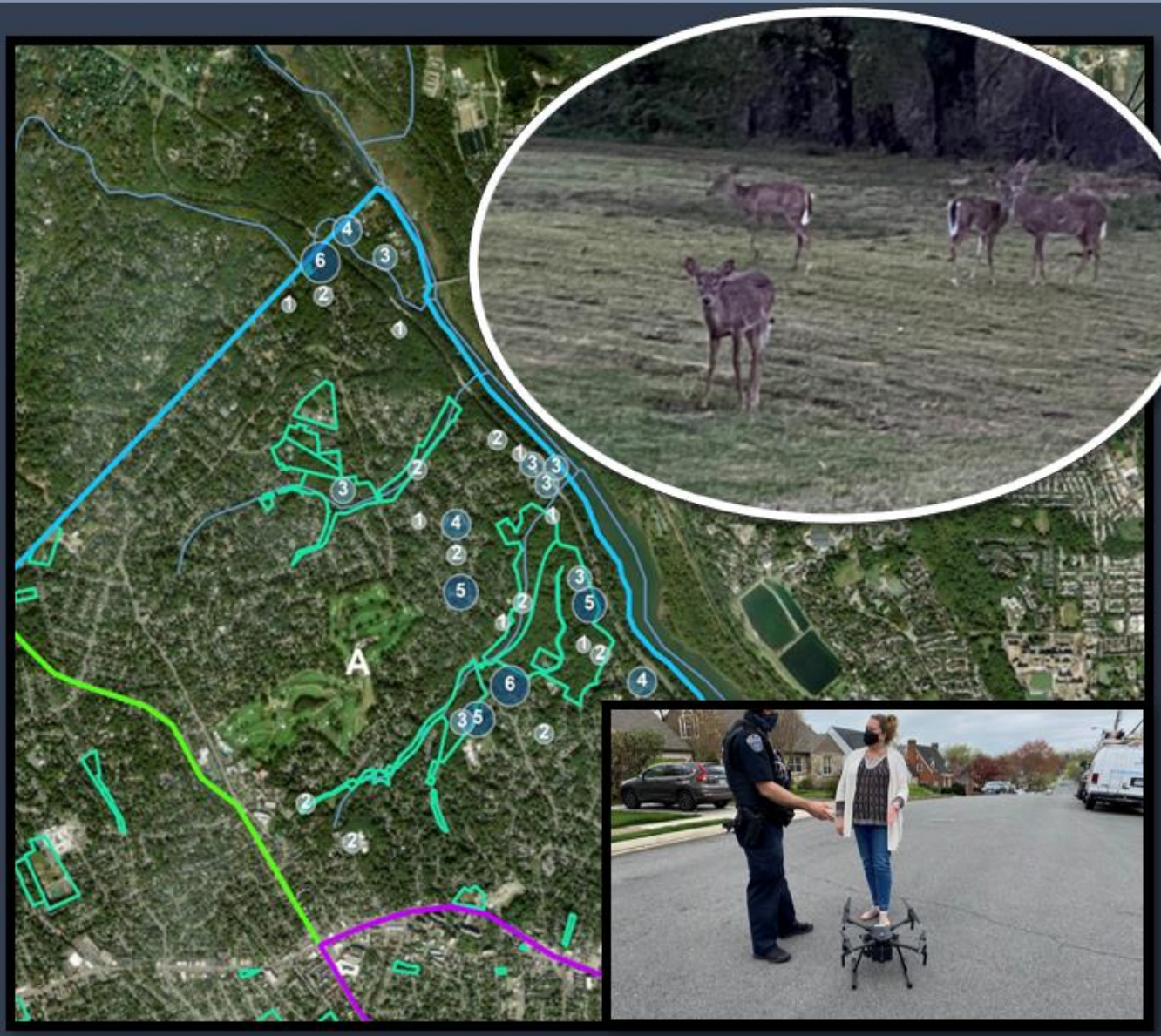
White-Tailed Deer (*Odocoileus virginianus*) Population Density Survey using sUAS Infrared:

Arlington County, Virginia- Spring *2021*



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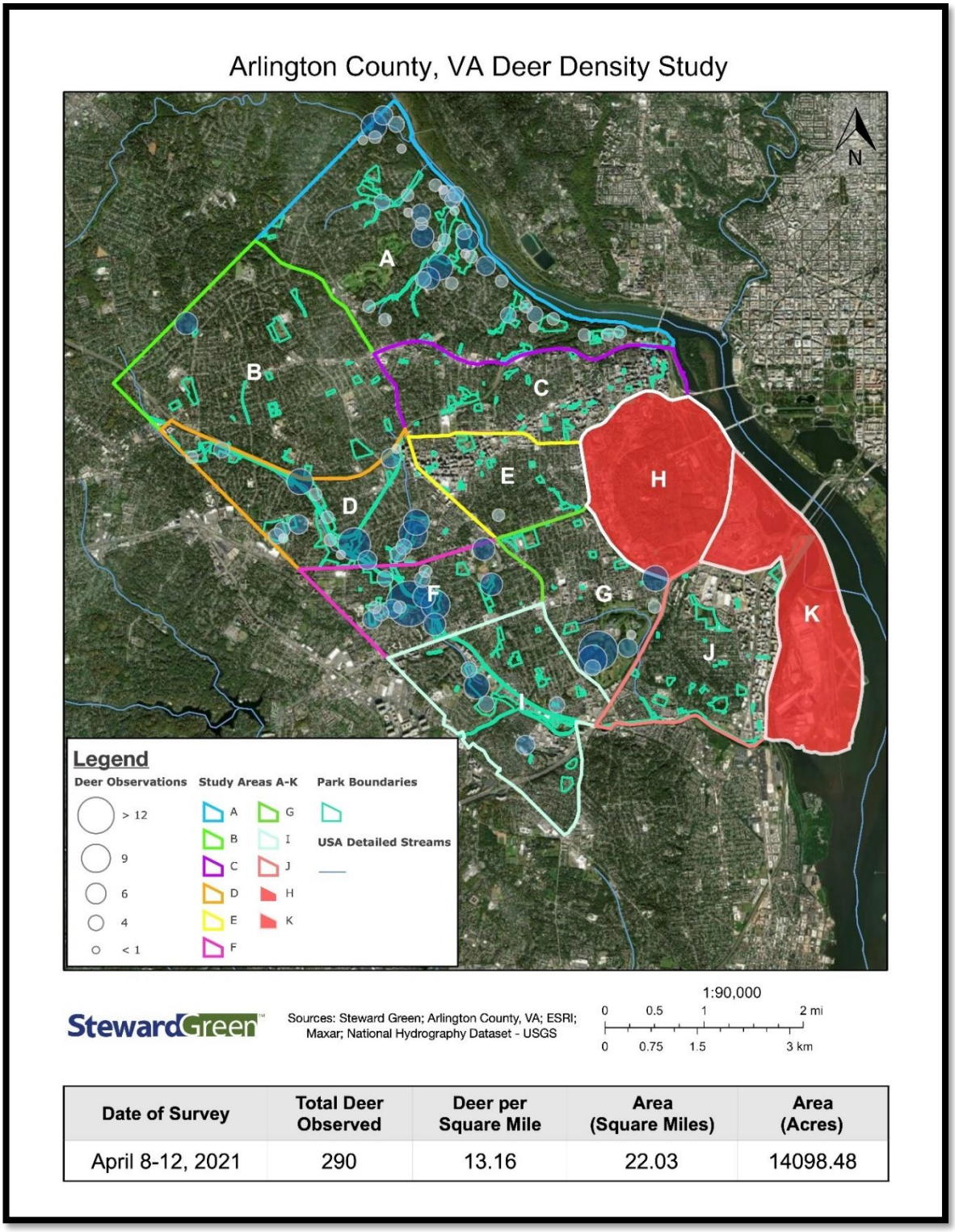
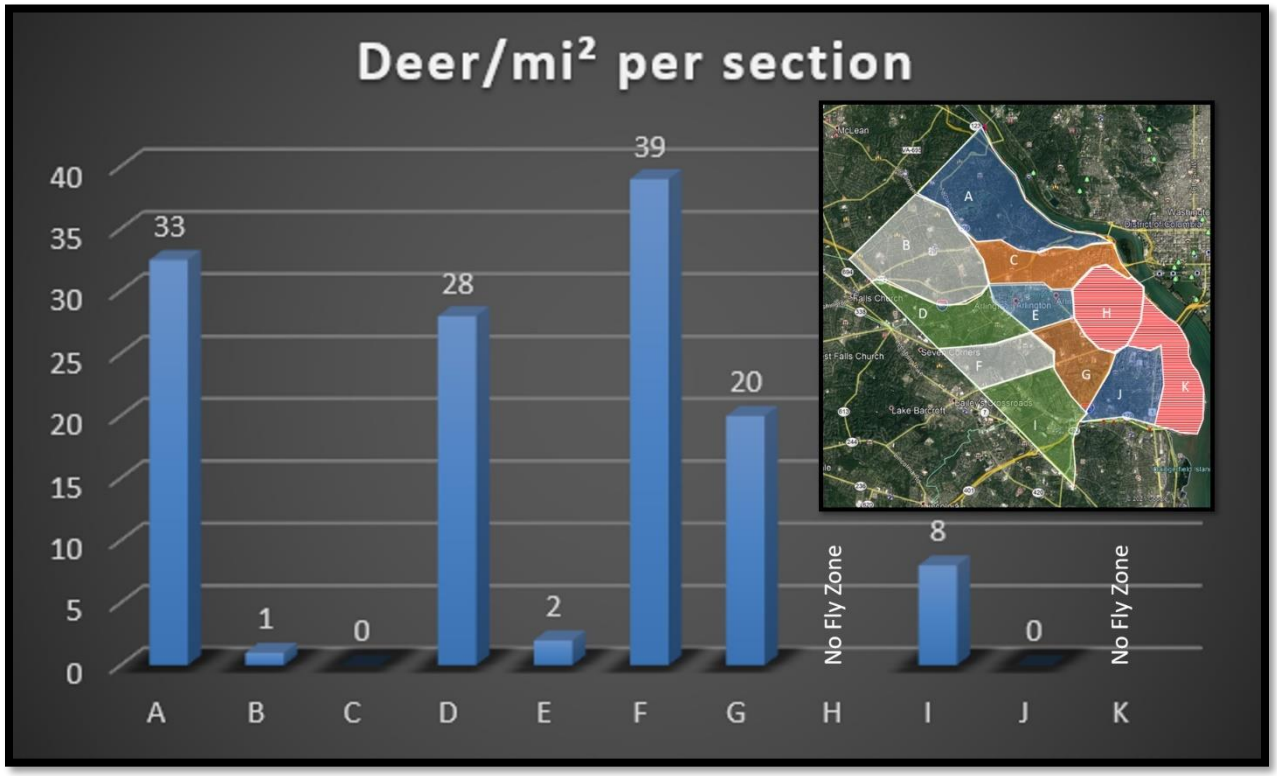
Executive Summary

Steward Green LLC (SG) is providing Arlington County Department of Parks and Recreation with deer population density estimates within the entire county, where allowed, using UAS (unmanned aerial system), or “drone”.



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	290	13.16	22.03	14098.48

Areas were manually flown systematically, identifying and mapping deer that were counted through the process, providing the Pilot-in-Command (PIC) with enough control to maneuver around visual obstacles. The infrared heat signatures collected produced a reliable method of counting the deer in analysis by an experienced, skilled technician. Arlington County was divided into 11 areas by main roads and highways, totaling approximately 14,098 acres flown (about 22 square miles). This area consisted of a mix of urban, suburban, and industrial landscapes fragmented by woodland parcels, parks, streams, and minor open water, with the Potomac River adjacent to the northeast.



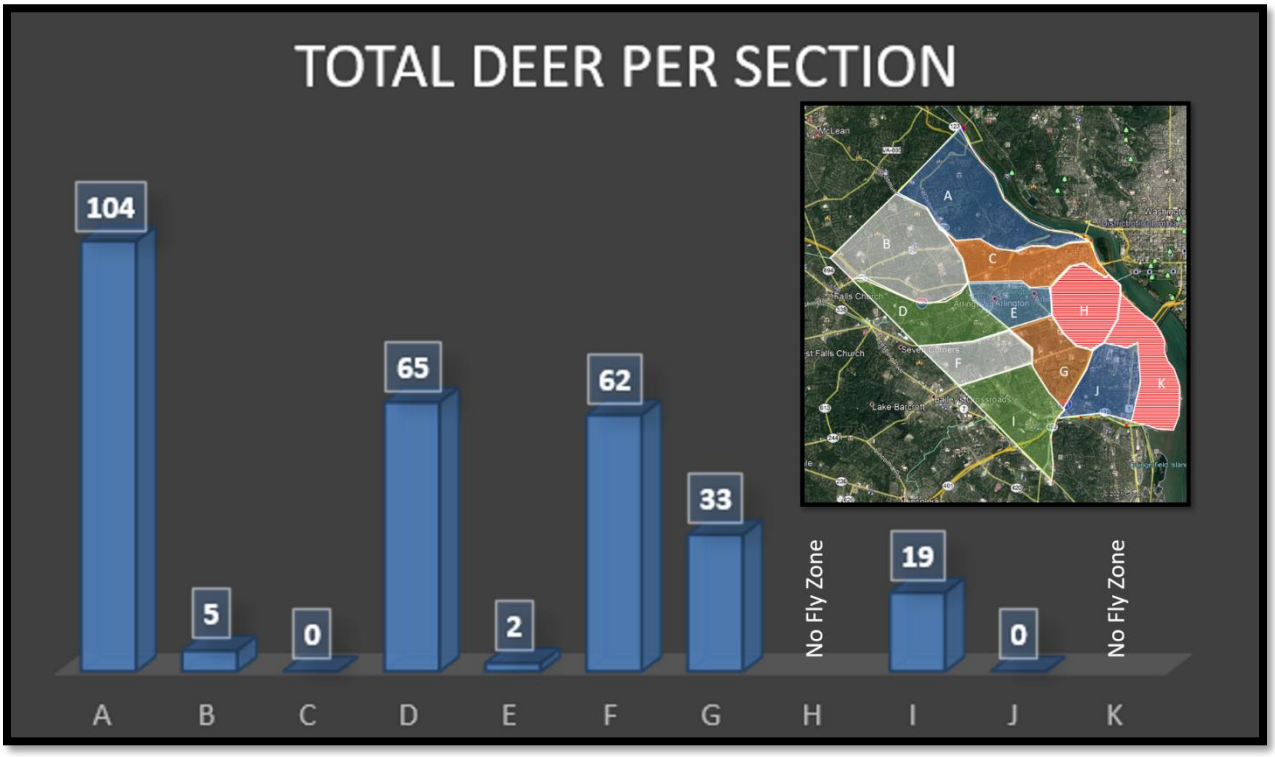
We confirmed 290 deer for the entire combined areas flown, for an averaged 13 deer per square mile. Taking a closer look at the section data, we see expected higher deer counts in sections that have more forested areas or stream corridors, with densities that begin to be concerning with 20, 28, 33 and 39 deer per square mile in Sections G, D, A and F respectively. Add in the challenges of daytime data collection and those numbers are likely higher. Thermal imagery was analyzed both in the field and then more thoroughly in the lab to determine accurate heat signatures of minimum, or confirmed, deer counts. The number counted as confirmed is based on a few factors. As with any infrared data collection, there can be areas that are unseen, such as underneath *evergreen trees*, or other obstacles, where deer can be present yet not seen as a heat signature.

Limiting factors to this study included daytime data collection constraints, obtaining permissions for flying in this area and real-time conflicting low flying helicopters and airplanes. Daytime data collection provided thermal competition that disallowed us to confirm deer because the images were not as clear and contrasted from how they are typically seen when performed at night. Activity during the day also had a competing role. As a result, there were possible deer observed in the data collection that were not counted in the minimum deer analysis. If data is collected in the future, we strongly recommend

obtaining nighttime clearance. This information was then used to create geographic location maps with points of interest (the heat signatures of deer), mission and data information.

Healthy deer density is considered to be 5-15 deer per square mile by many wildlife biologists, ecologists, and environmental professionals. *Forest ecology* suffers tremendously from deer *over-browsing*. Impacts to the *forest understory* start becoming *deleterious* when population densities surpass 20 deer per square mile, impeding upon *forest regeneration* (Drake et al. 2002). All the areas surveyed in this study have a deer density that is likely beyond the threshold of *carrying capacity*, have intensified invasive *flora*, have depleted habitat for (tick eating) ground nesting birds (oven birds, etc.) (Alverson et al. 1988), and have possible starvation/disease for the deer (McCullough 1979, McShea et al. 1997).

Moving forward, we recommend more aggressive deer management in Sections A, D, F and G. We advise that Arlington County Parks and Recreation keep a steady watch on the other sections' white-tailed deer populations as Arlington County is in a unique position in the Northeastern US to maintain biodiverse habitats and reduced problems a denser herd can incur. This can be achieved by continued data collection and monitoring, a quality deer management program, and most importantly, through public education of ecosystem services and wildlife management.



Please Note: Italicized words and phrases throughout this report are defined in the glossary starting on page 36.

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2021 White-Tailed Deer (Odocoileus virginianus) Population Density Survey using sUAS Infrared: Arlington County, Virginia

Overabundance Issues: An Overview

White-tailed deer provide many positive benefits including wildlife viewing, photography, and recreational hunting that contribute hundreds of millions of dollars in economic benefits annually (Drake et al. 2005). They are commonly found on the edge of habitats, or *ecotones*, where forested areas meet a variety of public and private lands including agricultural areas, suburban neighborhoods, public parks, golf courses, and corporate landscapes. These fragmented landscapes can serve as wildlife refuges. However, high deer densities within these fragments can lead to intolerable levels of damage to native ecosystems, crops, commercial and residential landscaping, as well as increased safety concerns from deer-vehicle collisions and tickborne illnesses. The economic impacts from unwanted deer-human interactions in Virginia, including damage to vehicles, agricultural crops, and commercial and residential landscaping are significant. Property damages due to vehicular collisions with deer have been estimated to exceed $200 million annually based on a conservative average cost per claim at $3,300 (VDGIF, 2015). Additionally, damage by white-tailed deer has been estimated at approximately $2 billion in the United States annually (Boulander et al. 2014). Although management objectives for deer in suburban areas are commonly less than 20 deer per square mile, to reduce threats from extensive deer browse to biodiversity densities may need to be less than 10 deer per square mile. Further, situations are site-specific, meaning density estimate recommendations do not translate to all areas and that managers should recognize the importance of reducing negative impacts from higher deer density and not just an arbitrary reduction in deer numbers (Boulander et al. 2014). An additional consideration for deer management is that adult does can produce two and sometimes three fawns per year under ideal conditions (Boulander et al. 2014).

Figure 2. Deer abundance observed. Photo credit: Chuck Gallagher

Figure 1. Deer eating landscape plants. Photo credit: Mark Grinbaum

Forest Ecology

Forest ecology suffers tremendously from deer *over-browsing*. Impacts to the *forest understory* start becoming harmful when population densities surpass 20 deer per square mile, impeding forest regeneration (Drake et al. 2002). Nearly all of the US Piedmont Plain's forests from Georgia to Maine are over-browsed and, in many areas, over-browsing is severe (Baiser et al 2008). Kelly (2019) noted impacts of concern to forest managers in northern New Jersey from increased densities of white-tailed deer including declines in seedlings, saplings, trees, herbs, and shrubs as well as a shift from mostly native to exotic species. In other areas, deer densities of less than 15 deer per square mile have been recommended to reduce negative impacts from deer browsing on woody and herbaceous plants (Waller and Alverson 1997). At densities greater than 100 deer per square mile, woodlands are void of understory from constant deer pressure through *herbivory*. Without proper understory, new seedlings never become mature trees. Thus, the forest is lost through *attrition* and the overall structure and composition of vegetation changes as non-native and invasive plant species invade the area. Deer change the landscape by eating native plants and leaving the less desirable invasive species. They introduce invasive flora, such as Japanese stilt grass and wavy leaf basket grass. Other impacts from deer include *erosion* and *sedimentation* because they eat deep-rooted native plants that hold soils in place (Alverson et al. 1988, Cote et al. 2004, Horsely et al. 2003).

Figure 3. Landscape plants eaten by deer. Photo credit: Gene Huntington

Without *biodiversity* in the woodlands, other species suffer as well as direct and indirect results of deer overabundance (Alverson et al. 1988). *Insectivorous* birds, that also eat ticks, nesting on or near the ground such as Ovenbirds (*Seiurus aurocapilla)* and other *neo-tropical migratory birds* do not have habitat, which can contribute to population declines. When understory habitat is disappearing, biodiversity decreases across the board, negatively affecting other species of flora and *fauna* (Horsley et al. 2003). For instance, insects and pollinators lose food sources and host plants. When more of the understory is eaten, root systems that hold soil in place are lessened causing erosion and sedimentation to increase. Failure to acknowledge such ecological interactions and allowing such dense populations of deer work directly against the preservation of natural diversity (Alverson et al. 1988). Native planting, reforestation, and other conservation programs are exceedingly difficult to implement with high deer densities.

Vehicular Accidents

Figure 4. Many vehicle collisions due to deer do not get reported Photo credit: Joseph Paulin

The number of claims in Virginia is high, despite that many minor accidents do not even get reported. According to an annual report on animal collisions based on insurance claims to StateFarm, the odds of hitting an animal for a VA driver in 2020-2021 are 1 in 72. This ranks Virginia as 12th in the country for level of risk to animal collisions. Nearby West Virginia has maintained its status as the state of highest risk for the 15th consecutive year (State Farm, 2021). Animal collisions in this report may also involve accidents with cats, dogs, large rodents, farm animals, and other large wild animals. However, 67% of nearly 2 million animal collisions reported between July 1, 2019 and June 30, 2020 were due solely to deer (Belt, 2020). From October to December of 2019, the Department of Motor Vehicles (DMV) states 3,477 reported deer-vehicle collisions in Virginia in just a 3 month span, yielding an 11% increase in incidents and a 16% increase in injuries (Inside Nova, 2020). Over the entire year of 2019, deer-related crashes resulted in 566 injuries and 1 fatality statewide from DMV data (Inside Nova, 2020). Aside from safety concerns, deer collisions can be quite costly; the American Automobile Association (AAA) reported the average insurance claim for deer collisions in 2018 was approximately $4,000 in VA (Inside Nova, 2020).

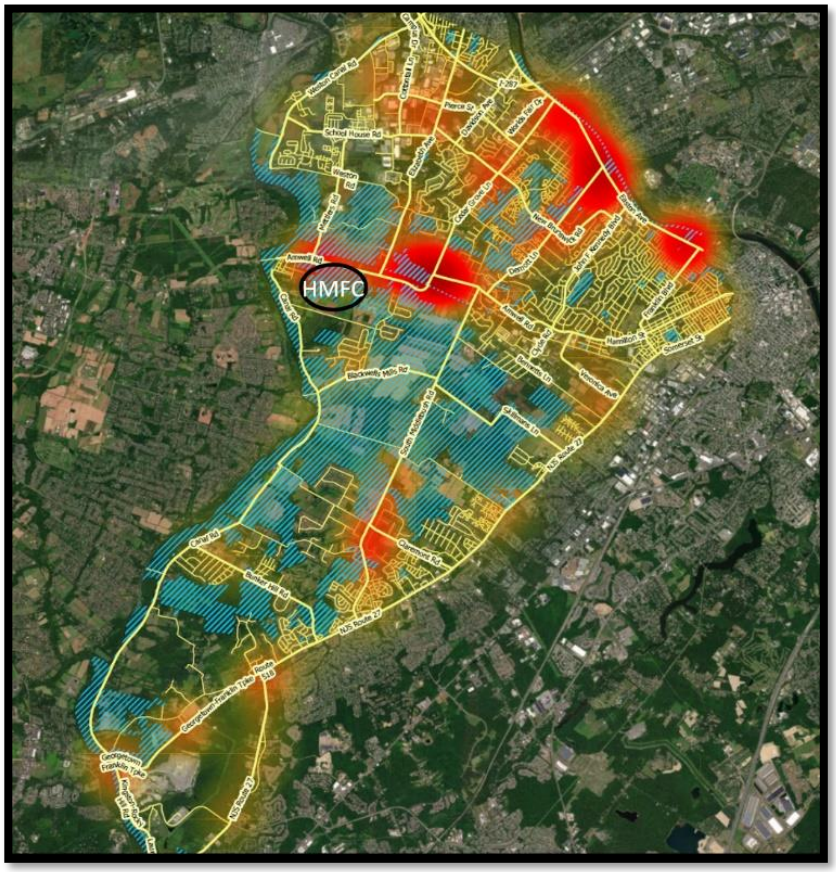


Figure 5. Example of a vehicle collision due to deer map in NJ. Credit: Rutgers Landscape Architecture Geodesign Studio

It is important to note that these data are based on reported incidents, meaning there could be many more occurrences of deer collisions not reported. These data may also not reflect accidents in which the driver did not actually collide with deer due to swerving the vehicle, but may have hit something else like a tree, telephone pole, or another vehicle. Additionally, the number of deer struck by vehicles but not retrieved is unknown.

Figure 6. When deer densities are high, deer health can suffer. Photo credit: Gene Huntington

Disease

Tickborne illnesses, such as Lyme disease, Rocky Mountain spotted fever, and ehrlichiosis have tripled in Virginia over the last two decades (Lucas, 2019). In fact, over the year period from June 2020 to June 2021, there were 10,000+ reported cases of tick bites in the United States, 5% of which were in the state of Virginia. Half of all positive Symptoms for these illnesses can range from mild to life-threatening and may leave long-term effects. Ticks use deer to feed, mate, reproduce, and disperse (Cote et al. 2004, Kent 2018). With large populations of deer and dwindling habitat for insectivorous ground nesting birds, such conditions have allowed ticks to thrive, the recent Lyme disease epidemic. Lonestar ticks (Amblyomma americanum) are most prevalent in Arlington according to Arlington's Natural Resources Manager, Alonso Abugattas Jr, stating that related diseases to humans include Southern Tick Associated Rash Illness (STARI), Tularemia (Deer fly fever), Ehrlichiosis, Alpha-gal syndrome (Red meat allergy). Other ticks, including Dog, Wood and Black legged ticks, while less prevalent, can cause diseases such as Lyme disease and Rocky Mountain spotted fever.

Deer also contract diseases more easily when density is high and foraging becomes challenging. Diseases include *epizootic hemorrhagic disease* (EHD), *chronic wasting disease* (CWD), blue tongue (BTV), deer warts and parasitic worms. Deer have also been noted to starve in over densified conditions (citations).

Methodology

Objective: Provide Arlington County Department of Parks and Recreation with an estimate of the white-tailed deer *population density* for the entire county, where allowed, using UAS.

Study Area: The county was divided into (11) areas by main roads and highways, totaling approximately 14,098 acres (about 22 square miles). These areas consisted of a mix of urban, suburban, and industrial landscapes, fragmented by woodland parcels, parks, streams, and minor open water, with the Potomac River adjacent to the northeast. Throughout the county there is also much suburbia, infrastructure such as utility lines, ROW's, major roads, housing, and mixed-use development.

Figure 7. Steward Green Geospatial Analyst Ellie Huntington is keeping her eye on the UAV. Photo credit: Toni Genberg

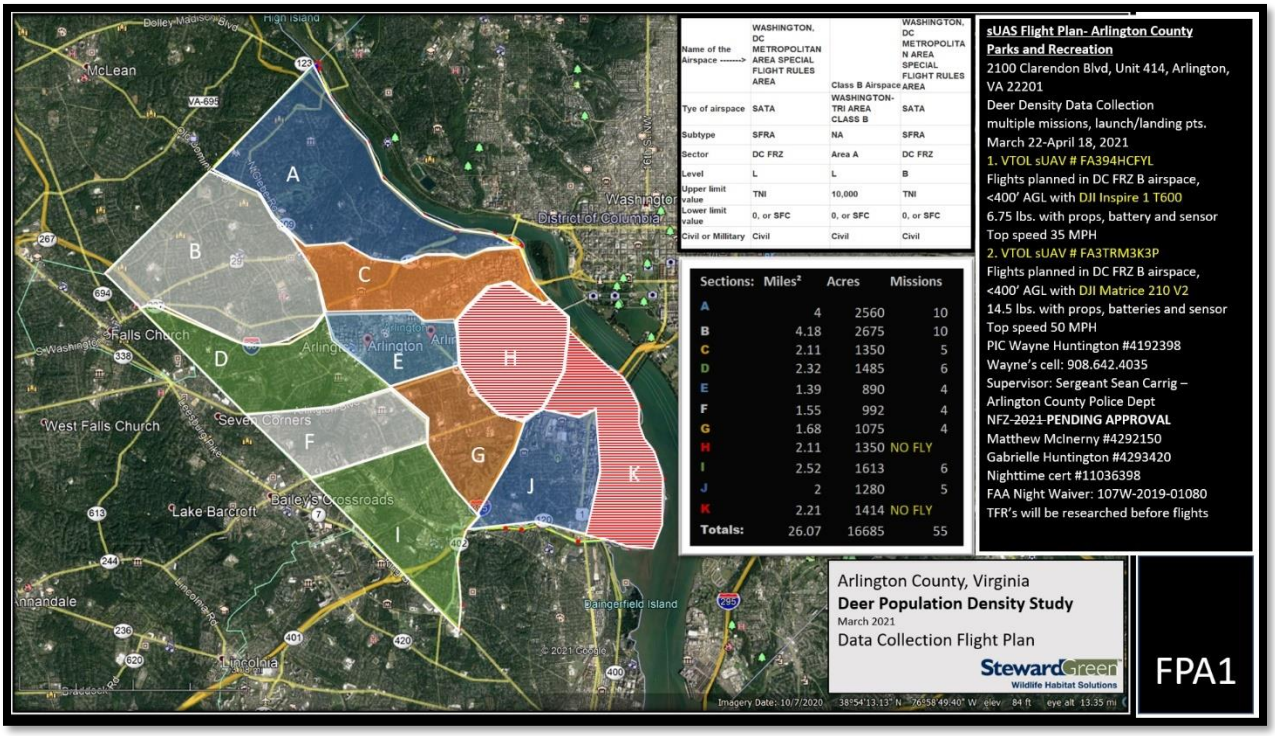


Figure 8. Arlington County Deer Population Density Study Area Sections

Infrared Accuracy

Steward Green LLC (SG) is providing Arlington County Department of Parks and Recreation with *infrared* thermal *digital aerial* imagery analysis and reporting within the study areas. The intent of the data collection is to confirm deer population densities at the time of data collection. The best time to collect heat signature data such as this is at night while ground temperatures have better contrast with live animals. We repeatedly requested permission from FAA and TSA that nighttime flights be allowed for this study. While they did concede to flights during twilight, they would not grant permission for night flights this time. The data collection

Figure 9. Deer in urban setting. Photo credit: Mark Grinbaum

Figure 10. Steward Green's UAV launching for another data collection mission. Photo credit: Toni Genberg

required daytime *thermal Forward-Looking Infrared* (FLIR) aerial *photogrammetry* of the study areas, most importantly collecting imagery that will best indicate white-tailed deer *heat signatures*. Optimum data collection is during the night and during colder months before the *deciduous trees* have produced leaves, allowing infrared sensors penetration to the ground. The colder ground temperatures contrast greater with heat signatures produced by deer. The infrared heat signatures produce a reliable method of "counting" the deer in analysis by an experienced, skilled technician. *Vertical Take-Off and Landing* (VTOL) *Unmanned Aerial Systems* (UAS), or drones, were used legally and safely to collect the data. Flights were completed less than 400' *above ground level* (AGL). Equipment was *calibrated* in the field to ensure geographic accuracy.

Overcount Prevention

Flights were conducted manually to produce the best results, as using this method allows the technician to pause, hover, circle areas, zoom and even change the sensor angle when there are questionable heat signatures behind structures, underneath cover, grouped together, etc. This is different from traditional methods using *fixed wing* airplanes or now even drones that fly *strip transects* with fixed optics. Areas were pre-determined, separated by highways or major streets. Areas are flown systematically, reducing risk of overcounting as groups of deer are identified through the process and noted. Geo-referencing was performed in the field for accurate locations, vegetation type and mapping. Analysis was performed both in the field and afterward in the lab to determine the number of deer counted in the study. *Esri Data Collector* was used in the field to record numbers and make field notes. This method is becoming increasingly more dependable for the population density data collection of *ungulates* (Chabot and Bird 2015, Drake et al. 2003).

Thermal imagery was analyzed both in the field and then more thoroughly in the lab to determine accurate heat signatures of minimum, or confirmed, deer counts. The number counted as confirmed is based on a few factors. As with any infrared data collection, there can be areas that are unseen, such as underneath *evergreen trees*, or other obstacles, where deer can be present yet not seen as a heat signature. Daytime data collection provided thermal competition that disallowed us to confirm deer because the images were not as clear and contrasted as they are typically when performed at night. Activity during the day also had a competing role. As a result, there are possible deer observed in the data collection that are not counted in the minimum deer analysis. If data is collected in the future, we strongly recommend obtaining nighttime clearance.

This information was then used to create geographic location maps with points of interest (the heat signatures of deer), mission and data information.

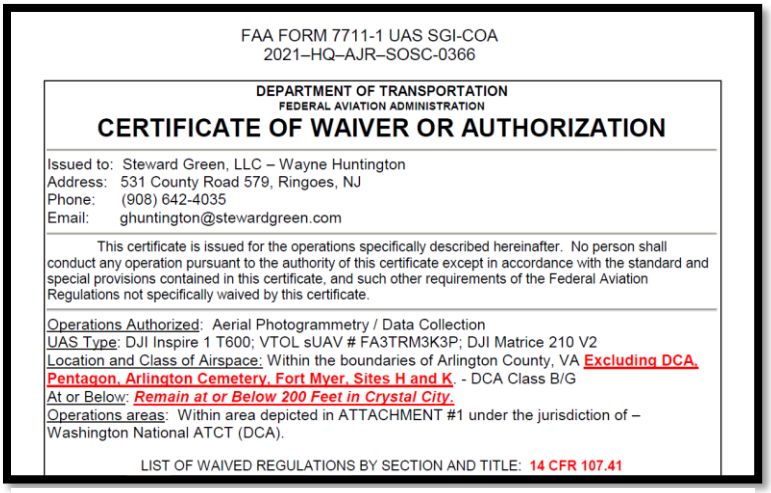
Species-specific

With a trained wildlife biologist or experienced professional performing the analysis, deer can be distinguished from other ungulates such as cattle, horses, sheep, goats, etc., and other mammals such as fox, raccoon, and coyote. Scale, location, and habit are the main determining factors.

Figure 11. It is important for a qualified wildlife biologist or experienced technician be able to distinguish species.

Operational Requirements and Project Challenges

SG is approved to perform UAS operations based on our certifications with *Federal Aviation Administration* (FAA) and standard procedures. Our *missions* were performed below 400 feet AGL within the study area, and TSA required we fly under 200 feet AGL in Crystal City. All of Arlington County falls within the Washington DC *Flight Restricted Zone* (FRZ). The National Capitol Region is governed by a *Special Flight Rules Area* (SFRA), of which flying an unmanned aircraft within the 15-mile radius of Ronald Reagan Washington National Airport is prohibited without specific FAA authorization, which Steward Green obtained through a certificate of waiver from FAA, TSA, Homeland Security, Secret Service, and the DCA. We collected the UAS data legally and safely. Before any sUAS, (small UAS), flights were conducted, SG determined whether there were any *Temporary Flight Restrictions* (TFRs) issued by FAA. In this case, there was not, yet constant communication with the above-mentioned authorities, along with careful operating procedures ensured safe operations.



FAA FORM 7711-1 UAS SGI-COA
2021–HQ–AJR–SOSC-0366

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

CERTIFICATE OF WAIVER OR AUTHORIZATION

Issued to: Steward Green, LLC – Wayne Huntington
Address: 531 County Road 579, Ringoes, NJ
Phone: (908) 642-4035
Email: ghuntington@stewardgreen.com

This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.

Operations Authorized: Aerial Photogrammetry / Data Collection
UAS Type: DJI Inspire 1 T600; VTOL sUAV # FA3TRM3K3P; DJI Matrice 210 V2
Location and Class of Airspace: Within the boundaries of Arlington County, VA **Excluding DCA, Pentagon, Arlington Cemetery, Fort Myer, Sites H and K**. - DCA Class B/G
At or Below: ***Remain at or Below 200 Feet in Crystal City.***
Operations areas: Within area depicted in ATTACHMENT #1 under the jurisdiction of – Washington National ATCT (DCA).

LIST OF WAIVED REGULATIONS BY SECTION AND TITLE: **14 CFR 107.41**

Figure 12. Example portion of Certificate of Waiver from FAA

Minor technical difficulties we were able to overcome in the field. Site access and range presented to become challenges at some of the park areas. Moreover, low flying helicopters had to be circumnavigated by us to conduct our work safely. There were times when we performed crew management decisions to avoid the helicopter routes by either shifting location or times of our missions. The previously stated approvals sought, and communications were challenging at first, yet we had designed a protocol and delegations to make it as safe as possible and meet compliances. Daytime operations provided more challenges due to thermal competition, activity, and sun glare.

Process

Site reconnaissance included FAA mandatory daytime inspections of the project area to evaluate *ingress/egress*, potential launch/landing points, site hazards, obstructions, flight patterns, etc. and if the missions would have been flown at night. We elected to perform these examinations, though not mandatory, to become as familiar with the area as we could, making our missions as safe as possible. High voltage electric lines and towers, cell phone and radio towers, water towers, severe changes in elevation, large trees, etc., were some of the issues noted during inspection. Launch/landing sites were also pre-determined.

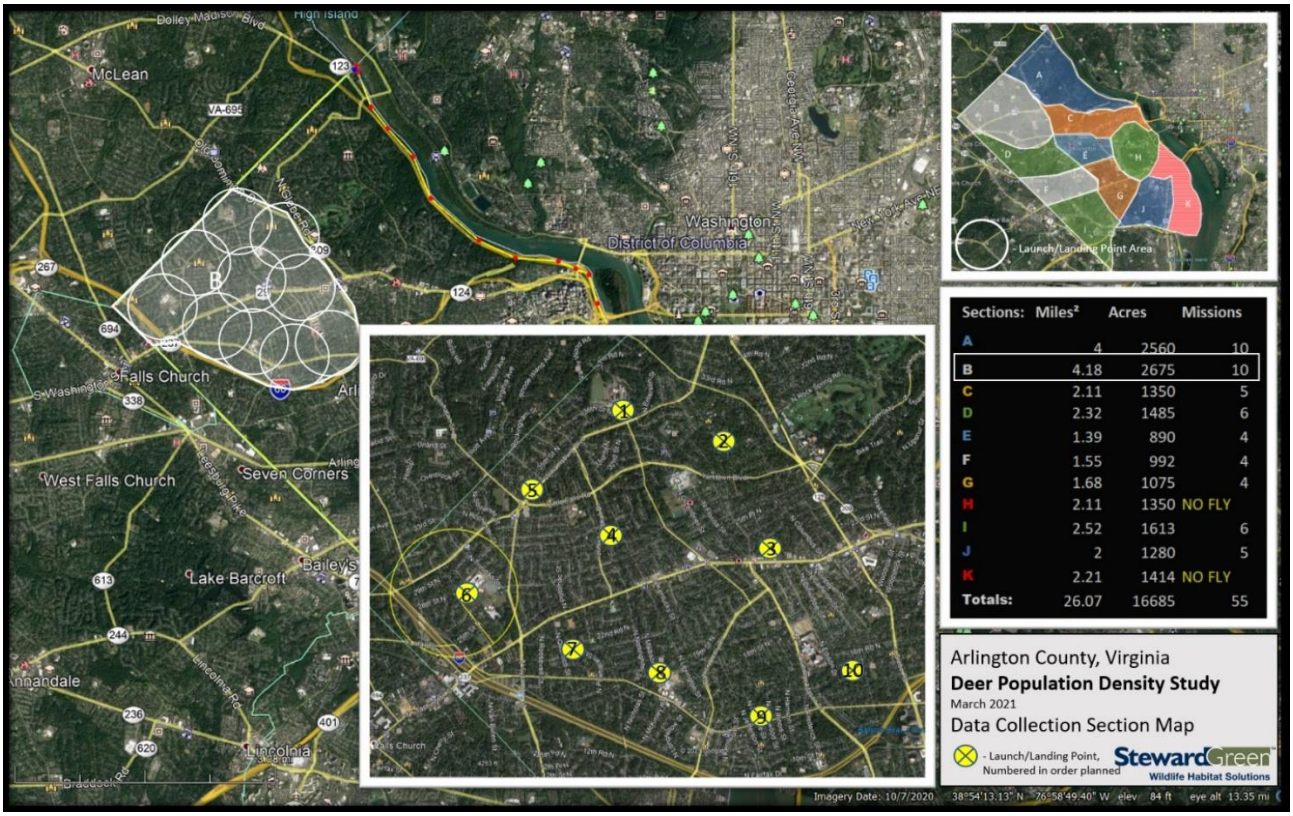


Figure 13. Example- sUAS launch/recovery coverage for Section B

The Arlington County study areas required 65 missions from morning twilight beginning to evening twilight end, covering areas systematically, with one *Pilot in Command* (PIC), 2 *Visual Observers* (VOs), 1 *Law Enforcement Officer* (LEO) and at times another observer familiar with the area. All missions were conducted safely. Conditions were adequate, as the ground temps were cool enough and the skies were clear. Evergreen tree coverage was minimal to moderate, depending on the section. Note that waiting any longer in the season would have been problematic as the leaves were starting to emerge on some of the deciduous trees such as the maples.

Other heat signatures observed included hikers, boulders, field springs, pockets of water, streams, streetlights, active chimneys, drain inlets, electric transformers, cars in driveways, dogs, raptors, waterfowl, and other mammals.

Images were collected using a VTOL sUAS with high-resolution visual imaging thermal infrared sensors flying manual missions to ensure complete coverage of the study area, adequate *image overlap*, and *repeatability*. sUAV was equipped with up lighting visible to 5 statute miles. We completed data collection of all project areas flown, approximately 14,098 acres, about 22 square miles.

Figure 14. Arlington Regional Master Naturalist Toni Genberg captures photos of the data collection in progress. Photo credit: Gene Huntington

Results

We confirmed 290 deer for the entire combined areas flown, or 13 deer per mi² averaged. When we take a closer look at the section data, we see expected higher numbers in sections that have more forested areas or stream corridors, with densities that begin to be concerning, with 20, 28, 33 and 39 deer per square mile in Sections G, D, A and F respectively. Add in the challenges of daytime data collection and those numbers are likely higher.

Planned:				Actual:					
Sections:	Miles²	Acres	Missions	Sections:	Miles²	Acres	Missions	Total Deer	Deer/Mi²
A	4	2560	10	A	3.2	2048	21	104	33
B	4.18	2675	10	B	4.14	2650	11	5	1
C	2.11	1350	5	C	2.16	1382	6	0	0
D	2.32	1485	6	D	2.32	1485	6	65	28
E	1.39	890	4	E	1.33	851	2	2	2
F	1.55	992	4	F	1.58	1011	4	62	39
G	1.68	1075	4	G	1.62	1037	6	33	20
H	2.11	1350	NO FLY	H		0	NO FLY		
I	2.52	1613	6	I	2.47	1581	6	19	8
J	2	1280	5	J	2.18	1395	3	0	0
K	2.21	1414	NO FLY	K	0	0	NO FLY		
Totals:	26.1	16685	55	Totals:	21	13440	65	290	13

Figure 15. Planned vs. Actual coverage and missions.

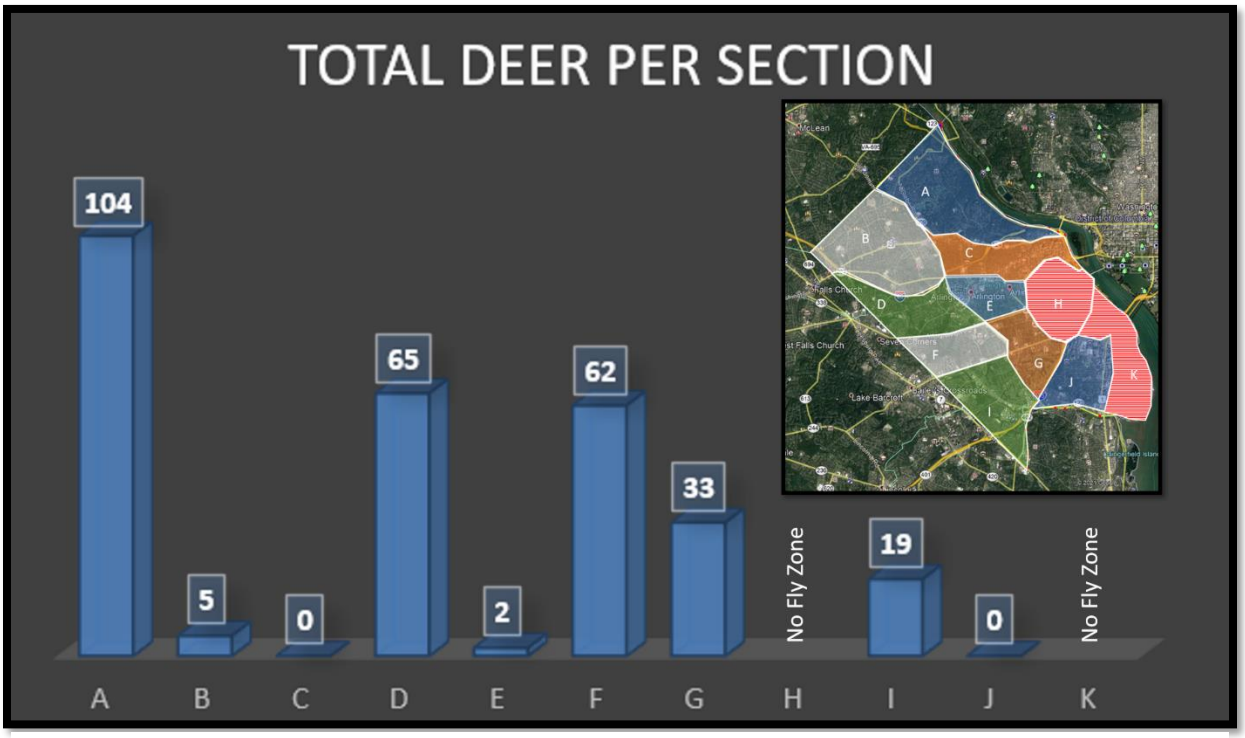


Figure 16. Total deer per section

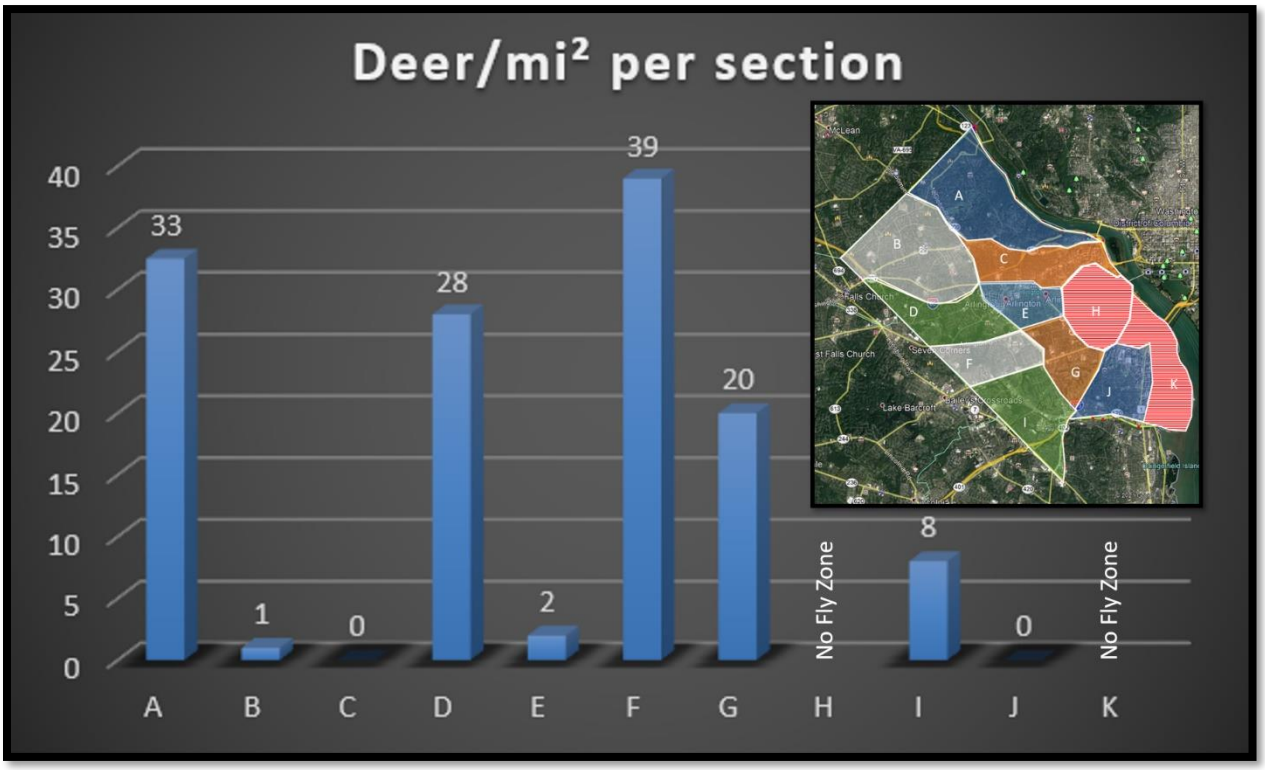
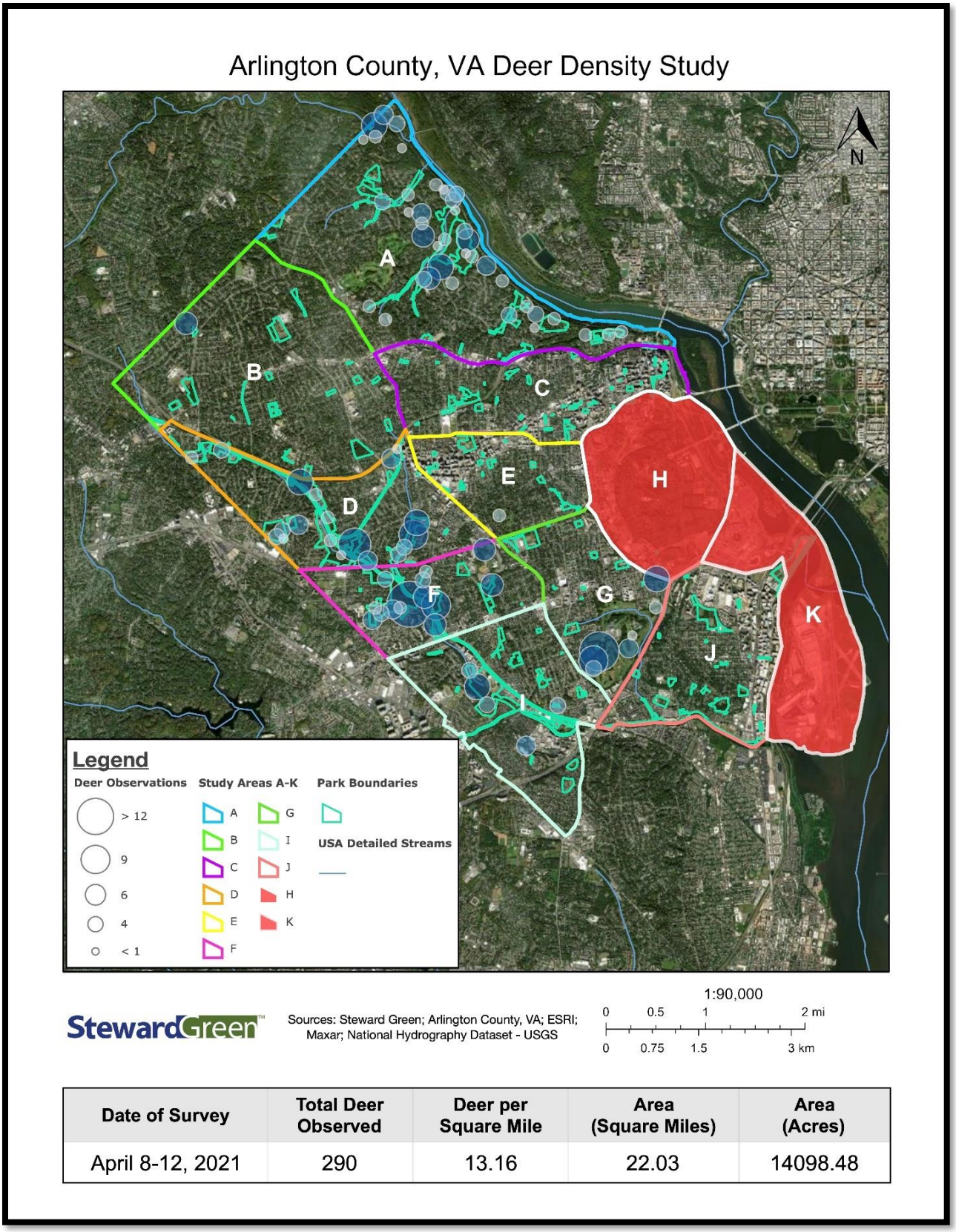


Figure 17. Deer per mi² per section



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	290	13.16	22.03	14098.48

Figure 18. Total study area results

Sections

As noted earlier in the report, we divided the county into feasible sections, so we could collect data as systematically as possible and reduce over/under counting. This system allowed us to spread the data collection over a period of days. We used major roads and highways as the section delineations. Some sections had many deer while others had no data collected that represented deer. Again, based on the herbivory we observed in all sections, and our experience with these types of observations, we believe there were deer present that could not be confirmed with thermal detection during the day. This was because of the thermal signature competition, glare, and activity during the daytime. Some sections were easier to detect heat signatures belonging to deer, such as Section A, because there were more woodlands. However, because we were not allowed to fly over George Washington Memorial Parkway, we could not view all of Section A.

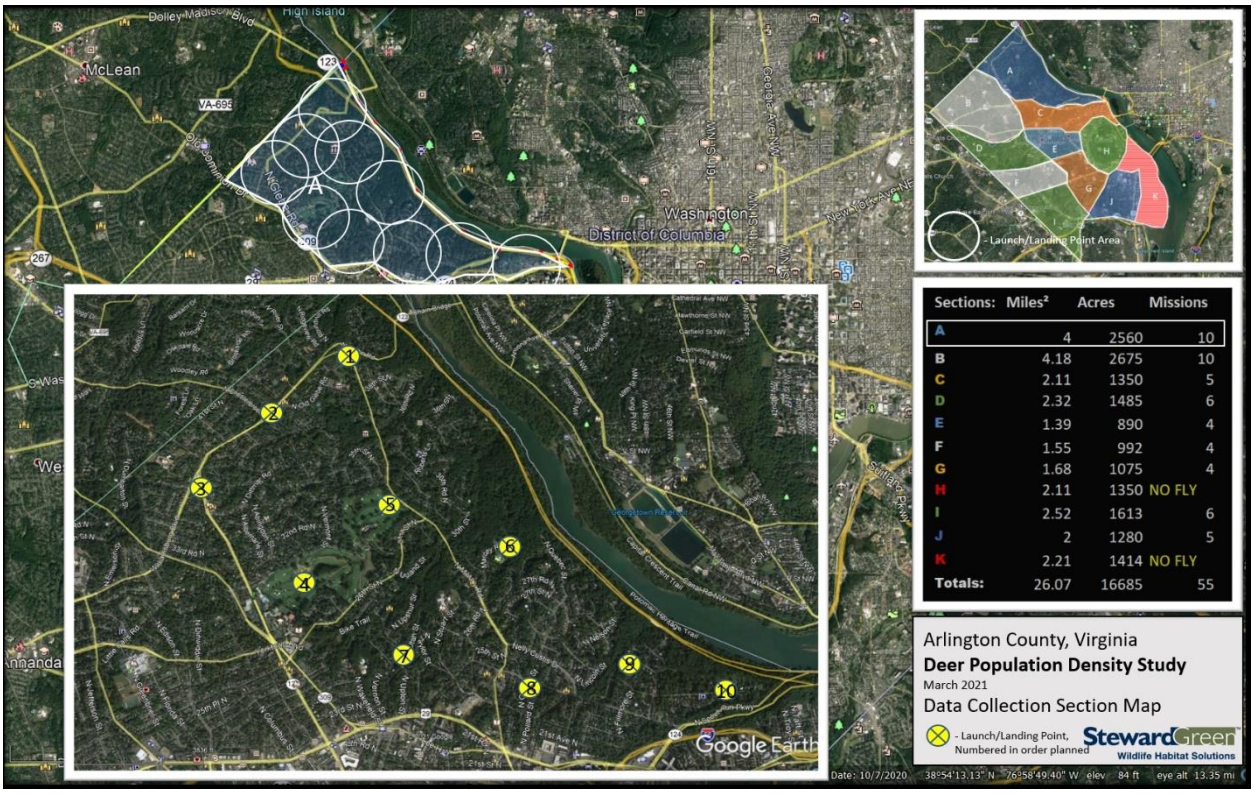
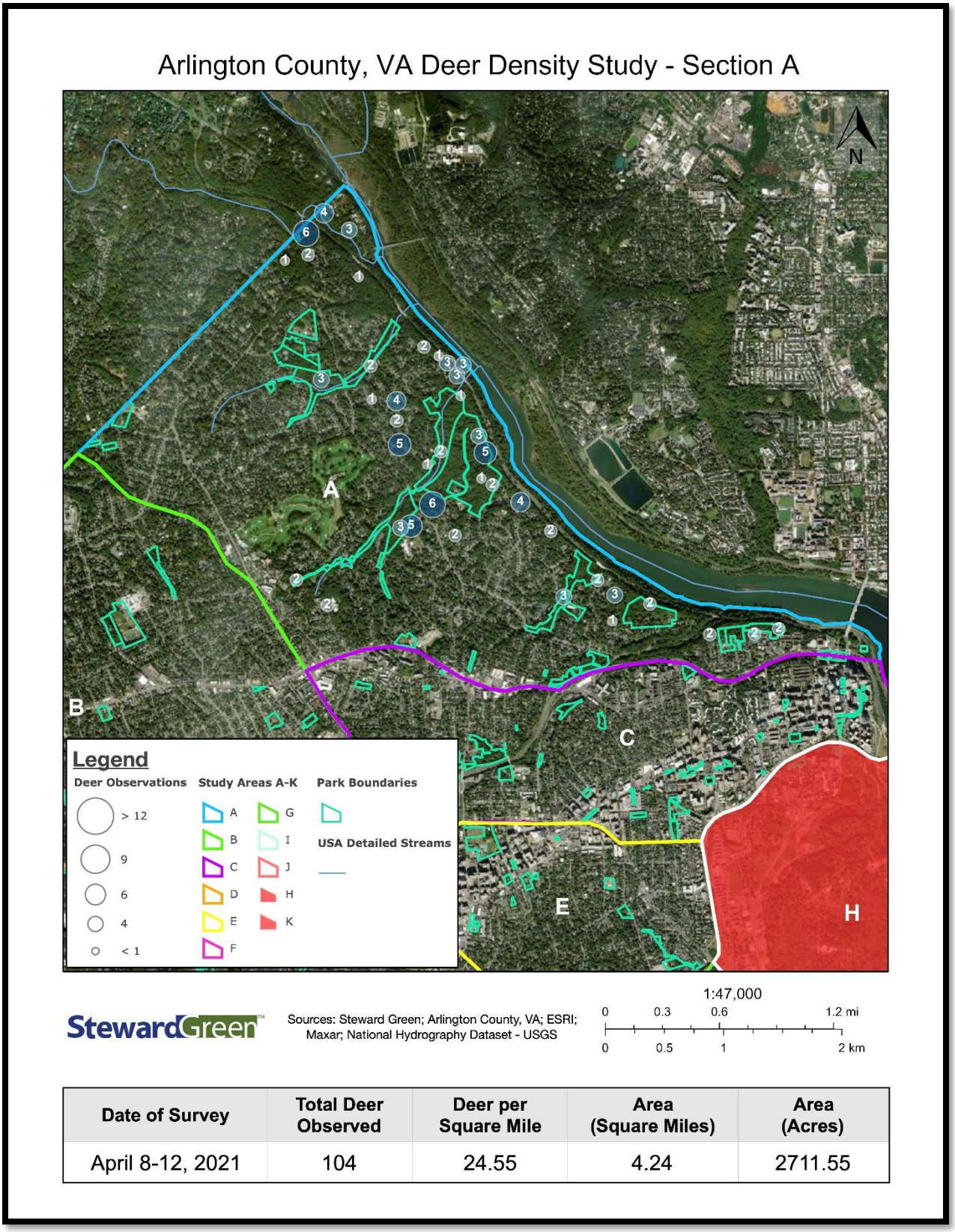


Figure 19. Section A Map of launch/recovery points

Section A was flown on Thursday April 8 and then again on Friday April 9, 21 missions in total as compared to the 10 missions planned. We decided to abort missions by mid-morning on April 8th due to significant sun glare and low flying helicopter traffic. We also needed to adjust our communications plan with Homeland Security to comply with the revisions they wanted to make. We observed 104 deer over 2,048 acres, or 33 deer per mi² in Section A. Because we collected data in Section A on two consecutive days, to prevent over/under counting, we flew missions on April 8th north of 26th and 30th streets. On April 9th we flew south of those same streets. We used those streets as borders and note deer accordingly to reduce error, making note of deer that could have been within range.



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	104	24.55	4.24	2711.55

Figure 20. Section A results

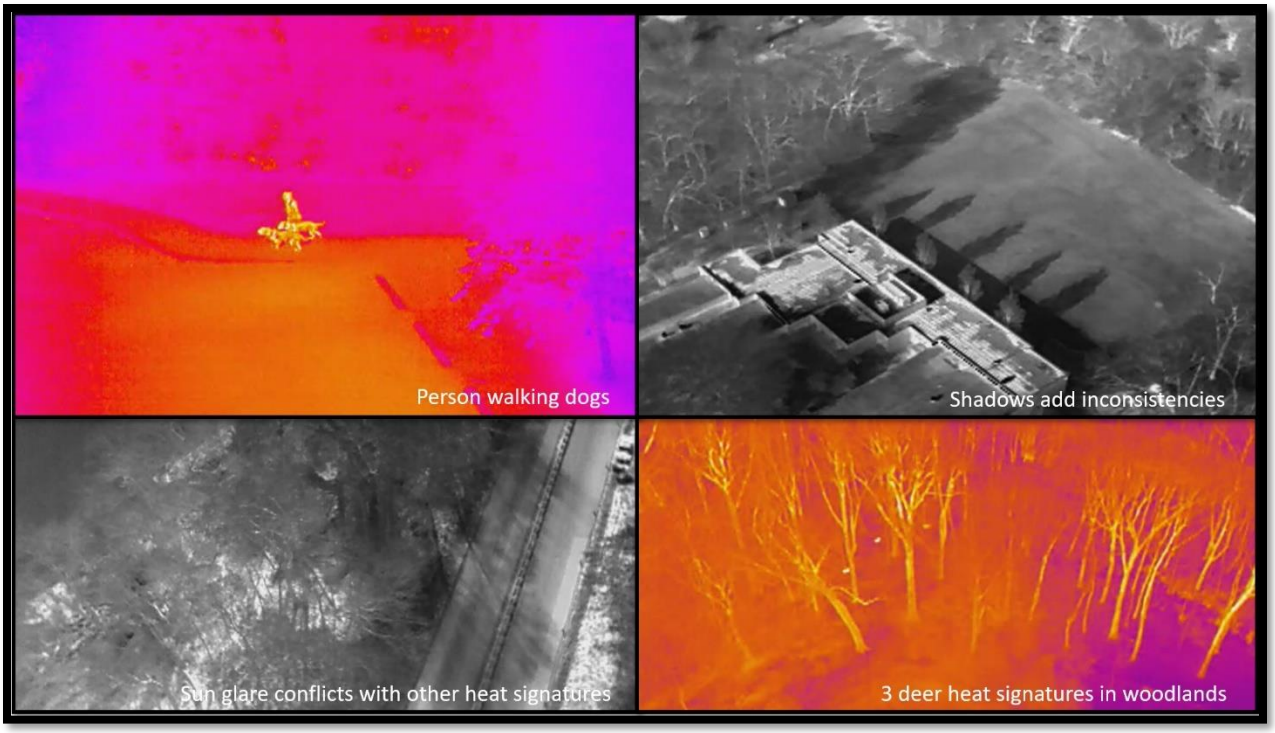


Figure 21. Section A thermal examples

Section B was much more suburban than Section A. We flew all of Section B on Friday, April 9th, only observing 5 deer in 11 missions. Section B had much activity present while we were conducting the missions making observations more difficult than if we had flown at night. The 5 deer we witnessed were in Minor Hill Park. We flew again the next day to see if we could observe the same 5 deer again, which we did locate them, about 1,000 linear feet away from the first observation.

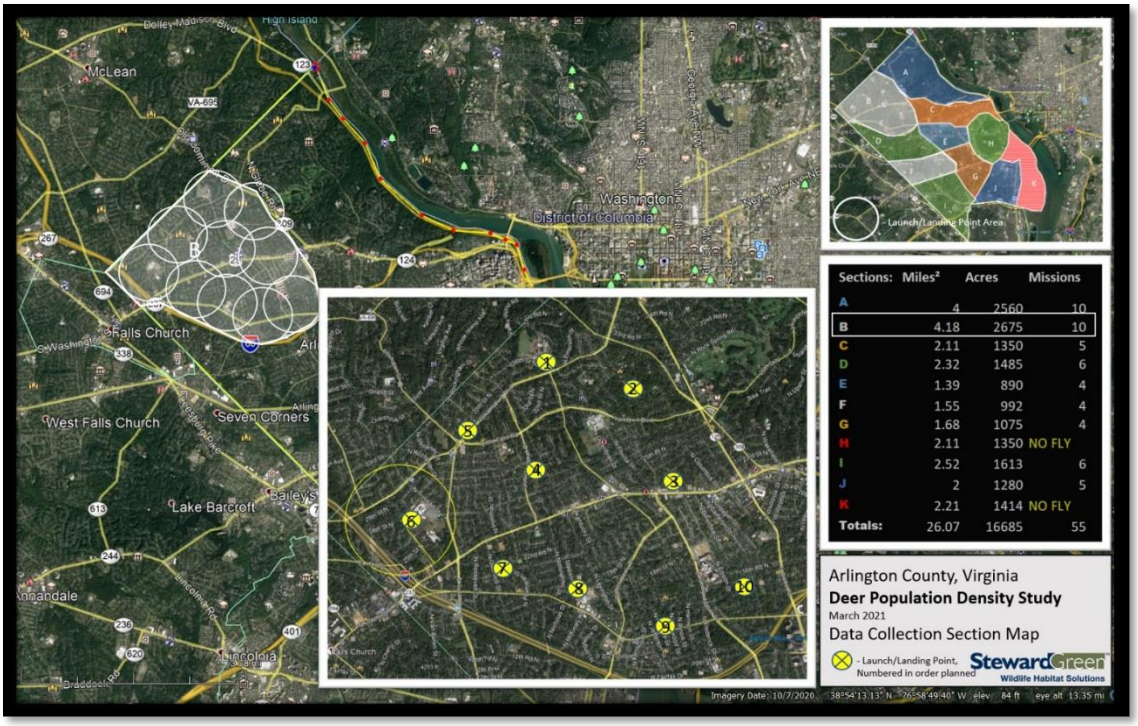
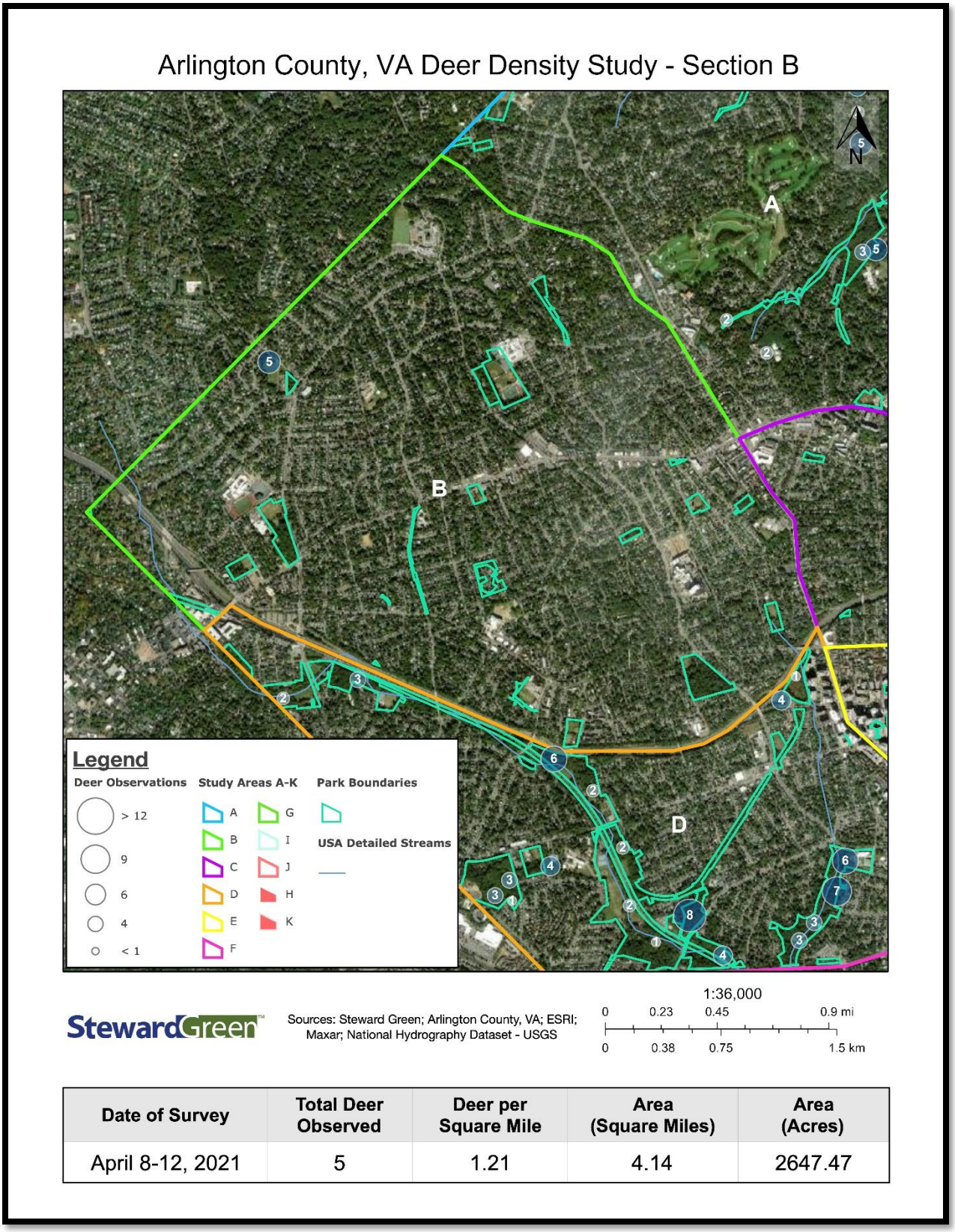


Figure 22. Section B launch/recovery map



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	5	1.21	4.14	2647.47

Figure 23. Section B results

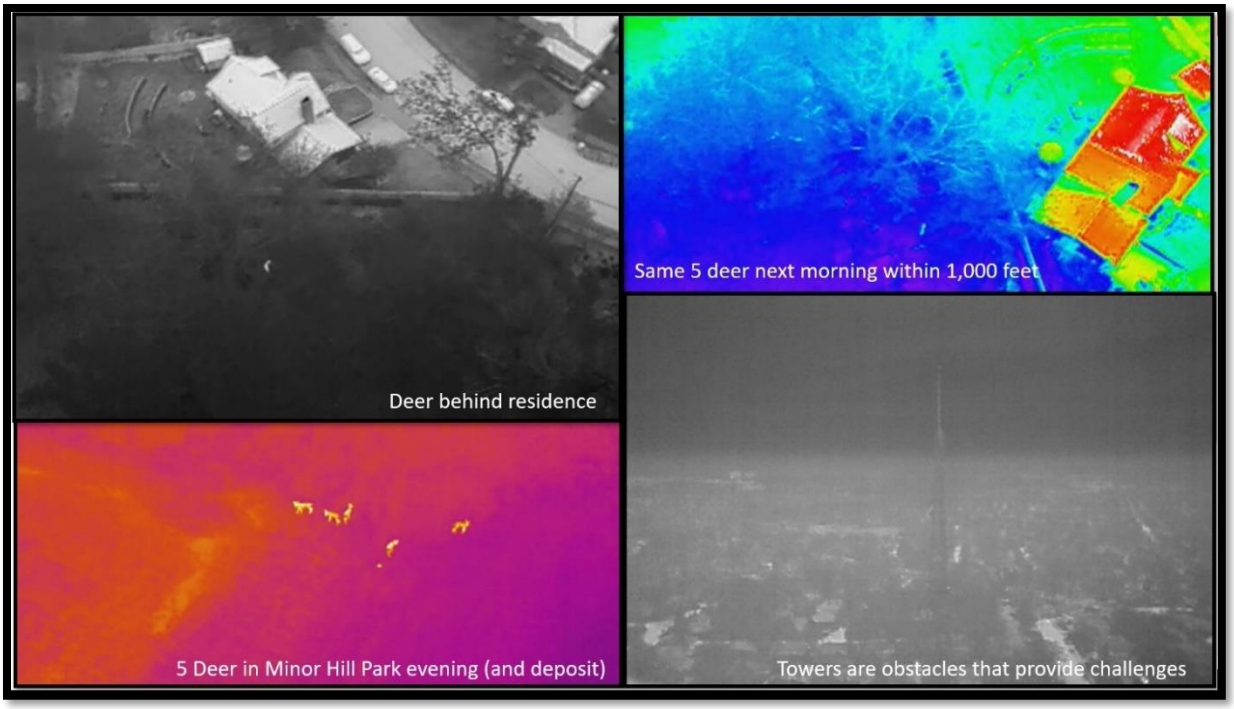


Figure 24. Section B thermal examples

Section C was a much smaller area than the previous sections. We collected data in 6 missions on Saturday, April 10, yet could not confirm any deer heat signatures.

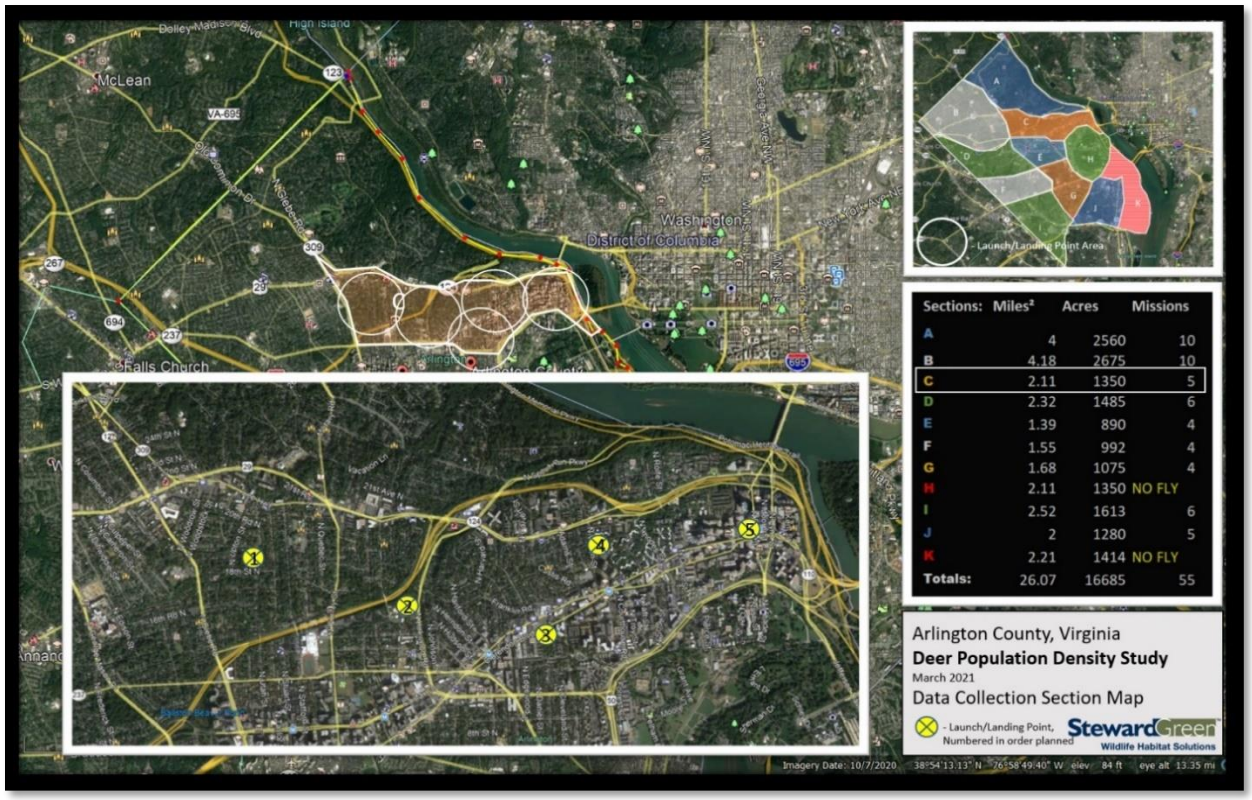
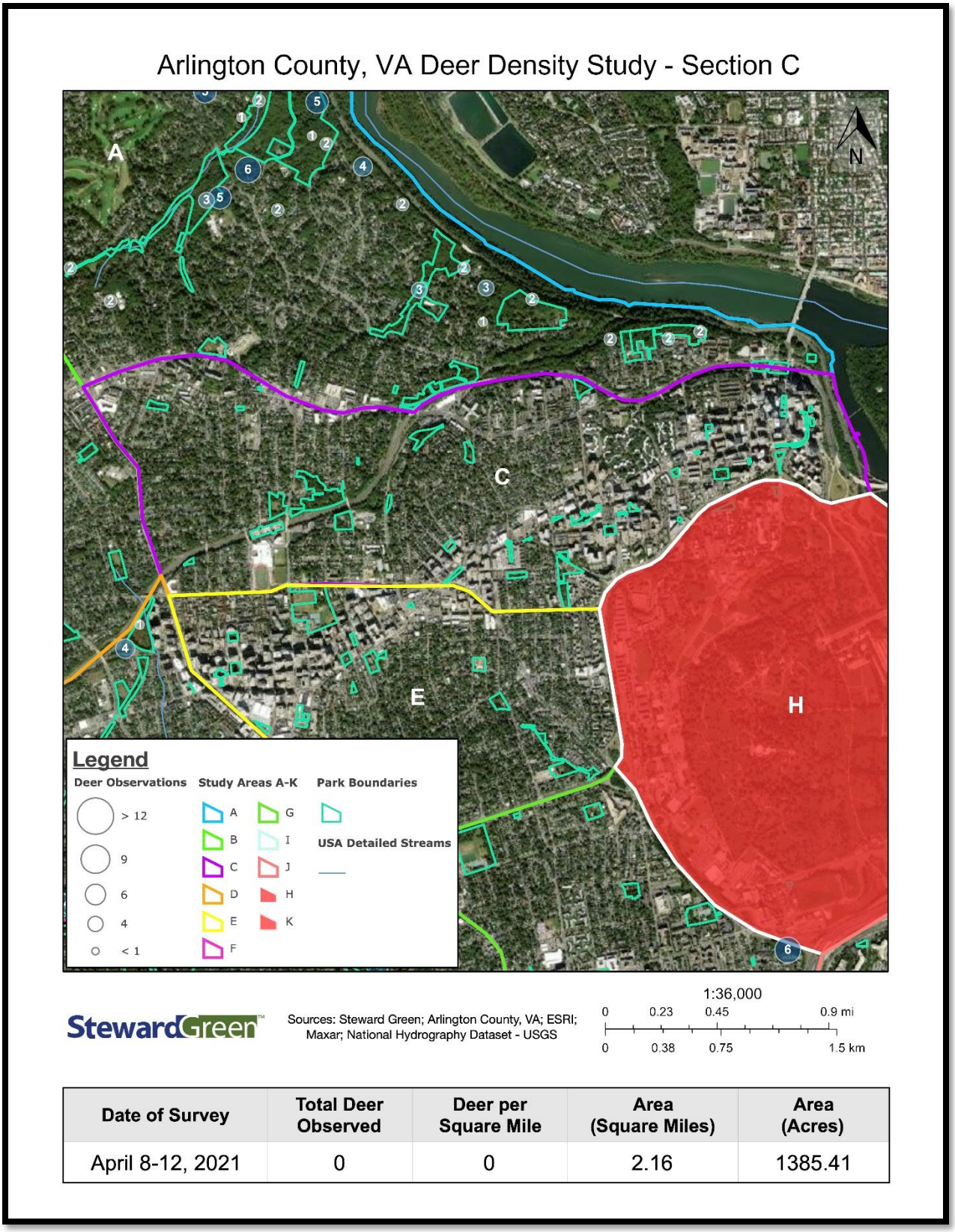


Figure 25. Section C launch/recovery map



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	0	0	2.16	1385.41

Figure 26. Section C results

Figure 27. Section C thermal examples

Section D was flown on Monday, April 12. We observed 65 deer on 1,485 acres, or 28 deer per mi² in 6 missions.

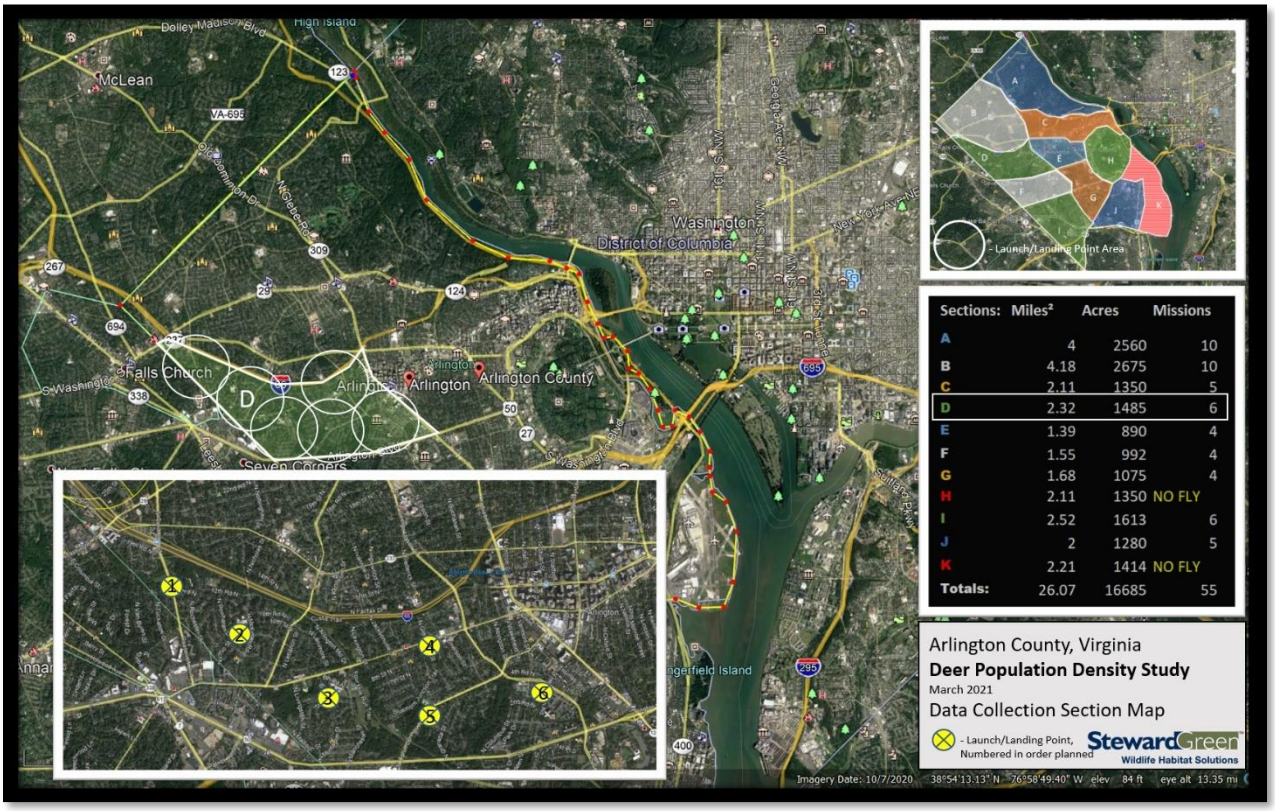
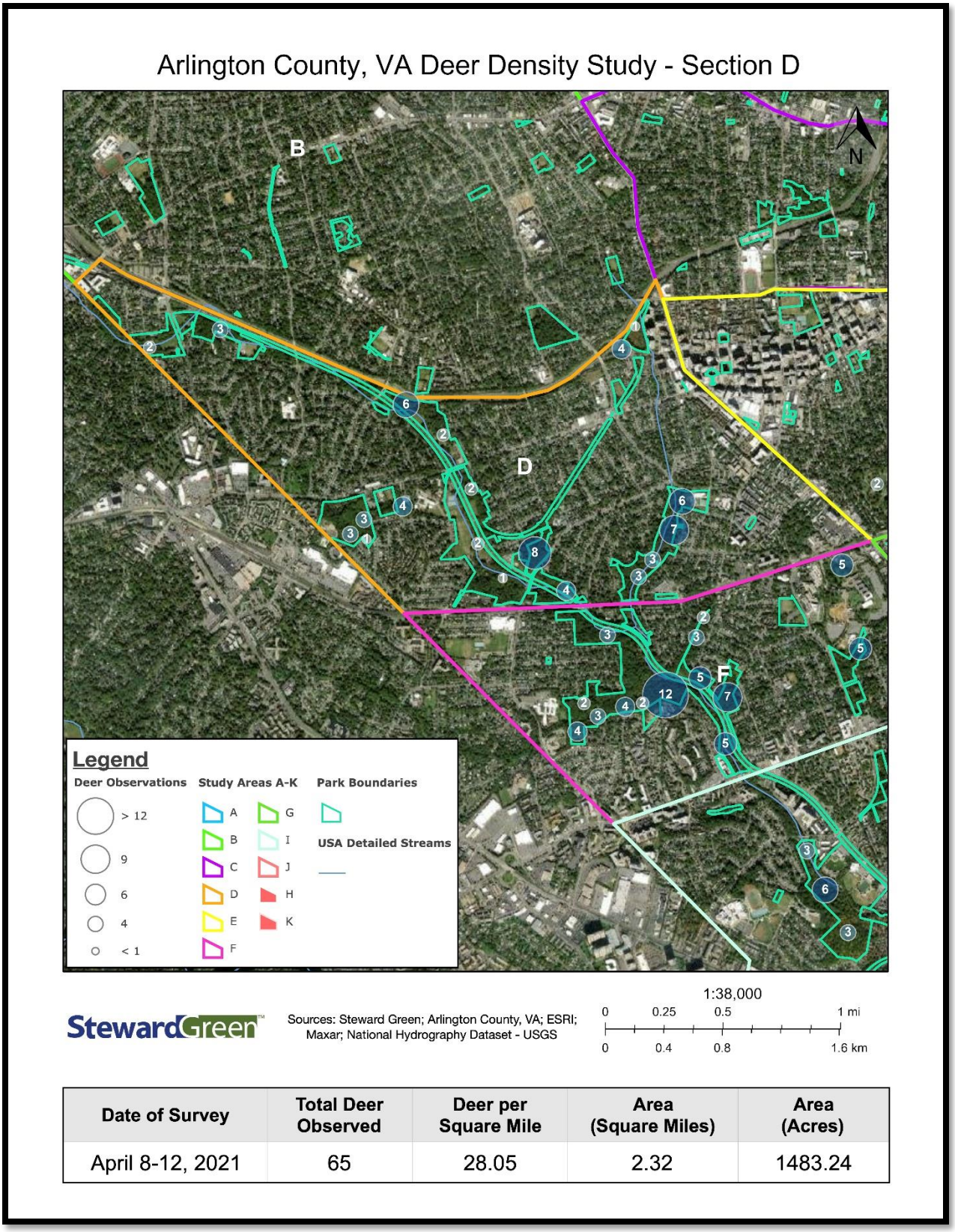


Figure 28. Section D launch/recovery map



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	65	28.05	2.32	1483.24

Figure 29. Section D results

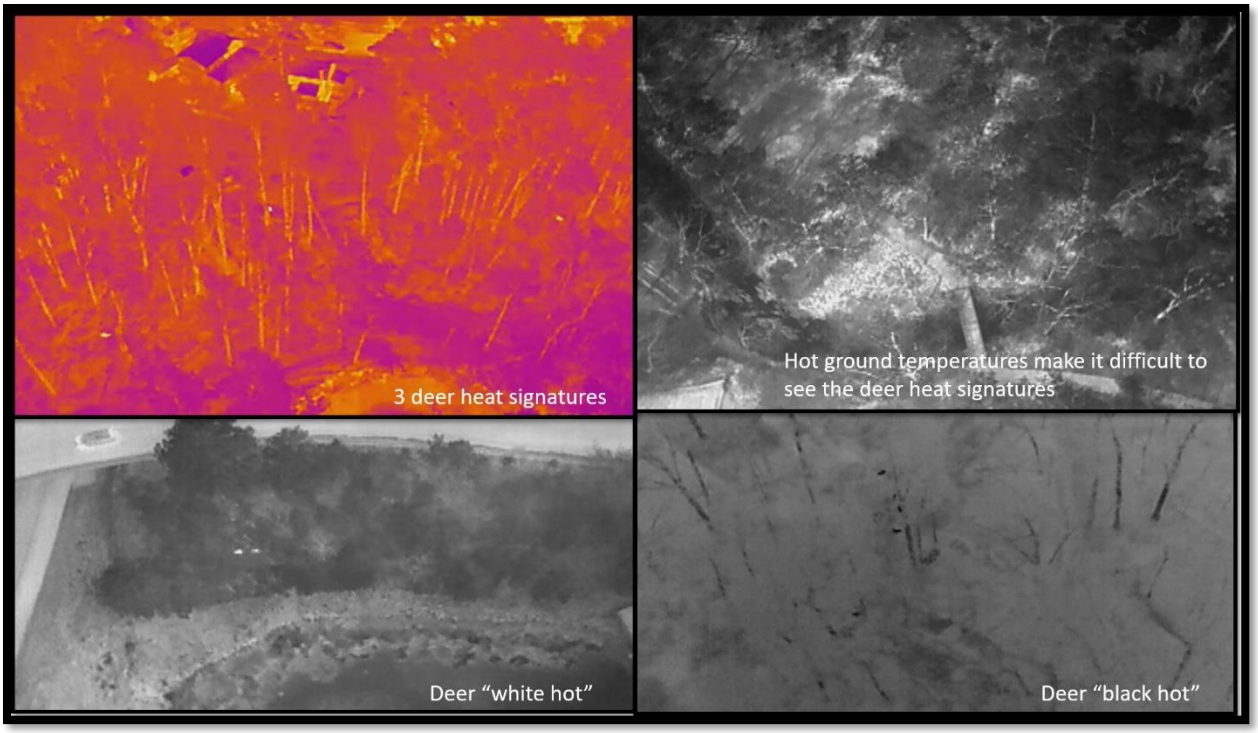


Figure 30. Section D thermal examples

Section E was by far the smallest section, at 851 acres, we witnessed 2 deer in total, needing only 2 missions on Saturday, April 10. Remove WUSA photo

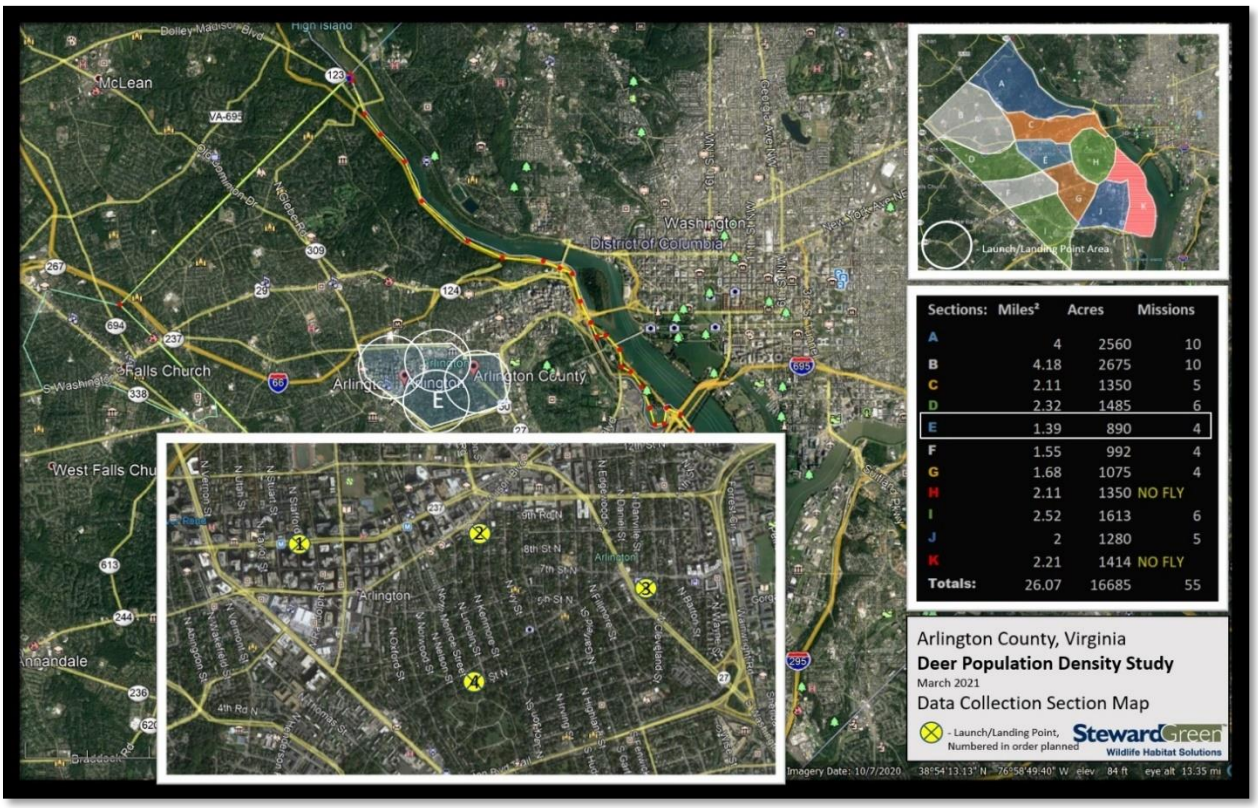
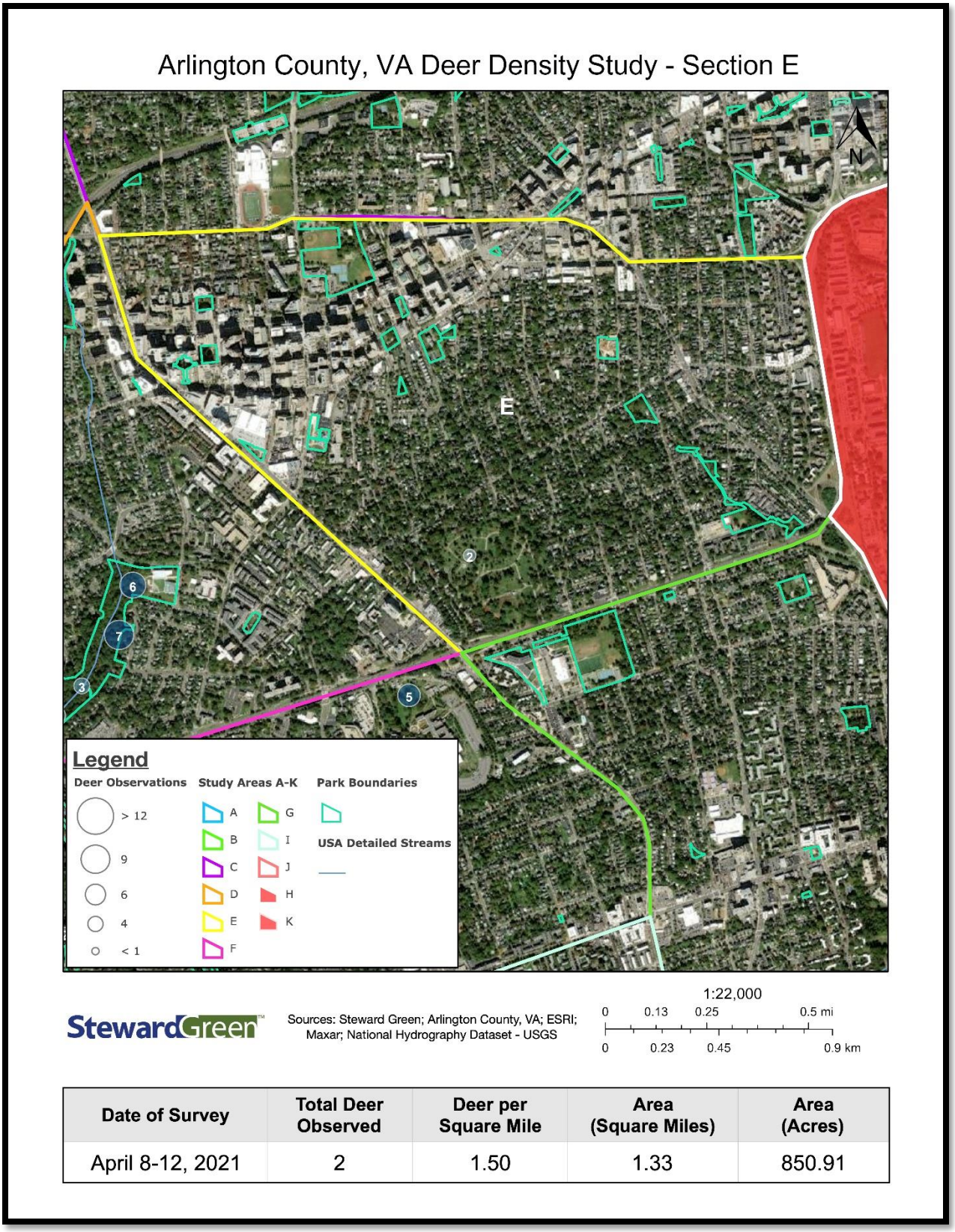


Figure 31. Section E launch/recovery map



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	2	1.50	1.33	850.91

Figure 32. Section E results

Section F was also small in size yet had more stream corridor. During 4 missions we observed 62 deer on 1,011 acres for 39 deer per mi², the highest section density noted. Section F was flown on Sunday, April 11, 2021.

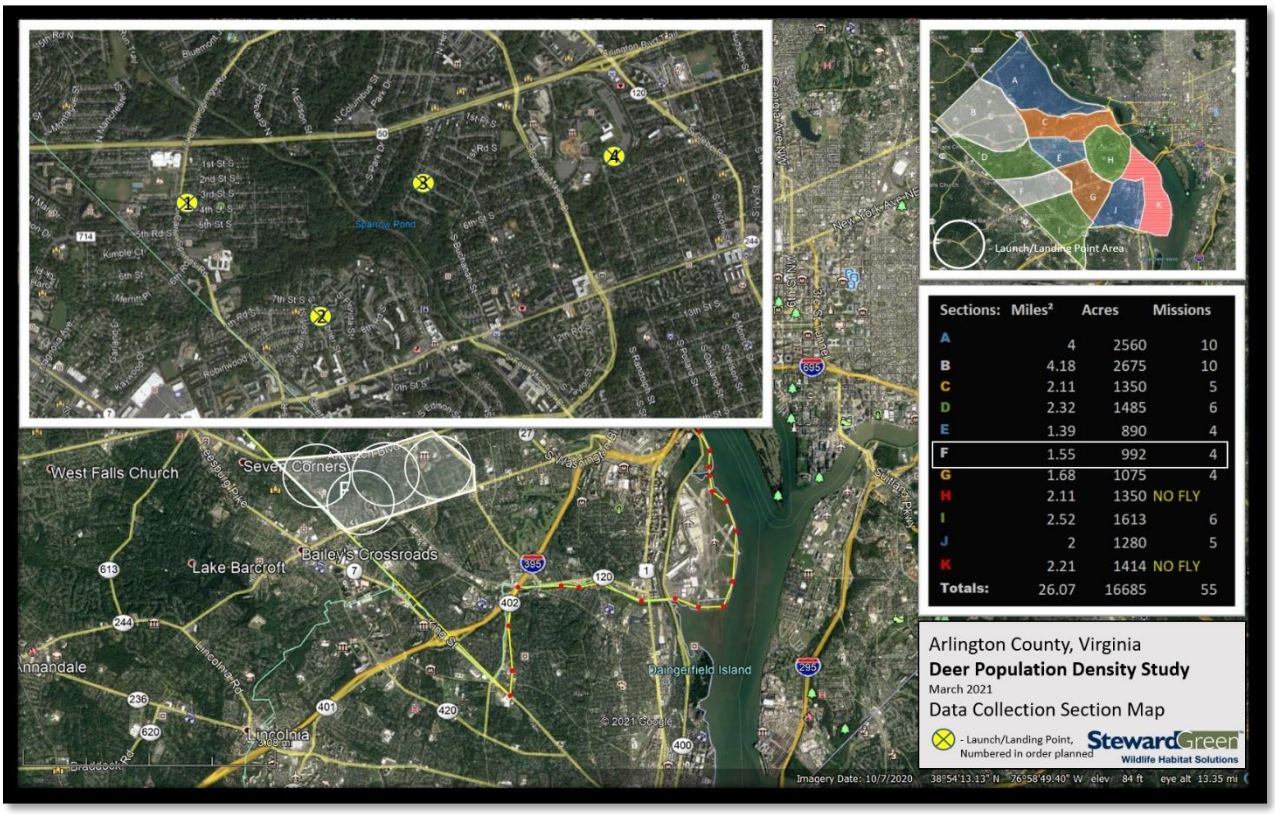
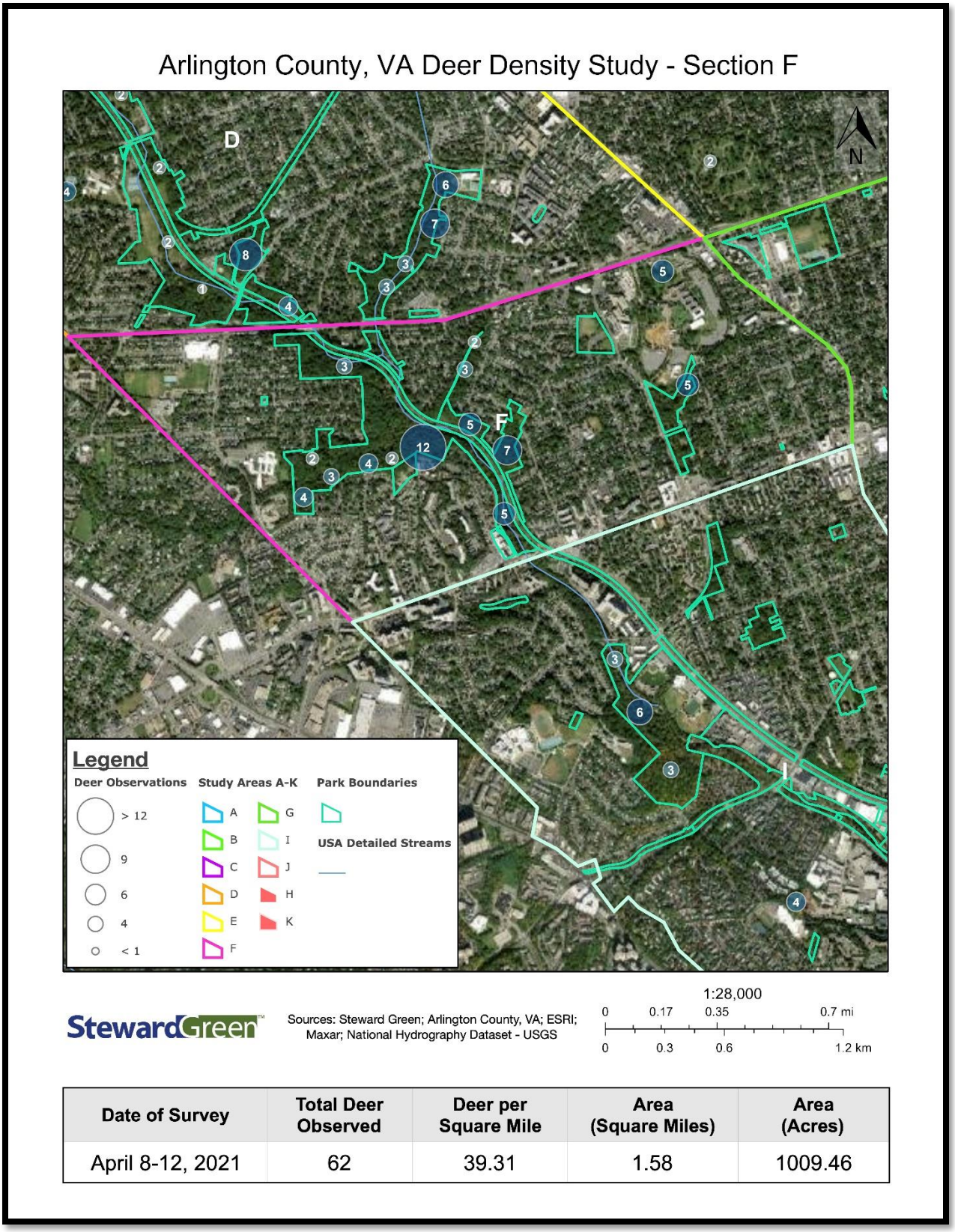


Figure 33. Section F launch/recovery map



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	62	39.31	1.58	1009.46

Figure 34. Section F results

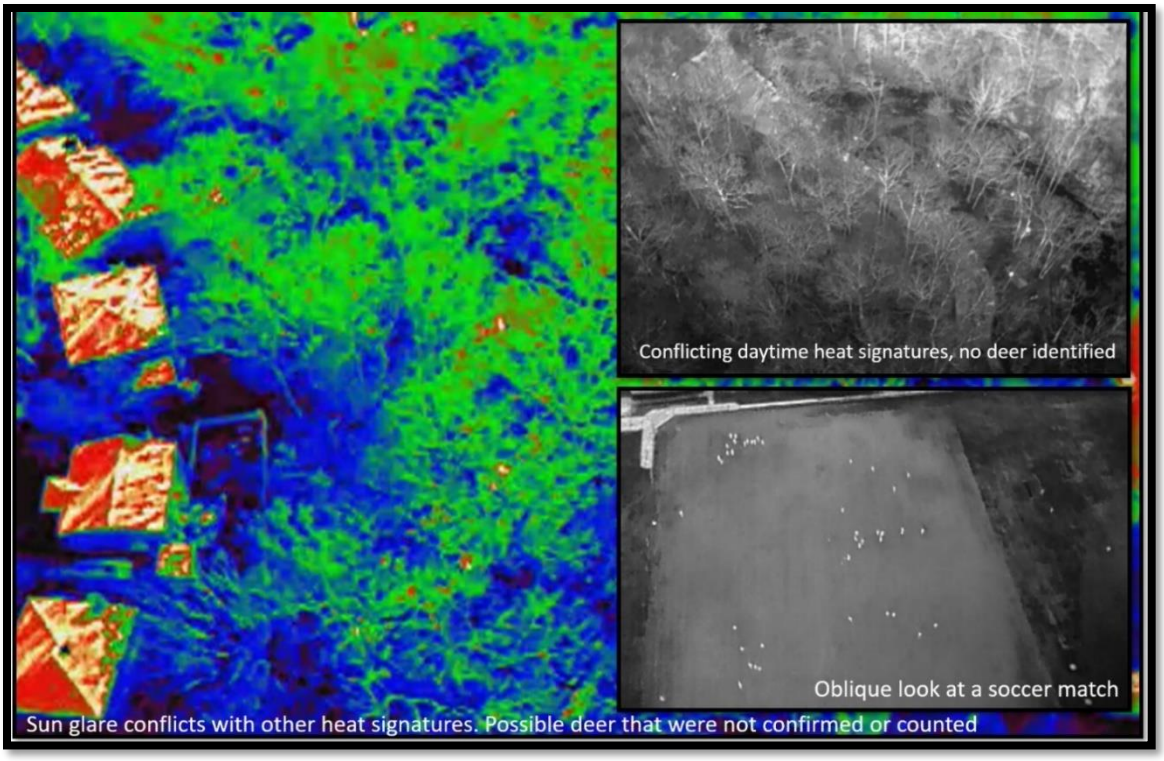


Figure 35. Section F thermal examples

Section G was almost the same size as Section F at 1,037 acres flown. There were 33 deer confirmed, or 20 deer per mi² observed during the 6 missions flown on Sunday, April 11. Thanks goes to (NOVA) Parks for Potomac Overlook access.

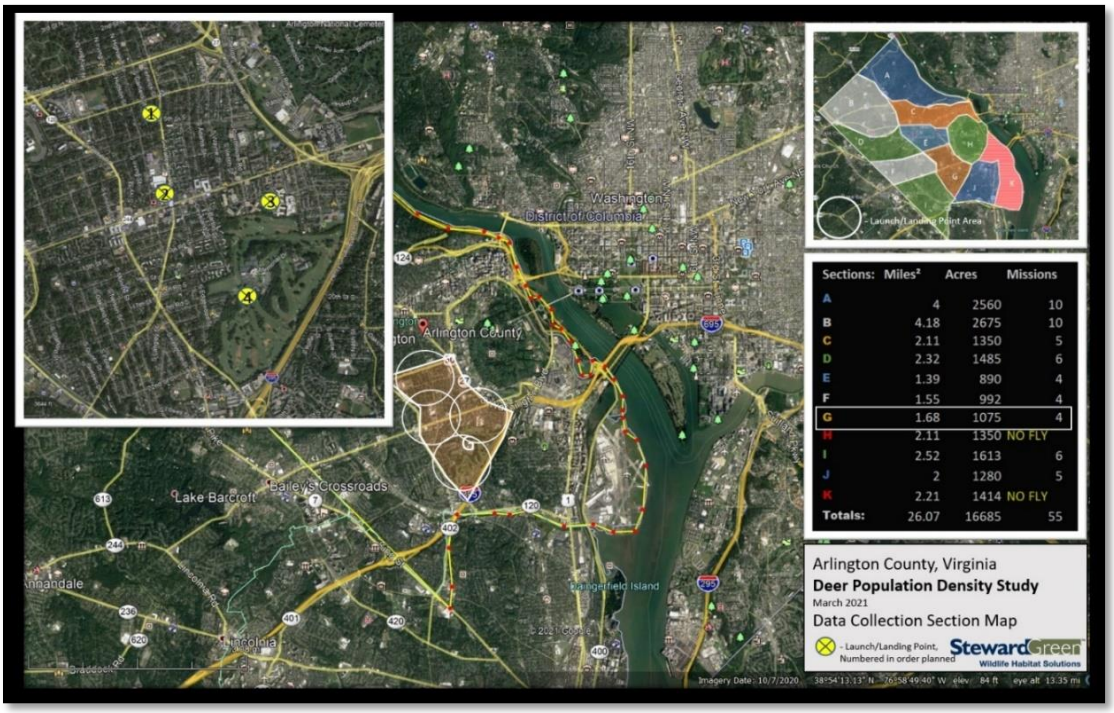
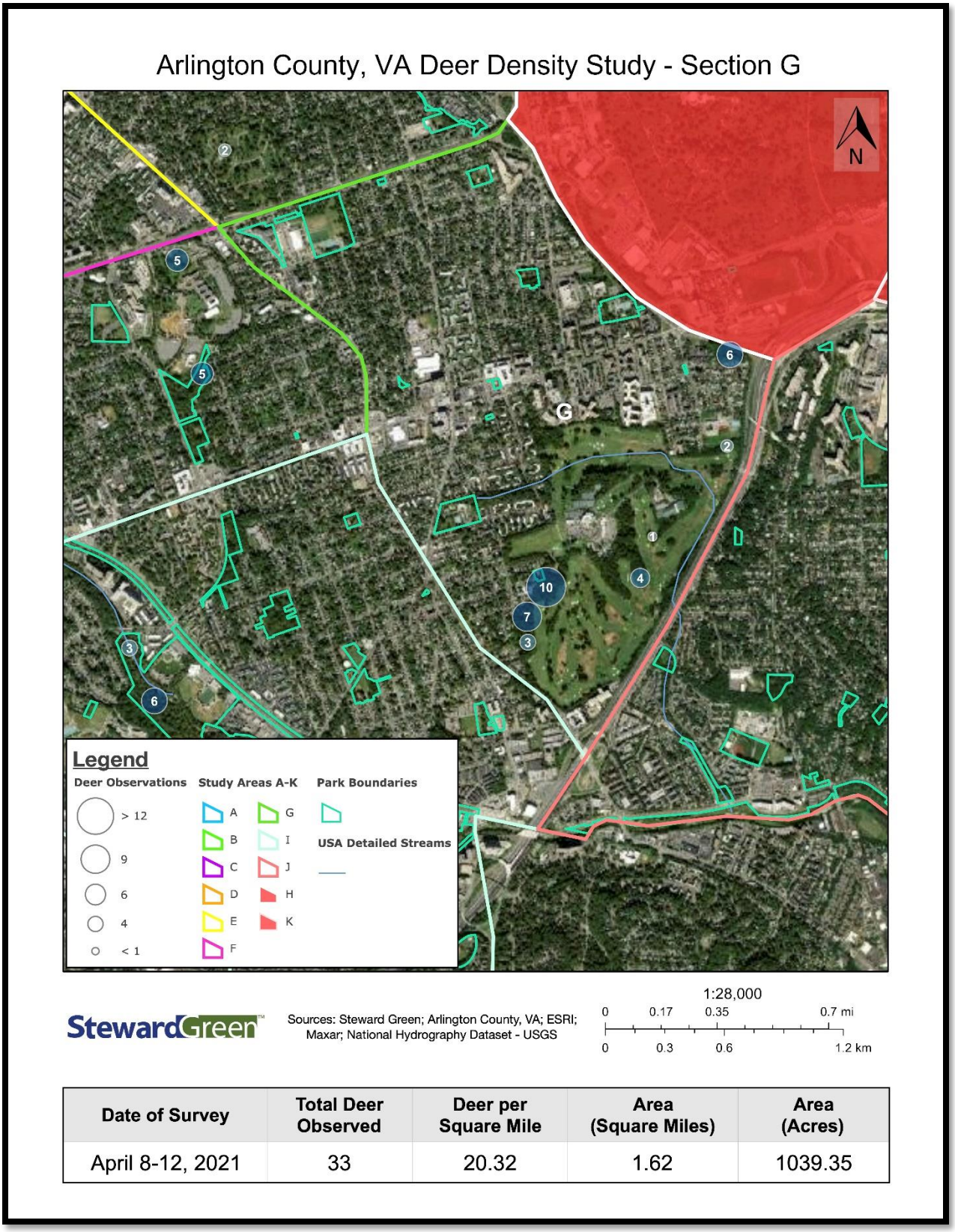


Figure 36. Section G launch/recovery map



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	33	20.32	1.62	1039.35

Figure 37. Section G results

Section H was determined a no fly zone as we were not granted permission to fly over Arlington National Cemetery or Fort Myer.

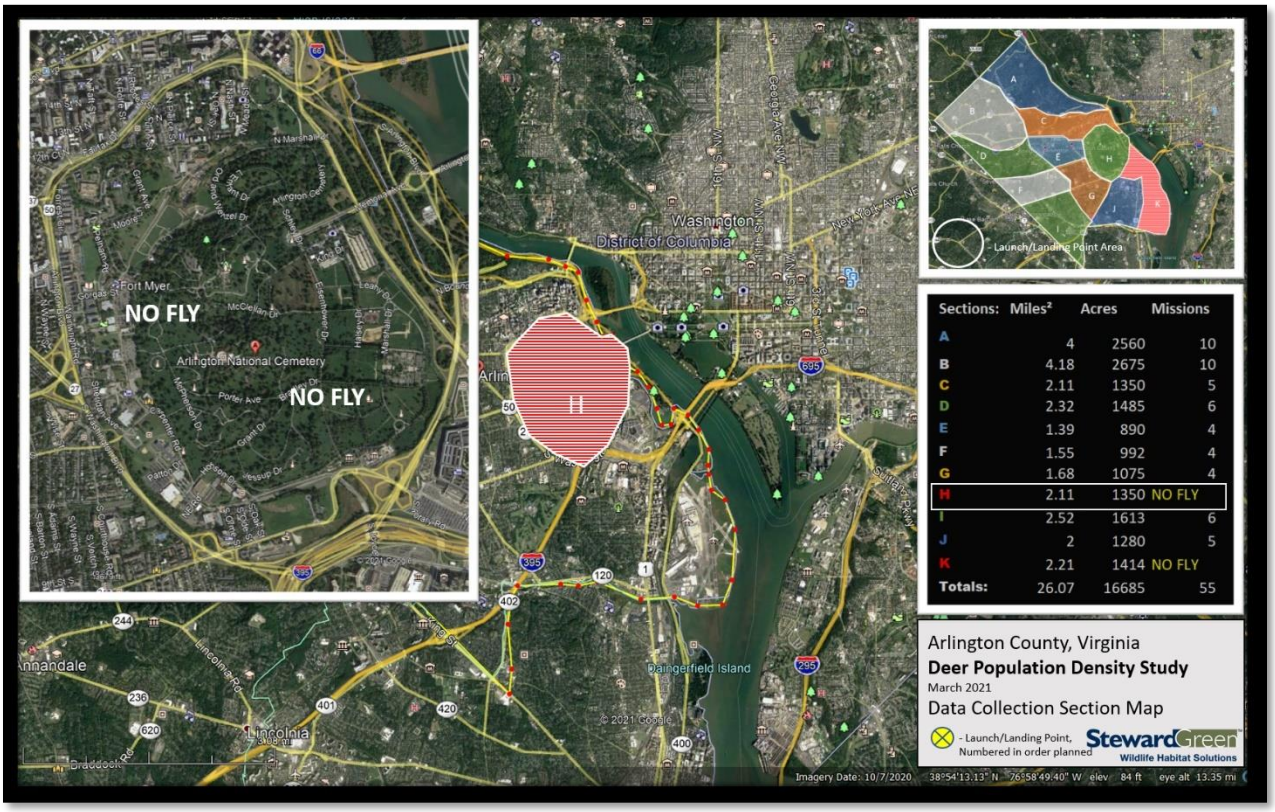
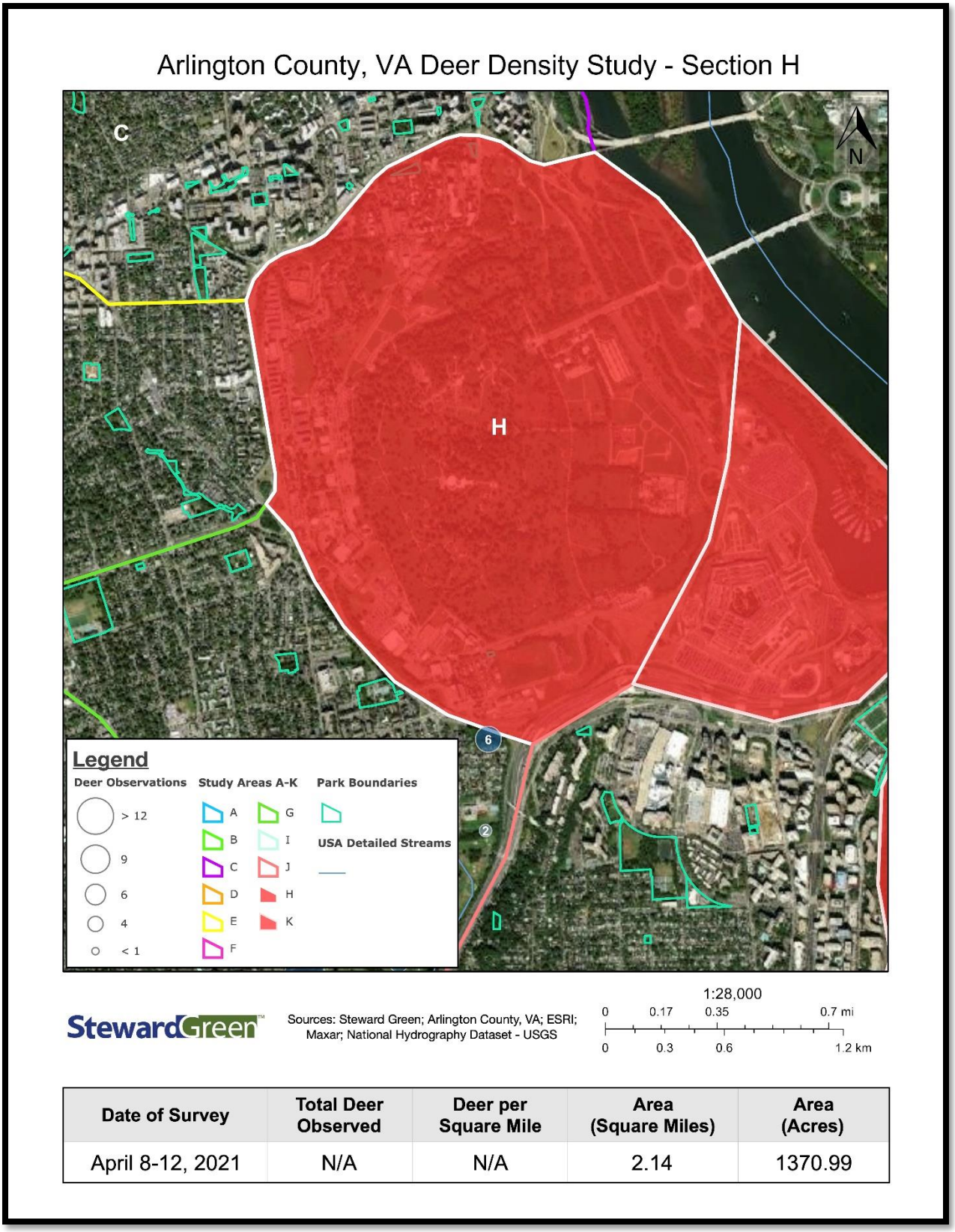


Figure 38. Section H No Fly Zone



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	N/A	N/A	2.14	1370.99

Figure 39. Section H No Fly Zone

Section I was flown on Sunday, April 11, we flew 6 missions and observed 19 deer in total on 1,581 acres.

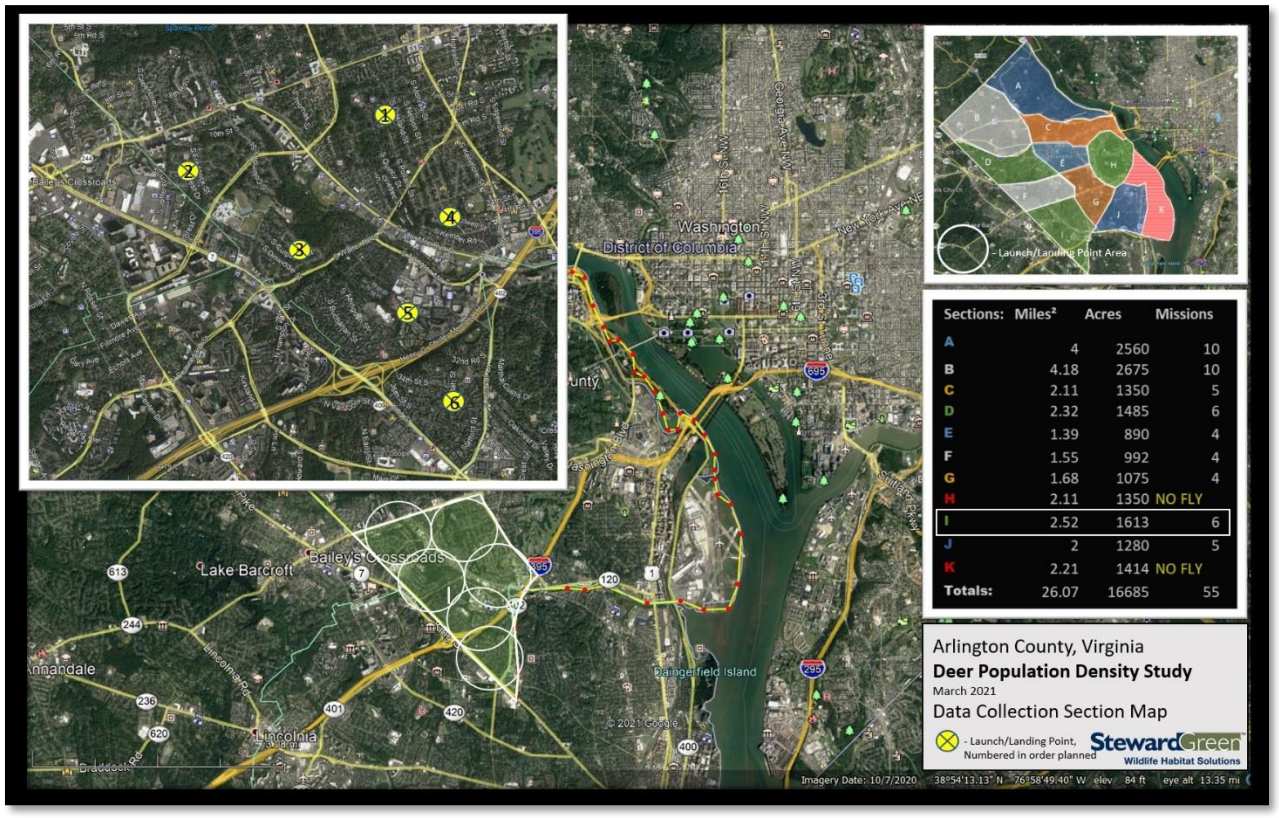
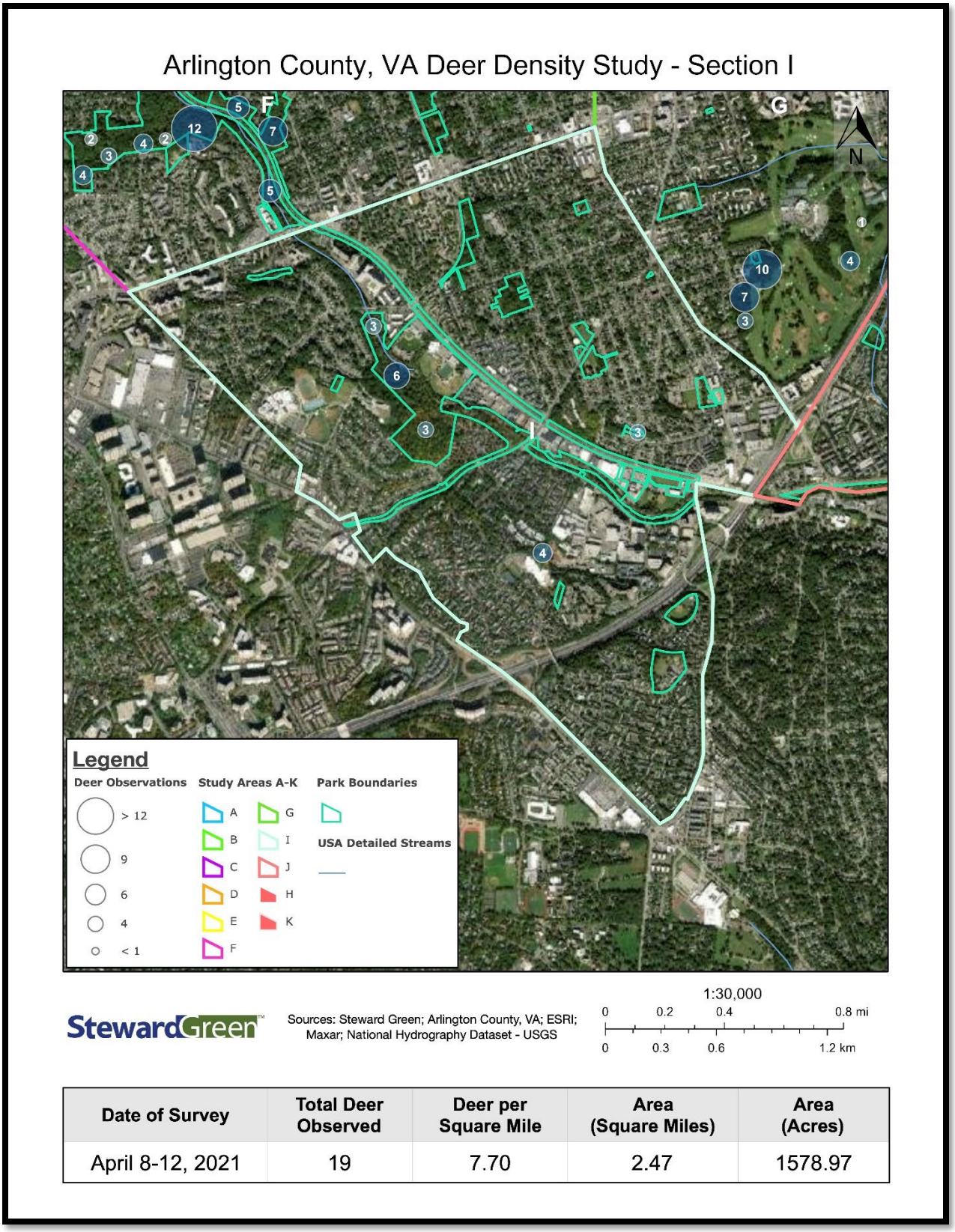


Figure 40. Section I launch/recovery map



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	19	7.70	2.47	1578.97

Figure 41. Section I results

Section J and Section C were the two sections we did not confirm deer. We flew 1,395 acres, flying 3 missions on Sunday, April 11. We specifically flew Section J on Sunday morning to anticipate the least amount of air traffic from DCA, a decision that was rewarded with almost no air traffic that morning. Crystal City was also in Section J, providing a bit more of a challenge as TSA required a reduce AGL for UAS flight over that area.

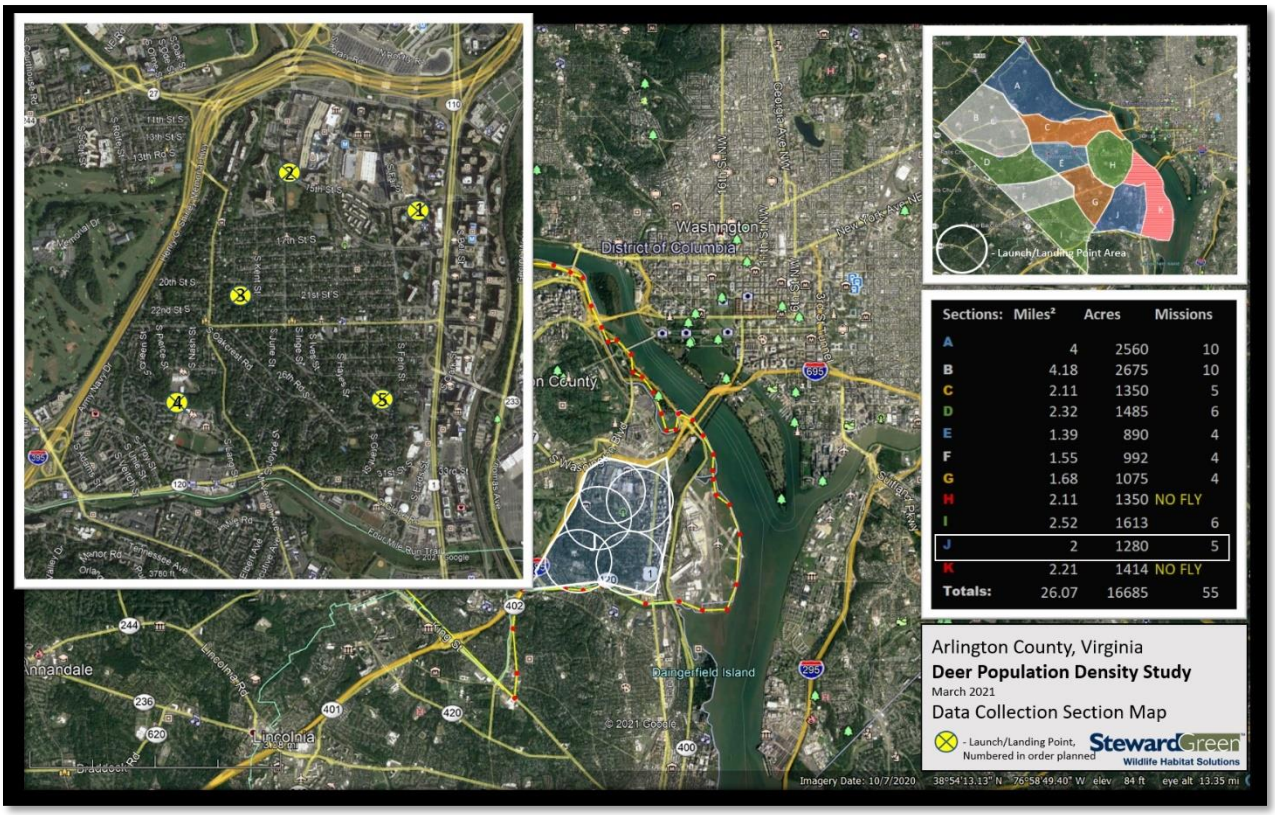
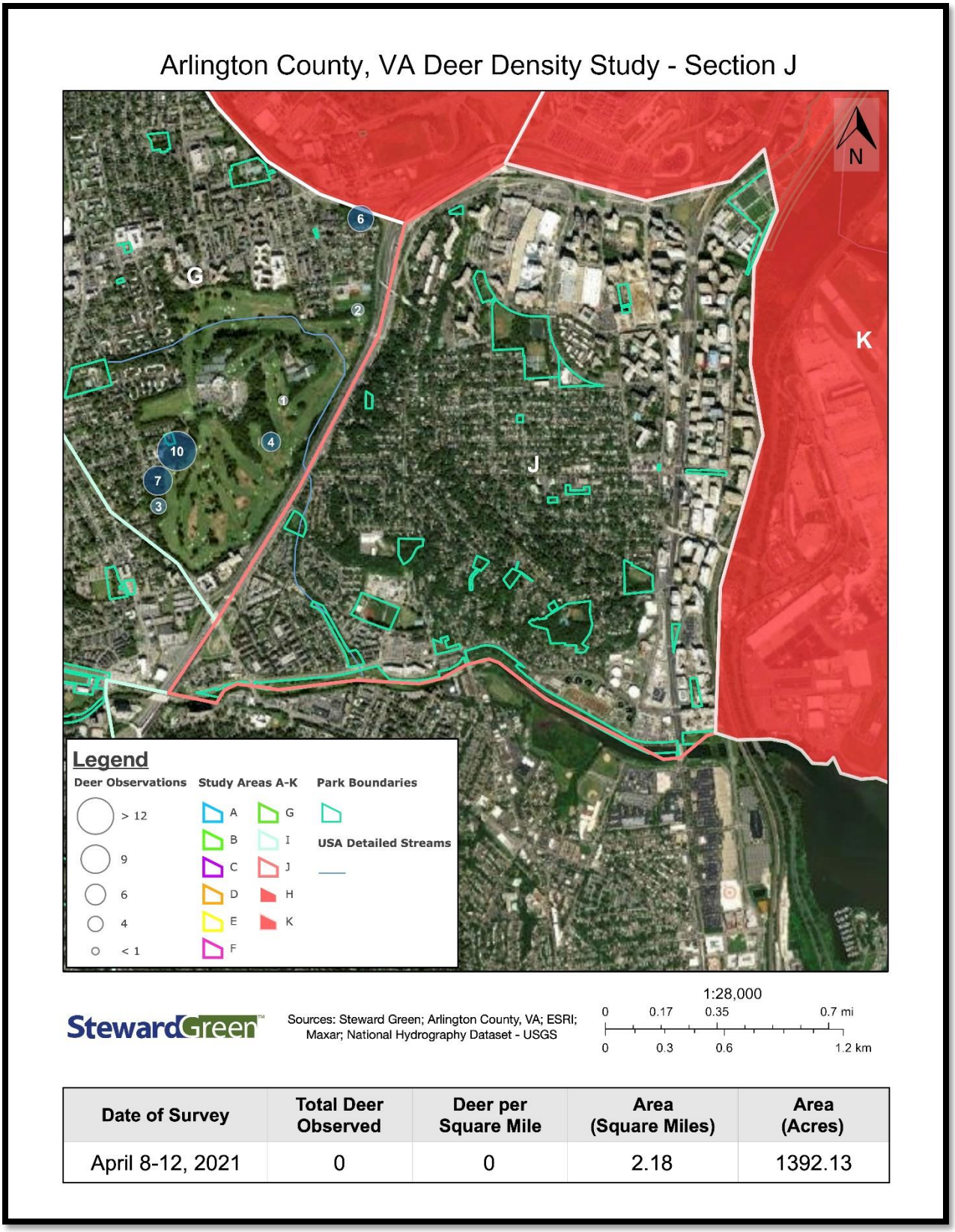


Figure 42. Section J launch/recovery map



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	0	0	2.18	1392.13

Figure 43. Section J results

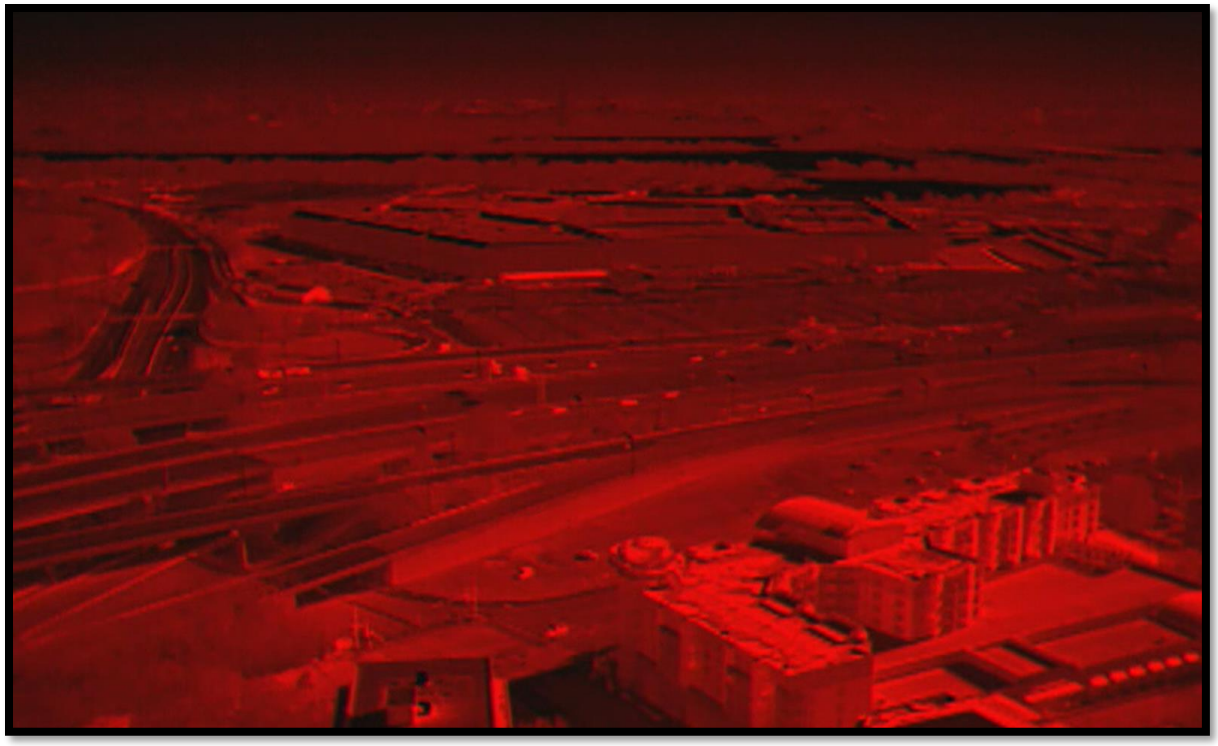


Figure 44. View of Pentagon area from Section J

Section K was another “no-fly” zone due to the Pentagon and Ronald Reagan Washington National Airport.

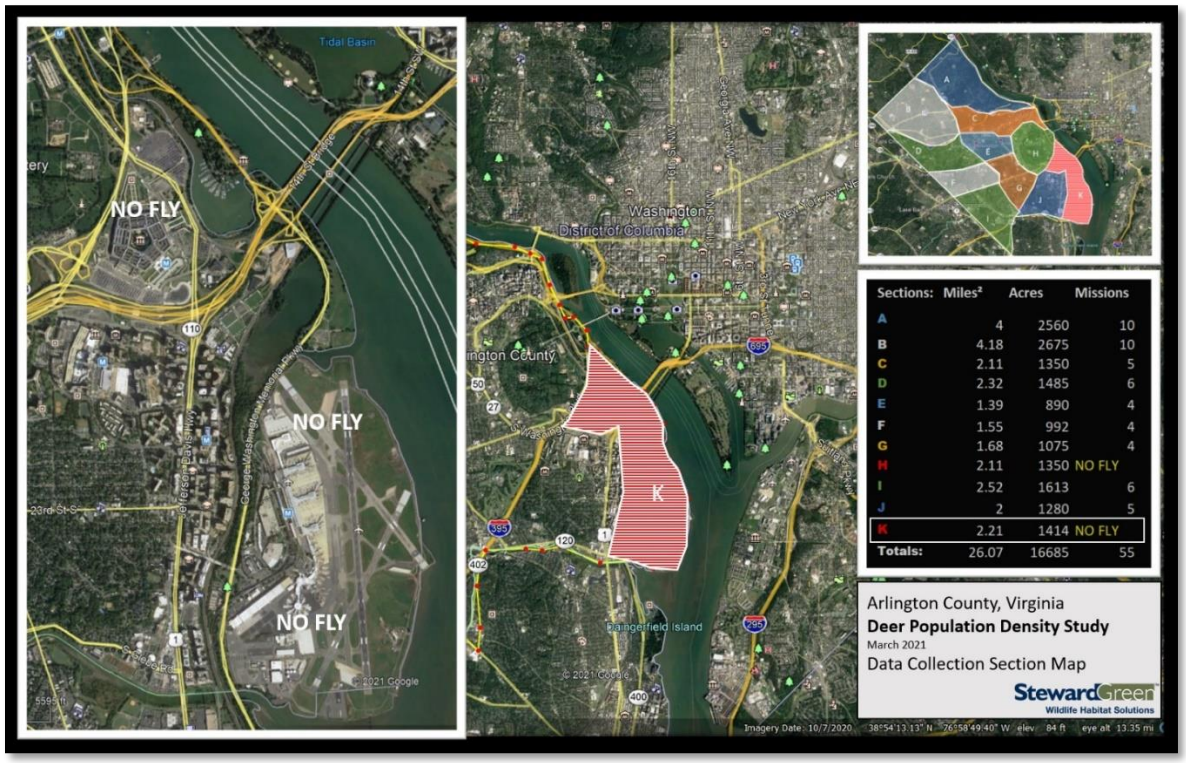
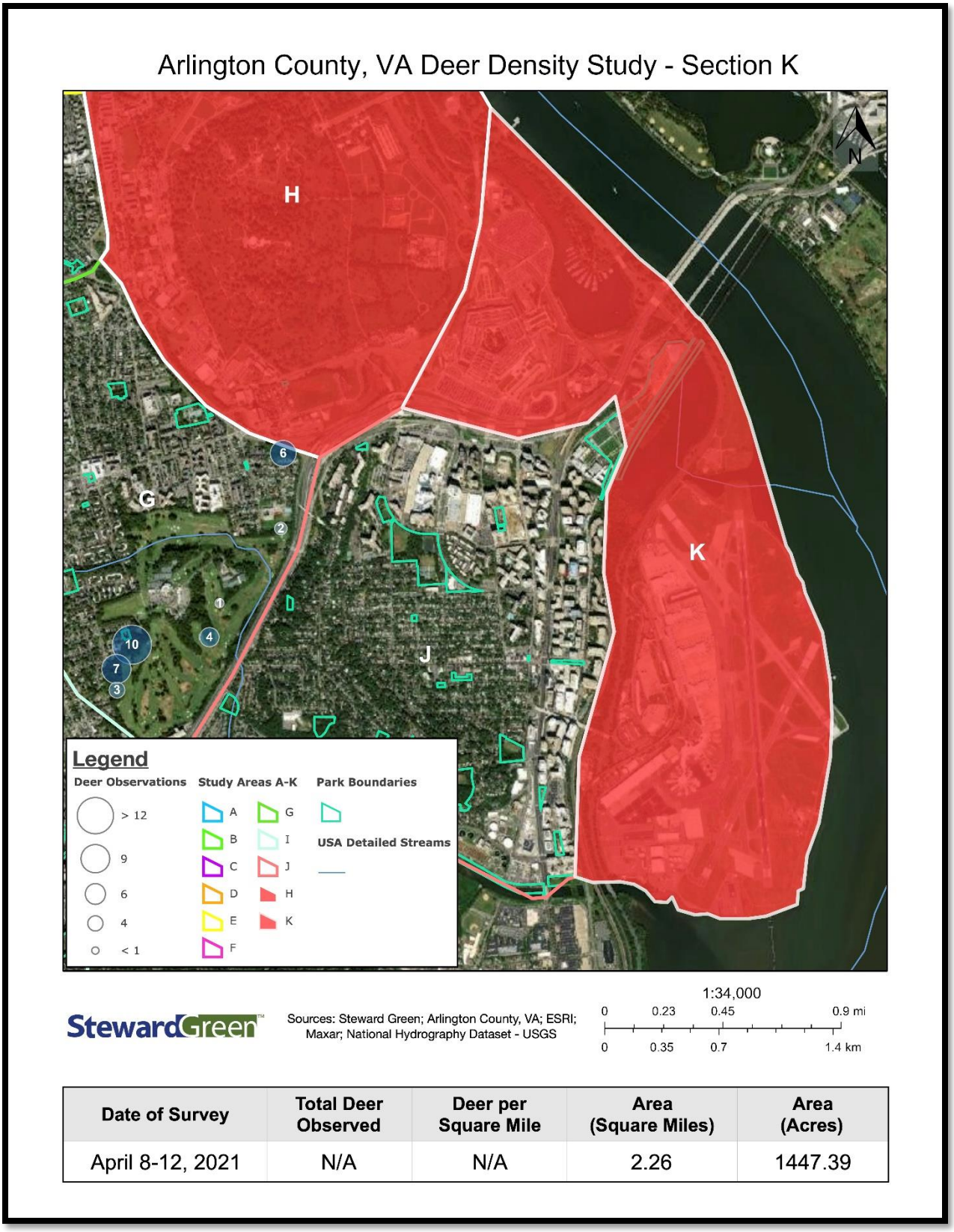


Figure 45. Section K No Fly Zone



Date of Survey	Total Deer Observed	Deer per Square Mile	Area (Square Miles)	Area (Acres)
April 8-12, 2021	N/A	N/A	2.26	1447.39

Figure 46. Section K No Fly Zone

Glossary of Terms

Above Ground Level (AGL) – Height sUAV is above ground level

Aerial – Happening or operating in or from the air.

Calibrate – To correlate the readings of an instrument with those of a standard in order to check the instrument's accuracy; to adjust to take external factors into account or to allow comparison with other data (Lexico 2020).

Carrying Capacity – Maximum number of species supported in an environment, dependent on the health of that environment, without degrading the health of other species or ecosystem services.

Deciduous Trees – Tree species that lose their leaves at the end of their growing season (Biology Dictionary 2020).

Deleterious – Causing harm or damage (Lexico 2020).

Digital – Relating to, using, or storing data or information in the form of digital signals via computer technology (Lexico 2020).

Egress – A way out (Lexico 2020).

Esri Data Collector – A mobile data collection app made to capture and edit data accurately and easily from the field and return it to the office (Esri 2020).

Evergreen Trees – Trees that retain their green leaves/needles throughout the year (Lexico 2020).

Federal Aviation Administration (FAA) – The agency of the US Department of Transportation responsible for the regulation and oversight of civil aviation within the US, as well as operation and development of the National Airspace System. Its primary mission is to ensure safety of civil aviation (SKYbrary 2016).

Fixed Wing – An aircraft designed similar to that of an airplane, allowing for a larger flight range, yet requiring a larger takeoff/landing zone (DroneDeploy 2017).

Flight Restricted Zone (FRZ) – areas restricted by FAA, TSA and Homeland Security from flight, in the case of this report, areas restricted from UAS flights.

Flora – The plants of a particular region, habitat, or geological period (Lexico 2020).

Forest Ecology – The scientific study of the interrelated patterns, processes, flora, fauna, and ecosystems in forests (Wikipedia 2020).

Fauna – Also known as "wildlife"; the animals of a particular region, habitat, or geological period (Lexico 2020).

Forest Regeneration – The act of renewing tree cover by establishing young trees naturally or artificially (Watson et al. n.d.).

Forest Understory – Also known as "undergrowth" or "underbrush"; refers to the underlying layer of vegetation (saplings, shrubs, and other plant life) growing beneath a forest's canopy.

Forward-Looking Infrared (FLIR) – Technology that detects thermal energy, or variances in heat.

Heat Signature – A visual representation of the unique exterior temperature of an object or living thing.

Image Overlap – The amount by which one photograph includes the area covered by another photograph and is typically expressed as a percentage (Natural Resources Canada 2016).

Infrared – Electromagnetic radiation having a wavelength just greater than that of the red end of the visible light spectrum but less than that of microwaves. Infrared radiation wavelengths range from 800 nm to 1 mm and are emitted particularly by heated objects (Lexico 2020).

Ingress – A place or means of entrance or access (Lexico 2020).

Law Enforcement Officer (LEO) – Required by FAA, TSA and Homeland Security, the LEO is a mandatory presence with the PIC for any UAS mission in the FRZ and 15 mile radius SFRA.

Maximum Count – Includes deer counted in the data that have been confirmed, plus deer that are likely, but not confirmed. These numbers are considered probable yet have not been confirmed due to poor visibility or obstacles obstructing the line of vision.

Minimum Count – Deer counted in the data that have been confirmed by an experienced professional/wildlife biologist based on shape, size, scale, movement, habit, etc. and has not already been counted.

Mission – A flight conducted for the purpose of collecting data. Multiple missions may be flown from the same launch/landing site if necessary.

Over-browsing – Eating vegetation so much that it becomes detrimental to the environment.

Photogrammetry – The use of photography in surveying and mapping to measure distances between objects (Lexico 2020).

Pilot in Command (PIC) – The person controlling the sUAV and ultimately responsible for the entire operation, cause and effect of the drone as per Part 107 of FAA rules and regulations

Population Density – Represents the number of species within a specific measured area.

Repeatability – The capability of performing the process of data collection in repetition, increasing efficiency and accuracy of the study.

Sampling Areas – Sub-areas of study defined by counties, townships, city blocks, or other well-defined geographic sections of the population of which the survey is being conducted.

Site Reconnaissance – A daytime survey to identify actual and potential hazards, to become familiar with the layout of the sampling site, and to identify launch/landing locations and access to said locations.

Special Flight Rules Area (SFRA) – The National Capital Region is governed by a Special Flight Rules Area (SFRA) within a 30-mile radius of Ronald Reagan Washington National Airport, which restricts all flights in the greater DC area. The SFRA is divided into a 15-mile radius **inner** ring and a 30-mile radius **outer** ring. Flying an unmanned aircraft within the 15-mile radius **inner** ring is prohibited without specific FAA authorization. (FAA 2020)

Strip Transects – A methodology that involves defining a strip of a certain width within the area of study, collecting data only within these constraints. The estimated densities are then extrapolated to the uncovered areas to gain a population estimate (Aars 2019).

Temporary Flight Restriction (TFR) – A type of Notice to Airmen (NOTAM) that defines an area restricted to air travel due to a hazardous condition, a special event, or a general warning for the entire FAA airspace (FAA n.d.).

Thermal – Relating to heat (Lexico 2020).

Ungulate – A hoofed mammal (Lexico 2020).

Unmanned Aerial System (UAS) – Or a small Unmanned Aerial System (sUAS) describes a drone system, complete with ground station, hardware, software, displays, etc., necessary for flight. sUAS's are UAV's that weigh less than 55lb.

Unmanned, or uncrewed Aerial Vehicle (UAV) – a drone, the actual unit that takes flight.

Vertical Take-Off and Landing (VTOL) – Single or multiple rotor aircraft capable of taking off, hovering, and landing vertically, allowing for greater maneuverability.

Visual Observer (VO) – The person responsible for maintaining situational awareness and visual line-of-sight, as well as for alerting the rest of the crew about potential hazards during sUAS operations (UAV Coach).

Steward Green LLC has been consulting clients for many years in conservation, wildlife habitat regeneration and ecosystem services development. Our lead consultant has been performing successful heat signature work since 2001, starting with helicopter, then airplane mounted Forward-Looking Infrared (FLIR). In 2013, we started using sUAS with thermal infrared sensors as the technology became more reliable, the data collected with better quality, more affordable and safer than traditional methods. This report was authored by Gene Huntington and Ellie Huntington, Steward Green, edited by Alonso Abugattas Jr, Arlington County Department of Parks and Recreation. Final editing and formatting by Cameron McKenzie, Steward Green.

Mapping. All maps throughout this report were created by Steward Green™ unless otherwise stated, using ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used herein under license. Copyright © Esri. All rights reserved. For more information about Esri® software, please visit www.esri.com. All data included in this report was collected in the Winter of 2021 using thermal imagery obtained by sUAS. Data was recorded in the field using the Collector for ArcGIS data collection application. Imagery was later reviewed to ensure data accuracy. All maps were created using the Web Mercator coordinate system.

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, Esri ArcGIS World Imagery Base Layer, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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