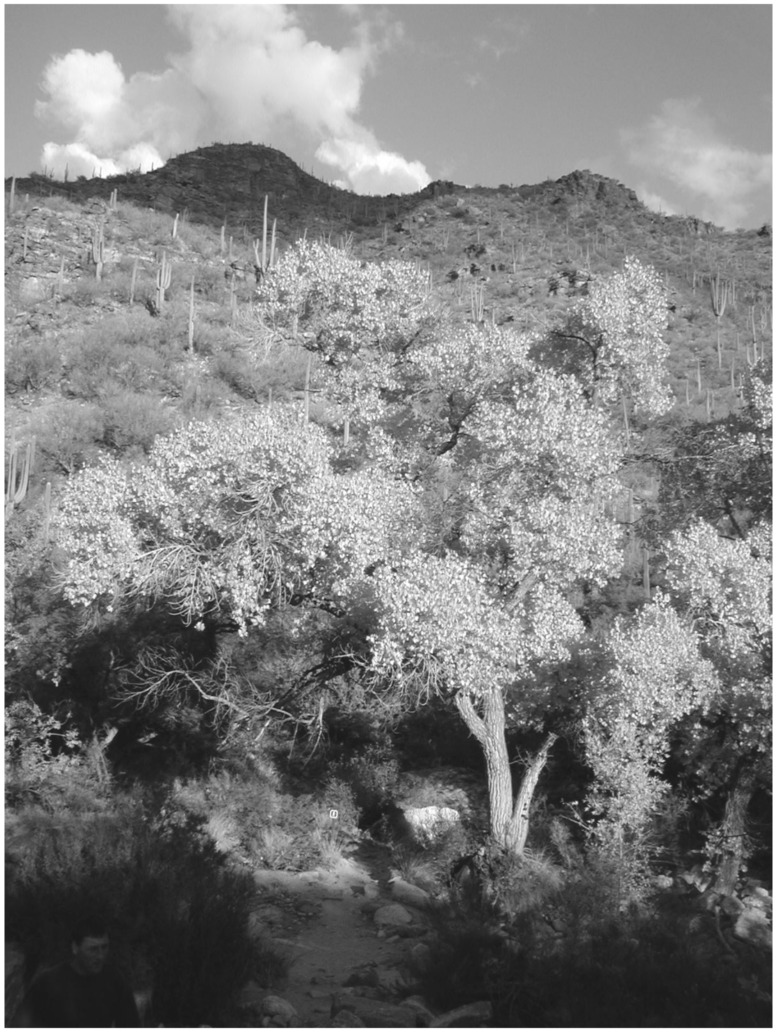
Spur Cross Conservation Area: Travel Simulation Model of Visitor Use



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Introduction

Outdoor recreation is on the increase world wide as people have more leisure time, greater mobility, and more disposable income. In addition there is a proliferation of new types of recreation such as mountain bike riding, snow boarding, canyoning and other emerging activities that have different environmental requirements and are often in conflict with more traditional outdoor activities. As visitor numbers increase, there is a simultaneous increase in environmental impacts, crowding, and conflicts between different recreational types and users. These circumstances make recreation management a complex problem. Managers of natural areas must accommodate increasing visitor use while at the same time, maintaining environmental quality and assuring visitors have the high quality experience they anticipate.

Conventional methods used in the design and planning of park management facilities have depended on user surveys and traffic counts to estimate the requirements. However these methods fall far short of the real needs of managers who need to comprehensively evaluate the cascading effects of the flow of visitors through a sequence of sites and estimating the effects of increasing visitor flows through time. Managers require information on the spatial nature of the visitor to adequately manage for both the experience and to protect the recreation setting. This information includes the destination, arrival and departure times, number of visitors in a party, type of activity, nights camping etc. These spatial dynamic parameters likewise are imperative for constructing models to represent current conditions and testing out future management scenarios to reduce social and ecological impacts in a setting. In addition, managers need to know if designed capacities for parking, visitor centers, roads, camping areas, and day use facilities can accommodate projected visitor numbers. Crowding, conflicts between different recreation modes, impacts on environments and seasonal effects such as day length and weather are all factors park planners must consider in the design and location of new facilities.

There are many options available to park managers to deal with heavy visitor use. New sites can be opened up, a system of reservations can be implemented; areas can be closed so sites can recover from over use; facilities can be expanded or sites can be hardened to accommodate larger numbers of visitors. Each of these strategies will have different impacts on the overall system. The complex inter-relationships between these decisions are almost impossible for a manager to predict. It is in this context where simulation of recreation behavior is of real value.

This final report documents the development of a pilot project to examine the visitor flow patterns of recreation visitation in Spur Cross Conservation Area (SCRCA). This study utilizes existing and proposed trail data and estimates of visitor numbers at various entrances into Spur Cross to simulate their interactions throughout the proposed season. Since very little is known about visitor use patterns in the Conservation area at present, the data used to construct the simulation was derived from those knowledgeable about how the area is currently being used. Once a complete monitoring plan is developed and implemented for the SCRCA, the model developed and described herein can be rerun to derive a baseline simulation of current conditions.

Why Travel Simulation Modeling?

Understanding the spatio/temporal distribution of use is of fundamental importance to those who plan for and manage recreation use. The kind and amount of visitor use has profound effects on the quality of the natural resources, visitor experiences and facilities in recreation areas. Therefore, it is critically important to be able to monitor the flow of visitation, in space and over time, and to be able to predict how distributions are likely to change in response to both management actions and factors that are not subject to managerial control. In some situations this is easily done. However, the ease of monitoring and predicting use declines as the size of the recreation area increases, the complexity of traffic flow increases, and the degree to which traffic flow is tightly controlled by management decreases. Moreover, the importance of being able to monitor and predict visitor flow is particularly pronounced in places where biophysical conditions and experiential conditions are highly sensitive to intensity of use.

Increasingly, travel simulation modeling is gaining recognition as an important tool for park and wilderness planning and management. Although travel simulation models for parks and recreation have been experimented with for more than three decades, in the last decade the cost of modeling has plummeted and capabilities have soared. Specifically, simulation models can be used to:

- Provide a better understanding of the baseline spatial and temporal patterns of visitor use.
- Help predict how distributions of visitor use are likely to change in response to both management actions and factors not subject to managerial control.
- Allows for testing the feasibility and effectiveness of management plan alternatives.
- Allow for monitoring of hard-to-measure parameters (e.g. people at one time at a certain attraction or walking on particular trails) by using easily measured indicators (e.g. number of cars entering the park or parking at a trailhead).
- Support the planning and management of visitor use in situations where monitoring and predicting visitor flow is difficult.
- Improve communication of implications of management prescriptions to the public. Help with communication of management scenario implications – gives a visual explanation that can be powerful
- Link transportation systems and planning/design
- Support for decisions
- Helps with cost analysis
- Helps evaluate management actions (e.g., implementation of a shuttle system)
- Better understanding of problems and potential casual factors – leads to better solutions
- Testing of management alternatives – better than trial and error on the ground
- Need to ask whether the park is large and complex enough to warrant modeling – the more space in a park, the more need for modeling – but, small, site-specific sites may be good applications if use and/or impacts are complex

- Need validity test on the models – there has been some validation of models on existing conditions, not as much on models of management scenarios – moving in to artificial intelligence applications
- Data that is collected on visitor use is useful with or without modeling
- Data collection should be based on decision making needs
- Should we contract modeling or have in-house? Outsourcing keeps the technology on the cutting edge
- Level of appropriate public access to modeling data
- Modeling helps increase creativity in management scenarios without increasing risks
- Modeling has strong application to site-level design

Approaches to Travel Simulation Modeling
There are two modeling approaches that are currently being used to simulate visitor travel patterns in Outdoor recreation environments. The first approach was developed at the University of Vermont using a commercial simulation package called Extend.

- Extend Models use hierarchical blocks that represent specific parts of the recreation network (e.g. campsites, parking lots, roads, trails, intersections, etc.).

- Models are based on visitor use data collected on travel patterns (e.g. travel mode, time at attractions, time traveling, choices for hiking, etc.), which provide typical visitor profiles.

- Visitor arrivals and movements are programmed based on existing visitor data collected from trip diaries and permit data. Simulations to date can only model existing use patterns. Projected changes in user volumes can be modeled by assuming existing patterns of use will remain the same under increasing use volumes.

- *Extend* software has been used to model use patterns and encounter rates on the carriage roads at Acadia National Park; campsite sharing at Isle Royale National Park; people at one time at attraction sites in Arches National Park; and monitoring indicators of quality (encounters) at Hawaii Volcanoes National Park.

The second approach has been pioneered at the University of Arizona. This simulation tool has been specifically developed for recreation purposes. This approach to modeling recreation use, uses a special purpose simulator – Recreation Behavior Simulation (*RBSim*)

- The earliest version of RBSim (version 1) was park specific – in other words, the model could not be used at a different park. The latest versions are open architecture applications, and are not park specific.

- Four uses of the *RBSim* technology: (1) Models based on existing use information that assigns trip profiles to agents (hardwired trips similar to the *Extend* models); (2) Probabilistic models that determine choice of path based on probabilities at intersections. (3) Models based on behavior rules assigned to "smart agents." (4) Models based on a combination of hardwired, probabilisitic and/or smart agents.

- Smart agents are guided by probabilistic hierarchical rules that are based on logical assumptions (e.g. when you arrive at a park, you park your car) and visitor information (e.g. what have visitors identified as being major attractions in the park – camping near a lake). Rules can be site/context specific by subdividing the study area into locales and creating rules specifically for each locale.

- Each smart agent in the model is assigned a set of hierarchical rules that drive behavior in the model. As the agent travels through the park and events unfold in the model (e.g. facilities become full to capacity), the smart agent makes decisions based on the attributes assigned to it, such as mode of travel, personality profile, time constraints and proximity to different attraction nodes. In other words smart agents are autonomous and can make reasonable choices about travel paths without the need for prescribed itineraries. This makes them ideally suited for simulating new management conditions such as changes in road and trail networks, relocating facilities, closing access to areas, and other changes in the recreation network. These simulations are referred to as "Smart simulations".

- *Agent based simulations* have been used to model peak periods of use, facility capacities, and conflicts between user groups in Grand Canyon National Park; facilities management for parking and viewing platforms for Port Campbell National Park (Australia); interactions between wildlife and tourist travel in Misty Fjords National Monument in Alaska and back country campsite encounters in Humphrey's Basin in the Sierras, California.

RBSim Multi-Agent simulation of Visitor Travel Patterns

Both approaches have utility for modeling travel patterns. The prototype developed in this study to examine travel patterns at SCRCA utilizes RBSim RBSim 2 (Recreation Behaviour Simulation) (Gimblett & Itami, 1997; Gimblett, 1998; 1998a; Gimblett et al. 1999; Itami et al., 1999; Itami et al., 2000, Itami and Gimblett, 2000; Itami, in Press) is a computer simulation tool, integrated with a Geographic Information System (GIS) that is designed as a general management evaluation tool for any landscape. This capability is achieved by providing a simple user interface that will import landscape information required for the simulation from a geographic information system. Once the geographic data is imported into RBSim 2, the land manager can change a number of variables. In Misty Fjords for example, variables included the size of vessels, hull designs, and various speeds at which they traveled. Also considered were flight patterns for airplanes or helicopters that were largely dependant on daily weather conditions. In other settings variables could include number and kind of vehicles, the number of visitors, and facilities such as the number of parking spaces, road and trail widths and many other features.

RBSim 2 allows a land management to explore the consequences of change to one or more variables so that the quality of visitor experience is maintained or improved. The simulation model generates statistical measures of visitor experience to document the performance of any given management scenario. Management scenarios are saved in a database so they can be reviewed and revised. In addition, the results of a simulation are stored in a database for further statistical analysis. The software provides tables from the simulation data so land managers can identify points of over crowding, bottlenecks in circulation systems, and conflicts between different user groups.

Specifically RBSim 2 uses concepts from recreation research and artificial intelligence (AI) and combines them in a GIS to produce an integrated system for exploring the complex interactions between humans and the environment (Gimblett et al. 1996a; Gimblett et al. 1996b, Gimblett 1998, Gimblett and Itami, 1997, Itami et al., 1999; Itami et al., 2000; Itami and Gimblett, 2000). RBSim 2 joins two computer technologies:

- Geographic Information Systems to represent the environment
- Autonomous "intelligent" software agents to simulate human behavior within geographic space.

RBSim 2 uses autonomous agents to simulate recreation behavior. An autonomous agent is a computer simulation that is based on concepts from Artificial Life research. Agent simulations are built using object oriented programming technology. The agents are autonomous because once they are programmed they can move about their environment, gathering information and using it to make decisions and alter their behavior according to specific environmental circumstances generated by the simulation. Each individual agent has it's own physical mobility, sensory, and cognitive capabilities. This results in actions that echo the behavior of real animals (in this case, human) in the environment.

The process of building an agent is iterative and combines knowledge derived from empirical data with the intuition of the programmer. By continuing to program knowledge and rules into the agent, watching the behavior resulting from these rules and comparing it to what is known about actual behavior, a rich and complex set of behaviors emerge. What is compelling about this type of simulation is that, although it is impossible to predict the behavior of any single agent in the simulation, it is possible to observe the interactions between agents and draw conclusions that are impossible using any other analytical process or field research.

RBSim 2 simulation model consists of a number of object oriented software technology to model components of the overall simulation system. These software objects include:

- Network Object Model - contains network topology for roads, trails and other linear features organised as a forward star network with associated attributes and methods for calculating travel time and distances across the network.
- Terrain Model - contains elevation data represented as a regular grid of elevations.
- Graphics Engine - provides visualisation of the landscape as a map showing current location of recreation agents.
- Simulation Engine - controls the scheduling of agents, controls simulation events such as weather, road opening and closure, seasonal events and other user-defined events.

- Scenario Builder – for constructing a variety of scenarios to test out design, planning and management options.
- Output Object - stores run-time states for agents and the network.
- Agent object - represents a recreation personality type, mobility characteristics, and reasoning system.

Each of these components allows one to build their own agents, import GIS data to create a travel network, establish arrival times for surrogate visitors to start the simulation, build and test a scenario and derive temporal outputs for any node or linkage in the database.

Developing the Simulation Network for SCRCA

Geographic Information Systems (GIS) data was used to build the travel network typology that the agents utilize in the simulation. This involved taking the existing and proposed trail networks and translating the data into a form useful in the simulation. Figure 1 illustrates the trail network used in assessing recreation use in SCRCA. The typology consists of lines and nodes that can be attributed with information necessary for the agents to travel along the network.

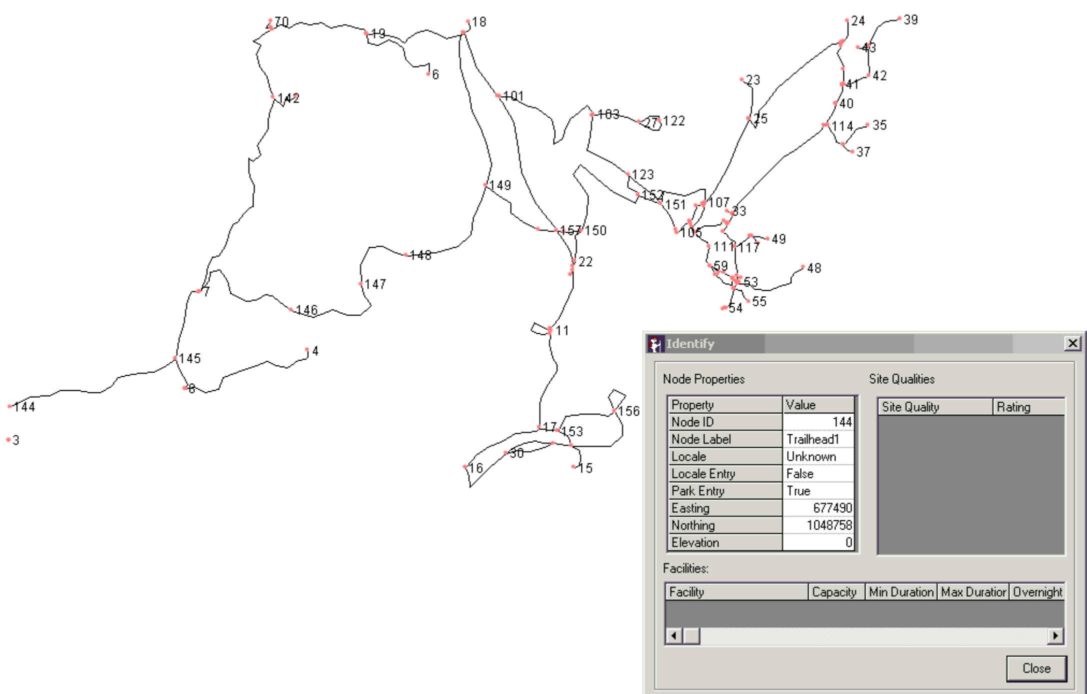

Figure 1 – View of the Trails Network for SCRCA

The nodes either represent intersections of trails, destinations (such as an archeological site) or trailheads or significant access points. Figure 2 illustrates the network and associated data that is attached to a node. For example the trailhead node *Trail Head 1* is where visitors would enter and follow the proposed Maricopa County trail. Trail speeds, type of trail, condition etc. are important attributes of the trail system that encourage or restrict movement patterns. This information is all encoded into the trail segments and agents in our simulations use this information to navigate along the network. The advantage of using simulation is that if trail conditions change or new trails are proposed, these adjustments can easily be made to the network and the baseline simulation reconstructed to illustrate the effects of these changes. This is anticipated in the future of this project as move concise trail alignments are constructed and recreation use data collected.

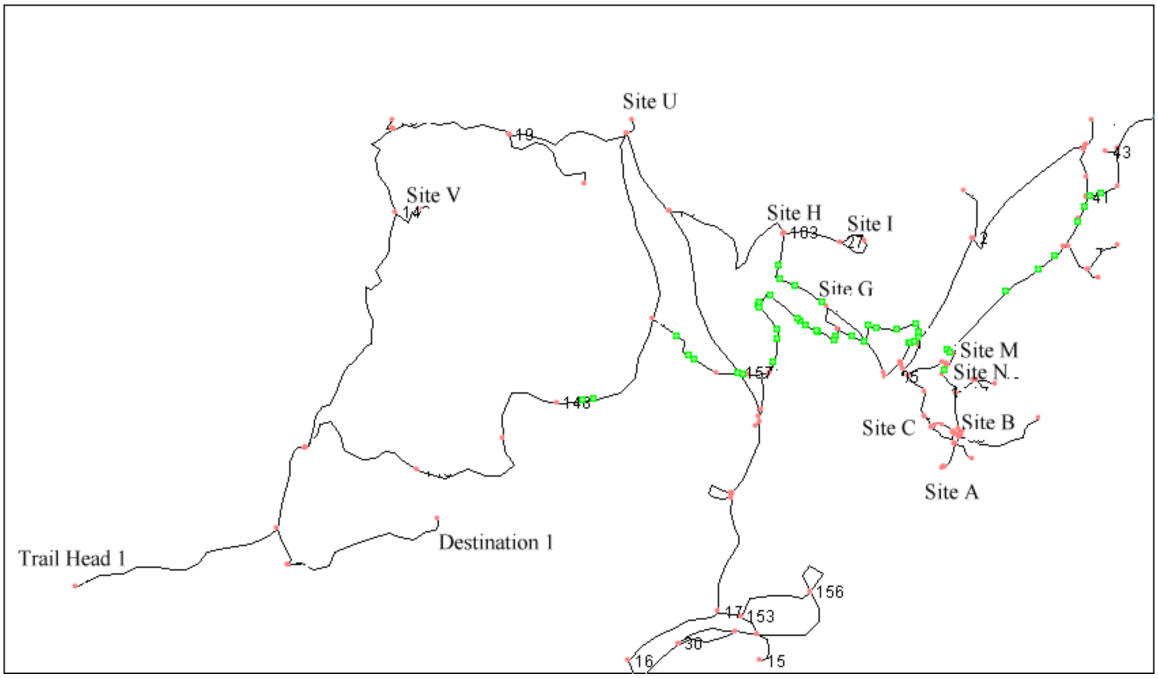

Figure 2 – Trails Network and Designated Visitation Sites

Agent Trip Schedules the Represent Expected Visitation Patterns

In the absence of any realistic, quantitative data on visitor use patterns or those currently entering SCRCA, anticipated recreation use levels from various trail entry points were developed. These visitor use levels are based on what is anticipated, not from what is currently known. An inventory and monitoring program would have to be established in an attempt to quantify this information. But the anticipated visitor use levels provide a solid basis for developing the prototype simulation. Data for each of the trips was used to create a trip schedule. Table 1 is a matrix of the types of trips anticipated, the time the trip would start, duration of the trip and expected visitor use levels for each trip by weekday and weekend. The simulation works based on simulating individual trips. By simulating all trips over a season it is possible to examine the expected use levels at various sites and provide some feedback to set social and environmental standards as well as monitor for these standards in the future. The trip schedule then in the simulation environment contains information essential for simulating any individual trip. The trips outlined in

Table 1 are converted into a useful format for the simulation. This is all handled within the simulation software. From the data outlined in Table 1 all trips conform to a database standard and are all converted into a monolith database that reorganizes and reconstructs all trips into an annual, monthly and daily schedule. When the simulation begins, each trip then is scheduled for a specified period of time and executes the trip in a sequential fashion. Each individual trip is launched in the simulation and traverses and navigates through the GIS represented landscape as a real trip would in a real landscape. The landscape in this simulation contains popular destinations (represented as nodes), topography for undertaking visibility analysis to capture information on encounters and visits to a destination and the routes that trips traverse.

SCRCA – Current Use Assumptions					
Trip Number and Name	**Season of Use Start Time**		**Duration**	**Visitor Use**	
	Cool Season – October – March	Warm Season - April – September		Weekday	Weekend
Trip #1 – Exploring SCRCA	8AM	9AM	2.5 Hours	7/day	20/day
Trip #2 – SCRCA – Short Loop	8AM	9AM	1.0 Hour	20/day – only one time per week – assume Wednesday	N/A
Trip #3 – ADA Loop	8AM	9AM	1.0 Hour	3/day – only 2 times per month – assume 1st and 3rd Monday	N/A
Trip #4 – SCRCA Moon Walk	N/A	***8PM**	1.5 Hour	35/day – only one time per month – assume full moon night – assume alternating month with Trip #5	
Trip #5 – SCRCA Moon Walk to First Mesa	N/A	***8PM**	1.5	35/day – only one time per month – assume full moon night – assume alternating month with Trip #4	
Trip #6 – SCRCA Speed walk	7AM	N/A	1.5	35/day – only one time per month – assume 1st Saturday	
Trip #7 – SCRCA Speed walk to First Mesa	7AM	N/A	1.5	35/day – only one time per month assume 2nd Saturday	
Trip #8 – Unguided General Public – Use Trips 1, 2, 3, and 9 (next)	From 6AM – 6PM		3.0 hours	7/day	33/day

Trip #9 – SCRCA Stables	8AM	9AM	45 minute (then elapse 2 hours) then 45 minute return	2/day – assume 30 day month	16/Saturday: 16/Sunday – assume 30 day month
Trip #10 SCRCA Maintenance Trip - Use Trips 1, 2, 3, and 9	6AM – 9PM		3.0 hours	1/day	5/day (Saturday and Sunday) interval equal every 3 hours
Trip #11 – SCRCA Riparian Short Loop	8AM	9AM	1.5	7/day – assume every Tuesday	20/day – assume every Saturday
Trip #12 – SCRCA Riparian Long Loop	8AM	9AM	3.0 hours	7/day – assume every Thursday	20/day – assume every Sunday
Trip #13 – SCRCA Elephant Fortress	8AM	N/A	5.0 hours	N/A	50/event – assume 1st Saturday in October, December, and February
Trip #14 – Southwest Horse Trail	8AM	9AM	4 hours	15/day	15/Saturday:15/ Sunday
Trip #15 – Maricopa County Regional Trail	6AM – 6PM		3.5 hours	5/day	40/Saturday:40/ Sunday

Table 1 – Table of Current Visitor Use Patterns for SCRCA

In any simulation, many modes of transportation or movement can be simulated. In the prototype developed for SCRCA, two agent types were constructed to represent recreation use. Remember agents or agent types are simply surrogates for visitors. For this simulation equestrians and hikers are anticipated to be the majority of visitors. The travel patterns or trips used to simulate both of these visitor or agent types were derived from data outlined in Table 1. These human or horse surrogates are programmed to

TypicalTrips : Table

TripI	Description	Network	EntryNode	ExitNode	ArrivalID	Arrival	MinDurat	MaxDurat	AveDuration	TravelM	TravelModeName
4	Trip #6 - SCRCA Speedwalk A	Trails Network	66	66	38	Arrivals at Spur Cross	4202	4922	4562	3	Foot
5	Trip #7 - SCRCA Speedwalk B	Trails Network	66	66	43	Arrivals at Spur Cross	3061	3124	3092.5	3	Foot
6	Trip #1 - Exploring SCRCA	Trails Network	66	66	2	Arrivals at Spur Cross	150	150	150	3	Foot
7	Trip #9 - SC Stables	Trails Network	66	66	24	Arrivals at Spur Cross	4443	4503	4473	1	Car
9	Trip #13 - Elephant Fortress	Trails Network	66	66	32	Arrivals at Spur Cross	2962	3093	3027.5	3	Foot
10	Trip #2 - SCRCA Short Loop	Trails Network	66	66	15	Arrivals at Spur Cross	3001	3063	3032	3	Foot
11	Trip #3 - ADA Loop	Trails Network	66	66	16	Arrivals at Spur Cross	2942	2943	2942.5	3	Foot
12	Trip #4 - SCRCA Moon Walk A	Trails Network	66	66	4	Arrivals at Spur Cross	3002	3063	3032.5	3	Foot
13	Trip #5 - SCRCA Moonlit Walk B	Trails Network	66	66	18	Arrivals at Spur Cross	3064	3123	3093.5	3	Foot
14	Mointoring Agent at Site J	Trails Network	127	127	12	Arrivals at Spur Cross	3379484	6402044	4890764	6	Stationary Agent
15	Maricopa County Trail	Trails Network	144	144	34	Arrivals at Spur Cross	35133	66213	50673	3	Foot
16	Trip #1 - Exploring SCRCA - Weekend	Trails Network	66	66	14	Arrivals at Spur Cross - Weeker	150	150	150	3	Foot
17	Trip #9 - SC Stables - Weekend	Trails Network	66	66	25	Arrivals at Spur Cross	4443	4503	4473	1	Car
18	Maricopa County Trail - Weekend	Trails Network	144	144	35	Arrivals at Spur Cross	35133	66213	50673	3	Foot
19	Monitoring Agent at Site I	Trails Network	122	122	12	Monitoring Agent at Site J	526173	527613	526893	6	Stationary Agent
20	Monitoring Agent at Trailhead 1	Trails Network	144	144	12	Monitoring Agent at Site J	524892	527013	525952.5	6	Stationary Agent
21	Monitoring Agent at Site A	Trails Network	66	66	12	Monitoring Agent at Site J	524404	525844	525124	6	Stationary Agent
22	Monitoring Agent at Site V	Trails Network	143	143	12	Monitoring Agent at Site J	524404	525844	525124	6	Stationary Agent
23	Monitoring Agent at Site B	Trails Network	130	130	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
24	Monitoring Agent at Site C	Trails Network	128	128	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
25	Monitorng Agent at Site D	Trails Network	134	134	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
26	Monitoring Agent at Site E	Trails Network	124	124	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
27	Monitoring Agent at Site F	Trails Network	135	135	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
28	Monitoring Agent at Site G	Trails Network	123	123	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
29	Monitoiring Agent at Site H	Trails Network	103	103	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
30	Monitoring Agents at Site K	Trails Network	33	33	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
31	Monitioring Agent at Site L	Trails Network	43	43	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
32	Monitoring Agent at Site M	Trails Network	126	126	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
33	Monitoring Agent at Site N	Trails Network	117	117	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
34	Monitoring Agent at Site U	Trails Network	18	18	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
36	Monitoring Agent at Site X	Trails Network	82	82	12	Monitoring Agent at Site J	432061	433501	432781	6	Stationary Agent
nber)			0	0	0		0	0	0	0	

Table 2 – Travel patterns Converted to Typical Trips from Visitor use Patterns in Table 1

move, stop, rest, seek out destinations etc. as if they were living in the real world. They speed up or slow down depending on whether they are going up or down hills, have visual capabilities to calculate encounters with each other etc. Table 2 illustrates how the trips in Table 1 are converted into typical trips in the simulation and represented in the database. Each trip is assigned an entry and exit node, a network or trail system that the agents will travel on, a trip duration and an arrival/departure curve.

Arrival Rates

Arrival/Departure curves provide the departure times of each agent in the simulation. In the simulation software, the capability exists to build an arrival or departure curve based on what is known about visitor arrivals at entry points such as trail heads. Figure 3 provides an example of an example of an arrival/departure curve for trip #1. A total of n=51 agents will randomly depart between the hours of 7am and 7pm on a daily basis, from April 1 through May 1.

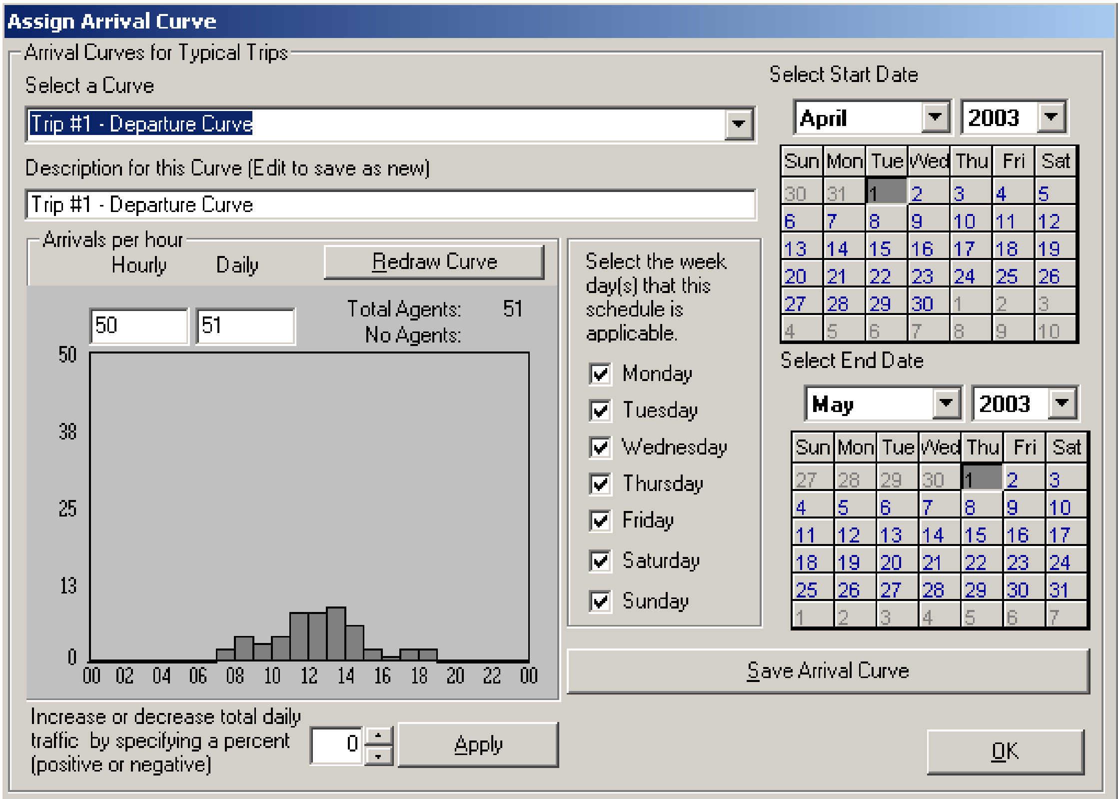

Figure 3 – Arrival/Departure Curve for Trip #1

The arrival/departure curves can also be constructed to test out increased numbers of visitors entering a particular area. For example if a survey was constructed and a sample of 50% was acquired of all visitors entering the area, then to simulate at 100% capacity or what you would expect to see in a typical year, this tool can be used to ramp up the agent numbers entering the simulation.

Monitoring Agents To Measure Number of Visits to Identified Sites

In the recreation literature the most dominant concern in many recreation settings is over crowding. Crowding effects a visitor expectation, can lead to conflicts and a decline in the recreation experience. It has been shown that a consistent indicator of crowding is encounters. It is not just how many visitors frequent an area at the same time, but also the type of recreation activity or mode of activity that has a major impact on both the social experience. This can as also lead to environmental or site impacts. To better understand the numbers of visitors entering SCRCA and arriving at particular sites, the simulation environment provides for the use of monitoring agents. A monitoring agent is placed in a fixed location in the simulation to monitor encounters. The only job that these agents have is to keep track of all the visits to the location they are stationed at over time. They not only count the number of other agents that visit the site, but keep track of who they are, when they visited the site, number of visitors per mode of transportation and the mode of travel. Figures 14, 15 & 16 provide examples of the use of monitoring agents on this project. The data for each of these monitoring agents or sites is statistically analyzed to determine the volume of visitations, who and in particular when (seasonality) of the visit. It is also possible to speculate on encounter levels and possible conflicts between use levels. Most importantly, the results of the simulation run can be used to determine in the future which sites should be more intensely monitored based on current and project visitor use levels.

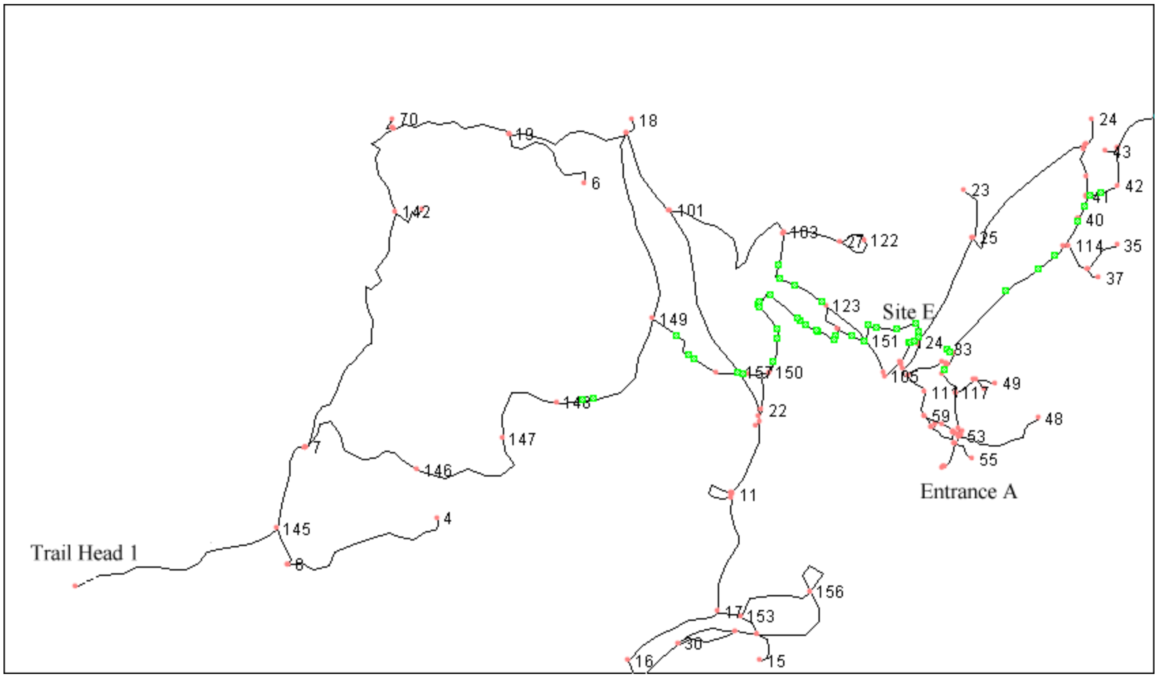

Figure 4 – Trails Network and Monitoring Sites

To demonstrate the potential of using monitoring agents and to provide information on visitor use levels, agents were placed at three locations to provide. The locations selected were the E*ntrance A to the South end of the study site,* one *interior Site E and the trailhead at the entrance to the Maricopa Trail*. These three sites were selected to provide information on numbers of visitors entering SCRCA and one in the interior to provide illustrate the monitoring agents ability to computer encounters between groups. Figure 4 provides a location of where the monitoring agents were placed.

Simulation Results for SCRCA

The simulation for SCRCA was constructed using the GIS data described earlier and the anticipated recreation use levels outlined in Tables 1 & 2. The simulation was run for the critical months outlined in Table 1. For purposes of this study, the monitoring agents were used to collect information at three distinct sites (See Figure 4). An analysis was completed for each of the areas to determine (Total Hourly Arrivals by Day, Year and Month). There are many other ways to summarize the data and they can be discussed further in future scenario run. Since visitors either come or go via either the trailhead of *Entrance A*, these measures provide some insight into total number of visits. Aside from total numbers arriving or departing the site what is equally important are the type of visits. A more detailed analysis was performed at *Site E* to examine the number and type of visitors who encounter each other on the trail while approaching *Site E*. Also, the number and type of visitors who encounter each other at *Site E*. Further, the number and type of visitors who encounter each other by the hour during the peak thanksgiving weekend (11/29/2003).

Monitoring Site - Entrance A
An assessment of the statistics gathered at Entrance A provides a quantitative view of use levels throughout the simulation period. Figures 5, 6 & 7 summarize some of the results for arrivals/departures at Entrance A.

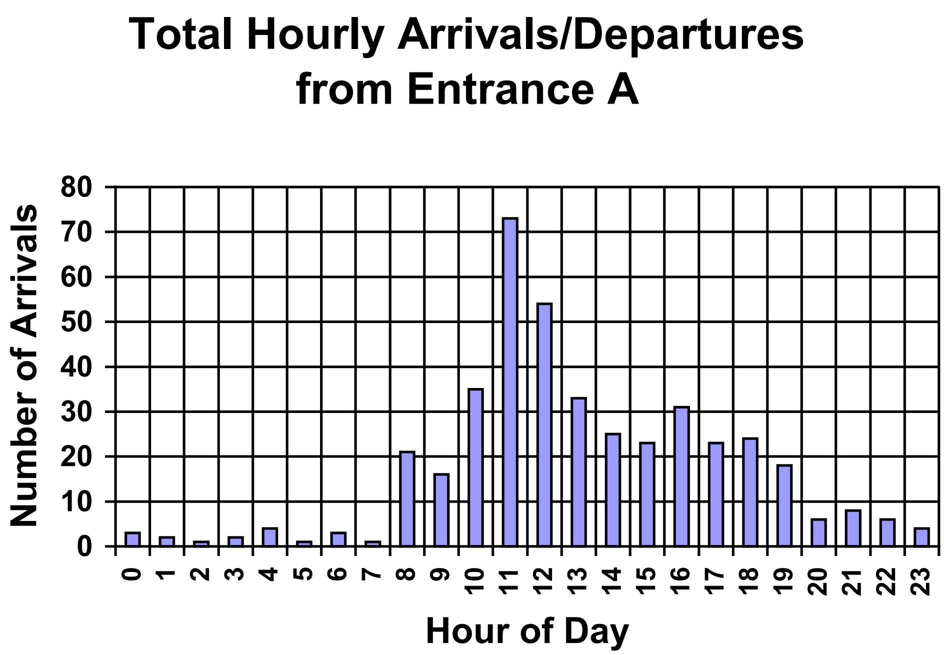

Figure 5 – Total Hourly Arrivals/Departure from Entrance A

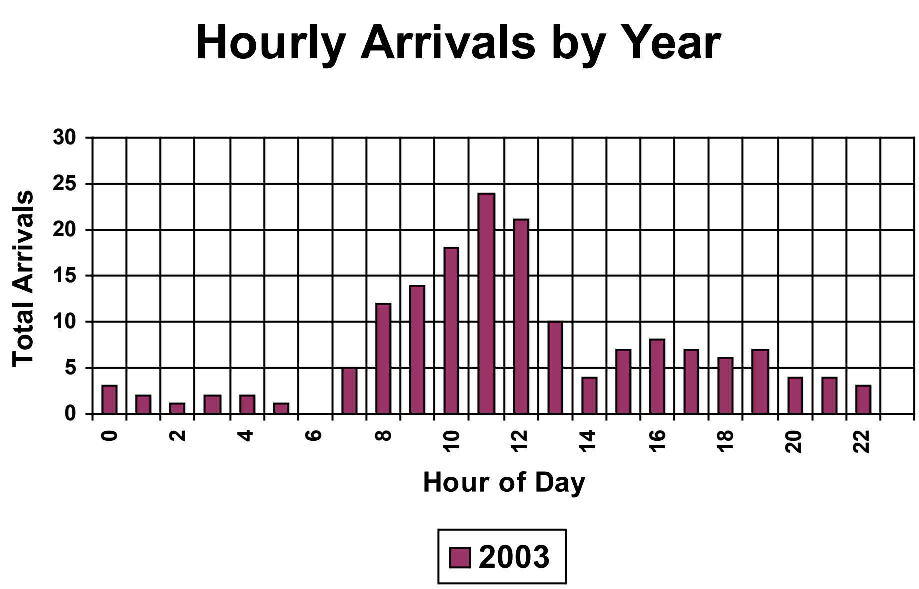

Figure 6– Total Hourly Arrivals/Departure from Entrance by Hour of the Day through out part of the year.

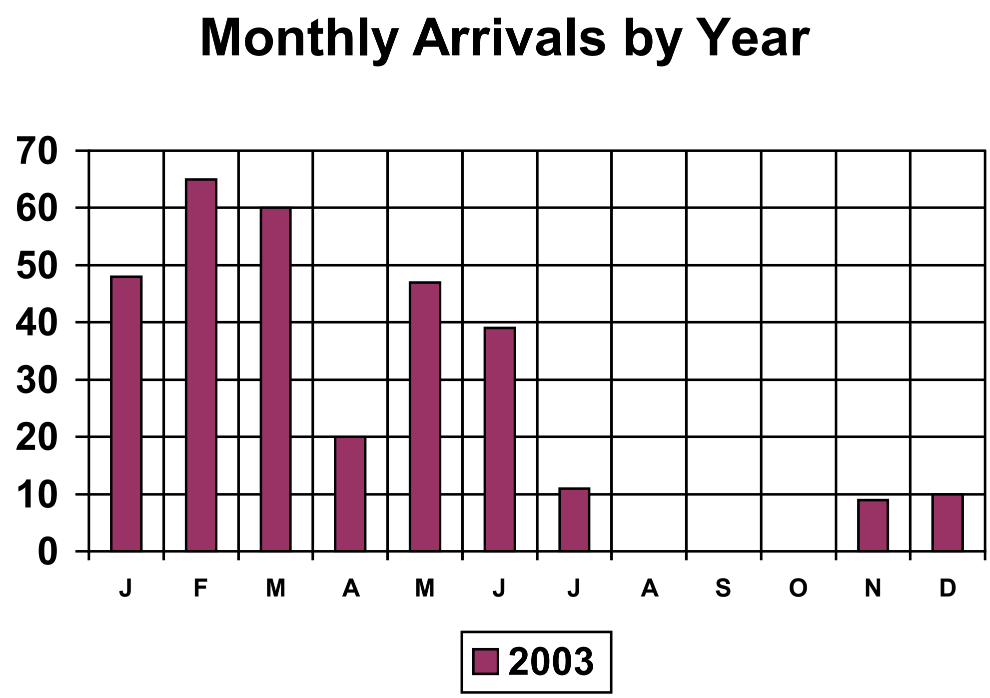

Figure 7 – Monthly Arrivals/Departure from Entrance A throughout the Year

Figure 5 reveals a very consistent pattern of arrivals starting at 8:00am and continuing through into the evening hours. Figure 6 illustrates the peak periods during the day coincide with the cooler winter times when more activity in SCRCA would be apparent. Figure 7 illustrates the busiest months of the year when you would expect to see consistent activity in the conservation area. As with most desert setting, visitation drops off during the summer months and begins to increase in late fall

Monitoring Site E

Figures 8, 9 &10 provide an analysis of the interior monitoring Site E. This site is an extremely popular site as the trail leads from the Entrance A to the northern section of SCRCA. This will be a popular trail and destination as evidenced by the number of visitors entering and exiting this site. Figure 8 clearly shows the same consistent daily patterns of use with visitors arriving early in the morning and departing prior to it getting dark. Figures 9 and 10 illustrate the daily patterns of use by typical week and throughout the year. Again, as would be expected, Saturday and Sundays (weekend) use patterns are much higher than throughout the week. Figure 10 reveals some interesting patterns of use throughout the year. As would be expected the late fall and winter months reveals peaks in use. In addition, there is an increase in summer use occurring. If an analysis was done specifically of the summer months to examine total hourly arrivals, much of this use could be accounted for by evening travel to avoid the summer heat.

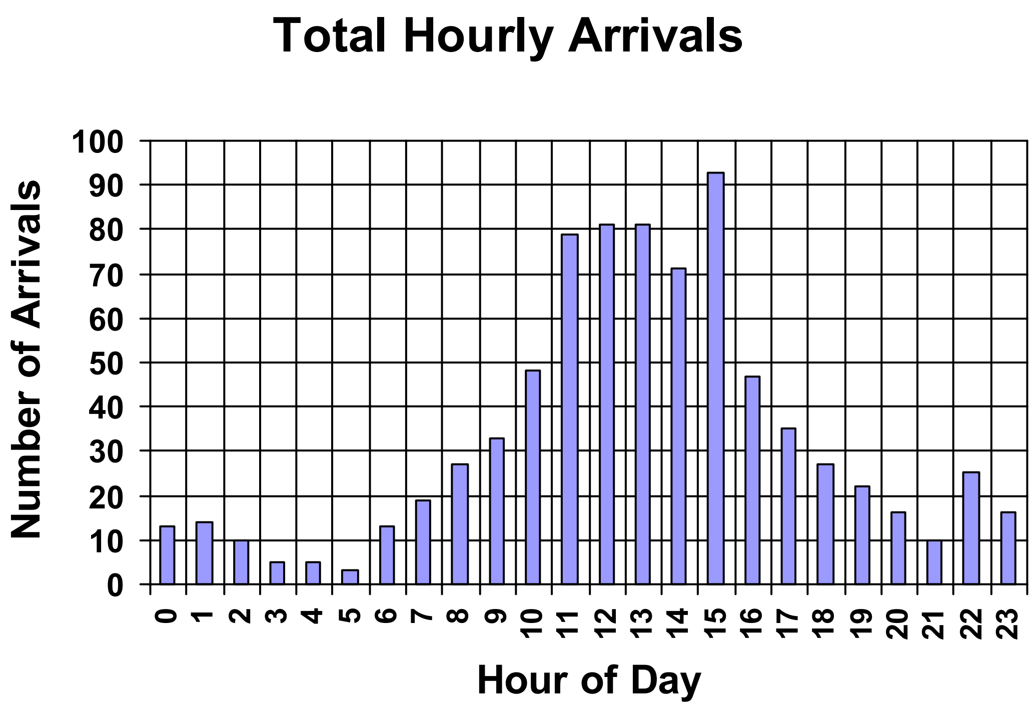

Figure 8 - Total Hourly Arrivals/Departure at Site E

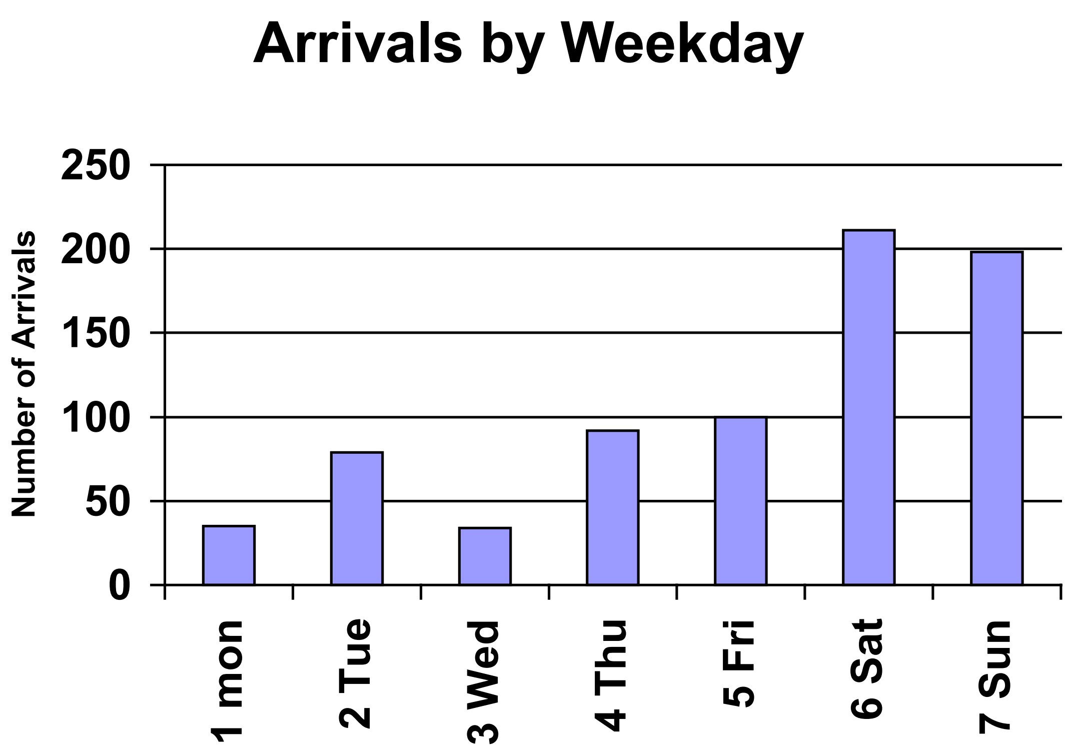

Figure 9 – Monthly Arrivals/Departure from Site E throughout the Year

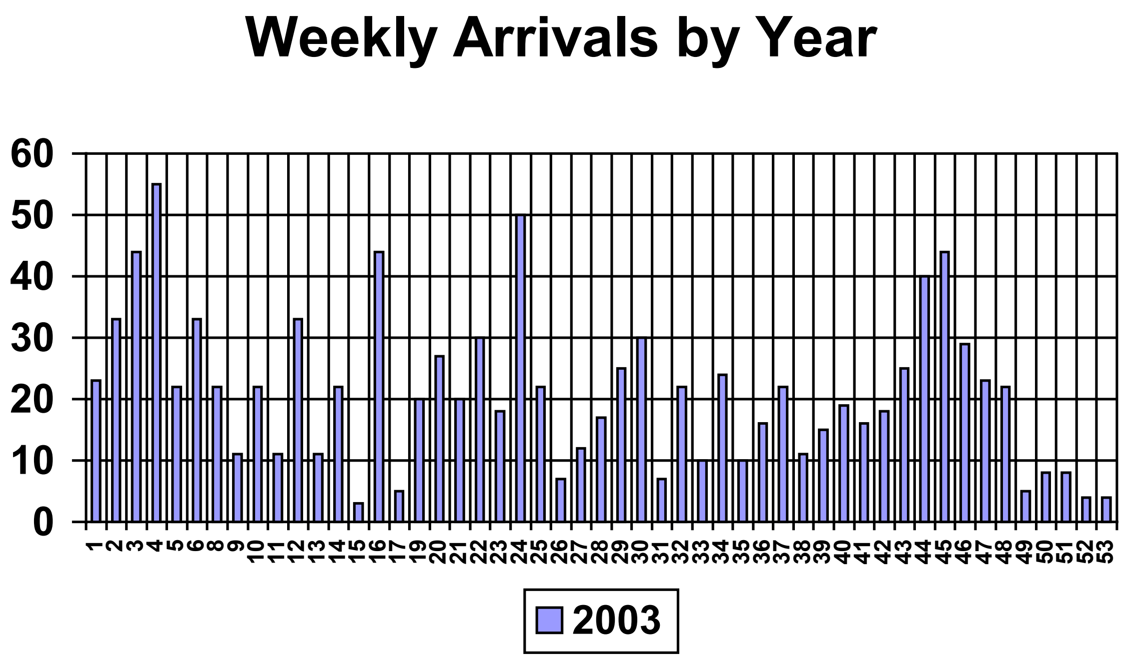

Figure 10 – Weekly Arrivals/Departure from Site E throughout the Year

Monitoring Site - Maricopa County Trail (Trail head 1)
Figures 11, 12 & 13 are an assessment of the visitor use trends entering the Maricopa County section of trail from Trail Head 1. Of the three areas monitored in the simulation this site has the potential to receive a high percentage of visitor use in the upcoming years. Figure 11 clearly shows what has been seen in the other analysis and that is a consistent pattern of daily use with expected arrivals and departures between 7:00am and 7:00pm. Figure 12 again confirms that the high use times will be weekends reaching the peak sometime during the day on Saturday. These numbers are averaged out for the entire year. Figure 13 illustrates the weekly patterns of use throughout the year. Again, no surprising that the winter months are peak times for visitors to be enjoying SCRCA.

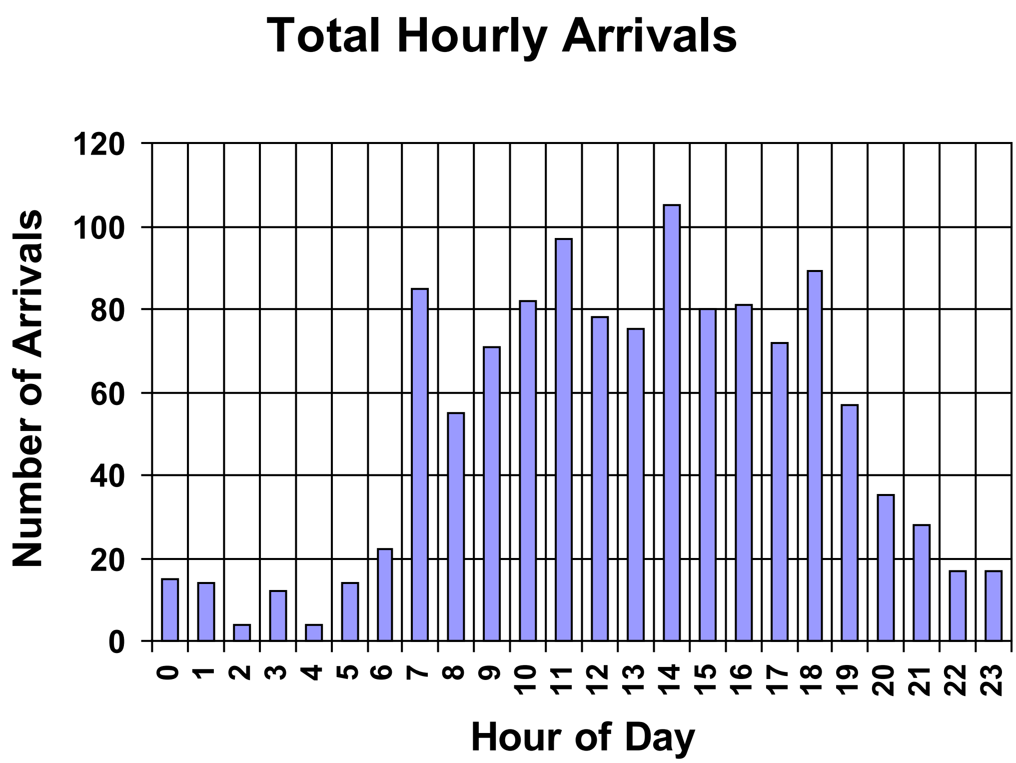

Figure 11 - Total Hourly Arrivals/Departure at Trail Head 1 on Maricopa Trail

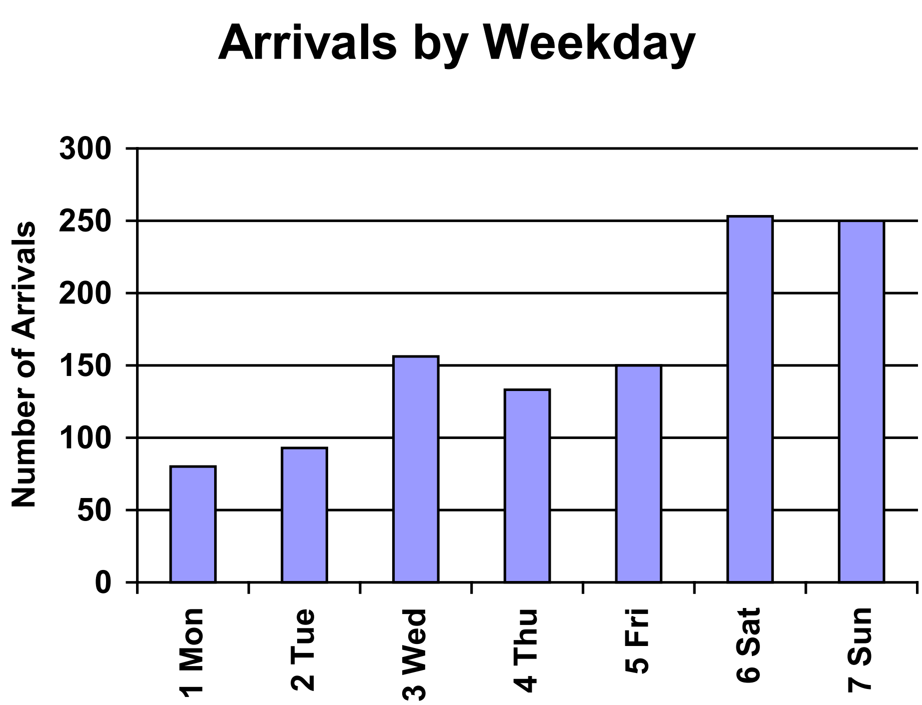

Figure 12 - Monthly Arrivals/Departure at Trail Head 1 on Maricopa Trail

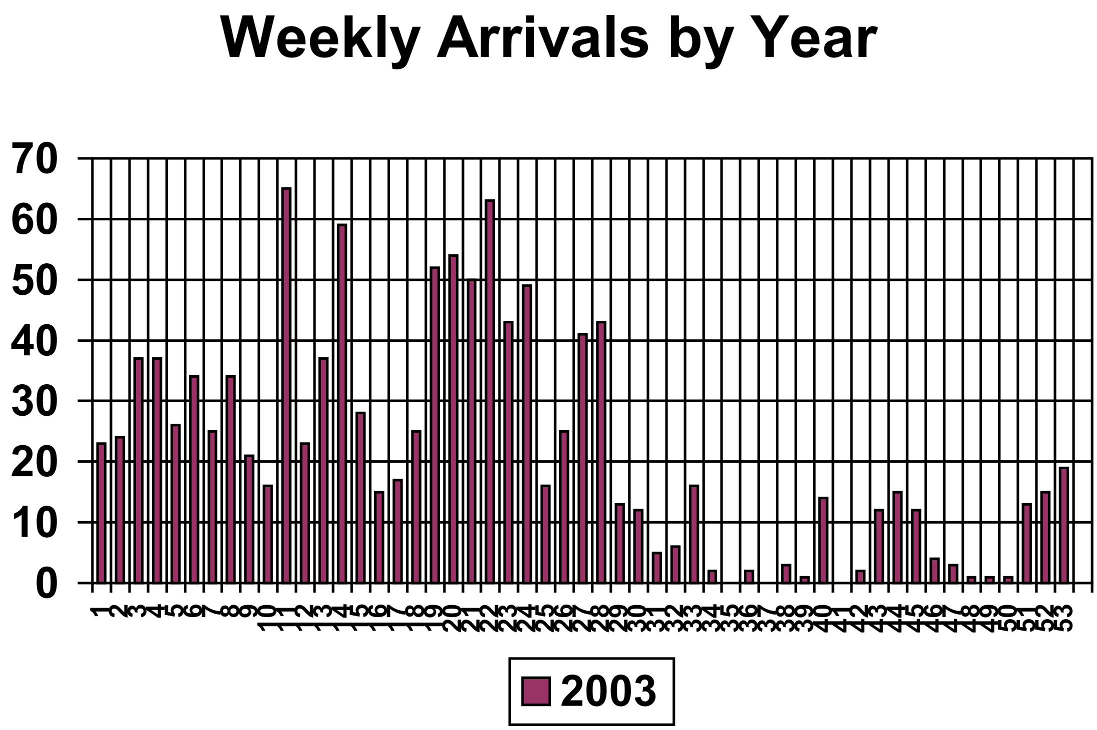

Figure 13 - Weekly Arrivals/Departure at Trail Head 1 on Maricopa Trail

Encounter Assessment on Trails Approaching and at Site E
The analysis above provides an assessment of general trends in visitation patterns throughout the day, week and by year, the following analysis reveals who the visitors are and how they are distributed across the months and by day.

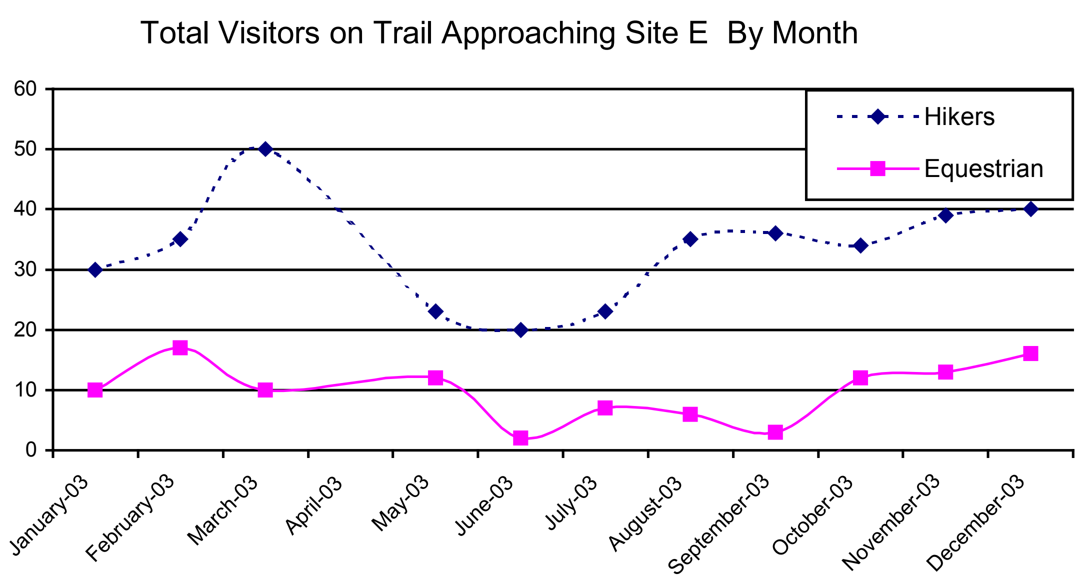

Figure 14 – Total Number of Visitors on Trail Segment Approaching Site E by Month

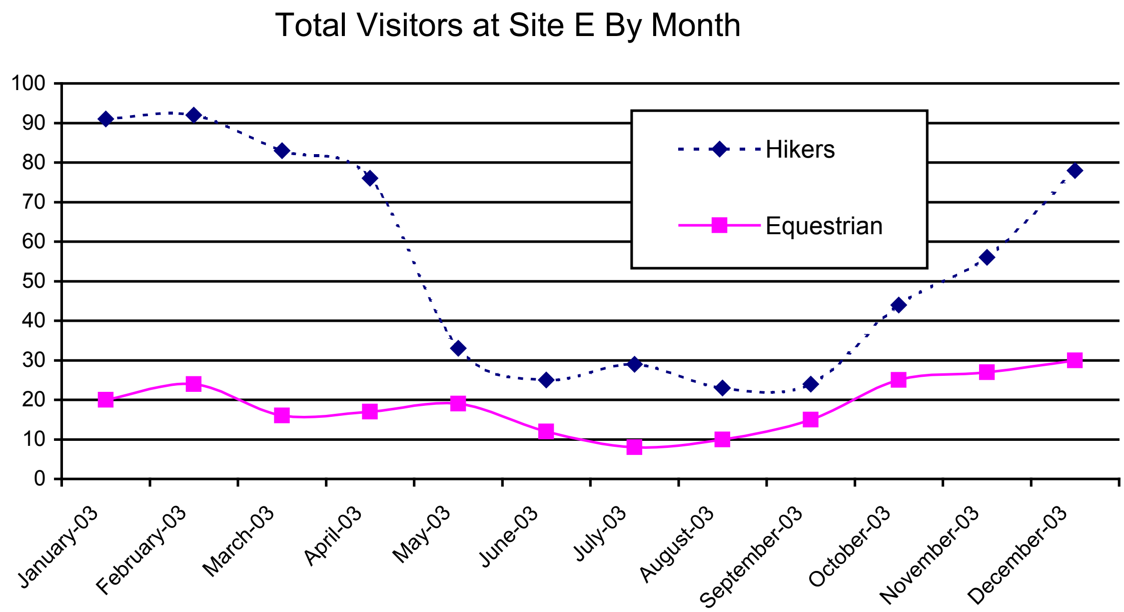

Figure 15 – Total Number of Visitors at Site E by Month

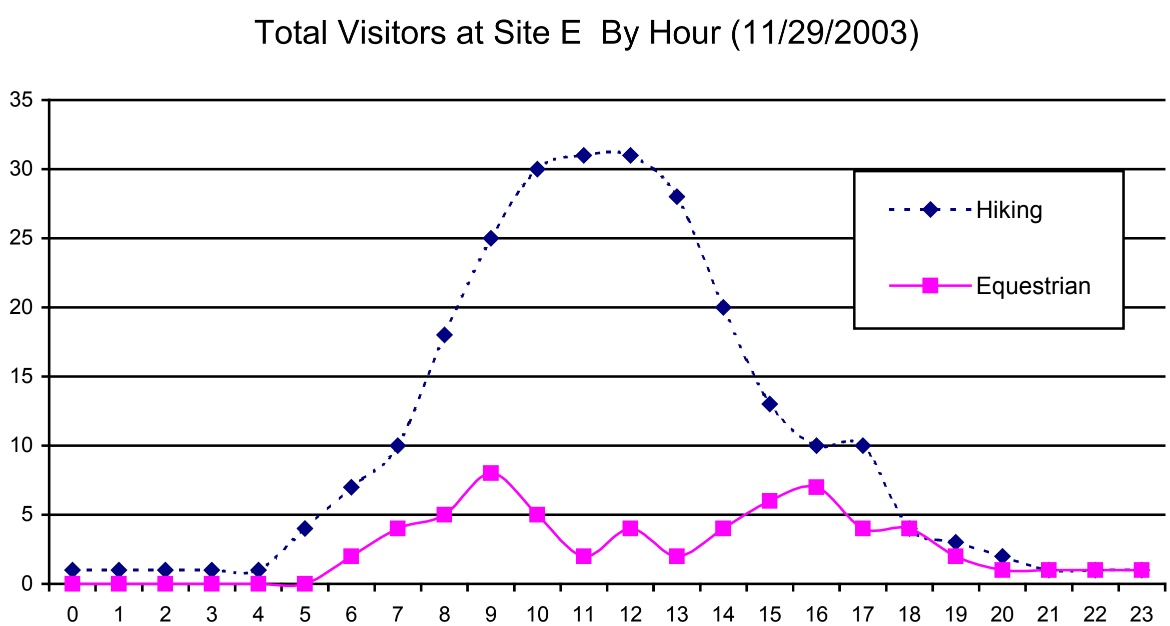

Figure 16– Total Number of Visitors at Site E by Hour

Figures 14, 15 & 16 reveal an interesting pattern of visitor encounters at Site E. An encounter is defined as one visitor passing through either the trail segment or site being monitored. If the agent in the simulation is within 100 feet of the monitoring agent, it is recorded. Figure 14 illustrates the number of encounters on the trail between visitor groups approaching Site E. Peak hiker visitation occurs around March and again tapers off by summer. Over n=50 encounters can be observed among hikers and less than ten equestrian riders during March. If there were excessive amounts of equestrian use at the same time as hikers than this might suggest a potential conflict between visitors. But staged out over the month, this probably is not a concern. But this analysis can clearly illustrate where potential bottlenecks or conflicts could occur given a set of conditions. Figure 15 illustrates the distribution of visitor use (hikers and equestrian) over the season at Site E. It is clear that the majority of the hiking use at Site E can be accounted for from January through April. Equestrian use, revealing a much lower volume is fairly consistent throughout the year as they travel through Site E. Figure 16 illustrates a daily representation of hiking and equestrian use in SCRCA. Again, peak times are as expected during the 7am – 7:00pm time period. There is only one observed time period around 6:00pm when equestrian and hikers are actually at Site E at the same time. While this might suggest a conflict between visitors, it looks like so few that it probably is not a concern. But this brings up one of the reasons for doing simulation. As real inventory and monitoring data are collected in SCRCA that analysis can clearly reveal at what times there are a high degree of interactions between recreation users, using the same destinations.

Discussion

An examination of the results of the simulation outputs for all the areas monitoring reveals relatively low levels of use. Recreation use is dispersed evenly across the landscape. But without real data about visitor use levels it is hard to say anything significant about visitor encounters or impacts. However based on the levels of use being simulated, there is potential for a number of encounter interactions between recreation groups to occur. What is required however is to have more accurate data about visitation through inventory and monitoring and to carefully examine the critical sites or destinations that would be anticipated to be visited frequently and monitor use at those sites as well. Both sets of data would provide a much more through and substantive set of quantitative information for examining visitor use levels and those associate social and environmental impacts.

Validation Study of the Simulation

The validity of the simulation outputs can only be determined by how accurately they replicate the current use patterns. In other words, a measure of how good the simulation outputs are is directly related to how well it replicates the pattern of the data that are used to develop the simulations. While the simulation currently replicates accurately the typical trips outlined in Table 1, further field studies will have to be undertaken to calibrate and validate the model. Along with this model validation would be to include other recreation groups not currently involved in the study, more local or public input on the their knowledge of the area and more refinement on the trips already in the database.

Scenario Development

Now that the simulation tool has been constructed and accurately mimics the anticipated use levels, aside from future inventory and monitoring of visitor use a number of realistic scenarios or alternatives need to be careful crafted and tested with local stakeholders. These scenarios should examine and outline appropriate visitor use levels, commercial and non-commercial use levels for all the destinations in SCRCA. It would be very easy to plug in jeep tours or any other commercial activity that might be desirable and evaluate their impacts. How much visitor use is too much, is a question that needs to be examined. What are alternative destinations of similar quality to those currently receiving significant levels of us, but where use could be dispersed. Adversely what would be the consequences of increasing use levels in existing high use areas. Then management objectives or guidelines can be constructed for these areas centered on these types of recreation and volume of use over typical seasons.

Long Term Monitoring in SCRCA

A long-term monitoring program needs to be developed to collect data that can be used for model calibration and verification. Since this model will be built on visitor use levels projected from expert judgment, this is by no means enough data to adequately simulate visitor use patterns. Many years worth of data should be considered essential for having a more accurate, reliable and defensible model. While the data for the 2003 could be considered a benchmark in terms of organizing visitation data, a long term monitoring program needs to be established to systematically collect data on visitor use patterns. One outcome of this project will be to identify where long-term monitoring sampling could be established and protocols for organizing data that could feed directly into the simulation environment. Change detection is an important component of any monitoring program and RBSim could identify where and how much change is occurring in various locations. A combination of automated counter pads, observation and travel dairies would provide a more comprehensive view of visitor flow patterns in SCRCA.

Monitoring Using Counter Pad Technology

There are a number of technological advancements that are being developed at the time of the writing of this document that provide mechanical ways to count visitors. A number of those technologies have been explored in a variety of research projects. But the STIL Trail Counter Pad /Data logger is an exceptional choice in areas where there is sparse land cover. The Trail Counter Pad is a robust, sensitive, person or vehicle counting system designed for long term, maintenance free operation in rural and park environments. It is a fully sealed system (IP67), maintenance free and made of strong durable materials. Only a minimal deflection of the Counter pad is required to advance the counter. A battery life in excess of 10 years and the full sealing allows this logger and counter system to be completely buried. This subsurface installation makes the unit undetectable and therefore immune to vandalism, environmental damage, and mischievously enhanced counts. It is typically buried beneath 150mm of soil.

Some of the Exceptional Features of the Pads are:

- Detects, verifies and records Counter pad deflections
- Proprietary mechano-acoustic sensing technology

- Can be used to count people or vehicles; thin enough to fit under a doormat
- Records about 160,000 time linked events before overwriting the oldest stored information. (Larger capacity available on request)
- Single pad, double pad (for wide tracks) or directional mode (two pads)
- LCD Displays total, and two directional totals (directional mode only)
- Data may be downloaded repeatedly without deleting the data loggers memory
- Data can be exported as CSV, Excel or ASCII formats
- Data can be downloaded on site by a laptop computer with infrared capability
- Available with output to trigger camera etc
- Data integrity checking
- Environmentally sealed system (IP67)
- 10 year Battery life

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In a number of research projects currently underway at the University of Arizona, the counter pad technology is being explored. Placement and depth of pad are critically important to capturing accurate data. Pads need to be placed where the width of the trails matches the size of the pad or are narrow either where it is possible to funnel visitors. This is important to ensure that each visitor in a party actually steps on the pad and triggers the receiver. If the pad is buried too deep and/or the soil is too compacted around the pad, it will not work properly making it subject to inaccurate counting. For more information on pad placement please contact the author of this report.

In addition, Scott Technical has entered into a research and development arrangement with the University of Arizona to continue to develop the technology for monitoring visitors or pedestrian traffic. They are currently exploring options to differentiate between recreation user types using some new sensor technology. This is very promising for the understanding not just how many visitors enter into an area but who they are. At the present the only way to differentiate is via travel diaries and observation.

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More information on the RBSim approach can be obtained at the following URL:

http://www.srnr.arizona.edu/~gimblett/RBSimBibliography.htm