DESERT RESEARCH INSTITUTE
UNIVERSITY OF NEVADA SYSTEM

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ABSTRACT

Snow sampling in the main recharge area of Eagle Valley indicates nonequilibrium fractionation of stable isotopes according to the relationship: $\delta D/H = 6.0(\delta\ ^{8}O/\ ^{6}O)-14$. There is significant correlation between isotopic depletion and elevation, as indicated by: $\delta D/H = -9.9^{o}/oo/1000$ ft and $\delta 18/16 = -1.48^{o}/oo/1000$ ft. Electrical conductivity and chloride enrichment from snow to lysimeter water produces an estimate of 3900 acre-ft/year of potential recharge to Eagle Valley from the Carson Range. Monitoring of lysimeters throughout the winter shows that the ground is not necessarily frozen under snow and that infiltration and recharge can occur during the winter.

Contour maps of sulfate, chloride, sodium, and deuterium concentrations in the valley aquifer suggest thermal/nonthermal water mixing. Aquifer stable isotope values and recharge area values indicate recharge to the aquifer via stream channel infiltration and deep percolation-fracture flow. Tritium and carbon-14 dating of nonthermal water in the aquifer indicates recharge from the Carson Range and in the vicinity the Carson River, with the oldest non-thermal water in the basin center. Carson Hot Springs is about 12,500 years old and is isotopically depleted, whereas Prison Hot Springs contains recent water and is not depleted.

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INTRODUCTION AND SCOPE

Eagle Valley is located along the western border of Nevada at the foot of the Sierra Nevada. This basin (see Figure 1), which covers about 117 square miles, encompasses Nevada's capital, Carson City, and the surrounding communities of New Empire and Stewart. Along with other developed basins in Nevada, Eagle Valley now relies heavily upon groundwater resources for its water supply. Since a previous study of the available water resources in Eagle Valley (Worts and Malmberg, 1966) concluded that surface and groundwater resources would be fully developed by 1980, it is necessary to have updated information on the groundwater system in Eagle Valley. In addition, since groundwater mining is discourged by state law, basin average annual recharge estimates are of great importance because they determine the amount of groundwater that can be withdrawn from a basin. The commonly used method for estimating recharge in Nevada has inherent inaccuracies, so other methods should be employed to complement these estimates.

The general objective of this investigation is to use environmental isotope and major ion changes in Eagle Valley to determine recharge source areas and recharge rates and flow patterns and mixing in zones of essentially lateral flow and discharge areas. In addition, an assessment will be made of the uncertainties in the isotopic determination of average annual and average recharge. All of the aforementioned tasks will be accomplished using environmental isotopes and hydrogeochemical patterns. This type of study has not previously been done in Nevada's arid basins, so it will serve as a benchmark for similar studies in other basins of Nevada.

In addition, the study will describe and quantify changes in water chemistry in the hydrologic cycle from precipitation, to infiltration, runoff, and finally, to groundwater flow. Previous investigators have concluded that most recharge to Eagle Valley is from the Carson Range in the western part of the valley. Therefore, a flow path from Snow Valley Peak in the west to the Carson River in the east will

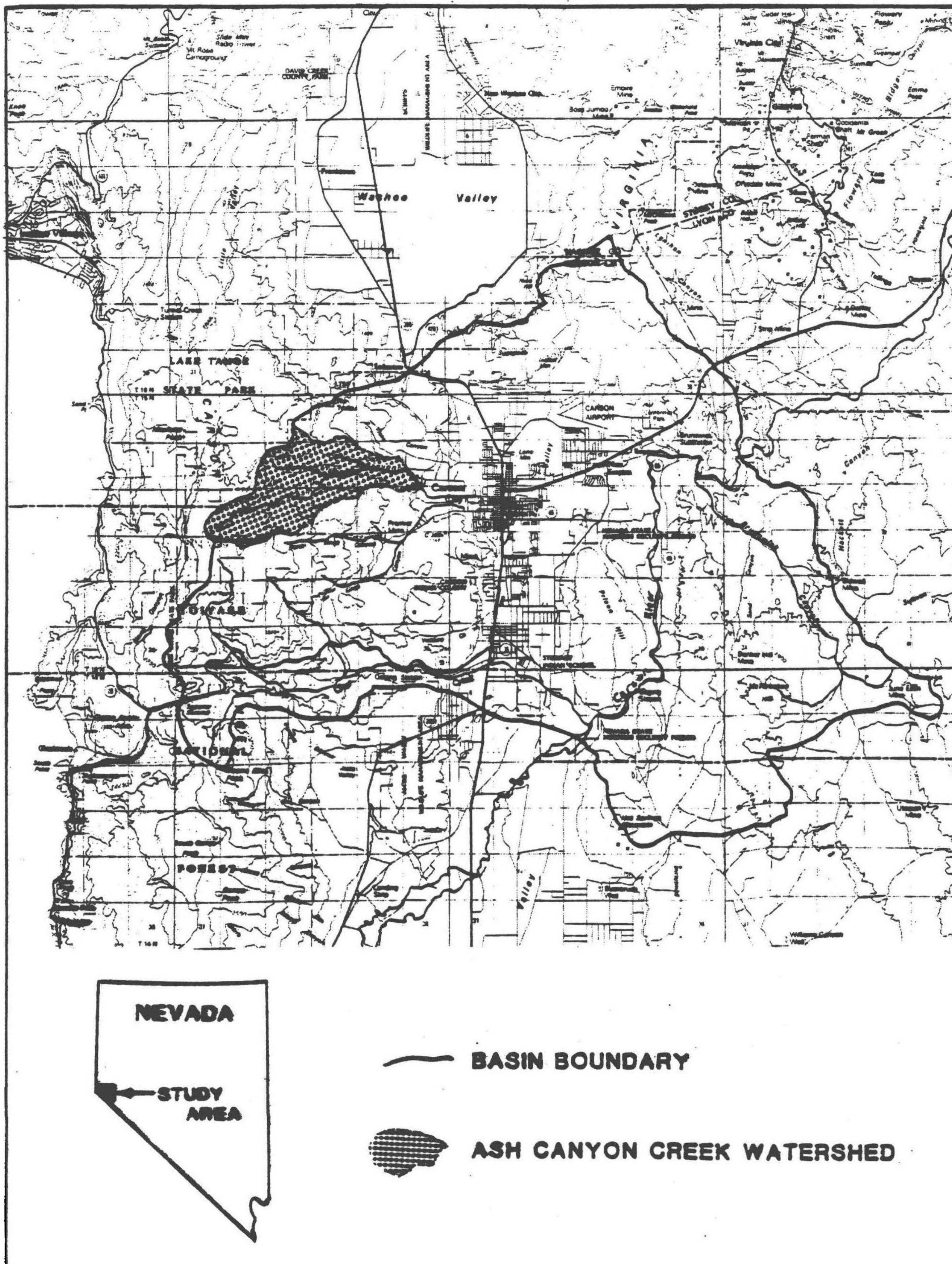

Figure 1. Eagle Valley Basin Location.

be examined in detail; this specific study was augmented by a more general study of chemical changes in the entire basin.

Stable isotopes of water (^2H and ^{18}O) and chloride ion changes from precipitation to soil water will be used in the recharge portion of the basin to: 1) calculate the volume of water available for recharge (after evaporation) from different elevations; 2) calculate the average recharge elevation; and 3) estimate an average isotopic composition of water that is potential recharge to the groundwater system. Stable isotope contents of wells in the valley aquifer will then be compared to the calculated potential imputs to the aquifer in order to quantify aquifer recharge mechanisms.

Major ion chemistry and stable isotope chemistry of water in the valley aquifer will be used to trace water from different recharge areas and estimate thermal/nonthermal water mixing. In other studies, (Freeze and Cherry, 1979) major ions have successfully been used to indicate groundwater flow direction and relative velocity. Stable isotopes have been used to differentiate waters with more than one source, and for estimating mixing (Bostick, 1978).

Estimation of the groundwater age will be accomplished by tritium and carbon isotope dating. Tritium, a naturally-occurring and anthropogenic radioactive isotope of hydrogen, becomes part of the groundwater system when removed from surface water, and decays quickly. Variations in tritium levels in a groundwater system can be used to estimate the age of water to a maximum of about 50 years.

Like tritium, carbon isotopes are also produced naturally in the atmosphere by cosmic ray bombardment. Radiocarbon age dating is essentially accomplished by measuring the activity of dissolved carbonate in groundwater and comparing it to modern activity. Unfortunately, carbonate in water comes from two different sources: initially from dissolved CO_2 in the soil zone in recharge areas and from dissolving carbonate along the groundwater flow path. Soil zone CO_2 can be measured and a stable isotope of carbon (C-13) can be used to correct for contamination by carbonate dissolution.

ENVIRONMENTAL SETTING

GEOGRAPHICAL SETTING

Eagle Valley is located along the western border of Nevada at the eastern foot of the Sierra Nevada. The basin, as described in this report, is defined as the area in which surface water drains into the Carson River from T14N, R20E, Sec. 9, to T15N, R21E, Sec. 5. This corresponds to a 177 square mile area with surface runoff from the Carson Range of the Sierra on the west, the Virginia Range on the north, and the Pine Nut Range on the east. A low alluvial divide separates Eagle Valley from Carson Valley to the south. This area also defines the boundary for potential flow into the Eagle Valley groundwater system, similar to the area defined by Mifflin (1968), although flow into the basin does not extend as far east as Bismark Peak as Mifflin described.

The Eagle Valley floor ranges from 4600 to 4800 feet in elevation with the mountains rising to 9200 feet in the Carson Range, 7000 feet in the Virginia Range and 6700 feet in the Pine Nut Mountains. The Carson River flows northward through the valley along the eastern margin of the alluvium. The major population centers in Eagle Valley are the state capital (Carson City), Stewart, and New Empire.

METEOROLOGY

Regional Weather Systems

Most of the storms that produce measurable precipitation in Eagle Valley come from the west, since the prevailing wind direction in northern California is west to east. There is a wide variation in storm source areas and characteristics. The types of storms that affect northern Nevada and the Sierra Nevada can be classified into five categories based on meteorological synoptic patterns and latitude of origin (Smith et al., 1979). These are:

(1) High (north) latitude front and upper trough (maritime polar air);

(2) Midlatitude front and upper trough (maritime polar air with some maritime tropical air);

(3) Low (equator) latitude front with deep upper trough (maritime tropical air);

(4) Confluent air masses brought together over a region along a frontal surface (with tropical air contributing most of the moisture); and

(5) Cold cyclone (mostly continental polar or modified maritime polar air, little or no frontal activity).

Midlatitude front, confluent air masses, and cold cyclones are the most common types of storms in the Sierra Nevada. Confluent air mass storms produce substantially more precipitation than do midlatitude and cold cyclone type storms. However, cold cyclone and midlatitude fronts produce lower snow lines than confluent air mass storms, since they are colder storms. The coldest storms pass over the Sierra Nevada between the winter solstice and the vernal equinox, the time of year with the least amount of solar radiation. As these storms move inland (east) toward the Sierra Nevada, adiabatic cooling produces precipitation. Approximately 90 percent of the moisture (which is mostly snow) that falls on the Sierra Nevada falls west of the divide, and 10 percent falls east of the divide. Samples from the Mojave Desert suggest that condensation occurs at about 6500 ft (2000 m) above the ground (Smith et al., 1979). In contrast, samples from the west slope of the Sierra Nevada suggest that condensation occurs, on the average at about 3000 to 5000 feet above the ground, illustrating that condensation over mountains occurs closer to the land surface.

Local Weather Systems

Eagle Valley, located on the eastern edge of the Sierra Nevada, receives winter storms that precipitate on the Sierra as well as summer thunderstorms from the southeast. Locally, three main storm types are recognized. The cold cyclone type produces light surface winds, little snow drifting, and a low amplitude profile of precipitation versus elevation: a ratio of 2:1 in amounts of precipitation measured at high and low elevations, respectively (Klieforth, 1981). The second major type of storm is the confluent air mass, which produces strong westerly or southwesterly air flow with precipitation, and profiles of 20:1 on the leeward (eastern) side of the mountains. The third type of storm, summer thunderstorms, move in from the southeast.

The amount of precipitation change in the Carson Range per elevation change has been calculated at 5.72in/1000ft (Worts and Malmberg, 1966), 6.67in/1000ft (Arteaga and Durbin, 1978), and 5.72in/1000ft (Klieforth, 1981; see Figure 2). The Virginia Range (north and east of Carson City) averages about 3.0in/1000ft elevation change. Comparison of meteorological data from the 1980-81 year to the average year is important in this study since isotopic content of precipitation is dependent upon temperature; precipitation and temperature data are presented in Tables 1 and 2.

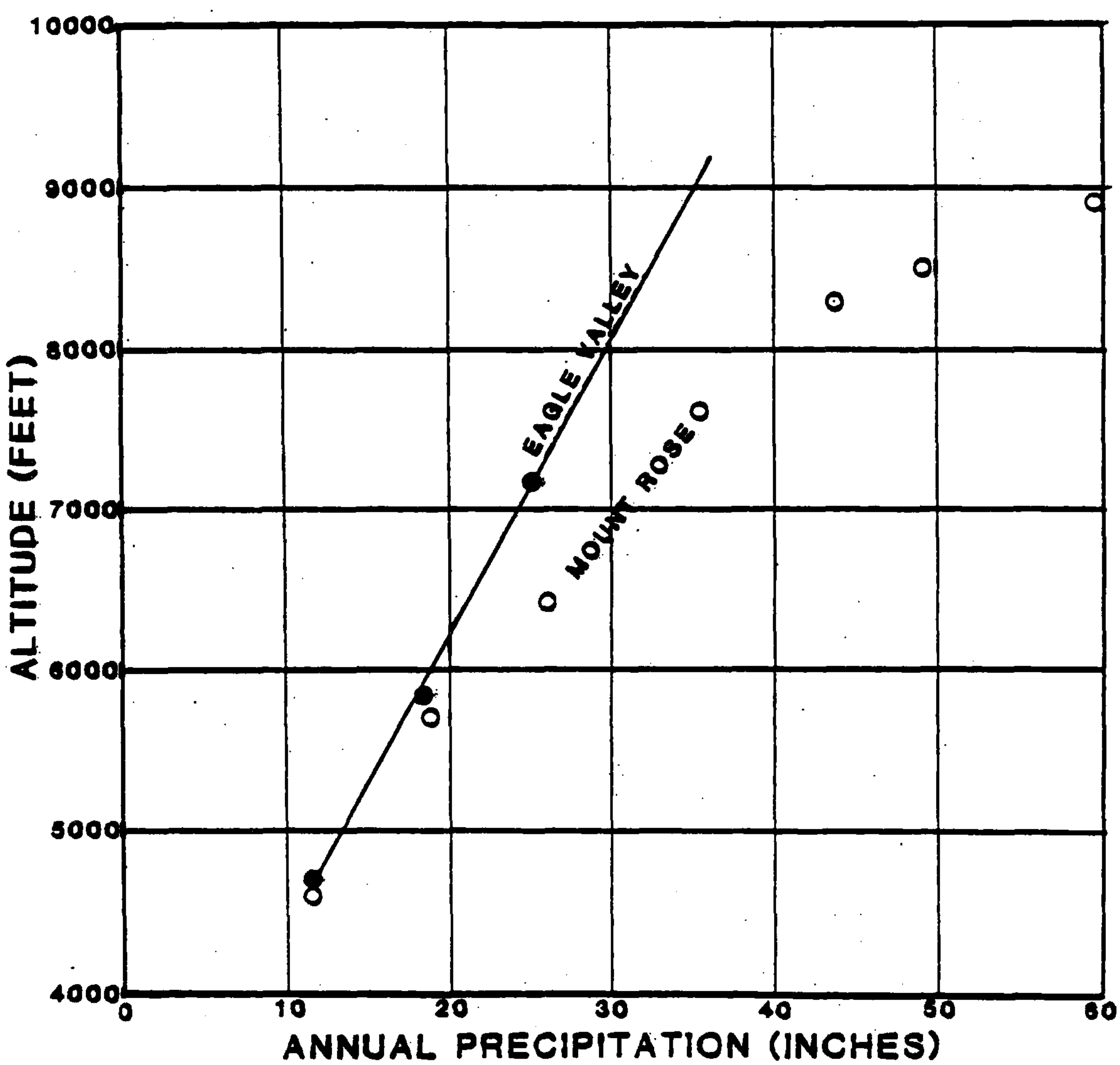

Figure 2. Annual Precipitation versus Elevation in the Carson Range (Klieforth, 1981).