ALBERTA WEATHER MODIFICATION CO-OP PROGRAM

J. T. Bishop

Alberta, Canada

I appreciate this opportunity to present several studies of the results of the cloud seeding program carried out by the Alberta Weather Modification Co-op over the period 1956-1968. The public interest created in this science by this program was a major factor in the decision of the Alberta Government to support the development of weather modification in Alberta. Many of you will have read about this program in the article by Dr. Irving P. Krick and Newton C. Stone covering this work in the recent Weather Modification Journal. This gives you some background.

It should be noted when this program began in 1956, this area was considered one of the worst hail areas in the world with commercial hail companies refusing to write any hail insurance at all. Numerous farmers reported being seriously hailed six and eight years out of ten. Therefore, as soon as it appeared possible to do something to reduce these immense losses, farmers organized to see what could be accomplished. In discussion it was considered if there was one chance in a hundred something could be done to reduce our immense hail losses we must give it that chance and we proceeded on that basis.

Our objective search for even such slim reason to justify proceeding with the development of this hope soon ran into conflict with scientific elements who were at the other end of the spectrum and refused to consider any evidence as valid unless it could be certified as such at 95 chances out of 100. A great deal of misunderstanding resulted from the failure of each group to understand the viewpoint of the other. This created confusion in the mind of the public that made it difficult to carry on.

Fortunately, today responsible people in both camps recognize the validity of both views and realize that real progress in the development of this science can only be made by proceeding simultaneously from both positions. As a result, I can now present the simple practical reports prepared by the Alberta Weather Modification Co-op without fear of misunderstanding from conservative researchers striving for a maximum validification of results.

First, I will present an example of our earlier attempts at analyzing results for ourselves in which we merely observed the amount of seeding done by ground generators and aircraft on major hail days and related this to known results. See Figure 1. This particular report is for the 1963 season and contributed to our observations that there appeared to be a definite relationships between the extent of operations and the amount of damage that occurred in a particular storm. Damage was comparatively limited when major operations were mounted. It appeared serious damage occurred when the potential for hail was underestimated which resulted in a less extensive operation, e.g. items underlined.

In addition, details of operations on individual storms gave strong evidence of rain increase.

FIGURE 1

Analysis Cloud Seeding Reports for Hail Suppression 1963.

Where maximum generator hours were operated for the most severe hail days plus required aircraft hours, very little hail damage ever occurred. Hail occurred only when ground generator preparations were less intense - tailored to apparently low risk days that exceeded expectations. It appears while aircraft make an essential contribution, they cannot overcome a deficiency of ground generator operations.

EXAMPLE:-

DATE	ELECTRIC GENERATOR	COKE GENERATOR	AIRCRAFT HOURS	RESULTS	COMMENTS
June 27	120	79	5½	Severe hail at Carbon	Very light operation. Worst hail of season.
July 7	112	336	6½ (2 aircraft after 6 p.m. to dark).	50% to 75% Clairsholm north - 100% north Bow River, Indus-Shepard. Rain across project. Hail again from Olds to Rocky Mountain House.	Well prepared. Heavy operation of ground generator. Excellent results.
July 5	108	332	17½	Trace of hail west of Airdrie - small area NE of Airdrie reported hail 37,000 foot cloud tops.	Heavy operations. Very good results.
July 6	96	224	9½	Severe threat, no damage. Storm Olds through north Three Hills rain	Excellent results.
July 30	120	177	12½	Beiseker storm - 2x10 miles. Storm continued across north of Drumheller as good rain. One report of damage east of Carbon.	Medium operations. Excellent results on project.
July 31	120	229	19½	Some hail reported Irricana area.	Good results.
Aug 2	120	251	21½	No known damage	Medium operation of ground generator, heavy aircraft
Aug 5	120	168	19	2 inches rain Three Hills area. Damage from second storm west of Linden	Medium operations. Heavy aircraft.
Aug 7	120	194	20½	No damage. Excellent results.	Heavy damage both west and east of project.
Aug 14	120	242	21	Spectacular storm through Kneehill, very light damage occasionally. Excellent results. Storm south Calgary north Strathmore. Light damage.	Excellent reslults.
Aug 15	120	288	16	Storms all over project. Hail damage near Huzar. 40,000 foot tops east of project.	Heavy damage east of project to several townships

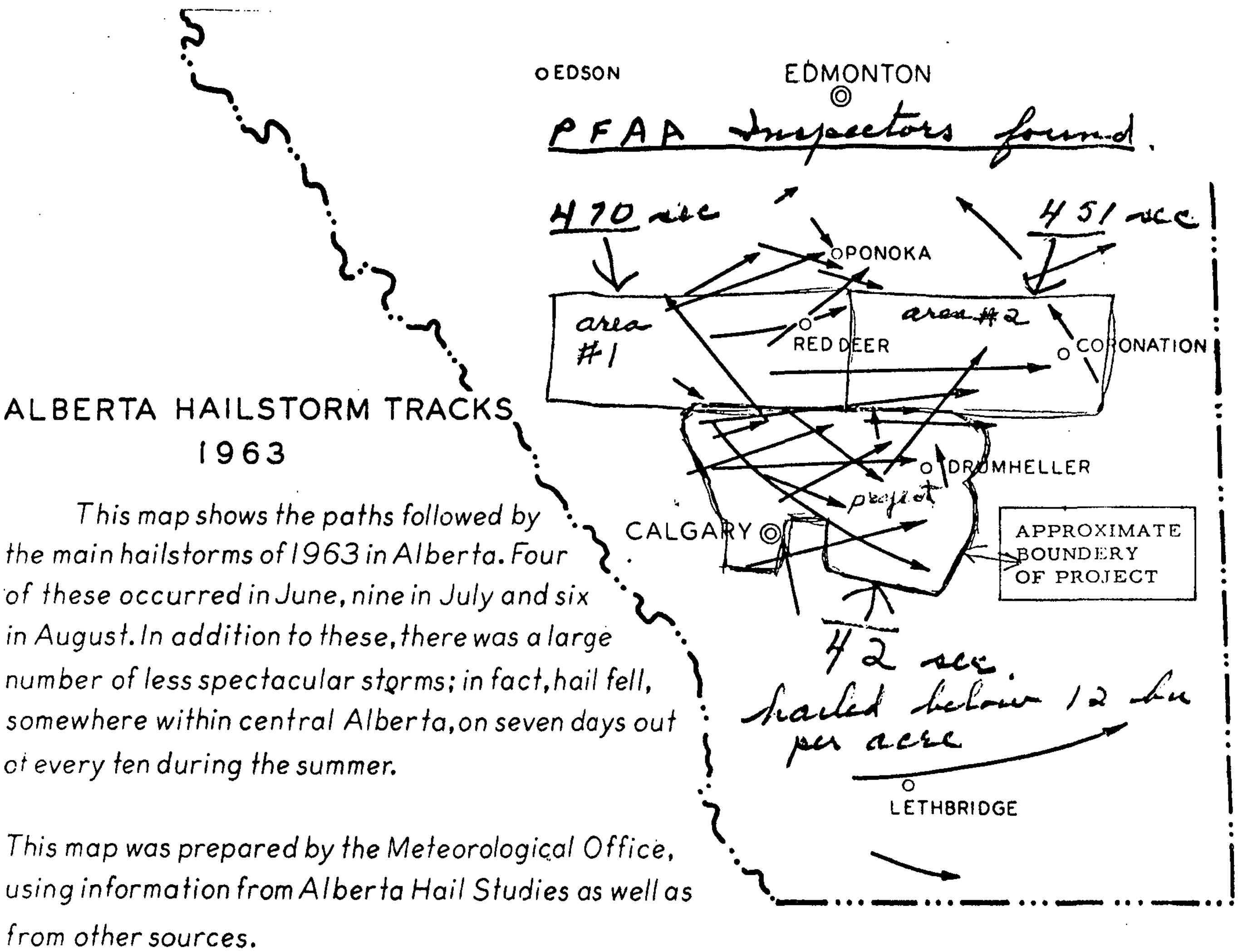
Electric generator always operated. NOTE: Most severe damage occurred in lightest coke generator operation - June 27 Carbon area. Smaller pockets of hail Beiseker and Linden - on medium generator operations. Practically no damage occurred on very heavy generator operations for severe threat. Aircraft were used on 45 days against specific storms, several individual storms in some days. On 8 days 12 storm tracks were reported in the project by Penhold - no serious damage resulted on 90% of the total area of these storm paths. Serious hail fell in approximately 1½% of the project area and only on days of lighter ground generator preparation. Maximum operations can be expected only if we prepare proper financing. Maximum results cannot be expected on an average of only 5¢ per acre over even a large project. It is now evident serious hail damage can be prevented in Alberta for less cost than is entailed in cleaning and treating seed grain.

Figure 2 is a map of the 1963 hailswaths recorded by the Alberta Hail Studies on which we superimposed the rough boundaries of the area supporting cloud seeding. This map was circulated to all farmers with the comment there appeared to be no difference between the project area and the outside area.

We were very much aware this assessment had been based on incomplete information because no attempt had been made by researchers to assess damage in relation to storm paths through the project. At the Research Council meeting a conversation was overheard which mentioned a township northwest of the project where crops were wiped out entirely in a storm, a fact we knew had not occurred anywhere in the project. In a search for ways to provide this it was realized the Federal Prarie Farm Assistance Act might have the answer because this represented a mass insurance of sorts and inspectors established actual yields for every low yield area in the country. Payments were then made to any area where a block of at least 12 sections dropped to below an average of 8 bushels an acre with higher payments to areas with averages of between 3 and 4 bushels per acre and highest to areas averaging 0 to 3 bushels.

PFAA supervisors were very cooperative in laying out the reports of their inspectors who had made on sight inspections and from the information received we established the facts presented in the next report (Fig. 3) based on PFAA records.

FIGURE 2



In answer to the question concerning the township that had been wiped out we found not one but 16 townships in adjacent areas had been hailed in their entirety to an average of below 8 bushels per acre; several being hailed to the 3 to 5 bushel average and one in which damage had been so severe no harvesting at all had been done. Yet, in the project, in spite of having had so many storms, there were no townships so damaged and only one case where 21 adjacent sections strung across three townships had qualified for payment in the 5 to 8 bushel range. Listed in this paper are the total number of sections in each yield division, for the project and two smaller areas, whether in a group of sufficient size to qualify for payments or not.

Fig. 3

ALBERTA WEATHER MODIFICATION ASSOCIATION EVALUATION OF 1963 WEATHER MODIFICATION PROGRAM BY ANALYSING PFAA INSPECTORS REPORTS TO ESTABLISH YIELDS ON A SECTION BASIS.

Our Weather Modification Program is in trouble because we have lacked a method of clearly evaluating what had been accomplished, leaving doubt in the minds of farmers. This problem has been overcome. We can now proceed with confidence.

For a reasonable farmer evaluation of 1963, we can compare the project to 2 comparison areas both approximately the same size, #1 to the northwest of the project, #2 to the northeast. Each area would be approximately 5000 sections in size. In each of these areas we can compare how many sections PFAA inspectors reported had yields of below 12 bus. per acre because of hail and list them in each bracket.

	PROJECT	#1	#2
Nil	3	39	44
0-3	2	89	104
3-5	8	133	87
5-8	10	120	132
8-12	19	89	84
Total	42	470	451

Research Council records show 10 hail storms in the project during July and August when damage is most permanent. Four of these affected both the project and comparison areas to the north. Hail reports in the project sent to Penhold are roughly similar in number to areas #1 and #2 to the north. Damage from these hail swaths in the project amounted to only about 7% of the damage in any of the other areas.

What does this mean in dollars to the farmer?
To evaluate this let us assume 300 acres in crop in each of the 5000 sections in all 3 blocks.--1,500,000 acres of crop in each block with maximum crop insurance under the National Crop Insurance Act on each crop acre - 12 bushels per acre = $18.00 per acre.
Payments for nil yield $18.00, for 0-3 yields - $16.00, for 3-5 yields-$12.00, for 5-8 yields -$8.00, for 8-12 yields - $3.00.

Results

~~Area~~	Project	#1	#2
Total Sec.	42	470	451
Amt. Paid	$95,700.	$1,494,700.	$1,442,400.
Premium %	0.35%	5.5%	5.35%
Premium necessary	6.3¢ per acre	99.6¢	96¢

Other Loss Factors

If we assume an average crop of 30 bushels per acre, a farmer being hailed to 12 bus. to start collecting insurance must first lose 18 bus per acre=$27.00 per acre. The loss of crop on listed land alone before insurance is collected would be

Project	#1	#2
$340,200.	$3,807,000.	$3,653,100

Total loss on land listed by PFAA as below 12 bus.

Project	#1	#2
$435,900.	$5,301,700.	$5,095,500.

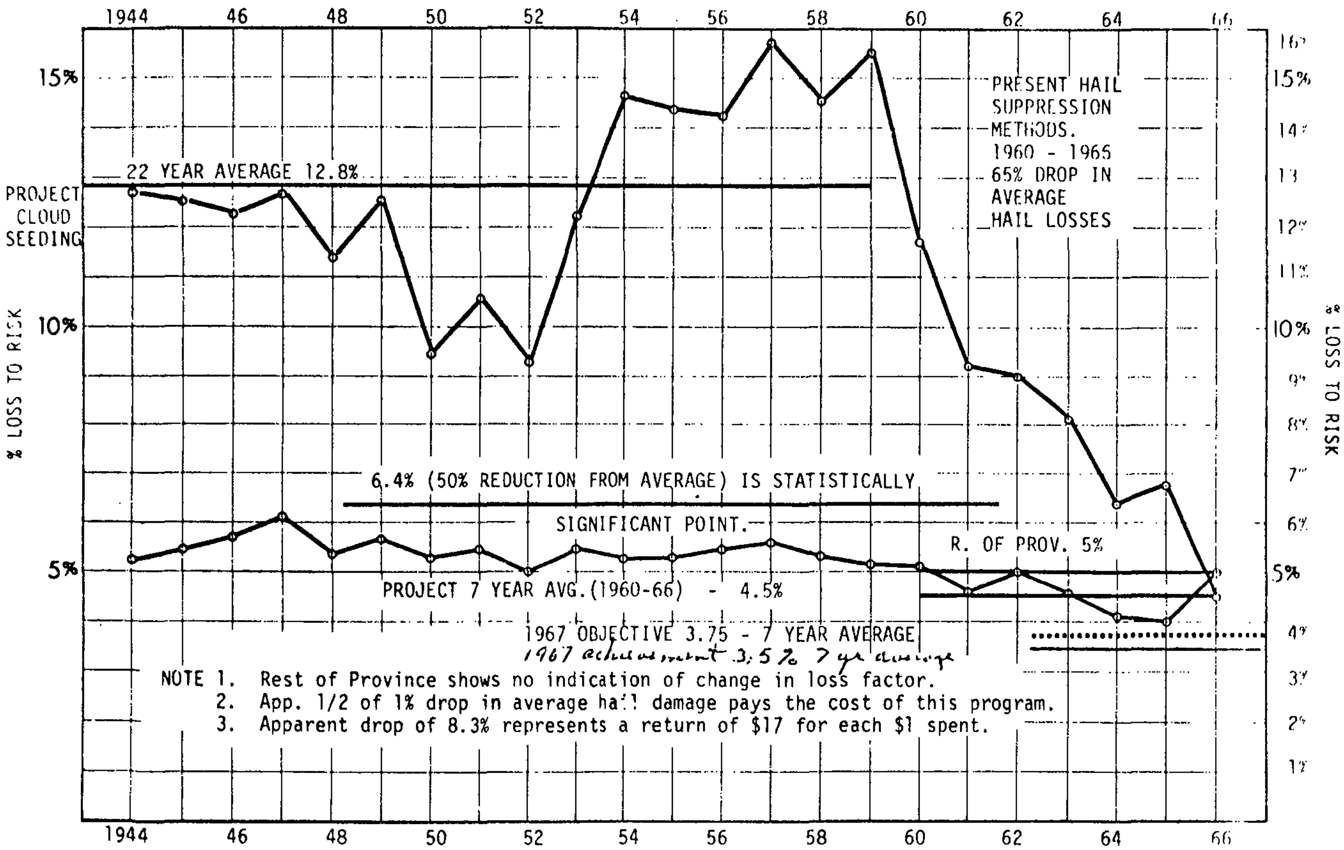
On the basis of this evaluation of the 1963 operation it is reasonable to assume farmers in the project saved in excess of $5 million worth of crop from hail damage besides any increased income from increased rainfall. Is this worth working for?

Of particular interest may be our efforts to put a dollar measure on the comparative losses by assuming all crops had been under All-Risk Crop Insurance, then being planned. It is notable that losses heavy enough to reduce yields to where this crop insurance would take effect were 15 times greater in adjacent areas of similar size than in the project. We, therefore, considered we had good reason to continue the program.

In 1965 researchers assembled Alberta Hail Insurance Board records which made the following graph possible.

FIGURE 4

7 YEAR RUNNING MEAN OF HAIL SUPPRESSION PROJECT AND REST OF PROVINCE
ALBERTA HAIL INSURANCE BOARD RECORDS 1938 - 66.
EACH POINT REPRESENTS AVERAGE L/R OF PREVIOUS 7 YEAR PERIOD.



Records represented by this graph have been audited as correct by Barrie and Barrie, Auditors and Accountants, Three Hills.

Alberta Weather Modification Coop Ltd.

The above graph is a 7-year mean graph which compares the loss to risk experience of the project to that of the Province. The line at 6.4% indicates the 50% level of reduction considered by researchers as necessary to be significant if maintained for 7 to 10 years. They stated that even then one would have to be careful because of the variability of hail insurance volumes which might distort reality. This level of significance for a 7 year period was first reached in 1964, held for the 1965 period and then dropped sharply to a 4.5% average for the 1966 period, down 65% below normal. The dotted line represents a challenge we projected for the 1967 period, calling for the 7 year period to drop to a low of 3.75%. This challenge was met and beaten with a 3.5% average being achieved. The 1968 operation, added to this, maintained this level of effectiveness giving us an 8 year period with losses to hail of only 1/3 of those of the lowest 8 year period in our history. Note Provincial averages remained near normal for this period.

The next report (Fig. 5) is a test of the validity of hail insurance records as a reliable measure of hail losses in spite of the wide variations in volumes of hail insurance written. Note that for various economic reasons there were four separate periods in history during which the volume of hail insurance written varied from a high average of 186% of normal to the low period when only 36% of average hail insurance was written.

Hail losses as a percent of normal for each period were computed and related to rainfall averages for each period also listed as a percentage of normal.

Please note the quite close relationship maintained between percent of normal hail damage and percent of normal rainfall in spite of the wide variation in volume of insurance written during history. This gave us reasonable indication that regardless of the variability of insurance volume written, these records are a fair measure of actual hail damage. This adds to the significance of the 70% plus reduction in hail damage sustained during this cloud seeding period.

The rainfall and hail damage relationship was further explored in the next study in which the Alberta Hail Insurance Board loss to risk factor was placed on the same graph as the June, July and August rainfall records, each as 7 year running mean graphs. (Fig. 6). Generally speaking, this demonstrates hail losses are high during high rainfall periods, low during low rainfall periods. It is particularly notable that by 1963 there were 44 points of reference in the 7 year mean graphs during which time the hail graph never dropped below the rainfall graph. Nevertheless, with all clouds seeded for suppression of hail during a period of normal rainfall hail losses dropped by over 70%.

To this was added a 7 year mean study of the wheat yield records of the Alberta Crop Insurance Corporation on which the yield study presented in the Weather Modification Journal was based. This was done by having each line of the graph represent 2 bushels. Thus, the 10% line represented a 20 year bushel per acre yield for graphing purposes.

You will note the basic yield trends were associated with those of the rainfall graph which is to be expected, but we were impressed with the manner in which the yearly mean details of the yield graph responded to the details of the hail graph for the same periods. Note how the yield averages climbed between the '43 period and the '46 period, corresponding to the hail peak of 1943 and reduced level of hail losses to 1946, a

<u>FIGURE 5.</u>

TEST OF ACCURACY OF HAIL INSURANCE RECORDS AS A MEASURE
OF REAL DAMAGE NOTING THE VALUE OF L/R TO PRECIPITATION
AS AN EVALUATION TOOL by J.T.Bishop,Director

Average insurance to 1960 $743,600. L/R 12% Average Precip. 8ins.

1st Period 1919 to 1928 High Insuracne Period
Average Insurance $1,392,000. -- 186% of Normal -- 11.5% L/R
Average Precipitation 7.93 ins. -- 99% of Normal
Average L/R 11.5% -- 95.5% of Normal
% Variation of L/R over rainfall <u>-3.5%</u>

2nd Period 1929 to 1936 Low Insurance Period
Average Insurance $273,000. -- 36% of Normal - 10.5% L/R
Average Precipitation 6.26 ins. -- 78% of Normal
Average L/R 10.5% -- 87% of Normal
% Variation of L/R over rainfall <u>+ 9%</u>

3rd Period 1938 to 1949 Medium High Insurance
Average Insurance $805,000. -- 108.5% of Normal -- 12.1%L/R
Average Precipitation 8.2 ins. -- 102.5% of Normal
Average L/R 12.1% 101% of Normal
% Variation of L/R over rainfall <u>-1.5%</u>

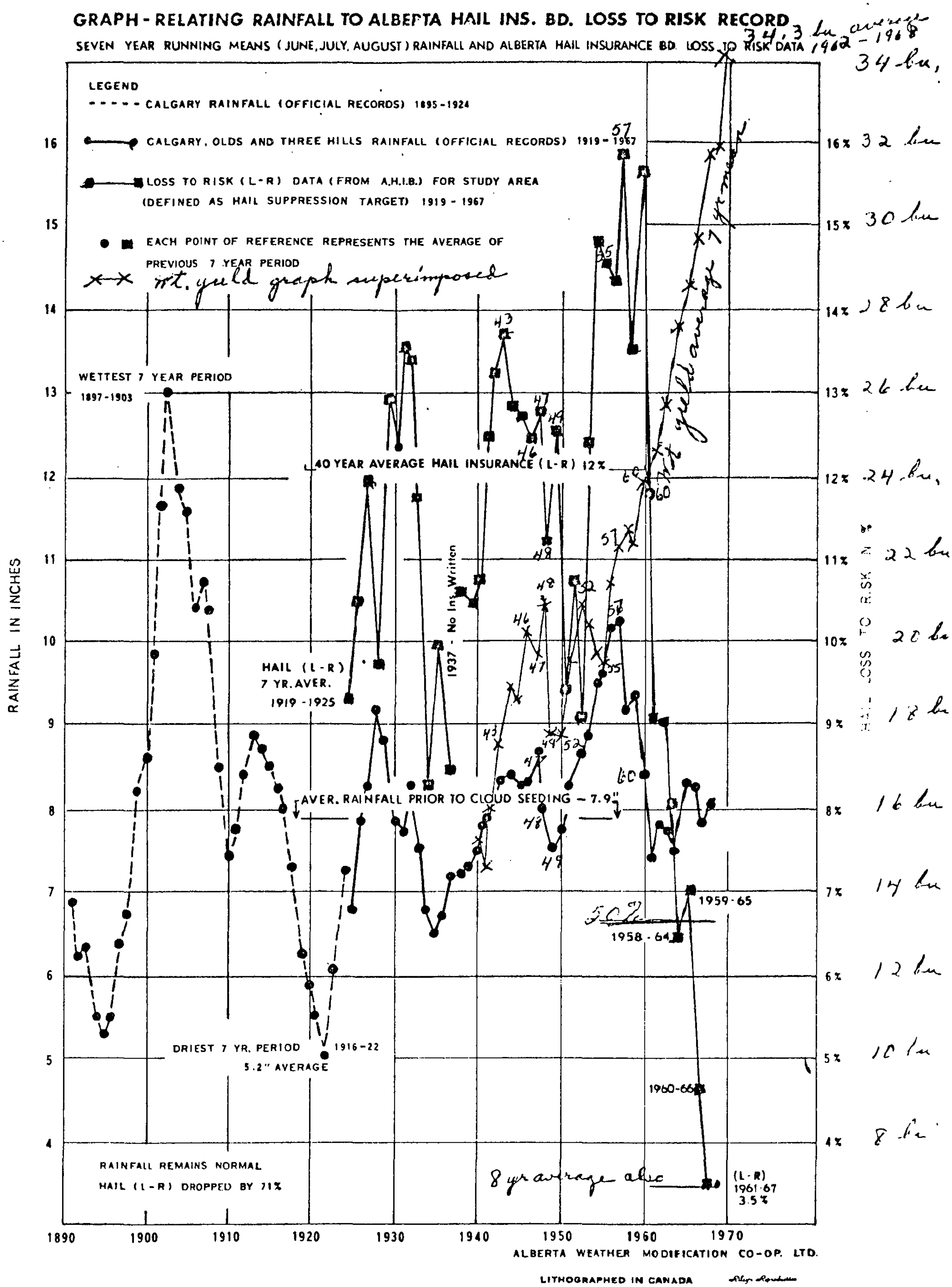
4th Period 1950 to 1959 Medium Low Insurance
Average Insurance $436,000. -- 55% of Normal -- 13.8% L/R
Average Precipitation 9.3 ins. -- 116% of Normal
Average L/R 13.8% 115% of Normal
% Variation of L/R over rainfall <u>-1%</u>

Seeded Period 1960 to 1968 .
Average Insurance $580,000. -- 80% of Normal -- 4.15% L/R
Average Precipitation 7.8 ins. -- 100% of Normal
Average L/R 4.15% -- 35% of Normal
% Variarion of L/R over rainfall -65% of Normal

Average L/R 1961 to 1968 <u>3.5%</u> <u>29%</u> of Normal -- <u>71%</u> 8 yr Variation from rain average

The outstanding fact this table demonstrates is the close relationship of hail damage to precipitation during each of the four periods of time for the 40 years of Hail Insurance records prior to 1960, regardless of the tremendous variation in volumes of insurance written and the wide range of average rainfall. This is concrete evidence that the randomization of the purchase of Hail Insurance gives reasonably dependable measure of actual damage that occurs from hail annually when these are averaged over the necessary period of years needed to overcome the sharp yearly variations, and also establishes that June, July and August precipitation is a valid control to use in a Weather Modification experiment of this nature.

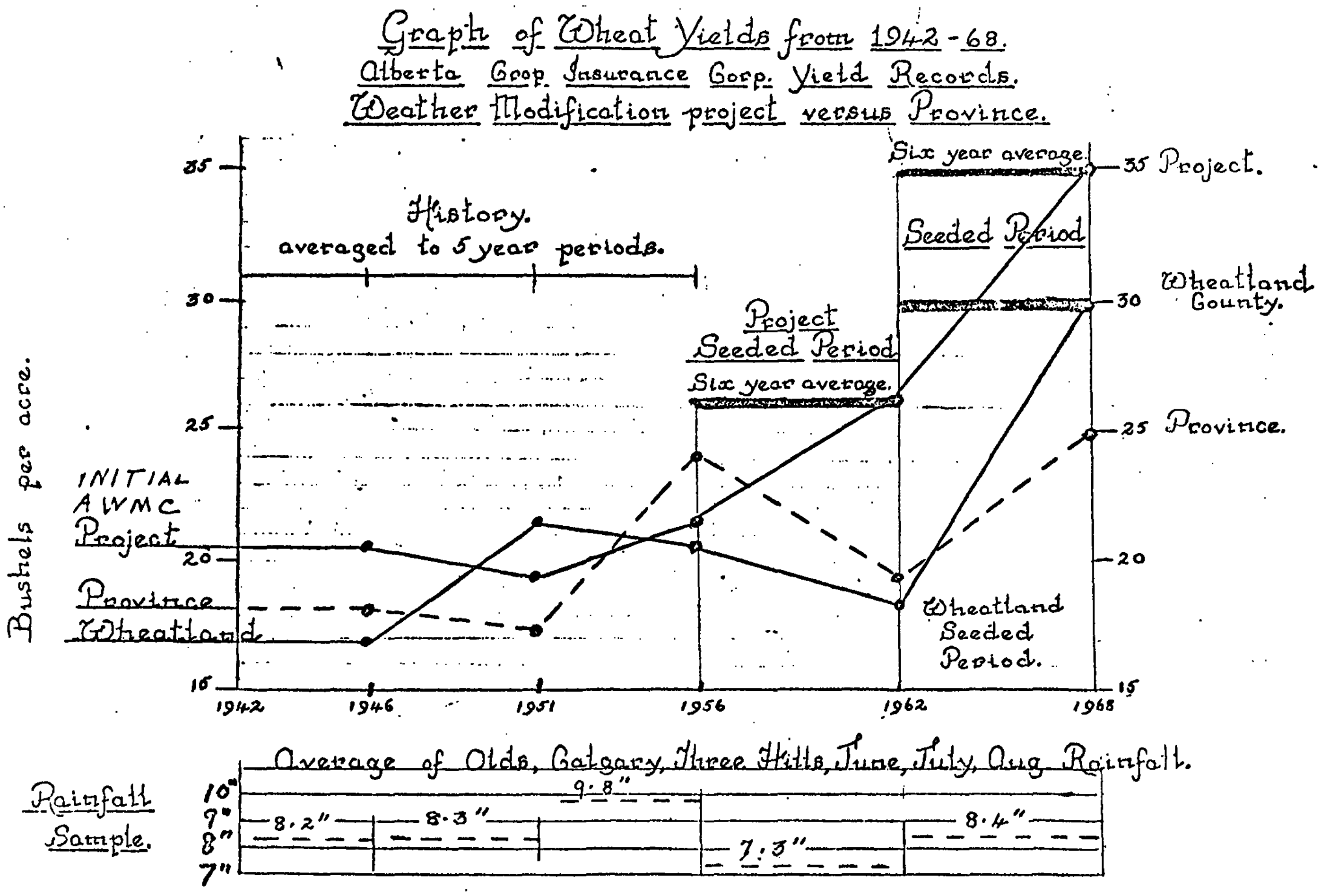
FIGURE 6.



GRAPH - RELATING RAINFALL TO ALBERTA HAIL INS. BD. LOSS TO RISK RECORD
SEVEN YEAR RUNNING MEANS (JUNE, JULY, AUGUST) RAINFALL AND ALBERTA HAIL INSURANCE BD. LOSS TO RISK DATA
34.3 bu average 1962 - 1968
LEGEND
CALGARY RAINFALL (OFFICIAL RECORDS) 1895-1924
CALGARY, OLDS AND THREE HILLS RAINFALL (OFFICIAL RECORDS) 1919-1967
LOSS TO RISK (L-R) DATA (FROM A.H.I.B.) FOR STUDY AREA (DEFINED AS HAIL SUPPRESSION TARGET) 1919 - 1967
EACH POINT OF REFERENCE REPRESENTS THE AVERAGE OF PREVIOUS 7 YEAR PERIOD
wt. yield graph superimposed
WETTEST 7 YEAR PERIOD 1897-1903
40 YEAR AVERAGE HAIL INSURANCE (L-R) 12%
1937 - No Ins. Written
HAIL (L-R) 7 YR. AVER. 1919-1925
AVER. RAINFALL PRIOR TO CLOUD SEEDING — 7.9"
wt yield average 7 yr mean
1959-65
1958-64
DRIEST 7 YR. PERIOD 1916-22 5.2" AVERAGE
1960-66
RAINFALL REMAINS NORMAL
HAIL (L-R) DROPPED BY 71%
8 yr average also
(L-R) 1961-67 3.5%
RAINFALL IN INCHES
LOSS TO RISK
34 bu, 32 bu 30 bu 28 bu 26 bu 24 bu, 22 bu 20 bu 18 bu 16 bu 14 bu 12 bu 10 bu 8 bu
1890 1900 1910 1920 1930 1940 1950 1960 1970
ALBERTA WEATHER MODIFICATION CO-OP. LTD.
LITHOGRAPHED IN CANADA

drop in yields for the '47 period corresponding to the higher hail losses recorded for that period. Again the peaking of yields for the '48 period corresponds to the sharp drop in hail losses for that period. Again, note the '52 yield peak corresponds to the low loss factor coupled with above normal rainfall. Then note that in spite of continually improving rainfall, average yields actually dropped for each of three successive periods in relation to unprecedented hail losses. This sets the stage for the immense increase in yields that are recorded for the cloud seeding period, during which time hail losses dropped to the unprecedented low demonstrated. Barley yield increases were a little less spectacular rising from 27.5 to 39.5 bushels per acre. Both wheat and barley yields rose sharply above Provincial averages.

FIGURE 7.



N.B. Heavy hail damage in the project area and Wheatland County during periods of history prevented a proper response of yields to rainfall. Yields broke all records during cloud seeding periods. Provincial averages, included as a simple control, includes high yields in and around project. This would raise Provincial averages noticeably, particularly during large-scale operations of 1963 - 68 period. Wheatland County yield average during seeded period was 2 bu. per acre higher than the best individual year in their history.

This graph (Fig. 7) is another yield study based on Crop Insurance records. Of particular significance is the experience of Wheatland County whose yields fell in sympathy with the provincial trends during the first period, when record yields were experienced in the adjacent cloud seeding project but climbed to the 30 bushel average indicated when they joined the project. This average was 2 bushels higher per acre than the best individual year in their history.

Indications are that rainfall was increased by 14% for this period in that rainfall levels for this period is 14% higher in relation to past history for the project than was the case for the control area chosen by researchers for comparison purposes. To negate this achievement the nul-hypothesis enthusiasts pointed out hail damage for this control had also dropped sharply from previous high levels and no cloud seeding had been done in this control area. A brief examination of this record soon verified the drop in losses there was not significant in that even at this low level damaging hail was a higher percentage of precipitation than had been the case during 7 previous 7-year periods while as I said before, our losses for 8 years were 1/3 of the lowest 8 year periods in history.

Ladies and gentlemen, I have a great deal of confidence in these simple evaluations but have been concerned as to why the more sophisticated analysis of researchers tended to mask or even discredit this clear-cut positive evidence, and also the further suggestion still more sophisticated evaluations would be necessary, until I turned to my dictionary. This tells me the meaning of sophisticate is "to mislead by false arguements". Enough said.

Mr. Chairman, these and other studies have convinced the directors and members of the Alberta Weather Modification Co-op of the worth of this method of cloud seeding as developed under Alberta conditions for Alberta. We believe these results should be viewed in relation to the statement on Page 44 of the 1962 U.S. National Science Foundation Weather Modification Report which states, "We know the clouds can be modified by cloud seeding and by other means, particularly clouds of certain varieties and origins. Not only can rainfall be somewhat augmented and hail discouraged under certain conditions, but certain kinds of supercooled fog can be dissipated". This statement is fully backed by our experience.

Speaking for the directors and members of the AWMC, we firmly believe this should end serious concern as to whether cloud seeding is practical or not and should spark the most widespread scientific interest in exploring everything that is involved in this appraoch by a thorough study of an ongoing large scale program that employs all available methods of seeding including ground generators, cloud base seeding and dropable flares. Scientific attention should also be directed to documenting the exact conditions under which hail damage still occurs and helping to overcome problems still evident.

We firmly believe that if the capabilities of the scientific community are united with the capabilities demonstrated by these reports, this science holds a potential to reduce hail damage by 85 to 90% and increase rainfall by 15 to 20% if desired. We consider that anything less than this total approach to this problem would be so inadequate under Alberta conditions as to even threaten the acceptance of this science as an asset to agriculture.