

**WEATHER MODIFICATION
ACTIVITIES IN TEXAS,
1978-1982**



LP-190

TEXAS DEPARTMENT OF WATER RESOURCES

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IN TEXAS, 1978 - 1982**

By

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and Thomas J. Larkin

LP-190

Texas Department of Water Resources

December 1983

TEXAS DEPARTMENT OF WATER RESOURCES

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ABSTRACT

Seventeen commercial weather modification projects and one rather comprehensive research program were conducted in west and northwest Texas during the years 1978-1982. These projects are individually summarized in this report. The objective of all of these projects was to increase rainfall by seeding convective clouds with silver iodide. The silver iodide was dispensed into the clouds either by aircraft or ground-based generators. Yearly evaluations of the longest running cloud seeding project in Texas coupled with recent research findings suggest that the potential to increase rainfall by cloud seeding exists in West Texas.

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WEATHER MODIFICATION ACTIVITIES IN TEXAS, 1978-1982

RATIONALE

The Texas economy is diverse, viable, and growing. The State has a total land area of 693,233 km² (267,339 square miles) with a 1980 population of about 14.228 million people. The State's population is projected to grow to 17.8 million by 1990 and 20.9 million by the year 2000.

Approximately 17.9 million acre-feet of Texas water (one acre-foot is 1,235 m³ or 325,851 gallons) is used each year to meet the needs of households, manufacturing, irrigation, steam-electric power generation, mining and livestock. Nearly 73 percent of the total water available each year, or 12.9 million acre-feet, is used by farmers and ranchers for irrigation to produce food and fiber to meet the demands of both the State and the Nation. By the year 2000, it is projected that 22.3 million acre-feet of water will be needed to meet the demands of the State, assuming that agricultural water-use is held at about 13.0 million acre-feet.

Though the State's supply of freshwater is sufficient to meet current needs, the areal distribution of much of it does not coincide with the locations of Texas cities, industries, and agricultural land. In some regions of the State, if additional water sources are not made available, regional water shortages will seriously affect the economy, which is dependent upon adequate water. This scenario is clearly evident in the fertile but semi-arid Texas High Plains area where the Ogallala aquifer, the major source of municipal and irrigation water, is being exhausted. Currently, the Ogallala supplies irrigation water to 23,900 km² (5.9 million acres). However, at present consumption rates, it is estimated that by the year 2000 the Ogallala will supply irrigation water to only 9,000 km² (2.2 million acres). Aside from the fact that ground water is becoming more scarce, it is also becoming more expensive to obtain as the water table declines and energy costs to pump the water continue to rise.

In order to meet the water needs of the State, and specifically in the Texas High Plains, additional and cost effective freshwater supplies must be developed. One relatively new technique of providing additional freshwater is to augment precipitation by cloud seeding. The value of this additional water has been demonstrated by recent exploratory studies by the Texas Department of Water Resources (Allaway *et al.*, 1975; Lippke, 1976; and Kengla *et al.*, 1979) which reveal the net economic effects of weather modification activities in a 330,000 km² (81 million-acre) project area of the southern High Plains. Given a 10 percent increase in rainfall during the growing season, the studies indicate an overall expansion in regional output of approximately \$3.68 million and a similar expansion of regional income of \$2.30 million.

HISTORY

Deliberate attempts by man to change or control the weather in Texas generally were unregulated and undocumented prior to 1967. Literature contains records of only a few "rain-

making'' experiments, the earliest of which describes an experiment carried out on the Texas High Plains during the early 1890's. This particular endeavor consisted of war-time simulations of heavy artillery bombardment of surrounding hills in an attempt to determine if significant correlations existed between the artillery explosions and occurrences of rainfall.

This experiment was based on observations made by Edward Powers that, during the Civil War, rain would develop after most major battles. He later published a book (Powers, 1890) documenting his observations. To test Powers' hypothesis, Congress appropriated \$10,000, while an additional \$2,000 were allocated by the Department of Agriculture, to support an experiment in the Texas High Plains. The experiment, conducted by General R. G. Dyrenforth and a party of scientists and technicians armed with cannons and explosives, ended inconclusively after one season of testing.

Mr. Charles William Post, founder of Post cereals, was also active in weather modification experiments in Texas during the period between 1911 and 1914 (Eaves, 1952). Because of ill health Mr. Post moved from Battle Creek, Michigan, to Texas in 1906, and purchased a quarter-million-acre ranch in Garza and Lynn counties on the Texas High Plains. His penchant for experimentation, coupled with his desire to grow grain in the semi-arid West Texas climate, led to the most spectacular of his experiments. Based on the Powers' hypotheses Post attempted to cause rain by dynamite blasts. Fifteen firing stations were established along the edge of the Cap Rock above Post, Texas, and from each station four pounds of dynamite were exploded every four minutes over a period of several hours or until rain occurred. Altogether he spent over \$50,000 on rain making experiments. The results of his experimentation, which spanned four years, were inconclusive.

For several decades subsequent to the Post experiment, no other weather modification projects in Texas were documented in the literature. However, in the mid-1940's, shortly after Vincent Schaefer demonstrated the effect dry ice had on super-cooled water droplets and, subsequently, on clouds, weather modification operations in Texas resumed (Hearings before the Committee on Commerce, U.S. Senate, 89th Congress, 1966). Since the number of commercial weather modification projects in Texas increased markedly beginning in the 1950's, it soon became necessary for the State of Texas to adopt a weather modification statute, not only to properly administer commercial cloud-seeding projects, but also to encourage research and development. Consequently, in 1967, the Texas Weather Modification Act, which charged the Texas Water Development Board to license and permit weather modification activities and to promote research and development in weather modification technology, was adopted.

STATUTORY RESPONSIBILITY

The State of Texas joined a number of other states which enacted weather modification legislation during the 1960's with enactment in 1967 of the present Texas Weather Modification Act. Later the Act was codified as Chapter 18 of the Texas Water Code, and it is the current State authority for regulating weather modification activities in Texas. Under provisions of this Act, the Texas Department of Water Resources was charged with the administration of the Act. In carrying out its statutory responsibilities, the Department established an advisory committee and formulated standards and instructions which were necessary to carry out weather modification research programs by cooperative agreements and contracts with public and private organizations.

An outstanding feature of the authority given the Department by the Act relates to a weather modification license and permit system. The Act requires that potential weather modifiers first obtain a license and a permit before beginning a project. A license is granted solely on the basis of the knowledge and ability of the applicant. A permit can be granted only to an applicant who holds a license. A separate permit must be obtained, however, for each separate project contemplated by a licensee. Permits are granted to a licensee based on the merits of the proposed project.

Although the Act does not specify the procedures for obtaining licenses and permits, it does authorize the Department to make regulations which establish procedures and conditions for their issuance. These regulations and procedures were developed shortly after the Act became law and have been amended from time to time. The revised rules, regulations and modes of procedure relating to the Texas Weather Modification Act, which were issued by the Texas Department of Water Resources on September 1, 1977, are currently in force. The conditions under which a license may be issued to an applicant are that the applicant:

- (1) submit a properly completed application;
- (2) pay the license fee; and
- (3) demonstrate competence in the field of meteorology which is reasonably necessary to engage in weather modification and control activities.

If, however, the applicant is an organization, competence must be demonstrated by the individual or individuals who are to be in control and in charge of operations for the applicant. The Department considers the competency of the individuals engaged in the operations to be of great significance. All of the powers authorized by the Act are exercised to ensure that only well qualified weather modifiers are granted a license.

The Act is rather inflexible regarding the issuance of permits to applicants. The best interests of the public are always dominant; statutorily, however, an applicant need meet only six conditions before being granted a permit. The applicant is required to:

- (1) hold a valid weather modification license;
- (2) submit a properly executed application;
- (3) pay the permit fee;
- (4) furnish proof of financial responsibility;
- (5) publish a notice of intent and submit proof of publication as required by the Act; and,
- (6) if the operation is to be conducted under contract, state the term of the contract.

(Anyone desiring to obtain a Texas weather modification license or permit is advised to secure from the Department a copy of the official rules, regulations and modes of procedure relative to Chapter 18 of the Texas Water Code, which are briefly described above.)

SUMMARY

The following is a numerical summary of the various types of weather modification projects conducted in Texas during the period 1978-82:

	Number of Projects				
	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>	<u>1982</u>
Operational cloud-seeding programs					
Rainfall enhancement	5	3	3	3	3
Precipitation management research programs	1	1	1	1	1

The Colorado River Municipal Water District conducted a cloud-seeding program during the period 1978-82 to increase rainfall and subsequent runoff into Lakes J. B. Thomas and E. V. Spence. The District's operational project utilized aircraft with silver iodide dispensing flare racks affixed to the aircraft's wings to deliver the seeding material directly into the clouds at cloud-base level.¹ Weather radar was used to select seedable clouds, direct aircraft and monitor seeding effects.

Irving P. Krick, Inc. of Texas used ground-based silver iodide generators with the intent of increasing rainfall over a number of target regions. During the period, Krick's programs consisted of the operation of generators located in Texas near the Oklahoma border intending to increase rainfall in several target areas in Oklahoma. Also, Krick, Inc. operations included two programs intended to increase rainfall over target areas within the State of Texas.

Programs of research and development in weather modification technology also were important during the period 1978-82. In cooperation with the U.S. Department of the Interior, Bureau of Reclamation, the Texas Department of Water Resources participated in a comprehensive research program, known as the High Plains Cooperative Program (HIPLEX), to develop a capability for producing additional rain from summertime convective clouds in the State's High Plains region.

CONCLUSIONS

The purposes of this report are to present a brief description of weather modification activities that occurred in Texas during the 1978-1982 period, to report how some individual weather modification operators view the success of their projects, and to report preliminary results of weather modification to augment West Texas water supplies based on the findings of the Texas High Plains Cooperative Program (HIPLEX).

¹ Amounts of silver iodide tabulated in this report are expressed in grams; to convert to pounds, multiply by 0.0022.

In general, the results of the Texas HIPLEX Program (Riggio *et al.*, 1982) suggest that the potential exists for significant increases in rainfall when convective clouds are seeded in appropriate ways for particular atmospheric conditions. The Texas HIPLEX Program has concluded that of the five major types of convective clouds observed in West Texas (which includes lines, cold clusters, warm clusters, cold cells and warm cells) small cold clusters appear to offer the greatest seeding potential for increasing rainfall. Also, seeding with relatively large quantities of silver iodide would have the greatest impact on cold clusters, and surrounding cloud systems, in terms of increasing rainfall significantly.

The results of the Texas HIPLEX Program agree with the cloud seeding approach of the Colorado River Municipal Water District (CRMWD). The CRMWD cloud seeding approach has been to seed cluster-type convective clouds with relatively large quantities of silver iodide.

Annual evaluations by the CRMWD of their cloud seeding projects indicate that for the 1978-1982 period more rainfall was recorded in the seeded area than the nonseeded area. For example, during the 1979 cloud seeding project the rainfall recorded in the target area was 26 percent greater than the rainfall recorded in the nonseeded area (Girdzus, 1979), and during the 1980 cloud seeding project the rainfall recorded in the target area was 28 percent greater than in the nonseeded area (Girdzus, 1980).

The CRMWD reported that cotton yield departures from normal (expressed in lbs/acre) for the seeded years showed that in the seeded counties, cotton yields were increased, while cotton yield increases in the downwind counties were less, and appreciably less in the upwind counties. For example, the average cotton yield departure from normal, as measured by lbs/acre, for the seeded counties for the period 1971-79 is 63 percent above normal, only 10 percent above normal for the upwind counties, and 56 percent above normal for the downwind counties (Girdzus, 1980).

Because of the large variability of natural weather phenomena, strict statistical procedures need to be followed and supported by technical cloud and atmosphere information before firm conclusions can be reached regarding the success or failure of any weather modification program. To some degree much of the technical information gathered from the Texas HIPLEX Program was utilized successfully in the CRMWD projects. Unfortunately, the CRMWD evaluation lacks the degree of statistical rigor to achieve acceptance of the scientific community and the evaluation results cannot be considered conclusive. Nevertheless, the CRMWD evaluation results and the Texas HIPLEX findings do corroborate each other and, therefore, suggest that indeed it may be possible to increase rainfall from West Texas convective clouds and that weather modification may be a viable means of increasing West Texas water supplies.

The following sections of this report describe those activities which were conducted during the period 1978-82 under the cited licenses and permits. A description of those activities which occurred in years prior to 1978 is contained in previous reports; Texas Water Development Board Report 175 describes weather modification activities for the period 1970-72, Report 187 covers activities for 1973 and Report 219 addresses activities for the period 1974-1977. Table 1 lists the projects for which Texas weather modification licenses and permits were issued for the period 1978-82.

**Table 1.—Weather Modification Programs
for which Licenses and Permits were Issued,
1978-82**

Project numbers	Licensed operators	Sponsor	Target area	Objective
Calendar Year 1978				
78-1-1	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	All of Borden and Mitchell Counties and portions of Dawson, Scurry, Howard, Martin, Nolan, Glasscock, Sterling, and Coke Counties	Rainfall Augmentation
78-2-1	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Red Bluff Water Power Control District 111 W. Second Street Pecos, Texas 79772	Portions of Culberson and Reeves Counties	Rainfall Augmentation
78-2-2	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Weather Modification, Inc. Box 604 Throckmorton, Texas 76083	All of Throckmorton, Shackelford, Young, and Stephens Counties	Rainfall Augmentation
78-2-3	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Cotton County Services, Inc. Randlett, Oklahoma 73562	No target area in Texas. Oklahoma target area: Cotton County	Rainfall Augmentation
78-2-4	Irving P. Krick, Inc. of Texas 611 S. Palm Canyon Drive Suite 216 Palm Springs, California 92262	Henry C. Hitch Ranch, Inc. Guymon, Oklahoma 73942	No target area in Texas. Oklahoma target area: a portion of Texas County	Rainfall Augmentation
Calendar Year 1979				
79-1-1	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	All of Borden and Mitchell Counties and portions of Dawson, Scurry, Howard, Martin, Nolan, Glasscock, Sterling, and Coke Counties	Rainfall Augmentation

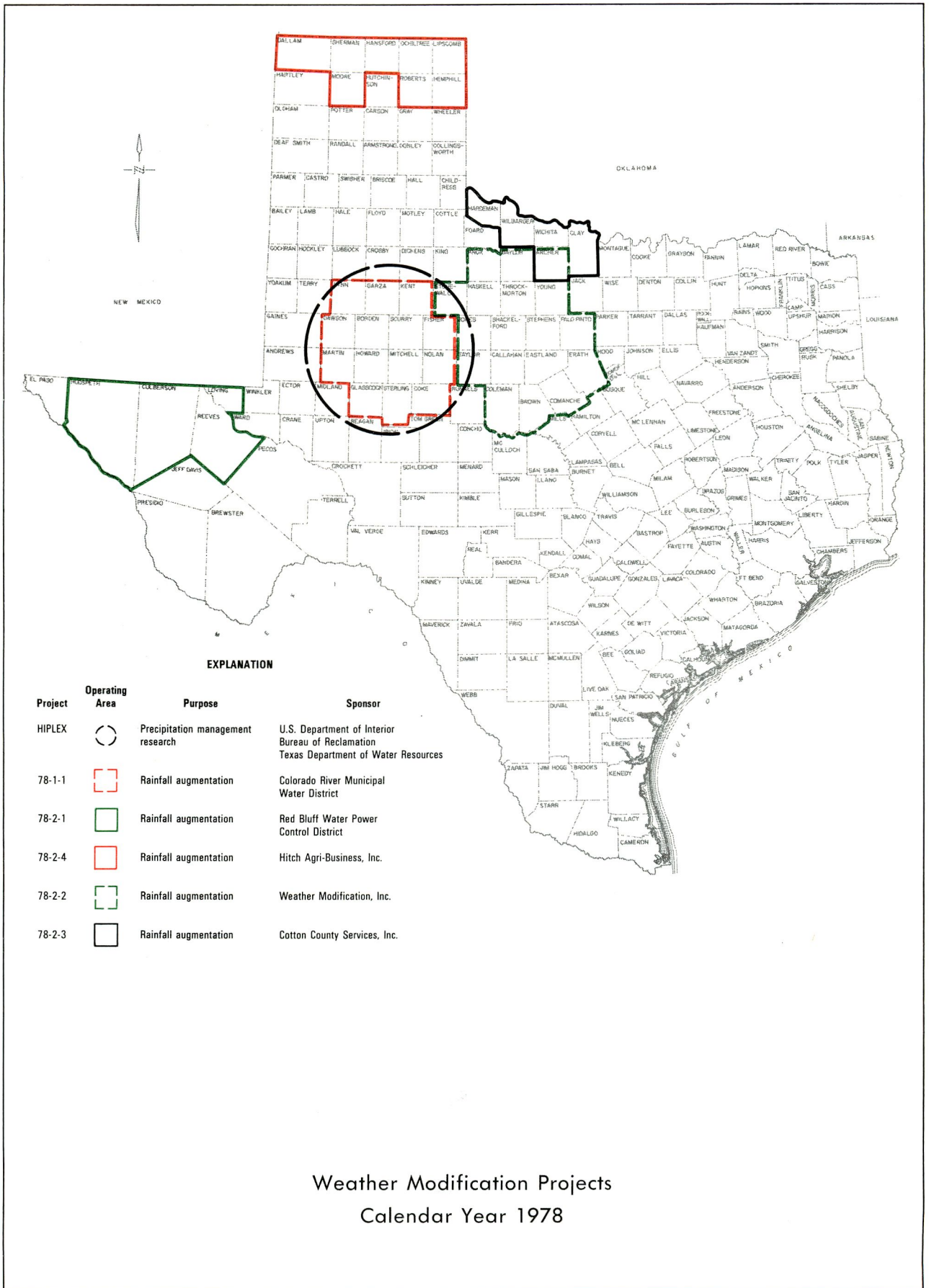
**Table 1.—Weather Modification Programs
for which Licenses and Permits were Issued,
1978-82—Continued**

Project numbers	Licensed operators	Sponsor	Target area	Objective
79-2-1	Irving P. Krick, Inc. of Texas 748 Vella Road Palm Springs, California 92264	Red Bluff Water Power Control District 111 W. Second Street Pecos, Texas 79772	Portions of Culberson and Reeves Counties	Rainfall Augmentation
79-2-4	Irving P. Krick, Inc. of Texas 748 Vella Road Palm Springs, California 92264	Hitch Agri-Business, Inc. Guymon, Oklahoma 73942	No target area in Texas. Oklahoma target area: a portion of Texas County	Rainfall Augmentation
Calendar Year 1980				
80-1-1	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	All of Borden and Mitchell Counties and portions of Dawson, Scurry, Howard, Martin, Nolan, Glasscock, Sterling, and Coke Counties	Rainfall Augmentation
80-2-1	Irving P. Krick, Inc. of Texas 748 Vella Road Palm Springs, California 92264	Red Bluff Water Power Control District 111 W. Second Street Pecos, Texas 79772	Portions of Culberson and Reeves Counties	Rainfall Augmentation
80-2-4	Irving P. Krick, Inc. of Texas 748 Vella Road Palm Springs, California 92264	Hitch Agri-Business, Inc. Guymon, Oklahoma 73942	No target area in Texas. Oklahoma target area: a portion of Texas County	Rainfall Augmentation
Calendar Year 1981				
81-1-1	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	All of Borden and Mitchell Counties and portions of Dawson, Scurry, Howard, Martin, Nolan, Glasscock, Sterling, and Coke Counties	Rainfall Augmentation

**Table 1.—Weather Modification Programs
for which Licenses and Permits were Issued,
1978-82—Continued**

<u>Project numbers</u>	<u>Licensed operators</u>	<u>Sponsor</u>	<u>Target area</u>	<u>Objective</u>
81-2-3	Irving P. Krick, Inc. of Texas 748 Vella Road Palm Springs, California 92264	Cotton County Services, Inc. Randlett, Oklahoma 73562 Comanche County Weather Modification Inc. Lawton, Oklahoma 73510	No target area in Texas. Oklahoma target area: Cotton, Tillman and Comanche Counties.	Rainfall Augmentation
81-2-4	Irving P. Krick, Inc. of Texas 748 Vella Road Palm Springs, California 92264	Hitch Agri-Business, Inc. Guymon, Oklahoma 73942	No target area in Texas. Oklahoma target area: a portion of Texas County.	Rainfall Augmentation
Calendar Year 1982				
82-1-1	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	Colorado River Municipal Water District Post Office Box 869 Big Spring, Texas 79720	All of Borden and Mitchell Counties and portions of Dawson, Scurry, Howard, Martin, Nolan, Glasscock, Sterling, and Coke Counties	Rainfall Augmentation
82-2-3	Irving P. Krick, Inc. of Texas 748 Vella Road Palm Springs, California 92264	Cotton County Services, Inc. Randlett, Oklahoma 73562 Comanche County Weather Modification, Inc. Lawton, Oklahoma 73510	No target area in Texas. Oklahoma target area: Cotton, Tillman and Comanche Counties.	Rainfall Augmentation
82-2-4	Irving P. Krick, Inc. of Texas 748 Vella Road Palm Springs, California 92264	Hitch Agri-Business, Inc. Guymon, Oklahoma 73942	No target area in Texas. Oklahoma target area: a portion of Texas County.	Rainfall Augmentation

**Weather Modification Projects
Calendar Year 1978**



EXPLANATION

Project	Operating Area	Purpose	Sponsor
HIPLEX		Precipitation management research	U.S. Department of Interior Bureau of Reclamation Texas Department of Water Resources
78-1-1		Rainfall augmentation	Colorado River Municipal Water District
78-2-1		Rainfall augmentation	Red Bluff Water Power Control District
78-2-4		Rainfall augmentation	Hitch Agri-Business, Inc.
78-2-2		Rainfall augmentation	Weather Modification, Inc.
78-2-3		Rainfall augmentation	Cotton County Services, Inc.

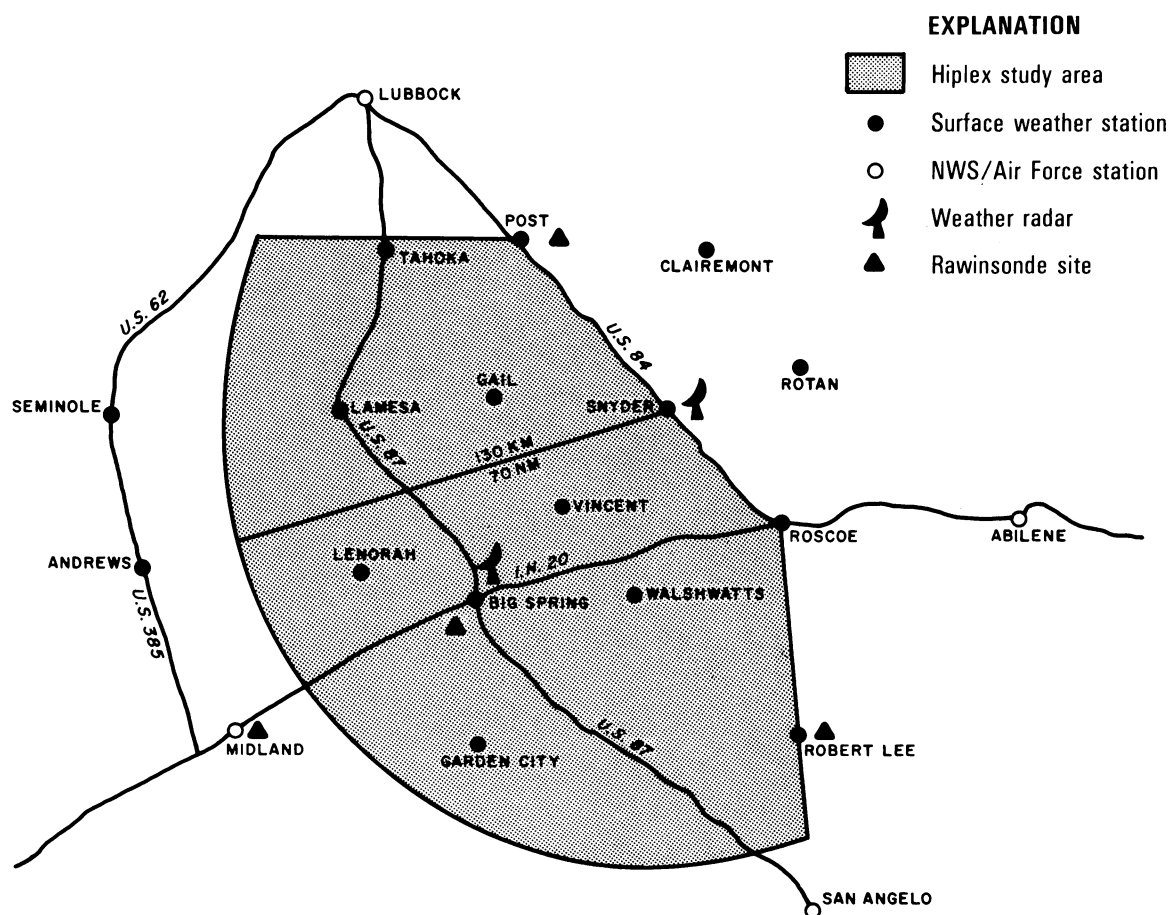
**Weather Modification Projects
Calendar Year 1978**

The 1978 Texas HIPLEX Program

The 1978 Texas High Plains Cooperative Program (HIPLEX) represents the fourth consecutive year of the Bureau of Reclamation and Department of Water Resources cooperative weather modification research program. The HIPLEX goal has been to establish a working technology to produce additional rainfall on the ground by seeding convective clouds in the semi-arid Plains States. The HIPLEX design to accomplish that goal consists of three dependent phases—the exploratory phase, the experimental phase and the technology transfer phase. The 1978 Texas HIPLEX Program was exploratory. Its objective was to collect meteorological information with which to better understand the physical atmospheric and precipitation processes associated with West Texas convective clouds and to use this information to develop a design document for the experimental phase of the Program.

The cooperative work and studies of a number of groups made up the 1978 Texas HIPLEX Program. The principal participating groups were:

Bureau of Reclamation
 Texas Department of Water Resources
 Colorado River Municipal Water District
 Texas A&M University (Department of Meteorology)
 Texas Tech University (Atmospheric Science Group)
 Meteorology Research, Inc.



The 1978 Texas HIPLEX Field Program

Their efforts included setting up and conducting field operations, and meteorological data collection, processing, analyses and interpretation. This is a summary of the work performed in 1978 by the aforementioned groups to help achieve the objective of the 1978 exploratory phase of the Texas HIPLEX Program.

The following table summarizes the 1978 Texas HIPLEX field operations. This table identifies mesoscale days, HIPLEX operational days, cloud sampling days, and nonoperational days. A mesoscale day was defined when upper-air weather measurements were made using the Texas HIPLEX rawinsonde network.

**Summary of 1978 Texas HIPLEX Field Operations for June and July
(with the Number of cloud-seeding missions given in parentheses)**

Date	Mesoscale Day		Hiplex Operational Day			
	Yes	No	Seeding Performed	No-seeding Performed	Sampling only	No
June 1	x			x		
2	x				x	
3		x				x
4	x			x		
5	x		(3)			
6	x		(1)			
7	x		(1)			
8		x				x
9		x				x
10		x				x
11		x				x
12		x				x
13	x		(3)			
14	x					x
15		x				x
16		x				x
17		x				x
18		x				x
19		x				x
20		x				x
21		x				x
22		x				x
23		x				x
24		x				x
25		x				x
26		x				x
27	x					x
28	x				x	
29	x				x	
30	x		(1)			

**Summary of 1978 Texas HIPLEX Field Operations for June and July—Continued
(with the Number of cloud-seeding missions given in parentheses)**

Month/Day	Mesoscale Day		Hiplex Operational Day			
	Yes	No	Seeding Performed	No-seeding Performed	Sampling only	No
July 1	x		(1)			
2		x			x	
3		x	(3)			
4		x				x
5		x				x
6		x				x
7		x				x
8		x				x
9		x				x
10		x				x
11		x				x
12		x				x
13		x				x
14		x				x
15		x			x	
16		x				x
17	x			x		
18		x				x
19		x				x
20		x	(1)			
21	x				x	
22	x					
23	x		(1)			
24	x				x	
25	x					
26		x	(1)			
27		x				x
28		x				x
29		x				x
30		x				x
31		x				x

Texas Department of Water Resources

During the previous three Texas HIPLEX field projects (1975-1977) the Department-operated Meteorological Facility was located at Howard County Airport northeast of Big Spring. Early in 1978 the Facility and the Texas HIPLEX Base of Operations were relocated to the Base Operations Building at the vacated Webb Air Force Base just southwest of Big Spring. The new facilities provided the Texas HIPLEX Program with additional room, to perform daily operations, and much improved aircraft support capabilities.

The 1978 Texas HIPLEX field project was conducted during the period June 1 through July 31. Department staff meteorologists served as Project Manager and on-site meteorologist. The responsibilities of the Project Manager included making decisions regarding deployment of aircraft, the type of mission to be flown and the overall direction of the field program. The on-site

Department staff meteorologist was responsible for the issuance of: 12- and 24-hour terminal forecasts, analyses of morning and afternoon local surface charts, collection and storage of daily climatological data, and the development and refinement of a local forecast decision tree.

At Department headquarters in Austin, staff meteorologists developed an objective rain-shower prediction numerical model and catalogued severe weather warnings to ascertain the frequency with which Texas HIPLEX field operations might have to be curtailed due to the presence of severe weather. Department economists completed the third part of a study concerning the impact of a rain-increase technology on the regional economy. Part three addressed the effects of rainfall on the level of municipal and industrial water supplies and water use patterns in the Texas HIPLEX study region.

Colorado River Municipal Water District

The Colorado River Municipal Water District, which is headquartered in Big Spring and conducts its own operational rain increase program, provided technical support to the 1978 Texas HIPLEX field project. Working under contract with the Department, the District operated and maintained an extensive raingage network consisting of 81 recording raingages and 81 fence post nonrecording raingages. The District provided the services of a radar meteorologist who was responsible for the maintenance and operation of the FPS-77 weather radar located at the Texas HIPLEX field Base of Operations at the vacated Webb Air Force Base. The radar was primarily used to assist aircraft crews in determining daily flight operation areas, in locating prime areas of cloud development and in monitoring routine weather systems.

The District provided a trained technician to operate an RD-65 rawinsonde unit for measuring and recording weather information at different levels of the atmosphere over Big Spring. This unit was part of a four unit network operated by Texas A&M University to collect and analyze environmental data.

In addition to these services the District contracted to the 1978 Texas HIPLEX field project two multi-engine aircraft for the purpose of cloud seeding and sampling. A Piper Aztec aircraft was used during the field project to collect cloud base meteorological information and to seed clouds in the inflow regions at cloud base. A Piper Pressurized Navajo was used to acquire cloud micro-physics measurements at higher levels in the cloud. In total both aircraft flew a total of 27 missions during the two month summer field project.

Texas A&M University

The Department of Meteorology at Texas A&M University was under contract with the Department of Water Resources to study the interrelationships between convective cloud development and maintenance, and the state of the environment surrounding the cloud. To accomplish this task comprehensive networks of surface and upper-air weather measuring stations were used to collect vital environmental information during the 1978 Texas HIPLEX field project.

Surface data were collected from a network of 16 weather stations. Measurements at each station consisted of temperature, relative humidity, pressure, and wind speed and direction. These data were automatically measured and recorded hourly. Upper-air measurements were

made at four stations within the Texas HIPLEX project area. These data consisted of temperature, relative humidity, pressure and wind speed and direction. Upper-air measurements were made every three hours beginning at 1000 CDT and ending normally at 2200 CDT on days which the Project Director declared to be operational.

The analyses performed by Texas A&M University were to evaluate cloud development, cloud growth rates and other cloud characteristics observed by radar relative to the environment. The atmospheric moisture budget was studied in depth to establish the energy source of convective activity and to determine the conditions which lead to a cutoff of the moisture source and hence to the dissipation of convective activity.

Texas Tech University

The Department of Geosciences at Texas Tech University contributed to the analytical phase of the 1978 Texas HIPLEX program by using satellite visible and infrared radiance data to produce detailed information on the formation, development and propagation of convective cloud systems in the Texas HIPLEX region. Satellite data were provided by the Geostationary Operational Environmental Satellite (GOES) at one-half hour intervals.

Texas Tech University scientists were also involved in developing rain-cell climatologies based on rainfall measurements gathered from the 1977 and 1978 recording raingage network. Rainfall data were analyzed to describe "natural" rainfall variability. It is important to understand and account for the natural rainfall variability in the Texas HIPLEX area to detect better any man-made rainfall increases. It is also important to document the amounts of rainfall measured on the ground from each of the different types of convective cloud systems. This information helps to identify which type of system would be the most feasible to study from an operational perspective.

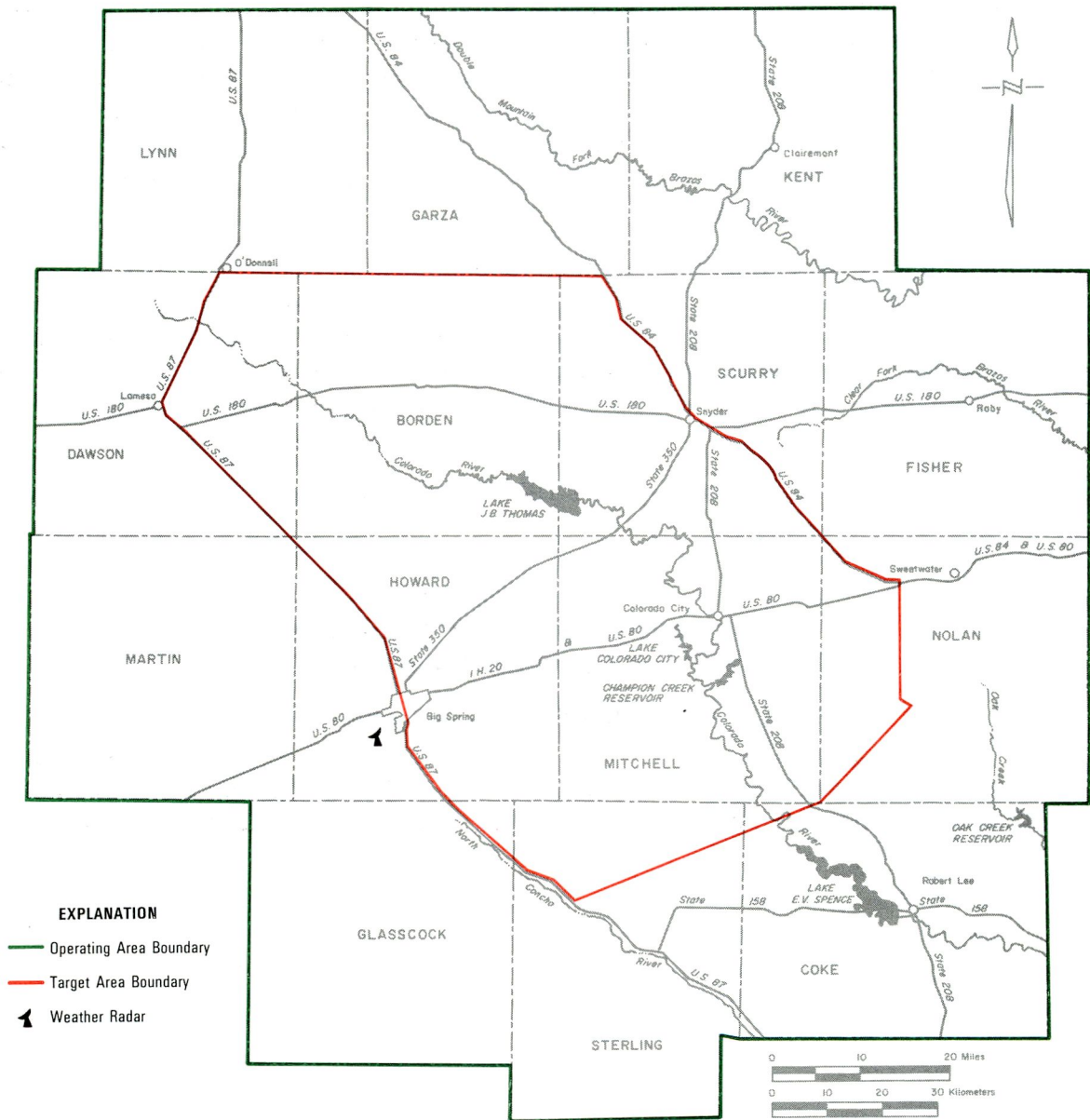
Meteorology Research, Inc.

The Department of Water Resources contracted with Meteorology Research, Inc. to operate and maintain an M-33 weather radar system located at Snyder, Texas and to collect, process and analyze radar data measured by the radar. The analyses of the radar data were oriented toward the study of small-scale rainshower patterns and their relationships with atmospheric conditions through development and interpretation of radar echo climatologies and in-depth studies of selected cases.

Meteorology Research, Inc. was also responsible for the maintenance and operation of a Piper Navajo cloud physics measuring aircraft and for the processing and analyses of the cloud physics data collected by the aircraft. The data collected included cloud ice crystal concentrations, liquid water content, air and dewpoint temperature, condensation and ice nuclei, and aircraft flight information. Analyses of the cloud physics data were directed at determining the primary precipitation mechanism of West Texas shower-producing convective cloud systems. Understanding the microphysical processes involved in forming rain leads the researcher toward identifying the most appropriate seeding hypotheses and methods which need to be employed in the experimental phase.

Project 78-1-1. Colorado River Municipal Water District Rainfall-Augmentation Program

The 1978 Colorado River Municipal Water District operational cloud seeding program began on March 1 and continued through September 30. Except during the period May 15 through August 15, when cloud seeding activities were performed under the direction of the Texas HIPLEX field project, all cloud seeding was performed expressly for District purposes. The purpose of the District's program was to increase surface runoff into Lakes J. B. Thomas and E. V. Spence watersheds. The operational cloud seeding activities were financed and conducted solely by the District. The program area consisted of a 14-county region in the northernmost reaches of the Colorado River Basin.



**The 1978 Colorado River Municipal Water District Weather
Modification Project Area**

The District's operational cloud seeding program utilized radar directed aircraft seeding techniques exclusively. Seeding was performed primarily at cloud base using silver iodide impregnated flares mounted on the wings of a Piper Aztec aircraft. The Aztec was capable of carrying 24 flares, with each flare containing 20 grams of silver iodide. With the assistance of a radar meteorologist, the pilot of the seeding aircraft would locate the target cloud's updraft region at cloud base and dispense the silver iodide directly into the updraft. The updraft would carry the nucleating material up into the cloud to levels below the freezing temperature where it could help initiate the rain-making process of the cloud. The amount and rate of output of the silver iodide was determined by the radar meteorologist based on updraft and radar echo characteristics. The number of flares ignited by the pilot would establish the silver iodide amount and rate for a particular cloud.

In 1978 the District acquired a Piper P-Navajo aircraft which provided for much improved cloud seeding capabilities when compared to the Aztec aircraft. The P-Navajo aircraft was able to climb and travel between clouds at greater speeds, remain on station longer and fly at higher altitudes. The latter capability provided the District with the opportunity to seed clouds from on top of the target cloud where the pilot could observe visually the growing turreted and inject silver iodide directly into the area of the cloud where the nucleating material would do the most good simply by flying directly into the region. This technique was also used in the Texas HIPLEX field project and was found to be highly successful.

Both seeding techniques required a weather radar and the services of a trained meteorologist to interpret the radar echoes. The District employed a full-time meteorologist and obtained the use of an FPS-77 weather radar system which was on loan to the City of Big Spring following the close of Webb AFB. The radar echo displays provided the meteorologist with cloud top height, intensity, movement and location information which was passed on to the seeding aircraft pilot during operations.

An operational summary of the District's 1978 weather modification program is provided in the following table.

**Project 78-1-1
Colorado River Municipal Water District
1978 Operational Summary**

Period of Flight Operations: April-September 1978

Month	Number of operational days	Observation flights		Seeding flights		Amount of silver iodide (grams)
		Number	Hours flown	Number	Hours flown	
Mar.	0	0	0	0	0	0
Apr.	2	0	.0	2	4.9	700
May	10	3	3.9	10	14.4	1,700
June	6	5	6.3	6	14.6	2,020
July	9	14	31.9	5	9.0	4,520
Aug.	6	1	.7	5	7.3	1,420
Sept.	2	1	1.3	1	2.4	80
Total	35	24	44.1	29	52.6	10,440

Project 78-2-1. Trans-Pecos Precipitation- Augmentation Program

In 1978 the firm of Irving P. Krick, Inc. of Texas was contracted by the Red Bluff Water Power Control District of Pecos, Texas to seed clouds to increase runoff into the Red Bluff reservoir. The 1978 program represents the third consecutive year of cloud seeding operations for the District.

Fourteen ground-based silver iodide dispensing generators were utilized in the program. The generators were located at various sites in Hudspeth, Culberson, Reeves and Loving Counties. The arc-type generators had a silver iodide output of approximately two grams per hour of operation. Silver iodide crystals were dispensed into the atmospheric air currents by vaporizing silver iodide impregnated electrodes with a high temperature electric arc. The microscopic silver iodide crystals were carried aloft to levels colder than freezing where, given the proper atmospheric conditions, the crystals served as ice nuclei to initiate the precipitation process.

The proper atmospheric conditions were determined by staff meteorologists located at the Krick home office in Palm Springs, California where surface and upper level weather parameters were monitored continuously. Given the particular weather conditions for each day, the meteorologists-in-charge would determine the appropriate generators to operate and for what period of time. These instructions were then telephoned to the cooperative generator operators in the field.

The Red Bluff weather modification project operated for 12 months beginning on January 1. The project was suspended from August 10 to September 5 as a result of a fire at the Krick Operations Center. The project was suspended a second time from September 21 to November 8 due to expected heavy rains and flooding in parts of southwest Texas.

An operational summary of the 1978 Trans-Pecos program is given in the following table.

Project 78-2-1 Trans-Pecos Precipitation-Augmentation Program 1978 Operational Summary

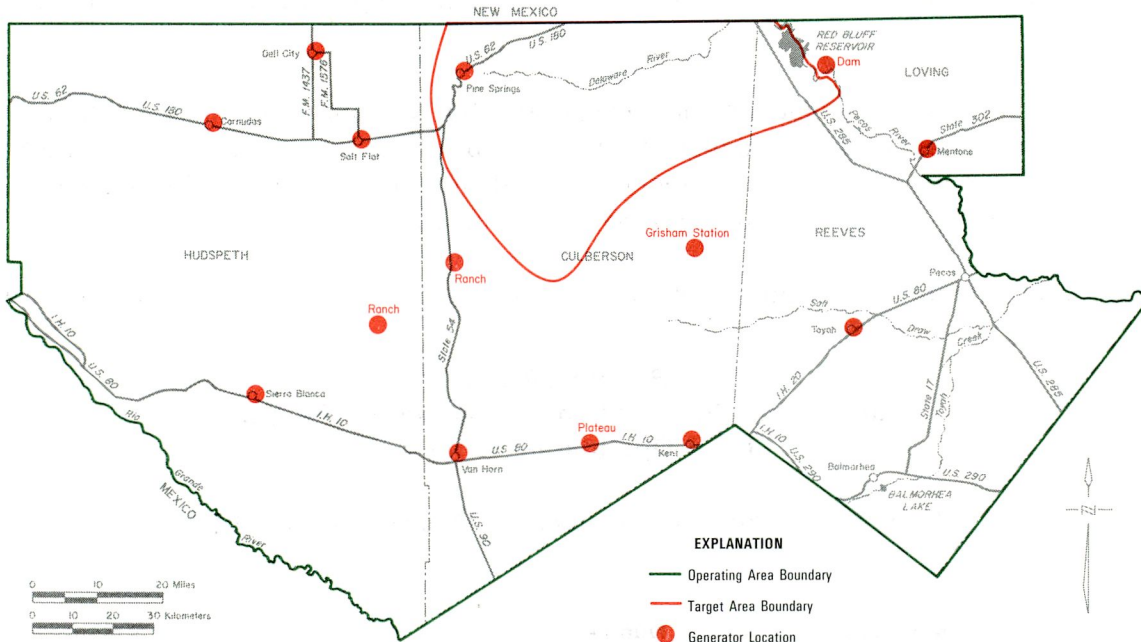
Period of Operation: January 1 - December 31, 1978

Month	Number of operational days	Number of generators in operation	Generator hours	Amount of silver iodide (grams)
Jan.	16	12	341.5	683.0
Feb.	13	8	236.5	473.0
Mar.	11	8	249.0	498.0
Apr.	9	8	192.0	384.0
May	15	11	326.5	636.5
June	19	11	334.0	668.0
July	20	10	283.0	566.0

**Project 78-2-1
Trans-Pecos Precipitation-Augmentation Program
1978 Operational Summary—Continued**

Period of Operation: January 1 - December 31, 1978

Month	Number of operational days	Number of generators in operation	Generator hours	Amount of silver iodide (grams)
Aug.	4	4	36.0	72.0
Sept.	9	4	128.0	256.0
Oct.	0	0	0.0	0.0
Nov.	8	7	131.0	262.0
Dec.	4	4	55.0	110.0
Total	128	87	2,312.5	4,608.5



The 1978 Weather Modification Project Area Operated by Irving P. Krick, Inc. of Texas in the Trans-Pecos

As in Krick's previous years' projects, a network of ground-based silver iodide generators were used to dispense the precipitation nucleating agent into the atmosphere. The generator network consisted of 21 arc-type generators with the capability of dispensing one-half gram of silver iodide per hour per generator or two grams of silver iodide per hour per generator.

Atmospheric conditions were monitored by trained meteorologists of the Krick firm. When atmospheric conditions appeared favorable, the meteorologist in charge would determine the appropriate generators to operate and for what period of time. These instructions were telephoned to the individual generator operators for implementation.

The 1978 operations began on March 1 and the program remained in effect until August 3 when it was terminated due to expected heavy rains and flooding from the remnants of tropical storm Amelia. No further operations were conducted during the remainder of the season.

An operational summary of this program is contained in the following table.

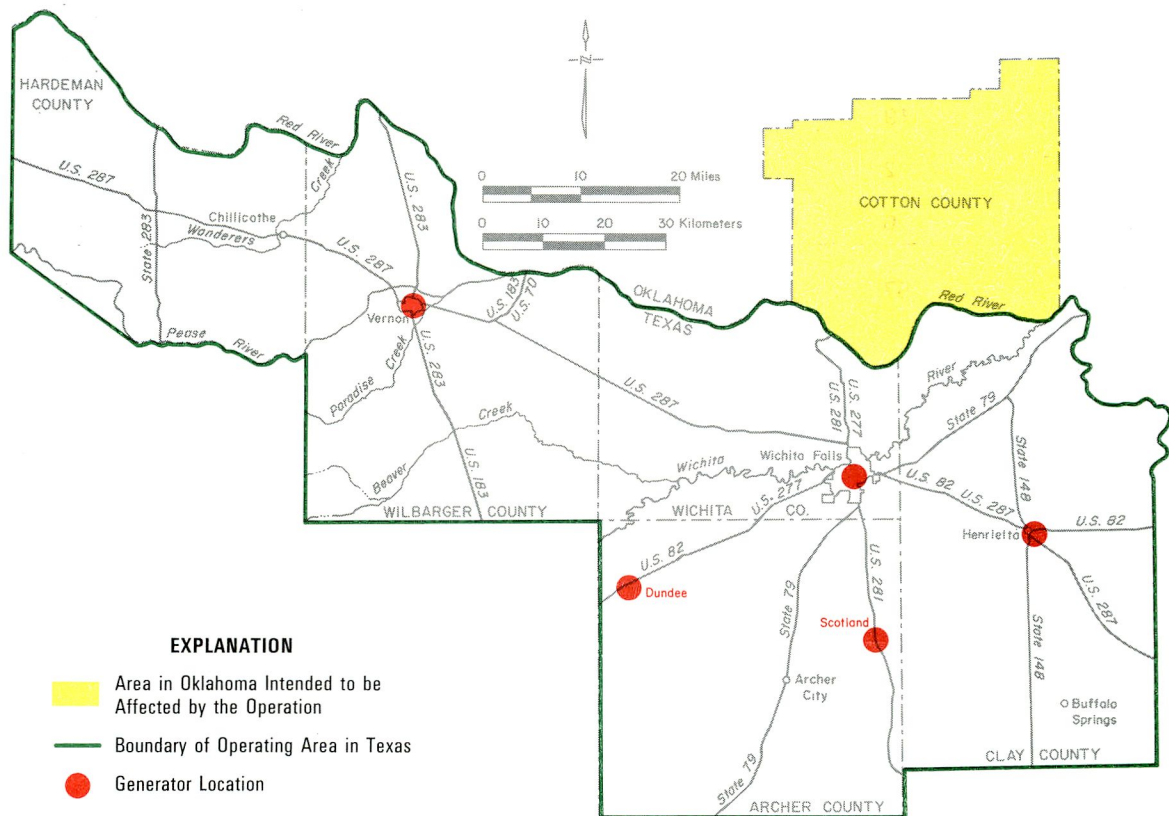
**Project 78-2-2
West-Central Texas Rainfall-Augmentation
1978 Operational Summary**

Period of Operation: March 1 - August 3, 1978

Month	Number of operational days	Number of generators in operation	Generator hours	Amount of silver iodide (grams)
Mar.	13	12	321.0	488.0
Apr.	11	12	459.0	720.0
May	11	21	1,161.5	1,713.0
June	14	14	554.0	689.0
July	13	14	508.0	543.5
Aug.	3	6	100.5	144.0
Total	65	79	3,104.0	4,297.5

Project 78-2-3. Oklahoma Precipitation-Augmentation Program (Red River Valley)

Irving P. Krick, Inc. of Texas continued for the seventh consecutive year to provide supplemental rainfall to the farmers and ranchers of Cotton County, Oklahoma on behalf of Cotton County Services, Inc. The area of intended effects was located in southwestern Oklahoma and bordered on the Texas-Oklahoma state line. Because of the target area's proximity to Texas, it was necessary to locate four ground-based generators in the Texas Counties of Archer, Clay, Wilbarger and Wichita. The four Texas generator sites were selected on the basis of expected trajectories of moisture laden windflow patterns to the target area located in Oklahoma. The Texas-located generators were only operated when the intended effects of the nucleating material were to occur in Oklahoma. No Texas cloud systems were to be affected.



The 1978 Weather Modification Project Area Operated by Irving P. Krick, Inc. of Texas in the Red River Valley

Operation of the generators was at the discretion of the Project Meteorologist who observed and monitored the weather from the Krick Weather Center in Palm Springs, California. Operations were dependent on weather conditions.

The Texas generators were activated by local residents under the guidance of a Krick, Inc. project meteorologist. The electric-arc type generators used in the Krick program dispensed silver iodide at a rate of two grams per hour per generator.

The 1978 Red River Valley project began on February 10 and was suspended on July 31 for the remainder of the season. An operational summary is given in the following table.

**Project 78-2-3
Oklahoma Precipitation-Augmentation Program
(Red River Valley)
1978 Operational Summary
Period of Operation: February 10 - July 31, 1978**

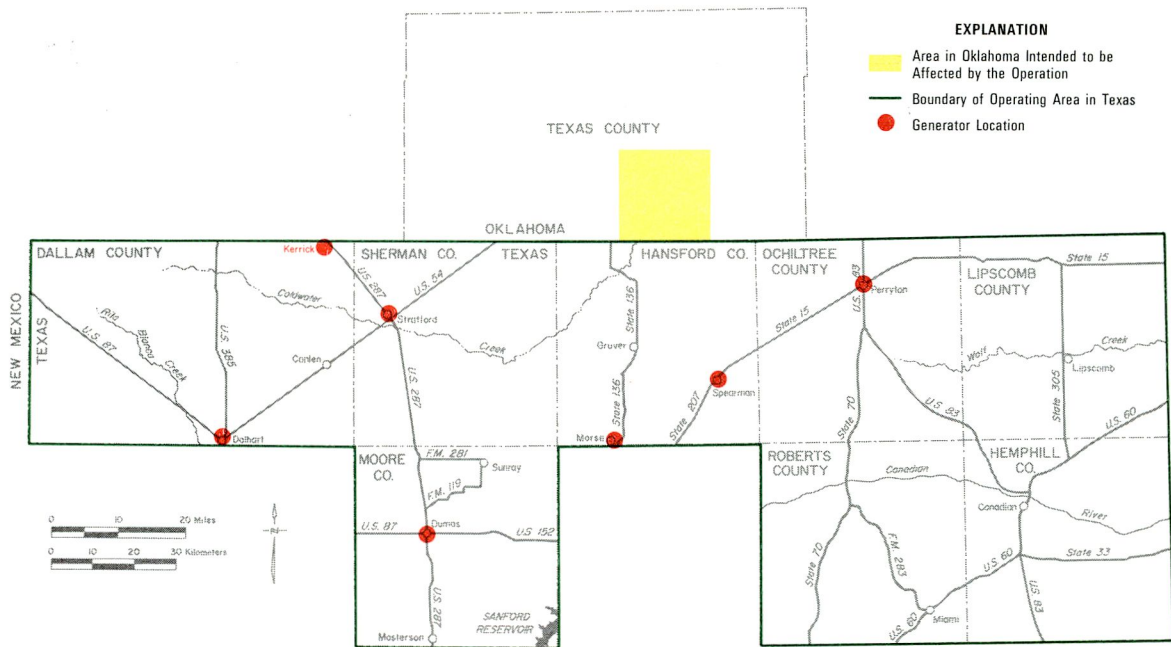
Month	Number of operational days	Number of generators in operation	Generator hours	Amount of silver iodide (grams)
Feb.	8	4	95.0	109.0
Mar.	9	4	171.0	214.5
Apr.	13	5	300.0	339.0
May	19	5	374.5	502.3
June	2	5	20.0	13.0
July	6	4	102.0	141.0
Total	57	27	1,062.5	1,318.8

Project 78-2-4. Oklahoma Precipitation-Augmentation Program (Texas Panhandle)

Cloud seeding activities for the purpose of increasing precipitation were conducted for the seventh consecutive year in the northern reaches of the Texas Panhandle. The period of operation was from February 1 through November 10. The operation was carried out by Irving P. Krick, Inc. of Texas under contract with the Henry C. Hitch Ranch, Inc. of Guymon, Oklahoma.

The intended area to be affected by the cloud seeding project was the Hitch Ranch located in Texas County, Oklahoma. The program design required that seven ground-based silver iodide generators be located in the Texas counties of Dallam, Sherman, Moore, Hansford and Ochiltree. Two models of the generators were employed, one model having an output of silver iodide crystals of one-half gram per hour and the other model having an output of approximately two grams per hour per generator. Heat from the electric arc vaporized the silver iodide to form crystals. The crystals were expelled from a seven-generator network and carried aloft into the rain-bearing clouds by air currents. Theoretically, the crystals served as ice nuclei to enhance the precipitation processes of clouds.

Large scale weather patterns, atmospheric instability, wind direction and speed and other weather parameters affecting the project area were monitored continuously by staff meteorologists at the Krick Weather Center. Based on established criteria, the staff meteorologists would decide which if any of the generators to operate and for how long. These instructions were



The 1978 Weather Modification Project Area Operated by Irving P. Krick, Inc. of Texas in the Panhandle

telephoned to the individual generator operators for implementation. The generators were operated by local residents who were trained in operating procedures.

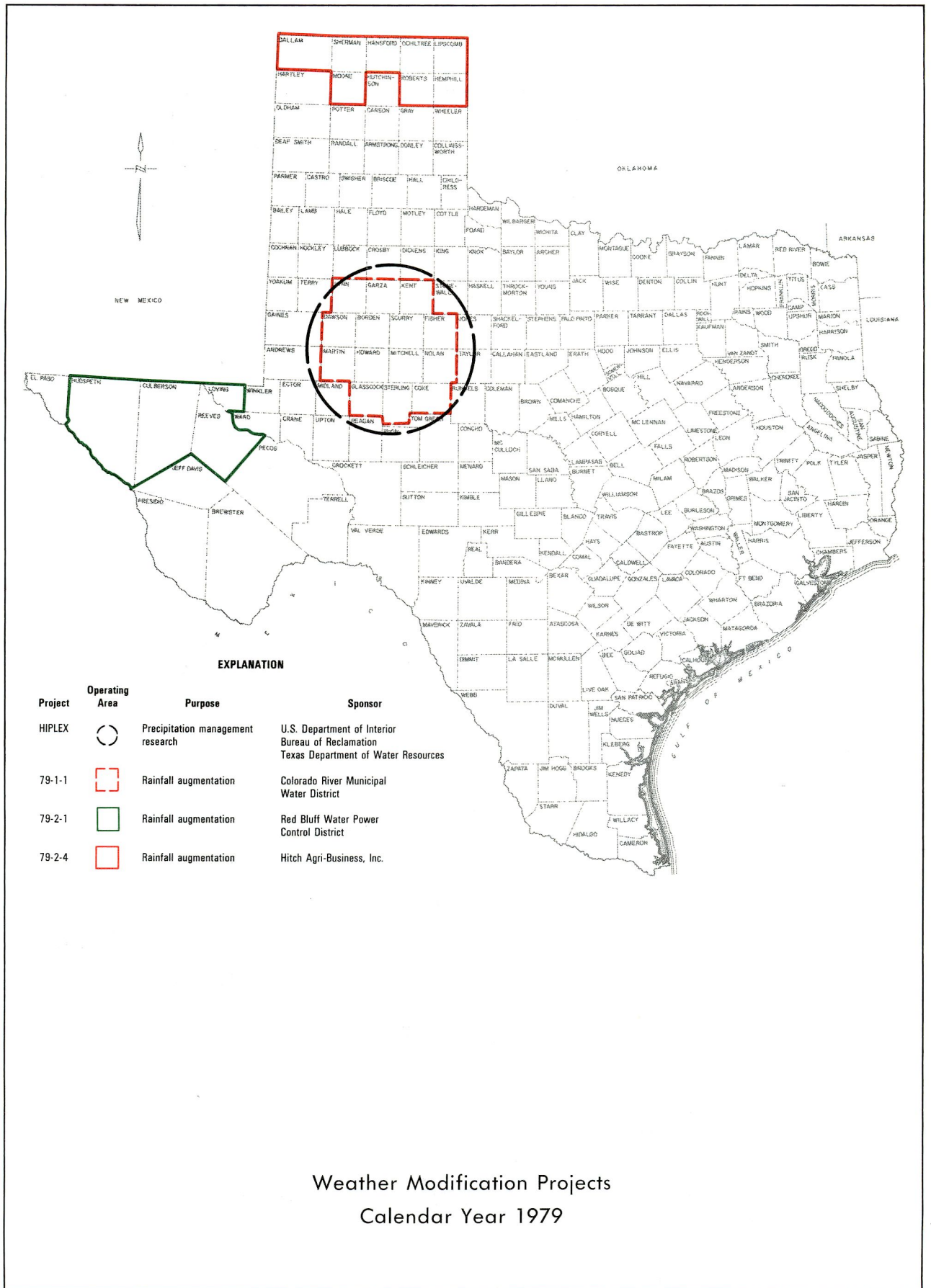
An operational summary of this program is provided in the following table.

**Project 78-2-4
Oklahoma Precipitation-Augmentation Program
(Texas Panhandle)
1978 Operational Summary**





Period of Operation: March - November 1978

Month	Number of operational days	Number of generators in operation	Generator hours	Amount of silver iodide (grams)
Feb.	4	4	51.0	58.5
Mar.	9	6	84.0	75.0
Apr.	13	6	197.0	175.0
May	22	8	360.8	226.9
June	15	6	162.0	96.0
July	14	6	147.5	94.8
Aug.	0	0	0	0
Sept.	9	6	145.0	173.0
Oct.	2	4	76.0	71.0
Nov.	3	4	44.0	71.5
Total	91	50	1,267.3	1,041.7

**Weather Modification Projects
Calendar Year 1979**



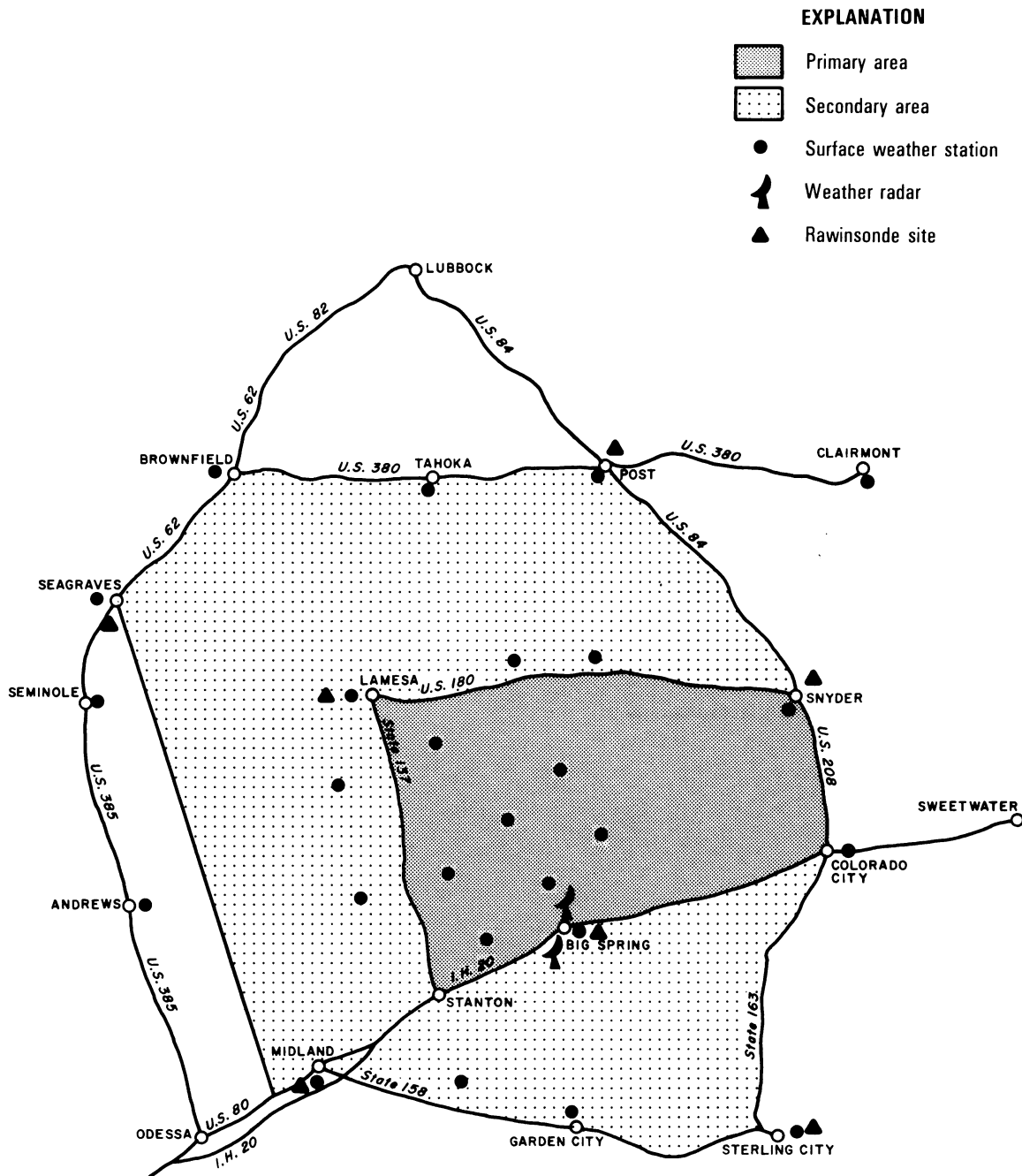
EXPLANATION

Project	Operating Area	Purpose	Sponsor
HIPLEX		Precipitation management research	U.S. Department of Interior Bureau of Reclamation Texas Department of Water Resources
79-1-1		Rainfall augmentation	Colorado River Municipal Water District
79-2-1		Rainfall augmentation	Red Bluff Water Power Control District
79-2-4		Rainfall augmentation	Hitch Agri-Business, Inc.

Weather Modification Projects
Calendar Year 1979

THE 1979 TEXAS HIPLEX PROGRAM

The 1979 Texas HIPLEX Program provided another year of valuable cloud and atmospheric information needed to achieve the goal of the HIPLEX Program. The HIPLEX goal has been to produce additional rain from summer convective clouds which develop over the Nation's High Plains region. The Texas High Plains region was one of three areas selected in the Nation where comprehensive atmospheric research was to be conducted. The 1979 Texas HIPLEX Program was managed again by the Texas Department of Water Resources under the overall guidance of the Bureau of Reclamation.



The 1979 Texas HIPLEX Field Program

The objective of the Texas HIPLEX Program has been to understand more fully the cloud and precipitation processes associated with natural and seeded rain-producing convective clouds which develop over the High Plains of Texas. During the 1979 Texas HIPLEX Program steps toward achieving this objective were made through the cooperative efforts of the following institutions and organizations:

- Bureau of Reclamation
- Texas Department of Water Resources
- Colorado River Municipal Water District
- Texas A&M University (Department of Meteorology)
- Texas Tech University (Atmospheric Science Group)
- Meteorology Research, Inc.
- North American Weather Consultants, Incorporated

This section presents the work performed by these organizations, with the exception of the Bureau of Reclamation, during the year 1979.

The following table summarizes the 1979 Texas HIPLEX operations. This table identifies mesoscale days, cloud seeding and cloud sampling days, and nonoperational days. A mesoscale day was when upper-air weather measurements were made using the Texas HIPLEX rawinsonde network.

Summary of 1979 Texas HIPLEX Field Operations

Date	Mesoscale Day		HIPLEX Operational Day			
	Yes	No	Mission performed	No-mission	Sampling/ recon. only	Tower fly-by
May	21			x		
	22			x		
	23		x	x		
	24		x	x		
	25		x	x		
	26	x			x	
	27	x			x	
	28	x				x
	29		x		x	
	30		x		x	
	31	x			x	
June	1	x		x		
	2		x	x		
	3		x	x		
	4	x		(2)		

Summary of 1979 Texas HIPLEX Field Operations—Continued

Date	Mesoscale Day		HIPLEX Operational Day			
	Yes	No	Mission performed	No-mission	Sampling/ recon. only	Tower fly-by
June	5	x				
	6			x		
	7			x		
	8	x		x		
	9			x		
	10			x		
	11			x		
	12			x		
	13			x		
	14			x		
	15			x		
	16			x		
	17			x		
	18			x		
	19			x		
	20			x		
	21			x		
	22			x		
	23			x		
	24			x	x	
	25		(1)			
	26				x	
	27			x		
	28			x		
	29			x		
	30			x		
July	1			x		
	2	x			x	
	3	x	(2)			
	4	x			x	
	5	x	(2)			
	6	x		x		
	7	x			x	
	8		(1)			
	9				x	
	10			x		
	11			x		
	12			x	x	
	13			x		
	14	x		x		
	15		(1)			
	16	x			x	
	17	x			x	
	18	x		x		
	19			x		
	20			x		

Texas Department of Water Resources

The Department continued its role as manager and administrator of the Texas HIPLEX Program. The work performed during 1979 centered on: the compilation, publication and transmittal of various Texas HIPLEX reports prepared by the Texas HIPLEX participants; the arrangement and coordination of group planning sessions; and, the continuation of HIPLEX-related studies. The Department negotiated, awarded, and administered eight contracts, helped develop the 1979 field operations and provided staff meteorologists who served as Chief Scientist, Field Program Manager, and Project Forecaster. The 1979 Texas HIPLEX field project began on May 21 and continued through July 20. During the period a total of nine aircraft missions were performed and eighteen comprehensive upper-air environmental data collection days were completed.

The project forecaster analyzed weather teletype, facsimile and satellite data and issued weather forecasts for each day's mission. The forecasts were derived from subjective analyses, prepared weather maps and from numerical models accessed by terminals located at the Texas HIPLEX Base of Operations.

At Department headquarters in Austin, the Department staff administered the various contracts between the Department and the participating groups and maintained liaison with those researchers conducting analyses at their respective institutions to assure coordinated results. Staff also helped develop the 1979 Texas HIPLEX field operations plan and a proposal for studies and work in 1980.

Colorado River Municipal Water District

The Colorado River Municipal Water District maintained and operated an extensive network of recording and nonrecording raingages, and provided the services of a rawinsonde operator and radar meteorologist. The District also provided the services of two multi-engine aircraft for the purpose of performing cloud sampling and seeding flights.

The raingage network used during the 1979 Texas HIPLEX field season consisted of 106 recording raingages capable of recording up to 12 inches of rainfall on a seven-day chart. The recording-raingage network was supplemented by a 81 fence-post raingage network generally located at the same site as the recording raingages.

The District operated two specially equipped aircraft in support of the 1979 Texas HIPLEX field project. The aircraft were high performance, all-weather turbocharged, pressurized Piper Navajo and a Model "D" Piper Aztec. Each aircraft was equipped with certain silver iodide cloud-seeding pyrotechnic devices for the purpose of conducting cloud base and cloud top calibration seeding operations. The P-Navajo was also equipped with an airborne cloud physics sensing and recording system for the purpose of collecting data regarding the precipitation process of Texas High Plains convective clouds.

The District also made temperature and moisture profile measurements of the atmosphere during the 1979 Texas HIPLEX field season. These measurements supplemented the atmospheric data collection network operated by Texas A&M University in support of their studies of interrelationships between cloud development and the environment.

Texas A&M University

The Department of Meteorology at Texas A&M University maintained and operated a network of surface and upper-air meteorological measuring instruments. The information gathered from the two data networks were used to understand better the interrelationships between cloud and rainfall development, and the environment. Additionally, Texas A&M University developed a radar echo climatology of the Texas High Plains region. The climatology was used to decide which type of convective cloud or system should be studied and, from an operational point of view, provide the greatest benefit to the area through rainfall enhancement.

A network of 25 solar-powered automatic surface weather stations was installed over and adjacent to the Texas HIPLEX operational area for use during the 1979 field season. These stations provided hourly readouts of temperature, relative humidity, pressure, wind speed and direction, and precipitation (as well as battery voltage). These data were transmitted to an orbiting satellite which retransmitted this information to the Bureau of Reclamation computer in Denver. In-house data terminals provided by the Bureau allowed Texas HIPLEX personnel to access these data in both raw and spatially or temporarily analyzed form within one-half hour of real-time.

Atmospheric soundings were made at three-hour intervals from a network of seven automatic tracking rawinsonde units placed over and adjacent to the HIPLEX operational area. Of these seven units, five were manned by Texas A&M University technicians (Seagraves, Post, Lamesa, Sterling City, and Snyder), one by Colorado River Municipal Water District technicians at Big Spring, and the final sounding was purchased from the National Weather Service at Midland Air Terminal.

Used in conjunction with the rawinsonde units were seven mini-computers. These units were programmed to process the raw baseline, wind, temperature, pressure, and moisture data provided by the soundings within one and one-half hours of balloon launch.

The surface and upper-air data were analyzed to examine atmospheric moisture sources and, therefore, energy sources for convective activity. These analyses were performed for different types of convective development. Moisture variations in the atmosphere were observed among the different types of convective development indicating strong ties between cloud development and its environment.

Texas A&M University was also actively involved in studying the make-up of the rain producing cloud to provide a comprehensive picture of the natural precipitation mechanisms in West Texas summertime convective clouds. Two instrumented aircraft flew from Big Spring during the field season and collected data on the thermodynamic, kinematic, and microphysical properties of growing convective clouds in the area. These data were recorded in real time and were processed using appropriate computer programs.

Texas Tech University

The Atmospheric Science Group at Texas Tech University was under contract with the Department of Water Resources to collect and analyze satellite, radar and rainfall information. These data were used for the purpose of documenting the variability of rainfall characteristics for different types of convective development. The satellite and radar data were used to classify the

convective activity according to horizontal and vertical dimensions, orientation and evolution. This information coupled with rainfall amounts and rainfall rates was used to determine the potential of certain types of convective clouds to produce rainfall.

Texas Tech University personnel operated and maintained the Bureau of Reclamation's weather research radar which was located at Howard County Industrial Park. Digital radar echo data were recorded on magnetic tape. Additionally, imagery data were recorded on video tape cassette and were used during daily operational briefings. The radar imagery also displayed the positions of the aircraft.

Satellite imagery data were collected at 30 minute intervals via in-house laserfax equipment operated by Texas Tech University personnel. These data were reviewed during the operational briefings and were archived for detailed post analyses.

Meteorology Research, Incorporated

The primary consideration of the 1979 Texas HIPLEX field program was to collect quality cloud physics data of growing convective rain-producing clouds. Toward this end the Texas HIPLEX field program operated two aircraft with cloud physics measurement capabilities. One aircraft, a Piper Pressurized Navajo, was to measure cloud information at the -10 °C level in the cloud. Meteorology Research, Inc. operated the Piper Turbocharged Navajo under contract with the Bureau of Reclamation.

A number of cloud physics and environmental sensing devices were used on the Navajo aircraft during the season. The aircraft was able to measure and record, in real time, the following parameters: cloud water and ice particle sizes and distributions; cloud liquid water content; air temperature and dew point temperature; aircraft horizontal and vertical airspeed, altitude, rate-of-climb and navigation; and, rainfall rate. These data were processed and later analyzed by Meteorology Research, Inc. under contract with the Bureau of Reclamation.

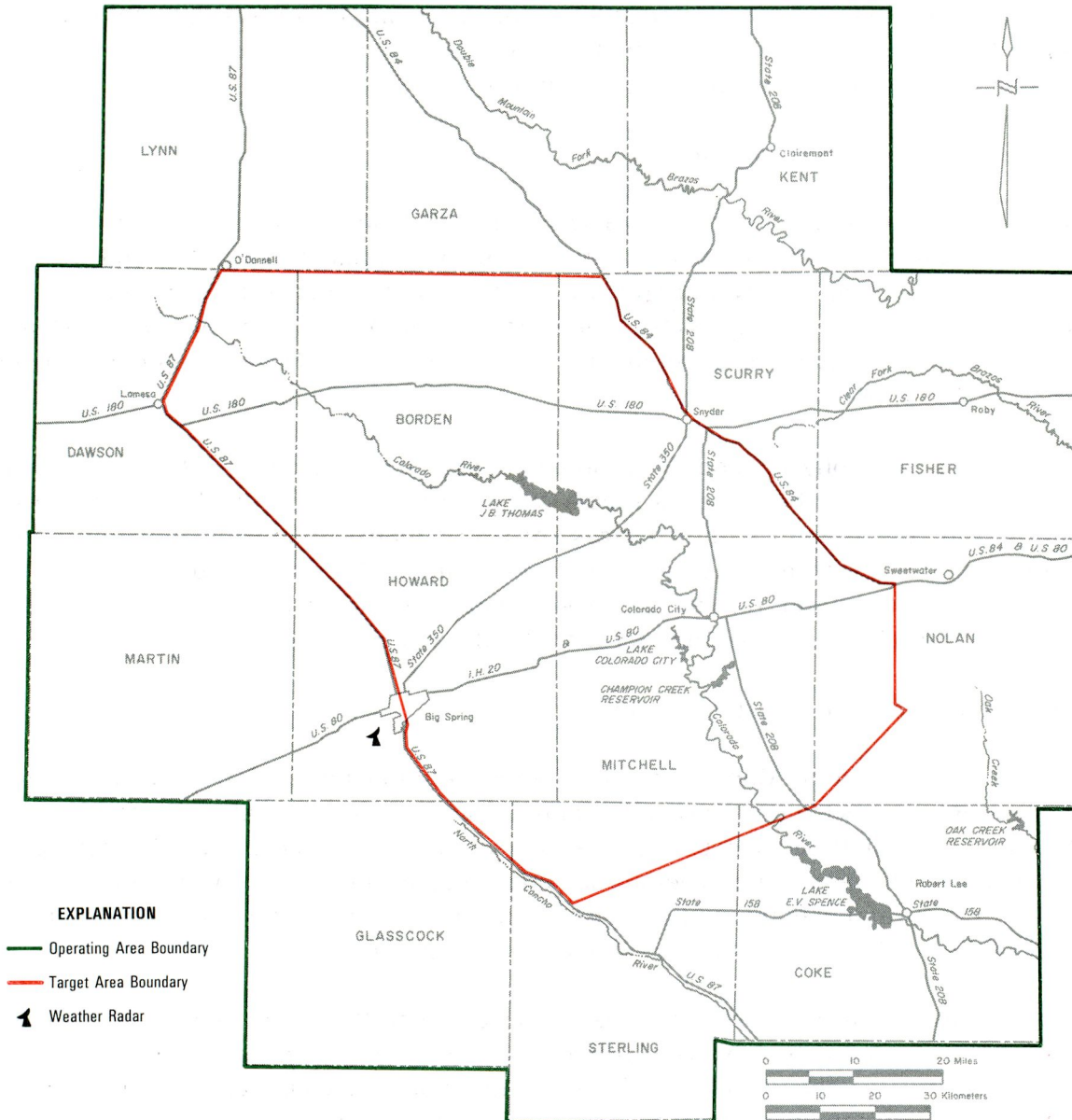
North American Weather Consultants, Inc.

North American Weather Consultants, Inc. (NAWC) entered into a contract with the Department of Water Resources to perform specific analyses of weather radar data collected during the 1976 through 1978 field season period. The tasks to be performed by NAWC included: an examination of cloud characteristics versus seeding; a generation of an echo summary; production of hourly radar-rainfall maps; and, interpretation of radar-echo patterns in terms of environmental conditions. NAWC did not participate in the field program.

These analyses provided useful information for planning the future Texas HIPLEX experiment. In brief, the radar echoes were classified as either cells, clusters, or lines. Of the total number of radar echoes observed (11,207), cells outnumbered clusters and lines by a factor of ten. However, in spite of their infrequency in the Big Spring area, lines account for over two-thirds of the total rain volume and clusters account for over one-fourth of the total rain volume. Cells, on the other hand, account for only about three percent of the total rain volume. Therefore, if a seeding technology was developed which could double the rain volume from cells, the contribution to the total rain volume would still be only a small percent. Because it is the intent of the Texas HIPLEX Program to provide a meaningful cloud-seeding technology, this study suggests that future research efforts should be directed at clusters or lines as opposed to cells.

Project 79-1-1. Colorado River Municipal Water District Rainfall-Augmentation Program

The 1979 Colorado River Municipal Water District's cloud seeding program was operated from March through October. All cloud seeding operations during this period were under the direction of the on-site District meteorologist, with the exception of cloud seeding activities during the Texas HIPLEX field season. The purpose of the District's cloud seeding program was to increase rainfall runoff into the watersheds of Lake J. B. Thomas and Lake E. V. Spence located in the northern reaches of the Colorado River basin.



The 1979 Colorado River Municipal Water District Weather Modification Project Area

The cloud seeding technique used by the District was similar to methods used in previous years. Flares producing silver iodide crystals were ignited into selected cumulus clouds from one of two aircraft flying either at the cloud base or at the -10 °C level in the cloud. The flare dispensed

silver iodide crystals at a rate of about two grams per minute or 30 grams per minute depending on the type of flare selected for the existing cloud and ambient air conditions.

Using the on-site weather radar the project meteorologist monitored certain cloud characteristics to determine whether the cloud could be treated to achieve the desired effects. The cloud characteristics included, but were not limited to, cloud top temperature; cloud top visual characteristics; and, cloud vertical and horizontal dimensions. Seeding amounts and duration were at the discretion of the project meteorologist based on radar and other meteorological information available.

The District utilized an FPS-77 weather radar and two cloud-seeding aircraft. The FPS-77 weather radar operated from the Big Spring airport for the purpose of detecting cloud characteristics to determine seeding criteria. The aircraft were high performance, all weather pressurized Piper Navajo and Piper Aztec. Both aircraft were fully equipped with special holding racks for mounting pyrotechnic cloud seeding devices. The District also maintained an extensive raingage network for evaluation purposes.

The District's 1979 report* on cloud seeding operations indicated that for the 9-year period 1971-79, more rainfall was associated with the seeded area than the unseeded area, and that rainfall in the target area was 26 percent greater than the rainfall in the control areas. Also, the District reported that cotton yield departures from normal for the seeded period showed that seeded counties increased cotton production by 54 percent while production in upwind and downwind counties was less appreciable, particularly in the upwind counties where only a 7 percent increase was noted.

An operational summary of the District's 1979 program is given in the following table.

**Project 79-1-1
Colorado River Municipal Water District
1979 Operational Summary**

Period of Flight Operations: March 1 - October 31, 1979

Months	Number of flights		Hours flown	Amount of silver iodide (grams)
	Seeding	Observation		
Mar.	0	1	1.5	0
Apr.	3	1	4.5	480
May	8	7	18.2	1,220
June	8	21	37.7	2,050
July	8	18	33.6	1,670
Aug.	12	0	15.5	6,700
Sept.	1	0	1.6	460
Total	40	48	112.6	12,580

*1979 - *Weather Modification, Precipitation Enhancement* prepared by John Girdzus, Report No. 79-1, Colorado River Municipal Water District, December, 1979. The "normal yields" of cotton reported during the 1940-1960 period of record were compared to cotton yields reported during the 1971-1978 cloud seeding period. The 1940-1960 period includes a severe drought. Also, during this period, significant advances were made in cotton technology. Thus, the differences in yields quoted here may be influenced by factors other than rainfall from cloud seeding.

Project 79-2-1. Trans-Pecos Precipitation-Augmentation Program

The year 1979 was the fourth consecutive year for the Red Bluff Water Power Control District of Pecos, Texas to contract with Irving P. Krick, Inc. of Texas to seed clouds for the purpose of increasing runoff into the Delaware Creek watershed. The program was activated on January 1 and continued through December 31. Brief suspensions of operations occurred on May 26 and 31; June 1, 2, and 8; July 20 and 31; and, August 1, 16 and 17 due to anticipated severe thunderstorms.

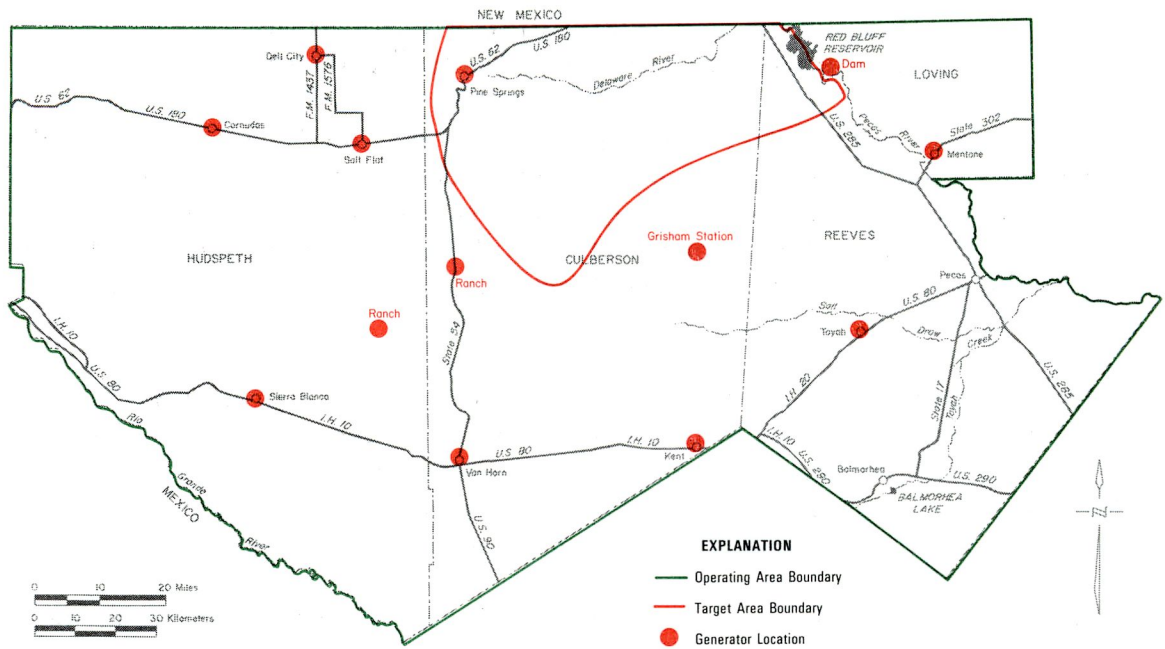
Thirteen ground-based silver iodide generators located within Culberson, Hudspeth, Reeves, and Loving Counties were used to dispense the cloud-seeding material. These generators were operated by residents under the guidance of a Krick, Inc. project meteorologist. Two types of generators used in this program had a silver iodide crystal output of one half and two grams of silver iodide per hour. Meteorologists of Krick, Inc. operated the program from its weather offices based in Palm Springs, California. Weather conditions in the Trans-Pecos were monitored by conventional weather-data dissemination circuits. Generators in the network were activated by telephone instruction to local generator operators when cloud conditions were determined to be receptive to seeding.

An operational summary of this program is contained in the following table.

Project 79-2-1 Trans-Pecos Precipitation-Augmentation Program 1979 Operational Summary

Period of Operation: January 1 - December 31, 1979

Month	Number of operational days	Number of generators in operation	Generator hours	Amount of silver iodide (grams)
Jan.	7	5	120	240.0
Feb.	4	6	91	182.0
Mar.	3	3	55	110.0
Apr.	6	4	90	180.0
May	14	7	209	419.0
June	9	8	106	212.0
July	19	8	194	389.0
Aug.	20	8	235	470.0
Sept.	7	4	78	156.0
Oct.	2	1	11	22.0
Nov.	7	5	62	124.0
Dec.	9	8	208	416.0
Total	107	67	1,459	2,920.0



The 1979 Weather Modification Project Area Operated by Irving P. Krick, Inc. of Texas in the Trans-Pecos

Project 79-2-4. Oklahoma Precipitation- Augmentation Program (Texas Panhandle)

This program was designed to increase precipitation over the Hitch Ranch through cloud seeding with ground-based silver iodide dispensing generators. It was operational from March through October. The year 1979 was the eighth consecutive year of operations conducted by Irving P. Krick, Inc. of Texas on behalf of the Hitch Agri-Business, Inc. The target area, where the seeding effects were to occur, was the Hitch Ranch located in the south central portion of Texas County, Oklahoma.

The program utilized a total of eight generators with six sites located in Texas. The generator site selection was based on anticipated windflow to allow the generators to dispense the silver iodide crystals in the prevailing wind currents. The crystals were carried aloft to levels in the target cloud system where they became effective ice crystal nuclei. These surrogate ice crystals collected cloud moisture and helped to initiate the rain formation process.

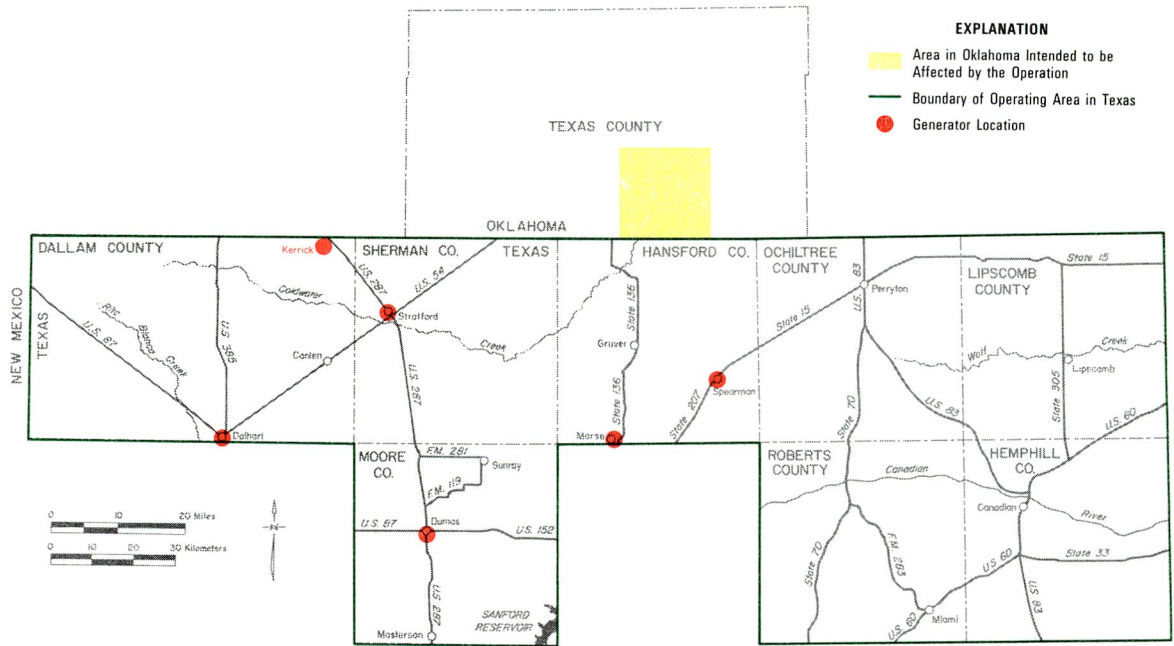
Staff meteorologists in the Krick, Inc. home office in Palm Springs, California directed the operation of the project and continuously monitored surface and upper air conditions in the vicinity of the project area. Weather parameters examined included large scale weather patterns, local weather conditions, atmospheric stability, and the speed and direction of the wind currents at levels ranging from the surface up to temperature levels in the cloud where the surrogate ice crystals become effective. The meteorologist in charge of the project telephoned operating directions to individual generator operators in advance of generator activation within the network.

An operational summary of this program is given in the following table.

Project 79-2-4 Oklahoma Precipitation-Augmentation Program (Texas Panhandle) 1979 Operational Summary

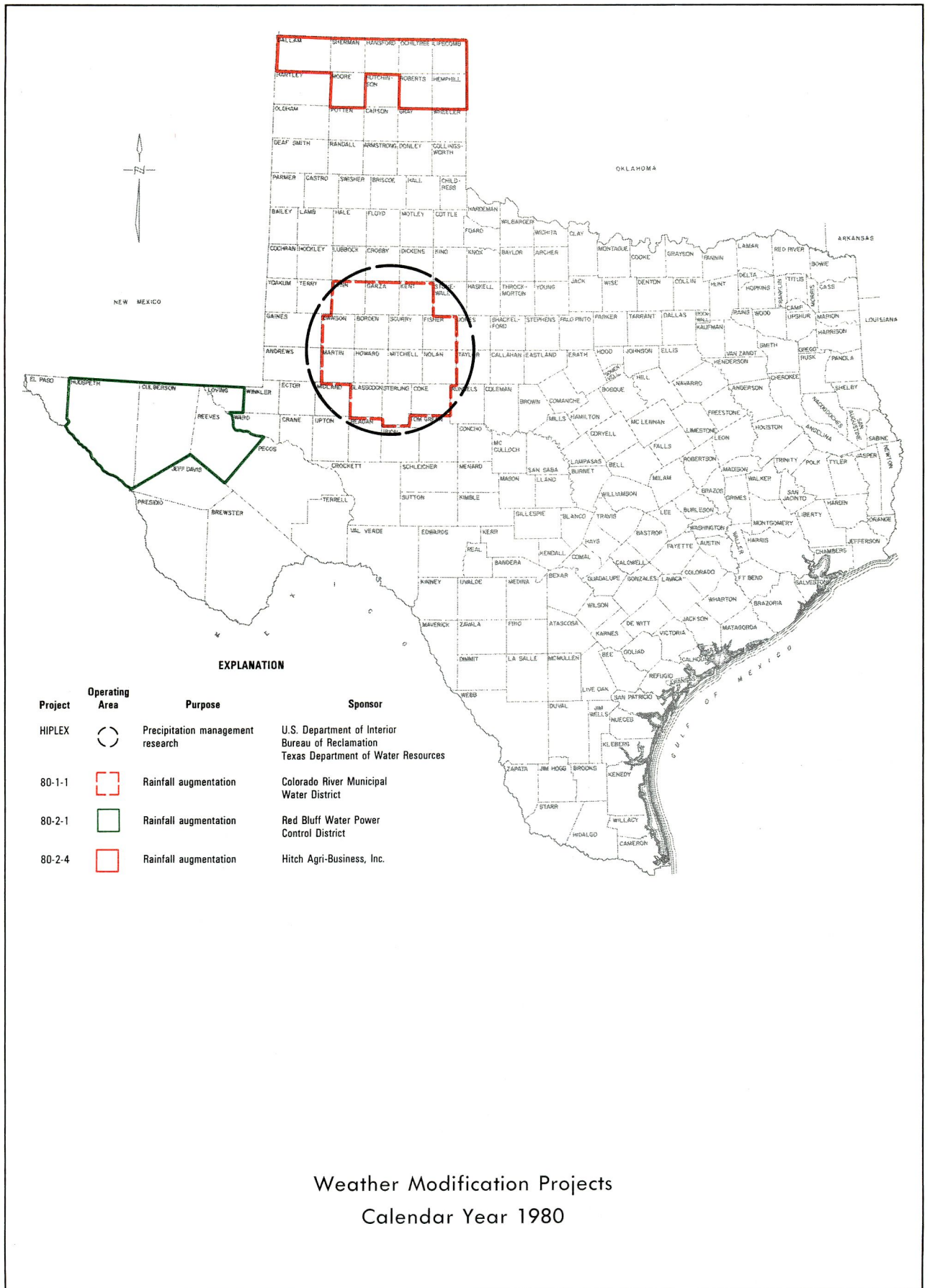
Period of Operation: March 19, 1979 - October 31, 1979

Month	Number of operational days	Number of generators in operation	Generator hours	Amount of silver iodide (grams)
Mar.	4	2	37.0	71.4
Apr.	16	6	150.3	190.6
May	17	5	144.0	195.1
June	13	5	129.0	169.5
July	11	5	94.0	99.5
Aug.	13	4	168.4	265.8
Sept.	3	2	19.0	9.5
Oct.	4	3	40.0	80.0
Total	81	32	781.7	1,081.4



The 1979 Weather Modification Project Area Operated by Irving P. Krick, Inc. of Texas in the Panhandle

**Weather Modification Projects
Calendar Year 1980**



EXPLANATION






Project	Operating Area	Purpose	Sponsor
HIPLEX		Precipitation management research	U.S. Department of Interior Bureau of Reclamation Texas Department of Water Resources
80-1-1		Rainfall augmentation	Colorado River Municipal Water District
80-2-1		Rainfall augmentation	Red Bluff Water Power Control District
80-2-4		Rainfall augmentation	Hitch Agri-Business, Inc.

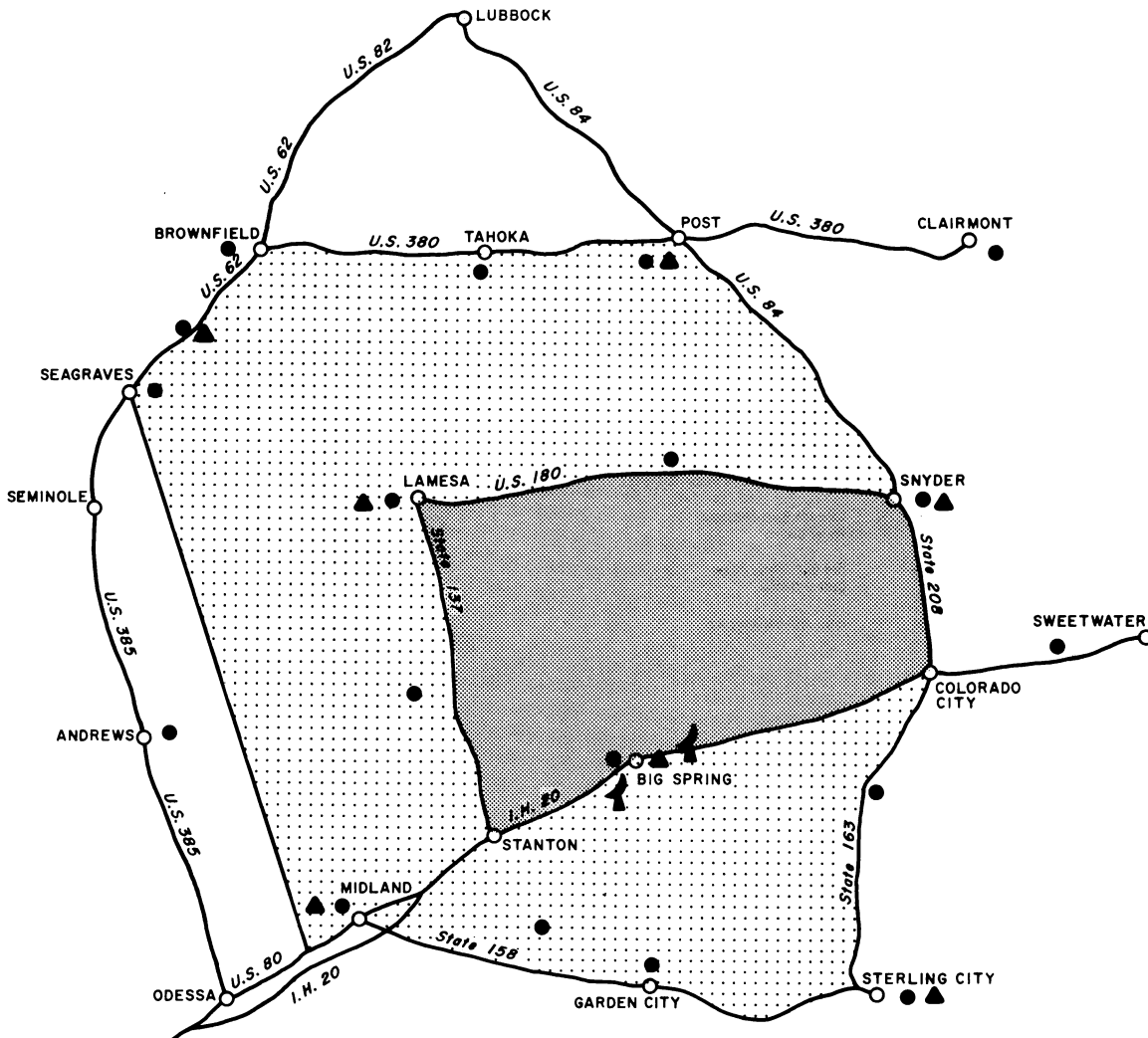
Weather Modification Projects
Calendar Year 1980

THE 1980 TEXAS HIPLEX PROGRAM

The year 1980 was the sixth consecutive year the Texas HIPLEX Program collected and analyzed environmental and convective cloud information for the purpose of determining if West Texas shower-producing clouds can be altered by man to increase their natural rain output. This

EXPLANATION

-  Primary area
-  Secondary area
-  Surface weather station
-  Weather radar
-  Rawinsonde site



The 1980 Texas HIPLEX Field Program

objective was accomplished through the cooperative efforts of the following governmental and university institutions:

- Bureau of Reclamation
- Texas Department of Water Resources
- The Colorado River Municipal Water District
- Texas A&M University (Department of Meteorology)
- Texas Tech University (Atmospheric Science Group)

The primary emphasis of the 1980 Texas HIPLEX Program was centered on analyses of data collected during previous years and the conduct of a minimal field program. The 1980 Texas HIPLEX field program began on May 15 and continued through June 30. The purpose of the field program was to maintain continuity among data-years of certain key environmental and convective cloud parameters. The analyses of previous years' data were geared toward determining: the type of convective clouds which appear more susceptible to cloud seeding; the environmental conditions which best complement cloud seeding; the appropriate cloud seeding technique for West Texas convective clouds; the physical sequence of events which take place from the time a cloud begins to develop to the time rain is falling on the ground; and, the most effective statistical evaluation technique for the Texas HIPLEX Program. After these issues are better understood, the Texas HIPLEX Program can develop an experimental design document which provides detailed instructions for the experimental phase of the Program.

The following table is a summary of the 1980 Texas HIPLEX field operations. A mesoscale day was when upper-air weather measurements were made using the Texas HIPLEX rawinsonde network.

Summary of 1980 Texas HIPLEX Field Operations

Date	Mesoscale status		HIPLEX aircraft operations	p-Navaho
	Yes	No		
May 15	x			
16		x		
17		x		
18	x		Sampling	
20		x	Sampling	
21	x		Reconnaissance	
22		x		
23	x			
24		x		
25		x		
26	x		Sampling	
27	x		Reconnaissance	
28	x			
29	x			
30		x		
31		x		
June 1	x		Reconnaissance	Sampling (1)
2	x		Sampling	Reconnaissance

Summary of 1980 Texas HIPLEX Field Operations—Continued

Date	Mesoscale status		HIPLEX aircraft operations	p-Navaho
	Yes	No		
June 3	x			
4		x	Cross-country	
5		x	Tower fly-by	Tower fly-by (1)
6		x		
7		x		
8	x			
9	x			
10	x		Reconnaissance	Reconnaissance
11		x		
12		x		
13		x	Tower fly-by (*)	Tower fly-by
14	x		Mesoscale mapping mission	
15		x	Interaircraft comparison	
16		x		
17	x			
18	x			
19	x			Sampling (2 events)
20	x			Sampling
21	x			Sampling (2 events)/ Seeding
22	x			Sampling (events)
23		x		
24		x		
25		x		
26		x		
27		x		
28		x		
29		x		
30		x		

(1) Interaircraft comparison

* Also a cross-country cloud sampling mission

Texas Department of Water Resources

The Texas Department of Water Resources continued its role as manager and administrator of the Texas HIPLEX Program. The Department negotiated, awarded and administered fourteen contracts with other Texas HIPLEX participants. The Department staff helped develop the 1980 field operations plan and provided staff to serve as Project Manager, Field Operations Manager, and Project Forecaster.

The Department was also actively involved with planning the next phase of the Texas HIPLEX Program, which is the experimental phase. The Department staff drafted a formal proposal to the Bureau of Reclamation for continued participation beginning in 1981. The proposal covered the 5-year period 1981-1985 and provided tentative information regarding the Texas HIPLEX cloud

seeding hypotheses, seeding techniques, the experimental unit, and a conceptual model based on previous analyses. It was proposed that prior to each field season, extensive re-evaluation of the conceptual model would be necessary based on continuing analyses and statistical evaluations of the environmental and convective cloud microphysical information.

Also the Department began a summary report of Texas HIPLEX work performed during the years 1975-1980. The purpose of the summary report was to synthesize the salient findings of the research performed by all Texas HIPLEX participants since the Program began in 1975. The summary report will present findings and offer recommendations for the experimental phase of the Program.

Colorado River Municipal Water District

The Colorado River Municipal Water District under contract with the Department of Water Resources maintained and operated an extensive network of recording and nonrecording rain-gages and provided the services of a radar meteorologist. Additionally, the District provided to the 1980 Texas HIPLEX field program a multi-engine aircraft for the purpose of performing cloud sampling and seeding flights.

Raingage data were collected by the District during the six-month period beginning on April 1 and ending on September 30. The data were collected from both the fence-post and recording raingages from the same network and in the same manner as during the 1979 field program. The raingage data were recorded in computer format and forwarded to Texas Tech University for further processing.

The cloud sampling aircraft flew a total of 27 flights during the 1980 field season, accounting for 42 hours of aircraft time. Prior to each flight all aircraft sensing instruments were calibrated. Two inter-aircraft comparison flights were also performed to determine if the on-board instrumentations were operating within designed tolerances.

Texas A&M University

The Department of Meteorology at Texas A&M University continued to play a significant role in improving the understanding of the environmental effects on the natural development of convective clouds in West Texas. During 1980 Texas A&M University focused on the analyses of the 1979 mesoscale environmental data. The analyses included evaluating the energetics and wind fields of the environment; developing water budget models; evaluating ambient air entrainment into the convective cloud; and, an examination of environmental response to convective cloud activity for both seeded and natural clouds.

Texas A&M University also performed research on cloud physics and the effects of seeding on the cloud. In addition, the university examined the effects of the environment on the microphysical make-up of the convective cloud and its impact on cloud responses to cloud seeding. This work was a continuation of the research performed in 1979.

An evaluation of the seeding effects was also initiated by Texas A&M University. This was done in terms of observing changes in the cloud's microphysics following seeding and in observ-

ing changes in radar characteristics and measured rainfall characteristics. The analyses were considered preliminary due to the limited number of cases studied.

A climatology of surface and upper-air synoptic parameters was prepared by Texas A&M University. These climatologies were compared and associated with characteristics of radar echoes to determine which parameters were related to radar echo development and the maintenance of the radar echo.

Texas Tech University

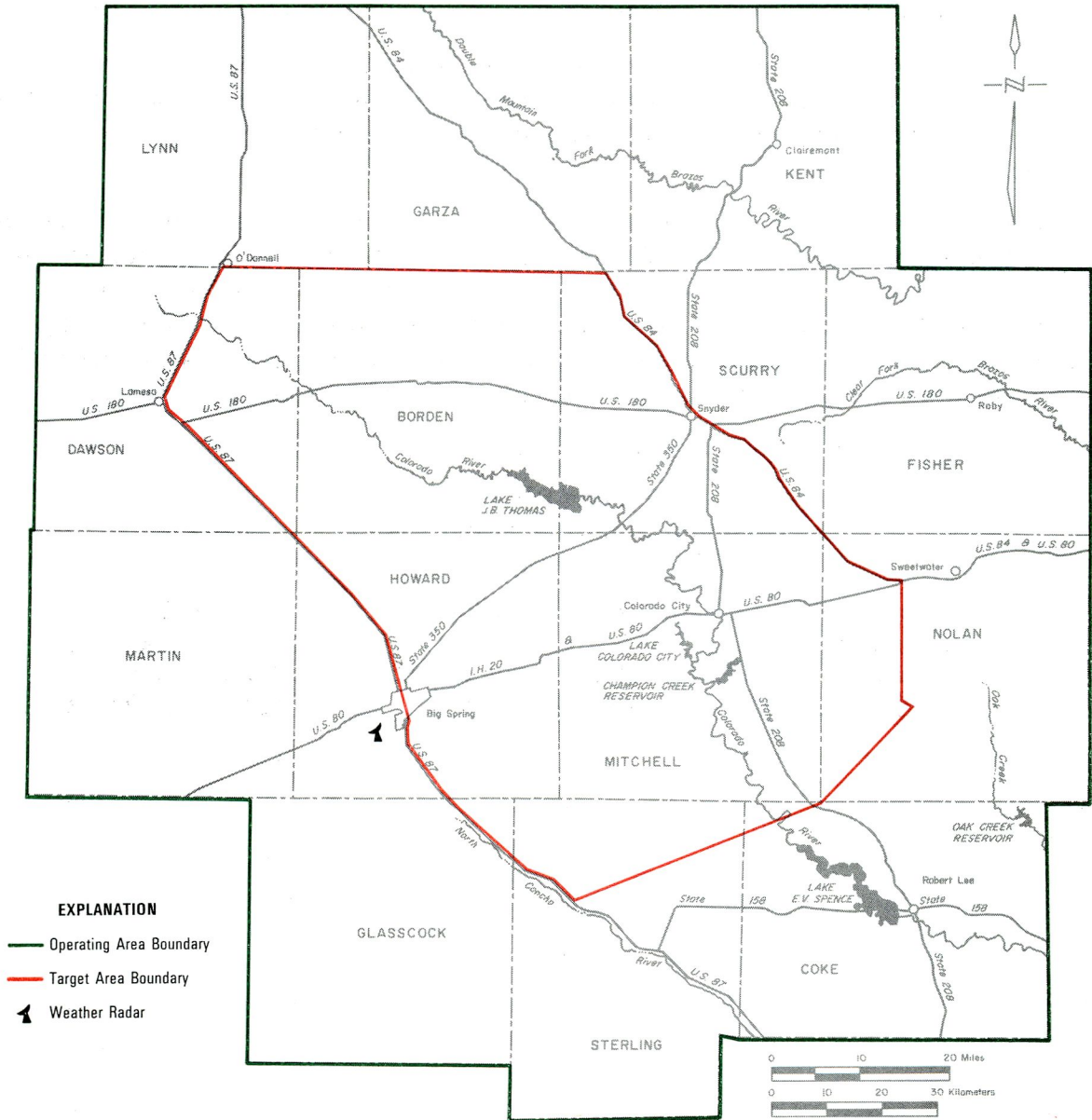
The research performed by the Atmospheric Science Group at Texas Tech University during 1980 was a continuation of work begun in 1979. The tasks included the integration and interpretation of radar data and satellite data to help explain observed rainfall patterns. The analyses of the radar data received the greatest amount of emphasis. These analyses investigated the structure, water budget and the precipitation efficiency of mesoscale convective clusters.

Analyses of the cloud microphysics by Texas Tech University began in 1980. A university scientist was the on-board aircraft observer for all cloud sampling missions during the 1979 and 1980 field seasons. The observer's duties included operating the cloud physics instrumentation and documenting cloud characteristics as observed from the aircraft. After the field season Texas Tech University scientists processed the data and analyzed the measured in-cloud parameters. The purpose of the analyses was to establish the precipitation mechanism and the precipitation efficiency for convective clouds which produce rain in West Texas.

Processing and analyses of the rainfall data were also the responsibility of Texas Tech University. The rainfall analyses were to determine natural variability of convective type rainfall through ground-measurements, and to construct a rainfall storm model for hydrologic application.

Project 80-1-1. Colorado River Municipal Water District Rainfall-Augmentation Program

In 1971 the Colorado River Municipal Water District initiated a rain increase program designed to increase surface runoff into Lakes J. B. Thomas and E. V. Spence. The year 1980 represents the tenth consecutive year during which the District funded and operated a cloud seeding program to increase rainfall on the ground. In addition to increasing surface runoff, the program was designed to increase water supplies for the agricultural and ranching communities.



**The 1980 Colorado River Municipal Water District Weather
Modification Project Area**

The project area included fourteen counties located in the Permian Basin of West Texas. Operational cloud seeding was done primarily during the spring, summer and fall months when convective cloud systems produce the greatest amount of the area's annual rainfall.

The seeding technique employed by the District was cloud-base seeding using a Piper Aztec aircraft as the seeding platform. Silver iodide was dispersed into the atmosphere by burning silver iodide impregnated flares. Flare racks were located on the inboard trailing edge of each wing. Each flare rack held 12 end-burning pyrotechnic flares. Each flare held 20 grams of silver iodide and would burn for either 40 seconds or seven minutes, depending on the type of flare used. A weather radar was used to determine cloud growth characteristics. Other real-time, conventionally-disseminated weather data were also available to the project meteorologist. All seeding decisions were made by the on-site meteorologist after discussions with the seeding aircraft pilot; however, any decisions concerning the safety of the aircraft were made by the pilot.

The average number of seeding flights per season made during the previous ten years was 36, however during 1980 only 16 seeding flights were flown. This relatively low number of flights was attributed to the drought conditions that plagued the West Texas area during the 1980 summer months.

Analysis performed by the District* of the rainfall patterns over the District's target area revealed that the target area received 28 percent more rainfall than the contiguous nonseeded areas during the seeding years. A look at the seeded years compared to the nonseeded years showed that rainfall increases in the target area for the seeded years were 47 percent greater than normal and 19 percent greater than normal for the surrounding areas. Also, these rainfall increases compared well with areas of greatest cotton yields increases from normal.

An operational summary for this program is given in the following table.

**Project 80-1-1
Colorado Municipal Water District
1981 Operational Summary**

Period of Flight Operations: March 1 - September 30, 1980

Month	Number of operational days	Observation flights		Seeding flights		Amount of silver iodide (grams)
		Number	Hours flown	Number	Hours flown	
Mar.	1	1	0.9	0	0	0
Apr.	2	0	0	2	3.3	160
May	3	0	0	3	5.0	320
June	14	14	18.3	3	7.6	940
July	13	13	24.0	0	0	0
Aug.	5	1	1.6	4	5.0	600
Sept.	5	1	2.3	4	6.3	950
Total	43	30	47.1	16	27.2	2,970

*1980 - *Weather Modification, Precipitation Enhancement*, prepared by John Girdzus, Report No. 80-1, Colorado River Municipal Water District, December 1980. The "normal yields" of cotton reported during the 1940-1960 period of record were compared to cotton yields reported during the 1971-1979 cloud seeding period. The 1940-1960 period includes a severe drought. Also, during this period, significant advances were made in cotton technology. Thus, the differences in yields quoted here may be influenced by factors other than rainfall from cloud seeding.

The program was operational on an almost continuous basis throughout the period January 1 through November 10. However, the project was suspended for portions of some days when the forecast or actual weather conditions presented a threat of heavy downpours and/or severe thunderstorms. These brief suspensions occurred on September 26, 27, and 28.

An operational summary of the 1980 program is given in the following table.

**Project 80-2-1
Trans-Pecos Precipitation-Augmentation Program
1980 Operational Summary**

Period of Operation: January - November 1980

<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Jan.	9	8	149	298.00
Feb.	7	6	131	262.00
Mar.	8	5	119	238.00
Apr.	9	7	123	246.00
May	18	9	265	530.00
June	20	10	253	506.00
July	22	7	284	568.00
Aug.	21	10	372	744.00
Sept.	16	9	229	458.00
Oct.	9	5	87	174.00
Nov.	0	0	0	0
Total	139	76	2,012	4,024.00

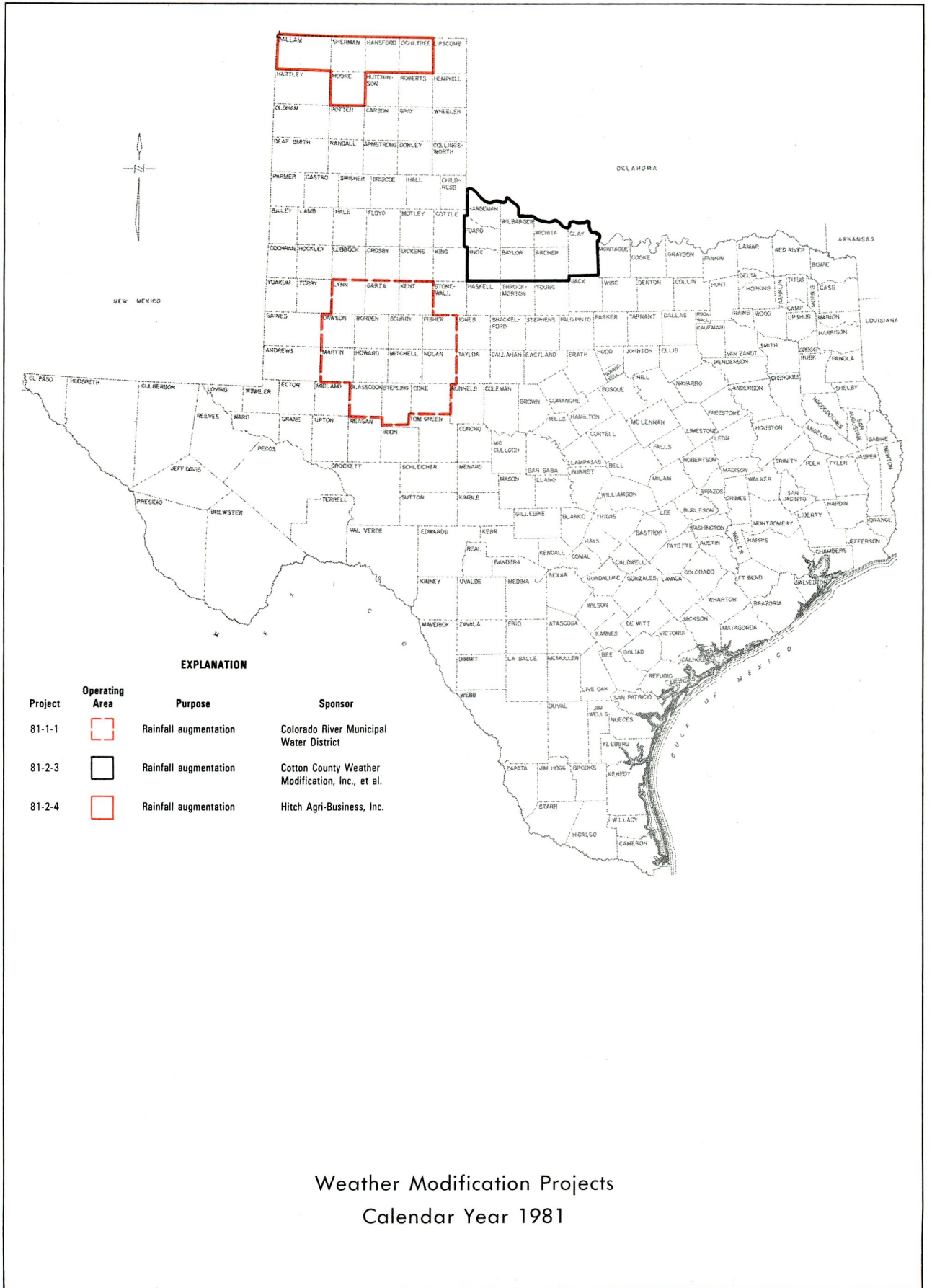
The program began on April 15 and remained operational through November 30. Only occasionally, when severe weather appeared to be a threat to the operations, were seeding operations suspended until the threatening conditions no longer existed.

**Project 80-2-4
Oklahoma Precipitation-Augmentation Program
(Texas Panhandle)
1980 Operational Summary**

Period of Operation: April - November 1980

Month	Number of operational days	Number of generators in operation	Generator hours	Amount of silver iodide (grams)
Apr.	6	3	103	168.00
May	12	4	135	223.00
June	12	4	124	128.25
July	10	5	85	117.50
Aug.	19	5	208	336.50
Sept.	8	3	83	139.00
Oct.	4	3	49	86.00
Nov.	3	3	44	47.50
Total	74	30	831	1,245.75

**Weather Modification Projects
Calendar Year 1981**



NEW MEXICO




OKLAHOMA

ARKANSAS

LOUISIANA

GULF OF MEXICO

EXPLANATION

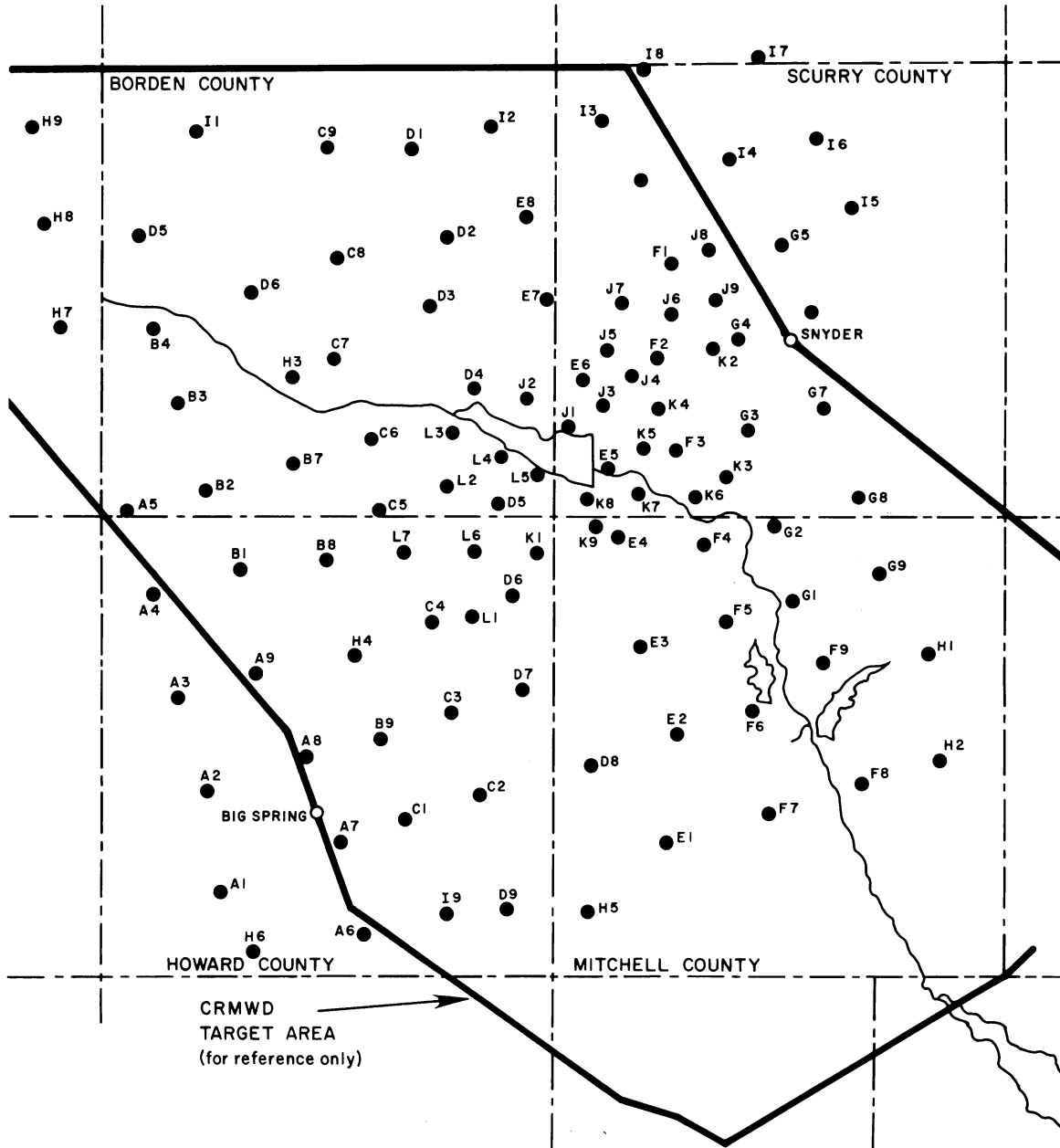
Project	Operating Area	Purpose	Sponsor
81-1-1		Rainfall augmentation	Colorado River Municipal Water District
81-2-3		Rainfall augmentation	Cotton County Weather Modification, Inc., et al.
81-2-4		Rainfall augmentation	Hitch Agri-Business, Inc.

**Weather Modification Projects
Calendar Year 1981**

THE 1981 TEXAS HIPLEX PROGRAM

The year 1981 was significant for the Bureau of Reclamation-sponsored High Plains Cooperative Program (HIPLEX). In early March, the Bureau was notified by the Department of Interior that as a result of the current administration's budget cuts the HIPLEX Program was to be "mothballed" indefinitely. This action left the Texas HIPLEX Program only partially complete with little hope that any additional Federal funding would be forthcoming in the near future.

The Texas HIPLEX Program was planned to be a three phase program with each subsequent phase depending on the completion of the preceding phase. Unfortunately, the "mothballing" of HIPLEX came prior to the completion of the Program's initial phase. This action adversely



The 1981 Texas HIPLEX Recording Raingage Network

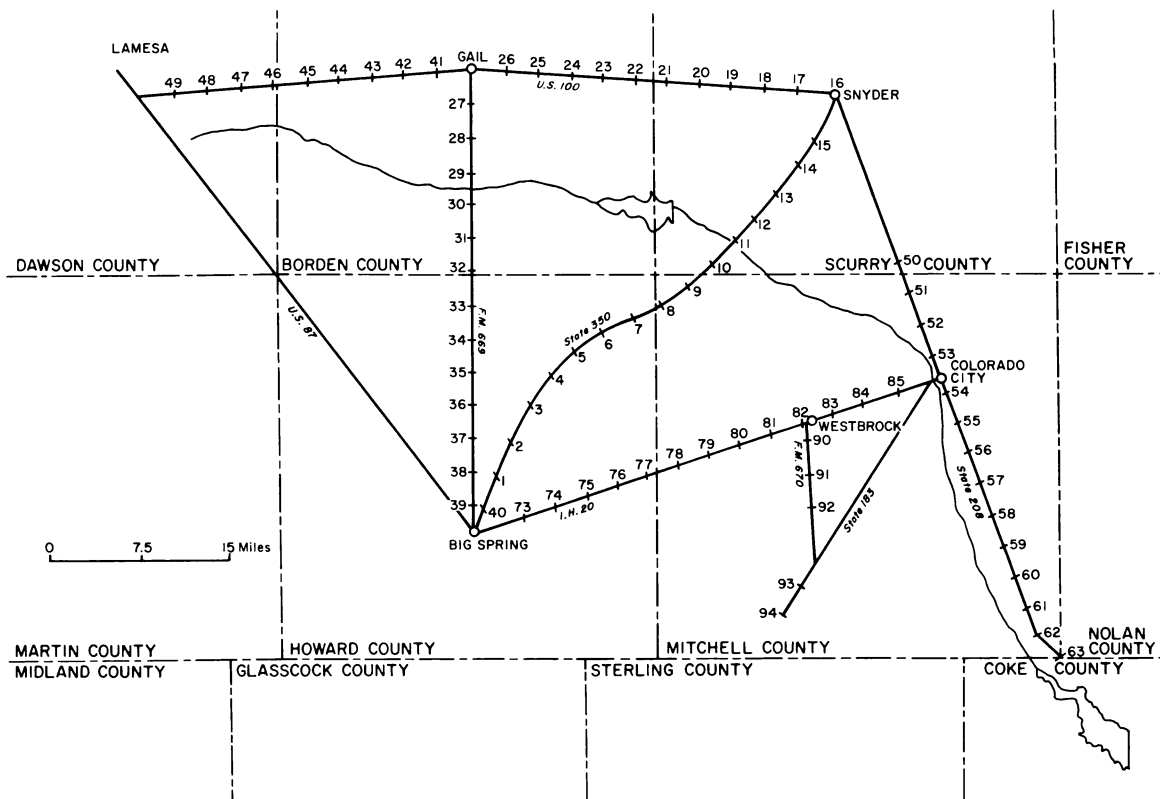
impacted the second phase of the Program which was the experimental phase. The second phase was not to begin until data collected during the initial phase were analyzed and integrated and the statistical design document was developed.

In recognition of the potential that rainfall augmentation technology may have as a viable water resource alternative, the State of Texas made limited funds available to continue the research efforts through data analysis with a goal of completing the experimental design document. However, due to the complete reduction in Federal funding no field program was conducted in 1981, which limited available information about some aspects of the rainmaking cycle.

The objective of the Texas HIPLEX Program continues to be to understand more completely the cloud and precipitation processes occurring in the Texas High Plains area. To this end each of the following organizations participated in the 1981 Texas HIPLEX Program.

- Bureau of Reclamation
- Texas Department of Water Resources
- Colorado River Municipal Water District
- Texas A&M University (Department of Meteorology)
- Texas Tech University (Atmospheric Science Group)

Their efforts focused mainly on analyses of data collected during the previous field projects of the Texas HIPLEX Program and were directed at completing the statistical design document.



The 1981 Texas HIPLEX Nonrecording Rainage Network

No field program was conducted during the summer months in West Texas this year, however, the raingage network was maintained as in years past.

Texas Department of Water Resources

The Department of Water Resources continued its role as manager and administrator of the Texas HIPLEX Program. The Department negotiated and administered a total of five Texas HIPLEX-related contracts and edited four major publications and numerous administrative and technical reports. In conjunction with personnel representing each of the participating organizations, Department staff prepared both the proposal for the 1982-1985 Texas HIPLEX Program and its Addendum. Finally, considerable work was performed on the summary report titled *Texas HIPLEX Summary Report 1975-1980*. The Summary Report synthesizes the major findings of research performed during the Texas HIPLEX exploratory phase.

Early in the year, Department staff met with representatives of the Bureau of Reclamation to discuss the Texas HIPLEX Proposal for 1982-1985. As a result of that meeting a consolidated working proposal for cloud seeding experimentation in West Texas was agreed upon and prepared. The proposal addressed the tentative cloud seeding hypotheses, the experimental unit, the conceptual model linking the physical chain of events which occur prior to rain reaching the ground, and the expected responses along the chain of events which occur as a result of cloud seeding. Representatives from both the Bureau and the Department concluded that, while significant progress toward achieving a full-scale rain-increase technology for the Texas HIPLEX region was evident, additional quantification and documentation was still needed. In particular, additional information was needed in the area of understanding better the cloud microphysics properties of the rain-producing clouds common to West Texas.

All endeavors to renegotiate a new multi-year contract with the Bureau to continue and complete the work already begun were terminated in early March when the Bureau notified the Department that in light of the administration's federal budget cuts, the overall HIPLEX program would be "mothballed." The State of Texas continued to provide funding for some areas of study.

The Colorado River Municipal Water District

During 1981, the Colorado River Municipal Water District continued to operate and maintain the Texas HIPLEX precipitation recording raingage network throughout the summer to ensure a complete record of precipitation patterns in the southern High Plains of Texas. The District continued to conduct its precipitation augmentation program independent of the Texas HIPLEX effort. However, cloud-seeding response information gained through the District's program is expected to impact future planning of the Texas HIPLEX Program.

Texas A&M University

Texas A&M University performed several analytical tasks during 1981. The university processed the 1980 field season data collected from the surface weather stations, the upper-air stations and the weather radar system. Studies were continued through the year in the area of cloud microphysics, mesoscale modelling and cloud and environmental responses to cloud seed-

ing. The latter studies provided important information regarding the role of the wind structure, low level moisture and stability to convective cloud development and maintenance.

Texas A&M University continued to perform analyses of the 1979 upper-air and surface mesoscale data base. The data were analyzed and interpreted in the same manner as in previous years. Emphasis was placed on case study days when convective clusters were recorded by the weather radar. The analyses examined the relationship between the convective clusters and environmental parameters which included wind velocity and moisture divergence, vertical wind flux, vertical flux of moisture and upper level wind patterns. The purpose of this type of research was to determine the impact of the mesoscale environmental wind patterns, energy sources and moisture on a cloud seeding experiment. These kinds of information will help distinguish days when cloud conditions are favorable for producing rain and days when cloud seeding will have no effect on the natural rain-making processes. It is important to include in the experiment only those days when cloud seeding effects are possible. Otherwise, the natural variability of convective rainfall will mask any man-made effects.

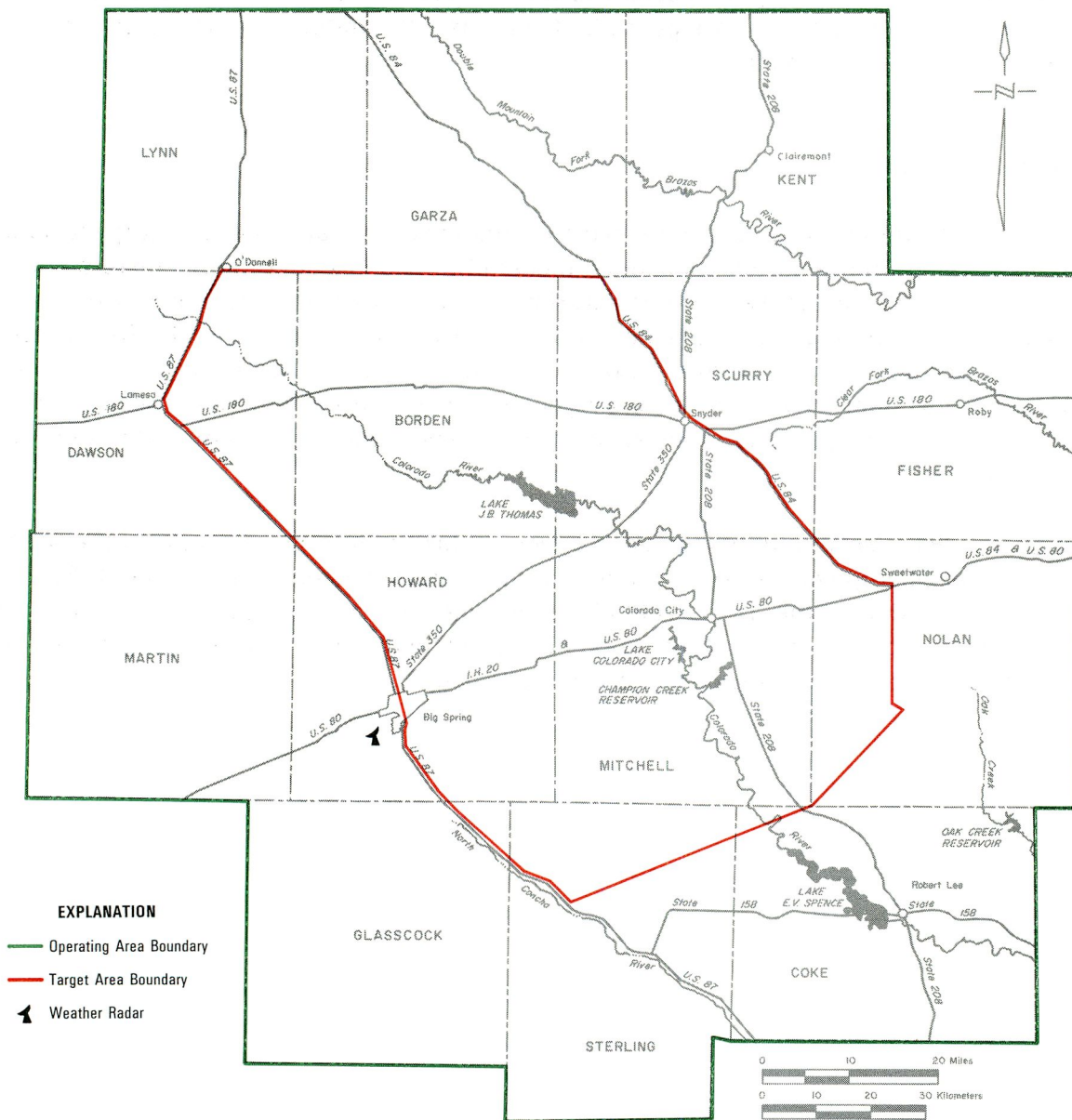
Texas Tech University

Texas Tech University continued work in the evaluation of rainfall, radar and satellite data in an effort to develop an integrated conceptual model of how convective cloud clusters and the environment interact. This task was addressed primarily by analysis of available cloud microphysical, mesoscale and raingage data collected during the 1977-1980 Texas HIPLEX field seasons and by review of the current literature. Texas Tech scientists have shown that interactions do occur between individual convective clusters when they are organized into a mesoscale precipitation system. These findings suggest that seeding convective clouds for dynamic effects may find application in West Texas.

The year 1981 also found Texas Tech University taking on a greater role in the area of convective cloud microphysic analytic studies. Cloud data collected in 1979 and 1980 were analyzed to better define the Texas HIPLEX cloud selection criteria; the type, amount and placement of the seeding material; the time frame to seed relative to cloud development; and, the expected cloud microphysical responses to cloud seeding.

Project 81-1-1. The Colorado River Municipal Water District Rainfall-Augmentation Program

The Colorado River Municipal Water District's rainfall-augmentation program was initially formed in the Spring of 1971 and has been sponsored and operated each year since by the District. The principle purpose of the program has been to increase surface runoff into the District's two storage reservoirs, Lake J. B. Thomas and Lake E. V. Spence. However, a secondary result of the weather modification program appears to have been to increase water supplies for the agricultural and the ranching communities in the target area. The project area has remained fixed in the northernmost reaches of the Colorado River basin and includes all or portions of fourteen counties located in the Permian Basin in West Texas. Cloud seeding operations were conducted during the spring, summer and fall months when convective cloud systems provided most of the area's rainfall.



**The 1981 Colorado River Municipal Water District Weather Modification Project
Area in West Texas**

Cloud seeding operations were performed by the District using a Piper Aztec aircraft. Silver iodide was dispensed into updraft regions at cloud base by igniting flares impregnated with silver iodide. The flares were contained in flare racks mounted on the trailing edge of each wing. Each flare rack held 12 end-burning pyrotechnics. The most commonly used flares during the 1981 season were two types of 20-gram flares which burned for either approximately seven minutes or forty seconds. Also available for use were flares containing 50 and 70 grams of silver iodide which were used primarily when heavy rainshower activity was in the area.

In support of the District's weather modification program a weather radar was used to monitor cloud development and help direct aircraft to the target clouds. The radar provided real-time displays of cloud development for the radar meteorologist to interpret and, after discussions with the seeding pilot, the radar meteorologist would decide the proper seeding technique for the given event. The radar provided cloud top height, cell intensity and cell location and movement.

The District employed a meteorologist licensed by the State of Texas and a full-time pilot. During the off season the meteorologist analyzed the data collected and reported the results of the cloud seeding program.

An operational summary of the 1981 program is given in the following table.

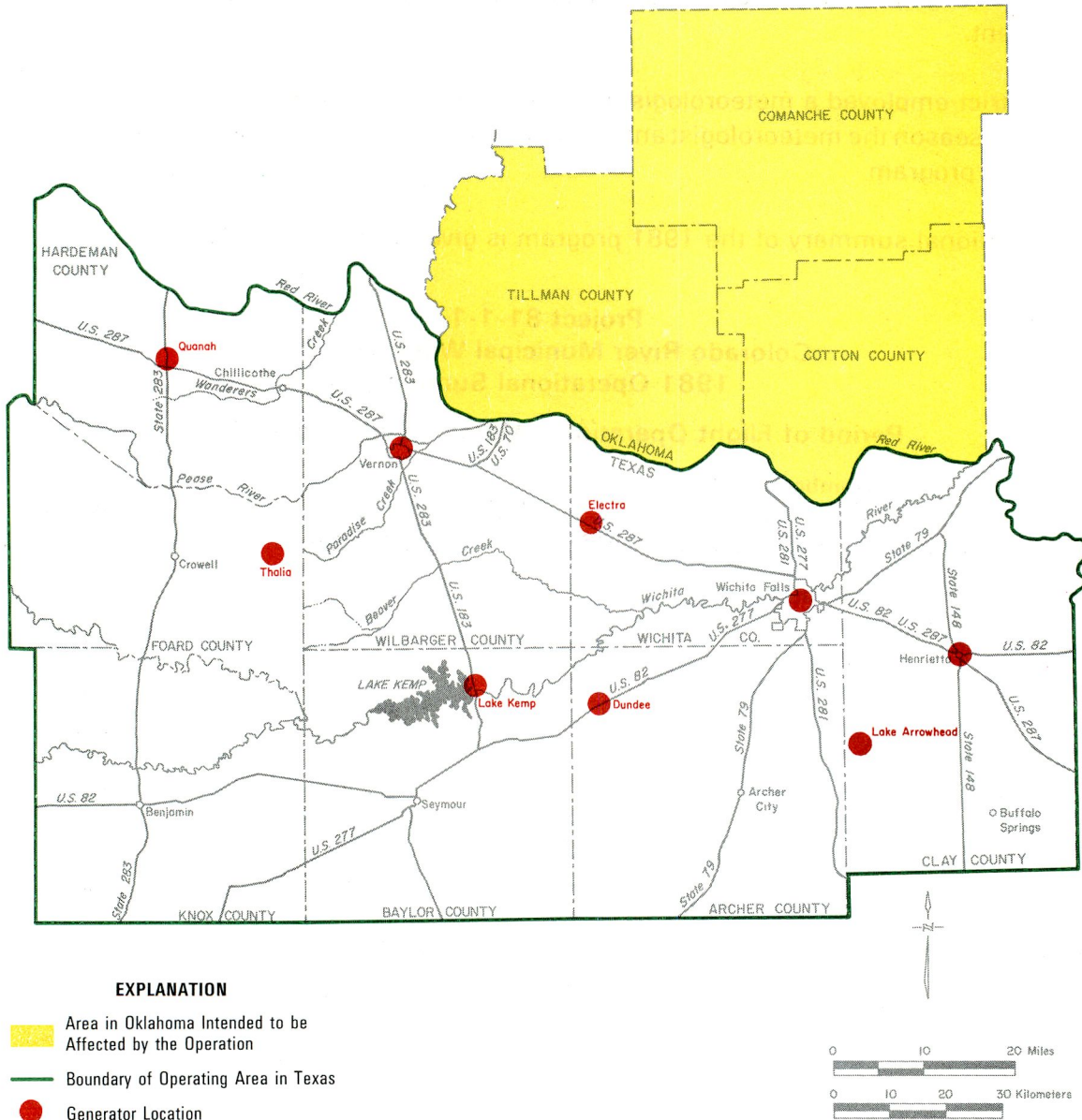
**Project 81-1-1
Colorado River Municipal Water District
1981 Operational Summary**

Period of Flight Operations: March - September 1981

<u>Month</u>	<u>Number of operational days</u>	<u>Seeding flights</u>		<u>Amount of silver iodide (grams)</u>
		<u>Number</u>	<u>Hours flown</u>	
Mar.	1	1	1.2	40
Apr.	7	8	11.9	2,470
May	2	2	3.0	210
June	1	1	1.2	200
July	2	2	2.7	360
Aug.	5	5	6.3	1,090
Sept.	3	3	4.1	330
Total	21	22	30.4	4,700

Project 81-2-3. Oklahoma Precipitation-Augmentation Program (Red River Valley)

The Irving P. Krick, Inc. of Texas company performed weather modification activities on behalf of Oklahoma sponsors Cotton County Weather Modification, Inc. and Comanche County Services, Inc. for the purpose of increasing rainfall in portions of southwest Oklahoma during the 1981 agricultural growing season. Similar cloud seeding programs by Krick, Inc. were carried out from 1972 through 1978 in the same area. The 1981 target area was situated in the Oklahoma counties of Cotton, Tillman and Comanche. The cloud seeding operations began in March and continued through October. The program was temporarily suspended in May and June at the sponsors' request for agricultural reasons.



The 1981 Weather Modification Project Area Operated by Irving P. Krick, Inc. of Texas in the Red River Valley

The size of the target area required Krick, Inc. to locate 22 ground-based silver iodide generators at various sites in the operational area; nine generators were located in Texas. Thirteen generators had an output of two grams of silver iodide per hour per generator and nine generators had an output of one-half gram of silver iodide per hour per generator. As in all ground-based generator type programs, the sites were located on the basis of expected wind flow patterns and meteorological expertise of the region. The ground-based generators were activated by local residents trained in operating procedures of the generators.

The generators used in this program produced silver iodide crystals by vaporizing silver iodide impregnated electrodes with a high temperature electric arc. The crystals were dispersed into the air currents and carried to cloud base and into the cloud by inflow currents at cloud base. Once in the cloud, cloud updrafts carried the crystals higher in the cloud to temperatures below freezing where the crystals act as ice crystals and help initiate the rainmaking process.

Cloud seeding operations were controlled by trained and State-licensed meteorologists operating out of the Krick, Inc. weather offices in Palm Springs, California. The meteorologist-in-charge monitored surface and upper-air data provided through National Weather Service teletype and map recording machines.

**Project 81-2-3
Oklahoma Precipitation-Augmentation Program
(Red River Valley)
1981 Operational Summary**

Period of Operation: March - October 1981

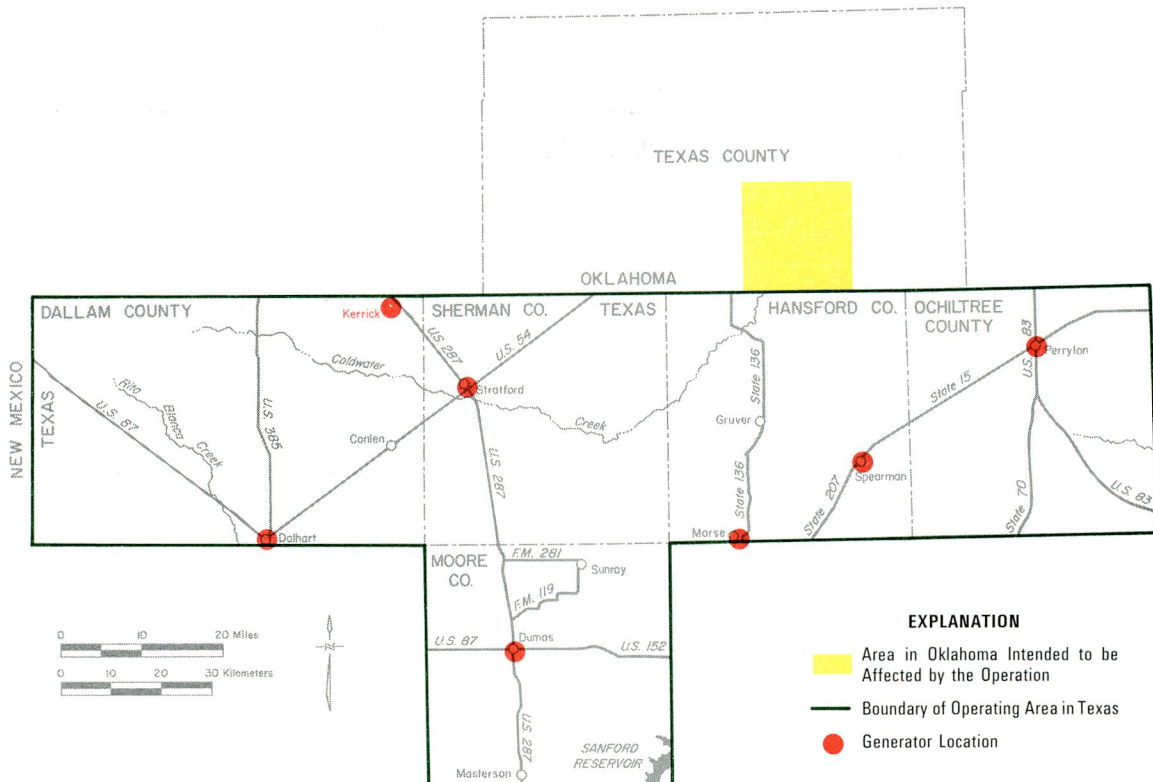
Month	Number of operational days	Number of generators in operation	Generator hours	Amount of silver iodide (grams)
Mar.	6	9	195.50	386.00
Apr.	17	9	426.75	738.75
May	14	8	570.75	1,130.00
June	1	1	1.45	3.50
July	10	6	257.00	450.00
Aug.	7	5	159.00	302.00
Sept.	12	7	228.00	433.75
Oct.	9	7	311.00	602.00
Total	76	52	2,149.45	4,046.00

Project 81-2-4. Oklahoma Precipitation-Augmentation Program (Texas Panhandle)

Weather modification operations were carried out by the Irving P. Krick, Inc. of Texas under contract with the Hitch Agri-Business, Inc. from March through October. The Hitch Ranch has supported weather modification activities in the same area continuously since 1972. The program has been operated each year for the purpose of increasing rainfall for agricultural and ranching benefit in the target area which is located between Guymon and Hitchland, in the south central portion of Texas County of Oklahoma. The operational design of the program called for the use of ground-based silver iodide generators to be located in areas surrounding the target area including parts of the northern Texas Panhandle. Nine generators were utilized with seven located in Texas.

The rainfall augmentation program was conducted by Krick, Inc. meteorologists operating from the company's weather offices located in Palm Springs, California. When atmospheric conditions became favorable for convective clouds to develop, generators were activated in the network to create a plume of silver iodide particles which were to be carried into developing cells by the mesoscale wind field. Generator operators were informed by telephone of when to switch on a generator and the period of time it was to run.

Monthly operational reports of generator activation are prepared by the Krick, Inc. meteorologists and submitted to federal and state agencies. An abbreviated version of these monthly reports is summarized in the adjoining table for the year's operational activity. The values in the table represent activation of generators located in the Texas side of the network.



The 1981 Weather Modification Project Area Operated by Irving P. Krick, Inc. of Texas in the Panhandle

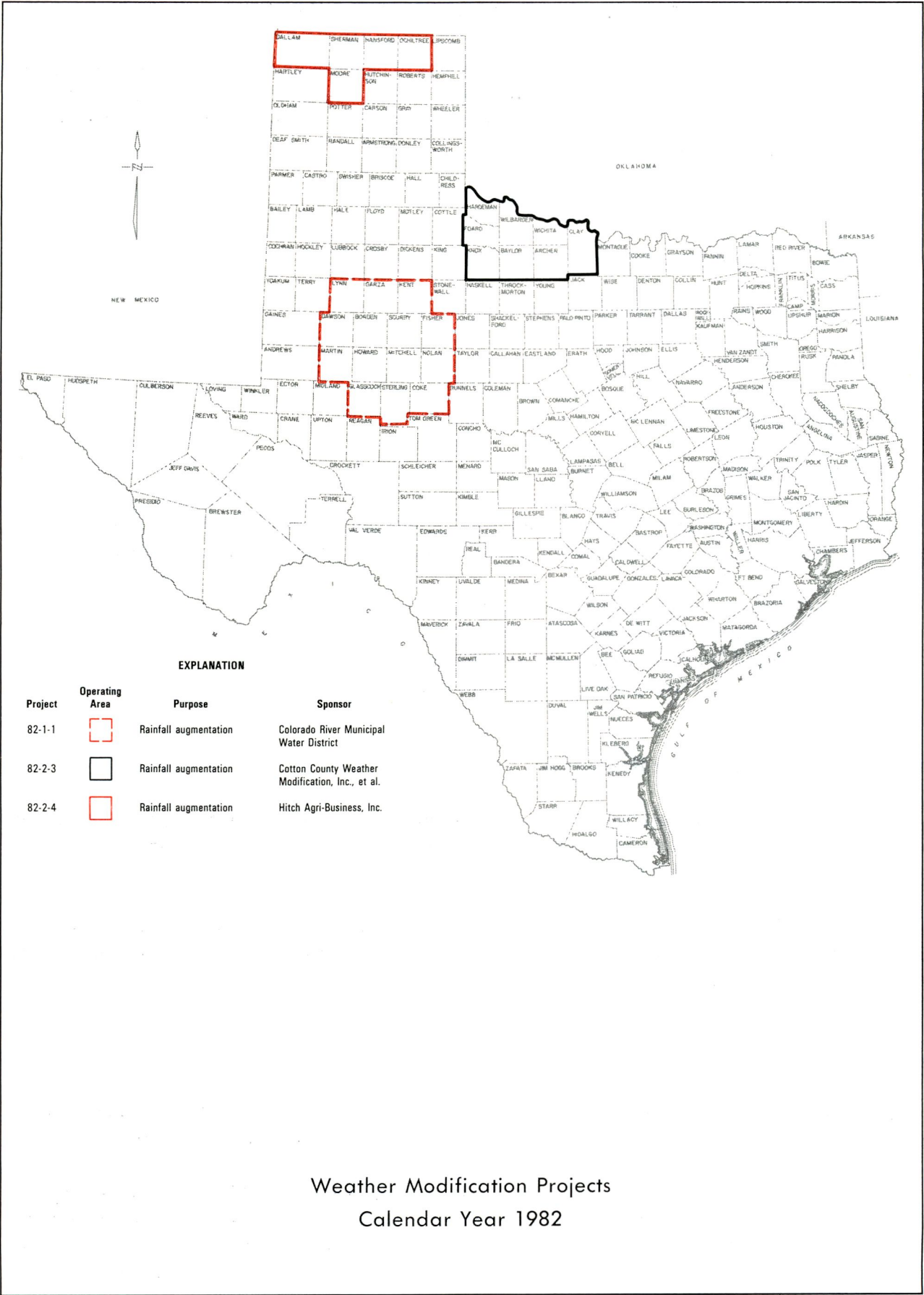
The Texas weather modification permit for this program was issued in October of 1980. The permit may remain valid for a four-year period providing the terms and conditions of the permit are satisfied.

**Project 81-2-4
Oklahoma Precipitation-Augmentation Program
(Texas Panhandle)
1981 Operational Summary**

Period of Operation: March - October 1981

<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Mar.	15	5	167.00	215.50
Apr.	10	5	136.50	152.25
May	24	5	295.00	345.51
June	14	6	185.25	152.22
July	20	5	281.25	308.13
Aug.	17	6	186.50	263.85
Sept.	12	4	132.50	168.25
Oct.	9	5	111.50	130.50
Total	121	41	1,495.50	1,736.21

**Weather Modification Projects
Calendar Year 1982**



NEW MEXICO

OKLAHOMA

GULF OF MEXICO

EXPLANATION

Project	Operating Area	Purpose	Sponsor
82-1-1		Rainfall augmentation	Colorado River Municipal Water District
82-2-3		Rainfall augmentation	Cotton County Weather Modification, Inc., et al.
82-2-4		Rainfall augmentation	Hitch Agri-Business, Inc.

**Weather Modification Projects
Calendar Year 1982**

THE 1982 TEXAS HIPLEX PROGRAM

The task for the 1982 Texas HIPLEX Program was to begin work on the experimental design document. A field program was not conducted during 1982. Analyses of data collected during the initial years of the Texas HIPLEX Program (1975-1980) tentatively identified most of the design components. These components include:

- experimental unit
- cloud seeding hypotheses
- experimental unit declaration criteria
- experimental procedure
- seeding technique
- statistical evaluation method

The 1982 Texas HIPLEX Program examined, quantified and confirmed the design components as comprehensively as available funding allowed. The participating groups included:

Texas Department of Water Resources
Colorado River Municipal Water District
Texas A&M University (Department of Meteorology)
Texas Tech University (Atmospheric Science Group)

Texas Department of Water Resources

Three contracts were negotiated and administered by the Department. Because of limited funds, two contracts with the universities terminated on August 31 and the contract with the District terminated October 31.

The 1975-1980 Texas HIPLEX Summary Report was completed by Department staff. The Summary Report synthesized the important findings of the numerous individual studies which comprised the 1975-1980 Texas HIPLEX Program.

Texas A&M University

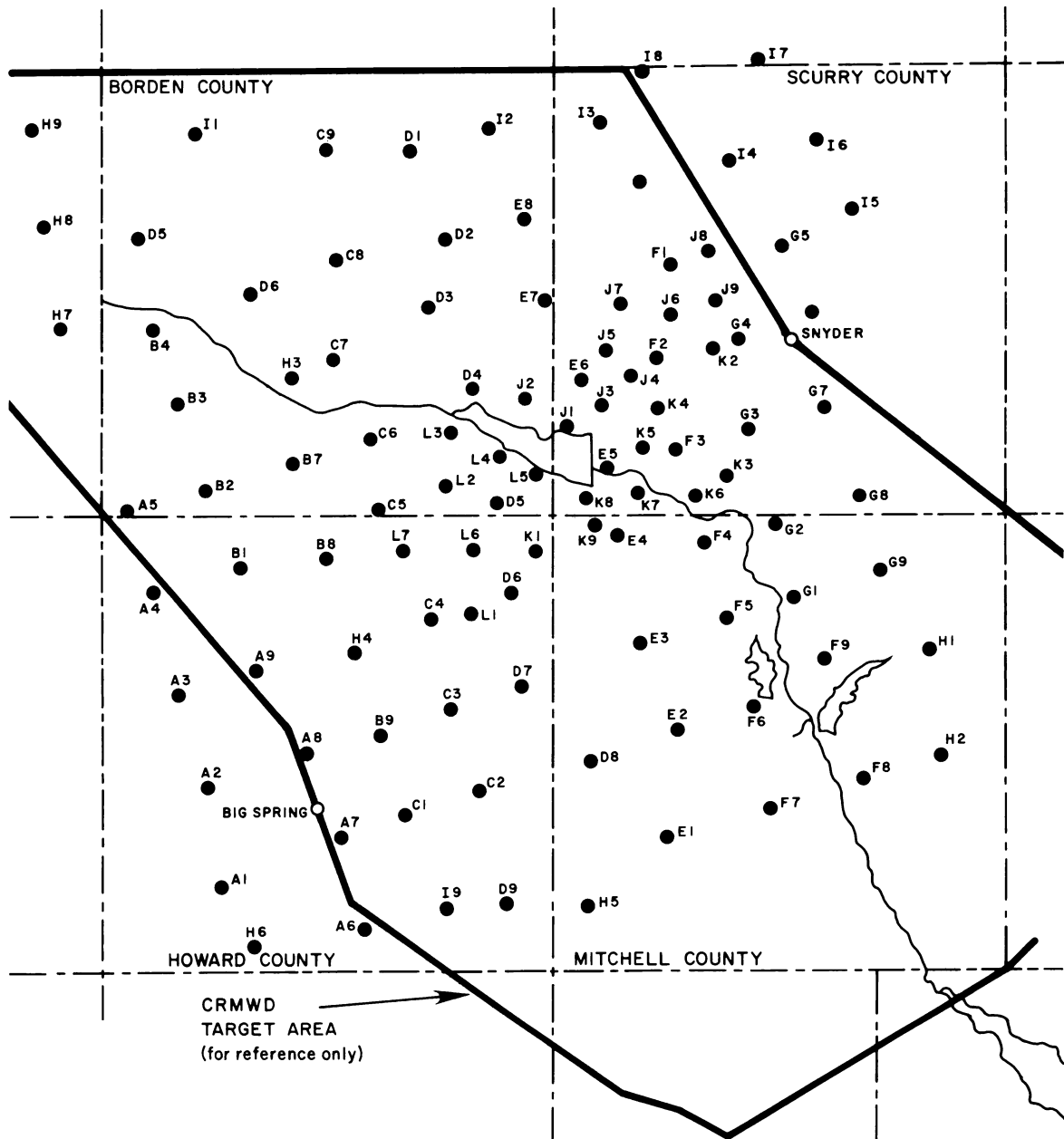
Texas A&M University completed all analyses of the 1976 through 1980 Texas HIPLEX mesoscale data. These data included surface and upper air meteorological information.

Initial development of numerical mesoscale models began in 1982. The models, when completed, will be used to: observe and understand environmental parameters; determine the impact of the environment on developing rainshower systems; identify the type of environmental conditions which offer the highest potential for rainfall enhancement; and to help verify cloud seeding effects.

Texas Tech University

Texas Tech University studied the properties of summer convective cloud systems of the Texas South Plains. In particular, Texas Tech looked at the microphysics of convective cells, the larger scale organization of the cloud systems, and the characteristics of the rainfall data.

The studies demonstrated that an experiment to enhance summer precipitation on the Texas High Plains is feasible. The experimental unit appears to be a small complex of convective clouds exceeding 7.5 kilometers in height. The cloud seeding method should be designed to increase the overall energy of the cloud system whereby it will cause an increase in upward-directed transport of surface water vapor. A statistical evaluation method was also identified.

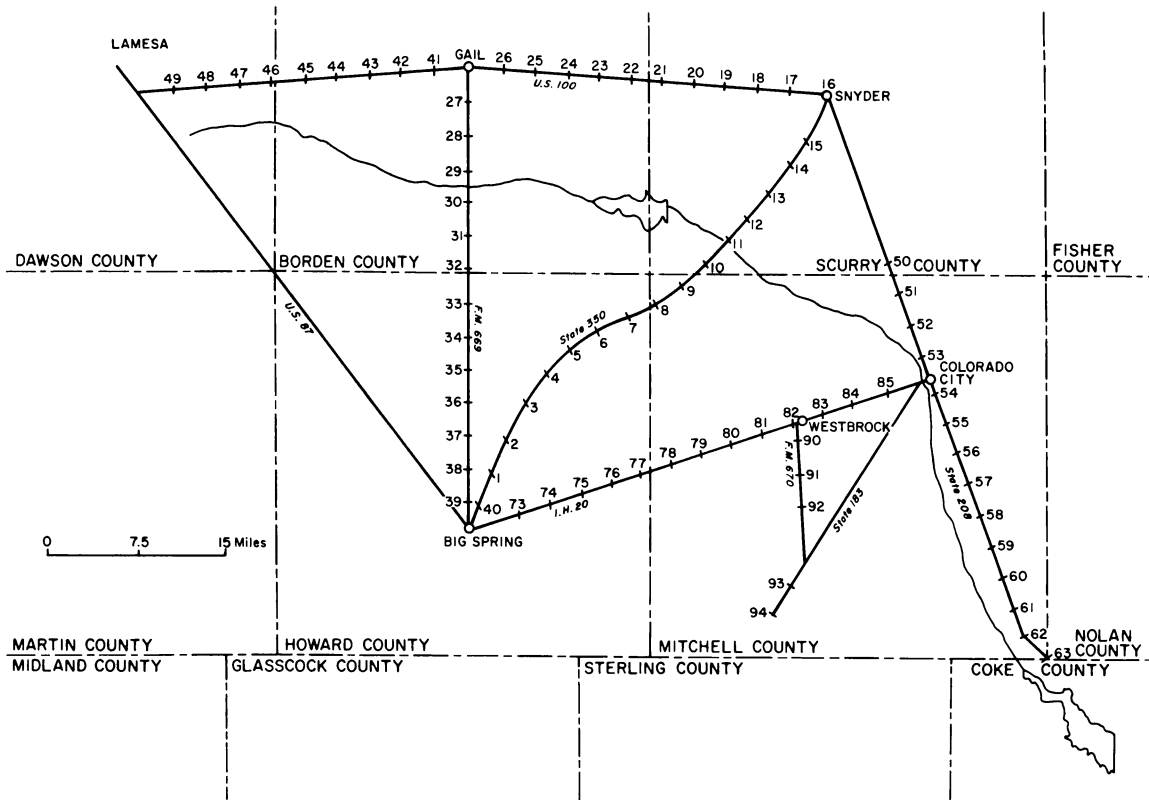


The 1982 Texas HIPLEX Recording Raingage Network

The Colorado River Municipal Water District

The Colorado River Municipal Water District has documented rainfall events over the Texas HIPLEX project area since 1975. The purpose of this activity was to establish a continuous, long-term record of the precipitation characteristics in the study area.

In 1982, the District operated the Texas HIPLEX raingage network and a weather radar during the May through September period. The raingage network had 106 recording raingages and 81 fence-post raingages from which data were collected, transcribed, and forwarded to the Atmospheric Science Group at Texas Tech University for analysis. The District also documented radar echo occurrence in the study area for the same period and transmitted those data to the Weather and Climate Section of the Texas Department of Water Resources.

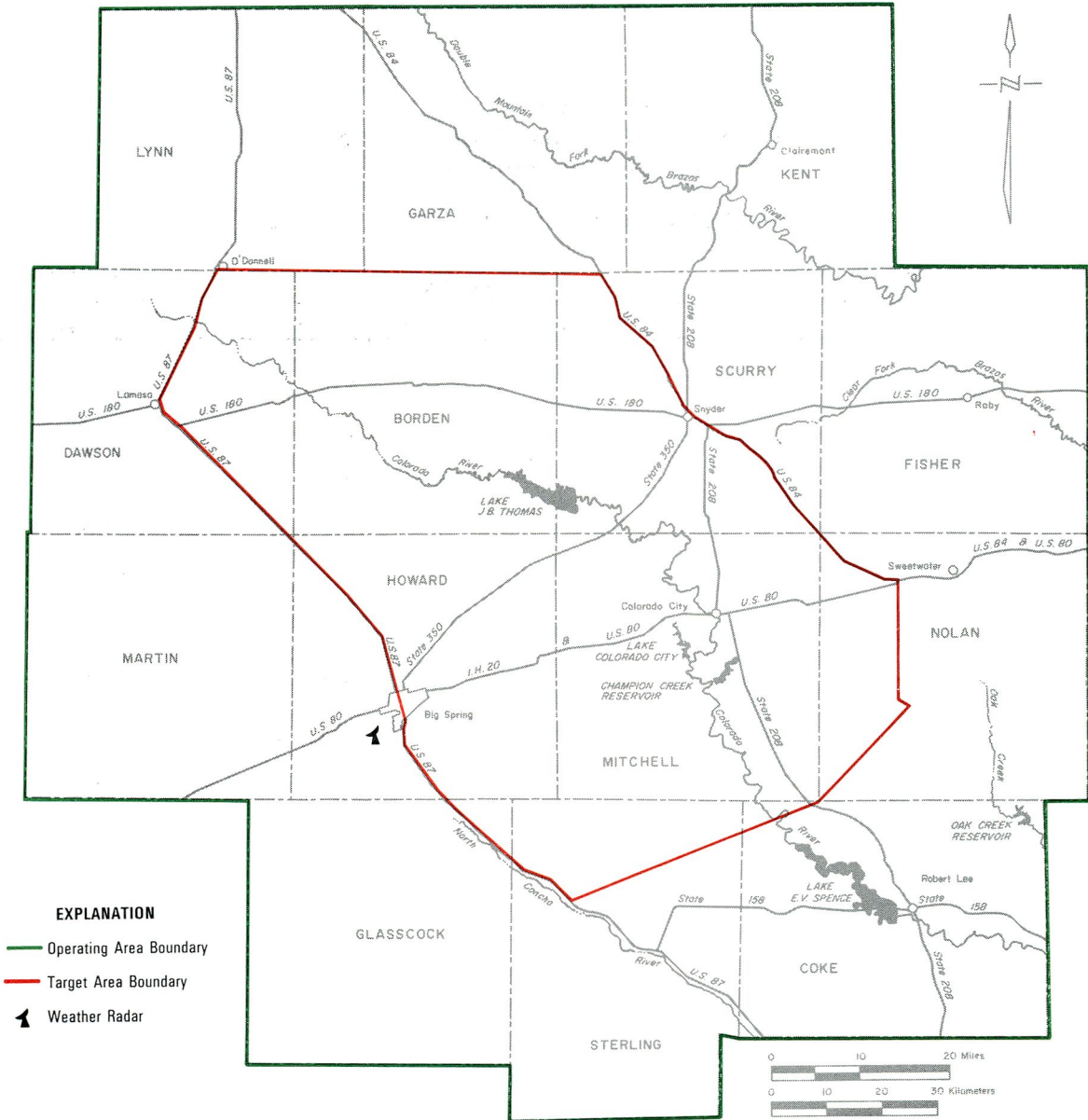


The 1982 Texas HIPLEX Nonrecording Raingage Network

Project 82-1-1. The Colorado River Municipal Water District Rainfall-Augmentation Program

The Colorado River Municipal Water District of Big Spring, Texas completed its 12th consecutive year of cloud-seeding to increase runoff into reservoirs located in the upper Colorado River basin. The District—a major water supplier of West Texas—operated its cloud seeding program during the March through October convective cloud season. According to the District’s analysis of county agricultural records, a secondary response to the District’s program had manifest itself as increased crop production in target area counties.

The District’s mode of weather modification was aircraft delivery of ice-nucleating particles (silver iodide pyrotechnics) into the updraft-inflow component of convective cells. Candidate-



**The 1982 Colorado River Municipal Water District Weather Modification Project
Area in West Texas**

clouds for seeding were selected by the program's meteorologist using a 3-centimeter weather radar based at Big Spring Industrial Airpark. The decision to nucleate a cell was made by the meteorologist based on the pilot's observation of cloud and near-cloud conditions, and radar-echo growth characteristics. Preceding atmospheric analyses were made by the meteorologist to determine if an operational day existed. Following all rainfall events, measured rainfall observations were collected from an extensive raingage network situated in the project area.

An operational summary of the District's 1982 weather modification program is given in the following table. The map delineates the operational and target areas of the program.

A Texas weather modification permit to operate this program was issued in January 1980. The permit may remain valid for a 4-year period providing all terms and conditions of permit are satisfied. The weather modification license is renewable annually, with similar requirements for renewal.

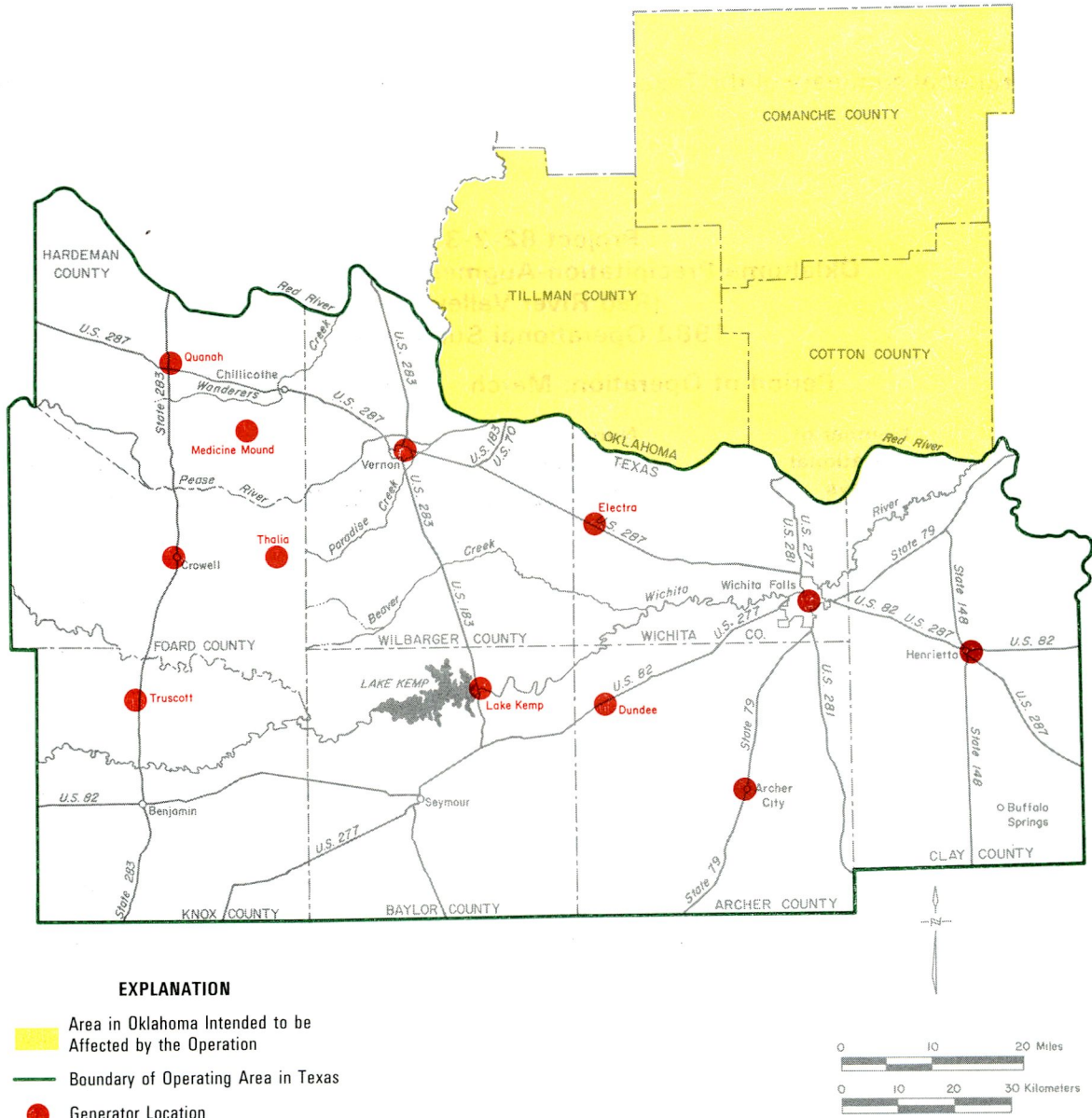
**Project 82-1-1
Colorado Municipal Water District
1982 Operational Summary**

Period of Operation: March - October 1982

Month	Number of operational days	Seeding flights		Amount of silver iodide (grams)
		Number	Hours flown	
Mar.	0	0	0	0
Apr.	2	2	0.7	220
May	6	8	6.5	1,780
June	4	4	3.4	990
July	3	3	3.1	1,010
Aug.	4	4	3.1	1,260
Sept.	1	1	0.5	280
Oct.	0	0	0	0
Total	20	22	17.3	5,540

Project 82-2-3. Oklahoma Precipitation-Augmentation Program (Red River Valley)

A precipitation augmentation program was operated in the Red River Rolling Plains region of Texas and Oklahoma during 1982 by Irving P. Krick, Inc. of Texas. Its purpose was to increase rainfall for agricultural benefit during the period March through October in Cotton, Tillman, and Comanche counties in Oklahoma. A network of ground-based silver iodide generators was set up in surrounding counties, and in Texas included the 8-county group of Hardeman, Wilbarger, Wichita, Clay, Foard, Knox, Baylor, and Archer. Twelve generators were situated in these counties to affect precipitation in Oklahoma.



The 1982 Weather Modification Project Area Operated by Irving P. Krick, Inc. of Texas in the Red River Valley

A Texas Weather Modification Permit was issued to Krick, Inc. in March 1981 to conduct this program over a 4-year period, ending in March 1985. This permit remains valid providing procedural and operational requirements are met each year by Krick, Inc. The 1982 program completes nine years of operating this type of precipitation augmentation program in this area since 1972.

Cloud-seeding operations were conducted by activating generators in the network during designated times. The program was controlled by Krick, Inc. meteorologists based in Palm Springs, California. Weather conditions in the project area were monitored for convective cloud development. The generators were activated at the discretion of the meteorologist-on-duty by telephone instruction to local generator operators. According to conditions of permit, the program was not to be operated when prevailing wind conditions would cause an effect over Texas counties.

An operational summary of the Texas-based generator network is provided in the following table.

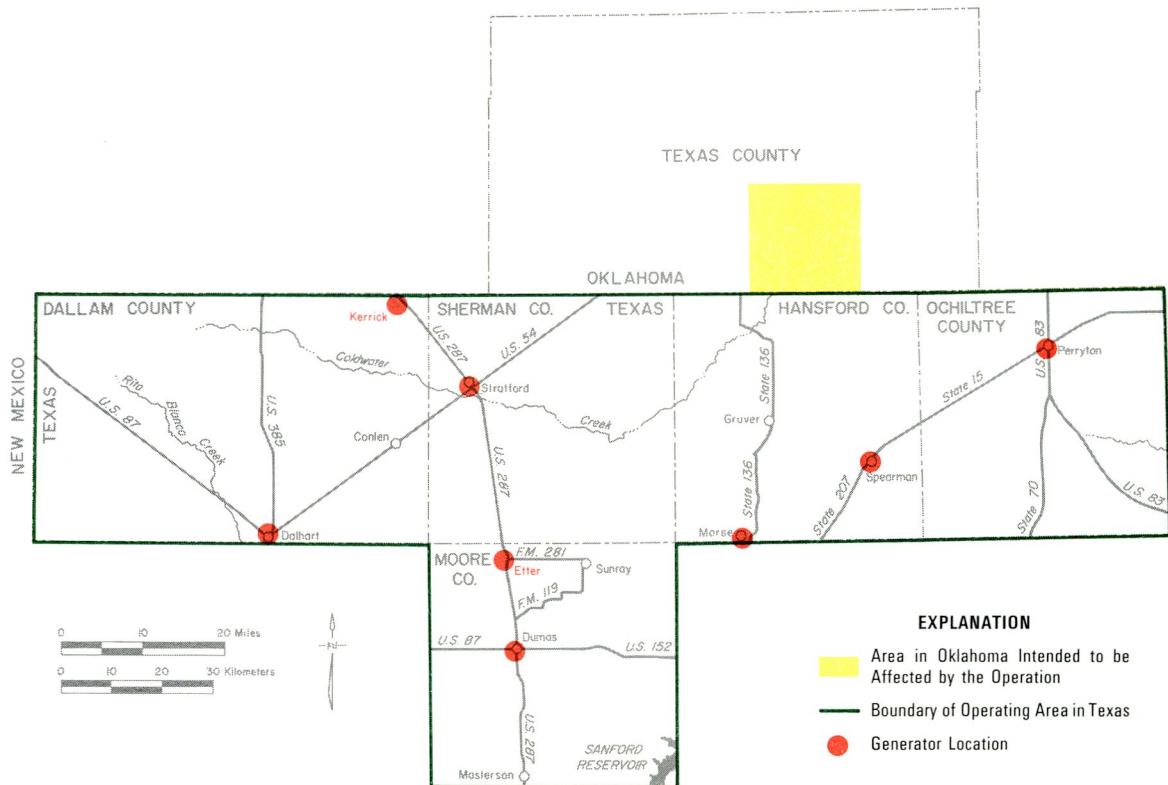
**Project 82-2-3
Oklahoma Precipitation-Augmentation Program
(Red River Valley)
1982 Operational Summary**

Period of Operation: March - October 1982

<u>Month</u>	<u>Number of operational days</u>	<u>Number of generators in operation</u>	<u>Generator hours</u>	<u>Amount of silver iodide (grams)</u>
Mar.	9	9	224.00	370.00
Apr.	17	10	546.55	1,035.00
May	9	9	373.00	682.65
June	0	0	0	0
July	4	4	34.00	68.00
Aug.	4	4	35.75	71.50
Sept.	10	9	305.00	610.00
Oct.	7	10	223.50	465.00
Total	60	55	1,741.80	3,302.15

Project 82-2-4. Oklahoma Precipitation-Augmentation Program (Texas Panhandle)

A weather modification program was conducted in the Texas Panhandle to increase precipitation in a section of Texas County, Oklahoma during the period March through October. The mode of cloud-seeding was by ground-based, silver iodide generator. An 8-generator network was situated upwind of the target area in the Texas counties of Dallam, Sherman, Hereford, Ochiltree, and Moore, and in Oklahoma. The generators were activated to dispense silver iodide particles into the prevailing wind towards the target area when atmospheric conditions were favorable for convective cloud formation.



The 1982 Weather Modification Project Area Operated by Irving P. Krick, Inc. of Texas in the Panhandle

This program was conducted by Irving P. Krick, Inc. of Texas to benefit agricultural operations for Hitch Agri-Business, Inc. of Guymon, Oklahoma. This was the 11th year weather modification activities were conducted in this area since 1972. The program was controlled by meteorologists of Krick, Inc. in Palm Springs, California where weather conditions affecting the target area were monitored. Generators in the network were activated by telephone contact with local generator operators. An operational summary of this program is given in the following table.

A Texas Weather Modification Permit to conduct this operation was issued to Krick, Inc. for the 4-year period beginning in October 1980. The operator may continue the operation each successive year of the permit when procedural and operational requirements are satisfied.

Project 82-2-4
Oklahoma Precipitation-Augmentation Program
(Texas Panhandle)
1982 Operational Summary, Texas Network
Period of Operation: March - October 1982

Month	Number of operational days	Number of generators in operation	Generator hours	Amount of silver iodide (grams)
Mar.	7	5	118.00	194.00
Apr.	13	5	104.70	92.50
May	23	6	356.00	479.50
June	21	4	326.75	285.86
July	17	5	292.25	274.80
Aug.	20	7	295.00	381.50
Sept.	16	5	209.75	301.12
Oct.	8	2	69.25	157.50
Total	125	39	177.17	2,166.78

REFERENCES

- Allaway, W., L. Lippke, R. F. Riggio, and C. Tuck, 1975: The economic effects of weather modification activities. Part I: Crop production in the Big Spring-Snyder area. Texas Water Development Board WR-1, Texas Department of Water Resources, Austin, Texas, 50 pp.
- Eaves, C. D., 1952: Charles William Post. The Handbook of Texas, Volume 2, 397 pp.
- Girdzus, J. P., 1979: 1979 Weather Modification Program Rain Enhancement, Colorado River Municipal Water District, Big Spring, Texas, 32 pp.
- _____, 1980: 1980 Weather Modification Program Rain Enhancement, Colorado River Municipal Water District, Big Spring, Texas, 32 pp.
- Hearings before the Committee on Commerce, U.S. Senate, 89th Congress, 1966. U.S. Government Printing Office, Washington, D.C.
- Kengla, M., R. Morey, J. Hull, and H. W. Grubb, 1979: The economic effects of weather modification activities. Part III: Irrigated and dryland agriculture with estimates of production, and income effects on the area economy. TDWR LP-21, Texas Department of Water Resources, Austin, Texas, 59 pp.
- Lippke, L. A., 1976: The economic effects of weather modification activities. Part II: Range production and interindustry analysis. TDWR LP-21, Texas Department of Water Resources, Austin, Texas, 83 pp.
- Powers, E., 1890: War and the Weather, E. Powers (Revised Edition) Delavan, Wisconsin.
- Riggio, R., W. Alexander, T. Larkin, and G. Bomar, 1982: Texas HIPLEX Summary report, 1975-1980. TDWR LP-184, Texas Department of Water Resources, Austin, Texas, 176 pp.