Volume 2

Derivation of a Spatial Distribution of Areal Recharge From Estimates Based on Estimates Reported in Reconnaissance Investigation Reports for the Spring Valley Area

Presentation to the Office of the Nevada State Engineer

Prepared by

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List of Acronyms and Abbreviations

afy	acre-feet per year
DEM	Digital Elevation Model
ET	Evapotranspiration
ft	feet
HA	Hydrographic Area
in.	inches
N/A	Not Available
NAD83	North American Datum of 1983
NDCR	Nevada Department of Conservation and Natural Resources
NDWR	Nevada Division of Water Resources
SNWA	Southern Nevada Water Authority
USGS	U.S. Geological Survey

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1.0 INTRODUCTION

This report describes the methodology and techniques used to derive a spatial distribution of precipitation recharge for the Spring Valley model. The resulting distribution will be used to generate an input file to the numerical groundwater model.

1.1 Recharge and Its Role

In general, precipitation is the main source of recharge to a given groundwater basin. For some of the closed basins or hydrographic areas (HAs) of Nevada, it is the sole source of recharge. Groundwater mechanisms and the role and importance of precipitation recharge are discussed in this section.

Under natural conditions, precipitation can become groundwater recharge via one of three mechanisms: direct recharge, indirect recharge, and localized recharge (Lerner et al., 1990, p. 6). Recharge can also be induced by stressing the flow system.

Direct recharge is defined as water added to the groundwater reservoir in excess of soil-moisture deficits and evapotranspiration (ET) by direct vertical percolation through the vadose zone. A Maxey-Eakin recharge estimate with insignificant surface water runoff could primarily be represented as a direct recharge estimate.

Indirect recharge is the percolation to the water table through the beds of surface water courses. Indirect recharge can occur along perennial stream channels with significant mountain front runoff. Groundwater recharge could be underestimated or mislocated if indirect recharge from areas with significant surface water runoff is not accounted for.

Localized recharge is an intermediate form of groundwater recharge resulting from the accumulation of surface water in the absence of well-defined channels. Locations of localized recharge could be ponds or lakes that are fed by springs, surface water runoff or precipitation.

An additional useful definition for this document is that of rejected recharge, which is runoff water that is lost to surface water evaporation under natural conditions, but that could be turned into groundwater recharge by pumping a set of strategically-placed production wells.

An estimate of precipitation recharge that is representative of reality is key to an accurate inventory of water resources of a given HA in Nevada. Precipitation recharge is also an important component of the basin groundwater budget and, therefore an important part of a numerical flow model. Furthermore, results of simulations of groundwater models are dependent on the precipitation recharge.

1.2 Purpose and Scope

The purpose of the analysis described in this report is to generate a distribution of precipitation recharge for the Spring Valley model. The specific objective is to derive one or more grids that represent the spatial precipitation recharge distributions and total volumes reported in the U.S. Geological Survey (USGS) Reconnaissance Reports (see Section 2.3). The grid(s) will be used to calculate precipitation recharge values at finite-element nodes by interpolation to generate a specified flux input file for the FEMFLOW3D model of Spring Valley.

The scope of the analysis discussed in this report is defined by the extent of the study area and literature survey, and the analysis techniques used to complete the analysis. The study area extends over the model area, a buffer area of approximately 5 kilometers width all around the model area, and basins that are adjacent to the model area and comprise the buffer area (Figure 1-1). The buffer area is needed to ensure that enough information is available outside the model area for proper interpolation of recharge along the boundary. The literature survey is limited to Reconnaissance Reports for Nevada and Utah (see Section 2.3) and the Nevada Water Planning Report No. 3 (Scott et al., 1971). Analysis techniques used include linear regressions using Microsoft Excel® and generating and viewing grids using ESRI ArcGIS.

1.3 General Approach

The general approach consists of the following steps:

- Conduct a literature review of the precipitation recharge estimates for basins located within the study area and limited to the USGS Reconnaissance Reports (see Section 2.3) and the Water Planning Report No. 3 published by the Nevada Division of Water Resources (NDWR) (Scott et al., 1971).
- Compile available precipitation recharge estimates and related information for each basin within the study area.
- Derive a method for generating a precipitation recharge distribution for the basins located within the study area.
- Produce precipitation map(s) for the model area and buffer area.
- Produce recharge map(s) for the model area and buffer area.

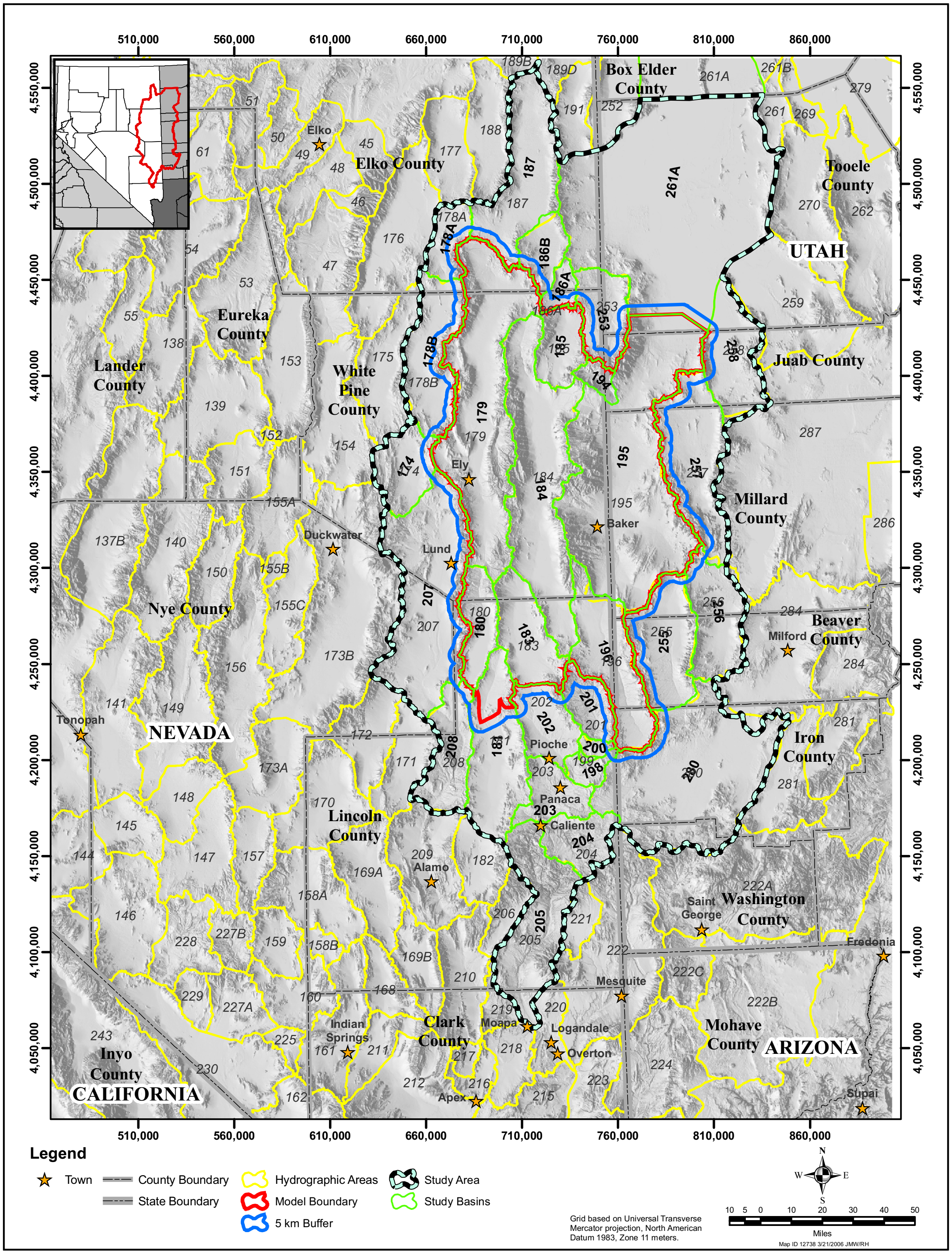

Figure 1-1
Map of the Study Area Including the Model Basins and the Basins Intersected by Buffer Zone

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2.0 AVAILABLE INFORMATION

This section presents descriptions of the main data types, methods of measurement, available data sources, and data quality evaluation.

2.1 Main Data Types

To estimate the precipitation recharge distribution of a given basin, the following data types are generally needed:

- Precipitation data
- Topography of the basin (land surface elevations or altitudes)
- Estimates of water runoff
- Location of important ephemeral and perennial streams
- Perennial stream information such as geometry, stage, streambed properties, and annual mean flow rates.

The precipitation data are usually point measurements obtained from meteorological stations. Precipitation estimates at selected points or for a given area may also be obtained from existing precipitation maps such as the Hardman (1936) map, for example.

For point data, the altitude of the meteorological station is usually reported with the precipitation data. The altitude of the station may be estimated from topographic maps or measured using global positioning system techniques, for example. Land surface altitudes may also be obtained from the Digital Elevation Model (DEM) developed by the USGS. The DEM data are available on a 30 by 30-meter (m) grid, but can be used at coarser resolutions designed to match the desired level of detail.

For some basins, storm runoff may be important to groundwater recharge. Runoff is defined as the volume of precipitation water that reaches the boundary between the mountain block and the basin-fill. Runoff may flow into surface water bodies. A portion of this water may directly evaporate into the atmosphere or transpirate via vegetation fed by the surface water. Another portion of this water may infiltrate to become groundwater recharge. Groundwater recharge from surface water mainly occurs through ephemeral or perennial streams. The location of such streams is, therefore, important because it indicates the potential location of such recharge. Additional perennial stream information such as geometry, stage, streambed properties, and annual mean flow rates is needed in cases where streamflow and infiltration through the streambed are explicitly simulated in the groundwater flow model.

2.2 Methods of Measurements

For a comprehensive review of recharge measurement methodologies, see report by Scanlon et al. (2002) titled “Choosing Appropriate Techniques for Quantifying Groundwater Recharge”. Scanlon et al. (2002) subdivided the recharge methods into three general categories corresponding to the hydrologic zones from which the data are obtained: surface water, unsaturated zone, and saturated zone. Several techniques can be used to measure recharge within each of the three zones. These techniques may be grouped into three general classes: physical, tracer, or numerical modeling approaches. Scanlon et al. (2002) focused on aspects of each approach that are important to the selection of appropriate techniques, such as the space and time scales, range, and reliability of recharge estimates. In Nevada, methods of estimating long-term primary recharge at the basin scale include (1) the Maxey-Eakin method (Maxey and Eakin, 1949, p. 40-41), (2) the chloride mass balance method (Dettinger, 1989; Russell and Minor, 2002), and (3) a modeling method developed for the Yucca Mountain Project model (Flint et al., 2002).

2.2.1 The Maxey-Eakin Method

The Maxey-Eakin method is the most widely used of the three methods in the study area. Estimates of recharge used by the Nevada State Engineer are based on the Maxey-Eakin method. These estimates were made during studies conducted by the USGS in cooperation with the Nevada Department of Conservation and Natural Resources, (NDCNR). These studies resulted in estimates of groundwater and surface water resources for 254 HAs of Nevada that were published in the “Ground-Water Reconnaissance and Water Resources Bulletin” series. The Bulletin series began first in the 1940s and consists of detailed reports. The water resources reconnaissance survey was authorized in 1960 by the State of Nevada legislature to make pertinent water-related information readily available (Eakin, 1960; Scott et al., 1971). Most of the Bulletin and Reconnaissance estimates were summarized in the NDCNR Water Planning Report No. 3 (Scott et al., 1971). The State of Utah, in cooperation with the USGS also developed a series of technical publications for the valleys in Utah started in the late 1960s (see Section 2.3).

The Maxey-Eakin method is a groundwater budget method. It is also based on the concept that areas of higher precipitation result in more groundwater recharge than areas with lower precipitation. Steps for estimating annual average groundwater recharge for a given hydrographic area using the original Maxey-Eakin method (Maxey and Eakin, 1949, p. 40-41) are as follows:

- The hydrographic area is subdivided into several zones based on precipitation rates based on the “Hardman” precipitation map(s) of Nevada (Hardman, 1936). Defined zones of precipitation are (1) less than 8 inches (in.), (2) 8 to 12 in., (3) 12 to 15 in., (4) 15 to 20 in., and (5) over 20 in.

- The recharge of each zone is calculated as a percentage of the average annual precipitation volume in that zone. The percentage term represents the assumed fraction of precipitation that becomes groundwater recharge. This term is called recharge efficiency.

- The zone recharge values are added up to derive an estimate of the total average annual groundwater recharge for the HA. The recharge efficiencies are adjusted until the groundwater budget is balanced.

Later, different versions of the Maxey-Eakin methods were developed using updated precipitation maps of Nevada (Hardman and Mason, 1949; Hardman, 1965) or topographic maps (1:250,000) as a surrogate for precipitation to define the zones of precipitation. Depending on the year the report was published, the average precipitation ranges between specified limits for each zone in most of the Reconnaissance Reports (see Section 2.3) were delineated based on different versions of the "Hardman" precipitation map(s) of Nevada (Hardman, 1936; Hardman and Mason, 1949; Hardman, 1965). The acreage of each precipitation zone was measured on the topographic maps (1:250,000) with a planimeter (Eakin et al., 1951, Bulletin 12, p. 26-27). The planimeter is an instrument for measuring the area of any plane figure by passing a tracer around the perimeter (Bates and Jackson, 1983, p. 388). Since then, the Maxey-Eakin method, or modified versions of it, have been used to develop groundwater recharge estimates for the flow systems of Nevada. General precipitation zones and recharge efficiencies used in Nevada are listed in Table 2-1.

Table 2-1
General Recharge Zones Used in the Reconnaissance Reports

Precipitation Zones (in.)	Applicable Ranges of Altitude (feet [ft])	Recharge (Percent)
>20	(>9,000) or (>10,000)	25
15-20	(>7,000) or (8,000 to 9,000) or (9,000 - 10,000)	15
12-15	(6,000 to 7,000) or (7,000 to 8,000) or (8,000 to 9,000)	7
8-12	(4,000 to 6,000) or (5,000 to 6,000) or (6,000 to 7,000) or (7,000 to 8,000)	3
<8	(<4,000) or 5,000 or 6,000 or 7,000	0

Source: Maxey and Eakin, 1949

2.2.2 Modern Implementation of the Maxey-Eakin Method

With the advent of computers and Geographic Information System software, a modern method of implementing the Maxey-Eakin method is through the use of equations to calculate precipitation and recharge at any point on the surface of a basin. This method is implemented in three major steps: (1) a linear relationship between precipitation and land surface altitude is identified; (2) a relationship is developed between the recharge efficiencies and the precipitation; and (3) the recharge rate at a given point on the surface of a given basin is calculated as the product of the precipitation value at that altitude multiplied by the value of the recharge efficiency for that value of precipitation. The linear relationship between precipitation and land surface altitude may be derived from point measurements of precipitation and their corresponding altitudes. Or it can be developed from the precipitation zones and their corresponding altitude ranges.

This method can easily be used to generate grids of precipitation and recharge. This is accomplished by calculating the recharge rate at the center of the grid cells as described above. The recharge volume associated with the grid cell is then calculated simply by multiplying the calculated rate by the area of the grid cell.

2.3 Description of Available Data Sources

Because the water budget used to construct the numerical groundwater flow model for the Spring Valley Area is primarily based on the USGS Reconnaissance Reports, the only sources of existing estimates of natural recharge used are the NDCNR Water Planning Report No. 3 (Scott et al., 1971) and the Reconnaissance Reports listed below. Although more recent estimates may be available, they were not used in this study.

A list of Reconnaissance Reports containing data relevant to the study area (Figure 1-1) follows:

- Water Resources Bulletin 8 for the White River Valley, Nevada (Maxey and Eakin, 1949, p. 40-41)
- Water-Resources Bulletin 12 for several basins of eastern Nevada (Eakin et al., 1951, p. 26-27) .
- Reconnaissance Report No. 13 for Cave Valley, Nevada (Eakin, 1962, p. 12)
- Reconnaissance Report No. 16 for Dry Lake and Delamar Valleys, Nevada (Eakin, 1963a, p. 17)
- Reconnaissance Report No. 21 for Pahranagat and Pahroc Valleys, Nevada (Eakin, 1963b, p. 18)
- Reconnaissance Report No. 24 for Lake Valley, Nevada (Rush and Eakin, 1963, p. 17)
- Reconnaissance Report No. 27 for the Meadow Valley Area, Nevada (Rush, 1964, p. 20)
- Reconnaissance Report No. 33 for Spring Valley (Rush and Kazmi, 1965, p. 21, 25, 26)
- Reconnaissance Report No. 34 for Big Snake Valley (includes Hamlin and Pleasant Valleys - 254) (Hood and Rush, 1965, p. 22)
- Water Resources Bulletin No. 33 for the White River area (Eakin, 1966, p. 261)
- Reconnaissance Report No. 42 for Steptoe Valley (Eakin et al., 1967, p. 23)

- Reconnaissance Report No. 49 for Butte Valley, Nevada (Glancy, 1968, p. 23)
- Reconnaissance Report No. 56 for Pilot Creek Valley area (Harrill, 1971, p. 18-19)
- Utah Technical Publication No. 24 for Deep Creek Valley, Tooele and Juab Counties, Utah and Elko and White Pine Counties, Nevada (Hood and Waddell, 1969, p. 19).
- Utah Technical Publication No. 47 for Wah Wah Valley Drainage Basin, Millard and Beaver Counties, Utah (Stephens, 1974, p. 12).
- Utah Technical Publication No. 51 for Pine Valley Drainage Basin, Millard, Beaver, and Iron Counties, Utah (Stephens, 1976, p. 12).
- Utah Technical Publication No. 56 for Tule Valley Juab and Millard Counties, Utah (Stephens, 1977, p. 10)
- Utah Technical Publication No. 64 for Fish Springs Flat Area, Utah (Bolke and Sumsion, 1978, p. 8)
- Utah Technical Publication No. 73 for Beryl-Enterprise Area, Escalante Desert, Utah (Mower, 1981, p. 27).

2.4 Data Quality Evaluation

As stated before, the main sources of data are the Reconnaissance Reports (see Section 2.3). As their name indicates, these documents report the results of studies made at the reconnaissance level only. These studies were conducted quickly without detailed field work or data analysis. Their objective was to assess the quantities of water resources available for development at that time. Additional limitations are those associated with the Maxey-Eakin method.

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3.0 DATA ANALYSIS METHODOLOGY

This section describes the data analysis objective and the data analysis methodology followed to attain it, including (1) compilation of reported precipitation and groundwater recharge for each basin in the study area, (2) development of altitude-precipitation relationships, (3) generation of a precipitation grid, (4) generation of a recharge grid, and (4) identification and discretization of groundwater recharge from surface water.

3.1 Analysis Objective

The objective of the data analysis is to derive a gridded spatial distribution of groundwater recharge for the model and buffer areas as follows:

- Total recharge estimates derived from the spatial distributions for basins located within the model area must be approximately equal to the estimates provided in the Reconnaissance Reports.

- Total recharge estimates derived from the spatial distributions for basins containing the buffer area may be approximated if Maxey-Eakin recharge estimates are not available.

3.2 Compilation of Reported Basin Recharge Information

The methodology consists primarily of compiling precipitation and recharge data from the Water Planning Report No. 3 (Scott et al., 1971) and the relevant Reconnaissance Reports (see Section 2.3) for each basin of the study area (Figure 1-1).

Reconnaissance Reports for Nevada basins usually include a table containing all information necessary to derive an estimate of total groundwater recharge from precipitation using the Maxey-Eakin method. Such information includes precipitation zones and corresponding surface elevations (altitude), recharge efficiencies, estimates of recharge for each precipitation zone, and a total recharge estimate for the basin. In some instances, the calculated recharge was redistributed between the mountain block and the alluvial apron. In other instances, recharge above the estimated Maxey-Eakin recharge was added to the Maxey-Eakin estimate.

The method of estimating groundwater recharge for basins in Utah is quite different from that used for basins in Nevada. The Utah method considers the spatial distribution of recharge based on surficial geology. Given that the only basins of interest to this study that are wholly located in Utah are those that intersect the buffer area, no information was compiled from reports on basins in Utah. One of the basins located within the model area, Snake Valley, is partly located in Utah, but an estimate of recharge for the whole basin is available in a Reconnaissance Report (Hood and Rush, 1965).

3.3 Development of Basic Altitude-Precipitation Relationships

Altitude-precipitation relationships are developed using the modern method of implementation of the Maxey-Eakin method described in Section 2.0. The first step in the relationship development process is to classify the basins of interest into groups that follow the same altitude-precipitation relationship. The second step is to develop each of the altitude-precipitation relationships for each of the groups identified.

3.3.1 Basin Classification

The precipitation zones used in the Maxey-Eakin method can be associated with land surface altitudes. The altitudes corresponding to a given precipitation zone may vary according to location. As shown in Table 2-1, the lower limit of the lowest zone is the 8-in. precipitation line. The altitude of this precipitation line dictates the altitude-precipitation relationship. Thus, to derive the altitude-precipitation relationships, each basin is classified according to the altitude of its 8-in. precipitation line.

No specific altitude-precipitation relationships will be developed for basins located in Utah and intersecting the buffer zone. Instead, the most common altitude-precipitation relationship identified for the other basins of the study area is assigned to these basins.

3.3.2 Development of Basic Precipitation-Altitude Relationships

Precipitation-altitude relationships are developed for each of the identified groups of basins following these steps:

1. Compile information to derive the five altitude-precipitation zones.
2. Convert zone data to point (or xyz) format.
3. Plot the points using altitude as X-axis and precipitation as Y-axis.
4. Fit a straight line through the points using the regression data analysis tool of Microsoft Excel.
5. Identify the equation of the fitted straight line.

3.3.3 Generation of Precipitation Grid for Study Area

The equations describing the precipitation-altitude relationships are used to generate a precipitation grid. The land surface altitude data used to generate the spatial distribution of precipitation is the DEM data converted to 800-m grid cells. The steps are as follows:

1. Convert the land surface altitude grid (DEM data) to point (or xyz) format.

2. For each DEM grid point, calculate a precipitation rate value using the appropriate precipitation-altitude equation.

3. Multiply each grid point value of precipitation rate by the area of a cell (800 m × 800 m) to calculate a precipitation volume per grid cell.

4. Calculate the total basin precipitation volume by adding the precipitation volumes of all grid cells containing non-zero and positive values.

3.4 Maxey-Eakin Recharge Grid From Basic Precipitation-Altitude Relationships

The spatial distribution of recharge is derived from the precipitation grid as follows:

1. Start with the xyz form of the grid containing the previously-calculated precipitation rate values.

2. For each grid point, calculate a recharge rate value using the step function of recharge efficiency as a function of precipitation.

3. Multiply each grid point value of recharge rate by the area of a cell (800 m × 800 m) to calculate a precipitation volume per grid cell.

4. Calculate the total basin recharge volume by adding the recharge volumes of all grid cells containing non-zero and positive values.

3.5 Refinement of Precipitation-Altitude Relationships

After the recharge grid for a given basin is created using the basic precipitation-altitude relationships described above, the resulting recharge volume of each basin located in the study area on the Nevada side are compared to the reported values. If the two values do not match within a reasonable margin of error, the spatial distribution is refined to produce a better match.

Significant differences in the recharge estimates may result from the use of the DEM data. The 800-m DEM grid has an area of 158.144 acres for each grid cell, so the accuracy of the area based on the 800-m grid will not be greater than 158 acres. Because the highest recharge in or near the study area is less than one foot per year, it implies that the accuracy of the recharge estimate using the

800-m grid is probably not greater than 100 acre-feet per year (afy). Because the acreages of the zones of the precipitation based on the 800-m DEM are slightly different from those reported in the Reconnaissance Reports, this difference creates differences in the total precipitation volumes for each zone in of a given basin.

For basins located within the model area, a margin of error of 10 percent of the reported recharge volume was selected as the cutoff error. If the difference between the recharge estimate derived from the spatial distribution and the reported estimate is less than 10 percent, the two values are considered to match and the process for that basin is complete. If, on the other hand, the difference between the two values is greater than 10 percent, the spatial distribution is refined to produce a better match. For basins located outside of the model area and containing the buffer area, the criterion was much less stringent and varied by basin, as is explained in Section 4.0.

The refinement methodology consisted of adjusting the parameters of the basic precipitation-altitude relationship of a given basin until the resulting total recharge volume matched the reported recharge volume within 10 percent. An additional constraint imposed during this precipitation-altitude relationship “calibration” is that the 8-in. precipitation altitude is forced to occur at the altitude specified in the Reconnaissance Report.

3.6 Groundwater Recharge from Surface Water

For basins where significant runoff occurs, a portion of the runoff water infiltrates to the groundwater system. Runoff water may infiltrate as it moves along either ephemeral or perennial streams located on the alluvial apron. The amount of groundwater recharge infiltrated along these streams may be a portion of the Maxey-Eakin recharge estimated for the basin or an additional amount estimated by different means.

4.0 DATA ANALYSIS

This section describes the data analysis for each of the four steps described in the previous section. As stated before, the four steps are: (1) compilation of reported basin recharge information, (2) development of altitude-precipitation relationships, (3) generation of Maxey-Eakin recharge grids, and (4) identification and discretization of groundwater recharge from surface water. All data relevant to estimating precipitation and recharge for the Spring Valley study area has been compiled into an Access database (Attachment A).

4.1 Reported Areal Recharge Information

Reported areal recharge of interest includes recharge from precipitation estimated using the Maxey-Eakin method and related information and potential recharge from surface water. Such information was extracted from reports relevant to this study and are discussed in the following text.

4.1.1 Maxey-Eakin Recharge

Published estimates of precipitation and recharge for all basins located within the study area were extracted from the reports listed in Section 2.0. The results are presented in Table 4-1.

For basins located in Nevada, the reported precipitation and groundwater recharge estimates based on the Maxey-Eakin method were extracted from the Reconnaissance Reports and NCDNR Water Planning Report No. 3 (Scott et al., 1971). For basins located within the study area on the Utah side, the needed information was extracted from the appropriate reports. All sources of information are listed in Table 4-1. Note that Water for Nevada (Scott et al., 1971) only listed precipitation for Pleasant, Snake, and Hamlin Valleys in Nevada, so the total precipitation volume of these three valleys in Water for Nevada is much less than reported in Reconnaissance Report 34 (Hood and Rush, 1965).

4.1.2 Potential Recharge From Surface Water

Three of the basins located within the model area have large amounts of runoff resulting in significant surface water which may affect the amount and/or distribution of the reported groundwater recharge. These three basins are: Spring Valley, Snake Valley including Pleasant and Hamlin valleys, and Steptoe Valley. Reported runoff estimates and other related information extracted from the Reconnaissance Reports are presented in Table 4-2. Each of the three basins are discussed in the following text.

Table 4-1
Published Estimates of Precipitation and Recharge for Basins in Study Area

Hydrographic Area Name	Hydrographic Area Number	Precipitation (afy)	Recharge (afy)	Reference	Precipitation (afy)	Recharge (afy)	Reference
Butte Valley (Northern Part)	178A	140,000	3,900	Glancy, 1968	140,000	3,900	Scott et al., 1971
Cave Valley	180	225,800	14,000	Eakin, 1962	220,000	14,000	
Dry Lake Valley	181	>118,000	5,000	Eakin, 1963a	340,000	5,000	
Lake Valley	183	293,000	13,000	Rush and Eakin, 1963	290,000	13,000	
Tippett Valley	185	160,000	6,900	Harrill, 1971	160,000	6,900	
Antelope Valley (Southern Part)	186A	58,000	1,500	Harrill, 1971	58,000	1,500	
Antelope Valley (Northern Part)	186B	120,000	3,200	Harrill, 1971	120,000	3,200	
Goshute Valley	187	N/A	10,400	Eakin et al., 1951	440,000	11,000	
Dry Valley	198	670,000	8,000	Rush, 1964	723,100	7,000	
Rose Valley	199						
Eagle Valley	200						
Panaca Valley	203						
Clover Valley	204						
Lower Meadow Valley Wash	205						
Spring Valley	201	178,000	10,000	Rush, 1964	180,000	10,000	
Patterson Valley	202	194,000	6,000	Rush, 1964	190,000	6,000	
Pahroc Valley	208	>57,000	2,200	Eakin, 1963b	190,000	2,200	
Butte Valley (Southern Part)	178B	420,000	15,000	Glancy, 1968	420,000	15,000	
Jakes Valley	174	N/A	17,000	Eakin, 1966	240,000	17,000	
Pleasant Valley	194	2,000,000	100,000	Hood and Rush, 1965	894,000[a]	70,800[a]	
Snake Valley	195			Hood and Rush, 1965			
Hamlin Valley	196			Hood and Rush, 1965			
Spring Valley	184	960,000	75,000	Rush and Kazmi, 1965	960,000	75,000	
Steptoe Valley	179	1,200,000	85,000	Eakin et al., 1967	1,200,000	85,000	
White River Valley	207	N/A	38,000	Eakin, 1966	750,000	38,000	
Deep Creek Valley	253	290,000	17,000	Hood and Waddell, 1969	N/A	N/A	N/A
Pine Valley	255	410,000	21,000	Stephens, 1976	N/A	N/A	N/A
Wah Wah Valley	256	290,000	7,000	Stephens, 1974	N/A	N/A	N/A
Tule Valley	257	400,000	7,600	Stephens, 1977	N/A	N/A	N/A
Fish Springs Flat	258	232,000	4,000	Bolke and Sumsion, 1978	N/A	N/A	N/A
Great Salt Lake Desert (West Part)	261A	200,000	4,800	Harrill, 1971	N/A	N/A	N/A
Beryl-enterprise Area	280	1,200,000	48,000	Mower, 1981	N/A	N/A	N/A

[a]The numbers reported for Nevada side only N/A = Not Available

Table 4-2
Summary of Reconnaissance Series Reported Data for Basins With Significant Surface Water

Hydrographic Basin Name	Discharge from Evapotranspiration	Runoff (afy)	Makey-Eakin Recharge Estimate (afy)	Perennial Yield (afy)	Reconnaissance Series Report Number
Spring Valley	70,000	90,000	75,000	100,000	33
Snake Valley	80,000	58,000	100,000	80,000	34
Steptoe Valley	70,000	78,000	85,000	70,000	42

Spring Valley

Rush and Kazmi (1965) reported a runoff value of 90,000 afy for Spring Valley (HA 184). Of the 90,000 afy of runoff, they estimated that 30,000 afy constitutes rejected recharge that gets lost to surface water evaporation under natural conditions. Furthermore, they stated that this rejected recharge could be induced to infiltrate into the groundwater flow system by a set of well-placed production wells. Based on this assumption, Rush and Kazmi (1965) added the amount of rejected recharge, 30,000 afy, to the basic perennial yield of 70,000 afy to end up with an estimated perennial yield of 100,000 afy for Spring Valley.

Snake Valley

Hood and Rush (1965) reported an annual runoff of 58,000 afy for Snake Valley, which includes Pleasant, Snake, and Hamlin Valleys. Although this is a significant amount of surface water, no discussion of rejected recharge was included in this reconnaissance report. However, Hood and Rush (1965) indicated that, in addition to the reported Maxey-Eakin recharge estimate of 100,000 afy, an additional amount of 2,700 afy occurs on the 270,000 acres of alluvium in Hamlin Valley. The estimated perennial yield for Snake Valley was reported as 80,000 afy (Table 4-2), an amount equal to the estimated groundwater ET. The perennial yield for Snake Valley is not affected by the additional recharge in Hamlin Valley.

Steptoe Valley

In USGS Reconnaissance Report No. 42, Eakin et al., (1967) reported an annual runoff of 78,000 afy in Steptoe Valley. As stated before, the reported Maxey-Eakin recharge estimate for this valley is 85,000 afy. Reconnaissance Report No. 42 does not include a discussion of additional recharge from surface water, nor does it assume that rejected recharge could be induced by production wells. It is, therefore, assumed that the only areal recharge suitable for input to the model is the Maxey-Eakin recharge. Also, the estimated perennial yield for Steptoe Valley remains as reported and equal to the estimate of ET 70,000 afy. These estimates are presented in Table 4-2.

4.2 Basic Altitude-Precipitation Relationships

As stated in Section 3.0 the basins were first grouped into classes following the same basic precipitation-altitude relationships. The basic relationships were then developed into equations.

4.2.1 Basin Classification

Basins located within the study area were classified according to the altitude of their 8-in. precipitation line (Table 4-3).

As shown in Table 4-3, for most of the basins in the study, the 8-in. precipitation line occurs at an altitude of 6,000 ft. These basins were assigned the precipitation-altitude relationship class of “6S”. Snake Valley, Pleasant Valley, and Hamlin Valley are the only valleys in Nevada (partly) where the 8-in. precipitation line occurs at an altitude of 5,000 ft. This basin was assigned the precipitation-altitude relationship class of “5S”. All basins in the study area, the altitude of their 8-in. precipitation line, and the name of their altitude-precipitation relationship group are presented in Table 4-3.

Table 4-3
Summary of Altitude of 8-in. Precipitation Line and Grouping of Hydrographic Areas in the Study Area Used in the Nevada Reconnaissance Reports

Name	HA	Symbol	Altitude for 8-in. Precipitation (ft)
Butte Valley (Southern Part)	178B	6S	6,000[a]
Steptoe Valley	179	6S	6,000[a]
Spring Valley	184	6S	6,000[a]
Tippett Valley	185	6S	6,000
Pleasant Valley	194	5S	5,000[a]
Snake Valley	195	5S	5,000[a]
Hamlin Valley	196	5S	5,000[a]
Jakes Valley	174	6S	6,000
White River Valley	207	6S	6,000[a]
Cave Valley	180	6S	6,000
Pahroc Valley	208	6S	6,000
Dry Lake Valley	181	6S	6,000
Lake Valley	183	6S	6,000
Patterson Valley	202	6S	6,000
Spring Valley	201	6S	6,000
Eagle Valley	200	6S	6,000
Rose Valley	199	6S	6,000
Dry Valley	198	6S	6,000
Panaca Valley	203	6S	6,000
Clover Valley	204	6S	6,000
Lower Meadow Valley Wash	205	6S	6,000

[a]The 8-in. altitude for these HAs are not clearly defined or the derived 8-in. altitude line is different from the 8-in. precipitation altitude line reported.

Basins located in Utah and intersecting the buffer zone were assigned the 6S precipitation-altitude relationship. This relationship is the most prevalent in the study area and is adequate for purposes of estimating the recharge of the model buffer area.

4.2.2 Basic Precipitation-Altitude Relationships

This section describes the two basic precipitation-altitude relationships developed for the basins in the study area: 5S and 6S.

The precipitation-altitude information for HAs assigned to the 5S and 6S groups are listed in Table 4-4. From the five precipitation-altitude zone data, a set of seven data points was generated by expanding the altitude ranges to single altitude values, assigning a corresponding precipitation value, and converting the precipitation value from inches to feet. A straight line was then fit to the seven data points and a corresponding equation derived (Table 4-4). The plotted points and the regression line are shown in Figure 4-1.

Table 4-4
Data and Regression for 5S and 6S Basins

Range of Altitude (ft)	Precipitation (in.)		Altitude (ft)	Precipitation (ft)	Equation
			5S		
<5000	<8		5,000	0.67	
5000-6000	8-12		5,500	0.83	
6000-7000	12-15		6,000	1.00	
7000-8000	15-20		6,500	1.13	Precipitation (ft) = 0.000321 x altitude (ft) - 0.9464
>8000	>20	→	7,000	1.25	
			7,500	1.46	
			8,000	1.67	
			6S		
<6000	<8		6,000	0.67	
6000-7000	8-12		6,500	0.83	
7000-8000	12-15		7,000	1.00	
8000-9000	15-20	→	7,500	1.13	Precipitation (ft) = 0.000321 x altitude (ft) - 1.2679
>9000	>20		8,000	1.25	
			8,500	1.46	
			9,000	1.67	

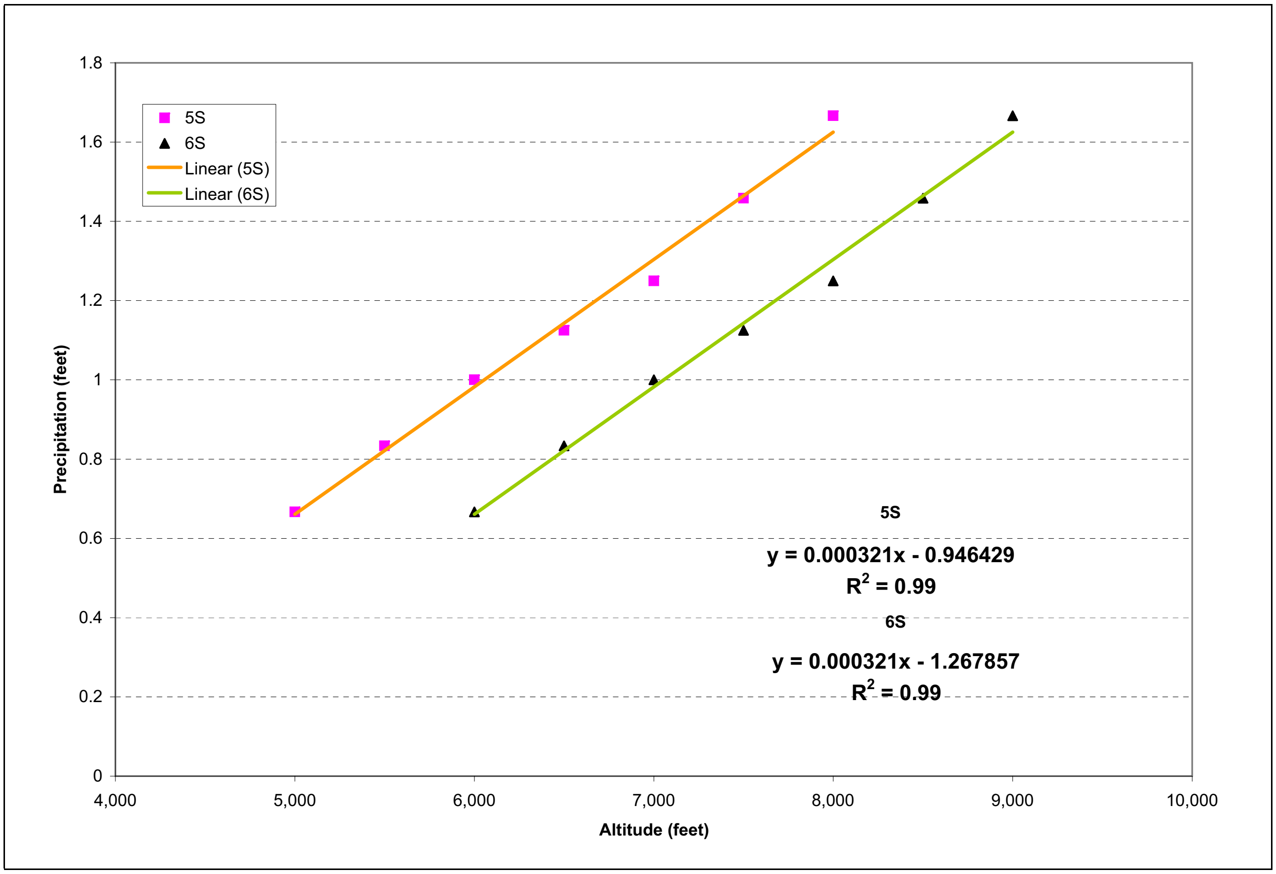

Figure 4-1
Precipitation-Altitude Relationships of Hydrographic Areas in Groups 5S and 6S

4.2.3 Precipitation and Recharge Distributions Using 5S and 6S Relationships

A precipitation grid was generated for the study area using the two basic precipitation-altitude relationships, 5S and 6S. A recharge grid was then derived following the approach described in Section 3.0. The total precipitation and recharge for each the basins located within the study area were then calculated and compared to the reported values (Table 4-5). Of particular interest are the recharge estimates for the basins located within the model area. All values derived using the 6S relationship compare to the reported values within 10 percent. The recharge value derived for Big Snake Valley using the 5S relationship is off by more than 100 percent (Table 4-5). Most of the recharge estimates derived for the basins located outside of the model area are within 30 percent of the reported values. The precipitation-altitude relationships for some of the basins were refined to reduce the differences between the values derived from the spatial distributions and the reported values. The relationship refinement process is described in the next section.

Table 4-5
Comparison of 5S and 6S Precipitation and Recharge Estimate With Reported Values

<table>
<tr><th rowspan="2">Valley Name</th><th rowspan="2">HA</th><th colspan="2">From Reconnaissance Reports</th><th colspan="2">From Scott et al., 1971</th><th colspan="2">5S and 6S</th><th>Percent Difference</th></tr>
<tr><th>Precipitation (afy)</th><th>Recharge (afy)</th><th>Precipitation (afy)</th><th>Recharge (afy)</th><th>Precipitation (afy)</th><th>Recharge (afy)</th><th>5S and 6S vs. Reconnaissance Reports or Scott et al. 1971</th></tr>
<tr><td colspan="9">Basins Located Within Model Area</td></tr>
<tr><td>Cave Valley</td><td>180</td><td>225,800</td><td>14,000</td><td>220,000</td><td>14,000</td><td>215,823</td><td>13,380</td><td>-4</td></tr>
<tr><td>Dry Lake Valley</td><td>181</td><td>>118,000</td><td>5,000</td><td>340,000</td><td>5,000</td><td>287,273</td><td>4,476</td><td>-10</td></tr>
<tr><td>Lake Valley</td><td>183</td><td>293,000</td><td>13,000</td><td>290,000</td><td>13,000</td><td>289,880</td><td>12,668</td><td>-3</td></tr>
<tr><td>Tippett Valley</td><td>185</td><td>160,000</td><td>6,900</td><td>160,000</td><td>6,900</td><td>172,014</td><td>6,953</td><td>1</td></tr>
<tr><td>Pleasant Valley</td><td>194</td><td rowspan="3">2,000,000</td><td rowspan="3">100,000</td><td rowspan="3">894,000[a]</td><td rowspan="3">70,800[a]</td><td rowspan="3">2,453,334</td><td rowspan="3">242,361</td><td rowspan="3">142</td></tr>
<tr><td>Snake Valley</td><td>195</td></tr>
<tr><td>Hamlin Valley</td><td>196</td></tr>
<tr><td>Spring Valley</td><td>184</td><td>960,000</td><td>75,000</td><td>960,000</td><td>75,000</td><td>962,196</td><td>72,591</td><td>-3</td></tr>
<tr><td>Steptoe Valley</td><td>179</td><td>1,200,000</td><td>85,000</td><td>1,200,000</td><td>85,000</td><td>1,220,759</td><td>95,200</td><td>12</td></tr>
<tr><td colspan="9">Basins Containing the Buffer Area</td></tr>
<tr><td>Antelope Valley (Southern Part)</td><td>186A</td><td>58,000</td><td>1,500</td><td>58,000</td><td>1,500</td><td>58,250</td><td>1,373</td><td>-8</td></tr>
<tr><td>Antelope Valley (Northern Part)</td><td>186B</td><td>120,000</td><td>3,200</td><td>120,000</td><td>3,200</td><td>127,574</td><td>3,255</td><td>2</td></tr>
<tr><td>Goshute Valley</td><td>187</td><td>N/A</td><td>10,400</td><td>440,000</td><td>11,000</td><td>420,199</td><td>10,773</td><td>4</td></tr>
<tr><td>Butte Valley (Southern Part)</td><td>178B</td><td>420,000</td><td>15,000</td><td>420,000</td><td>15,000</td><td>430,083</td><td>23,115</td><td>54</td></tr>
<tr><td>Jakes Valley</td><td>174</td><td>N/A</td><td>17,000</td><td>240,000</td><td>17,000</td><td>268,206</td><td>16,733</td><td>-2</td></tr>
<tr><td>White River Valley</td><td>207</td><td>N/A</td><td>38,000</td><td>750,000</td><td>38,000</td><td>739,481</td><td>33,973</td><td>-11</td></tr>
<tr><td>Butte Valley (Northern Part)</td><td>178A</td><td>140,000</td><td>3,900</td><td>14,000</td><td>3,900</td><td>145,078</td><td>6,910</td><td>77</td></tr>
<tr><td>Dry Valley</td><td>198</td><td rowspan="6">670,000</td><td rowspan="6">8,000</td><td rowspan="6">723,100</td><td rowspan="6">7,000</td><td rowspan="6">451,469</td><td rowspan="6">6,634</td><td rowspan="6">-17</td></tr>
<tr><td>Rose Valley</td><td>199</td></tr>
<tr><td>Eagle Valley</td><td>200</td></tr>
<tr><td>Panaca Valley</td><td>203</td></tr>
<tr><td>Clover Valley</td><td>204</td></tr>
<tr><td>Lower Meadow Valley Wash</td><td>205</td></tr>
<tr><td>Spring Valley</td><td>201</td><td>178,000</td><td>10,000</td><td>180,000</td><td>10,000</td><td>176,216</td><td>10,324</td><td>3</td></tr>
<tr><td>Patterson Valley</td><td>202</td><td>194,000</td><td>6,000</td><td>190,000</td><td>6,000</td><td>193,994</td><td>5,443</td><td>-9</td></tr>
<tr><td>Pahroc Valley</td><td>208</td><td>>57,000</td><td>2,200</td><td>190,000</td><td>2,200</td><td>165,433</td><td>1,860</td><td>-15</td></tr>
<tr><td>Deep Creek Valley</td><td>253</td><td>290,000</td><td>17,000</td><td>N/A</td><td>N/A</td><td>206,163</td><td>10,331</td><td>-39</td></tr>
<tr><td>Pine Valley</td><td>255</td><td>410,000</td><td>21,000</td><td>N/A</td><td>N/A</td><td>355,018</td><td>14,475</td><td>-31</td></tr>
<tr><td>Wah Wah Valley</td><td>256</td><td>290,000</td><td>7,000</td><td>N/A</td><td>N/A</td><td>225,146</td><td>6,127</td><td>-12</td></tr>
<tr><td>Tule Valley</td><td>257</td><td>400,000</td><td>7,600</td><td>N/A</td><td>N/A</td><td>266,475</td><td>5,534</td><td>-27</td></tr>
<tr><td>Fish Springs Flat</td><td>258</td><td>232,000</td><td>4,000</td><td>N/A</td><td>N/A</td><td>123,760</td><td>883</td><td>-78</td></tr>
<tr><td>Great Salt Lake Desert (West Part)</td><td>261A</td><td>200,000</td><td>4,800</td><td>N/A</td><td>N/A</td><td>473,720</td><td>4,785</td><td>0</td></tr>
<tr><td>Beryl-enterprise Area</td><td>280</td><td>1,200,000</td><td>48,000</td><td>N/A</td><td>N/A</td><td>781,311</td><td>14,266</td><td>-70</td></tr>
</table>

[a]The numbers reported for Nevada side only

4.3 Refined Precipitation-Altitude Relationships

The precipitation-altitude relationship refinement was conducted on a basin-by-basin basis. In other words, for any basin that was subjected to refinement, the basic precipitation-altitude equation was adjusted to a new equation that is only applied to that basin. The basins selected for refinement of their precipitation-altitude relationships and the refined relationships are discussed in the following text.

Basins selected for the refinement process are as follows:

Spring Valley: Although the difference between the reported recharge and the recharge derived from the distribution based on the 6S precipitation-altitude was only 3 percent, Spring Valley was selected for the refinement process because it is the main basin of interest in the model. It is very important that all components of the water budget, including precipitation recharge, are represented as closely as possible to the reported values.

Big Snake and Steptoe Valleys: These two basins are located within the model area and occupy special positions with respect to Spring Valley. Both of them are adjacent to Spring Valley and share one of their north-south boundaries with Spring Valley. Steptoe is located on the western side of Spring Valley, with Snake Valley on its eastern side.

Other Basins: Of the basins located outside of the model area on the Nevada side, only White River and South Butte Valleys relationships were refined because the recharge values derived from the spatial distribution differed by more than 3,000 afy. The precipitation-altitude relationships of all other basins intersecting the buffer area were not refined. The basic relationships yield reasonable recharge estimates for the portions of the buffer area they contain.

The refined precipitation-altitude relationships were developed for each of the selected HAs following the methodology described in Section 3.0. The derived relationships are presented in Table 4-6. The relationships are represented by straight lines with slopes labeled “a” and intercepts labeled “b” in Table 4-6. Each of the relationships is specific to the basin it represents and was, therefore, named after the basin in question (symbol in Table 4-6). The precipitation-altitude refinement calculations were set up in an Excel spreadsheet with the altitude points from the 800-m DEM and the recharge efficiencies shown in Table 2-1**.** Because each of the HAs has thousands of altitude points, it is not practical to show all points here. Rather, the spreadsheets are provided on a compact disk described in Attachment A.

4.4 Generation of Precipitation and Recharge Distribution for Study Area

The precipitation and recharge distributions derived for the whole study area are presented in this section. The estimates of precipitation and unadjusted recharge were generated first, followed by an adjustment of the recharge distribution in Spring Valley to account for infiltration from surface water.

Table 4-6
Precipitation-Altitude Equation for Other Nevada Hydrographic Areas

HA	Name	Symbol	Slope (a)	Intercept (b)
184	Spring Valley	Spring	0.000323	1.272571
179	Steptoe Valley	Steptoe	0.000317	1.275214
195	Big Snake Valley	Snake	0.000172	0.192449
178B	Butte Valley (Southern Part)	Butte S.	0.000159	0.206377
207	White River Valley	White R.	0.000341	1.380143

Precipitation (ft) = Slope (a) x Altitude (ft) - Intercept (b)

The estimates of precipitation and unadjusted recharge used are compared to the reported values (Table 4-7). The precipitation distribution was generated using the DEM grid and the precipitation-altitude equations described in the previous sections, a precipitation grid was developed for the whole study area. The corresponding map is presented in Figure 4-2. The derived estimates for the individual basins are presented in Table 4-7, which also includes a comparison to the reported values. As can be seen, the differences are significant for some of the basins. This is deemed acceptable considering the main objective of this exercise, which is matching the reported recharge estimates for basin located within the model area. The unadjusted recharge grid for the study area was then generated following the methodology described in Section 3.0. Estimates of precipitation recharge for the basins of the study area were derived from this grid and compared to the reported values (Table 4-7).

The precipitation recharge volume for Spring Valley was then adjusted from 75,000 afy to 65,000 afy to redistribute the difference, 10,000 afy, to the higher parts of the alluvial apron as described by Rush and Kazmi (1965). The adjustment was achieved by multiplying each grid cell by the ratio 65/75. The 10,000 afy of re-distributed recharge is assumed to infiltrate from perennial streams located on the alluvial apron and described in Section 4.5 and in the Water Resources Assessment for Spring Valley (SNWA, 2006). The corresponding recharge map is shown in Figure 4-3. As can be seen from this table, the recharge estimates derived from the distributions generated in this study match the reported values very well; however, the match for the basins containing the buffer area is not as close. Furthermore, the authors do not imply in any way that the recharge distributions generated for basins located in Utah are representative of recharge distributions reported in Utah reconnaissance reports.

One must keep in mind that the precipitation map and the recharge distributions for the basins containing the model buffer area are only intermediary products and should not be used for any other purpose. They are presented here only to document the steps taken to generate a recharge distribution for the numerical flow model.

Table 4-7
Comparison of Derived Recharge and Reported Recharge for HAs in the Study Area

Valley Name	HA	Reconnaissance Reports		Scott et al., 1971		Derived in This Study	
		Precipitation (afy)	Recharge (afy)	Precipitation (afy)	Recharge (afy)	Precipitation (afy)	Recharge (afy)
Basins Located Within Model Area							
Cave Valley	180	225,800	14,000	220,000	14,000	215,823	13,380
Dry Lake Valley	181	>118,000	5,000	340,000	5,000	287,273	4,476
Lake Valley	183	293,000	13,000	290,000	13,000	289,880	12,668
Tippett Valley	185	160,000	6,900	160,000	6,900	172,014	6,953
Pleasant Valley	194						
Snake Valley	195	2,000,000	100,000	894,000[a]	70,800[a]	2,055,647	100,051
Hamlin Valley	196						
Spring Valley	184	960,000	75,000	960,000	75,000	973,154	75,074
Steptoe Valley	179	1,200,000	85,000	1,200,000	85,000	1,178,805	85,069
Basins Containing the Buffer Area							
Butte Valley (Southern Part)	178B	420,000	15,000	420,000	15,000[a]	412,630	15,002
Jakes Valley	174	N/A	17,000	240,000	17,000[a]	268,206	16,733
White River Valley	207	N/A	38,000	750,000	38,000[a]	752,653	37,999
Antelope Valley (Southern Part)	186A	58,000	1,500	58,000	1,500	58,250	1,373
Antelope Valley (Northern Part)	186B	120,000	3,200	120,000	3,200	127,574	3,255
Goshute Valley	187	N/A	10,400	440,000	11,000	420,199	10,773
Butte Valley (Northern Part)	178A	140,000	3,900	14,000	3,900	145,078	6,910
Dry Valley	198						
Rose Valley	199						
Eagle Valley	200	670,000	8,000	723,100	7,000	451,469	6,634
Panaca Valley	203						
Clover Valley	204						
Lower Meadow Valley Wash	205						
Spring Valley	201	178,000	10,000	180,000	10,000	176,216	10,324
Patterson Valley	202	194,000	6,000	190,000	6,000	193,994	5,443
Pahroc Valley	208	>57,000	2,200	190,000	2,200	165,433	1,860
Deep Creek Valley	253	290,000	17,000	N/A	N/A	206,163	10,331
Pine Valley	255	410,000	21,000	N/A	N/A	355,018	14,475
Wah Wah Valley	256	290,000	7,000	N/A	N/A	225,146	6,127
Tule Valley	257	400,000	7,600	N/A	N/A	266,475	5,534
Fish Springs Flat	258	232,000	4,000	N/A	N/A	123,760	883
Great Salt Lake Desert (West Part)	261A	200,000	4,800	N/A	N/A	473,720	4,785
Beryl-enterprise Area	280	1,200,000	48,000	N/A	N/A	781,311	14,266

[a]Precipitation and recharge were reported on Nevada side only.

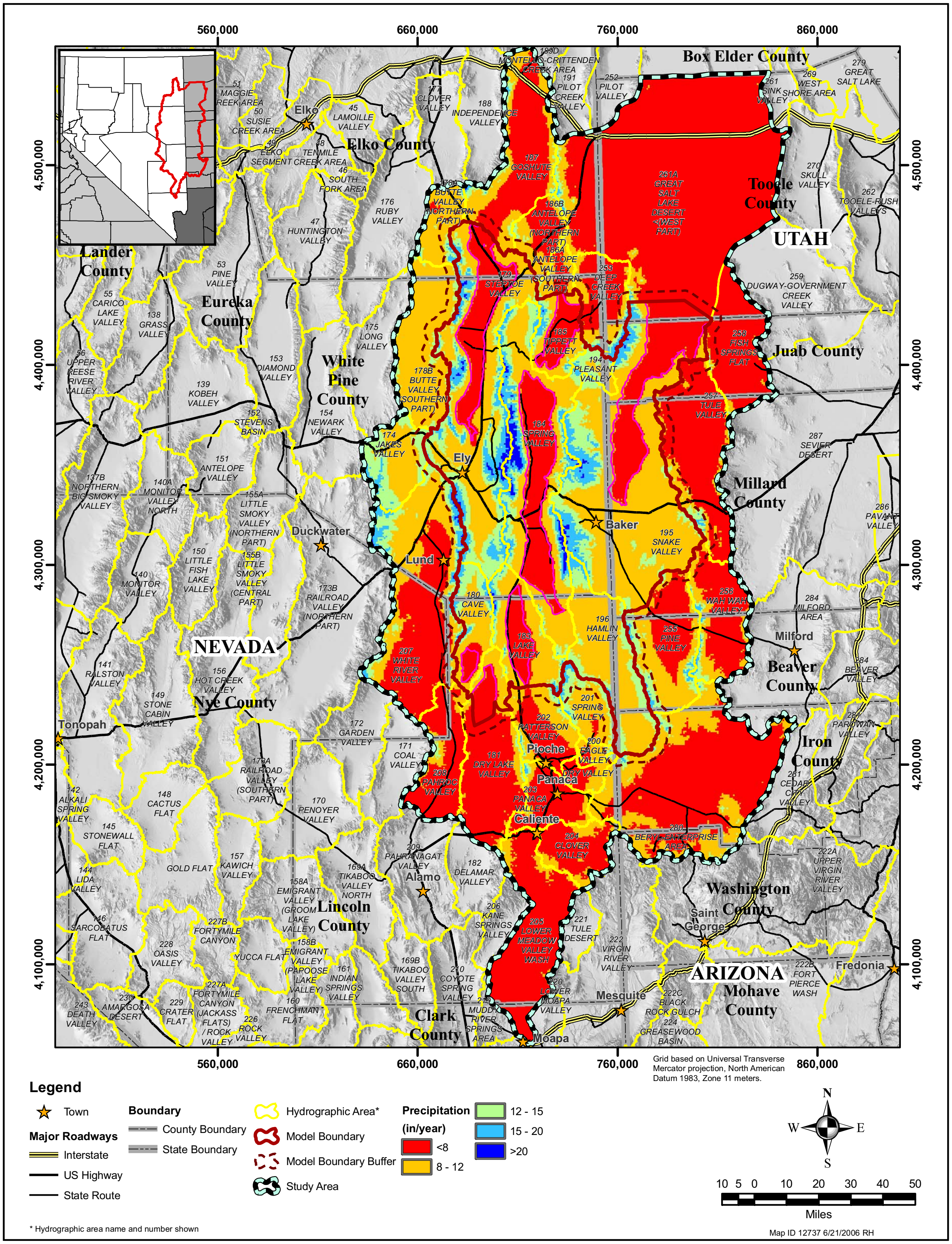

Figure 4-2
Distribution of Precipitation in the Study Area

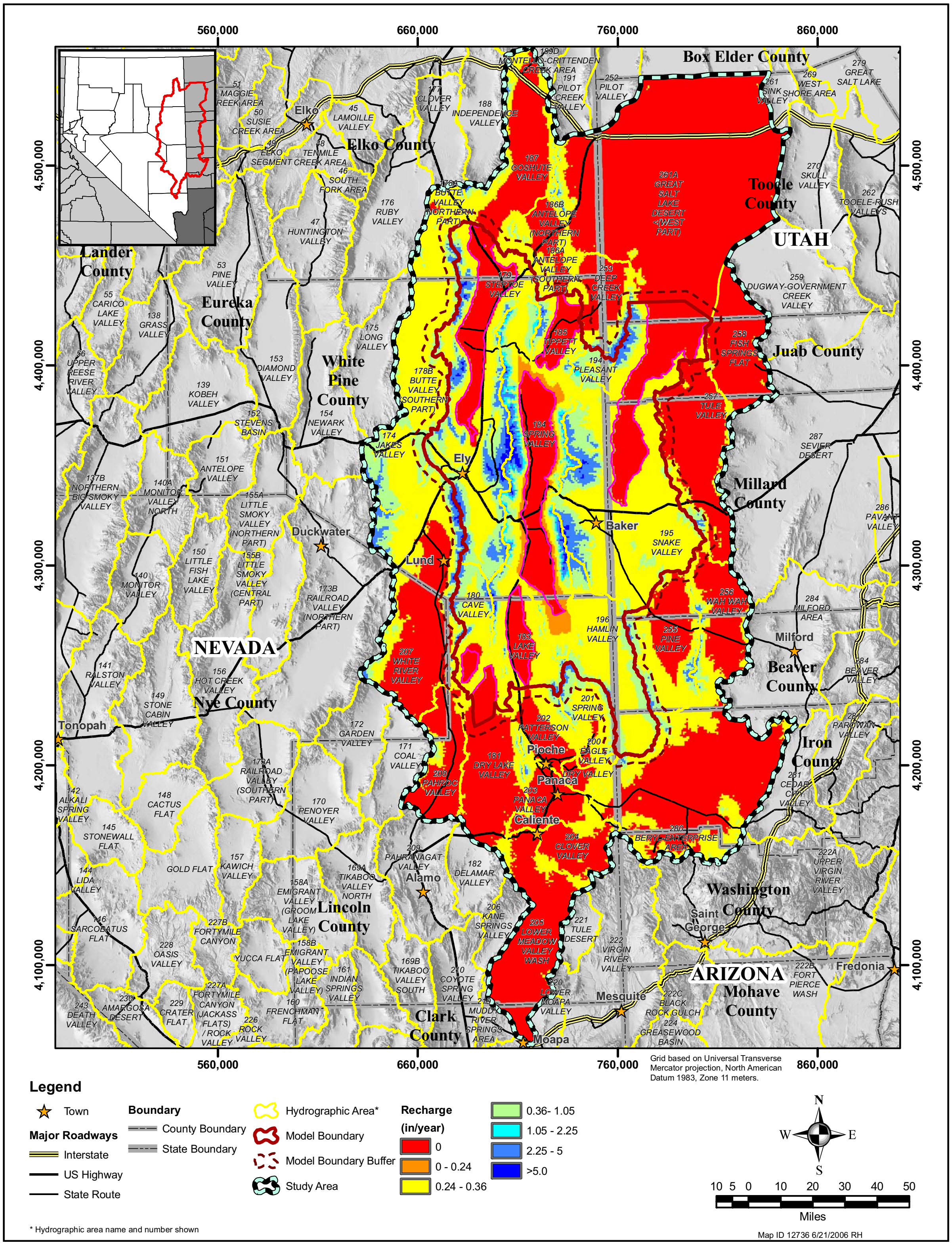

Figure 4-3
Distribution of Precipitation Recharge in the Study Area

4.5 Distribution of Groundwater Recharge From Surface Water

Except for two basins located in the model area, all other basins have estimated recharges that are based only on Maxey-Eakin with no attempt of spatial re-allocation or mention of additional recharge from surface water. The exceptions are Spring Valley and Big Snake Valley.

Spring Valley is an exception for two reasons. First, Spring Valley is the focus of this study because it is the subject of the water-right hearings. Second, Rush and Kazmi (1965) reallocated 10,000 afy of the Maxey-Eakin recharge to the alluvial apron. Third, Rush and Kazmi (1965) estimated the perennial yield for this valley differently than for the other valleys in the model area. The perennial yield for Spring Valley includes a component of surface water that could be captured by strategically placed production wells (Rush and Kazmi, 1965). These special circumstances require a more detailed representation of the recharge and surface water features of Spring Valley. Thus, additional details should include the perennial streams that occur on the alluvial apron, along which the 10,000 afy of the re-allocated Maxey-Eakin recharge is interpreted to infiltrate. The streams on Spring Valley are described in the Water Resources Assessment for Spring Valley Report (SNWA, 2006).

For Big Snake Valley, Reconnaissance Report 34 (Hood and Rush, 1965, p. 22) indicates that 2,700 afy of additional recharge could occur on 270,000 acres of alluvium in Hamlin Valley (Hood and Rush, 1965). The alluvium falls into altitude range of 6,000 to 7,000 ft and is at the end of the Big Spring Wash, so the 2,700 afy recharge mentioned in Reconnaissance Report 34 could be reasonably considered as the recharge occurring in the alluvial apron of this altitude zone. The total discharge of Big Spring Wash was reported as 7,000 afy, which is more than enough to justify the estimated 2,700 afy of recharge that was distributed along the alluvial apron. Thus, this additional recharge was assumed to enter the flow system along Big Spring Wash. The spatial distribution of the recharge points in Big Spring Wash are shown in Figure 4-4. The total rate of 2,700 afy was evenly distributed among the seven nodes representing the wash.

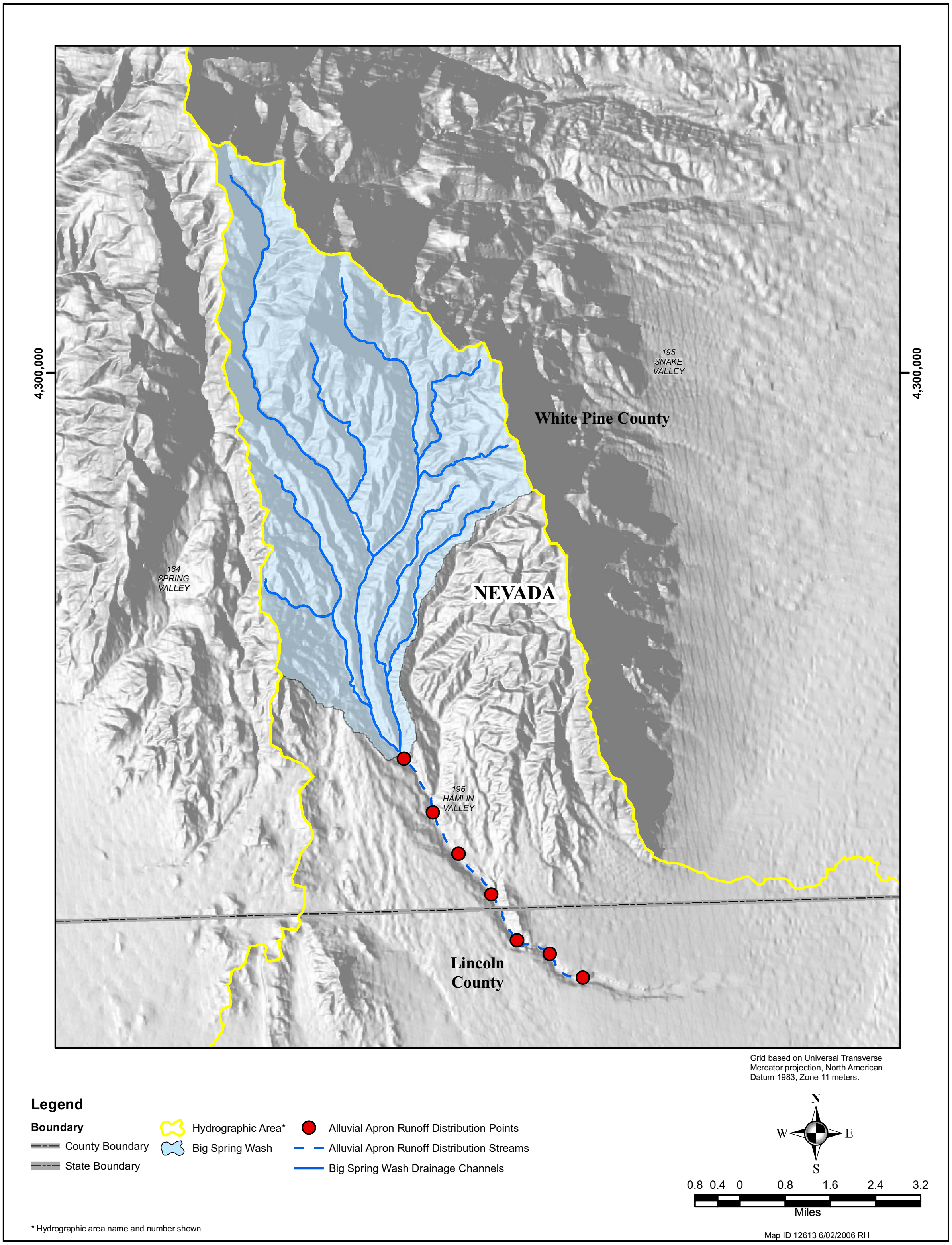

Figure 4-4
Potential Distribution of Recharge Occurring at Alluvial Apron in Hamlin Valley

5.0 AREAL RECHARGE DISTRIBUTION FOR MODEL

This section describes the spatial recharge distribution derived for the model and buffer areas from the analysis described in .Section 4.0.

5.1 Spatial Recharge Distribution for Model

The spatial precipitation distribution for the model and buffer areas was generated simply by clipping the map generated for the whole study area described in Section 4.0 (Figures 4-2). The spatial recharge distribution for the model and buffer areas includes three components: a Maxey-Eakin recharge distribution extracted from the map generated for the whole study area described in Section 4.0 (Figures 4-3), additional recharge by infiltration through streams in Spring Valley, and additional recharge on the alluvial apron of Hamlin Valley.

The resulting precipitation and recharge maps are shown in Figure 5-1 and Figure 5-2, respectively. The precipitation map, Figure 5-1, exhibits more precipitation at higher altitudes. These larger precipitation rates at higher altitude should correspond to larger recharge than the lower-altitude precipitation rates. An examination of the derived recharge map, Figure 5-2, shows that this statement is true. A comparison of the two maps also reveals that for areas of less than the 8-in. precipitation, the recharge is zero. These are indications that the recharge distribution presented in Figure 5-2 is consistent with the Maxey-Eakin method. In addition, a comparison of the recharge values derived from the spatial distribution and the reported recharge estimates is presented in Table 5-1. The absolute error between the total recharge derived and the recharge reported is less than 5 percent. This shows that the spatial distribution of recharge presented in Figure 5-2 is consistent with the estimates reported in the USGS Reconnaissance Reports (see Section 2.3).

Spring Valley and Big Snake Valley required some modifications to their spatial recharge distribution as explained in Section 4.0. Spring Valley required a spatial re-allocation of 10,000 afy of the Maxey-Eakin recharge to be redistributed to the alluvial basin. This recharge quantity will be simulated as infiltration through the streambeds of perennial streams located on the alluvial apron as described in the Water Resources Assessment for Spring Valley Report (SNWA, 2006). Additional recharge from surface water in Big Snake Valley occurs on the alluvial apron of Hamlin Valley. In this study, this recharge was directly applied to nodes located along Big Spring Wash as shown in Figure 4-4. The total rate of 2,700 afy was evenly distributed among the seven nodes representing the wash.

In summary, the spatial distribution of the derived recharge for the HAs in the model area represents the spatial distribution of the recharge reported in the Reconnaissance Reports, and the total derived recharge volume is consistent with the total recharge volume reported for most of these HAs. Thus,

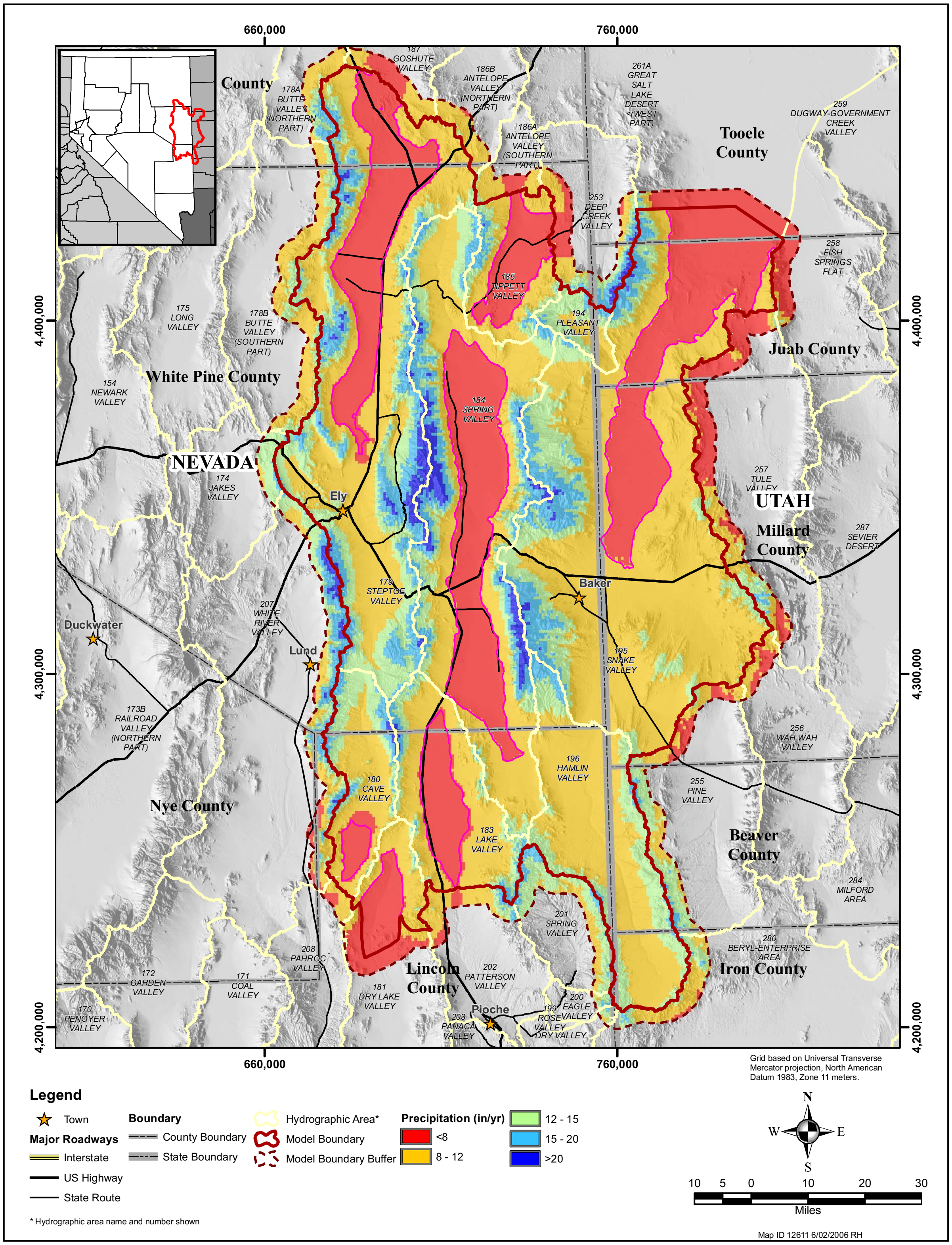

Figure 5-1
Spatial Distribution of Precipitation for the Model and Buffer Areas

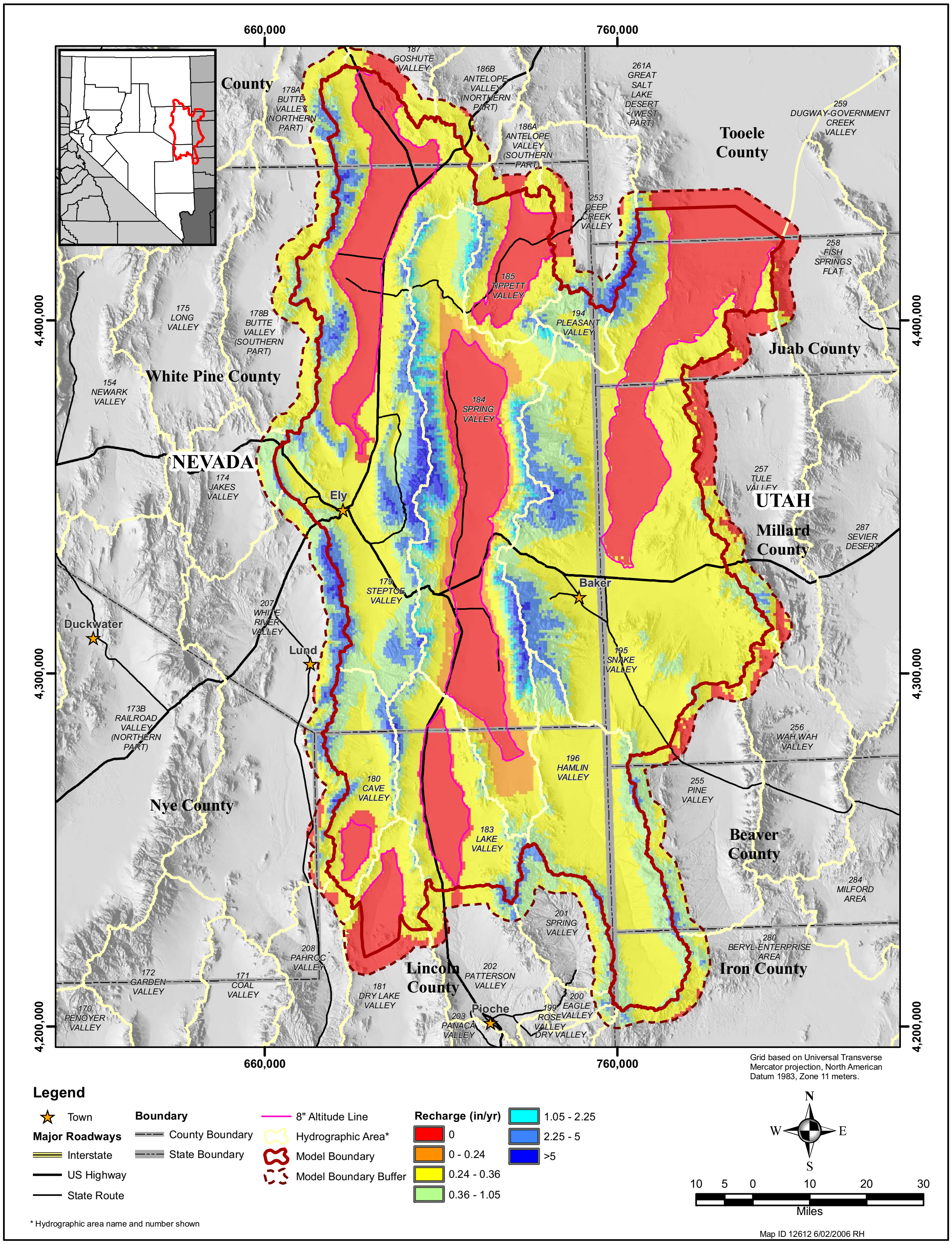

Figure 5-2
Spatial Distribution of Precipitation Recharge for the Model and Buffer Areas

Table 5-1
Comparison of Derived Recharge and Recharge Reported for HAs in Model Area

Valley Name	HA	Reconnaissance Recharge (afy)	Derived Recharge (afy)	Percent Difference
Cave Valley	180	14,000	13,380	-4
Dry Lake Valley	181	1,727[a]	1,727	0
Lake Valley	183	13,000	12,668	-3
Tippett Valley	185	6,900	6,953	1
Pleasant Valley	194	100,000	100,051	0
Snake Valley	195			
Hamlin Valley	196			
Spring Valley	184	65,000[b]	65,064[b]	0
Steptoe Valley	179	85,000	85,069	0
Total Recharge in Mountain Blocks		**285,627**	**284,912**	**0**
Recharge from Runoff		**12,700**	**12,700**	**0**
Total Recharge in Model Area		**298,327**	**297,612**	**0**

[a]This number is assumed because the model area only covers parts of this basin.
[b]This recharge only represents the recharge occurring in mountain blocks.

the spatial distribution of the derived recharge is adequate for preparing the input mesh for precipitation recharge to a groundwater flow model based on the water budgets reported in the Reconnaissance Reports.

5.2 Recharge Estimate Limitations

Although the process for deriving a physically realistic spatial distribution of recharge for some basins is somewhat complex, the resulting recharge distribution is an adequate spatial representation of the recharge estimates reported in the Reconnaissance Reports. The derived total recharge volumes for the basins of the model area are relatively well matched with their corresponding values in the Reconnaissance Reports. However, the derived precipitation map does not produce total well-matched precipitation volumes. This map should, therefore, not be used for any other purpose. The main cause of this discrepancy is the altitude data used to derive the precipitation estimates of this study. In the Reconnaissance Reports, precipitation zones were defined based on different versions of the Hardman Precipitation Maps. The areas of the precipitation zones were calculated in a simplified way that does not take into account the variation of altitude within a given zone. In contrast, the DEM data used in this study represent the actual topography of the basins, causing the altitudes to vary within a given precipitation zone. This causes the areas of the precipitation zones to be larger than those estimated in the Reconnaissance Reports. Larger area yields larger volumes of precipitation. In conclusion, although the methodology used in this study yields a precipitation distribution that does not match the reported precipitation volumes, the corresponding recharge distribution is consistent with the reported volumes of recharge.

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Attachment A

Spreadsheet Used to Derive Precipitation-Altitude Equations and Database Used to Calculate Recharge

A.1.0 INTRODUCTION

This attachment contains spreadsheets used for refining the precipitation-altitude equations for Spring Valley, Steptoe Valley, Big Snake Valley, Southern Butte Valley and White River Valley, and the database that was used to calculate recharge of points in each HA in the study area. The description of the attachment includes a summary of the data contents, the structure of the database, and directions on how to access the database.

A.2.0 DATA CONTENTS SUMMARY

This attachment consists of two parts. First part includes the five Excel spreadsheets "Butte_south.xls, Snake.xls, Spring_184.xls, Steptoe.xls, and White River.xls". Second part includes a Microsoft Access database that was used to calculate the recharge of points in each HA. The structure of the database is described in Section A.3.2. The precipitation-altitude equation table (Reconequ) in the database contains information on slope, intercept, acreages of a 800 m × 800 m grid cell, and their association of HA. The point data table "Nrsgridtemp" was extracted from DEM data. These two tables were used to form the main table "Recon" with a script called "Maketable". The "Recon" contains necessary information for calculating the Maxey-Eakin recharge for each point of each HA. This table contains 400,753 records for 32 different HAs.

A.3.0 IMPLEMENTATION

A.3.1 Derivation of Precipitation-Altitude Equations

1. The "Butte_south.xls" has derivation of the precipitation-altitude equation for Southern Butte Valley (HA 178B). This spreadsheet includes 2,993 rows and 11 columns. The cell B1 represents slope of the precipitation-altitude equation, and cell B2 represents intercept of the precipitation-altitude equation. "UTM_X", "UTM_Y", and "UTM_Z" represent Universal Transverse Mercator (UTM) North American Datum of 1983 (NAD83) coordinates and the altitude of a center of 800 m × 800 m grid cells that were extracted and processed from 30-m DEM for Southern Butte Valley. Column "Symbol" represents symbol of the precipitation-altitude equation for Southern Butte Valley used in this study. Column "Precipitation_ft" = Slope × UTM_Z - Intercept; The "Area_Acres" represents acreages of a 800 m × 800 m grid cell. The "precipitation_in" = Precipitation_ft × 12. The "precipitation_afy" = Precipitation_ft × Area_acres. The "Rech_efficiency" was assigned following the standard Maxey-Eakin recharge efficiency based on "precipitation_in". The "Recharge_afy" =

Precipitation_afy × Rech_efficiency. The sum of the recharge for all points in Southern Butte Valley should be the total recharge of this basin. Because the altitude of all points is fixed, the only variables to determine the total recharge are slope and intercept. There are two unknown variables in one equation, so this equation doesn't have unique solutions for slope and intercept. However, the total basin recharge here is the recharge reported in Reconnaissance Report 49, and altitude of each point in the basin is fixed, so the solutions of slope and intercept are very limited. If a constrain of the precipitation at 7,000 ft of altitude less than 11 in. is placed, the solutions of the equation will be very limited. In this study, the solutions of 0.000159 and 0.206377 were derived, which matches the total recharge reported and the precipitation at 7,000 ft of altitude.

2. The "Steptoe.xls" has derivation of the precipitation-altitude equation for Steptoe Valley (HA 179). This spreadsheet includes 7,893 rows and 11 columns. The cell B1 represents slope of the precipitation-altitude equation, and cell B2 represents intercept of the precipitation-altitude equation. "UTM_X", "UTM_Y", and "UTM_Z" represent UTM (NAD83) coordinates and the altitude of a center of 800 m × 800 m grid cells that were extracted and processed from 30-m DEM for Steptoe Valley. Column "Symbol" represents symbol of the precipitation-altitude equation for Steptoe Valley used in this study. Column "Precipitation_ft" = Slope × UTM_Z - Intercept. The "Area_Acres" represents acreages of a 800 m × 800 m grid cell. The "precipitation_in" = Precipitation_ft × 12. The "precipitation_afy" = Precipitation_ft × Area_acres. The "Rech_efficiency" was assigned following the standard Maxey-Eakin recharge efficiency based on "precipitation_in". The "Recharge_afy" = Precipitation_afy × Rech_efficiency. The sum of the recharge for all points in Steptoe Valley should be the total recharge of this basin. Because the altitude of all points is fixed, the only variables to determine the total recharge are slope and intercept. There are two unknown variables in one equation, so this equation doesn't have unique solutions for slope and intercept. However, the total basin recharge here is the recharge reported in Reconnaissance Report 42, and altitude of each point in the basin is fixed, so the solutions of slope and intercept are very limited. If a constrain of the precipitation at 6,000 ft of altitude less than 8 in. is placed, the solutions of the equation will be very limited. In this study, the solutions of 0.000317 and 1.275214 were derived, which matches the total recharge and the precipitation approximately at 6,000 ft of altitude reported in Reconnaissance Report 42.

3. The "Spring_184.xls" has derivation of the precipitation-altitude equation for Spring Valley (HA 184). This spreadsheet includes 6,755 rows and 11 columns. The cell B1 represents slope of the precipitation-altitude equation, and cell B2 represents intercept of the precipitation-altitude equation. "UTM_X", "UTM_Y", and "UTM_Z" represent UTM (NAD83) coordinates and the altitude of a center of 800 m × 800 m grid cells that were extracted and processed from 30-m DEM for Spring Valley. Column "Symbol" represents symbol of the precipitation-altitude equation for Spring Valley used in this study. Column "Precipitation_ft" = Slope × UTM_Z - Intercept. The "Area_Acres" represents acreages of a 800 m × 800 m grid cell. The "precipitation_in" = Precipitation_ft × 12. The "precipitation_afy" = Precipitation_ft × Area_acres. The "Rech_efficiency" was assigned following the standard Maxey-Eakin recharge efficiency based on "precipitation_in". The "Recharge_afy" = Precipitation_afy × Rech_efficiency. The sum of the recharge for all points in Spring Valley should be the total recharge of this basin. Because the altitude of all points is fixed, the only variables to determine

the total recharge are slope and intercept. There are two unknown variables in one equation, so this equation doesn't have unique solutions for slope and intercept. However, the total basin recharge here is the recharge reported in Reconnaissance Report 33, and altitude of each point in the basin is fixed, so the solutions of slope and intercept are very limited. If a constrain of the precipitation at 6,000 ft of altitude less than 8 in. is placed, the solutions of the equation will be very limited. In this study, the solutions of 0.000323 and 1.272571 were derived, which matches the total recharge and the precipitation at 6,000 ft of altitude reported in Reconnaissance Report 33.

4. The "Snake.xls" has derivation of the precipitation-altitude equation for Big Snake Valley (HAs 194, 195, and 196). This spreadsheet includes 14,894 rows and 11 columns. The cell B1 represents slope of the precipitation-altitude equation, and cell B2 represents intercept of the precipitation-altitude equation. "UTM_X", "UTM_Y, and "UTM_Z" represent UTM (NAD83) coordinates and the altitude of a center of 800 m × 800 m grid cells that were extracted and processed from 30-m DEM for Big Snake Valley. Column "Symbol" represents symbol of the precipitation-altitude equation for Big Snake Valley used in this study. Column "Precipitation_ft" = Slope × UTM_Z - Intercept. The "Area_Acres" represents acreages of a 800 m × 800 m grid cell. The "precipitation_in" = Precipitation_ft × 12. The "precipitation_afy" = Precipitation_ft × Area_acres. The "Rech_efficiency" was assigned following the standard Maxey-Eakin recharge efficiency based on "precipitation_in". The "Recharge_afy" = Precipitation_afy × Rech_efficiency. The sum of the recharge for all points in Big Snake Valley should be the total recharge of this basin. Because the altitude of all points is fixed, the only variables to determine the total recharge are slope and intercept. There are two unknown variables in one equation, so this equation doesn't have unique solutions for slope and intercept. However, the total basin recharge here is the recharge reported in Reconnaissance Report 34 (Hood and Rush, 1965), and altitude of each point in the basin is fixed, so the solutions of slope and intercept are very limited. If a constrain of the precipitation at 5,000 ft of altitude less than 8 in. is placed, the solutions of the equation will be very limited. In this study, the solutions of 0.000172 and 1.92449 were derived, which matches the total recharge and the precipitation at 5,000 ft of altitude reported in Reconnaissance Report 34.

5. The "White River.xls" has derivation of the precipitation-altitude equation for White River Valley (HA 207). This spreadsheet includes 6,418 rows and 11 columns. The cell B1 represents slope of the precipitation-altitude equation, and cell B2 represents intercept of the precipitation-altitude equation. "UTM_X", "UTM_Y", and "UTM_Z" represent UTM (NAD83) coordinates and the altitude of a center of 800 m × 800 m grid cells that were extracted and processed from 30-m DEM for White River Valley. Column "Symbol" represents symbol of the precipitation-altitude equation for White River Valley used in this study. Column "Precipitation_ft" = Slope × UTM_Z - Intercept. The "Area_Acres" represents acreages of a 800 m × 800 m grid cell. The "precipitation_in" = Precipitation_ft × 12. The "precipitation_afy"= Precipitation_ft × Area_acres. The "Rech_efficiency" was assigned following the standard Maxey-Eakin recharge efficiency based on "precipitation_in". The "Recharge_afy" = Precipitation_afy × Rech_efficiency. The sum of the recharge for all points in White River Valley should be the total recharge of this basin. Because the altitude of all points is fixed, the only variables to determine the total recharge are slope and intercept. There are two unknown variables in one equation, so

this equation doesn't have unique solutions for slope and intercept. However, the total basin recharge here is the recharge reported in Reconnaissance Report No. 33 (Rush and Kazmi, 1965) and altitude of each point in the basin is fixed, so the solutions of slope and intercept are very limited. If a constrain of the precipitation at 6,000 ft of altitude less than 8 in. is placed, the solutions of the equation will be very limited. In this study, the solutions of 0.000341 and 1.380143 were derived, which matches the total recharge and the precipitation at 6,000 ft of altitude reported in Reconnaissance Report No. 33 (Rush and Kazmi, 1965).

A.3.2 Calculation of Recharge for Points in Each Basin

The recharge calculation database has been constructed using Microsoft® Access 2000. The database contains five primary data tables and four scripts. The primary tables include:

- Nrsgridtemp - Extracted points from the 800 m DEM. These points have UTM (NAD 83) coordinates (meters) and altitude (ft). The points cover much large area than the study area.
- Reconequ - Hydrographic areas with their slope and intercept of precipitation-altitude equations. The slope and intercept here are derived from the spreadsheets described in Section A.3.1 and Section 4.2.2.
- Recon - This table was formed by combining Tables "Nrsgridtemp" and "Reconequ" with the script "Maketable."
- Basin_totals - This table is summed the recharge for all points by HA with the script "Sum."

A.3.3 Scripts Used in the Database

- Maketable - SQL script "SELECT [Nrsgridtemp].[HA], [Nrsgridtemp].[UTM_X], [Nrsgridtemp].[UTM_Y], [Nrsgridtemp].[UTM_Z], [reconequ].[Equl], [reconequ].[slopl], [reconequ].[interceptl], [reconequ].playamin, [reconequ].[Area] INTO [Local]FROM Nrsgridtemp INNER JOIN reconequ ON [Nrsgridtemp].[HA]=[reconequ].[HA];"
- Precip - SQL script "UPDATE Recon SET Recon.precip_ft = IIf(([Recon]![UTM_Z]*[Recon]![slopl]-[Recon]![interceptl])<0,0,([Recon]![UTM_Z]*[Recon]![slopl]-[Recon]![interceptl])), Recon.precip_in = [Recon]![precip_ft]*12, Recon.precip_afy = [Recon]![precip_ft]*[Recon]![Area];". This script was used to calculate precipitation depth in inches, feet, and afy with the derived precipitation-altitude equations;
- Recharge - SQL script " UPDATE Recon SET Recon.rech_eff = IIf([Recon]![precip_in]>20,0.25,IIf([Recon]![precip_in]>15 And [Recon]![precip_in]<=20,0.15,IIf([Recon]![precip_in]>12 And [Recon]![precip_in]<=15,0.07,IIf([Recon]![precip_in]>=8 And [Recon]![precip_in]<=12,0.03,0)))), Recon.recharge_in = [Recon]![precip_in]*[Recon]![rech_eff], Recon.recharge_afy =

[Recon]![precip_afy]*[Recon]![rech_eff];”. This script was used to calculate recharge efficiency and recharge;

- Sum - SQL script “INSERT INTO Basin_Totals (HA, Area, precip_afy, rech_afy) SELECT Recon.HA, Sum(Recon.Area) AS SumOfArea, Sum(Recon.precip_afy) AS SumOfprecip_afy, Sum(Recon.recharge_afy) AS SumOfrecharge_afy FROM Recon GROUP BY Recon.HA.” This script was used to sum the area, precipitation, and recharge by basin in Table “Recon”.

A.4.0 ACCESS TO DATA IN ATTACHMENT

The spreadsheets in this attachment can be opened on the CD-ROM with Microsoft Excel 2000 or later version. The recharge dataset may be accessed on the CD-ROM as a Microsoft Access 2002 database.

Access:

- Recharge_recon_studyarea.mdb

Excel spreadsheets

- Butte_south.xls
- Snake.xls
- Spring_184.xls
- Steptoe.xls
- White River.xls

A.5.0 REFERENCES

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