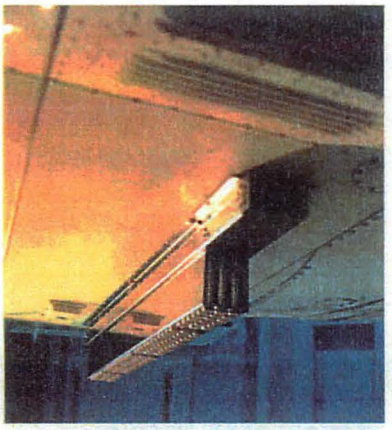
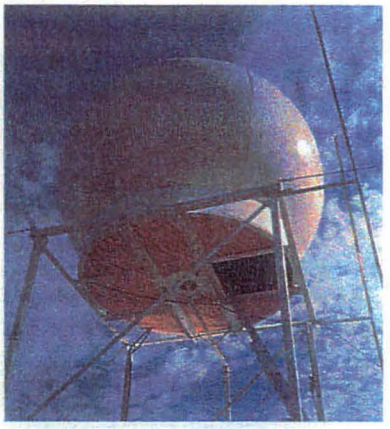
# Edwards Aquifer Precipitation Enhancement Program

## Final Report 2001



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# Edwards Aquifer Precipitation Enhancement Program

# Final Report 2001

*February 2002*

**A program designed for the Seeding of Convective Clouds with Glaciogenic Nuclei to Augment Precipitation for the Edwards Aquifer region.**

**By**


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## EXECUTIVE SUMMARY

This report summarizes the activities and data collected during the 2001 field operations of the Edwards Aquifer Precipitation Enhancement Program. This was the third year of a program conducted by Weather Modification Inc. (WMI) of Fargo, North Dakota, for the Edwards Aquifer Authority (the Authority) of San Antonio, Texas. The program was funded by the Edwards Aquifer Authority, the Texas Natural Resources Conservation Commission, and the Texas Department of Agriculture, with the sole intent being enhancement of precipitation through cloud seeding. The project area covered 6.37 million acres across south Texas, including all or parts of the following 12 counties: Bandera, Bexar, Blanco, Caldwell, Comal, Guadalupe, Hays, Kendall, Kerr, Medina, Real, and Uvalde. Seeding operations were conducted 24 hours-a-day, seven days a week from April 15 through September 15.

The facilities and procedures for this project were as follows: One C-band weather radar, computers, and a communications system were set up at the centrally located Hondo Regional Airport in Hondo, Texas, to monitor storms and control aircraft. The radar operated continuously throughout the five-month period. The storms, as detected by radar, were posted on the WMI Internet Home Page at 15-minute intervals, thus allowing remote near real-time viewing of operations. Two specially equipped cloud seeding aircraft were dedicated to the project; both were stationed in Hondo. On August 13, 2001, a hangar containing one of the aircraft caught fire and was destroyed, along with the aircraft. A replacement aircraft arrived at Hondo on August 14. Both aircraft were relocated to the Castroville Airport, 15 miles east of Hondo, on the morning of August 14.

High yield formulations of silver-iodide pyrotechnics and acetone solutions were used to generate high concentrations of very fast acting ice-nuclei. High performance aircraft crewed by experienced pilots and directed by experienced radar meteorologists treated developing regions of the storms by direct injection with the seeding agents.

The 2001 field program successfully achieved its objective, to seed those cells thought to have the potential to produce precipitation. During the five-month project, the two aircraft safely completed 58 flights totaling 152 hours 58 minutes. A total of 21.7 kg of seeding agent was dispensed in the form of 834 ejectable flares and approximately 82.8 gallons of silver iodide - acetone solution, which was burned in wing-tip generators.

This final report for 2001 provides a general overview of the program and describes the methodology used. Pictures, tables, graphs, and references are used to summarize the operational activities. All of the project's radar data, meteorological data, and reports (weekly operations summaries and monthly reports) have been recorded onto CD-ROM and are available to the Authority.

## ACKNOWLEDGEMENTS

WMI wishes to acknowledge the support of Bobby Bader, Program Coordinator, Edwards Aquifer Authority and George Bomar, State Meteorologist, Texas Department of Licensing and Regulations. Their continued assistance and cooperation was greatly appreciated.

A number of agencies and people deserve recognition and thanks. The assistance of Air Traffic Control (ATC) facilities at Houston is gratefully acknowledged. The cooperation by the ATC played an important role in allowing the project pilots to treat developing storms in an efficient and timely manner. Special thanks are extended to the City of Hondo, which provided the property where the WMI radar trailer was sited and authorized the use of the radar tower. Special thanks are also extended to Tim Fousse, the FBO Manager at the Castroville Airport. The cooperation of these people contributed to the success of the project.

WMI also acknowledges the contributions, teamwork, and professionalism of the staff. They were: Jason Straub, project meteorologist; Jeremy Price, Ron Chambless, Erin Morris, Trevor Hartsock, Bob Stauffacher, and Jon Lapine, project pilots; Jon Clark, electronics technician, and Tim Sedlock, Chief Meteorologist, who filled in during Jason's vacation.

# TABLE OF CONTENTS

# LIST OF FIGURES



## LIST OF TABLES

## INTRODUCTION

Significant benefits are realized from increased precipitation. Agricultural gains include increased crop yields, improved grazing conditions, reduced irrigation costs and improved water quality. Societal benefits include increased reservoir capture of runoff, where it is used for drinking water supplies and recreational purposes.

The Edwards Aquifer region's precipitation distribution averages 24" across the region, but just slightly higher in the northeast (Figure 1).

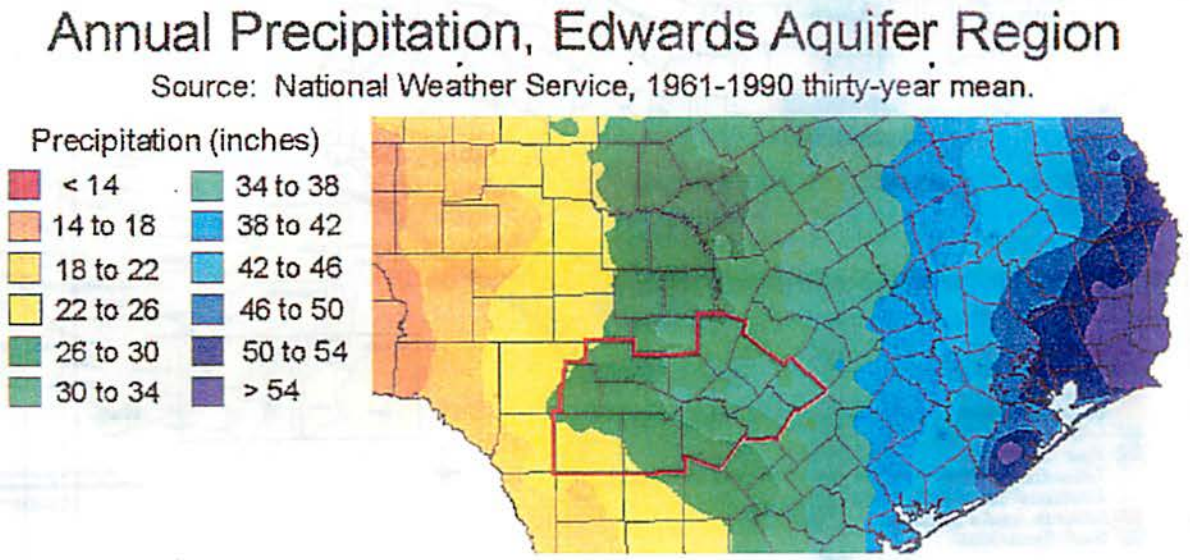


**Figure 1: Average annual precipitation (30-year mean) for the Edwards Aquifer Region of Texas. The 12-county project area is outlined in red.**

The Edwards Aquifer Precipitation Enhancement Program (EAPEP) target area covered 6.37 million acres covering all or parts of 12 Counties in south central Texas, including parts of the Texas Hill Country. The target area, relative to the other programs in the state, is shown in Figure 2. Two aircraft specially equipped to dispense silver iodide were stationed in Hondo until August 14, when they relocated to the Castroville Municipal Airport, 15 miles east of Hondo. The radar was located at the Hondo airport.

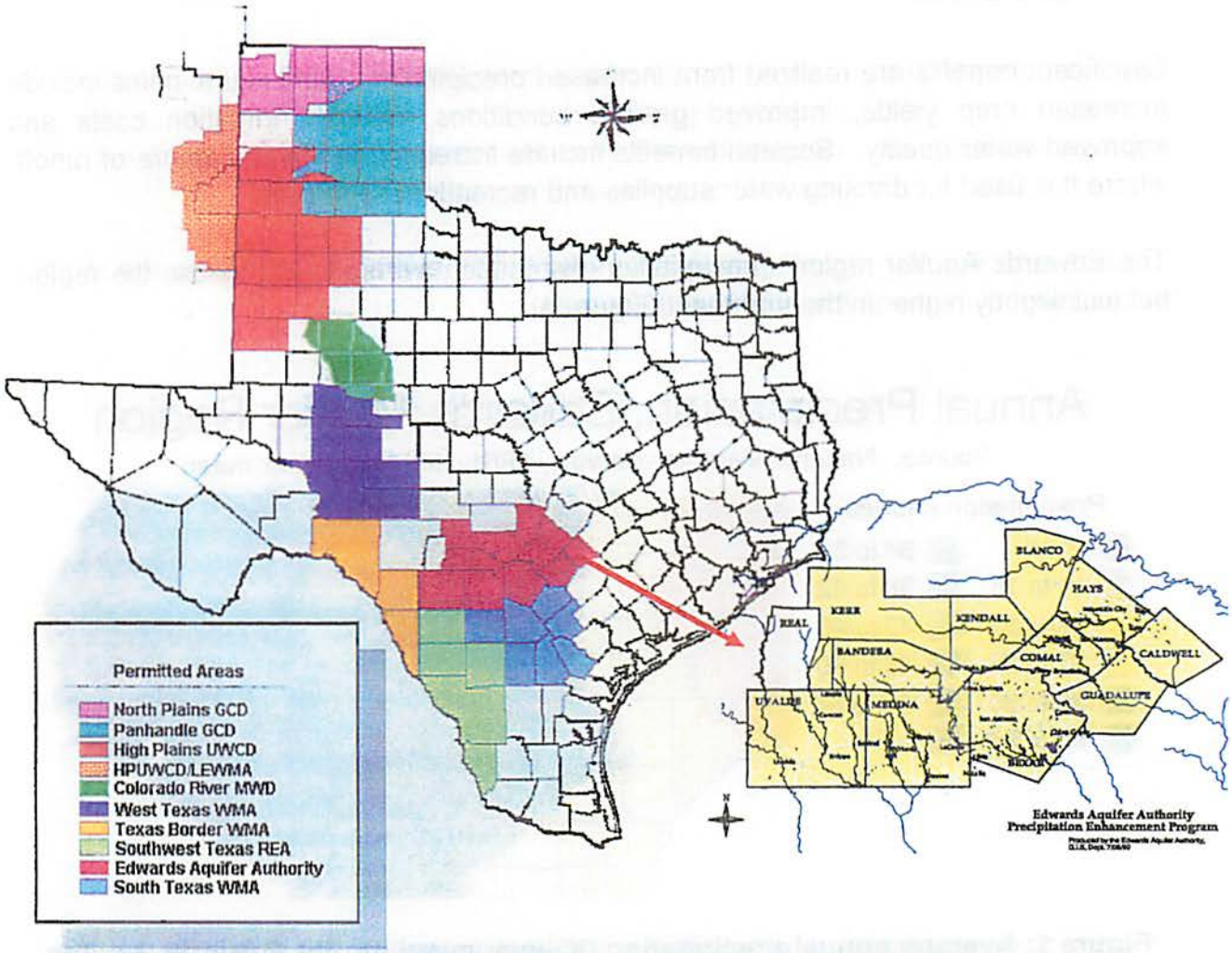


**Figure 2: Edwards Aquifer Precipitation Enhancement Program Target Area in Relation to the other Texas Programs**

Weather Modification Inc. (WMI) has been a leader in the field of precipitation augmentation since the early 1960's. With extensive knowledge and experience in cloud seeding technology, WMI is recognized for its successful operations in Texas, Oklahoma, the northern Great Plains, Mexico, Canada, and numerous other cloud modification projects around the world. WMI was awarded the contract to conduct the Edwards Aquifer Precipitation Enhancement Program (EAPEP) in April 2001, to provide the requisite personnel and equipment for the 12-county rain enhancement project.

WMI conducted the 2001 operational cloud-seeding field season from April 15 through September 15, 2001. The project is based upon the technology developed and employed in the long-term operational projects that have been in continuous operation in North Dakota since the late 1960's.

This program utilized the latest cloud seeding technology available. Project strengths included:

- A fast-acting, high-yield formulation silver iodide seeding solution used in the wing-tip ice nuclei generators;
- High performance twin-engine turbocharged Cessna 340A aircraft, for quick response and timely cloud treatment;
- Experienced meteorologists and flight crews to direct and conduct the seeding activities;
- Direct injection of seeding agents as the primary treatment method;
- Real-time GPS-based aircraft tracking and seeding data telemetry to the radar, superimposed on the evolving radar depiction of the storm systems to ensure treatment of the most suitable candidates and facilitate the direction of the seeding aircraft.

As in the 2000 project, the ejectable flares used for treatment at cloud top in the 2001 project were advanced pyrotechnics manufactured by Ice Crystal Engineering, LLC, of Davenport, North Dakota. These flares have been proven effective in tests conducted at the Cloud Simulation and Aerosol Laboratory at Colorado State University (DeMott, 1999).

## PROJECT OBJECTIVES

The goal of the EAPEP is to enhance rainfall in the target area by using state-of-the-art cloud seeding technology and procedures in the treatment of suitable convective clouds.

It is the goal of Weather Modification, Incorporated (WMI) to aid the Authority in attaining the project objectives by providing:

1. 24 hours a day, 7 days a week weather surveillance using one C-band weather radar.
2. Cloud seeding capability through the use of two specially equipped aircraft.
3. Radar and seeding data for possible project analysis of cloud seeding operations.

An additional, and overriding, goal is to conduct the operations safely with due regard for life and property on the ground and in the air.

## OVERVIEW OF METHODS

The Authority's objective is to seed clouds with silver iodide to augment naturally occurring precipitation. Seeding agent can be delivered to suitable clouds by aircraft using one of two methods:

1. Direct injection by release of cloud seeding agents at cloud top; or
2. Release of ice nuclei into the updraft by sub-cloud base seeding.

### Cloud Seeding Methodology-Seeding Techniques for Rainfall Increase

In **cloud base seeding**, silver iodide complexes are produced either by the combustion of acetone-based solutions or by the burning of silver-iodide flares attached to racks on the trailing edges of the wings. The nuclei thus produced are ingested by the target clouds' updrafts, transported upward to the regions containing supercooled liquid water, and mixed through a significant portion of the cloud volume, where nucleation (freezing) occurs (Boe et al. 1997). If treatment is timely, the seeding agent should reach the supercooled portions of the cloud at about the time the cloud top is growing through the -10°C level. Nucleation in these seeded clouds is believed to occur, on average, at temperatures about 5 to 10°C warmer than most natural nucleation. Given typical cloud growth rates, this affords a "head start" in precipitation development on the order of 3 to 5 min (for example, see Smith et al. 1997).

In **direct-injection seeding**, ejectable silver iodide flares are used. Again, clouds growing through the -10°C level are targeted. The seeding flares are placed into the supercooled cloud where nucleation is desired, so the updrafts in these cases are relied upon only to provide a continuing source of condensate, not to transport the seeding agent upward from cloud base. This delivery technique thus requires less anticipation on the part of those directing the seeding and may have a more immediate effect.

In both cases, the intent is to glaciate portions of the cloud, initiating ice development minutes earlier than would naturally have been the case (Kahan et al. 1995). For smaller or more isolated convective towers, glaciogenic seeding may accelerate hydrometeor growth sufficiently to allow the cloud to produce precipitation-sized hydrometeors during its short lifetime (microphysical effects, see Silverman 1986), while adding buoyancy that may stimulate updrafts and prolong the cloud lifetime as well (dynamic effects, see Rosenfeld and Woodley 1993, Rosenfeld et al. 1994, and Rosenfeld and Woodley 1996). Both contribute to increased precipitation production.

Storm cells (defined by radar) with maximum reflectivity greater than 35 dBZ within the cloud layer above the -5°C level and located within the project areas, were seeding candidates. Radar observers and aircraft controllers were responsible for making the "seed" decision and directing the cloud seeding missions. Patrol flights were generally launched before clouds met the radar reflectivity seeding criteria. These patrol flights provided an immediate response to developing cells. In general, a patrol was launched in the event of visual reports of vigorous towering cumulus clouds or when radar cell tops exceeded 22,000 ft (22 kft) height on days when the forecast called for precipitation.

More than one aircraft was often launched, depending upon the number of storms in each area, the lead time required for a seeding aircraft to reach the proper location and altitude, and projected overlap of coverage and on-station time for multiple aircraft missions. Only one aircraft can generally work safely at cloud top and one aircraft at cloud base for each storm.

The decision to seed either at cloud top or cloud base was based upon storm structure, visibility, cloud base height, and the time available for aircraft to reach seeding altitude.

Cloud base seeding was conducted by flying just below cloud base, within the main inflow of single cell storms, or within the inflow associated with the growth of new cloud turrets (often in advance of the shelf cloud) located on the upshear side of multicell storms.

Cloud top seeding was typically conducted between -5°C and -15°C. The 20-gram flares fell approximately 4,000 ft (approximately 10°C) during their approximately 40-sec

burn time. The seeding aircraft penetrated the edges of single convective cells meeting the seeding criteria (Figure 3). For multicell storms, or storms with new cloud turrets developing on their flanks (feeder clouds), the seeding aircraft penetrated and seeded the tops of the developing cumulus towers on the upshear sides of convective cells, as they grew up through the -10°C altitude.

**Figure 3: A cloud seeding aircraft dropping ejectable flares at cloud top (photo courtesy John Ulan).**

According to the operations plan, if the radar reflectivity criteria are met, seeding of all cells is to be continued. However, seeding is effective only within cloud updrafts and in the presence of supercooled cloud water, i.e. the developing stage of the thunderstorm.

## Seeding Rate

A seeding rate of one 20-gram flare every 5 seconds was used while in updraft during cloud penetration. A slightly higher rate was used (e.g. 1 flare every 2 seconds), if updrafts were very strong (e.g. > 2000 ft/min) and the storm was particularly intense. Passes were repeated as new turrets grew to aircraft (seeding) altitude. If none did, the crew waited 5 to 10 minutes to allow for the seeding material to take effect, as evidenced by visual signs of glaciation. This ensured the optimum usage of seeding agent. Calculations and laboratory tests show that this seeding rate will initially produce more than 1300 ice crystals per liter.

For cloud base seeding, the two wing-tip generators were used. Cloud base seeding passes were repeated until no further updraft (inflow) was found. Base seeding was not conducted if downdrafts were encountered at cloud base, since downdrafts are indicative of the dissipating stage.

## Seeding Materials

Silver iodide is dispensed using ejectable flares and acetone burners. The silver iodide and acetone seeding solution recipe used in 2001 appears below.

### 2001 WMI Airborne Generator Seeding Solution

Chemical Formulation: 2% (by weight) AgI - 0.5 $NH_4I$ - 0.1 $C_6H_4Cl_2$ - 1.0 $NaClO_4$

Recommended Burn Rate: ~2.5 gallons per hour

Nucleation Mechanism: Condensation Freezing

Total Solution Weight: 33.5 lbs. (5 gallons)

Volume: ~ 5.0 gallons, scale for other amounts

Aerosol Produced by Combustion: $AgI_{0.85}AgCl_{0.15}NaCl$

| Constituent | Chemical Formulation | Molecular Wt.(g/mole) | Mass (g) | Weight (lb.) | Volume (gal) |
|---|---|---|---|---|---|
| Silver Iodide | AgI | 234.77 | 304.2 | 0.67 | n/a |
| Ammonium Iodide | $NH_4I$ | 144.94 | 93.9 | 0.21 | n/a |
| Paradichloro-benzene | $C_6H_4Cl_2$ | 147.00 | 19.0 | 0.042 | n/a |
| Sodium Perchlorate, 99% | $NaClO_4$ | 140.48 | 181.8 | 0.40 | n/a |
| Water | $H_2O$ | 17.99 | 607.7 | 1.34 | 0.202 |
| Acetone | $(CH_3)_2CO$ | 58.08 | 13985.5 | 30.84 | 4.645 |

**Table 1: Silver Iodide - Acetone Solution Specifics**

A WMI pressurized acetone generator is shown in Figure 4. The acetone burners require regular preventive maintenance in order to function properly and reliably. Crews kept a close watch on igniter rods, valves, and seals to ensure reliable operation, and were resupplied with adequate spares and tools as required.

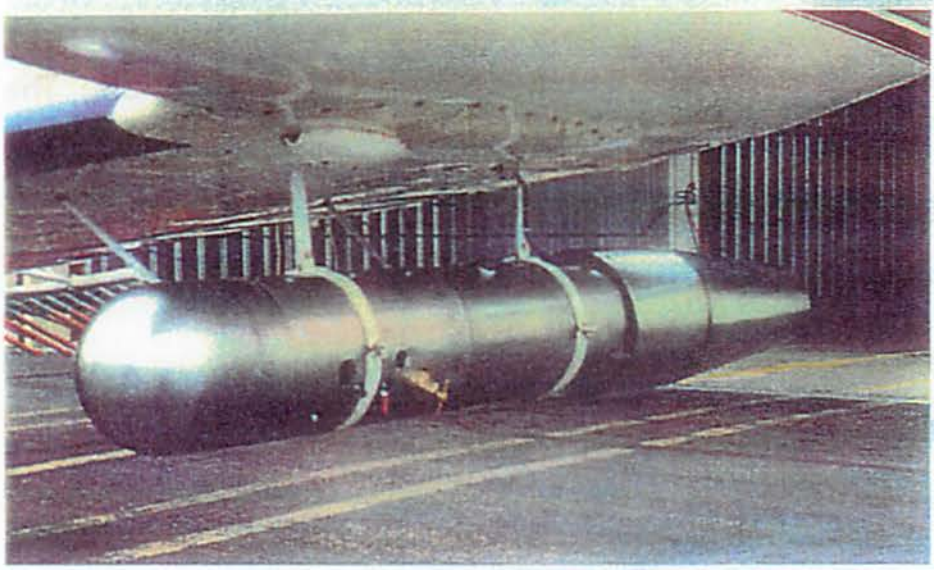

**Figure 4: An acetone generator on a Cessna 340 aircraft.**

In 2001, WMI used silver iodide flares manufactured by Ice Crystal Engineering, LLC (ICE) in Davenport, ND. These ejectable flares contain 20 grams of seeding material, burn for approximately 40 seconds, and fall approximately 4,000 ft.

## Flare Tests

The ice nucleating effectiveness of the ICE flares used by WMI are documented (Demott, 1999). The Cloud Simulation and Aerosol Laboratory (SimLab) at Colorado State University (CSU) has performed routine testing of the ice nucleating ability of aerosols produced from cloud seeding flares for many years (Garvey, 1975). The primary product of the laboratory characterization is the "effectiveness plot" for the ice nucleant, which provides the number of ice crystals formed per gram of nucleant burned as a function of a range of cloud temperatures.

Specified temperatures for testing in the isothermal cloud chamber were -4°C, -6°C, and -10°C. Three pyrotechnics were tested at each temperature. The liquid water content of the chamber clouds was set to 0.5 $g/m^3$ and 1.5 $g/m^3$, which is representative of the range found in the clouds of south Texas. The average effectiveness at each cloud temperature is given in Table 2.

| Temperature (°C) | Effectiveness (# ice nuclei/g) |
|---|---|
| -4.0°C | $1.04 \times 10^{11}$ |
| -6.1°C | $6.62 \times 10^{12}$ |
| -10.5°C | $3.07 \times 10^{13}$ |

**Table 2: Average Ice Nuclei Effectiveness of ICE Silver Iodide Flares per gram of at 1.5 g/m$^3$ Liquid Water Content.**

Significant conclusions from these recent tests for the ICE flares (Table 2) are:

1. The aerosol particles produced by the new ICE pyrotechnics were highly efficient ice nucleating aerosols. Yield values were approximately $1x10^{11}$, $5x10^{12}$, and $3x10^{13}$ ice crystals per gram pyrotechnic at -4°, -6°, and -10°C in 1.5 g/m$^3$ clouds in the CSU isothermal cloud chamber. Improvement compared to the previous pyrotechnic formulation used by ICE was modest at -6°C, but most significant (factor of 3 increase in yield) at -4°C.

2. The ICE pyrotechnics burned with a fine smoke and a highly consistent burn time of ~ 37 seconds.

3. Rates of ice crystal formation were very fast, suggestive of a rapid condensation freezing process. The balance of observations showed no significant difference in the rate data obtained at varied cloud densities, supporting a conclusion that particles activate ice formation by condensation freezing. (DeMott, 1999)

## PROGRAM ELEMENTS AND INFRASTRUCTURE

A schematic figure of the operational elements for the precipitation enhancement project is shown in Figure 5 on the next page. Details of the individual elements are described in more detail in the following sections.

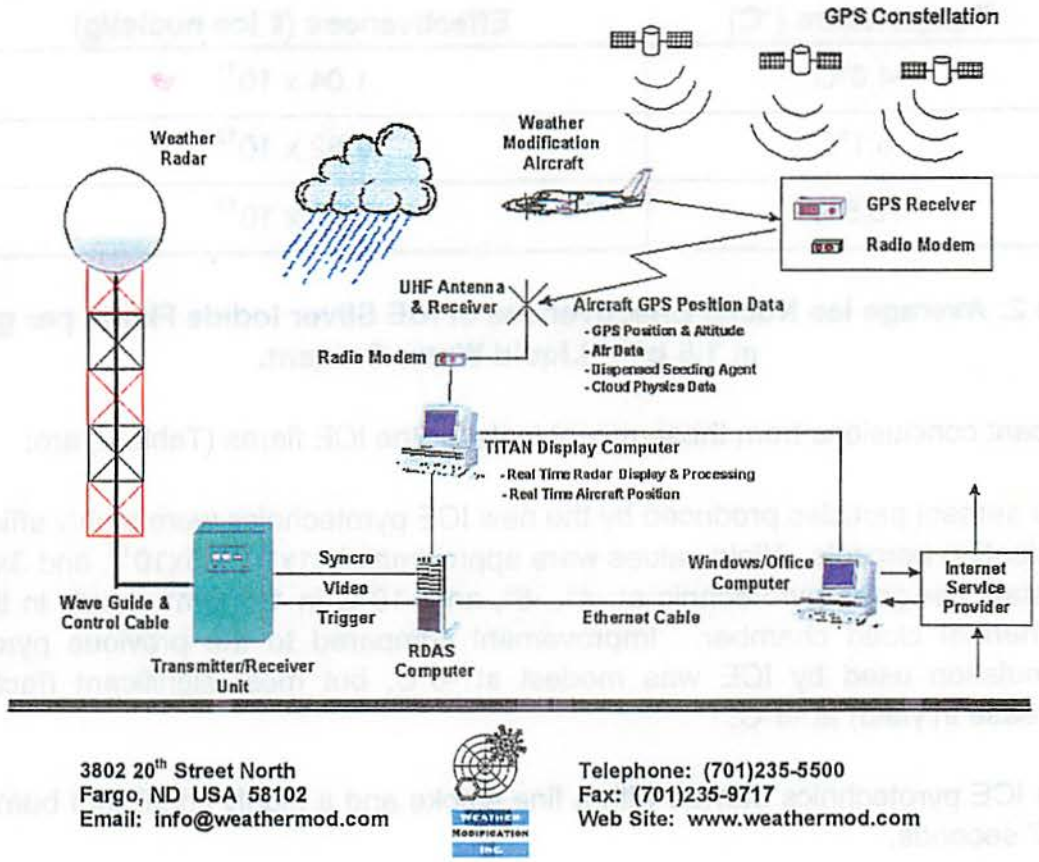


**Figure 5: A schematic of the operational elements of the Edwards Aquifer Precipitation Enhancement Program.**

## Air Traffic Control

Prior to the start of field operations, Federal Aviation Administration (FAA) Air Route Traffic Control Centers (ATC) facilities were notified of the planned weather modification flights to be conducted over south Texas from April 15 through September 15, 2001. Permission was granted by ATC to file pre-defined flight plans for the project aircraft, with special designations and fixed transponder codes, as Seed 1 for Cessna 340A N3904G and Seed 2 for Cessna 340A N340AX, both stationed in Hondo. N3904G was destroyed in a hangar fire on August 13. On August 15, WMI relocated C340A N340FR to the project to replace N3904G as Seed 1. Direct dial-up telephone numbers were used to notify air traffic controllers of cloud seeding launches. Aircraft were launched to specific locations defined by Very High Frequency (VHF) Omnidirectional Range (VOR) and DME (Distance Measuring Equipment) coordinates. Clearances were given to project aircraft within a 10 nautical mile radius of the specified storm locations. Cloud top aircraft were given 2,000-ft clearance above their altitude and 5,000 ft below their altitude. Cloud base aircraft were given a +/-1,000-ft altitude clearance. This procedure worked very well in general. On a few occasions, seeding aircraft were asked to climb

to a higher altitude or to suspend seeding to allow other commercial aircraft to pass below them. The ATC clearances and codes are shown in Figure 6.

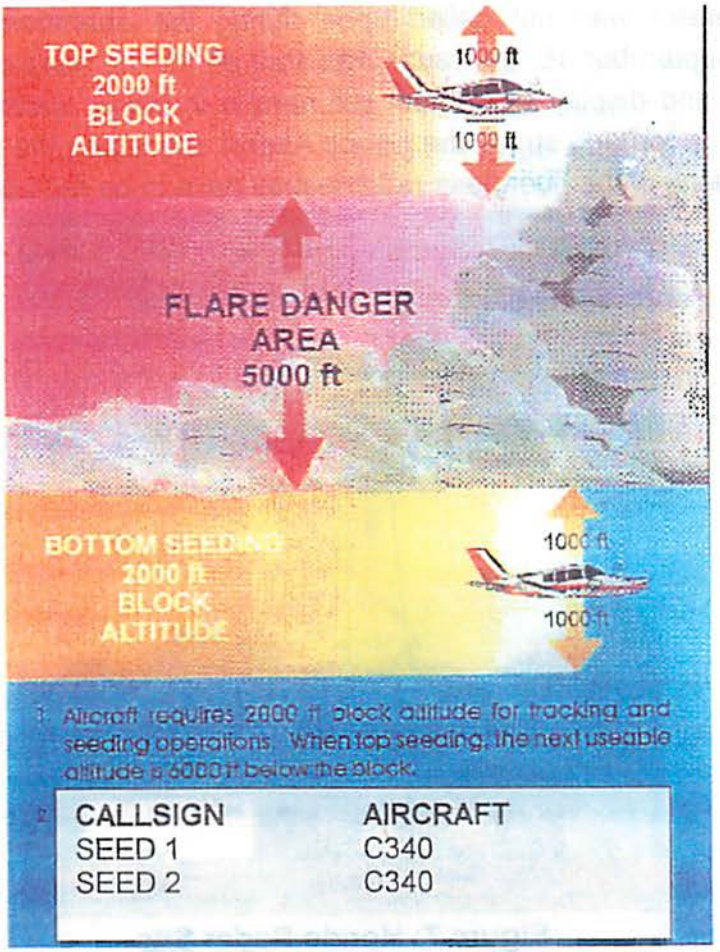


**Figure 6: Schematic figure showing aircraft cloud seeding block altitudes required for Air Traffic Control (ATC).**

## RADAR CONTROL AND COMMUNICATIONS CENTER

The radar control room contains a WMI radar console, the radar data acquisition system (RDAS) computer, the AirLink computer with radio telemetry modem for GPS tracking information, as well as the TITAN (Thunderstorm, Identification, Tracking, Analysis, and Nowcasting) computer and display. The project meteorologists communicate with the seeding aircraft using a VHF radio.

### Weather Radar

The project weather radar was located on a radar tower previously used by the National Weather Service in Hondo, shown in Figure 7. The radar is an Enterprise Electronics Corporation WSR-74C, C-band radar with an 8-ft diameter antenna. The radar operated

around the clock throughout the operational period of April 15 through September 15. A gas-powered generator was used to provide emergency power in the case of a power failure. Commercial power was very reliable at the radar during the summer. The emergency generator was not called upon during the operations, but it was tested frequently. On September 16, the radar was shut off for the season, however the tower, radar transmitter and display equipment will remain in place, waiting for next year. On October 12, 2001, a tornado struck the Hondo Airport, damaging the radome. Prior to next season, four sections of the fiberglass radome may have to be replaced.

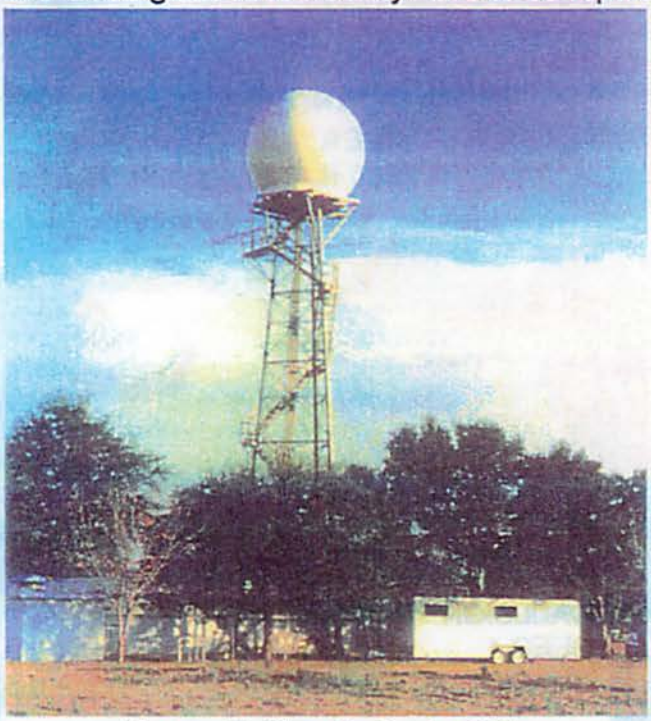

Figure 7: Hondo Radar Site

The radar signal processor is an RDAS (Radar Data Acquisition System) produced by Electronic Systems Development, South Africa. The display and analysis system is the TITAN (Thunderstorm Identification, Tracking, Analysis, and Nowcasting system) software package available from the National Center for Atmospheric Research (Dixon and Wiener 1993). More details and examples of the TITAN system displays and products are given in a later section. The weather radar offered by WMI is a sensitive instrument capable of detecting rainfall rates of 1mm/hr or less out to 70 nautical mile (NM) range. Storm echoes can be displayed on either the Plan Position Indicator (PPI) or Range Height Indicator (RHI) displays. Echo intensity and echo top height can also be measured.

## Radar Calibration Checks

The quantitative use of radar requires that various parameters of the system be aligned and calibrated. With regular calibration, the radar provided accurate measurement of storm position and intensity.

The terms within the radar equation relating to the radar hardware and electrical components are constants. For water (cloud droplets and rain drops), the radar equation then takes the form (Rinehart, 1997):

$$z = C\, p_r\, r^2$$

Thus, calculation of the radar reflectivity factor, z, is simply a matter of getting the power from a target, $p_r$, of known range, r (times a constant, C, the radar constant). The new RDAS radar acquisition software performs digital signal processing to simulate a quadratic response of the receiver output (Terblanche, 1996) and uses a reference range of 100 km. The Hondo radar was found to be stable within +/-1 dB from day to day, and the radar constant varied by less than 1 dB over the summer.

## Aircraft Flight Tracking Global Positioning System (GPS)

The radar-equipped WMI operations center also received, displayed, and recorded data from the aircraft GPS tracking systems. This system superimposed the aircraft positions on the radar constant-altitude plan position indicator (CAPPI) display, enabling the meteorologist to accurately direct the seeding aircraft to optimum seeding locations within the storm system. The color-coded aircraft position on the PPI display allowed discrimination between each project aircraft. A sample flight track plot for both aircraft is shown in Figure 8.

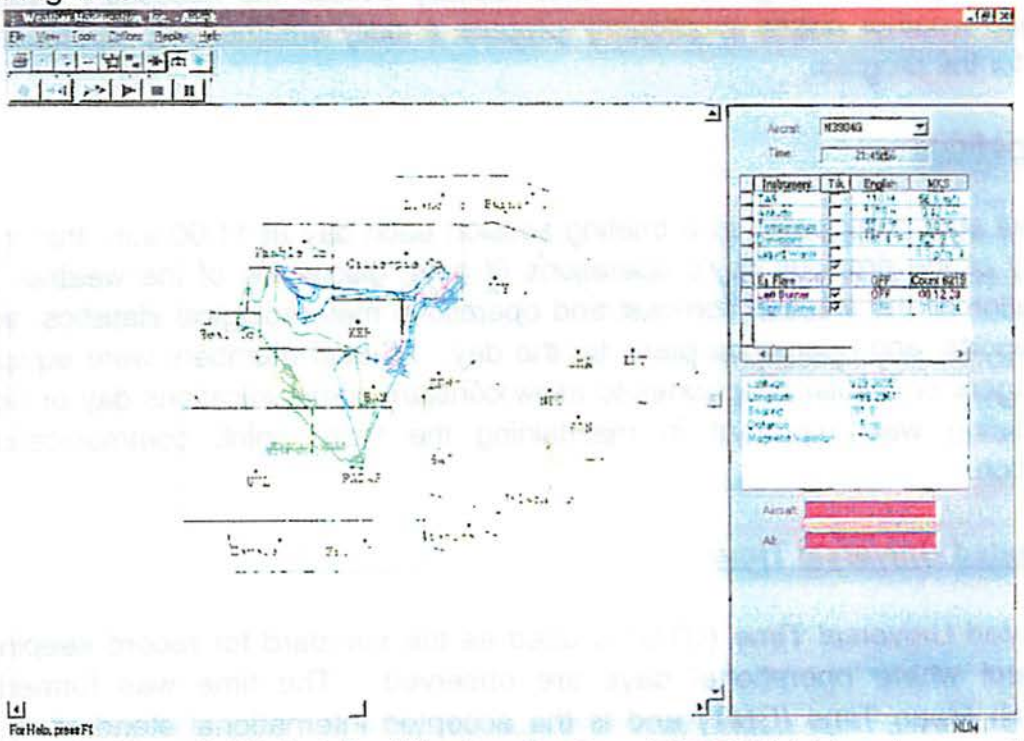

**Figure 8: Aircraft Global Positioning System (GPS) flight tracks, seeding locations, and real-time meteorological information via the AirLink telemetry system.**

The AirLink display is shown in Figure 8. AirLink is a Windows-based program that allows the meteorologist to track and display the seeding events: i.e. the exact times and locations of flare drops and total time and locations of the acetone generator usage.

## Meteorological Data

WMI meteorologists used data from the Internet for forecasting purposes. Daily synoptic observations and upper air data were used to determine the atmospheric conditions (temperature, humidity, pressure, and wind field) over the project area. The radar and satellite data were also used to support operations. The list of some of the Internet web pages utilized by the meteorologists includes:

| | |
|---|---|
| Ohio State University Gopher | http://asp1.sbs.ohio-state.edu/ |
| Unisys Weather | http://weather.unisys.com/ |
| UCAR | http://www.rap.ucar.edu/weather/ |
| Storm Prediction Center | http://www.spc.noaa.gov/ |
| WeatherTap | http://www.weathertap.com/ |
| WMI Index of /radar/Hondo | http://www.weathermod.com/radar/edwards |

Access to high quality, real-time weather information was readily available on the Internet. WMI made special arrangements to automatically access the necessary analyses and prognostic weather charts to properly prepare a daily weather and operations/update briefing for the program.

## Daily Briefings

All project staff participated in a briefing session each day at 11:00 a.m. that included a summary of the previous day's operations (if any), discussion of the weather situation, presentation of the weather forecast and operations meteorological statistics, equipment status reports, and operations plans for the day. All staff members were equipped with either pagers or cellular telephones to allow constant communications day or night. The daily briefing was important in maintaining the team spirit, communications, and cooperation.

## Coordinated Universal Time

Coordinated Universal Time (UTC) is used as the standard for record keeping during the project where operational days are observed. The time was formerly called Greenwich Mean Time (GMT) and is the accepted international standard of time for general aviation and meteorological observations, reporting, and communication. Although a seeding operation may occur on two separate UTC 'days', it is recorded as

the same day for operational purposes. In Texas, UTC is five hours ahead of Central Daylight Time (CDT). For example, if seeding operations commenced at 5 PM CST (2200 UTC) on May 1st and continued until 9 PM CST (0200 UTC), the 'operational day' would be logged as May 1 although operations continued into May 2nd on the UTC clock. UTC can be converted to Central Daylight Time (CDT) by subtracting 5 hours, and can be converted to Central Standard Time (CST) by subtracting 6 hours.

The standard convention incorporated by the Texas project is to express all aircraft, radar, and meteorological times in UTC, however, for convenience, the summary tables are all organized according to the local calendar "storm" day. In other words, a storm that occurred on the evening of May 1st, 2001 at 8:00 p.m. (0100 UTC, May 2nd, 2001) is shown to occur on May 1st in all of the project summary tables and logs.

## Seeding Amounts

The amount of seeding agent dispersed on each day of operations during the 2001 season is shown in Figure 9. A total of 21.7 kg of seeding agent was dispensed on 29 days of cloud seeding. There were 46 seeding flights performed from April 15 through September 9 of the operational period.

Figure 9 shows that the most active days of the season were August 31, and August 27, with more than 1500 grams of seeding agent being dispersed on each day. There were eight days on which more than 1000 grams of seeding agent were dispersed. That is 27.6% of the days on which seeding took place.

The amount and type of seeding material used on the project during the 1999, 2000, and 2001 seasons are shown in Figure 10. The figure shows that less silver iodide - acetone solution was used this season than last season, and that fewer ejectable flares were used this season than in previous seasons.

## Weather Forecasting

The project meteorologist provided a detailed weather forecast each day that was communicated to the project pilots. The forecast was developed using real time weather information obtained from the Internet from a wide range of weather-associated sites. The decision-making flow chart for the Edwards Aquifer Precipitation Enhancement Program is shown in Figure 11.

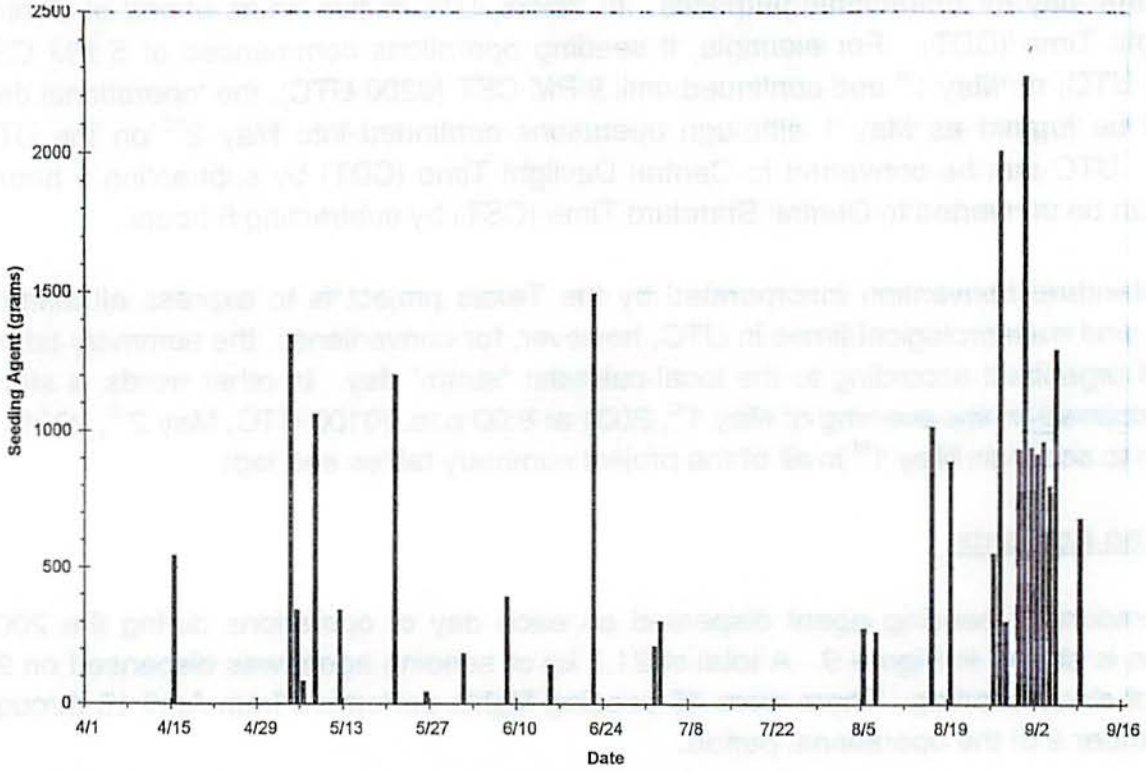


**Figure 9: Amount of Seeding Agent dispensed per operational day in 2001.**

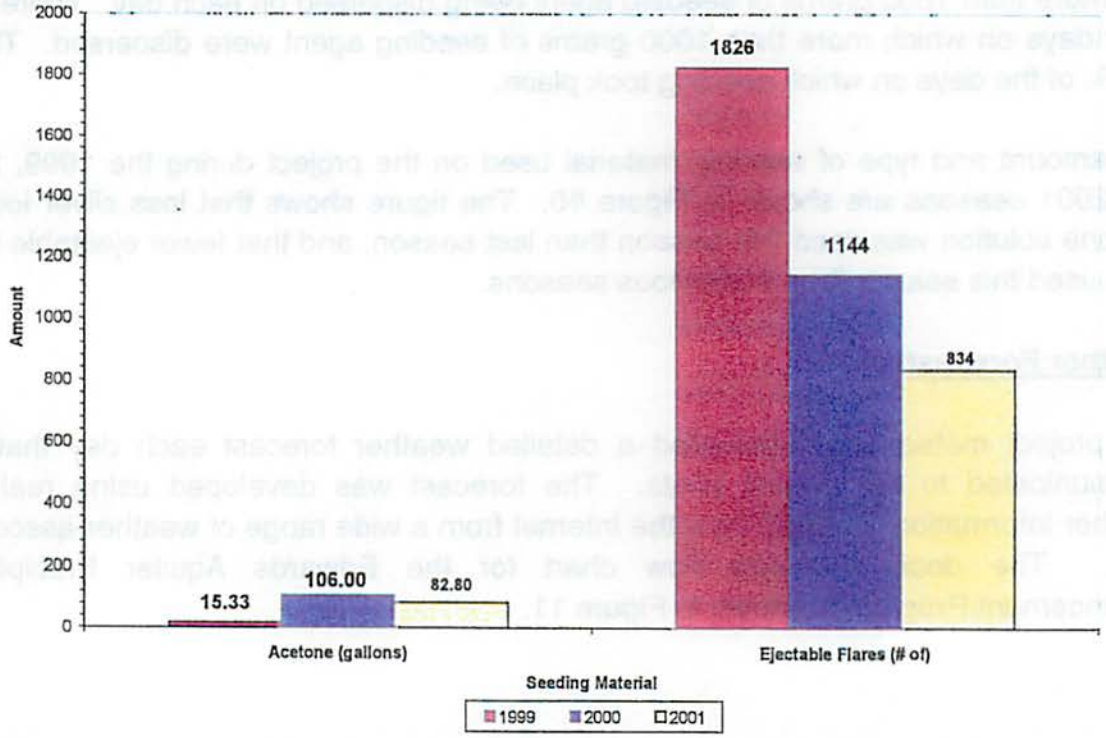


**Figure 10: Amount and Type of Seeding Materials Used, 1999, 2000, and 2001 Seasons.**

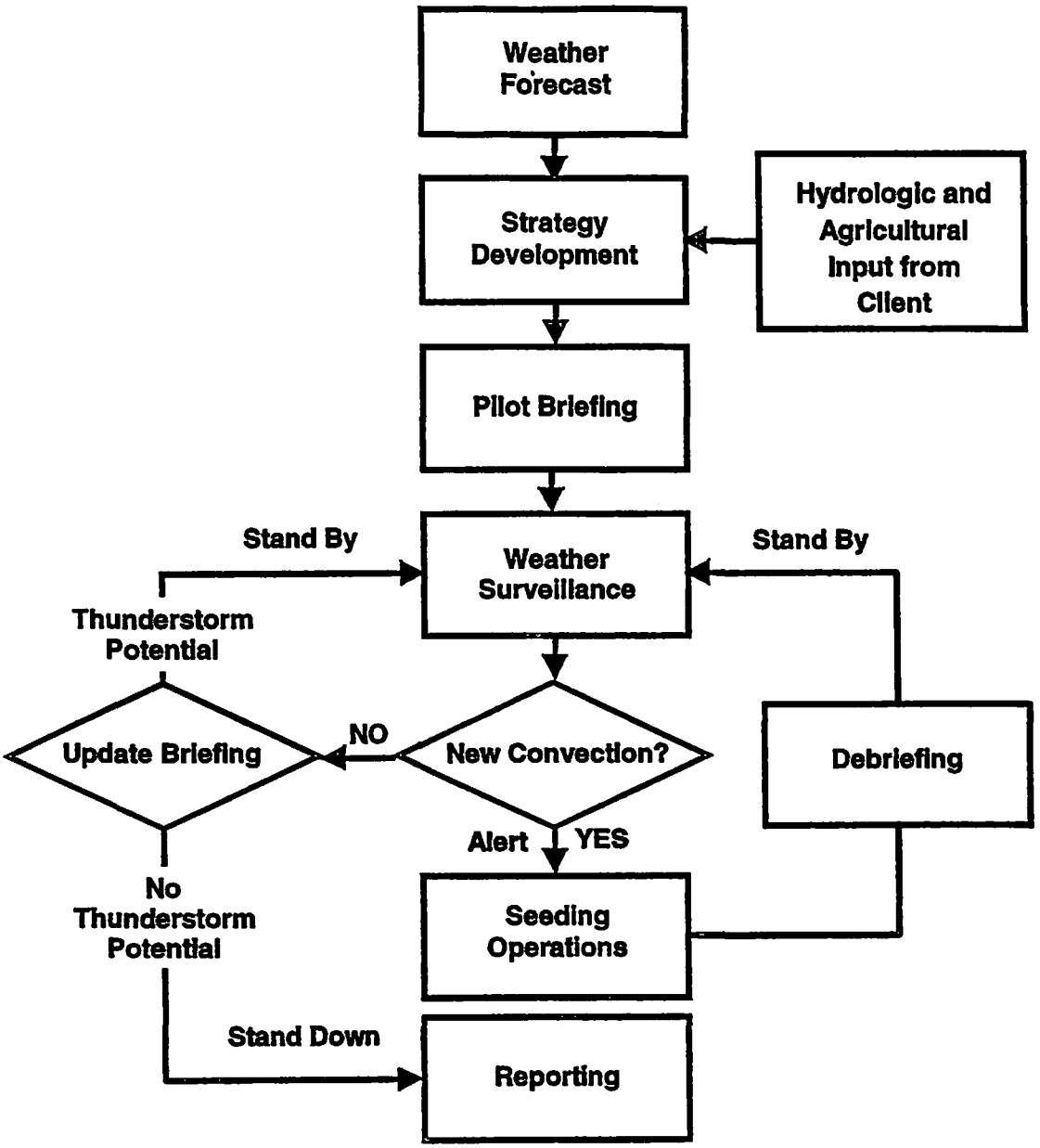


**Figure 11: Decision-Making Flow Chart for the Edwards Aquifer Precipitation Enhancement Program.**

Project meteorologists routinely used the following data to prepare a daily operations briefing for the EAPEP:

- Regional upper air analyses at 850 mb, 700 mb, 500 mb, and 200 mb.
- A representative atmospheric sounding from Del Rio or Corpus Christi when available.

- Surface analysis of the United States.
- Current computer models (ETA, RUC, NGM, etc.).
- National Weather Service (NWS) zone forecasts
- National and regional radar summaries
- Satellite imagery
- Storm Prediction Center (SPC) Convective Outlooks (AC)

All of the meteorological data collected during the field season has been stored on CD-ROM for future reference purposes.

For simplicity, the weather forecast was once again subjectively synthesized into a single number referred to as the "convective day category" or CDC. This technique was developed for the Alberta Hail Suppression Project by Strong (1979) and gives the cloud conditions and possibility of seeding activity for the day. A description of the weather conditions for each CDC is given in the Table 3. With higher CDC values, there is generally a better chance of finding precipitation enhancement opportunities.

| CDC | Description |
|---|---|
| -3 | No deep convection |
| -2 | Overcast nimbostratus, producing rain |
| -1 | Broken to overcast conditions with some rain |
| 0 | Cumulus clouds with tops warmer than –5°C |
| +1 | Towering Cumulus, short-lived convective targets not suitable for seeding |
| +2 | Towering Cumulus, long-lived convective targets suitable for seeding |
| +3 | Mesoscale Convective Systems (MCSs), storms systems, or line storms |
| +4 | Deep convection with hail potential |
| +5 | Deep convection containing hail & threat of severe weather |

**Table 3: Description of Convective Day Category (CDC) values.**

The chronology of daily CDC (convective day category) values for Hondo is shown in Figure 11 and as a frequency of occurrence histogram in Figure 12.

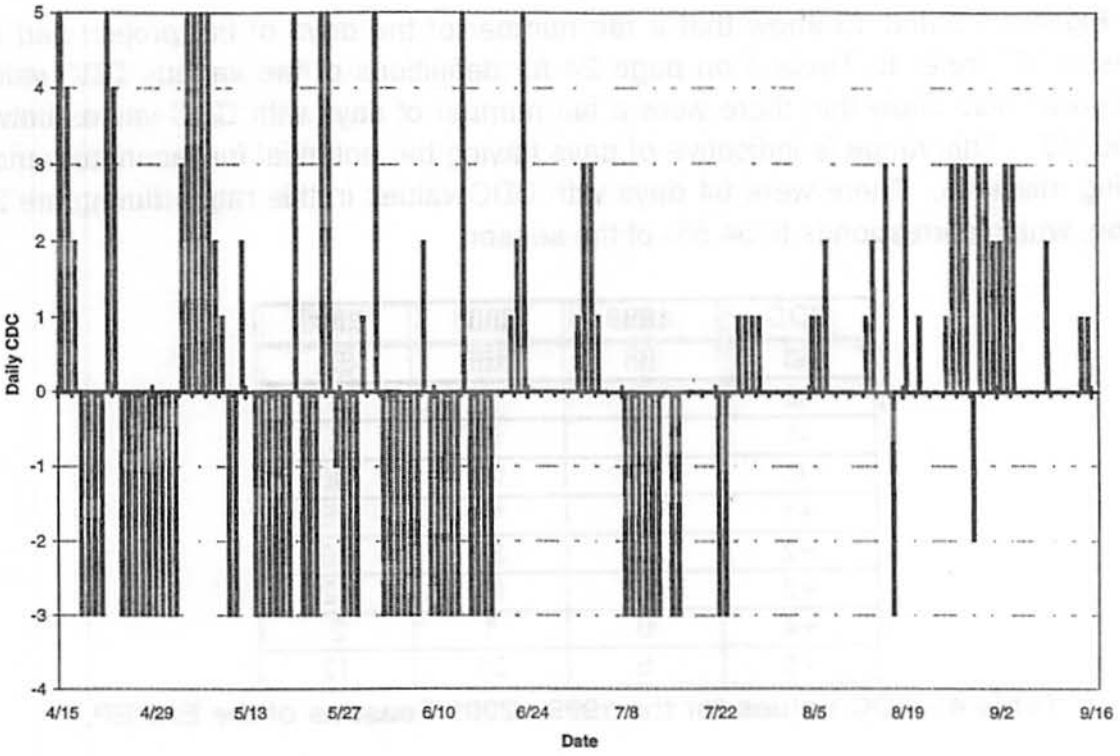


**Figure 12: The chronology of daily CDC values for Hondo.**

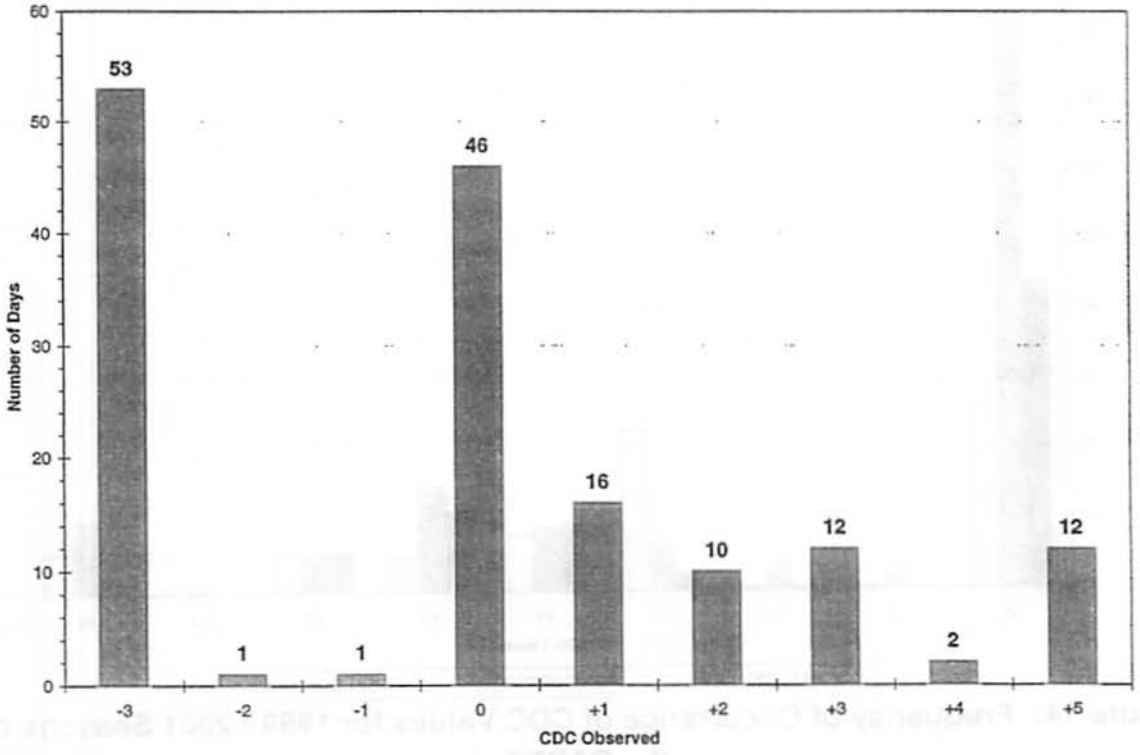


**Figure 13: CDC values for Hondo as a frequency of occurrence histogram.**

Both Figures 12 and 13 show that a fair number of the days of the project had CDC values of '-3' (refer to Table 3 on page 24 for definitions of the various CDC values). The figures also show that there were a fair number of days with CDC values between '0' and '+3'. This range is indicative of days having the potential for reconnaissance or seeding missions. There were 84 days with CDC values in this range during the 2001 season, which corresponds to 54.5% of the season.

| CDC | 1999 | 2000 | 2001 |
|---|---|---|---|
| -3 | 88 | 166 | 53 |
| -2 | 1 | 5 | 1 |
| -1 | 1 | 8 | 1 |
| 0 | 5 | 14 | 46 |
| +1 | 19 | 18 | 16 |
| +2 | 23 | 30 | 10 |
| +3 | 12 | 11 | 12 |
| +4 | 0 | 1 | 2 |
| +5 | 5 | 21 | 12 |

**Table 4: CDC Values for the 1999 - 2001 Seasons of the EAPEP.**

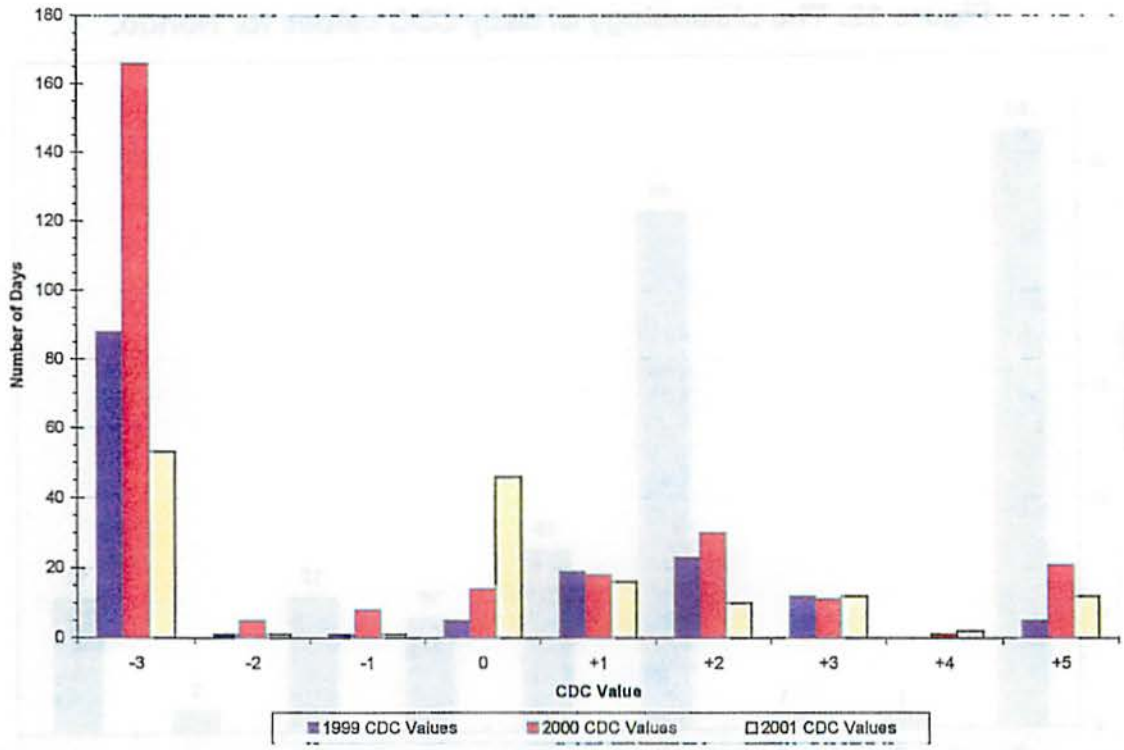


**Figure 14: Frequency of Occurrence of CDC Values for 1999 - 2001 Seasons of the EAPEP.**

The frequency of occurrence of the various CDC values for the 1999, 2000, and 2001 seasons are shown in Table 4 and Figure 14. Both show the distribution of CDC values

for each season and how the seasons compare to one another. The CDCs of greatest interest are the +1 and +2 days. Lower values indicate clouds were too small, greater values indicate widespread deep convection and possible severe weather, though some seeding was done on these days.

Though the +1 and +3 CDC days were essentially constant all three seasons, the +2 days, the days on which opportunities would be best, were markedly reduced in 2001, from 23 (1999) and 30 (2000), to 10 in 2001. These numbers reflect what actually occurred, not the forecast values. This alone indicates that the number of opportunities in the 2001 season was significantly less, as there were about half the number of days on which optimum conditions were observed.

## Forecasting Performance

The following table indicates the forecasting performance for the Edwards Aquifer Precipitation Enhancement Program with respect to the forecast and observed weather conditions as defined by the CDC. The forecasts were verified by the meteorologist's own observations, checking the weather conditions as reported by the National Weather Service, and by the reports from project personnel. Referring to Table 5, the exact forecast type of weather was observed on 106 of 153 days or 69.3% of the time. The forecast was correct to within one CDC on 124 days or 81.1% of the time.

**Observed Convective Day Category (CDC) Weather**

| Forecast CDC | -3 | -2 | -1 | 0 | +1 | +2 | +3 | +4 | +5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| -3 | 41 | | | 2 | 1 | | | | | 44 |
| -2 | | | | | | | | | | 0 |
| -1 | | | | | | | | | | 0 |
| 0 | 1 | | | 30 | 4 | | | | | 35 |
| +1 | 6 | | | 10 | 6 | | | | 1 | 23 |
| +2 | 5 | | 1 | 2 | 3 | 8 | | 1 | 2 | 22 |
| +3 | | 1 | | 1 | 2 | | 12 | | | 16 |
| +4 | | | | 1 | | 2 | | | | 3 |
| +5 | | | | | | | | 1 | 9 | 10 |
| | 53 | 1 | 1 | 46 | 16 | 10 | 12 | 2 | 12 | 153 |

Percent correct exact CDC category = 106 of 153 = 69.3%

Percent correct within one CDC category = 124 of 153 = 81.1%

**Table 5: Table of Forecast versus Observed CDC Daily Values**

## Flight Operations

Two specially equipped cloud seeding aircraft were dedicated to the project. The aircraft and crews provided 24-hour coverage, seven days a week throughout the period. Both aircraft were initially stationed in Hondo, permitting flight crews to see the radar before launches, and allowing a fast response to launch decisions.

When development of convection was unlikely, the seeding aircraft were placed on *weather watch*. The pilots were free to do as they wished but still required to carry their pager or cell phone. When convective development was imminent or was occurring, the seeding aircraft were placed on *stand-by*. *Stand-by* occurred when clouds were not yet seedable, but the aircraft were required to launch and reach a target cloud within 30 miles of the airport 45 minutes after the request to launch had been made by the meteorologist. When seedable clouds were imminent all aircraft were placed on *alert* and aircraft were able to launch and reach the target cloud within 30 miles of the airport in 25 minutes after the request to launch had been made by the meteorologist. Aircraft were available and prepared to commence a seeding mission at any time and the seeding of a storm often continued after darkness with due regard to safety. The meteorologist provided frequent updates of the status as the day progressed.

## Flight Hours

A total of 152 hours 58 minutes were flown operationally during the 2001 season. Figure 15 shows the Hondo flight hours for each month in 1999, 2000, and 2001. The Figure shows that, except for May, August, and September, the flight hours for the 2001 season were lower each month than during the previous two seasons. May saw more flight hours during the 2001 season than during the 2000 season but fewer than during the 1999 season. August and September saw more flight hours during the 2001 season than during the previous two seasons. August saw a marked increase in flight hours during the 2001 season.

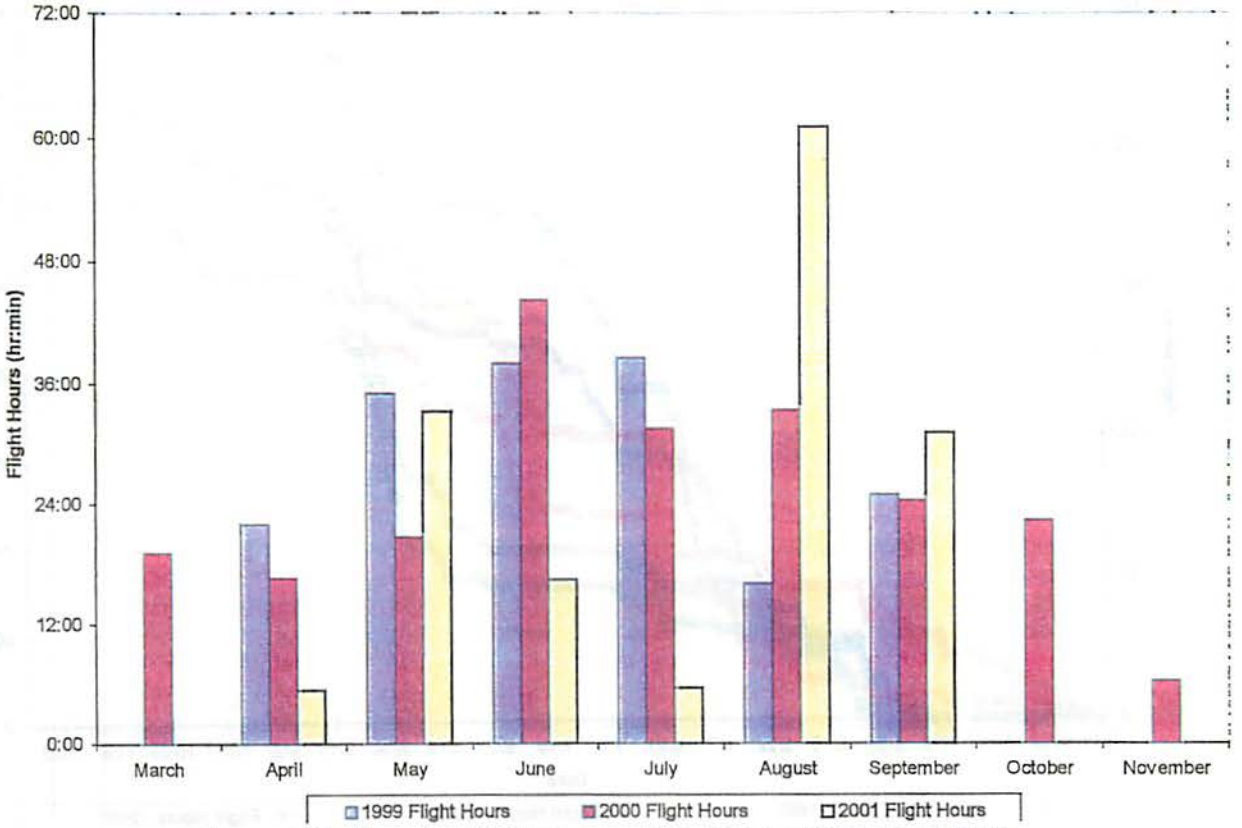


**Figure 15: Hondo flight hours for 1999, 2000, and 2001**

The cumulative flight hours and seeding agent used throughout the project for the 1999, 2000, and 2001 seasons are shown in Figure 16. The Figure shows that both the flight hours and the seeding agent dispensed during the 2001 season were lower than the previous two seasons. The progression of both remained below the progressions for the previous two seasons. The total number of flight hours for the 2001 season (152.97 hrs) was 30.1% lower than the 2000 season total (218.80 hrs) and 12.6% lower than the 1999 season total (174.93 hrs). The total amount of seeding agent dispensed during the 2001 season (21.7 kg) was 25.9% lower than the 2000 season total (29.3 kg) and 42.1% lower than the 1999 season total (37.5 kg).

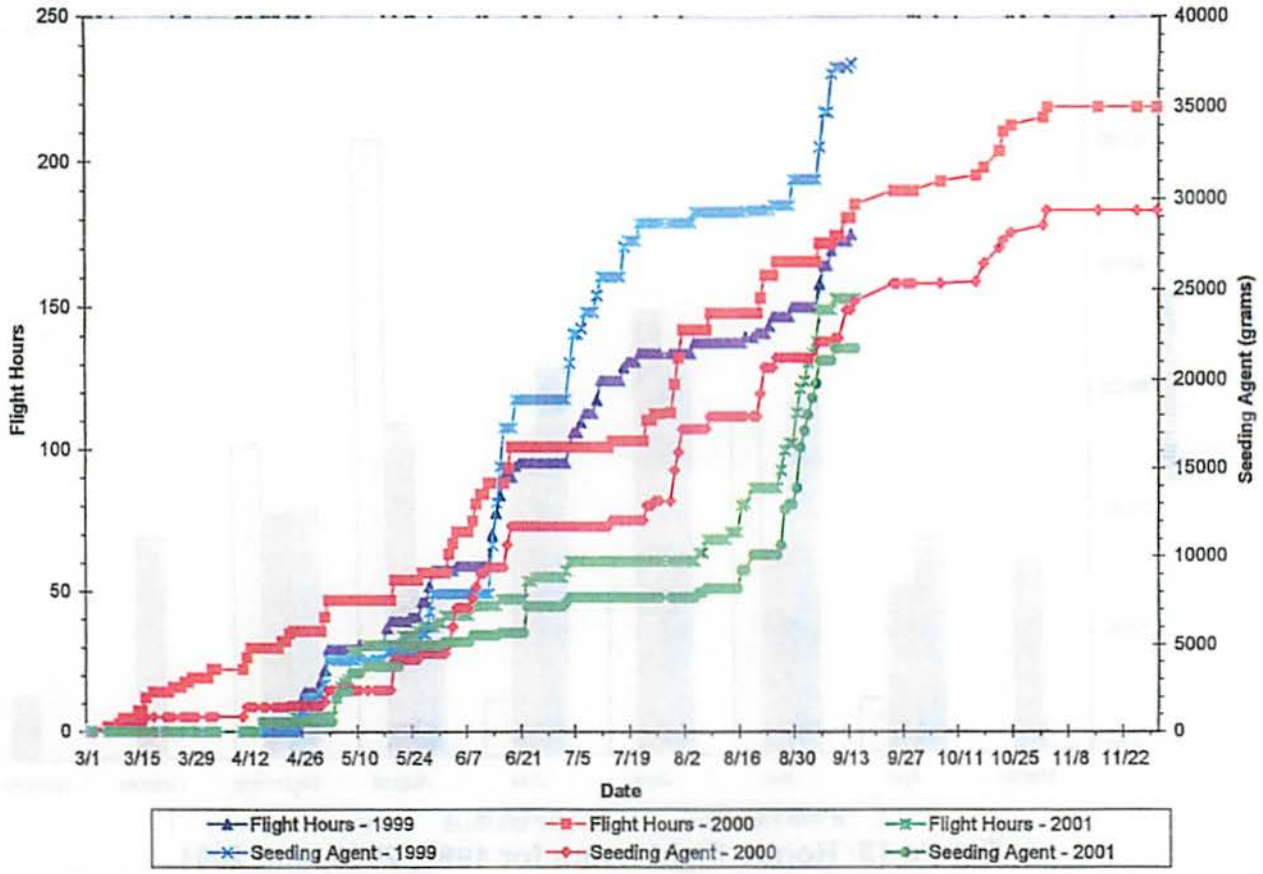


**Figure 16: Cumulative flight hours during the 1999, 2000, and 2001 EAPEP.**

## Cloud Seeding Aircraft

### Cessna 340 Aircraft

Cloud seeding was conducted using two Cessna 340 aircraft equipped with ejectable flare racks and acetone burners. The aircraft registered as N340AX, designated as Seed 2, is shown in Figure 17 on the next page. Cessna 340 aircraft are pressurized, twin-engine, six cylinder, turbo-charged, fuel-injected, all weather aircraft. Both C340 aircraft have weather avoidance radar and a GPS navigation system. The maximum operating altitude is approximately 30 thousand feet with a flight endurance of 5 hours. The C340's indicated air speed for cloud penetrations is typically 155 knots. The nominal rate of climb is 1000 ft/min from sea level to 16 thousand feet, and 700 ft/min from 16 to 20 thousand. Each C340 aircraft carried 204 20-gram ejectable silver iodide flares and two seven-gallon acetone burners. Complete specifications for the C340 are given in Appendix E.


**Figure 17: Cessna 340 Cloud Seeding Aircraft.**

## Radar Data Acquisition, Display, and Archival

The radar data are first ingested by the RDAS, which samples directly the raw radar signal and, using the latest calibration data, processes it. Separate, but in parallel with the RDAS, is the AirLink system, which acquires, via radio modem, flight telemetry data from the aircraft. The AirLink system processes and displays the flight data, but also transforms it into a format compatible with the primary radar display system. The primary radar display and processing system in the WMI field office facility in Hondo utilizes the TITAN software package. On a large, user-interactive screen, TITAN displays and manipulates the radar data provided by RDAS, with GPS-based flight tracks provided by AirLink superimposed. This integrated, state-of-the-art system provides the user-meteorologist with comprehensive real-time information about storm location, development (and decay), movement, history, and intensity, as well as accurate aircraft position and seeding data. For an example, see Figure 18.

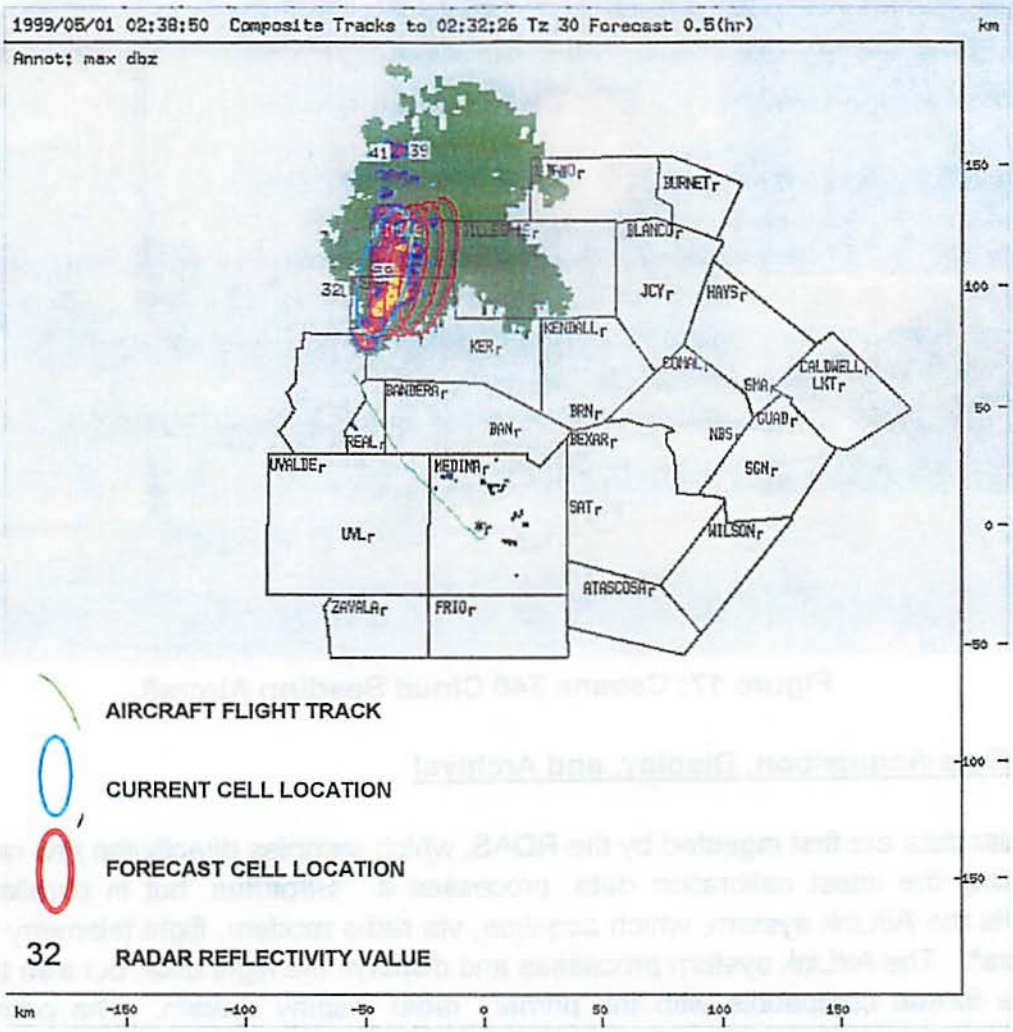


**Figure 18: TITAN image of a thunderstorm from Hondo**

Both the weather radar data and GPS flight track data were archived on CD-ROM for later playback and future analysis. A color printer was used to print hard copies of the radar echo and flight tracks. These also depicted the target area and county boundaries.

A TITAN radar map was automatically posted on an Internet web site every fifteen minutes, providing public access to near real-time project data. These maps displayed storm radar reflectivity data, as well as project GPS aircraft positions.

## TITAN Radar Displays

WMI has acquired the TITAN radar analysis and display software through the National Center for Atmospheric Research (NCAR) in Boulder, CO. TITAN is a software system that ingests radar data, converts it into Cartesian coordinates, identifies individual storm cells, displays past storm tracks, and projects future storm position, based on current movement (Dixon and Wiener, 1993). TITAN computes and displays a number of relatively sophisticated storm and track parameters in real-time. Among these are vertical and horizontal storm cross-sections, vertically-intregrated liquid water content (VIL), and history of maximum storm echo height, height of the maximum reflectivity, and so forth. A detailed description of TITAN's storm and track properties can be found in Mather et al. (1996). The Hondo TITAN system was set to objectively track storm cells having a radar reflectivity greater than 30 dBZ.

## SELECTED CASE DAYS

### May 8, 2001 Case

Outflow from thunderstorms the previous evening over north Texas pushed a weak cold front into the target area during the afternoon. This provided a focus for surface moisture that is almost always pushing in from the Gulf of Mexico.

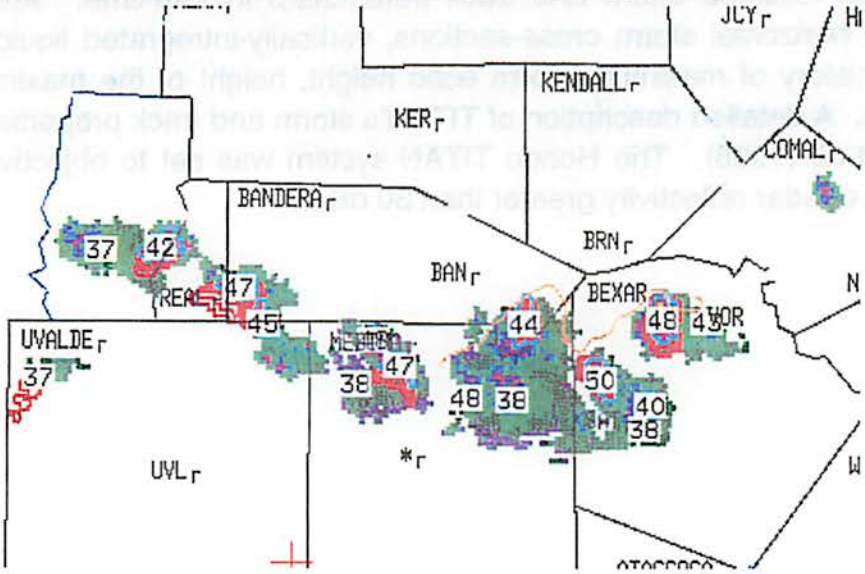


**Figure 19: 8 May 2001, 1831Z**

Figure 19 shows a seeding aircraft (Seed 1) making passes along the north side of a line of showers and thunderstorms drifting southward. The aircraft is base seeding and is using its wingtip acetone burners.

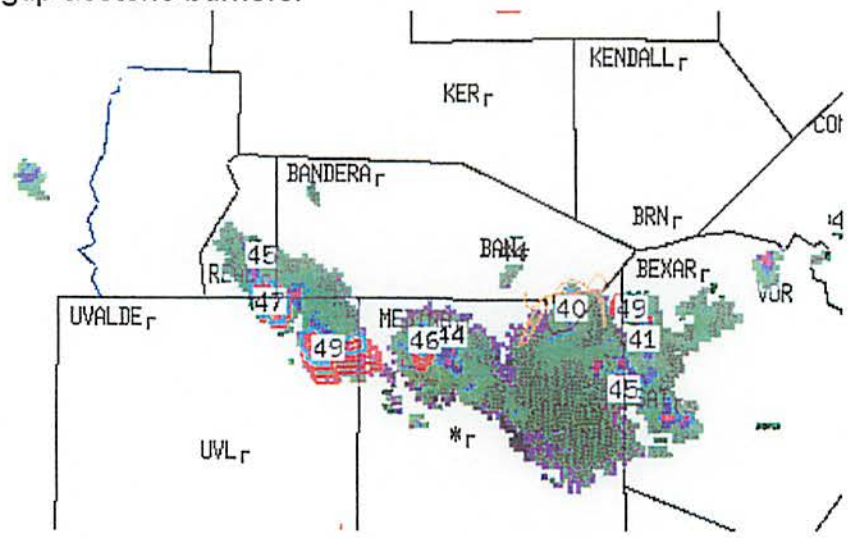


**Figure 20: 8 May 2001, 1900Z**

Figure 20 shows the line has barely moved in one half hour. Currently Seed 1 is seeding outside of Bexar County due to Severe Thunderstorm Warnings. A second aircraft, Seed 2 (tracking unavailable), is doing top seeding on the western portion of the line in Uvalde County. Note the areas seeded in Medina County are still thriving and raining, while the unseeded area in Bexar County, where the warning was, has quickly dissipated.

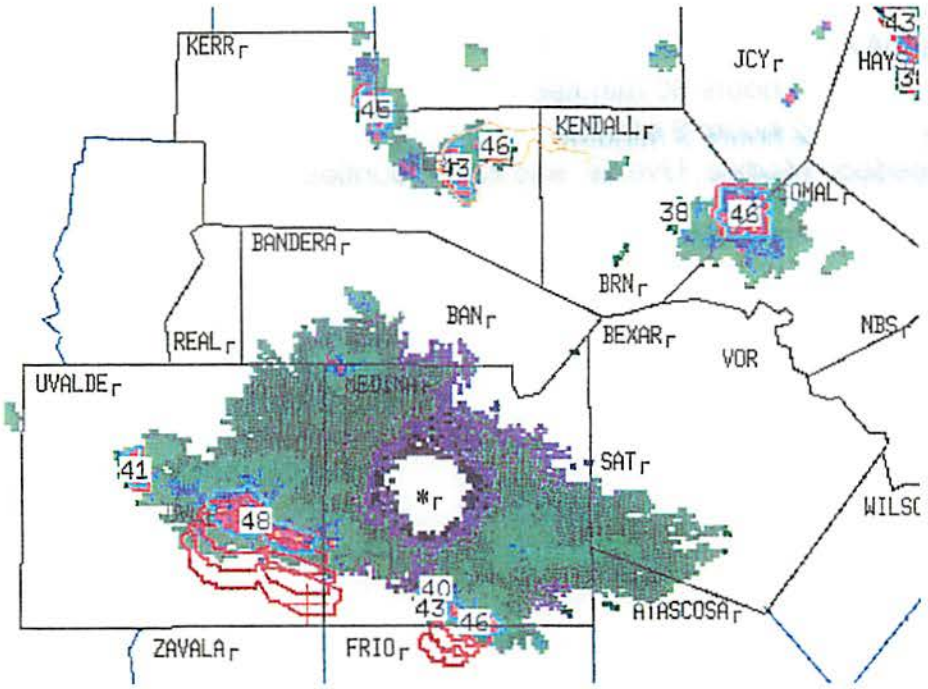


**Figure 21: 8 May 2001, 2019Z**

Figure 21 shows the seeded line of showers and thunderstorms one hour later. Note that the seeded area is still raining in Uvalde and southern Medina Counties, while all that is left of showers in Bexar County is the leftover anvil reflection in southwest Bexar County. Seed 1 has relocated to new activity building up in Kerr County over Kerrville, while Seed 2 is continuing seeding on the original line in Uvalde County. The area in Eastern Kendall County/Western Comal County was severe and thus off limits. It dissipated in the same fashion as the severe thunderstorm in Bexar County earlier.

Seed 2 continued seeding until the original line pushed out of the target area. Seed 1 focused on its new area for about another hour until it pushed westward out of the area.

**Flight Totals**

Seed 1 (N3904G)

Flight Time: 3 hours 30 minutes
Generators: 2 hours 39 minutes
Counties Seeded: Medina, Bandera, Bexar, Kendall, and Kerr Counties

Seed 2 (N340AX)
Flight Time: 3 hours 30 minutes
Generators: 2 hours 3 minutes
Counties Seeded: Medina, Uvalde, and Kerr Counties

## May 21, 2001 Case

On this date, a cold front had stalled across the target area. This front had previously pushed into the target area without precipitation. Activity developed as a small shortwave trough in the upper levels of the atmosphere and entered the target area from the west. All activity was pushing eastward.

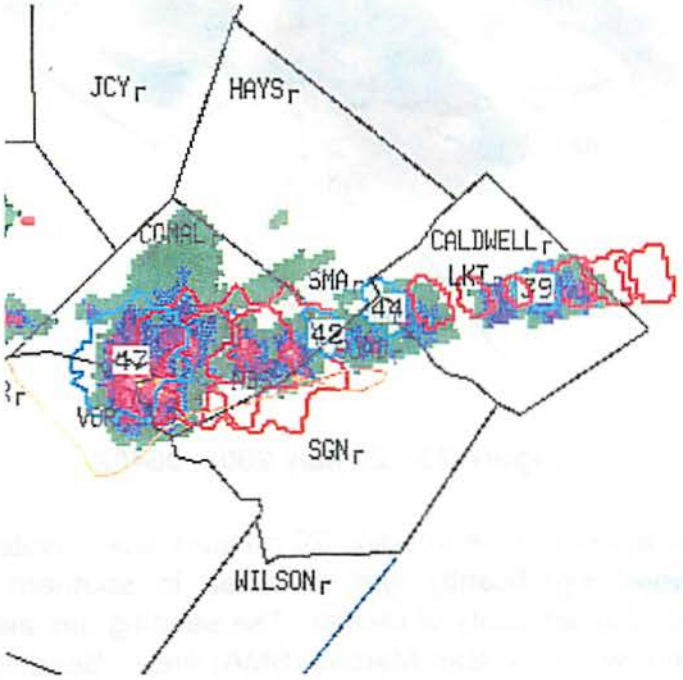


**Figure 22: 21 May 2001, 0620Z**

Figure 22 shows the line on thunderstorms from Comal County northeastward into Caldwell County. Seed 1 was making passes on the southeast side, where the best seeding conditions were available.

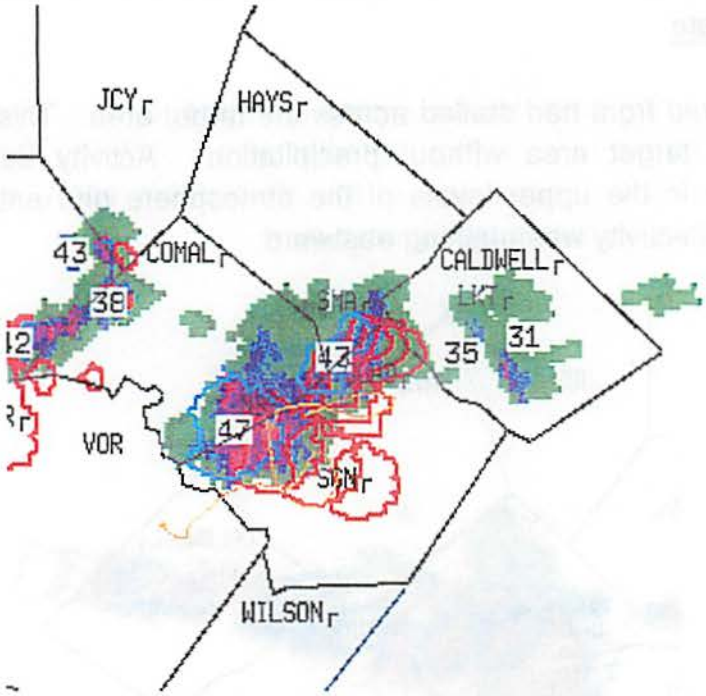


**Figure 23: 21 May 2001, 0640Z**

Figure 23 shows the effects of the seeding 20 minutes later. Note the area in Caldwell County has weakened significantly, yet the area in southern Comal County has continued to drop copious amounts of rainfall. The seeding has also expanded the area toward the northeast toward the San Marcos (SMA) area. Seeding continued on these and other new rains farther west until they also push eastward out of the target area.

### Flight Totals

Seed 1 (N3904G)

| | |
|---|---|
| Flight Time: | 3 hours 30 minutes |
| Ejectable Flares: | 57 |
| Generators: | 24 minutes |
| Counties Seeded: | Kendall, Comal, Guadalupe, and Bexar Counties |

## July 3, 2001 Case

On this date the sea breeze boundary once again pushed off the Gulf of Mexico into the southeastern portions of the target area. These storms were pushing northwestward between 20 and 25 miles per hour. Even with temperatures around 100°F, most showers today were not able to hold together for more than 10-15 minutes and didn't drop measurable amounts of rainfall. This case study focuses on a shower that was kept together by seeding for more than a half hour and dropped over 0.25 inches of rain. This may not seem like much, but in mid-July, this is significant precipitation.

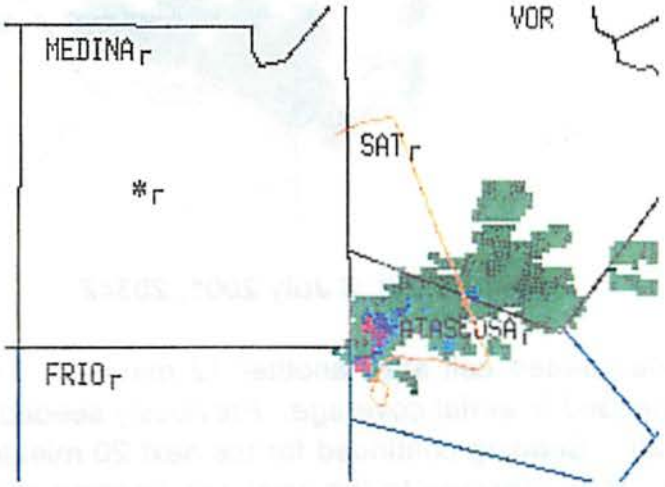


**Figure 24: 3 July 2001, 2011Z**

Figure 24 shows the seeding aircraft preparing to make its first penetration into a prospective target at 2011Z, or 3:11PM local time. The seeding aircraft did find good seeding conditions and fired 2 ejectable flares.

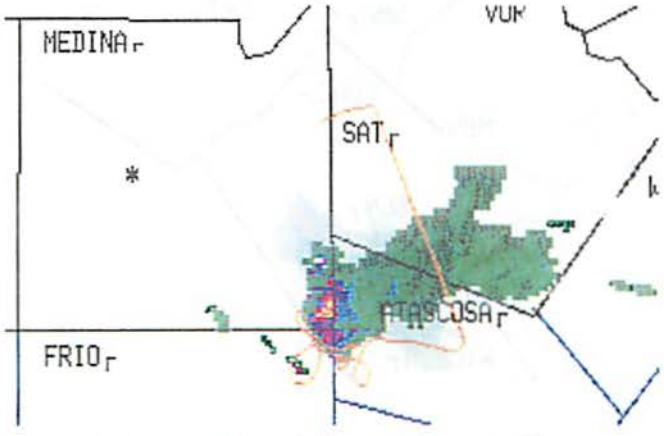


**Figure 25: 3 July 2001, 2023Z**

Figure 25 show the seeded cell 12 minutes later. Note the increased reflectivity as it slowly moves to the northeast. Seeding continued along the southern and western sides of this cell and on new cells forming toward the southwest.

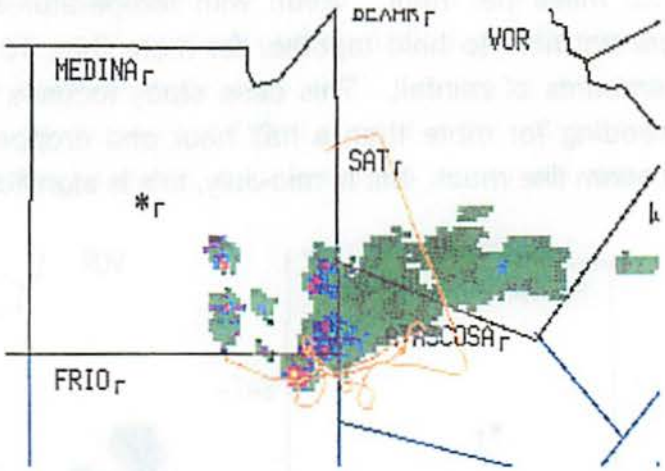


**Figure 26: 3 July 2001, 2034Z**

Figure 26 shows the seeded cell after another 12 minutes. The cell has weakened slightly, but has expended in aerial coverage. Previously seeded cells to the southwest are now dropping rain. Seeding continued for the next 20 minutes until these showers started to dissipate. High pressure to the west was keeping showers from developing any farther west. So the seeding focus was moved toward the northeast.

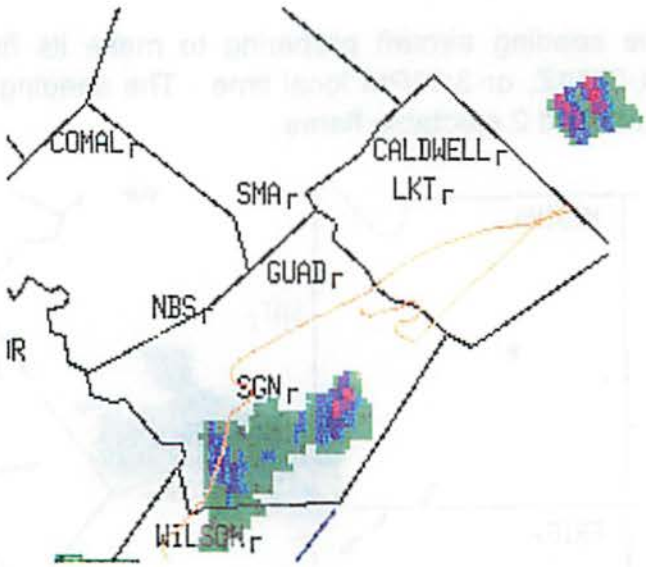


**Figure 27: 3 July 2001, 2202Z**

Figure 27 shows the seeding aircraft making a pass along the eastern edge of the target area. On the previous pass to the northeast, seeding penetrations showed unfavorable seeding conditions. Cloud tops did not contain any liquid water, and updrafts were minimal at best. As the aircraft returned to the southwest, new towering cumulus clouds were observed by the pilots in northeast Caldwell County and northeast Guadalupe County. A seeding pass was made and good seeding conditions were again found.

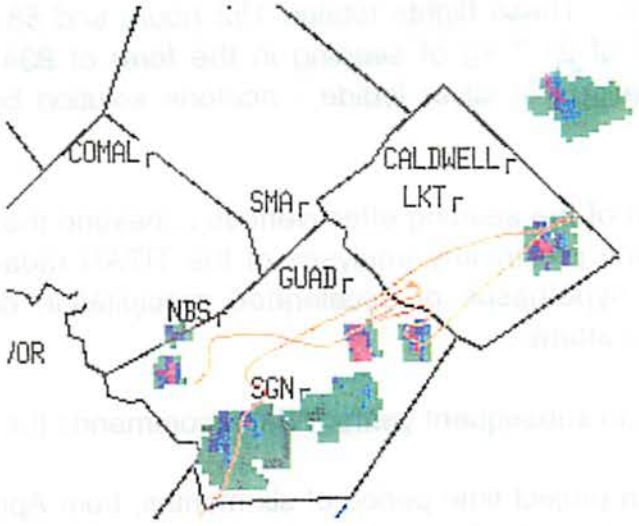


**Figure 28: 3 July 2001, 2214Z**

Figure 28 shows the seeded showers 12 minutes later. Note the showers in Caldwell and Guadalupe Counties. Passes were made between these showers for the next half hour. The showers again dissipated as they movedinto drier and more stable air to the west.

**Flight Totals**

Seed 1 (N3904G)

| | |
|---|---|
| Flight Time: | 3 hours 25 minutes |
| Ejectable Flares: | 15 |
| Counties Seeded: | Medina and Caldwell Counties |

# CONCLUSION AND RECOMMENDATIONS

The 2001 field operations were successful in prolonging rain events as indicated in the case days shown. However, operations were somewhat limited by the number of days suitable for seeding, as indicated in the seasonal comparison of CDCs, especially during June, July, and early August. The difference between 2001 and the preceding two seasons in apparent in Table 4. During the five-month project, the aircraft safely completed 58 missions. These flights totaled 152 hours and 58 minutes on 36 days, and dispersed a total of 21.7 kg of seeding in the form of 834 ejectable flares and approximately 82.8 gallons of silver iodide - acetone solution burned in the wing-tip generators.

A detailed assessment of the seeding effectiveness is beyond the scope of the present contract of WMI. Some preliminary analyses of the TITAN radar storm tracking data support the physical hypotheses of accelerated precipitation development and the promotion of rain within storms.

To improve operations in subsequent years, WMI recommends the following:

1. Maintaining a project time period of six months, from April 1 to September 30, with options to begin a month earlier (in March) and to extend the project through the month of October, if necessary. The rainiest periods around south Texas are during the late spring and early autumn, with May and September being the rainiest months of the year. Extending the project, specifically through September, would provide additional valuable opportunities for recharging the Edwards Aquifer during peak convective rainfall periods.

2. The 15-mile buffer zone around the southeastern edge of the target area was not always sufficient. Most summertime precipitation events pushed in from the southeast, along the sea breeze boundary. The Authority may wish to consider the possible expansion of this zone to provide increased opportunity to begin to work more of such convection as it moves northward into the target area.

3. The Authority is encouraged to involve university scientists and other experts to analyze the radar and aircraft data that is archived from the operation.

4. Base seeding aircraft in Castroville instead of Hondo. Castroville is more centrally located, which would result in shorter reaction times from launch to seeding. Castroville also has much better Fixed Base Operations, which helps in seeding reaction times, maintenance, and fuel availability.

5. The Authority is encouraged to explore the possibility of gaining permission from the Texas Department of Licensing and Regulation to continue to seed non-severe storms for rain enhancement within counties placed under severe thunderstorm warnings by the National Weather Service. This would allow operations to continue in many cases previously forced to suspend.

Weather Modification, Inc. looks forward to continuing operations with the Edwards Aquifer Authority and achieving our objective of increasing rainfall.

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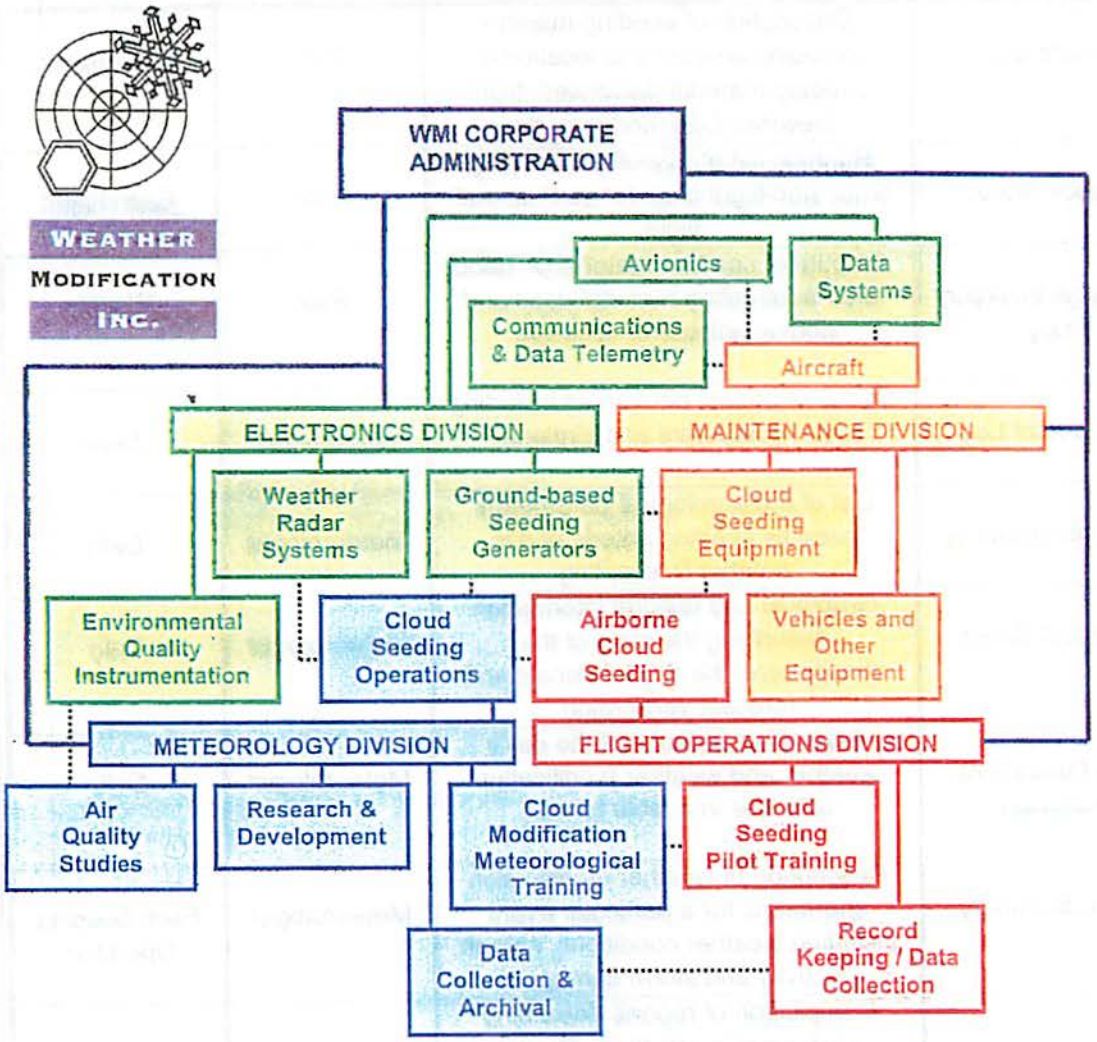
# Appendix

## A. Organization Chart



## B. List of Texas Reports

| Report | Description | Author | Frequency |
|---|---|---|---|
| Flight Log | Description of seeding mission including amount and location of seeding material dispensed, flight crewmembers and remarks. | Pilot | Each Flight |
| Hobbs Sheet | Running list of takeoff and landing times and flight crew for each aircraft flight. | Pilot | Each Flight |
| Chemical Inventory Log | Amount of seeding material on hand after subtracting material used and adding shipments received. | Pilot | Weekly |
| Equipment Log | Status of project equipment including radar, computers and airplanes. | Meteorologist | Daily |
| Meteorological Log | List of meteorological parameters used as seeding criteria and in weather forecasting. | Meteorologist | Daily |
| Forecast Sheet | Graphical and textural information describing the state of the atmosphere, the day's forecast and forecast verification. | Meteorologist | Daily |
| Daily Operations Summary | Textural description of the day's weather and weather modification activities in a table format. | Meteorologist | Daily |
| Storm Summary | Description of weather modification operations for a particular event including weather conditions, aircraft activity and storm damage. | Meteorologist | Each Seeding Operation |
| Weekly Report | Compilation of reports describing each week's activities. Report includes daily operations summary, flight forms, equipment log and a table of flight hours and seed material used. Submitted to Client. | WMI | Weekly |
| NOAA Daily Log | Federal report of seeding activities including amount, location and type of nucleant material used and duration of activities. Submitted to Client. | WMI | Daily |

## C. Aircraft Flight Summary Tables

Mission types are indicated as follows:

rain = rain enhancement seeding operations
recon = reconnaissance mission, conditions proved unsuitable for seeding
repos = aircraft was repositioned to be in a better location prior to the onset of expected convective weather.

| Date | Aircraft | Take-off | Landing | Duration | eject | L Burner | R Burner | Tot Burner | Type |
|---|---|---|---|---|---|---|---|---|---|
| April 15, 2001 | 3904G | 23:56 | 3:15 | 3:19 | 27 | | | 0:00 | rain |
| April 23, 2001 | 340AX | 6:12 | 8:20 | 2:08 | | | | 0:00 | recon |
| May 4, 2001 | 340AX | 23:33 | 3:33 | 4:00 | | 0:50 | 2:30 | 3:20 | rain |
| May 4, 2001 | 3904G | 22:40 | 1:30 | 2:50 | 41 | 0:15 | | 0:15 | rain |
| May 5, 2001 | 340AX | 6:21 | 7:18 | 0:57 | | | | 0:00 | repos |
| May 5, 2001 | 3904G | 19:30 | 22:35 | 3:05 | 17 | | | 0:00 | rain |
| May 6, 2001 | 340AX | 23:53 | 1:18 | 1:25 | 4 | | | 0:00 | rain |
| May 7, 2001 | 3904G | 19:55 | 21:00 | 1:05 | | | | 0:00 | recon |
| May 8, 2001 | 3904G | 17:55 | 21:25 | 3:30 | | 2:25 | 0:14 | 2:39 | rain |
| May 8, 2001 | 3904G | 22:10 | 23:55 | 1:45 | 13 | | | 0:00 | rain |
| May 8, 2001 | 340AX | 12:47 | 14:21 | 1:34 | 5 | | | 0:00 | rain |
| May 8, 2001 | 340AX | 18:43 | 21:50 | 3:07 | | 0:51 | 1:17 | 2:08 | rain |
| May 12, 2001 | 340AX | 19:31 | 21:43 | 2:12 | 17 | | | 0:00 | rain |
| May 21, 2001 | 3904G | 4:50 | 8:20 | 3:30 | 57 | 0:24 | | 0:24 | rain |
| May 25, 2001 | 340AX | 0:50 | 2:14 | 1:24 | | | | 0:00 | recon |
| May 26, 2001 | 3904G | 3:55 | 5:35 | 1:40 | 2 | | | 0:00 | rain |
| May 30, 2001 | 340AX | 17:08 | 18:20 | 1:12 | | | | 0:00 | recon |
| June 1, 2001 | 340AX | 22:06 | 0:54 | 2:48 | 9 | | | 0:00 | rain |
| June 8, 2001 | 3904G | 19:35 | 23:00 | 3:25 | | 1:36 | 1:04 | 2:40 | rain |
| June 15, 2001 | 340AX | 3:46 | 6:11 | 2:25 | 7 | | | 0:00 | rain |
| June 22, 2001 | 3904G | 18:50 | 22:50 | 4:00 | 64 | | | 0:00 | rain |
| June 22, 2001 | 340AX | 20:30 | 22:48 | 2:18 | | 1:26 | | 1:26 | rain |
| June 24, 2001 | 3904G | 0:35 | 2:05 | 1:30 | | | | 0:00 | recon |
| July 2, 2001 | 340AX | 17:34 | 19:46 | 2:12 | | 1:26 | | 1:26 | rain |
| July 3, 2001 | 3904G | 19:42 | 23:07 | 3:25 | 15 | | | 0:00 | rain |
| August 5, 2001 | 340AX | 21:50 | 0:40 | 2:50 | 13 | 0:01 | 0:05 | 0:06 | rain |
| August 7, 2001 | 3904G | 19:05 | 21:50 | 2:45 | | 1:32 | 0:07 | 1:39 | rain |
| August 7, 2001 | 340AX | 20:02 | 21:58 | 1:56 | 1 | | | 0:00 | rain |
| August 13, 2001 | 340AX | 23:00 | 1:40 | 2:40 | | | | 0:00 | recon |
| August 16, 2001 | 340FR | 19:20 | 22:20 | 3:00 | 27 | | | 0:00 | rain |
| August 16, 2001 | 340FR | 23:55 | 2:25 | 2:30 | | 1:16 | 0:43 | 1:59 | rain |
| August 16, 2001 | 340AX | 20:30 | 0:24 | 3:54 | 2 | | 0:59 | 0:59 | rain |
| August 17, 2001 | 340FR | 2:57 | 3:30 | 0:33 | | | | 0:00 | repos |
| August 19, 2001 | 340FR | 16:27 | 18:47 | 2:20 | 24 | 0:05 | 0:05 | 0:10 | rain |
| August 19, 2001 | 340AX | 14:00 | 17:25 | 3:25 | | 2:37 | | 2:37 | rain |
| August 26, 2001 | 340FR | 23:05 | 2:10 | 3:05 | | 2:32 | | 2:32 | rain |
| August 26, 2001 | 340AX | 22:40 | 1:54 | 3:14 | 9 | | | 0:00 | rain |

| Date | Aircraft | Take-off | Landing | Duration | eject | L Burner | R Burner | Tot Burner | Type |
|---|---|---|---|---|---|---|---|---|---|
| August 27, 2001 | 340FR | 19:55 | 23:45 | 3:50 | 68 | | 1:15 | 1:15 | rain |
| August 27, 2001 | 340AX | 19:10 | 22:24 | 3:14 | 23 | | | 0:00 | rain |
| August 28, 2001 | 340AX | 15:35 | 18:00 | 2:25 | 15 | | | 0:00 | rain |
| August 30, 2001 | 340FR | 13:25 | 15:10 | 1:45 | | | | 0:00 | recon |
| August 30, 2001 | 340FR | 19:25 | 23:45 | 4:20 | | 2:00 | 0:58 | 2:58 | rain |
| August 30, 2001 | 340AX | 18:07 | 21:38 | 3:31 | 25 | | | 0:00 | rain |
| August 30, 2001 | 340AX | 0:16 | 1:17 | 1:01 | | | | 0:00 | recon |
| August 31, 2001 | 340FR | 0:35 | 2:30 | 1:55 | | | | 0:00 | recon |
| August 31, 2001 | 340FR | 23:05 | 1:40 | 2:35 | 58 | | | 0:00 | rain |
| August 31, 2001 | 340AX | 20:45 | 0:15 | 3:30 | 52 | | | 0:00 | rain |
| August 31, 2001 | 340AX | 2:20 | 3:06 | 0:46 | | | 0:27 | 0:27 | rain |
| September 1, 2001 | 340FR | 19:15 | 21:55 | 2:40 | 47 | | | 0:00 | rain |
| September 2, 2001 | 340FR | 20:15 | 23:25 | 3:10 | | 2:26 | | 2:26 | rain |
| September 2, 2001 | 340AX | 18:25 | 21:40 | 3:15 | 28 | | | 0:00 | rain |
| September 3, 2001 | 340AX | 23:00 | 2:18 | 3:18 | 48 | | | 0:00 | rain |
| September 4, 2001 | 340FR | 22:25 | 1:30 | 3:05 | 40 | | | 0:00 | rain |
| September 4, 2001 | 340AX | 1:40 | 2:40 | 1:00 | | | | 0:00 | recon |
| September 5, 2001 | 340FR | 12:40 | 14:55 | 2:15 | 18 | | | 0:00 | rain |
| September 5, 2001 | 340FR | 19:55 | 0:45 | 4:50 | | 3:04 | | 3:04 | rain |
| September 5, 2001 | 340AX | 18:20 | 22:05 | 3:45 | 24 | | | 0:00 | rain |
| September 9, 2001 | 340AX | 11:50 | 15:40 | 3:50 | 34 | | | 0:00 | rain |

Total number of flights: 61
Total flight time: 152 hrs 58 min
Ejectable flares used: 834
Wing-tip generator usage: 34 hrs 30 min

## D. Daily Operations Summary

| Date | Weather | Activities Summary |
|---|---|---|
| 15 April 2001, Sunday | An outflow boundary from severe weather yesterday in Oklahoma drifted into the target area today. This combined with peak heating temperatures around 90 degrees was enough to break through the cap and spark isolated thunderstorms. These thunderstorms lasted until after sunset, but were weaker without daytime heating. | Seed 2 flew one seeding flight during the evening hours in Real and Medina Counties.<br><br>Seed 1 (N3904G) – top seed<br>Engine On – 2356Z<br>Engine Off – 0315Z<br>Time – 3 hours 19 minutes<br>Flares – 27 ejectable flares |
| 16 April 2001, Monday | Yesterday's boundary has drifted to the coast, leaving the area in hot and humid early summer weather. Overnight a strong cold front pushed into the target area, but was unable to break through the cap for most of the night. A couple isolated thunderstorms were able to mature into strong storms, but upper level winds were nonexistent, so the storms stayed stationary and poured copious amounts of rain in a couple isolated areas. | No seeding activities from Hondo. |
| 17 April 2001, Tuesday | Isolated stationary thunderstorms along the cold front continued from yesterday, mainly over Blanco County. The front itself quickly pushed through early, leaving strong north winds and temperatures in the lower 60s. | No seeding activities from Hondo. Ground School. |
| 18 April 2001, Wednesday | Mid level moisture from the Pacific Ocean kept skies cloudy for most of the day, but these clouds were in the middle levels of the atmosphere and did not spark and precipitation. | No seeding activities from Hondo. |
| 19 April 2001, Thursday | Moisture return from the Gulf of Mexico helped raise temperatures and humidity levels across Texas today. Skies were partly cloudy. | No seeding activities from Hondo. |
| 20 April 2001, Friday | Another day of warm and humid conditions for the first day of Fiesta. Skies were mostly sunny and temperatures were in the upper 80s. | No seeding activities from Hondo. |
| 21 April 2001, Saturday | Another day of hot and humid conditions with highs in the upper 80s. | No seeding activities from Hondo. |
| 22 April 2001, Sunday | The cold front/dryline arrived in South Central Texas during the overnight, with severe thunderstorm warning to our west in Kimble and Edwards Counties. The storms weakened enough for an attempt at seeding, but as the pilots arrived at altitude, the combination of overcast conditions and no moonlight kept them from performing any seeding. | One reconnaissance flight was flown by Seed 2 during the overnight hours over Kerr and Bandera Counties.<br><br>Seed 2 (N340AX) – top recon<br>Engine On – 0612Z<br>Engine Off – 0820Z<br>Time – 2 hours 8 minutes |
| 23 April 2001, Monday | The cold front stretched across the target area this morning, continuing the imbedded showers and thunderstorms. This line stalled across southern Medina, Bexar, and Guadalupe counties for most of the day, dropping 3-5 inches over the same areas. This prompted many flash flood warnings across this area, which precluded any seeding activities until flooding conditions receded. The front finally exited the area during the evening, leaving cooler and drier air in its wake. | No seeding activities from Hondo. No seeding is performed during Flash Flood Warnings. |
| 24 April 2001, Tuesday | Mostly clear skies prevailed behind the cold front as stable air filtered in behind it. Highs were in the low 70s. | No seeding activities from Hondo. |

| Date | Weather | Activities Summary |
|---|---|---|
| 25 April 2001, Wednesday | Low humidity resulted in clear skies. Temperatures below normal, in the low 70s. | No seeding activities from Hondo. |
| 26 April 2001, Thursday | Another fair weather day, with sunny skies and high in the 70s. An upper level ridge is keeping the weather fair and mild. | No seeding activities from Hondo. |
| 27 April 2001, Friday | More fair weather. No clouds, temperatures in the 70s. | No seeding activities from Hondo. |
| 28 April 2001, Saturday | The upper level ridge is slowly working its way eastward, opening the door for a slight return of Gulf of Mexico moisture. But it was still a beautiful day with highs in the low 80s. | No seeding activities from Hondo. |
| 29 April 2001, Sunday | Fair weather under strong high pressure kept skies clear and temperatures in the upper 70s. | No seeding activities from Hondo. |
| 30 April 2001, Monday | Another day of mostly sunny skies and warm temperatures. High pressure still has a firm grip on the southern U.S. | No seeding activities from Hondo. |
| 1 May 2001, Tuesday | Southeasterly winds have started to slowly return Gulf moisture to the southern plains ahead of an upper level low in Nevada. Temperatures were in the lower 80s. | No seeding activities from Hondo. |
| 2 May 2001, Wednesday | More Gulf of Mexico moisture brought about a sultry day with highs in the mid 80s. | No seeding activities from Hondo. |
| 3 May 2001, Thursday | The first shortwave rotating around the upper low in Colorado pushed through the area overnight, with widespread stratus showers. These showers were not favorable for seeding due to cloud top temperatures being above the freezing level. Local rainfall amounts of ½ inch were common. | No seeding activities from Hondo. |
| 4 May 2001, Friday | A surface trough of low pressure moving in from the Panhandle combined with an upper level shortwave from the southwest to spark a line of thunderstorms. This line was originally severe, but as it crossed into the target area it weakened enough for seeding operations. This line moved eastward across the target area, dropping 1.5 to 2 inches of rainfall along the way. This line worked its way out of the target area before midnight. Behind it, a weak outflow boundary stalled across northern Uvalde and Bandera Counties, raining more, in areas that had already seen rain from the previous line. Flash flood warnings were posted late in the evening, but no aircraft were even launched. | Two seeding flights were flown during the day, one by Seed 1 in Real, Kerr, Uvalde, Bandera, and Gillespie Counties, and one by Seed 2 in Kerr, Bandera, Medina, and Bexar Counties.<br><br>Seed 1 (N3904G) – top seed<br>Engine On – 2240Z<br>Engine Off – 0130Z<br>Time – 2 hours 50 minutes<br>Flares – 41 ejectable flares, 15 minutes acetone burner (all right side)<br><br>Seed 2 (N340AX) – base seed<br>Engine On – 2333Z<br>Engine Off – 0333Z<br>Time – 4 hours<br>Flares – 3 hours 20 minutes acetone burners (2 hours 30 minutes right, 50 minutes left burner) |
| 5 May 2001, Saturday | Ample moisture remained even after yesterday's thunderstorms, setting up another round of possible storms. Today's trigger was the seabreeze boundary, which pushed northwestward off the gulf of Mexico early in the afternoon, affecting the eastern half of the target area. This one line of showers pushed through, partially stabilizing the atmosphere in that area. No other forcing mechanisms, like the seabreeze front, entered the target area during the rest of this day. | One seeding flight was flown by Seed 1 during the afternoon in Guadalupe and Comal Counties.<br><br>Seed 1 (N3904G) – top seed<br>Engine On – 1930Z<br>Engine Off – 2235Z<br>Time – 3 hours 5 minutes<br>Flares – 17 ejectable flares |
| 6 May 2001, Sunday | A warm and humid day in the middle to upper 80s helped to fuel a multitude of thunderstorms across all of Texas during the evening. The first | Seed 2 flew one flight during the evening hours in Frio County. |

| Date | Weather | Activities Summary |
|---|---|---|
| | cells developed in eastern Frio and Western Atascosa Counties, and drifted northeastward into the San Antonio area. Seeding was terminated very early on, as warnings were issued. There were many severe weather reports with this storm of golf ball and larger sized hail. Other cells developed with this cell to form a solid line of severe weather along the I-35 corridor. These storms stayed severe and kept developing well after sundown. The line slowly drifted to the east out of the region around midnight. | Seed 2 (N340AX) – top seed<br>Engine On – 2353Z<br>Engine Off – 0118Z<br>Time – 1 hour 25 minutes<br>Flares – 4 ejectable flares |
| 7 May 2001, Monday | Outflow boundaries from yesterday's activity sparked isolated showers, mainly along and north of the target area. Most activity was short-lived and unsuitable for seeding. | Seed 1 flew a recon flight during the afternoon around Gillespie County.<br><br>Seed 1 (N3904G) – top recon<br>Engine On – 2000Z<br>Engine Off – 2100Z<br>Time – 1 hour |
| 8 May 2001, Tuesday | Large amounts of available moisture were present today, lacking only a focusing mechanism to fire showers and thunderstorms. During the morning, an outflow boundary from activity the previous evening along the Red River sparked a thunderstorm that crossed over extreme NW Kerr County. Then during the afternoon, convection fired along a decaying cold front stretching from Real to Bexar County. A couple severe thunderstorms warning were issued, as reports of ¾ inch hail were reported. With light upper level winds, storms were free to push in any direction, some pushing southward, some westward. All this activity died off as peak heating waned at sunset. | 4 seeding flight were flown today, 2 by Seed 1 during the afternoon hours, and 2 by Seed 2 in the morning and afternoon.<br><br>Seed 1 (N3904G)<br>Flight 1 – base seed<br>Engine On – 1755Z<br>Engine Off – 2125Z<br>Time – 3 hours 30 minutes<br>Flares – Acetone burners – 2 hours 39 minutes (Left side – 2:25, Right side – 14 minutes)<br>Seeded Counties – Medina, Bandera, Bexar, Kendall, Kerr<br><br>Flight 2 – top seed<br>Engine On – 2210Z<br>Engine Off – 2345Z<br>Time – 1 hour 45 minutes<br>Flares – 13 Ejectable Flares<br>Seeded Counties – Kerr<br><br>Seed 2 (N340AX):<br>Flight 1 – top seed<br>Engine On – 1247Z<br>Engine Off – 1422Z<br>Flares – 5 Ejectable Flares<br>Seeded Counties – Kimble<br><br>Flight 2 – base seed<br>Engine On – 1843Z<br>Engine Off – 2150Z<br>Time – 3 hours 30 minutes<br>Flares – Acetone burners – 2 hours 3 minutes (Left side – 51 minutes, right side – 1:12)<br>Seeded Counties – Medina, Uvalde, Kerr |
| 9 May 2001, Wednesday | With yesterday's storms depleting the amount of moisture in the local atmosphere, storms today were hard pressed to keep together for more than 20 minutes. A couple showers were able to develop, but were quickly squashed by building high pressure. | No seeding activities from Hondo. |
| 10 May 2001, Thursday | High pressure led to mostly sunny skies and temperatures in the lower 80s. | No seeding activities from Hondo. |

| Date | Weather | Activities Summary |
|---|---|---|
| 11 May 2001, Friday | Another day of partly to mostly sunny skies with highs in the 80s. A cold front is slowly pushing southward from Oklahoma, which should affect the area's weather tomorrow. | No seeding activities from Hondo. |
| 12 May 2001, Saturday | The "cold" front has stalled over the target area today providing a focus for the abundant moisture from the Gulf of Mexico. Most activity developed during peak heating hours and was isolated in nature. All activity died off around sunset. | One seeding flight was flown during the afternoon hours by Seed 2.<br><br>Seed 2 (N340AX) – top seed<br>Engine On – 1931Z<br>Engine Off – 2143Z<br>Time – 2 hours 12 minutes<br>Flares – 17 Ejectable Flares<br>Seeded Counties – Bandera, Medina |
| 13 May 2001, Sunday | Last week's front is quickly washing out, leaving gulf moisture and much above average temperatures. A couple towering cumulus clouds were able to form, but were unable to get to seedable elevations. | No seeding activities from Hondo. |
| 14 May 2001, Monday | The front has totally washed out now. Today was another day of hot and humid weather under mostly sunny skies. | No seeding activities from Hondo. |
| 15 May 2001, Tuesday | Another day of hot and humid weather with highs in the upper 80s. | No seeding activities from Hondo. |
| 16 May 2001, Wednesday | More hot and humid weather with highs in the upper 80s and lower 90s. | No seeding activities from Hondo. |
| 17 May 2001, Thursday | More hot and humid weather with highs in the upper 80s and lower 90s. | No seeding activities from Hondo. |
| 18 May 2001, Friday | More hot and humid weather with highs in the upper 80s and lower 90s. | No seeding activities from Hondo. |
| 19 May 2001, Saturday | One more hot and humid day ahead of a storm system in Oklahoma brought temperatures into the range from upper 80s to upper 90s. | No seeding activities from Hondo. |
| 20 May 2001, Sunday | A shortwave pushed toward south Texas today, sparking severe weather during peak heating in the afternoon. As the sun set a line of thunderstorms held together and pushed into the target area from the northwest. Later into the night, the line weakened into an unseedable line. | No seeding activities from Hondo. |
| 21 May 2001, Monday | The line from late yesterday continued to push through the target area, adding welcome rains to the aquifer. This line pushed out of the area during the early morning, leaving mostly sunny skies and decreasing the humidity. | Seeding was done by Seed 1 during the overnight hours in Kendall, Comal, Guadalupe, and Bexar Counties.<br><br>Seed 1 (N3904G) – top seed<br>Engine On – 0450Z<br>Engine Off – 0820Z<br>Time – 3 hours 30 minutes<br>Seeding – Ejectable Flares – 57<br>Acetone Burners – 24 minutes (all left side) |
| 22 May 2001, Tuesday | Another mild and dry day as the air stayed crisp. High temperatures were only in the middle 70s. | No seeding activities from Hondo. |
| 23 May 2001, Wednesday | Another day of beautiful weather underneath a small area of high pressure. | No seeding activities from Hondo. |
| 24 May 2001, Thursday | A strong cold front pushed into south Texas during the evening, sparking severe weather. Marble sized hail was observed as the line passed the radar. This line quickly pushed through the area and to the coast during the overnight hours. | One recon flight was flown by Seed 2 during the early overnight hours (May 25th Zulu) around Kerr and Gillespie Counties. Storms were classified as severe before seeding could commence, precluding seeding.<br><br>Seed 2 (N340AX) – top seed<br>Engine On – 0050Z<br>Engine Off – 0214Z |

| Date | Weather | Activities Summary |
|---|---|---|
| | | Time – 1 hour 24 minutes |
| 25 May 2001, Friday | Yesterday's cold front stalled across the target area, setting the stage for another round of severe weather. This activity started to develop during the evening as an upper level shortwave pushed through Texas. This line pushed toward the south and dissipated almost as quickly as it developed. | One seeding flight was flown during the early overnight hours (May 26th Zulu) in Bexar County.<br><br>Seed 1 (N3904G) – top seed<br>Engine On – 0355Z<br>Engine Off – 0535Z<br>Time – 1 hour 40 minutes<br>Flares – 2 Ejectable Flares (Bexar County) |
| 26 May 2001, Saturday | An outflow boundary from storms in North Central Texas scraped the edge of the target area during the morning, sparking a couple of minor showers. These showers were unseedable due to their short-lived nature. The day saw mostly clear skies and hot temperatures. Overnight, a large storm complex from the Panhandle pushed toward the target area. Just before it arrived it quickly dissipated, leaving only unseedable stratus rains in Uvalde County. This area quickly pushed south out of the area. | No seeding activities from Hondo. |
| 27 May 2001, Sunday | With last week's frontal boundary dissipating, high pressure was able to build back in today, keeping skies mostly clear and temperatures hot for late May. | No seeding activities from Hondo. |
| 28 May 2001, Monday | Another day of mostly sunny skies under strong high pressure. | No seeding activities from Hondo. |
| 29 May 2001, Tuesday | Another day of sunny weather under strong high pressure. | No seeding activities from Hondo. |
| 30 May 2001, Wednesday | An upper level impulse ahead of a cold front in Kansas combined with the stagnant Gulf moisture trapped over south Texas to spark a couple isolated showers during peak heating. These showers were very short lived and were not conducive to seeding. | No seeding activities from Hondo. |
| 31 May 2001, Thursday | The remnants of a massive thunderstorm complex over the Texas Panhandle crossed the South Texas region during the pre-dawn hours. These remnants were extremely weak, producing few targets over twelve thousand feet. Any target that did reach the freezing level instantly froze, leaving no supercooled liquid water, which is needed for seeding. This area was clear of the target area by mid-morning. | No seeding activities from Hondo. |
| 1 June 2001, Friday | An outflow boundary from a storm in the Texas Panhandle crossed the target area again today. Unlike yesterday's storm, this one arrived in the area during the afternoon hours, adding to the convective forcing. Some of these storms became severe, and thus were unseedable. Parts of this storm were seedable and were seeded. These storms weakened and dissipated at sunset as heating waned. | Seed 2 flew one flight during the afternoon hours in Comal, Hays, and Bexar Counties.<br><br>Seed 2 (N340AX) – top seed<br>Engine On – 2206Z<br>Engine Off – 0054Z<br>Time – 2 hours 48 minutes<br>Flares – 9 Ejectable Flares (Comal – 5; Hays – 3; Bexar – 1) |
| 2 June 2001, Saturday | High pressure forced yesterday's front northward out of the area, leaving hot temperatures and mostly clear skies. | No seeding activities from Hondo. |
| 3 June 2001, Sunday | Weak high pressure has built over South Texas, keeping skies mostly clear and temperatures in the low 90s. | No seeding activities from Hondo. |
| 4 June 2001, Monday | Another day of hot and dry weather under high pressure. | No seeding activities from Hondo. |
| 5 June 2001, | A tropical wave in the western Gulf of Mexico | No seeding activities from Hondo. |

| Date | Weather | Activities Summary |
|---|---|---|
| Tuesday | quickly built into Tropical Storm Allison. The precipitation around this storm started to push across the Houston area this afternoon. The subsidence around this system kept convection from firing in the target area. | |
| 6 June 2001, Wednesday | Tropical storm Allison made landfall during the predawn hours around Galveston Island. Most of the rainfall stayed in the Houston area. | No seeding activities from Hondo. |
| 7 June 2001, Thursday | The remnants of Allison stalled over eastern Texas, dropping copious amounts of rainfall over that area. Rainbands started pushing towards the target area late, but dissipated as daytime heating subsided. | No seeding activities from Hondo. |
| 8 June 2001, Friday | Rainbands from Allison finally pushed into the target area as it slowly drifted southwestward. Most of the Rainbands were only isolated convection, but during the afternoon, convection started to hold together. All activity dissipated as heating subsided before sunset. | Seed 1 flew one seeding mission during the afternoon hours in Medina, Bexar, Wilson, Atascosa, and Bandera Counties.<br><br>Seed 1 (N3904G) – base seed<br>Engine On – 1935Z<br>Engine Off – 2300Z<br>Time – 3 hours 25 minutes<br>Flares – Acetone burners – 2 hours 40 minutes (Left side: 1:36; Right side: 1:04) |
| 9 June 2001, Saturday | Allison turned back toward the southeast, pulling along with it seedable convection. A couple isolated showers did drift into the eastern target area, but were only isolated and didn't build up to seedable heights | No seeding activities from Hondo. |
| 10 June 2001, Sunday | High pressure moved back into Texas, clearing skies and temperatures in the middle 90s. | No seeding activities from Hondo. |
| 11 June 2001, Monday | Another day of mostly sunny skies and above average temperatures. The heat continues. | No seeding activities from Hondo. |
| 12 June 2001, Tuesday | Another day of mostly sunny skies and temperatures in the 90s. | No seeding activities from Hondo. |
| 13 June 2001, Wednesday | One more day of summer-like weather. Highs were in the 90s and skies were mostly clear. | No seeding activities from Hondo. |
| 14 June 2001, Thursday | A large area of convection fired in Old Mexico during the evening hours. This activity pushed northward into deep south Texas, arriving in the target area just after sunset. Most activity had already become iced and was unseedable, but seedable pockets were found and seeded. This activity weakened to unseedable criteria around midnight. | Seed 2 flew one seeding flight during the early overnight hours in Bandera and Kendall counties.<br><br>Seed 2 (N340AX) – top seed<br>Engine On – 0346Z<br>Engine Off – 0611Z<br>Time – 2 hours 25 minutes<br>Flares – 7 ejectable flares |
| 15 June 2001, Friday | During the overnight hours, a long line of convection started to push toward the target area. This line quickly weakened as it moved away from its initiating cold front through Northern Texas, leaving only light stratus showers. The rest of the day saw mostly clear skies, as most convective activity had pushed into Deep South Texas. | No seeding activities from Hondo. |
| 16 June 2001, Saturday | Another day of hot and humid conditions as high pressure built over most of Texas, pushing the cold front in North Texas back into Oklahoma. | No seeding activities from Hondo. |
| 17 June 2001, Sunday | Partly cloudy under high pressure. Temperatures were in the low to mid 90s. | No seeding activities from Hondo. |
| 18 June 2001, Monday | Another day of partly cloudy skies and highs in the mid 90s. | No seeding activities from Hondo. |
| 19 June 2001, Tuesday | Another day of partly cloudy skies and highs in the mid 90s. | No seeding activities from Hondo. |

| Date | Weather | Activities Summary |
|---|---|---|
| 20 June 2001, Wednesday | Another day of partly cloudy skies and highs in the mid 90s. | No seeding activities from Hondo. |
| 21 June 2001, Thursday | A cold front pushed into the target area overnight. Without daytime heating, showers were unable to fire over the target area. | No seeding activities from Hondo. |
| 22 June 2001, Friday | Yesterday's cold front stalled over the area. This time, heating was available and was able to spark showers and thunderstorms over the area. This line of scattered showers slowly pushed southward, exiting the area during the evening. | Two seeding flight were flown in the afternoon, one by Seed 1 in Kerr, Bexar, Kendall, Medina, and Bandera Counties, and one flight by Seed 2 in Bexar, Kendall, and Kerr Counties.<br><br>Seed 1 (N3904G) – top seed<br>Engine On – 1850Z<br>Engine Off – 2250Z<br>Time – 4 hours<br>Flares – 64 ejectable flares<br><br>Seed 2 (N340AX) – base seed<br>Engine On – 2030Z<br>Engine Off – 2248Z<br>Time – 2 hours 18 minutes<br>Flares – Acetone Burners – 1 hour 26 minutes (all left side) |
| 23 June 2001, Saturday | Outflow from a large thunderstorm complex in the Panhandle combined with a mid-level disturbance to spark showers and thunderstorms. These storms were imbedded and hard to find definite seedable targets. Overnight these storms dumped tropical amounts of rain between 3 and 5 inches in 4 hours over the San Antonio area, prompting flood warnings. This area slowly pushed southeastward during the overnight hours. | Seed 1 flew one reconnaissance flight during the evening hours.<br><br>Seed 1 (N3904G) – top recon<br>Engine On – 0035Z<br>Engine Off – 0205Z<br>Time – 1 hour 30 minutes |
| 24 June 2001, Sunday | More stable air behind the thunderstorm complex from the previous day kept convection from firing. This left skies mostly sunny and temperatures in the low 90s. | No seeding activities from Hondo. |
| 25 June 2001, Monday | Upper level high pressure built into Texas today, further stabilizing the atmosphere and keeping the weather quiet. Highs were in the low 90s. | No seeding activities from Hondo. |
| 26 June 2001, Tuesday | Another day of quiet weather under strong high pressure with highs in the low 90s. | No seeding activities from Hondo. |
| 27 June 2001, Wednesday | High pressure is still in control of the weather, keeping skies mostly sunny and hot. | No seeding activities from Hondo. |
| 28 June 2001, Thursday | One more day of hot and humid weather with highs in the 90s. | No seeding activities from Hondo. |
| 29 June 2001, Friday | An upper level low cut off from the jet stream is pushing westward towards Texas. Currently it is centered in eastern Arkansas. It is slowly breaking down the high over Texas. But for now, the high is still strong enough to keep convection from firing in the target area. | No seeding activities from Hondo. |
| 30 June 2001, Saturday | Another day under weakening high pressure. The low, now centered in NE Texas, continues to push southwestward into Texas. The seabreeze was able to form off the Gulf of Mexico, but was pushing toward Houston, rather than northwestward toward San Antonio. | No seeding activities from Hondo. |
| 1 July 2001, Sunday | An upper level low pressure area building in from eastern Texas set the stage for widespread showers and thunderstorms. Unfortunately, the moisture had no trigger to focus convection on. | No seeding activities from Hondo. |

| Date | Weather | Activities Summary |
|---|---|---|
| 2 July 2001, Monday | Low pressure at upper levels was able to weaken the atmosphere enough to spark showers and thunderstorm along the seabreeze boundary today. As these moved northward, they weakened and dissipated as they pushed into more stable air. | Seed 2 flew one seeding mission during the early afternoon hours in Medina, Uvalde, Bandera, and Kerr Counties.<br><br>Seed 2 (N340AX) – base seed<br>Engine On – 1734Z<br>Engine Off – 1946Z<br>Time – 2 hours 12 minutes<br>Flares – Acetone burners – 1 hour 26 minutes (all right side) |
| 3 July 2001, Tuesday | Another day of showers on the seabreeze boundary. Today's showers were more isolated and quick to dissipate. These showers dissipated after peak heating, around sunset. | Seed 1 flew one seeding missions during the late afternoon hours in Medina and Caldwell Counties.<br><br>Seed 1 (N3904G) – top seed<br>Engine On – 1942Z<br>Engine Off – 2307Z<br>Time – 3 hours 25 minutes<br>Flares – 15 Ejectable flares |
| 4 July 2001, Wednesday | The seabreeze was able to set up today, but was unable to push into the target area. The target area only saw scattered clouds and temperatures in the 90s. | No seeding activities from Hondo. |
| 5 July 2001, Thursday | High pressure built in over the target area from the Four Corners area, stabilizing the atmosphere and letting temperatures rise into the mid 90s. | No seeding activities from Hondo. |
| 6 July 2001, Friday | Another day of strong high pressure kept skies mostly clear and temperatures high. | No seeding activities from Hondo. |
| 7 July 2001, Saturday | High pressure is in complete control, keeping skies clear and letting temperatures get ever closer to the 100 degree mark. | No seeding activities from Hondo. |
| 8 July 2001, Sunday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 9 July 2001, Monday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 10 July 2001, Tuesday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 11 July 2001, Wednesday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 12 July 2001, Thursday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 13 July 2001, Friday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 14 July 2001, Saturday | A weak front pushed into NE Texas today. Unfortunately, the convection associated with it didn't hold together under the high pressure in western Texas. So skies remained clear and temperatures hovered around 100 degrees. | No seeding activities from Hondo. |
| 15 July 2001, Sunday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 16 July 2001, Monday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 17 July 2001, Tuesday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures | No seeding activities from Hondo. |

| Date | Weather | Activities Summary |
|---|---|---|
| | around 100 degrees. | |
| 18 July 2001, Wednesday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 19 July 2001, Thursday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 20 July 2001, Friday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 21 July 2001, Saturday | Strong high pressure controlling the weather across Texas kept skies clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 22 July 2001, Sunday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. No showers were able to enter the target area today. | No seeding activities from Hondo. |
| 23 July 2001, Monday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. No showers were able to enter the target area today. | No seeding activities from Hondo. |
| 24 July 2001, Tuesday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. One shower was able to push into the target area, but quickly dissipated. | No seeding activities from Hondo. |
| 25 July 2001, Wednesday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. No showers were able to enter the target area today. | No seeding activities from Hondo. |
| 26 July 2001, Thursday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. No showers were able to enter the target area today. | No seeding activities from Hondo. |
| 27 July 2001, Friday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. No showers were able to enter the target area today. | No seeding activities from Hondo. |
| 28 July 2001, Saturday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. No showers were able to enter the target area today. | No seeding activities from Hondo. |
| 29 July 2001, Sunday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. No showers were able to enter the target area today. | No seeding activities from Hondo. |
| 30 July 2001, Monday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. No showers were able to enter the target area today. | No seeding activities from Hondo. |
| 31 July 2001, Tuesday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over | No seeding activities from Hondo. |

| Date | Weather | Activities Summary |
|---|---|---|
| | southeast Texas. No showers were able to enter the target area today. | |
| 1 August 2001, Wednesday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. No showers were able to enter the target area today. | No seeding activities from Hondo. |
| 2 August 2001, Thursday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. No showers were able to enter the target area today. | No seeding activities from Hondo. |
| 3 August 2001, Friday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. No showers were able to enter the target area today. | No seeding activities from Hondo. |
| 4 August 2001, Saturday | High pressure to the north has push abundant moisture across Texas, and has let the seabreeze boundary become active over southeast Texas. A few isolated, short-lived showers were able to enter the target area today into Bexar County over early evening. Tops of activity struggled past 18.0 kft...-5C and –10C were 18.4+ and 20.8+ kft respectively. Conditions were not suitable for seeding. | No seeding activities from Hondo. |
| 5 August 2001, Sunday | A weak shortwave trough will push south across the target area this afternoon bringing cooler air aloft and will allow some uplift out ahead of it. The seabreeze boundary will become more active than recent days over south/central Texas. A couple of thundershowers will likely be able to enter the target area today. | One seeding flight was performed at top late Sunday afternoon/early evening across Bexar County. A couple small cells formed out ahead of a weak short-wave disturbance moving southward. Cell movement was to the southwest. Seed 2 reported good supercooled liquid water and updrafts during their mission. Other cells formed just east of the target area and moved southward.<br><br>Seed 2 (N340AX) – top seed<br>Engine On – 2150Z<br>Engine Off – 0040Z<br>Time – 2 hours 50 minutes<br>Seeding – Ejectable Flares – 13 |
| 6 August 2001, Monday | A few weak isolated,short-lived showers were able to develop over Uvalde and Kinney counties late this afternoon, but were not conducive to seeding. The seabreeze boundary will be more pronounced on Tuesday with higher moisture values. | No seeding activities from Hondo. |
| 7 August 2001, Tuesday | Mostly sunny, warm and continued humid. The seabreeze boundary will be a little stronger this afternoon and give the chance for more widespread convection. Cooler temperatures aloft and deeper moisture also support this the likelihood for enhanced convection. | Isolated convective cells started forming around 1830Z across Bandera, Kerr and Kendall counties. Seed 1 was originally launched toward top at 1855Z, but due to problems with ATC and the arrival corridor for San Antonio airport, they were re-directed to base. They seeded numerous individual cells across the target area finding good inflow. Movement of the cells was near stationary to slowly north. They RTB at 2122Z when activity was diminishing and moving north out of the target area.<br><br>Seed 2 was launched to top at 1945Z toward the northeast portion of the target area over Blanco County. While climbing out of Hondo, they too had problems with ATC and had to be re-directed toward |

| Date | Weather | Activities Summary |
|---|---|---|
| | | Kerr County on additional convection there. They reconned several cells reporting light supercooled liquid water but not many updrafts. They RTB to Hondo at 2129Z when activity was falling off and decent targets could not be found.<br><br>Seed 1 (N3404G) – base seed<br>Engine On – 1905Z<br>Engine Off – 2115Z<br>Time – 2 hours 10 minutes<br>Seeding – Acetone burners – 1 hours 39 minutes<br>(Left side – 92 minutes, Right side – 7 minutes)<br><br>Seed 2 (N340AX) – top seed<br>Engine On – Z<br>Engine Off – Z<br>Time – hours minutes<br>Seeding – Ejectable Flares – 1 |
| 8 August 2001, Wednesday | This morning was partly sunny with low stratus type clouds, more humid and continued warm. No discernible boundaries are present for anything except weak and isolated convection this afternoon mainly over the western target area. | No seeding activities from Hondo. |
| 9 August 2001, Thursday | Upper level high pressure has built in again, leaving skies mostly sunny and temperatures hovering around 100 degrees. | No seeding activities from Hondo. |
| 10 August 2001, Friday | Another day of mostly clear skies as upper level high pressure keeps the atmosphere capped. Temperatures will still be around 100 degrees. | No seeding activities from Hondo. |
| 11 August 2001, Saturday | Another day of mostly clear skies under high pressure. Highs were still just reaching 100 degrees. | No seeding activities from Hondo. |
| 12 August 2001, Sunday | High pressure is in control of the target area, but is weakening. Highs are still hovering around 100 degrees, as have the last 3 weeks. | No seeding activities from Hondo. |
| 13 August 2001, Monday | The first in a series of cold front stalled in central Texas this evening. Storms were able to reach the buffer zone, but were unable to penetrate into the target area before daytime heating was lost.<br><br>Note: Seed 1 (N3904G) was destroyed in a hangar fire during the evening. | One reconnaissance flight was flown by Seed 2 during the evening hours in Burnet County.<br><br>Seed 2 (N340AX) – top recon<br>Engine On – 2300Z<br>Engine Off – 0140Z<br>Time – 2 hours 40 minutes |
| 14 August 2001, Tuesday | Yesterday's front slowly drifted into the target, sparking numerous showers and thunderstorms, mainly during peak heating. These storms dissipated after sunset.<br><br>Note: The replacement aircraft for the one lost in the fire arrived today. N340FR will now be known as Seed 1. | No seeding activities from Hondo. Aircraft undergoing required maintenance. |
| 15 August 2001, Wednesday | A lull between cold fronts left skies mostly sunny and temperatures again hot. Temperatures were around 100 degrees. | No seeding activities from Hondo. |
| 16 August 2001, Thursday | Outflow from storms on the second cold front sparked a line of showers and thunderstorms that slowly rolled through the target area during the day. The storms started to weaken during the early evening, but then the outflow collided with the seabreeze boundary and formed large thunderstorms that stalled over the southeastern | Three flights were flown today. Seed 1 flew two flights during the afternoon and evening hours in Kerr, Bandera, Comal, Caldwell, Hays, Guadalupe, and Bexar Counties. Seed 2 flew one flight during the afternoon in Bandera, Real, Medina, Kendall, Blanco, and Comal Counties. |

| Date | Weather | Activities Summary |
|---|---|---|
| | target area. These storms lasted about three hours before slowly dissipating. | Seed 1 (N340FR):<br>Flight 1 – top seed<br>Engine On – 1920Z<br>Engine Off – 2220Z<br>Time – 3 hours<br>Flares – 27 Ejectable flares<br><br>Flight 2 – base seed<br>Engine On – 2355Z<br>Engine Off – 0225Z<br>Time – 1 hour 30 minutes<br>Flares – Acetone burners – 1 hour 59 minutes (1 hour 16 minutes left, 43 minutes right)<br><br>Seed 2 (N340AX) – top and base seed<br>Engine On – 2030Z<br>Engine Off – 0024Z<br>Time – 3 hours 54 minutes<br>Flares – 3 Ejectables, Acetone burners – 59 minutes (all right side) |
| 17 August 2001, Friday | Cold front #2 stalled from Dallas to Midland, sparking many showers and thunderstorms there. Unfortunately, no outflow or other forcing mechanisms were able to arrive in the target area. This left skies mostly clear and temperatures around 100 degrees. | No seeding activities from Hondo. |
| 18 August 2001, Saturday | A lull between systems left skies partly cloudy and temperatures still around 100 degrees. | No seeding activities from Hondo. |
| 19 August 2001, Sunday | An unseen upper level disturbance pushed across the target area during the morning, sparking showers and thunderstorms. These storms were mostly stratus variety, but pockets of seedable convection were identified, especially after sunrise. These storms pushed eastward and exited the region during the mid afternoon, leaving mostly sunny skies. | Two seeding flights were flown today, one by Seed 1 during the early afternoon in Real and Uvalde County, and one flight by Seed 2 during the morning in Kerr and Kendall Counties.<br><br>Seed 1 (N340FR) – top seed<br>Engine On – 1627Z<br>Engine Off – 1847Z<br>Time – 2 hours 20 minutes<br>Flares – 24 Ejectables<br><br>Seed 2 (N340AX) – base seed<br>Engine On – 1400Z<br>Engine Off – 1725Z<br>Time – 3 hours 25 minutes<br>Flares – Acetone burners – 2 hours 37 minutes (all left side) |
| 20 August 2001, Monday | Mostly sunny and humid condition prevailed after yesterday's system. Seabreeze showers were able to form, but were unable to arrive in the target area. | No seeding activities from Hondo. |
| 21 August 2001, Tuesday | More sunny and humid weather. A few seabreeze showers were able to form and push into the target area, but did not last more than 20 minutes before dissipating. | No seeding activities from Hondo. |
| 22 August 2001, Wednesday | Another sunny and humid day with highs in the mid to upper 90s. One seabreeze shower was able to form during the evening hours, but quickly dissipated. | No seeding activities from Hondo. |
| 23 August 2001, Thursday | Another day of sunny and humid weather. No seabreeze showers were able to form. | No seeding activities from Hondo. |
| 24 August 2001, Friday | Another day of sunny and humid weather. No seabreeze showers were able to form. | No seeding activities from Hondo. |

| Date | Weather | Activities Summary |
|---|---|---|
| 25 August 2001, Saturday | Another day of sunny and humid weather. No seabreeze showers were able to form. | No seeding activities from Hondo. |
| 26 August 2001, Sunday | An upper level trough slowly pushing in from the northwest sparked showers and thunderstorms in the deep Gulf moisture covering South Texas. Light upper level winds kept storms from moving quickly, allowing storm totals to quickly accumulate. Convective activity pushed out of the area during the late evening hours, leaving behind heavy stratus rains. High rainfall report from Hondo of 4.06 inches. | Two flights were flow today. One flight was flown by Seed 1 during the evening hours in Bexar and Comal Counties, and one flight by Seed 2 during the afternoon in Hays, Comal, and Uvalde Counties.<br><br>Seed 2 (N340AX) – top seed<br>Engine On – 2240Z<br>Engine Off – 0154Z<br>Time – 3 hours 14 minutes<br>Flares – 9 ejectables<br><br>Seed 1 (N340FR) – base seed<br>Engine On – 2300Z<br>Engine Off – 0205Z<br>Time – 3 hours 5 minutes<br>Flares – Acetone Burners – 2 hours 32 minutes (all left side) |
| 27 August 2001, Monday | More scattered showers and thunderstorms popped up under the combination of humid tropical air and upper level low pressure. Like yesterday, little upper levels motion kept storm from moving fast, allowing them to drop ample amounts of precipitation. These storms weakened after sunset and did not form stratus showers like yesterday, so extremely high rainfall reports were not received. | Two flights were flown today, one by each aircraft. Seed 1 flew during the afternoon hours in Medina, Bandera, and Bexar Counties. Seed 2 flew during the afternoon hours in Kendall, Bexar, and Hays Counties.<br><br>Seed 1 (N340FR) – top and base seed<br>Engine On – 1955Z<br>Engine Off – 2345Z<br>Time – 3 hours 50 minutes<br>Flares – 68 ejectable, Acetone burners – 1 hour 15 minutes (all left side)<br><br>Seed 2 (N340AX) – top seed<br>Engine On – 1910Z<br>Engine Off – 2224Z<br>Time – 3 hours 14 minutes<br>Flares – 23 ejectables |
| 28 August 2001, Tuesday | An early morning outflow boundary went through the target area from Southeast to Northwest. This line of showers was very short, just barely making it to seedable heights. This early boundary seemed to stabilize the atmosphere, keeping more storms from forming during most of the day. | One flight was flown today during the morning hours in Comal, Hays, and Blanco Counties.<br><br>Seed 2 (N340AX) – top seed<br>Engine On – 1535Z<br>Engine Off – 1800Z<br>Time – 2 hours 25 minutes<br>Flares – 15 ejectables |
| 29 August 2001, Wednesday | Without sharp forcing from a seabreeze or outflow boundary, today's showers were of the stratiform variety. These showers did not reach a height to which seeding was viable. These showers only made it to about 13 thousand feet. This also allowed Gulf moisture to build over the target area, priming the atmosphere for whenever a boundary should enter the area. | No seeding activities from Hondo. |
| 30 August 2001, Thursday | And then the rains came...<br><br>During the morning, showers and thunderstorms started to push northward into the eastern sections of the target areas. These showers tapped the low level moisture from the previous days, allowing showers to fall at a much higher rate. This rainfall started to form over the same | Five flights were flown today, 3 by Seed 1 and one by Seed 2.<br><br>Seed 1 (N340FR):<br>Flight 1 – top recon<br>Engine On – 1320Z<br>Engine Off – 1515Z<br>Time – 1 hour 55 minutes |

| Date | Weather | Activities Summary |
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| | areas during the day, also known as "training". This helped rainfall totals to skyrocket. Doppler estimates of 6 to 10 inches of Wilson, Guadalupe, and eastern Bexar Counties were not uncommon. The western half of the target area saw some sunshine, which let convection to fire without a boundary. Activity continued into the night. Flash flood warnings were issued all day, starting at 10AM in Comal, Wilson, Bexar, and Guadalupe counties. These warnings would be extended through the night and into the next morning. | Flight 2 – base seed<br>Engine On – 1925Z<br>Engine Off – 4 hours 15 minutes<br>Flares – acetone burners – 2 hours 58 minutes (Right side- 2:00, left side- 0:58)<br>Counties Seeded – Kerr, Bandera, Real<br><br>Flight 3 – top and base recon<br>Engine On – 0035Z<br>Engine Off – 0230Z<br>Time – 1 hour 55 minutes<br><br>Seed 2 (N340AX):<br>Flight 1 – top seed<br>Engine On – 1807Z<br>Engine Off – 2138Z<br>Time – 3 hours 31 minutes<br>Flares – 24 ejectables<br>Counties Seeded – Frio, Medina<br><br>Flight 2 – base seed<br>Engine On – 0220Z<br>Engine Off – 0306Z<br>Time – 46 minutes<br>Flares – acetone burners – 27 minutes (right side)<br>Counties Seeded - Medina |
| 31 August 2001, Friday | The main trough of low pressure pushed to the coast today, leaving behind partly sunny skies. Low level moisture was still present, so an outflow boundary from the northwest had ample fuel to fire showers and thunderstorms. As has been the case this week, these storms were also slow moving, and flash flood warnings were issued fairly often. These storms pushed through the area and kept going to the Gulf Coast. | Two flights were flown today, one by each aircraft. Seed 1 flew during the evening hours in Bandera, Kerr, and Medina Counties. Seed 2 Flew during the late afternoon and evening hours in Medina, Bandera, and Frio Counties<br><br>Seed 1 (N340FR) – top seed<br>Engine On – 2305Z<br>Engine Off – 0140Z<br>Time – 2 hours 35 minutes<br>Flares – 58 ejectable<br><br>Seed 2 (N340AX) – top seed<br>Engine On – 2045Z<br>Engine Off – 0015Z<br>Time – 3 hours 30 minutes<br>Flares – 52-54 ejectables |
| 1 September 2001, Saturday | Showers popped up in the humid atmosphere again today right along the leading edge of the Hill Country. These storms would form, drift off to the southeast, and slowly dissipate as they lost their forcing mechanism. This lasted a few hours, then slowed down as heating of the day waned. | Seed 1 flew one flight during the afternoon hours in Uvalde and Medina Counties.<br><br>Seed 1 (N340FR) – top seed<br>Engine On – 1915Z<br>Engine Off – 2155Z<br>Time – 2 hours 40 minutes<br>Flares – 47 ejectables |
| 2 September 2001, Sunday | Moisture left over from last week's rains left the atmosphere very humid. Southwest winds pushed up against the hill country, sparking scattered showers. They would form, drift off the hills, and dissipate. These showers weakened during the day. | Both aircraft flew one seeding flight during the afternoon hours. Seed 1 flew in Medina, Bexar, and Comal counties, while Seed 2 flew in Bexar and Medina Counties.<br><br>Seed 1 (N340FR) – base seed<br>Engine On – 2015Z<br>Engine Off – 2325Z<br>Time – 3 hours 10 minutes<br>Flares – acetone burners – 2 hours 26 minutes (all |

| Date | Weather | Activities Summary |
|---|---|---|
| | | right side)<br><br>Seed 2 (N340AX) – top seed<br>Engine On – 1825Z<br>Engine Off – 2140Z<br>Time – 3 hours 15 minutes<br>Flares – 28 Ejectables |
| 3 September 2001, Monday | A large outflow boundary pushed through the target area during the evening hours, sparked by a large area of thunderstorms in North Central Texas. The best seeding features were on the southwestern side as it pushed through Kerr, Bandera, and Uvalde Counties. As the sun set, the line started to weaken, with seedable features starting to disappear. As this line pushed into southern Bexar County, it resparked thunderstorms which slowly pushed out of the target area.<br><br>As Seed 2 landed to refuel, it had engine troubles that kept it from relaunching. | One seeding flight was flown during the evening hours by Seed 2 in Real, Kendall, Bandera, Uvalde and Medina Counties.<br><br>Seed 2 (N340AX) – top seed<br>Engine On – 2300Z<br>Engine Off – 0218Z<br>Time – 3 hours 18 minutes<br>Flares – 48 ejectables<br><br>Note: Seed 1 unavailable due to required maintenance. |
| 4 September 2001, Tuesday | The seabreeze boundary pushing in from the southeast sparked showers and thunderstorms that pushed northwestward. As Seed 1 reached this area, the seabreeze showers started to dissipate. Seed 1 was relocated to a shower forming over Medina Lake. This shower quickly built toward the south-southwest into the Hondo area. As this built southward out of the target area, Seed 1 relocated to investigate showers in Kendall and Kerr Counties. | Seed 1 flew one seeding flight was flown during the evening hours in Caldwell, Hays, and Medina Counties. Seed 2 flew one recon flight during the evening hours in Bandera and Kerr Counties.<br><br>Seed 1 (N340FR) – top seed<br>Engine On – 2225Z<br>Engine Off – 0130Z<br>Time – 3 hours 5minutes<br>Flares – 40 ejectables<br><br>Seed 2 – (N340AX) – base recon<br>Engine On – 0140Z<br>Engine Off – 0240Z<br>Time – 1 hour |
| 5 September 2001, Wednesday | Early morning saw a small area of disturbed weather across the northwest target area. As the sun rose, these showers spread out and weakened. Some seedable targets were found, but quickly weakened. Seed 1 was relocated to a small area of showers in Bexar County. This shower was very weak and had no seedable targets. All tops were at temperatures above freezing.<br><br>During the early afternoon, a second wave built in from the northwest on an outflow boundary. As this pushed into the area, Seed 2 found good seedable targets. Workable areas were restricted due to active military areas in the western areas. As these thunderstorms drifted through the area, they slowed down and dropped copious amounts of rain on already saturated grounds. Flash flood warnings were issued sometime during the day for all counties in the target area except for Uvalde County. Convection pushed out of the target area during the late evening hours, leaving blowoff stratus showers, which kept dropping flooding rains mainly over the eastern half of the target area. | Three flights were flown during the day. 2 flights were by Seed 1 during the morning and afternoon hours in Medina, Zavala, Uvalde, and Bandera Counties. One flight was flown by Seed 2 during the afternoon in Kerr, Bandera, Gillespie, Kendall, Bexar, and Medina Counties.<br><br>Seed 1 (N340FR):<br>Flight 1 – top seed<br>Engine On – 1240Z<br>Engine Off – 1455Z<br>Time – 2 hours 15 minutes<br>Flares – 18 Ejectables<br><br>Flight 2 – base seed<br>Engine On – 1955Z<br>Engine Off – 0045Z<br>Time – 4 hours 50 minutes<br>Flares – acetone burners - 3 hours 4 minutes (all left side)<br><br>Seed 2 (N340AX) – top and base seed<br>Engine On – 1820Z<br>Engine Off – 2205Z<br>Time – 3 hours 45minutes<br>Flares – 24 Ejectables – acetone burners – 20 |

| Date | Weather | Activities Summary |
|---|---|---|
| | | minutes (all left side) |
| 6 September 2001, Thursday | A small area of showers and thunderstorms pushed through the area during the early morning hours dropping more rainfall. These were not seeded due to the flash flood warning from the previous evening. These showers dissipated around sunrise, leaving mostly cloudy skies and cooler than average temperatures. | No seeding activities from Hondo. |
| 7 September 2001, Friday | High pressure between systems kept the weather quiet, but kept low-level moisture in place, making for a warm and humid day. | No seeding activities from Hondo. |
| 8 September 2001, Saturday | One more day of quiet weather ahead of an unusually powerful cold front expected tomorrow morning. | No seeding activities from Hondo. |
| 9 September 2001, Sunday | The remnants of a large convective system pushed an outflow boundary through the area during the early morning hours. This sparked showers and thunderstorms as it pushed southeastward. Due to the early morning time period, feeders were few and far between. Workable areas were found and seeded as the sun rose. This line pushed through the area around noon. This stabilized the atmosphere, keeping any more showers from forming today. | Seed 2 flew one flight during the early morning hours in Hays, Guadalupe, and Bexar Counties.<br><br>Seed 2 (N340AX) – top seed<br>Engine On – 1150Z<br>Engine Off – 1540Z<br>Time – 3 hours 50 minutes<br>Flares – 34 Ejectables |
| 10 September 2001, Monday | The atmosphere stabilized under high pressure at all levels today, keeping skies mostly sunny and temperatures around 90 degrees. | No seeding activities from Hondo. |
| 11 September 2001, Tuesday | **All operations grounded after terrorist attack on the World Trade Centers in New York.**<br><br>Another day of total high pressure kept the weather uneventful. No opportunities. | No seeding activities from Hondo. |
| 12 September 2001, Wednesday | All operations remained grounded after terrorist attack on the World Trade Centers in New York. Another day of total high pressure kept the weather uneventful. No opportunities. | No seeding activities from Hondo. |
| 13 September 2001, Thursday | All operations remained grounded after terrorist attack on the World Trade Centers in New York. Another day of total high pressure kept the weather uneventful. No opportunities. | No seeding activities from Hondo. |
| 14 September 2001, Friday | Moisture from a hurricane off the west Mexican coast pushed some mid level moisture into the northwest target area. This allowed a couple isolated showers to pop up during peak heating. These showers dissipated before any work could be done on them. FAA allows flight operations to resume. | No seeding activities from Hondo. |
| 15 September 2001, Saturday | Drier air returned to mid levels, keeping any suitable clouds from forming. High temperatures were around 90 degrees. | No seeding activities from Hondo. |

## E. Specifications for Cessna C340A Aircraft

Turbocharged piston twin engine, pressurized cabin
6290 lbs gross takeoff weight
4400 lbs empty weight (typical)
1890 lbs useful load (typical)
310 hp per engine
280 mph max speed (in unmodified configuration)
263 mph manufacturer's recommended cruise speed
82 mph stall in landing configuration
183 - 203 gals fuel capacity
29,800 feet all engine service ceiling
15,800 feet single engine service ceiling
1650 feet per minute all engine rate of climb
315 feet per minute single engine rate of climb
2175 feet for take off distance over 50 foot tall obstruction
1615 feet for take off ground roll
1850 feet landing distance over 50 foot tall obstruction
770 feet landing ground roll
34 ft. 4 in. length
12 ft. 7 in. height
38 ft. 1 in. wingspan

## F. Glossary of Terms and Acronyms

Definitions are those found within the Glossary of Meteorology, where applicable. Italicized print in this section indicates an alternative glossary entry that the reader may also wish to review.

**AirLink**—Exclusive aircraft position and data telemetry system developed by Weather Modification, Inc.

**AgI**– see *silver iodide.*

**AMS**– American Meteorological Society, 45 Beacon Street, Boston, MA 02108-3693.

**ASCE**—American Society of Civil Engineering, Reston, Virginia.

**attenuation**– in physics, any process in which the flux density (or power, amplitude, intensity, illuminance, etc.), of a "parallel beam" of energy decreases with increasing distance from the energy source, for example, the reduction of intensity of the electromagnetic wave (radar signal) along its path from and back to the radar. Attenuation thus lessens the ability of a radar to sense all clouds and precipitation, such that the depicted information is inaccurate or incomplete.

**burn-in-place flare**– a pyrotechnic device burned in a fixed position, such as the trailing edge of an aircraft wing. Compare *ejectable flare.*

**Cartesian coordinates** – The common X-Y coordinate system, where positive X is distance east, and positive Y is distance north. Negative X is therefore west, and negative Y, south. For example, Cartesian coordinates of X=30 mi, Y= -30 mi, would be a point 30 mi east and 30 mi south, or 42.4 mi southeast. See also, *Polar coordinates.*

**CCN**– cloud condensation nuclei. The tiny particles, either liquid or solid, upon which condensation of water vapor first begins in the atmosphere, they are necessary for the formation of cloud droplets.

**CDC** – Convective Day Category. Numerical value accorded each forecast to indicate the scale of storm development expected on that day. CDC values range from –3 (no seedable weather assured) to +5 (severe weather likely).

**CD-ROM**—compact disk, read-only memory. The common compact diskette (CD) used for data archival and musical recordings.

**CDT** – Central Daylight Time. Five hours slower than GMT, CUT, and UTC. For example, 5:00 p.m. CDT equals 10 p.m. (22:00) GMT.

**cell**– a convective element (cloud) which in its life cycle, develops, matures, and dissipates, usually in about 30 min.

**cloud base seeding**—the release of cloud seeding agent into updrafts beneath developing cloud turrets, which transport the seeding agent aloft into the precipitation development zones.

**cloud droplets**– a particle of liquid water from a few microns to tens of microns in diameter, formed by condensation of atmospheric water vapor, and suspended in the atmosphere with other droplets for form a cloud. These liquid water droplets are too small to precipitate.

**cloud model**– physical description of cloud processes programmed into a computer to simulate cloud development and evolution. Very useful in understanding the relative importance of the many factors that influence cloud development, and the only way in which *exactly the same cloud* can be both seeded and unseeded.

**coalescence**– in cloud physics, the merging of two water drops into a single larger drop. This occurs through the collision or two drops, which then unite.

**conceptual model**– a theoretical model of hail development, based upon current knowledge and scientific concepts. See also *cloud model.*

**control area**– an area where cloud seeding operations do not take place, preferably similar in character and near to the *target area.* The behavior of storms over the control area is compared to those treated over the target area, to assess differences and thus measure project effectiveness. See also, *target area*, *seeding area*, and *seeded area.*

**CUT** – Coordinated Universal Time. See also, *UTC, GMT.* Five hours ahead of Central Daylight Time; for example, 10:00 p.m. CUT (22:00) equals 5:00 p.m. (17:00) CDT.

**dBZ**— measurement of radar reflectivity. An open-ended, logarithmic scale. With common weather radars, a value of 20 dBZ typically denotes the threshold for the lightest precipitation, while 45 dBZ is commonly taken to be the threshold reflectivity for hail.

**direct targeting**– the placement of seeding agents directly into the target cloud mass by release during penetration by aircraft.

**droplet spectrum**– the numbers and sizes of the droplets within the cloud volume of interest.

**dynamic seeding**– the treatment of clouds with the intent of utilizing the latent heat produced by additional freezing and perhaps in some cases by condensation or deposition to invigorate cloud development.

**EAA** – Edwards Aquifer Authority, San Antonio, Texas.

**EAPEP**—Edwards Aquifer Precipitation Enhancement Program.

**ejectable flares**– pyrotechnic devices that are ignited and released (ejected) from aircraft. Compare *burn-in-place flare.*

**FAA**– Federal Aviation Administration. The governmental entity that regulates aircraft operations, safety, and use of airways in the United States. Analogous entities also exist in most other nations.

**flanking line**– developing convective cells on the flank (side) of a mature thunderstorm.

**glaciogenic**– causing the formation of ice.

**glaciogenic seeding**– treatment of clouds with materials intended to increase and/or initiate the formation of ice crystals.

**GMT** – Greenwich mean time, same as Universal Time Coordinates (UTC) or Coordinated Universal Time (CUT). Five hours ahead of Central Daylight Time; for example, 10:00 p.m. GMT (22:00) equals 5:00 p.m. (17:00) CDT.

**GOES**– Geostationary Operational Environmental Satellite. These are the latest NOAA weather satellites, presently operational over the continental U.S.

**GPS**– Global Positioning System. A global, satellite-based navigation positioning system which provides consistently accurate positions.

**graupel**– white, opaque, approximately round (sometimes conical) ice particles having a snow-like structure, and about 2-5 mm in diameter. Also known as snow pellets, they form in convective clouds when supercooled water droplets freeze to an ice particle upon impact.

**hail**– Precipitation in the form of balls or irregular lumps of ice, always produced by convective clouds, nearly always by cumulonimbus. An individual unit of hail is called a hailstone. By convention, hail has a diameter of 5 mm or more.

**hydrometeor**– any product of condensation or deposition, or condensation and freezing, in the atmosphere. This includes cloud water or ice of any size, either suspended in the air or precipitating.

**hygroscopic**– pertaining to a marked ability to accelerate the condensation of water vapor; having the property of attracting water, or having the effect of encouraging the formation of larger droplets.

**hygroscopic seeding**– treatment of clouds with hygroscopic materials which encourage the formation of larger droplets, changing the cloud droplet spectrum in such a way as to enhance development of precipitation through coalescence.

**ice nucleus**– any particle that serves as a nucleus for the formation of ice crystals in the atmosphere.

**IFR** - Instrument Flight Rules. The FAA regulations pertaining to flight at altitudes of 18,000 feet above mean sea level or higher over U.S. airspace, or in any meteorological conditions necessitating the use of aircraft instrumentation for safe navigation.

**IN**– see *ice nucleus.*

***in situ* measurement**– measurements made in place, as within the cloud of interest. Compare *remote sensing.*

**JWM**– Journal of Weather Modification, the official journal of the Weather Modification Association.

**KCl**– see *potassium chloride.*

**latent heat**– The heat released or absorbed per unit mass by a system in a reversible, isobaric-isothermal change of phase. More simply, the heat released when water vapor condenses (latent heat of condensation), or when liquid water drops freeze (latent heat of fusion). In the case of water droplets freezing upon contact with hail, the latent heat elevates the surface temperature of the growing hailstone.

**mb** – millibar, a unit of pressure. Standard sea level pressure is 1013.25 mb. Upper atmosphere weather charts are routinely prepared for 1000 mb (roughly sea level),

850 mb (about 5,000 ft), 7000 mb (about 10,000 feet), 500 mb (about 18,000 ft), 300 mb (about 30,000 ft), 250 mb (about 35,000 ft), and 200 mb (about 40,000 ft).

**NCAR**– National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO, 80307-3000.

**NOAA**– National Oceanic and Atmospheric Administration, U.S. Department of Commerce. The parent organization of the U.S. National Weather Service, and the federal agency to which all U.S. weather modification activities must be reported.

**nowcasting**– very short-term forecasting, from the present to about 30 minutes.

**Polar coordinates** -- a coordinate system in which the direction is specified in degrees (from zero to 360), and a range provides the distance. For example, polar coordinates of 135° direction and 42.4 mi range specify a location 30 mi east and 30 mi south, or in the southeast.

**potassium chloride**– KCl, a simple salt often used as a primary ingredient in hygroscopic cloud seeding pyrotechnics.

**radiosonde** (or rawinsonde)– an instrument package that senses and transmits weather information such as pressure, temperature, and humidity. Radiosondes are carried aloft by weather balloons twice daily from numerous sites all over the world, and can also be employed by projects to bolster local forecasting efforts.

**raindrop**– a drop of water of diameter greater than 0.5 mm falling through the atmosphere. In careful usage, falling drops with diameters lying in the interval 0.2 to 0.5 mm a called drizzle drops rather than raindrops, though this is frequently overlooked.

**RDAS** – Radar Data Acquisition System. The hardware and software that acquires the radar data and passes it on to TITAN for further processing and display. RDAS also controls the radar itself.

**remote sensing**– the remote measurement of properties of interest, as with radar and satellite. Compare *in situ measurement.*

**response time**– the time that elapses from identification of a seeding opportunity until the release of seeding agent actually begins.

**seeding agents**– agents dispensed by any means in or near a cloud volume which are intended to modify (seed) the cloud characteristics.

**silver iodide**– AgI, a common glaciogenic seeding agent.

**sodium chloride**– NaCl, the chemical composition of common table salt. Because of its hygroscopic properties, historically, it was occasionally used for hygroscopic seeding. Hygroscopic seeding agents have more recently employed potassium chloride (KCl).

**supercell**– thunderstorms characterized by an intense, quasi-steady state mature updraft. Such storms account for a large fraction of all tornadoes, and much of the large hail.

**supercooled water**– water, still in liquid state, at temperatures less than 0°C (32°F). Under ideal conditions in the free atmosphere, water may exist in a supercooled state to temperatures as cold as -40°C (-40°F).

**target area**– the area for which cloud seeding operations are targeted, usually near a *control area* similar in character and climatology. The behavior of treated storms over the target area is compared to untreated storms over the control area, to assess differences and thus measure project effectiveness. See also, *control area*, *seeding area*, and *seeded area*.

**terminal velocity**– the particular falling speed, for any given object moving through a fluid of specified physical properties, at which the drag forces and buoyant forces exerted by the fluid on the object just equal the gravitational force acting on the object. For hydrometeors, the greatest fall speed relative to the surrounding air that a hydrometeor will attain, as determined by the mass of the particle and frictional drag of the air through which it is falling.

**thermal**– a relatively small-scale, rising current of air produced when the atmosphere is heated enough locally by the earth's surface to produce absolute instability in the lowest layers.

**TITAN**– Thunderstorm Identification, Tracking, Analysis, and Nowcasting. Software for the display and analysis of weather radar data, widely used in operational convective cloud seeding programs.

**UTC** – Universal Time Coordinates. See also *GMT*, *CUT*. Five hours ahead of Central Daylight Time; for example, 10:00 p.m. UTC (22:00) equals 5:00 p.m. (17:00) CDT.

**VIL**– vertically integrated liquid. A radar estimate of the cloud liquid water, from the lowest angle sampled through cloud top. Used as an indicator of the presence of hail, and also of updraft vigor.

**wing-tip generator**– ice nucleus generators mounted at the tips of aircraft wings, or sometimes below the wings, also usually near the ends.

**WMA**– Weather Modification Association, P.O. Box 26926, Fresno, CA 93729-6926.

**WMI**— Weather Modification, Inc., Fargo, North Dakota.

**WMO**– World Meteorological Organization, 7 bis, Avenue de la Paix, CH 1211 Geneva 2, Switzerland.

**WSR-74C** -- The 1974 vintage weather radars, built by Enterprise Electronics Corporation, deployed in the U.S. by the National Weather Service during the 1970's. These radars are often reconditioned and equipped with TITAN for use by television stations, universities, and weather modification programs.