Estimating Visitation to Boulder Open Space and Mountain Parks

Sponsored by the City of Boulder Open Space and Mountain Parks and conducted by

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HDNRU Report No. 80

March 2009

Acknowledgements

The authors would like to thank Matt Jones and Deonne VanderWoude for project management. Deonne VanderWoude coordinated data collection and helped with data analysis and report review, with Karen McNeill providing data collection assistance for this project. Dave Kuntz and Joe Mantione provided project oversight. Marianne Giolitto helped with data analysis, report review, and revision.

We would also like to acknowledge our peer reviewers: Dr. David Cole, Dr. Jeff Marion, and Dr. Peter Newman.

This study began under a contract with Park Studies, Inc. The survey and preliminary data analysis are the work of Park Studies, Inc. Final data analysis, results and conclusions reported in this study are solely those of the authors and OSMP staff.

Suggested American Psychological Association Citation:

Vaske, J. J., Shelby, L. B., & Donnelly, M. P. (2009). *Estimating visitation to Boulder Open Space and Mountain Parks.* (HDNRU Report No. 80). Report for Boulder Open Space and Mountain Parks. Fort Collins: Colorado State University, Human Dimensions of Natural Resources.

Executive Summary

This study estimated the number of person visits at the City of Boulder Open Space and Mountain Parks (OSMP) between June 1, 2004 and May 31, 2005. The study objective was to provide baseline data for monitoring trends in visitation. This information will be used to improve service delivery and visitor satisfaction.

Estimates were based on a variety of data sources and procedures:

1. Thirty-nine infrared monitors were used to estimate the number of person visits in four volume categories (i.e., Very High, High, Medium, and Low visitation).
2. Estimated person visits for Very Low volume access points were based on field staff observations.
3. Inductive loop monitor counts of bikers and field staff observations of bikers and non-bikers were used to derive person visit estimates for Greenways managed by OSMP.
4. Estimates for the Fourth of July Trailhead, a remote location, were based on an inductive loop monitor that counted cars and field staff observations of the number of people per car.
5. Field staff observations were used to estimate the number of OSMP person visits for individuals who were less than 36 inches in height (e.g., children).

Reduction of the infrared monitor data followed a multi-step process:

1. Outlier identification and replacement
2. Missing value identification and replacement
3. Infrared monitor count calibrations
4. Estimated monitor counts
5. Confidence intervals

Estimates of person visits for the *entire study period (June 1, 2004 to May 31, 2005)* for *all trails* in the Very High to Low trail volume designations were based on the following calculations:

1. Average estimated monitor counts
2. Systemwide extrapolation of monitor counts
3. Total estimated person visits

The grand total visitation estimate for OSMP system for the study year (June 1, 2004 to May 31, 2005) is the sum of the person visit estimates:

Grand Total = Very High to Low trail volume access person visits +
Very Low trail volume access person visits +
Greenways person visits +
Fourth of July Trailhead person visits +
People less than 36 inches in height.

In addition, estimates of the number of visitors at each monitored access location were made.

Major Findings

Person Visit Estimate (Grand Total). Combining the estimates from all data sources, there were 4,680,666 estimated person visits to OSMP properties between June 1, 2004 and May 31, 2005. The bounds for this estimate range from 4,376,890 to 5,008,584. Specific estimates are shown below:

	Estimated Person Visits	Lower Bound	Upper Bound
Very High to Low volume locations	3,825,577	3,656,448	3,994,706
Very Low volume locations	208,931	167,144	250,717
Greenways managed by OSMP	435,724	379,038	515,312
Fourth of July Trailhead	14,182	8,868	20,738
People under 36 inches in height	196,252	165,392	227,111
Total	**4,680,666**	**4,376,890**	**5,008,584**

Visitation Patterns

Results from the monitored Very High to Low locations inform management decisions on opportunities to provide improved visitor service and resource protection.

- The distribution of visits over the year was relatively constant with 6% to 10% of total visits each month. Summer was busiest (29% of total visits), followed by spring (27%) and fall (25%), then winter (19%).
- Sunday was the busiest day of the week, followed by Saturday with both over 19% of the total visits. Weekday visits were relatively consistent with each weekday having about 12% of the total visits.
- Weekend visitation was centered on the middle of the day, while weekday visitation was distributed throughout the day, with highest visitation from 4 to 6 p.m. Nighttime visitation was low relative to daytime visitation, with only 1.4% of the total annual person visits occurring between the hours of 11 p.m. and 6 a.m.
- The monitor near the Bobolink Trailhead (South Boulder Creek trail) recorded the greatest number of visitors passing its infrared monitor during the study year.

Recommendations

Active infrared counters give managers a reliable and accurate tool for recording visitation at specific locations as well as the entire trail system. We encourage the continued use of these monitors at OSMP. Given that at the time of the study visitors could access OSMP properties from at least 236 different locations and OSMP owned approximately 40 infrared monitors, not every location was systematically monitored. Some individuals in this study never passed a monitor, but visited OSMP, and should be included in the estimation process. Surveys provide a vehicle for determining person visits for those individuals who did not pass a monitor. Coupling the use of infrared monitors with visitor surveys is encouraged.

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Introduction

The population of Colorado increased 31% between 1990 and 2000 (U.S. Census, 2000), with a projected additional increase of 14% by 2015. Outdoor recreation in Colorado has witnessed similar increases. For example, an estimated 3.5 million people annually visit Rocky Mountain National Park. Such estimates, however, have traditionally relied on backcountry passes issued to overnight visitors, trailhead registers (e.g., sign-in forms at a trailhead), and parking lot observations. Although a backcountry pass system can provide a reliable count of overnight visitation, not all locations use registration systems. Trailhead registers are problematic because the accuracy of the visitor counts varies according to register location and the ease of filling out the form. Parking lot counts are labor intensive and constrained by the number of days selected for observation. Similarly, many automated trail monitoring systems (e.g., seismic or magnetic detectors) are cumbersome, labor intensive, and inefficient (Hollenhorst, Whisman & Ewert, 1992).

To overcome these constraints, active infrared trail counters have been used to facilitate the task of estimating the number of person visits (Bates, Wallace, & Vaske, 2006; Vaske & Donnelly, 2007; Gasvoda, 1999). The counters operate continuously (24 hours per day) and record a date and time stamp for each event (count) logged. Date / time records provide a mechanism for monitoring trends in visitation patterns. In addition, the counters are relatively small, lightweight and weatherproof. Field installation and data retrieval are less labor intensive than many automated counting systems.

Bates et al. (2006) examined backcountry visitor use patterns in Rocky Mountain National Park using infrared monitors. Vaske and Donnelly (2007) used infrared monitors to compare 2004 and 2006 summer visitors at Boulder Open Space and Mountain Parks (OSMP). Results indicated that the monitors provided reliable and accurate person visits estimates.

Study Objective

The study objective was to provide baseline data for monitoring trends in visitation. This report estimates the number of OSMP person visits between June 1, 2004 and May 31, 2005. It estimates the number of visitors at monitored locations. It also estimates the number of dog visits.

This information will be used to improve service delivery and visitor satisfaction. For example, knowing the busiest places and times can help target ranger patrol and educational outreach. More generally, understanding changes in visitation over time provides a rough gauge of resources needed to provide a good visitor experience and to protect the natural systems that provide the underpinning for that experience. For more information see “Discussion” section at end of report.

Methods

This study estimated the total number of person visits to OSMP using a variety of sources:

1. For busier locations (i.e., Very High, High, Medium, and Low volume), 39 active infrared monitors were used to estimate the number of person visits.
2. Estimates of person visits at Very Low volume access points were based on field staff observations.

3. Estimates for Greenways managed by OSMP were derived from inductive loop monitor counts of bikers and field staff observations of bikers and non-bikers.
4. Estimates for the Fourth of July Trailhead, a remote location, were based on an inductive loop monitor that counted cars and field staff observations of the number of people per car.
5. For visitors who were less than 36 inches in height (e.g., children) estimates were based on field staff observations.

In addition, the study used data from the 39 infrared monitors and the 2004 - 2005 OSMP visitor survey to estimate the number of visitors at an individual monitored location. Methods for estimating the total number of person visits to OSMP during the year spanning June 1, 2004 to May 31, 2005 will be presented first followed by methods for estimating the number of visitors at a given monitored location.

Estimating Total Person Visits at Very High to Low Volume Access Locations With Infrared Monitors

Equipment

Trailmaster 1550 (TM 1550) active infrared monitors were used to count visitor numbers at 39 Very High, High, Medium and Low volume access locations (Figures 1 and 2). The TM 1550 sends low energy pulses from the transmitter to the receiver allowing for longer battery life (up to 10 months) and less downtime in the field. The unit functions in weather conditions ranging from -40° F to 130° F.

Figure 1. Trailmaster 1550 Receiver

Figure 2. Trailmaster 1550 Transmitter

Recognizing Measurement Error

Although infrared monitors offer advantages (e.g., low maintenance, continuous operation), measurement errors can occur. The accuracy and reliability of the data can be influenced by errors associated with: (a) the counts obtained from the monitors, and (b) the procedures used in estimating visitation from the count data (see Deland, 1976; Hornback & Eagles, 1999; O'Rourke, 1994; Watson, Cole, Turner, & Reynolds, 2000, for reviews). The following are some common, but not all, measurement errors that can occur.

Counting Errors

1. Placement of equipment is critical; miscounts occur if the receiving "eye" is struck by direct sunlight.
2. Misalignment between the transmitter and the receiver can result in inaccurate counts.
3. Soil, dust or snow on the transmitter or receiver can lead to miscounting visitors.
4. Blowing vegetation or heavy snow can lead to miscounting.

Estimation Errors

1. On trail systems where visitors enter and exit at the same location, an adjustment is required to avoid double counting.
2. If the monitor is installed to accommodate an average human waist height of three feet, but not count dogs, then people less than 36 inches (e.g., children) are not included in the count.
3. People walking side-by-side on wider trails or passing the monitor at the same time can be miscounted.
4. Monitors cannot differentiate human versus non-human presence.

The methodology employed in this study minimizes and/or accounts for many of these measurement errors.

Infrared Monitor Location and Installation

Monitor placement was determined based on previous monitoring efforts and discussions with OSMP managers. Guidelines for monitor site selection included:

1. Popular trailheads in the OSMP system of trails.
2. Naturally narrow trails that funnel people past the monitor single-file.
3. Locations with a clear and straight sight line between the transmitter and receiver to avoid misalignment.
4. Sites that avoided detracting from the visitor experience.
5. Scenic overlooks, crests of steep grades and natural resting areas were avoided because visitor behavior in these areas can cause miscounts.

Visitors access OSMP properties from at least 236 different locations. These access locations vary in the amount of visitation they receive. For purposes of this report, these 236 locations were grouped into five volume categories: Very High, High, Medium, Low, and Very Low. Volume designations were based on experienced field ranger observations and were distributed throughout the five major sectors managed by OSMP (Table 1). The figures in Appendix A depict these sectors. (None of the access locations identified as Very Low (98) were monitored with an infrared monitor. Methods associated with estimating visitation at the Very Low volume access locations are described later).

Table 1. OSMP trail system by sector and volume

Access volume	Northeast	Northwest	Southeast	Southwest	Southwest Flagstaff	Total
Very High	0	1	0	2	0	**3**
High	1	4	3	2	1	**11**
Medium	9	15	3	8	7	**42**
Low	23	14	11	15	19	**82**
Total	**33**	**34**	**17**	**27**	**27**	**138**

All of the Very High (n = 3) and High (n = 11) volume locations were monitored to improve the accuracy of the visitation estimates (Table 2). Two fifths (40%, n = 17) of the 42 trails designated as Medium volume and 10% (*n* = 8) of the 82 Low volume locations had infrared monitors. Monitor placement for the Medium and Low volume locations was selected randomly.

Table 2. Infrared monitors by volume access locations

Access volume	Total access locations	Monitored access locations	Percent of trails monitored within access volume
Very High	3	3	100%
High	11	11	100%
Medium	42	17	40%
Low	82	8	10%
Total	**138**	**39**	**28%**

Once the sites were selected, monitors were temporarily mounted and tested for accuracy (i.e., transmitter and receiving units were aligned). After alignment, the monitors were “hard mounted” and calibrated again. Monitors were securely attached to a post or tree at approximately three feet above the ground. To deter vandalism and theft, armored boxes were used at all locations and half inch metal banding was used for tree installation locations. Units were also camouflaged to blend with the surrounding vegetation. Most visitors were not aware of the monitors except during calibrations and data downloads. After installation, the receiver was programmed with the correct date, time of day, unit number and sensitivity setting.

Infrared Monitor Data Collection

Data were downloaded in the field to a Trailmaster ™ Data Collector which later was plugged into a PC. Data were generally downloaded weekly from each unit. The Trailmaster recorded: (a) the number of daily counts at each location, and (b) the date and time of each event. The data were imported into SPSS, SAS and Excel for analysis.

Infrared Monitor Data Reduction

Terms like *counts, person visits,* and *visitors* are sometimes used interchangeably by both researchers and the public. For the purpose of this study,

- a ***count*** results when a visitor passes an infrared monitor. It is what the monitor records.
- a ***person visit*** consists of two counts, one count for entering the trail system and one count for leaving the trail system.
- a ***visitor*** is the person actually visiting OSMP.

Visitors may make multiple *person visits* to OSMP each resulting in one or more counts (Vaske & Donnelly, 2007).

Given that most of the data for this study were derived from monitor counts, the number of visits that a given visitor may have made to OSMP in a given year cannot be determined (see Vaske & Donnelly, 2008 for an analysis of OSMP visitor trip characteristics).

Reduction of monitor counts to allow estimation of the total number of person visits at *all of the Very High to Low volume locations* followed a multi-step process. The details of these steps are described below, but the general process involved the following sequence:

- Outlier identification and replacement
- Missing value identification and replacement
- Infrared monitor count calibrations
- Estimated monitor counts
- Confidence intervals

Estimating Visitation at Locations with Infared Monitors

Step 1 – Outlier Identification in Infrared Monitor Counts

An outlier is an observation that lies outside the overall pattern of a distribution (Vaske, 2008). For example, there were unusually high counts at Flatirons Vista Trailhead on several days during February and March 2005. These large values were likely caused by the movement of cattle from one location to another. On the North Fork of the Shanahan Trail, a broken branch swaying in front of the monitor increased the count by approximately 5,000. Blowing vegetation at the 6th Street location probably increased the monitor count by several thousand in July 2004. Whatever the reason for the outliers, outliers may result in an inflated estimate.

A variety of procedures has been suggested in the literature for detecting outliers (see Vaske, 2008 for a review). The simplest approach involves a visual inspection of a variable's distribution. For the OSMP monitor counts, each monitor has 8,760 rows of hourly count data (i.e., 365 days * 24 hours per day = 8,760 rows per unit). Data recorded by the minute were collapsed into hour increments. The data were sorted (i.e., by [1] unit, [2] season, [3] day-of-week, and [4] hour) and each of the rows per unit were examined. For example, if the counts for monitor "X" were 5, 3, 7, 1023, 9, 2 and 4, the 1023 is an obvious outlier. A visual inspection of the data constituted a first step in outlier identification. Based on visual analysis, the monitors were recording valid information, on average, 97.91% of the time (Table 3). Second, a

quantitative assessment of potential outliers was based on several strategies suggested in the literature.

For an approximately normally distributed variable, outlier values can be defined as any value beyond 3 standard deviations of the mean (Vaske, 2008). In a normal distribution, 99% of all observations fall within 3 standard deviations. Observations beyond 3 standard deviations could be treated as extreme values. Examination of the 99th percentile (or any percentile) failed to reliably and accurately identify outliers due to insufficient sample size when the data are grouped by unit, season, day-of-week, and hour. For percentile analysis there must be hundreds of observations for each unit by hour.

Another approach is to use the median to identify outliers. The median of a normal distribution divides the data into two halves. The interquartile range or some multiple of the median is often used for this analysis.[1] This is the best approach for a dataset broken down to small numbers of observations (i.e., by unit by hour) for which means and standard deviations cannot be reliably computed. When the one hour time blocks did not have an adequate number of observations, four hour time blocks were created to provide the medians. Examination of the data suggested that the median multiplied by 20 was a reasonable break point for outlier identification. Any value that exceeded 20 times the median was considered an outlier and was replaced with the mean for a given unit, season, day, and hour.

This combined methodology (i.e., visual inspection and quantitative assessment) resulted in monitor count values (not including 0s) having distributions that never exceeded 4 times the standard deviation for unit by season by day by hour.

Step 2 – Missing Value Identification and Replacement

For a variety of reasons (e.g., low batteries, monitor maximum count exceeded, data accidentally erased), not all monitors functioned during the entire study period (June 1, 2004 to May 31, 2005). To account for missing data points (Table 3), three strategies were employed:

1. When there was a small amount of missing data (i.e., < 2 weeks), missing values were replaced with a **specific mean** – the mean of the same time period the week before and the week after for each monitor location. For example, if for a given monitor, a Monday was missing data for 6 a.m., the mean of the Monday at 6 a.m. in the week before and the Monday at 6 a.m. in the week after (excluding holidays) was calculated to replace the data.
2. When the amount of missing data was large (i.e., > 2 weeks) and / or when the potential replacement values were also missing (e.g., missing data at the same time the week before and week after), a **general mean** was created for each monitor by season by day-of-week by hour (excluding holidays). For example, if data were missing for monitor "Y" during the spring on a Monday at 7 a.m., the average monitor counts for that monitor during the spring on Monday at 7 a.m. was used as the replacement value. Boulder Falls was the exception due to its amount of missing data (14%). For this unit the general mean was calculated by season by weekend vs. weekday by hour (excluding holidays).

[1] With the interquartile approach, the median of the variable of interest is computed. The median of a normal distribution divides the data into two halves. The medians of each of these two halves are then calculated. The result is three points: (a) the first middle point (the median), (b) the median of the lower half of the distribution, and (c) the median of the upper half of the distribution.

3. Given the small amount of data available to calculate holiday replacements, all holiday replacements used the specific mean process described above, but using all other holidays to calculate the replacement.

For 31 of the 39 monitors, 2% or less of the data was replaced using these methods. Missing value replacements exceeded 5% for only four monitors: North Fork Shanahan Trail (6%), Ranger Trail (7%), Boy Scout Trail (9%) and Boulder Falls (14%).

Step 3 – Infrared Monitor Count Calibrations

Infrared monitors were calibrated to ensure accurate and reliable data. Actual visitor counts (as observed by field staff) were compared with the counts recorded by the monitor to determine the percentage of events not recorded or over recorded. Over recording only occurred on 6 of the 104 calibration periods (Table 4).

Monitors were randomly selected for calibration from the pool of all monitors. As a result, not every monitor was calibrated and some monitors received multiple calibrations. The human calibration included observations of the monitor's performance in the morning, afternoon and evening. The direction of visitor travel (entering or leaving), the size of the visitor groups, and weather conditions were also recorded.

To adjust for inaccuracies in the count data (i.e., undercounting), a monitor's total count was multiplied by an average Ratio Inflation Factor (RIF). The RIF was based on field staff observations. For example, during calibrations it was noted that groups of visitors were more likely to be under represented than individuals passing by in single file. A single RIF was used for all monitors due to the limited number of calibrations at any given monitored location (Table 4). The average Ratio Inflation Factor was 1.2083. This suggests that, overall, the monitors captured 83% (=1 / 1.2083) of the visitors that passed any of the calibrated locations. The calibration data were also used to calculate a standard error (SE = 0.0267) for the RIF. This SE was used to calculate the confidence intervals for the estimated monitor counts.

Step 4 – Estimated Infrared Monitor Counts

An *Estimated Monitor Count* was calculated for each of the 39 locations by multiplying the average Ratio Inflation Factor by the monitor count:

Estimated Monitor Count = Average Ratio Inflation Factor * Monitor Count

For example, for the Chautauqua Trail in the study year, the estimated monitor count was:
Estimated Monitor Count = 1.2083 * 184,523 = 222,959

Table 3. Valid data, outliers, missing data and percent replaced for each infrared monitor

	Valid Data [1]		Outliers		Missing Data		
Unit # Monitor	Number of Rows	Percent of Rows	Visual Outliers	Quantitative Outliers	Small Amount	Large Amount	% Replaced
1 Boulder Falls	7548	86.16	33	118	206	855	14
2 Settlers Trailhead - West	8558	97.69	0	8	194	0	2
3 Mt Sanitas Trail	8717	99.51	0	32	11	0	< 1
4 Sanitas Valley Trail	8741	99.78	0	8	11	0	< 1
5 Sanitas Valley View Trail	8666	98.93	0	11	83	0	1
6 Wonderland Trail - Poplar Avenue	8737	99.74	0	12	11	0	< 1
7 Wonderland Trail - Utica East	8652	98.77	0	0	108	0	1
8 Foothills Trail - Locust Place	8689	99.19	0	35	36	0	1
9 Fourmile Trailhead	8649	98.73	0	23	88	0	1
10 Foothills Trail - Near US 36	8671	98.98	0	9	80	0	1
11 Eagle Trail West	8513	97.18	0	4	243	0	3
12 Boulder Valley Ranch - South	8710	99.43	0	10	40	0	1
13 Lefthand Trailhead	8602	98.2	0	28	130	0	2
14 Eagle Trailhead	8568	97.81	0	8	184	0	2
15 Cottontail Trail South	8692	99.22	0	9	59	0	1
16 East Boulder Trail - White Rocks	8709	99.42	0	4	47	0	1
17 Sawhill Entrance West	8729	99.65	0	14	17	0	< 1
18 East Boulder Trail - Valmont	8718	99.52	0	6	36	0	< 1
19 Bobolink Trailhead	8736	99.73	0	6	18	0	< 1
20 Dry Creek Trailhead	8710	99.43	0	9	41	0	1
21 South Boulder Creek - Community Center	8570	97.83	15	36	139	0	2
22 Steinbach Continental View	8727	99.62	0	15	18	0	< 1
24 South Boulder Creek - Marshall	8731	99.67	1	15	13	0	< 1
25 Marshall Mesa Trailhead	8525	97.32	0	19	216	0	3
26 Greenbelt Plateau Trailhead	8704	99.36	2	42	12	0	1
27 Flatirons Vista Trailhead	8384	95.71	5	35	12	324	4
28 Doudy Draw Trailhead	8739	99.76	0	9	12	0	< 1
29 South Mesa Trailhead	8609	98.28	0	4	147	0	2
30 South Boulder Creek - Broadway	8740	99.77	0	8	12	0	<1
31 North Fork Shanahan Trail	8275	94.46	7	49	19	410	6
32 Lower Bear Canyon Trail	8663	98.89	0	6	91	0	1
34 6th Street	8404	95.94	26	71	259	0	4
35 Bluebell Road	8643	98.66	0	16	101	0	1
36 Chautauqua Trail	8550	97.6	0	15	195	0	2
37 Gregory Canyon Trail	8580	97.95	0	5	175	0	2
38 Ranger Trail	8065	92.07	2	7	0	686	7
39 Ute Trail	8714	99.47	0	26	20	0	1
40 Upper Crown Rock	8514	97.19	5	37	204	0	3
41 Boy Scout Trail	7967	90.95	2	7	15	769	9
Total	**334419**	**97.89**	**99**	**786**	**3421**	**3044**	**2.70%**

[1]Each unit has 8,760 rows of data (i.e., 365 days * 24 hours per day).

Table 4. Infrared monitor calibrations, percent accurate and ratio inflation factor statistics.

Monitor Location	Human Count	Monitor Count	Ratio Inflation Factor	Percent Accurate	Date Calibrated
Marshall Mesa Trailhead	23	23	1	100	5/27/2004
Marshall Mesa Trailhead	20	13	1.54	65	7/7/2004
Marshall Mesa Trailhead	32	27	1.19	84	10/28/2004
Marshall Mesa Trailhead	28	23	1.22	82	1/9/2005
Greenbelt Plateau Trailhead	2	1	2	50	5/18/2004
Greenbelt Plateau Trailhead	2	2	1	100	7/8/2004
Greenbelt Plateau Trailhead	8	8	1	100	1/23/2005
Greenbelt Plateau Trailhead	8	8	1	100	1/23/2005
Dry Creek Trailhead	42	37	1.14	88	6/12/2004
Dry Creek Trailhead	37	35	1.06	95	6/23/2004
Bobolink Trailhead	89	75	1.19	84	6/12/2004
Bobolink Trailhead	67	48	1.4	72	7/9/2004
Bobolink Trailhead	149	123	1.21	83	10/8/2004
S. Boulder Ck. Marshall	33	27	1.22	82	6/12/2004
S. Boulder Ck. Marshall	61	27	2.26	44	7/8/2004
S. Boulder Ck-Community Center	40	20	2	50	6/12/2004
S. Boulder Ck-Community Center	20	16	1.25	80	7/12/2004
Chautauqua Trail	85	66	1.29	78	6/25/2004
Chautauqua Trail	66	54	1.22	82	7/9/2004
Chautauqua Trail	72	41	1.76	57	10/22/2004
Chautauqua Trail	19	15	1.27	79	11/18/2004
Chautauqua Trail	32	25	1.28	78	1/15/2005
Chautauqua Trail	84	63	1.33	75	5/27/2005
South Mesa Trailhead	31	26	1.19	84	5/18/2004
South Mesa Trailhead	15	13	1.15	87	7/9/2004
South Mesa Trailhead	7	8	0.88	114	11/30/2004
Bluebell Rd	16	13	1.23	81	5/19/2004
Bluebell Rd	44	41	1.07	93	6/23/2004
Bluebell Rd	57	47	1.21	82	9/24/2004
Bluebell Rd	134	105	1.28	78	2/20/2005
Bluebell Rd	58	45	1.29	78	3/11/2005
Doudy Draw Trailhead	3	2	1.5	67	5/18/2004
Doudy Draw Trailhead	3	2	1.5	67	7/8/2004
Doudy Draw Trailhead	23	20	1.15	87	11/6/2004
Flatirons Vista Trailhead	2	2	1	100	5/19/2004
Flatirons Vista Trailhead	2	2	1	100	7/8/2004
N. Fork Shananhan Trail	8	6	1.33	75	5/24/2004
N. Fork Shananhan Trail	13	10	1.3	77	7/9/2004
Lower Bear Canyon Trail	23	14	1.64	61	6/12/2004
Lower Bear Canyon Trail	6	4	1.5	67	7/7/2004
Lower Bear Canyon Trail	27	19	1.42	70	1/9/2005
S. Boulder Ck.-Broadway	12	12	1	100	6/12/2004
S. Boulder Ck.-Broadway	2	2	1	100	8/3/2004
S. Boulder Ck.-Broadway	9	8	1.13	89	9/29/2004
6th St.	1	2	0.5	200	6/23/2004
6th St.	2	2	1	100	7/7/2004
Upper Crown Rock	2	2	1	100	5/27/2004
Upper Crown Rock	12	9	1.33	75	7/9/2004
Upper Crown Rock	12	22	0.55	183	12/31/2004
Gregory Canyon Trail	48	48	1	100	6/12/2004
Gregory Canyon Trail	16	15	1.07	94	7/12/2004
Gregory Canyon Trail	7	7	1	100	1/7/2005
Ranger Trail	7	8	0.88	114	7/10/2004

Table 4. continued

Monitor Location	Human Count	Monitor Count	Ratio Inflation Factor	Percent Accurate	Date Calibrated
Boy Scout Trail	5	5	1	100	7/10/2004
Ute Trail	3	2	1.5	67	7/10/2004
Sawhill-Entrance West	2	2	1	100	5/29/2004
Sawhill-Entrance West	7	6	1.17	86	7/2/2004
Eagle Trail-West	16	22	0.73	138	5/29/2004
Eagle Trail-West	3	3	1	100	7/2/2004
Eagle Trailhead	16	12	1.33	75	5/29/2004
Eagle Trailhead	14	8	1.75	57	7/2/2004
Eagle Trailhead	85	68	1.25	80	2/26/2005
Eagle Trailhead	32	26	1.23	81	4/24/2005
Boulder Valley Ranch-South	11	10	1.1	91	5/29/2004
Boulder Valley Ranch-South	13	12	1.08	92	7/2/2004
East Boulder Tr.-White Rocks	21	13	1.62	62	6/14/2004
East Boulder Tr.-White Rocks	34	19	1.79	56	7/8/2004
East Boulder Tr.-Valmont	22	23	0.96	105	6/14/2004
East Boulder Tr.-Valmont	37	37	1	100	7/8/2004
East Boulder Tr.-Valmont	7	7	1	100	5/17/2005
Cottontail Trail-South	13	8	1.63	62	6/14/2004
Cottontail Trail-South	1	1	1	100	7/10/2004
Lefthand Trailhead	1	1	1	100	6/14/2004
Lefthand Trailhead	5	3	1.67	60	7/10/2004
Lefthand Trailhead	2	2	1	100	5/23/2005
Foothills Trail-Near US 36	38	30	1.27	79	5/26/2004
Foothills Trail-Near US 36	3	3	1	100	7/2/2004
Settlers Trailhead-West	22	20	1.1	91	5/24/2004
Settlers Trailhead-West	8	6	1.33	75	7/7/2004
Sanitas Valley Trail	36	31	1.16	86	5/25/2004
Sanitas Valley Trail	37	33	1.12	89	6/25/2004
Sanitas Valley Trail	27	20	1.35	74	1/11/2005
Sanitas Valley Trail	51	46	1.11	90	5/12/2005
Mt. Sanitas Trail	17	17	1	100	5/25/2004
Mt. Sanitas Trail	28	28	1	100	6/25/2004
Mt. Sanitas Trail	96	94	1.02	98	10/17/2004
Sanitas Valley View Trail	14	14	1	100	5/25/2004
Sanitas Valley View Trail	14	13	1.08	93	6/25/2004
Sanitas Valley View Trail	12	12	1	100	3/16/2005
Wonderland Trail-Poplar Ave.	68	55	1.24	81	5/29/2004
Wonderland Trail-Poplar Ave.	34	25	1.36	74	7/7/2004
Wonderland Trail-Poplar Ave.	51	47	1.09	92	10/4/2004
Wonderland Trail-Poplar Ave.	17	13	1.31	76	5/20/2005
Fourmile Trailhead	17	14	1.21	82	5/29/2004
Fourmile Trailhead	29	20	1.45	69	7/7/2004
Fourmile Trailhead	21	16	1.31	76	4/27/2005
Boulder Falls	98	78	1.26	80	6/13/2004
Boulder Falls	77	62	1.24	81	7/10/2004
Boulder Falls	206	164	1.26	80	9/5/2004
Boulder Falls	257	201	1.28	78	6/5/2005
Wonderland Trail-Utica East	69	61	1.13	88	6/27/2004
Wonderland Trail-Utica East	23	22	1.05	96	7/7/2004
Foothills Trail-Locust Place	4	4	1	100	6/21/2004
Foothills Trail-Locust Place	15	12	1.25	80	2/20/2005
Average			**1.2083**		
Standard Error			0.0267		

Step 5 – Confidence Intervals

This step calculated the confidence intervals for the estimated monitor counts at each monitored location. The logic was based on the following:

$$\text{Variance of Ratio Inflation Factor} = (\text{Standard Error of Ratio Inflation Factor})^2$$

$$\text{Variance}_{\text{(Estimated Monitor Counts)}} = (\text{Monitor Counts})^2 * (\text{Variance of the Ratio Inflation Factor})$$

$$\text{Bounds} = 2 * \sqrt{\text{Variance (Estimated Monitor Counts)}}$$

$$\text{Confidence Interval} = \text{Estimated Monitors Count} \pm \text{Bounds}$$

Confidence intervals (i.e., $\text{Confidence Interval} = \text{Estimated monitors count} \pm \text{Bounds}$) were calculated for the estimated monitor count at each monitored location.

An Empirical Illustration

To illustrate these calculations (Equations 1 – 6), consider the following equations for data from the Bobolink Trailhead:

$$EMC = \left(\overline{RIF}\right) * \left(MC\right) \qquad \text{Equation 1}$$

$$Var\left(\overline{RIF}\right) = \left[SE\left(\overline{RIF}\right)\right]^2 \qquad \text{Equation 2}$$

$$Var\left(EMC\right) = \left(MC\right)^2 * Var\left(\overline{RIF}\right) \qquad \text{Equation 3}$$

$$B = 2 \cdot \sqrt{Var\left(EMC\right)} \qquad \text{Equation 4}$$

$$B_{Lower} = EMC - B \qquad \text{Equation 5}$$

$$B_{Upper} = EMC + B \qquad \text{Equation 6}$$

Where:

EMC	= Estimated Monitor Count	Var	= Variance of Ratio Inflation Factor
$\overline{RIF}$	= Average Ratio Inflation Factor	SE	= Standard Error of Ratio Inflation Factor
MC	= Monitor Count	B	= Bounds

For the Bobolink Trailhead example we have:

Equation 1: $EMC = \left(\overline{RIF}\right) * \left(MC\right) = \left(1.2083\right) * \left(246{,}313\right) = 297{,}620$

Equation 2: $Var\left(\overline{RIF}\right) = \left[SE\left(\overline{RIF}\right)\right]^2 = \left(0.0267\right)^2 = 0.000713$

Equation 3: $Var\left(EMC\right) = \left(MC\right)^2 * Var\left(\overline{RIF}\right) = \left(246{,}313\right)^2 \cdot \left(0.000713\right) = 43{,}257{,}777$

Equation 4: $B = 2 * \sqrt{Var\left(EMC\right)} = 2 * \sqrt{43{,}257{,}777} = 13{,}154$

Equation 5: $B_{Lower} = EMC + B = 297{,}620 - 13{,}154 = 284{,}466$

Equation 6: $B_{Upper} = EMC + B = 297{,}620 + 13{,}154 = 310{,}774$

Following the calculations in this example, we would conclude that the estimated monitor count for the Bobolink Trailhead in the study year was 297,620. We are 95% confident that the true count is between 284,466 and 310,774.

Total Estimated Person Visits – Very High to Low Volume Access Locations

Estimating total person visits involves accounting for visitors who never passed by a monitor and converting "monitor counts" to "person visits." Because only 39 of the 138 access locations identified as having Very High to Low visitation rates were equipped with infrared monitors, some portion of the visitors to OSMP did not pass a monitor during their visit and therefore are not represented in the EMC. To account for these uncounted visitors, OSMP employed the following calculations. First, the EMC from monitored locations was *averaged by volume*. The average EMC for each volume stratum was then multiplied by the number of access locations within each stratum to yield a total EMC (monitored and unmonitored) for each stratum. For example, 17 access locations were monitored within the Medium volume stratum. The average EMC from these 17 locations was 77,443. Multiplying 77,443 by 42 (the number of Medium volume locations across the system) yields 3,252,599 which is the extrapolated EMC for the Medium volume.

Because the EMC is the number of times a visitor passes a monitor (i.e., the infrared monitor records one count when a visitor enters the OSMP trail system and one count when a visitor exits the trail system), the total EMC for each volume stratum must be divided by two to obtain person visits. The total estimated person visits for *all of the Very High to Low access locations* is the sum of the estimated person visits per volume stratum. Following our example for the Medium volume access locations, we would divide 3,252,599 by two to obtain 1,626,300 person visits for the Medium volume. Summing across all four volumes yields the total person visits to OSMP for all of the Very High to Low access locations during the study year. [2]

Bounds around the person visit estimate are derived in a similar fashion to that described for the estimated monitor count. Confidence intervals around the EMC for each monitored location (see Step 5 above) were averaged by volume stratum, multiplied by the number of access locations in a given volume stratum, and divided by two to obtain bounds around the estimated person visits per volume stratum.

Estimating Total Person Visits at Other Locations and People Less Than 36 Inches

In addition to the Very High to Low volume locations, person visits were estimated for other situations. These situations are Very Low trail volume access points, Greenways, Fourth of July Trailhead, and for people less than 36 inches tall. The following procedures were employed to derive these estimates.

Very Low Volume Access Locations

The survey (see Vaske & Donnelly, 2008, for details) conducted in conjunction with the visitor estimation study was based on a stratified random design. For estimating visitation at the Very Low trail volume access locations, two stratification variables are relevant: (a) day-of-week, and (b) time-of-day. All weekend days and weekdays within the study period were considered for inclusion in the study. Three time-of-day sampling periods were selected (morning, mid-day, afternoon.). Morning was defined as 6:00 a.m. to 10:00 a.m.; mid-day was defined as 11:00 a.m. to 3:00 p.m., and afternoon was defined as 4:00 p.m. to 9:00 p.m. Sampling hours provided

[2] Using these methods we only obtain a rough estimate of person visits by volume. We know from the visitor survey data that some individuals enter OSMP at an access location in one volume and exit OSMP via an access location in a different volume. However, for the purposes of calculating an estimate of person visits for the entire system, it does not matter whether we divide the extrapolated volume EMC by two and then sum the results for a total systemwide estimate of person visits or sum the extrapolated volume EMCs first and then divide by two to obtain the total systemwide estimate of person visits.

coverage from 6:00 a.m. until 9:00 p.m. during the summer months. As the daylight in the seasons shortened and lengthened, these hours were adjusted to mirror visitation and address field staff safety. For sampling periods greater than three hours, the three hour period was randomly selected within the available hours.

Specific days and time frames for conducting surveys were randomly selected based on the grid shown in Table 5. This process was repeated for each season. In total, 48 of the 98 Very Low trail volume access locations were sampled – 12 per season. Observers counted the number of visitors (adults and children) present during the survey sampling period. These counts were extrapolated out to all available time periods for the Very Low accesses to estimate visits.

Table 5. Sampling grid for selecting days and survey times

	Daily Time Frame Stratum		
Day of Week Stratum	a.m. 6, 7, 8, 9, 10	mid-day 11, 12, 1, 2, 3	p.m. 4, 5, 6, 7, 9
Weekend			
Weekday			

Greenways on OSMP-Managed Lands

Visitation to Greenways on lands managed by OSMP was estimated using: (a) existing inductive loop monitors that recorded bike visits and (b) an observer who recorded the number of adult and children non-bikers and bikers. These Greenways trails included in this analysis were not built by OSMP but are located on OSMP lands and require OSMP management.

Some of the City of Boulder Greenways, Boulder Creek and Pearl Parkway Paths, are on Open Space and Mountain Parks lands. These lands are located roughly between Foothills Parkway and 63rd Street on the west and east and Valmont and Arapahoe on the north and south. The trails are maintained by the Public Works Department, but have management implications for OSMP (e.g., undesignated trail development, illegal camping). A portion of the Boulder Creek Path in Boulder Canyon is on OSMP land. However, it was not included in the visitation estimate because no monitor was available.

The portion of Greenways located between Bobolink Trailhead and the East Boulder Community Center was not included in Greenways visitation estimate. The placement of the infrared monitor at the Bobolink Trailhead allowed OSMP to count visitors on the natural surface trail adjacent to South Boulder Creek and those traveling on the paved Greenways trail. As a consequence, visitors to this portion of the Greenways are included in the visitation estimate for the Very High to Low volume access locations.

Since the inductive loop monitor only counts bikes, the estimate for each Greenways location was calculated by estimating the proportion of bicyclists compared to non-bikers, then adding the non-bikers to the bikers for a total. The proportion of bicyclists was estimated through observation using the stratified random approach (i.e., a day was split into three periods: morning, mid-day, and afternoon). The two Greenways locations (Boulder Creek Path/Arapahoe and 55th/Pearl) were visited for one randomly selected hour during each time period for both weekdays and weekends yielding six observation periods per trail per quarter. Values for the three weekday periods were combined to give an overall weekday proportion of cyclists. Values for the three weekend periods were rolled up to give an overall proportion of cyclists for the weekends.

For the total Greenways estimate, the Boulder Creek Path/Arapahoe estimate was combined with half the 55th/Pearl estimate. The proportion of visitors that passed both monitors during a single visit is unknown. Halving the 55th/Pearl estimate provided one way to account for visitors that may have passed both monitored locations in one visit. The Greenways estimate is conservative because additional visitors may gain access to the Boulder Creek Path or OSMP lands from any of about 10 unmonitored feeder paths and because the Boulder Canyon bike path was not monitored.

Fourth of July Trailhead

The Fourth of July Trailhead was monitored using: (a) an inductive loop monitor to count cars and (b) an observer to record the number of adults and children per car. To estimate total visits at this remote site, the total number of vehicles was multiplied by the average number of people per car. An estimate was only made for the summer months (June, July, August) because the site is largely inaccessible the remainder of most years due to snow.

The monitor only counted cars as they entered and exited the trailhead and was 100% accurate; both assumptions were validated by human observations. From June 10 to August 7 (59 days), 7,612 vehicles were recorded. The average number of vehicles recorded per day during this sampling period was 129 (Table 6). Since all vehicles must drive over the inductive loop once when entering and once when leaving, this average was halved to yield the average number of vehicles at the Fourth of July Trailhead per day.

Table 6. Inductive loop monitor observations at the Fourth of July Trailhead (summer, 2004)

Date	Cumulative Monitor Reading	Cumulative Number of Days	Cumulative Vehicles / Day
June 10	0	1	
June 17	654	8	82
July 29	6,494	50	130
August 7	7,612	59	129

The vehicle occupancy rate was estimated using a simple random sampling approach. The entire summer season had 1,472 visit hours available for sampling (i.e., 92 days in the season with each day having a visit length of 16 hours). From this sampling space, four hours were randomly selected for observation. During each observation time, an observer recorded the number of vehicles passing the monitor as well as the number of occupants in each vehicle. A total of 51 vehicles with 122 occupants were observed for an overall average of 2.39 people per vehicle (Table 7). Based on these observations, the estimated number of visitors was calculated for the Fourth of July Trailhead.

Table 7. Vehicle occupancy at the Fourth of July Trailhead (summer, 2004)

Sample	Number of vehicles	Number of occupants	Occupants per vehicle
1	7	23	3.29
2	11	19	1.73
3	13	34	2.62
4	20	46	2.30
Total	**51**	**122**	**2.39**

People Less Than 36 Inches in Height

Due to the height of the monitors, people less than 36 inches in height were likely not counted by the monitors. To estimate the total number of people less than 36 inches in height who visited OSMP, the proportion of people less than 36 inches in height to taller visitors (i.e., greater than 36 inches in height) was computed. This proportion was derived from information recorded during 14 random survey administration periods each quarter (Vaske and Donnelly, 2008). An estimate of the number of people less than 36 inches in height was calculated by multiplying the proportion of people less than 36 inches in height to taller visitors by the estimated number of taller person visits per season. Because the survey was only administered at the Very High to Very Low volume access locations, only the estimated number of taller visitors from the Very High to Low volume access locations was used in this calculation. As a result, the estimate is a conservative estimate of the total number of people less than 36 inches in height visiting OSMP.

Total Person Visit Estimates for OSMP Systemwide

The grand total for the study year (June 1, 2004 to May 31, 2005) was the sum of the person visit estimates:

Grand Total = Very High to Low trail volume access person visits +
Very Low trail volume access person visits +
Greenways person visits +
Fourth of July Trailhead person visits +
People less than 36 inches in height.

Estimating Number of Visitors at Specific Monitored Locations

In addition to estimating the total person visits to OSMP, we estimated the *number of visitors* to an individual monitored location. This required using a slightly different approach than the methods used to estimate the total person visits for the entire system. As noted previously, a visitor passing the infrared monitor results in a *count*. A *person visit* consists of two counts, one count for entering the trail system and one count for leaving the trail system. A *visitor* is the person actually visiting OSMP. At the individual locations, we wanted to estimate the *number of visitors* that pass the infrared monitor to better understand how busy a specific location is.

An example may help illustrate the difference between counts, person visits, and visitors. If Visitors A and B enter OSMP from the Chautauqua Trailhead, the monitor located at the trailhead would register two counts, one for each visitor. Visitor A hikes to Woods Quarry and retraces his steps to return to his vehicle. Upon passing the infrared monitor on his return, a third count is recorded. Rather than returning to the Chautauqua Trailhead, Visitor B exits OSMP via the Gregory Canyon Trailhead. Visitor C enters OSMP at the South Mesa Trailhead and after a 6.5 mile hike, exits at the Chautauqua Trailhead. When Visitor C passes the infrared monitor at the Chautauqua Trailhead, the monitor registers a fourth count.

In this example, ***three visitors*** pass the infrared monitor resulting in ***four counts*** and approximately ***two person visits***. The two person visits consist of Visitor A's visit, half of Visitor B's visit, and half of Visitor C's visit. (Although it is not as simple as this, roughly speaking, the other halves of Visitor B's and C's visits are recorded at Gregory Canyon and South Mesa Trailheads, respectively.)

To estimate the number of visitors that pass a given monitor, the estimated monitor counts (EMC) need to be adjusted so that visitors who pass the same monitor twice in a single visit, as Visitor A did in our example, are only counted once. We used information gained during the

visitor survey (Vaske & Donnelly, 2008) to determine the proportion of visitors who passed by a given monitor once and the proportion that passed by twice during their visit to OSMP. We then converted these proportions of *visitors* to the proportions of the *EMC* that resulted from visitors passing the monitor once or twice. The proportion of the EMC that results from visitors passing the monitor twice was divided by two and multiplied by the EMC. This product was then subtracted from the EMC.

Using the example above of Visitors A, B, and C to illustrate the calculation, we would know from our survey data that one third of the visitors passed the monitor twice and two thirds passed the monitor once. However, one half of the monitor count (i.e. ½ of four, or two) is due to a visitor passing the monitor twice. We want to subtract out half of these counts so that a visitor who passes the monitor twice is only counted as a single visitor. This is accomplished by dividing ½ by two, yielding ¼. Multiplying ¼ by the monitor count of four yields one and subtracting one, from the EMC yields three.

The following equation summarizes the adjustment described above:

Number of visitors = EMC – EMC*(Proportion of the EMC resulting from double counting/2)

We simplified the equation by factoring out the EMC:

Number of visitors = EMC * [1 - (Proportion of the EMC resulting from double counting/2)]

Setting [1 - (Proportion of the EMC resulting from double counting/2)] equal to a new variable, the "Adjustment Factor", we have:

Number of visitors = EMC * Adjustment Factor

Calculating the Adjustment Factor

In the 2004 - 2005 visitor exit survey, visitors were asked to indicate where they entered and exited OSMP properties. Using this survey data, we calculated the adjustment factors for each volume stratum. (There were too few surveys at some of the monitored locations to calculate adjustment factors for specific monitored locations.) Because some visitors enter at one volume stratum and exit at another, we calculated an adjustment factor for visitors that entered and exited OSMP via access locations in the same volume stratum and a second for those that entered one volume stratum and exited another. Table 8 displays the four possible combinations of visitor behavior for individuals who entered and exited at the *same* volume stratum across all four volume strata (i.e., Very High to Low). Table 9 shows the same information for individuals who entered and exited at a *different* volume stratum.

Table 8. Visitor entered and exited at the *same* volume stratum

Volume	Monitored Entrance	Monitored Exit	Number	Proportion of Survey Sample	Proportion of EMC	Adjustment Factor
Very High						
	No	No	0	0	0	
	Yes	No	0	0	0	
	No	Yes	0	0	0	
	Yes	Yes	1251	1	1	
Total			**1251**	**1**		**0.5**
High						
	No	No	0	0	0	
	Yes	No	0	0	0	
	No	Yes	0	0	0	
	Yes	Yes	684	1	1	
Total			**684**	**1**		**0.5**
Medium						
	No	No	165	0.635	0	
	Yes	No	32	0.123	0.209	
	No	Yes	5	0.019	0.033	
	Yes	Yes	58	0.223	0.758	
Total			**260**	**1**		**0.621**
Low						
	No	No	72	0.713	0	
	Yes	No	0	0	0	
	No	Yes	7	0.069	0.150	
	Yes	Yes	22	0.218	0.942	
Total			**101**	**1**		**0.529**

For visitors who entered and exited the *same* volume stratum and that volume stratum was a Very High or High, 100% of visitors entered and exited at a monitored location (Table 8). This is because all Very High and High volume access locations had a monitor. Because only two in five Medium and one in ten Low volume access locations were monitored, visitors had the opportunity to enter and/or exit at an unmonitored location. For example, Table 8 shows that 63.5% of the visitors to the Medium volume access locations who entered and exited at the *same* volume stratum did not enter or exit from a monitored location. Since they never pass a monitor and therefore do not affect any monitor count, their numbers are not used in calculating the adjustment factor for the EMC at a given monitored location. (They are accounted for in the total person visit estimation for the system via the averaging described in the section of the methods addressing the systemwide person visit estimate.)

Table 9. Visitor entered and exited at a *different* volume stratum

Volume	Monitored Entrance	Monitored Exit	Number	Proportion of Survey Sample	Proportion of EMC	Adjustment Factor
Very High						
	No	No	0	0	0	
	Yes	No	0	0	0	
	No	Yes	53	0.707	0.546	
	Yes	Yes	22	0.293	0.454	
Total				**1**		**0.773**
High						
	No	No	0	0	0	
	Yes	No	0	0	0	
	No	Yes	32	0.615	0.444	
	Yes	Yes	20	0.385	0.556	
Total			**52**	**1**		**0.722**
Medium						
	No	No	8	0.174	0	
	Yes	No	35	0.761	0.854	
	No	Yes	0	0	0.000	
	Yes	Yes	3	0.065	0.146	
Total			**46**	**1**		**0.927**
Low						
	No	No	2	0.182	0	
	Yes	No	9	0.818		
	No	Yes	0	0	0	
	Yes	Yes	0	0	0	
Total			**11**	**1**		**1**

The remaining 36.5% of the visitors to the Medium volume access locations who entered and exited at the same volume stratum did pass by a monitor and affect its count. Seventy-six percent of the EMC at the Medium volume access location was due to visitors who entered and exited a monitored location. Half of these counts need to be removed to properly adjust the EMC to estimate the *number of visitors* at a monitored location. The adjustment factor shown in Table 8 is the proportion of the EMC due to visitors who entered and exited a monitored location divided by two and subtracted from 1 to yield an adjustment factor of 0.621. We followed similar procedures to calculate the other adjustment factors shown in Tables 8 and 9.

We weighted the adjustment factors shown in Tables 8 and 9 with the percent of the survey sample that visited each volume type (i.e., Very High to Low) to produce a set of Final Adjustment Factors (Table 10). For example, 93% of the visitors at the High volume access locations, entered and exited at the same volume type; 7% entered and exited at a different volume type. Multiplying the High volume adjustment factors by these respective percentages (i.e., 0.500 * 0.929 = 0.465, and 0.722 * 0.071 = 0.051) and summing the products (i.e., 0.465 + 0.051) yielded a final adjustment factor of 0.516 for the High volume access locations. A similar

procedure was followed for the remaining volume access locations. We multiplied the final adjustment factors shown in Table 10 by the EMC for each monitored location to yield the number of visitors at each monitored location.

Table 10. Final infrared adjustment factors

	Entered – Exited Same Volume				Entered – Exited Different Volume			
Volume	Adjust Factor	Proportion of Sample	Adjust Factor Proportion		Adjust Factor	Proportion of Sample	Adjust Factor Proportion	Final Adjust Factor
Very High	0.500	0.943	0.472		0.773	0.057	0.044	0.515
High	0.500	0.929	0.465		0.722	0.071	0.051	0.516
Medium	0.621	0.850	0.528		0.927	0.150	0.139	0.667
Low	0.529	0.902	0.477		1	0.098	0.098	0.575

There are some important things to note about the procedures used to estimate the number of visitors at a given monitored location.

First, we did not estimate the number of *unique* visitors. If Visitor A, in our example above, returns to OSMP the next day, our procedures result counting him as two visitors. We do not have the data to estimate the number of unique visitors to OSMP.

Second, estimates of the number of visitors to a given location cannot be added to estimates of the number of visitors at another location or set of locations to obtain an estimate of the number of visitors at a group of locations. For example, one could not add the estimate of the number of visitors who pass by the Chautauqua monitor to the estimates from the Bluebell, 6th Street, and Gregory Canyon to obtain an estimate for the larger "Chautauqua area." Such additions would result in double counting of visitors that *do not* enter and exit from the same location. In our example above, adding the estimated number of visitors passing the Chautauqua monitor to the estimated number of visitors passing the Gregory Canyon monitor would result in a double counting of Visitor B, once at Chautauqua and once at Gregory Canyon.

Estimating Dog visitation at OSMP

An estimate of the number of dog visits to OSMP was derived from survey questions that asked visitors to indicate the number of dogs with them on the trip. (This survey was completed in conjunction with the visitation estimate - see Vaske & Donnelly, 2008, for details). The Very High to Low trail volume access locations were included in this analysis. Excluded from this analysis were Very Low trail access locations, Greenways and Fourth of July Trailhead, so the estimate is conservative.

Peer Review

Peer reviewers with natural resource/recreation expertise and experience conducting visitation estimates evaluated the report. Modifications were made based on their comments.

Results

Total Estimated Person Visits – Very High to Low Volume Trails

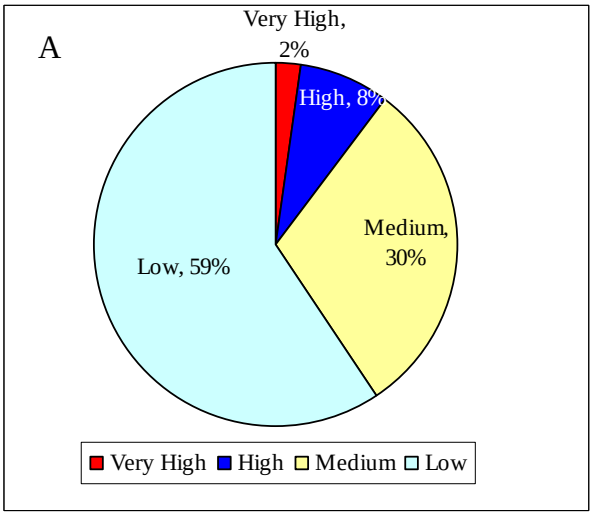
The estimated number of person visits for the *entire study period (June 1, 2004 to May 31, 2005)* for *all trails* in the Very High to Low volume designations is shown in Table 11. Extrapolating the estimated monitor counts (EMC) from the monitored locations across the OSMP system for these trail designations yielded a total estimated person visits of 3,825,577. The lower bound of this estimate was 3,656,448 and the upper bound was 3,994,706.

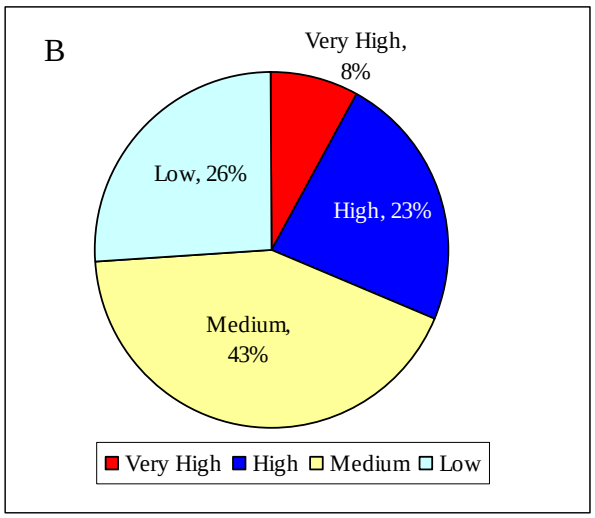
Table 11. Estimated person visits for *all* Very High to Low volume designations

Volume	Total EMC at Monitored Locations by Volume	Number of Monitored Locations	Annual Average at Monitored Locations	Number of Unmonitored Locations	Estimated Total EMC at Unmonitored Locations	Total EMC Monitored and Unmonitored	Total Person Visits (2004-2005)	Lower Bound	Upper Bound
Very High	614,979	3	204,993	0	0	614,979	307,490	293,896	321,084
High	1,782,454	11	162,041	0	0	1,782,454	891,227	851,826	930,628
Medium	1,316,528	17	77,443	25	1,936,071	3,252,599	1,626,299	1,554,401	1,698,198
Low	195,231	8	24,404	74	1,805,891	2,001,122	1,000,561	956,326	1,044,796
Total	**3,909,193**	**39**		**99**		**7,651,155**	**3,825,577**	**3,656,448**	**3,994,706**

As expected, the distribution of person visits was not proportional to the number of access locations in a given volume stratum (Figure 3). While access locations designated as Very High or High volume comprised only 10% of the total number of access locations, we estimated 31% of the total number of person visits occurred at these locations. Conversely, roughly 60% of the access locations were designated as Low volume, but these Low volume locations received just over 25% of the total person visits to OSMP during the study year.

Figure 3. A. Proportion of access locations in a given volume B. Proportion of annual person visits in a given volume





Season, Month and Time-of-Day

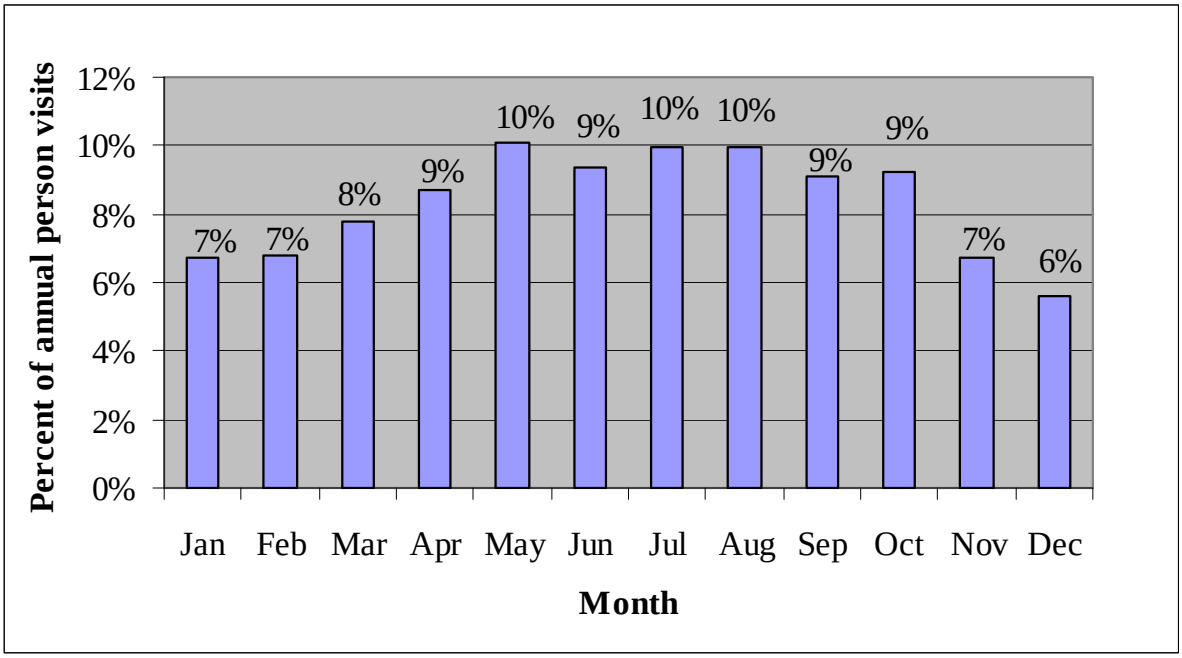
The time and date stamp feature of the infrared monitors allows the data collected from the Very High to Low volume access locations to be examined by season, month, day of week, and hour. Summer was the busiest season with nearly 30% of the total number of person visits (Table 12); person visits were only slightly less in the spring (27%) and fall (25%). May, July, and August were the busiest months (Figure 4). Not surprisingly, the lowest visitation occurred during the winter months with fewest number of person visits recorded for December.

Table 12. Estimated person visits by season [1].

	Percent	Estimated Person Visits	Lower Bound	Upper Bound
Summer	29%	1,120,828	1,071,276	1,170,380
Fall	25%	956,912	914,607	999,217
Winter	19%	732,120	699,753	764,487
Spring	27%	1,015,718	970,813	1,060,623
Total	**100%**	**3,825,577**	**3,656,448**	**3,994,706**

1 Very High to Low volume access locations only.

Figure 4. Percent of annual person visits by month for all of the Very High to Low volume access locations.



Weekend days were busier than weekdays relative to the percentage of each category in the study year (Figure 5). Weekend days accounted for 26% of the study year, while 37% of the total person visits occurred on weekend days. Sunday was the busiest day of the week. Person visits were evenly distributed across all weekdays (Table 13). Weekend visitation was centered more around the middle of the day, while weekday visitation was distributed throughout the day, with greatest visitation from 4 to 6 p.m. (Table 14). Very little visitation occurred between 9 p.m. and 6 a.m., with the percentage of person visits in each of the hour slots in this time frame being less than 1% of the total person visits for a given day category. In total, nighttime use (11 p.m. to 6

a.m.) accounted for only 1.4% of the total person visits. Holidays accounted for 5% of the study year and 6% of the total visitor counts, contrary to expectations that holidays would have a greater contribution to visitor counts.

Figure 5. A. Proportion weekdays, weekend days, and holidays during the study year
B. Proportion of person visits on weekdays, weekend days, and holidays during the study year

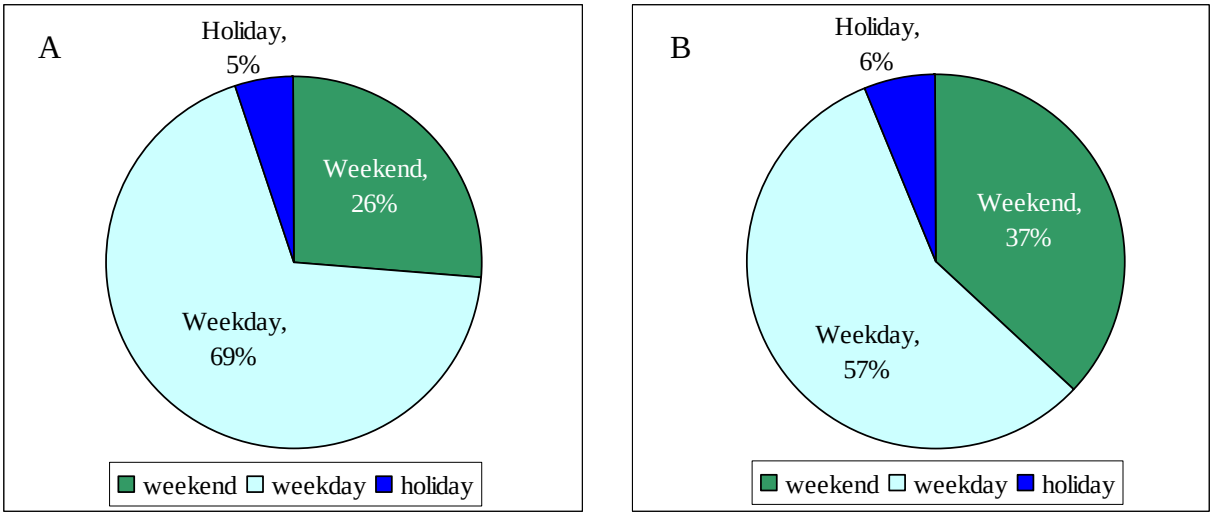


Table 13. Estimated person visits day-of-week [1]

	Percent	Estimated Person Visits	Lower Bound	Upper Bound
Monday	12%	451,704	431,734	471,674
Tuesday	12%	454,323	434,237	474,408
Wednesday	12%	737,402	704,801	770,002
Thursday	12%	815,325	779,279	851,370
Friday	12%	463,902	443,393	484,412
Saturday	19%	460,663	440,297	481,028
Sunday	21%	442,259	422,707	461,812
Total	**100%**	**3,825,577**	**3,656,448**	**3,994,706**

1 Very High to Low volume access locations only

Table 14. Estimated person visits by weekday, weekend or holiday and hour [1]

Hour	Weekday Person Visits	Weekday Percent	Weekend Person Visits	Weekend Percent	Holiday Person Visits	Holiday Percent
Midnight	3,544	0.16%	1,341	0.09%	161	0.07%
1:00 a.m.	3,272	0.15%	1,190	0.08%	210	0.09%
2:00 a.m.	1,475	0.07%	970	0.07%	70	0.03%
3:00 a.m.	1,205	0.06%	968	0.07%	46	0.02%
4:00 a.m.	1,664	0.08%	1,892	0.13%	72	0.03%
5:00 a.m.	14,671	0.68%	2,718	0.19%	527	0.22%
6:00 a.m.	80,108	3.70%	15,487	1.09%	2,742	1.13%
7:00 a.m.	135,956	6.29%	50,127	3.53%	6,904	2.85%
8:00 a.m.	156,254	7.22%	91,328	6.43%	12,181	5.03%
9:00 a.m.	168,050	7.77%	119,710	8.43%	17,196	7.10%
10:00 a.m.	165,694	7.66%	143,618	10.11%	22,073	9.12%
11:00 a.m.	166,446	7.70%	150,683	10.61%	25,848	10.67%
Noon	167,731	7.76%	144,396	10.16%	25,950	10.72%
1:00 p.m.	152,305	7.04%	140,924	9.92%	26,611	10.99%
2:00 p.m.	150,770	6.97%	144,015	10.14%	25,676	10.60%
3:00 p.m.	154,492	7.14%	134,559	9.47%	23,748	9.81%
4:00 p.m.	174,992	8.09%	107,215	7.55%	19,524	8.06%
5:00 p.m.	168,274	7.78%	71,433	5.03%	13,180	5.44%
6:00 p.m.	141,284	6.53%	44,144	3.11%	9,602	3.97%
7:00 p.m.	91,425	4.23%	29,156	2.05%	5,276	2.18%
8:00 p.m.	41,621	1.92%	13,826	0.97%	2,516	1.04%
9:00 p.m.	12,195	0.56%	5,143	0.36%	993	0.41%
10:00 p.m.	5,992	0.28%	3,604	0.25%	624	0.26%
11:00 p.m.	3,458	0.16%	2,090	0.15%	432	0.18%
Total	**2,162,878**	**100.00%**	**1,420,537**	**100.00%**	**242,162**	**100.00%**

[1]Very High to Low volume access locations only

Very Low Volume Accesses Estimate

For the 98 Very Low volume access locations, observers counted visitors for three hours at 12 randomly selected locations per quarter (Table15). Across all four seasons a total of 84 adult visitors were observed with an average of 0.58 visits per hour. The average daily person visit totals ranged from 3.06 (Spring) to 9.72 (Summer). The data were extrapolated to all available time periods for Very Low access locations to estimate person visits. Given the small sample sizes, an 80% confidence interval was used. The total estimated person visits for the Very Low trail volume accesses was 208,931 with a lower bound of 167,144 and an upper bound of 250,717.

Table 15. Estimated person visits for Very Low volume accesses by season

	Observed Visits	Hours Sampled	Visits per Hour	Hours in Day	Avg. Daily Total	Days per Season	Seasonal estimate	# of accesses	Total Estimated Person Visits	Lower Bound	Upper Bound
Summer	35	36	0.97	10	9.72	92	894	98	87,656	70,124	105,187
Fall	23	36	0.64	10	6.39	91	581	98	56,976	45,581	68,371
Winter	15	36	0.42	10	4.17	90	375	98	36,750	29,400	44,100
Spring	11	36	0.31	10	3.06	92	281	98	27,549	22,039	33,059
Total	**84**		**0.58**						**208,931**	**167,144**	**250,717**

Greenways Managed by OSMP Estimate

To estimate the total number of person visits to the Greenways trails managed by OSMP, 80% confidence intervals were constructed for the two locations where inductive loop monitors were installed. It was assumed that the monitors only recorded bicyclists and that these counts were recorded without error. The total number of person visits to each of the Greenways trails was computed by summing the estimates and the endpoints of the lower and upper bounds (Table 16). The estimated total number of person visits to monitored Greenways locations was computed by summing the totals for each individual location. An estimated 435,724 individuals visited Greenways trails during the study year. The bounds for this estimate range from 379,038 to 515,312.

Table 16. Estimated person visits for Greenways managed by OSMP by season

Location	Season	Estimated Person Visits	Lower Bound	Upper Bound
Boulder Creek@ Arapahoe	Summer	135,267	123,045	150,269
	Fall	108,633	94,771	127,306
	Winter	50,129	44,915	56,711
	Spring	95,441	85,511	108,137
Total		389,470	348,252	442,423
55th and Pearl	Summer	19,486	12,728	28,634
	Fall	10,543	6,706	24,941
	Winter	5,670	3,283	4,158
	Spring	10,555	8,079	15,156
Total		46,254	30,796	72,889
Total		**435,724**	**379,038**	**515,312**

Fourth of July Trailhead Estimate

The Fourth of July Trailhead estimate was based on an inductive loop monitor and field staff observations. From June 10 to August 7, 2004, a total of 7,612 vehicle counts were recorded. Based on field staff observations, the average number of vehicles per day was 129 and the corresponding standard error of this estimate was 13.77. Inflating to account for the full 92 day summer season, the estimated total number of vehicles passing the monitor was 11,868 with a corresponding standard error (SE) of 1,266. Because the sample size was small, a conservative 80% margin of error (ME) was computed as twice the standard error. The conservative 80% ME

was 2,533. A conservative 80% confidence interval (CI) for the total number of vehicles that passed the monitor during the summer season was estimated as 11,868 ± 2,533. This implies that we are 80% confident that the true number of vehicles that passed this monitor during the summer of 2004 was between 9,334 and 14,402.

Since these vehicles were counted entering and exiting the area it was necessary to halve these values to obtain a CI for the number of vehicles carrying visitors to this trail. An estimated 5,934 ± 1,266 vehicles took visitors to Fourth of July Trailhead.

To obtain an estimate for the total number of person visits to the Fourth of July Trailhead during the summer season, it was necessary to obtain vehicle occupancy observations. Based on field staff observations, the occupancy ratio was 122 / 51 = 2.39 occupants per vehicle. The corresponding SE for this estimate was 0.247 and an approximate 80% ME was 0.494. The associated 80% CI is 2.39 ± 0.494 = 1.90 to 2.88. This interval implies that we can be 80% confident that the true occupancy rate for vehicles at Fourth of July Trailhead is between 1.90 and 2.88 persons/vehicle.

To estimate the total number of person visits to Fourth of July Trailhead, the results from the monitor counts and the occupancy observations were combined. The estimated number of person visits was 5,934 * 2.39 = 14,182. A lower bound for the number of visits was computed by finding the product of the lower bounds for the vehicle and ratio estimates. The upper bound for the number of visits was also computed as the product of the upper bounds. For the summer season an approximate lower bound was 1.9 * 4,667 = 8,868 while a corresponding upper bound is 20,738.

People Less than 36 Inches in Height Estimate

There were an observed 147 people less than 36 inches in height for 3,022 taller visitors giving a ratio of 4.9% (Table 17). An estimated 196,252 person visits were made by individuals less than 36 inches in height to the OSMP trail system for the 2004 – 2005 study year. The 95% confidence interval for this estimate was 165,392 and 227,111. The error for this estimate was ±0.8%.

Table 17. Estimated person visits for people less than 36 inches in height by season

	Observed Children	Observed Adults	Estimated Person Visits < 36” tall	Lower Bound	Upper Bound
Summer	10	198	58,785	49,541	68,028
Fall	44	978	49,319	41,564	57,074
Winter	34	863	37,400	31,519	43,281
Spring	59	983	50,748	42,768	58,728
Total	**147**	**3,022**	**196,252**	**165,392**	**227,111**

Overall OSMP Person Visits Estimate (2004 – 2005)

Combining the estimates from all data sources, there were 4,680,666 estimated person visits to OSMP properties between June 1, 2004 and May 31, 2005. (Table 18) The bounds for this estimate ranged from 4,376,890 to 5,008,584.

Table 18. Total estimated person visits at OSMP (2004-2005 study year)

	Estimated Person Visits	Lower Bound	Upper Bound
Very High to Low volume locations [1]	3,825,577	3,656,448	3,994,706
Very Low volume locations [2]	208,931	167,144	250,717
Greenways [3]	435,724	379,038	515,312
Fourth of July Trailhead [4]	14,182	8,868	20,738
People under 36 inches in height [5]	196,252	165,392	227,111
Total	**4,680,666**	**4,376,890**	**5,008,584**

1. Based on infrared monitor counts
2. Based on field staff observations
3. Based on inductive loop monitor counts of bikers and field staff observations of non-bikers
4. Based on inductive loop monitor counts of cars and field staff observations of the number of people per car
5. Based on field staff observations

Estimated Number of Visitors at Individual Monitored Locations

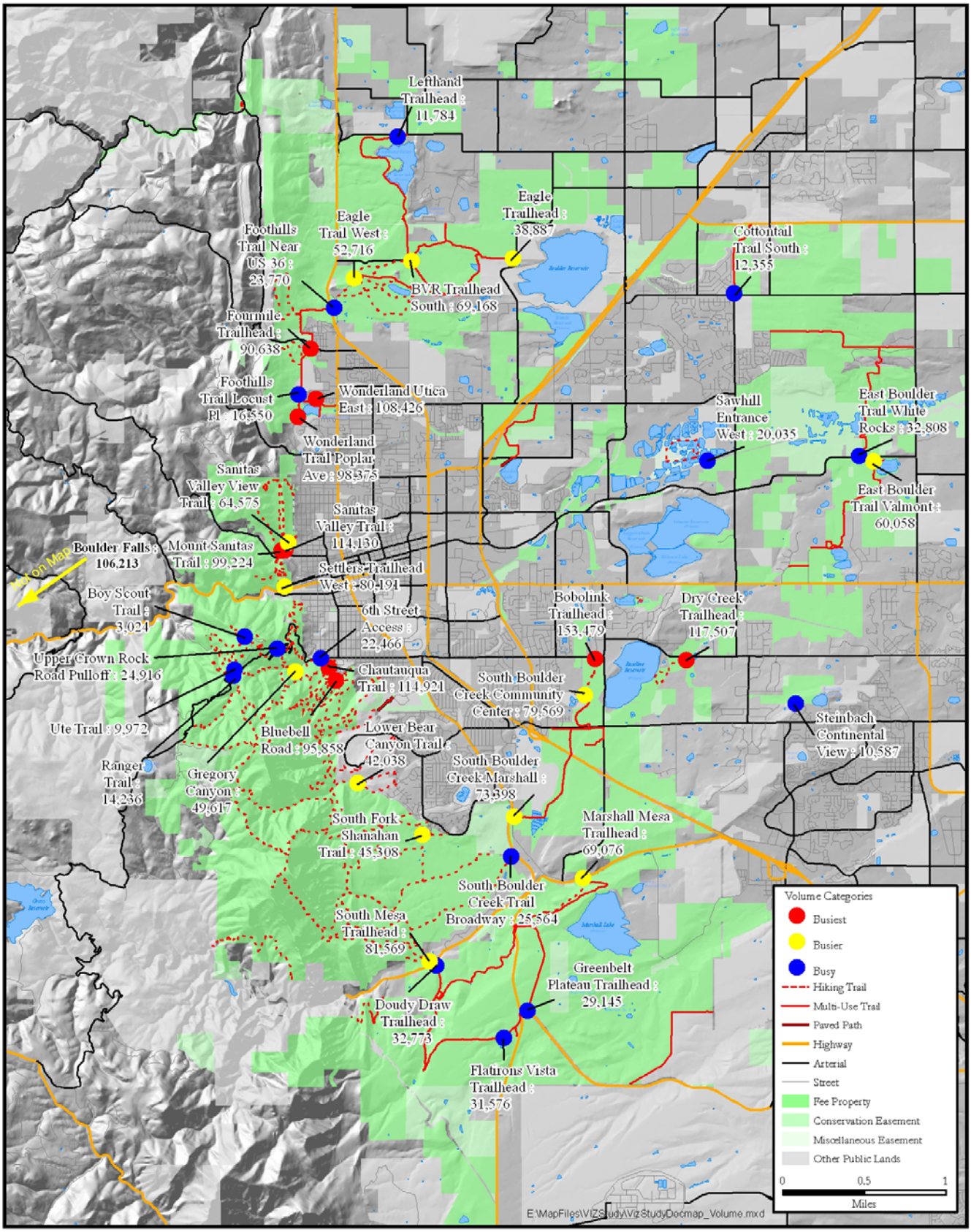
Table 19 and Figure 6 present the results for the estimated number of visitors at individual monitored locations. (See discussion in the Methods section for explanation of visitors vs. person visits.) Bobolink Trailhead was the busiest monitored access location with over 150,000 visitors passing the infrared monitor during the study year. Other busy access locations included Dry Creek Trailhead (117,507 visitors), Chautauqua Trail (114,921 visitors), and Sanitas Valley Trail (114, 130 visitors). On the other end of the scale, the Boy Scout and Ute Trails received the lowest number of visitors.

In general, Very High and High volume access locations had the highest estimated number of visitors. However, because the trail volume designations were based on OSMP staff's judgments prior to data collection, exceptions did occur. For example, the estimated number of visitors that passed the monitor at Wonderland Trail – Utica East (a Medium trail designation) was 108,426 which is larger than several of the trails designated as High volume. Access locations labeled as Low volume generally saw the fewest number of visitors.

Table 19. Estimated number of visitors at monitored access locations

	Volume	Estimated Number of Visitors	Lower Bound	Upper Bound
Boulder Falls	VH	106,213	101,517	110,909
Bluebell Rd	VH	95,858	91,620	100,096
Chautauqua Trail	VH	114,921	109,841	120,002
Mt Sanitas Trail	H	99,224	94,837	103,611
Sanitas Valley Trail	H	114,130	109,085	119,176
Sanitas Valley View Trail	H	64,575	61,720	67,430
Wonderland Trail - Poplar Ave	H	98,375	94,026	102,725
Eagle Trailhead	H	38,887	37,168	40,606
Bobolink Trailhead	H	153,479	146,693	160,264
Dry Creek Trailhead	H	117,507	112,312	122,702
Marshall Mesa Trailhead	H	69,076	66,022	72,130
Doudy Draw Trailhead	H	32,773	31,324	34,222
South Mesa Trailhead	H	81,569	77,963	85,176
Gregory Canyon Trail	H	49,617	47,423	51,810
Settlers Trailhead - West	M	80,191	76,646	83,737
Wonderland Trail - Utica East	M	108,426	103,632	113,220
Fourmile Trailhead	M	90,638	86,631	94,645
Foothills Trail - Near US 36	M	23,770	22,719	24,821
Eagle Trail West	M	52,716	50,386	55,047
Boulder Valley Ranch - South	M	69,168	66,110	72,225
East Boulder Trail - White Rocks	M	32,808	31,357	34,258
Sawhill Entrance West	M	20,035	19,150	20,921
East Boulder Trail - Valmont	M	60,058	57,403	62,714
South Boulder Creek - Community Center	M	79,569	76,051	83,086
South Boulder Creek - Marshall	M	73,398	70,153	76,643
Greenbelt Plateau Trailhead	M	29,145	27,856	30,433
Flatirons Vista Trailhead	M	31,576	30,180	32,972
North Fork Shanahan Trail	M	45,308	43,305	47,311
Lower Bear Canyon Trail	M	42,038	40,179	43,896
Ranger Trail	M	14,236	13,606	14,865
Upper Crown Rock	M	24,916	23,814	26,017
Foothills Trail - Locust Place	L	16,550	15,818	17,281
Lefthand Trailhead	L	11,784	11,263	12,305
Cottontail Trail South	L	12,355	11,809	12,902
Steinbach Continental View	L	10,587	10,119	11,055
South Boulder Creek - Broadway	L	25,564	24,434	26,694
6th St	L	22,466	21,473	23,459
Ute Trail	L	9,972	9,531	10,413
Boy Scout Trail	L	3,024	2,890	3,158

Figure 6. Number of visitors at monitored access points



Examining visitor estimates at the busier access locations by season, day, and hour helps reveal patterns at individual locations that may be masked when the system is considered as a whole. Figure 7 shows the percent of the total visitor estimate by season at six of the busier access locations: Sanitas Valley, Wonderland-Utica, Bobolink, Dry Creek, South Mesa, and Chautauqua. The individual access locations show slightly different visitation distributions than observed for the system as a whole. (Recalling from Table 12, summer was estimated to be the busiest season (29%) followed by spring (27%), fall (25%), and winter (19%) for the entire OSMP system.) Compared to the systemwide seasonal distribution, Chautauqua and South Mesa saw disproportionally higher visitation in the summer and lower visitation in the winter. Visitation at Sanitas Valley was roughly evenly distributed among seasons, while fall was the most popular season for visitation at Dry Creek.

Figure 8 presents the distribution of visitors at the same six access locations across days of the week. For the study year, approximately 26% of the days were weekend days, 69% were weekdays, and 5 % were holidays. South Mesa and Chautauqua saw disproportionally higher visitation on weekend days and holidays. At South Mesa, the number of visitors was nearly equally distributed between weekend days and weekdays despite the fact that there were 2.5 times as many weekdays and weekend days. In contrast, at the Wonderland-Utica access location, the proportion of visitors on weekdays to visitors on weekend days more closely mirrored the proportion of weekdays to weekend days during the study year.

Visitation patterns throughout a given day also differed by location. On weekdays, visitation at Wonderland-Utica and Dry Creek shows the same bimodal pattern observed for the system as a whole, with peaks in the early morning and late afternoon (Figure 9). Interestingly, Wonderland-Utica also exhibits a bimodal visitation pattern on weekend days, whereas when data is combined for the entire system, weekend days show a concentration of visitation near the middle of the day. At South Mesa and Chautauqua, visitation was centered near the middle of the day for both weekend days and weekdays.

Figure 7. Distribution of visitors by season at six busy access locations.

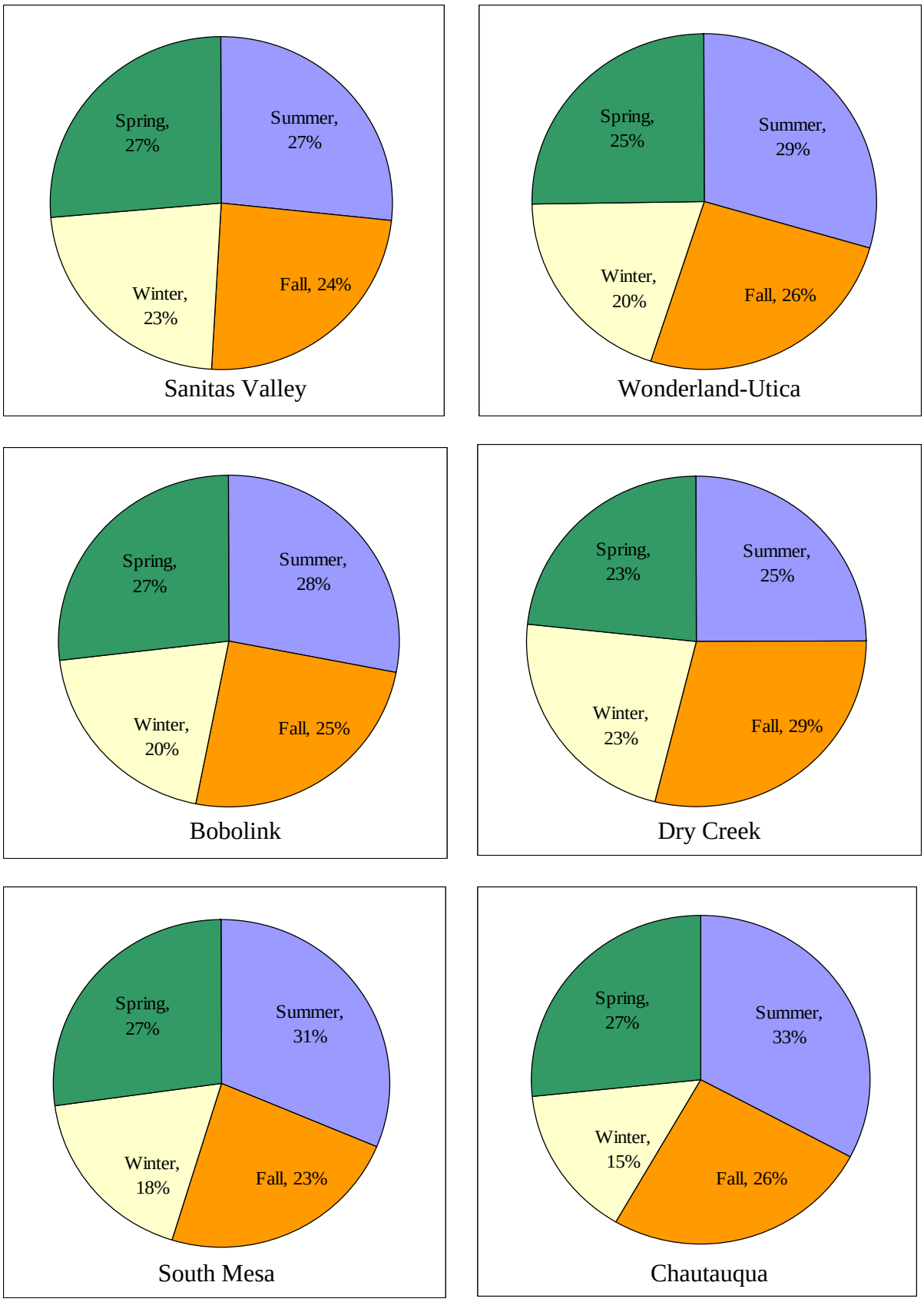


Figure 8. Distribution of visitors by day at six busy access locations

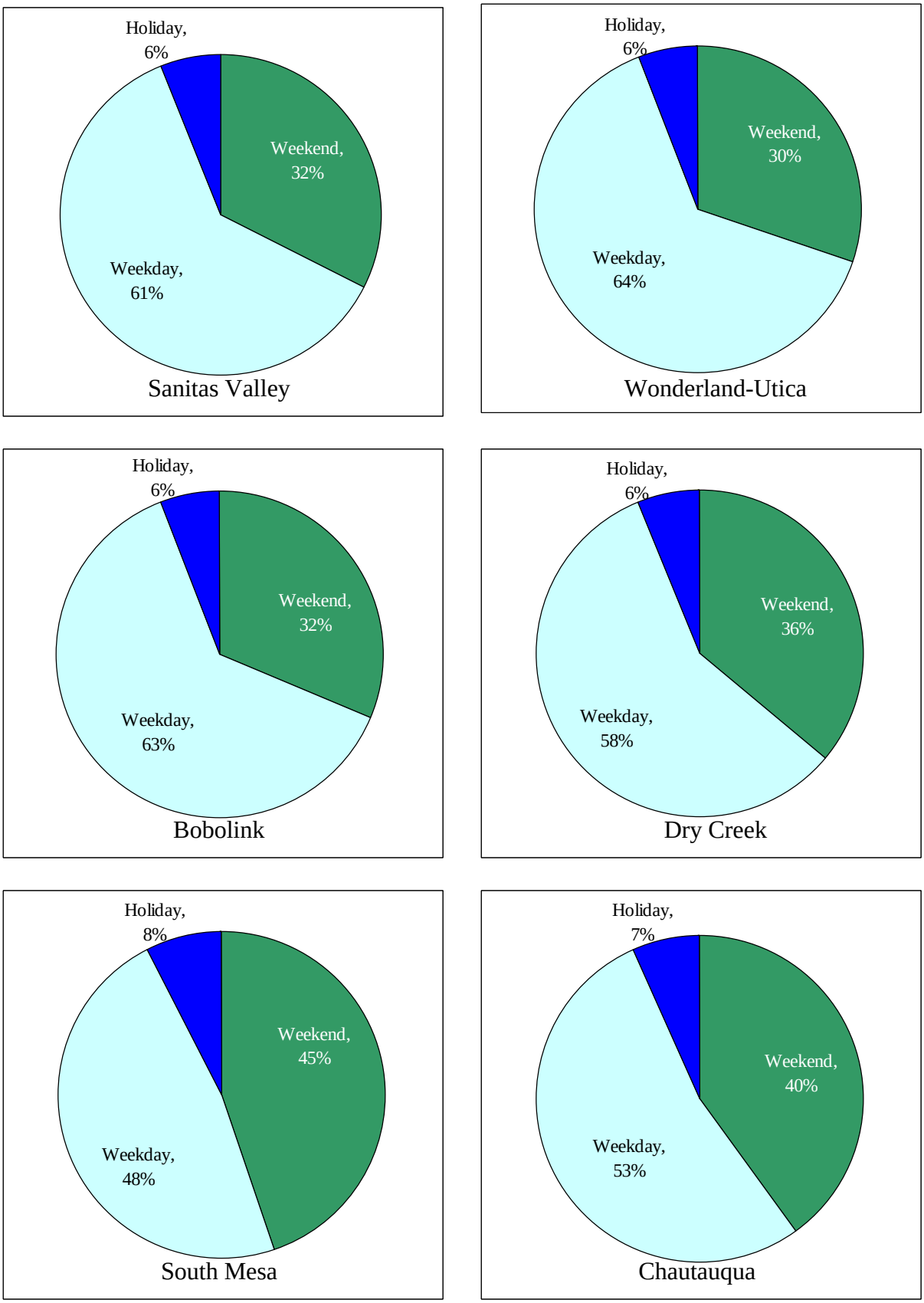
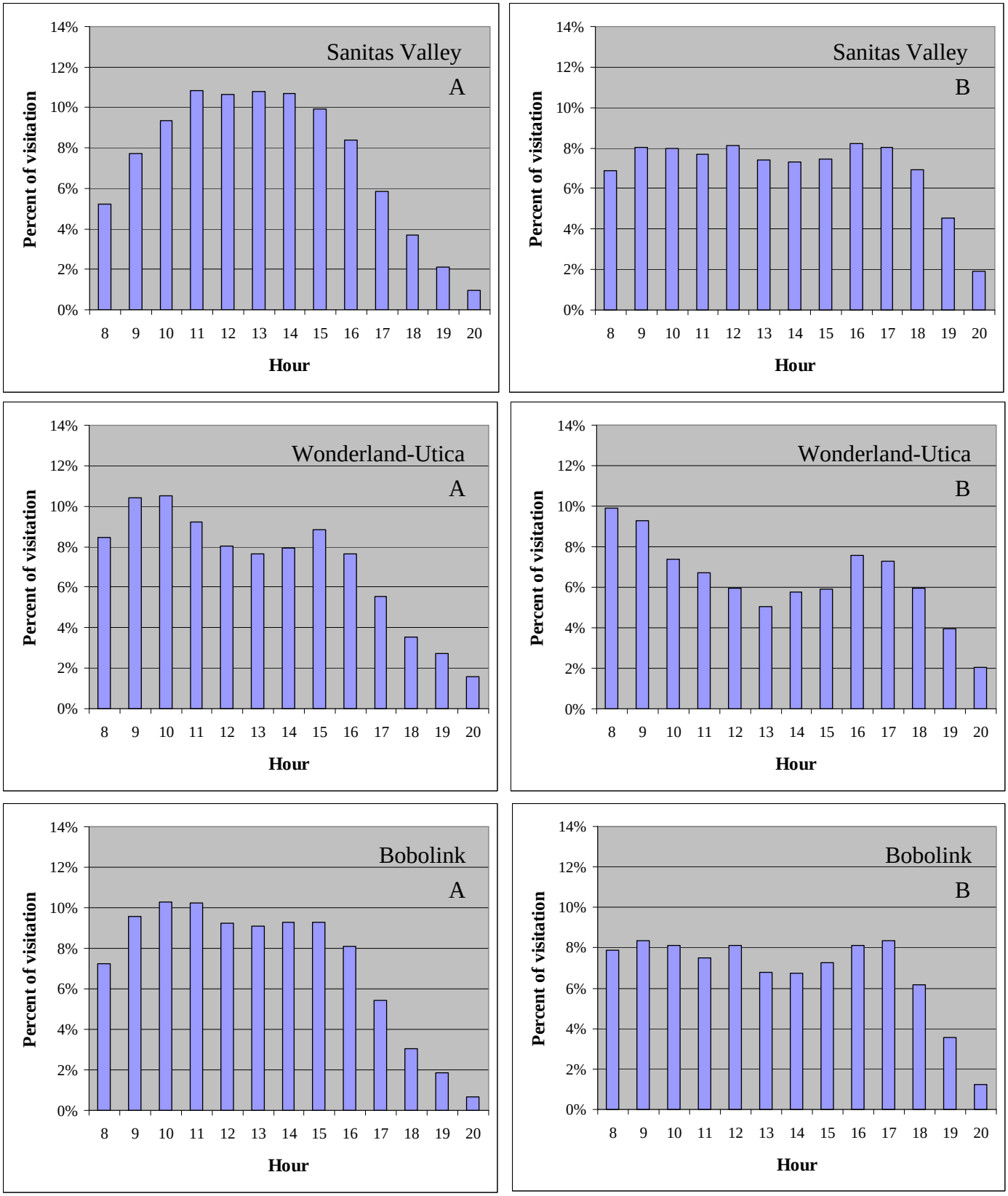
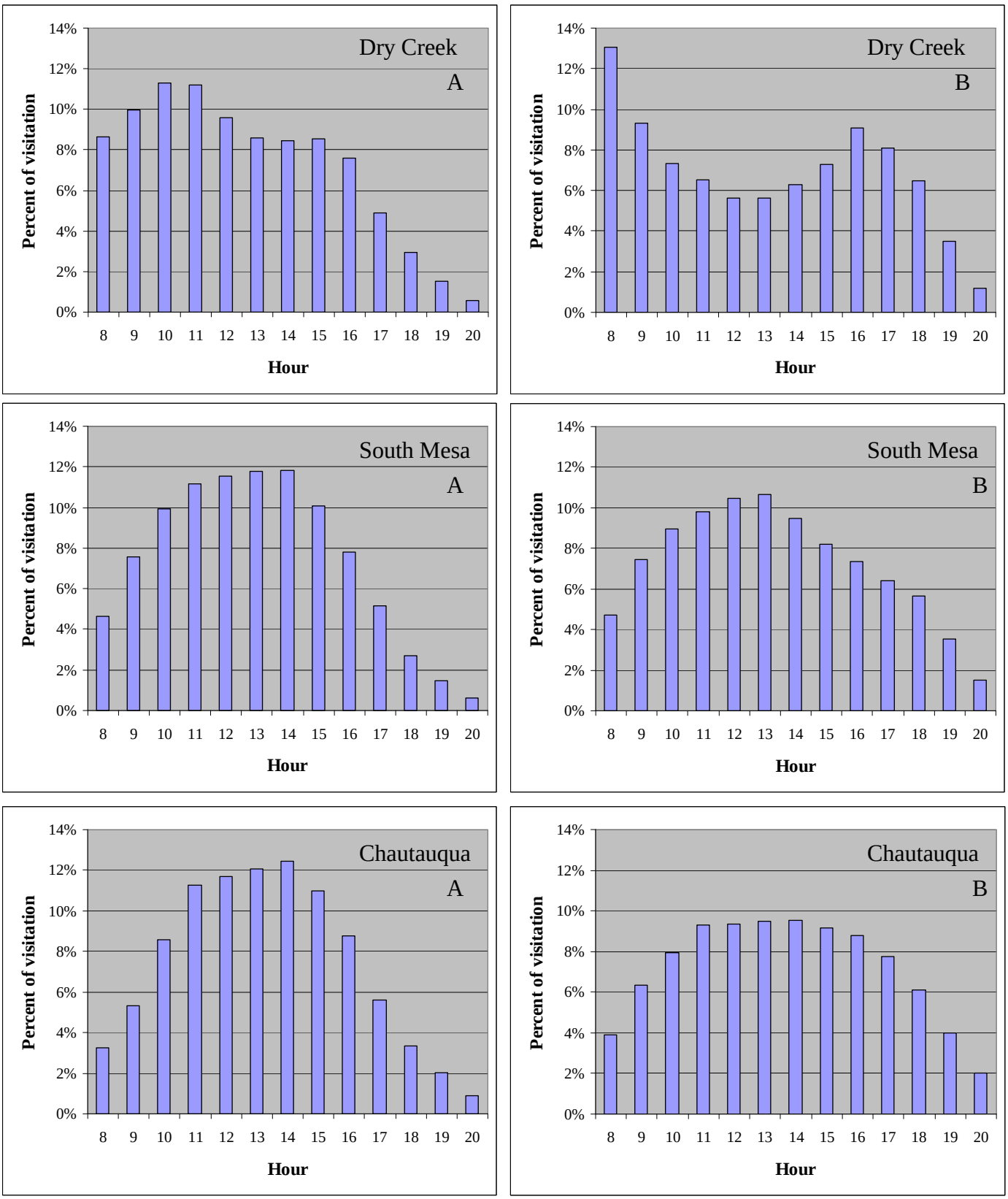


Figure 9. Distribution of visitors by hour (8 a.m. to 8 p.m.) by day at six busy access locations (A=weekend day, B=weekday).




Dry Creek
A
Dry Creek
B
South Mesa
A
South Mesa
B
Chautauqua
A
Chautauqua
B
Percent of visitation
Hour
0%
2%
4%
6%
8%
10%
12%
14%
8 9 10 11 12 13 14 15 16 17 18 19 20

Dog Visit Estimate

The estimated number of dog visits was based on: (a) the estimated person visits per season at the Very High to Low volume access locations, and (b) survey responses to questions regarding the number of dogs the visitors had with them (Vaske & Donnelly, 2008). About a third (34%) of the visitors had a dog with them on the visit when they completed a questionnaire (Table 20). Similar percentages resulted for the fall (33%), winter (35%), and spring 2005 (32%). Of those visiting with a dog, the overall average number of dogs per person visit across all seasons was 1.44. This average ranged from 1.36 (Spring 2005) to 1.56 (Summer 2004).

Table 20. Dog walking at OSMP by season

	Season[1]			
	Summer 2004	Fall 2004	Winter 2004-2005	Spring 2005
Did you have a dog with you?				
No	65	67	65	68
Yes	35	33	35	32
If yes, number of dogs on this visit				
1	62	76	58	68
2	29	17	34	29
3 +	9	7	8	3
Average	**1.56**	**1.35**	**1.50**	**1.36**

1. Cell entries are percents.
Source: (Vaske & Donnelly, 2008)

Multiplying the probability of a dog with a visitor by the estimated number of person visits, the estimated number of person visits with dogs was 1,289,342. Given the average number of dogs per visit for those visiting with a dog (i.e., 1.44), the estimated number of dogs visiting OSMP during the study year was 1,864,679. The lower bound for this estimate was 1,782,242 and the upper bound was 1,947,117. These estimates are conservative because person visit estimates from the 98 Very Low access points, Greenways, and the Fourth of July were not included in the calculations.

Table 21. Estimated OSMP dog visits (2004-2005 study year) by season

	Estimated Person Visits	Probability of a Dog with a Visitor [1]	Estimated Number of Person Visits with Dogs	Average Number of Dogs per Person Visit	Estimated Number of Dogs	Lower Bound	Upper Bound
Summer	1,120,828	0.35	392,290	1.56	611,972	584,917	639,027
Fall	956,912	0.33	315,781	1.35	426,304	407,457	445,151
Winter	732,120	0.35	256,242	1.5	384,363	367,370	401,356
Spring	1,015,718	0.32	325,030	1.36	442,040	422,498	461,583
Total	**3,825,577**		**1,289,342**	**1.44**	**1,864,679**	**1,782,242**	**1,947,117**

1 Based on Vaske and Donnelly, 2008

Discussion

Several of the challenges OSMP faces in estimating the annual number of person visits to the properties it manages have already been highlighted. These challenges include having a very porous boundary. Staff identified over 230 locations where visitors can access OSMP properties. The list of identified locations does not include points where individual property owners whose land abuts OSMP can access OSMP property by literally "walking out their back doors." Other challenges that have been noted are that OSMP owns fewer infrared monitors than access locations, preventing OSMP from equipping every access location with a monitor, and measurement errors associated with the monitors themselves (see the Methods section).

One challenge that has not been mentioned previously, however, is determining how to account for visitors that do not pass one of the infrared monitors. While these visitors do not register any counts on the infrared monitors, they should be included in the annual estimate of person visits to OSMP. Various methods exist for "adding" these uncounted visitors to the total annual estimate.

Initially, we used an approach that adjusted (i.e. increased) the monitor counts at individual locations to account for visitors that did not pass an infrared monitor. From the visitor survey data, we knew the proportion of visitors in each volume stratum that did not enter or exit at a monitored location. We used this proportion to inflate monitor counts by volume stratum. (As we do in the methods we present in this document, we also inflated the monitor counts by the ratio inflation factor to account for measurement errors associated with the monitors.) Finally, we summed estimates for each volume stratum to obtain an estimated total person visits to the system.

We presented our initial work for peer review from researchers doing similar work. While we received positive feedback from three of the four reviewers, one reviewer offered an alternative approach to account for visitors that did not pass an infrared monitor. To evaluate this reviewer's approach against our initial approach, we developed a simulation of visitors to a hypothetical, small scale "model OSMP land system." This hypothetical system consisted of 26 access locations with varying levels of visitation and had a known number of total visitors. As we did during the current study, we assigned a monitor to all of the Very High and High volume access locations and a portion of the Medium and Low volume access locations in our hypothetical OSMP. Visitation patterns (i.e. the number of visitors that pass an infrared monitor) could be varied in the hypothetical OSMP.

Using the simulation, we tested our initial method for accounting for visitors that did not pass an infrared monitor, variations on our initial method, and the method suggested by the reviewer. While all methods performed satisfactorily, the methods suggested by the reviewer typically performed the best by most closely matching the known number of visitors to the hypothetical OSMP. The method suggested by the reviewer also consistently produced the most conservative estimate. Given these results, we adopted the reviewer's suggested method and the results presented in this document were obtained using this method.

Regardless of the methods used to estimate the total number of person visits to OSMP, the "bottom line" result is the same: OSMP receives a lot of person visits each year. Of course, any visitor to Chautauqua Meadow on a sunny Saturday in May could have arrived at that finding without worrying about how to account for various visitation patterns. While the study confirms many long-held assumptions (i.e. weekends are typically busier than weekdays, weekdays are busiest in the mornings and late afternoons), it challenges others. One such assumption is that the

“shoulder” seasons (i.e. Spring and Fall) receive the greatest number of person visits. Results from this study show that two of the three busiest months are July and August.

Other assumptions challenged by the results of this study are the relative busyness of some of the individual access locations. Staff rated Doudy Draw and Eagle Trailheads as High volume access locations, but these locations only received 32,773 and 38,887 visitors, respectively. These numbers are more typical of access locations in the lower end of the Medium volume category. Conversely, the Wonderland-Utica access location, which was estimated to be a Medium volume location, registered 108,426 visitors for the year, the fifth highest of the monitored locations.

Understanding the spatial distribution of visitors on OSMP at a given time has implications for service delivery and therefore visitor satisfaction. The most obvious example of this is coordinating ranger patrols and outreach staff programs to ensure OSMP has adequate staff to serve visitors at the busiest locations and times. Results from this work show that Chautauqua and South Mesa receive disproportionally higher visitation in the summer and on weekends. Ranger and outreach staffing could increase at these times to accommodate visitors. Similarly, bathroom facilities should be well stocked at these locations and times with weekend staff prepared to respond to shortages.

The timing of routine trail maintenance could be adjusted to avoid the busiest times at given locations. For example, data from this study show the number of visitors passing the infrared monitors at Wonderland-Utica and Dry Creek locations peaks in the early morning and wanes to a low in the early afternoon. In contrast, on weekdays at South Mesa and Chautauqua the number of visitors passing the infrared monitors does not peak until early afternoon. To minimize disruption to visitors, crews conducting routine maintenance might schedule their work day such that they work near South Mesa and Chautauqua trailheads in the morning and the Wonderland-Utica and Dry Creek areas in the early afternoon.

Some access locations receive regular visitation and should receive a consistent level of service delivery (e.g., ranger and outreach staffing, trash can service, etc.) Sanitas Valley is one such location. Visitor numbers were relatively evenly distributed among the seasons. The proportion of visitors on weekends to visitors on weekdays more closely mirrored the distribution of these days for the study year compared to other locations. Visitation was also relatively evenly distributed throughout a given weekday. These patterns suggest Sanitas Valley receives regular visitation regardless of factors that might affect visitation patterns at other access locations and the scheduling of service delivery should reflect these findings.

Summary

Active infrared counters give managers a reliable and accurate tool for recording visitation at specific locations as well as the entire trail system. Visitation estimates can facilitate: (a) annual reporting, and (b) the allocation of resources for patrolling, trail maintenance, and scheduling infrastructure improvements. Although active infrared monitors have limitations (e.g., animal counts, large groups), these problems can be mitigated with careful observation and calibrations. Malfunctions do occur but become less important if monitors are used for multiple seasons. If field staff are trained to calibrate, monitor and download the data, problems with specific monitors can be detected early and the estimates will become more accurate.

Visitor surveys (e.g., Vaske & Donnelly, 2008) complement these visitation estimates by describing visitors in terms of their: (a) demographic characteristics (e.g., sex, age, residence), (b) trip characteristics (e.g., trip duration, activity participation), and (c) evaluations of the experience (e.g., perceived conflict, satisfaction with OSMP). Survey data can also provide the foundation for adjusting estimates appropriately. Given that visitors can access OSMP properties from at least 236 different locations and OSMP owns approximately 40 infrared monitors, not every location can be systematically monitored. Some individuals in this study never passed a monitor, but they visited OSMP and should be included in the estimation process. Surveys provide a vehicle for determining the proportion of visitors who were not seen by a monitor.

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Appendix A

OSMP Study Sectors

Figure 10. System map with monitored locations

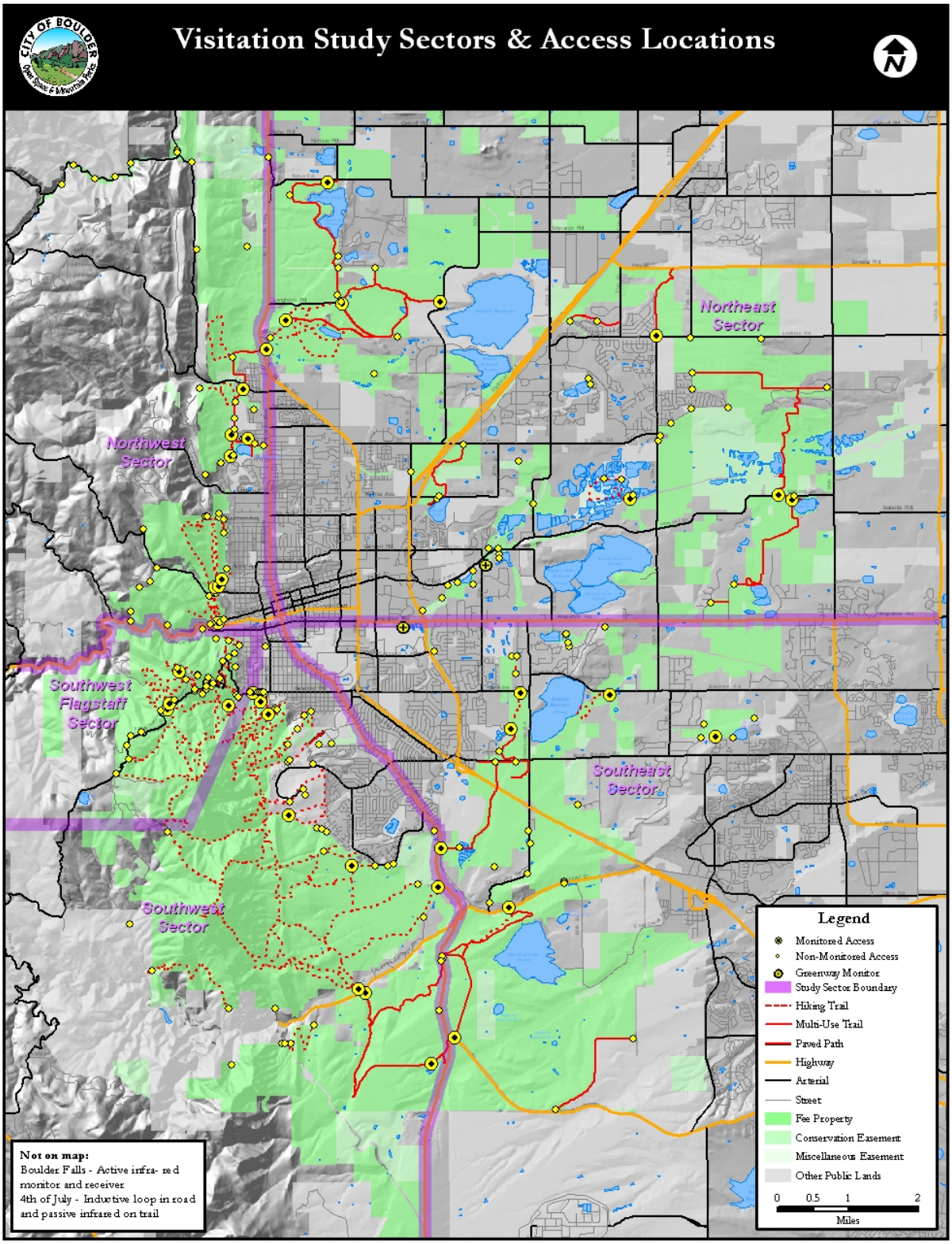

Figure 11. Northeast sector map

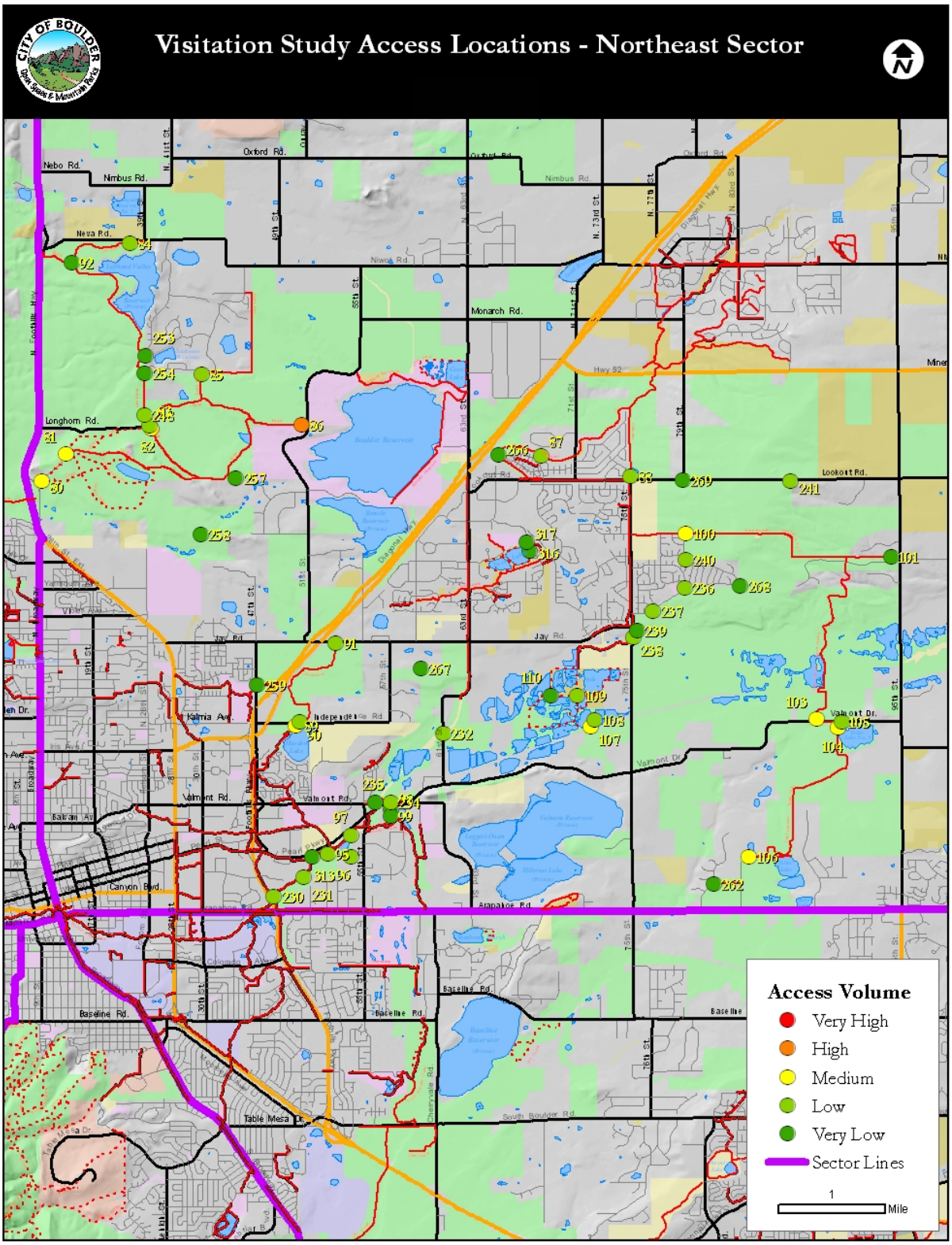

Figure 12. Northwest sector map

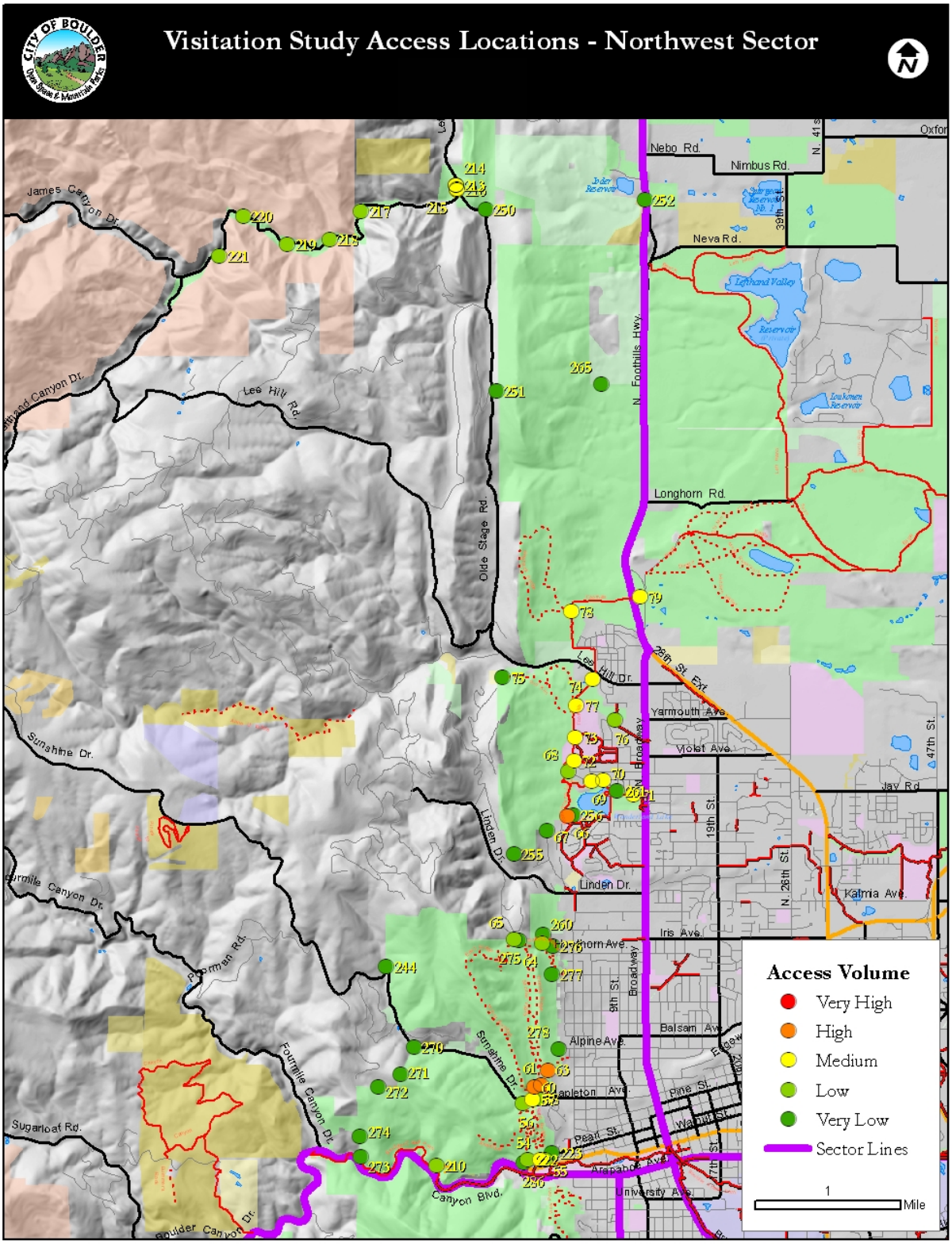

Figure 13. Southeast sector map

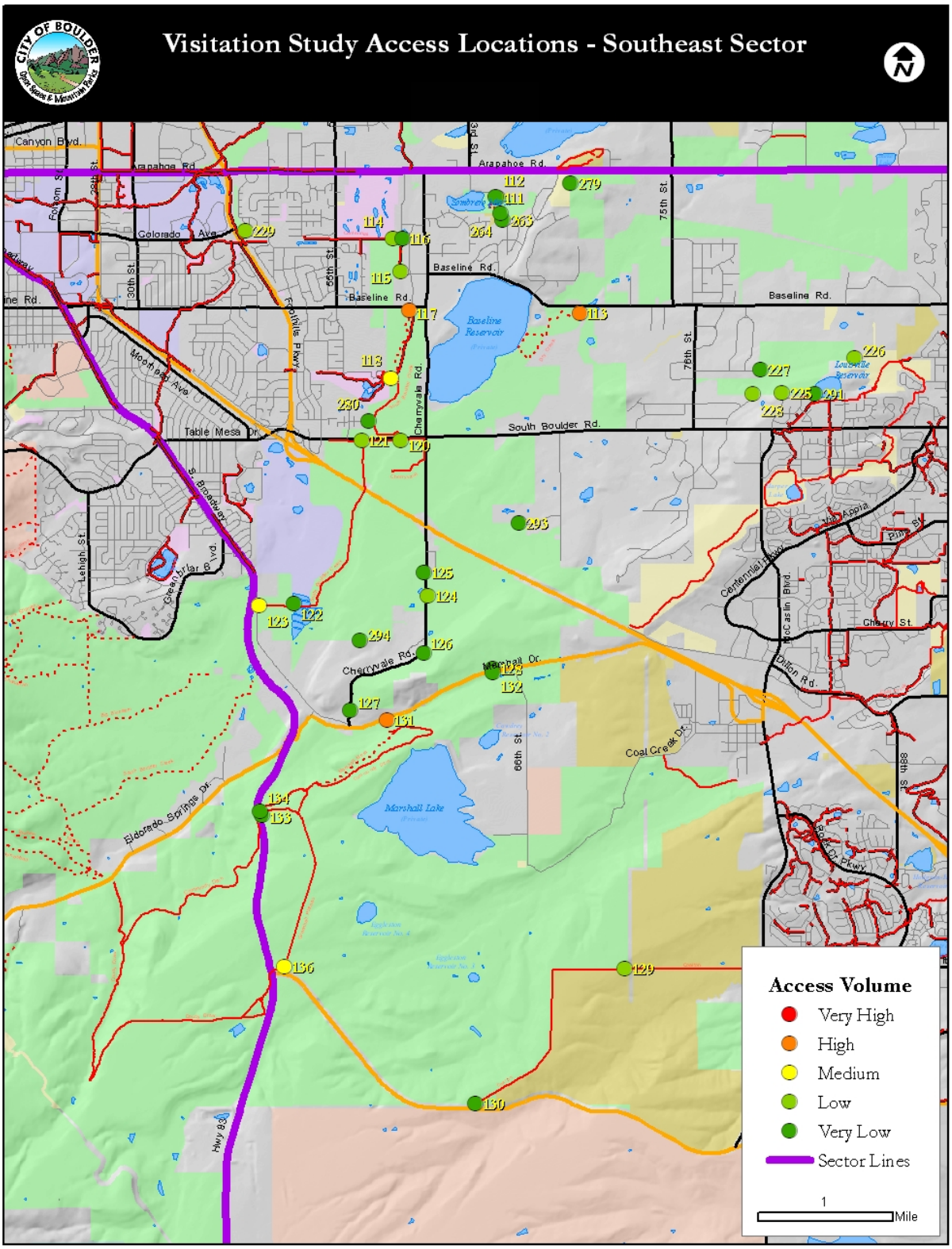

Figure 14. Southwest sector map

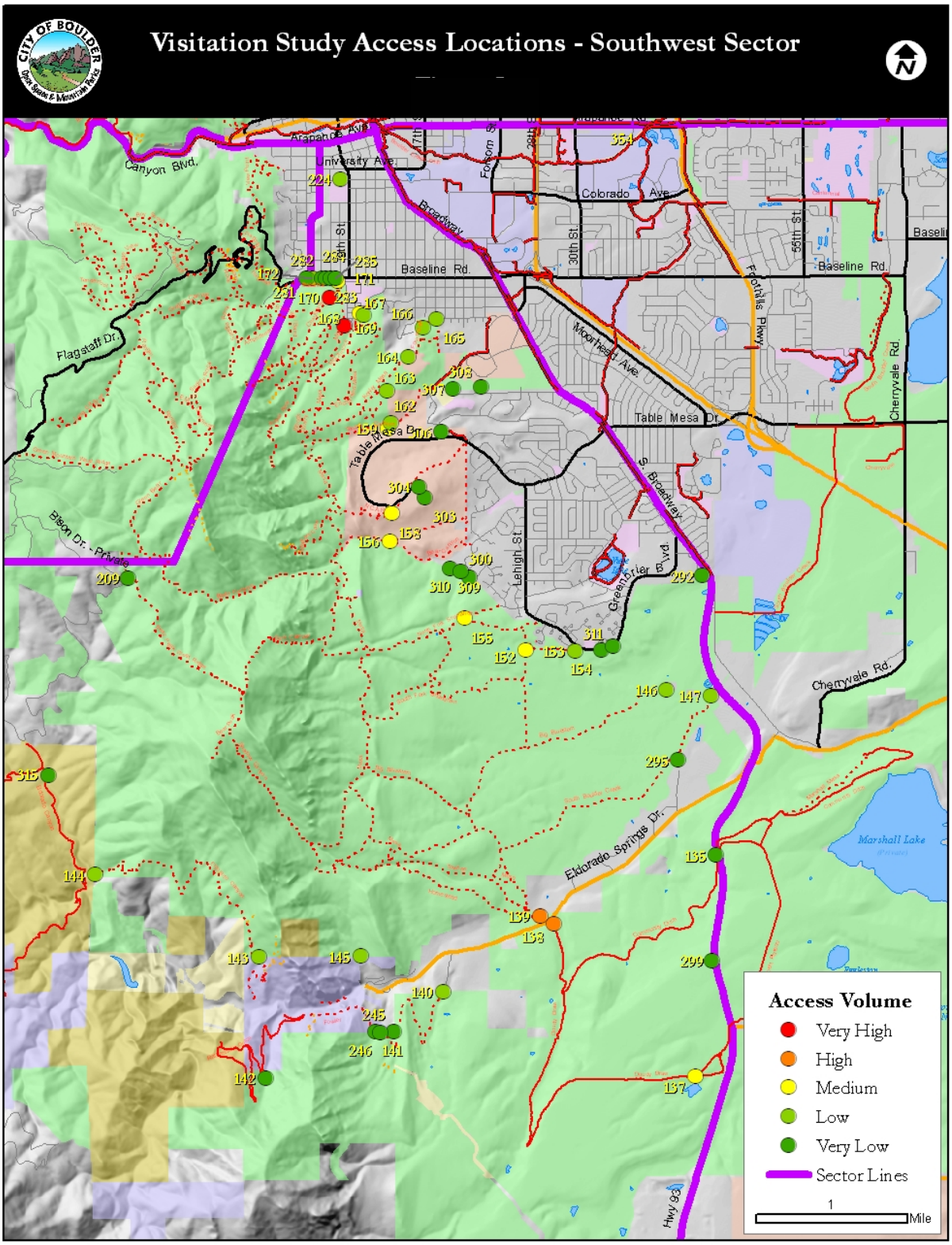
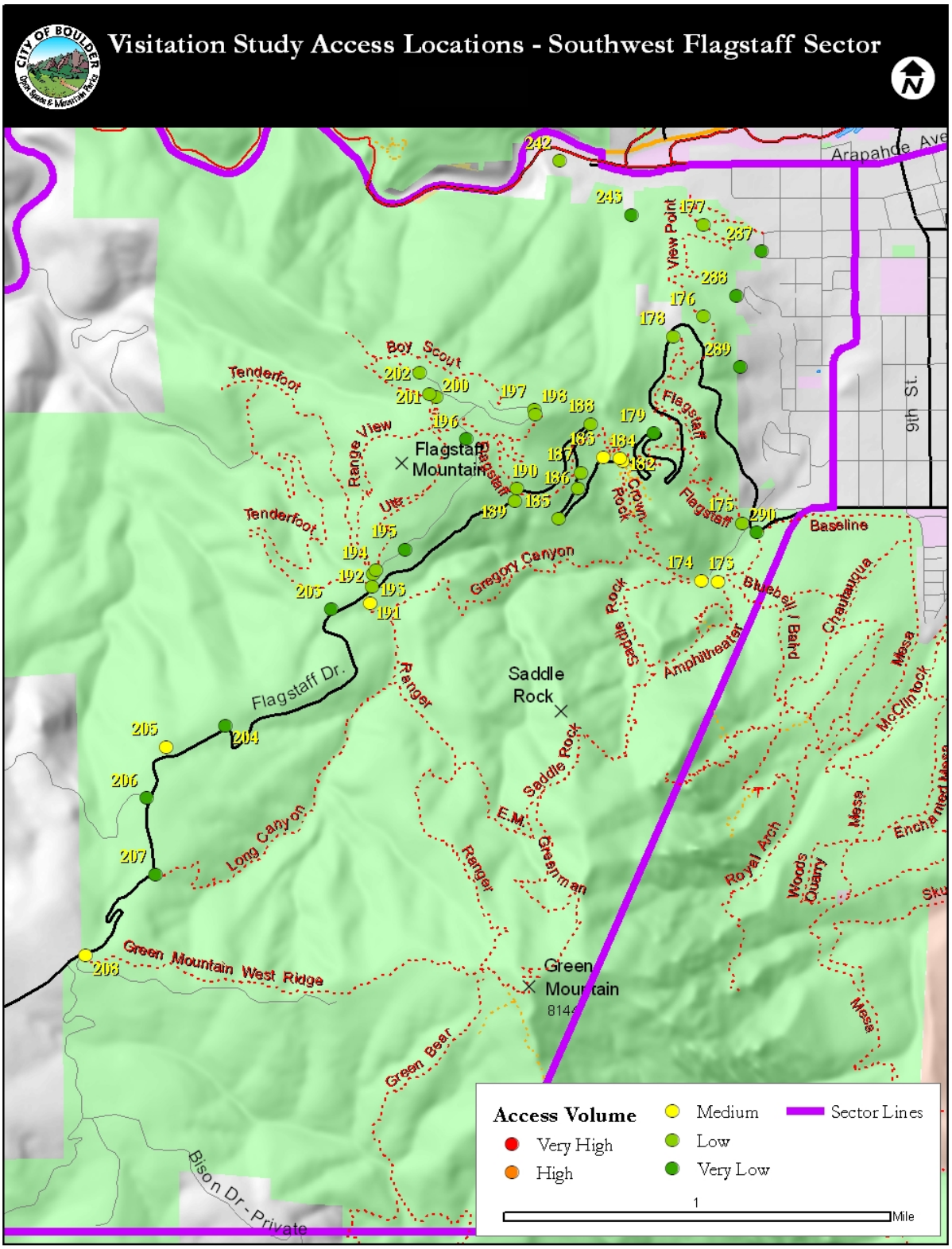
Figure 15. Southwest Flagstaff sector map