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GENERAL EDITOR

ARROYO HONDO ARCHAEOLOGICAL SERIES

1
The Contemporary Ecology of
Arroyo Hondo, New Mexico
N. Edmund Kelley

2
Prehistoric Pueblo Settlement Patterns:
The Arroyo Hondo, New Mexico, Site Survey
D. Bruce Dickson, Jr.

CONTEMPORARY ECOLOGY
OF ARROYO HONDO

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THE CONTEMPORARY ECOLOGY OF ARROYO HONDO, NEW MEXICO

N. Edmund Kelley

With an Appendix by Richard W. Lang

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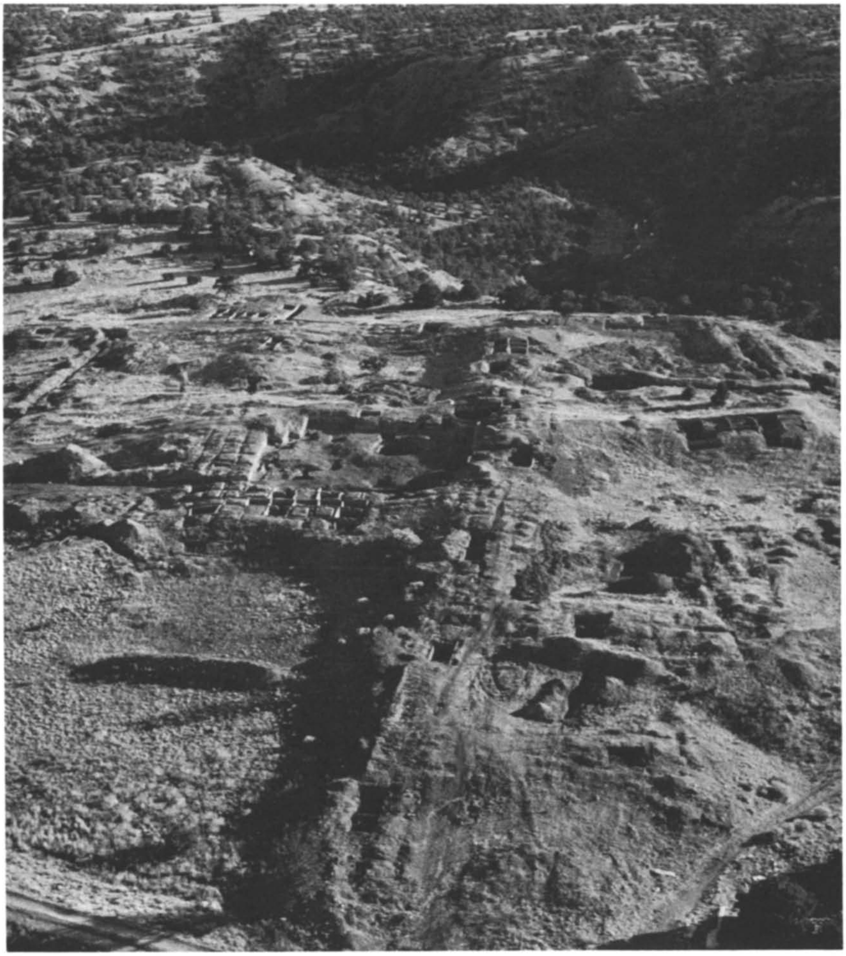
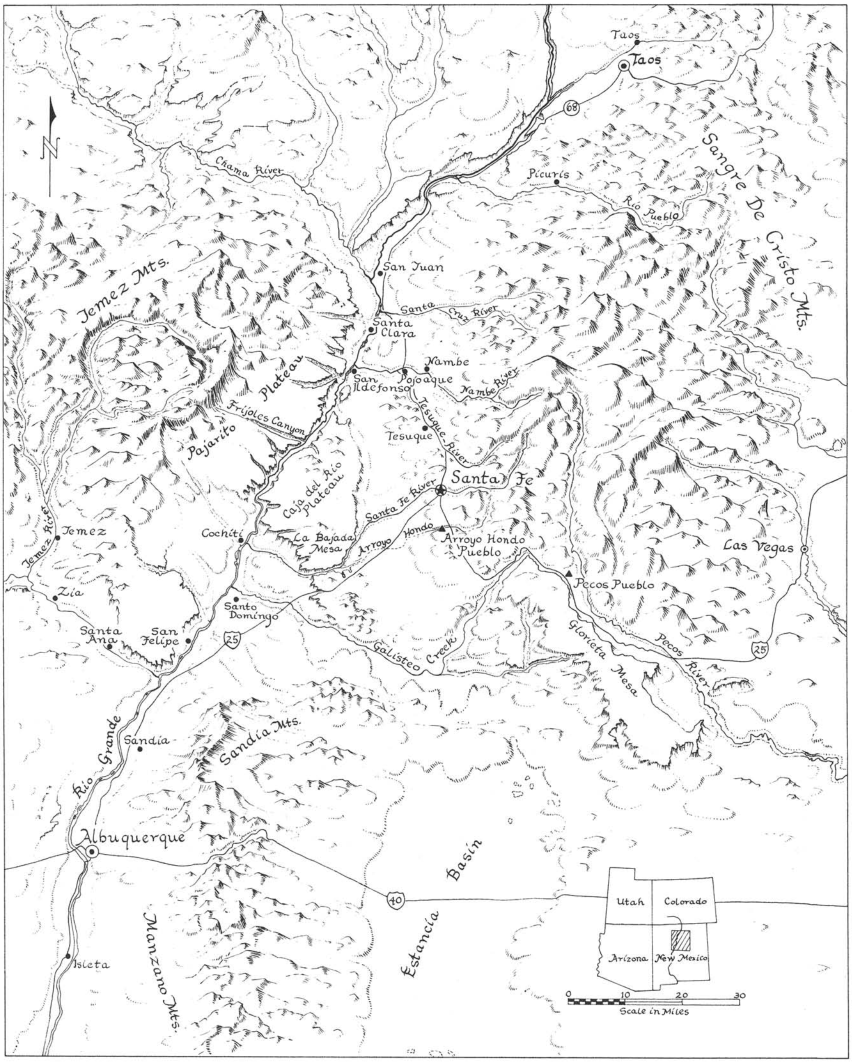


FIG. 1. Aerial View of Arroyo Hondo Pueblo after the Final Season of Excavation.

Foreword

The rapid emergence of large pueblos during the fourteenth century A.D. was a critical change in the culture history of New Mexico's northern Rio Grande valley. To investigate this development and its ramifications, Arroyo Hondo Pueblo (LA 12) was chosen in 1970 as the focus of a School of American Research archaeological project (Fig. 1). Three main interests formed the framework of the research: (1) the characteristics of northern Rio Grande Pueblo culture in the large fourteenth-century towns; (2) the factors leading to the growth and change of these pueblos; and (3) the use of Arroyo Hondo Pueblo, along with comparative ethnographic material, in examining the cross-cultural implications of the relationship between rapid population growth and culture change.

Arroyo Hondo Pueblo, located about 4½ miles south of Santa Fe, New Mexico (Map 1), contained at its peak approximately 1,000 rooms. Test excavations carried out at the site in July, 1970, were followed by full-scale excavations during the summers from 1971 through 1974, in addition to ecological and archaeological surveys of the surrounding area. The National Science Foundation supported the project with grants GS–28001 and GS–42181. Laboratory processing took place during the winter months, along with research on the literature pertaining to the relationship of demographic and cul-



MAP 1. Location of Arroyo Hondo Pueblo in the Northern Rio Grande Region.

tural change. The project's preliminary results were published in three field reports (Schwartz 1971, 1972; Schwartz and Lang 1973). After completion of the fieldwork, a film, "The Rio Grande's Pueblo Past," was made in collaboration with the National Geographic Society describing the project and presenting a few initial conclusions.

The excavations demonstrated that Arroyo Hondo Pueblo was founded about A.D. 1300 by a few families who built one or two small roomblocks. Following this initial settlement, the town grew rapidly until by A.D. 1330 it covered nearly 6 acres and included 24 roomblocks around 10 plazas. During the middle of the fourteenth century, the pueblo underwent an equally rapid depopulation and was virtually abandoned. Sometime in the 1370s, a new occupation began. The town was partially rebuilt but this time contained only 9 roomblocks around 3 plazas. Arroyo Hondo Pueblo was permanently abandoned about A.D. 1425.

During the course of the project it became clear that the amount of archaeological material recovered and the complexity of the ideas emerging called for publication of more than a single volume. Therefore, a series of ten volumes was planned, nine to present information and ideas on specific topics and one to serve as a final synthesis volume. Although each of the first nine volumes focuses on a particular set of data, it is also intended that each will stand independently in terms of its contribution to northern Rio Grande archaeology as a comprehensive presentation of descriptive data or as an analysis of those data, or as both. Each specialized topic was assigned to one or two individuals who compiled and analyzed the data, in many cases beginning at the fieldwork stage, and who wrote the monograph on that topic.

This first volume in the series has been made possible by an additional National Science Foundation grant (BNS76-82510 AO2). The topics of the subsequent Arroyo Hondo monographs and their authors are:

Site survey, by D. Bruce Dickson, Jr.
Architecture, by John D. Beal
Ceramics, by Richard W. Lang
Lithic artifacts, by Laurance Linford
Bone, shell, and other artifacts, by Marshall A. Beach, Christopher Causey, and Tamsin Venn

Skeletal and mortuary remains, by Ann M. Palkovich
Paleoethnobotany and nutrition, by Wilma Wetterstrom
Paleoecology, including:
  Pollen analysis, by Vorsila Bohrer
  Dendroclimatology, by Martin R. Rose, Jeffrey S. Dean, and William J. Robinson
  Faunal remains, by Richard W. Lang and Arthur H. Harris
Project synthesis, by Douglas W. Schwartz.

The synthesis volume places the site in historical perspective within its larger northern Rio Grande context, integrates the contributions of the preceding volumes in terms of the culture and dynamics of the pueblo, and addresses the broader questions of the relationship between rapid population growth and cultural change.

THE CONTEMPORARY ECOLOGY OF ARROYO HONDO

As a background against which to understand the prehistoric environment of Arroyo Hondo Pueblo and as a foundation for analyzing its economy, a thorough knowledge of the area's current topography, geology, soil, climate, hydrology, vegetation, and animal life was considered essential. Therefore, project ecologist N. Edmund Kelley was asked to examine the contemporary Arroyo Hondo environment. His assignment was to study (1) the ecology of the area immediately surrounding Arroyo Hondo Pueblo, from which the prehistoric inhabitants presumably drew a large part of their sustenance and (2) the additional economic resources that might have been obtained within a larger region from the Sangre de Cristo Mountains to the Rio Grande.

Part of the results of Kelley's work became his master's thesis for the University of New Mexico Department of Biology (Kelley 1973). The full results of his study are presented here. In thoroughly describing Arroyo Hondo Pueblo's present-day environment, Kelley lays an essential base for other volumes in the series.

ACKNOWLEDGMENTS

With the publication of the first volume of the Arroyo Hondo Archaeological Series, I would like to acknowledge some important debts relating to the total project. Although I served as principal investigator and had supervisory responsibility for the fieldwork, laboratory analysis, and completion of each monograph, the research from its conception has been a cooperative venture. Each of the monographs is the primary responsibility of its author or authors, but as in the case of Ed Kelley's, each volume has also resulted from a good mixture of joint scholarship and friendship. Every volume in the series is also the product of a long chain of support from many individuals, both those who have been with the project from its inception and those who served as advisors or reviewers of the manuscripts. The latter are acknowledged in the individual volumes, but I would here like to single out three key colleagues for appreciation of their intelligence, effort, and dedication. John D. Beal, Jane Kepp, and Richard W. Lang have all made special contributions to the project, in field archaeology, interpretation, editing, and publication development. As must be the case in all meaningful collaborations, it is difficult in the end to determine the distinctive accomplishments of specific individuals. All those involved in the project have been part of a collectively reinforcing process, the dynamics of which defy characterization but the results of which I feel are infinitely better for that collaboration.

Douglas W. Schwartz

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SCHWARTZ, DOUGLAS W., AND RICHARD W. LANG

1973 *Archaeological Investigations at the Arroyo Hondo Site: Third Field Report–1972* (Santa Fe: School of American Research).

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Acknowledgments

This study was suggested by Dr. Douglas W. Schwartz of the School of American Research and Dr. Loren Potter of the University of New Mexico Department of Biology as part of a larger archaeological research project conducted by the School of American Research at Arroyo Hondo Pueblo, New Mexico. I am deeply indebted to Dr. Potter for his assistance and encouragement throughout the course of the study, without which completion of the work would have been impossible, as well as to Dr. Schwartz, who set the goals for the study and made it possible for me to perform the research. Financial assistance for the duration of the fieldwork was provided by the School of American Research under National Science Foundation Grants GS-28001 and GS-42181.

Thanks are also due to Dr. William Martin for the use of the University of New Mexico herbarium and for his help in identifying flora, to Dr. Hal McKay and Lynn Fifield for assisting in identifications, and to Dr. James Gosz and Dr. Ivan Bennett for advice and assistance in locating sources of information.

I particularly wish to express my appreciation to Jim Folks, U.S. Soil Conservation Service, for the soil survey reports and aerial photos; Frank Houghton, state climatologist, for furnishing climatological records; and George Laskar, U.S. Geological Survey, for his advice in drafting and mapping procedures. Government agencies whose staffs cooperated in obtaining records, maps, and unpublished materials include the U.S. Geological Survey; the U.S. Forest Service, Santa Fe and Cibola districts; the National Weather Service, Albuquerque; and the U.S. Bureau of Land Management, which provided survey records from the late 1800s. Their assistance is gratefully acknowledged.

The photographs in Figures 20 and 24 were taken by Richard W. Lang and those in Figures 19 and 21 by Jane Whitmore. All others were taken by David G. Noble, who also printed all the photographs used in illustration. Figure 7 was drawn by George Laskar, and Winfield Coleman drew Figure 6 and Maps 3–5. All other maps and line art in this volume are by Richard W. Lang. The high-quality work of all these individuals is much appreciated.

1
Introduction

This study examines the present-day ecology of the area around Arroyo Hondo Pueblo, a large, fourteenth-century Rio Grande pueblo located at the foot of the Sangre de Cristo Mountains 4½ miles south of the Plaza of Santa Fe, New Mexico (see Map 1, p. x). From 1971 to 1974, this prehistoric pueblo was the subject of a major archaeological research project conducted by the School of American Research. The excavations recovered many clues to the past environment: remains of corn and other prehistoric domesticated plants, wild plant remains recovered through flotation, pollen samples collected throughout the site for later analysis, artifacts made from locally available materials, and the remains of more than 60 species of animals. In order to be meaningful for analysis and interpretation, these data must be seen in an overall ecological perspective. This monograph provides details filling out that perspective through the study of the present environment.

RESEARCH DESIGN AND TECHNIQUES

To accomplish the project's objectives, the fieldwork was divided into two parts. First, work was undertaken to determine in detail the nature of the present environment in the immediate region of the Arroyo Hondo site, the area that may have been the prehistoric territory of the people who lived there. Chapters 2 through 7 and Appendix A present the results of research generated by that first objective, describing the geology and physiography, hydrology, climate, soils, and vegetation of the area.

Since the archaeological project also attempted to see Arroyo Hondo Pueblo in a larger geographical and historical context, it was desirable to provide information on the larger ecological region of which Arroyo Hondo is a part. Appendix B presents the results of the work stemming from this second objective, outlining the critical ecological information about the zones away from the Arroyo Hondo territory toward the mountaintops to the north and the Rio Grande to the south and west. Appendix C lists vertebrates observed during the Arroyo Hondo archaeological research; a complete analysis of the fauna of Arroyo Hondo will be published in a later monograph in this series.

Delineation of the Study Area

Every social group has a territory: land it uses and/or visualizes as its own. There may also be additional areas it uses or holds in common with others that is nonexclusive, shared territory. It is almost impossible to know exactly the location of a prehistoric group's territory, but some reasonable guesses can be made. One approach to this determination is through an examination of the locations of other prehistoric sites in the same general area. This method involves the assumption that at the time the Arroyo Hondo site was occupied, other pueblos were distributed over the adjacent landscape, their distances from one another determined partly by the amount of economic-support-base land needed by the pueblos' populations. The territories of these pueblos could then be defined operationally by hypothetical boundary lines drawn between adjacent sites.

An archaeological survey conducted by D. Bruce Dickson, Jr., had as one of its goals the delineation of an Arroyo Hondo "sustaining area" based on the method just described (Dickson 1979). However, the study area for the ecology project was established before Dickson's final results were available. Preliminary information suggested that the nearest known sites were located about 5 miles to the north and south of Arroyo Hondo Pueblo. Points midway between these sites and Arroyo Hondo were arbitrarily set up as the boundaries of the study area, and an equal distance was used to establish the east and west boundaries. The result was an area 5 miles on a side with Arroyo Hondo Pueblo at its center (Map 2).

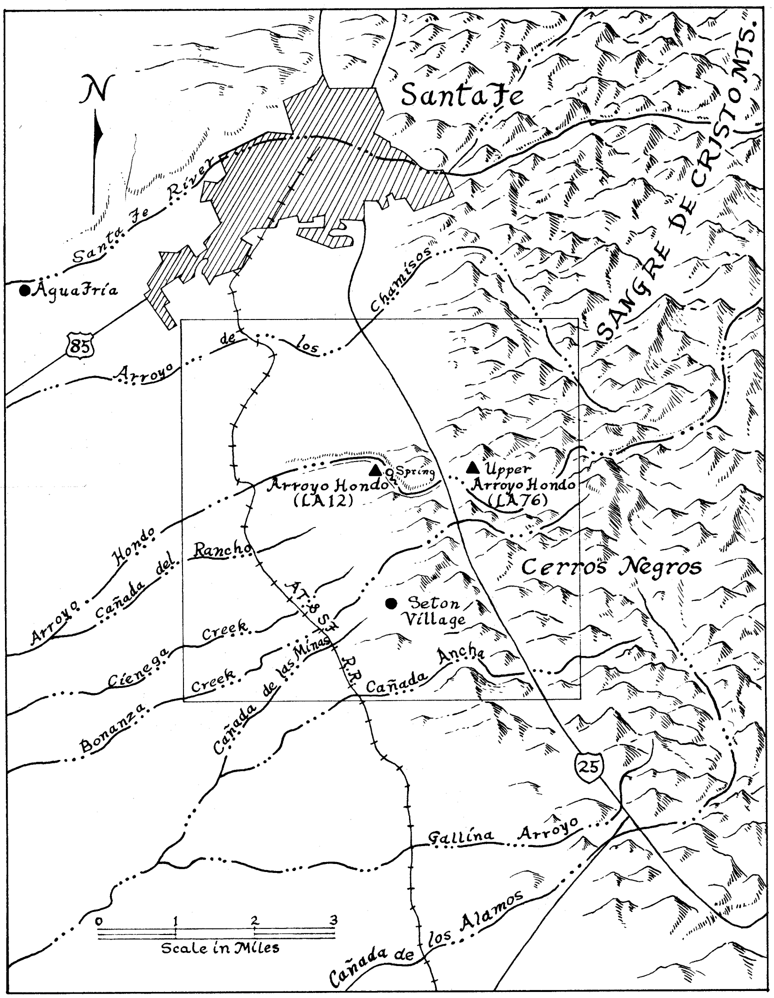
Research Procedures and Techniques

The ecological fieldwork covered approximately three field seasons. In the summer of 1970, Harold Stacy did a preliminary review of the site's ecology as background for preparation of the project proposal to the National Science Foundation. Major work for this monograph was done during the summers of 1971 and 1972. During 1971, after the study area had been established, initial work was done on the geology, physiography, hydrology, soils, and life-forms. Physiographic study defined the topography, erosional history, and influences on soil development and water movement. Geological work revealed possible source areas for artifact materials from the pueblo, as well as influences on water supply. Hydrology, climate, and soil types were pertinent to determining agricultural potential. Finally, 110 species of plants were classified, with their distance from the site noted, and a chart of life zones within 20 miles of the site was drawn, listing the species identified in each zone. A contour map of the area was made, showing the life zones, and preliminary library research on the geology of the area was undertaken.

In 1972, microenvironmental analysis of the study area was carried out, looking specifically at variations within the area itself. A soils map was completed to be used in the study of agricultural potential, and work was carried out on piñon nut production and food value. In the spring of 1973, Harold Stacy and Richard Lang compiled a faunal list for the area from observations and fieldwork (Appendix C).

A composite base map of the study area was prepared from two U.S. Geological Survey topographic maps, Santa Fe and Seton Village quadrangles. Geology, soils, and vegetation were portrayed using the base map. Geologic features on Map 3 (p.18) are from Spiegel and Baldwin (1963: Plates 1 and 4), and verification was based on field identification of rock types.

Aerial-photo working maps showing soil types outlined were obtained from the U.S. Soil Conservation Service, Santa Fe District,



MAP 2. The Study Area Established for the Ecology Project.

and reproduced to the same scale (1:24,000) as the topographic maps. Soil survey reports were used to determine the characteristic soils presented on Map 4 (p.50). On the aerial photos, vegetational communities (Map 5, p. 58) were outlined, with confirmation of boundaries by field identification using triangulation method and topographic maps. Acreage figures for soils and vegetation were determined by a Gelman planimeter.

Quantitative data for the phytosociological study were collected using the elb-survey (line-strip) method described by Woodin and Lindsey (1954) and Potter (1957), which uses a sampling unit of 800 by 20 feet. The 20-foot width was bisected with a steel tape measure to determine intercept distances of tree and shrub species along the line. All trees and shrubs within 10 feet of either side of the tape were recorded for density and basal area. Data on these species were collected and recorded for each 50-by-20-foot quadrat along the 800-foot elb, which extended 400 feet along one arm and an equal distance at right angles. Data for herb strata were collected by placing a 0.5-by-1-meter quadrat at 20-foot intervals along the arms of the elb. Total percentage of coverage and percentage of total cover for each species were recorded for each quadrat. The elb was shortened to 400 feet in the small acreage areas to ensure that it did not cross the mapped boundaries into the adjacent community.

Collection of flora was initiated in late June, 1972, to locate and identify native edible plant species that may have been used by the occupants of the pueblo. All plants collected were pressed and taken to the herbarium of the University of New Mexico in Albuquerque for confirmation of the tentative identifications. Field notes indicated location and abundance of each species. Identification and characteristics of edible and medicinal plants were determined from the following sources: Robbins, Harrington, and Freire-Marreco 1916; Sweet 1962; Harrington 1964, 1967; Kearney and Peebles 1969; Kirk 1970; Martin, Hutchins, and Woodmansee 1971; and communication on several occasions with family members of Mr. Francis Garcia of Santo Domingo Pueblo. Classification of native versus introduced species was determined from Kearney and Peebles 1969; Harrington 1967; Kirk 1970; and Hitchcock 1971. The collection resulted in identification of 271 species from the study area. Edible or medicinal plants account for 55 percent of the total; native edible plants make up 40 percent and native plants used medicinally 6 percent of the collection.

THE PUEBLO IN ITS ENVIRONMENT

The people who occupied Arroyo Hondo Pueblo in the fourteenth century chose for their territorial center an area within the piñon-juniper association that lies upon the Precambrian rocks of the foothills of the Sangre de Cristo Mountains and on sedimentary deposits at their southwestern base. As the earliest settlers surveyed the area from the lip of the steep-sided arroyo that crosscuts their territory, they probably saw an environment very similar to today's. To the south and west down the gently sloping alluvial plain, the piñon and juniper interfinger with a vast expanse of shortgrass plains disappearing over the horizon to the Rio Grande valley. To the south, beyond the grasslands, the Sandia Mountains loom on the horizon, and to the southwest several small, juniper-covered monzonite hills rise out of the plain. Approximately 10 miles to the west, the lava-capped La Bajada and Caja del Rio mesas lie between the Santa Fe River and the White Rock Canyon of the Rio Grande, with the Jemez Mountains forming an impressive backdrop on the horizon. To the north, a slight increase in the elevation of the plain allows the piñon and juniper to extend down the piedmont and onto the northern portion of the Caja del Rio, connecting the Sangre de Cristo range and the Jemez Mountains through a continuous expanse of woodland. Along the eastern margin of the plain, the piñon- and juniper-covered foothills of the Sangre de Cristos rise abruptly above the piedmont at the foot of the towering conifer-covered peaks of the main mountain mass (Figs. 2 and 3).

Climate and the Mountains

The Sangre de Cristo Mountains to the east and northeast of the pueblo climb to elevations of more than 13,000 feet. The proximity of this mountain mass to Arroyo Hondo has a pronounced impact on the climate, forming an effective barrier to air-mass movement. Orographic lifting caused by the Sangre de Cristos is responsible for nearly all the summer precipitation and much of the winter snow that accumulates in the area. In addition, the elevation of the mountains protects the area during winter from cold arctic air that moves down the Great Plains to the east. Occasionally this cold air spills over the mountains and brings very dry, cold weather to Arroyo Hondo, usually lasting only a few days.

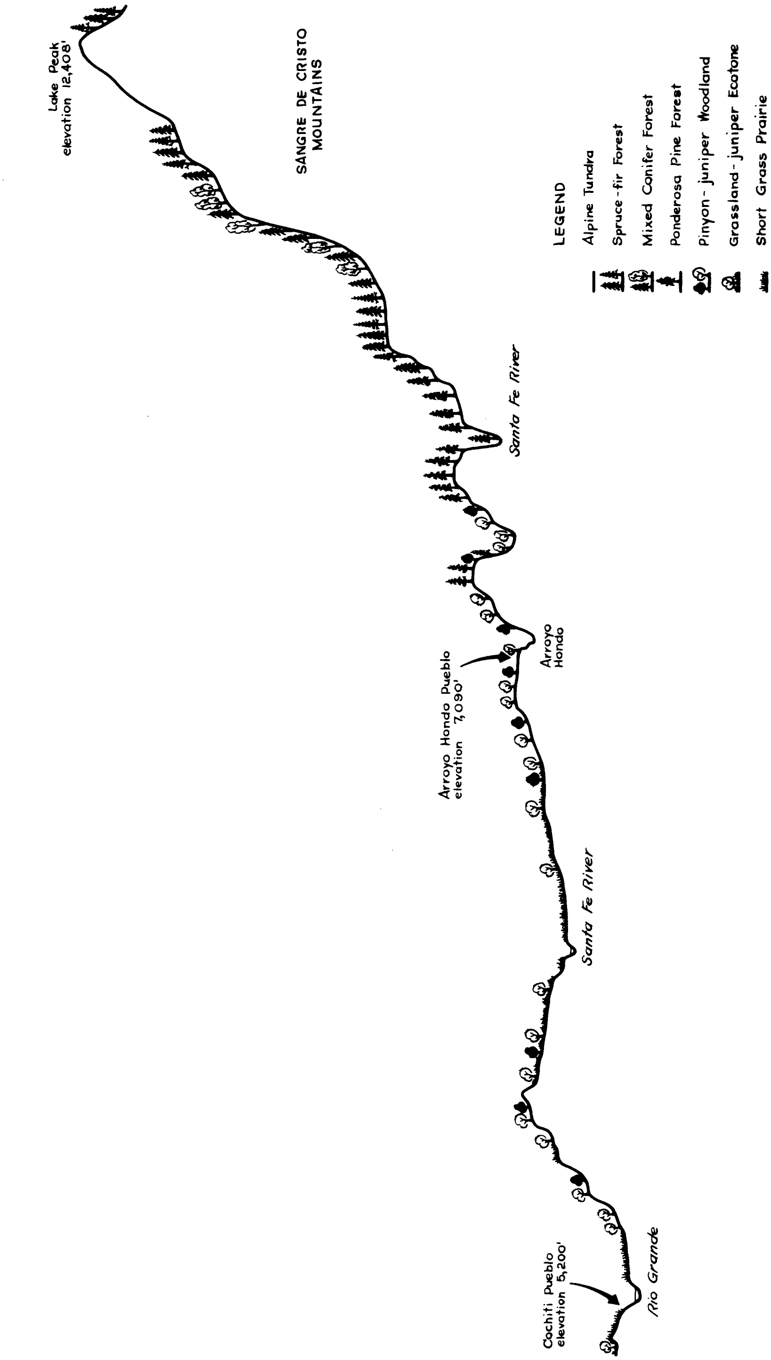


FIG. 2. Thirty-Eight Mile Transect of Vegetational Zones from the Rio Grande Valley to the Sangre de Cristo Mountains.

FIG. 3. View to the Northeast of Arroyo Hondo Pueblo, from the Piedmont through the Foothills to the Higher Peaks of the Sangre de Cristo Range.

Winter precipitation occurs when maritime polar air masses are depressed south to a storm track that crosses the Southwest and reaches the Arroyo Hondo area. Summer precipitation occurs when moist tropical maritime air from the Gulf of Mexico is thrust into the area and forced upward by the mountains. The overall climate can be characterized as semiarid, with cool summers and short, moderate winters. At the present time, precipitation is summer dominant, with a dry spring season.

Water and Agriculture

To the earliest settlers at the pueblo, perhaps the most important consideration in their choice of a village site was that Arroyo Hondo Canyon has the only permanent water supply in the area. Hydrologic features, stream-gauging-station data, and survey records suggest that Arroyo Hondo has contained a perennial stream transversing the entire territory during periods of high precipitation. In the canyon, just west of the mountain front, the Indian settlers would have found several large springs and an extensive tract of arable land upon which crops could successfully be grown (Fig. 4). The flow from these springs was obviously sufficient to meet the demands of what was ultimately a relatively large pueblo population.

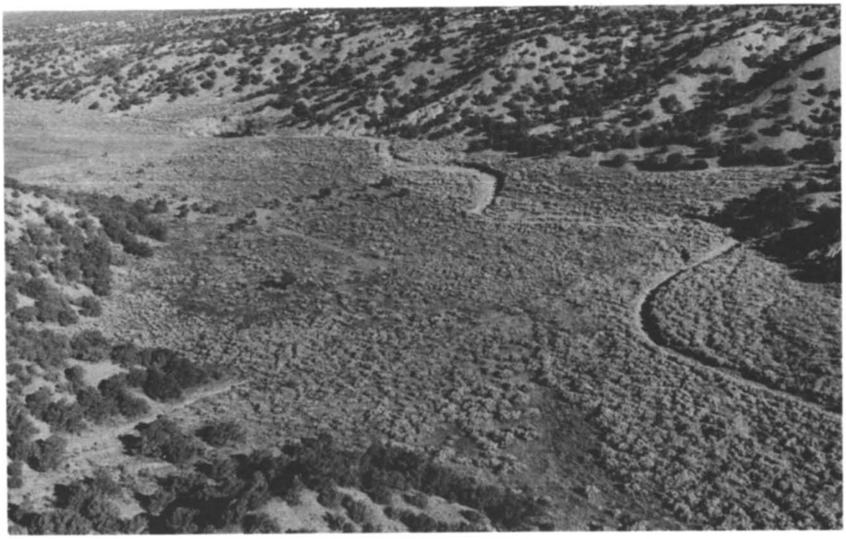


FIG. 4. The Floodplain of Arroyo Hondo about One-Half Mile West of the Pueblo.

In order to support the pueblo's peak population, the Arroyo Hondo people must have practiced agriculture fairly extensively. We know that the Arroyo Hondo area has sustained agriculture in historic times. Dry farming of corn and beans was practiced from around the 1890s until the drought of the early 1950s. Precipitation was generally above average during the 50-year period from 1896 to 1945, keeping the soil moisture high enough to support dry farming. Similar conditions of high precipitation would have been necessary during the period of maximum population at Arroyo Hondo Pueblo.

Food from the Environment

In addition to food obtained from domesticated crops, the people of Arroyo Hondo Pueblo would have drawn on edible plants and animals present in their environment. The numerous piñon pines of the area produce the major natural food for harvesting and would have provided a substantial supplement to the community's diet during the years of high nut production.

Although 47 percent of the flora native to the area are edible, such species are generally confined to highly disturbed soils and are not available in great abundance today. Under cooler, moister conditions, blue grama grass, which has sod-forming characteristics, would effectively exclude edible plant species. Cultivated fields and the eroding bottoms and sides of arroyos would have provided disturbed soils where native edible plants could be found in prehistoric times. From calculations relating agricultural land to estimated population, it can be inferred that during certain phases of Arroyo Hondo prehistory suitable habitats for wild edible plants probably exceeded 2,000 acres. That is, acreage available to local edible plants would have been limited when Arroyo Hondo's population and farmed land were small, but disturbed soil areas open to edible plant invasion during and following the period of maximum human population would have been considerably larger.

Local animal populations undoubtedly were an important source of protein and raw materials for the manufacture of clothing, tools, and ornaments. In Arroyo Hondo's predominantly wooded territory, the mule deer was probably a prime item on the prehistoric bill of fare. Although greatly reduced during the past century and a half, the deer population has recovered substantially during recent years, and deer are not uncommon today in the woodlands and forests east of Arroyo Hondo Pueblo. Westward into the woodland fringe and the grasslands, another large ungulate, the pronghorn antelope, was likely to be found, although it is now locally extinct. In addition to these larger animals, a great variety of other species would have inhabited the diverse life zones of the Arroyo Hondo sustaining area. Birds and small mammals, including the ubiquitous cottontails and hares, the still relatively abundant ground and tree squirrels, wild turkey, quail, and grouse, would have offered significant returns for hunting and trapping efforts and may have constituted a critical supplement during periods of low crop yield.

Local Architectural Materials

Secure in the knowledge that they could grow crops on the fertile terrace deposits and gather and hunt, the first settlers near the end of the thirteenth century established two communities on locations of poor soil adjacent to arable land: the Arroyo Hondo site on a level area of the piedmont overlooking the springs, and the upper Arroyo Hondo site on a gravelly rise east of the Arroyo Hondo fault and near the upper spring.

When mixed with water, the heavy clay soils of both locations made good adobe for wall, floor, and roof construction. At the lower site, bricklike andesite rock, which is exposed at the surface along the northwest periphery of the pueblo, was used in the construction of some walls. Two small quarries are apparent in this surface exposure, which may have been the source of the slabs used in a few rooms and some kiva buildings and of grinding slabs and other tools, although a more accessible source can be seen several hundred feet north in the canyon walls. At a later date, about A.D. 1370, large cobbles in the arroyo bottom and eroding out of the Ancha formation were collected for use in wall footings.

Piñon, juniper, and ponderosa pine should have been plentiful for roofing and heating materials, although a large human population presumably would eventually have placed a heavy burden on the surrounding woodland and forest associations in its quest for these resources. Archaeological data indicate that ponderosa pine was preferred for building purposes. Its common occurrence at Arroyo Hondo also suggests that this pine was growing close at hand, probably along the north-facing wall of the canyon and on shaded northern exposures of the adjacent lower foothills where a few of these trees grow today.

Tools from the Environment

The geological resources available in the Arroyo Hondo area provided its early inhabitants with a wide variety of materials that could be used in the production of tools, utensils, and ornaments. The granite and gneiss of the foothills were used for manos and metates and the andesite of the canyon for grinding slabs, choppers, hoes, and other tools. Muscovite, biotite, quartz, and other minerals associated with the Precambrian rocks were fashioned into useful and artistic forms, and the pebble cherts of the Ancha formation were collected as a raw material for knives, scrapers, drills, projectile points, and other sharp-edged implements. Along the canyon wall east and west of the site and underlying the pueblo are extensive outcrops of clay, which were probably readily accessible for pottery. Geologic specimens from more distant sources are also present at Arroyo Hondo.

The local plant and animal life represented another storehouse of useful materials. From these came the substances used in the creation of cordage, thongs, handles, bows and arrow shafts, cups, scrapers, awls and needles, flint-knapping tools, musical instruments, footgear and clothing, and feathers for adornment and blankets—to mention only portions of the limited inventory that has survived the rigors of time and the elements.

Beyond the Study Area

In the direction of the Rio Grande, an excursion from the pueblo territory down the piedmont into the shortgrass plains would have brought the early Arroyo Hondoan into contact with geologic materials and edible plants not common to the immediate village locality. These plains lie below the piñon-juniper zone, approximately 3 miles south and west of the pueblo. The flat, westward-sloping topography of the piedmont makes foot travel easy, and great distances can be covered in a day's journey. Combined hunting, gathering, and collecting of geological material would have made such trips profitable.

The monzonite hills along the southern edge of the plain about 15 miles from Arroyo Hondo Pueblo, which contain "a higher proportion of high-grade turquoise than any other deposits in the United States" (Spiegel and Baldwin 1963:82), were the source of much, if not all, of the turquoise recovered during the excavation of Arroyo Hondo Pueblo. As with the foothills, cherts and clays also occur in the shortgrass plains. Important food plants of the plains are Indian ricegrass, dropseed, sagebrush, and cactus.

A line drawn westward from the pueblo some 20 miles would cross the shortgrass plains, the lower Santa Fe River valley, and the Caja del Rio and extend into the White Rock Canyon of the Rio Grande. The escarpment of the lava-covered Caja del Rio Mesa forms the west bank of the Santa Fe River some 12 miles from the pueblo and is the closest source of the basaltic rock used for some metates, manos, and other tools recovered from the ruin. Small amounts of obsidian can be found scattered across the top of the lava mesas, but the best source is in the Jemez Mountains west of the Rio Grande. Although it is unlikely that the occupants of Arroyo Hondo had direct access to them, numerous edible plants grow in greater numbers along the mesa escarpment and in the Santa Fe River valley than in the Arroyo Hondo area. Rocky Mountain beeplants, currants, sweet clover, chenopods, and amaranth species are the major edibles to be gleaned from this area. A more plentiful supply of waterfowl also could have been hunted seasonally along the river.

The piedmont north of the pueblo is covered with piñon and juniper that extend westward across the northern part of the Caja del Rio to the Rio Grande, where the river lies adjacent to the piñon-juniper zone of the Pajarito Plateau and Jemez Mountain area. The major feature of the area north of Arroyo Hondo is the Santa Fe River, along the banks of which were located one or more contemporaneous pueblos.

Into the mountains beyond the Arroyo Hondo study area, piñon-juniper woodland extends over the foothills east and southeast of the pueblo to Glorieta Mesa. Sandstone, shales, and slate of Pennsylvanian age can be found approximately 10 miles from Arroyo Hondo in this direction, and bentonite and other clay materials not common to Arroyo Hondo occur in this area.

East and northeast of the piñon-juniper woodland at successively greater elevations lie the four zones of the Sangre de Cristos: the ponderosa pine zone, the mixed conifer association, the spruce-fir association, and the alpine tundra and meadows. This mountainous territory would have been of at least seasonal importance to the Arroyo Hondoans or other Pueblo peoples, primarily for hunting and gathering.

Access to these higher vegetation zones is provided by the drainage pattern of Arroyo Hondo. The Arroyo Hondo foothills make up a series of ridges and valleys trending north-northwest, which become progressively higher toward the main mountain mass. Arroyo Hondo cuts southwest across these valleys and ridges, forming a transverse drainage system that offers the path of least resistance for foot travel into the uppermost reaches of the Arroyo Hondo drainage.

Hunting and gathering trips to elevations of around 9,000 feet would have enabled the people of Arroyo Hondo Pueblo to exploit the plant and animal resources of both the ponderosa pine and the mixed conifer zones. Great distance from the pueblo, higher elevations and colder temperatures, and short growing seasons would have rendered the other two montane zones, the spruce-fir association (9,000–12,000 feet) and the alpine tundra and meadows (12,000 feet and higher), of less importance to the inhabitants of the pueblo than the lower zones. However, the spruce-fir association does contain several edible plant species, and much of the game that inhabits the mixed conifer zone would also be present in this zone. A much smaller number of plant and animal resources would be found in the alpine zone.

THE DANGER OF CLIMATE CHANGE

Along with its positive potentials for settlement, an occupation of the Arroyo Hondo locality by subsistence farmers in the fourteenth and fifteenth centuries also held certain important liabilities. The foothills location of the pueblo is significant in that climatic factors there are marginal at best. Arroyo Hondo Pueblo is situated at the narrowest point of the piñon-juniper zone of the Santa Fe area. Although this location possesses beneficial aspects in its potential for orographic rainfall and the ready access it affords to the resources of zones immediately lower and higher, minor climatic changes can have dramatic consequences because of the narrowness of the zone.

The area is extremely sensitive to minor fluctuations in temperature and precipitation, which determine the crop-growing season and water supply. A prolonged drying trend culminating in drought would have affected the Pueblo farmers of Arroyo Hondo essentially as it did the dry farmers in this area in the 1900s, and a series of long, cold winters would have been equally devastating. The growing season for corn is marginal at the present time, and an extension of winter conditions into the spring or the fall or both for a period of two to three weeks would drastically reduce, or possibly preclude, the harvest of cultivated crops. Late spring frost would kill young plants, and replanting would not allow time for the crops to mature. The local fauna and native flora could cushion the immediate effects of these events but could not in themselves support a relatively large human population for any length of time.

2
Physiography and Geology

PHYSIOGRAPHY

The Arroyo Hondo study area is on the eastern edge of the Rio Grande trough in the low, rolling foothills of the Sangre de Cristo range, between the eastern and western prongs of the Rocky Mountain province. Northeast of the study area the peaks of the Sangre de Cristo Mountains rise to altitudes of more than 13,000 feet. A few miles southeast the Great Plains province abuts the eastern prong of the Rocky Mountain province and the northeastern edge of the Basin and Range province (Thornbury 1965). Westward from the low foothills, an alluvial plain, or piedmont, is inclined toward the Rio Grande. Elevations within the 25-square-mile study area range from 6,650 to 8,200 feet. The surface drainage pattern is from northeast to southwest. The eastern half of the study area is a series of ridges trending north-northwest, separated by fault-formed valleys; this area will be referred to as the Foothills section. The western half, or Piedmont section, lies on the alluvial plain.

The Foothills section encompasses 42.4 percent (6,784 acres) of the study area and contains its most rugged topography. The highest peaks are along the northeastern and eastern boundaries, with elevations ranging from 7,900 to 8,200 feet. Lower hills along the western edge of the Foothills section rise to elevations of 7,200 to 7,500 feet.

The Piedmont section abuts the mountain front at approximately the 7,000-foot level to the south of Arroyo Hondo; north of Arroyo

Hondo it begins about the 7,200-foot level. This section makes up 57.6 percent (9,216 acres) of the study area. The piedmont cover, called the Plains surface, has a gradient of 140 feet per mile near the mountain front and 50 feet per mile on the western edge of the study area. Numerous arroyos dissect this surface. Downfaulting southwest of the area during the Pleistocene epoch initiated the present erosional pattern.

The center of the study area, where the ruins of Arroyo Hondo Pueblo are located, lies at a point on the eastern extension of the piedmont and along the western edge of the Arroyo Hondo fault.

GEOLOGY

The geologic history of the southern Rocky Mountains and the Rio Grande trough has been reconstructed and discussed by numerous writters (for example, Kelley and Silver 1952, Spiegel and Baldwin 1963, and Baldwin and Kottlowski 1968). A generalized outline of geologic events (Fig. 5) shows the chronological sequence beginning with the Precambrian deformations and ending with erosional processes of recent history.

The physiographic divisions of the study area (Piedmont and Foothills) also represent its two main geologic areas. The Foothills section consists of mountain peaks and foothills of Precambrian rock, the Piedmont of alluvium underlain by Tertiary volcanics, Cenozoic sediments, and Precambrian basement rock.

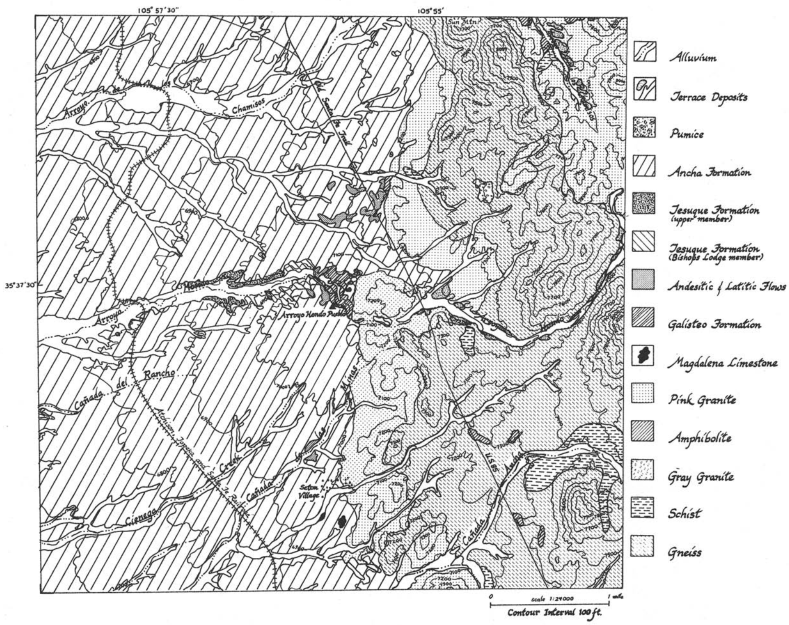
Stratigraphy

The Precambrian rocks of the Foothills section are pink and gray granite, gneiss, schist, pegmatite and aplite dikes, and amphibolite. Gneiss makes up the bulk of this half of the study area, and pink granite forms the foothills, which separate the piedmont to the west from the higher gneissic hills to the east. Outcrops of schist are scattered through this eastern section, as are smaller outcrops of amphibolite. There are only a few pegmatite and amphibolite dikes in the section and one small outcrop of gray granite in the northern part. Weathered parent and alluvial materials form a thin veneer over most of this section, allowing only small outcrops to be visible.

Era	Geologic Period	Rock Units		Geologic Events
Cenozoic era	Quaternary: Recent and Pleistocene	Eolian deposits, cover alluvium, terrace gravel		Climatic changes, successive erosion cycles with little tectonic activity.
	Pleistocene and Tertiary Pliocene	Santa Fe group	Lava flows, dikes, and pyroclastics	Sedimentation and extrusion of thin wide-spread volcanic units, masking older structure.
			Ancha formation	Severe faulting, especially at margins of Rio Grande trough.
	Pliocene and Miocene		Tesuque formation	Subsidence of Rio Grande trough accompanied by deposition of thick terrestrial basin-filling sediments derived principally from Precambrian rocks on uplifted margins.
	Miocene and Oligocene	Cieneguilla limburgite		Early states of trough subsidence and filling characterized by deposition of material derived from volcanic deposits and by local volcanic activity. Extrusion of basic flows and breccias.
	Oligocene and Eocene	Intrusions; andesite and latite flows, pyroclastics, breccia		Intrusion and extrusion of intermediate rocks.
		Galisteo formation		Development of isolated basins of deposition; sediments largely derived from Paleozoic and Mesozoic sedimentary units; moderate relief.
Paleozoic Era	Pennsylvanian	Magdalena group		Widespread marine, nonmarine deposition controlled by oscillating shorelines; generally low relief. Broad, low positive areas controlled sedimentation.
	Precambrian	Precambrian rocks		Sedimentation, intrusion, metamorphism.

FIGURE 5. Geologic Timetable for the Arroyo Hondo Study Area. Adapted from Spiegel and Baldwin (1963 : 118).

The Piedmont section of the study area has a more complex stratigraphic sequence, with Precambrian rock probably underlying the entire area. Not all of the rock units shown in Map 3 are present in the study area, but outcrops of some occur along the walls of Arroyo Hondo Canyon west of the Precambrian pink-granite foothills. Rock units visible there are the Galisteo, Tesuque, and Ancha formations, andesitic lava flow, and alluvia (eolian deposits, slope wash, and stream and terrace deposits).



MAP 3. Geologic Features in the Arroyo Hondo Study Area.

The Galisteo formation is composed of reddish siltstone, sandstone, and conglomerate with inclusions of volcanic conglomerate and andesitic tuff. This formation is exposed along its contact with the granite foothills for about 2,000 feet in Arroyo Hondo.

An andesitic lava flow is exposed for about 500 feet along the sides of Arroyo Hondo to the west of the Galisteo formation. It is a surface feature from the north wall of the canyon to the western edge and underlies a portion of the pueblo ruin.

Just west of the andesitic flow, outcroppings of the Bishop's Lodge member of the Tesuque formation, consisting of volcanic and tuffaceous sediments, sand, and sandstone, occur along the arroyo sides for a distance of approximately 2,500 feet. Then the uppermost part of the Tesuque formation, a pinkish-tan, silty-to-conglomerate sand and sandstone, can be traced along the north wall of the arroyo for approximately 6,000 feet.

The Ancha formation, which consists of silt, sand, and gravel to depths of 100 to 300 feet, overlies all others and forms many talus slopes along the canyon that hide portions of different formations on both sides of the arroyo westward from the granite foothills. It is the predominant surface feature in this section. Within the Ancha formation is a layer of pumice that has been tentatively associated with volcanic units of the Valles caldera west of the Rio Grande. The thickness of this pumice layer ranges from a few inches to 12 feet, and it is overlain by 6 to 50 feet of the Ancha formation in the Arroyo Hondo area.

Alluvial materials consisting of silt, sand, and both ancient and modern gravels are found in all the arroyos and in slope wash and terrace deposits in the study area.

Geologic Structure

The structural features of the study area are a result of deformation during the four main stages of geologic development: (1) the long and complex Precambrian prehistory, (2) the Laramide orogeny of late Mesozoic and early Cenozoic time, (3) the igneous intrusions of middle Cenozoic time, and (4) the development of the Rio Grande trough during late Cenozoic time.

The structures in the Precambrian rocks range from small-scale features of foliation and fracture cleavage to the larger features of joints, faults, dikes, veins, and breccia zones. The breccia zones are most abundant in the Precambrian granite.

There are four faults in the study area, the Chamisos, Piedras Negras, Arroyo Hondo, and Seton Village faults. The Arroyo Hondo fault is a thrust fault, but the other three are the more characteristic normal faults of the area. The Arroyo Hondo fault is exposed in the Arroyo Hondo Canyon, 600 yards west of Interstate Highway 25. The fault strikes N45°W and dips 26° with downward displacement on the west side. Spiegel and Baldwin (1963: 70–72) believe that this fault fixed the position of Arroyo Hondo. Associated with the Arroyo Hondo fault is a series of springs that produce an intermittent stream, the only stream in the study area.

The Seton Village fault lies parallel to and southwest of the Arroyo Hondo fault and is believed to be the western margin of Precambrian exposures. The Piedras Negras fault is northeast of the Arroyo Hondo fault and converges toward it in the north-central section of the study area. The Piedras Negras and Arroyo Hondo faults form the sides of an uplifted block, or horst, which causes the Precambrian rocks to extend northwestward from Arroyo Hondo. These faults explain most of the offset of the mountain front at the Santa Fe River.

The Ancha formation covers the structural features in the western half of the study area. Spiegel and Baldwin (1963:74) say that geophysical evidence was used to determine the structure of the sub-Ancha rocks but that this is largely unsupported by geologic data. It is believed that much of the material that predated the Santa Fe group was thinned or removed completely by erosion during the early stages of the Rio Grande trough subsidence. Outcrops of pre–Santa Fe units within the study area are small and relatively unimportant, with the exception of Galisteo formation outcrops.

The Tesuque and Ancha formations of the Santa Fe group are the most significant units in the study area because of their importance to the hydrologic cycle. Their relative thickness and thinness determine, to a great degree, the amount and depth of groundwater.

3
Hydrology

The hydrologic cycle is concerned with the transportation of water by the air, over the ground surface, and through the earth's strata (Wisler and Brater 1949). This ecological study is concerned with that portion of the atmospheric water that reaches the earth's surface and becomes either surface runoff or groundwater (Fig. 6).

SURFACE WATER

Surface runoff occurs when the infiltration capacity of the surface materials is exceeded or when the permeable zone becomes completely saturated. Rapid runoff from intense summer thunderstorms is a result of the former, and spring runoff from melting snow is associated with the latter (Spiegel and Baldwin 1963:157). The amount of any runoff during the summer months is determined largely by the duration and intensity of individual thunderstorms. The total winter and spring runoff is determined mostly by the snowpack depth and its melting rate. The yearly amount of runoff is further determined by (1) the size, shape, altitude, and topography of the drainage basin; (2) distribution of precipitation and direction of storm movement over the basin; and (3) the soil type, including the depth of appreciable permeability and the residual moisture content of the substratum (Wisler and Brater 1949).

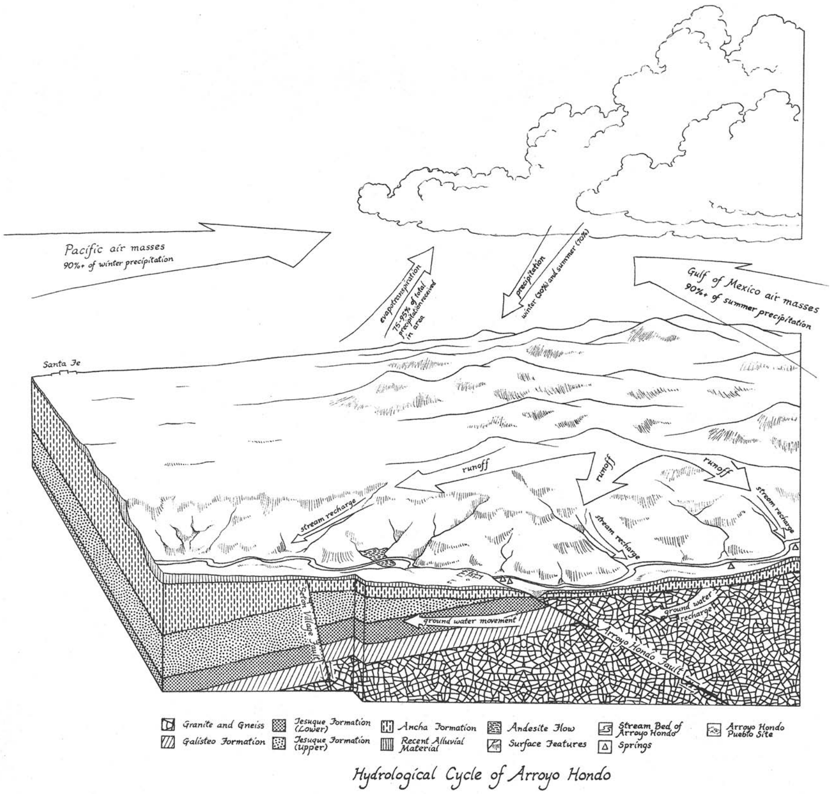


FIG. 6. Hydrologic Cycle of the Santa Fe Area.

Surface runoff that originates within the study area is predominantly from summer thunderstorms. Winter snow accumulations are usually insufficient to produce any appreciable winter or spring runoff from within these boundaries. The runoff from the study area flows toward the Rio Grande in the main arroyos. The major runoff through the area occurs from precipitation received in the northeast by the headwaters of the Arroyo Hondo. This is the only arroyo with a permanent water supply in the study area and is thus the most important of the hydrologic features. The headwater area has an average elevation of 8,200 feet and encompasses 6.7 square miles. A gauging station that was operated on the Arroyo Hondo from 1913 to 1922 recorded the average flow from the basin as 535 acre feet per year (Spiegel and Baldwin 1963). The runoff through the Arroyo Hondo fluctuates greatly from year to year. Winters that allow a large snowpack to accumulate within the Arroyo Hondo headwaters will obviously produce a larger and more continuous streamflow than runoff during an average year. Years with below-normal winter precipitation may not produce any surface runoff.

GROUNDWATER

That portion of precipitation not lost through evapotranspiration and surface runoff becomes the groundwater increment. Groundwater movement through the study area basically parallels the northeast-to-southwest surface drainage pattern. The principal aquifers of the foothills are the Precambrian rocks and recent valley alluvium. The valley alluvium and the Tesuque and Ancha formations are the piedmont aquifers.

The Precambrian crystalline rocks of the foothills and mountains have a small unit capacity for water storage but are the most important natural water source in the study area. The precipitation that infiltrates these rocks emerges as springs along the Arroyo Hondo, and these provide the base flow of the interrupted stream along the floor of the canyon.

A major period of arroyo downcutting began during the late 1800s in the Southwest and has continued to the present (Hastings and Turner 1965). The channel fill of the piedmont may have been deepened during this period. Trauger (1972:15) states that the small springs and streams went dry in Grant County, New Mexico, between 1886 and 1901. It is probable that during this period the Arroyo Hondo streamflow was also greatly reduced. The stream in the canyon now flows where the less permeable and less easily eroded Precambrian rocks and Galisteo formation lie at the surface. In the deep alluvial material, the stream flows underground. Where Arroyo

Hondo enters the Piedmont section, the stream disappears completely into the alluvial fill and flows at the surface only during periods of heavy runoff. In contrast, White (1880) recorded a stream in Arroyo Hondo 1 foot wide and 1 inch deep, 3.5 miles west of where the present surface flow becomes an underflow. The 6-year precipitation average preceding White's 1880 notation was slightly more than 16 inches.

The winter snowpack of 1972–73 in the Arroyo Hondo basin was sufficient to maintain a stream in the canyon until early July. The stream was flowing about 20 feet wide and 6 inches deep some 3 miles west of the usually dry stretch of the piedmont portion of the canyon. The snowfall depth was undoubtedly greater in the higher portions of the basin than at the pueblo's 7,000-foot elevation.

The precipitation and streamflow records of Arroyo Hondo indicate that the present precipitation average of 14 inches is insufficient to maintain a permanent stream in the Piedmont section of the canyon. When the precipitation averages 16 inches for 3 years, streamflow is maintained for at least 3 miles down the piedmont.

Irrigation wells along the Arroyo Hondo near the western boundary of the study area provided evidence that the underflow is 10 to 20 feet below the present stream bed. One well, located in terrace deposits in the Arroyo Hondo, has a water table at 18 feet below the surface. A second well, 18 feet higher in elevation and a few hundred yards north of the arroyo channel and beyond the terrace deposits, has a depth of 187 feet to the water table. Other wells south of Arroyo Hondo also have water tables 180 to 200 feet lower than that of the arroyo's channel (Spiegel and Baldwin 1963). This indicates that the arroyo's underground stream flows through the western half of the canyon via local gravel deposits on top of a relatively impermeable substratum.

The relatively impermeable Bishop's Lodge member of the Tesuque formation dips southwest at 9° and underlies the Arroyo Hondo stream bed westward from the fault zone for approximately 1 mile. At this point, the more permeable upper member of the Tesuque formation becomes the immediate substratum for the stream bed. This upper member is one of the most important aquifers west of the study area (see Fig. 6).

The upper member of the Tesuque formation and the Ancha formation play an important part in groundwater recharge from precipitation received within the study area. This groundwater surfaces as springs near Cienega and Cieneguita, several miles west of the study area (Spiegel and Baldwin 1963). The Tesuque and Ancha formations are the main aquifers for groundwater movement through the Piedmont section. Although they contain a large amount of groundwater and provide a good water source for small wells, they have no potential to produce springs within the area. Thus, the larger portion of surface runoff originates in the foothills to the east. The perennial springs that emerge in Arroyo Hondo adjacent to the pueblo ruin also rely on the foothills groundwater as a continuous supply. The amount of surface-water flow supplied by these springs fluctuates in relation to the amount of precipitation received in the Arroyo Hondo basin. The spring flow is less during drought periods and would have an impact upon the amount of water available for irrigation.

4

Climate

"Climate" is the sum total of the weather experienced at a place in the course of a year and over the years. The local conditions are discussed here in terms of (1) the averages of precipitation, temperature, humidity, winds, and growing season, and (2) the local anomalies, or seasonal variations, which are under regional or hemispheric influences. The proximity of the study area to the city of Santa Fe allowed the use of the city's climatological data. The center of the study area, 4.5 miles southeast of the Santa Fe Plaza, lies at the same 7,000-foot elevation.

PRECIPITATION

The orientation and altitude of the mountain ranges surrounding the study area, and its interior continental location, give it a semiarid climate (Bsk in the Köppen climate classification system; Trewartha 1968). Haurwitz and Austin (1944:143) state that the Bsk climates "owe their origin to their position in the interior of the continents where any air arriving from the oceans has already become rather dry." The two major sources of precipitable moisture for the Santa Fe area are the Pacific Ocean to the west and the Gulf of Mexico to the southeast. Trewartha (1968:384) says of type B (Bsk) climates: "In both Eurasia and North America, the aridity of the deep continental interiors is further intensified by highlands which surround extensive regions in the interior and act to block the entrance of humid maritime air masses and rain-producing storms."

Lying between the study area and the Pacific ocean are several high mountain chains (the Sierra Nevada and Cascade ranges) and plateaus (the Colorado Plateau and smaller plateaus within the Basin and Range province), which modify and dry out the air masses moving from the Pacific. Air masses from the Gulf of Mexico are not so highly modified upon reaching the Santa Fe area but still are relatively dry. These two air masses are seasonal in dominance; summer precipitation originates in the Gulf of Mexico, and winter moisture arrives from the Pacific Ocean.

The Gulf of Mexico air masses produce 70 percent of the total annual precipitation for the Santa Fe area. Stressing the significance of tropical maritime (mT) masses, Trewartha (1968:184) says, "in the southwestern United States, warm-season thunderstorms appear to be related to westward thrusts of mT-Gulf air aloft . . . . They are usually localized with respect to mountain masses." These westward thrusts of tropical maritime air masses, plus orographic lifting caused by the Sangre de Cristo Mountains, are responsible for nearly all the summer precipitation within the study area. A thermal low over the Southwest permits a gradient that facilitates easier movement of these thrusts into the area. Most of this precipitation is from thunderstorms; their frequency in this area is second only to that of Florida in the continental United States.

Moisture that produces winter precipitation is brought into the Southwest by eastward-moving low-pressure cells that originate in the northern Pacific. This maritime polar air mass is a relatively mild, moist, convectively unstable air mass upon reaching the West Coast, but by the time it reaches Santa Fe, it has become a relatively dry, cold, stable air mass. Precipitation occurs only when favorable conditions exist:

> As this humid, unstable air advances inland, its shower activity is greatly increased when it is forced to ascend over the cooler land air along the coast and also over the coastal ranges. Rain in the lowlands and heavy snowfall in the mountains are characteristic of the winter season. . . . As the maritime air continues inland over successive mountain ranges and plateaus of the intermontane region, the cold land lowers the air's surface temperature, while condensation on the highlands causes the low levels of the air mass to become drier. (Trewartha 1968:180)

Precipitation from both orographic and frontal lifting occurs during the winter in the Santa Fe area. Orographic uplift will produce prodigious amounts of snow on the highest peaks of the mountains, with diminishing amounts toward the valleys. Frontal lifting produces the larger accumulations of snow in the lower, nonmountainous area (Strahler 1967).

Generally, the area's dominant air mass is cool, dry Pacific air that usually has become stable and brings relatively mild temperatures and clear skies during the winter months. Occasionally, cold arctic air from the Canadian interior, Alaska, or the frozen Arctic Sea spills over the mountains from the east and brings very cold temperatures to the area, but usually this lasts only a few days. Gulf air rarely moves into the area during midwinter, but thrusts do occur in early winter and early spring, putting moist, warm air in contact with the cooler air from the Pacific. This frontal system may produce precipitation in the form of rain or snow during these times.

The yearly and monthly precipitation averages present an incomplete picture of the actual precipitation regime for the area because monthly averages do not indicate that any one storm can exceed the precipitation average for any month of the year (Table 1). Summer precipitation is less predictable than winter precipitation (Table 2); likewise, a yearly precipitation figure is not predictable from the average. The 14.40-inch yearly average does not indicate that a series of years may occur with above- or below-average precipitation, nor does it indicate the period of time over which these conditions can prevail. One 7-year period, 1950 through 1956, had below-average precipitation (6.68 to 14.06 inches annually), with the average for this period being 10.77 inches per year.

The cumulative departure graph (Fig. 7) better illustrates the conditions just described. This graph presents the annual precipitation by water year (October 1 through September 30) and the cumulative departure in percentage from the average precipitation at Santa Fe since 1868. It indicates cycles of increasing or decreasing precipitation during this 103-year period.

The precipitation pattern between 1895 and 1950 is of interest to this study because the precipitation average (14.30 inches) during this period was sufficent to allow dry farming of corn and beans. This 55-year span had periods of 4 to 6 years with below-average

TABLE 1.
Precipitation Data, Santa Fe Area (1850–1970)

	Precipitation (inches)							Snowfall (inches)		
Month	Average	Greatest	Year	Least	Year	Greatest in 24 hrs	Year	Average	Greatest	Year
January	0.66	3.02	1916	0.00	1853[a]	1.22	1892	7.4	27.3	1916
February	0.75	5.20	1865	0.01	1869	0.82	1928	6.6	18.7	1911
March	0.82	2.59	1856	0.00	1863	1.21	1940	5.0	18.2	1946
April	0.95	4.82	1950	0.00	1853	1.36	1916	2.4	13.2	1916
May	1.34	5.58	1929	0.00	1859[a]	2.47	1948	0.5	4.9	1935
June	1.07	4.38	1949	0.01	1939	2.15	1927	0.0	0.0	
July	2.45	7.45	1853	0.40	1951	2.83	1953	0.0	0.0	
August	2.28	7.89	1855	0.36	1899	1.67	1932	0.0	0.0	
September	1.51	5.38	1855	0.00	1861	2.83	1929	0.2	4.0	1936
October	1.16	4.19	1881	0.00	1865	1.83	1911	0.2	12.8	1906
November	0.68	3.54	1854	0.00	1860	1.29	1905	3.1	14.8	1908
December	0.73	2.27	1885	0.00	1871	0.95	1960	6.3	20.0	1924
Year	14.40	24.80	1854	5.03	1917	2.83	1929[a]	31.7	27.3	1916

[a]Record occurred more than one year.

TABLE 2.
Deviations from the Mean Monthly and Annual Precipitation ($\overline{Y}$) for a 30-Year Period (1931–61)in the Santa Fe Area. Figures in matrix indicate number of years in which a given month showed a particular deviation.

	Deviations (by 1.0 inch)[a]																				
Month	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	$\overline{Y}$	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
January									4	7	11	6	2								
February										12	11	5	1	1							
March									4	8	8	5	5								
April									3	12	7	6	1	0	0	0	0	1			
May								5	5	4	8	3	1	2	1	1					
June								3	6	7	5	3	2	2	0	1	1				
July								8	2	3	6	2	3	3	1	0	2				
August								2	6	6	7	3	2	4							
September								4	3	7	7	2	3	2	1	0	1				
October									6	9	8	1	1	3	2						
November									7	6	7	7	3								
December									1	9	12	6	1	1							
Annual	1	1	1	1	1	2	1	0	4	2	2	1	1	4	3	1	0	0	2	1	1

[a]Deviations are by 0.5 on each side of the class marks above.

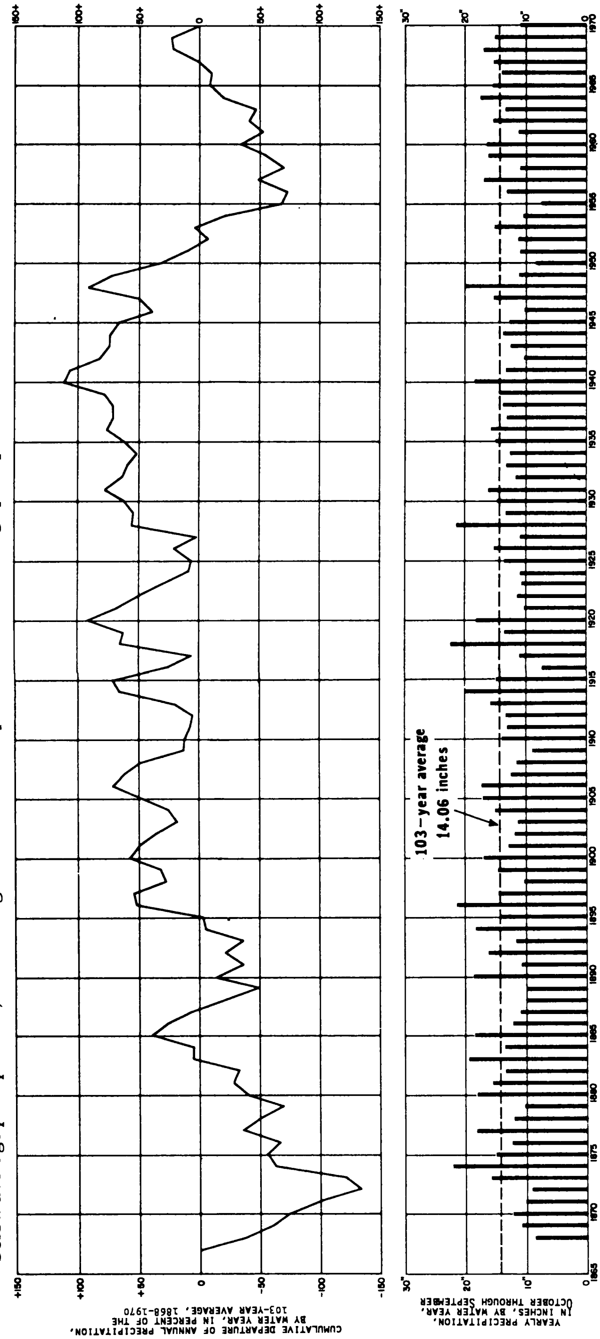


FIG. 7. Precipitation by Water Year at Santa Fe and Cumulative Departure of Annual Precipitation for the 103-Year Period 1868–1970. A horizontal trend indicates a period of approximately average precipitation; a downward trend from left to right indicates a period of below average precipitation; and a rising trend indicates a period of above average precipitation.

precipitation, but evidently they were not severe enough to discourage dry farming in the area. Since 1950, precipitation and soil moisture have declined, and the only crop raised has been wheat (Folks 1968). Dry farming in the Arroyo Hondo area was successful during a period with a "world-wide regime of strengthened atmospheric circulation" (Lamb 1972:259).

A period of declining precipitation began in 1941 and continued through 1956, with a brief (2-year) period of above-average precipitation. The 10-year period 1947–56 has a precipitation average of 12.03 inches per year. Dry farming of corn and beans was halted in the early 1950s, and this fact indicates that a drought lasting 9 or 10 years can prevent successful dry farming. Schulman (1956:67) believes that the 1955 drought was the most severe since that of the late 1200s. Trauger (1972:15,16) found that similar conditions prevailed in Grant County, in southwestern New Mexico, during this period. The drought of the 1950s was accompanied by a worldwide weakening of the atmospheric circulation (Lamb 1972:262).

Considering the precipitation averages during periods of dry farming and the droughts of the late 1800s and early 1950s, it appears that if annual precipitation is more than 14 inches, dry farming can be successful. However, if annual precipitation drops below 14 inches, dry farming is precarious or impossible. Precipitation of less than 13 inches a year constitutes near-drought or drought conditions, under which complete crop failures would be common.

TEMPERATURE

The Arroyo Hondo area lies in a zone that receives large amounts of solar radiation throughout the year. Maps of solar radiation received at the earth's surface indicate that between 700 and 750 gm cal per cm^2 (gram calories per square centimeter) per day are received in this vicinity during June and 250–300 gm cal per cm^2 per day during December (Trewartha 1968:24). This is due to latitudinal location, high number of days with clear skies (Table 3), and altitude. As Haurwitz and Austin explain:

> Only the distribution of the cloudiness explains why the maximum radiation reaching the earth's surface is at 30° and 40°

TABLE 3.
Precipitation, Clouds, and Wind in the Santa Fe Area

	Precipitation (average number of days of occurrence)					*Cloud Cover (average number of days of occurrence)*				*Wind (velocities and direction)*			
Month	Thunderstorms	Rain (.01" +)	Rain (.10" +)	Rain (.25" +)	Snow (trace +)	Clear	Partly Cloudy	Cloudy	Dense Fog	Avg. Vel. (mph)	Prevailing Direction	Highest mph	Direction (highest velocities)
January	0	6	2	1	6	17	9	5	-	6.9	NE	35	NW
February	0	7	2	1	6	13	9	6	-	7.2	N	38	W
March	1	7	2	1	5	14	11	6	-	7.9	SW	40	E
April	2	6	2	1	3	13	12	5	0	8.2	SW	41	SW
May	7	7	3	2	1	14	13	4	0	8.0	SW	41	SW
June	10	6	3	1	0	16	12	2	0	7.2	SW	38	N
July	19	13	6	3	0	9	18	4	0	6.3	SE	36	W
August	16	12	6	3	0	10	17	4	-	5.9	SE	32	E
September	7	8	4	2	0	16	10	4	-	6.0	SE	37	N
October	2	5	3	1	1	19	8	4	-	6.5	SE	42	SE
November	0	5	2	1	2	18	8	4	-	6.7	N	41	SE
December	0	6	2	1	5	17	9	5	1	6.7	N	37	SW
Yearly	64	88	37	18	29	176	136	53	1	6.9	SE	42	SE

> latitude. This latitude zone is in summer the region of the subtropical high-pressure belt where the cloudiness is small, owing to the atmospheric subsidence . . . . there is definite increase of the solar radiation with altitude since the amount of air through which the sun's rays have to pass decreases with elevation. (1944:12)

The large amount of solar radiation received in the study area has a greater effect on winter temperatures than on summer temperatures. G. F. Von Eschen, state climatologist, wrote in "The Climate of Santa Fe, New Mexico" (1960):

> Winters are crisp, clear, and sunny. Because of the predominantly clear winter weather, there is considerable daytime warming with shade temperatures normally reaching the low 40's at midday. An average winter includes no more than 13 days when the temperature fails to get above freezing. Winter nights are usually cold, for the temperature falls below the freezing mark most nights from early November to mid-April, and a below-zero reading can be expected about every other year.

Cold nighttime temperatures are the result of a loss of long-wave radiation.

During the summer months, temperatures above 90°F rarely occur, although this area receives high solar radiation. The cloud cover that occurs with high frequency in conjunction with afternoon thundershowers reflects a large amount of solar radiation, thus reducing the amount of insolation (receipt of solar radiation energy by the earth) at the ground surface. This factor and the 7,000-foot elevation combine to produce pleasant summer weather for the Santa Fe area, as described by Von Eschen: "In midsummer, the high temperature is normally in the low 80's, with an average of only seven days a year when the maximum temperature reaches 90°. . . . Summer nights are cool, with the temperatures usually falling to the mid-50's before morning" (1960:57).

Table 4 presents the average temperatures and the record highs and lows for the Santa Fe area, and Table 5 indicates the departures from the means. The means give an incomplete picture of the actual temperatures of Santa Fe; the annual mean and the monthly means for the summer have greater reliability than do the means for the winter temperatures. This phenomenon is in inverse reliability to the precipitation means, as seen by comparing Tables 2 and 5.

TABLE 4.
Temperature Data, Santa Fe Area (1874–1960)

	Temperatures (°F)				Record Temperatures (°F)			
Month	*Average*	*Daily max.*	*Daily min.*	*Range*	*High*	*Year*	*Low*	*Year*
January	29.9	41.0	19.3	21.7	76	1875	−13	1883
February	33.7	44.9	22.5	22.4	75[a]	1879	−15	1951
March	39.2	51.6	26.8	24.8	82	1879	− 2	1922[a]
April	48.0	61.7	34.5	27.2	85	1943	3	1945
May	56.6	70.7	42.9	27.8	89[a]	1872	20	1909
June	66.4	81.4	52.1	29.3	98	1954	33	1877[a]
July	70.4	84.3	56.7	27.6	98	1947	42	1950
August	68.6	82.2	55.0	27.2	97	1878	40	1882
September	62.9	76.5	49.1	27.4	93	1948	21	1918
October	52.0	65.2	38.7	26.5	85	1878	13	1906
November	39.0	51.5	26.5	25.0	77	1878	−11	1880
December	32.0	43.3	21.2	22.1	65	1878	−13	1879
Yearly	50.0	62.9	37.1	25.8	98	1947[a]	−15	1951

[a]Record occurred more than one year.

TABLE 5.
Deviations from the Mean Monthly and Annual Temperature ($\overline{Y}$) for a 30-Year Period (1931–1961) in the Santa Fe Area. Figures in matrix indicate number of years in which a given month showed a particular deviation.

	Deviations (by 1.0°F)																				
Month	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	$\overline{Y}$	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
January				2	1	0	1	3	1	4	4	1	4	2	4	2	1				
February	1	0	0	1	1	1	0	3	2	3	4	2	4	1	3	1	2	1			
March						2	1	2	4	2	5	1	9	3	0	1					
April						1	2	3	2	4	9	3	1	2	0	0	2	1			
May					1	1	1	2	1	7	3	5	5	2	1	1					
June					1	0	0	4	3	6	4	3	4	2	2	1					
July								2	1	10	7	6	2	1	1						
August									6	7	6	6	4	1							
September							1	2	4	6	2	10	2	3							
October						1	0	2	8	3	4	3	4	2	1	0	0	1			
November						3	2	3	1	3	2	5	5	2	2	0	2				
December			1	1	0	2	4	2	0	3	0	4	4	4	0	4	1				
Annual									2	7	14	5	1	1							

HUMIDITY

The relative humidity averages around 50 percent for the year. The 7,000-foot elevation and cool temperatures make the relative humidity somewhat higher than might be expected for this location. The relative humidities are lowest during the summer rainy season and highest during the winter months with the least precipitation. This apparent anomaly is explained by the inverse relationship between air temperature and specific humidity, or the weight of water vapor held by a given air mass at a given temperature.

> Not only does the capacity [of the air for water vapor] increase at higher temperatures, but it increases at an increasing rate. . . . Thus a 10°C increase from 0° to 10° advances the capacity only 4.6 g, but an equivalent increase of 10°C from 25° to 35° results in an increased capacity of 16.6 g, or three to four times as much. Obviously warm summer air is able to contain more moisture than cold winter air. (Trewartha 1968:127-28)

Therefore, even though a summer air mass may contain more water vapor than a winter air mass, the latter generally would have a higher relative humidity.

Even with the average relative humidity of approximately 50 percent, the evapotranspiration rate is very high: "An estimated 75–95 percent of the precipitation, varying inversely with the altitude, is returned to the atmosphere by evapotranspiration in the area; and the remaining 5–25 percent becomes surface-water and groundwater available for use in the Santa Fe area" (Spiegel and Baldwin 1963:102). This large evapotranspiration loss is credited to spring winds and, in part, to the high solar radiation value: "The sun shines in Santa Fe 75 percent of the possible hours, with this percentage fairly constant throughout the year" (Von Eschen 1960).

WINDS

The predominant wind directions and velocities vary from season to season. Spring (March through June) is the windiest period, with average velocities of 7.2 to 8.2 miles per hour (mph), predominantly from the southwest. In summer (July through October), the prevailing winds are from the southeast, with average velocities between 5.9 and 6.5 mph. In winter, the direction reverses and the prevailing winds have a northerly component with average speeds of 6.7 to 7.2 mph (Table 3). The predominant wind direction appears to be controlled to some degree by the surrounding mountains (Von Eschen 1954). Winds speeds average about 7 mph annually. Strong winds (with velocities exceeding 25 mph for a short time) occur approximately 60 days per year (Von Eschen 1960). Wind speeds and temperature play important roles in determining the evapotranspiration rate.

GROWING SEASON

The frost-free period for the Arroyo Hondo area averages about 165 days per year. The last spring frost can be expected during the first week of May and the first fall frost usually about the middle of October (U.S. Department of Agriculture 1941). Although the growing season is relatively short, the overall climate allows successful farming (Tinsley 1909).

EXTREMES AND VARIATIONS

The present climate of Arroyo Hondo can be summarized as having mild winter and summer temperatures, with spring drought and summer-dominant precipitation. Climate, however, "comprises not only those conditions that can obviously be described as 'near average' or 'normal' but also the extremes and all the variations" (Lamb 1972:5). The average conditions have been described in the preceding pages; attention will be given here to a few of the extremes and variations that occur in the Arroyo Hondo area.

Winter

Extremely cold, dry winter weather occurs rather infrequently in the Arroyo Hondo area, but when it does, it is associated with polar outbreaks of arctic air. The cold air originates in high-pressure centers located over the "snow and ice-covered areas of interior Canada north of about latitude 50° or 55°, as well as over Alaska and the frozen Arctic seas. It enters the United States from Canada, usually between the Rocky Mountains and the Great Lakes" (Trewartha 1968:175). When this cold arctic air moves southward down the Great Plains to the southern end of the Rocky Mountains, it may spill over into the Rio Grande valley, bringing unusually cold temperatures to the entire area.

Figure 8 illustrates conditions that brought extremely cold, dry weather to the Arroyo Hondo area in January, 1971, when extreme temperatures reached −20°F and below-zero readings continued for more than a week. The entire north-central Rio Grande valley experienced extremely cold temperatures, with the lower elevations recording temperatures only a few degrees warmer than Arroyo Hondo.

The frequency with which these polar outbreaks reach the Arroyo Hondo area greatly influences the severity of the winter climate. If these polar outbreaks were persistent and regular, the area would probably experience longer, drier, and colder winters than at present.

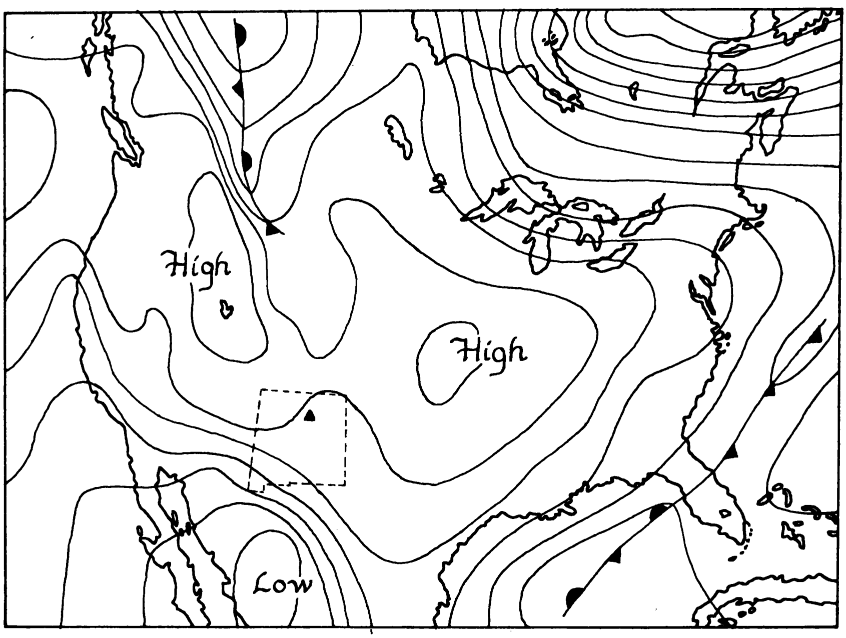


FIG. 8. Surface Weather Map for January 6, 1971 (after U.S. Department of Commerce daily weather map).

The Arroyo Hondo area generally does not receive large amounts of winter precipitation. Periodically the area receives a one-day snowfall of 10 inches or more, but this does not occur every winter. The total amount of winter precipitation received at Arroyo Hondo depends upon the frequency with which Pacific-originated low-pressure cells cross the area, an event that occurs when a high-pressure system dominates the northwest coast, forcing the eastward-moving lows to a more southerly position (Fig. 9). Numerous low-pressure cells cross the Arroyo Hondo area during the winter, but some of them contain enough moisture to produce precipitation only when lifted either orographically or in frontal systems. As explained previously, the orographic precipitation produces greater snowfall at higher elevations, and frontal storms produce the larger accumulations at lower elevations. Figure 9 illustrates the conditions that produced more than 5 inches of snow at Arroyo Hondo in January, 1973. When the frequency of the low-pressure systems transversing Arroyo Hondo increases, so does the probability

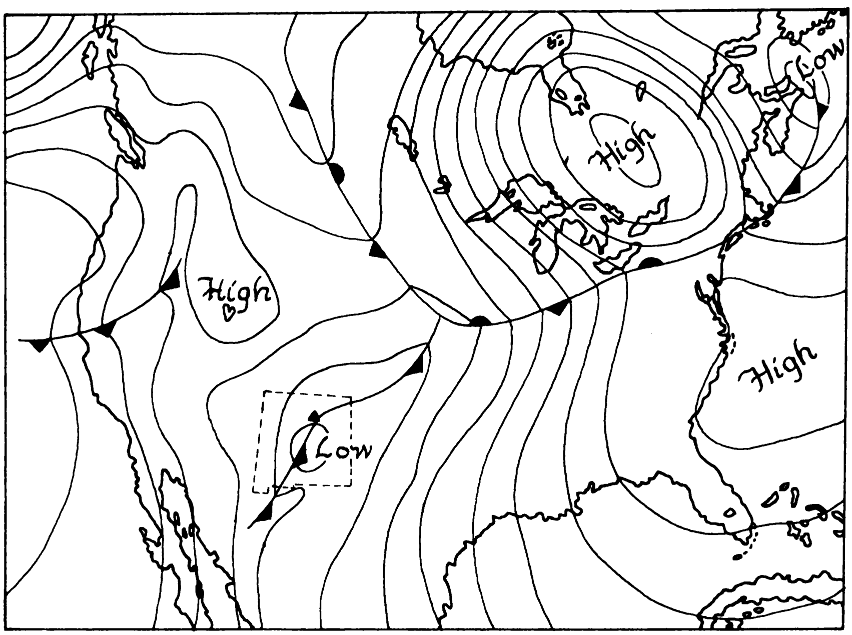


FIG. 9. Surface Weather Map for January 31, 1973 (after U.S. Department of Commerce daily weather map).

of orographic and frontal-system storms. An increase in winter storms would give Arroyo Hondo cooler and wetter winters than at present.

Warm, dry conditions prevail during winter periods when the Southwest is dominated by high-pressure systems. The high-pressure system illustrated in Figure 10 keeps the low-pressure storm track far north of Arroyo Hondo.

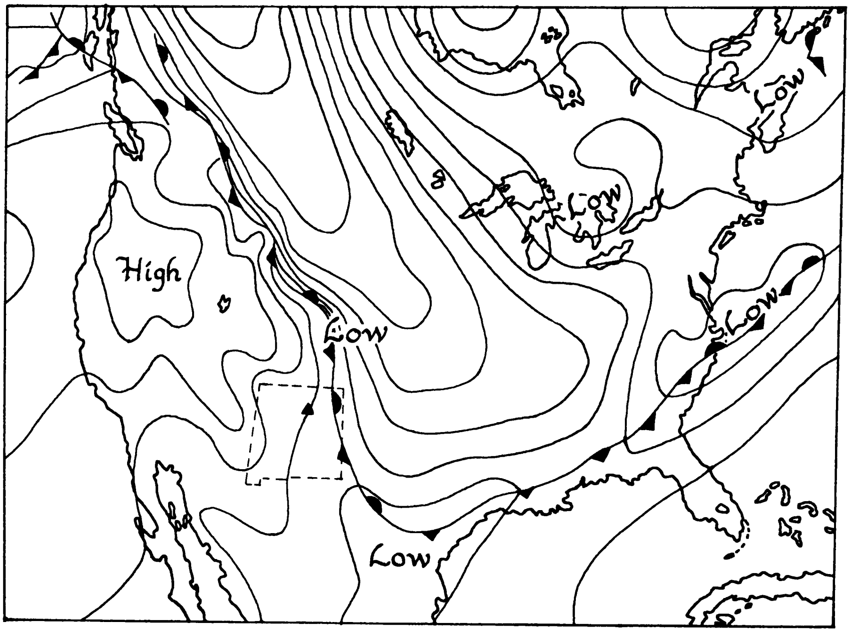


FIG. 10. Surface Weather Map for January 31, 1971 (after U.S. Department of Commerce daily weather map).

Summer

Variability in location and strength is characteristic of the high- and low-pressure systems during the warm and cold seasons of the year. During the summer, the Pacific and Gulf of Mexico high-pressure systems become larger and advance to more northern positions, where they become the dominant climatic factors affecting the Arroyo Hondo area.

The Pacific high, when it is large and well developed, extends inland and lies above the relatively persistent thermal low of the arid Southwest. The downward motion of the air from the eastern side of the high pressure aloft prevents lifting of the surface air to altitudes sufficient to produce precipitation. The Arroyo Hondo area experiences clear skies and high temperatures when the Pacific high is dominant. These conditions can be seen in Figure 11, which depicts a clear day in July, 1971, on which temperatures reached 100° at Arroyo Hondo.

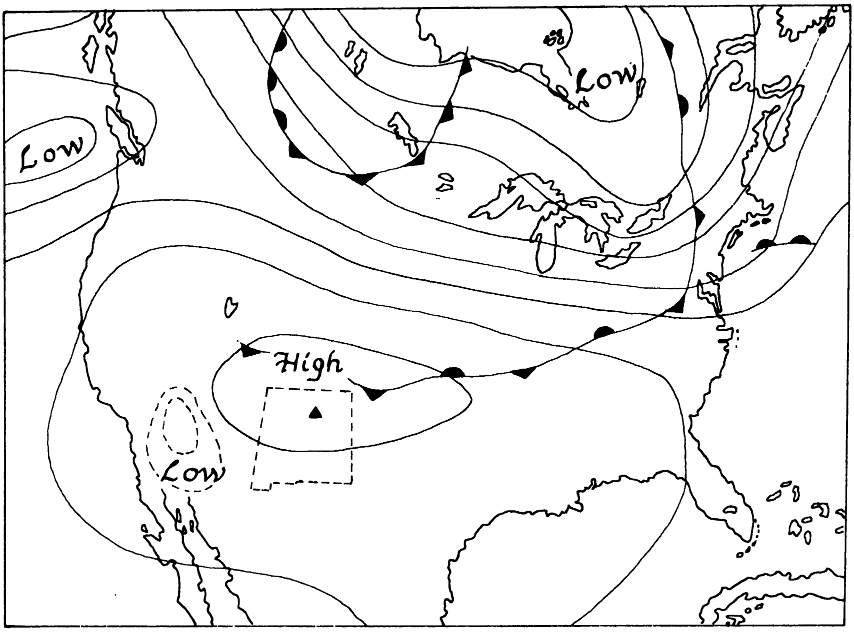


FIG. 11. Five-Hundred-Millibar Weather Map for July 14, 1971 (after U.S. Department of Commerce daily weather map). Fronts and dashed lines are surface weather.

In the Northern Hemisphere, air from the western side of a high-pressure system can be lifted slightly more easily than air from the eastern side. The air from the Gulf of Mexico comes from the western side of a high-pressure system and then is forced to rise 7,000 feet as it is thrust across the land surface between the Gulf and the Arroyo Hondo area. As the air rises it cools, so that its moisture-holding capacity is reduced. The thermal low, when present over the Southwest, facilitates easier movement of these thrusts into the area in the lower layer of the atmosphere. When this air reaches the Arroyo Hondo area it is still relatively dry, but it has the potential to produce precipitation if lifted sufficiently. Generally, it must be lifted to greater altitudes than allowed by the Pacific high pressure aloft. Thus, the frequency of thunderstorm activity is greatest when the Pacific high aloft is weak or nonexistent. Most of the summer precipitation is from thunderstorms. Figure 12 indicates the development and thrust of Gulf air into the Southwest and the Arroyo Hondo area. The conditions presented in this figure produced widespread thunderstorms in New Mexico, with Arroyo Hondo receiving approximately 0.75 inch of rain on an August day in 1972.

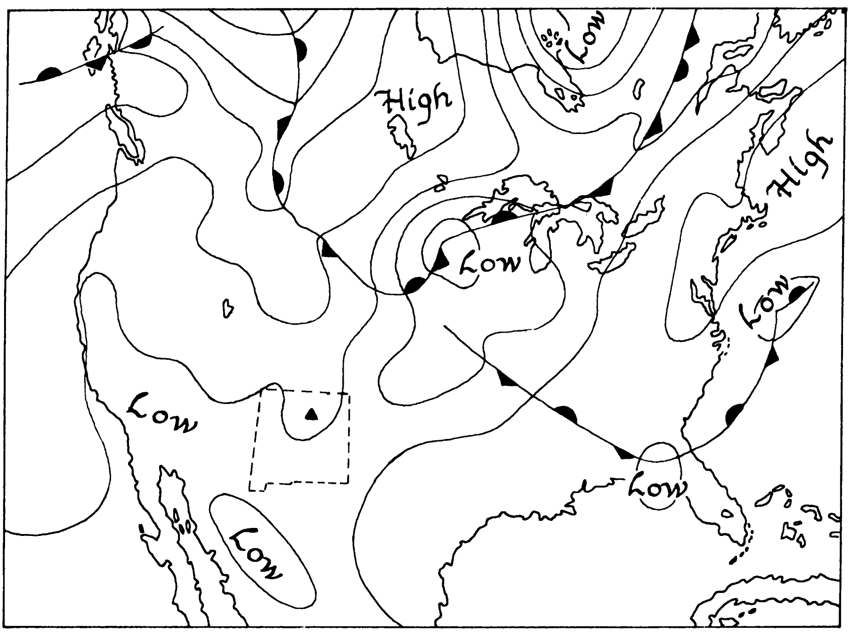


FIG. 12. Surface Weather Map for August 6, 1972 (after U.S. Department of Commerce daily weather map).

CLIMATE DYNAMICS

The weather data of the winter examples were used to demonstrate the climatic influence of the dominant pressure system, acting as a steering mechanism on the westerly wind belt:

> The greater part of one year, of a group of years, or even of a whole climatic epoch, may be defined by some long-lasting anomaly in the position of the upper westerlies. This steers the sequence of surface depression and anticyclones and even controls the places where they develop. (Lamb 1972:254)

There is some evidence that the atmospheric circulation was depressed slightly southward from its present position between 1830 and 1930:

> Wahl (1968) has demonstrated how the temperatures and rainfall anomalies of the 1830's in the United States corresponded to a more southern position of the commonest cyclone tracks and penetrations farther south than in recent decades (1931–60) of the cold air outbreaks over the centre of the continent. . . . (Lamb 1972:289)

Southward displacement of the atmospheric circulation is generally associated with the spread and advancement of the arctic snow and ice fields. According to Griffin, "at the present time the mean seasonal position of the ice and snow margin appears to exercise the main control over the strongest thermal gradients" (Lamb 1966:64). Strong thermal gradients produce turbulent and stormy weather. Lamb also reports

> that while the extent of ice in the Atlantic sector (western and northern Atlantic plus Greenland and Berents Seas) decreased by 18% from 1901–20 to 1921–39, ice extent in the Pacific sector increased by 22% over the same years. This seems to imply that while the circulation zones, and in particular, the subpolar cyclonic activity, penetrated increasingly far north in the Atlantic sector and along the northwest coast of Asia, the secular trend was southward in the Pacific sector. (1972:299)

This southward shift of the winter storm track corresponds to the period when dry farming in the Santa Fe area was successful. As the Pacific ice rapidly retreated in the late 1940s, the Santa Fe and Arroyo Hondo areas began to suffer droughts that brought an end to dry farming.

The retreat of the Pacific ice would move the winter storm track slightly northward, and the frequency of precipitation-producing storms in the Santa Fe area would diminish. The ice retreat would probably also affect the summer precipitation in the area. The more northerly position of the ice would allow the subtropical high-pressure system of the south Pacific to reach a position farther north and extend its drying influence inland over the area, as is common during dry summers at the present time. An increase in summer precipitation would be expected when the Pacific high remains farther south.

Considering the climatic effect produced by the expansion and retreat of polar ice in the north Pacific, it seems reasonable to assume that Arroyo Hondo could easily have extremely cold winter conditions, such as occurred in January, 1971, if the ice and snow fields of western and interior Canada extended southward, increasing the strength of polar outbreaks from these sources. With an increase in strength, polar air invasions of the Rio Grande valley would become more frequent, producing a much cooler climate than Arroyo Hondo presently enjoys.

If both the north Pacific and continental ice and snow fields were extended southward, Arroyo Hondo would probably have a winter climate both colder and wetter than presently exists. If the polar sea ice retreated and the continental snow and ice remained in a more southern position, the area would probably suffer very cold, dry winters.

Expansion of both continental and sea ice would, in effect, shift the atmospheric circulation toward the equator. This would probably reduce the size and strength of the subtropical high-pressure areas and place them in a more southern position where they would have less influence on Arroyo Hondo during the summer months. These conditions would probably decrease the amount of summer precipitation and the area would be more dependent on winter moisture. If only the Pacific ice were expanded, both winter and summer precipitation would be expected to increase. If the Pacific ice retreated and the continental snow and ice were expanded, both winter and summer moisture would be slightly reduced. When both continental and Pacific snow and ice fields are in their present positions, the present climate of mild winter and summer temperatures with spring drought and summer-dominant precipitation is established.

CLIMATE AND AGRICULTURE

Agricultural potential at the Arroyo Hondo site would depend on which of the previously discussed climatic factors dominated the area. The present climate allows crops to be grown only if watered artificially. Experimental gardens planted near the pueblo site during the archaeological field season of 1972 indicated that one harvest of modern Indian corn could be expected each year, with adequate irrigation. Beans and squash were also planted in these gardens; harvesting, from mid-August through September, was continuous only at the irrigated locations. A local resident in the Arroyo Hondo area planted and irrigated a small plot of cotton during this time and harvested most of the crop before the late summer rains. Dry farming would be successful during years of above-average precipitation, but failure due to drought could be expected at regular intervals in each century.

If the Pacific ice expanded southward, conditions would be similar to those between 1900 and the late 1940s and dry farming could be successful. If both sea and continental ice and snow fields advanced, the Arroyo Hondo would be susceptible to increased winter precipitation and colder temperatures due to the combined effects of more local snow cover and more frequent invasions of continental polar air. This situation would probably be accompanied by frost occurring later in the spring and earlier in the fall. In effect, this would shorten the growing season to a length that would allow only modern, fast-maturing corn to be harvested. Beans and squash could be grown, but the total yields would be less, due to the shorter growing season. A very fast-maturing cotton could be harvested, if it were similar to that which the Hopi are reported to have grown, with a life cycle of approximately 80 days.

Colder temperatures and increased snow cover in the foothills would produce a spring runoff that would flow farther down the piedmont than it now does. This would make more suitable for agriculture those irrigable areas at lower elevations with longer growing seasons. If colder temperatures and increased snow moisture were dominant for 20 years, it is entirely probable that ponderosa pine, which occurs presently as isolated trees along the north-facing bank of Arroyo Hondo, would flourish in the shaded areas adjacent to the pueblo ruins.

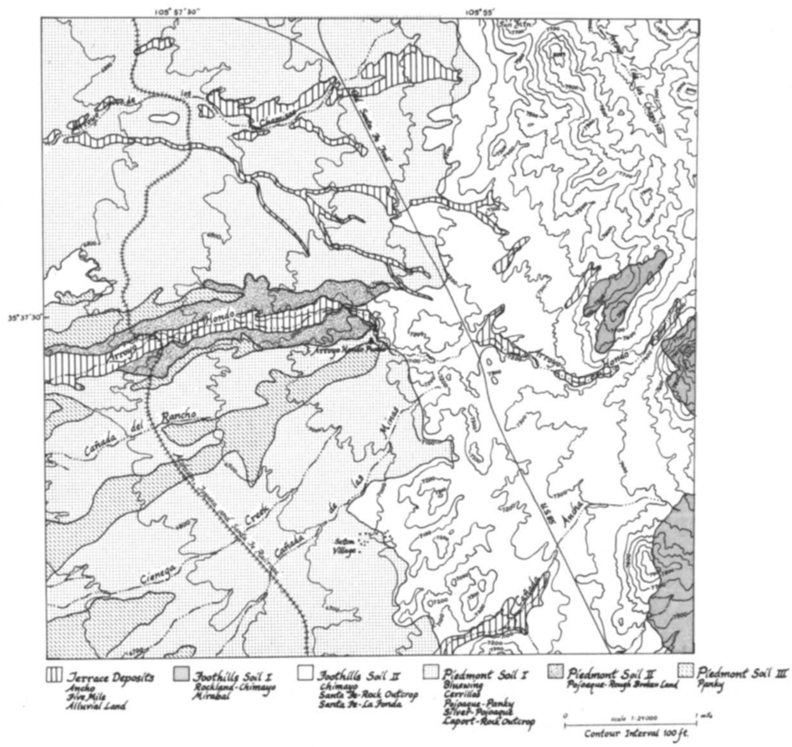
The recorded climatic history indicates that drought conditions in the Arroyo Hondo area were associated with the retreat of the north Pacific ice. Local factors are more important in determining an area's climate, but unless major and widespread changes occur in the landscape, these factors influence only the type of air mass that is present in the area at any given time. Therefore the local factors were omitted in order to view the larger and more important features of climate, which could account for longer periods of time in which deviations from the "normal" climatic regime could occur.

5
Soils

Fifteen soil classifications for the Arroyo Hondo study area have been determined and described by the Soil Conservation Service (SCS), Santa Fe district (Folks 1968). To facilitate locating soils with similar potential for prehistoric agriculture, we combined these soil classifications, according to characteristics and location within the study area, into six major formations: Terrace Deposits, Foothills Soils I and II, and Piedmont Soils I, II, and III (Map 4).

The SCS also recognizes eight land-capability classes, numbered I through VIII, with soils having the greatest contemporary agricultural capability rated I and those having the least rated VIII (Buckman and Brady 1969). Only classes VI through VIII occur in the study area (class VIII is the exposed bedrock of the area). However, this capability classification does not identify those soils, or limited areas within a soil class, that could be productive using prehistoric agricultural techniques. On the basis of the SCS land-capability classifications and of our field observations, we reclassified the soils as to their agricultural potential for a prehistoric Pueblo farmer. This new classification was applied to the six major formations to determine the areas where agriculture might have been practiced by the inhabitants of Arroyo Hondo Pueblo.

The new classification rates soils on a scale of 0 through 3. Soils rated 0 have no agricultural potential; those rated 3 are associated



MAP 4. Soil Types Present in the Arroyo Hondo Study Area.

with previously or presently cultivated fields. Soils rated 1 are the highly eroded canyon walls of Arroyo Hondo in the Piedmont section, with extremely limited agricultural potential. Those rated 2 are shallow Piedmont soils of limited agricultural potential.

Table 6 shows the six major soil types established for the Arroyo Hondo study area, their ratings for prehistoric agricultural potential, and their corresponding SCS classifications and land-capability classes.

TABLE 6.
Major Soil Formations and Prehistoric Agricultural Potential in the Arroyo Hondo Study Area. (SCS soil classifications from Folks 1968; land-capability classes from Buckman and Brady 1969.)

Soil Type	*Primitive Agricultural Potential (0–3)*	*SCS Classification*	*SCS Land-Capability Class (I–VIII)*
Terrace Deposits	3	Ancho Clay Loam Five Mile Loam Alluvial Land	VI
Foothills Soil I	0	Rockland and Chimayo soils Mirabal Stony Loam	VIII
Foothills Soil II	0	Chimayo Stony Loam Santa Fe-Rock complex Santa Fe-La Fonda association	VIII
Piedmont Soil I	2	Bluewing Gravelly Sandy Loam Cerrillos Fine Sandy Loam Pojoaque-Panky association Silver-Pojoaque association Laporte-Rock outcrop complex	VII
Piedmont Soil II	1	Pojoaque-Rough Broken Land complex	VII
Piedmont Soil III	3	Panky Fine Sandy Loam	VI

TERRACE DEPOSITS

Three soils make up the Terrace Deposit soil type. Ancho Clay Loam occurs along the Arroyo de los Chamisos and its tributaries, and Five Mile Loam is distributed along Cañada Ancha and Arroyo Hondo and its tributaries; thus these two soils occur in both the Piedmont and the Foothills sections of the study area. Alluvial Land soil occupies a small area at the eastern edge of Arroyo Hondo. Terrace Deposit soils occupy 679 acres (4.2 percent) of the study area, with 465 acres in the Piedmont section and 214 acres in the Foothills section. Limited areas on these soils were being farmed in 1972 in Arroyo Hondo. Terrace deposits occupy 0 to 10 percent slopes and are well-drained, moderately permeable, mixed alluvial material. The surface layer, 5 to 10 inches thick, is brown loam or brown clay loam. It is alkaline, with a pH of 7.9 to 8.6. The subsoil loams, 40–50 inches deep, contain free lime with a pH of 8.4 to 9.0. Runoff is medium, with erosion hazard slight to medium for most of the terrace deposits but high along the arroyo channels, which are being downcut at the present time. These deposits have moderate fertility, with an effective rooting depth of 36–60 inches (Folks1968).

FOOTHILLS SOIL I

Foothills Soil I has two soil types. The first, Rockland and Chimayo, occurs on the higher peaks and ridges along the southeastern boundary of the study area; the second, Mirabal Stony Loam, occurs along both sides of Arroyo Hondo on the eastern edge of the study area. Both soils are in the Foothills section. Foothills Soil I (288 acres, or 1.8 percent of the study area) has the largest percentage of exposed bedrock (40–70 percent) and lies on the steepest slopes (30–100 percent) of the study area. The soils of this formation are shallow (less than 20 inches thick), with stones constituting 40–70 percent of the profile. The surface layer is grayish-brown loam 5 to 6 inches thick, with brown to brownish-gray cobbly loam subsoils 15 to 16 inches thick overlying granite or gneiss bedrock. The pH of the surface layer is 7.0 and that of the subsoil is 6.8. These soils are moderately permeable. Runoff is rapid and erosion hazard moderate. The soils have moderate fertility, with effective rooting depths of 7 to 20 inches.

FOOTHILLS SOIL II

Three soils are included in the Foothills II category. Chimayo Stony Loam covers most of the northeast quarter of the study area, extending southeast from Sun Mountain to the western edge of Foothills Soil I north of Arroyo Hondo, then eastward along the canyon to the boundary of the map. The Santa Fe–Rock complex lies on the granite foothills bordering the piedmont south of Arroyo Hondo. The Santa Fe–La Fonda association covers the remaining portion of the Foothills section. Foothills Soil II occupies 6,282 acres (39.3 percent) of the study area on slopes of 5–100 percent, with exposed bedrock constituting up to 30 percent of the surface layer. The soils are well drained and shallow and consist of alluvial and eolian material incorporated with granite, gneiss, and schist parent material. The surface layer is a brown or grayish-brown, sandy to gravelly clay loam 3 to 4 inches thick, with a pH of 7.0; the subsoil is a sandy or gravelly clay loam with a pH of 6.8 to 7.0. Stones and cobbles occur throughout the profile. These soils are moderately permeable. Runoff is medium to rapid with moderate erosion hazard. Fertility is moderate to high and the effective rooting depth is less than 20 inches.

PIEDMONT SOIL I

Piedmont Soil I occupies 7,418 acres on the Piedmont section of the study area (46.4 percent) and contains five soils. The Bluewing Soils, on the tops of the rolling hills between the arroyos north of Arroyo Hondo, are predominant on the northern half of the piedmont. The Cerrillos Fine Sandy Loam occurs along the hillsides that flank the arroyos of the northern half of the Piedmont section. The Pojoaque-Panky association lies on the piedmont along the southern edge of Arroyo Hondo, with a few small areas along the northern rim. The Silver-Pojoaque association covers most of the southern half of the Piedmont section and is the most extensive of all the piedmont soils. The Laporte-Rock outcrop complex occurs in very limited and isolated areas of the piedmont and is associated with small outcrops of limestone. These well-drained soils, which formed from alluvial and eolian materials, occupy slopes of 0 to 10 percent. The surface layers have a pH of 7.8 to 8.6 and consist of brown to reddish-brown, gravelly or sandy clay loam 3 to 7 inches thick; the subsoils have a pH of 8.0 to 8.8 and are brown, gravelly, sandy or silty clay loams 8 to 50 inches deep. Strong concentrations of lime occur at depths of 8 to 60 inches. Permeability of these soils is moderate to slow. Runoff is medium to very rapid, with moderate to high erosion hazard. Fertility ranges from low to high, with effective rooting depths of 8 to 60 inches.

PIEDMONT SOIL II

Piedmont Soil II has only one SCS soil type, the Pojoaque–Rough Broken Land complex. This soil occupies 400 acres (2.5 percent) of the study area on slopes of 1 to 25 percent, forming the sides of Arroyo Hondo and occurring as small areas along the Piedmont-Foothills interface in the northern half of the study area. It is well-drained, mixed alluvial material 24 to 60 inches deep. The surface layer is light reddish-brown sandy clay loam about 7 inches thick, the subsoil a red-brown gravelly or sandy clay loam about 18 inches thick. The pH ranges from 7.6 to 8.5 throughout the profile. The soil is moderately permeable, and runoff is rapid, with moderate to high erosion hazard. The fertility is low and the effective rooting depth is between 24 and 60 inches.

PIEDMONT SOIL III

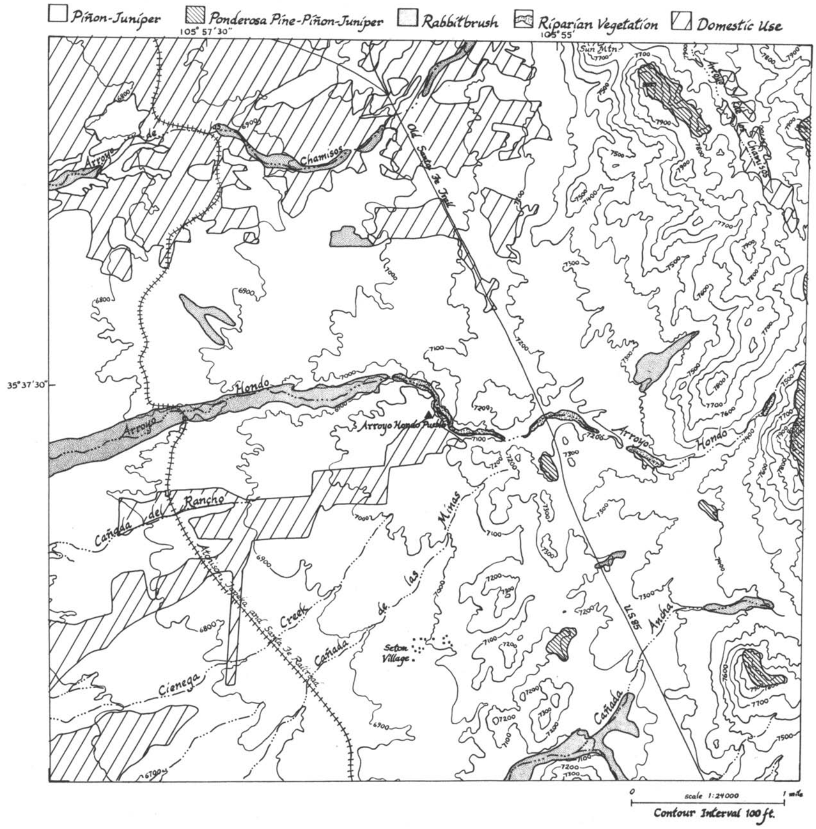
Piedmont Soil III also has only one SCS soil type, the Panky Fine Sandy Loam, occurring in small, isolated areas on the piedmont north of Arroyo Hondo with more extensive and continuous coverage on the piedmont south of the canyon. It covers 933 acres (5.8 percent) of the study area. The numerous abandoned and presently cultivated fields in the southern Piedmont section are on Panky soils located on flat, gently southwest-sloping grades of 0–5 percent. The soil is well drained and 20 to 40 inches deep, developing on an old mixed alluvium. The surface layer is light brown, fine sandy clay loam, 3 inches deep, with a pH of 8.0; the subsoil is reddish-brown clay loam about 21 inches thick, with a pH of 8.2 to 8.4. A substratum is pinkish-white sandy clay loam 5 to 16 inches thick, with a pH of 8.6. A caliche layer underlies this soil at a depth of 20 to 40 inches. This soil is moderately permeable, runoff is medium, and erosion hazard is moderate. Fertility is also moderate, and the effective rooting depth is 20 to 40 inches.

6
Vegetation

The piñon-juniper belt of the southern Sangre de Cristo Mountains occurs in the elevation range from approximately 6,500 feet to 8,000 feet in the vicinity surrounding Arroyo Hondo Pueblo. The lower elevation is the shortgrass plains–piñon-juniper ecotone, 4.5 to 5 miles south and southwest of the pueblo site. The ponderosa pine forest, at elevations of 8,000 to 9,000 feet, begins 2.5 miles northeast of the pueblo. The mixed conifer association above the ponderosa pine zone occupies elevations between 8,500 and 10,000 feet, some 6 to 10 miles northeast of the pueblo site. The propinquity of these vegetational areas provides a great variety of flora and fauna to augment those of the study area.

The Arroyo Hondo area is divided into five major vegetational zones: piñon-juniper (*Pinus edulis–Juniperus monosperma*); ponderosa pine (*Pinus ponderosa*)-piñon-juniper; rabbit brush (*Chrysothamnus nauseosus*); riparian; and domestic (Map 5). Each of these will be described in the sections that follow.

Appendix A includes a taxonomic classification with identification of edible or medicinal uses of the plants, an abundance rating for each of the vegetational areas, and a determination of whether the plant is native to the North American continent or was introduced to the area. Introduced plants account for 14 percent of the total collection, with 63 percent of these being edible species.



MAP 5. Vegetational Communities in the Arroyo Hondo Study Area.

PIÑON-JUNIPER WOODLAND

The piñon-juniper woodland covers 12,534 acres and forms the dominant vegetation (78.3 percent) of the study area (Figs. 13 and 14). Of twelve areas sampled, elevations ranged from 6,800 to

FIG. 13. Open Piñon-Juniper Woodland near Arroyo Hondo Pueblo.

7,600 feet. An analysis of variance indicated that the sampled stands of piñon-juniper are homogeneous. The test, a two-level nested analysis of variance with unequal sample size (Sokal and Rohlf 1969:274), determined that the composition of each stand was similar to that of the others and that the stands sampled were not significantly ($P < .05$) different from each other. This homogeneity may be explained in part by the southern aspect and the rolling topography, which allow most of the area to receive large amounts of solar radiation. Tables 7, 8, and 9 give the phytosociological data for the major plants in this association.

Woodin and Lindsey (1954) sampled the piñon-juniper association a few miles north of Santa Fe, and Krenetsky (1964) sampled the piñon-juniper association on the Picuris Grant in Taos County, New Mexico. Comparison of their results indicates that at the present, the area north of Santa Fe is more similar to the Arroyo Hondo area, which, however, has a slightly higher density of trees and more foliage cover per acre than Woodin and Lindsey's sample area. The coverage and stand density at Arroyo Hondo suggest that this

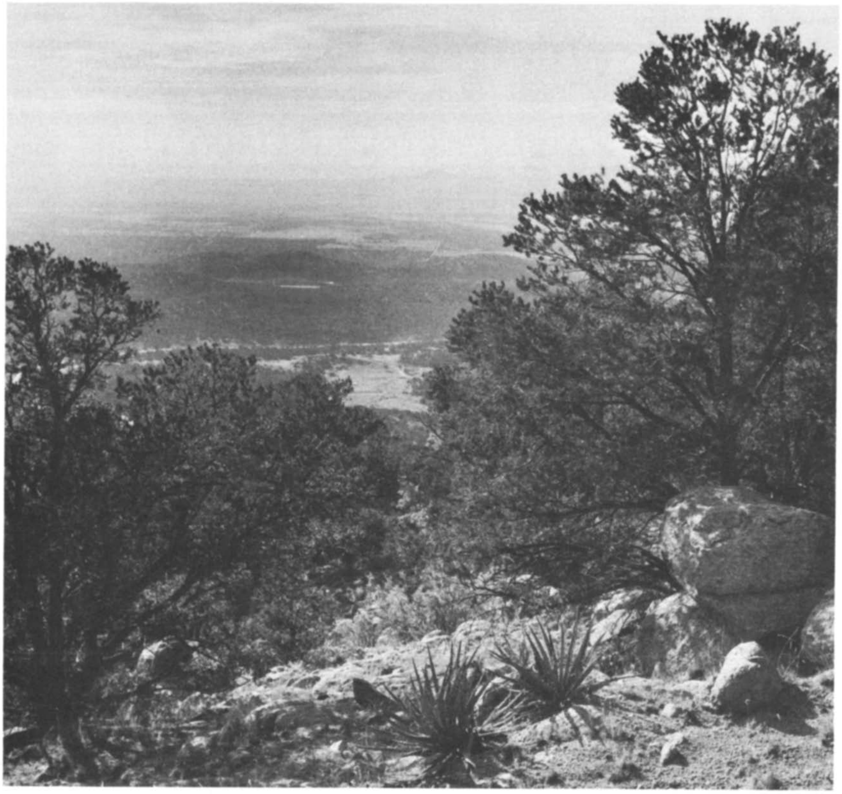


FIG. 14. Dense Piñon-Juniper Woodland in the Foothills Overlooking Arroyo Hondo Pueblo.

site would provide more firewood and building materials than the areas north of Santa Fe. Also, a larger piñon nut crop could be expected during productive years. This largest single natural crop, containing 3,364 calories per pound (Woodin and Lindsey 1954), is the most valuable food source in the entire study area.

Of the 271 plant species collected and identified, 50 percent can be found in the piñon-juniper association. Of the total native edible plants, 51 percent occur in this association, although with the exception of the piñon and juniper they are not abundant. Introduced species account for 8 percent of the plants here.

Although drier than the higher elevation zones, the piñon-juniper zone surrounding Arroyo Hondo is not very susceptible to rampant fires that destroy large tracts of trees. The drier conditions produce

TABLE 7.
Mature Tree Stratum (Trees over 3 Inches dbh) of the Piñon-Juniper Woodland[a]

Species	Cover[b]			Density		Frequency		Importance[c]
	Basal Area per Acre (sq ft)	Foliage Cover per Acre (sq ft)	Relative Foliage Cover (%)	Density per Acre	Relative Density (%)	Frequency Index (%)	Relative Frequency (%)	(%)
Pinus edulis Colorado piñon	38	7,119	60.8	172	60.4	82.3	49.7	57
Juniperus monosperma One-seed juniper	48	4,511	39.2	112	39.6	83.3	50.3	43

[a]Species arranged in descending order of importance percentage. Data based on 12 elbs, each 800 by 20 feet.
[b]Total foliage cover is 26.0 percent.
[c]Importance percentage is determined by adding relative foliage cover, relative density, and relative frequency and dividing the sum by three.

TABLE 8.
Shrub Stratum (Tree Reproduction and Shrubs less than 4 Inches dbh, but 3 Feet Tall or Over) of the Piñon-Juniper Woodland[a]

Species	*Cover*[b]		*Density*		*Frequency*		*Importance*[c]
	Foliage per Acre (sq ft)	Relative Foliage Cover (%)	Density per Acre	Relative Density (%)	Frequency Index (%)	Relative Frequency (%)	(%)
Pinus edulis Colorado piñon	344	.8	195	59.2	66.7	41.6	34
Juniperus monosperma One-seed juniper	431	1.0	89	26.9	63.5	39.7	23
Opuntia imbricata Cholla	9	<.1	19	5.6	15.6	9.7	5
Quercus undulata Wavyleaf oak	4	<.1	5	1.4	2.1	1.3	3
Fallugia paradoxa Apache plume	22	<.1	9	2.6	7.3	4.6	2
Quercus grisea Gray oak	13	<.1	3	1.0	2.1	1.3	1
Cercocarpus montanus Mountain mahogany	9	<.1	5	1.5	1.0	.6	1
Lycium pallidum Wolfberry	9	<.1	5	1.5	1.0	.6	1
Quercus gambelii Gambel oak	9	<.1	1	.3	1.0	.6	1

[a] Species arranged in order of descending importance. Data based on 12 elbs, each 800 by 20 feet.
[b] Total foliage cover is 1.9 percent.
[c] Importance percentage is determined by adding relative foliage cover, relative density, and relative frequency and dividing the sum by three.

TABLE 9.
Herb Stratum (Herbaceous Plants Only) of the Piñon-Juniper Woodland[a]

	Cover[b]		*Frequency*		*Constancy*
Species	Mean Herb Cover	Relative Coverage (%)	Frequency Index (%)	Relative Frequency (%)	(%)
Bouteloua gracilis Blue grama	23.4	87.3	77.5	91.0	100
Gutierrezia lucida Snakeweed	5.3	2.8	1.0	1.0	67
Muhlenbergia torreyi Ring muhly	4.1	1.6	1.0	1.0	42
Salsola kali Russian thistle	6.0	.2	1.0	1.0	33
Kochia americana Red sage	21.7	4.1	1.0	1.0	33
Yucca glauca Soapweed yucca	11.7	.9	1.0	1.0	25
Descurainia pinnata Tansy mustard	3.0	.1	1.0	1.0	17
Opuntia sp. Prickly pear	9.1	2.1	1.0	1.0	17
Hymenoxys richardsonii Bitterweed	1.3	.4	1.0	1.0	17
Echinocereus triglochidiatus Claret cup	.5	.5	1.0	1.0	8

[a]Species arranged in order of decreasing constancy percentage. Data are based on 240 quadrats 1 by 0.5 meter.
[b]Total foliage cover is 12.8 percent.

two situations that effectively reduce fire hazards to the zone: (1) trees generally are spaced far enough apart that fire does not leap from crown to crown and (2) sparse ground cover provides little fuel.

The piñon-juniper zone at Arroyo Hondo would be susceptible to fire under wetter climatic conditions than prevail today. An increase in precipitation over several years would increase the cover of grasses and forbs, allowing dead plant material to accumulate sufficiently to sustain a fire over large areas. Assuming that a fire did sweep through the piñon-juniper zone in the Arroyo Hondo area, under the present conditions the regrowth vegetation would probably be juniper, gray oak (*Quercus grisea*), prickly pear and cholla (*Opuntia* spp.), and a variety of grass species, with blue grama (*Bouteloua gracilis*) dominant.

Increased precipitation would favor regrowth of shrubs, forbs, and grasses such as occurred on a burn area in the upper portions of the piñon-juniper zone north of Rowe, New Mexico, in the Pecos area. R. W. Lang and I were given a tour of this burn area in April, 1974, by Charles Wright, forest ranger of the Pecos District. This burn occurred on July 1, 1971, and burned only a small portion of the upper part of the piñon-juniper zone as it swept down from the ponderosa pine zone. Various grasses were reseeded by the U. S. Forest Service immediately after the fire.

I made a quick survey to identify the regrowth vegetation and its relative abundance. The following list rates the plants as identified in the field, in descending order of abundance (plants rated 1 were most abundant, those rated 5 least abundant).

Plants	*Abundance rating*
Quercus gambelii (Gambel oak)	1
Cercocarpus montanus (Mountain mahogany)	1
Artemisia frigida (Estafiata)	2
Brickelia sp. (Brickelia)	2
Stipa robusta (Sleepy grass)	2
Yucca baccata (Blue yucca)	3
Rhus sp. (Sumac)	4
Gutierrezia sp. (Snakeweed)	4
Aster sp. (Aster)	4

Eriogonum sp. (Eriogonum)	4
Penstemon sp. (Penstemon)	4
Helianthus sp. (Sunflower)	5
Achillea lanulosa (Western yarrow)	5
Sporobolus sp. (Dropseed grass)	5
Verbascum sp. (Mullein)	5
Sitanion sp. (Squirreltail grass)	5
Muhlenbergia sp. (Muhly)	5

PONDEROSA PINE–PIÑON-JUNIPER COMMUNITY

This community occurs as small, isolated stands of the ecotone along the shaded arroyo bottoms in the lower (7,100–7,500 feet) portion of the Foothills section (Fig. 15). Along the eastern border and in the northeastern corner of the study area it begins at 7,600 feet on slopes with a northern aspect and at 7,900 feet on those facing south. It occupies 133 acres and is a minor part of the vegetation (0.8 percent).

All stands are growing on exposed gneissic bedrock with scattered areas having a thin, rocky soil cover. The shrub and herb strata are practically nonexistent in this community (less than 2 percent of ground cover) due to lack of soil and the large amount of ponderosa leaf litter. Blue grama comprises 95 percent of the herbaceous species, and snakeweed (*Gutierrezia lucida*), broomweed (*Gutierrezia sarothrae*), and pingue (*Hymenoxys richardsonii*) complete the re-

FIG. 15. The Ponderosa Pine–Piñon-Juniper Community.

maining 5 percent. The total shrub cover, less than 1 percent, is composed of piñon, one-seed juniper, rabbit brush, Gambel oak (*Quercus gambelii*), Apache plume (*Fallugia paradoxa*), and Rocky Mountain juniper (*Juniperus scopulorum*). The piñon and one-seed juniper account for 80 percent of this cover. The data for the tree stratum are given in Table 10.

The ponderosa pines are predominantly mature trees of 18.2 inches average dbh (diameter breast high), with diameter extremes from 4.8 to 28.6 inches. Ponderosa saplings and seedlings were absent in the three stands sampled. The elevations of the sampled area range from 7,200 to 7,900 feet.

Ponderosa pine grows under conditions of higher moisture and lower temperatures than piñon and juniper. The absence of seedlings and the size distribution of the ponderosa pines in the stands indicate that conditions at present allow only survival and are not adequate for reproduction.

Only 12 percent of the total species identified from the study area were found growing in this community. Of the total native edible species only 16 percent occurred here, and with the exception of the dominant trees, they were very rare. Introduced plants accounted for 6 percent of the species in this community.

RABBIT BRUSH COMMUNITY

Rabbit brush is the dominant vegetation on the relatively fertile terrace deposits of the arroyos, with blue grama growing in the open areas between the shrubs (Fig. 16). This community occupies 428 acres (2.7 percent) of the study area. The sampled areas were in the Arroyo Hondo, Arroyo de los Chamisos, and Cañada Ancha. Shrubs other than rabbit brush are clumped in small areas and account for less than 1 percent of the total coverage. These are four-wing saltbush (*Atriplex canescens*), currant (*Ribes cereum*), big sagebrush (*Artemisia tridentata*), and wolfberry (*Lycium pallidum*). The tree stratum is not present on these terrace deposits. Tables 11 and 12 give the phytosociological data for the major vegetational types on the terrace deposits.

The main channels of the arroyos carry the rapidly moving floodwaters through the area. Slow-moving overflow inundates the broad terrace deposits without damaging the dense stands of rabbit brush

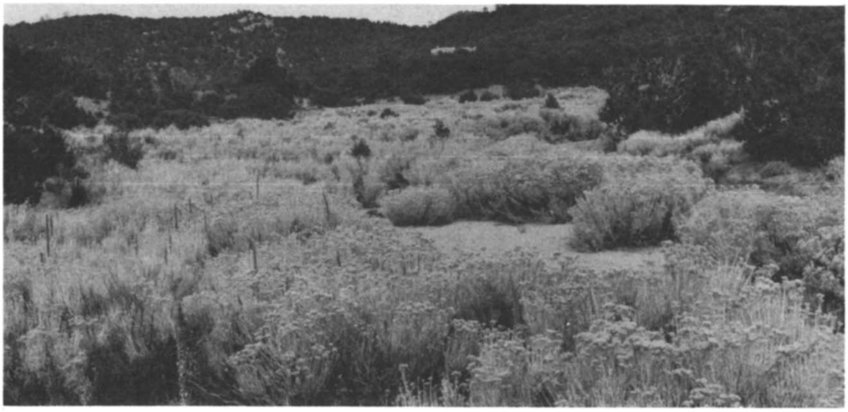


FIG. 16. The Rabbit Brush Community.

that are distinctive to these terraces. With a dependable water supply (for example, regular floods or a perennial stream), these terrace deposits could easily be irrigated.

Of the total plants identified, 45 percent grow on the terrace deposits. Although not occurring in abundance, 48 percent of all the edible plants occur here. Introduced plants account for 12 percent of the species in this community.

RIPARIAN COMMUNITY

This community includes all plants growing in the Arroyo Hondo where there is a perennial stream or the water table is less than 3 feet below the land surface (Fig. 17). Limited to the narrow portions of the canyon, this area occupies only 21 acres (0.1 percent) of the study area. Large trees are absent and the smaller tree species were placed in the shrub stratum. Tables 13 and 14 give the phytosociological data for this community.

Most of the species in this community have a tendency to be clumped and are not found growing along the full extent of the stream, in part because the exposed bedrock is washed free of any soil by occasional floods. This flooding also uproots and washes away much of the vegetation, accounting for the absence of larger trees (*Populus* and *Salix*).

This community has 38 percent of the total species identified for

TABLE 10.
Mature Tree Stratum (Trees over 3 Inches dbh) of the Ponderosa Pine–Piñon-Juniper Community[a]

	Cover[b]			*Density*		*Frequency*		*Importance*[c]
Species	Basal Area per Acre (sq ft)	Foliage Cover per Acre (sq ft)	Relative Foliage Cover (%)	Density per Acre	Relative Density (%)	Frequency Index (%)	Relative Frequency (%)	(%)
Pinus ponderosa Ponderosa pine	30	2,601	72.6	17	29.4	70	35	46
Pinus edulis Colorado piñon	6	798	19.1	78	50.0	60	30	33
Juniperus monosperma One-seed juniper	2	116	4.5	22	14.7	50	25	15
Juniperus scopulorum Rocky Mountain juniper	1	88	3.8	9	5.9	20	10	7

[a]Species arranged in descending order of importance percentage. Data based on 5 elbs, each 400 by 20 feet.
[b]Total foliage cover is 8.3 percent.
[c]Importance percentage is determined by adding relative foliage cover, relative density, and relative frequency and dividing the sum by three.

TABLE 11.
Shrub Stratum (Tree Reproduction and Shrubs less than 4 Inches dbh, but 3 Feet Tall or Over) of the Rabbit Brush Community[a]

	Cover[b]		Density		Frequency		Importance[c]
Species	Foliage per Acre (sq ft)	Relative Foliage Cover (%)	Density per Acre	Relative Density (%)	Frequency Index (%)	Relative Frequency (%)	(%)
Chrysothamnus nauseous Rabbit brush	13,447	83.3	2,418	83.1	85	74	80
Fallugia paradoxa Apache plume	4	16.6	2	16.4	30	26	20

[a] Species arranged in order of descending importance. Data based on 5 elbs, each 400 by 20 feet.
[b] Total foliage cover is 30.9 percent.
[c] Importance percentage is determined by adding relative foliage cover, relative density, and relative frequency and dividing the sum by three. Species with less than 1.0 percent importance: *Atriplex canescens*, *Ribes cereum*, *Artemisia tridentata*, *Juniperus monosperma*, *Lycium pallidum*.

TABLE 12.
Herb Stratum (Herbaceous Plants Only) of the Rabbit Brush Community[a]

	Cover[b]		Frequency		Constancy
Species	Mean Herb Cover (%)	Relative Coverage (%)	Frequency Index (%)	Relative Frequency (%)	(%)
Bouteloua gracilis Blue grama	16.8	41.9	48	33.8	80
Gutierrezia lucida Snakeweed	19.3	4.3	10	7.0	80
Chenopodium album Lamb's-quarters	22.0	4.6	12	8.4	80
Verbascum thapsus Mullein	45.0	3.6	2	1.4	80
Melilotus offinalis Yellow sweet clover	23.0	1.5	4	2.8	60
Melilotus albus White sweet clover	22.0	1.0	2	1.4	60
Sphaeralcea coccinea Globe mallow	15.0	1.6	2	1.4	60
Oryzopsis hymenoides Indian ricegrass	11.0	4.5	6	4.2	60
Bouteloua curtipendula Side-oats grama	1.5	1.5	4	2.8	60

Sporobolus cryptandrus Sand dropseed	20.6	9.2	10	7.0	40
Mentzelia albicaulis Whitestem stickleaf	30.0	1.8	4	2.8	40
Tragopogon pratensis Meadow goatsbeard	5.2	1.5	2	1.4	40
Salsola kali Russian thistle	42.5	2.5	2	1.4	20
Sisymbrium altissimum Tumble mustard	15.0	1.2	2	1.4	20
Portulaca oleracea Common purslane	13.2	1.0	8	5.6	20
Sitanion hystrix Squirreltail	12.5	1.2	2	1.4	20
Bromus japonicus Japanese brome	11.2	8.4	14	9.8	20
Hilaria jamesii Galleta	8.3	4.5	6	4.2	20
Thelesperma megapotamicum Indian tea	1.7	1.2	2	1.4	20

[a]Species arranged in order of descending constancy percentage. Data based on 100 quadrats 1 by 0.5 meter.
[b]Total foliage cover is 21.7 percent. Herbs with less than 1.0 percent relative cover: *Cleome serrulata*, *Brickellia californica*, *Gilia giliodes*, *Phlox nana*, *Physalis fendleri*.

TABLE 13.
Shrub Stratum (Tree Reproduction and Shrubs less than 4 Inches dbh, but 3 Feet Tall or Over) of the Riparian Community

	Cover[b]		*Density*		*Frequency*		*Importance*[c]
Species	Foliage per Acre (sq ft)	Relative Foliage Cover (%)	Density per Acre	Relative Density (%)	Frequency Index (%)	Relative Frequency (%)	(%)
Salix exigua Willow	2	59.1	20	56.2	30	50	55
Salix amygdaloides Willow	1	15.9	7	18.8	15	25	20
Rhus trilobata Squawbush	1	18.2	2	12.5	5	8	13
Salix gooddingii Willow	<1	6.8	4	12.5	10	17	12

[a]Species arranged in order of descending importance. Data based on 5 elbs, each 400 by 20 feet.
[b]Total foliage cover is 12.7 percent.
[c]Importance percentage is determined by adding relative foliage cover, relative density, and relative frequency and dividing the sum by three.

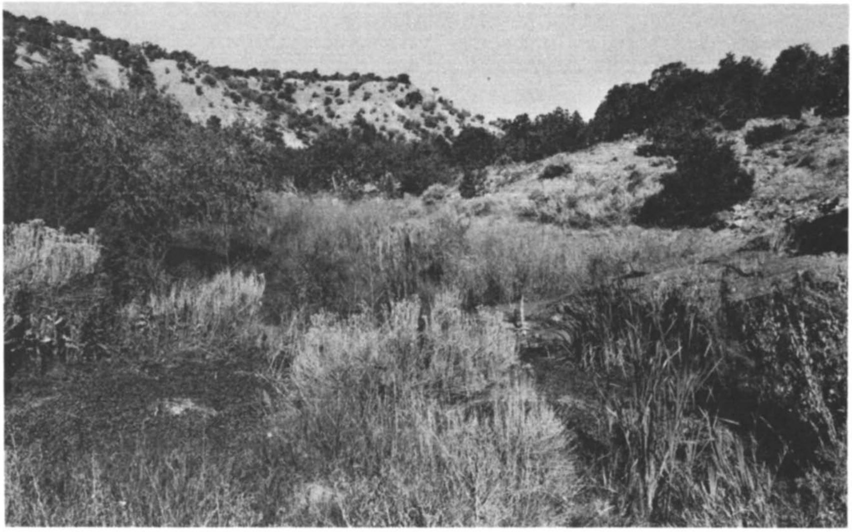


FIG. 17. The Riparian Community near the Spring below Arroyo Hondo Pueblo.

the study area and 47 percent of the edible species, which are slightly more abundant in this community than in any of the others. Introduced plants account for 22 percent of the total stream-side vegetation.

DOMESTIC AREAS

The domestic areas were not sampled for phytosociological data, but plants were collected along property boundaries north of Arroyo Hondo and in the larger fields to the south.

The domestic area is second in size, encompassing 2,884 acres (18 percent) of the study area. Before domestic use it probably consisted of piñon-juniper woodland. North of Arroyo Hondo it includes cleared fields, a cemetery, business property, and housing developments. South of the arroyo are numerous homes, but these are scattered and have used the natural vegetation as their landscaping, so they were included in the piñon-juniper association. The domestic areas in the southern half are cleared fields that were dry farmed in the first half of this century (Folks 1968) but are now either abandoned or used as pasture (Fig. 18).

About 36 percent of the total collected plants were found in the domestic areas, of which 32 percent are native edible plants. Introduced plants account for 20 percent of the species in this community.

TABLE 14.
Herb Stratum (Herbaceous Plants Only) of the Riparian Community[a]

Species	Cover[b]: Mean Herb Cover (%)	Cover[b]: Relative Coverage (%)	Frequency: Frequency Index (%)	Frequency: Relative Frequency (%)	Constancy (%)
Melilotus officinalis Yellow-sweet clover	50.0	11.6	75	25.9	100
Lactuca serriola Prickly lettuce	10.0	10.6	20	6.9	100
Sporobolus contractus Spike dropseed	70.0	7.4	25	8.6	80
Melilotus albus White sweet clover	47.0	8.4	20	6.9	80
Rumex crispus Curly dock	40.0	5.3	10	3.4	80
Equisetum laevigatum Marestail	50.0	7.9	15	5.2	60
Equisetum arvense Horsetail	37.5	4.0	15	5.2	60
Oenothera hookeri Evening primrose	11.2	6.8	25	8.6	60
Typha latifolia Cattail	45.0	5.3	5	1.7	40

Scirpus olneyi Bulrush	22.5	2.4	5	1.7	40
Epilobium adenocaulon Willowweed	3.4	6.3	20	6.9	40
Potentilla anserina Silverweed	3.0	.5	10	3.4	40
Muhlenbergia filiformis Pull-up muhly	95.0	10.0	10	3.4	20
Mentha arvenis Mint	60.0	.8	5	1.7	20
Panicum capillare Witchgrass	55.0	5.8	10	3.4	20
Juncus saximontanus Rush	52.5	5.5	15	5.2	20
Cyperus esculentus Yellow nut grass	7.5	1.3	5	1.7	20

[a]Species arranged in order of decreasing constancy percentage. Data based on 100 quadrats 1 by 0.5 meter.
[b]Total foliage cover is 46.2 percent.

FIG. 18. Previously Cultivated Domestic Areas Adjacent to Arroyo Hondo Pueblo.

7

Summary and Conclusions

The site chosen by the earliest settlers of Arroyo Hondo is centered in the piñon-juniper association, which lies upon the foothills of the Sangre de Cristo Mountains. A vast expanse of shortgrass plains occupies the lower elevations to the south and west of the pueblo. To the north a slight increase in elevation of the plain allows the piñon and juniper to form a continuous woodland westward from the Sangre de Cristo range to the Jemez Mountains. East of the pueblo, conifer-covered peaks of the Sangre de Cristos rise above the piñon-juniper–covered foothills.

The proximity of the Sangre de Cristos has a pronounced impact on the climate of Arroyo Hondo. The orographic lifting of air masses caused by the mountain mass is responsible for much of the precipitation received at Arroyo Hondo. The barrier effect provided by this range protects the area from cold arctic air that moves down the Great Plains during the winter. The present climate is characterized as semiarid, with cool summers and short, moderate winters. Precipitation is summer dominant, with a dry spring season.

The precipitation received over the Arroyo Hondo drainage system determines the amount of water flow from the springs and in the stream through the Arroyo Hondo Canyon. At present the water flow of the springs is sufficient to provide potable water for a primitive people but is insufficient as an irrigation supply. If the first settlers practiced either irrigation or dry farming techniques at Arroyo Hondo, the amount of precipitation received in the area would have had to be equal to or more than that received between the 1890s and the early 1950s. The flow of the stream and the springs was obviously sufficient in the fourteenth century to meet the demands of what was a relatively large Pueblo population.

The Arroyo Hondo area has sustained agriculture in historic times. Dry farming of corn and beans was practiced from the turn of the century until the drought of the early 1950s. The best locations for primitive agriculture in the Arroyo Hondo area are the fertile terrace deposits within the study area and those west of the study area boundary to below the confluence of the Arroyo Hondo and Cienega Creek. In addition, the better soils of the piedmont would also have been cultivated during the peak population period. The large size of Arroyo Hondo Pueblo at its peak attests the fact that availability of arable land and sufficient moisture to support dependable crop yields were not problems during portions of the occupational periods. However, a precipitation decline of the magnitude noted for the middle years of the twentieth century would have forced abandonment of these farmlands.

Domesticated crops would have been the principal food supply for the Arroyo Hondo inhabitants, but numerous species of edible plants and animals could have been gleaned from the environs to provide a substantial supplement to the community's diet. In addition to providing a supplemental food supply, the pueblo's environment would have provided materials for construction, fuel for heating and cooking, tools, hunting equipment, utensils and cookware, cloth, bedding, religious objects, musical instruments, art objects, and other artifacts.

Even today the Arroyo Hondo environment could provide all these materials and necessities except for the cultivated food supply. Primitive irrigation and dry-farming techniques would support only a few people under the present climatic conditions. From its earliest settlement, through its largest population around A.D. 1330, to its final abandonment about 1425, the pueblo's occupation pattern was probably a response to climatic change, as has been the more recent agricultural history of the area.

The archaeological research undertaken at the Arroyo Hondo site was designed in part to determine just why the pueblo was abandoned. It is our hope that the perspective on the region's environment presented in this volume, taken from contemporary data, will supplement archaeologically derived information on the environment and its changes in prehistoric times. Seen from the present, the environmentally marginal location of the pueblo in relation to agriculture certainly would appear to be a critical factor in Arroyo Hondo's cultural history.

Appendix A

FLORA OF THE ARROYO HONDO STUDY AREA

The following list of plants from the vegetation communities in the Arroyo Hondo area is based upon field identifications I made between May, 1971, and October, 1972. It is by no means a complete inventory of the plant species to be found in the various communities, but is intended to give the reader some indication of the vegetational characteristics of the different elevational ranges located near the Arroyo Hondo area (Table 15).

TABLE 15.
Selected Flora of the Arroyo Hondo Study Area

Family, Genus, Species	*Location/ Abundance Class*[a]	*Edible/ Medicinal (E/M)*	*Introduced to Area*
Amaranthaceae (amaranth)			
Amaranthus albus	A1, C2,	E	
Pigweed	D3, E3		
Anacardiaceae (cashew)			
Rhus Trilobata	D1	E	
Squawbush			
Asclepiadaceae (milkweed)			
Asclepias asperula	A1	E	
Antelope horns			
Asclepias sp.	A1	E	
Milkweed			
Asclepias subverticillata	A2	E	
Poison milkweed			

[a]Location and Abundance Class Code:

A - Piñon-juniper	1 - Very rare
B - Ponderosa pine–piñon-juniper	2 - Rare
C - Rabbit brush	3 - Common
D - Riparian	4 - Abundant
E - Domestic	5 - Very abundant

Family, Genus, Species	Location/ Abundance Class[a]	Edible-Medicinal (E/M)	Introduced to Area
Asclepias viridiflora Milkweed	A2	E	
Boraginaceae (borage)			
Cryptantha fendleri Hiddenflower	A3		
Cryptantha flava Hiddenflower	A3		
Cryptantha jamesii Hiddenflower	A2		
Cryptantha minima Hiddenflower	A3		
Cryptantha virginensis Hiddenflower	A3		
Lappula redowskii Stickseed	A2		
Cactaceae (cactus)			
Corypantha sp. Pincushion	A2	E	
Echinocereus triglochidiatus Claret cup	A3	E	
Opuntia imbricata Cholla	A4		
Opuntia sp. Prickly pear	A3	E	
Cannabinaceae (hemp)			
Cannabis sativa Hemp	D1	E	
Capparidaceae (caper)			
Cleome serrulata Rocky Mountain beeplant	A2, B1, C3, D1, E2	E	
Caryophyllaceae (pink)			
Arenaria fendleri Sandwort	A1		
Cerastium brachypodum Mouse-ear chickweed	A1		
Chenopodiaceae (goosefoot)			
Atriplex canescens Four-wing saltbush	C1	E	
Chenopodium album Lamb's-quarters	A2, C2, D1, E2	E	X
Chenopodium ambrosioides Mexican tea	A1, D2	E	X
Chenopodium fremontii Fremont's goosefoot	A1, C2	E	
Chenopodium glaucum Goosefoot	A1, C2	E	X
Chenopodium watsoni Watson's goosefoot	A1, C3	E	

Family, Genus, Species	Location/ Abundance Class[a]	Edible-Medicinal (E/M)	Introduced to Area
Eurotia lanata Winter fat	A1, B1, C1, E2	M	X
Kochia americana Red sage	A2, C1, E4	E	
Kochia scoparia Summer-cypress	A2, C1, E4	E	X
Salsola kali Russian thistle	A1, C1, E3		X
Compositae (sunflower)			
Achillea lanulosa Western yarrow	D3	E	
Ambrosia psilostachya Western ragweed	D1, E1	E	
Antennaria marginata Pussytoes	A1, D1	E	
Artemisia carruthii Sagebrush	C1	E	
Artemisia filifolia Sand sagebrush	C2, D1	E	
Artemisia frigida Estafiata	C1, D1	E	
Artemisia tridentata Big sagebrush	C1	E	
Aster arenosus Aster	A2, C1, E2		
Aster commutatus Aster	A2, C1, E2		
Aster foliaceus Aster	A2, C1, E2		
Bahia dissecta Yellow ragweed	A2, C1, E2		
Berlandiera lyrata Berlandiera	A1, E1	E	
Brickellia californica Pachaba	A1, C3	M	
Brickellia grandiflora Brickelbush	C2		
Chrysopsis foliosa Golden aster	A2, E1		
Chrysopsis villosa Golden aster	A1, E1	M	
Chrysothamnus nauseosus Rabbit brush	A1, B1, C5		
Cirsium ochrocentrum Santa Fe thistle	A2, B1, C1, D3	E	
Cirsium neomexicanum New Mexico thistle	A2, C1, D3, E1	E	

Family, Genus, Species	Location/ Abundance Class[a]	Edible-Medicinal (E/M)	Introduced to Area
Conyza canadensis Horseweed	A1, C2, E1		
Erigeron divergens Daisy fleabane	A2, E3		
Erigeron flagellaris Trailing fleabane	A2, D2, E1		
Franseria acanthicarpa Burweed	C1		
Franseria dumosa White bur-sage	A1, C2		
Gaillardia pinnatifida Blanketflower	A2		
Grindelia aphanactis Gumweed	A1, C1, D1	E	
Grindelia squarrosa Gumweed	A2, C1, D2	E	
Gutierrezia lucida Snakeweed	A2, B1, C1, E4		
Gutierrezia sarothrae Broomweed	A2, B1, C2, E3		
Haplopappus gracilis Goldenweed	A2, C2		
Haplopappus spinulosus Goldenweed	A2, C2		
Helianthus annuus Annual sunflower	C3, E2	E	
Helianthus anomalus Sunflower	C3, E1	E	
Hymenoxys acaulis Bitterweed	A1, C1	E	
Hymenoxys argentea Bitterweed	A1, C1	E	
Hymenoxys richardsonii Bitterweed	A3, B1, C2, E3	E	
Lactuca serriola Prickly lettuce	C1, D3	E	X
Pectis angustifolia Fetid marigold	A1	E	
Psilostrophe tagetina Paper daisy	A1		
Ratibida tagetes Prairie coneflower	C1	E	
Senecio longilobus Threadleaf groundsel	A3, C1, E2	M	
Senecio multicapitatus Groundsel	A1, C1		
Sonchus asper Sow thistle	E2	E	X

Family, Genus, Species	Location/ Abundance Class[a]	Edible-Medicinal (E/M)	Introduced to Area
Taraxacum laevigatum Red-seeded dandelion	D2	E	X
Thelesperma megapotamicum Indian tea	A2, C2, E3	E	
Tragopogon pratensis Meadow goatsbeard	D2, E2	E	X
Verbesina encelioides Crownbeard	E1	M	
Xanthium saccharatum Cocklebur	D2, E2		
Zinnia grandiflora Rocky Mountain zinnia	D1		
Zinnia pumila Zinnia	A1, D1		
Convolvulaceae (morning glory)			
Convolvulus arvensis Field bindweed	E2		X
Cuscuta campestris Dodder	E1		
Cruciferae (mustard)			
Camelina microcarpa False flax	A1, E2		X
Descurainia pinnata Tansy mustard	A3, C1, E4	E	
Descurainia sophia Tansy mustard	A3, C1, E3	E	X
Erysimum asperum Wallflower	A2, B1, C1, D1		
Lepidium densiflorum Peppergrass	A2, C1, E2	E	
Lepidium montanum Peppergrass	A1, C1, E2	E	
Rorippa nasturtium-aquaticum Watercress	D3	E	X
Rorippa sinuata Cress	D1		
Sisymbrium altissimum Tumble mustard	D3, E3	E	X
Sisymbrium linearifolium Tumble mustard	D3, E3	E	
Cucurbitaceae (gourd)			
Cucurbita foetidissima Buffalo gourd	C2, E3	E	
Cupressaceae (cypress)			
Juniperus monosperma One-seed juniper	A5, B4, C2, E1	E	
Juniperus scopulorum Rocky Mountain juniper	B3	E	

Family, Genus, Species	*Location/ Abundance Class*[a]	*Edible-Medicinal (E/M)*	*Introduced to Area*
Cyperaceae (sedge)			
Cyperus esculentus Yellow nut grass	D3	E	
Scirpus olneyi Bulrush	D3	E	
Elaeagnaceae (oleaster)			
Elaeagnus angustifolia Russian olive	D1		X
Equisetaceae (horsetail)			
Equisetum arvense Horsetail	D2	E	
Equisetum laevigatum Marestail	D3	E	
Euphorbiaceae (spurge)			
Croton texensis Doveweed	A3, C2, E3	M	
Euphorbia sp. Spurge	A1, C1, E2		
Euphoriba dentata Spurge	A1, C1, E2		
Fagaceae (oak)			
Quercus gambelii Gambel oak	A1, B1	E	
Quercus grisea Gray oak	A2, B1	E	
Quercus undulata Wavyleaf oak	A2	E	
Geraniaceae (geranium)			
Erodium cicutarium Alfileria	D2		X
Geranium caespitosum Purple geranium	C1, D2		
Geranium fremontii Cranesbill	A1, B1, C2, D1		
Gramineae (grass)			
Agropyron repens Quack grass	D2, E2	E	X
Agropyron smithii Western wheatgrass	D2, E2	E	
Agrostis alba Redtop	D2, E1		
Agrostis nigra Bent grass	D1		
Agrostis palustris Bent grass	D1		
Aristida adscensionis Six-weeks three-awn	C1, E1		

Family, Genus, Species	Location/ Abundance Class[a]	Edible-Medicinal (E/M)	Introduced to Area
Aristida fendleriana Fendler three-awn	E1		
Aristida glabrata Three-awn	E1		
Bouteloua breviseta Grama	A2		
Bouteloua curtipendula Side-oats grama	A3, C3		
Bouteloua gracilis Blue grama	A5, B3, C4, E3		
Bouteloua trifida Grama	A2		
Bromus anomalus Nodding brome	C2, D1		
Bromus carinatus California brome	D1		
Bromus inermis Smooth brome	C2, D1		
Bromus japonicus Japanese brome	C1, D1, E1		X
Chloris virgata Feather finger grass	E2		
Hilaria jamesii Galleta grass	A3, C1		
Hordeum jubatum Foxtail barley	C1, E3		
Koeleria cristata June grass	D2		
Lycurus phleoides Wolftail	D1		
Muhlenbergia asperifolia Scratch grass	D2		
Muhlenbergia filiformis Pull-up muhly	D3		
Muhlenbergia metcalfei Muhly	A1		
Muhlenbergia pauciflora New Mexican muhly	A2		
Muhlenbergia repens Creeping muhly	A1		
Muhlenbergia torreyi Ring muhly	A3, E1		
Muhlenbergia utilis Aparejo grass	D1, E1		
Muhlenbergia wrightii Spike muhly	A1		

Family, Genus, Species	*Location/ Abundance Class*[a]	*Edible-Medicinal (E/M)*	*Introduced to Area*
Munroa squarrosa False buffalo grass	A1		
Oryzopsis humenoides Indian ricegrass	A2, C2, D2	E	
Oryzopsis micrantha Littleseed ricegrass	C1	E	
Panicum capillare Witchgrass	D3	E	
Panicum sp. Panic grass	D2	E	
Phleum pratense Timothy	D1		X
Polypogon maritimus Beard grass	D1		X
Polypogon monspeliensis Rabbitfoot grass	D1		X
Setaria viridis Green bristle grass	C1, E1	E	X
Sitanion hystrix Squirreltail	C3, D1, E3		
Sporobolus contractus Spike dropseed	A2, C1, D3	E	
Sporobolus cryptandrus Sand dropseed	A2, C3, D1	E	
Stipa comata Needle-and-thread	A1		
Stipa lettermanii Letterman needlegrass	A1		
Stipa scribneri Scribner needlegrass	A1		
Triticum aestivum Wheat	E1	E	X
Juncaceae (rush)			
Juncus balticus Wire rush	D2		X
Juncus saximontanus Rush	D3		
Juncus sp. Rush	D2		
Labiatae (mint)			
Hedeoma drummondii False pennyroyal	A1, C2		
Mentha arvensis Mint	D3	E	
Mentha spicata Mint	D1	E	X

Family, Genus, Species	Location/ Abundance Class[a]	Edible-Medicinal (E/M)	Introduced to Area
Marrubium vulgare Horehound	C1, E2	E	X
Moldavica parviflora Dragonhead	A1, C2	E	
Monarda austromontana Bee balm	A1, C1	E	
Monarda pectinata Bee balm	A1, C1	E	
Leguminosae (pea)			
Astragalus lentiginosus Locoweed	A1, E2		
Astragalus mollissimus Locoweed	A1, E2		
Astragalus pinonis Locoweed	A1, E2		
Desmanthus illinoenisis Bundle flower	C1		
Lupinus palmeri Lupine	A2, B1, C3, D2	E	
Medicago lupulina Black medic	D1	E	X
Medicago sativa Alfalfa	D1, E3	E	X
Melilotus albus White sweet clover	A3, C3, D3, E3	E	
Melilotus indicus Indian sweet clover	D1	E	
Melilotus officinalis Yellow sweet clover	A3, C3, D3, E3	E	
Robinia neomexicana New Mexican locust	D1	M	
Trifolium arizonicum Clover	D1	E	
Trifolium dubium Shamrock	D1	E	X
Trifolium gymnocarpon Clover	D1	E	
Trifolium pinetorum Clover	D1	E	
Trifolium repens White clover	D1	E	X
Liliaceae (lily)			
Allium cernuum Nodding onion	B2, D2	E	
Allium bigelovii Bigelow onion	C1	E	

Family, Genus, Species	Location/ Abundance Class[a]	Edible-Medicinal (E/M)	Introduced to Area
Asparagus officinalis	D1, E2	E	X
Asparagus			
Yucca baccata	A2, B1	E	
Banana yucca			
Yucca glauca	A3, B1	E	
Soapweed yucca			
Linaceae (flax)			
Linum puberulum	A1	M	
Flax			
Loasaceae (loasa)			
Mentzelia albicaulis	C3, E2	E	
Whitestem stickleaf			
Mentzelia pumila	C2		
Stickleaf			
Loranthaceae (mistletoe)			
Phoradendron juniperinum	A4, B2		
Juniper mistletoe			
Malvaceae (mallow)			
Malva neglecta	A1, E2	E	X
Common mallow			
Sphaeralcea coccinea	A1, B1, C2,		
Globe mallow	E1		
Sphaeralcea fendleri	A3, B1, C1,		
Globe mallow	E1		
Nyctaginaceae (four-o'clock)			
Abronia fragrans	C3		
Sand verbena			
Abronia pumila	C3		
Sand verbena			
Mirabilis comata	C1		
Four-o'clock			
Mirabilis linearis	C1		
Four-o'clock			
Mirabilis multiflora	A3, E2	M	
Four-o'clock			
Mirabilis oxybaphoides	C1, E1		
Four-o'clock			
Oxybaphus linearis	A1		
Umbrella wort			
Onagraceae (evening primrose)			
Epilobium adenocaulon	D2	E	
Willowweed			
Gaura coccinea	C3		
Scarlet gaura			
Gaura parviflora	C1		
Gaura			
Oenothera caespitosa	C1		
Tufted evening primrose			

Family, Genus, Species	Location/ Abundance Class[a]	Edible-Medicinal (E/M)	Introduced to Area
Oenothera coronopifolia	C1		
Evening primrose			
Oenothera englemannii	C3		
Evening primrose			
Oenothera gypsophila	C3		
Evening primrose			
Oenothera hookeri	C3		
Evening primrose			
Oenothera procera	C1		
Evening primrose			
Papaveraceae (poppy)			
Corydalis aurea	D1, E1		
Corydalis			
Eschscholtzia californica	D1	M	
California poppy			
Pinaceae (pine)			
Pinus edulis	A5, B4, E3	E	
Colorado piñon			
Pinus ponderosa	B4	E	
Ponderosa pine			
Pseudotsuga menzeisii	A1, B2	E	
Douglas fir			
Plantaginaceae (plantain)			
Plantago purshii	A3, E3	E	
Woolly Indian wheat			
Polemoniaceae (phlox)			
Gilia aggregata	A1, B2, C3		
Skyrocket			
Gilia gilioides	A2, C3		
Gilia			
Gilia longiflora	A2, C3		
Gilia			
Gilia multiflora	A1, C2	M	
Gilia			
Gilia pumila	A1, C1		
Gilia			
Phlox nana	A3, B2, C3		
Santa Fe phlox			
Portulacaceae (purslane)			
Portulaca oleracea	C3, E3	E	
Common purslane			
Polygonaceae (buckwheat)			
Eriogonum cernuum	A1, D1	E	
Nodding eriogonum			
Eriogonum jamesii	A1	E	
Antelope sage			
Eriogonum polycladon	D1	E	
Sorrel wild buckwheat			

Family, Genus, Species	Location/ Abundance Class[a]	Edible-Medicinal (E/M)	Introduced to Area
Eriogonum racemosum Redroot wild buckwheat	A1	E	X
Polygonum pennsylvanicum Smartweed	D2	E	
Polygonum persicaria Knotweed	D2	E	X
Rumex crispus Curly dock	D2, E1	E	X
Rumex fueginus Sorrel	D1	E	
Rumex hymenosepalus Canaigre	D2	E	
Polypodiaceae (fern)			
Cheilanthes fendleri Fendler's lip fern	B1, D1		
Woodsia oregana Rock fern	B1, D1		
Ranunculaceae (buttercup)			
Clematis ligusticifolia Western virgin's bower	C1	M	
Ranunculus aquatilis Buttercup	D2	E	
Rosaceae (rose)			
Cercocarpus montanus Mountain mahogany	A1	E	
Fallugia paradoxa Apache plume	A3, B2, C3, D2, E2	M	
Fragaria bracteata Bracted strawberry	B1	E	
Potentilla anserina Silverweed	D3	E	
Salicaceae (willow)			
Populus fremontii Fremont cottonwood	C2, D2	E	
Salix amygdaloides Peach-leaf willow	D2	E	
Salix exigua Sandbar willow	D3	E	
Salix gooddingii Goodding willow	D2	E	
Saxifragaceae (saxifrage)			
Ribes cereum Wax currant	C1	E	
Scrophulariaceae (figwort)			
Castilleja integra Paintbrush	A3	E	

Family, Genus, Species	Location/ Abundance Class[a]	Edible-Medicinal (E/M)	Introduced to Area
Castilleja linariaefolia Paintbrush	A3, C1	E	
Mimulus guttatus Monkeyflower	D2	E	
Penstemon barbatus Scarlet beardtongue	A2, B2, D3	E	
Verbascum thapsus Mullein	A3, B1, C3, D3	M	X
Veronica americana American brooklime	D1	E	
Solanaceae (nightshade)			
Datura meteloides Sacred datura	C1	M	
Datura quercifolia Datura	E1	M	
Lycium pallidum Wolfberry	C1, E1	E	
Physalis fendleri Ground cherry	A2, C3	E	
Physalis hederaefolia Ground cherry	A3, C2, E3	E	
Physalis heterophylla Ground cherry	A1, C1, E2	E	
Physalis pruinosa Ground cherry	A1, C1	E	
Solanum elaeagnifolium Horse nettle	E1	E	
Solanum jamesii Wild potato	C2	E	
Solanum nigrum Black nightshade	C2, E2	E	
Solanum rostratum Buffalo bur	E2		
Solanum triflorum Nightshade	E2	M	
Tamaricaceae (tamarix)			
Tamarix pentandra Tamarix	C1, E2		X
Typhaceae (cattail)			
Typha latifolia Cattail	D3	E	
Ulmaceae (elm)			
Ulmus pumila Elm	C2, D1, E3		X
Verbenaceae (vervain)			
Verbena bipinnatifida Vervain	A1, E3		

Family, Genus, Species	*Location/ Abundance Class*[a]	*Edible-Medicinal (E/M)*	*Introduced to Area*
Verbena gooddingii Vervain	A2, C1, E2		
Verbena macdougalii Vervain	A1, E2		
Verbena wrightii Vervain	A1, E1		
Zygophyllaceae (caltrop)			
Kallstroemia hirsutissima Caltrop	C1		
Kallstroemia parviflora Caltrop	C1		
Tribulus terrestris Goathead	C1, E2		

Appendix B

VEGETATION ZONES BEYOND THE STUDY AREA

Although they lie outside the study area, the shortgrass plains to the south and west of Arroyo Hondo Pueblo (Fig. 19) and the montane forests and alpine tundra of the Sangre de Cristo range to its east and northeast (Figs. 20–22) were presumably of at least seasonal importance to the Arroyo Hondo people as resource areas of food and raw materials. Consequently, the following brief descriptions of these nearby zones were compiled, primarily from field observation. Data on soils were derived from tests performed on samples from various vegetational zones and from the Soil Management Report, Tesuque Ranger District, Santa Fe National Forest.

ALPINE TUNDRA AND MEADOW/SPRUCE-FIR FOREST ASSOCIATION

Soils of the alpine tundra and meadows, found in the southern Sangre de Cristo range at elevations of 12,000 feet and higher, are moderately deep, sandy loams distributed over rocky terrain. These soils are generally dark (nearly black) and very acid, having a pH of 4.4 to 5.8. The parent material is glacial till and alluvium derived

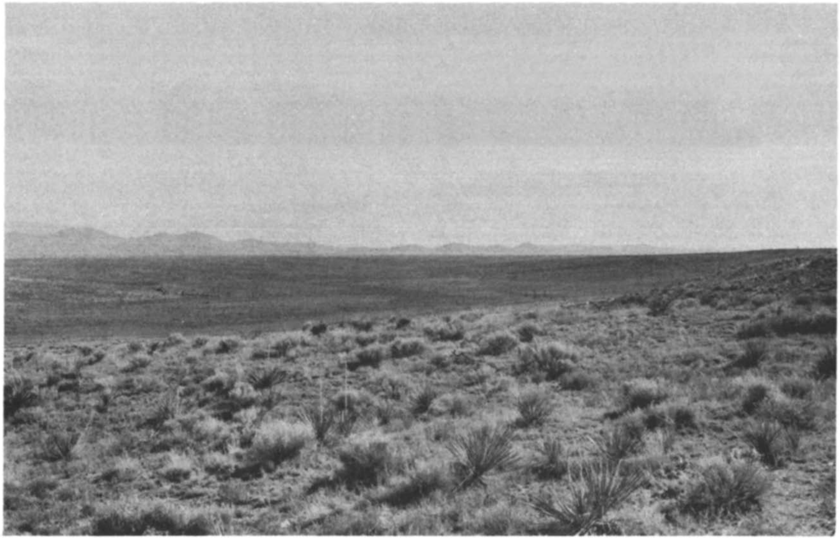


FIG. 19. The Shortgrass Plains Southwest of Arroyo Hondo Pueblo.

FIG. 20. The Spruce-Fir Forest in the Sangre de Cristo Mountains.

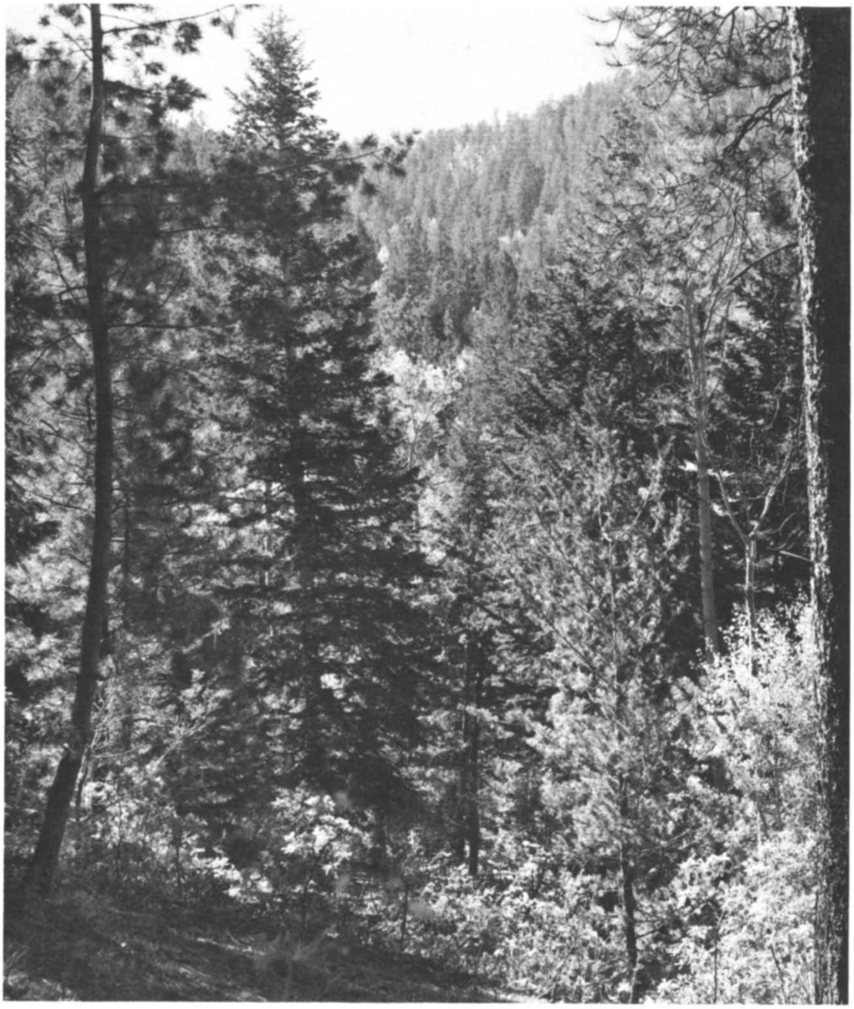


FIG. 21. The Mixed Conifer Forest in the Sangre de Cristo Mountains.

from granite, gneiss, and schists. Soils of this type, which are classed as Nambe-Katherine, were not tested during the study. However, considering the nature of parent material, it is unlikely that potassium would become a limiting factor for plant growth. Phosphorus, on the other hand, could constitute such a factor in this type of soil. Phosphorus forms insoluble compounds of iron and

FIG. 22. The Ponderosa Pine Forest in the Sangre de Cristo Mountains.

aluminum phosphates within the pH range of 3.0 to 4.0 and practically insoluble iron phosphate in the range of 5.0 to 6.0, thus creating a double limitation if there is a large amount of phosphorus in the soil, since it ties up all the available iron that would otherwise be used by plant life. Within the pH range found in the alpine soils, nitrogen could become a limiting factor also. Ammonification proceeds rapidly within a pH range of 3.5 to 7.0, while nitrification proceeds slowly at a pH range of 4.5 to 6.5. Below pH 5.5, ammonia compounds build up because of the slowness of conversion to nitrogen compounds. Therefore, if nitrogen is used faster by the plants than it is converted from ammonia compounds, it would become a limiting factor. Nitrogen compounds from other sources on the alpine tundra would be minimal, with lightning probably being the best producer. Plants of the tundra have become adapted to the use of ammonia compounds. Therefore nitrogen is limiting only to those plants that cannot utilize ammonia.

Soils of the spruce-fir association, found at elevations between 9,000 and 12,000 feet, are moderately deep, coarse-textured, light brown to dark gray, and very acidic, having a pH of 4.0 to 5.5. They are generally found on moderately steep to steep slopes having a

2-to-4-inch layer of litter. Parent materials are alluvial, sedimentary, granite, gneiss, and schists. Tests made on these soils indicated that potassium was not deficient. Due to the low pH value, phosphorus is evidently tied up in insoluble iron and aluminum compounds and large amounts (tons per acre) would need to be applied to bring the pH up to normal levels. As previously stated, the addition of phosphorus would create an iron deficiency in these soils, which, like those of the alpine tundra, are classed as Nambe-Katherine. Present phosphorus deficiency is 14 percent. Nitrogen was also slightly deficient (4 percent) in the soils tested, a condition that, as explained above, could be expected.

Growing periods for most plant life in these zones are relatively short. Temperatures dip below freezing later in the spring and earlier in the fall than is the case at lower elevations, just as snow will remain longer in the spring and begin earlier in the fall. The spring snow cover acts as an insulator, keeping the soil temperature from rising as rapidly as the elevational air temperature. This snow cover may persist well into May and temperatures may continue to dip to freezing at night throughout the first week of June. Consequently, the soil may not thaw until the end of May or early June. With the thawing and rising soil temperatures, germination of seeds begins a life cycle that will be completed by the time heavy frosts occur in autumn. The first week of September may see the earliest fall frosts, and it is during this month that snowfall begins. The growing season at this elevation ranges from 120 to 150 days per year, averaging around 130. Only early-maturing, short–life-cycle plants and cold-tolerant species are well adapted to these climatic conditions. These plants are also able to use ammonia rather than nitrogen products. The mean yearly temperature for this elevational range is around 38°F. Monthly mean temperatures are given in Table 16.

Precipitation for these zones is generally greater than that of the lower zones discussed subsequently and in the body of the text. Mean rainfall is between 25 and 30 inches per year, most of it occurring during the summer months (Table 17). While there are no official statistics on the quantitative mean and range for snowfall at these elevations, it seems safe to assume that they receive at least an amount equivalent to that of the lower mixed conifer zone, which is about 100 inches per year; and, as suggested by the 1-year record, snowfall is very likely more than this.

TABLE 16.
Mean Monthly Temperatures by Elevation Range (30-Year Record)

Month	*Temperature (°F)*				
	4,500-5,500 ft.	5,500-7,500 ft.	7,500-8,500 ft.	8,500-9,500 ft.	9,500 ft.+[a]
January	29.1	29.9	21.4	20.8	20.6
February	35.4	33.7	25.3	21.7	21.3
March	42.0	39.2	30.0	25.6	24.1
April	50.8	48.0	40.3	35.6	33.9
May	59.1	56.6	49.0	46.7	44.2
June	68.3	66.4	57.7	56.2	54.1
July	72.5	70.4	63.9	59.3	57.1
August	70.8	68.6	62.5	57.6	55.2
September	64.0	62.9	56.2	51.7	50.2
October	52.4	52.0	46.3	42.9	41.5
November	39.7	39.0	33.1	30.4	29.8
December	31.0	32.0	24.5	23.9	23.7
Annual Mean	51.3	50.0	42.5	39.4	38.0

[a] One-year record only.
FROM: U.S. Weather Bureau, Albuquerque, New Mexico.

TABLE 17.
Precipitation Averages by Elevation Range

Month	Precipitation (inches)							
	5,000-6,500 ft.		6,500-7,500 ft.		7,500-9,000 ft.		9,000 ft.+[a]	
	Rain	Snow	Rain	Snow	Rain	Snow	Rain	Snow
January	0.54	3.4	0.68	7.4	1.75	20.7	1.75	20.0
February	0.41	2.3	0.69	6.6	1.90	21.7	1.77	23.9
March	0.50	3.1	0.78	5.0	1.70	16.0	2.32	22.9
April	0.77	0.7	0.83	2.4	1.35	6.6	1.18	10.4
May	0.93	0.1	1.38	0.5	1.50	2.3	0.99	2.3
June	0.69	0.0	1.17	0.0	0.96	0.2	0.78	0.1
July	1.43	0.0	2.14	0.0	1.96	0.0	2.85	0.1
August	1.58	0.0	2.23	0.0	2.69	0.0	3.19	0.0
September	0.75	0.0	1.41	0.2	2.13	0.4	1.61	0.1
October	1.03	0.0	1.09	0.2	1.63	2.8	1.94	6.0
November	0.41	1.1	0.60	3.1	0.99	10.2	1.25	8.3
December	0.47	3.3	0.70	6.3	1.73	18.7	2.43	24.6
Total	9.51	14.0	13.70	31.7	20.29	99.6	22.06	118.7

[a]One-year record only.

FROM: U.S. Weather Bureau, Albuquerque, New Mexico.

Although the alpine zone is a harsh environment subject to arctic temperatures, strong winds, and heavy snow cover during most of the year, many species of vegetation have adapted to these conditions. Within this zone are a minimum of 26 families, 61 genera, and 95 floral species (Harold McKay, professor of biology, University of New Mexico, 1971: personal communication). Due to differences in terrain and local animal activity, the total ground cover varies greatly over the fell and boulder fields, talus slopes, snow flushes, wet and dry meadows, and stream margins of the alpine zone. The dominant plant species in the southern Sangre de Cristo range are bluegrass (*Poa* spp.), shrubby cinquefoil (*Potentilla fruticosa*), and the sedges (*Carex* spp.).

The spruce-fir forest is also a harsh environment, but unlike the alpine zone this association is not constantly exposed to elemental excesses, its many deep canyons and high ridges offering some protection from wind and providing summer shade that helps to retain soil moisture. The cool temperatures of the zone also retard soil moisture evaporation. Like the alpine tundra-meadow, the spruce-fir forest receives more rain and snowfall during the year than most of the lower zones. The shorter growing season, however, partially limits the number of species dominants. Thirty-six families, 96 genera, and 95 species constitute the minimum floral group of the spruce-fir zone, and total ground cover is about 75 percent, herb cover being approximately 55 percent. The dominant species are Engelmann spruce (*Picea engelmannii*), blue spruce (*P. pungens*), corkbark fir (*Abies lasiocarpa*), geranium (*Geranium richardsonii*), pussytoes (*Antennaria parvifolia*), sedges, fringed bromegrass (*Bromus ciliatus*), Arizona fescue grass (*Festuca arizonica*), bluegrass, and dwarf juniper (*Juniperus communis*) (Table 18).

TABLE 18.
Vegetation Species of the Spruce-Fir Zone (9,000 to 12,000 Feet) Adjacent to the Arroyo Hondo Study Area

Family, Genus, Species[a]	*Native*	*Usable*[b]
GYMNOSPERMAE		
Cupressaceae (cypress)		
Juniperus communis (Dwarf juniper)	X	
Pinaceae (pine)		
Abies concolor (White fir)	X	X
Abies lasiocarpa (Corkbark fir)	X	
Picea engelmannii (Engelmann spruce)	X	X
Picea pungens (Blue spruce)	X	

Pinus flexilis (Limber pine)	X	
Pinus strobiformis (Mexican white pine)	X	
Pseudotsuga taxifolia (Douglas fir)	X	X
ANGIOSPERMAE		
Monocotyledones		
Iridaceae (iris)		
Iris missouriensis (Western blue flag)	X	
Liliaceae (lily)		
Veratrum californicum (Skunk cabbage)	X	X
Poaceae (grass)		
Agropyron trachycaulum (Slender wheatgrass)	X	
Bromus anomalus (Nodding brome)	X	X
Bromus ciliatus (Fringed brome)	X	
Festuca arizonica (Arizona fescue grass)		
Poa interior (Inland bluegrass)	X	
Dicotyledones		
Berberidaceae (barberry)		
Berberis repens (Creeping mahonia)	X	X
Campanulaceae (bluebell)		
Campanula rotundifolia (Bluebell)	X	
Caprifoliaceae (honeysuckle)		
Sambucus racemosa (Rocky Mountain red elder)	X	X
Compositae (sunflower)		
Achillea lanulosa (Western yarrow)	X	X
Antennaria aprica (Pussytoes)	X	
Cruciferae (mustard)		
Erysimum capitatum (Western wallflower)	X	
Geraniaceae (geranium)		
Geranium richardsonii (Cranesbill)	X	
Leguminosae (pea)		
Trifolium dasyphyllum (Alpine clover)	X	
Vicia americana (American vetch)	X	
Onagraceae (evening primrose)		
Epilobium angustifolium (Fireweed)	X	
Oxalidaceae (wood sorrel)		
Oxalis violacea (Violet wood sorrel)	X	X
Ranunculaceae (buttercup)		
Aquilegia triternata (Red columbine)	X	
Rosaceae (rose)		
Fragaria ovalis (Strawberry)	X	X
Potentilla sp. (Cinquefoil)	X	X
Salicaceae (willow)		
Populus tremuloides (Trembling aspen)	X	X
Scrophulariaceae (figwort)		
Penstemon whippleanus (Dusky penstemon)	X	X
Umbelliferae (carrot)		
Osmorrhiza obtusa (Sweet cicely)	X	X
Pseudocymopterus montanus (Mountain parsley)	X	X
Violaceae (violet)		
Viola canadensis (Canadian violet)	X	

[a]Numerous unlisted species occur in this zone; they were either not identified or not observed.

[b]"Usable" means that the species could be used for food, medicine, building, or fuel.

MIXED CONIFER FOREST/PONDEROSA PINE FOREST

As with the soils of the higher elevations, those of the mixed conifer forest, found at elevations of about 8,000 to 9,500 feet, are also derived from granite, gneiss, and schists, but are classed as Bobtail Seal and Cundiyo Edlow soils, extending into those of the Mirabal-Supervisory. These soils range from silt to sandy loam, and may be several inches to several feet in thickness. Colors range from pinkish-gray through grayish-brown to brownish-gray, and pH values range from 4.4 to 6.6. Tests indicate that available potassium is abundant. Phosphorus is about 80 percent as deficient as in the Nambe-Katherine soils of the spruce-fir zone, and nitrogen deficiency is approximately the same, or 3 percent.

Soils of the ponderosa pine association, at elevations of 7,600 to 9,000 feet, are derived from sandstone, shale, granite, gneiss, and schist and are classed as the Mirabal-Supervisory and Chimayo-Carcajo soils. Soil type range is red sandy loam, reddish-brown to light reddish-brown gravelly sandy loam, dark grayish-brown gravelly loam, and brown sandy loam. These soils are shallow to deep, are situated on steep slopes and ridges, and are generally associated with large amounts of scattered and intermixed rock. Most of the ponderosa pine terrain is covered by needle litter ranging from a mere scattering to 6 inches in depth. Depending upon the amount of calcic parent material in the area, pH values range from 5.2 to 7.6. Tests indicate no potassium deficiency and only slight (2 percent) phosphorus deficiency, except in very acid soils having a pH of 5.2 to 5.5 where the phosphorus is tied up in iron and aluminum compounds, making the ponderosa pine forest nearly as deficient as the spruce-fir zone. Nitrogen deficiency in the acid soils equaled that noted for the spruce-fir soils, while the higher pH soils (5.6 to 7.6) exhibited a deficiency of less than 1 percent.

The growing period for most plants found within this elevational range is between 125 and 185 days per year, with the shorter period being characteristic of the mixed conifer association and the longer period occurring nearer the 7,500-foot elevations that mark the lower limits of the ponderosa pine forest. The average growing season is around 145 days per year, and in the mixed conifer and upper ponderosa pine associations, the growing season is influenced by the same factors governing that of the alpine tundra and spruce-fir zones, although to a somewhat lesser extent. The rise in temperature and the last frost occur only a few days earlier in the spring, and cold temperatures and fall frosts come a few days later in autumn, thus slightly extending the growing period. Near the 7,500-foot level, the growing season is further extended by the earlier spring warming of the south-facing slopes, which also remain warm later into the fall. The last freezing frost of the lower ponderosa pine zone usually occurs around the end of May, and the first freezing frost of fall around the middle of September. Heavy frosts in these zones may occur as late as June or as early as the first or second week of September.

Cold-tolerant or short-life-cycle plants are well adapted to the upper mixed conifer elevations; plants having longer life cycles and lower tolerance to cold are sustained in the lower ponderosa zone. These plants are comparable in their nitrogen requirements to those of the spruce-fir zone.

The mean yearly temperature of the mixed conifer zone is around 40°F, and for the ponderosa pine zone, 42.5°F. Mean monthly temperatures for a 30-year period are given in Table 16. Rain precipitation averages 20 inches per year with an additional 100 inches of snow during the winter months. Rains are heaviest in July, August, and September, with about 2 inches per month, the rest of the year averaging 1.5 to 1.7 inches per month. Under these conditions of precipitation, water is not a common limiting factor, as the normally luxuriant plant growth of these elevations testifies. However, the colder soil temperatures of all the upper zones, which last late into the spring, reduce the effective available moisture to all plant life. Rain and snowfall means by month, based on a 30-year period, are given in Table 17.

The environment of the mixed conifer forest may be characterized as one of harsh winters ameliorated by slightly earlier springs and later falls than those of the higher elevations, providing an additional week or more of warm weather and allowing soils to warm and seed germination to begin a few days earlier in the spring. It is also a moist environment that can support heavy vegetation cover, within which cool summer air temperatures help slow the rate of soil moisture evaporation. A minimum of 48 botanical families, containing 173 genera and 334 species, are found here (McKay 1971: personal communication). Total ground cover is around 85 percent, herb cover about 60 percent. Dominant plant species are white fir (*Abies concolor*), Douglas fir (*Pseudotsuga taxifolia*), Engelmann spruce, aspen (*Populus tremuloides*), limber pine (*Pinus flexilis*), ponderosa pine (*P. ponderosa*), Gambel oak (*Quercus gambelii*), mountain mahogany (*Cercocarpus montanus*), vetches (*Vicia* spp.), peavine (*Lathyrus* spp.), geranium, snowberries (*Symphoricarpos* spp.), Rocky Mountain red elder (*Sambucus racemosa*), bluegrass, clover (*Trifolium* spp.), and yellow sweet clover (*Melilotus officinalis*) (Table 19).

TABLE 19.
Vegetation Species of the Mixed Conifer Zone (8,000 to 9,500 Feet) Adjacent to the Arroyo Hondo Study Area

Family, Genus, Species[a]	*Native*	*Usable*[b]
GYMNOSPERMAE		
Cupressaceae (cypress)		
Juniperus communis (Dwarf juniper)	X	
Juniperus scopulorum (Rocky Mountain juniper)	X	X
Pinaceae (pine)		
Abies concolor (White fir)	X	X
Picea engelmannii (Engelmann spruce)	X	X
Pinus ponderosa (Ponderosa pine)	X	X
Pseudotsuga taxifolia (Douglas fir)	X	X
ANGIOSPERMAE		
Monocotyledones		
Iridaceae (iris)		
Iris missouriensis (Western blue flag)	X	
Liliaceae (lily)		
Veratrum californicum (Skunk cabbage)	X	X
Zygadenus elegans (Death camus)	X	
Poaceae (grass)		
Agropyron trachycaulum (Slender wheatgrass)	X	
Bromus anomalus (Nodding brome)	X	X
Festuca ovina (Sheep fescue)	X	
Poa interior (Inland bluegrass)	X	
Poa pratensis (Kentucky bluegrass)	X	
Dicotyledones		
Berberidaceae (barberry)		
Berberis repens (Creeping mahonia)	X	X
Campanulaceae (bluebell)		
Campanula rotundifolia (Bluebell)	X	
Caprifoliaceae (honeysuckle)		
Sambucus racemosa (Rocky Mountain red elder)	X	X
Symphoricarpos sp. (Snowberry)	X	X
Compositae (sunflower)		
Achillea lanulosa (Western yarrow)	X	X
Agoseris glauca (Mountain dandelion)	X	
Aster bigelovii (Bigelow aster)	X	X

Erigeron divergens (Fleabane)	X	
Hymenoxys richardsonii (Bitterweed)	X	X
Cruciferae (mustard)		
Erysimum capitatum (Western wallflower)	X	
Geraniaceae (geranium)		
Geranium richardsonii (Cranesbill)	X	
Leguminosae (pea)		
Melilotus officinalis (Yellow sweet clover)		
Thermopsis pinetorum (Big golden pea)	X	
Trifolium fendleri (Fendler's clover)	X	
Vicia americana (American vetch)	X	
Linaceae (flax)		
Linum lewisii (Western blue flax)	X	X
Onagraceae (evening primrose)		
Epilobium angustifolium (Fireweed)	X	
Oenothera hookeri (Evening primrose)	X	
Oxalidaceae (wood sorrel)		
Oxalis violacea (Violet wood sorrel)	X	X
Plantaginaceae (Plantain)		
Galium asperrimum (Rough bedstraw)	X	X
Galium boreale (Northern bedstraw)	X	X
Polemoniaceae (phlox)		
Gilia sp. (Gilia)	X	
Polemonium sp. (Jacob's ladder)	X	
Ranunculaceae (buttercup)		
Aquilegia triternata (Red columbine)	X	
Thalictrum fendleri (Meadow rue)	X	X
Rosaceae (rose)		
Fragaria ovalis (Strawberry)	X	X
Potentilla anserina (Silverweed)	X	X
Potentilla hippiana (Cinquefoil)	X	X
Rosa sp. (Rose)	X	X
Salicaceae (willow)		
Populus tremuloides (Trembling aspen)	X	X
Saxifragaceae (saxifrage)		
Huechera parvifolia (Alumroot)	X	X
Ribes sp. (Currant; gooseberry)	X	X
Scrophulariaceae (figwort)		
Castilleja linariaefolia (Indian paintbrush)	X	X
Penstemon barbatus (Scarlet beardtongue)	X	X
Penstemon whippleanus (Dusky penstemon)	X	X
Umbelliferae (carrot)		
Osmorrhiza obtusa (Sweet cicely)	X	X
Pseudocymopterus montanus (Mountain parsley)	X	X
Violaceae (violet)		
Viola canadensis (Canadian violet)	X	

[a]Numerous unlisted species occur in this zone; they were either not identified or not observed.
[b]"Usable" means that the species could have been used for food, medicine, building, or fuel.

Although the higher elevations of the ponderosa pine forest receive about the same yearly moisture as the mixed conifer forest, yearly precipitation at the lower altitudes of the ponderosa pine forest may be 5 to 10 inches less. The yearly temperature range is wide throughout this zone, offering a varied environment to many species. Pine forests, however, usually occupy those soils of mountainous regions that are poorest, in that little soil has accumulated in these areas. Granitic outcrops are favored locations of ponderosa pine growth, and pines usually occupy very rocky, steep terrain where soil is easily eroded. The pine needles are very acidic and help break down into soil the bedrock on which the ponderosas grow. In dense ponderosa forests this needle cover may reach a depth of 10 inches or more, in which case it retards seedling rooting and the development of lush, heavy ground cover. Ponderosa forests are, therefore, usually devoid of such cover, total ground cover being only about 40 percent and herb cover approximately 5 percent. Dominant flora consists of ponderosa pine, Gambel oak, blue grama grass (*Bouteloua gracilis*), side-oats grama (*B. curtipendula*), pine dropseed grass (*Blepharoneuron tricholepis*), squirreltail grass (*Sitanion hystrix*), mountain brome (*Bromus marginatus*), mountain mahogany, and Rocky Mountain juniper (*Juniperus scopulorum*) (Table 20).

Three types of forest fire occurring in these zones have potential for greatly altering the local composition and subsistence value of the forest for both animals and men. Extremely hot, general fires produce a primary sere in which the vegetation and duff microorganisms are destroyed and a bare habitat is created. The result is erosion and a long recovery period during which the establishment of cover growth and tree seedlings is greatly retarded due to loss of soils and the fire's sterilization effect. Other types of fires primarily burn only fallen branches and the needle layer of the forest floor, or move through the tops of the trees as well as the duff and understory. These may leave seeds, roots, and humus undamaged, or only partially damaged, resulting in parklike conditions or an increase of invader species, including oak, in the ponderosa pine forest. An invasion of aspen, bromegrass, wheatgrass, berry bushes, and other plants occurs in the mixed conifer zone. Through the presence of these invaders and the burrowing mammals that they attract, as well as rotting fire debris, the local humus and upper subsoil are much

TABLE 20.
Vegetation Species of the Ponderosa Pine Zone (7,800 to 9,000 Feet) Adjacent to the Arroyo Hondo Study Area

Family, Genus, Species[a]	*Native*	*Usable*[b]
GYMNOSPERMAE		
Cupressaceae (cypress)		
Juniperus scopulorum (Rocky Mountain juniper)	X	X
Pinaceae (pine)		
Abies concolor (White fir)	X	X
Pinus ponderosa (Ponderosa pine)	X	X
Pseudotsuga taxifolia (Douglas fir)	X	X
ANGIOSPERMAE		
Monocotyledones		
Liliaceae (lily)		
Allium neomexicanum (Nodding onion)	X	X
Veratrum californicum (Skunk cabbage)	X	X
Poaceae (grass)		
Agropyron smithii (Western wheatgrass)	X	X
Blepharoneuron tricholepis (Pine dropseed)	X	X
Bouteloua gracilis (Blue grama)	X	
Dicotyledones		
Berberidaceae (barberry)		
Berberis repens (Creeping mahonia)	X	X
Campanulaceae (bluebell)		
Campanula rotundifolia (Bluebell)	X	
Capparidaceae (caper)		
Cleome serrulata (Rocky Mountain bee plant)	X	X
Caprifoliaceae (honeysuckle)		
Sambucus racemosa (Rocky Mountain red elder)	X	X
Symphoricarpos oreophilus (Mountain snowberry)	X	X
Compositae (sunflower)		
Achillea lanulosa (Western yarrow)	X	X
Artemisia sp. (Sagebrush)	X	X
Aster bigelovii (Bigelow aster)	X	X
Cirsium undulatum (Wavy leaf thistle)	X	X
Erigeron macranthus (Fleabane)	X	
Gaillardia pinnatifidia (Blanketflower)	X	X
Helianthus annuus (Annual sunflower)	X	X
Hymenoxys richardsonii (Bitterweed)	X	X
Rudbeckia laciniata (Cutleaf coneflower)	X	
Taraxacum laevigatum (Red seeded dandelion)		X
Cruciferae (mustard)		
Erysimum capitatum (Western wallflower)	X	
Fagaceae (oak)		
Quercus gambelii (Gambel oak)	X	X
Geraniacea (geranium)		
Geranium richardsonii (Cranesbill)	X	
Labiatae (mint)		
Mentha arvensis (Mint)	X	X
Monarda menthaefolia (Bee balm)	X	X

Leguminosae (pea)		
Lupinus sp. (Lupine)	X	
Melilotus albus (White sweet clover)		
Melilotus officinalus (Yellow sweet clover)	X	
Robinia neomexicana (New Mexico locust)	X	
Thermopsis pinetorum (Big golden pea)	X	
Linaceae (flax)		
Linum lewisii (Western blue flax)	X	X
Loasaceae (loasa)		
Mentzelia albicaulis (Whitestem stickleaf)	X	X
Plantaginaceae (plantain)		
Galium aparine (Goosegrass)	X	X
Polemoniaceae (phlox)		
Polemonium foliosissimum (Jacob's ladder)	X	
Ranunculaceae (buttercup)		
Aquilegia triternata (Red columbine)	X	
Clematis pseudoalpina (Virgin's bower)	X	X
Thalictrum fendleri (Meadow rue)	X	X
Rosaceae (rose)		
Fragaria ovalis (Strawberry)	X	X
Potentilla hippiana (Cinquèfoil)	X	X
Prunus virginiana (Chokecherry)	X	X
Rosa fendleri (Fendler's rose)	X	X
Rosa neomexicana (New Mexico rose)	X	X
Salicaceae (willow)		
Populus tremuloides (Trembling aspen)	X	X
Salix irrorata (Willow)	X	X
Saxifragaceae (saxifrage)		
Ribes cereum (Wax currant)	X	X
Scrophulariaceae (figwort)		
Castilleja linariaefolia (Indian paintbrush)	X	X
Penstemon sp. (Beardtongue)	X	X
Verbascum thapsus (Miner's candle)		X
Umbelliferae (carrot)		
Heracleum lanatum (Cow parsnip)	X	X
Osmorrhiza obtusa (Sweet cicely)	X	X
Pseudocymopterus montanus (Mountain parsley)	X	X
Violaceae (violet)		
Viola canadensis (Canadian violet)	X	

[a]Numerous unlisted species occur in this zone; they were either not identified or not observed.
[b]"Usable" means that the species could have been used for food, medicine, building, or fuel.

improved. In the ponderosa zone, such areas are ultimately reoccupied by mature, even-aged pines, and the needle layer is reestablished, unless new fires occur. In the mixed conifer zone, ponderosa may develop in poor soils on warm slopes of the lower elevations, while the better soils may be covered by a mature aspen forest. In this late seral stage, the aspen forest will provide the conditions necessary for the reestablishment of fir, spruce, and pine, which eventually shade out the aspen. If a second, extensive fire occurs before this process has reached its climax, the area may be invaded by oak, which then becomes dominant.

Whatever the extent of fire damage to these upper vegetational zones, in some ways the fires would have been beneficial to primitive man. The plant species that invade the burned areas are a major food source for many of the animal inhabitants of the mountainous regions. In his description of fire effects on wildlife in Idaho, Leege (1968:237) says: "When these conifer stands are destroyed by fire, grasses and forbs immediately take over the site. Soon, shrub seedlings grow in size and form dense brushfields. These shrubs are the life line for deer and elk as the buds and annual twig growth provide the winter food supply."

In the upper reaches of the Arroyo Hondo drainage an increase in shrubs would be necessary to attract and maintain a more extensive population of larger game animals. The majority of the shrubs that invade a burn in this area would not only provide browse for deer but increase the yield of berries and nuts for human consumption. Little is known of the precise effects of fire in its various forms on piñon-juniper woodland. However, both in the upper woodland of the study area where the piñon and juniper begin to interfinger with the ponderosa pine forest and at lower elevations where they are dominant (near the village of San Jose and on the north face of Rowe Mesa along the Pecos River east of Arroyo Hondo), burn areas have been primarily taken over by oak, and other edible plants such as rose and raspberry are common (Charles Wright, Pecos Ranger Station, Santa Fe National Forest, 1974:personal communication). Thus, fire in the upper Arroyo Hondo area and at the general elevation of the site would tend to increase the total natural food supply.

The vegetation of the piñon-juniper woodland (6,800 to 7,600 feet) lying between the ponderosa pine forest and the shortgrass plains has been discussed in the body of the text and will not be reexamined here.

SHORTGRASS PLAINS

The shortgrass plains zone occurs below the woodland at elevations of approximately 5,000 to 6,700 feet. Here, soils are derived from sandstone, shale, the Santa Fe formation, basalt, cinders, and eolian and alluvial mixed-parent rocks. The soil types belong to the Majada-Apache-Montoso and the Calabasas-Tetilla-Caja groups and consist of dark reddish-gray loam; grayish-brown or brown, gravelly sandy loam; brown silt loam; light brown heavy loam; brown, heavy, very fine sandy loam; brown, very fine sandy loam; light reddish-brown silt loam; light brown loamy sand; and light grayish-brown loamy sand. Very small amounts of litter are found on these soils, and the pH values range from 7.0 to 8.6. Tests indicate a potassium deficiency of 1 to 2 percent and a phosphorus deficiency of 2 to 6 percent. Such deficiencies are of minor importance and probably do not constitute a limiting factor in plant growth. Nitrogen deficiency ranges from 2 to 8 percent and could become a limiting factor under agricultural use of a type in which crops are removed and soils are not fertilized.

The growing period for this elevational range is 130 to 220 days per year, the mean yearly season being 170 days. Average temperatures are about 2° higher per month (exceptions being December and January, when they are lower) than those of the piñon-juniper zone. The last freezing frost of spring usually occurs around the end of April or the first of May, although it can occur as late as mid-May, while the first freezing frosts of fall normally take place around the last week of October but can come as early as the last week of September. The mean yearly temperature is about 51°F, and monthly mean temperatures for a 30-year period are given in Table 16.

By comparison with the upper zones, the grassland zone receives the least amount of moisture, the average rainfall being 9 to 10 inches per year and the mean snowfall 14 inches (Table 1.17). Most precipitation occurs during the summer months, with the winter and spring periods being relatively dry. During the winter, the piñon-juniper zone receives over twice the amount of moisture received by the grassland zone.

Depending upon their specific requirements, both short- and long-cycle plants may do well in this zone, and different species will be found blooming from spring through fall. Because of high summer temperatures, evaporation is rapid in the grasslands, and while the soils of the rolling sandhills are generally fertile, a lack of water limits plant life to species that can remain dormant for long periods. Consequently, many of the xeromorphic plants are found growing in this zone. However, along the arroyos and washes, which receive an abundant amount of runoff water, long-cycle plants occur. The dominant vegetation includes grama grasses (*Bouteloua* spp.), muhly (*Muhlenbergia* spp.), Indian ricegrass (*Oryzopsis hymenoides*), dropseed (*Sporobolus* spp.), galleta grasses (*Hilaria jamesii*), winter fat (*Eurotia lanata*), Russian thistle (*Salsola kali*), sage (*Salvia* spp.), rabbit brush (*Chrysothamnus nauseosus*), and cacti (*Opuntia* spp.) (Table 21).

TABLE 21.
Vegetation Species of the Shortgrass Plains Zone (5,000 to 6,700 Feet) Adjacent to the Arroyo Hondo Study Area

Family, Genus, Species[a]	*Native*	*Usable*[b]
GYMNOSPERMAE		
Cupressaceae (cypress)		
Juniperus monosperma (One-seeded juniper)	X	X
ANGIOSPERMAE		
Monocotyledones		
Liliaceae (lily)		
Yucca baccata (Banana yucca)	X	X
Yucca glauca (Soapweed yucca)	X	X
Poaceae (grass)		
Agropyron smithii (Western wheatgrass)	X	X
Andropogon gerardi (Big bluestem)	X	X
Aristida diverticata (Poverty three-awn)		
Bouteloua gracilia (Blue grama)	X	
Bromus sp. (Brome)		
Eragrostis sp. (Love grass)		
Muhlenbergia sp. (Muhly)		
Muhlenbergia torreyi (Ring muhly)		
Oryzopsis hymenoides (Indian ricegrass)	X	X
Panicum sp. (Panic grass)		
Sporobolus sp. (Dropseed)	X	X
Dicotyledones		
Asclepiadaceae (milkweed)		
Asclepias latifolia (Broad-leaved milkweed)		
Cactaceae (cactus)		
Corypantha sp. (Pincushion cactus)	X	X
Echinocereus sp. (Strawberry cactus)	X	X
Opuntia sp. (Prickly pear)	X	X
Opuntia imbricata (Cholla)	X	X
Mammillaria sp. (Pincushion cactus)	X	X

Capparidaceae (caper)		
Cleome serrulata (Rocky Mountain bee plant)	X	X
Chenopodiaceae (goosefoot)		
Atriplex canescens (Four-wing saltbush)	X	X
Chenopodium sp. (Goosefoot)	X	X
Kochia americana (Red sage)	X	X
Kochia scoparia (Summer cypress)		X
Salsola kali (Russian thistle)		X
Compositae (sunflower)		
Artemisia sp. (Sagebrush)	X	X
Aster sp. (Aster)	X	X
Chrysothamnus nauseosus (Rabbit brush)	X	X
Circium sp. (Thistles)	X	X
Gutierrezia sarothrae (Snakeweed)	X	X
Helianthus annuus (Annual sunflower)	X	X
Lactuca serriola (Prickly lettuce)		X
Sonchus asper (Sow thistle)		
Xanthium strumarium (Cocklebur)		
Convolvulaceae (morning glory)		
Convolvulus arvensis (Field bindweed)		
Cuscuta megalocarpa (Dodder)		
Cruciferae (mustard)		
Lepidium sp. (Pepper grass)	X	X
Cucurbitaceae (gourd)		
Cucurbita foetidissima (Buffalo gourd)	X	X
Euphorbiaceae (spurge)		
Croton texensis (Doveweed)		
Leguminosae (pea)		
Lathryus sp. (peavine)		
Melilotus albus (White sweet clover)		
Melilotus officinalis (Yellow sweet clover)		
Oxytropis sp. (Locoweed)		
Loranthaceae (mistletoe)		
Phoradendron juniperinum (Juniper mistletoe)	X	
Malvaceae (mallow)		
Sphaeralcea sp. (Globe mallow)		
Nyctaginaceae (four-o'clock)		
Mirabilis multiflora (Four-o'clock)		
Polemoniaceae (phlox)		
Gilia sp. (Gilia)		
Polygonaceae (buckwheat)		
Polygonum aviculare (Knotweed)	X	
Rosaceae (rose)		
Fallugia paradoxa (Apache plume)		
Salicaceae (willow)		
Populus sp. (Cottonwood)	X	X
Salix sp. (Willow)	X	X
Saxifragaceae (saxifrage)		
Ribes sp. (Currant)	X	X

Scrophulariaceae (figwort)		
Castelleja integra (Indian paintbrush)	X	X
Penstemon sp. (Beardtongue)	X	X
Solanaceae (nightshade)		
Datura metelioides (Indian apple)	X	X
Physalis sp. (Ground cherry)	X	X
Solanum elaeagnifolium (Horse nettle)		
Tamaricaceae (tamarisk)		
Tamarix gallica (Tamarisk)		
Ulmaceae (elm)		
Ulmus pumila (Siberian elm)		
Verbenaceae (vervain)		
Verbena bracteata (Vervain)		
Zygophyllaceae (caltrop)		
Tribulus terrestris (Goathead)		

[a]Numerous unlisted species occur in this zone; they were either not identified or not observed.
[b]"Usable" means that the species could have been used for food, medicine, building, or fuel.

Appendix C

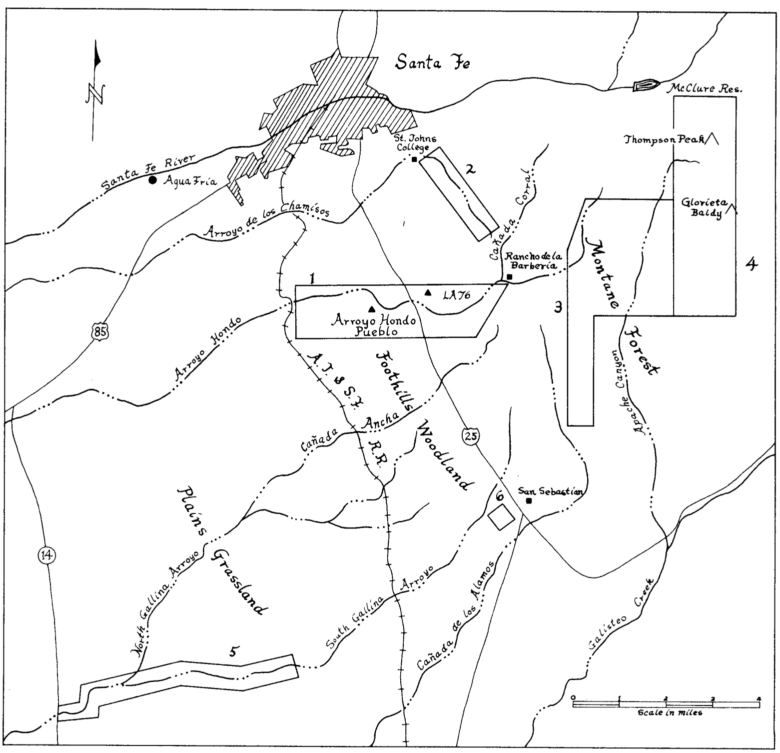
ACCOUNTS OF VERTEBRATES OBSERVED DURING THE ARROYO HONDO PROJECT

Richard W. Lang

The observations presented here on vertebrate species of the Arroyo Hondo study area and adjacent portions of the piedmont and montane zones are based upon field data collected by N. Edmund Kelley, Harold G. Stacy, and me between May, 1970, and June, 1974. Although the following annotated list by no means reflects the full vertebrate spectrum of these localities, it does constitute a record of the more common and conspicuous resident and migrant species found in the area today, as well as a few probable rarities, and supplies additional information on their seasonal and habitat associations. With the exception of Stacy's records, notations on observed fauna were, for the most part, made rather casually or as a secondary activity by Kelley and Lang. For a more complete index of the faunal variety that might be expected within the proposed sustaining area of Arroyo Hondo Pueblo, the reader is referred to the works of Gehlbach (1956) and Van Denburgh (1924) for the amphibians and reptiles; Bailey (1928) and Ligon (1961) for the birds; and Bailey (1931), Hall and Kelson (1959), and Findley et al. (1975) for the mammals.

SAMPLING STATIONS

With the exception of a few notations indicated in the text, the sightings recorded here represent six sampling stations: two within Kelley's primary study area, two outside the study area but within the territory probably used by the Arroyo Hondoans at one time or another, and two located to the south of this (Map 6). These last are within the Gallina Arroyo drainage area, which, in its lower course, essentially duplicates Arroyo Hondo habitats not closely examined for faunal data. In addition, the lower reaches of the Gallina have been less affected by recent human activity than has its counterpart in the Arroyo Hondo drainage. Although all of the life zones and intracommunity associations in the near vicinity of Arroyo Hondo are represented through these six stations, the degree of



MAP 6. Observation Stations in which Faunal Species Were Recorded.

attention that each received during the project was far from equal, most of our recording activity being concentrated in the site vicinity and the middle portion of the Arroyo Hondo. The following are brief descriptions of the sites of these recording stations.

1. *Arroyo Hondo and the immediately adjacent piedmont and foothill terrain* between the intersection of Arroyo Hondo and the Atchison, Topeka and Santa Fe Railway track on the west and Rancho La Barberia, within Arroyo Hondo Canyon, on the east (see Map 6), a transect approximately 4.25 miles long and 1.0 mile wide, which includes the site of Arroyo Hondo Pueblo. The majority of the data on local fauna, particularly the amphibians, reptiles, and birds, comes from this station, which was traversed by the author at fairly regular intervals and during all seasons from 1971 through 1973. The physiography of this station is described in detail in Chapter 2 of this volume.

2. *Upper Arroyo de los Chamisos*, about 3.0 miles northeast of Arroyo Hondo Pueblo at elevations between about 7,200 and 7,800 feet. The arroyo is a tributary of the Santa Fe River, flowing intermittently during the fall and early spring. Arroyo de los Chamisos forms a wide canyon here, although the arroyo itself is deep, relatively narrow, and steep banked over most of its upper course. The arroyo heads at a gentle divide between it and Cañada Corral, a dry tributary of Arroyo Hondo, the central portion of which is subsumed under this station heading. In the arroyo bottom and on the side walls of upper Arroyo de los Chamisos, Apache plume, rabbit brush, and several species of grasses are conspicuous. Willow and a few young cottonwoods are also present in seep areas in association with heavier grass cover. The terraces above the arroyo course are predominantly covered by vegetation of the rabbit brush community, while former domestic areas exhibit a more extensive grass cover in which snakeweed and lupine are abundant. Bordering vegetation is mixed ponderosa-piñon-juniper woodland (see Fig. 15, p.65). This station represents a transect approximately 2.0 miles long and 0.5 mile wide, traversed by Stacy on September 20, 1973, and January 9, 1974, and by Lang in late November of 1973. A small spring is present near the canyon head.

3. *The upper reaches of Arroyo Hondo and Apache canyons* (Fig. 23), between about 4.0 and 6.5 miles northeast of Arroyo Hondo

Pueblo at elevations between approximately 7,500 and 8,500 feet. This area is characterized by steeply eroded canyons and feeder arroyos, narrow-bottomed valleys, and narrow ridgetops. In its lower portions the dominant vegetation is the ponderosa pine–piñon-juniper community, which grades into ponderosa pine with scattered oak on the ridges and higher south-facing slopes. Spruce and Douglas fir occur on some of the deeply shaded north-facing slopes, where they are mixed with ponderosa pine. Permanent water is available in both Arroyo Hondo and Apache canyons. This area was traversed by Stacy on August 18, 1973, and February 9 and April 15, 1974, and by Lang on April 27, 1974.

FIG. 23. Ponderosa Pine Forest in Station 3 with Higher Montane Forests of Station 4 in Background.

4. *Glorieta Baldy and the headwaters of Arroyo Hondo and Apache canyons* (Fig. 23), approximately 6.5 to 8.0 miles northeast of Arroyo Hondo Pueblo at elevations between 8,500 and 10,200 feet, and 10,553 at Thompson Peak, about 1.5 miles northwest of Glorieta Baldy. This area is typified by the ponderosa pine, mixed conifer, and spruce-fir forest associations, with some open meadow areas. A thick growth of mature spruce-fir dominates the upper slopes, peaks,

and ridges, grading into mixed conifer with dense aspen stands. The area was traversed by Stacy on August 25, 1973.

5. *The southern branch of Gallina Arroyo* (Fig. 24), between New Mexico State Road 14 on the southwest and the head of this branch at the western boundary of the Cañada de los Alamos Grant on the northeast, between 8.0 and 11.0 miles southwest of Arroyo Hondo Pueblo and at elevations of 6,100 to 6,500 feet. Gallina Arroyo is a tributary of Galisteo Creek. The portion covered lies within the shortgrass plains. Vegetation is predominantly grama grass, with scattered juniper. Many annuals and summer flowers, primarily composites, are found in the arroyo bottom. This area, approximately 6.0 miles long and 0.5 mile wide, was traversed by Stacy on August 16, 1973, and April 20–21, 1974.

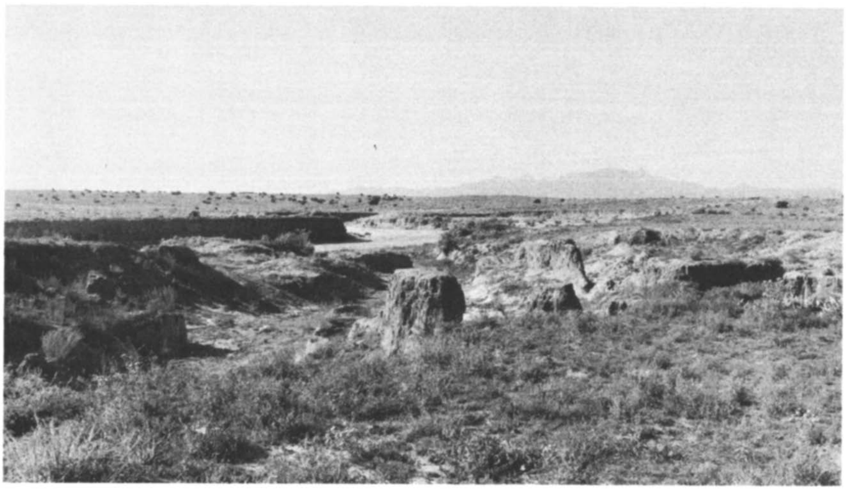


FIG. 24. General View of Gallina Arroyo, Station 5.

6. *The area of the upper south branch of Gallina Arroyo,* west of San Sebastian and Interstate 25, approximately 5.0 miles southeast of Arroyo Hondo Pueblo and at the same general elevation, slightly over 7,000 feet. Although this area is within the piñon-juniper woodland, a large section of it was chained in a piñon-juniper eradication program about 17 years ago. Brush piles, rabbit brush, cholla, snakeweed, and small junipers, piñons, and oak provide good ground cover for small mammals (Fig. 25). This area was visited by Stacy on August 18, 1973.

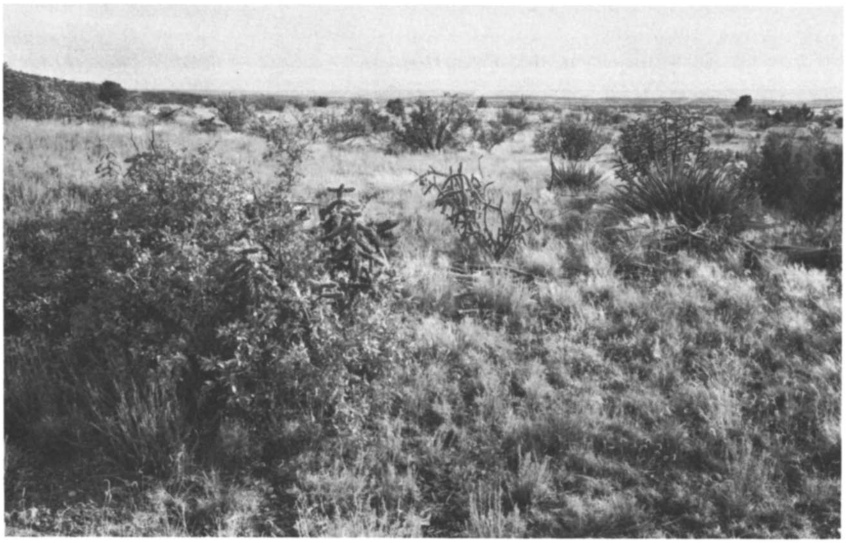


FIG. 25. Upper Gallina Arroyo, Station 6.

ANNOTATED LIST OF OBSERVED SPECIES

Amphibians

Tiger salamander (Ambystoma tigrinum). Tiger salamanders of variable coloration were observed in association with aquatic/riparian habitat in Arroyo Hondo Canyon (Station 1) below the springs near the site and in grassland surrounded by piñon-juniper woodland at the site, where they were commonly encountered in the loose, damp backfill of excavated rooms.

Western spadefoot toad (Scaphiopus hammondi). This toad was observed in the primary study area (Station 1) in piñon-juniper woodland, grassland, and riparian habitats where water or damp soil was to be found. It is the most prominent amphibian in the site area today, being common in the canyon and in association with standing, temporary pools or damp arroyo beds during the summer rainy period of late July through September. The spadefoot is regularly found in the backfill of excavated rooms, where it has burrowed into the loose, damp soil. Several hibernating adults were found in such contexts at depths of between 68.0 cm and 1.55 m below the surface.

Woodhouse's toad (Bufo woodhousei). Woodhouse's toad was relatively common in the canyon riparian habitat (Station1) and was noted in herbaceous cover along the irrigation ditch directly south of Arroyo Hondo Pueblo. It was also present in piñon-juniper woodland north of Arroyo Hondo in association with semipermanent water near domestic areas. Woodhouse's toad was also observed in streamside meadows near ponderosa pine stands and piñon-juniper–rabbit brush cover of the upper canyon below Rancho La Barberia (Station 3).

Leopard frog (Rana pipiens). Present in permanent pools with considerable aquatic vegetation in Arroyo Hondo Canyon just below the lower springs (Station 1), this frog was less commonly sighted than the other amphibians noted above and, like these, was sighted in the summer.

Reptiles

Ornate box turtle (Terrepene ornata ornata). A single individual was found in the grassland of the site area (Station 1) near open piñon-juniper woodland during the 1973 summer excavation season.

Collared lizard (Crotaphytus collaris). Two individuals were sighted, one in open piñon-juniper grassland and the other on rocky, eroded slopes of the piñon-juniper woodland near the site (Station 1).

Lesser earless lizard (Holbrookia maculata). A single individual was collected from an accumulation of dead cholla in the open grassland area of the site (Station 1) proper during the 1974 field season.

Eastern fence lizard (Sceloporus undulatus). The eastern fence is the most common lizard observed in the site vicinity (Station 1), where it was most regularly sighted in areas of rock piles formed by excavation discards and in the relatively thick herbaceous growth of the ruin's plaza areas. All specimens collected were referable to the southern plateau subspecies, *S. u. elongatus*.

Short-horned lizard (Phrynosoma douglassi). This lizard was occasionally sighted in recently disturbed areas, grassland, and open piñon-juniper of the site area and adjacent terrain (Station 1). The observed individuals were of the desert subspecies, *P. d. ornatissium*.

Plateau whiptail (Cnemidophorous velox). This lizard was observed in the same areas as was the fence lizard but appeared to be somewhat less common.

Western hognose snake (Heterodon nasicus). The western hognose was present in shortgrass plains on Gallina Arroyo near N.M. State Road 14 (Station 5) and was also reported by Stacy for Agua Fria, New Mexico, along the Santa Fe River, about 5.5 miles northwest of Arroyo Hondo Pueblo.

Western coachwhip (Masticophis flagellum leneatulus). This snake, an example of the reddish colored variety, was found on Arroyo Hondo road to the east of the site (Station 1) in association with rocky, piñon-and-juniper-covered, northwest-facing slopes and the rabbit brush community of the floodplain.

Gopher snake (Pituophis catenifer). All individuals collected could be referred to *P. c. sayi*, the bullsnake. They were found in riparian, rabbit brush, and piñon-juniper woodland and grassland habitats. One immature individual was dropped over the site by an adult raven (*C. corax*). All specimens were from Arroyo Hondo Canyon (Station 1).

Garter snake (Thamnophis sp.). One individual was observed at its burrow on an eroded tributary arroyo margin near rabbit brush, grass, and limited piñon-juniper cover about 300 yards south of the lower canyon spring (Station 1); another was found in the rank vegetation along the stream below the spring.

Western rattlesnake (Crotalus viridis). A single individual was found on the site (Station 1) in open grassland near piñon-juniper woodland. Another was observed in grassland on the north side of the Gallina Arroyo floodplain 0.5 mile west of the railway grade (Station 5).

Birds

Mallard (Anas platyrhynchos). A single female (?) was observed feeding in a pool just below the upper Arroyo Hondo site (LA 76) and above Interstate 25, in Arroyo Hondo Canyon (Station 1) and was referred to *A. platyrhynchos* on geographic grounds, the alternative being *A. diazi*, the Mexican duck. The sighting occurred on June 8, 1972.

Ruddy duck (Oxyura jamaicensis). A flock of about 16 ruddy ducks was observed moving west toward the piedmont from upper Arroyo Hondo Canyon in late September, 1973. These ducks were probably using the canyon pools below Ranch La Barberia (Station 1).

Turkey vulture (Cathartes aura). Turkey vultures were commonly sighted, either as solitary birds or in flocks of up to 8 individuals, over all of the Arroyo Hondo Canyon area (Station 1) during May and June of 1971 through 1973. They appeared to be nesting in the high, rocky foothills at the canyon's head. The number of pairs observed each year increased during this three-year period from 1 to 4. In 1973, at least one pair remained in the area through early August. In 1974, turkey vultures began to appear in the Santa Fe area as early as April 14.

Cooper's hawk (Accipiter cooperii). A single hawk was observed in the near-stream piñon-juniper woodland adjacent to LA 76 (Station 1) in late October, 1972.

Red-tailed hawk (Buteo jamaicensis). A solitary bird was noted in piñon-juniper woodland above Arroyo Hondo Canyon and over the lower spring area (Station 1) on July 5 and 6, 1973. Another hawk was sighted in the area of a prairie dog colony beside Gallina Arroyo (Station 5) on January 5, 1974.

Swainson's hawk (Buteo swainsoni). A single dead bird was found along Interstate 25 about 3.5 miles north of Arroyo Hondo in early July, 1971.

Peregrine falcon (Falco peregrinus). A single individual was sighted over the piñon-juniper of the lower foothills northeast of LA 76 at an elevation of about 7,000 feet (Station 1) on January 13, 1973.

Sparrow hawk (Falco sparverius). This falcon is the most commonly observed falconiform bird found today in the foothills and piedmont adjacent to and within the study area (Station 1). During the period of May through October from 1971 through 1973, it was most often sighted in piñon-juniper woodland near relatively extensive tracts of open grassland with rabbit brush, flowering annuals, snakeweed, and cholla. One individual was recorded in December.

Blue grouse (Dendragapus obscurus). One mature bird and three juvenile birds were observed at the edge of a meadow adjacent to spruce-fir forest southeast of the fire tower at Glorieta Baldy lookout (Station 4), elevation 10,199 feet, on August 25, 1973. In this and portions of the Sangre de Cristo Mountains to the north, the blue grouse is also commonly seen in mixed conifer forest.

Scaled quail (Callipepla squamata). One pair was observed feeding in grassland near the site (Station 1) in July, 1971. Two "coveys" of quail were flushed by Stacy on August 16, 1973, in the Gallina Arroyo locality (Station 5): one from an area of bare eroded ground occupied by summer flowering plants on the north-facing slope of Gallina Arroyo and the other from the crest of a ridge covered with yucca, a few scattered junipers, grass, and a mixture of summer flowers on the arroyo's north side 0.25 mile west of the old railway grade. Gallina Arroyo presumably receives its name from these quail.

Gambel's quail (Lophortyx gambelii). One pair was observed feeding in a disturbed soil area covered with the previous summer's growth of flowering annuals in the site area (Station 1) at an elevation of 7,090 feet on June 2, 1972. Ligon (1961:97) notes a previous maximum elevational record of 6,500 feet for this quail.

Turkey (Meleagris gallopavo). Turkey tracks were noted on April 15, 1974, along the stream in upper Arroyo Hondo Canyon (Station 3), in an area of grassy meadows surrounded by ponderosa pine forest with some spruce-fir and at an elevation of 8,000 to 8,200 feet, between 1.0 and 2.5 miles above Rancho La Barberia. No fewer than 8 birds were represented. On August 18, 1973, old turkey droppings were found to be common in the general Arroyo Hondo headwaters area and particularly noticeable on the ridges between the Arroyo Hondo and Apache Canyon (Station 3).

Killdeer (Charadrius vociferus). Three individuals were present in the canyon riparian habitat and along the irrigation ditch south of the site and adjacent to domestic pastureland (Station 1) between June 8 and June 21, 1973.

Mourning dove (Zenaidura macroura). Doves were sighted almost daily in the general site vicinity (Station 1) in piñon-juniper woodland and near-woodland grassland and in the canyon riparian habitat during June, July, and August from 1971 through 1973. The earliest record is March 25, 1972, and the latest is October 20, 1973. Twenty to 25 doves were reported by Stacy for the grassland area of the lower south branch of Gallina Arroyo (Station 5), mainly in the bottoms of draws and arroyos, on August 16, 1973. The largest total number of dove sightings on any one day in the Arroyo Hondo area was 8 individuals.

Great horned owl (Bubo virginianus). Solitary individuals, very likely the same bird, were observed near the site (Station 1) in the piñon-juniper of the canyon sides on June 21, 1972, and in September, 1973. On the former occasion the bird was flushed and pursued by a flock of piñon jays.

Burrowing owl (Speotyto cunicularia). A pair of these now relatively rare owls was observed in an abandoned prairie dog burrow on the eastern fringe of the Gallina Arroyo colony (Station 5) recorded by Stacy (see *Cynomys gunnisoni*, page 133) on August 16, 1973.

Roadrunner (Geococcyx californianus). One bird was observed in open piñon-juniper near the site (Station 1) during the summer (June-August) of 1971. Roadrunners appear to be somewhat more common at the same general elevation north of Arroyo Hondo along Arroyo de los Chamisos below Saint Johns College (Station 2), and are regularly sighted in juniper-grassland and on the margins of the piñon-juniper directly north of the Santa Fe River and northwest of Santa Fe at about 6,500 feet elevation.

Common nighthawk (Chordeiles minor). Nighthawks are very common over the canyon and nearby terrain north of the site (Station 1) by late June or early July, continuing into August. This summer visitor was not sighted prior to May 24 or after September 2 in the site vicinity. A few were observed in the Gallina Arroyo (Station 5) area on the evening of August 16, 1973.

Hummingbird (Trochilidae). A single individual was sighted in open piñon-juniper near the site (Station 1) on August 11, 1973, but was not identified.

Red-shafted flicker (Colaptes cafer). The earliest canyon/site vicinity (Station 1) record for the flicker is September 10, 1972, and the latest April 13, 1974. Flickers were numerous during late September through about October 20 in 1972 and 1973. In 1972, individual birds continued to be sighted rather commonly through February 3, and the latest flicker record for 1973 is of a single individual observed on November 24. None were seen during the summer months, and all records are for piñon-juniper and riparian habitats.

Lewis's woodpecker (Asyndesmus lewis). A single male was observed in the rabbit brush community near piñon-juniper woodland along a tributary of Cañada de las Minas between Interstate 25 and Seton Village on May 17, 1970.

Hairy woodpecker (Dendrocopos villosus). One individual was observed on December 2, 1973, in open piñon-juniper near the site (Station 1).

Downy woodpecker (Dendrocopos pubescens). A single bird was noted in piñon-juniper woodland of the canyon about 0.5 mile below the site (Station 1) on November 12, 1972.

Cliff swallow (Petrochelidon pyrrhonota). The cliff swallow was relatively common in the canyon (Station 1) at pools below the lower springs during June and July of 1971 and 1972. The earliest canyon record is May 31, 1972.

Steller's jay (Cyanocitta stelleri). A flock of about 500 birds was observed at Arroyo Hondo Pueblo in late September, 1972. Others were sighted during November of that year, and they were relatively common from December 3, 1972, through January 25, 1973. The winter of 1972–73 was marked by exceptionally heavy snows in both the mountains and the foothills, which appeared to drive the Steller's jays to lower elevations in greater numbers than usual. None were noted in the primary study area during the winters of 1971–72 and 1973–74.

Scrub jay (Aphelocoma coerulescens). The scrub jay is common in the primary study area throughout the year, and is typically associated with piñon-juniper woodland.

Common raven (Corvus corax). Ravens can be sighted in the Arroyo Hondo drainage (Stations 1–4) throughout the year, normally as solitary individuals or pairs but on occasion as small family groups or larger flocks. Some of the birds observed appear to nest in the granite outcrops of the higher foothills east of the site at elevations of about 8,000 feet and higher. During the winter of 1972–73, common ravens were present in groups of 4 to 8 by late January. Small flocks of ravens continued to be sighted until early March, 1973. No groups exceeding 6 individuals in number were noted during other winters.

Common crow (Corvus brachyrhynchos). Crows were not commonly sighted during the period from 1971 through 1973 in the Arroyo Hondo area (Station 1). One pair was noted in May, 1971, and a second on November 9, 1973, both in the vicinity of the canyon stream near the site. However, on February 3, 1973, three flocks composed of 20 to 28 birds each and totaling 74 individuals were sighted over Arroyo Hondo near the site, and on February 11, 1978, a flock of close to 100 was encountered in the piñon-juniper woodland between Arroyo Hondo and Gallina Arroyo at an elevation of about 7,500 feet. The flock was accompanied by a pair of common ravens.

Piñon jay (Gymorhinus cyanocephala). Flocks and, occasionally, solitary birds or small groups are relatively common in the piñon-juniper woodland bordering the canyon (Station 1) from mid-June through October. The earliest flock sighting was on May 28, 1972, and the latest in November of that year.

Clark's nutcracker (Nucifraga columbiana). Three pairs were observed on the Arroyo Hondo–Apache Canyon divide above Cañada de los Alamos (Station 3) on April 27, 1974. Two pairs were sighted in ponderosa pine forests, at an elevation of about 8,100 feet; the remaining pair, in ponderosa pine–piñon-juniper at about 7,600 feet.

Mountain chickadee (Parus gambeli). One individual was sighted in the canyon (Station 1) about 1.0 mile above the site on February 25, 1972, and a second in the canyon near the lower springs on March 10, 1972. A pair was observed in the canyon about 0.5 mile below the site on October 20, 1972.

Black-capped chickadee (Parus atricapillus). A single individual was noted just above LA 76 (Station 1) in November, 1972.

Plain titmouse (Parus inornatus). One bird was observed in the upper canyon about 1.5 miles east of the site (Station 1) in November, 1972.

Rock wren (Salpinctes obsoletus). Rock wrens were observed nesting during June and July of 1972 and 1973 in the earth walls of Kiva 12-C-1 and the masonry walls of Roomblock XI at Arroyo Hondo Pueblo.

Mockingbird (Mimus polyglottos). Solitary mockingbirds were noted on the evenings of June 20, 1971, and June 13, 1972, in the piñon-juniper woodland near the site.

Robin (Turdus migratorius). The robin is a common migratory visitor in the primary study area during the fall and is widely distributed in the upper foothills and mountains of the Arroyo Hondo drainage, generally above 7,500 feet, during the summer months. Individual birds were observed in the site vicinity and in the canyon between about 7,000 and 8,000 feet of elevation on March 19 and April 30, 1972, and on June 28 and February 3, 1973. Relatively large flocks of 50 or more birds were noted on September 23 and October 15, 1972, and January 14 and November 9, 1973. None were recorded between February 3 and March 19 above 6,800 feet, and they appear to be locally abundant only from late September through mid-January, when they concentrate in the piñon-juniper woodland along the canyon and in its feeder arroyos above the latter elevation. Observations northwest of Santa Fe in the juniper-grassland suggest that they may have been common in this association from mid-January through mid-March on lower Arroyo Hondo in 1974 and perhaps during previous years when they were scarce at higher elevations.

Western bluebird (Sialia mexicana). One individual was noted in early August, 1971, and a small flock was sighted near Arroyo Hondo Pueblo in early December, 1972.

Mountain bluebird (Sialia currucoides). One pair was noted near the site on June 21, 1973.

Townsend's solitaire (Myadestes townsendi). Between 2 and 4 birds were noted on September 23, October 15, November 26, and March 26, 1972, and on January 14 and February 3 and 11 of 1973, and one pair on April 25, 1974, in the general site vicinity. *M. townsendi* appears to be locally absent during the summer and late spring, at which times it is relatively common in the high mountain zones to the east.

Bohemian waxwing (Bombycilla garrula). Between January 30 and February 2, 1973, a flock of over 45 waxwings congregated in a number of large Russian olive trees on the eastern fringe of Santa Fe, about 1,000 yards from the Santa Fe River. This is a rare occurrence, undoubtedly reflecting the winter conditions of that year. During the same period, no waxwings were observed at Arroyo Hondo.

Redwinged blackbird (Agelaius phoeniceus). One pair of these birds was observed on September 9, 1972, in riparian habitat just below the lower springs of Arroyo Hondo Canyon (Station 1).

Brown-headed cowbird (Molothrus ater). One pair was noted in the riparian growth of the canyon near the lower springs (Station 1) and in the adjacent piñon-juniper woodland on June 8 and 21, 1972, and June 21, 1973. Cowbirds were also observed during June and July, 1971, but specific dates were not recorded.

Western tanager (Piranga ludoviciana). One pair was seen between June and August, 1971, and on June 24, 1972, in the canyon riparian habitat below the lower springs.

Black-headed grosbeak (Pheucticus melanocephalus). One pair was observed in piñon-juniper woodland near the site on June 5, 1972.

Evening grosbeak (Hesperiphona vespertina). A flock of 18 grosbeaks was recorded on November 25, 1972, in piñon-juniper woodland above the lower springs.

House finch (Carpodacus mexicanus). House finches were present in November, 1972. Small groups of 4 to 8 were noted in piñon-juniper woodland near the site on June 14 and December 22, 1972, and January 26, 1973.

Rufous-sided towhee (Pipilo erythrophthalmus). One pair was noted in open piñon-juniper near the site on June 22, 1973.

Brown towhee (Pipilo fuscus). One of the most common birds of the open piñon-juniper woodland near the site, the brown towhee is abundant during June and July and common from August through October. One was noted on January 26, 1973. These towhees appear to be very scarce or absent between February and April in the Arroyo Hondo area.

Oregon junco (Junco oreganus). Both the black-headed and the pink-sided races are represented in Station 1, the former appearing to be the more common. The Oregon junco was always noted in the company of the more abundant gray-headed junco (*J. caniceps*). As with the gray-headed, the Oregon junco is strictly a winter visitor in the primary study area. From 2 to 4 individuals were observed on March 19, 1972, December 3, 1972, and January 27, 1973. None were sighted prior to December or later than March 19.

Gray-headed junco (Junco caniceps). These juncos seem to appear first in the primary study area of Arroyo Hondo canyon around October 21 and are present through the end of April. Large flocks occur in the rabbit brush community and adjacent piñon-juniper cover of the canyon from late January through February.

Mammals

Masked shrew (Sorex cinereus). One individual was collected from under a log at a stream edge in meadows near ponderosa pine forest in Arroyo Hondo Canyon, about 1.5 miles above Rancho La Barberia (Station 3), on April 15, 1974.

Bats (Chiroptera). Bats were occasionally sighted at dusk in the site area.

Nuttall's cottontail (Sylvilagus nuttalli). Three cottontails were recorded during a four-hour period on August 25, 1973, during Stacy's traverse of the Thompson Peak Trail (Station 4) from Glorieta Baldy to its junction with the trail to McClure Reservoir, a distance of about 3.0 miles at elevations of 10,199 to 8,800 feet. One individual was noted in spruce-fir forest adjacent to meadowland, at about 10,000 feet on Glorieta Baldy; another was spotted in mixed conifer habitat dominated by aspen, where much tree-fall debris was present, on the west side of the ridge southeast of Thompson Peak, at about 10,400 feet; and the third was found in spruce-fir about 1.0 mile west of the peak, at about 8,800 feet.

Desert cottontail (Sylvilagus auduboni). The desert cottontail is the most common lagomorph today in the canyon and piñon-juniper uplands of the primary study area (Station 1). In transects run through this area *S. auduboni* was found to occur in an average ratio of about 2:1 to the black-tailed jackrabbit (*Lepus californicus*) at elevations between 6,800 and 7,500 feet (the latter in riparian and rabbit-brush cover within the canyon). During the summer of 1973, cottontail density appeared to be very high on the piedmont near the site and in the chained area west of San Sebastian (Station 6). Sign and sightings also suggest that cottontails are abundant on upper Arroyo de los Chamisos (Station 2) up to at least 7,800 feet where rabbit brush and other preferred cover is present. Observed habitats were piñon-juniper woodland, open piñon-juniper, rabbit brush, riparian growth, and domestic areas overgrown with grass, snakeweed, rabbit brush, cholla, prickly pear, and yucca. In the shortgrass plains of the Gallina Arroyo area (Station 5), one cottontail was observed under a pile of lumber scraps on August 16, 1973; tracks representing 3 individuals were noted on January 5, 1974, but no fresh sign or individuals were observed on April 20, 1974.

Snowshoe hare (Lepus americanus). Droppings and tracks representing 1 or 2 snowshoe hares were noted in deep snow along the main fork of Arroyo Hondo at about 8,300 feet (Station 3) in association with willow and rose on February 9, 1974. The surrounding vegetation was predominantly spruce-fir and ponderosa pine.

Black-tailed jackrabbit (Lepus californicus). The black-tailed jackrabbit was most commonly seen within the study area (Station 1) in the open piñon-juniper with snakeweed and scattered rabbit brush or overgrown domestic areas on the piedmont, and in the rabbit-brush community of the canyon. Occasional individuals were sighted in relatively dense piñon-juniper, and one was observed in ponderosa pine–piñon-juniper cover at about 7,600 feet (Station 3). Stacy reported only one set of jackrabbit tracks during his visits to the open grassland of the Gallina Arroyo area (Station 5).

Chipmunk (*Eutamias* spp.). A single chipmunk (*Eutamias* spp.) was noted on rocky, piñon-juniper-covered slopes of the canyon directly below the lower springs (Station 1). Others were observed in association with ponderosa pine–piñon-juniper near Rancho La Barberia in the upper canyon and in ponderosa pine with limited grass cover and occasional spruce at about 8,600 feet on the divide between Arroyo Hondo and Apache canyons (Station 3).

Spotted ground squirrel (Spermophilus spilosoma). Spotted ground squirrels are numerous in the shortgrass plains of the Gallina Arroyo area (Station 5), where many burrows were found on both the floodplains and the higher terraces above them. Above the lower elevation grasslands this squirrel appears to be very rare. During the period from spring 1971 through 1974, none were observed in the primary study area (Station 1), although one individual of this species was found dwelling beneath a large cardboard box during cleanup of the grassy site area on April 4, 1975.

Rock squirrel (Spermophilus variegatus). This is the only characteristic and relatively common ground squirrel of the primary study area. It was noted (1) in areas of cobble-strewn, rabbit-brush, or piñon-juniper–covered slopes on the margins of Arroyo Hondo Canyon (Station 1) below the site and on Arroyo de los Chamisos opposite Saint Johns College (Station 2); (2) on a feeder arroyo of the canyon north of LA 76 in piñon-juniper woodland near open, overgrown domestic land, where a den had been established in a road culvert; and (3) in open rabbit-brush–grassland near ponderosa pine–piñon-juniper at Cañada de los Alamos at 7,600 feet.

Golden-mantled ground squirrel (Spermophilus lateralis). This ground squirrel was observed in the upper limits of the spruce-fir forest near alpine meadows on the west face of Lake Peak, about 13 miles northeast of Arroyo Hondo. It also may well be present in the ponderosa pine forest of the Arroyo Hondo drainage.

Gunnison's prairie dog (Cynomys gunnisoni). A *C. gunnisoni* colony measuring 200 yards east-west and about 100 yards north-south was found in the Gallina Arroyo locality (Station 5), within the arroyo's floodplain. Stacy reports that he "counted seventeen, moved twenty yards, counted nineteen, moved about fifteen yards and counted nineteen." No prairie dogs were found in Station 1.

Abert's squirrel (Sciurus aberti). Abert's squirrel is found as close to Arroyo Hondo Pueblo as 1.2 miles east of the site, within the canyon in association with stands of ponderosa pine on northwest-facing slopes. Evidence of this squirrel was encountered below the ponderosa pine forest about 3.5 miles east of the site. Sightings continued into the mixed conifer forests on the west face of Glorieta Baldy (Station 4). Nowhere in the area studied does Abert's squirrel appear to be common.

Red squirrel (Tamiasciurus hudsonicus). Red squirrels were observed in spruce trees on the northwest face of Thompson Peak (Station 4) at an elevation of about 9,800 feet. The range of this squirrel may follow the distribution of Douglas fir and spruce into lower elevations locally. Although no red squirrels were sighted in the upper canyon, probable red squirrel sign was found in association with stands of spruce-fir along the north-facing slopes at elevations as low as 8,000 feet (Station 3).

Southern pocket gopher (Thomomys bottae). This gopher is common at the site, where its burrows occur on the margins of overgrown plaza areas and in the damp, deep, and well-vegetated soils of dammed arroyo heads. In the canyon area, populations are concentrated in areas of good grass cover and deep sandy soils above the floodplain and adjacent to the mouths of feeder arroyos above and below the lower springs in the primary study area. West of this, where the canyon widens and the piñon-juniper woodland meets the grassland, gopher burrows are commonly found on the near-arroyo, deep-soiled terraces and ridges of the piedmont, either in the open or beneath piñon or juniper trees. Along the shallow, broad arroyos north and south of Arroyo Hondo Canyon, gopher activity is common on the sandy, grass-covered floodplains and into the gently sloping, open high ground surrounded by piñon-juniper woodland. In the upper canyon (Station 3), the southern pocket gopher ranges as high as 8,200 feet, where it occurs in streamside meadows surrounded by ponderosa pine forest. Burrows of this gopher were also found on ridges of relatively deep, sandy loam in the chained area west of San Sebastian (Station 6), and more than 40 *T. bottae* mounds were noted on the arroyo slopes in the Gallina Arroyo (Station 5) locality.

Ord's kangaroo rat (Dipodomys ordi). Although present in the piñon-juniper woodland of the primary study area (Station 1), *D. ordi* appears to be relatively rare there, only one individual being sighted and no burrows found. Stacy reports many abandoned kangaroo rat (*Dipodomys sp.*) colonies in the Gallina Arroyo area (Station 5).

Deer mouse (Peromyscus maniculatus). Although this is the only mouse identified with certainty in the primary study area, where it appears to be the most common small cricetid rodent, others are undoubtedly present. Deer mice were found in the site area and were particularly conspicuous in the nearby rabbit-brush community of the canyon.

Woodrat (*Neotoma* spp.). Rat nests in rock piles and rock overhangs or as mounds of twigs and branches within the canyon are common in the primary study area, particularly on the canyon sides in piñon-juniper growth. Stacy reports two active woodrat nests at the base of juniper trees west of San Sebastian (Station 6). Although no individuals were collected during the study, these nests probably represent the white-throated woodrat, N. *albigula*, the only woodrat found by Stacy in the lower elevations of the Santa Fe area during several years of trapping and observation (personal communication).

Porcupine (Erethizon dorsatum). Very few porcupines were observed in the primary study area and adjacent portions of the piñon-juniper woodland, and none were noted in higher elevations in the Arroyo Hondo drainage. Coyote droppings containing porcupine quills were found in the canyon below the lower springs.

Coyote (Canis latrans). The coyote appears to be relatively common in the Arroyo Hondo drainage from the grasslands into the mixed conifer and spruce-fir forest of the Apache Canyon-Glorieta Baldy area (Stations 1, 3, and 4). Although coyotes were seldom seen or heard during the study, scat and tracks were regularly encountered. Droppings contained the hair and bones of lagomorphs and mice, porcupine quills and fur, beetles, fir and spruce needles, and twigs. Coyotes are also reported as common in the Gallina Arroyo area (Station 5). Kelley sighted one adult 300 yards north in the canyon below the pueblo ruin on September 8, 1973.

Gray fox or red fox (Urocyon cinereoargenteus or Vulpes vulpes). Evidence, in the form of tracks and droppings, indicates the occurrence of fox in the canyon and piñon-juniper woodland of the primary study area (Station 1). Fox scat containing apricot seeds was reported by Stacy in the meadowland of upper Arroyo Hondo Canyon adjacent to ponderosa pine forest (Station 3). *Urocyon* is probably the fox represented.

Black bear (Ursus americanus). Bears occasionally appear during the early spring and fall in the lower Santa Fe River Canyon within the Santa Fe city limits, about 4.0 miles northeast of Arroyo Hondo Pueblo. No bears or their sign were observed in the Arroyo Hondo drainage.

Raccoon (Procyon lotor). Although no evidence of raccoon activity was found in Arroyo Hondo Canyon, raccoons are reported from the lower Santa Fe River Canyon and the springs of Tetilla Canyon, north of the confluence of the Santa Fe River and the Rio Grande.

Long-tailed weasel (Mustela frenata). A single individual was observed crossing Arroyo Hondo road just east of the site.

Badger (Taxidea taxus). Two unoccupied badger dens were found in arroyo sides in piñon-juniper woodland within the primary study area (Station 1), but no animals were seen.

Skunk (Spilogale putorius or *Mephitis mephitis)*. Although no skunks were sighted during the project, their nocturnal presence in the general site vicinity could occasionally be deduced through other evidence. Stacy reports skunk scat near the railway cut in the Gallina Arroyo area (Station 5). Droppings contained plant fiber, crickets, darkling beetles, and grasshoppers.

Bobcat (Lynx rufus). Bobcat tracks were observed on one occasion in the canyon below the lower springs (Station 1).

Mule deer (Odocoileus hemionus). Deer tracks were noted in the riparian habitat below the lower springs (Station1) on two occasions, once in late July, 1971, and again in November, 1972. Tracks were common in the piñon-juniper woodland southeast of Arroyo Hondo Pueblo near Canyon Ancha in late April, 1974. On August 18, 1973, tracks and old droppings were noted west of San Sebastian (Station 6). Fresh sign was found in the canyon meadow about 2.2 miles east of Rancho La Barberia, and tracks were noted in ponderosa pine forest on three ridge saddles between Apache Canyon and Arroyo Hondo Canyon (Station 3). On February 9, 1974, a partial skeleton was found in spruce-fir cover southwest of Thompson's Peak, and on August 25, 1973, a deer was encountered in the same general area. On August 25, tracks representing an adult and fawn were found in and around the fire tower on Glorieta Baldy (Station 4).

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