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QUANTITATIVE EVALUATION OF A METHOD FOR ESTIMATING RECHARGE TO THE DESERT BASINS OF NEVADA

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ABSTRACT

Watson, Ph., Sinclair, P. and Waggoner, R., 1976. Quantitative evaluation of a method for estimating recharge to the desert basins of Nevada. J. Hydrol., 31: 335—357.

This paper investigates the Maxey-Eakin method for estimating recharge to groundwater basins in Nevada, the objective being to determine whether or not a statistically rational basis exists for its use. The major assumption of this study is that the groundwater discharge within a basin can be equated to the groundwater recharge (i.e., hydrologic equilibrium exists).

Within the first 58 reports of the Nevada *Ground-Water Resources — Reconnaissance Series*, there are a total of 212 hydrologic basins represented. However, because of certain inadequacies, data from only 63 basins could be used in this study.

Multiple-linear regression was used as the closest approximation to the techniques of Maxey and Eakin. Simple-linear regressions were also used to generate six predictive equations which are similar in principle to Maxey and Eakin's method. It is clear from the variability of the coefficients of the seven predictive equations, including Maxey and Eakin's, that none of them can be used to reliably predict recharge. However, they can be used as first approximations of recharge.

INTRODUCTION

The purpose of this paper is to investigate the Maxey-Eakin method for estimating recharge to groundwater basins to see whether or not a statistically rational basis exists for its use. A secondary objective is to examine the possibility of improving upon this method.

The study area is the State of Nevada which lies within the physiographic province of the Great Basin. The Great Basin can be defined as that portion of the Basin and Range province which is characterized by the lack of drainage to the ocean. The area is quite arid, the mean annual precipitation being approximately 8 in. (203 mm). There are few major perennial streams and rivers, thus groundwater plays a significant role in water supply.

Nearly all water supply available to the Great Basin is derived from precipitation within the region and from existing groundwater in storage. Additional

water supplies for Nevada include runoff from the Sierra Nevada Mountains and water imported from the Colorado River.

Part of the precipitation that falls upon the closed basins of Nevada recharges the state's many groundwater basins. The remainder of the precipitation either directly evaporates or becomes surface runoff. The surface runoff is used for agricultural irrigation and other purposes. Ultimately, nearly all of the precipitation is discharged within the state by evapotranspiration. A small part of the precipitation in the peripheral region of the state is discharged to the Colorado and Snake rivers as surface and subsurface outflows.

The increasing urbanization and agricultural development of Nevada has increased the demand on all sources of supply, especially groundwater. Development has sharply increased the need for information on the volumes of groundwater in storage and the rates of natural recharge. Availability of such information is necessary to allow rational planning for further development consistent with the available water supplies. Overdevelopment, i.e., pumping more groundwater than is recharged, can result in lowering the water table to the point where it is uneconomical to pump the water to the surface for some uses. Other possible undesirable effects can include: saline-water intrusion from playas to adjacent wells when the hydraulic gradient is from the playa to the wells, similar contamination from other sources, and land subsidence caused by reduction of pore-water pressure in fine-grained sediments.

An attempt was made to meet the need for information on groundwater recharge in the State of Nevada by Eakin, Maxey and others between 1947 and 1951. The method they developed for estimating recharge is hereafter referred to as the Maxey-Eakin method and is described on p. 339.

The Maxey-Eakin method has been used by the U.S. Geological Survey in its cooperative program with the State of Nevada, Department of Conservation and Natural Resources in preparation of their *Ground-Water Resources — Reconnaissance Series* reports. The goals of the report series are to develop preliminary water-budget estimates and determine the quantity of available water supplies for all the valleys in the state. To date, 212 valleys have been described in 58 reports as shown in Fig.1.

Now that the *Reconnaissance Series* have been largely completed, there is a body of information with which the Maxey-Eakin method can be examined.

PRESENT METHODS OF RECHARGE ESTIMATION

The process of estimating recharge to a basin is at best approximate due to the large numbers of variables that influence this phenomenon. Groundwater recharge can be defined as the volume of water entering the groundwater system over some period of time. The period of time is often taken as a year, and an average of several-years data is generally used to minimize seasonal and yearly fluctuations. The principal methods used for estimating recharge are described below. They include the Maxey-Eakin method, and variations of a general water budget, including application to influent—effluent streams, zones of aeration, well fields and infiltration using lysimeters.

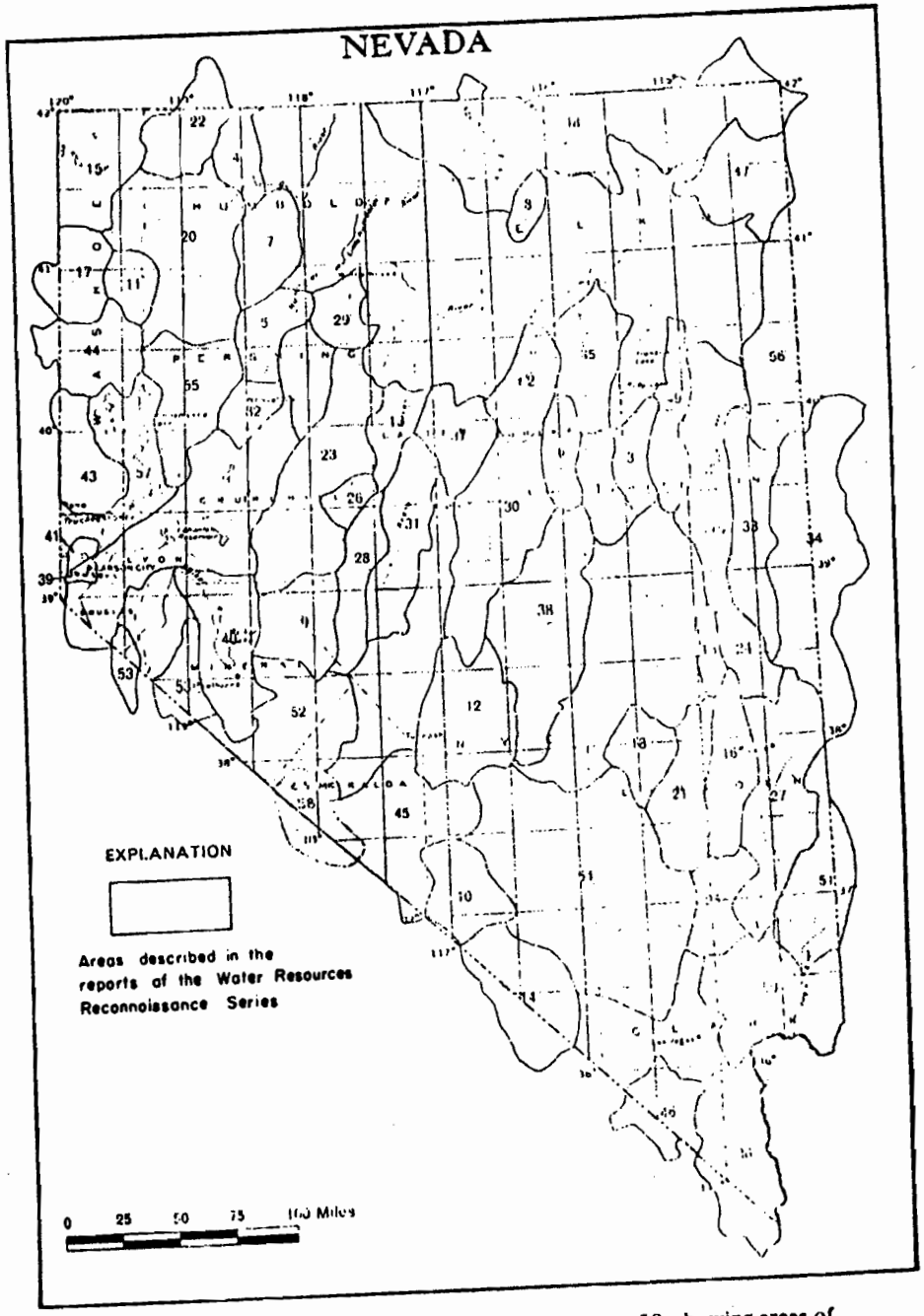


Fig.1. Index map adapted from *Reconnaissance Series* Report 58, showing areas of Nevada described in Reports 1—58 of the *Water Resources Reconnaissance Series*.

Water budget

The water budget involves an accounting of all inflows and outflows from a specific area. However, due to the inherent difficulty in collecting the necessary data for all components, application of a total water budget is generally not practical. The total water budget requires that all surface-water inflows and outflows, inter-basin groundwater inflows and outflows, changes in groundwater storage, precipitation, evapotranspiration (by native plants and agriculture), pumpage and evaporation from surface-water bodies be accounted for. If all of the above components are known, then it is possible to use this budget to determine recharge as a residual. The principal problem with this method is that only three of the seven components are directly observable (i.e., surface-water flows, precipitation, and pumpage). The processes used in estimating the remaining four components are all indirect and as such their accuracies are difficult to verify. As an example of estimating inter-basin groundwater flow, a commonly used procedure is to calculate the product of transmissivity (T) (i.e., hydraulic conductivity (K) and thickness (M), where $KM = T$), gradient of the head (I) and cross-sectional width (W). Except where estimates of T and I are available from well data, their values are assumed. Even 'observable' precipitation is suspect. Rain-gauge readings may not be representative of the actual basin-wide precipitation over an area, particularly where the relief is extreme.

Influent—effluent streams

The water-budget approach has been applied to streams. In the case of an influent stream (i.e., water passing from the stream to the groundwater system) it is possible to measure or calculate inflows, outflow and losses by evapotranspiration from the stream to determine the infiltration. This would be a prediction of recharge for that specific area, providing there is no inter-basin groundwater inflow.

In the case of the effluent stream (i.e., water passing from the groundwater system to a stream) hydrograph separation is perhaps the most widely used method for calculating recharge. Unfortunately, it only applies to perennially flowing streams, which are scarce in the arid regions. In theory, following a storm, or season of storms, a stream will carry water from the following sources: runoff from the land surface, interflow and naturally discharging groundwater (base flow). When the first two components have ceased to supply water to the stream, only the groundwater component remains. By separating this component from the others in the streamflow hydrograph, it is possible to calculate the total groundwater outflow (Domenico, 1972, pp. 48–52). If there is no inter-basin transfer of groundwater, then this base flow should be equal to the recharge. The simplicity of this method has lead to its wide use. It also has appeal because streamflow is a 'measurable' quantity. It should be noted, however, that hydrograph separation methods are approximate and empirical.

Zone of aeration

It is possible to estimate recharge through a water budget of the zone of aeration (i.e., the soil zone lying between the ground surface and the water table). The estimation involves the volume of water falling on an area, surface runoff, and the amount of water removed from the zone of aeration by evapotranspiration. The difference is the recharge.

Infiltration using lysimeters

Infiltration studies use lysimeters to measure the change in water content of the vadose zone throughout the year. This is measured at various levels from the land surface to below the root zone. With this information and an estimate of vertical permeability, it is possible to calculate the recharge. The primary problems with this method are the assumed permeability value, its variation in three-dimensional space and time, and the estimation of evapotranspiration.

Well fields

In a well field, water-level fluctuations can be used in recharge estimations. Two methods are used in this regard, both of which depend on a water budget and knowledge of the distribution of effective permeability within the well fields.

The first method uses the hydrograph data in conjunction with the effective permeability, to calculate the change in the volume of storage. This value plus natural discharge and pumpage equals recharge.

The second method measures the natural discharge and pumpage when there is no net change in water level (i.e., no change in storage). This is set equal to recharge.

Maxey-Eakin method

The method of recharge estimation used in the *Ground-Water Resources Reconnaissance Series* by the State of Nevada, Department of Conservation and Natural Resources was developed by Maxey and Eakin between 1947 and 1951.

In the Maxey-Eakin method, the recharge to a groundwater basin is calculated from specific percentages of the precipitation which is estimated to fall upon several elevation zones in the mountains surrounding that groundwater basin. In *Water Resources Bulletin No. 6*, Maxey and Robinson (1947, p.17) stated that possibly 20% of the total precipitation between the elevations of 6,000 and 8,000 ft. (1,829–2,438 m) recharges the groundwater reservoirs. The next reference in print concerning the philosophy and development of the method is in *Bulletin No. 8* of the same series (Maxey and

Eakin, 1949, p.40). In this document Maxey and Eakin constructed the system using the zones of assumed equal rainfall shown on Hardman's (1936) precipitation map of Nevada (see Table I and Fig.2). On this map (Fig.2) are shown zones of precipitation of less than 5 in. (127 mm), 5—8 in. (127—203 mm), 8—12 in. (203—305 mm), 12—15 in. (305—381 mm), 15—20 in. (381—490 mm), and more than 20 in. (490 mm). The first two zones were combined by Maxey and Eakin into a single less than 8-in. (203-mm) zone. The five zones are transferred from Hardman's map from which the area of each zone is determined by planimeter. The product of the area of each zone (in acres) and the mean of the precipitation range (in feet) gives the total volume

TABLE I

The Hardman zones used in this report

Hardman zones	Maxey-Eakin recharge (%)
> 20 in. (490 mm)	25
15—20 in. (381—490 mm)	15
12—15 in. (305—381 mm)	7
8—12 in. (203—305 mm)	3
< 8 in. (203 mm)	0

TABLE II

Drainage basins in Nevada used in the development of the Maxey-Eakin equation for estimating groundwater recharge

Antelope Valley[c]	Kawich Valley[c]
Big Smoky Valley[d]	Las Vegas Valley[a]
Buena Vista Valley[d]	Pahrump Valley[a]
Clover Valley[d]	Paradise Valley[d]
Diamond Valley[d]	Penoyer Valley[c]
Fish Lake Valley[d]	Railroad Valley[c]
Grass Valley[d]	Reveille Valley[c]
Goshute Valley[c]	Ruby Valley[c]
Hot Creek Valley[d]	Spring Valley[d]
Independence Valley[c]	White River Valley[b]
Indian Spring Valley[b]	

[a] Maxey and Robinson (1947).
[b] Maxey and Eakin (1949).
[c] Eakin et al. (1951).
[d] G.B. Maxey, personal communication (1974).

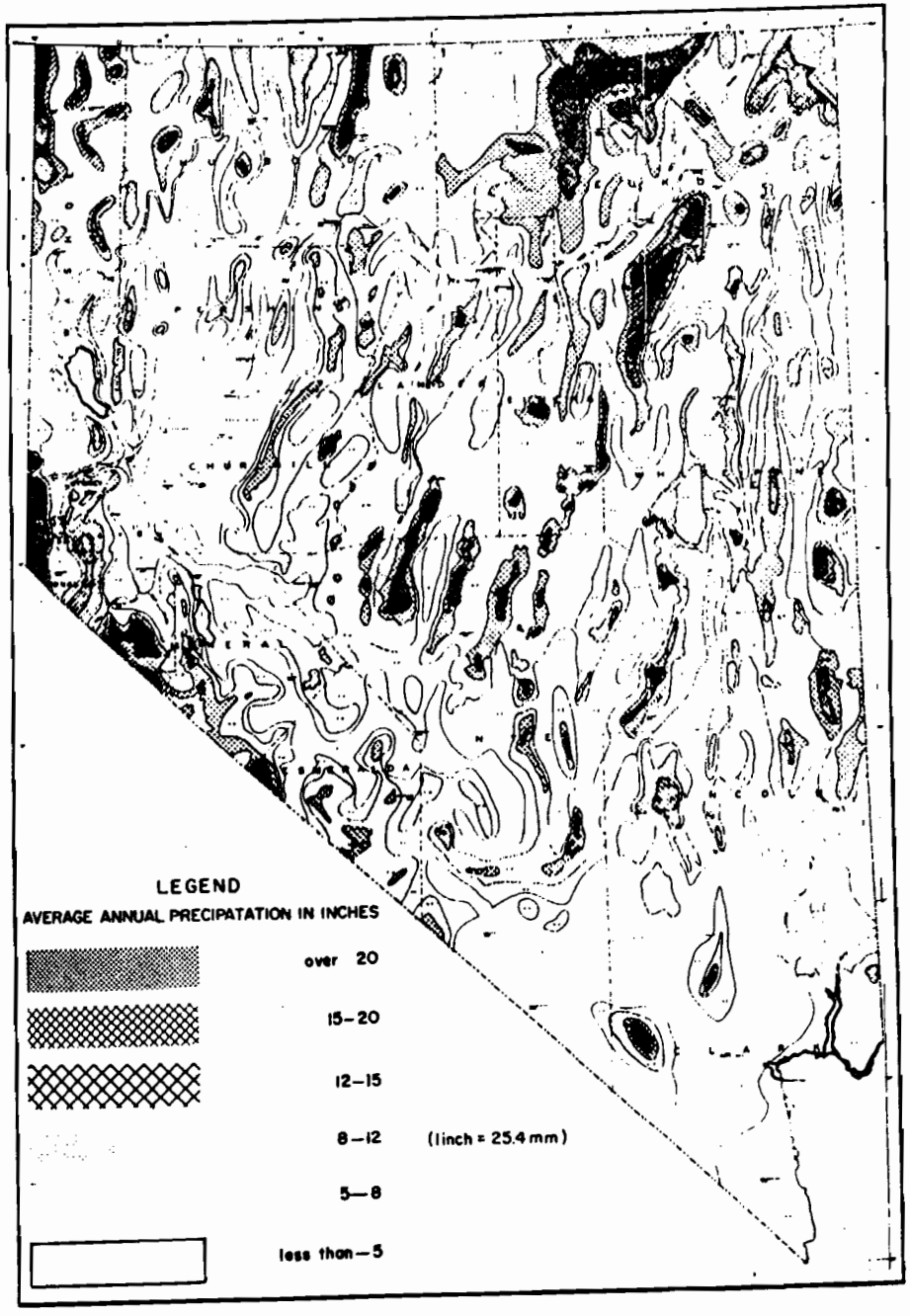


Fig.2. Precipitation map of Nevada from Hardman (1936), showing areas of assumed equal rainfall.

of precipitation in that zone (in acre·ft./year). Without explanation, the authors of *Bulletin No. 8* stated: "... the amount of water from the successive zones that reach the groundwater reservoir is estimated as 0, 3, 7, 15 and 25 percent of the precipiation in the respective zones" (Maxey and Eakin, 1949, p.40). A total of 21 valleys (Table II) were used in the development of the percentages (G.B. Maxey, personal communication, 1974). Assuming that the valleys were in a state of hydrologic equilibrium: "... recharge percentages were then balanced by trial and error with the estimated discharge" (Maxey and Eakin, 1949, pp. 40—41).

NATURE OF THE DATA

Definitions

Discharge, as used in this study, refers to water moving out of a valley due to natural or man-induced processes. Groundwater discharge was estimated from pumpage, evapotranspiration, springflow, streamflow, groundwater outflow as determined by the TIW method (see p.338), and evaporation from lakes, playas and streams, but *not* as a residual in a water budget.

Recharge, as used in this study, is the volume of water that infiltrates through the consolidated and unconsolidated rocks to the water table. This is the quantity that this paper attemtps to estimate. The term potential recharge has been used in the *Reconnaissance Series* reports as the volume recharge predicted by the Maxey-Eakin method. This volume could be realized by lowering near-surface water tables through pumping.

In this study, the areas with high water tables were not used in the analyses. It was felt that the observed groundwater discharge would not correlate with the precipitation, due to insufficient infiltration. However, for estimation purposes the results of this study can still be applied to basins with high water tables to give a value of potential recharge.

Assumptions

The major assumption of this study is that the groundwater discharge within a basin can be equated to the groundwater recharge. In other words, the basin is in hydrologic equilibrium and there are no long-term changes in groundwater storage. The predictive equations derived relate discharge to precipitation in each zone and, therefore, only give values of discharge. Under the equilibrium assumption for all basins used in this study, discharge can then be related to recharge.

It is likely that several of the valleys used in this study are not in equilibrium since agricultural development was taking place while the *Reconnaissance Series* reports were being prepared. This problem adds an indeterminate error to the predictive equations.

Reasons for rejection

Within the present 58 reports of the Nevada *Ground-Water Resources Reconnaissance Series*, there are a total of 212 subareas or hydrologic basins. However, because of problems such as inhomogeneity of data, incomplete descriptions of methodology used in developing hydrologic estimates, and other related problems, only about a third of the data could be used in this study. The basic criteria for rejection of subareas or basins are as follows.

(1) The Hardman zones were not developed or were inconsistent with those used in this study. [25*]

(2) Discharges of subareas with standard Hardman zones could not be separated from discharges of subareas in (1) above. [5]

(3) 37 subareas within six major groundwater basins could not be used individually because their lumped discharge was given only for those six basins. [31]

(4) Discharge only given as 'minor' (i.e., no numerical value or zero). [2]

(5) The water table or capillary fringe was thought by the *Reconnaissance Series*' authors to be too close to the ground surface to allow for significant infiltration. As such they did not apply the Maxey-Eakin system to these areas. [3]

(6) The value if discharge is set equal to the value of recharge as computed by the Maxey-Eakin method (i.e., difference method). Computing discharge as a residual in a water budget does not yield independent recharge—discharge information. However, considering the accuracy of the original data from the series reports, it has been arbitrarily decided to allow 10% or less of total discharge to be computed by the difference method. This allowed two additional valleys to be used in the computations. The difference between the recharge and discharge estimates is usually ascribed to inter-basin groundwater flow. [50]

(7) Comparison of the predicted value of recharge derived from the Maxey-Eakin method to the value of discharge indicates three cases where there is at least an order of magnitude difference between the values. The difference probably represents groundwater inflow or outflow that cannot be quantitatively determined. As such, they were excluded from the calculations because they would grossly bias results of the regressions. [3]

(8) Evaporation from playas, which is either unreliable or not estimated. [4]

(9) Groundwater inflow or outflow, which is known to exist but was not estimated. [6]

(10) No method of determination given for large fractions of discharge. [1]

(11) Precipitation was thought by the *Reconnaissance Series*' authors to be less than the Hardman zones indicate. They chose to adjust the Maxey-Eakin percentages rather than the Hardman zones. [1]

*Number in square brackets gives total number of subareas rejected for the stated reasons.

(12) Subsurface inflow determined by an independent model (not explained) in an adjoining valley. [1]

(13) Discharge that is supported by surface water and groundwater but cannot be subdivided into those two components. This is often the result of artificial recharge by agricultural ditches. [10]

(14) Valleys that were reported on twice in the *Ground-Water Reconnaissance Series* reports. [7]

Thus from the total of 212 valleys, only 63 could be used in the subsequent regressions. Table A-I (Appendix p.351) contains a 'reason for rejection' column. The numbers listed, correspond to those fourteen above.

METHODOLOGY

The basic aim of this paper is to examine the statistical validity of the Maxey-Eakin system for estimating recharge. For this purpose, multiple-linear regression is used as the technique that most clearly approximates the trial-and error methods of Maxey and Eakin.

A second aim of this paper is to develop new predictive equations for estimating recharge through the use of simple-linear regressions.

Multiple-linear regression

The multiple-linear regression model involves a least-squares estimation for the coefficients of an equation of the form:

$$Y = b_0 + \sum_{n=1}^{5} b_i X_i \qquad (1)$$

where Y is the dependent variable (discharge); X_i are the independent variables; b_i are coefficients for each independent variable X_i and give the amount of change in Y for a unit change in the respective X_i; and b_0 is the intercept on the Y-axis.

The multiple-linear regression technique is not an exact duplicate of the method used by Maxey and Eakin. The principal difference is in the treatment of those cases where zeros exist in some zones, but not in others. If, for example, the range of elevation within the basin dictates zeros (i.e., non-existent precipitation zones), for the greater than 20-in. (490 mm) and less than 8-in. (203 mm) zones, while the other three zones have non-zero data, Maxey and Eakin would ignore these zeros in determining the b coefficients (eq.1). However, the multiple-linear regression technique considers those zeros as real values of the independent variables. Thus, zeros affect the equation of the regression. No method has been found to remove their influence.

Simple-linear regressions

In an attempt to develop additional predictive equations, simple-linear regressions of each independent variable to the dependent variable were run. Only the non-zero data from the set of 63 was used. Thus the number of observations varies with each zone (Table IV, see p.346).

Another predictive equation was developed by summing all the zones, and the total is regressed against discharge using a simple-linear regression. Since the sum does not contain zeros, all 63 observations were used (Table IV).

Intercepts

When using simple or multiple-linear regression routines, the best fit generally is obtained by allowing the routine to choose its own intercept on the dependent axis. If the data are such that a non-zero intercept is statistically significant, then a regression of the same data with a forced zero intercept will be biased. Unfortunately in this situation under study it is physically unrealistic to have a non-zero intercept because this would imply that discharge was occurring without precipitation.

Discharge without precipitation can occur as a result of inter-basin groundwater inflow, but the purpose of this study is to identify local precipitation—discharge—recharge relationships. To accomplish this, the recognized inter-basin flow was removed from the groundwater discharge value or the valley was rejected altogether.

In the case of the simple-linear regressions the non-zero intercept may occur as a result of the influence of the other four zones (variables) being ignored.

DISCUSSION OF RESULTS

The following discussion is limited to regressions with zero intercepts for the reasons discussed above. The coefficients and the 95% confidence limits for the multiple-linear regressions, simple-linear regressions, and total precipitation models are presented in Tables III and IV.

The 95% confidence limits are the square root of the variance times the t statistic at a 5% level of significance. This is only an approximation, because the residuals are not normally distributed.

Examination of Maxey-Eakin and multiple-linear regression methods

The results in Table III indicate that the multiple-linear regression coefficients are highly variable. This indicates the regressions are highly dependent upon the included data. To estimate discharge it is essential to have an equation that is a reliable predictor. However, the multiple-linear regression developed here is only satisfactory as a general approximation of the discharge. The Maxey-Eakin method was developed from less data than is included in this study. Since their coefficients are similar to those shown in Table III, it seems reasonable that their equation has no greater ability to predict than the

TABLE III

Results of multiple-linear regressions showing variability of the coefficients; 63 observations

Precipitation zones (in.)*	Coefficients (%)	95% confidence intervals (%)
> 20	24	± 15
15–20	19	± 16
12–15	1	± 6
8–12	4	± 2
< 8	0	± 1

*1 in. = 25.4 mm.

one developed here; however, it is possible that their equation may have greater stability, because they ignored the zeros.

Simple-linear regression estimates

Since the multiple-linear regression system does not seem to have much predictive value, the use of simple-linear regressions were also investigated. The linear regressions (Table IV) show a somewhat more stable set of regression coefficients. The coefficients are more stable, but not so stable that they can necessarily be used as reliable predictive equations. Obviously the coefficients for the less than 8-in. zone are very unreliable. This could reflect the fact that most discharge takes place in this zone, thus preventing recharge. Alternately the lack of recharge could be explained by the small amount of precipitation over great depths of unsaturated alluvium.

TABLE IV

Results of simple-linear regressions showing variability of the coefficients

Precipitation zones (in.)*	Number of observations	Coefficients (%)	95% confidence intervals (%)
> 20	23	63	± 14
15–20	44	36	± 5
12–15	57	15	± 2
8–12	63	9	± 2
< 8	51	3.4	± 2.2
Total precipitation	63	3.4	± 0.6

*1 in. = 25.4 mm.

CONCLUSIONS

Examination of the multiple-linear regressions shown in Table III suggests the regression coefficients may be an alternative to the present Maxey-Eakin coefficients. The greater number of observations in that set imply that it could generate a more reliable equation than Maxey and Eakin's. However, due to the variability of the coefficients shown in Table III, the predictive capability of the Maxey-Eakin equation as well as the multiple-linear regression equation derived in this paper are suspect. As such, we do not recommend the indiscriminate use of either set of coefficients for estimating recharge. It is apparent from Table III that neither of these predictive equations can be used as anything more than a first approximation to recharge.

A comparison of the coefficients shown in Tables III and IV would suggest better predictive capability of the simple-linear regression over the multiple-linear regression. This may be the result of the multiple-linear regression model being too complex for the quality of the data. The simpler models are all that these data can support.

The simple-linear regressions can be interpreted as a correlation between precipitation in a single zone and the total groundwater discharge from the valley. There can be no hydrologic interpretation of the results. The inference is that some percentage of the precipitation in that zone has the same value as the discharge for the entire valley.

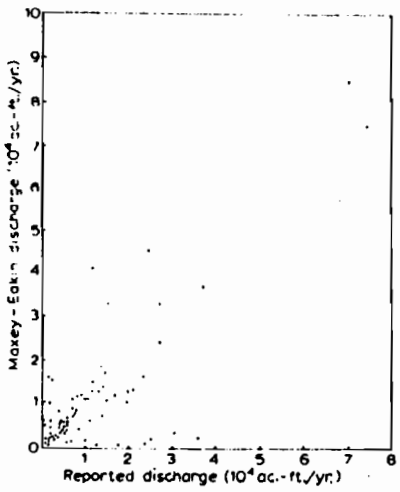
An advantage of the simple-linear regression is that they give six predictive equations. Multiplication of the precipitation for each zone, or the total of precipitation, by their respective coefficients gives up to six estimates of discharge for the valley under study. Thus, it is possible to cross-check the predicted value of discharge. However, caution must be exercised in applying these six simple-linear equations when small areas are encountered. The highest and the lowest zones in any particular valley must be treated with care. For example, unless there is sufficient area in the highest zone, the predicted value of discharge may be erroneously small. Similarly, extremely large areas in the lowest zone may give very large estimates of discharge. If these conditions exist, greater weight should be given to the central zones. Unfortunately, no criteria can be specified for judging what is too large or too small. It must be a subjective judgement made by the investigators involved.

These estimating systems fail in the case where only one zone in a valley exists. For instance, if only the greater than 20-in. zone exists in the valley under consideration, three recharge estimating equations apply: (1) the greater than 20-in. (490 mm) multiple-linear regression coefficient (24%); (2) the greater than 20-in. simple-linear regression coefficient (63%); and (3) the total precipitation coefficient (3.4%). There can be only one volume of precipitation for the valley which has to be multiplied by three different percentages, giving three widely varying estimates of discharge. When two zones exist a similar difficulty can be seen to influence the problem, but to a lesser degree. The subjective judgment of the investigators applying these equations has an important role in solving these problems.

Table A-I and Figs. 3—10 give the observed discharge (column 2), the predicted discharge by the Maxey-Eakin method (column 3) and the seven predictive equations described in this study. The scatter patterns clearly show the lack of accuracy in any of the predictive equations. A comparison of Figs. 3—10 suggest that the Maxey-Eakin method is slightly better than the others shown in this paper. However, this is not necessarily true because the Maxey-Eakin method was used in calculating some component of the reported discharge in 50 valleys (see reason 6, p. 343). This obviously reduces the scatter on Fig.3 only.

Local planning agencies and governing bodies with authority to make decisions regarding development which is dependent upon water availability should treat with skepticism developer's claims of greater water availability based on any form of recharge estimate. Accuracy of these estimates has been shown to be at best a few hundred to a few thousand acre—feet per year. Rational treatment of recharge estimates would dictate that they be 'rounded' off to the next lower thousand or half-thousand acre—feet per year. Any attempts to imply greater precision should be rejected as being unwarranted and misleading.

The authors of this paper feel that the basic approach taken in these estimating systems has utility since it is the only practical method available for



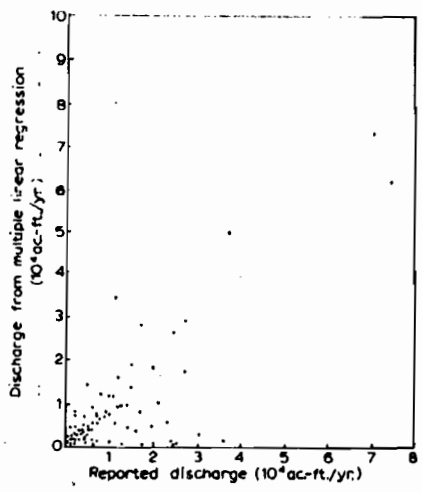
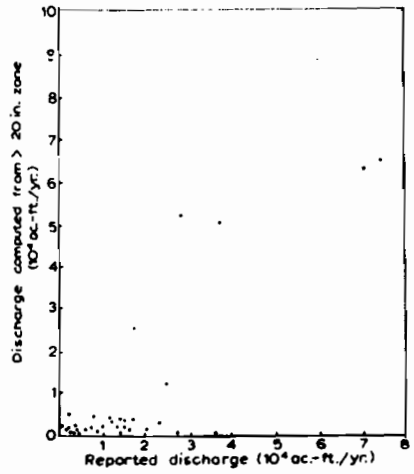


Fig.3. Scatter diagram of the reported discharge vs. the discharge computed by the Maxey-Eakin method, 139 points (1 acre·ft./year = 1,233 m³/year).

Fig.4. Scatter diagram of the reported discharge vs. computed discharge from multiple-linear regression, 139 points (1 acre·ft./year = 1,233 m³/year).



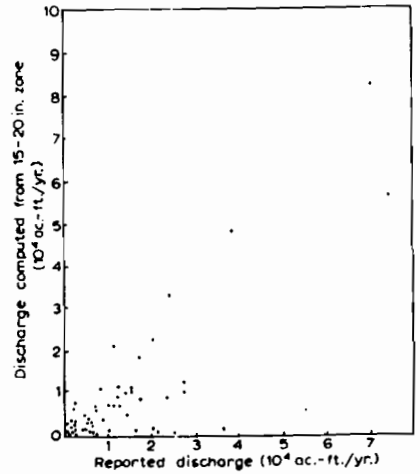


Fig.5. Scatter diagram of the reported discharge vs. discharge computed by simple-linear regression from the greater than 20-in. (490 mm) zone, 44 points (1 acre·ft./year = 1,233 m³/year).

Fig.6. Scatter diagram of the reported discharge vs. discharge computed by simple-linear regression from the 15—20-in. (381—490 mm) zone, 89 points (1 acre·ft./year = 1,233 m³/year).

Nevada. Unfortunately, it does not take into account the many variables that influence recharge. The geologic and hydrologic characteristics of the consolidated and unconsolidated rocks, antecedent moisture, and vegetation very strongly affect the rate of recharge. Until these parameters, as well as many others, are investigated and incorporated quantitatively into an equation(s), little improvement can be made.

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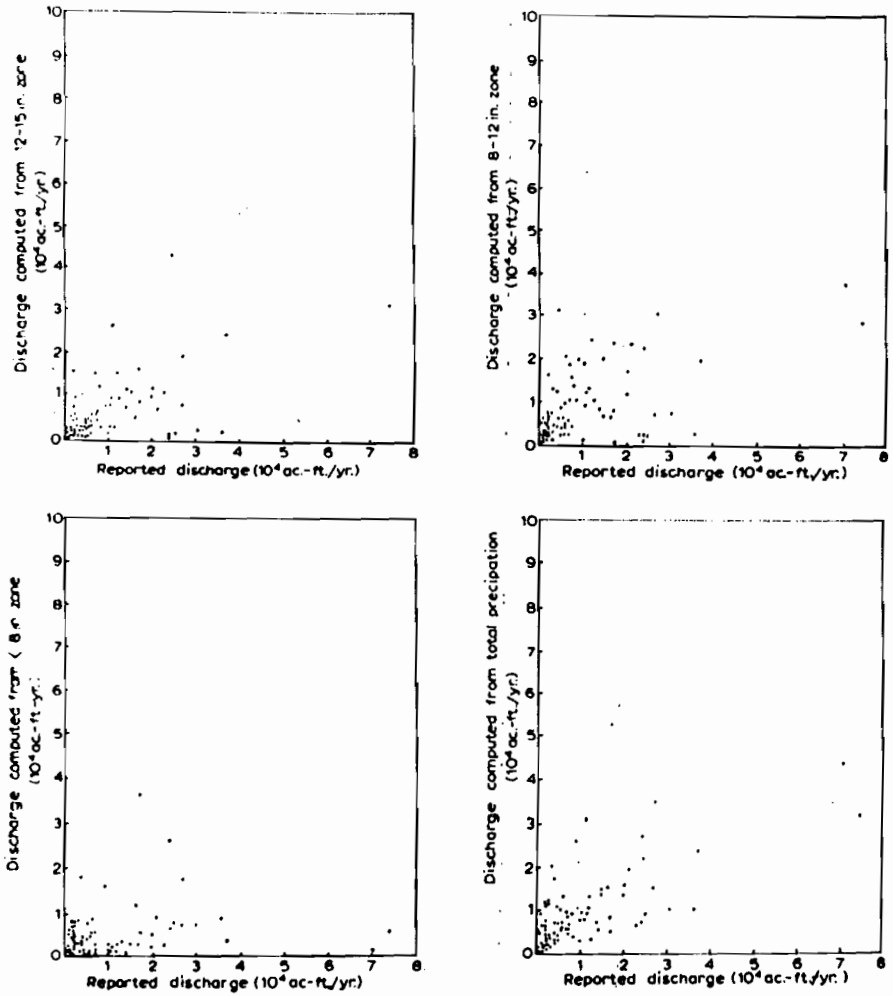

Fig.7. Scatter diagram of the reported discharge vs. discharge computed by simple-linear regression from the 12—15-in. (305—381-mm) zone, 130 points (1 acre·ft./year = 1,233 m^3/year).

Fig.8. Scatter diagram of the reported discharge vs. discharge computed by simple-linear regression from the 8—12-in. (203—305-mm) zone, 143 points (1 acre·ft./year = 1,233 m^3/year).

Fig.9. Scatter diagram of the reported discharge vs. discharge computed by simple-linear regression from the less than 8-in. (203-mm) zone, 120 points (1 acre·ft./year = 1,233 m^3/year).

Fig.10. Scatter daigram of the reported discharge vs. discharge computed by simple-linear regression from the total of precipitation model, 143 points (1 acre·ft./year = 1,233 m^3/year).

APPENDIX — TABLE A-I

Comparison of observed and computed groundwater discharge (recharge) for 212 valleys reported in the State of Nevada *Water Resources Reconnaissance Series* (acre·ft./year; 1 acre·ft./year = 1,233 m^3/year)

Report Number	Location Name	Reason for Rejection	Reported Discharge	Maxey-Eakin Discharge/Recharge	Discharge/Recharge Computed by Multiple-Linear Regression	Greater Than 20 inch (490mm) Zone	15-20 inch (381-490mm) Zone	12-15 inch (305-381mm) Zone	8-12 inch (203-305mm) Zone	Less than 8 inch (203mm) Zone	Total Precipitation
		1	2	3	4	5	6	7	8	9	10
						Discharge (Recharge) computed by simple-linear regression					
1	NEWARK	8	14440	17500	13281	3307	9986	11760	19497	2550	13957
2	PINE		24400	45500	26922	12159	33480	43050	22185	0	22246
3	LONG	6	10000	10000	6537	0	2880	15450	16182	1598	11695
4	PINE FOREST		15000	10000	4441	0	1800	9900	10952	2210	8908
5	IMLAY	10	5400	3800	3337	0	2517	3007	4715	7750	10550
6	DIAMOND	8	23000	16300	5857	3739	8928	10590	2114	2516	6766
7	DESERT		900	5000	4248	0	3600	3000	6030	6120	9020
8	INDEPENDENCE	1			0	0	0	0	0	0	0
9	GARBS		4700	5200	12453	0	0	3360	31407	4760	17796
10A	SARCOPATUS		7000	1200	1210	0	540	1800	2252	5100	6375
10B	OASIS	1			0	0	0	0	0	0	0
11	HUALAPAI FLAT		5200	4000	1813	0	2736	4755	2036	802	2934
12A	RALSTON	9	2550	16000	3158	0	756	4350	7308	8160	12073
12B	STONECAPIN	9	2025	16000	3135	0	1620	4200	6177	8500	12019
13	CAVE	6	14000	14000	9048	3859	10249	11592	8232	493	7514
14	AMARGOSA DESERT	7	24000	1500	931	0	0	1515	693	26690	27304
15A	LONG	9	11000	6000	4859	0	0	3300	12702	2455	8167

APPENDIX — TABLE A-I (*continued*)

		1	2	3	4	5	6	7	8	9	10
15B	MASSACRE LAKE		4500	3500	2135	0	0	2955	5959	116	3114
15C	MOSQUITO	9	1600	700	412	0	0	270	1087	51	537
15D	BOULDER	6	2030	2000	1058	0	0	2130	3149	126	1839
15E	SURPRISE (NV)	6	1500	1500	812	0	0	1500	2392	0	1275
15F	COLEMAN (NV)	6	1000	1000	811	0	0	525	2123	0	949
15G	GUANO (NV)	6	7500	7500	5663	0	0	6620	15225	0	6997
16A	DRY LAKE	6	5000	5000	4263	720	1692	2535	8230	7514	11511
16B	CELAMAR	6	1000	1000	1057	0	0	675	2532	3536	4678
17A	DUCK LAKE		7500	9000	6873	0	0	5544	18259	1176	5573
17B	SURPRISE (NV)	5	700	500	433	0	0	269	1069	189	667
18A	GARDEN	6	10000	10000	8139	5644	7884	5681	5855	3563	7725
18B	COAL	6	2000	2000	2017	0	216	1125	4698	3723	5834
19A	ANTELOPE		7000	11000	6563	1213	6307	14952	10547	714	8884
19B	MIDDLE PRESS R.		17000	7000	4673	518	4895	7785	6558	507	5315
20	BLACK ROCK DES.	9	11700	41100	32737	0	21024	26280	59247	0	31096
20A	S. DF W.R. RE	3	NO	2000	2275	0	0	0	5655	0	2310
20B	JACKSON MTS.	3	NO	3400	2334	0	2052	2775	3958	0	2370
20C	PINE FOREST RAN.	3	NO	3500	2615	0	3560	2645	1575	0	1754
20D	E. SIDE R.R.D.	3	NO	5000	2513	0	4464	5045	1035	0	2576
20E	W. ARM R.R.D.	3	NO	8000	3513	0	4464	8570	5081	0	4440
20F	GRANITE BASIN	3	NO	2000	1272	0	576	1695	2837	0	1544
20G	HIGH ROCK LAKE	3	NO	17000	15225	0	0	0	37845	0	14790
20H	SUMMIT LAKE	3	NO	4200	2435	0	5504	4110	0	0	1452
21A	FAHRANAGAT	14	25700	1900	1233	0	263	1480	2671	7803	9252
21B	PAHROC	6	2200	2200	1812	0	324	1410	4045	4471	6402
22A	VIRGIN		6500	7500	5653	0	0	0	20010	0	7820
22B	GRIDLEY LAKE		2000	6700	4231	0	3204	1575	6829	0	3729
22C	CONTINENTAL LAKE		15500	11000	10911	0	7272	3450	13357	1020	9663
22D	PUEBLO	6	2200	2000	973	0	0	2190	2932	286	1928
23A	DIXIE		16000	6000	7669	1701	1116	5475	6429	11535	15487
23B	JERSEY		700	500	534	0	250	577	1031	1337	1910
23C	PLEASANT		2000	7000	5572	1597	1236	1580	2453	2261	3799
23D	FAIRVIEW	6	0	100	393	0	0	255	1236	2877	3437
23E	EASTGATE		500	6100	4415	2820	2585	7190	5272	2746	5645
24	LAKE		11000	12000	9447	4410	6637	8306	12472	1587	9671
25	COYOTE & KANE SP	7	2600	2600	2017	364	1332	2190	2601	4953	10525
26	EDWARDS CREEK		7300	5000	5334	7014	6038	6210	4253	3784	6772
27	MEADOW	6	27000	24000	16977	264	10430	18900	30731	13047	35430
27A	SPRING	3	0	10000	2500	0	1540	11035	7331	0	5726
27B	PATTERSON	3	NO	6000	4736	164	2844	4000	8874	1934	6591
27C	REMAINDER	3	NO	8000	7461	384	2376	7990	16416	16049	22772

		1	2	3	4	5	6	7	8	9	10
28A	SMITH CREEK		8500	12000	11930	4851	11098	12045	13659	0	9377
28B	IONE		4000	6000	7545	1651	5832	10520	12190	0	7807
29	GRASS	0	16025	12000	8350	3843	8568	8865	7877	3570	8677
30A	MONITOR (S)	1			0	0	0	0	0	0	0
30B	MONITOR (N)	1			0	0	0	0	0	0	0
30C	ANTELOPE	1			0	0	0	0	0	0	0
30D	KOEEN		15000	11000	18138	2331	11523	11100	30450	0	15630
30E	STEVENS BASIN	1			0	0	0	0	0	0	0
31	UPPER PRESS R.	11	37000	36700	49730	49612	48355	24192	19053	3669	23867
32A	UPPER LOVELOCK		34000	1200	1279	0	0	510	2690	6222	7385
32B	OREANA SUBAREA		1400	2000	1631	1008	1536	1008	1035	680	1541
33	SPRING		74100	75000	52563	54990	56150	35900	28352	3814	32708
34	SNAKE	1			0	0	0	0	0	0	0
35A	HUNTINGTON CREEK	5	NO	NO	192177	49644	303120	31200	15921	0	44601
35B	SOUTH FORK	5	NO	NO	16821	36936	5400	2010	1135	0	3342
35C	DIXIE CREEK	5	NO	NO	8914	5514	5056	9950	12615	0	7987
36A	ELDORADO	5	1100	1100	1350	0	0	300	3543	5100	6758
36B	PIUTE	6	1700	1700	2111	0	0	120	4735	6120	6017
36C	COLORADO RIVER	6	200	200	330	0	0	0	535	5740	5977
37A	GRASS		12700	13000	9072	3720	9000	9300	10440	2856	10030
37B	CARICO LAKE		4700	4200	2775	567	1692	3750	4872	2516	5460
38A	LITTLE FISH LAKE		10700	11000	7454	2646	7200	8700	8613	1564	7725
38B	HOT CREEK		6100	7000	4835	0	2484	5400	9570	9160	13359
38C	LITTLE SMOKY (N)		6100	4000	3059	0	1080	3150	6612	4420	7820
38D	LITTLE SMOKY (S)	9	2700	1400	1330	0	15	540	3132	5440	6788
39A	CARSON RANGE	1			0	0	0	0	0	0	0
39B	VIRGINIA RANGE	2	NO	200	130	0	0	165	365	0	180
40A	WHISKY FLAT		4900	5400	3531	1308	3960	4200	4099	4080	7058
40B	LAKE SUBAREA	13	800	600	114	0	0	0	174	1750	1428
40C	SCHURZ SUBAREA	13	17200	500	334	0	0	510	696	7100	5488
40D	RAWHIDE FLATS		900	150	232	0	0	0	415	2340	2550
41A	CARSON RANGE	1			0	0	0	0	0	0	0
41B	VIRGINIA RANGE	2	40	1000	33	0	396	1800	0	0	445
41C	VALLEY FLOOR	2	40	1100	-243	0	0	2400	0	0	544
42	STEPTOE		70000	85000	74937	67000	82800	80472	37838	1000	45247
43A	HONEY LAKE		10250	1900	1573	0	1260	1155	1131	2108	2931
43B	NEWCOMB LAKE		140	300	237	0	265	210	217	0	158
43C	DRY		2800	2400	1603	0	2304	2100	1479	239	1510
43D	RED ROCK		1070	900	373	0	756	690	87	150	411
43E	BRDELL		240	1100	770	0	223	840	1827	41	966
43F	ANTELOPE	6	300	300	301	0	32	105	731	0	312

APPENDIX — TABLE A-1 (*continued*)

		1	2	3	4	5	6	7	8	9	10
43G	WARM SPRINGS		2025	6000	4643	0	6450	4500	4176	1020	4284
43H	COLD SPRINGS		150	900	491	0	468	660	1044	0	602
43I	LEMON		1500	1900	1636	0	976	370	7443	173	1649
43J	SPANISH SPRINGS	13	1100	600	523	0	156	745	1131	476	1312
43K	SUN		227	50	53	0	0	0	167	71	133
43L	LONG	6	700	700	435	0	792	585	155	9	281
44A	SMOKE CREEK DES.		15900	17000	18778	1764	22650	11400	16770	5440	16721
44B	SAN EMIDIO DES.		3150	2100	1123	0	324	2250	2744	1938	3567
44C	PAINTERS FLAT		1200	1300	632	0	0	1780	1914	0	1051
44D	SAND		30	10	537	0	0	102	1475	68	669
44E	DRY	5	223	200	245	0	0	0	409	0	238
44F	PILGRIM	5	510	500	210	0	0	51	437	253	471
44G	SKEDADDLE CREEK		11	407	3	0	0	0	11	102	106
45A	ORIENTAL WASH	5	700	300	232	0	0	330	565	1700	1589
45B	GRAPEVINE CANYON	6	20	50	91	0	0	27	77	1532	1658
45C	RALSTON	14			0	0	0	0	0	0	0
45D	STONECAPIN	14			1	0	0	0	0	0	0
45E	CLAYTON	6	6000	1500	1143	0	350	1155	2252	5100	6250
45F	ALKALI SPRING	6	400	100	209	0	0	0	244	7400	3495
45G	LICA	6	700	500	525	0	0	360	957	5440	5996
45H	STONEWALL		200	100	192	0	0	16	157	3740	3805
46A	MESQUITE	5	1500	1500	1014	67	540	1425	1757	4420	5484
46B	IVANPAH	5	1500	1000	1253	31	220	812	2437	6232	7914
46C	JEAN LAKE	5	100	100	35	0	0	76	148	1020	1095
46D	HIDDEN	4	MINOR	MINOR	12	0	0	0	0	374	374
47	THOUSAND SPRINGS		21900	12700	9553	0	853	7395	23751	8874	19913
47A	MERREL SIDING	7	NO	2600	1711	0	432	1125	3915	646	2472
47B	TOANO	3	NO	5000	4224	0	356	2850	10440	3740	8500
47C	ROCKY BUTTE	3	NO	1300	1035	0	0	720	2697	1326	2543
47D	MONTELLO	3	NO	4000	2561	0	59	2700	6639	3162	6795
47E	GROUSE CR. (NV)	3	NO	700	569	0	0	315	1479	163	813
48A	GOOSE CREEK	1			0	0	0	0	0	0	0
48B	SALMON FALLS CR.	1			0	0	0	0	0	0	0
48C	PRUNEAU	1			0	0	0	0	0	0	0
48D	JARBIDGE RIVER	1			0	0	0	0	0	0	0
48E	OWYHEE RIVER	1			0	0	0	0	0	0	0
48F	S. FORK OWYHEE	1			0	0	0	0	0	0	0
48G	E. LITTLE OWYHEE	1			0	0	0	0	0	0	0
49A	BUTTE (N)		8690	3900	6014	1260	3600	3150	9614	27	4984
49B	BUTTE (S)		11925	15000	15632	3654	11520	15000	24012	0	14069
50A	LOWER MOAPA	13	1010	40	115	0	0	24	87	2990	7749

		1	2	3	4	5	6	7	8	9	10
50B	GARNET VALLEY	6	600	400	353	0	0	140	819	1599	1459
50C	CALIFORNIA WASH	13	12470	60	190	0	0	0	174	3400	3468
50D	HIDDEN	6	400	400	343	0	0	225	861	579	966
50E	BLACK MOUNTAINS		1500	70	237	0	0	0	131	5800	6075
50F	GOLD BUTTE	6	1700	1000	901	0	0	690	2001	5100	6039
50G	GRASSWOOD	6	400	400	497	0	0	435	1344	959	1459
51A	LOWER VIRGIN R.	13	7500	3600	3156	0	479	2220	7146	7548	10905
51B	TULE DESERT	6	2100	2100	1959	0	76	795	4872	1496	3587
51C	ESCALANTE DESERT	6	2300	2300	732	0	2016	9450	679	0	2038
52A	ALKALI (N)		700	400	237	0	0	285	651	0	723
52B	ALKALI (S)	6	1400	1400	653	0	194	1500	1740	190	1229
52C	GARFIELD FLAT	6	300	300	322	0	0	132	757	850	1169
52D	MONTE CRISTO		400	500	337	0	0	440	787	2788	3203
52E	RHODES		700	600	233	0	0	495	722	1598	1992
52F	SODA SPRING (E)		900	600	514	0	0	375	1218	1904	2465
52G	SODA SPRING (W)		30	100	144	0	0	0	270	1088	1193
52H	TEELS		1600	1300	1210	0	0	660	2958	2652	3559
52I	ADORE		40	300	139	0	0	255	490	0	218
52J	COLUMBUS		3600	700	619	0	594	495	748	3094	3546
52K	MOUTOON	6	900	600	633	0	0	330	1742	714	1469
52L	MONO	6	700	700	310	0	0	750	957	0	544
52M	QUEEN	6	2000	2000	1644	1953	1440	900	1644	323	1175
53A	ANTELOPE	1			0	0	0	0	0	0	0
53B	N. OF WASSUK RA.	2	NO	10000	5633	1386	7550	9600	5220	782	5787
53C	WASSUK RANGE	1			0	0	0	0	0	0	0
54AA	ASH MEADOWS		17000	37000	28437	25011	18576	16140	23693	37196	53218
54A	GROOM LAKE	3	NO	3200	2134	57	540	2700	4872	5730	8350
54B	PAPOOSE LAKE	3	NO	10	42	0	0	0	11	1156	1160
54C	TIKAPOO (N)	3	NO	2600	1853	69	828	2259	3557	5780	7766
54D	TIKAPOO (S)	3	NO	3400	2875	693	2808	1950	3645	3094	5029
54E	LAS VEGAS (W)	3	NO	4700	4234	7560	2448	1110	513	513	1601
54F	THREE LAKES (N)	3	NO	2000	1650	882	684	1320	2523	2482	3879
54G	THREE LAKES (S)	3	NO	6000	5145	6930	3600	2100	1827	2516	4420
54H	INDIAN SPRINGS	3	NO	10000	9055	8820	7550	3750	4795	5100	9010
54I	YUCCA FLAT	3	NO	700	603	0	0	495	1392	2656	3512
54J	FRENCHMAN FLAT	3	NO	100	277	0	0	0	278	5100	5239
54K	JACKASS FLATS	3	NO	300	211	0	0	255	496	850	1102
54L	ROCK VALLEY	3	NO	30	53	0	0	0	78	850	881
54M	MERCURY	3	NO	250	135	0	198	210	734	1122	1299
54AB	PAHUTE MESA		9000	12000	8054	0	846	7545	19444	17000	26389
54N	GOLD	3	NO	3800	2837	0	654	2850	6351	5440	8633

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*Note change in title.

APPENDIX — TABLE A-1 (*continued*)

1	2	3	4	5	6	7	8	9	10
540 KEMICH	2	40	2236	2	162	7003	5916	2124	3163
54P BUCKSKIN MCCA	2	43	1077	0	0	1350	2794	1744	3194
540 JACKASS FLATS	2	40	436	0	0	540	657	1700	2196
542 CAMP FLAT	2	41	222	0	0	74	655	1976	2066
545 CAMP	2	40	1231	0	0	0	0	0	5214
547 AMARGOSA [illegible] (M)	1	0	0	0	0	0	0	0	0
540 ALKALI (S)	1	0	0	0	0	0	0	0	0
544C SARCOBATUS FLAT	2	0	2420	0	594	649	4222	1432	20657
54W CACTUS FLAT	2	40	470	0	54	0	256	4080	4581
54M STONEWALL FLAT	1	0	0	0	0	0	0	0	0
54X LITTLE VALLEY	1	0	0	0	0	0	0	0	0
54Y SARCOBATUS FLAT	4	0	0	0	0	0	0	0	0
554 KUMIVA	4	0	120	0	120	0	2244	3067	4060
558 GANNETT SPRINGS	4	0	2	0	230	1660	2420	4424	11994
55C FISHBOWL	4	0	0	0	0	100	0	510	212
55P BARTYS MOT DE.	5	0	160	0	0	12	0	1924	2001
564 PILOT CREEK	4	0	0	0	1224	1660	2249	2024	4277
568 GREAT SALT L. TL.	4	0	4030	2442	2960	3450	3424	-040	6219
56C ANTELOPE (N)	5	0	3000	2442	1194	2260	4432	1467	2091
56P ANTELOPE (S)	4	0	1030	0	1656	4200	1734	0	1966
560 DEEP CREEK (NV)	4	0	2230	1242	1460	1250	2871	1304	2914
564 TIPPETT	4	0	4030	4142	6120	5430	5555	1724	5763
56F FISHLEY	12	0	030	0	1476	950	840	724	1452
578 CROSS FLAT	12	0	2030	1054	1400	1	574	1020	1466
57C FLEGENT	1	0	0	0	0	0	0	0	0
57G PAGANIP LAKE	12	0	4400	6636	5430	4650	4793	4421	7939
57P SPANISH SPRINGS	12	0	0	0	0	0	0	0	0
57W SUN VALLEY	12	0	0	0	0	0	0	0	0
57G TEAGY SEGMENT	12	0	2100	2103	0	936	7650	992	5052
57M TRUCKEE CAN (NV)	1	0	0	0	0	0	0	0	0
57X TRUCK. CAN. NV&CA	1	0	0	0	0	0	0	0	0
571 TRUCKEE MEADOWS	1	0	0	0	0	0	0	0	0
57J TRUCK. CAN. (CA)	1	0	0	0	0	0	0	0	0
57K WASH SPRINGS	14	0	0	0	0	0	0	0	0
57L WASHOE	14	0	0	0	0	0	0	0	0
57M MINERAL LAKE	2	0	2600	1014	1232	2400	1657	2440	4646
57N AIRSTRIP LANDC	2	40	550	472	504	1075	457	241	819
50 FISH LAKE		22103	33000	25256	42250	12220	7140	7140	15010