MAPPING SOCIAL TRAIL IMPACTS IN PICTURE CANYON NATURAL AND

CULTURAL PRESERVE FOR THE CITY OF FLAGSTAFF

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Abstract

On October 31, 2012, The City of Flagstaff obtained land near the industrial park neighborhood now called Picture Canyon Natural and Cultural Preserve (PCNCP) from the Arizona State Land Department (ASLD). Picture Canyon was purchased with voter-approved funding and currently has three main authorized trails, the Don Weaver trail, Tom Moody loop trail, and the Arizona trail, for recreational activity. Residents adjacent to the park drove all-terrain vehicles (ATVs) through the area creating a network of double-track trails, which damaged soils and vegetation. Single-track trails were also present, primarily around culturally and environmentally sensitive sites alongside the Rio de Flag. Since the establishment of the Natural and Cultural Preserve, new park regulations restrict off-roading to help conserve the open space. The main goal of this project is to produce a trail map database of currently authorized trails and social trails for the City of Flagstaff Sustainability Program. A Geographic Information Systems (GIS) trail map will help restore, manage, and revegetate existing social trails. A total of 97 social trails were collected using the Environmental Systems Research Institute (ESRI) Collector application on an iPhone. Data were collected on five classifications, which were trail identification number, trail classification, trail location, vegetation classification, and trail length in miles. The editing warranted that trail features interconnected, and photos were hyperlinked to the trail start and endpoints, while the attribute fields were adequately filled. Two web applications were created using the ArcGIS Online service to provide data for users in a functional layout. The results show that there were 10.97 miles of social trails within the boundary. The total social trail distance was double the authorized trail distance.

Keywords: Picture Canyon Natural and Cultural Preserve, Geographic Information Systems (GIS), trail mapping, social trails, trail classification

Table of Contents

LIST OF TABLES

LIST OF FIGURES

Chapter 1: Introduction

During the 1990s, the Arizona State Land Department (ASLD) had an unusable site for residents and businesses until the City of Flagstaff purchased the study area, called Picture Canyon Natural and Cultural Preserve, in 2012 (Enyedy, 2015). The community can utilize the land for limited outdoor recreational activities and enjoy the wildlife area, environmental studies site, and petroglyphs. The wildlife area is located near the deep water pond and provides information on the different types of birds present. The environmental study area informs visitors about the plants and animals on the site. All-terrain vehicle (ATV) usage was allowed under the Arizona State land jurisdiction. A city policy restricts off-highway vehicles within the boundary of the preserve. Since the establishment of the Picture Canyon, the local government's main priority is to establish methods that can prevent illegal motorized activity from happening on existing social trails. A proposed solution to this issue is to create a natural and cost-efficient barrier to prohibit unauthorized activities. One method being utilized by the city to reduce illegal recreational activity is by putting branches across popular social trails. These social trails have the most severe vegetation classification and are a priority for the city to consider revegetating. The City of Flagstaff Sustainability Department continues to incorporate more recreational trails for locals to enjoy.

Study Area

Picture Canyon is a four hundred- and seventy-eight-acre open space natural and cultural preserve located in the City of Flagstaff in the Industrial Park neighborhood. It is one of four city-owned areas classified as open spaces meaning that it is environmentally protected and managed by volunteers. The purpose of open spaces is to protect the land from being urbanized and developed as the City of Flagstaff continues to grow.

The Picture Canyon Natural and Cultural Preserve area (Figure 1 and Figure 2) is an important historical site to several local indigenous communities in Northern Arizona. The landscape and topology of the terrain provided the essential resources for the northern Sinagua to settle in the area. Historical handcrafted Sinagua petroglyphs appear on basaltic rock and can be viewed at specific sites in Picture Canyon.

The semi-arid landscape is covered in Ponderosa Pines and cinder cone hills, which are most prevalent near the eastern boundary. Three geological rock formations, which consist of primarily basalt lava, cinder cone, and limestone. The historic Kaibab formation directs the Rio de Flag through the park (Enyedy, 2015).

The Rio de Flag is an ephemeral stream for most of its course. Picture Canyon is one of two sections where the Rio is a constant flow, creating a lush and ecological environment. The perennial stream is only possible because of an agreement with the Wildcat Hill Wastewater Treatment Plant that releases water into the Rio de Flag. One of the main natural attractions is the waterfall, which would not exist without the added water supply from the plant.

Research Questions

The following are research questions that were formulated in this Practicum.

How many social trails exist within the boundary?

Where are the concentration of double- and single-track trails?

What areas need maintenance and revegetation efforts?
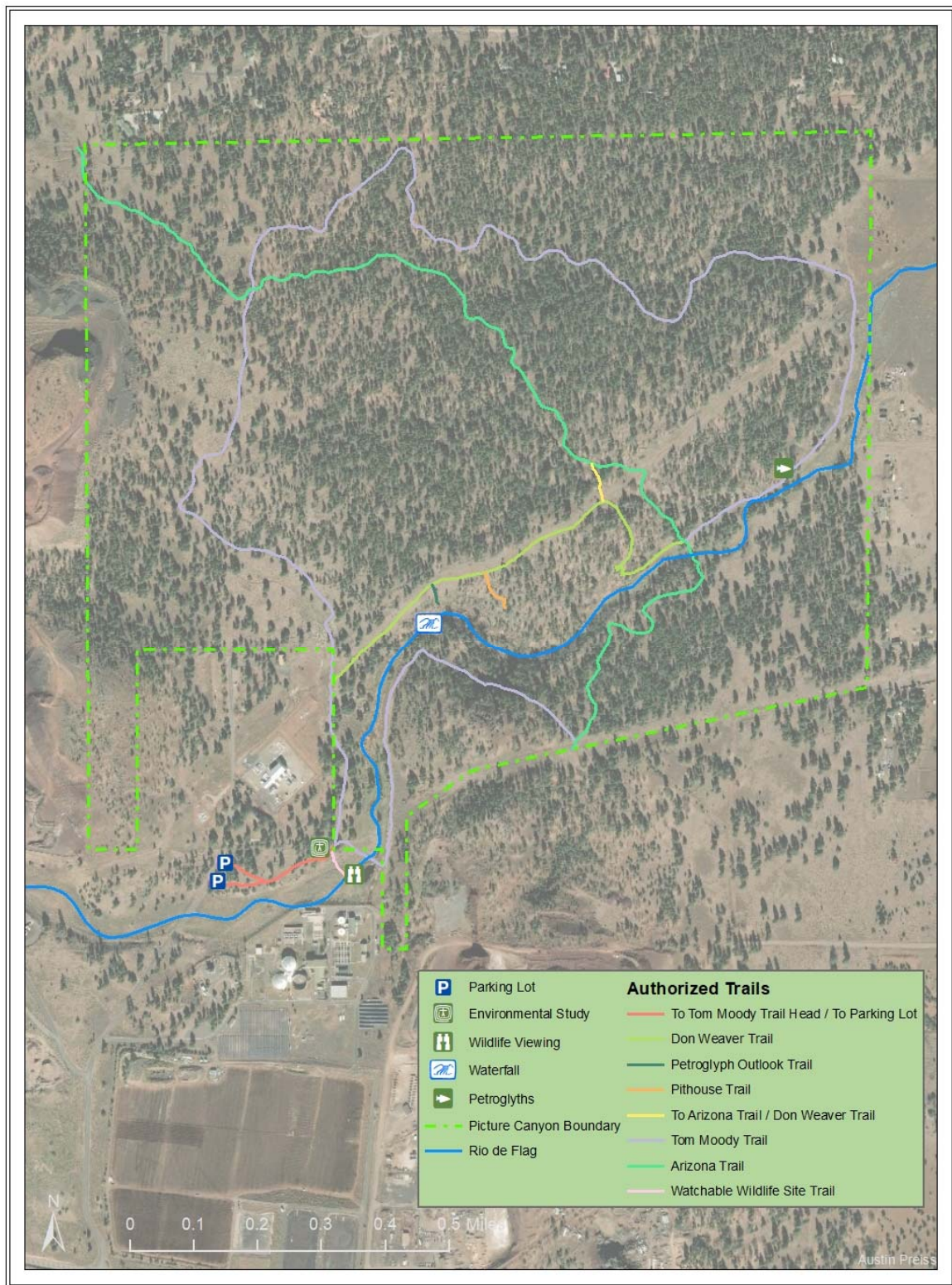
Figure 1: Study Area Map of Picture Canyon with authorized trail network and preserve boundary
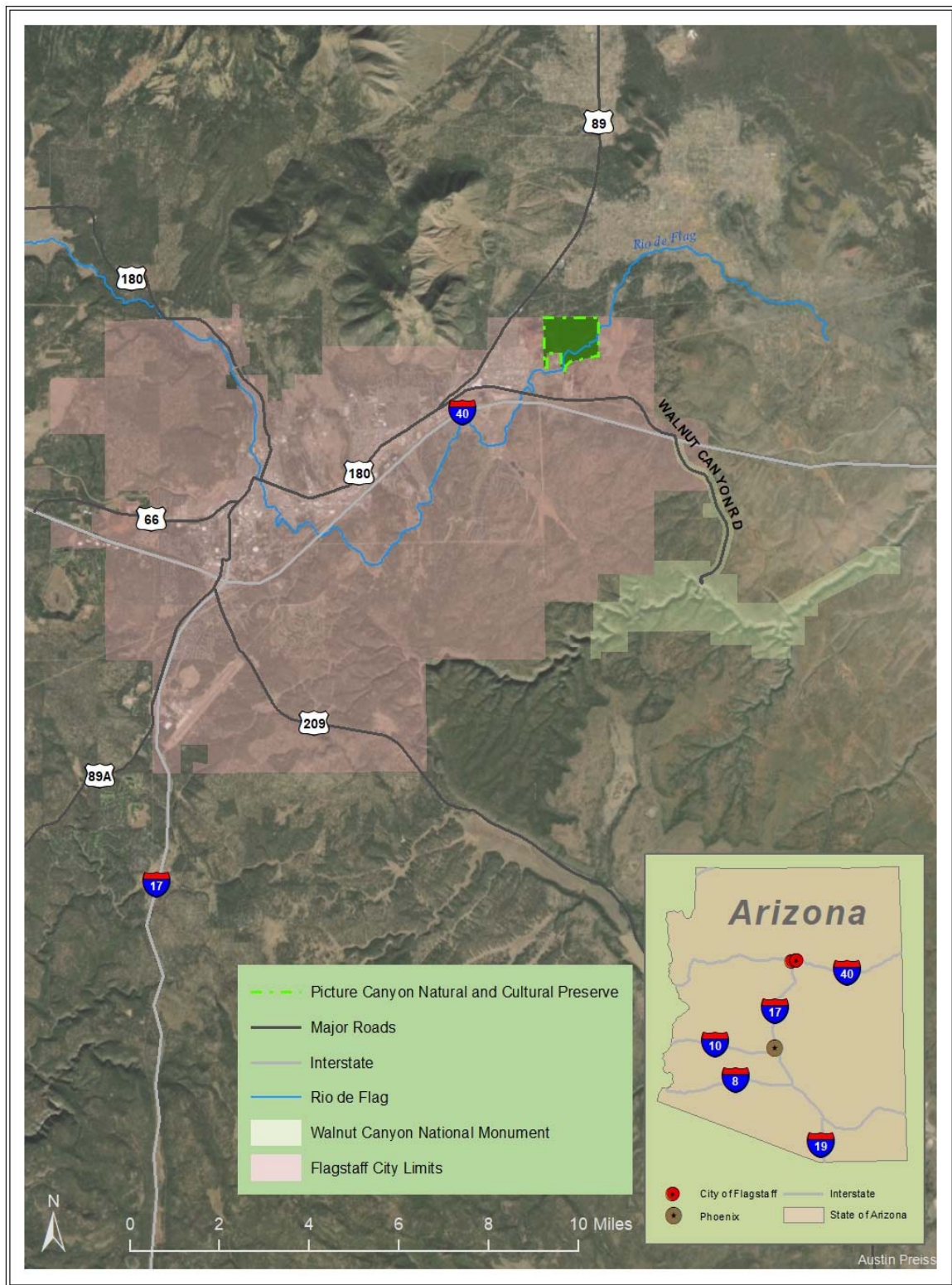
Figure 2: Regional Map of Picture Canyon location relative to the City of Flagstaff and surrounding mountains and forests

Chapter 3: Literature Review

The state of Arizona has many outdoor attractions that residents and tourists visit each year. Publications relay numerous facts on natural parks and outdoor recreation that present information on social trails, technology, and trail conditions. Arizona residents pursue outdoor adventures throughout the state, with almost 60% of the population estimated to have used non-motorized trails in the year 2019 (Duval, Frisvold, & Bickel, 2020). Trails are used by adventure hikers who are motivated by physical fitness, challenge, and achievement (Ewert, 1994). The City of Flagstaff urban trail system is a program that helps connect the community by creating a network of trails open for outdoor activities (Duval et al., 2020). Roughly 50 miles of urban trails are available for the community (Haisheng & Yanping, 2014). Flagstaff was selected from survey responses as a top hiking destination within the state because of its vast array of trails throughout the region (Duval et al., 2020). The preserve is a special place of interest for many people to enjoy historical and cultural sites. Northern Arizona area has many acres of sacred land that many different indigenous native Americans consider home.

For this study, social trails have been defined as "informal trails created by erosion due to foot traffic from people and animals" (Halabisky & Moskal, 2012). These trails cause environmental disturbances and create physical complications for outdoor enthusiasts. For example, hikers can become dehydrated and lose orientation if official trails are not marked properly. Having a method to reduce unauthorized trails is essential for the City of Flagstaff Sustainability Program. Recreational activities can have an ecological effect on the growth of vegetation (Walden-Schreiner & Leung, 2013). For this practicum project, I have extended the social trail definition to include double-track trails created by ATVs, as these have been particularly damaging in parts of the Picture Canyon area.

Many social trail research projects are done by using standalone GPS (Global Positioning Systems) survey equipment or smartphone-based editing applications such as ESRI Collector. Data collection applications have recently become popular on smartphone devices in the past four years. Using a smartphone application offers great functionality through basic GPS (Merry & Bettinger, 2019). A standard GPS produces a precision average of 5-10 meters (Walden-Schreiner & Leung, 2013). The data collection level of accuracy with a smartphone depends on the topology and the number of connected satellites (Merry & Bettinger, 2019). In an urban environment, for example, the average error with an iPhone 4S has been reported as 6.5 meters (Merry & Bettinger, 2019). There are advantages and disadvantages to both methods for data collection (Table 1).

Table 2: Advantages and disadvantages between GPS surveying and phone-based application surveying with ESRI Collector Application

Non-phone-based GPS survey		Phone-based application survey	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Sub-meter accurate if survey-grade	Costly if survey-grade	User friendly for collecting and updating features	No disconnecting editing
Not relying on cellular signals	Privacy issues?	Attach photos to features	Limited documentation
	Not user friendly for beginners	Simple interface	Cellular service needed for some features
	More software needed	Mostly free to use	

Specific trail characteristics and conditions of authorized trails are preferred depending on the type of recreational activity. Picture Canyon allows day-use recreational activity such as cross-country skiing, geocaching, hiking, running, horseback riding, mountain biking, and wildlife watching on all authorized trails. Environmental impacts such as loss of vegetation and mature trees often result in trail widening and trail erosion by hikers (Dorwart, Moore, & Leung,

2009). The ability for informal trails to rapidly increase and deteriorate creates both ecological and social concerns (Marion, Leung, & Nepal, 2006). The restoration process to eliminate, restore, and maintain focused locations can be achieved after observations. Expressing the community's attitude on trail infrastructure can influence land management agencies to implement new recreation policies. Trail developments can improve the well-being of individuals, communities, and regional economies. (Duval et al., 2020). As the City of Flagstaff grows it is vital to expand trails to make sure outdoor recreation can be

Since 2017, other graduate students of NAU Geography, Planning & Recreation have conducted research analysis on social trails in different locations. Most social trail data collection methods generate by using personal smartphone and tablet devices. This technique is less expensive and provides accurate data collection while presenting similarities and differences of prior Master of Science projects and comparing them to this practicum work on social trails in Picture Canyon (Table 2).

Table 3: Similarities and differences of research analysis on social trails by NAU graduate students

Corryn Smith 2017 Thesis – "Using Geospatial Technologies to Locate Travel Networks: A Case Study in Flagstaff, Arizona"	
Similarities	**Differences**
City of Flagstaff owned	Not just social trails but other features
Project areas purchased around same time	More scientific research using GIS
Mapped double- and single-track trails	Thesis compared to Practicum
Field mapping with ESRI Collector App	Used satellite imagery to conduct research
Field work conducted in a Ponderosa Pine environment	
Madeleine Bryan 2018 Practicum - "A Ten-Year Comparison of the Flagstaff Social Trail Network in the Mount Elden Dry Lake Hills"	
Similarities	**Differences**
Field mapping with ESRI Collector App	Temporal comparison
Location (regional setting)	Location (exact)
Methods (field mapping)	Number of trails used
Classes of trails with photos that are georeferenced	More treatment of trail classes (vegetation disturbance and single vs double track)
Final Product	
Emily Garrett 2018 Practicum - "Recreation and Vegetation Assessments in Petrified Forest National Park, Arizona"	
Similarities	**Differences**
Social trail vegetation classification	Location in Petrified Forest National Park
Solutions to restore vegetation in social trails	Type of vegetation outside social trails
Pictures showing project area	Scientific with biotic material
	Few social trails mapped

Chapter 4: Methodology

Project Setup

Before the start of the project, I met with Robert Wallace, who is an open space specialist for the City of Flagstaff Sustainability Section, to discuss potential projects in the City of Flagstaff's open space areas. Mr. Wallace mentioned that there is an abundance of single track and double track social trails that need to be mapped. That data related to what paths should be prioritized for the revegetation process in Picture Canyon. It was determined that two web maps would be created, one for the public use and the other one for private us.

A couple of field visits were conducted for familiarization with streaming trails, obtaining consistent accuracy, and uploading data on the ESRI online service. During the testing stage with the ESRI Collector application, the accuracy of the collection differed considerably from the central area of the preserve to the Rio de Flag, where efficiency was plus or minus fifteen feet. The central region of the study area had the best accuracy of fewer than ten feet for this project because the topology consisted of open Ponderosa Pines and hilly terrain. While down in the canyon, the Rio de Flag river occasionally had the lowest accuracy of twenty feet.

Adding pictures of each social trail's start and endpoint to the web map provides a visual of the trail location and current vegetation classification. The start and endpoint features were necessary, so the hyperlinks are georeferenced to the picture locations. The start point and endpoint indicate the direction of the streaming service. All pictures associated with the trails had to be downloaded into a folder and individually relinked to each trail using the trail identification number to match the attachments to the corresponding point feature. The web application has the point features hyperlinked and can be shown when the user zooms into the interactive application (Figure 3). Specific trails were hard to identify vegetation conditions from the pictures because of the trails were covered by leaves in the canyon (Figure 3).

Figure 3: Example of trail covered by leaf litter

Figure 4: Hyperlinked photos (Example Trail 2.09)
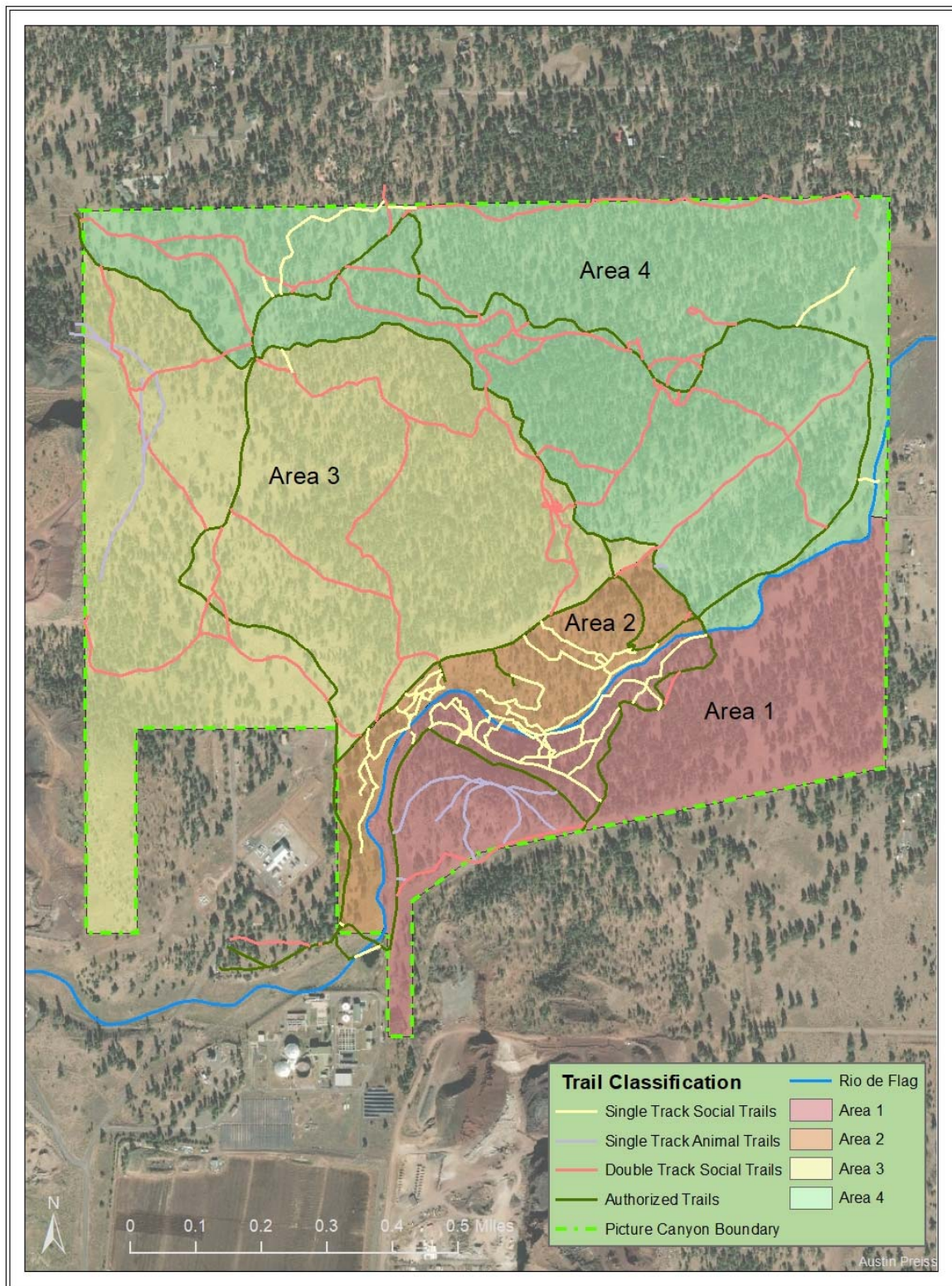
Figure 5: Map of Picture Canyon areas that were used to subdivide the preserve for systematic mapping and analysis

Attribute Field Types

Determining what attribute fields should be added to each trail was a difficult task. After reading recent peer practicums and theses who conducted similar field data collections on social trails. It was determined that trail data collected for this practicum should include all of these fields: trail identification number, trail classification, trail location, vegetation classification, and trail length in miles of all unauthorized trails (Table 3).

Table 4: Attribute fields for field collection

Trail Identification Number ▲	Trail Classification	Trail Location	Vegetation Classification	Trail Length (in Miles) ⊕
1.01	Single Track	Area 2	Barren	0.16
1.02	Single Track	Area 2	Stunted Vegetation	0.13

Each social trail has a unique identification number associated with it. The first number before the decimal place indicates the type of trail: (1) for a single track and (2) for double track. The numbers after the decimal place are the unique ID number for that trail.

Trail classification states what type of trail it is. There are four types of trails: Authorized trails, double track trails, single track trails, and single-track animal trails. All trails, except the authorized trails, are classified as social trails.

Trail locations were arbitrarily drawn by dividing Picture Canyon into four areas by splitting the Rio de Flag river, and the Arizona Trail created four sections (Figure 5). The extent boundary of Area 1, Area 2, Area 3, and Area 4 are described (Table 4). The purpose of dividing the study area into multiple areas was to make sure all trails were mapped within the polygon before moving onto the next section. Results were divided by region, so the revegetation and conservation process could indicate where the heavily impacted areas are located.

Table 5: Boundary extent of all location areas in Picture Canyon

AREA 1 Boundary Extent		
Northwest	North-Rio de Flag	*Northeast*
West-Rio de Flag	**AREA 1**	East-Picture Canyon Boundary
Southwest	South-Picture Canyon Boundary	*Southeast*
AREA 2 Boundary Extent		
Northwest	North-Don Weaver Trail	*Northeast*
West-Picture Canyon Boundary	**AREA 2**	East-Arizona Trail
Southwest	South-Rio de Flag	*Southeast*
AREA 3 Boundary Extent		
Northwest	North-Arizona Trail	*Northeast*
West-Picture Canyon Boundary	**AREA 3**	East-Don Weaver Trail
Southwest	South-Picture Canyon Boundary	*Southeast*
AREA 4 Boundary Extent		
Northwest	North-Picture Canyon Boundary	*Northeast*
West-Arizona Trail	**AREA 4**	East-Rio de Flag
Southwest	South-Arizona Trail	*Southeast*

Vegetation classes were established to determine the overall severity of the social trail (Table 5). The categories were classified as a) barren, meaning no vegetation is present, b) some bare ground, meaning trampled vegetation with the bare ground present, and c) stunted vegetation, meaning there was noticeable impeded vegetation growth with moderate foot traffic. The hyperlinked pictures from the trails were used to determine what informal condition class that trail belongs in. The vegetation classification was arbitrarily determined from the start point because that tended to have the worst trail condition than the endpoint. The initial start point to streaming a social trail was located off one side of an authorized trail. Foot traffic tended to disperse over the course of the social trail length because the social trail often splits into another unauthorized trail. Understanding the current condition of each social trail will help the City of Flagstaff prioritize trail revegetation and maintenance (Appendix B).

Table 6: Vegetation classification of the social trails (adopted from NPS)

Informal Trail Condition Classes		
Stunted Vegetation	**Some Bare Ground**	**Barren**
Distinct trail feature present	Distinct trail feature present	Distinct trail feature present
Trail boundary present	Trampled and matted vegetation	Trail boundary present and distinct in most areas
Moderate repeated human use evident	Heavy repeated human use evident	Extensive repeated human use evident
Noticeable growth	Noticeable impeded vegetation growth	No vegetation present
	Some bare ground present in trail tread	Bare ground present in trail tread throughout

The last attribute is the trail length that is calculated in miles the standard unit of measurement for hiking trials in the United States of America. This field calculates each line segment that was streamed during fieldwork.

Database

Before creating any new feature data, I received permission to access the City of Flagstaff Enterprise geodatabase that had available data files on Picture Canyon and the surrounding area. A personal geodatabase called PictureCanyon.gdb was created to ensure that all data associated with my project was stored in one location for easy access and maintenance. A listing of all features stored in the Picture Canyon geodatabase is provided below (Figure 6). The social trail data was transferred to the City of Flagstaff's GIS department to be uploaded into the Enterprise geodatabase.
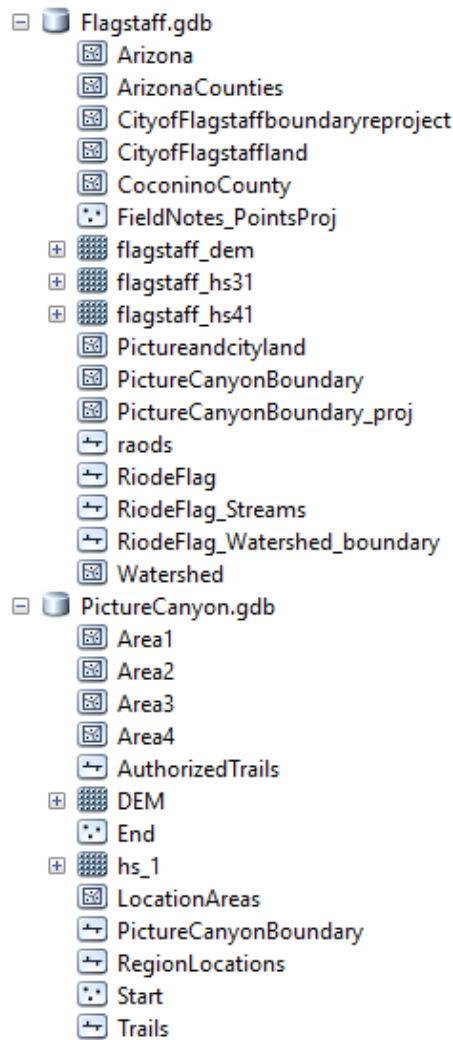
Figure 6: The City of Flagstaff geodatabase and the Picture Canyon geodatabase I created for this project

Chapter 5: Field Data Collection

Hardware

This project needed a field mapping protocol and necessary equipment that could stream different polylines while hiking through rugged terrain in Picture Canyon. An ESRI features template was selected for the data field collection. The model had five different categories for points, lines, and polygons, but only three-line features were necessary for my project. Data was

collected using an iPhone 6s while running the collector application to stream multi polylines: Authorized trails, single track social trails, and double track social trails (Figure 7). At the start of collection, single track animal trails were not collected as an independent feature, and instead classified under single-track.
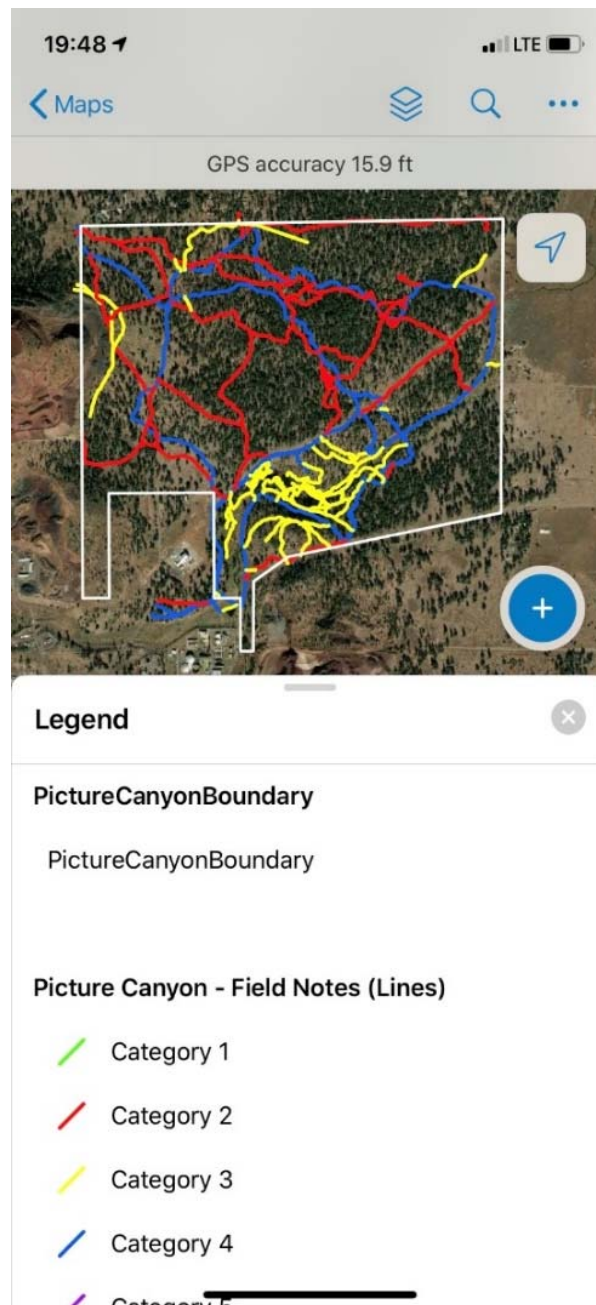
Figure 7: ESRI Collector Application on the iPhone 6s shows authorized trails (Blue lines), single track trails (Yellow lines) and double track trails (Red lines)

Software

ArcMap 10.7.1 was the primary application used to edit collected trails, property boundaries, and other features. A file geodatabase was created within ArcCatalog to save all shapefiles for this project in an Arizona Central State Plane Coordinate System and North American 1983 Datum. The coordinate system and datum are what the City of Flagstaff uses on all GIS files stored on the enterprise geodatabase. An organizational account had to be added to have access to the ESRI online NAU GRAIL (Geospatial Research and Information Laboratory) portal and ESRI Collector application.

ArcGIS Online Web Map/Application

Instead of storing the practicum data in a local file geodatabase, it was more beneficial to upload all the data into a web map. Web maps make adjusting data relatively easy once layers are shared with the ESRI ArcGIS online content page. A web application provides a more interactive display for users to view the web map with an array of tools and functions in ArcGIS online. A web application is accessible on computers with the URL, and on most personal portable devices by scanning a QR code (Table 8). Public web application called Picture Canyon for Public Domain shows all authorized trails, the distance of each trail, the location of the user, and satellite imagery provided by ESRI (Table 3). Widgets are tools that users can perform multiple functions. For example, widgets can show the attribute table, user location, coordinates, scale bar, zoom functionality, legend, various base maps, and social media sharing options (Email, Facebook, Twitter, and Google+) were added to enhance the user functionality. Anyone can access public web maps. The organizational web application dramatically benefits the city operations because it has detailed attribute data.

Table 8: QR codes to access the two ESRI trail web applications

Picture Canyon for Public Domain (Authorized Trails)
https://grail.maps.arcgis.com/apps/webappviewer/index.html?id=f93d235655154261a3ae0df7e179def8
Picture Canyon Features (Authorized Trails, Social Trails and Picture Attachments)
http://grail.maps.arcgis.com/apps/webappviewer/index.html?id=491a5ed035204670841f1cee0d917a08

Chapter 6: Timeline and Overview of Workflow

Table 7: Timeline of practicum completion

October 2018	The City of Flagstaff Sustainability Program approved my project to map social trails in Picture Canyon.
January 2019	I tore my ACL skiing which put me behind schedule to start mapping a section of the canyon and started physical therapy during the spring semester.
Summer 2019 (May to August)	I moved to Illinois to start my GIS summer internship with Lake County Public Works Department.
September 2019	Went out to Picture Canyon every weekend to map social trails. Conditions were perfect.
October 2019	Finished all field work and put data into a personal geodatabase
November 2019	Start writing up the proposal.
December 2019	First committee meeting to discuss my project and provide beneficial feedback on my proposal.
January 2020	Geodatabase finalized and final trail statistics generated.
February 2020	Created two ESRI online applications (One for all social trails and another for just authorized trails)
March 2020	Complete practicum draft.
April 2020	Practicum defense.
May 2020	Final revisions made to practicum and graduation.

This practicum was completed during the 2018/2019-2019/2020 academic years (Table 7). The workflow below is a brief overview of how to create two web applications in the ESRI online service.

1. Gather data on the history of Picture Canyon, authorized trails and problems occurring within the park boundary

2. Create an ESRI GRAIL account and add an ESRI editing template to stream three different lines in a web map: authorized trails, single track social trails, and double track trails

3. Set up Collector application and proper attribute field properties

4. Started systematically mapping trails by each sub-area ensuring that no trails were missing

5. Collected photographs at the start and end of each line feature

6. Interconnect streaming lines and georeferenced the attached start and end pictures to each trail

7. Update attribute fields by adding trail ID numbers, vegetation classifications and locations

8. Create two web applications one for public use and one for organizational use
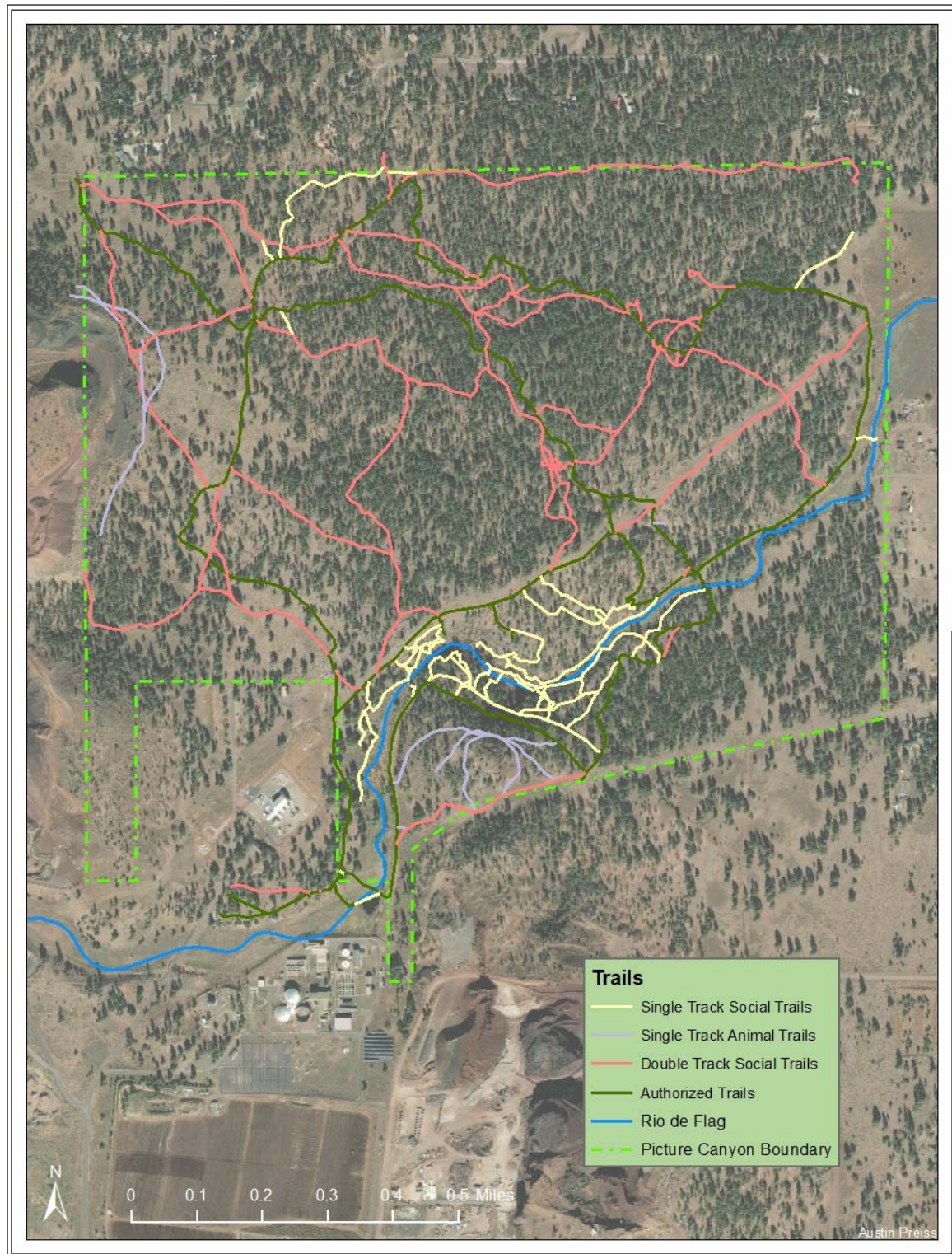
Figure 8: All social trails in Picture Canyon

Results

Table 8: Authorized Trails Statistics, Trail Length (in miles) and Trail Vegetation (B-Barren, SBG-Some Bare Ground, SV-Stunted Vegetation)

Authorized Trails	Trail Statistics	Trail Length (in miles)	Trail Vegetation
Total Authorized Trails:	9	5.97 miles	B-9 SBG-0 SV-0

Table 9: Social Trails Statistics, Trail Length (in miles) and Trail Vegetation (B-Barren, SBG-Some Bare Ground, SV-Stunted Vegetation)

Social Trails	Trail Statistics	Trail Length (in miles)	Trail Vegetation
Total Social Trails:	97	10.97 miles	B-38 SBG-41 SV-18

Table 10: Trail Classification Statistics, Trail Length (in miles) and Trail Vegetation (B-Barren, SBG-Some Bare Ground, SV-Stunted Vegetation)

Single Track Trails	Trail Statistics	Trail Length (in miles)	Trail Vegetation
Total Single Track Trails:	43	3.26 miles	B-13 SBG-19 SV-11
Single Track Animal Trails	**Trail Statistics**	**Trail Length (in miles)**	**Trail Vegetation**
Total Animal Trails:	10	1.23 miles	B-1 SBG-8 SV-1
Double Track Trails	**Trail Statistics**	**Trail Length (in miles)**	**Trail Vegetation**
Total Double Track Trails:	44	6.48 miles	B-24 SBG-14 SV-6

The goal of this project was to create geographic data in a readily accessible GIS format, showing all unauthorized trails in Picture Canyon from field data collection. After completion, all of the developed GIS layers, including AuthorizedTrails.shp, Trails.shp, PictureCanyonBoundary.shp, were uploaded onto my ESRI online GRAIL content page and then placed into a web map. After completing the mapping fieldwork for this project, there were forty-four unauthorized double-track trails and fifty-three illegal single-track trails that were identified in Picture Canyon (Figure 8, Table 10, and Appendix A). One service road was independently collected because segments of the Don Weaver trail is on the service road. At the

same time, the rest is not adapted for recreational activity, officially making it an unauthorized double track trail.

There was a total of 107 trails collected for this project, including authorized trails. From the total, forty-three single track social trails were located, which accounts for nearly 50% of all trails in the area, while forty-four double track social trails were discovered, which is close to 41% of all trails. Ten single track animal trails account for 9% of trails throughout Picture Canyon Natural and Cultural Preserve (Table 10). The one service road that was collected is 1% of the trails found in the canyon. A total distance of 10.97 miles of social trails was collected in the field, while the entire length of all authorized trails is 5.97 miles.

From data collection, many of the single-track trails are located near the waterfall, which is one of the natural attractions within the Natural and Cultural Preserve. Many of the double track trails were centrally located mainly inside the Tom Moody loop. The double track trails are classified as barren when there was no vegetation between the tire tracks. A few of the single-track trails were caused by wildlife from herds of elk and deer trotting through the area. Evidence of wildlife footprints and droppings were found in the middle of the trail while conducting fieldwork. Many of the animal trails have a steeper trail grade compared to the authorized trails. If hikers were to use these routes, there would likely have been some switchbacks for the rough terrain.

The results were divided by area location for analysis on social trails. Area one had a total of twenty-six social trails and a total distance of 2.40 miles (Appendix B Table 17). The trail vegetation classifications were evenly split between some bare ground with twelve and barren with ten. This area had the highest number of single-track animal trails in the study area, with six totaling in a length of .65 of a mile and all had a vegetation classification of some bare

ground. Area two had the most single-track social trails with nineteen trails that had a total length of 1.37 miles (Appendix B Table 18). This area had the same some bare ground vegetation classification as area one. Overall, area two had the lowest social trail length compared to the other regions, with a total range of 1.49 miles. Area three consists of primarily double track social trials with 2.89 miles compared to the overall total social trail distance of 3.48 in the area (Appendix B Table 19). Double track trails tended to have a better vegetation condition compared to area four. Zone four is the most northern region in Picture Canyon and one of the largest. Area four borders many neighborhoods to the north, which makes for ideal ATV access into the park at night. For the data results, this area leads all previous regions in the number of double track trail with twenty-three and a total double track trail length of 3.15 miles (Appendix B Table 20). The vegetation classification of these trails is significantly barren, meaning that this region should be a primary focus for starting the conservation process.

Discussion

During this practicum, new methods were utilized that helped gain experience in online-based software like the ESRI collection application and ArcGIS online services. Learning new approaches to complete data collection and upload information for the city was challenging because online services and data collection applications are not taught or utilized in my classes. I suggest creating a course that demonstrates the process of collecting assets in the field using an app and showing students how to share an application. Many companies want GIS technicians or GIS analysts who have experience collecting data using an application and editing features in ArcMap and ArcGIS Pro. Switching my focus from using ArcMap to understanding the functionality of the ArcGIS Online web map, was a slow transition period. There were many questions like how to save layer content, and what the different sharing properties meant. The

most notable problem was not project-based but rather a physical issue for me because I tore my anterior cruciate ligament (ACL) skiing in January 2019. This injury was a significant setback in delaying the project and data collection until the fall of 2019. It took three months to collect all social trails in Picture Canyon. Identifying trail vegetation classifications in the fall was difficult because of leave cover especially trails in the canyon.

For this project, it would have been helpful to get visitors' opinions on what should be improved or changed in the Natural and Cultural Preserve. It seemed like families with children often underestimating the distance to petroglyphs and were seen on social trails heading back to the parking lot. Providing information to the public on how much water to bring and overall distance to the petroglyphs will hopefully prepare families for a long journey to explore the cultural sites.

Technology such as the ESRI Collector application was beneficial for this project and would recommend to anyone mapping trails in open spaces. The simple interface made collecting relatively easy and provides GIS online experience is not taught in classes. The Picture Canyon authorized trials were not in trail applications like AllTrails, which was a complaint of one hiker that I encountered. In the conclusion section, I will interpret the individual statistics within each area and propose a solution that could be implemented by the city.

Conclusion

In conclusion, data collection for this project was appreciated and will be utilized by Robert Wallace and his team at the City of Flagstaff. The project reveals areas of vegetation that are severely damaged because of extensive foot traffic on social trails. By inputting my researched trail data, the sustainability department can identify highly disturbed areas and

corridors or areas that could be further examined by adding a trail counter to a sample of barren trails. The results could justify why this heavily used social trail could be added as an authorized trail. Statistics collected on each trail show that area four had the longest total distance with 3.60 miles of social trails, while area two had the shortest overall distance with 1.49 miles of social trails. Many of the double track trails in area four have a more extended range because there are no natural barriers preventing travel in the region. Compared to area two, which has steep canyon walls and natural features, such as the Rio de Flag that limit possible travel distance. Singletrack social trails were short because of the proximity of cultural and natural sites of interest to each other and the authorized trail system. It was evident that throughout Picture Canyon, the ATV double track social trails were longer and more interconnected than single track trails because a large proportion of the terrain was seamless for this recreation activate. Evidence of recent ATV usage does not seem to be an issue during the day because illegal off-roading was not present while doing field collection. One solution is setting up a night vision camera at double track social trails to see if any activity is happening from nearby residents.

The City of Flagstaff has plans to cut and log trees within Picture Canyon Natural and Cultural Preserve in the summer of 2020. Results from the restoration effects might increase the total number of social trails in area four close to the northern boundary, where double track social trails are prevalent. Analyzes could be conducted to ensure that the restoration process benefited Picture Canyon and prevent further illegal activity in the area.

I highly recommend visiting Picture Canyon Natural and Cultural Preserve for a day to explore this magical and historical place. You will get to see features like the deep water pond, an iconic waterfall, and petroglyphs depending on what trails you end up hiking.

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Appendix A

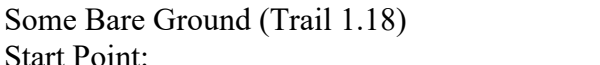*Table 11: Attribute table of all trail features*

Trail Identification Number	Trail Classification	Trail Location	Vegetation Classification	Trail Length (in miles)
1.01	Single Track	Area 2	Barren	0.16
1.02	Single Track	Area 2	Stunted Vegetation	0.13
1.03	Single Track	Area 2	Some Bare Ground	0.18
1.04	Single Track	Area 1	Stunted Vegetation	0.04
1.05	Single Track	Area 1	Barren	0.03
1.06	Single Track	Area 1	Barren	0.11
1.07	Single Track	Area 1	Some Bare Ground	0.24
1.08	Single Track	Area 1	Some Bare Ground	0.05
1.09	Single Track Animal Trail	Area 1	Some Bare Ground	0.01
1.10	Single Track	Area 1	Some Bare Ground	0.02
1.11	Single Track	Area 1	Barren	0.06
1.12	Single Track	Area 1	Some Bare Ground	0.02
1.13	Single Track Animal Trail	Area 3	Stunted Vegetation	0.07
1.14	Single Track Animal Trail	Area 3	Barren	0.40
1.15	Single Track Animal Trail	Area 3	Some Bare Ground	0.09
1.16	Single Track	Area 2	Barren	0.17
1.17	Single Track	Area 2	Some Bare Ground	0.02
1.18	Single Track	Area 2	Some Bare Ground	0.25
1.19	Single Track	Area 2	Some Bare Ground	0.03
1.20	Single Track	Area 2	Stunted Vegetation	0.11
1.21	Single Track	Area 2	Some Bare Ground	0.07
1.22	Single Track	Area 2	Some Bare Ground	0.03
1.23	Single Track	Area 2	Some Bare Ground	0.05
1.24	Single Track	Area 2	Stunted Vegetation	0.07
1.25	Single Track	Area 2	Some Bare Ground	0.01
1.26	Single Track	Area 2	Some Bare Ground	0.01
1.27	Single Track	Area 2	Some Bare Ground	0.01
1.28	Single Track	Area 2	Barren	0.01
1.29	Single Track	Area 2	Some Bare Ground	0.01
1.30	Single Track	Area 2	Stunted Vegetation	0.04
1.31	Single Track Animal Trail	Area 4	Some Bare Ground	0.02
1.32	Single Track	Area 4	Stunted Vegetation	0.03
1.33	Single Track	Area 4	Barren	0.22
1.34	Single Track	Area 3	Some Bare Ground	0.03
1.35	Single Track	Area 4	Some Bare Ground	0.11
1.36	Single Track	Area 4	Barren	0.04
1.37	Single Track	Area 4	Stunted Vegetation	0.03

1.38	Single Track Animal Trail	Area 1	Some Bare Ground	0.26
1.39	Single Track Animal Trail	Area 1	Some Bare Ground	0.13
1.40	Single Track Animal Trail	Area 1	Some Bare Ground	0.09
1.41	Single Track Animal Trail	Area 1	Some Bare Ground	0.09
1.42	Single Track Animal Trail	Area 1	Some Bare Ground	0.07
1.43	Single Track	Area 1	Some Bare Ground	0.14
1.44	Single Track	Area 1	Barren	0.15
1.45	Single Track	Area 1	Barren	0.16
1.46	Single Track	Area 1	Barren	0.06
1.47	Single Track	Area 1	Barren	0.03
1.48	Single Track	Area 1	Stunted Vegetation	0.04
1.49	Single Track	Area 1	Stunted Vegetation	0.04
1.50	Single Track	Area 1	Barren	0.14
1.51	Single Track	Area 1	Stunted Vegetation	0.05
1.52	Single Track	Area 1	Some Bare Ground	0.05
1.53	Single Track	Area 2	Stunted Vegetation	0.01
2.00	Double Track	Area 3	Barren	0.22
2.01	Double Track	Area 2	Stunted Vegetation	0.01
2.02	Double Track	Area 1	Barren	0.27
2.03	Double Track	Area 1	Barren	0.05
2.04	Double Track	Area 4	Barren	0.14
2.05	Double Track	Area 4	Barren	0.20
2.06	Double Track	Area 4	Barren	0.12
2.07	Double Track	Area 4	Barren	0.13
2.08	Double Track	Area 4	Some Bare Ground	0.10
2.09	Double Track	Area 3	Some Bare Ground	0.04
2.10	Double Track	Area 3	Some Bare Ground	0.18
2.11	Double Track	Area 3	Some Bare Ground	0.27
2.12	Double Track	Area 3	Some Bare Ground	0.01
2.13	Double Track	Area 3	Barren	0.12
2.14	Double Track	Area 3	Stunted Vegetation	0.24
2.15	Double Track	Area 3	Some Bare Ground	0.05
2.16	Double Track	Area 3	Some Bare Ground	0.17
2.17	Double Track	Area 4	Barren	0.29
2.18	Double Track	Area 4	Some Bare Ground	0.21
2.19	Double Track	Area 4	Barren	0.07
2.20	Double Track	Area 3	Stunted Vegetation	0.24
2.21	Double Track	Area 3	Stunted Vegetation	0.13
2.22	Double Track	Area 3	Barren	0.37
2.23	Double Track	Area 3	Some Bare Ground	0.41
2.24	Double Track	Area 4	Barren	0.08
2.25	Double Track	Area 4	Barren	0.07
2.26	Double Track	Area 4	Barren	0.03

2.27	Double Track	Area 4	Barren	0.05
2.28	Double Track	Area 4	Barren	0.42
2.29	Double Track	Area 4	Barren	0.15
2.30	Double Track	Area 4	Some Bare Ground	0.06
2.31	Double Track	Area 2	Stunted Vegetation	0.01
2.32	Double Track	Area 3	Stunted Vegetation	0.08
2.33	Double Track	Area 3	Some Bare Ground	0.17
2.34	Double Track	Area 3	Barren	0.19
2.35	Double Track	Area 4	Some Bare Ground	0.01
2.36	Double Track	Area 4	Some Bare Ground	0.09
2.37	Double Track	Area 4	Barren	0.26
2.38	Double Track	Area 4	Barren	0.37
2.39	Double Track	Area 4	Barren	0.14
2.40	Double Track	Area 4	Barren	0.05
2.41	Double Track	Area 2	Some Bare Ground	0.10
2.42	Double Track	Area 4	Barren	0.03
2.43	Double Track	Area 4	Barren	0.08
Arizona Trail	Authorized Trail		Barren	1.52
Don Weaver Trail	Authorized Trail		Barren	0.65
Petroglyph Outlook Trail	Authorized Trail		Barren	0.03
Pithouse Trail	Authorized Trail		Barren	0.06
Service Road	Double Track	Area 4	Barren	0.42
To Arizona Trail / Don Weaver Trail	Authorized Trail		Barren	0.05
To Tom Moody Trail Head / To Parking Lot	Authorized Trail		Barren	0.06
To Tom Moody Trail Head / To Parking Lot	Authorized Trail		Barren	0.17
Tom Moody Trail	Authorized Trail		Barren	3.39
Watchable Wildlife Site Trail	Authorized Trail		Barren	0.04

Appendix B

Table 12: Sample photographs of single-track social trail classes

Vegetation Classification Single Track Example	
Barren (Trail 1.06) Start Point:	End Point:
Some Bare Ground (Trail 1.18) Start Point:	End Point:

Stunted Vegetation (Trail 1.32)
Start Point:

End Point:

Table 13: Sample photographs of double track social trail classes

Vegetation Classification Double Track Example	
Barren (Trail 2.39) Start Point: 	End Point:
Some Bare Ground (Trail 2.11) Start Point:	End Point:

Stunted Vegetation (Trail 2.32)

Start Point:

End Point:

Table 14: Authorized Trails Statistics, Trail Length (in miles) and Trail Vegetation (B-Barren, SBG-Some Bare Ground, SV-Stunted Vegetation)

Authorized Trails	Trail Statistics	Trail Length (in miles)	Trail Vegetation
Total Authorized Trails:	9	5.97 miles	B-9 SBG-0 SV-0

Table 15: Social Trails Statistics, Trail Length (in miles) and Trail Vegetation (B-Barren, SBG-Some Bare Ground, SV-Stunted Vegetation)

Social Trails	Trail Statistics	Trail Length (in miles)	Trail Vegetation
Total Social Trails:	97	10.97 miles	B-38 SBG-41 SV-18

Table 16: Trail Classification Statistics, Trail Length (in miles) and Trail Vegetation (B-Barren, SBG-Some Bare Ground, SV-Stunted Vegetation)

Single Track Trails	Trail Statistics	Trail Length (in miles)	Trail Vegetation
Total Single Track Trails:	43	3.26 miles	B-13 SBG-19 SV-11
Single Track Animal Trails	**Trail Statistics**	**Trail Length (in miles)**	**Trail Vegetation**
Total Animal Trails:	10	1.23 miles	B-1 SBG-8 SV-1
Double Track Trails	**Trail Statistics**	**Trail Length (in miles)**	**Trail Vegetation**
Total Double Track Trails:	44	6.48 miles	B-24 SBG-14 SV-6

Table 17: Area 1 Trail Statistics, Trail Length (in miles) and Trail Vegetation (B-Barren, SBG-Some Bare Ground, SV-Stunted Vegetation)

AREA 1	Trail Statistics	Trail Length (in miles)	Trail Vegetation
Single Track:	18	1.43 miles	B-8 SBG-6 SV-4
Single Track Animal Trail:	6	0.65 miles	B-0 SBG-6 SV-0
Double Track:	2	0.32 miles	B-2 SBG-0 SV-0
Total Social Trails:	26	2.40 miles	B-10 SBG-12 SV-4

Table 18: Area 2 Trail Statistics, Trail Length (in miles) and Trail Vegetation (B-Barren, SBG-Some Bare Ground, SV-Stunted Vegetation)

AREA 2	Trail Statistics	Trail Length (in miles)	Trail Vegetation
Single Track:	19	1.37 miles	B-3 SBG-11 SV-5
Single Track Animal Trail:	0	0.00 miles	B-0 SBG-0 SV-0
Double Track:	3	0.12 miles	B-0 SBG-1 SV-2
Total Social Trails:	22	1.49 miles	B-3 SBG-12 SV-7

Table 19: Area 3 Trail Statistics, Trail Length (in miles) and Trail Vegetation (B-Barren, SBG-Some Bare Ground, SV-Stunted Vegetation)

AREA 3	Trail Statistics	Trail Length (in miles)	Trail Vegetation
Single Track:	1	0.03 miles	B-0 SBG-1 SV-0
Single Track Animal Trail:	3	0.56 miles	B-1 SBG-1 SV-1
Double Track:	16	2.89 miles	B-4 SBG-8 SV-4
Total Social Trails:	20	3.48 miles	B-5 SBG-10 SV-5

Table 20: Area 4 Trail Statistics, Trail Length (in miles) and Trail Vegetation (B-Barren, SBG-Some Bare Ground, SV-Stunted Vegetation)

AREA 4	Trail Statistics	Trail Length (in miles)	Trail Vegetation
Single Track:	5	0.43 miles	B-2 SBG-1 SV-2
Single Track Animal Trail:	1	0.02 miles	B-0 SBG-1 SV-0
Double Track:	23	3.15 miles	B-18 SBG-5 SV-0
Total Social Trails:	29	3.60 miles	B-20 SBG-7 SV-2
Service Road:	1	0.42 miles	B-1 SBG-0 SV-0