ANNUAL EVALUATION REPORT 2014 **State of Texas**

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Cloud seeding operations 2014 began over the Texas Weather Modification Target Area in March (Wichita Falls Project), but because of data unavailability the first evaluated operational day was April 3rd (first operational day for the WTWMA target area) . This annual report is a compilation of the evaluation reports already made and published for five local projects: Panhandle, North Texas (two subprojects, Wichita Falls and Rolling Plains), Trans-Pecos, WTWMA, STWMA target areas (EAA target area is included in the last one). A total of **351 clouds** were seeded and identified by TITAN in **137 target area operational days**. Table 1 summarizes the general figures:

Table 1: Generalities

First evaluated operational day: **April 3rd, 2014 (WTWMA)**
Last operational day: **October 10th, 2014 (WTWMA)** **Season: 191 days**

Net Number of operational days: 137
Most active period: May to September: 126 ~ 92 % of the operational days,
Less active months: April: 10 ~ 7.3 % of the operational days
October: 1 ~ 0.7 % of the operational days

According to the daily reports, operational days were qualified as:

Eighty-two with excellent performance
Twenty-seven with very good performance
Thirteen with good performance
Four with fair performance

Additionally, ten days with non proper data, and one was defined as experimental

Number of seeded clouds: 351
(173 small seeded clouds, 67 large seeded clouds, 111 type B seeded clouds)

Missed Opportunities: 12 (~ 3.3 % of the seedable conditions)

Small Clouds

Table 2 shows the average results from the classic TITAN evaluations for the 173 small seeded clouds which obtained proper control clouds.

Table 2: Seeded Sample versus Control Sample (173 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	61 min	42 min	1.45	45 (**29**)
Area	66.7 km^2	45.5 km^2	1.47	47 (**38**)
Volume	223.4 km^3	130.5 km^3	1.71	71 (**45**)
Top Height	9.1 km	8.2 km	1.11	11 (**3**)
Max dBz	51.2	49.3	1.04	4 (**1**)
Top Height of max dBz	3.7 km	3.7 km	1.00	0 (**-2**)
Volume Above 6 km	62.6 km^3	32.3 km^3	1.94	94 (**63**)
Prec.Flux	450.7 m^3/s	264.3 m^3/s	1.71	71 (**52**)
Prec.Mass	1927.3 kton	782.2 kton	2.46	146 (**112**)
CloudMass	166.7 kton	91.1 kton	1.83	83 (**52**)
η	11.6	8.6	1.35	35 (**40**)

Bold values in parentheses are modeled values, whereas η is defined as the quotient of Precipitation Mass divided by Cloud Mass, and is interpreted as efficiency. A total of **906 AgI and 78 hygroscopic flares** were used in this sub-sample with an excellent timing (**84 %),** for an effective AgI dose about **70 ice-nuclei per liter,** which might have reached slightly higher levels in some individual cells. An excellent increase of 112 % in precipitation mass together with an increase of 52 % in cloud mass illustrates that the seeded clouds grew at expenses of the environmental moisture (they are open systems) and used only a fraction of this moisture for their own maintenance. The increases in lifetime (29 %), area (38 %), volume (45 %), volume above 6 km (63 %), and precipitation flux (52 %) are notable. There are slight increases in maximum reflectivity (1 %), and in top height (3 %). The seeded sub-sample seemed 40 % more efficient than the control sub-sample. Results are evaluated as **excellent** for this sub-sample.

An increase of 112 % in precipitation mass for a control value of 782.2 kton in 173 cases means:

Δ_1 = 173 x 1.12 x 782.2 kton ≈ 151 559 kton ≈ 122 914 ac-f **(mean layer: 0.52 in)**

Large Clouds

The sub-sample of 67 large seeded clouds received a synergetic analysis. In average the seeding operations on these large clouds affected 76 % of their whole volume, with an excellent timing (99 % of the material went to the clouds in their first half-lifetime). A total of **1027 AgI and 136 hygroscopic flares** were used in this sub-sample for an effective silver iodide average dose near **70 ice-nuclei per liter**.

Also in average, large clouds were 21 minutes old when the operations took place; the operation lasted about 32 minutes, and the large seeded clouds lived 258 minutes (4 hours and 18 minutes).

Table 3 shows the corresponding results:

Table 3: Large Seeded Sample versus Virtual Control Sample (67 couples, averages)

Variable	**Seeded Sample**	**Control Sample**	**Simple Ratio**	**Increases (%)**
Lifetime	258 min	215 min	1.20	20
Area	1539 km^2	1307 km^2	1.18	18
Volume	7202 km^3	6125 km^3	1.18	18
Volume Above 6 km	2720 km^3	2220 km^3	1.22	22
Prec.Flux	13 345 m^3/s	9 687 m^3/s	1.38	38
Prec.Mass	91 426 kton	54 849 kton	1.67	67

An increase of 67 % in precipitation mass for a control value of 54 849 kton in 67 cases may mean:

Δ_2 = 67 x 0.67 x 54 849 kton ≈ 2 462 172 kton ≈ 1 996 821 ac-f **(mean layer: 0.94 in)**

Type B Clouds

The sub-sample of 111 type B seeded clouds also received a synergetic analysis.
In average the seeding operations on these type B clouds affected 17 % of their whole volume with an excellent timing (80 % of the material went to the clouds in their first half-lifetime). A total of **1279 AgI and 243 hygroscopic flares** were used in this sub-sample for an effective silver iodide average dose about **105 ice-nuclei per liter.** .

Also in average, type B clouds were 133 minutes old when the operations took place; the operation lasted about 33 minutes, and the type B seeded clouds lived 304 minutes (5 hours and 4 minutes)

Table 4 shows the results:

Table 4: Type B Seeded Sample versus Virtual Control Sample (111 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	304 min	294 min	1.03	3
Area	3217 km^2	3105 km^2	1.04	4
Volume	9373 km^3	9070 km^3	1.03	3
Volume Above 6 km	3054 km^3	2923 km^3	1.05	5
Prec.Flux	15 221 m^3/s	14 613 m^3/s	1.04	4
Prec.Mass	113 672 kton	106 117 kton	1.07	7

An increase of 7 % in precipitation mass for a control value of 106 117 kton in 111 cases may mean:

Δ_3 = 111 x 0.07 x 106 117 kton ≈ 824 529 kton ≈ 668 693 ac-f **(mean layer: 0.09 in)**

The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3$ = 2 788 428 ac-f ≈ 2.79 millions ac-f

Micro-regionalization

Increases in precipitation mass were analyzed county by county in an attempt to better describe the performance and corresponding results. **Table 5** below offers the details:

Table 5: Results per county

County	Initial seeding	Extended seeding	Acre-feet (increase)	Inches (increase)	Rain gage (season value)	% (increase)
Panhandle Ground Water Conservation District Program						
Armstrong	**11**	**14**	**97 300**	**1.97**	**17.36 in**	**11.3**
Carson	**9**	**19**	**95 500**	**1.93**	**20.47 in**	**9.4**
Donley	**1**	**5**	**43 900**	**0.88**	**19.96 in**	**4.4**
Gray	**2**	**9**	**58 700**	**1.22**	**15.19 in**	**8.0**
Potter	**11**	**12**	**71 900**	**1.49**	**17.63 in**	**8.5**
Roberts	**1**	**6**	**61 200**	**1.23**	**17.25 in**	**7.1**
Wheeler	**1**	**6**	**39 100**	**0.81**	**15.10 in**	**5.4**
Hemphill		1	7 800			
Hutchinson		2	17 700			
Collingsworth	1	2	8 100			
Ochiltree		1	7 800			
Randall		4	42 500			
Lipscomb		1	8 000			
Sub-total	**37**	**82**	**559 500 ac-f**	**(16 % outside the target area)**		
Averages (only for the bold values)				**1.36 in**	**17.57 in**	**7.7 %**

North Texas Program: Wichita Falls

Motley	1	1	6 200	0.12	19.57 in	0.6 %
Cottle	---	2	13 300	0.27	18.21 in	1.5 %
Foard	4	8	19 500	0.51	17.27 in	~ 3 %
King	2	3	8 900	0.18	16.61 in	1.1 %
Wichita West	**7**	**14**	**47 900**	**0.27**	**17.92 in**	**1.6 %**
Wilbarger	1	9	26 400	0.51	17.54 in	2.9 %
Baylor	3	11	42 100	1.12	15.11 in	7.4 %
Throckmorton	5	10	43 900	0.91	12.68 in(*)	7.2 %
Wichita Central	**9**	**30**	**112 400**	**0.85 in**	**15.11 in**	**5.8 %**
Wichita	1	5	21 600	0.64	16.11 in	4.0 %
Archer	4	12	39 400	0.86	15.19 in	5.7 %
Young	2	11	44 300	0.90	14.23 in(*)	6.3 %
Clay	3	12	42 500	0.72	17.00 in	4.2 %
Wichita East	**10**	**40**	**147 800**	**0.78 in**	**15.63 in**	**5.1 %**

North Texas Program: Rolling Plains

Stonewall	3	3	9 200	0.20	n/a	
Knox	6	10	29 800	0.66	14.67	4.5 %
Haskell	2	11	13 000	1.13	12.07(*)	9.3 %
Jones	2	3	5 500	0.11	n/a	
Rolling Plains	**13**	**27**	**57 500 ac-f**	**0.53 in**	**13.37 in**	**6.9 %**

Outside the North Texas target areas

Hardeman	---	2	3 100	0.08	19.87 in[(*)]	0.4 %
Jack	---	9	41 500	0.85	14.60 in[(*)]	5.8 %

(*) interpolated values

Sub-totals	**39**	**122**	**410 200 ac-f**			
Averages				**0.66 in**	**16.08 in**	**~ 4.9 %**

Outside the target areas (downwind effect): 44 600 ac-f (~ 11 % of the total increase)

West Texas Weather Modification Association Program

Sterling	**14**	**16**	**92 000**	**1.16**	**10.59 in**	**11.0 %**
Reagan	**13**	**22**	**175 900**	**2.80**	**15.52 in**	**18.0 %**
Irion	**16**	**25**	**154 500**	**2.74**	**13.18 in**	**20.9 %**
Tom Green	**18**	**28**	**108 100**	**2.65**	**15.46 in**	**17.1 %**
Crocket	**11**	**19**	**179 700**	**1.19**	**13.01 in**	**9.1 %**
Schleicher	**26**	**39**	**164 400**	**2.35**	**15.38 in**	**15.3 %**
Sutton	**11**	**17**	**95 000**	**1.24**	**9.20 in**	**13.5 %**
Outside TA	2	8	~ 118 800	**(~ 11 % of the total amount)**		

Sub-totals	**111**	**174**	**1 088 000 ac-f**			
Averages (only for the bold values)				**2.02 in**	**14.13 in**	**15.0 %**

Trans-Pecos Weather Modification Program

Culberson	**6**	**6**	**6 200**	**0.03**	**9.86**	**0.3**
Reeves	**30**	**31**	**41 500**	**0.29**	**4.08**	**7.1**
Pecos	**14**	**16**	**45 300**	**0.19**	**5.19**	**3.7**
Ward	**5**	**6**	**30 200**	**0.68**	**5.81***	**11.7**
Loving	**2**	**2**	**9 200**	**0.25**	**2.30***	**11.0**

Outside 36 700 (~ 22 % of the total increase)
(downwind effect over Winkler, Ector and Crane Counties)

Sub-totals	**57**	**61**	**169 100 ac-f**			
Averages				**0.29 in**	**5.45 in**	**6.8 %**

South Texas Weather Modification Association Program

Uvalde	**5**	**8**	**8 500**	**0.10**	**15.86 in**	**0.6**
Bandera	**5**	**8**	**2 600**	**0.07**	**18.93 in**	**0.4**
Medina	**10**	**12**	**19 200**	**0.25**	**12.26 in**	**2.0**
Bexar	**3**	**9**	**44 700**	**0.67**	**16.12 in**	**4.2**
Frío	**5**	**8**	**11 700**	**0.20**	**12.26 in**	**1.6**
Atascosa	**17**	**24**	**78 700**	**1.19**	**18.23 in**	**6.5**
McMullen	**16**	**22**	**55 600**	**0.94**	**8.19 in**	**11.5**
Wilson	**6**	**14**	**42 500**	**1.00**	**15.13 in**	**6.6**
Karnes	**20**	**30**	**47 300**	**1.19**	**15.79 in**	**7.5**
Live Oak	**4**	**13**	**61 400**	**1.12**	**8.94 in***	**12.5**
Bee	**12**	**15**	**35 400**	**0.75**	**9.69 in**	**7.7**

Outside	7	15	16 800			
Sub-totals	**107**	**172**	**424 200 ac-f**			
Averages				**0.68 in**	**13.76 in**	**5.6 %**

(**Initial seeding** means the counties were the operations began, whereas **extended seeding** means the counties favored by seeding after the initial operations took place).

(*) Interpolated values

Table 6: Synoptic Summary

Program	Initial	Extended	Acre-feet	Increase	Season Rain	%
PGCD	**37**	**82**	**559 500**	**1.36 in**	**17.57 in**	**7.7**
North Texas	**39**	**122**	**410 200**	**0.66 in**	**16.08 in**	**4.9**
WTWMA	**111**	**174**	**1 088 000**	**2.02 in**	**14.13 in**	**15.0**
Trans-Pecos	**57**	**61**	**169 100**	**0.29 in**	**5.45 in**	**6.8**
STWMA	**107**	**172**	**424 200**	**0.68 in**	**13.76 in**	**5.6**
Totals	**351**	**611**	**2 651 000 ac-f**			
Averages				**1.00 in**	**13.40 in**	**8.0 %**

Outside the target areas (downwind effect): 306 400 ac-f (~ 12 % of the total increase)

Total amount of flares used: 3212 (AgI) plus 457 (Hygroscopic)

Final Comments

1) Results are evaluated as **excellent**.

2) The micro-regionalization analysis showed increases per county; the average increase in precipitation, referred to an average seasonal value, is about **8.0 %**;

3) Radar estimations of precipitation should be considered as measurements of trend. Nevertheless, **seeding operations improved the dynamics of seeded clouds**.

4) During the 2014 cloud seeding campaign in Texas, hygroscopic seeding became an important component of the operations, especially for the North Texas, West Texas, and South Texas Programs. When possible, **it is recommended to perform dual seeding operations in order to obtain the desire synergy** (see details on the corresponding aforementioned regional evaluation reports).