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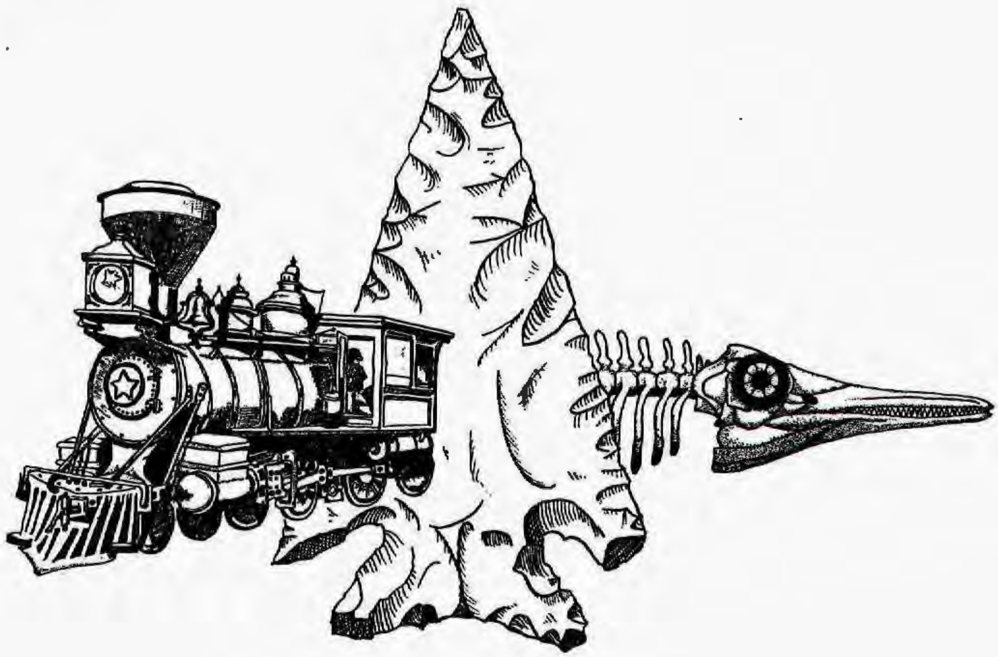

A Cultural Resources Model for Pine Valley, Nevada

by

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Final Report on Department of Energy Agreement DE-FC26-01BC15337

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The work reported here has many roots. Models and spatial hypotheses in management and archaeology have a long, long history. One cannot begin to state the intellectual debts owed.

This project could never have succeeded without the prior work done by David Zeanah and the staff of Intermountain Research. The seminal studies sponsored by the U.S. Fish and Wildlife Service, then by the Naval Air Station, Fallon, provided the impetus for this project. The Bureau of Land Management Railroad Valley planning project is the immediate progenitor of this work. Without the Bureau's initiation of that work, this work would not exist. The Department of Energy made possible this study, a sponsorship and collaboration that could never have occurred without the assistance of the Bureau of Land Management and, especially, the Nevada Division of Minerals.

The staff of the Nevada Division of Minerals were responsible for all of the outreach and public coordination. They did a terrific job. John Snow and Alan Coyner of the Division served as our industry and agency coordinators. Wanda Martin kept the administrative wheels turning at the Division for the project.

The BLM Elko Field Office staff, especially Bryan Hockett and Tim Murphy, were great supporters and helped the project proceed in a rational fashion. The Bureau of Land State Office staff – Dr. Pat Barker and Steve Wells – were instrumental in keeping the momentum of the work moving forward from Railroad Valley. The Nevada Petroleum Society, represented by Jerry Walker, were able and active collaborators in helping us to understand the perspectives of industry. The Nevada State Museum and the Nevada State Historic Preservation Office were, as always, extremely helpful.

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We authors would be remiss if we did not thank the staff members of our respective organizations. This project is theirs too. Only the errors, gaffes, and mistakes are ours.

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CHAPTER 1 – OVERVIEW AND INTRODUCTION

The Pine Valley cultural resources model project is intended to use a combination of scientific modeling, existing archaeological and geological information, and management practice to create tools for managing cultural resources in oil and gas development. The tools consist of information management, planning tools, and management recommendations. The impetus of this project is on-going oil and gas development within the study area, but both the tools and approaches are useful in planning, management, and compliance work on federal lands generally.

The cultural resource management process for post-lease management of an oil and gas development on federal lands can often be a labyrinth (Figure 1.1). For a typical APD or seismic project on federal lands, the process might include:

- an intensive archaeological inventory accomplished by fieldwork
- a preliminary report to federal land managing agency
- further fieldwork and report revisions as required by the agency
- project design changes or fieldwork to mitigate effects
- further review by the agency
- consultation with the state and other agencies
- possible further fieldwork
- report revisions
- project design changes
- issuance of a permit

It is hardly surprising that this process can be unpredictable, expensive, and slow, as the interagency task force on applications for permits to drill found in 1996. The Bureau of Land Management (BLM), Gnomon Inc., and the Nevada Division of Minerals (NDOM), undertook the project reported here to improve the efficiency of this process through appropriate technological and scientific research. The work reported here has been supported by Department of Energy Agreement DE-FC26-01BC15337.

The overall goal of this project is to develop a mode of operation in which the entire process of use of public lands is informed of potential and actual cultural resource values. Through a combination of better information management and predictive modeling, the land use planning process can proceed more efficiently. Essentially, one develops the "best evidence" cultural resource information first, including a model of the likelihood of encountering cultural resources.

After resource modeling and management planning, one could estimate the risk of cultural resources delaying or adding to the expense of a given land use, such as seismic exploration or oil and gas development. In oil and gas settings, this approach can be useful before even bidding the lease. An operator could choose to avoid expensive leasing in areas where cultural resource compliance would be costly or untimely – thus

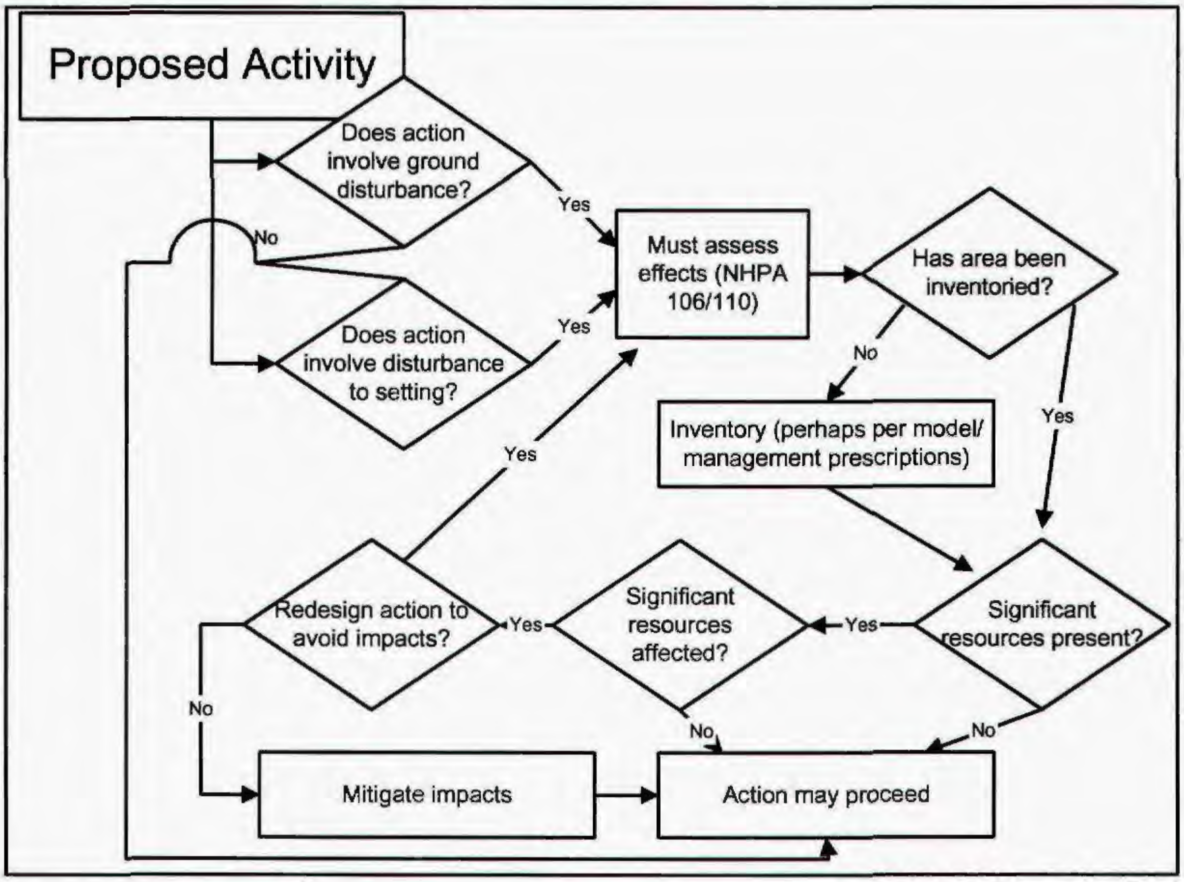


Figure 1.1. Cultural resources investigation and management under Section 106 of the National Historic Preservation Act.

preserving the resource itself. Or, one could identify otherwise less attractive oil and gas targets that have few potential cultural resource conflicts. After a lease is issued, the cultural resource manager in the public land agency can turn to the model to assess whether significant cultural resources are likely to be present in any areas identified for exploration or development, and can also check for nearby known resource-free ground.

If suitable ground is available in the same location, then the project could be redesigned. If cultural resources are likely to be dense and significant, the resource manager can alert the applicant in advance. Finally, if cultural resource likelihood is low then the resource manager may recommend less intense fieldwork. All of these actions streamline the regulatory process, enhancing fossil energy development on public lands and effective environmental protection.

The rest of this report presents an approach that allows regulators and developers to make faster and better leasing and permit decisions. This approach should make public lands accessible to oil and gas operations more rapidly. As well, this process streamlines compliance with environmental regulations by making the regulatory process swifter, more open, and more predictable.

The resource modeling approach outlined here illustrates: (1) the systematic compilation of a large amount of archival field data into an electronic archive; (2) the geomorphic, archaeological, and historical study of areas in the western U.S of interest to oil and gas developers; (3) the creation of a "risk" model for land development related to oil and gas exploration, drilling, or development within the model area; and (4) resource management planning to facilitate development.

THE MANAGEMENT OF CULTURAL RESOURCES

Cultural resources are managed under Section 106 of the National Historic Preservation Act of 1966 (NHPA). Section 106 is deceptively simple. It requires Federal agencies to afford the President's Advisory Council on Historic Preservation (ACHP) the opportunity to comment on any undertakings that could affect significant cultural resources. However, over the last four decades, affording the ACHP the opportunity to comment has become exceedingly complex, costly, and time consuming. Briefly, the process has three phases (Figure 1.1): (1) an identification phase in which the agency attempts to find all significant resources; (2) an evaluation phase in which known resources are evaluated to determine if they are eligible for inclusion on the National Register of Historic Places (NRHP); and (3) a mitigation phase in which impacts to eligible resources are reduced or eliminated.

Due to the historic emphasis on finding and evaluating individual sites, the general lack of systematic cultural resource distribution data, and a generally risk-averse conservative approach among cultural resource specialists and land managers, the Section 106 process is largely reactive. Cultural resource studies are done on a piecemeal basis as each lease, road, pipeline corridor, or other action is proposed and subsequently evaluated. Almost every land development action necessitates field studies that are expensive time-consuming, and unpredictable in their economic and temporal resolution.

In oil and gas development, this process often comes as a "surprise" to the to developer because there were no stipulation or warnings included in the lease package when it was bid, indicating there were or could be significant cultural resources within the leased area that could add to the cost and processing time of developing the lease. If the potential resource conflicts could have been known, then the lessee might have made different leasing choices.

In Nevada for example, the vast majority of land uses proposed annually are subjected to Class III field inventory that is funded by the land use proponent and conducted by a private contractor. In a Class III inventory, the Area of Potential Effect (APE) is inventoried by walking thirty meter transects over the entire area and recording all cultural resources within it. These resources are then evaluated using NRHP criteria and all resources determined to be eligible for the NRHP are "treated" in some manner to reduce or eliminate effects to them. After the contractor conducts the inventory and develops a report, the Federal Agency and the State Historic Preservation Office (SHPO) review the report. The site records associated with the report are filed in a repository and become available for use when evaluating future land use applications after the report is accepted.

This process usually requires sixty to ninety days and costs at least thirty-five dollars an acre. It can take a lot longer and cost a lot more. One of the most frustrating aspects of the current process is its unpredictability. Under current practice it is impossible to predict what types of resources will be found, how long it will take to find them; and what measures will be necessary to mitigate impacts to them. All too often land managers cannot provide a reasonable timeline for processing an application and developers cannot plan necessary actions to implement their development plans. Fortunately, the standard approach is not the only way to comply with the National Historic Preservation Act.

The Section 106 process as currently implemented is not inherent in the NHPA but is a process created through the historic practice of cultural resources managers. This means that the process can be changed to improve its efficiency and predictability significantly, without sacrificing significant cultural resources. One of the ways in which this can be done is by developing landscape-based probabilistic models of past land use and applying those models to develop resource management plans that adjust the amount of required cultural resource inventory to the likelihood of discovering significant resources (Figure1.1). These plans can also be used to inform land-use proponents and managers of the likelihood that operation in a particular place will (or will not) entail significant costs in time or funds.

AN OVERVIEW OF MODEL FORMULATION

The approach reported here begins from an anthropological and geological model of the archaeological record. This scientific model serves as the basis of a management model. The formulation of the models is technically complex; here, we outline their development in simplified fashion (Figure 1.2).

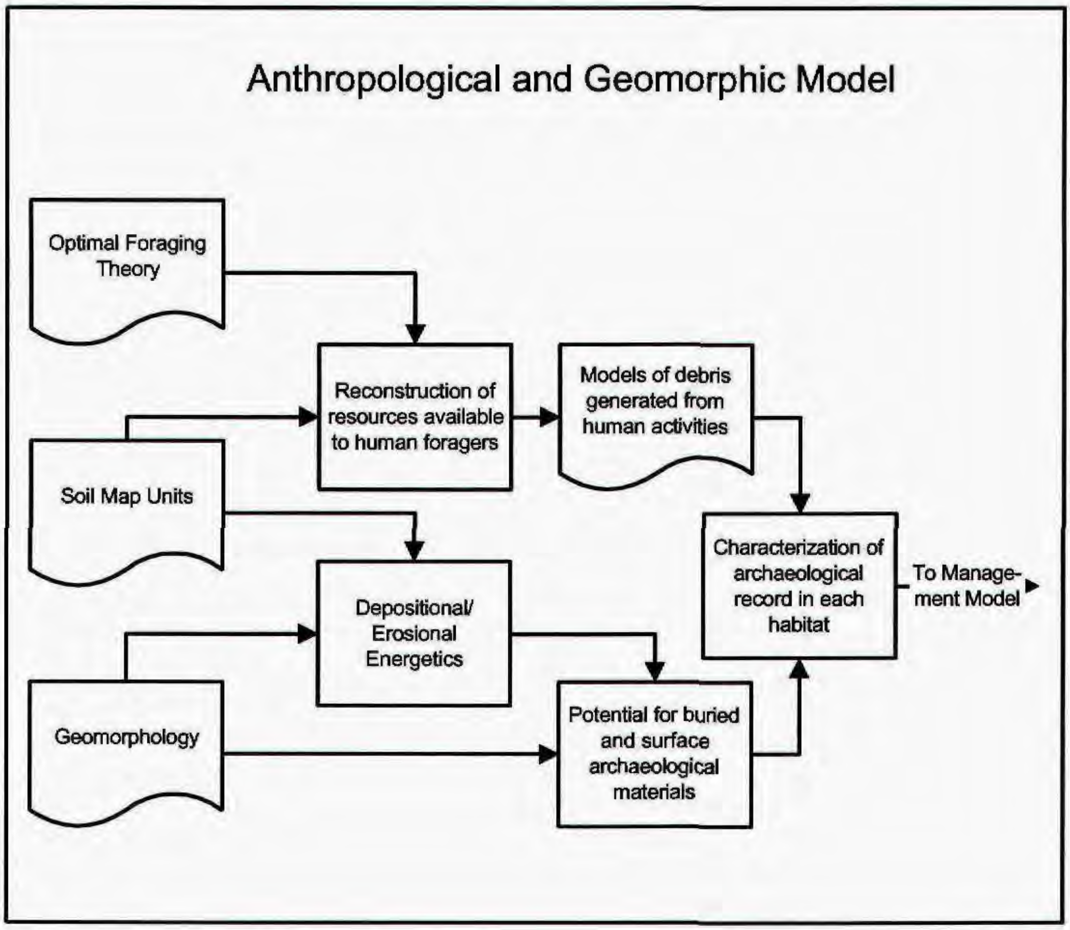


Figure 1.2. Model formulation.

The anthropological and geological model is intended to predict where cultural resources are likely to be found as surface and as buried deposits. Three major components comprise the model: principles of human foraging behavior, reconstruction of past environments in terms of human forage potential within the model area, and consideration of Late Pleistocene and Holocene geomorphology and depositional energetics within the model area.

Human foraging behavior is predicted by ecological theory called optimal foraging theory. To simplify, optimal foraging theory predicts that humans will attempt to maximize net caloric intake and minimize the occurrence of critical ("mortal") risks. To simplify hugely, human foragers (hunters and gatherers) will minimize the risk of starvation and maximize their caloric intake. Humans do this by planning their movement across a landscape based on its resources.

Model formulation measures the potential resources in a landscape based upon contemporary and fossil soils. Soils are the result of climate, geology, vegetative history, and erosion or deposition. Thus, soil types are a good proxy measure of potential vegetation at a particular time. Vegetation, in turn, determines animal life. The model builds upon the soil units an area map of "attractiveness" of different parts of a landscape to human foragers. These are referred to as habitats.

The third component of the anthropological model is the geomorphic history of an area. Erosion and deposition will obscure, remove, or expose archaeological materials. Areas with no surface archaeological materials may contain abundant buried materials; conversely areas with lots of surface material may not contain any buried archaeology. Geomorphology is the "filter" through which the archaeological record is always seen.

These three components are combined to create a predictive model of where archaeological remains should be (a) visible; (b) present, but buried and so invisible; (c) not present. The predictive model also states the kinds of archaeological phenomena that will be found in different habitats. The predictive model is tested using known archaeological information.

A management model (Figure 2.3) uses the anthropological model as its basis. Particular kinds of archaeological phenomena are considered eligible to the National Register of Historic Places. Combining the archaeological predictions of the anthropological model with appropriate contemporary criteria for NRHP eligibility, the "sensitivity" of different habitats is forecast. Areas of broadly similar sensitivity are combined into areas of similar "risk" of encountering National Register eligible sites. There can be different risk characteristics too. For example, because of late Holocene deposits followed by stability, an area may have almost no risk of significant *surface* archaeology, but a high risk of *buried* archaeology.

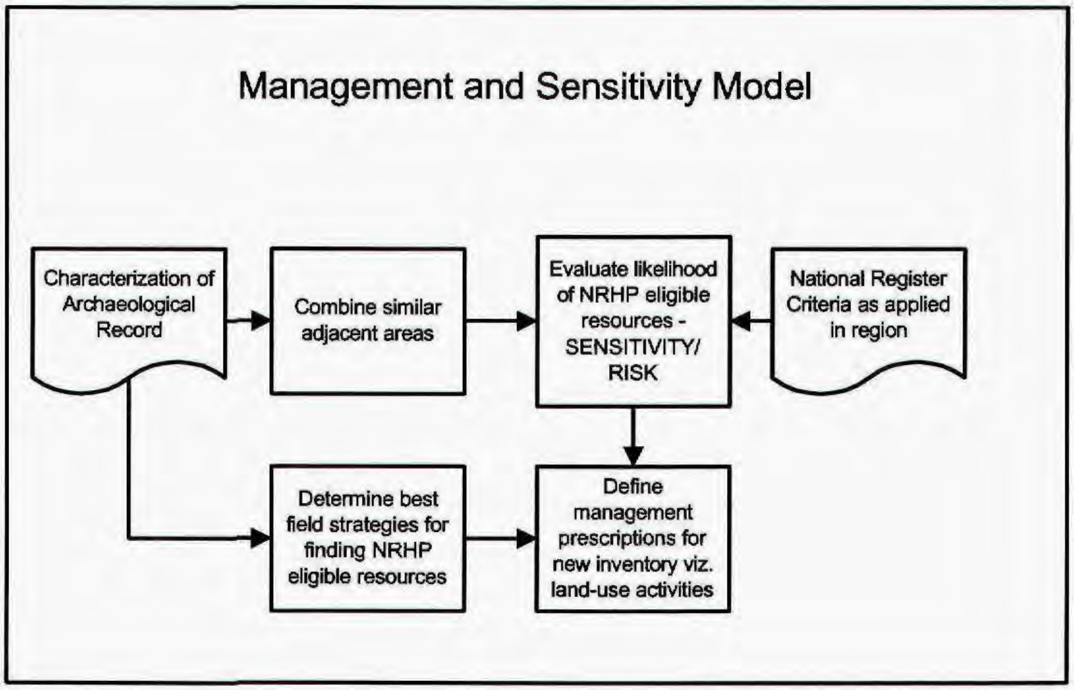


Figure 1.3. Management and sensitivity model.

THE PINE VALLEY STUDY

The study reported here grew out of a previous study in Railroad Valley, Nevada. The Railroad Valley study area encompassed approximately 530,000 acres (roughly 825 square miles) in eastern central Nevada. The Railroad Valley study (Zeanah et al. 1999) was conducted by Intermountain Research on behalf of the Bureau of Land Management. Results of that study were sufficiently useful that there was keen interest in extending the area of study to other oil and gas settings in the Great Basin and, importantly, testing the approach in a different terrain.

The Railroad Valley study resulted in several useful products: (a) a GIS and database of all known cultural resources and cultural resource inventories within the study area; (b) an anthropological model; (c) a management model that predicted sensitivity of particular areas, also mapped within the GIS as management zones; (d) a management plan containing specific protocols for different management zones. The management plan was made effective through review and acceptance by the BLM and by the Nevada State Historic Preservation Office.

The Pine Valley study generates similar products. Unlike the Railroad Valley study, no formal management plan is presented as an outcome of the Pine Valley project. The GIS data and database are available to professional cultural resource managers through the Bureau of Land Management. The anthropological model and general management model are discussed in this report.

The report begins with a consideration of the natural and cultural setting of Pine Valley, Nevada. The presentation turns to a discussion of the model-building methodologies (Chapters 3, 4, and 5), followed by model predictions (Chapters 6 and 7). Finally, we consider the management implications of the Pine Valley modeling exercise.

CHAPTER 2--THE PINE VALLEY MODEL AREA

INTRODUCTION

Pine Valley was chosen for this study largely because of management considerations. From a research perspective, the study area could just as easily have been in a different valley. Although each of the many valleys in the Basin and Range physiographic province has unique features, Pine Valley is similar to many other valleys tributary to the Humboldt River. In this section, the characteristics of the Pine Valley model area are discussed. Many of the features of Pine Valley can be seen in other valleys. Thus, much of the following discussion pertains in some way to other nearby valleys. Unique or different characteristics of Pine Valley are discussed where appropriate.

The environmental setting of Pine Valley is described first. The geography, hydrology, geology, physiography and soils of Pine Valley are described briefly. Next, the regional paleoenvironmental sequence is presented. Against the natural setting, then, the regional and area prehistory, ethnography, and history are sketched.

PROJECT AREA DEFINITION

The project area is located in northeastern Nevada (Figure 2.1). In the southern part of Pine Valley Denay Valley and Garden Valley join Pine Valley. The study area boundary is the Pine Valley hydrographic basin, so Denay and Garden Valleys are part of the study area. Pine Creek is the major hydrographic feature within the project area.

Pine Valley is roughly triangular in shape, with one apex at the northern terminus of the valley where it meets the Humboldt River and two apices at the southwest and southeast valley boundaries. Pine Valley is roughly fifty miles north-south (along its axis), and at the base of the "triangle" approximately thirty miles east-west. The project area covers approximately 1,005 square miles (roughly 643,000 acres or 292,000 hectares). Elevation in the project area ranges from 4840 feet (1475 meters) where Pine Valley Creek meets the Humboldt in Palisade Canyon to 10,133 feet (3089 meters) at Roberts Creek Mountain in the Roberts Mountains. Much of the floor of Pine Valley lies between 6000 feet and 5100 feet (1830 to 1555 meters).

The extreme eastern portion of the project area lies in Elko County with the remainder in Eureka County. More than 82% of the study area is federal land administered by the Bureau of Land Management, Elko and Battle Mountain Field Offices. Private property makes up the rest of the study area. Private land is concentrated in the northern third of Pine Valley, both on the valley floor and to the crests of the Cortez Range on the west and the Pinon Range on the east.

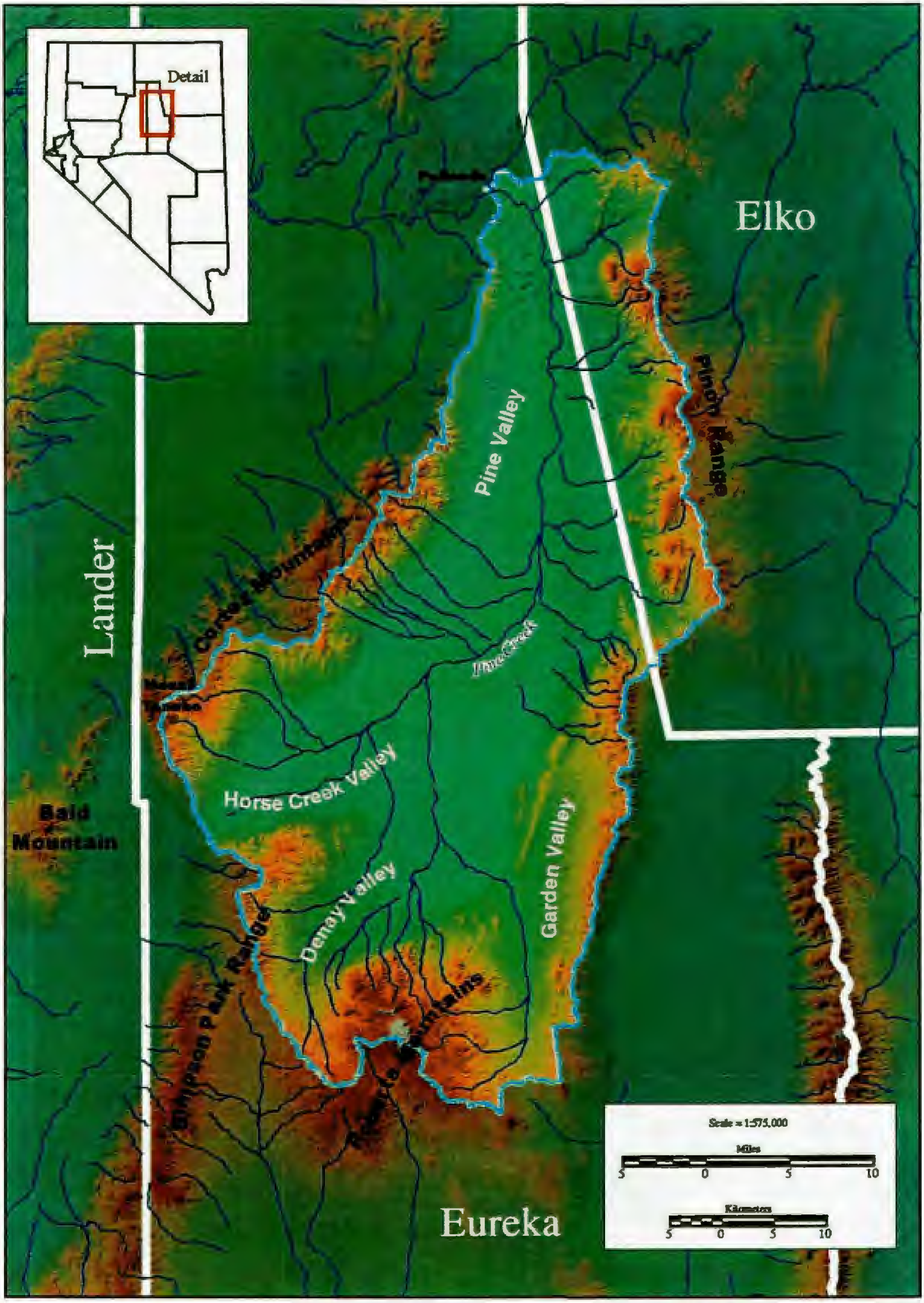


Figure 2.1. Project region map.

GEOGRAPHY

Pine Valley is within the Great Basin section of the Basin and Range physiographic province, an area characterized by "Isolated ranges (largely dissected block mountains) separated by aggraded desert plains" (Fenneman and Johnson 1946: map legend). One can define the Great Basin in many ways: as a hydrographic unit, as a floristic entity, as a physiographic province, and as a Native American cultural area (see Grayson 1993. Pine Valley lies in the center of all of these definitions. Much of the Great Basin (in any definition) is internally drained, with streams never reaching a body of water that connects to an ocean. Geomorphology and climate control the internal drainage patterns. Internally drained and sediment-filled basins within the Basin and Range province are termed "bolsons". Bolsons are down-dropped blocks surrounded by uplifted blocks. The don-dropped block forms an internal, closed, basin. Pine Valley is a semi-bolson, for it is externally drained. The accumulation and connection of surface waters is a function of geomorphology and climate. Evidence of shallow lakes, regional lakes, and changes in drainage pattern are indicators of climatic changes that occurred in the past.

Adjacent bolsons contained lakes during the Pleistocene (more than 10,000 years before present)(see Figure 2.3). Grass Valley, to the south-southwest of Pine Valley contained Pleistocene Lake Gilbert. To the east, across the Sulphur Springs Range, Diamond Valley contained Pleistocene Lake Diamond. Both Grass Valley and Diamond Valley contain playas and probably have a history of limited, shallow, open water during the past 10,000 or so years. The greatest lakes in the basin and range province were on the western margin (Lake Lahontan) and eastern margin (Lake Bonneville). The smaller bolson lakes adjacent to Pine Valley were never part of these large lake systems.

Pine Valley is bounded by parallel mountain ranges to the east and west (see Figure 2.2). The north-northeast trending Cortez Mountains (maximum elevation 9162 feet at Mount Tenabo) form the western boundary of the basin. To the east, lie the extremely narrow, steep, north-south trending Sulphur Springs Range (maximum elevation 8168 ft. at Coffin Mt.). The northeast part of the Pine Valley hydrographic basin is formed by the Pinon Range (maximum elevation 8170 feet at the Ravens Nest). The crests of the Cortez and Pinon Mountains are less than 9 miles apart in northern Pine Valley. Pine Creek exits the valley through a canyon between the two ranges, debouching into the Humboldt River near the head of Palisade Canyon. (Palisade Canyon is itself cut through the Cortez Range.)

The southern margin of Pine Valley is formed by the Roberts Mountains (maximum elevation 10,133 ft. at Roberts Creek Mt.) and by the northernmost portion of the Simpson Park Mountains (maximum elevation 7628 ft. at Twin Peaks).

Passes are an important feature of the valley's geography, for mountain slopes are steep and rocky. The pass (5980 ft.) between the Cortez Mountains and Twin Peaks separates Pine Valley from Grass Valley to the south-southwest. The next pass to the east (6938 ft.) is formed between Twin Peaks and the Roberts Mountains. It divides Pine Valley from Monitor Valley to the south. Finally, the easternmost pass (6700 ft.) is situated

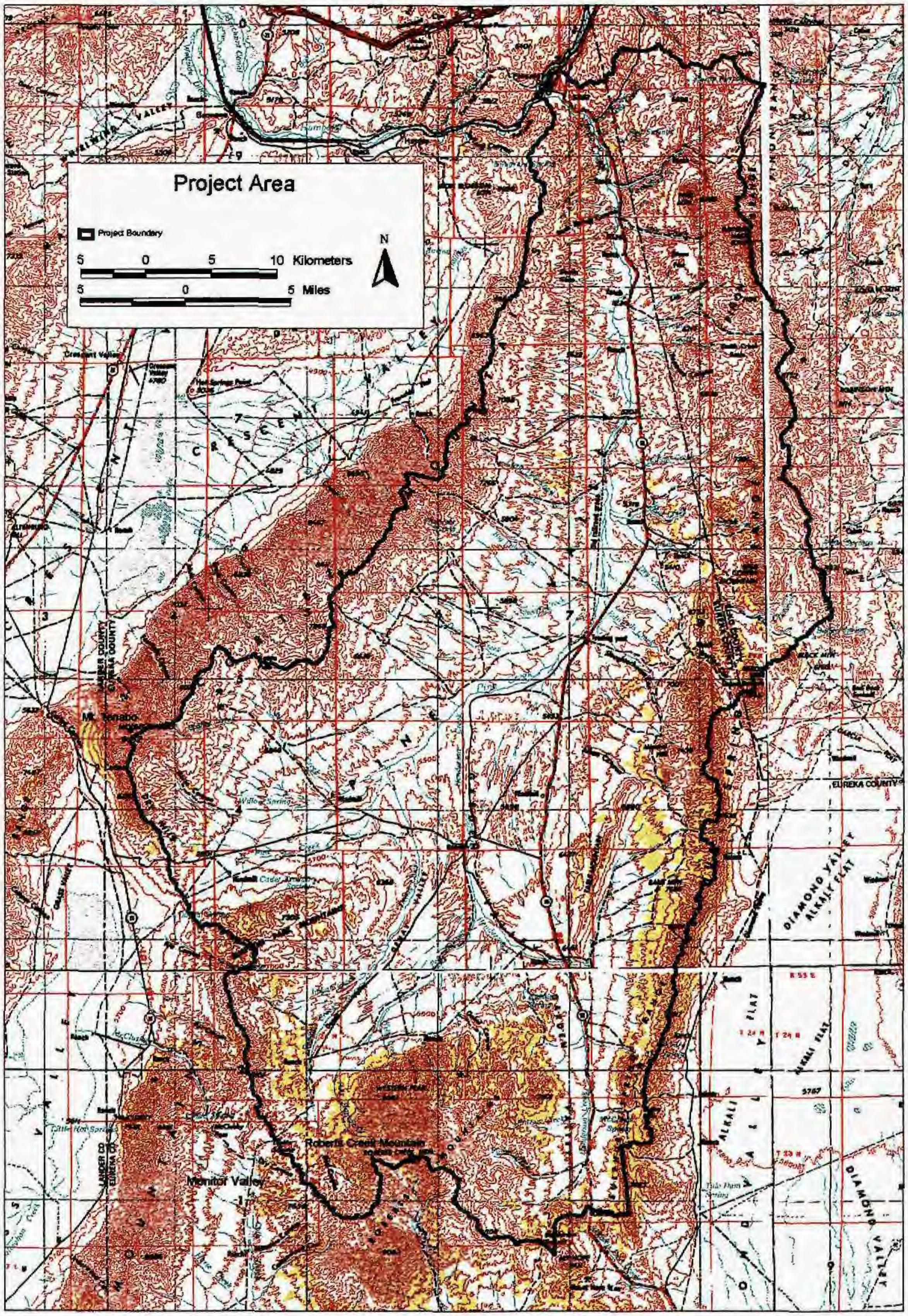


Figure 2.2. Project Area.

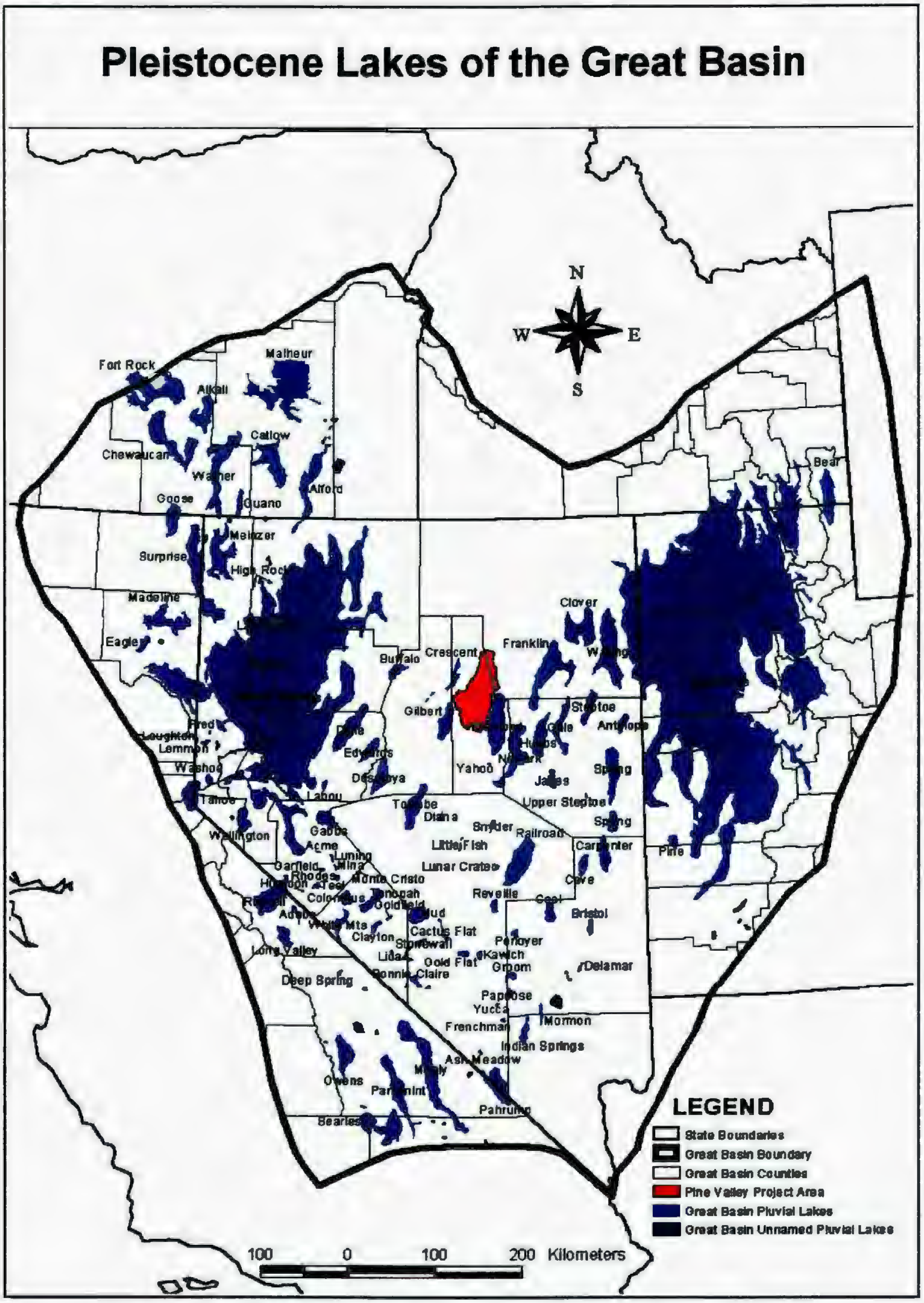


Figure 2.3. Pleistocene lakes of the Great Basin (after Mifflin and Wheat 1979 and King 1975).

between Roberts Mountain and the southern portion of the Sulphur Springs Range and forms the divide between Pine Valley and Kowh Valley.

GEOLOGY

The mountain ranges mentioned above are, for the most part, bounded by normal faults. The ranges are composed of Paleozoic, Mesozoic, and early Cenozoic sedimentary and igneous rocks (Figure 2.4). As described by Smith and Ketner (1975), the exposed Paleozoic rocks in the area are Ordovician through Permian-age and were deposited in a broad geosyncline. These sediments included an eastern carbonate and a western siliceous/volcanic assemblage, both of predominantly marine origin (Roberts et al. 1967). Evidence for at least two Paleozoic episodes of uplift are preserved in these rocks. Of particular note are Middle Paleozoic compressional tectonics which caused considerable uplift and deformation including thrust-faulting (Roberts Mountain Thrust - early Mississippian (Coats 1987). Compressional deformation renewed during the Mesozoic (Smith and Ketner 1976) when marine deposition ended, probably during the Triassic. Volcanism predominated during the Jurassic. Broad basins formed in the greater Pine Valley region during Cretaceous through early Tertiary time when a variety of lacustrine and terrestrial sediments were deposited including non-local tephra (Smith and Ketner 1976). Thick deposits of poorly sorted gravel dating to this era are present in the Cortez Mountains (Roberts et al. 1967). Local volcanoclastic rocks began to be deposited along with other basin fill by the late Eocene/early Oligocene.

By mid-Tertiary Miocene times, tensional deformation began to predominate, resulting in the formation of the normal faults that outlined the present-day mountain/basin structures. Early basin fill sediments (Carlin Formation - Miocene) included many aggraded, ash-rich units. Some of these are now uplifted on the flanks of the mountains. Continued normal faulting along with tilting (predominantly to the east), steepened the western flanks of the mountains and deepened the basins (Roberts et al. 1967). The younger Plio-Pleistocene Hay Ranch Formation formed within the confines of the more restricted present-day basin and it consists of fanglomerates and conglomerates along the mountain fronts (Roberts et al. 1967) with finer textured lacustrine and ashy/tuffaceous sediments in the interior of the basin (Smith and Ketner 1976). The more resistant lithologies within the formation support ridges and benches in the basin, some of which are abandoned basin-floors.

During the past million years (the Pleistocene), the formation of pediments of these sediments has occurred. Deposition of alluvium, fan sediments, and slope deposits (Regnier 1960) has continued. Quaternary tectonic activity is the main controlling factor on the erosion of the basin (Coats 1987; Regnier 1960) including the development/preservation of aggradational landforms such as fans and terrace treads.

From an archaeological standpoint, this geologic history yielded several important sources of stone for prehistoric tools (Turner et al. 1984). Lower Mississippian rocks contain cherts, quartzites, and siliceous argillites that crop out extensively in the Pinon Range. Mesozoic and Tertiary intrusions led to hydrothermal alterations of host rocks that produced, not only extractable ore deposits, but also siliceous sinter that formed

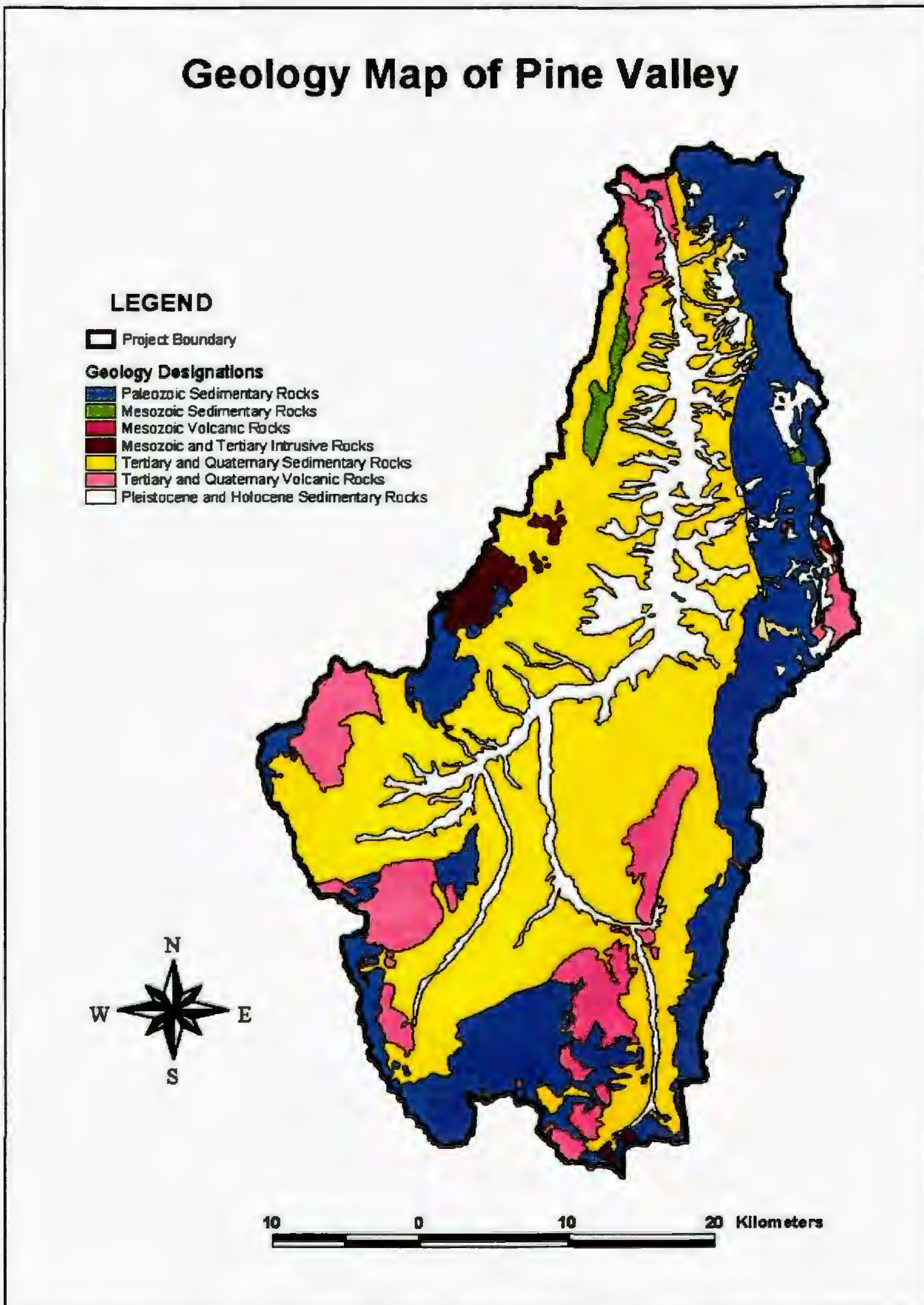


Figure 2.4. Geologic map of Pine Valley (Data from Coats 1987 and Roberts et al. 1967).

cherts on the southeastern flank of the Cortez Mountains. See Figure 2.5 for the distributions of potential bedrock sources of chipped stone raw material.

HYDROLOGY

The major hydrologic feature in the Pine Valley hydrologic unit (USGS hydrographic unit code 16040104) is Pine Creek. Pine Creek is a tributary to the Humboldt River. The Humboldt heads in eastern Nevada along the western flank of the Ruby and Snake Mountains then drains westward across much of northern Nevada. Tributaries to the Humboldt flow both south and north to the river from the parallel trending, fault-block valleys. Pine Creek is one of the north-draining tributaries.

Numerous small drainages from the surrounding mountains feed Pine Creek (Figure 2.5). Perennial springs can be found along the mountain slopes and on the valley floor. Some of these small tributaries are considered to have perennial reaches according to the Environmental Protection Agency BASINS and National Hydrologic Data datasets. At the southern, or upper, end of the valley: Henderson Creek, Pete Hanson Creek, and Denay Creek have perennial reaches. In the northeastern part of the valley, Trout Creek, Ferdelford Creek, and Cole Creek are said to have perennial flow in some parts of their beds. One must consider carefully the nature of "perennial" in regard to all of these streams: Pine Creek itself is perennial only in its northern, lower, reaches. Long-term records from the USGS gaging station (number 10323000) at the mouth of Pine Creek show that on average March and April are the months of greatest flows of 30 to 40 cubic feet per second (cfs) and July through September have the least flows of 2 to 3 cfs. Some years have had flows as little as 0.1 cfs at the mouth of Pine Creek -- less than a washroom faucet. Historically, some low-ground in the northern part of Pine Valley was probably seasonal marsh, since General Land Office plat maps from around 100 years ago depict marshy areas.

LANDFORMS

Various landforms are characteristic of semi-bolsons within the Great Basin. Peterson (1981) has devised a classification system for these landforms. The classification system divides the semi-bolson into major physiographic parts that include the bounding mountains, piedmont slopes, and the basin floor (Figures 2.7 and 2.8).

Bounding Mountains

The bounding mountains form the hydrologic boundaries of the semi-bolson. Within Pine Valley, the bounding mountains are composed of a highly deformed mixture of intrusive and extrusive volcanic rocks, pre-Cenozoic detrital rocks, and chemically precipitated rocks. Ridges, steep slopes, and narrow canyons are the most common landforms.

Piedmont Slopes

The primary geological processes operating within Pine Valley at the margin of the mountains and the basin are intermittent stream channel transport, debris flow deposition, slope wash, and sheetwash. These processes have led to alluvial fan formation. Periods

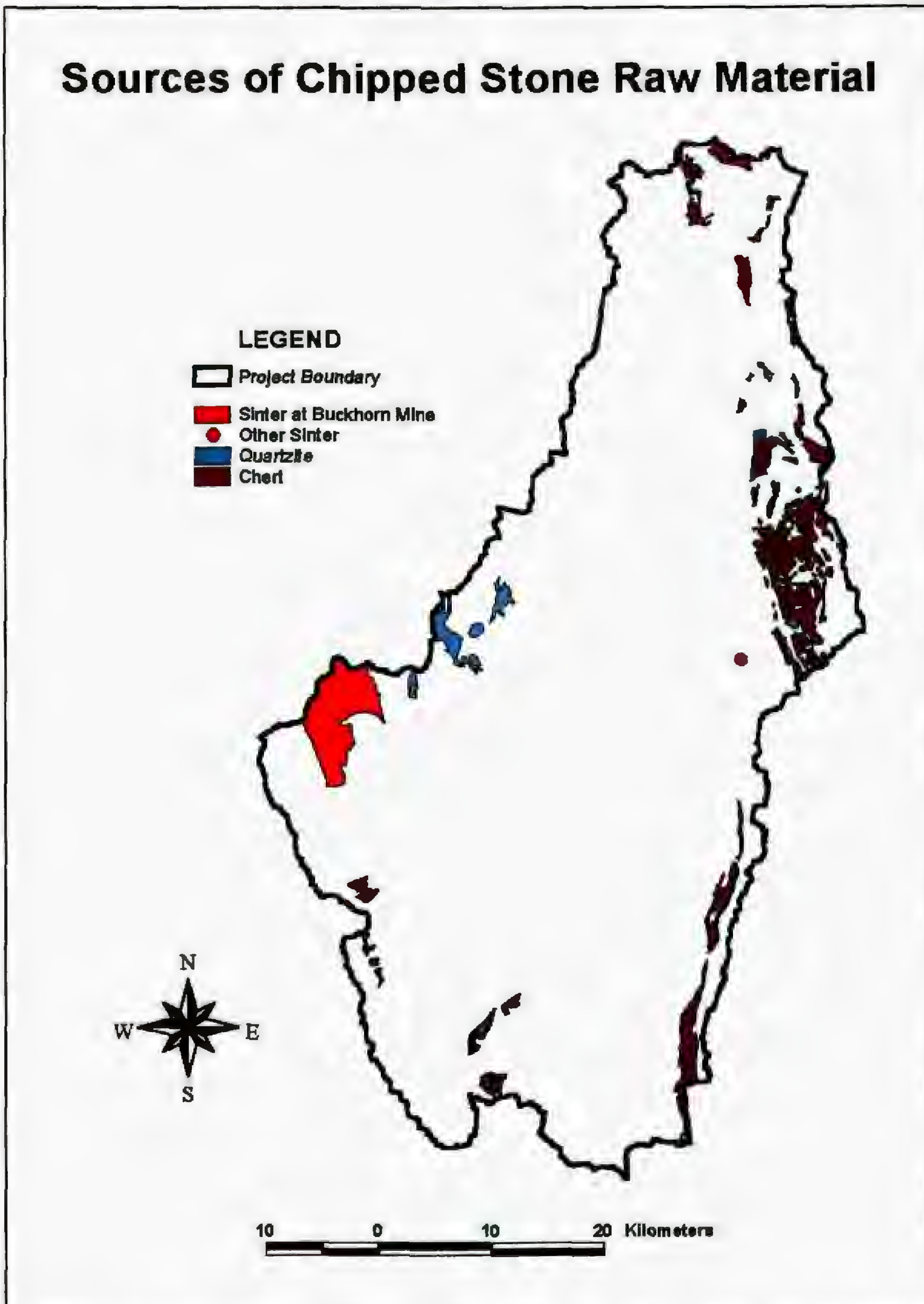


Figure 2.5. Bedrock sources of chipped stone raw material (Data from Coats 1987 and Roberts et al. 1967).

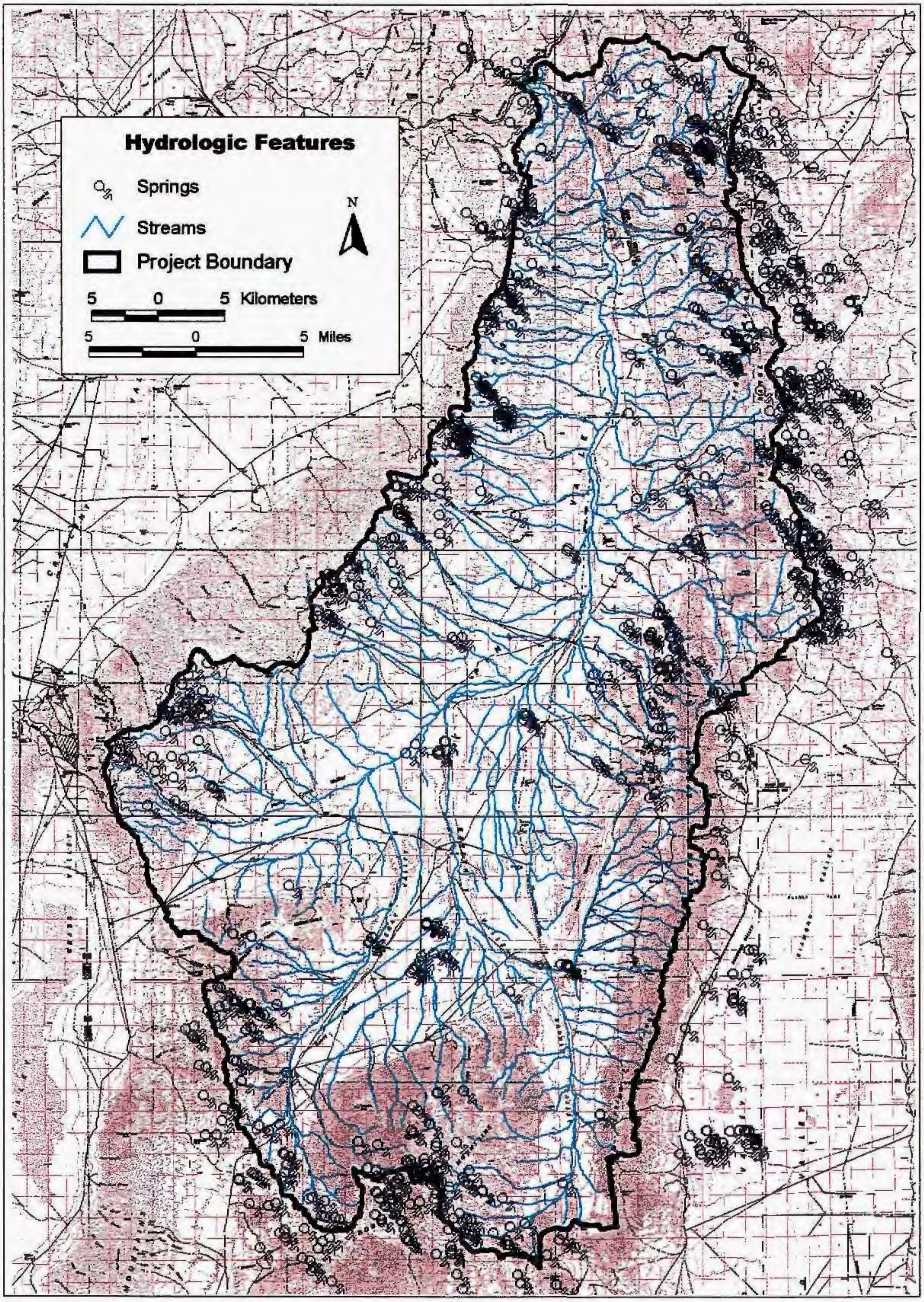
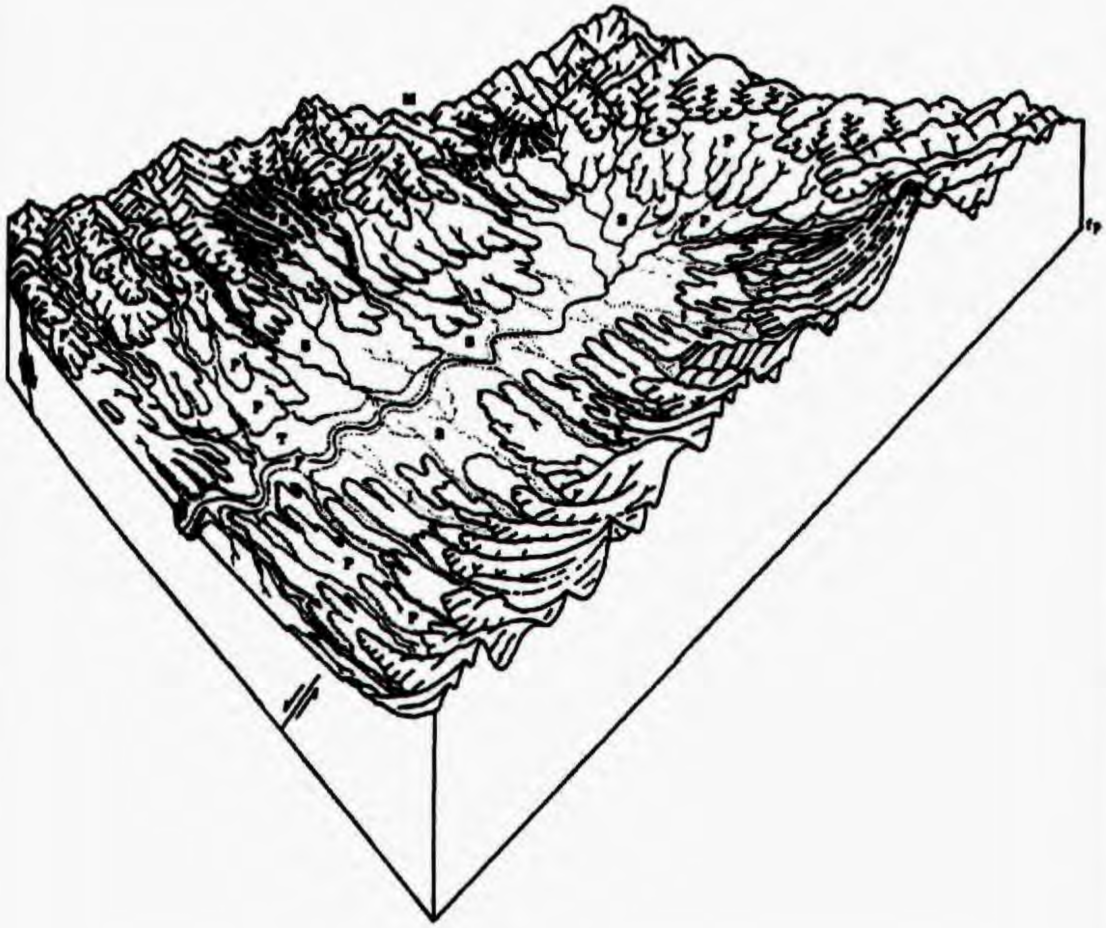
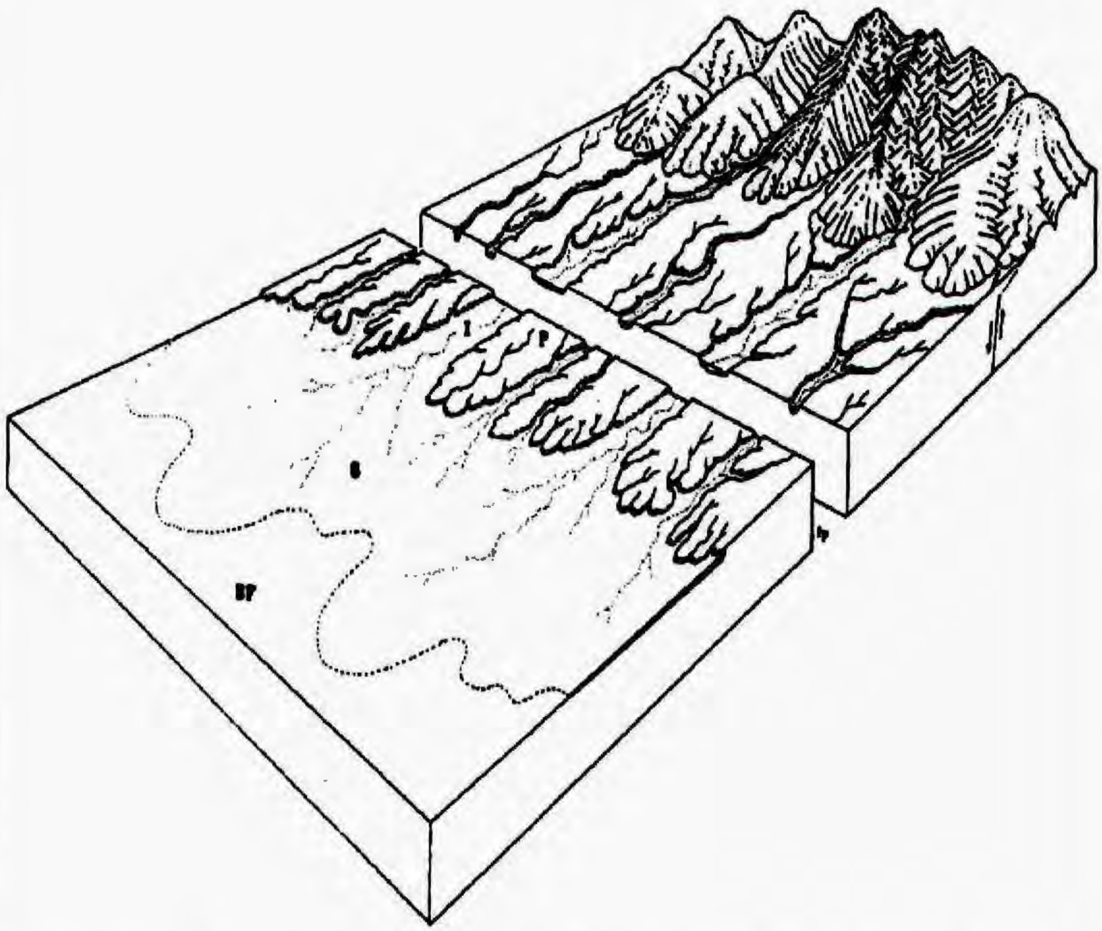


Figure 2.6. Pine Valley hydrology.



"A semi-bolson that displays the effects of several cycles of dissection and deposition. The major landforms are: ballenas (B), fan skirts (S), an axial stream terrace (T), and an axial stream flood plain (F). Aluvial fans are not distinguished from fan piedmonts. Component landforms of inset fans (I) are between fan remnants. The basin is bounded on two sides by mountains (M)."

Figure 2.7. Features of a semi-bolson (after Foster 1989:Figure 2; modified from Peterson 1981).



"A fan skirt (S) that merges along its lower boundary with a basin floor (BF) and that was formed by coalescing alluvial fans originating at gullies cut in a dissected fan piedmont (P) remnants and mouths of the inset fans form the upper boundary of the fan skirt. It is the same age surface as the inset fans, but is younger than the relict summits of the fan remnants. It may be the same age or younger than the basin floor surface, but as shown here it is younger because its alluvium overlaps the basin floor surface."

Figure 2.8. Features of a fan skirt (after Foster 1989:Figure 3; modified from Petersen 1981).

of active alluvial fan formation produced extensive coalescent fans or bajadas. As well, in past times (Plio-Pleistocene), Pine Valley was a closed basin providing accommodation space for the aggradation of lake sediments within the central basin. Together, these deposits formed the Pleistocene basin fill within Pine Valley. Tectonic activity has provided the opportunity for this ancient fill to be dissected and for younger fill (mostly alluvium and fan deposits) to be inset below the older bajada surfaces/basin floors. In this way, the piedmont slopes have formed. Piedmont slopes can be divided into several distinct major landform components including alluvial fans, ballenas, and fan piedmonts.

Alluvial fans are convex in cross section and cone-shaped in plan view with their apex upstream, often extending into a canyon mouth. Ballenas are "...distinctively round-topped ridge line remnants of fan alluvium. The broadly rounded shoulders of the ridge meet from either side to form a narrow crest and merge smooth with the concave back slopes. In ideal examples, the slightly concave foot slopes of adjacent ballenas merge to form a smoothly rounded drainageway." (Blackburn 1997:891). Piedmont fans are often composed of coarse gravelly material (large cobbles and boulders). Generally, the material composing piedmont alluvial fans is coarser than is currently being deposited suggesting to some investigators that they formed within pluvial eras (Pierce and Scott 1982). Very ancient piedmont slopes sometimes overlie, or are themselves composed of, older basin fill that includes volcanoclastic and lacustrine basin fill as well as ancient conglomerates and fanglomerates.

Fan piedmonts are fan remnants which are incised along the central portion of drainage-ways emanating from canyon mouths, but which are preserved and still abut the bounding mountain front between adjacent canyon mouths. Fan piedmonts are often stair-stepped exhibiting a sequential series of younger to older incised fan surfaces. Incision was probably partially controlled by uplift, however, entrenched channels suggest horizontal corrasion by relatively competent streamflow which could probably occur only during pluvial eras. This would suggest that fan building and piedmont incision reflect two distinct hydrologic regimes within the Pleistocene (Peterson 1981).

Fan Skirts

Fan skirts are composed of younger sediment deposited at the terminus of the piedmont slope. It is generally much finer than the bouldery material composing the piedmont slope. Fan skirts are composed of inset fans at the floor of channels entrenched into the fan piedmont and of broad fan aprons spreading out from the terminus of the entrenched channels. Fan skirts are low-angle aggradational surfaces built mostly by intermittent sheet floods. For the most part, fan skirts are post-Pleistocene in age. Sometimes subtly different ages of fan skirts can be identified. The fan skirts of different ages probably show Holocene changes in hydrological regimes and tectonic movement.

Basin Floors

Basin floors can be divided into alluvial flats, alluvial plains, and axial stream flood plains. An alluvial flat is a lower angle, extension of the fan skirt. As with the fan skirt, sometimes several subtle geomorphic surfaces can be identified. When several surfaces are identified, the upper surface is termed an alluvial flat remnant and the active surface is the alluvial flat. An alluvial plain is generally continuous with the alluvial flat and situated between it and the inset terraces of the modern stream. Often, alluvial plains formed as the most extensive postglacial-era basin floor and aggradational surface. In the project area, when tephra from the eruption of Mount Mazama is present, it underlies the alluvial plain surface. This indicates that the deposits which form the alluvial plain aggraded through the middle Holocene. The modern channel of Pine Creek and any low, late Holocene terraces are inset within this alluvial plain in what can be considered the flood plain.

SOILS

Soils within the project area (Figure 2.9) vary from deep, young, well-watered soils of alluvial floodplains (Aquents) such as those that occur along Pine Creek to more mature and drier upland soils in the surrounding mountains (Haplargids) (Blackburn 1997; Foster 1989).

Soils along the bottomlands of Pine Valley stand out as a distinct, north to south-southwest trending band of well-watered, young, soils developed in floodplain alluvium derived from ash-rich parent material. On poorly drained locations, soils are mostly Aeric Halaquepts (Figure 2.9: Designation A). These formed in sodic parent material and exhibit alkali characteristics. On more well-drained locations where parent material is rich in pyroclastic sediment, Durorthidic Torriorthents have formed (Figure 2.9: Designation A). These soils contain a horizon weakly cemented by silica.

Next to the bottomlands, adjacent fan skirts and inset fans contain Durorthidic Xeric Torriorthents (Figure 2.9: Designations B, D) and Xerollic Haplargids (Figure 2.9: Designations F, K, L, M). The former soils are found on younger parent material and are similar to the better-drained floodplain soils. The latter soils are on older materials. The Haplargids have a subsurface zone of illuvial clay accumulation as well as some silica cementation.

On the older, higher, portions of the valley fans soils differ depending upon the parent material. On the west side of the valley the parent material is sodic and the resultant soils are primarily Xerollic Natrargids (Figure 2.9: Designation E). These lie on fan piedmont remnants and contain a zone of sodium-influenced illuvial clay accumulation. Soils on the east side of the valley, formed mostly in pyroclastic rich sediments, are not as sodium enriched. These soils (Xeric Torriorthents and Durorthidic Xeric Torriorthents) are poorly horizonated, with weak silica cementation. They lie on low hills and some inset fans (Figure 2.9: Designations B, D).

Steep, shallow, and rocky soils dominate on the adjacent mountains. The steeper areas are heavily eroded and only weakly horizonated soils form Torriorthents (Figure 2.9: Designation G). Areas with significant orographic precipitation support soils which have well-developed Xerolls and humic A horizons. In these settings,geomorphically stable locations often have both A horizons and clay-enriched B horizons (Argixerolls) Torriorthents (Figure 2.9: Designation H, I, J).

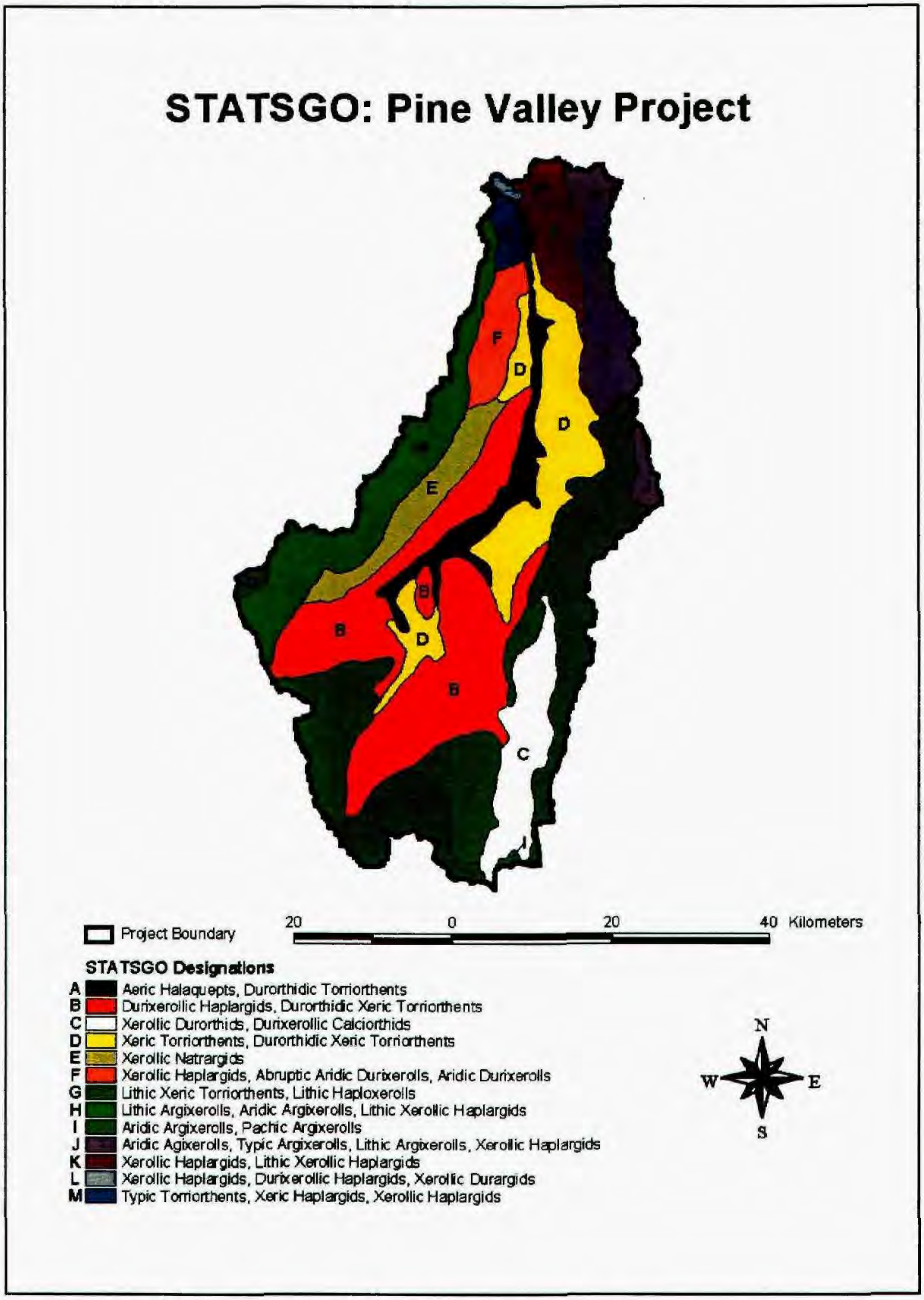


Figure 2.9. Soil map of the Pine Valley vicinity (Data from Soil Conservation Service 1994).

PALEOENVIRONMENTAL CONTEXT

Pine Valley has not always been as we see it today. During the time of human occupation of North America, for approximately fourteen thousand years, the earth's climate has changed in may different ways. Climate changes induce other environmental changes. These include changes in plant communities, concomitant changes in the animals that one way or another depend upon plants, and differing mixes of geomorphic processes in Pine Valley. Understanding the prehistory of Pine Valley necessitates, then, some consideration of its paleonvironmental history for this would have affected human use of the valley and how archaeological sites have formed or been destroyed.

Cyclical changes in the geometry of the earth's orbit are thought to be a primary cause of climatic change (Imbrie and Imbrie 1980). Changes in orbital geometry (axial tilt, precession of the equinox, and orbital shape) cause variation in the amount of solar radiation the earth receives. This forces the earth's atmosphere to behave in a predictable manner. Initial results of models comparing orbital geometry and climatic data suggest reasonable agreement between the model's predictions and the paleoenvironmental record (COHMAP Project Members 1988; Thompson et al. 1993; Davis and Sellers 1994). Paleoclimatic models predict the position of the jet stream, the strength of the summer monsoon over western North America, the positions of cyclonic and anti-cyclonic activity, annual surface temperature, and annual precipitation from 18,000 to 6000 years BP (before present).

As mentioned above, Great Basin pluvial lakes are especially important proxies with which such models are tested. Isotope data from 5500 BP to the present generally suggest that levels of Pleistocene Lake Bonneville were at maxima when winter precipitation dominated and westerly flow patterns similar to those that exist today, were prevalent. Lake level minima occurred when summer precipitation dominated and Mexican monsoon circulation from the southeast was strengthened (McKenzie and Eberli 1987). It is likely that such patterns existed prior to 5500 BP as well, at least for the Holocene era. It may take less than a decade to change from the steady-state conditions of one millennial-scale cycle to another. Such a change in climatic regime could thus be experienced within an individual's lifetime (Madsen 2000).

The summary of regional environmental history below utilizes information and conclusions from a wide variety of sources. Like all historical studies, the study of past environment necessarily depends upon a complex web of evidence, sound interpretation, and conjecture. Where reasonable or necessary to do so, we have highlighted different interpretations of paleoenvironmental history, although it makes a more complicated exposition.

Contemporary climate data demonstrate that environmental change can be regional or even sub-regional in scale. Some of the complexity in interpretations of past environments is no doubt due to different regions varying in their environmental records. For Pine Valley, the best evidence for Pine Valley paleoenvironments would be found in the valley. However, there is relatively little available paleoenvironmental information for Pine Valley. Instead, we rely mostly upon nearby and regional data. We rely to a somewhat lesser extent, on the interpretation of regional data.

Paleoenvironmental history, like human prehistory, can best be presented understood in periods of time. However, the use of time periods does not imply marked boundaries between each period. The limits of dating events in the past and the nature of climatic (or even human behavioral) phenomena dictate that the boundaries between periods be considered quite broad and gradual.

Full Glacial Period (18,000 - 15,000 BP)

The general-circulation model (COHMAP Project Members 1988) for the last glacial maximum (around 17,000 BP) predicts that the jet stream was split around the Laurentide Ice Sheet with a southern stream-arm depressed far below the present jet stream position. This is thought to have resulted as strong anticyclonic circulation developed over the ice sheet producing cold, dry, easterly, summer winds over the project region. This hypothesis is currently being tested using paleocirculation data from the Bonneville Basin (Jewell et al. 1998). Winters were probably no colder than at present, but seasonality was much reduced resulting in colder summers. Annual temperature in the study area was 8-10° C colder than present. The summer monsoon was absent and the Pacific subtropical-high was very weak. Cold, dry conditions are predicted for the study area. The simulation produced by Davis and Sellers (1994) generally agrees with this representation, except that they predicted summer precipitation to have been considerably higher than it is today (up to 4 mm/day) and that most of the precipitation was drawn from the Pacific Ocean by summer westerlies.

During the height of glaciation, around 17,000 BP, the project region was in proximity to locations of mountain glaciers (Currey and James 1982). Mountain glaciers were active in the Ruby Mountains (Porter et al. 1983), continental glaciers were present on the Great Plains 800 km (497 mi) northeast of the project area (Andrews 1987), and permafrost was present to the north and east (Péwé 1983). Streams had higher capacities and competencies (Baker 1983; Schumm and Brakenridge 1987). Steppe tundra may have existed on the Snake River Plain (Wells 1983) and Wyoming Basin (Mears 1981) during this time, supporting a variety of Pleistocene megafauna. Megafauna included muskox, mammoth, camel, Pleistocene bear, Pleistocene bison and horse (Grayson 1991). Some of these species have been found in Mineral Cave within the project area (Bryan Hockett, personal communication 2001).

Lake Bonneville was filling by 18,000 BP but remained well below the Wisconsin (Bonneville shoreline) maximum, though alpine glaciers in the western edge of the Great Basin were near their late Wisconsin maxima. Stratigraphic studies and radiocarbon dates indicate that lake maxima typically lagged behind alpine glacial maxima by several thousand years (Thompson et al. 1993). The cold climate resulted in low evaporation rates that were responsible for the growth and high stand of Lake Bonneville during the full glacial period (Currey 1990; Currey and James 1982).

Lake Lahontan reached a highstand around 18,000 BP, rising as the climate became colder (Davis 1982); not all Pleistocene lakes of the Great Basin rose and fell at the same time due, it is believed, to variability in storm track direction and polar front position. There is some variation in dates with Lake Franklin reaching a highstand at 18,500 BP to 15,070 BP (Elston 1999; Rhode 1998).

Deglaciation (15,000 - 11,000 BP)

Around 15,000 BP, changes in the geometry of the earth's orbit and axial tilt initiated a warming trend according to COHMAP Project Members (1988). As a result, seasonality started to become more pronounced and the split jet stream shifted northward. The Pacific subtropical-high, and the monsoon were still weak and precipitation remained low. Due to summer warming, evapotranspiration began to increase so conditions became dryer. Simulations performed by Thompson et al. (1993) agree that temperatures were rising in the western United States, but predict that stronger-than-present westerlies during winter would probably have kept precipitation levels above those of the present.

Much of the regional data is in close agreement with the predictions. By 14,000 BP, the once- extensive ice cap on Yellowstone Plateau had disappeared (Richmond 1986) and mountain glaciers in the Rocky Mountains receded (Porter et al. 1983). Rapid deglaciation of the Laurentide and Cordilleran ice sheets occurred after 13,000 BP (Teller 1987). During the same period, the extensive pluvial lakes in the Great Basin, including Lake Bonneville, shrank to post-glacial low levels (Currey 1990). Alluvial systems were in a period of major readjustment following the cessation of glacial outwash (Schumm and Brakenridge 1987). A wide variety of now-extinct Pleistocene megafauna were present, including bison, mammoth, horse and camel (Grayson 1991).

Haynes (1990) suggests that a millennium of severe drought occurred between 12,000-11,000 B. P. Lake Bonneville may have been lower at 12,000 BP than at any time in the post-glacial/Holocene era, including the Altithermal interval (Murchison 1989). This late Pleistocene drought coincides with the first human presence in western North America (Haynes 1990) and also with the extinction of the Pleistocene megafauna (with the exception of bison) (Grayson 1991). Elston (1999) reports that many animal species were on the decline due to the volatility of the climate affecting the distribution and extent of marshlands and lakes when human hunters appeared about 11,500 BP

Much of the data from this period is contradictory, however. Deposition of "red beds" (oxidized sediments) along with mirabilite around the Great Salt Lake suggest that temperatures were cool and dry during the low lake period (Currey 1990; Thompson et al. 1993). Hydrogen isotope ratios from cellulose in pack rat (*Neotoma*) middens west of the Salt Lake valley suggest significant shifts in climate patterns, probably reflecting cooler temperatures and more winter-dominated precipitation between 14,000 and 11,000 BP, though plant macrofossil assemblages from these middens changed relatively little (Thompson et al. 1993).

Midden data west of the Great Salt Lake, studied by Rhode and Madsen (1995), represent a suite of flora and fauna that are typical of cool and dry conditions from 14,000 to

10,800 BP. South of Railroad Valley, in the Pahranagat Range of Nevada, limber pine grew at 1500 m asl (4921 ft) suggesting summer temperatures quite a bit lower than today during 13,000 to after 11,000 BP (Elston 1999). Freshwater fish remains were found in the West Desert portion of the Great Salt Lake basin, suggesting that a large, cold, relatively freshwater lake existed until shortly before 11,300 BP Pollen (Madsen and Currey 1979; Spencer et al. 1984) and wood remains from lake sediments in the northeastern Bonneville basin (Scott et al. 1983) suggest the possibility that the Wasatch Front supported coniferous forests, indicating a cooler, wetter environment. This may have been a result of lake effects and orographic effects which can cause an increase in precipitation (Rhode and Madsen 1995).

Overall, the paleoclimate of this time remains unclear. The region was probably quite dry, as extreme desiccation did occur sometime during this period, and precipitation that did occur was probably winter dominated. Temperatures may have been either cool or warm compared to today. Rhode and Madsen (1995) suggest that the post-Provo regression may have been prolonged until after 12,000 BP, with the cycle of regression and then transgression to the Gilbert level restricted to a relatively narrow span of time (between 11,500-10,500 BP). It is likely that the Wasatch Front received more precipitation than much of the Great Basin.

Terminal Pleistocene/Holocene Transition (11,000 - 9000 BP)

Although ice sheet size and shape affected jet stream movement during the last glacial/deglacial cycle, by 11,000-10,000 BP its influence had diminished and the summer and winter positions of the jet stream had become similar to those of today (Benson et al. 1990). The climate simulations of Thompson et al. (1993) predict that winter precipitation and temperatures 9000 years ago differed little from the present. Summer temperatures and insolation were predicted to be greater than they are today in the western United States. The COHMAP model (COHMAP Project Members 1988) predicts that by the end of the Pleistocene, summer insolation and seasonality were at post-glacial maximum values and temperatures were generally 2-4° C higher than today. This caused the jet stream to rejoin and continue a northward migration which, in turn, produced a strengthened monsoon.

Under modern conditions the shift of the jet stream, northward in the summer and southward in the winter, produces seasonal patterns of precipitation in the western United States. In the winter the jet stream is positioned over the northern tier of the western states. Pacific storms track the jet stream inland and drop their moisture over the middle Rocky Mountains. In the summer the jet stream shifts to a northward track through Canada. The result is drier summers in the Northwest but stronger onshore flow along the Gulf of Mexico and the Gulf of California. This strong onshore flow produces a monsoonal pattern of summer dominant precipitation in the southern Great Basin, southern Colorado Plateau and up through the southern portion of the western Great Plains. COHMAP predicts that this pattern was stronger during the late Pleistocene and early Holocene.

Topography plays an important role in the distribution of seasonal precipitation (Whitlock and Bartlein 1993). Mountains tend to catch winter and early spring precipitation from the Pacific storm track whereas areas in the summer-wet zone experience precipitation from convectional storms. Basins throughout the area are dry. Whitlock and Bartlein (1993) suggest that the overall effect of warmer global temperatures at the Pleistocene-Holocene boundary was to make areas within the present-day distribution of summer-dry areas dryer, and winter-wet areas wetter. These individual trends ameliorated as the Holocene progressed and caused the continuation of distinct paleoenvironmental histories. This suggests that maximum Holocene aridity occurred in the early Holocene (9000-7000 BP) within summer-dry areas, but later (>6000 BP) in summer-wet areas.

Proxy data indicate a brief, but intense, increase in effective precipitation occurred between 11,000-9,000 BP. Warming, increased seasonality, and strengthened monsoonal flow influenced the Southwest (Carrara et al. 1991). Pollen profiles from the summer-dry, Snake River Plain indicate continued aridity during this period (Barnosky et al. 1987), while those from monsoonal areas show the effects of increased moisture (Beiswenger 1991; Whitlock and Bartlein 1993). In the southern Colorado Plateau, timberline rose and lower tree lines descended as a result of a strengthened monsoon (Carrara et al. 1991; Markgraf and Scott 1981; Petersen 1988). Pack rat midden data evaluated by Rhode and Madsen (1995) indicate that Bonneville Basin flora was progressively dominated by sagebrush and shadscale scrub brush between 11,000 and 9200 BP, suggesting that summer temperatures were increasing. In the east-central Great Basin, rapid warming is thought to have occurred at 10,310 BP, as indicated by an increase in Douglas-fir and declining numbers of limber pine (Wells 1983).

There is good evidence that precipitation increased in the Bonneville basin between 11,000-10,000 BP. This is illustrated most strikingly by a lake level rise to the Gilbert Shoreline (Currey 1990). Currey (1990) suggests that this may have been the result of increased monsoonal flow similar to that documented for the southern Basin and Range by Spaulding and Graumlich (1986) especially vis a vis the Sevier River (Don Currey, personal communication, 2001). Madsen (2000) correlates a return of Lake Bonneville with the Younger Dryas and refers to the presence of diving ducks in Homestead Cave to show a large fresh water lake existed.

Other records suggest an increase in snow pack at this time indicating a short-term shift to cooler temperatures and increased winter precipitation (Benedict 1973; Currey and James 1982; Davis 1988). There is also evidence for a short, but sharp, cooling trend of world-wide significance at about this time (Paterson and Hammer 1987).

Early Holocene (9000 - 7500 BP)

There is no well-dated, glacial evidence for the early Holocene to the east of the study region (Davis 1988). In the Sierras the Hilgard cirque glaciation is dated to the latest Pleistocene/earliest Holocene (Curry 1971; Burke and Birkeland 1983). Climatic models predict conditions similar to those of the terminal Pleistocene/Holocene transition period (Thompson et al. 1993; Davis and Sellers 1994). At the beginning of this period the

Great Salt Lake was still quite high, but shortly after 9000 BP the lake level plummeted to an unknown low and remained low until a minor transgression occurred just before 7500 BP.

Much of the evidence concerning temperatures and aridity during this time is contradictory. In Yellowstone National Park, Lodge pole pine and Douglas fir expanded into high elevations, suggesting a Holocene drought. Winter-dominated precipitation is also inferred (Whitlock and Bartlein 1993; Thompson et al. 1993). Records from high elevations across the western interior suggest that summer temperatures were warmer than they are today (Thompson et al. 1993). Pollen data from the Steen Mountains, in the far northwest Great Basin, also indicate that conditions were warmer than at present (Mehringer 1985), as do coprolites from Hogup Cave (west side of the Hogup Mountains, dated 8300 BP) that are high in sodium and contain halophytic vegetal foods (Murchison 1989).

The few pack rat midden records available for this time in the Great Basin suggest montane and woodland taxa at the elevation of modern pinyon/juniper woodlands. This evidence, along with hydrogen isotope data (Siegal 1983) and pollen records indicating more abundant sagebrush, point toward cooler/moister conditions than today (Thompson et al. 1993). No clear record of elevated tree lines exist in the Great Basin from this time, but that may be due to the history of preservation, or it may be because warmer temperatures experienced in the Rocky Mountains did not extend into the Basin (Thompson et al. 1993).

Middle Holocene (7500 - 5000 BP)

This period encompasses the Altithermal interval (Antevs 1955). The Great Salt Lake fell to low levels between 6800 and 6000 BP (Murchison 1989). Slightly higher lake levels preceded this low (7600-7000 BP) and followed it (6000-5200 BP). Low lake levels and aridity returned near the end of the Altithermal and continued into the following early Neopluvial spanning the period from 5200-3800 BP. Insolation at 6000 BP was still greater than it is presently during the summer and less than at present during the winter, according to the predictions of Thompson et al. (1993), though not as drastically as was predicted for 9000 BP. Summer temperatures are predicted to have been 2° C higher than at present.

Xeric conditions appeared to be increasing in the Great Basin by 7500 BP, when salt-tolerant species were established on the basin floors and fauna adapted to dry conditions increased and expanded their ranges (Thompson et al. 1993). Sub alpine conifers were present in stands well above their modern limit, indicating that the mean summer temperature was almost 2°C warmer than today (Thompson et al. 1993). Pollen from the far northwest Great Basin suggests low levels of effective moisture between 8300 and 5400 BP and temperatures above present temperatures between 7000 and 3500 BP (Mehringer 1985). Rhode (1998) states the Great Basin was drier and warmer between 7000-4000 BP. Limber pines disappeared from low-elevation areas and pinyon and Utah juniper communities expanded their ranges in the Bonneville basin (Madsen 2000).

In contrast to the evidence for warm, dry conditions, boreal mammals (including pika and heather vole) survived outside their modern ranges in the Great Basin until mid-Holocene times (Thompson et al. 1993). This indicates that summer temperatures were lower than at present. Since the Altithermal represents a period of extensive desiccation of the Great Salt Lake, and because most evidence suggests increasing temperatures and aridity within the Great Basin, it is most likely that the project area experienced climatic conditions that were warmer and dryer than those of today.

Middle to Early-Late Holocene (5000 - 3500 BP)

An early neoglacial era (Recess Peak) cirque glaciation has been proposed for the Sierra Nevada (Burke and Birkeland 1983). Similar ages are reported for glacial activity in the Wasatch Range (Anderson and Anderson 1981) and the La Sal Mountains (Richmond 1986).

Judging from the Great Salt Lake volume fluctuation record (Currey 1990), conditions of relatively low effective precipitation continued into the period between 5000-3500 BP. Murchison (1989) indicates that lake levels fell after a minor, late Altithermal, high stand that occurred between 6000 and 5200 BP. A low stand equivalent to the average Altithermal level prevailed from 5000-3500 BP. Currey and James (1982) suggest that this pattern agrees with a wide variety of geological and biological data from the northeastern Great Basin, which indicate arid conditions within this time frame.

Oxygen isotopes from stratigraphic cores near the Great Salt Lake indicate a warming trend early on in the period (McKenzie and Eberli 1987). High chenopod/sagebrush pollen ratios found in the far northwest portion of the Great Basin suggest that temperatures were above those at present during the interval of 7000 to 3500 BP, but that very low levels of effective moisture only lasted until 5400 BP (Mehringer 1985). At 4700 BP the onset of cooler and moister conditions in the Great Basin occurred, but did not reach its maximum until after 3800 BP (Thompson et al. 1993). Madsen (2000) suggests the dates of 4400-2950 BP to be both wetter and cooler than that of today. Similarly, Rhode (1998) believes the climate of 4000 BP wetter and cooler.

It is probable that conditions around the Great Salt Lake were fairly dry and warm throughout most of this period, with temperatures higher and aridity more intense than at present. However, the region did experience increasing effective moisture and declining temperatures sometime after 4700 BP, as reflected by a gradually increasing lake level.

Middle-Late Holocene (3500 - 1000 BP)

The Great Salt Lake attained its highest levels since 9000 BP during the period of 3500-1000 BP. Murchison (1989) plots this high stand as occurring between 3200-1800 BP. The lake rose over 5 m during this period. Denton and Karlén (1973) suggest that a worldwide Neoglacial episode occurred between 3300-2400 BP. Madsen (2000) sees evidence of glaciation (Rocky Mountains) and major cooling in core and shoreline records from the Great Salt Lake. Further, he shows that lower Utah juniper tree lines were decreased by ~50-100 m or more as suggested by middens from Antelope Island in the Great Salt Lake and other nearby mountain ranges.

Palynologists in the Basin and Range and adjacent portions of the Colorado Plateau have attempted to identify fine-resolution records in late Holocene pollen sequences (Newman 1988, Newman 1993a, Newman 1993b; Petersen 1988). Portions of these records support a glacial episode, while others are not so indicative of cooler temperatures. According to Newman (1993a, Newman 1993b), cooler temperatures and winter precipitation dominated from 3700-3300 BP producing an expansion of woodland. Woodlands then became more restricted in the middle Neolacustrial. Between 3000-2900 BP cool, dry conditions prevailed, followed by a shift to summer moisture and warmer temperatures that lasted until 2000 BP.

At Cave of 100 Hands (west of Sevier, Utah) alternating dominance between arboreal and non-arboreal pollen was observed to have lasted from 2000 to 1350 BP. Non-arboreal pollen increased between 1300 and 1000 BP. This evidence, combined with pine/sagebrush and pinyon/juniper ratios indicate that conditions were cool and dry from 1350 to 1200 BP, while warm and dry conditions with mostly summer precipitation prevailed between 1200 and 1000 BP (Newman 1988). Pollen and plant macrofossil data indicate the period of maximum warmth in the Uintas occurred between 4600-2100 BP (Carrara et al. 1985). In the northern Great Basin, grassland and forest began expanding by 4000 BP and recovered ground lost during the Altithermal, indicating more mesic conditions (Mehringer 1985). Lindsay (1980) suggests that slightly cooler conditions produced the pollen frequencies observed at Cowboy Cave (central Colorado Plateau) between 3300-1800 BP

The Great Salt Lake experienced several deepening and freshening occurrences from about 3000-2000 BP according to core samples taken from the Bonneville Basin (Rhode 1998). Currey and James (1982) suggest grassland expansions in the northern Great Basin indicate mesic conditions were again prevalent around 1500 BP. Slope wash stability at Pint-Size Shelter (near the Muddy Creek Basin in southeast Utah) also indicates mesic soil moisture regimes, brought on by intensified winter-wet circulation between 3390 and 1790 years ago (Currey and James 1982). Overall, conditions were quite variable, spatially as well as temporally, during the middle Neolacustrial.

Early-Latest Holocene (1000 - 500 BP)

Lake levels of the Great Salt Lake fell to their post-Altithermal low during this period (Currey 1990). According to Murchison (1989) this occurred between 1300 BP and 600 BP. The level at this time was above average Altithermal stands, but well below the terminal Pleistocene and middle Neopluvial high stand. Terrain available for wetland development would have increased as the lake level declined.

Newman (1988) determined that the dominance of sagebrush pollen over pollen from bunch grasses, west of Sevier, Utah, indicates that the climate was cool and moist from 1000 to 900 BP. High bunch grass/sage pollen ratios from the Sevier region suggest warm, xeric conditions prevailed, dominated by summer precipitation, from 900 to 600 BP; while pollen records from the Colorado Plateau (Petersen 1988) imply cooling and drying after 850 BP. Pollen ratios indicate cool, xeric conditions in the eastern Great Basin from 600 to 100 BP (Newman 1988). However, Currey and James (1982) view grassland expansion in the northeastern Great Basin as a sign of a mesic environment around 600 BP.

Elston (1999) notes severe droughts took place at 900 and 300 BP, and the "Little Ice Age" of 400-300 BP with its associated cooler temperatures and greater winter precipitation caused an increase of pinyon pine into the southern Great Basin. Tree ring data from the Sierra Nevada region suggests slightly warmer and drier conditions than present throughout most of the period, while the later years were dominated by cooler, moister conditions (Graumlich 1993). Madsen (2000) opines that plant remains from caves in the Bonneville basin suggest that the driest and the warmest period of the Holocene was during the last 600-1000 years.

Terminal-Latest Holocene (500 - 150 BP)

A final high stand occurred in the Great Salt Lake during the terminal prehistoric era (Currey 1990), inundating most of the wetland terrain that was exposed during the early-late Neolacustrial. Murchison (1989) places this high stand at about 450-150 BP. Thereafter, the lake dropped to modern levels reflecting a relatively drier historic climate. Pollen data, including high bunchgrass/sagebrush ratios, from the Sevier, Utah area (Newman 1988) suggests cool, xeric conditions with mostly summer precipitation throughout the period. Additional pollen data from central Utah indicates high juniper/pine and grass/sagebrush ratios, typical of low effective moisture and summer-dominated precipitation that lasted until 400 BP, followed by maximum pine-to-juniper ratios, indicative of warm, wet summers combined with winter precipitation and an overall increase in effective moisture (Newman 1993a, Newman 1993b). On the Colorado Plateau, pollen records are interpreted to represent low summer temperatures with low winter and summer moisture levels continuing until 150 BP (Petersen 1988).

The mountain ranges to the east of the Great Salt Lake basin appear to have experienced cold temperatures and possibly xeric conditions. It is unclear whether temperatures in the project area were cool or warm at this time, but the high lake level may represent a cooler climate with low evaporation rates. Most data from surrounding localities endorse this interpretation.

PREHISTORIC CULTURAL CONTEXT

The following section reviews the prehistory, ethnography and history of the Pine Valley Study area. This synthesis of Pine Valley and regional prehistory draws from previous investigations within the study area as well as a regional overview of the *Central Subregion* of the western Great Basin (Elston 1986:135-148). Grayson (1993) gives also provides a summary of trends in Great Basin prehistory that may be useful to the non-technical reader.

The archaeological record within that portion of the Great Basin shows a gradual shift from a dispersed foraging strategy of resource acquisition undertaken by small populations to one of more intensive collection by larger groups. These adaptive shifts are marked by the reliance on a broader range of low yield resources resulting in overall higher processing costs. Over time, as populations increased, foraging areas decreased in size but were more intensively utilized. A greater reliance on plant materials is manifested by more complex plant processing technologies and a less elaborate stone tool complex. Elston (1986) postulates that these changes may have been driven by a complex interaction between climate, population pressure and possibly migration (Elston 1982; O'Connell, Jones and Simms 1982).

Chronologically, occupational periods within the central Great Basin are defined by a series of adaptive strategies that express regional trends over the larger area. These strategies are further refined within the context of regional phases, each of which are represented by different assemblages and settlement patterns within the archaeological record. Adaptive strategies are broadly framed within a Pre-Archaic to Late Archaic continuum. Table 2.2 depicts the central Great Basin chronology and relates it to regional paleoenvironmental history.

Pre-Archaic (11,000 BP to 8,000 BP)

The Pre-Archaic marks the transition from Pleistocene to Holocene climatic conditions. Sites are usually associated with pluvial lake, shoreline features, riparian areas, marshes or along old river terraces. Diagnostic tools include a variety of stemmed projectile points (Great Basin Stemmed series) as well as fluted Clovis and unfluted lanceloate types (Beck and Jones 1997). Core choppers, hammerstones, crescents, specialized scrapers, small graving tools and drills are common, but grinding implements are generally absent. Sites usually lack a buried component. Structural remains, storage facilities or other archaeological features are rare.

Archaeological evidence suggests that subsistence strategies involved procurement of low cost/high return wetland resources. Pre-Archaic cultures hunted big game (including declining populations of megafauna), smaller game animals, and gathered easily processed lacustrine and marsh related resources such as cattail pollen, shoots and green seeds. Pre-Archaic population density was likely low, consisting of small but mobile hunter-gatherer bands.

Pine Valley was not a closed basin during the Early Holocene and thus contained no pluvial lakes. During historic times, marshes were known to exist in the northern portion of the valley near the present Hay and Tomera Ranches. They may have provided suitable habitat for exploitation during the Pre-Archaic. The Grass Valley phase in Monitor Valley and Dry Gulch Phase in the Upper Humboldt Valley are regional characterizations of the Pre-Archaic in the study area.

Table 2.1. Regional chronology

Paleoenvironmental Sequence	B.P.		Adaptive Strategy	Phases: Monitor Valley	Phases: Upper Humboldt Valley
Terminal Holocene	0	2000	Late Archaic	Yankee Blade	Eagle Peak
Early-Latest Holocene		1300		Underdown	Maggie Creek
Middle-Late Holocene	1000	700		Revielle	James Creek
		A.D.			
	2000	0	Middle Archaic		
		B.C.			
	3000	1000			
		1300			South Fork
Middle to Early-Late Holocene	4000	2000		Devils Gate	
Middle Holocene	5000	3000	Early Archaic	Clipper Gap	No Name
		3400			
	6000	4000		?	
	7000	5000	?		?
Early Holocene	8000	6000	Pre-Archaic	Grass Valley	Dry Gulch
Terminal Pleistocene-Holocene Transition	9000	7000			
	10,000	8000			
Deglaciation	11,000	9000			
Full Glacial	15,000				
	18,000				

Early Archaic (7,000 to 4,000 BP)

Marshes and lakes dried up as warming and drying trends of the early Holocene continued into the middle Holocene. Origins of the Early Archaic are somewhat obscure in the archaeological record, beginning sometime after 7000 BP but becoming more visible between 4500 and 4000 BP.

Specialized artifacts, fluted points and crescents disappear from the archaeological record, while a variety of smaller, randomly flaked projectile points and groundstone appear. Triple T concave base projectile points (Thomas 1981, 1983a) from Gatecliff shelter and Triple T Shelter are common time markers of the Clipper Gap phase in the Monitor Valley sequence. They are gradually replaced by the Gatecliff projectile point series (Thomas 1983a) during the Devils Gate and No Name phases.

Site settings shift from lakeshore environments to a wider variety of locales including those near perennial streams, springs, caves and rock shelters. Hunting camps in upland settings and pine nut harvesting within the pinyon-juniper zone, at least within Monitor and Reese River Valleys (Thomas and Bettinger 1976, Thomas 1988), suggest a sharp population increase and utilization of upland resources.

Middle Archaic (4000 BP to 1500 BP)

Climatic conditions during the Middle Archaic were cool and moist. While high altitude resources may have been more difficult to exploit during this period, the climatic regime may have created shallow lakes and marshes in lowland environments. Technological change is minimal during the transition from the early to middle Archaic. Settlement and subsistence patterns, population density, and stylistic elaboration mark the major change of adaptive strategy between the two periods.

Population density appears to have increased significantly, and a greater diversity of resources appears to have been exploited. Both residential sites and seasonal field camps were utilized and re-occupied. They contain features such as hearths, cache pits, food storage pits, and house depressions. Caching of tools in caves and rock shelters suggests that groups exploited a limited territory.

Big game hunting remained an important subsistence strategy along with seed gathering and processing. Elko series projectile points are the most abundant point type associated with the Middle Archaic. Bifaces and seed grinding equipment also occur. Trade with groups outside of the Great Basin is evidenced by the occurrence of marine shell beads, and portable rock art in the form of incised stones makes its first appearance during this period. The Middle Archaic is associated with the Reveille phase in Central Nevada, and the James Creek phase within the Upper Humboldt River Valley.

Late Archaic (1500 BP to Historic Contact)

Sometime around 2000 BP a warming and drying trend began reaching a peak around 1500 BP. While the climate remained milder than that of the Early Archaic, climatic change, along with increased population pressure, spurred important cultural change.

Subsistence strategies expanded to include exploitation of more diverse resources within a wider range of ecosystems. Plant food resources, especially pinyon were emphasized and smaller game such as rabbits, birds, and rodents replaced larger mammals in the diet. Sedentism increased as evidenced by the occurrence of large village sites and construction of substantial houses. Specialized campsites, especially those in high altitude sites are abandoned in favor of more centralized locales. Settlement patterns culminate with the large valley floor villages described by historic ethnographers.

Around 1500 BP, the atlatal was replaced by the bow and arrow, and projectile points became smaller in overall dimensions. Rose Spring and Eastgate types (Rosegate Series) are common during the first part of the Late Archaic (Underdown, Maggie Creek), but are replaced by Desert Side-notched and Cottonwood types (Desert Series) during the later part of the period (Yankee Blade, Eagle Peak). Expedient flake tools replaced bifaces and tools manufactured from quarried raw materials. After 900 BP pottery enters the archaeological record. Some contacts with horticultural cultures are indicated by the occasional occurrence of Fremont and Anasazi pottery sherds.

At some time during the Late Prehistoric, Numic language and cultural traditions documented by ethnographers assert an influence over most of the Great Basin. Whether these traditions develop in situ, as proposed by Gross (1977) or were spread by invading groups from the south (Lamb 1958) remains a topic of discussion (Bettinger and Baumhoff 1982, 1983; Simms 1983; Elston 1982; O'Connell, Jones and Simms 1982).

ETHNOGRAPHIC CULTURAL CONTEXT

The project area is situated within the ethnographic territory of the Western Shoshone (Steward 1938), a Numic-speaking people of the Uto-Aztecan linguistic family (Fowler and Fowler 1971: 5-6). Territory extended northeastward from Death Valley through central Nevada and northwestern Utah. Peter Skene Ogden made initial European contact with the Western Shoshone as he traversed the territory in 1827. As western exploration increased between 1830 and 1850 encounters became more frequent. Accounts by James H. Simpson during topographical surveys in 1849 and 1869 (Simpson 1869, 1876) provide the earliest detailed ethnographic statements on the Western Shoshone.

The technology and adaptive strategy of the Western Shoshone was relatively complex despite the deprecatory observations of early explorers and settlers (Thomas, Pendleton and Cappannari 1986: 265). Much of what is known of the Western Shoshone is derived from the works of Steward (1938). Subsistence and settlement strategies employed by the Western Shoshone are identical to that of the late archaic. The uplands were exploited for a variety of seeds and roots, pine nuts and small game including deer and rabbit. Bighorn sheep and antelope were also taken. Grass and hard seeds were exploited in the lowlands, and rabbits harvested during annual rabbit drives.

Population density at the time of historic contact was relatively low, approximately one person per 3.8 square miles in the Pine Valley area (Steward 1938:141). In 1873, the Western Shoshone in Pine Valley numbered around 400. The Western Shoshone lived in semi-permanent campsites that were seasonally re-occupied. Campsites were strategically located in order to provide access to water and within the proximity to a range of resources and procurement areas.

Steward (1938: Figure 11) identifies three Western Shoshone villages within the project area (Figure 2.10). *Bauwiyoi,* located at the base of Roberts Mountain is a group of six encampments. Fifteen or sixteen families resided at *To:dzagadu*, a village consisting of several encampments scattered between springs on the west slope of the Sulphur Springs Range east of Mineral Hill. At the north end of Pine Valley, approximately 56 people inhabited a winter village near Palisade. Stewards map shows that seeds, roots and rabbits were taken in the Pine Valley lowlands. Pine nuts were harvested in the Roberts Mountains and the Sulphur Springs Range.

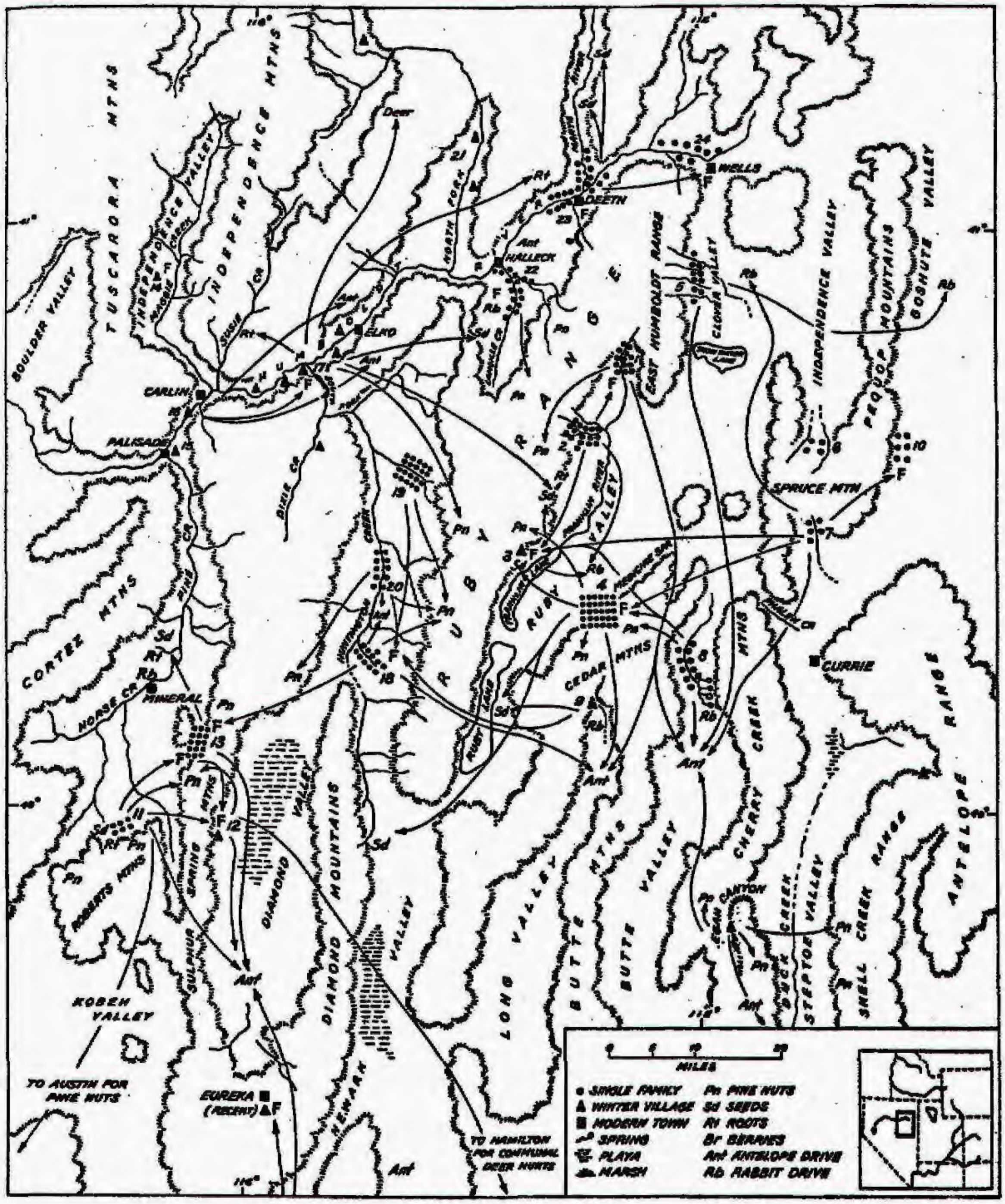


FIGURE 11.—Villages and subsistence areas of the upper Humboldt River region.
60285—38 (Face p. 141)

Figure 2.10. Steward's map of ethnographic villages and subsistence areas (Steward 1938; Figure 11.).

HISTORIC CULTURAL CONTEXT

Exploration

In the early 1800's, explorers and fur trappers provide the first historic accounts of Eureka County. Peter Odgen, leader of the Fifth Snake Country Expedition, explored the region along the Humboldt River between Elko and Carlin, just north of Pine Valley, in 1828. Zenas Leonard, a clerk with the Walker-Bonneville Fur Trapping Expedition in 1833, provided a later historical account of the Humboldt basin. He recorded the party's passage through Palisade Canyon, along the northern edge of the county.

During the 1840's and 1850's California bound emigrant parties followed the Humboldt route through northern Eureka County as did the E.G. Beckwith survey for the transcontinental railroad in 1854. Beckwith entered Pine Valley from Pony Canyon then continued southward towards the present Slagowski Ranch before exiting through a pass north of Mount Tenabo in the Cortez Mountains (Patterson 1969:86) Beckwith's route is identified as "Old Emigrant Road" on 1869 and 1909 General Land Office survey plats (Vierra 2001:14)

Transportation

Woodward and Chorpening's "Jackass Mail" or "Jackass Express" was the first mail and express outfit to traverse Eureka County. Established in 1851, it followed the Humboldt River until 1854 when George Chorpening, the surviving partner of the enterprise, received permission to abandon the Humboldt route in favor of a southern route from San Diego to Salt Lake. A new contract in 1858 re-established the route along the Humboldt, but Chorpening moved the eastern portion of the line, diverting it southward from Gravelly Ford near Beowawe, through Pine Valley and over Railroad Pass into Huntington Valley and points east (Goodwin 1969:133,134). This central route was the same as that pioneered by Captain Simpson in 1859 and constructed by Colonel Fredrick Lander in 1860.

In 1860, the contract for the express mail was transferred to Jones, Russell and Company (later Russell, Majors and Waddell) and until its demise in 1861; the route was plied by the Pony Express (Goodwin 1969). Several stations were established along the route to provide fresh mounts for the Pony Express riders and to maintain company equipment and livestock.

John Butterfield's Overland Mail and Stage Company, commenced operation along the Pony Express route in March of 1861, and assumed the express mail contract upon the demise of the Pony Express. The Overland Stage utilized many of the Pony Express stations, and the Overland Mail route marks the location of the first permanent occupation by Caucasians in central Nevada (Goodwin 1969:137).

With the completion of the Transcontinental Railroad in 1869, the Overland Mail lost its express mail contract and went out of business (Conkling and Conkling 1947). At the same time, the White Pine Mining District (Hamilton and Treasure Hill) was developing and within six weeks, during the spring of 1869, six stage lines began operation from the Central Pacific railhead at Carlin or Elko to the White Pine mines (Goodwin 1969:140).

Initially, the stage routes traversed privately constructed and maintained toll roads. Toll rates were stipulated according to the particular use, while stage and freight operators arranged to use the road under contract. An important adjunct to the collection of fees along the toll road was the tollhouse and appurtenant structures, often including a hotel and bar (Goodwin 1969:155). The authority to grant road franchises was maintained by the territory or state, and finally, during the 1860's, to the counties. As counties took over operation of the toll roads, the fees were abolished, and their general condition improved. The Central Pacific reached Carlin in December 1868, and by August of 1869, the Payne & Palmer and James Russell Stage Lines began service over the White Pine Toll Road to Mineral Hill, Eureka and Austin. The route extended from Carlin southwesterly through Woodruff and Cole Canyon, then south up Pine Valley.

With the discovery of silver ore in Eureka during late 1868, the Central Pacific railroad developed the town of Palisade as a freight and passenger terminus for the Eureka and White Pine mines. In the summer of 1869, William Paddleford, one of the first Pine Valley Ranchers, constructed the Palisade Toll Road through Pine Valley from Palisade to Mineral Hill. In June of 1870, the Woodruff and Ennor Company, opened a stage line using the Paddleford road, and extended service to Eureka via Garden Pass over their own Pine Valley Toll Road.

In 1870, W.L. "Nick of the Woods" Pritchard built a freight road and stage lines (Pritchard Fast Freight Lines) serving Mineral Hill and Eureka. Likewise, the National Transportation Company ("N.T.") provided service to Mineral Hill and Eureka utilizing the northern portion of the Paddleford road. The N.T. route then crossed Union Pass into Diamond Valley and Eureka.

Stage and freighting companies were the dominant mode of transportation until the completion of the *Eureka & Palisades Railroad* (E&P) in 1875. With the 1869-1870 silver boom in Eureka, several towns along the Central Pacific line showed great interest in becoming a principal point of departure for a rail line to Eureka, Hamilton and Pioche. Elko was the first town to pursue the rail link, incorporating the *Eastern Nevada Railroad* in Carson City on January 20, 1871. Preliminary grading commenced just west of Elko, but progress was stalled while the contractors, two Utah stage men, Gilmer and Salisbury, purposely delayed construction to allow Utah's *Salt Lake, Sevier Valley and Pioche* railroad to reach the White Pine mines first (Goodwin 1969:194).

Angered by the pretensions and delays, Eureka's citizens incorporated the *Eureka and Palisade Railroad* in November of 1873 began construction without the state's franchise or county bond subsidy. In 1874, investors representing the Bank of California and the Comstock's V&T Railroad took over the project and completed construction in the summer of 1875.

The *Eureka and Palisade Railroad* hauled more than 31,000,000 pounds of bullion (silver rich lead with traces of gold) in one year (1878) and on return trips hauled huge amounts of timber from the Sierra Nevada Mountains. Most of the prime bullion from Eureka was shipped to bullion agents in San Francisco.

The Eureka boom began its decline during the middle 1880's, and by 1897 the focus of the railroad was on other areas. Floods and fires were common occurrences in Eureka and most Nevada Mining camps. Both would also plague the railroad. The *Eureka and Palisade Railroad* went bankrupt but was reorganized in 1901 as a Utah company called the *Eureka and Palisade Railway*. After the reorganization, alignments were rebuilt and repaired. Tragedy struck again in 1910 when eleven miles of track and several bridges in northern Pine Valley were washed out by a series of foods. Pine Creek, which had previously been 100 yards wide, expanded to ten times that width and effectively created a lake that extended 30 miles south from Palisade (Myrick 1962:101) When the train returned to service, in May of 1912, it was known as the *Eureka-Nevada Railway Company*. Washouts continued to plague the line.

Despite decreased ore production and increased competition from automobiles and trucks, the *Eureka and Palisade Railroad* continued operation for another 26 years. During that time service declined to the point that only weekly service by Motorcar No. 23 was provided instead of the multiple daily freight and passenger trains of it's heyday. Finally, on September 21, 1938, after a series of political disputes and additional floods, the line was finally abandoned (Myrick 1962: 111).

Ranching

Early transportation through the project area relied heavily upon horses, mules, and oxen, requiring large amounts of fodder. Development within Pine Valley was largely due to the need for support and services for travelers and early settlers. Many stage and express stations later continued their existence as ranches. Contemporary ranches continue to operate where once early stations had operated, representing over 120 years of continuous operation (Tomera Ranch, Rand Ranch, Bailey Ranch). The north end of Pine Valley with its meadows and marshes provided an opportunity for many operations to harvest native grasses. By the 1860's several hay ranches were operating along Pine Creek in the northern portion of the project area. Paddleford's House, Archy McDonald's House, Pine Valley House, Rawlin's House (Rand Ranch) James Donahue's Cabin and the Hay Ranch are all depicted within the northern portion of the valley on the 1869 General Land Office plat.

The Eureka and Palisade Railroad operated the Hay Ranch. It consisted of "2,500 acres of fenced bottom land, from which 1,000 tons of hay are cut annually." (Angel 1881:428). By 1880, the area from Palisade south to the Hay Ranch contained thirteen ranches, including five dairy farms, and a school district in which there were thirteen students (Angel 1881:428). Several ranches, many associated with railroad stations along the *Eureka and Palisade Railroad* line, are shown on early plats of southern Pine Valley and Garden Valley. These include Mineral Station, Alpha Station and Pine Station.

Homesteads within the project area are most frequently located along the bottomlands of more reliable stream courses and adjacent to numerous travel ways.

Mining, Milling and Commerce

With the discovery of the Comstock Lode in 1859, a surge in prospecting occurred across Nevada. As ores were discovered, mining districts were established. Prospecting, mineral extraction and processing activities lead to the development of ephemeral mining camps and towns across the state.

Several mining districts lie within the project area. The Cortez and Buckhorn districts encompass most of Mt. Tenabo and surrounding slopes of the Cortez Range in the southern portion of the project area. The Cortez District was discovered in 1863 by prospectors from Austin (Lincoln 1923:86). Simon Wenban, an original locator, partnered with George Hearst in 1864 and began shipping gold and silver ore to Austin for processing. Proceeds from the venture helped establish the Hearst fortune. An 8 stamp mill was subsequently erected in Mill Canyon to process ores, and later enlarged to 16 stamps. According to the Reese River Reveille, some 20 mines were operating on Mt. Tenabo by January of 1867 (Angel 1881:429). That same year, Wenban bought Hearst out, and acquired all of the important mines in the district. A larger mill was erected at Cortez in1886. Wenban was associated with the mill and mineral extraction until his death in 1892. The Tenabo properties were sporadically worked by a number of lessees until 1919 when the Consolidated Cortez Silver Mines Co. took possession. They erected a 100 ton concentration and cyanide mill in 1923.

The Buckhorn (Mill Canyon) District is located north of Mt. Tenabo on the northwest slope of the Cortez Range. It adjoins and is often considered part of the Cortez District. The Mill Canyon district was discovered in 1863 and a mill was erected in 1864. Early assessments within the district were not very productive, and the mill was contracted to reduce ore from the neighboring Cortez District. In 1908, Joe Lynn discovered ores within the Buckhorn claim. Principal claims were acquired by George Wingfield and the Buckhorn Mines Co. in 1910 and ores processed by a 300 ton cyanide mill at Buckhorn or at an 800 horsepower electric plant at Beowawe until 1916 when the operation shut down (Lincoln 1923:85).

Mineral Hill District is located on the western slopes of the Sulphur Springs Range near Table Mountain. The district was discovered by prospectors from Austin in 1868 and soon thereafter, a 15 stamp mill was erected. Angel (1881:435) reports that eighteen miners work the district, six of who own mines. Two families reside within the district. The mine and mill was sold to the Mineral Hill Silver Mining Company, an English concern, who erected a 20 stamp mill and roasting furnace. Those operations proved unsuccessful and in 1880, it was sold to the Austin and Spencer Company. They operated the mines and mill until 1887. Small amounts of ore were extracted by several companies between 1912 and 1919 (Lincoln 1923:95).

The Alpha District is located east of Alpha in northern Garden Valley. A 10 stamp mill was built west of the prospects, did not prove to be successful (Lincoln 1923:85).

Chapter 3 -- Archaeological and Environmental Information Collection

Extensive amounts of archaeological and environmental information were collected as part of this study. A variety of sources of archaeological records and data were utilized. Similarly, there was no single source of environmental, soils, or biological data. This chapter describes how the data used in this study were gathered: its sources, its problems, and how it was converted from information to analytical data.

ARCHAEOLOGICAL INFORMATION

Information on cultural resources and cultural resource investigations was gathered from several different sources. These included the Nevada State Museum, the Bureau of Land Management Elko and Battle Mountain Field Offices, the Bureau of Land Management State Office in Reno, and the Nevada State Historic Preservation Office. All of these agencies were extremely cooperative and made our task much easier. Most of the records in these offices were on paper; a few electronic files were found too. Much of the paper information was converted into digital formats as part of the collection and analysis done by this project. The rest of this section describes the materials gathered and their conversion into project data.

Cultural Resource Archive Maps

Data entry began with digitization and tabular data entry of site and inventory locations depicted on maps obtained from the Nevada State Museum cultural records archive. These archival maps were scanned, and then geo-referenced to the project co-ordinate system. Data entry was not restricted to the project area but included all data on any USGS quadrangles intersected by the project boundaries. Map scales varied from 1:24,000 to 1:250,000. Spatial accuracy of the plotted data is dependent upon map scale and precision of the original map plot. Tabular data relating to map plots included accessioned Smithsonian site number, data source (map scale), digitizing date and name of data entry person.

Sites and inventories were digitized either as points, lines or polygons depending upon size and resource type. Digitizing was accomplished from scanned, geo-referenced, images of the archive maps. These were displayed on-screen in Arcview 3.1 (Environmental Systems Research Institute) and digitized into "shapefile" formats. Any non-linear site with an area greater than 2.5 acres was plotted as a polygon to the extent of its depicted boundary. Linear features were plotted using similar size criteria. Centerlines were digitized, and then buffered to a default width of 30 meters. Sites less than 2.5 acres in size were plotted as points. Upon completion, draft plots of the quads were produced then checked against the original to assure completeness and accuracy.

Archaeological Site Forms and Reports

Archaeological site records and survey reports were gathered from the Nevada State Museum archives and pertinent data entered into an Access database. Fields containing all associated project number, lead agency, Nevada State Historic Preservation Office SHPO concurrence, report title, author, acreage surveyed, type of investigation, and summary site data comprise the investigations database.

Site database structure was derived from the Intermountain Antiquities Computer System (IMACS) encoding format. It contains text and codes for administrative and cultural components of a given site. A related Microsoft Access database, compiled from site record and report synthesis was also populated in order to allow for a more detailed analysis of assemblage components.

A number of reports submitted to the Nevada Site Museum have yet to be accessioned into the permanent archive. These un-accessioned records were also entered into respective inventory and site databases. Site and inventory areas were then digitized and entered into the appropriate GIS layer. Site files and map plots at the Battle Mountain and Elko BLM Field Offices were then checked against the map plots and any additional reports or site records were added to appropriate databases using the process for un-accessioned records. All site records gathered for data entry were scanned into a publicly readable document file to allow electronic access.

Upon entry of all records into the databases, GIS entries, the analytical database, and image files were crosschecked against each other to insure completeness.

General Land Office (GLO) Plats

General Land Office plats are historic records of survey for selected townships or portions of townships. Portions of Nevada were systematically surveyed during the 1860's. Topographic features on historic plats include roads, telegraph lines, homesteads, agricultural fields, and in some cases vegetation or terrain features. A list of townships was compiled for the project area from electronic files and available GLO plats were reproduced from microfilmed archives at the Bureau of Land Management Nevada State Office.

Since mapping standards of the late 19th century produced a somewhat inaccurate map plot, topographic features on the GLO plats were encoded by indicating presence or absence (by default) of specific cultural features within each section. This *Access* database contained fields then for each section within that township; the presence of any transportation, communication, settlement, or agriculture/mining/industry features was tabulated. If no historic features were present within a section, or if the surveyor did not evaluate the section, those constraints were also noted. The location and general extent of hydrographic features like springs and marshes were digitized into GIS layers from the GLO plats.

Automated Data

Electronic data was available for some aspects of cultural resources. The Nevada State Historic Preservation Office maintains a log of all resources that they consider eligible to the National Register of Historic Places. This was used to determine resource legal status.

The BLM Elko Field Office maintains a log of all site numbers and status determinations that they make; this too was useful in compiling the cultural resource information.

For several years, the Nevada State Museum tracked site and project numbers issued by federal agencies and by the museum or Nevada SHPO. This database was very useful in finding records and in preventing duplicate entry of records with different numbers.

Cultural Resource Information Gaps

Although we made every effort to find site records, reports, and legal status determinations, gaps remain in the information. The most notable shortcomings are the age of site records from the study area. Many of the larger, most obvious, sites were last recorded in the 1970's. These records do not meet current standards and were difficult to translate into the analytical database structure. Where possible, we used the narrative reports of the 1970's to augment the site records themselves.

A second gap lies in fieldwork that was begun but never was completed. Some projects on public lands were cancelled after archaeological fieldwork was conducted. In a few instances, site records and a narrative report were never completed and turned over to the Bureau of Land Management. One can consider the archaeological fieldwork as either never having occurred at all, or one can gather whatever information is available from the field archaeologists who conducted the work. We chose to garner whatever information we could from the field archaeologists and incorporate it in to the project data.

NATURAL RESOURCES AND ENVIRONMENTAL INFORMATION

Natural resources information was gathered from a variety of sources, including published maps, data compilations made for environmental research investigations, management datasets maintained by the Bureau of Land Management, and even satellite imagery.

Soils, Sediments, Landforms

A very important source of information was the Natural Resources Conservation Service (NRCS) soil survey data. Two different scales of NRCS survey data were used: statewide (STATSGO) and county-level (Order II survey; SSURGO). Not all of the project area is covered by the larger scale, county-level, information. Nor is all of the county-level information for Nevada in electronic format. We were fortunate in that the portions of the Pine Valley study area that have been mapped at the county level are also available electronically. The statewide data (SSURGO) is also available electronically. NRCS electronic formats comprise Arc/INFO (Environmental Systems Research Institute) coverages and associated data tables.

Vegetation

The U.S. Fish and Wildlife Service GAP (USFWS GAP) analysis data comprise GIS data for vegetation communities, species presence/absence, and surface ownership. These data were retrieved from the University of Nevada Biological Resources Research Center (the USFWS GAP contractor for Nevada) and reviewed. The NRCS soil survey data was found to contain more detailed breakdowns of vegetation communities. One could derive much the same map as the USFWS GAP vegetation by combining vegetation communities from the NRCS county-level data. Hence, the USFWS GAP vegetation data was not used. The species component, being presence/absence, was also not useful for this study. Land ownership was derived from BLM sources for the most part and was used (though only in minor ways) in this study.

Geomorphology and Geology

There are no single sources of detailed geomorphological information for the Pine Valley study area. During the study, we did use the county geological map series (Nevada Bureau of Mines and Geology).

Initially, a LANDSAT multispectral 30m pixel image was examined for the study area. Infrared bands (near infrared), and panchromatic spectral bands were combined to create a false color image in which green vegetation shows as bright red. Vegetation must pretty well fill a 30m pixel before it will appear red, and discernible green vegetation features on the imagery typically require at least 9 pixel aggregations. Green vegetation was sought as an indicator of wetland landforms and potential dune settings. In both of these places, vegetation may be more verdant and dense. The imagery analysis revealed no dune fields and only obvious areas of wetland – galleries of green along perennial stream courses and irrigated fields.

Hydrology

Hydrological information was gathered first from the Bureau of Land Management springs, seeps, and wells GIS data available over the internet. For the prehistoric study, man-made springs and wells were discarded from further consideration. Springs shown on contemporary 1:24,000 quadrangles were digitized if they were not present in the BLM data. It was a simple matter to find GIS data for the few perennial streams in the study area. These were derived from a 1:24,000 digital line graph (DLG) dataset published by the United States Geological Survey.

Digital Topography

Some parts of the analysis involved using digital terrain models to assess slope, aspect, and proximity to various natural or cultural features. A digital terrain model was constructed from the 30m digital elevation models for the study area. These were retrieved as individual quadrangles of data and then combined into a single terrain model.

Natural Resource Information Gaps

There are gaps in the natural resource information available to the study. Especially important is the lack of NRCS county-level survey in the very northern part of the study area. We were unable to find information on large-game ranges in the study area at any useful scale. The available Nevada Division of Wildlife maps are on a regional scale – too small to be useful to this study.

CHAPTER 4. LANDSCAPE SENSITIVITY

ARCHAEOLOGICAL LANDSCAPE SENSITIVITY MODEL

Landscapes vary in their potential to contain buried archaeological sites that might affect the implementation of land management decisions. These variations are not randomly distributed across the landscape. Land management decisions can be enhanced by knowledge of these variations. The goal of constructing the archaeological landscape sensitivity model is to subdivide the project area into zones that are more or less likely to contain settings conducive to the preservation of important, buried prehistoric sites. This was accomplished by considering site formation and destruction factors that affect the contextual integrity of archaeological occupation zones. Consideration was given to whether a location contained postglacial era deposits or instead had been a residual surface for the last 14,000 years. As well, a consideration was given as to the energy regime of the depositional environment. High-energy depositional environments are predicted to have low contextual integrity due to disruptions during burial.

The spatial variation in the intensity of formation processes across the landscape is primarily a function of depositional environment. This variation is controlled by slope, transport energy, and resultant sediment.

Artifact dispersal occurs in most depositional environments (Butzer 1982). An exception to this is eolian silt (loessal) environments. Lack of dispersal in loess is the result of a low surface wind shear (because vegetation is usually present) and the low impact energy of the silt particles. Many surface sites on flat, vegetated surfaces are eventually, albeit slowly, covered with loess. Other common depositional environments can be ranked into two categories of potential burial dispersal. A relatively low to moderate energy category includes alluvial overbank, sheetflow (including slope wash), and eolian sand environments. The moderate to high-energy category would include alluvial channel, debris flow, and colluvial depositional environments. For most water and air entrained sediments, artifact movement is a function of their size and density (Gifford and Behrensmeyer 1976).

The considerations discussed above allowed the construction of a model that classifies the landscape in terms of its archaeological sensitivity. This model is used to predict where sediment younger than 12,000 B.P. occurs. It also predicts locations where geological site formation processes might lead to the better preservation of significant archaeological resources. Favorable locations are mapped ("very high and high archaeological landscape sensitivity") and differentiated from locations with surface sediments older than 12,000 B.P. and/or with little potential to preserve reasonably intact archaeological sites ("very low and low archaeological landscape sensitivity").

NRCS soils mapping was used to use classify the relevant depositional and site formation criteria. Individual soil map units were the smallest spatial unit used in the analysis. Map unit descriptions acquired from the NRCS contain information on the soil taxon, sediment type, and landform type within each map unit. Early attempts to classify archaeological sensitivity utilized a manual, light table, approach to superimpose taxon, deposit type, and landscape type characteristics to determine archaeological landscape sensitivity (Eckerle 1995). A geographic information system (GIS) approach was used in this project to simplify the process of assigning archaeological sensitivity to soils map units.

Scale of Soils Mapping

Several scales of soils mapping were utilized in this project. County level mapping (SSURGO) was used where possible. Unfortunately, portions of, Eureka and Elko County were not available at the SSURGO scale of soils mapping. Thus, we choose to supplement the SSURGO data with multi-county NRCS STATSGO soils mapping.

Sensitivity Criteria

The goal of the archaeological landscape sensitivity model is to use the soils mapping data to help predict the location of sediments that are the right age and type to contain buried archaeological sites. Soils mapping generates information on a number of variables relevant to this goal. For this analysis the following variables were tabulated: map unit number, taxonomic classification, percent slope, landform type, and deposit type. The map unit information was entered into a database (designed by Eric Ingbar and William Eckerle using Microsoft Access). A discussion of each of these variables follows.

Map Units

Soil map units delineate areas of similar soils. Map units can consist of a single series, an association composed of 2 series, or a complex of three or more soil series. The soils map units are described in the *Soil Survey of Eureka County Area, Nevada* (Foster 1989) and the *Soil Survey of Elko County, Nevada, Central Part* (Blackburn 1997). Some of the important variables extracted from the map unit descriptions are described below.

Soil Taxonomic Classification

The taxonomic classification of the principal surface soil(s) in each map unit was tabulated. These are listed to the family or great group level of classification. Implicit in the classification are soil features that have genetic and chronological significance (Soil Survey Staff 1975). Birkeland (1999; Birkeland et al. 1991) presents information on soil chronosequences in the western United States. A general, time dependent sequence of horizon development can be identified and includes from youngest to oldest; A (surface organic accumulation); Bw (oxidation or weak structural development); Bt (clay accumulation) and Bk (calcium carbonate accumulation); K (very well developed calcium carbonate accumulation) and Bym (very strongly developed gypsum accumulation). In terms of the taxonomic classes present in our study area, a relevant sequence would be as follows from youngest to oldest: 1) Orthents and Fluvents, 2) Camborthids at the great group level and calcic and argic variants at the family level of other great groups, 3) Argids and Calciorthids, and 4) Paleargids and Paleorthids. A tentative age estimate for these groupings is 1) <1000 B.P., 2) 1000-10,000 B.P., 3) 10,000-100,000 B.P. and 4) >100,000 B.P. These estimates can be used to calculate the age of the deposits on which a soil is formed and thus provide insight to where post-Clovis age sediment (i.e. <12,000 B.P.) is located.

Landform

Landform is a good indicator of depositional setting. Good potential depositional settings for archaeological sites are often found in floodplains, low (overbank) terraces, inset alluvial fans, and footslopes. Channels, summits, rock outcrops, cliffs, and steep slopes are poor potential depositional settings.

Deposit Type

Parent material provides an estimate of both the depositional energy regime and depth of burial. Although we did not formally use deposit type in this analysis, we visually cross-checked the other categories to assure that they compared favorably to sensitive deposit types. Depositional settings most likely to contain sites with good integrity are floodplain deposits, low angle alluvial fan, and slope wash deposits. Those with a poor chance of site integrity are residuum, regolith, channel gravel, and talus.

Percent Gravel (clasts >2mm)

Percent gravel (>2mm) was tabulated for the soils. Percent gravel for each horizon within each soil series was presented as a range of values from which the median was selected to represent the series. This variable is thought to provide a good proxy measure for the energy regime of the deposit and/or the proximity (shallowness) of regolith.

Percent Cobbles and Larger (clasts >3" (5.5 cm)

Content of cobbles present in each map unit was tabulated. The maximum percentage for each soil series was weighted according to percent that the soil series comprised of the total map unit. Rock outcrop and/or bedrock are considered to contain 100% fragments >3 in. For larger clasts the weighted averages for each soil series was derived and then all the component series averaged to get a representative figure for the map unit as a whole.

Archaeological Landscape Sensitivity Outline

The criteria discussed above were outlined to facilitate the reclassification of the soil map units into archaeological landscape sensitivity areas. This outline is presented below. The analysis involved identifying the sensitivity zones in a sequential manner based on what we felt was the most clear-cut and reliable characteristics. Once an area was assigned to a particular sensitivity zone, it was excluded from further analysis. The sequence was very high, high, very low, low. Moderate represented the remainder when the analysis was complete. Manual inspection of variables/values included within the moderate category suggests that the included map units, indeed are transitional between high and low with regards to sensitivity criteria. Some adjustments were needed to accommodate both the STATSGO and the SSURGO databases and these are specified below:

1. VERY HIGH SENSITIVITY AREAS meet all of the following criteria
   1. Include map units which contain a component where the depth to bedrock is 40

in. or deeper and the component composes 10% or more of the map unit.

2. Include map units which contain a component where the minimum slope is 10% or less.
3. Include map units which contain a component where clasts 3 inches or greater in diameter compose 8% or less by volume of the soil matrix.
4. Include map units which contain a component where clasts 2 mm or greater compose 20% or less by volume of the soil matrix and the component composes 10% or more of the map unit.
5. Include map units which contain a component having a **likely** Holocene age soil taxon (Camborthids, Cryoborolls, Endoaquolls, Fluvaquents, Halaquepts, Haplaquolls, Haploxerolls, Natrargids, and Torriorthents) and the component composes **30% or greater** of the map unit.
6. Include map units that contain a component having a landform designated as "low terraces and floodplains".

2. HIGH SENSITIVITY AREAS meet all of the following criteria
   1. Meet all of the criteria for very high sensitivity except do not meet criteria 'f'.

3. MODERATE SENSITIVITY AREAS meet all of the following criteria
   1. Meet all of the criteria for very high sensitivity except does not meet criteria 'e', and 'f'.
   2. Include map units that contain a component having a **likely** Holocene age soil taxon (Camborthids, Cryoborolls, Endoaquolls, Fluvaquents, Halaquepts, Haplaquolls, Haploxerolls, Natrargids, and Torriorthents) and the component composes **less than 30% of the map unit**.
   3. Include map units which contain a component having a **probable** Holocene age soil taxon (Argixerolls, Durorthids, Haplargids, and Nadurargids) and the component composes **30% or greater** of the map unit.

4. LOW SENSITIVITY AREAS meet all of the following criteria
   1. Include map units which contain a component where the depth to bedrock is 35 inches or less, contains no inclusions, and the component composes 10% or more of the map unit.
   2. Include map units that contain a component where the minimum slope is greater than or equal to 10%.
   3. Include map units which contain a component where clasts 3 inches or greater in diameter compose 8% or more by volume of the soil matrix.
   4. Include map units which contain a component where clasts 2 mm or greater compose 30% or more by volume of the soil matrix and the component composes 10% or more of the map unit.
   5. Include map units which contain a component having a **probable** Holocene age soil taxon (Argixerolls, Durorthids, Haplargids, and Nadurargids) and the component composes **30% or less** of the map unit.
   6. Include map units that contain a component having a **questionable** Holocene age soil taxon (Calciorthids, Calcixerolls, Durixerolls, Rendolls) and the component composes **30% or more** of the map unit.

7. Does not meet the criteria for VERY LOW SENSITIVITY

5. VERY LOW SENSITIVITY AREAS meet all of the following criteria
    1. Include map units which contain a component where the depth to bedrock is 25 inches or less, contains no inclusions, and the component composes 10% or more of the map unit.
    2. Include map units that contain a component where the minimum slope is greater than or equal to 15%.
    3. Include map units which contain a component where clasts 3 inches or greater in diameter compose 15% or more by volume of the soil matrix.
    4. Include map units which contain a component where clasts 2 mm or greater compose 40% or more by volume of the soil matrix and the component composes 10% or more of the map unit.
    5. Include map units which contain a component having a **questionable** Holocene age soil taxon (Calciorthids, Calcixerolls, Durixerolls, Rendolls) and the component composes **30% or less** of the map unit.
    6. Include map units that contain a component having an **unlikely** Holocene age soil taxon (Durargids, Paleargids, Paleorthids, Palexerolls), and the component composes **30% or more** of the map unit. **Probable** Holocene age soil taxon (Argixerolls, Durorthids, Haplargids, and Nadurargids) and the component composes **30% or less** of the map unit.
    7. Plus, they include only those map units which contain a component having a **questionable** Holocene age soil taxon (Calciorthids, Calcixerolls, Durixerolls, Rendolls) and the component composes **30% or more** of the map unit.
    8. Does not meet the criteria for VERY LOW SENSITIVITY.

Conclusions and Recommendations

A discussion of the sensitivity classification is presented here. These zones predict locations where geological conditions favor: (1) retention of archaeological behavioral-spatial context, (2) the preservation or perishable archaeological materials (bone and charcoal), and (3) the stratigraphic separation of archaeological occupation zones. Again, the reader is cautioned that the sensitivity model predicts where site preservation conditions are good and not locations that were attractive to human activity (see Chapter 7).

Very High Sensitivity Zone

Locations predicted to have very high archaeological landscape sensitivity within Pine Valley (Figure 4.1) are situated primarily along the floodplains and low terraces of Pine Creek and its major tributaries. Areas included within this zone meet stringent criteria for sediment accumulation depth (depth to bedrock), depositional energy regime (minimum slope, bedload transport energy [e.g. percent of 3" clasts and percent of clasts greater than 2 mm]), and sediment age using likely Holocene-age surface soils as a proxy. This zone comprises 35.9% of the total project area. The very high sensitivity area contains all the tested site locations reported by Turner et al. (1984) as well as the palynological locations analyzed by Thompson (1984). Investigations at these locations tend to support our conclusion that this zone can contain stratified, intact, occupation

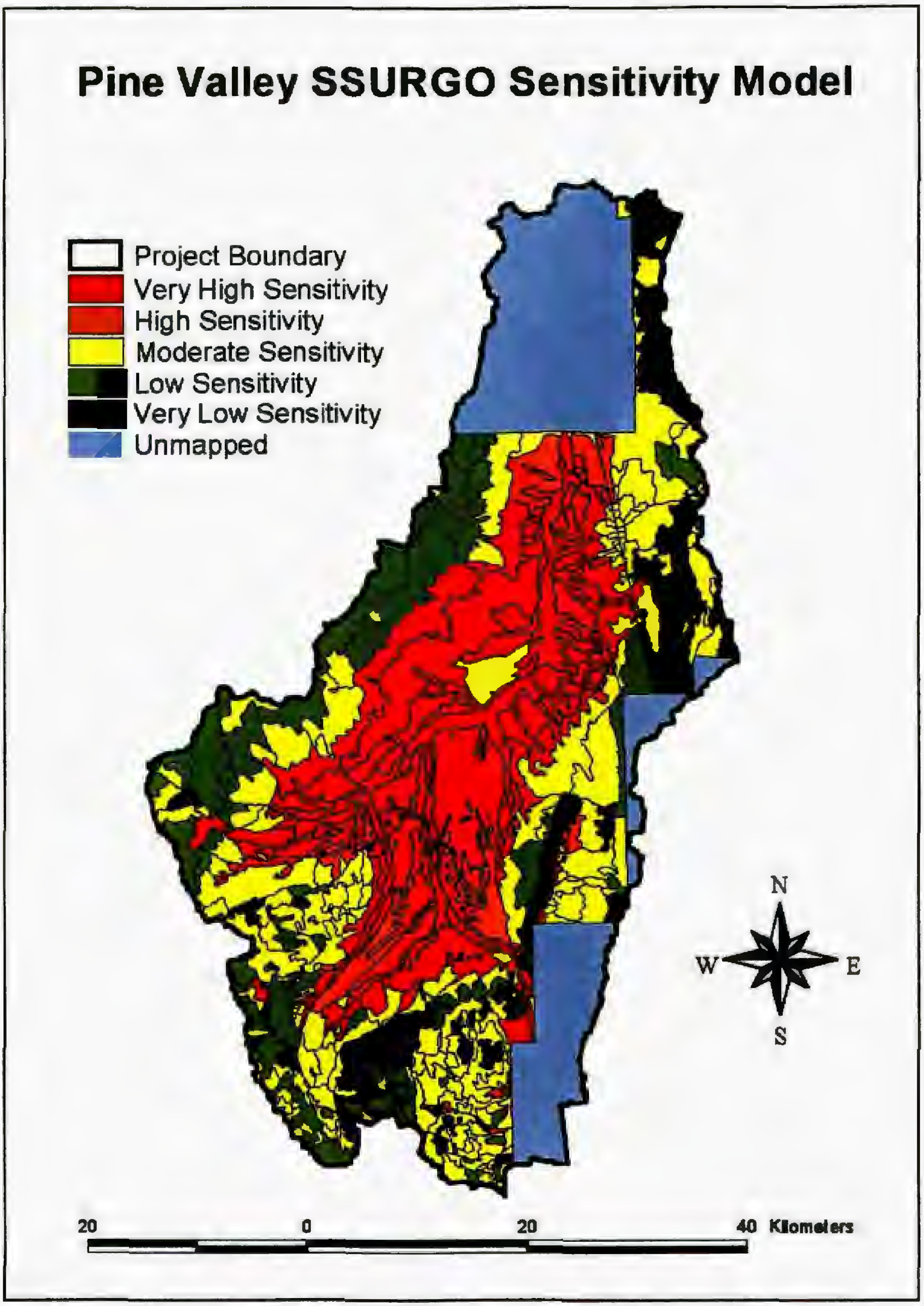


Figure 4.1. Archaeological landscape sensitivity map for Pine Valley at the SSURGO soil mapping scale.

zones that yield perishable materials like bone and charcoal and which span nearly the entire span of the Holocene. Earth disturbing construction activities within this zone should only be undertaken under the most controlled circumstances. Intensive archaeological inventory, prospecting, and complete construction monitoring would be necessary to totally prevent the inadvertent destruction of significant archaeological resources within this zone. Very deep trenching, probably only attainable with a caterpillar-track mounted, backhoe would be necessary to evaluate these areas for the presence of sites.

High Sensitivity Zone

Some locations not necessarily situated along the Pine Creek or the lower reaches of the major tributaries are mapped as having high archaeological landscape sensitivity. NRCS map units assigned to the high sensitivity zone are in all respects identical to the very high sensitivity zone, but were not designated as "low terraces and floodplains" by the soil scientists who mapped the area. On the SSURGO sensitivity map (Figures 4.1 and 4.3) the high sensitive areas are concentrated north and south of the main zone of very high sensitivity. This zone comprises 4.3% of the total project area. We expect that the high sensitivity area will contain cultural occupation zones that are similar to those in the very high zone. As archaeological endeavors continue in Pine Valley, the utility of this zone category might be reevaluated and combined with the very high zone. Like the very high sensitivity zone, earth disturbing construction activities within this zone should only be undertaken within the most controlled circumstances. Intensive archaeological inventory, prospecting, and complete construction monitoring would be necessary to totally prevent the inadvertent destruction of significant archaeological resources. As in the very high sensitivity zone, very deep trenching, probably only attainable with a caterpillar-track mounted, backhoe would be necessary to evaluate these areas for the presence of sites.

Moderate Sensitivity Zone

Some areas within Pine Valley are similar in many respects to the very high and high sensitivity zones, except for the fact that they contain small areas of likely Holocene-age soils within larger areas of only probable Holocene age soils. The areas of likely Holocene-age soils compose less than 30% of the map units. Otherwise, these map units contain, soil taxon such as Argixerolls, Durorthids, Haplargids, and Nadurargids which, either overlie latest Pleistocene/earliest Holocene age sediment, or even older deposits. It is possible that Early Archaic and Paleoindian age occupations might be buried in or under these surface soils, however dating of these soil taxon under local soil formation conditions is necessary to demonstrate this. Still, given that smaller areas of younger soils are present, the moderate zone still presents a management concern for the protection of archaeological resources. Professional on-site/project specific, geoarchaeological evaluations might help identify the smaller sensitive portions of specific map units within this zone. This zone comprises 31.0% of the total project area. In addition to normal 106 process inventory and evaluation, this zone deserves construction monitoring of known archaeological resources and construction monitoring of linear construction projects such as pipeline trenches and highway construction. Like the very high and high zones, the deposits might be deep in the moderate sensitivity zone and deep testing is necessary to evaluate these areas for the presence of buried occupation zones.

Low Sensitivity Zone

Areas predicted to have a low landscape sensitivity include soil map units that have a thinner mantel of sediment, steeper slope, and both more total gravel and more cobble-sized gravel. As well, this zone is mostly mantled by surface soils that are of questionable Holocene age (Calciorthids, Calcixerolls, Durixerolls, and Rendolls), with the inclusion of small areas of soils of only probably Holocene age (the predominant soils in the moderate sensitivity zone). Thus, there is a much smaller chance for occupation integrity, perishable preservation, and stratigraphic separation of occupations in this zone. This zone comprises 17.8% of the total project area. As with the other zones, field archaeologists permitted to conduct 106 process activities in Pine Valley should consult the U.S. Department of Agriculture (SCS and NRCS) soil reports for Eureka and Elko counties prior to undertaking field work in Pine Valley. This is to determine the settings, landforms, parent materials that occur within soil map unit inclusions so as to be alert to potential locations too small to be mapable using the NRCS database. In addition to normal 106 process inventory and evaluation, this zone deserves construction monitoring of known archaeological resources and construction monitoring of linear construction projects only on a case-by-case basis given uniquely recognized geoarchaeological opportunities. Unlike the very high and high zones, the deposits are not as deep in the moderate sensitivity zone and, where necessary, rubber-tired backhoe testing is probably adequate to evaluate these areas for the presence of buried occupation zones.

Very Low Sensitivity Zone

At the lowest extreme of the sensitivity scale is the very low sensitivity zone. Some areas within Pine Valley contain a combination of attributes such as to render them unlikely to contain intact, well-preserved, and stratigraphically separated occupation zones. This is because the NRCS map units they occupy have a very shallow depth to bedrock (<25"), they are on steep slopes, have relatively large amounts of gravel including cobble sized and greater, and their major soil types are thought to be too old to engulf any intact and buried cultural material. These areas comprise the very low sensitivity zone. Much of this zone is situated on steep slopes in mountainous areas. As with the other zones, inclusions of other soils occur within the boundaries of the very low sensitivity zone, thus there is still a small chance that some of these areas might contain intact, well-preserved, and stratigraphically separated occupation zones. This zone comprises 11.0% of the total project area. If potential archaeologically sensitive inclusions are not identified, construction monitoring and other post-inventory discovery techniques can be minimized without overt risk to sensitive cultural resources.

A sensitivity map was also made using the STATSGO soils database that is constructed at an appropriate scale for analysis at a multi-county level of analysis. This was done due to the fact that digital SSURGO coverage was incomplete for Eureka and Elko Counties. The STATSGO sensitivity map (Figure 4.2) was constructed using the identical attributes and values as the SSURGO sensitivity map (Figure 4.1) with some minor exceptions noted in the outline presented above. These two maps are compared in Figure 4.3.

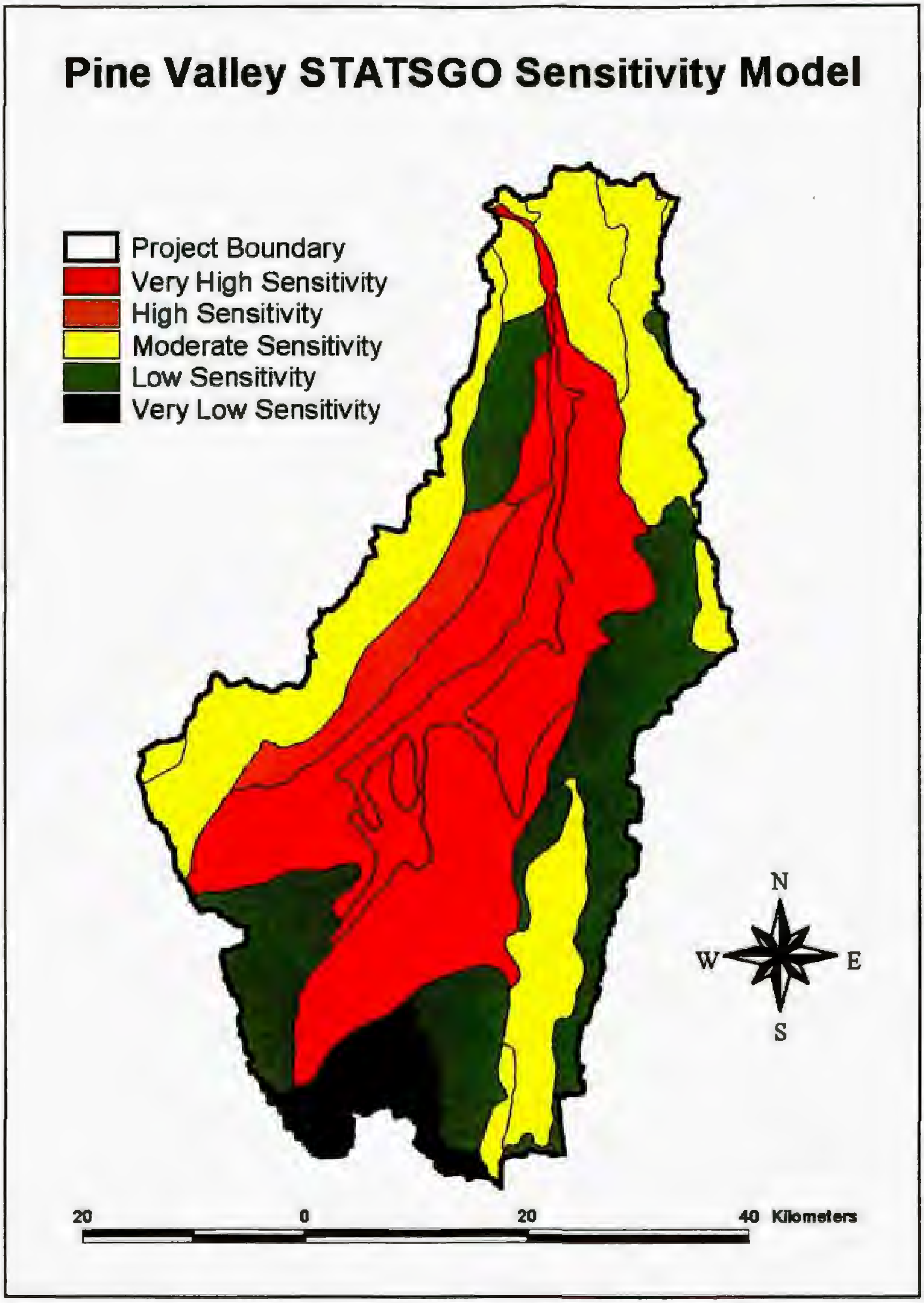


Figure 4.2. Archaeological landscape sensitivity map for Pine Valley at the STATSGO soil mapping scale.

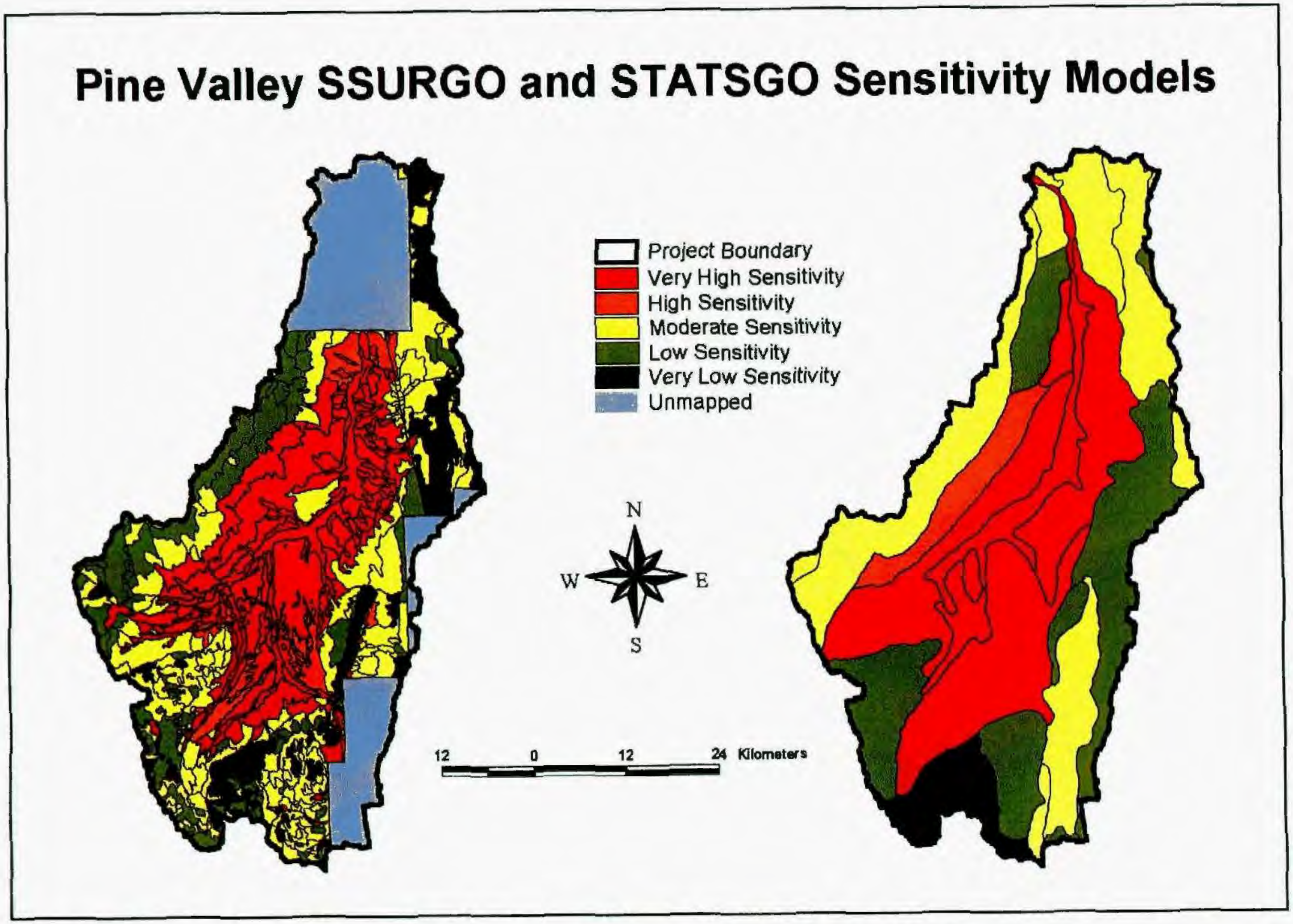


Figure 4.3. Archaeological landscape sensitivity for Pine Valley comparing SSURGO and STATSGO maps.

CHAPTER 5 -- HABITAT DEFINITION AND DESCRIPTION

This chapter develops a detailed model of environmental variability in Pine Valley. First, the advantages and limitations of the range type concept in a prehistoric plant community modeling application are considered. Then, soil map units and range types are transformed into a set of Pine Valley habitats. Habitat characterizations are refined according to proximity to perennial water. Finally, the suitability of habitats for various classes of wildlife important to hunter-gatherer foraging is ranked. This final step provides a typology of habitats in the Pine Valley study area derived from soils, vegetation, water, and slope.

RANGE AND HABITAT CONCEPTS

To model hunter-gatherer ecology in the study area, the spatial distribution of resources as they probably existed during the early nineteenth century, when hunter-gatherers inhabited northern Nevada, must be estimated, and then extrapolated back into antiquity. Alone, modern vegetation and wildlife inventories are inadequate for this task because ranching, irrigation, fire control, mining, construction, and other developments have altered the biota of the study area. Elsewhere in the Great Basin (Raven and Elston 1989; Zeanah et al. 1995; Zeanah and Elston 1997; Zeanah et al. 1999) and the Great Plains (Eckerlie and Hobey 1999), the range type concept has served as a means to model prehistoric biota; one that minimizes historic and modern distortion.

A range site is a distinctive set of geological, topographic, and hydrological circumstances that fosters a particular potential natural vegetation community (Dyksterhuis 1949, 1958). Such a community is represented by the vegetation that develops in particular physiographic circumstances defined as the range type, if left undisturbed for a sufficient time under current climatic conditions (Society for Range Management 1983). Range and soil scientists classify potential natural vegetation by analyzing the productivity and composition of vegetation growing on protected relict sites of particular soils covered by climax vegetation, or sample plots of soils left undisturbed long enough for the potential natural community to re-establish. These analyses generate estimates of total and species-specific annual herbage productivity in kilogram per hectare for each range type (Passey et al. 1982).

Range sites strongly correlate with soil types because both vary according to the same geological, topographic, climatic and hydrological conditions (Dyksterhuis 1958; Aandahl and Heerwagen 1964). The NRCS uses range types as a management tool for linking soil-mapping data to potential natural vegetation. Therefore the spatial distribution of potential natural vegetation can be inferred from soil maps.

Range types serve as a basis for estimating prehistoric plant communities because they describe relict stands that correlate with soil, allowing the distribution of potential natural vegetation to be extrapolated from soil maps, notwithstanding disruption to current vegetation. However, an important caveat is that modern potential natural vegetation communities are not the living fossils of vanished prehistoric associations. Rather, they reflect modern equilibrium as affected by historic alterations (cf. Young et al. 1976). For example, historic livestock grazing has fostered expansion of sagebrush and a variety of forbs and grasses at the expense of the indigenous species that flourished before the introduction of cattle (Young et al. 1976; Young and Tipton 1990). These introduced and invasive species are modern members of the climax vegetation of the Great Basin.

Too, natural disturbance process such as flooding, erosion, wildfire, and overgrazing (Young et al. 1976) and activities of prehistoric hunter-gatherers such as the intentional burning of range lands and sowing of wild seeds (Steward 1938) frequently disrupted the climax of prehistoric vegetation, allowing success ional communities to flourish. Furthermore, paleoenvironmental studies indicate that major changes occurred to the composition of plant communities in the northeastern Great Basin during the Holocene (Rhode 1998). Modern potential natural vegetation is not identical to the plant communities that existed before these shifts occurred, Therefore, range scientists (Tausch et al. 1993) caution that potential natural vegetation has varied dynamically over time as individual species have adapted to long term climatic change through adaptation, migration, and hybridization.

The foregoing observations compel acknowledgement of the temporal and spatial dynamics of the biotic landscape of northeastern Nevada, but as long as these limitations are kept in mind, range types nevertheless serve as useful analytical tools in consideration of prehistoric environments. Range types and their associated vegetation represent consistent and quantitative descriptions of modern plant community composition and productivity that serve to extrapolate the climax landscape that existed before modern times, so long as generally the same soil, topography, hydrology, and climate structuring the modern landscape were operating in the past.

The farther back in time that the range type landscape is projected, the more likely it is that these conditions varied significantly. Nevertheless, the landscape provides a baseline that estimates prehistoric resource distributions, because plant communities are modeled according to soil type. Since soil formation reflects the interaction of vegetation and environment over long periods of time, soil types should reflect, grossly but reliably, the vegetation that typically grew on them as long as those soils existed.

Although specific compositions of present range types may differ from their prehistoric predecessors, they should be fundamentally similar in productivity, structure, and function (Tausch et al. 1993:445). Range types that are lush in biomass today should have been so in the past, despite differences in particular species composition or stage of succession, so long as modern soil type and hydrology were present. Range types that currently favor particular plant species should have been favorable for those or similar species in the past (although the precise percentage contribution of the species to the community may have been different). The paleoenvironmental record can serve as a guide for estimating how the distribution of critical resources may have varied in the past. For example, the effects on habitat productivity and composition of a constriction of pinyon-juniper woodland, an expansion of marsh wetlands, or sowing of seed plots can be extrapolated from an understanding of the modern structure of potential natural plant communities.

Thus, range types remain useful heuristic tools for modeling prehistoric resource distributions. Modern range types will form the basis of a model of Pine Valley habitats that will characterize of the climax resource structure that existed before the intrusion of European-Americans. As such, it will serve as a model landscape that can be integrated with data on ethnographic Shoshone subsistence and settlement strategies. This, in turn, constitutes a predictive baseline to compare with archaeological site distributions. Moreover, the paleoenvironmental record serves as a guide to how the ethnographic resource landscape may have differed from that of prehistory.

SOIL MAP UNITS, RANGE TYPES, AND HABITATS

Having discussed the framework in which range types are employed to model prehistoric resource distributions, a landscape of habitats is now constructed for the Pine Valley study area. NRCS STATSGO soil maps are of insufficient resolution to allow habitat classification. Consequently, only those portions of the study area encompassed by county level SSURGO coverage are considered.

Table 5.1 lists 127 SSURGO soil types from the Central Elko County Soil Survey (prefix 767-), and the Eureka County Area Soil Survey (prefix 776-), soil surveys mapped in Pine Valley study area. Table 5.2 lists 49 range types associated wholly or partially with one or more soils in the Pine Valley study area. These range types originate from the Humboldt Area (prefix 024XY-), Owyhee High Plateau (prefix 025XY-), and Central Nevada Basin and Range (prefix 028BY-) Nevada major land resource areas (United States Soil Conservation Service 1981).

Table 5.3 lists the concordance between soil map units and range types comprising at least 15% of the potential natural vegetation community associated with each soil. One map unit lacks associated range types because it refers to open water (soil map unit 7761510) in several small reservoirs on the valley floor. The remaining 126 soil map units associate with one or more of the 49 range types in 82 different combinations.

Table 5.1. SSURGO soil map units in the Pine Valley study area.

Soil Map Unit	Soil Name	Area (ha)	Soil Map Unit	Soil Name	Area (ha)	Soil Map Unit	Soil Name	Area (ha)
776661	Akerue-Simpark-Robson Association	377	776531	Granzan Variant-Granzan-Highams Variant Association	338	776270	Poorcal Loam, 0 To 4 Percent Slopes	336
7761060	Allker Gravelly Sandy Loam, 2 To 8 Percent Slopes	5080	7671631	Hackwood-Hapgood-Cleavage Association	471	776813	Quarz-Chen-Duff Association	4146
776511	Ansping-Hymas Association	1443	776922	Handy Loam, 2 To 8 Percent Slopes	2282	7671725	Quarz-Cleavage-Loncan Association	673
767640	Arcia-Tusel-Hackwood Association	406	776923	Handy-Rubyhill Association	832	776814	Quarz-Duff Association	756
776830	Atrypa Gravelly Loam, 30 To 50 Percent Slopes	3587	776462	Haunchee-Hatur-Rock Outcrop Association	773	776811	Quarz-Highams-Atrypa Variant Association	2500
776831	Atrypa-Mau Association	2291	776221	Hodedo Stony Loam, 2 To 8 Percent Slopes	136	7671724	Quarz-Mcivey-Cleavage Association	424
776883	Batan Silt Loam	90	776223	Hodedo Very Stony Loam, 15 To 30 Percent Slopes	382	7671729	Quarz-Tusel-Cleavage Association	1538
776881	Batan-Ocala Association	8220	776222	Hodedo-Coils Association	1012	776431	Ramires-Singletree Association	77
776975	Bregar Variant-Hymas-Quarz Association	439	767201 / 776332	Hopeka-Cavehill Association	8026	776691	Ravenswood-Shagnasty-Walti Association	628
776971	Bregar-Fortank-Jivas Association	1848	767206	Hopeka-Grina-Izod Association	41	776293	Ricert-Nevador Association	4933
776972	Bregar-Jivas-Duff Association	4230	776330	Hopeka-Solak-Ados Association	199	776491	Rock Outcrop-Labshaft Association	1380
7761011	Bubus Very Fine Sandy Loam, Slightly Saline-Alkali, 2 To 8 Percent Slopes	404	776331	Hopeka-Solak-Rock Outcrop Association	429	776492	Rock Outcrop-Winu-Decram Association	409
776681	Chad-Cleavage-Softscrabble Association	2624	776241	Humboldt Loam, Drained, Slightly Saline, Rarely Flooded	1324	776600	Rubyhill Sandy Loam, 0 To 4 Percent Slopes	1214
776682	Chad-Gando-Softscrabble Association	2641	776501	Hymas-Ansping Association	3096	776764	Shagnasty-Ravenswood-Rock Outcrop Association	4269
7671881	Chen, Moderately Steep-Chen-Lerrow Association	1922	776630	Jesse Camp Silt Loam	623	776762	Shagnasty-Softscrabble Association	4889
7671880	Chen-Arcia-Cleavage Association	3862	776371	Kobeh-Shipley Association	1011	776941	Short Creek Association	2965
7671889	Chen-Mcivey-Arcia Association	154	767060 / 776841	Kodra Loam, 0 To 4 Percent Slopes	2493	767501	Short Creek-Short Creek, Very Steep Association	112
776425	Chen-Pie Creek-Ramires Association	308	776471	Labshaft-Winu Association	158	776521	Soughe Variant-Pie Creek-Singletree Association	243
776423	Chen-Ramires Association, Moderately Steep	951	767700	Leevan-Cleavage-Arcia Association	1110	767469	Stampede-Donna Association	15
776422	Chen-Ramires Association, Steep	927	767701	Leevan-Pernog-Rock Outcrop Association	950	767574	Sumine-Cleavage-Cleavage, Very Cobbly Association	1979
776565	Cherry Spring Variant-Tomera-Bregar Association	1458	767702	Leevan-Quarz-Mcivey Association	1481	767586	Sumine-Loncan-Cleavage Association	974
767241	Cleavage-Cleavage, Very Cobbly-Loncan Association	504	767723	Lerrow-Cotant-Bregar Association	589	767070 / 776341	Tenvorrd-Kodra Association	866

Soil Map Unit	Soil Name	Area (ha)	Soil Map Unit	Soil Name	Area (ha)	Soil Map Unit	Soil Name	Area (ha)
776280	Coils Loam, 2 To 8 Percent Slopes	528	776111	Lien-Hayeston Association	2575	776382	Toeja-Puett Association	449
776283	Coils-Umil Assoication	386	776361	Loncan Variant Loam	141	7761202	Tulase Silt Loam, 0 To 2 Percent Slopes*	3985
7761352	Cortez-Tenvorrd Association	4127	767080	Loncan Variant Loam, 0 To 2 Percent Slopes	83	7761201	Tulase Silt Loam, 2 To 8 Percent Slopes	3419
767452	Donna-Bilbo-Stampede Association	642	776610	Needle Peak Silt Loam, Occasionally Flooded*	696	776202	Umil-Hayeston Association	258
776951	Donna-Stampede Association	1816	7761022	Nevador-Ricert-Tulase Association	1306	776641	Valcrest-Tomera Association	6219
776981	Ebic-Ziram-Jivas Association, Moderately Steep	591	776171	Nuc-Maghills Association	1528	767413	Vanwyper-Bilbo-Soughe Association	524
776982	Ebic-Ziram-Jivas Association, Steep	2310	776172	Nuc-Maghills Complex, 2 To 8 Percent Slopes*	380	776783	Walti-Glean Association	370
767993	Eboda-Quarz-Loncan Association	<1	776161	Ocala Silt Loam, Occasionally Flooded	1641	776781	Walti-Softscrabble-Chad Association	68
776311	Eightmile-Loncan-Glean Association	599	767491	Orovada-Puett Association	22	776782	Walti-Softscrabble-Robson Association	1288
776822	Enko-Davey-Mcconnel Association	1686	776141	Pedoli-Poorcal Association	35	7761510	Water	20
767229 / 776823	Enko-Puett Association	3395	776143	Pedoli-Silverado Association	846	776962	Weigle Gravelly Loam, 15 To 30 Percent Slopes	359
776870	Fortank Very Stony Loam, 4 To 8 Percent Slopes	984	767121	Pernog-Rock Outcrop Association	95	776961	Weigle-Pedoli Variant Association	425
776451	Foxmount-Haunchee-Rock Outcrop Association	717	767345	Perwick-Puett-Rad Association	267	776770	Welch Loam, Drained, 0 To 4 Percent Slopes*	810
776452	Foxmount-Winu-Hackwood Association	63	7761233	Perwick-Puett-Tulase Association, Eroded	10100	776772	Welch Silt Loam, 0 To 2 Percent Slopes*	250
776801	Freznik-Quarz-Jivas Association	1632	7761232	Perwick-Tulase Association	9085	776891	Whitepeak-Quarz-Softscrabble Association	118
776802	Freznik-Whitepeak Association	692	776121	Piltdown Fine Sandy Loam	509	776480	Winu-Mosquet Association	468
7671234	Fulstone-Igdell-Mcivey Association	385	7761411	Pineval-Tulase-Perwick Association	24798	776481	Winu-Spinlin Association	1243
776851	Glean-Gando Association	41						

Table 5.2 List of range types in the Pine Valley study area.

Range Type Number	Range Type Name	Range Type Number	Range Type Name
024XY002NV	Loamy 5-8 p.z.	025XY025NV	Chalky Knoll
024XY003NV	Sodic Terrace 6-8 p.z.	025XY027NV	Loamy 12-14 p.z.
024XY005NV	Loamy 8-10 p.z.	025XY051NV	Eroded Shallow Claypan 12-16 p.z.
024XY006NV	Dry Floodplain	025XY059NV	Juos Wsg: 0r2
024XY007NV	Saline Bottom	025XY065NV	Potrt Wsg: 1r7
024XY011NV	Sodic Flat 6-8 p.z.	028BY003NV	Loamy Bottom 10-14 p.z.
024XY017NV	Sandy 8-10 p.z.	028BY004NV	Saline Bottom
024XY030NV	Shallow Calcareous Loam 8-10 p.z.	028BY007NV	Loamy 10-12 p.z.
024XY033NV	Steep North Slope 10-12 p.z.	028BY010NV	Loamy 8-10 p.z.
024XY049NV	P-J/Arvr2	028BY011NV	Shallow Calcareous Loam 8-10 p.z.
024XY051NV	P-J/Aram	028BY013NV	Silty 8-10 p.z.
025XY001NV	Moist Floodplain	028BY016NV	Shallow Calcareous Slope 8-10 p.z.
025XY003NV	Loamy Bottom 8-14 p.z.	028BY017NV	Loamy 5-8 p.z.
025XY004NV	Loamy Slope 16+ p.z.	028BY024NV	Loamy Bottom 14+ p.z.
025XY005NV	Wet Meadow	028BY029NV	Loamy 16+ p.z.
025XY009NV	South Slope 12-14 p.z.	028BY030NV	Loamy 12-16 p.z.
025XY010NV	Steep North Slope	028BY034NV	Mountain Ridge 12-14 p.z.
025XY012NV	Loamy Slope 12-16 p.z.	028BY037NV	Claypan 12-14 p.z.
025XY014NV	Loamy 10-12 p.z.	028BY038NV	Mountain Ridge 14+ p.z.
025XY015NV	South Slope 8-12 p.z.	028BY042NV	Mahogany Thicket
025XY017NV	Claypan 12-16 p.z.	028BY043NV	Calcareous Mahogany Savannah
025XY018NV	Claypan 10-12 p.z.	028BY060NV	Pimo-Juos Wsg: 0r4
025XY019NV	Loamy 8-10 p.z.	028BY067NV	Potrt Wsg: 1r7
025XY022NV	Cobbly Claypan 8-12 p.z.	028BY085NV	Calcareous Loam 16+ p.z.
025XY024NV	Mountain Ridge		

Table 5.3 Concordance among soil map units, range types, and habitats in the Pine Valley study area.

Soil Map Units	Range Types	Percentage Represented	Number
776293/7761203	024XY002NV/024XY005NV	30-75/15-65	1
7761011	024XY002NV	100	2
776881	024XY003NV/024XY007NV/024XY011NV	35/25/25	3
776883	024XY003NV	100	4
7761022	024XY005/NV024XY002NV/025XY019NV	40/30/20	5
7761060	024XY005NV	100	6
776610	024XY006NV	95	7
776565	024XY030NV/025XY019NV/025XY022NV	40/30/20	8
776221/776223/776501 /776511/776764/776830	024XY049NV	75-100	9
776975	024XY049NV/025XY009NV	70/20	10
776691	024XY049NV/028BY037NV	65/20	11
776521	024XY049NV/025XY018NV/025XY012NV	50/20/20	12
776222/776321/776831	024XY049NV/028BY007NV	45-75/15-45	13
776311/776762	024XY049NV/028BY030NV	50-60/25-35	14
776111	024XY051NV/028BY011NV/028BY010NV	40/30/15	16
776330/776331	024XY051NV/028BY016NV	40-55/25-35	17
776241	025XY001NV	100	18
767080/776361	025XY003NV	100	19
776772	025XY005NV	100	20
776811	025XY009NV/024XY051NV/025XY059NV	40/30/20	21
7671729	025XY009NV/025XY010NV/025XY024NV	35/25/25	22
767702/776813/7671724	025XY017NV/025XY009NV/025XY012NV	25-40/35-40/15-25	23
767586/776972/7671725	025XY009NV/025XY012NV/025XY024NV	20-40/15-55/15-30	24
767574	025XY009NV/025XY017NV/025XY024NV	40/30/15	25

Soil Map Units	Range Types	Percentage Represented	Number
767723	025XY009NV/025XY017NV/025XY051NV	35/30/20	26
767640	025XY012NV/025XY010NV/025XY065NV	40/30/15	27
776814	025XY014NV/025XY009NV/025XY012NV	50/20/15	28
776431	025XY014NV/025XY012NV	45/40	29
776382	025XY014NV/025XY014NV/025XY025NV	40/30/15	30
767469/776951	025XY014NV/025XY018NV	40-45/40-45	31
776923	025XY014NV0/28BY010NV	55/30	32
776922	025XY014NV	100	33
776941	025XY015NV/024XY033NV	50/40	34
767501	025XY015NV/025XY012NV	50/40	35
767413	025XY015NV/025XY019NV	55/35	36
7671889	025XY017NV/025XY012NV	30/55	37
7671880	025XY017NV/025XY012NV/025XY024NV	40/25/20	38
776422/776423	025XY017NV/025XY014NV	45/40	39
776981/776982/7671881	025XY017NV/025XY009NV	60-70/15-25	40
776425	025XY017NV/025XY018NV/025XY014NV	40/25/20	41
767241/767700	025XY017NV/025XY024NV/025XY012NV	45/20/20	42
767701	025XY017NV/028BY042NV	40/35	43
776801	025XY018NV/025XY009NV	35/50	44
767261	025XY018NV/025XY014NV/025XY019NV	40/30/20	45
767452	025XY018NV/025XY015NV/025XY014NV	45/30/15	46
7671234	025XY018NV/025XY017NV/025XY012NV	35/30/20	47
776802	025XY018NV/025XY018NV	65/20	48
776822	025XY019NV/024XY017NV/025XY019NV	50/20/20	49
767229/767491/776823/7761232/7761411	025XY019NV/025XY025NV	40-65/25-50	50
767060/767070/776341/776581/ 776641/776841/7761201/ 7761202/7761352	025XY019NV	85-100	51
776971	025XY024NV/025XY019NV/025XY009NV	50/20/20	52
776550	025XY024NV/025XY012NV	70/20	53
767993	025XY027NV0/25XY009NV/025XY012NV	40/30/15	54
767345/7761233	025XY059NV/025XY019NV	75/15	55
7671631	025XY065NV/025XY004NV/025XY024NV	45/25/15	56
776630	028BY003NV	100	57
776161	028BY004NV	100	58
776280/776282	028BY007NV	90-100	59
776283	028BY007NV/028BY011NV	50/40	60
776141/776143/776270/776600/ 776870	028BY010NV	85-100	61
776371	028BY010NV/028BY013NV	60/30	62
776202	028BY011NV0/28BY010NV	70/20	63
776171	028BY011NV/028BY013NV	70/20	64
776172	028BY011NV/028BY017NV	70/20	65
776201	028BY011NV	100	66
776661	028BY016NV/028BY037NV	75/10	67
776961/776962	028BY016NV	85-100	68
776121	028BY017NV	100	69
776770	028BY024NV	95	70
776481	028BY029NV/028BY037NV	45/40	71
776480/776492/776551	028BY029NV/028BY038NV	25-60/15-50	72
776681/776682/776701/776851	028BY030NV/028BY034NV	20-65/20-35	73
776891	028BY037NV/028BY007NV/028BY030NV	35/25/25	74
776781/776782/776783	028BY037NV/028BY030NV	40-70/15/35	75
767121	028BY042NV	45	76
776531	028BY042NV/025XY009NV/025XY024NV	40/35/15	77
776452	028BY042NV/028BY029NV/028BY067NV	50/20/15	78

Soil Map Units	Range Types	Percentage Represented	Number
776451	028BY042NV/028BY043NV	40/30	79
776462/776471	028BY043NV/028BY029NV	45-50/30-35	80
767206	028BY060NV/025XY059NV/024XY030NV	40/30/20	81
767201/776332	028BY060NV/028BY085NV	55/30	82
776491	028BY043NV	35	83
7761510	NA	100	84

Note that the summed percentage of range types listed for each soil often fails to sum 100% because rock outcrops and minor range types take up the remaining proportion of each soil map unit. Also notice that some range type combinations occur in varying percentages given as ranges in the table. A unique numeric identifier designates each range type combination.

Review of these 82 soil-derived biotic associations revealed that they fail to adequately capture biotic communities associated with wetlands, because these usually occur in parcels too small to map. This is a critical shortcoming because the distribution of perennial water strongly affects the productivity, composition, and diversity of plant communities and their suitability for wildlife in arid settings. Four categories of wetland communities were recognized from USGS maps and assigned appropriate range type associations from the Owyhee High Plateau and Central Nevada Basin and Range.

Each kind of wetland was designated as an additional range type combination (Table 5.4) and added as shapefiles into the soil map unit database. Perennial water sources were recorded by simply reviewing all USGS maps encompassing the study area and digitizing the location of every mapped stream, seep, and spring. Mapped sources were then divided into three elevation categories: < 1829 m (6000 ft), 1829-2286 m (7500 ft), and > 2286 m. All area within 25 m of each spring and axial stream, and 10 m of each tributary stream was designated as part of the wetland.

Table 5.4 List of Wetland Habitats Defined from USGS Maps

Description	Elevation	Range Types	Range Type Name	Percentage Represented	Number
Lowland Axial Stream Floodplains	**< 1829 m.**	**025XY001NV**	**Moist Floodplain**	**100**	**85**
Lowland Perennial Inset Fans, Springs and Seeps	**< 1829 m.**	**025XY005NV/ 028BY044NV**	**Wet Meadow/ Wetland**	**80/20**	**86**
Mid-Elevation Axial Floodplains, Springs and Seep	**1829-2286 m**	**028BY001NV/ 028BY044NV**	**Wet Meadow 10-14 p.z./ Wetland**	**80/20**	**87**
Upland Streams, Springs, and Seeps	**2286 m**	**028BY022NV**	**Wet Meadow 14+ p.z.**	**70**	**88**

THE PINE VALLEY HABITAT LANDSCAPE

Altogether 86 separate combinations of range types were identified within Pine Valley and designated with an identification number ranging from 1 to 88 (numbers 15 and 84 were assigned to provisional range type/soil combinations that were later discarded). Table 5.5 summarizes biotic characteristics of the range type configurations and assigns each to wetland, saltbush, sagebrush, pinyon-juniper, or montane biotic communities. The biogeographical literature of the Great Basin (cf. Cronquist et al. 1986) often employs similar designations representing gross classifications of plant communities. Such categories are convenient for designating habitats because, although habitats sometimes crosscut boundaries among community types, they usually qualify unequivocally as one or another community based on predominant shrub and grass species. However, note that Range Type Combination number 1 classifies as either a sagebrush or saltbush community depending on the proportional contribution of constituent range types.

Counting Range Type Combination 1 twice, five range type combinations qualify as wetland, six as saltbush, 49 as sagebrush, 17 as pinyon-juniper, and ten as montane. Each of these 87 range type/community associations is defined as a separate habitat; thus, "habitat" refers to a particular potential natural plant community defined by a specific assortment of range types. Note that each habitat is assigned an alphanumeric symbol bearing a letter prefix (WT, ST, SG, PJ, or MN) that represents the community to which it belongs. This is followed by the USDA plant symbols for the dominant shrub and grass species. The habitat symbol ends with the numeral identifying the range type combination. Table 5.6 summarizes physiographic characteristics of each habitat. Figure 5.1 shows the spatial distribution of these associations in the Pine Valley study area.

Table 5.5. Biotic characteristics of Pine Valley habitats.

Number	Annual Productivity Poor-Normal-Favorable (kg/ha)	%Shrubs-%Grasses-%Forbs	Dominant Tree	Dominant Shrub	Dominant Grass	Dominant Forb	Community	Habitat
1	347-521-745	42-51-7	NA	*Artemisia tridentata wyomingensis*	*Achnatherum thurberianum*	*Sphaeralcea*	Sagebrush	SG-ARTRT/ACTH7-1
1	319-479-764	62-35-3	NA	*Atriplex confertifolia*	*Achnatherum hymenoides*	*Sphaeralcea*	Saltbush	ST-ATCO/AHCT-1
2	336-504-840	70-28-2	NA	*Atriplex confertifolia*	*Achnatherum hymenoides*	*Sphaeralcea*	Saltbush	ST-ATCO/AHCT-2
3	398-666-907	45-49-5	NA	*Sarcobatus vermiculatus*	*Leymus cinereus*	*Nitrophila*	Saltbush	ST-SAVE4/LECI4-3
4	336-504-672	79-14-7	NA	*Atriplex confertifolia*	*Sitanion hystrix*	*Nitrophila*	Saltbush	ST-ATCO/SIHY-4
5	370-554-790	42-53-5	NA	*Artemisia tridentata wyomingensis*	*Achnatherum thurberianum*	*Astragalus*	Sagebrush	SG-ARTRT/ACTH7-5
6	448-672-896	31-60-9	NA	*Artemisia tridentata wyomingensis*	*Achnatherum thurberianum*	*Sphaeralcea*	Sagebrush	SG-ARTRT/ACTH7-6
7	638-1170-1596	20-76-4	NA	*Artemisia tridentata ssp. tridentata*	*Leymus cinereus*	*Astragalus*	Sagebrush	SG-ARTRT/LECI4-7
8	302-448-627	36-57-7	NA	*Artemisia arbuscula var. nova*	*Achnatherum thurberianum*	*Sphaeralcea*	Sagebrush	SG-ARAR8/ACTH7-8
9	235-392-549	42-52-6	*Pinus monophylla*	*Artemisia vaseyana*	*Achnatherum thurberianum*	*Balsamorhiza sagittata*	Pinyon-Juniper	PJ-ARVA2/ACTH7-9
10	392-594-840	35-57-8	*Pinus monophylla*	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Balsamorhiza sagittata*	Pinyon-Juniper	PJ-ARVA2/PSSPS-10
11	308-498-689	41-52-6	*Pinus monophylla*	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Balsamorhiza sagittata*	Pinyon-Juniper	PJ-ARVA2/PSSPS-11
12	414-638-885	32-58-9	*Pinus monophylla*	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Balsamorhiza sagittata*	Pinyon-Juniper	PJ-ARVA2/PSSPS-12
13	353-554-756	39-55-6	*Pinus monophylla*	*Artemisia vaseyana*	*Achnatherum thurberianum*	*Crepis acuminata*	Pinyon-Juniper	PJ-ARVA2/ACTH7-13
14	454-672-890	39-54-7	*Pinus monophylla*	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Balsamorhiza sagittata*	Pinyon-Juniper	PJ-ARVA2/PSSPS-14
16	263-386-560	41-53-7	*Juniperus osteosperma*	*Artemisia arbuscula var. nova*	*Achnatherum hymenoides*	*Sphaeralcea*	Pinyon-Juniper	PJ-ARAR8/AHCT-16
17	196-265-434	41-53-6	*Pinus monophylla*	*Artemisia arbuscula var. nova*	*Pseudoroegneria spicata*	*Crepis acuminata*	Pinyon-Juniper	PJ-ARAR8/PSSPS-17
18	2016-2800-3920	14-74-12	NA	*Salix*	*Leymus cinereus*	Multiple	Wetland	WT-SALIX/LECI4-18
19	2240-3920-5040	12-81-7	NA	*Artemisia tridentata ssp. tridentata*	*Leymus cinereus*	Multiple	Sagebrush	SG-ARTRT/LECI4-19
20	1120-1904-3360	4-72-24	NA	*Artemisia cana ssp. viscidula*	*Deschampsia cespitosa*	*Potentilla*	Sagebrush	SG-ARCA13/DECE-20
21	442-582-862	25-64-11	*Juniperus*	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Phlox*	Pinyon-	PJ-ARVA2/PSSPS-21

Number	Annual Productivity Poor-Normal-Favorable (kg/ha)	%Shrubs-%Grasses-%Forbs	Dominant Tree	Dominant Shrub	Dominant Grass	Dominant Forb	Community	Habitat
			osteosperma				Juniper	
22	484-654-958	18-69-13	NA	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Crepis acuminata*	Sagebrush	SG-ARVA2/PSSPS-22
23	582-829-1154	22-63-14	NA	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Crepis acuminata*	Sagebrush	SG-ARVA2/PSSPS-23
24	367-539-773	24-61-14	NA	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Crepis acuminata*	Sagebrush	SG-ARVA2/PSSPS-24
25	473-685-952	21-64-15	NA	*Artemisia vaseyana*	*Pseudoroegneria spicata*	Multiple	Sagebrush	SG-ARVA2/PSSPS-25
26	454-655-924	23-63-14	NA	*Artemisia arbuscula*	*Pseudoroegneria spicata*	*Eriogonum*	Sagebrush	SG-ARAR8/PSSPS-26
27	582-818-1165	20-65-16	*Populus tremula ssp. tremuloides*	*Artemisia vaseyana*	*Festuca idahoensis*	*Crepis acuminata*	Montane	MN-ARVA2/FEID-27
28	610-818-1086	23-65-12	NA	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Crepis acuminata*	Sagebrush	SG-ARVA2/PSSPS-28
29	616-851-1131	25-63-12	NA	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Crepis acuminata*	Sagebrush	SG-ARVA2/PSSPS-29
30	504-686-868	26-63-11	*Juniperus osteosperma*	*Artemisia tridentata wyomingensis*	*Pseudoroegneria spicata*	*Eriogonum*	Sagebrush	SG-ARTRT/PSSPS-30
31	470-661-851	23-66-10	NA	*Artemisia arbuscula*	*Pseudoroegneria spicata*	*Eriogonum*	Sagebrush	SG-ARAR8/PSSPS-31
32	504-694-885	29-62-10	*Juniperus osteosperma*	*Artemisia tridentata wyomingensis*	*Pseudoroegneria spicata*	Multiple	Sagebrush	SG-ARTRT/PSSPS-32
33	672-896-1120	24-65-11	NA	*Purshia tridentata*	*Pseudoroegneria spicata*	Multiple	Sagebrush	SG-PUTR2/PSSPS-33
34	459-661-918	22-70-8	*Juniperus osteosperma*	*Artemisia tridentata wyomingensis*	*Pseudoroegneria spicata*	*Crepis acuminata*	Sagebrush	SG-ARTRT/PSSPS-34
35	594-840-1187	23-67-10	*Juniperus osteosperma*	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Lupinus*	Sagebrush	SG-ARVA2/PSSPS-35
36	487-689-974	21-74-6	*Juniperus osteosperma*	*Artemisia tridentata wyomingensis*	*Pseudoroegneria spicata*	Multiple	Sagebrush	SG-ARTRT/PSSPS-36
37	566-851-1165	25-61-15	NA	*Artemisia vaseyana*	*Festuca idahoensis*	*Crepis acuminata*	Sagebrush	SG-ARVA2/FEID-37
38	409-655-885	24-60-16	NA	*Artemisia arbuscula*	*Festuca idahoensis*	*Crepis acuminata*	Sagebrush	SG-ARAR8/FEID-38
39	470-711-902	23-62-15	NA	*Artemisia arbuscula*	*Pseudoroegneria spicata*	Multiple	Sagebrush	SG-ARAR8/PSSPS-39
40	431-700-924	22-61-17	NA	*Artemisia arbuscula*	*Pseudoroegneria spicata*	Multiple	Sagebrush	SG-ARAR8/PSSPS-40
41	426-661-851	23-63-14	NA	*Artemisia arbuscula*	*Pseudoroegneria spicata*	*Eriogonum*	Sagebrush	SG-ARAR8/PSSPS-41
42	392-638-857	24-59-17	NA	*Artemisia arbuscula*	*Festuca idahoensis*	*Crepis acuminata*	Sagebrush	SG-ARAR8/FEID-42
43	846-1254-1579	50-38-12	*Cercocarpus ledifolius*	*Artemisia arbuscula*	*Pseudoroegneria spicata*	*Lupinus*	Montane	MN-ARAR8/PSSPS-43
44	549-739-1042	21-68-12	NA	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Eriogonum*	Sagebrush	SG-ARVA2/PSSPS-44
45	470-672-874	25-67-9	NA	*Artemisia tridentata wyomingensis*	*Pseudoroegneria spicata*	*Eriogonum*	Sagebrush	SG-ARTRT/PSSPS-45
46	470-672-907	22-70-9	*Juniperus osteosperma*	*Artemisia tridentata wyomingensis*	*Pseudoroegneria spicata*	*Eriogonum*	Sagebrush	SG-ARTRT/PSSPS-46
47	448-694-930	23-63-14	NA	*Artemisia arbuscula*	*Pseudoroegneria spicata*	*Crepis acuminata*	Sagebrush	SG-ARAR8/PSSPS-47
48	381-571-762	23-68-10	NA	*Artemisia arbuscula*	*Pseudoroegneria spicata*	Multiple	Sagebrush	SG-ARAR8/PSSPS-48
49	426-627-829	30-65-5	NA	*Artemisia tridentata wyomingensis*	*Pseudoroegneria spicata*	*Sphaeralcea*	Sagebrush	SG-ARTRT/PSSPS-49
54	577-874-1254	20-65-15	NA	*Artemisia vaseyana*	*Festuca idahoensis*	*Crepis acuminata*	Sagebrush	SG-ARVA2/FEID-54
55	235-395-554	33-58-9	*Juniperus osteosperma*	*Artemisia tridentata wyomingensis*	*Pseudoroegneria spicata*	*Phlox*	Pinyon-Juniper	PJ-ARTRT/PSSPS-55

Number	Annual Productivity Poor-Normal-Favorable (kg/ha)	%Shrubs-%Grasses-%Forbs	Dominant Tree	Dominant Shrub	Dominant Grass	Dominant Forb	Community	Habitat
56	**563-853-1254**	**25-45-30**	***Populus tremula* ssp. *tremuloides***	***Symphoricarpos***	***Agropyron trachycaulum***	***Senecio***	**Montane**	**MN-SYMPH/AGTR-56**
57	**1680-2800-5600**	**12-88-0**	**NA**	***Artemisia tridentata* ssp. *tridentata***	***Leymus cinereus***	**Multiple**	**Sagebrush**	**SG-ARTRT/LECI4-57**
58	**896-1680-2464**	**19-77-4**	**NA**	***Sarcobatus vermiculatus***	***Leymus cinereus***	**Multiple**	**Saltbush**	**ST-SAVE4/LECI4-58**
59	**672-896-1120**	**28-64-7**	***Pinus monophylla***	***Artemisia vaseyana***	***Achnatherum thurberianum***	***Crepis acuminata***	**Pinyon-Juniper**	**PJ-ARVA2/ACTH7-59**
60	**448-650-829**	**33-59-7**	***Juniperus osteosperma***	***Artemisia arbuscula* var. *nova***	***Achnatherum thurberianum***	***Crepis acuminata***	**Pinyon-Juniper**	**PJ-ARAR8/ACTH7-60**
61	**448-672-896**	**40-53-7**	***Juniperus osteosperma***	***Artemisia tridentata wyomingensis***	***Achnatherum hymenoides***	***Sphaeralcea***	**Sagebrush**	**SG-ARTRT/AHCT-61**
62	**386-571-773**	**47-47-6**	***Juniperus osteosperma***	***Artemisia tridentata wyomingensis***	***Achnatherum hymenoides***	***Sphaeralcea***	**Sagebrush**	**SG-ARTRT/AHCT-62**
63	**286-487-650**	**43-50-7**	***Juniperus osteosperma***	***Artemisia arbuscula* var. *nova***	***Achnatherum hymenoides***	***Sphaeralcea***	**Sagebrush**	**SG-ARAR8/AHCT-63**
64	**274-465-627**	**48-45-7**	***Juniperus osteosperma***	***Artemisia arbuscula* var. *nova***	***Achnatherum hymenoides***	***Sphaeralcea***	**Sagebrush**	**SG-ARAR8/AHCT-64**
65	**241-420-560**	**47-46-7**	***Juniperus osteosperma***	***Artemisia arbuscula* var. *nova***	***Achnatherum hymenoides***	***Sphaeralcea***	**Sagebrush**	**SG-ARAR8/AHCT-65**
66	**280-504-672**	**44-49-7**	***Juniperus osteosperma***	***Artemisia arbuscula* var. *nova***	***Achnatherum hymenoides***	**Multiple**	**Sagebrush**	**SG-ARAR8/AHCT-66**
67	**129-256-384**	**49-44-7**	***Juniperus osteosperma***	***Artemisia arbuscula* var. *nova***	***Achnatherum hymenoides***	***Phlox***	**Sagebrush**	**SG-ARAR8/AHCT-67**
68	**112-252-392**	**53-41-6**	***Juniperus osteosperma***	***Artemisia arbuscula* var. *nova***	***Achnatherum hymenoides***	**Multiple**	**Sagebrush**	**SG-ARAR8/AHCT-68**
69	**224-336-448**	**64-31-5**	**NA**	***Atriplex confertifolia***	***Achnatherum hymenoides***	***Sphaeralcea***	**Saltbush**	**ST-ATCO/AHCT-69**
70	**1596-2369-4256**	**25-75-0**	**NA**	***Artemisia vaseyana***	***Leymus cinereus***	**Multiple**	**Sagebrush**	**SG-ARVA2/LECI4-70**
71	**633-874-1215**	**32-60-7**	***Pinus monophylla***	***Artemisia vaseyana***	***Achnatherum lettermani***	**Multiple**	**Pinyon-Juniper**	**PJ-ARVA2/ACLE9-71**
72	**409-610-862**	**31-62-8**	**NA**	***Artemisia vaseyana***	***Achnatherum lettermani***	***Lupinus***	**Sagebrush**	**SG-ARVA2/ACLE9-72**
73	**224-314-414**	**35-57-8**	***Pinus monophylla***	***Artemisia vaseyana***	***Pseudoroegneria spicata***	***Lupinus***	**Pinyon-Juniper**	**PJ-ARVA2/PSSPS-73**
74	**577-795-1014**	**34-58-8**	***Pinus monophylla***	***Artemisia vaseyana***	***Pseudoroegneria spicata***	***Crepis acuminata***	**Pinyon-Juniper**	**PJ-ARVA2/PSSPS-74**
75	**465-672-879**	**38-55-8**	***Pinus monophylla***	***Artemisia arbuscula***	***Pseudoroegneria spicata***	**Multiple**	**Pinyon-Juniper**	**PJ-ARAR8/PSSPS-75**
76	**857-1210-1512**	**59-31-10**	***Cercocarpus ledifolius***	***Artemisia vaseyana***	***Achnatherum thurberianum***	**Multiple**	**Montane**	**MN-ARVA2/ACTH7-76**

Number	Annual Productivity Poor-Normal-Favorable (kg/ha)	%Shrubs-%Grasses - %Forbs	Dominant Tree	Dominant Shrub	Dominant Grass	Dominant Forb	Community	Habitat
77	1061-1474-1921	48-41-11	*Cercocarpus ledifolius*	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Lupinus*	Montane	MN-ARVA2/PSSPS-77
78	1196-1714-2145	52-37-11	*Cercocarpus ledifolius*	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Lupinus*	Montane	MN-ARVA2/PSSPS-78
79	1064-1512-1915	57-35-8	*Cercocarpus ledifolius*	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Balsamorhiza sagittata*	Montane	MN-ARVA2/PSSPS-79
80	756-1058-1428	43-51-6	*Cercocarpus ledifolius*	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Balsamorhiza sagittata*	Montane	MN-ARVA2/PSSPS-80
81	287-330-607	37-55-8	*Juniperus osteosperma*	*Artemisia arbuscula var. nova*	*Achnatherum thurberianum*	*Phlox*	Pinyon-Juniper	PJ-ARAR8/ACTH7-81
82	359-554-718	33-63-4	*Cercocarpus ledifolius*	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Lupinus*	Montane	MN-ARVA2/PSSPS-82
83	353-510-666	52-44-5	*Cercocarpus ledifolius*	*Artemisia vaseyana*	*Pseudoroegneria spicata*	*Balsamorhiza sagittata*	Montane	MN-ARVA2/PSSPS-83
85	1646-2901-3248	10-79-11	NA	*Salix*	*Leymus cinereus*	Multiple	Wetland	WT-SALIX/LECI4-85
86	1053-2150-3024	3-77-20	NA	*Salix/Rosa*	*Deschampsia cespitosa*	*Potentilla*	Wetland	WT-SALIX/DECE-86
87	1232-2419-3920	2-85-13	NA	*Salix/Rosa*	*Carex*	*Potentilla*	Wetland	WT-SALIX/CAREX-87
88	1568-2240-3584	7-93-0	NA	*Artemisia cana*	*Deschampsia cespitosa*	Multiple	Wetland	WT-ARCA13/DECE-88

Table 5.6. Physiographic characteristics of Pine Valley habitats.

Habitat	Soil Type	Soil Texture	Landform	Precipitation (in)	Rock Outcrop	Slope (%)	Annual Flooding
MN-ARAR8/ PSSPS-43	colluvium and residuum	cobbly loam/ very stony loam	hills/ mountains/ ridges/ slopes	14	Present	15-50	None
MN-ARVA2/ ACTH7-76	residuum	very stony loam	mountains/ ridges/ slopes	14	Present	15-50	None
MN-ARVA2/ FEID-27	colluvium and residuum	gravelly loam/ silt loam	hills/ knobs/ pediments/ plateaus/ slopes	16		15-50	None
MN-ARVA2/ PSSPS-77	colluvium and residuum	very gravelly loam	mountains/ slopes	16		30-75	None
MN-ARVA2/ PSSPS-78	alluvium, colluvium, and residuum	gravelly loam/ silt loam/ stony loam	hills/ mountains/ ridges/ slopes	18		15-50	None
MN-ARVA2/ PSSPS-79	colluvium and residuum	gravelly loam/ very gravelly loam	mountains/ ridges/ slopes	17	Present	15-75	None
MN-ARVA2/ PSSPS-80	colluvium and residuum	stony loam/ gravelly loam	mountains/ ridges/ slopes	16	Present	15-75	None
MN-ARVA2/ PSSPS-82	colluvium and residuum	bouldery silt loam/ gravelly loam	mountains/ pediments/ ridges/ slopes	13		15-50	None
MN-ARVA2/ PSSPS-83	colluvium and residuum	very stony loam	mountains/ slopes	14	Present	15-50	None
MN-SYMPH/ AGTR-56	alluvium, colluvium, and residuum	gravelly loam/ silt loam	hills/ mountains/ ridges	16		8-30	None
PJ-ARAR8/ ACTH7-60	alluvium	loam/ gravelly loam	fans/ piedmonts	10		2-8	None
PJ-ARAR8/ ACTH7-81	colluvium and residuum	silt loam/ very gravelly loam	hills/ low terraces and floodplains/ mountains/ piedmonts/ ridges/ slopes	10		15-50	None
PJ-ARAR8/ AHCT-16	alluvium	sandy loam/ gravelly sandy loam	ballenas/ fans/ piedmonts	9		0-15	Rare
PJ-ARAR8/ PSSPS-17	colluvium and residuum	gravelly loam/ very gravelly loam	mountains/ ridges/ slopes	12	Present	4-50	None
PJ-ARAR8/ PSSPS-75	colluvium and residuum	stony loam/ cobbly loam	hills/ mountains/ plateaus/ slopes	14		8-50	None
PJ-ARTRT/ PSSPS-55	alluvium and residuum	gravelly loam/ sandy loam/ silt loam	fans/ hills/ low terraces and floodplains/ mountains/ pediments/ plateaus	9		2-50	None
PJ-ARVA2/ ACLE9-71	colluvium and residuum	stony silt loam/ very stony loam	mountains/ slopes	15		8-30	None
PJ-ARVA2/ ACTH7-13	alluvium, colluvium, and residuum	loam/ stony loam/ gravelly loam	fans/ piedmonts/ hills/ mountains/ slopes	12		2-30	None
PJ-ARVA2/ ACTH7-59	alluvium, colluvium, and residuum	loam/ stony loam	fans/ hills/ piedmonts/ slopes	10		2-30	None
PJ-ARVA2/ ACTH7-9	alluvium, colluvium, and residuum	loam/ gravelly loam/ cobbly loam/	fans/ mountains/ piedmonts/ slopes	13	Present	2-50	None
PJ-ARVA2/ PSSPS-10	colluvium and residuum	cobbly loam/ very gravelly loam	hills/ mountains/ pediments/ plateaus	13		15-50	None
PJ-ARVA2/ PSSPS-11	colluvium and residuum	gravelly loam/ extremely stony loam	hills/ mountains/ plateaus/ slopes	14		8-30	None
PJ-ARVA2/ PSSPS-12	colluvium and residuum	very gravelly loam/ loam	hills/ mountains/ ridges/ slopes	11		15-50	None
PJ-ARVA2/ PSSPS-14	colluvium and residuum	stony loam/ gravelly loam	hills/ mountains/ plateaus/ slopes	15		15-75	None

Habitat	Soil Type	Soil Texture	Landform	Precipitation (in)	Rock Outcrop	Slope (%)	Annual Flooding
PJ-ARVA2/ PSSPS-21	colluvium and residuum	loam/ very gravelly loam	hills/ mountains/ pediments/ plateaus/ slopes	12		15-50	None
PJ-ARVA2/ PSSPS-73	colluvium and residuum	cobbly loam/ gravelly loam	hills/ mountains/ plateaus/ ridges/ slopes	15		8-75	None
PJ-ARVA2/ PSSPS-74	colluvium and residuum	very gravelly loam/ very stony loam	hills/ mountains/ pediments/ plateaus/ ridges/ slopes	12		2-30	Rare
SG-ARAR8/ ACTH7-8	alluvium, colluvium, and residuum	very cobbly loam/ silt loam	fans/ piedmonts	10		2-30	None
SG-ARAR8/ AHCT-63	alluvium	sandy loam/ gravelly loam	fans/ low terraces and floodplains/ piedmonts	10		0-8	None
SG-ARAR8/ AHCT-64	alluvium	gravelly sandy loam/ gravelly loam	fans/ piedmonts	10		2-8	Occasional
SG-ARAR8/ AHCT-65	alluvium	gravelly sandy loam/ gravelly loam	fans/ piedmonts	10		2-8	Rare
SG-ARAR8/ AHCT-66	alluvium	gravelly loam	fans/ piedmonts	10		2-8	None
SG-ARAR8/ AHCT-67	colluvium and residuum	very stony loam/ very cobbly loam	hills/ mountains/ ridges/ slopes	11		8-50	None
SG-ARAR8/ AHCT-68	alluvium and residuum	loam/ gravelly loam	hills/ ridges/ slopes	10		15-30	None
SG-ARAR8/ FEID-38	colluvium and residuum	gravelly loam/ cobbly loam	hills/ mountains/ slopes	13		4-50	None
SG-ARAR8/ FEID-42	colluvium and residuum	gravelly loam/ cobbly loam	hills/ knobs/ mountains/ plateaus/ ridges	14		15-70	None
SG-ARAR8/ PSSPS-26	colluvium and residuum	cobbly clay loam/ gravelly loam	hills/ mountains/ pediments/ piedmonts/ plateaus/ slopes	13		8-30	None
SG-ARAR8/ PSSPS-31	alluvium	gravelly loam	piedmonts/ valley sides/ fan remnants/ valley fans	10		2-15	None
SG-ARAR8/ PSSPS-39	colluvium and residuum	cobbly loam/ gravelly clay loam	fans/ hills/ mountains/ piedmonts/ slopes	14		15-50	None
SG-ARAR8/ PSSPS-40	colluvium and residuum	stony loam/ gravelly loam/ cobbly clay loam	hills/ mountains/ plateaus/ ridges/ slopes/ piedmonts	13		4-50	None
SG-ARAR8/ PSSPS-41	alluvium, colluvium, and residuum	cobbly loam/ gravelly clay loam	hills/ mountains/ slopes	12		15-50	None
SG-ARAR8/ PSSPS-47	alluvium and colluvium	cobbly loam/ gravelly silt loam	fan remnants/ piedmonts/ plateaus	12		2-15	None
SG-ARAR8/ PSSPS-48	residuum	stony clay loam/ stony loam	mountains/ ridges/ slopes	12		8-30	None
SG-ARCA13/ DECE-20	alluvium	clay loam	low terraces and floodplains	12		0-2	Frequent
SG-ARTRT/ ACTH7-1	alluvium	fine sandy loam/ silt loam	fans/ low terraces and floodplains	8		0-8	None

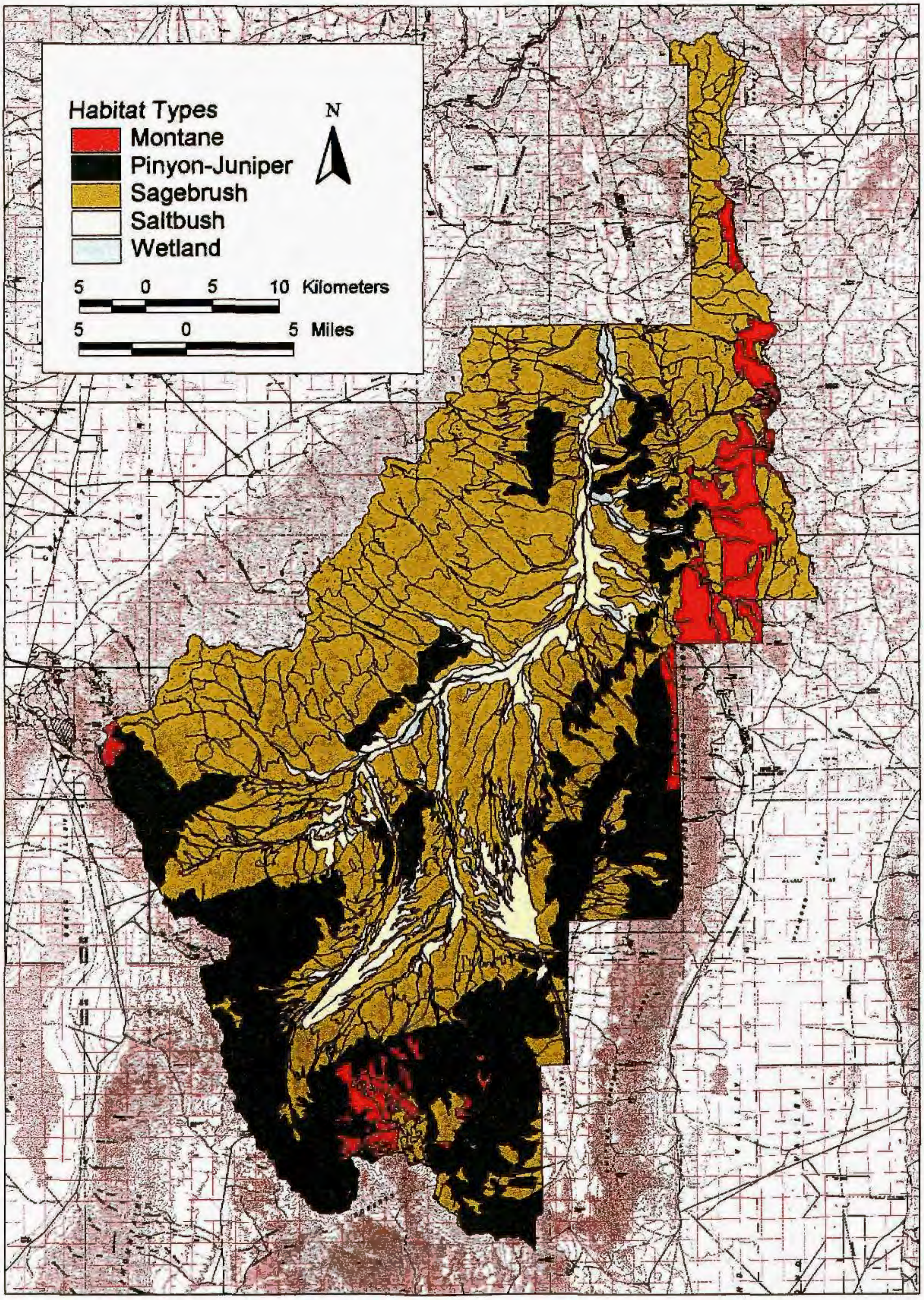


Figure 5.1. Spatial distribution of habitat types.

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Range type descriptions provide quantitative descriptions of plant communities, including species ethnohistorically recorded as having been collected for food by hunter-gatherers. This provides a simple way to model the distribution and productivity of plant food resources in Pine Valley. However, a predictive model of hunter-gatherer foraging decisions based on optimal foraging theory must also consider animal resources, simply because most game offer higher foraging returns than do most plants (Simms 1987). Thus, fauna must be included in the Pine Valley model. Although soil and range data do not directly measure the spatial distribution or abundance of fauna, they do permit observation of the distributions of many forage plants of that fauna. Also, variability in water and soil acts upon wildlife distribution as well as plant habitat (Cooperrider et al. 1986). Therefore, the Pine Valley habitat landscape can be used to assess the suitability of plant habitat types for animal habitat based on the production of forage and on physiographic requirements of particular game animals. The following section discusses habitat suitability for selected game species.

Large Mammals

Pronghorn antelope, mule deer, and bighorn sheep are important food sources of ethnographic hunter-gatherers (Steward 1938). The habitat distribution of all three species can be inferred from slope, association with water, and forage abundance.

Typical pronghorn habitat is a low, open, gently rolling terrain in sagebrush and greasewood-saltbush plant communities. Antelope generally shun steeper slopes (Kindschy et al. 1982; Yoakum 1980) in order to rely on their keen eyesight and high running speeds to flee predators (Frison 1978:251). In contrast, mule deer generally prefer steep, rough, or broken terrain offering steep relief. This kind of topography offers effective escape from predators and easy access to a variety of feeding niches within a small area (Kerr 1979). Relief is even more vital for sheep habitat, the defining characteristic of which is precipitous, remote topography. Mountain sheep use steep bluffs, cliffs, rock rims, and outcrops as escape terrain. Similarly, bedding and lambing areas are restricted to steeper slopes. Although adult rams occasionally venture as far as 3 km from steep relief, mountain sheep usually remain within 0.8 km of abrupt escape terrain even when rich, well watered foraging patches lie not much farther away (Van Dyke et al. 1983; Wehausen 1983).

Given the different slope preferences of these three species, a slope suitability score can be calculated for each habitat by individually weighting the slope intervals presented in Table 5.7 for each of the three large mammals. The antelope slope suitability score is calculated by the following equation.

$SSS\ antelope = (3 * p{<}3\%) + (2 * p3\text{-}9\%) + (p9\text{-}18\%)$ (Equation 1)

where:
SSS antelope = antelope slope suitability score
p<3% = proportion of a habitat of 3% or less slope
p3-9%= proportion of a habitat between 3% and 9% slope
p9-18% = proportion of a habitat of 9% to 18% slope

Table 5.7. Proportional breakdown of Pine Valley habitats by slope interval and proximity to water.

Habitat	Total Area (ha)	<3% Slope	3-9% Slope	9-18% Slope	>18% Slope	< 50 m from Water	50 m-3 km from Water	3 km-6 km from Water	> 6 km Water
MN-ARAR8/PSSPS-43	947	0.01	0.07	0.37	0.56	0.00	1.00	0.00	0.00
MN-ARVA2/ACTH7-76	95	0.04	0.10	0.28	0.58	0.00	1.00	0.00	0.00
MN-ARVA2/FEID-27	401	0.02	0.18	0.37	0.43	0.01	0.99	0.00	0.00
MN-ARVA2/PSSPS-77	336	0.01	0.09	0.32	0.59	0.00	1.00	0.00	0.00
MN-ARVA2/PSSPS-78	62	0.00	0.00	0.10	0.90	0.00	1.00	0.00	0.00
MN-ARVA2/PSSPS-79	704	0.00	0.03	0.21	0.76	0.00	0.81	0.18	0.00
MN-ARVA2/PSSPS-80	919	0.00	0.03	0.20	0.77	0.00	0.99	0.00	0.00
MN-ARVA2/PSSPS-82	7917	0.02	0.23	0.38	0.37	0.00	0.79	0.21	0.00
MN-ARVA2/PSSPS-83	1374	0.00	0.02	0.17	0.81	0.00	0.66	0.34	0.00
MN-SYMPH/AGTR-56	469	0.01	0.09	0.45	0.46	0.00	1.00	0.00	0.00
PJ-ARAR8/ACTH7-60	385	0.55	0.45	0.01	0.00	0.00	1.00	0.00	0.00
PJ-ARAR8/ACTH7-81	41	0.17	0.67	0.13	0.03	0.00	0.69	0.31	0.00
PJ-ARAR8/AHCT-16	2518	0.39	0.58	0.03	0.00	0.00	0.27	0.67	0.06
PJ-ARAR8/PSSPS-17	626	0.07	0.35	0.38	0.20	0.00	0.63	0.37	0.00
PJ-ARAR8/PSSPS-75	1703	0.07	0.53	0.31	0.09	0.00	0.89	0.11	0.00
PJ-ARTRT/PSSPS-55	10252	0.38	0.52	0.09	0.01	0.00	0.88	0.10	0.02
PJ-ARVA2/ACLE9-71	1224	0.02	0.37	0.47	0.14	0.01	0.99	0.00	0.00
PJ-ARVA2/ACTH7-13	9583	0.14	0.61	0.22	0.03	0.00	0.72	0.20	0.07
PJ-ARVA2/ACTH7-59	733	0.44	0.48	0.07	0.00	0.00	1.00	0.00	0.00
PJ-ARVA2/ACTH7-9	12749	0.04	0.34	0.39	0.24	0.00	0.62	0.35	0.03
PJ-ARVA2/PSSPS-10	431	0.01	0.33	0.54	0.11	0.00	1.00	0.00	0.00
PJ-ARVA2/PSSPS-11	614	0.02	0.29	0.47	0.22	0.02	0.98	0.00	0.00
PJ-ARVA2/PSSPS-12	240	0.00	0.14	0.35	0.50	0.01	0.99	0.00	0.00
PJ-ARVA2/PSSPS-14	5431	0.03	0.30	0.46	0.22	0.00	0.92	0.08	0.00
PJ-ARVA2/PSSPS-21	2448	0.06	0.41	0.40	0.14	0.00	1.00	0.00	0.00
PJ-ARVA2/PSSPS-73	6202	0.07	0.42	0.40	0.11	0.01	0.88	0.12	0.00
PJ-ARVA2/PSSPS-74	115	0.44	0.54	0.02	0.00	0.00	1.00	0.00	0.00
SG-ARAR8/ACTH7-8	1434	0.16	0.62	0.19	0.02	0.00	0.02	0.73	0.25
SG-ARAR8/AHCT-63	258	0.85	0.15	0.00	0.00	0.00	1.00	0.00	0.00
SG-ARAR8/AHCT-64	1518	0.85	0.14	0.00	0.00	0.00	0.53	0.47	0.00
SG-ARAR8/AHCT-65	375	0.46	0.54	0.01	0.00	0.00	0.98	0.02	0.00

Habitat	Total Area (ha)	<3% Slope	3-9% Slope	9-18% Slope	>18% Slope	< 50 m from Water	50 m-3 km from Water	3 km-6 km from Water	> 6 km Water
SG-ARAR8/AHCT-66	1413	0.72	0.28	0.01	0.00	0.00	0.61	0.21	0.19
SG-ARAR8/AHCT-67	374	0.04	0.41	0.46	0.10	0.00	0.70	0.29	0.00
SG-ARAR8/AHCT-68	779	0.19	0.60	0.18	0.03	0.00	0.76	0.24	0.00
SG-ARAR8/FEID-38	3791	0.03	0.32	0.40	0.25	0.00	0.99	0.01	0.00
SG-ARAR8/FEID-42	1597	0.01	0.12	0.38	0.49	0.00	1.00	0.00	0.00
SG-ARAR8/PSSPS-26	580	0.04	0.56	0.34	0.05	0.00	1.00	0.00	0.00
SG-ARAR8/PSSPS-31	1809	0.29	0.60	0.09	0.03	0.00	0.99	0.01	0.00
SG-ARAR8/PSSPS-39	1839	0.04	0.43	0.37	0.16	0.01	0.99	0.00	0.00
SG-ARAR8/PSSPS-40	4754	0.04	0.49	0.36	0.11	0.00	0.97	0.02	0.00
SG-ARAR8/PSSPS-41	298	0.26	0.51	0.19	0.04	0.00	1.00	0.00	0.00
SG-ARAR8/PSSPS-47	379	0.02	0.48	0.44	0.07	0.01	0.99	0.00	0.00
SG-ARAR8/PSSPS-48	685	0.09	0.63	0.26	0.03	0.00	0.89	0.11	0.00
SG-ARCA13/DECE-20	222	0.90	0.09	0.01	0.00	0.09	0.91	0.00	0.00
SG-ARTRT/ACTH7-1	834	0.74	0.25	0.01	0.00	0.04	0.84	0.12	0.00
SG-ARTRT/ACTH7-5	1288	0.90	0.10	0.00	0.00	0.00	1.00	0.00	0.00
SG-ARTRT/ACTH7-6	5039	0.71	0.27	0.02	0.00	0.00	0.80	0.20	0.00
SG-ARTRT/AHCT-61	3341	0.66	0.32	0.02	0.00	0.00	0.61	0.33	0.06
SG-ARTRT/AHCT-62	1002	0.99	0.01	0.00	0.00	0.00	0.43	0.57	0.00
SG-ARTRT/LECI4-19	216	0.76	0.22	0.02	0.00	0.00	1.00	0.00	0.00
SG-ARTRT/LECI4-57	570	0.68	0.28	0.04	0.00	0.00	0.28	0.58	0.14
SG-ARTRT/LECI4-7	650	0.94	0.06	0.00	0.00	0.05	0.94	0.02	0.00
SG-ARTRT/PSSPS-30	438	0.52	0.40	0.08	0.00	0.00	0.67	0.33	0.00
SG-ARTRT/PSSPS-32	824	0.59	0.39	0.02	0.00	0.00	0.25	0.63	0.11
SG-ARTRT/PSSPS-34	2897	0.17	0.49	0.28	0.06	0.00	0.88	0.12	0.00
SG-ARTRT/PSSPS-36	515	0.07	0.58	0.30	0.06	0.00	0.81	0.19	0.00
SG-ARTRT/PSSPS-45	203	0.13	0.78	0.08	0.00	0.00	1.00	0.00	0.00
SG-ARTRT/PSSPS-46	626	0.14	0.69	0.14	0.03	0.01	0.99	0.00	0.00
SG-ARTRT/PSSPS-49	1673	0.94	0.06	0.00	0.00	0.00	0.66	0.34	0.00
SG-ARTRT/PSSPS-50	36853	0.65	0.33	0.02	0.00	0.00	0.80	0.19	0.00
SG-ARTRT/PSSPS-51	21212	0.74	0.24	0.02	0.00	0.00	0.81	0.18	0.00
SG-ARTRT/PSSPS-52	1832	0.03	0.45	0.43	0.09	0.00	0.23	0.66	0.12
SG-ARVA2/ACLE9-72	1980	0.01	0.13	0.41	0.46	0.01	0.99	0.00	0.00
SG-ARVA2/FEID-37	151	0.01	0.40	0.43	0.15	0.02	0.98	0.00	0.00
SG-ARVA2/FEID-53	855	0.01	0.08	0.44	0.47	0.00	1.00	0.00	0.00
SG-ARVA2/FEID-54	0	0.45	0.55	0.00	0.00	0.00	1.00	0.00	0.00
SG-ARVA2/LECI4-70	682	0.65	0.23	0.10	0.02	0.14	0.86	0.00	0.00

Habitat	Total Area (ha)	<3% Slope	3-9% Slope	9-18% Slope	>18% Slope	< 50 m from Water	50 m-3 km from Water	3 km-6 km from Water	> 6 km Water
SG-ARVA2/PSSPS -22	**1511**	**0.01**	**0.18**	**0.46**	**0.36**	**0.00**	**1.00**	**0.00**	**0.00**
SG-ARVA2/PSSPS -23	**5976**	**0.03**	**0.34**	**0.42**	**0.21**	**0.00**	**0.92**	**0.07**	**0.00**
SG-ARVA2/PSSPS -24	**5806**	**0.02**	**0.18**	**0.45**	**0.35**	**0.00**	**0.78**	**0.21**	**0.00**
SG-ARVA2/PSSPS -25	**1952**	**0.02**	**0.24**	**0.46**	**0.28**	**0.00**	**1.00**	**0.00**	**0.00**
SG-ARVA2/PSSPS -28	**739**	**0.07**	**0.74**	**0.18**	**0.02**	**0.00**	**1.00**	**0.00**	**0.00**
SG-ARVA2/PSSPS -29	**75**	**0.02**	**0.16**	**0.64**	**0.19**	**0.00**	**1.00**	**0.00**	**0.00**
SG-ARVA2/PSSPS -35	**108**	**0.16**	**0.50**	**0.24**	**0.10**	**0.00**	**1.00**	**0.00**	**0.00**
SG-ARVA2/PSSPS -44	**1609**	**0.19**	**0.70**	**0.11**	**0.00**	**0.00**	**0.97**	**0.03**	**0.00**
SG-PUTR2/PSSPS -33	**2261**	**0.47**	**0.42**	**0.10**	**0.01**	**0.00**	**0.58**	**0.31**	**0.11**
ST-ATCO/AHCT-1	**4916**	**0.97**	**0.03**	**0.00**	**0.00**	**0.00**	**0.79**	**0.21**	**0.00**
ST-ATCO/AHCT-2	**361**	**0.94**	**0.06**	**0.00**	**0.00**	**0.10**	**0.90**	**0.00**	**0.00**
ST-ATCO/AHCT-69	**499**	**0.85**	**0.15**	**0.00**	**0.00**	**0.00**	**1.00**	**0.00**	**0.00**
ST-ATCO/SIHY-4	**90**	**0.86**	**0.14**	**0.00**	**0.00**	**0.00**	**1.00**	**0.00**	**0.00**
ST-SAVE4/LECI4-3	**7787**	**0.97**	**0.03**	**0.00**	**0.00**	**0.03**	**0.95**	**0.02**	**0.00**
ST-SAVE4/LECI4-58	**1526**	**0.92**	**0.08**	**0.00**	**0.00**	**0.05**	**0.95**	**0.00**	**0.00**
WT-ARCA13/DECE-88	**94**	**0.01**	**0.26**	**0.39**	**0.34**	**0.22**	**0.77**	**0.01**	**0.00**
WT-SALIX/CAREX-87	**1564**	**0.21**	**0.42**	**0.24**	**0.13**	**0.14**	**0.65**	**0.18**	**0.02**
WT-SALIX/DECE-86	**1459**	**0.69**	**0.23**	**0.05**	**0.03**	**0.02**	**0.77**	**0.20**	**0.01**
WT-SALIX/LECI4-18	**1267**	**0.99**	**0.01**	**0.00**	**0.00**	**0.02**	**0.98**	**0.00**	**0.00**
WT-SALIX/LECI4-85	**589**	**0.95**	**0.05**	**0.00**	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**

Note that the score assigns a value of zero to all area greater than 18% slope.

Similarly, the following score measures the slope suitability of habitats for mule deer by weighting the values of slope intervals differently, and assigning a value of zero to all areas of less than 3% slope

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SSS deer= (3 p9-18%)+(2*p>18%) +(p3-9%)* (Equation 2)

where:
SSS deer = mule deer slope suitability score
p3-9%= proportion of a habitat between 3% and 9% slope
p9-18% = proportion of a habitat of 9% to 18% slope
p>18%= proportion of a habitat greater than 18% slope

Also assigning a value of zero to all areas of less than 3% slope, the slope suitability of habitats for bighorn sheep is measured by the following equation.

*SSS sheep= (3*p>18%)+(2*p9-18%) +(p3-9%)* (Equation 3)

where:
SSS sheep = bighorn sheep slope suitability score
p3-9%= proportion of a habitat between 3% and 9% slope
p9-18% = proportion of a habitat of 9% to 18% slope
p>18%= proportion of a habitat greater than 18% slope

Table 5.8 gives the slope suitability score for each large mammal species in each habitat, as calculated from Table 5.7 and equations 1, 2, and 3.

Handy drinking water is extremely important for antelope habitats (Kindschy et al. 1982; O'Gara and Yoakum 1992; Yoakum 1980). Although individual antelope occasionally may wander as far as 8 km from water, pronghorn populations cluster near their water sources as demonstrated by wildlife inventories in Wyoming documenting that 95% of a population of 12,000 pronghorns remained within 6.5 km of water (Yoakum 1980:15). Although proximity of drinking water seems less important to mule deer ecology than to antelope habitats, mule deer are nevertheless likely to remain within 6.5 km of a water source (Kerr 1979). Particularly important are riparian zones which deer use as fawning areas and migration corridors, and because they provide good forage, cover, and access to water (Lekenby et al. 1982). Proximity of drinking water is also important to mountain sheep habitats; populations generally cluster within 1.6 to 3.2 km of water sources, especially during summer months (Van Dyke et al. 1983).

Propinquity of water affects the suitability of habitat for all large game so a score was devised to measure the relative proximity of habitats to water. Table 5.7 presents the relative proportion of the total area in hectares of each habitat in each of four ordinal categories of distance from water: < 50 m, 50 m - 3000 m, 3000 m - 6,000 m, and > 6,000

m. From these data, a score measuring the relative proximity of water to each habitat is calculated by the following equation.

$WPS = (3*p<50m)+(2*p50m\text{-}3000m)+(p3000m\text{-}60000m)$ (Equation 4)

where:

WPS = water proximity score

$p<50m$ = proportion of a habitat within 50 m of a perennial water source

p50m-3000m = proportion of a habitat between 50 m and 3 km of a perennial water source

p3000m-6000m = proportion of a habitat between 3 and 6 km of a perennial water source

Note that the water proximity score assigns a value of zero to all area more than 6 km from a water source. The water proximity score calculated in equation 4 serves to measure habitat suitability for all three large mammals because of their similar water requirements (Table 5.8).

Pronghorn generally are browsers and shrubs are their major food source, but they also consume grasses and forbs. Typically, low sagebrush dominates the best summer ranges of antelope, whereas winter ranges maintain saltbush, greasewood, and winterfat. Rangelands maintaining a desirable mixture of plant classes represent best antelope habitats (Kindschy et al. 1982); Yoakum (1980) estimates that assortments of 30 to 40% grasses, 10 to 30% forbs, and 5 to 30% shrubs are optimums. Mule deer are also browsers relying most heavily on shrubs in late summer, fall, and winter. Mountain mahogany and antelope bitterbrush are particularly attractive to mule deer. Succulent grasses and forbs make up a greater portion of mule deer diet in spring and early summer. Mountain sheep are primarily grazers, subsisting on grasses augmented by browse and forbs in spring and summer (Van Dyke et al. 1983:8; Wehausen 1983).

Comprehensive lists of forage plants of all three large mammal species are tallied elsewhere (Zeanah et al. 1995: 132, 135, 138-139). Table 5.9 sums the amount of normal year forage in each habitat and assigns ordinal forage scores to each. These scores are based on the number of standard deviations above or below the mean forage yield for all 87 habitats, assuming a normal distribution.

Given the three parameters of suitable habitat for large mammals, the quality of each habitat in the Pine Valley study area is estimable by multiplying the water proximity score (WPS), slope suitability score (SSS), and forage score. Table 5.10 gives the resulting scores for each species. The score directly measures the quality of a habitat for each species, and is assumed to indirectly monitor the probability that a particular game animal occurs in any specific habitat.

Table 5.8. Water proximity and slope suitability scores for pronghorn antelope, mule deer, and bighorn sheep.

Habitat	SSS Antelope	SSS Deer	SSS Sheep	Water Proximity Score	Habitat	SSS Antelope	SSS Deer	SSS Sheep	Water Proximity Score
MN-ARAR8/PSSPS-43	0.52	2.28	2.48	3.00	SG-ARTRT/ACTH7-1	2.74	0.27	0.26	2.92
MN-ARVA2/ACTH7-76	0.60	2.09	2.40	3.00	SG-ARTRT/ACTH7-5	2.90	0.10	0.10	3.00
MN-ARVA2/FEID-27	0.78	2.16	2.22	3.01	SG-ARTRT/ACTH7-6	2.69	0.32	0.31	2.80
MN-ARVA2/PSSPS-77	0.51	2.22	2.49	3.00	SG-ARTRT/AHCT-61	2.64	0.37	0.36	2.56
MN-ARVA2/PSSPS-78	0.10	2.10	2.90	3.00	SG-ARTRT/AHCT-62	2.99	0.01	0.01	2.43
MN-ARVA2/PSSPS-79	0.26	2.18	2.74	2.82	SG-ARTRT/LECI4-19	2.74	0.28	0.26	3.00
MN-ARVA2/PSSPS-80	0.26	2.17	2.74	3.00	SG-ARTRT/LECI4-57	2.64	0.39	0.36	2.14
MN-ARVA2/PSSPS-82	0.91	2.10	2.09	2.79	SG-ARTRT/LECI4-7	2.93	0.07	0.07	3.03
MN-ARVA2/PSSPS-83	0.21	2.14	2.79	2.66	SG-ARTRT/PSSPS-30	2.43	0.64	0.57	2.67
MN-SYMPH/AGTR-56	0.65	2.34	2.35	3.00	SG-ARTRT/PSSPS-32	2.57	0.44	0.43	2.14
PJ-ARAR8/ACTH7-60	2.54	0.47	0.46	3.00	SG-ARTRT/PSSPS-34	1.78	1.45	1.22	2.88
PJ-ARAR8/ACTH7-81	1.98	1.12	1.02	2.69	SG-ARTRT/PSSPS-36	1.65	1.58	1.35	2.81
PJ-ARAR8/AHCT-16	2.35	0.68	0.65	2.20	SG-ARTRT/PSSPS-45	2.03	1.05	0.97	3.00
PJ-ARAR8/PSSPS-17	1.28	1.90	1.72	2.63	SG-ARTRT/PSSPS-46	1.93	1.18	1.07	3.01
PJ-ARAR8/PSSPS-75	1.59	1.64	1.41	2.89	SG-ARTRT/PSSPS-49	2.94	0.06	0.06	2.66
PJ-ARTRT/PSSPS-55	2.27	0.82	0.73	2.87	SG-ARTRT/PSSPS-50	2.62	0.40	0.38	2.80
PJ-ARVA2/ACLE9-71	1.27	2.05	1.73	3.01	SG-ARTRT/PSSPS-51	2.71	0.30	0.29	2.81
PJ-ARVA2/ACTH7-13	1.86	1.32	1.14	2.65	SG-ARTRT/PSSPS-52	1.43	1.91	1.57	2.11
PJ-ARVA2/ACTH7-59	2.36	0.71	0.64	3.00	SG-ARVA2/ACLE9-72	0.68	2.27	2.32	3.01
PJ-ARVA2/ACTH7-9	1.18	1.97	1.82	2.59	SG-ARVA2/FEID-37	1.27	2.00	1.73	3.02
PJ-ARVA2/PSSPS-10	1.24	2.19	1.76	3.00	SG-ARVA2/FEID-53	0.63	2.35	2.37	3.00
PJ-ARVA2/PSSPS-11	1.12	2.13	1.88	3.02	SG-ARVA2/FEID-54	2.45	0.55	0.55	3.00
PJ-ARVA2/PSSPS-12	0.64	2.21	2.36	3.01	SG-ARVA2/LECI4-70	2.50	0.57	0.50	3.14
PJ-ARVA2/PSSPS-14	1.13	2.11	1.87	2.92	SG-ARVA2/PSSPS-22	0.83	2.26	2.17	3.00
PJ-ARVA2/PSSPS-21	1.39	1.87	1.61	3.00	SG-ARVA2/PSSPS-23	1.20	2.01	1.80	2.93
PJ-ARVA2/PSSPS-73	1.45	1.84	1.55	2.89	SG-ARVA2/PSSPS-24	0.87	2.24	2.13	2.78
PJ-ARVA2/PSSPS-74	2.42	0.60	0.58	3.00	SG-ARVA2/PSSPS-25	1.01	2.17	1.99	3.00
SG-ARAR8/ACTH7-8	1.93	1.24	1.07	1.77	SG-ARVA2/PSSPS-28	1.86	1.30	1.14	3.00
SG-ARAR8/AHCT-63	2.85	0.16	0.15	3.00	SG-ARVA2/PSSPS-29	1.00	2.44	2.00	3.00
SG-ARAR8/AHCT-64	2.85	0.16	0.15	2.53	SG-ARVA2/PSSPS-35	1.73	1.42	1.27	3.00
SG-ARAR8/AHCT-65	2.45	0.55	0.55	2.98	SG-ARVA2/PSSPS-44	2.08	1.03	0.92	2.97
SG-ARAR8/AHCT-66	2.71	0.30	0.29	2.42	SG-PUTR2/PSSPS-33	2.34	0.74	0.66	2.47
SG-ARAR8/AHCT-67	1.38	1.98	1.62	2.71	ST-ATCO/AHCT-1	2.97	0.04	0.03	2.79
SG-ARAR8/AHCT-68	1.93	1.21	1.07	2.76	ST-ATCO/AHCT-2	2.94	0.06	0.06	3.10
SG-ARAR8/FEID-38	1.14	2.01	1.86	2.99	ST-ATCO/AHCT-69	2.85	0.15	0.15	3.00
SG-ARAR8/FEID-42	0.64	2.25	2.36	3.00	ST-ATCO/SIHY-4	2.86	0.14	0.14	3.00
SG-ARAR8/PSSPS-26	1.59	1.69	1.41	3.00	ST-SAVE4/LECI4-3	2.97	0.03	0.03	3.02
SG-ARAR8/PSSPS-31	2.14	0.92	0.86	3.00	ST-SAVE4/LECI4-58	2.92	0.08	0.08	3.05
SG-ARAR8/PSSPS-39	1.35	1.86	1.65	3.01	WT-ARCA13/DECE-88	0.95	2.10	2.05	3.21
SG-ARAR8/PSSPS-40	1.46	1.80	1.54	2.98	WT-SALIX/CAREX-87	1.70	1.41	1.30	2.91
SG-ARAR8/PSSPS-41	1.98	1.16	1.02	3.00	WT-SALIX/DECE-86	2.57	0.45	0.43	2.80
SG-ARAR8/PSSPS-47	1.45	1.92	1.55	3.01	WT-SALIX/LECI4-18	2.99	0.01	0.01	3.02
SG-ARAR8/PSSPS-48	1.77	1.46	1.23	2.90	WT-SALIX/LECI4-85	2.95	0.05	0.05	4.00
SG-ARCA13/DECE-20	2.89	0.12	0.11	3.09					

Table 5.9 Forage quantity and forage scores in each habitat for pronghorn antelope, mule deer, and bighorn sheep.

Habitat	Bighorn Forage (kg/ha)	Sheep Forage Score	Mule Deer Forage (kg/ha)	Deer Forage Score	Pronghorn Forage (kg.ha)	Antelope Forage Score
MN-ARAR8/PSSPS-43	1207	3	1236	3	727	3
MN-ARVA2/ACTH7-76	1169	3	1185	3	556	2
MN-ARVA2/FEID-27	737	3	818	3	704	3
MN-ARVA2/PSSPS-77	1427	4	1451	4	859	4
MN-ARVA2/PSSPS-78	1554	4	1653	4	849	4
MN-ARVA2/PSSPS-79	1466	4	1490	4	829	4
MN-ARVA2/PSSPS-80	1057	3	1140	3	862	4
MN-ARVA2/PSSPS-82	508	2	531	2	455	2
MN-ARVA2/PSSPS-83	498	2	510	2	390	2
MN-SYMPH/AGTR-56	591	2	782	3	569	2
PJ-ARAR8/ACTH7-60	638	2	635	2	609	3
PJ-ARAR8/ACTH7-81	324	2	323	2	303	1
PJ-ARAR8/AHCT-16	378	2	371	2	357	1
PJ-ARAR8/PSSPS-17	253	2	251	2	235	1
PJ-ARAR8/PSSPS-75	665	2	672	2	633	3
PJ-ARTRT/PSSPS-55	388	2	390	2	388	2
PJ-ARVA2/ACLE9-71	709	2	798	3	650	3
PJ-ARVA2/ACTH7-13	650	2	655	2	599	3
PJ-ARVA2/ACTH7-59	885	3	896	3	835	4
PJ-ARVA2/ACTH7-9	560	2	560	2	496	2
PJ-ARVA2/PSSPS-10	589	2	594	2	530	2
PJ-ARVA2/PSSPS-11	496	2	498	2	451	2
PJ-ARVA2/PSSPS-12	614	2	636	2	567	2
PJ-ARVA2/PSSPS-14	750	3	750	2	668	3
PJ-ARVA2/PSSPS-21	574	2	582	2	537	2
PJ-ARVA2/PSSPS-73	927	3	929	3	836	4
PJ-ARVA2/PSSPS-74	789	3	795	3	736	3
SG-ARAR8/ACTH7-8	413	2	424	2	413	2
SG-ARAR8/AHCT-63	472	2	456	2	456	2
SG-ARAR8/AHCT-64	452	2	437	2	445	2
SG-ARAR8/AHCT-65	408	2	366	2	400	2
SG-ARAR8/AHCT-66	489	2	467	2	478	2
SG-ARAR8/AHCT-67	220	2	215	2	217	1
SG-ARAR8/AHCT-68	205	2	197	2	203	1
SG-ARAR8/FEID-38	613	2	653	2	595	3
SG-ARAR8/FEID-42	599	2	636	2	583	2
SG-ARAR8/PSSPS-26	633	2	654	2	607	3
SG-ARAR8/PSSPS-31	646	2	666	2	621	3
SG-ARAR8/PSSPS-39	685	2	711	2	660	3
SG-ARAR8/PSSPS-40	693	2	722	2	670	3
SG-ARAR8/PSSPS-41	631	2	657	2	615	3
SG-ARAR8/PSSPS-47	652	2	690	2	634	3
SG-ARAR8/PSSPS-48	536	2	559	2	532	2
SG-ARCA13/DECE-20	1515	4	1743	4	778	3
SG-ARTRT/ACTH7-1	488	2	443	2	483	2
SG-ARTRT/ACTH7-5	517	2	475	2	515	2
SG-ARTRT/ACTH7-6	640	2	640	2	618	3
SG-ARTRT/AHCT-61	646	2	646	2	605	3
SG-ARTRT/AHCT-62	553	2	553	2	528	2
SG-ARTRT/LECI4-19	3830	7	3588	6	1568	5
SG-ARTRT/LECI4-57	2800	6	2750	5	732	3

Table 5.9 continued.

Habitat	Bighorn Forage (kg/ha)	Sheep Forage Score	Mule Deer Forage (kg/ha)	Deer Forage Score	Pronghorn Forage (kg.ha)	Antelope Forage Score
SG-ARTRT/LECI4-7	1082	3	1074	3	452	2
SG-ARTRT/PSSPS-30	666	2	679	2	628	3
SG-ARTRT/PSSPS-32	676	2	687	2	634	3
SG-ARTRT/PSSPS-34	652	2	655	2	634	3
SG-ARTRT/PSSPS-36	674	2	676	2	662	3
SG-ARTRT/PSSPS-45	640	2	660	2	622	3
SG-ARTRT/PSSPS-46	647	2	663	2	632	3
SG-ARTRT/PSSPS-49	546	2	558	2	533	2
SG-ARTRT/PSSPS-50	495	2	503	2	493	2
SG-ARTRT/PSSPS-51	626	2	641	2	626	3
SG-ARTRT/PSSPS-52	463	2	479	2	454	2
SG-ARVA2/ACLE9-72	670	2	786	3	601	3
SG-ARVA2/FEID-37	794	3	851	3	754	3
SG-ARVA2/FEID-53	404	2	432	2	398	2
SG-ARVA2/FEID-54	847	3	866	3	781	3
SG-ARVA2/LECI4-70	2369	5	2369	5	971	4
SG-ARVA2/PSSPS-22	635	2	651	2	608	3
SG-ARVA2/PSSPS-23	826	3	862	3	781	3
SG-ARVA2/PSSPS-24	748	3	784	3	701	3
SG-ARVA2/PSSPS-25	660	2	683	2	631	3
SG-ARVA2/PSSPS-28	791	3	818	3	740	3
SG-ARVA2/PSSPS-29	809	3	851	3	758	3
SG-ARVA2/PSSPS-35	802	3	835	3	766	3
SG-ARVA2/PSSPS-44	714	2	734	2	678	3
SG-PUTR2/PSSPS-33	876	3	896	3	823	4
ST-ATCO/AHCT-1	435	2	323	2	450	2
ST-ATCO/AHCT-2	452	2	302	2	476	2
ST-ATCO/AHCT-69	328	2	195	2	328	1
ST-ATCO/SIHY-4	317	2	260	2	416	2
ST-SAVE4/LECI4-3	454	2	540	2	317	1
ST-SAVE4/LECI4-58	1440	4	1560	4	447	2
WT-ARCA13/DECE-88	2240	5	2240	5	1222	5
WT-SALIX/CAREX-87	1676	4	1986	5	1594	5
WT-SALIX/DECE-86	1327	4	1738	4	709	3
WT-SALIX/LECI4-18	2359	5	2587	5	1109	5
WT-SALIX/LECI4-85	1823	4	2326	5	907	4

Table 5.10. Habitat suitability scores for game species in Pine Valley.

Habitat	Pronghorn Antelope	Mule Deer	Bighorn Sheep	Jackrabbit/ Hare	Ground Squirrel	Woodrat/ Marmot	Small Mammals	Waterfowl	Sage Grouse
MN-ARAR8/PSSPS-43	4.71	20.55	22.3	9	0	12	0	0	6.28
MN-ARVA2/ACTH7-76	3.61	18.84	21.58	6	0	12	0	0	3.61
MN-ARVA2/FEID-27	7.05	19.5	20	9	6.01	0	6.01	3.01	9.41
MN-ARVA2/PSSPS-77	6.16	26.64	29.84	12	0	0	0	0	6.16
MN-ARVA2/PSSPS-78	1.17	25.17	34.83	12	12	0	6	3	1.76
MN-ARVA2/PSSPS-79	2.96	24.56	30.82	9	0	16.89	0	0	6.66
MN-ARVA2/PSSPS-80	3.1	19.53	24.65	9	0	11.99	0	3	15.51
MN-ARVA2/PSSPS-82	5.09	11.74	11.67	4	0	0	0	0	10.19
MN-ARVA2/PSSPS-83	1.11	11.4	14.85	2	0	5.32	0	0	2.23
MN-SYMPH/AGTR-56	3.89	21.1	14.12	6	3	0	6	3	3.89
PJ-ARAR8/ACTH7-60	22.84	2.81	2.77	6	9	0	3	0	45.69
PJ-ARAR8/ACTH7-81	5.33	6.06	5.51	2	0	0	0	0	10.66
PJ-ARAR8/AHCT-16	5.19	2.98	2.85	4	4.41	0	2.2	0	20.76
PJ-ARAR8/PSSPS-17	3.38	9.98	9.03	2	0	5.26	0	0	13.51
PJ-ARAR8/PSSPS-75	13.79	9.47	8.17	6	0	0	0	2.89	41.38
PJ-ARTRT/PSSPS-55	12.99	4.67	4.2	4	5.73	0	2.87	0	12.99
PJ-ARVA2/ACLE9-71	11.48	18.53	10.4	6	0	0	0	3.01	45.94
PJ-ARVA2/ACTH7-13	14.81	7.02	6.05	4	0	0	0	0	29.63
PJ-ARVA2/ACTH7-59	28.41	6.38	5.74	8	12.02	0	6.01	0	42.62
PJ-ARVA2/ACTH7-9	6.11	10.19	9.42	6	0	7.76	0	0	24.43
PJ-ARVA2/PSSPS-10	7.45	13.13	10.55	6	0	0	0	0	22.35
PJ-ARVA2/PSSPS-11	6.77	12.86	11.35	4	0	0	0	0	20.31
PJ-ARVA2/PSSPS-12	3.86	13.28	14.19	6	0	0	0	3.01	11.57
PJ-ARVA2/PSSPS-14	9.9	12.33	16.39	6	0	0	0	2.92	29.69
PJ-ARVA2/PSSPS-21	8.34	11.25	9.68	6	0	0	0	0	16.67
PJ-ARVA2/PSSPS-73	16.76	15.99	13.45	6	0	0	0	2.89	37.71
PJ-ARVA2/PSSPS-74	21.74	5.44	5.26	6	0	0	0	3	65.21
SG-ARAR8/ACTH7-8	6.84	4.41	3.8	4	3.55	0	1.77	0	13.68
SG-ARAR8/AHCT-63	17.08	0.94	0.92	4	6	0	3	0	51.23
SG-ARAR8/AHCT-64	14.43	0.8	0.78	4	5.07	0	2.53	0	28.86
SG-ARAR8/AHCT-65	14.6	3.3	3.27	4	5.95	0	2.98	0	29.19
SG-ARAR8/AHCT-66	13.13	1.45	1.41	4	0	0	0	0	39.39
SG-ARAR8/AHCT-67	3.75	10.71	8.74	1	0	0	0	0	14.99
SG-ARAR8/AHCT-68	5.33	6.69	5.87	1	0	0	0	0	21.33
SG-ARAR8/FEID-38	10.24	12.05	11.13	6	0	0	0	2.99	13.66
SG-ARAR8/FEID-42	3.84	13.49	14.18	4	0	0	0	3	7.67
SG-ARAR8/PSSPS-26	14.34	10.17	8.46	6	0	0	0	0	19.12
SG-ARAR8/PSSPS-31	19.23	5.49	5.15	6	0	0	0	3	38.46
SG-ARAR8/PSSPS-39	12.19	11.19	9.91	9	0	0	0	0	16.25
SG-ARAR8/PSSPS-40	13.02	10.7	9.2	9	0	0	0	0	17.36
SG-ARAR8/PSSPS-41	17.85	6.94	6.1	6	0	0	0	3	23.8

Habitat	Pronghorn Antelope	Mule Deer	Bighorn Sheep	Jackrabbit/ Hare	Ground Squirrel	Woodrat/ Marmot	Small Mammals	Waterfowl	Sage Grouse
SG-ARAR8/PSSPS-47	13.09	11.59	9.35	6	0	0	0	3.01	26.17
SG-ARAR8/PSSPS-48	10.28	8.45	7.09	4	0	0	0	2.9	30.83
SG-ARCA13/DEC E-20	26.76	1.44	1.35	10	0	0	0	9.26	35.68
SG-ARTRT/ACTH7-1	15.99	1.59	1.54	4	5.85	0	2.92	0	47.98
SG-ARTRT/ACTH7-5	17.37	0.62	0.62	4	8.99	0	3	0	52.12
SG-ARTRT/ACTH7-6	22.63	1.82	1.72	9	8.41	0	2.8	0	67.88
SG-ARTRT/AHCT-61	20.3	1.92	1.85	6	7.69	0	2.56	0	81.19
SG-ARTRT/AHCT-62	14.54	0.03	0.03	4	7.29	0	2.43	0	43.63
SG-ARTRT/LECI4-19	41.07	5.11	5.56	24	15.01	0	18.02	6.01	295.67
SG-ARTRT/LECI4-57	16.98	4.2	4.57	12	6.42	0	10.7	4.28	113.19
SG-ARTRT/LECI4-7	17.77	0.65	0.61	6	3.03	0	6.06	6.06	53.32
SG-ARTRT/PSSPS-30	19.53	3.42	3.03	6	8.02	0	2.67	0	26.04
SG-ARTRT/PSSPS-32	16.52	1.9	1.83	6	6.42	0	2.14	0	33.04
SG-ARTRT/PSSPS-34	15.34	8.33	7.03	6	0	0	0	0	20.45
SG-ARTRT/PSSPS-36	13.96	8.9	7.57	9	0	0	0	0	18.61
SG-ARTRT/PSSPS-45	18.31	6.27	5.79	6	0	0	0	3	36.62
SG-ARTRT/PSSPS-46	17.47	7.1	6.43	6	0	0	0	3.01	23.29
SG-ARTRT/PSSPS-49	15.66	0.33	0.33	4	7.99	0	2.66	0	46.97
SG-ARTRT/PSSPS-50	14.68	2.26	2.14	4	5.61	0	2.8	0	29.36
SG-ARTRT/PSSPS-51	22.9	1.7	1.6	6	8.43	0	2.81	0	45.79
SG-ARTRT/PSSPS-52	6.02	8.09	6.65	4	0	0	0	0	12.04
SG-ARVA2/ACLE9-72	6.17	20.46	13.95	9	0	9.03	0	3.01	24.67
SG-ARVA2/FEID-37	11.57	18.18	15.65	9	0	0	0	3.02	34.7
SG-ARVA2/FEID-53	3.79	14.09	14.22	4	0	0	0	3	7.58
SG-ARVA2/FEID-54	22.05	4.95	4.95	9	0	0	0	3	29.4
SG-ARVA2/LECI4-70	31.41	8.95	7.8	20	0	0	0	6.27	235.58
SG-ARVA2/PSSPS-22	7.52	13.58	13	6	0	0	0	0	10.02
SG-ARVA2/PSSPS-23	10.56	17.66	15.79	9	0	0	0	2.93	14.08
SG-ARVA2/PSSPS-24	7.24	12.44	11.86	9	0	0	0	2.78	9.65
SG-ARVA2/PSSPS-25	9.09	13.05	11.95	9	0	0	0	0	12.12
SG-ARVA2/PSSPS-28	16.73	11.75	10.3	9	0	0	0	3	22.3
SG-ARVA2/PSSPS-29	9.04	21.98	17.96	9	0	0	0	3	18.07
SG-ARVA2/PSSPS-35	15.54	12.77	11.47	9	0	0	0	3	20.72
SG-ARVA2/PSSPS-44	18.56	6.12	5.46	9	0	0	0	2.97	24.75
SG-PUTR2/PSSPS-33	23.12	5.49	4.85	9	0	0	0	0	52.03
ST-ATCO/AHCT-1	16.56	0.2	0.19	4	5.58	0	2.79	0	33.11
ST-ATCO/AHCT-2	18.22	0.39	0.38	2	6.2	0	3.1	0	54.67
ST-ATCO/AHCT-69	8.54	0.91	0.91	1	6	0	3	0	34.16
ST-ATCO/SIHY-4	17.17	0.83	0.83	2	3	0	3	3	8.59
ST-SAVE4/LECI4-3	8.96	0.19	0.19	2	3.02	0	3.02	6.03	8.96
ST-SAVE4/LECI4-58	17.79	1.03	1	12	3.05	0	9.14	6.1	0
WT-ARCA13/DECE-88	15.19	33.78	33	25	3.21	0	12.85	16.06	72.91
WT-SALIX/CAREX-87	24.81	20.6	15.13	35	11.66	0	11.66	17.49	0
WT-SALIX/DECE-86	21.55	5.03	4.85	10	2.8	0	11.19	13.99	28.74

Habitat	Pronghorn Antelope	Mule Deer	Bighorn Sheep	Jackrabbit/ Hare	Ground Squirrel	Woodrat/ Marmot	Small Mammals	Waterfowl	Sage Grouse
WT-SALIX/LECI4-18	45.21	0.14	0.14	25	0	0	0	12.09	90.42
WT-SALIX/LECI4-85	47.23	1	0.77	20	8	0	20	24	59.03

Medium and Small Mammals

Great Basin hunter-gatherers consumed numerous medium and small sized mammals (Steward 1938; there is sufficient information to model three categories of medium mammals in Pine Valley: jackrabbits/hares, large ground squirrels, and woodrats/marmots. Also, various small mammals including white-tailed antelope squirrel, kangaroo rat, vole, grasshopper mouse, deer mouse, pinyon mouse, least chipmunk, and pocket gopher are considered collectively.

Although the habitats of Nuttall's cottontail, black-tailed jackrabbit, and white-tailed jackrabbit differ, there are considerable similarities. Generally, white-tailed jackrabbit and cottontail occupy sagebrush and montane plant communities at higher elevations than black-tailed jackrabbits (Masser et al. 1984; United States Fish and Wildlife Service 1978:105). Rabbits and hares are eclectic regarding habitat diversity, but they prefer areas of low growing shrubs and trees for the escape cover they provide. Although rabbits will feed in open grasslands and meadows where they are vulnerable to predators, they usually remain within 300 m of protective brush cover (Chapman and Willner 1986; United States Fish and Wildlife Service 1978:105). Table 5.11 lists the average ground cover expected for each habitat and assigns a relative score to each based on the statistical spread for all habitats.

Unlike many other animals considered herein, proximity of water is not critical for rabbits and hares; lagomorphs may drink but usually satisfy their water requirements by eating succulent plants. Nevertheless, population densities may parallel closely the distribution of water sources because of the greater densities of succulent plants near water (Chapman and Willner 1986). Because of this correlation, the water proximity score calculated in equation 4 also pertains to modeling lagomorph habitats.

Rabbits and hares prefer succulent forbs and grasses, especially during summer when moisture needs are highest. They are nevertheless quite eclectic diners, feeding on shrub vegetation whenever succulents are unavailable (United States Fish and Wildlife Service 1978:105). Known food plants of rabbits and hares are listed elsewhere (Zeanah et al. 1995: 144). Table 5.11 tallies the quantity of jackrabbit/hare forage species in kilograms per hectare, for each habitat in the Pine Valley study area, assigning a forage score based on standard deviations above or below the mean. The suitability of habitats for jackrabbits and hares is then calculated by simply multiplying the forage score, cover score, and water proximity scores. Again, the score (Table 5.10) directly measures habitat quality, and indirectly monitors lagomorph abundance.

Large ground squirrels that were prey for ethnographic Great Basin hunter-gatherers include golden-mantled ground squirrel, Belding's ground squirrel, and Townsend's ground squirrel. Ground squirrels thrive in greasewood-saltbush, sagebrush, and montane plant communities, but are particularly fond of deep, well-drained soils that permit burrowing (United States Fish and Wildlife Service 1978; Masser et al. 1984; Rickart 1987). To reflect this preference, each habitat is scored a value of "1" if it occurs on a loamy soil with a depth to bedrock greater than 20 inches to bedrock, and "0" if it occupies only rocky or shallow soils (Table 5.12). Zeveloff (1988:122) and Rickart

Table 5.11. Jackrabbit and hare cover and forage scores for habitats in Pine Valley.

Habitat	% Cover	Cover Score	Hare Forage	Hare Forage Score	Habitat	% Cover	Cover Score	Hare Forage	Hare Forage Score
MN-ARAR8/PSSPS-43	32.88	3	608	3	SG-ARTRT/ACTH7-1	20.25	2	478	2
MN-ARVA2/ACTH7-76	28.13	3	452	2	SG-ARTRT/ACTH7-5	20.75	2	515	2
MN-ARVA2/FEID-27	37.88	3	625	3	SG-ARTRT/ACTH7-6	30	3	604	3
MN-ARVA2/PSSPS-77	42	4	726	3	SG-ARTRT/AHCT-61	15	2	631	3
MN-ARVA2/PSSPS-78	43.88	4	717	3	SG-ARTRT/AHCT-62	13.5	2	542	2
MN-ARVA2/PSSPS-79	37	3	685	3	SG-ARTRT/LECI4-19	52.5	4	1417	6
MN-ARVA2/PSSPS-80	34.88	3	759	3	SG-ARTRT/LECI4-57	40	4	732	3
MN-ARVA2/PSSPS-82	22.63	2	418	2	SG-ARTRT/LECI4-7	33.25	3	511	2
MN-ARVA2/PSSPS-83	14	2	330	1	SG-ARTRT/PSSPS-30	26	2	582	3
MN-SYMPH/AGTR-56	28.5	3	440	2	SG-ARTRT/PSSPS-32	23.75	2	609	3
PJ-ARAR8/ACTH7-60	19.5	2	584	3	SG-ARTRT/PSSPS-34	25	2	587	3
PJ-ARAR8/ACTH7-81	24.75	2	291	1	SG-ARTRT/PSSPS-36	26.25	3	632	3
PJ-ARAR8/AHCT-16	18.5	2	352	2	SG-ARTRT/PSSPS-45	25.5	2	597	3
PJ-ARAR8/PSSPS-17	18.38	2	223	1	SG-ARTRT/PSSPS-46	25.5	2	598	3
PJ-ARAR8/PSSPS-75	17.38	2	602	3	SG-ARTRT/PSSPS-49	22.5	2	536	2
PJ-ARTRT/PSSPS-55	24.38	2	364	2	SG-ARTRT/PSSPS-50	18.75	2	496	2
PJ-ARVA2/ACLE9-71	26.13	2	608	3	SG-ARTRT/PSSPS-51	25	2	641	3
PJ-ARVA2/ACTH7-13	24.38	2	550	2	SG-ARTRT/PSSPS-52	23	2	420	2
PJ-ARVA2/ACTH7-59	25	2	791	4	SG-ARVA2/ACLE9-72	30.75	3	565	3
PJ-ARVA2/ACTH7-9	27.5	3	431	2	SG-ARVA2/FEID-37	33	3	666	3
PJ-ARVA2/PSSPS-10	27.25	3	466	2	SG-ARVA2/FEID-53	23	2	351	2
PJ-ARVA2/PSSPS-11	21.38	2	400	2	SG-ARVA2/FEID-54	36.75	3	697	3
PJ-ARVA2/PSSPS-12	27.75	3	507	2	SG-ARVA2/LECI4-70	61.75	5	835	4
PJ-ARVA2/PSSPS-14	24.25	2	589	3	SG-ARVA2/PSSPS-22	32.13	3	541	2
PJ-ARVA2/PSSPS-21	29.75	3	486	2	SG-ARVA2/PSSPS-23	33.25	3	692	3
PJ-ARVA2/PSSPS-73	23.88	2	746	3	SG-ARVA2/PSSPS-24	32.5	3	624	3
PJ-ARVA2/PSSPS-74	19.88	2	674	3	SG-ARVA2/PSSPS-25	27.25	3	559	3
SG-ARAR8/ACTH7-8	21.5	2	418	2	SG-ARVA2/PSSPS-28	32.25	3	675	3
SG-ARAR8/AHCT-63	15.25	2	456	2	SG-ARVA2/PSSPS-29	33.75	3	688	3
SG-ARAR8/AHCT-64	15.25	2	438	2	SG-ARVA2/PSSPS-35	33	3	701	3
SG-ARAR8/AHCT-65	14.25	2	397	2	SG-ARVA2/PSSPS-44	28.75	3	619	3
SG-ARAR8/AHCT-66	17.5	2	471	2	SG-PUTR2/PSSPS-33	35	3	763	3
SG-ARAR8/AHCT-67	7.38	1	206	1	ST-ATCO/AHCT-1	13.88	2	454	2
SG-ARAR8/AHCT-68	7.5	1	195	1	ST-ATCO/AHCT-2	12.5	1	484	2
SG-ARAR8/FEID-38	26.25	3	523	2	ST-ATCO/AHCT-69	10	1	336	1
SG-ARAR8/FEID-42	25.38	2	512	2	ST-ATCO/SIHY-4	12.5	1	428	2
SG-ARAR8/PSSPS-26	26.25	3	540	2	ST-SAVE4/LECI4-3	11.88	1	415	2
SG-ARAR8/PSSPS-31	25.75	2	583	3	ST-SAVE4/LECI4-58	27.5	3	916	4
SG-ARAR8/PSSPS-39	26.38	3	594	3	WT-ARCA13/DECE-88	67.5	5	1120	5
SG-ARAR8/PSSPS-40	26.5	3	590	3	WT-SALIX/CAREX-87	65	5	1608	7
SG-ARAR8/PSSPS-41	24.25	2	559	3	WT-SALIX/DECE-86	75	5	554	2
SG-ARAR8/PSSPS-47	26	2	574	3	WT-SALIX/LECI4-18	77.5	5	1094	5
SG-ARAR8/PSSPS-48	21.25	2	509	2	WT-SALIX/LECI4-85	70.75	5	938	4
SG-ARCA13/DECE-20	80	5	550	2					

Table 5.12. Large ground squirrel forage and soil suitability scores.

Habitat	Ground Squirrel Forage (kg/ha)	Ground Squirrel Forage Score	Soil Score	Habitat	Ground Squirrel Forage (kg/ha)	Ground Squirrel Forage Score	Soil Score
MN-ARAR8/PSSPS-43	550	3	0	SG-ARTRT/ACTH7-1	444	2	1
MN-ARVA2/ACTH7-76	484	3	0	SG-ARTRT/ACTH7-5	478	3	1
MN-ARVA2/FEID-27	362	2	1	SG-ARTRT/ACTH7-6	573	3	1
MN-ARVA2/PSSPS-77	748	4	0	SG-ARTRT/AHCT-61	585	3	0
MN-ARVA2/PSSPS-78	712	4	1	SG-ARTRT/AHCT-62	514	3	1
MN-ARVA2/PSSPS-79	727	4	0	SG-ARTRT/LECI4-19	1116	5	1
MN-ARVA2/PSSPS-80	744	4	0	SG-ARTRT/LECI4-57	555	3	1
MN-ARVA2/PSSPS-82	446	2	0	SG-ARTRT/LECI4-7	296	1	1
MN-ARVA2/PSSPS-83	346	2	0	SG-ARTRT/PSSPS-30	565	3	1
MN-SYMPH/AGTR-56	*287*	*1*	*1*	SG-ARTRT/PSSPS-32	584	3	1
PJ-ARAR8/ACTH7-60	586	3	1	SG-ARTRT/PSSPS-34	454	2	0
PJ-ARAR8/ACTH7-81	295	1	0	SG-ARTRT/PSSPS-36	601	3	0
PJ-ARAR8/AHCT-16	347	2	1	SG-ARTRT/PSSPS-45	576	3	0
PJ-ARAR8/PSSPS-17	231	1	0	SG-ARTRT/PSSPS-46	579	3	0
PJ-ARAR8/PSSPS-75	618	3	0	SG-ARTRT/PSSPS-49	498	3	1
PJ-ARTRT/PSSPS-55	374	2	1	SG-ARTRT/PSSPS-50	461	2	1
PJ-ARVA2/ACLE9-71	565	3	0	SG-ARTRT/PSSPS-51	595	3	1
PJ-ARVA2/ACTH7-13	586	3	1	SG-ARTRT/PSSPS-52	380	2	0
PJ-ARVA2/ACTH7-59	808	4	1	SG-ARVA2/ACLE9-72	500	3	0
PJ-ARVA2/ACTH7-9	*496*	*3*	*0*	*SG-ARVA2/FEID-37*	*461*	*2*	*0*
PJ-ARVA2/PSSPS-10	512	3	0	SG-ARVA2/FEID-53	255	1	0
PJ-ARVA2/PSSPS-11	444	2	0	SG-ARVA2/FEID-54	508	3	0
PJ-ARVA2/PSSPS-12	485	3	0	SG-ARVA2/LECI4-70	757	4	0
PJ-ARVA2/PSSPS-14	634	3	0	SG-ARVA2/PSSPS-22	421	2	0
PJ-ARVA2/PSSPS-21	498	3	0	SG-ARVA2/PSSPS-23	581	3	0
PJ-ARVA2/PSSPS-73	769	4	0	SG-ARVA2/PSSPS-24	539	3	0
PJ-ARVA2/PSSPS-74	692	4	0	SG-ARVA2/PSSPS-25	489	3	0
SG-ARAR8/ACTH7-8	395	2	1	SG-ARVA2/PSSPS-28	627	3	0
SG-ARAR8/AHCT-63	436	2	1	SG-ARVA2/PSSPS-29	575	3	0
SG-ARAR8/AHCT-64	428	2	1	SG-ARVA2/PSSPS-35	581	3	0
SG-ARAR8/AHCT-65	385	2	1	SG-ARVA2/PSSPS-44	618	3	0
SG-ARAR8/AHCT-66	456	2	0	SG-PUTR2/PSSPS-33	743	4	0
SG-ARAR8/AHCT-67	201	1	0	ST-ATCO/AHCT-1	409	2	1
SG-ARAR8/AHCT-68	187	1	0	ST-ATCO/AHCT-2	431	2	1
SG-ARAR8/FEID-38	362	2	0	ST-ATCO/AHCT-69	328	2	1
SG-ARAR8/FEID-42	354	2	0	ST-ATCO/SIHY-4	286	1	1
SG-ARAR8/PSSPS-26	465	2	0	ST-SAVE4/LECI4-3	145	1	1
SG-ARAR8/PSSPS-31	568	3	0	ST-SAVE4/LECI4-58	142	1	1
SG-ARAR8/PSSPS-39	493	3	0	WT-ARCA13/DECE-88	244	1	1
SG-ARAR8/PSSPS-40	467	2	0	WT-SALIX/CAREX-87	665	4	1
SG-ARAR8/PSSPS-41	468	2	0	WT-SALIX/DECE-86	196	1	1
SG-ARAR8/PSSPS-47	455	2	0	WT-SALIX/LECI4-18	412	2	0
SG-ARAR8/PSSPS-48	497	3	0	WT-SALIX/LECI4-85	309	2	1
SG-ARCA13/DECE-20	228	1	0				

(1987) record that Townsend's ground squirrel populations are particularly large at desert springs, and reproduction frequently occurs near wet meadow, riparian, palustrine, and lacustrine habitats (Masser et al. 1984:84). Thus, the water proximity score of habitats, given in Table 5.8, also pertains to ground squirrel habitat evaluation.

Ground squirrels eat seeds, succulent green vegetation of forbs and grasses, as well as a few insects. Generally, squirrels eat green forbs after emerging from hibernation in January or February and gradually shift reliance to grass seed before aestivating in June or July (Yensen and Quinney 1992).

In particular, winterfat, Sandberg's bluegrass, and various forbs are favored foods distribution. of ground squirrels (Johnson 1977; Rogers and Gano 1980; Yensen and Quinney 1992). Zeanah et al. (1995:147) list common forage plants of ground squirrel. Table 5.12 lists the quantity of forage in kg/ha for each habitat in the Pine Valley study area. Ordinal forage scores are assigned to each habitat according to a normal curve distribution. A score measuring the suitability of habitats for large ground squirrels is then calculable by multiplying the water proximity score, soil score and forage score (Table 5.10).

Distributions of woodrats and marmots overlap: bushy-tailed woodrats occur in sagebrush, pinyon-juniper, and mountain brush vegetation communities; desert woodrats are common in greasewood-shadscale, and sagebrush communities; and marmots are most common in montane communities and wet meadows (Maser et al. 1984; United States Fish and Wildlife Service 1978). Together, all three species live in diverse biotic settings. Woodrats and marmots require drinking water to survive, so water proximity is pertinent to evaluating their habitat.

Rock outcrops that provide protection from predators and weather are a critical element of woodrat and marmot habitat that strongly affects population densities (Llewellyn 1981). Because of the importance of rock outcrops to woodrats and marmots, habitats occupying soils with rock outcrops are assigned a value of "1", whereas habitats lacking outcrops are scored "0" (Table 5.13).

Woodrats and marmots eat various forbs (Johnson and Hansen 1979), the succulent parts of shrubs and grasses, and seeds (Zeveloff 1988:216-217). Zeanah et al. (1995: 148) list food plants of woodrats and marmots. Table 5.13 lists the quantity of forage species in
In each rock outcrop-bearing habitat in the Pine Valley study area. Each habitat is scored for the abundance of forage based on the deviation of forage from the mean of all habitats. The suitability of these habitats for woodrats and marmots is calculated by multiplying the forb, forage, and water proximity scores (Table 5.10).

Ethnographic hunter-gatherers procured a variety of small mammals, including white-tailed antelope squirrel, kangaroo rat, vole, grasshopper mice, deer mice, pinyon mice, least chipmunk, and pocket gopher. Many small mammals such as pinyon mouse, vole, and chipmunk require drinking water, and so this means that in arid settings the distributions of these mammals are tethered to water sources to the extent required by

Table 5.13. Woodrat and marmot forage and soil suitability scores.

Habitat	Woodrat Forage (kg/ha)	Woodrat Forage Score	Rock Outcrop Score	Habitat	Woodrat Forage (kg/ha)	Woodrat Forage Score	Rock Outcrop Score
MN-ARAR8/PSSPS-43	130	2	1	SG-ARTRT/ACTH7-1	166	2	0
MN-ARVA2/ACTH7-76	97	2	1	SG-ARTRT/ACTH7-5	169	2	0
MN-ARVA2/FEID-27	95	1	0	SG-ARTRT/ACTH7-6	194	3	0
MN-ARVA2/PSSPS-77	147	2	0	SG-ARTRT/AHCT-61	390	5	0
MN-ARVA2/PSSPS-78	164	2	0	SG-ARTRT/AHCT-62	286	4	0
MN-ARVA2/PSSPS-79	192	3	1	SG-ARTRT/LECI4-19	362	5	0
MN-ARVA2/PSSPS-80	270	4	1	SG-ARTRT/LECI4-57	252	3	0
MN-ARVA2/PSSPS-82	152	2	0	SG-ARTRT/LECI4-7	170	2	0
MN-ARVA2/PSSPS-83	123	2	1	SG-ART RT/PSSPS-30	141	2	0
MN-SYMPH/AGTR-56	85	1	0	SG-ARTRT/PSSPS-32	205	3	0
PJ-ARAR8/ACTH7-60	225	3	0	SG-ARTRT/PSSPS-34	106	2	0
PJ-ARAR8/ACTH7-81	111	2	0	SG-ARTRT/PSSPS-36	104	2	0
PJ-ARAR8/AHCT-16	205	3	0	SG-ARTRT/PSSPS-45	135	2	0
PJ-ARAR8/PSSPS-17	123	2	1	SG-ARTRT/PSSPS-46	118	2	0
PJ-ARAR8/PSSPS-75	219	3	0	SG-ARTRT/PSSPS-49	171	2	0
PJ-ARTRT/PSSPS-55	95	1	0	SG-ARTRT/PSSPS-50	153	2	0
PJ-ARVA2/ACLE9-71	212	3	0	SG-ARTRT/PSSPS-51	159	2	0
PJ-ARVA2/ACTH7-13	233	3	0	SG-ARTRT/PSSPS-52	101	2	0
PJ-ARVA2/ACTH7-59	189	3	0	SG-ARVA2/ACLE9-72	186	3	1
PJ-ARVA2/ACTH7-9	268	4	1	SG-ARVA2/FEID-37	139	2	0
PJ-ARVA2/PSSPS-10	216	3	0	SG-ARVA2/FEID-53	93	1	0
PJ-ARVA2/PSSPS-11	220	3	0	SG-ARVA2/FEID-54	127	2	0
PJ-ARVA2/PSSPS-12	197	3	0	SG-ARVA2/LECI4-70	466	6	0
PJ-ARVA2/PSSPS-14	256	3	0	SG-ARVA2/PSSPS-22	86	1	0
PJ-ARVA2/PSSPS-21	118	2	0	SG-ARVA2/PSSPS-23	133	2	0
PJ-ARVA2/PSSPS-73	243	3	0	SG-ARVA2/PSSPS-24	122	2	0
PJ-ARVA2/PSSPS-74	220	3	0	SG-ARVA2/PSSPS-25	110	2	0
SG-ARAR8/ACTH7-8	145	2	0	SG-ARVA2/PSSPS-28	134	2	0
SG-ARAR8/AHCT-63	288	4	0	SG-ARVA2/PSSPS-29	143	2	0
SG-ARAR8/AHCT-64	245	3	0	SG-ARVA2/PSSPS-35	125	2	0
SG-ARAR8/AHCT-65	236	3	0	SG-ARVA2/PSSPS-44	118	2	0
SG-ARAR8/AHCT-66	300	4	0	SG-PUTR2/PSSPS-33	159	2	0
SG-ARAR8/AHCT-67	135	2	0	ST-ATCO/AHCT-1	177	3	0
SG-ARAR8/AHCT-68	150	2	0	ST-ATCO/AHCT-2	198	3	0
SG-ARAR8/FEID-38	116	2	0	ST-ATCO/AHCT-69	128	2	0
SG-ARAR8/FEID-42	114	2	0	ST-ATCO/SIHY-4	157	2	0
SG-ARAR8/PSSPS-26	110	2	0	ST-SAVE4/LECI4-3	155	2	0
SG-ARAR8/PSSPS-31	127	2	0	ST-SAVE4/LECI4-58	164	2	0
SG-ARAR8/PSSPS-39	126	2	0	WT-ARCA13/DECE-88	163	2	0
SG-ARAR8/PSSPS-40	117	2	0	WT-SALIX/CAREX-87	14	1	0
SG-ARAR8/PSSPS-41	121	2	0	WT-SALIX/DECE-86	43	1	0
SG-ARAR8/PSSPS-47	125	2	0	WT-SALIX/LECI4-18	270	4	0
SG-ARAR8/PSSPS-48	117	2	0	WT-SALIX/LECI4-85	189	3	0
SG-ARCA13/DECE-20	54	1	0				

their mobility and moisture requirements. Wildlife studies consistently indicate that wetlands maintain higher densities of small mammals than drier habitats (Clary and Medin 1992; Feldhammer 1979). However, white-tailed antelope squirrel, kangaroo rat, grasshopper mouse, and deer mouse can metabolize moisture from succulent plants and consequently do not require drinking water. The densities of these mammals correspond significantly to soil depth and soil texture and should coincide with wetland plant communities only (as was the case with rabbits) if the distributions of forage species or other critical habitat variables happen to correlate with proximity to water. Indeed, these mammals should occur in greatest proportion in forage patches too remote from water for competing mammals to rely on (Brown 1973; Brown and Liebermann 1973). Nevertheless, the water proximity score calculated in equation 4 is pertinent to evaluating small mammal habitats because of the importance of water to certain small mammal species and the correlation of water with forage species.

Small mammals prefer deep, well drained, and easily dug soils (Brown 1973; Brown and Liebermann 1973), so the soil ranking developed for ground squirrels (Table 5.12) also applies to smaller mammals. Small mammals subsist on a wide variety of grasses and forbs so Table 5.14 tallies the normal year productivity of grasses and forbs in kg/ha for each habitat and assigns a forage score to each according to statistical intervals. Multiplying the foraging suitability score, water proximity score, soil score calculates the suitability of habitats for small mammals (Table 5.10).

Birds

Two categories of avifauna are potential game for hunter-gatherers in Pine Valley: waterfowl and upland game birds. Wetlands of the Pine Valley study area do not support permanent populations of waterfowl and shorebirds, but may host occasional migratory visitors. Waterfowl inhabit a variety of feeding and nesting habitats in wetlands. Canada goose typically nests in emergent vegetation, preferring islands as nesting sites (Eng 1986b:373). They feed on terrestrial and aquatic vegetation in saltgrass meadows and emergent marshes. Canvasback and redhead duck prefer nesting in protected emergent vegetation closely juxtaposed with open water, uplands, and islands (Eng 1986b:375). They feed in emergent and submergent settings (Hamilton and Auble 1993:11-13). Mallards nest in upland settings near wetlands, feeding in saltgrass meadows and emergent vegetation (Eng 1986b:372, 375; Hamilton and Auble 1993:11-13).

Waterfowl rely heavily on aquatic invertebrates to provide protein for molting, egg formation, and hatchling growth (Hamilton and Auble 1993:11-13). Adults subsist on a variety of aquatic vegetation, but sago pondweed is a major food (Eng 1986b; Thompson and Hallock 1988:63). Waterfowl forage plants are listed elsewhere (Zeanah et al. 1995: 151), however Table 5.15 tallies the quantity of waterfowl forage by Habitat in Pine Valley, assigning an ordinal score to each. The suitability of Pine Valley habitats for waterfowl is measured by multiplying water proximity score by forage score.

Upland game birds used as food by ethnographic hunter-gatherers include sage grouse, blue grouse, and mountain quail. However, the present discussion emphasizes sage

grouse over other species, because blue grouse and mountain quail typify high altitude,
Table 5.14. Small mammal forage scores in Pine Valley habitats.

Habitat	Forbs (kg/ha)	Grasses (kg/ha)	Total	Small Mammal Forage Score	Habitat	Forbs (kg/ha)	Grasses (kg/ha)	Total	Small Mammal Forage Score
MN-ARAR8/PSSPS-43	150	477	627	2	SG-ARTRT/ACTH7-1	36	266	302	1
MN-ARVA2/ACTH7-76	121	375	496	1	SG-ARTRT/ACTH7-5	28	294	321	1
MN-ARVA2/FEID-27	131	532	663	2	SG-ARTRT/ACTH7-6	60	403	464	1
MN-ARVA2/PSSPS-77	162	604	766	2	SG-ARTRT/AHCT-61	47	356	403	1
MN-ARVA2/PSSPS-78	189	634	823	2	SG-ARTRT/AHCT-62	34	268	303	1
MN-ARVA2/PSSPS-79	121	529	650	2	SG-ARTRT/LECI4-19	274	3175	3450	6
MN-ARVA2/PSSPS-80	72	611	683	2	SG-ARTRT/LECI4-57	0	2464	2464	5
MN-ARVA2/PSSPS-82	22	349	371	1	SG-ARTRT/LECI4-7	47	889	936	2
MN-ARVA2/PSSPS-83	26	224	250	1	SG-ARTRT/PSSPS-30	75	432	508	1
MN-SYMPH/AGTR-56	256	384	640	2	SG-ARTRT/PSSPS-32	69	430	500	1
PJ-ARAR8/ACTH7-60	46	384	429	1	SG-ARTRT/PSSPS-34	53	463	516	1
PJ-ARAR8/ACTH7-81	26	182	208	1	SG-ARTRT/PSSPS-36	41	510	551	1
PJ-ARAR8/AHCT-16	27	205	232	1	SG-ARTRT/PSSPS-45	60	450	511	1
PJ-ARAR8/PSSPS-17	16	140	156	1	SG-ARTRT/PSSPS-46	60	470	531	1
PJ-ARAR8/PSSPS-75	56	388	445	1	SG-ARTRT/PSSPS-49	31	408	439	1
PJ-ARTRT/PSSPS-55	36	229	265	1	SG-ARTRT/PSSPS-50	16	337	353	1
PJ-ARVA2/ACLE9-71	61	524	586	1	SG-ARTRT/PSSPS-51	13	450	464	1
PJ-ARVA2/ACTH7-13	46	386	432	1	SG-ARTRT/PSSPS-52	54	309	363	1
PJ-ARVA2/ACTH7-59	63	573	636	2	SG-ARVA2/ACLE9-72	71	561	632	2
PJ-ARVA2/ACTH7-9	34	291	325	1	SG-ARVA2/FEID-37	128	519	647	2
PJ-ARVA2/PSSPS-10	48	339	386	1	SG-ARVA2/FEID-53	70	255	326	1
PJ-ARVA2/PSSPS-11	30	259	289	1	SG-ARVA2/FEID-54	131	568	699	2
PJ-ARVA2/PSSPS-12	57	370	427	1	SG-ARVA2/LECI4-70	0	1777	1777	3
PJ-ARVA2/PSSPS-14	53	413	465	1	SG-ARVA2/PSSPS-22	85	451	536	1
PJ-ARVA2/PSSPS-21	64	372	437	1	SG-ARVA2/PSSPS-23	121	552	672	2
PJ-ARVA2/PSSPS-73	74	530	605	2	SG-ARVA2/PSSPS-24	102	502	604	2
PJ-ARVA2/PSSPS-74	64	461	525	1	SG-ARVA2/PSSPS-25	103	438	541	1
SG-ARAR8/ACTH7-8	31	255	287	1	SG-ARVA2/PSSPS-28	98	532	630	2
SG-ARAR8/AHCT-63	34	244	278	1	SG-ARVA2/PSSPS-29	102	536	638	2
SG-ARAR8/AHCT-64	33	209	242	1	SG-ARVA2/PSSPS-35	84	563	647	2
SG-ARAR8/AHCT-65	29	193	223	1	SG-ARVA2/PSSPS-44	89	503	591	1
SG-ARAR8/AHCT-66	35	247	282	1	SG-PUTR2/PSSPS-33	99	582	681	2
SG-ARAR8/AHCT-67	18	113	131	1	ST-ATCO/AHCT-1	14	168	182	1
SG-ARAR8/AHCT-68	15	103	118	1	ST-ATCO/AHCT-2	10	141	151	1
SG-ARAR8/FEID-38	105	393	498	1	ST-ATCO/AHCT-69	17	104	121	1
SG-ARAR8/FEID-42	108	376	485	1	ST-ATCO/SIHY-4	35	71	106	1
SG-ARAR8/PSSPS-26	92	413	504	1	ST-SAVE4/LECI4-3	33	326	360	1
SG-ARAR8/PSSPS-31	74	444	517	1	ST-SAVE4/LECI4-58	67	1294	1361	3
SG-ARAR8/PSSPS-39	107	441	547	1	WT-ARCA13/DECE-88	0	2083	2083	4
SG-ARAR8/PSSPS-40	123	448	570	1	WT-SALIX/CAREX-87	314	2056	2371	4
SG-ARAR8/PSSPS-41	93	416	509	1	WT-SALIX/DECE-86	430	1656	2086	4
SG-ARAR8/PSSPS-47	97	437	534	1	WT-SALIX/LECI4-18	336	2072	2408	5
SG-ARAR8/PSSPS-48	57	388	445	1	WT-SALIX/LECI4-85	319	2292	2611	5
SG-ARCA13/DECE-20	457	1371	1828	4					

Table 5.15. Waterfowl forage quantity and forage score in Pine Valley.

Habitat	Waterfowl Forage (kg/ha)	Waterfowl Forage Score	Habitat	Waterfowl Forage (kg/ha)	Waterfowl Forage Score
MN-ARAR8/PSSPS-43	0	0	SG-ARTRT/ACTH7-1	0	0
MN-ARVA2/ACTH7-76	0	0	SG-ARTRT/ACTH7-5	0	0
MN-ARVA2/FEID-27	8	1	SG-ARTRT/ACTH7-6	0	0
MN-ARVA2/PSSPS-77	0	0	SG-ARTRT/AHCT-61	0	0
MN-ARVA2/PSSPS-78	10	1	SG-ARTRT/AHCT-62	0	0
MN-ARVA2/PSSPS-79	0	0	SG-ARTRT/LECI4-19	151	2
MN-ARVA2/PSSPS-80	17	1	SG-ARTRT/LECI4-57	50	2
MN-ARVA2/PSSPS-82	0	0	SG-ARTRT/LECI4-7	37	2
MN-ARVA2/PSSPS-83	0	0	SG-ARTRT/PSSPS-30	0	0
MN-SYMPH/AGTR-56	8	1	SG-ARTRT/PSSPS-32	0	0
PJ-ARAR8/ACTH7-60	0	0	SG-ARTRT/PSSPS-34	0	0
PJ-ARAR8/ACTH7-81	0	0	SG-ARTRT/PSSPS-36	0	0
PJ-ARAR8/AHCT-16	0	0	SG-ARTRT/PSSPS-45	6	1
PJ-ARAR8/PSSPS-17	0	0	SG-ARTRT/PSSPS-46	6	1
PJ-ARAR8/PSSPS-75	4	1	SG-ARTRT/PSSPS-49	0	0
PJ-ARTRT/PSSPS-55	0	0	SG-ARTRT/PSSPS-50	0	0
PJ-ARVA2/ACLE9-71	22	1	SG-ARTRT/PSSPS-51	0	0
PJ-ARVA2/ACTH7-13	0	0	SG-ARTRT/PSSPS-52	0	0
PJ-ARVA2/ACTH7-59	0	0	SG-ARVA2/ACLE9-72	30	1
PJ-ARVA2/ACTH7-9	0	0	SG-ARVA2/FEID-37	11	1
PJ-ARVA2/PSSPS-10	0	0	SG-ARVA2/FEID-53	4	1
PJ-ARVA2/PSSPS-11	0	0	SG-ARVA2/FEID-54	3	1
PJ-ARVA2/PSSPS-12	7	1	SG-ARVA2/LECI4-70	136	2
PJ-ARVA2/PSSPS-14	6	1	SG-ARVA2/PSSPS-22	0	0
PJ-ARVA2/PSSPS-21	0	0	SG-ARVA2/PSSPS-23	5	1
PJ-ARVA2/PSSPS-73	12	1	SG-ARVA2/PSSPS-24	6	1
PJ-ARVA2/PSSPS-74	4	1	SG-ARVA2/PSSPS-25	0	0
SG-ARAR8/ACTH7-8	0	0	SG-ARVA2/PSSPS-28	3	1
SG-ARAR8/AHCT-63	0	0	SG-ARVA2/PSSPS-29	8	1
SG-ARAR8/AHCT-64	0	0	SG-ARVA2/PSSPS-35	8	1
SG-ARAR8/AHCT-65	0	0	SG-ARVA2/PSSPS-44	5	1
SG-ARAR8/AHCT-66	0	0	SG-PUTR2/PSSPS-33	0	0
SG-ARAR8/AHCT-67	0	0	ST-ATCO/AHCT-1	0	0
SG-ARAR8/AHCT-68	0	0	ST-ATCO/AHCT-2	0	0
SG-ARAR8/FEID-38	5	1	ST-ATCO/AHCT-69	0	0
SG-ARAR8/FEID-42	4	1	ST-ATCO/SIHY-4	11	1
SG-ARAR8/PSSPS-26	0	0	ST-SAVE4/LECI4-3	41	2
SG-ARAR8/PSSPS-31	6	1	ST-SAVE4/LECI4-58	55	2
SG-ARAR8/PSSPS-39	0	0	WT-ARCA13/DECE-88	611	5
SG-ARAR8/PSSPS-40	0	0	WT-SALIX/CAREX-87	938	6
SG-ARAR8/PSSPS-41	3	1	WT-SALIX/DECE-86	651	5
SG-ARAR8/PSSPS-47	9	1	WT-SALIX/LECI4-18	426	4
SG-ARAR8/PSSPS-48	12	1	WT-SALIX/LECI4-85	1033	6
SG-ARCA13/DECE-20	201	3			

coniferous forests (Masser et al. 1984; United States Fish and Wildlife Service 1978) and is unlikely ever to have been abundant in the Pine Valley study area. Sagebrush is critical to sage grouse habitats because it provides protective cover from weather and predators, and represents the major over winter food source for sage grouse (Call 1979; Call and Masser 1985; Eng 1986a; Roberson 1984). Sage grouse may forage occasionally in greasewood-saltbush vegetation communities in winters when deep snow drives them out of sagebrush. Similarly, in dry summers sage grouse may migrate to pinyon-juniper or mountain brush where water and succulent vegetation are available. However, greasewood-saltbush and montane communities are marginal areas for sage grouse and they reproduce almost exclusively in sagebrush communities (Call and Masser 1985; Masser et al. 1984; Roberson 1984).

Table 5.16 lists the quantity of sagebrush (defined here as all species belonging to the genus *Artemisia*) in kg/ha in each habitat in the Pine Valley study area. Each habitat is assigned an ordinal sagebrush score based on the quantity of sagebrush in that habitat.

Drinking water is a necessary component of sage grouse habitats: in summer months the birds may venture no farther than 1.5 to 3.5 km from a stream, spring, or seep (Call 1979; Eng 1986b), but in winter may use snow as a water source (Call and Masser 1985). Sage grouse generally prefer flat or gently rolling terrain to steeper slopes. Sage grouse use open meadows closely juxtaposed with patches of dense sagebrush as strutting grounds or leks while mating in the spring, and use meadows as foraging patches to provision hatchlings and fledglings with insects and succulent vegetation (Call 1979; Call and Masser 1985). Therefore, the water proximity score calculated in equation 4 is pertinent to evaluating sage grouse habitats.

Sage grouse subsist on three categories of food: insects vital to the young, succulent grasses and forbs in summer, and sagebrush leaves for overwintering. Elsewhere, we have listed specific forage plants favored by sage grouse (Zeanah et al. 1995: 154). Table 5.16 tallies all forage plants by habitat in kg/ha. Once again, these values are simplified into ordinal scores. Habitat suitability for sage grouse is then determined by multiplying the sagebrush, forage, and water proximity scores (Table 5.10).

Table 5.16. Sagebrush cover and sage grouse forage scores for Pine Valley habitats.

Habitat	Sage (kg/ha)	Sage Score	Sage Grouse Forage (kg/ha)	Sage Grouse Forage Score	Habitat	Sage (kg/ha)	Sage Score	Sage Grouse Forage (kg/ha)	Sage Grouse Forage Score
MN-ARAR8/PSSPS-43	81	2	175	2	SG-ARTRT/ACTH7-1	123	3	155	2
MN-ARVA2/ACTH7-76	40	1	113	2	SG-ARTRT/ACTH7-5	125	3	157	2
MN-ARVA2/FEID-27	79	2	145	2	SG-ARTRT/ACTH7-6	158	3	203	3
MN-ARVA2/PSSPS-77	83	2	184	2	SG-ARTRT/AHCT-61	180	4	221	3
MN-ARVA2/PSSPS-78	98	2	220	3	SG-ARTRT/AHCT-62	120	3	150	2
MN-ARVA2/PSSPS-79	121	3	227	3	SG-ARTRT/LECI4-19	302	6	694	6
MN-ARVA2/PSSPS-80	229	5	359	4	SG-ARTRT/LECI4-57	252	5	429	4
MN-ARVA2/PSSPS-82	83	2	134	2	SG-ARTRT/LECI4-7	111	2	200	3
MN-ARVA2/PSSPS-83	100	2	147	2	SG-ARTRT/PSSPS-30	116	2	162	2
MN-SYMPH/AGTR-56	51	1	186	2	SG-ARTRT/PSSPS-32	131	3	176	2
PJ-ARAR8/ACTH7-60	123	3	150	2	SG-ARTRT/PSSPS-34	86	2	131	2
PJ-ARAR8/ACTH7-81	60	1	80	2	SG-ARTRT/PSSPS-36	80	2	125	2
PJ-ARAR8/AHCT-16	108	2	128	2	SG-ARTRT/PSSPS-45	123	3	163	2
PJ-ARAR8/PSSPS-17	81	2	90	2	SG-ARTRT/PSSPS-46	107	2	151	2
PJ-ARAR8/PSSPS-75	159	3	234	3	SG-ARTRT/PSSPS-49	117	3	152	2
PJ-ARTRT/PSSPS-55	64	1	103	2	SG-ARTRT/PSSPS-50	113	2	141	2
PJ-ARVA2/ACLE9-71	181	4	290	3	SG-ARTRT/PSSPS-51	128	3	159	2
PJ-ARVA2/ACTH7-13	147	3	164	2	SG-ARTRT/PSSPS-52	83	2	120	2
PJ-ARVA2/ACTH7-59	133	3	160	2	SG-ARVA2/ACLE9-72	172	4	286	3
PJ-ARVA2/ACTH7-9	170	4	187	2	SG-ARVA2/FEID-37	124	3	208	3
PJ-ARVA2/PSSPS-10	140	3	170	2	SG-ARVA2/FEID-53	82	2	120	2
PJ-ARVA2/PSSPS-11	145	3	170	2	SG-ARVA2/FEID-54	113	2	179	2
PJ-ARVA2/PSSPS-12	144	3	181	2	SG-ARVA2/LECI4-70	291	6	485	5
PJ-ARVA2/PSSPS-14	163	3	224	3	SG-ARVA2/PSSPS-22	68	2	121	2
PJ-ARVA2/PSSPS-21	83	2	131	2	SG-ARVA2/PSSPS-23	111	2	195	2
PJ-ARVA2/PSSPS-73	161	3	263	3	SG-ARVA2/PSSPS-24	100	2	171	2
PJ-ARVA2/PSSPS-74	150	3	220	3	SG-ARVA2/PSSPS-25	90	2	158	2
SG-ARAR8/ACTH7-8	107	2	137	2	SG-ARVA2/PSSPS-28	114	2	178	2
SG-ARAR8/AHCT-63	134	3	166	2	SG-ARVA2/PSSPS-29	126	3	193	2
SG-ARAR8/AHCT-64	107	2	134	2	SG-ARVA2/PSSPS-35	103	2	171	2
SG-ARAR8/AHCT-65	112	2	137	2	SG-ARVA2/PSSPS-44	101	2	161	2
SG-ARAR8/AHCT-66	141	3	174	2	SG-PUTR2/PSSPS-33	139	3	199	3
SG-ARAR8/AHCT-67	88	2	106	2	ST-ATCO/AHCT-1	114	2	139	2
SG-ARAR8/AHCT-68	95	2	108	2	ST-ATCO/AHCT-2	121	3	145	2
SG-ARAR8/FEID-38	103	2	171	2	ST-ATCO/AHCT-69	67	2	75	2
SG-ARAR8/FEID-42	102	2	169	2	ST-ATCO/SIHY-4	31	1	46	1
SG-ARAR8/PSSPS-26	93	2	159	2	ST-SAVE4/LECI4-3	12	1	47	1
SG-ARAR8/PSSPS-31	118	3	161	2	ST-SAVE4/LECI4-58	0	0	164	2
SG-ARAR8/PSSPS-39	112	2	177	2	WT-ARCA13/DECE-88	163	3	1039	8
SG-ARAR8/PSSPS-40	103	2	181	2	WT-SALIX/CAREX-87	0	0	847	7
SG-ARAR8/PSSPS-41	112	2	172	2	WT-SALIX/DECE-86	21	1	374	4
SG-ARAR8/PSSPS-47	117	3	180	2	WT-SALIX/LECI4-18	85	2	512	5
SG-ARAR8/PSSPS-48	117	3	153	2	WT-SALIX/LECI4-85	60	1	468	5
SG-ARCA13/DECE-20	27	1	375	4					

CHAPTER 6 – IMPLICATIONS OF FORAGING BEHAVIOR

The distribution of biotic habitats within Pine Valley was described in Chapter 5. In this chapter, the food items contained in these habitats, as known from ethnographic and archaeological sources, are identified and ranked according to energetic return rate. This resource landscape serves to rank habitats, and to predict where hunter-gatherers settled and foraged in the study area.

DEVELOPMENT OF A THEORETICAL MODELING APPROACH

Ethnographic descriptions of Shoshone bands in Pine Valley and nearby areas (Steward 1938) inform that indigenous people foraged in an arid environment where critical resources were distributed unevenly in space and time, and often were rare and unreliable. Because of this, food and water distributions strongly influenced where prehistoric hunter-gatherers chose to live and work.

Behavioral ecology is a Darwinian paradigm that uses optimal foraging theory to model foraging behavior. These models assume that, all other things being equal, organisms that forage efficiently enjoy a fitness advantage over less competent competitors. Therefore, natural selection favors organisms that make choices that improve the cost-effectiveness of foraging (Smith and Winterhalder 1992:53). Often such models simplify the task of measuring the fitness advantage bestowed by efficient foraging by presupposing that forager decisions are motivated to maximize net energetic foraging return rates (kilocalories per hour).

Usually behavioral ecologists use optimal foraging models to predict how living organisms search for food so that they can test hypotheses directly against observed behavior. In the case of archaeological site sensitivity predictions, optimal foraging models serve to retrodict the use of resource patches by generations of hunter--gatherers, and test expectations against the archaeological record. Such an approach requires neither an assumption that there was only one optimal strategy for foraging in Pine Valley, nor that the behavior of all prehistoric hunter-gatherers in Pine Valley was always optimal. However, the archaeological record is eloquent testimony that hunting and gathering was a successful economic lifeway in northern Nevada for millennia, and that ethnographic foragers benefited from generations of hard-won, local experience in this lifestyle. Obviously, it must have been possible to pursue many foraging strategies in Pine Valley, but some must have been more cost-efficient than others. Those hunter-gatherers who chose better strategies must have been better fed and raised healthier children by doing so.

Over time, locations offering the best places to live and forage attracted more hunter-gatherer activity than less favorable locations. The archaeological record reflects such preferences in the position, size, composition, and diversity of archaeological assemblages. Consequently, prehistoric archaeological site distributions can be predicted by replicating prehistoric resource distributions and using optimality models to predict how prehistoric people could best forage in that landscape. Such predictions are testable by analysis of archaeological survey data.

Given this theoretical predilection, prehistoric hunter-gatherers of northeastern Nevada are assumed to have striven for foraging efficiency. Using optimal foraging models as a guide, prehistoric hunter-gatherers are assumed to have done best by living and foraging in habitats providing highest caloric return rates. The foraging options of hunter-gatherers can be modeled by ranking the energetic productivity and spatial distribution of resources that habitats contain. Development of an optimal foraging analysis of the land-use decisions of Pine Valley hunter-gatherers also requires consideration of three organizational constraints of ethnographic subsistence and settlement strategies which optimal foraging models fail to consider: seasonality, sexual division of labor, and central place foraging. Seasonality structures intra-annual fluctuation in the availability of resources, whereas sexual division of labor and central place foraging are fundamental tactics of hunter-gatherers for scheduling procurement of simultaneously available but spatially dispersed resources (Flannery 1968; Isaac 1978). Introduction of these constraints into the Pine Valley model improves the realism and accuracy of its predictions.

Thus, this chapter considers a set of subsistence resources that are contained in the habitats defined in the previous chapter. Caloric costs and benefits serve to rank the relative values of these resources. Next, the ethnographic record serves to divide resources into men's and women's prey, and then into sets of resources that are simultaneously available in the same season. These sets of resources are projected against the habitat landscape to calculate the overall foraging returns available in each habitat and rank habitats by their seasonal productivity as foraging patches for either sex.

Optimal Foraging Models

Evaluating the foraging potential of Pine Valley habitats requires consideration of three optimal foraging models: diet breadth, patch choice, and the marginal value theorem. The diet breadth model (DBM) predicts whether a forager should harvest a resource upon encounter based on the caloric return offered by that resource, compared with the return that could be gained from bypassing that resource and searching for more profitable alternatives (Schoener 1971). The model calculates the return rate of exploiting a particular food based on the time required to pursue and process (handling time) that resource and the number of calories thereby gained. Return rates are thus expressed as calories per hour and this figure ranks the caloric value of different resources. However, estimates of handling cost only calculate time necessary to extract energy from a resource after it has been found, ignoring the search time necessary to track down that resource. This means that the post-encounter caloric return rate of a resource in a DBM is independent of its abundance (i.e., the rate at which a forager successfully encounters the resource). Foragers maximize average energetic returns for searching and harvesting all dietary items in an environment only by harvesting those resources that offer return rates greater than the rate for shunning that resource and exclusively seeking, collecting, and processing only higher ranked resources. Thus, the DBM specifically models trade-offs in energetic return rates between search and handling costs.

The average foraging return rate (E/T) obtainable from any set of resources within an environment is calculated as follows (Stephens and Krebs 1986):

$$E/T = \frac{\left(\sum_{i}^{n} R_i * E_i\right)}{\left[1+\left(\sum_{i}^{n} R_i * h_i\right)\right]} \qquad \text{(equation 5)}$$

where:
E = total calories acquired from foraging for all resources up to and including resource i,
T = total time spent foraging (handling and search time) for all resources up to and including resource i,
E_i = calories available in a unit of resource i (kcal/kg),
h_i = handling time per unit of resource i (hr/kg) and
R_i = encounter rate with resource i per unit of search time (kg/hr).

According to the DBM, any specific resource (*i*) should be in the diet only so long as:

$$E/T < E_i / h_i. \qquad \text{(equation 6)}$$

The DBM makes three specific predictions: 1) Foragers will take any resource in the optimal diet whenever they come across it. 2) Whether any resource is within the optimal diet depends on the availability of all higher ranked resources, not on the abundance of that particular resource. 3) Optimal diet breadth contracts and expands in response to fluctuations in the abundance of higher ranked resources; if high ranked resources become sufficiently common then low ranked resources may fall from the diet, but diet breadth expands if higher ranked resources become sufficiently rare (Schoener 1971).

To conceptualize DBM predictions, imagine that a gatherer forages in an environment where ground squirrel (*Ei/hi* = 5,900 kcal/hr), shadscale seed (*Ei/hi* = 1,200 kcal/hr), and pickleweed seed (*Ei/hi* = 180 kcal/hr) are available. If the gatherer takes ground squirrels so often that she can achieve average foraging returns (*E/T*) greater than 1,200 kcal/hr by seeking, collecting, and processing squirrel alone, she would lower her overall foraging return rate by harvesting shadscale or pickleweed seeds no matter how often she comes across them. If squirrels become sufficiently rare that her overall return rate falls below 1,200 kcal/hr, she would profit by adding shadscale seed to her diet, no matter how scarce shadscale may be, but she should also continue to take squirrel whenever she has the opportunity (no matter how rarely). However, as long as her average foraging returns for seeking and harvesting squirrel and shadscale together remain greater than 180 kcal/hr, she maximizes her overall return rate by forsaking pickleweed seed regardless of how common pickleweed may be.

Bettinger (1993: 49-50) points out one shortcoming in the way that the DBM can realistically reflect the foraging behavior of Great Basin hunter-gatherers. The DBM calculates optimal behavior according to momentary circumstances, but such contingency based predictions can be misleading if other constraints select for foraging efficiency over the longer term. For example, a forager whose selective constraint is to avoid starvation over an extended period of time, but who optimizes behavior according to momentary contingencies, may collect the necessary calories less efficiently than a forager who takes resources that seem less than optimal concerning momentary returns. According to Bettinger, this problem may be particularly relevant to foragers who store food. Therefore, thoughtful application of the DBM to model the foraging strategies of prehistoric Great Basin hunter-gatherers must consider the possibility that low ranked but storable, resources, like seeds, may have been procured to maximize long-term (i.e., annual), rather than momentary foraging returns (cf. Simms 1987).

The DBM assumes resources to be homogeneously distributed through the environment, but principles of the model can be adjusted to predict foraging decisions in environments where resources are unevenly distributed among patches (MacArthur and Pianka 1966). A patch is merely a concentration of food, and the patch choice model (PCM) assumes that foragers encounter patches randomly and individually. The model predicts which patches foragers should elect to forage in, whenever encountered, in order to maximize their overall caloric return rate. Just as the DBM ranks resources by rate of caloric return per unit of handling time, the PCM also ranks patches according to caloric return, but does so by including search time within the patch along with handling time as a measure of cost. However, the time necessary to travel between patches is not considered a cost in ranking patches. Thus, just as the ranks of food resources in the DBM are independent of resource abundance (search time), patch type rankings are independent of patch abundance (travel time), and the PCM compares trade-offs in energetic return rate between combined search and handling costs with travel costs.

The mathematically expression of the PCM is as follows (Charnov 1976; Stephens and Krebs 1986:25-27).

$$E/T = \frac{\sum_{i=1}^{n} R_i E_i - C_s}{1 + \sum_{i=1}^{n} R h_i} \qquad \text{(equation 6)}$$

where:
E = total calories acquired from foraging for all patches up to and including patch i,
T = total time spent foraging (handling, search, and travel time) for all patches up to and including patch i,
R_i = encounter rate with patch type i per unit of time (kg/hr)
E_i = calories available in an example of patch i (kcals/kg),
C_s = energetic cost per unit of time expended in foraging in all patches up to and including patch i, and
h_i = search and handling time per unit of patch i (hr/kg).

Therefore, the equation indicates that a forager should choose a patch only as long as the returns for searching for and handling resources within the patch exceed the overall returns for traveling to and foraging within higher ranked patches, or:

$$E / T < E_i / h_i. \qquad \text{(equation 7)}$$

Like the DBM, the PCM expects foragers to prefer the most energetically profitable patches and predicts that a change in resource abundance may alter the breadth of patch selection. However, other patch choice predictions are not so straightforward as those of the DBM because search time is considered a cost in ranking patches. Although the rank of patches is independent of the abundance of patches, it is not independent of the abundance of resources within patches. This makes it unclear whether the optimal breadth of patches will broaden, narrow, or remain stable when resource abundance changes. This is because changing the abundance of resources may alter both search time within patches (because the abundance of resources within patches may change) and travel time between patches (because patch abundance may change). Thus, effects of fluctuating resource abundance on patch breadth are contingent on whether travel, search, or handling time comprise the bulk of costs required for exploiting resources in patches.

Consider patches containing resources that are easily found but costly to harvest and process (seeds for example). Increasing the quantity of seeds should increase the number of profitable seed patches and, therefore, lower travel time between patches. However, increasing the abundance of seeds is unlikely to reduce search costs sufficiently to raise average foraging returns within seed patches, because seeds tend to be easily located anyway. In this situation, foragers should select a narrower array of higher ranked seed bearing patch types because more examples of these patches are available (i.e., the abundance of higher ranked patch types increases causing the breadth of patch types to narrow).

In contrast, increasing the abundance of resources that are harder to find than handle (for example large game) will increase overall returns within hunting patches as well as number of hunting patches. This is simply because large game must always be sought out, and increasing their abundance in a hunting niche must significantly reduce the time necessary to find them. In this situation, patch breadth may broaden as resources become more abundant, because more patch types are sufficiently high ranked to fall within optimal patch breadth (i.e., the rankings of patches increase).

This means that the effects of paleoenvironmental change on the distribution of intrapatch resources with different allotments of search and handling costs must be considered before predicting the effects of such change on patch selection in Pine Valley. The need for such consideration becomes particularly evident when sexual division of labor is considered; women tend to pursue prey that are most expensive in handling costs, whereas men pursue prey where searching is the higher cost. Therefore, the same paleoenvironmental change may have diametrically opposite effects on the patch selection of male and female foragers because of the nature of resources they procure.

Another ambiguity in PCM predictions concerns its assumption that foragers encounter patches sequentially rather than simultaneously. If a forager has the simultaneous option of exploiting more than one patch, then travel time can significantly alter optimal patch choice in ways that contradict the expectation that foragers maximize their foraging returns by choosing highest ranked patches. As travel time increases (greater distance between patches), it constitutes a greater proportion of the total costs necessary to exploit patches, while the proportional contribution of search and handling costs diminishes. Thus, if a forager is sufficiently close to a low ranked patch, then the additional travel time required to reach a more distant but higher ranked patch may lower its overall return below that of the nearby patch. The forager will achieve greater foraging returns for exploiting the lower ranked, but local, patch.

The complications of simultaneous patch encounters are particularly critical to predicting patch choice of central place foragers, who may choose among a set of simultaneously available patches of varying distances from a home base camp, rather than sequentially encountering patches on a foray (Kaplan and Hill 1992:180; Stephens and Krebs 1986:38-45). For example, imagine a scenario applicable to the arid Great Basin where hunter-gatherers must camp near water, but the best foraging patches are far from water sources. Depending on the particular circumstances of travel costs and relative patch returns, those hunter-gatherers may find it more profitable to forage in lower ranked patches that are close to home than in distant, but profitable, patches. This means that consideration of patch choice among central place foragers must consider constraints of central place locations such as the distribution of potable water.

The Marginal Value Theorem (MVT) is a variant of the PCM that assumes that the return rate for foraging in a patch declines the longer it is utilized (diminishing returns) and predict the point at which a forager should abandon the patch to optimize energetic return rates (Charnov 1976). The solution to the dilemma is simple, a forager should move out of a patch when the return rate for foraging in the patch falls below the average return for travelling, searching, and foraging in the environment as a whole. An implication of this is that prehistoric hunter-gatherers should have preferred to forage in resource patches offering foraging return rates higher than the environmental average, and avoided lower than average patches.

Neither the DBM, PCM, nor MVT specifically predict where hunter-gatherers should elect to forage; all ignore constraints pertinent to those facing central place hunter-gatherers. Yet they can serve as the framework for an optimal foraging approach to modeling the locations of central place foraging and settlement decisions once appropriate constraints are considered. The habitats described in Chapter 5 are types of patches that differ in the assortment and proportion of resources they contain. To maximize caloric intake, Pine Valley hunter-gatherers should prefer to forage in habitats (patches) providing higher than average return rates. The average return rate obtainable from the optimal diet of each habitat type (*E/T*) can be calculated by using equation 1 of the diet breadth model and considering the abundance and energetic return rates of resources available within each habitat. Habitats then can be ranked according to the average return obtainable given the net return rate and abundance of resources contained within each habitat type, and the average foraging return rate obtainable from the entire study area assemblage of habitats.

However, the array of prey available within each habitat varies seasonally, so habitat types are also ranked separately for each season of the year. Too, ethnographic male and female hunter-gatherers pursue different sets of prey. In this model, sexual division of foraging effort is assumed to be determined by trade-offs between child care and resource variability that are not monitored by these optimal foraging models. Therefore, after considering how extrinsic constraints of variability and mobility determined the array of resources available to each sex, habitat types are ranked separately for men and women.

For the moment, we assume Pine Valley hunter-gatherers favored habitat types that offered highest returns for both men and women, but sexual division of labor and central place foraging tactics would have allowed them to exploit simultaneously more than one patch. How Pine Valley foragers may have reconciled conflicts between the foraging interests of men and women will be considered after evaluation of the foraging utility of habitats for male and female foragers.

RANKING MAJOR RESOURCES IN PINE VALLEY BY RETURN RATE

Using the optimal foraging theory to model hunter-gatherer foraging decisions in Pine Valley requires estimation of the distribution, abundance, and caloric return rate (*Ei/hi*) of food items available within the study area. Based on range type descriptions that quantitatively estimate the distribution and abundance of plant species by soil map units, the 87 habitats defined for the Pine Valley study area directly measure plant food distributions and abundance. Thirty-five categories of edible plant can be identified from the 114 plant species and classifications individually tallied in range type descriptions pertaining to the Pine Valley study area. Table 6.1 lists these plant food items known from ethnographic records to have been eaten by ethnographic Great Basin hunter-gatherers (Fowler 1986), which occur in Pine Valley habitats. Adding the nine categories of game considered in Chapter 5, the distribution and abundance of 44 food items can be directly mapped in the Pine Valley habitat landscape.

Principles of the DBM can predict which resources should harvest in each habitat in order to maximize their overall foraging return rate (*E/T*) and estimate the foraging return rate obtainable from the optimal diet within each habitat type. To do so, the net return rates (*Ei/hi*) of food items in Pine Valley must be estimated to rank the resources. Fortunately, a growing body of replicative and ethnographic studies provide a body of caloric return rates for many of these resources (Barlow 1995; Bullock 1994; Couture 1986; Hooper 1994; Jones and Madsen 1991; Larralde and Chandler 1981; Madsen et al. 1997; Simms 1987; Smith and Martin 2001; Todt and Hannon 1998). Table 6.2 lists game and plant resources for which experimentally derived caloric return rates are available.

Critics sometimes question the reliability of rankings derived from experimental data, such as those presented in Table 6.2, because today's experimenters cannot precisely replicate past foraging returns (Bettinger 1991:103). However, independent experiments have replicated many of the return rate estimates, and the range of return rates by resource class (i.e., seeds, tubers, nuts, small game, large game) is similar to those ethnographically observed among modern hunter-gatherers who pursue similar arrays of prey (Cane 1987; O'Connell and Hawkes 1981). These facts offer reassurance as to the rough accuracy of the experimental data.

Table 6.1 Ethnographically recorded food items monitored in Pine Valley Habitats.

Resource	*Scientific Name*	Category	Edible Portion
Indian ricegrass	*Achnatherum hymenoides*	Grass	seeds
wheatgrass	*Agropyron*	Grass	seeds
Columbia onion	*Allium columbianum*	Forb	bulbs
serviceberry	*Amelanchier*	Shrub	berries
saltbush	*Atriplex*	Shrub	seeds
balsamroot	*Balsamorhiza*	Forb	root
sedge	*Carex*	Grass	seeds
hawksbeard	*Crepis*	Forb	leaves
inland saltgrass	*Distichlis spicata*	Grass	seeds
wildrye	*Elymus*	Grass	seeds
jointfir	*Ephedra*	Shrub	seeds
barley	*Hordeum*	Grass	seeds
rush	*Juncus*	Grass	seeds
biscuitroot	*Lomatium*	Forb	roots
mat muhly	*Muhlenbergia richardsonis*	Grass	seeds
evening primrose	*Oenthera spp.*	Forb	stems, roots
pricklypear	*Opuntia*	Forb	stems, fruits
limber pine	*Pinus flexilis*	Tree	seeds
singleleaf pinyon	*Pinus monphylla*	Tree	seeds
bluegrass	*Poa*	Grass	seeds
sego pondweed	*potamogeton*	Forb	seeds, roots, stalks
chokecherry	*Prunus*	Shrub	fruits
gooseberry	*Ribes*	Shrub	berries
rose	*Rosa*	Shrub	fruits
dock	*Rumex*	Forb	seeds, stems, leaves
common arrowhead	*Sagittaria latifolia*	Forb	seeds
bulrush	*Scirpus*	Grass	seeds, roots
squirreltail	*Sitanion*	Grass	seeds
globemallow	*Sphaeralcea*	Forb	seeds
alkali sacaton	*Sporobolous airoides*	Grass	seeds
princesplume	*Stanleya*	Forb	leaves, stems, seeds
needlegrass	*Stipa*	Grass	seeds
seepweed	*Suaeda*	Forb	seeds
clover	*Trifolium*	Forb	seeds, leaves
cattail	*Typha*	Grass	seeds, roots, pollen, shoots

Table 6.2. Experimentally derived return rates for resources monitored in Pine Valley study area habitats.

Resource	Edible Portion	Caloric Return Rate (kcal/hr)	Source
barley	seeds	140-275	Simms 1987
basin wildrye	seeds	270-490	Simms 1987; Bullock 1994
bighorn sheep	large game	18,000-31500	Simms 1987
biscuitroot	roots	1220-3800	Couture et al. 1986
bluegrass	seeds	420-490	Simms 1987
Bottlebrush squirreltail	seeds	90	Simms 1987
bulrush	seeds	300-1700	Simms 1987
bulrush	roots	160-260	Simms 1987
cattail	pollen	2750-9350	Simms 1987
cattail	rhizome	40-3966	Simms 1987; Jones and Madsen 1991, Madsen et al. 1997
cattail	seeds	260	Madsen et al. 1997
cattail	shoots	432-846	Madsen et al. 1997
chokecherry	fruits	250	Todt and Hannon 1998
cottontail rabbit	medium game	9000-9800	Simms 1987; Winterhalder 1981
duck	small game	1975-2700	Simms 1987
princesplume	leaves	150	Hooper 1994
Indian ricegrass	seeds	300-400	Simms 1987; Jones and Madsen 1991; Larralde and Chandler 1981
inland saltgrass	seeds	140-160	Simms 1987
jackrabbit	medium game	13500-15,500	Simms 1987; Winterhalder 1981
large ground squirrel	medium game	5400-6300	Simms 1987
muhly/ dropseed	seeds	160-300	Simms 1987
mule deer	large game	18,000-50000	Simms 1987: Zeanah et al. 1995
Nuttal sunflower	seeds	470-510	Simms 1987
pickleweed	seeds	90-270	Simms 1987; Barlow and Metcalfe 1995
pinyon	seeds	1000-1700	Simms 1987; Barlow and Metcalfe 1995
pronghorn antelope	large game	16,000-31500	Simms 1987
sage grouse	small game	1200-1800	Winterhalder 1981
sedge	seeds	200	Simms 1987
serviceberry	berries	250	Todt and Hannon 1998
shadscale	seeds	1000-1200	Simms 1987
small ground squirrel	small game	2800-3600	Simms 1987

Nevertheless, given the experimental nature of the return rates, predicting foraging decisions based on deceptive precision of return rates should be avoided. For example, it would be spurious to predict that hunter-gatherers should prefer wildrye seeds over ricegrass seeds because the former return a few more calories per hour than the latter. This minor difference between return rates is too small for predictive purposes, given the limited number of experiments conducted thus far. For this reason, the resource are grouped into rank classes defined by gross ranges of similar return rates, allowing comparison of potential return rates available from foraging in different habitats without eliciting predictions based on miniscule differences in return rates. This approach also allows return rates to be estimated for those resources lacking experimental data, based on similarities in package size (i.e., seed size, caloric contents, etc.) and handling methods (i.e., snares, seed beaters) with resources of experimentally known return rates. Table 6.3 presents the array of rank classes. Notice that Ranks 1 through 3 have equal intervals of 300 kcal/hr (up to 900 kcal/hr). In contrast, Rank 4 contains resources yielding from 900 to 1,499 kcal/hr, Rank 5 resources provide between 1,500 and 3,499 kcal/hr, Rank 6 contains resources producing between 3,500 and 8,999 kcal/hr, Rank 7 resources provide more than 9,000 kcal/hr, and Rank 8 resources yield 20,000 or more kcal/hr.

Note in Table 6.2 that caloric return rates (E_i/h_i) are known for only a portion of food items listed in Table 6.1. This means that caloric return rates must be estimated for the remaining resources. Estimating return rates for resources lacking experimental data is a valid approach for ranking resources so long as the estimates are based on similarities in package size (i.e., seed size, caloric content, etc.) and handling methods (i.e., snares, seed beaters) with resources of experimentally known return rates. Using return rate rank classes simplifies this task because unknown resources need only be assigned to a return rate interval rather than to a specific return rate estimate. Table 6.3 lists the remaining food items in the Pine Valley habitat database, assigning each a return rate class and a net return rate (E_i/h_i) representing the mid-point of the return rate interval.

DIET AND SEXUAL DIVISIONS OF LABOR

Sexual division of labor is a fundamental aspect of the organization of hunter-gatherer subsistence strategies (Bird 1999; Hawkes 1996) that ethnographic Great Basin groups shared (Kelly 1932:79; Steward 1938:44, 1941:253; Stewart 1941:406). Males and females procured different assortments of resources: males typically hunted whereas females emphasized gathering. Sexual division of labor complicates the task of modeling hunter-gatherer foraging strategies because men and women simultaneously procured different prey, sometimes in different places, returning to a common hearth to share food. However, evolutionary ecologists working among modern hunter-gatherers warn that sexual division of labor cannot be overlooked when applying optimal foraging models to humans because men and women have different motives for seeking different sets of prey under different constraints (Hill et al. 1987; Simms 1987:36; Hawkes 1996). Thus, this model evaluates men's and women's foraging strategies separately.

Table 6.4 indicates whether men or women foraged for particular food resources. Ethnographic descriptions of Shoshone (Steward 1941:312-313) are specific that women accomplished most seed gathering, whereas men usually harvested no seeds except pinyon nuts For this reason, Table 6.4 lists all seeds as women's resources, and lists only pinyon nuts as a men's resource. The preeminence of women's labor in seed procurement justifies an assumption that women also harvested pollen, roots, bulbs, leaves, stems, and fruits, whereas men usually gathered none.

Ethnographers note that women often participated in communal antelope and jackrabbit drives (Fowler 1989: 78; Kelly 1932:79). Antelope drives took place in Diamond Valley, outside of the study area (Steward 1938: 142), allowing the stalking of individual antelope to be left as an exclusively male activity within this model, but communal rabbit drives were a regular autumn event within Pine Valley (Steward 1938:119-120). For this reason a role is assigned for both men and women in driving rabbits. Women are also noted as being skilled in snaring small rodents (Fowler 1989:23; Kelly 1932:79). Therefore, Table 6.4 assigns small mammals to both men and women.

Table 6.3 Resource ranking by return rate class.

Resource	Edible Portion	Class Rank	Range of Caloric Return (kcal/hr)
bighorn sheep	large game	8	> 20,000
mule deer	large game	8	
pronghorn antelope	large game	8	
cottontail rabbit	medium game	7	9,000-20,000
jackrabbit	medium game	7	
cattail	pollen	6	3,500-9,000
Cattail	rhizome	6	
large ground squirrel	medium game	6	
biscuitroot	roots	5	1,500-3,500
bulrush	seeds	5	
sage grouse	small game	5	
small ground squirrel	small game	5	
waterfowl	small game	5	
balsamroot	root	4	900-3,500
onion	bulbs	4	
pinyon	seeds	4	
limber pine	seeds	4	
shadscale	seeds	4	
cattail	shoots	3	600-900
jointfir	seeds	3	
prickly pear	stems, fruits	3	
saltbush	seeds	3	
seepweed	seeds	3	
basin wildrye	seeds	2	300-600
bluegrass	seeds	2	
Indian ricegrass	seeds	2	
wheatgrass	seeds	2	
alkali sactaon	seeds	1	< 300
barley	seeds	1	
bottlebrush squirreltail	seeds	1	
bulrush	roots	1	
cattail	seeds	1	
chokecherry	fruits	1	
clover	seeds, leaves	1	
dock	seeds, stems, leaves	1	
evening primrose	stems, roots	1	
galleta	seeds	1	
globemallow	seeds	1	
golden princesplume	leaves, stems, seeds	1	
green molly	seeds	1	
hawksbeard	leaves	1	
inland saltgrass	seeds	1	
muhly/ dropseed	seeds	1	
needlegrass	seeds	1	
rush	seeds	1	
sedge	seeds	1	
sego pondweed	seeds, roots, stalks	1	
gooseberry	berries	1	
serviceberry	berries	1	
woods,rose	fruits	1	

Table 6.4 Sexual division of labor and seasonality for food items monitored in Pine Valley habitat landscape.

Plant Resource	Food Category	Return Class	Rate	Men's Prey	Women's Prey	Spring	Summer	Fall	Winter
alkali sacaton	seeds	1			X			X	
arrowleaf balsamroot	root	4			X	X			
basin wild rye	seed	2			X		X	X	
bighorn sheep	game	8		X		X	X	X	X
biscuitroot	root	5			X	X			
bluegrass	seed	2			X		X		
bottlebrush squirreltail	seed	1			X		X		
bulrush	seed	3			X			X	
bulrush	root	1			X			X	
cattail	pollen	6			X		X		
cattail	root, seed	1			X			X	X
clover	seed, leaf	1			X	X			
common arrowhead	root	1			X			X	X
cottontail/jackrabbit	game	7		X	X[1]	X	X	X[3]	X
dropseed/scratchgrass	seed	1			X		X	X	
evening primrose	stem, root	1			X	X			X
foxtail barley	seed	1			X		X		
galleta	seed	2			X		X		
glasswort	seed	1			X	X		X	X
globemallow	seed	1			X			X	X
gooseberry	berry						X		
Indian ricegrass	seed	2			X		X		
inland saltgrass	seed	1			X		X	X	
large ground squirrel	game	6		X		X			
limber pine	nut	4			X	X			
mat muly	seed	1			X		X	X	
mule deer	game	8		X		X	X	X	X
needlegrass	seed	2			X		X	X	
jointfir	seed	3			X		X		
chokecherry	fruit	3			X		X		
onion	root	4			X	X			
pricklypear	fruit	3			X		X		
princesplume	leaf, stem, seed	1			X	X			
pronghorn antelope	game	8		X		X	X	X	X
rush	seed	1			X			X	
sage grouse	game	5		X	X	X	X		
sego pondweed	root, stalk	1			X		X		
saltbush	seed	3			X			X	X
sedge	seed	1			X	X			
seepweed	seed	3			X			X	
serviceberry	berries	1			X		X		
shadscale	seed	4			X			X	X

Table 6.4 cont.

Plant Resource	Food Category	Return Rate Class	Men's Prey	Women's Prey	Spring	Summer	Fall	Winter
silver buffaloberry	fruit	3		X		X		
singleleaf pinyon	seed	4	X[2]	X			X	
small mammals	game	5	X		X	X	X	X
hawksbeard	leaf	1		X	X			
tufted hairgrass	seed	1		X		X	X	
waterfowl	game	5	X		X		X	X
dock	seed, stem, leaf	1		X		X	X	
wheatgrass	seed	2		X		X	X	
wild rose	fruit	3		X		X		
wildiris	root	1		X		X	X	
wolfberry	fruit	3		X		X		
woodrate/marmot	game	7	X		X	X	X	

Notes
1- in cooperation with men on drives
2- *in cooperation with women*
3- drives

The greatest difference between men's and women's prey lies in resource rank; men do not procure most of the relatively low ranked resources, whereas women do not procure most higher ranked resources. This reflects the different investment in search and handling time required to gather plant resources as opposed to that required to hunt prey. Men's prey are mobile and unpredictable, requiring considerable investment of search time to find. As discussed previously under the patch choice model, this means that an increase in the abundance of men's resources may cause men's patch (habitat) selection to broaden, whereas diminished abundance may cause patch selection to narrow. In contrast, women's resources are relatively stationary and predictable, and entail higher investment in handling time than in search time. Therefore, women's patch selection may narrow as gathered resource abundance increases and expand as gathered abundance declines.

SEASONAL VARIATION IN FORAGING OPPORTUNITIES

Technically, diet breadth and patch models can predict forager choice only among resources that are available simultaneously (that a forager encounters sequentially), and thus incur an opportunity cost when a forager forsakes one resource in favor of another. So far, all Pine Valley resources have been considered collectively without regard to synchronicity, but now patterns in the temporal availability of resources must be controlled to predict diet breadth and patch returns accurately. For example, that bulrush seeds provide higher caloric returns than Indian ricegrass is not informative about the preference of gatherers for either resource, because seeds of the two ripen in different seasons. By procuring one, a gatherer does not forfeit her opportunity to harvest the other; she can take each in season. Whether either or both appear in the diet is not a function of their rank and abundance relative to one another, but of the abundance of concurrently available higher ranked resources.

Since the set of available resources changes seasonally, optimal diet should vary seasonally as well. Consequently, Table 6.4 divides resources into seasonal sets according to seasonal availability. "Seasons" are defined according to annual shifts in resource availability in Pine Valley. Spring begins in late February or early March, as forbs appear and ground squirrels and small mammals come out of hibernation. Summer, beginning in June, offers cattail pollen, grass seed, and berries. Fall begins in late August or early September when pinyon pine nuts, and the seeds of bulrush, shadscale, and saltbush are available. Winter begins with the first significant snow, usually middle November, leaving only a few plant and animal resources available for foraging. Note that all seasons offer pronghorn antelope, mule deer, and bighorn sheep. However, the habitat distribution of these resources changes seasonally. All three species are assumed to range in upper elevation habitats during summer and lower elevation habitats during winter.

ESTIMATING RESOURCE ENCOUNTER RATES IN PINE VALLEY HABITATS

Preceding discussions have organized food resources according to caloric return rates, seasonal availability, and the gender of the forager who acquires them. Now, data on the density of food items in Pine Valley serve to estimate the rates at which hunter-gatherers should encounter resources within habitats. Given an estimate of the density of resource items per square kilometer, the following equation calculates an encounter rate in kilograms per hour (Winterhalder et al. 1989:325):

$$R_i = d_i * wt_i * S_v * S_r \qquad \text{(equation 9)}$$

where,

R_i = weight of resource i encountered per unit of time (kg/hr),

d_i = number of resource i per km^2,

wt_i = edible weight (kg) per resource i,

S_v = forager search speed (km/hr), and

S_r = forager search radius (km).

By estimating the density of food items per square kilometer in the habitat landscape, it is possible to calculate an encounter rate for randomly searching for those food items within that habitat. Estimation of resource density differs for plant foods and game, so the two categories are considered separately. For both categories, forager search speed (S_v) is assumed to be 1.5 km/hr. Search radius (S_r) is 10 m for all plant resources, and 20 m for game.

Plants

The range type descriptions that define habitats offer precise estimates of the quantity of herbage in kilograms per hectare. However, it is unclear how raw herbage rate translates to what the forager actually encounters (i.e., stands or individual plants). Simms (1987:48-53) and Zeanah (1996:295-299) estimated encounter rates with plants by calculating the percentage ground coverage of those plants. Range type descriptions approximate the percentage plant cover of vegetation communities associated with each range type, and these can be extrapolated to each habitat. Furthermore, percentage cover and total herbage weight are significantly correlated among the habitats ($r=.82$, $p=.0001$), allowing the percentage cover of each plant resource within each habitat type to be gauged from the percentage weight of that species.

Following Simms (1987:49), all plants are assumed to occur in stands of 10 m^2. Therefore, every square kilometer within a habitat contains 10,000 plots that may contain a stand of any particular plant resource indigenous to that habitat. The percentage cover estimated for each plant resource calculates how many stands of that resource occur per square kilometer of any habitat. For example, if a particular plant resource comprises 2% of total herbage weight within a habitat with 40% plant cover, then it is presupposed that 80, 10 m^2 stands of that resource occur randomly dispersed within each square kilometer of that habitat. This value determines the number of items (10 m^2 stands) of each plant resource per square kilometer (d_i), in each habitat.

Modeling edible weight in kilograms obtainable in each stand (wt_i) is also problematic because total herbage weight is not equivalent to the quantity of edible seed, root, fruit, or green harvested by a forager. An extensive literature review revealed no consistent way to estimate the quantity of edible tissue that a given quantity of herbage biomass might produce. Too, the MVT consideration of diminishing returns shows that it is unrealistic to assume that a forager would exhaust all edible resource in a particular stand (i.e., a small patch) before finding it more productive to move on to the next stand. A simplifying assumption is to hold constant the time that a forager can harvest any stand, and use experimentally derived harvest rates to calculate the amount of resource procured in that span. In his collection experiments, Simms (1987:50) set the time for collection of a stand at half an hour, the time he found reasonable for harvesting a 10m^2 stand of most plant resources. This time limit also serves here.

Game

Unlike flora, the habitat database offers no direct measure of faunal abundance within each habitat type. However, in Chapter 5 the biotic and physical characteristics of the habitat type landscape served to rank the probability that habitats contain particular game animals. Using these data, the rates at which hunter-gatherers should encounter different game can be inferred for specific habitats. To do this, the habitat suitability scores presented in Table 5.10 are standardized so that the habitat with highest suitability is ranked 1 and all other habitats ranked proportionally thereof.

Translating these probabilities into encounter rates in kilograms per hour (R_i) depends on whether the procurement strategy involves stalking, driving, or trapping. For trapping strategies, we follow the simulation of Zeanah (1996:300-303), which assumes that the searching forager comes across procurement locations (i.e., nests, burrows, and leks) rather than individual animals. Under this assumption, estimates of the density of small animal populations in similar geographic areas approximate the number of items encountered per square kilometer (*di*) in each habitat. The maximum expected densities of waterfowl nests, sage grouse leks, and the burrows of small mammals, large ground squirrels, marmots/woodrats, and rabbits/hares have been estimated elsewhere (Zeanah 1996:300-303). These densities are assumed to occur in the best habitats for each game category in Pine Valley (relative habitat suitability score = 1), with densities diminishing proportionally to relative habitat suitability score for all other habitats. For example, jackrabbit burrows can occur in densities of 1.5 per km^2 of prime rabbit habitat (Masser et al. 1984:84). If the relative suitability score for rabbits for a particular Pine Valley habitat is .02, then the expected density of rabbit burrows in that habitat is .03 burrows per square kilometer.

The edible weight in kilograms (wt_i) obtainable at each trapping point is the amount that a hypothetical trapper who sets a line of 20 snares or deadfall traps at each trapping spot can harvest. After 24 hours, four traps (20%) successfully capture an animal. These estimates are consistent with the size of ethnographic trap lines (Fowler 1989:23; Kelly 1932:88), and the successful trapping rate of modern wildlife biologists in the Great Basin (Brown 1973:777; Clary and Medin 1992:106; Feldhammer 1979:210; Jenkins 1979:24; McAdoo et al. 1983:52; Oldemeyer and Allen-Johnson 1989:393). These simple assumptions allow calculation of an encounter rate (R_i) for each habitat in the Pine Valley study area using equation 5.

The procedure for estimating encounter rates (R_i) for game procured by stalking or driving techniques differs from those for plants and trapped animals for two reasons. First the units encountered per kilometer are individual animals rather than plant stands or burrows, requiring estimates of the number of individuals per square kilometer that are difficult to derive. Second, it is unrealistic to assume that pedestrian hunters armed with bow and arrow could successfully detect, pursue, and dispatch every elusive quarry they come across, simply because many mobile animals will escape. Therefore, an encounter rate estimate based simply on animal densities will overestimate the successful encounter rates feasible for stalking or driving game. For these reasons, we follow Simms' (1987:55-72) encounter rate estimates for stalking and driving game animals. Simms' estimates derive from historical, ethnographic, and wildlife conservation literature regarding documented success rates of hunts and drives in the Great Basin. They are applied to the Pine Valley habitat landscape simply by assuming that these rates are feasible in the most sensitive habitat for each game category (relative habitat suitability score = 1). For all other habitats, encounter rates diminish proportionally to relative habitat suitability score. For example, Simms estimates that bighorn can be successfully encountered at a rate of 0.15 kg/hr in good sheep habitat. If the relative suitability score for sheep for a Pine Valley habitat is .5, then the encounter rate for hunting sheep in that habitat is .075 kg/hr.

Modeling Seasonal Foraging Opportunities for Men and Women Based on the Pine Valley Habitat Landscape

Using equations 5 and 6, and estimates of caloric return and encounter rates for each resource, an optimal overall foraging return rate (*E/T*) was calculated for each habitat, by season and gender. Table 6.5 presents the resulting overall returns rates for men and women.

ARCHAEOLOGICAL PREDICTIONS

How prudent hunter-gatherers should have organized their foraging activities in Pine Valley is inferred by estimating the distribution of resources in each habitat, subdividing these resources by season and sex, and modeling their available caloric returns. These expectations now serve to predict how the distribution and composition of the archaeological record will vary according to habitat. Specifically, the relative composition, function, size, and diversity of archaeological assemblages likely to occur in each habitat are forecast based on the productivity of foraging and on the likelihood that hunter-gatherers lived there. From these inferences, habitat types are scaled into predicted archaeological complexity scores.

Assumptions about Archaeological Site Formation Processes

If the archaeological record directly reflected foraging activity, then predicting the archaeology of habitats would be simple; archaeological remains should be most dense, diverse, and complex in habitats yielding highest overall foraging returns. However, hunter-gatherer foraging behavior does not translate directly into the archaeological record; deviations between the two reflect effects on site formation processes of central place foraging, mobility strategy, sexual division of labor, food sharing, food storage, tool manufacture, tool curation, and refuse disposal (Binford 1979, 1980). Consequently, four current understandings of how hunter-gatherer subsistence-settlement systems affect archaeological site formation processes temper expectations about the archaeological record of habitats.

First, residential bases that serve as the hub of hunter-gatherer settlement bias the archaeological record, inasmuch as base camps are the central places where foragers prepare, share, store, and consume food; manufacture, repair, and discard tools; and construct, maintain, and cache facilities for human habitation (Thomas 1983a). Therefore, base camps contribute disproportionately to archaeological formation processes.

Although other site types exist and habitats that are residentially unoccupied may contain complex archaeological sites, the archaeological remains of foraging activity represent, for the most part, field processing and hunting loss. Only in situations where resources are abundant or recurrent in the same location over long periods of time should non-habitation sites produce archaeological manifestations comparable to those of base camps.

Second, constellations of environmental characteristics other than simple foraging productivity strongly influence residential base locations. For example, proximity to

Table 6.5 Men's and women's overall foraging returns (kcal/hr) by habitat and season.

Habitat	Area (km^2)	Women's Winter Return	Women's Spring Return	Women's Summer Return	Women's Autumn Return	Men's Winter Return	Men's Spring Return	Men's Summer Return	Men's Autumn Return
MN-ARAR8/PSSPS-43	9	135	434	439	944	594	594	594	1280
MN-ARVA2/ACTH7-76	1	120	352	436	837	545	545	545	1099
MN-ARVA2/FEID-27	4	141	569	443	791	497	704	425	1173
MN-ARVA2/PSSPS-77	3	137	467	444	1090	502	502	502	1435
MN-ARVA2/PSSPS-78	1	140	441	443	1113	606	995	538	1484
MN-ARVA2/PSSPS-79	7	139	442	442	1004	736	736	736	1405
MN-ARVA2/PSSPS-80	10	146	323	444	956	656	656	590	1317
MN-ARVA2/PSSPS-82	79	140	158	442	1150	216	216	216	1162
MN-ARVA2/PSSPS-83	14	138	237	436	536	289	289	289	715
MN-SYMPH/AGTR-56	5	141	393	438	555	437	543	361	898
PJ-ARAR8/ACTH7-60	4	709	206	441	1011	243	576	243	982
PJ-ARAR8/ACTH7-81	1	610	220	440	1127	123	123	123	1130
PJ-ARAR8/AHCT-16	25	797	121	436	1155	126	299	126	1155
PJ-ARAR8/PSSPS-17	6	668	112	430	1144	259	259	259	1153
PJ-ARAR8/PSSPS-75	18	142	139	441	953	324	325	246	1053
PJ-ARTRT/PSSPS-55	103	142	29	443	448	192	411	192	525
PJ-ARVA2/ACLE9-71	12	145	113	441	831	390	391	312	1016
PJ-ARVA2/ACTH7-13	96	143	345	443	1150	202	203	203	1161
PJ-ARVA2/ACTH7-59	7	141	352	444	1049	357	780	358	1134
PJ-ARVA2/ACTH7-9	126	144	367	440	1164	307	307	307	1174
PJ-ARVA2/PSSPS-10	4	145	425	444	1176	252	252	252	1184
PJ-ARVA2/PSSPS-11	6	145	313	441	1168	231	231	231	1176
PJ-ARVA2/PSSPS-12	2	145	427	443	1166	335	335	254	1180
PJ-ARVA2/PSSPS-14	54	144	374	443	1165	321	321	242	1176
PJ-ARVA2/PSSPS-21	24	142	281	446	1146	238	238	238	1163
PJ-ARVA2/PSSPS-73	63	132	140	434	567	241	241	159	692
PJ-ARVA2/PSSPS-74	1	141	204	442	966	324	325	243	1060
SG-ARAR8/ACTH7-8	14	683	132	442	831	146	285	146	482
SG-ARAR8/AHCT-63	3	885	108	430	976	170	401	171	504
SG-ARAR8/AHCT-64	15	927	108	427	1005	150	347	151	485
SG-ARAR8/AHCT-65	4	1084	110	426	1117	187	414	187	519
SG-ARAR8/AHCT-66	14	984	112	431	1043	128	128	128	466
SG-ARAR8/AHCT-67	4	698	39	400	784	156	156	156	456
SG-ARAR8/AHCT-68	8	806	0	365	833	119	120	120	206
SG-ARAR8/FEID-38	38	142	449	440	509	342	342	262	817
SG-ARAR8/FEID-42	16	142	413	439	447	317	317	236	638
SG-ARAR8/PSSPS-26	6	141	372	444	509	255	255	255	750
SG-ARAR8/PSSPS-31	19	143	306	444	509	311	311	230	787
SG-ARAR8/PSSPS-39	18	142	427	443	751	288	288	288	1016
SG-ARAR8/PSSPS-40	48	141	438	443	751	285	286	286	1013
SG-ARAR8/PSSPS-41	3	142	381	443	509	319	319	238	795
SG-ARAR8/PSSPS-47	4	142	401	442	509	345	345	264	819
SG-ARAR8/PSSPS-48	7	142	218	443	448	275	276	195	598
SG-ARCA13/DECE-20	2	148	148	667	830	489	490	258	1205
SG-ARTRT/ACTH7-1	8	1113	29	438	1138	172	396	173	505
SG-ARTRT/ACTH7-5	13	1110	30	440	1136	168	507	169	501
SG-ARTRT/ACTH7-6	50	146	28	444	770	256	568	257	979
SG-ARTRT/AHCT-61	34	401	0	431	636	191	192	192	689
SG-ARTRT/AHCT-62	10	579	24	426	693	140	420	141	475
SG-ARTRT/LECI4-19	2	142	169	449	1892	765	1198	649	2290
SG-ARTRT/LECI4-57	6	141	133	448	1045	459	675	356	1326
SG-ARTRT/LECI4-7	6	974	60	447	1073	375	480	218	824
SG-ARTRT/PSSPS-30	4	248	357	445	664	228	529	229	720
SG-ARTRT/PSSPS-32	8	278	278	443	607	191	436	191	685
SG-ARTRT/PSSPS-34	29	140	221	444	509	239	240	240	735
SG-ARTRT/PSSPS-36	5	140	127	446	751	268	269	269	998
SG-ARTRT/PSSPS-45	2	143	265	445	509	315	316	234	791
SG-ARTRT/PSSPS-46	6	142	198	445	509	320	321	239	796
SG-ARTRT/PSSPS-49	17	447	58	443	651	152	456	153	487
SG-ARTRT/PSSPS-50	369	391	84	442	632	172	388	172	505
SG-ARTRT/PSSPS-51	212	143	28	444	449	168	487	169	502

Table 6.5 (continued)

Habitat	Area (km^2)	Women's Winter Return	Women's Spring Return	Women's Summer Return	Women's Autumn Return	Men's Winter Return	Men's Spring Return	Men's Summer Return	Men's Autumn Return
SG-ARTRT/PSSPS-52	18	142	236	443	448	167	167	167	504
SG-ARVA2/ACLE9-72	20	145	92	440	448	424	425	348	738
SG-ARVA2/FEID-37	2	143	526	443	751	443	444	366	1136
SG-ARVA2/LECI4-70	7	146	107	449	1576	612	614	469	1997
SG-ARVA2/PSSPS-22	15	140	460	445	509	269	269	269	763
SG-ARVA2/PSSPS-23	60	142	478	445	751	433	433	358	1128
SG-ARVA2/PSSPS-24	59	142	380	443	448	297	297	221	620
SG-ARVA2/PSSPS-25	20	141	403	444	751	296	297	297	1024
SG-ARVA2/PSSPS-28	7	143	430	446	751	396	397	318	1093
SG-ARVA2/PSSPS-29	1	143	486	445	751	468	468	393	1160
SG-ARVA2/PSSPS-35	1	142	349	446	751	404	404	326	1100
SG-ARVA2/PSSPS-44	16	142	347	446	751	341	341	261	1042
SG-PUTR2/PSSPS-33	23	144	442	446	751	277	278	278	1006
ST-ATCO/AHCT-1	49	1152	28	414	1166	156	372	157	490
ST-ATCO/AHCT-2	4	1158	31	377	1164	151	390	152	320
ST-ATCO/AHCT-69	5	1157	30	374	1161	96	330	97	181
ST-ATCO/SIHY-4	1	1164	122	327	1170	234	346	150	396
ST-SAVE4/LECI4-3	78	1085	109	432	1102	266	375	99	423
ST-SAVE4/LECI4-58	15	945	89	445	1163	455	558	306	1311
WT-ARCA13/DECE-88	1	143	149	407	1946	1083	1196	863	2508
WT-SALIX/CAREX-87	16	2759	149	5462	2561	1063	1356	771	3065
WT-SALIX/DECE-86	15	3182	149	5600	899	674	758	371	1324
WT-SALIX/LECI4-18	13	147	148	448	1921	742	743	482	2323
WT-SALIX/LECI4-85	6	3265	187	5623	1639	1011	1203	604	2089
Mean Return kcal/hr/km2		359	195	528	807	259	379	227	821
Standard Deviation kcal/hr/km2		458	159	664	329	137	159	98	389

potable water is a prerequisite of hunter-gatherer base camps (Steward 1970:120-121; Taylor 1964), so that habitat types adjacent water sources will be more appropriate for habitation than habitat types with similar foraging potential but lacking water sources. Well drained but level terrain is also a requirement for human residence (Peterson 1973), so that those with inundated or steep terrain will be less likely to contain residential bases than equally productive but level and dry habitat types.

Third, removed from residential base camps, men's hunting activities are more archaeologically visible than those of women's gathering (Thomas 1983b:439) because men emphasize a reductive lithic technology, field maintenance of which leaves abundant, archaeologically visible residues (i.e., debitage and discarded tools) on the landscape. In contrast, women generally employ technologies (i.e., ceramics, ground stone, baskets, digging sticks) that do not as often leave archaeologically preserved detritus on the foraging landscape. Too, since men must hunt game and transport kills over large distances from base camps, they frequently construct hunting facilities, field process resources, and prepare overnight field camps. Women, as a rule, forage within a few hours walk of base camp and are less likely to field process food or construct field camps and facilities. Consequently, men's subsistence activities are more likely to leave enduring archaeological signatures on the landscape (i.e., faunal remains, debitage, processing tools, hearths, hunting blinds) than are those of women (i.e., isolated ground stone or ceramic fragments). However, residential base camp assemblages should strongly represent women's subsistence activities and residential locations should reflect primarily women's foraging concerns.

Finally, the ubiquity of lithic material in the archaeological record generally will bias the record toward sites where the procurement of toolstone and initial manufacture of lithic tools occurred (Elston 1988). Since toolstone sources most frequently occur in upland terrain, sites in upland habitats frequently host lithic debris from toolstone processing. Sites nearest toolstone sources possess assemblages rich in lithic material reflecting early stage tool manufacture (hammerstones, cores, early stage bifaces, and associated debitage). Materials representing middle stage manufacture (middle stage bifaces, heat-treated bifaces, and associated debitage) are abundant in field camps convenient to toolstone sources. Finished and discarded tools, as well as evidence of late stage manufacture are most prevalent in areas remote from toolstone sources.

Working from these four basic assumptions, the preceding ranking of habitat foraging potential can be used to scale expectations about the archaeological record of habitats. Presumably, habitats providing highest foraging returns for women are most likely to contain frequently reused, archaeologically visible residential base camp locations, a potential that is enhanced by proximity to water or toolstone but diminished by excessive aridity. High foraging returns for men further improve the potential for base camps. Habitats rich in men's resources, but not women's, should be relatively rich in archaeological remains; residential base camps are unlikely, but logistic field camps and hunting locations will be common. Habitats bearing women's foraging resources, but not men's, should have low archaeological visibility, but their archaeological record should bear a unique signature of women's foraging activities. Proximity to toolstone sources will complicate this order of habitat archaeological visibility; those habitats near toolstone will exhibit more extensive archaeological records than habitats of similar foraging or habitation utility but lacking toolstone.

ASSESSING THE ARCHAEOLOGICAL SENSITIVITY OF HABITATS

The foraging return rates obtainable in each of 87 habitats were calculated for each season for each gender. This yields a complicated matrix of rankings that must be simplified to generate straightforward predictions about the archaeological record.

The first step toward simplification refers to principles of the PCM and MVT. Prehistoric hunter-gatherers are assumed to have preferred to forage in the habitats yielding the highest foraging returns in each season, while avoiding lower return habitats. This expectation can be systematically quantified by calculating an adjusted average and standard deviation foraging return in kilocalories per hour per square kilometer for the entire Pine Valley habitat landscape (Table 6.5). Based on the MVT, a forager travelling through Pine Valley can be expected to bypass habitats yielding returns lower than the average rate while preferring to forage in habitats offering higher than average returns. Foragers should linger longest in the highest return habitats. These simplistic expectations can be quantified into the seven-point, gender score presented below, and summarized in Table 6.6.

1 – Habitats offering returns more than two standard deviations below the mean return for foraging in all Pine Valley habitats during one season, by one gender.
2 – Habitats offering returns more than one standard deviation below the Pine Valley seasonal mean.
3 - Habitats offering returns less than one standard deviation below the Pine Valley seasonal mean.
4 - Habitats offering returns less than one standard deviation above the Pine Valley seasonal mean.
5 - Habitats offering returns more than one standard deviation above the Pine Valley seasonal mean.
6 - Habitats offering returns more than two standard deviations above the Pine Valley seasonal mean.
7 - Habitats offering returns more than three standard deviations above the Pine Valley seasonal mean.

The second step toward simplification compares men's and women's scores in each season to derive a combined seasonal score (Table 6.6). The seven combined seasonal score categories are characterized thus:

1- Poor (gender score 1, 2, or 3) for both men and women.
2- Good for women (gender score 4, 5, 6, or 7), and bad for men (gender score 1, 2, or 3).
3- Good for men (gender score 4, 5, 6, or 7), bad for women (gender score 1, 2, or 3)
4- Good (gender score 4 or 5) for both men and women.

5- Best for men (gender score 6 or 7), and good for women (gender score 4 or 5).
6- Best for women (gender score 6 or 7), good for men (gender score 4 or 5).
7- Best (gender score 6 or 7) for both men and women

Note that these scores are consistent with expectations about the effects of sexual division of labor and central place foraging on archaeological site formation processes. Habitats scoring 4 through 7 have foraging value simultaneously for both men and women, but women's foraging utility takes precedence. Men's and women's subsistence sites should occur in all four categories, but generally diminish from score 7 to score 4, although score 5 habitats may have more men's sites than score 6 habitats. What is more important, score 7 should be most likely and score 4 least likely to contain residential base camps, which are possible in all four categories. In contrast, combined score 3 habitats should lack residential bases and women's subsistence sites, but contain men's subsistence sites. Score 2 habitats may contain women's subsistence sites, but lack residential bases and men's subsistence sites. Score 3 habitats rank higher than score 2 because of the expected higher archaeological visibility of men's activities than women's activities. Finally, score 1 habitats have little or no foraging utility for men or women and, therefore, should have the most scant archaeological records.

The next step toward simplification distills combined gender scores for each habitat in each season into combined foraging score for each habitat (Table 6.7). Criteria for assigning scores are these:

1 - Habitats with seasonal scores of 1 in all four seasons.
2 - Habitats with seasonal scores of 2 in at least one season, and 1 in all remaining seasons.
3- Habitats with seasonal scores of 3 in at least one season, and 1 in all remaining seasons.
4- Habitats with seasonal scores of 4 in at least one season, or 2 and 3 in at least two seasons, and 1 in all remaining seasons.
5- Habitats with seasonal scores of 5 in at least one season, and 1, 2, 3, or 4 in all remaining seasons.
6- Habitats with seasonal scores of 5 in at least one season, and 1, 2, 3, 4 or 5 in all remaining seasons.
7- Habitats with seasonal scores of 7 in at least one season.

The final step cross-stratifies the combined foraging scores according to water and toolstone source (Table 6.7). A value of 1 is added to the combined foraging score of all portions of habitats lying within 1 km of a perennial water source. This adjustment tracks the importance of potable water in determining central place locations and hunter-gatherer foraging activity. All areas of habitat lying on a landform geologically likely to contain usable toolstone have one point added to their combined foraging score to adjust for effects of a nearby toolstone source on the archaeological record. Conversely, all areas of habitat lying on geologic landforms that are unlikely to yield toolstone have 1 point subtracted from their combined foraging score

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Table 6.6. Gender and combined seasonal foraging scores for Pine Valley habitats.

Habitat	Women's Winter	Men's Winter	Combined Winter	Women's Spring	Men's Spring	Combined Spring	Women's Summer	Men's Summer	Combined Summer	Women's Autumn	Men's Autumn	Combined Autumn
MN-ARAR8/PSSPS-43	3	5	3	5	5	4	3	6	3	3	4	3
MN-ARVA2/ACTH7-76	3	5	3	4	5	4	3	6	3	3	3	1
MN-ARVA2/FEID-27	3	4	3	6	6	7	3	5	3	2	3	1
MN-ARVA2/PSSPS-77	3	4	3	5	4	4	3	5	3	3	4	3
MN-ARVA2/PSSPS-78	3	5	3	5	7	5	3	6	3	3	4	3
MN-ARVA2/PSSPS-79	3	6	3	5	6	5	3	7	3	3	4	3
MN-ARVA2/PSSPS-80	3	5	3	4	5	4	3	6	3	3	4	3
MN-ARVA2/PSSPS-82	3	2	1	3	2	1	3	2	1	4	3	2
MN-ARVA2/PSSPS-83	3	3	1	4	3	2	3	3	1	2	2	1
MN-SYMPH/AGTR-56	3	4	3	5	5	4	3	4	3	2	3	1
PJ-ARAR8/ACTH7-60	4	2	2	4	5	4	3	3	1	3	3	1
PJ-ARAR8/ACTH7-81	4	2	2	4	2	2	3	1	1	3	3	1
PJ-ARAR8/AHCT-16	4	2	2	3	3	1	3	1	1	4	3	2
PJ-ARAR8/PSSPS-17	4	3	2	3	3	1	3	3	1	4	3	2
PJ-ARAR8/PSSPS-75	3	3	1	3	3	1	3	3	1	3	3	1
PJ-ARTRT/PSSPS-55	3	2	1	2	4	3	3	2	1	1	2	1
PJ-ARVA2/ACLE9-71	3	3	1	3	4	3	3	3	1	3	3	1
PJ-ARVA2/ACTH7-13	3	2	1	5	4	4	3	2	1	4	3	2
PJ-ARVA2/ACTH7-59	3	3	1	4	6	5	3	3	1	3	3	1
PJ-ARVA2/ACTH7-9	3	3	1	5	3	2	3	3	1	4	3	2
PJ-ARVA2/PSSPS-10	3	2	1	5	3	2	3	3	1	4	3	2
PJ-ARVA2/PSSPS-11	3	2	1	4	3	2	3	3	1	4	3	2
PJ-ARVA2/PSSPS-12	3	3	1	5	3	2	3	3	1	4	3	2
PJ-ARVA2/PSSPS-14	3	3	1	5	3	2	3	3	1	4	3	2
PJ-ARVA2/PSSPS-21	3	2	1	4	3	2	3	3	1	4	3	2
PJ-ARVA2/PSSPS-73	3	4	3	4	4	4	3	4	3	3	3	1
PJ-ARVA2/PSSPS-74	3	3	1	4	3	2	3	3	1	3	3	1
SG-ARAR8/ACTH7-8	4	2	2	3	3	1	3	2	1	3	2	1
SG-ARAR8/AHCT-63	5	2	2	3	4	3	3	2	1	3	2	1
SG-ARAR8/AHCT-64	5	2	2	3	3	1	3	2	1	3	2	1
SG-ARAR8/AHCT-65	5	2	2	3	4	3	3	2	1	3	2	1
SG-ARAR8/AHCT-66	5	2	2	3	2	1	3	1	1	3	2	1
SG-ARAR8/AHCT-67	4	2	2	3	2	1	3	2	1	2	2	1
SG-ARAR8/AHCT-68	4	1	2	2	2	1	3	1	1	2	1	1
SG-ARAR8/FEID-38	3	3	1	5	3	2	3	3	1	2	2	1
SG-ARAR8/FEID-42	3	3	1	5	3	2	3	3	1	1	2	1
SG-ARAR8/PSSPS-26	3	2	1	5	3	2	3	3	1	2	2	1
SG-ARAR8/PSSPS-31	3	3	1	4	3	2	3	3	1	2	2	1
SG-ARAR8/PSSPS-39	3	3	1	5	3	2	3	3	1	2	3	1
SG-ARAR8/PSSPS-40	3	3	1	5	3	2	3	3	1	2	3	1
SG-ARAR8/PSSPS-41	3	3	1	5	3	2	3	3	1	2	2	1

Table 6.6. (continued)

Habitat	Women's Winter	Men's Winter	Combined Winter	Women's Spring	Men's Spring	Combined Spring	Women's Summer	Men's Summer	Combined Summer	Women's Autumn	Men's Autumn	Combined Autumn
SG-ARAR8/PSSPS-47	**3**	**3**	**1**	**5**	**3**	**2**	**3**	**3**	**1**	**2**	**2**	**1**
SG-ARAR8/PSSPS-48	**3**	**3**	**1**	**4**	**3**	**2**	**3**	**2**	**1**	**1**	**2**	**1**
SG-ARCA13/DECE-20	**3**	**4**	**3**	**3**	**4**	**3**	**4**	**3**	**2**	**3**	**3**	**1**
SG-ARTRT/ACTH7-1	**5**	**2**	**2**	**2**	**4**	**3**	**3**	**2**	**1**	**4**	**2**	**2**
SG-ARTRT/ACTH7-5	**5**	**2**	**2**	**2**	**4**	**3**	**3**	**2**	**1**	**4**	**2**	**2**
SG-ARTRT/LECI4-57	**3**	**4**	**3**	**3**	**5**	**3**	**3**	**4**	**3**	**3**	**4**	**3**
SG-ARTRT/LECI4-7	**5**	**3**	**2**	**3**	**4**	**3**	**3**	**2**	**1**	**3**	**3**	**1**
SG-ARTRT/PSSPS-30	**3**	**2**	**1**	**5**	**4**	**4**	**3**	**3**	**1**	**2**	**2**	**1**
SG-ARTRT/PSSPS-32	**3**	**2**	**1**	**4**	**4**	**4**	**3**	**2**	**1**	**2**	**2**	**1**
SG-ARTRT/PSSPS-34	**3**	**2**	**1**	**4**	**3**	**2**	**3**	**3**	**1**	**2**	**2**	**1**
SG-ARTRT/PSSPS-36	**3**	**3**	**1**	**3**	**3**	**1**	**3**	**3**	**1**	**2**	**3**	**1**
SG-ARTRT/PSSPS-45	**3**	**3**	**1**	**4**	**3**	**2**	**3**	**3**	**1**	**2**	**2**	**1**
SG-ARTRT/PSSPS-46	**3**	**3**	**1**	**4**	**3**	**2**	**3**	**3**	**1**	**2**	**2**	**1**
SG-ARTRT/PSSPS-49	**4**	**2**	**2**	**3**	**4**	**3**	**3**	**2**	**1**	**2**	**2**	**1**
SG-ARTRT/PSSPS-50	**4**	**2**	**2**	**3**	**4**	**3**	**3**	**2**	**1**	**2**	**2**	**1**
SG-ARTRT/PSSPS-51	**3**	**2**	**1**	**2**	**5**	**3**	**3**	**3**	**1**	**2**	**2**	**1**
SG-ARTRT/PSSPS-52	**3**	**2**	**1**	**4**	**2**	**2**	**3**	**2**	**1**	**1**	**2**	**1**
SG-ARVA2/ACLE9-72	**3**	**5**	**3**	**3**	**5**	**3**	**3**	**5**	**3**	**2**	**4**	**3**
SG-ARVA2/FEID-37	**3**	**4**	**3**	**6**	**4**	**6**	**3**	**4**	**3**	**2**	**3**	**1**
SG-ARVA2/FEID-53	**3**	**3**	**1**	**5**	**3**	**2**	**3**	**3**	**1**	**1**	**2**	**1**
SG-ARVA2/FEID-54	**3**	**3**	**1**	**6**	**3**	**2**	**3**	**3**	**1**	**2**	**3**	**1**
SG-ARVA2/LECI4-70	**3**	**5**	**3**	**3**	**5**	**3**	**3**	**5**	**3**	**5**	**6**	**5**
SG-ARVA2/PSSPS-22	**3**	**3**	**1**	**5**	**3**	**2**	**3**	**3**	**1**	**2**	**2**	**1**
SG-ARVA2/PSSPS-23	**3**	**4**	**3**	**5**	**4**	**4**	**3**	**4**	**3**	**2**	**3**	**1**
SG-ARVA2/PSSPS-24	**3**	**4**	**3**	**5**	**4**	**4**	**3**	**4**	**3**	**2**	**3**	**1**
SG-ARVA2/PSSPS-25	**3**	**3**	**1**	**5**	**3**	**2**	**3**	**3**	**1**	**2**	**3**	**1**
SG-ARVA2/PSSPS-28	**3**	**4**	**3**	**5**	**4**	**4**	**3**	**3**	**1**	**2**	**3**	**1**
SG-ARVA2/PSSPS-29	**3**	**4**	**3**	**5**	**4**	**4**	**3**	**4**	**3**	**2**	**3**	**1**
SG-ARVA2/PSSPS-35	**3**	**4**	**3**	**4**	**4**	**4**	**3**	**4**	**3**	**2**	**3**	**1**
SG-ARVA2/PSSPS-44	**3**	**3**	**1**	**4**	**3**	**2**	**3**	**3**	**1**	**2**	**3**	**1**
SG-PUTR2/PSSPS-33	**3**	**3**	**1**	**5**	**3**	**2**	**3**	**3**	**1**	**2**	**3**	**1**
ST-ATCO/AHCT-1	**5**	**2**	**2**	**2**	**3**	**1**	**3**	**2**	**1**	**4**	**2**	**2**
ST-ATCO/AHCT-2	**5**	**2**	**2**	**2**	**4**	**3**	**3**	**2**	**1**	**4**	**1**	**2**
ST-ATCO/AHCT-69	**5**	**1**	**2**	**2**	**3**	**1**	**3**	**1**	**1**	**4**	**1**	**2**
ST-ATCO/SIHY-4	**5**	**2**	**2**	**3**	**3**	**1**	**3**	**2**	**1**	**4**	**1**	**2**
ST-SAVE4/LECI4-3	**5**	**3**	**2**	**3**	**3**	**1**	**3**	**1**	**1**	**3**	**1**	**1**
ST-SAVE4/LECI4-58	**5**	**4**	**4**	**3**	**5**	**3**	**3**	**3**	**1**	**4**	**4**	**4**
WT-ARCA13/DECE-88	**3**	**7**	**3**	**3**	**7**	**3**	**3**	**7**	**3**	**6**	**7**	**7**
WT-SALIX/CAREX-87	**7**	**7**	**7**	**3**	**7**	**3**	**7**	**7**	**7**	**7**	**7**	**7**
WT-SALIX/DECE-86	**7**	**5**	**6**	**3**	**6**	**3**	**7**	**4**	**6**	**3**	**4**	**3**
WT-SALIX/LECI4-18	**3**	**6**	**3**	**3**	**6**	**3**	**3**	**5**	**3**	**6**	**6**	**7**
WT-SALIX/LECI4-85	**7**	**7**	**7**	**3**	**7**	**3**	**7**	**6**	**7**	**5**	**6**	**5**

Table 6.7 Combined seasonal and total foraging scores and toolstone/water cross-stratification for Pine Valley habitats.

Habitat	Combined Winter	Combined Spring	Combined Summer	Combined Autumn	Combined Foraging Score	Toolstone Sources Unlikely (-1)	Toolstone Sources Likely (+1)	Water Sources Present (+1)
MN-ARAR8/PSSPS-43	3	4	3	3	4	x	x	x
MN-ARVA2/ACTH7-76	3	4	3	1	4	x	x	x
MN-ARVA2/FEID-27	3	7	3	1	7	x	x	x
MN-ARVA2/PSSPS-77	3	4	3	3	4			x
MN-ARVA2/PSSPS-78	3	5	3	3	5	x	x	
MN-ARVA2/PSSPS-79	3	5	3	3	5	x	x	x
MN-ARVA2/PSSPS-80	3	4	3	3	4	x	x	x
MN-ARVA2/PSSPS-82	1	1	1	2	2	x	x	x
MN-ARVA2/PSSPS-83	1	2	1	1	2	x	x	x
MN-SYMPH/AGTR-56	3	4	3	1	4	x	x	x
PJ-ARAR8/ACTH7-60	2	4	1	1	4		x	x
PJ-ARAR8/ACTH7-81	2	2	1	1	2	x	x	
PJ-ARAR8/AHCT-16	2	1	1	2	2	x	x	x
PJ-ARAR8/PSSPS-17	2	1	1	2	2	x	x	x
PJ-ARAR8/PSSPS-75	1	1	1	1	1	x	x	x
PJ-ARTRT/PSSPS-55	1	3	1	1	3	x	x	x
PJ-ARVA2/ACLE9-71	1	3	1	1	3	x	x	x
PJ-ARVA2/ACTH7-13	1	4	1	2	4	x	x	x
PJ-ARVA2/ACTH7-59	1	5	3	1	5	x		x
PJ-ARVA2/ACTH7-9	1	2	1	2	2	x	x	x
PJ-ARVA2/PSSPS-10	1	2	1	2	2		x	x
PJ-ARVA2/PSSPS-11	1	2	1	2	2	x		x
PJ-ARVA2/PSSPS-12	1	2	1	2	2			x
PJ-ARVA2/PSSPS-14	1	2	1	2	2	x	x	x
PJ-ARVA2/PSSPS-21	1	2	1	2	2	x	x	x
PJ-ARVA2/PSSPS-73	3	4	3	1	4	x	x	x
PJ-ARVA2/PSSPS-74	1	2	1	1	2	x		x
SG-ARAR8/ACTH7-8	2	1	1	1	2		x	
SG-ARAR8/AHCT-63	2	3	1	1	4	x		
SG-ARAR8/AHCT-64	2	1	1	1	2	x	x	x
SG-ARAR8/AHCT-65	2	3	1	1	4	x		x
SG-ARAR8/AHCT-66	2	1	1	1	2	x	x	x
SG-ARAR8/AHCT-67	2	1	1	1	2	x		x
SG-ARAR8/AHCT-68	2	1	1	1	2	x		
SG-ARAR8/FEID-38	1	2	1	1	2	x	x	x
SG-ARAR8/FEID-42	1	2	1	1	2	x	x	x
SG-ARAR8/PSSPS-26	1	2	1	1	2	x	x	x
SG-ARAR8/PSSPS-31	1	2	1	1	2	x		x
SG-ARAR8/PSSPS-39	1	2	1	1	2	x		x

Table 6.7 (continued)

Habitat	Combined Winter	Combined Spring	Combined Summer	Combined Autumn	Combined Foraging Score	Toolstone Sources Unlikely (-1)	Toolstone Sources Likely (+1)	Water Sources Present (+1)
SG-ARAR8/PSSPS-41	1	2	1	1	2	x		x
SG-ARAR8/PSSPS-47	1	2	1	1	2	x	x	x
SG-ARAR8/PSSPS-48	1	2	1	1	2		x	x
SG-ARCA13/DECE-20	3	3	2	1	4	x		x
SG-ARTRT/ACTH7-1	2	3	1	2	4	x		x
SG-ARTRT/ACTH7-5	2	3	1	2	4	x		x
SG-ARTRT/ACTH7-6	1	3	1	1	3	x	x	x
SG-ARTRT/AHCT-61	2	3	1	1	4	x	x	x
SG-ARTRT/AHCT-62	2	3	1	1	4	x		
SG-ARTRT/LECI4-19	3	3	3	7	7	x	x	x
SG-ARTRT/LECI4-57	3	3	3	3	3	x		x
SG-ARTRT/LECI4-7	2	3	1	1	4	x		x
SG-ARTRT/PSSPS-30	1	4	1	1	4	x		x
SG-ARTRT/PSSPS-32	1	4	1	1	4	x		x
SG-ARTRT/PSSPS-34	1	2	1	1	2	x	x	x
SG-ARTRT/PSSPS-36	1	1	1	1	1	x	x	x
SG-ARTRT/PSSPS-45	1	2	1	1	2	x	x	x
SG-ARTRT/PSSPS-46	1	2	1	1	2	x	x	x
SG-ARTRT/PSSPS-49	2	3	1	1	4	x		x
SG-ARTRT/PSSPS-50	2	3	1	1	4	x	x	x
SG-ARTRT/PSSPS-51	1	3	1	1	3	x	x	x
SG-ARTRT/PSSPS-52	1	2	1	1	2		x	x
SG-ARVA2/ACLE9-72	3	3	3	3	3	x	x	x
SG-ARVA2/FEID-37	3	6	3	1	6	x	x	x
SG-ARVA2/FEID-53	1	2	1	1	2		x	x
SG-ARVA2/FEID-54	1	2	1	1	2		x	
SG-ARVA2/LECI4-70	3	3	3	5	5	x	x	x
SG-ARVA2/PSSPS-22	1	2	1	1	2	x	x	x
SG-ARVA2/PSSPS-23	3	4	3	1	4	x	x	x
SG-ARVA2/PSSPS-24	3	4	3	1	4	x	x	x
SG-ARVA2/PSSPS-25	1	2	1	1	2	x	x	x
SG-ARVA2/PSSPS-28	3	4	1	1	4	x	x	x
SG-ARVA2/PSSPS-29	3	4	3	1	4	x		x
SG-ARVA2/PSSPS-35	3	4	3	1	4	x	x	x
SG-ARVA2/PSSPS-44	1	2	1	1	2		x	x
SG-PUTR2/PSSPS-33	1	2	1	1	2	x	x	x
ST-ATCO/AHCT-1	2	1	1	2	2	x		x
ST-ATCO/AHCT-2	2	3	1	2	4	x		x
ST-ATCO/AHCT-69	2	1	1	2	2	x		x
ST-ATCO/SIHY-4	2	1	1	2	2	x		
ST-SAVE4/LECI4-3	2	1	1	1	2	x	x	x

Table 6.7 continued

Habitat	Combined Winter	Combined Spring	Combined Summer	Combined Autumn	Combined Foraging Score	Toolstone Sources Unlikely (-1)	Toolstone Sources Likely (+1)	Water Sources Present (+1)
ST-SAVE4/LECI4-58	4	3	1	4	4	x		x
WT-ARCA13/DECE-88	3	3	3	7	7	x	x	x
WT-SALIX/CAREX-87	7	3	7	7	7	x	x	x
WT-SALIX/DECE-86	6	3	6	3	6	x	x	x
WT-SALIX/LECI4-18	3	3	3	7	7	x	x	x
WT-SALIX/LECI4-85	7	3	7	5	7	x		x

The resulting scale ranges from scores 0 to 9. However, it seems unlikely that habitats already predicted to have a meager archaeological record based on foraging potential, could have a measurably lower archaeological signature because of the lack of toolstone. Similarly, it seems unlikely that habitats already scored as high as 6 and 7 based on foraging potential (already closely tied to water distributions) could have significantly enhanced archaeological records based on the proximity of water and/or toolstone. For these reasons, final archaeological complexity score is simplified to a six-point scale, combining scores 0-3 and 7 –9 into single categories. This final step yields a final archaeological complexity score ranging from 1 to 6. The prehistoric archaeological record should correlate strongly with the ranking: habitat types scoring 6 should bear the most sites, with the largest and most diverse assemblages, whereas habitat types scoring 1 should yield the fewest sites, with the smallest and most homogeneous assemblages. These archaeological sensitivity scores are linked in a GIS database to each soil map unit in the Pine Valley Study area.

Moreover, predictions are made about constituent site types in each soil map unit in the database, based on the various ranking scales. The relative probabilities of men's or women's foraging sites are ranked as unlikely, likely, or very likely based on the gender scores for each habitat. The relative likelihood of residential bases and logistic camps is ranked into a similar scale of unlikely, possible, likely, or very likely based on the combined foraging score and cross-stratification of habitats by water source. Finally, the potential for lithic reduction and quarrying sites is predicted by a similar gradation of unlikely, possible, likely, or very likely based on the cross-stratification of habitats by toolstone source.

Chapter 7 -- Archaeological Assessment of the Pine Valley Predictive Model

In Chapter 6, habitat types were ranked on a four-point archaeological sensitivity scale, anticipating that rank would correlate with the prehistoric archaeological record. In this chapter, survey data are used to assess how well this ranking forecasts archaeological findings. Survey data collected by numerous archaeological inventories conducted in Pine Valley over the last two decades serve as the yardstick for testing model predictions. However, the reader is forewarned of limitations in the suitability of extant survey data for model testing purposes. Inventory data were collected on behalf of undertakings that collectively do not represent a statistically valid sample of Pine Valley habitats. Moreover, variation among inventory methods and site recording standards further biases the database. Notwithstanding, the current inventory sample is suitable for a preliminary evaluation of how well Pine Valley archaeology corresponds to expectations generated by the habitat model; adequate testing of the model must remain an ongoing process until inventories achieve representative sampling of all habitats.

A set of 524 prehistoric sites and 335 isolates are recorded in the archaeological database for the Pine Valley study area, of which 689 spatially intersect with mapped inventory areas (Figure 7.1.). For testing purposes, only those sites that overlap a mapped inventory area are considered so that the density of sites and isolates per inventory hectare can be considered for each sensitivity score.

The variable quality of data recorded in the Pine Valley site sample presents one dilemma for model testing. For example, 206 of the 689 prehistoric archaeological sites lack artifact counts and record only the presence or absence of artifact and feature types. In the remaining sample of sites and isolates, differences in recording intensity, observer bias, and data collection strategy make it unlikely that differences in artifact frequencies can be regarded as reliable. For these reasons, the presence or absence of artifact and feature categories on archaeological sites and isolates is used for analysis rather than artifact or feature counts. From a management perspective, this approach is preferable to non-site approaches (i.e., Thomas 1988), because the units of analysis are sites bearing particular artifacts rather than the distribution of artifacts themselves. Therefore, subsequent tests consider the number of sites bearing particular artifact categories by archaeological sensitivity rank. In cases where individual sites are sufficiently large to occur on more than one sensitivity rank, the higher ranked habitat is taken as the appropriate score.

EVALUATION OF CONSTITUENT MODEL PREDICTIONS

Sensitivity score predictions were derived from more specific expectations about the distribution of lithic toolstone sources, and theoretical predictions about the relative probability of men's and women' foraging activities, and habitation. Therefore model testing begins with individual assessments of how well these constituent predictions fare against the archaeological database. This task requires linkage of behavioral expectations with their most likely archaeological expressions. To do so, we turn to traditional

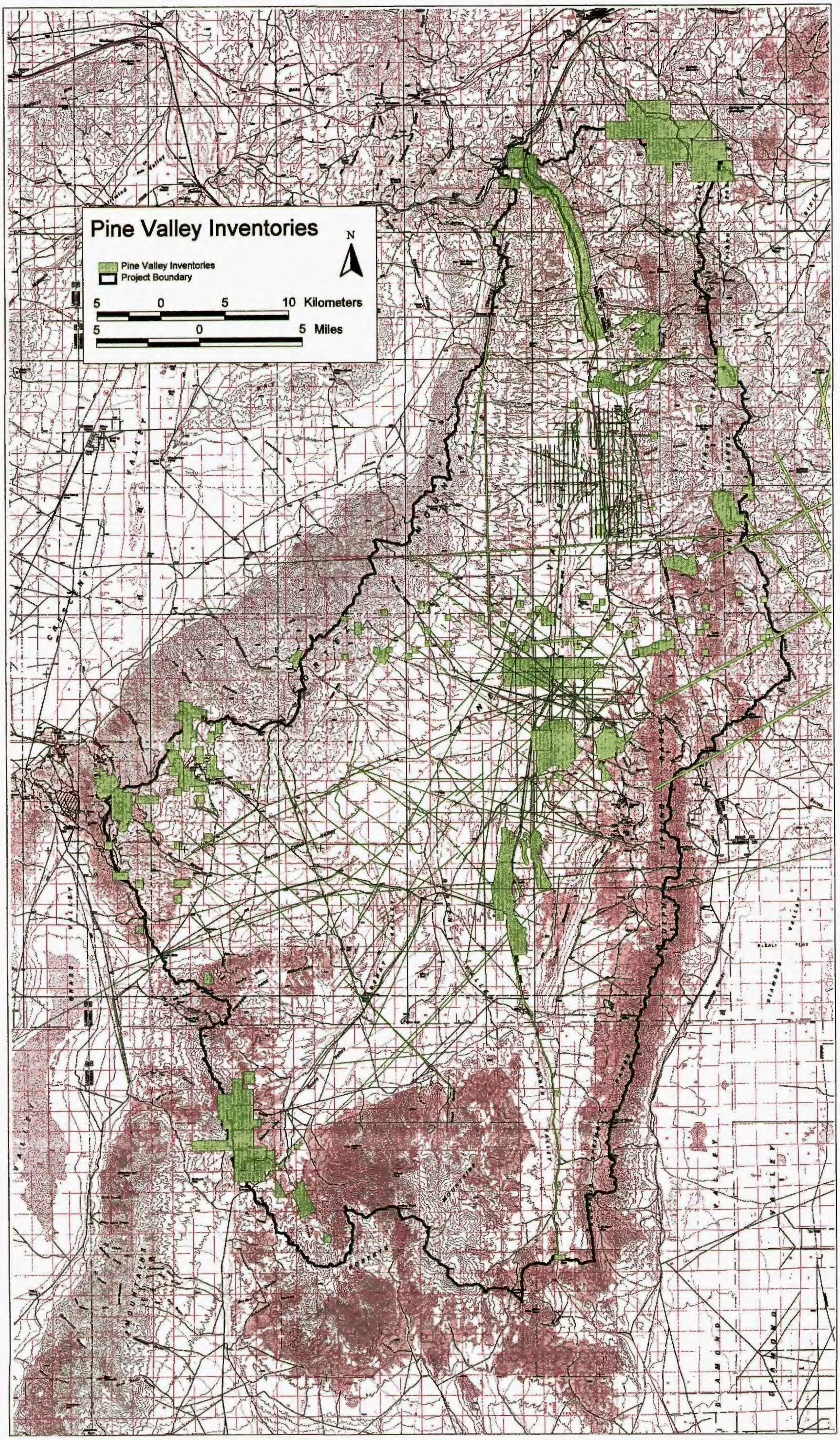

Figure 7.1. Pine Valley inventories.

conventions of archaeological assemblage variability often used in Great Basin settlement pattern studies (Bettinger 1977, Thomas 1973). Ground stone tools and ceramic sherds are assumed to reflect women's foraging activities, whereas projectile points, bifaces, and unifacial flake tools (utilized flakes, unifaces, and scrapers) are taken to be more reliable indicators of men's foraging. Fabrication tools (burins, drills, gravers, choppers, knives, shaft-straighteners), and features (bone scatters, fire affected rock, charcoal stains, and stone circles) are manifestations of residential and logistic occupation. Cores, bifaces, and lithic quarries are signs of lithic toolstone procurement and reduction. Although these linkages undoubtedly oversimplify the complexities of archaeological site formation processes, and the techno-economic aspects of traditional Shoshone society, they are derived from traditional ethnography, and shown by archaeological settlement pattern studies to reflect assemblage variability in the Great Basin (Thomas 1972; 1983a).

Lithic Toolstone and Reduction Activities

In Chapter 6, the distribution of raw material for chipped stone tools was recognized as significantly influencing the distribution of prehistoric archaeological sites irrespective of other biotic factors, simply because of the quantity of debris generated by the procurement and reduction of toolstone. For this reason, the distribution of known and likely lithic toolstone sources was used to adjust the predicted archaeological sensitivity of habitats. Lithic quarrying and reduction sites were predicted to be highly probable in areas known to contain toolstone sources, moderately probable on geological deposits likely to yield usable toolstone, possible on geological deposits with unknown likelihood of usable toolstone, and unlikely in geological deposits thought to lack toolstone deposits.

Table 7.1 lists inventory coverage in hectares, site counts, and site densities for sites bearing lithic sources, cores, and bifaces in each of these relative categories. The tables show that habitats predicted as very likely to contain toolstone have the highest densities of sites in all three categories. Densities generally diminish with predicted rank with exception of the density of sites with recorded sources in unlikely areas (0.6 sites per 1000 hectares), and sites with cores in areas with possible sources (13.4 sites per 1000 hectares). These minor discrepancies illustrate the utility of the model in pinpointing sites associated with lithic quarrying activities that cannot be predicted from the extant database.

Table 7.1. Sites per 1000 hectares by predicted probability of lithic source availability.

Rank	Inventory Area (hectares)	Sites with Lithic Sources	Density (per 1000 hectares)	Sites with Cores	Density (per 1000 hectares)	Sites with Bifaces	Density (per 1000 hectares)
Very likely	375	4	10.7	10	26.7	18	48.0
Likely	4090	11	2.7	40	9.8	70	17.1
Possible	2245	0	0.0	30	13.4	32	14.3
Unlikely	12916	8	0.6	42	3.3	105	8.1
Total	19625	23	1.2	122	6.2	225	11.5

Women's Foraging Activities

The likelihood of women's foraging activities was predicted from the simulated overall foraging return rate in each habitat compared with the mean foraging return rate per square kilometer obtainable from all Pine Valley habitats in each season. The resulting seven-point gender scale for each season was simplified to a single three-point scale for model testing based on the following criteria. Evidence of women's foraging was judged to be *very likely* if a habitat offered foraging returns higher than one standard deviation above the Pine Valley seasonal mean in at least one season; *likely* if a habitat offered foraging returns within one standard deviation of the Pine Valley seasonal mean in at least one season; and *unlikely or least likely* if a habitat yielded foraging returns lower than one standard deviation above the Pine Valley seasonal mean in at least one season.

Table 7.2 lists inventory coverage in hectares for each of these three categories, as well as the counts and densities of sites bearing ground stone tools and ceramics. The table shows that habitats predicted to be *very likely* to contain evidence of women's foraging activity have the highest densities of sites with groundstone and ceramics (40.5 and 14.1 sites per 1000 hectares respectively), whereas habitats predicted *least likely* to host women's foraging bore the lowest densities of the same two categories (4.9 and 1.1 sites per 1000 hectares respectively).

Table 7.2. Sites per 1000 hectares by predicted probability of women's foraging activity.

Rank	Inventory Area (hectares)	Sites with Groundstone Tools	Density of sites with Groundstone (per 1000 hectares)	Sites with Ceramics	Density of sites with Ceramics (per 1000 hectares)
Very Likely	568	23	40.5	8	14.1
Likely	14548	58	4.0	11	0.8
Unlikely	4510	16	3.5	3	0.7
Total	19625	97	4.9	22	1.1

Men's Foraging Activities

The probability of men's foraging activity was ranked according to the same procedures used for women's foraging and simplified into a three-point scale according to the same criteria. Table 7.3 lists inventory areas, and the numbers and densities of sites with projectile points, bifaces, and unifacial tools in each rank. Habitats ranked as very likely to contain evidence of men's subsistence activities have the highest densities of sites with points (76.7 sites per 1000 hectares), bifaces (86.9 sites per 1000 hectares), and unifacial tools (46 sites per 1000 hectares). Densities of sites with unifaces diminish with rank as expected, but sites with points and bifaces occur in unexpectedly high densities (11.4 and 14.3 sites per 1000 hectares respectively) on habitats judged unlikely to host men's foraging activities. Review of the locations of the anomalous sites reveals that most occur in two clusters in the extreme western and southern portions of the study area. Both occupy similar physiographic circumstances at the headwaters of large drainage basins closely associated with passes into neighboring Grass and Monitor Valleys, and both are closely associated with areas known to contain lithic toolstone sources (Figure 2.5). This suggests that the discrepancies result either from men's lithic quarrying activity or aspects of male hunting behavior that were not adequately incorporated into the ethnographically based model. Antelope drives that Steward (1938:119-120) records as taking place outside of the study area in Diamond Valley (and thus not considered in the Pine Valley model) seem a plausible candidate. In any case, the minor divergence of model predictions from empirical reality illustrates how the model can pinpoint sites that represent anomalous cases and serve as a context for evaluating site significance and develop research designs.

Table 7.3. Sites per 1000 hectares by predicted probability of men's foraging activity.

Rank	*Inventory* Area (hectares)	*Sites with* Points	*Density of* Sites with Points (per 1000 hectares)	*Sites with* Bifaces	*Density of* Sites with Bifaces (per 1000 hectares)	*Sites with* Unifacial Tools	*Density of* sites with Unifacial Tools (per 1000 hectares)
Very Likely	391	30	76.7	34	86.9	18	46.0
Likely	9675	74	7.6	54	5.6	109	11.3
Unlikely	9559	109	11.4	137	14.3	70	7.3
Total	19625	213	10.9	225	11.5	197	10.0

Evidence of Residential and Logistic Occupation

Expectations regarding habitability were derived comparing men's and women's seasonal returns in each habitat. Habitats with high predicted probabilities of containing both men's and women's foraging activity in the same season were predicted to be *very likely locations of residential base camps*. Habitats predicted to attract foraging attention of only one gender in a season were judged to be *very likely locations of logistic field camps*. Following this logic for all habitats in all season resulted in a four-point ranking of the likelihood of a habitat containing logistic or base camps. Evidence of features and fabrication tools are regarded as evidence of both logistic camps and residential bases; the two site categories should differ in the relative association of artifacts associated with men's and women's foraging activities. Since men are more likely to be occupants of logistic camps, whereas both men and women should occupy residential bases, we expect that the ranking of logistic camps will more closely correlate with projectile points than ceramics while the ranking for residential bases will correlate with both.

Table 7.4 presents the densities of sites with features, fabrication tools, ceramics, and points by rank sensitivity for residential occupation. In all four instances, site densities are highest in habitats judged most likely to contain residential base camps and diminish progressively by rank as expected.

Table 7.4. Sites per 1000 hectares by predicted probability of residential occupation.

Rank	Inventory Area (hectares)	Sites with Features	Density of Sites with Features (per 1000 hectares)	Sites with Fabrication Tools	Density of Sites with Fabrication Tools (per 1000 hectares)	Sites with Ceramics	Density of Sites with Ceramics (per 1000 hectares)	Sites with Points	Density of Sites with Points (per 1000 hectares)
Very Likely	292	5	17.1	11	37.6	7	23.9	23	78.7
Likely	140	2	14.2	3	21.4	1	7.1	8	57.0
Possible	1685	7	4.2	17	10.1	4	2.4	25	14.8
Unlikely	17508	21	1.2	51	2.9	10	0.6	157	9.0
Total	19625	35	1.8	82	4.2	22	1.1	213	10.9

Table 7.5 presents densities of sites bearing the same four attributes by rank sensitivity for logistic occupation. In all four cases densities are highest in habitats predicted very likely to contain logistic camps and lowest in habitats unlikely to contain camps. However, sites with features, and fabrication tools occur in slightly higher densities in habitats where camps are possible than in habitats where they are likely. We suspect this reflects the overlap of these same attributes with residential bases and the association of women's activities with residential bases and men's activities with logistic camps. This suspicion is supported by the densities of sites with ceramics, which exhibit the same trends as sites with features and fabrication tools, versus sites with points, which correlate perfectly with logistic occupation sensitivity rank.

Table 7.5. Sites per 1000 hectares by predicted probability of logistic occupation.

Rank	Inventory Area (hectares)	Sites with Features	Density of Sites with Features (per 1000 hectares)	Sites with Fabrication Tools	Density of Sites with Fabrication Tools (per 1000 hectares)	Sites with Ceramics	Density of sites with Ceramics(per 1000 hectares)	Sites with Points	Density of Sites with Points (per 1000 hectares)
Very Likely	431	7	16.2	14	32.4	8	18.5	31	71.84
Likely	4841	12	2.5	25	5.2	5	1.0	61	12.60
Possible	2040	6	2.9	17	8.3	4	2.0	24	11.76
Unlikely	12313	10	0.8	26	2.1	5	0.4	97	7.88
Total	19625	35	1.8	82	4.2	22	1.1	213	10.85

Overall Site Densities by Predicted Sensitivity Score

Constituent expectations about the likelihood of lithic reduction, men's and women's foraging, and residential activities fared well when compared against the Pine Valley archaeological database. In all cases, the model accurately predicted habitats most and least likely to contain evidence of such behaviors. Discrepancies between predictions and empirical data concerned middling "possible" and "likely" rankings that probably do not result from flaws in model formulations. Instead, they are likely consequences of 1) ambiguities in archaeological testing criteria (i.e., distinguishing logistic from residential camps and lithic reduction from men's foraging sites), or 2) aspects of the prehistoric aboriginal ecology of Pine Valley that have not previously been recognized in extant environmental, ethnographic, or archaeological databases (i.e., undocumented lithic toolstone sources, and hunting strategies not recorded ethnographically). In the latter case it has been pointed how such discrepancies serve to pinpoint sites where information about poorly understood aspects of Pine Valley prehistory may be obtained. Thus, the model's utility as context for evaluating site significance and developing research designs, in addition to its value as a planning tool, has been illustrated.

Now, the success of the combined four-point archaeological sensitivity ranking in predicting the prehistoric archaeological record of Pine Valley is evaluated. Table 7.6 presents inventory area, site numbers, and site densities by predicted archaeological sensitivity rank. As the model predicts, site densities are greatest in Rank 4 habitats (211.1 sites per 1000 hectares) and least in Rank 1 habitats (25.8 sites per 1000 hectares).

Table 7.6 Sites per inventoried hectares by predicted archaeological sensitivity rank.

Sensitivity Rank	Inventory Area (hectares)	All Prehistoric Sites	Density (per 1000 hectares)	Significant Sites	Density (per 1000 hectares)
4	332	70	211.1	14	42.2
3	451	45	99.7	5	11.1
2	4899	214	43.7	34	6.9
1	13944	360	25.8	24	1.7
Total	19625	689	35.1	77	3.9

Figure 7.2 depicts archaeological sensitivity within the project area. High and very high sensitivity occur consistently along watercourses, in the pinon zone and near lithic sources. Allowing for scale discrepancies, high and very high sensitivity areas correlate well with the ethnographic model presented by Steward (1938).

ASSESSMENT OF THE ARCHAEOLOGICAL BURIAL MODEL

The archaeological burial sensitivity model forecasts where one is likely to find archaeological materials buried in low-energy sediments. Note that the model does not forecast that there should actually *be* archaeological materials in those settings. Rather, sediments of an appropriate age (younger than about 10,000 years) and of low energy (roughly sand-sized particle deposition) should be present. Testing this model does not actually require archaeological materials. A model test requires only that one determine the age and energetic regime of sediments. In practice, archaeological materials are probably the least expensive age indicator.

Assessment of this model is difficult at present. Little systematic subsurface observation has been done in Pine Valley. Site excavations show that there are, indeed, sites with buried materials in useful depositional contexts. It is a large step from these scattered occurrences to a systematic assessment of the model itself.

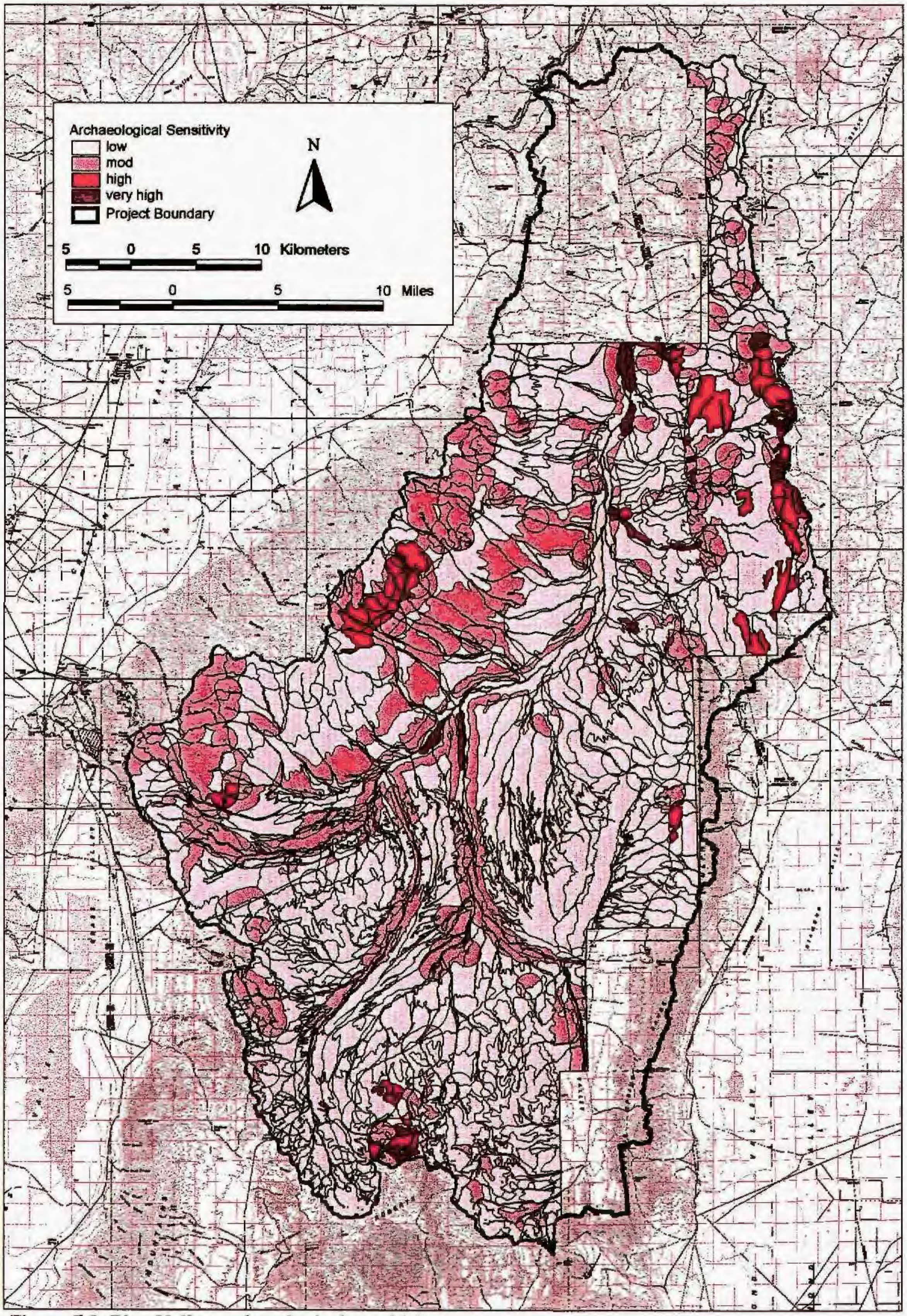

Figure 7.2. Pine Valley archaeological sensitivity.

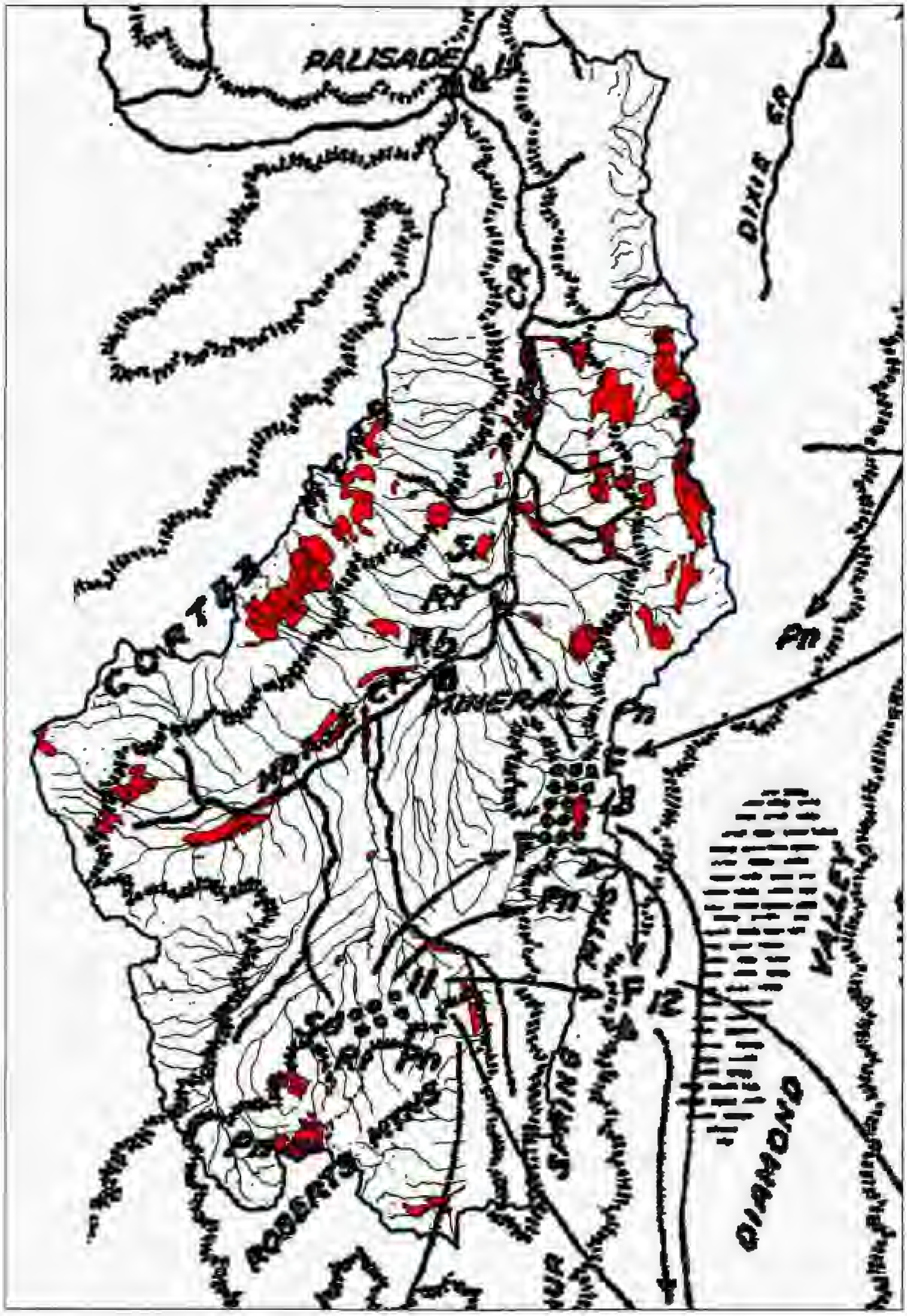

Figure 7.3. Correlation of high and very high sensitivity with Steward's ethnographic map (1938).

One can outline procedures for continuing the assessment of the buried archaeology model. Negative evidence is of importance in this model too (as it is in the anthropological model). That is, excavation and examination of subsurface deposits has to include areas of high and low burial probability. If one consistently finds buried archaeological material in the low probability area, then the model is probably faulty. The converse is not true: a lack of archaeology in a high potential area could be due to a lack of archaeology overall. So, assessing the model requires systematic testing outside of known (i.e., surface) archaeological sites and dating of sediments that contain no archaeology. From a practical viewpoint, the knowledge needed to assess the burial model will have to accumulate over time as trenches, site test excavations, and other ground disturbances occur.

ASSESSMENT OF THE HISTORIC RESOURCES SENSITIVITY MODEL

The goal of the historic resources overlay for Pine Valley is quite different from the prehistoric foraging and archaeological models. Historic settlement patterns resulted from very different factors than those used to model prehistoric settlement and subsistence. To evaluate for historic resource potential, GLO plats for the project area were assessed for the presence of transportation, communication settlement and agricultural/industrial features within mapped sections.

Figure 7.5 depicts correlation between each of the feature types across the Pine Valley landscape. The presence of historic GLO features correlate well with the valley's historic use. Transportation features dominate the landscape. Settlement features logically fall along the cluster along Pine Creek where agriculture is dominant and are also associated with mining within surrounding ranges.

The composite feature classes provide the best approximation for historic resource sensitivity. As the number of composite classes increases, the likelihood of encountering historic resources should also increase.

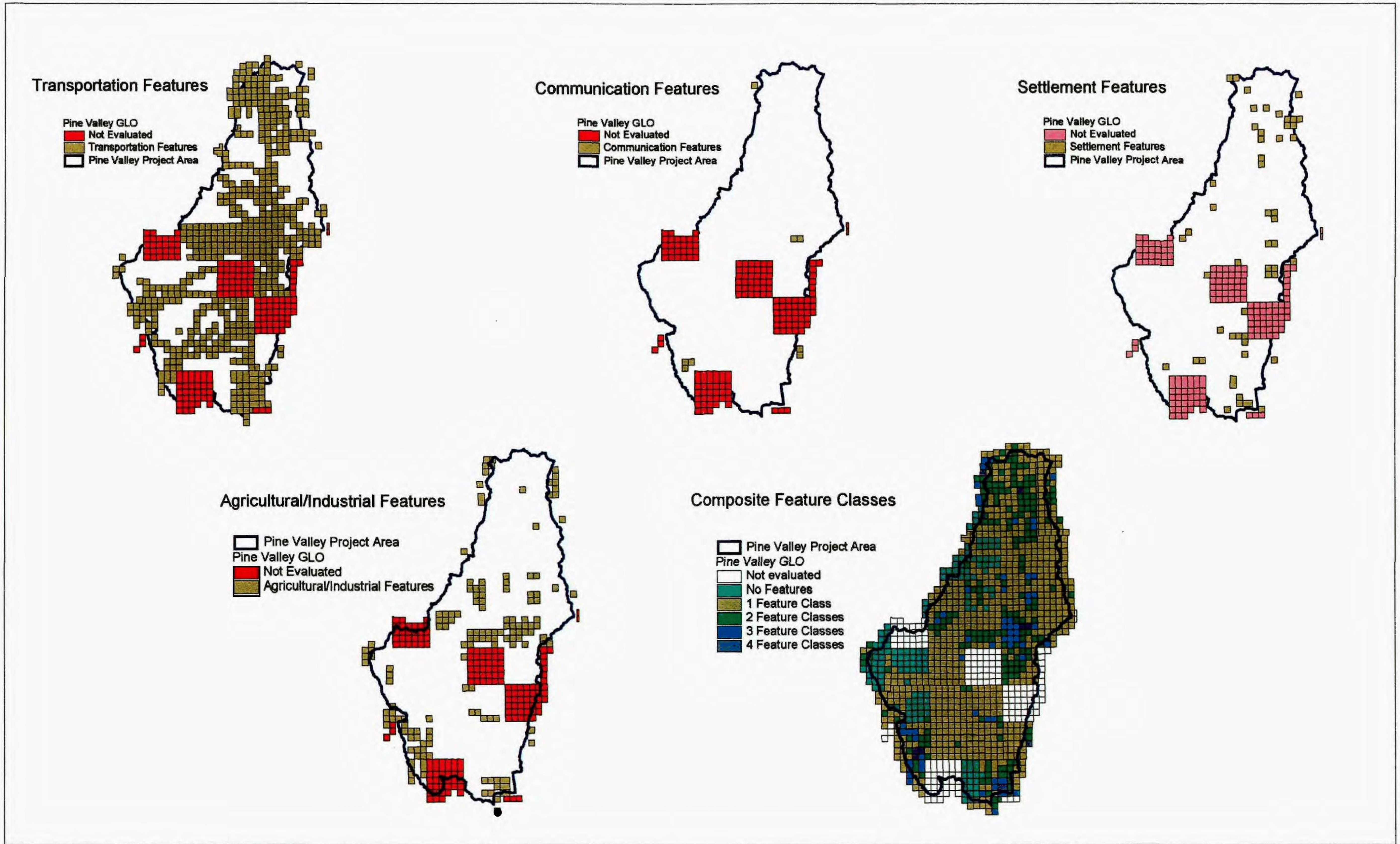

Figure 7.4. Pine Valley GLO correlations.

CHAPTER 8 – THE PINE VALLEY MODELS AS TOOLS

The Pine Valley study uses an anthropological and geomorphic research approach to create management tools. Basically, three tools were created: a landscape model of the likelihood of different parts of Pine Valley containing surface or subsurface archaeology; a landscape model of whether archaeology is likely to be buried; a map that summarizes 19^{th} and 20^{th} century cultural features from the historic General Land Office plats.

This chapter explores the use of the models as management tools. The benefits and the shortcomings are considered. Some of the benefits accrue immediately as agencies manage with these tools. Other benefits will take longer to be realized. Similarly, the models certainly have shortcomings. These limit their wise use in some important ways.

Ultimately, how or whether these tools get used is beyond the scope of this project. The one certainty is that effective use of a model-based tool requires the model itself to change. In this sense, the historic GLO summary is not so much a model as it is a statement of historical fact (granted, the facts are all from a single source). Both of the prehistoric models are open to revision and refinement. Models die from disuse because no new information is gathered to evolve the model. The chapter closes with a consideration of this problem.

THE GLO COMPILATION

The GLO plat compilation is a summary of historical documents far more than it is a model *per se.* Nevertheless it has management utility in that one can immediately tell whether settlements, roads, telegraph or telephone lines, farms, ranches, or mines were present at some time in the past.

The compilation works best as a screening tool with which to eliminate or flag areas where activities or features were present historically. One cannot rely wholly upon the GLO maps though, for they have their biases too. So, areas where *no* features are shown on the GLO maps may contain interesting historical resources.

The GLO compilation can be maintained by adding new historical data, adding categories to the map overlay (e.g., one might add a category of historic range improvements), or adding wholly new kinds of information as new map units (e.g., parcel shapes, ages, and conveyance purposes of land entries).

THE PREHISTORIC MODELS

The two prehistoric models (the foraging/habitat sensitivity model and the burial potential model) are complementary tools intended to address two aspects of the archaeological record: the aggregation of "things" that make up archaeological sites and the disappearance of such things through burial or erosion.

Sensitivity Scores and National Register Status

Table 7.6 presents the densities of sites within the different habitat sensitivity ranks. The table also includes the densities of sites judged potentially eligible to the National Register of Historic Places by field recorders and/or evaluated by agency staff as eligible for National Register of Historic Places. National Register eligible or potentially eligible sites in this status are also predicted by sensitivity rank; significant sites are most dense in Rank 4 habitats (42.2 sites per 1000 hectares), and least dense in Rank 1 habitats (1.7 sites per 1000 hectares.

The Pine Valley archaeological site sensitivity model was not explicitly devised to predict the occurrence of National Register Eligible sites; its' success in doing so is most likely a consequence of its prediction of all site densities in general. Certainly, the model considers data relevant only to Criterion D of the National Register (National Park Service 1991).

The correlation of significant sites with archaeological site sensitivity rank highlights the utility of the model as a project planning tool. The site sensitivity rank of a landscape cell allows managers to anticipate the likelihood that an undertaking will affect properties eligible for the NRHP. Moreover, agency archaeologist may want to consider the correlation between significant sites and sensitivity rank when evaluating the National Register eligibility of sites discovered in future inventories. One might wish to give special consideration to the "rare" sites: sites meeting the significance and integrity standards for inclusion on the National Register and in habitats deemed unlikely to contain such sites. The presence of such anomalies highlights their potential for yielding significant information about Pine Valley prehistory.

Refining the Management Utility of the Model

Archaeological sites are field-mapped at large map scales. Boundaries are often determined to be zones a few meters in width. While there is debate about the reality of such edge-determinations for something as messy as human debris, the resulting site boundaries are the units land managers must work with on a daily basis. Site boundaries become more abstracted as an individual site gets plotted on smaller scale maps (typically 1:24,000 scale). Nevertheless, the spatial extent of prehistoric archaeological sites may exceed the accuracy of the data used to construct the model. Indeed, this is why we chose to count sites that lie in more than one sensitivity rank as lying on the most sensitive rank unit.

There is a spatial incongruity between mapped site boundaries and the soil, drainage, and slope units on which the predictive model is based. For example, 171 of the 689 prehistoric archaeological sites and isolates occur on more than one sensitivity rank. This problem is particularly prevalent among sites associated with relatively small springs and drainages where site boundaries extend onto adjacent soils of lower expected sensitivity for prehistoric resource. In the preceding tests, the highest rank was taken as the appropriate score for sites associated with more than one rank, and associations with the lower sensitivity rank units were excluded from subsequent comparisons. While we are confident that this convention monitors the predictive capability of the model, it does so at the cost of some of its management utility, because portions of some sites occur on soil map units whose sensitivity score do not predict the presence of such sites. Using irregular polygons derived from the model factors results in a high number of very small "sensitive" areas. These are difficult to utilize in land management.

To make the model usable for managers requires its transformation from a set of irregular polygons to a raster matrix of grid cells weighted by the sensitivity value of the *highest* ranked habitat in the cell. This transformation is described below.

The landscape sensitivity/habitat complexity scores were recalculated using a grid of 500m cells (Figure 8.1). Each cell was given a score based upon the area within it taken up by a given rank value. Higher rank values (more sensitive) were given more weight in the average calculations, in order to avoid having a cell with a small but highly sensitive island surrounded by low sensitivity habitats appear to be a low sensitivity cell. In short, the assumptions are conservative: high ranks should always be considered sensitive areas even if they are a small proportion of a cell. The 500m grid of weighted averages was then classified into four ranks (low, moderate, high, very high). This avoided narrow high sensitivity corridors, like stream corridors, disappearing into a sea of moderate sensitivity broad flood plain.

The GIS layer for this model can be used as a screening tool for the likelihood of encountering sites that are likely to be judged eligible to the National Register. Note that the model does not really explain *why* such sites are judged eligible, simply that they are more likely to occur in particular habitats. Because the model predicts areas of higher site densities overall, it is also a useful tool to forecast the sheer number of sites one will encounter in a given unit of inventory.

The archaeological deposition model crosscuts the habitat model, literally. The geomorphic model adds the perpendicular dimension of sediment covering archaeological materials. In many ways, the two are independent of each other and their interaction contains some interesting possibilities for the occurrence of prehistoric archaeology (Table 8.1).

Table 8.1. Interaction of depositional and landscape rank models.

Landscape complexity	Potential for buried materials	Expectation
High	High	Subsurface exposures are likely to contain archaeology; younger archaeology at surface or near surface
High	Low	High density of surface archaeology, possibly as large "run-on" sites. Materials of all ages found on or near surface.
Low	High	Nothing seen on surface or in subsurface exposures
Low	Low	Nothing seen on surface or in subsurface exposures

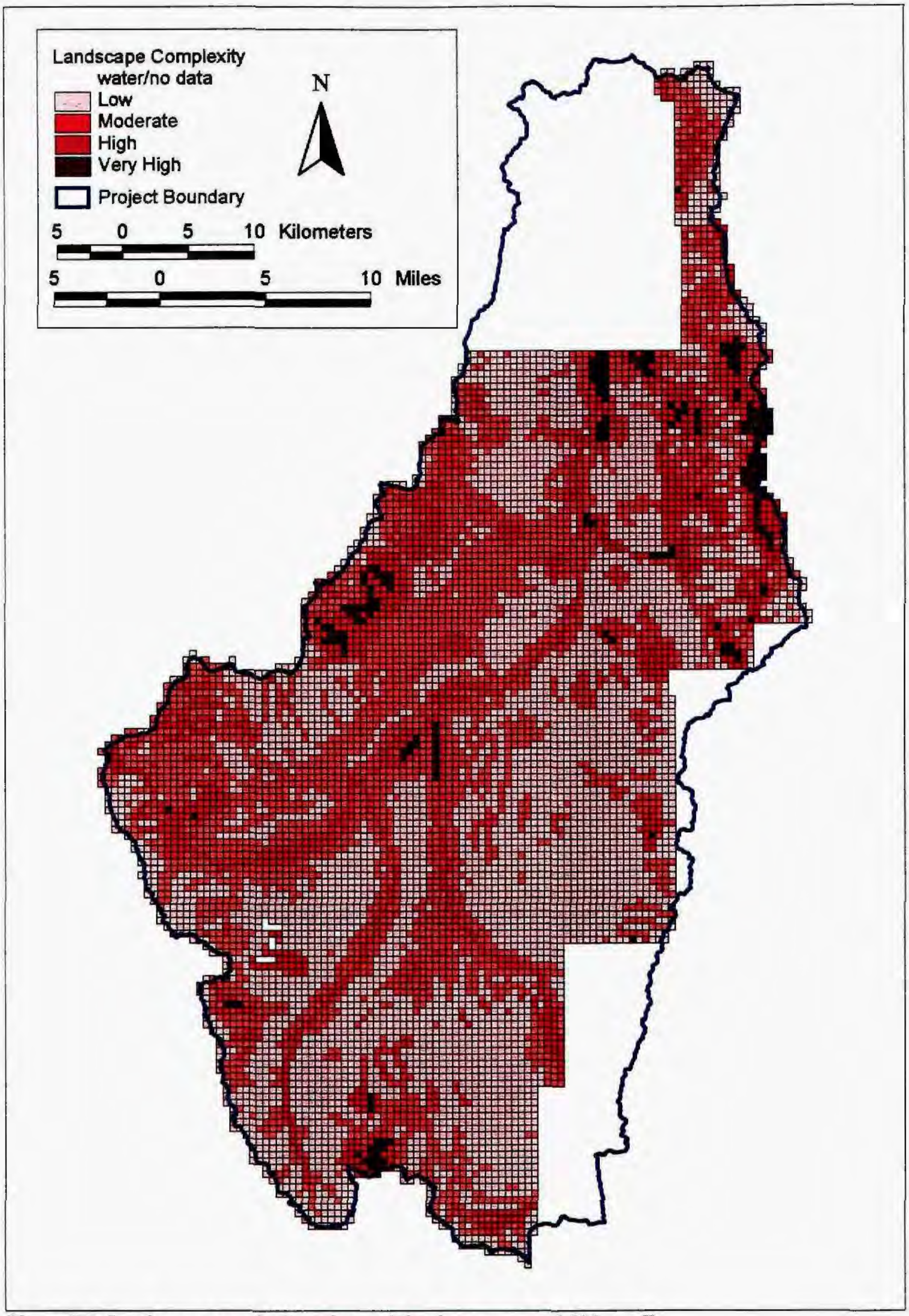

Figure 8.1. Landscape complexity using weighted averages and 500m cells.

As Table 8.1 makes clear, one can find nothing on the surface during an archaeological inventory and yet still be in an area rich in archaeology. This situation results in "discoveries" – unexpected subsurface findings. These usually occur in the middle of large-scale construction and have a major economic impact when work is stopped by them. The depositional model can be used to forecast the likelihood of discoveries and even to schedule ground disturbance before a construction project is in full swing.

An even more effective use is as a planning tool prior to opening an area for a specific land use (or conversely to determine areas that should be closed to specific uses). One way in which to make such a use is shown in Figure 8.2, in which lease packages for minerals are formulated using a model as input to the process. So, before leases are marketed they are screened and appropriate *caveat emptor* statements have been made about them.

Maintenance

Any tool needs maintenance. Throughout this volume the tools being created are termed "models". Alternate terms are equally valid: "hypothesis" or (redundantly) "working hypothesis". Semantics aside, the models must be considered hypotheses needing further evaluation and elaboration. Here, we explore the process of further development.

One of the most obvious shortcomings of the prehistoric models is the data used to test them. The pool of cultural resource inventories can in no way be considered a random sample of the model space. Fieldwork standards have differed over the years. Site records vary in quality (see discussion in Chapter 7) useful for analysis.

Current BLM fieldwork standards specify how new fieldwork will be done. Site recording follows a standard format. Nevertheless, one encounters significant variation in adherence to these standards, even in recent fieldwork. Above, (Chapter 3), reference was made to the problem of incomplete, halted, inventories on public lands. This generates partial records that cannot be considered as meeting contemporary standards. In short, the existing standards are adequate but need consistent application.

Additional recording and some other observations taken in the field during cultural resource inventories are important new standards to put in place. Nor are these tedious or time-consuming. Each inventory area should have additional data collected for it by the archaeologists in the field. The following are minimal survey unit attributes that should be collected systematically:

- dominant vegetation percentages (vegetation communities should be sketched on to a 1:24,000 map if the survey covers areas greater than 40 acres)
- general surface texture (fine sediments, desert pavement, gravelly-sandy, etc.)
- distance to perennial and predictable natural water sources

On large linear inventories, one might record these attributes in mappable segments.

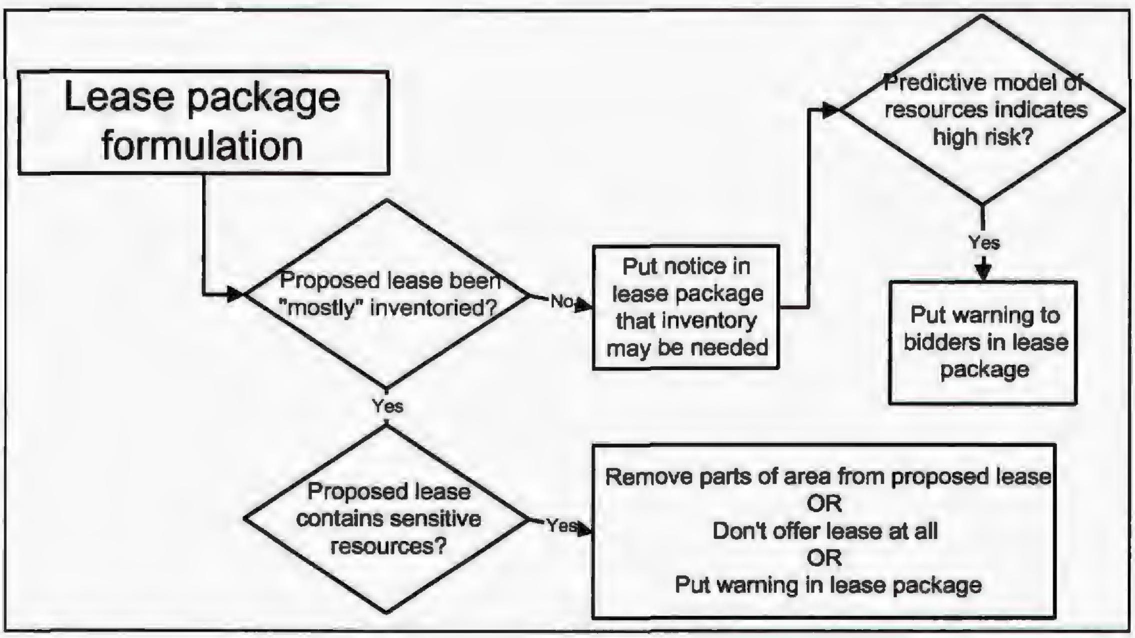

Figure 8.2. Proactive uses of cultural resources sensitivity models.

Similar information should be recorded for all archaeological sites encountered. Additionally, projectile points should be keyed using a standard method so that descriptions are consistent regardless of the meaning one may ascribe to projectile point types. A separate site data sheet or an explicit section of the site recording form should record at least the presence/absence (or better yet, counts) of key indicators used in the site discussion:

- projectile points
- hearths
- groundstone
- ceramics
- fabricating tools
- processing tools
- greatest depth to buried materials if test excavations were undertaken

In the Railroad Valley study (Zeanah et al. 1999), inventory requirements for particular habitat rankings were eased. The very low percentage of inventory in Pine Valley overall makes such a recommendation hazardous. However, systematic collection of new observations might have delineation of areas where reduced surface inventory is possible as the goal. This gives a focus to continued testing of the models. Indeed, one might consider whether there are other models that need to be developed too, perhaps including more spatially extensive considerations of National Register eligibility determinations.

In Chapter 7, we discussed the importance of seeking anomalies to the expectations of the model. Tracking such anomalies is part of hypothesis-testing and reformulation. However, one must be well aware of whether one is finding anomalies to "National Register-ness" as sites are found that are clearly of interest and novel or if one is finding sites in unexpected places or containing unexpected materials.

The subsurface archaeological model requires additional testing in different ways. As mentioned above (Chapter 7), testing this model requires dating of sediments. The only way to do this cost-effectively is by systematic monitoring and examination of subsurface exposures. Backhoe trenches are the most effective tool for this. One of course depends upon finding archaeological materials that will be visible in roughly dug trenches (hearths, most commonly). More subtle archaeological manifestations may remain invisible. So, in areas of logistical use and high deposition, one may never see the buried archaeology at all in trenches. Monitoring of subsurface exposures needs to be recorded like any other form of inventory so that it becomes part of the Pine Valley cultural resource database.

SUMMARY AND CONSIDERATION

Managing the cultural resources in Pine Valley necessitates a shift in perspective from anthropology to conservation. The anthropological and archaeological constituent predictions of the model are borne out quite well. Indeed, the tools of management start from these constituent predictions, for most prehistoric archaeological sites are managed to conserve their value in research. However, the multiple use goals of public land management necessarily force one to rank cultural resources in terms of their importance. Federal land policy relies heavily upon the criteria for the National Register of Historic Places (National Park Service 1991) in, giving priorities to the protection of particular archaeological sites.

Table 8.2 summarizes the rankings and proportions of the Pine Valley study area that fall within different categories of sensitivity or risk. A fairly small portion of the valley is expected to fall in the high surface sensitivity category. This lies mostly along watercourses and in particularly favorable settings (see Chapter 7). The point was made above that having a model need not preclude or foreclose further investigation; Table 8.2 suggests this is particularly true in Pine Valley for one would be "held back" by very little high sensitivity ground.

It is important to realize that the tools created by this study are not the only tools. For instance, the information content of different sorts of sites remains completely unexamined by this study. A single component, perhaps single event, site may have much greater research value than an extensive lithic scatter with dozens of formed tools. No judgement is made about this category of information.

Table 8.2. Proportional sensitivity of Pine Valley study area. Area with no predictions excluded. Columns sum to 100%.

Sensitivity	Surface	Subsurface
High	14%	41%
Moderate	46%	32%
Low	38%	27%

Criterion D of the National Register is the most frequently utilized reason for giving priority, or significance, to a particular prehistoric archaeological site. Criterion D emphasizes the scientific research importance of a resource (deemed "a property" in National Register terminology). One of the attractions of an explicitly formulated anthropological model is that it offers an explanation of the archaeological record – the model attempt to answer the question "why are sites located where they are found?" Insofar as one accepts the explanation the model offers, this question ceases to be a research issue and thus also ceases to be an argument for a site's importance under Criterion D of the National Register. Nevertheless, there may still be other reasons to consider a site worthy of protection under Criterion D.

The most common criticism of cultural resource models, especially those created for prehistoric archaeology, is that they preclude gathering new knowledge because no new observations are collected. In short, since there seems nothing left to explain, no new data are sought. So, the model can never be falsified. The tool can never be improved. This is a problem in how such models are used, not in a model or hypothesis itself.

None of the authors of this report are cultural resources specialists in land managing agencies. Yet extensive discussion with colleagues who work for land managing agencies convinces us that the working hypotheses – the models – presented here can be improved inside of day to day cultural resources management. To do so requires a shift in management mode away from project-based management toward plan-based management. Our understanding of cultural resources management and land management suggests this will not be an easy transition, for it requires a change in approach above the cultural resources specialist role.

However, as managerial modes change to area-based hypotheses (and we are hopeful that the change will happen), the importance of area-based models will grow. Someday, perhaps a decade from now, the current generation of Pine Valley models will appear crude. We look forward to that day.

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