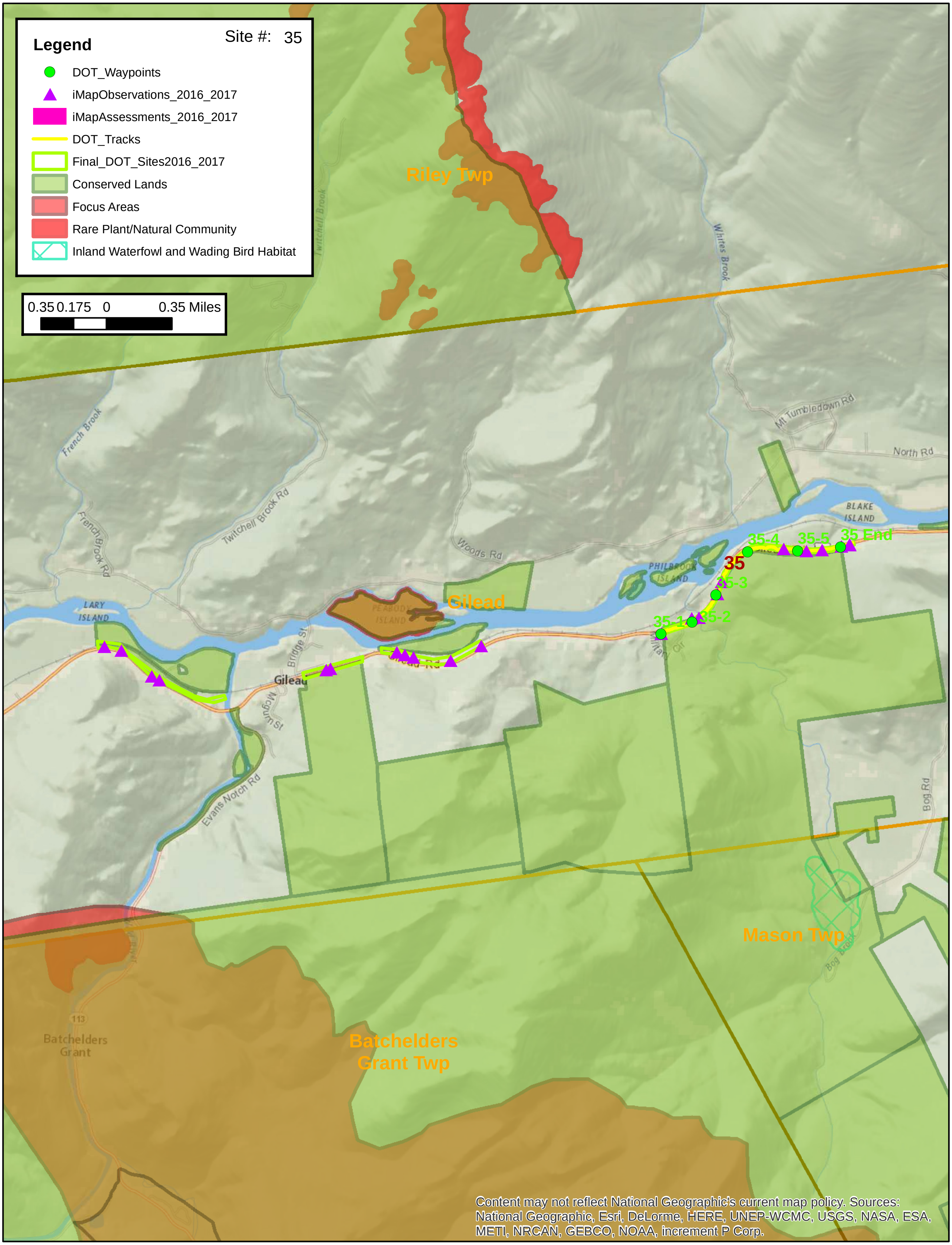

Legend
Site #: 31
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.1 0.05 0 0.1 Miles
Crawford
31
31-1
31-2
31-3
31-4
31-5
31-End
Wesley
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.


Legend
Site #: 32
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.1 0.05 0 0.1 Miles
West Branch New Stream
32-1
32-2
32-3
32-4
32-5
32-End
32
Wesley
Carlow Rd
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

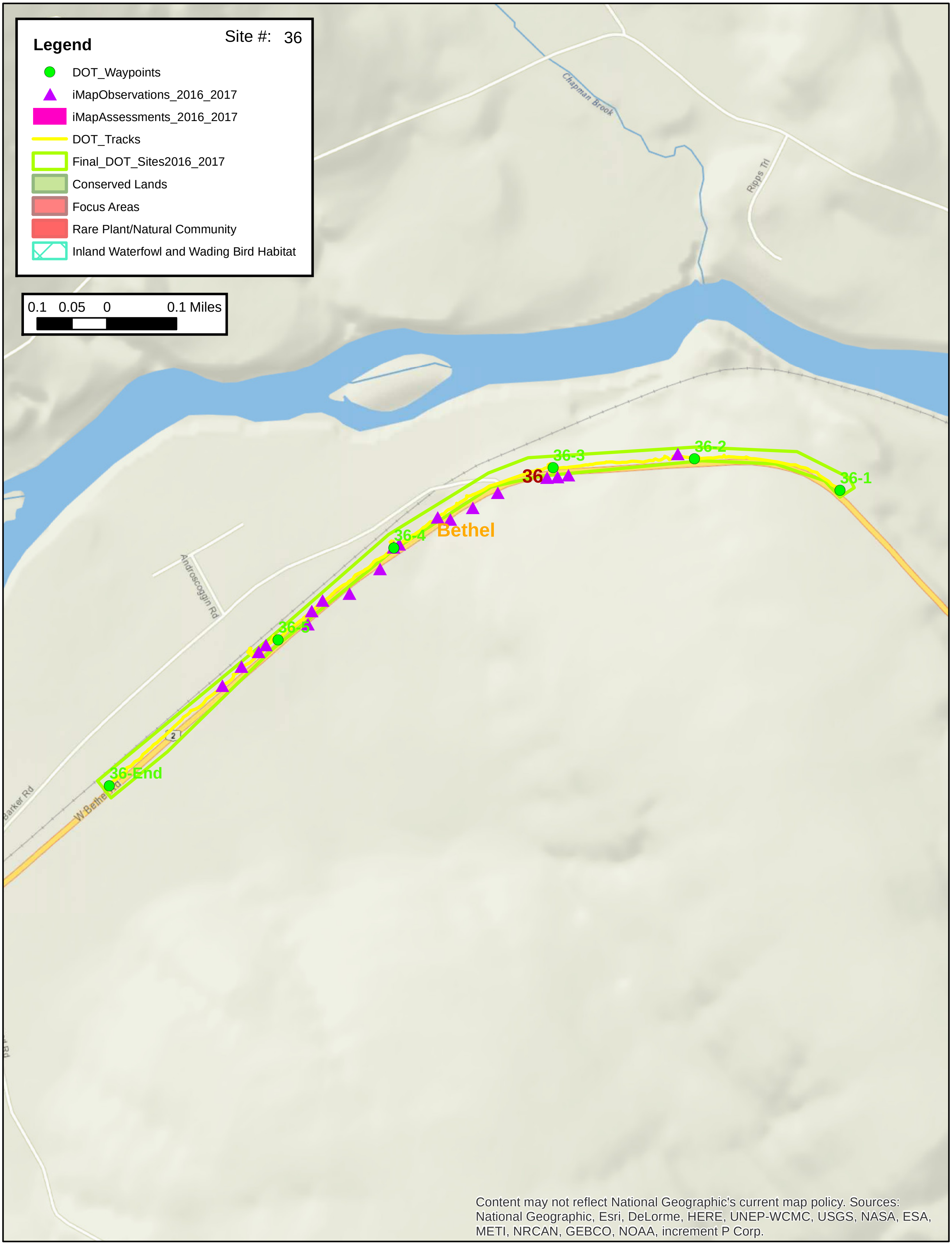

Legend
Site #: 33
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.065 0.0325 0 0.065 Miles
33-1
33-2
33
Presque Isle
33-3
1
33-4
Kolby Rd
Evergreen Ln
Chestnut Ln
Beach Ave
Craig Rd
33-End
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

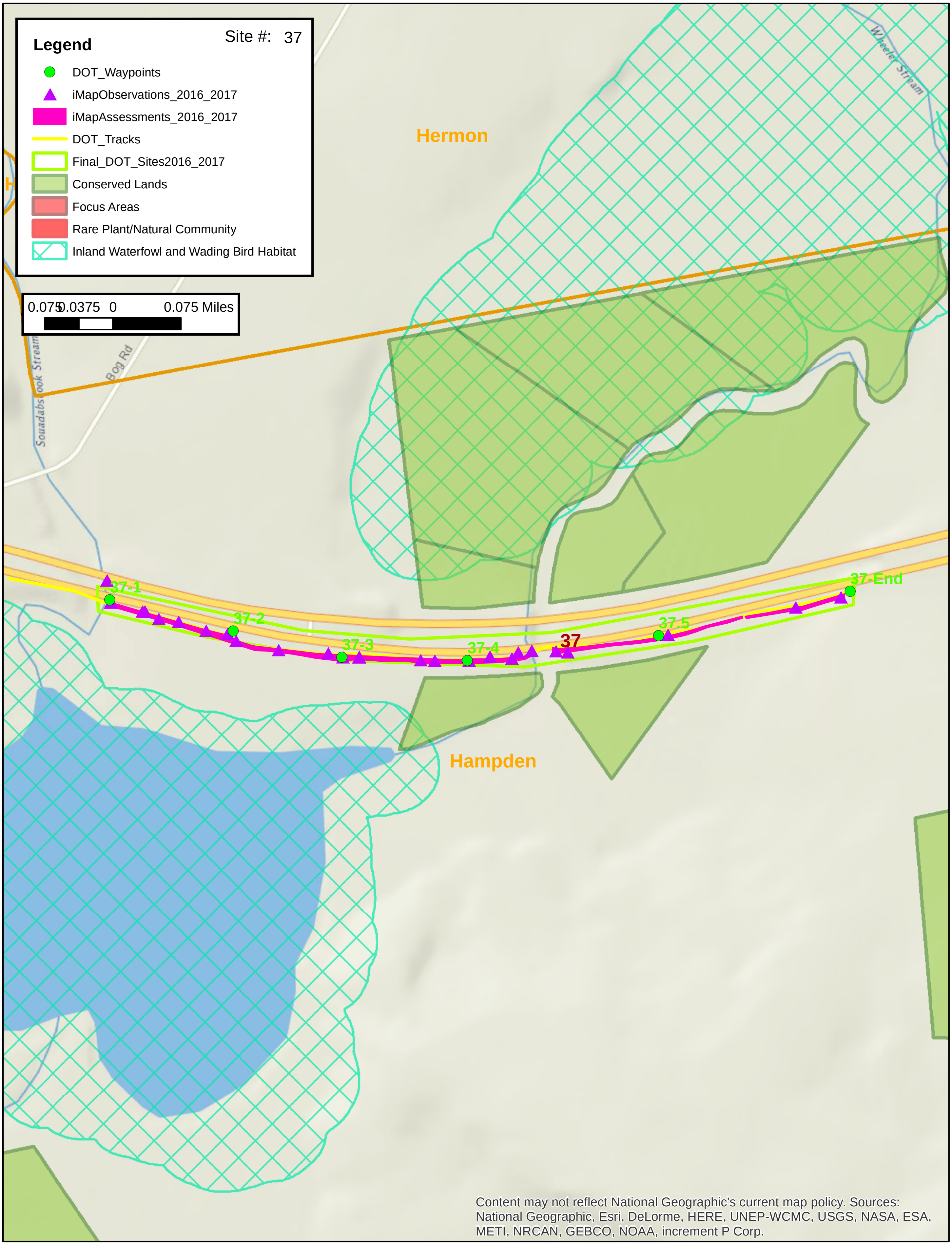


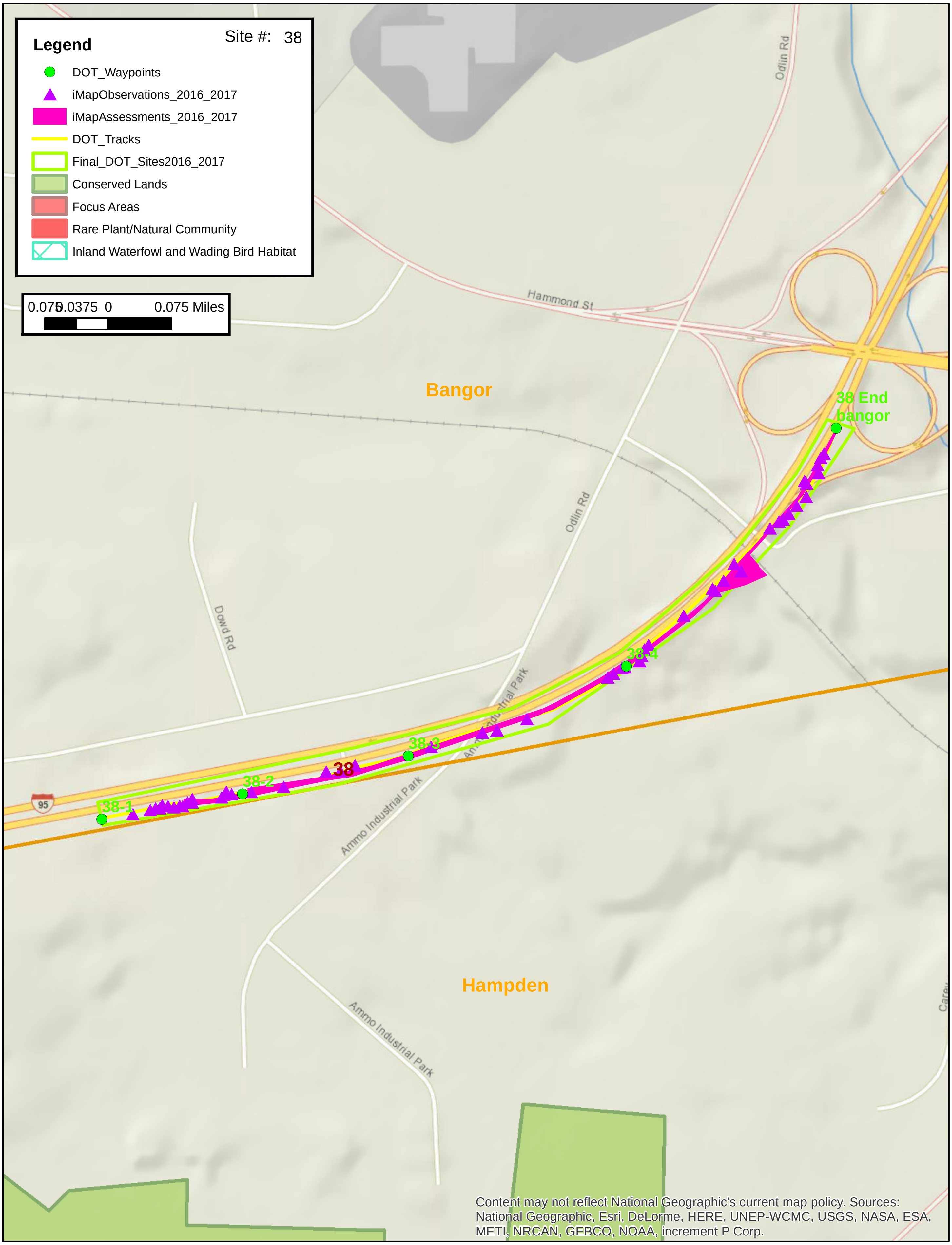
Legend
Site #: 34
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.065 0.0325 0 0.065 Miles
34-2
34
34-3
Presque Isle
Jamieson Rd
34-4
1
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.



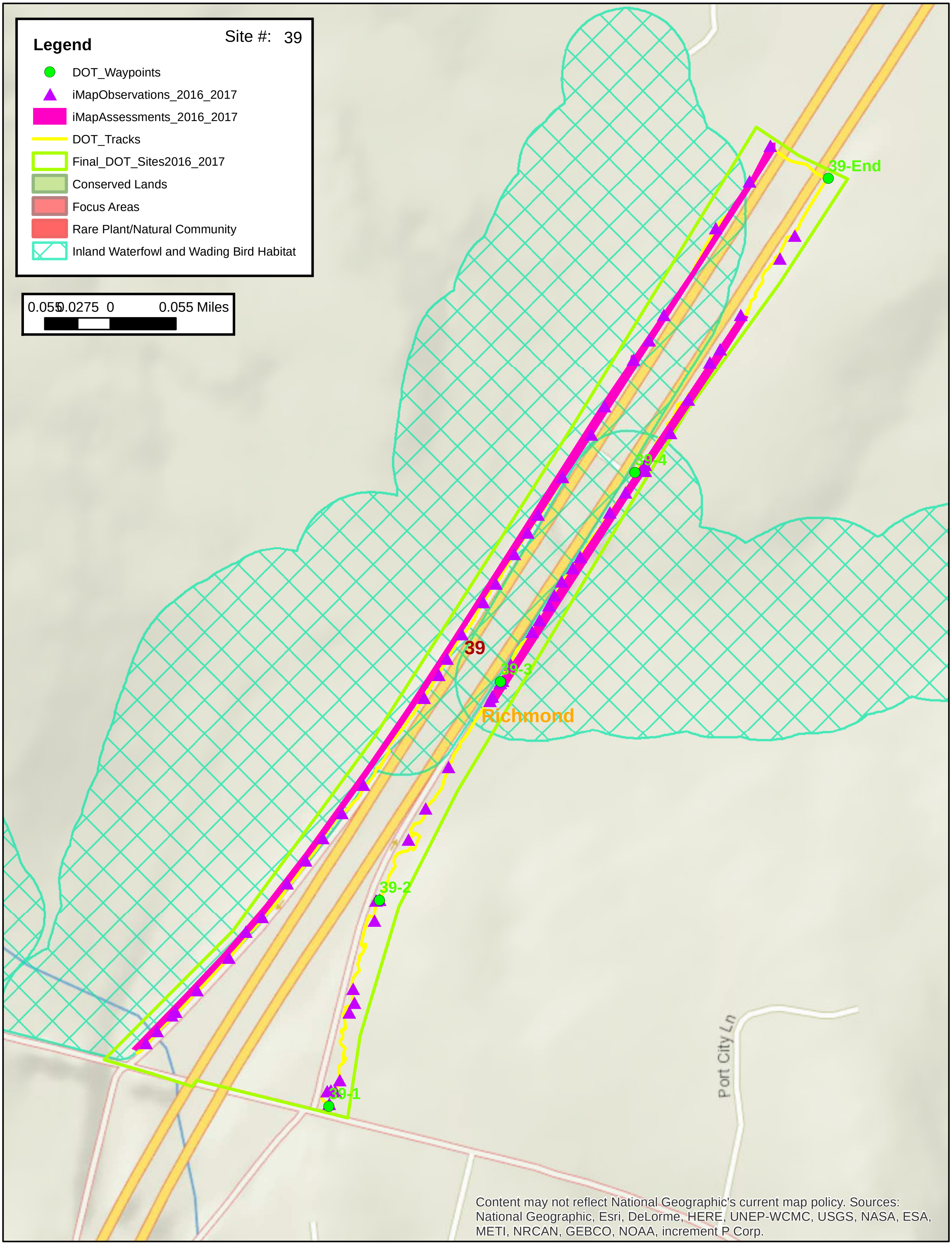
Legend
Site #: 35
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.35 0.175 0 0.35 Miles
Riley Twp
Gilead
Mason Twp
Batchelders Grant Twp
35
35-1
35-2
35-3
35-4
35-5
35 End
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

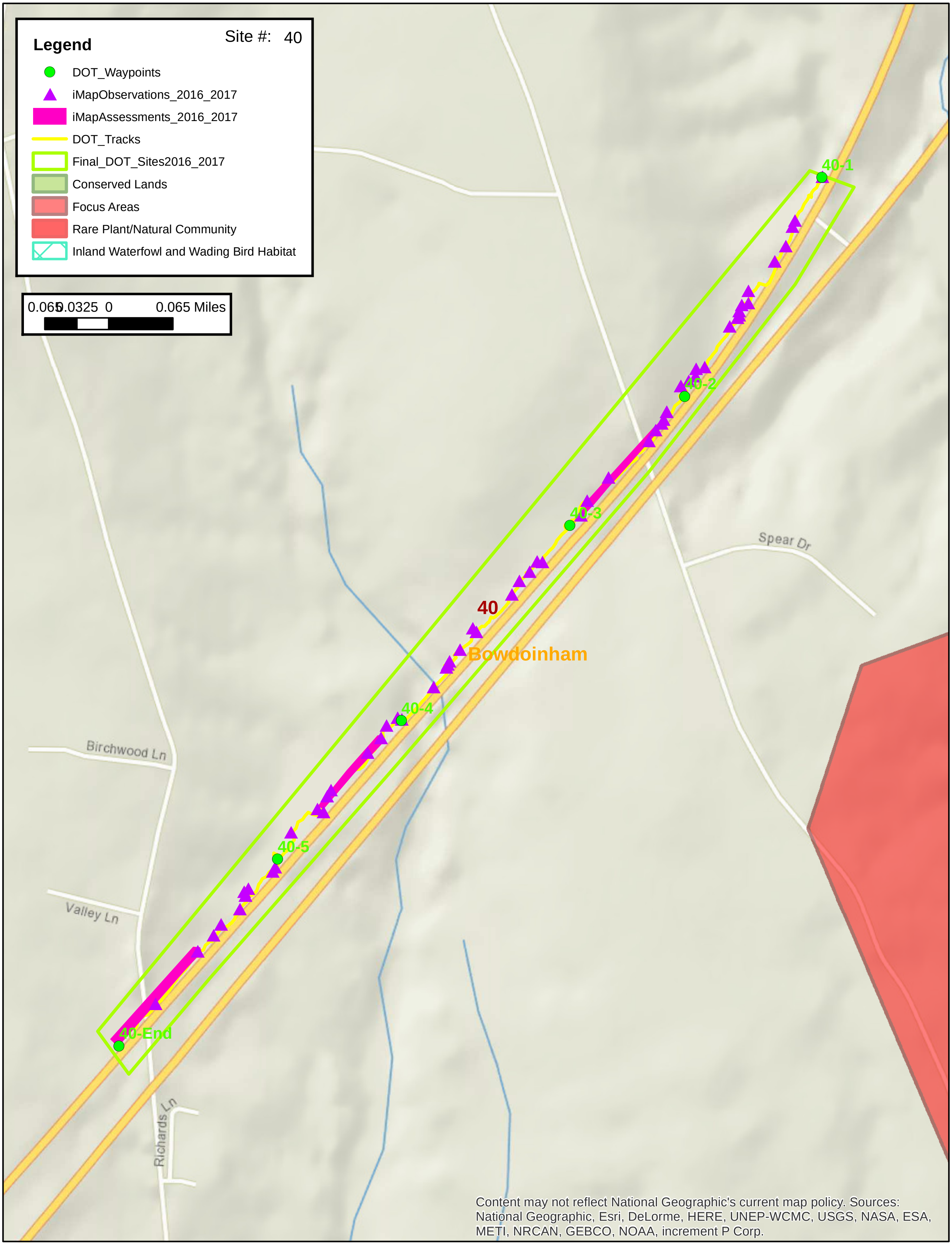

Legend
Site #: 36
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.1 0.05 0 0.1 Miles
Chapman Brook
Ripps Trl
Androscoggin Rd
Barker Rd
W Bethel Rd
36
36-1
36-2
36-3
36-4
36-5
36-End
Bethel
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.


Legend
Site #: 37
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.075 0.0375 0 0.075 Miles
Hermon
Hampden
Bog Rd
Wheeler Stream
37-1
37-2
37-3
37-4
37
37-5
37-End
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.



Legend
Site #: 38
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.075 0.0375 0 0.075 Miles
Bangor
Hampden
Hammond St
Odlin Rd
Dowd Rd
Ammo Industrial Park
95
38-1
38-2
38
38-3
38-4
38 End bangor
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.


Legend
Site #: 39
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.055 0.0275 0 0.055 Miles
39-End
39-4
39
39-3
Richmond
39-2
39-1
Port City Ln
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.



Legend
Site #: 40
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.065 0.0325 0 0.065 Miles
40-1
40-2
40-3
40
Bowdoinham
40-4
40-5
40-End
Spear Dr
Birchwood Ln
Valley Ln
Richards Ln
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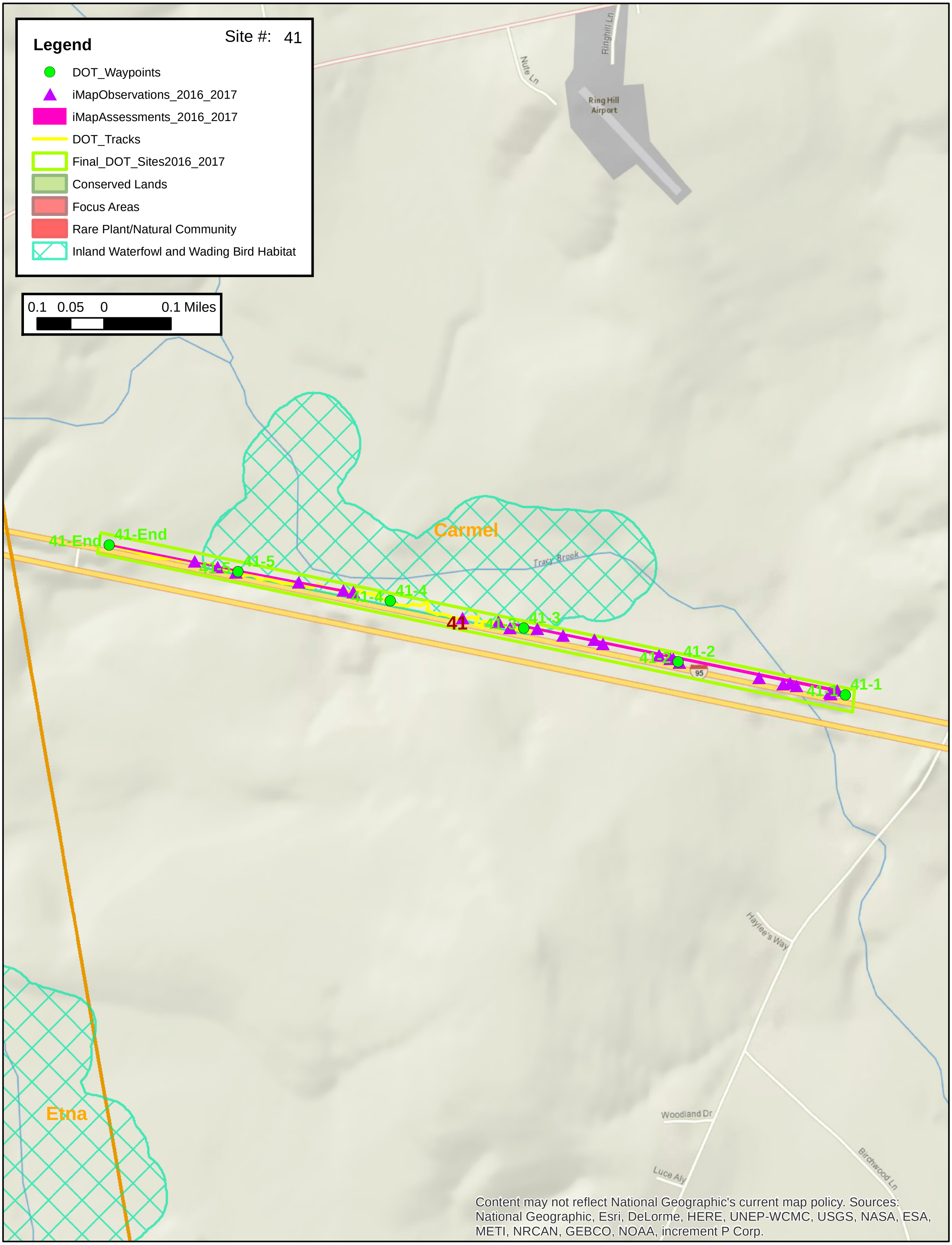

Legend
Site #: 41
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.1 0.05 0 0.1 Miles
Ringhill Ln
Nute Ln
Ring Hill Airport
Carmel
Tracy Brook
41-End
41-5
41-4
41-3
41-2
41-1
41
95
Haylee's Way
Woodland Dr
Luce Aly
Birchwood Ln
Etna
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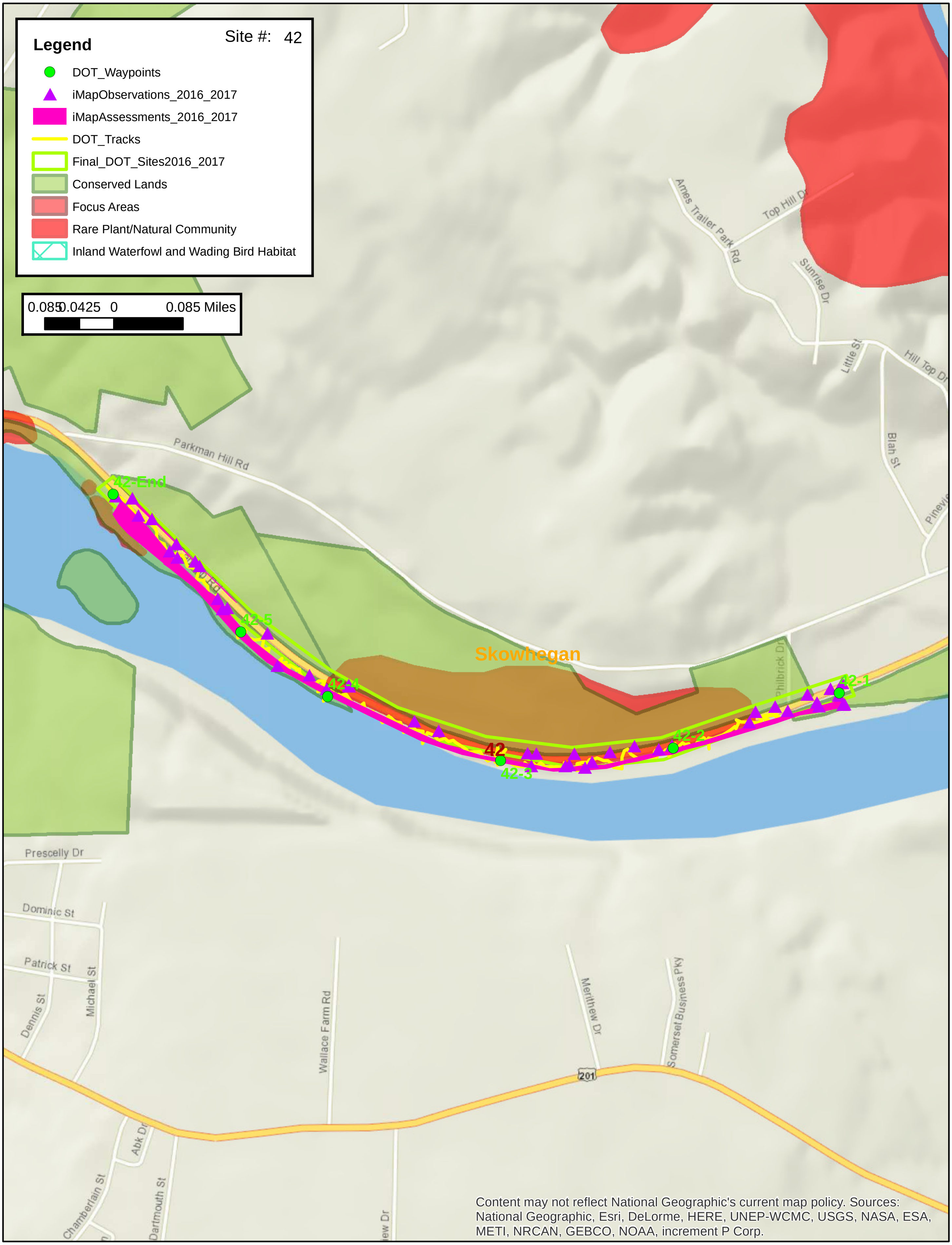
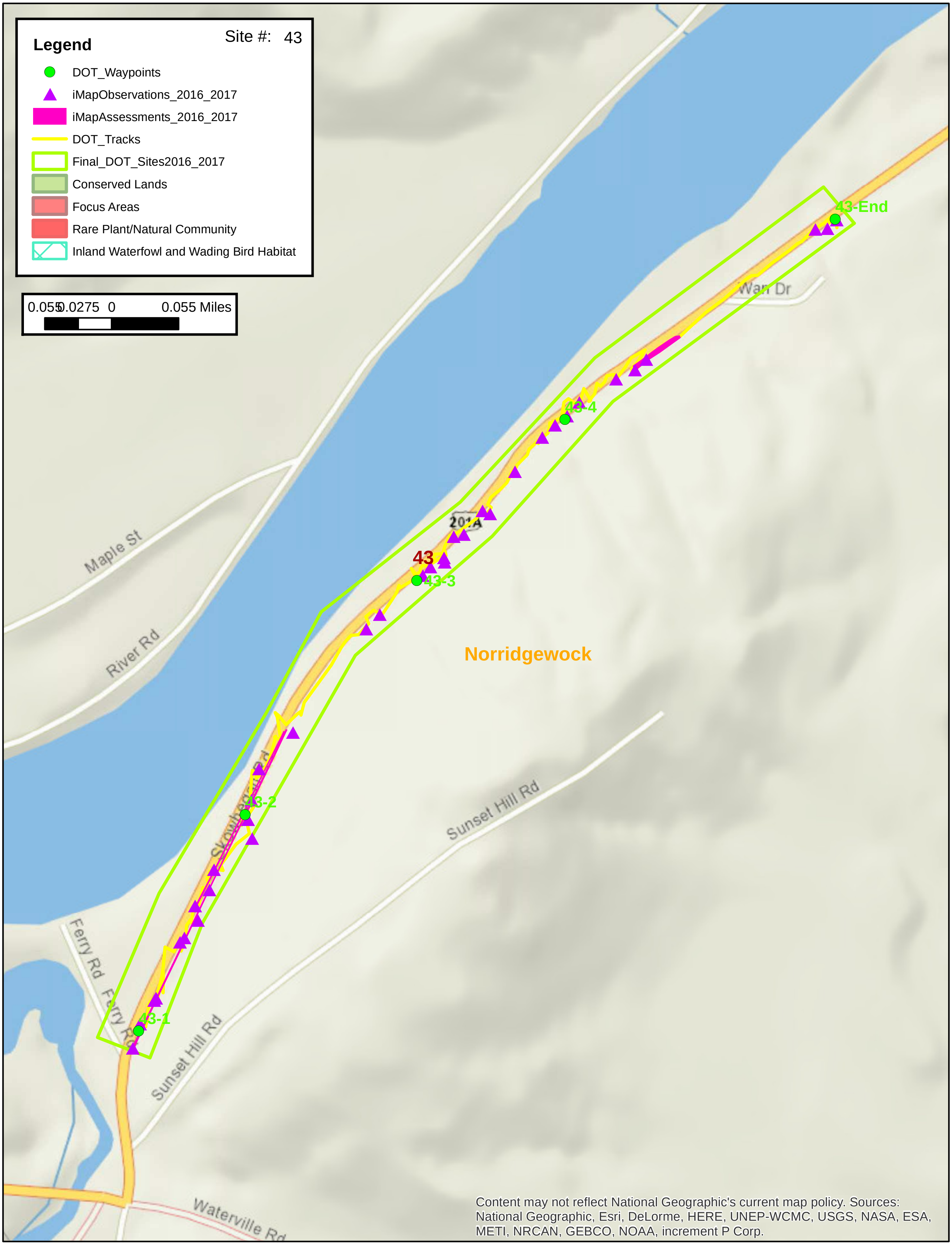


Legend
Site #: 42
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.085 0.0425 0 0.085 Miles
Parkman Hill Rd
Ames Trailer Park Rd
Top Hill Dr
Sunrise Dr
Little St
Hill Top Dr
Blah St
Skowhegan
42-End
42-5
42-4
42
42-3
42-2
42-1
Prescelly Dr
Dominic St
Patrick St
Michael St
Dennis St
Wallace Farm Rd
Merithew Dr
Somerset Business Pky
201
Abk Dr
Chamberlain St
Dartmouth St
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.



Legend
Site #: 43
DOT_Waypoints
iMapObservations_2016_2017
iMapAssessments_2016_2017
DOT_Tracks
Final_DOT_Sites2016_2017
Conserved Lands
Focus Areas
Rare Plant/Natural Community
Inland Waterfowl and Wading Bird Habitat
0.055 0.0275 0 0.055 Miles
43-End
43-4
43
43-3
43-2
43-1
201A
Norridgewock
Maple St
River Rd
Sunset Hill Rd
Ferry Rd
Waterville Rd
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Appendix 3

	A
1	**Compiled comprehensive list: MNAP dominant, MNAP invasives, and Drummond**
2	Abies balsamea
3	Acer negundo
4	Acer Platanoides
5	Acer rubrum
6	Acer saccharinum
7	Acer saccharum
8	Achillea millefolium
9	Achillea ptarmica
10	Aegopodium podograria
11	Aesclepias syrica
12	Agalinis tenuifolia
13	Ageratina altissima
14	Agrostis canina
15	Agrostis gigantea
16	Agrostis sp.
17	Ajuga reptans
18	Alnus incana
19	Alnus sp.
20	Ambrosia artemisiifolia
21	Amelanchier canadensis
22	Amelanchier sp.
23	Amphicarpaea bracteata
24	Anaphalis margaritacea
25	Andropogon gerardii
26	Anemone quinquifolia
27	Antennaria howelli
28	Antennaria neglecta
29	Antennaria plantaginifolia
30	Antennaria sp.
31	Anthemis arvensis
32	Anthoxanthum odoratum
33	Apios americana
34	Apocynum androsaemifolium
35	Apocynum cannabinum
36	Aquilegia sp.
37	Aralia hispida
38	Aralia nudicaulis
39	Arctium lappa
40	Arctium minus
41	Arctostaphylos uva-ursi
42	Aronia melanocarpa
43	Aronia sp.

Appendix 3

	A
1	**Compiled comprehensive list: MNAP dominant, MNAP invasives, and Drummond**
44	Artemisia vulgaris
45	Aruncus dioicus
46	Asclepias incarnata
47	Asclepias syriaca
48	Asparagus officinalis
49	Aster macrophyllus
50	Aster spp.
51	Athyrium angustum
52	Avena sp.
53	Berberis thunbergii
54	Berberis vulgaris
55	Betula alleghaniensis
56	Betula papyrifera
57	Betula populifolia
58	Betula sp.
59	Bidens frondosa
60	Bidens spp.
61	Bidens tripartita spp comosa
62	Brassica nigra
63	Brassica rapa
64	Brassica spp.
65	Bromus ciliatus
66	Bromus inermis
67	Calamagrostis canadensis
68	Calystegia sepium
69	Campanula rotundifolia
70	Campanula sp.
71	Cardamine pensylvanica
72	Carex spp.
73	Carex vulpanoidea
74	Carum carvi
75	Castenea dentata
76	Celastrus orbiculatus
77	Centaurea nigra
78	Centaurea jacea
79	Centaurea spp.
80	Centauria stoebe ssp. micranthos
81	Cephalanthus occidentalis
82	Chamaenerion angustifolium
83	Chamaepericlymenum canadense
84	Chamerion angustifolium
85	Chelone glabra

Appendix 3

	A
1	**Compiled comprehensive list: MNAP dominant, MNAP invasives, and Drummond**
86	Chimaphila umbellata
87	Cichorium intybus
88	Cicuta maculata
89	Circaea canadensis
90	Cirsium arvense
91	Cirsium muticum
92	Cirsium pumilum
93	Cirsium vulgare
94	Clematis virginiana
95	Clethera alnifolia
96	Clintonia borealis
97	Comptonia peregrina
98	Convallaria majalis
99	Convolvulus arvensis
100	Cornus canadensis
101	Cornus rugosa
102	Cornus sericea
103	Corylus americana
104	Crataegus sp.
105	Cuscuta sp.
106	Cyperus sp.
107	Cypripedium acaule
108	Dactylis glomerata
109	Danthonia spicata
110	Daucus carota
111	Dennstaedtia punctilobula
112	Desmodium canadense
113	Dianthus armeria
114	Dicanthelium clandestinum
115	Dicanthelium sp.
116	Diervilla lonicera
117	Digitaria spp.
118	Doellingeria umbellata
119	Eleagnus umbellata
120	Eleutherococcus pentaphyllus
121	Elymus repens
122	Epigaea repens
123	Epilobium ciliatum
124	Epilobium ciliatum ssp. glandulosum
125	Epilobium hirsutum
126	Epilobium sp.
127	Epipactis helleborine

Appendix 3

	A
1	**Compiled comprehensive list: MNAP dominant, MNAP invasives, and Drummond**
128	Equisetum spp.
129	Eragrostis spectabilis
130	Erechtites hieraciifolius
131	Erigeron annuus
132	Erigeron canadensis
133	Erigeron strigosus
134	Eriophorum virginicum
135	Euonymus alatus
136	Eupatorium maculatum
137	Eupatorium perfoliatum
138	Eupatorium spp.
139	Eurybia macrophylla
140	Eurybia radula
141	Euthamia graminifolia
142	Eutrochium maculatum
143	Fallopia cilinodis
144	Fallopia convolvulus
145	Fallopia japonica
146	Festuca elatior
147	Festuca filiformis
148	Festuca ovina
149	Festuca rubra
150	Festuca rubra or ovina
151	Festuca sp.
152	Fragaria sp.
153	Fragaria virginiana
154	Frangula alnus
155	Fraxinus americana
156	Fraxinus pennsylvanica
157	Fraxinus spp.
158	Galeopsis bifida
159	Galinsoga parviflora
160	Galinsoga quadriradiata
161	Galium asprellum
162	Galium mollugo
163	Galium palustre
164	Galium sp.
165	Galium verum
166	Gaultheria procumbens
167	Gaylussacia baccata
168	Geranium maculatum
169	Geranium pratense

Appendix 3

	A
1	**Compiled comprehensive list: MNAP dominant, MNAP invasives, and Drummond**
170	Geum canadense
171	Glechoma hederacea
172	Glyceria canadensis
173	Glyceria grandis
174	Graminoids
175	Gymnocarpium dryopteris
176	Hamamelis virginiana
177	Helianthus sp.
178	Helianthus tuberosus
179	Hemerocallis fulva
180	Hemerocallis spp.
181	Heracleum maximum
182	Hesperis matronalis
183	Hieracium aurantiacum
184	Hieracium caespitosum
185	Hieracium kalmii
186	Hieracium kalmii or umbellatum
187	Hieracium lachenalii
188	Hieracium paniculatum
189	Hieracium pilosella
190	Hieracium praealtum
191	Hieracium sabaudum
192	Hieracium spp.
193	Houstonia caerulea
194	Hylotelephium sp.
195	Hylotelephium telephium
196	Hypericum perforatum
197	Hypericum sp.
198	Ilex mucronata
199	Ilex verticillata
200	Impatiens capensis
201	Impatiens glandulifera
202	Ionactis linariifolia
203	Ipomoea purpurea
204	Iris versicolor
205	Juncus effusus
206	Juncus gerardii
207	Juncus sp.
208	Juniperus communis
209	Juniperus horizontalis
210	Kalmia angustifolia
211	Lactuca canadensis

Appendix 3

	A
1	**Compiled comprehensive list: MNAP dominant, MNAP invasives, and Drummond**
212	Lactuca serriola
213	Lactuca sp.
214	Lamium amplexicaule
215	Larix laricina
216	Larix laricinia
217	Lathyrus latifolius
218	Lawn grasses
219	Leersia oryzoides
220	Leontodon autumnalis
221	Lepidium sp.
222	Leucanthemum vulgare
223	Ligustrum spp.
224	Lilium philadelphicum
225	Linaria canadense
226	Linaria vulgaris
227	Linum usitaissimum
228	Lobelia cardinalis
229	Lonicera morrowii
230	Lonicera spp.
231	Lotus corniculatus
232	Luecanthemum vulgare
233	Lupinus polyphyllus
234	Lychnis coronaria
235	Lychnis flos-cuculi
236	Lycopus americanus
237	Lycopus uniflorus
238	Lyonia ligustrina
239	Lysimachia borealis
240	Lysimachia ciliata
241	Lysimachia punctata
242	Lysimachia quadrifolia
243	Lysimachia terrestris
244	Lythrum salicaria
245	Maianthemum canadense
246	Maianthemum racemosum
247	Malus pumila
248	Malus sp.
249	Malva moschata
250	Matteuccia struthiopteris
251	Medicago lupulina
252	Medicago sativa
253	Melilotus albus

Appendix 3

	A
1	**Compiled comprehensive list: MNAP dominant, MNAP invasives, and Drummond**
254	Melilotus officinalis
255	Mentha aquatica
256	Mentha arvensis
257	Mentha sp.
258	Mentha spicata
259	Mimulus ringens
260	Mitchella repens
261	Monarda fistulosa
262	Monotropa uniflora
263	Morella caroliniensis
264	Muhlenbergia mexicana
265	Nabalus albus
266	Nabalus trifoliolatus
267	Nasturtium officinale
268	Nuphar variegata
269	Nuttallanthus canadensis
270	Nyssa sylvatica
271	Oclemena acuminata
272	Oclemena nemoralis
273	Odontites vernus
274	Oenothera biennis
275	Oenothera parviflora
276	Oenothera perennis
277	Onoclea sensibilis
278	Osmunda claytoniana
279	Osmunda regalis
280	Osmundastrum cinnamomeum
281	Oxalis stricta
282	Panicum virgatum
283	Parthenocissus quinquefolia
284	Pastinaca sativa
285	Persicaria amphibia
286	Persicaria arifolia
287	Persicaria maculosa
288	Persicaria spp.
289	Persicaria ssp.
290	Phalaris arundinacea
291	Phleum pratense
292	Phragmites australis
293	Physalis sp.
294	Picea rubens
295	Pimpinella saxifraga

Appendix 3

	A
1	**Compiled comprehensive list: MNAP dominant, MNAP invasives, and Drummond**
296	Pinus glauca
297	Pinus resinosa
298	Pinus rigida
299	Pinus strobus
300	Plantago lanceolata
301	Plantago major
302	Poa nemoralis
303	Poa palustris
304	Poa pratensis
305	Pogonia ophioglossoides
306	Polygonatum pubescens
307	Polygonum pensylvanicum
308	Pontederia cordata
309	Populus alba
310	Populus balsamifera
311	Populus tremuloides
312	Potentilla anglica
313	Potentilla recta
314	Potentilla simplex
315	Prenanthes altissima
316	Prunella vulgaris
317	Prunus pensylvanica
318	Prunus serotina
319	Prunus spp.
320	Prunus virginiana
321	Pseudognaphalium obtusifolium
322	Pseudognaphalium viscosum
323	Pteridium aquilinum
324	Pyrola americana
325	Quercus ilicifolia
326	Quercus rubra
327	Ranunculus acris
328	Ranunculus repens
329	Ranunculus spp.
330	Rhamnus cathartica
331	Rhinanthus minor
332	Rhinanthus minor ssp. minor
333	Rhododendron canadense
334	Rhododendron tomentosum
335	Rhodora canadense
336	Rhus hirta
337	Rhus hirta-typhina

Appendix 3

	A
1	**Compiled comprehensive list: MNAP dominant, MNAP invasives, and Drummond**
338	Ribes americanum
339	Ribes sp.
340	Robinia hispida
341	Robinia pseudoacacia
342	Rosa carolina
343	Rosa multiflora
344	Rosa nitida
345	Rosa rugosa
346	Rosa spp.
347	Rosa virginiana
348	Rubus allegheniensis
349	Rubus flagellaris
350	Rubus hispidus
351	Rubus idaeus
352	Rubus spp.
353	Rudbeckia hirta
354	Rumex acetosa
355	Rumex acetosella
356	Rumex crispus
357	Rumex spp.
358	Sagittaria latifolia
359	Salix spp.
360	Sambucus nigra
361	Sanginaria canadensis
362	Saponaria officnalis
363	Satureja hortensis
364	Schedonorus arundinaceous
365	Schedonorus pratensis
366	Schedonorus sp.
367	Schizachyrium scoparium
368	Schoenoplectus sp.
369	Scirpus hattorianus
370	Scirpus microcarpus
371	Scirpus spp.
372	Scorzoneroides autumnalis
373	Scutellaria galericulata
374	Secale cereale
375	Securigera varia
376	Sedum sp.
377	Setaria pumila
378	Silene alba
379	Silene sp.

Appendix 3

	A
1	**Compiled comprehensive list: MNAP dominant, MNAP invasives, and Drummond**
380	Silene vulgaris
381	Sisyrinchium montanum
382	Smilax herbacea
383	Soladago altissima
384	Solanum dulcamara
385	Solidago bicolor
386	Solidago canadensis
387	Solidago flexicaulis
388	Solidago gigantea
389	Solidago hispida
390	Solidago juncea
391	Solidago nemoralis
392	Solidago puberula
393	Solidago rugosa
394	Solidago sempervirens
395	Solidago sp.
396	Solidago spp.
397	Solidago squarrosa
398	Soligado rugosa
399	Sonchus arvensis
400	Sonchus asper
401	Sonchus oleraceus
402	Sorbaria sorbifolia
403	Sorbus americana
404	Sorbus decora
405	Sparganium americanum
406	Spartina alternaflora
407	Spartina patens
408	Spartina pectinata
409	Spergularia rubra
410	Spiraea alba
411	Spiraea tomentosa
412	Stellaria graminea
413	Swida amomum
414	Swida racemosa
415	Swida rugosa
416	Swida sericea
417	Swida sp.
418	Symphiocarpos albus
419	Symphyotrichum + others spp.
420	Symphyotrichum ciliolatum
421	Symphyotrichum cordifolium

Appendix 3

	A
1	**Compiled comprehensive list: MNAP dominant, MNAP invasives, and Drummond**
422	Symphyotrichum lanceolatum
423	Symphyotrichum lateriflorum
424	Symphyotrichum novae-angliae
425	Symphyotrichum novae-belgii
426	Symphyotrichum pilosum
427	Symphyotrichum puniceum
428	Symphyotrichum spp.
429	Symplocarpus foetidus
430	Syringa vulgaris
431	Tanacetum vulgare
432	Taraxacum officinale
433	Thalictrum pubescens
434	Thalictrum thalictroides
435	Thelypteris palustris
436	Thuja occidentalis
437	Tiarella cordifolia
438	Tilia americana
439	Toxicodendron radicans
440	Tragopogon dubius
441	Tragopogon pratensis
442	Triadenum viginicum
443	Trifolium arvense
444	Trifolium aureum
445	Trifolium compestre
446	Trifolium pratense
447	Trifolium pratense and T. repens
448	Trifolium repens
449	Trifolium spp.
450	Triglochan maritima
451	Tripleurospermum inodorum
452	Tsuga canadensis
453	Turf grass
454	Tussilago farfara
455	Typha angustifolia
456	Typha latifolia
457	Typha spp.
458	Ulmus americana
459	Unknown grass-not in flower
460	Urtica dioica
461	Uvularia sessilifolia
462	Vaccinium angustifolium
463	Vaccinium corymbosum

Appendix 3

	A
1	**Compiled comprehensive list: MNAP dominant, MNAP invasives, and Drummond**
464	Vaccinium macrocarpon
465	Vaccinium myrtilloides
466	Valeriana officinalis
467	Verbascum thapsus
468	Verbena hastata
469	Veronica chamaedrys
470	Veronica scutellata
471	Viburnum acerifolium
472	Viburnum dentatum
473	Viburnum lentago
474	Viburnum opulus
475	Viburnum sp.
476	Vicia cracca
477	Vicia sativa
478	Vicia spp.
479	Viola sp.
480	Vitis sp.
481	Vitus labrusca

Roadside Bumblebee and Butterfly Survey
Final Report to the Maine Department of Transportation

Dr. Frank Drummond, University of Maine
March 27, 2018

Ten sites in five regions were sampled at three times, spring (30 May - 7 June), early summer (6 - 17 July), and mid-late summer (17 -24 August). Paired sites (2 per location) were located in Penobscot (#11, 12, 27, 28), Aroostook (#3,4), Oxford (#35, 36), and Sagadahoc Counties (#39, 40). This final report includes all three sampling periods and summarizes flowering plant, bumblebee and butterfly species diversity. In general, the 2017 spring was moderately wet, although this is a phenomenon that is becoming more the norm than the anomaly (Drummond et al. 2017[1]). The summer was hot and was characterized by less than average rainfall, resulting in drought conditions in many areas across Maine and early senescence of roadside flora. Because of this we did not conduct sampling in the fall since many plant species had died and little floral resource was available for pollinator sampling.

FLORA. A total of 235 plant taxa (230 species and 5 species complexes or groups (such as all goldenrods)) were recorded and identified across all ten sites. It should be kept in mind that we only recorded plant species in flower. This means that while several genera and species of plants such as Japanese knotweed were present, sometimes in high density, they were not recorded if not in bloom. We also did not report grasses in flower, with one exception, Timothy grass. This species has been shown to be bumblebee forage in Maine[2]. Grasses are also important to many of the butterfly species such as the European skipper that utilize them for roosting locations at night and as larval food. Table 1 lists the most common plant taxa observed in flower during each of the three sampling periods. Upon inspection of the plant diversity in Table 1, it can be seen that overall, the species diversity is high (Shannon index = 4.544) and is quite even and not dominated by only a few species. The Simpson's evenness index (1-D) is 0.986 (on a scale of 0.0 to 1.0 community, representing the range of a community dominated by just a few species (0.0) to a community represented by many species all in fairly common abundance (1.0)). Figure 1 illustrates the relative proportional representation of the most common ten plant taxa including species complexes for each sampling round.

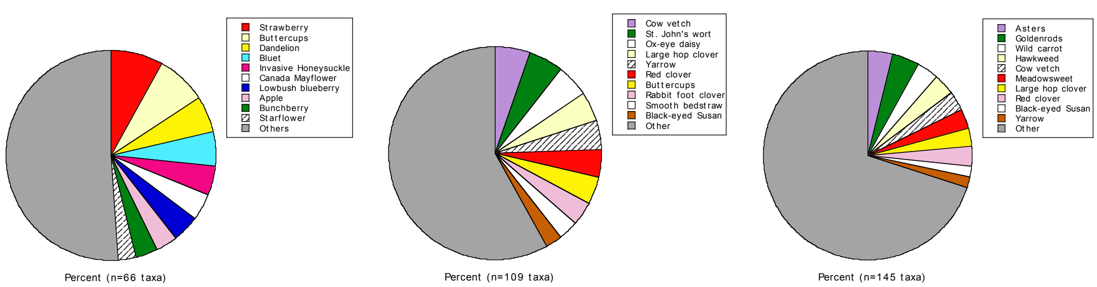


Figure 1. Percent occurrence (by segment across all sites) of most common plant species and species complexes in flower in round 1 (left), round 2 (middle), and round 3 (right).

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[1] Drummond, F.A., A.C. Dibble, C. Stubbs, S. Bushmann, J. Ascher, and J. Ryan. 2017. A Natural History of Change in Native Bees Associated with Lowbush Blueberry in Maine. Northeastern Naturalist. 24 (15): 49-68.

[2] Rivernider, R., Venturini, E., and F. Drummond. 2017. Timothy grass, a pollen forage for bumble bees. J. Kansas Entomol. Soc. 90(1): 63-68.

Table 1. Relative abundances[1,2] of common flowering plants along roadsides in Maine, 2017.

Sample Date[3]	Genus	species	Common name	Percent[1] occurrence	Mean rank[4] abundance	Plant origin
June	*Fragaria*	*virginiana*	Strawberry	74	1.49 + 0.90	native
June	*Taraxacum*	*officinale*	Dandelion	52	1.00 + 0.00	exotic
June	*Houstonia*	*caerulea*	Azure bluet	48	1.17 + 0.48	native
June	*Maianthemum*	*canadense*	Canada mayflower	40	1.25 + 0.55	native
June	*Vaccinium*	*angustifolium*	Lowbush blueberry	38	1.47 + 0.84	native
June	*Cornus*	*canadensis*	Bunchberry	30	1.87 + 1.06	native
June	*Prunus*	*virginiana*	Choke cherry	28	1.29 + 0.47	native
June	*Cornus*	*sericea*	Red osier dogwood	28	1.50 + 0.94	native
June	*Lysimachia*	*borealis*	Star flower	28	1.07 + 0.27	native
June	*Stellaria*	*graminea*	Common starwort	26	1.00 + 0.00	exotic
June	*Sisyrinchium*	*montanum*	Blue-eyed grass	22	1.18 + 0.41	native
June	*Potentilla*	*simplex*	Common cinquefoil	22	1.00 + 0.00	native
June	*Rumex*	*acetosella*	Red sorrel	18	1.11 + 0.33	exotic
June	*Eleagnus*	*umbellata*	Autumn olive	16	1.38 + 0.52	exotic
June	*Ranunculus*	*repens*	Creeping buttercup	14	1.00 + 0.00	exotic
July	*Viccia*	*cracca*	Cow vetch	98	2.20 + 1.02	exotic
July	*Hypericum*	*perferatum*	St. John's wort	92	1.39 + 0.65	exotic
July	*Luecanthemum*	*vulgare*	Ox-eye daisy	90	1.44 + 0.76	exotic
July	*Trifolium*	*aureum*	Large hop clover	84	1.88 + 1.06	exotic
July	*Achillea*	*millefolium*	Yarrow	80	1.28 + 0.51	native
July	*Trifolium*	*pratense*	Red clover	76	1.47 + 0.73	exotic
July	*Trifolium*	*arvense*	Rabbit foot clover	68	2.00 + 1.07	exotic
July	*Galium*	*mollugo*	Smooth bedstraw	54	1.67 + 0.88	exotic
July	*Ranunculus*	*repens*	Creeping buttercup	50	1.16 + 0.37	exotic
July	*Rudbeckia*	*hirta*	Black-eyed Susan	46	1.13 + 0.34	native
July	*Securigera*	*varia*	Crown vetch	44	2.59 + 1.56	exotic
July	*Lysimachia*	*terrestris*	Swamp candle	42	1.24 + 0.44	native
July	*Daucus*	*carota*	Wild carrot	42	1.38 + 0.92	exotic
July	*Lotus*	*corniulatus*	Birds foot-trefoil	36	1.33 + 0.59	exotic
July	*Spirea*	*alba*	Meadowsweet	36	1.00 + 0.00	native
August	*Solidago*	*canadensis*	Canada goldenrod	100	1.48 + 0.74	native
August	*Euthamia*	*graminifolia*	Grass-leaved goldenrod	90	1.09 + 0.29	native
August	*Daucus*	*carota*	Wild carrot	84	1.21 + 0.52	exotic
August	*Viccia*	*cracca*	Cow vetch	80	1.03 + 0.16	exotic
August	*Hieracium*	*caespitosum*	Meadow hawkweed	76	1.03 + 0.16	exotic
August	*Spirea*	*alba*	Meadowsweet	76	1.08 + 0.27	native
August	*Trifolium*	*aureum*	Large hop clover	72	1.14 + 0.42	exotic
August	*Trifolium*	*pratense*	Red clover	72	1.25 + 0.55	exotic
August	*Symphyotrichum*	*lateriflorum*	Calico aster	56	1.07 + 0.26	native
August	*Soladago*	*gigantea*	Smooth goldenrod	52	1.27 + 0.60	native
August	*Soladago*	*bicolor*	White goldenrod	50	1.04 + 0.20	native
August	*Rudbeckia*	*hirta*	Black-eyed Susan	46	1.00 + 0.00	native
August	*Symphyotrichum*	*novae-angliae*	New England aster	46	1.18 + 0.39	native
August	*Achillea*	*millefolium*	Yarrow	42	1.00 + 0.00	native
August	*Securigera*	*varia*	Crown vetch	40	1.45 + 0.60	exotic

[1] Based upon percent of segments (n=50) occupied, selected 15 most common species for each date.
[2] Common plant species complexes not always identified to individual species. These common complexes in June were: *Ranunculus* spp. (72%), Invasive *Lonicera* spp. (40%), *Hieracium* spp. (82%), and *Malus* spp. (30%); in July were: *Ranunculus* spp. (72%), and Hieracium spp. (40%); and in August were: all aster-like species (*Symphyotrichum* + other genera, 100%), and all *Solidago* spp. (100%).
[3] Sample dates within each month were, sample date 1 in June: 30 May – 7 June; sample date 2 in July: 6 July – 17 July, and sample date 3 in August: 17 August – 24 August.
[4] Rank abundance for plant species averaged only across segments that particular species were recorded. Ranks were: 1) Trace or barely detectable (<1% of flowering), 2) 1-5% of land area (low abundance), 3) 6-10% (moderate abundance), 4) 11-25% (common abundance), 5) 26-50% (high abundance), and 6) >51% of land area (extremely high abundance).

Figure 2 shows typical roadside landscapes during the three sampling periods.

Figure 2. Sampled roadside landscapes in spring (left), early summer (middle), and mid – late summer (right).

As mentioned previously, overall plant community species richness and diversity was high with low dominance, however, when the five regions that the sites were nested within were looked at, there was little difference from the overall diversity. Plant community evenness averaged 0.983 $\pm$ 0.003 (standard error) for the five sites, indicating that all regions possessed highly even diversity. Plant species richness and Shannon's diversity did not appear to be characterized by an east to west or north to south gradient. However, it does appear that the two sites on state roads had a small, but measurable higher plant diversity and richness than did those sites on freeways (routes 295 and 95). Figure 3 shows the sample site regions and Figure 4 shows plant species richness and Shannon's diversity among regions.

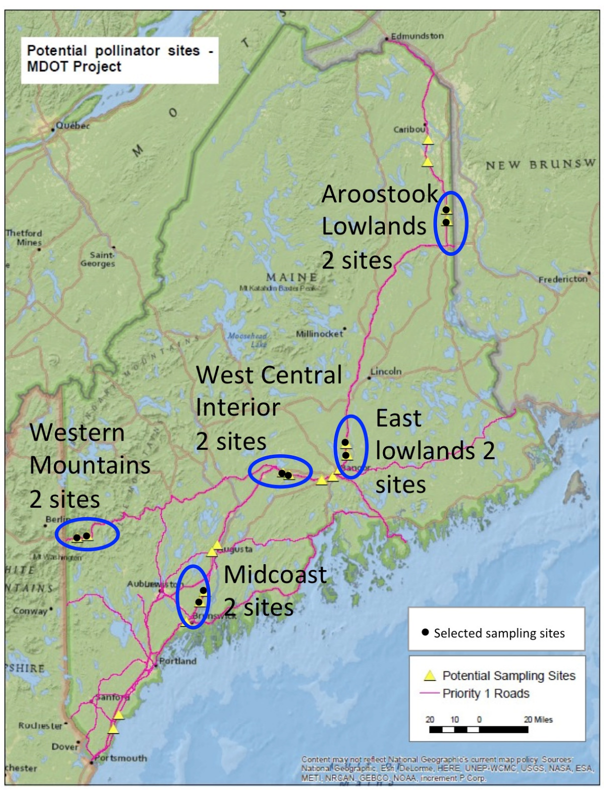

Figure 3. Map of sampling sites and their respective geographic region.

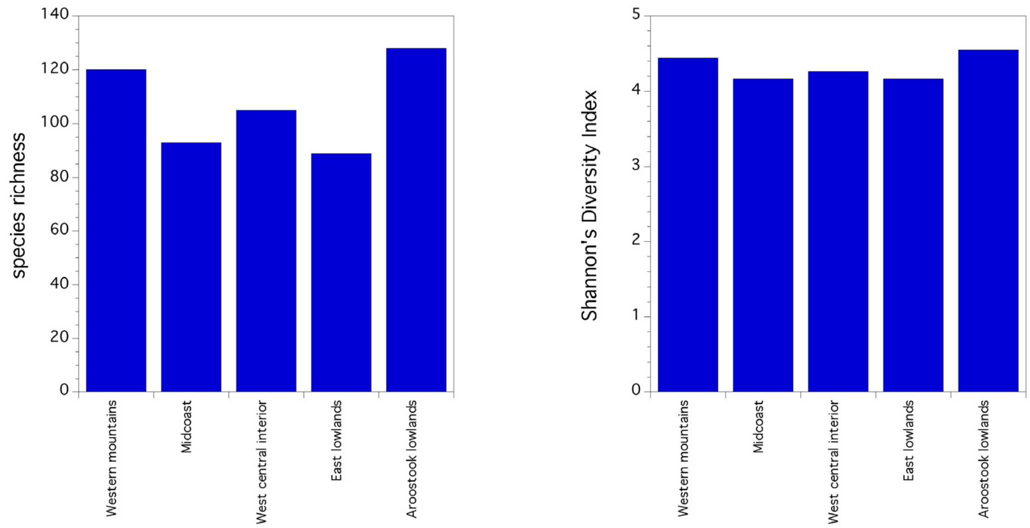

Figure 4. Plant species richness and diversity across the five sampling regions.

Uncommon flowering plant species, those only occurring in one segment out of all of the sampled segments, numbered 19 in round 1 and 22 in round 2, and 44 in round 3 (both native and exotic). Native species in flower that were only found in only one segment among all segments and had an abundance of one individual plant or one aggregate patch of plants in round 1 were: heartleaf foam flower, bristly sarsaparilla, Canada mayflower, common cinquefoil, rhodora, sour top blueberry; and the shrubs: nannyberry and round leafed dogwood. In round 2, the uncommon native plants in bloom were: yellow water lily, winterberry, staghorn sumac, marsh bedstraw, bristly sarsaparilla, little sundrops, hemp dogbane, and common boneset. In round 3 the uncommon flowering native plants in bloom were: blue vervain, blue heart-leafed aster, bog aster, Canadian toadflax, cut-leaved water-horehound, downy goldenrod, fringed bindweed, harebell, Jerusalem artichoke, lesser daisy fleabane, late goldenrod, northern willow herb, panicled hawkweed, pearly everlasting, pussytoes, spotted Joe-pye weed, spreading dogbane, stout goldenrod, swamp thistle, sweet everlasting, tall lettuce, threelobe beggar ticks, white snakeroot, wild lettuce, and zigzag goldenrod. This list of uncommon native flowering plants does not mean that the plant population was uncommon, but only that those individuals "in flower" were uncommon during our sampling effort.

Potentially troublesome plant species recorded were invasive honeysuckle (20 segments) in round 1, wild parsnip (8 segments) in round 2, and Japanese knotweed (1 segment) in round 3. Exotic plant species in general were common and abundant along Maine roadsides (Table 1, Fig. 5). In round 1, 34.4% of the flowering plant occurrences (species occurrences over all sites) were exotic or non-native (this includes naturalized species). In round 2, 63.7% of the identified flowering plant species occurrences were exotic, and in round 3, 35.2% of plant species identified to date are exotic. Therefore, it is the case that exotic plant species constitute a large proportion of the flora along roadsides. In fact, our estimates are most likely an underestimate of exotic plant relative abundance since exotic grasses were not recorded. As will be seen later pollinators utilize many of these exotic species. Both patch size and % landcover occupied by native and exotic plants in bloom varied by sample date (Fig. 6). Patch size was greater for native flowering plants compared to exotics in the spring, but less than exotic flowering plants in the early summer ($F_{(2,54)} = 18.574$, $P < 0.0001$). There was no difference in patch size between native and exotic flowering plants in late summer. Only in the early summer was the % landcover occupied by exotic flowering plants greater than flowering native plants ($F_{(2,54)} = 9.899$, $P = 0.0002$).

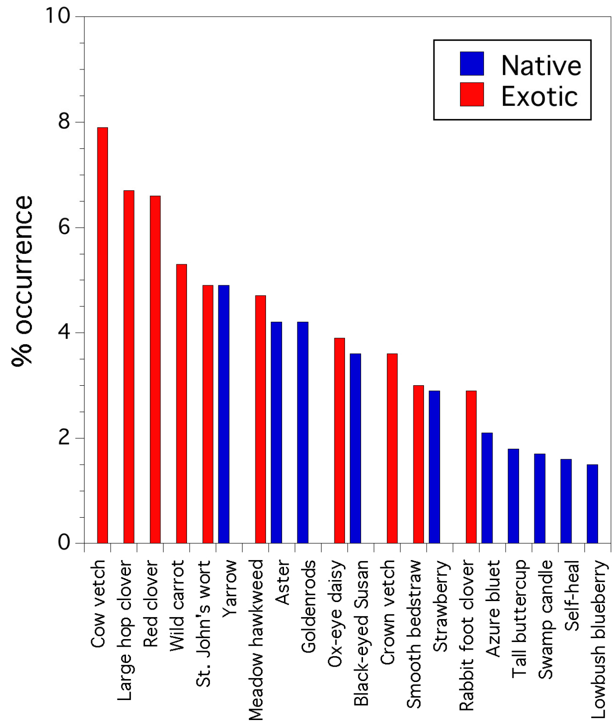

Figure 5. The percent occurrence pooled across all three sampling periods and all segments surveyed along Maine roadsides.

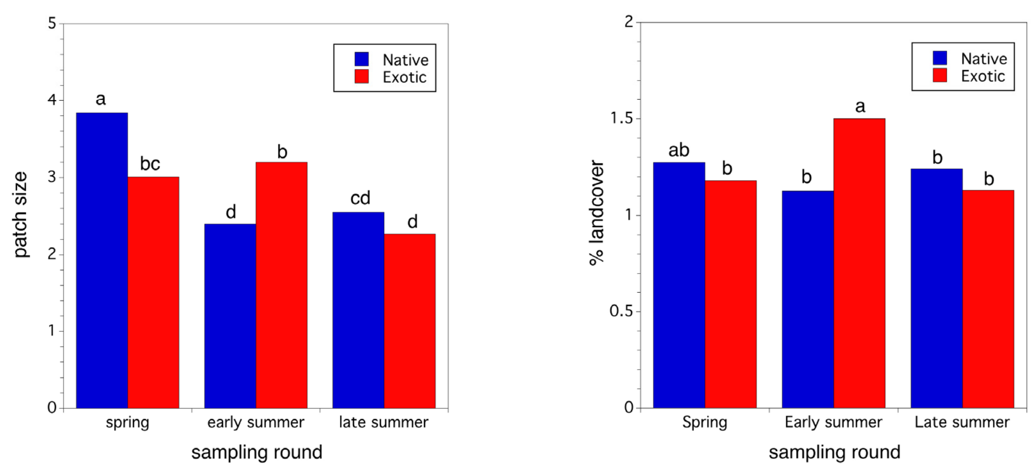

Figure 6. Mean patch size (left graph) and % landcover (right graph) of native versus exotic plants along Maine roadsides at each sampling period.

We also aggregated the floral records by plant genus. Overall, 139 genera were identified and recorded, 45 genera were found in flower during round 1, 82 genera were found in flower during round 2, and 86 genera were found in round 3. The three most common genera over the entire season were *Trifolium* (some clovers)*, Solidago* (goldenrods), *Hieracium* (hawkweeds), *Ranunculus* (buttercups), and *Symphyotrichum* (some of the asters). The most common genera for each sampling period are shown in Figure 7. The top three most common were: *Fragaria* (strawberry), *Ranunculus* (buttercup), and *Cornus* (dogwood) in round 1; *Trifolium* (some clovers), *Vicia* (some vetches), and *Hypericum* (St. John's worts) in round 2; and *Solidago* (goldenrods), *Hieracium* (hawkweeds), and *Symphyotrichum* (some of the asters) in round 3.

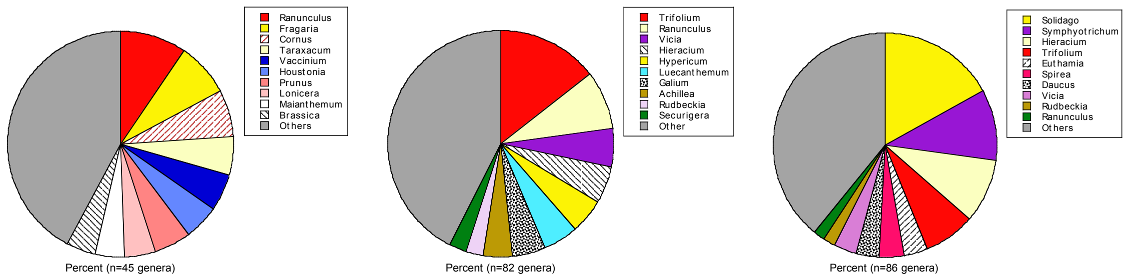

Figure 7. Percent occurrence (by segment across all sites) of most common plant genera in flower in round 1 (left), round 2 (middle), and round 3 (right).

Estimated plant density (% land cover) averaged over all sites for the 9 most common species is depicted in Figure 8. It can be seen that in round 1, that bunchberry, lowbush blueberry, invasive honeysuckle, and wild strawberry were the most abundant in terms of the percent of occupied land area along roadsides (one invasive species). In round 2, cow vetch, large hop clover and rabbit foot clover were the most abundant (all three exotic species). Goldenrods in the genus *Solidago* occupied the largest amount of land area followed by asters of the genus *Symphyotrichum* (both native taxa).

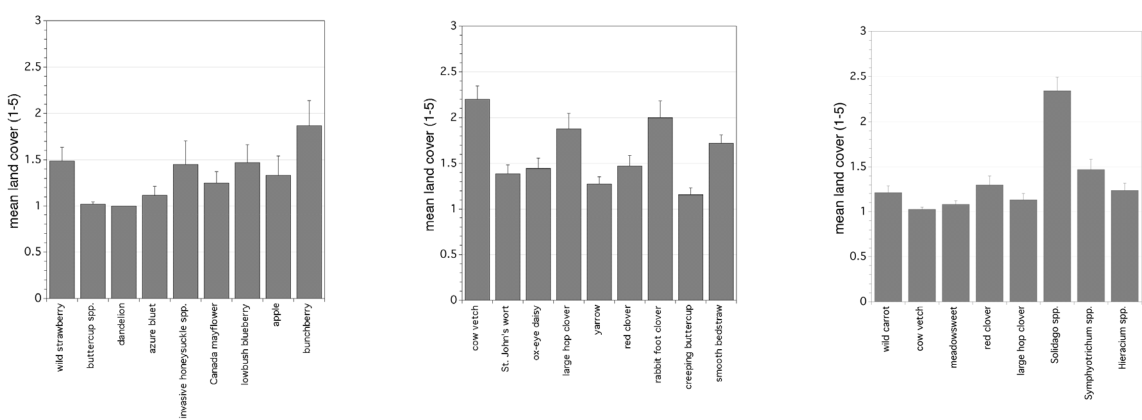

Figure 8. Average flowering plant density (by site) and standard error (bars) for the 9 most common plant species in round 1 (left), round 2 (middle), and round 3 (right). The mean land cover ranks are: 1) <1 % area of land cover, 2) 1-5%, 3) 6-10%, 4) 11-25%, 5) 26-50%, 6) > 50% land area of a segment covered by a specific plant species.

In rounds 1-3, flowering plant generic richness (# of flowering plants of 1 or more species within a genus, for all genera recorded) and flowering plant species richness (# species in bloom recorded) were significantly related at the segment level, over all three sample periods ($P < 0.0001$, $r^2 = 0.91$, Fig. 9) and there was no evidence of an interaction among years in this relationship ($P = 0.214$). Because of this high correlation, only species richness was investigated to determine if plant diversity at the segment level determined mean plant patch size, mean % landcover of blooming plants, and the product of mean patch size and % landcover of blooming plants. The only significant relationship that we uncovered was that between flowering plant species richness and mean rank patch size ($F_{(3,145)} = 42.305$, $P < 0.0001$, $r^2 = 0.467$). Forty-seven percent of the variation in mean patch size, averaged for all plants in bloom in each segment for each sampling period, was explained by sampling date (seasonal phenology) and flowering plant species richness. The relationship between flowering plant species richness and sampling period, and patch size were both negative and statistically significant. Specifically, flowering plant species richness ($F_{(1,145)} =$ 3.705, $P = 0.056$, slope = - 0.017 $\pm$ 0.009) having a negative effect on mean patch size suggests that as species richness increases in segments, competition for resources increases and patch size per species per segment decreases (Fig. 9). This is not a negative impact on total flowering plant resources for pollinator utilization. Figure 9 shows that total patch size of all flowering plants in a segment increases with flowering plant species richness ($F_{(1,147)} = 599.963$, $P < 0.0001$, $r^2 = 0.803$).

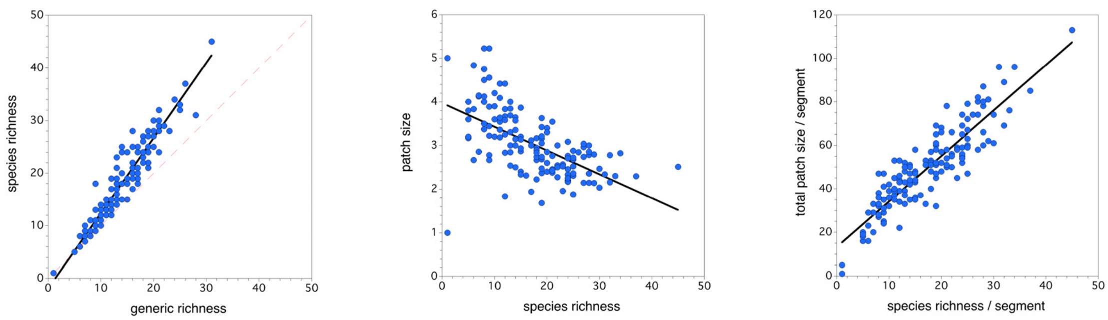

Figure 9. The relationship between flowering plant generic richness and flowering plant species richness pooled over all three rounds, red dashed line is the 1:1 slope of equality (left graph). The relationship between flowering species richness and mean patch size per plant (middle graph). The relationship between flowering species richness and total patch size per segment (right graph).

POLLINATORS. Table 2 lists the relative abundance of bumblebees observed in 2017 along Maine roadsides. A total of 12 species of bumblebees were recorded. The highest numbers of species were captured during the early summer (Table 2). In the spring and early summer the Common Eastern and the Tricolor bumblebees were the most common species (Table 2). The bee community became dominated in mid-late summer by the Common Eastern Bumblebee. The endangered, federally listed, Rusty-patched bumblebee was not recorded. The Yellow-banded bumblebee, currently, under consideration for listing was recorded, but only comprised 4% of the bumblebee relative abundance that we observed (Table 2). We recorded the yellow-banded bumblebee at 5 of the 10 sites in round 2, but none in round 3. We have observed in the past several years that this species disappears in the mid-late summer. We are not sure if this is due to disease (Bushmann et al. 2012[3]) or if it is a naturally fast maturing species. An additional note on the bumble bee diversity in the late summer is that the tricolor or orange belted bumble bee, *Bombus ternarius*, on of our most common bumble bee throughout the state was uncommonly low in relative abundance (11.7%), however, it was still captured at (5 of 10 sites). This supports several observers in Maine in 2017 who reported this species to be low in occurrence across the state.

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[3] Bushmann, S.L., F. A. Drummond, L. A. Beers, and E. Groden. 2012. Wild bumblebee (Bombus) diversity and *Nosema* (Microsporidia: Nosematidae) infection levels associated with lowbush blueberry (*Vaccinium angustifolium*) production and commercial bumblebee pollinators. Psyche 2012, Article ID 429398, 11 pp., doi:10.1155/2012/429398.

Table 2. Relative abundances[1] of bumblebee species along roadsides in Maine, 2017.

Sample Date[2]	Genus	species	Common name	Relative[1] Abundance (%)
June	*Bombus*	*impatiens*	Common Eastern Bumblebee	36.8
June	*Bombus*	*ternarius*	Tri-colored Bumblebee	20.0
June	*Bombus*	*sp.*	Not determined[3]	20.0
June	*Bombus*	*bimaculatus*	Two-spotted Bumblebee	10.0
June	*Bombus*	*perplexus*	Confusing Bumblebee	3.3
June	*Bombus*	*vagans*	Half-black Bumblebee	3.3
June	*Bombus*	*terricola*	Yellow-banded Bumblebee	3.3
June	*Bombus*	*borealis*	Northern Amber Bumblebee	3.3
July	*Bombus*	*impatiens*	Common Eastern Bumblebee	27.8
July	*Bombus*	*vagans*	Half-black Bumblebee	17.5
July	*Bombus*	*ternarius*	Tri-colored Bumblebee	16.7
July	*Bombus*	*bimaculatus*	Two-spotted Bumblebee	11.0
July	*Bombus*	*borealis*	Northern Amber Bumblebee	11.0
July	*Bombus*	*terricola*	Yellow-banded Bumblebee	4.2
July	*Bombus*	*griseocolis*	Brown-belted Bumblebee	4.2
July	*Bombus*	*perplexus*	Confusing Bumblebee	3.8
July	*Bombus*	*rufocinctus*	Red-belted Bumblebee	1.9
July	*Bombus*	*sp.*	Not determined	0.7
July	*Bombus*	*sandersoni*	Sanderson Bumblebee	0.4
July	*Bombus*	*frigidus*	Frigid Bumblebee	0.4
July	*Bombus*	*fervidus*	Yellow Bumblebee	0.4
August	*Bombus*	*impatiens*	Common Eastern Bumblebee	78.3
August	*Bombus*	*ternarius*	Tri-colored Bumblebee	11.7
August	*Bombus*	*vagans*	Half-black Bumblebee	3.9
August	*Bombus*	*terricola*	Yellow-banded Bumblebee	1.7
August	*Bombus*	*borealis*	Northern Amber Bumblebee	1.4
August	*Bombus*	*bimaculatus*	Two-spotted Bumblebee	1.1
August	*Bombus*	*fervidus*	Yellow Bumblebee	0.8
August	*Bombus*	*sp.*	Not determined	0.5
August	*Bombus*	*griseocolis*	Brown-belted Bumblebee	0.3
August	*Bombus*	*rufocinctus*	Red-belted Bumblebee	0.3

[1] Based upon percent relative abundance of each species and undetermined species during each sampling period.
[2] Sample dates within each month were, sample date 1 in June: 30 May – 7 June; sample date 2 in July: 6 July – 17 July, and sample date 3 in August: 17 August – 24 August.
[3] Not determined because of poor condition or photo that was not definitive.

Comparison of the diversity of bumblebees in our sampling in 2017 with historic records of bumblebees in Maine is shown in Figure 10. It can be seen that most of the bumblebee relative abundances for the species we recorded are similar to historic records. However, the Common Eastern bumblebee was much greater abundance in our records compared to historic records and the Yellow-banded bumblebee was in much greater abundance in historical records than what we observed. The Red-belted and Yellow bumblebees were also in greater abundance historically than in 2017. Comparing our data to more recent statewide collections in 2015 and 2016 (Fig. 10) we found that we observed greater abundance of the Common Eastern bumble bee, but less abundance of the Tricolor and Half-black bumblebees. The Diversity of bumblebees in 2017 across the five regions suggested that diversity varied significantly (Fig. 10). Table 3 lists species richness, Shannon's diversity index, and evenness (1-D) for the 2017 roadside habitats by region. Bumblebee species richness, diversity, and evenness tended to be greater along the state roads

(Western mountains and Aroostook lowlands) compared to the federal highways (95 and 295).

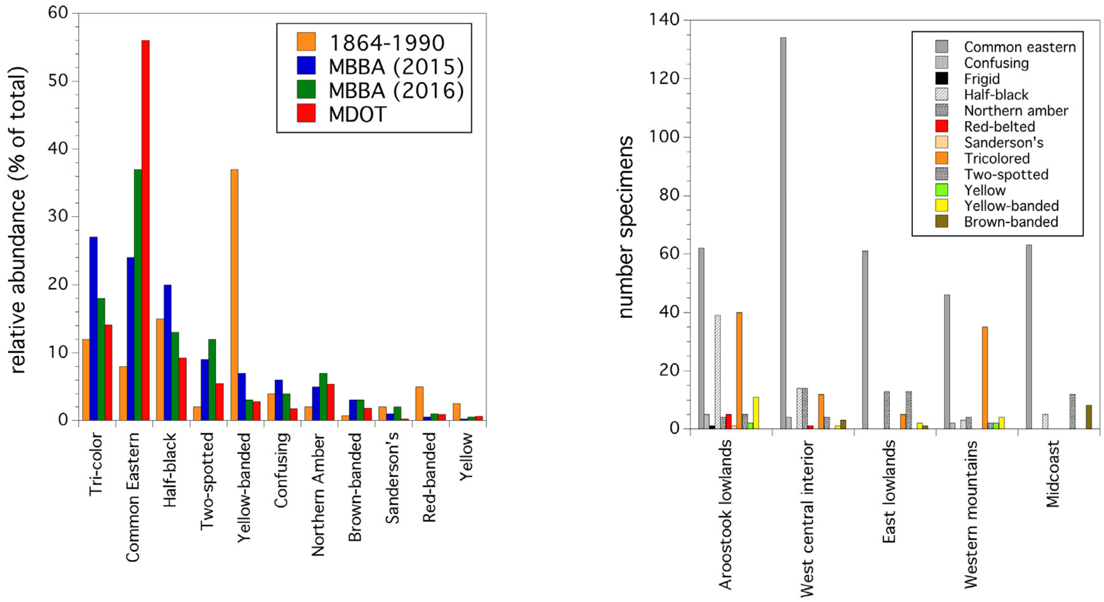

Figure 10. Comparison of bumblebee relative abundance in Maine 2017 along roadsides compared to historical abundance (1864-1990) and more recent surveys conducted statewide in 2015 and 2016 (left graph). Bumblebees recorded by region (right graph).

Table 3. Diversity measures for bumblebees surveyed along Maine roadsides in 2017.

Region	Species Richness	Shannon's Diversity	Evenness
Aroostook lowlands	11	1.715	0.765
West central interior	9	1.024	0.469
East lowlands	6	1.065	0.546
Western Mountains	8	1.329	0.646
Midcoast	4	0.674	0.457
All regions	12	1.482	0.639

Butterfly diversity was higher than bumblebee diversity along roadsides in 2017. Maine has at least 118 native butterflies (Maine butterfly survey, http://mbs.umf.maine.edu). We recorded 28 genera and 31 species. Table 4 lists the relative abundance of species during the three sampling periods. More species were observed in the early summer than during the other two sampling periods. Monarch butterflies, are under consideration for a federal endangered species listing, and were collected in very low abundance, although several individuals were observed but not collected. Two exotic species were representative of the butterfly community along roadsides, the Cabbage white and the European skipper. Dominance was also a characteristic of the butterfly community. Figure 11 suggests that when the ten most abundant species are considered, three species comprise 90% of the relative abundance. When the 2017 roadside relative abundance of just the top ten most abundant butterfly species is compared to Maine Department of Inland Fisheries and Wildlife data (MDIFW) from across Maine, some differences can be seen (Fig. 11). Common ringlet and European skipper abundances are much higher in the 2017 roadside survey,

Table 4. Relative abundances[1] of butterfly species along roadsides in Maine, 2017.

Sample Date[2]	Genus	species	Common name	Relative[1] Abundance (%
June	*Glaucopsyche*	*lygdamus*	Silvery Blue	49.7
June	*Coenonympha*	*tullia*	Common Ringlet	25.2
June	*Papilio*	*canadensis*	Eastern Tiger Swallowtail	7.3
June	*Phyciodes*	*cocyta*	Northern Crescent	5.3
June	*na*	*na*	Not determined[3]	3.1
June	*Thorybes*	*pylades*	Northern Cloudywing	2.0
June	*Pieris*	*rapae*	Cabbage White**	2.0
June	*Carterocephalus*	*palaemon*	Arctic Skipper	2.0
June	*Celastrina*	*ladon*	Spring Azure	2.0
June	*Chlosyne*	*nycteis*	Silvery Checkerspot	0.7
June	*Vanessa*	*virginiensis*	American Lady	0.7
July	*Thymelicus*	*lineola*	European Skipper**	79.4
July	*Satyrodes*	*eurydice*	Eyed Brown	3.5
July	*Polites*	*mystic*	Long Dash	2.8
July	*Polites*	*peckius*	Peck's Skipper	2.5
July	*Coenonympha*	*tullia*	Common Ringlet	2.1
July	*Euphyes*	*vestris*	Dun Skipper	2.1
July	*Colias*	*philodice*	Clouded Sulphur	1.4
July	*Phyciodes*	*cocyta*	Northern Crescent	1.0
July	*Vanessa*	*virginiensis*	American Lady	0.7
July	*Ancyloxypha*	*numitor*	Least Skipper	0.7
July	*Anatrytone*	*logan*	Delaware Skipper*	0.4
July	*Erynnis*	*icelus*	Dreamy Duskywing	0.4
July	*Cupido*	*comyntas*	Eastern Tailed-blue	0.4
July	*Speyeria*	*cybele*	Great Spangled Fritllary	0.4
July	*Poanes*	*hobomok*	Hobomok Skipper	0.4
July	*Limenitis*	*artgenus*	Red-spotted Purple	0.3
July	*Boloria*	*selene*	Silver-bordered Fritillary	0.3
July	*Epargyreus*	*clarus*	Silver-spotted Skipper	0.3
July	*Glaucopsyche*	*lygdamus*	Silvery Blue	0.3
July	*Celastrina*	*ladon*	Spring Azure	0.3
July	*na*	*na*	Not determined	0.3
August	*Coenonympha*	*tullia*	Common Ringlet	83.9
August	*Cupido*	*comyntas*	Eastern Tailed-blue	3.4
August	*Thorybes*	*pylades*	Northern Cloudywing	3.1
August	*Phyciodes*	*tharos*	Pearl Crescent*	1.8
August	*Pieris*	*rapae*	Cabbage White**	1.3
August	*Cercyonis*	*pegala*	Common Wood-nymph	1.3
August	*Colias*	*philodice*	Clouded Sulphur	1.0
August	*Boloria*	*selena*	Silver-bordered Frtitillary	0.9
August	*Phyciodes*	*cocyta*	Northern Crescent	0.8
August	*Danus*	*plexippus*	Monarch	0.5
August	*Colias*	*eurytheme*	Orange Sulphur	0.5
August	*Lycaena*	*phlaeas*	American Copper	0.3
August	*Thymelicus*	*lineola*	European Skipper**	0.3
August	*Speyeria*	*cybele*	Great Spangled Fritllary	0.3
August	*Limenitis*	*artgenus*	Red-spotted Purple	0.3
August	*Boloria*	*bellona*	Meadow Fritillary	0.3

[1] Based upon percent relative abundance of each species during each sampling period.

[2] Sample dates within each month were, sample date 1 in June: 30 May – 7 June; sample date 2 in July: 6 July – 17 July, and sample date 3 in August: 17 August – 24 August.
[3] Not determined due to poor quality specimen.
* Considered rare and of conservation status (Webster, R. and P.G. deMaynadier. 2005. A Baseline Atlas and Conservation Assessment of the Butterflies of Maine. 127 pp.).
** Exotic species.

but Northern crescent, Eastern tailed-blue, Cabbage white and Clouded sulphur abundances are lower in the 2017 survey.

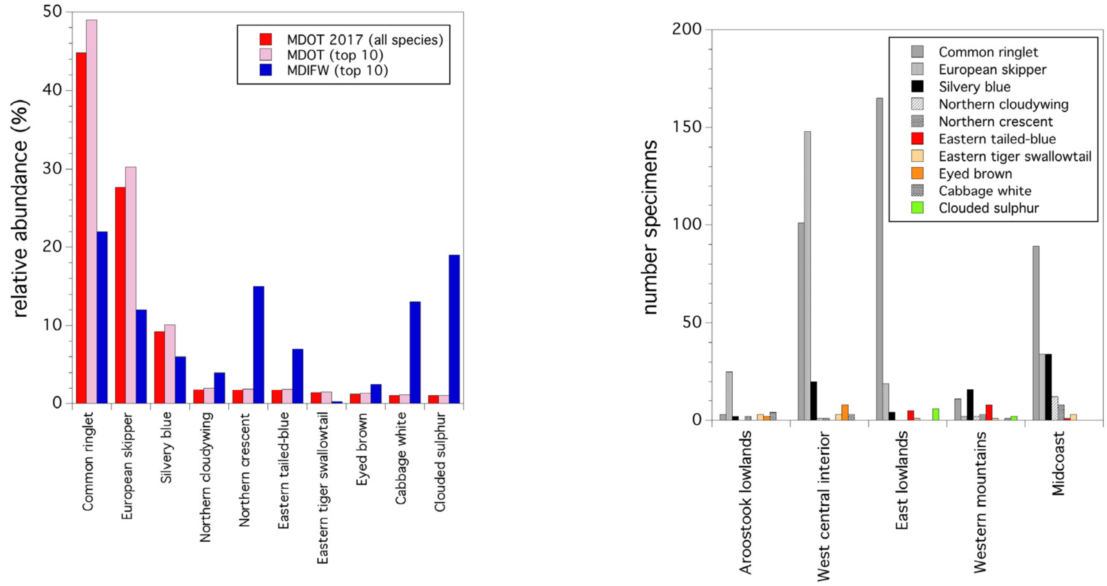

Figure 11. Comparison of 2017 roadside sampled butterfly relative abundance for the top ten most abundant species and Maine Department of Inland Fisheries and Wildlife data (MDIFW) for the same species (Left graph). Top ten most abundant butterflies by region (Right graph).

Table 5 illustrates measures of diversity for the entire community and within each sampled geographic region. It can be seen with butterfly diversity (Table 5), that similar to bumblebee diversity, the regions where state roads were sampled (Western mountains and Aroostook lowlands) had higher species richness, diversity, and evenness compared to sites along federal highways (95 and 295). However, Figure 11 shows that when only the ten most abundant butterflies are considered, the Aroostook lowlands and the Western mountain regions tend to have the lowest overall abundance due to the low captures of the Common ringlet and European skipper.

Table 5. Diversity measures for butterflies surveyed along Maine roadsides in 2017.

Region	Species Richness	Shannon's Diversity	Evenness
Aroostook lowlands	12	1.925	0.749
West central interior	16	1.356	0.635
East lowlands	9	0.822	0.348
Western Mountains	21	2.528	0.876
Midcoast	14	1.688	0.729
All regions	31	1.774	0.708

A total of 653 bumblebees and 824 butterflies were recorded along the roadside habitat. Highways might be considered “cafeterias” for pollinators, but also killing zones for pollinators. Our survey showed that only 0.97% of butterflies observed were found dead along the side of roads, but 13.0% of bumblebees observed were found dead along the side of the road. We are not confident that these statistics accurately represent death rates due to vehicle collisions and whether there is a bias towards finding heavier dead bumblebees along the sides of roads compared to lighter dead butterflies that might be more apt to be moved off site by wind generated by speeding traffic. However, this data does provide justification for a follow-up study on the toll that traffic might exert on pollinator populations that recruit to flowering plants along roadsides. But this being said, we did not find greater numbers of dead bees associated with federal interstate highways compared to state roads. The two lowest collections of dead bees were in the east lowlands along route 95 (0%) and the Midcoast region along route 295 (1%).

Bumblebees were almost exclusively collected on flowers while they were foraging, only 0.6% were collected in flight. Figure 12 shows the dominant flowering plants bumblebees were collected on during the three sampling periods. A total of 46 flowering plant species were observed where bumblebees were collected. It can be seen that in the spring bumblebees concentrated on invasive honeysuckle, apple, and vetch. During the early summer bumblebees concentrated upon crown and cow vetch, and during the mid-late summer they concentrated on goldenrods, and crown vetch. We compared the host plants of the Yellow-banded bumblebee, which is being considered for listing as an endangered species. Unfortunately, of the 18 individuals recorded, 7 (38.9%) were found dead on the roadside and one was captured in flight. The remaining 10 were captured on goldenrod (3), vetch, crown and cow (3), red clover (1), spreading dogbane (1), St. John’s wort (1), and tansy (1). The sample size was too small to determine if Yellow-banded bumblebees forage on a distinct community of flowering plants compared to the rest of the bumblebee community. This is not surprising since bumblebees are considered generalist foragers that while having preferences also visit a wide range of taxa for pollen and nectar.

Host plants were ranked as native, exotic, or unknown. The unknown classification primarily refers to the grasses that constitute a mixture of native and exotic species. Over all three sampling periods, bumblebees were collected significantly more on exotic plant species (59.7%) compared to native plant species (40.3%) ($X^2_{(9)}$ = 64.958, P = 0.0001). The seasonal collection of bumblebees on exotic vs native plants was: spring, 92.6% exotic; early summer, 93.5% exotic, and mid-late summer, 38.7% exotic plants compared to native plant collections.

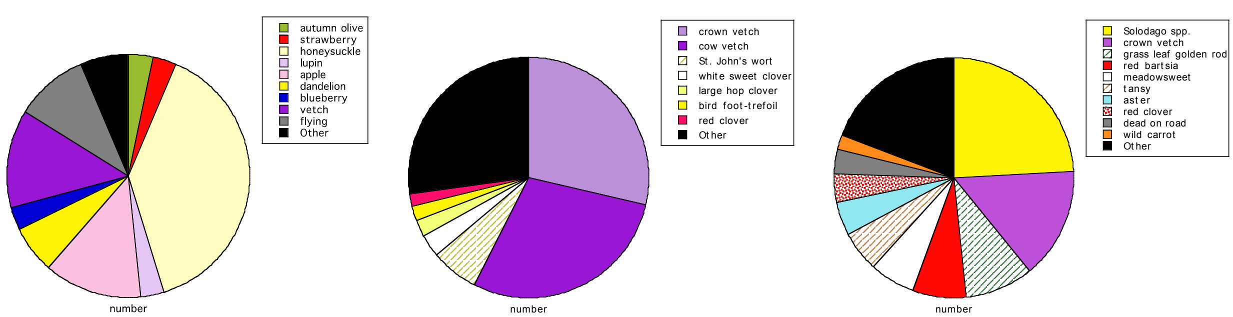

Figure 12. Bumble bee capture locations for round 1 (left), round 2 (middle) and round 3 (right).

Butterflies were often captured in flight (43.1%) or non-nectar plant sources (20.1%, oviposition and resting sites; mostly grasses). Capturing butterflies in flight occurred mostly in the spring (Fig. 13). Figure 13 also shows that the grasses dominate the summer collections of butterflies and a much smaller percent of butterflies were flushed while sampling and caught while flying in the summer. We did not identify grass species, except for Timothy grass and so we were not able to classify their origin. Butterflies were collected upon significantly more exotic flowering plants (81.1%) compared to native flowering plants (18.9%; $X^2_{(9)}$ = 46.371, P < 0.0001).
The seasonal collection of butterflies on exotic vs native plants was: spring, 44.0% exotic; early summer, 95.7% exotic, and mid-late summer, 41.7% exotic plants compared to native plant collections.

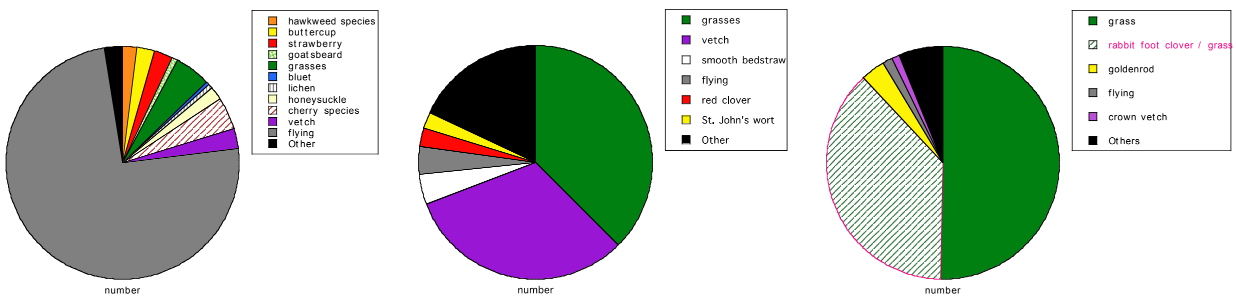

Figure 13. Butterfly capture locations for round 1 (left), round2 (middle), and round 3 (right).

Figure 13 shows that in the spring butterflies utilized a large number of flowering species in the spring such as strawberry, hawkweeds, buttercups, bluet, invasive honeysuckle, and cherry species. However, they also were collected in grasses and lichens. Early summer nectaring palnts were vetches (crown and cow) smooth bedstraw, St. John's wort, and red clover. Mid-late summer forage plants were rabbit foot clover mixed with grasses, goldenrods, and crown vetch. Grasses provided the most common capture sites in late summer.

Statistical models incorporating sample period (rounds 1 -3) were used to determine if bumblebee, butterfly abundance, or total pollinators collected (square root transformed) were related to ranked flowering plant percent landcover, and flowering plant species richness. Generic plant richness was not modeled because generic richness and species richness are highly correlated (see Fig. 9). Flowering plant percent landcover cover across sites did not explain a significant amount of the variation in bumblebee (P = 0.664) or butterfly (P = 0.129) abundance, when considered separately. However, when these taxa were pooled and total pollinator captures was modeled (bumble bees + butterflies), flowering plant percent landcover did not show any relationship with total pollinator density (P > 0.05). A significant positive relationship was observed with flowering plant species richness, sampling period, and the sampling period X flowering plant species richness interaction ($F_{(5,24)}$ = 6.092, P = 0.0009). These findings suggest that management practices that increase flowering plant richness may lead to an increase in total pollinators. Flowering plant species richness was the only significant predictor (P = 0.042, Fig. 14). This relationship with flowering plant species richness showed no interaction with sample round or seasonal phenology (P = 0.299), suggesting that for all sample periods, as flowering plant species richness increased among sites, total pollinator numbers increased. *The variation in total pollinator abundance explained by flowering plant species richness was 55.9 %, suggesting that flowering plant richness is a major determinant of pollinator abundance along roadsides.*

SUMMARY. Less frequently mowed roadside vegetation has resulted in diverse floral communities. Two hundred and thirty-five plant taxa (230 species and 5 species complexes) were recorded in bloom. Flowering plant species richness was high and communities along roadsides were represented by high evenness. Higher flowering plant species richness was associated with two regions, the Western Mountains and the Aroostook lowlands. About one third of the flowering plant species richness was comprised of exotic species in the spring and mid-late summer, and two-thirds of the flowering plant community was comprised of exotic species in the early summer. Average flowering plant patch size decreases with increasing flowering plant richness, but total plant patch size of all species increases.

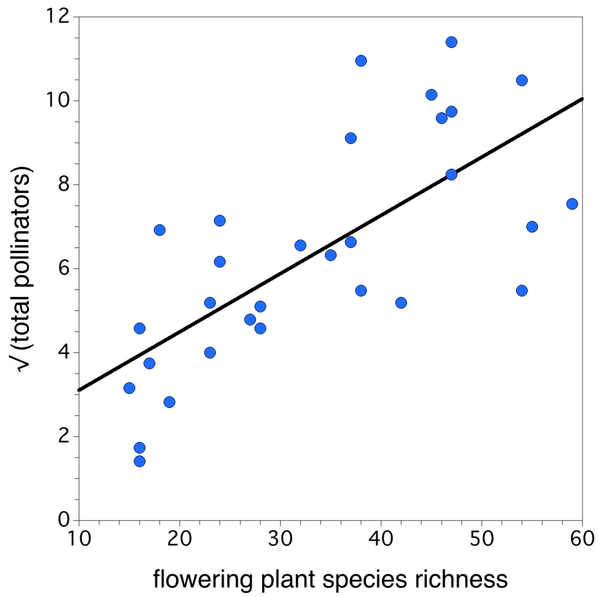

Figure 14. Relationship between flowering plant species richness vs total pollinators (each data point represents a site during a particular sampling period).

Bumblebees were represented by 12 species, but three species, the Common Eastern bumblebee, the Tricolor bumblebee and the Half-black bumblebee, constituted most of the abundance. Bumblebee species richness, diversity, and evenness tended to be greater along the state roads (Western mountains and Aroostook lowlands) compared to the federal highways (95 and 295).

Butterfly diversity was higher than bumblebee diversity along roadsides in 2017. The diversity observed comprised 28 genera and 31 species. More species were observed in the early summer than during the other two sampling periods. Two exotic species were representative of the butterfly community along roadsides, the Cabbage white and the European skipper. Dominance was also a characteristic of the butterfly community. Three species comprise 90% of the relative abundance. Bumblebees were collected on 46 flowering plant species. Over all three sampling periods, bumblebees were collected significantly more on exotic plant species compared to native plant species. Butterflies were often captured in flight or non-nectar plant sources and resting sites; mostly grasses. Capturing butterflies in flight occurred mostly in the spring and grasses dominate the summer collections of butterflies. Butterflies were collected upon significantly more on exotic flowering plants compared to native flowering plants.

A significant positive relationship was observed with flowering plant species richness, sampling period, and the sampling period X flowering plant species richness interaction. This finding suggests that management practices that increase flowering plant richness may lead to an increase in total pollinators. This relationship with flowering plant species richness demonstrates that as flowering plant species richness increased among sites, total pollinator numbers increased. The variation in total pollinator abundance explained by plant species richness was 55.9 %, suggesting that flowering plant richness is a major determinant of pollinator abundance along roadsides.

CONCLUSIONS. Less intensive management of roadside vegetation will promote flowering plant species diversity, patch size, and % landcover in flowering species. This in turn should enhance total pollinator numbers along roadsides. Therefore, reduced management should increase valuable ecosystem resources leading to better pollination of wild flowers and agricultural crops.

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