

## THE SANTA BARBARA RANDOMIZED CLOUD SEEDING PROGRAM

By

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## INTRODUCTION

The Santa Barbara Project is a three-year cloud seeding program designed to obtain the quantity and quality of information that only a well designed experiment can yield. It is unique in that the combined talents and skills of numerous interested parties are being brought to bear upon the program. Organizations participating in, or supporting the program include: The State Water Resources Department, the University of California, Santa Barbara County, the President's Advisory Committee on Weather Control, the National Science Foundation, the Weather Bureau, the Office of Naval Research, the Forestry Service, North American Weather Consultants, and Meteorology Research, Inc.

## HISTORY

In a way, the project is an outcome of the State Water Resources Board's cloud seeding evaluation efforts which appear in Bulletin #16.<sup>2/</sup> In that volume there appears a report of the evaluation of cloud seeding in various parts of California including the projects conducted in Santa Barbara County during the 1950-51 and 1951-52 seasons and part of that conducted during the 1952-53 season. Tables are shown which summarize the results of statistical analyses based upon target to control precipitation relationships in the seeded years and in historical years. In Santa Barbara County statistically significant increases are shown for the type of storms accounting for a large fraction of the precipitation experienced there. On the basis of the tabulated data, it was concluded that it would appear strongly probable that weather in California has been modified by cloud seeding operations. However, this statement was qualified in the discussion where there were presented a number of reservations regarding the use of historical data in evaluation. The Statistical Laboratory of the University of California, who collaborated on the report, suggested the use of a randomizing procedure for overcoming this weakness and obtaining documentary evidence. This consists essentially of not seeding every storm during the course of a project, but reserving some unseeded cases for comparison purposes. These unseeded storms would be shuffled in a random fashion among the seeded storms. Statistical tests would be most powerful if half the storms were reserved for comparison purposes. Therefore, selection by a coin flip would be possible.

The elimination of the possibility of error due to undetected long-term trends in historical target to control area relationships is obvious. Additional rain gauges could also be installed in target and control areas because the need for long historical records is automatically eliminated. This factor alone can make possible the determination of results in considerably greater detail, which might lead eventually to improvement of cloud seeding techniques.

In the Spring of 1956 preliminary discussions were held by North American Weather Consultants with the Board of Supervisors of Santa Barbara County, with the State Water Resources Department as represented by Mr. Robin Reynolds, and with Dr. Jerzy Neyman and staff members of the Statistical Laboratory of the University of California, regarding the possibility of establishing such a project in Santa Barbara County. The response was such as to justify going ahead and making plans for commencement during the coming season. This involved obtaining financial support from the County for the actual seeding operations to be conducted by North American Weather Consultants, and support for the Statistical Laboratory from the National Science Foundation and the Office of Naval Research. The State Water Resources Division offered to coordinate the project and establish and maintain an extensive special rain gauge network.

Subsequently the U. S. Weather Bureau loaned 35 recording gauges to the Project, an item of major importance, and these have been installed and are being maintained by the State Water Resources Department. A great deal of aid has been received from the U. S. Forestry Service in this connection. The President's Advisory Committee on Weather Control is sponsoring a weather-radar study. The radar is being operated by Meteorology Research, Inc. at the Forestry Service Lookout on La Cumbre peak, in the target area.

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<sup>2/</sup> State Water Resources Board "Weather Modification Operations in California." Bulletin #16, June 1955.

# Santa Barbara County Project

NORTH AMERICAN WEATHER CONSULTANTS  
 SANTA BARBARA MUNICIPAL AIRPORT • SANTA BARBARA, CALIFORNIA  
 WOODLAND 8-5481  
 TELETYPE 18 0923

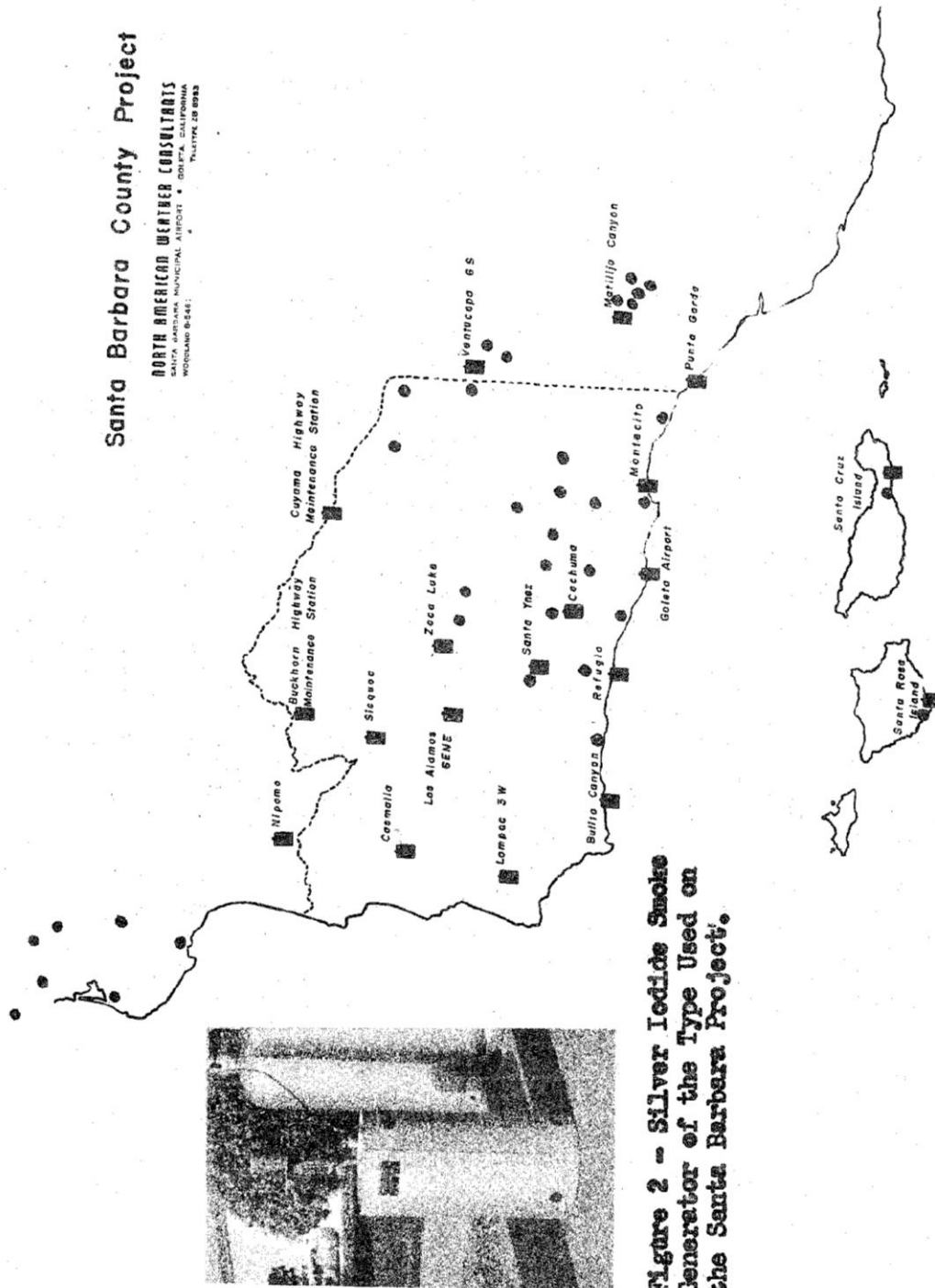


Figure 2 - Silver Iodide Smoke Generator of the Type Used on the Santa Barbara Project.

Figure 1- Ground Based Silver Iodide Smoke Generator Layout and Recording Rain Cage Network. Generators are Designated by Rectangles, Rain Cages by Dots. Control Area No. 1 (Piedras Blancas Area) is not shown.

## OPERATIONS TO DATE

Seeding operations began in January 1957. They are to be conducted during the months of January through April during the next 3 years. No seeding is to be done during November and December due to the presence of late maturing crops in the coastal plains, for which additional rain is not welcomed. The silver iodide smoke ground generator layout is shown in Figure 1. In seeding, it is necessary to take into account the wind pattern at the surface and aloft, for the seeding effects develop in the area from 10 to 40 miles downwind of the generator site. This is due in part to the time required for the entrainment and dilution of the smoke within convection cells and for transport of the  $-50^{\circ}\text{C}$  level and above where the smoke becomes effective as a nucleating agent. Additional time is required to generate precipitation-size ice particles at these levels. It is seen from the layout that not only are there generators established wherever possible within the county, but also some lie to the southeast, to the northwest, and two are on the Channel Islands of Santa Cruz and Santa Rosa. This wide distribution ensures coverage under a variety of possible wind flow patterns. Not all generators are operated at one time for if they were, areas outside the target area, possibly including control areas, would be seeded.

Figure 1 also shows the recording rain gauge layout for the target area and for the 3 control areas: Point Piedras Blancas area, San Luis Obispo area, and Channel Islands. The instrumentation is heaviest in the Santa Ynez watershed portion of the target area as it is highly desirable to determine variations in effects with elevation. A great deal of difficulty was experienced in making weekly visits to the gauges in this area because of the rugged terrain, and lately helicopters are being used. The Santa Ynez range, which parallels the east-west oriented coastline, rises abruptly from the narrow coastal plain to the crest line of 3000 to 4000' elevation. To the north lies the drainage basin of the Santa Ynez and still farther north another range which has peaks of 5000 to 6000' elevation.

Figure 2 shows various views of the silver iodide smoke generator employed. An 8-gallon tank holds 2% silver iodide in acetone solution which is forced under 10 psi pressure into a head, where it is mixed with propane, then burned in a flame-holder. The silver iodide vaporizes, then is quenched as it passes swiftly into the colder ambient air. Small smoke crystals are thus sublimated from the vapor; about  $10^{13}$  being formed per second.

The manner in which the seeding under the randomizing plan is carried out is as follows: Between the hours of 0800 and 0900, and 2000 and 2100 PST North American Weather Consultants examines weather maps, charts, and current weather information and decides whether the weather is, or will become seedable during the ensuing 12-hour period. The meteorological decision, either to seed, or to not seed, is then sent by teletype to Berkeley where a representative of the Statistical Laboratory replies with the statistical decision either to seed or to not seed. Seeding is then conducted in the next 12-hour period only if both decisions are affirmative. On the other hand, if the meteorological decision is to not seed, none is conducted regardless of whether the statistical decision was to seed or to not seed. There are two permissible exceptions. These occur when subsequent information discloses that the meteorological decision was faulty. For instance, a storm might accelerate and reach the target area prior to the end of a 12-hour period for which no seedable conditions were predicted. In this case, seeding is permitted provided the statistical decision had been to seed, but the case is discarded from the sample. The other exception is when a predicted seedable storm does not occur within the 12-hour period; this again is simply a forecast error and is discarded as no seeding could, or would be done.

So far this year we have experienced an abundance of precipitation, and of seedable situations, in January only. Normal precipitation occurred in February; March was dry, and April thus far <sup>1/</sup> is also dry. Table I summarizes the various decisions, meteorological and statistical, which were made from January 10 through April 12. Seeding was done prior to January 10 but it was not randomized as the rain gauge network was not yet ready. During much of January, when the meteorologist said no seeding, no statistical decision was made. This accounts for one of the extra contingencies in the Table. There also occurred one of those unfortunate cases, present even in the best regulated experiments, where communication difficulties resulted in a generator being left on when it should have been turned off; this accounts for the other extra contingency.

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<sup>1/</sup> However, a good storm was seeded on April 17th, while the Snow Conference was in session.

## SANTA BARBARA PROJECT SUMMARY

Jan. 10 - April 12, 1957

Meteoro- logical Decision	Statistical Decision	Actual	Jan. Total	Feb. Total	Mar. Total	Apr. Total	Total
S	S	S	5	3	3	0	11
S	NS	NS	3	5	0	0	8
NS	NS	NS	4	23	30	15	72
NS	S	NS	2	24	29	9	64
NS	ND	NS	27	-	-	-	27
S	S	NS	0	0	0	0	0
NS	S	S	1	1	0	0	2
S	NS	S*	1	0	0	0	1

\* Seeded by error  
 S - Seed  
 NS - Not seed  
 ND - No decision

It is seen that there were a total of 19-12 hour periods for which seedability was predicted. The statistical decision permitted seeding on 11 of these cases. In addition, there occurred 2 forecast errors where no seeding was predicted but seedable conditions did develop and seeding was done. In no case was seeding called for which did not subsequently develop. As would be expected, the bulk of the cases (163) involved no seeding predicted and none done.

No complete statistical analyses of results can be accomplished prior to completion of the Project; however, a cursory review of precipitation to date shows that, thus far, we have had only 4 storms yielding over an inch in the mountains. Of these, two were completely seeded, but one of them occurred prior to January 10 and will therefore not be included in the sample. One storm was partially seeded, the 12-hour break occurring midway through the storm. This happened to be the heaviest storm of the season (5.12" at Gibraltar Dam). The fourth was not seeded at all. It is unfortunate that this season has provided us with a below normal number of seeding opportunities.

The Santa Barbara Project was difficult to get under way because of the variety of groups involved and the widespread dispersion of their headquarters. However, it is felt that the broad scope of interests of the participants will prove to be a strong asset in the long run. Near to the commencement of the project various research groups in the country were informed of the nature of the project and invited to make use of the opportunity by making physical observations, such as ice nuclei counts, wind current surveys, and other cloud physics studies, during the course of the project. It was, however, too late to obtain additional participation for this year. Also, subsequent to the commencement of the project, on February 22, 1957, a formal organization was formed consisting of a Board of Directors and an Executive Committee composed of representatives of the organizations directly concerned with the project. This group is meeting here at 1:30 P.M. on April 19 and welcomes attendance at their meeting by Western Snow Conference members.

It is our expectation that 3 years from now we shall have a much firmer grasp of the detailed nature of weather modification than exists today, as a result of the data gathered on this project.