A REAPPRAISAL OF AN EARLY CLOUD SEEDING EVALUATION

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During parts of 1951 and 1952, cloud seeding was done for the purpose of increasing water storage in the Salmon and Stillwater reservoirs of the Niagara Mohawk Power Company in northwestern New York State. Attempts to evaluate the results by reference to precipitation, both by the cloud seeder [1; 2] and by the Advisory Committee on Weather Control [3], failed to achieve either a test of sufficient sensitivity to detect increases in the order of 30 per cent or to show a significant departure of the precipitation, either positive or negative, from expectation. The failure arose from an insufficiency of precipitation data to characterize the target and a lack of good control data. However, an evaluation that compared the runoff from the seeded watersheds with that from nearby control watersheds for the seeded seasons and the fourteen preceding seasons achieved an indication of 32 per cent increase in runoff with a probability of chance occurrence less than 0.005 [4; 5]. The use of runoff as a criterion for evaluation was also, of course, especially appropriate to the purpose of the cloud seeding program.

The passage of time affords an opportunity to reappraise this evaluation by testing the runoffs of subsequent unseeded seasons according to the same criteria used for the seeded seasons. If the particular historical period chosen peculiarly favored a spurious indication of runoff increase, this fact would have an opportunity to show itself as an apparent runoff increase when no seeding was done.

In the original evaluation, the target datum was taken as the logarithm of the mean of the runoffs in inches of water from the Salmon and Stillwater watersheds, and the control datum was the logarithm of the mean of the runoffs in inches of water from the Hinckley and Cranberry Lake watersheds (see fig. 1), each taken month by month for the months June through November from 1937 through 1950 and June through August of 1951 as unseeded history. The regression equation given by the least-square analysis was $y=1.281x-0.108$, with a correlation coefficient of 0.90 and a standard error of estimate of 0.162.

The first seeding season covered September, October, and November of 1951. During this season the cloud seeding was performed by the power-company personnel under the technical direction of the cloud-seeding company, but the utilization and maintenance of equipment were considered unsatisfactory. The t-test of results of these months, individually and combined in a z-test, are shown in table 1.

TABLE 1. Results of 1951 seeding operations.

	Sep.	Oct.	Nov.	Combined
Actual target runoff, in.	1.16	3.25	1.33	5.74
Expected runoff, in.	0.85	3.43	0.96	5.24
Indicated increase, in.	+0.31	−0.18	+0.37	+0.50
t-test	+0.82	−0.10	+0.84	
z-test				+0.90
Probability of "*z*"				0.18

In the second season of seeding, June through November of 1952, the entire project was the responsibility of the cloud seeder, and equipment, utilization and maintenance were kept on a satisfactory basis. The results of these months are shown in table 2.

TABLE 2. Results of 1952 seeding operations.

	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Combined
Actual target runoff, in.	1.30	1.42	0.48	0.82	1.91	2.73	8.66
Expected runoff, in.	1.17	1.48	0.38	0.40	0.89	1.33	5.65
Indicated increase, in.	+0.13	−0.06	+0.10	+0.42	+1.02	+1.40	+3.01
t-test	+0.29	−0.12	+0.62	+1.86	+2.03	+1.90	
z-test							+2.68
Probability of "*z*"							0.0037

Thus the first season gave an encouraging but not significant increase, while the second season, with positive departures in five months out of six, showed an increase that amply meets the usual criteria for significance.

The question is now raised whether this indication is spurious, perhaps caused by some unrelated peculiarity of the runoffs during the historical period. In order to further test the soundness of the evaluation, the runoffs for four subsequent unseeded seasons have now been tested in the same manner as the seeded months. The results are shown in table 3.

TABLE 3. Results of four subsequent seasons without seeding

Month	Target runoff	Expected runoff	Indicated increase	*t*-test
Jun. '53	0.66	0.55	+0.11	+0.49
Jul. '53	0.50	0.44	+0.06	+0.33
Aug. '53	0.62	1.40	−0.78	−2.16
Sep. '53	0.90	0.54	+0.36	+1.36
Oct. '53	0.72	0.66	+0.06	+0.22
Nov. '53	1.52	0.86	+0.66	+1.52
Jun. '54	2.01	3.05	−1.04	−1.11
Ju. '54	0.48	0.32	+0.16	+1.06
Aug. '54	0.94	0.55	+0.39	+1.42
Sep. '54	1.55	1.92	−0.37	−0.57
Oct. '54	1.80	2.06	−0.26	−0.37
Nov. '54	3.11	3.13	−0.02	−0.03
Jun. '55	1.60	1.64	−0.04	−0.07
Jul. '55	0.21	0.37	−0.16	−0.31
Aug. '55	0.06	0.44	−0.38	−5.25
Sep. '55	0.45	0.28	+0.17	+1.24
Oct. '55	3.53	2.14	+1.39	+1.32
Nov. '55	2.18	2.61	−0.43	−0.49
Jun. '56	1.67	2.16	−0.49	−0.68
Jul. '56	1.17	0.74	+0.43	+1.21
Aug. '56	0.54	0.54	+0.00	+0.00
Sep. '56	1.78	2.22	−0.44	−0.59
Oct. '56	1.12	1.22	−0.10	−0.23
Nov. '56	2.08	1.78	+0.30	+0.41
Combined	31.20	31.62	−0.42	

The corresponding value of the *z*-test for the combined results is −0.26, giving a probability of 0.60 that this departure would be exceeded by chance.

The departures, then, accumulated during the seasons 1953 through 1956, without cloud seeding, are quite what would be expected by chance, and the number of positive departures equals the number of negative ones. Furthermore, no one of these four seasons shows an accumulation of departures, positive or negative, comparable in size to the positive departure that occurred during the 1952 seeding season. The validity of the original evaluation is thereby further confirmed, and the acceptability of the hypothesis that cloud seeding significantly increased the 1952 runoff is further enhanced.

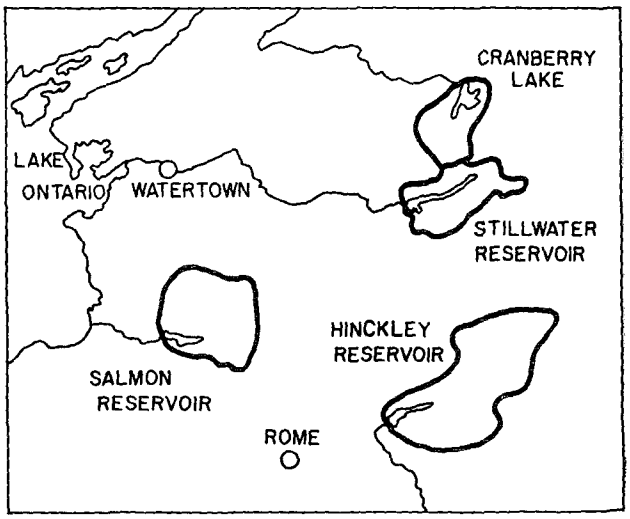

FIG. 1. Location of watersheds used as target (Salmon and Stillwater) and as controls (Cranberry and Hinckley).

REFERENCES

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