SUMMARY OF RESULTS OF A RANDOMIZED CLOUD SEEDING PROJECT IN ARIZONA

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During the summers of the four year period 1957 to 1960, a series of randomized cloud seeding tests was conducted over the Santa Catalina Mountains in southeastern Arizona. The design of the program has been described by Battan and Kassander [1]. Briefly, one of two succeeding pairs of days was seeded according to a suitable randomization procedure. Silver iodide seeding was carried out by means of an airborne generator of Australian design. The aircraft was flown at an altitude where the temperature was about $-6°$ C along a line perpendicular to the wind at that altitude and located upwind of the mountain target.

A network of 29 recording raingages was distributed as shown in figure 1. The seeding runs ranged from two to over four hours in duration, starting at

TABLE I

SUMMARY OF MEAN RAINFALL PER STATION DURING THE PERIOD 1300 TO 1800 MST ON SEEDED AND NOT SEEDED DAYS—1957 TO 1960

Year	Number of Pairs	Seeded Days	Not Seeded Days	$\frac{S}{NS}$
1957	16	0.067	0.059	1.14
1958	16	0.059	0.041	1.44
1959	20	0.026	0.094	0.28
1960	17	0.0175	0.034	0.51
All data	69	0.041	0.059	0.70
With August 17–18, 1959 excluded	68	0.042	0.045	0.93

about 1230 MST. Effects of seeding on rainfall were sought by examining the rainfall during the period 1300 to 1800 MST.

Details of the preliminary analysis have been given in [2]. Table I summarizes the rainfall data by year and also shows the number of pairs involved.

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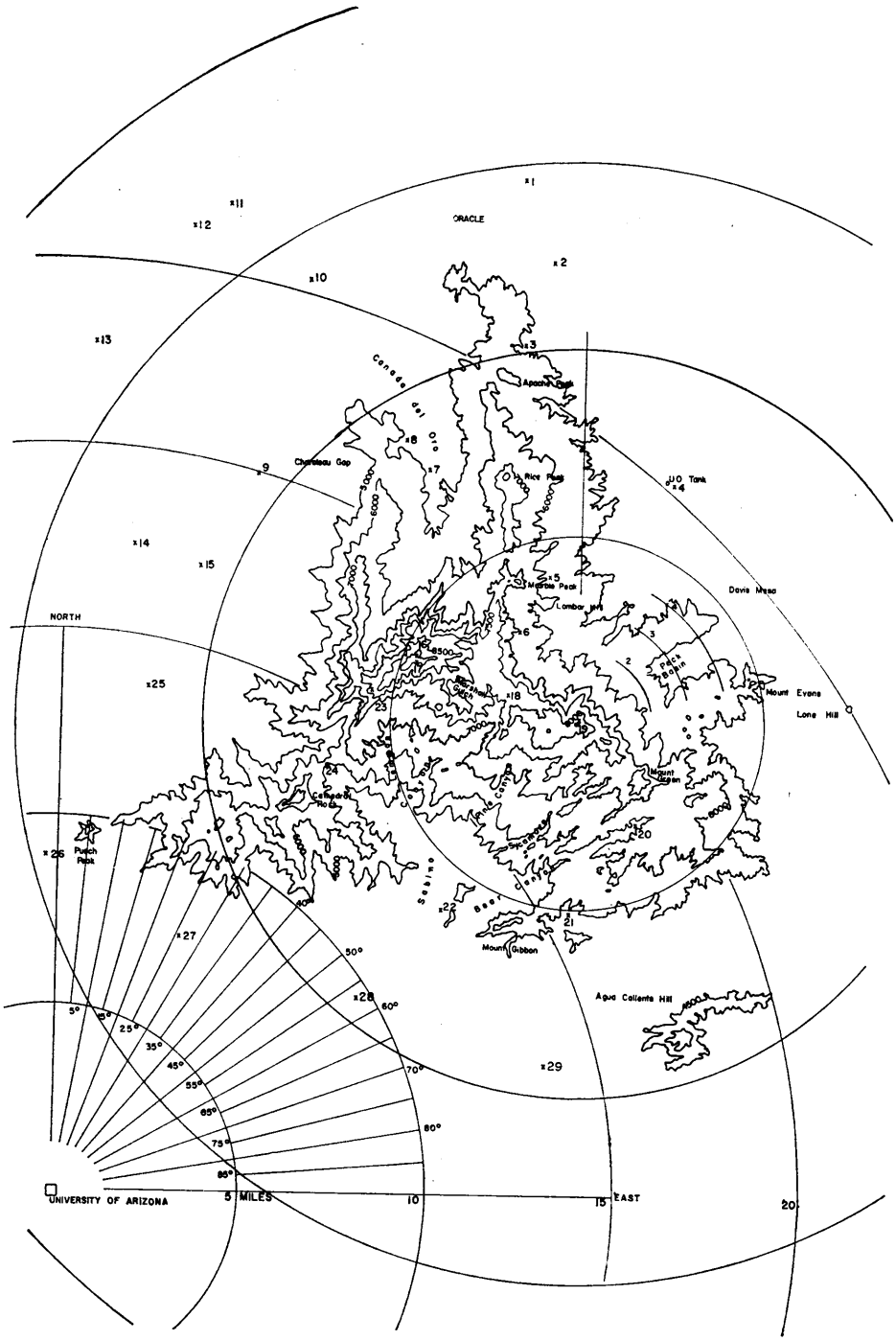

FIGURE 1

Target area and location of 29 recording raingages used during the period 1957 to 1960.

The last line shows the results given in the report cited above. It excludes one pair of days when the rainfall on the not seeded day was extremely high. The validity of rejecting this pair can be argued, and hence the summary shows the results with and without it. Clearly, these data cannot support the position that, over the four summer period, the precipitation was increased.

At the outset of this program, it was believed there would be a significant day to day correlation in rainfall amounts, and it was planned to use the Wilcoxon signed rank test. After collecting the data it was found that the day to day correlation of rainfall amounts was virtually nonexistent within the pairs of days used in these tests. The null hypothesis that seeding had no effect was tested employing all 69 pairs by means of the signed rank test and the Mann-Whitney U Test and yielded one tail probabilities of 0.30 and 0.45, respectively.

Following the preliminary analysis of the first four years of results, the experimental program was changed and a new set of tests was begun. The most important changes were the following: (1) the flight altitude was established at 1000 to 2000 feet below the cloud bases, but still along a line upwind from the mountain, and perpendicular to the wind direction at flight altitude; (2) the number of raingages was increased to 35 and concentrated over a smaller area as shown in figure 2; (3) the criteria for selecting suitable days was made more restrictive in order to reduce the relative frequency of experimental days with zero rainfall.

A summary of the rainfall data during the summers of 1961, 1962, and 1964 is given in table II.

TABLE II

SUMMARY OF MEAN RAINFALL PER STATION DURING THE PERIOD 1300 TO 1800 MST—1961, 1962, 1964

Year	Number of Pairs	Seeded Days	Not Seeded Days	$\frac{S}{NS}$
1961	17	0.035	0.106	0.33
1962	7	0.029	0.039	0.74
1964	13	0.101	0.072	1.40
All data	37	0.057	0.082	0.70

As with the earlier data, the signed rank test and the Mann-Whitney U Test were used to test the null hypothesis that seeding had no effect. The one tailed probabilities were found to be 0.16 and 0.30, respectively.

In summary, the statistical tests cited above indicate that the observed results could easily have occurred by chance, and thus the hypothesis that seeding had no effect cannot be reasonably rejected. The data do not support the idea that silver iodide seeding can increase precipitation at the ground. Indeed, the observed differences are such as to suggest that if there were any effect at all it was to cause a reduction of rainfall. However, it is important to recognize that these

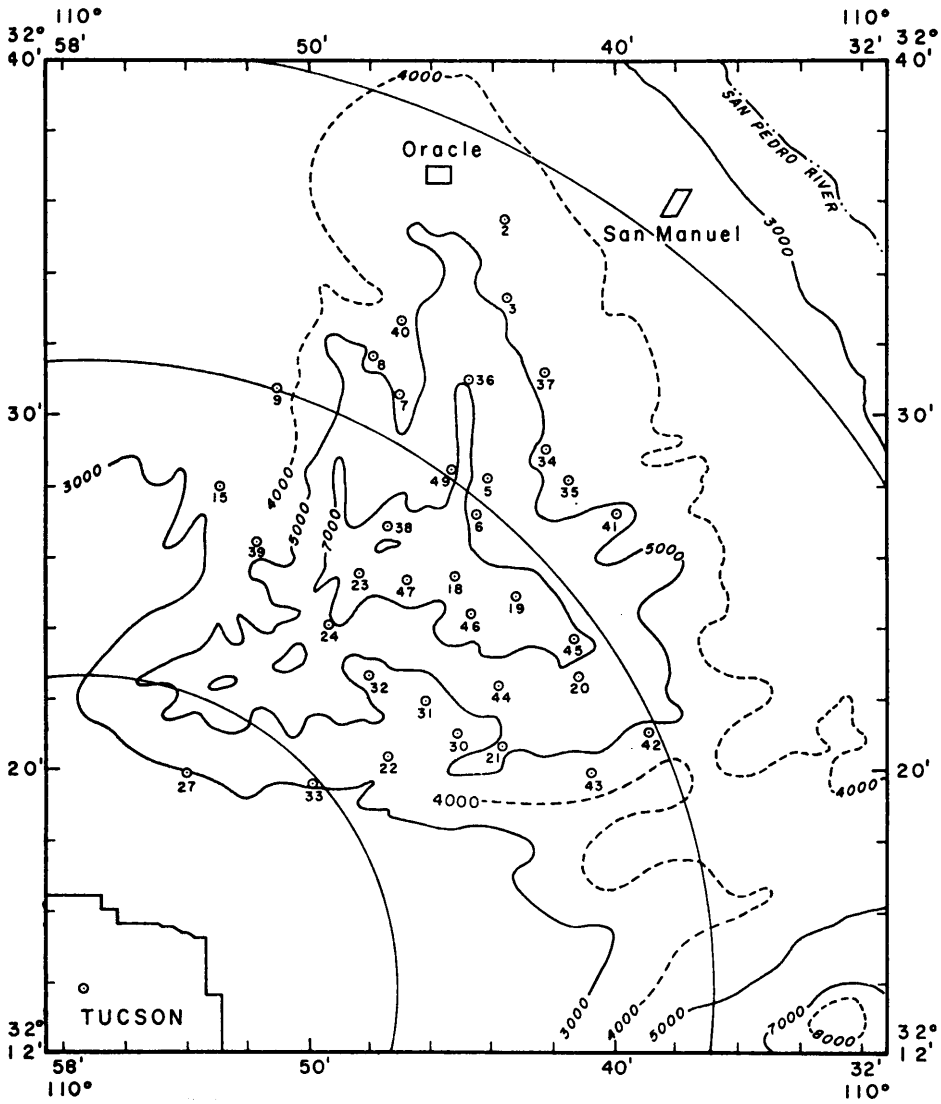

FIGURE 2

Target area and location of 35 recording raingages used during 1961, 1962 and 1964.

tests used a specific type of seeding on a specific class of clouds. These results cannot be directly extrapolated to other techniques, other regions, or even other clouds of similar appearance elsewhere. Furthermore, it should be recognized that the failure of this program to demonstrate an increase of rainfall does not allow the conclusion that it demonstrates that silver iodide seeding cannot increase precipitation.

Finally, the authors wish to note that analyses of the observations made during this program are still in progress. A complete report is being planned for publication in the meteorological literature.

REFERENCES

[1] L. J. BATTAN and A. R. KASSANDER, JR., "Design of a program of randomized seeding of orthographic cumuli," *J. Meteor.*, Vol. 17 (1960), pp. 583–590.

[2] L. J. BATTAN and A. R. KASSANDER, JR., "Evaluation of effects of airborne silver-iodide seedings of convective clouds," *Scientific Report,* No. 18, Institute of Atmospheric Physics, University of Arizona, 1962.