Summer Visitor Use and Resource Monitoring at Focal Attractions and Trails in Yellowstone National Park

Summer 2017 Data Collection Effort

June 4th, 2018

Report by:

Ashley D'Antonio, Ph.D.

Susan Sidder, Ph.D. student

Oregon State University

College of Forestry

Grand Canyon of the Yellowstone River as viewed from Artist Point

(photo by Ashley D'Antonio)

Table of Contents

Executive Summary iii

Key Findings iv

Acknowledgements v

Introduction 1

Sampling Period & Study Sites 2

- Sampling Period 2
- Study Sites 2
  - Artist Point 4
  - Fairy Falls 4
  - Midway Geyser Basin 5
  - Norris Geyser Basin 6
  - Old Faithful 7

Methods 9

- Visitor Use Estimation 9
  - Parking Lot Counts 9
  - Automatic Trail Counters 9
  - Trail Counter Calibrations 10
- Visitor Use/Capacity Measures 10
  - People At One Time (PAOT) Counts 11
  - Visitor Encounters 11
- Visitor Spatial Behavior 11
  - GPS-Based Tracking of Visitors 12
  - Waypoint Mapping of Visitor Behaviors & Resource Impacts 13

Results 14

- Artist Point 15
  - Visitor Use Estimation 15
  - Visitor Use/Capacity Measures 17
  - Visitor Spatial Behavior 19
- Fairy Falls 23
  - Visitor Use Estimation 24
  - Visitor Use/Capacity Measures 27
  - Visitor Spatial Behavior 28

Midway Geyser Basin 33
Visitor Use Estimation 33
Visitor Use/Capacity Measures 36
Visitor Spatial Behavior 38
Norris Geyser Basin 43
Visitor Use Estimation 43
Visitor Use/Capacity Measures: 46
Visitor Spatial Behavior 48
Old Faithful 52
Visitor Use Estimation 52
Visitor Use/Capacity Measures: 54
Visitor Spatial Behavior 56
Social Trails 60
Data Integration 84
Recommendations 91
Appendices 91
Appendix A: Summer 2017 YCC Crew Data Collection Calendar 92
Appendix B: Locations of PAOT Counts at Each Focal Attraction Site 92
Appendix C: GPS-based Tracking Download & Cleaning Procedures 92
Appendix D: Visitor Behavior & Resource Impact Categories 92
Appendix E: Summary Tables for Parking Lot Counts 92
Appendix F: Average Hourly Vehicle Counts for Focal Attraction Sites by Date 92
Appendix G: Density of Visitor Behaviors & Resource Impacts 92
Appendix H: Summary of All Visitor Behaviors and Resource Impact Waypoints 92
Appendix I: Maps of Locations of Individual Visitor Behaviors and Resource Impact Waypoints 92
References 93

Executive Summary

During the summer of 2017, Youth Conservation Corps Crews in Yellowstone National Park (YELL) assisted with a citizen science-based visitor use monitoring project. The YCC Crews collected social science and resource-related data at five focal attraction sites in YELL: Artist Point in the Grand Canyon of the Yellowstone, Fairy Falls trail and the newly opened Grand Prismatic Spring Overlook, Midway Geyser Basin, Norris Geyser Basin, and Old Faithful. Data collection methodologies included: visitor use estimations via parking lot counts and automatic trail counters, measures of visitor experience including counts of encounters on trails and People At One Time (PAOT), as well as measures of the spatial behavior and impacts of visitors using GPS-based methodologies. The YCC Crews successfully collected high-quality data via this citizen science project. The data is limited in sample size and that it was only collected between approximately 9:00am and 4:00pm (16:00) on weekdays. Despite these limitations the data can be used to monitor changes in visitor use over time and highlight potential visitor use issues at each focal attraction site. This report summarizes the data collected by the YCC Crews in 2017 and presents a template for how future monitoring data using these protocols could be analyzed and summarized in the future. Accompanying the report are revised versions of the protocols used by the YCC Crews in 2017 which have been updated based on feedback from YELL staff.

The data collected in 2017 highlight that across all focal attraction sites, visitor use appears to begin to peak around 11:00am and remains high throughout the day with very little drop in use into the afternoon hours. The highest levels of visitor use occur at the key destinations at each site (ex: Old Faithful Geyser, Lower Falls Overlook, Grand Prismatic Spring) and visitor behaviors and resource impacts of interest are associated with these areas of high levels of visitor use. Parking at Midway Geyser Basin is not sufficient given the level of visitor use at this site and undesignated and roadside parking were frequently observed at Midway Geyser Basin. Artist Point trailhead appears to be a very dynamic location with much variability in terms of visitor use levels, trail encounters, and People At One Time (PAOT) counts across a day. Littering and seeing litter (both in and outside thermal areas) was by far the most common resource impact observed and mapped by the YCC Crews across all focal attraction sites. Some of the focal attraction sites have extensive networks of social trails of moderate length but the boardwalks in the hydrothermal areas appear to be doing a relatively good job at keeping visitors on-trail. The majority of social trails summarized in this report were associated with roadways and designated trails. The report ends with recommendations for improvements to this citizen science project including permanent installation of trail counters to estimate visitor use and adding one additional person to the YCC Crews.

Key Findings

In general, the YCC Crews collected sound data at the five focal attraction sites with little issues or difficulties. It is important to note that the findings from this monitoring project are based on a relatively small sample size per site and were collected only on weekdays from the end of June through early August. Despite these limitations, the data appear to be of high enough quality for monitoring purposes at these focal attractions over time. See the "Recommendations" section for ways to improve this monitoring effort. Overall, it is important to note that the YCC Crews and YELL staff did an excellent job in this effort – especially in terms of making adjustments in the field to methods and protocols in a way that balanced feasibility while maintaining quality data collection and the overall study design. The level and quality of data collected by the YCC Crews is sufficient for monitoring purposes.

Below are a few key findings from the YCC Crew data collected in the summer of 2017.

- In terms of overall visitor use at all the focal attraction sites – all sites appear to be busiest between approximately 11:00am with a slight, but often not substantial, drop in use around 2:00pm (14:00) or 3:00pm (15:00).

- There seems to a slight increase in use during the last week of July (between approximately July 24th to July 27th); possibly a result of the Pioneer Day holiday celebrated in Utah (?).

- In terms of spatial behavior, most visitors did tend to visit and spend more time at the obvious attractions at each focal attraction site (ex: Lower Falls overlook, Grand Prismatic Spring, etc.). But visitors were mapped that traveled beyond these focal destinations at each site.

- Visitor behaviors and resource impacts of interest tend to be associated with the locations that have the highest densities of visitor use.

- Litter was the most common resource impact observed by the YCC Crews. This could be because the litter is a resource impact that can remain in the system across many days/weeks. Therefore, the same piece of litter – while not mapped multiple times in a single day – could have been mapped many times across the span of the sampling season.

- Midway Geyser Basin appears to have some of the most acute issues related to parking that may be cascading into potential social and ecological issues. Midway Geyser Basin has the highest rate of undesignated and roadside parking as well as some of the highest visitor use levels within a relatively short, confined trail system. Midway Geyser Basin had the highest number of behavior and resource impacts mapped via waypoints and had the highest amount of social trail-related impacts.

- While Norris and Old Faithful have larger parking areas and thus can accommodate more vehicles compared to the other focal attraction sites, the visitors to Norris Geyser Basin and Old Faithful have a greater extent of a trail system in which to recreate – possibly dispersing issues

like social trails and behaviors that may be of concern (such as visitors off-boardwalk or obstructions to visitor flow).

- People At One Time (PAOT) counts varied considerably across the sampling period at all of the focal attraction sites. These results indicate that even at the busiest sites and even during peak use, the flow of visitors through these trail systems varies greatly resulting in a wide range of PAOT that visitors could experience at attraction sites. For example, at Old Faithful – even during midday peak use – PAOT counts near Beehive Geyser Basin were observed in the single digits. Overall, visitor use at any given attraction site seems to ebb and flow across the day and peaks of use at a key destination at a site may not necessarily correspond to peaks in overall use levels as indicated by trail counters or parking lot counts.

- At the parkwide level, approximately 90,500 meters of social trails exist in YELL – the majority of these are contained along designated trails and roadways.

- The proliferation of social trails appears to an issue at the site level, especially at locations like Midway Geyser Basin and Fairy Falls. The majority of the social trails are of moderate levels of impact in terms of condition class rating.

Acknowledgements

The data collection that is summarized here would not have been possible without substantial assistance, both in the field and during project development, and insightful input from Ryan Atwell, Alicia Murphy, and Kyle Meakins. Sue Mills and Amanda Bramblett provided additional guidance and substantial amounts of their time helping me to understand, proving access to, and sharing ideas about the social trails data that will be incorporated into this study - I thank them for their time and insights. Additionally, many thanks to the YCC Crew participants, their crew leaders, and Peggy Osborn and Sam Bennet for the many hours they spent in the field collecting data. Peggy's feedback on the monitoring protocols were incredibly insightful and helpful during protocol revisions. Allison Klein and Evan Crane were instrumental in the processing, delivery, and cleaning of all the GPS-related data collected by the YCC Crews; the data transfer to Oregon State could not have happened without them. Alicia Murphy, Sarah Haas, Ray McPadden, and Christina White provided incredibly helpful and detailed comments on the draft version of this report. Oregon State undergraduates, Ian Redding and Morgan De Meyer, were responsible for data entry and QA/QC checks. Ian Redding contributed significantly to the GIS analysis of the GPS tracking and waypoint data. Susie Sidder, a PhD student at Oregon State, was heavily involved in the analysis and writing of this report – especially in relation of the social trails data.

Introduction

Between 2014 and 2016 Yellowstone National Park (YELL) saw a 21% increase in visitation. In 2017, YELL experienced its second busiest year on record – receiving over 4.1 million visits to the park (National Park Service, 2018). This rapid increase in visitors over a short period of time has led to management concerns related to congestion (especially along roadways and in parking lots), impacts to the visitor experience, and biophysical resource impacts. Monitoring is an important component of understanding recreation resources and trends related to visitor use and impacts over time (Hammitt et al., 2015). However, many national parks and other protected areas have limited resources in terms of time, staff, and funding to devote to continued and consistent monitoring efforts.

This project utilized citizen science data collected by Youth Conservation Corp (YCC) members (referred to as "YCC Crews" in this report) to implement monitoring protocols at key locations in YELL. YCC Crews are made up of high school-aged participants from around the country that spend a month in YELL working and learning about the cultural, historical, and natural resources of the park. During 2017, one week of each YCC Crew's residence in the park involved social science data collection at five focal attraction sites within YELL: Artist Point, the newly opened Fairy Falls trail to overlook Grand Prismatic Spring, Midway Geyser Basin, Norris Geyser Basin, and the Old Faithful Area (see Figure 1).

Figure 1: Basemap showing general locations of focal attractions in Yellowstone (YELL) where Youth Conservation Corp (YCC) Crews collected data during summer 2017 circled in orange. Fairy Falls trail is located in the Midway Geyser Basin area.

These locations were chosen through collaboration with YELL staff and based on the following selection criteria: the sensitivity of biophysical resources to impacts from visitor use and levels of visitor use indicated from previous studies. The focal attraction sites in this study also included the new Fairy Falls designated trail to the Grand Prismatic Spring overlook to begin gathering baseline data for this location. Monitoring protocols for various social science measures were developed by Oregon State University and implemented by the YCC Crews with assistance from their crew leaders and coordination/logistical assistance from YELL staff.

Social Science Data Collected by YCC Crews included:

- Visitor Use Estimation
    - Automatic trail counters (Pettebone et al., 2010)
    - Hourly parking lot counts (Monz et al., 2014)
- Visitor Use/Capacity Measures
    - People at One Time (PAOT) counts (Manning, 2007)
    - Visitor Encounters (Manning, 2011)
- Visitor Spatial Behavior
    - GPS-based tracking of visitor behavior (D'Antonio et al., 2010)
    - Waypoint marking of locations of visitor behaviors and resource impacts of interest

This report presents descriptive analyses of the 2017 data collected by the YCC Crews. This document summarizes the data, organized by focal attraction site, and provides examples of ways that these types of data can be reported and visualized in the future monitoring efforts. The report also contains a basic summary of social trails data that has been collected by YELL for several years. The social trails data is summarized both at the park-wide level as well as at the level of the focal attraction sites to provide information on biophysical resource impacts. The report ends with recommendations for future monitoring efforts using YCC Crews.

Sampling Period & Study Sites

Sampling Period

Data collection occurred on weekdays between June 19, 2017 and August 11, 2017 (see Appendix A for data collection schedule). During the first week of data collection, YCC Crews attempted to visit and collect data at two sites each day. This was quickly discovered to be unfeasible given travel time between sites within YELL. Therefore, starting on June 23, 2017, data collection only occurred at one site per day. YCC Crews only worked on weekdays; therefore, no data collection occurred on weekend days. Data collection by the YCC Crews took place primarily between 9:00am and 3:00pm (15:00); a few days extended to 4:00pm (16:00). Mondays and Fridays were half days of data collection (see Appendix A) to allow for crews to take care of weekly, logistical tasks. YCC Crew leaders and YCC staff were responsible for organizing and scanning data sheets, data downloads, and transferring data to Oregon State University for entry, analysis, and reporting.

Study Sites

YCC Crews collected data at five study sites (referred to in this report as "focal attraction" sites): Fairy Falls, Artist Point, Midway Geyser Basin, Norris Geyser Basin, and Old Faithful (Figure 1). Four of the five focal attraction sites were known to be experiencing high levels of visitation. The fifth location, Fairy Falls, is a new trail which opened in July of 2017 to provide an overlook of the Midway Geyser Basin Area. Three of the sites – Midway Geyser Basin, Norris Geyser Basin, and Old Faithful – contain sensitive hydrothermal features. The trails at these three hydrothermal locations are largely boardwalk-based trails (see Example 1). A limited number of parking spots are available at all of these focal attraction sites with the exception of the Old Faithful area; which has a large series of parking lots. During summer of 2017, the Norris Geyser Basin parking lot would often be closed by YELL staff when parking exceeded capacity of the designated parking spots.

Example 1: Example of a boardwalk-style trail in Yellowstone National Park

Below, in the section to follow, each focal attraction site is briefly described and a map is provided of the area where the YCC Crews focused their data collection efforts. The maps also show trail counter locations (green stars), the extent of the trail where visitor encounters were recorded (brown trail segments), and where People At One Time (PAOT) counts were conducted (orange circles). The monitoring protocols used to collect these data will be described in detail in the "Methods" section of this report.

Artist Point

The Artist Point trail is located on the South Rim of the Grand Canyon of the Yellowstone River. Key attractions at Artist Point are views of the Grand Canyon and an overlook of Lower Falls. The approximately 0.2 mile trail to the overlook begins at the Artist Point parking area and is wide, relatively flat, and paved. The area also provides access to the South Rim Trail and trails that lead to Lily Pad Lake, Ribbon Lake, and Clear Lake. Data collection by the YCC Crews focused on the Artist Point trailhead and the short loop trail that takes visitors to the Artist Point overlook (see Figure 2).

Figure 2: Artist Point focal attraction site. Symbols on map: trail counter locations (green stars), the extent of the trail where visitor encounters were recorded (brown trail segments), and where People At One Time (PAOT) counts were conducted (orange circles). The most northern orange circle is the overlook to Lower Falls of the Yellowstone River.

Fairy Falls

The Fairy Falls trailhead is accessible via the Grand Loop Road and located just south of the parking area for the Midway Geyser Basin. The Fairy Falls trailhead provides access to Fairy Falls (a 2.5 mile hike) and the Imperial Geyser Basin (approx. 3 mile hike). During summer 2017, a new trail was built along the Fairy Falls trail to provide an overlook of Grand Prismatic Spring. Along with the new trail, the Fairy Falls parking area was improved and expanded. The new Grand Prismatic Overlook Trail is located 0.6 miles from the Fairy Falls trailhead and provides a viewing platform at the top (see brown trail in Figure 3). The YCC Crews focused their 2017 data collection efforts on the Fairy Falls trailhead and the new Grand Prismatic Spring Overlook Trail.

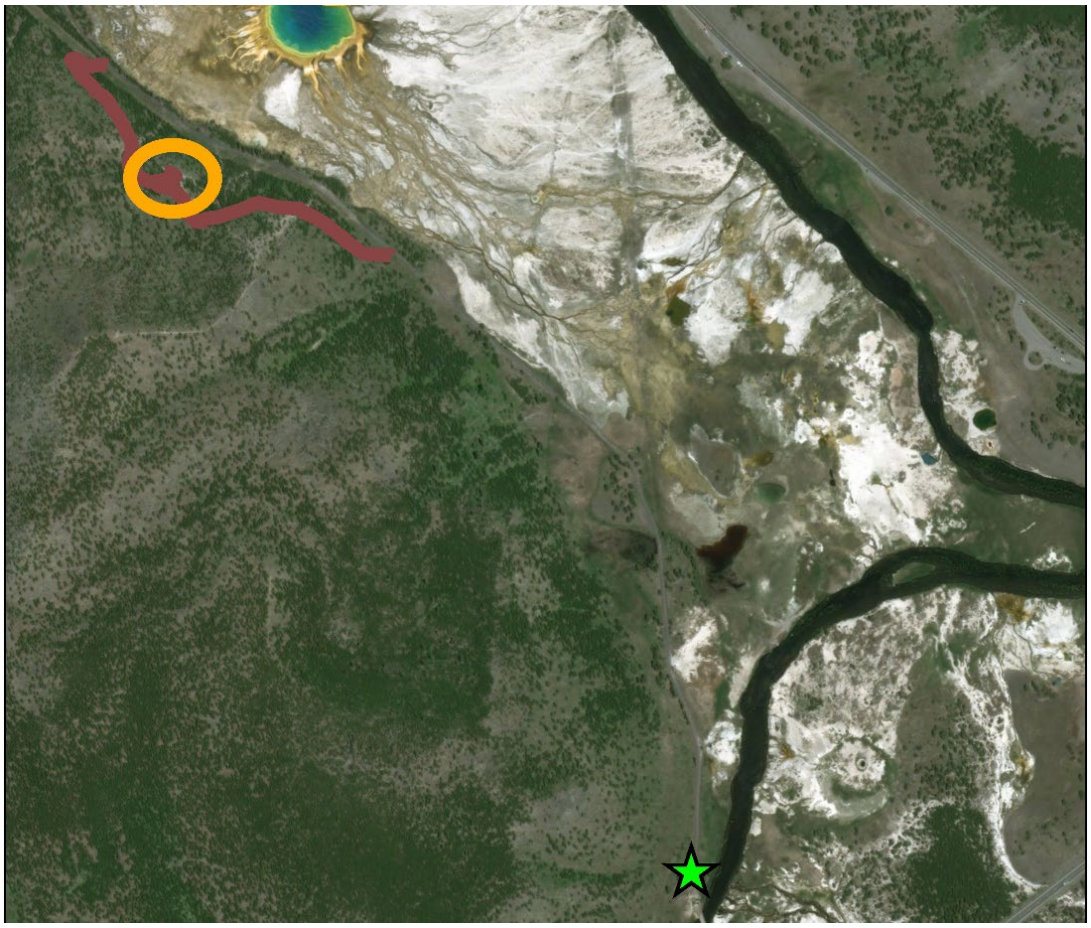

Figure 3: Fairy Falls focal attraction site. Symbols on map: trail counter locations (green stars), the extent of the trail where visitor encounters were recorded (brown trail segments), and where People At One Time (PAOT) counts were conducted (orange circle). The viewing platform for Grand Prismatic Spring is located within the orange circle.

Midway Geyser Basin

Midway Geyser Basin, located on the Grand Loop Road of YELL, is a popular stopping location in the park for viewing hydrothermal features. Grand Prismatic Spring, the largest hot spring in YELL, is located here. The geyser basin proper is accessed from the Midway Geyser Basin parking area where visitors cross a bridge over the Firehole River to access a boardwalk trail through the geyser basin. The boardwalks provide a less than 1 mile loop through the geyser basin (Figure 4).

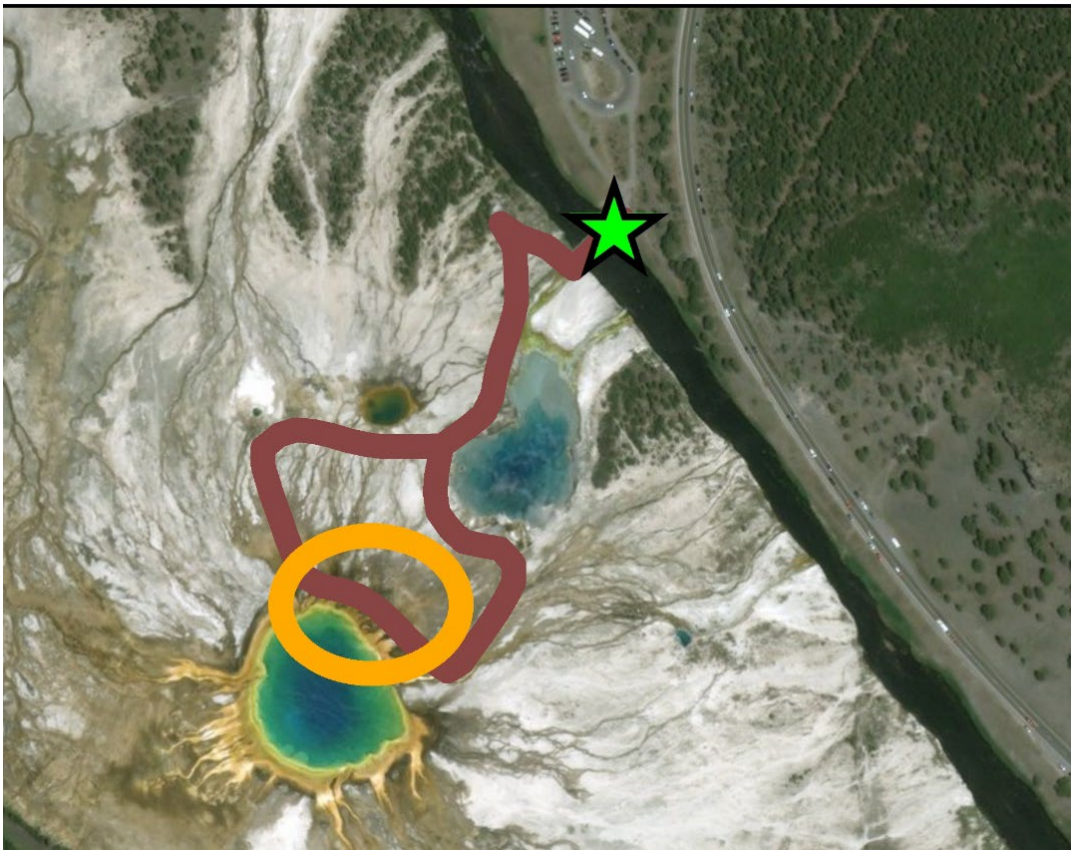

Figure 4: Midway Geyser Basin focal attraction site. Symbols on map: trail counter locations (green stars), the extent of the trail where visitor encounters were recorded (brown trail segments), and where People At One Time (PAOT) counts were conducted (orange circle).

Norris Geyser Basin

The Norris Geyser Basin is another popular, hydrothermal feature-focused destination in YELL. The Norris Geyser Basin is accessed via a large parking lot and contains a trail system of both paved and boardwalk-style trails. The Norris Geyser Basin Museum is also located here. During the 2017 data collection effort, the YCC Crews focused on the Porcelain Basin area of the Norris Geyser Basin. This is an approximately 1-mile loop trail made up of mostly boardwalks, but some paved trail, that can be access from the Norris Geyser Basin Museum (Figure 5).

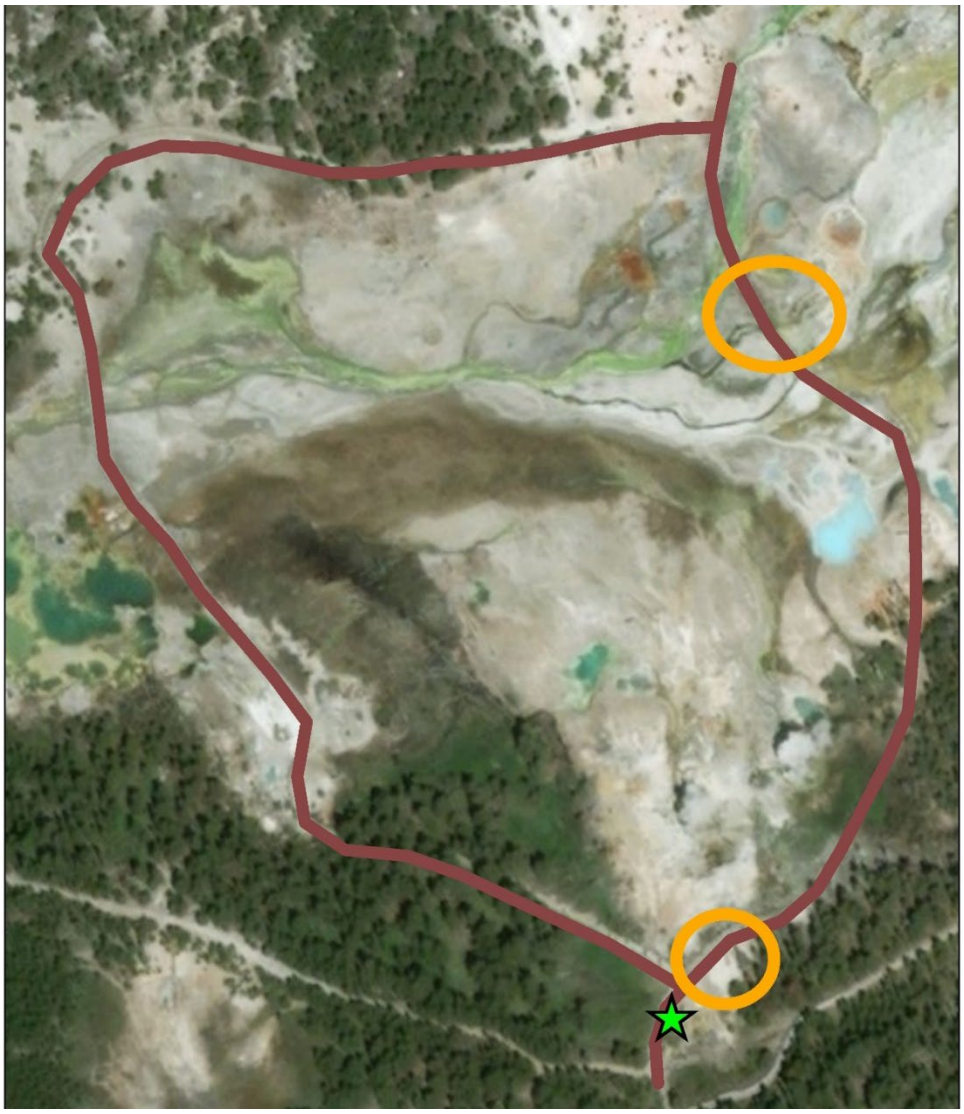

Figure 5: Norris Geyser Basin focal attraction site; data collection focused on Porcelain Basin (shown here). Symbols on map: trail counter locations (green stars), the extent of the trail where visitor encounters were recorded (brown trail segments), and where People At One Time (PAOT) counts were conducted (orange circle).

Old Faithful

The Old Faithful area of YELL, named after the Old Faithful Geyser, is one of the most popular destinations in YELL. Numerous other hydrothermal features are found at this location as well as a visitor center, the Old Faithful Inn, and a variety of lodging, food and shopping locations. Due to the popularity of this location and the many amenities here, the Old Faithful area has the largest parking lot of all the focal attraction sites in this study.

Geyser Hill is located just north of the Old Faithful Geyser and provides a boardwalk loop around many other geysers including Beehive Geyser and Doublet Pool. To access Geyser Hill visitors must walk around the Old Faithful Geyser area and cross the Firehole River via a bridge. The trails leading to Geyser Hill as well as the Old Faithful Geyser area were the focus of the YCC Crew data collection efforts for 2017 (Figure 6).

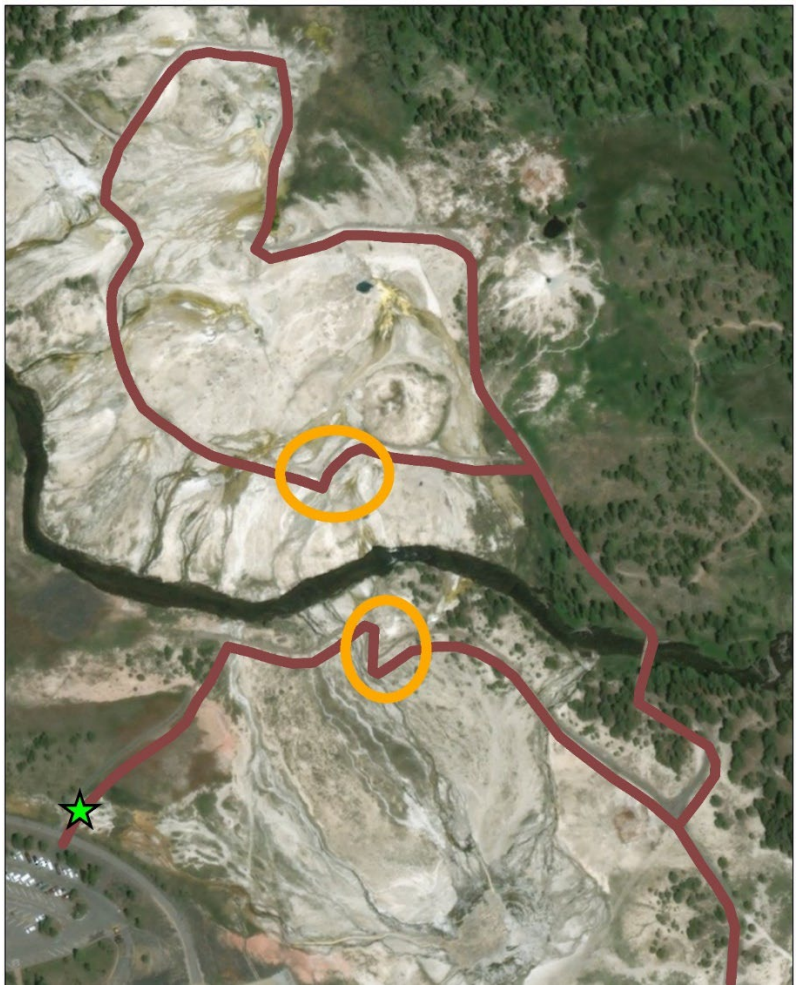

Figure 6: Old Faithful focal attraction site; data collection focused on Geyser Hill (shown here). Symbols on map: trail counter locations (green stars), the extent of the trail where visitor encounters were recorded (brown trail segments), and where People At One Time (PAOT) counts were conducted (orange circle).

Methods

The detailed monitoring protocols and data sheets utilized in 2017 by the YCC Crews were delivered to YELL in June of 2017. The methods used to collect data in 2017 are briefly described below. Please see the monitoring protocols for more detail related to these data collection methods. Revisions to these protocols were made based on feedback provided by the YCC Crew leaders, volunteers, and YELL staff. Revised monitoring protocols and data sheets are provided with this report as a separate series of documents.

Visitor Use Estimation

In order to understand visitor use levels at each focal attraction site, two different methodologies were used: parking lot counts and automatic trail counters. Parking lot counts occurred in the parking lots at each focal attraction site; with the exception of Old Faithful. The parking lot at Old Faithful was too large to be safely counted by the YCC Crews. One automatic trail counter was placed at the trailheads of Artist Point, Fairy Falls, and Midway Geyser Basin. At Norris Geyser Basin the trail counter was placed at the start of the Porcelain Basin Loop. At Old Faithful the trail counter was placed on the trail Northeast of Old Faithful Geyser. See Figures 2 through 6 for trail counter locations for each focal attraction site, marked with a green star.

Parking Lot Counts

At each focal attraction site (except for Old Faithful as previously noted) YCC Crews counted and recorded the number of vehicles in the trailhead parking lots on the hour for each hour they were collecting data (Monz et al., 2014). The YCC Crews also recorded the number of vehicles parked in undesignated spots (any spot that was not delineated by lines or other features), RVs, tour buses, motorcycles, NPS vehicles, and bicycles. If a queue of cars was formed waiting for a parking spot while the count was occurring, the YCC Crews would record the number of cars waiting in line. Opportunistically, counts of restroom lines as well as the number of cars parked along roadways on entry roads to the trailhead were also recorded. Parking lot data is summarized by date and time of day; average and standard deviations of total vehicles and other vehicles counts of interest are presented in this report.

Automatic Trail Counters

No permanent trail counters were used in this study. At the beginning of each data collection period, the YCC Crews installed an automatic TRAFx (TRAFx, 2018a) trail counter at the trailhead (or beginning of the trail system of interest) of the focal attraction site to be sampled that day. See Figures 2 through 6 for trail counter locations for each focal attraction site (shown as green stars). At the end of the day, the trail counter was uninstalled from the focal attraction site. Data was downloaded from the trail counters weekly and uploaded to TRAFx's DataNet website (TRAFx, 2018b). Trail counter data is summarized by the average and standard deviation of visits (visits = total number of counter hits) across the day. Automatic trail counters almost always underestimate visitor use as they undercount when large groups pass the counter at once or individuals walk shoulder to shoulder. Therefore, counter calibration techniques should always be used with automatic trail counter placement (see next section).

Trail Counter Calibrations

Trail counters, even when carefully placed, will have some level of error in their use estimates. Observational techniques can be used to calibrate the trail counters and calculate a measure of counter error (Pettebone et al., 2010). This error measure can be used to "correct" trail counter use estimates. To calibrate the trail counters, YCC Crews manually counted visitors as they passed the automatic trail counter. In additional to overall counts, the YCC crews recorded the direction of travel for visitors as well.

Counter calibration counts must line up perfectly in time with the way the TrafX automatic trail counters "bin" the use estimate data. The TRAFx counters were set to summarize the count data into 1-hour bins. Unfortunately, due to miscommunication and unclear language in the protocols, the majority of the YCC Crew calibration counts did not start and end on the hour. Therefore, for 2017, the data could not be used to calibrate – or correct – the automatic trail counter use estimates. The calibration counts conducted by the YCC Crews did not line up with the output from the TRAFx counters. The counter calibration protocols and data sheets to be used by the YCC Crews in 2018 have been revised to be clearer about the importance of starting and ending counts on the hour.

Therefore, the visitor use estimates summarized by the automatic trail counters throughout this report should be interpreted as **underestimates** of actual visitor use levels at the focal attraction sites. Also, because of the small sample sizes at each site and some technical issues with the counters that led to a few unusually low values, the standard deviations of the automatic trail counters are high at all locations. However, the use estimates are still helpful in understanding average patterns of use across the day in terms of peak use and generalized use levels – meaning the data can be used to understand when the trailheads are their busiest and how long use remains high (or low) throughout the day. However, these estimates should not be interpreted as a true measure of the number of visitors at each location per hour.

Despite these issues with the automatic trail counters, the YCC Crews collected a large amount of high quality, manual counts of visitor use during the calibration procedures. So, in this report, the calibration data will be used to summarize the average and standard deviation of the use estimates overall and by direction in 15-minute increments at each counter location. These counts were not conducted throughout the day and cannot be used to understand patterns of use levels but are likely a more accurate estimate of total use counts in an average hour during the sampling period. A *rough* estimate of average hourly use can be calculated by multiplying the 15-minute average counts by four. However, these estimates may not be representative of counts across an entire day. Meaning if the calibrations were always done by the YCC Crews at the busiest time of the day, an estimate taken by multiplying the 15-minute average counts by four to equal an hour's worth of counts may not be accurate for hourly counts at 9:00am or 3:00pm (15:00).

Visitor Use/Capacity Measures

Visitor use estimates using trail counters and parking lot counts can provide a good understanding of the number of visitors entering a trail system. However, they do not provide a complete picture of what other visitors might be experiencing in terms of visitor use levels on trails or at important locations such as overlooks. In order to better understand visitor use within the trail system at the focal attraction sites and the level of use that may be experienced by other visitors, the YCC Crews recorded visitor encounters on trails (Manning, 2011) and People At One Time (PAOT) counts at key locations in the trail systems (Manning, 2007).

People At One Time (PAOT) Counts

At each focal attraction site, one or two key locations were selected for conducting People At One Time (PAOT) counts. Figures 2 through 6 highlight these locations using orange ovals and Appendix B shows these locations in greater detail. At each of the locations highlighted in orange, the YCC Crews counted and recorded the number of visitors found in that space at that time. These PAOT counts occurred approximately every 20 minutes or as frequently as YCC Crew were able given the length of the trail system. The time that the PAOT count occurred was also recorded.

Artist Point had two PAOT locations (Figure 2 and Appendix B); the lower bench area which has a view of Lower Falls and the Lower Falls overlook. At Fairy Falls the PAOT location was the viewing platform for the Grand Prismatic Spring Overlook (Figure 3 and Appendix B). Midway Geyser Basin has a section of boardwalk trail, close to Grand Prismatic Spring, where PAOT counts occurred (Figure 4 and Appendix B). At Norris Geyser Basin, the PAOT counts occurred on the stairs leading down to the Porcelain Basin boardwalk and on the boardwalk near Whirligig Geyser (Figure 5 and Appendix B). Old Faithful also had two locations for PAOT counts: one on the lower part of Geyser Hill in the "Z" section of the boardwalk and one on the "L" section of boardwalk near Beehive Geyser (Figure 6 and Appendix B). Old Faithful is unique in that it also had a special PAOT count that occurred only during Old Faithful eruptions. If an eruption of Old Faithful occurred during data collection and the YCC Crews were able, they also documented the estimated number of visitors found on the viewing platform at Old Faithful.

This count estimation at Old Faithful during eruptions was collected by having two YCC crew members head to the platform approximately 10 min before the predicted start of the eruption. One YCC crew member would start at each end of the viewing platform and walk toward to middle; counting visitors as best as they could along the way. Once the YCC crews met in the middle, they added together their counts for the total number of visitors estimated to be on the viewing platform prior to the eruption.

PAOT counts are summarized by the average and standard deviation of the number of visitors counted at the PAOT location(s). All counts are also presented on a graph, organized by the time of day when the count was taken. These graphs can show the minimum and maximum counts, when those counts where taken (in terms of time of day), and the variability in the PAOT counts.

Visitor Encounters

In-between PAOT counts, the YCC Crews hiked segments of the trail system at each of the focal attraction sites and counted the number of visitors they ***passed***. The trail segments where visitor encounters were documented are shown as dark brown lines on Figures 2 through 6. To provide context for these visitor encounter counts, YCC Crews also documented where the counts started, ended, and which direction they traveled while counting. The start and end time of these counts were also recorded. Visitor encounters are summarized by date with the average, standard deviation, minimum, and maximum counts represented in table format for each day of data collection.

Visitor Spatial Behavior

Visitor use estimation techniques and counts of visitors within a trail system can provide an accurate picture of visitor use levels at a given site. However, these numbers do not provide information on the behavior of visitors. The YCC Crews employed two different, spatially-based methods to understand visitor behavior at the focal attraction sites: GPS-based tracking of visitor behavior and waypoint mapping of observed behaviors and impacts.

GPS-Based Tracking of Visitors

To better understand where visitors go while at the focal attraction areas, the YCC Crews randomly selected visitors to participate in a GPS-based tracking study during the sampling periods at each focal attraction site (D'Antonio et al., 2010). Visitors who volunteered to participate would carry a small, handheld GPS unit with them while they visited the focal attraction site. The GPS unit recorded the visitor's location every 10 seconds.

GPS units were handed out at the trailheads, near the parking lots, at Artist Point, Fairy Falls, Midway Geyser Basin and Norris Geyser Basin. At Old Faithful, the GPS units were handed out between the Visitor Center and Old Faithful Geyser. Because the GPS units were handed out at the trailheads, visitors may have hiked beyond or into different trail systems than the ones where PAOT counts, encounter counts, and the waypoint mapping (described below) occurred.

Upon completing their hike or visit to the location, the GPS unit would be returned to the YCC Crews who saved the GPS track. Visitors were instructed to return the GPS units to dropboxes or visitor centers if the YCC Crews were not still at the focal attraction site by the time the visitors returned from their hike/visit. Once a week the GPS units were collected by YELL staff from the YCC Crews and the visitor GPS tracks were downloaded as point data. The point data was sent to Oregon State University for processing. The point data was cleaned of erroneous points (ex: points on the road when GPS units were not turned off at the end of the day, points collected at the trailhead while waiting for the GPS unit to be handed out to visitors) before completing any analysis. See Appendix C for GPS download and cleaning procedures used for this report.

Cleaned GPS tracks were analyzed in GIS using a kernel density procedure – which shows areas where high and low densities of visitor tracking points can be found. These high density areas are locations where many visitors go during their visit to the focal attractions site and/or where visitors spend more time during their visit. Kernel density analysis provides an *estimate or prediction* of where most of the visitor use is occurring based on the data collected in the field. This approach was used to help reduce the impact of outliers in the dataset (meaning the behavior of one tracked visitor who did something unique does not impact the overall density map). The output from the Kernel Density analysis therefore produces a prediction of how many visitor tracking points would be found in given area. In this case, a 5 meter radius was used as the analysis area; this value is determined to be appropriate for GPS-based tracking as this is a reasonable radius for understanding social considerations such as crowding and visitor flow through boardwalks. In other words, a visitor is likely aware of the 5 meters directly around them and this radius is consider appropriate for a "human scale" analysis.

Therefore, it is important to note that the width of the density layer in the map is **not** reflective of off-trail use or visitors being off-boardwalk; it is an artifact of the 5 meter radius around each "visitor" used to calculate the Kernel Density. Kernel Density maps are best interpreted as a means of highlighting locations of potential management concern or further examination; they show where the majority of visitors are going and/or where visitors are lingering. The raw, cleaned GPS-based tracking points are provided in the report to help visualize off-trail or off-boardwalk behavior.

Finally, also using the GPS-based tracking points, the average time visitors spent at each focal attraction site was calculated. The minimum and maximum amount of time spent at each location was also calculated from the GPS data. Any times under 1 minute were dropped from the analysis as these times were likely due to GPS-based error. This is a very time intensive analysis process when the GPS-based tracking dataset is large (which it is in this study). Therefore, while the same analysis can be completed at key locations (such as time spent on the Old Faithful viewing platform or in proximity to Grand Prismatic Spring), no further detailed analysis of this kind was able to be performed for specific locations within each focal attraction site for this report.

Waypoint Mapping of Visitor Behaviors & Resource Impacts

GPS-based tracking can document where visitors go as well as how long they may spend in a trail system or at a location. However, it does not document other behaviors of interest or impacts that may be related to visitor behavior. To better understand visitor behavior and resulting impacts from visitor use at the focal attraction sites, a waypoint mapping protocol was developed for the YCC Crews. Using small, handheld GPS units – the YCC Crews systematically hiked the trail segments of interest (see brown trail sections in Figure 2 through 6) and marked a waypoint when they observed a behavior of interest or a resource impact of concern. See Appendix D for the list of behaviors and impacts that were documented during waypoint mapping.

Each waypoint was assigned a unique ID and a behavior/impact code (also listed in Appendix D) was assigned to that waypoint ID on a separate data sheet. Resource impacts such as piece of trash or footprints in geyser basins were recorded and marked with a waypoint only once during each sampling period to prevent over sampling of these longer lasting impacts. Behaviors of interest, such as visitors hiking off-trail or off-boardwalks or blocking trails, were recorded and marked with a waypoint each time they were observed. Appendix D also outlines which behaviors/impacts were mapped once vs. every time they were observed.

YCC Crews also took photos of behaviors or impacts that they found interesting or thought deserved extra documentation. Once a week, the GPS units used to map the waypoints were downloaded. The waypoints were emailed to Oregon State University. After data entry was completed for the behavior/impact codes data sheets, the codes were assigned to the waypoints and analyzed in GIS. A simple point density analysis was completed in GIS to show where the majority of the waypoints were located at each focal attraction site. Then maps of individual codes were created to show where specific behaviors or resource impacts are occurring at each focal attraction site.

Results

The results in this report are summarized by focal attraction site. Unless otherwise noted, all data collection methods described above occurred at all focal attraction sites. For a full breakdown and the data collection effort at each focal attraction site by the YCC Crews, please see the "Data Summary from Summer 2017 Data Collection Effort" document delivered to YELL as part of this project on February 1st, 2018 (D'Antonio, 2018). An overview of the YCC Crews 2017 data collection effort is provided in Table 1. Due to the limited number of days that sampling occurred at each focal attraction site in this study, the sample size (N) of the data collection is often shown with the results tables.

While the results are discussed by focal attraction site, Table 2 summarizes the overall GPS-based tracking effort from this study for all focal attraction sites. The GPS-based tracking portion of the study is the only monitoring protocol that required voluntary participation by visitors to be including in the study. Overall, the YCC Crews had a high response rate for the GPS-based tracking portion of the study; between 83% and 93%. Group sizes in this study ranged from 3.2 visitors per group at Fairy Falls to 4.2 visitors per group at Artist Point.

Table 1: Overall data collection effort by YCC Crew during the summer of 2017.

Focal Attraction Site	# Periods of Data Collection	Data Collection Effort (hh:mm)*	Hours of Automatic Counter Data Collected (hh:mm)*	Hours of Counter Calibration Data Collected (hh:mm)	# GPS Tracks Collected^
Artist Point	5	13:35	14:03	5:30	71
Fairy Falls	5	16:06	15:54	4:30	84
Midway Geyser Basin	10	37:00	41:58	10:30	157
Norris Geyser Basin	10	30:22	30:22	14:15	211
Old Faithful	10	29:14	28:33	11:30	108

*Occasionally the start and/or end times of data collection or counter installation/uninstallation were not recorded. Therefore, the estimated hours of data collection effort are conservative.

^Number of GPS tracks reported is total collected prior to data cleaning but does not include GPS tracks lost during Week 1 data download.

Table 2: Summary of GPS-based tracking data collection effort and response rate.

Focal Attraction Site	Number of Acceptances*	Number of Rejections	Response Rate	Group Size Average	Group Size ±Standard Deviation
Artist Point	78	16	83%	4.2	5.0
Fairy Falls	84	6	93%	3.2	1.8
Midway Geyser Basin	187	28	87%	3.3	1.8
Norris Geyser Basin	244	25	91%	3.8	3.5
Old Faithful	126	9	93%	3.6	2.5

*Number of acceptances does not equal the number of GPS tracks analyzed in this study since some tracks were lost during data downloading and data clean-up. Refer to Table 1 for GPS track numbers. Number of acceptances is only used to calculate response rate.

Artist Point

Visitor Use Estimation

See Appendix E for full summary tables of parking lot counts. Appendix F contains graphs of average, hourly vehicle counts for each focal attraction site parking lot by date. Hourly counts at the Artist Point parking lot indicate that the parking lot begins to fill at 10:00am and stays full with, on average, 100 to 120 vehicles in the parking lot (Figure 1.1). The parking lot, which has designated spots for 109 vehicles (Otak, 2017), appears to remain close to full (with an overall average of 100 vehicles) through the end of the YCC Crews data collection period which ended each day between 3:00pm (15:00) and 4:00pm (16:00). Interestingly, at the start of the YCC Crews days – at 9:00am – there are already 80 vehicles in the Artist Point parking lot on average.

In addition to counting the total number of vehicles, the YCC Crews would record the type of vehicles found in the parking lots at each hourly count as well as the number of people waiting in line for the restrooms (if there was a line). Tables 1.1 and 1.2 summarize two variables (tour bus numbers and restroom line counts) that were of interest to managers at YELL. At Artist Point, the number of average tour buses ranges from 4 to 6 buses per day with most of these being counted early or later in the day by the YCC crews. Overall, restroom line counts average 12 people in line with the busiest time for restroom lines being midday (between 11:00am and 12:00pm).

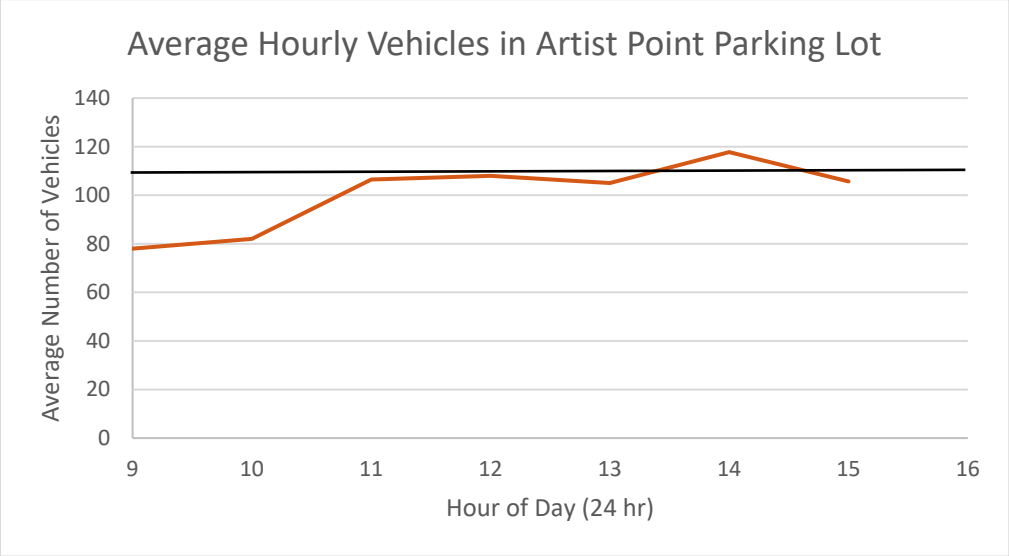

Figure 1.1: Average number of vehicles counted in the Artist Point parking lot per hour. Very few undesignated parking or roadside vehicles were counted, so these values are not shown on the graph. Black line on graph represents the 109 designated parking spots that are at Artist Point (parking spot number pulled from Otak, 2017).

Table 1.1: Average number of tour buses and restroom line counts summarized by sampling day. These counts were taken at the same time as the parking lot counts. SD = standard deviation.

	Tour Bus Counts		Restroom Line Counts	
Date	**Average**	**(±SD)**	**Average**	**(±SD)**
6/21/2017	4	2	14	4
6/23/2017	6	3	11	4
6/29/2017	2	2	12	8
7/3/2017	6	2	14	2
7/19/2017	2	2	11	5
Overall	**4**	**2**	**12**	**1**

Table 1.2: Average number of tour buses and restroom line counts summarized by time of day. These counts were taken at the same time as the parking lot counts. SD = standard deviation.

	Tour Bus Counts		Restroom Line Counts	
Time	**Average**	**(±SD)**	**Average**	**(±SD)**
9:00	4	2	12	4
10:00	5	4	6	3
11:00	0	0	16	11
12:00	0	N/A	20	N/A
13:00	2	2	10	1
14:00	4	1	13	3
15:00	5	3	10	2
16:00	N/A	N/A	N/A	N/A
Overall	**3**	**2**	**12**	**5**

An automatic trail counter was installed at the trailhead at Artist Point near the parking area (Figure 2) while YCC Crews collected data at the focal attraction site. The counter data indicates that, on average across the sampling period, there are approximately 200 to 500 visits (or individual counter hits) at the trailhead per hour (Table 1.3). Counter calibrations, manual counts of visitors that occur in 15-minute increments, show that an average of 300 visitors can pass through the trailhead area in this short period of time (Table 1.4); likely indicating an underestimate of visitor counts by the automatic trail counter at this location. Based on the counter calibrations, an equal number of visitors enter and exit the Artist Point trailhead (approx. 150 visitors on average in each direction in a 15-min increment). Temporally, visitor use at Artist Point seems to increase until 10:00am and remain relatively steady through the afternoon, beginning to drop off around 3:00pm (15:00) (Figure 1.2).

Table 1.3: Average total number of visits per hour counted via an automatic trail counter at the Artist Point trailhead. SD = standard deviation; N = sample size.

Time	Average*	±SD	N
9:00	461	274	3
10:00	522	98	3
11:00	206	265	4
12:00	387	540^	2
13:00	308	347	4
14:00	494	307	5
15:00	338	375	3
16:00	314	N/A	1

*Excludes 0 values deemed as erroneous.

^Consistent counter failure occurred at Noon each day resulting in a large SD here.

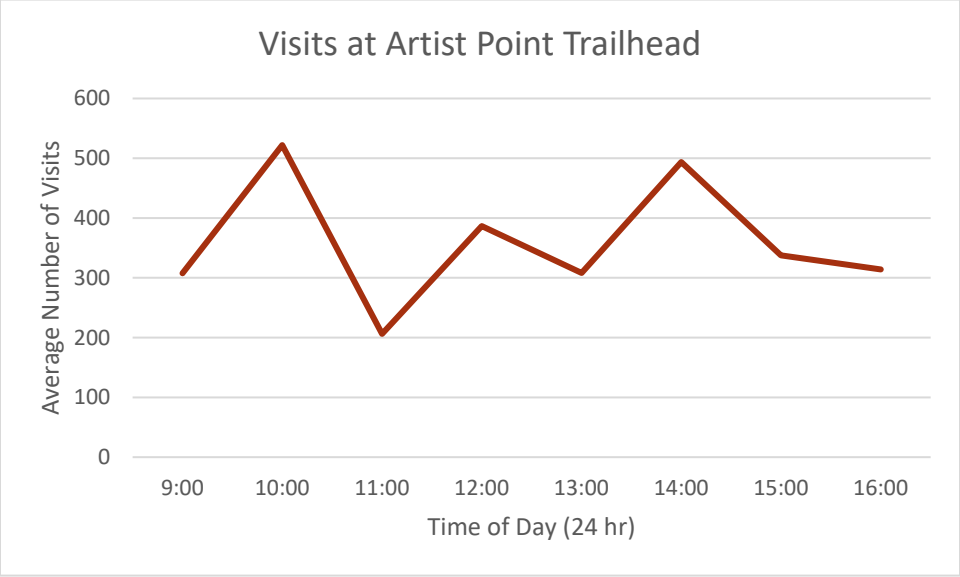

Figure 1.2: Average number of total visits (i.e. counts) per hour as estimated by the automatic trail counter.

Table 1.4: Summary of trail counter calibration counts and observations of tour groups at Artist Point trail counter location. SD = standard deviation; N = sample size.

Average in 15-minute Increments (N = 22)								Tour Groups	
Total				Entering Trail System		Exiting Trail System		N = 7	
Average	±SD	Min	Max	Average	±SD	Average	±SD	Average	±SD
306	105	140	500	155	52	154	67	41	11

Visitor Use/Capacity Measures

On average, YCC Crews encounter 127 visitors while hiking the 0.2 mile loop at Artist Point (see Figure 2 for map of trail section). Encounters range from 36 (recorded on 6/29/2017 at 10:30am) to 313 (recorded 6/29/2017 at 1:20pm/13:20) visitors per loop of the 0.2 mile trail (Table 1.5). PAOT counts showed high variability across time and dates of data collection (Table 1.6 and Figure 1.3 – 1.4) for both PAOT locations at Artist Point (Figure 2). On average, the PAOT at the bench overlook location is 23 visitors with a slightly higher PAOT at the Lower Falls overlook of 28 visitors on average (Table 1.6). Figure 1.3 shows that maximum PAOT counts at the bench overlook ranges between 45 and approximately 50 visitors with low values of approximately 5 visitors. At the Lower Falls overlook area, PAOT counts range from approximately 55 visitors to lows of approximately 5 visitors (Figure 1.4). Overall, encounters and PAOT showed a large amount of variability at Artist Point – indicating a dynamic system in terms of visitor use and flow.

Table 1.5: Summary of trail encounters (number of visitors passed) for the entire 0.2 mile loop at Artist Point. SD = standard deviation; N = number of counts that equaled the entire trail length.

Date	Average	±SD	Min	Max	N
6/21/2017	187	29	160	218	3
6/23/2017	129	49	57	209	8
6/29/2017	114	73	36	313	15
Overall:	**127**	**66**	**36**	**313**	**26**

Table 1.6: People At One Time (PAOT) summary for PAOT locations (see Figure 2) at Artist Point. SD = standard deviation; N = sample size.

	Rock Bench			Falls Overlook		
Date	**Average**	**±SD**	**N**	**Average**	**±SD**	**N**
6/21/2017	30	8	10	N/A	N/A	N/A
6/23/2017	31	10	6	39	12	6
6/29/2017	15	13	14	24	13	14
Overall	**23**	**13**	**30**	**28**	**14**	**20**

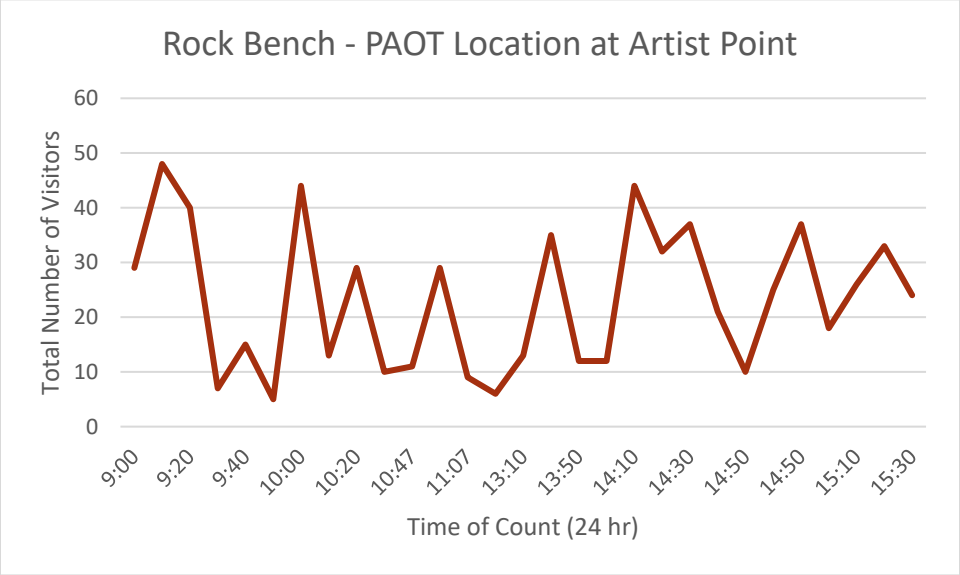

Figure 1.3: All individual PAOT counts organized by time at the Rock Bench location at Artist Point.

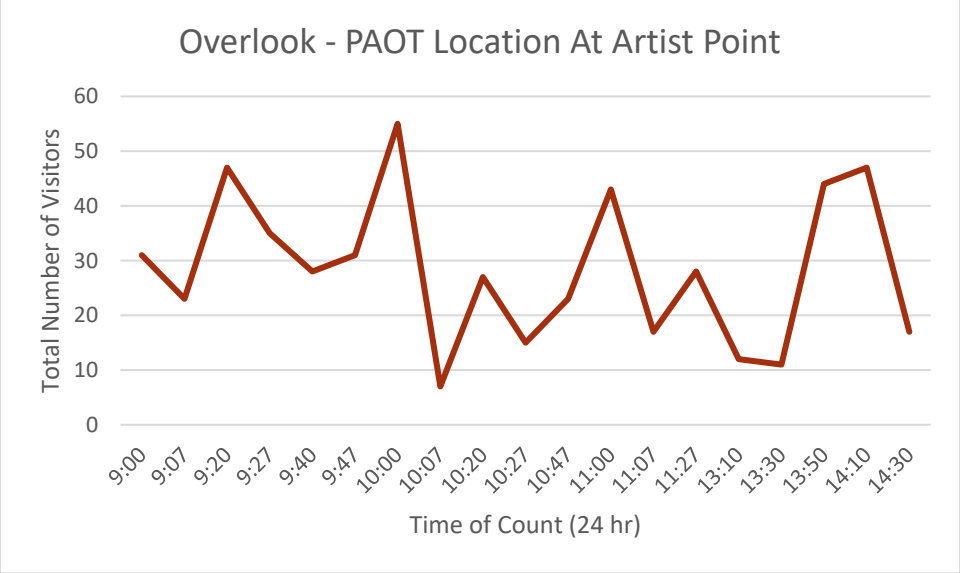

Figure 1.4: All individual PAOT counts organized by time at the Overlook location at Artist Point.

Visitor Spatial Behavior

GPS-based tracking data (Figure 1.5a) at Artist Point indicates that most visitors stay relatively close to the parking lot and trailhead area (Figure 1.5b). Very few GPS tracked visitors travel beyond the short, loop trail that takes visitors to the Lower Falls viewing areas. However, some visitors do hike to Ribbon Lake and complete loops along the South Rim trail. Table 1.7 shows that, on average, visitors spend 45 minutes at the Artist Point focal attraction site with a standard deviation of almost 1 hour. The maximum amount of time a visitor spent in the area was 4 hours.

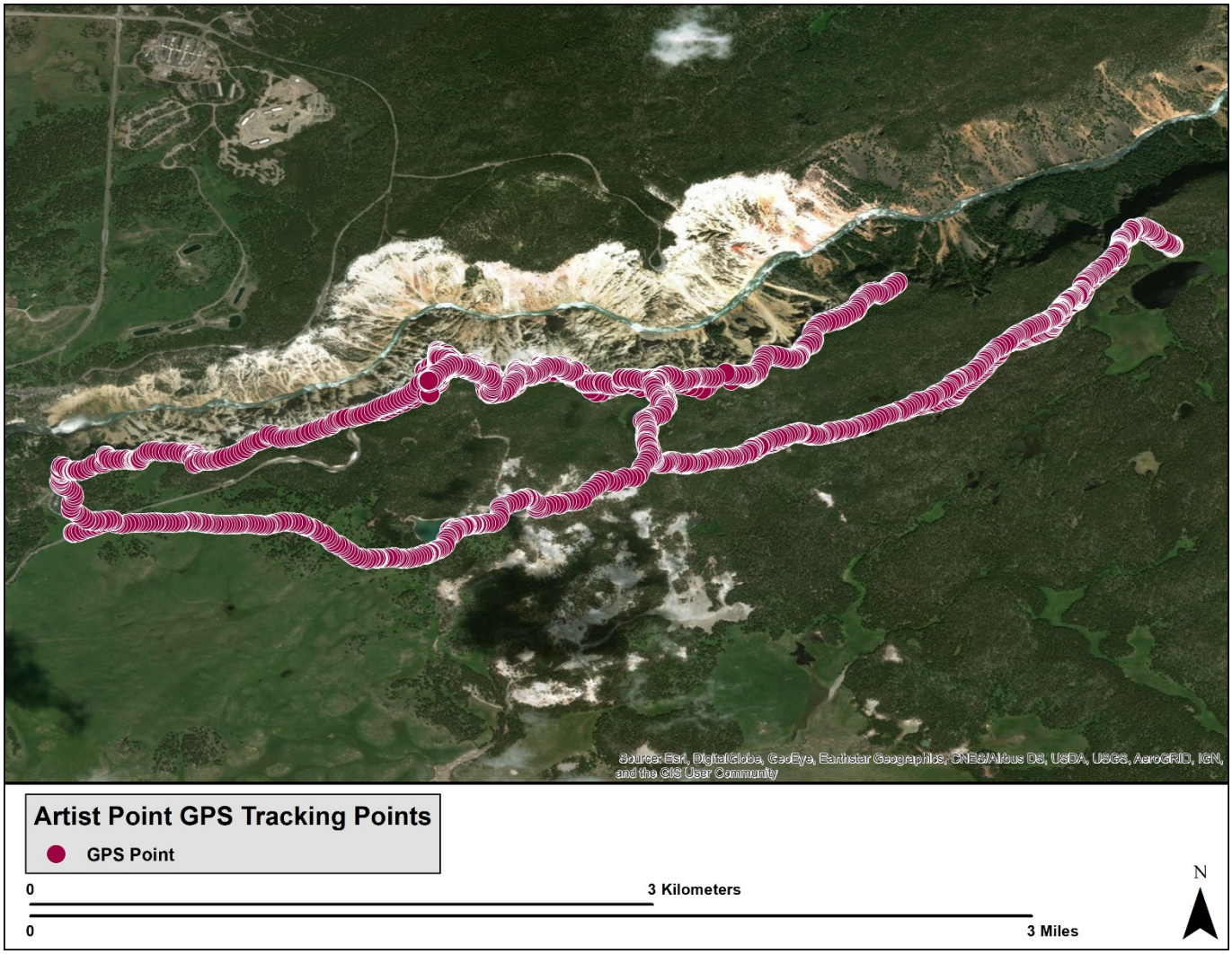

Figure 1.5a: Raw, cleaned GPS-based tracking point data collected from visitors at Artist Point. GPS units were handed out at the trailhead.

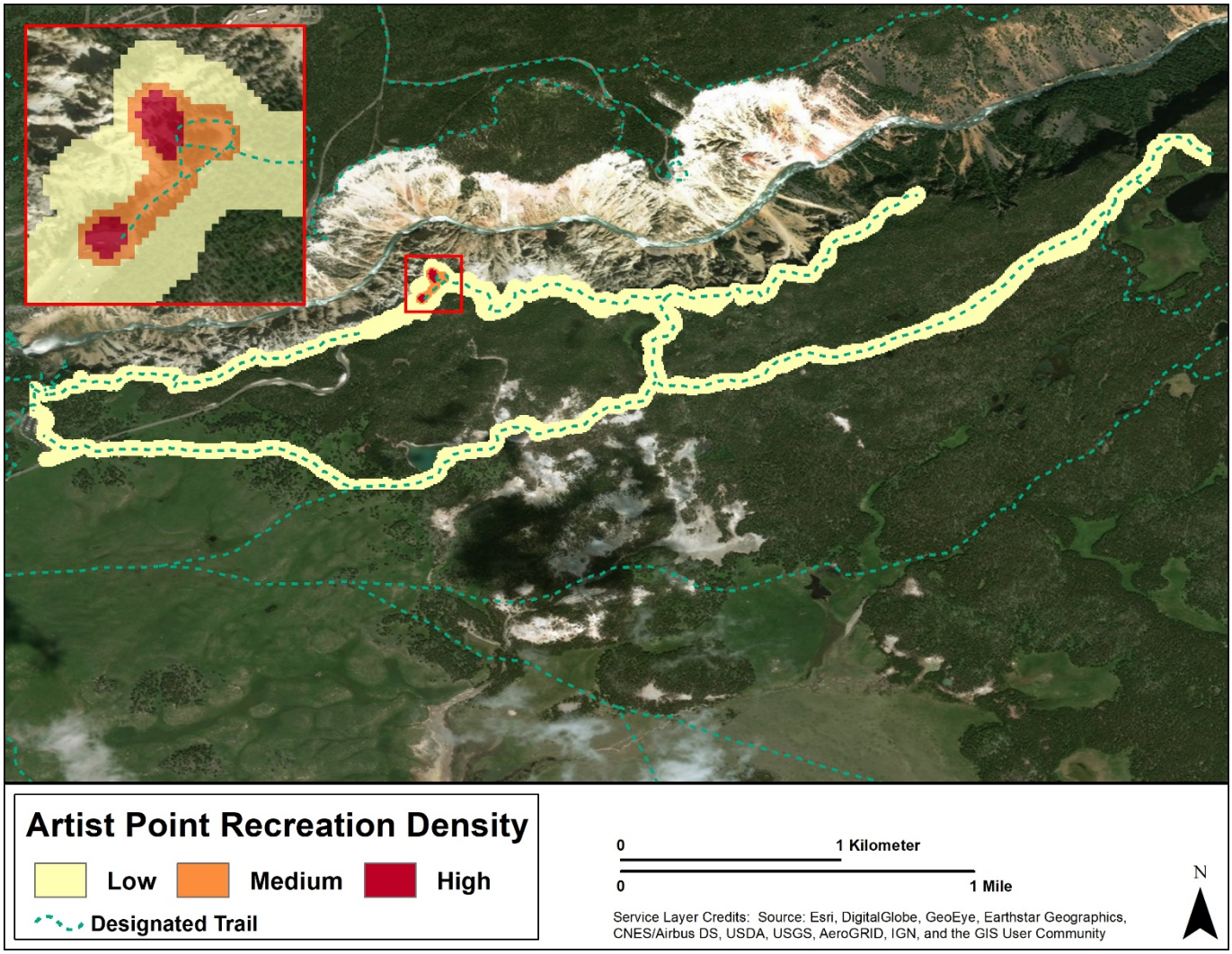

Figure 1.5b: Density of GPS-based tracking points collected from visitors at Artist Point. GPS units were handed out at the trailhead. Low densities = an estimated count of 1 - 13 visitor points per 1 m^2; medium = 14 - 45 points per 1 m^2; high = 46 – 96 points per 1 m^2.

Table 1.7: Descriptive information extracted from the GPS-based tracking data on the amount of time visitors spent at the Artist Point focal attraction site location. Note: times less than 1 minute were removed from the analysis. SD = standard deviation.

	Time (h:mm:ss)
Average	0:43:24
±SD	0:55:41
Minimum	0:01:00
Maximum	4:01:04

Appendix G shows the density of waypoints; highlighting where the majority of waypoints were mapped along the trail. See Appendix H for summary of all waypoints collected at each focal attraction site. Appendix I contains maps of locations of individual visitor behaviors and resource impact waypoints. Figure 1.6 shows that the majority (77%) of behaviors of interest or resource impacts observed at Artist Point are related to the YCC Crews finding litter along the trail (Figure 1.7). Most of these waypoints were mapped near the trailhead location or near the overlook locations where the PAOT counts were recorded (Appendix G).

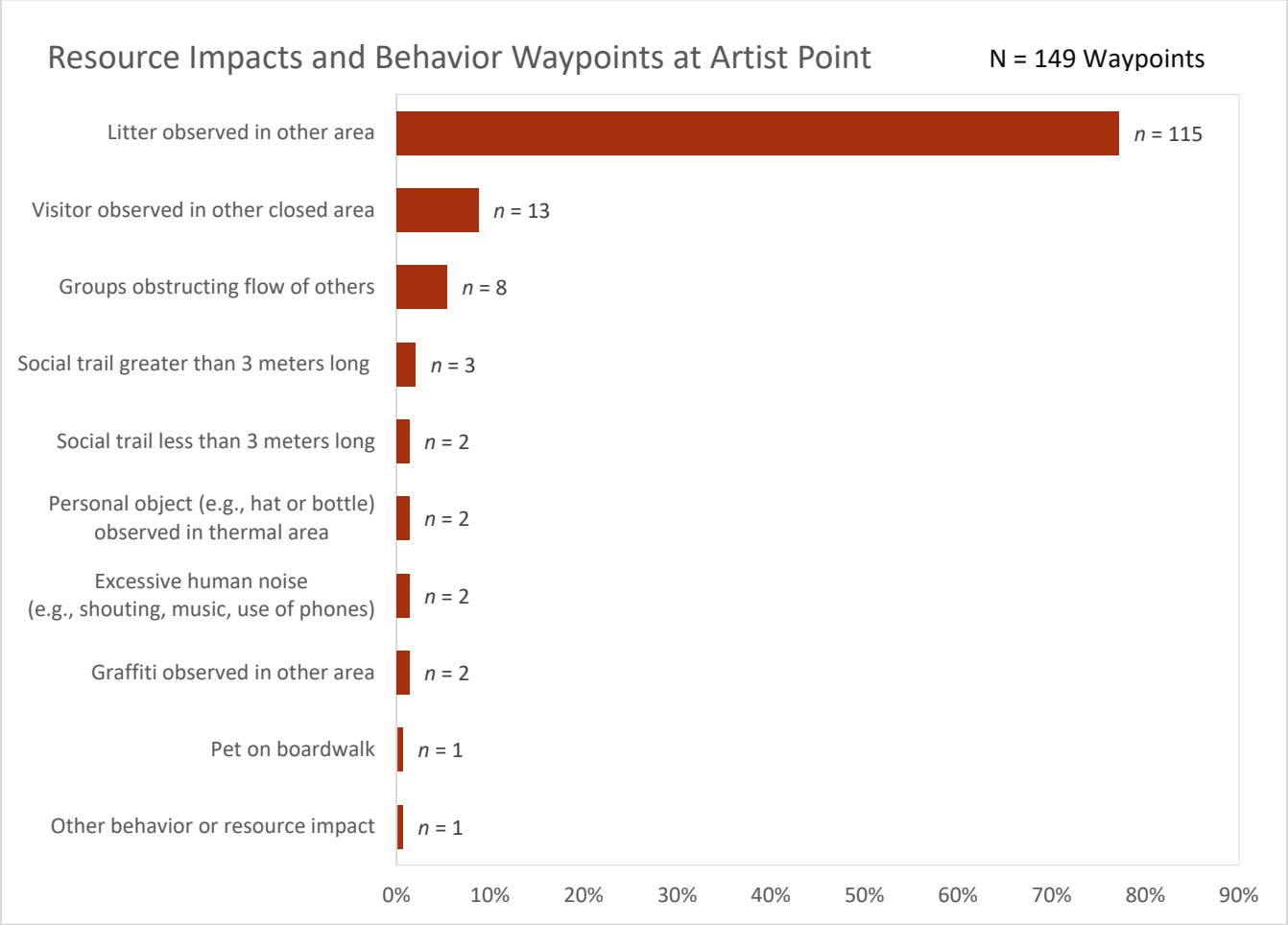

Figure 1.6: Frequency and counts of codes for the visitor behavior and resource impacts marked by waypoints along the Artist Point trail.

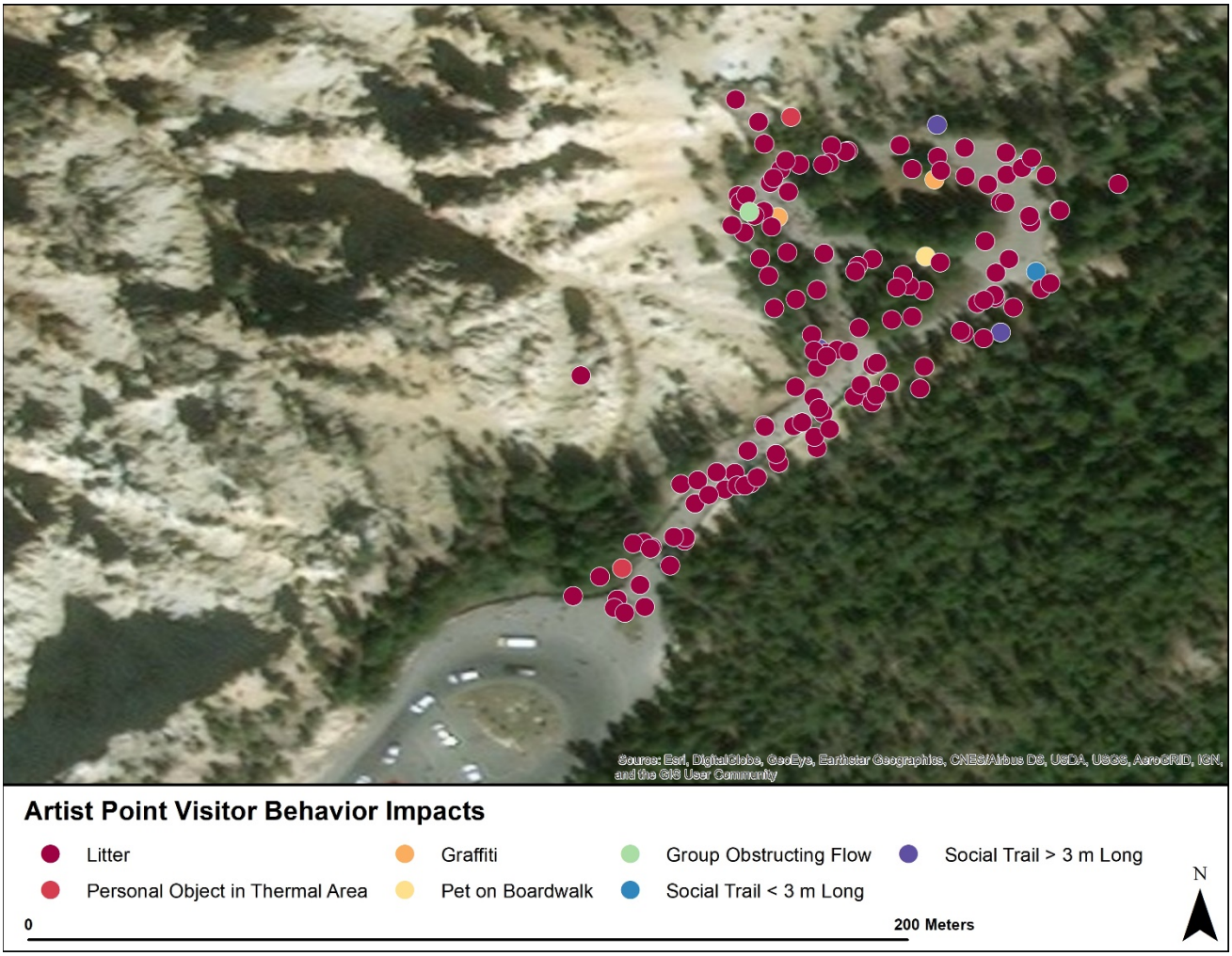

Figure 1.6: Location of specific visitor behavior and resource impacts waypoints along the Artist Point trail.

Fairy Falls

Visitor Use Estimation

See Appendix E for full summary tables of parking lot counts. Appendix F contains graphs of average, hourly vehicle counts for each focal attraction site parking lot by date. Hourly parking lot counts at the Fairy Falls trailhead, which has 74 designated parking spots, shows a steady increase in average vehicle numbers from 40 at 9:00am to a peak of approximately 120 vehicles by 1:00pm (13:00). The overall average for vehicles in the Fairy Falls parking lot is 78 vehicles (Appendix E). Undesignated and roadside parking a Fairy Falls begins to increase across the day as the parking lot begins to fill (Figure 2.1). Undesignated parking at Fairy Falls ranges from an average of 0 to 23 vehicles with roadside parking ranging, on average, from 0 to 12 vehicles (Figure 2.1 and Appendix E). Interestingly, Appendix F shows that average vehicle use at Fairy Falls increased rapidly from the Grand Prismatic Spring Overlook trail opening in July to early August.

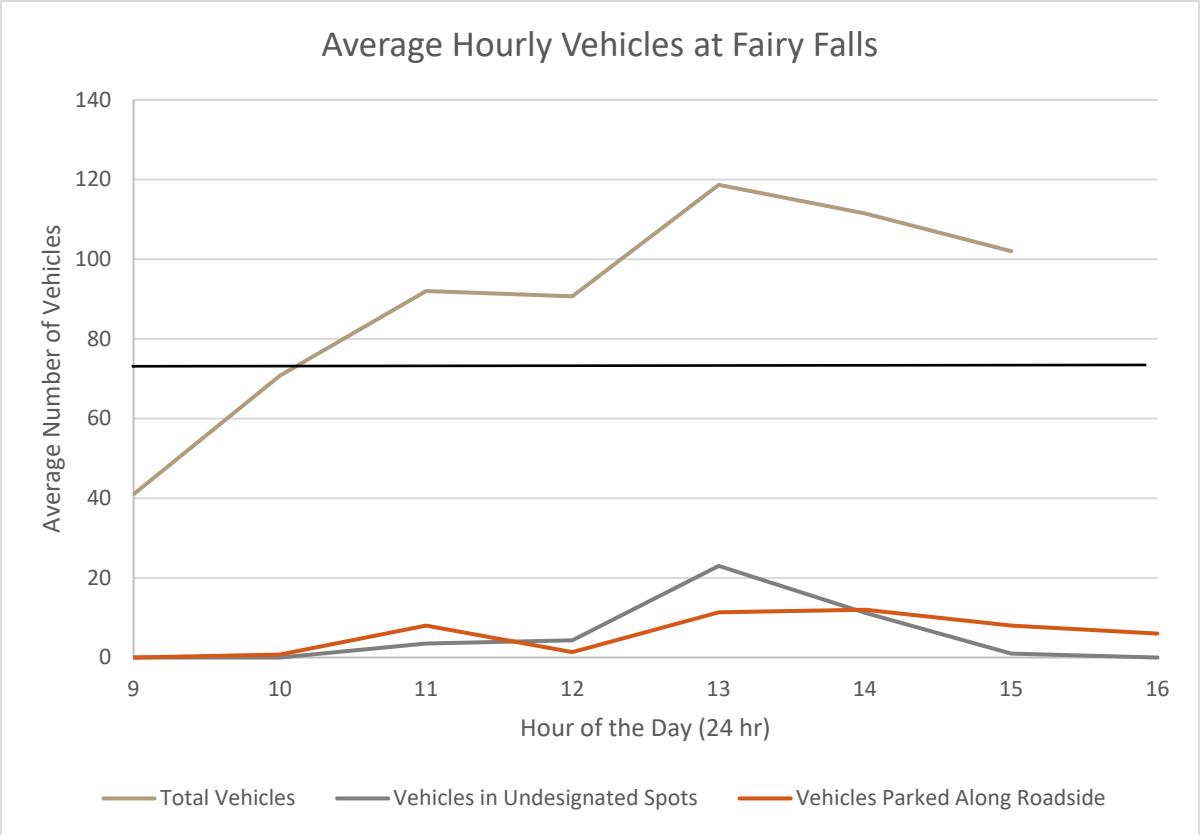

Figure 2.1: Average number of vehicles counted in the Fairy Falls parking lot. Graph also shows undesignated parking and roadside parking across the day. Black line on graph represents the 74 designated parking spots that are at Fairy Falls trailhead parking spot.

Tables 2.1 and 2.2 summarize the number of tour buses that were observed at the Fairy Falls parking lot during the sampling period. There was no restroom at Fairy Falls during the time the YCC Crews were collecting data, so there are no restroom line counts for Fairy Falls from 2017. No tour buses were observed at Fairy Falls until August, at which point only a single, occasional tour bus was observed, usually between 10:00am and 2:00pm (14:00).

Table 2.1: Average number of tour buses and restroom line counts summarized by sampling day. These counts were taken at the same time as the parking lot counts. SD = standard deviation.

	Tour Bus Counts		Restroom Line Counts	
Date	**Average**	**(±SD)**	**Average**	**(±SD)**
7/20/2017	0	0	N/A	N/A
7/24/2017	0	0	N/A	N/A
7/28/2017	0	0	N/A	N/A
8/1/2017	1	1	N/A	N/A
8/9/2017	1	1	N/A	N/A
Overall	**0**	**0**	**N/A**	**N/A**

Table 2.2: Average number of tour buses and restroom line counts summarized by time of day. These counts were taken at the same time as the parking lot counts. SD = standard deviation.

	Tour Bus Counts		Restroom Line Counts	
Time	**Mean**	**(±SD)**	**Mean**	**(±SD)**
9:00	0	N/A	N/A	N/A
10:00	1	1	N/A	N/A
11:00	0	1	N/A	N/A
12:00	0	N/A	N/A	N/A
13:00	0	1	N/A	N/A
14:00	0	1	N/A	N/A
15:00	0	N/A	N/A	N/A
16:00	0	N/A	N/A	N/A
Overall	**0**	**0**	**0**	**0**

Based on visitor use estimates from the automatic trail counter placed at the Fairy Falls trailhead (see Figure 3) during YCC Crew data collection, there are between 6 and 360 visits (or counter hits) at the trailhead per hour (Table 2.3). Counter calibrations indicate these estimates are fairly accurate with approximately 146 visitors, on average, counted at this trailhead every 15 minutes. Use is relatively even in both directions (Table 2.4). Unlike Artist Point, a clearer use trend can be observed over time at Fairy Falls (Figure 2.2). Visitor use at Fairy Falls increases rapidly in the morning hours, levels off at approximately 240 and 360 visits per hour during midday, and then begins to drop off at 2:00pm (14:00).

Table 2.3: Average total number of visits per hour counted via automatic trail counter located at Fairy Falls trailhead. SD = standard deviation; N = sample size.

Time	Average*	±SD	N
9:00	121	63	3
10:00	266	184	4
11:00	360	163	4
12:00	239	256	5
13:00	300	116	4
14:00	174	124	4
15:00	97	167	3
16:00	50	N/A	1

*Excludes 0 values deemed as erroneous.

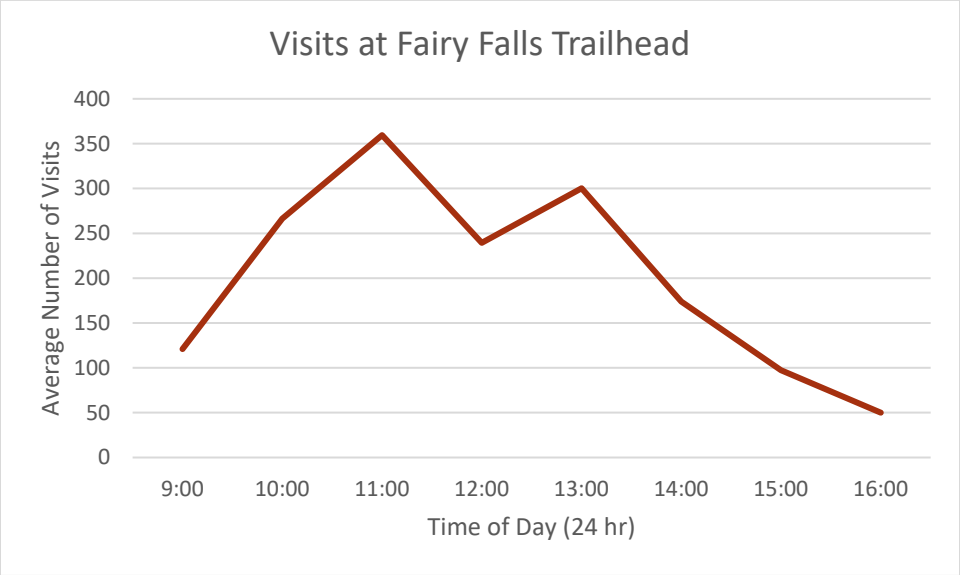

Figure 2.2: Average number of total visits (i.e. counts) per hour as estimated by the automatic trail counter.

Table 2.4: Summary of trail counter calibration counts and observations of tour groups at Fairy Falls trail counter location. SD = standard deviation.

Average in 15-minute Increments (N = 13)								Tour Groups
Total				Entering Trail System		Exiting Trail System		N = N/A
Average	±SD	Min	Max	Average	±SD	Average	±SD	
146	43	61	203	81	20	65	65	

Visitor Use/Capacity Measures

While hiking the new Grand Prismatic Spring Overlook trail, an approximately 0.4 mile trail which just opened July 2017, YCC Crews encountered approximately 300 other visitors on average (Table 2.5). The number of encounters observed by the YCC Crews on this trail ranges from 98 (recorded on 8/9/2017) to almost 400 visitors (recorded on 8/1/2017) (Table 2.6). Fewer visitors are observed at the PAOT location for Fairy Falls (see Figure 3): the Grand Prismatic Spring overlook viewing platform (Table 2.6 and Figure 2.3). On average, 36 visitors are observed on that platform at one time with a maximum observation of 54 visitors. Temporally, visitor use on the platform remains relatively stable across the day (Figure 2.3).

Table 2.5: Summary of trail encounters (number of visitors passed) for the new approximately 0.4 mile Grand Prismatic Spring Overlook trail at Fairy Falls. SD = standard deviation; N = number of counts that equaled the entire trail length.

Date	Average	±SD	Min	Max	N
7/24/2017	324	53	271	377	3
7/28/2017	253	106	142	354	3
8/1/2017	365	34	299	394	6
8/9/2017	212	95	98	328	4
Overall:	**298**	**91**	**98**	**394**	**16**

Table 2.6: People At One Time (PAOT) summary for PAOT location at Fairy Falls. SD = standard deviation; N = sample size.

	Grand Prismatic Overlook		
Date	**Average**	**±SD**	**N**
7/20/2017	54	N/A	1
7/24/2017	45	4	3
8/1/2017	34	10	6
Overall	**36**	**11**	**10**

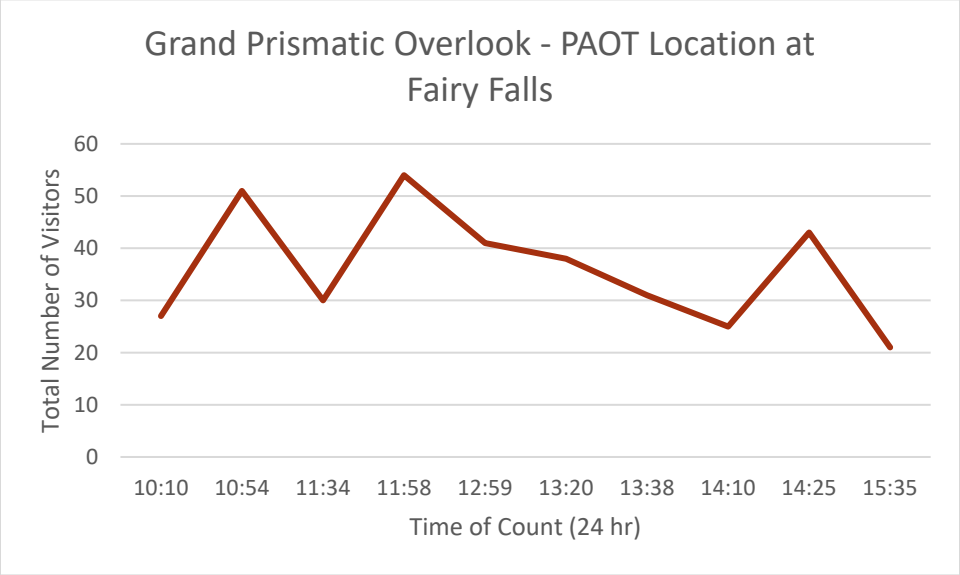

Figure 2.3: All individual PAOT counts organized by time at the Grand Prismatic Overlook platform at Fairy Falls.

Visitor Spatial Behavior

Figures 2.4a and 2.4b show that majority of visitors who start their visit at the Fairy Falls trailhead are hiking to the Grand Prismatic Spring Overlook. However, some visitors do venture further into the trail system with another popular stopping location being Fairy Falls proper. Table 2.7 shows that, on average, visitors to the Fairy Falls trail spend just over 1 hour recreating at the focal attraction site. The maximum recorded visit lasted approximately 4 hours.

Appendix G shows the density of waypoints; highlighting where the majority of waypoints were mapped along the trail. At Fairy Falls, mapped waypoints were spread relatively evenly across the trail from the trailhead to the Grand Prismatic Spring overlook. See Appendix H for summary of all waypoints collected at each focal attraction site. Appendix I contains maps of locations of individual visitor behaviors and resource impact waypoints. Most of the waypoints of visitor behaviors and resource impacts mapped at Fairy Falls were for litter that was observed and found on or along the trail (79%) (Figures 2.5 and 2.6). Visitors were observed littering at 6% of the waypoints.

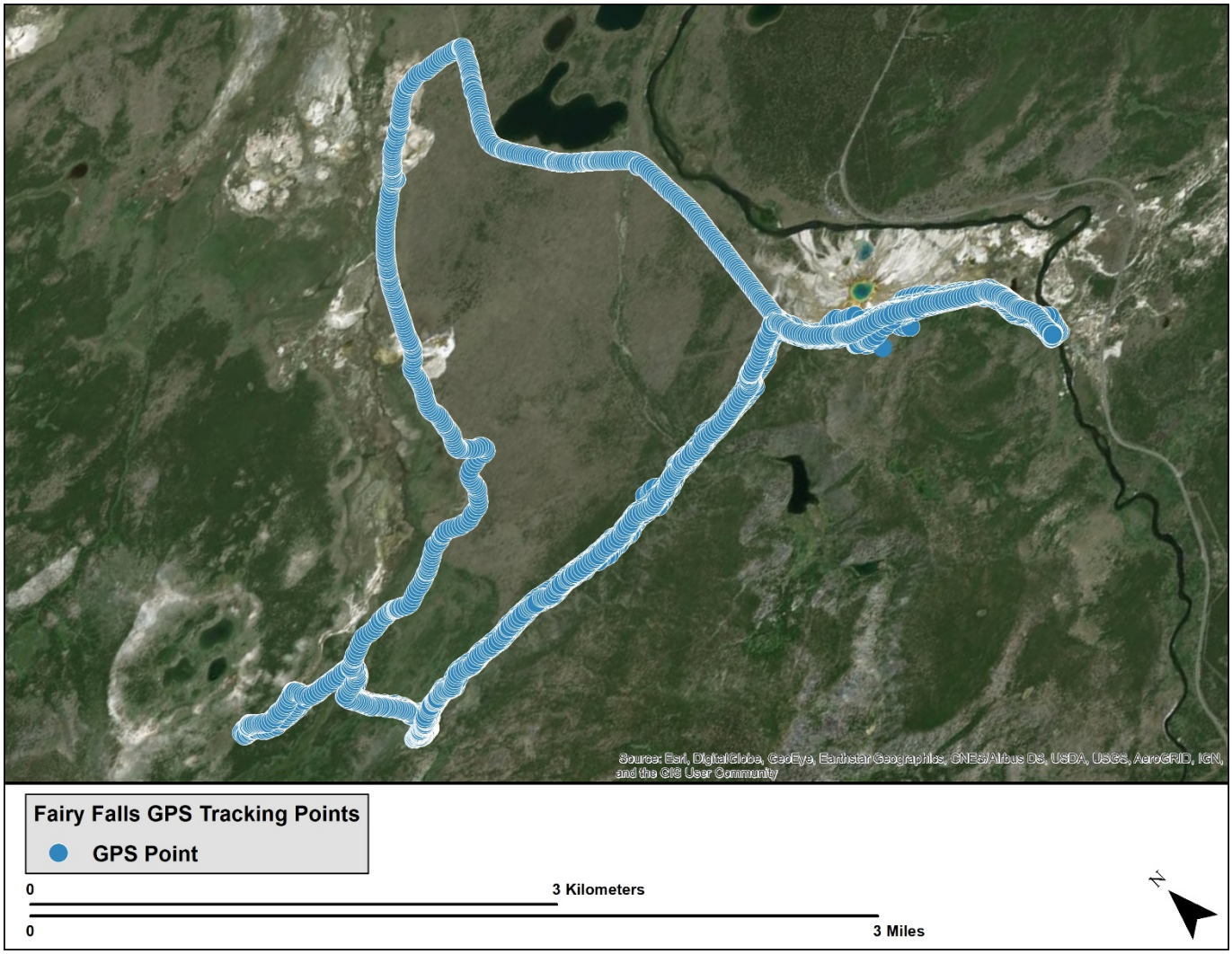

Figure 2.4a: Raw, cleaned GPS-based tracking point data collected from visitors at Fairy Falls. GPS units were handed out at the trailhead.

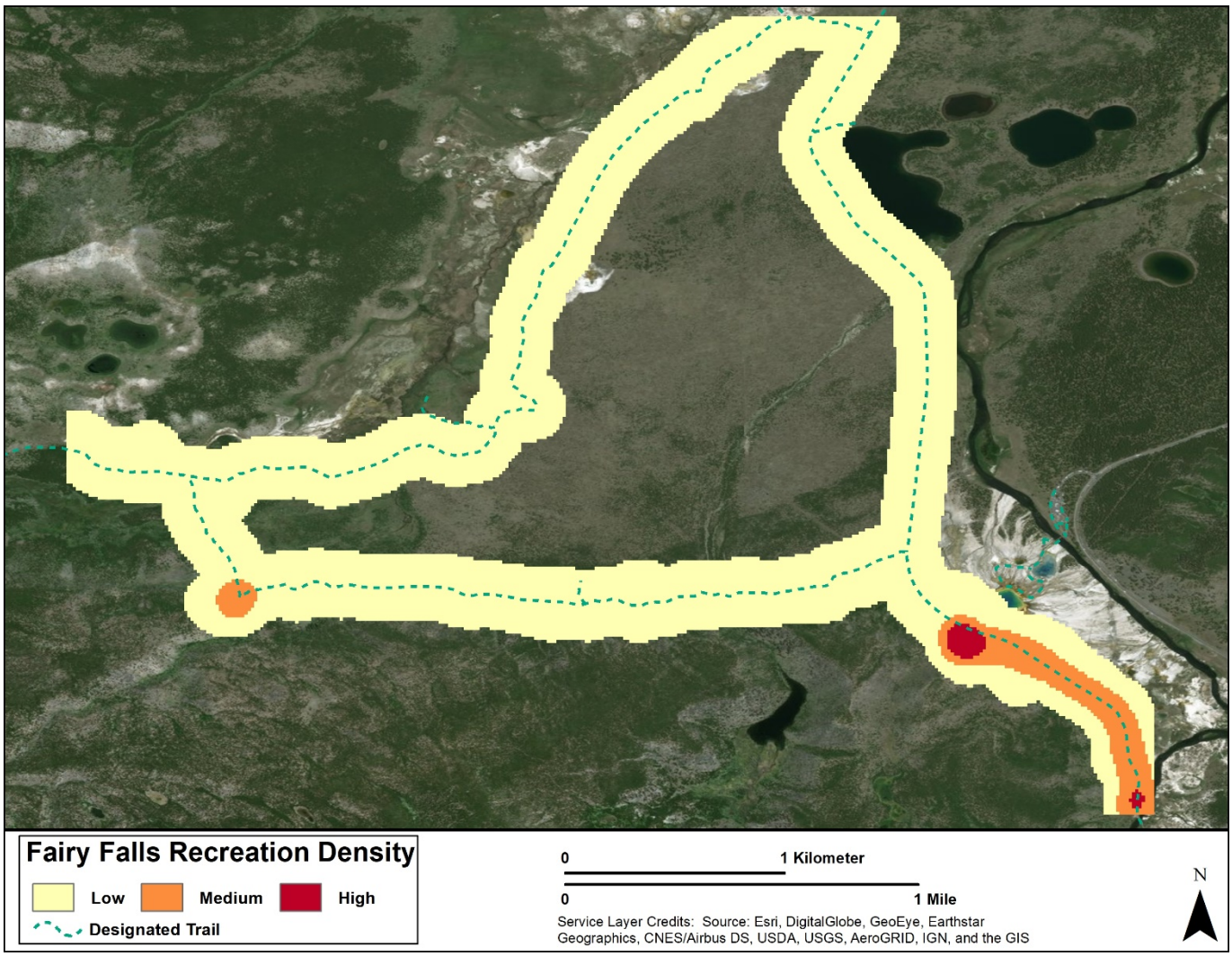

Figure 2.4b: Density of GPS-based tracking points collected from visitors at Fairy Falls. GPS units were handed out at the trailhead. When making comparisons with Figure 2.4a, please note that this figure is at a slightly different orientation. Low densities = an estimated count of 1 – 8 visitor points per 1 m^2; medium = 9 - 25 points per 1 m^2; high = 25 – 50 points per 1 m^2.

Table 2.7: Descriptive information extracted from the GPS-based tracking data on the amount of time visitors spent at the Fairy Falls focal attraction site location. Note: times less than 1 minute were removed from the analysis. SD = standard deviation.

	Time (h:mm:ss)
Average	1:12:29
±SD	0:54:13
Minimum	0:02:30
Maximum	4:12:50

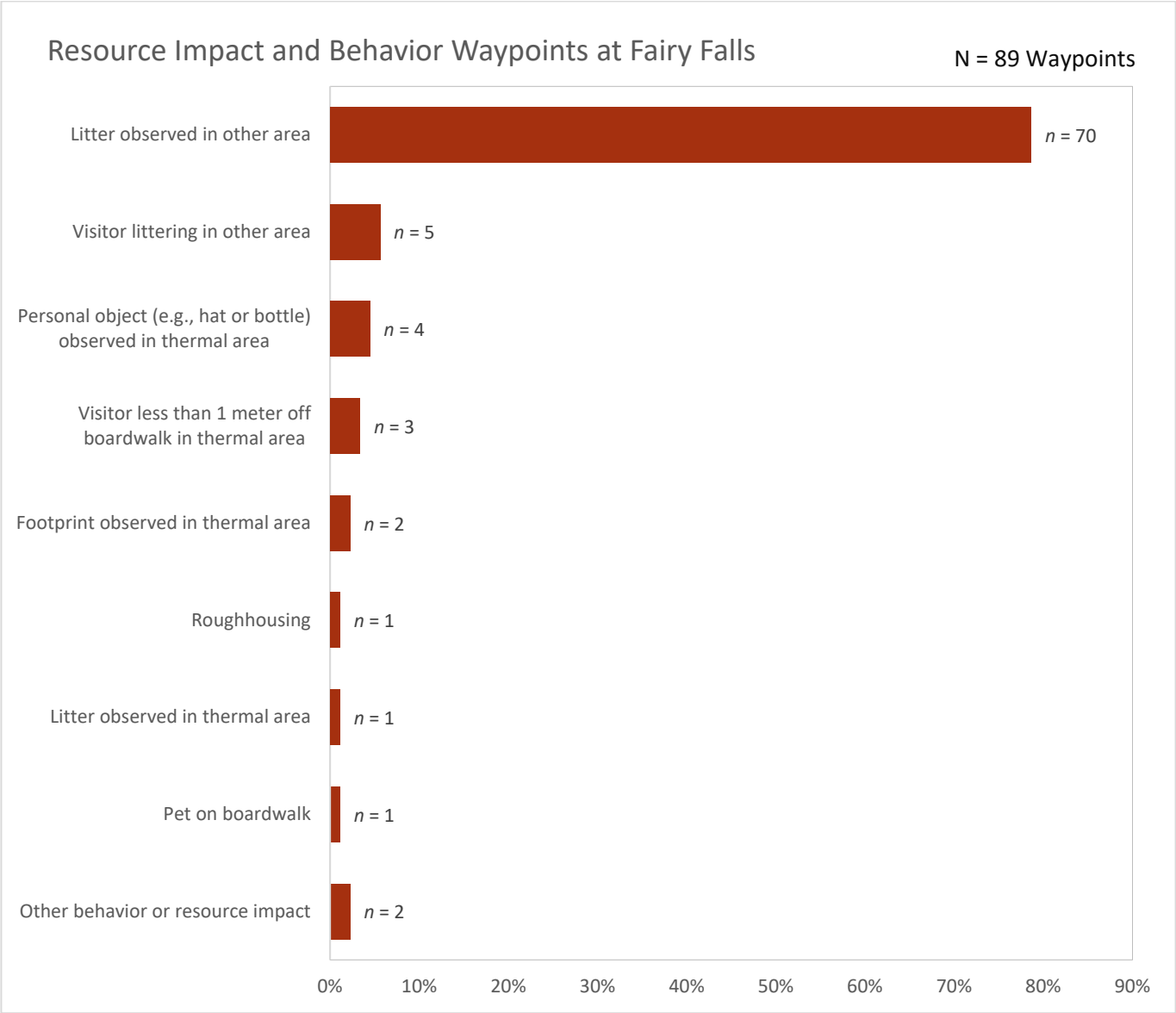

Figure 2.5: Frequency and counts of codes for the visitor behavior and resource impacts marked by waypoints along the Fairy Falls trail.

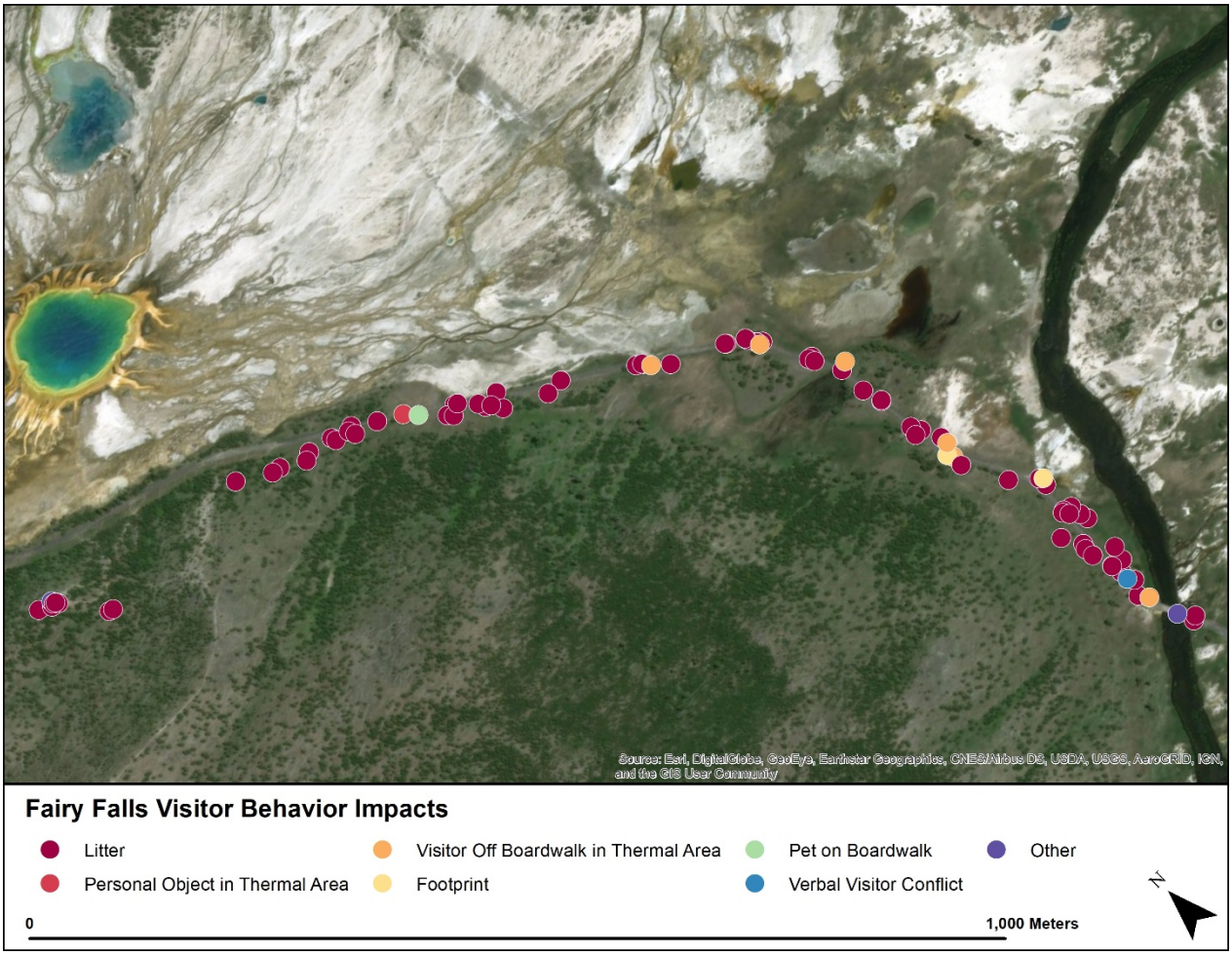

Figure 2.6: Location of specific visitor behavior and resource impacts waypoints along the Fairy Falls trail.

Midway Geyser Basin

Visitor Use Estimation

See Appendix E for full summary tables of parking lot counts. Appendix F contains graphs of average, hourly vehicle counts for each focal attraction site parking lot by date. When YCC Crews arrive at Midway Geyser Basin at 9:00am and began hourly vehicle counts, on average, there are already 60 vehicles in designated parking spot and 16 vehicles in undesignated parking spots (Figure 3.1). Midway Geyser Basin's parking lot has 55 designated parking spaces (Otak, 2017). As designated parking spots fill up at Midway Geyser Basin and peak at 88 vehicles (on average) – roadside parking rapidly increases as well. Roadside parking peaks at 12:00pm and ranges from 1 to 57 vehicles per hour with an average of 29 vehicles parked along the road at Midway Geyser Basin at any given time (Appendix E). There appears to always be some number of vehicles parked outside of designated spots at Midway Geyser Basin with undesignated parking ranging between an average of 11 and 35 vehicles per hour. Appendix E also shows that large queues are common in the Midway Geyser Basin parking lot. Based on the overall averages from parking lot counts at Midway Geyser Basin – the combined designated, undesignated, and roadside parking results in 111 vehicles parked at Midway Geyser Basin (twice the number of designated spots) on average with an average of 25 vehicles in a queue (Appendix E).

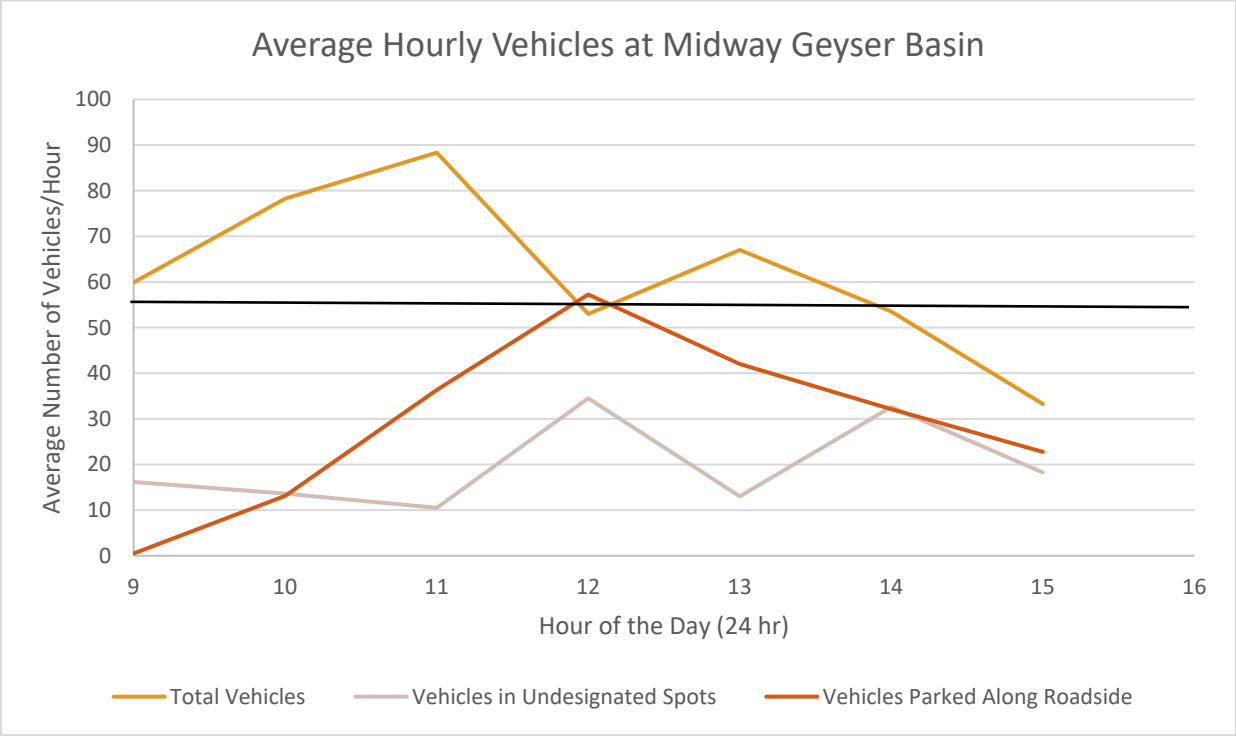

Figure 3.1: Average number of vehicles counted in the Midway Geyser Basin parking lot. Graph also shows undesignated parking and roadside parking across the day. Black line on graph represents the 55 designated parking spots that are at Midway Geyser Basin (parking spot number pulled from Otak, 2017).

Tables 3.1 and 3.2 summarize two variables (tour bus numbers and restroom line counts) that were also recorded by the YCC Crews during the hourly parking lot counts. At Midway Geyser Basin, the overall average number of tour buses observed in the parking lots is 3 per day and 3 per hour. Tour bus numbers appear to be highest in the morning and at midday (12:00pm). Restroom lines at Midway average 17 people per hour with the longest lines, on average, occurring at 11:00am and 12:00pm.

Table 3.1: Average number of tour buses and restroom line counts summarized by sampling day. These counts were taken at the same time as the parking lot counts. SD = standard deviation.

	Tour Bus Counts		Restroom Line Counts	
Date	**Average**	**(±SD)**	**Average**	**(±SD)**
6/20/2017	2	1	9	11
6/22/2017	7	5	15	4
6/26/2017	4	4	4	4
6/27/2017	3	N/A	8	N/A
6/30/2017	2	1	4	6
7/5/2017	6	2	9	10
7/20/2017	3	2	4	4
7/27/2017	3	2	0	0
8/2/2017	2	2	16	5
8/8/2017	3	2	32	10
Overall	**3**	**2**	**10**	**9**

Table 3.2: Average number of tour buses and restroom line counts summarized by time of day. These counts were taken at the same time as the parking lot counts. SD = standard deviation.

	Tour Bus Counts		Restroom Line Counts	
Time	**Average**	**(±SD)**	**Average**	**(±SD)**
9:00	4	3	5	10
10:00	4	2	9	9
11:00	4	1	48	89
12:00	5	3	15	17
13:00	3	3	9	9
14:00	2	1	2	31
15:00	3	2	5	3
16:00	N/A	N/A	N/A	N/A
Overall	**3**	**3**	**17**	**16**

Based on the automated trail counter (see Figure 4), Midway Geyser Basin trailhead receives between 400 and slightly over 800 visits per hour (Table 3.3) averaged across the sampling period. The busiest time at the Midway Geyser Basin trailhead is between 10:00am and 2:00pm (14:00) (Figure 3.2). Manual calibration counts at the trailhead indicate that within a 15-minute increment, on average approximately 360 visitors can pass through the trailhead. Use in either direction at the trailhead is relatively even (Table 3.4). Three tour groups were reliably observed at the Midway Geyser Basin trailhead during the YCC Crews data collection with an average tour group size of 33 visitors (Table 3.4).

Table 3.3: Average total number of visits per hour counted via automatic trail counter located at Midway Geyser Basin trailhead. SD = standard deviation; N = sample size.

Time	Average*	± SD	N
9:00	448	221	7
10:00	505	125	7
11:00	827	181	5
12:00	535	490^	7
13:00	740	320	7
14:00	796	181	6
15:00	409	337	6
16:00	N/A	N/A	N/A

*Excludes 0 values deemed as erroneous.

^Consistent counter failure occurred at Noon each day resulting in a large SD here.

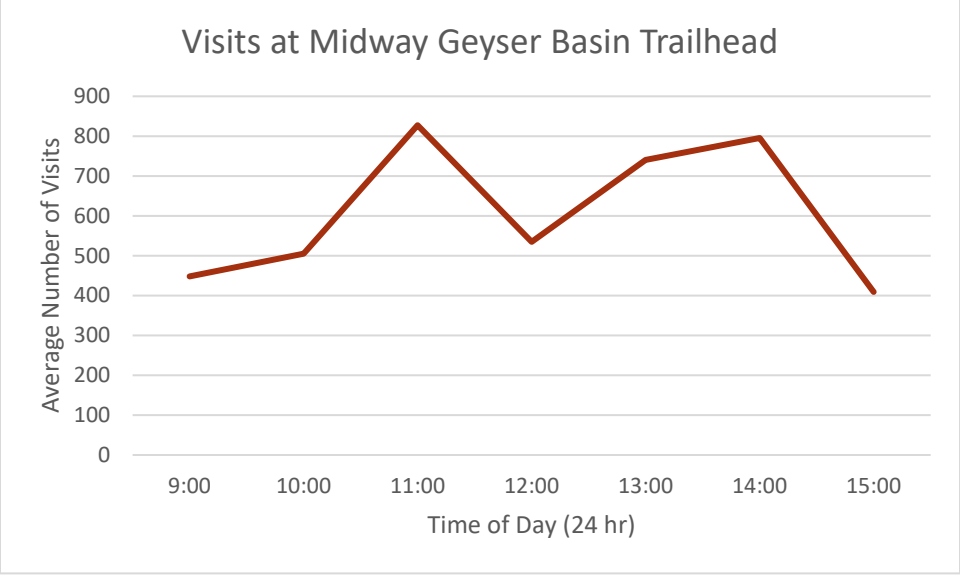

Figure 3.2: Average number of total visits (i.e. counts) per hour as estimated by the automatic trail counter.

Table 3.4: Summary of trail counter calibration counts and observations of tour groups at Midway Geyser Basin at trail counter location. SD = standard deviation; N = sample size.

Average in 15-minute Increments (N = 38)								Tour Groups	
Total				Entering Trail System		Exiting Trail System		N = 3	
Average	±SD	Min	Max	Average	±SD	Average	±SD	Average	±SD
363	77	179	483	178	49	185	56	33	11

Visitor Use/Capacity Measures

When hiking the 1-mile boardwalk loop at Midway Geyser Basin, on average, YCC Crews would encounter between approximately 152 (recorded on 6/26/2017) and 767 (recorded on 7/27/2017) other visitors (Table 3.5). The overall average number of encounter recorded by the YCC Crews was 337 visitors in a loop hike of the Midway Geyser Basin boardwalk trail. At Midway Geyser Basin, PAOT counts occurred at the boardwalk overlooking Grand Prismatic Spring (see Figure 4). On average, 78 visitors at one time were at this location (Table 3.6). PAOT counts ranged on average from 35 to 100 on the boardwalk at Grand Prismatic Spring. PAOT counts showed a wide range of variability across time (Figure 3.3). There is a noticeable increase in total PAOT at the Grand Prismatic Spring overlook boardwalk between 11:00am and 2:00pm (14:00) (Figure 3.3).

Table 3.5: Summary of trail encounters (number of visitors passed) for the entire 1 mile boardwalk loop at Midway Geyser Basin. N = number of counts that equaled the entire trail length.

Date	Average	±SD	Min	Max	N
6/22/2017	285	64	186	345	6
6/26/2017	279	109	152	509	10
6/30/2017	228	46	177	265	3
7/5/2017	402	149	247	668	17
7/27/2017	573	201	295	767	4
8/2/2017	265	74	178	422	9
8/8/2017	322	104	160	441	13
Overall:	**337**	**141**	**152**	**767**	**62**

Table 3.6: People At One Time (PAOT) summary for PAOT location at Midway Geyser Basin. SD = standard deviation; N = sample size.

	Grand Prismatic Spring Boardwalk Overlook		
Date	**Average**	**±SD**	**N**
6/20/2017	100	16	6
6/22/2017	95	18	4
6/26/2017	64	16	10
6/30/2017	52	11	3
7/5/2017	81	28	15
7/27/2017	92	37	17
7/28/2017	35	18	3
8/2/2017	71	21	9
8/8/2017	69	44	11
Overall	**78**	**32**	**78**

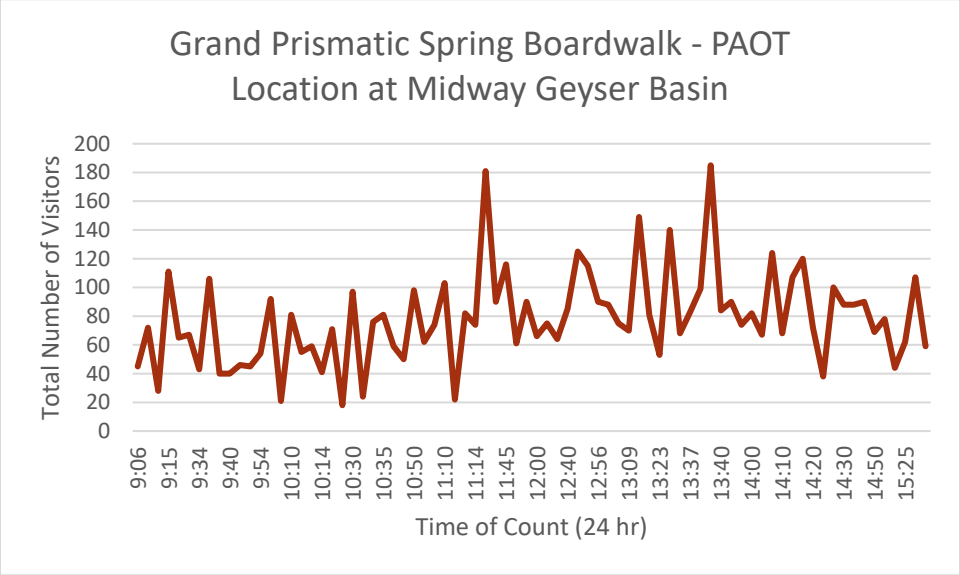

Figure 3.3: All individual PAOT counts organized by time at the Grand Prismatic Spring overlook on the boardwalk at Midway Geyser Basin.

Visitor Spatial Behavior

Figures 3.4a and 3.4b indicates, not surprisingly, that the majority of GPS-tracked visitors at Midway Geyser Basin stop at and/or are drawn to Grand Prismatic Spring and the Excelsior Geyser pool. Due to the loop nature of the hike, there is also higher visitor density located at the "stick" part of the lollipop-shaped boardwalk trail system at Midway Geyser Basin. Table 3.7 summarizes how long GPS-based tracked visitors recreated at the Midway Geyser Basin. Visits average approximately 30 minutes with a standard deviation of 18 minutes. The maximum recorded visit to Midway Geyer Basin was 2 hours and 47 minutes.

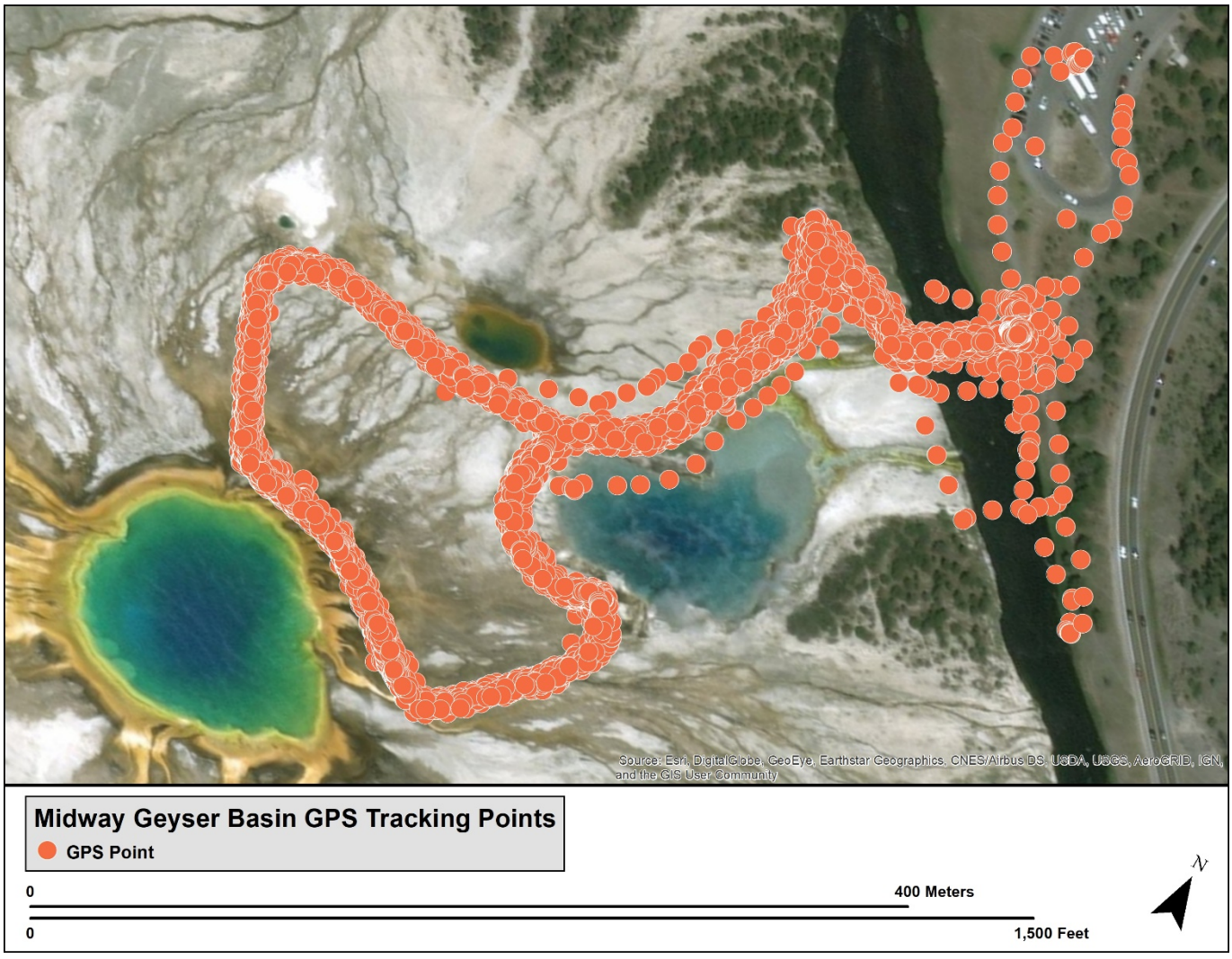

Figure 3.4a: Raw, cleaned GPS-based tracking point data collected from visitors at Midway Geyser Basin. GPS units were handed out at the trailhead.

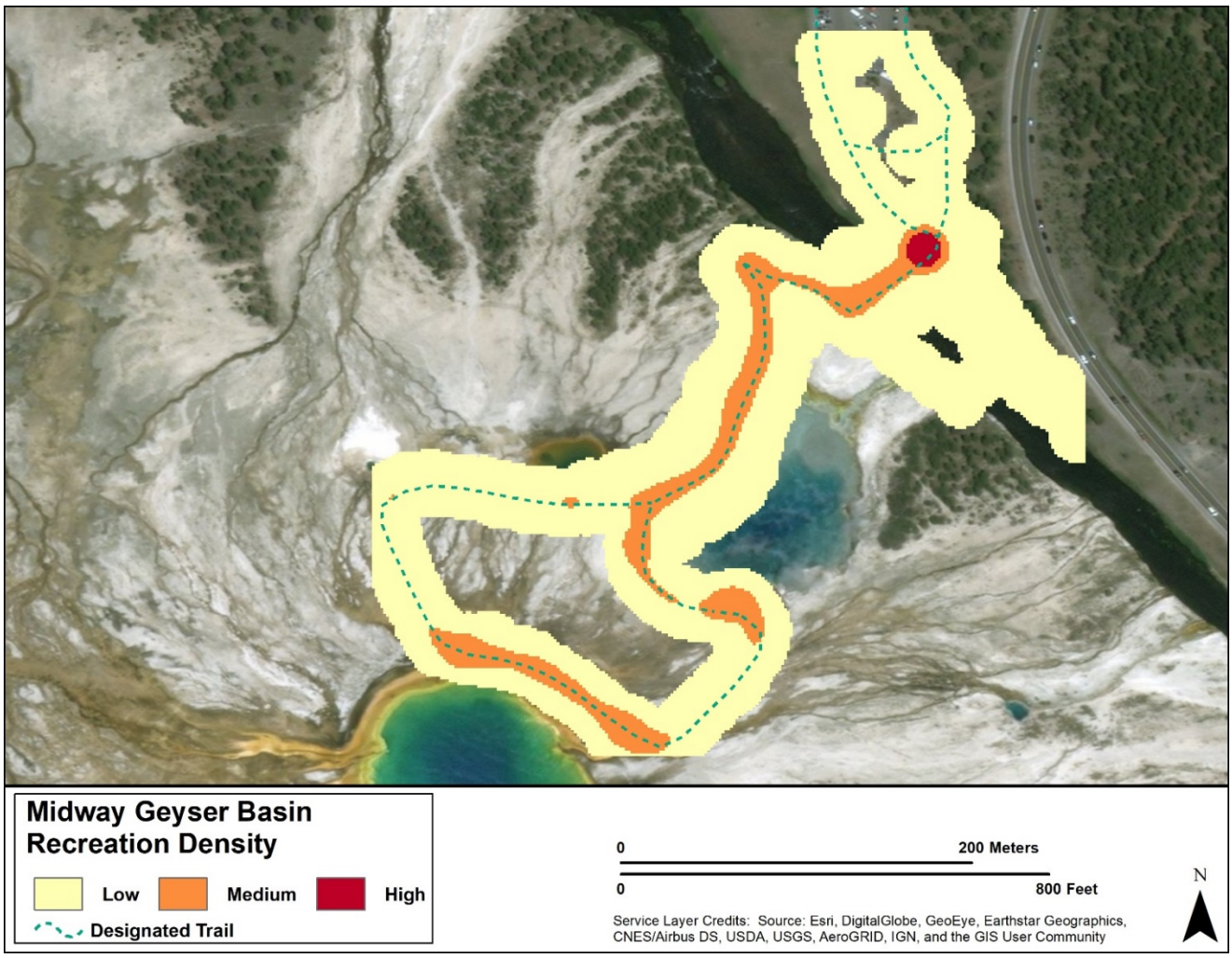

Figure 3.4b: Density of GPS-based tracking points collected from visitors at Midway Geyser Basin. GPS units were handed out at the trailhead. Note: High density spot near the trailhead is likely due to the GPS units being handed out and returned to the YCC crews at this location. When making comparisons with Figure 3.4a, please note that this figure is at a slightly different orientation. Low densities = an estimated count of 1 - 3 visitor points per 1 m^2; medium = 4 - 20 points per 1 m^2; high = 21 – 53 points per 1 m^2.

Table 3.7: Descriptive information extracted from the GPS-based tracking data on the amount of time visitors spent at the Midway Geyser Basin focal attraction site location. Note: times less than 1 minute were removed from the analysis. SD = standard deviation.

	Time (h:mm:ss)
Average	0:32:53
±SD	0:18:57
Minimum	0:07:01
Maximum	2:47:26

Appendix G shows the density of waypoints; highlighting where the majority of waypoints were mapped along the trail. See Appendix H for summary of all waypoints collected at each focal attraction site. Appendix I contains maps of locations of individual visitor behaviors and resource impact waypoints. The majority of waypoints were mapped at Grand Prismatic Spring, Excelsior Geyser Pool, and where the loop section of the trail begins (Appendix G). Most of the waypoints marked at Midway Geyser Basin are related to litter (59%), either litter in the thermal areas or just general litter observed outside of thermal areas (Figure 3.5). Graffiti or a personal object in the thermal area each made up 8% of the waypoints mapped at Midway Geyser Basin. A total of 4% of the waypoints marked were for footprints in the thermal area and 11% represented the flow of visitors being obstructed on the trail (Figure 3.5). Figure 3.6 shows where other waypoints were located – most visitor behavior-associated waypoints (such as visitors off-boardwalk, flow obstruction, etc.) occurred where visitors get the best views of Grand Prismatic Spring.

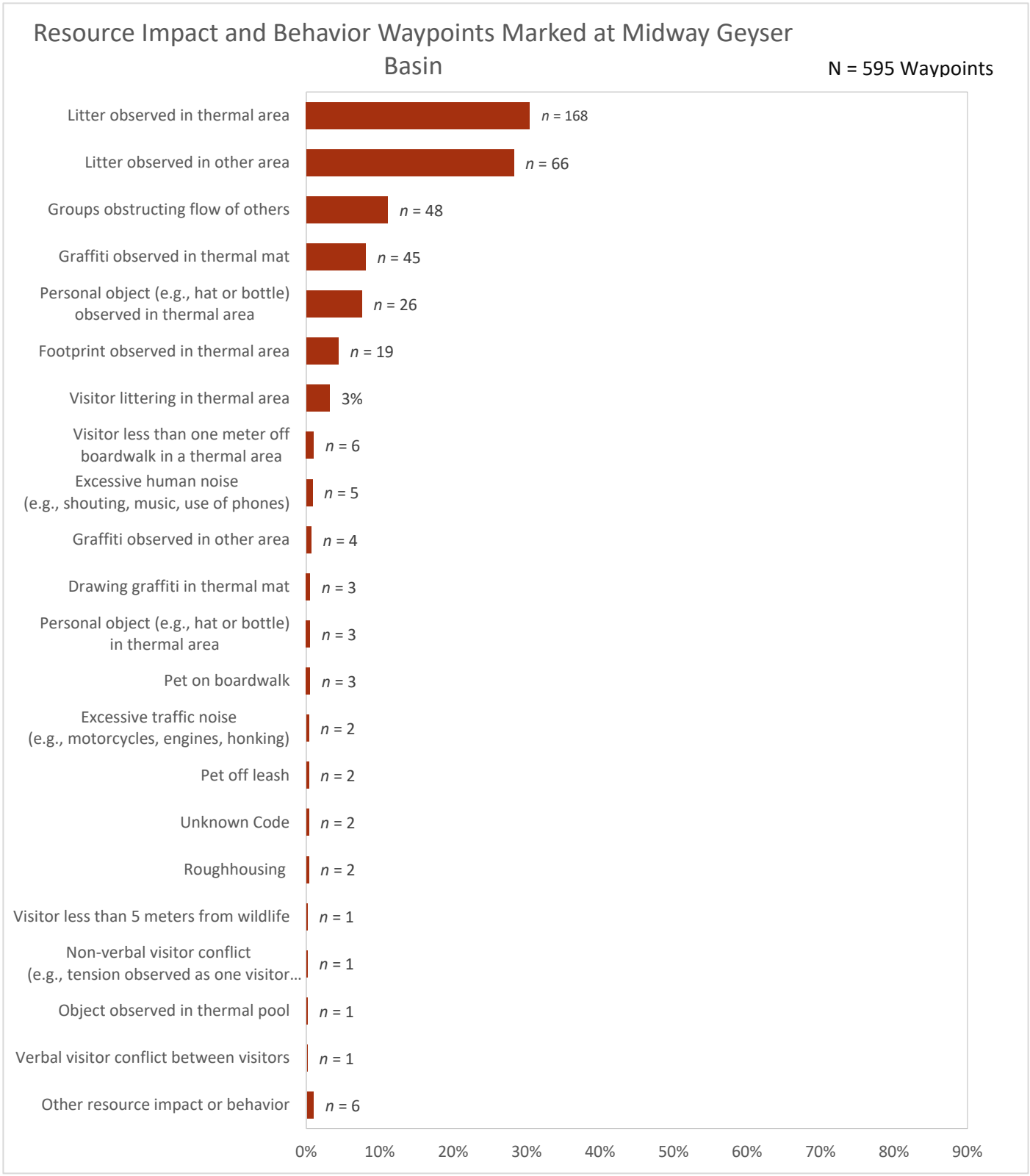

Figure 3.5: Frequency and count of codes for the visitor behavior and resource impacts marked by waypoints along the Midway Geyser Basin trail.

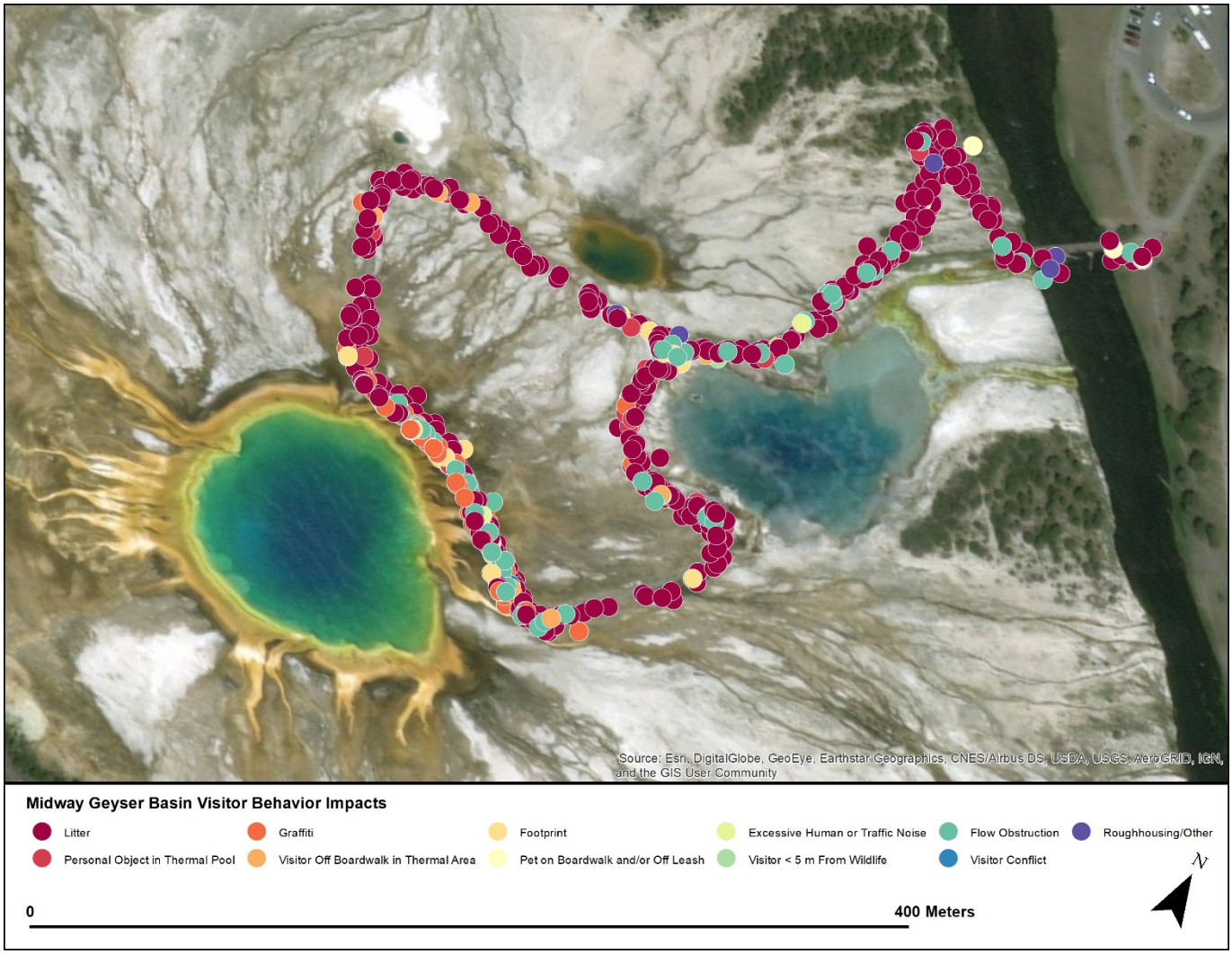

Figure 3.6: Location of specific visitor behavior and resource impacts waypoints along the Midway Geyser Basin trail.

Norris Geyser Basin

Visitor Use Estimation

See Appendix E for full summary tables of parking lot counts. Appendix F contains graphs of average, hourly vehicle counts for each focal attraction site parking lot by date. It is important to note that the parking lot at Norris Geyser Basin was closed to use when it was deemed full by park staff and when park staff were available to enforce the closure. These closures were not consistent or regular but did occur throughout the sampling period of the YCC crews. However, due to where the YCC crews were collecting data, they were not able to document when the parking lot was closed vs opened. Therefore, some of the variability and patterns of use (such as the drop in use at 1:00pm/13:00) at Norris Geyser Basin could be driven by the parking lot closures but there is no way to examine the relationship between the data collected by the YCC crews and these parking lot closures.

Vehicle use at the Norris Geyser Basin increases rapidly from first counts at 9:00am to 12:00pm (Figure 4.1). Average vehicle use peaks at 188 vehicles with an overall average of 146 vehicles per hour (Appendix F). The Norris Geyser Basin parking lot contains 143 designated parking spots (Otak, 2017). Since the Norris Geyser Basin parking lot is actively managed (closed when it became full) – there is little undesignated parking and smaller queues than were observed at other focal attraction site parking lots (Appendix E). Vehicle use at Norris Geyser Basin remains high through the end of the YCC Crews data collection period, showing no drop in the vehicle counts during the afternoon hours (Figure 4.1).

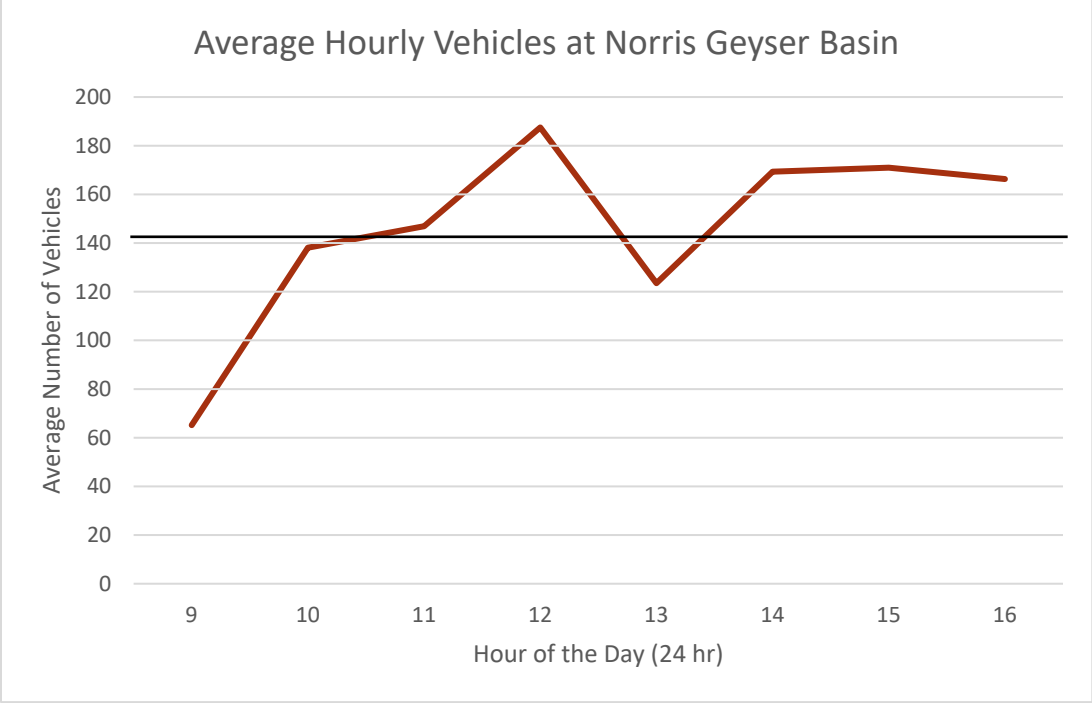

Figure 4.1: Average number of vehicles counted in the Norris Geyer Basin parking lot per hour. Very few undesignated parking were counted, so these values are not shown on the graph. Roadside parking counts were not taken at Norris Geyser Basin regularly. Black line on graph represents the 143 designated parking spots that are at Norris Geyser Basin (parking spot number pulled from Otak, 2017)

Tables 4.1 and 4.2 summarize two variables (tour bus numbers and restroom line counts) that were of interest to managers at YELL. At Norris Geyser Basin, the number of average tour buses range from 0 to 4 per day and 1 to 3 per hour. Restroom lines at the restrooms in Norris Geyser Basin average 5 people per hour with the highest line length occurring between 11:00am and 12:00pm.

Table 4.1: Average number of tour buses and restroom line counts summarized by sampling day. These counts were taken at the same time as the parking lot counts. SD = standard deviation.

	Tour Bus Counts		Restroom Line Counts	
Date	**Average**	**(±SD)**	**Average**	**(±SD)**
6/19/2017	2	1	1	1
6/21/2017	4	3	9	8
6/26/2017	0	1	0	0
6/27/2017	2	1	4	7
7/6/2017	2	1	7	3
7/12/2017	1	1	6	5
7/26/2017	1	1	2	2
8/3/2017	3	3	8	8
8/11/2017	1	1	1	2
Overall	**2**	**1**	**4**	**3**

Table 4.2: Average number of tour buses and restroom line counts summarized by time of day. These counts were taken at the same time as the parking lot counts. SD = standard deviation.

	Tour Bus Counts		Restroom Line Counts	
Time	**Average**	**(±SD)**	**Average**	**(±SD)**
9:00	2	2	2	2
10:00	3	2	4	3
11:00	2	3	6	7
12:00	2	2	9	8
13:00	1	1	3	4
14:00	1	1	5	4
15:00	1	0	5	4
16:00	3	1	8	7
Overall	**2**	**1**	**5**	**2**

An automatic trail counter was placed on the Porcelain Basin loop trail (see Figure 5) at Norris Geyser Basin. The automatic trail counter estimates indicate that during the YCC Crew sampling period, the Porcelain Basin loop receives between 218 and 477 visits per hour on average (Table 4.3). Use on the Porcelain Basin loop appears to increase steadily in the morning and peaks at 11:00am (Figure 4.2) but remains relatively high throughout the end of the day. Manual counts of visitors in 15-minute increments conducted by the YCC Crews show that an average of 222 visitors pass through the start of the Porcelain Basin loop in a 15-minute time span (Table 4.4). Due to the loop nature of the Porcelain Basin area, use is relatively even in both directions into and out of the loop trail (Table 4.4).

Table 4.3: Average total number of visits per hour counted via automatic trail counter located just past the Norris Geyser Basin Museum on the Porcelain Basin loop. SD = standard deviation.

Time	Average*	±SD	N
9:00	218	43	7
10:00	456	231	6
11:00	352	206	6
12:00	249	274	6
13:00	280	217	6
14:00	373	212	6
15:00	363	224	7
16:00	477	48	3

*Excludes 0 values deemed as erroneous.

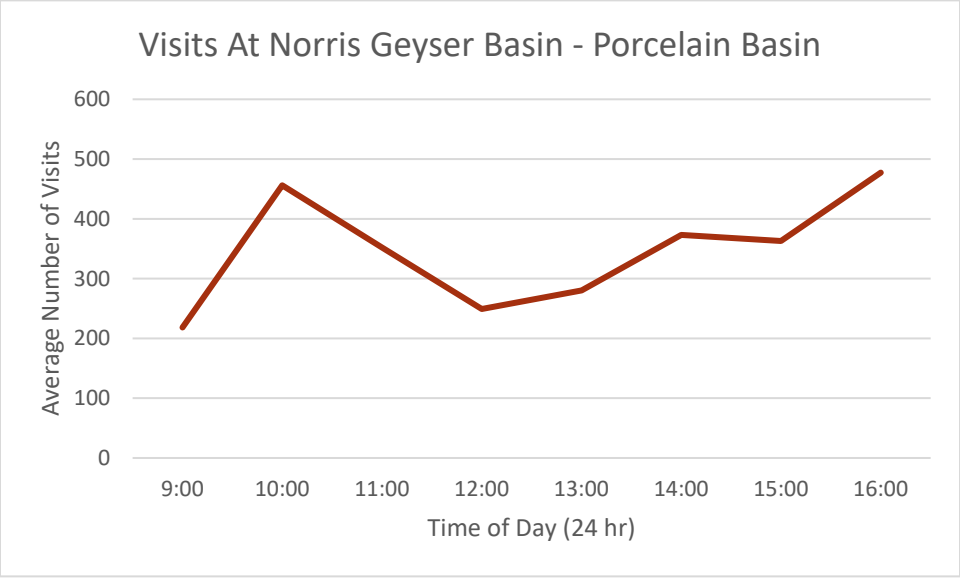

Figure 4.2: Average number of total visits (i.e. counts) per hour as estimated by the automatic trail counter.

Table 4.4: Summary of trail counter calibration counts and observations of tour groups at Norris Geyser Basin at trail counter location. SD = standard deviation.

Average in 15-minute Increments (N = 55)								Tour Groups	
Total				Entering Trail System		Exiting Trail System		N = 1	
Average	±SD	Min	Max	Average	±SD	Average	±SD	Average	±SD
222	67	83	356	118	43	104	42	45	N/A

Visitor Use/Capacity Measures

Visitor encounters along the 1-mile Porcelain Basin trail averages 169 visitors per hike of the entire loop (Table 4.5). Encounter counts conducted by the YCC Crews ranged from 17 visitors (recorded on 7/6/2017) to 436 visitors (recorded on 7/27/2017) in a single hike of the entire loop trail (Table 4.5). The Norris Geyser Basin focal attraction site included two PAOT locations in Porcelain Basin – on the stairs down to the boardwalk and on the boardwalk trail near Whirligig Geyser (see Figure 5). On average, the stairs had higher PAOT counts (42 visitors) compared to the boardwalk area (23 visitors) (Table 4.6). At both PAOT locations, counts were highly variable across a day (Figures 4.3 and 4.4). However, there appears to be a slight increase in PAOT counts during midday (between approximately 11:00am and 1:00pm/13:00) at the stairs down to the boardwalk section of the Porcelain Basin trail.

Table 4.5: Summary of trail encounters (number of visitors passed) for the entire 1 mile Porcelain Geyser Basin loop at Norris Geyser Basin. SD = standard deviation; N = number of counts that equaled the entire trail length.

Date	Average	±SD	Min	Max	N
6/19/2017	119	52	75	177	3
6/21/2017	80	66	37	197	5
6/27/2017	149	21	134	163	2
7/6/2017	129	54	17	246	15
7/26/2017	291	101	110	436	8
8/3/2017	174	50	65	227	9
8/7/2017	255	81	109	333	6
8/11/2017	108	67	45	219	5
Overall:	**169**	**94**	**17**	**436**	**53**

Table 4.6: People At One Time (PAOT) summary for PAOT locations at Norris Geyser Basin. SD = standard deviation; N = sample size.

	Porcelain Basin Stairs			Porcelain Basin Boardwalk		
Date	**Average**	**±SD**	**N**	**Average**	**±SD**	**N**
6/19/2017	21	15	5	22	13	2
6/21/2017	8	7	5	21	19	5
6/27/2017	23	10	6	38	12	5
7/26/2017	32	21	12	23	11	12
8/3/2017	22	13	9	19	8	9
8/11/2017	26	8	6	14	7	4
Overall	**42**	**15**	**43**	**23**	**12**	**37**

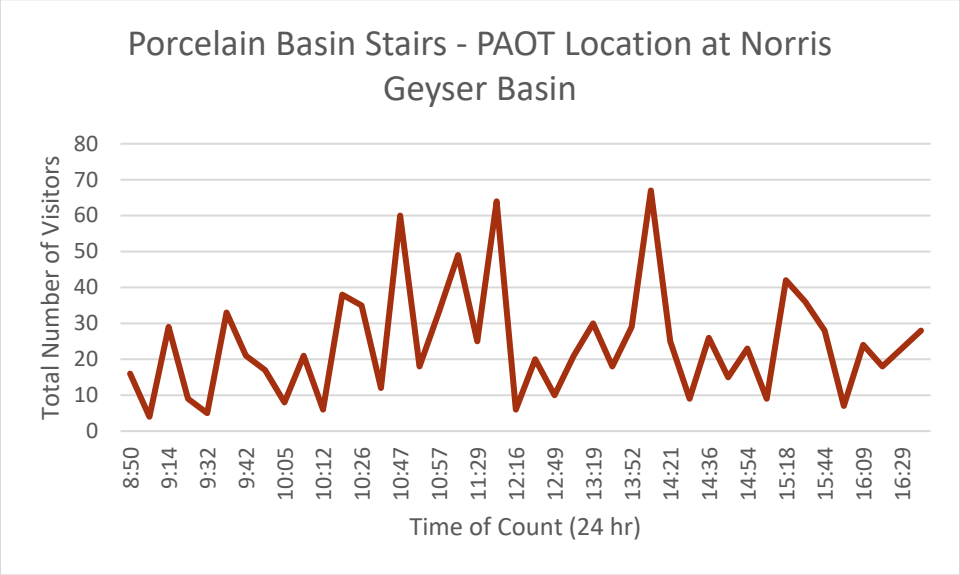

Figure 4.3: All individual PAOT counts organized by time at the stairs leading down to the Porcelain Basin boardwalk at Norris Geyser Basin.

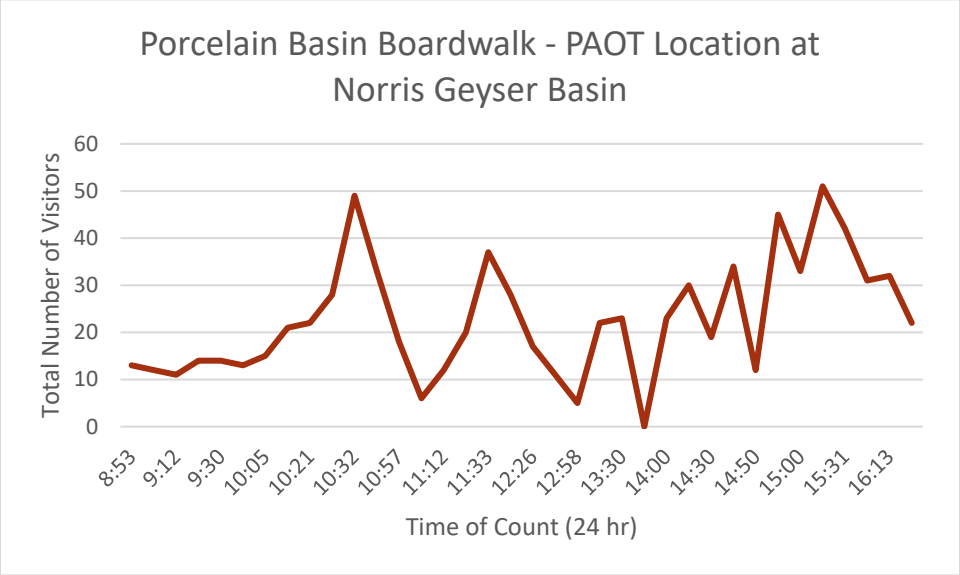

Figure 4.4: All individual PAOT counts organized by time at the boardwalk overlooking Whirligig Geyser at Norris Geyser Basin.

Visitor Spatial Behavior

Results from GPS tracking visitors at Norris Geyser Basin shows that visitors use is relatively dispersed (Figures 4.5a and 4.5b). Locations of high densities of visitor tracking points occur at thermal features of interest and at the Norris Geyser Museum. But visitor spatial patterns are varied overall. Table 4.7 describes the length of visit for the Norris Geyser Basin as measured by the GPS-based tracking methods. On average, visitors spend approximately 1 hour at the Norris Geyser Basin with a standard deviation of 40 minutes. The maximum recorded trip was 3 ½ hours.

Appendix G shows the density of waypoints; highlighting where the majority of waypoints were mapped along the trail. Waypoints were only mapped along the Porcelain Basin trail and the majority of waypoints were marked along the stair section where the PAOT counts were taken as well as along the boardwalk to Whirligig Geyser (see Appendix G). See Appendix H for summary of all waypoints collected at each focal attraction site. Along the Porcelain Basin loop trail, 41% of the waypoints marked were for litter observed outside of the thermal area and 28% was for litter observed in the thermal areas (Figures 4.5 and 4.6). Appendix I contains maps of locations of individual visitor behaviors and resource impact waypoints.

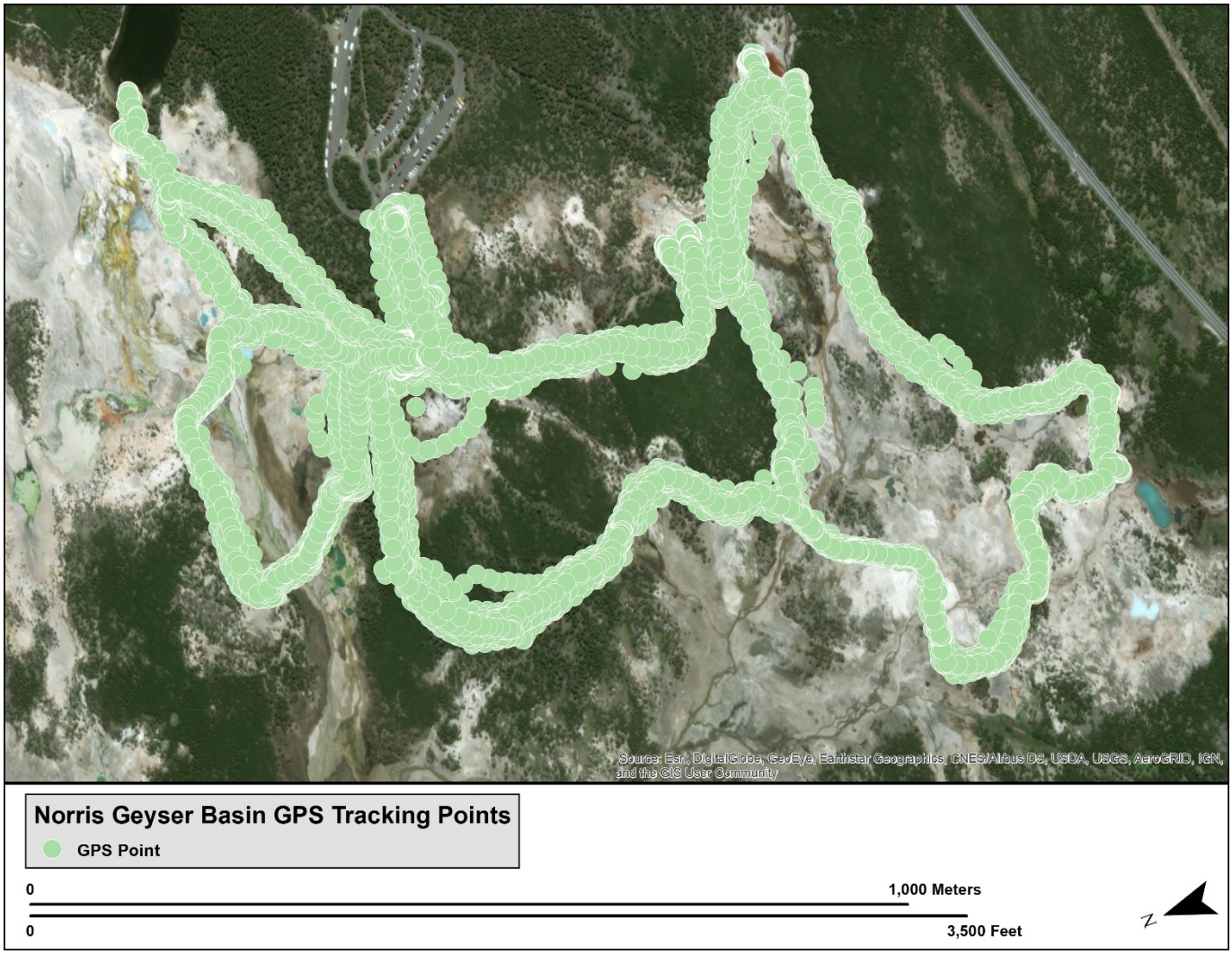

Figure 4.5a: Raw, cleaned GPS-based tracking point data collected from visitors at Norris Geyser Basin. GPS units were handed out at the trailhead near the parking lot.

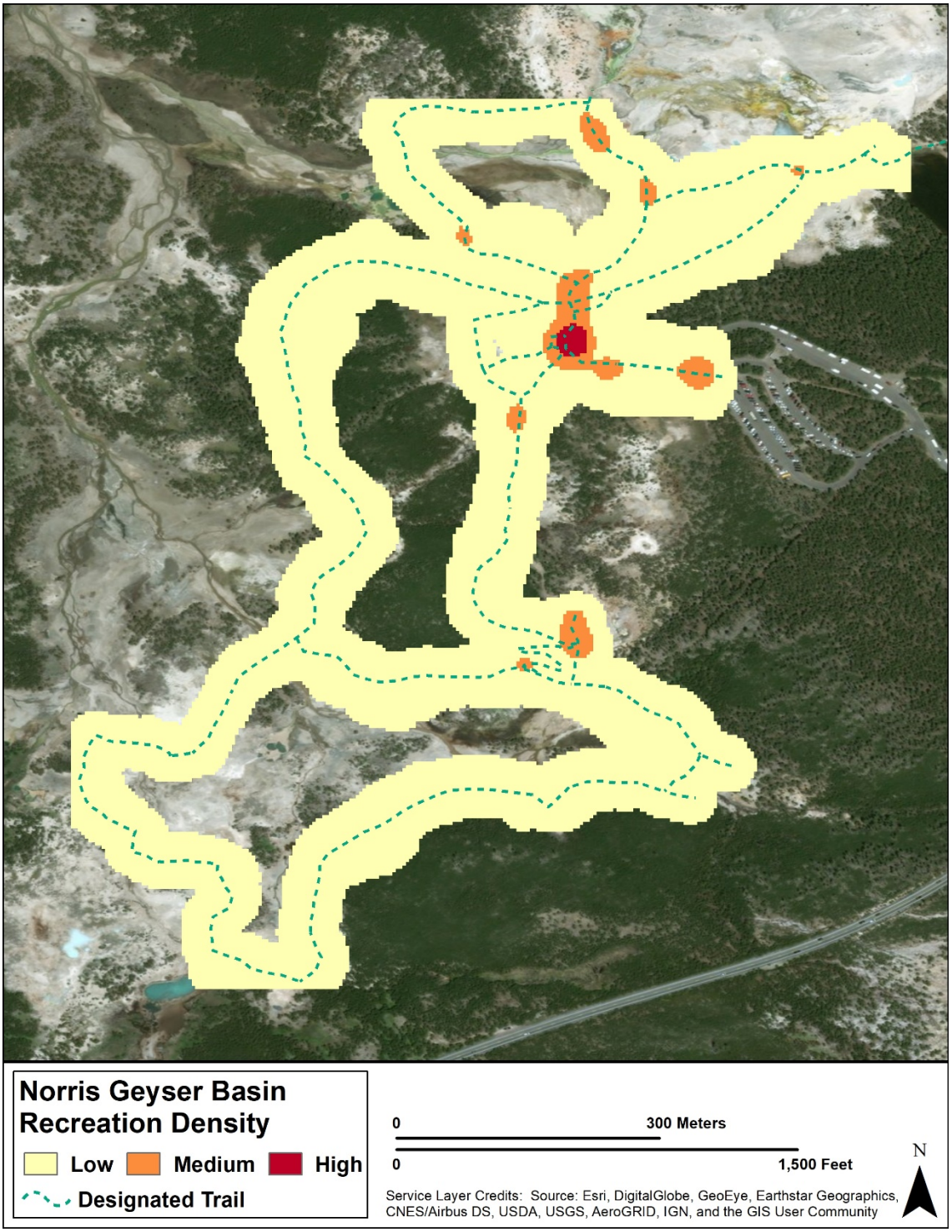

Figure 4.5b: Density of GPS-based tracking points collected from visitors at Norris Geyser Basin. GPS units were handed out at the trailhead near parking lot. When making comparisons with Figure 4.5a, please note that this figure is at a slightly different orientation. Low densities = an estimated count of 1 – 13 visitor points per 1 m^2; medium = 14 - 65 points 1 m^2; high = 66 – 161 points 1 m^2.

Table 4.7: Descriptive information extracted from the GPS-based tracking data on the amount of time visitors spent at the Norris Geyser Basin focal attraction site location. Note: times less than 1 minute were removed from the analysis. SD = standard deviation

	Time (h:mm:ss)
Average	0:56:27
±SD	0:39:04
Minimum	0:01:00
Maximum	3:32:02

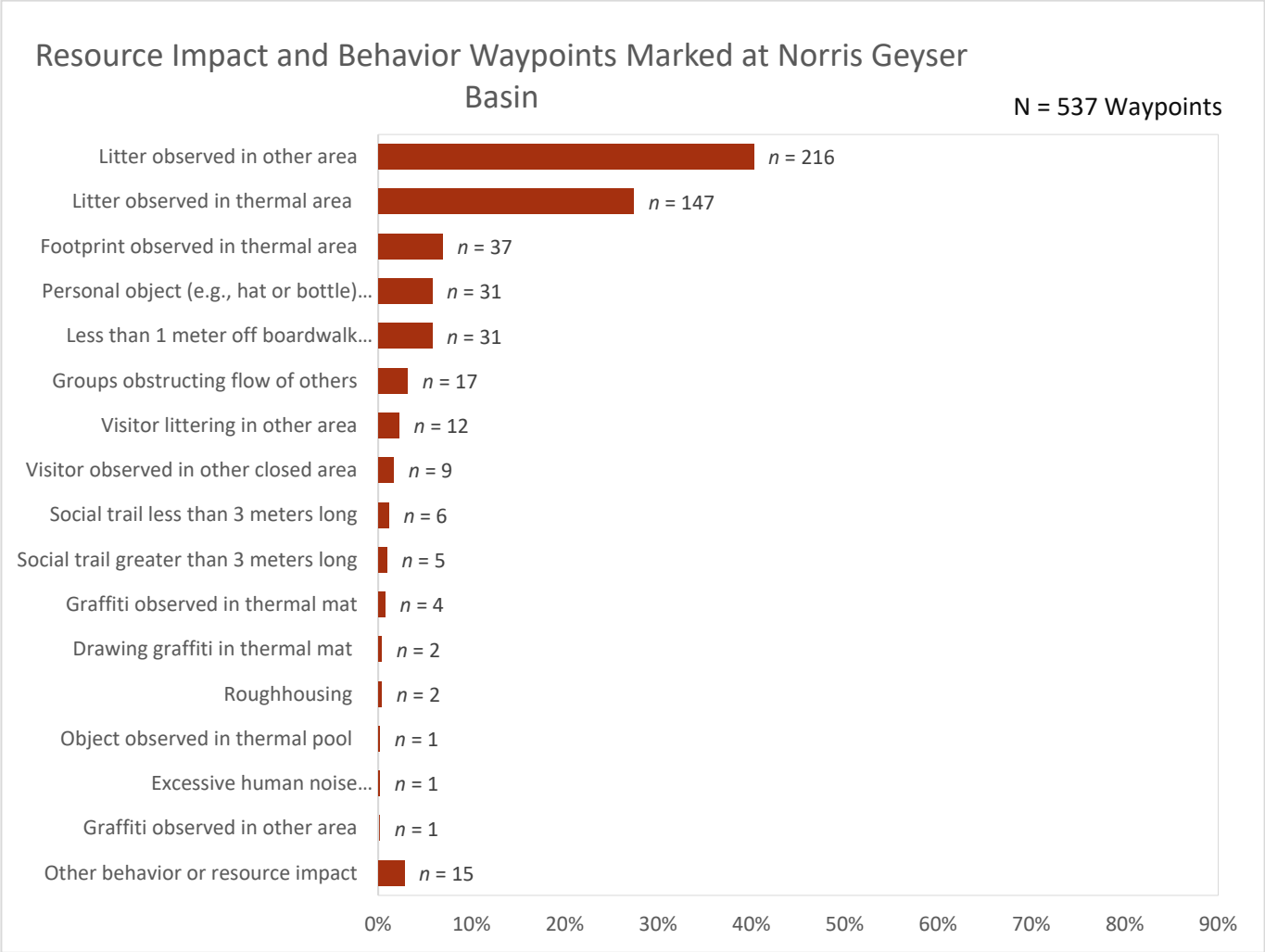

Figure 4.6: Frequency and counts of codes for the visitor behavior and resource impacts marked by waypoints along the Porcelain Basin loop at Norris Geyser Basin.

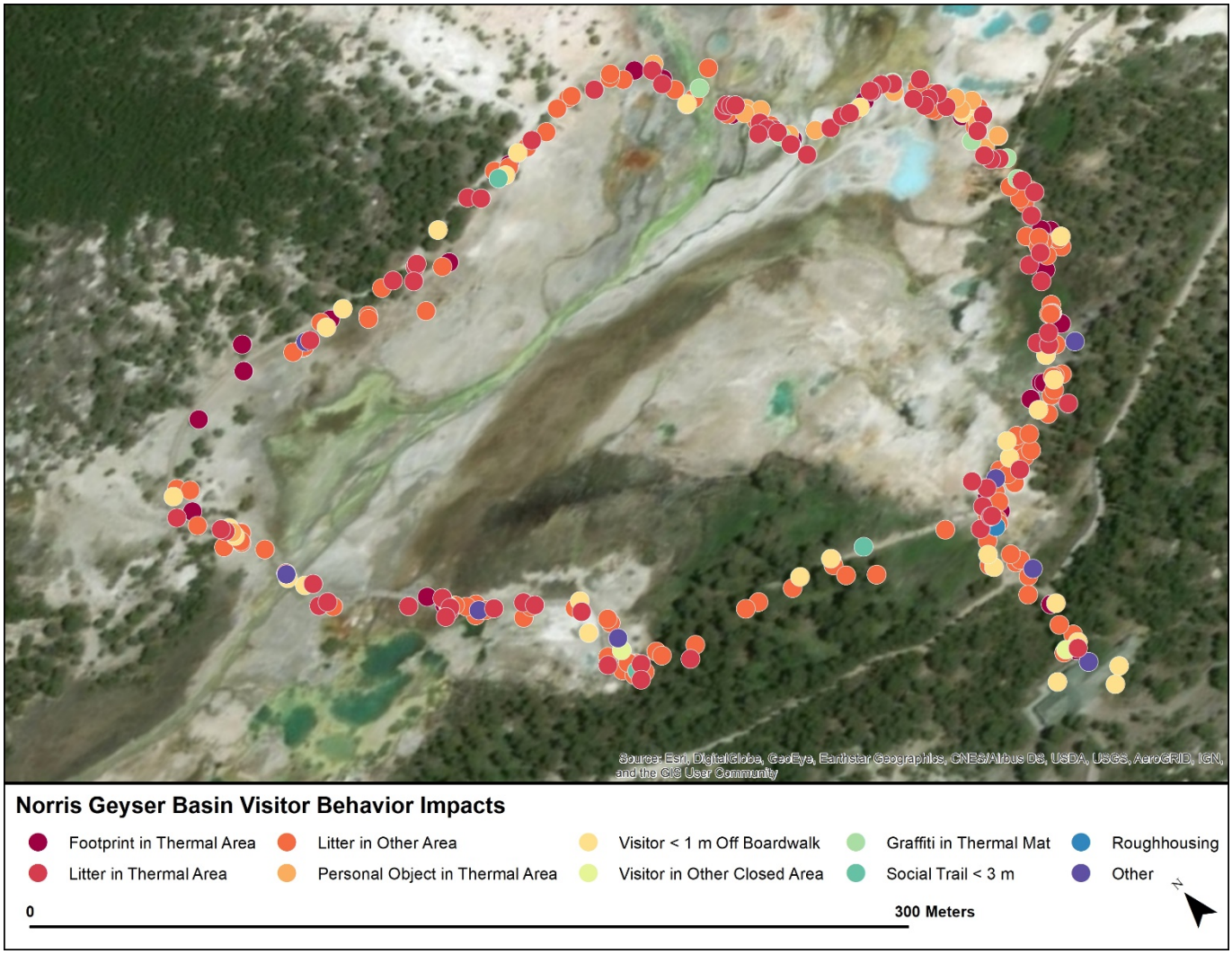

Figure 4.7: Location of specific visitor behavior and resource impacts waypoints along the Porcelain Basin trail at Norris Geyser Basin.

Old Faithful

Visitor Use Estimation

Parking lot counts were not collected at Old Faithful due to the size and complexity of the parking lots there.

At Old Faithful, the automatic trail counter was placed to the Northwest of the Old Faithful area on the trail leading to Geyser Hill (see Figure 6). Results from the automatic counter indicate that on average, this section of trail receives between 135 and approximately 500 visits per hour (Table 5.1) during the sampling period. Use at this location seems to peak between 11:00am and 2:00pm (14:00) (Figure 5.1). Calibrations at this counter location found that in a 15-minute increment, an average of 195 visitors pass by (Table 5.2). Unlike other trail counter locations in this study, more visitors enter (meaning head into the trail) at the counter location than exit (head outwards towards the parking area) (Table 5.2).

Table 5.1: Average total number of visits per hour counted via automatic trail counter located at the trail at Old Faithful leading to Geyser Hill. SD = standard deviation; N = sample size.

Time	Average*	±SD	N
9:00	135	119	8
10:00	270	164	8
11:00	496	235	7
12:00	258	256	8
13:00	358	260	7
14:00	414	245	7
15:00	153	229	7
16:00	202	94	2

*Excludes 0 values deemed as erroneous.

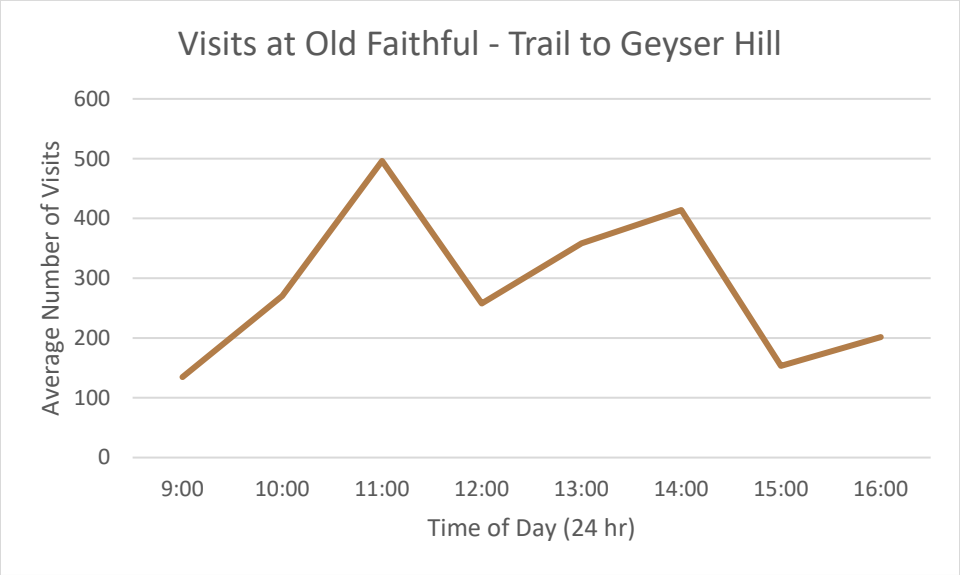

Figure 5.1: Average number of total visits (i.e. counts) per hour as estimated by the automatic trail counter.

Table 5.2: Summary of trail counter calibration counts and observations of tour groups at Old Faithful at trail counter location. SD = standard deviation.

Average in 15-minute Increments (N = 43)								Tour Groups	
Total				Entering Trail System		Exiting Trail System		N = 1	
Average	±SD	Min	Max	Average	±SD	Average	±SD	Average	±SD
195	90	25	388	120	80	76	46	34	N/A

Visitor Use/Capacity Measures

YCC Crews counted visitor encounters along the approximately 0.6 mile trail for Geyser Hill and on average encountered 347 other visitors along the trail (Table 5.3). The minimum number of encounters recorded was 128 visitors (recorded on 6/28/2017) and the maximum was 634 visitors (recorded on 7/25/2017) in a single hike of the trail. The Old Faithful focal attraction site, and specifically the Geyser Hill trail, has two PAOT locations – the "Z" section of the trail on the lower area of the Old Faithful Geyser Basin area and the boardwalk near Beehive Geyser (see Figure 6). On average, the "Z" bridge has 28 people at one time in that area while the Beehive Geyser section of the boardwalk – on average – had 18 visitors (Table 5.4). Both PAOT locations had a significant amount of variability (Figures 5.2 and 5.3) – possibly due to the fact that Old Faithful eruptions can be seen from both of these locations and PAOT may be influenced by Old Faithful eruption schedules. Additionally, it's important to note that the "Z" section of the trail also had one day (7/25) that was a significant outlier – a single PAOT count occurred at the "Z" section of trail that equaled 195 visitors (Figure 5.2). PAOT counts were also taken during Old Faithful eruptions (Table 5.4 and Figure 5.4). A total of 12 eruption counts were taken during the YCC Crews data collection effort at Old Faithful. On average, 1553 visitors are on the platform in front of Old Faithful during eruption times (Table 5.4). Eruptions later in the day, appear to have slightly more PAOT on the platform (Figure 5.4).

Table 5.3: Summary of trail encounters (number of visitors passed) for the entire approximately 0.6 mile loop of Geyser Hill and down to the "Z" bridge area. N = number of counts that equaled the entire trail length.

Date	Average	±SD	Min	Max	N
6/20/2017	425	233	260	589	2
6/22/2017	350	71	299	400	2
6/28/2017	200	62	128	278	4
7/25/2017	471	146	247	634	5
7/31/2017	384	132	291	477	2
8/4/2017	333	25	315	350	2
8/10/2017	288	63	205	352	4
Overall:	**347**	**137**	**128**	**634**	**21**

Table 5.4: People At One Time (PAOT) summary for PAOT locations at Old Faithful and Geyser Hill. SD = standard deviation; N = sample size.

	"Z" Bridge			Beehive Geyser			Old Faithful Eruption		
Date	**Average**	**±SD**	**N**	**Average**	**±SD**	**N**	**Average**	**±SD**	**N**
6/20/2017	19	13	8	N/A	N/A	N/A	N/A	N/A	N/A
6/22/2017	24	22	3	21	13	3	N/A	N/A	N/A
6/28/2017	14	8	5	21	15	5	1527	N/A	1
7/7/2017	28	16	6	5	4	4	1353	553	2
7/25/2017	105	84	4	31	18	4	1477	673	4
7/31/2017	9	N/A	1	27	N/A	1	2799	N/A	1
8/4/2017	9	10	2	19	24	2	910	N/A	1
8/10/2017	23	7	5	12	4	5	1596	152	3
Overall	**28**	**35**	**31**	**18**	**14**	**24**	**1553**	**587**	**12**

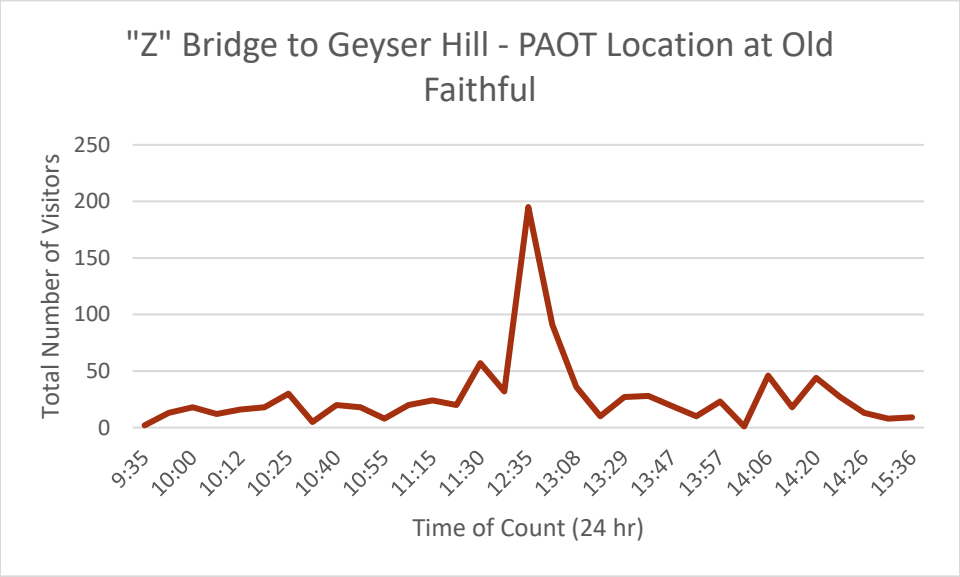

Figure 5.2: All individual PAOT counts organized by time at the boardwalk where there is a "Z" turn leading to Geyser Hill at Old Faithful.

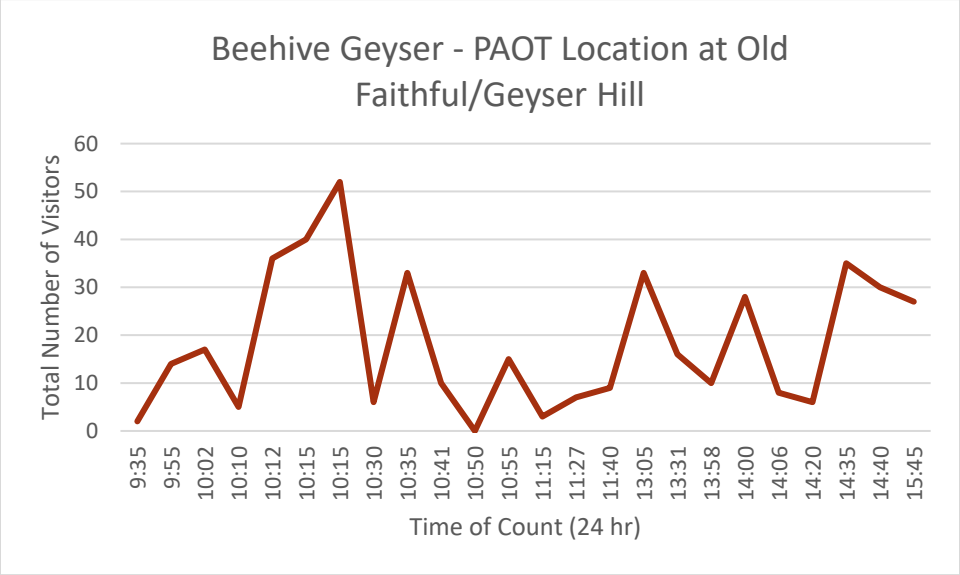

Figure 5.3: All individual PAOT counts organized by time at the boardwalk near Beehive Geyser at Geyser Hill at Old Faithful.

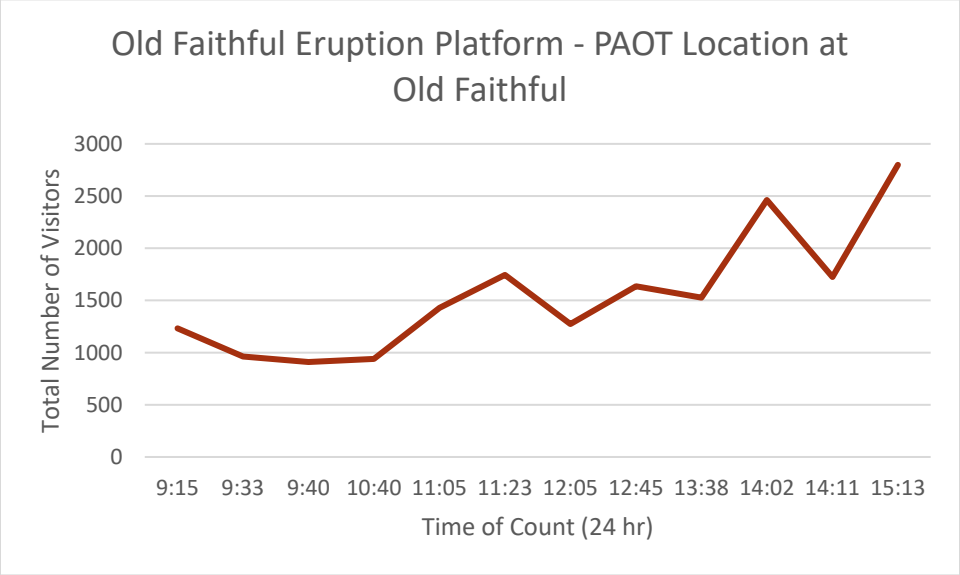

Figure 5.4: All PAOT counts organized by time at the viewing platform at Old Faithful. These counts only occurred during eruptions.

Visitor Spatial Behavior

GPS-based tracking of visitors at Old Faithful show that most visitors stay within the Old Faithful and Geyser Hill basins when at Old Faithful (Figures 5.5a and 5.5b). However, visitors do venture beyond these areas to other hydrothermal features in the Old Faithful Area. Visitors were tracked hiking to Solitary Geyser and the Observation Point (Figure 5.5b) as well as the Upper Geyser Basin and Castle Grand Area. Table 5.7 summarizes the trip characteristics in time for visitors to the Old Faithful focal attraction site that were GPS tracked. On average, visitors spend just over 1 ½ hours in the Old Faithful area with a standard deviation of 1 hour and 11 minutes. The longest recorded visit by the GPS tracks was almost 7 hours long.

Appendix G shows the density of waypoints; highlighting where the majority of waypoints were mapped along the trail. See Appendix H for summary of all waypoints collected at each focal attraction site. Appendix I contains maps of locations of individual visitor behaviors and resource impact waypoints. Waypoints marked at Old Faithful were relatively disperse (Appendix G), with high densities of waypoints mapped at the bridge over the Firehole River, at the “Z” bridge and on the boardwalk that loops around the Northern edge of Old Faithful Geyser Basin. Of the waypoint marked, 80% are for litter observed both in (36%) and out of (44%) thermal areas (Figure 5.6). A total of 6% of the waypoints marked locations where footprints were found in the thermal areas.

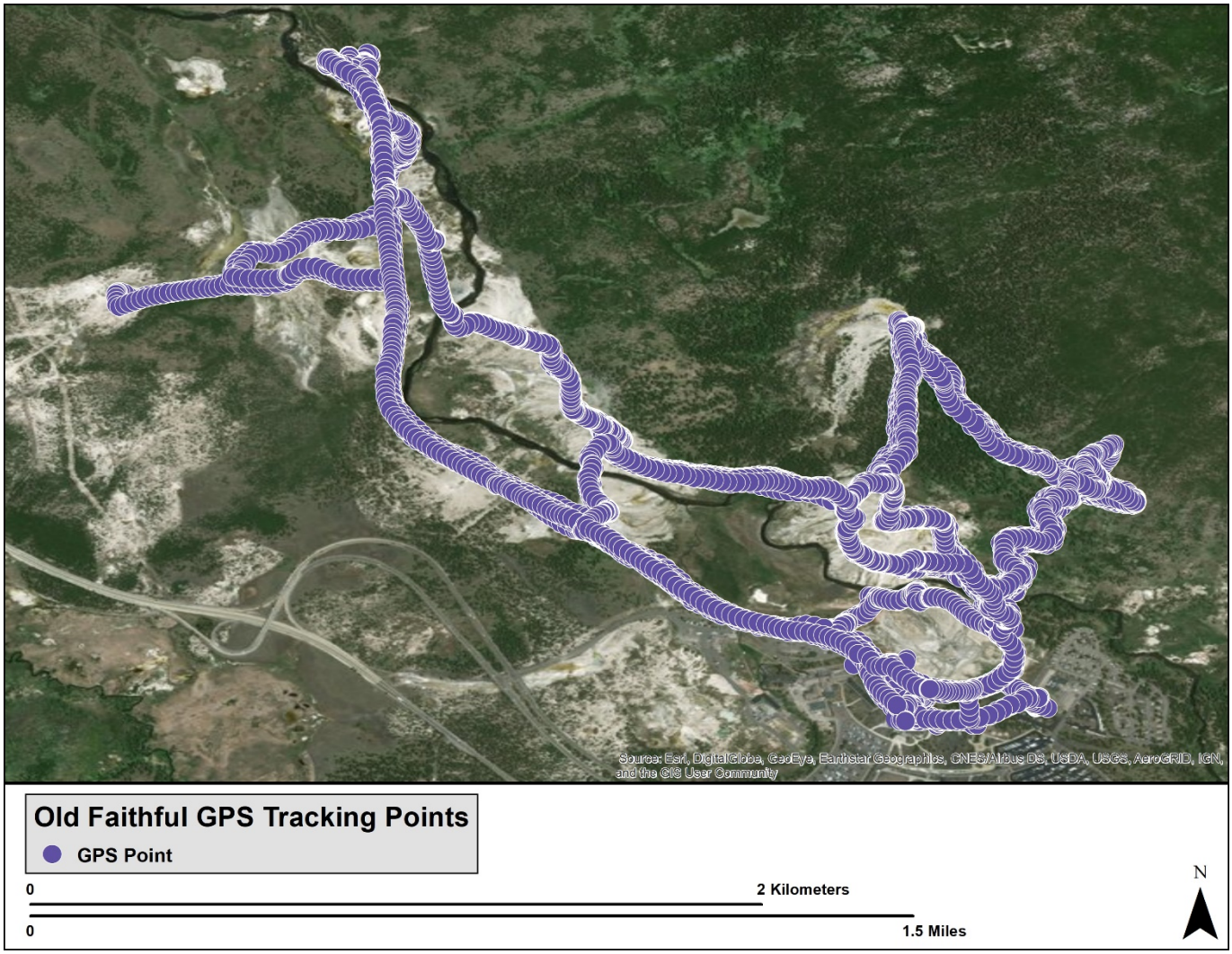

Figure 5.5a: Raw, cleaned GPS-based tracking point data collected from visitors at Old Faithful. GPS units were handed out between visitor center and Old Faithful Geyser.

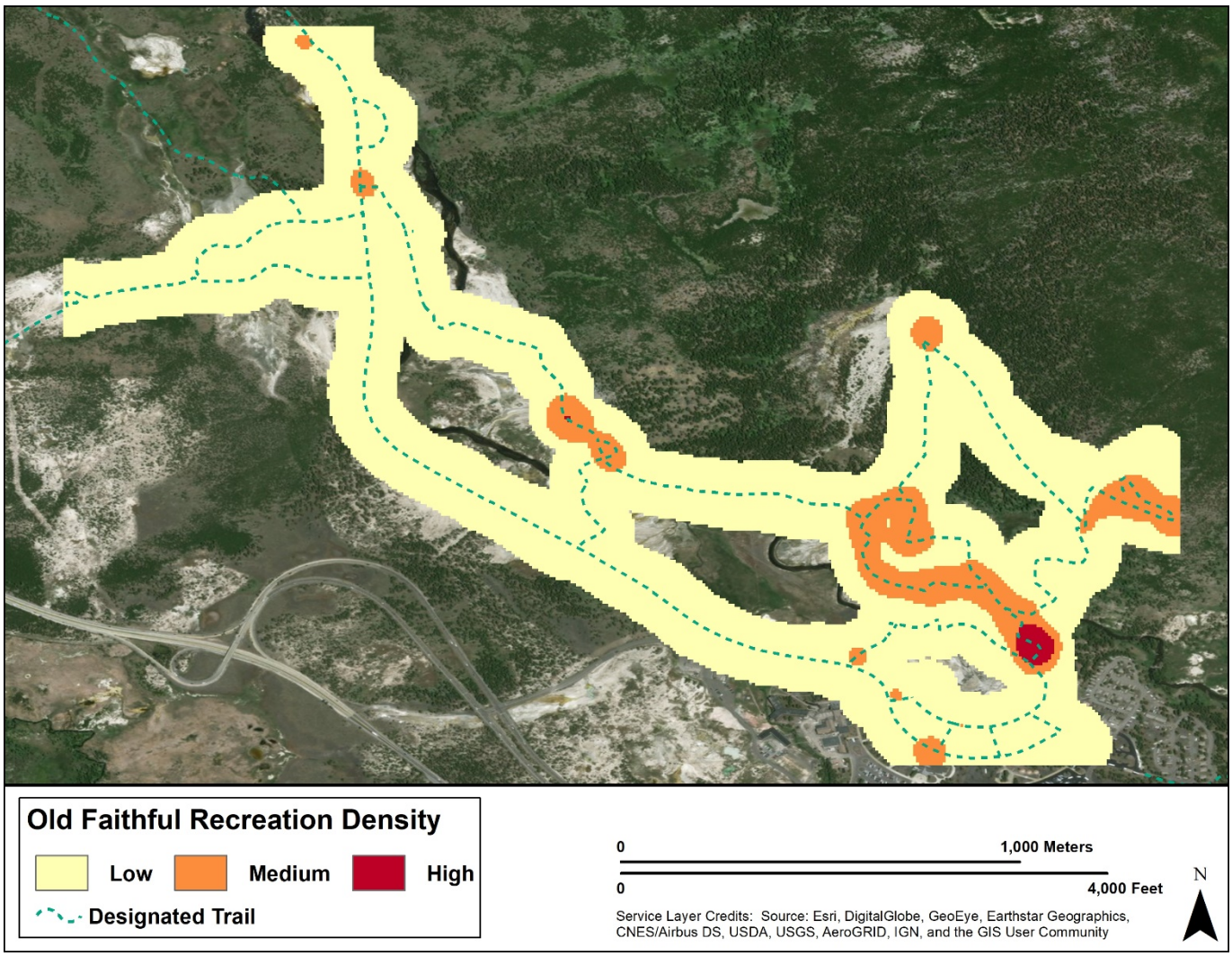

Figure 5.5b: Density of GPS-based tracking points collected from visitors at Old Faithful. GPS units were handed out between visitor center and Old Faithful Geyser. Low densities = an estimated count of 1 – 3 visitor points per 1 m^2; medium = 4 - 15 points 1 m^2; high = 16 – 33 points 1 m^2.

Table 5.7: Descriptive information extracted from the GPS-based tracking data on the amount of time visitors spent at the Old Faithful focal attraction site location. Note: times less than 1 minute were removed from the analysis. SD = standard deviation.

	Time (h:mm:ss)
Average	1:36:48
±SD	1:11:53
Minimum	0:01:00
Maximum	6:53:59

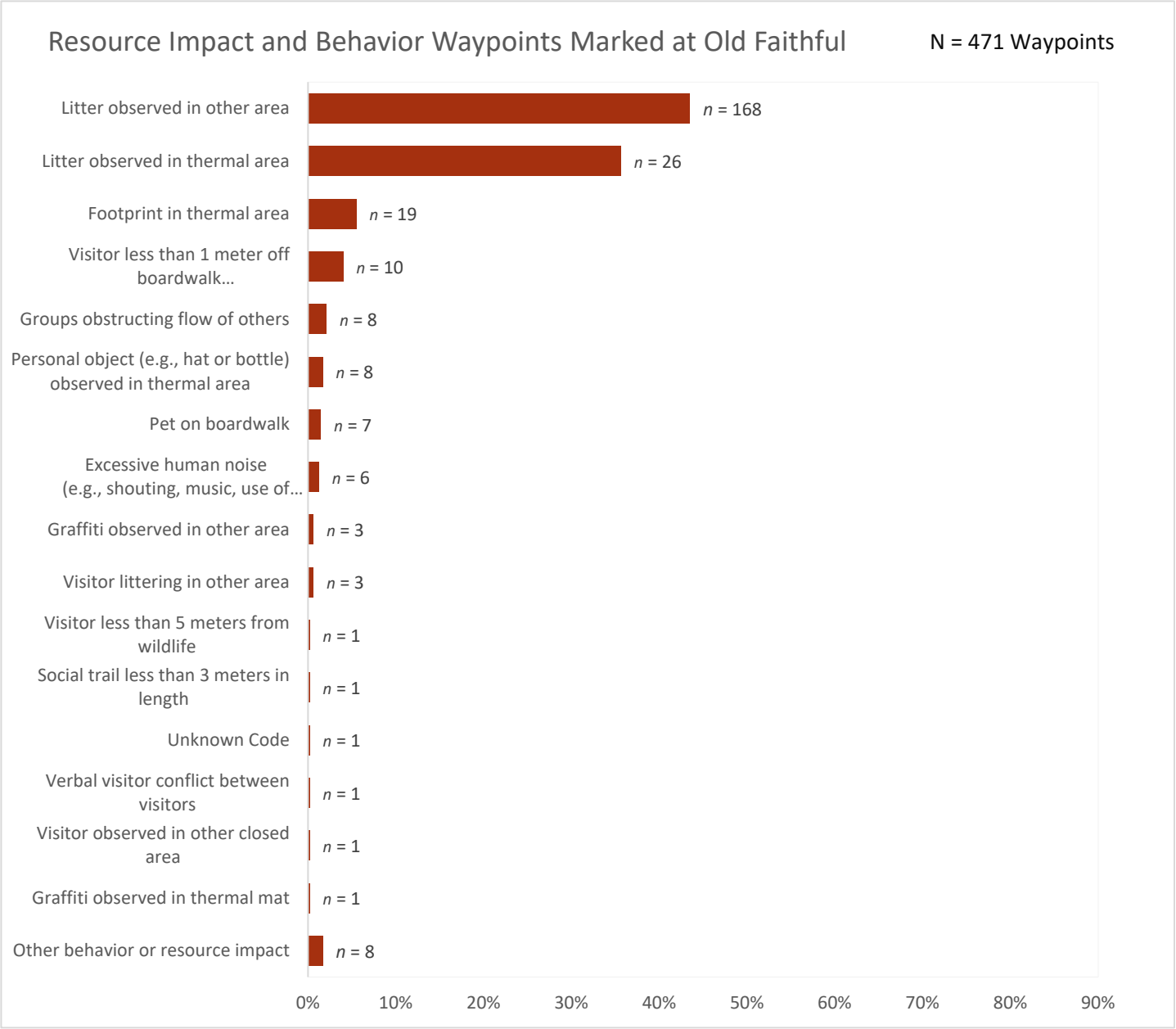

Figure 5.6: Frequency and counts of codes for the visitor behavior and resource impacts marked by waypoints along the Old Faithful/Geyser Hill trail.

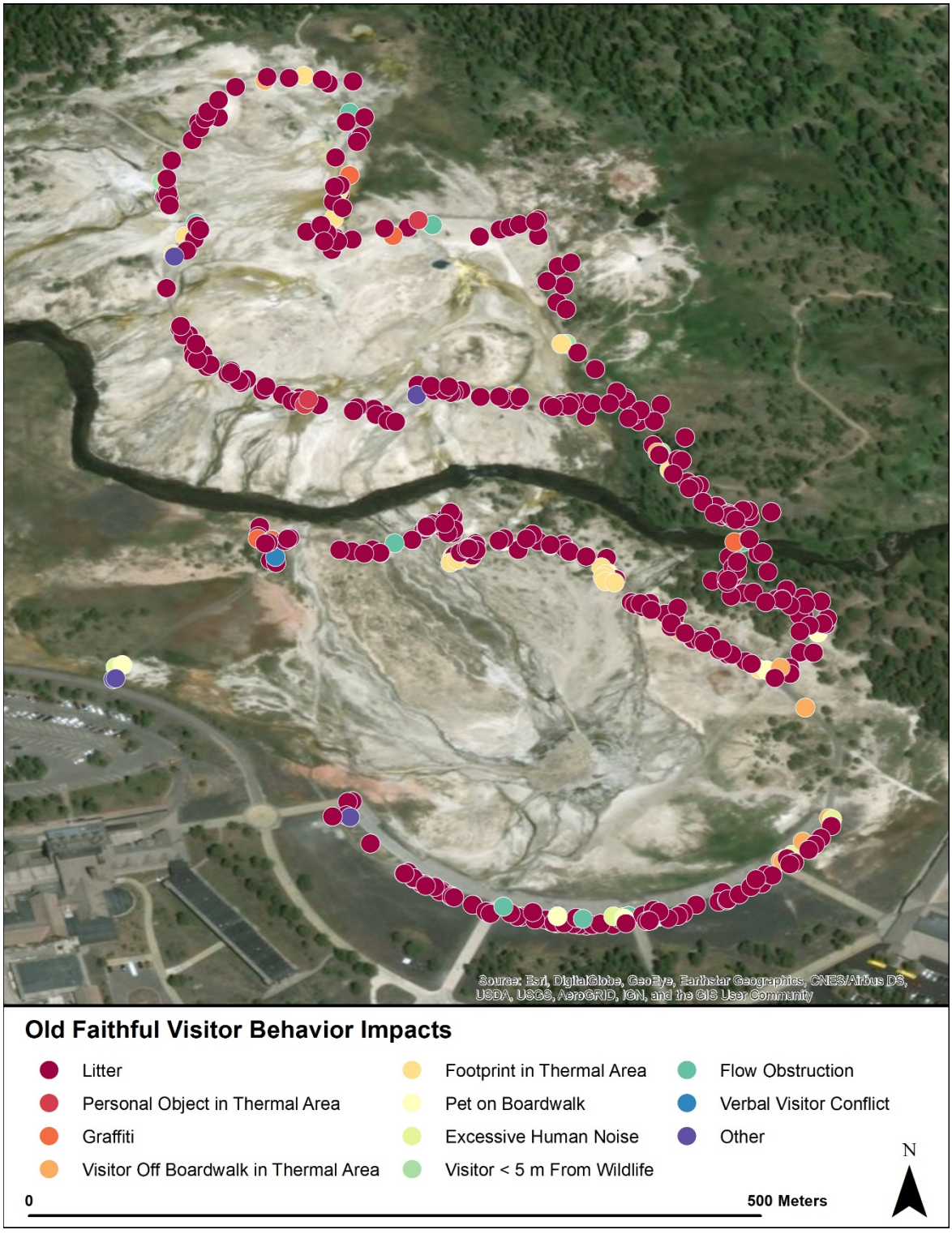

Figure 5.7: Location of specific visitor behavior and resource impacts waypoints at Old Faithful.

Social Trails

Over a number of years, YELL staff have been systematically mapping and recording the level and extent of impact caused by social trails in the park. As part of scope of the monitoring project presented in this report, the social trails data and protocols were provided to Oregon State University for analysis. As added value to the YCC Crew project, the social trails data is summarized below. Oregon State University will be continuing analysis of the social trails data using methods presented in Gutzwiller et al. 2017 for a forthcoming publication. Communication will continue with YELL related to that data analysis and any subsequent publications. Below a parkwide summary as well as summaries by focal attraction site are presented for the social trails data provided to Oregon State University. These results include any social trails mapped through Summer 2017.

Note: For all analyses, data records with a condition class of "0" have been removed from the analysis. This resulted in the removal of 70 records from the parkwide summary for Social Trails, 3 records from the parkwide summaries for Impacted Area and Impacted Site, and 1 record from the parkwide summary for Trailhead Impacts.

Parkwide, recreation impacts exist in YELL, with the majority of these impacts occurring close to designated trails and/or near YELL roads (Figure 6.1). Overall, 1,731 social trails comprising 90,447 meters of trail exist in the park, with average social trail length being approximately 52 meters (Table 6.1).

Based on average condition class ratings (where 1 = lowest level of impact to vegetation and soil and 5 = highest level of impact to vegetation and soil), these social trails are of moderate impact. YELL also has non-linear impacted locations in the form of patches of bare ground, impacted areas, and impacted areas near trailheads (i.e., trailhead impacts). These areas combined comprise 564 unique locations in the park and approximately 153,713 square meters of park area. Based on average condition class ratings, impacted areas and impacted areas near trailheads are of moderate impact, while bare ground areas are of severe impact due to the complete loss of vegetation at these locations.

Table 6.1. The level and extent of resource impacts recorded parkwide in Yellowstone National Park.

Data Layer Summarized	#	Average Condition Class* (± SD)	Average Length (m) (± SD)	Average Area (m^2) (± SD)	Total Length (m)	Total Area (m^2)
Social Trails	1731	3.10 (± 1.30)	52 (± 104)	—	90,447	—
Impacted Site[1]	476	3.60 (± 1.25)	—	221 (± 515)	—	105,219
Bare Ground	151	5.00 (± 0.00)	—	124 (± 354)	—	18,670
Impacted Area	325	2.95 (± 0.98)	—	266 (± 570)	—	86,550
Trailhead Impacts	88	2.77 (± 1.19)	—	551 (± 888)	—	48,493

[1]Impacted Site analyses include data from Bare Ground and Impacted Area layers.

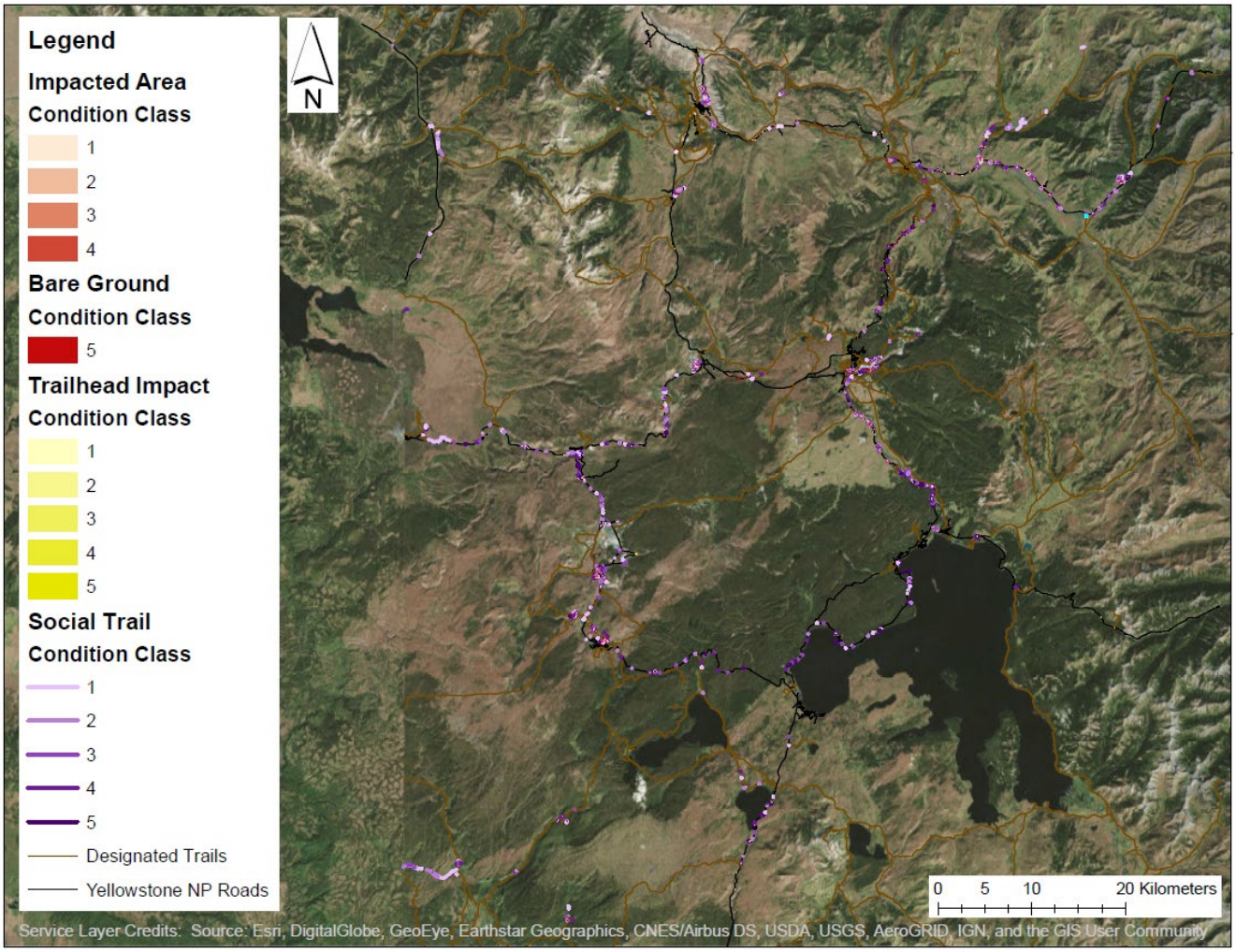

Figure 6.1. Resource impact locations and levels of impact in Yellowstone National Park.

The extent of the GPS-based tracking data collected by the YCC Crews in 2017 informed the analysis area for social trails at each focal attraction site. Therefore, the summaries of social trail impacts can be conceptualized as the level and extent of impact that could be experienced by a visitor to this focal attraction site. The resource impacts are visualized in a series of maps throughout this section of the report. In these maps, the impacts are color-coded by condition class to highlight the level of soil and vegetation damage for this particular type of impact; the darker the color the more impacted the feature is.

Each focal attraction site has an overview map (Figure *X.X*a) which shows the analysis area as a *non-shaded* region over satellite imagery; these maps are meant to illustrate the extent of the resource impacts at each focal attraction site. Each overview map has a series of between two and three numbered, inset maps (Figures *X.X*b. *X.X*c, *X.X*d) highlighting locations where subsequent maps were created to better visualize the level of impacts by condition class ratings. In these inset maps, the analysis area, is shown as a *shaded background* to help the resource impacts standout against the satellite imagery. Park designated road and trails are also included on the resource impact maps to help visualize how the pattern of impacts is related to park facilities and trails.

In the Artist Point focal attraction site analysis area, recreation impacts are spread throughout the analysis area, with impacts occurring near park roads or designated trails (Figure 6.2a – 6.2d). Social trails are the most frequently occurring recreation impact, with 46 social trails documented in the analysis area (Table 6.2). The frequency and extent of bare ground patches and impacted area patches at Artist Point are comparable among these two impact types, with 14 impacted area sites comprising 893 meters squared and 19 bare ground sites comprising 1,328 meters squared. Based on average condition class, bare ground impacts are severe with social trail and impacted area impacts being moderate. No impacted areas near trailheads were documented in the Artist Point focal location analysis area.

Table 6.2. The level and extent of resource impacts recorded in the Artist Point focal attraction site.

Data Layer Summarized	#	Average Condition Class* (± SD)	Average Length (m) (± SD)	Average Area (m^2) (± SD)	Total Length (m)	Total Area (m^2)
Social Trails	46	3.26 (± 1.20)	18 (± 15)	—	806	—
Impacted Site[1]	33	4.00 (± 1.30)	—	67 (± 66)	—	2,222
Bare Ground	19	5.00 (± 0.00)	—	70 (± 65)	—	1,328
Impacted Area	14	2.64 (± 0.84)	—	64 (± 69)	—	893
Trailhead Impacts	0	—	—	—	—	—

[1]*Impacted Site analyses include data from Bare Ground and Impacted Area layers.*

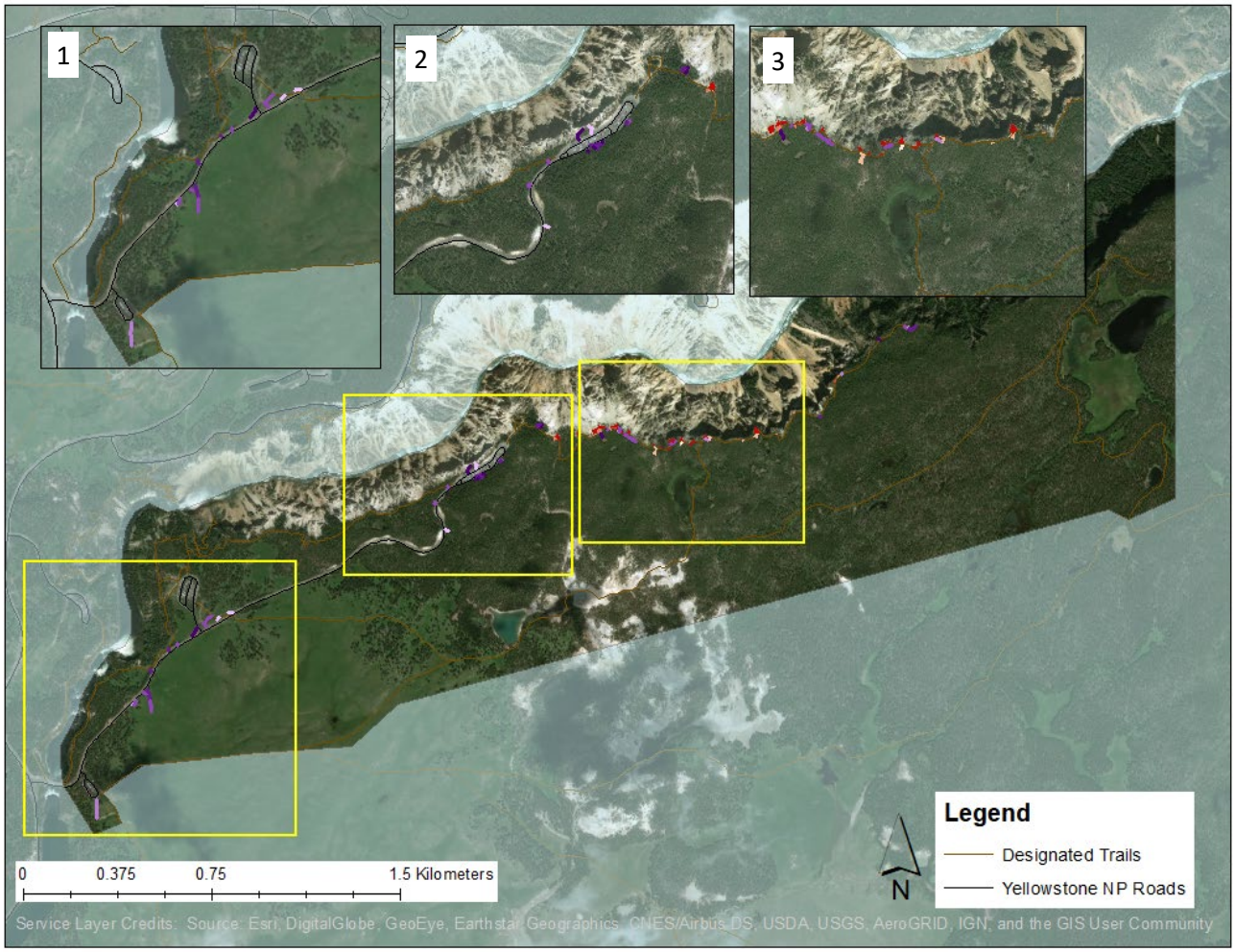

Figure 6.2a. Resource impact locations and levels of impact in the Artist Point focal location site analysis area (non-shaded in this figure). Inset maps are shown in greater detail in Figures 6.2b – 6.2d with the analysis shown as a shaded background.

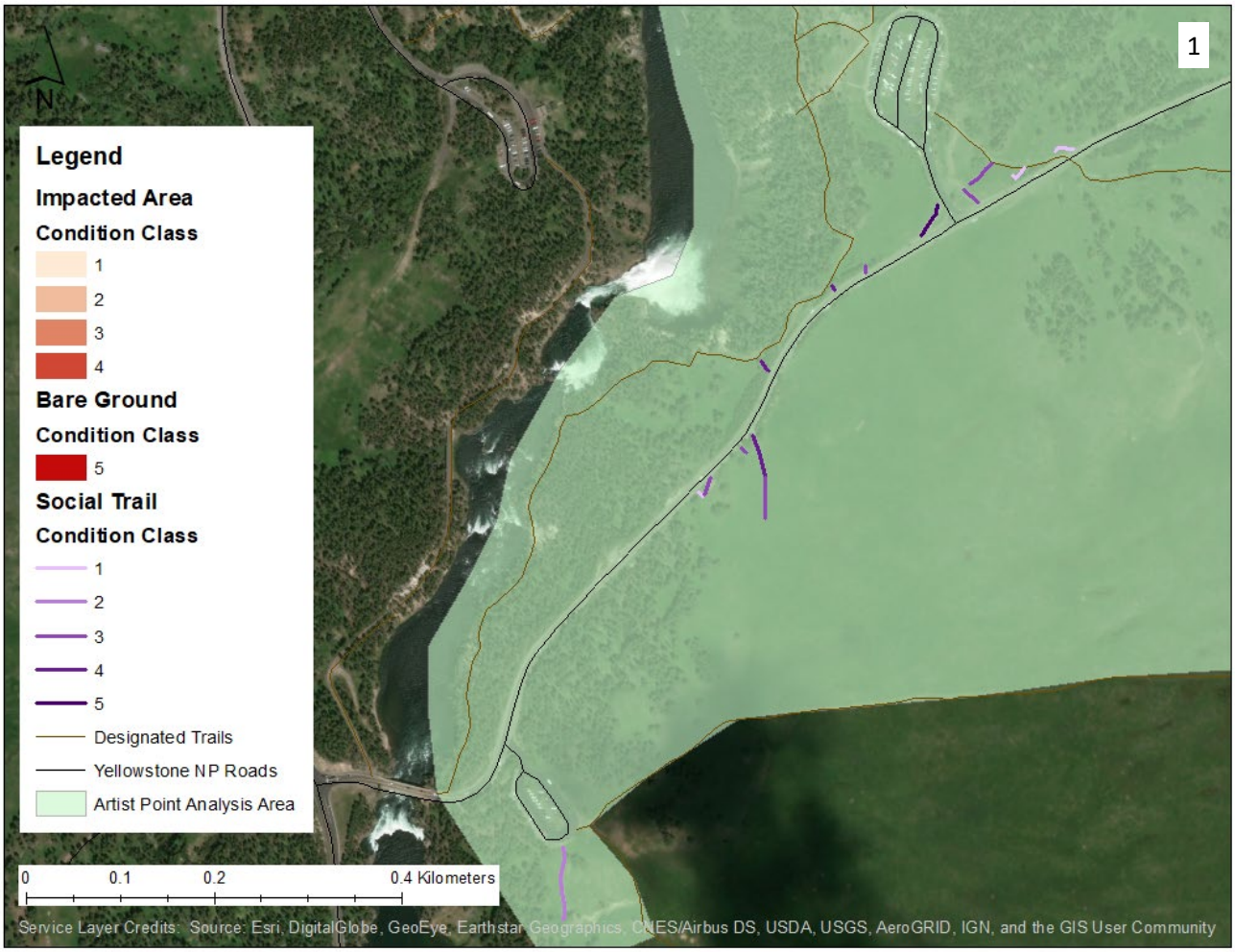

Figure 6.2b. Resource impact locations and levels of impact in the southwest corner of the Artist Point focal location site analysis area (shaded area).

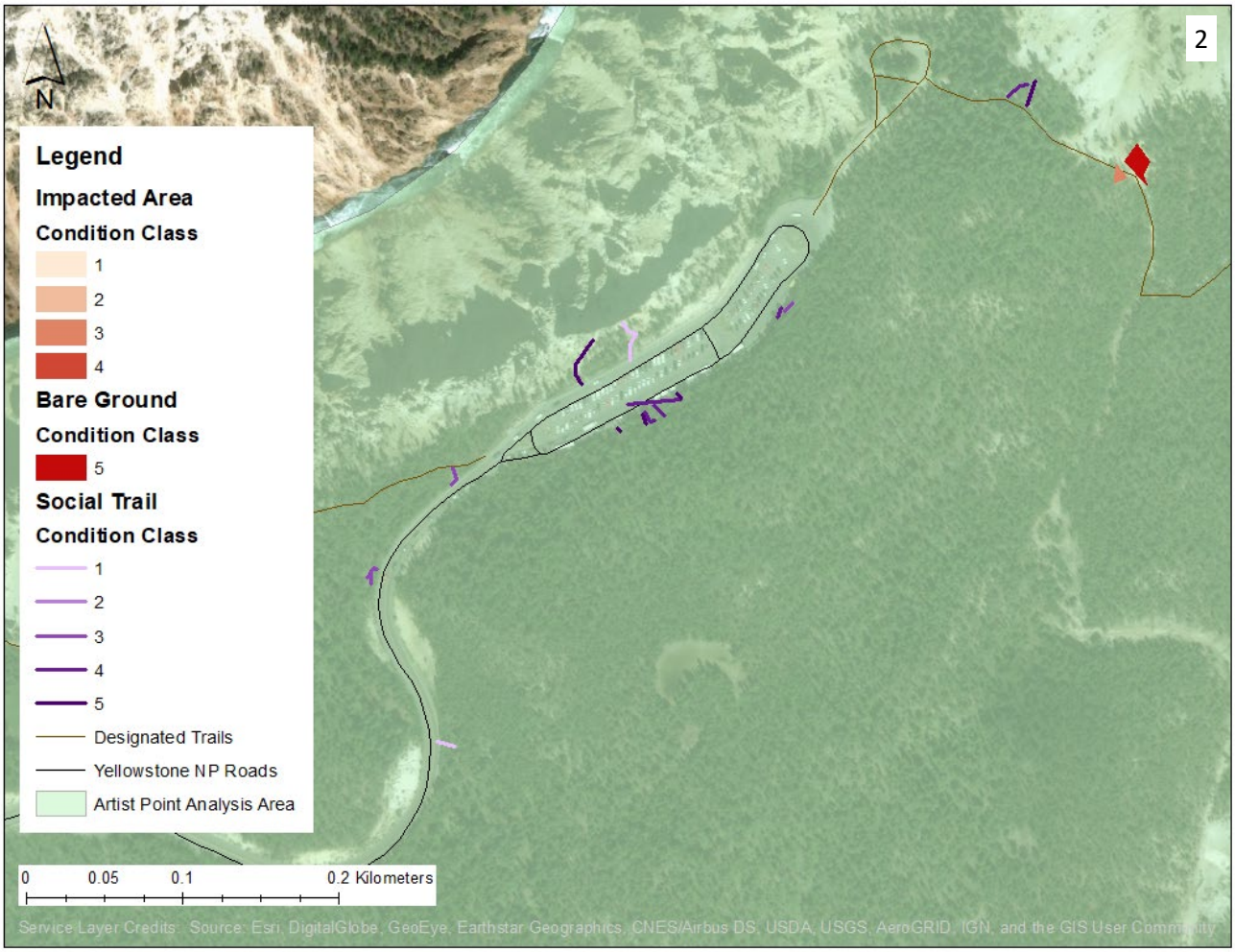

Figure 6.2c. Resource impact locations and levels of impact in the central part of the Artist Point focal location site analysis area (shaded area).

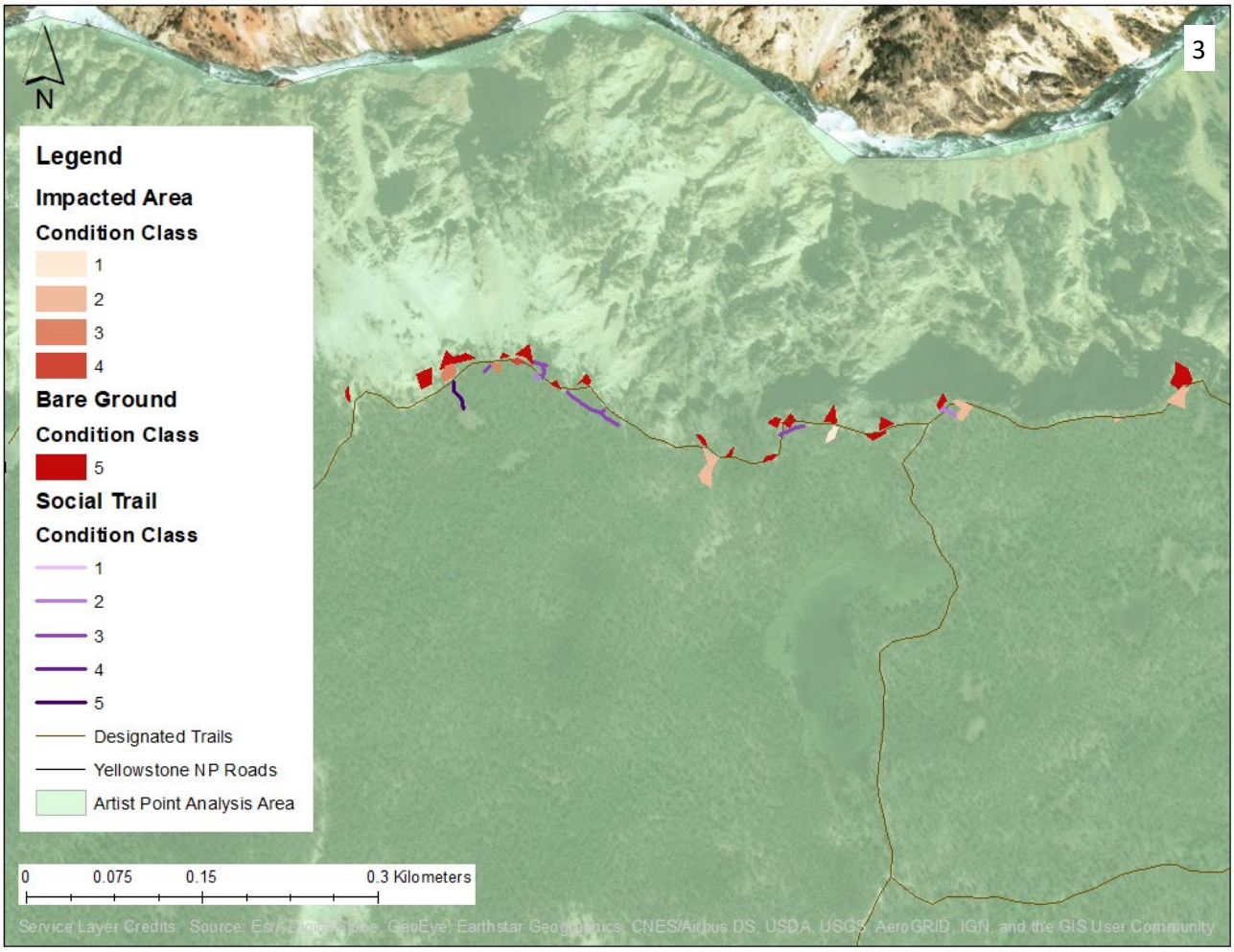

Figure 6.2d. Resource impact locations and levels of impact in the eastern part of the Artist Point focal location site analysis area (shaded area).

In the Fairy Falls focal location site analysis area, recreation impacts are concentrated near the viewing platforms for Midway Geyser Basin (Figure 6.3a – 6.3c). Bare ground patches are the most frequently occurring recreation impact, with 151 bare ground patches documented in the analysis area (Table 6.3). Bare ground patches also comprise the largest total area with 18,670 square meters of bare ground area occurring in the Fairy Falls analysis area. Based on average condition class, bare ground impacts are severe at Fairy Falls, with social trail and impacted area impacts being moderate. Only one impacted areas near a trailhead was documented in the Fairy Falls location analysis area, comprising 1803 square meters. This summary provides an excellent baseline since these data were collected *before* the new Grand Prismatic Overlook trail was created – the new trail may alleviate pressure on social trails along the Fairy Falls trail from visitor seeking an overlook view on Midway Geyser Basin.

Table 6.3. The level and extent of resource impacts recorded in the Fairy Falls focal attraction site.

Data Layer Summarized	#	Average Condition Class* (± SD)	Average Length (m) (± SD)	Average Area (m^2) (± SD)	Total Length (m)	Total Area (m^2)
Social Trails	34	3.03 (± 0.97)	68 (± 69)	—	2309	—
Bare Ground	151	5.00 (± 0.00)	—	124 (± 354)	—	18670
Trailhead Impacts	1	1 (—)	—	1803 (—)	—	1803

[1]*Impacted Site analyses include data from Bare Ground and Impacted Area layers.*

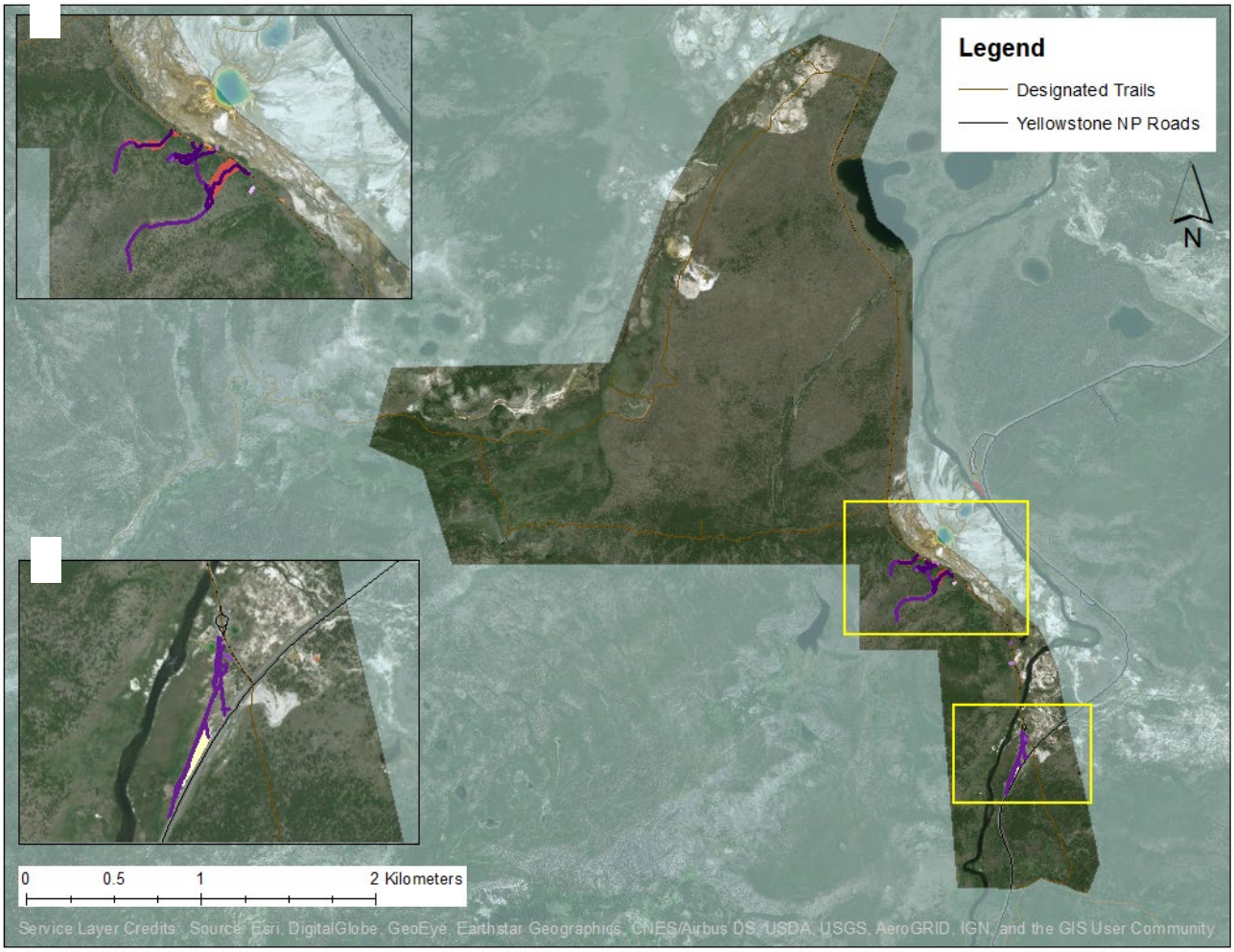

Figure 6.3a. Resource impact locations and levels of impact in the Fairy Falls focal attraction site analysis area (shown in non-shaded area here). Inset maps are shown in greater detail in Figures 6.3b – 6.3c with the analysis shown as a shaded background.

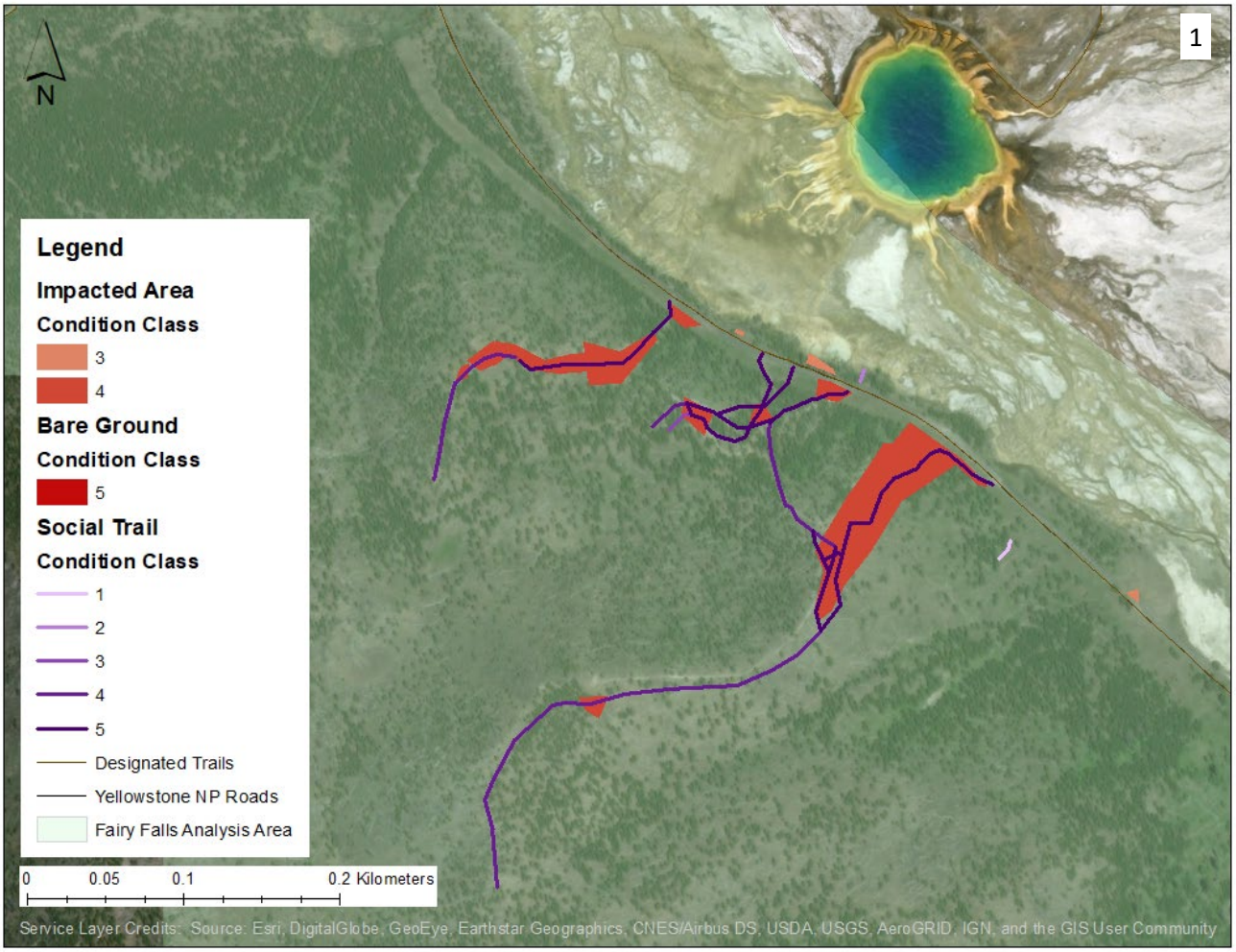

Figure 6.3b. Resource impact locations and levels of impact near what is now the Grand Prismatic Overlook trail in the Fairy Falls focal attraction site analysis area (shown as shaded area).

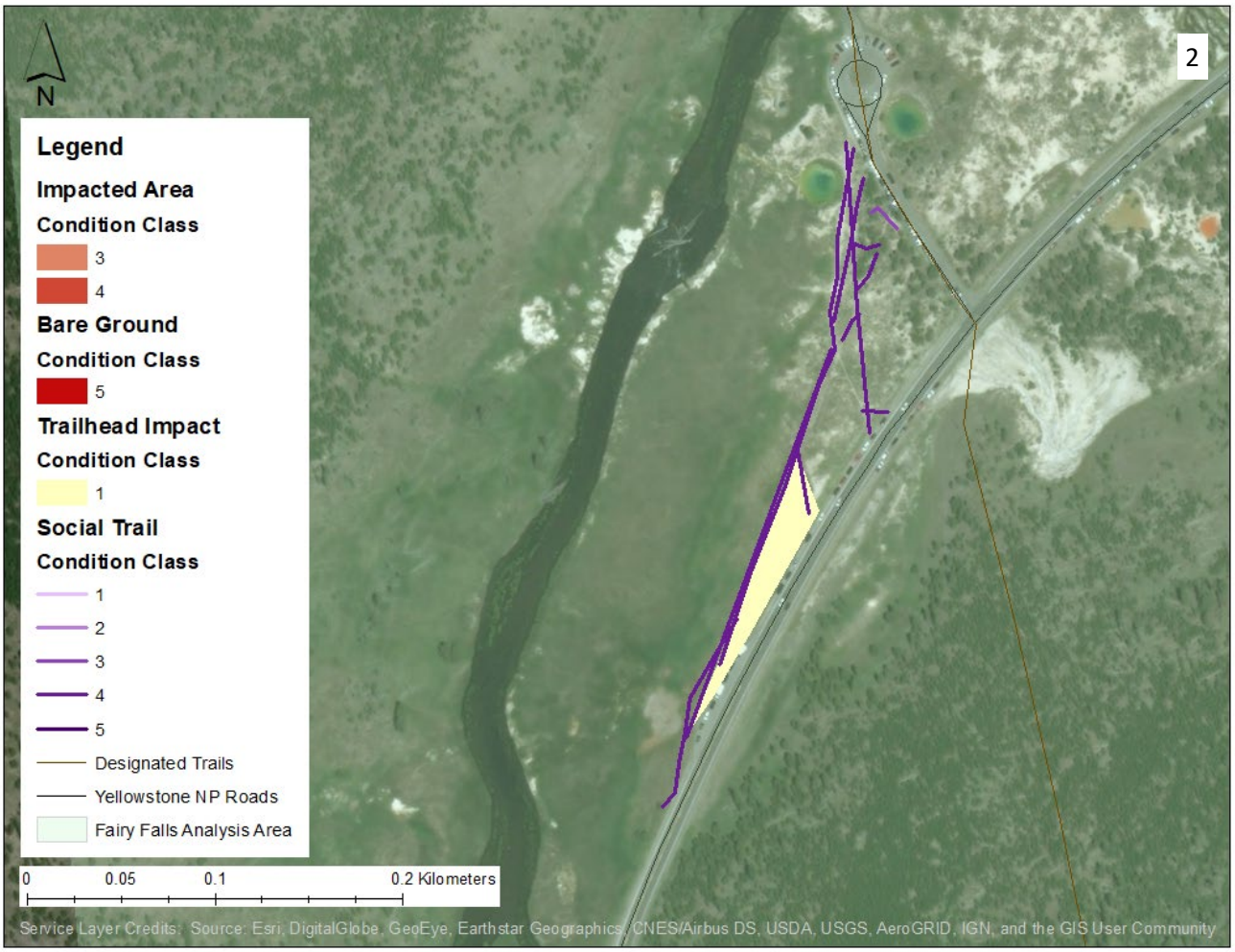

Figure 6.3c. Resource impact locations and levels of impact associated with the parking lot in the Fairy Falls focal attraction site analysis area (shown as shaded area).

In the Midway Geyser Basin focal attraction site analysis area, recreation impacts tend to cluster around the parking area and access point to the viewing boardwalk (Figures 6.4a – 6.4d). Social trails are the most frequently occurring recreation impact, with 152 social trails documented in the analysis area (Table 6.4). Despite the substantially lower frequency of occurrence for patches of bare ground, impacted areas, and impacted areas near trailhead, these types of recreation impacts have a comparatively large footprint in the Midway Geyser Basin focal attraction site — the average area of these recreation impacts ranges from 471 square meters to 953 square meters. Based on average condition class ratings, social trails, impacted areas, and impacted areas near trailheads have comparable levels of moderate to severe impacts, with average condition class ratings above 3.0 for each of these impact types.

Table 6.4. The level and extent of resource impacts recorded in the Midway Geyser Basin focal attraction site.

Data Layer Summarized	#	Average Condition Class* (± SD)	Average Length (m) (± SD)	Average Area (m^2) (± SD)	Total Length (m)	Total Area (m^2)
Social Trails	152	3.73 (± 1.02)	44 (± 69)	—	6670	—
Impacted Site[1]	12	3.67 (± 0.98)	—	471 (± 852)	—	5656
Bare Ground	2	5.00 (± 0.00)	—	447 (± 472)	—	895
Impacted Area	10	3.40 (± 0.84)	—	476 (± 929)	—	4761
Trailhead Impacts	6	3.33 (± 0.52)	—	953 (± 1580)	—	5719

[1]*Impacted Site analyses include data from Bare Ground and Impacted Area layers.*

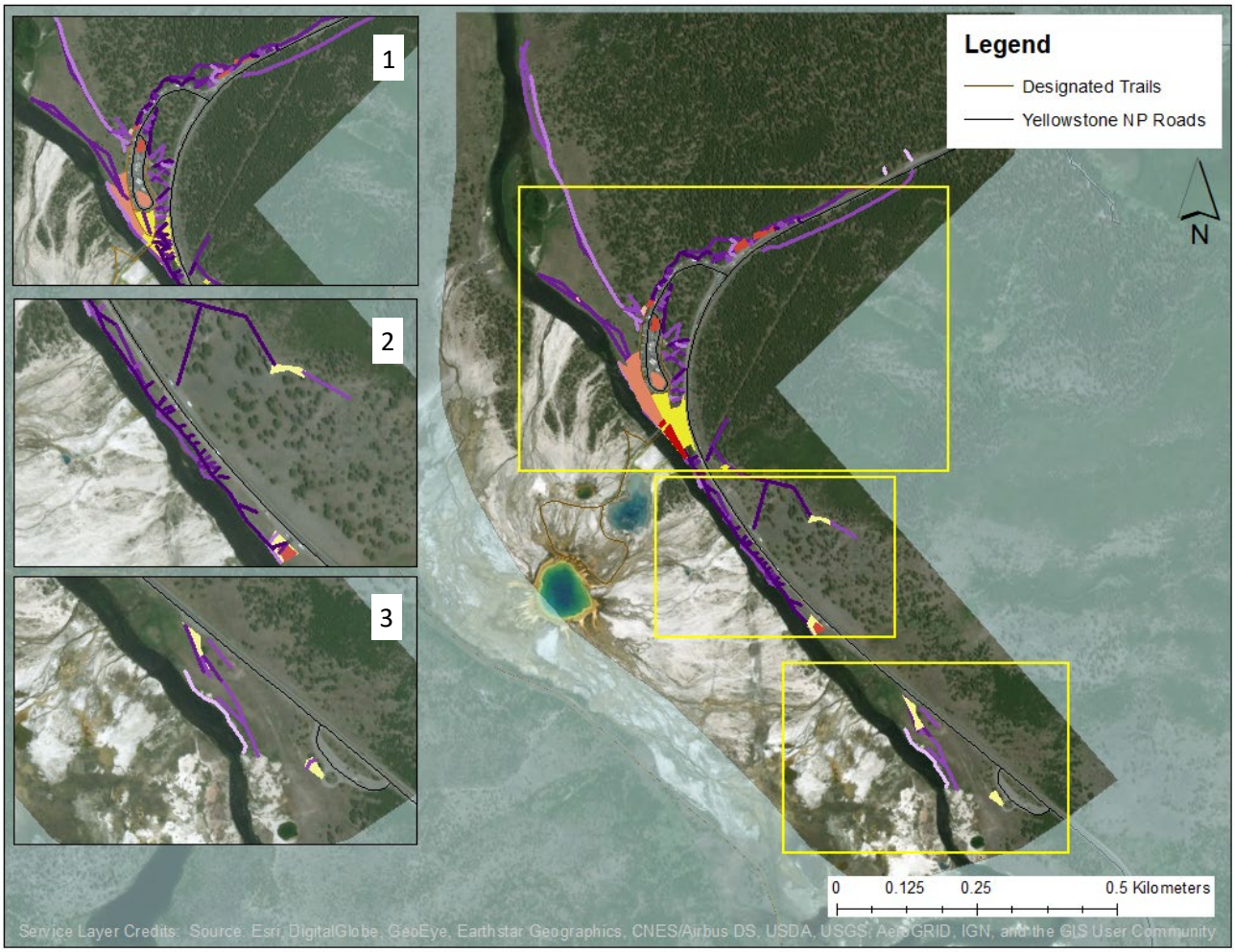

Figure 6.4a. ***Resource impact locations and levels of impact in the Midway Geyser Basin focal attraction site analysis area (shown in non-shaded area here). Inset maps are shown in greater detail in Figures 6.4b – 6.4d with the analysis shown as a shaded background.***

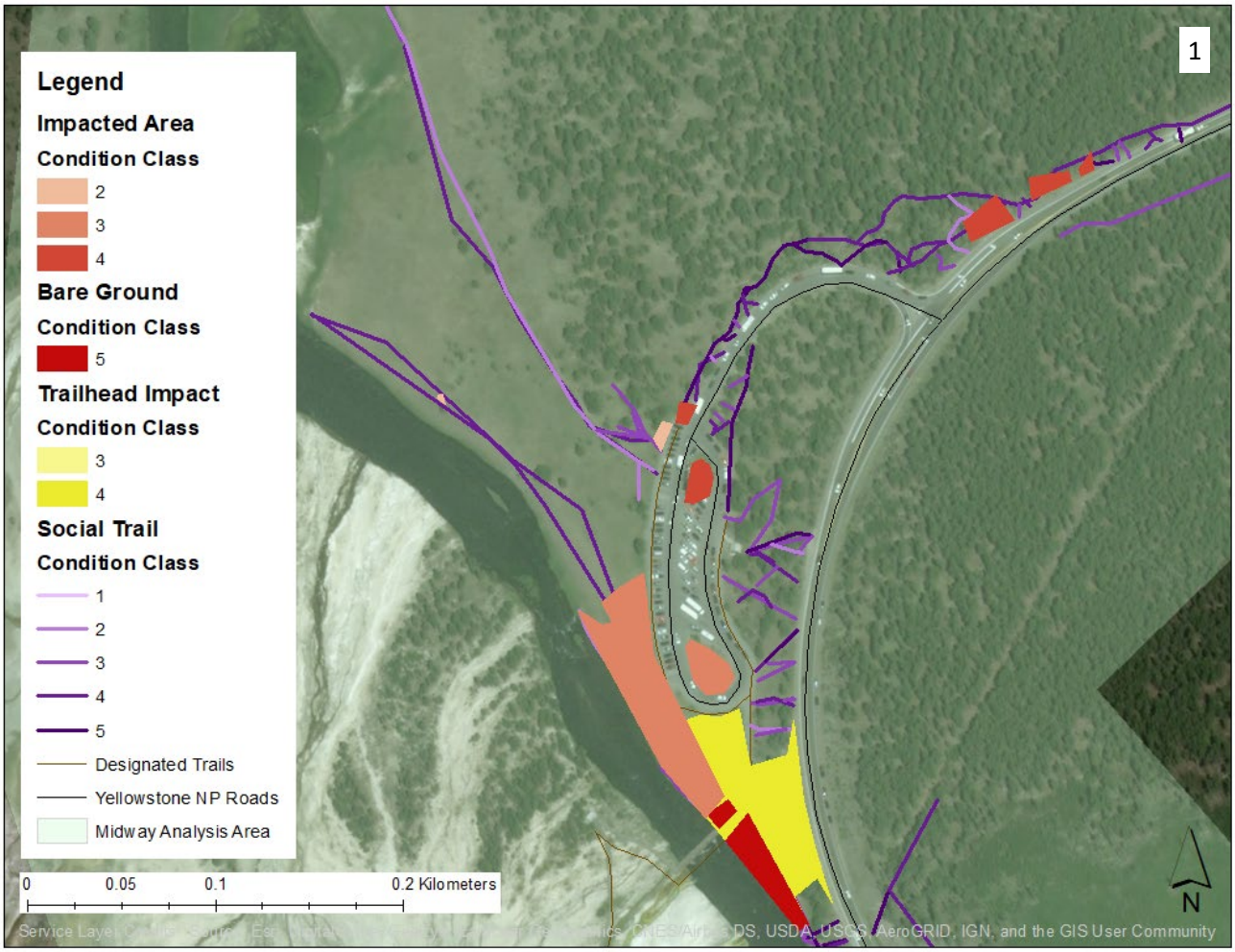

Figure 6.4b. Resource impact locations and levels of impact associated with the roadway and parking lot in the northern area of the Midway Geyser Basin focal attraction site analysis area (shown in shaded area).

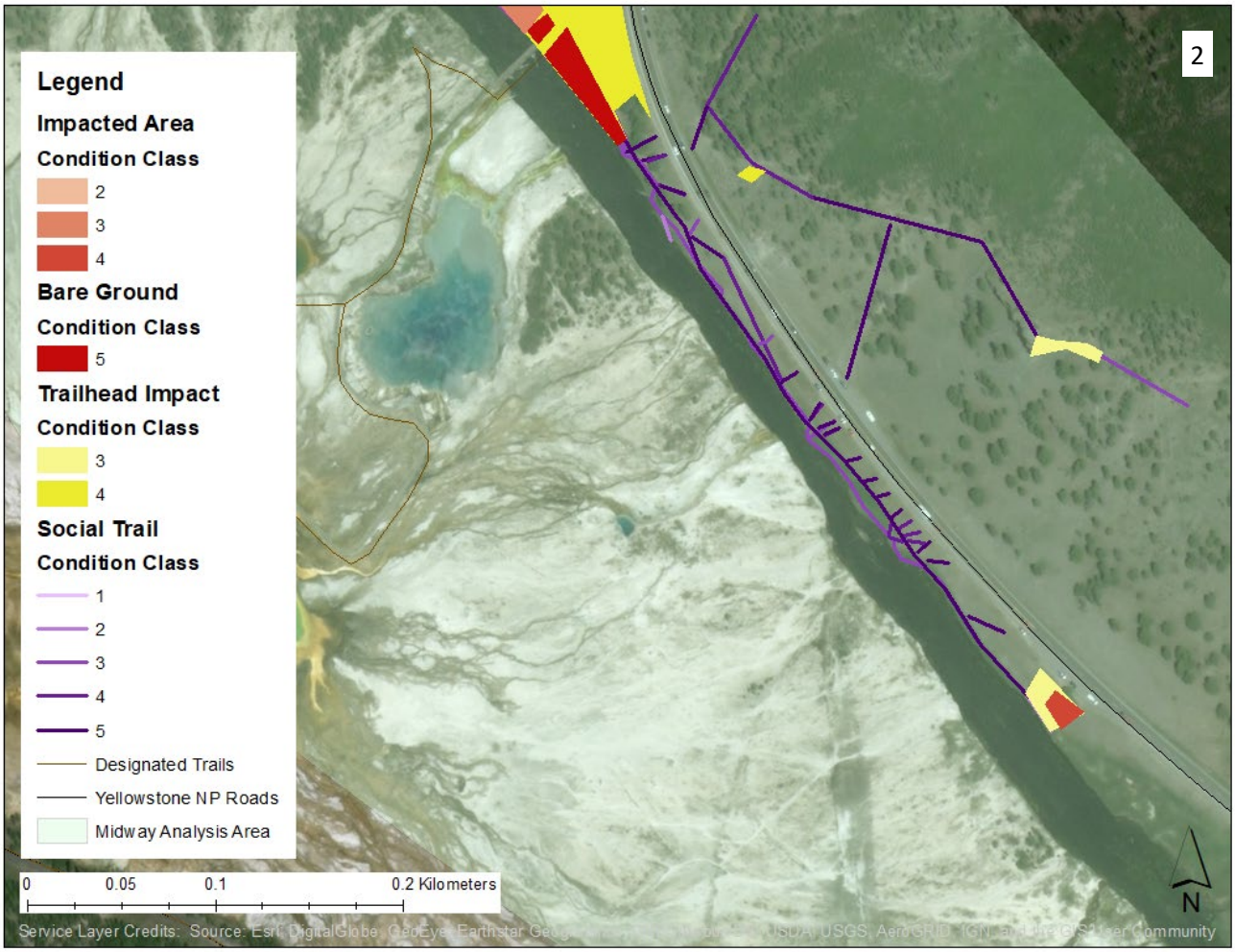

Figure 6.4c. Resource impact locations and levels of impact associated with the roadway and parking lot in the central area of the Midway Geyser Basin focal attraction site analysis area (shown in shaded area).

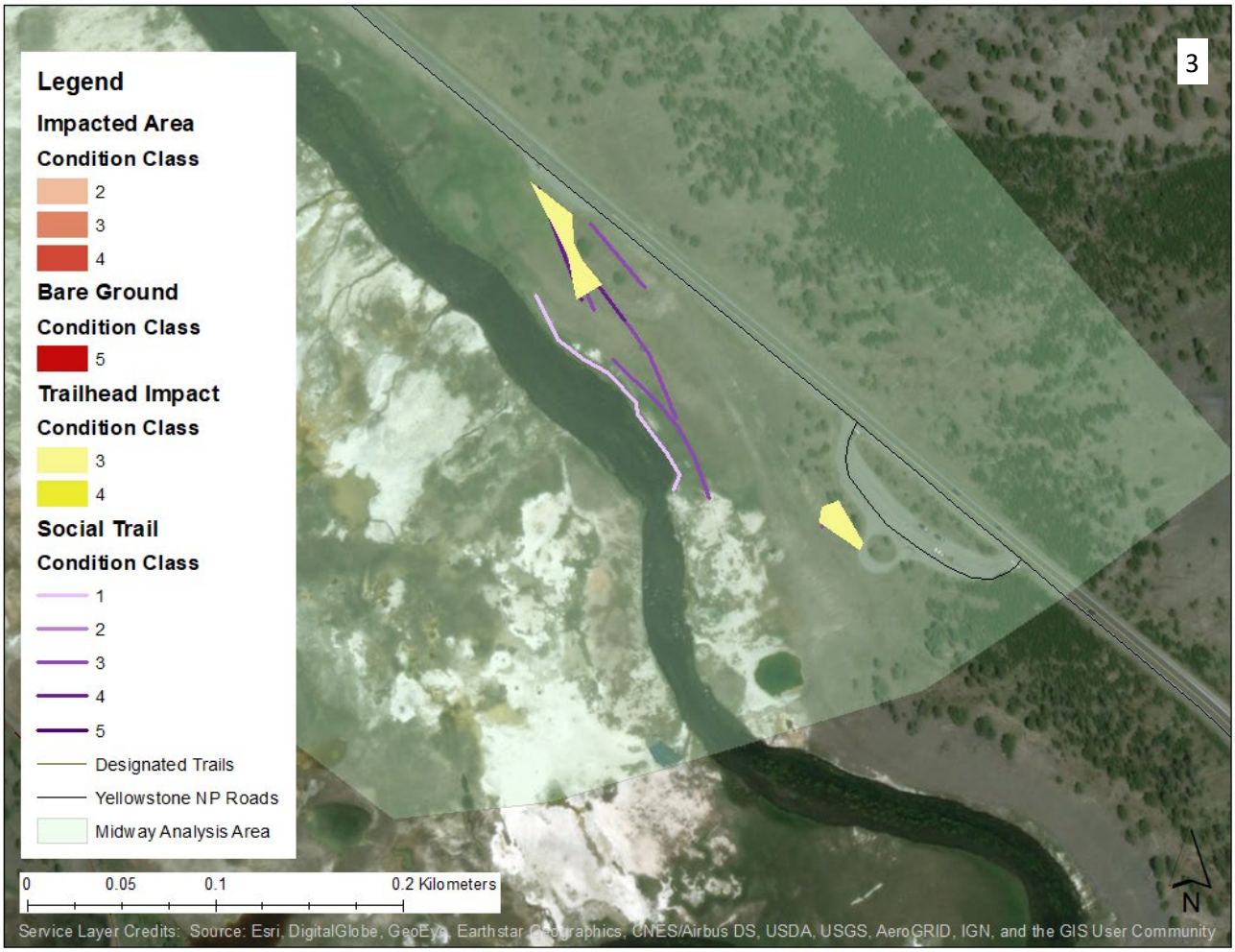

Figure 6.4d. Resource impact locations and levels of impact associated with the roadway and parking lot in the southern area of the Midway Geyser Basin focal attraction site analysis area (shown in shaded area).

In the Norris Geyser Basin focal attraction site analysis area, recreation impacts are spread throughout the analysis area, with impacts occurring near park roads or designated trails (Figure 6.5a – 6.5c). Social trails are the most frequently occurring recreation impact, with 44 social trails documented in the analysis area (Table 6.5). Impacted area sites and social trails have moderate impact at Norris Geyser Basin, with average condition class ratings for these locations being between 2.5 and 3.0. The number of bare ground patches is minimal in the Norris Geyser Basin focal location analysis area, with only 7 documented bare ground patches. However, the extent, defined by square meters of patches, of the bare grounds patches is comparable to the impacted area patches with the bare ground locations comprising 237 square meters of impact and the impacted area locations comprising 308 square meters of impact. Additionally, bare ground patches area on average larger than impacted area patches. No impacted areas near trailheads were documented in the Norris Geyser Basin focal location analysis area.

Table 6.5. The level and extent of resource impacts recorded in the Norris Geyser Basin focal location of Yellowstone National Park.

Data Layer Summarized	#	Average Condition Class* (± SD)	Average Length (m) (± SD)	Average Area (m^2) (± SD)	Total Length (m)	Total Area (m^2)
Social Trails	44	2.75 (± 1.14)	12 (± 12)	—	524	—
Impacted Site[1]	26	3.23 (± 1.49)	—	21 (± 30)	—	545
Bare Ground	7	5.00 (± 0.00)	—	34 (± 50)	—	237
Impacted Area	19	2.58 (± 1.17)	—	16 (± 18)	—	308
Trailhead Impacts	0	—	—	—	—	—

[1]*Impacted Site analyses include data from Bare Ground and Impacted Area layers.*

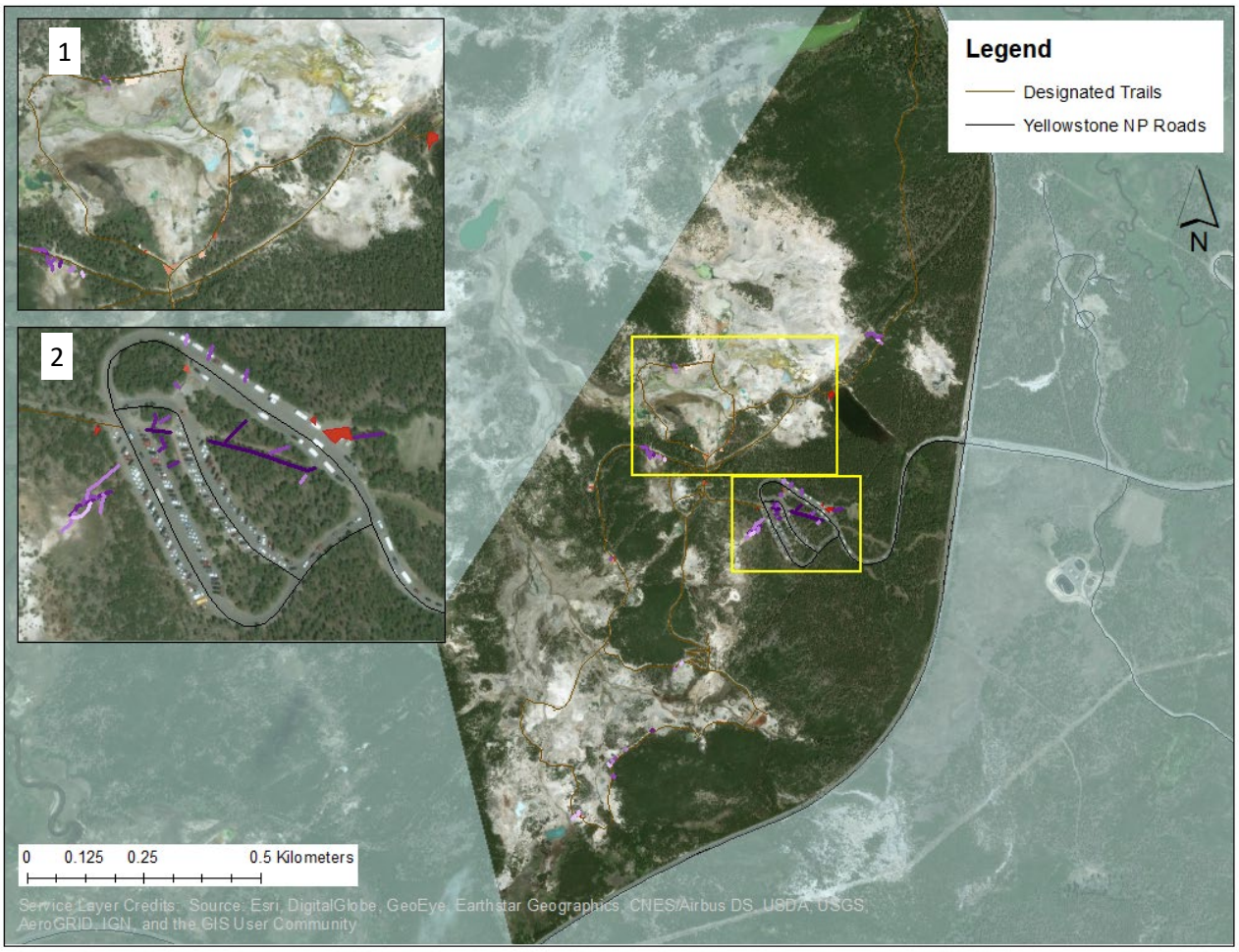

Figure 6.5a. Resource impact locations and levels of impact in the Norris Geyser Basin focal attraction site analysis area (shown here as the non-shaded area). Inset maps are shown in greater detail in Figures 6.5b – 6.5c with the analysis shown as a shaded background.

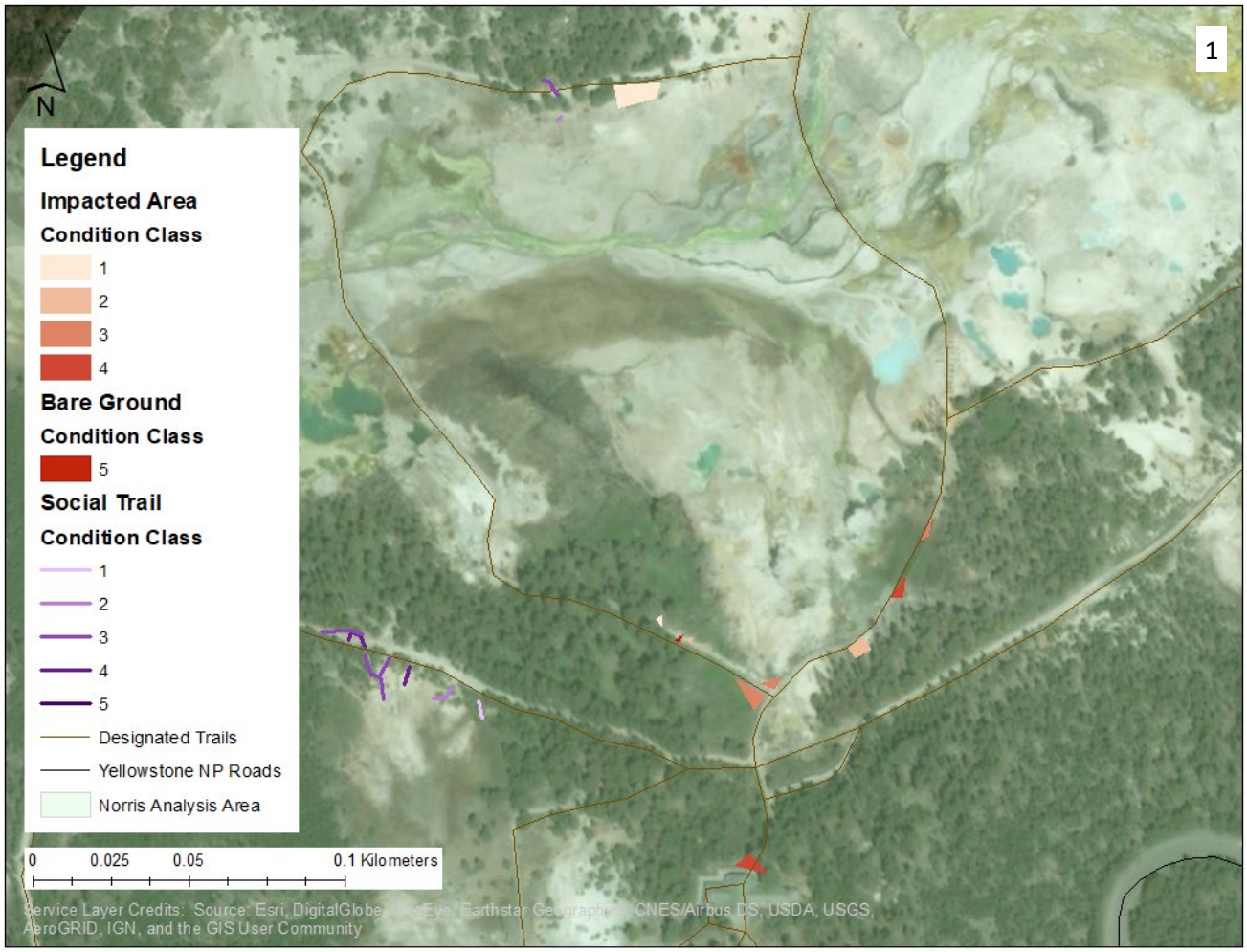

Figure 6.5b. Resource impact locations and levels of impact around the Porcelain Geyser Basin in the Norris Geyser Basin focal attraction site analysis area (shown here in the shaded area).

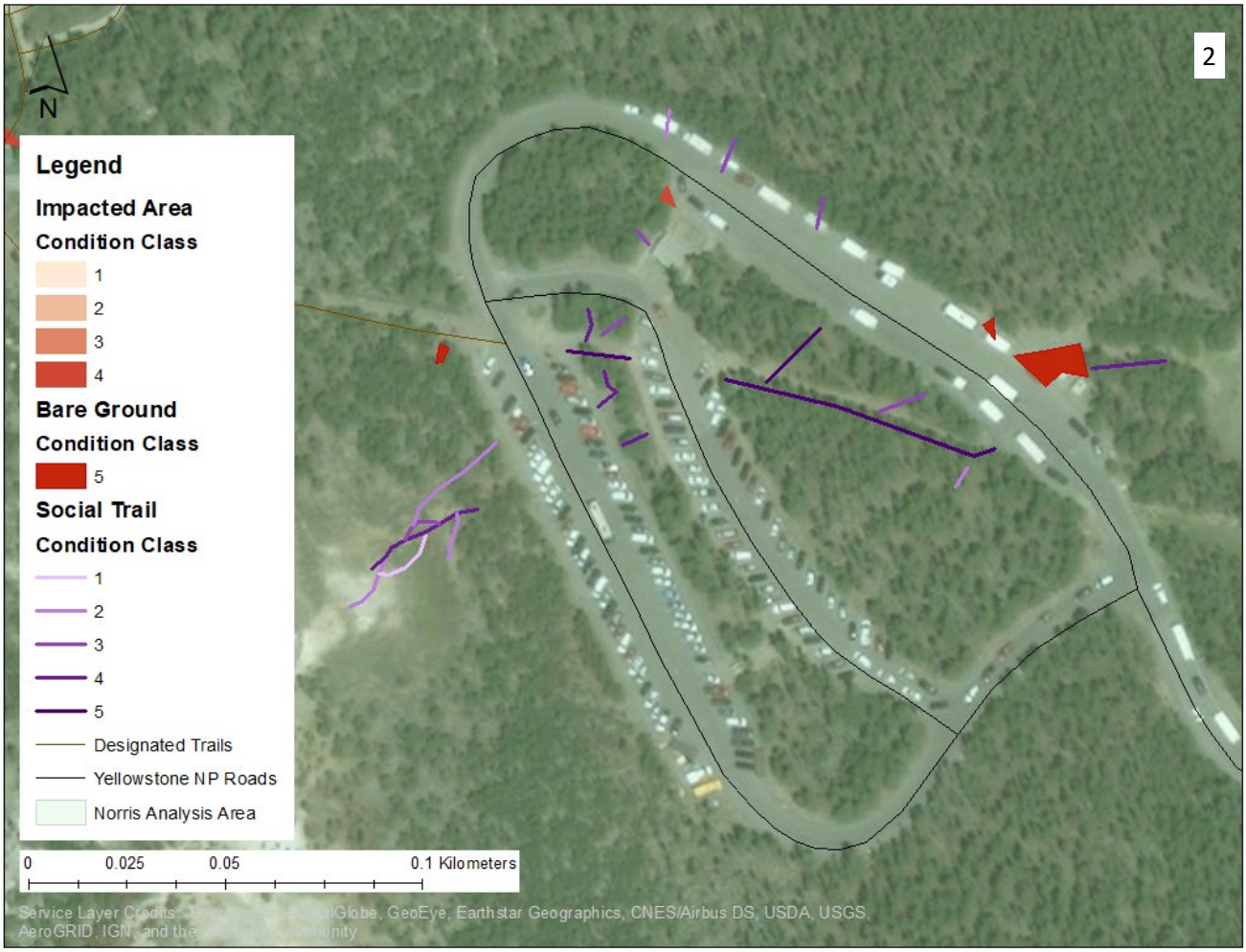

Figure 6.5c. Resource impact locations and levels of impact around the parking lot in the Norris Geyser Basin focal attraction site analysis area (shown here in the shaded area).

In the Old Faithful focal location site analysis area, recreation impacts are concentrated in three areas: on the west and east sides of the parking area and north of Old Faithful along the designated trail (6.6a – 6.6d) Social trails are the most frequently occurring recreation impact, with 73 social trails documented in the analysis area (Table 6.6). Based on average condition class, bare ground impacts are severe at Old Faithful, with social trail and impacted area impacts being moderate to severe with average ratings about 3.0. Two impacted areas near a trailhead were documented in the Old Faithful focal location analysis area, one at the Hamilton Store and one at the Log Cabins. These two impacted areas near a trailhead comprised a total of 677 square meters of impacted area.

Table 6.6. The level and extent of resource impacts recorded in the Old Faithful focal location in Yellowstone National Park.

Data Layer Summarized	#	Average Condition Class* (± SD)	Average Length (m) (± SD)	Average Area (m^2) (± SD)	Total Length (m)	Total Area (m^2)
Social Trails	73	3.51 (± 1.29)	32 (± 33)	—	2305	—
Impacted Site[1]	32	3.84 (± 1.11)	—	161 (± 194)	—	5138
Bare Ground	10	5.00 (± 0.00)	—	129 (± 162)	—	1288
Impacted Area	22	3.32 (± 0.95)	—	175 (± 209)	—	3850
Trailhead Impacts[2]						
Hamilton Store	—	1 (—)	—	—	—	520
Log Cabins	—	5 (—)	—	—	—	157

[1]*Impacted Site analyses include data from Bare Ground and Impacted Area layers.*

[2]*Due to low number of sites at this location, data for each trailhead impact site is reported independently.*

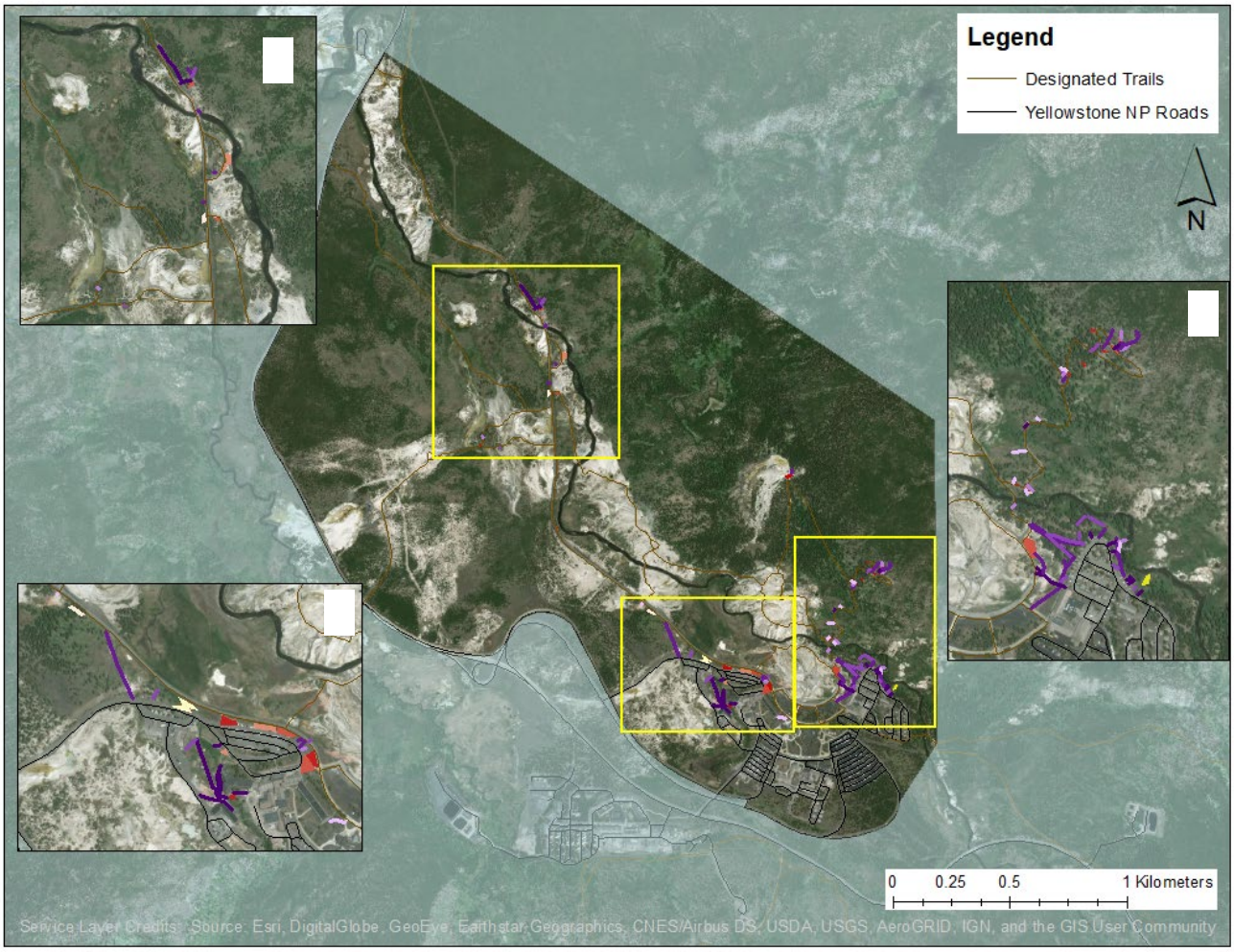

Figure 6.6a. Resource impact locations and levels of impact in the Old Faithful focal attraction site analysis area. Inset maps are shown in greater detail in Figures 6.6b – 6.6d with the analysis shown as a shaded background.

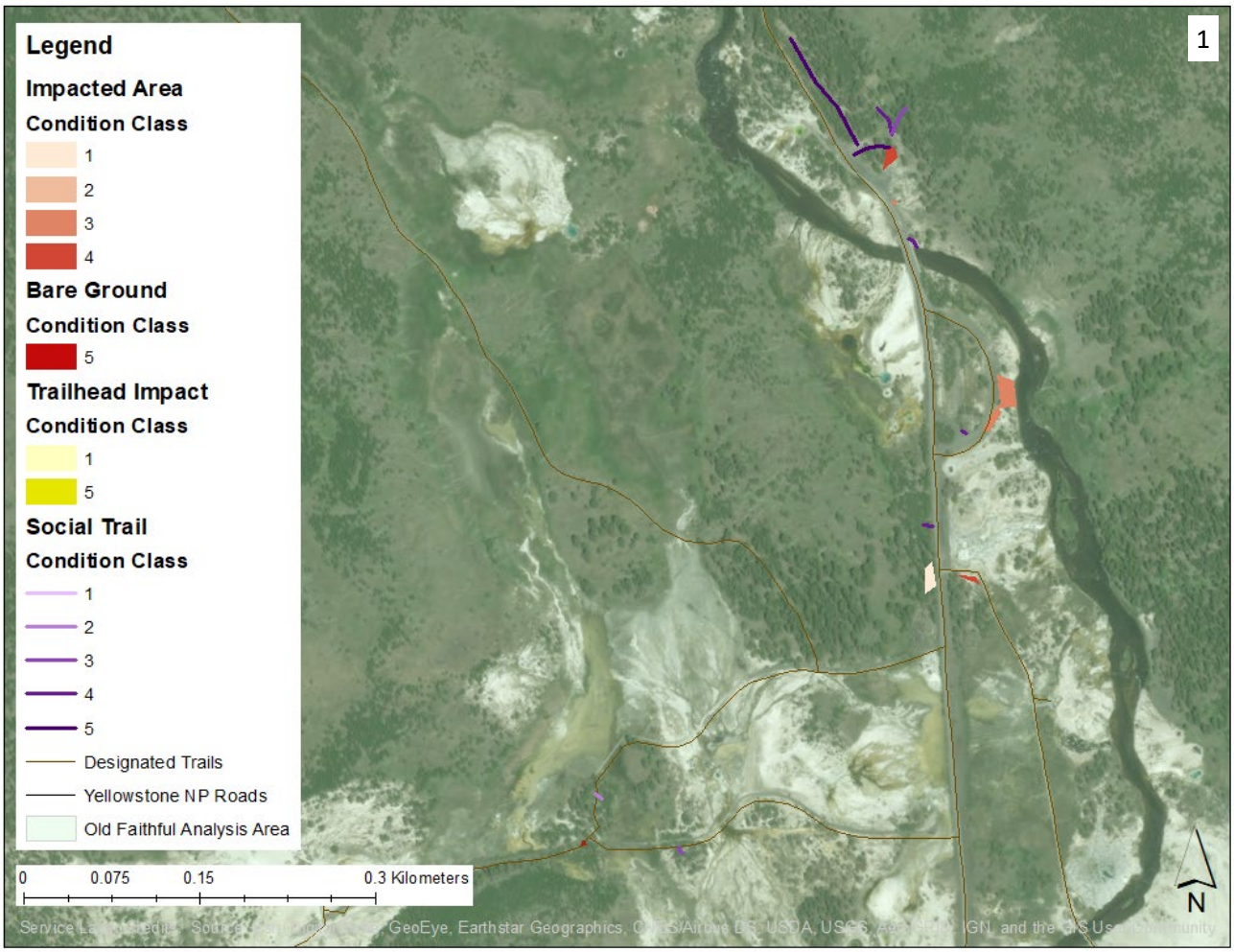

Figure 6.6b. Resource impact locations and levels of impact northwest of the Old Faithful focal attraction site analysis area (shown here in the shaded area).

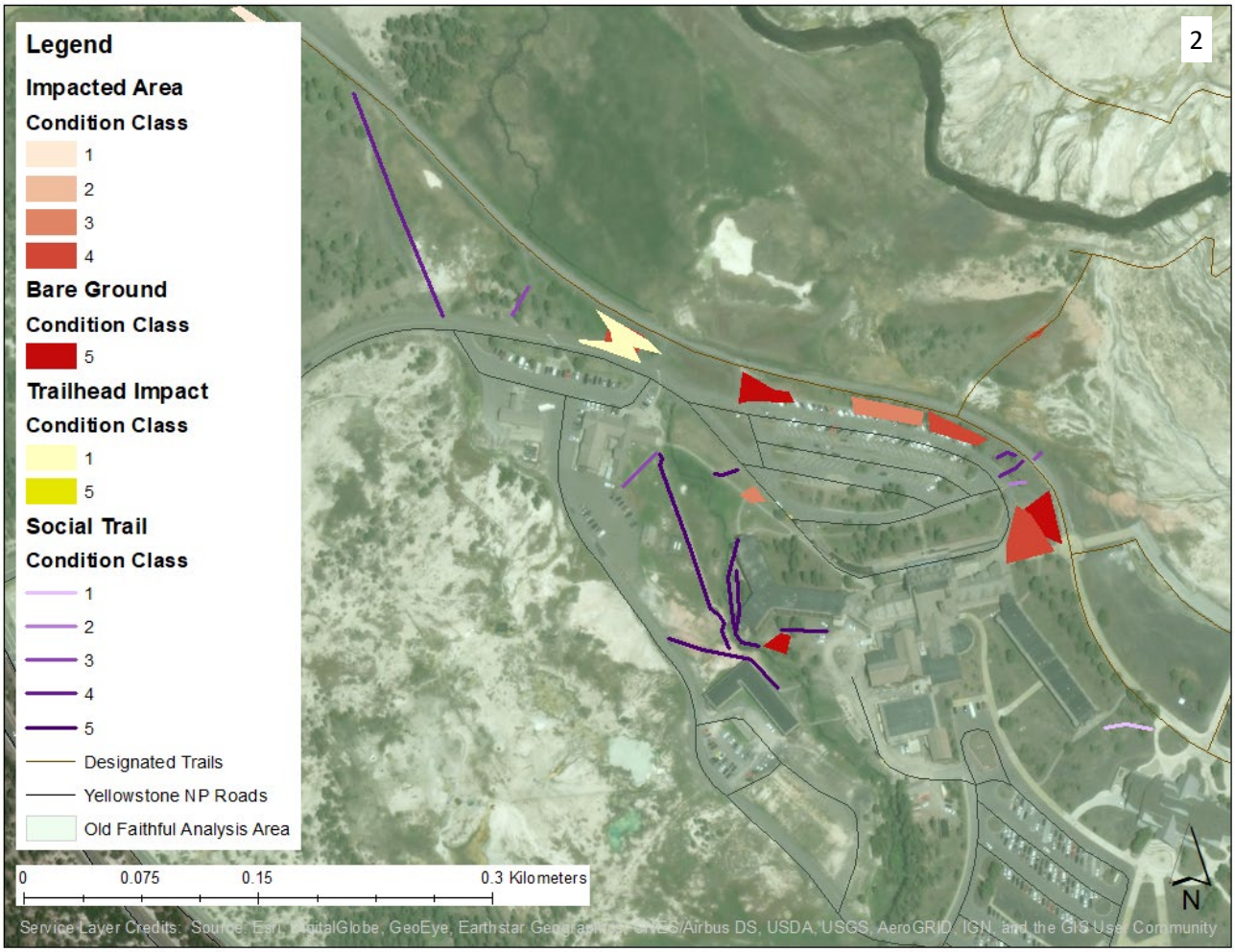

Figure 6.6c. Resource impact locations and levels of impact associated with the parking lot in the western portion of the Old Faithful focal attraction site analysis area (shown here in the shaded area).

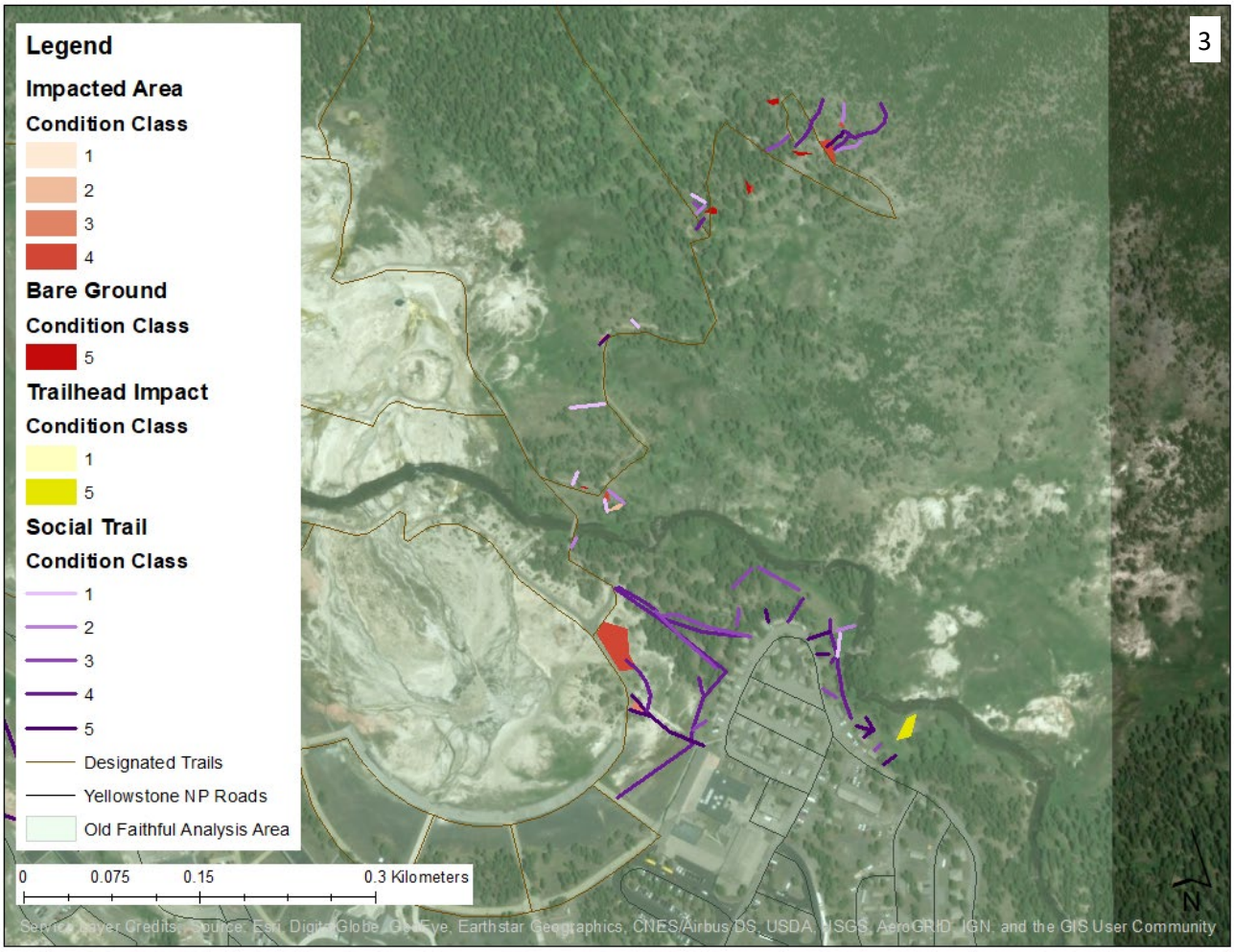

Figure 6.6d. Resource impact locations and levels of impact in the eastern section of the Old Faithful focal attraction site analysis area (shown here in the shaded area).

Data Integration

This section of the report presents examples of ways the data collected by the YCC Crews can be combined. Figures 7.1. and 7.2 compare visitor use across the focal attraction sites. For the average number of vehicles parked at each focal attraction site across the day, all sites – except for Fairy Falls – appear to reach their peak of use at 11:00am to 12:00pm (Figure 7.1). Use at all parking lots remains high through the end of data collection by the YCC Crews (15:00 to 16:00).

Norris Geyser Basin has the largest available parking in the designated parking lot, followed by Fairy Falls, Artist Point, and Midway Geyser Basin (Figure 7.1). Interestingly, despite having the smallest parking lot – Midway Geyser Basin had the highest number of estimated visitors at the trailhead compared to the other focal attraction sites (Figure 7.2). Comparatively, Norris Geyser Basin and Old Faithful had the lowest use estimate at the counter locations for the five focal attraction sites examined by the YCC Crews. Norris Geyser Basin and Old Faithful may have been "busier" overall based on parking lot counts (for Norris Geyser Basin only) and visitor use estimation, but these two focal attraction sites have a larger trail system in which to disperse visitor. At Midway Geyser Basin, Artist Point, and Fairy Falls – all visitors are funneled into the same trail system from the parking lot – resulting in higher use estimates at the trail counter location.

The dynamics of Midway Geyser Basin, Artist Point, and Fairy Falls – large numbers of visitors entering a fairly limited trail system – resulted in these three sites having a higher concentration of visitors on the trail compared to Norris Geyser Basin and Old Faithful (Table 7.2). Combining the encounter data with the total trail length hiked while recording encounters, shows that Artist Point has 6 visitors per 10 meters of trail. Midway Geyser Basin and Fairy Falls both have 5 visitors per 10 meters of trail (Table 7.2).

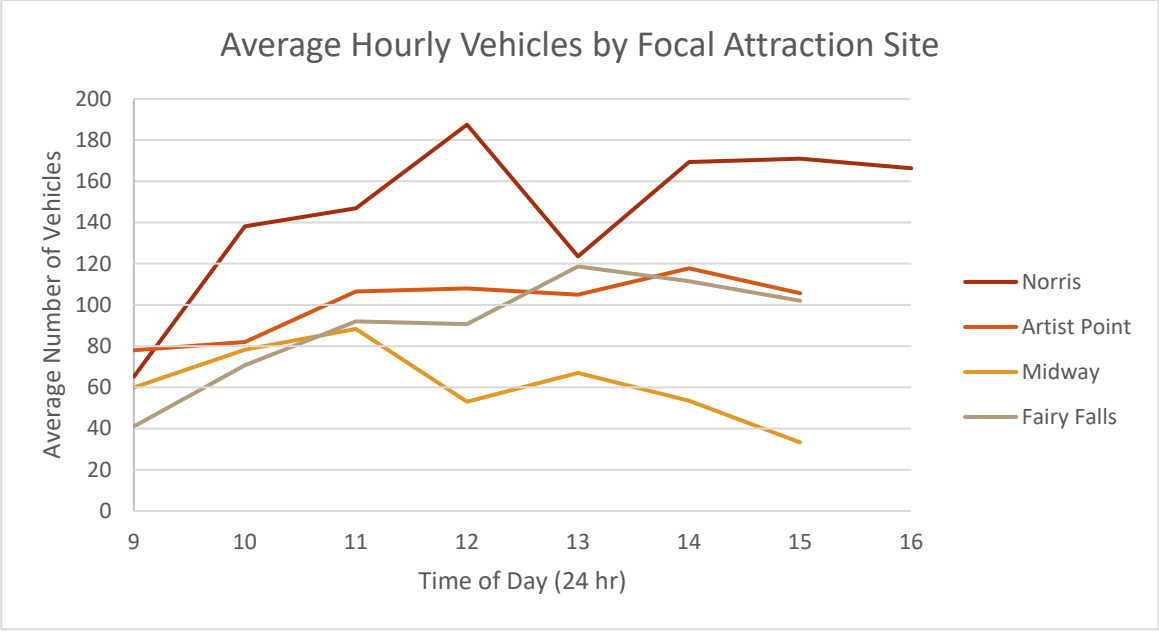

Figure 7.1: Total Vehicles in Parking Lots for all focal attraction sites.

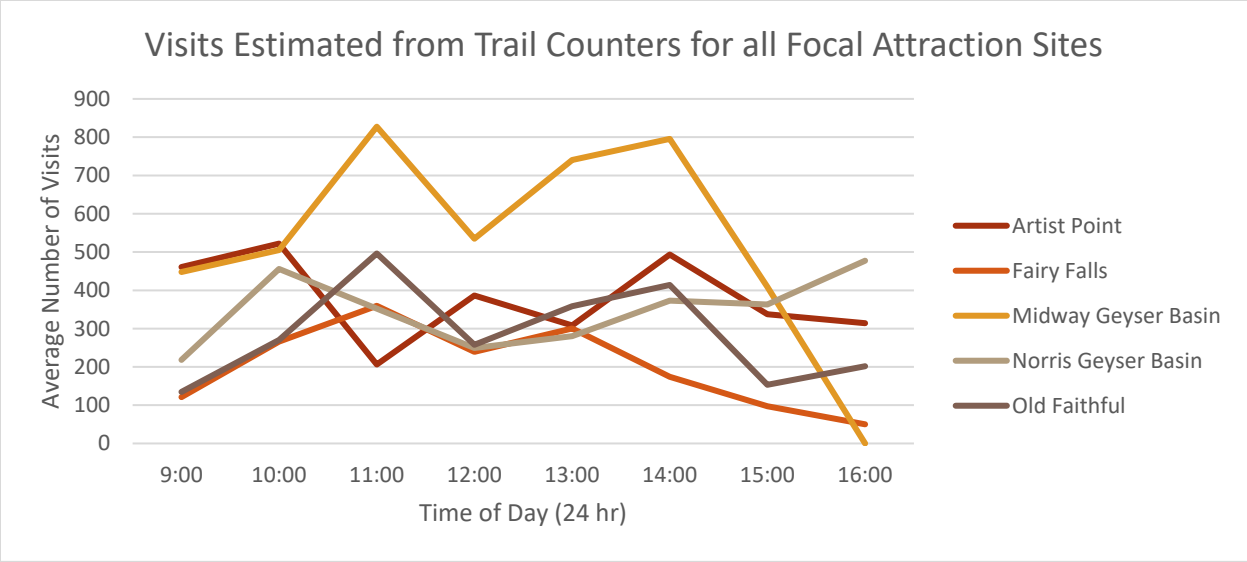

Figure 7.2: Average number of total visits (i.e. counts) per hour as estimated by automatic trail counters located at all focal attraction sites.

Table 7.1: Summary of encounters for length of trail at each focal attraction site.

Focal Attraction Site	Focal Area Trail Length (m)	Average Number of Encounters	Encounters/10 meters of trail
Artist Point	227	127	6
Fairy Falls	589	298	5
Midway Geyser Basin	739	337	5
Norris Geyser Basin	710	169	2
Old Faithful	1052	347	3

Figures 7.3 through 7. 6 demonstrate how overlays of the various spatial data collected by the YCC Crews and YELL staff can help highlight patterns of visitor behavior and resource impacts. For example, at Artist Point (Figure 7.3), there is little social trailing associated with the high densities of visitor use – but the waypoints mapped overlap with the areas of high density visitor use. Comparatively, in Figure 7.5 which shows Midway Geyser Basin – social trailing appears to be associated with parking along the roadway when parking is not available in the designated parking lot and not high densities of visitor use on the trail itself. This can indicate that the boardwalk is doing a relatively good job at keeping people on trail in the hydrothermal area. At Midway Geyser Basin, like at Artist Point, higher densities of visitor use overlaps with higher densities of waypoints – especially at the Grand Prismatic Spring overlook area.

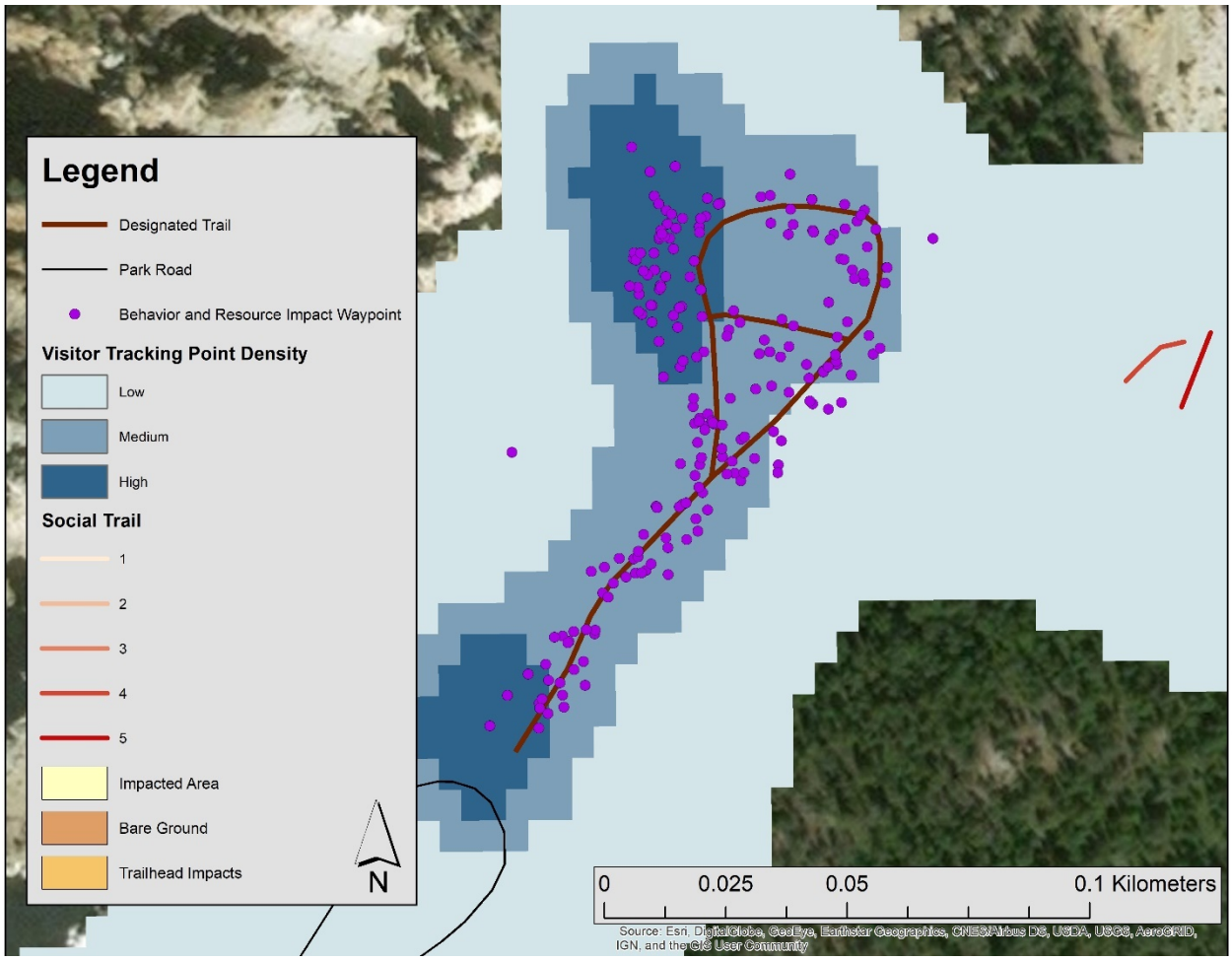

Figure 7.3: Integrative map showing visitor use, marked waypoints, and resource impacts at Artist Point.

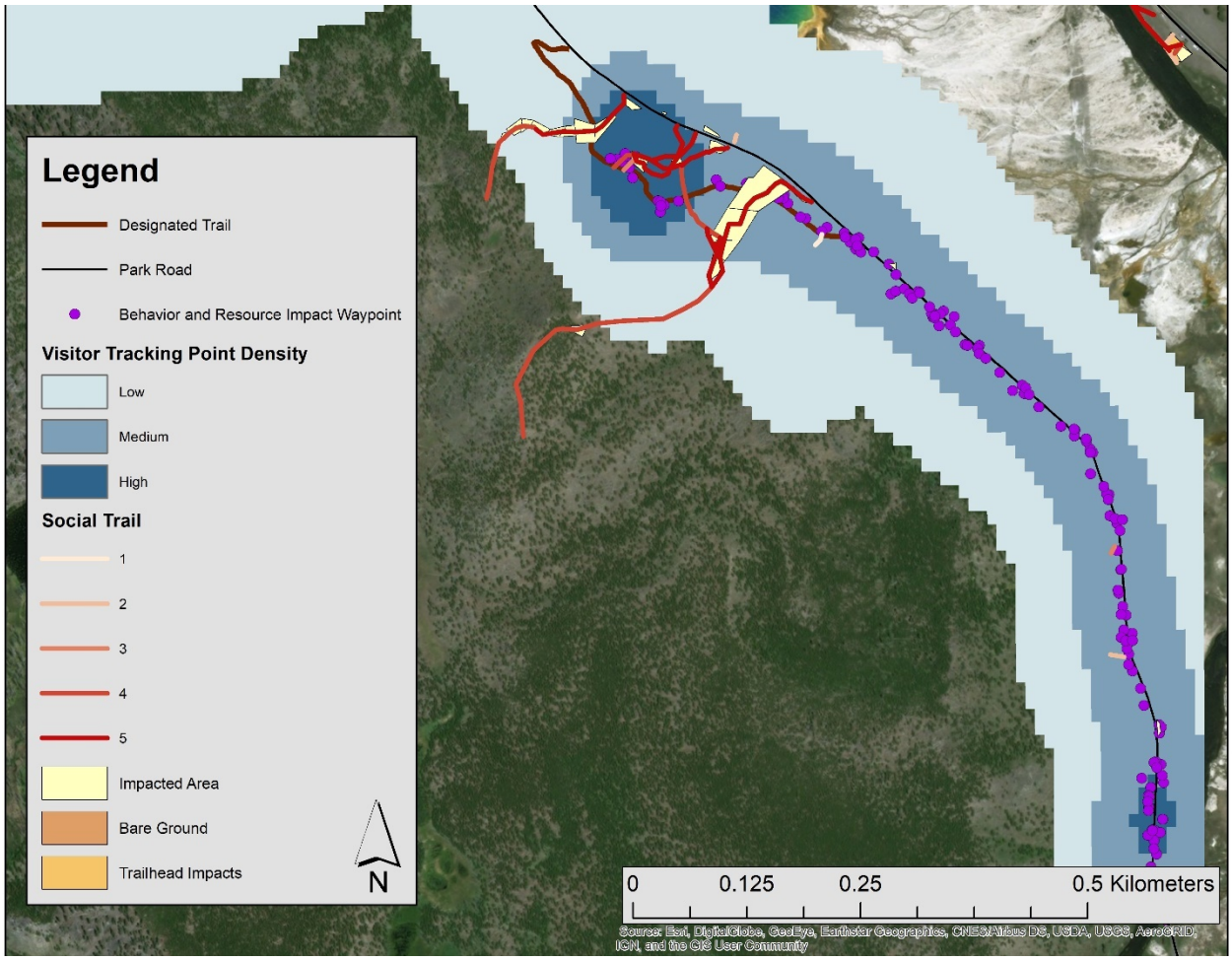

Figure 7.4: Integrative map showing visitor use, marked waypoints, and resource impacts at Fairy Falls.

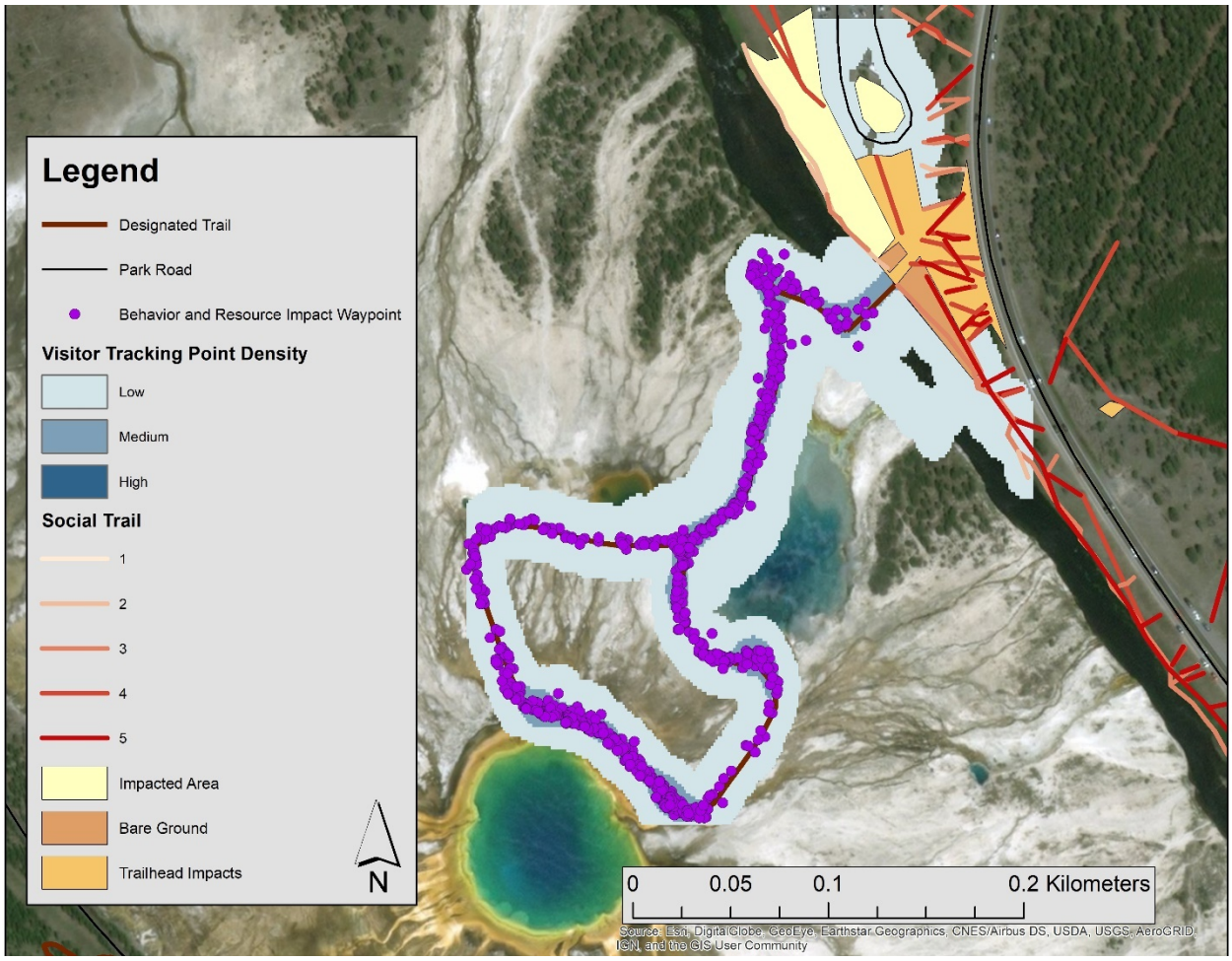

Figure 7.5: Integrative map showing visitor use, marked waypoints, and resource impacts at Midway Geyser Basin.

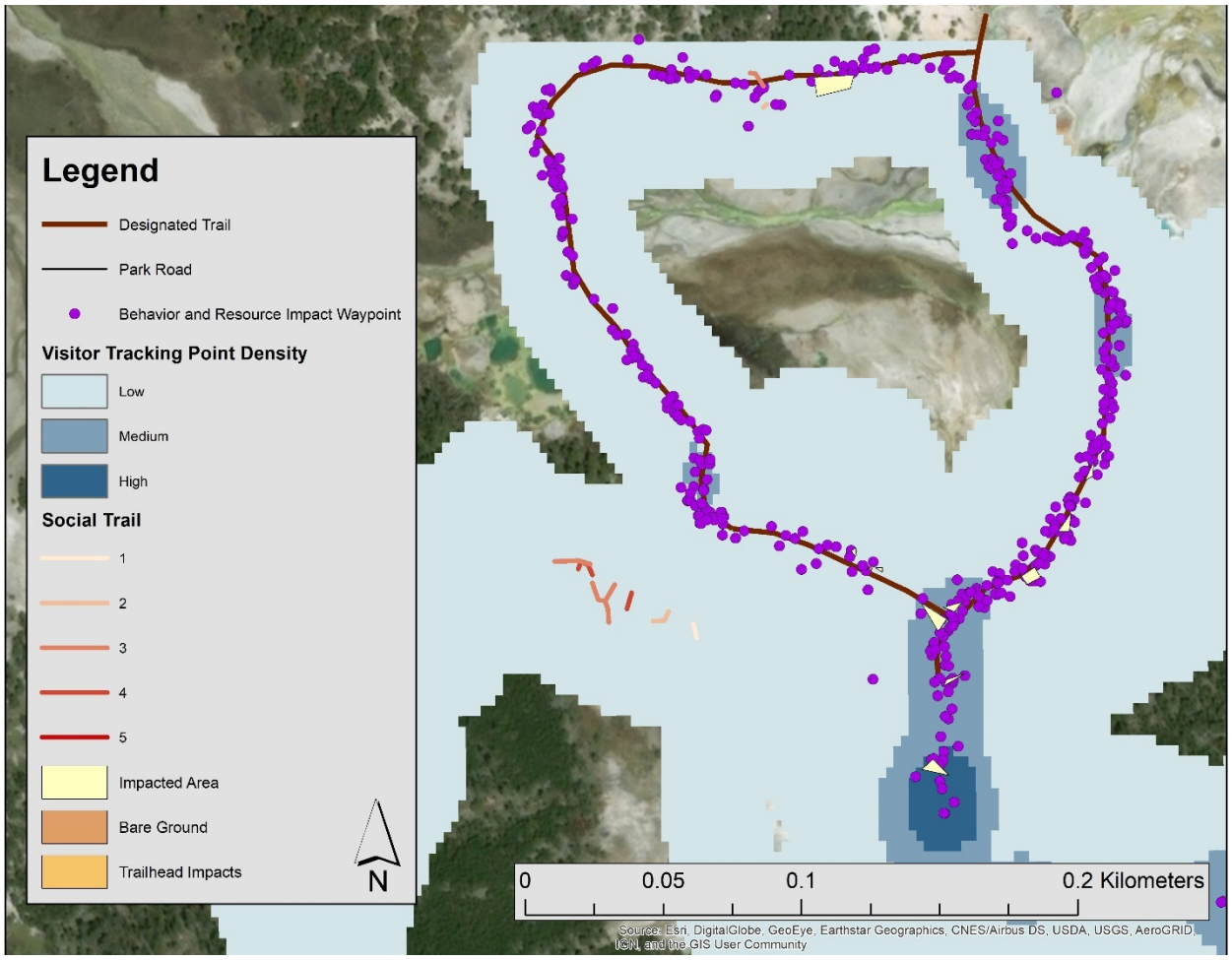

Figure 7.6: Integrative map showing visitor use, marked waypoints, and resource impacts at Norris Geyser Basin.

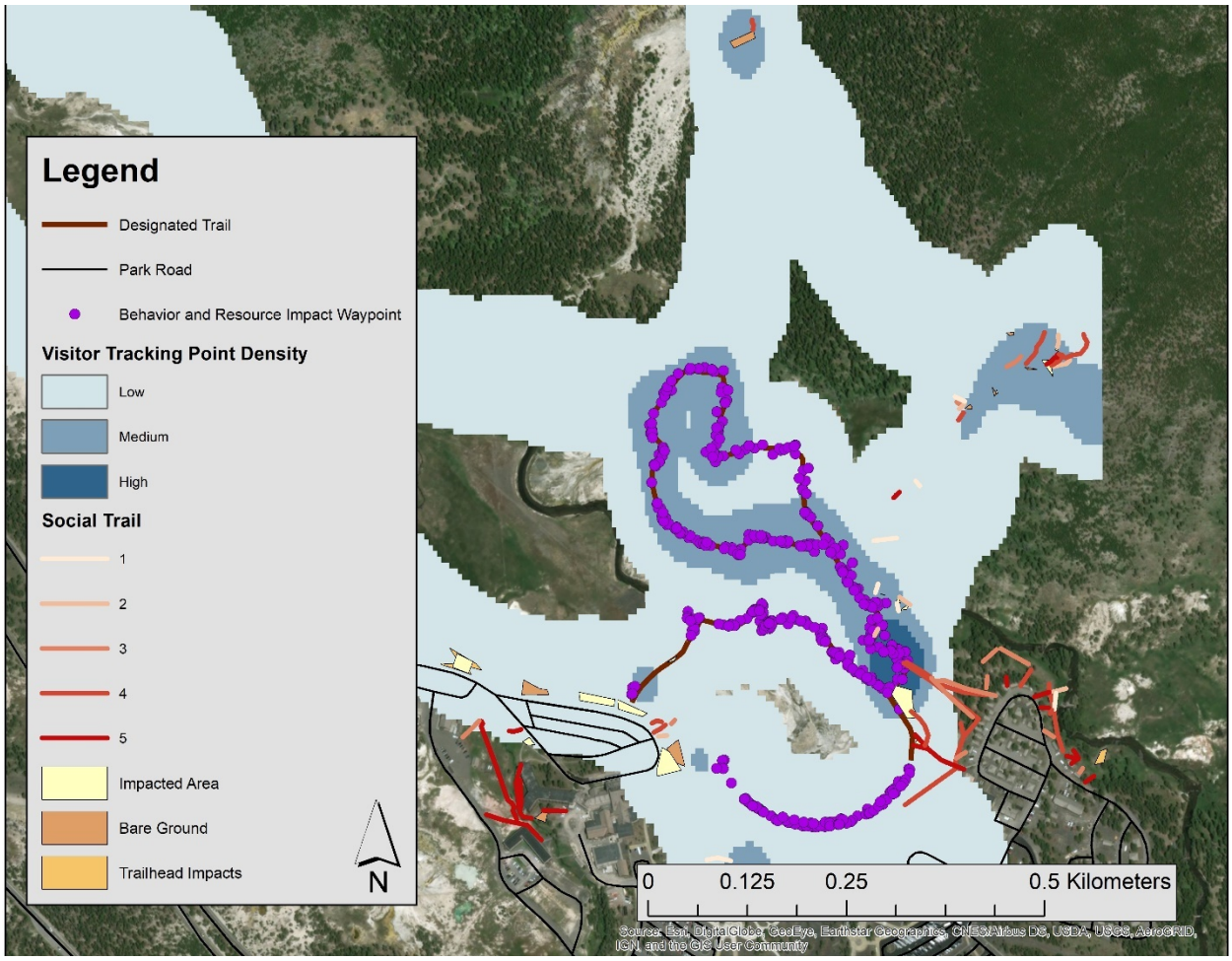

Figure 7.7: Integrative map showing visitor use, marked waypoints, and resource impacts at Old Faithful.

Recommendations

Overall, the YCC Crews and YELL staff did an excellent job collecting high quality, consistent monitoring data during summer 2017. The following bullet-points are general recommendations on how to improve the citizen science monitoring effort based on analysis of the data and comments from YELL staff related to experiences in the field during summer 2017.

- Some of the data collected shows a high amount of variability (high standard deviations, outlier days pulling up or down averages, etc.). While any dataset will have some level of variability, the limited sample sizes at some of the locations could make discerning longer-term trends in the data more difficult. **More sampling days** at some of the more dynamic locations – such as Artist Point – or ideally, all the locations could result in a dataset with less overall variability (or easier to identify outliers). More sampling days would also provide additional data to help compensate for technical issues; such as the trail counters at Artist Point and Midway appearing to fail every day around Noon (possibly due to the location of the sun).

- While the counter data collected in 2017 was useful and helpful in understanding total visitor use at each site - **careful, permanent installations of trail counters** at the focal attraction sites would provide higher quality, more consistent, census-level data. Permanently installing trail counters at focal attraction sites prior to YCC Crews data collection would also reduce the amount of set-up and take-down procedures that must occur in the field. Census-level data from trail counters would also provide a weekend visitor use level measure that would allow for a comparison of weekend vs. weekday use to see how generalizable the YCC Crew data collection may be to weekend visitor use.

- Feedback from YELL staff, who spent significant time in the field with the YCC Crews, indicated that it would have been helpful to have **one additional person on the YCC Crews.** It was felt this person would be helpful especially during counter calibrations as well as during behavior mapping to remember where items (such as trash or personal objects) had already been mapped, and for additional assistance at Old Faithful (which was one of the more complicated focal attraction sites).

Appendices

Appendix A: Summer 2017 YCC Crew Data Collection Calendar

Appendix B: Locations of PAOT Counts at Each Focal Attraction Site

Appendix C: GPS-based Tracking Download & Cleaning Procedures

Appendix D: Visitor Behavior & Resource Impact Categories

Appendix E: Summary Tables for Parking Lot Counts

Appendix F: Average Hourly Vehicle Counts for Focal Attraction Sites by Date

Appendix G: Density of Visitor Behaviors & Resource Impacts

Appendix H: Summary of All Visitor Behaviors and Resource Impact Waypoints

Appendix I: Maps of Locations of Individual Visitor Behaviors and Resource Impact Waypoints

References

D'Antonio, A. (2018). Summer Visitor Use and Resource Monitoring at Focal Attractions and Trails in Yellowstone National Park: Data Summary from Summer 2017 Data Collection Effort. Technical Report. Corvallis, OR.

D'Antonio, A., Monz, C, Lawson, S., Newman, P., Pettebone, D., Courtemanch, A., (2010). GPS-based measurements of backcountry visitors in parks and protected areas: examples of methods and applications from three case studies. Journal of Parks and Recreation Administration, 28, 42-60.

Gutzwiller, K., D'Antonio, A., Monz, C. (2017). Wildland recreation disturbance: broad-scale spatial analysis and management. Frontiers in Ecology and the Environment, 15 (9).

Hammitt, W. E., Cole, D. N., & Monz, C. A. (2015). Wildland recreation: ecology and management. John Wiley & Sons.

Manning, R. E. (2007). Parks and carrying capacity: Commons without tragedy. Washington: Island Press

Manning, R.E. (2011). Studies in Outdoor Rereation: Search and Research for Satisfaction. Oregon: Oregon State University Press.

Monz, C., D'Antonio, A., Heaslip, K. (2014). Moose-Wilson Corridor Use Levels, Types, Patterns, and Impacts in Grand Teton National Park: Technical Report – Summer/Fall 2013. Logan, Utah

National Park Service (2018). 2017 - Second busiest year on record. Press Release. Retrieved from: 2017 - Second busiest year on record

Otak (2017). Yellowstone National Park: Transportation and Mobility Study. Final Technical Report.

Pettebone, D., Newman, P., & Lawson, S. (2010). Estimating visitor use at attraction sites and trailheads in Yosemite National Park using automated visitor counters. Landscape and Urban Planning, 97, 229-238.

TRAFx (2018a). TRAFx Infrared Trail Counter. Retrieved from: https://www.trafx.net/brochures/TRAFx_Infrared_Trail_Counter.pdf?v=170803

TRAFx (2018b). TRAFx Datanet. Retrieved from: https://www.trafx.net/datanet/demo