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Estimating Water Yields in Utah by Principal Component Analysis

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ESTIMATING WATER YIELDS IN UTAH BY PRINCIPAL COMPONENT ANALYSIS

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INTRODUCTION

The basic hydrologic data required to determine the water yield are usually unavailable for small basins and streams while increasing emphasis is being placed on their development. Therefore, some methods and techniques for estimating the amount of water available for development of these small units is needed.

The purpose of this study is to use the concepts and techniques of statistical analysis to develop equations which are useful in estimating the water yield of watersheds for which no stream flow records are available. The approach is an extension of earlier studies at Utah State University (1, 10) in which physiographic and topographic parameters were related to mean annual runoff of Utah watersheds. Previous studies used multiple regression techniques primarily. The work reported herein utilizes the same data as in the earlier work but analysis is based on the multivariate technique of principal component analysis. Results and evaluations derived from the principal component analysis are compared with those obtained from multiple regression analysis.

PREVIOUS WORK AND PRESENT STATUS

The increased use of statistical methods in hydrology in recent years has perhaps been most apparent in research papers reporting results based on multiple regression techniques. The hydrologist uses these techniques because he is working largely with uncontrolled experiments.

Nixon and Schwab (14) developed a rational approach for estimating the water yield for watersheds in southern Iowa, from five watershed characteristics, climate, land use, land slope, soil and management and conservation practices. To estimate the water yield for any watershed, the median annual water yield is multiplied by a rating factor of the watershed. Spreen (20) correlates the precipitation in western Colorado to elevation of the station, maximum land slope, exposure of the station to the inflow of air masses, and the orientation of this exposure. A study to develop simple equations for estimating mean annual runoff from Utah data was initiated in 1958. In this study, factors which are easily obtained from maps and published data were selected to correlate with the mean water yield of a watershed. Watersheds with gaging stations above all major diversions were used in the study and assumed the watersheds were representative of those to which the equations would be applied. Results of this work for the northern part of the state were reported in a thesis by Jeppson (10). Later Bagley, Jeppson and Milligan (1) extended the analysis to cover the entire state and applied the relation thus developed in obtaining regional runoff inventories.

Sharp, Gibbs, Owen and Harris (17) discuss the limitations of the multiple regression approach in water yield studies. They include in their presentation comments both on the association of errors and on the apparently erroneous results which may be obtained when the independent variables are highly correlated.

The premises upon which multiple regression and correlation analysis is based are as follows:

1. No errors exist in the independent variables, errors occur only in the dependent variable.

2. The independent variables are statistically independent.

3. The variance of the dependent variable (runoff) does not change with changes in magnitude of the independent variables.

4. The observed values of the dependent variable are uncorrelated events.

5. The population of the dependent variable (runoff) is normally distributed about the regression line for any fixed level of the independent variables under consideration.

The first two assumptions are obviously violated by hydrologic data, for measurements of all variables, both dependent and independent, contain certain amounts of error. A glance at the correlation matrix of nearly any hydrological data used in multiple regression reveals that most variables exhibit some and often high degrees of correlation. The fact that small values of precipitation are associated with low values of runoff which exhibit a low variance while large precipitation events generate runoff events with large variance cause doubt in the third assumption for at least this related physiographic parameter. The fourth assumption is violated in the case of runoff data because streamflow is often related to the antecedent flow. Studies on the distribution of runoff events reveal that they do not follow a normal distribution thus causing the last assumption to be violated.

Although many of the assumptions upon which multiple regression analysis are based are violated, it is widely used because it does provide an easy way to evaluate a large number of factors simultaneously and also the extent of the violations may not affect the results appreciably. However, with the wide availability of high speed computers, a much larger variety of procedures is available that may remove some of the uncertainties resulting from violations of the assumptions implicit in multiple regression analysis. These procedures involve a wide field of statistical analysis known as multivariate analysis. One of the procedures known as principal component analysis has been cited in recent literature (5, 21) as a possible improvement to the ordinary multiple regression approach of relating various hydrologic phenomena because it transforms the original independent variables which in reality may be highly correlated into a set of new factors called principal components which are truly orthogonal.

DESCRIPTION OF THE STATISTICAL PROCEDURES

Multiple Regression Analysis

When information is available on two or more related variables, it is natural to seek a way of expressing the form of the functional relationship, and to know the strength of the relationship. The regression method is used to determine the "best" functional relation among the variables. The criterion used to determine the "best" is that linear function which minimizes the sum of the squared deviations between the predicted and observed values of the dependent variable.

The general form of an ordinary multiple regression model is

$$Y = b_0 + b_1 X_1 + b_2 X_2 + \ldots + b_m X_m + e \qquad (1)$$

Where

Y = observed value of water yield

X's are the factors related to the water yield

b_0 = constant term of the regression equation

$b_1, b_2, .., b_m$ = regression coefficients

e = error or amount of deviation between the predicted and observed Y. The procedure for obtaining the unknown coefficients may be found in most textbooks on statistics (15, 18).

An index to the "goodness of fit" of the derived expression is given by the fraction of the original deviation in the dependent variable eliminated by the regression equation and is represented by R^2 where

$$R^2 = \frac{\text{Sum of squares due to regression}}{\text{Total sum of squares}}$$

The closer R approaches 1 the more accurate the estimate of the regression equation will be.

Principal Component Analysis

Principal component analysis is a method by which the information (measured by statistical variance in the sample space) contained in the matrix of predictor variables (in this study the matrix of physiographic observations) is transformed into another matrix of factors which are linearly independent and are called orthogonal factors. The set of orthogonal factors which contain all of the significant information of the original data matrix are called principal components.

For example, if all the data are linear functions of one of the variates, then one variate expresses all of the information contained in the entire array or sample space and conversely if all of the data are linearly independent no amount of linear mathematical rearrangement can reduce the number of variates needed to express all of the information contained in the original array. Most hydrologic data lie between these two examples where it might be possible to eliminate a few of the original independent variates because they contribute little or nothing to the information contained in the remaining group.

The technique which yields the set of transformations which define the orthogonal factors has been discussed in recent books (3, 4, 9) and papers (5, 19, 21, 22) and is briefly outlined as follows:

First, it is necessary to solve the characteristic matrix equation

$$\left[r_{ij} - \lambda I\right] = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (2)$$

where r_{ij} represents the correlation matrix, I denotes the unit matrix and λ is an undetermined scalar multiplier.

Equation 2 yields an m-rooted polynomial in λ where m is the rank of the correlation matrix r_{ij}. If there are no linearly dependent variables in the original array then m also is the same as the number of original variates in the sample space. The roots of equation 2 are called characteristic roots or eigenvalues of the matrix. For each root, there exists a corresponding vector, ν_j, (j = 1, 2, ..., m), called an eigenvector, whose elements comprise the solution to the simultaneous equations implied by Equation 2. That is

$$\begin{bmatrix} (1-\lambda_i) & r_{12} & r_{13} & \cdots & r_{1m} \\ r_{21} & (1-\lambda_i) & r_{23} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ r_{m1} & r_{m2} & & \cdots & (1-\lambda_i) \end{bmatrix} \cdot \begin{bmatrix} \nu_{1i} \\ \nu_{2i} \\ \vdots \\ \nu_{mi} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} \qquad (3)$$

If the original variates denoted by x_j are standardized, i.e. measured about their respective sample means and divided by their respective standard deviations, the principal components, D_i, are defined by

$$D_i = \sum_{j=1}^{m} v_j x_j \qquad (4)$$

The D_i are uncorrelated (by definition) and have variance λ_i where λ_i is the ith root of the characteristic equation. It can be shown that for the case in which r_{ij} is positive-definite, which all correlation matrices must be, that

$$\sum_{i=1}^{m} \lambda_i = m \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (5)$$

and

$$\frac{\lambda i}{m} (100) = P_i \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (6)$$

where P_i is the precentage of variation accounted for by the ith principal component. Therefore, the eigenvector corresponding to the largest eigenvalue defines the principal component that accounts for the largest percent of variation in the original sample space. The eigenvector corresponding to the next largest eigenvalue yields the principal component that accounts for the next largest percent of variation in the sample space. And so on until all variation is accounted for.

There are various ways of obtaining solutions to the above equations which are not discussed here, but most computer centers have library programs that will calculate eigenvalues and corresponding eigenvectors.

Principal Component Analysis

The particular principal component analysis computer program used in this study was BMD02M, "Regression on Principal Components," from the program library of Western Data Processing Center. This program computes the principal components of standardized data and regresses the dependent variable on the principal components.

Tables 10, 11, 12 and 13 show the eigenvectors of the orthogonal factors for the watersheds in the Great Salt Lake division, Uinta division, Southern division, and the entire state respectively. These eigenvectors are the linear transformation necessary to define each orthogonal factor. The orthogonal factors for the three divisions and the entire state are shown in Tables 14, 15, 16 and 17 respectively. The coefficients of regression equations using orthogonal factors for standardized independent variables for the Great Salt Lake division are tabulated in Table 18 and those for the Uinta, Southern and entire state are tabulated in Tables 19, 20 and 21 respectively. The output also contains the reduction in residual sum of squares due to using orthogonal factors and correlation coefficients of the stepwise regression equations. These are shown in Tables 22, 23 and 24 for the three divisions and in Table 25 for the entire state.

Table 10. Summary of eigenvectors of the orthogonal factors for the watersheds in the Great Salt Lake Division.

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14	Factor 15
1	P_{WY}	-0.3301	-0.0784	-0.0254	-0.2525	-0.3646	-0.0124	-0.0433	-0.1810	-0.1055	-0.0945	-0.0526	-0.1176	-0.3560	-0.0701	-0.6960
2	P_{O-A}	-0.3495	-0.0483	-0.0280	-0.1822	-0.2628	0.0355	-0.0298	-0.2533	-0.2171	0.0209	0.0764	0.1203	-0.2404	-0.4491	0.6153
3	E	-0.2330	0.3213	-0.2543	0.1128	-0.4133	0.1832	0.0534	0.0866	-0.1101	-0.4769	0.1162	0.2529	0.4084	0.2546	0.0255
4	E_M	-0.2724	0.3517	0.0464	-0.0472	0.0357	0.1449	0.2694	0.0879	-0.3668	0.5930	0.2665	-0.3067	0.1398	0.1566	-0.0361
5	D	-0.1815	0.0481	-0.1479	0.7426	0.2259	0.1130	-0.0649	-0.3841	-0.2297	0.0863	-0.2514	0.1509	-0.1149	-0.0480	-0.1196
6	S_S	-0.1636	-0.4203	0.0501	0.3973	0.0085	-0.0623	0.3460	0.4485	-0.0615	-0.2132	0.4409	-0.0972	-0.1678	-0.1695	-0.0380
7	A_S	0.1998	0.0881	-0.5773	0.1092	-0.2693	-0.3548	0.4039	-0.2303	0.3510	0.1981	0.0697	-0.1276	-0.0191	-0.0944	0.0146
8	$S_{L(N-S)}$	-0.2932	0.1029	-0.0664	-0.0417	0.2149	-0.6719	-0.1891	0.1675	-0.1634	-0.0598	-0.1323	-0.0464	0.3971	-0.3417	-0.1061
9	$S_{L(E-W)}$	-0.2341	-0.1550	-0.4200	-0.1492	0.3328	0.4767	-0.2134	-0.0182	0.3391	0.0604	0.2268	-0.0544	0.2470	-0.2937	-0.1309
10	S_L	-0.3159	0.0195	-0.3353	-0.0951	0.2962	-0.2375	-0.2187	0.0535	0.0536	-0.1150	0.1133	-0.0988	-0.4152	0.5714	0.2138
11	L	-0.2138	-0.4274	0.2287	-0.0145	-0.0816	-0.2224	-0.0103	-0.3307	0.1511	0.2854	0.2902	0.4353	0.2902	0.2970	-0.0555
12	X	0.2776	-0.0052	-0.1569	0.2231	-0.3700	-0.0579	-0.6815	0.2214	-0.1300	0.2844	0.2996	0.0032	-0.0667	-0.0416	-0.0304
13	F_S	-0.3043	-0.0291	0.3065	0.2707	-0.2717	0.0229	-0.1834	-0.0741	0.4350	-0.0270	-0.1691	-0.5884	0.1573	0.0803	0.1724
14	G	-0.0880	-0.4985	-0.3093	-0.0687	-0.1906	0.1135	0.0756	0.3312	-0.1915	0.2442	-0.5739	0.0029	0.1347	0.1635	0.0941
15	V	0.2776	-0.3330	-0.1196	-0.0766	0.0631	-0.0120	-0.0411	-0.4258	-0.4531	-0.2760	0.1751	-0.4632	0.2544	0.1073	0.0488

Table 11. Summary of eigenvectors of the orthogonal factors for the watersheds in the Uinta Division.

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14
1	P_{WY}	0.3771	0.2097	-0.0928	0.2159	0.3327	0.1059	0.0748	0.2845	0.1769	0.4342	0.0944	0.3808	0.4199	0.0093
2	P_{O-A}	0.3241	-0.1431	-0.3993	0.0062	0.1397	0.2652	0.1584	-0.0054	-0.1132	-0.4063	0.6102	0.0339	-0.2185	-0.0116
3	E	0.3682	0.3187	0.0293	-0.0504	0.1788	0.1532	-0.0426	-0.1685	0.3601	-0.1466	-0.4370	0.1561	-0.5546	-0.0128
4	E_M	0.4064	0.2603	0.0218	-0.1277	-0.0264	-0.2259	-0.0163	0.0066	0.2656	-0.0813	-0.1033	0.7355	0.2655	0.0205
5	D	0.2497	0.0064	-0.3317	0.2821	-0.1501	-0.1773	-0.7597	-0.0363	-0.2849	-0.0867	-0.1413	0.0673	0.0612	-0.0106
6	S_S	0.0591	0.0973	0.3337	0.3420	-0.6013	0.4741	-0.1332	0.2236	0.1849	0.0743	0.2091	-0.0575	-0.1256	-0.0037
7	A_S	-0.0465	0.0831	0.0201	-0.7641	0.0483	0.2149	-0.4406	0.2210	-0.0166	0.2492	0.2149	0.0362	-0.0980	-0.0053
8	$S_{L(N-S)}$	0.3017	-0.3373	0.1810	-0.1550	0.0361	0.4344	0.0675	0.0418	-0.2692	-0.1766	-0.3904	-0.0892	0.3124	-0.4244
9	$S_{L(E-W)}$	0.1574	-0.2819	0.4530	0.0882	0.1841	-0.2928	-0.1995	-0.3253	0.1413	0.1694	0.3515	0.0839	-0.1460	-0.4630
10	S_L	0.2590	-0.3539	0.3662	-0.0177	0.1237	0.0704	-0.0943	-0.1711	-0.0719	-0.0140	-0.0041	0.0258	0.0610	0.7775
11	L	0.1277	-0.4553	-0.2959	0.1128	0.0172	-0.0154	0.1062	0.2298	-0.0133	0.5499	-0.1564	-0.3482	-0.4067	0.0075
12	X	0.2183	0.4117	0.0795	-0.0469	-0.1559	0.0364	0.2310	-0.3851	-0.6277	0.3597	0.0725	-0.0355	-0.1199	0.0012
13	F_S	0.3371	-0.0549	0.1769	-0.1951	-0.3301	-0.5101	0.2150	0.4968	-0.1451	-0.1708	-0.0301	0.2865	-0.1357	-0.0076
14	G	-0.1532	0.2270	0.3342	0.2628	0.5164	0.0182	-0.1192	0.4536	-0.3565	-0.1490	0.0253	-0.2430	-0.2188	-0.0016

Table 12. Summary of eigenvectors of the orthogonal factors for the watersheds in the Southern Division.

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14
1	P_{WY}	0.2552	0.4708	-0.0433	-0.1833	-0.1158	-0.0660	-0.0580	-0.1262	-0.0982	-0.1225	-0.3682	-0.1545	-0.6757	-0.0070
2	P_{O-A}	0.2693	0.3999	-0.0647	-0.1116	-0.2875	0.0158	-0.0663	-0.3779	0.3432	0.5035	0.1255	0.2492	0.2709	0.0014
3	E	0.1610	0.4682	0.2635	-0.2161	-0.0087	0.0895	0.2247	0.1878	-0.1357	-0.2883	0.4658	-0.3940	0.2756	-0.0006
4	E_M	-0.1120	-0.0642	0.4925	-0.3184	0.4610	-0.1440	-0.0540	0.1061	0.3328	0.3393	0.2189	0.0039	-0.3424	0.0027
5	D	0.3367	-0.0188	-0.2855	-0.0959	0.3818	0.1687	-0.1700	0.2071	-0.5004	0.5092	-0.0467	-0.1702	0.0977	0.0027
6	S_S	0.2873	0.0624	-0.1664	-0.1465	0.5618	0.2571	0.2126	-0.0677	0.3606	-0.3539	-0.2979	0.2211	0.1991	0.0058
7	A_S	-0.1380	0.0434	0.4727	0.1353	-0.0605	0.6512	0.3207	-0.1609	-0.2704	0.1750	-0.1929	0.1762	-0.0676	0.0061
8	$S_{L(N-S)}$	0.4282	-0.2236	0.0165	-0.0044	-0.0281	-0.0135	0.0149	-0.1161	-0.2375	-0.1945	0.4539	0.4597	-0.2541	0.4201
9	$S_{L(E-W)}$	0.2802	-0.4274	0.0796	-0.0981	-0.2010	0.0941	0.1643	-0.1677	0.2476	0.0937	-0.1645	-0.5761	0.0345	0.4321
10	S_L	0.3758	-0.3526	0.0620	-0.0570	-0.1169	0.0501	0.1090	-0.1501	0.0114	-0.0451	0.1515	-0.0651	-0.1114	-0.7979
11	L	-0.1301	-0.0950	-0.3133	-0.5228	-0.3391	0.1836	0.3436	0.5063	0.1022	0.1079	0.0031	0.2094	-0.1213	0.0051
12	X	0.2947	-0.0007	0.2709	0.1720	-0.2102	0.2946	-0.5715	0.5115	0.2424	-0.1045	-0.1145	0.0785	0.0377	-0.0048
13	F_S	-0.1411	-0.1515	0.1916	-0.6635	-0.0805	-0.0051	-0.4147	-0.2779	-0.2699	-0.1980	-0.1834	0.0893	0.2664	-0.0053
14	G	0.2867	-0.0052	0.3613	0.0305	-0.0761	-0.5620	0.3258	0.2490	-0.1731	0.0877	-0.3910	0.2107	0.2403	0.0007

Table 13. Summary of eigenvectors of the orthogonal factors for the watersheds in the State.

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14
1	P_{WY}	-0.2350	-0.4532	0.0388	0.2776	0.1101	0.2781	0.0882	0.2072	0.0987	0.0235	0.0226	0.1076	0.7054	0.0150
2	P_{O-A}	-0.3472	-0.2251	-0.0121	0.2593	0.3029	0.2365	-0.1429	0.2481	0.0510	0.1450	-0.4514	-0.1692	-0.5268	-0.0091
3	E	0.2022	-0.5174	-0.1314	0.0055	-0.0390	-0.0761	0.1420	0.1453	0.0064	0.1972	0.3810	0.5418	-0.3856	-0.0041
4	E_M	0.1572	-0.4421	-0.3528	-0.0938	-0.1283	-0.0391	0.1919	-0.1227	-0.0421	0.0357	0.1290	-0.7346	-0.0249	-0.0143
5	D	-0.2317	-0.0372	-0.2192	0.3387	-0.0620	-0.7568	-0.0566	0.0721	0.3631	-0.2436	-0.0606	0.0198	0.0253	0.0138
6	S_S	-0.2825	-0.0607	0.1668	0.1970	-0.5983	-0.1346	-0.3373	-0.0160	-0.3794	0.4549	0.0705	-0.0580	0.0277	-0.0124
7	A_S	0.2696	-0.1776	-0.0374	-0.4099	-0.0302	-0.0222	-0.7083	0.3768	0.2633	0.0009	-0.0588	-0.0489	0.1185	0.0197
8	$S_{L(N-S)}$	-0.3691	-0.0927	-0.1466	-0.2549	0.2440	-0.1117	-0.1250	0.1147	-0.5452	-0.3398	0.2002	0.0257	-0.0062	0.4648
9	$S_{L(E-W)}$	-0.3431	0.0143	0.0081	-0.4991	-0.0929	-0.0743	0.2872	-0.0874	0.3843	0.4243	-0.1570	0.0527	0.0375	0.4149
10	S_L	-0.4012	-0.0219	-0.0749	-0.4160	0.1219	-0.1179	0.0568	0.0296	-0.0942	0.0206	0.0504	0.0514	0.0418	-0.7810
11	L	-0.2469	0.3819	-0.2396	0.1567	0.0592	0.2635	-0.1004	0.2016	0.3078	0.1388	0.6561	-0.1679	-0.0858	0.0124
12	X	-0.1021	-0.2464	0.4775	0.0212	0.3443	-0.0857	-0.3046	-0.5897	0.1906	0.0122	0.2976	-0.0914	-0.0607	0.0163
13	F_S	-0.1917	-0.1033	-0.4595	-0.0144	-0.3357	0.3713	-0.2400	-0.4863	0.1430	-0.3001	-0.1408	0.2548	-0.0584	-0.0098
14	G	-0.1714	-0.1332	0.5055	-0.1141	-0.4445	0.1465	0.1855	0.2555	0.1882	-0.5163	0.1257	-0.1139	-0.2061	-0.0086

Table 14. Values of each orthogonal factor for the 26 watersheds in the Great Salt Lake Division.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14	Factor 15
Woodruff Cr.	0.5083	0.3421	-0.3980	0.1202	-0.0872	-0.0714	0.0371	-0.0665	0.0134	-0.0689	0.0381	-0.0247	-0.0928	0.0621	0.0286
Farmington Cr.	-0.1833	-0.3129	-0.0144	-0.2204	-0.2592	-0.1876	-0.0084	-0.0410	-0.1516	0.0034	-0.1034	0.0366	-0.0275	-0.0238	0.0166
Holmes Cr.	-0.5662	-0.3954	-0.3184	0.2909	0.1975	-0.1099	-0.1379	0.1280	0.0007	0.0681	0.0077	0.0668	0.0321	0.0229	0.0197
Parrish Cr.	-0.1613	-0.5148	-0.0837	0.1845	0.0807	0.1859	0.0215	-0.0279	0.0009	0.0979	-0.0149	-0.0519	-0.0136	0.0132	-0.0340
Rick Cr.	0.0813	-0.6684	0.0623	0.0047	-0.1977	0.3038	0.1069	0.0711	0.1763	-0.1167	0.0908	-0.0172	0.0168	-0.0025	0.0241
Centerville Cr.	-0.0506	-0.5796	0.0105	0.0197	-0.0046	-0.0843	0.1145	0.1457	-0.0486	-0.0136	0.0534	-0.0383	-0.0418	-0.0309	-0.0116
City Cr.	-0.0497	-0.0676	0.2786	-0.0842	-0.1158	-0.1746	-0.0197	-0.1541	-0.0130	-0.0762	-0.0185	-0.0471	0.0494	0.0498	-0.0295
Blacksmith Fork	0.6236	0.0630	0.1018	0.0468	-0.1030	0.0145	-0.0950	0.0252	0.0339	0.1261	-0.0033	-0.0135	0.0400	0.0334	0.0131
E. Fk. Little Bear R.	0.4856	-0.0110	0.0456	-0.0767	-0.1105	0.0312	-0.0762	-0.0129	-0.0067	0.0834	0.0571	0.0593	0.0337	0.0214	-0.0028
Hardscrabble Cr.	0.2006	-0.1072	-0.1308	-0.1228	-0.0339	-0.0655	0.0918	-0.1629	0.1270	0.0737	-0.0351	0.0733	0.0094	-0.0278	0.0494
Mill Cr. nr. Bountiful	-0.1325	-0.2156	0.0622	-0.0898	-0.1100	-0.1624	0.0185	-0.0560	-0.0699	-0.0212	-0.0518	-0.0316	0.0076	0.0155	0.0056
Stone Cr.	-0.0674	-0.5019	-0.0345	0.0719	0.0358	-0.1674	0.0663	0.1097	-0.0632	-0.0374	-0.0597	0.0027	-0.0002	0.0114	-0.0175
South Fk. Ogden R.	0.7149	0.2560	0.1442	0.0062	0.2123	0.1388	-0.0914	0.2150	-0.0669	-0.1845	-0.0813	0.0902	0.0093	0.0055	0.0036
Lost Cr.	0.3350	0.0552	0.0967	0.0880	0.0363	0.0910	-0.1786	-0.0616	0.0445	-0.0337	-0.0045	-0.0590	0.0060	-0.0160	0.0169
Big Cr.	0.6579	0.3416	-0.4254	0.1594	0.2052	-0.2410	-0.0876	0.0598	0.0530	-0.0158	0.0268	-0.0748	0.0301	-0.0383	-0.0204
Birch Cr.	1.0301	0.3275	-0.1126	0.1730	-0.3286	0.0341	0.3172	-0.0166	-0.0434	0.0277	-0.0086	0.0303	0.0222	-0.0276	-0.0303
Hobble Cr.	0.0244	0.2557	0.0583	-0.2741	0.4173	0.2225	0.2395	0.0918	-0.0466	0.1149	-0.0949	-0.0711	-0.0025	0.0125	0.0233
American Fork	-0.7105	0.3255	-0.1139	-0.2549	0.0318	0.1138	-0.0007	0.0070	-0.0873	-0.0433	0.0416	-0.0337	0.0274	-0.0012	0.0032
Fork Cr.	-0.3100	0.3540	0.6719	0.2741	0.1654	-0.2537	0.1671	0.0528	-0.0005	0.0349	0.1171	0.0240	-0.0197	-0.0007	0.0143
Dry Cr.	-0.9804	0.2496	-0.0379	0.6208	0.0292	0.1859	0.0154	-0.1995	-0.0827	-0.0460	-0.0530	0.0121	0.0081	-0.0176	0.0053
Big Cottonwood Cr.	-0.6493	0.2720	-0.2421	-0.2769	-0.0733	0.1709	0.0457	0.0119	-0.0563	0.0250	0.0967	0.0807	-0.0104	0.0155	-0.0405
Parleys Cr.	0.2126	-0.0652	0.1975	-0.1347	0.1176	0.0824	-0.0269	-0.1622	0.1165	-0.0577	-0.0527	0.0067	-0.0193	-0.0068	-0.0201
Mill Cr. nr. SLC	-0.3629	0.0923	-0.1172	-0.3041	0.0793	-0.0994	-0.0315	-0.0689	-0.0845	-0.0656	0.1014	-0.0326	0.0298	-0.0252	0.0264
Emigration Cr.	0.1871	-0.1477	0.0548	-0.1610	0.4224	-0.0501	-0.1221	-0.1382	0.1027	0.0261	0.0188	0.0546	-0.0412	-0.0152	-0.0337
Little Cottonwood Cr.	-1.0916	0.5125	0.0024	-0.0754	-0.3028	-0.1056	-0.0314	0.1790	0.2658	0.0093	-0.0892	-0.0124	-0.0106	-0.0049	-0.0126
Logan River	0.2544	0.1401	0.2424	0.0147	-0.3042	0.1670	-0.3341	0.0711	-0.1136	0.0903	0.0216	-0.0295	-0.0422	-0.0245	0.0029

Table 15. Values of each orthogonal factor for the 34 watersheds in the Uinta Division.

Stations	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14
Little Brush Cr.	-0.5210	0.3082	0.0357	-0.0855	0.1316	0.0059	-0.0278	-0.0174	-0.1866	-0.0035	-0.0295	0.0116	0.0422	0.0007
Bruch Cr.	-0.3378	0.1021	0.3859	-0.0167	0.1853	0.1160	-0.1269	-0.2386	-0.0295	0.1181	0.1314	0.0081	-0.0125	
Ashley Cr.	-0.2629	0.2112	0.0965	-0.1844	-0.0766	-0.1503	-0.0345	0.0863	0.0157	-0.0706	-0.0307	-0.0456	0.0480	0.0019
Ashley Cr. below Trout Cr.	-0.4629	0.4281	-0.1531	-0.0952	0.1297	0.0644	0.1053	-0.0765	-0.0014	0.0732	-0.0797	0.0767	0.0031	0.0045
South Fork Ashley Cr.	-0.1043	0.3584	-0.1135	-0.1059	0.1410	0.1192	0.1248	-0.0562	0.0229	-0.0291	-0.0489	-0.0288	0.0373	0.0001
East Fork Dry Fork	-0.3184	0.2720	0.0757	0.3013	0.0966	-0.1216	0.0881	-0.1500	0.0263	-0.0581	-0.0300	-0.0238	-0.0439	-0.0016
East Fk. Dry Fk. at mouth	-0.2301	0.1498	0.2202	0.2639	-0.0746	-0.1756	0.1171	-0.0376	-0.0411	-0.1017	-0.0214	0.0070	-0.0163	0.0006
North Fork Dry Fork	-0.1490	0.3294	0.1992	0.0358	-0.1810	0.0846	-0.1936	0.1604	-0.0028	0.0068	-0.0049	-0.1127	-0.0247	0.0011
Dry Fork	-0.0494	0.2500	-0.0588	-0.1933	-0.0244	-0.0294	0.0517	-0.0431	0.0856	0.0061	-0.0077	0.0128	0.0141	0.0027
Whiterocks River	0.2297	0.1340	0.0548	-0.1684	0.0401	-0.1191	0.0213	0.1377	-0.0622	-0.0802	0.0616	0.0875	-0.0262	-0.0011
Whiterocks River above P.C.	0.1696	0.2238	0.0054	-0.1078	0.1109	0.0167	-0.0413	0.0030	0.0278	0.0161	0.0005	0.0514	-0.0050	-0.0009
Carter Cr.	-0.0772	0.3021	0.0019	-0.0412	-0.1079	0.0486	0.1577	-0.0359	-0.0047	-0.0427	0.0469	-0.0393	-0.0543	0.0008
Farm Cr.	-0.2429	-0.1976	0.4923	-0.0915	-0.1015	-0.0100	-0.1347	-0.0730	-0.1496	0.0459	-0.0679	0.0394	-0.0074	-0.0004
Clover Cr.	0.1434	0.3252	0.1144	0.4913	-0.3129	0.0486	-0.0006	0.1038	0.2430	0.1370	-0.0069	0.1073	0.0139	0.0008
Uinta R. above Clover Cr.	0.4919	0.0483	0.0315	-0.2206	0.1113	0.1123	-0.0138	-0.0468	0.0485	-0.0191	-0.0444	-0.0365	0.0646	-0.0000
Uinta R. below Gilbert Cr.	0.4581	0.3046	-0.2042	0.0172	0.1390	0.2014	-0.0791	-0.0491	0.0984	0.0224	-0.0077	-0.0453	-0.0072	0.0015
Yellowstone Cr. bel. S. Cr.	0.4834	0.0500	0.0753	-0.1513	0.1400	-0.1130	-0.1272	0.0166	0.0328	0.0281	0.0163	-0.0382	-0.0368	0.0026
Yellowstone Cr.	0.4436	0.0101	0.0121	-0.2867	-0.0882	-0.2657	0.0013	0.0525	0.0800	0.0218	-0.0343	0.0261	0.0076	0.0025
Lake Fork	0.5142	-0.0105	-0.0581	-0.1608	0.0452	0.0531	-0.0794	0.0079	0.0563	0.0314	0.0008	-0.0187	0.0068	-0.0018
Rock Cr. nr. Mt. Home	0.4182	-0.1740	0.0901	-0.1906	0.0999	-0.1763	-0.0114	0.1109	-0.0568	0.0256	0.0175	0.0319	-0.0435	-0.0010
Rock Cr. nr. Hanna	0.4318	-0.1330	0.0286	0.2066	0.1455	-0.0654	0.1448	-0.0852	0.0271	-0.0476	-0.0745	-0.0271	-0.0370	0.0013
Duchesne River	0.3042	-0.1105	-0.1701	0.2221	0.1006	-0.0791	0.1885	-0.1117	0.0124	0.0297	0.0752	-0.0446	0.0096	0.0036
Provo River	0.2273	0.0609	-0.7142	0.4655	-0.0808	-0.1333	-0.3897	-0.0442	-0.1819	-0.0060	-0.0258	0.0058	-0.0162	-0.0030
Weber River	0.3445	-0.3865	0.0296	0.0972	0.0546	-0.1593	0.1604	-0.0393	-0.2055	0.0839	0.0632	0.0208	0.0478	0.0018
Wolf Cr.	-0.1380	-0.3366	-0.2422	-0.0943	-0.1561	0.2413	0.0144	0.0226	-0.1274	-0.0050	-0.0378	0.0376	-0.0338	0.0255
West.Fork Duchesne River	-0.2712	-0.1568	-0.3774	-0.1456	-0.0992	0.0125	0.1863	0.1412	-0.0519	0.0391	-0.0691	0.0034	-0.0122	-0.0248
West Fork Duchesne River below Dry H.	-0.2029	-0.1872	-0.3993	-0.0290	-0.0679	0.1518	0.0352	0.0467	-0.0297	0.0651	-0.0189	-0.0292	-0.0403	-0.0056
Water Hollow	-0.1359	-0.6409	-0.3628	-0.2732	-0.4514	0.0059	0.0089	-0.2587	0.1317	-0.0520	0.0519	0.0040	0.0093	-0.0022
White River	-0.5139	-0.4438	-0.1080	-0.0527	0.3089	0.1023	-0.0418	0.2060	0.0527	0.0435	0.0778	-0.0175	-0.0052	0.0026
North Fork White River	-0.4447	-0.3613	-0.2137	0.3261	0.2443	-0.0500	0.0957	0.1558	0.1136	-0.0500	0.0485	-0.0074	0.0352	0.0045
Minnie Maud Cr.	-0.5585	-0.6396	0.3221	0.0022	0.1129	-0.1686	-0.2356	-0.0530	0.1870	-0.0225	-0.0757	-0.0016	-0.0024	-0.0002
Carter Creek at mouth	-0.2598	0.2846	0.2438	-0.0273	-0.4089	-0.1035	0.0671	0.0859	-0.0526	0.0406	0.0926	-0.0721	0.0247	0.0037
Brown Duck Cr.	0.1077	0.1701	0.0234	0.0169	-0.0113	0.2298	-0.1287	0.0225	0.0011	-0.2151	0.0941	0.0877	0.0094	-0.0067
Hades Cr.	0.5132	-0.5442	0.6370	0.2759	-0.0949	0.3055	0.0976	0.0565	-0.0794	-0.0311	-0.0622	-0.0194	0.0188	-0.0054

Table 16. Values of each orthogonal factor for the 24 watersheds in the Southern Division.

Stations	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14
Summit Cr.	0.9094	-0.4211	0.1254	-0.1616	0.0436	0.0974	0.1698	0.0834	0.0681	-0.0586	-0.0587	-0.1117	-0.0061	0.0018
Price River	0.0207	0.3664	0.0806	0.4312	-0.4577	0.0370	-0.0667	0.0503	0.1255	-0.0129	-0.0504	0.0207	-0.0255	-0.0061
Gooseberry Cr.	0.3355	0.3234	-0.1420	0.0062	-0.4334	-0.1873	-0.3625	-0.0162	0.0078	-0.0302	0.0075	-0.0673	0.0120	0.0080
Pleasant Cr.	0.7122	0.2099	-0.1379	-0.1574	0.1606	0.1310	-0.1391	0.0004	0.0321	0.0475	-0.1340	0.0304	-0.0058	-0.0024
Huntington Cr.	0.2581	-0.0296	0.3269	0.1618	-0.2537	0.1530	0.0415	0.0209	-0.0366	0.0951	0.1284	0.0292	-0.0097	-0.0002
Cottonwood Cr.	-0.0282	-0.0159	0.3643	-0.0833	-0.0984	0.1677	-0.1297	-0.0469	0.0109	-0.0072	0.0289	-0.0402	0.0225	-0.0025
Ferron Cr.	-0.1266	-0.0777	0.3126	0.0502	-0.0737	0.1093	-0.0378	0.0511	-0.0274	-0.0314	0.0163	0.0202	0.1257	-0.0011
Muddy Cr.	-0.1094	0.2701	0.2659	0.0197	-0.0547	0.0234	-0.0436	0.0422	-0.0628	-0.0589	-0.0626	0.1368	-0.0493	0.0044
Twin Cr.	0.8590	-0.2677	-0.1726	-0.0484	0.1955	0.1633	-0.1293	0.0388	-0.2090	0.0418	0.0876	0.0628	-0.0102	-0.0015
Ivie Cr.	-0.2631	-0.3770	0.0940	0.3142	0.1995	0.0929	0.1168	0.1946	0.1294	0.0954	-0.0353	-0.0801	-0.0269	0.0024
Chalk Cr. nr. Fillmore	0.2618	-0.3271	-0.2710	0.1263	-0.0902	0.0639	0.1156	0.1146	0.1495	-0.0353	0.0193	0.0893	0.0100	0.0011
Indian Cr.	0.5027	0.2305	0.1900	0.3636	0.3097	-0.3066	0.2897	-0.2887	0.0590	0.0560	0.0347	0.0407	0.0200	0.0026
Center Cr.	-0.1962	-0.3641	0.0624	-0.4357	-0.0442	-0.1007	0.1599	-0.0127	-0.0349	-0.1194	-0.1006	0.0751	0.0069	0.0001
Beaver River	-0.0488	0.1567	0.1112	-0.5165	0.0889	-0.1664	-0.0579	0.0460	0.1069	0.0431	0.1075	0.0229	-0.0506	-0.0011
Sevier River	-0.7412	0.1191	-0.0362	-0.0907	0.0303	-0.0497	0.0829	0.2034	-0.1469	0.1892	-0.0390	0.0104	0.0224	0.0026
Castle Cr.	0.0942	-0.3023	0.2730	0.1474	0.0391	-0.3897	-0.1290	-0.0642	-0.2008	0.0243	-0.0830	-0.0808	-0.0214	-0.0035
Mill Cr. nr. Moab	-0.6149	-0.3255	0.2566	0.0504	0.4721	-0.1708	-0.3573	0.0093	0.1478	-0.0731	0.0458	0.0194	0.0058	-0.0006
North Cr.	-0.4865	-0.1220	-0.0845	0.0213	0.0209	0.3256	0.0183	-0.1507	-0.0671	-0.0591	0.0636	-0.0586	-0.0690	0.0008
Pine Cr.	-0.5022	-0.1325	-0.1576	0.0207	0.0254	0.4006	-0.0538	-0.2913	0.0057	0.0412	-0.0764	0.0007	0.0179	0.0016
Coal Cr.	-0.0976	-0.0189	-0.1376	-0.3758	-0.2248	-0.0826	0.1910	-0.0368	0.0047	-0.0404	0.0833	-0.0616	0.0293	-0.0009
East Fork Boulder Cr.	-0.2443	0.8664	0.3303	-0.0905	0.0665	0.0278	0.2550	0.0416	-0.0419	-0.0731	-0.0113	-0.0418	-0.0139	-0.0012
East Fork Deer Cr.	0.0554	0.7178	-0.6470	0.0683	0.4458	0.0512	-0.0647	0.0801	-0.0073	-0.0470	0.0140	-0.0414	0.0271	-0.0011
Henrieville Cr.	-0.3235	-0.3423	-0.5128	0.4093	-0.1236	-0.1853	0.1146	0.0561	-0.1157	-0.1264	0.0379	0.0125	-0.0083	-0.0008
North Fork Virgin R.	-0.2266	-0.1367	-0.4939	-0.2308	-0.2434	-0.2050	0.0163	-0.1253	0.1031	0.1392	-0.0234	0.0126	-0.0029	-0.0025

Table 17. Values of each orthogonal factor for the 84 watersheds in the State.

Stations	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14
(Great Salt Lake Division)														
Woodruff Cr.	-0.0189	0.1153	0.1061	-0.0458	0.1621	-0.1032	-0.0738	0.0026	0.0824	-0.0074	0.0229	0.0199	0.0138	-0.0884
Farmington Cr.	-0.3766	-0.0542	0.1858	0.0760	0.0532	0.1830	-0.0481	0.1129	-0.0416	-0.0903	-0.0040	-0.0220	-0.0014	-0.0013
Holmes Cr.	-0.6707	-0.0277	0.1112	-0.0762	-0.1751	-0.1708	-0.0820	0.0420	-0.0242	-0.0068	0.0382	-0.0082	-0.0371	0.0036
Parrish Cr.	-0.4302	0.0477	0.1773	0.0577	-0.2319	-0.0477	-0.0381	-0.0121	0.1162	0.0449	-0.0252	-0.0304	0.0088	0.0015
Rick Cr.	-0.2961	0.0997	0.2944	0.1096	-0.3100	0.1644	-0.0707	-0.0473	0.0974	0.1817	-0.0463	0.0430	-0.0129	-0.0016
Centerville Cr.	-0.4091	0.0575	0.2600	0.0685	-0.2262	0.0538	-0.1181	0.0326	-0.0970	0.0759	0.0272	-0.0386	0.0144	-0.0009
City Cr.	-0.2351	0.0465	0.0138	0.0967	0.0929	0.1324	-0.0656	-0.0399	-0.0574	-0.0764	0.0034	0.0311	0.0436	-0.0006
Blacksmith Fork	0.0467	0.2055	0.1505	0.0373	0.0822	0.0334	-0.0373	-0.1156	0.0649	-0.0591	0.0306	-0.0143	-0.0072	0.0040
East Fork Little Bear R.	-0.0194	0.1629	0.1763	0.0303	0.1057	0.0629	-0.0073	-0.0555	0.0601	-0.0046	0.0184	-0.0208	-0.0017	0.0057
Hardscrabble Cr.	-0.1639	0.1174	0.1408	-0.0283	0.0966	0.0594	-0.0328	0.0424	0.0877	-0.0189	-0.0344	-0.0106	-0.0117	0.0067
Mill Cr. nr. Bountiful	-0.3352	0.0049	0.1072	0.0587	0.0191	0.1078	-0.0655	0.0341	-0.0504	-0.0640	0.0048	-0.0072	0.0132	-0.0059
Stone Cr.	-0.4121	0.0656	0.2270	0.0442	-0.1700	0.0007	-0.1074	0.0483	-0.0942	-0.0183	0.0507	-0.0098	0.0106	-0.0001
South Fork Ogden River	0.0878	0.2994	0.1749	0.0142	0.1220	-0.0815	0.0500	-0.1122	-0.0314	-0.0026	0.0567	0.0293	-0.0149	0.0039
Lost Cr.	-0.1160	0.1683	0.0676	0.0362	0.0842	-0.0106	-0.0199	-0.1230	0.0773	-0.0211	-0.0205	0.0361	0.0019	0.0070
Big Cr.	-0.0350	0.2177	0.1050	-0.1761	0.1821	-0.2037	-0.0808	-0.0417	-0.0195	-0.0527	0.0832	0.0160	0.0266	0.0160
Birch Cr.	0.3091	0.2018	0.2101	0.1346	0.0681	-0.0370	-0.1172	-0.0281	0.0883	-0.0107	0.0519	-0.0312	0.0002	0.0075
Hobble Cr.	-0.1255	0.1264	0.0472	-0.0998	0.0858	-0.0071	0.1448	-0.0195	0.0130	0.0180	-0.0222	-0.1281	-0.0047	0.0013
American Fork	-0.4542	-0.1610	-0.0810	-0.0751	0.1603	0.0795	0.0957	0.0416	-0.0045	0.0274	-0.0436	-0.0422	-0.0028	0.0026
Fort Cr.	-0.2417	0.0687	-0.2005	0.1937	0.0254	-0.0651	-0.1658	-0.1532	-0.2569	-0.0047	0.0303	-0.0560	0.0061	-0.0031
Dry Cr.	-0.6138	-0.1889	-0.2399	0.1767	-0.0948	-0.2509	-0.0803	-0.0373	0.1222	-0.0250	-0.0759	0.0208	-0.0458	0.0031
Big Cottonwood Cr.	-0.4204	-0.1743	-0.0055	-0.0716	0.1445	0.0843	0.1059	0.0864	0.0569	0.0791	-0.0388	-0.0570	0.0107	-0.0116
Parleys Cr.	-0.1352	0.1774	0.0756	0.0329	0.1035	0.0717	0.0264	-0.0637	0.0722	-0.0004	-0.0489	0.0323	0.0404	0.0047
Miller nr. SLC	-0.3967	-0.0497	0.0110	-0.0914	0.1863	0.0853	0.0330	0.0587	-0.0641	0.0286	-0.0229	-0.0334	0.0060	0.0065
Emigration Cr.	-0.2352	0.2298	0.0958	-0.0894	0.1447	-0.0429	0.0483	-0.0334	0.0207	0.0191	-0.0214	-0.0049	0.0530	0.0078
Little Cottonwood Cr.	-0.5525	-0.2742	-0.2064	-0.0515	0.1088	0.1867	-0.0379	-0.0157	-0.0581	-0.0832	-0.0273	0.0482	0.0168	0.0015
Logan River	-0.0979	0.0520	0.0931	0.1411	0.1246	0.1233	0.0041	-0.1404	0.0798	-0.0508	-0.0164	-0.0061	-0.0125	0.0031
(Uinta Division)														
Little Brush Cr.	0.3270	-0.0574	0.2588	-0.0315	-0.0403	-0.0217	-0.0180	0.0460	0.0021	-0.1029	-0.0256	0.0027	-0.0026	0.0014
Brush Cr.	0.1906	-0.0831	0.2689	-0.2136	-0.0292	-0.0627	0.0504	0.0701	0.0191	0.0786	-0.0207	0.0091	0.0242	0.0083
Ashley Cr.	0.3015	-0.1201	0.0605	-0.0638	-0.0877	-0.0004	-0.0532	-0.0590	0.0016	-0.0588	-0.0303	-0.0246	-0.0065	-0.0011
Ashley Cr. bel. Trout Cr.	0.4025	-0.1015	0.2251	0.0634	0.0284	0.0220	-0.0085	0.0545	-0.0259	-0.0191	0.0056	0.0356	0.0253	0.0009
South Fork Ashley Cr.	0.3033	-0.2149	0.1246	0.0402	0.0406	0.0274	0.0080	0.0452	-0.0581	-0.0162	0.0208	-0.0199	-0.0033	0.0007
East Fork Dry Fork	0.2158	-0.0715	0.2148	0.0673	-0.0601	-0.0225	0.2212	-0.0652	-0.0156	0.0087	0.0043	0.0119	-0.0423	-0.0015
E. Fk. Dry Fk. at mouth	0.1448	-0.0557	0.1423	0.0245	-0.1081	0.0049	0.1700	-0.1454	-0.0366	-0.0248	-0.0186	0.0291	-0.0438	-0.0051
North Fork Dry Fork	0.2351	-0.1781	0.1208	-0.0194	-0.1615	-0.0666	-0.0603	0.0045	-0.0042	-0.0470	0.0246	-0.0435	0.0001	-0.0014
Dry Fork	0.2914	-0.1917	0.0205	-0.0095	0.0134	0.0130	-0.0489	-0.0235	-0.0112	0.0294	-0.0105	-0.0047	0.0119	0.0003
Whiterocks River	0.1275	-0.2629	-0.0366	-0.0479	-0.0481	0.0595	-0.0617	-0.0468	0.0524	-0.0585	-0.0382	0.0248	-0.0070	-0.0009
Whiterocks R. above P. C.	0.1789	-0.2724	0.0237	-0.0252	-0.0012	-0.0013	-0.0229	0.0251	0.0318	0.0001	0.0080	0.0145	0.0265	0.0023
Carter Cr.	0.2559	-0.1664	0.0817	0.0346	-0.0238	0.0363	-0.0077	-0.0540	-0.0565	0.0195	-0.0070	-0.0171	-0.0452	-0.0029
Farm Cr.	0.1006	0.0045	0.1087	-0.2508	-0.0754	-0.0726	-0.0378	-0.0557	-0.0183	-0.0077	-0.0048	0.0690	-0.0034	0.0008
Clover Cr.	0.0933	-0.2144	0.0470	0.1975	-0.1227	-0.0229	0.1271	-0.1085	-0.0411	0.1004	0.0426	0.0508	0.1049	-0.0016
Uinta R. above Clover Cr.	0.0974	-0.3431	-0.0988	-0.0879	0.0690	-0.0115	-0.0448	0.0271	-0.0251	0.0256	0.0409	-0.0220	0.0207	0.0019

Uinta R. below Gilbert Cr.	0.1438	-0.3823	-0.0193	0.0907	0.0630	-0.0536	0.0092	0.0933	0.0070	0.0451	0.0617	-0.0389	0.0216	0.0015
Yellowstone Cr. bel. S. cr.	0.0680	-0.3320	-0.1041	-0.1031	-0.0143	-0.0173	-0.0151	-0.0007	0.0961	0.0101	0.0297	-0.0224	0.0138	0.0014
Yellowstone Cr.	0.1286	-0.2797	-0.2180	-0.0777	-0.0047	0.0279	-0.0784	-0.1174	0.0654	0.0213	-0.0001	0.0045	0.0289	0.0007
Lake Fork	0.0720	-0.3172	-0.1325	-0.0434	0.0550	-0.0244	-0.0649	0.0217	0.0292	0.0413	0.0348	-0.0189	0.0239	0.0036
Rock Cr. nr. Mt. Home	0.0148	-0.2393	-0.1287	-0.1245	-0.0060	0.0521	-0.0491	-0.0454	0.0878	-0.0236	0.0092	0.0182	0.0056	0.0022
Rock Cr. nr. Hanna	-0.0375	-0.2151	-0.0539	0.0222	0.0447	0.0193	0.1812	-0.0710	-0.0197	0.0348	0.0620	0.0190	-0.0345	-0.0026
Duchesne River	0.0114	-0.1622	-0.0323	0.0973	0.0897	0.0314	0.1593	-0.0615	0.0003	0.0734	0.0210	-0.0332	-0.0089	-0.0008
Provo River	0.0568	-0.1234	-0.0526	0.3804	0.0710	-0.2685	0.0753	0.0250	0.1450	-0.0419	-0.0028	-0.0439	-0.0041	0.0047
Weber River	-0.1010	-0.0944	-0.0784	-0.0367	0.0730	0.0459	0.0787	-0.1028	0.0262	0.0101	0.0029	0.0061	0.0123	0.0010
Wolf Cr.	0.1338	0.0323	0.0106	0.0322	0.1221	-0.0391	-0.1498	0.0437	-0.0759	0.0112	0.0008	0.0367	-0.0470	-0.0119
West Fork Duchesne River	0.2510	0.0258	0.0045	0.1021	0.0896	0.0706	-0.1171	-0.0072	-0.0425	0.0237	0.0074	0.0074	-0.0227	0.0142
W. Fk. Duchesne River below Dry H.	0.2042	0.0106	0.0349	0.1122	0.1145	-0.0156	-0.0954	0.0633	-0.0295	-0.0293	0.0203	-0.0101	-0.0258	0.0059
Water Hollow	0.1873	0.1471	-0.2053	-0.0180	0.2229	-0.1104	-0.1691	-0.0985	-0.0832	0.2096	-0.0801	0.0021	-0.0696	0.0032
White River	0.1574	0.0791	0.1869	-0.0854	0.0486	0.0637	-0.0397	0.1619	0.0282	-0.0219	-0.0068	-0.0070	0.0013	0.0040
North Fork White River	0.0981	0.0875	0.1747	0.1028	0.0344	0.0622	0.1622	0.0454	-0.0045	-0.0106	-0.0102	-0.0051	-0.0109	-0.0010
Minnie Maud Cr.	0.1084	0.1733	0.1097	-0.2622	-0.0266	-0.0847	0.0734	-0.0020	0.0279	0.0624	-0.0175	0.0566	-0.0150	0.0035
Carter Cr. at mouth	0.2620	-0.0775	0.0721	-0.0228	-0.1507	0.0168	-0.0628	-0.1581	-0.0415	-0.0015	-0.0383	-0.0428	0.0054	-0.0036
Brown Duck Creek	0.1335	-0.2443	0.0752	0.0139	-0.0128	-0.0661	-0.0407	0.0491	-0.0431	-0.0091	-0.0562	0.0223	-0.0364	-0.0008
Hades Creek	-0.2727	-0.1481	-0.0212	-0.1905	-0.0338	0.0167	0.1006	-0.0752	-0.1620	0.0388	0.0874	0.0648	-0.0151	-0.0028
(Southern Division)														
Summit Cr.	-0.2503	0.0372	-0.0895	-0.1821	-0.0736	-0.1676	0.0698	0.0413	0.0539	0.0059	0.0747	0.0132	-0.0032	0.0043
Price River	0.1420	0.0699	0.0707	-0.0019	0.1079	0.0918	-0.0082	0.0990	-0.0094	0.0423	-0.0250	0.0205	-0.0075	0.0022
Gooseberry Cr.	-0.0665	0.0393	-0.0582	0.1129	0.0750	0.0660	0.0975	-0.0245	0.0020	-0.0371	-0.0389	0.0944	-0.0233	0.0069
Pleasant Cr.	-0.1592	-0.0174	-0.1108	0.1014	-0.0260	-0.1440	0.0036	0.0476	0.0311	-0.0206	-0.0157	0.0286	0.0147	0.0027
Huntington Cr.	0.0357	0.0284	-0.0649	-0.1473	0.0369	-0.0274	-0.0506	0.0930	0.0258	-0.0176	0.0088	-0.0002	-0.0409	0.0040
Cottonwood Cr.	0.0905	0.0242	-0.1621	-0.1053	-0.0448	0.0511	-0.0669	-0.0223	0.0406	-0.0093	-0.0196	0.0152	-0.0174	0.0004
Ferron Cr.	0.1362	0.0874	-0.1192	-0.1046	-0.0644	0.0342	-0.0578	-0.0014	0.0256	-0.0289	0.0016	0.0076	-0.0410	-0.0002
Muddy Cr.	0.1532	0.0272	-0.0981	0.0049	-0.0474	0.0899	-0.0653	0.0592	-0.0071	-0.0577	0.0114	0.0038	0.0100	0.0028
Twin Cr.	-0.2257	0.0546	-0.1524	-0.0164	-0.0094	-0.2939	0.0097	0.0276	-0.0035	-0.0940	0.0139	0.0415	0.0109	0.0045
Ivie Cr.	0.1851	0.2226	-0.0716	-0.1182	-0.0627	-0.1049	0.0319	0.0373	0.0150	0.0444	0.0180	-0.1019	0.0236	0.0009
Chalk Cr. nr. Fillmore	-0.0663	0.2412	-0.0749	-0.0557	0.0110	-0.0694	0.0591	0.0596	-0.0251	0.0417	0.0666	-0.0276	-0.0140	0.0021
Indian Cr.	0.0485	-0.0458	0.0351	-0.0586	-0.0715	-0.1209	0.1280	0.2097	-0.1513	-0.0410	-0.1530	-0.0172	-0.0184	-0.0043
Center Cr.	-0.0021	0.2099	-0.2727	-0.0947	-0.1781	0.1472	0.0251	-0.0051	0.0377	-0.0434	0.0801	-0.0036	-0.0011	-0.0030
Beaver River	0.0134	0.0518	-0.2717	0.0778	-0.1029	0.1108	0.0679	-0.0026	0.0111	-0.0270	0.0618	-0.0267	-0.0468	-0.0044
Sevier River	0.2695	0.2343	-0.2304	0.0991	-0.1073	0.0815	-0.0099	0.0836	0.0845	-0.0377	0.0506	-0.0468	-0.0077	-0.0004
Castle Cr.	0.0434	0.0765	-0.0795	-0.1150	-0.1169	-0.0440	0.1247	-0.0320	-0.0216	-0.1542	-0.0910	0.0053	0.0286	-0.0031
Mill Cr. nr. Moab	0.2702	0.1588	-0.1945	-0.0355	-0.1486	0.0176	0.0530	-0.1858	-0.1014	-0.0577	-0.0761	-0.0903	0.0159	-0.0079
North Cr.	0.1977	0.2124	-0.2559	-0.0566	-0.0379	0.0280	-0.0798	0.0357	-0.0002	0.0603	-0.0277	0.0251	0.0587	0.0017
Pine Cr.	0.1768	0.2286	-0.2616	-0.0388	-0.0478	0.0372	-0.1246	0.0196	0.0262	0.0733	-0.1055	0.0098	0.0519	0.0015
Coal Cr.	-0.0107	0.1861	-0.2557	-0.0005	-0.0755	0.1336	0.0748	0.0743	0.0365	0.0276	0.0716	0.0448	-0.0405	-0.0019
East Fork Boulder Cr.	0.2797	-0.0741	-0.1096	0.1067	-0.0847	0.1386	-0.0464	0.2055	0.0079	0.0208	0.0305	0.0436	-0.0102	-0.0017
East Fork Deer Cr.	0.1135	0.1060	-0.1308	0.3718	-0.0096	-0.1561	0.0732	0.1293	-0.0751	0.0434	-0.0207	0.0611	0.0361	-0.0008
Henrieville Cr.	0.1224	0.3874	-0.0807	-0.0021	-0.0046	-0.0326	0.1338	0.0683	-0.0897	-0.0099	0.0103	0.0235	0.0431	-0.0006
North Fork Virgin R.	-0.0346	0.3077	-0.2428	0.0883	-0.0340	0.1172	0.1272	0.0419	0.0213	0.0280	-0.0138	-0.0103	-0.0175	-0.0034

Table 19. Egienvalues, cumulative proportion of total variance, and coefficients of regression equations for the analysis of Uinta Division.

Eigenvalues

4.0654	3.0708	2.2714	1.3791	0.9748	0.6313	0.5479	0.3749
0.3312	0.1446	0.1043	0.0734	0.0295	0.0016		

Cumulative proportion of total variance

0.29	0.51	0.67	0.77	0.84	0.89	0.92	0.95
0.97	0.99	0.99	1.00	1.00	1.00		

Coefficients of regression equations using orthogonal factors for standardized independent variables

Intercept	10.6141164
Coeff. of factor	
1	11.3946134
2	0.6443955
3	- 6.5398867
4	0.5471651
5	6.7261587
6	- 2.4584332
7	- 0.5257256
8	- 1.2042626
9	-16.1577375
10	1.2859127
11	-16.7057650
12	-15.7376238
13	9.9445006
14	8.2388368

Table 20. Eigenvalues, cumulative proportion of total variance, and coefficients of regression equations for the analysis of Southern Division.

Eigenvalues

4.3656	2.7176	1.8616	1.3870	1.2540	0.8349	0.6360	0.3364
0.2406	0.1431	0.1073	0.0841	0.0316	0.0002		

Cumulative proportion of total variance

0.31	0.51	0.64	0.74	0.83	0.89	0.93	0.96
0.97	0.98	0.99	1.00	1.00	1.00		

Coefficients of regression equations using orthogonal factors for standardized independent variables

Intercept	7.1929160
Coeff. of factor	
1	9.0950645
2	7.1816297
3	- 1.7783582
4	- 3.3103988
5	0.5661619
6	2.7362303
7	- 5.4512215
8	8.7245253
9	- 6.2346119
10	- 0.8841201
11	6.6727305
12	6.0857539
13	0.4831579
14	-75.3204069

Table 21. Eigenvalues, cumulative proportion of total variance, and coefficients of regression equations for the analysis of State.

Eigenvalues

4.7428	2.5024	1.8628	1.0758	0.9170	0.7935	0.6240	0.5112
0.3638	0.2557	0.1597	0.1156	0.0661	0.0095		

Cumulative proportion of total variance

0.34	0.52	0.65	0.73	0.79	0.85	0.89	0.93
0.96	0.97	0.99	0.99	1.00	1.00		

Coefficients of regression equations using orthogonal factors for standardized independent variables

Intercept	9.8457116
Coeff. of factor	
1	-11.9483027
2	-20.9651089
3	- 5.5595341
4	14.8529350
5	8.0916208
6	- 5.3157883
7	- 5.1644294
8	2.6158484
9	8.5779911
10	-11.0135244
11	9.0799360
12	14.6991757
13	-28.2978663
14	44.4225082

Table 22. Reduction in residual sum of squares due to using orthogonal factors and multiple correlation coefficients of the stepwise equations.

Residual sum sq.	28.3118286
Total sum sq.	1087.7168427

Orthogonal factors	Reduction in sum of squares	Accumulative reduction in sum of squares	Correlation coefficients
1	732.4214401	732.4214401	0.821
5	148.8196507	881.2410908	0.900
4	72.7763968	954.0174876	0.937
12	34.3862939	988.4037815	0.953
9	15.9436042	1004.3473857	0.961
10	11.6338952	1015.9812809	0.966
14	9.9867220	1025.9680029	0.971
7	9.2077668	1035.1757697	0.976
2	8.8135710	1043.9893407	0.980
15	7.6879613	1051.6773020	0.983
11	3.9088088	1055.5861108	0.985
8	1.8896822	1057.4757930	0.986
3	1.1772424	1058.6530354	0.987
6	0.5943731	1059.2474085	0.987
13	0.1576801	1059.4050886	0.987

Table 23. Reduction in residual sum of squares due to using orthogonal factors and multiple correlation coefficients of the stepwise equations.

Residual sum sq. 109.3289337
Total sum sq. 921.6161575

Othogonal factors	Reduction in sum of squares	Accumulative reduction in sum of squares	Correlation coefficients
1	527.8405991	527.8405991	0.757
3	97.1475506	624.9881497	0.823
9	86.4666100	711.4547597	0.879
5	44.0995560	755.5543157	0.905
11	29.0976365	784.6519522	0.923
12	18.1782041	802.8301563	0.933
6	3.8153185	806.6454748	0.936
13	2.9130340	809.5585088	0.937
2	1.2751397	810.8336485	0.938
18	0.5436573	811.3773058	0.938
4	0.4129002	811.7902060	0.939
10	0.2391188	812.0293248	0.939
17	0.1514230	812.1807478	0.939
14	0.1065151	812.2872629	0.939

Table 24. Reduction in residual sum of squares due to using orthogonal factors and multiple correlation coefficients of the step-wise equations.

Residual sum sq. 318.1004333
Total sum sq. 730.0650253

Othogonal factors	Reduction in sum of squares	Accumulative reduction in sum of squares	Correlation coefficients
1	361.1234055	361.1234055	0.703
2	140.1629982	501.2864037	0.829
8	25.6033280	526.8897317	0.850
7	18.8978236	545.7875553	0.865
4	15.2001107	560.9876660	0.877
9	9.3538616	570.3415276	0.884
6	6.2509627	576.5924903	0.889
3	5.8873065	582.4797968	0.893
11	4.7786182	587.2584150	0.897
12	3.1155727	590.3739877	0.899
14	1.0694409	591.4434286	0.900
5	0.4019567	591.8453853	0.900
10	0.1118718	591.9572571	0.900
13	0.0073675	591.9646246	0.900

Table 25. Reduction in residual sum of squares due to using orthogonal factors and multiple correlation coefficients of the stepwise equations.

Residual sum sq. 640.4382935
Total sum sq. 2982.5747375

Othogonal factors	Reduction in sum of squares	Accumulative reduction in sum of squares	Correlation coefficients
2	1099.8857269	1099.8857269	0.607
1	677.0912552	1776.9769821	0.772
4	237.3390694	2014.3160515	0.822
5	60.0377188	2074.3537703	0.834
3	57.5773973	2131.9311676	0.845
13	52.8929381	2184.8241057	0.856
10	31.0157948	2215.8399005	0.862
9	26.7701790	2242.6100795	0.867
12	24.9762173	2267.5862968	0.872
6	22.4226334	2290.0089302	0.876
14	18.8158882	2308.8248184	0.880
7	16.6431761	2325.4679945	0.883
11	13.1705462	2338.6385407	0.885
8	3.4980882	2342.1366289	0.886

DISCUSSION

A summary comparing the results from both types of regression analysis is given in Tables 26 and 27. Table 26 compares the percent of the variation in water yield that each orthogonal factor explains with the percent of information from the original physiographic data matrix that it contains. The orthogonal factors are ranked in descending order with respect to the amount of variance in measured water yield that each would account for. For example, orthogonal factor 1 in the Great Salt Lake Division accounts for, or reduces the variance in measured water yield by 67 percent and contains 46 percent of the information in the physiographic data matrix. It may be noted from Table 26 that the rank of the orthogonal factors with respect to water yield is not well correlated with their rank with respect to the physiographic data. In other words, the fact that a particular orthogonal factor ranks high in explaining variation in the data matrix does not guarantee that it will rank high in explaining variation in some other parameter for which a predictive relationship is sought.

This fact needs particular emphasis because a common procedure in using principal component analysis is to only calculate the orthogonal factors whose eigenvalues are greater than unity and assume that all the significant information is contained therein. The acceptance of this procedure would have resulted in the inclusion of only the first four or five orthogonal factors as the principal components for subsequent regression with water yield. Table 26

Table 26. Comparison of reduction in variance of water yield by each orthogonal factor and physiographic information each factor contains.

	Great Salt Lake Division			Uinta Division			Southern Division			State		
Rank according to runoff correlation	Orthogonal factor	Reduction in variance of water yield (%)	Physiographic information contained (%)	Orthogonal factor	Reduction in variance of water yield (%)	Physiographic information contained (%)	Orthogonal factor	Reduction in variance of water yield (%)	Physiographic information contained (%)	Orthogonal factor	Reduction in variance of water yield (%)	Physiographic information contained (%)
1	1	67	46	1	57	29	1	55	31	2	37	18
2	5	14	7	3	11	16	2	12	20	1	23	34
3	4	7	7	9	9	2	8	4	3	4	8	8
4	12	3	1	5	5	7	7	3	4	5	2	6
5	9	1	2	11	3	0	4	2	1	3	2	13
6	10	1	1	12	2	1	9	1	1	13	2	1
7	14	1	0	6		5	6	1	6	10	1	1
8	7	1	3	13		0	3	1	13	9	1	3
9	2	1	19	2		22	11	1	1	12		0
10	15		0	8	1 (ranks 7–14)	3	12		1	6		6
11	11		0	4		10	14	1 (ranks 10–14)	0	14	1 (ranks 9–14)	0
12	8		2	10		2	5		9	7		4
13	3	1 (ranks 11–15)	8	7		3	10		1	11		2
14	6		4	14		0	13		0	8		4
15	13		0									
Total		97	100		88	100		81	100		77	100

Table 27. Comparison of correlation coefficients derived from multiple regression (MR) and principal component regression (PC) for equal number of terms in the equations.

No. of	Great Salt Lake Division		Uinta Division		Southern Division		State	
terms	(MR)	(PC)	(MR)	(PC)	(MR)	(PC)	(MR)	(PC)
1	.850	.821	.676	.757	.730	.703	.731	.607
2	.914	.900	.782	.823	.833	.829	.809	.772
3	.929	.937	.806	.879	.867	.850	.824	.822
4	.940	.953	.830	.905	.876	.865	.850	.834
5	.959	.961	.862	.923	.882	.877	.858	.845
6	.965	.966	.895	.933	.886	.884	.868	.856
7	.969	.971	.910	.936	.888	.889	.870	.862
8	.977	.976	.922	.937	.892	.893	.875	.867
9	.982	.980	.931	.938	.900	.897	.881	.872
10	.985	.983	.938	.938	.900	.899	.833	.876
11	.986	.985	.939	.939	.900	.900	.885	.880
12	.986	.986	.939	.939	.901	.901	.885	.883
13	.987	.987	.939	.939	.901	.901	.886	.885
14	.987	.987	.939	.939	.901	.901	.886	.886
15	.987	.987						

shows that this could have greatly restricted the predictive power of any equations developed using the first four factors only. For example, if only orthogonal factors 1, 2, 3 and 4 had been used for the Great Salt Lake division in obtaining a regression equation for water yield a correlation coefficient of 0.86 would have resulted, whereas using factors 1, 5, 4 and 12 gave a correlation coefficient of 0.95. Similar observations may be made for factors in each of the other divisions. This indicates that when principle component analysis is to be used with regression that enough factors should be derived to account for all of the variance in the data matrix of "independent" variables. Otherwise the information thrown out may be that which is most or quite highly correlated with the dependent variable for which a relationship is sought.

Table 27 gives a comparison of the multiple correlation coefficients of the various equations developed using both ordinary multiple regression and principal component regression. The comparison indicates that principal component regression did not yield better predictive equations that ordinary regression when all variables are included in the predictive equation. In fact, when a single parameter is highly correlated with the water yield, the correlation coefficient of the most highly correlated orthogonal factor may be less than that of a single highly correlated physiographic parameter. This case is shown in Table 27 for the equations developed using data for each division except the Uinta Division. In fact, each of the equations developed using all 84 watersheds in the State derived from ordinary multiple regression had equal or higher correlations than the corresponding equations derived from principal component analysis. The ordinary multiple regression equations developed from Southern division data had equal or higher correlations until 7 terms had been used and those in the Salt Lake division until 2 terms had been used in the principal component analysis. All principal component equations for the Uinta division had higher correlation coefficients than their corresponding ordinary multiple regression equations. This seems to indicate that as the homogeneity of the "independent" variable or information matrix is reduced the more difficult or less likely it is that any single variable will be entirely contained in any one orthogonal factor. In other words the information a single parameter contains will be more widely distributed throughout the whole set of orthogonal factors. Consequently, no single orthogonal factor may be as highly correlated with the dependent variable as the original single untransformed parameter.

A common objective in the application of principal component regression analysis is to reduce the number of variates in the model, thereby effecting an economy in representation and, as a corollary, to develop a rank list for the importance of the several variates. One disadvantage of the principal component analysis is the difficulty in assessing the real physiographic significance of the new factors represented by the relative magnitudes of each element in the eigenvectors of the eigenvector matrix. In the analysis of the Great Salt Lake division, a 0.953 multiple correlation coefficient is obtained when only four orthogonal factors were included in the regression analysis. By considering just those variables of each factor that have large coefficients in the eigenvector it appears that the first factor is a general "precipitation" factor, the fifth is "elevation-latitude," the fourth is "drainage density," and the twelveth appears to be a "slope factor-vegetative" factor, however, the values of the other elements of the respective eigenvectors are not insignificant so these interpretations are still quite arbitrary. An examination of the eigenvector elements for the entire study reveals a similar difficulty so an interpretation of the physiographic significance of each orthogonal factor is not attempted here.

The application of the principal component regression equations is more complicated and more tedious than the ordinary ones because the evaluation of each orthogonal factor requires evaluation or measurement of every physiographic parameter used in the analysis. Thus, even if the equation involving only orthogonal factor one for the Great Salt Lake division was deemed suitable, the evaluation of the value of factor one would necessitate the measurement of all 15 of the physiographic parameters used in the ordinary regression analysis, dividing each element of raw data by its standard deviation and then multiplying that result by its respective element in the factor one eignevector. However, in this report, a simple procedure is proposed to simplify the evaluation of each factor. This procedure is to draw an isogram of each orthogonal factor and then determine the factor value from it much as one determines precipitation from an isohyetal map or elevation from a topographic map. Orthogonal factors 1, 5 and 4 for the Great Salt Lake division have been plotted in Figure 1 to illustrate the procedure. The regression of water yield on these three factors will give a multiple correlation coefficient of 0.937.

The feasibility of using the iso-maps shown in Figure 1 was tested by comparing values of runoff obtained from them with that obtained by using equations given in Special Report 18, Utah Agricultural Experiment Station, for some watersheds in the Great Salt Lake division. The choice of the watersheds used for comparison was primarily a matter of expediency because runoff values for them had been previously computed by Mr. Frank Haws in connection with some other work he was doing. They were thought to be quite suitable for comparison purposes because none of them were used in the development of the regression equations and thus would give some idea concerning the extrapolative power of the two methods. The results are summarized in Table 28 and reveal that the average error from the principal component analysis equations is considerably less than the corresponding error from the multiple regression equations for these watersheds.

It must be emphasized that these results are not conclusive because the iso-maps in Figure 1 are merely first approximations and to be generally used would require a considerable amount of refinement by calculating factor values for watersheds in areas that will provide definition where uncertainties now exist. However, the results do indicate that the principal component equations may be superior for extrapolative purposes.

Appendix C

Table 33. Percent of total area covered by type of vegetation for the Great Salt Lake Division

Watershed	Coniferous trees	Broadleaf trees	Brush lands	Sagebrush	Saltbrush	Herbaceous[a]	Pinon-juniper
Woodruff Cr.	30	17		53			
Farmington Cr.			100				
Holmes Cr.			30	50		20	
Parrish Cr.			60	40			
Ricks Cr.			50	50			
Centerville Cr.			29	71			
City Cr.			92	8			
Blacksmith Fk.	28	27	7	38			
East Fk. Little Bear R.		30	37	33			
Hardscrabble Cr.		58	42				
Mill Cr. nr. Bountiful			100				
Stone Cr.		7	47	46			
South Fk. Ogden R.		24	54	22			
Lost Cr.	3	29	27	35	6		
Big Cr.	17	18		65			
Brich Cr.		20		80			
Hobble Cr.	23	70				7	
American Fk.	18	23	34			25	
Fort Cr.			50	10		40	
Dry Cr.			65			35	
Big Cottonwood Cr.	46	11	7	14		22	
Parleys Cr.		43	56	1			
Mill Cr. nr. SLC	61	25	14				
Emigration Cr.			87	13			
Little Cottonwood Cr.	17			10		73	
Logan R.	51	13	11	18		1	6

[a]Also includes desert type, foothill types, mountain types, and barren inaccessible.