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JULY 16th NUCLEAR EXPLOSION: METEOROLOGICAL REPORT

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REPORT WRITTEN BY:

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ABSTRACT

A meteorological service was developed for the nuclear explosion in accordance with standard techniques of short and long range forecasting developed by California Institute of Technology and the AAF Weather Division. Long range forecasts were used in operational planning and short range forecasts were used in the operation. Weather records were made before, during and after the operation to be used by the different test groups.

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JULY 16TH NUCLEAR EXPLOSION: METEOROLOGICAL REPORT

I. INTRODUCTION

Equipment The weather equipment available for this operation consisted of the following: Two AAF portable weather stations, two radiosonde sets, four theodolites and pilot balloon sets, two field radar sets, two smoke generators, one hundred smoke pots, one weather teletype receiving the CAA hourly airway weather reports, one Hallicrafter SX-28 receiving international weather and airway pilot reports, one automatic wind-recording instrument, one C-45 Beechcraft airplane equipped with a pressure, temperature and humidity-recording device, one 16-mm motion picture camera for documentation and smoke studies, twenty modified microbarographs, two regular microbarographs, one Army carryall, and one radio-equipped Army staff car.

Information Additional weather information was available from the Class A Army Air Force Weather Station at Alamogordo Airbase, and from the Class B Army Air Force Weather Station at Kirtland Field. Special forecasts were received from the Army Air Force Weather Division in Washington, D.C. A daily telephone conference with a special Weather Division forecaster was held each day for a week preceding the operation. The Weather Division's regular 10-day forecast with prognostic charts was received via air mail.

Hourly weather observations were kept at two locations, namely Base Camp and Outpost located about 100 yards east of the tower. Beginning June 25, the weather schedule included hourly observations at both locations, with winds aloft made 0330 and 1530 at the Outpost and 0930 and 2130 at Base Camp. Radiosonde observations were made from Base Camp at 0330 and 1530. Radar sets were located at point P, and in the Tularosa Valley, each making at least one high-altitude ascent per day. The Tularosa Valley location made a scheduled run at 0330.

The C-45 instrument-equipped aircraft made weather flights in the early morning hours, and was used to obtain information as to temperature, humidity, and wind structure near and around the Sierra Oscuro. In addition to the regular weather runs, the comparative altitude of the lower inversion in both the Jornada del Muerto and the Tularosa Valley was obtained. The height of the thermals as a function of time after sunrise was obtained roughly. Smoke studies from releases on the Oscuro were made and motion pictures taken during these operations. Balloons were released at short intervals, and the C-45 aircraft was able to fly compass courses which were checked from the ground which gave information as to movement in the upper air.

Long-range forecasts were available for operational planning purposes. A double check was obtained by the use of the long-range forecasts of the AAF Weather Division, and those made by TR-4. Short-range forecasts were available for the operation and again a double check was possible. Observations and measurements before, during and after the operation served as a further weather guard over the operation.

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II. FORMULATION

Although the weather program for the second Trinity operation was more extensive than the May 7th operation, the problems considered were similar:

1. What weather specifications are functional in the operation?
2. Could optimum specifications be met, and if so could a time of optimum condition be forecasted?

A circular was sent to all groups requesting that information be submitted listing the weather elements favorable and unfavorable to each. The replies were used in forming a composite picture of the weather needs of the operation, and are as follows:

1. Elements to be recorded before, during and after the operation.

   A. Wind direction and velocity at all levels.
   B. Temperature at all levels.
   C. Humidity at all levels.
   D. Visibility, both vertical and horizontal.
   E. Pressure at the point of operation.
   F. Air density at the point of operation (to be obtained from pressure, temperature and humidity).

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2. Conditions least favorable to the operation.

   A. Haze, dust, mirage effects, precipitation, restrictions of visibility below 45 miles.
   B. Humidity greater than 85% at the surface or aloft which might result in condensation by the shock wave.
   C. Thunderstorms within 35 miles at the time of operation or for 12 hours following.
   D. Rain at the location within 12 hours of the operation.
   E. Surface winds greater than 15 mph during and after the operation.
   F. Winds aloft blowing toward Base Camp or any population center within 90 miles of the site.

3. Best conditions for the operation.

   A. Visibility greater than 45 miles.
   B. Humidity below 85% at all levels.
   C. Clear skies.
   D. Temperature lapse rate aloft slightly stable to prevent dropping of the cloud.
   E. Little or no inversion between 5000 and 25,000 feet to allow cloud to reach maximum altitude.
   F. A thick surface inversion or none at all to prevent internal reflections and mirage effects.
   G. Winds aloft fairly light, preferred direction from between [illegible]° south of west and 25° south of west. Steady movement desirable to anticipate track of cloud. Horizontal and vertical wind shears desirable for maximum dissipation of the cloud, although such a condition increases the tracking problem.
   H. Low level winds light and preferred drift away from base camp and shelters.
   I. No precipitation in the area (35 miles) within 12 hours of the operation.
   J. Predawn operation desired by the photographic group, although 0930 operation considered best for thermals dissipating the lower levels of the cloud.

III. PROCEDURE

Types of Operation Two methods of using weather information were considered for the operation:

1. Assuming that reliable weather forecasts are available, an operation of this type may be set up to take advantage of the most favorable weather by coordinating the construction and development program to the forecast. Such coordination is economical in time and usually results in the most efficient operation. The favorable days as forecasted will usually meet the greatest number of weather specifications and the forecast will be most accurate.

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2. The other type of operation occurs under conditions which require the forecast to be made for a date which is already fixed. Such a procedure usually results in a sacrifice of certain weather specifications and the urgency of the operation must be compared with the sacrifices to be made. Furthermore, dates which are arbitrarily fixed sometimes fall within weather periods which are extremely difficult to predict, such as periods of stagnation or poorly defined dynamic sequences. Provided a fairly accurate forecast can be made, the operation can then be tailored to the condition expected, or if the operation is too rigid, it can be delayed until enough specifications can be met.

Events The May 7th Trinity operation was conducted according to the forecast, and the second operation was originally planned in a similar fashion. During the first week in July, the date of July 16th became fixed. This changed the weather-operation relationship and introduced a consideration of the minimum specifications under which the operation could be conducted.

On June 21st, a request was received for an evaluation of July weather for the purpose of selecting days during which the operation could be successfully conducted. The forecast made on June 21st indicated that periods for favorable operation would be generated by the upper air trough passages expected on the days of July 13th and July 19th and 20th.

On June 30th, a second forecast was made substantiating the timing of the troughs to be July 13th and July 19th and 20th. The favorable day selection was predicated on the observations of previous upper air troughs and the conclusion that these influences produced proper wind structure for about one day before and one day after the central portion of the trough moved over New Mexico. This forecast indicated the dates of July 18, 19, 20, 21 as first choice, with the dates of July 12 and 14 as second choice. It was expected that the morning of July 13 would be unfavorable due to thunderstorms in the central portion of the trough. This would eliminate the 12th also, as rain the next day would be unfavorable.

On July 6th, a third forecast was made indicating the day of July 13th to be analogous to July 1st, each being the beginning date of a weather process during which Gulf air would move into the Trinity area. The 13th regime was expected to begin a period of thunderstorm activity, with an expected persistence of this condition for at least four days. The persistence actually lasted five days, which spoiled the 18th but left the morning of the 19th favorable as predicted. By July 6th it was expected that the morning of the 16th would be in a period of stagnation with the area dominated by slowly moving Gulf air. The wind structure was expected to be dominated by easterly winds in the lower levels, moisture layers, and afternoon thunderstorms. By fixing the date of operation for the morning of the 16th, weather permitting, it became necessary to tailor the operation and adjust certain aspects of the operation to the expected wind structure.

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It was known that the morning of the 16th was to be in a very difficult period from the forecasters' standpoint. In order to safeguard the operation from the standpoint of weather, the additional services of the best forecasters available were desired. Col. B. Holzman, who had been one of the two AAF representatives in the European operation and D-Day operation was selected and he in turn requested Major J. Wallace of the AAF Long Range Unit be assigned to the New Mexico weather and be available for a daily telephone conference. In this way three judgments and all AAF information were available for the operation.

On July 12th, the AAF Weather Division forecast made by Major Wallace substantiated the original analysis indicating trough passages at Trinity late July 12th, and again on July 20th. This forecast indicated the period from July 14-19 to be in modified Gulf air with winds below 20,000 feet from the southeast with general thunderstorms. From the card punch file in Washington, Major Wallace selected the day of July 28, 1900 to be the most similar day in the past 40 years to the day of July 16, 1945. Hemisphere weather maps were obtained from the Alamogordo Air Base and the weather map of July 28, 1900 was studied closely from the short-range standpoint.

The July 13th forecast considered the trough passage and thunderstorm at 0200-0300 of the 13th to be an indication that the trough timing was correct. The forecast again indicated the most favorable days to be the 18, 19, 20 and 21. The days from July 15th through the 17th were expected to be characterized by light southerly and easterly winds in the levels below 15,000 feet and light winds above 15,000 feet. Light thunderstorms were expected during the afternoons of the 15th, 16th and 17th. The wind structure of the 16th was expected to include a deep layer of easterly winds.

The forecasts of July 12th and 13th compared favorably. The possibility of the stagnant condition producing a shallow, moderate, or deep layer of southeast winds was considered, and sample cases were studied from the winds aloft of July 5th, July 8th and July 10th. The case of July 8th turned out to be the most analogous case, although July 5th was considered to be the most likely on the July 13th analysis. The precautionary program was adjusted to consider the selected cases. It was believed that the track of the cloud would be a function of the depth of the easterly winds and the energy released into the atmosphere. It was decided that a low order test or deep easterly winds would move the main body of the cloud toward the northwest. For moderate energies, and moderately deep easterly winds, the cloud could be divided, with the lower portions moving toward the northwest, and the upper portion moving toward the northeast. For very high energy or shallow easterly winds, the main body of the cloud would move toward the northeast. The second consideration proved to be correct with the cloud moving toward the northwest in the lower levels, and toward the northeast above 18,000 feet.

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The July 15th forecast held to the previous forecast in regard to wind structure. It departed from the previous forecasts by calling for no precipitation in the immediate area of the test. This turned out to be an incorrect analysis. Inversions were forecasted between 500 and 700 feet, at 17,000 feet, with the isothermal layer or lower stratosphere beginning at 52,000 feet. The wind structure held with easterly and southeasterly flow below 19,000 feet shifting to SW and WSW above 19,000 feet. Velocities light below 15 mph.

During the afternoon of July 15th, a conference was held. The weather possibilities were discussed together with the possibility of sacrificing some of the measurements if the operation were to be conducted the next morning in the stagnant condition. The forecast at this time was optimistic and called for conditions under which an operation could occur during the early morning of the 16th. It was decided to set up the operation with the final decision to be made in a meeting at 0200 and 0330 of the 16th, at which time the operation could be called off in the event of unfavorable weather.

About 2000 of the 15th, thunderstorms of local nature moved into the Trinity area. These thunderstorms stagnated and reduced the 17,000-foot inversion. Thirty-mph winds were recorded until 2330. Rain which had been quite local reached the zero point about 0230 of the 16th, and a two o'clock conference at Base Camp was held with rain influencing Base Camp, West and South 10,000, and the 0 point.

At 0215, the forecast still held optimistic for an operation by 0600. No operation was expected at 0400 but rapid clearing was expected between dawn at 0500 and sunrise at 0600. On this basis the operation continued.

At 0400 the wind structure was prepared for K. T. Bainbridge and Col. Warren as follows:

7-16-45 0445

Winds aloft very light, variable to 40,000 feet

Surface		Calm.
1200 ft.	250°	11 mph
4200	240	4
4800	160	1
10,000	110	13
15,000	150	12
17,000	250	4
18,000	220	11
20,000	220	15

Inversion about 17,000 feet, with humidity between 12,000 and 18,000 feet greater than 80%. Altitudes shown are above surface at Trinity, with conditions holding for the next two hours. Sky now broken becoming scattered at 0515.

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With this information K. T. Bainbridge returned to S 10,000 from O, and set the time of operation at 0530.

The operation occurred at 0530, and the shock wave was observed to condense three moisture layers as it moved upward into the atmosphere.

IV. WEATHER AT THE TIME OF OPERATION

Sky clear to the east and over O and S 10,000. Edge of solid overcast extended from base camp west of W 10,000 at 12,000 feet above the surface.

Visibility greater than 60 miles.

Surface wind from ESE 3-6 mph below 500 feet.

Temperature 68°F
Saturation temperature 61°F
Relative humidity 77%
Surface pressure 851.7 millibars
1st inversion at 100 feet, very slight
2nd inversion at 500 feet, very slight
3rd inversion at 17,000 feet, slight
Three layers of humidity greater than 95% existed between 12,000 and 20,000 feet
These layers condensed out in the shock wave

Thermal structure aloft 0555 7-16-45 Base Camp

Altitude Meters	Pressure	Temp. C	Rel. Humidity
Surface	860 mbs	19.4°C	81%
490 M	812	17.4	57
1190	748	12.3	56
1560	716	12.0	50
1890	688	9.0	50
2560	633	6.2	51
3850	540	-2.5	85
4610	484	-9.2	99
4850	476	-8.9	95
6170	400	-18.1	78
7020	357	-24.0	36
7510	333	-30.5	43
8020	310	-34.5	63
8750	279	-39.7	58
11,890	170	-70.4	Too cold

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Winds Aloft: Composite of 0545 Base Camp pibal, 0400 Outpost pibal, and 0200 Point P rawin 7-16-45

Surface - 500 ft.	Wind from 110°	3-5 mph
720	160	7
1380	200	6
2040	230	7
2670	250	8
3300	250	10
3900	240	8
4500	230	7
5100	220	8
5700	220	12
6300	220	11
6900	200	8
7500	190	7
8100	170	9
8700	170	12
9300	160	12
9900	150	13
10,500	140	13
11,100	130	16
11,700	120	16
12,300	140	12
12,900	160	10
13,000	150	13
14,000	150	12
15,000	180	4
16,000	250	4
17,000	240	8
18,000	220	11
19,000	220	12
20,000	220	15
25,000	230	16
30,000	230	27
35,000	240	19
40,000	290	18
44,000	280	11

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V. WEATHER BEFORE AND AFTER THE OPERATION

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HOURLY OBSERVATIONS

BASE 7-15-45

0030	Ovc/	U		79	47	SSE	18	580	33%
0130	Ovc/	U		79	46	SSE	12	584	32
0230	Ovc/	U		77	48	SSE	10	588	35
0330	Sctd/	U		76	52	SSE	12	590	43
0430	Sctd/	U		74	52	SSW	14	594	46
0530	80 Bkn	U		73	54	SSE	7	595	52
0630	80 Sctd	U		73	56	SSE	8	594	56
0730	80 Bkn	U		76	56	SSW	8	606	51
0830	Bkn/	U		81	56	S	10	604	44
0930	Sctd/	U		82	55	S	7	603	38
1030	Clear	U		86	54	S	10	599	34
1130	Clear	U		87	54	E	6	598	32
1230	Clear	U		90	54	SE	10	590	29
1330	80 Sctd	U		92	55	SSW	10	587	28
1430	80 Sctd	U		93	52	SSW	4	580	25
1530	90 Sctd 80Sctd	U		96	47	SE	6	576	19
1630	80 Bkn/Bkn	U		94	49	SSW	10	571	22
1730	80 Bkn/Bkn	U		91	49	S	7	562	24
1830	80 Ovc/Bkn	U	TRW-	82	49	SSW	20	560	31
1930	85 Ovc/Bkn	U	TRW-	86	48	E	10	569	27
2030	85 Ovc	U	TRW-	84	53	E	18	574	35
2130	85 Ovc/Bkn	U	T	80	52	E	8	583	38
2230	Ovc/85Sctd	U		83	46	ESE	15	582	28
2330	Sctd/	U		82	48	ESE	15	585	31

OUTPOST 7-15-45

0030									
0130									
0230	80 Bkn	U		75	48	SE	15	505	39
0330	Bkn/80Sctd	U		74	50	SE	20	507	43
0430	Bkn/	U		72	52	SE	15	511	50
0530	Bkn/	U		70	54	SE	13	515	56
0630	Bkn/	U		69	55	SE	20	515	61
0730	Sctd/	U		69	56	SE	14	527	63
0830	Sctd/	U		78	59	SE	11	524	52
0930	Sctd/	U		80	58	SE	15	522	47
1030	Clear	U		83	58	SE	15	521	42
1130	Clear	U		85	57	SE	11	517	38
1230	Clear	U		87	54	SSE	14	511	32
1330	Clear	U		88	53	SSE	15	506	30
1430	Clear	U		90	52	SE	15	500	27
1530	55 Sctd	U		92	50	SSE	16	494	24
1630	55 Sctd	U		94	49	SSE	6	484	22
1730	55 Sctd/Bkn	U		92	48	S	15	482	22
1830	60 Bkn /Bkn	U		88	46	SSW	17	482	24
1930	60 Ovc /Bkn	U		82	51	E	13	493	34
2030	60 Bkn	U	TRW-	73	58	ENE	12	503	60
2130	60 Bkn/ Bkn	U	RW-	78	--	E	16	508	--
2230	60 Bkn/ Bkn	U		76	51	ENE	14	504	41
2330	80 Bkn/ Bkn	U		78	47	Calm		510	34

[redacted]

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HOURLY OBSERVATIONS

Base 7-16-45

0030	Ovc/	U	R-	78	51	NNW	20	606	39%	
0130	50 Ovc	U	TRW	68	62	ESE	9	617	78	
0230	50 Ovc	U	RW-	68	59	S	4	616	73	
0330	Ovc/60 Sctd	U		68	61	SSE	4	611	77	Binovc
0430	Ovc/60 Sctd	U		68	61	S	2	610	77	
0545	Ovc/	U		69	62	Calm		607	80	Bks to NE
0630	Ovc/	U		68	62	WNW	5	610	81	
0730	Ovc/	U		67	61	ENE	2	612	81	
0830	Bkn/	U		69	60	NE	2	616	73	
0930	Bkn/	U		71	59	SE	2	620	66	
1030	Sctd/	U		79	55	NW	2	614	43	
1130	Clear	U		82	56	N	2	610	40	
1230	Sctd/	U		85	57	SW	4	606	38	
1330	75 Sctd	U		87	56	SE	4	596	34	
1430	Sctd/65Sctd	U		90	54	SSW	6	589	27	
1530	Bkn/ 65Sctd	U		93	52	ESE	9	583	25	
1630	Bkn/65 Sctd	U		93	52	S	10	577	25	
1730	Bkn/65 Sctd	U		92	52	SE	12	570	25	
1830	Bkn/75 Sctd	U		86	52	SW	6	570	31	
1930	Ovc/75 Sctd	U		86	51	S	4	572	30	
2030	Ovc/75 Sctd	U		83	52	S	10	577	34	
2130	90 Bkn/Bkn	U		79	56	NNW	12	587	44	
2230	90 Bkn	U		77	56	NE	11	594	51	
2330	80 Bkn	U		78	55	E	6	595	45	

OUTPOST 7-16-45

0030	80 Ovc	U		73	54	NNW	7	516	50	
0130	80 Bkn	U		70	54	N	3	530	58	
0230	80 Ovc/Bkn	U	RW 0210-0245	70	55	S	4	---	60	
0330	90 Ovc/Bkn	U		64	60	SSE	3	---	85	
0430	Bkn/90Sctd	U		--	--	---	-	----	--	6As/230

Observations suspended at 0430, 0530 observation extrapolated.

0530	Sctd/	U		68	61	SE	3	517	77

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TEMPERATURE, PRESSURE, HUMIDITY
7-16-45
Station at 1440 M.

Base 7-16-45 0013

Press	Alt. M.	Temp	Hum.
860	1440	25.7	42%
794	2140	23.0	49
676	3510	9.6	85
662	3670	10.0	89
621	4210	6.1	94
526	5560	-3.5	100
444	6860	-14.5	100
434	7040	-14.3	99
400	7650	-19.7	100
365	8300	-23.8	---
310	9500	-32.0	---
242	11190	-43.8	---
201	12410	-53.5	---

Base 7-16-45 0335

Press	Alt. M.	Temp	Hum.
861	1440	20.0	77%
827	1780	18.9	62
729	2830	10.3	73
588	4600	-1.7	90
560	5000	-4.0	37
505	5800	-8.7	96
482	6180	-10.3	100
400	7580	-18.2	100

Base 7-16-45 0555 8

860	1440	19.4	81%
812	1930	17.4	57
748	2630	12.3	56
716	3000	12.0	50
688	3330	9.0	50
633	4000	6.2	51
540	5290	-2.5	85
484	6150	-9.2	99
476	6290	-8.9	95
400	7610	-18.1	78
357	8460	-24.0	36
333	8950	-30.5	43
310	9460	-34.5	63
279	10190	-39.7	58
170	13330	-70.4	--

Base 7-16-45 1355

860	1440	29.5	34%
812	1940	22.1	34
763	2480	18.9	43
678	3490	11.3	47
653	3800	9.5	51
614	4310	5.2	51
602	4470	5.5	51
562	5030	2.0	52
524	5590	-2.5	64
512	5780	-2.6	58
453	6730	-8.6	65
424	7250	-10.5	30
400	7680	-12.5	30
326	9200	-20.5	--
218	12090	-40.4	--
140	15000	-57.2	--
106	16700	-66.3	--
70	19200	-68.7	--

On 1355 Raob, isothermal layer begins at 16,700 meters or 54,700 ft. above sea level, or approximately 50,000 ft above the point of operation. This level may be the beginning of the stratosphere. Please note the temperature and humidity variation at the 400 millibar level.

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WINDS ALOFT
7-15-45

Outpost 0405

720	140°	35
1380	170	23
2040	190	17
2670	200	14
3300	210	18
3900	200	22
4500	210	21
5100	210	21
5700	220	22
6300	230	19
6900	240	14
7500	230	12
8100	230	10
8700	240	6
9300	260	2
10500	350	4
11100	10	8
11700	20	10
12300	20	11
12900	10	13
13500	10	14
14100		
14700		
15300		
15900		
16500		
17100		
17700		
18300		

Outpost 0930

160°	19
170	22
180	20
200	18
210	24
220	25
220	24
220	23
230	22
240	15
260	9
290	8
330	9
340	8
350	8

Base 0932

170°	4
230	6
240	8
230	9
230	12
230	15
240	12
260	8
290	7
310	6
320	4
10	2
70	4
70	11
60	15
50	11
50	10
20	8
350	11
10	13
30	13
40	9
350	3
270	7
290	6
300	7
290	10
270	11
260	11

George 0942

1000	180°	12
2000	180	18
3000	210	20
4000	220	16
5000	240	11
6000	260	8
7000	310	2
8000	300	3
9000	300	3
10000	50	9
11000	50	10
12000	70	14
13000	60	13
14000	50	13
15000	40	13
16000	30	10
17000	30	7
18000	30	5
19000	10	2
20000	280	4
21000	290	7
22000	280	10
23000	280	11
24000	280	12
25000	270	12
26000	270	11
27000	270	13
28000	280	16
29000	280	18
30000	280	18

Peter 1014

1000	230°	11
2000	230	11
3000	230	12
4000	230	12
5000	230	11
6000	250	8
7000	290	6
8000	310	5
9000	80	10
10000	90	14
11000	80	13
12000	70	13
13000	40	13
14000	30	12
15000	10	11
16000	360	12
17000	360	8
18000	270	3
19000	270	6
20000	280	9
21000	290	8
22000	290	9
23000	280°	12
24000	270	15
25000	260	16
26000	270	18
27000	270	17
28000	280	13
29000	310	16
30000	330	8

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WINDS ALOFT
7-15-45

Outpost 1255			Base 1303		George 1430			Peter 1435	
720	180°	7	150°	8	1000	210°	11	200°	9
1380	180	9	150	9	2000	210	12	210	8
2040	190	9	160	9	3000	210	15	220	9
2670	210	9	170	11	4000	200	14	220	8
3300	210	8	180	8	5000	180	10	220	9
3900	170	4	220	6	6000	150	9	220	8
4500	140	6	200	7	7000	140	6	220	5
5100	150	6	210	8	8000	130	4	170	6
5700	160	6	230	10	9000	110	6	150	10
6300	130	4	250	9	10000	90	10	100	8
6900	70	6	260	6	11000	70	13	80	9
7500	50	8	140	2	12000	50	14	50	11
8100	40	9	120	3	13000	30	15	20	13
8700	40	10	110	2	14000	10	15	10	14
9300	40	10	60	6	15000	360	19	350	18
9900	30	11	50	11	16000	340	22	350	12
10500	20	10	50	14	17000	350	16	330	8
11100	10	10	50	14	18000	360	9	280	5
11700	350	10	50	14	19000	350	2	280	6
12300	340	13	40	13	20000	320	1	290	5
12900	320	18	40	13	21000	280	6	290	8
13500	310	24	30	13	22000	260	12	280	10
14100	310	21	10	12	23000	260	14	280	12
14700	330	11	360	13	24000	260	14	270	15
15300	330	5	350	16	25000	270	16	270	15
15900	---	0	330	20	26000	280	19	270	17
16500	---	0	320	25	27000	280	16	280	18
17100	---	0	320	23	28000	290	16	280	19
17700	---	0	320	12	29000	290	14	290	20
18300	---	-	340	7	30000	280	23	290	20
					31000			270	19
					32000			270	20
					33000			270	21
					34000			280	20
					35000			290	22
					36000			300	20
					37000			300	16
					38000			300	16
					40000			330	10
					41000			330	9
					42000			300	12
					43000			300	12
					44000			290	10
					45000			180	10
					46000			170	16

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WINDS ALOFT
7-15-45

Base	1535	
720	000°	00
1380	---	0
2040	---	0
2670	000	0
3300	---	0
3900	---	0
4500	000	0
5100	---	0
5700	150	6
6300	140	7
6900	110	8
7500	90	8
8100	70	7
8700	60	8
9300	in cloud	
9900		
10500		
11100		
11700		
12300		
12900		
13500		
14100		
14700		
15300		
15900		
16500		
17100		
17700		
18300		

Outpost	1540
180°	20
170	19
170	16
160	17
160	19
190	21
190	26
200	29
200	30
210	28
220	24
220	15
210	7
190	6
180	6
120	3
70	7
60	11
50	16
30	17
20	17
20	15
20	15
10	19
350	24
340	27
330	29
330	25
340	16
350	12

Outpost	1845
210°	24
210	22
210	20
210	14
200	11
200	10
200	10
210	10
220	8
220	10
210	6
in cloud	

Base	1900
250°	12
220	9
190	11
180	12
190	11
180	10
170	13
180	13
180	12
180	14
180	15
190	13
220	9
260	5
340	6
360	10
350	9
340	7
in cloud	

Base	2148	
720	90°	13
1380	80	14
2040	80	14
2670	100	16
3300	120	17
3900	150	17
4500	160	16
5100	160	12
5700	170	13
6300	180	18
6900	190	19
7500	190	20
8100	190	20
8700	200	18
9300	210	17
9900	210	15
10500	210	12
11100	210	11
11700	220	12

Outpost	2300
90°	18
110	10
160	6
170	7
180	7
180	8
180	10
190	12
200	15
210	15
210	13
230	15
240	17
240	12
240	13
230	15
in cloud	

George	2230	
1000	50°	29
2000	50	26
3000	60	20
4000	80	20
5000	90	18
6000	100	13
7000	130	8
8000	150	6
9000	160	4
10000	200	2
11000	190	2
12000	150	2
13000	150	3
14000	130	7
15000	180	9
16000	230	5
17000	280	5
18000	300	7
19000	290	6
20000	250	6
21000	230	12
22000	240	17
23000	240	17
24000	250	15
25000	260	15
26000	270	11
27000	270	9
28000	260	10
29000	280°	13
30000	280	14
31000	270	14
32000	270	14
33000	260	16
34000	260	15
35000	260	14
36000	260	16
37000	270	14
38000	270	12
39000	270	13
40000	260	13
41000	240	11
42000	240	12
43000	240	10
44000	220	15

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WINDS ALOFT
7-16-45

Outpost 0215

720	360°	14
1380	340	19
2040	330	20
2670	320	16
3300	310	12
3900	300	12
4500	300	14
5100	300	13
5700	290	11
6300	270	5
6900	110	6
7500	90	11
8100	110	19
8700	120	14
9300	130	13
9900	120	13
10500	110	13
11100	140	10
11700	170	10
12300	180 in cloud	5

Outpost 0240

720	210°	14
1380	220	13
2040	230	8
2670	240	6
3300	250	7
3900	260	9
4500	270	12
5100	280	16
5700	290	17
6300	310	14
6900	310	7
7500	220	3
8100	130	9
8700	120	14
9300	120	13
9900	120	12
10500	130	14
11100	130	18
11700	130	21
12300	120	24
12900	120	26

in cloud

Peter 0202

1000	230°	6
2000	290	6
3000	290	7
4000	290	10
5000	300	12
6000	320	8
7000	350	5
8000	100	7
9000	120	11
10000	110	13
11000	120	16
12000	140	11
13000	150	13
14000	150	12
15000	180	4
16000	250	4
17000	240	8
18000	220	11
19000	220	12
20000	220	15
21000	230	17
22000	240	18
23000	240	19
24000	230	17
25000	230	16
26000	230	17
27000	230	17
28000	240	21
29000	240	23
30000	230	27
31000	220	26
32000	220	27
33000	220	26
34000	230	24
35000	240	19
36000	250	18
37000	260	18
38000	280	19
39000	290	18
40000	290	18
41000	300	10
42000	300	8
43000	280	10
44000	280	11

George 0300

290°	9
290	7
290	7
280	8
270	10
270	10
260	10
210	7
130	14
130	14
130	8
90	10
90	8
110	6
150	5
170	8
190	5
220	6
230	7
250	9
250	10
230	13
230	12
240	10
240	16
240	15
250	15
250	17
250	18
260	16

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WINDS ALOFT
7-16-45

Base 0311

720	240°	6
1380	230	10
2040	250	11
2670	270	12
3300	240	9
3900	250	7
4500	240	4
5100	160	1
5700	210	3
6300	210	8
6900	200	12
7500	200	13
8100	180	12
8700	160	10
9300	130	10
9900	110	13
10500	100	17
11100	100	12
11700	110	8
12300	120	7
12900	130	8
13500	in cloud	
14100		
14700		

Outpost 0400

200°	7
210	9
200	8
220	7
260	7
280	8
300	9
300	8
290	5
180	1
160	9
200	15
190	15
180	12
160	12
150	13
140	13
130	16
120	16
140	12
160	10
in cloud	

Base 1545

160°	7
200	6
230	7
250	8
250	10
240	8
230	7
220	8
220	12
220	11
200	8
190	7
170	9
170	12
in cloud	

Base 0640

330°	4
260	3
230	4
250	4
270	3
250	4
230	4
230	7
230	10
230	13
220	12
170	10
160	11
160	12
170	14
180	16
180	15
190	13
190	12
190	7
160	7
170	5
210	4
220	3
In Dust	

George 0640

1000	260°	5
2000	260	8
3000	230	7
4000	230	7
5000	340	3
6000	210	4
7000	150	5
8000	150	6
9000	150	5
10000	170	8
11000	160	12
12000	160	12
13000	250	6
14000	250	6
15000	260	10
16000	250	8
17000	250	8
18000	250	2
19000	210	4
20800	240	9
25100	240	13
28300	250	16
31200	240	25
34400	270	10
37200	240	9
41300	260	8
44000	250	16

Base 0929

720	160°	3
1380	150	3
2040	140	3
2670	160	3
3300	160	5
3900	150	5
4500	170	5
5100	190	7
5700	210	10
6300	200	11
6900	180	11
7500	170	21
8100	180	11
8700	190	11
9300	210	12
9900	200	13
10500	180	13
11100	170	16
11700	170	16
12300	190	11
12900	210	3
13500	320	2
14100	280	2
14700	270	3
15300	270	2
17100		
18300		

Base 1232

240°	1
120	2
140	5
130	7
130	7
130	6
130	8
140	10
150	10
150	8
150	5
190	3
240	3
240	4
250	6
270	8
280	10
280	8
270	5
250	4
240	5
260	5
260	6
250	6
250	6
220	11
190	17

Base 1550

140	9
100	4
100	3
140	5
150	7
170	7
180	7
180	6
170	5
180	4
70	2
310	5
310	6
320	4
310	5
290	6
280	6
290	6
280	7
290	5
270	3
270	3
270	1
130	3
180	5
210	8
210	16

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VI. SPECIAL STUDIES

<u>Smoke Operations</u> Smoke studies were conducted from the top of the Oscuro by F. Oppenheimer and J. Mattingly. Aircraft observations were coordinated with the smoke operation and motion pictures were taken from the air.

July 7th Smoke Operation on the Oscuro Mountains

"In order to determine the path of a cloud passing over the Oscuro mountains, four smoke stations were set up between 5 A.M. and 7 A.M. on July 7th.

1) One station on top of the ridge at an elevation of about 8000 ft.
2) One station 50 ft. below the top of the ridge on the East slope.
3) One in the valley to the East about 2400 ft. below the top.
4) One station about 600 ft. below the top of the ridge on the East slope.

"The stations were on an East-West line about 21 miles north of "O".

"Smoke pots were used for all stations except the one in the valley where an oil smoke generator was used.

"Stations: At 5 A.M. smoke from stations 1 and 2 behaved identically. The smoke went due west pouring off the side of the escarpment and settling in the valley where, when observed from a plane, it appeared to lie on the valley floor. At about 6 A.M. the smoke stream changed direction and went ESE rising slightly from the crest. It continued to rise at about a 5° angle for 4 to 5 miles (as long as it could be followed).

"Station 3: The smoke in the valley streamed down the valley (SE) staying very close to the ground (75-100 ft.). This condition persisted from 5 A.M. until 7 A.M. when the generator was turned off.

"Station 4: At about the time that the wind began to change on top of the ridge (6:15) smoke was generated at a station about 600 ft. below the top. This smoke stayed close to the hillside until it was 800 to 1000 ft. above the floor of the valley at which point it left the ground and did not descend any further. The smoke in travelling down the hillside changed its direction from E to SE right after it had left the ground it travelled SE essentially parallel to the smoke generated in the valley.

"The smoke was observed by Mr. J. M. Hubbard in a plane, by an observer on the east side of the ridge and by a photographer, T/5 Wallis, in the valley. As the films are not yet developed this report does not include any photographic information."

[redacted]

"CONCLUSION: The behavior of the smoke on the east and west sides of the ridge was found to be quite different. On the west it penetrated the inversion and dropped to the valley floor. On the east it did not penetrate the inversion and remained about 800 ft. above the valley floor. It is possible that on other occasions smoke on the east side would also descend to the floor. It would seem likely, however, that the steep escarpment on the west side as contrasted with the more gradual slope on the east is a sufficiently significant difference to account for the difference in the behavior of the smoke."

F. Oppenheimer

July 14-15th Smoke Observations on Eastern Slopes of Oscuro Mountains

"Date: July 14, 1945
Site: 21 degrees north of 0 on Oscura eastern slopes
Station 1: 1900 feet above valley floor
Station 2: 2300 feet above valley floor
Time: 0535 to 0750
Winds were light. Before sunrise the smoke from both points drifted downslope to the deep canyon that was directly to the north. The canyon filledup and the smoke spread down to the mountain base where it spread thinly and clung closely to the surface. There was no surface inversion present.

"After sunrise the direction changed almost immediately from downslope to upslope flow. The smoke began to move up the canyon and that from the highest station appeared to spread over the crest on to the western slope.

"Date: July 15, 1945
Site: Due east of 0 on the eastern slope of the Oscuras
Station 1: 1200 feet above the valley floor
Station 2: 1500 feet above the valley floor
Station 3: 1700 feet above the valley floor
Station 4: 200 feet below the mountain crest
Time: 0530 to 0715
Winds were light at all stations except the topmost which had a strong south wind blowing parallel to the ridge. At the other stations the smoke spilled downslope into the canyons and out on to the valley floor. There was no surface inversion present in the valley.

"After sunrise the three lower stations changed to upslope directions; the topmost station continued with strong southerly winds.

"At sunset the night previous and with a clear sky a shallow inversion began forming over the valley. At the same time the daytime upslope winds switched to a downslope flow and the smoke layered down the valley spreading the full width of the valley atop of the inversion. The path was SE heading directly over the bombing range and the range camp. After midnight the sky became clouded and the shallow inversion decayed."

[redacted]

"CONCLUSIONS: From sunset to sunrise with light winds the smoke will flow slowly downslope, filling up the canyons and then spreading on to the valley floor. This is true for all elevations along the eastern slopes except near the crest where there is a tendency for the smoke always to spill back over the western side. With a strong gradient wind that is parallel to the ridge, the higher elevations follow the gradient direction but with the lower elevations showing still a slow downslope flow. The smoke near the crest with the increased wind velocity dissipated to a large extent. If there is an inversion present the smoke will remain above the ground within the inversion layer, the height above the ground depending upon the depth of the inversion. But whether or not an inversion is present it is not important unless it extends from the surface up to 1500 or 2000 ft. (Very shallow inversions are normal now, July) because in either case the smoke is trapped in the valley for two or more hours after sunrise between the Oscuras and the first line of hills that parallel the Oscuras on the east a few miles. All passage to the east is blocked until at least two hours after sunrise. In the meantime the smoke drifts slowly southeastward, following the contours to the lowest levels and spreading as it moves. Then surface heating begins to increase the dilution."

J. F. Mattingly

A generalized conclusion from such little data is a bit dangerous. It might be said that the above conclusion is essentially correct under similar specialized conditions of stagnation. - JMH

Aircraft Studies

July 7, 1945 Smoke Operation

A study was made of wind currents along the west face and east slope of the Sierra Oscuro at dawn of July 7th. A group under the direction of F. Oppenheimer ascended the east slope of the Oscuro by jeep with smoke pots and a smoke generator during the afternoon of July 6th. At dawn of July 7th, the operation was carried out as planned with the weather airplane arriving on the scene at approximately 0515. This report includes the aircraft study of this operation.

The weather airplane, a C-45 Beechcraft, left Kirtland Field at 0435. The pressure, temperature, humidity recorder was operating throughout the flight. The aircraft passed over the base camp at an altitude of 600 feet at 0511 and then proceeded to pass over the zero point and crossed the Oscuro at 9000 feet M.S.L. at 0519. The fire of the first smoke position, located at the crest of the Oscuro slightly north of the zero point, was seen at 0523. The airplane circled the origin of smoke until 0544. The smoke moved down the west slope of the escarpment and appeared as a white waterfall reaching the talus slide and moving along it until it reached a point in the valley about halfway between the escarpment and zero. The smoke spread out laterally along

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the valley floor and appeared to be only about 100 feet thick. Motion pictures were taken of this smoke trail beginning about 0525. At 0535, two smoke origins were noticed along the east slopes of the Oscuro. One source appeared to be located about half way up the slope and the lower source well down in the valley. At 0544, the aircraft descended for a close view of the smoke flow. The direction of the two smoke streams appeared to follow the valley contours and the top appeared to be flat and about 100 feet above the terrain. The direction of flow was toward the southeast. Motion pictures were taken of this first descent. The aircraft then circled the south end of the Oscuro and returned along the west slope where the westward flow of the smoke from the crest was noted and photographed. A second descent was made along the east slope and the two sources were again photographed at 0558. The plane again circled the Oscuro and a third descent was made along the east slope into the valley at 0608 which netted a third complete motion picture record. At 0612 the aircraft returned to Kirtland Field and was landed at 0646. At 0612, the smoke from the top of the Oscuro appeared to spread out along the top of the ridge and seemed to stop waterfalling over the west escarpment. There were actually two sources at the crest but they were so close together as to be considered as one source when viewed from aloft. The aircraft observation was abandoned at 0612 as fuel was running low.

The smoke operation of July 7 was successful from a meteorological standpoint and showed the normal downslope drainage on both slopes of the Oscuro. On the west slope the smoke appeared to descend below the slight inversion. Along the east slope smoke from the intermediate altitude rode aloft above the inversion and smoke from the valley floor remained below the inversion.

In addition to the daily flights made by the C-45 for the purpose of obtaining a record of the horizontal distribution of temperature, pressure, humidity and thermal activity, certain special flights were made:

7/11/45 Col. Warren, Capt. Lyon, Col. Holzman were flown in the C-45 over the Trinity area and the area to the northeast for the purpose of surveying the region over which the cloud was expected to travel.

July 14, 1945 Smoke Operation

"The C-45 aircraft was over the Sierra Oscura at 0615 the morning of July 14, 1945. Smoke was observed coming from smoke pots on top of the ridge and the smoke train was blowing from east to west, falling down the escarpment and forming a layer in the bottom of the valley.

"Smoke from the smoke pots on the east slope drifted north to a canyon and then down the canyon in an easterly direction to the valley. Motion pictures were taken of the smoke trails."

[redacted]

Sgt. J. C. Alderson

July 15, 1945 Smoke Operation

The C-45 aircraft was over the Sierra Oscura for the smoke operation of July 15, 1945. Motion pictures were taken of the smoke trails.

July 15, 1945 Balloon Operation

The C-45 aircraft flew over the base camp before the smoke operation, and returned half an hour later. Meanwhile, balloons were released in clusters of two at intervals of two minutes. The ascent rate of the balloons was approximately 600 feet per minute. When the aircraft returned there was a trail of balloons separated by about 1200 feet extending to about 18,000 feet. The train of balloons was well defined, and it was possible to chart a compass course at the various levels and as the airplane was flown along the course, toward Base Camp. It was possible to determine by theodolite observation the course of the airplane and therefore the balloon to approximately one degree. Such a study would be of value in a homogeneous wind field, and it wasthought that this technique could be used to study the wind structure before the operation as a further check upon the rawin andpilot balloon observations.

7/18/45 The C-45 aircraft was flown over the Trinity area with Mr. J. E. Mack and Sgt. York for the purpose of making photographs and motion pictures of the crater. The ship was flown at altitudes of 2000 feet, 10,000 feet and 500 feet above the crater. On the return to Kirtland Field, the ship was flown over the track of the cloud on a compass course of 30 degrees and pictures taken of the terrain.

7/29/45 The C-45 aircraft was tested for radiation by Mr. J. Magee, and it was found that there was little or no contamination on the fusilage, but the motors were positive with the greatest concentration in the air filters of the carburators. The ship was flown in the area 48 hours after the shot and was flown for a total of 20 hours between 7/18/45 and 7/29/45.

Dilution Studies

"The only data on dilution with respect to various meteorological conditions that I know have been taken at Hanford. But there all the work on dilution was done in the lowest 200 to 300 feet of the atmosphere. The three stability conditions of the atmosphere, stable, neutral, and unstable have been investigated quite thoroughly with regard to the dilution each condition produces. It is questionable whether or not the dilution rates found in the lower layers can be

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"applied to the great altitudes the smoke reached on May 7th. There is no question, however, that certain characteristics will be similar, for example, in stable air smoke of the same density as air will stratify, fan out laterally and widen slowly downwind. The average rate of dilution found under stable conditions varied somewhat with the degree of stability but is of the order of

$$\log Y_m = \frac{\log X - 1}{0.7}$$

where Y_m is the average dilution of the cloud

and X is the distance from the stack in ft.

In this case the smoke issuing from the top of the stack was considered to be of unit concentration and dilution started there. The above equation holds true for the average of the mean cloud dilutions out to 7000 ft from the stack.

"The least dilution is that momentarily observed in the densest or least diluted part of a cloud segment. The least dilution followed rather closely, again out to 7000 ft.,

$$Y_a = 400 + 0.47\,X$$

where Y_a is the least dilution

and X is distance from the stack (ft) - 3000 (ft)

In tabular form the dilutions are as follows;

distance from stack	1000'	2000'	3000'	4000'	5000'	6000'	7000'
average dilution (times)	700	1900	3500	5400	7500	9700	12600
least dilution "	150	300	500	800	1300	1800	2300

"From the above equations, if extrapolation may be used, the average dilution which should occur by the time a cloud has drifted <u>in stable air</u> from the point above Trinity where the cloud reaches equilibrium with the air density (assumed to be the smoke column after the shot) to over Carrizozo this dilution of the cloud should be $1.4 \cdot 10^6$ within which there will be less diluted portions which will have been subjected to a dilution of $1.0 \cdot 10^5$, using a distance of 200,000 ft, app. 40 miles. This further assumes that the concentration at the top of the smoke column where stratification of the smoke begins is 1. I hesitate to extrapolate to 40 miles when taken have been taken out from a smoke source only 1.5 miles.

"In unstable air the rate of dilution is quite different because the air is composed of an infinite number of eddies of all dimensions. These eddies produce a high rate of dilution, a rate so great that we have been unable to obtain an appreciable number of readings as close as 2000 ft from the stack. We did not trust our instruments

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"beyond a dilution of 10,000 when working in the field though calibration in a laboratory showed the instruments would detect smoke diluted about 50,000 times from that in the stack. In unstable air the least and average dilutions at various distances from the stack are as follows:

distance from stack	1000'	2000'
least dilution	900	2500
average dilution	4000	16000

"Again with free use of extrapolation at 10,000 ft the average dilution should be well over $1.0 \cdot 10^5$, perhaps 10^6 and the least diluted portions somewhat less, perhaps 10^4.

"Assuming that the smoke column from the shot will stratify 10,000 ft above the surface, that it remains at that altitude until over Carrizozo and then unstable air brings it to the surface at that point, the cloud would then have been diluted $1.0 \cdot 10^5$ or perhaps $1.4 \cdot 10^6$ plus the dilution in the unstable air so necessary to bring it to the ground which would be 10^5 or 10^6. On the other hand, if the shot was made under the unstable conditions of the day time, the dilution could reach perhaps 10^{100} before reaching Carrizozo if extrapolation can be trusted.

"In answer to the second question there are several meteorological conditions to be considered for the dress rehearsal.

"(1) Like the first shot, only a wind somewhere between northwest and southwest should be used. A due west wind carries air to Carrizozo and one slightly north of west carries it toward Roswell. In view of the fact that extrapolation is dangerous on so serious a problem probably a wind slightly south of west would be most desirable.

"Normally there is a change of wind direction with increase of altitude. The greater this change per unit distance vertically, the greater the dilution, hence if a time can be picked when there is a change of direction at the altitude of anticipated "mushrooming" or stratification of smoke the hazard would be further reduced.

"(2) The vertical temperature structure for maximum dilution should be super-adiabatic in which active "thermals" or eddies are present. This situation exists from about 3 hrs after sunrise to about sunset, with a maximum activity and vertical penetration of eddies during early afternoon.

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VII. CONCLUSION

The meteorological program prepared for the July 16th nuclear explosion at Trinity consisted of the procurement of excellent equipment, adaquate personnel, sufficient data, together with combined judgment in the evaluation of the weather problem and weather forecast.

A program was developed by which an economical and efficient use of weather could be obtained. The problem changed complexion and developed into a fixed date operation in which the operation was tailored to the weather.

It is suggested that future operations be conducted under a program which fits the weather to the operation, and that the operation be carried out on days of optimum conditions according to the weather forecast.

An operation such as the Trinity nuclear explosion requires a precision forecast about ten days in advance. Extended forecasts in this range have been carried out by a limited number of forecasters in the AAF Weather Division and at Cal Tech. It is suggested that future operations be safeguarded with the best long range forecasters available, as the nature of the operation and the precision and range of the forecast makes the problem extremely difficult.

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P. E. Church, Consultant on dilution.

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