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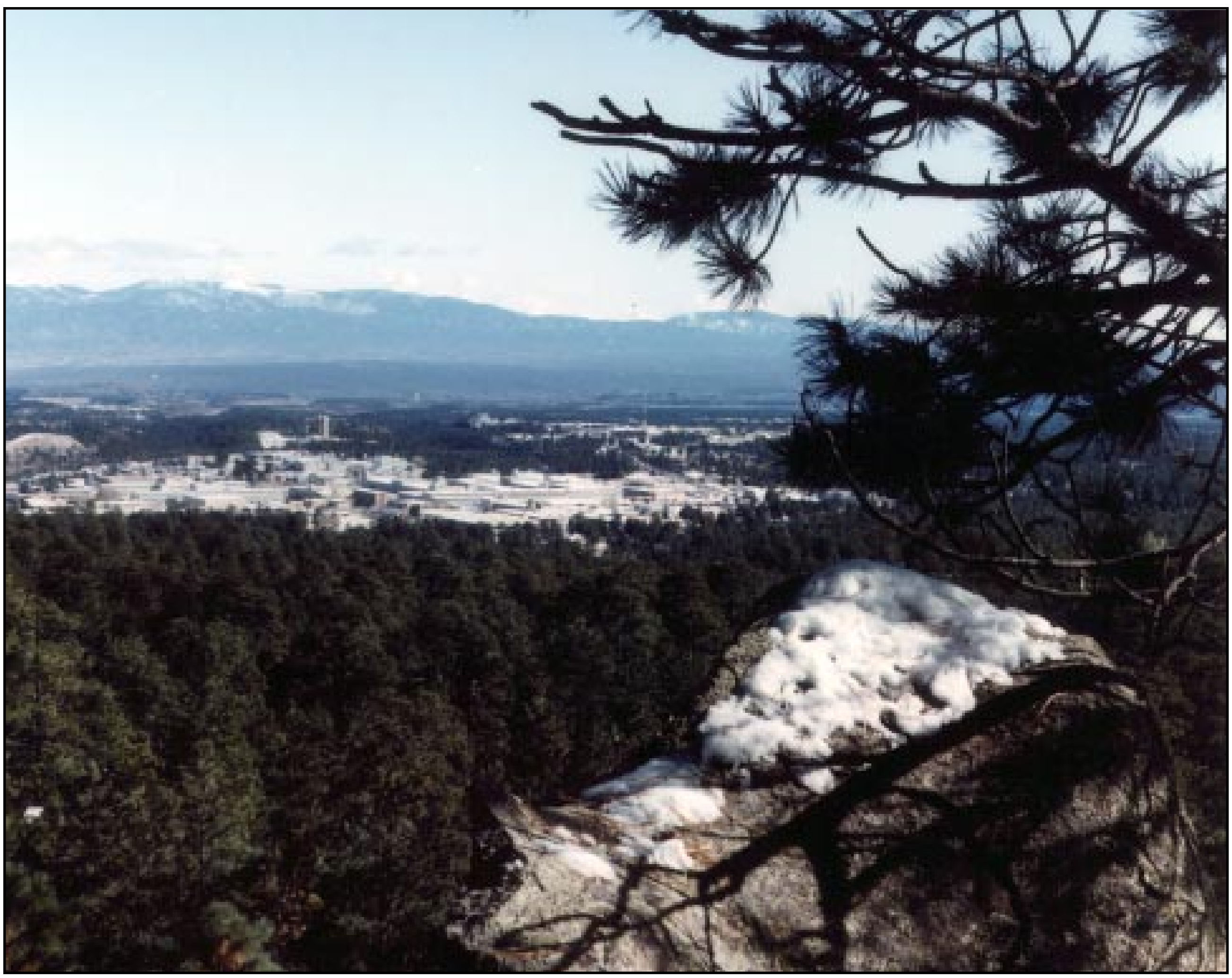

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Abstract

A study to determine the accuracy and feasibility of using satellite imagery technology to locate or predict specific habitat, using the Jemez Mountains salamander (*Plethodon neomexicanus)* as a model species, was conducted. It appears that a satellite imagery map, based solely on a small suite of physical characteristics (elevation, vegetation, and gradient), was not successful in predicting habitat for Jemez Mountains salamander. Inclusion of additional habitat features would be required to strengthen the predictive power of the map. It is possible that information obtained through geological maps, soil conservation units, and vegetation data bases could be entered into the Geographic Information System to strengthen the predictive value of these maps. It was determined that satellite imagery could be used as an initial screening process to determine potential salamander habitat.

1.0 Introduction

The Record of Decision for the Dual Axis Radiographic Hydrodynamic Test Facility Environmental Impact Statement (1995) mandates the completion of a Habitat Management Plan (HMP) for Species of Concern (SOC) and those species considered threatened and endangered that occur on, or utilize, the 43 square miles of the Los Alamos National Laboratory (LANL). One of the objectives in developing the HMP is to gather data pertaining to the habitat requirements of both threatened and endangered species (TES) and SOC in an effort to delineate the area used by a particular species.

A study to determine the accuracy and feasibility of using satellite imagery technology to locate or predict specific habitat, using the Jemez Mountains salamander (*Plethodon neomexicanus)* as the model species, was initiated by LANL in May 1996. This species was selected on the basis that it is currently listed by the State of New Mexico as threatened, is considered a federal SOC, and has a range which encompasses those lands owned and administered by LANL. The purpose of this study was to provide habitat and distributional data for Jemez Mountains salamander based on satellite imagery. Work discussed in this report was carried out by Louise Trippe and Timothy Haarmann as a part of the development of the LANL TES HMP.

1.1 Study Objectives

- Assess the feasibility of using satellite imagery as a tool to locate Jemez Mountains salamander habitat and populations.

- Evaluate stand level characteristics in targeted areas in order to ground truth satellite imagery based maps.

- Consult with LANL personnel in field surveys to identify any suitable Jemez Mountains salamander habitat on LANL property.

The following information is presented in this report:

- a written assessment explaining the accuracy and feasibility of using satellite imagery to predict suitable Jemez Mountains salamander habitat,
- a satellite imagery map based on selected habitat variables submitted to Earth Data Analysis Center (EDAC), and
- a list of Jemez Mountains salamander sites visited within the Jemez Mountains.

1.2 Geographic Distribution, Habitat Associations, and Natural History of Jemez Mountains Salamander

Jemez Mountains salamander is a member of the lungless salamanders family, Plethodontidae. It is described as a small (total length = 55 mm [2.2 in.]), slender salamander, uniformly brown with shiny, brassy flecking along the back, sooty to pale gray below, and paler on the throat and tail (Stebbins and Riemer 1950). The fifth hind toe is absent or reduced. This species represents a biological anomaly as it is the only representative of this family and genus found in the southern Rocky Mountains. It is a terrestrial salamander endemic to north-central New Mexico, where it inhabits high-elevation coniferous forests and associated habitats within the Jemez Mountains. The entire range of this species extends for less than 1,632 square kilometers (1,011 square miles) located in Sandoval, Rio Arriba, and Los Alamos Counties. Within its range, Jemez Mountains salamander appears to exist as a series of disjunct populations, separated by geophysical and vegetational features (Painter unpub. report, 1993). Populations are found primarily on land administered by the USDA Forest Service, Santa Fe National Forest, although it has been reported to occupy land owned by the Santa Clara Indian Pueblo, Bandelier National Monument, LANL, and private individuals. This species has been recorded from 2190 m (7183 ft) to 3290 m (10,791 ft). A site located on LANL property represents the lowest known elevation (2190 m [7183 ft]) that this salamander has been found (Ramotnik 1986).

Jemez Mountains salamander is most often found under decaying logs and under rocks in mixed coniferous forests (Reagan 1967, Ramotnik 1986). The most common tree species associated with Jemez Mountains salamander are white fir *(Abies concolor),* Engelmann spruce *(Picea engelmanii),* blue spruce (*Picea pungens),* quaking aspen (*Populus tremuloides),* Douglas fir *(Pseudotsuga menziesii),* ponderosa pine *(Pinus ponderosa),* and Rocky Mountain maple *(Acer glabrum)* (Reagan 1967, Ramotnik 1986). Other tree species found in Jemez Mountains salamander habitat include subalpine fir (*Abies lasiocarpa),* Gambel oak *(Quercus gambelii),* wavyleaf oak *(Quercus undulata),* and several species referred to as non-oak deciduous (Painter unpub. report, 1989). Shrub and forb species associated with these forested areas include: Colorado blue columbine (*Aquilegia caerulea*), Richardson's geranium (*Geranium richardsonii*), dwarf juniper (*Juniperus communis*), pinesap (*Monotropa latisquama*), Virginia creeper (*Parthenoeissus inserta*), New Mexico locust (*Robinia neomexicana*), thimbleberry (*Rubus parviflorus*), and Canada violet (*Viola canadensis*) (Reagan 1972). Although studies are currently underway to determine the impact of timber harvesting on Jemez Mountains salamander (Painter, unpub. report,1993), no conclusive evidence exists to date describing the impact of timber harvesting, fire, or mining on this species. Ramotnik (1988) found no significant difference in size classes of fir and spruce between transects with salamanders (10 total) and those transects without (33 total). Reagan (1972) also reports locating five salamanders at the edge of meadows.

The most consistent and perhaps the most important component of Jemez Mountains salamander habitat is thought to be the presence of fragmented rock in the soil profile (substrate) (Painter, personal comm.). Reagan (1972) describes the presence of remnant talus at all locations where salamanders were found. This type of substrate, in which extrusive rhyolite is broken down to produce a talus slope, stems from the volcanic origin of the Jemez Mountains. Talus is known to be an important feature for several *Plethodon* species. Given the narrow range of climatic conditions that are necessary for *Plethodons* to exist, it is believed that these animals move through the permeable talus interstices during unfavorable surface conditions to seek preferred temperature and moisture regimes. Reagan (1972) and references therein have suggested that the talus, which provides open channels to the subterranean environment, may account for the survival of this species in the harsh environment of the Rocky Mountains (Ramotnik 1986). During periods of prolonged precipitation, animals move up from their talus retreats to the surface where cover objects such as downed woody debris are widely used. Ramotnik (1986) located all salamanders in her 1985 survey period in downed logs. Downed woody material, however, comprised >94% of the 800 cover objects searched, and logs contributed to 95% of this downed woody material (Ramotnik 1985). Jemez Mountains salamander has been found using other surface objects, such as talus and fine woody debris for cover (Reagan 1972).

Several studies have suggested that slope is an important factor in suitable Jemez Mountains salamander habitat (Ramotnik 1986, Reagan 1972). Ramotnik. (1988) identified slope as the most useful variable in determining the presence of Jemez Mountains salamander. It was speculated that, due to the combined effects of gravity and movement of water and soil, steep slopes may be less compacted and contain more interstitial spaces in the soil. Subsequent investigations, however, have found Jemez Mountains salamander to exist at a wide range of slopes (from 0 to 100% gradient) (Painter unpub. report 1993, Scott et al. unpub. report 1987).

Although the salamander does not appear to be confined to slopes of a particular aspect, much of the published data suggests that suitable habitat is most often found on north-facing slopes or sheltered canyons. Because a north-facing slope is more protected from direct solar radiation, evaporation and sublimation occur at a slower rate (West 1959). Gradual snow melt enables water to soak into substrates rather than being lost by sublimation or runoff (Anderson 1963). Differences in available moisture may vary between north- and south-facing slopes as much as 21% (West 1959). Narrow canyon walls also provide protection from wind and direct solar radiation, thus allowing for similar conditions with respect to snow accumulation. Ramotnik (1986), however, found that elevation had a greater effect on microhabitat variables such as ground cover, temperature, and moisture of logs than either slope or aspect.

Moisture is an important component of Jemez Mountains salamander habitat. This species is a lungless salamander which requires that its skin be in contact with moist surfaces for respiration (Goin et al. 1978). Observations of Jemez Mountains salamander on the surface are typically during the summer months following periods of heavy rain. This species may be opportunistically responding to suitable surface conditions such as moisture and temperature (Ramotnik 1986, Reagan 1972). Reagan (1972) reports that salamanders were only seen active on the surface at night when litter and foliage were “dripping wet” from afternoon thundershowers or night storms. All salamanders he found during the day were inactive in the coiled position. Dietary analysis of 39 specimens further suggests that these animals are nocturnal foragers (Reagan 1972). Because important data is lacking for the 39 individuals used in Reagan’s dietary analysis, a more rigorous study is currently underway (Painter unpub. report, 1993). It is known, however, that Jemez Mountains salamander preys on a wide array of invertebrates such as mites, spiders, crickets and other orthopterans, flies, and ants (Painter unpub. report, 1993). Both research carried out by Reagan (1972) and Painter (1993 unpub.) found that ants were the most frequently consumed prey item.

2.0 Methodology

2.1 Establishing Criteria/Variables

An extensive literature review was conducted in order to obtain all available published information describing the natural history, ecology, and habitat associations of Jemez Mountains salamander. Additional information and recommendations were obtained through personal communication with Marilyn Altenbach, New Mexico Natural Heritage Program, and Charles Painter, New Mexico Department of Game and Fish, both of whom are currently conducting studies of Jemez Mountains salamander. Information was then evaluated and those elements most consistent in descriptions of the salamander’s habitat were prioritized. Once a list of habitat parameters had been defined, a meeting with EDAC representatives took place to review the preferred variables. Of the original seven preferred variables, only three could be parameterized by EDAC for the production of a Jemez Mountains salamander habitat-based map (Table 1). It was decided that both Frijoles and Guaje Mountain U.S. Geological Survey (USGS) Quadrangle (7.5 min. series) maps would be used, as they encompass the areas directly north and south of LANL.

2.2 Ground Truthing of Satellite Imagery Maps and Consultation of LANL Personnel in Identifying Suitable Jemez Mountains Salamander Habitat

In order to characterize the habitat features of Jemez Mountains salamander, 12 locations were visited in Sandoval and Los Alamos Counties where populations of Jemez Mountains salamander are known to exist (Appendix A). At each site, information on stand structure and composition, gradient (%

slope), aspect, elevation, and substrate was recorded. Gradient was measured using a clinometer, and elevation was taken from a USGS topographical map. The habitat data from sites known to support Jemez Mountains salamander was used as a reference to validate the specific spectral classes depicted on the satellite imagery maps (Figure 1). An additional 13 sites were visited in an effort to ground truth (qualitatively) and assess stand level characteristics of those areas identified on the maps as potential Jemez Mountains salamander habitat. Of the 13 sites visited, four had been targeted in prior years as suitable habitat likely to support populations of this salamander. No amphibian field surveys were conducted due to inappropriate weather conditions.

Maps of locations where Jemez Mountains salamander surveys had been conducted were provided by the New Mexico Natural Heritage Program. These maps were superimposed on to the satellite imagery map to determine if there were any correlations between the targeted area on the satellite imagery map and the areas where Jemez Mountains salamander had been found.

3.0 Results

Seven habitat attributes were identified as being important to the mapping project (Table 1). Because data for three of the attributes were not available, the selected list of habitat features to be used in generating the satellite maps included (1) all mixed coniferous stands, (2) elevation range of 2000–3300 m (6560–10824 ft), and (3) a gradient > than 5%.

Table 1. List of preferred and selected habitat variables used in the development of a habitat-based map for Jemez Mountains salamander.

Preferred Variables	Selected Variables
Geological material	Elevation
Elevation	Vegetation
Moisture	Gradient
Vegetation	
Cover Objects	
Aspect	
Gradient	

A gradient of >5% was used as a means of eliminating mesa tops from the resulting map and should not be interpreted as a specific variable for Jemez Mountains salamander. Habitat-based maps, including elevational contours, major drainages, and roads were generated, using the three selected habitat attributes, for Guaje Mountain and Frijoles USGS quadrangles (7.5 min. series).

Information on stand structure and composition, gradient, aspect, elevation, and substrate was recorded at 12 known Jemez Mountains salamander sites (Table 2). Five of these sites are located in Frijoles and Guaje Mountain Quadrangles, and provided reference data which verified the spectral classes targeted as potential Jemez Mountains salamander habitat.

Table 2. List of known locations of Jemez Mountains salamander visited. Definitions of substrate, forest structure, and composition are given in Appendix B.

Site Name	Elevation m (ft)	Gradient(% Slope)	Aspect	Forest Composition	Forest Structure	Substrate
Pony Canyon	2543 (8480)	55	N	MixCon	Mature	Rock
Oat Canyon	2472 (8240)	55	N	MixCon	Mature	Rock
Unnamed Canyon	2472 (8240)	~57*	N	MixCon	Mature	Rock
Bear Canyon	2608 (8606)	57	N	Mix Con	Mature	Rock
Bear Canyon	2590 (8547)	69	S	MixCon	Mature	Rock
Barley Canyon	2575 (8497)	45	S	PinPon	Mature	Rock
Ski Hill	2745 (9150)	Flat	N**	Mix Con	Pole	No Rock
u. Water Canyon	2548 (8408)	68	W	MixCon	Mature	Rock
u. Water Canyon	2560 (8448)	60	N	MixCon	Mature	Rock
Pueblo Canyon	2160 (7200)	~60*	N	PinPon	Mature	Rock
Acid Canyon	2160 (7200)	~55	N	MixCon	Mature	Rock
Los Alamos Canyon	2133 (7039)	~50	N	MixCon	Mature	Rock

* Slope was estimated due to disfunctional clinometer. Gradient values for Bear Canyon, Barley Canyon, and upper Water Canyon were obtained through site descriptions included in Ramotnik (1986).

** The aspect listed for the Ski Hill Site refers to the slope above location where the salamander was found.

We visited 13 sites in order to qualitatively ground truth the satellite imagery maps (Table 3). These sites were selected on the basis that they were depicted as the same spectral classes as known Jemez Mountains salamander sites. It was found that, at this level of resolution, there was no distinction drawn between ponderosa pine-dominated stands and mixed-coniferous stands. In Guaje Canyon, certain portions of the canyon that actually contained habitat attributes, as defined by the list of variables, were not included in the same spectral class as other areas meeting the same set of variables. These areas and their spectral class were subsequently located on another higher-resolution satellite imagery map of the same quadrangle, and all areas delineated by this spectral class were added to the final map produced by EDAC. Due to time constraints on the project, a more quantitative and systematic ground truthing process was not possible.

When the map of selected survey sites was superimposed on to the satellite imagery based map, all locations of these surveys were included in the same spectral classes. The habitat-based satellite imagery map did not differentiate between those sites where salamanders had been found and those areas where survey efforts had not resulted in locating salamanders.

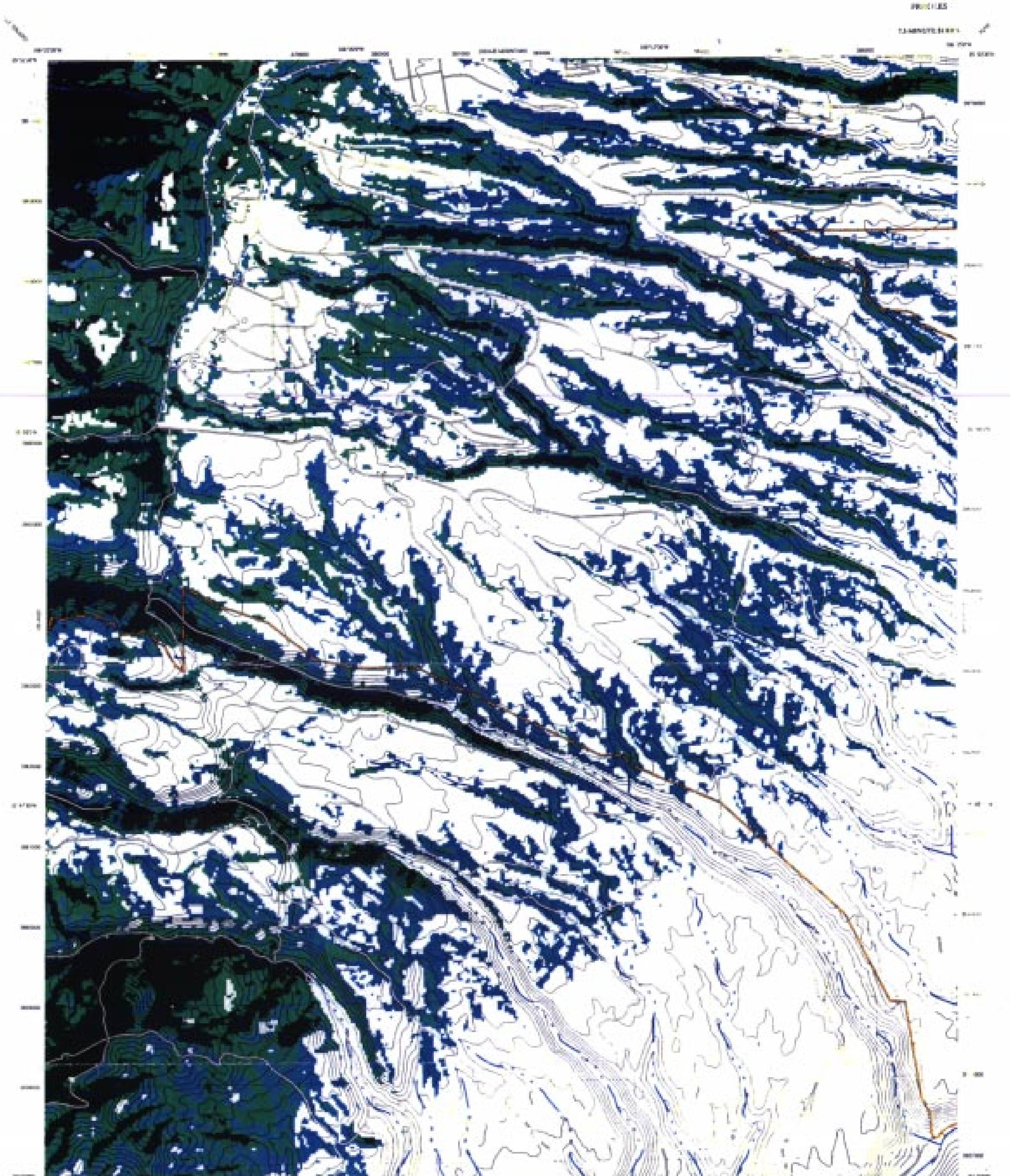

Figure 1. The colored areas show the predicted Jemez Mountains salamander habitat.

Table 3. List of areas visited for ground truthing of satellite imagery maps. Forest composition is defined in Appendix B.

LOCATION	PRIOR SURVEY YES/NO	RESULTS CLASS	SPECTRO-COMP.	FOREST HABITAT	POTENTIAL
Water Canyon 1	YES	POS	DG	MIX CON	YES
Water Canyon 2	YES	NEG	DG	MIX CON	YES
Water Canyon 3	YES	NEG	DG	MIX CON	YES
2 Mile Canyon	NO------	DG	MIX CON		YES
Ancho Canyon	NO------	DG	PINPON	NO	
Canada del Buey	NO------	DG	PINPON	NO	
Mortandad Canyon	NO------	DG	MIX CON		YES
Bayo/Barranca	NO------	DG	PINPON	NO	
Rendija Canyon 1	NO------	DG	PINPON	NO	
Rendija Canyon 2	NO------	DG	PINPON	NO	
Rendija Canyon 3	NO------	DG	PINPON	NO	
Pueblo Canyon	NO------	DG	MIXCON	YES	
Guaje Canyon	YES	NEG	DG	MIXCON	YES

4.0 Conclusions

Satellite imagery technology is one of many remote sensing tools available to resource managers or researchers from a variety of disciplines. This technology can prove to be extremely useful. However, careful consideration needs to be given to determine whether or not it will provide the information needed to fulfill certain project requirements. Evaluating certain factors such as the level of required detail and the size of the targeted area can serve to facilitate this decision-making process. Additional factors include the spatial, temporal, and radiometric resolutions of certain satellite imaging types, as each can greatly influence the feasibility of producing a satellite image classification. In assessing the success of employing satellite imagery technology for the purpose of predicting and delineating habitat of Jemez Mountains salamander, each of these elements have been considered.

The spectral and radiometric resolution of these maps did not discern between mixed coniferous stands and those dominated by ponderosa pine. Since the salamander has been found in stands where ponderosa pine is the dominant canopy species (Painter personal comm.), it is in fact an asset that these areas were not effectively ruled out. The resulting maps, however, show an extremely large area highlighted as potentially suitable to support populations of Jemez Mountains salamander.

It appears that the satellite imagery map, based solely on a small suite of physical characteristics, was not successful in predicting habitat for Jemez Mountains salamander. This was made apparent when a map of surveyed areas was superimposed onto the satellite imagery map. Each of the locations targeted for survey were selected based on overall appearance as suitable habitat after visual inspections. Each of these locations were included in the same spectral classes, whether or not salamanders were found in the survey. Although the satellite imagery map included all areas recognized as “potential” after visual inspections, it did not preferentially tease out those areas where salamanders had been found.

Due to limitations in both available data (Geographic Information System [GIS] layers, ancillary data), important components of Jemez Mountains salamander habitat such as soil characteristics, moisture qualities, and surface cover objects were omitted, and a much coarser set of habitat variables was used. Inclusion of additional habitat features would be required to strengthen the predictive power of the map. It is possible that information obtained through geological maps, soil conservation units, and vegetation databases could be entered into the GIS. In this way, these features that are now unmappable could, in turn, be layered onto the more spatial data already available.

In addition to the technological limitations of using satellite imagery for this purpose, there are elements of this species’ natural history that contribute to the difficulty in predicting or locating actual habitat occupied by the salamander. Populations may be small and isolated, existing in only one small section of a drainage or slope. Factors other than habitat suitability may preclude the existence of Jemez Mountains salamander in a given area. Ramotnik (1988) suggests that unsuitability of the surrounding area may prevent access to more optimal habitat, or that climatic events could also have eliminated salamanders from an area without sufficient time to recolonize.

Logistical data constraints discussed above hinder the success of employing satellite imagery as a tool to locate suitable Jemez Mountains salamander habitat. However, the entire process could be “fine-tuned” using additional data which would yield more accurate results. As an initial screening process to determine which locations might be field surveyed, satellite imagery works well. Finally, a visual inspection, as outlined in Painter (1989), remains the most practical method for Jemez Mountains salamander habitat assessment. In using this method, an area is first located on a USGS quad or orthro-quad map in order to determine the elevation of the site. If the area is at an elevation of 2440 m (8052 ft) or greater, the area is considered potential Jemez Mountains salamander habitat and is visited for an on-ground assessment. The assessment focuses on dominant tree species, percent cover, slope, aspect, and “overall conditon of the site.” If the habitat appears to be suitable salamander habitat, than a high-grade search is carried out. In the absence of a more inclusive data base from which specific habitat based classifications can be defined, this technique remains the most practical method for identifying and assessing Jemez Mountains salamander habitat.

Appendix A: Twelve locations where Jemez Mountains salamander are known to exist.

Location	Date	County	Quad
Pony Canyon	01-5-96	Sandoval	Seven Springs
Oat Canyon	01-5-96	Sandoval	Seven Springs
Unnamed Canyon	01-5-96	Sandoval	Seven Springs
Bear Canyon	01-5-96	Sandoval	Seven Springs
Bear Canyon	01-5-96	Sandoval	Seven Springs
Barley Canyon	01-5-96	Sandoval	Seven Springs
Ski Hill	02-5-96	Los Alamos	Valle Toledo
U. Water Canyon	02-5-96	Los Alamos	Frijoles
U. Water Canyon	02-5-96	Los Alamos	Frijoles
Pueblo Canyon	02-5-96	Los Alamos	Guaje Mt.
Acid Canyon	02-5-96	Los Alamos	Guaje Mt.
Los Alamos Canyon	02-5-96	Los Alamos	Guaje Mt.

Appendix B: Definitions of substrate, forest structure, and composition.

Forest Structure: Defined by the dominant canopy species. Categories included

1) Mixed coniferous (MixCon),
2) Ponderosa pine dominated (PinPon),
3) Mixed coniferous-deciduous, and
4) Deciduous.

Forest Structure: Defined by the seral class at the specific location visited.

Substrate: Recorded the presence of rock within the substrate.

5.0 References

Anderson 1963: H.W. Anderson, "Managing California's Snow Zone Lands for Water," Pacific SW Forest and Range Exper. Sta., Berkeley, CA.

DOE (U.S. Department of Energy) 1995: "Dual Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement," U.S. DOE report DOE/EIS-0228 (August 1995).

Goin 1978: C.J. Goin, O.B. Goin, and G.R. Zug, Introduction to Herpetology. 3rd ed. W.H. Freeman and Co., San Francisco, 378 pp.

Painter 1989: C.W. Painter, "Investigations into the Distribution and Habitat Requirements of the Jemez Mountains Salamander (*Plethodon neomexicanus)*" Unpublished report. On file with: U.S.F.S., Santa Fe National Forest, Jemez Ranger District, Jemez Springs, NM 87025.

Painter 1993: C.W. Painter and M.J. Altenbach, "A Final Report on the Investigations into the Distribution and Habitat Requirements of the Jemez Mountains Salamander (*Plethodon neomexicanus*)," Unpublished report. On file with: U. S. F. S., Santa Fe National Forest, Jemez Ranger District, Jemez Springs, NM 87025.

Ramotnik 1986: C. Ramotnik, "Status Report Plethodon Neomexicanus (Stebbins and Riemer) Jemez Mountains Salamander, U.S. Fish and Wildlife Service, Fort Collins, Colorado (July 1986).

Ramotnik 1988: C.A. Ramotinik and N.J. Scott, "Habitat Requirements of New Mexico's Endangered Salamanders." pp 54-63 in Management of Amphibians, Reptiles, and Small Mammals in North America. Gen. Tech. Rep. RM-166. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Range and Experiment Station.

Reagan 1967: D.P. Reagan, "Aspects of the Life History and Distribution of the Jemez Mountains salamander *Plethodon neomexicanus*.," M.S. Thesis, University of New Mexico, Albuquerque. 38 pp.

Reagan 1972: D.P. Reagan, "Ecology and Distribution of the Jemez Mountains Salamander *Plethodon neomexicanus*.," *Copeia*, 1972:486-492.

Stebbins 1950: R.C. Stebbins and W.J. Riemer, "A New Species of Plethodontid Salamander from the Jemez Mountains of New Mexico," *Copeia*, 1950:73-80.

Scott 1987: N.J. Scott, C.A. Ramotnik, M.J. Altenbach, and B.E. Smith, "Distribution and Ecological Requirements of Endemic Salamanders in Relation to Forestry Management; Summary of 1987 Activities. Part 2," Santa Fe National Forest. Unpublished report. On file with: U.S. Forest Service, 517 Gold Ave., SW, Albuquerque, NM 87102.

West 1959: A.J. West, "Snow Evaporation and Condensation," pp. 66-74 in *Western Snow Conference Proceedings*. Colorado State University, Ft. Collins, CO.