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Half Dome Cables Visitor Use Model Scenario Analysis Final Report Yosemite National Park

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DATA ■ ANALYSIS ■ SOLUTIONS

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Chapter 1: INTRODUCTION

In 1920, the Sierra Club developed a cable system that provides access to the summit of Half Dome for visitors without technical rock climbing ability (Personal Communication, Bret Meldrum, July, 2007). Today, the hike to the summit of Half Dome is arguably the most iconic and popular backcountry excursion for visitors to Yosemite National Park. The culmination of the hike involves ascending the last 400 vertical feet of Half Dome via the cable system.

Most visitors ascend, and subsequently descend, the Half Dome summit between its two parallel cables. However, some visitors travel outside of the cables, incurring increased exposure to unarrested falls from the granite dome. The occurrence of this behavior, coupled with recent accidents involving falls from the cables, has made risk management on Half Dome a priority at the park. Much of the safety concern is related to the amount of time spent on the cables during periods of high use. Thus, the National Park Service (NPS) considers it paramount to understand how visitor numbers affect the length of time hikers are forced to stay on the cables for the ascent and descent, and to what extent length of time spent on the cables contributes to the prevalence of visitors traveling outside the cables.

Furthermore, the Half Dome Trail and cables route are located in Congressionally designated wilderness. The Wilderness Act defines wilderness as possessing “outstanding opportunities for solitude or a primitive and unconfined type of recreation.” These areas “may also contain ecological, geological, or other features of scientific, educational, scenic, or historic value” (Hendee & Dawson, 2002). Consequently, issues related to visitor use of the Half Dome Trail and cables route are salient, not only with respect to visitor safety, but also in terms of the experiential wilderness values for which the NPS is mandated to manage the area.

In 2008, the NPS conducted a study of visitor use on the Half Dome Trail and cables in partnership with Resource Systems Group (RSG), Virginia Tech (VPI), and Colorado State University (CSU). The results of the study quantify relationships among visitor use, crowding, impeded travel, and potentially unsafe behavior on the Half Dome Trail and cables route. In particular, statistical models and a computer simulation model of visitor use were developed in the study to estimate the degree to which visitors’ ability to ascend and descend the cables and wilderness experience values are impacted by alternative levels of visitor use on the Half Dome cables (Lawson et al., 2009).

Results of the 2008 study suggest that when there are fewer than 30 people at one time (PAOT) on the Half Dome cables, visitors are able to ascend and descend the cables without being impeded by the presence of others. When there are 30 or more PAOT on the Half Dome cables, visitors’ ability to ascend and descend the cables begins to be impeded by the presence of others. Results of the study further suggest that visitors generally perceive the Half Dome cables to be unacceptably crowded when there are 70 or more PAOT on the cables. Subsequently, the NPS introduced the terms “Free Flow Threshold”, which refers to 30 PAOT on the Half Dome cables route, and “Visitor Informed Standard”, which refers to 70 PAOT on the cables (Pettebone et al., 2010). These terms are used throughout this report, for consistency with the NPS’s terminology.

In 2010, the NPS implemented an interim permit system that required visitors to obtain one of a restricted number of permits to hike to the summit of Half Dome via the cables route on weekends and holidays; visitors were not required to obtain a permit to summit Half Dome via the cables route on weekdays. The permit system was designed to restrict visitor use on the Half Dome cables to approximately 400 people per day on weekends and holidays.

Visitor use monitoring was conducted by park staff during the 2010 summer season to assess the effects of the permit system on visitor use conditions on the Half Dome Trail and cables route (Pettebone et al., 2010). Park staff found that on days when permits were required, visitor use on the Half Dome trail averaged about 300 people per day, while on non-permit days, visitor use averaged just under 650 people per day. Accordingly, park staff found that on permit days, the 30 PAOT “Free Flow Threshold” was exceeded only 15% of the time and the 70 PAOT “Visitor Informed Standard” was not exceeded on

any observation day. In contrast, park staff found that on weekdays, when permits were not required, the “Free Flow threshold” of 30 PAOT was exceeded the majority (65%) of the time and the 70 PAOT “Visitor Informed Standard” was exceeded about one-quarter (23%) of the time.

Presently, the NPS is developing a long-term management plan for visitor use on the Half Dome Trail and cables route, and results from the 2008 study and 2010 visitor use monitoring are helping to inform that planning process. The purpose of the work presented in this report is to use the computer simulation model developed as part of the 2008 study to assess the effects of alternative planning scenarios on visitor use, crowding, and travel impediments on the Half Dome Trail and cables route. In particular, the Half Dome visitor use model was used in this project to estimate:

- 1) Mean and maximum PAOT and travel times (i.e., ascent and descent times) on the Half Dome cables when daily visitor use is restricted via a permit quota of 400 people per day.
- 2) The maximum daily visitor use that can be accommodated on the Half Dome cables without exceeding mean “free flow” (i.e., unimpeded) ascent times, as measured during the 2008 visitor use study.
- 3) The maximum daily visitor use that can be accommodated on the Half Dome cables without exceeding 30 PAOT under ordinary circumstances.
- 4) The total amount of time it would take all visitors on the Half Dome summit and cables to descend to the subdome in the case of a weather event or other circumstances that would require all visitors to descend at one time.
- 5) The maximum daily visitor use that can be accommodated, in the case of implementing a via ferrata system (i.e., an anchoring system using cables, steps, and/or ladders) on Half Dome, without exceeding the “Free Flow Threshold” of 30 PAOT and the “Visitor Informed Standard” of 70 PAOT.

Thus, the results of the work presented in this report will help the NPS assess the potential benefits and consequences of alternative visitor use management strategies being considered in the planning process for the Half Dome Trail and cables route.

The remainder of this report is organized as follows: Chapter 2 describes the geographic scope of the Half Dome visitor use model and the methods used to collect data with which to develop the visitor use model; Chapter 3 presents the model algorithm and programming used to develop the computer simulation model of visitor use on the Half Dome Trail and cables route; and Chapter 4 presents descriptions and tabular results of scenario analyses conducted with the Half Dome visitor use model. A copy of the Half Dome visitor use model is archived with the NPS at Yosemite National Park.

Chapter 2: HALF DOME VISITOR USE MODEL DATA COLLECTION METHODS

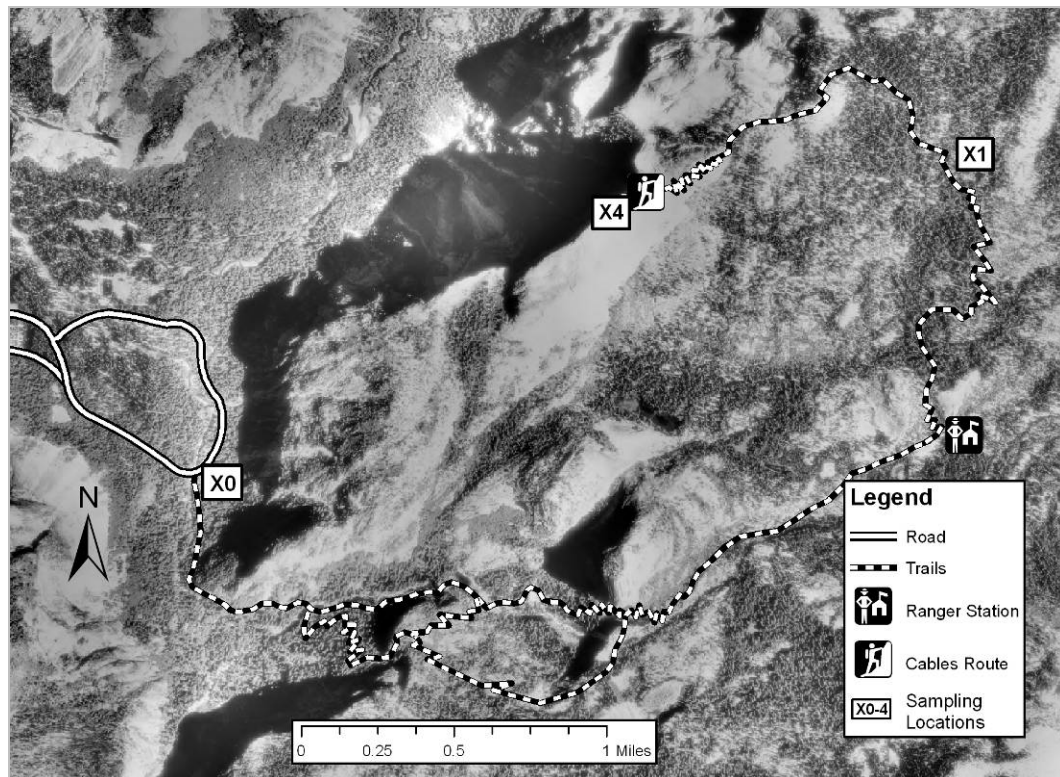
As stated, the purpose of the work presented in this report is to use the Half Dome visitor use model to assess the effects of alternative planning scenarios on visitor use, crowding, and travel impediments on the Half Dome Trail and cables route. This chapter describes: 1) the geographic scope of the Half Dome visitor use computer simulation model; and 2) the data collection methods used to gather the visitor use information needed to develop the Half Dome visitor use model.

It should be noted, the 2009 *Half Dome Cables Modeling and Visitor Use Estimation Final Report* (hereafter referred to as the 2009 Half Dome Report) prepared by RSG describes in detail the data collection, analysis, and modeling methods used in the 2008 study, including those used to develop the computer simulation model of visitor use on the Half Dome Trail and cables route (Lawson et al., 2009). Thus, the information in this chapter duplicates some of the information contained in the 2009 Half Dome Report.

2.1 Geographic Scope of the Half Dome Visitor Use Model

The geographic scope of the Half Dome visitor use model includes the most popular day-use route to the summit of Half Dome, which begins at the Happy Isles trailhead (denoted as “X0” in Figure 1) in Yosemite Valley. The hiking route ascends via the Mist Trail and/or John Muir Trail to the John Muir Trail’s junction with the Half Dome Trail (denoted as “X1” in Figure 1 and Figure 2).

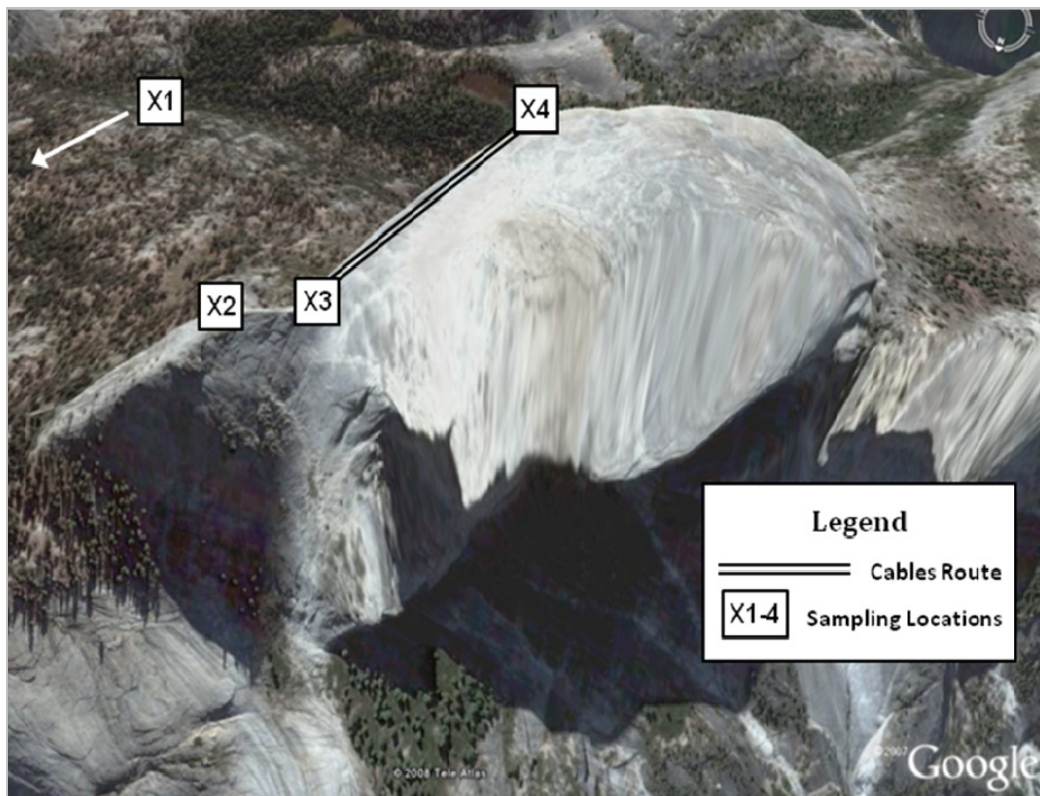
Figure 1. Geographic Scope of the Half Dome Visitor Use Model - Happy Isles to Half Dome Summit



The Half Dome Trail ascends from the John Muir Trail along the northeast ridge of Half Dome to an area known as the subdome, a small false summit (denoted as “X2” in Figure 2). Upon reaching the subdome, visitors get their first view of the cables route and often use the area to rest and organize their groups before climbing the cables. The base of the cables route (denoted as “X3” in Figure 2) is located in a small saddle between the subdome and Half Dome’s true summit, and the top of the cables (denoted as “X4” in Figure 1 and Figure 2) is located on the northeastern corner of Half Dome’s broad, flat summit.

The cables route extends approximately 600 feet at an average grade of approximately 100% (Personal Communication, Bret Meldrum, July, 2007). The route is furnished with two parallel steel cables extending its entire length, forming a double handrail. The cables are approximately 3’ apart and are supported off the ground by stanchions spaced at intervals of approximately 10’.

Figure 2. Detailed View of the Half Dome Visitor Use Model Study Area from Half Dome Trailhead to Half Dome Summit



2.2 Half Dome Visitor Use Model Data Collection

Visitor counts and visitor surveys were conducted during the summer of 2008 to collect information needed to develop the Half Dome visitor use model. This section of the report describes the data collection methods used to gather the information needed to develop the computer simulation model, beginning with the sampling locations.

2.2.1 Sampling Locations

Within the area for which the Half Dome visitor use model was developed, there were two primary types of sampling locations where field staff were stationed to collect information used to develop the visitor use model: 1) trailheads; and 2) destination points. Trailheads represent locations where visitors enter and exit the geographic bounds of the modeling area, while destination points mark the locations of key

destinations along the hiking route (i.e., the subdome, base of the cables, and Half Dome summit). The sampling locations are marked on the schematic diagrams of the study area with text boxes numbered X0-X4 (Figure 1 and Figure 2).

2.2.2 Visitor Counts

Visitor counts were conducted during July and August 2008 to document the number of Half Dome hikers embarking from the Happy Isles trailhead and total visitor use of the Half Dome Trail, by time of day and day of week. The visitor counts were conducted 24 hours per day at the Happy Isles trailhead and on the Half Dome Trail at its junction with the John Muir Trail (denoted as “X0” and “X1”, respectively, in Figure 1) via mechanical trail traffic counters, beginning July 11, 2008 and ending August 10, 2008. Data needed to calibrate or correct the mechanical trail traffic counter data were collected via direct observation on a subset of the days during which the trail counters were in operation. The procedures used to collect visitor counts via mechanical trail traffic counters and associated calibration data were designed by researchers at RSG and VPI, in consultation with Yosemite National Park, and are described in detail in the 2009 Half Dome Report prepared by RSG and archived with Yosemite National Park.

The visitor count data were used to derive estimates of visitor use on the Half Dome Trail and cables route, the results of which are reported in the 2009 Half Dome Report and include estimates of: 1) the number of Half Dome hikers embarking from the Happy Isles trailhead, by time of day and day of week; and 2) visitor use of the Half Dome Trail, by time of day and day of week. These data were used as primary inputs into the computer simulation model of visitor use of the Half Dome Trail and cables route. The methods by which these data were incorporated in to the Half Dome visitor use model are described later in this report.

2.2.3 Happy Isles and Half Dome Trail Hiking Route Surveys

Hiking route surveys were administered to random samples of visitors at the Happy Isles trailhead and on the Half Dome Trail, at its junction with the John Muir Trail (denoted as “X0” and “X1”, respectively, in Figure 1) during the summer of 2008. The purpose of the hiking route surveys was to collect information needed to model visitor behavior within the Half Dome visitor use model.

Specific information collected via the hiking route surveys and used as primary inputs for development of the Half Dome visitor use model include visitors’:

- 1) Group sizes;
- 2) Hiking destinations (i.e., Half Dome Trail or other locations) of those visitors intercepted at Happy Isles;
- 3) Hiking times from the Happy Isles trailhead to the Half Dome Trail (for those visitors who started their Half Dome hikes at Happy Isles);
- 4) Hiking times from the Half Dome Trail’s junction with the John Muir Trail to the subdome;
- 5) Lingering times at the subdome;
- 6) Wait times in queue at the base of the Half Dome cables;
- 7) Ascending and descending travel times on the cables route;
- 8) Lingering times on the Half Dome summit;
- 9) Hiking times from the subdome back to the Half Dome Trail’s junction with the John Muir Trail; and
- 10) Behavior on the cables route (i.e., whether they went outside the cables on ascent and/or descent).

The methods used to administer the hiking route survey cards at the Happy Isles trailhead and on the Half Dome Trail are described in detail in the 2009 Half Dome Report. Descriptive results of the hiking route surveys are also reported in the 2009 Half Dome Report. Further, the appendices of the 2009 Half Dome Report include copies of the hiking route survey cards and survey logs used to record information about survey response rates. Electronic copies of the hiking route survey data are archived with Yosemite National Park and code sheets corresponding to these data files are contained in an appendix in the 2009 Half Dome Report.

2.2.4 Photographic Observations

Photographic observations of visitor use on the Half Dome cables route were recorded on 16 days in July and August, 2008, and 13 days between June and September, 2010. The photographic observations were recorded in 20 minute intervals from 9:00 AM to 3:40 PM, which produced 21 photographic observations per day. The photographic observations were recorded to document the number of people at one time on the cables route, including the number of people ascending or descending the route outside the parallel cables. Each photograph also documents the presence or absence of a queue at the base of the cables.

The photographic observations were recorded from the subdome (the approximate sampling location is denoted as “X2” in Figure 2) and capture visitor use on the visible portion of the cables from that vantage point, which is estimated to be a 600 foot section of the cables route. Additional details regarding the photographic observation methods and descriptive results are reported in the 2009 Half Dome Report and 2010 Half Dome Monitoring Report.

The visitor measures derived from the photographic observations, coupled with the Half Dome Trail hiking route survey data, provide an empirical basis to model relationships among: 1) use density on the cables; 2) the amount of time visitors spend on the cables; and 3) the presence and length of a queue at the base of the Half Dome cables. This information was incorporated into the Half Dome visitor use model to model visitors travel times ascending and descending the cables route as a function of the number of other visitors on the cables. The information was also used to model the presence and length of a queue at the base of the Half Dome cables as a function of the number of people on the cables route at one time.

2.2.5 Visitor Survey Concerning Perceptions of Safety and Crowding

A visitor survey was conducted in the summer of 2008 at the subdome on the Half Dome Trail (the sampling location is denoted as “X2” in Figure 2). The purpose of the survey was to assess visitors’ perceptions of safety and crowding on the Half Dome cables route. As part of the survey, visitors were asked to evaluate a series of digitally edited photographs depicting a range of PAOT on the Half Dome cables. The purpose of these questions was to identify thresholds of visitor use on the Half Dome cables beyond which visitors perceived conditions to be unacceptably crowded and unsafe.

Information about visitor-based crowding and safety thresholds were incorporated into the Half Dome visitor use model to serve as benchmarks against which to evaluate the outcomes of alternative planning scenarios simulated in this project. For example, the Half Dome visitor use model was used to estimate the maximum daily visitor use that can be accommodated on the Half Dome Trail and cables route, in the case of implementing a via ferrata system on Half Dome, without exceeding the “Visitor Informed Standard” of 70 PAOT derived from results of the survey.

The methods used to administer the visitor survey are described in detail in the 2009 Half Dome Report. Descriptive results of the hiking route surveys are also reported in the 2009 Half Dome Report. Further, the appendices of the 2009 Half Dome Report include a copy of the visitor survey, digitally edited photographs used in conjunction with the survey depicting a range of PAOT on the Half Dome cables, and the survey log used to record information about survey response rates.

Chapter 3: HALF DOME VISITOR USE MODEL DEVELOPMENT

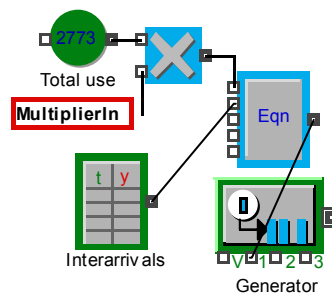
As noted, the Half Dome visitor use model developed from visitor use data collected during summer 2008 was used in this project to analyze alternative planning scenarios for the Half Dome Trail and cables route. This chapter of the report presents the methods used to develop the Half Dome visitor use model.

3.1 Model Algorithm and Programming

The computer simulation model of visitor use on the Half Dome Trail and cables route was developed using Extend v.7 (2007) discrete-event systems simulation software. The structure of the model consists of hierarchical blocks (H-blocks) that: 1) simulate visitor use and behavior on the John Muir and Half Dome trails, at the subdome, on the Half Dome cables, and on the Half Dome summit; and 2) monitor people at one time (PAOT) at points of interest (i.e., on the cables route, at the subdome, on the Half Dome summit). Each type of hierarchical block contained within the study model is described in the following paragraphs.

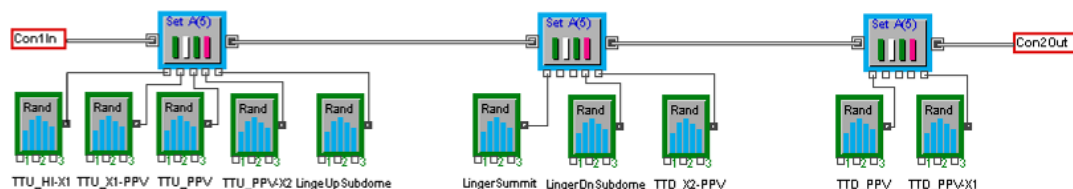
The Trailhead H-block is used within the study model to generate simulated visitor groups embarking on hikes from the Happy Isles trailhead to the Half Dome Trail and cables route (Figure 3). Visitor group arrival rates within the model vary by time of day and day of week, and are based on the visitor counts and calibrations conducted at Happy Isles during summer 2008. The arrival rates specified within the model can be “ramped up” or “ramped down” to model changes in visitation from that measured during summer 2008 (e.g., to model alternative permit quotas).

Figure 3. Half Dome Visitor Use Model - Trailhead H-Block.



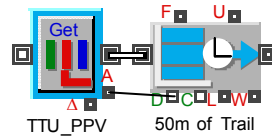
After leaving the Trailhead H-block, simulated visitor groups are routed within the model to an Attribute H-block (Figure 4). The Attribute H-block is designed to assign attribute values to simulated visitor groups, including values that define each simulated group's size, and the amount of time they spend hiking on trails, traveling on the cables route, and lingering at the subdome and on the Half Dome summit. The distributions of group sizes, travel times, and lingering times assigned to simulated visitors are based on results of the 2008 Happy Isles and Half Dome Trail hiking route surveys.

Figure 4. Half Dome Visitor Use Model - Attribute H-Block.



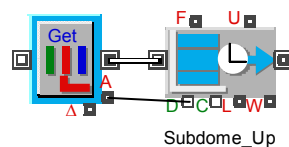
After being assigned attribute values, simulated visitor groups are routed to hike from Happy Isles to the Half Dome Trail, and from there to the subdome. Trail Section H-blocks simulate visitor use and travel along the hiking trails (Figure 5), based on the distributions of hiking times recorded in the Happy Isles and Half Dome Trail hiking route surveys.

Figure 5. Half Dome Visitor Use Model - Sample Trail Section H-Block.



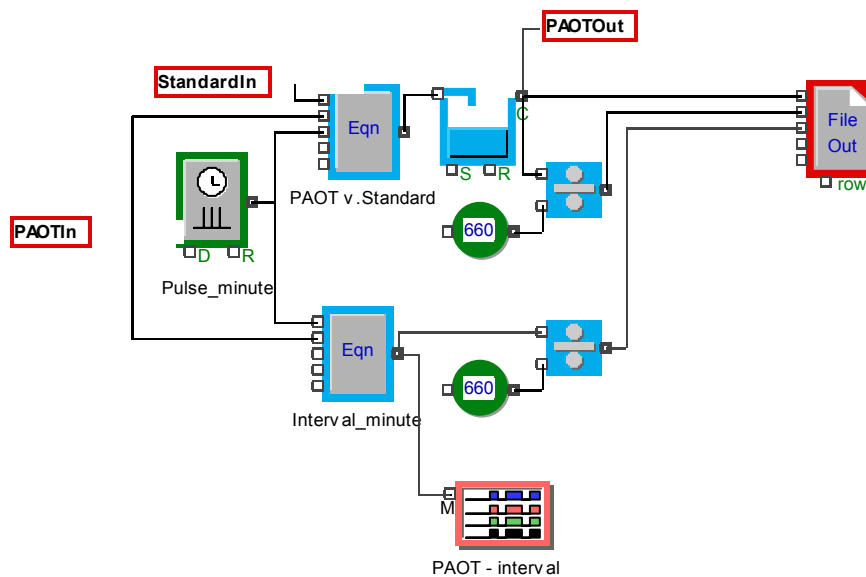
Next, simulated visitor groups are routed to the Subdome Area H-block where they “linger” for periods of time based on the distribution of subdome lingering times recorded in the Half Dome Trail hiking route survey (Figure 6). It should be noted that simulated visitor groups are routed back to the Subdome Area H-block after descending the Half Dome cables route and that the distribution of lingering times used within the model for these groups returning from the cables is different than the distribution of subdome lingering times used for visitor groups on their way to the cables.

Figure 6. Half Dome Visitor Use Model - Subdome Area H-Block.



A PAOT Calculator H-block (Figure 7) is connected to the Subdome Area H-block to monitor the number of people in the subdome area at one time, at one minute intervals throughout the course of each simulated visitor use day. The PAOT Calculator H-block contains File Output blocks that report to an ASCII text file the percentage of time, within a simulated visitor use day, user-specified standards of quality for PAOT in the subdome area are exceeded.

Figure 7. Half Dome Visitor Use Model - PAOT Calculator H-Block.



After lingering at the subdome, simulated visitor groups are routed to the base of the Half Dome cables route, represented within the model by the Cables Route H-block (Figure 8). Within the Cables Route H-block, visitors are assigned a travel time to ascend the cables, based on the total number of people on the cables route at that time. Queue formation is modeled within the Cables Route H-block, based on the number of people on the cables route each time a visitor arrives at the base of the cables to begin ascending the route. It should be noted that simulated visitor groups are routed back to the Cables Route H-block after lingering on the Half Dome summit and that visitor groups are assigned a travel time for descending the cables based on the total number of people on the cables route at the time they begin their descent.

Figure 8. Half Dome Visitor Use Model - Cables Route H-Block

A PAOT Calculator H-block (Figure 6) is connected to the Cables Route H-block to monitor the total number of people on the Half Dome cables at one time, at one minute intervals throughout the course of each simulated visitor use day. The PAOT Calculator H-block contains File Output blocks that report to an ASCII text file the percentage of time, within a simulated visitor use day, user-specified standards of quality for PAOT on the Half Dome cables are exceeded.

Figure 9. Half Dome Visitor Use Model - Half Dome Summit H-Block.

In summary, the computer model simulates Half Dome hikers' behavior as they: 1) arrive at the Happy Isles trailhead to begin their hike; 2) hike from Happy Isles to the Half Dome Trail, and from there, to the subdome; 3) linger at the subdome before ascending the cables route; 4) wait in queue at the base of the cables, if a queue is present; 5) ascend the cables route; 6) linger on the Half Dome summit; 7) descend the cables route; 8) linger at the subdome after descending the cables route; and 9) hike from the subdome to the junction of the Half Dome Trail and John Muir Trail.

replications was used to determine the number of replications needed to generate reliable model estimates. Information and results of the replications analyses are presented in the appendices of the 2008 *Half Dome Cables Modeling and Visitor Use Estimation Final Report*.

Chapter 4: HALF DOME VISITOR USE MODEL SCENARIO ANALYSES

As noted, the NPS is presently developing a long-term management plan for visitor use on the Half Dome Trail and cables route. To help inform this process, RSG conducted a series of simulations with the Half Dome visitor use model to assess the effects of alternative planning scenarios on visitor use, crowding, and travel impediments on the Half Dome Trail and cables route. In particular, the visitor use model was used to estimate:

- 1) **Scenario 1:** Mean and maximum PAOT and travel times (i.e., ascent and descent times) on the Half Dome cables when daily visitor use is restricted via a permit quota to 400 people per day.
- 2) **Scenario 2a:** The maximum daily visitor use that can be accommodated on the Half Dome cables without exceeding mean “free flow” (i.e., unimpeded) ascent times, as measured during the 2008 visitor use study.
- 3) **Scenario 2b:** The maximum daily visitor use that can be accommodated on the Half Dome cables without exceeding 30 PAOT under ordinary circumstances.
- 4) **Scenario 3:** The total amount of time it would take all visitors on the Half Dome summit and cables to descend to the subdome in the case of a weather event or other circumstances that would require all visitors to descend at one time.
- 5) **Scenario 4:** The maximum daily visitor use that can be accommodated, in the case of implementing a via ferrata system on the Half Dome cables route, without exceeding the “Free Flow Threshold” of 30 PAOT and the “Visitor Informed Standard” of 70 PAOT.

Thus, the results of the work presented in this report will help the NPS assess the potential benefits and consequences of alternative visitor use management strategies being considered in the planning process for the Half Dome Trail and cables route. Each of the five scenarios evaluated with the Half Dome visitor use model are described in this chapter, and results are reported.

4.1 Scenario Descriptions

This section describes each of the five planning scenarios analyzed with the Half Dome visitor use model. The scenarios that were analyzed in this project were selected by Yosemite National Park staff, and are based on alternative visitor use management strategies that are being considered by the NPS in the process of developing a long-term management plan for visitor use on the Half Dome Trail and cables route.

4.1.1 Scenario 1 – Permit Quota, 400 Hikers per Day

As noted, during weekends in summer 2010, the NPS implemented an interim permit system which was intended to limit daily weekend visitor use on the Half Dome Trail and cables route to a maximum of roughly 400 people per day. For summer 2011, the NPS has extended the permit quota system from just weekends and holidays to all days of the week; thus, visitor use on the Half Dome cables will be limited to a maximum of roughly 400 people per day on all days during the 2011 visitor use season.

To assess the effects of the permit quota system, simulations with the Half Dome visitor use model were conducted to estimate the daily and hourly mean PAOT on the subdome, Half Dome cables, and Half Dome summit when daily visitor use averages 400 people per day. Results of these simulations also provide estimates of daily and hourly mean cables ascent and descent times when daily visitor use averages 400 people per day. Thus, Scenario 1 analysis results provide information about the effects of the park’s current permit quota system on visitor use, crowding, and travel impediments on the Half Dome cables.

4.1.2 Scenario 2a – Free Flow Travel on the Half Dome Cables (Travel Time)

Results of the Half Dome visitor use study conducted by RSG in 2008 suggest that under “free flow” conditions, visitors’ mean cables ascent time is roughly 21 minutes. Further, the results of the 2008 study suggest that even with relatively minimal congestion-related delays of visitors’ progress on the cables, one or more visitors can be expected to travel outside the cables. Thus, Scenario 2a “solves for” the maximum daily visitor use that can be accommodated on the Half Dome cables without exceeding mean free flow ascent times, as measured during the 2008 visitor use study. Results for Scenario 2a presented in this chapter include daily and hourly mean PAOT on the subdome, Half Dome cables, and Half Dome summit, as well as daily and hourly mean cables ascent and descent times

4.1.3 Scenario 2b – Free Flow Travel on the Half Dome Cables (PAOT)

Results of the Half Dome visitor use study conducted by RSG in 2008 suggest that when there are 30 or more people on the Half Dome cables at one time, visitors’ ascent times exceed free flow conditions and at least one visitor can be expected to travel outside the cables. Thus, Scenario 2b “solves for” the maximum daily visitor use that can be accommodated on the Half Dome Trail and cables route without exceeding 30 PAOT on the Half Dome cables under ordinary circumstances. Results for Scenario 2b presented in this chapter include daily and hourly mean PAOT on the subdome, Half Dome cables, and Half Dome summit, as well as daily and hourly mean cables ascent and descent times.

4.1.4 Scenario 3 – Lightning Storm and Mass Descent

The purpose of the simulations conducted with the Half Dome visitor use model for Scenario 3 was to estimate the total amount of time it would take all visitors on the Half Dome summit and cables to descend to the subdome in the case of a lightning storm or other circumstances that would require all visitors to descend at one time. Five alternative levels of visitor use on the Half Dome summit and cables were modeled to analyze Scenario 3, based on results of photographic observations of PAOT on the cables conducted during the summers of 2008 and 2010. Each of these sets of simulations is described below.

Permit Days, 2010: During a subset of permit days during summer 2010, photographic observations of cables PAOT were conducted. A maximum of 51 PAOT was observed on the cables during permit days in summer 2010. A regression model of the relationship between cables PAOT and simultaneous summit PAOT estimated that with 51 PAOT on the cables, there would simultaneously be 47 PAOT on the Half Dome summit (Pettebone, et al., 2010). Thus, simulations were conducted to estimate the total amount of time it would take for 51 people on the cables and 47 people on the summit to simultaneously descend to the subdome. An alternative set of results was estimated for the 2010 and 2011 interim permit quota based on the level of visitor use the permit system was designed to allow (i.e., 400 people per day).

Saturdays/Holidays, 2008: As noted, during a sample of days in summer 2008, photographic observations of cables PAOT were conducted. Visitor use was highest on Saturdays and holidays, and a maximum of 111 PAOT was observed on the cables during Saturday and holiday sampling days. A regression model of the relationship between cables PAOT and simultaneous summit PAOT estimated that with 111 PAOT on the cables, there would simultaneously be 88 PAOT on the Half Dome summit (Pettebone, et al., 2010). Thus, simulations were conducted to estimate the total amount of time it would take for 111 people on the cables and 88 people on the summit to simultaneously descend to the subdome. An alternative set of results was estimated for Saturdays and holidays during summer 2008, based on the inclusion of visitor use data from two days during summer 2008 that were potential outliers (3,072 visitors on Saturday, July 19 and 2,409 on Saturday, July 26).

Non-permit Days, 2010: During a subset of non-permit days during summer 2010, photographic observations of cables PAOT were conducted. A maximum of 117 PAOT was observed on the cables during non-permit days in summer 2010. A regression model of the relationship between cables PAOT and simultaneous summit PAOT estimated that with 117 PAOT on the cables, there would simultaneously

be 93 PAOT on the Half Dome summit. Thus, simulations were conducted to estimate the total amount of time it would take for 117 people on the cables and 93 people on the summit to simultaneously descend to the subdome.

4.1.5 Scenario 4 – Via Ferrata System on Half Dome

The purpose of the simulations conducted with the Half Dome visitor use model for Scenario 4 was to estimate visitor use-related effects of implementing a via ferrata system on Half Dome. To simulate the effects of implementing a via ferrata system, visitors' travel times programmed into the model were based on the mean and standard deviation of travel times in the 95th percentile of those observed during the 2010 Half Dome monitoring program. In particular, a mean ascent time of 78 minutes, with a standard deviation of 8 minutes, and a mean descent time of 70 minutes, with a standard deviation of 28 minutes, were used to model travel times, in the case of a via ferrata system on Half Dome.

These data were assumed to represent the travel times of those visitors using an anchoring system to ascend and descend the Half Dome cables during 2010. Thus, they are assumed to be a reasonable proxy for travel times to ascend and descend Half Dome, in the case of implementing a via ferrata system. This assumption is based on direction from Yosemite National Park Visitor Use and Social Sciences Branch staff who managed the 2010 Half Dome visitor use monitoring study. In particular, park staff noted that a small proportion (roughly 5%) of visitors in 2010 were observed using personal anchoring systems (e.g., climbing harnesses with gear to anchor to the Half Dome cables) to ascend and descend the Half Dome cables route (Personal Communication, Bret Meldrum and David Pettebone, January, 2011).

Two series of simulations were conducted to estimate the maximum daily visitor use that can be accommodated, in the case of implementing a via ferrata system on Half Dome, without exceeding alternative thresholds for PAOT on the cables. These two series of simulations are referred to in this report as the "Free Flow Threshold" simulations and "Visitor Informed Standard" simulations, and are described in the following paragraphs

Free Flow Threshold Simulations: As noted, results of the 2008 Half Dome visitor use study suggest that when there are 30 or more people on the Half Dome cables at one time, visitors' ascent times exceed free flow conditions and at least one visitor can be expected to travel outside the cables. Thus, in the 2010 Half Dome Monitoring Report, the NPS introduced the term "Free Flow Threshold", which refers to 30 PAOT on the Half Dome cables route. Accordingly, the "Free Flow Threshold" simulations solve for the maximum daily visitor use that can be accommodated, in the case of implementing a via ferrata system on Half Dome, without exceeding 30 PAOT on the Half Dome cables under ordinary circumstances. Results include daily and hourly mean PAOT on the subdome, Half Dome cables, and Half Dome summit, as well as daily and hourly mean cables ascent and descent times.

Visitor Informed Standard Simulations: As noted, results of the 2008 Half Dome visitor use study suggest that when there are 70 or more people on the Half Dome cables at one time, visitors generally report feeling unsafe and crowded. Thus, in the 2010 Half Dome Monitoring Report, the NPS introduced the term "Visitor Informed Standard", which refers to 70 PAOT on the Half Dome cables route. Accordingly, the "Visitor Informed Standard" simulations solve for the maximum daily visitor use that can be accommodated, in the case of implementing a via ferrata system on Half Dome, without exceeding 70 PAOT on the Half Dome cables under ordinary circumstances. Results include daily and hourly mean PAOT on the subdome, Half Dome cables, and Half Dome summit, as well as daily and hourly mean cables ascent and descent times.

4.2 Scenario Analysis Results

This section describes results of simulations conducted with the Half Dome visitor use model to analyze each of the five planning scenarios described above. The results are presented in tabular and graphical format, and supplemented with narrative text.

4.2.1 Scenario Analysis Results – Scenarios 1, 2a, and 2b

Results of simulations to analyze Scenario 1 (Permit Quota, 400 People per Day), Scenario 2a (Free Flow – Travel Time), and Scenario 2b (Free Flow – PAOT) are summarized in Table 1 and Table 2, and Figure 10 – Figure 15. The tabular results for Scenarios 1, 2a, and 2b are supplemented with results of simulations with the Half Dome model of visitor use conditions on Saturdays and holidays during summer 2008. The simulation results from summer 2008 Saturdays and holidays are included to serve as a “baseline” against which to compare and contrast the results for Scenarios 1, 2a, and 2b.

Results in Table 1 include estimates of mean and maximum travel times to ascend and descend the Half Dome cables route under “baseline” conditions on Saturdays and holidays during summer 2008, and resulting from Scenarios 1, 2a, and 2b. The results suggest that mean ascent and descent times on Saturdays and holidays during summer 2008 were substantially higher than “free flow” travel times estimated in the 2008 Half Dome visitor use study. Specifically, free flow ascent and descent times were estimated to be 21 minutes and 16 minutes, respectively, while estimates from the Half Dome visitor use model suggest ascent and descent travel times on Saturdays and holidays during summer 2008 were, on average, 32 minutes and 23 minutes, respectively. Further, maximum ascent and descent travel times estimated from simulations of visitor use conditions on Saturdays and holidays during summer 2008 are 70 minutes and 60 minutes, respectively.

Results for Scenario 1 (Table 1; Figure 10 – Figure 13) suggest that with a permit quota limiting daily visitor use on the Half Dome Trail and cables route to 400 people per day, mean ascent and descent travel times are close to, but higher than free flow ascent and descent travel times. Further, simulation results for Scenario 1 suggest that with a permit quota limiting Half Dome visitor use to 400 people per day, maximum ascent and descent times (54 minutes and 47 minutes, respectively) are substantially higher than free flow ascent and descent travel times.

Results for Scenario 2a (Table 1; Figure 10 – Figure 13) suggest that daily visitor use on the Half Dome Trail and cables route would need to be limited to about 140 people per day to allow visitors, on average, to ascend and descend the cables without being impeded by the presence of other visitors. That being said, even with daily visitor use on the Half Dome Trail and cables route limited to about 140 people per day, maximum ascent and descent times (37 minutes and 32 minutes, respectively) are estimated to be substantively higher than free flow travel times.

As described in the preceding section of this report, the Scenario 2b analysis uses an alternative approach to estimate the maximum daily visitor use that can be accommodated on the Half Dome Trail and cables route without crowding on the cables that impedes visitors’ movement. Results for Scenario 2b (Table 1; Figure 10 – Figure 13) suggest that daily visitor use on the Half Dome Trail and cables route would need to be limited to about 225 people per day to ensure that, under ordinary circumstances, there are no more 30 PAOT on the cables route. As noted, results of the 2008 Half Dome visitor use study suggest that when there are fewer than 30 PAOT on the Half Dome cables, visitors are generally able to ascend and descend the cables without being impeded by the presence of other visitors.

Table 1. Half Dome Visitor Use Model Simulation Results, Baseline and Scenarios 1, 2a, & 2b – Cables Ascent and Descent Times.

	Baseline Saturdays/Holidays, 2008 Mean Daily Use = 692		Scenario 1 400 people/day Mean Daily Use = 406 (± 6.3)		Scenario 2a Free Flow (Ascent Time) Mean Daily Use = 140 (± 3.8)		Scenario 2b Free Flow (PAOT) Mean Daily Use = 227 (± 4.6)	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Ascent Time	32 (± 1.0)	70	26 (± 0.2)	54	21 (± 0.2)	37	23 (± 0.2)	42
Descent Time	23 (± 0.8)	60	21 (± 0.2)	47	17 (± 0.1)	32	18 (± 0.2)	38

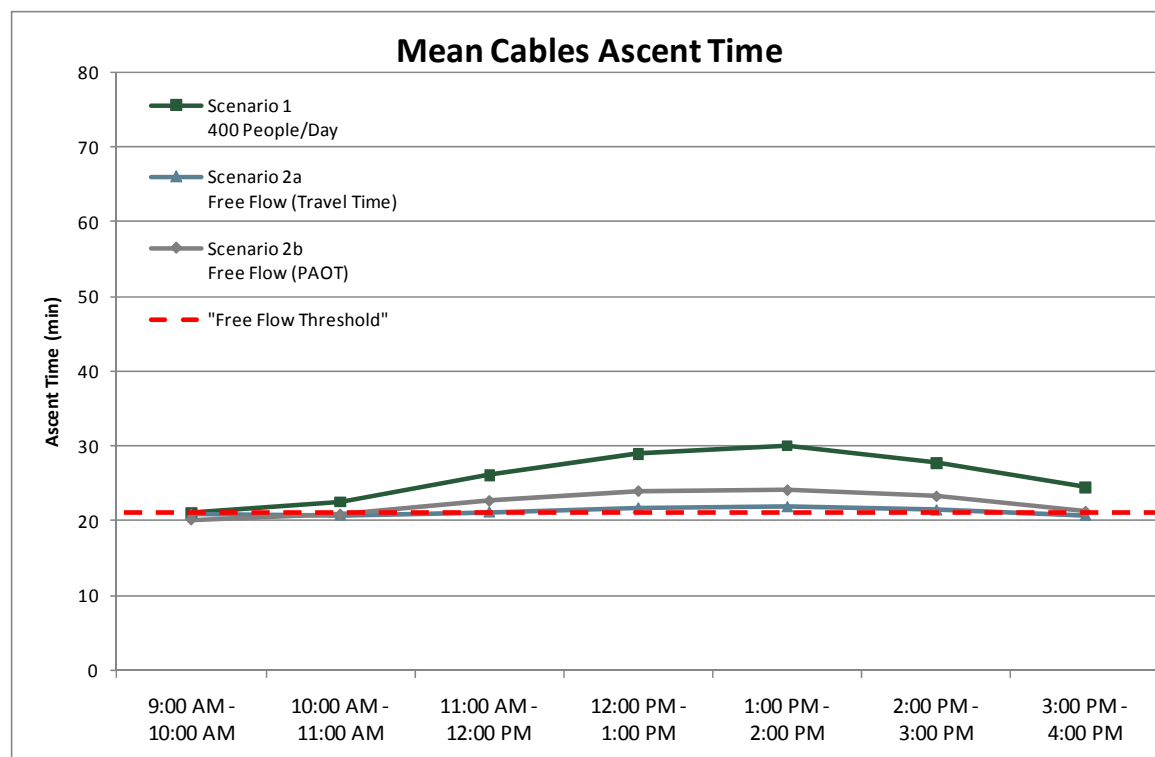
NOTE: Numbers in parentheses are 95% confidence interval half-widths.

NOTE: Mean free flow ascent time = 21 minutes (based on 2008 visitor use study).

NOTE: Scenario 2a results = Mean ascent time is not statistically greater than mean free flow ascent time.

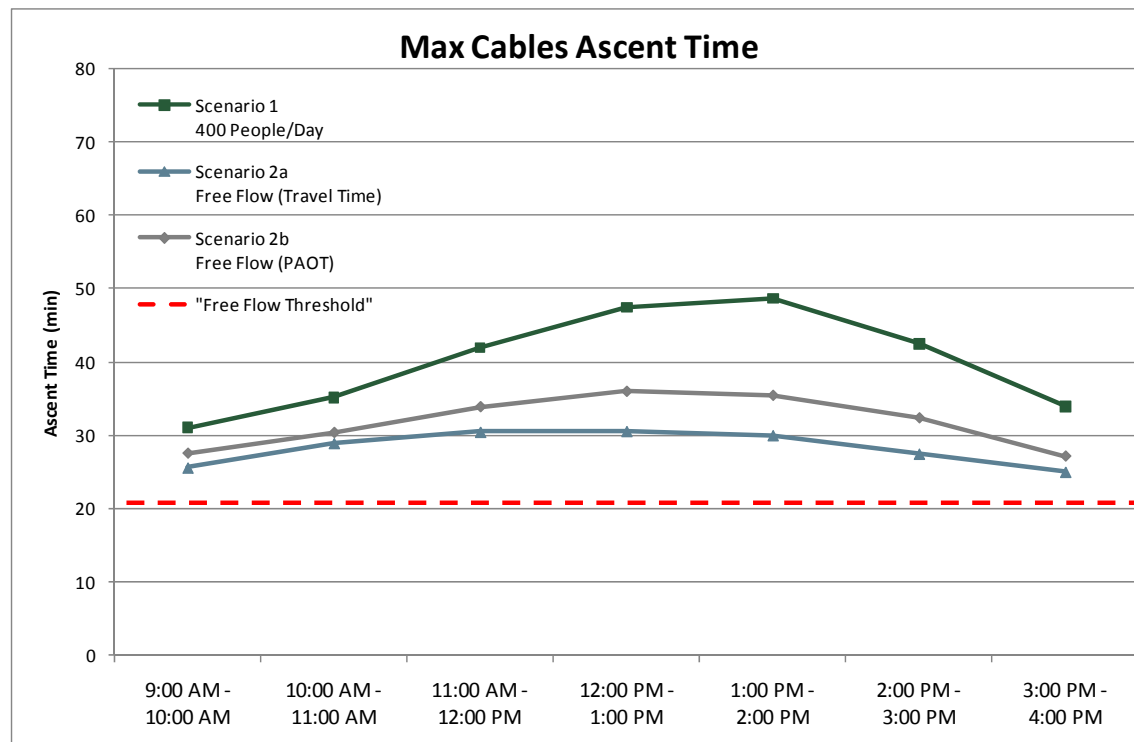
NOTE: Scenario 2b results = PAOT on the cables does not exceed 30 under ordinary circumstances.

Figure 10. Half Dome Visitor Use Model Simulation Results, Scenarios 1, 2a, & 2b: Mean Cables Ascent Time.



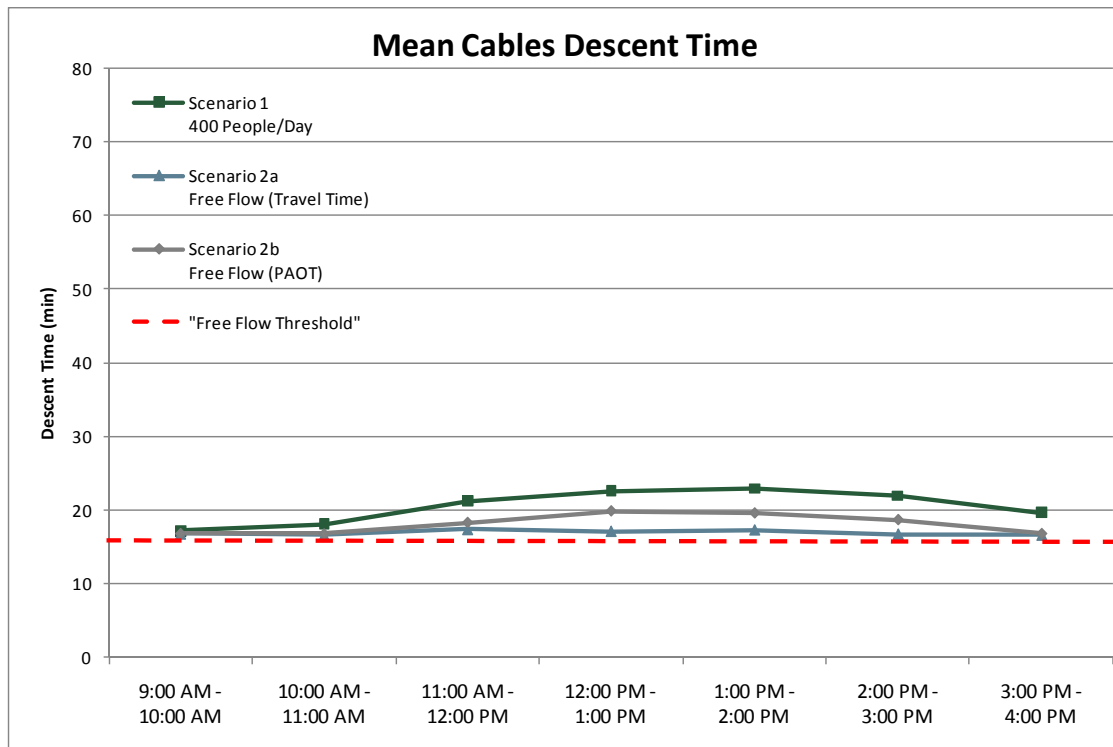
NOTE: "Free Flow" ascent time = 21 minutes (Lawson et al., 2009).

Figure 11. Half Dome Visitor Use Model Simulation Results, Scenarios 1, 2a, & 2b: Max Cables Ascent Time.



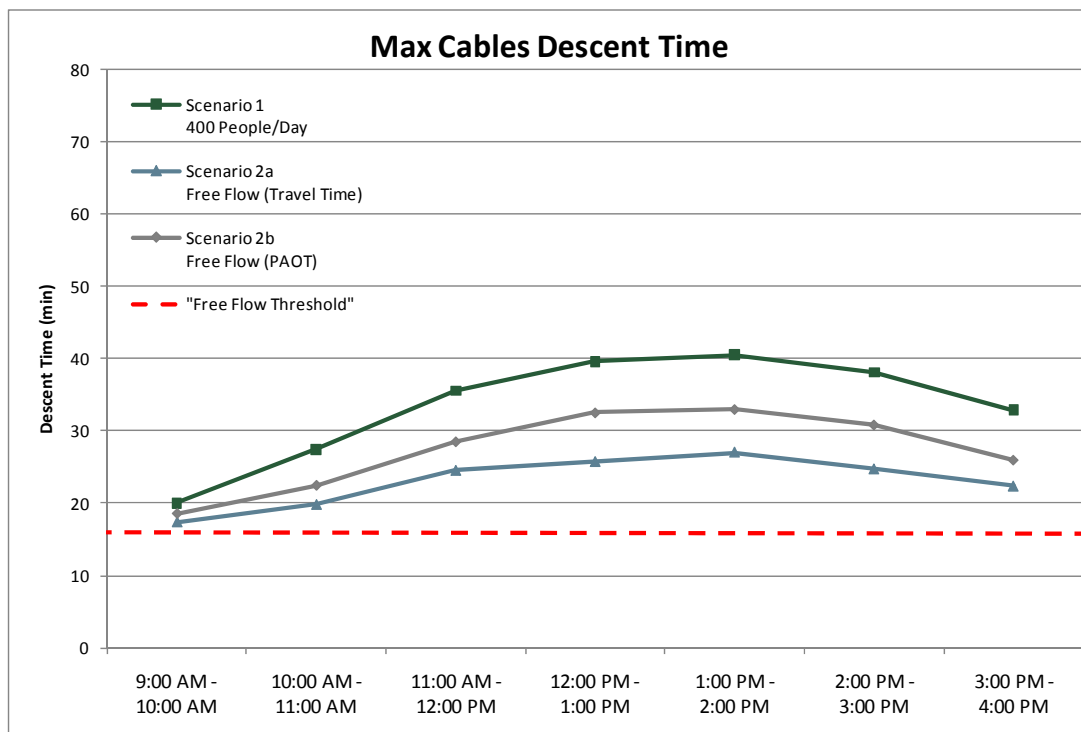
NOTE: "Free Flow" ascent time = 21 minutes (Lawson et al., 2009).

Figure 12. Half Dome Visitor Use Model Simulation Results, Scenarios 1, 2a, & 2b: Mean Cables Descent Time.



NOTE: "Free Flow" descent time = 16 minutes (Lawson et al., 2009).

Figure 13. Half Dome Visitor Use Model Simulation Results, Scenarios 1, 2a, & 2b: Max Cables Descent Time.



NOTE: "Free Flow" descent time = 16 minutes (Lawson et al., 2009).

Results of Half Dome visitor use model simulations suggest that on Saturdays and holidays during summer 2008 there were, on average more than 30 PAOT on the cables route (Table 2). Thus, visitor use on the Half Dome cables on Saturdays and holidays during summer 2008 was generally intensive enough to cause crowding-related delays for visitors trying to ascend and descend the cables route.

Results for Scenario 1 suggest that with a permit quota that limits daily visitor use on the Half Dome Trail and cables route to 400 people per day, there are, on average, fewer than 30 PAOT on the Half Dome cables (Table 2; Figure 14 and Figure 15). However, the results for Scenario 1 suggest that with a quota of approximately 400 people per day, maximum PAOT on the Half Dome cables may be as high as about 80 people (NOTE: estimates of maximum PAOT reported in Table 2 and Figure 15 for Scenario 1 differ slightly because they are based on daily and hourly averages, respectively). This result explains why mean travel times for Scenario 1 are greater than free flow travel times, despite the fact that PAOT on the Half Dome cables is, on average, less than 30 people.

Results for Scenario 2a suggest that with daily visitor use on the Half Dome Trail and cables route limited to approximately 140 people per day, there would be, on average, substantially fewer than 30 PAOT on the Half Dome cables (Table 2; Figure 14 and Figure 15). Further, the results for Scenario 2a suggest that with a quota of approximately 140 people per day, maximum PAOT on the Half Dome cables would be just under 30 people (NOTE: estimates of maximum PAOT reported in Table 2 and Figure 15 for Scenario 2a differ slightly because they are based on daily and hourly averages, respectively). This result is consistent with results for Scenario 2a, which suggest that a maximum of about 140 people per day can be accommodated on the Half Dome Trail and cables route without causing any crowding-related delays for visitors trying to ascend and descend the cables route (Table 1).

Results for Scenario 2b suggest that with daily visitor use on the Half Dome Trail and cables route limited to approximately 225 people per day, there would be, on average, substantially fewer than 30 PAOT on the Half Dome cables (Table 2; Figure 14 and Figure 15). However, the results for Scenario 2b suggest that with a quota of approximately 225 people per day, maximum PAOT on the Half Dome cables would be about 50 people (NOTE: estimates of maximum PAOT reported in Table 2 and Figure 15 for Scenario 2b differ slightly because they are based on daily and hourly averages, respectively). These results are consistent with results for Scenario 2b, which suggest that with a maximum of about 225 people per day allowed on the Half Dome Trail and cables route, visitors would generally be able to ascend and descend the cables route without being impeded by the presence of others, but there would be peak periods during the day when there were crowding-related delays on the cables route (Table 1).

Table 2. Half Dome Visitor Use Model Simulation Results, Baseline and Scenarios 1, 2a, & 2b - PAOT on Subdome, Cables, & Summit

	Baseline Saturdays/Holidays, 2008 Mean Daily Use = 692		Scenario 1 400 people/day Mean Daily Use = 406 (± 6.3)		Scenario 2a Free Flow (Ascent Time) Mean Daily Use = 140 (± 3.8)		Scenario 2b Free Flow (PAOT) Mean Daily Use = 227 (± 4.6)	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max
PAOT - Subdome	13 (± 1.0)	67	9 (± 0.2)	40	3 (± 0.1)	19	5 (± 0.1)	25
PAOT - Cables	37 (± 2.8)	146	21 (± 0.4)	83	6 (± 0.2)	29	10 (± 0.3)	52
PAOT - Summit	36 (± 2.5)	126	23 (± 0.4)	86	8 (± 0.3)	36	13 (± 0.3)	52

NOTE: Numbers in parentheses are 95% confidence interval half-widths.

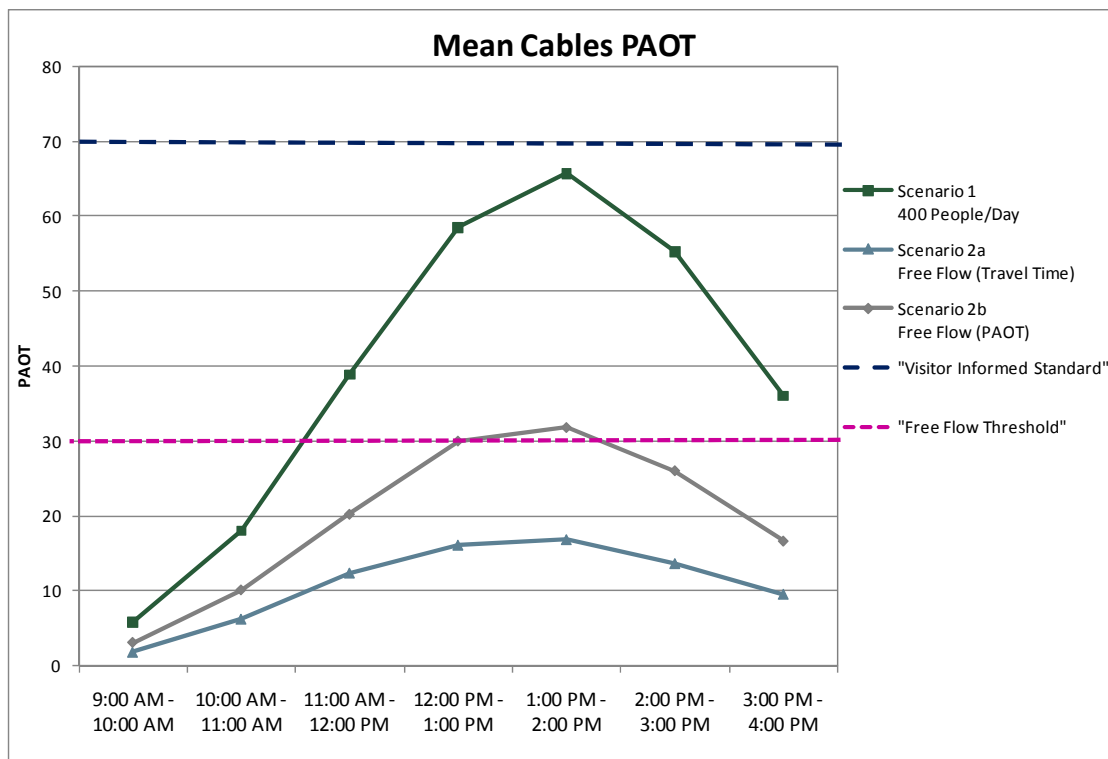
NOTE: Free Flow Threshold = 30 PAOT on the cables (based on 2008 visitor use study).

NOTE: Visitor Informed Standard = 70 PAOT on the cables (based on 2008 visitor use study).

NOTE: Scenario 2a results = Mean ascent time is not statistically greater than mean free flow ascent time.

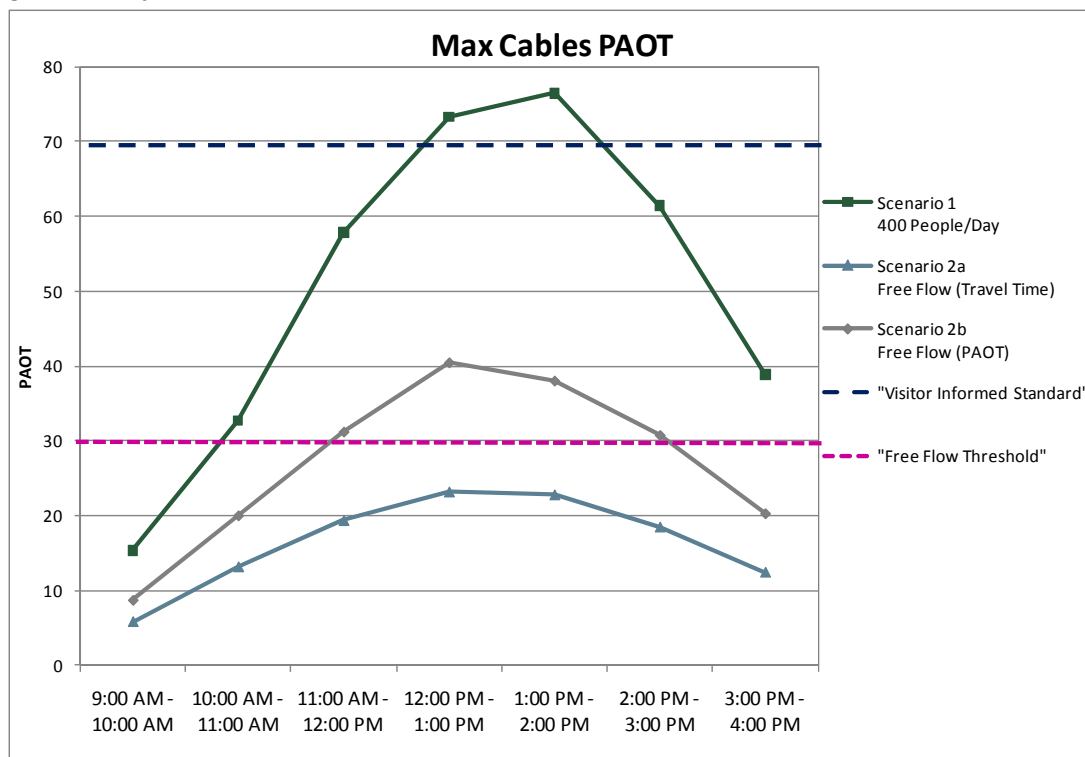
NOTE: Scenario 2b results = PAOT on the cables does not exceed 30 under ordinary circumstances.

Figure 14. Half Dome Visitor Use Model Simulation Results, Scenarios 1, 2a, & 2b: Mean Cables PAOT.



NOTE: "Free Flow Threshold" = 30 PAOT; "Visitor Informed Standard" = 70 PAOT (Lawson et al., 2009).

Figure 15. Half Dome Visitor Use Model Simulation Results, Scenarios 1, 2a, & 2b: Max Cables PAOT.



NOTE: "Free Flow Threshold" = 30 PAOT; "Visitor Informed Standard" = 70 PAOT (Lawson et al., 2009).

4.2.2 Scenario Analysis Results – Scenario 3

Results of simulations to analyze Scenarios 3 (Lightning Storm and Mass Descent) are summarized in Table 3. The results for Scenarios 3 include estimates of the total amount of time it would take all visitors on the Half Dome summit and cables to descend to the subdome in the case of a lightning storm or other circumstances that would require all visitors to descend at one time. As noted, five alternative levels of visitor use on the Half Dome summit and cables were modeled, the results of which are reported here.

The first set of results for Scenario 3 were estimated based on visitor use on the Half Dome Trail and cables observed during Saturdays and holidays in summer 2008. There were two days during the 2008 study period that were identified as potential outliers, because measures of visitor use on the Half Dome Trail on those days were substantially higher than observed on any of the other days during the study period (3,072 on Saturday, July 19 and 2,409 on Saturday, July 26). Therefore, results of Scenario 3 were estimated for Saturdays and holidays in summer 2008 based on mean daily visitor use calculated with and without the “outlier days” included; these results are described in the following paragraphs.

On Saturdays and holidays in summer 2008, daily visitor use on the Half Dome Trail and cables averaged 925 people per day, with the “outlier days” included (Table 3). At this level of daily visitor use, results of a regression model suggest a maximum of 131 would be on the Half Dome cables at one time, and results of a second regression model suggest a corresponding maximum of 103 people on the Half Dome summit. The simulation results suggest that with 131 people on the cables route and 103 people on the summit, it would take close to an hour and a half (approximately 85 minutes) for everyone to descend the Half Dome summit and cables to the subdome. The results further suggest that, visitors on the summit would be delayed on the summit for up to about 45 minutes while they wait for space to enter the top of the cables and begin their descent to the subdome.

On Saturdays and holidays in summer 2008, daily visitor use on the Half Dome Trail and cables averaged 700 people per day, with the “outlier days” excluded (Table 3). At this level of daily visitor use, a maximum of 111 people were observed on the Half Dome cables at one time, and results of a regression model suggest a corresponding maximum of 88 people on the Half Dome summit. The simulation results suggest that with 111 people on the cables route and 88 people on the summit, it would take more than 1 hour (approximately 70 minutes) for everyone to descend the Half Dome summit and cables to the subdome. The results further suggest that, visitors on the summit would be delayed on the summit for up to about 30 minutes while they wait for space to enter the top of the cables and begin their descent to the subdome.

Results for Scenario 3 (Table 3), suggest that on non-permit days during summer 2010, daily visitor use on the Half Dome Trail and cables averaged about 635 people per day. At this level of daily visitor use, a maximum of 117 people were observed on the Half Dome cables at one time, and results of a regression model suggest a corresponding maximum of 93 people on the Half Dome summit. The simulation results suggest that with 117 people on the cables route and 93 people on the summit, it would take more than 1 hour (approximately 75 minutes) for everyone to descend the Half Dome summit and cables to the subdome. The results further suggest that, visitors on the summit would be delayed on the summit for up to about 35 minutes while they wait for space to enter the top of the cables and begin their descent to the subdome.

As noted, the NPS instituted an interim permit quota to allow a maximum of 400 people per day on the Half Dome Trail and cables route on weekends during summer 2010 (Table 3). At this level of daily visitor use, results of a regression model suggest a maximum of 51 people would be on the Half Dome cables at one time, and results of a second regression model suggest a corresponding maximum of 46 people on the Half Dome summit. The simulation results suggest that with 51 people on the cables route and 46 people on the summit, it would take just over 45 minutes for everyone to descend the Half Dome summit and cables to the subdome. The results further suggest that, visitors on the summit would be delayed on the summit for up to about 10 minutes while they wait for space to enter the top of the cables and begin their descent to the subdome.

While the NPS permit quota during summer 2010 was designed to allow a maximum of 400 people per day on the Half Dome Trail and cables route on weekends, monitoring data collected during summer 2010 suggest that on permit days, visitor use averaged about 300 people per day (Table 3). At this level of daily visitor use, a maximum of 51 people were observed on the Half Dome cables at one time, and results of a regression model suggest a corresponding maximum of 47 people on the Half Dome summit. The simulation results suggest that with 51 people on the cables route and 47 people on the summit, it would take just over 45 minutes for everyone to descend the Half Dome summit and cables to the subdome. The results further suggest that, visitors on the summit would be delayed on the summit for up to about 10 minutes while they wait for space to enter the top of the cables and begin their descent to the subdome.

Table 3. Half Dome Visitor Use Model Simulation Results, Lightning Storm and Mass Descent Scenario*.

	Mean Daily Use at Half Dome Trail Jct.	Maximum Cables PAOT	Simultaneous Summit PAOT**	Mean Delay on Summit	Maximum Delay on Summit	Total Descent Time
Saturdays/Holidays, 2008 (w/ Outliers)	925	131***	103	26.4 (±0.10)	43.4 (±0.16)	83.7 (±0.47)
Saturdays/Holidays, 2008 (w/o Outliers)	692	111	88	17.2 (±0.07)	31.7 (±0.12)	72.0 (±0.46)
Non-permit Days, 2010	635	117	93	20.1 (±0.09)	35.3 (±0.15)	75.8 (±0.46)
2010 & 2011 Interim Permit Quota	400	51***	46	3.3 (± 0.03)	8.6 (±0.08)	47.0 (±0.52)
Permit Days, 2010 (Observed)	301	51	47	3.4 (± 0.03)	8.7 (±0.08)	47.1 (±0.45)

*Numbers in parentheses are 95% confidence interval half-widths.

**Estimated using 2010 regression model (Summit PAOT = $9.786 + (0.714 * \text{Cables PAOT})$).

***Estimated using 2010 regression model (Max Cables PAOT = $-10.038 + (0.152 * \text{Daily Use at HDT Jct.})$).

4.2.3 Scenario Analysis Results – Scenario 4

Results of simulations to analyze Scenarios 4 (Via Ferrata System on Half Dome) are summarized in Table 4 and Table 5, and in Figure 16 – Figure 21. Overall, the results suggest that implementing a via ferrata system on Half Dome would dramatically reduce the number of people that, under ordinary circumstances, could be accommodated per day on the Half Dome Trail and cables without exceeding the “Free Flow Threshold” of 30 PAOT or “Visitor Informed Standard” of 70 PAOT. In particular, results suggest that, in the case of implementing a via ferrata system on Half Dome, a maximum daily visitor use of about 70 people could be accommodated without exceeding the “Free Flow Threshold”, and a maximum daily visitor use of about 170 people could be accommodated without exceeding the “Visitor Informed Standard” (Table 4; Figure 20 and Figure 21).

The constrained “capacities” estimated to be associated with a via ferrata system on Half Dome are due, in large part, to the substantially slower pace at which visitors would be estimated to ascend and descend Half Dome than they do with the present cables system (Table 4; Figure 16 – Figure 19). In particular, results of the Half Dome visitor use model simulations suggest visitors mean ascent travel time would be roughly 80 minutes, and their mean descent time would be about 70 minutes.

Table 4. Half Dome Visitor Use Model Simulation Results, Via Ferrata Scenario – Cables Ascent and Descent Times.

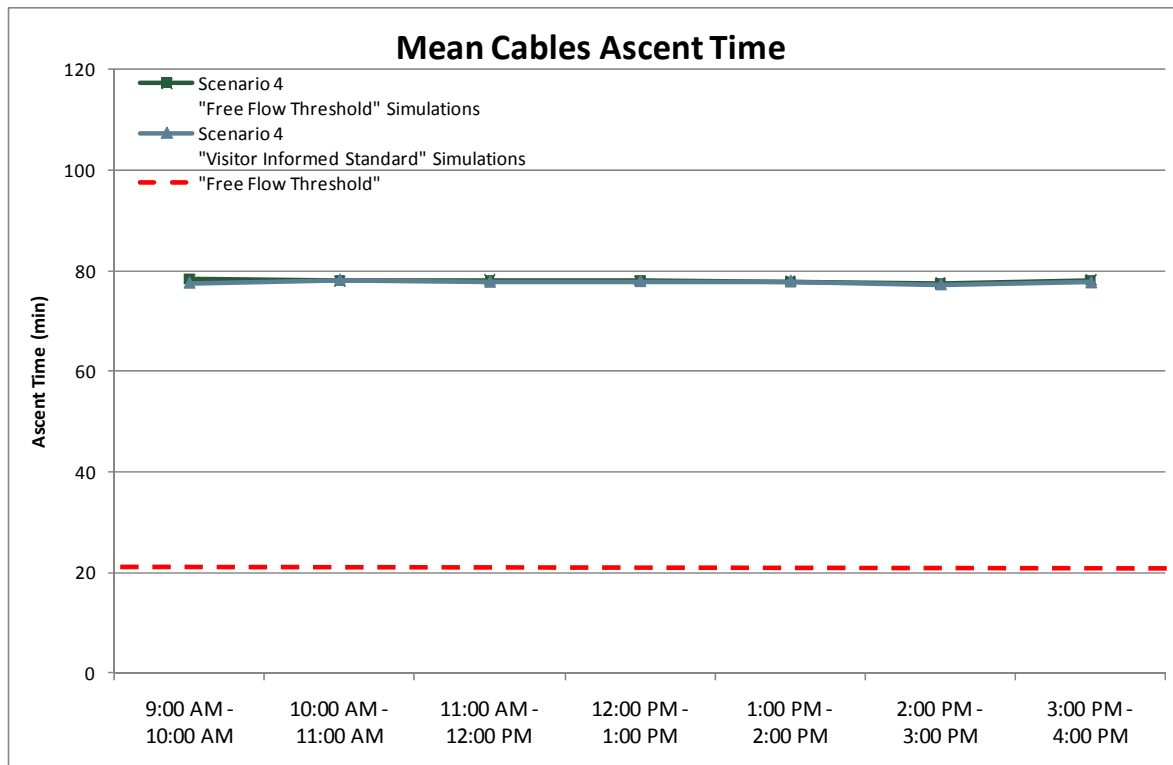
	Free Flow Threshold Simulations		Visitor Informed Standard Simulations	
	Mean Daily Use ¹ = 69 (± 2.5)		Mean Daily Use ² = 171 (± 4.3)	
	Mean	Max	Mean	Max
Ascent Time	78 (± 0.2)	92	78 (± 0.1)	96
Descent Time	70 (± 2.7)	129	70 (± 0.5)	146

NOTE: Numbers in parentheses are 95% confidence interval half-widths.

¹Daily visitor use that can be accommodated without PAOT on the cables exceeding 30 under ordinary circumstances.

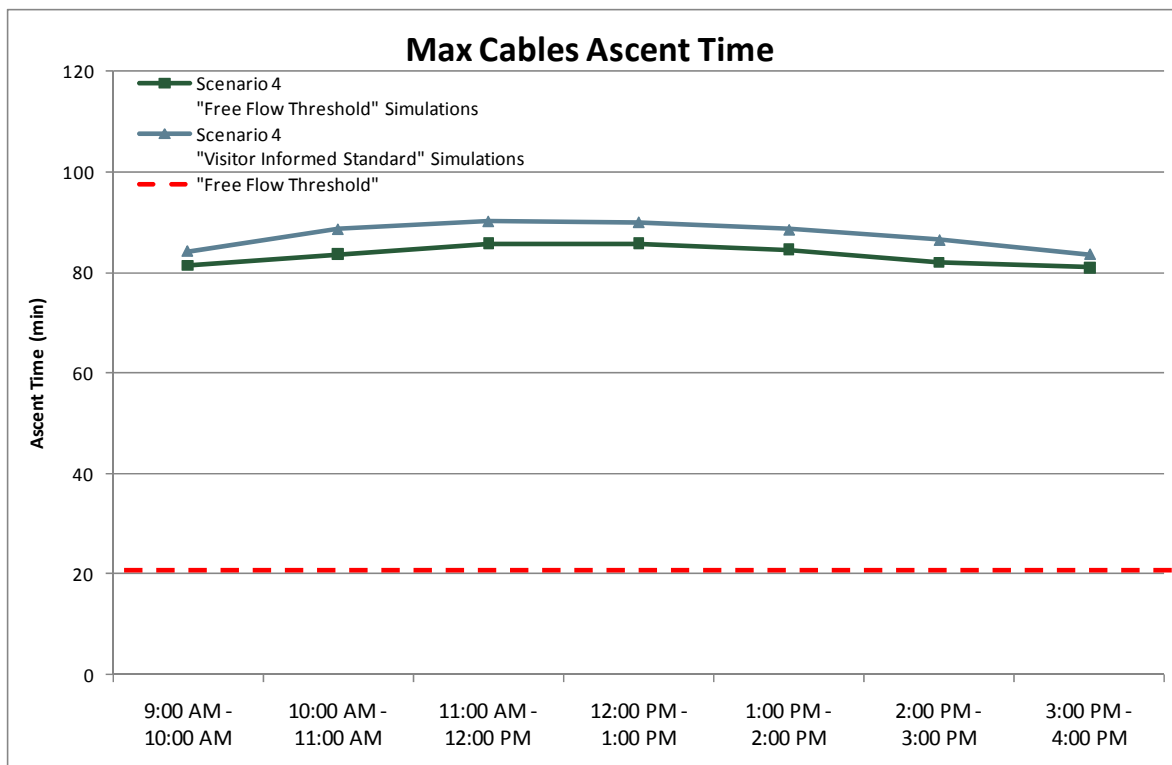
²Daily visitor use that can be accommodated without PAOT on the cables exceeding 70 under ordinary circumstances.

Figure 16. Half Dome Visitor Use Model Simulation Results, Scenario 4: Mean Cables Ascent Time.



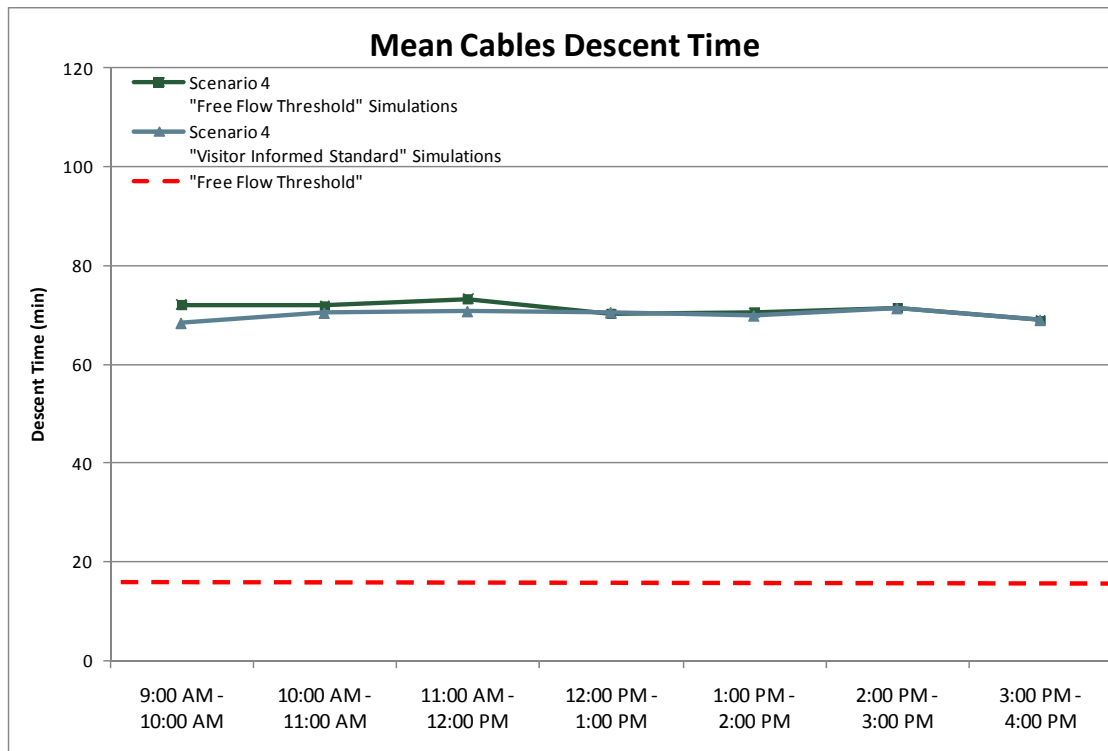
NOTE: "Free Flow" ascent time = 21 minutes (Lawson et al., 2009).

Figure 17. Half Dome Visitor Use Model Simulation Results, Scenario 4: Max Cables Ascent Time.



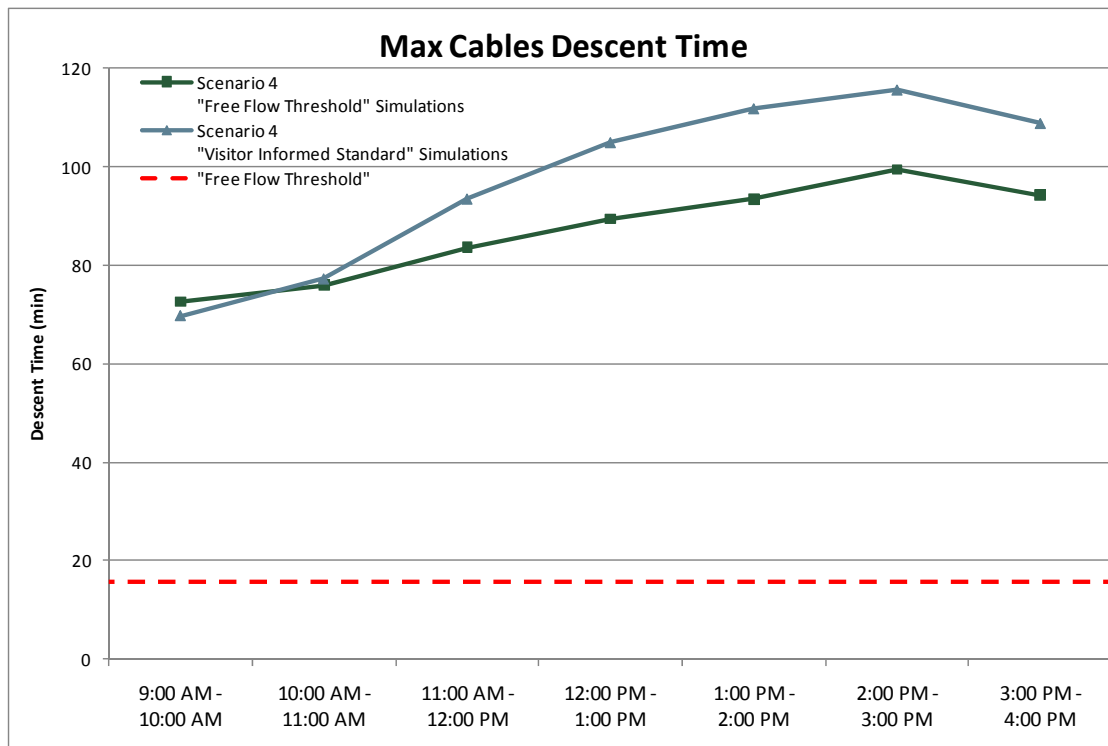
NOTE: "Free Flow" ascent time = 21 minutes (Lawson et al., 2009).

Figure 18. Half Dome Visitor Use Model Simulation Results, Scenario 4: Mean Cables Descent Time.



NOTE: "Free Flow" descent time = 16 minutes (Lawson et al., 2009).

Figure 19. Half Dome Visitor Use Model Simulation Results, Scenario 4: Max Cables Descent Time.



NOTE: "Free Flow" descent time = 16 minutes (Lawson et al., 2009).

Results of the simulations with the Half Dome visitor use model for Scenario 4 suggest that, because of the relatively low number of visitors using the Half Dome Trail and cables route during the day, but very long travel times to ascend and descend Half Dome by way of the via ferrata system, there would generally be few people on the cables at one time, but there would be concentrated periods of time when PAOT would be relatively high (Table 5; Figure 20 and Figure 21). It should be noted, estimates of maximum PAOT reported in Table 5 and Figure 21 for Scenario 4 differ slightly because they are based on daily and hourly averages, respectively.

Table 5. Half Dome Visitor Use Model Simulation Results, Via Ferrata Scenario - PAOT on Subdome, Cables, & Summit

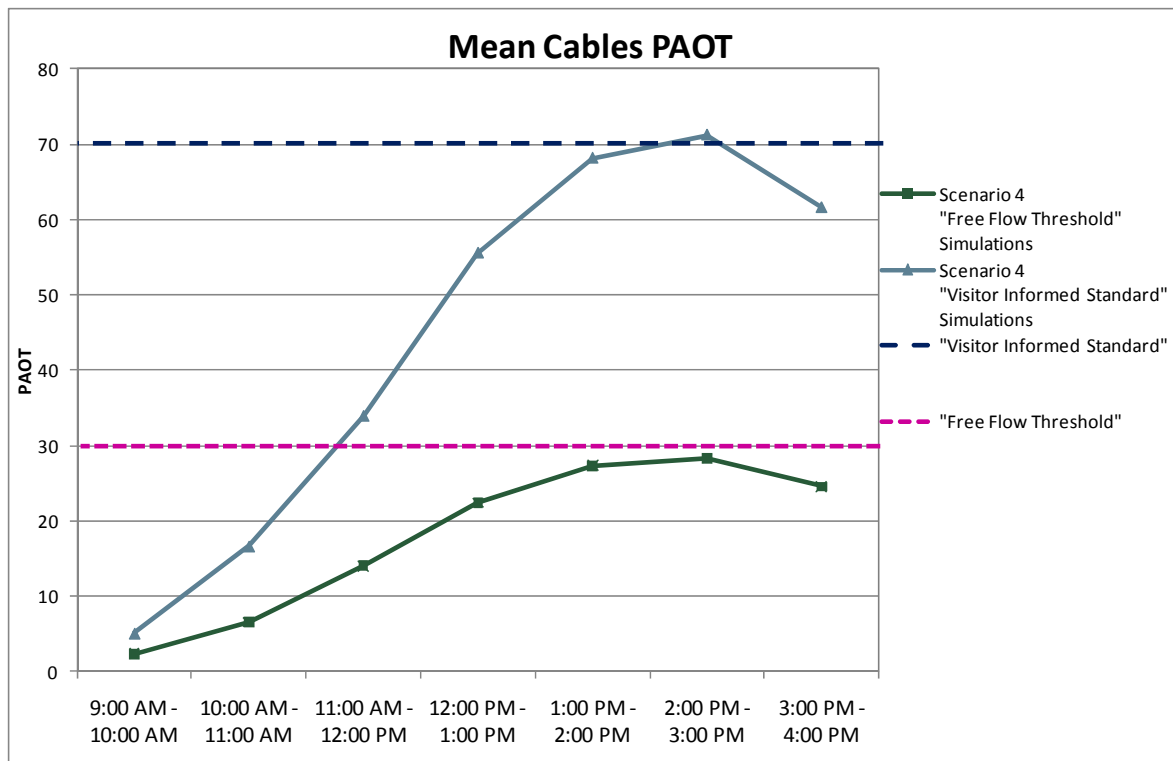
	Free Flow Threshold Simulations		Visitor Informed Standard Simulations	
	Mean Daily Use ¹ = 69 (± 2.5)		Mean Daily Use ² = 171 (± 4.3)	
	Mean	Max	Mean	Max
PAOT - Subdome	1 (± 0.1)	11	4 (± 0.1)	19
PAOT - Cables	11 (± 0.4)	38	27 (± 0.7)	84
PAOT - Summit	4 (± 0.2)	21	10 (± 0.3)	41

NOTE: Numbers in parentheses are 95% confidence interval half-widths.

¹Daily visitor use that can be accommodated without PAOT on the cables exceeding 30 under ordinary circumstances.

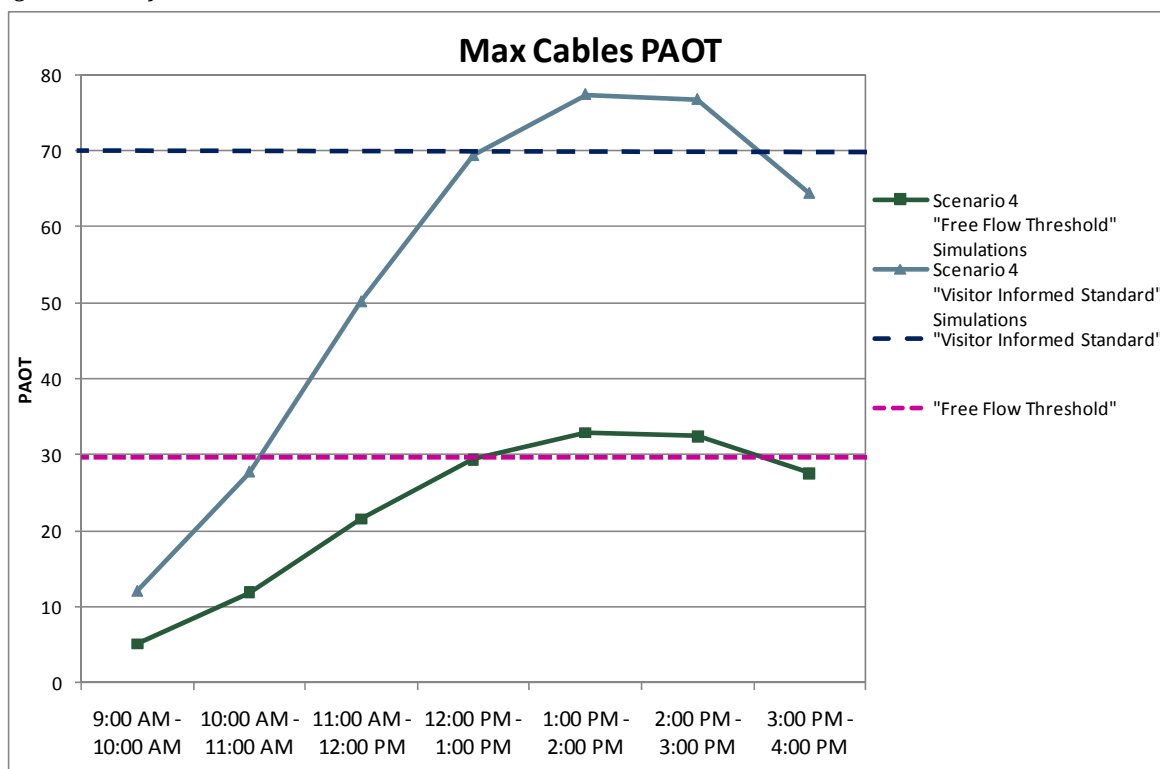
²Daily visitor use that can be accommodated without PAOT on the cables exceeding 70 under ordinary circumstances.

Figure 20. Half Dome Visitor Use Model Simulation Results, Scenario 4: Mean Cables PAOT.



NOTE: "Free Flow Threshold" = 30 PAOT; "Visitor Informed Standard" = 70 PAOT (Lawson et al., 2009).

Figure 21. Half Dome Visitor Use Model Simulation Results, Scenario 4: Max Cables PAOT.



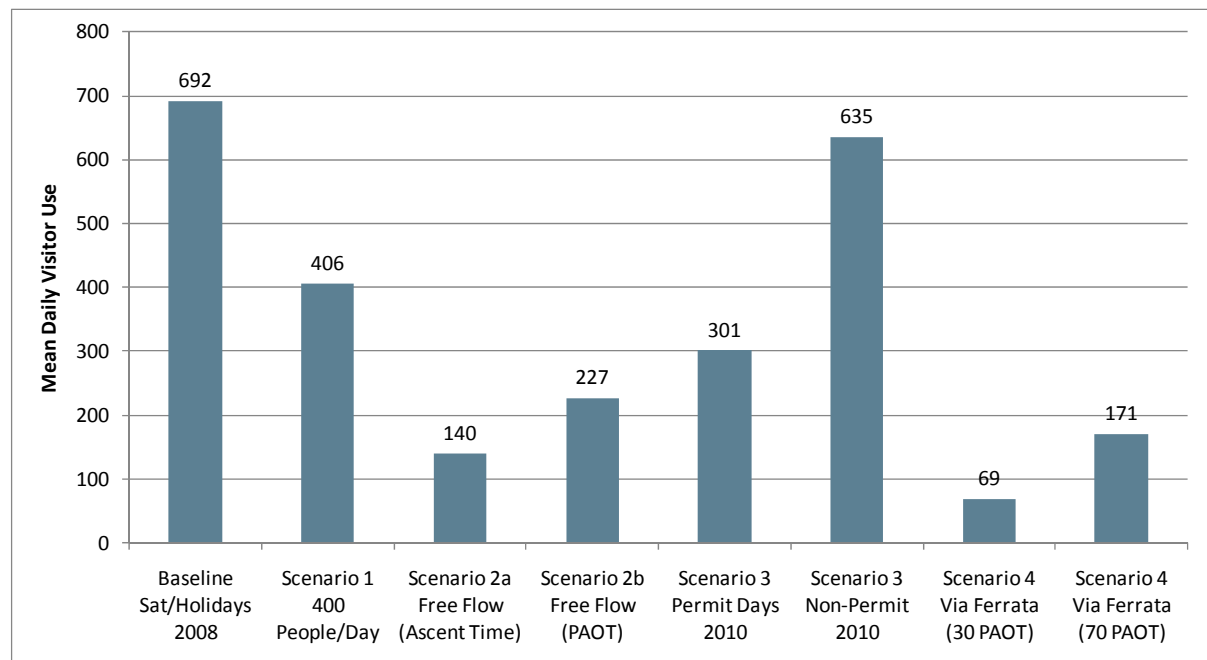
NOTE: "Free Flow Threshold" = 30 PAOT; "Visitor Informed Standard" = 70 PAOT (Lawson et al., 2009).

Chapter 5: CONCLUSION

Results of the work presented in this report, coupled with information from the 2008 Half Dome visitor use study and 2010 Half Dome visitor use monitoring, will help the NPS assess the potential benefits and consequences of alternative visitor use management strategies being considered in the planning process for the Half Dome Trail and cables route. In particular, results of scenario analyses conducted with the Half Dome visitor use model and presented in this report provide a quantitative basis to assess the effects of alternative planning scenarios on visitor use, crowding, and travel impediments on the Half Dome Trail and cables route.

As a summary of the findings this project, Figure 22 reports the mean daily visitor use that would occur on the Half Dome Trail and cables route under each of the scenarios that were analyzed in this report. The results suggest that scenarios designed to provide for “free flow” conditions on the Half Dome cables route (Scenarios 2a and 2b) would require substantially reduced daily visitor use than that which was observed during Saturdays and Holidays in 2008 and during non-permit days in 2010. Implementing a via ferrata system on Half Dome would require restricting use to about half of that allowed on permit days during summer 2010 in order to ensure the “Visitor Informed Standard” was not exceeded under ordinary circumstances, and by about 75% to ensure the “Free Flow Threshold” was not exceeded under ordinary circumstances. Thus, decisions about managing visitor use on the Half Dome Trail and cables route requires balancing tradeoffs among visitor access, crowding, and safety.

Figure 22. Mean Daily Visitor Use on the Half Dome Trail and Cables Route, by Scenario



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