2021

Analysis of Amur Honeysuckle Stem Density as a Function of Spatial Clustering, Horizontal Distance from Streams, Trails, and Elevation in Riparian Forests, Greene County, Ohio

Greg Michael Grierson Jr.
Wright State University

ANALYSIS OF AMUR HONEYSUCKLE STEM DENSITY AS A FUNCTION OF SPATIAL CLUSTERING, HORIZONTAL DISTANCE FROM STREAMS, TRAILS, AND ELEVATION IN RIPARIAN FORESTS, GREENE COUNTY, OHIO

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science

By

GREG MICHAEL GRIERSON JR.

B.A. Wright State University, 2019

2021

Wright State University

WRIGHT STATE UNIVERSITY

GRADUATE SCHOOL

April 28, 2021

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Greg Michael Grierson Jr. ENTITLED Analysis of Amur honeysuckle Stem Density as a Function of Spatial Clustering, Horizontal Distance from Streams, Trails, and Elevation in Riparian Forests, Greene County, Ohio BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science.

Christopher Barton, Ph.D.
Thesis Director

Chad Hammerschmidt, Ph.D.
Interim Chair, Department of Earth and Environmental Sciences

Committee on Final Examination:

David Peterman, Ph.D.

Ryan McEwan, Ph.D.

Barry Milligan, Ph.D.
Vice Provost for Academic Affairs
Dean of the Graduate School

ABSTRACT

Grierson Jr., Greg Michael. M.S., Department of Earth and Environmental Sciences, Wright State University, 2021. Analysis of Amur honeysuckle Stem Density as a Function of Spatial Clustering, Horizontal Distance from Streams, Trails, and Elevation in Riparian Forests, Greene County, Ohio

The non-native invasive shrub Amur honeysuckle—*Lonicera maackii* (Rupr.) Herder (Gorchov and Trisel, 2003)—is one of the most prolific invasive plant species across Midwestern and Northeastern landscapes of the United States. The locations of 2,095 individual Amur honeysuckle stems were geolocated using handheld GPS units in the understory of mixed growth forests at two study sites located approximately 5 km apart in northwestern Greene County, OH. Each site has undergone different levels of anthropogenic disturbance through time. The stem position data was used to measure the spatial clumping distribution and the density of Amur honeysuckle. The spatial clumping of Amur honeysuckle stems was measured using the fractal box counting method at each study site without regard for streams, trails, or elevation. The density of Amur honeysuckle (number of stems per square meter) was measured in zones as a function of the horizontal distance perpendicular to the edge of streams, trails, and within elevation (area between contour lines).

Amur honeysuckle density is found to be uncorrelated with its proximity to streams, trails, and elevation. The density of Amur honeysuckle as a function of distance from streams and trails does not reveal an edge effect. The fractal dimension (scaling exponent) was computed to be ~1.5 at each of the two sites which means that the spatial clustering is the same for actively managed (partial Amur honeysuckle removal) and unmanaged sites. These results suggest that the invasion potential of Amur honeysuckle is robust, and its distribution may not be constrained in riparian forests by the variables included in this study.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Figure Page

LIST OF TABLES

LIST OF EQUATIONS

Equation Page

LIST OF ACRONYMS

NRCS – National Resource Conservation Service

ODNR – Ohio Department of Natural Resources

USDA – United States Department of Agriculture

SPI – Section of Foreign Plant Investigation

SCS – Soil Conservation Service

NISC – National Invasive Species Council

FRMP – Five Rivers MetroParks

PAR – Photosynthetically Active Radiation

MoMBA – MetroParks Mountain Bike Area

WSU – Wright State University

GPS – Global Positioning Satellite

UTM – Universal Transverse Mercator

NGS – National Geodetic Survey

DDM – Decimal, Degrees, Minutes

ACKNOWLEDGEMENTS

I would like to express my gratitude to my advisor Dr. Christopher Barton and committee members, Dr. David Peterman and Dr. Ryan McEwan for their continued guidance and support. Dr. Barton and Dr. Peterman have both given assistance regarding the arduous processing of the data. Dr. McEwan's expertise in Amur honeysuckle has been very helpful during the interpretation stage of this study. My sincere thanks to Wright State University for the Graduate Teaching Assistantship and Stipend during the 2020-2021 academic year. Thanks to the Conservation Department of Five Rivers MetroParks, and other members of the Five Rivers MetroParks agency for their wealth of information about their invasive species management protocols, expenses, and trail development strategies at MetroParks Mountain Bike Area. I would like to thank my wife and my parents for their unwavering support and assistance throughout this experience. Pursuing a higher education would not have been possible without their help.

1.0 INTRODUCTION

Throughout this report, the common name Amur honeysuckle, for *Lonicera maackii* (Rupr.) Herder (Gorchov and Trisel, 2003) is used. Amur honeysuckle is an invasive shrub that has broadened its range to many areas across the United States (Gorchov and Trisel, 2003; Rachel Elizabeth McNeish et al., 2018; Shields et al., 2014). This invasive shrub has the potential to further disrupt terrestrial-aquatic ecosystem connections which could alter food-web dynamics for animal populations and communities (McNeish and McEwan, 2016). Additionally, anthropogenic development in these sensitive areas could further enhance the density of Amur honeysuckle.

1.1. Amur honeysuckle - Botanical Description and History of Dispersion

Amur honeysuckle is a non-indigenous, woody perennial shrub that can grow up to 5 m in height (Figure 1A). This multi-stemmed shrub, of the family Caprifoliaceae, invades many temperate ecosystems outside of its endemic distribution, including Ohio (Hutchinson and Vankat, 1998). Its distribution is independent of many factors compared to other plants (shade tolerance, drought tolerance, heat and severe cold). However, the United States Department of Agriculture reports Amur honeysuckle to grow in areas with soil pH between 5.5–8.0. The National Resource Conservation Service (NRCS) and Ohio Department of Natural Resources describes Amur honeysuckle as having oppositely arranged leaves that are ovate to lance-ovate in shape and measure 3.5-8.5 cm long (Smith, 2010) and (Figure 1B). NRCS states that the leaves are dark green above and lighter on the lower surface with acuminated tips and pubescent veins. The flowers measure 1.5-2 cm long, are bilabiate, white, and found in erect pairs that are on the stalk bearing the flower or fruit (peduncles) shorter than the stalk that joins the leaf to the stem (petioles) (Figure 1B). The flowers appear on the plant during the reproduction period, much later than other honeysuckles—late May to early June (USDA Forest Service, 2010). The NRCS states that the fruit are dark red in color, spherical in shape, measure 6 mm in diameter and become ripe on the plant in the late fall (Figure 1B). The fruit will not appear on Amur honeysuckle until the plant has reached 3 – 5 years old (Luken and Thieret, 1996).

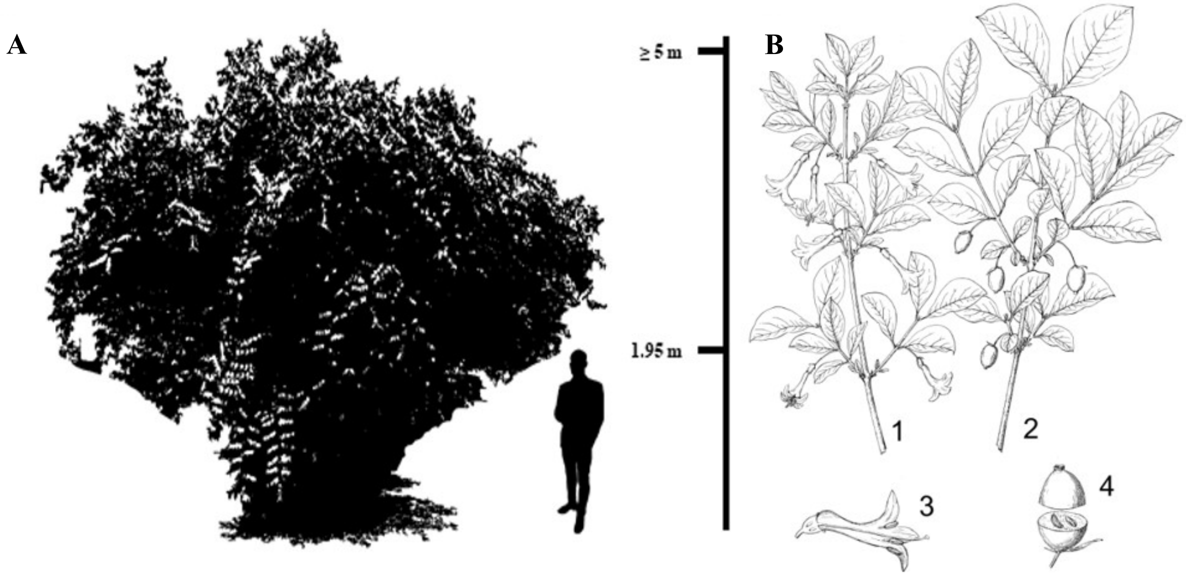

Figure 1: (A) Amur honeysuckle silhouette with a height ranging from 1.95m to greater than or equal to 5m. (B) Illustration of Amur honeysuckle showing floral stem (1), fruit stem (2), flowering body (3), and fruit (4). (A) and (B) were modified from Cuantu (2021; CleanPNG.com).

The fruits persist on the branches into the winter and wildlife feed on them and further scatter the seeds (Guiden et al., 2015); particularly from deer through frugivory at greater distances (Castellano and Gorchov, 2013). Birds feed on the seeds and defecate them which further disperses Amur honeysuckle from its parent plant—but at minimal distances (Hutchinson and Vankat, 1998). Another possible mechanism of dispersal could be headwater streams after large fruit-drops leading to larger order streams and rivers.

Amur honeysuckle originated in Northeastern Asia, from Southeastern Russia to Northwestern China (Luken and Thieret, 1996; Hutchinson and Vankat, 1997; Pfeiffer and Gorchov, 2015). The dispersal pathway of this species from its endemic range to Ohio is a mixture of botanical exploration and experimental propagation. The pathway to The United States began with a nine-month Russian botanical expedition, from Irkutsk to the Amur and Ussuri River valleys near the East China Sea beginning in April 1855 when naturalist, and professor, Richard Maack of St. Petersburg University, Russia collected and documented numerous plant species (Bretschneider, 1898). Maack propagated Amur honeysuckle in the St. Petersburg Botanical Garden in 1883 (Bretschneider, 1898; Luken and Thieret, 1996). The first documented introduction from Russia to the United States was in 1897 when United States Secretary of Agriculture (USDA) James Wilson selected Niels Hansen to gather cold-tolerant alfalfa and Amur honeysuckle became a species of interest to Hansen (Luken and Thieret, 1996). The first documented introduction to the United States from Great Britain was in 1898, when Amur honeysuckle was introduced by Ernest H. "Chinese" Wilson (Figure 2), during a "Plant Introduction Experiment" conducted by the (USDA) Section of Foreign Plant Investigation (SPI) in Washington, D.C. At the time of the experiment (1898) seeds were dispersed to the New York Botanical Garden (Luken and Thieret, 1995/1996). After USDA and SPI supplied the Soil Conservation Service (SCS) with viable seeds, the success of SCS cultivar releases between the 1960s – 1984 lead to Amur honeysuckle spreading to parts of New England, Michigan, even Texas via commercial nurseries, private gardeners, and the SCS (Luken and Thieret, 1995,1996; Figure 2). No one has documented where and when it came into Ohio or how it spread throughout the state, but Braun (1961) stated Amur honeysuckle arrived in Hamilton County, Ohio between the 1960s and 70s.

The high tolerance of Amur honeysuckle, to a broad range of habitats, gives it the ability to extend over a range of climate zones and soil types (Bauer et al., 2012; Lieurance and Landsbergen, 2016; McEwan et al., 2010). The success of Amur honeysuckle can also be attributed to other biological factors which inhibit the growth of endemic flora and increase the competitiveness of this invasive species. These factors include potential allelopathic toxins, extended-leaf phenology, and dense shrub canopy (Bauer et al., 2012; Borth et al., 2018; Custer et al., 2017; Demars and Runkle, 1992; Hopfensperger et al., 2017; Hutchinson and Vankat, 1997, 1998; McEwan et al., 2010).

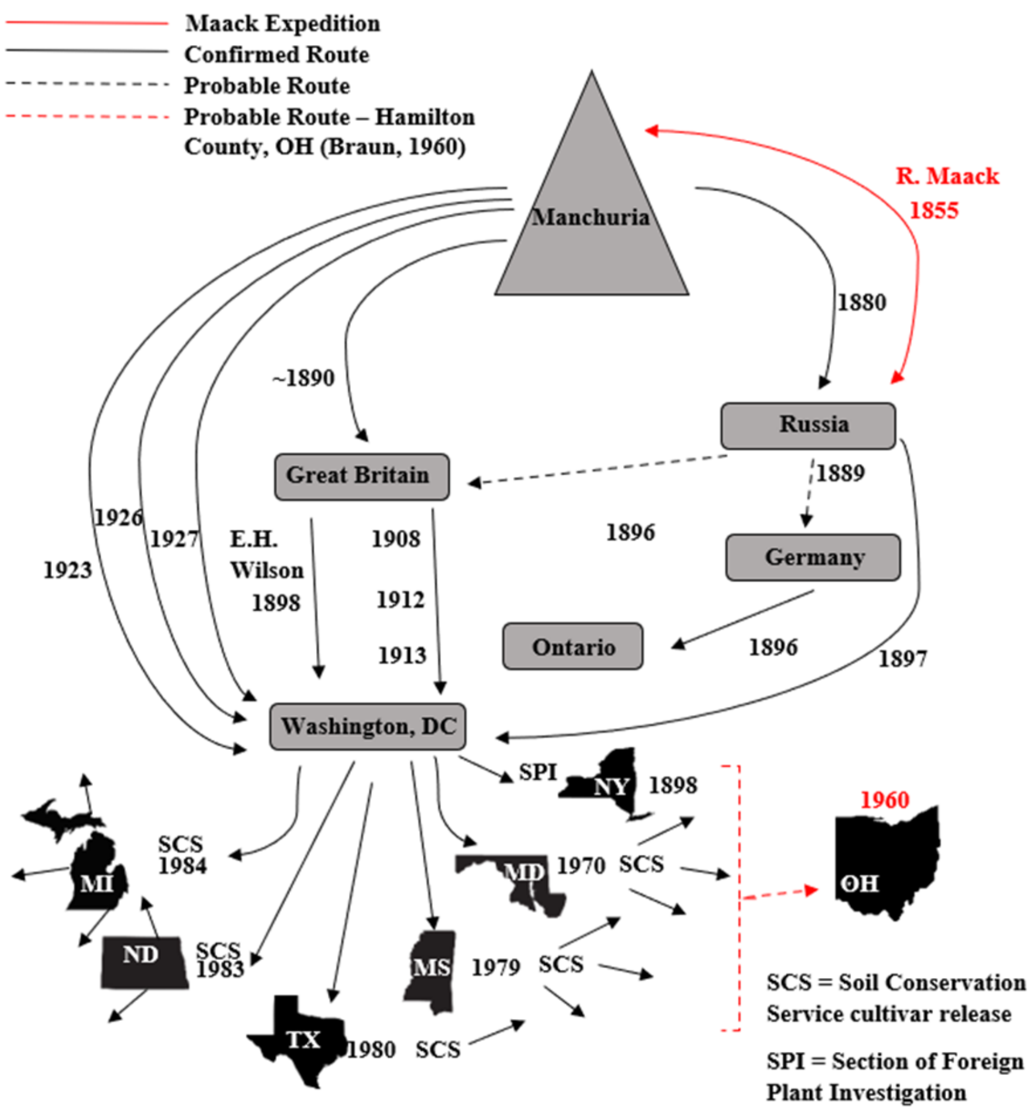

Figure 2: Amur honeysuckle origin in Manchuria and distribution through time. Dotted black lines are probable routes of distribution and solid black lines are confirmed routes of distribution. Solid Red line indicates the Maack expedition to Amur River Valley and the dotted red line indicates probable route based on Braun's observation of Amur honeysuckle in Hamilton County, OH (1960). Modified from (Luken and Thieret, 1996). Note distribution in USA was first in New York state and then in Ohio 62 years later.

1.2. Previous Work

Managing invasive species often involves multiple efforts throughout the stages of invasion. Prevention of transport and/or introduction is the primary means to avoid an ecosystem invasion, which damages endemic communities and has adverse economic impacts (Congressional Research Service, 2017; Shields et al., 2015). The National Invasive Species Council (NISC) reported the sum of interagency federal dollars spent FY2014 – 2016 exceeded \$1.8 billion annually for research, prevention, restoration, control and management of invasive species, including Amur honeysuckle (The National Invasive Species Council, 2015; See Table A.1). Five Rivers MetroParks (FRMP) estimate their expenditures to be ~ \$30,000 annually for Amur honeysuckle management including volunteers, staff, and contractors (Personal communication, Grace Dietsch, FRMP Biologist, 2021).

Ohio Invasive Plants Council and Cascadia Prairie-Oak Partnership state a variety of management/removal strategies for Amur honeysuckle (and other bush honeysuckle). Some examples include cut-stump, basal bark and foliar spray treatments, prescribed burning and mowing/ cutting (Ohio Invasive Plants Council, 2010; Cascadia Prairie-Oak Partnership, 2019). Cut-stump and basal bark treatments are generally performed from fall-to-early-winter before active growth (Cascadia Prairie-Oak Partnership, 2019). Typically, glyphosate is considered the most effective for less sensitive habitats (1% concentration for foliar spray; Ohio Invasive Plants Council, 2010; Communication from Five Rivers MetroParks Biologist, Grace Dietsch, 2021). Triclopyr is another effective chemical treatment but is cautioned when deployed in areas where surface and sub-surface runoff are higher (i.e., riparian areas, bays, watersheds; Netherland and Jones, 2015; Cascadia Prairie-Oak Partnership, 2019). Basal bark treatment methods tend to be more effective than foliar spray for larger honeysuckle and have the potential to protect native species recovery from herbivores (Miller, 1988; Ohio Invasice Plants Council, 2010; Cascadia Prairie-Oak Partnership, 2019).

Caprifoliaceae is a clade of approximately 800 species of dicotyledonous flowering plants including *Lonicera*, one of 42 genera which includes Amur honeysuckle. The published literature contains hundreds of studies of Amur honeysuckle invasion, dispersal, and species disruption a few of which are presented below (Martin et al., 2009; Rachel E. McNeish and McEwan, 2016).

Castellano and Boyce (2007) investigated the relative importance of native woody plant Eastern Red Cedar (*Juniperus virginiana)* and invasive Amur honeysuckle at a roadcut in Northern Kentucky. A spatial analysis was performed by dividing the sampling area into nine 25 m^2 quadrats with 5 m sides. All woody plants within each quadrat (at least 50 cm in height) was given a coordinate (0, 0) relative to the southeastern corner of each quadrat and given one of three height classes (50 – 100 cm, 101 – 200cm, and 201 – 275 cm). Amur honeysuckle is multi-stemmed, and the centermost trunk was used for the sample coordinate (relative to the highest living limb) where five major woody species were calculated as a sum of relative density. Relative density in this context was considered: 1. density of individual species, 2. actual density (undefined) of all species, 3. relative dominance (the degree of dominance a plant species exerts on other opponents). Additionally, the woody plants were measured using an Accupar ceptometer to identify photosynthetically active radiation (PAR). This device measures light interception in dense canopies. A mathematical test of a converging series of data (light above canopy : light below canopy) was used for (PAR) and soil depth at 30 cm below each plant. Ripley's K function (Dixon, 2014) was used to quantify the spatial patterns where the number of extra events (Amur honeysuckle occurrences) within a distance of a randomly chosen event was measured. Additionally, a Non-parametric Mann-Whitney Test was performed to compare differences between two independent ordinal groups (soil depth data and photosynthetically active radiation). Castellano and Boyce (2007) reported an importance value >77% (relative density + relative dominance)/200 for Amur honeysuckle over any native species in the study. This was a significantly higher percentage when compared to the other native species measured (e.g., Eastern

Red Cedar, Green Ash) with importance values between ~ 1 and 13%. Amur honeysuckle colonized wider ranges of soil depths (Castellano and Boyce., 2007). As a result of the PAR test (Eastern Red Cedar favored higher PAR locations compared to Amur honeysuckle), Castellano and Boyce (2007) hypothesized that niche partitioning may have occurred. Therefore, disturbed areas (in this case a roadcut) is an example of anthropogenic disturbance where edges are directly displacing native species (Eastern Red Cedar) and an invasive species (i.e., Japanese honeysuckle) has proliferated.

Cameron et al. (2016) examined the effects of Amur honeysuckle on an Ohio native species, *Acer saccharum* (Sugar Maple), saplings. Of the 16 plots examined, eight of which had Amur honeysuckle and eight had no Amur honeysuckle, seedling recruitment was lower when the size of Amur honeysuckle was greater than surrounding understory vegetation. Contrary to lower seed recruitment, seedling to sapling transition (for Sugar Maple) was evident and could potentially be attributed Amur honeysuckle dense canopy protecting the saplings from herbivory (Cameron et al., 2016; Hutchinson and Vankat, 1997).

Custer et al. (2017) reported negative effects on the aquatic macroinvertebrate, *Hyalella azteca*, from the flower biomass of Amur honeysuckle in riparian headwater streams. Additionally, he reports higher mortality for *H. azteca* when exposed to Amur honeysuckle fruit in in the field compared to laboratory exposures. These findings were among the first to determine a negative linkage between invasive plant parts (flowers and fruit) and a riparian stream organism (Custer et al., 2017).

Merriam (2003) and a team of thirty-eight volunteers measured six non-indigenous plants—one of which was *Lonicera japonica* (Japanese honeysuckle) and their edge preference across North Carolina at six sites. An edge is described as an area where two or more ecological features come together and is widely recognized in created edges (i.e., roads, power lines, bridges, buildings, and farm fields) and landscape patterns where invasive species can thrive (edge preference) because of light availability, native species absence, and disturbed soil (Harper et al., 2005). The field sampling included 417 sub-sites that could be identified on USGS maps (1:100,000) of which six edge types could be identified (streams, rivers, roads, interstates, electrical and railroads) totaling ~177,000 meters of edges measured across the state. He reports that Japanese honeysuckle occupied an average of 25.9% of all edge types per thousand meters of measured occurrence (Merriam, 2003) compared to the other five invasive species in the study with a range of 0.6 – 7.5% edge occupancy. Invasive shrubs like Japanese honeysuckle and Amur honeysuckle have become more naturalized in the Cumberland Plateau and Mountain Region and in other states (See Table A.2) where their continued spread has surpassed invasion and has been considered established (Lemke et al., 2011; Merriam, 2003).

1.3. Purpose of this Study

Determining the spatial clustering distribution of Amur honeysuckle may help to establish a metric for potentially sensitive areas subject to invasion. Heavily invaded areas can serve as a datum for comparison with newly invaded areas. Furthermore, different levels of anthropogenic disturbance can be investigated by comparing invasive species response to human-made features (e.g., hiking trails). With knowledge of potentially sensitive areas, land managers, recreational trail developers and conservation agencies could modify, or adapt, their site plans (trail development, remediation, preservation, etc.) and improve their inventory of plant diversity (native versus non-native) to develop comprehensive risk maps. The purpose of the current study is to measure the spatial clustering and the density of Amur honeysuckle as a function of 1. distance from streams,

2. elevation, 3. distance from human-made trails. These measurements were made at two sites and will be compared based on the degree of anthropogenic disturbance. One site has little or no disturbance, the other site is considered highly disturbed, where disturbance is typically measured by visual evidence, through historical records, or remote sensing. To measure density, areas (termed zones) are established as a function of distance from a stream or trail, or within elevation contours. Human alterations and natural disturbances (i.e., tree-falls, erosional events, forest fires) affect terrestrial landscapes (Runkle, 2013; Stireman et al., 2014) and may affect the susceptibility of riparian forests to invasion by Amur honeysuckle. Disturbances, both natural and anthropogenic, can affect riparian forests at different levels. Amur honeysuckle at streams edge can create opportunities for fruit drops and further dispersal by natural disturbances (i.e., flooding, erosion, etc.; Custer et al., 2017). Anthropogenic disturbances (i.e., logging, runoff, road construction, trail building etc.) can directly alter riparian forests by way of native plant displacement, which can further promote dispersal of Amur honeysuckle as well.

Species invasions are often considered to occur in stages each of which involve complex relationships between invading species and native competitors (Arthur et al., 2012; Castellano and Boyce, 2007; Custer et al., 2017; Rachel Elizabeth McNeish et al., 2018). A passage from Wilson, Panetta, and Lindgren (2017), "*Detecting and Responding to Alien Plant Incursions,"* identifies four main stages of invasion—1. pre-introduction, 2. incursion, 3. expansion, and 4. dominance—which align with their four major management goals—1. prevention, 2. eradication, 3. containment, and 4. impact reduction. The relationship between the four main stages and the four management goals provides a strategy to remediate invaded ecosystems to establish an action plan including: risk maps (based on invasion potential), active and passive surveillance, timelines, budgets and individual species pathways (Castellano and Boyce, 2007; Wilson, Panetta, and Lindgren, 2017).

1.4. Riparian Forests

Riparian zones are among the leading ecotones (a region of transition between any two biological communities) in terms of diversity and complexity (Naiman and Décamps, 1997) which contain vegetation along river and stream margins. Riparian forests are dynamic biophysical habitats which act as a an interface between terrestrial and aquatic ecosystems containing wooded margins along streams or rivers (Naiman and Décamps, 1997; National Research Council, 2002; McNeish et al., 2018). A biophysical habitat is considered any biotic or abiotic surrounding of an organism in an environment. Wildlife use these areas as a corridor for sustenance while other organisms utilize it for dispersal (Moffatt et al., 2004). The width of the streams at both study sites varies from 2 – 5 meters with features including fallen trees, rocks, and sediment overfill. The ability of riparian forests to transfer nutrients, water, and filter pollutants between terrestrial and aquatic landscapes is essential for ecosystem health (Borth et al., 2018; He et al., 2020; McNeish et al., 2018). Invasive shrub Amur honeysuckle has become a hinderance to such processes because of understory domination, nitrogen fixation, and throughfall chemistry (Custer et al., 2017; Gorchov and Trisel, 2003; He et al., 2020; Pfeiffer and Gorchov, 2015; Wilfong et al., 2009). Amur honeysuckle dominates understory vegetation and emits allelopathic toxins altering the aquatic landscape (Borth et al., 2018; Custer et al., 2017).

1.5. Study Areas, Climate and Soil

The spatial clustering and the density of Amur honeysuckle were measured as a function of distance from streams, trails and elevation at two locations. The two locations were the Wright State Biology Preserve (Site 1; Figure 3) and the Five Rivers Metro Parks—MetroParks Mountain Bike Area (MoMBA; Site 2; Figure 3).

The Wright State Woods is combination of three primary stands with a mixture of late successional and early successional growth tree species and is ~ 80,000 m^2. Wright State Biology Preserve (the older-growth portion of the Wright State Woods) study area will be referred to as Site 1 throughout this report. While not entirely meeting the definition of old-growth, Site 1 falls close to the definition because this stand has only been subject to minor selective cutting and natural disturbances over the last 60 years with few trails (Figure 7) (personal communication from Dr. James Runkle, WSU, 2020). Site 1 is within 150 m of the Wright State University Campus South parking area (Lot 13), two roads and a building (Athletic Pavilion) (see Figure 7).

The Five Rivers MetroParks Mountain Bike Area (MoMBA) will be referred to as Site 2. Site 2 is also close to meeting the definition of old growth but is more anthropogenically disturbed due to mountain bike-optimized trails and features (e.g., ramps, jumps, berms, bridges) (personal communication from Eric Sauer, Manager of Planning, Five Rivers MetroParks, 2019). MoMBA has ~ 14 kilometers of mountain-bike-only trails cutting across topography (slopes both natural and engineered/ gradual and steep). Site 2 is within MoMBA between a park boundary with an agricultural farm (~ 50 m away) to the northeast at slightly higher elevation. The primary management goals of Amur honeysuckle for this recreational area are 1. trail access 2. minimal branch interference for mountain bikers and 3. improved sight-lines for mountain biker safety (personal communication from Mark Allen, Trail Specialist, Five Rivers MetroParks, 2021).

These two sites provide an opportunity to compare the degree of influence of anthropogenic disturbance on the severity of Amur honeysuckle. Both sites are in Bath Township, in northwestern Greene County, in southwestern Ohio. Site 1 is located at longitude -84°3' W and latitude 39°46' N (Figure 3). Site 2 is located at longitude -84°09' W and latitude 39°81' N (Figure 3). The climate of Greene County, OH is described as continental with significant variation in annual temperature, where summers are hot and dry, and winters are very cold (Demars and Runkle, 1992).

Figure 3: Satellite image showing the Location of the two study sites – White circle in the SE corner is Site 1 – white square in the NW corner is Site 2.

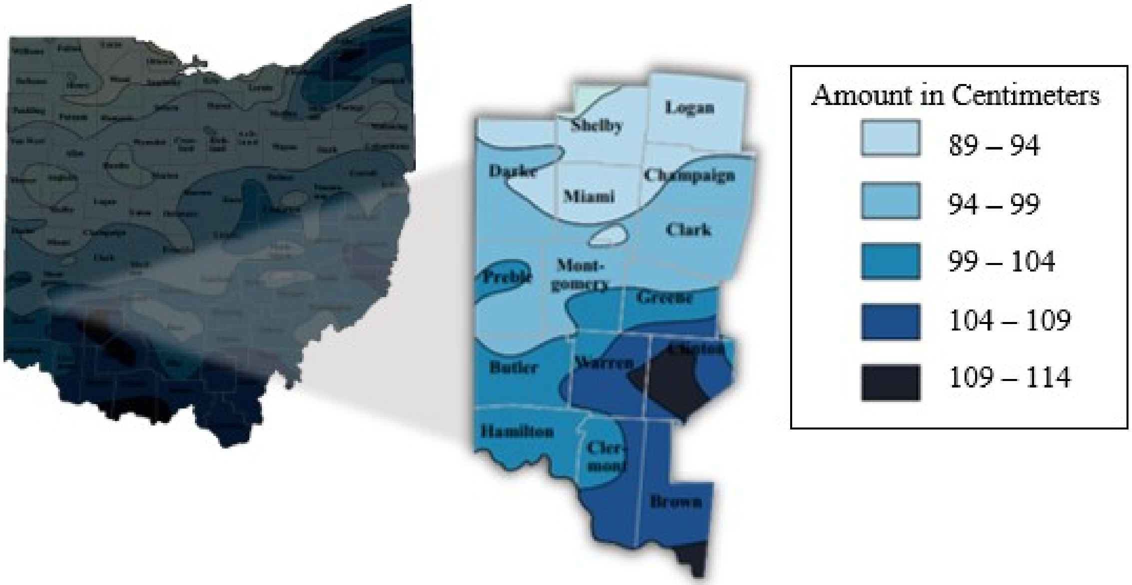

Figure 4: Map of Ohio contoured, and color coded to show the range of annual precipitation (Left) with a detailed map of southwest Ohio (Center). Modified from the ODNRs Division of Soil and Water 50-year study. This figure was modified from ODNRs Division of Soil and Water 50-year study fact report.

The range in annual precipitation is the same at the two study sites, 94 - 109 cm. Greene County, OH is underlain by glacial till and the till is mostly ground limestone (Department of Natural Resources, 2005). The soils are characterized as mixed soils—Miamian-Kokomo-Eldean with a silty-loam composition ("A-horizon" of 13 – 25 cm deep) and a subsoil of higher clay content ("B-horizon" of 20 – 90 cm deep) which are well-drained (Ohio Department of Natural Resources, 2016). The soil components of Site 1 (Figure 5) are a combination of Miamian (MhD2, MhB) and Kokomo (CeB). The soils components of Site 2 (Figure 6) are a combination of Miamian (MhD2), Miamian-Hennepin (MpE), and Milton (MtC2). The information in Figures 5 and 6 were obtained from the United States Department of Agriculture (USDA) Web Soil Survey Database (2021). Most of the soil for both sites are underlain by upland glacial till with a K_{sat} value (hydraulic conductivity) of 0.02 m/s which is a relatively high value similar to gravel in terms of drainage. The pH for both sites is slightly alkaline around 8 below the zone of disturbance (See soil components; Figure A.22 – A.26) which is hospitable for Amur honeysuckle and corroborates information provided by the National Resources Conservation Service, United States Department of Agriculture, and Hopfensperger et al. (2017).

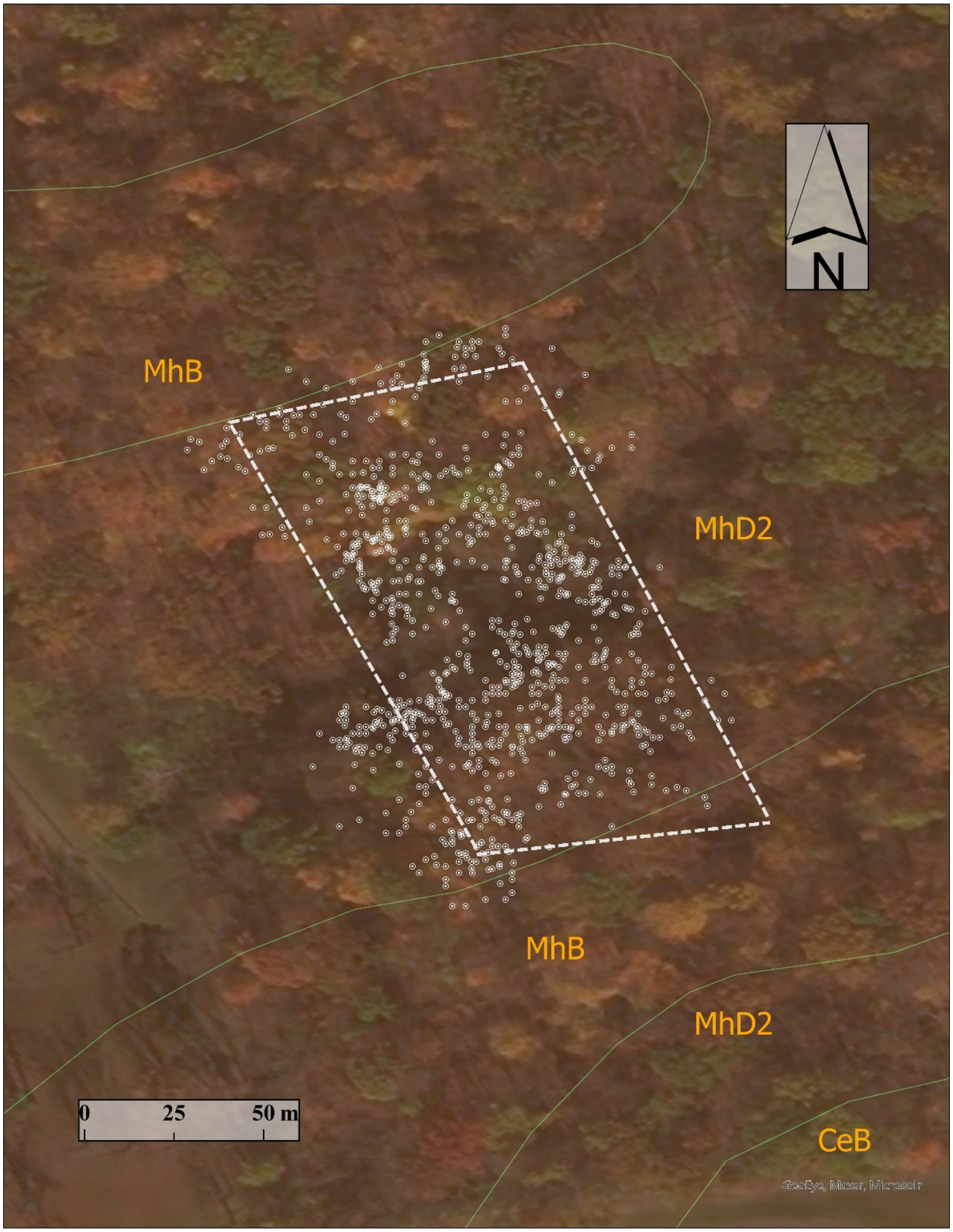

Figure 5: Soils map of site 1. Soil types mapped by the USDA Web Soil Survey Database (2021). Soil components are Miamian (MhD2, MhB) and Kokomo (CeB). 1,030 white dots are Amur honeysuckle stem locations. Original Site boundary in white dashed lines.

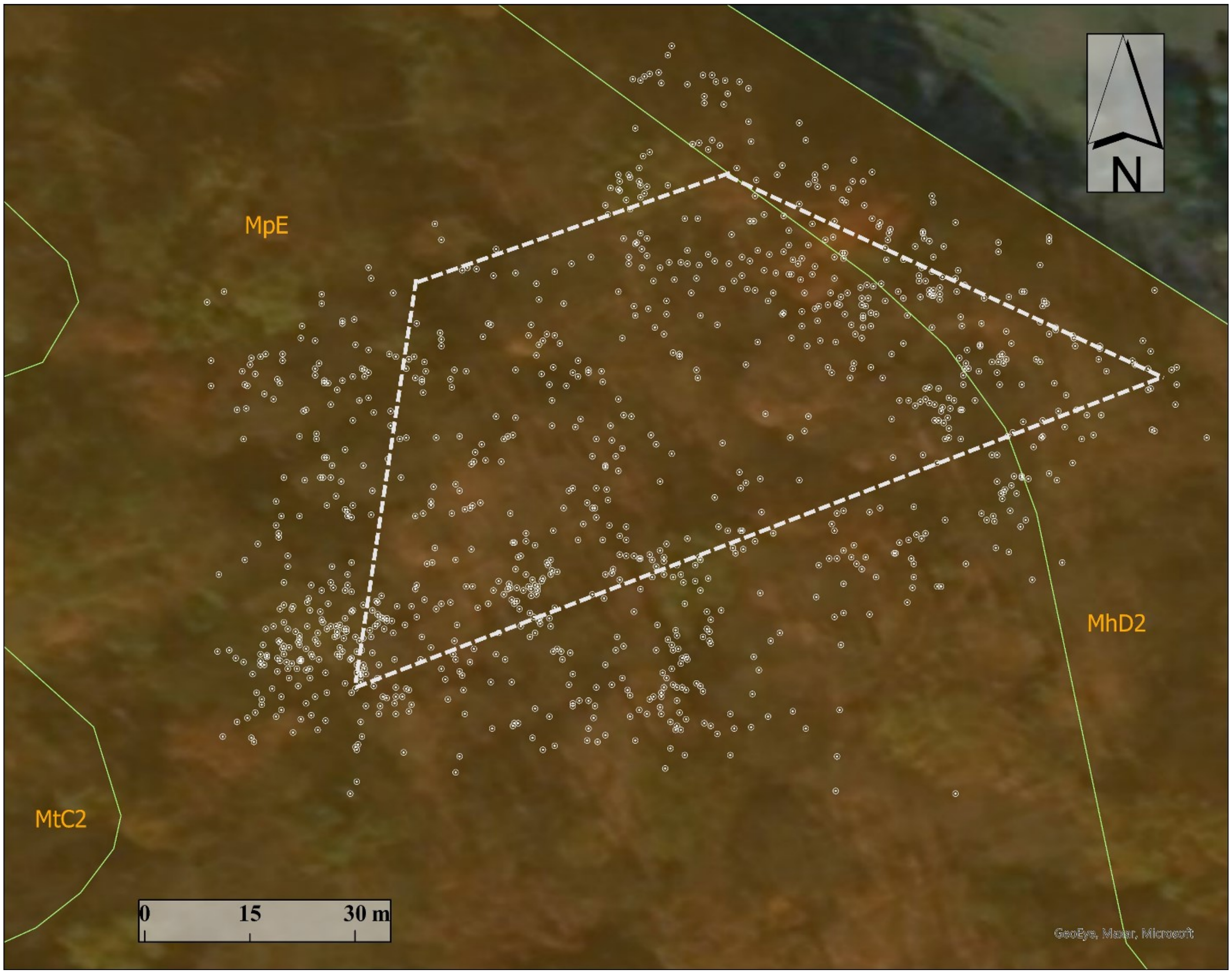

Figure 6: Soils map of Site 2. Soil types mapped by the USDA Web Soil Survey Database (2021). Soil components are Miamian (MhD2), Miamian-Hennepin (MpE), and Milton (MtC2). 1,065 white dots are Amur honeysuckle stem locations. Original Site boundary in white dashed lines.

1.6. Undisturbed Landscapes and Fragmented Landscapes

Long-term monitoring of plant invasions in forests has revealed that the length of time (lag time) between the initial invasion and the spread is often shorter in undisturbed forests (a forest that is established, shows natural age structure, with no significant human intervention) than in disturbed forests (human intervention, clearcutting, fires, established invasion), because invasive species can remain in low numbers (dormant) through time until a disturbance event occurs

(Martin et al., 2009). A forest that is fragmented creates the opportunity for invasive plants to get a foothold and proliferate. Forests are typically fragmented by roads, agriculture, and homes, and can also be broken up by tree-falls from natural disturbance (e.g., windthrow) as observed by Runkle (2013) in an Ohio Beech-Maple forest (Hueston Woods). Landscape modification, or disturbance of any kind, is from the cities farthest edge to the city center (rural-to-urban gradient) and is seen at both Site 1 and Site 2 which implicates direct (physical disturbance, fragmentation) and indirect effects (lesser species diversity) on forest and stream ecosystems (Cameron et al., 2015). In forested watersheds, anthropogenic disturbances (i.e., logging activities, trails, or other construction, agriculture, and recreational activities) can cause stream sediment load which can modify stream hydrology where aquatic life is most affected (Davies and Nelson, 1994; Moffatt et al., 2004). More spatially extensive activities such as cutting, engineering, or species invasion, increases the potential for environmental and biological changes in streams. Such disturbances are important to minimize for streams, riparian buffer strips and trail corridor width design, because they may catalyze invasive species colonization (Castellano and Boyce, 2007; Davies and Nelson, 1994).

Pathways for invasion are exploited by Amur honeysuckle due to its resilience and high density, which depletes nutrient availability and reduces species richness in a variety of North American landscapes (Musson and Mistch, 1999; McNeish et al., 2018). Nutrient richness is evident in aquatic environments and adjacent riparian forests because of many factors including soil moisture, organic material, nutrient availability stream nitrogen dynamics and biomass subsidies (Custer et al., 2017). Anthropogenic contributions include point and non-point source pollution (e.g., agricultural runoff), which exacerbates irregular environmental components such as nitrogen and phosphorous loading in riparian zones (Zhang et al., 2020).

1.7. Recreational Trail Types

Trails and trail construction are complex and are influenced by many factors including location, topography, soil type, access, wildlife, and rare/threatened or endangered species. The interagency definition of a trail was created by United States Forest Service/National Parks Service/ Bureau of Land Management (2002). A trail is "a linear route managed for human-powered, utilization of land by trees for timber, reforestation (stock), or off-highway vehicles, or for historic or heritage values." There are other forms of trails created by wildlife such as canids, equids, cervids and bovids. Recreational trails (for foot travel, camping, bicycling, and off-highway vehicles) promote access with minimal environmental impact away from the trail (Tomczyk et al., 2017). Components of recreation on and off of trails determine its impact on an environment (Cole, 1993; Tomczyk et al., 2017). Among these components, the amount of use, the type of recreational activity, the recreationists conduct, the scale of the recreational activity over a given area, and trail-use through time (Cole, 1993; Kirschbaum et al., 2001; Tomczyk et al., 2017). Additional considerations when designing trails are the slope and water drainage to mitigate trail erosion. Recreational trail design, while dependent on the type of activity, must also consider the specifications appropriate for access and use with conservation in mind. The following specifications for single-use trails are further laid out in accordance to standards created by the Student Conservation Association, International Mountain Bike Association (International Mountain Bicycling Association, 2018), and the U.S. Forest Service Outdoor Recreation Accessibility Guidelines (Forest Service Outdoor Recreation Accessibility Guidelines, 2006).

1.7.1. Design of Foot Trails and Single-Use Bikeways

Foot trails are linear corridors designed for foot travel. The construction of such trails is established by clearing a trail corridor (the area where the trail will be lain). The typical corridor-width is 2 m wide, ~ 1 m on either side of the centerline of the trail and ~ 3 m high over the above the trail to avoid vertical interference from overhead trees or obstacles.

Mountain Bike-optimized trails, or Mountain Bike Only trails, are single-use corridors with mountain bike-optimized features to enhance the mountain biking experience. These optimized features include targeted areas with natural obstacles (large rocks, treefalls, stream crossings) which can be more skills-focused or play-focused (International Mountain Bicycling Association, 2018). The width for mountain bike tread ranges from 0.3 – 0.6 m ,corridor width it is 0.3 – 1.2 m on either side of the tread where tread width and corridor width are designed for different levels of difficulty (Communication from Randy Ryberg, 2021; Five Rivers MetroParks STI, 2021).

2.0 METHODS OF DATA COLLECTION

2.1. Establishing the Site Boundaries

Boundaries were established at both sites using pace measurements, handheld GPS, and pin flags. Pin flags were placed at each corner and their location was recorded using handheld GPS. The purpose of the site boundary was to establish survey limits in the field. The pin flags served as a visual boundary for the stem measurement. A sighting compass was used to maintain the bearing from North to South. Site boundaries were paced in increments of ~ 1.8 m. Topographic features, trees, and natural objects were also used as boundary reference points. The boundaries for Sites 1 and 2 are shown on Figures 5 and 6 as white dashed lines. Note that the site boundaries outline quadrilateral shapes and different boundaries were used to construct zones for measuring the density of Amur honeysuckle stems (see Section 1.5).

2.2. Recording the Location of Amur honeysuckle Stems

The position of Amur honeysuckle stems was measured at Site 1 (Figure. 7) by walking parallel linear transects approximately 3 m apart. The positions of each Amur honeysuckle in front of and between them were recorded. At the end of each transect the data collector turned 180^{o} and repeated the process in the opposite direction (Figure 9). The positions of Amur honeysuckle stems were collected at the two sites with handheld GPS devices. Each Amur honeysuckle stem location was recorded using both GPS devices at Site 1 to reduce sampling time and using one GPS device at Site 2 because one of the two devices was found to have better receiving capabilities. Sampling outside of the site boundaries occurred due to disrupted sight lines from thick vegetation. All recorded stem locations were converted from degrees-decimal minutes format to the Universal Transverse Mercator (UTM) coordinate system in meters with the program Corpscon 6®. The latter coordinate system was used because it utilizes a cylindrical projection system, which corrects for distortions from approximating spherically projected data on a two-dimensional plane.

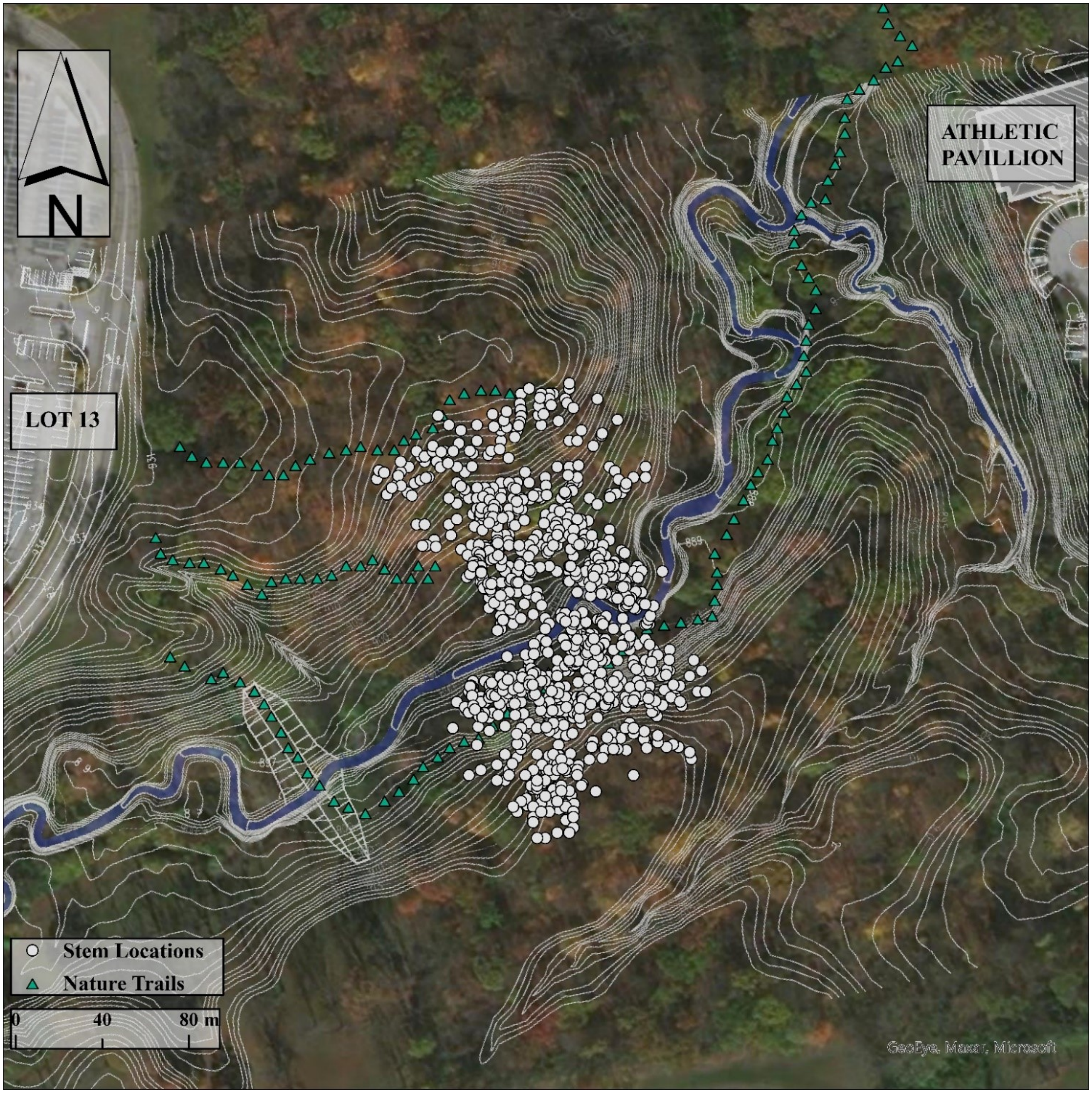

Figure 7: Georeferenced satellite image containing Site 1 with ~0.6-meter contours in ArcGIS Pro Stem locations are shown as white dots (= 2.5 m for visual purposes / not true to scale). Stream is shown in blue. Foot trails are marked by green triangles. The study site area containing the white dots is 9,840m^2

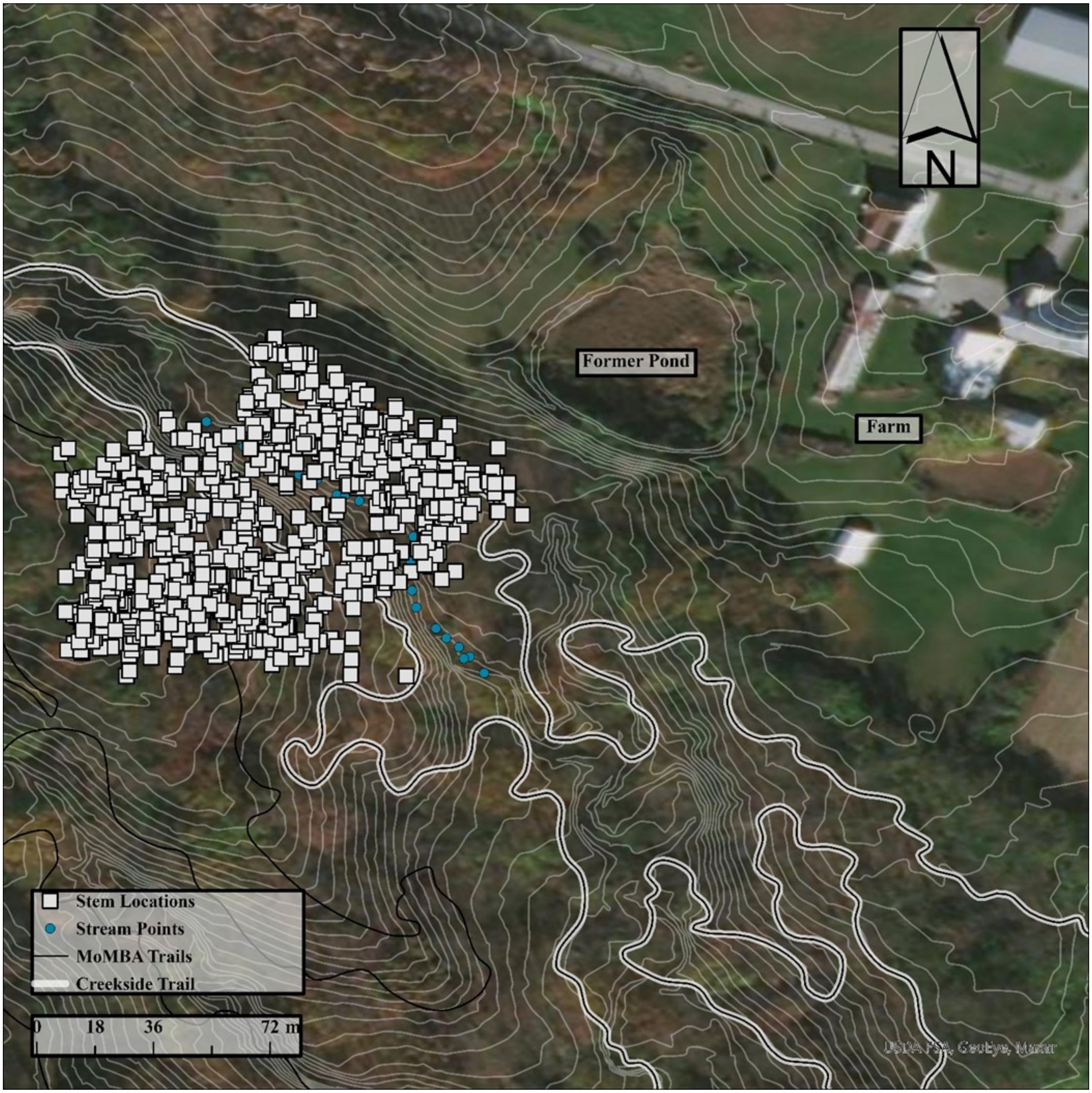

Figure 8: Georeferenced satellite image containing Site 2 with ~0.3-meter contours in ArcGIS Pro. Stem locations are shown as white squares (= 4 m for visual purposes / not true to scale). The site is 5,987m^2. 4485 Union Rd, Dayton, OH 45424 southeast of parking area and park entrance. MoMBA Trails are black lines and include Creekside Trail (highlighted in white) where stem locations were measured.

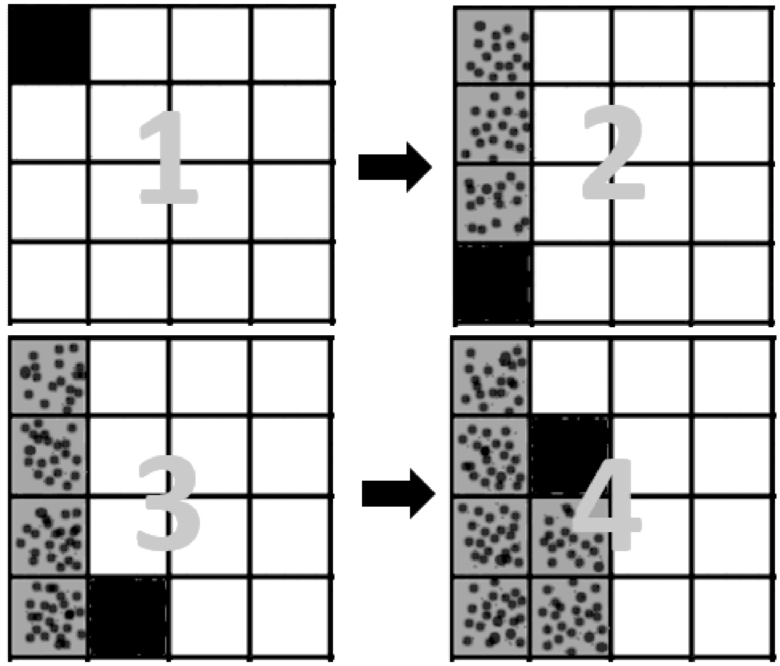

Figure 9: Graphical cartoon representation of the sampling method– Phase grids are marked 1, 2, 3, 4. Black squares indicate researcher presence - Grey square indicates completed sampling area - Dots within grey squares mark the measured position of Amur honeysuckle – Grid numbers mark the phase in the data collection sequence with black arrows indicating transition

Phases 1 - 4 in Figure 9 show the sampling method performed at both sites. All stems and cut stumps higher than 12 cm were measured. Amur honeysuckle's base is typically multi-stemmed. Only one stem location per plant was measured.

2.3. Instrument Limitations in Measuring Stem Locations, Drift, and Positional Error

GARMIN® Ltd. states that the two devices used in this study (GARMIN ® INSTINCT Rugged Watch and GARMIN ® Foretrex 401), under optimal conditions are capable of an accuracy of ± 3 meters, i.e., a radius of 3 m, or a 6 m diameter (Garmin Ltd., 2021). That accuracy is degraded by factors including, satellite number and configuration (drift), canopy cover, cloud cover, and location on the earth, all of which change during the day and throughout the sampling period.

GPS instrumental drift occurs from changes in the number, positions, and types of satellites received throughout the day. For early GPS receivers drift was recorded by a GPS instrument set at a known location (benchmark) automatically sampled every second, while at the same time GPS measurements would be taken nearby by a second instrument (location of points) and the time of each measurement would be recorded. At the end of the day, the drift data would be used to correct the location data collected by the second GPS instrument. The stem location data collected in this study was not corrected for drift in this manner.

In the current study, instrumental drift was assessed by recording data points in November 2020 (leaves were still on the trees) in a setting similar to both study sites including tree canopy, but not at the same month, day, and time that the Amur honeysuckle stem positions were measured. The position where drift was measured was geolocated using Google Earth Pro to be N 39º 51.589 ', W 84º 14.572 '. Note that there is controversy in the literature over the accuracy of point locations in Google Earth (see Figure 10 plot and caption). The accuracy of Google Earth is reported to be as small as +- 1 meter to as much as +- 8 meters depending on positional registration error around the globe (Goudarzi and Landry, 2017; Guo et al., 2020; Pulighe, 2016). Areas confined by mountain ranges (or low-lying valleys) can reach error values of 16 + meters, where urban regions (cities, outer edge of cities) can yield greater accuracy close to 1 m (Goudarzi and Landry, 2017). Developed areas generally have better Google Earth Pro accuracy because there are more features that can be used to properly register and rectify the aerial photographs (road crossings, buildings, etc.). Table 3 shows Google Earth Pro locations for three benchmarks installed by the National Geodetic Survey (NGS) around Greene County, OH and Dayton, OH (National Geodetic Survey

Data Explorer, 2021; Table 3). The location of these three benchmarks were measured using Google Earth Pro. Note, there can be human error in locating the Google Earth Pro pointer to the center of the benchmarks whose visibility is at the limits of Google Earth Pro. Additionally, there may be some degree of human error in positioning the placemark at the true earth coordinates. Alignment of the point marker in Google Earth Pro was tested and revealed the same coordinates at each benchmark when repeated five times (See Table 3 caption). The benchmark positions (in Google Earth; Table 3) show a positional registration error. The three benchmarks show an error of 1 – 3 m in Northing and 0.06 – 2.7 m in Easting.

Table 3: Three benchmark locations around Montgomery County and Greene County Ohio. The National Geodetic Survey "Actual Coordinates" are compared to Google Earth Pro points (GE Point) inferred by Google Earth Imagery. All coordinates are listed in UTM meters. The points within each box are the cursor placement measurements taken at each benchmark. The differences are reported in meters.

	Actual		GE Point		Difference	
Benchmark	N	E	N	E	ΔN	ΔE
J3507	4409679.076	751777.414	4409680.926	751777.353	1.850	0.061
			4409680.926	751777.353		
			4409680.926	751777.353		
			4409680.926	751777.353		
			4409680.926	751777.353		
			4409680.926	751777.353		
MAD-1	4409595.789	748947.083	4409599.490	748946.962	3.701	0.121
			4409599.490	748946.962		
			4409599.490	748946.962		
			4409599.490	748946.962		
			4409599.490	748946.962		
			4409599.490	748946.962		
JY1107	4397353.653	763359.194	4397349.855	763356.462	3.798	2.732
			4397349.855	763356.462		
			4397349.855	763356.462		
			4397349.855	763356.462		
			4397349.855	763356.462		
			4397349.855	763356.462		

To record GPS drift, a time window between 11:30am (EST) and 6:30pm (EST) was chosen to include the sampling times (but not the same days) for stem location measurements. The drift data should be collected at the same day and time other GPS instruments are collecting stem locations. To measure the drift, the data were collected simultaneously by both GPS devices side by side every five minutes (Figure 10) for a total of eighty measurements over ~7 hours.

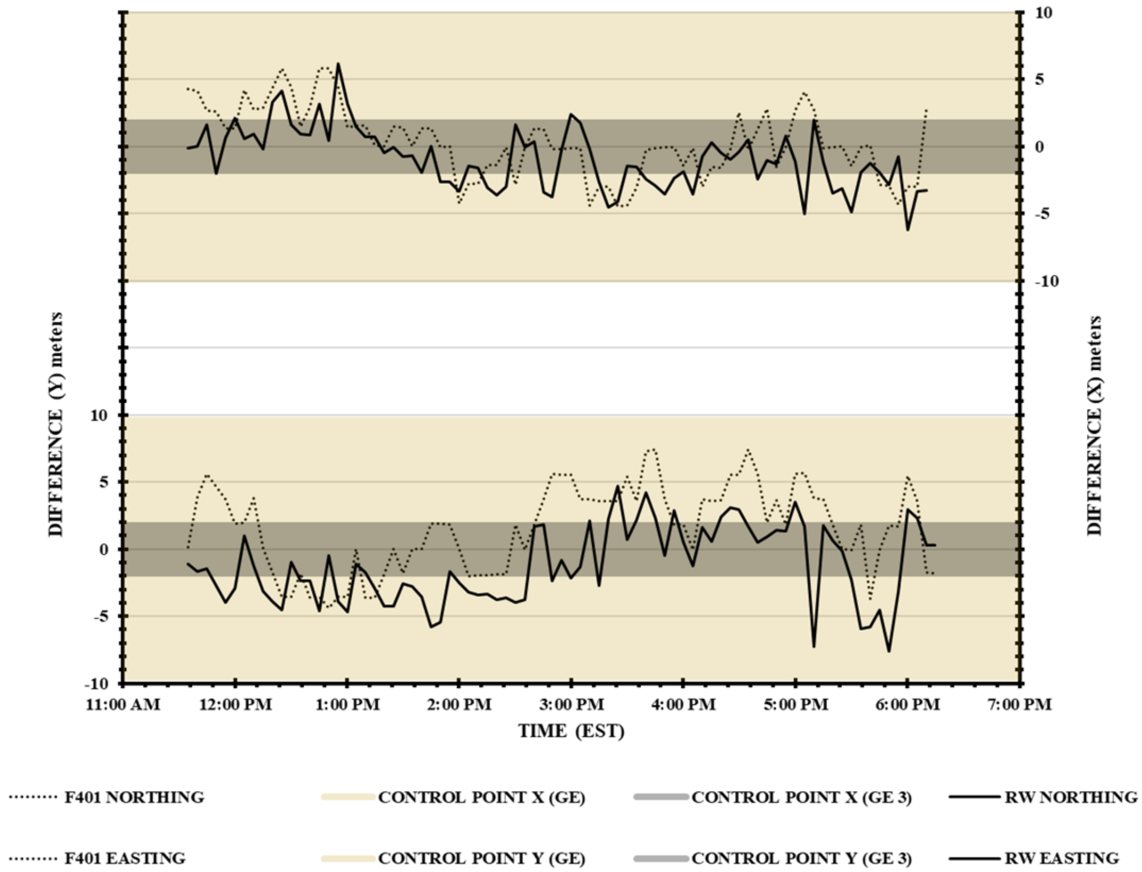

Figure 10: (RW) is the GARMIN® INSTINCT Rugged Watch (solid black) and (F401) is the GARMIN® Foretrex 401 (dotted black). The UTM Northing for both devices and Google Earth (GE) coordinate (CONTROL POINT Y – GE) is at the lower portion of the graph. The UTM Easting for both devices and Google Earth coordinate (CONTROL POINT X – GE) is at the upper portion of the graph. The control point is represented by tan bands with a ~30 m wide band for Easting and a ~20 m wide band for Northing. Variance in Google Earth accuracy based on studies of Google Earth and Google Maps accuracy (Goudarzi and Landry, 2017; Guo et al., 2020; Pulighe, 2016).

Instrumental drift recorded by each GPS unit with time indicates a range of approximately 8 m for both the Northing and Easting (Figure 10). The Google Earth Pro coordinate is (N 39º 51' 589"; W 84º 14' 572") whose accuracy is not guaranteed by Google (Goudarzi and Landry, 2017; Guo et al., 2020; Pulighe, 2016) and was located at a site with tree cover. The GARMIN ® Foretrex 401 (F401) shows eight instances where point location was 6 m away from the control point for Northing (i.e., 10% of all points) and four instances where point location was 6 m away from the control point for Easting (i.e., 5% of all points). The GARMIN ® INSTINCT Rugged Watch (RW) shows five instances where point location was 8 m away from the control point for Northing (i.e., 6% of all points) and one instance of 6 m away (i.e., 0.8% of all points) and five instances of 5 m from the control point (i.e., 6% of all points) for Easting. Figure 11 (A,B and C) shows the percentage of points near the MAD-1 DQ4041 Benchmark at Huffman Dam. Although there are reported differences in Northing and Easting measurements (as seen in Figure 10), more than 70% of the points measured fall within the 3 – 4 m radius (Figure 11C). The GARMIN ® Foretrex 401 (Figure 11A) showed 60% of data points were within 3 m of the benchmark and 90% of data points were within 3 m for the GARMIN ® Rugged Watch (Figure 11B).

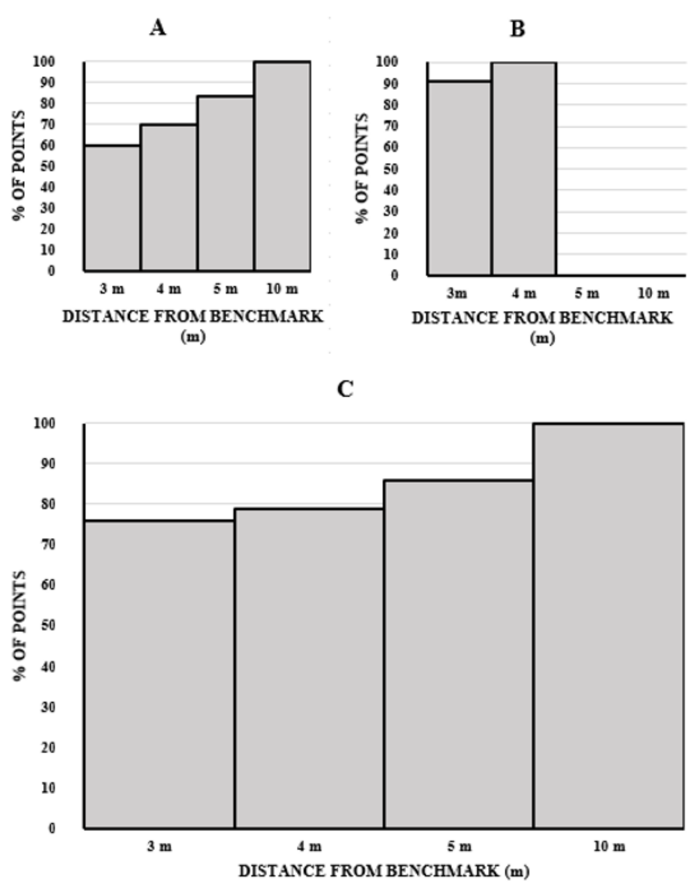

Figure 11: Comparison plots of handheld GPS receiver positional point density as a percentage with distance from the MAD-1 DQ4041 benchmark at Huffman Dam in meters. Garmin Foretrex 401 (A) and Garmin Rugged Watch (B). Both devices are show together in (C) as percentage of points within the distance ranges shown.

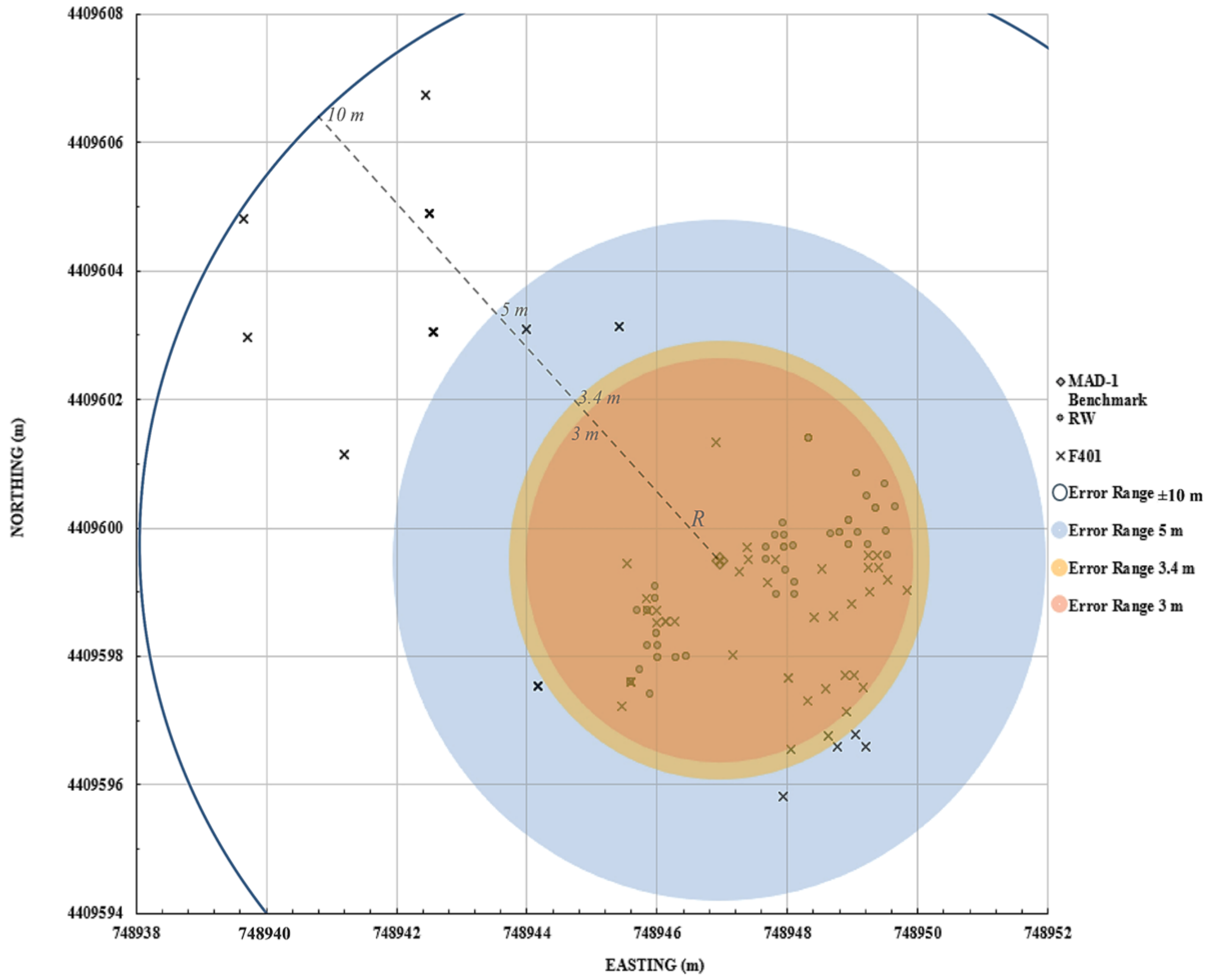

Figure 12: Radial point plot with GPS receiver registration differences. Grey circles are the Garmin Rugged Watch (RW) and black X's are the Garmin Foretrex 401 (F401). The grey diamond in the center of the error circles is the MAD-1 DQ4041 Benchmark at Huffman Dam. The error circle radii are 3 m, 3.4 m (Standard Deviation), 5 m, and 10 m.

Figure 12 shows the clustering (density is number of points/area) of points measured using both handheld GPS units at the Huffman Dam benchmark (MAD-1 DQ4041). Figure 12 shows the points clustering around the MAD-1 DQ4041 Benchmark (grey diamond). The distances from the benchmark are measured in meters as a radius of 3, 4, 5 and 10 m (= 6, 8, 10 and 20 m diameter). GARMIN® Ltd. states that the two devices, under optimal conditions are capable of an accuracy of ± 3 meters, i.e., a radius of 3 m, or a 6 m diameter (Garmin Ltd., 2021), the standard deviation of points (~4 m), and the reported error using Google Earth Pro is 5 – 10 m.

Due to the range of error due to drift alone, as shown in Figure 10, a maximum range of error of 10 m (diameter) around each stem GPS location is the estimated error adopted in this thesis. However, a large proportion of the drift error falls within smaller error ranges for the time and day the drift was measured. For the purposes of this study, the measured GPS stem locations was used (ignoring the error) for the analyses performed on the spatial clustering of Amur honeysuckle stems and for stem density analysis with distance from streams and trails and with elevation at the two sites (see Figure 15, 16, 17). The bin size for the zones used for density counting are ≥ the 10 m drift error. Another source for error includes the branches and leaves of the forest overstory and the stems and leaves of the Amur honeysuckle understory was not measured in this study but could add an error of 2-5 m to the drift error (Johnson and Barton, 2004).

2.4. Stem Location Data Preparation for Fractal Analysis

The stem location coordinates from both sites were transferred from notebooks into Microsoft Excel (Appendix, Table A5) and scatter plots of stem locations were created (Figures 12a and 13a). The plots were enlarged in Microsoft Excel without changing the aspect ratio of the plot (aspect ratio should be 1:1 to prevent stretching in any direction). To increase resolution (pixel count) in the point plots, Sites 1 and 2 had to be enlarged. Enlargement of the plot size was accomplished using the shape tool (Microsoft Excel) to create a perfect square to expand the gridlines of each point plot evenly in x and y directions. The plots were then stripped of gridlines, axes, indices, and titles leaving only stem locations as black points on a white background (Figures 12b and 13b). Daniel's XL ToolBox (an open-source plugin) was used to export the stem location plots from Microsoft Excel. The export settings are described in sequence. The file type was exported as a rasterized graphics container (tagged image file – 'TIFF') with a minimum resolution of 900 dpi (dots per inch). The color space of the table was set to Red, Green, Blue (RGB) with a 'transparent canvas' and the color profile was set to Standard Red, Green, Blue (sRGB). The output in the 'Single Graphics Export' of the plot was not stretched.

The exported point plot was then imported to GIMP 2.10.10 (a GNU image manipulation software) to invert the color selection of the point plot as a negative. The finished plot for Site 1 is shown in Figure 13B and for Site 2 is shown in Figure 14B.

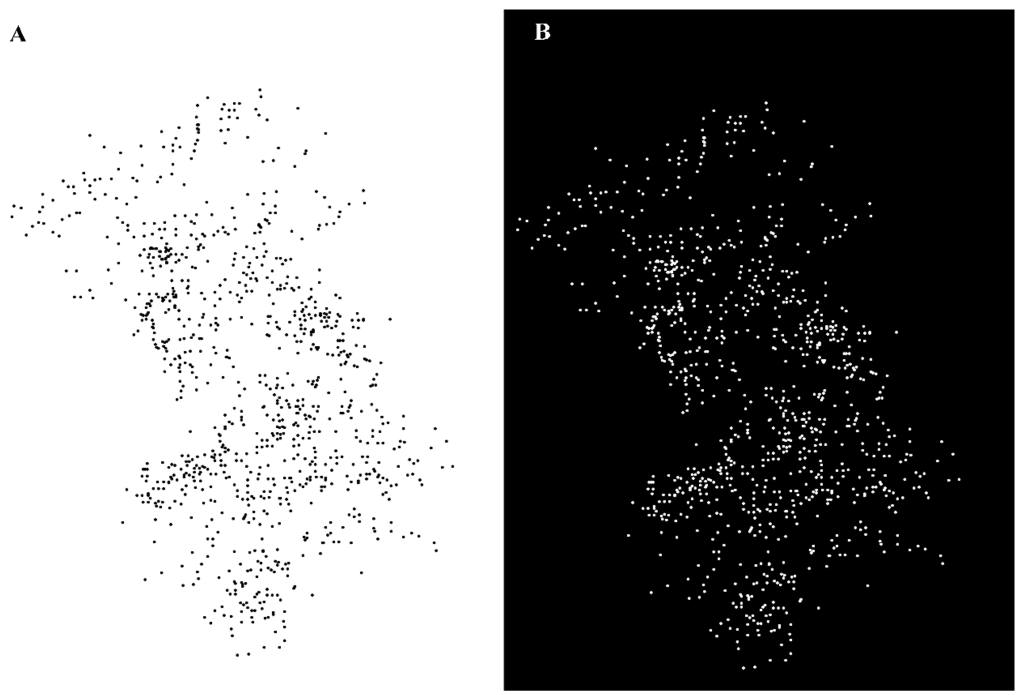

Figure 13: Stem location plot for Site 1 created in (A) Microsoft Excel and white background with black points and (B) ; a point plot with inverted color-scale created in GIMP 2.10.10 on black background with white points for box-counting analysis using Benoit 2.0.

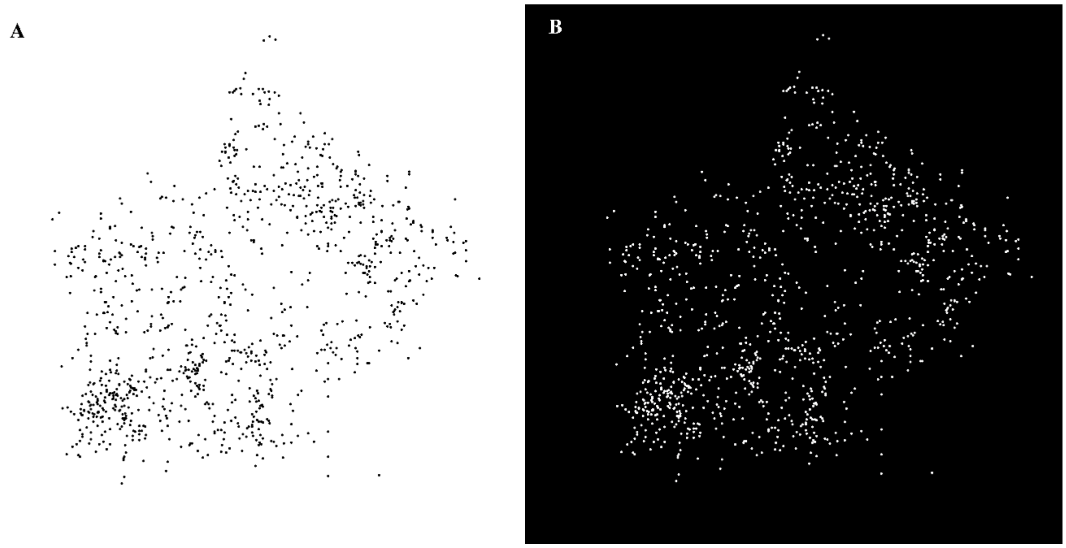

Figure 14: Stem location plot for MoMBA—Site 2 created in (A) Microsoft Excel and white background with black points and (B) ; a point plot with inverted color-scale created in GIMP 2.10.10 on black background with white points for box-counting analysis using Benoit 2.0.

2.5. Fractal Analysis of Stem Location Plots

The 2-D box-counting fractal analysis software Benoit 2.0©, (Trusoft Inc., 1997) quantifies the spatial clustering of points lying in a plane in terms of the fractal dimension of binary images with only two possible pixel values (maximum darkness of 0 and maximum brightness of 255 in 8-bit images). Benoit 2.0© sees only white pixels.

Where there is only one point, the fractal dimension is 0, where there are many points and the clustering is due to a random process, the fractal dimension is 2. The 2-D box-counting method was used to quantify the scaling exponent of stem clustering which can quantify how Amur honeysuckle occupies space at different scales.

The box or grid dimension is the exponent *D* in the equation:

$$N(d) \sim C^{*}d^{\,D} \tag{1}$$

where *N(d)* is the minimum number of boxes of side length *d* necessary to cover a data set of points lying on a two-dimensional plane. C is a constant (called the activity) which is the *N(d)* intercept when *d* = 1 (Mandelbrot, 1982; Feder, 1988; Turcotte, 1997). The basis of this method is that Equation 1 defines the dimension (D).

The scaling exponent *D* is measured by counting the number of boxes occupied by one or more data points *N(d)* of linear size *d* necessary to cover the dataset for a range of values of *d* and plot (with log-log axes) *N(d)* (on the y-axis) versus *d (on the x-axis)*. If the dataset is fractal, the data will follow a straight line with a negative slope. Only power functions plot as straight lines in log-log space, with a slope of -*D*. To plot points that are evenly spaced in log-log space, Benoit 2.0© chooses box sizes *d* that follow a geometric progression (e.g., d = 1, 2, 4, 8...). For analysis of point patterns in a plane, the smallest box size should be two times larger than the distance between the two closest points in the data set or twice the accuracy in point location. The largest box size should be smaller than the box size where the ratio of number of occupied boxes to box size becomes constant.

Benoit 2.0© addresses the issue of counting the minimum number of occupied boxes by rotating the grid of boxes (for each box size) over the data (in angular steps chosen by the user) and counting the number of occupied boxes at each rotational step and then selecting the minimum number of occupied boxes counted for each box size.

2.6. Determining the Lower Cutoff in Box Size in Benoit 2.0©

Benoit 2.0 analyzes the data in terms of pixels. To convert pixels to meters, the pixel values were recorded for the northernmost and southernmost points for Site 1 and Site 2 in the computer program GIMP 2.10.10 (GIMP, 2019). These values were then subtracted to determine the number of pixels between the northern and southernmost points. The corresponding distances in meters between the same points were recorded at each site. The difference in meters was divided by the difference in pixel values, resulting in a transform factor in m/px (meters per pixel). This transform factor was multiplied by the pixel values reported by Benoit 2.0 to yield box lengths in meters. The smallest box sizes shown in Figure 18 is 20 m (twice the maximum error of 10 m (diameter) in GPS stem location).

2.6.1. Preparation of Stem Location Maps for Stem Density Measurement

To analyze the density of Amur honeysuckle*,* the following steps were taken for each site: 1. Stem location data import to ESRIs ArcGIS Pro from Microsoft Excel, 2. Determination of Bin-size, 3. Location of bin boundaries. 1. ArcGIS Pro requires coordinate locations in DDM (Decimal, Degrees, Minutes). Once stem locations were loaded, the spatial reference had to be set to the correct "Geographic Coordinate System" (WGS 1984). 2. The point sizes of each stem location were reduced from 10 pt to 5 pt to minimize overlap where the accuracy of the stem location is 10 m. The diameter of the stem location points as drawn in Figures 15, 16, 17 is ≤ 1 meter. The stem locations are shown as transparent circles with a solid perimeter with point in the center (see Figures A29–A34 in the Appendix). If a point fell on a zone boundary, and the greater portion of the ring was on one side of the zone boundary, the point is counted in the adjacent zone. Topographic lines were imported as georeferenced raster layers to capture elevation changes across both sites. Zone construction is described in sections 2.8.1 – 2.8.3. The zones for Stream and Trail stem counting were created with French curves, a General drafting compass, Starrett and Co. Engineers Scale and Nº2. pencil on large print paper. The boundaries of the zones were different for streams, trails, and elevation because the shape of each boundary is governed by the shape of each object of interest, which serve as reference features for boundary construction.

2.6.2. Creation of Stream Zones for Stem Density Measurements

To quantify horizontal distance from the stream, in 2-D space, the stream was divided into evenly spaced 15 m wide zones parallel to the stream segments, without concern for elevation. At the stream, the zone was split in half using the stream center (3.3 cm from stream center at Site 1 and 4.9 cm at Site 2). The total width of stream Zone 0 is 15 m. The remaining zone boundaries follow the shape of the previous zone boundary (Figure 15).

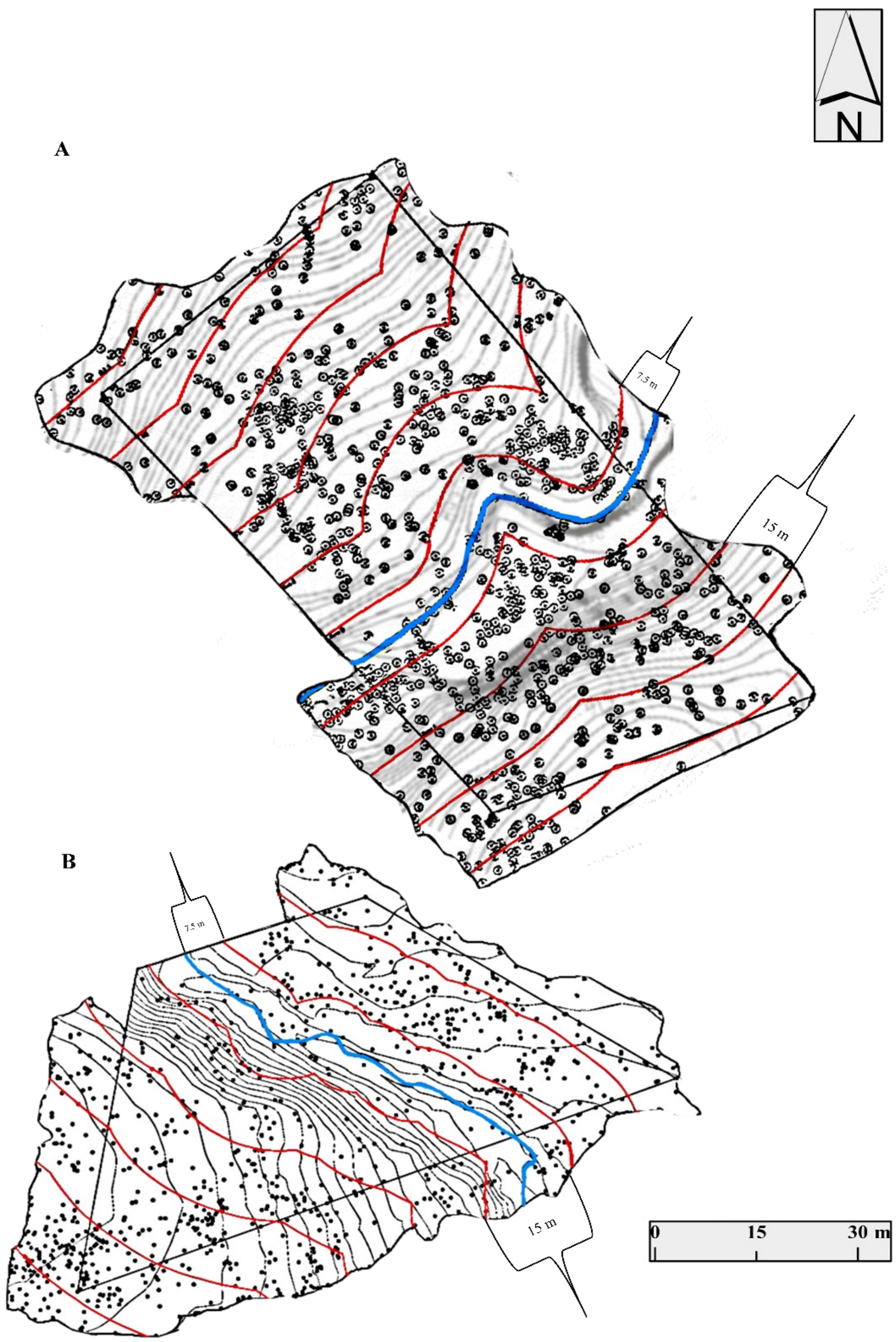

Figure 15: Site 1 (a) and Site 2 (b) Map with stream zone zero bounded in red. Stream Zone 0 is 15 m wide. Boundaries for sequential zones are red and are 15 m apart. Elevation contour lines are black. The contour interval is 0.3 m (a) and 0.6 m (b). Blue line is stream center.

2.6.3. Creation of Trail Zones

Trails are edges in that understory vegetation abuts and stops at the trails. Multiple trails at both sites converge from different directions which merged the trail zones away from the trail (See Figure 16). Trail zones were constructed in increments of 20 m on both sides of trails without regard for elevation because trails at the two sites typically cut across topography. The trail zones were constructed to be slightly larger than the size of the maximum stem location error (10 m) around the center point (stem location). Zone 0 contains the trail itself and is 20 m wide and encompasses the trail. The adjacent zones are 10 m wide. In some cases, the trail zones would converge on one another making a zone of convergence. Therefore, the zone does not continue beyond the point of convergence. French curves were used to achieve the curvature of the trail zones (Figure 16).

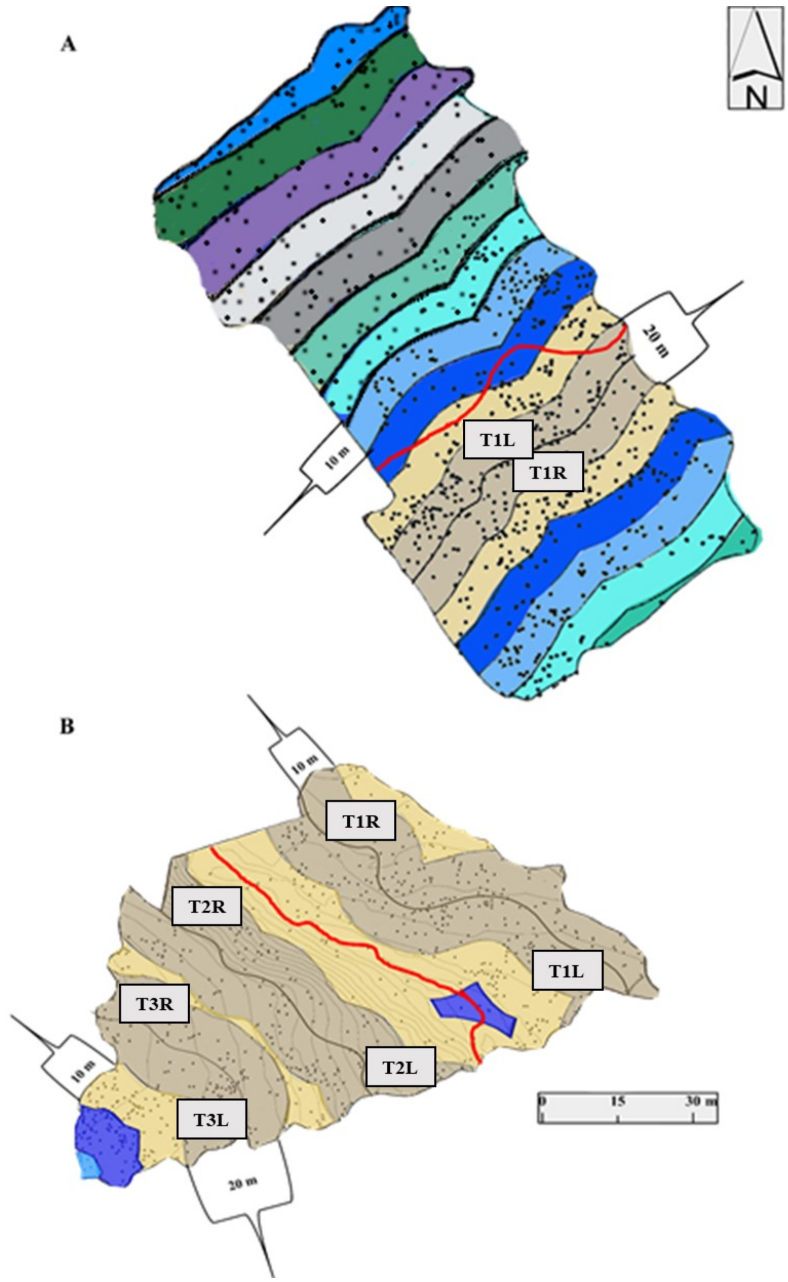

Figure 16: Site 1 (A) and Site 2 (B) Map showing seventeen trail zones (A) and fourteen trail zones (B) each 10 m wide on either side of the trail and perpendicular to trails edge. The zones containing the physical trail is tan and the trails are colored black. The adjacent zones are gold, blue, light blue, seafoam, and sage with distance from the trail. A zone convergence is shown in sage at the top right (A) and in dark blue at the right edge of the figure (B). Stream is in red. Trail 1 (T1) through Trail 3 (T3) were analyzed by density of stems left (L) and right (R).

Additional analyses of Amur honeysuckle stem density at trails edge were performed. The stem density on the left and right sides of each trail at both sites were analyzed with horizontal distance from trails edge and 10 m away on both sides. Site 1 only had one complete trail segment that crossed the site boundary, where Site 2 had three trail segments. All points outside of the 10 m zone were not evaluated in this analysis. The following zones were analyzed in the manner shown in Figure 16 for Trail 1 (T1) at Site 1 (Figure 16A) and Trails 1 – 3 (T1 – T3) at Site 2 (Figure 16B).

2.6.4. Creation of Elevation Zones

In order to measure the effect of elevation on Amur honeysuckle, zones were established within 10 ft (~3 m) elevation intervals starting at the lowest observable contour within the site boundary at both sites. The horizontal widths of these zones are variable and depend upon the slope of the topography. Variable zone areas, however, were normalized by dividing the recorded counts by the area of each corresponding zone (see below). The zones at the lowest elevation were split by the stream at Site 1 and 2 (Figure 17A and B).

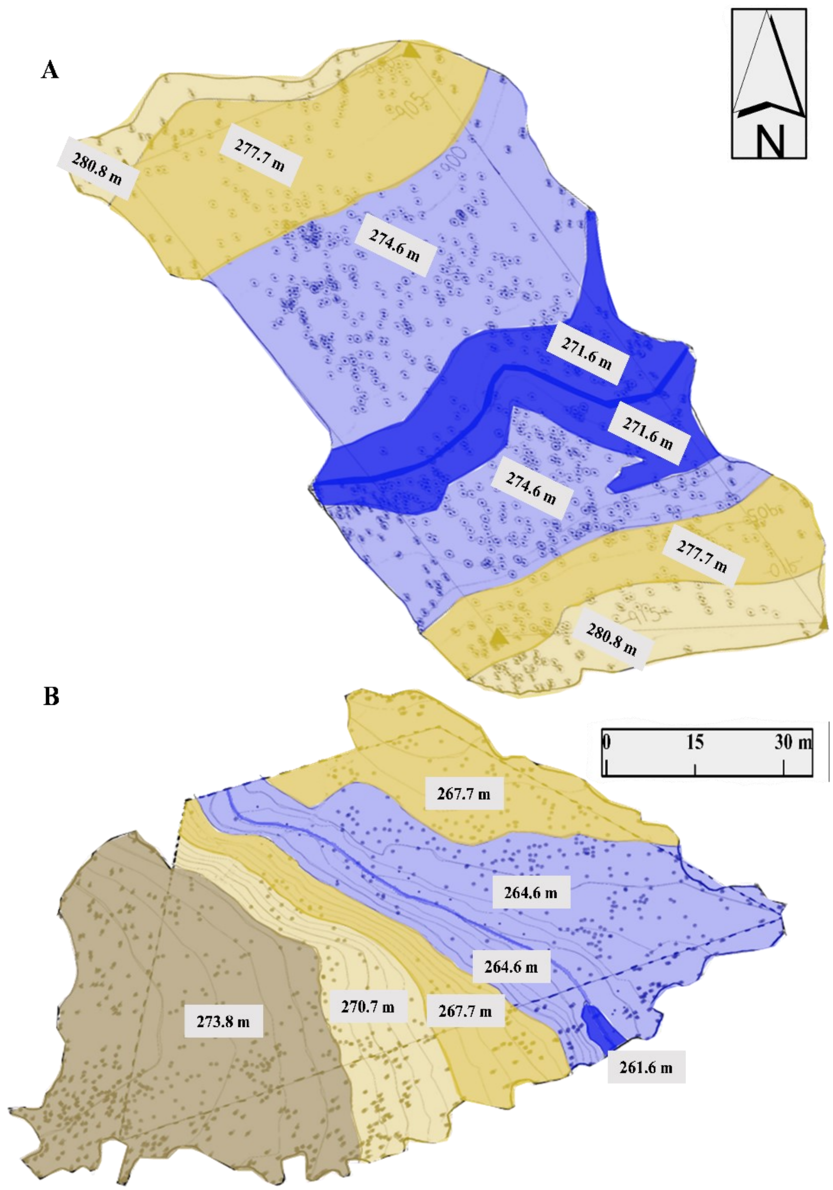

Figure 17: Topographic maps of elevation with 3 m elevation color-coded zones defined. (A) Site 1 and (B) Site 2.

2.7. Stem Density Analysis

Stem density as a function of horizontal distance from the stream, distance from trails, and elevation were measured by counting the number of stems in each zone and dividing by the area of the zone, the area in m^2 of each zone was computed using the measurement tool in ArcGIS Pro. The boundary at the end of each zone is irregular because it marks the location where data collection ends. Zones for streams and trails cut across topography. Each trail zone was designated a zone base number and zone sub number to keep track of the count in the corresponding zone. For example, if there are three zone 0's that correspond to different areas of the site immediately next to the trail, the map zones would be denoted with 0_1, 0_2 , 0_3. The end result is all three Zone

0 stem totals as one value (Table 4). For elevation, the corresponding zone would total the stem count for that particular elevation (Table 4).

Table 4: Stem count by zone for streams, trails, and elevation analyses. Stream zones start at 0 where zones (+) are North of the stream and zones (-) are South. Trail zones start at 0 and increase by factor of 1. Elevation zones start at the lowest elevation for both sites and increase by ~ 3 m per zone. The total number of stems for each zone are displayed on the far right in bold. Area of each zone in m^2.

Table 4 a	**Wright State Woods - Site 1 - Stream Zones and Located Stems**										
ZONE	-4	-3	-2	-1	0	1	2	3	4	5	6
COUNT	43	81	115	158	126	125	105	99	52	36	10
Area m^2	355.44	951.52	1056.6	1063.42	1173.71	1123.46	1061.46	925.15	963	617.36	166.94
TOTAL											**950**
	MoMBA - Site 2 - Stream Zones and Located Stems										
ZONE	-5	-4	-3	-2	-1	0	1	2			
COUNT	42	147	135	141	96	107	182	103			
Area m^2	162.11	479.99	711.28	908.49	957.63	1071.67	840.79	748.74			
TOTAL											**953**
Table 4 b	**Wright State Woods - Site 1 - Trail Zones and Located Stems**										
ZONE	0	1	2	3	4	5					
COUNT	172	227	160	202	94	47					
Area m^2	1310.77	1918.48	2125.44	1824.58	1236.6	593.66					
TOTAL											**902**
	MoMBA - Site 2 - Trail Zones and Located Stems										
ZONE	0	1	2	3							
COUNT	520	242	69	5							
Area m^2	3258.25	1671	217.42	17.26							
TOTAL											**836**
Table 4 c	**Wright State Woods - Site 1 - Elevation Zones and Located Stems**										
ZONE (m)	271.6	274.6	277.7	280.8							
COUNT	191	477	184	82							
Area m^2	1673.81	4159.34	2798.39	1277.15							
TOTAL											**934**
	MoMBA - Site 2 - Elevation Zones and Located Stems										
ZONE (m)	261.6	264.6	267.7	270.7	273.8						
COUNT	2	265	171	113	434						
Area m^2	31.55	1798.41	1297.75	714.85	2053.69						
TOTAL											**985**

2.8. Stem Location Data

Streams, trails, and elevation maps were scanned and imported into ArcGIS Pro. The six scans were georeferenced to ensure accuracy when measuring the area of each zone. This was achieved by using contour lines and basemap features (roads and buildings). The measurement tool (ArcGIS Pro) was set to ‘metric’ and ‘area/m^2’. Each was using the mouse cursor. All zones are closed shapes whose areas were measured.

For trails, a 20 m wide zone was centered on the trail. Adjacent zones (10m) were measured individually to determine the left and right side of 20m trail zone. This approach grouped the adjacent zones into 20 m bins.

For elevation, the area of the zones ranged with topography (Figure 17). To obtain correct measurements for each elevation zone, the entire elevation contour was traced from a starting point and back to the starting point to create a polygon. The adjacent zone were measured in the same way, but the previous elevation zone were subtracted (if it was within the previous zone) to ensure no overlap of zone measurements occurred.

3.0 RESULTS

The distributions of Amur Honeysuckle at both sites were investigated in terms of spatial clustering and density. Stem density is interpreted based on the proximity to each feature of interest (horizontal distance from the streams and trails, and with elevation).

3.1 Fractal Analysis

Fractal analysis was deployed to test the spatial clustering of Amur honeysuckle stems and stump cuts to attempt to understand their distribution in Sites 1 and 2. Both sites show clustering with scaling exponents of ~1.5 for box sizes ranging from 20 – 100 m. A scaling exponent of 1.5 indicates that this pattern of points (stem locations) falls between evenly spaced points lying in a plane (D = 2), or along a straight line (D= 1). They show the close to the same scaling exponent, even though Site 2 is more actively managed. Disturbed areas and actively managed areas were expected show greater scaling exponents compared to unmanaged areas. While the distributions of Amur honeysuckle at Sites 1 and 2 do not follow identical spatial patterns, their similarity in the scaling exponent reveals the same spatial clustering.

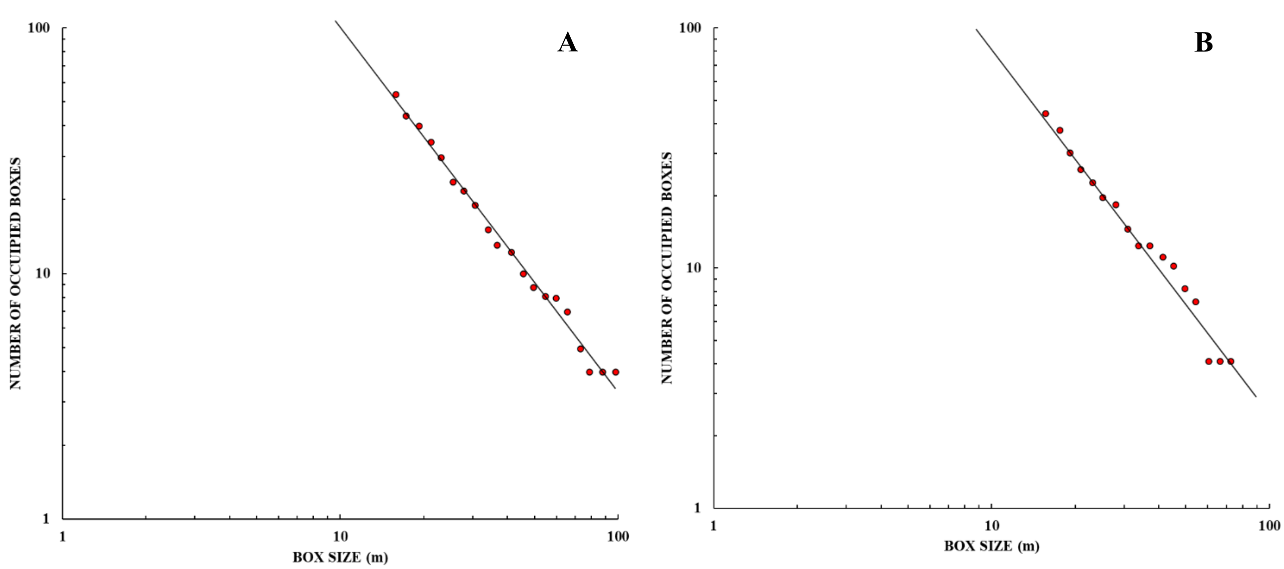

Figure 18: Plot of box size (m) vs. Number of Occupied Boxes for stem locations at Site 1 (A) and Site 2 (B). The Fractal dimension is 1.47 (A) and 1.53 (B) for box sizes ranging from 16 m – 100 m (red points). The Black lines are the power function fit to the red points.

3.2 Stem Density as a Function of Distance from Streams

Across elevation and streams the lower elevations generally show less honeysuckle presence compared to higher elevations at Site 2. Site 1 (Figure 19A) generally has higher honeysuckle density near the stream although these differences are weaker compared to Site 2. This trend is ambiguous at Site 1 and is mostly due to the decline in density to the northwest, suggesting another factor is governing this distribution. Site 2 (Figure 19B) shows the opposite trend with higher density away from the streams, supporting that another factor is influencing these patterns.

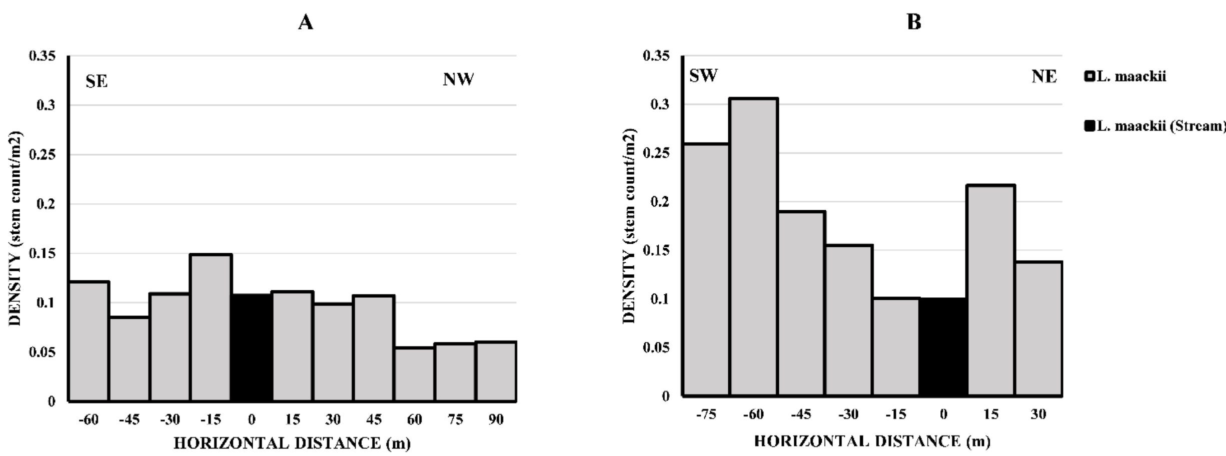

Figure 19: Histograms for Site 1 (A) and Site 2 (B) showing stem density (normalized as c/m^2 or count/sqm) and distance from streams. Site 1 Zones (-) are southeast of the stream and Zones (+) are northwest of the stream. Site 2 Zones (-) are southwest of the stream and Zones (+) are northeast of the stream

3.3 Stem Density as a Function of Distance from Trails

Site 1 (Figure 20C) generally shows fewer stems near the trails on either side of the trail compared to Site 2 (Figure 20D). However, the opposite trend is found at Site 2 (Figure 20D) with the zones exhibiting higher stem densities < 100% in T3L and T1L. The data suggests that a greater number of stems will be at trails edge at Site 2. The left side of each trail at both sites are consistently higher after being normalized by area. The spike in trail 1 (T1R; Figure 20D) is located at a higher elevation compared to Trail 2 (T2) and Trail 3 (T3) suggesting that elevation is a factor.

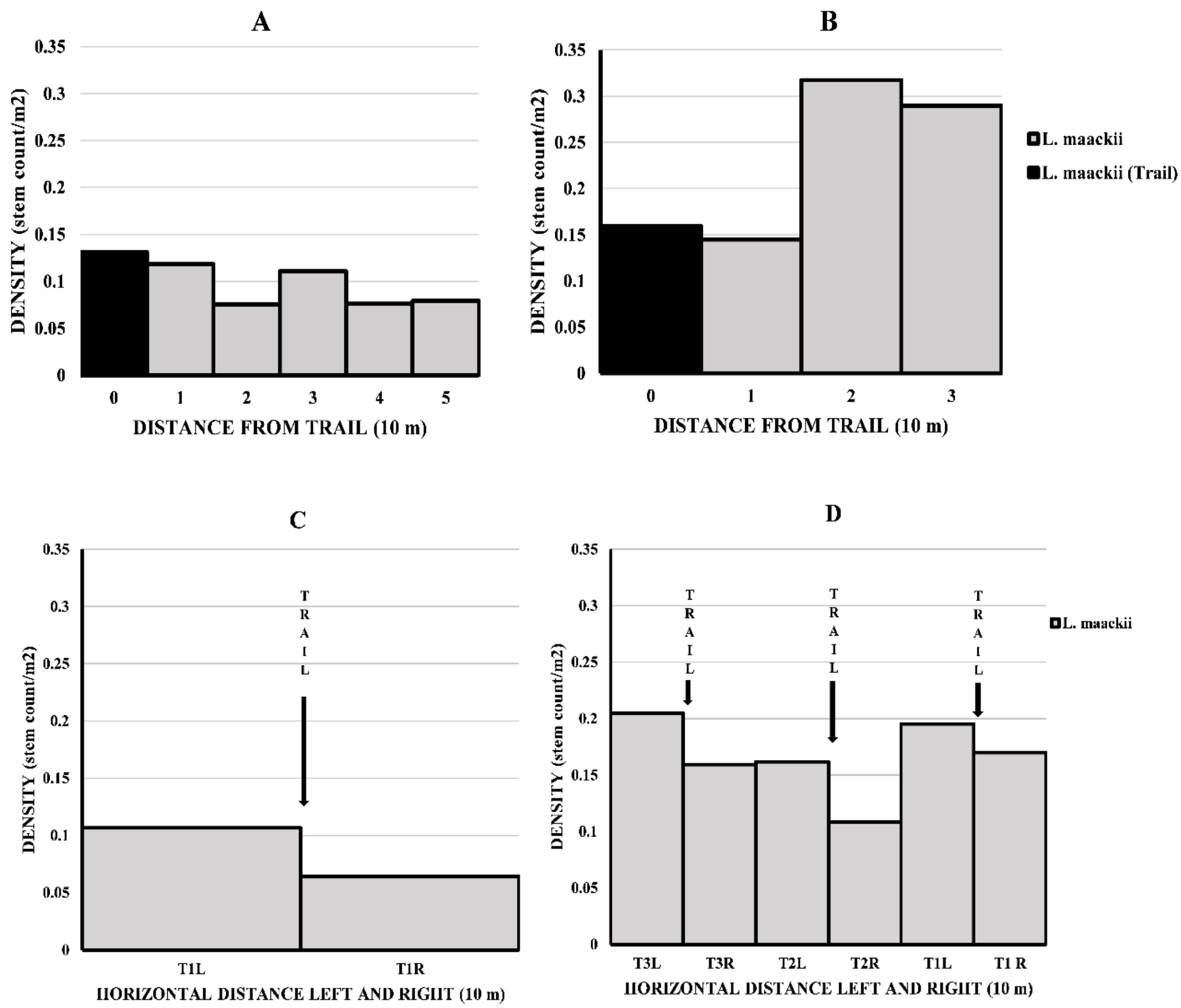

Figure 20: Stem density in proximity to trails for Site 1 (A) and Site 2 (B). Site 1 (C) and Site 2 (D) are stem density on the left and right side of the trails within 10 m. (normalized as c/m^2 or count/sqm).

Figure 20A and Figure 20B show that the area with more active management (Figure 20B) has more stems per meter squared. The less anthropogenically disturbed site (Figure 20A) has less stems per meter squared overall. The closer you are to the trail, the greater number of Amur honeysuckle stems will occur at Site 2 (Figure 20D). The normalized data shows the density of Amur honeysuckle stems around 0.15 c/m^2 at T1R and T2L and T2R. The greater density of stems is found to be on the left side of each trail.

3.4 Stem Density as a Function of Elevation

Site 1 (Figure 21A) general showed a fewer number of stems with gentle increase in elevation. Site 2 (Figure 21B) showed the opposite of Site 1 with a greater number of stems with an increase in elevation. Site 1 (Figure 21C) shows that lower elevations typically have higher honeysuckle density. This generally seems to align with the stream proximity analysis, although farther zones in the southeast have higher counts at higher elevations, suggesting some of the data is obscured by lumping zones together in the elevation analysis. Site 2 (Figure 21D) shows the opposite trend, with higher density in higher elevation zones with the exception of zone 273.8 – 276.8 showing fewer stems (which could be a factor based on zone size). The normalized data shows a greater density of stems between 271.6 m and 277.7 m elevation and a lesser density with increased elevation (277.7 – 283.8 m elevation) for Site 1 (Figure 21C). Stem location data at Site 1 (Figure 21C) suggest that lower elevation will have greater Amur honeysuckle (which could be a factor of stream presence, general soil moisture content, or soil composition). Site 2 (Figure 21D) suggest that higher elevation will yield a greater density of Amur honeysuckle (which could be a factor of light availability).

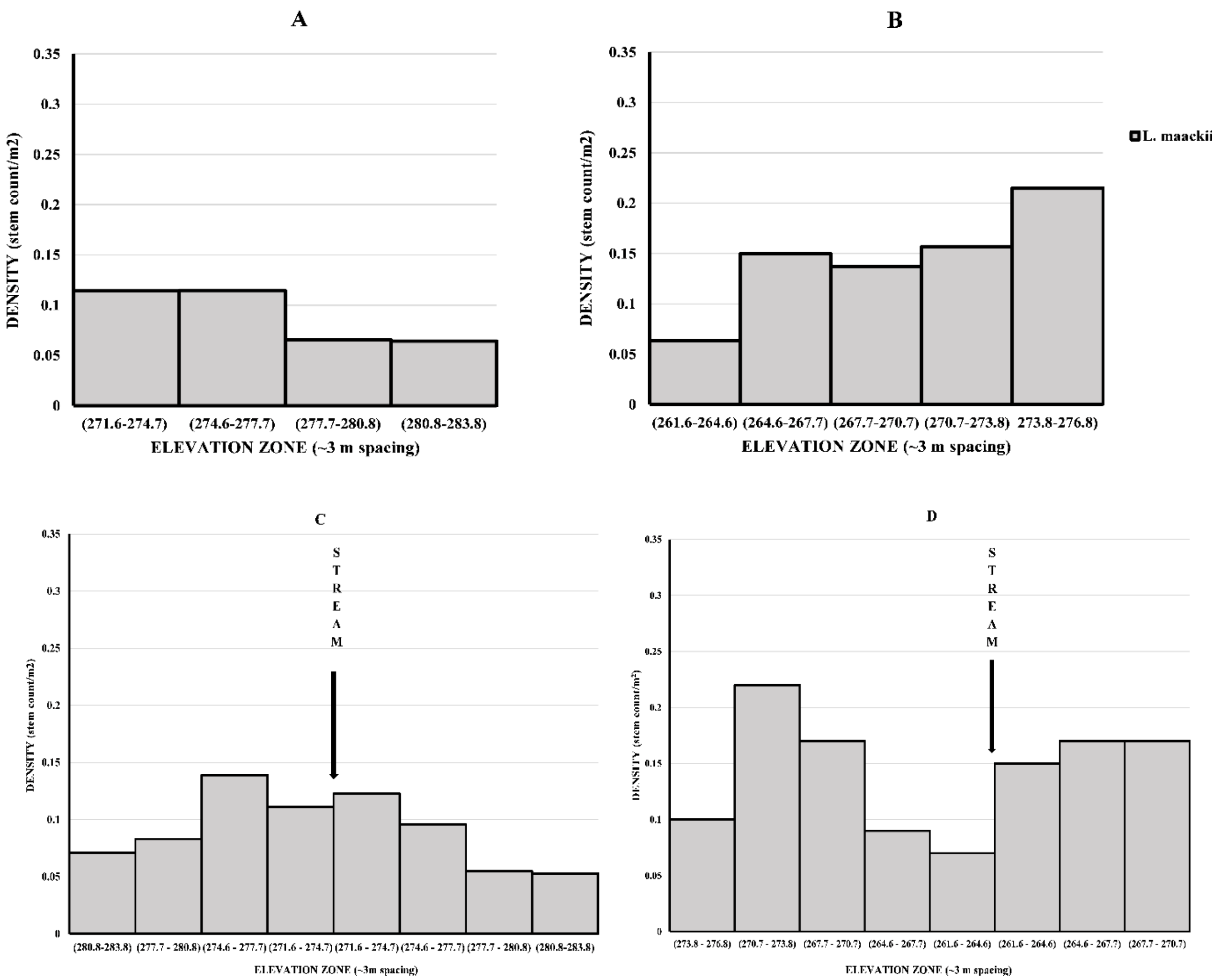

Figure 21: Site 1 (A) and Site 2 (B) density as a function of elevation. Site 1 (C) and Site 2 (D) density as a function of elevation on either side of the stream. Zone spacing was based on 3 m contour intervals across both sites. Normalized count for each elevation zone by c/m^2 or stem count/sqm.

4.0 DISCUSSION

4.1 Fractal Distribution

Both sites had similar scaling exponents around 1.5 (Figure 18), though their levels of anthropogenic disturbance are different widely between Site 1 and Site 2. A scaling exponent of 1.5 indicates that this pattern of points (stem locations) falls between evenly spaced points lying in a plane ($D = 2$), or a single point (D=0). More actively managed areas could have lower scaling exponents compared to unmanaged areas because removal would create holes (unoccupied area) of variable sizes in the data sets. The results also suggest that easily invaded forests with similar mature forest features (i.e., organic materials, leaf litter, sub-canopy, mature hardwood trees, etc.), and with similar climates and ecological factors, might have similar scaling exponents for their honeysuckle stem distributions. However, any similarities and ranges of scaling exponents would need to be confirmed with future studies. With knowledge of the stem scaling exponents in other settings, the scaling exponents found in the current study could be a basis for tracking the process of invasion of Amur honeysuckle. Land managers could use stem scaling exponents as a proxy for invasion severity. The effectiveness of different more aggressive removal strategies could be monitored using stem in invaded areas. Furthermore, the scaling properties of honeysuckle populations can be monitored through time, which might improve management strategies for removing or containing this ecosystem-damaging, invasive plant.

4.2. Stem Density as a Function of Horizontal Distance from Stream

The analyses of honeysuckle density with respect to streams and elevation are interrelated but do not show trends across areas at the scale of this study. Site 1 shows subtle differences in honeysuckle density (Figure 19A); it is generally greater near the stream. In contrast, Site 2 shows more dramatic differences, with density increasing away from the stream (Figure 19B). These opposing trends are intriguing because many plants are sensitive to their location around bodies of water (Bolte et al., 2007; Dawson, 1996; Scherrer et al., 2011). While other factors (soil moisture, throughfall, light availability) are likely governing the density of honeysuckle in these areas, this lack of correlation to stream proximity reinforces that honeysuckle is a robust plant capable of tolerating a broad range of environmental conditions (Beans et al., 2012; Gorchov and Trisel, 2003; McEwan et al., 2010). The observed honeysuckle densities demonstrate that this invasive plant may have fewer colonization constraints compared to endemic species occupying the same niche. However, these forest sites do not create unique establishment opportunities at the scale of this study. Additionally, there were no discernable patterns to the proximity of either streams or trails even though Amur honeysuckle has been well documented to be edge-bearing (Harper et al., 2005; Henkin et al., 2013; Lieurance and Landsbergen, 2016; Merriam, 2003).

4.3. Stem Density as a Function of Horizontal Distance from Trails

There is no clear directional relationship between stem density and distance from the trail on either side of each trail (Figure 20C and D). Site 1 is generally undisturbed, there is minimal honeysuckle removal, recreational use, heavy equipment use, and infrequent trail maintenance compared to Site 2. Therefore, the density of Amur honeysuckle near trails has not been goverend by these anthropogenic factors. Its distribution is not influenced by streams or elevation. Honeysuckle density at Site 2 is lower near the trails (Figure 20B). This pattern suggests that the land management goals at Site 2 focus on removing Amur honeysuckle closer to trails edge to preserve visibility and trail accessibility and are little or less on areas away from the trails. The size of the zones used in this study for measuring density with horizontal distance from trails may have been too wide to detect these changes. Therefore, smaller trail zones and more accurate stem location measurement would be necessary to detect the any change in stem density due to removal of stems near trails.

4.4. Stem Density as a Function of Elevation Changes Across Topography

Slope angle governs the honeysuckle stem count and computing honeysuckle density removes the slope effect. The largest counts correspond to the zones which have the greatest horizontal distance between contour lines (gentle slopes). Site 1 (Figure 17A) has more evenly spaced contour lines within each elevation zone. This is most evident in the Site 1 zones (Zone 1, Zone 2; 271.6 m to 274.6 m) which have higher Amur honeysuckle density in relatively flat areas. The topography of Site 2 (Figure 17B) is generally irregular with variably horizontal distance between contour lines within each zone. Comparable trends are observed in this area but is not as straightforward as the Site 1 because of this irregularity. Like the analyses of horizontal distance from streams, honeysuckle density follows opposite trends at the two sites – with lower elevations yielding lower densities at Site 1 and higher densities at Site 2. Elevation is coupled to proximity to streams, which is partially responsible for the similar pattern. However, the analyses in this study show that honeysuckle can tolerate a wide range of environmental conditions (stream proximity, slope angle, and moisture content), which can act as constraints for many endemic plants competing with this invasive (Dawson, 1996; Scherrer et al., 2011).

4.5. Considerations for Management of Honeysuckle in Riparian Forests

The decrease in honeysuckle density away from the trails at Site 1 demonstrates that if left alone, this plant will thrive (clean slates; Gorchov and Trisel, 2003). The more active Amur honeysuckle removal strategies at Site 2 reduce density near trails (See Section 1.2). However, the robustness (dispersal capacity) of Amur honeysuckle and its density independence from distance from streams, trails, and elevation indicates that Amur honeysuckle will repopulate these areas from stocks nearby and possible from elsewhere in the forest. The success in dominating forest understories is well documented for Amur honeysuckle (Gorchov and Trisel, 2003; McEwan et al., 2010; McNeish and McEwan, 2016) and poses many challenges for managing/ or completely eradicating this invasive. Stream proximity, slope, elevation, and edges (trails) might act as pathways or barriers to the dispersal and colonization of other understory plant species such as common plantain, red clover and white clover, and dandelion (Dickens et al., 2005); honeysuckle is indifferent to these factors. This is supported by the same scaling exponent for spatial clustering of stems at the two sites. The indifference of honeysuckle to these variables suggests that its removal alongside trails is an effort in futility. More aggressive or different management strategies are needed to eradicate Amur honeysuckle.

Measuring the scaling exponent of the clustering of stems in an invaded area might be useful as a metric of invasion of Amur honeysuckle. The scaling exponent of stem clustering might be smaller for less heavily invaded areas. Amur honeysuckle density is found to be indifferent to its proximity to streams, trails, and elevation. This behavior means high risk of invasion potential regardless of constraining features (streams, elevation, moisture). A whole-system approach to Amur honeysuckle removal might help to limit repopulation even with frugivore and avian dispersal.

Allelopathic toxins are a barrier for many plants in proximity to Amur honeysuckle (Bauer et al., 2012; Borth et al., 2018; Custer et al., 2017) but the impacts vary based on microorganismal effects and the native species in proximity to it (McEwan et al., 2010; Bauer et al., 2012; McNeish and McEwan, 2016). These allelopathic toxins also have a negative effect on Amur honeysuckle germination success (Bauer et al., 2012). This could explain the natural limiting effects on stem clustering exponent of 1.5 at Site 1. The soils of both sites are ideal for Amur honeysuckle propagation based on soil pH, organic material and hydraulic conductivity, though old growth forests are less susceptible to invasion compared to immature forests (Communication with Dr. James Runkle, 2019). The stream zones at both sites were not evenly-spaced across topography and the streams were meandering (as seen in Figure 14A and B). The presence of streams in old-growth might make them more susceptible to invasion than they would otherwise be.

Site 1 is 9,840 m^2 and Site 2 is 5,987 m^2 and the elevation ranges at Site 1 is 30 m and at Site 2 is 36 m. Investigation of Amur honeysuckle over larger areas and elevation ranges using NDVI with countywide aerial imagery has been done by Wilfong et al., (2009). The study concluded that NDVI was a good predictor for Amur honeysuckle presence using extended-leaf habit with aerial imagery. With higher-resolution imagery than is now available, patterns of Amur honeysuckle invasion could be studied at the regional scale across southwest Ohio which might provide insight for ecologists and foresters.

Each of the analyses of the spatial pattern of find that Amur honeysuckle thrives over a wide range of environmental conditions. The independence of Amur honeysuckle to the investigated features (streams, trails, and elevation) points to its environmental plasticity within riparian forests. The measures used in this study might be further adapted to improve monitor the effectiveness of management strategies, and monitoring, of this highly prolific invasive shrub.

5.0 REFERENCES

Bauer, J. T., Shannon, S. M., Stoops, R. E., and Reynolds, H. L. (2012). Context dependency of the allelopathic effects of Lonicera maackii on seed germination. Plant Ecology, 213(12), 1907–1916. https://doi.org/10.1007/s11258-012-0036-2

Birkby, R. (2005). Lightly on the land: The SCA trail-building and maintenance manual. Seattle, WA. Mountaineers, *The Mountaineers Books*, p. 16-20 and 139 - 150.

Borth, E. B., Custer, K. W., and McEwan, R. W. (2018). Lethal Effects of Leaf Leachate from the Non-Native Invasive Shrub Amur Honeysuckle (Lonicera maackii) on a Model Aquatic Organism (Hyalella azteca). *Ecoscience*, *25*(2), p. 189–197. https://doi.org/10.1080/11956860.2018.1426261

Bolte, A., Czajkowski, T., and Kompa, T. (2007). The north-eastern distribution range of European beech - A review. Forestry, 80(4), p. 413–429. https://doi.org/10.1093/forestry/cpm028

Bretschneider, E. V. (1898). History of European botanical discoveries in China: Vols. I, II (pp. 613–644).

Cameron, G. N., Culley, T. M., Kolbe, S. E., Miller, A. I., and Matter, S. F. (2016). Relationships between an invasive shrub Amur honeysuckle (Lonicera maackii, Caprifoliaceae) and environmental factors on recruitment of sugar maple trees (Acer saccharum, Aceraceae) in southwestern Ohio1,2. Journal of the Torrey Botanical Society, 143(4), p. 386–397. https://doi.org/10.3159/TORREY-D-15-00036.1

Cascadia Prairie-Oak Partnership. (2019). Management Guide for Lonicera maackii (Amur honeysuckle). In Management Guide for Lonicera Maackii (pp. 1–5).

Castellano, S. M., and Boyce, R. L. (2007). Spatial Patterns of Juniperus virginiana and Lonicera maackii on a Road Cut in Kentucky , Published by : Torrey Botanical Society Stable URL : https://www.jstor.org/stable/20063910 REFERENCES Linked references are available on JSTOR for this article : Spa. 134(2), p. 188–198.

Custer, K. W., Borth, E. B., Mahoney, S. D., and McEwan, R. W. (2017). Lethal and sublethal effects of novel terrestrial subsidies from an invasive shrub (Lonicera maackii) on stream macroinvertebrates. *Freshwater Science*, *36*(4), 750–759. https://doi.org/10.1086/694895

Davies, P. E., and Nelson, M. (1994). Relationships between riparian buffer widths and the effects of logging on stream habitat, invertebrate community composition and fish abundance. *Marine and Freshwater Research*, *45*(7), 1289–1309. https://doi.org/10.1071/MF9941289

Dawson, T. E. (1996). Determining water use by trees and forests from isotopic, energy balance and transpiration analyses: The roles of tree size and hydraulic lift. Tree Physiology, 16(1–2), p. 263–272. https://doi.org/10.1093/treephys/16.1-2.263

Demars, B. B., and Runkle, J. R. (1992). Groundlayer vegetation ordination and site-factor analysis of the Wright State University Woods (Greene County, Ohio). *Ohio Journal of Science*, *92*(4), 98–106.

Demars, B. G., and Boerner, R. E. J. (1997). FOLIAR NUTRIENT DYNAMICS AND RESORPTION IN NATURALIZED LONICERA MAACKII (CAPRIFOLIACEAE) POPULATIONS IN OHIO , USA1. 84(1), 112–117. https://doi.org/10.2307/2445888

Dickens, S. J. M., Gerhardt, F., and Collinge, S. K. (2005). Recreational portage trails as corridors facilitating non-native plant invasions of the Boundary Waters Canoe Area Wilderness (U.S.A.). Conservation Biology, 19(5), 1653–1657. https://doi.org/10.1111/j.1523-1739.2005.004285.x

Garman, G. C., and Mullen, D. M. (1979). The Value of Riparian Zones for Protecting Aquatic Systems : General Concerns and Recent Studies in Maine 1. p. 315–319.

Gorchov, D. L., and Trisel, D. E. (2003). Competitive effects of the invasive shrub, Lonicera maackii (Rupr.) Herder (Caprifoliaceae), on the growth and survival of native tree seedlings. Plant Ecology, 166(1), p. 13–24. https://doi.org/10.1023/A:1023208215796

Goudarzi, M. A., and Landry, R. J. (2017). Assessing Horizontal Positional Accuracy of. Geodesy and Cartography, 43(2), 56–65. https://doi.org/10.3846/20296991.2017.1330767Guo, J., Zhang, J. X., Zhao, H. T., Li, C., Zhou, J., Tu, H. J., and Zhao, Y. (2020). Horizontal accuracy assessment of google earth data over typical regions of asia. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 43(B3), 1333–1338. https://doi.org/10.5194/isprs-archives-XLIII-B3-2020-1333-2020

Guo, J., Zhang, J. X., Zhao, H. T., Li, C., Zhou, J., Tu, H. J., and Zhao, Y. (2020). Horizontal accuracy assessment of google earth data over typical regions of asia. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 43(B3), p. 1333–1338. https://doi.org/10.5194/isprs-archives-XLIII-B3-2020-1333-2020

Harper, K. A., Macdonald, S. E., Burton, P. J., Chen, J., Brosofske, K. D., Saunders, S. C., Euskirchen, E. S., Roberts, D., Jaiteh, M. S., and Esseen, P. A. (2005). Edge influence on forest structure and composition in fragmented landscapes. Conservation Biology, 19(3), p. 768–782. https://doi.org/10.1111/j.1523-1739.2005.00045.x

He, Y., Wang, P., Sheng, H., Wang, D., Huang, M., and Cao, C. (2020). Sustainability of riparian zones for non-point source pollution control in Chongming Island: Status, challenges, and perspectives. *Journal of Cleaner Production*, *244*, 118804.

https://doi.org/10.1016/j.jclepro.2019.118804

Henkin, M. A., Medley, K. E., Abbitt, R. J., and Patton, J. M. (2013). Invasion dynamics of nonnative Amur honeysuckle over 18 Years in a southwestern Ohio forest. American Midland Naturalist, 170(2), p. 335–347. https://doi.org/10.1674/0003-0031-170.2.335

Honeysuckle. Columbia Electronic Encyclopedia, 6th Edition. (2020):1. Accessed February 20, 2021, https://searchebscohostcom.ezproxy.libraries.wright.edu/login.aspx?direct=trueanddb=lkhandAN=134520350andsite=eds-live

Hopfensperger, K. N., Boyce, R. L., and Schenk, D. (2017). Removing invasive lonicera maackii and seeding native plants alters riparian ecosystem function. Ecological Restoration, 35(4), p. 320–327. https://doi.org/10.3368/er.35.4.320

Huebner, C. D. (2021). Patterns of invasive plant abundance in disturbed versus undisturbed forests within three land types over 16 years. Diversity and Distributions, 27(1), p. 130–143. https://doi.org/10.1111/ddi.13175

Hutchinson, T. F., and Vankat, J. L. (1998). Landscape structure and spread of the exotic shrub Lonicera maackii (Amur honeysuckle) in Southwestern Ohio forest. *American Midland Naturalist*, *139*(2), p. 383–390. https://doi.org/10.1674/0003-0031(1998)139[0383:LSASOT]2.0.CO;2

Hutchinson, T. F., and Vankat, J. L. (1997). Invasibility and effects of Amur honeysuckle in southwestern Ohio forests. Conservation Biology, 11(5), p. 1117–1124. https://doi.org/10.1046/j.1523-1739.1997.96001.x

Ilhardt, B. L., Verry, E. S., and Palik, B. J. (2000). Defining Riparian Areas. Forestry and the Riparian Zone, p. 23–41. https://extension.unh.edu/resources/files/Resource006641_Rep9557.pdf

International Mountain Bicycling Association. (2018). Guidelines for a quality trail experience: Mountain bike trail guidelines. International Mountain Bicycling Association, p. 8–40.

Johnson, C. E., and Barton, C. C. (2004). Where in the world are my field plots? Using GPS effectively in environmental field studies. Frontiers in Ecology and the Environment, 2(9), p. 475–482. https://doi.org/10.1890/1540-9295(2004)002[0475:WITWAM]2.0.CO;2

Julie B. Kirschbaum, Peter W. Axelson, Patricia E. Longmuir, Kathleen M. Mispagel, Julie A. Stein, D. A. Y. (2001). Designing Sidewalks and Trails for Access: Part II Of II: Best Practices Design Guide. September, 2001. https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/sidewalk2/pdf.cfm

Lemke, D., Hulme, P. E., Brown, J. A., and Tadesse, W. (2011). Distribution modelling of Japanese honeysuckle (Lonicera japonica) invasion in the Cumberland Plateau and

Mountain Region, USA. Forest Ecology and Management, 262(2), p. 139–149. https://doi.org/10.1016/j.foreco.2011.03.014

Lieurance, D., and Landsbergen, K. (2016). The influence of light habitat on the physiology, biomass allocation, and fecundity of the invasive shrub Amur honeysuckle (Lonicera maackii, Caprifoliaceae)1. *The Journal of the Torrey Botanical Society*, *143*(4), p. 415. https://doi.org/10.3159/torrey-d-15-00056.1

Luken, J. O., Kuddes, L. M., and Tholemeier, T. C. (1997). Response of Understory Species to Gap Formation and Soil Disturbance in Lonicera I maackii Thickets. 5(3), p. 229–235.

Luken, J. O., and Thieret, J. W. (1996). Amur Honeysuckle, its fall from grace. BioScience, 46(1), p. 18–24. https://doi.org/10.2307/1312651

Luken, J. O., and Thieret, J. W. (1995). Ascent, decline,. Department of Biological Sciences, p. 480–497.

Lynch, K. R., and Lynch, K. R. (2016). Effects of invasive shrub honeysuckle (Lonicera maackii) and forest composition on bird communities in woodland stands.

Martin, P. H., Canham, C. D., and Marks, P. L. (2009). Why forests appear resistant to exotic plant invasions: Intentional introductions, stand dynamics, and the role of shade tolerance. Frontiers in Ecology and the Environment, 7(3), p. 142–149. https://doi.org/10.1890/070096

Merriam, R. W. (2003). The Abundance , Distribution and Edge Associations of Six Non-Indigenous , Harmful Plants across North Carolina Author (s): Robert W . Merriam Source : The Journal of the Torrey Botanical Society , Oct . - Dec ., 2003 , Vol . 130 , No . 4 Published by : 130(4), p. 283–291.

McEwan, R. W., Arthur-Paratley, L. G., Rieske, L. K., and Arthur, M. A. (2010). A multi-assay comparison of seed germination inhibition by Lonicera maackii and co-occurring native shrubs. Flora: Morphology, Distribution, Functional Ecology of Plants, 205(7), p. 475–483. https://doi.org/10.1016/j.flora.2009.12.031

McNeish, R. E., and McEwan, R. W. (2016). A review on the invasion ecology of Amur honeysuckle (Lonicera maackii, Caprifoliaceae) a case study of ecological impacts at multiple scales. Journal of the Torrey Botanical Society, 143(4), p. 367–385. https://doi.org/10.3159/TORREY-D-15-00049.1

McNeish, R. E., Benbow, M. E., and McEwan, R. W. (2018). Riparian invasion of Lonicera maackii influences throughfall chemistry and rainwater availability. *Ecological Research*, *33*(5), p. 1021–1030. https://doi.org/10.1007/s11284-018-1620-2

Miller, G. W. (1988). Economics of herbicide application methods in hardwoods. Proceedings of the Conference Forestry Herbicides in the Northeast, p. 89–100.

Moffatt, S. F., McLachlan, S. M., and Kenkel, N. C. (2004). Impacts of land use on riparian forest along an urban - Rural gradient in southern Manitoba. Plant Ecology, 174(1), p. 119–135. https://doi.org/10.1023/B:VEGE.0000046055.27285.fd

Musson, J., and Mitsch, W. J. (1999). The effects of the invasive shrub Lonicera maacki on species richness and soil moisture in the bottomland hardwood forest at the ORWRP, p. 121–126.

Naiman, R. J., and Décamps, H. (1997). The ecology of interfaces: Riparian zones. Annual Review of Ecology and Systematics, 28(102), p. 621–658. https://doi.org/10.1146/annurev.ecolsys.28.1.621

National Research Council. (2002). Riparian Areas: Functions and Strategies For Management In Riparian Areas, The National Academy Press, p. 23 – 48. https://doi.org/10.17226/10327

Netherland, M. D., and Jones, K. D. (2015). A three-year evaluation of triclopyr for selective whole-bay management of Eurasian watermilfoil on Lake Minnetonka, Minnesota. Lake and Reservoir Management, 31(4), p. 306–323. https://doi.org/10.1080/10402381.2015.1085114

ODNR Natural Resources Division of Soil and Water. (2011). Precipitation in Ohio. *Fact Sheet*, *92–11*, 2. http://soilandwater.ohiodnr.gov/portals/soilwater/pdf/inventory/fctsht11.pdf

ONR. (2016). Soil regions of Ohio. Ohio Department of Natural Resources (ONR) Brochure, p. 1–6. http://water.ohiodnr.gov/soil-conservation/ohio-soil-regions

Pfeiffer, S. S., and Gorchov, D. L. (2015). Effects of the Invasive Shrub Lonicera maackii on Soil Water Content in Eastern Deciduous Forest. *The American Midland Naturalist*, *173*, p. 38–46.

Porter, E., Forschner, B., and Blair, R. (2001). Woody vegetation and canopy fragmentation along a forest-to-urban gradient. Urban Ecosystems, 5(2), p. 131–151. https://doi.org/10.1023/A:1022391721622Pulighe, G. (2016). Horizontal accuracy assessment of very high-resolution Google Earth images in the city of Rome , Italy. 9(4), p. 342–362.

Ramey-Gassert, L. K., and Runkle, J. R. (1992). Effect of land use practices on composition of woodlot vegetation in Greene County, Ohio. Ohio Journal of Science, 92(1), p. 25–32.

Runkle, J. R., DiSalvo, A., Graham-Gibson, Y., and Dorning, M. (2007). Vegetation release eight years after removal of Lonicera maackii in west-central Ohio. Ohio Journal of Science, 107(5), p. 125–129.

Scherrer, D., Bader, M. K. F., and Körner, C. (2011). Drought-sensitivity ranking of deciduous tree species based on thermal imaging of forest canopies. Agricultural and Forest Meteorology, 151(12), p. 1632–1640. https://doi.org/10.1016/j.agrformet.2011.06.019

Shields, J. M., Jenkins, M. A., Saunders, M. R., Gibson, K. D., Zollner, P. A., and Dunning, J. B. (2015). Influence of Intensity and Duration of Invasion by Amur Honeysuckle (Lonicera maackii) on Mixed Hardwood Forests of Indiana . Invasive Plant Science and Management, 8(1), p. 44–56. https://doi.org/10.1614/ipsm-d-14-00044.1

Shields, J. M., Jenkins, M. A., Zollner, P. A., and Saunders, M. R. (2014). Effects of Amur honeysuckle invasion and removal on white-footed mice. Journal of Wildlife Management, 78(5), p. 867–880. https://doi.org/10.1002/jwmg.730

Smith, K. and Smith A. (2010). Controlling Non-Native Invasive Plants in Ohio Forests: Bush Honeysuckle. In Ohio State Extension Program (Vol. 035, Issue September), p. 1-6

Stireman, J. O., Devlin, H., and Doyle, A. L. (2014). Habitat fragmentation, tree diversity, and plant invasion interact to structure forest caterpillar communities. Oecologia, 176(1), p. 207–224. https://doi.org/10.1007/s00442-014-3014-7

The National Invasive Species Council. (2015). Invasive species interagency crosscut budget, p. 1 – 4. http://www.invasivespecies.gov

Tjaden, R. L., Weber, G. M., et al. (2004). Riparian Buffer Management. Agriculture, p. 2–5.

Tomczyk, A. M., Ewertowski, M. W., White, P. C. L., and Kasprzak, L. (2017). A new framework for prioritizing decisions on recreational trail management. Landscape and Urban Planning, 167(June), p. 1–13. https://doi.org/10.1016/j.landurbplan.2017.05.009

United States Soil Conservation Service. (1931) Average annual precipitation in inches, -60, southwest Ohio River basin study area, Ohio. Lincoln, Nebr.: USDA-SCS. *Map.* Retrieved from the Library of Congress, https://www.loc.gov/item/81691036/.

Vasileios C. Drosos, and Chrisvaladis Malesios. (2012). Measuring the Accuracy and Precision of the Garmin GPS Positioning in Forested Areas: A Case Study in Taxiarchis-Vrastama University Forest. *Journal of Environmental Science and Engineering B*, *1*(4), p. 566 – 576 https://doi.org/10.17265/2162-5263/2012.04.015

Wilfong, B. N., Gorchov, D. L., and Henry, M. C. (2009). Detecting an Invasive Shrub in Deciduous Forest Understories Using Remote Sensing. Weed Science, 57(5), p. 512–520. https://doi.org/10.1614/ws-09-012.1

Wilson, J. R. U., Faulkner, K. T., Rahlao, S. J., Richardson, D. M., Zengeya, T. A., and van Wilgen, B. W. (2018). Indicators for monitoring biological invasions at a national level. Journal of Applied Ecology, 55(6), p. 2612–2620. https://doi.org/10.1111/1365-2664.13251

Wilson, J. R., Panetta, F. D., andamp; Lindgren, C. (2017). Detecting and responding to alien plant incursions. Cambridge University Press, p. 9 – 51.

Zhang, N., Zhang, Q., Li, Y., Zeng, M., Li, W., Chang, C., Xu, Y., and Huang, C. (2020). Effect of groundcovers on reducing soil erosion and non-point source pollution in citrus orchards on red soil under frequent heavy rainfall. Sustainability (Switzerland), 12(3), p. 1146. https://doi.org/10.3390/su12031146

APPENDIX

National Invasive Species Council Financial Audit

Table A.1: Abbreviated crosscut budget report for federal spending FY2014-2016 Actual and Enacted

CROSSCUT BUDGET INTERAGENCY FUNDING FOR INVASICE SPECIES ACTIVITIES (IN THOUSANDS $)

FY2014 ACTUAL

Category	DHS	DOC	DOD	DOI[1]	DOS	DOT	EPA[2]	USDA	TOTAL
Research	0	1,450	4,648	17,976	2,285	235	0	230,081	256,675
Prevention	704,521	8	8,448	7,388	1,015	3,926	54,600	93,019	872,925
Control & Management	0	337	109,705	44,456	12,382	0	0	502,772	669,652
Restoration	0	1,315	12,244	6,318	0	0	0	19,132	39,009
Total	704,521	3,110	135,045	76,138	15,682	4,161	54,600	845,004	1,838,261

CROSSCUT BUDGET INTERAGENCY FUNDING FOR INVASICE SPECIES ACTIVITIES (IN THOUSANDS $)

FY2015 ACTUAL

Category	DHS	DOC	DOD	DOI[1]	DOS	DOT	EPA[2]	USDA	TOTAL
Research	0	918	9,611	18,977	2,337	231	0	236,319	268,393
Prevention	745,041	63	30,327	9,342	1,120	1,081	53,000	97,812	937,786
Control & Management	0	261	57,352	45,548	11,654	0	0	527,291	642,106
Restoration	0	1,454	17,318	4,625	0	0	0	23,658	47,055
Total	745,041	2,696	114,608	78,492	15,111	1,312	53,000	885,080	1,895,340

CROSSCUT BUDGET INTERAGENCY FUNDING FOR INVASICE SPECIES ACTIVITIES (IN THOUSANDS $)

FY2016 ENACTED

Category	DHS	DOC	DOD	DOI[1]	DOS	DOT	EPA[2]	USDA	TOTAL
Research	0	925	6,029	19,970	2,194	1,585	0	237,692	268,395
Prevention	776,300	8	31,850	11,184	565	810	57,000	100,064	977,781
Control & Management	0	126	61,066	46,643	12,002	0	0	526,498	646,335
Restoration	0	54	18,638	4,332	0	0	0	25,145	48,169
Total	776,300	1,113	117,583	82,129	14,761	2,395	57,000	889,399	1,940,680

[1] Does not include $1.4 million for administration

[2] EPA does not allocate or monitor funding for the Great Lakes Restoration Initiative (GLRI) according to the functional categories utilized by nisc.

Regions of Amur honeysuckle Spread and "Naturalization"

Table A.2: Range of Amur honeysuckle spread obtained from the United States Department of Agriculture Fire and Effects Information System. States with Amur honeysuckle considered to be more naturalized are in red.

Table 2. USDA FIRE EFFECTS INFORMATION SYSTEM (FEIS)

UNITED STATES

Amur honeysuckle range:

AL	AR	CT	DE	GA	ID	IL
IN	IA	KS	KY	LA	MD	MA
MI	MS	MO	NE	NJ	NY	NC
ND	OH	OK	PA	RI	SC	TN
TX	VA	WV	WI			

Due to the dynamic influences of Amur honeysuckle (although it has become more naturalized), it is still considered spreading because it has not reached its full potential (Merriam, 2003).

Greene County Soil Information—Specific to Both Sites

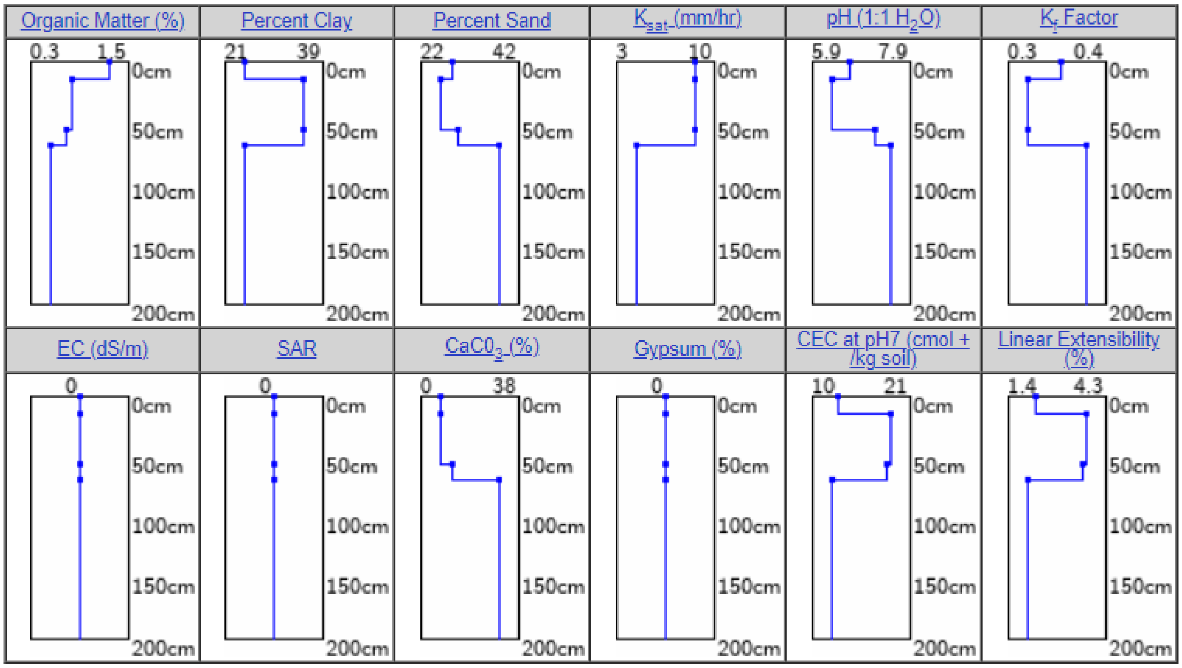

Figure A.22: Miamian Soil Information – MoMBA. Soil Component information obtained from University of California Davis Department of Agriculture and Natural Resources Database.

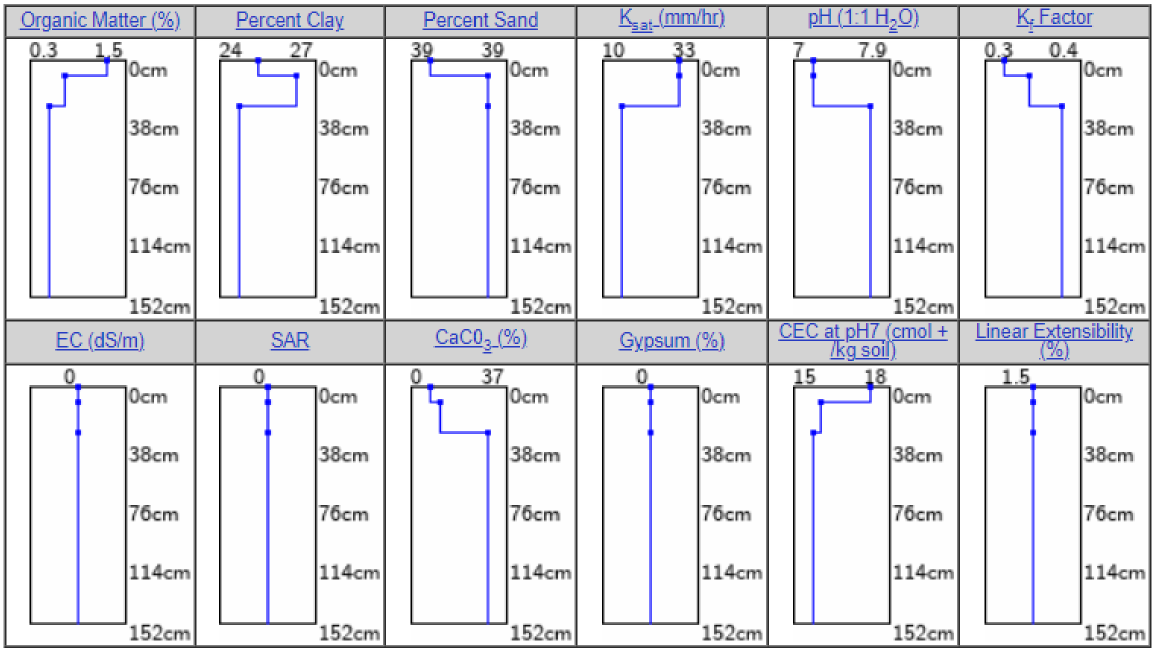

Figure A.23: Hennepin Soil Information – MoMBA. Soil Component information obtained from University of California Davis Department of Agriculture and Natural Resources Database.

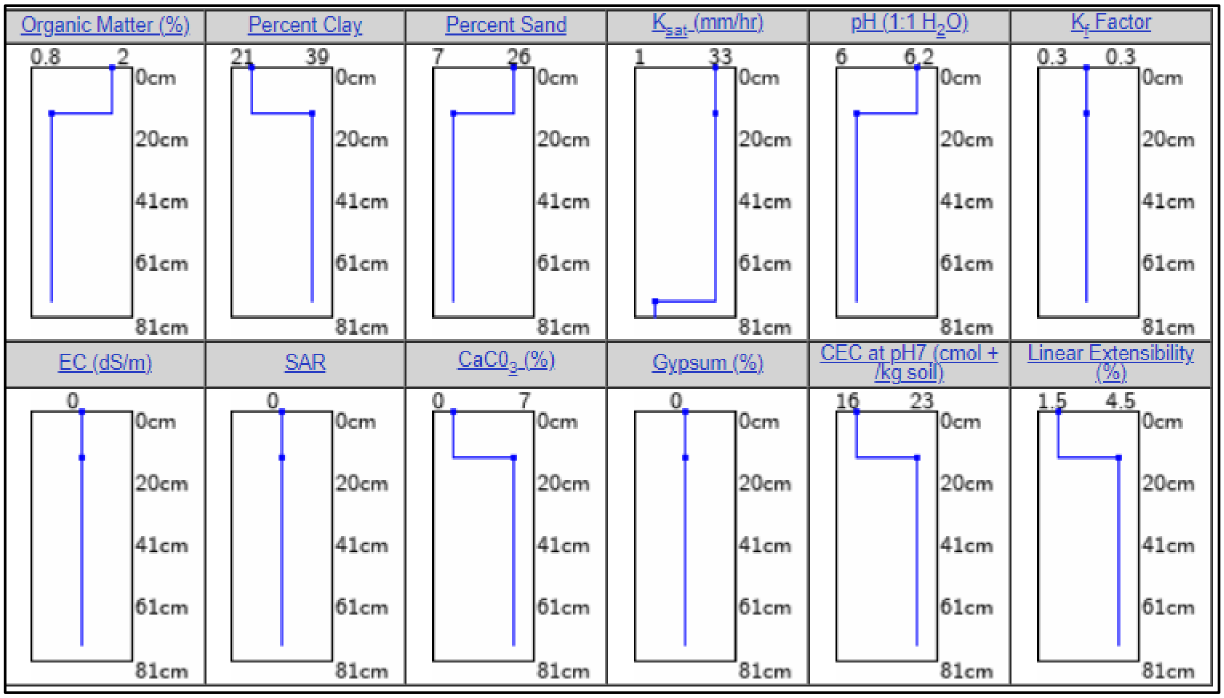

Figure A.24: Milton Soil Information – MoMBA. Soil Component information obtained from University of California Davis Department of Agriculture and Natural Resources Database.

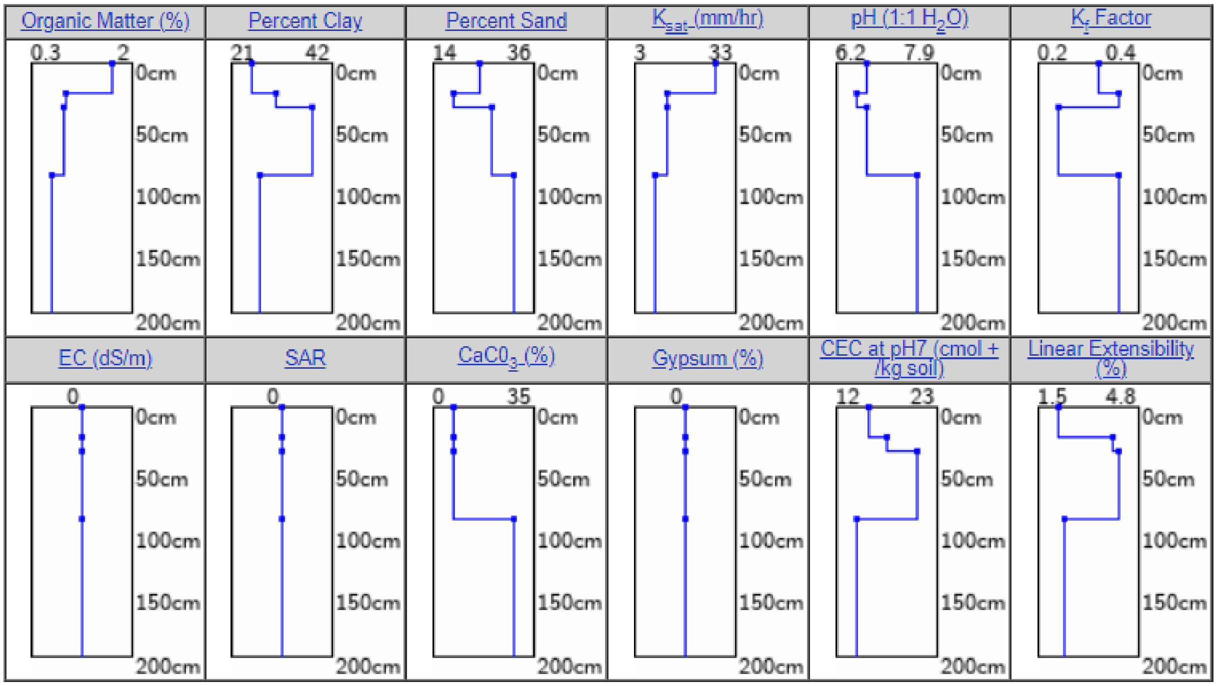

Figure A.25: Miamian Soil Information – WSU. Soil Component information obtained from University of California Davis Department of Agriculture and Natural Resources Database.

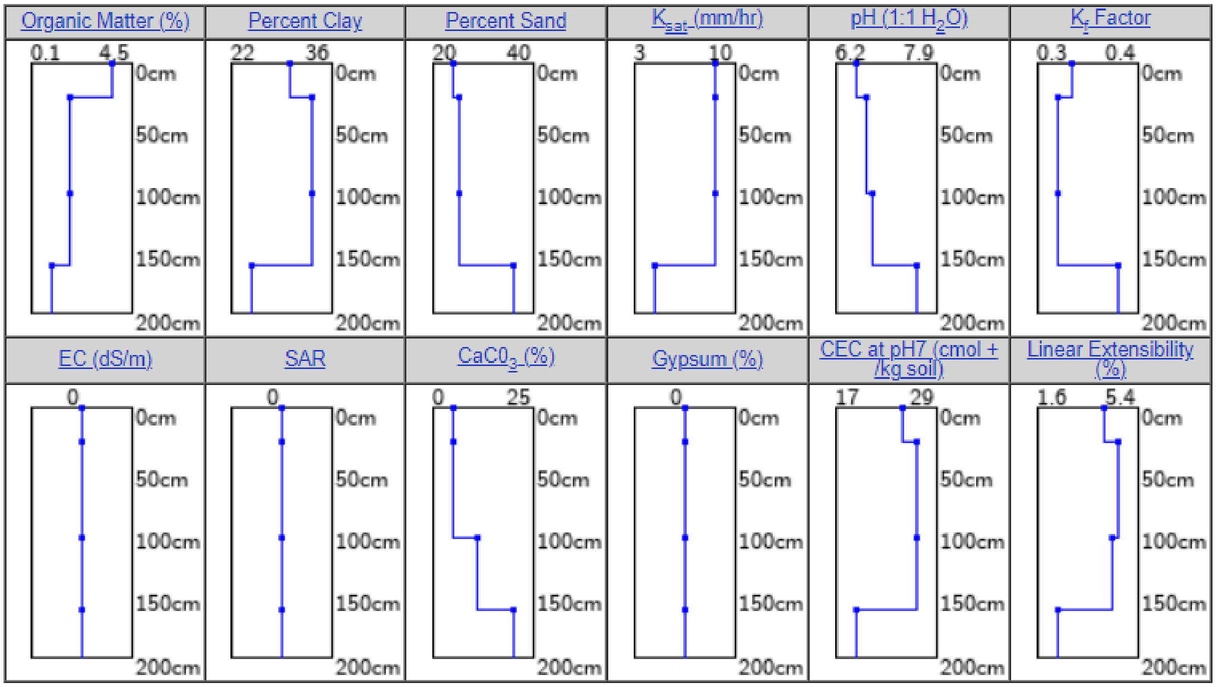

Figure A.26: Kokomo Soil Information – WSU. Soil Component information obtained from University of California Davis Department of Agriculture and Natural Resources Database.

Stem Location Data

Table A.5: Stem Location Data (UTM Coordinates) for Site 1 (A) and Site 2 (B) through page 80.

Table 5A – WSU Site 1			Table 5B – MoMBA Site 2		
Point	Northing (Y)	Easting (X)	Points	Northing (Y)	Easting (X)
1	4407540.683	752081.232	1	4411171.779	748980.678
2	4407543.069	752080.581	2	4411136.672	749028.814
3	4407544.788	752076.523	3	4411090.804	748939.748
4	4407545.647	752074.494	4	4411156.414	748946.755
5	4407544.647	752072.241	5	4411147.686	748991.604
6	4407546.209	752069.045	6	4411155.809	748996.481
7	4407548.614	752068.966	7	4411153.029	748996.429
8	4407546.248	752064.614	8	4411163.861	748993.506
9	4407547.159	752064.155	9	4411162.83	748990.254
10	4407544.047	752065.258	10	4411160.489	748986.616
11	4407550.325	752059.049	11	4411153.213	748990.71
12	4407549.939	752064.207	12	4411153.061	748991.714
13	4407543.067	752058.002	13	4411153.566	749001.554
14	4407547.257	752055.863	14	4411152.044	749000.318
15	4407548.814	752052.525	15	4411153.796	748991.548
16	4407545.086	752051.79	16	4411150.655	748986.079
17	4407545.669	752052.628	17	4411158.883	748982.812
18	4407547.282	752051.003	18	4411158.768	748984.958
19	4407542.828	752050.721	19	4411161.441	748981.729
20	4407543.003	752050.43	20	4411163.666	748981.799
21	4407544.499	752045.236	21	4411157.921	748981.701
22	4407544.347	752046.241	22	4411151.848	748988.612
23	4407545.823	752046.05	23	4411150.729	748988.362
24	4407543.774	752045.688	24	4411149.947	748987.102
25	4407540.015	752049.67	25	4411148.111	748987.59
26	4407534.606	752037.272	26	4411145.511	748987.389
27	4407536.674	752038.205	27	4411145.072	748985.261
28	4407537.419	752038.323	28	4411138.481	748993.332
29	4407540.618	752034.216	29	4411143.476	748987.456
30	4407541.119	752038.201	30	4411145.928	748988.804
31	4407544.124	752033.815	31	4411146.312	748989.22
32	4407540.126	752030.517	32	4411138.784	748974.182
33	4407537.791	752032.737	33	4411152.356	748981.453
34	4407540.428	752034.08	34	4411153.133	748976.857
35	4407536.745	752040.346	35	4411151.62	748975.907
36	4407537.58	752037.603	36	4411147.707	748975.177
37	4407533.341	752032.598	37	4411144.594	748976.278
38	4407530.984	752028.531	38	4411149.761	748975.681
39	4407534.922	752029.974	39	4411146.509	748972.502
40	4407536.9	752028.194	40	4411144.658	748972.562
41	4407530.434	752028.692	41	4411145.333	748970.54
42	4407528.286	752025.333	42	4411135.889	748976.275
43	4407531.535	752028.37	43	4411139.154	748974.17
44	4407531.839	752026.359	44	4411139.316	748973.45
45	4407539.2	752019.258	45	4411141.874	748972.367
46	4407525.785	752028.13	46	4411145.652	748968.959
47	4407524.551	752030.029	47	4411149.497	748973.262
48	4407527.577	752031.93	48	4411149.237	748970.985
49	4407525.254	752028.862	49	4411151.111	748971.638
50	4407528.91	752033.03	50	4411153.614	748974.556
51	4407528.336	752032.477	51	4411152.231	748977.601
52	4407522.931	752037.085	52	4411152.158	748986.745
53	4407521.584	752035.557	53	4411154.716	748985.661
54	4407521.371	752034.707	54	4411153.772	748985.121

55	4407526.512	752038.968	55	4411151.112	748983.065
56	4407523.4	752040.07	56	4411151.912	748979.182
57	4407517.57	752037.404	57	4411158.045	748974.126
58	4407522.376	752037.103	58	4411157.907	748981.273
59	4407527.917	752036.635	59	4411164.48	748984.058
60	4407537.143	752041.19	60	4411163.296	748987.525
61	4407530.529	752042.837	61	4411157.76	748988.134
62	4407528.094	752047.633	62	4411165.794	748984.587
63	4407526.181	752034.548	63	4411160.841	748991.747
64	4407525.769	752033.276	64	4411165.762	748989.302
65	4407521.624	752031.126	65	4411163.875	748988.22
66	4407523.507	752032.064	66	4411162.959	748988.536
67	4407523.474	752031.065	67	4411164.615	748988.196
68	4407523.385	752028.352	68	4411171.775	748986.249
69	4407522.3	752023.529	69	4411169.393	748987.041
70	4407524.691	752023.022	70	4411165.261	748979.605
71	4407529.373	752024.583	71	4411169.013	748981.054
72	4407528.333	752026.76	72	4411150.784	748984.361
73	4407549.072	752060.377	73	4411155.992	748979.335
74	4407550.923	752060.316	74	4411158.091	748975.553
75	4407552.726	752058.827	75	4411148.373	748978.583
76	4407550.829	752057.461	76	4411151.046	748969.64
77	4407550.923	752060.316	77	4411136.994	748976.097
78	4407543.334	752054.849	78	4411143.359	748978.175
79	4407534.271	752060.863	79	4411151.763	748974.616
80	4407543.287	752053.421	80	4411151.883	748972.613
81	4407539.305	752044.978	81	4411152.73	748970.157
82	4407535.417	752039.389	82	4411153.636	748969.556
83	4407537.079	752033.618	83	4411154.353	748968.819
84	4407534.947	752025.114	84	4411154.543	748968.955
85	4407540.732	752032.069	85	4411160.847	748969.179
86	4407538.976	752034.985	86	4411163.951	748967.792
87	4407531.387	752029.518	87	4411163.586	748967.947
88	4407535.135	752030.824	88	4411161.879	748966.717
89	4407531.387	752029.518	89	4411160.426	748967.621
90	4407529.443	752026.724	90	4411163.914	748966.651
91	4407531.293	752026.663	91	4411158.326	748965.69
92	4407533.003	752022.32	92	4411159.145	748968.091
93	4407530.918	752015.243	93	4411159.612	748965.362
94	4407533.003	752022.32	94	4411162.513	748969.125
95	4407521.995	752025.54	95	4411155.852	748969.341
96	4407518.295	752025.662	96	4411161.698	748966.866
97	4407525.837	752029.701	97	4411163.063	748968.964
98	4407535.229	752033.679	98	4411168.434	748974.645
99	4407527.969	752038.205	99	4411178.092	748975.474
100	4407527.875	752035.35	100	4411174.211	748975.743
101	4407529.725	752035.289	101	4411169.059	748976.768
102	4407527.875	752035.35	102	4411175.136	748975.713
103	4407535.323	752036.534	103	4411180.742	748971.531
104	4407535.464	752040.817	104	4411176.741	748973.804
105	4407533.613	752040.878	105	4411168.346	748977.648
106	4407529.96	752042.427	106	4411176.404	748980.528
107	4407515.064	752040.059	107	4411175.59	748978.269
108	4407520.615	752039.876	108	4411174.096	748977.889
109	4407520.333	752031.311	109	4411178.125	748976.473
110	4407518.765	752039.937	110	4411177.297	748979.499
111	4407513.167	752038.692	111	4411190.642	748979.779
112	4407513.026	752034.409	112	4411191.516	748978.179
113	4407524.127	752034.044	113	4411182.051	748971.917
114	4407511.035	752030.188	114	4411178.304	748970.61
115	4407510.941	752027.333	115	4411176.833	748970.944
116	4407516.445	752025.722	116	4411177.698	748969.059
117	4407520.239	752028.456	117	4411177.286	748967.787

118	4407519.957	752019.89	118	4411178.087	748969.618
119	4407519.957	752019.89	119	4411177.129	748968.649
120	4407523.705	752021.196	120	4411167.75	748976.382
121	4407521.761	752018.402	121	4411177.431	748977.924
122	4407540.545	752026.359	122	4411190.544	748976.783
123	4407553.637	752030.215	123	4411177.213	748976.931
124	4407561.038	752029.972	124	4411168.642	748975.353
125	4407564.738	752029.85	125	4411161.416	748969.589
126	4407557.337	752030.094	126	4411170.45	748968.295
127	4407561.132	752032.827	127	4411166.592	748969.277
128	4407561.038	752029.972	128	4411162.351	748969.844
129	4407564.738	752029.85	129	4411151.925	748973.897
130	4407557.478	752034.376	130	4411155.135	748970.079
131	4407564.926	752035.56	131	4411155.051	748967.51
132	4407561.273	752037.11	132	4411162.993	748966.824
133	4407559.422	752037.171	133	4411167.171	748969.973
134	4407561.366	752039.965	134	4411164.913	748968.904
135	4407554.2	752047.346	135	4411162.61	748972.121
136	4407565.302	752046.981	136	4411151.555	748968.196
137	4407567.105	752045.492	137	4411152.48	748968.165
138	4407570.758	752043.943	138	4411152.345	748964.028
139	4407572.562	752042.455	139	4411162.7	748991.972
140	4407576.309	752043.761	140	4411166.789	748992.41
141	4407570.711	752042.516	141	4411161.197	748991.307
142	4407568.439	752029.729	142	4411155.586	748989.633
143	4407570.43	752033.95	143	4411160.536	748993.757
144	4407567.011	752042.637	144	4411158.713	748994.673
145	4407561.413	752041.392	145	4411158.209	748990.547
146	4407565.302	752046.981	146	4411154.785	748987.802
147	4407567.199	752048.347	147	4411153.351	748983.563
148	4407569.049	752048.287	148	4411156.751	748985.595
149	4407563.358	752044.187	149	4411152.912	748987.149
150	4407567.105	752045.492	150	4411146.871	748983.631
151	4407565.349	752048.408	151	4411147.999	748984.166
152	4407574.6	752048.104	152	4411148.304	748982.156
153	4407559.939	752052.874	153	4411148.462	748981.294
154	4407563.639	752052.752	154	4411152.884	748980.579
155	4407560.174	752060.011	155	4411153.864	748982.261
156	4407565.443	752051.263	156	4411152.695	748986.156
157	4407561.93	752057.095	157	4411150.645	748985.794
158	4407567.387	752054.058	158	4411155.984	748990.477
159	4407569.237	752053.997	159	4411163.824	748992.364
160	4407574.788	752053.814	160	4411165.189	748994.462
161	4407567.434	752055.485	161	4411153.805	748991.833
162	4407569.237	752053.997	162	4411147.598	748994.606
163	4407565.537	752054.119	163	4411148.264	748992.299
164	4407573.125	752059.585	164	4411146.479	748994.357
165	4407564.015	752064.172	165	4411145.406	748995.534
166	4407567.669	752062.623	166	4411145.174	748994.114
167	4407574.975	752059.524	167	4411146.65	748993.923
168	4407573.266	752063.868	168	4411154.689	748996.232
169	4407569.754	752069.7	169	4411157.298	748996.719
170	4407575.116	752063.807	170	4411156.124	749000.471
171	4407578.911	752066.54	171	4411148.371	749001.294
172	4407580.573	752060.769	172	4411150.184	749000.093
173	4407571.369	752062.501	173	4411153.089	748998.284
174	4407571.51	752066.784	174	4411149.05	748993.702
175	4407571.463	752065.356	175	4411141.376	748991.238
176	4407582.517	752063.564	176	4411149.444	748994.403
177	4407580.714	752065.052	177	4411146.571	748991.497
178	4407577.06	752066.601	178	4411146.747	748991.206
179	4407571.698	752072.494	179	4411145.294	748992.11
180	4407571.698	752072.494	180	4411154.981	748999.508

181	4407575.68	752080.938	181	4411156.859	749000.304
182	4407570.082	752079.693	182	4411157.044	749000.298
183	4407572.073	752083.914	183	4411156.738	748996.594
184	4407572.073	752083.914	184	4411157.626	748995.422
185	4407564.626	752082.73	185	4411158.186	748995.547
186	4407564.626	752082.73	186	4411158.455	749003.823
187	4407564.72	752085.585	187	4411155.083	749002.647
188	4407579.099	752072.251	188	4411155.772	749001.053
189	4407565.912	752065.539	189	4411162.072	749001.134
190	4407565.912	752065.539	190	4411161.152	749001.307
191	4407567.622	752061.195	191	4411144.487	749007.134
192	4407558.23	752057.217	192	4411151.804	749004.325
193	4407561.695	752049.958	193	4411150.685	749004.076
194	4407561.648	752048.53	194	4411144.047	749005.006
195	4407561.695	752049.958	195	4411150.925	749000.068
196	4407561.601	752047.103	196	4411149.282	748995.123
197	4407563.498	752048.469	197	4411151.526	749001.477
198	4407557.995	752050.079	198	4411150.823	749002.643
199	4407559.704	752045.736	199	4411148.2	749001.728
200	4407559.657	752044.308	200	4411139.911	748997.427
201	4407557.76	752042.942	201	4411139.926	749009.282
202	4407555.44	752028.727	202	4411156.754	749014.162
203	4407555.628	752034.437	203	4411156.199	749014.18
204	4407553.919	752038.781	204	4411155.833	749008.622
205	4407555.769	752038.72	205	4411154.538	749008.664
206	4407548.18	752033.253	206	4411148.285	749010.01
207	4407555.534	752031.582	207	4411142.781	749017.331
208	4407551.552	752023.139	208	4411144.196	749015.285
209	4407549.89	752028.91	209	4411143.248	749014.602
210	4407555.487	752030.155	210	4411143.826	749015.297
211	4407559.188	752030.033	211	4411147.11	749013.762
212	4407551.928	752034.559	212	4411144.881	749013.549
213	4407551.928	752034.559	213	4411141.818	749010.506
214	4407552.162	752041.697	214	4411149.071	749011.413
215	4407549.983	752031.765	215	4411152.836	749013.29
216	4407549.796	752026.054	216	4411147.494	749014.178
217	4407551.552	752023.139	217	4411147.855	749013.881
218	4407549.608	752020.344	218	4411143.146	749017.176
219	4407549.796	752026.054	219	4411141.394	749020.233
220	4407555.158	752020.162	220	4411141.676	749017.51
221	4407545.954	752021.894	221	4411141.764	749020.221
222	4407542.207	752020.588	222	4411139.909	749020.138
223	4407544.057	752020.527	223	4411133.892	749028.761
224	4407544.01	752019.099	224	4411141.205	749025.81
225	4407540.169	752014.938	225	4411138.272	749021.049
226	4407534.665	752016.549	226	4411139.845	749023.854
227	4407532.815	752016.609	227	4411136.024	749025.978
228	4407530.824	752012.388	228	4411129.378	749032.336
229	4407536.375	752012.205	229	4411130.293	749026.307
230	4407534.337	752006.556	230	4411134.797	749016.734
231	4407532.345	752002.334	231	4411132.799	749017.941
232	4407556.445	752002.97	232	4411132.096	749019.107
233	4407561.949	752001.36	233	4411132.147	749020.677
234	4407558.108	751997.199	234	4411142.657	749024.905
235	4407558.342	752004.337	235	4411138.689	749028.177
236	4407556.398	752001.543	236	4411139.077	749028.736
237	4407548.81	751996.076	237	4411139.299	749024.158
238	4407556.351	752000.115	238	4411130.117	749026.599
239	4407563.846	752002.727	239	4411135.83	749025.699
240	4407565.696	752002.666	240	4411138.79	749025.602
241	4407561.996	752002.788	241	4411149.73	749025.961
242	4407558.718	752015.757	242	4411150.293	748980.663
243	4407556.774	752012.963	243	4411149.525	748979.831

244	4407558.389	752005.765	244	4411145.261	748985.398
245	4407558.389	752005.765	245	4411137.911	748981.495
246	4407560.286	752007.131	246	4411141.098	748982.676
247	4407554.595	752003.031	247	4411141.774	748986.368
248	4407554.548	752001.604	248	4411140.719	748988.117
249	4407560.24	752005.704	249	4411141.506	748989.519
250	4407558.436	752007.192	250	4411137.833	748990.496
251	4407562.231	752009.925	251	4411144.272	748989.144
252	4407554.689	752005.886	252	4411136.432	748992.97
253	4407558.389	752005.765	253	4411137.107	748990.948
254	4407560.333	752008.559	254	4411137.736	748993.213
255	4407552.933	752008.802	255	4411137.986	748995.204
256	4407554.83	752010.169	256	4411143.837	748992.872
257	4407562.371	752014.208	257	4411144.804	748994.126
258	4407564.316	752017.002	258	4411145.572	748994.958
259	4407560.615	752017.124	259	4411147.288	748996.473
260	4407558.859	752020.04	260	4411145.332	748998.965
261	4407556.774	752012.963	261	4411148.63	748997.858
262	4407562.465	752017.063	262	4411150.253	748990.806
263	4407565.837	752006.949	263	4411147.575	748993.893
264	4407566.072	752014.086	264	4411141.433	748998.663
265	4407562.325	752012.781	265	4411136.548	748996.537
266	4407560.568	752015.696	266	4411142.024	748994.073
267	4407566.307	752021.224	267	4411146.529	748990.213
268	4407562.606	752021.346	268	4411148.204	748990.444
269	4407564.269	752015.575	269	4411143.509	748994.168
270	4407562.559	752019.918	270	4411142.556	748993.342
271	4407568.345	752026.873	271	4411143.722	748995.018
272	4407581.296	752026.447	272	4411145.406	748995.534
273	4407568.063	752018.308	273	4411147.969	749000.307
274	4407564.363	752018.43	274	4411147.723	748998.459
275	4407571.904	752022.469	275	4411143.755	749001.73
276	4407567.922	752014.026	276	4411147.668	749002.46
277	4407564.738	752029.85	277	4411131.135	748983.858
278	4407566.541	752028.362	278	4411130.845	748997.722
279	4407566.495	752026.934	279	4411130.813	749002.437
280	4407577.549	752025.142	280	4411133.033	749002.365
281	4407573.754	752022.408	281	4411133.658	749004.487
282	4407573.754	752022.408	282	4411135.911	749005.413
283	4407575.652	752023.775	283	4411133.352	749000.783
284	4407568.157	752021.163	284	4411133.495	748999.493
285	4407568.204	752022.591	285	4411135.42	749001.716
286	4407570.101	752023.957	286	4411133.463	748998.494
287	4407570.524	752036.805	287	4411133.741	749001.342
288	4407570.477	752035.378	288	4411132.779	749000.23
289	4407572.28	752033.889	289	4411135.221	749001.294
290	4407570.383	752032.523	290	4411137.206	749005.371
291	4407568.533	752032.584	291	4411148.926	749001.276
292	4407574.083	752032.401	292	4411148.196	749001.586
293	4407572.327	752035.317	293	4411150.208	749000.806
294	4407572.421	752038.172	294	4411149.68	748995.967
295	4407574.271	752038.111	295	4411148.94	749001.704
296	4407576.168	752039.478	296	4411149.334	749002.406
297	4407576.121	752038.05	297	4411145.337	749004.821
298	4407578.018	752039.417	298	4411148.839	749004.279
299	4407574.647	752049.532	299	4411148.409	749002.436
300	4407574.553	752046.676	300	4411149.792	749005.105
301	4407580.01	752043.639	301	4411148.011	749007.305
302	4407574.647	752049.532	302	4411143.465	749009.881
303	4407573.125	752059.585	303	4411141.337	749007.094
304	4407578.441	752052.265	304	4411141.522	749007.088
305	4407572.703	752046.737	305	4411139.015	749009.74
306	4407580.01	752043.639	306	4411139.597	749004.865

307	4407581.86	752043.578	307	4411138.88	749005.602
308	4407583.757	752044.945	308	4411137.697	749009.069
309	4407582.001	752047.861	309	4411138.136	749005.484
310	4407574.6	752048.104	310	4411134.009	749003.904
311	4407578.3	752047.982	311	4411132.691	749003.233
312	4407583.71	752043.517	312	4411132.534	749004.095
313	4407583.616	752040.662	313	4411129.754	749004.043
314	4407582.048	752049.288	314	4411133.732	749006.77
315	4407578.629	752057.975	315	4411128.459	749004.085
316	4407582.329	752057.853	316	4411133.2	749001.788
317	4407585.983	752056.304	317	4411130.475	749003.448
318	4407589.448	752049.045	318	4411132.391	749005.385
319	4407585.842	752052.021	319	4411132.386	749005.242
320	4407588.115	752064.808	320	4411138.15	749005.912
321	4407595.422	752061.71	321	4411139.158	749008.45
322	4407577.107	752068.029	322	4411139.181	749009.164
323	4407606.476	752059.917	323	4411136.12	749011.834
324	4407606.523	752061.345	324	4411140.735	749005.685
325	4407606.476	752059.917	325	4411140.305	749009.555
326	4407606.194	752051.352	326	4411149.08	749011.698
327	4407606.288	752054.207	327	4411137.817	749007.065
328	4407604.579	752058.55	328	4411136.041	749009.409
329	4407599.122	752061.588	329	4411135.267	749002.72
330	4407598.887	752054.45	330	4411132.131	749003.108
331	4407604.391	752052.84	331	4411130.827	749002.865
332	4407606.288	752054.207	332	4411124.902	749002.915
333	4407608.326	752059.856	333	4411125.484	748998.039
334	4407602.635	752055.756	334	4411118.407	748996.841
335	4407600.785	752055.817	335	4411116.974	749004.03
336	4407606.429	752058.49	336	4411131.229	749003.852
337	4407600.738	752054.39	337	4411128.26	749003.663
338	4407606.147	752049.924	338	4411125.961	749001.309
339	4407607.998	752049.863	339	4411128.853	749010.499
340	4407620.949	752049.437	340	4411123.168	749012.256
341	4407617.249	752049.559	341	4411128.316	749005.375
342	4407613.689	752053.963	342	4411126.207	749008.872
343	4407535.845	752035.517	343	4411126.225	749009.442
344	4407535.845	752035.517	344	4411123.821	749015.234
345	4407535.845	752035.517	345	4411125.384	749017.754
346	4407548.826	752030.374	346	4411128.747	749018.645
347	4407547.548	752036.561	347	4411139.686	749013.289
348	4407548.359	752038.678	348	4411132.549	749015.95
349	4407551.216	752035.44	349	4411123.353	749012.25
350	4407556.045	752035.853	350	4411122.021	749011.15
351	4407555.774	752038.863	351	4411122.525	749009.563
352	4407558.79	752040.478	352	4411112.761	749011.166
353	4407555.27	752040.451	353	4411110.942	749006.511
354	4407553.994	752041.065	354	4411118.501	749011.122
355	4407564.481	752033.289	355	4411120.874	749010.045
356	4407561.226	752035.682	356	4411117.261	749012.876
357	4407566.556	752040.08	357	4411117.7	749009.291
358	4407558.948	752050.905	358	4411118.029	749007.995
359	4407561.042	752046.978	359	4411116.965	749009.458
360	4407561.428	752041.821	360	4411122.923	749016.12
361	4407560.317	752041.857	361	4411127.465	749013.401
362	4407558.915	752049.906	362	4411128.788	749014.215
363	4407560.993	752051.124	363	4411129.426	749011.052
364	4407560.293	752058.007	364	4411123.325	749011.394
365	4407565.312	752058.556	365	4411120.929	749011.757
366	4407561.174	752062.265	366	4411130.352	749016.736
367	4407562.469	752062.222	367	4411128.978	749014.352
368	4407563.469	752064.476	368	4411130.944	749012.145
369	4407562.682	752063.073	369	4411131.198	749014.28

370	4407555.451	752068.455	370	4411116.318	749012.336
371	4407557.268	752067.395	371	4411121.068	749010.324
372	4407556.874	752066.694	372	4411121.443	749010.455
373	4407559.355	752068.899	373	4411120.138	749010.212
374	4407561.509	752066.827	374	4411113.269	749009.721
375	4407562.228	752060.515	375	4411117.122	749008.596
376	4407559.996	752065.876	376	4411111.471	749017.064
377	4407562.392	752065.512	377	4411108.959	749013.861
378	4407564.791	752070.863	378	4411123.006	749012.975
379	4407572.035	752071.483	379	4411136.421	749015.395
380	4407562.697	752074.791	380	4411139.33	749013.729
381	4407559.402	752070.326	381	4411139.579	749010.008
382	4407562.276	752073.233	382	4411129.344	749019.911
383	4407559.442	752077.184	383	4411115.054	749001.95
384	4407565.672	752075.122	384	4411105.368	749000.265
385	4407566.45	752076.239	385	4411108.772	748996.726
386	4407566.744	752073.943	386	4411105.783	748990.253
387	4407560.904	752076.565	387	4411110.552	748994.526
388	4407560.797	752067.708	388	4411112.172	748998.758
389	4407570.175	752071.258	389	4411103.568	748996.181
390	4407575.578	752072.223	390	4411103.66	748993.322
391	4407574.632	752065.967	391	4411103.072	748992.341
392	4407565.989	752062.249	392	4411099.515	748985.458
393	4407561.643	752065.251	393	4411097.234	748983.675
394	4407560.729	752059.993	394	4411100.657	748986.42
395	4407567.155	752052.636	395	4411111.223	748992.361
396	4407561.552	752051.248	396	4411107.421	749000.77
397	4407570.155	752048.107	397	4411109.831	748995.121
398	4407561.203	752046.258	398	4411115.099	748991.95
399	4407566.25	752047.664	399	4411117.513	748992.157
400	4407558.936	752044.904	400	4411112.167	748998.616
401	4407556.34	752033.556	401	4411110.756	749000.804
402	4407557.324	752040.955	402	4411114.068	749000.125
403	4407562.436	752033.07	403	4411114.836	749000.957
404	4407556.265	752031.272	404	4411114.3	749001.546
405	4407550.838	752029.593	405	4411111.487	749000.495
406	4407551.834	752031.704	406	4411107.695	749003.475
407	4407557.539	752036.232	407	4411107.709	749003.903
408	4407550.274	752029.326	408	4411108.906	749000.864
409	4407557.799	752027.22	409	4411113.666	748999.138
410	4407556.129	752027.132	410	4411118.712	749000.545
411	4407559.625	752026.446	411	4411117.814	748995.718
412	4407563.101	752030.762	412	4411113.133	748994.156
413	4407554.817	752021.03	413	4411111.195	748991.505
414	4407547.521	752018.841	414	4411111.51	748995.495
415	4407554.163	752018.051	415	4411112.356	748993.039
416	4407536.923	752017.618	416	4411111.459	748993.925
417	4407549.66	752005.051	417	4411110.233	748990.394
418	4407548.312	752009.097	418	4411116.015	748991.634
419	4407543.171	752004.836	419	4411117.907	748992.858
420	4407554.541	752007.034	420	4411114.511	748985.256
421	4407564.012	752002.15	421	4411114.765	748981.676
422	4407563.813	752001.728	422	4411112.184	748982.046
423	4407560.506	752002.551	423	4411111.601	748981.208
424	4407557.005	752003.095	424	4411106.138	748984.1
425	4407564.413	752008.71	425	4411107.571	748976.911
426	4407561.647	752009.087	426	4411112.65	748973.603
427	4407558.229	752017.774	427	4411103.098	748970.343
428	4407550.16	752014.61	428	4411101.331	748972.972
429	4407559.968	752008.714	429	4411109.791	748976.839
430	4407561.769	752012.799	430	4411107.988	748978.326
431	4407561.106	752009.534	431	4411108.047	748974.467
432	4407554.291	752005.042	432	4411111.701	748972.92

433	4407553.37	752005.215	433	4411110.841	748969.234
434	4407555.729	752003.708	434	4411109.467	748972.564
435	4407553.042	752006.512	435	4411113.464	748975.862
436	4407559.383	752013.449	436	4411114.718	748980.249
437	4407563.154	752015.469	437	4411117.429	748983.875
438	4407561.854	752015.368	438	4411122.05	748983.582
439	4407558.05	752012.349	439	4411120.685	748981.484
440	4407553.966	752012.055	440	4411119.297	748978.672
441	4407560.779	752010.831	441	4411115.241	748979.233
442	4407563.962	752011.869	442	4411112.331	748980.898
443	4407565.025	752010.405	443	4411113.335	748983.294
444	4407566.048	752013.373	444	4411114.769	748981.819
445	4407562.718	752013.482	445	4411122.004	748987.868
446	4407565.362	752009.394	446	4411127.892	748986.677
447	4407565.032	752016.264	447	4411128.869	748988.216
448	4407567.681	752012.319	448	4411130.918	748988.578
449	4407564.943	752013.552	449	4411121.444	748982.03
450	4407564.709	752017.704	450	4411122.901	748981.269
451	4407563.21	752017.182	451	4411126.911	748979.281
452	4407573.935	752022.259	452	4411125.25	748973.765
453	4407564.016	752019.156	453	4411126.489	748972.011
454	4407567.627	752016.322	454	4411121.322	748972.607
455	4407566.66	752015.067	455	4411122.654	748967.993
456	4407574.791	752014.514	456	4411115.036	748967.241
457	4407569.063	752020.562	457	4411117.39	748965.593
458	4407567.218	752020.765	458	4411118.102	748964.713
459	4407567.569	752020.182	459	4411117.381	748965.308
460	4407563.051	752023.618	460	4411115.128	748964.381
461	4407561.405	752024.244	461	4411120.17	748965.646
462	4407570.443	752023.089	462	4411124.68	748967.641
463	4407570.818	752023.219	463	4411123.348	748966.542
464	4407569.569	752024.69	464	4411124.597	748965.073
465	4407568.986	752023.851	465	4411119.702	748962.661
466	4407566.548	752022.931	466	4411127.016	748965.423
467	4407565.058	752022.694	467	4411132.224	748960.397
468	4407561.799	752024.945	468	4411125.813	748968.319
469	4407565.101	752023.979	469	4411130.286	748969.173
470	4407575.747	752021.056	470	4411130.444	748968.311
471	4407577.013	752025.731	471	4411127.766	748971.398
472	4407579.546	752023.933	472	4411132.645	748967.668
473	4407576.031	752024.048	473	4411141.17	748967.819
474	4407578.947	752028.24	474	4411128.917	748966.932
475	4407578.022	752028.27	475	4411126.886	748967.141
476	4407580.617	752028.328	476	4411123.163	748966.548
477	4407581.929	752034.429	477	4411120.022	748966.793
478	4407575.77	752038.634	478	4411117.279	748962.169
479	4407572.814	752038.874	479	4411116.348	748956.343
480	4407578.119	752036.841	480	4411123.532	748955.109
481	4407575.817	752040.061	481	4411128.708	748960.511
482	4407577.805	752038.567	482	4411129.735	748963.62
483	4407567.974	752043.749	483	4411136.609	748964.254
484	4407573.674	752036.845	484	4411142.766	748971.338
485	4407573.929	752038.98	485	4411144.362	748969.144
486	4407574.142	752039.83	486	4411137.867	748963.07
487	4407573.714	752043.703	487	4411136.239	748964.266
488	4407576.642	752042.606	488	4411136.47	748965.687
489	4407582.791	752038.117	489	4411136.854	748960.389
490	4407579.335	752045.662	490	4411139.948	748958.717
491	4407576.042	752046.913	491	4411134.434	748960.039
492	4407577.215	752043.159	492	4411136.183	748962.554
493	4407582.52	752041.127	493	4411135.887	748959.135
494	4407584.48	752038.776	494	4411141.299	748960.387
495	4407579.466	752038.369	495	4411140.207	748960.994

496	4407583.527	752037.95	496	4411140.517	748959.127
497	4407586.986	752036.121	497	4411141.456	748959.525
498	4407582.026	752043.001	498	4411128.607	748963.086
499	4407585.169	752037.181	499	4411126.686	748955.292
500	4407587.094	752039.404	500	4411133.716	748949.35
501	4407581.604	752041.443	501	4411135.988	748950.847
502	4407580.005	752043.496	502	4411140.859	748952.546
503	4407580.958	752044.322	503	4411136.349	748956.263
504	4407580.553	752048.909	504	4411142.727	748953.056
505	4407633.545	752049.452	505	4411142.552	748953.348
506	4407579.007	752046.959	506	4411139.415	748948.022
507	4407579.183	752046.667	507	4411134.822	748949.171
508	4407582.096	752045.142	508	4411149.856	748955.824
509	4407587.928	752042.235	509	4411138.459	748958.48
510	4407587.949	752048.522	510	4411141.206	748957.534
511	4407588.989	752046.344	511	4411154.217	748947.541
512	4407589.221	752047.766	512	4411150.424	748950.521
513	4407590.198	752049.306	513	4411150.035	748949.962
514	4407588.287	752047.511	514	4411153.116	748953.575
515	4407587.385	752048.255	515	4411134.995	748965.878
516	4407571.863	752060.627	516	4411135.647	748963.142
517	4407580.641	752057.194	517	4411134.31	748961.9
518	4407581.889	752055.724	518	4411146.239	748958.513
519	4407589.65	752055.183	519	4411142.695	748957.771
520	4407593.73	752055.335	520	4411148.45	748958.155
521	4407593.136	752059.784	521	4411150.18	748960.099
522	4407599.237	752059.441	522	4411151.35	748961.917
523	4407596.965	752057.943	523	4411147.632	748967.18
524	4407596.965	752057.943	524	4411145.772	748961.242
525	4407581.58	752057.592	525	4411149.407	748953.41
526	4407580.043	752055.928	526	4411099.21	748993.181
527	4407580.02	752055.214	527	4411090.139	748993.333
528	4407583.444	752057.96	528	4411095.402	748984.306
529	4407587.693	752063.25	529	4411089.787	748988.202
530	4407588.082	752063.809	530	4411087.428	748989.708
531	4407589.581	752064.331	531	4411107.73	748993.189
532	4407590.9	752065.003	532	4411078.896	749006.411
533	4407594.452	752066.029	533	4411078.839	748993.272
534	4407606.713	752061.481	534	4411083.654	748993.258
535	4407606.767	752068.768	535	4411088.959	748985.515
536	4407595.066	752062.15	536	4411087.419	748983.709
537	4407593.482	752059.058	537	4411087.173	748981.86
538	4407594.133	752056.322	538	4411089.198	748975.795
539	4407594.702	752056.732	539	4411087.339	748975.57
540	4407596.567	752057.099	540	4411086.798	748976.016
541	4407596.672	752054.666	541	4411086.779	748975.445
542	4407597.431	752055.213	542	4411084.17	748974.958
543	4407597.649	752056.206	543	4411081.377	748974.478
544	4407596.016	752057.26	544	4411085.155	748971.07
545	4407600.756	752054.961	545	4411085.789	748967.764
546	4407594.909	752063.013	546	4411084.836	748966.938
547	4407604.979	752053.821	547	4411084.983	748965.79
548	4407612.802	752055.136	548	4411086.653	748965.879
549	4407608.148	752054.432	549	4411088.152	748966.402
550	4407607.323	752051.886	550	4411092.417	748966.548
551	4407608.628	752052.129	551	4411090.539	748965.753
552	4407609.719	752051.522	552	4411089.238	748959.939
553	4407608.4	752050.851	553	4411090.222	748950.336
554	4407604.913	752051.823	554	4411095.801	748951.012
555	4407608.548	752049.702	555	4411097.346	748952.961
556	4407607.29	752050.887	556	4411097.259	748961.677
557	4407604.515	752050.978	557	4411097.287	748962.533
558	4407591.401	752040.835	558	4411089.743	748964.064

559	4407598.718	752049.311	559	4411089.822	748966.49
560	4407607.847	752045.295	560	4411092.158	748969.985
561	4407608.939	752044.688	561	4411091.427	748970.294
562	4407613.283	752047.26	562	4411092.843	748968.249
563	4407607.612	752055.021	563	4411093.805	748969.36
564	4407604.26	752060.133	564	4411095.595	748967.445
565	4407603.672	752047.862	565	4411098.25	748969.358
566	4407609.063	752042.826	566	4411091.909	748973.707
567	4407609.986	752048.369	567	4411089.869	748973.63
568	4407664.603	752025.136	568	4411090.942	748972.453
569	4407670.435	752033.519	569	4411087.871	748974.838
570	4407667.063	752043.633	570	4411094.689	748973.759
571	4407670.435	752033.519	571	4411092.658	748973.968
572	4407668.021	752016.449	572	4411093.963	748974.211
573	4407669.966	752019.243	573	4411088.467	748970.391
574	4407668.397	752027.869	574	4411091.354	748973.725
575	4407668.35	752026.442	575	4411090.854	748975.455
576	4407666.453	752025.075	576	4411088.297	748976.538
577	4407662.471	752016.632	577	4411087.46	748979.279
578	4407650.853	752001.294	578	4411083.296	748976.558
579	4407654.366	751995.462	579	4411083.459	748981.552
580	4407656.404	752001.112	580	4411086.373	748980.029
581	4407656.075	751991.119	581	4411089.194	748981.366
582	4407648.486	751985.652	582	4411092.049	748983.701
583	4407644.833	751987.201	583	4411087.806	748978.554
584	4407642.842	751982.98	584	4411092.242	748978.267
585	4407644.692	751982.919	585	4411092.973	748977.957
586	4407644.645	751981.491	586	4411093.329	748977.517
587	4407640.804	751977.33	587	4411092.367	748976.406
588	4407637.338	751984.59	588	4411092.705	748975.395
589	4407638.86	751974.536	589	4411091.326	748972.869
590	4407642.56	751974.415	590	4411089.425	748971.359
591	4407646.448	751980.003	591	4411088.897	748972.234
592	4407644.692	751982.919	592	4411088.948	748973.803
593	4407646.636	751985.713	593	4411092.723	748975.966
594	4407648.486	751985.652	594	4411093.061	748974.955
595	4407635.817	751994.643	595	4411092.367	748976.406
596	4407639.611	751997.377	596	4411098.075	748975.363
597	4407646.777	751989.996	597	4411098.607	748974.632
598	4407642.983	751987.262	598	4411097.811	748972.943
599	4407641.367	751994.461	599	4411099.522	748968.603
600	4407632.21	751997.62	600	4411097.667	748968.52
601	4407651.135	752009.859	601	4411162.036	748965.855
602	4407654.835	752009.738	602	4411090.506	748964.754
603	4407656.685	752009.677	603	4411090.113	748964.052
604	4407656.685	752009.677	604	4411092.689	748963.54
605	4407655.023	752015.448	605	4411094.183	748963.92
606	4407657.155	752023.952	606	4411096.182	748962.712
607	4407657.155	752023.952	607	4411099.784	748959.595
608	4407668.256	752023.587	608	4411100.659	748957.996
609	4407666.5	752026.503	609	4411092.781	748954.967
610	4407666.688	752032.213	610	4411092.855	748957.25
611	4407672.285	752033.458	611	4411096.532	748950.703
612	4407650.365	752042.753	612	4411096.685	748955.411
613	4407642.682	752034.432	613	4411102	748959.381
614	4407638.7	752025.988	614	4411102.541	748958.934
615	4407633.055	752023.316	615	4411103.37	748961.621
616	4407636.521	752016.056	616	4411107.398	748960.205
617	4407632.633	752010.468	617	4411106.269	748959.67
618	4407636.333	752010.346	618	4411102.023	748960.094
619	4407636.427	752013.201	619	4411101.098	748960.124
620	4407632.539	752007.613	620	4411101.871	748961.099
621	4407632.539	752007.613	621	4411100.765	748961.278

622	4407634.624	752014.69	622	4411101.464	748959.969
623	4407634.389	752007.552	623	4411105.155	748959.564
624	4407634.295	752004.697	624	4411105.714	748959.688
625	4407634.201	752001.842	625	4411105.663	748958.119
626	4407630.407	751999.109	626	4411107.176	748959.069
627	4407630.501	752001.964	627	4411107.024	748960.074
628	4407628.416	751994.887	628	4411108.374	748961.744
629	4407630.172	751991.971	629	4411109.267	748960.715
630	4407620.921	751992.275	630	4411104.951	748958.999
631	4407620.545	751980.855	631	4411106.237	748958.671
632	4407620.639	751983.71	632	4411106.01	748957.393
633	4407624.903	752000.719	633	4411105.039	748955.996
634	4407626.8	752002.085	634	4411106.87	748955.366
635	4407626.847	752003.513	635	4411112.518	748958.181
636	4407625.279	752012.139	636	4411110.465	748957.677
637	4407625.232	752010.711	637	4411110.27	748957.397
638	4407625.185	752009.284	638	4411112.292	748956.903
639	4407627.035	752009.223	639	4411110.016	748960.977
640	4407632.492	752006.185	640	4411108.176	748967.036
641	4407630.782	752010.529	641	4411108.384	748967.743
642	4407627.176	752013.506	642	4411108.944	748967.868
643	4407621.672	752015.116	643	4411112.977	748966.594
644	4407630.923	752014.811	644	4411118.547	748966.984
645	4407634.624	752014.69	645	4411116.099	748965.778
646	4407630.923	752014.811	646	4411114.911	748969.102
647	4407631.017	752017.666	647	4411111.002	748968.515
648	4407636.662	752020.339	648	4411113.061	748969.162
649	4407640.315	752018.79	649	4411106.295	748977.524
650	4407631.252	752024.804	650	4411110.235	748973.396
651	4407631.487	752031.942	651	4411109.727	748974.841
652	4407642.541	752030.149	652	4411108.385	748973.457
653	4407637.225	752037.469	653	4411111.109	748971.797
654	4407635.281	752034.675	654	4411110.378	748972.106
655	4407637.178	752036.042	655	4411110.517	748970.673
656	4407639.075	752037.408	656	4411110.522	748970.816
657	4407651.933	752034.127	657	4411110.868	748970.09
658	4407652.027	752036.982	658	4411107.487	748968.629
659	4407655.774	752038.288	659	4411105.354	748965.699
660	4407654.159	752045.487	660	4411106.266	748970.954
661	4407659.897	752051.014	661	4411107.344	748975.633
662	4407643.574	752061.555	662	4411107.973	748972.184
663	4407639.874	752061.677	663	4411108.445	748975.311
664	4407639.733	752057.394	664	4411110.916	748977.231
665	4407634.041	752053.294	665	4411110.55	748977.386
666	4407631.815	752041.935	666	4411102.261	748978.798
667	4407633.384	752033.308	667	4411100.592	748978.709
668	4407631.534	752033.369	668	4411098.931	748978.906
669	4407631.487	752031.942	669	4411099.828	748978.02
670	4407623.898	752026.475	670	4411103.358	748978.334
671	4407618.535	752032.368	671	4411103.594	748979.897
672	4407616.591	752029.574	672	4411110.79	748973.378
673	4407614.6	752025.352	673	4411096.049	748975.715
674	4407618.254	752023.803	674	4411096.627	748976.41
675	4407614.788	752031.062	675	4411099.92	748975.16
676	4407616.356	752022.436	676	4411100.656	748974.993
677	4407616.356	752022.436	677	4411099.333	748974.18
678	4407616.075	752013.871	678	4411100.952	748978.412
679	4407617.925	752013.81	679	4411099.296	748978.751
680	4407617.925	752013.81	680	4411097.871	748974.798
681	4407617.878	752012.382	681	4411095.276	748974.74
682	4407617.784	752009.527	682	4411096.993	748976.255
683	4407612.139	752006.855	683	4411096.794	748975.833
684	4407614.084	752009.649	684	4411104.389	748975.872

685	4407612.045	752004	685	4411113.593	748968.431
686	4407613.943	752005.366	686	4411104.841	748967.001
687	4407610.148	752002.633	687	4411111.996	748959.198
688	4407614.037	752008.221	688	4411113.629	748958.145
689	4407608.251	752001.266	689	4411114.096	748961.13
690	4407606.495	752004.182	690	4411112.889	748963.883
691	4407608.298	752002.694	691	4411109.632	748960.561
692	4407602.322	752040.618	692	4411105.557	748954.837
693	4407660.637	752022.837	693	4411106.537	748956.519
694	4407663.973	752022.87	694	4411103.059	748957.775
695	4407666.762	752023.207	695	4411103.781	748957.18
696	4407664.492	752016.137	696	4411097.134	748963.538
697	4407660.995	752016.823	697	4411097.643	748962.093
698	4407661.356	752016.526	698	4411099.211	748959.043
699	4407662.281	752016.495	699	4411105.876	748958.969
700	4407646.366	752000.013	700	4411104.16	748957.453
701	4407649.717	751994.901	701	4411106.445	748959.379
702	4407647.253	751998.84	702	4411108.541	748961.167
703	4407659.279	751987.155	703	4411107.981	748961.043
704	4407646.876	751992.993	704	4411107.893	748958.332
705	4407631.728	751977.343	705	4411105.793	748956.4
706	4407634.562	751973.391	706	4411105.987	748956.68
707	4407637.536	751973.722	707	4411103.688	748954.326
708	4407634.054	751974.837	708	4411106.037	748952.536
709	4407630.744	751969.944	709	4411106.014	748951.822
710	4407636.177	751966.193	710	4411103.521	748949.19
711	4407639.161	751966.809	711	4411102.762	748948.643
712	4407638.482	751968.689	712	4411100.616	748950.998
713	4407633.206	751971.578	713	4411103.096	748953.203
714	4407630.665	751978.807	714	4411103.738	748950.182
715	4407635.139	751979.66	715	4411097.378	748948.247
716	4407636.319	751981.765	716	4411095.977	748956.434
717	4407637.12	751983.597	717	4411099.655	748955.6
718	4407640.99	751988.614	718	4411104.326	748956.877
719	4407646.55	751988.717	719	4411112.287	748956.761
720	4407642.559	751991.278	720	4411108.596	748957.166
721	4407633.505	751997.578	721	4411150.271	748951.525
722	4407641.731	751999.879	722	4411146.644	748942.502
723	4407645.989	752005.456	723	4411148.6	748940.01
724	4407647.507	752006.549	724	4411150.071	748939.677
725	4407648.16	752009.528	725	4411142.577	748937.064
726	4407645.118	752012.773	726	4411142.804	748938.342
727	4407656.011	752011.7	727	4411135.819	748934.284
728	4407656.046	752007.125	728	4411136.573	748934.688
729	4407658.383	752010.621	729	4411134.894	748934.314
730	4407660.472	752006.551	730	4411139.705	748934.157
731	4407661.562	752011.517	731	4411134.844	748938.458
732	4407660.066	752016.711	732	4411133.83	748935.777
733	4407658.016	752016.35	733	4411134.187	748935.337
734	4407656.707	752015.964	734	4411134.252	748937.334
735	4407652.59	752014.67	735	4411133.817	748935.349
736	4407661.069	752024.681	736	4411135.986	748939.421
737	4407664.303	752027.29	737	4411135.811	748939.712
738	4407665.231	752032.975	738	4411132.938	748936.806
739	4407663.636	752035.171	739	4411126.758	748934.721
740	4407658.837	752030.042	740	4411135.844	748946.424
741	4407654.908	752045.748	741	4411130.168	748942.752
742	4407605.532	752031.224	742	4411123.498	748942.684
743	4407635.749	752026.371	743	4411141.26	748947.819
744	4407626.729	752016.807	744	4411140.34	748947.992
745	4407628.043	752017.336	745	4411137.772	748943.076
746	4407627.141	752018.08	746	4411138.6	748940.05
747	4407630.75	752020.819	747	4411142.472	748945.209

748	4407624.396	752013.454	748	4411137.134	748946.239
749	4407623.107	752008.066	749	4411137.837	748945.074
750	4407627.093	752005.363	750	4411137.449	748944.515
751	4407624.711	752006.155	751	4411136.144	748944.272
752	4407626.011	752006.256	752	4411134.72	748946.032
753	4407626.456	752008.527	753	4411132.874	748946.235
754	4407623.187	752010.493	754	4411134.35	748946.044
755	4407634.568	751996.113	755	4411134.881	748945.313
756	4407631.131	752004.229	756	4411136.131	748949.557
757	4407627.051	752004.078	757	4411126.523	748944.585
758	4407627.178	752007.932	758	4411127.274	748956.273
759	4407627.084	752005.077	759	4411127.07	748955.708
760	4407626.248	752007.82	760	4411129.804	748954.334
761	4407624.428	752003.164	761	4411120.224	748950.218
762	4407622.957	752003.498	762	4411126.315	748943.877
763	4407621.5	752004.26	763	4411091.554	748945.722
764	4407624.47	752004.448	764	4411128.133	748942.818
765	4407622.865	751995.069	765	4411119.775	748947.804
766	4407617.059	751993.117	766	4411124.64	748937.933
767	4407615.201	751987.319	767	4411120.954	748944.195
768	4407613.262	751984.667	768	4411119.002	748941.116
769	4407613.025	751983.103	769	4411115.227	748938.953
770	4407612.815	751987.969	770	4411115.953	748938.501
771	4407612.185	751996.993	771	4411115.639	748945.939
772	4407613.968	752000.507	772	4411117.175	748947.603
773	4407620.481	752001.436	773	4411116.037	748946.783
774	4407619.28	752004.333	774	4411116.139	748949.922
775	4407625.362	752003.419	775	4411111.268	748948.223
776	4407627.227	752003.786	776	4411116.944	748951.895
777	4407620.749	752009.573	777	4411117.324	748952.169
778	4407630.096	752006.55	778	4411116.741	748951.331
779	4407626.016	752006.398	779	4411119.313	748950.676
780	4407624.213	752007.887	780	4411123.434	748952.113
781	4407624.791	752008.582	781	4411125.867	748952.891
782	4407622.927	752008.215	782	4411117.73	748947.585
783	4407624	752007.036	783	4411117.722	748953.013
784	4407624.782	752008.297	784	4411129.688	748956.48
785	4407628.297	752008.181	785	4411123.661	748953.391
786	4407626.808	752007.944	786	4411124.734	748952.213
787	4407623.99	752006.751	787	4411123.055	748951.839
788	4407624.028	752007.893	788	4411120.086	748963.077
789	4407621.946	752006.532	789	4411126.63	748947.867
790	4407623.77	752011.331	790	4411126.898	748950.429
791	4407621.326	752015.842	791	4411080.074	748951.524
792	4407623.284	752019.064	792	4411082.664	748945.726
793	4407630.481	752018.256	793	4411087.941	748942.84
794	4407627.469	752016.783	794	4411082.308	748951.879
795	4407629.855	752016.133	795	4411088.179	748961.544
796	4407634.287	752015.701	796	4411084.127	748962.247
797	4407631.779	752023.929	797	4411083.53	748960.981
798	4407632.428	752026.766	798	4411086.31	748955.32
799	4407632.083	752021.919	799	4411088.248	748952.258
800	4407625.573	752026.706	800	4411086.754	748957.591
801	4407627.521	752029.643	801	4411087.129	748957.722
802	4407623.613	752040.347	802	4411085.159	748959.786
803	4407623.845	752041.768	803	4411087.143	748958.15
804	4407624.126	752039.044	804	4411076.738	748940.062
805	4407628.236	752034.478	805	4411078.426	748940.722
806	4407634.93	752035.258	806	4411083.611	748940.696
807	4407634.209	752035.854	807	4411082.867	748940.577
808	4407633.023	752033.606	808	4411083.232	748940.422
809	4407633.56	752033.017	809	4411084.736	748941.088
810	4407633.749	752033.154	810	4411086.766	748940.879

811	4407639.708	752034.101	811	4411086.826	748937.02
812	4407643.345	752037.697	812	4411089.005	748941.377
813	4407643.152	752048.707	813	4411093.445	748941.233
814	4407641.737	752050.754	814	4411089.477	748944.504
815	4407638.819	752052.136	815	4411089.352	748946.365
816	4407636.124	752054.655	816	4411095.676	748947.159
817	4407637.428	752054.897	817	4411095.676	748947.159
818	4407633.791	752051.301	818	4411093.604	748951.798
819	4407632.425	752049.203	819	4411094.455	748949.485
820	4407629.689	752044.863	820	4411094.15	748951.494
821	4407626.215	752034.973	821	4411098.387	748950.785
822	4407624.353	752029.033	822	4411095.482	748952.594
823	4407624.47	752032.601	823	4411091.573	748952.007
824	4407624.721	752034.594	824	4411092.988	748949.961
825	4407622.292	752033.959	825	4411098.826	748947.2
826	4407626.847	752031.666	826	4411103.478	748942.192
827	4407622.924	752030.651	827	4411102.09	748939.38
828	4407619.556	752029.619	828	4411098.645	748941.635
829	4407620.088	752028.887	829	4411094.731	748940.905
830	4407622.404	752026.096	830	4411091.808	748942.143
831	4407621.615	752030.266	831	4411092.932	748942.535
832	4407617.8	752032.535	832	4411094.181	748941.066
833	4407620.172	752031.457	833	4411093.057	748940.674
834	4407617.275	752027.836	834	4411093.598	748940.228
835	4407613.741	752027.381	835	4411090.36	748943.19
836	4407611.9	752027.727	836	4411089.056	748942.947
837	4407605.763	752021.355	837	4411095.758	748938.301
838	4407613.191	752010.679	838	4411091.373	748940.158
839	4407612.339	752007.277	839	4411092.076	748938.992
840	4407613.097	752007.824	840	4411093.487	748936.804
841	4407612.884	752006.973	841	4411092.691	748935.115
842	4407615.753	752009.737	842	4411096.558	748940.132
843	4407613.032	752005.825	843	4411091.378	748946.014
844	4407613.746	752010.66	844	4411089.998	748932.061
845	4407612.02	752008.859	845	4411086.923	748934.303
846	4407613.173	752010.108	846	4411090.119	748935.77
847	4407615.695	752013.597	847	4411089.161	748934.802
848	4407614.833	752009.91	848	4411087.515	748935.427
849	4407611.954	752006.861	849	4411085.503	748936.206
850	4407610.225	751999.344	850	4411085.045	748933.507
851	4407614.057	752003.219	851	4411093.5	748931.518
852	4407611.102	752003.459	852	4411099.458	748932.467
853	4407611.263	752002.739	853	4411099.115	748933.335
854	4407610.551	752003.62	854	4411100.508	748936.289
855	4407608.682	752003.11	855	4411099.597	748936.748
856	4407607.919	752002.421	856	4411098.515	748937.64
857	4407607.891	752001.564	857	4411096.119	748938.003
858	4407606.813	752002.6	858	4411095.425	748939.454
859	4407605.389	752004.362	859	4411090.43	748945.33
860	4407602.445	751999.314	860	4411092.317	748940.698
861	4407603.593	752000.419	861	4411093.427	748940.662
862	4407607.998	752049.863	862	4411093.612	748940.656
863	4407607.951	752048.436	863	4411095.615	748939.591
864	4407607.951	752048.436	864	4411097.053	748938.259
865	4407611.651	752048.314	865	4411102.28	748939.517
866	4407615.164	752042.482	866	4411090.189	748943.624
867	4407607.951	752048.436	867	4411094.787	748942.618
868	4407606.147	752049.924	868	4411096.429	748941.85
869	4407602.212	752042.908	869	4411095.583	748944.306
870	4407603.921	752038.565	870	4411099.279	748944.043
871	4407605.866	752041.359	871	4411100.43	748945.291
872	4407608.044	752051.291	872	4411101.582	748946.539
873	4407607.998	752049.863	873	4411104.015	748947.317

874	4407607.763	752042.726	874	4411109.224	748948.004
875	4407604.156	752045.703	875	4411111.213	748952.225
876	4407600.409	752044.397	876	4411109.677	748950.561
877	4407598.371	752038.748	877	4411109.02	748947.44
878	4407596.943	752051.656	878	4411105.463	748946.27
879	4407602.353	752047.191	879	4411101.813	748942.246
880	4407605.678	752035.649	880	4411103.057	748940.635
881	4407612.844	752028.268	881	4411101.452	748942.544
882	4407616.591	752029.574	882	4411100.921	748943.275
883	4407614.741	752029.635	883	4411100.939	748943.846
884	4407618.488	752030.94	884	4411098.048	748940.369
885	4407611.275	752036.894	885	4411098.432	748940.785
886	4407605.866	752041.359	886	4411095.66	748935.304
887	4407622.47	752039.384	887	4411097.279	748933.823
888	4407624.274	752037.895	888	4411097.645	748933.669
889	4407618.629	752035.223	889	4411096.664	748931.987
890	4407607.528	752035.588	890	4411094.379	748930.061
891	4407606.495	752004.182	891	4411096.872	748932.694
892	4407606.401	752001.327	892	4411097.149	748929.828
893	4407604.645	752004.243	893	4411096.288	748926.142
894	4407600.944	752004.365	894	4411097.529	748935.815
895	4407595.487	752007.402	895	4411095.683	748930.304
896	4407599.188	752007.281	896	4411099.379	748930.041
897	4407593.778	752011.746	897	4411098.019	748933.799
898	4407595.581	752010.258	898	4411095.059	748933.896
899	4407595.628	752011.685	899	4411094.708	748940.192
900	4407591.787	752007.524	900	4411096.762	748940.696
901	4407593.872	752014.601	901	4411090.407	748944.617
902	4407591.928	752011.807	902	4411088.002	748944.695
903	4407586.518	752016.272	903	4411088.418	748946.11
904	4407586.377	752011.989	904	4411103.659	748942.043
905	4407584.527	752012.05	905	4411106.023	748946.394
906	4407591.928	752011.807	906	4411099.565	748941.462
907	4407597.526	752013.052	907	4411102.35	748941.657
908	4407595.628	752011.685	908	4411101.142	748938.697
909	4407595.581	752010.258	909	4411100.198	748938.156
910	4407601.226	752012.93	910	4411096.507	748938.562
911	4407597.901	752024.472	911	4411096.747	748934.555
912	4407601.226	752012.93	912	4411095.498	748930.31
913	4407601.085	752008.647	913	4411094.674	748927.766
914	4407597.572	752014.479	914	4411095.202	748926.892
915	4407606.824	752014.175	915	4411096.062	748924.864
916	4407604.926	752012.808	916	4411094.365	748929.633
917	4407606.73	752011.32	917	4411095.928	748932.153
918	4407612.515	752018.275	918	4411095.35	748931.458
919	4407614.459	752021.069	919	4411097.58	748931.671
920	4407612.656	752022.558	920	4411098.574	748933.781
921	4407607.293	752028.45	921	4411108.926	748927.445
922	4407614.224	752013.932	922	4411105.919	748931.828
923	4407607.058	752021.313	923	4411103.228	748934.487
924	4407605.161	752019.946	924	4411099.657	748938.603
925	4407605.067	752017.091	925	4411098.589	748939.923
926	4407597.666	752017.334	926	4411099.657	748938.603
927	4407597.572	752014.479	927	4411099.999	748937.734
928	4407590.219	752016.15	928	4411099.897	748934.595
929	4407588.462	752019.066	929	4411103.787	748934.612
930	4407596.051	752024.533	930	4411102.993	748944.35
931	4407588.744	752027.631	931	4411101.291	748943.263
932	4407590.782	752033.281	932	4411100.518	748942.288
933	4407586.941	752029.12	933	4411101.277	748942.835
934	4407590.829	752034.708	934	4411100.139	748942.015
935	4407588.932	752033.342	935	4411099.801	748943.026
936	4407587.223	752037.685	936	4411091.702	748944.575

937	4407581.719	752039.295	937	4411103.044	748945.92
938	4407585.044	752027.753	938	4411104.417	748942.59
939	4407574.224	752036.684	939	4411104.866	748939.29
940	4407615.955	752044.028	940	4411105.027	748938.571
941	4407618.997	752040.784	941	4411106.087	748936.965
942	4407615.52	752042.042	942	4411102.247	748932.805
943	4407615.323	752047.336	943	4411102.205	748931.521
944	4407612.705	752046.565	944	4411099.777	748930.885
945	4407609.503	752044.955	945	4411100.873	748936.135
946	4407611.534	752044.745	946	4411097.76	748931.522
947	4407610.461	752045.924	947	4411095.314	748936.03
948	4407608.26	752046.568	948	4411094.828	748932.475
949	4407606.7	752044.19	949	4411093.907	748932.648
950	4407606.988	752047.324	950	4411094.989	748931.755
951	4407605.039	752044.387	951	4411100.369	748932.009
952	4407572.836	752045.161	952	4411102.622	748932.935
953	4407606.557	752045.481	953	4411102.774	748931.931
954	4407603.093	752047.167	954	4411099.667	748938.888
955	4407603.302	752047.874	955	4411099.296	748938.9
956	4407599.592	752047.711	956	4411098.362	748938.645
957	4407598.885	752048.734	957	4411098.709	748937.919
958	4407602.662	752045.323	958	4411099.264	748937.901
959	4407598.334	752048.895	959	4411105.777	748938.832
960	4407598.097	752047.331	960	4411107.257	748938.784
961	4407596.62	752053.096	961	4411099.981	748937.164
962	4407597.231	752043.501	962	4411103.117	748936.776
963	4407600.561	752043.391	963	4411108.936	748939.158
964	4407604.114	752044.418	964	4411108.311	748937.036
965	4407602.333	752035.33	965	4411104.944	748936.002
966	4407602.162	752035.765	966	4411101.979	748935.956
967	4407604.462	752038.118	967	4411092.617	748932.832
968	4407605.933	752037.784	968	4411087.685	748929.279
969	4407607.542	752036.016	969	4411086.325	748927.324
970	4407613.648	752035.816	970	4411084.239	748925.82
971	4407615.393	752038.188	971	4411083.61	748929.269
972	4407620.531	752036.732	972	4411088.148	748932.121
973	4407616.341	752038.871	973	4411091.076	748931.026
974	4407617.191	752036.556	974	4411084.156	748928.965
975	4407616.957	752040.708	975	4411087.205	748931.58
976	4407618.707	752043.223	976	4411089.559	748929.932
977	4407615.634	752039.895	977	4411097.038	748932.117
978	4407615.231	752038.907	978	4411096.026	748935.15
979	4407602.813	752004.875	979	4411091.539	748933.867
980	4407604.279	752004.398	980	4411093.986	748935.073
981	4407600.118	752007.393	981	4411095.064	748934.038
982	4407597.736	752008.186	982	4411102.127	748934.808
983	4407598.586	752005.871	983	4411099.009	748935.767
984	4407599.673	752005.121	984	4411098.075	748935.512
985	4407598.757	752005.437	985	4411095.249	748934.032
986	4407598.467	752007.876	986	4411093.787	748934.651
987	4407600.474	752006.953	987	4411094.661	748933.052
988	4407594.38	752013.155	988	4411093.94	748933.646
989	4407593.146	752015.054	989	4411088.819	748929.956
990	4407591.476	752014.966	990	4411086.917	748928.447
991	4407589.148	752011.755	991	4411093.042	748928.819
992	4407591.476	752014.966	992	4411095.845	748929.585
993	4407592.844	752011.491	993	4411094.92	748929.615
994	4407593.698	752009.319	994	4411109.634	748932.136
995	4407587.696	752012.661	995	4411105.356	748937.274
996	4407583.93	752010.784	996	4411105.647	748934.837
997	4407600.999	752011.651	997	4411108.154	748932.184
998	4407596.364	752011.518	998	4411106.798	748924.658
999	4407600.326	752008.101	999	4411111.192	748928.8

1000	4407608.833	752007.678	1000	4411112.192	748931.053
1001	4407610.217	752010.348	1001	4411112.747	748931.035
1002	4407609.329	752011.52	1002	4411090.465	748929.331
1003	4407601.657	752014.774	1003	4411130.023	748926.902
1004	4407602.411	752015.178	1004	4411133.043	748922.947
1005	4407609.42	752008.659	1005	4411136.558	748922.833
1006	4407610.582	752010.193	1006	4411144.685	748922.14
1007	4407614.342	752017.5	1007	4411146.226	748923.947
1008	4407610.569	752021.054	1008	4411137.072	748927.244
1009	4407606.815	752025.179	1009	4411129.805	748925.909
1010	4407603.728	752021.422	1010	4411135.189	748926.306
1011	4407605.047	752022.093	1011	4411133.659	748930.498
1012	4407608.06	752017.993	1012	4411129.857	748933.192
1013	4407605.583	752021.504	1013	4411130.051	748933.472
1014	4407607.316	752017.874	1014	4411126.327	748932.879
1015	4407601.172	752016.933	1015	4411123.465	748935.971
1016	4407601.196	752017.647	1016	4411123.455	748935.686
1017	4407597.247	752021.493	1017	4411123.455	748935.686
1018	4407598.704	752020.73	1018	4411122.373	748936.578
1019	4407595.7	752025.116	1019	4411118.132	748937.145
1020	4407596.042	752024.247	1020	4411120.185	748937.649
1021	4407590.083	752023.3	1021	4411139.294	748938.599
1022	4407593.68	752020.038	1022	4411138.119	748942.351
1023	4407593.327	752026.195	1023	4411135.454	748940.152
1024	4407590.017	752038.165	1024	4411134.886	748939.742
1025	4407587.972	752037.946	1025	4411131.939	748940.266
1026	4407587.873	752034.948	1026	4411090.716	748937.037
1027	4407581.74	752034.293	1027	4411120.675	748935.633
1028	4407579.367	752035.371	1028	4411120.24	748933.648
1029	4407578.23	752045.841	1029	4411117.178	748930.605
1030	4407576.751	752029.026	1030	4411115.226	748933.24

National Geodetic Survey Data Sheets for Three Benchmarks

The NGS Data Sheet

See file dsdata.pdf for more information about the datasheet.

```
PROGRAM = datasheet95, VERSION = 8.12.5.12
Starting Datasheet Retrieval...
1        National Geodetic Survey,   Retrieval Date = MARCH 23, 2021
 DQ4041 ********************************************************************
 DQ4041  DESIGNATION -  MAD 1
 DQ4041  PID         -  DQ4041
 DQ4041  STATE/COUNTY-  OH/MONTGOMERY
 DQ4041  COUNTRY     -  US
 DQ4041  USGS QUAD   -  FAIRBORN (2016)
 DQ4041
 DQ4041                         *CURRENT SURVEY CONTROL
 DQ4041  ___________________________________________________________________
 DQ4041* NAD 83(1986) POSITION- 39 47 59.7    (N) 084 05 32.1    (W)   HD_HE
 DQ4041* NAVD 88 ORTHO HEIGHT -   258.800 (meters)      849.08  (feet) ADJUS
 DQ4041  ___________________________________________________________________
 DQ4041  GEOID HEIGHT    -        -33.137 (meters)                     GEOID
 DQ4041  DYNAMIC HEIGHT  -        258.659 (meters)      848.62  (feet) COMP
 DQ4041  MODELED GRAVITY -    980,073.2   (mgal)                       NAVD
 DQ4041
 DQ4041  VERT ORDER      -  FIRST     CLASS II
 DQ4041
 DQ4041.The horizontal coordinates were established by autonomous hand held
 DQ4041.observations and have an estimated accuracy of +/- 10 meters.
 DQ4041.
 DQ4041.The orthometric height was determined by differential leveling and
 DQ4041.adjusted by the NATIONAL GEODETIC SURVEY
 DQ4041.in April 2017.
 DQ4041
 DQ4041.Significant digits in the geoid height do not necessarily reflect ac
 DQ4041.GEOID18 height accuracy estimate available here.
 DQ4041
 DQ4041.Click photographs - Photos may exist for this station.
 DQ4041
 DQ4041.The dynamic height is computed by dividing the NAVD 88
 DQ4041.geopotential number by the normal gravity value computed on the
 DQ4041.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 DQ4041.degrees latitude (g = 980.6199 gals.).
 DQ4041
 DQ4041.The modeled gravity was interpolated from observed gravity values.
```


3/23/2021 DATASHEETS

```
DQ4041
DQ4041;                    North         East     Units  Estimated Accuracy
DQ4041;SPC OH S      -   201,020.      463,648.      MT  (+/- 10 meters HH2
DQ4041
DQ4041_U.S. NATIONAL GRID SPATIAL ADDRESS: 16SGK4894709595(NAD 83)
DQ4041
DQ4041                          SUPERSEDED SURVEY CONTROL
DQ4041
DQ4041.No superseded survey control is available for this station.
DQ4041
DQ4041_MARKER: DR = REFERENCE MARK DISK
DQ4041_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
DQ4041_STAMPING: MAD 1 1991
DQ4041_MARK LOGO: OH2090
DQ4041_PROJECTION: RECESSED 5 CENTIMETERS
DQ4041_MAGNETIC: O = OTHER; SEE DESCRIPTION
DQ4041_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
DQ4041+STABILITY: SURFACE MOTION
DQ4041_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
DQ4041+SATELLITE: SATELLITE OBSERVATIONS - May 03, 2016
DQ4041
DQ4041  HISTORY     - Date     Condition        Report By
DQ4041  HISTORY     - 1991     MONUMENTED       OH2090
DQ4041  HISTORY     - 20160503 GOOD             BES
DQ4041
DQ4041                          STATION DESCRIPTION
DQ4041
DQ4041'DESCRIBED BY BRUMBAUGH ENGINEERING & SURVEYING LLC 2016 (MWN)
DQ4041'THE STATION IS LOCATED ABOUT 10.0 MI (16.2 KM) SOUTH-SOUTHWEST OF NE
DQ4041'CARLISLE, 6.0 MI (9.7 KM) EAST-NORTHEAST OF DAYTON AND 4.1 MI (6.7 K
DQ4041'WEST-SOUTHWEST OF FAIRBORN.  OWNERSHIP-- CITY OF DAYTON WATER
DQ4041'DEPARTMENT.
DQ4041'
DQ4041'TO REACH FROM THE INTERSECTION OF STATE ROUTE 4 AND STATE ROUTE 444
DQ4041'TRAVEL NORTH ON STATE ROUTE 4 AND EXIT APPROXIMATELY 0.24 MI (0.39
DQ4041'KM)PAST THE 444W TO 4N RAMP ONTO LOWER VALLEY PIKE. THE MONUMENT IS
DQ4041'LOCATED ON THE TOP OF THE DAM ON THE EAST SIDE OF HUFFMAN PRAIRIE
DQ4041'BIKEWAY APPROXIMATELY 0.20 MI (0.32 KM) NORTH OF THE SPILLWAY BRIDGE
DQ4041'
DQ4041'IT IS 42.8 FT (13.0 M) SE OF A RAILROAD SPIKE IN THE SW SIDE OF THE
DQ4041'PAVEMENT, 14.9 FT (4.5 M) SW OF THE NE GUARD RAIL, 10.7 FT (3.3 M) N
DQ4041'OF A MAGNAIL SET IN THE SW SIDE OF THE PAVEMENT, 2.0 FT (0.6 M) NW O
DQ4041'THE NW EDGE OF PAVEMENT AND ABOUT LEVEL WITH THE GROUND.
DQ4041'
DQ4041'NOTE-ACCESS TO THE DISK IS THROUGH A CAST IRON TRAFFIC MONUMENT BOX.

*** retrieval complete.
Elapsed Time = 00:00:02
```


Figure A.27: MAD-1 National Geodetic Survey Data Sheet

The NGS Data Sheet

See file dsdata.pdf for more information about the datasheet.

```
PROGRAM = datasheet95, VERSION = 8.12.5.12
Starting Datasheet Retrieval...
1        National Geodetic Survey,   Retrieval Date = MARCH 23, 2021
 JZ3507 ********************************************************************
 JZ3507  DESIGNATION -  M 140 RESET
 JZ3507  PID         -  JZ3507
 JZ3507  STATE/COUNTY-  OH/GREENE
 JZ3507  COUNTRY     -  US
 JZ3507  USGS QUAD   -  FAIRBORN (2016)
 JZ3507
 JZ3507                         *CURRENT SURVEY CONTROL
 JZ3507
 JZ3507* NAD 83(1986) POSITION- 39 47 59.4    (N) 084 03 33.1    (W)   HD_HE
 JZ3507* NAVD 88 ORTHO HEIGHT -    245.334 (meters)      804.90  (feet) ADJUS
 JZ3507
 JZ3507  GEOID HEIGHT    -        -33.134 (meters)                      GEOID
 JZ3507  DYNAMIC HEIGHT  -        245.199 (meters)      804.46  (feet) COMP
 JZ3507  MODELED GRAVITY -    980,071.9   (mgal)                       NAVD
 JZ3507
 JZ3507  VERT ORDER      -  FIRST     CLASS II
 JZ3507
 JZ3507.This mark is at Wright Patterson Afb Airport (FFO)
 JZ3507
 JZ3507.The horizontal coordinates were established by autonomous hand held
 JZ3507.observations and have an estimated accuracy of +/- 10 meters.
 JZ3507.
 JZ3507.The orthometric height was determined by differential leveling and
 JZ3507.adjusted by the NATIONAL GEODETIC SURVEY
 JZ3507.in April 2017.
 JZ3507
 JZ3507.Significant digits in the geoid height do not necessarily reflect ac
 JZ3507.GEOID18 height accuracy estimate available here.
 JZ3507
 JZ3507.Click photographs - Photos may exist for this station.
 JZ3507
 JZ3507.The dynamic height is computed by dividing the NAVD 88
 JZ3507.geopotential number by the normal gravity value computed on the
 JZ3507.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 JZ3507.degrees latitude (g = 980.6199 gals.).
```



```
 JZ3507
 JZ3507.The modeled gravity was interpolated from observed gravity values.
 JZ3507
 JZ3507;                     North         East     Units  Estimated Accuracy
 JZ3507;SPC OH S     -   200,961.      466,478.      MT  (+/- 10 meters HH2
 JZ3507
 JZ3507_U.S. NATIONAL GRID SPATIAL ADDRESS: 16SGK5177709679(NAD 83)
 JZ3507
 JZ3507                         SUPERSEDED SURVEY CONTROL
 JZ3507
 JZ3507  NAVD 88 (04/22/14)  245.316  (m)          804.84   (f) SUPERSEDED
 JZ3507  NGVD 29 (04/22/14)  245.53   (m)          805.5    (f) RESET
 JZ3507
 JZ3507.Superseded values are not recommended for survey control.
 JZ3507
 JZ3507.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 JZ3507.See file dsdata.pdf to determine how the superseded data were derive
 JZ3507
 JZ3507_MARKER: DV = VERTICAL CONTROL DISK
 JZ3507_SETTING: 36 = SET IN A MASSIVE STRUCTURE
 JZ3507_SP_SET: BRIDGE WING WALL
 JZ3507_STAMPING: M 140 RESET 1985
 JZ3507_MARK LOGO: NGS
 JZ3507_MAGNETIC: N = NO MAGNETIC MATERIAL
 JZ3507_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 JZ3507
 JZ3507  HISTORY     - Date     Condition        Report By
 JZ3507  HISTORY     - 1985     MONUMENTED       NGS
 JZ3507  HISTORY     - 20160427 GOOD             BES
 JZ3507
 JZ3507                         STATION DESCRIPTION
 JZ3507
 JZ3507'DESCRIBED BY NATIONAL GEODETIC SURVEY 1985
 JZ3507'AT THE SOUTH EDGE OF THE MAIN AIRPORT OF WRIGHT-PATTERSON AIR FORCE
 JZ3507'BASE, 0.2 KM (0.10 MI) WEST ON HEBBLE CREEK ROAD FROM THE JUNCTION
 JZ3507'WITH HEBBLE CREEK AVENUE, IN THE NORTHWEST PART OF BRIDGE OVER HEBBL
 JZ3507'CREEK.
 JZ3507
 JZ3507                         STATION RECOVERY (2016)
 JZ3507
 JZ3507'RECOVERY NOTE BY BRUMBAUGH ENGINEERING & SURVEYING LLC 2016 (MWN)
 JZ3507'RECOVERED AS DESCRIBED.

*** retrieval complete.
Elapsed Time = 00:00:01
```


Figure A.28: JZ3507 National Geodetic Survey Data Sheet

The NGS Data Sheet

See file dsdata.pdf for more information about the datasheet.

```
PROGRAM = datasheet95, VERSION = 8.12.5.12
Starting Datasheet Retrieval...
1       National Geodetic Survey,   Retrieval Date = MARCH 23, 2021
 JY1107 *********************************************************************
 JY1107  DESIGNATION -  938
 JY1107  PID         -  JY1107
 JY1107  STATE/COUNTY-  OH/GREENE
 JY1107  COUNTRY     -  US
 JY1107  USGS QUAD   -  XENIA (2016)
 JY1107
 JY1107                       *CURRENT SURVEY CONTROL
 JY1107  ______________________________________________________________________
 JY1107* NAD 83(1986) POSITION- 39 41 07.59   (N) 083 55 44.49   (W)   AD_HE
 JY1107* NAVD 88 ORTHO HEIGHT -   285.768 (meters)      937.56  (feet) ADJUS
 JY1107  ______________________________________________________________________
 JY1107  GEOID HEIGHT    -         -33.066 (meters)                    GEOID
 JY1107  DYNAMIC HEIGHT  -         285.608 (meters)      937.03  (feet) COMP
 JY1107  MODELED GRAVITY -     980,057.6   (mgal)                      NAVD
 JY1107
 JY1107  VERT ORDER      -  SECOND    CLASS 0
 JY1107
 JY1107.The horizontal coordinates were determined by differentially correct
 JY1107.hand held GPS observations or other comparable positioning technique
 JY1107.and have an estimated accuracy of +/- 3 meters.
 JY1107.
 JY1107.The orthometric height was determined by differential leveling and
 JY1107.adjusted by the NATIONAL GEODETIC SURVEY
 JY1107.in June 1991.
 JY1107
 JY1107.Significant digits in the geoid height do not necessarily reflect ac
 JY1107.GEOID18 height accuracy estimate available here.
 JY1107
 JY1107.Click photographs - Photos may exist for this station.
 JY1107
 JY1107.The dynamic height is computed by dividing the NAVD 88
 JY1107.geopotential number by the normal gravity value computed on the
 JY1107.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 JY1107.degrees latitude (g = 980.6199 gals.).
 JY1107
```



```
JY1107.The modeled gravity was interpolated from observed gravity values.
JY1107
JY1107;                    North         East    Units  Estimated Accuracy
JY1107;SPC OH S     -   188,078.0     477,423.2     MT  (+/- 3 meters HH1 GI
JY1107
JY1107_U.S. NATIONAL GRID SPATIAL ADDRESS: 17SKD4881596947(NAD 83)
JY1107
JY1107                       SUPERSEDED SURVEY CONTROL
JY1107
JY1107  NGVD 29 (??/??/92)  285.946  (m)          938.14   (f) ADJ UNCH
JY1107
JY1107.Superseded values are not recommended for survey control.
JY1107
JY1107.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
JY1107.See file dsdata.pdf to determine how the superseded data were derive
JY1107
JY1107_MARKER: DD = SURVEY DISK
JY1107_SETTING: 17 = SET INTO TOP OF METAL PIPE DRIVEN INTO GROUND
JY1107_SP_SET: BUILDING
JY1107_STAMPING: 938
JY1107_MARK LOGO: USGS
JY1107_MAGNETIC: P = MARKER IS A STEEL PIPE
JY1107_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
JY1107_SATELLITE: THE SITE LOCATION WAS REPORTED AS NOT SUITABLE FOR
JY1107+SATELLITE: SATELLITE OBSERVATIONS - March 10, 2020
JY1107
JY1107  HISTORY     - Date     Condition        Report By
JY1107  HISTORY     - 1912     MONUMENTED       USGS
JY1107  HISTORY     - 1935     GOOD             CGS
JY1107  HISTORY     - 19981130 GOOD             USPSQD
JY1107  HISTORY     - 20011227 GOOD             INDIV
JY1107  HISTORY     - 20050107 GOOD             INDIV
JY1107  HISTORY     - 20100402 GOOD             GEOCAC
JY1107  HISTORY     - 20200310 GOOD             USPSQD
JY1107
JY1107                       STATION DESCRIPTION
JY1107
JY1107'DESCRIBED BY COAST AND GEODETIC SURVEY 1935
JY1107'AT XENIA.
JY1107'AT XENIA, GREENE COUNTY, AT THE INTERSECTION OF EAST MAIN STREET
JY1107'AND NORTH DETROIT STREET, 34 YARDS NORTH OF THE NORTH CURB OF EAST
JY1107'MAIN STREET, 27 YARDS EAST OF THE EAST CURB OF NORTH DETROIT
JY1107'STREET, AT THE COUNTY COURTHOUSE, AT THE SOUTH ENTRANCE, 0.6 INCH
JY1107'WEST OF THE WEST SIDE, AND 0.8 FOOT ABOVE THE PAVEMENT.  A UNITED
JY1107'STATES GEOLOGICAL SURVEY STANDARD DISK, STAMPED 938.
JY1107
JY1107                       STATION RECOVERY (1998)
JY1107
```


Figure A.29: JY1107 National Geodetic Survey Data Sheet

Positional Registration and Standard Deviation of Stem Data

The accuracy of any given GPS instrument can be evaluated by placing the instrument on a benchmark of known position and measuring the position. When this is done over a period of time (hours), then one must correct for the drift to obtain the accuracy of the instrument. GPS error was computed here without correcting for the drift. While Standard deviation provides a measure of positional error, some points deviate from their true value(s) by even larger distances (when the recording takes place without movement). Within the drift plot (Figure 10), eight measurements deviate from their true values ranging from 6 – 8 m (~ 2 – 2.5 times Standard deviation). One-hundred fifty data points were recorded (October 2020) over three separate recording periods (≤ 1 hour) by both GPS devices and compared to the known benchmark location of MAD -1 DQ4041 NGS Monument - Huffman Dam (N 39º 47.997, W 84º 5.535; Figure 11). The standard error in the northing (Y), and easting (X) directions were computed using Equation 1 (Drosos and Malesios, 2012):

$$S = \sqrt{\sigma_x^2 + \sigma_y^2} \tag{2}$$

Standard deviation (*S)* is the square root of the sum of squared standard error (σ) of UTM coordinates in the Northing (y) and Easting (x) directions. The term σ_x is the easting standard error and σ_y is the northing standard error. Each standard error in the x and y direction was computed with the equation:

$$\sigma = \sqrt{\frac{\Sigma(\alpha - \mathrm{c})^2}{n-1}} \tag{3}$$

The α is the mean of the UTM coordinates in the *x* or *y* directions. The term *c* is any UTM coordinate in the corresponding *x* or *y* directions. The term *n* is the total number of UTM coordinates. The computed *S* error value is 3.4 m.

Original Zone Maps for Site 1 and Site 2 Streams, Trails and Elevation Analyses

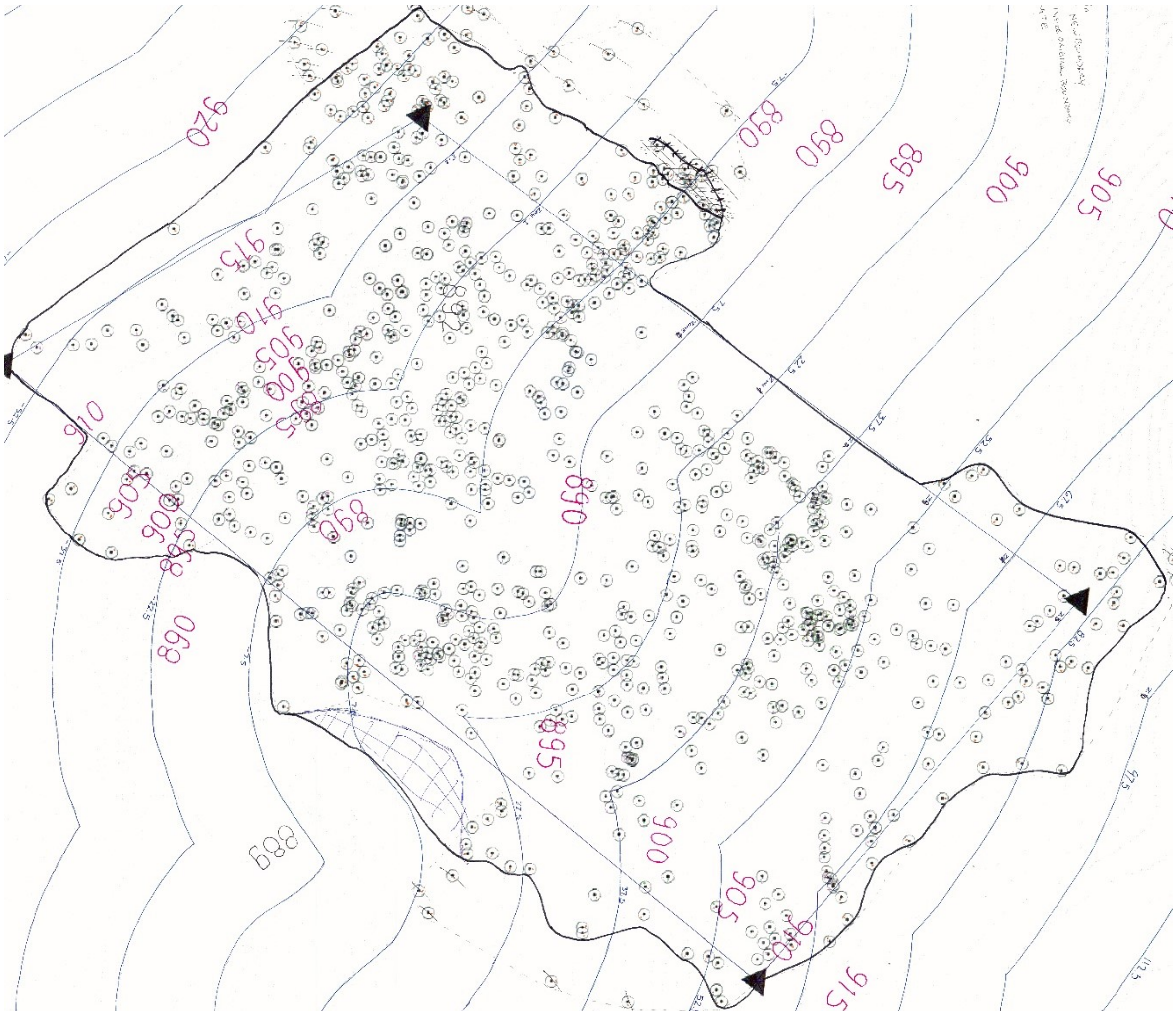

Figure A.30: Site 1 Stream Analysis with hand drawn zones at 15 m on either side of the stream. The blue lines are the stream zones, and the black jagged line is the site boundary with rules applied. The stem locations are a black point with a ring around it.

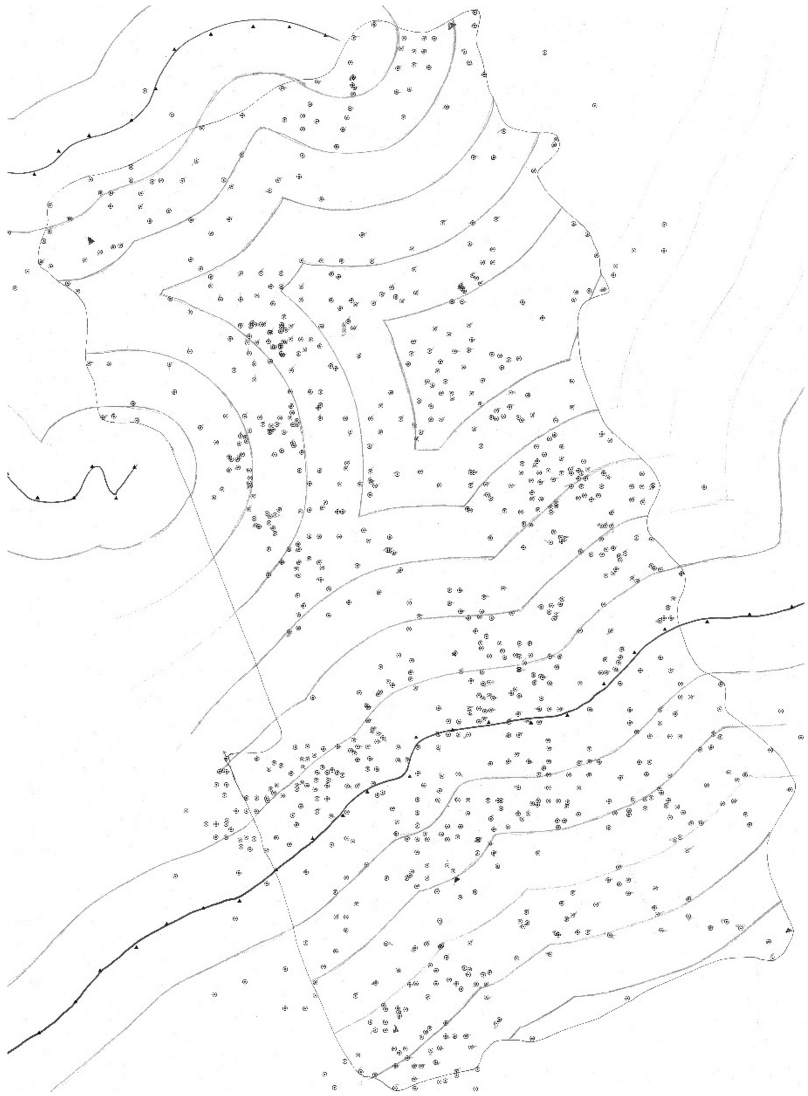

Figure A.31: Site 1 Trail Analysis with hand drawn zones at 10 m on either side of the trail. The grey lines are the trail zones, and the jagged line is the site boundary with rules applied. The black bold line is the trail. The stem locations are a black point with a ring around it.

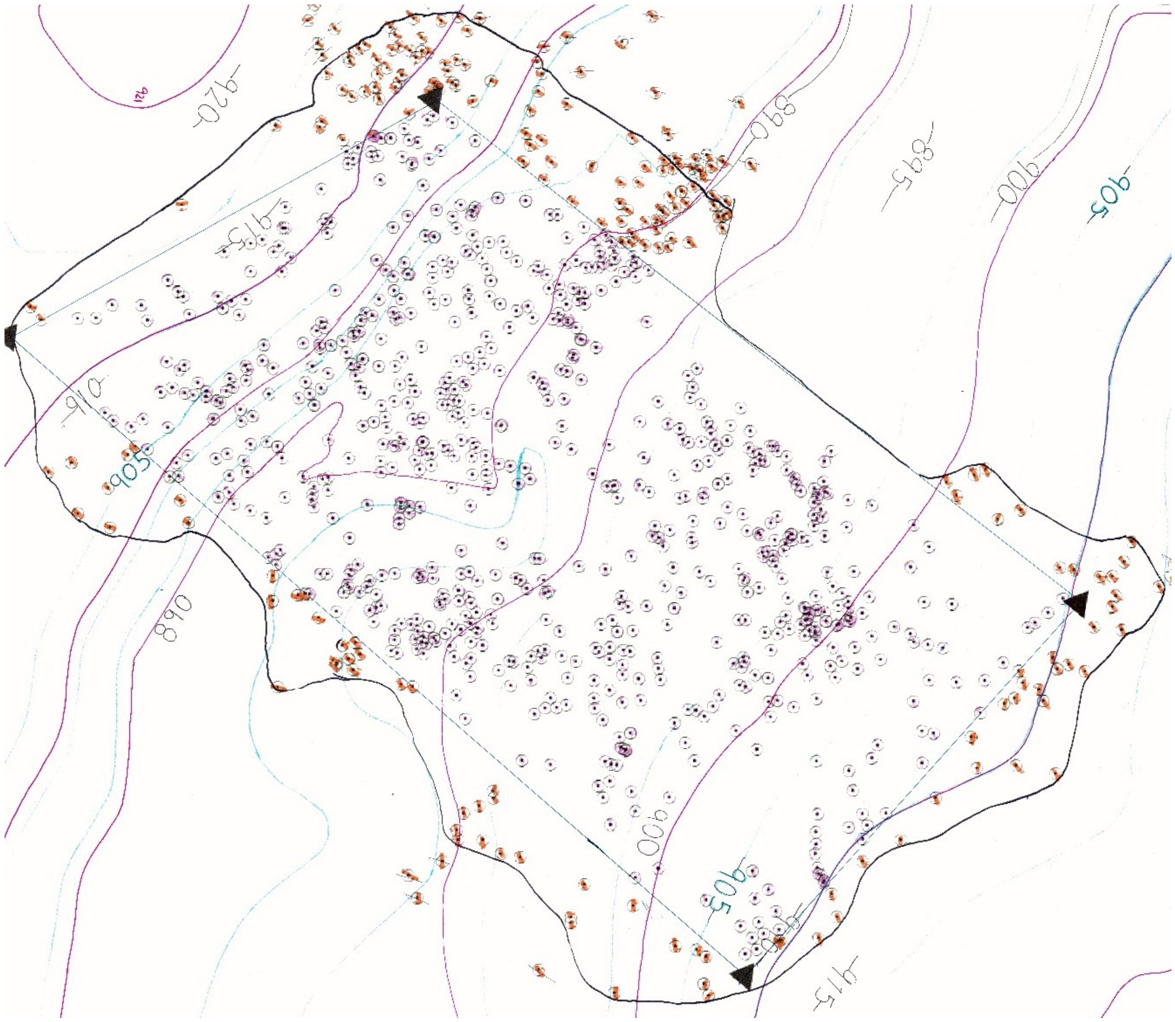

Figure A.32: Site 1 Elevation Analysis with hand drawn zones at 3 m contour spacing on either side of the stream. The pink lines are the elevation zones (at 3 m), and the black jagged line is the site boundary with rules applied. The stem locations are black points with a ring around it.

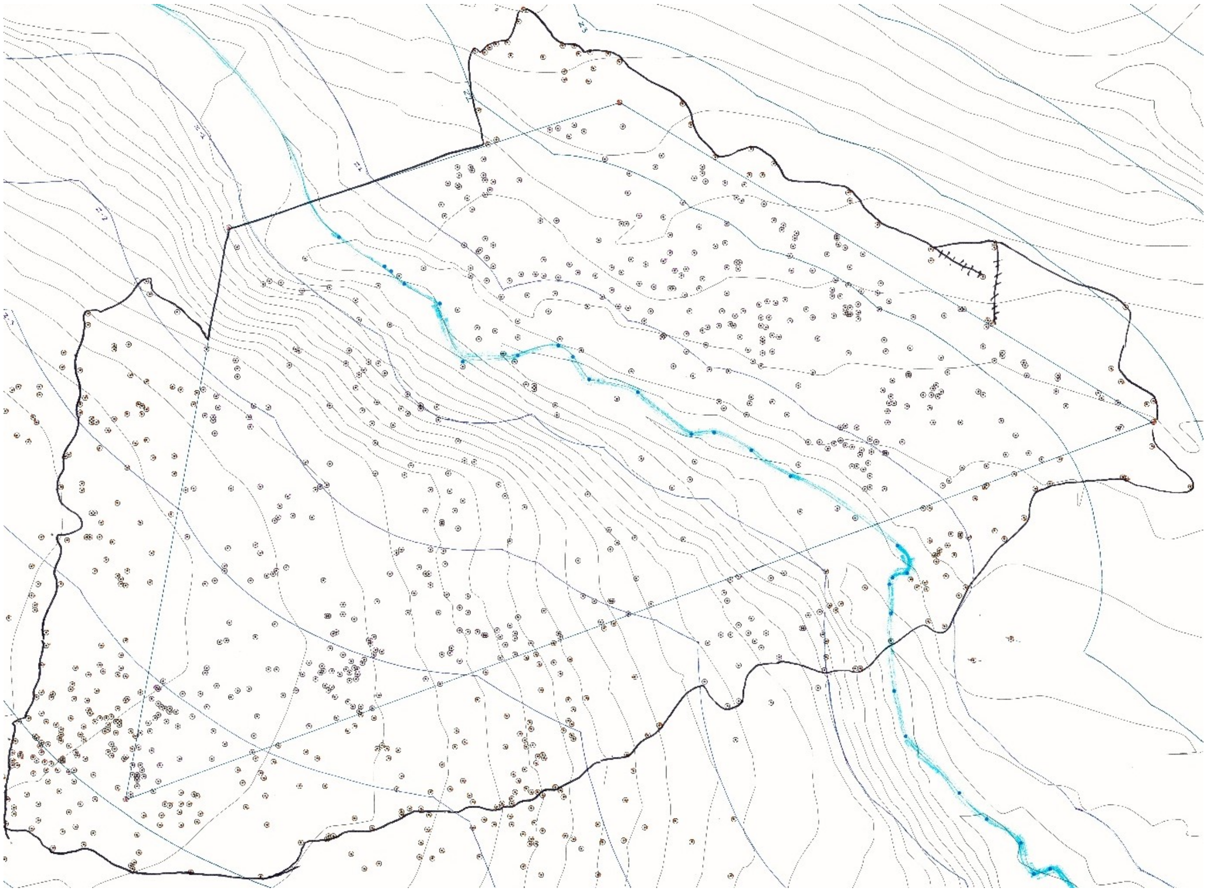

Figure A.33: Site 2 Stream Analysis with hand drawn zones at 15 m on either side of the stream. The blue lines are the stream zones, and the black jagged line is the site boundary with rules applied. The stem locations are a black point with a ring around it.

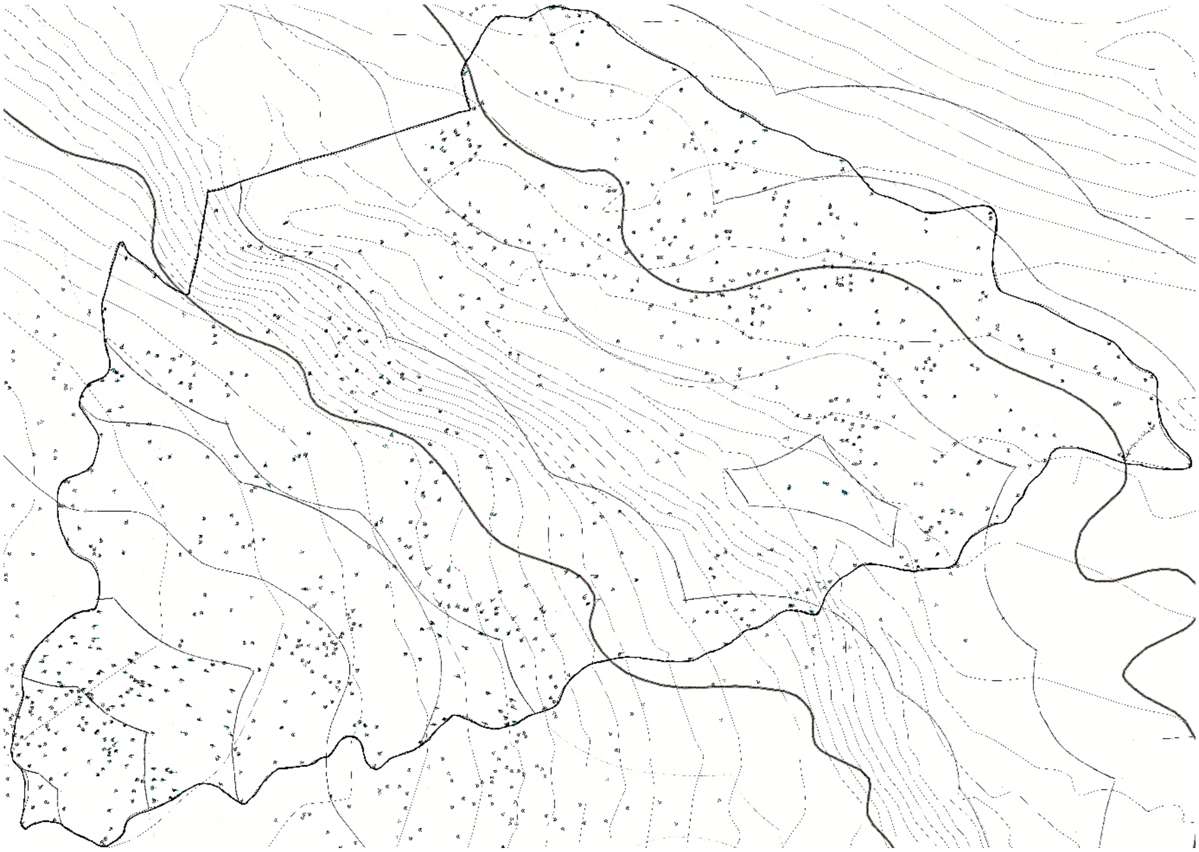

Figure A.34: Site 2 Trail Analysis with hand drawn zones at 10 m on either side of the trail. The smooth grey lines are the trail zones, the sharp grey lines are the contour lines, and the jagged black line is the site boundary with rules applied. The black bold line (within the boundary) are the trails. The stem locations are a black point with a ring around it.

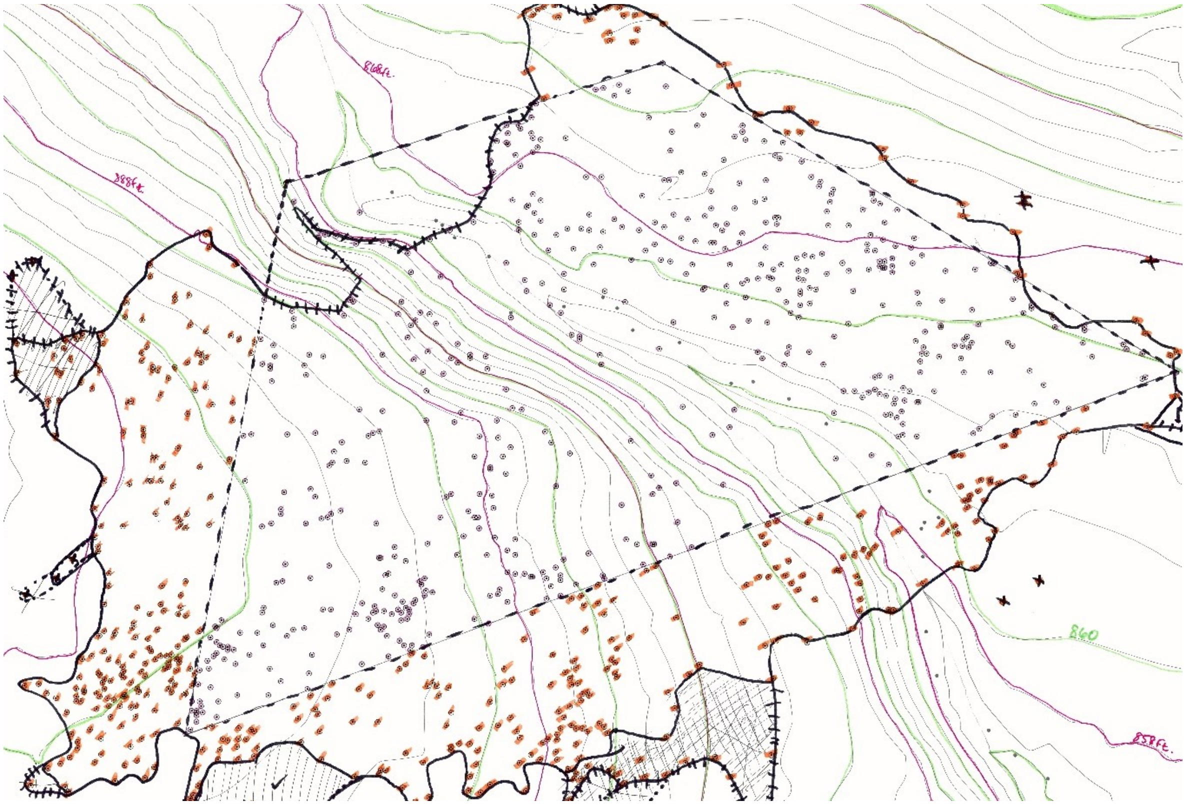

Figure A.35: Site 2 Elevation Analysis with hand drawn zones at 3 m contour spacing on either side of the stream. The pink lines are the elevation zones (at 3 m), and the black jagged line is the site boundary with rules applied. The stem locations are black points with a ring around it.