

CLOUD-SEEDING IN WESTERN VICTORIA IN 1966

By E. E. Adderley

Division of Radiophysics, C.S.I.R.O., Sydney

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ABSTRACT

In August, September and October 1966 the Victorian Department of Agriculture carried out a cloud-seeding operation in Western Victoria. G. O'Mahony of the Central Office, Bureau of Meteorology, made an assessment of the operation and concluded: "There is no evidence in the present case which points to the rainfall having been affected in any way by the silver iodide". The results of the original assessment and a closer examination of O'Mahony's assessment show that this conclusion is invalid.

1. INTRODUCTION

During the months of August, September and October 1966 the Victorian Department of Agriculture carried out a cloud-seeding operation over an area in the Wimmera and Mallee districts of Western Victoria. The Department of Agriculture sought technical advice on the operation from the C.S.I.R.O.'s Division of Radiophysics and further requested that the C.S.I.R.O. attempt an assessment of the results of the operation.

The basis of this assessment was a network of 45 rain gauges - 21 in the target area and 12 in each of two control areas to the north and south of the target area.

The gauges were selected, before the operation began, as those gauges in the appropriate areas which had continuous records from 1925 to 1965.

In December 1966 a preliminary analysis of the operation was completed and sent to the Department of Agriculture. On the basis of this analysis the Department concluded that an increase of rainfall had occurred due to cloud-seeding and on a moderately conservative estimate of the amount of the increase concluded that it represented an addition to the value of the wheat crop of \$2,000,000.

In the September 1967 issue of the Australian Meteorological Magazine, G. O'Mahony of the Central Office, Bureau of Meteorology, Melbourne, published his assessment of the operation and concludes: "There is no evidence in the present case which points to the rainfall having been affected in any way by the silver iodide".

This paper summarises the analysis upon which the Department of Agriculture's assessment of the operation was based, and attempts to discover why two divergent conclusions came to be drawn from apparently the same data.

2. THE ANALYSIS

The raw data upon which the C.S.I.R.O. analysis was made were the monthly rainfall totals of 21 stations in the target area, and 12 stations in each of two control areas which are north and south of the target area. The mean of the gauge readings in each area is taken as a measure of the rainfall in the area. The list of gauges used is given in Table 1.

Table 1

Target Area		North Control Area	South Control Area
Ouyen	Dimboola	Loxton	Frances
Walpeup	Minyip	Renmark	Kybybolite
Beulah	Jeparit	Paruna	Naracoorte
Berriwillock	Warracknabeal	Pinnaroo	Charam
Birchip	Wycheproof	Lake Victoria Storage	Edenhope
Culgoa	Murtoa	Wentworth	Glenorchy
Hopetoun	Boort	Balranald	Goroke
Kenmare	Charlton	Euston	Harrow
Sealake	Kerang	Bannerton	Natimuk
Ultima		Merbein	Balmoral
Woomelang		Murrayville	Ararat
Quambatook		Mildura	Willaura

During the three operational months the rainfall was 4.79 inches in the target area, and 2.82 inches and 6.35 inches in the north and south control areas respectively.

The ratio of the target area rainfall to the mean control area rainfall during the period was 1.045. The median ratio for the years 1925 to 1965 is 0.834.

For purposes of comparison similar ratios were computed for each of the 41 years 1925 to 1965. These 41 values and their years of occurrence, together with the 1966 value, are shown in order of magnitude in Table 2. From this it is seen that the 1966 ratio was exceeded twice only in the 41 years. (When the original analysis was made in November 1966, only unchecked rainfall figures were available for some of the stations. With these figures the ratio was exceeded only once in the 41 years.)

The probability of the 1966 value occupying third or higher rank is $3/42$ or 0.07.

Also in Table 2 are the corresponding ratios for the three months separately. All the 1966 values occupy high ranks indicating that the three-monthly value is not the result of a single freak occurrence.

There is thus evidence that the rainfall in the target area was unusually high compared with that in the control areas, and that this occurred in the region and during the period when cloud-seeding was carried out. While no statistical or other examination can "prove" or indeed "disprove" that the seeding caused an increase in the target area, the results are consistent with the consensus of previous experience that silver iodide can cause increases in precipitation. As in experiments carried out earlier by C.S.I.R.O. Division of Radiophysics, it is desirable that operations such as this be repeated for a number of successive years. There is every evidence that this will be so in the case of the Victorian Department of Agriculture's operation in Western Victoria.

It must also be emphasised that this is an assessment of an operation undertaken with the specific intention of augmenting the rainfall over a specified area. It is not the analysis of a designed experiment.

Table 2. Ordered ratios of target area rainfall to control area rainfall

Aug.+Sept. +Oct.		August	September	October
	Year			
1.085	1959	1.094	1.531	1.570
1.048	1935	1.074	1.314	1.510
1.045	- 1966	1.071	1.145	1.466
1.037	1961	1.015	1.138	1.414
1.029	1964	0.958	1.105	1.338
1.025	1963	0.920-1966	1.072-1966	1.305
0.989	1954	0.908	1.066	1.290
0.987	1949	0.894	1.032	1.161
0.984	1956	0.863	1.003	1.140
0.974	1960	0.854	0.987	1.105-1966
0.965	1950	0.844	0.962	1.087
0.953	1937	0.839	0.948	1.075
0.928	1955	0.835	0.939	1.057
0.914	1940	0.824	0.892	1.051
0.895	1932	0.824	0.891	1.041
0.887	1947	0.817	0.887	1.019
0.872	1934	0.814	0.883	1.004
0.863	1962	0.803	0.855	0.991
0.854	1958	0.803	0.824	0.986
0.853	1941	0.800	0.808	0.984
0.851	1965	0.796	0.759	0.969
0.834	1930	0.791	0.706	0.913
0.829	1942	0.774	0.682	0.880
0.823	1952	0.774	0.663	0.868
0.795	1943	0.758	0.643	0.835
0.759	1948	0.743	0.618	0.833
0.759	1927	0.726	0.616	0.802
0.754	1928	0.718	0.600	0.786
0.734	1936	0.700	0.593	0.769
0.726	1953	0.680	0.592	0.746
0.720	1951	0.663	0.569	0.659
0.712	1933	0.620	0.564	0.655
0.706	1945	0.615	0.560	0.630
0.702	1946	0.600	0.552	0.628
0.687	1931	0.599	0.531	0.616
0.685	1929	0.598	0.527	0.594

Table 2. (Continued)

Aug.+Sept. +Oct.		August	September	October
	<u>Year</u>			
0.679	1926	0.588	0.481	0.515
0.642	1933	0.578	0.467	0.468
0.635	1925	0.448	0.422	0.440
0.616	1957	0.415	0.409	0.419
0.550	1944	0.322	0.399	0.312
0.473	1938	0.154	0.254	0.160

3. DISCUSSION

As compared with the above, O'Mahony's paper presents the results of tests made on three smaller sets of data:

1. Using five stations from the target area and a control area consisting of the three stations, Bordertown, Kaniva and Serviceton, immediately west of the target area.
2. Using five stations in the target area and two stations from each of the north and south control areas.
3. Using eight stations in the target area and five stations from each of the north and south control areas.

The results from these three sets of data expressed as the rank of the ratio of target to control area rainfall among the ratios from the historical data are given in Table 3.

Table 3

Data Set No.	Rank of T/C
1	22
2	6
3	9

The selection of all three sets of data was made post hoc, which by usual standards makes them rather dubious material upon which to make statistical pronouncements.

The justification given by O'Mahony for the use of these three sets of data rather than the full network available was the existence of correlation coefficients generally greater than 0.8 between pairs of stations in these areas.

The three stations comprising the western control area were selected to satisfy three conditions, two of which are:

- (a) The control stations must be so situated that they are not exposed to seeding material.
- (b) There should be a good correlation between rainfall values in the target and control areas.

O'Mahony considered that the western control area gauges satisfied condition (a) better than the north and south control area gauges, and in fact stated "A control area has been selected carefully to ensure that no part of it can be subjected to the seeding material in any meteorological situation normally associated with rainfall". That this requirement is not satisfied is shown in Fig. 1, which shows the areas in which seeding was carried out during the three operational months. It can be seen that seeding was carried out in the western control area. This alone invalidates any negative conclusion drawn from this analysis.

Seeding was done in this area because (a) on occasions with wind drift towards the target area suitable clouds occurred there and not in the target area, and (b) the area was not a control area and the extent to which down-wind effects of seeding occur is at present unknown.

The three western control area stations were also considered to satisfy condition (b), because of a correlation coefficient of 0.783 between these three stations and five in the target area. This compares rather unfavourably with a correlation coefficient of 0.906 (not quoted by O'Mahony) between 21 gauges in the target area and 12 each in the north and south control areas over the same period.

The sets of data numbers 2 and 3, are small numbers of gauges selected post hoc by O'Mahony from the full network. That the selection of smaller numbers of gauges was at least unjustified can be demonstrated as follows.

A random selection of 5 gauges from the 21 in the target area was made 1000 times, and the ranks of the 1966 ratios of the five gauges selected to the four control area gauges of data set 2 determined among the relevant historical ratios. The distribution of the 1000 ranks so obtained is as follows:

Rank	No. of cases	Rank	No. of cases
1	164	7	48
2	231	8	15
3	201	9	11
4	133	10	3
5	126	11	1
6	67		

With a selection of only five gauges from the target area the result varies from a highly significant rank 1 to a non-significant rank 11. Of the 1000 samples only 30, or 3%, had a lower ranking than the selection made by O'Mahony.

A similar test with eight gauges from the target area and the ten control gauges of data set 3 gave the following result.

Rank	No. of cases	Rank	No. of cases
1	109	8	79
2	116	9	67
3	148	10	25
4	135	11	15
5	109	12	1
6	100	13	1
7	95		

In this case only 42 or 4.2% of the 1000 random samples had lower ranking than that chosen by O'Mahony.

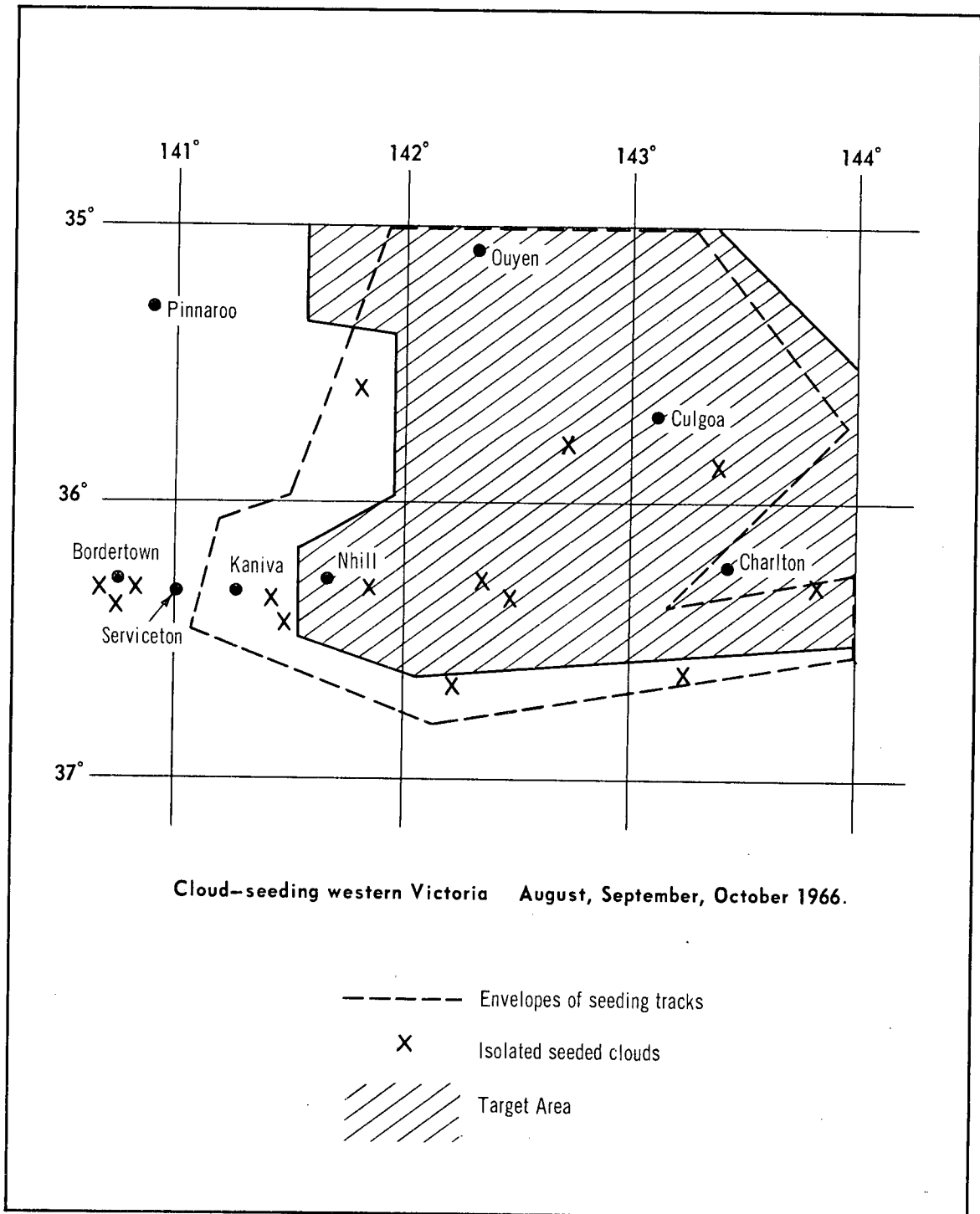


Fig. 1 Map of cloud-seeding operational area, 1966.

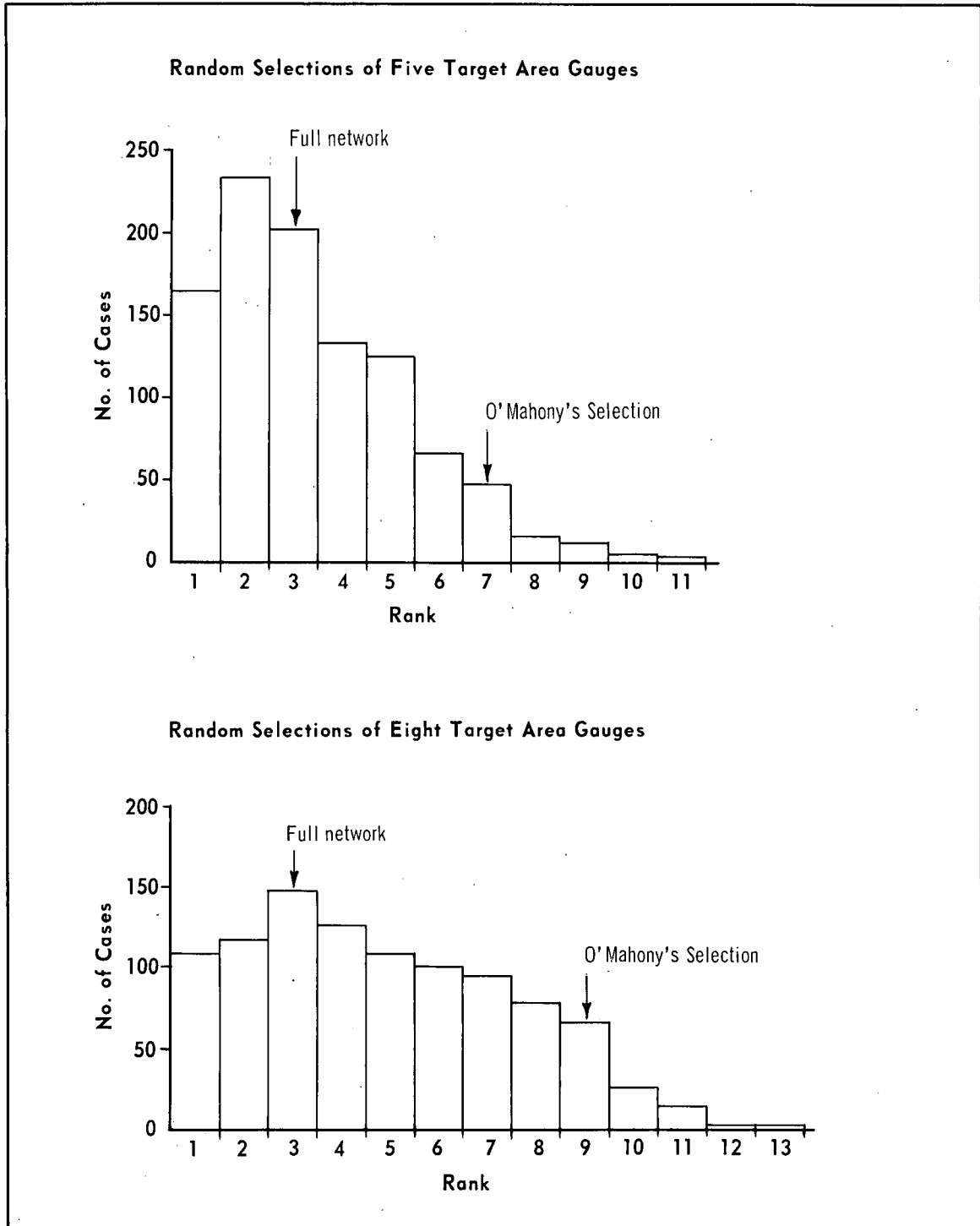


Fig. 2 Histograms of results obtained from random sampling of rain gauges.

Histograms of these two distributions are given in Fig. 2.

It is difficult to understand why O'Mahony chose to ignore the result obtained from the whole network and concentrated attention on a small and what appears to be a non-representative selection of gauges.

4. CONCLUSION

The conclusion drawn by O'Mahony that "There is no evidence in the present case which points to the rainfall having been affected in any way by the silver iodide" is invalid because:

- (a) The selections of gauges made by O'Mahony are not representative of the results; the larger number of gauges available contain evidence which was ignored.
- (b) The selection of gauges was made post hoc.
- (c) The main analysis was made on a selection of gauges as controls which have been shown not to satisfy the conditions assumed by O'Mahony.

The conclusion of "not proven" and "not provable" is valid, but for reasons other than those given by O'Mahony. It is not within the province of statistical tests to "prove" or "disprove"; they merely provide information from which conclusions may be drawn.

Since O'Mahony applied his tests to data which are not truly representative of the area over which the seeding operation was carried out, it is not at all surprising that his conclusions differ from those of the Department of Agriculture.