Analyzing Front Country Social Trails Data from Lava Beds National Monument

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Executive Summary

Social Trails are informal trails that people create by walking in natural areas not designated for travel and have been identified through previous studies as threats to our natural environment (Leung, Marion &Nepal, 2006). Preliminary assessments at Lava Beds National Monument in Northern California have indicated the need to assess and map social trails in order to evaluate trail impacts on the monument's unique cultural and geological resources. In 2011, a research project was conducted to map all social trails in eight visitor use areas at Lava Beds National Monument and assess the resource damages of those social trails. Attribute data on soil type, soil compaction, general trail condition, primary resource wear, root exposure, visibility, vegetation condition, trail length, trail width, destination, and visitor count was collected using Arcpad software and a GPS unit on all trail segments in order to determine the condition class of each social trail. The density of social trails and severity of resource damage was mapped using ArcGIS software and compared to historic aerial photographs in order to determine the age and original source of the trails. The study found that there are 641 social trails in the eight visitor areas surveyed, totaling over 13 km of trails. The Cave Loop area had the greatest number of trails (214), the Fleener Chimney area had the highest density of trails (2.3% cover), and the Three Sisters trail and campground area had the greatest total trail distance (2, 292 m). Aerial photographs showed the presence of social trails in the Black Crater and Fleener Chimney areas since 1944. The data from this study will be used to develop Lava Beds National Monument's first Trail Management Plan.

Keywords: social trails, national parks, Lava Beds National Monument, aerial photographs

Analyzing Front Country Social Trails Data from Lava Beds National Monument

Social trails are informal trails that people create by walking in natural areas not designated for travel. These trails are a threat to vegetation, soils, habitats, and other natural resources (Marion, Leung, & Nepal, 2006). In addition to being a threat to natural resources, social trails can also be aesthetically displeasing. Performing an assessment of social trails can help determine why a trail might have been created in the first place, and then in turn can aid in the development of a management plan to either adopt a trail as a formally designated trail or rehabilitate and deny access to the social trail. At Lava Beds National Monument (LABE) in Northern California (see Figure 1), social trails were associated with degradation of resources near lava tube entrances and with the trampling of important native plant species.

In 2011, a study was conducted to map social trails and document impact levels in eight problem areas of the monument (see Figure 2) using Garmin and Trimble GPS units as well as ArcGIS software. Attribute data was collected on each trail segment, and based on the attribute data, condition assessments were performed. The data showed that the Cave Loop area had the highest number of trails (214), while Fleener Chimneys had the highest density of social trails (2.3% cover). Three Sisters trail and campground had the highest total distance of trails at 2,292 meter. Aerial photographs showed that social trails on Black Crater and in Fleener Chimneys had been there since at least 1944. Based on the condition assessments, it was determined that Fleener Chimneys, Black Crater, and Captain Jack's Stronghold are top priority areas for trail rehabilitation. The results of the study will be used to create a trail management plan for Lava Beds National Monument.

Lava Beds National Monument is located in Northeastern California, around 50 miles south of Klamath Falls, Oregon, and covers over 46,000 acres of both Modoc and Siskiyou Counties. The greatest part of the monument is covered by the Medicine Lake shield volcano. The monument has over 700 documented caves and possesses a wealth of geological features. The monument was also the site of the Modoc War in 1872-1873, one of the costliest of the nineteenth century Indian wars (Lava Beds National Monument [LABE] History, n.d.). Lava Beds National Monument welcomes more than 110,000 visitors every year who are primarily there to experience the caves and other volcanic features of the monument (LABE History, n.d.). Established access routes to caves and geologic sights are in poor condition or misleading which results in social trails from parking areas, roads, and other access areas. These social trails are a threat to resources such as vegetation, soil, and wildlife habitat, and are also a threat to geological and cultural features.

From lava flows to caves and cinder cones, LABE is home to a variety of sensitive natural resources. Geologic features are made of igneous rock from volcanic eruptions that occurred hundreds to thousands of years ago. These features are fragile and can be permanently damaged by foot traffic or even the gentle brush of a shoulder on the side of a cave. The degree of damage from social trails depends on the sensitivity of the resource; therefore social trails are a major threat in areas such as LABE (Neusome, Moore, & Dowling, 2002). The damage, as shown in Figure 3 at Black Crater in 2010, is irreversible considering that the only way to create this geologic resources is with a new volcanic eruption (National Park Service, 2010).

Other sensitive natural resources at the monument that are affected by visitor use are native plants and wildlife. Many sagebrush plants in the monument have taken up to 80 years to

grow to their current size. Wildfires in the monument have swept some areas, such as Captain Jack's Stronghold, clear of old sagebrush plants. New sagebrush seedlings are growing; however, these tiny plants can be easily trampled, making it hard for native plant re-growth, and easy for invasive plant growth. Some of these plants are also home to certain wildlife species, so destruction of native plants can also mean destruction of wildlife habitat. The use of archival aerial photos to determine the age of social trails can help determine if the vegetation and habitat damage worsens over time and can also help in determining a time frame for rehabilitation (Potito & Beatty, 2005).

Several social trail and visitor capacity studies have produced data showing that social trails are a critical natural resource problem in national parks and public lands. Assessment of trail conditions in Great Smoky Mountains National Park, for example, used trail condition attribute data to analyze resource impacts of trail use and then used the information to develop a trail management plan for the park (Leung & Marion, 1999). Similar research projects in Denali National Park, Great Smoky Mountains National Park, and Boston Harbor Islands have demonstrated impacts of social trails such as trampling on soils and vegetation; the need for use of GIS in analyzing resource based indicators for social trails; and use of GIS for examining resource damages and general trail condition. In Denali National Park, a social trails assessment was originally performed in 1987 and trails were mapped using military grade GPS units. Another social trails assessment was performed in 1998 and all trails were still visible (Rochefort & Swinney, 2000). This suggests that rehabilitation of social trails could take many years and a social trails assessment is necessary for rehabilitation efforts.

Using a Geographic Information System to manage data collected in social trails assessments is crucial to developing a management plan in both a timely and cost efficient manner. GIS is a collaboration of hardware, software, and data for obtaining, managing, analyzing, and reporting all geographic information (Environmental Systems Research Institute, 2011). Developing a data dictionary that includes attributes for social trail width, length, soil compaction, and visitor use is essential to collecting high quality data (Leung, Shaw, Johnson, & Duhaime, 2002). By using GIS to manage the data collected, social trails can easily be categorized by attribute. Mapping the assessed areas using GIS makes data reporting and analysis more efficient (Leung & Marion, 1999).

Choosing proper assessment techniques is important for any successful field project. In previous social trail assessments on public land, there have been two main assessment techniques: sampling-based method and census-based method (Marion, Leung, and Nepal, 2006). The appropriate approach to collecting data mainly depends on time, money, and the information desired (Marion, Leung, & Nepal, 2006). Census-based data collection involves collecting as much attribute information as possible on each trail visited. A sampling-based method simply involves an inventory of trails. The sampling-based method is used when time and money are limited (Marion, Leung, & Nepal, 2006). For the purposes of the LABE project, the census-based method rather than sampling-based method was used to fully assess the condition of social trails and to evaluate resource impacts in eight resource use areas.

The eight survey units associated with this project (Captain Jack's Stronghold, Big Painted - Lyons Road Trail, Campground - Three Sisters Trail, Cave Loop, Fleener Chimneys, Boulevard-Balcony Trailhead, Gillem's Camp, and Black Crater) encompass the most significant

resources of the monument and are the most popular visitor areas (see Figure 2). While LABE has established trails providing access to resources or vistas of these resources, visitor enthusiasm has led to the creation of vast networks of social trails that alter access to and between significant resources. Some of the damage from these social trails is permanent; other damage, however, is still repairable, but continued disregard for social trail management may lead to additional irreversible damage. LABE needs detailed documentation and analysis of social trails to develop management strategies and to mitigate impacts associated with social trails. Inaction will allow significant resource impacts to continue to degrade LABE's most critical resources.

Methods

The methods of data collection and analysis of this project were determined in collaboration with Jason Mateljak, Information Technology and GIS Specialist, LABE; David Larson, Chief of Resource Management, LABE; Ryan Janway, Biological Science Technician, LABE; and Leslie Veal, Senior Environmental Sciences student at The Oregon Institute of Technology in Klamath Falls, OR. Many of the methods used in this project were previously used in similar projects in areas such as Great Smoky Mountains National Park, Denali National Park, and Boston Harbour Islands National Park.

Before field studies were conducted, safety procedures were established to ensure safety of field technicians. A radio, provided by LABE, was carried in the field at all times. Monument personnel were notified of field collection times and when to expect field workers back at headquarters. Dressing appropriately for weather conditions was a must. The weather in

Northern California is unpredictable in the spring months and the only month with no recorded snowfall at LABE is August. Wearing layers was the best way to dress for the area's climate as it was freezing in the mornings and evenings and quite warm during the daytime. Steel toe hiking boots were worn to avoid injuries from the lava rock terrain. An adequate water supply was always carried. National Park Service tailgate safety data sessions were also performed daily for reminders on wildlife safety, weather safety, and first aid. These safety data sheets are available at LABE.

Materials used for the project included: Trimble® GeoXT handheld GPS, ArcGIS® software, archive aerial photos of Lava Beds National Monument, high resolution scanner, and digital camera. Proper use of the Trimble GPS unit, ArcGIS and Arcpad is detailed in instruction manuals and tutorials. The Trimble unit belongs to LABE, therefore, the instruction manual also resides at LABE. Instructions on ArcGis and ArcPad are located in the tutorial sections of the disk for each, and further instruction can be found in textbooks.

The study began by surveying all eight visitation area. For each area, social trails were mapped using a Trimble GPS unit to collect a combination of point data, track logs, and polygons. Social trails were identified by walking the Monument's established trail systems and by identifying informal offshoot trails. Cave entrances and significant geologic and cultural features were also assessed for social trail presence. A trail GIS layer was used to collect attribute data on the actual trail segments, including soil type, soil compaction, general trail condition, primary resource wear, root exposure, visibility, vegetation condition, trail length, trail width, destination, date, collected by, visitor count, and notes (see attribute data collected in Appendix A). Using Arcpad 8.0, all attribute data was collected using the Trimble unit and then

uploaded at the end of every field collection to ArcGIS. In addition to this layer, polygons and points layers were also created. The polygons layer was used at areas where there was a wide area of soil compaction or resource degradation at the end of a social trail surrounding a cave or other feature, for example. The points layer was used when marking significant features along the trail and when track logging was not the desirable method of collection. All field work was tracked using data collection sheets (see Appendix B).

Using the attribute data and specified criteria, an assessment of each social trail's condition was determined. Condition assessment used a four-point condition-class system based on Leung et al, 2002 and Marion et al, 2006. The four general condition classes of a social trail segments include: lightly developed, moderately developed, highly developed, and severely developed/impacting. Once GPS and field sheet data was downloaded and processed, the data analysis was performed. The sum of social trail lengths per survey unit, per significant resource type, and for all units combined was reported as well as the density per survey unit, number of offshoot points, proximity to sensitive resources, and likelihood of visitor use. All attribute information collected was also reported per condition class assigned. Additionally, the location and size of current social trails was compared to historic aerial photographs. Aerial photographs were obtained the USDA Forest Service, Modoc National Forest and LABE aerial photograph archives. Analysis of both historic and current damage to vegetation, soil, and landmarks helped determine the impact level of the social trail.

There were some problems encountered during the data collection phase of the project. On more than one occasion, the GPS unit had trouble connecting to satellites. Repairs to the unit had to be made by LABE personnel before further data collection could be performed. Aerial

photos were scanned at OIT, but then later had to be rescanned at LABE to achieve a higher resolution. All aerial photos were stored on the R drive at LABE and also on an external hard drive purchased for the project. The external hard drive crashed and the geo-rectified photos that were not saved on other media were lost. These photos had to be reprocessed in order to conduct data analysis. Additional aerial photos and GIS maps and data are filed in the R drive at LABE under "LABE_base data/aerial/aerial_old."

Results

Summary Statistics

After all eight visitation areas were surveyed and all social trails were mapped, statistical analysis was performed. The total number of social trails were counted as well as the sum of all social trails lengths and density calculated per visitation area and for all areas combined. The total length of social trails per survey unit, in proximity of known sensitive resources was calculated along with the sum of social trail length and density according to each condition class. The likelihood of visitor use was calculated based on social trail characteristics and researcher knowledge of the resources. Analysis of aerial photos was also used to determine the age of social trails and the change in condition over time.

Tables 1 through 4 show summary statistics for the eight survey units within LABE. Table 1 shows a total of 641 social trails mapped within the eight survey units at LABE, equaling 13 km of informal trails. The shortest distance covered by a social trail was .12 meters (Gillem's Camp), while the maximum distance was 304 meters (Black Crater). Table 2 shows the area of social trails by width categories. The most notable category, a width of 1-2 ft., had a trails area

of 4,425m^2. In comparison, the next largest category is trails with less than a 1 ft. width, with an area of only 571 m^2. The total area covered by social trails was found to be 5,613 m^2. The density of social trails within the 509 acres of survey area was .27% coverage. Table 3 shows that the total length of social trails within the severely developed condition class was 32.49 meters. This is the smallest distance of all the categories. On the other hand, the lightly developed condition class contained the greatest total distance with 7,319 meters of social trails.

Table 4 shows summary statistics for all eight survey units and Figure 4 shows a GIS map of each visitation area that includes all mapped social trails and their condition classes. Figure 2 shows each of the survey units in relationship to park boundaries and other features. Each survey unit was analyzed individually in order to assess trail impact on the resources in that particular area. Appendix C contains GIS maps imposed on 2009 aerial photographs showing condition classes for all the social trails for each area.

Big Painted to Captain Jack's Ice Caves.

There were a total of 75 social trails mapped within this survey unit with a total length of 1,640 meters. The total area covered by social trails within this survey unit was 869 m^2, leading to .19% cover. Most social trails within this survey unit were found to have a destination of a cave or geological feature. The area, however, is not as well-traveled in comparison to other parts of the Monument, and therefore, shows slightly less impacts due to social trails. The impact that does exist is focused mostly on vegetation, rather than geologic or cultural resources.

Black Crater.

Black Crater survey unit had a total of 24 social trails with a total length of 1045 meters. This survey unit had a high number of social trails with lava rock as the surface of the social trail and the greatest impacts of the trails are on the non-recoverable geological resource. This area had the smallest average social trail width, at .35 m, which may have contributed to the small calculated density of social trails within this survey unit, which was only .15% cover. Because of Black Crater's proximity to the main road through the Monument, it receives a fair amount of visitor use in comparison with other areas.

Boulevard/Balcony Caves.

This was the smallest survey unit, covering only 5 acres of the monument. There were a total of 26 trails mapped within the survey unit. The total distance of social trails was 574 meters. This area had 1.4% coverage, being the second highest density of social trails per survey unit. Visitor use at Boulevard and Balcony Caves is moderate. Although the caves are close to the main road, there are only a few caves there and there is a well-established and well-used access trail that minimizes the need for social trails. Social trail impacts are mainly on vegetation.

Cave Loop.

This survey unit (see photograph, Figure 5) had a total of 214 mapped social trails, by far the highest number of trails mapped per survey unit. This is not surprising, since Cave Loop has a high concentration of easily accessible caves, it is a heavily visited area in the Monument and the social trails have significant likelihood of visitor use. However, the survey unit had the

lowest calculated density, .09% cover, of all the survey units; the low density calculation is probably due to this area having the largest survey unit. The impacts of social trails on the survey unit include damage to caves entrances and vegetation. There is also an aesthetic impact from such a high number of trails in this area.

Fleener Chimneys.

While this survey unit only covers a total of 8 acres, Fleener Chimneys (see photograph, Figure 6) had a calculated density of 2.3%, the highest density of all eight survey units. There were a total of 102 social trails mapped within the survey unit with a total length of 1,264 meters. Similar to the Black Crater survey unit, Fleener Chimneys social trails occur mostly on non-renewable resources, such as lava rock and lava chimney formations. The high density of social trails reflects the high visitor use in this area; the unique and easily accessible geologic formations are an obvious draw for visitors.

Gillem's Camp.

This survey unit (see photograph, Figure 7) had only four social trails mapped, the lowest social trail count of all eight survey units. The four trails mapped added up to a total of 167 meters of trail. Although previous uses of this area included a US military camp during the Modoc Indian War as well as a previous visitor center site (removed in the 1960's), the only remaining use of the area is for a visitor bathroom and trailhead for Gillem's Bluff Trail. The likelihood of visitor use in this area is low. Existing social trails are on pumice soils where impact is concentrated on vegetation, aerial photographs show some trail revegetation. Some

trails shown in aerial photographs from 1944 are no longer visible in 2005, demonstrating the resilience of pumice substrates and capability for long-term self-restoration.

Captain Jack's Stronghold.

This survey unit had the second highest total distance of social trails of all eight survey areas, totaling 2,100 meters. Although most trails within this survey unit have pumice surfaces, these trails are in close proximity to cultural and historic resources. Likelihood of visitor use on these social trails is high because this is the main location of the Modoc Indian War in 1872-1873. Artifacts from the war can be found in the area, enticing visitor exploration. Additionally, this area is of cultural significance to local native American tribes in the region. Impacts of the social trails in this area include destruction of valuable historic sites and collection of artifacts, in addition to impacts on the geologic features.

Three Sisters Trail/ Campground.

This survey unit (see photograph, Figure 8) had a total distance of 2,292 meters of social trails, making it the highest total distance of social trails for all eight survey units. The total area covered by social trails within this survey unit was 1,421 m^2, also the highest calculated for all eight survey units. Likelihood of visitor use in the area is high for several reasons. First, the area includes the entire campground, an area of significant and consistent use. Secondly, the trailhead for the Three Sisters Trail is located here as well. None of the social trails in this area are on bare rock or geologic resources. Main impacts are to vegetation resources.

Aerial Photo Analysis

Aerial photos from 1944, 1946, 1967, 1974, 1981, 1995, and 2009 were used to determine the age of social trails in the most sensitive resource areas. Two of the eight pre-determined survey units were chosen for photo analysis based on the condition class of the most degraded 10% of the social trails mapped in the 2011 assessment. Black Crater and Fleener Chimneys aerial photos from the past seven decades were used to determine the recovery rate of social trails and the age of social trails within those survey units.

Black Crater.

Most of the trails found in the Black Crater survey unit are covering the non-renewable geological feature within the area—the crater itself. This makes this area of high concern. All the social trails mapped within the area were present in aerial photographs from 1967, 1974, 1984, and 2009 (see Appendix D, Figures D1-D4). One trail that was previously used as a formal trail prior to a new parking area being established at Black Crater was still visible on the aerial photos, but showed major recovery over time. The lack of recovery of all other trails visible on aerial photos suggests that visitors have been using the same paths for at least the last 60 years.

Fleener Chimneys.

Aerial photos of Fleener Chimneys, like Black Crater, also show the presence of social trails for at least 60 years. These trails have been created on non-renewable resources such as lava and volcanic features, making it a high priority area for rehabilitation or prevention of further degradation. Appendix E, Figures E1-E5, show aerial photos from 1944, 1967, 1974,

1984, and 2005. All photos show a continued presence of social trails within the area; it is interesting to note however, that although social trails have been present for a significant period of time, it does not appear that new trails are being created, nor are present social trails widening or worsening.

Discussion

Based on the results of the study, several priority areas of concern include Fleener Chimneys, Black Crater, and Captain Jack's Stronghold because of social trail proximity to sensitive resources and condition assessment results. Some impacted areas need rehabilitation or treatment; in areas where rehabilitation is not possible, closure or viewing platforms may be the only option for stopping continued resource impact. Although the 2011 study was fairly comprehensive, key data gaps and study limitations should be addressed before continuing with other studies or the creation of a trail management plan.

The proximity to sensitive resources are a major consideration for prioritizing sensitive areas; these resources can be geological features or cultural resources documented in ArcGIS through mapping of the social trails. The areas of close proximity between social trails and resources were Fleener Chimneys, Black Crater, and Captain Jack's Stronghold. Condition assessments in these areas also indicate fairly high densities of social trails. Both Black Crater and Fleener Chimneys have social trails that cover the actual sensitive resource, such as the crater or chimneys. Trails on lava rock are incapable of rehabilitation and should therefore be given priority for action in a management plan. Although the trails within Captain Jack's Stronghold survey unit are in pumice soils which can be rehabilitated, this area is also in high

risk of impact because the trails are in the historical and cultural site itself. Additionally, a large amount of historic artifacts are at risk of being damaged or stolen. Some work has already been done in this area to keep visitors on formal trails. Roping has been placed on both sides of the formal trail for part of the tour and signs are posted informing visitors of the cultural importance of the area and the importance of remaining on the formal trails only. Effectiveness of these measures needs to be evaluated to see if further actions need to be taken in this area.

In general, social trails on pumice type soils like at Gillem's Camp or Three Sisters Trail/Campground can be rehabilitated with a cover of additional pumice, plant litter, and revegetation with native plant species. Another strategy for pumice soil areas would be to discourage visitor use of these social trails. This could be accomplished through signage, visitor education, or barriers to use. Aerial photos show that significant improvements in vegetation and visibility can take place with very little intervention when use of the social trail is decreased (as with the retired trail eliminated from use by the new Black Crater parking area).

On the other hand, trails that are on bare rock surfaces, such as Black Crater and Fleener Chimneys, are virtually impossible to rehabilitate. Because another volcanic eruption would be the only way to replace lava rock and repair damage, these resources are essentially non-renewable. Although rehabilitation is not an option for these areas, further resource damage can be prevented if visitor use ceases. Building viewing platforms and possibly roping off access to these features could help preserve the sensitive resources. Or, some of these trails may demonstrate needed access to key resources and the social trails could be incorporated into the formal trail system. Again, visitor education and signage are also options for preventing further degradation.

One key data gap in this study is an analysis of visitor use in each of the eight areas studied. Some data is collected from cave visitor counters to assess cave visitation and there are also trail registers to keep data on formal trail use, but none of this data provides information on which survey area is the one most used by visitors, and therefore a priority area for treatment.

The ultimate goal of this project was to provide essential information for a trail management plan similar to plans devised for Mammoth Cave National Park, Saguaro National Park, and Cuyahoga Valley National Park. In order for that to take place park managers need to conduct an in-depth analysis of the GIS data collected, prioritize areas and social trails needing treatment, and secure funding sources for rehabilitation, incorporation into the formal trail system, or trail closure. A long term plan, with treatment options can then be implemented over a 10-15 year time period. In addition to the creation of a trails management plan, related studies could be conducted on different treatment or rehabilitation methods. For instance, three trails in one area could receive three different treatments such as layering of additional pumice, additional pumice and revegetation, and no treatment and this could be evaluated over a period of three to five years to assess effectiveness. Finally, only the aerial photographs required for the scope of this study were georectified. An additional project could be completed to georectify the remaining photographs in order to create a complete geodata base of aerial photos for each year for which photos are available.

Finally, through the use of a Trimble GPS and GIS software, the density and total length of all social trails was determined in eight visitation areas of Lava Beds National Monument in Northern California. Based on the condition of the vegetation, primary resources, soil, and the visibility of the trails, condition classes for each trail were established. These condition classes

and map analysis will help LABE determine what course of action, if any, should be taken in each visitation area, and a management plan will be written and implemented for the entire Monument. This 2011 study will support the Monument in fulfilling its purpose as stated in the 2010 LABE Draft General Management Plan and Environmental Assessment, which is "…to protect and interpret volcanic and natural features of scientific interest, and evidence of prehistoric and historic human settlement, use, and conflict" (National Park Service, 2010, p.31).

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Table 1

Summary Statistics from the Analyzing Front Country Social Trails Study at Lava Beds National Monument, 2011.

Total Count	641
Minimum Distance	.12 meters
Maximum Distance	304.22 meters
Sum of all Trails Distance	13336.09 meters
Mean Distance	22.72 meters

Table 2

Total Area and Density per Width Category Data from the Analyzing Front Country Social Trails Study at Lava Beds National Monument, 2011.

<1ft width	**.1524m width**	571.477 m^2
1-2ft width	**.4572m width**	4425.913 m^2
2-3ft width	**.762m width**	435.576 m^2
>3ft width	**1.0668m width**	180.952 m^2
	Total Area	5613.915 m^2
	Total Density	.27% coverage

Table 3

Social Trail Length per Condition Class Data from the Analyzing Front Country Social Trails Study at Lava Beds National Monument, 2011.

Condition Class	Total Length (m)
Severely Developed	32.49
Highly Developed	1844.61
Moderately Developed	4975.36
Lightly Developed	7319.11

Table 4

Density, Distance, and Width Calculations for Social Trails Survey Units for the Analyzing Front Country Social Trails Study at Lava Beds National Monument, 2011.

Survey Unit	Area (Acres)	Social Trail Count	Total Distance (m)	Average Width (m)	Total Area (m^2)	Density per Unit (%cover)
Big Painted to Captain Jack's Ice Caves	112.73	75	1639.97	.53	869.19 m^2	.19
Black Crater	61.60	24	1045.14	.35	365.80 m^2	.15
Boulevard/Balcony Caves	5.00	26	574.26	.48	275.64 m^2	1.4
Cave Loop	152.84	214	1045.14	.54	564.38 m^2	.09
Fleener Chimneys	7.99	102	1263.91	.59	745.71 m^2	2.3
Gillem's Camp	23.39	4	167.08	.61	101.91 m^2	.11
Captain Jack's Stronghold	72.13	94	2099.98	.47	986.99 m^2	.34
Three Sisters Trail/Campground	73.51	116	2292.11	.62	1421.11 m^2	.48

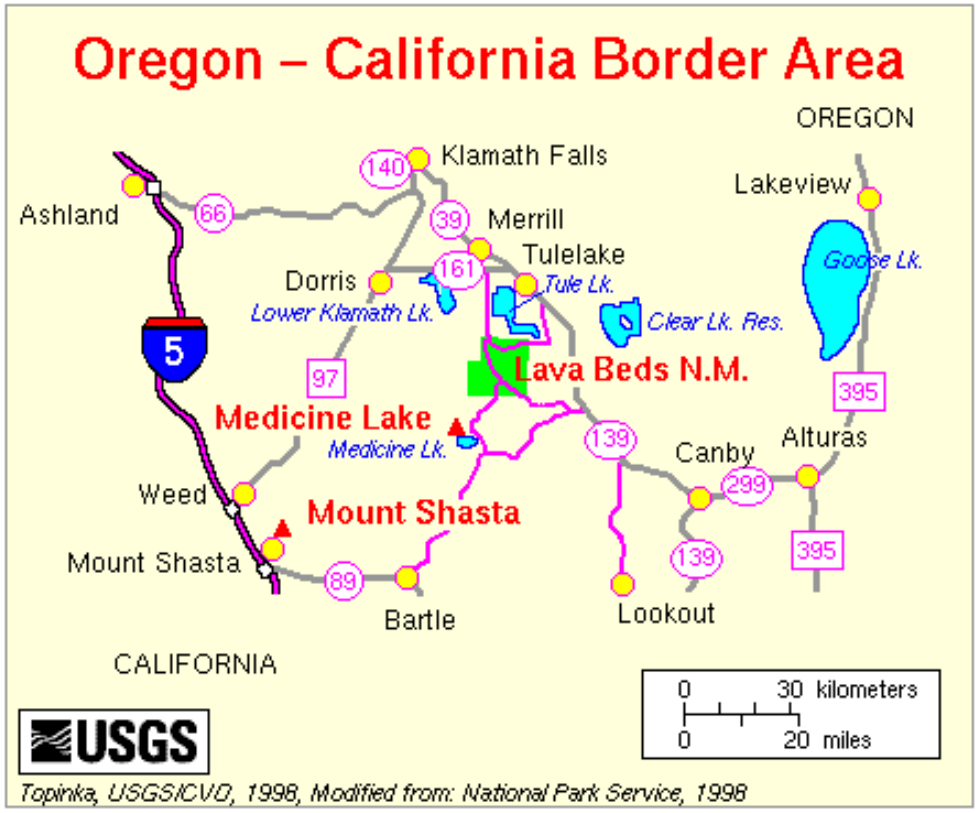

Figure 1. Location of Lava Beds National Monument, site of the 2011 Social Trails Assessment Project (USGS, 1998).

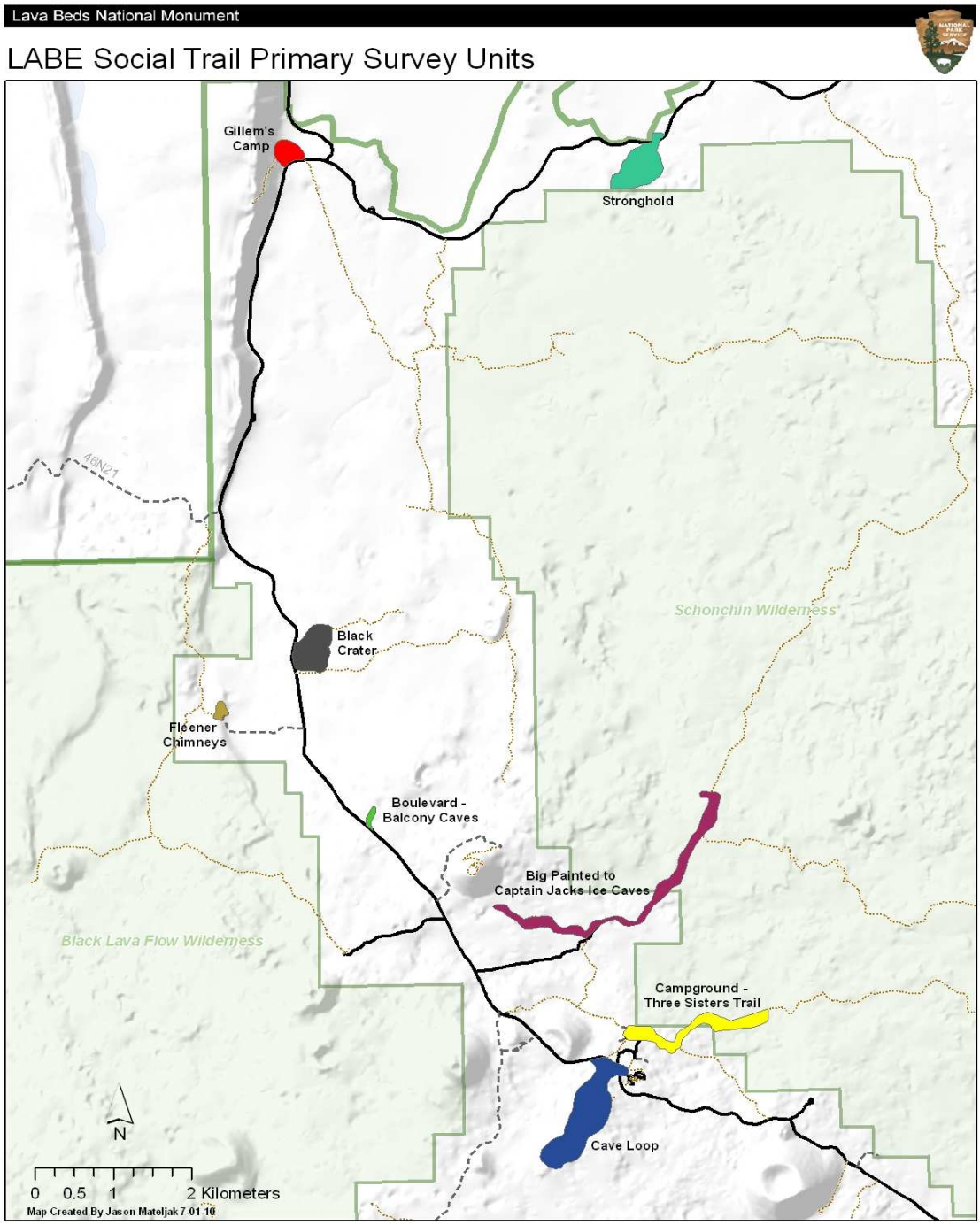

Figure 2. Map of Lava Beds National Monument, site of 2011 LABE Social Trails Assessment Project. From Jason Mateljak, 2009. Reprinted with

Figure 3. Social trail at Black Crater, 2010 Trails Assessment. From Ryan Janway, reprinted with permission.

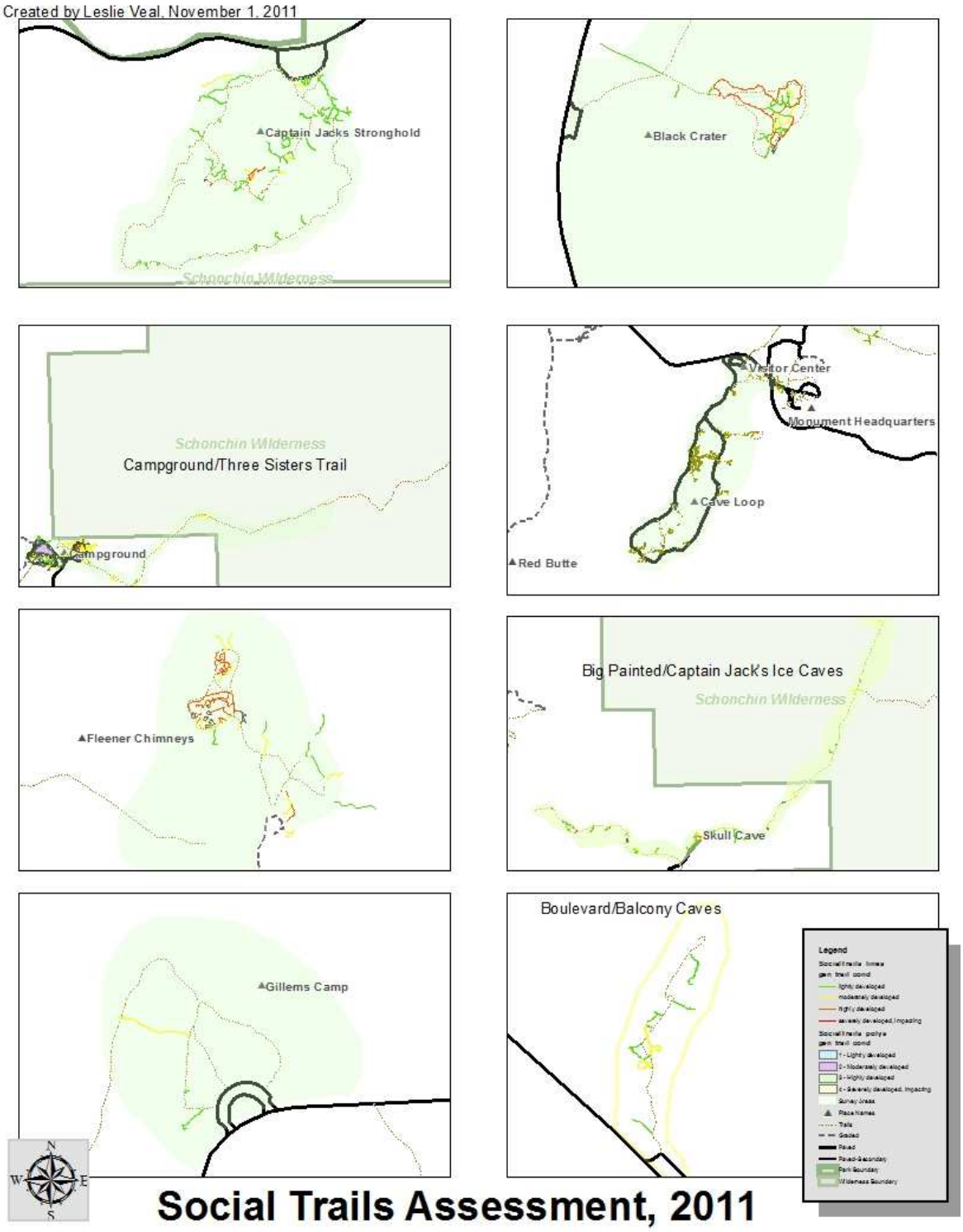

Figure 4. Map of all survey units for the 2011 Analyzing Front Country Social Trails Study. Map created by Leslie Veal, 2011.

*Figure 5.*Social trail in Cave Loop, 2010 Trails Assessment.
From Ryan Janway, Reprinted with permission.

Figure 6. Social trail at Fleener Chimneys, 2010 Trails Assessment. From Ryan Janway, reprinted with permission.

Figure 7. Social trail at Gillem's Camp, 2010 Trails Assessment. From Ryan Janway, reprinted with permission.

Figure 8. Social trail in Three Sisters- Campground area, 2010 Trails Assessment. From Ryan Janway, reprinted with permission.

Appendix A

Attribute Information Collected for the 2011 Analyzing Front Country Trails Study

1) Soil type

   _cryptobiotic

   _pumice

   _bare rock

   _other

2) Soil compaction

   _light

   _moderate

   _severe

3) General trail condition

   _lightly developed

   _moderately developed

   _highly developed

   _severely developed

4) Primary resource wear

   _light

   _moderate

   _high

   _severe

5) Root exposure

_yes

_no

6) Visibility

_low

_medium

_high

7) Vegetation condition

_good

_fair

_poor

8) Trail length

_short

_medium

_long

9) Trail width

_0-1ft

_1-2ft

_2-3ft

_>3ft

10) Destination

_cave

_parking lot

_formal trail

_scenic overlook

_building/facilities

_unknown

_other

11) Date

12) Collected by

_Leslie Veal

_Brandon Whiteley

13) Visitor count

_(short integer)

14) Notes

_(50 Character maximum)

Appendix B

Data Collection Sheet for the 2011 Analyzing Front Country Trails Study

Collected by:

Date:

Time:

Weather:

Goal:

Description of data collected:

File structure:

GPS make/model:

Notes:

Appendix C

GIS Maps Showing Condition Classes for Social Trails at Lava Beds National Monument

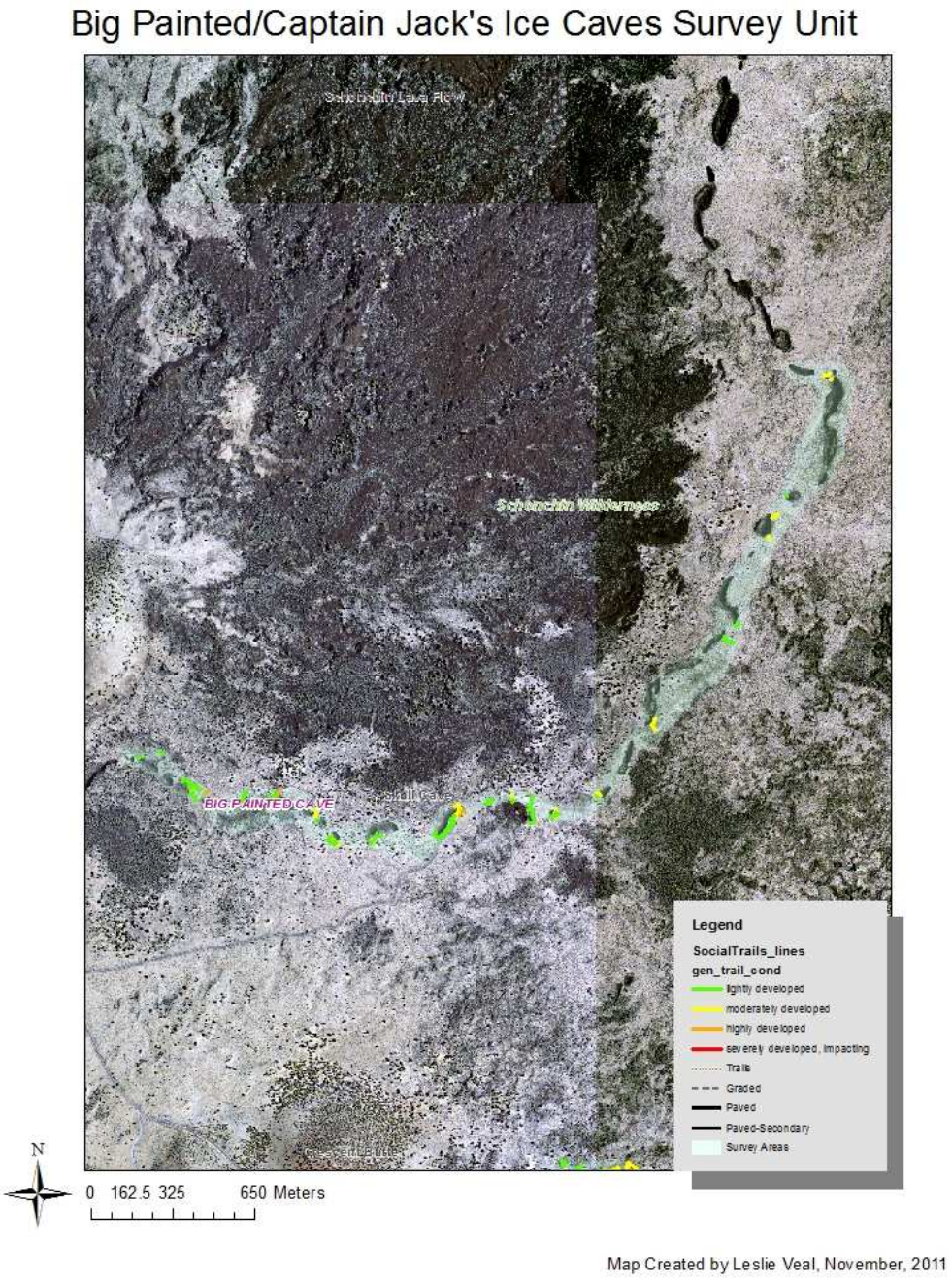

*Figure C1.*Map of social trails within the Captain Jack's Stronghold survey unit based on condition class. Map created by Leslie Veal, 2011.

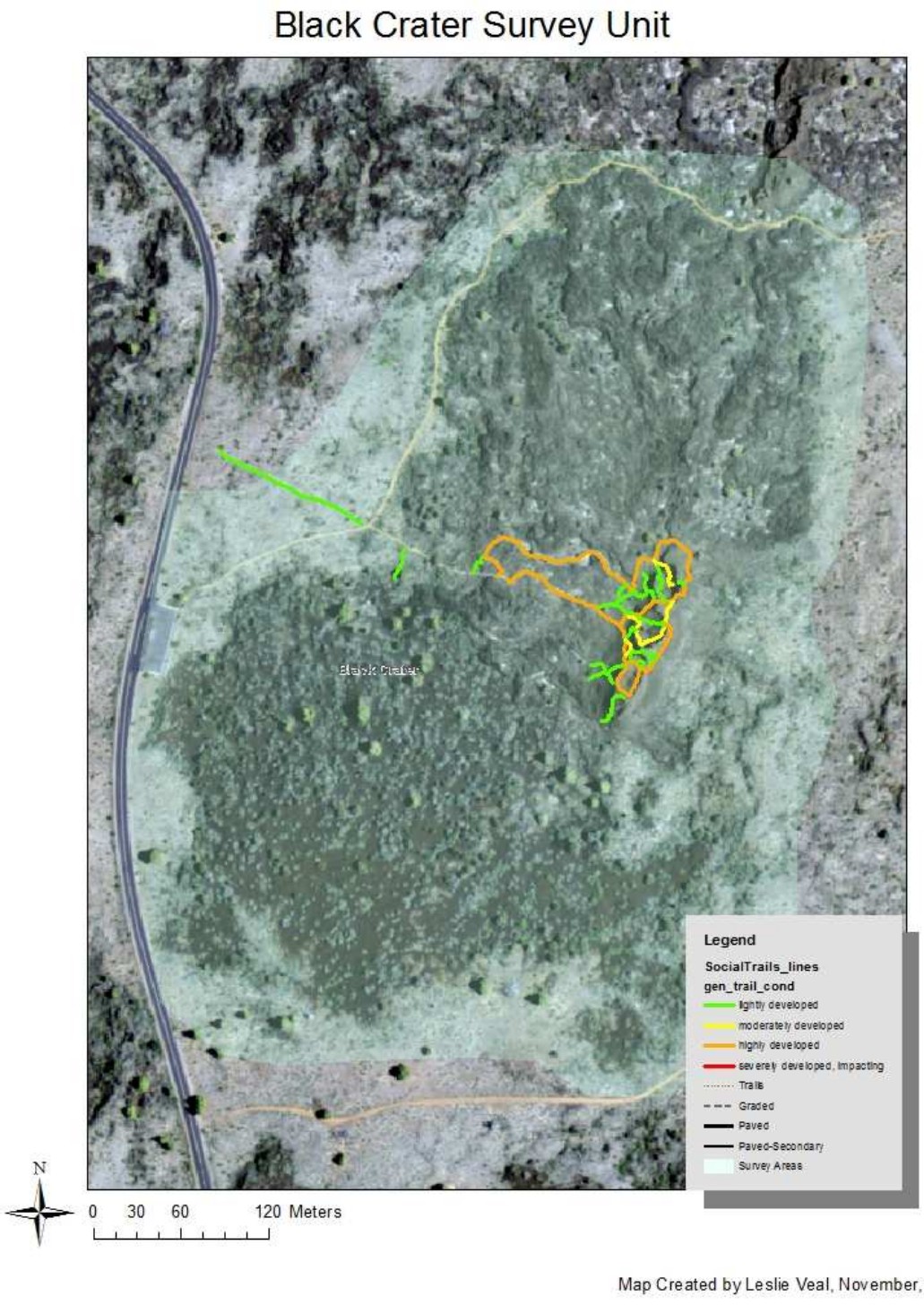

*Figure C2.*Map of social trails within the Black Crater survey unit based on condition class. Map created by Leslie Veal, 2011.

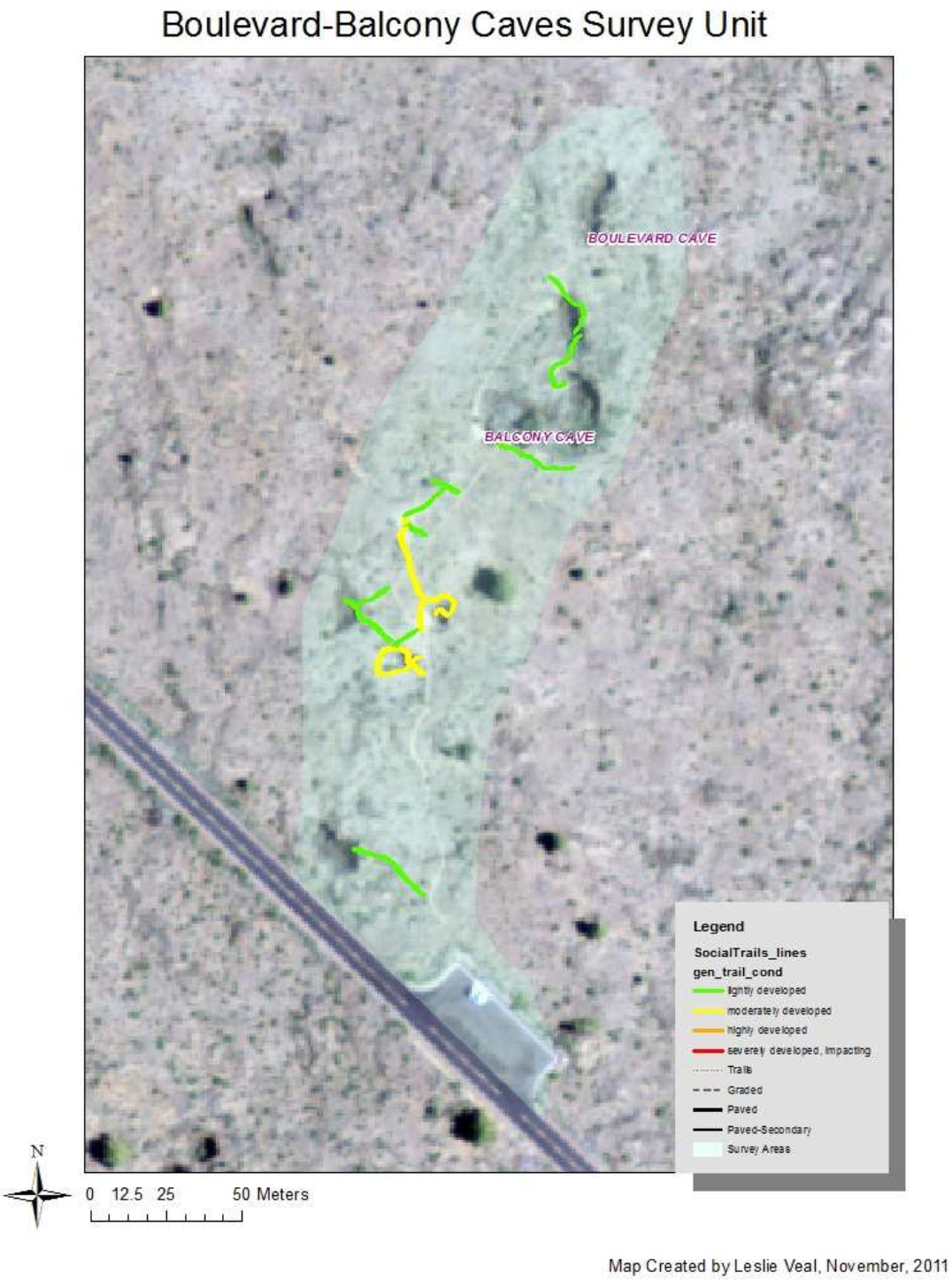

*Figure C3.*Map of social trails within the Boulevard/Balcony Caves survey unit based on condition class. Map created by Leslie Veal, 2011.

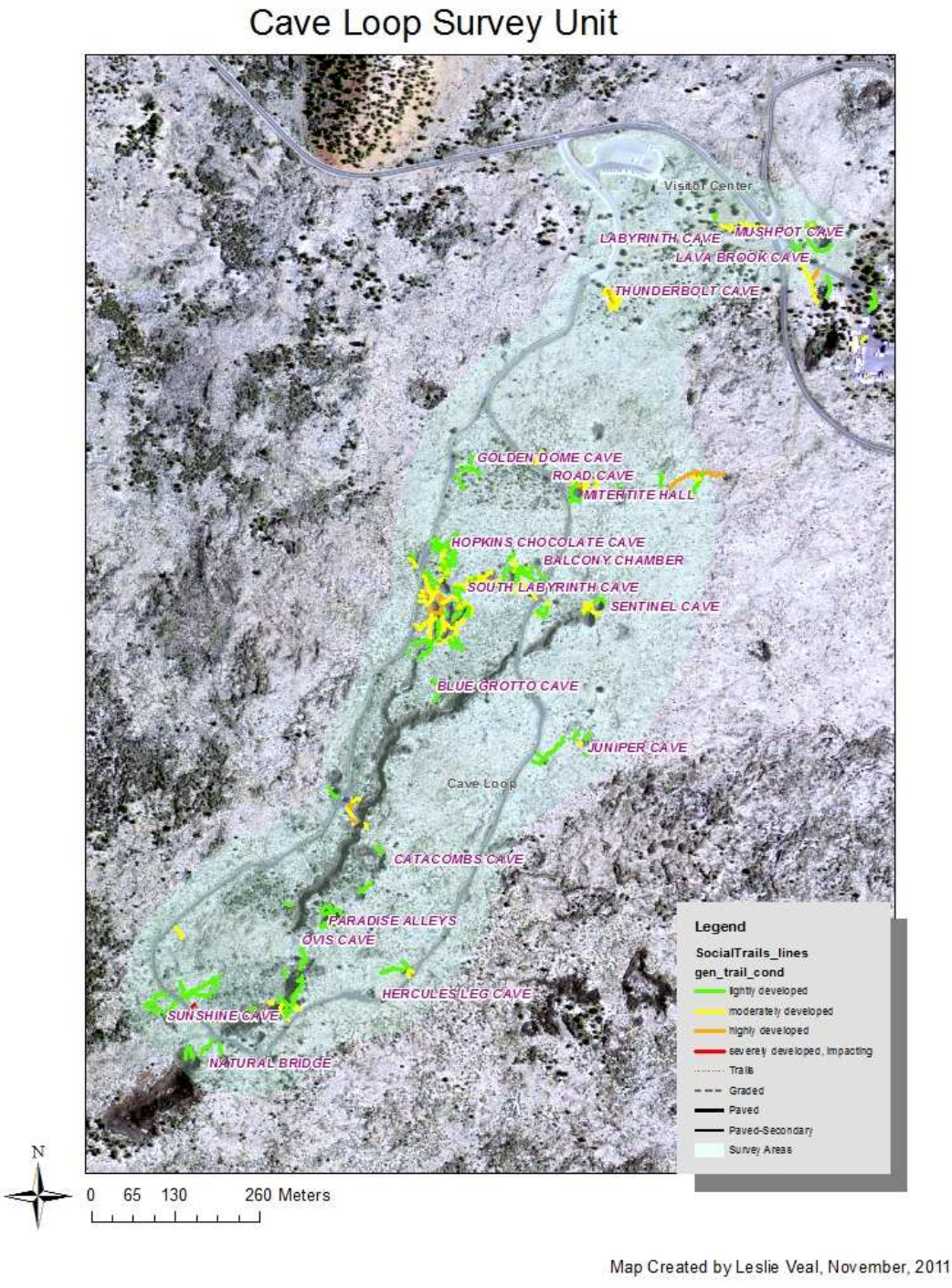

*Figure C4.*Map of social trails within the Cave Loop survey unit based on condition class. Map created by Leslie Veal, 2011.

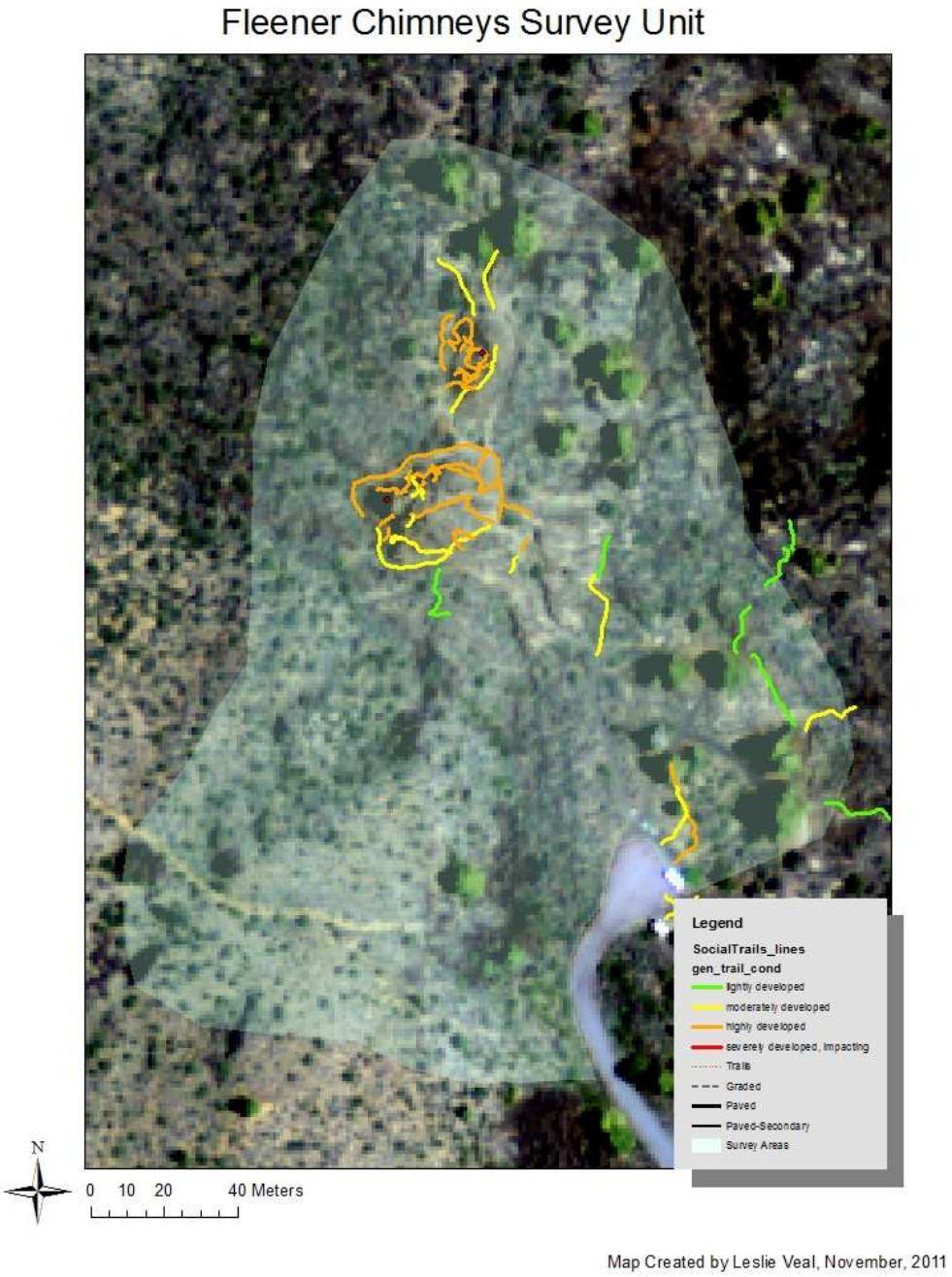

*Figure C5.*Map of social trails within the Fleener Chimneys survey unit based on condition class. Map created by Leslie Veal, 2011.

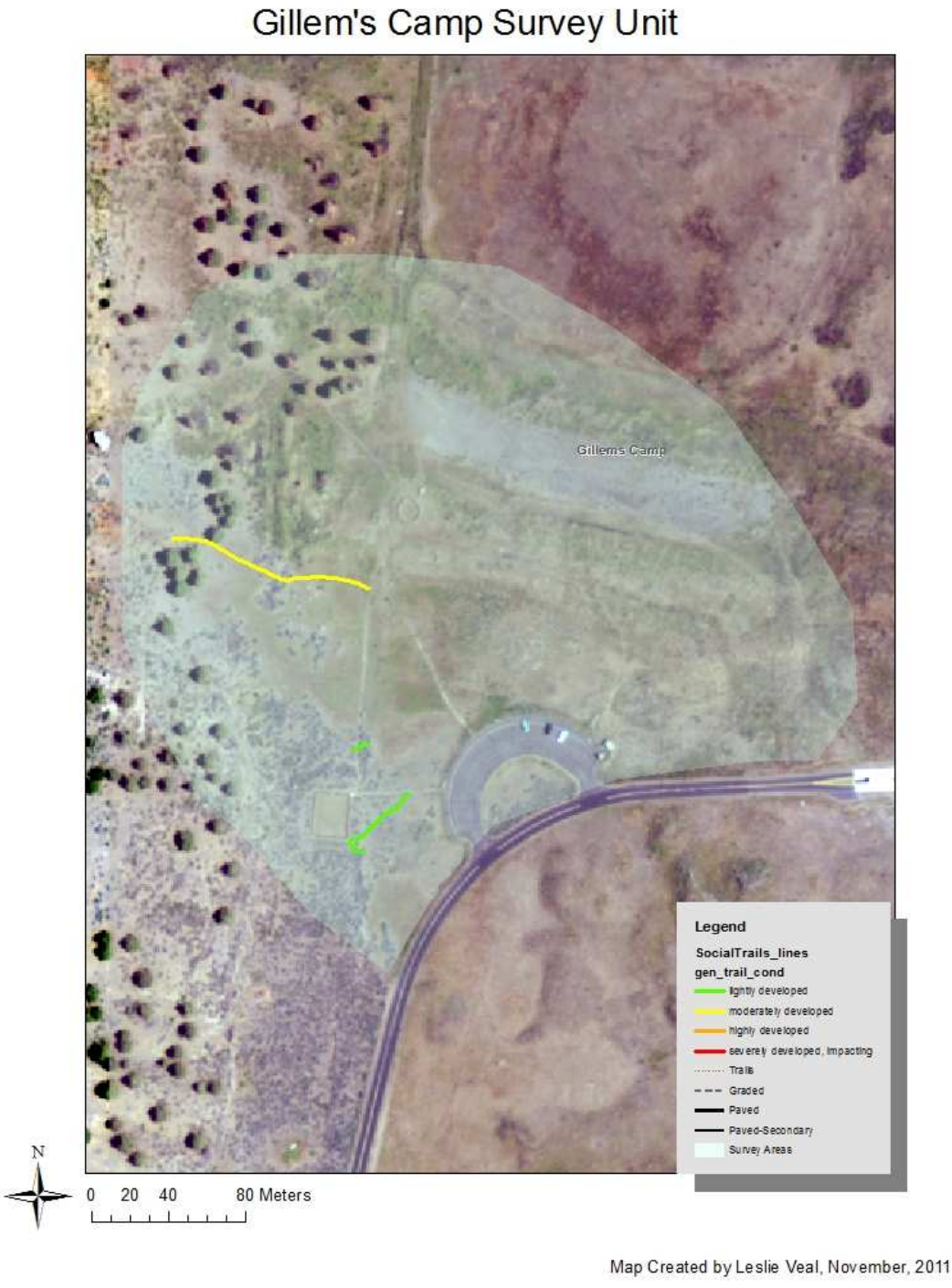

*Figure C6.*Map of social trails within the Gillem's Camp survey unit based on condition class. Map created by Leslie Veal, 2011.

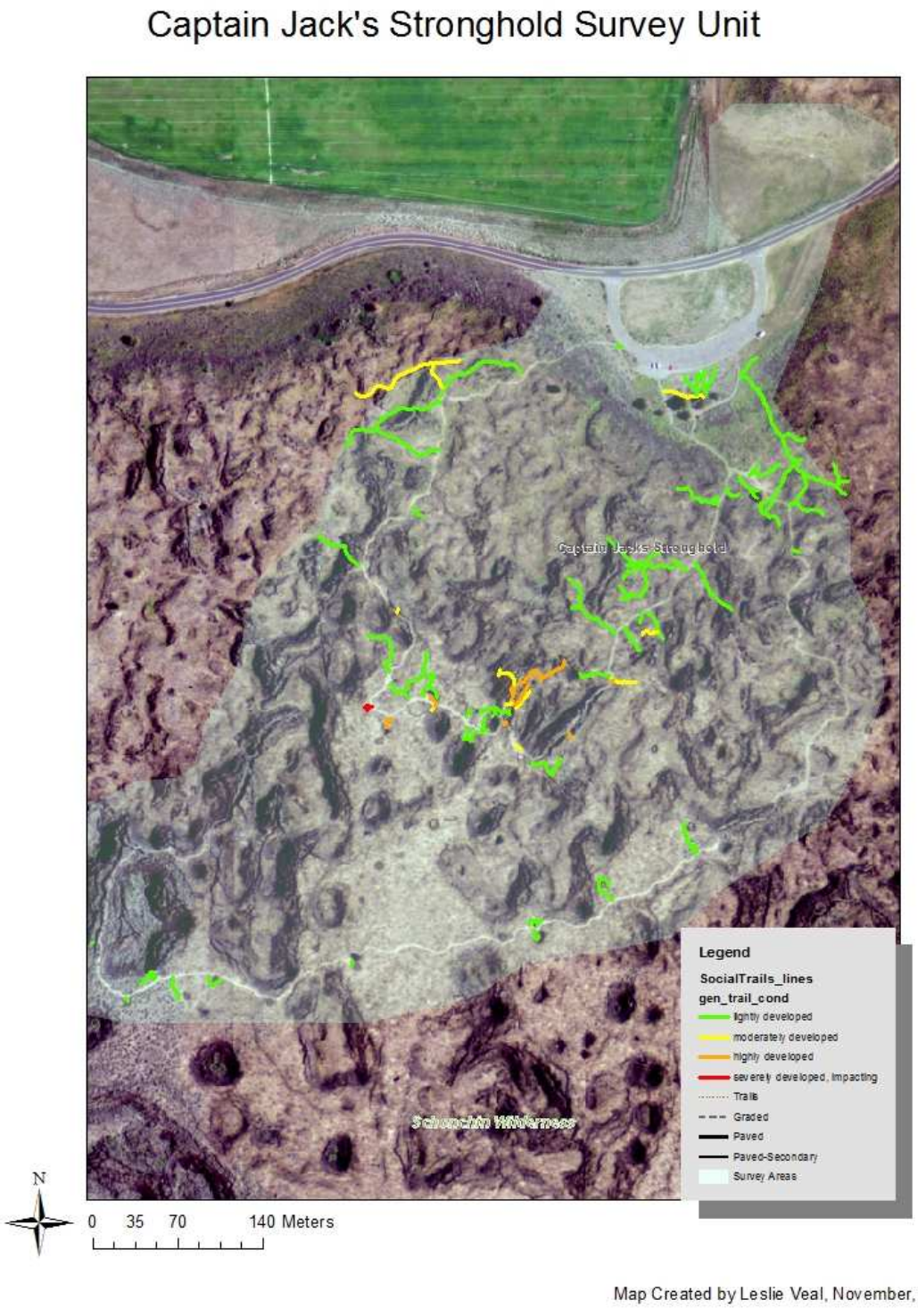

Figure C7. Map of social trails within the Captain Jack's Stronghold survey unit based on condition class. Map created by Leslie Veal, 2011.

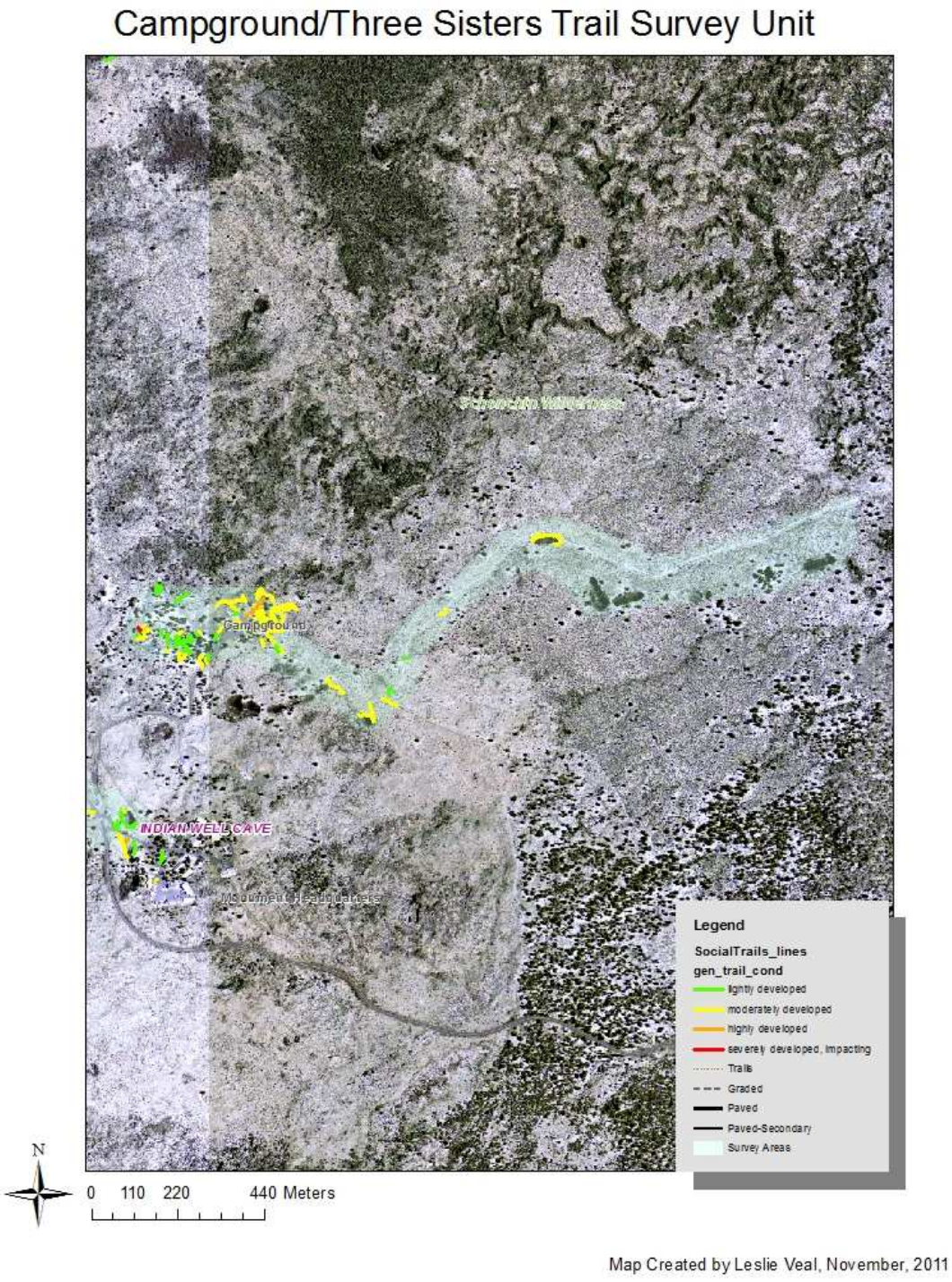

*Figure C8.*Map of social trails within the Campground/Three Sisters Trail survey unit based on condition class. Map created by Leslie Veal, 2011.

Appendix D

Aerial Photographs of Black Crater, Lava Beds National Monument

Figure D1. 1967 aerial photo of Black Crater. Photo provided by USDA Forest Service.

Figure D2. 1974 aerial photo of Black Crater. Photo provided by USDA Forest Service.

Black Crater, 1984

Figure D3. 1984 aerial photo of Black Crater. Photo provided by USDA Forest Service.

Black Crater, 2009

Figure D4. 2009 aerial photo of Black Crater. Photo provided by USDA Forest Service.

Appendix E

Aerial Photographs of Fleener Chimneys, Lava Beds National Monument

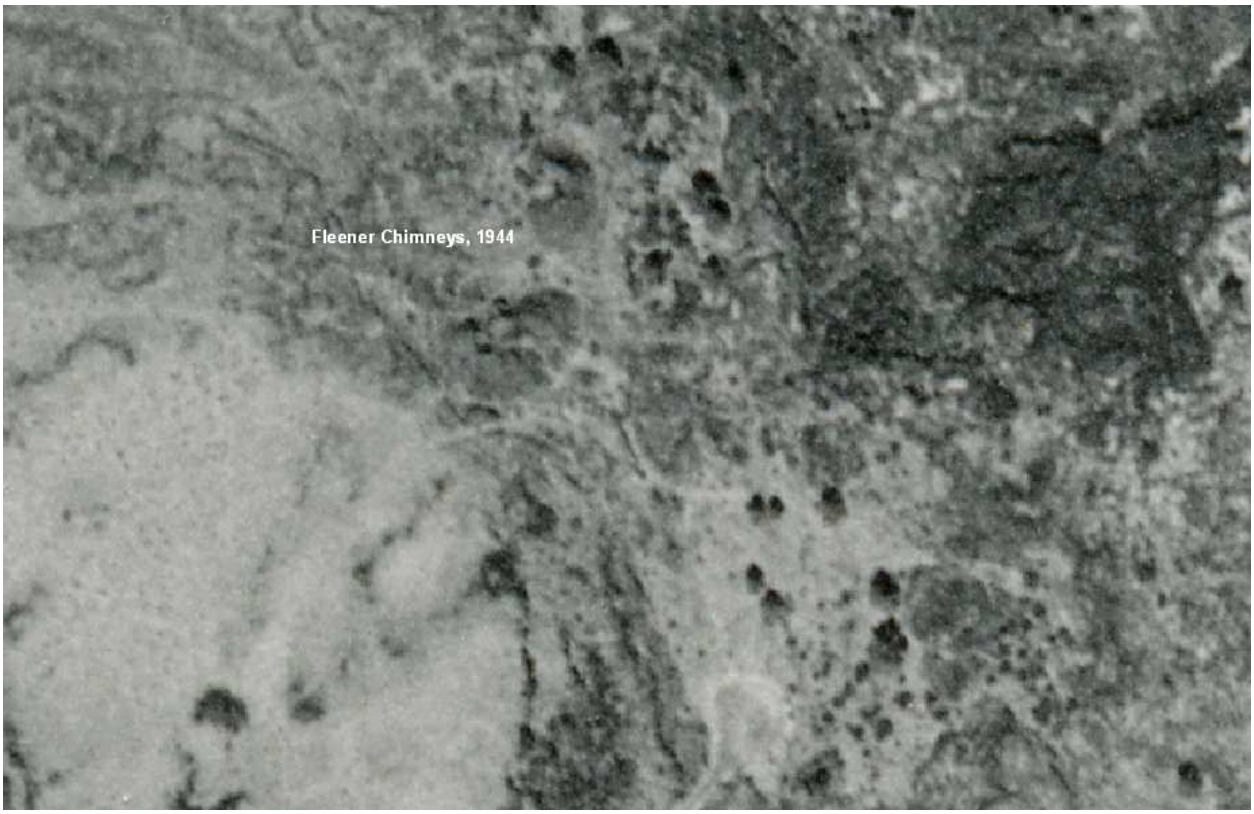

Figure E1. 1944 aerial photo of Fleener Chimneys. Photo provided by USDA Forest Service, Modoc National Forest.

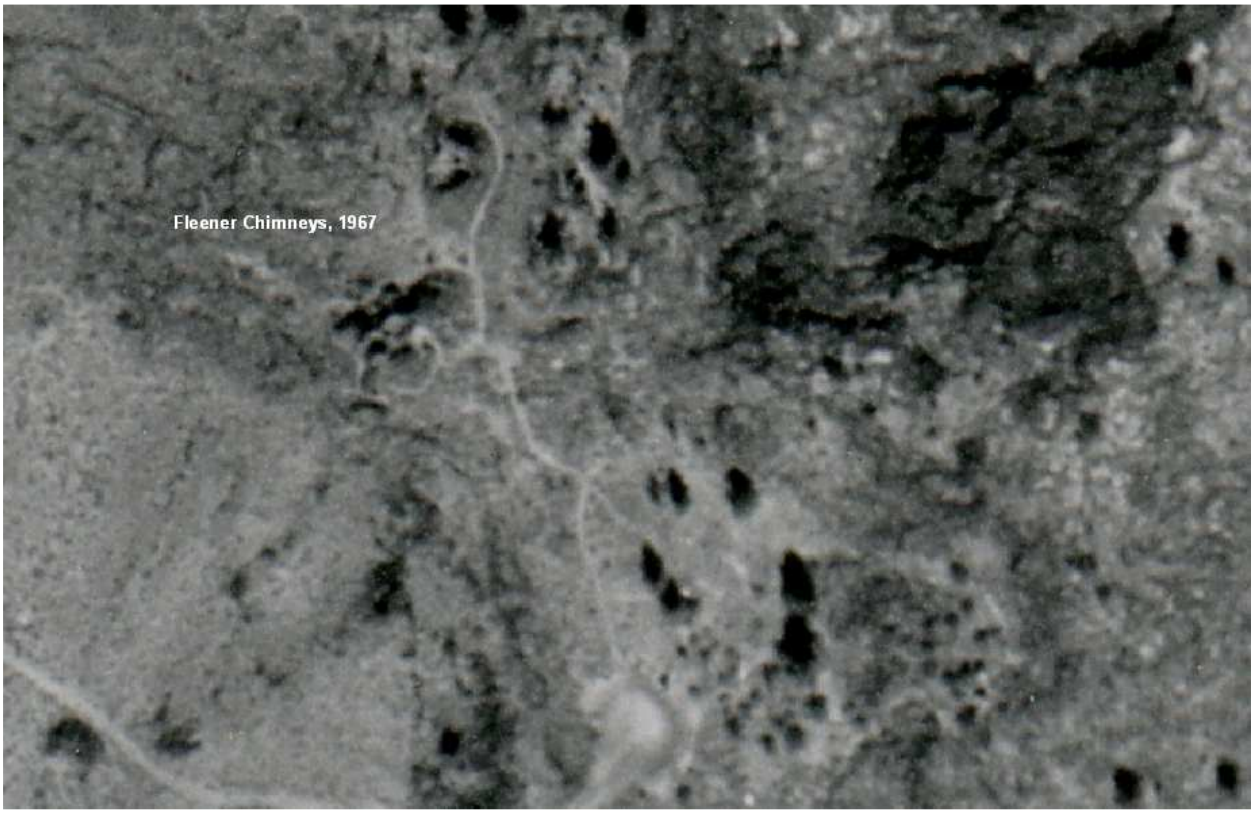

Figure E2. 1967 aerial photo of Fleener Chimneys. Photo provided by USDA Forest Service, Modoc National Forest.

Figure E3. 1974 aerial photo of Fleener Chimneys. Photo provided by USDA Forest Service, Modoc National Forest.

Figure E4. 1984 aerial photo of Fleener Chimneys. Photo provided by USDA Forest Service, Modoc National Forest.

Figure E5. 2005 aerial photo of Fleener Chimneys. Photo provided by USDA Forest Service, Modoc National Forest.