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SEVEN YEARS OF WEATHER MODIFICATION IN CENTRAL AND SOUTHERN UTAH

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Abstract. A **post-hoc** statistical evaluation of an operational cloud seeding project, designed to enhance winter snowfall in the mountainous sections of central and southern Utah, was based on comparison between several control areas and multiple target areas. Linear regression equations were developed for each control-target area combination based on average January-March precipitation, 1956-1973; from 1974 through 1980 the target was seeded consistently during these months. Ratios of observed to calculated precipitation are presented for the target areas and several sub-target areas based on the predictions using the control area precipitation as predictor for the seeded years. Significance of the results was determined using a one-tailed Wilcoxon-Mann-Whitney ranking test.

On the basis of this evaluation it is concluded that seeding has been successful in increasing the January-March precipitation within the intended target areas over the seven year seeded period. The results vary depending on the control area, but all are positive. Indicated increases range from about eight percent to twenty-eight percent within the various target sub-sectors. Over the total Primary Target precipitation increases of between 13 and 20 percent are indicated. These results appear to be highly significant in most of the target areas. Some evidence of positive extra-area effects are noted "downwind" from the target, but with less statistical significance than the target areas.

1. INTRODUCTION

Utah is one of the driest of the 50 states; much of the precipitation that does fall accumulates as high elevation snowpack from October to April. For irrigated agriculture, important in the state, streamflow from these accumulated snowpacks is necessary, and any additional runoff that can be acquired is valuable. An operational weather modification program in central and southern Utah began in the 1973-74 winter and has continued each winter through the present. Sponsors of the program are the Utah Water Resources Development Corporation (formerly Southern Utah Water Resources Development Corporation) and the State of Utah, Division of Water Resources (DWR), an active participant since 1975.

The program goal has been to increase winter snowpack at higher elevations of participating counties in central and southern Utah. North American Weather Consulants (NAWC), the weather modification contractor since the program's inception, has evaluated the effectiveness of the program for both five and seven years of operation. The more recent 7-year evaluation of seeding of winter-spring seeding 1974-1980, is reported here.

2. BACKGROUND

The intended target areas of the program, as defined in an earlier design study (Thompson **et al.**, 1978), encompasses some 19,000 sq km (12,000 sq mi) of mountains in central and southern Utah. Commissioners or water conservancy districts of counties potentially involved in the program vote annually whether to participate. The DWR then shares the cost of the program. On the average, 12 counties have particpated annually since the state involvement began in 1975 (Figure 1).

Both silver iodide (AgI) ground generators and seeding aircraft were used in selected storm periods until 1979, after which only ground generators were used. Manually operated units are supplemented by remotely controlled units at higher elevations. For the current 1980-81 season, 75 manual and 4 remote generators were installed.

The program is strictly an operational program designed to optimize any benefits, without any randomization. Portions of naturally occurring storms deemed seedable by established seedability criteria (Thompson **et al.**, 1978) are seeded. Consequently, evaluation has relied upon comparisons of target and control precipitation.

The earlier evaluation of five years of seeding (Thompson, 1979) also was based upon comparisons of target control precipitation, but only from January to March. This was the only period consistently seeded during the five years. This five-year evaluation work was independently verified by the

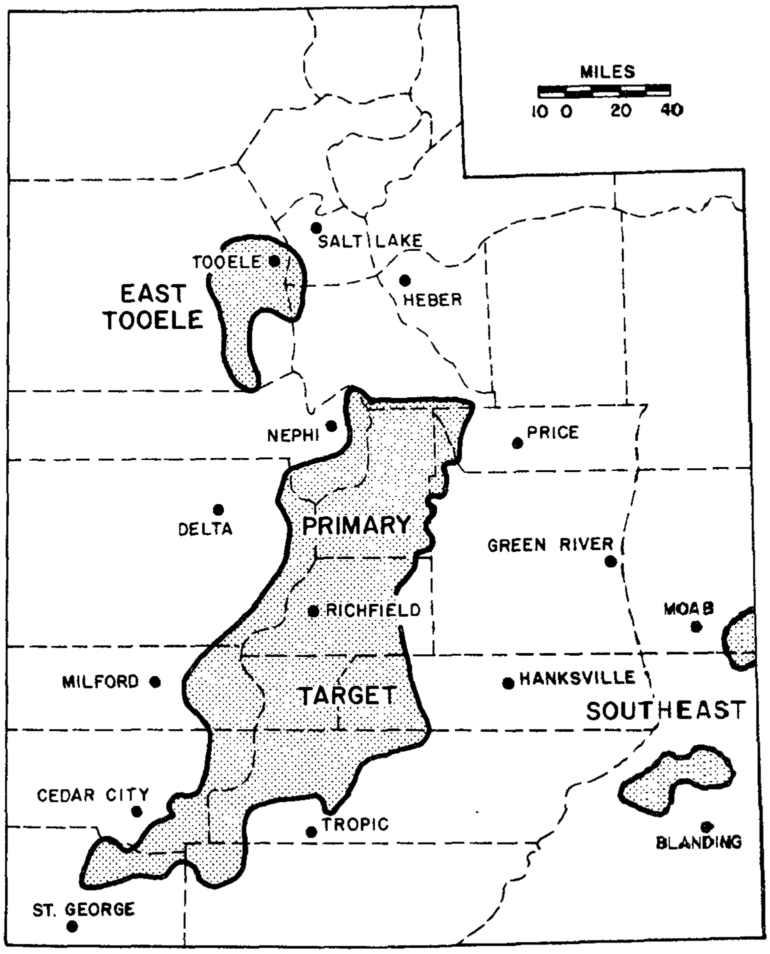

Fig. 1. County seats of Utah counties involved in weather modification program and project target areas (hatched), 1974-1980.

Division of Water Resources (Div. of Water Resources, 1981).

Thompson (1979) found that the 1974-78 January-March precipitation in the Primary Target was greater than that predicted by the regression equations. Some differences between observed and calculated values were highly significant, particularly in the southern half of the target. For the total target, the indicated increase due to seeding was approximately 18 percent, highly significant at the .018 level by the Wilcoxon-Mann-Whitney rank test.

Both this evaluation and that of the DWR were reviewed by a Technical Advisory Board organized by the DWR to provide guidance and expertise. Dr. Ruben Gabriel, Univ. of Rochester statistician, reviewed the five-year evaluation as part of a National Oceanic and Atmospheric Administration (NOAA) program to design a comprehensive evaluation of both the Utah and North Dakota state/local seeding programs.

The major recommendation of both the Technical Advisory Board and Dr. Gabriel was for additional analyses using other stations as control areas, since the evaluation used control stations selected **post hoc**. The new analyses were suggested to confirm that comparable results could be achieved with different controls. In addition, Dr. Gabriel recommended elimination of four of the stations in the original ten station control due to their proximity to the target.

These recommendations have been followed; the results of the evaluation, updated to cover seven years of seeding, 1974-1980 follows.

3. EVALUATION APPROACH

To cover seven years of seeding the evaluation approach is the same as that of the five-year evaluation; e.g., statistical, using the correlation between a control area and a target area to determine the apparent effectiveness of seeding. Like the previous five-year evaluation, the basic data consist of January through March precipitation.

The control in the five-year evaluation consisted of ten precipitation measuring stations in west-central Utah (one station was actually just over the state line in Nevada). As suggested by Dr. Gabriel, four stations in the eastern part of the control, near the western edge of the target, were eliminated, leaving a six station control (C_1 in Fig. 2). A second control (C_2) included six precipitation stations located in Nevada, Arizona, and Utah. Few stations in eastern Nevada and northern Arizona have long-term stable records of precipitation so Lehman Cave National Monument, Nevada was included in both controls. Otherwise, C_2 stations were much farther removed from the target than C_1. Combining the average precipitation at each of the 11 individual stations of C_1 and C_2 produced yet another control (C_3) extending from eastern Nevada and western Utah to northwestern Arizona. Table 1 provides a listing of all the precipitation stations. All three of the controls were used to develop regression equations for the various targets (Table 2); ratios of observed target precipitation to calculated precipitation were determined for each target-control relationship (Table 3).

Four target areas, e.g., Central, South Central, Dixie and the east Tooele County target area (not included in the five-year evaluation), and two supplemental areas (Eastern and North Central) were used. The Eastern area is not in the intended target area, but was included to investigate potential extra area effects. The North Central area was selected to seek seeding effects in an area not expected to be directly affected by the seeding. In this manner, some assessment could be made of whether there was some bias in the seeded years favoring the likelihood of detecting a "seeding effect".

The isolated target areas in southeastern Utah were not evaluated in the five-year evaluation and have also been excluded from this evaluation due to lack of long-term precipitation stations. Precipitation gage locations are indicated in Fig. 2 by a circle and storage gage locations are shown by an "X". Most precipitation gages are in valleys at lower elevations, with storage gages at elevations above 3360 m (8000 ft MSL). Seeding in the east Tooele area did not begin until 1975-76, so the evaluation for that section is for January-March, 1976-1980.

Precipitation stations with reliable long-term records were sought in the Climatological Data for Arizona, Nevada and Utah, published by the National Climatic Center, NOAA, Storage-Gage Precipitation Data for western United States, also published by the National Climatic Center, and the Water Supply Outlook for Utah, published by the Soil Conservation Service, USDA. Except for some storage gages, data were available back to about 1950. However, another seeding project had been conducted in southern Utah from 1951 to 1955 (Hales **et al**, 1955). To eliminate any possible effect from that seeding these years were excluded and the historical data base was formed from January-March precipitation 1956-1973.

3.1 Data Quality

The control area stations had consisent data, although occasional monthly totals were reported as estimated. Precipitation data were available in the Central target for 17 low elevation stations and 17 storage gages at higher elevations. Less than five percent of the data were missing but, on those occasions when they were, estimates were made from surrounding locations by plotting the available data on charts and drawing isohyetals around the missing data areas. For the eight storage gages installed during 1956 and the one in 1957, data were estimated from surrounding data in a similar manner. The storage gages normally were read at or near the end of each month. When two or more months were combined, an interpolated value for the desired period was computed from the known percentage of precipitation which fell at the surrounding sites.

In the South Central target area, the 12 low elevation precipitation gages all have consistent records. Data were available from five storage gages, although 1956 data were estimated at two. Less than three percent of the historical data were missing from the storage gages, and all was available in the seeded years.

The Dixie target area has five lower elevation precipitation stations, and two storage gages, at lower elevations than the ones in the Central and South Central target areas. These sites were not activated until 1959 and the data for the first three years have been estimated from surrounding locations.

The six precipitation gages in the Eastern supplementary area, just east of the Wasatch Plateau all had good data. The North Central supplemental area had ten stations at both low and high elevations, three of which were storage gage sites at intermediate levels between 2250 and 2450 meters. To select stations less likely to be affected by the seeding generator sites to the west and northwest (i.e., generator locations used to seed the Stansbury and Oquirrh Mountains in east Tooele

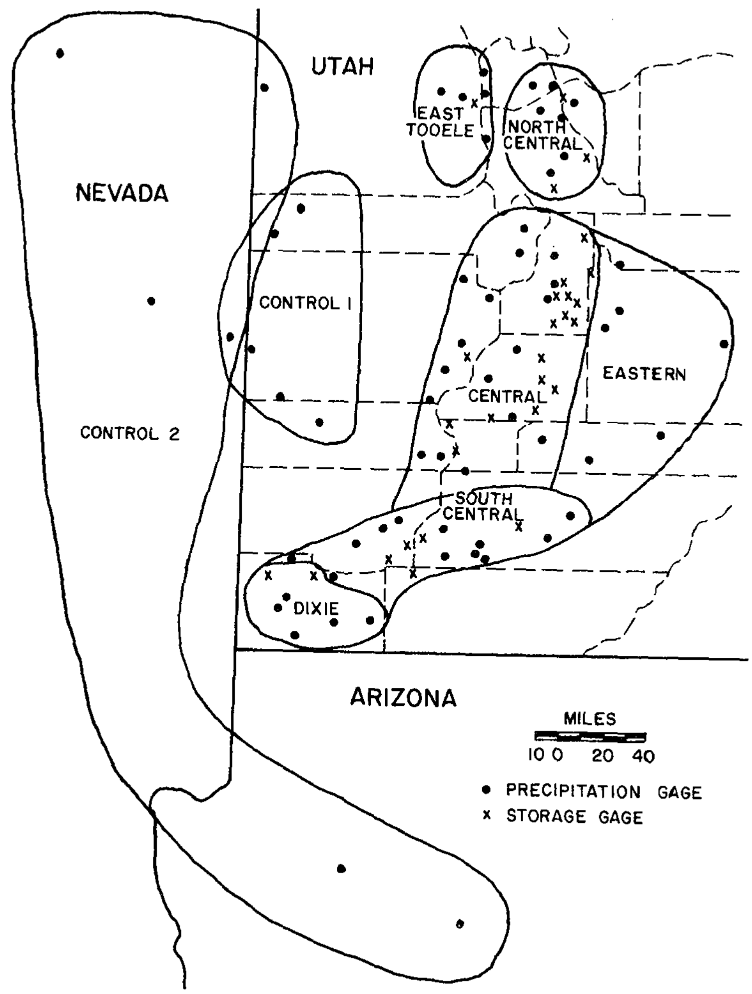

Fig. 2. Control, target, and supplemental areas.

County), precipitation gages in the Salt Lake and Provo areas were not chosen.

3.2 Data Compilation

Precipitation for each station within a group, either the controls or the various target groups, was summed for three months, January through March, for each individual year. These three monthly totals were then summed for all the stations within the group and averaged to obtain a "yearly" average.

Station histories of the precipitation gages indicate that many have been moved from a few to several hundred meters; elevation changes were generally less than 30 meters, but occasionally as much as 120 meters. A few gages have been moved one to as much as five kilometers, but records at the nearest gages suggest no appreciable changes have occurred.

The storage gages' histories indicate a more stable pattern with little movement. Minor elevation changes (generally less than 60 meters) occurred at about half the sites. None of the moves was significant enough to change the station precipitation pattern and thereby affect the regression computations.

4. RESULTS

Separate linear regressions were developed relating average January-March precipitation, (1956-1973), in each of the target areas to that in the three control groups (C_1, C_2, and C_3). These equations were then applied to 1974-1980 control area precipitation to estimate the target area precipitation if it had not been seeded.

Ratios of the observed target precipitation (Yo) to the calculated precipitation (Yc) were computed and tested by the Wilcoxon-Mann-Whitney ranking test (onetailed). Where appropriate, target groups were stratified by elevation (valley precipitation gages and mountain storage gages).

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Table 1. Precipitation stations.

Index No.	Name	Lat.	Long.	Elev (ft)	Group	Avg. Jan-Mar Precip. (inches) 1956-73	1974-80
Arizona							
6328	Peach Springs	35-32	113-25	4810	C2	2.63	4.17
9359	Williams	35-15	112-11	6750	C2	5.00	7.04
Nevada							
2573	Elko FAA AP	40-50	115-47	5075	C2	2.65	3.15
2631	Ely WSO AP	39-17	114-51	6257	C2	2.14	2.71
4514	Lehman Cave N.M.	39-00	114-13	6825	C1,2	3.17	3.35
Utah							
0449	Bartholomew PH	40-10	111-30	5140	NC	7.67	9.35
0519	Beaver	38-17	112-38	5920	CE	2.40	3.51
0527	Beaver Canyon PH	38-16	112-29	7275	CE	5.15	8.03
0534	*Beaver Dams	39-08	111-33	8000	CE	7.99	9.92
0684	*Big Flat	38-18	112-21	10290	CE	9.32	13.23
0700	Bingham Canyon 2NE	40-34	112-08	5620	ET	6.05	6.13
0733	*Blacks Fl. UM Ck.	38-41	111-36	9400	CE	6.86	8.79
0849	Boulder	37-55	111-25	6700	SC	2.01	3.93
0892	*Box Creek	38-30	112-02	9800	CE	7.79	10.72
1002	Bryce Canyon FAA AP	37-42	112-09	7585	SC	2.32	4.83
1008	Bryce Canyon NP Hdq.	37-39	112-10	7915	SC	3.13	4.98
1012	*Buck Flats	39-08	111-27	9400	CE	9.64	12.42
1144	Callao	39-54	113-43	4330	C1	1.00	1.06
1171	Capitol Reef NP	38-17	111-16	5500	EA	.65	1.70
1214	Castle Dale	39-13	111-01	5660	EA	1.22	2.33
1239	*Castle Valley	37-40	112-44	9580	SC	7.82	10.55
1267	Cedar City FAA AP	37-42	113-06	5620	SC	2.17	3.73
1432	Circleville	38-10	112-16	6060	CE	1.83	2.09
1759	Cottonwood Weir	40-37	111-27	4960	NC	6.14	7.10
1792	Cove Fort	38-36	112-35	5990	CE	3.35	4.80
2057	Deer Creek Dam	40-24	111-32	5270	NC	6.39	9.94
2116	Desert Exp. Range	38-36	113-45	5252	C1	.97	1.73
2255	*Duck Creek RS	37-31	112-42	8700	SC	9.87	14.51
2279	*Dutchman GS	40-32	111-36	7560	NC	11.65	15.14
2558	Enterprise	37-34	113-43	5340	SC	3.87	6.72
2565	*Ephraim Alpine Meadows	39-18	111-27	10000	CE	12.54	15.25
2573	*Ephraim Hdq. GBRC	39-19	111-29	8700	CE	9.89	12.13
2574	*Ephraim Majors Flat	39-20	111-31	6880	CE	5.37	6.69
2576	*Ephraim Oaks	39-21	111-31	7655	CE	6.61	8.31
2578	Ephraim Sorensen Fld.	39-21	111-35	5670	CE	2.76	3.90
2592	Escalante	37-46	111-36	5810	SC	1.73	3.50
2696	Fairfield	40-16	112-05	4876	ET	2.47	4.54
2752	*Farnsworth Lake	38-46	111-40	9600	CE	11.22	12.41
2798	Ferron	39-05	111-08	5930	EA	1.53	2.69
2828	Fillmore	38-57	112-19	5120	CE	4.41	5.18
2847	*Fish Lake RS	38-33	111-43	8700	CE	4.65	6.68
3097	Garfield	40-43	112-12	4300	ET	3.68	5.35
3138	Garrison	38-56	114-02	5275	C1	1.41	2.22
3298	*Gooseberry RS	38-48	111-41	8000	CE	7.66	8.80
3301	*Gooseberry Res.	39-41	111-19	8700	CE	10.37	13.85
3348	Grantsville	40-36	112-27	4290	ET	2.77	3.04
3418	Green River Avn.	39-00	110-10	4070	EA	.95	2.02
3506	Gunlock PH	37-17	113-43	4060	DX	3.70	6.56
3611	Hanksville	38-22	110-43	4308	EA	.67	1.62
3776	Hatch	37-39	112-26	6910	SC	1.66	4.17
3809	Heber	40-30	111-25	5630	NC	4.37	5.97
3896	Hiawatha	39-29	111-01	7220	EA	2.82	4.15
4005	*Hobble Ck. Sum.	40-11	111-22	7420	NC	9.56	11.90
4527	Kanosh	38-48	112-46	5050	CE	3.57	4.92
4668	*Kimberly Mine	38-29	112-23	9100	CE	10.36	12.67
4764	Koosharem	38-31	111-53	6950	CE	1.57	2.60
4968	La Verkin	37-12	113-16	3200	DX	3.73	6.07
5065	Levan	39-33	111-52	5315	CE	4.07	4.53
5131	*Little Grassy Ck.	37-29	113-51	6100	DX	7.15	13.10
5148	Loa	38-24	111-39	7080	CE	.97	1.29

Table 1 (Cont'd.)

Index No.	Name	Lat.	Long.	Elev (ft)	Group	Avg. Jan-Mar Precip. (inches) 1956-73	1974-80
Utah							
5197	*Long Flat	37-30	113-25	8000	DX	6.25	9.59
5402	Manti	39-15	111-38	5740	CE	3.33	4.49
5603	*Middle Canyon	40-29	112-12	7000	ET	9.40	13.30
5837	Moroni	39-32	111-35	5525	CE	2.45	3.34
5906	*Mount Baldy RS	39-08	111-30	9500	CE	10.14	13.01
6135	Nephi	39-43	111-50	5133	CE	3.75	4.59
6181	New Harmony	37-29	113-18	5290	SC	5.50	9.56
6357	Oak City	39-23	112-20	5070	CE	3.16	4.70
6601	Panguitch	37-49	112-27	6720	SC	1.70	2.49
6606	*Panguitch Lake RS	37-43	112-38	8320	SC	3.68	5.99
6686	Parowan Apt.	37-51	112-50	5930	SC	3.57	3.10
6708	Partoun	39-39	113-53	4750	C1	1.09	1.50
6729	*Payson RS	39-56	1-1-38	8050	NC	9.89	11.37
6840	*Pine Creek	38-53	112-15	8780	CE	12.83	15.56
7230	*Red Pine Ridge	39-27	111-16	9000	CE	11.17	13.28
7260	Richfield Radio KSVC	38-46	112-05	5270	CE	1.78	2.37
7516	Saint George	37-07	113-34	2760	DX	2.49	4.52
7557	Salina	38-37	111-52	5190	CE	2.50	3.13
7714	Scipio	39-15	112-06	5306	CE	3.36	4.97
7846	Silver Lake Brighton	40-36	111-35	8740	NC	15.00	16.01
8119	Spanish Fk. PH	40-05	111-36	4720	NC	5.04	6.28
8456	Summit	37-48	112-56	5950	SC	3.03	3.72
8733	Timpanogos Cave	40-27	111-42	5640	NC	6.94	9.02
8771	Tooele	40-32	112-18	5070	ET	4.09	5.55
8847	Tropic	37-38	112-05	6280	SC	2.72	4.47
9136	Veyo Power House	37-21	113-39	4600	DX	3.94	6.66
9152	Wah Wah Ranch	38-29	113-25	4960	C1	1.27	1.34
9352	*Webster Flat	37-35	112-54	9200	SC	11.27	18.49
9382	Wendover Autob.	40-44	114-02	4237	C2	.98	1.31
9512	*Widtsoe Esc. #3	37-50	111-53	9640	SC	6.39	9.65
9717	Zion National Park	37-13	112-59	4050	DX	4.66	7.46

* - Storage gage

Group

C1 - Control 1
C2 - Control 2
CE - Central target
NC - North Central
SC - South Central
DX - Dixie
EA - Eastern
ET - East Tooele

In general, the correlation coefficients (Table 2) were good to very good ($\geq$ .80) for most of the target-control relationships, although a few were .73 to .79. They were poorest with the six station control in western Utah (C_1) and improved with both the expanded six station control (C_2) and the combined eleven station control (C_3).

Differences between observed and predicted precipitation increased from north to south in the three sections of the Primary Target area (i.e., Central, South Central and Dixie), and become correspondingly more significant statistically in the southern regions. In general, C_1 provides the greatest and C_2 the least indication of differences. C_3 (the combined control) typically provides an estimate between these two controls, and often provides the highest statistical significance of the three.

While the indicated results of seeding for each of the sub-sections are important, perhaps the most important aspect is the apparent effect of seeding for the total Primary Target (Table 3, Group 4). The ratio of seeded precipitation to that calculated using C_1 indicates an increase of approximately 20% during the seeded seven year period (January-March from 1974-80). Results could be attributed to chance alone in less than 3 cases out of 100. The ratio determined from C_2 indicates approximately a 13% increase, but the level of significance remains high (.032). The results from the combined eleven station control (C_3) indicate a 16% increase significant at the .01 level.

Table 2. Linear regression equations developed for target areas.

Target Group	Linear Regression Equations		
1) Central			
Low elevation	$Yc=1.2\ C_1 + 1.19$	$Yc= .78\ C_2 + .8$	$Yc=1.08\ C_3 + .78$
High elevation	$Yc=2.56\ C_1 + 5.28$	$Yc=1.69\ C_2 + 4.41$	$Yc=2.3\ C_3 + 4.4$
Combined	$Yc=1.88\ C_1 = 3.24$	$Yc=1.24\ C_2 + 2.61$	$Yc=1.69\ C_3 + 2.59$
2) South Central			
Low elevation	$Yc=1.86\ C_1 - .02$	$Yc=1.18\ C_2 - .48$	$Yc=1.61\ C_3 - .99$
High elevation	$Yc=4.21\ C_1 + 1.55$	$Yc=2.66\ C_2 + .46$	$Yc=3.64\ C_3 + .41$
Combined	$Yc=2.55\ C_1 + .47$	$Yc=1.62\ C_2 - .21$	$Yc=2.21\ C_3 - .22$
3) Dixie	$Yc=3.28\ C_1 - .3$	$Yc-2.03\ C_2 - 1.07$	$Yc=2.8\ C_3 - 1.12$
4) Primary Target ($\Sigma 1,2,3$)			
Low elevation	$Yc=1.84\ C_1 + .48$	$Yc=1.17\ C_2 - .02$	$Yc=1.61\ C_3 - .04$
High elevation	$Yc=2.93\ C_1 + 4.44$	$Yc=1.91\ C_2 + 3.52$	$Yc=2.61\ C_3 + 3.5$
Combined	$Yc=2.26\ C_1 + 1.98$	$Yc=1.45\ C_2 + 1.32$	$Yc=1.99\ C_3 + 1.3$
5) Eastern Tooele	$Yc=1.11\ C_1 + 3.1$	$Yc= .65\ C_2 + 2.94$	$Yc=1.00\ C_3 + 2.72$
6) Eastern Supplemental	$Yc= .74\ C_1 + .21$	$Yc= .48\ C_2 - .01$	$Yc= .64\ C_3$
7) North Central Supplemental	$Yc=2.07\ C_1 + 5.2$	$Yc=1.26\ C_2 + 4.77$	$Yc=1.75\ C_3 + 4.71$

where:

Yc = Target group calculated precipitation (inches)
C_1 = Revised control group precipitation (inches)
C_2 = Expanded control group precipitation (inches)
C_3 = Combined (C_1+C_2) control group precipitation (inches)

In eastern Tooele county results of five years of seeding were very similar for each control. Computations from both C_1 and C_2 indicated a precipitation increase of approximately 17% in the target during the seeded period, while the results utilizing C_3 were 15%. The significance levels were .04 to .055.

In the Eastern supplemental area ratios of observed to calculated precipitation were high, with reasonably high statistical significance, suggesting a rather strong possibility of a positive extra-area effect in an area normally "downwind" of the primary target area during storm periods. Although indicated seeding effects yield large percentages in this Eastern region, the absolute magnitudes are relatively small since the normal wintertime precipitation is low.

In the North Central supplemental area ratios of observed to calculated precipitation are greater than one, although they do not approach statistical significance. This region could be affected intermittently by the seeding in either the Eastern Tooele County or northern portion of the Primary Target area.

As indicated in Fig. 3, most of the apparent effects of seeding seem to have occurred during the last three years, although a sizable increase in observed over calculated precipitation is indicated also in 1974. In all, five

Table 3. Summary of correlations, ratios and significance for various sub-sectors of target

Target Group	Correlation Coefficient (r) C_1	C_2	C_3	Ratio (Yo/Yc) C_1	C_2	C_3	Statistical Significance (P) C_1	C_2	C_3
1. Central									
Low elevation	.760	.829	.832	1.178	1.113	1.132	.234	.194	.122
High elevation	.730	.804	.798	1.135	1.083	1.106	.070	.178	.055
Combined	.755	.829	.825	1.144	1.086	1.113	.079	.110	.079
2. South Central									
Low elevation	.846	.896	.889	1.360	1.235	1.282	.028	.010	.017
High elevation	.891	.937	.935	1.262	1.173	1.213	.007	.004	.002
Combined	.874	.922	.918	1.303	1.202	1.244	.012	.007	.002
3. Dixie	.885	.917	.918	1.329	1.228	1.268	.089	.028	.055
4. Primary Target (Σ1,2,3)									
Low elevation	.883	.935	.934	1.272	1.176	1.210	.055	.032	.015
High elevation	.799	.867	.862	1.162	1.102	1.125	.032	.062	.024
Combined	.852	.913	.910	1.204	1.132	1.161	.028	.024	.010
5. Eastern Tooele	.813	.796	.806	1.175*	1.175*	1.155*	.055	.055	.049
6. Eastern (supplemental)	.785	.847	.830	1.522	1.399	1.476	.163	.070	.070
7. North Central (supplemental)	.758	.774	.780	1.137	1.103	1.117	.314	.273	.272

* Eastern Tooele for five-year period, 1976-80.

of the seven seeded years indicate increases over expected values. Little seeding effect is suggested in the drought years of 1976 and 1977, which had few seeding opportunities due to lack of storminess. The year 1975 also indicates that little seeding effect, for reasons that are not as apparent.

5. CONCLUSIONS

Post hoc analyses using three separate controls to predict target precipitation from three sets of regression equations, while differing in indicated percentage increase, generally agree qualitatively. All indicate that the January-March target area precipitation, 1974-1980 (1976-80 for East Tooele), was greater than that predicted by the regression equations. Some differences between observed and calculated (expected) values were highly significant. In the five-year evaluation, Thompson (1979) noted that the southern portion of the Primary Target had higher ratios which achieved greater significance than those in the northern portion. This trend has continued through the seven-year evaluation; the indicated increases in the south are about twice those in the north. The southern area indicates statistical significance about one order of magnitude greater than the northern portion, except for Dixie where several seeding suspensions during the last two years, might account for the lower significance level.

Evidence of positive extra area effects continues to appear to the east of the target, but the results are not highly significant. North of the target, an indication of a minor seeding effect, is even less statistically significant than east of the target where carryover effects could be occurring for the last five years, from seeding in Tooele County.

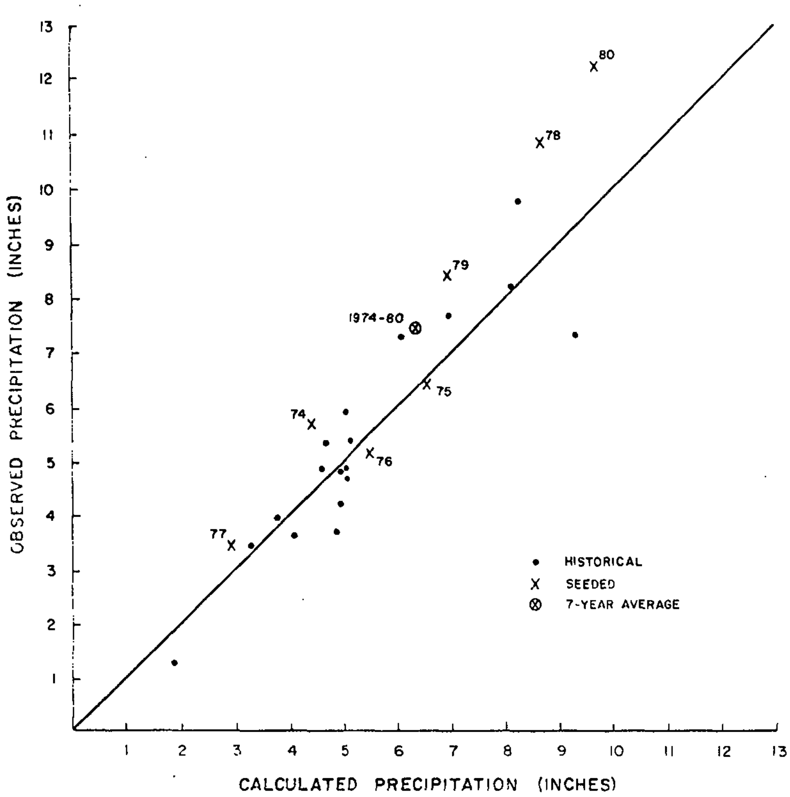

Fig. 3. Comparison of calculated precipitation (based on combined controls, C_1 and C_2) vs. observed January-March precipitation for unseeded and seeded periods, primary target area (low and high elevations combined).

The five-year evaluation (Thompson, 1979) concluded that seeding had increased January-March precipitation within the intended target area of the Utah seeding program. This seven-year evaluation utilizing the revised control and extended area controls corroborates the previous results.

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REFERENCES

Hales, J. Vern, T. E. Hoffer, and E. Peck, 1955: Evaluation of the effects of cloud seeding in southern Utah. Univ. of Utah **Bulletin Vol 46, No. 15**, Salt Lake City, UT, 35 pp.

Thompson, J. R., R. W. Shaffer, C. E. Wisner, and D. A. Griffith, 1978: A design study for a cloud seeding program for the State of Utah. **NAWC Report No. 77-15.** NAWC to State of Utah, Div. of Water Resources.

______, 1979: Evaluation of five years of operations of a central and southern Utah weather modification program, 1974-78. **NAWC Report No. SBWM-79-1.** NAWC to Utah Water Resources Development Corp. and Utah Div. of Water Resources.

Utah Div. of Water Resources, 1981: Evaluation of five years of operation of a Central and Southern Utah weather modification program.