Because the mature hailstorm consists of complex airflows and precipitation trajectories cloud seeding does not affect all hail embryo sources. It does, however, modify the primary hail formation process. ***In other words; the cloud seeding cannot eliminate all of the hail, but can reduce the size and amount of hail.***

A schematic diagram of the conceptual storm model showing the hail origins and growth processes within a hailstorm is shown in Figure 6. The cloud seeding methodology applied to the new growth zone of the storm is illustrated. As mentioned previously, cloud seeding cannot prevent or completely eliminate the occurrence of damaging hail. We presently do not have the ability to predict with any certainty exactly the amounts and sizes of hail that would occur if cloud seeding did not take place. Therefore, we do not have the ability to predict with certainty the net effect of the seeding. The new growth zones of potential hailstorms are seeded, and the amounts and types of precipitation at the surface are observed, as well as the radar reflectivity characteristics of the storm before, during, and after seeding. It is anticipated that the successful application of the technology will yield a decrease of damaging hail by approximately 50% from what would have occurred if seeding had not taken place.

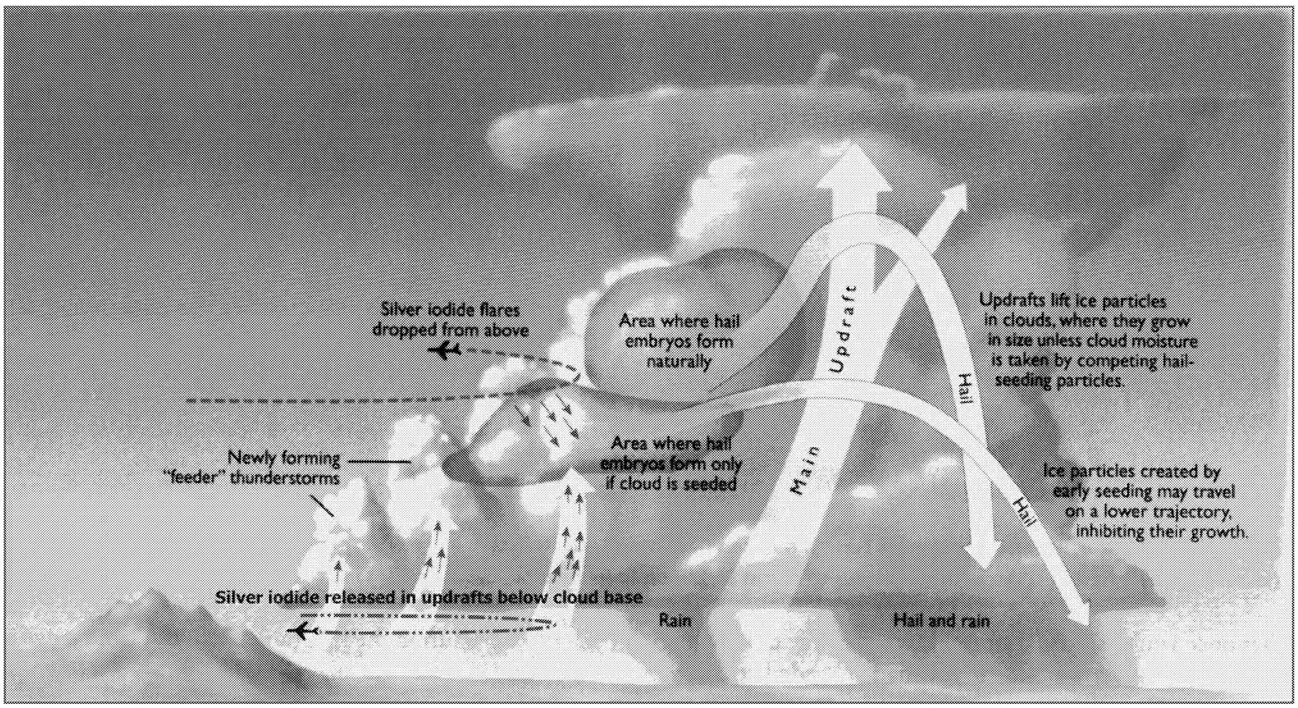


Figure 6. The conceptual model for hail suppression is illustrated graphically (adapted from WMO 1995). This schematic shows generalized cloud seeding flight paths at feeder-cloud tops and below cloud bases, those typically employed for mature thunderstorms.

This expectation is consistent with the results reported in North Dakota (Smith et al. 1997) and in Greece (Rudolph et al. 1994). The decrease in hail can only be measured as an average over time (e.g. 5 years or more) within the operations area, and then compared with the historical values for the same area. Because of these uncertainties, the evaluation of any hail mitigation program requires a statistical analysis. The characteristics of both seeded and unseeded storms vary considerably, such that any storm trait can be found in either category.

A meaningful evaluation of the project might be feasible if insurance loss data for hailstorms was made available, and a step in this direction was taken in 2011 when two of the companies participating in the AHSP through the ASWMS provided limited storm loss data to Dr. Terry Krauss, the ASWMS Director. However, such data are considered proprietary and the other companies have not yet followed suit. (This kind of evaluation is mentioned further in the recommendations at the conclusion of this report.) An additional complicating factor is that hail, by itself, is not always differentiated as the cause of the insured damage, e.g., a window might be broken by hail, high winds, or by surface-based debris borne by the high winds, and to the insurance adjuster it makes little difference; storm damage has occurred.

EFFECTS OF HAIL SUPPRESSION EFFORTS ON RAINFALL

A common question about cloud seeding concerns the effect on the rainfall. The effects of seeding to mitigate hail damage on storm rainfall are not dramatic, but slightly positive. The target area specifically, and Alberta as a whole, lack the high density time-resolved precipitation measurements necessary to provide a scientifically-meaningful rainfall analysis. However, evaluation of another long-term hail suppression program in neighboring North Dakota that does have such a precipitation network found that rainfall is increased about 5 to 10 percent compared to that from similar unseeded clouds (Johnson 1985). Since methodology, seasons, and seeding agents are the same, and since the storms themselves are very similar, it is reasonable to believe that effects in rainfall in Alberta are similar. All this is wholly consistent with the concept that the number of precipitation embryos is increased by glaciogenic seeding.

There is a common (yet quite false) belief by much of the public and even a few meteorologists that thunderstorms operate at near 100% efficiency in producing rainfall. This is not logical, for 100% efficiency would require that all moisture processed by a storm would fall to the ground; no cloud, even, could remain. This is far from the case. There have been numerous studies of the fluxes of air and water vapor through convective clouds; these are summarized in Figure 7.

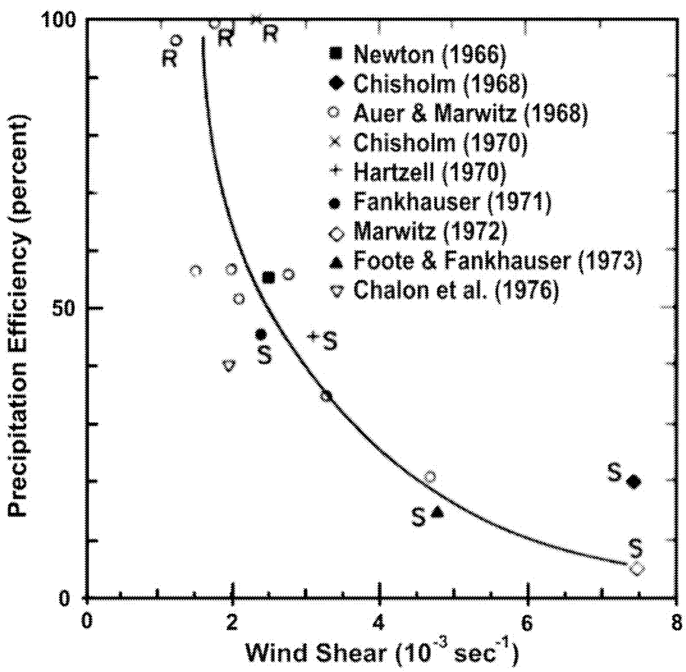


Figure 7. Precipitation efficiency for High Plains convective storms. Known supercell hailstorms are labeled "S". Storms that produced rain only are labeled "R". (Figure from Browning 1977, copyright American Meteorological Society, Boston, MA, used by permission)

Precipitation efficiencies can vary widely from as little as 2% for storms studied by Marwitz (1972) and Dennis et al. (1970) to near 100% for a select few. Marwitz (1972d) and Foote and Fankhauser (1973) show that in the case of High Plains storms there is an inverse relation between the precipitation efficiency and the environmental wind shear in the cloud-bearing layer. [Wind shear is the change in wind speed and direction at various altitudes.] The least efficient storms tend to be supercell hailstorms; the highly efficient storms tend not to produce hail at all. The average wind shear on hail days in Alberta is approximately 2.5 x 10-3 sec-1. This average shear value corresponds to an average precipitation efficiency of approximately 50% (see again Figure 7). For reasons previously stated, it logically follows that the production of large, damaging hail is largely a result of natural storm inefficiency.

Krauss and Santos (2004) performed an exploratory analysis of the project volume-scan C-band radar data, using the TITAN storm tracking software, to obtain radar-derived rainfall from 160 seeded and 1167 non-seeded storms, on 82 days with seeding, during the summers of 2001 and 2002 in Alberta. The seeded storms (stratified according to maximum radar-derived cell top height) had greater mean durations (+ 50%), greater mean precipitation fluxes (+ 29%) and had greater mean total area–time integral of precipitation (+ 54%). There was statistical evidence support the claim that seeding caused an increase in rainfall. The seeding effect was estimated to be a factor of 2.2 increase in the mean rainfall volume (averaged for categories 7.5–11.5 km height storms) with an average 95% confidence interval of (1.4, 3.4). The effect on point rainfall is less than the effect on rain volume because the seeding effect is composed of increases in the mean area and duration of the precipitation as well as the flux. The average increase in rainfall depth was approximately 12% which agrees well with the results from North Dakota.

The introduction of more precipitation embryos through seeding earlier in a clouds lifetime is highly advantageous, reducing the amount and size of any hail, and making the cloud more efficient as a rain producer in the process. Seeding a hailstorm means that less water is lost via the entrainment of dry environmental air through the sides and top of the cloud, or lost by ice crystals vented through the cloud anvil at high altitudes.

6.0 The Operations Plan

IDENTIFICATION OF HAIL-PRODUCING STORMS

The height of the 45 dBZ contour (a radar echo-intensity level) was a criterion tested in the Swiss hail suppression program. The Swiss research found that all hailstorms had 45 dBZ contours above the altitude of the –5°C temperature level (Waldvogel et al. 1979). There was a False Alarm Rate (FAR) of 50%, largely because some strong rainstorms also met the criterion. However, it is much preferable to make an error and assume that a heavy rainstorm is going to produce hail than to mistakenly believe that a hailstorm is only going to produce heavy rain. Studies of Alberta hailstorms also indicated that 50% of all Alberta hail storms had a maximum radar reflectivity greater than 45 dBZ, above the -5°C level (Humphries et al. 1987). The Russian criteria for hail identification stated that the height of the 45 dBZ contour had to exceed the height of the 0°C isotherm by more than 2 km (Abshaev 1999). Similarly, the criteria used by the National Hail Research Experiment in the USA (1972-1974) for a declared hail day was defined by radar maximum reflectivity greater than 45 dBZ above the -5°C level (Foote and Knight 1979). Our experience suggests that the Swiss/Alberta/Russian/USA criterion is reasonable (Makitov 1999). The physical reasoning behind it is simply that radar reflectivity (≥45 dBZ) implies that significant supercooled liquid water exists at temperatures cold enough for large hail growth.

In Alberta, the TITAN cell identification program is set to “track” any cell having more than 10 km^3 of 40 dBZ reflectivity, extending above 3 km altitude (MSL). Each such cell tracked by TITAN is then considered to be a potential hail cell; therefore, this represents our seeding criterion. A storm is a candidate for immediate seeding if the storm cell (as defined by TITAN) is moving towards, and is expected to reach, a town or city within the target area in less than 30 min.

ONSET OF SEEDING

In order for cloud seeding to be successful, it is the goal of the program to seed (inject ice nucleating agents) the developing "new growth" cloud towers of potential hail-producing storms at least 20 minutes before the storm cell moves over a town or city within the target zone. For the Alberta project, the principal targets are the towns and cities within the project area (Table 1). Since 20 minutes is the minimum time reasonably expected for the seeding material to nucleate, and have the seeded ice crystals grow to sufficient size to compete for the available supercooled liquid water (and yield positive results), the 30 minute lead time is generally thought to be advisable.

CLOUD SEEDING METHODOLOGY

Radar meteorologists are responsible for initiating cloud seeding and patrol flights, alerting air crews of the presence of developing weather sufficiently in advance that aircraft will be ready for immediate flight when that time comes, in accordance with operational protocols. The meteorologists advise the Hailstop aircraft when to takeoff, and guide them to the storms of concern. Patrol flights are often launched before clouds within the target area meet the radar reflectivity seeding criteria, especially over or near the cities of Calgary and Red Deer. These patrol flights ensure a quicker response to developing cells. In general, a patrol flight is launched in the event of visual reports of vigorous towering cumulus clouds, or when radar cell tops exceed 25 kft (7.6 km) height over the higher terrain in the western part of the operations area, especially *on those days when the forecast calls for hailstorms.*

Launches of additional aircraft are determined by the number and spacing of storms and the flight time required for each seeding aircraft to reach the desired location and altitude. Overlap of coverage (airspace) and on-station time are also considered. In general, only one aircraft can work safely at cloud top for each active thunderstorm complex to avoid collisions, and for air traffic control (ATC) considerations. If, when multiple storms develop they are sufficiently spaced, more than one aircraft can work at cloud top simultaneously, but horizontal separation must be enough to ensure there is no chance of either aircraft impinging on the other's assigned airspace. [Cloud top seeding is always done under instrument flight rules (IFR), so separation is required by regulation as well as for safety.]

When the storm clouds of interest are relatively small (especially common when storms first develop), there is often room only for one seeding aircraft to operate beneath the rain free cloud base as well. However, when storms are larger and visibility is good, multiple aircraft can often be used safely at cloud base on the same complex. This is possible because flight operations below cloud base are usually conducted under visual flight rules (VFR) and out of cloud, so separation of aircraft can be ensured visually. To accomplish this, all cloud base seeding aircraft must be constantly aware of each other's locations. In addition, a landing light may be turned on for added visibility. Responsibility for safe separation of aircraft is not a responsibility of the project meteorologists, though they can usually monitor the relative positions in real-time through the AirLink tracking system. Rather, the flight crews have this responsibility. Multiple aircraft are most often used on the same storm when the storms assume a linear structure and develop new growth (towering cumulus) along the leading edge of the line. The project utilizes four aircraft to provide uninterrupted seeding coverage (at either cloud-base or cloud-top) and/or to seed up to four storms simultaneously, if required.

Factors that determine which seeding strategy is used (cloud top or cloud base seeding) include: storm structure, visibility, cloud base height, and/or time necessary for Hailstop aircraft to reach seeding altitude. Cloud base seeding is conducted by flying just below the cloud base within the developing inflow of growing cumulus congestus (towering cumulus) clouds, or the inflow associated with the new growth zone in advance of the shelf cloud located on the upshear side of linear multi-cell storms (squall lines). Care is taken not to seed the strong updrafts of mature storms, for such clouds are too advanced in their development and hail development, if it has occurred, is too far advanced to be averted.

SEEDING PROCEDURES

Cloud top seeding is usually conducted at altitudes where cloud temperatures are between the -5°C and -15°C and closer to the former when possible, typically at altitudes of about 16,000 to 18,000 feet MSL. Cloud top seeding is done primarily with small pyrotechnics, comprised of 20 grams of silver iodide seeding agent, which are ejected into the supercooled updrafts of the developing cloud towers. Each flare burns for ~37 seconds, while falling about 2,700 ft (0.8 km). Nevertheless, a minimum 3,000 ft vertical separation (~1.5 km) is always maintained between cloud top and cloud base seeding aircraft (Figure 8).

The cloud top seeding aircraft penetrate or skim the tops of developing, supercooled, largely ice-free (and therefore free of radar echo), cumulus congestus cells as they mature. When multicell storms are present or when more isolated storms have feeder clouds, the seeding aircraft penetrate or skim the tops of the developing cumulus towers as they grow up through the -10°C flight level. The direction of flight is determined by the location of any more mature, adjacent cells, which cannot be safely penetrated.

When the growing cells of interest are embedded within surrounding cloud, and also with most convective complexes at night, there are no clearly defined feeder turrets visible to the flight crews. Seeding aircraft can use their on-board weather radars to help position themselves in these cases; however, aircraft radars are designed for weather avoidance, not for the detection of non-precipitating clouds, and so "see" only mature cells - those beyond the growth stage where seeding can be effective. In these instances, seeding aircraft will skim the storm edge at altitudes between -5°C and -10°C, near the region of tightest radar reflectivity gradient.

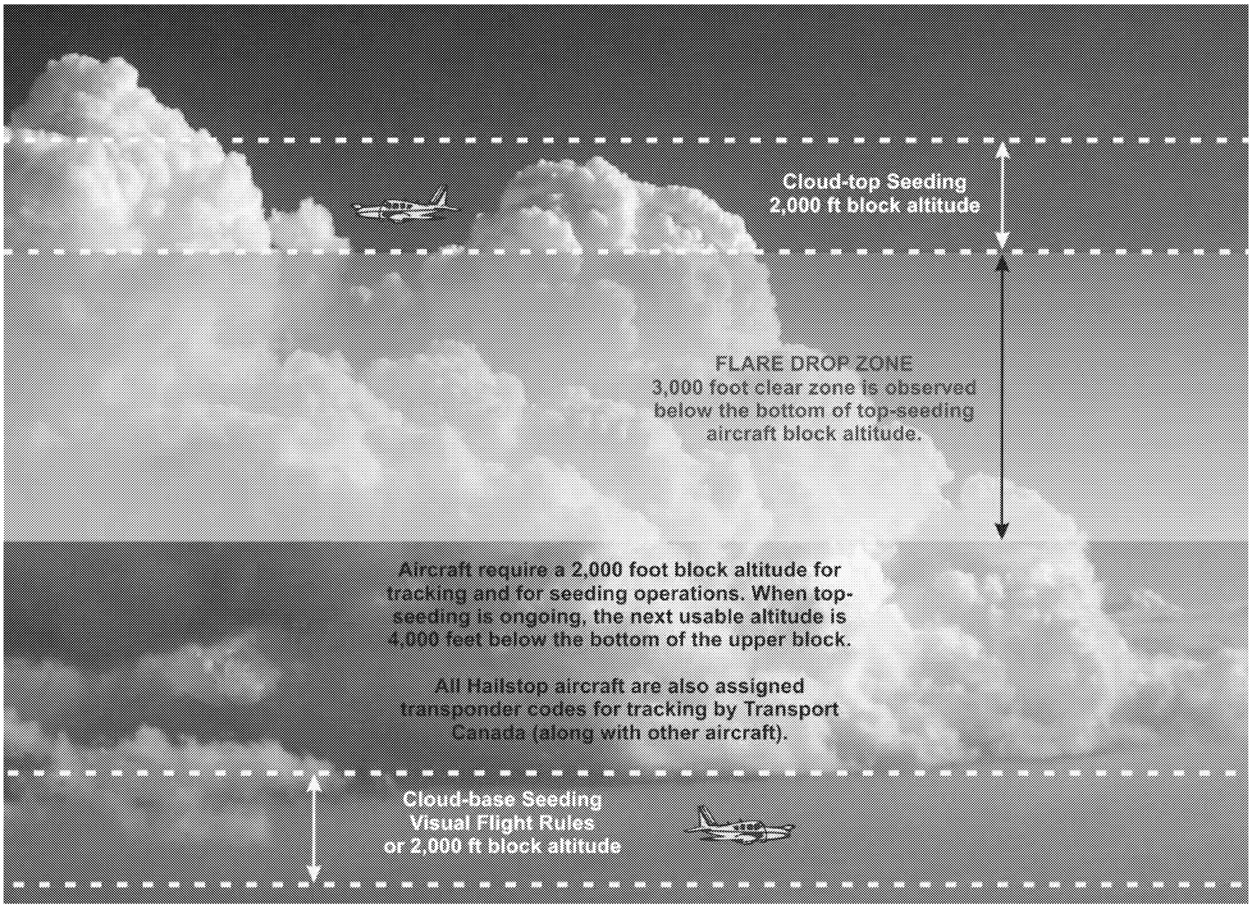


Figure 8. Separation of aircraft by altitude. This diagram illustrates how the separation of cloud-base and cloud-top seeding aircraft is achieved. (WMI graphic by Bruce Boe)

Seeding is done primarily by ejecting multiple 20-gram flares into cloud elements when updrafts and liquid water are encountered. A burn-in-place flare may be ignited also, especially when turrets are closely spaced and seedable cloud volumes are frequently encountered. Nocturnal seeding may also be performed from below the cloud base altitude when visibility is sufficient.

An idea of what night seeding is like is provided by Figure 9. Lightning can often help provide illumination at the cloud base and at cloud top, but such illumination is irregular, very brief, and by nature, "flat", meaning that human eyes struggle to perceive much depth and distance perception. Nevertheless, lightning does help in conducting nocturnal operations. On occasion, additional illumination may be provided by moonlight, especially if the upper reaches of the storm anvil do not shadow the developing turrets. In any case, the seedable clouds are those that have not yet produced precipitation, and therefore those devoid of radar echoes. For safety reasons flight operations require aircraft to avoid heavily electrified regions, and also close proximity to known hail and hail aloft, as indicated by the project radar. Wind shear and terrain clearance pose additional hazards. Though operations after dark are infrequent in Alberta because of the long summer days and lingering twilight hours, seeding operations are conducted whenever storms develop, even in the wee hours of the morning. Typically, this happens only a few times each season, though the number of such flights has been increasing in recent seasons (2011, 2012).

CESSATION OF SEEDING

If the radar reflectivity criteria continue to be met, seeding of all cells still in a position to threaten damage to towns or cities is to be continued. However, seeding is effective only within cloud updrafts and in the presence of supercooled cloud water, i.e. the developing stage in the evolution of the thunderstorm. The mature and dissipating stages of a storm cannot be effectively seeded because seeding only works by enhancing ice development in clouds that are primarily ice-free, characteristics which only are manifest in developing cloud turrets. Storm complexes having no new development are destined for decay. While a few storms simply develop, mature, and decay without initiating secondary development, those that have the potential to produce hail almost always produce cool outflows that initiate more new growth adjacent to the mature and dissipating portions of the storm. This new growth extends storm life and is seedable, so aircraft must operate in some proximity to mature, electrified clouds and dangerous wind shears, which include violent up and downdrafts. Safety thus becomes of paramount importance. The history of aviation is filled with accounts of aircraft destroyed by thunderstorms, and the potential today is just as real as ever.

Safety of project aircraft and crews is ensured by strict adherence to flight policies that are designed to keep aircraft from ever entering mature portions of the storms, and from flying into extreme winds, hail, and lightning.

Strong radar reflectivities can only persist when new cloud development continues; when it doesn't, decay is inevitable. Thus, when storms maintain their intensities, developing cloud regions must exist, even though it is sometimes hard to find them. Such mature storm complexes are seedable only when the developing clouds are accessible to the seeding aircraft. If they are embedded within the mature clouds, hidden by decaying clouds, and cannot be approached from below (cloud base), seeding cannot safely occur. Storm cells being tracked by radar are not seeded if there are no indications of developing updraft or supercooled liquid water, or when the storm does not threaten a town or city.

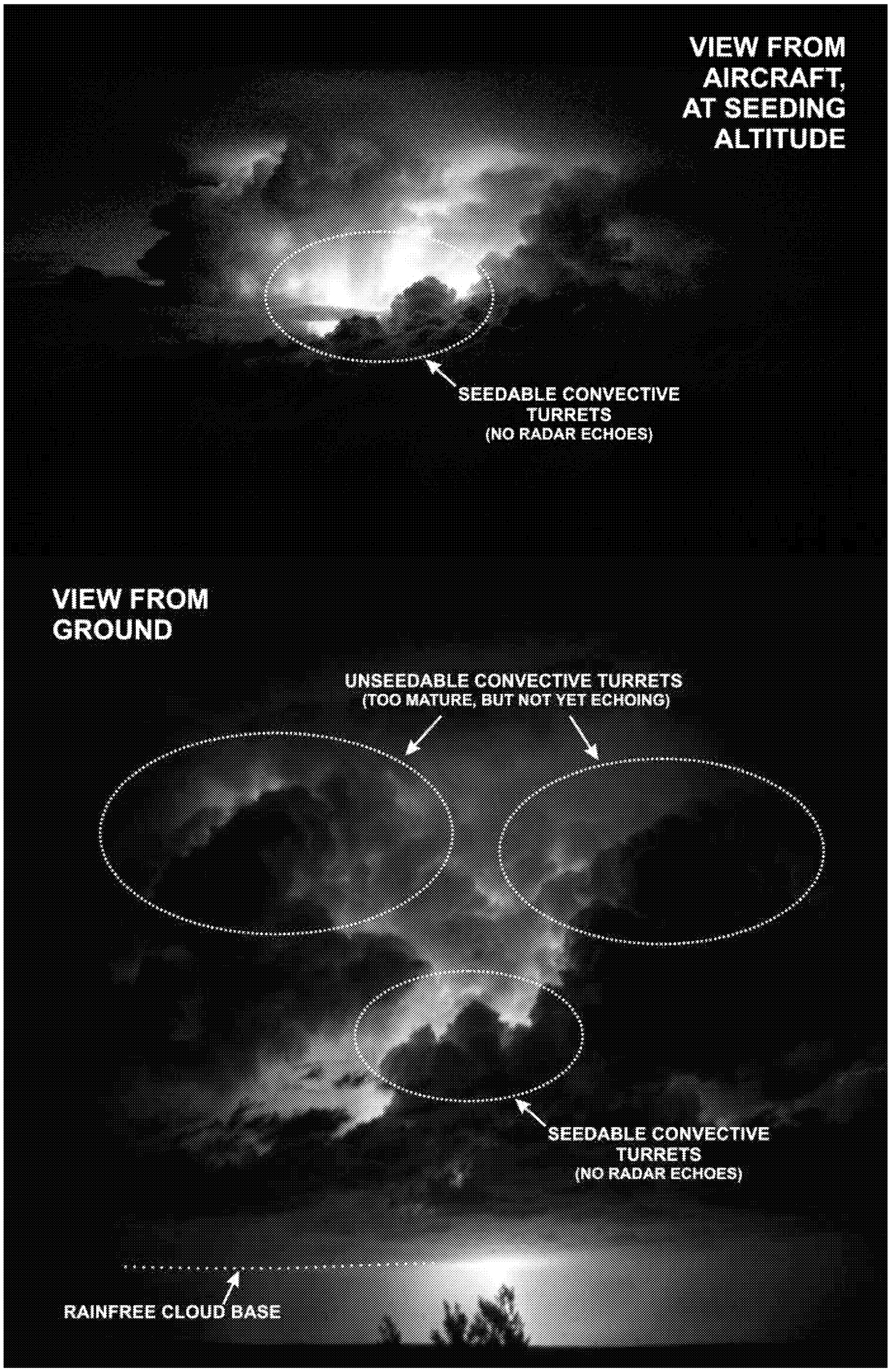


Figure 9. When seeding nocturnal thunderstorms lightning is a friend. It illuminates, if only sporadically, many cloud details that would otherwise go unseen. The single lightning flash in the upper image reveals a developing cloud turret at aircraft seeding altitude, while the multiple flashes in the lower time-exposure from the ground reveal much more: the rain-free cloud base (near which base-seeding aircraft would operate), smaller, developing turrets that might be seedable if cold enough, larger maturing cells that are too cold and ice-laden (and close to being detected by radar), and the mature thunderstorm behind that has produced the lightning. (WMI photographs: Matthias Morel (top) and Bruce Boe (bottom))

SEEDING RATES

Silver iodide is dispensed in three ways: (1) a seeding solution can be burned from wing-tip-borne ice nucleus generators, (2) pyrotechnics can be burned "in place", while held to special racks affixed to the trailing edges of the aircraft wings, and (3) small pyrotechnics can be ignited and ejected into cloud tops from racks mounted on the aircraft fuselage.

A seeding rate of one 20 gram flare every 5 sec while in supercooled updraft is typically used during cloud penetrations. A higher rate is used (e.g. 1 flare every 2 to 3 sec) if updrafts are very strong (e.g. greater than 2000 ft/min) or if the storm is particularly intense. Cloud seeding passes in the same region are immediately warranted if there are visual signs of continued new cloud growth or if the radar reflectivity gradient of the parent cell remains tight (indicative of continued growth and persistent updrafts). If not, a 5 to 10 min waiting period may be used between penetrations, to allow the seeding to take effect and for visual signs of glaciation to appear, or for radar reflectivities to decrease and gradients to weaken. Such waiting reduces the amount of seeding material used. Calculations show that the seeding rate of one flare every 5 sec will produce >1300 ice crystals per litre averaged over the plume within 2.5 min. This is more than sufficient to deplete the liquid water content produced by updrafts up to 10 m s^{-1} (2000 ft/min), thereby preventing the growth of hailstones within the seeded cloud volumes (Cooper and Marwitz 1980).

For effective hail suppression, sufficient dispersion of the particles is required for the AgI plume from consecutive flares to overlap by the time the cloud particles reach hail size. The work by Grandia et al. (1979) based on turbulence measurements within Alberta feeder clouds indicated that the time for the diameter of the diffusing line of AgI to reach the integral length scale (200 m) in the inertial subrange size scales of mixing, is 140 seconds. This is insufficient time for ice particles to grow to hail size, therefore, dropping flares at 5 sec (assuming a true-airspeed of 80 m s^{-1}) intervals should provide sufficient nuclei and allow adequate dispersion to effectively deplete the supercooled liquid water and reduce the growth of hail particles. The use of the 20 gram flares and a frequent drop rate provides better seeding coverage than using larger flares with greater time/distance spacing between flare drops. In fact, the above calculations are conservative when one considers that the centre of the ice crystal plume will have a greater concentration of ice crystals.

For cloud base seeding a seeding rate using two solution-burning generators or one burn-in-place flare is typically used, dependent on the updraft speed at the cloud base. For an updraft >500 ft min^{-1}, generators and consecutive flares per seeding run are typically used. Cloud seeding runs are repeated until inflow (updraft area) has diminished or until the storm of concern has passed all urban areas. Solution-burning ice nucleus generators are used to provide continuous silver iodide seeding if extensive regions of light or moderate updraft are found at cloud base in advance of the shelf cloud region. Base seeding is not conducted if only downdrafts are encountered at cloud base, since this would waste seeding material.

SEEDING AGENTS

The cloud seeding pyrotechnics used by WMI are exclusively silver iodide formulation flares manufactured by Ice Crystal Engineering (ICE) of Kindred, North Dakota. The ejectable flares contain 20 grams of seeding material and burn for approximately 37 sec and fall approximately 3000 ft before burning up. The burn-in-place (BIP) flares contain 150 grams of seeding material, and burn for approximately 4 min. Arrangements were made with Solution Blend Services, a Calgary-based company, to pre-mix all seeding solution from reagent grade raw materials provided by WMI. All handling, mixing, storage, and labelling requirements established by law and regulation were fully satisfied.

FLARE EFFECTIVENESS

The Cloud Simulation and Aerosol Laboratory (SimLab) at Colorado State University (CSU) has tested the ice nucleating ability of aerosols produced from cloud seeding flares and solutions for many years (Garvey 1975, DeMott 1999). [Note: The SimLab is now closed and no longer performs such tests; a new testing facility to conduct these standardized tests is not yet available.] The current ICE pyrotechnics were tested at CSU in 1999 as reported by DeMott (1999). Aerosols were collected and tested at nominal temperatures of -4, -6 and -10°C. At least two tests were done at each temperature, with greater emphasis placed on warmer temperatures. The cloud chamber liquid water content (LWC) was 1.5 g m^{-3} for most tests, but 0.5 g m^{-3} for some, enough to confirm the dependence of nucleation rate upon cloud droplet concentration. The primary product of the laboratory characterization is the "effectiveness plot" for the ice nucleant which gives the number of ice crystals formed per gram of nucleant as a function of cloud temperature. Yield results for the ICE flares at various sets of conditions are shown in Figure 10 and are tabulated in Table 2.

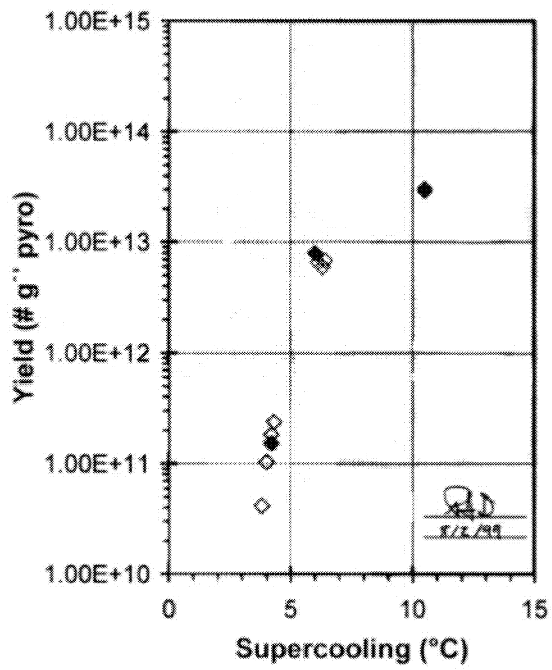


Figure 10. Yield of ice crystals per gram of pyrotechnic burned is shown as a function of cloud supercooling temperature (T < 0°C). Open diamond symbols are for tests with cloud LWC (liquid water content) of 1.5 g m^{-3}, while the filled symbols are for experiments with LWC equal to 0.5 g m-3. The lack of any dependence upon cloud liquid water content indicates that the nuclei thus produced function by the condensation-freezing mechanism. (Figure from DeMott 1999)

TABLE 2. Yield (per gram) of the ICE Glaciogenic Pyrotechnic (DeMott 1999).

Temp (°C)	LWC ($g\ m^{-3}$)	Raw Yield (g^{-1} AgI)	Corr. Yield (g^{-1} AgI)	Raw Yield (g^{-1} pyro)	Corr. Yield (g^{-1} pyro)	Yield (per pyro)
-3.8	1.5	$3.72x10^{11}$	$3.87x10^{11}$	$4.01x10^{10}$	$4.18x10^{10}$	$8.36x10^{11}$
-4.0	1.5	$9.42x10^{11}$	$9.63x10^{11}$	$1.02x10^{11}$	$1.04x10^{11}$	$2.08x10^{12}$
-4.2	1.5	$1.66x10^{12}$	$1.70x10^{12}$	$1.80x10^{11}$	$1.84x10^{11}$	$3.67x10^{12}$
-4.3	1.5	$2.15x10^{12}$	$2.21x10^{12}$	$2.32x10^{11}$	$2.39x10^{11}$	$4.77x10^{12}$
-6.1	1.5	$6.01x10^{13}$	$6.13x10^{13}$	$6.49x10^{12}$	$6.62x10^{12}$	$1.32x10^{14}$
-6.3	1.5	$5.44x10^{13}$	$5.56x10^{13}$	$5.87x10^{12}$	$6.00x10^{12}$	$1.20x10^{14}$
-6.4	1.5	$6.22x10^{13}$	$6.34x10^{13}$	$6.72x10^{12}$	$6.85x10^{12}$	$1.37x10^{14}$
-10.5	1.5	$2.81x10^{14}$	$2.85x10^{14}$	$3.03x10^{13}$	$3.07x10^{13}$	$6.15x10^{14}$
-10.5	1.5	$2.34x10^{14}$	$2.37x10^{14}$	$2.87x10^{13}$	$2.91x10^{13}$	$5.81x10^{14}$
-4.2	0.5	$1.41x10^{12}$	$1.45x10^{12}$	$1.53x10^{11}$	$1.57x10^{11}$	$3.14x10^{12}$
-6.0	0.5	$7.42x10^{13}$	$7.73x10^{13}$	$8.01x10^{12}$	$8.34x10^{12}$	$1.67x10^{14}$
-10.5	0.5	$2.38x10^{14}$	$2.41x10^{14}$	$2.91x10^{13}$	$2.96x10^{13}$	$5.92x10^{14}$

TABLE 3. Activation Rate of Nuclei Produced by ICE Pyrotechnic (DeMott 1999).

Temp (°C)	LWC (gm^{-3})	k (min^{-1})	kdil (min^{-1})	kact (min^{-1})	T1/e (min)	T90% (min)	Yield Correction
-4.0	1.5	1.093	0.023	0.935	0.94	4.32	1.023
-4.2	0.5	0.713	0.019	0.694	1.44	5.71	1.028
-6.3	1.5	1.775	0.038	1.737	0.48	1.12	1.020
-6.0	0.5	0.724	0.028	0.696	1.43	5.21	1.041
-10.5	1.5	3.200	0.045	3.155	0.32	0.73	1.014
-10.5	0.5	2.488	0.040	2.448	0.41	0.94	1.016

Tests were also performed using the method of DeMott et al. (1983) to determine the characteristic times for effective ice nuclei activation; these are summarized in Figure 11 and Table 3. The primary results of the CSU SimLab tests of the glaciogenic cloud seeding pyrotechnics manufactured by ICE are summarized as follows (from DeMott 1999):

- The aerosol particles produced by the new ICE pyrotechnics were highly efficient ice nucleating aerosols. Yield values were approximately 1x1012, 5x1013 and 3x1014 ice crystals per gram pyrotechnic effective at -4, -6 and -10°C in 1.5 g m-3 clouds in the CSU isothermal cloud chamber. Improvement compared to the previous pyrotechnic formulation used by ICE was modest at -6°C, but most significant (factor of 3 increase in Yield) at -4°C.
- The ICE pyrotechnics burned with a fine smoke and a highly consistent burn time of ~37 s.
- Rates of ice crystal formation were very fast, suggestive of a rapid condensation freezing process. The balance of observations showed no significant difference in the rate data obtained at varied cloud densities, supporting a conclusion that particles activate ice formation by condensation freezing.

The CSU isothermal cloud chamber tests indicate that, on a per gram basis of pyrotechnic, these values are comparable to the best product available worldwide in the pyrotechnic format. High yield and fast acting agents are important for hail suppression since the time-window of opportunity for successful intervention of the hail growth process is often less than 10 minutes. More information about the ICE glaciogenic pyrotechnics can be found on the internet at www.iceflares.com.

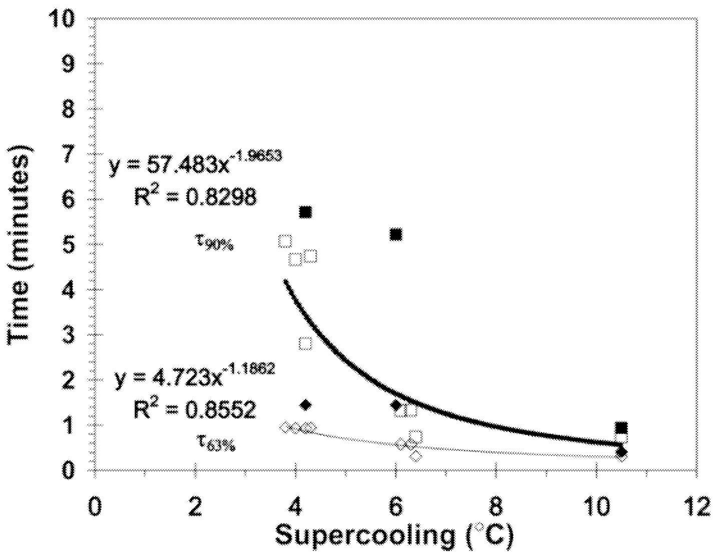


Figure 11. Activation time as a function of supercooling. Times for 63% (diamond symbols) and 90% (square symbols) ice formation versus supercooling (T<0°C) for the ICE pyrotechnic aerosols. Open and filled symbols are for cloud LWC (liquid water content) of 1.5 and 0.5 g m-3, respectively. (DeMott 1999)

7.0 Program Elements and Infrastructure

INFRASTRUCTURE

The flow of information within the project is illustrated in block diagram form in Figure 12. The focal point of the project is the Operations Centre, located at the Olds-Didsbury Airport, approximately halfway between the two largest metropolitan areas, Calgary and Red Deer.

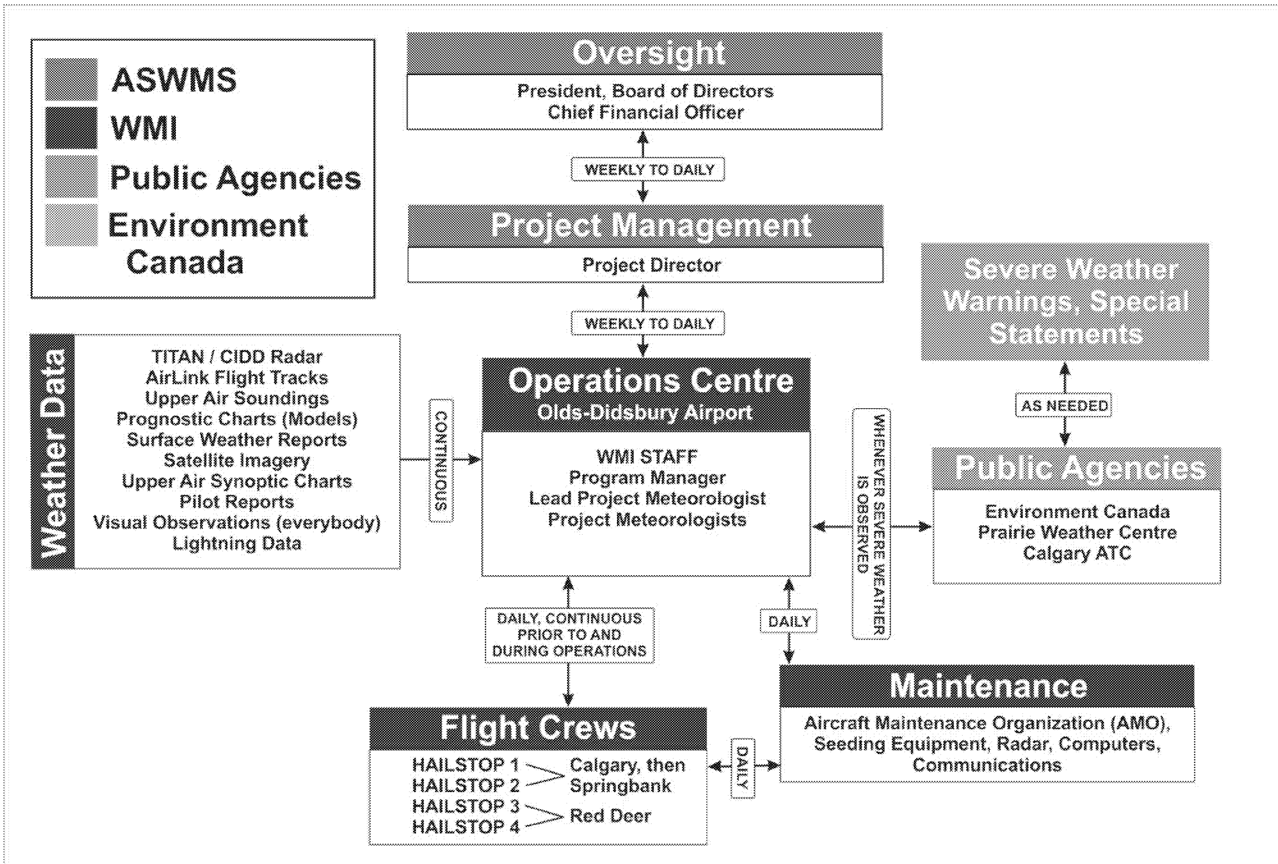


Figure 12. Schematic of Program Infrastructure. Though program objectives and directives originate with the project sponsor, the Alberta Severe Weather Management Society (ASWMS), the majority of project communications occur among the meteorologists (Operations Centre), pilots (Calgary/Springbank and Red Deer), and the various maintenance providers. The approximate frequencies of these interactions are also shown.

The ASWMS Board is comprised of individual insurance industry employees nominated by their respective companies. The ASWMS President serves as the primary liaison between the Board and Weather Modification, Inc. (WMI), though all Board members receive the project summary reports compiled and disseminated weekly by WMI during the operational period, which is June 1 through September 15, annually.

THE OPERATIONS CENTRE

Environment Canada operates two weather radars in Alberta, one in Carvel, near Edmonton, and the other at Strathmore, east of Calgary. While good for surveillance of the province, neither provides the detail and flexibility needed for hail suppression operations in the target area. Thus, radar support for the project required that a third radar be installed. Since the project's inception in 1996 the Operations Centre and radar have been based at the Olds-Didsbury Airport, centrally located in the target area. (See again Figure 3.)

An illustrated schematic diagram (Figure 13) of project activities occurring at and around the Operations Centre provides more detail about the origins and flow of data critical for operations. Technical specifications of all project-operated facilities and equipment are given in the appendix of this report.

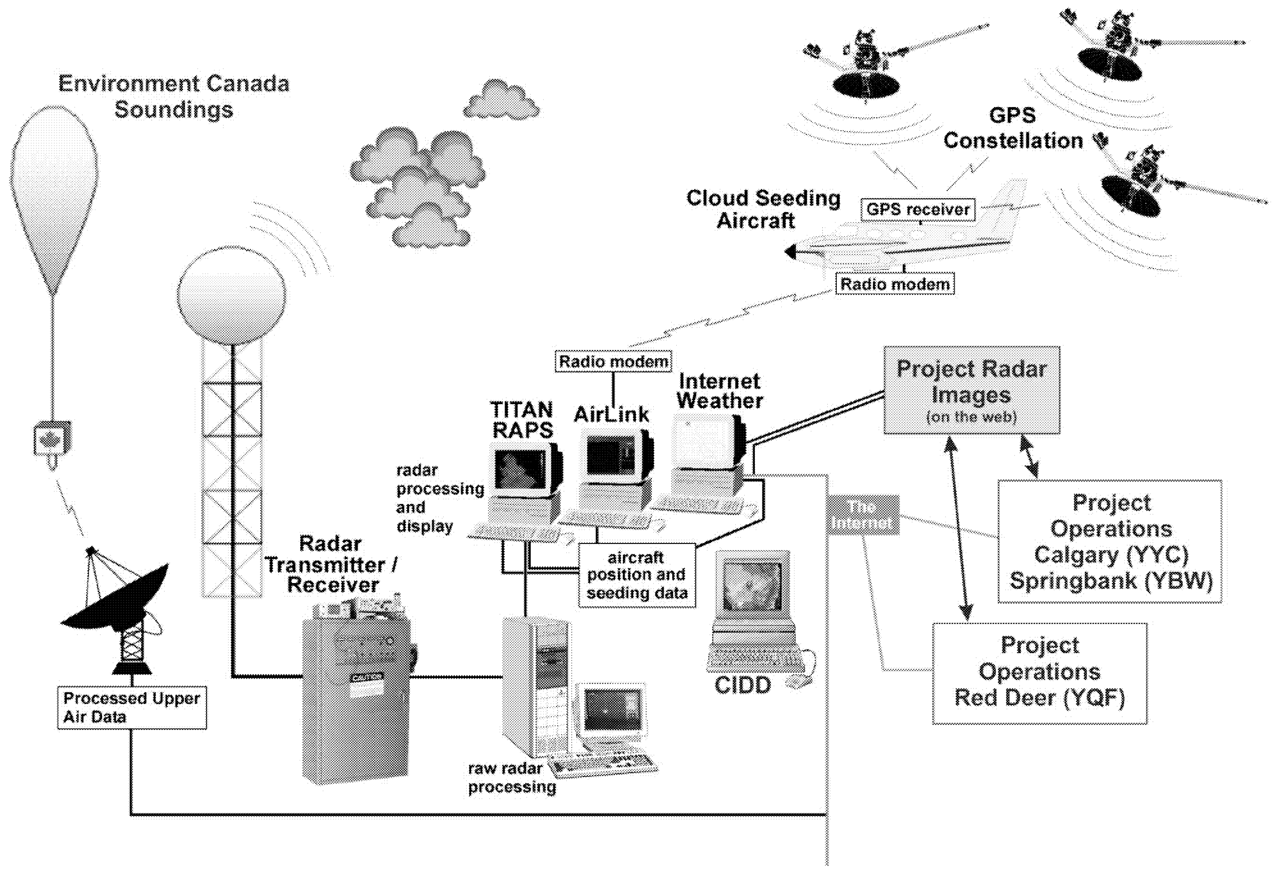


Figure 13. Alberta Hail Suppression Program operational elements. Position and seeding data from each of the four aircraft are telemetered in real-time, ingested, and displayed. Positions are plotted directly on the radar display to optimize pilot-meteorologist interactions. Updated radar images are sent to the internet every five minutes, and are thus available to any flight crews not yet airborne. The only regular upper air sounding in Alberta is released from Edmonton, well north of the protected area, so model-derived soundings are used for operational forecasting.

All project operations are directed and monitored from the WMI radar installation at the Olds-Didsbury Airport (official airport identifier: CEA3). Project offices for radar operation and monitoring, weather forecasting, recordkeeping, and overall administration are located on the airfield just south of the main ramp. Immediately adjacent to the Operations Centre offices is the easily recognizable radar tower and radome (Figure 14).

The project control room contains the following: radar displays and processing computers, the AirLink flight telemetry system, computers with internet connectivity for access to external weather data, VHF radios for direct communication with project aircraft, and telephone.

Figure 14 (right). The WMI project Operations Centre. is located at the Olds-Didsbury Airport, about 70 km (44 miles) north of the Calgary Airport, roughly halfway between the project's most important cities: Calgary and Red Deer. The radar antenna is housed within the dome, and the transmitter and receiver in the shed at the tower base. Operations are conducted from within the meteorological office housed within the adjacent hangar. In this image from 12 August 2012 at 7:50 PM, the bulbous clouds overhead, known as mammatus, were produced by the severe storm over Calgary, many miles to the south. (WMI photograph by Bradley Waller)

DIGITAL WEATHER RADAR

The primary radar display and control is achieved through the *Thunderstorm Identification, Tracking, Analysis, and Nowcasting* (TITAN) acquisition and processing software. The TITAN software processes and displays the full-sky volume scan radar data, producing a variety of graphical images that are useful in real-time as operations are conducted, and also in post-analysis. [Note: the term *volume scan* refers to radar data collected during a complete set of 360°, full-azimuth scans, each at progressively higher antenna elevation angles. About five minutes are required for the radar to complete each volume scan.]

The TITAN software helps the meteorologists identify potential hailstorms and, with the flight tracks of project aircraft superimposed, improves the guidance of aircraft to the hail-growth regions of active thunderstorms. The primary (and largest) TITAN display window is referred to as the *RVIEW* window. The operator can select the RVIEW window to display any of a number of TITAN parameters either as observed for specific constant altitude plan views (called CAPPIs), or as a *composite view*, that shows the maximum value observed at each coordinate anywhere above the surface. Composite reflectivity TITAN images are sent to the WMI web server after the completion of each volume scan, at approximately 5 minute intervals.

Operating in tandem with TITAN is the *Configurable Interactive Data Display* (CIDD) radar processing system. The CIDD is similar to TITAN in function. There are advantages to both systems, so WMI uses both. The CIDD is typically set up to run a continuous animated 1-hour movie loop.

Both TITAN and CIDD are available in the operations room on dedicated displays, that is, flat-panel monitors dedicated full-time to those purposes. In addition, a supplemental TITAN RVIEW window is not used interactively, but used to port (send) TITAN data to the web upon the completion of each complete volume scan made by the radar. This is done so that the web image always has the same information and appearance for all scans.

GROUND SCHOOL

A ground school was conducted prior to the commencement of the project field operations on May 28th and 29th, 2012 for all available project personnel at the Intact Insurance training room downtown Calgary. Operational procedures about who does what, where, when and why, as well as general conduct and reporting requirements were presented and reviewed at the ground school. Two representatives of NAV Canada in Calgary and Edmonton participated in the ground school. A copy of the ground school program and samples of the flight log and radar log forms, are included in the appendices.

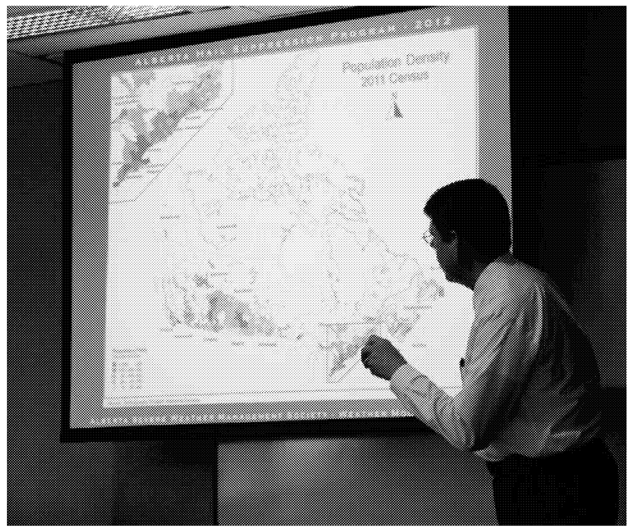


Figure 15 (right). Bruce Boe, WMI Director of Meteorology presents on the 2011 Canada Population Density during the 2012 AHSP ground school on May 29, 2012. (WMI photograph by Cindy Dobbs)

The pre-project ground school training topics included:

- i. program overview and design, project area, target areas, and priorities
- ii. overview of operations and procedures
- iii. cloud seeding hypotheses for hail suppression
- iv. cloud seeding theory and techniques
- v. aviation weather problems and special procedures
- vi. aircraft controlling techniques and procedures
- vii. seeding aircraft equipment and characteristics
- viii. weather radar equipment and basic principles
- ix. basic meteorological concepts and severe weather forecasting
- x. weather phenomena, fronts, and storms
- xi. daily routines and procedures
- xii. communications procedures
- xiii. computers, documentation, and reporting procedures
- xiv. safety, security precautions and procedures

PUBLIC RELATIONS

A total of fourteen groups toured the project Operations Centre at the Olds-Didsbury airport as part of the Alberta Insurance Council accreditation program.

The tours, organized and led by Ms. Lynne Fawcett of Intact Insurance, each included a presentation by ASWMS Program Director Dr. Terry Krauss, a tour of the room and equipment used to direct the cloud seeding operations, and a chance to see one of the project seeding aircraft and its associated equipment (Figure 16). Recent storms were also replayed on the radar. In total 195 persons took part in this program, which helps those working in the industry understand the program.

In addition to the equipment used in the project, attendees learn about Alberta's long history in hail suppression research and operations, the scientific basis for the program, and how the seeding agent (silver iodide) functions to reduce hail.

Figure 16. WMI Co-pilot Janelle Newman explains the Cessna 340 aircraft (Hailstop 2) to a group of insurance industry employees during a tour of the Olds-Didsbury Airport on August 24, 2012. (WMI photograph by Jody Fischer)

8.0 Flight Operations

Four specially equipped cloud seeding aircraft were dedicated to the project. One Beech C90A King Air and a Cessna 340A were based in Calgary (Springbank after June 25), and a C90A and another C340A were based in Red Deer. The procedures used in 2012 remained the same as the previous years. The Calgary office and aircraft were initially stationed at the Landmark Aviation hangar at the Calgary International Airport, but because of new arrival scheduling procedures at the airport operations were for the first time shifted to the Springbank Airport west of Calgary. This change was implemented on June 25th, without interruption of service. A WMI Red Deer office was again set up in the Air Spray hangar at the Red Deer Regional Airport, as had been done in 2010 and 2011.

When convective clouds were detected by radar or visually observed to be developing, the seeding aircraft were placed on standby status, and the crew of at least one sent to their airport. Aircraft on standby status are able to launch and reach a target cloud within about 30 min after the request to launch has been made by the controlling meteorologist. When seedable clouds are imminent, the seeding aircraft are dispatched to investigate. Aircraft were available and prepared to commence a seeding mission at any time and the seeding of storms often continued after dark with due regard to safety (see again Figure 9).

AIR TRAFFIC CONTROL

Prior to the start of field operations, arrangements were made with NAV Canada managers of Air Traffic Services in Calgary and Edmonton to coordinate the cloud seeding aircraft operations. Permission was granted to file pre-defined flight plans for the project aircraft, with special designations and fixed transponder codes. The designated aircraft were as follows: Hailstop 1 for the King Air C90 airplane (N904DK) based in Calgary/Springbank, Hailstop 2 for the C340 aircraft (N457DM) based in Calgary/Springbank, Hailstop 3 for the King Air C90 aircraft (N522JP) stationed in Red Deer, and Hailstop 4 for the C340 aircraft (N123KK) based in Red Deer. For mechanical reasons, the C340 serving as Hailstop 4 was swapped for another (N234PS) on 12 July.

Figure 17 (right). WMI Captain Jenny Thorpe and Co-pilot Janelle Newman (HS2), conduct a Patrol flight on August 23, 2012. (WMI photograph by Jody Fischer)

Direct-line telephone numbers were used to notify air traffic controllers of cloud seeding launches. Aircraft were launched to specific locations defined by VOR and DME coordinates. Distinct air traffic clearance was given to project aircraft within a 10 nautical mile radius of the specified storm location. Cloud top aircraft were given a 2,000 ft block with 6,000 ft clearance below bottom of their block. Cloud base aircraft were given a ± 1,000 ft altitude clearance (see again Figure 8). This procedure works very well in general. On a few occasions, seeding aircraft are asked to briefly climb to higher altitudes over the city of Calgary, or to suspend seeding for a few minutes to allow other commercial aircraft to pass below them, but such interruptions are infrequent.

CLOUD SEEDING AIRCRAFT

Two different models of twin-engine aircraft were utilized on the project. Hailstop 1 and Hailstop 3, the cloud-top seeding aircraft, were Beech King Air C-90s, a turboprop (propjet) aircraft. Both cloud-base seeding aircraft (Hailstop 2 and 4) were Cessna model 340A aircraft. All four aircraft were each equipped with fuselage-mounted flare racks carrying ejectable flares, and also wing racks for burn-in-place flares. The two Cessna 340As also were equipped with solution-burning ice nucleus generators affixed to their wingtips.

Beech King Air C90

A photo of the Beechcraft King Air C90 (Hailstop 1) is shown in Figure 18. Complete aircraft specifications are given in the Appendix. The King Air C90 is a high-performance twin-engine turboprop aircraft that has been proven repeatedly in seeding operations. Each of the King Airs was equipped with three belly-mounted racks each having the capacity for 102 20-gram ejectable cloud seeding flares, for an aircraft total of 306 flares. Each also carried racks affixed to the trailing edges of the wings that held 12 150-gram "burn-in-place" flares per wing. As this nomenclature implies, the burn-in-place pyrotechnics are not ejected, but are burned while attached to the wing rack.

The two turboprop seeding aircraft (Hailstop 1, Calgary/Springbank, and Hailstop 3, Red Deer) were used primarily for seeding at cloud top by direct penetration of growing cloud turrets, most often those flanking large storm complexes, as shown previously in Figure 8. Such turrets are precipitation-free at the time of seeding, and consequently (radar) echo-free as well, though more mature adjacent cells may be producing strong radar returns. This means that those monitoring operations will often see the flight tracks of properly positioned aircraft *near* the echoing storm complexes, but not necessarily *in* them. This direct targeting makes very effective use of these aircraft, which function most efficiently at higher altitudes.

Figure 18. WMI Beechcraft King Air C90, HS1 aircraft on the ramp in Olds-Didsbury. (Photograph by Terry Krauss)

Cessna 340A

The two other seeding aircraft, Hailstop 2 (Calgary/Springbank) and Hailstop 4 (Red Deer) were Cessna 340A aircraft whose primary role was seeding the growing cloud turrets while within updrafts at cloud bases. The Cessna 340s are pressurized, twin-engine, six cylinder, turbocharged and fuel-injected all weather aircraft, equipped with weather avoidance radar and GPS navigation system (Figure 19). Complete specifications for the C340 are given in the Appendix.

The C340 aircraft both carry a 102-position belly rack for 20-gram ejectable flares (used in cloud top seeding, which they also can do very effectively), and wing racks for at least 24 150-gram burn-in-place flares, as well as two wing-tip ice nucleus generators that burn silver iodide seeding solution. Each generator has a capacity of 26.5 litres (7.0 U.S. gallons), sufficient for continuous seeding for about 2.5 hours.

Although the C340 can seed effectively at cloud top, even in known icing conditions, these aircraft are not as fast or powerful as the turboprop aircraft and so are more efficient and cost-effective when utilized in cloud-base seeding operations, their primary role in Alberta.

Figure 19. Hailstop 4, a Cessna 340A seeding aircraft is shown on the ramp in Olds Didsbury. Most notable on the aircraft (and absent from the turboprop aircraft) are the wing-tip ice nucleus generators, the silver torpedo-like appurtenances below the wing-tip fuel tanks. (WMI photograph by Jody Fischer)

9.0 Radar Control and Communication Centre

The project Operations Centre was once again located at the Olds-Didsbury Airport (identifier CEA3), near the geographical centre of the protected area, and approximately equidistant from Calgary and Red Deer. The office contains a modest reception and work area, the operations room from which the weather is monitored and operations conducted, and a washroom. The reception/work area has two desks, telephone, a printer/copier/scanner/fax, and a digital projector used for presentations about the program. A small refrigerator, coffee pot, and water cooler were also available.

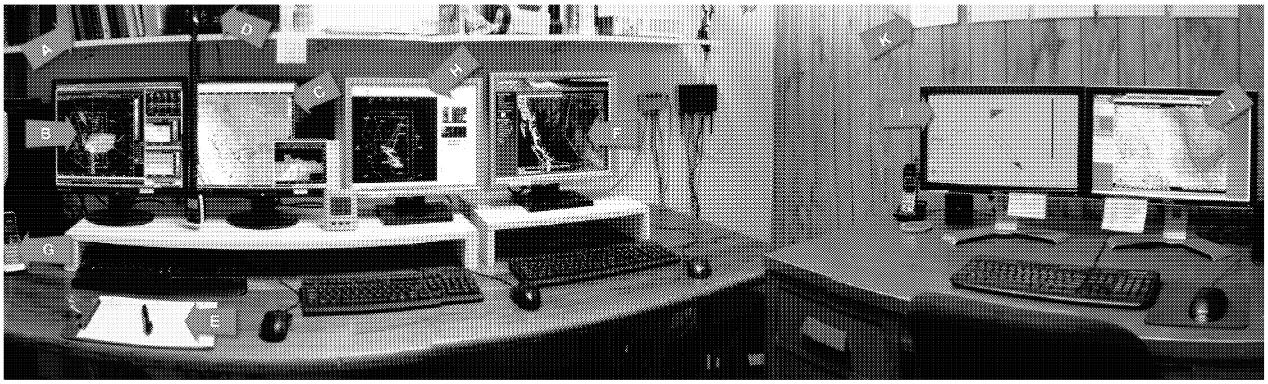


Figure 20. The configuration of the Operations Room. Equipment includes (A) reference manuals, (B) TITAN displays, (C) CIDD, (D) VHF radio for communications with aircraft, (E) radar log, (F) internet data displays, (G) telephone, (H) AirLink display, (I and J) forecasting/nowcasting support displays, and (K) radio and radar licenses. (WMI wide-angle photograph by Daniel Gilbert)

The project's radar control room contains an AirLink computer with radio telemetry modem for GPS aircraft tracking acquisition, as well as the TITAN computer and display for the radar, and the meteorological data acquisition (internet) computer. Controllers communicated with the seeding aircraft using a VHF radio. The controlling duties were led by Dan Gilbert, who was assisted by Brad Waller, and Joe Pehoski.

A weather station affixed to the sub-structure of the radar antenna tower telemetered temperature, pressure, wind, and humidity into the office, where it was recorded by computer. A wedge-type precipitation gauge near the front door allowed the recording of daily rainfall totals.

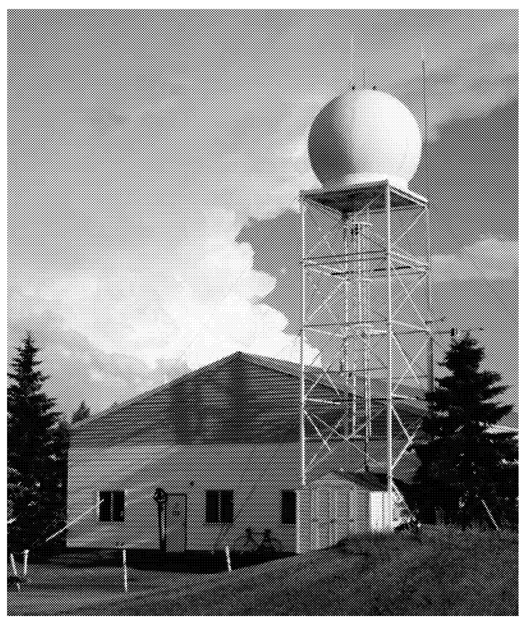


Figure 21 (right). The project Operations Centre at the Olds-Didsbury Airport. (WMI photograph by Bradley Waller)

High speed internet was again installed at the Calgary/Springbank and Red Deer airport offices so that the pilots could closely monitor the storm evolution and motion prior to takeoff. This gave them better comprehension of the storm situation they were going to encounter when they were launched.

The operations room is configured to place all the needed resources within easy reach of the operations director. Project reference and equipment manuals are shelved on the upper left. Telephones are available, with remote handsets. The desk top provides the space needed for data recording (logs) and data entry (keyboard/mouse). The VHF radio needed for ground-to-air communication is placed directly in front of the operations director. To the far right is a third computer with dual monitors (Fig. 20, I, J), for continuous, dedicated access to internet weather data from other sources. There is ample room for a second meteorologist in the operations room when needed to assistance with radio communications, data entry, or general weather surveillance.

RADAR

In 2011, the WR-100 radar that had served the project from 1996 through 2010 was replaced with a new set built by WMI that has significantly increased sensitivity as well as Doppler capability. This new transmitter and receiver allows improved detection of developing storms, but also displays mature storms with greater clarity. This change has had a significant, positive impact on operations.

An upgraded TITAN radar display and analysis computer system was installed in 2010. This system was further updated prior to the 2011 season with a new operating system, and the backup computer was pre-loaded with an image of the primary so that in the event of a system failure an immediate swap would be possible. No TITAN failures occurred during the 2012 season, however.

The TITAN radar images were sent to the WMI web server at 5 minute intervals. A larger battery backup system for the radar, TITAN, and the other mission critical equipment in the operations room made it possible to hold all essential computers on battery more than long enough to start the backup generator and switch over to local power. The backup generator was run for a short period (10-15 minutes) each month to ensure functionality should it have been needed.

Radar Calibration Checks

The radar was thoroughly calibrated when set up prior to the beginning of the 2012 season, and features routine automatic calibration of receiver and peaking of the transmitter automatic frequency control. Radar specifications are given in Table 4, below.

TABLE 4. Specifications of the WMI C-Band Weather Radar.

Parameters	Units / Values
Minimum Detectable Signal	-108 dBm
Radar Noise Figure	2.9 dB @ 1 MHz
Dynamic range	70 dB Receiver noise-dominated 100 dB compressed; @150 m range gate
Bandwidth	Automatically matched to gate spacing: .738 MHz at 150 m
Sensitivity	Reflectivity 0 dB RF SNR -9 dBZ @ 50 km 0.8 μ sec pulse length
Frequency Range	5.30 – 5.8 GHz (C-band) (5.62 GHz 2011 value)
Pulse Repetition Frequency	800

AIRCRAFT TRACKING

The project Operations Centre was equipped to receive and record data from all project aircraft, using data radio and WMI's AirLink tracking system. These GPS-based systems provided the exact real-time positions of the aircraft, allowing them to be superimposed on the TITAN RVIEW display. This allowed the meteorologist(s) controlling flight operations to accurately direct the aircraft to optimum seeding positions relative to each storm system. Each aircraft track was displayed in a different color, providing unambiguous identification. Examples of the raw AirLink data flight tracks, as well as 10-minute track segments superimposed on the TITAN displays are provided later in this report in the detailed descriptions of the August 12, 2012 storm that moved over Calgary.

AirLink also displays where the seeding events took place, but these were not displayed on the tracks in the TITAN RVIEW because doing so adds excessive clutter to the already "busy" image. In addition to being telemetered to the Operations Centre, the position and seeding event data are recorded on board the aircraft, and thus are not lost if the telemetry between aircraft and radar is interrupted.

10.0 Summary of Seeding Operations

A brief summary of each day indicating the weather and operational activities is given in the Appendix. Further details regarding flight times and the amount of seeding are given in the Flights and Operations Summary tables, also in the Appendix.

The summer of 2012 was again quite active from a weather perspective. There were thunderstorms reported within the project area on 70 days this summer, compared with 73 days in 2011. However, 22 of the 70 days produced storms having hail or radar vertically-integrated liquid (VIL) values commensurate with the Convective Day Category of +4 (golf ball size hail), indicating an unusual number of very strong storms. The weather became much less active by mid-August, and only two seeding missions were flown after August 14th.

Four specially equipped cloud seeding aircraft were dedicated to the project. One Beech C90A King Air and a Cessna 340A were based in Calgary (Springbank after June 25), and a C90A and another C340A were based in Red Deer. The procedures used in 2012 remained the same as the previous years. The Calgary office and aircraft were initially stationed at the Landmark Aviation hangar at the Calgary International Airport, but because of new arrival scheduling procedures at the airport operations were for the first time shifted to the Springbank Airport west of Calgary. This change was implemented on June 25th, without interruption of service. A WMI Red Deer office was again set up in the Air Spray hangar at the Red Deer Regional Airport, as had been done in 2010 and 2011.

The aircraft and crews provided a 24-hour service, seven days a week throughout the period. Eight full-time pilots and three meteorologists were assigned to the project this season. In addition, WMI's Chief Pilot, Mr. Jody Fischer, served as overall program manager. The 2012 crew was well experienced. The Red Deer aircraft team was led by Mr. Roger Tilbury, who has been flying cloud research and cloud seeding missions since the 1970s, and Mr. Joel Zimmer who has been with the Alberta program for 10 years. In addition to Mr. Fischer, the Calgary (Springbank) team was anchored by Mr. Brook Mueller and Mr. Mark Friel, both of whom also had considerable experience. The radar crew was anchored by Mr. Daniel Gilbert, now with three seasons' experience in Alberta, in addition to seven seasons' work in a similar capacity on a hail suppression program in North Dakota.

Overall, the personnel, aircraft, and radar performed exceptionally well and there were no interruptions or missed opportunities. A gear failure in the radar antenna drive placed the radar temporarily out of service at 6:01 pm on June 17th, while operations were being conducted near Rocky Mountain House. Radar support for the operations immediately began using imagery from the Environment Canada radar near Strathmore, though real-time aircraft flight tracks were still being received at the radar on AirLink. Once the problem was isolated, a replacement drive gear was found in the on-site spare parts and repairs began. Flight operations were completed without difficulty. The repairs were completed by 4:53 pm the following day. A second, similar failure occurred on August 6th at about 5:00 pm but repairs were quickly made and the radar was back in operation by 8:45 that same evening, without loss of storm coverage.

All of the project's radar data, meteorological data, and reports have been recorded onto a portable hard drive as a permanent archive for the Alberta Severe Weather Management Society. These data include the daily reports, radar maps, aircraft flight tracks, as well as meteorological charts for each day. The data can be made available for outside research purposes through a special request to the Alberta Severe Weather Management Society. In addition, ASWMS Program Director Dr. Terry Krauss was provided the entire season's TITAN (radar) data, as he has that software running on a computer in his office. This will enable mutual (WMI and ASWMS) examination of the data set in the off season, prior to the 2013 program.

FLIGHTS

The weather pattern was less active in June than 2011, but even so 70.1 hours were flown for seeding and patrol. July was the busiest month; the four project aircraft flew a total of 181.6 hours during seeding and patrol flights. A "patrol" flight is a flight flown to check cloud intensity or in anticipation of clouds becoming intense enough to warrant seeding, but during which no seeding was actually conducted. A total of 74.4 hours were flown in August, and only 4.5 hours in September.

During this season, there were 300.1 hours flown on 43 days with seeding and/or patrol operations. A total of 116 storms were seeded during 115 seeding flights (271.1 flight hours) on the 37 seeding days. There were 28 patrol flights (30 hours), and 24 short "public relations" flights on which one aircraft was flown to the Olds-Didsbury Airport to be available for viewing by insurance company employees attending tours of the operations centre and radar.

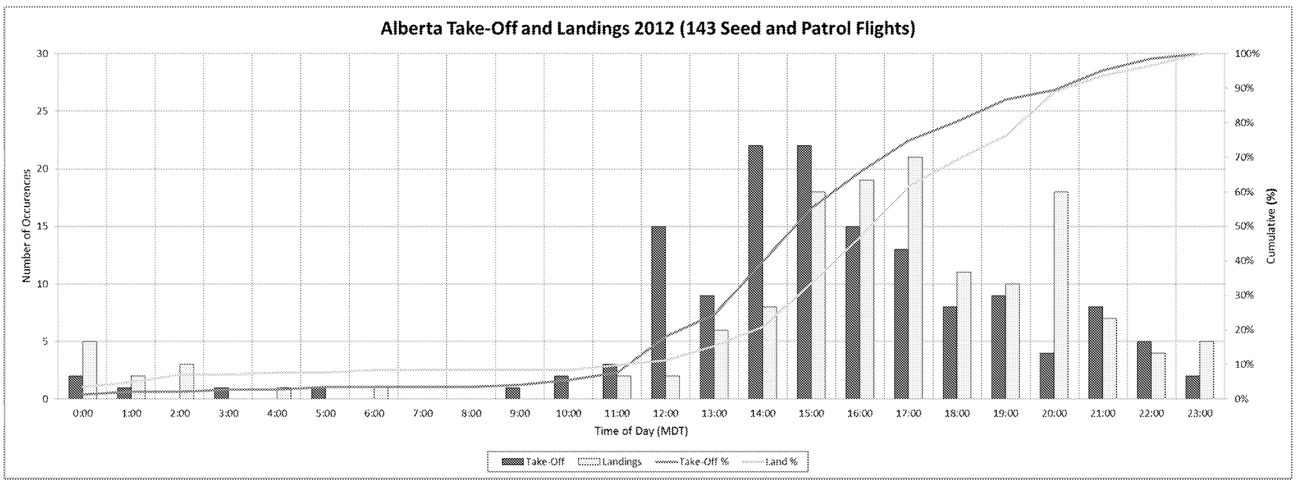


Figure 22. Takeoffs and landings by time of day (Mountain Daylight Time). As has been the history of the project, most flight operations were conducted during the afternoons and evenings, strongly synchronized with the diurnal heating, and thus convection. An increased percentage of the flights were initiated between midnight and the noon briefing times, reflecting the increased attention to stronger nocturnal storms.

SEEDING AMOUNTS

The amount of silver-iodide nucleating agent dispensed during the 2012 field season totaled 314.6 kg. This was dispensed in the form of 7,717 ejectable (cloud-top) flares (154.34 kg seeding agent), 914 burn-in-place (cloud-base) flares (137.1 kg seeding agent), and 260.3 gallons of silver iodide seeding solution (23.12 kg seeding agent).

The amount of AgI dispensed on each day of operations in 2012 is shown in Figure 23. There were 11 days on which greater than 10 kg of seeding material was dispensed. Most of these were days on which all four aircraft seeded, but not all.

The amount of seeding agent dispensed per storm was above average (2.7 kg per storm), but rates this great or greater were recorded in 2011 and 2004 (3.0 kg/storm), and 2006 (3.3 kg/storm). With a full season's experience with the new, more sensitive radar the operations team felt more confident in the seeding rates in 2012.

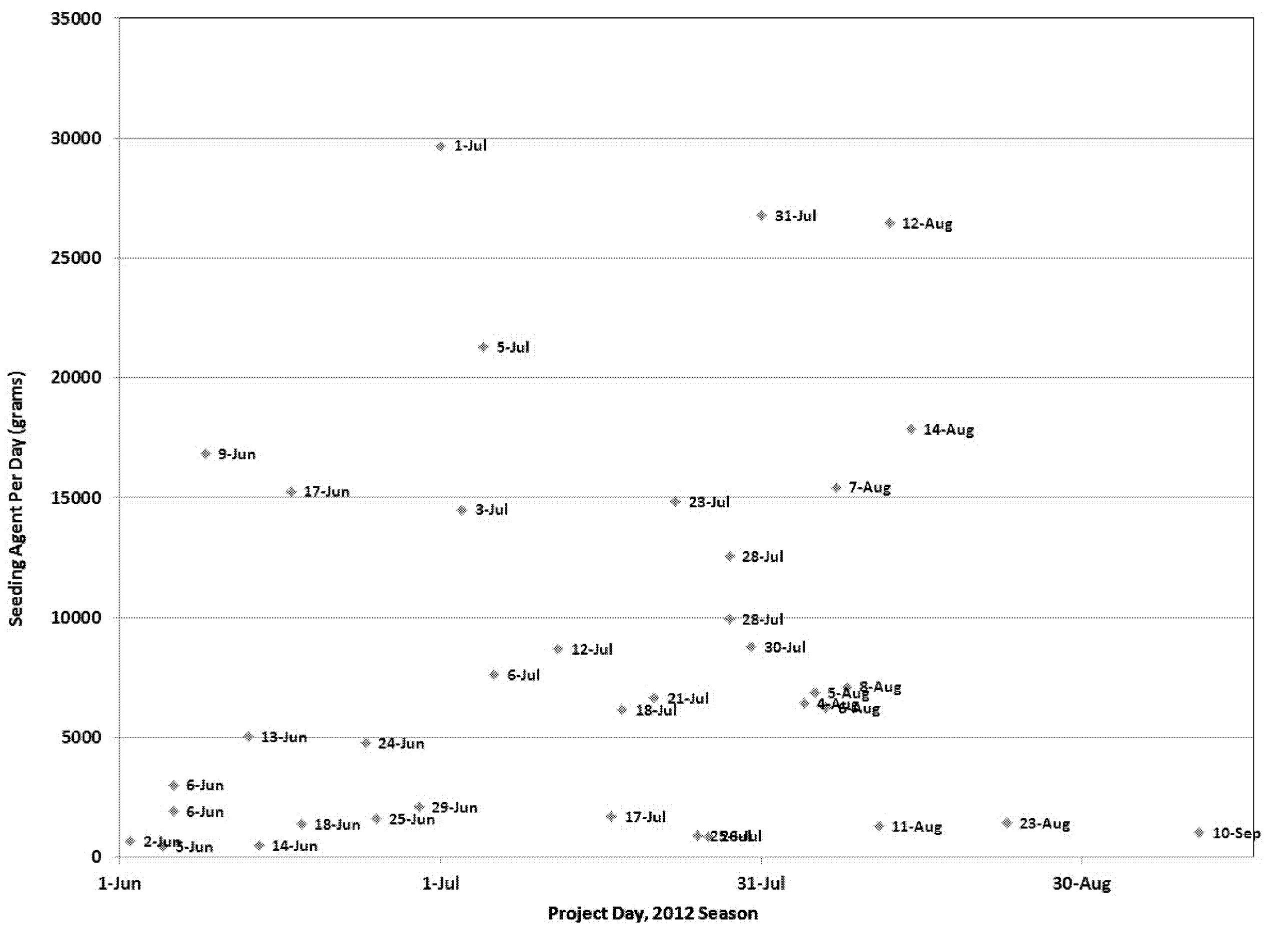


Figure 23. Amount of seeding material dispensed per operational day in 2012.

Table 5 gives a list of the operational statistics for the past seventeen years of the Alberta Hail Suppression Project. These statistics can be useful in understanding how the current season compared with those before, and for planning purposes. This summer ranked second all-time in terms of activity. Though seeding occurred on only 37 days [the mean is 31 days, the record (2011) was 48 days] those days were very active; 143 project missions were flown for patrol and seeding.

The *Season Activity Rank* shown at the bottom of Table 5 was calculated as follows: Each parameter for each year was divided by the project mean for that parameter to produce a normalized value. Then, the normalized values of *Storm Days with Seeding*, *Aircraft Missions*, *Total Flight Time*, *Number of Storms Seeded*, *Ejectable Flares*, *BIP Flares*, and *Seeding Solution* were summed for each season. The seasons were then ranked. *Total Seeding Agent*, *Seeding Agent per Day*, *Seeding Agent per Hour*, and *Seeding Agent per Storm* were not included in the ranking as those are all quantities derived from the others.

A summary of the flare usage, by aircraft, during the past 17 years is given in Table 6. The Cessna 340s (Hailstop 2 and Hailstop 4) are used mainly as cloud base seeding aircraft because they have less performance than the two turbine aircraft and are equipped with the liquid AgI solution burners. Hailstop 1 in Calgary had been a Piper Cheyenne II for all 15 seasons through 2010, but was replaced with a Beech C90 King Air beginning with the 2011 season. The King Airs are newer, have the same engines as the Cheyenne (the Pratt and Whitney of Canada PT-6A), and parts are more readily available. Hailstop 2 in Calgary has been a Cessna 340A for all 17 years. Hailstop 3 in Red Deer was a C340 for 4 years (1996-99), a Cheyenne II in 2000, 2003 and 2005, and a King Air C90 in 2004, and now from 2006 to present. The advantages of the C90 are that it has slightly longer endurance for increased seeding time, and good performance for reaching the far western regions of the target area near Rocky Mountain House in a reasonable amount of time (i.e. less than 30 min). The second C340, Hailstop 4, was added in 2008 and based in Red Deer.

All aircraft remained serviceable for the entire operational period, and there were no significant maintenance issues - except for a mechanical issue with N123KK (Hailstop 4), it was determined to be unairworthy on the morning of July 8th. N123KK was replaced with another WMI C340, N234PS on July 12th. No operations were missed during the downtime.

The best seeding coverage consists of seeding a storm simultaneously using two aircraft; one at cloud base and another at cloud top (-10°C) along the upwind "new growth" side of the storm. The King Air aircraft have proven themselves as excellent cloud-top seeders. The seeding strategy has been to stagger the launch of the seeding aircraft, and use one aircraft to seed at cloud base and one aircraft at cloud top when the storm is immediately upwind or over the highest priority areas. However, if multiple storms threaten three or more areas at the same time, generally only one aircraft is used on each storm, or more aircraft are concentrated on the highest population area around Calgary. Seeding was conducted on the following 37 days: June 2nd, 4th, 5th, 6th, 9th, 13th, 14th, 17th, 18th, 24th, 25th, 29th, July 1st, 3rd, 5th, 6th, 12th, 17th, 18th, 20th, 23rd, 25th, 26th, 27th, 28th, 30th, 31st, August 4th, 5th, 6th, 7th, 8th, 10th, 12th, 14th, 23rd, and September 10th. All four aircraft were used for seeding operations on the following 9 days (local time) this season: June 17th, July 1st, 3rd, 5th, 23rd, 27th, and 31st, and August 8th and 12th. Patrol flights were flown on June 2nd, 4th, 17th, 18th, 24th, and 30th, on July 1st, 8th, 10th, 12th, 22nd, 25th, 27th, 28th, 30th, and 31st, August 5th, 8th, 11th, 20th, 22nd, and 23rd, and on September 10th.

TABLE 5. Operational Statistics for Seeding and Patrol Flights, 1996 through 2012.

	Mean	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Storm Days with Seeding	31.5	29	38	31	39	33	36	27	26	29	27	28	19	26	20	42	48	37
Aircraft Missions (Seeding & Patrol)	101	71	92	96	118	130	109	92	92	105	80	92	76	112	37	91	134	143
Total Flight Time (hours)	207.8	159.1	188.1	189.9	251.3	265.2	208.3	157.4	163.6	227.5	157.9	190.2	115.3	194.7	109.3	271.8	383.0	300.1
Number of Storms Seeded	93	75	108	153	162	136	98	54	79	90	70	65	41	56	30	118	134	116
Total Seeding Agent (kg)	195.8	163.3	110.8	111.1	212.7	343.8	195.0	124.2	173.4	270.9	159.1	214.0	99.7	122.9	48.4	263.8	400.1	314.6
Seeding Agent per Day (kg)	6.1	5.6	2.9	3.6	5.5	10.4	5.4	4.6	6.7	9.3	5.9	7.6	5.2	4.7	2.4	6.3	8.3	8.5
Seeding Agent per Hour (kg)	0.97	1.00	0.60	0.60	0.80	1.30	0.90	0.80	1.10	1.20	1.00	1.10	0.90	1.00	0.84	1.10	1.13	1.16
Seeding Agent per Storm (kg)	2.2	2.2	1.0	0.7	1.3	2.5	2.0	2.3	2.2	3.0	2.3	3.3	2.4	2.2	1.6	2.2	3.0	2.7
Ejectable Flares	4610	3817	2376	2023	4439	9653	5225	3108	4465	6513	3770	4929	1622	1648	451	5837	10779	7717
BIP Flares	619	542	356	496	690	940	533	377	518	877	515	703	413	548	237	851	1020	914
Seeding Solution (gal)	154.6	80.5	144.3	193.8	297.5	141.3	140.8	80.3	92.6	132.7	94.2	145.4	77.0	113.5	56.5	227.5	350.2	260.3
Season Activity Rank	-	14	10	8	4	3	7	15	11	6	13	9	16	12	17	5	1	2

*June 15th to September 15th during 1996 and 1997. AgI solution for 2010-12 reflects the actual number of gallons of acetone solution burned.

TABLE 6. Cloud seeding flares usage comparison by aircraft. EJ refers to 20 g ejectable AgI flares. BIP refers to 150 g burn-in-place AgI flares. AgI solution refers to the time (hrs.) that the acetone burners were used.

Year	Hailstop 1 Calgary (Springbank)	Hailstop 2 Calgary (Springbank)	Hailstop 3 Red Deer	Hailstop 4 Red Deer
	FLIGHT hrs: FLARES (EJ and BIP)	FLIGHT hrs: FLARES (EJ & BIP) , SOLUTION	FLIGHT hrs: FLARES (EJ & BIP), SOLUTION	FLIGHT hrs: FLARES (EJ & BIP), SOLUTION
2012	76.0 3250 EJ, 232 BIP C90 King Air	87.4 0 EJ, 224 BIP, 71.9 hr Cessna 340	83.0 4464 EJ, 198 BIP C90 King Air	84.5 3 EJ, 260 BIP, 62.9 hr Cessna 340
2011	97 4783 EJ, 239 BIP C90 King Air	104.6 244 EJ, 269 BIP, 91.4 hr Cessna 340	98.9 5646 EJ, 273 BIP C90 King Air	108.0 106 EJ, 239 BIP, 92.3 hr Cessna 340
2010	61.9 1612 EJ, 132 BIP Cheyenne II	82.4 74 EJ, 236 BIP, 52.9 hr Cessna 340	96.3 4154 EJ, 200 BIP C90 King Air	68.0 2 EJ, 286 BIP, 63.5 hr Cessna 340
2009	21.5 250EJ, 27 BIP Cheyenne II	31.2 0EJ, 65 BIP, 5.95 hr Cessna 340	24.0 201EJ, 48 BIP C90 King Air	32.6 0 EJ 97 BIP, 16.6 hr Cessna 340
2008	64.5 953 EJ, 88 BIP Cheyenne II	44.3 0EJ, 171 BIP, 26.8 hr Cessna 340	50.8 695 EJ, 169 BIP C90 King Air	35.1 0 EJ, 120 BIP, 18.6 hr Cessna 340
2007	40.0 979 EJ, 81 BIP Cheyenne II	41.2 0EJ, 155 BIP, 30.8 hr Cessna 340	34.1 643 EJ, 177 BIP C90 King Air	
2006	54.0 3217 EJ, 179 BIP Cheyenne II	70.2 72EJ, 248 BIP, 58.2 hr Cessna 340	66.0 1640 EJ, 276 BIP C90 King Air	
2005	49.1 2750 EJ, 169 BIP Cheyenne II	44.8 0EJ, 121 BIP, 37.7 hr Cessna 340	63.9 1020 EJ, 225 BIP Cheyenne II	
2004	83.2 5574 EJ, 359 BIP Cheyenne II	62.2 0EJ, 196 BIP, 53.1 hr Cessna 340	82.1 939 EJ, 322 BIP C90 King Air	
2003	63.9 3598 EJ, 250 BIP Cheyenne II	54.2 0EJ, 130 BIP, 37.1 hr Cessna 340	45.5 867 EJ, 138 BIP Cheyenne II	
2002	57.1 1994 EJ, 163 BIP Cheyenne II	49.3 2 EJ, 73 BIP, 32.1 hr Cessna 340	51.0 1112 EJ, 141 BIP Cheyenne II	
2001	62.4 3174 EJ, 216 BIP Cheyenne II	74.8 4 EJ, 215 BIP, 56.3 hr Cessna 340	68.1 2093 EJ, 102 BIP Cheyenne II	

2000	89.5 4755 EJ, 379 BIP Cheyenne II	77.4 164 EJ, 193 BIP, 56.5 hr Cessna 340	97.4 4734 EJ, 368 BIP Cheyenne II	
1999	91.3 3795 EJ, 313 BIP Cheyenne II	81.4 244 EJ, 197 BIP, 59.6 hr Cessna 340	78.6 400 EJ, 180 BIP, 59.4 hr Cessna 340	
1998	62.2 1880 EJ, 107 BIP Cheyenne II	68.4 134 EJ, 199 BIP, 29.2 hr Cessna 340	59.4 9 EJ 190 BIP, 48.3 hr Cessna 340	
1997	70.2 1828 EJ, 62 BIP Cheyenne II	58.0 264 EJ, 128 BIP, 25.9 hr Cessna 340	60.0 284 EJ, 166 BIP, 31.8 hr Cessna 340	
1996	61.6 2128 EJ, 143 BIP Cheyenne II	45.8 895 EJ, 192 BIP, 9.4 hr Cessna 340	51.7 794 EJ, 207 BIP, 22.8 hr Cessna 340	

STORM TRACKS

A map of all hailstorm tracks (determined by radar) during 2012 is shown in Figure 24. July was the busiest month, as is typically the case, but the first half of August was also very active. There were at least ten hailstorms that tracked across or within the city limits of Calgary during July and early August. The most notable of these was the storm of August 12, which moved southeast across the city and produced considerable hail, some golf ball size. [An overview of this storm is included later in this document.]

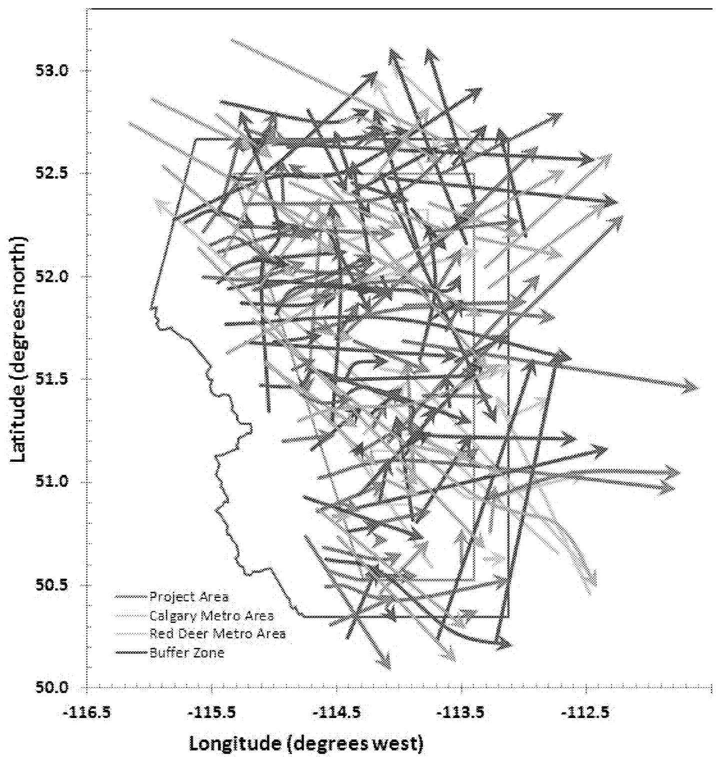


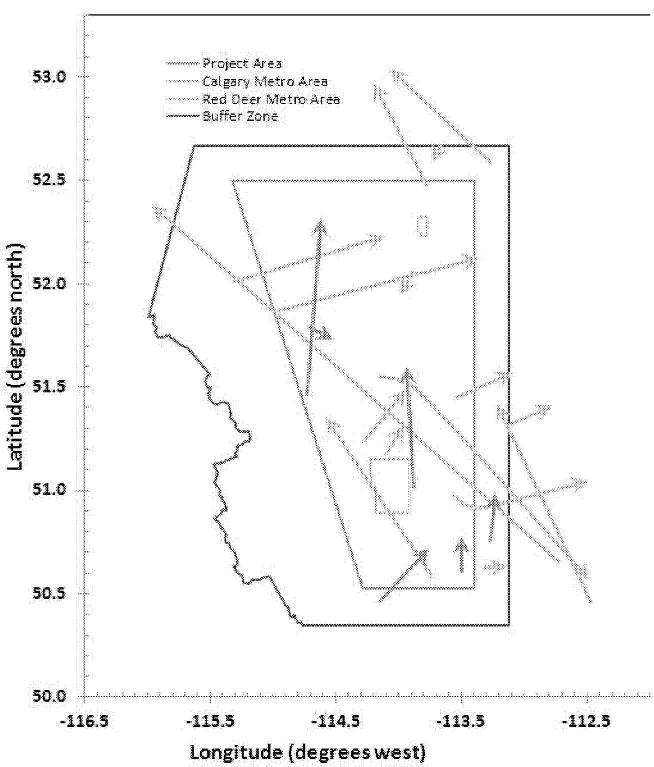
Figure 24. Map of all potential hailstorm tracks within radar coverage during 2012, as indicated by a minimum vertically-integrated liquid (VIL, from the radar) of at least 30. This map shows all of the 116 storms seeded, plus others of hail potential that did not move near cities or towns. All storms must be carefully monitored because as the tracks show, direction of movement often changes. June storms are green, July red, August blue, and September violet. For each, the lighter color denotes storms that occurred during the first half of the month.

The number and distribution of storm tracks during 2012 was very similar to previous seasons, July being the most active month, and August second most active. There were very few storms in late August, and only five cells are plotted for September. New last season in the storm tracks graphics, was the plotting of more than just starting and ending points when cells turned appreciably. This was done to afford the reader a better perspective of actual storm behavior. This is continued for the 2012 season.

Larger than golf ball size hail was reported on July 28th east southeast of Airdrie and south of Irricana. The 12th of August also saw a report of larger than golf ball size hail in the northwestern part of Calgary.

Golf ball size hail was reported or observed by radar signature on June 13th east of the town of Linden; July 1st southwest of High River, north of Three Hills, and near Linden; the 5th of July in northwestern Calgary; on the 12th of July northwest of Rocky Mountain House, southwest of High River, and southwest of Calgary; then on the 13th of July southwest of Calgary; and the 17th of July northwest of Rocky Mountain House. Hail up to golf ball size was also reported on the 18th of July near Rimbey, southwest of Ponoka, and east of Lacombe; the 23rd of July north of Rocky Mountain House and northwest of Caroline; on the 25th of July southwest of Three Hills; on the 27th of July south and southeast of High River and near Irricana; on the 30th of July north of Sundre; and the 31st of July southwestern Calgary, near the town of Three Hills, and east southeast of Strathmore. The month of August saw up to golf ball size hail on the 4th, north of Lacombe; on the 5th south and southeast of Rocky Mountain House; on the 6th west of Sylvan; the 7th in eastern Calgary and near Irricana; on the 8th west of Rocky Mountain House, west of Sundre, south of Red Deer, and east of the town of Acme; the 10th northwest of Lacombe and northwest of Rocky Mountain House; on the 14th near Turner Valley and west of High River; on the 20th southwest of Cremona; on the 21st north and south of Rocky Mountain House; and on the 23rd northwest of Caroline and east southeast of Red Deer.

Walnut size hail was reported or observed by radar signature on June 2nd near Strathmore; June 6th southeast of Strathmore; on June 9th northeast of Innisfail; on the 17th of June in Rocky Mountain House; June 24th south of Sundre and east southeast of Airdrie; July 3rd north northeast of Sundre and near Three Hills, on the 8th of June west southwest of Cremona, July 10th north of Rocky Mountain House, on the 20th of July south of Strathmore, the 22nd of July west of Strathmore, July 26th east northeast of Airdrie, and west of the town of Caroline on the 10th of September.



The weather pattern was less active in June than 2011, but even so 70.1 hours were flown for seeding and patrol. July was the busiest month; the four project aircraft flew a total of 181.6 hours during seeding and patrol flights. A "patrol" flight is a flight flown to check cloud intensity or in anticipation of clouds becoming intense enough to warrant seeding, but during which no seeding was actually conducted.

Figure 25. Storm Tracks for the month of June 2012. The lighter green is those storms occurring in the first half of the month, the darker shade the latter half. All storms having VIL of at least 30 are plotted; the boundary of the operations area and protected area also are shown.

Figure 26. Storm Tracks for the month of July 2012. The lighter red is those storms occurring in the first half of the month, the darker shade the latter half. All storms having a VIL of at least 30 are plotted; the boundary of the operations area and protected area also are shown.

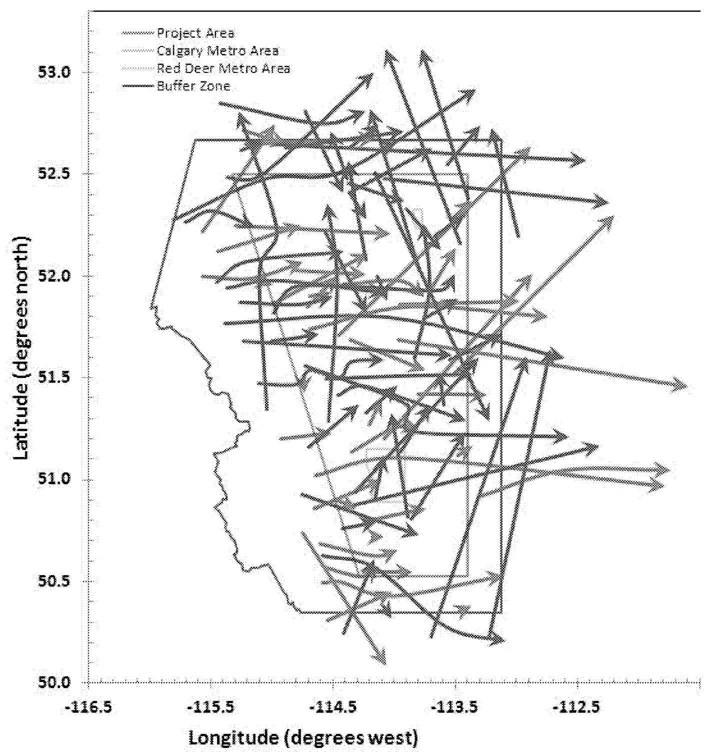


Figure 27. Storm tracks for the month of August 2012. The lighter blue is those storms occurring in the first half of the month, the darker shade the latter half. All storms having a VIL of at least 30 are plotted; the boundary of the operations area and protected area also are shown.

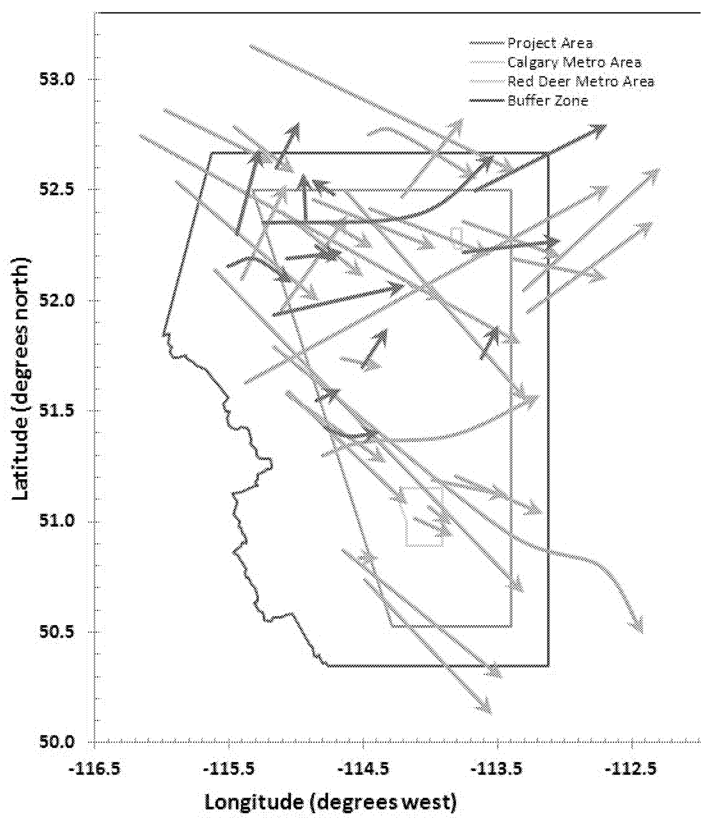
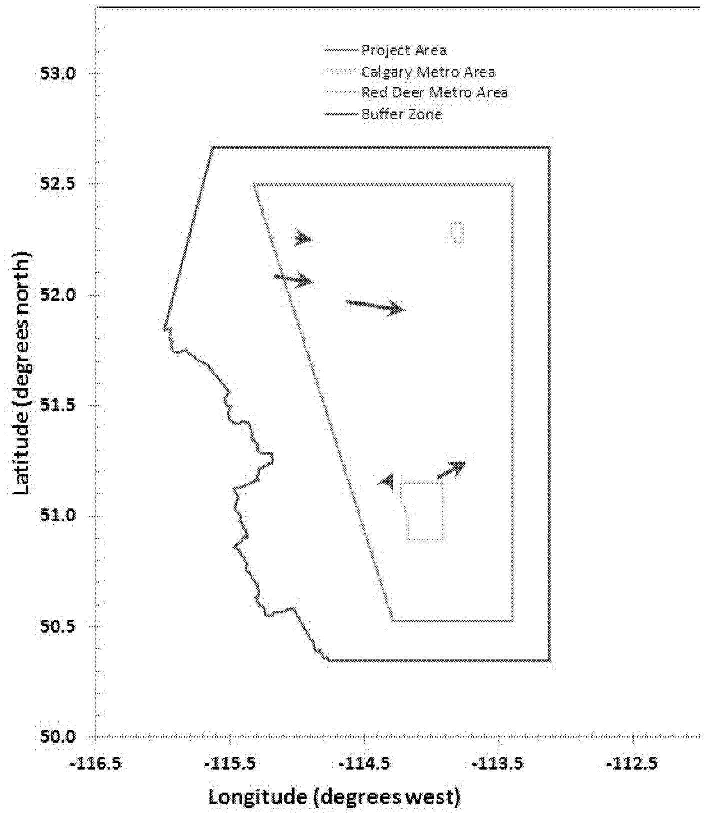


Figure 28. Storm tracks for the month of September 2012, up to the end of project on the 15th. All storms having a VIL of at least 30 are plotted; the boundary of the operations area and protected area also are shown.



11.0 Weather Forecasting

A project forecast was prepared each operational day throughout the project period by the assigned project meteorologist. In addition to the real-time information available from the project radar at the Olds-Didsbury Airport, the forecasting meteorologist used local weather observations as well as a vast array of weather data available on the internet.

COORDINATED UNIVERSAL TIME

The standard reference time chosen for the project field operations is universal time coordinates (UTC), also known as coordinated universal time (CUT), or Greenwich Mean Time (GMT). This is the accepted international standard of time for general aviation and meteorological observations, reporting, and communication. In Alberta, UTC is 6 hours ahead of local Mountain Daylight time. For example, 12:00 noon local Alberta time is equal to 18:00 UTC, and 6:00 PM local is equal to 24:00 or 00:00 UTC. This causes some confusion, especially with non-project personnel, since many of the thunderstorms occurred late in the day and continue beyond 6:00 PM local time, which is midnight or 00:00 hours UTC. The standard convention incorporated by the Alberta project is to report all aircraft, radar, and meteorological times in UTC; however, the summary tables are all organized according to the local calendar "storm" day with respect to Mountain Daylight Time for convenience.

PURPOSE

The primary function of the daily forecast is to impart to project personnel a general understanding of that day's meteorological situation, particularly as it relates to the potential for hail-producing storms. In this role it is useful, but because the data in hand are limited in temporal and spatial resolution, and because the forecasters themselves are human and thus fallible, the forecast can never be taken as the final word as to whether activity will or will not develop. Forecasts of no or limited convective activity do not relieve any project personnel of their hail-fighting responsibilities, and *should not reduce vigilance or readiness of meteorological staff or flight crews*. In theory, the project could function effectively without project forecasts. In reality, the forecasts are useful for a number of reasons:

- Elective maintenance of project-critical facilities (radar and aircraft) can be conducted on days when the probability of workable storms is less.
- Forecasts offer insight regarding the time at which convection is likely to initiate, thus allowing some intelligence in handling decisions about aircraft standby times.
- Preferred areas, e.g. northern, central, or southern portions of the protected area that are more prone to see action are identified in the forecasts, providing the logical basis for assignment of which aircraft are initially placed on standby.
- Forecasts attempt to quantify the available atmospheric instability, and thus the likelihood of explosive cloud/storm development. Days having high potential for rapid cloud growth require more immediate action.
- Post-hoc forecast verification conducted by the meteorologists is a helpful tool to increase our understanding of Alberta thunderstorms, especially the atmospheric indicators (precursors) in the pre-storm environment. As this knowledge improves, so will our ability to anticipate and react to the initial deep convection.

So, while in *theory* the forecasts are not needed, they are useful and probably essential. The ultimate defense against the unexpected, unforecast, explosively-developing severe storm would be to always have aircraft airborne, patrolling the skies, scanning for the first sign of intense vertical cloud growth. More realistically, one might have flight crews constantly waiting, ready to scramble. The funding available for the project does not allow either of these, however, so the forecast becomes the primary tool through which the available resources can be allocated in the most effective manner.

It is also worth noting that even when equipment and personnel work together efficiently as a well-oiled, smooth-running machine, hail damage can still occur. A typical thunderstorm releases as much energy in its lifetime as a nuclear bomb. Cloud seeding can affect the microphysical (precipitation) processes, but we do not yet have the knowledge or tools to affect the energy released. Nature, in the end, sometimes offers more than can be handled.

PROCESS AND DISSEMINATION

Project forecasts were valid from 6:00 AM through 6:00 AM the next day, and also include a day-two outlook. The daily forecast preparation began with an assessment of the current weather conditions. The latest METARs, weather station data, radar and satellite imagery were noted and saved. The latest surface and upper air analysis maps were printed and saved. All data were saved with file names that utilize the proper WMI file naming procedures, with YYYYMMDD at the beginning of the file name. Once the forecaster had a grasp of the current conditions, outside agency forecasts were examined in order to give a first-best-guess of the day's probable events. Often times, project personnel would request a "pre-forecast" before the official forecast is ready. NAV Canada, Environment Canada forecasts and BUFKIT soundings are always useful for this purpose.

The forecaster then examined the various operational prognostic model output. Typically, the WRF was the most up to date in the early morning. All forecasters had their own preference for operational models, but some of the choices available include the WRF/NAM, GFS, ECMWF, SREF and the Canadian models. Model data were archived daily (but not printed) for the 250 mb, 500 mb, 700 mb, and pressure surfaces. Saved maps include the most current map (usually 12Z) through hour 48. Certain features are always of interest at certain levels:

- The 250 mb best reflects the location of the upper jet stream winds, around 35,000 feet. This map was analyzed for the general wave pattern (ridge/trough), upper level diffluence, and jet streaks. The right entrance and left exit quadrants of an upper jet streak are considered favorable regions for enhanced upward motions. Storm days with "upper support" tend to produce more vigorous convection than days without.

- The 500 mb level reflects the middle of the atmosphere around 18,000 feet, which is generally the boundary between upper and lower level weather features (aka: the level of non-divergence). 500 mb charts were examined for temperatures, humidity, wave pattern, and especially vorticity. Advection of 500 mb vorticity from broad scale troughs, lows, or shortwaves tends to "force" air parcels to rise. This can be a trigger to help break through low level temperature inversions, or just simply enhance the amount of vertical motion in the atmosphere. Cold, dry conditions at this level are conducive to an unstable atmosphere. Many convective stability indices utilize temperature and dew point between the surface and 500 mb. History shows that some of the worst hail storms occurred on days with only moderate instability but with strong 500 mb vorticity advection and upper jet support.

- 700 mb is the lower to mid-level of the atmosphere around 10,000 feet near the convective cloud base. The 700 mb charts are most typically used to determine the amount of low level moisture over a region. High amounts of 700 mb moisture are conducive to an unstable atmosphere. Relative Humidity, theta-E (equivalent potential temperature), and vertical velocity charts are all useful tools at this level. Shortwave troughs are sometimes evident on 700VV charts when they are not easily identified at 500 mb. The presence of a theta-E ridge at or below 700 mb should be a red flag that nocturnal convection is possible. 700 mb charts should also be analyzed for the presence of an inversion or "cap" that inhibits surface based convection, although this is usually more easily identified on a sounding than on a map.

- Surface prognostic (forecast) charts (progs) were analyzed for the presence of lifting mechanisms such as troughs, lows, fronts, and dry lines. Such lifting mechanisms are triggers for initiating thunderstorms when the atmosphere is unstable. Moist, warm surface conditions are indicative of an unstable atmosphere. After sunset however, the lowest levels of the atmosphere tend to "decouple" from the upper and middle atmosphere as the air mass cools from the bottom up. This means that surface temperature and moisture are most important during the daytime and evening hours and can have less impact at night. It is a good idea to consult multiple sources for surface prog charts, as some analyses will omit important features. There can be major differences from one source to the next when it comes to surface analysis and timing. In general, surface dew points greater than 9°C are considered sufficient for large hail storms. Thunderstorm development becomes unlikely with dew points less than 5°C. Surface charts may also be utilized to determine areas with upslope flow. Low-level easterly winds flowing up the eastern slopes of the mountains are frequently the cause for storm initiation for the project.

After all model charts have been saved, the forecaster created a daily meteorogram. This is a one-page tool that includes multiple strip charts of the forecaster's choosing. Typical parameters for the meteorogram include temperature and dew point, cloud cover, wind direction/speed, CAPE, Lifted Index, Convective Inhibition, etc. The meteorogram is typically created for both Calgary and Red Deer every morning, but other locations can be utilized depending on where the forecaster thinks the best chance for deep convection (thunderstorms) will occur on that day. The meteorogram is printed and saved in the archives. The strip charts are valid through at least three days and can be a great tool for determining the extended outlook.

The next step was to create a daily sounding, or Skew-T diagram. Unfortunately, the closest real weather balloon site is Edmonton, which is too far away to use for forecasting in the project area. Forecast soundings from the numerical models were thus preferred, which could be generated through a host of different internet sources.

The 12Z and 00Z WRF/NAM soundings were archived for both Red Deer and Calgary on a daily basis. These data were also utilized for running the HAILCAST model when necessary. At this point the forecaster chose a location and valid time for the daily forecast sounding. This was the time and place with the worst-case scenario for the highest CDC (Convective Day Category) through the next 24 hours, typically Red Deer or Calgary. Most forecasts were made based on expected conditions at 00Z because the atmosphere is usually most unstable in the late afternoon. However this may be sooner or later depending on the timing of surface features, etc. Once the place and time were decided, the selected forecast sounding was opened with the RAOB software and modified as deemed physically plausible, to provide a worst-case scenario (most intense convection possible). This often involved raising or lowering the surface temperature to best represent the expected maximum temperature for the day. The amount of surface moisture could be modified as well, but this was done with care so as not to overdo it. This has a large effect and can be the cause of busted forecasts. Once the sounding was modified, all convective parameters were recorded on the *daily metstats sheet*, and the sounding was printed. An image of the sounding was always saved, which was emailed with the rest of the forecast.

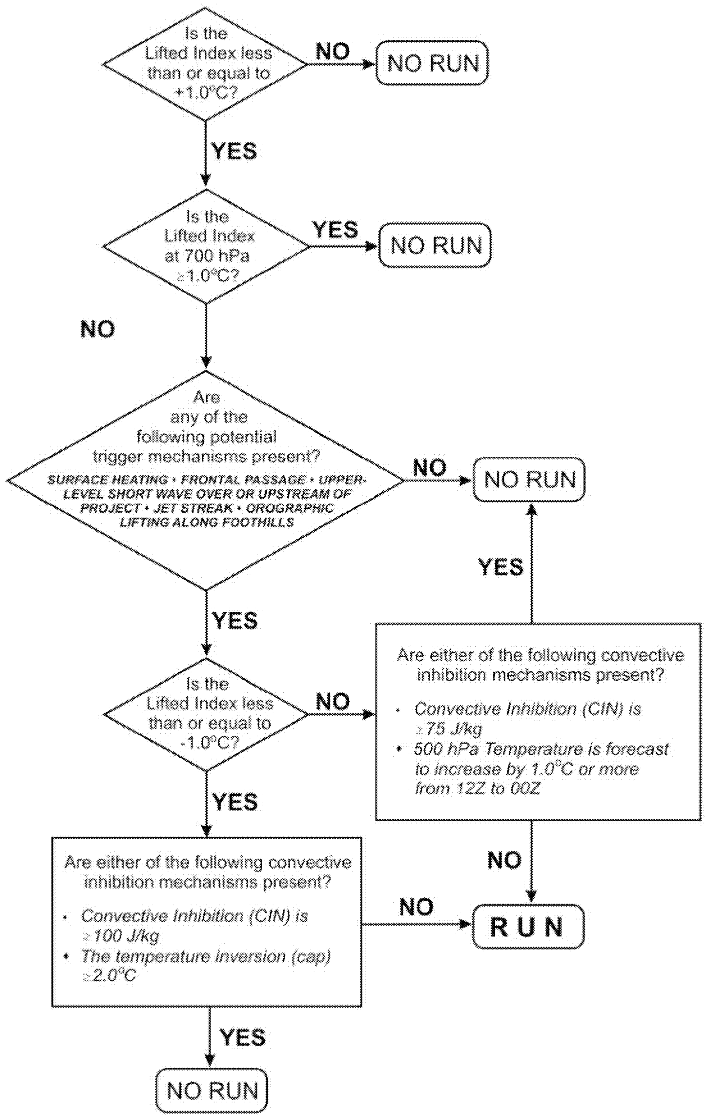


Figure 29. The flow chart used to determine if the Hailcast model (Brimelow et al. 2006) should be run. Essentially, the chart process eliminates the model runs from those days when hail is unlikely.

The forecaster then completed the daily forecast sheet. The map interpretation was drawn by hand, and included the following for the chosen valid time: 500 mb height analysis, surface analysis (including fronts, lows, highs, troughs, and dry lines), position of upper jet streaks, and position of any shortwaves or vorticity maxima/lobes. The Synopsis section included a brief explanation of the features that were most relevant to the forecast. Each forecast box contained a concise description of the expected weather for the entire 24 hour period through the next morning at 9:00 AM. The rest of the forecast parameters and winds were taken directly from the modified sounding, and were identical to the forecast sounding that was printed out. The forecast sheet also included a checklist. The purpose of the checklist is to make sure the forecaster does not inadvertently miss or forget an important weather feature.

Before making the final decision about the likelihood and size of hail, the forecaster sometimes needed to run the HAILCAST model (Brimelow et al., 2006). To determine whether or not to run the model, a decision tree is used (Figure 29). Research has shown that the model works well with some conditions, but has been found lacking under other scenarios. The decision tree is meant to remove situations where the model is not helpful. If the model is to be run, the forecast sounding data was modified to the required HAILCAST sounding format and saved as text files in the appropriate folder. Then the model was run with the expected high temperature and dew point for the day. The average output from the models is included on the forecast sheet.

Finally, the decision was made as to the Convective Day Category (CDC). This was the last decision before the forecast was sent out to project personnel. The CDC was marked on the forecast sheet, and the sheet scanned and saved according to WMI file naming procedures. It was then emailed to the "forecast" list through the company email exchange using the Olds radar email account. The subject line of the email uses the format "YYYYMMDD AB forecast". The forecaster attached the scanned forecast sheet and saved sounding image to the email and sent it at 11:30 local time, or about 30 minutes prior to the daily briefing.

DAILY BRIEFINGS

All project staff participated in a telephone conference call weather briefing each day at 12:00 noon (local time). Teamwork depends on good communications, and so all personnel were required to attend the daily briefing at one of three locations: the radar, the Calgary Airport office, or the Red Deer Airport office. This briefing session included a debriefing and summary of the previous day's operations (if any), discussion of the weather situation, presentation of the weather forecast and operational meteorological statistics, predicted hail threat, cloud base heights and temperatures, upper level winds, storm motion, equipment status reports, and operational plans for the day. After the briefing, crews were put on telephone standby or asked to remain at the airport on standby. All personnel were equipped with telephones to allow quick access and constant communications, day or night.

If no seeding was expected within the next few hours after briefing (i.e. clear skies), flight crews were put on telephone standby. If operations were likely within the next few hours or actively growing cumulus were present, then crews were put on Airport Standby immediately following the briefing. During briefing, one crew at each site was always designated as "first up" or the first aircraft to be called if needed. Weather conditions and aircraft maintenance dictated which crews will be first up on any given day. If ceilings are very low, top seeders were designated as first up. If an aircraft is scheduled for maintenance, however routine, then it will not be first up since it may have delays in launch time. When not on airport standby, crews are on telephone standby (maximum 60 minutes from airport) at any time unless consulting with the project manager or meteorologists.

THE CONVECTIVE DAY CATEGORY (CDC)

The daily weather forecast established the *Convective Day Category* (CDC) that best described the conditions that were expected for each day. The CDC (Strong 1979) is an index that gives the potential for hailstorm activity and thus seeding operations. A description of the weather conditions for each CDC is given in Table 7. The distinction between the -2 and -1 category is sometimes difficult, since overcast or prolonged rains eventually break up into scattered showers. The maximum vertically-integrated liquid (VIL) recorded by TITAN is used for forecast verification of hail size in the absence of surface hail reports. Radar VIL values are used within the project area or buffer zones on the north, east, and south sides (not including the mountains or foothills of the western buffer zone). This may have increased the number of declared hail days from the early project years, which relied on a human report of hail fall at the surface; however, it is believed to be a more realistic measure of hail. The +1 category minimum hail size is assumed to be 5 mm since this is a common minimum size for hail used by numerical modelers, and also the recognized size threshold for hail. Smaller ice particles, those less than 5 mm diameter, are generally called snow pellets or graupel.

TABLE 7. The Convective Day Category.

CDC	Strategy	Description
-3	No Seed	Clear skies, fair weather cumulus, or stratus (with no rain). No deep convection.
-2	No Seed	Towering cumulus, altocumulus, alto-stratus, or nimbostratus producing rain for several hours or weak echoes (e.g. virga).
-1	No Seed	Scattered convective rain showers but no threat of hail. No reports of lightning.
0	Patrol flights and potential seeding.	Thunderstorms (at least one) but no hail. VIL < 20 kg/m^2 within the project area or buffer zones on north, east, and south sides.
+1	Seed	Thunderstorms with pea or shot size hail (0.5 to 1.2 cm diameter). 20 kg/m^2 < VIL < 30 kg/m^2
+2	Seed	Thunderstorms with grape size hail (1.3 to 2.0 cm diameter). 30 kg/m^2 < VIL < 70 kg/m^2
+3	Seed	Thunderstorms with walnut size hail (2.1 to 3.2 cm diameter). 70 kg/m^2 < VIL < 100 kg/m^2
+4	Seed	Thunderstorms with golf ball size hail (3.3 to 5.2 cm diameter). VIL > 100 kg/m^2
+5	Seed	Thunderstorms with greater than golf ball size hail (>5.2 cm diameter).

Various meteorological parameters were also forecast in addition to the CDC. These parameters were used in developing a seeding strategy and were passed on to pilots during the weather briefing. The meteorological parameters were recorded each day and archived for future analysis.

METEOROLOGICAL STATISTICS

A complete listing of the daily meteorological statistics is given in the Appendix. A summary of the important daily atmospheric parameters used as inputs for the daily forecast of the CDC and threat of hail is given in Table 8. A comparison of these atmospheric parameters with other seasons indicates that 2012 was warmer and more humid than average. Hail days are defined by either a report of hail at the surface or by a vertically-integrated-liquid water (VIL) measurement from the radar of at least 20 kg/m^2.

TABLE 8. Summary of 2012 Daily Atmospheric Parameters (All Days).

	ALL DAYS (107)			
Parameter	Average	Standard Deviation	Maximum	Minimum
Forecast Convective Day Category	+1.1	2.0	+4	-3
Precipitable Water (inches)	0.8	0.2	1.5	0.3
0°C Level (kft)	11.8	2.0	16.9	8.1
-5°C Level (kft)	14.1	2.7	17.8	-5.0
-10°C Level (kft)	16.6	3.3	20.1	-10.0
Cloud Base Height (kft)	9.1	2.1	15.6	2.9
Cloud Base Temperature (°C)	5.4	4.9	15.3	-10.6
Maximum Cloud Top Height (kft)	29.6	8.9	42.0	9.2
Temp. Maximum (°C)	22.3	4.3	31.0	12.0
Dew Point Temperature (°C)	10.0	4.3	18.0	-6.0
Convective Temp (°C)	22.3	5.1	33.8	11.2
Conv. Available Potential Energy (J/kg)	656.7	571.6	2384.0	0.0
Total Totals Index	52.7	4.1	60.7	38.4
Lifted Index	-2.1	2.6	7.3	-6.9
Showalter Index	-1.4	2.6	7.4	-6.0
Cell Motion - Direction (from, deg)	254	66	360	5
Cell Speed (knots)	21.7	8.9	43.0	2.0
Storm Motion - Direction (from, deg)	262	85	360	5
Storm Speed (knots)	14.4	6.5	35.0	1.0
Low Level Wind Direction (from, deg)	253	68	360	5
Low Level Wind Speed (knots)	15.9	7.3	34.0	1.0
Mid-Level Wind Direction (from, deg)	259	53	355	30
Mid-Level Wind Speed (knots)	26.1	12.1	65.0	5.0
High Level Wind Direction (from, deg)	246	59	345	10
High Level Wind Speed (knots)	46.0	23.8	102.0	2.0
Observed Convective Day Category	+1.03	2.35	+5	-3

Perhaps the most interesting statistic in 2012 was, like 2011, the observed dew point temperatures. The dew point is the temperature at which, if air is cooled, dew forms. Unlike relative humidity which varies depending upon the actual air temperature, dew point is not related to air temperature and so provides a much truer indicator of actual water vapor content of the air. Since thunderstorms are powered by the heat released when water vapor condenses and later freezes, the dew point is an indicator of the available "fuel" to drive storms. This has long been recognized.

The ASWMS Program Director, Dr. Terry Krauss, noted that he always becomes rather wary when the dew point approaches double-digits, and his "mental alarms go off" when it reaches +12°C. The maximum observed daily maximum dew point for the whole season (all days) at the Operations Centre averaged +10°C which was exactly the same as the 2011 season! The 2012 season also saw warmer and moister than normal conditions persist into the overnight hours. This resulted in several severe thunderstorms occurring during the nighttime hours.

The same parameters given in Table 8 are also provided in Table 9, but specifically for those days on which hail was reported. During the 2012 season, hail was observed or detected by radar on 56 of the 107 project days, or 52% of all days. Comparison of Tables 8 and 9 reveals what one would expect: hail is more common when moisture (precipitable water) is greater, when stability is less (Lifted Index), and when convective available potential energy, or CAPE, is greater. This is not surprising. One interesting note is that though a CDC of +5 was never forecast in 2012, two +5 days occurred. The forecasting for the season is examined in greater detail in the following section.

TABLE 9. Summary of 2012 Daily Atmospheric Parameters for Hail Days.

	HAIL DAYS (56)			
Parameter	Average	Standard Deviation	Maximum	Minimum
Forecast Convective Day Category	+2.4	1.0	+4	0
Precipitable Water (inches)	0.9	0.2	1.3	0.5
0°C Level (kft)	12.1	1.9	14.5	8.1
-5°C Level (kft)	14.2	3.2	17.6	-5.0
-10°C Level (kft)	16.7	4.1	20.1	-10.0
Cloud Base Height (kft)	8.5	1.8	12.5	2.9
Cloud Base Temperature (°C)	7.6	3.5	15.3	-0.6
Maximum Cloud Top Height (kft)	34.3	5.2	41.5	13.5
Temp. Maximum (°C)	22.9	4.4	31.0	15.0
Dew Point Temperature (°C)	11.9	3.4	18.0	3.0
Convective Temp (°C)	22.5	4.8	32.1	12.4
Conv. Available Potential Energy (J/kg)	971.4	528.1	2384.0	26.0
Total Totals Index	54.6	2.7	60.7	48.5
Lifted Index	-3.6	1.5	-1.0	-6.9
Showalter Index	-2.8	1.5	0.6	-6.0
Cell Motion - Direction (from, deg)	246	63.2	360	5
Cell Speed (knots)	20.7	9.7	43.0	2.0
Storm Motion - Direction (from, deg)	258	76.7	360	10
Storm Speed (knots)	13.5	7.2	35.0	1.0
Low Level Wind Direction (from, deg)	244	66.6	360	10
Low Level Wind Speed (knots)	15.1	7.4	34.0	2.0
Mid-Level Wind Direction (from, deg)	248	49.7	340	40
Mid-Level Wind Speed (knots)	24.6	13.7	65.0	5.0
High Level Wind Direction (from, deg)	236	43.4	310	100
High Level Wind Speed (knots)	41.6	21.9	91.0	2.0
Observed Convective Day Category	+3	1.1	+5	+1

FORECASTING PERFORMANCE

The following tables indicate the forecasting performance for the summer season with respect to the forecast and observed weather conditions as defined by the "Convective Day Category" or CDC within the project area. A CDC greater than zero indicates hail. The forecasts were verified by the weather observations as reported by Environment Canada, crop insurance reports received from the Agriculture Financial Services Corporation in Lacombe, and also by public reports of hail in the press, radio, and television, as well as by the reports from project personnel. The Vertical Integrated Liquid (VIL) radar parameter was also used as a verification tool, but secondary to actual hail reports. The CDCs forecast compared to those actually observed in 2012 are summarized in Table 10.

TABLE 10. Comparison of CDCs Forecasts & Observations.

FORECAST DAYS	OBSERVED DAYS: No Hail	OBSERVED DAYS: Hail	Totals
No Hail	35 [33%]	1 [1%]	36 [34%]
Hail	16 [15%]	55 [51%]	71 [66%]
Totals	51 [48%]	56 [52%]	107

Hail fell within the project area on 56 of 107 days (52%), leaving 51 days without hail (48%). The forecast was correct in forecasting "no-hail" on 35 of 51 observed no-hail days (69%) but more importantly, correctly forecast "hail" days on 55 of 56 days (98%). The forecast failed to correctly predict hail on just one of the 56 hail days (2%) and incorrectly forecast hail (false alarms) on 16 of the 51 days when no-hail was observed (31%), thus the successful prediction of hail was not without cost.

The one forecast "bust" (failing to predict hail when hail occurred) of the season occurred on June 25th. The project forecast called for thunderstorms over the southern half of the protected area, during the afternoon and evening. For this day the atmosphere was expected to be only slightly unstable, but a shortwave trough started to push through from southwest during the midafternoon hours. The trough had strong vorticity advection associated with it which aided with triggering off thunderstorms. A single hail producing thunderstorm moved northeastward through the far southern half of the project area before dissipating east of Okotoks. Radar data suggested that this storm may have produced grape size hail north of High River. Overall, the WMI meteorologists did a good job with forecasting large hail this year.

The Heidke Skill Score (HSS) for WMI this past year (from Table 11) was 0.68, up slightly from 0.65 in 2011. The HSS varies from –1 for no skill to +1 for perfect forecasts. The forecasting skill is considered significant if HSS is greater than 0.4.

TABLE 11. Probability of Detection (POD), False Alarm Ratio (FAR), Heidke Skill Score (HSS) and Critical Success Index (CSI) performance of Hailcast and WMI from 2002 to 2012.

	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002
POD (Hailcast)	.75	.72	.77	.91	.80	.82	.69	.84	.91	.76	.81
POD (WMI)	.98	.85	.85	.83	.68	.76	.69	.61	.60	.86	.83
FAR (Hailcast)	.22	.21	.31	.29	.35	.30	.31	.45	.47	.56	.34
FAR (WMI)	.23	.13	.14	.13	.20	.11	.14	.18	.30	.16	.33
HSS (Hailcast)	.51	.49	.46	.44	.43	.46	.35	.31	.39	.33	.56
HSS (WMI)	.68	.65	.72	.63	.49	.66	.55	.42	.51	.63	.59
CSI (Hailcast)	.62	.64	.56	.45	.52	.50	.42	.40	.51	.39	.57
CSI (WMI)	.76	.75	.73	.56	.52	.62	.53	.42	.49	.59	.59

The Critical Success Index (CSI) is the ratio of the successful hail forecasts divided by the sum of all hail forecasts plus the busts. The CSI does not incorporate the null event (no-hail forecast and no-hail observed), and is also a popular measure of the skill of forecasts. The CSI for WMI this past season was 0.76, compared to 0.75 for 2011.

Comparisons of the CDCs that were forecast and observed on a daily basis are made in Table 12. The exact forecast weather type (CDC) was observed on 41 of 107 days or 38% of the time. However, the forecast was correct to within one CDC category on 81 days or 76% of the time. There was only one day when, according to the radar-estimated VIL, grape sized hail fell and hail was not forecast.

Overall the WMI forecasters and Hailcast displayed considerable skill in forecasting large hail since all 36 days with walnut or larger size hail were correctly forecast to produce large hail. There were no "surprise storms" this season. When compared with the analogous table from 2011 (not shown), the 2012 tables shows a tightening of the scatter in forecasts vs. observed hail size, indicative of improvement.

TABLE 12. Forecast vs. Observed CDC Daily Values for 2012.

Maroon shading indicates that the forecast and observed CDCs were the same (perfect forecasts). Blue shading indicates that the observed CDC was greater than those forecast (under-forecasts). Gray shading indicates that the observed CDCs were less than those forecast (over-forecasts).

Observed Convective Day Category (CDC) 2012

Forecast CDC	-3	-2	-1	0	1	2	3	4	5	
-3	5	1								*6*
-2	2	3	2							*7*
-1	1	3	9	2						*15*
0			4	3		1				*8*
1			3	6	2	4	2			*17*
2			4	1	1	7	4	9		*26*
3		2		2	1	3	6	7	1	*20*
4						1		6	1	*8*
5									0	*0*
	8	*7*	*22*	*14*	*4*	*16*	*12*	*22*	*2*	107

Percent correct exact CDC category = 41/107 = 38% *(44% in 2012)*
Percent correct within one CDC category = 81/107 = 76% *(72% in 2012)*

The breakdown of CDC values for each of the past 16 seasons is shown in Table 13. This year had above average number of large hail days (56 in 2012, 38 is average), and above average number of thunderstorm days (70 in 2012, 63 is average). Perhaps the most notable characteristic of the summer was that unusually high number of +4 CDC days. Golf ball size hail occurred on a record 22 days!

TABLE 13. Seasonal Summary for 2012 of Observed Convective Day Categories (CDCs).

	DAYS WITH NO SEEDING				DAY WITH HAIL (maximum hail size)					
	Mostly Clear Skies	Clouds, Virga	Showers	Thunder No Hail	Pea	Grape	Walnut	Golf Ball	> Golf Ball	
SEASON	**CDC -3**	**CDC -2**	**CDC -1**	**CDC 0**	**CDC +1**	**CDC +2**	**CDC +3**	**CDC +4**	**CDC +5**	TOTAL
1996	27	21	12	11	5	12	3	1	1	93
1997	7	19	6	28	19	11	3	0	0	93
1998	14	24	2	29	23	8	2	4	1	107
1999	21	18	8	24	22	10	2	1	1	107
2000	13	21	8	26	18	9	2	9	1	107
2001	20	4	19	18	19	18	5	4	0	107
2002	27	8	20	16	15	17	3	1	0	107
2003	24	7	20	28	8	12	2	5	1	107
2004	11	4	28	29	15	11	3	5	1	107
2005	13	13	22	28	17	9	1	2	2	107
2006	19	14	15	24	19	5	6	3	2	107
2007	15	17	15	26	17	8	5	2	2	107
2008	15	7	10	34	17	15	2	6	1	107
2009	22	11	10	41	15	2	3	2	1	107
2010	3	10	9	37	11	27	8	1	1	107
2011	15	5	14	8	7	22	20	15	1	107
2012	8	7	22	14	4	16	12	22	2	107
Totals	274	210	240	421	251	212	82	83	18	1791
Average	16	12	14	25	15	12	5	5	1	
Max.	27	24	28	41	23	27	20	22	2	
Min.	3	4	2	8	4	2	1	0	0	

For Table 13 and the other tabulations in this report, the "observed CDC" is taken to be the greater of the hail sizes reported by Environment Canada, and the Agricultural Financial Services in Lacombe, or the hail sizes estimated from the vertically-integrated liquid (VIL) measured by the project radar.

In general, Alberta had a near normal summer temperature-wise. Spring and summer were active until the latter half of August, when activity diminished sharply. Until then, thunderstorms were frequent, and many tended to be severe and produce larger hail than the historical average for the previous 15 years.

THE HAILCAST MODEL

The Hailcast model (Brimelow, 1999, Brimelow *et al.,* 2006) was again used this summer to objectively forecast the maximum hail size over the project area. Hailcast consists of two components, namely a steady-state one-dimensional cloud model and a 1-dimensional, time dependent hail model with detailed microphysics. The reader is referred to Brimelow (1999) for a detailed explanation of the model.

Forecast soundings for Red Deer and Calgary were downloaded daily from the Storm Machine website. A decision tree scheme was used to determine whether or not the soundings should be used to initialize the model. The decision tree is based on the work of Mills and Colquhoun (1998). The Hailcast model was not run if the atmospheric profile showed significant inhibition at 700 mb (approximately 10,000 feet) or warming greater than 1°C aloft during the day. Table 11 shows the Hailcast Forecast versus Observed table of Daily CDC values for the period June 1st to September 15th 2012.

The performance of the HAILCAST model in 2012 was only fair. The probability of detection (POD) of hail events was 0.75, which was not as high as the WMI forecaster (0.98). The false alarm ratio (FAR) for HAILCAST in 2012 was 0.22, while for the WMI forecasters it was 0.23.

The Heidke Skill Score (HSS) for Hailcast was 0.51 due to the false-alarms, which is slightly above the value of 0.4 which is generally considered to be the threshold level of skill. The Critical Success Index (CSI) for Hailcast was .62, significantly less than the .76 for the WMI forecaster. These results demonstrate that while Hailcast is a useful tool it has weaknesses similar to many models and the results need to be interpreted within the context of the overall meteorological situation, taking into consideration other synoptic, mesoscale, and dynamic aspects that are not included in the one-dimensional model. One must also keep in mind that the input to Hailcast was routinely the 12-hour prognostic soundings of the WRF model. It is important to look at the full 24 hours of forecast soundings to use as input for Hailcast. Further research into the refinement of the Hailcast decision tree remains warranted, and of course, due care must be taken to input the proper sounding.

12.0 Communications

Reliable communications for all project personnel and managers is essential for smooth and effective operations. These communications take place on a number of levels, with mixed urgencies. Real-time information-sharing and operational decision-making require immediate receipt of messages so appropriate actions can be taken. Time is of the essence. Routine daily activities such as completion of project paperwork and reports manifest less urgency, but still require due short-term attention. There are also project matters of importance on a weekly (or longer) time frame; these can be handled still more casually.

In the current age of widespread cellular telephone usage and coverage, mobile telephones have proven to be the most dependable means for project communications. Other real-time, project-essential communications occur between the Operations Centre and project aircraft; these are accomplished by voice radio transmissions. Aircraft positions and seeding actions are communicated to the Operations Centre via data radio.

For intra-project communications, all project personnel have cellular telephones. Pilots, who were on-call and have flexible hours, always carried their mobile phones, and kept them well-charged and turned on. Meteorological staff did likewise, but because of their more structured hours and location (primarily the Operations Centre) were more reliably contactable via land (telephone) lines.

INTERNET ACCESS

High-speed internet access was established at the airport offices for the flight crews based in Calgary and Red Deer. Such access ensured real-time awareness of storm evolution and motion prior to launches, while giving the pilots better knowledge of the storm situation they would encounter once launched.

USE OF E-MAIL AND TEXT MESSAGES

E-mail and text messaging were discouraged when immediate receipt of information was essential because the sender would not know with certainty if/when the recipient had received or would receive the message. Both were acceptable for non-urgent situations; however in that context e-mail was preferred whenever any record of the message content and/or timeliness is needed. The on-site program manager routinely sent blanket text message notifications of aircraft launches to all project field personnel, so everybody knew when operations commenced, and which aircraft was the first to fly.

WEATHER RADIOS

In 2010, WMI added alarm-equipped weather radios at the residences of project personnel in Calgary and Red Deer to heighten the awareness of thunderstorms within the province as a whole. These radios sound an alert tone whenever Environment Canada issues a warning. The radios were added as a precautionary measure to further ensure awareness of such warnings when personnel were not at their duty stations (respective airports or the radar).

13.0 Case Study

A detailed review and summary of the largest event of the 2012 season is provided below. The recapitulation reveals the sequence of events in dealing with the storm: when various aircraft were dispatched to respond to the developing threats, how the storms evolved and where they moved, when seeding began and ended by each aircraft, and how (in a general sense) the storms responded to treatment.

AUGUST 12TH CASE STUDY: A SEVERE STORM THROUGH CALGARY

Summary

An early afternoon discrete supercell developed over the foothills approximately 80 km southwest of Rocky Mountain House, west of the town of Caroline, meandering very slowly south-southeastward toward Calgary throughout the day. The cell became organized west of Sundre where it began dropping walnut to golf ball size hail. The cell then began back-building west of Cremona and spawned a second cell west of the parent cell. These two cells then merged 30 km north of Cochrane. The resulting storm became more organized before moving directly through northern Calgary around 10 pm. This severe supercell produced widespread loonie to walnut-size hail over the northern half of Calgary with a few isolated stones reaching slightly larger than golf balls. Intense seeding occurred well upwind of Calgary and over Calgary until the cell had moved out of the city. All four seeding aircraft were utilized to protect Calgary. The storm was thoroughly seeded with both base seeders and both top seeders. All crew, aircraft, and seeding equipment functioned successfully to deliver abundant seeding material to the correct clouds at the optimum time. It is rare that any storm is seeded as aggressively as was this one on August 12th.

Chronology

HS3 was the first aircraft launched at 6:11 pm as the cell was located along the foothills near Sundre tracking toward Cochrane. HS3 patrolled the cell without seeding for two hours before seeding began. Top seeding began at 8:31 pm about 30 km north of Cochrane. As top seeding was initiated, HS2 was launched for base seeding at 8:32 pm. At 8:54 pm, HS3 was directed to switch to an aggressive dosage rate northwest of Calgary. HS2 reached the storm at 8:58 pm and began base seeding with wing tip generators and burn-in-place flares (BIPs). HS3 descended to shed airframe icing at 9:02 pm, and then resumed top seeding seven minutes later at 9:09 pm.

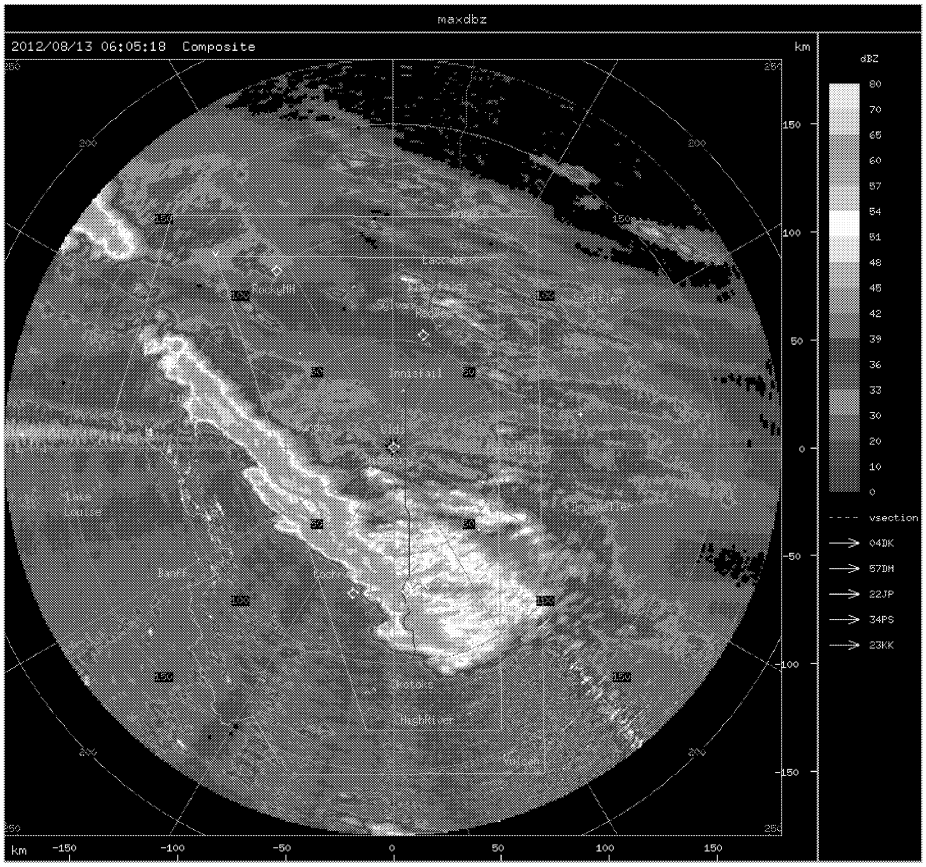


Figure 30. The maximum radar reflectivity map for the August 12th, 2012 storm day. The storm initiated over the foothills west of Caroline and tracked southeastward directly through northern Calgary. The storm dissipated southeast of Calgary.

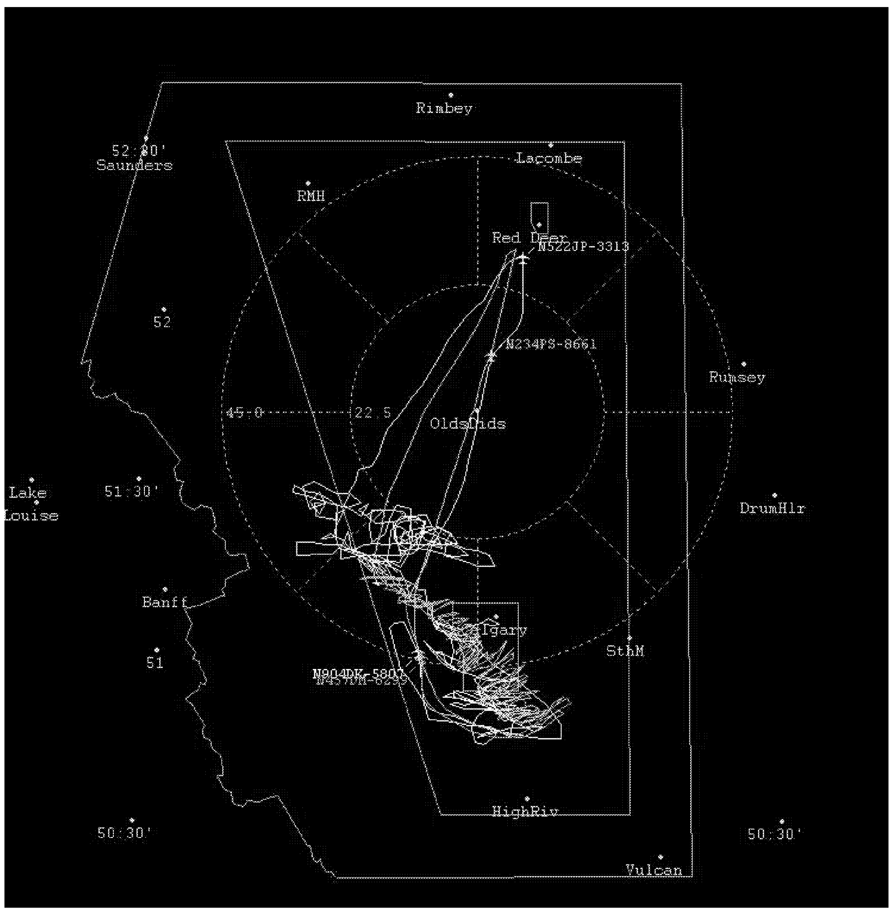
HS4 was launched at 9:10 pm to seed at cloud base along with HS2 in the same area of inflow on the south side of the storm. HS1 was then launched at 9:19 pm to climb to cloud top and be ready to replace HS3 once they depleted their arsenal of flares. At 9:53 pm, HS4 reached the storm northwest of Calgary and began seeding at cloud base along with HS2 utilizing both wing tip generators and BIPs. At 9:58 pm, HS1 had climbed to cloud top and took over top seeding over northern Calgary. As HS1 took over top seeding, HS3 remained in the area with their last few remaining flares. It should be noted that at this time, all four aircraft were seeding the storm as it was nearing the Calgary city limits (Fig. 31).

HS3 descended to the -5°C level seeding until 10:24 pm when their last flare was expended and they returned to base. HS1 continued seeding at cloud top while HS2 and HS4 seeded at cloud base as the storm continued to push through Calgary. At 11:12 pm and 11:20 pm respectively, HS2 and HS4 departed the area as they had expended most of their seeding material and the storm was exiting Calgary. HS1 remained at cloud top as a precautionary measure and seeded at a low dosage rate over far southeastern Calgary for about 20 minutes. At 11:44 pm, HS1 was out of flares and the storm was no longer a threat so they returned to base. HS1 was the last plane to land. The storm ultimately dissipated southeast of Calgary.

In summary: HS3 took off at 6:27 pm and landed at 10:48 pm. They were airborne for 4 hrs 21 minutes. HS3 utilized 288 ejectable flares and 23 burn-in-place flares. HS2 took off at 8:51 pm and landed at 11:31 pm. They were airborne for 2 hrs 40 minutes. They utilized 27 burn-in-place flares and had 268 minutes of wing tip generator time. HS4 took off at 9:29 pm and landed at 11:55 pm. They were airborne for 2 hrs 26 minutes. HS4 utilized 18 burn-in-place flares and had 178 minutes of wing tip generator time. HS1 took off at 9:35 pm and landed at 11:57 pm. They were airborne for 2 hrs and 22 minutes. During the course of their seeding mission, HS1 dispensed 296 ejectable flares and 22 burn-in-place flares.

All Hailstop aircraft combined for a total of 11 hrs 49 minutes of flight time for the storm day. Wing tip generators were burned for a combined 446 total minutes. A combined total of 584 ejectable flares and 90 burn-in-place flares were also utilized for a grand total of 26,455 grams of silver iodide seeding material released. Considering this entire amount was dispensed on the one and only storm of the day, it can be said that this storm was seeded very aggressively compared to the average seeded storm. There were only two storm days during the 2012 season with higher daily amounts of seeding material released, and they were both days with multiple seeded storms (eight seeded storms on July 1st, and six seeded storms on July 31st).

Figure 31. The combined flight tracks for all Hailstop aircraft flights on 12 August 2012. The white track is Hailstop 1, the orange blue and green for Hailstop 2, 3, and 4 respectively.



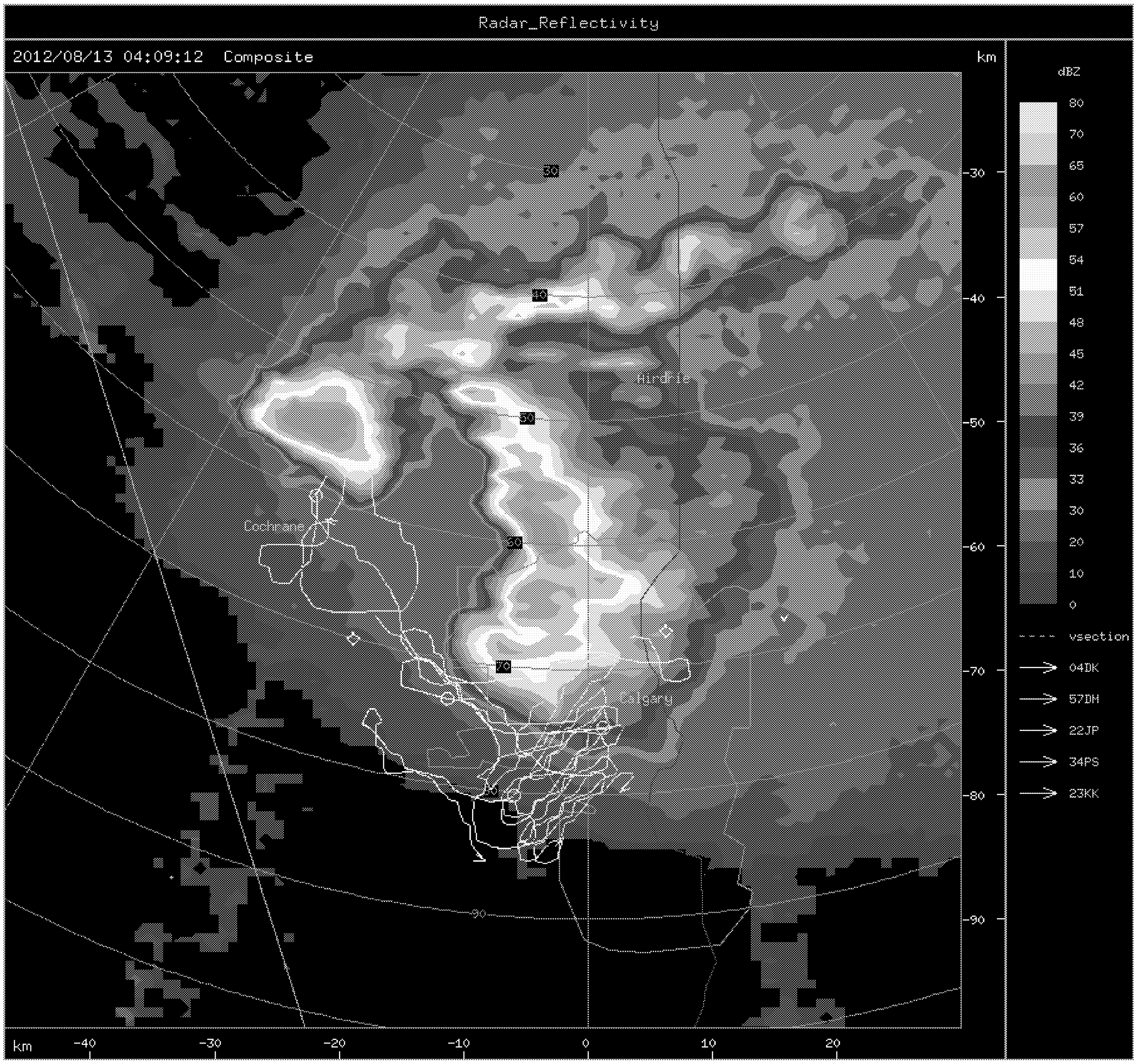


Figure 32. Aircraft tracks and radar reflectivity at 04:09 UTC (10:09 pm MDT 12 August 2012), showing all four planes seeding the storm as it is entering Calgary.

The VIL radar parameter (vertically integrated liquid) is used to estimate hail size. The max VIL track for the day (Fig. 33) indicates that hail sizes decreased over northwest Calgary which is consistent with desired seeding effects. Note the nearly solid tracks of white and red from the foothills to near Cochrane and then the lower yellow and orange values over northwestern Calgary. This indicates that the hail damage over these parts of Calgary could have been much worse.

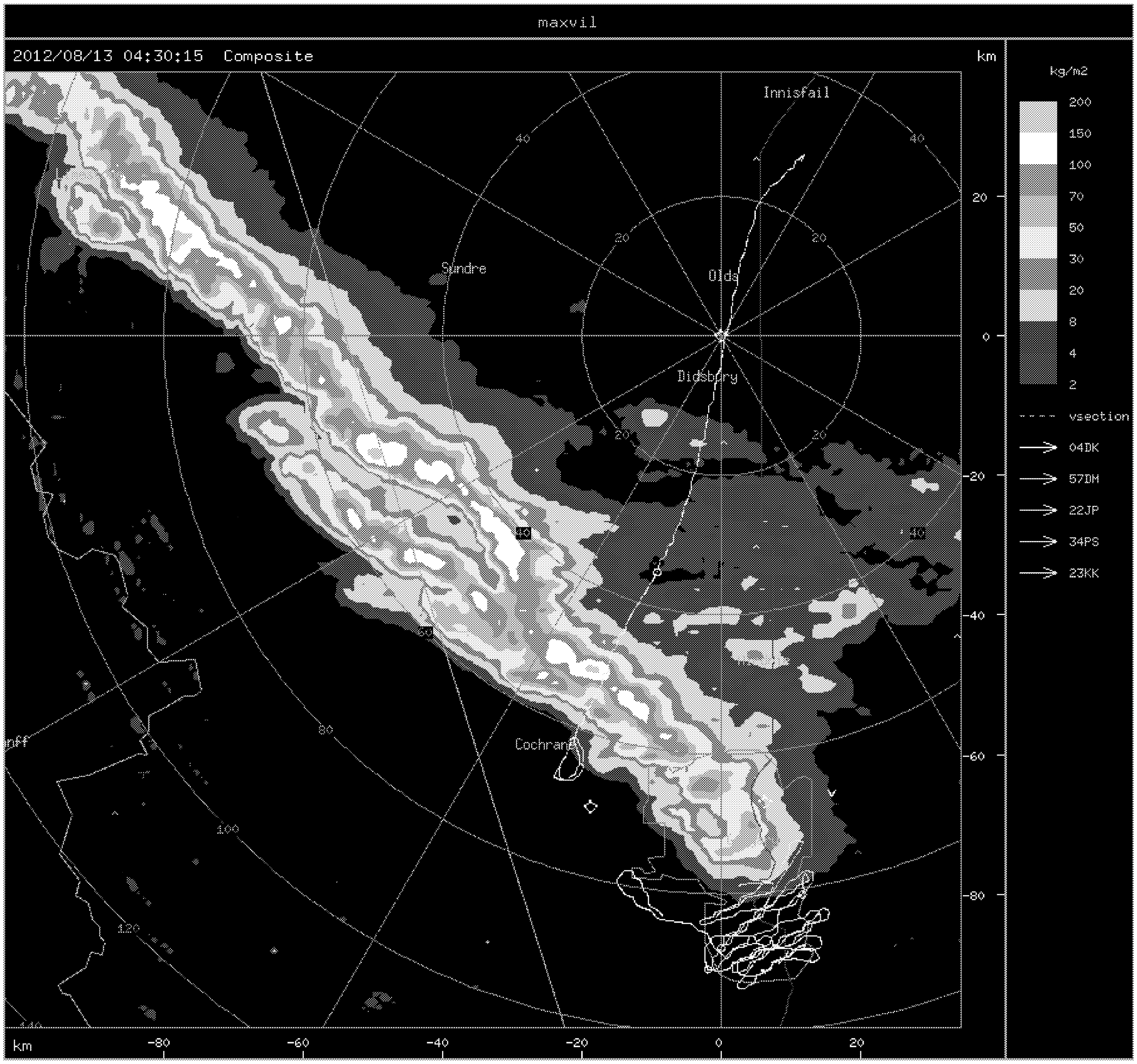


Figure 33. The maximum Vertically Integrated Liquid (VIL) radar parameter which is used to estimate hail size. Figure indicates lower VIL over northern and northwest Calgary.

14.0 Climate Perspectives

The daily and accumulated rainfall for Calgary and Red Deer from 10 October 2011 through 9 October 2012 are shown in Figures 34 and 35 respectively. Both Calgary and Red Deer had dry springs until mid-April. Both locations were above normal through the six weeks prior to project start, and remained so for a month after project end, but Calgary's precipitation surplus shows an additional increase about the time the project began on June 1st.

Calgary finished the project (15 September) above average, at about 124% of normal. Red Deer finished at about 118% of normal. The radar site at the Olds-Didsbury Airport received 261.8 mm between 1 June and 15 September 2012.

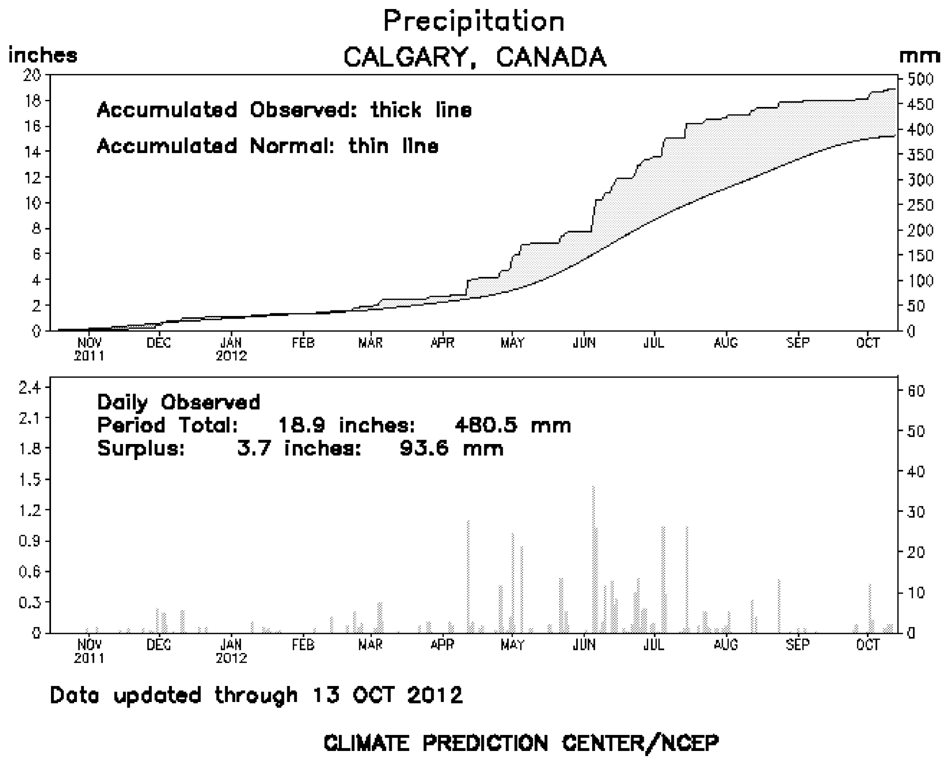


Figure 34. Daily and accumulated rainfall for Calgary from 14 October 2011 through 13 October 2012.

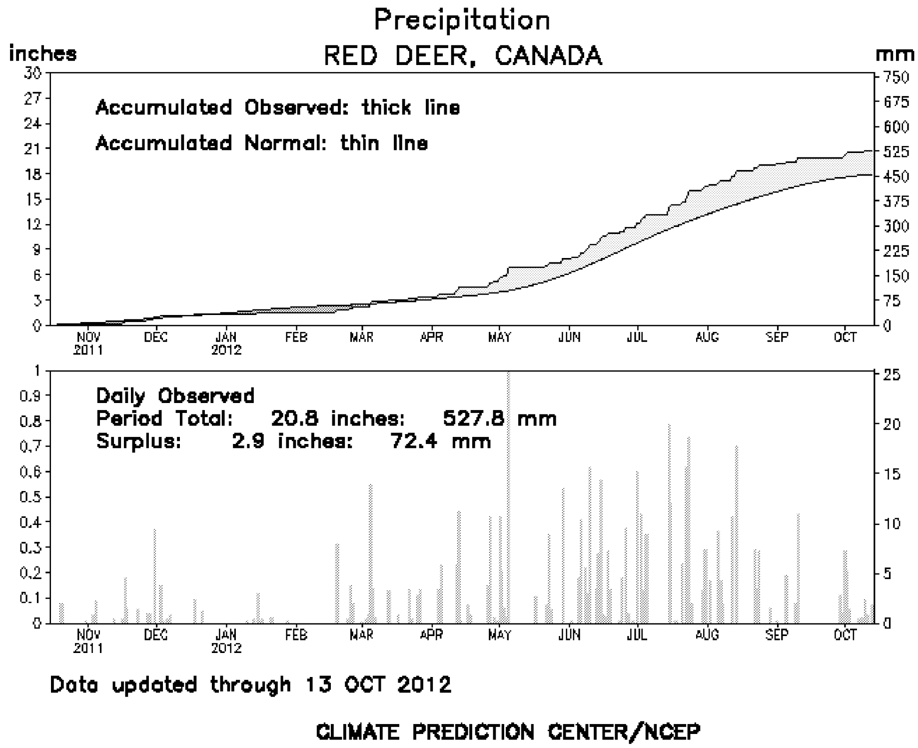


Figure 35. Daily and accumulated rainfall for Red Deer from 14 October 2011 through 13 October 2012.

As a whole, Canada experienced a wetter than normal summer in 2012 (4% above the 1961-90 normal). The summer of 2012 ranked as the 19th wettest out of the 65 years of record. Over the period of record the wettest summer was 2005 (15% above normal) and the driest was 1958 (14% below normal). The precipitation percent departure map for summer 2012 (Figure 36) shows wetter than normal conditions in southern B.C., Alberta, most of Saskatchewan, central Manitoba, Yukon, southern Northwest Territories, northern and eastern Nunavut, and northern Quebec. Drier than normal areas include, northern B.C., northern Northwest Territories, southern Manitoba, northern Ontario, southern Ontario and Quebec, Newfoundland and Labrador, and Nova Scotia.

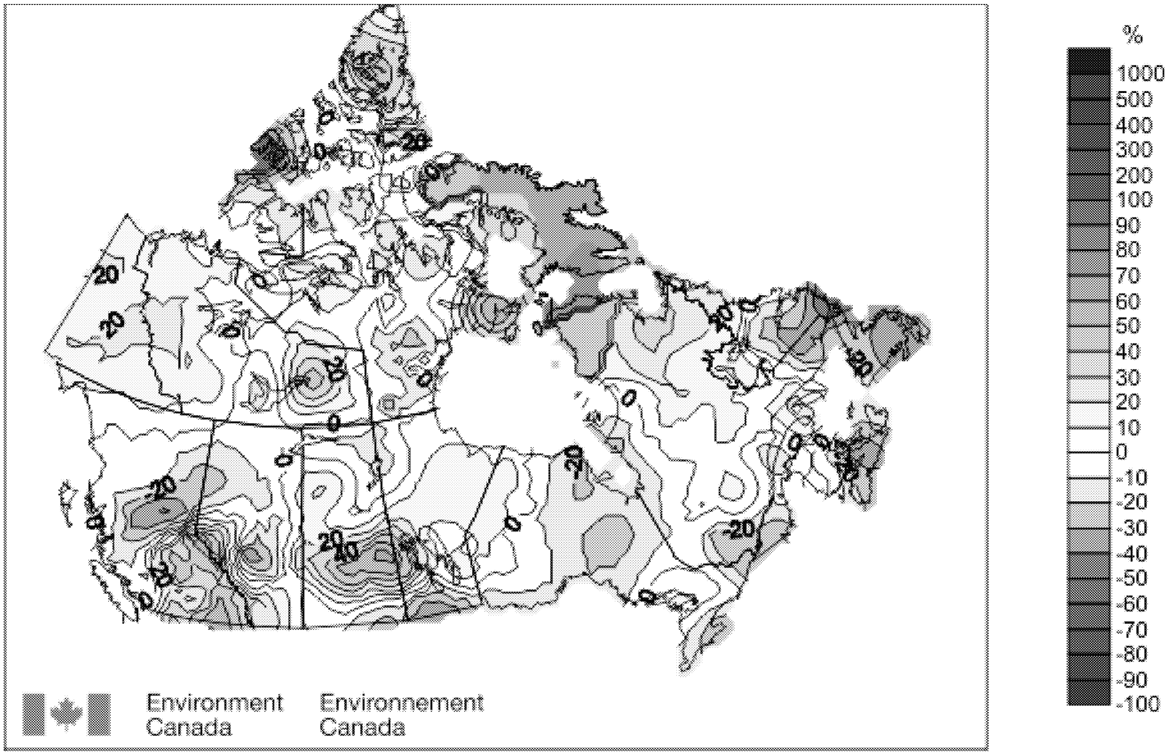


Figure 36. Departures from normal precipitation during the summer of 2012 (June, July, and August) in Canada. (Graphic from Environment Canada)

It should be noted that "normal" precipitation in northern Canada is generally much less than it is in southern Canada, and hence a percent departure in the north represents much less difference in actual precipitation than the same percentage in the south. The national precipitation rankings are therefore often skewed by the northern departures and do not represent rankings for the volume of water falling on the country.

The national average temperature for the summer of 2012 was 1.9°C above normal (1961-1990 average), based on preliminary data, which makes this summer the warmest on record since nationwide records began in 1948. The previous record was held by 1998 with a temperature of 1.7°C above normal. At 1.0°C below normal, 1968 was the coolest. As the temperature departures map below shows, virtually all of the country was above normal this summer, with most of the Northwest Territories, northern Yukon, northern Quebec, and Labrador all experiencing temperatures at least 2.5 degrees above normal. The coastal areas of British Columbia through to the Yukon had temperatures closest to normal this summer.

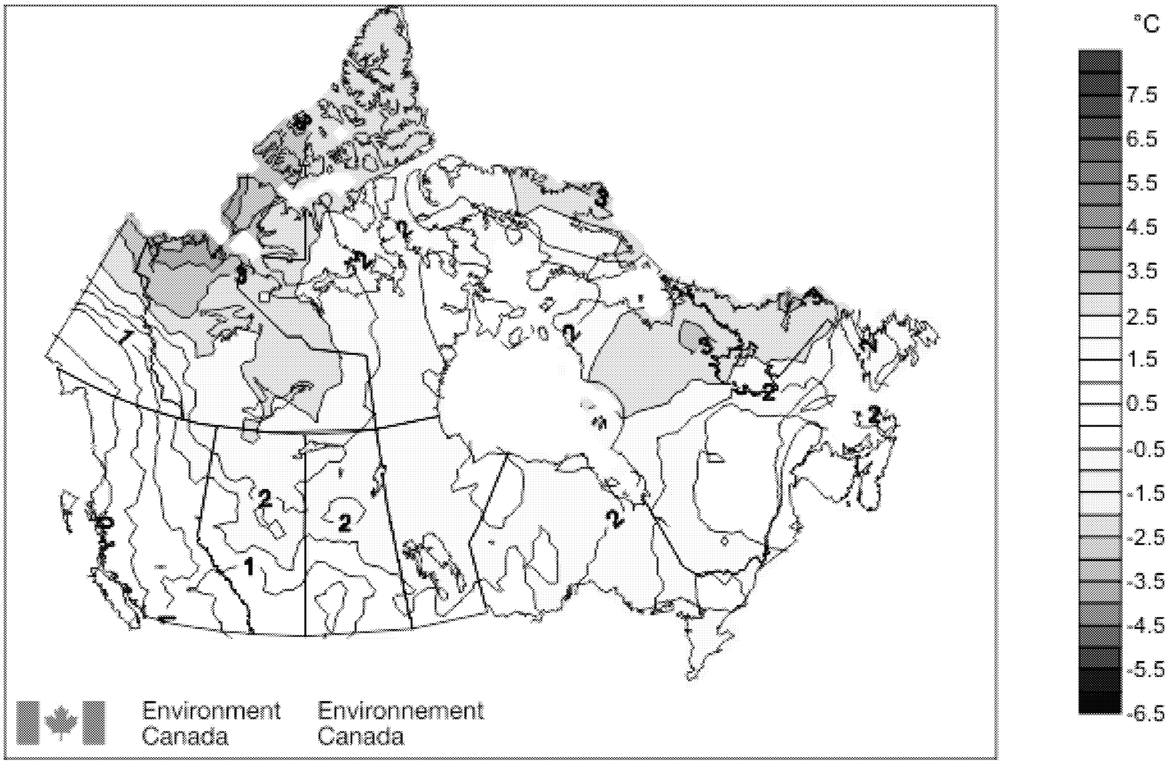


Figure 37. Departures from normal temperature during the summer of 2012 (June, July, and August) in Canada (from Environment Canada).

Previous research (Krauss and Santos 2004) has suggested that the cloud seeding increases the rainfall; therefore, the increased rainfall around Calgary, compared with the surrounding area shown in Figure 36 is consistent with previous findings.

EL NIÑO/SOUTHERN OSCILLATION (ENSO) DISCUSSION

The links between sea surface temperatures in the equatorial Pacific Ocean and the weather and climate of Alberta are not clearly defined. However, there has been a slightly positive correlation between hot, dry summers and El Niño (warm ocean) conditions; and cool, wet, stormy summers with La Niña (cool ocean) conditions.

Equatorial Pacific Ocean sea surface temperature (SST) anomalies for the period November 2011 to October 2012 are shown in Figure 38 (http://www.cpc.ncep.noaa.gov/products/). The 2012 season was similar to the 2011 season with respect to SST anomalies. The last two winters have seen La Niña (cool SST) episodes during the winter/spring months with subsequent transition (warming) to Niño neutral conditions through the summer months. Both 2011 and 2012 saw similar, well above average storm seasons as well.

There is one notable difference in the SST trends from 2011 to 2012. In the fall of 2011, SSTs began cooling again, returning to La Niña again during the winter. According to dynamical and statistical SST forecasts, the 2012 winter season looks to do the opposite, with SST anomalies warming to Niño neutral through the fall and winter months. This discussion is a consolidated effort of the National Atmospheric and Oceanic Administration (NOAA), NOAA's National Weather Service, and their funded institutions. Oceanic and atmospheric conditions are updated weekly on the Climate Prediction Center web site (El Niño/La Niña Current Conditions and Expert Discussions, see links below).

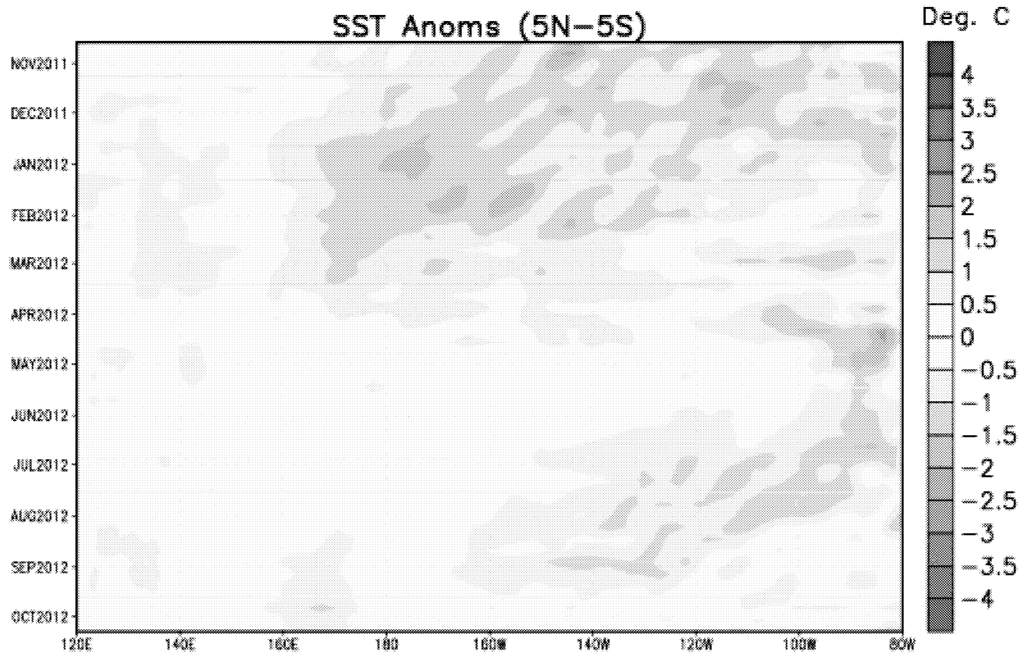


Figure 38. Pacific Ocean sea surface temperature (SST) anomalies for the period November 2011 to October 2012.

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.ppt
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_update/ssttlon5_c.gif

15.0 Alberta Crop Hail Insurance Summary

Figure 39 shows the annual Loss-to-Risk ratios for the Province of Alberta as determined by the straight hail crop insurance statistics collected by the Alberta Financial Services Corporation in Lacombe, Alberta. These statistics are for the entire province of Alberta. The average loss-to-risk ratio for the period 1978 to 1995 (before this project began) is 4.4% and the average for the period 1996 to 2012 (the current project period) is 4.9%. In considering these numbers it is important to remember that the AHSP targets only those storms threatening cities and towns in the protected area. Thus, many storms, even those within the protected area but not posing threats to urban areas are not treated. When coupled with the large number of hailstorms that occur within Alberta but outside the protected area, this implies that the frequency of damaging hailstorms is increasing climatologically.

The crop-hail loss data are presented herein exactly for that reason, to provide a baseline of sorts as to the natural frequency of storms, and how that may be changing.

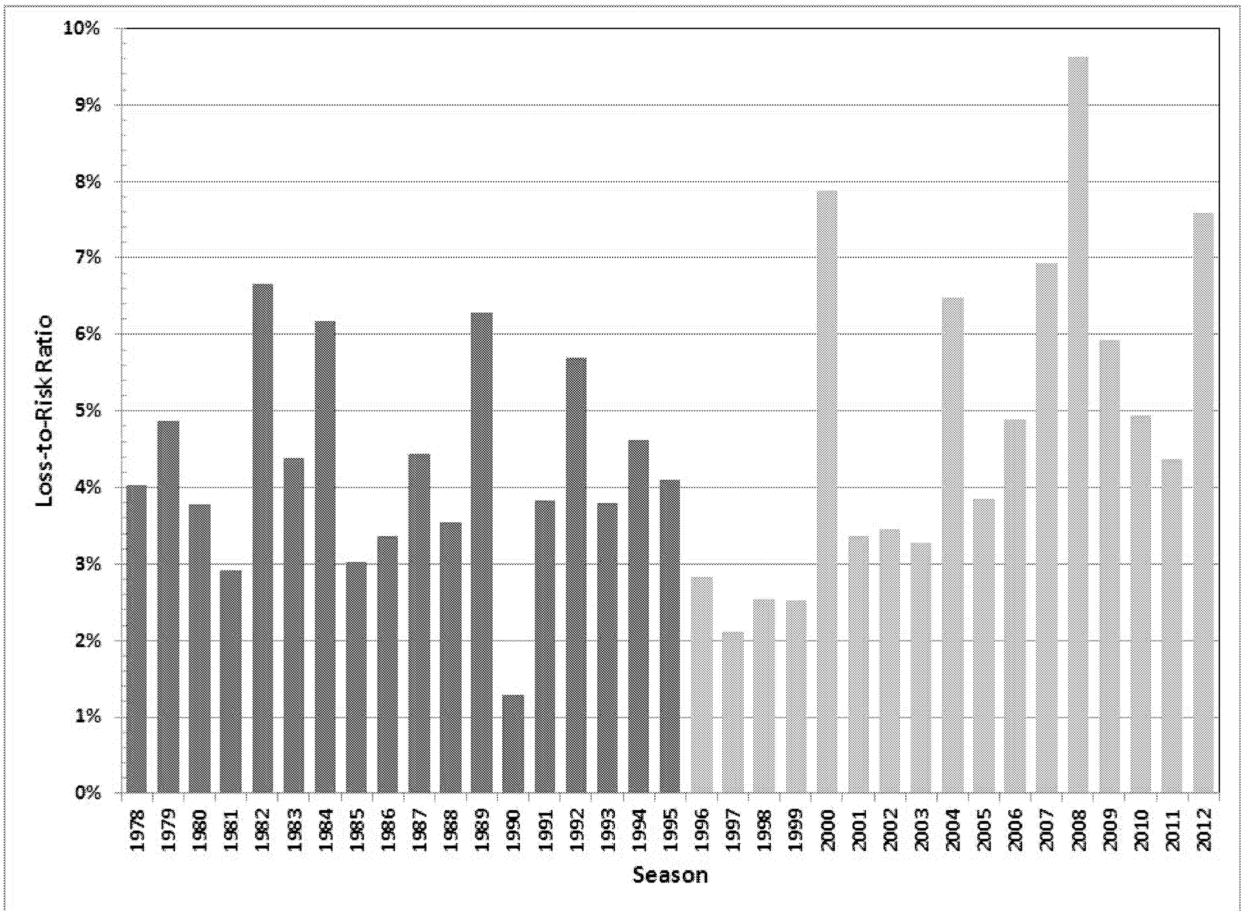


Figure 39. Alberta Financial Services Corporation straight hail insurance loss-to-risk statistics for the entire Province of Alberta from 1978 through 2012.

Eight of the first ten years of the project period (1996-2005 inclusive) had below-average crop-hail damage in the province, and the hail damage during 2000 and 2004 appeared as spikes with above-average damage. However, the next 3 years had an exponential increase in crop-hail damage. Though followed by a decline in the following three years (2009-2011), all of those years are still well above the long-term climatological mean. In 2012, crop-hail losses spiked again, exceeding 7.5%. These data indicate that the threat of damaging hail storms in Alberta has increased, especially over the past 7 years.

While the area planted each year to crops remains essentially unchanged, the amount of insurance purchased each growing season varies. This depends largely upon the crops planted and growing conditions (anticipated harvests). There has been no marked trend in the last decade in either the dollar amount of insurance sold, nor in the number of acres insured, so the observed trend is not due to either of these.

The property and casualty insurance industry is quite different, however. Each of the companies belonging to the ASWMS considers its premiums and losses to be confidential, and there at present exists no analog to the Alberta Agriculture Financial Services Corporation, so the changes in risk and losses are not known outside each company. However, it is widely acknowledged that with the population growth of southern Alberta has become significantly increased exposure to property. The Calgary metropolitan area has increased dramatically since the program began in 1996, and most other communities have followed suit. It stands to reason that the apparent increase in damaging hailstorms coupled with the dramatically increased urban area demonstrates the need for this program.

16.0 Conclusions and Recommendations

The 2012 field operations ran very smoothly and were very successful. Though there was a major, damaging hailstorm over Calgary (a review of this storm on August 12 was previously presented), it was seeded heavily throughout, and all four aircraft were used. These operations were reviewed by Dr. Krauss, who found that the seeding was conducted as it should have been. Aircraft arrived at the storm on-time at both cloud base and cloud top, and the seeding rates were consistent with the severity of the storm.

The equipment and staff performed at a very high level. We feel this can be attributed to the following:

- No key staff changes, neither within the WMI project team and the ASWMS oversight.
- The new, high-sensitivity Doppler radar.
- The ability of WMI to immediately replace aircraft having major maintenance problems, as was done in early July with Hailstop 4 (Red Deer Cessna C340).

A formal statistical evaluation of the hail suppression program is still not possible without acquiring more comprehensive, detailed, high resolution property insurance claim data. Preliminary assessments from unofficial reports within the insurance industry suggest that the program has been a financial success but this has not been verified. The crop-damage statistics, however, do not indicate a reduction in hail for the target area. Furthermore, there appears to be a climatological trend towards increasing hail within the target area over the past few years, and this is expected to continue into the near future, especially if La Niña conditions continue. The fact that the crop damage data does not show a reduction in damage within the target area may be explained by the fact that hailstorms are not seeded if they do not threaten a town or city. This also means that any reduction in property insurance payouts is not due to climate change since there has been an increase in storm activity. The 2012 crop-hail season was the worst on record, experiencing a loss-ratio of 113%.

The following observations and recommendations are presented for consideration by the ASWMS and WMI senior management next year. This does not, however, mean that there is not room for other improvements.

- Addition of a fifth seeding aircraft to the project would be highly beneficial to the project for multiple reasons. On the busiest and most threatening storm days, a fifth seeder would provide much needed backup for when resources are stretched thin due to multiple severe storms across the project. Throughout the 2012 season, there were three major storms directly over Calgary in which dwindling aircraft resources affected the aggressiveness and timing of the seeding. On July 1st, July 31st, and August 12th, an extra plane would absolutely have meant that more seeding agent could have been released earlier into the Calgary hailstorms. Additionally, seeding could have begun more quickly if resources were not being stretched for optimum utilization. These are just the three major examples that directly impacted Calgary in 2012. There are multiple similar examples from the last few seasons where an additional aircraft could have provided protection for other lower priority cities which went unprotected while all aircraft were seeding for larger cities. The 2011 and 2012 seasons are the first and second busiest storm seasons since the project began. Project meteorological statistics clearly indicate an increase in the frequency and severity of hailstorms across the region. With this trend likely to continue, it is necessary to increase the available seeding resources in order to meet this challenge.

- The aging weather station located at the operations centre is developing problems; the wind vane no longer turns freely, and the humidity sensor used for the calculation of the dew point temperature can no longer be trusted. In addition, the software allows display and access only from within the operations centre itself. A new system is available that would eliminate the instrumentation issues and allow data to be checked any time, real-time, via the internet. WMI will replace the aging station with this or another system of similar capability. (For an example, see: http://www.davisnet.com/weather/products/weather_product.asp?pnum=06152.)

- Fourteen very successful lectures and tours were given at the Olds-Didsbury radar and operations centre for 195 staff members of insurance companies within central Alberta this past summer. The tenth tour of the summer, conducted on August 21st was notable in that it included six persons from the Mountain View County Office near the Olds-Didsbury Airport. (Including the county workers there were 201 attendees.) These lecture-tours continue to be accredited with the Alberta Insurance Council. These were well-received, and should be continued. Other participating companies are becoming more aware of the program and tours, and have shown interest to engage in these informative activities. To improve seating at the tours, the lecture portion (delivered by Dr. Terry Krauss) was for the first time, given in the Olds-Didsbury Terminal/Office, maintained by the Olds-Didsbury Flying Club (of which WMI is a member).

- An informational brochure about the project (a one-page, two-sided handout) continues to be in overhaul. The board has provided thorough feedback on a first draft. This should be completed and available in time for the 2013 program.

- After the 2011 hail season, Dr. Krauss requested of the board members that their companies provide to him storm damage data so that a scientific evaluation of the program might be undertaken. Two companies obliged by releasing limited data sets and Dr. Krauss has been examining the data thus provided. It is our understanding that these initial data were both useful and encouraging, meaning that some differences between protected and un-protected areas were observed. We understand that this initial analysis is confidential, without revealing the identities of the companies. We encourage those companies participating in the AHSP that have not yet released data to Dr. Krauss to do so, so that a more complete assessment might be obtained.

Bruce Boe, Director of Meteorology
Jody Fischer, Project Manager, Chief Pilot
Daniel Gilbert, Chief Meteorologist, Alberta Lead Meteorologist
Hans Ahlness, Vice President of Operations
Bradley Waller, Field Meteorologist

December 2012

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APPENDICES

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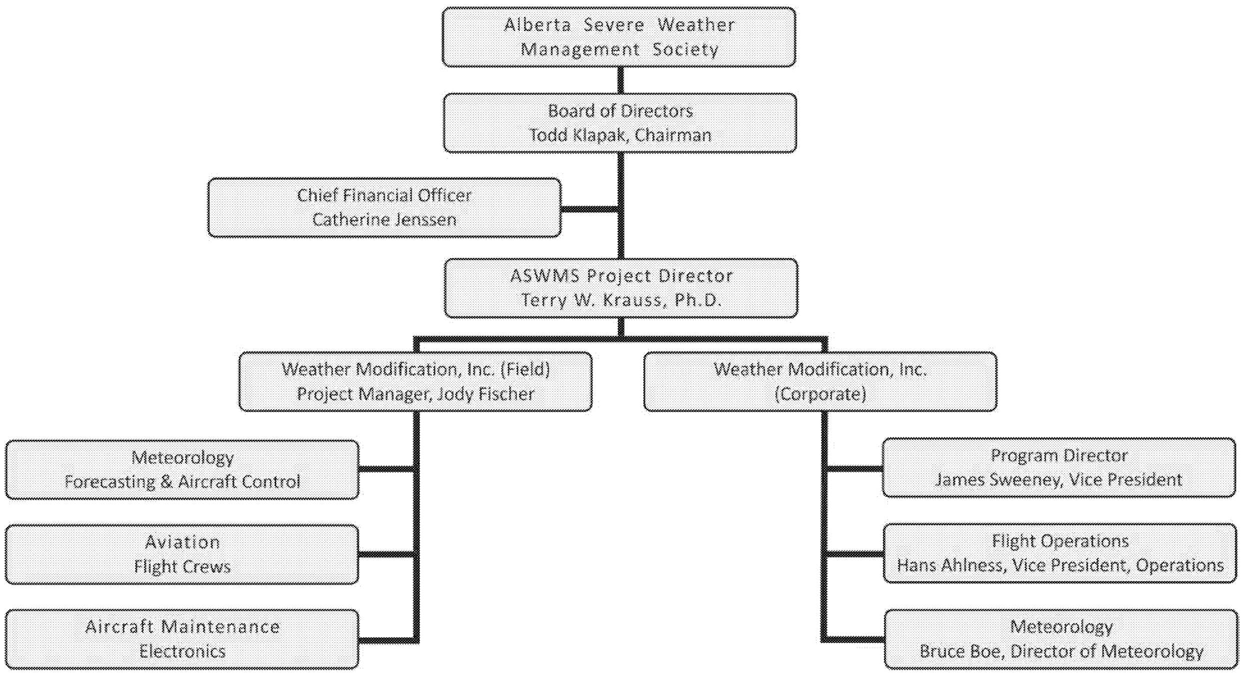
Appendix A - Organization Chart



Appendix B – Daily Weather and Activities Summary Table

ALBERTA HAIL SUPPRESSION PROJECT 2012
DAILY SUMMARY REPORTS

Date 2012	Weather	Activities Summary
June 01, Friday	Jet energy was located directly over the area. A mid-level ridge built over the region during the daylight hours. At the surface, a cold front was progged to begin pushing into southern AB during the overnight hours. The Red Deer and Calgary soundings showed that the atmosphere was slightly unstable. Isolated convective rain showers occurred during the late afternoon hours with no lightning. These showers were observed just within the project area's western border near Caroline. 34.5 max dBz Tmax YC = 22.1C and no rain. Tmax QF = 23.2C and no rain. Tmax Radar = 21.8C and no rain.	HS4 performed a maintenance flight in the early afternoon hours to test the Airlink tracking system. The aircraft tracking functioned properly. The aircraft took off from YQF at 1851Z and landed back in YQF at 1904Z. Flight Summary HS4: 1834Z-1908Z; no seeding; maintenance flight.
June 02, Saturday	The upper level jet remained directly over the project area. A midlevel shortwave trough was pushing through the project area during the mid and late afternoon hours. At the surface, a cold front was progged to pass through the project area in the afternoon. Low level moisture amounts were expected to increase during the afternoon hours. The sounding data suggested a moderately unstable atmosphere with decent speed shear. The first wave of convection began to move through the project area around noon. These relatively weak storms moved W to E across the region. The next wave of stronger thunderstorms was first seen W of Rocky MH at around 21Z. A line of convection slowly moved through the entire project area. The southernmost cells along the line mainly saw the most intense cells. The strongest storm of the day formed northeast of Calgary and moved southeastward over the town of Strathmore. Pea sized hail was reported over western Strathmore. Max cell top: 11.4km, 62.5 max dBz, 74.9 max VIL Tmax YC = 20.3C and 0.6mm of rain. Tmax QF = 20.0C and 0.2mm of rain. Tmax Radar = 21.6C and 1.0mm of rain.	HS4 conducted a currency flight in the early afternoon. They took off from YQF at 1847Z and landed back at YQF at 1912Z. HS1 was launched at 2009Z for cells over southern Calgary. They were airborne out of YYC at 2028Z and climbed to cloud top. They patrolled the area between Calgary and Strathmore, but they found no seedable activity. Radar indicated no significant hail threats. HS1 RTB to YYC at 2116Z and landed at 2130Z. HS4 was launched from YQF at 2101Z to the area SW of Rocky MH. They were airborne at 2122Z. At 2140Z, HS4 reached the cells west of Rocky MH and began base seeding storm #1 with generators finding 500fpm to 1000fpm inflow. At 2156Z, they repositioned further south and began seeding storm #2 west of Caroline. At 2228Z, they shut off acetone generators and repositioned south of Sundre for patrol near Cremona. Seeding resumed at 2315Z on storm #3 west of Didsbury. HS4 was replaced at cloud base by HS2 and RTB at 2347Z. They landed at YQF at 0007Z (06/03). HS2 was launched at 2303Z for a developing line NW of Airdrie. They were airborne out of YYC at 2318Z and began base seeding storm #3 with generators west of Carstairs at 2331Z. The storm moved east of the threatened cities at 2347Z, and generators were turned off.

		HS2 patrolled between Carstairs and Linden, and then resumed base seeding storm #3 at 0018Z (06/03) as the cells were approaching Acme and Linden. Seeding ended at 0036Z (06/03). HS2 patrolled for a few more minutes before RTB to YYC at 0045Z (06/03). They landed at YYC at 0056Z (06/03). <u>Flight Summary</u> HS4: 1840Z-1920Z; no seeding; currency flight. HS1: 2020Z-2135Z; no seeding; patrol Calgary to Strathmore. HS4: 2110Z (06/02)-0012Z (06/03); 160 minutes acetone generators; #1 Rocky MH, #2 Caroline, #3 Didsbury, patrol Cremona. HS2: 2316Z (06/02)-0059Z (06/03); 72 minutes acetone generators; #3 Carstairs and Acme.
June 03, Sunday	The upper level jet was positioned along the US/Canada border. Midlevel temperatures warmed during the daytime hours. A weak shortwave trough was expected to push through southern AB. No major surface features were over southern AB. The atmosphere was slightly unstable with weak speed shear. Central Alberta saw scattered convective rain showers during the afternoon and early evening. These convective cells were weak, and no lightning strikes were observed. 46.5 max dBz Tmax YC = 19.0C and a trace of rain. Tmax QF = 18.0C and no rain. Tmax Radar = 17.0C and no rain.	No aircraft operations.
June 04, Monday	A strong large scale trough was moving into the western US, transporting substantial moisture as far north as northern Montana. Severe storms were expected to form in northern Montana in the evening hours, developing a low level jet which would help to destabilize southern Alberta. A potent shortwave, visible on models, was expected to move through after midnight and be the main trigger for the project area. Storms formed in Montana during the evening hours, and a subsequent low level jet clearly occurred in the project area, increasing dewpoints substantially. Shortwaves initiated several waves of weak, elevated, embedded convection in the late overnight period into the next forecast period. There were a few lightning strikes, but no hail reports in the project area. Radar suggested that pea sized hail may have fallen inside the project area. Max cell top: 12.9 km, 58.5 max dBz, 21.1 max VIL	HS1 was launched at 0919Z (06/05) for top seeding on a line of cells moving northward from near High River. HS1 was airborne at 0940Z (06/05) and began top seeding storm #1 over southern Calgary at 1005Z (06/05) dragging BIPs in embedded conditions. The cell shifted rapidly northward through Calgary and became much weaker. As the storm reached the Airdrie area, it was no longer a hail threat and seeding ended. HS1 found a gap in the line and was directed to RTB at 1040Z (06/05). They landed in YYC at 1055Z (06/05). <u>Flight Summary</u> HS1: 0930Z (06/05)-1100Z (06/05); 3 BIP; #1 Calgary.

	Tmax YC = 21.0C and a trace of rain. Tmax QF = 21.0C and no rain. Tmax Radar = 20.0C and 5.6mm rain.	
June 05, Tuesday	The right entrance of the jet was helping to intensify lee cyclogenesis in southern Montana during the morning hours. The large scale trough was expected to tilt into the area through the day, and a closed low pressure system in the gulf of Alaska was expected to move to the SE throughout the day. In the evening hours, the Alaska and Montana lows were expected to begin to interact, moving the Montana low northwest directly through the project area. The entire project area had substantial moisture and significant instability. As the low moved through the project area, the associated vorticity and warm front was expected to initiate severe, elevated convection during the overnight period. Storms initiated south of the project area around 9pm moving NNW. While some cells were strong, embedded conditions made seeding nearly impossible. Weak thunderstorms continued through the overnight period. There were no hail reports inside the project area or buffer zone. Four confirmed tornadoes occurred N of the town of Tabr east of Lethbridge on HWY3. Radar data indicated that grape size hail may have fallen inside of the project area. Max cell top: 14.4km, 64.0 max dBz, 65.5 max VIL Tmax YC = 16C and 36.2mm rain. Tmax QF = 19C and 4.6mm rain. Tmax Radar = 13.9C and 18.5mm rain.	HS1 was launched at 0252Z (06/06) for multiple new cells developing SE of Calgary moving toward Calgary. HS1 was airborne at 0317Z (06/06) and began top seeding with embedded conditions at 0336 (06/06) dragging BIPs and dropping EJs on storm #1 SE of Calgary. They were forced to stay well east of a developing line as it pushed northward through Calgary. At 0429Z (06/06) seeding conditions deteriorated with lots of mixed up and downdraft reported and widespread weak growth all around the area. HS1 RTB to YQF at that time. YYC was inaccessible with convection over the airport. HS1 landed in YQF at 0451Z (06/06). HS1 ferried the aircraft home from YQF to YYC after weather conditions improved. They took off at 0941Z (06/06) and landed back in YYC at 1016Z (06/06). <u>Flight Summary</u> HS1: 0304Z (06/06)-0455Z (06/06); 11 BIP, 68 EJ; #1 Calgary. HS1: 0932Z (06/06)-1021Z (06/06); no seeding; ferry flight YQF to YYC.
June 06, Wednesday	A southeasterly upper level jet was in place over project area during the morning hours. This southeasterly jet was expected to shift eastward during the day. The mid-levels saw very strong vorticity advection during the morning and early afternoon hours. This large lobe of vorticity was the main trigger for thunderstorm development. The low level jet remained strong along the AB/SK border in the morning. At the surface, lee cyclogenesis also occurred during early morning hours; the surface low that resulted moved northwestward in the afternoon. The Calgary 18Z modified sounding showed a moderately unstable atmosphere with strong speed shear. The first strong storm of the day moved into the eastern buffer at around 15Z. This tall convective cell then continued northwestward through Strathmore and Airdrie. Radar data showed a small area SW of Strathmore where walnut sized hail could have fallen. Quarter sized hail was reported in the Airdrie area. Other	HS1 was launched at 1517Z for a fast NW moving cell southeast of Strathmore. HS1 was airborne at 1550Z and began top seeding storm #1 with BIPs and EJs at 1604Z as the cell was approaching Airdrie and Crossfield. Seeding conditions were visual on the north side of the cell with good updrafts and moderate liquid water. Seeding ended for storm #1 at 1632Z as HS1 repositioned to eastern Calgary for a new developing weaker cell. Seeding began for storm #2 over Calgary at 1642Z. Conditions were more embedded with this cell with less growth and weaker radar returns. Seeding ended at 1657Z as the weak cell was no longer threatening any cities. HS1 RTB to YYC at 1706Z and landed at 1726Z. <u>Flight Summary</u> HS1: 1534Z-1730Z; 6 BIP, 50 EJ; #1 Airdrie to Cremona, #2 Calgary.

	cells formed east of Calgary before also continuing northwestward across the project area. The surface low moved northwestward during the afternoon hours, and the atmosphere stabilized. The dry slot of the low aided in drying the lower levels which helped to further stabilize the atmosphere. Max cell top: 12.1km, 67.0 max dBz, 72.1 max VIL Tmax YC = 16.5C and 26.0mm of rain. Tmax QF = 18.9C and 10.4mm of rain. Tmax Radar = 17.1C and 1.8mm of rain.	
June 07, Thursday	The upper level jet was positioned east and south of the area during the daytime hours. A jet streak was expected to begin nosing its way into southern AB during the overnight hours. A midlevel closed low was positioned just off the coast of southern BC. In the evening, a shortwave trough was expected to slide across the region but the atmosphere was only slightly unstable with weak speed shear. Clear skies were observed throughout the day, with some midlevel clouds moving in overnight. The late night and early morning saw some stratus rain showers. Max cell top: 4.6km, 48.0 max dBz, 5.5 max VIL Tmax YC = 19C and no rain. Tmax QF = 21C and no rain. Tmax Radar = 18.9C and no rain.	No aircraft operations.
June 08, Friday	A closed low was located off the coast of Washington with the jet located to its south. Conditions over the project area were moistening, with pressures dropping, and rather cool temperatures under significant cloud cover. The project area was under the influence of a trough which was expected to strengthen throughout the day as the closed low moved directly east towards Southern Alberta. Associated cool midlevel temperatures and vorticity were expected to respectively create high lapse rates, and triggers for a few thunderstorms. Storms were forecast to initiate in the early evening and be short lived due to a poor wind shear profile. Rain showers and stratus conditions prevailed throughout the day with many pulse storms around the area throughout the day. One potential hail producing cell initiated in the SE corner of the project area during the afternoon, but it moved to the NE out of the area. Overnight there was continued stratus rain and showers. Max cell top: 11.4km, 61.0 max dBz, 30.6 max VIL	No aircraft operations.

	Tmax YC = 13C and 0.6mm rain. Tmax QF = 12C and 5.6mm rain. Tmax Radar = 12.6C and a trace of rain.	
June 09, Saturday	The upper level low was situated directly over the project area with a deep trough below us and cloudy skies with stratiform rain and some showers. Winds had a significant easterly component. Weak thunderstorms were expected to initiate in the northern project area where temperatures were slightly higher. No hail threat was expected due to the cool temperatures, weak instability, and shear. Cells were expected to move to the southwest during the forecast period. Thunderstorms began in the early afternoon when an isolated cell directly over the Olds-Didsbury Airport produced up to 1.2cm hail for 20 minutes. Numerous thunderstorms began in the northern buffer zone, and later in the afternoon, in the southern half of the project area. The maximum VIL occurred about 2 miles NE of Innisfail. During the evening, cells became stratiform, and stratus rain occurred all night. Max cell top: 11.4km, 66.5 max dBz, 78.8 max VIL Tmax YC = 14C and 2.6mm rain. Tmax QF = 16C and 3.0mm rain. Tmax Radar = 10C and 28mm rain.	HS3 was launched at 1944Z for cells near Lacombe. They were airborne at 2014Z and began seeding storm #1 near Lacombe at 2024Z with good liquid and updraft. HS3 repositioned to storm #2 near Ponoka at 2031Z and began seeding that cell at 2039Z. At 2111Z, they stopped seeding and began patrol while also descending to shed ice. At 2153Z, they repositioned to a cell approaching Red Deer and began seeding storm #4. Activity then diminished and HS3 was low on flares so they RTB at 2301Z. They landed at YQF at 2312Z. HS4 was launched for base seeding at 2009Z and airborne at 2025Z. They patrolled the area near Rocky MH and Caroline briefly. Nothing seedable was noted, and ceilings were too low to continue patrol. They RTB at 2057Z and landed in YQF at 2104Z. HS1 was launched at 2057Z for top seeding near Calgary. They were airborne at 2123Z and began seeding storm #3 over Calgary and Okotoks at 2136Z. HS1 began seeding on storm #5 at 2302Z for back building activity near Calgary. Seeding ended and HS1 began patrol east of Calgary at 2348Z. HS1 RTB at 2355Z and landed in YYC at 0011Z (06/10). HS3 was launched for their second flight of the day at 0020Z (06/10). They were airborne at 0042Z (06/10) and began top seeding storm #6 north of Red Deer at 0047Z (06/10). The storm became linear and then weakened below hail criteria. Seeding ended at 0112Z (06/10) when HS3 RTB. They landed back at YQF at 0121Z (06/10). <u>Flight Summary</u> HS3: 2006Z-2319Z; 5 BIP, 296 EJ; #1 Lacombe, #2 Lacombe and Ponoka, patrol Lacombe, #4 Red Deer. HS4: 2020Z-2108Z; no seeding; patrol Rocky MH and Caroline. HS1: 2113Z (06/09)-0013Z (06/10); 21 BIP, 236 EJ; #3 Okotoks, #5 Calgary, patrol Calgary. HS3: 0033Z (06/10)-0125Z (06/10); 3 BIP, 93 EJ; #6 Red Deer.
June 10, Sunday	Stratiform rain was occurring over the project area during the morning with a strong NW wind. A trough associated with the closed low, now to the East, lingered over SE Alberta providing a	No aircraft operations.

	chance for showers during the morning. Slight ridging was occurring, and pressure was rising. A stationary front along the foothills was expected to be a focus for weak thunderstorms during the early evening. Overnight, no significant weather was expected. Scattered convective rain showers fell through the early nighttime hours. These showers mainly occurred north of Calgary and no lightning strikes were observed. Max cell top: 6.1km, 58.5 max dBz, 16.8 max VIL Tmax YC = 15.5C and 11.6mm of rain. Tmax QF = 15.9C and 15.6mm of rain. Tmax Radar = 13.4C and 3.6mm of rain.	
June 11, Monday	The upper level jet was positioned east and north of the area. A midlevel ridge built over the region during the daylight hours. A moderate amount of the low level moisture was still present from the previous day. The main trigger for thunderstorm development was a surface trough over central AB and differential surface heating. The wind shear profile suggested that the thunderstorms would be short-lived. The region saw a few light convective rain showers in the afternoon and evening. No lightning strikes occurred inside of the project area. 41.0 max dBz Tmax YC = 22.6C and no rain. Tmax QF = 23.1C and no rain. Tmax Radar = 21.4C and no rain.	No aircraft operations.
June 12, Tuesday	AB saw no upper level jet energy. The midlevel ridge over the region was expected to shift eastward and erode slightly. A shortwave trough pushed through the region during peak heating. At the surface, a low with an associated cold front pushed southward over AB during the day. The cold front was expected to begin moving into the northern part of the project area during the early evening hours. During the overnight hours a theta-e ridge was in place along the AB/SK border. The 00Z Red Deer sounding indicated a moderately unstable atmosphere with weak speed shear. Storms were visible well outside the NE buffer throughout the day. A few convective showers formed over the foothills during the evening, but they did not move into the project area. During the late nighttime and early morning hours, a few convective cells formed in the eastern buffer zone. These cells produced a few lightning strikes before moving to the east.	No aircraft operations.

	Max cell top: 8.4km, 53.0 max dBz, 12.9 max VIL Tmax YC = 23.8C and no rain. Tmax QF = 24.4C and no rain. Tmax Radar = 23.0C and no rain.	
June 13, Wednesday	Upper level divergence was aiding lee cyclogenesis during the morning hours, with cyclogenesis expected to occur throughout the day. A surface trough was obvious, extending from SE Alberta north through the center of the province. Several weak shortwaves moving through the area were expected to be sufficient to trigger thunderstorms over the foothills beginning in the afternoon due to very moist, warm low levels. Shear was poor, so thunderstorms were expected to be short-lived and not significant hail producers. Storms began over the foothills around noon, with a few cells forming spontaneously over the city of Calgary. Numerous cells formed in both the eastern and western part of the project area, moving into the center of the project area around the trough. Some cells were severe with the potential for large hail, but these mainly occurred in the eastern buffer. Storms continued throughout the afternoon, disintegrating into stratus rain by the early evening. There were reports of pea sized hail in NW Calgary, Airdrie, and Strathmore. Max cell top: 12.9km, 66.5max dBz, 125.6max VIL Tmax YC = 17.5C and 12.6mm rain. Tmax QF = 19.9C and 3.6mm rain. Tmax Radar = 17.5C and 7.5mm rain.	HS2 was launched at 1755Z for cells forming over N Calgary. They were airborne at 1808Z and immediately began base seeding storm #1 with generators and BIPs while restricted by ATC to stay south of YYC. At 1833Z they repositioned to Cochrane. They turned acetone generators off at 1844Z. They began seeding storm #2 NW of Calgary with acetone generators at 1900Z. At 1910Z, they repositioned to a more threatening cell in W Calgary, and began seeding storm #3 with generators and BIPs at 1915Z. At 1923Z, they repositioned N of YYC back to storm #2. HS2 was directed to patrol Calgary without seeding at 2008Z. HS2 was directed to RTB at 2019Z. They landed at YYC at 2032Z. HS1 was launched at 1757Z for cells developing over Calgary. They were airborne at 1827Z and began top seeding storm #1 over Calgary at 1838Z with EJ flares. They also seeded storm #2 NW Calgary starting at 1845Z. At 1904Z, HS1 descended to shed ice. At 1931Z, HS1 started seeding storm #3 over W Calgary and then moved back to storm #2 over N Calgary seeding with EJ and BIP flares. The cells over Calgary weakened and HS1 repositioned near Olds at 2000Z for patrol. They began seeding storm #4 over Olds at 2017Z. At 2046Z they descended to shed ice. As they were climbing back to altitude, radar indicated nothing seedable and they were directed to RTB at 2051Z. They landed back in YYC at 2112Z. HS4 was launched at 1956Z and airborne at 2012Z. They headed west of YQF for patrol near Sylvan. HS4 began briefly base seeding storm #5 near Penhold at 2116Z using generators. They then repositioned north and began seeding storm #6 over Red Deer at 2138Z with generators. The cell weakened and HS4 turned generators off at 2218Z to begin patrolling Lacombe to Red Deer. They RTB to YQF at 2248Z and landed at 2253Z. <u>Flight Summary</u> HS2: 1801Z-2036Z; 6 BIP 198 minutes acetone generators; #1 Calgary, #2 NW Calgary, #3 W Calgary. HS1: 1812Z-2117Z; 9 BIP, 97 EJ; #1 Calgary, #2 NW Calgary, #3 W Calgary, patrol Calgary, #4 Olds, patrol Olds.

		HS4: 2005Z-2258Z; 100 minutes acetone generators; patrol Sylvan, #5 Penhold, patrol Lacombe to Red Deer, #6 Red Deer.
June 14, Thursday	A weak surface trough was located over the project area causing some towering cumulus over the foothills. Convection during the early afternoon was expected to be inhibited by some mid-level ridging. The left exit of a jet streak, with an associated strong shortwave trough, was expected to move directly through the project area during the evening and overnight period. Positive vorticity advection would occur over the project area beginning in the late afternoon, and occur until after sunrise the following day. Modest instability was expected during the daytime with fair speed shear. As the shortwave moved through the area during the overnight period, mid and upper level cold air advection was expected to occur, which had the potential to destabilize the atmosphere. The forecast was for showers and a few moderate thunderstorms to begin in the later afternoon, moving down from the foothills. Convection was expected to last until about 9Z, and more storms after sunrise were also a possibility. The storms first formed along the foothills during the early afternoon. This line of convection moved from west to east across the project area. Storm #1 formed SW of Calgary and moved through the metropolitan area. The strongest cell of the day formed in the eastern buffer zone between Three Hills and Strathmore. Radar data suggested that grape sized hail may have fallen within the eastern buffer zone. The rest of the forecast period saw embedded convective rain showers. Max cell top: 9.9km, 61 max dBz, 36.2 max VIL Tmax YC = 17.7C and 6.6mm of rain. Tmax QF = 18.6C and 7.0mm of rain. Tmax Radar = 16.9C and 22.8mm of rain.	HS1 was launched to cloud top at 2334Z (06/14) for growth over W Calgary. They were airborne at 2358Z (06/14) and began seeding storm #1 over Calgary with ejectable flares at 0012Z (06/15). The cell gradually diminished in intensity with the pilots reporting limited liquid water. At 0029Z (06/15), HS1 began patrolling in SW Calgary. Finding no threatening convection, they were directed to RTB at 0038Z (06/15). They landed in YYC at 0058Z (06/15). Flight Summary HS1: 2347Z (06/14)-0102Z (06/15); 24 EJ; #1 Calgary, patrol SW Calgary.
June 15, Friday	The southern half of AB saw positive vorticity advection from the upper level jet. At the mid-levels, an open wave midlevel low was over SK and one band of vorticity rotated counter-clockwise around the low toward the project area. The 00Z Red Deer sounding suggested that thunderstorms up to 8km tall were possible. Red Deer was more unstable than Calgary. Starting in the late evening, a midlevel ridge started to build over the area which made the atmosphere stable. The entire project area saw stratiform rain showers during the early morning hours. In the afternoon, the northeastern part of the project area saw scattered convective rain showers.	No aircraft operations.

	Conditions then cleared in the evening and overnight. Max cell top: 3.9km, 50.0 max dBz, 3.1 max VIL Tmax YC = 16.6C and no rain. Tmax QF = 17.2C and 14.4mm of rain. Tmax Radar = 15.3C and 0.7mm of rain.	
June 16, Saturday	The upper level jet was positioned over southern BC for most of the day. A midlevel ridge was in place over southern AB which helped to inhibit any thunderstorm development. A shortwave trough was expected during late overnight hours, but the atmospheric conditions were only expected to be slightly unstable. Stratiform rain showers fell over parts of the project area during the morning. The cloud cover then cleared during the afternoon. In the evening, stratiform clouds again flowed west to east over southern AB. The overnight hours saw isolated to scattered convective rain showers. At around the time of sunrise (11Z), a few weak convective cells were observed east of Red Deer and one lightning strike occurred. Max cell top: 8.4km, 52 max dBz, 12.8 max VIL Tmax YC = 23.5C and a trace of rain. Tmax QF = 22.9C and 0.8mm of rain. Tmax Radar = 23.1C and no rain.	No aircraft operations.
June 17, Sunday	The upper level jet was positioned south of the area, so jet energy was minimal over the region. The area saw a couple of shortwave troughs during the day. These troughs had weak to moderate vorticity advection. Better vorticity advection was expected south of the project area. The 18Z Red Deer sounding indicated that the atmosphere would be moderately unstable with pulse thunderstorms likely. Thunderstorms began to form along the foothills during the late morning. As the line of convection pushed eastward through the project area, the stronger growth was along the southern edge of the line. At 1930Z, cells formed directly over eastern Calgary. This cluster of growth continued to become more severe as it tracked eastward towards Strathmore. The next wave of thunderstorms started to push into the northwestern part of the area at 00Z. These storms eventually dissipated in the late evening. Radar data suggested that grape sized hail may have fallen southeast of Strathmore. Dime size hail was reported SE of Strathmore near the town of Namaka. In the evening, nickel to quarter sized hail fell in Rocky MH. Max cell top: 12.1km, 63.5 max dBz, 66.5 max	HS4 was launched at 1854Z for cells approaching Airdrie. They were airborne at 1912Z and began base seeding storm #1 at 1930Z with generators and BIPs. At 1959Z, they shifted east to another storm approaching Strathmore and were seeding storm #2 by 2006Z. This storm moved directly through Strathmore. As the storm exited the project area, HS4 stopped seeding and RTB at 2045Z. They landed back in YQF at 2122Z. HS1 was launched at 1942Z for storms developing between Calgary and Strathmore. They were airborne at 2000Z and began top seeding storm #2 west of Strathmore at 2007Z. They seeded the storm with BIPs and EJs until it reached Strathmore and then RTB back to YYC at 2039Z. They landed at 2101Z. HS2 was launched at 1956Z for patrol. They were airborne at 2012Z and began patrol W of Okotoks as an outflow boundary pushed southward through the area. Nothing seedable developed and HS2 RTB at 2127Z. They landed in YYC at 2143Z. HS2 was launched again at 2207Z as new cells developed west of Okotoks. They were airborne at 2223Z. The cells rapidly

	VIL At 0001Z (06/18), the radar became inoperative. An elevation gear problem was identified as the cause. The Strathmore radar was used for operations. Tmax YC = 21.4C and a trace of rain. Tmax QF = 18.4C and 0.5mm of rain. Tmax Radar = 17.4C and 4.8mm of rain.	dissipated, and HS2 RTB at 2253Z after a brief patrol west of Okotoks. They landed in YYC at 2316Z. HS3 was launched at 2324Z (06/17) for a hailstorm approaching Rocky MH from the NW. They were airborne at 2348Z (06/17). HS3 was directed to begin top seeding storm #3 at 0003Z (06/18) NW of Rocky MH. They began making cloud penetrations, and HS3 then descended to shed ice at 0023Z (06/18). When they climbed back to seeding altitude, pilots realized that the seeding system had not yet been armed, and no flares had been fired. At 0048Z (06/18), the system was armed, and cloud penetrations resumed SE of Rocky MH. Seeding continued until the cell moved through Innisfail. At 0240Z (06/18) HS3 briefly began seeding an adjacent cell #5 over Bowden. They only made one seeding run before the cell dissipated, and they were directed to RTB at 0248Z (06/18). They landed back in YQF at 0306Z (06/18). HS4 was launched at 2340Z (06/17) for a hailstorm approaching Rocky MH from the NW. They were airborne at 2353Z (06/17) and began base seeding storm #3 NW of Rocky MH at 0013Z (06/18) with generators and BIPs. They seeded the cell from Rocky MH to near Innisfail. At 0234Z (06/18) HS4 stopped seeding and RTB. They were replaced by HS2. HS4 landed back in YQF at 0248Z. HS2 was launched at 0057Z (06/18). They were airborne at 0113Z (06/18) and began patrol NW of Airdrie. At 0128Z (06/18) they began seeding storm #4 near Carstairs. Only one generator was functioning at this time. They seeded with one generator and BIPs until 0146Z (06/18). At 0208Z (06/18) HS2 landed at Olds-Didsbury briefly to fix their malfunctioning generator. They were airborne again at 0224Z (06/18) with both generators working. They took over seeding for HS4 on storm #3 near Innisfail at 0231Z (06/18) with both generators functioning. HS2 repositioned and began seeding storm #5 near Bowden/Olds at 0246Z (06/18). At 0320Z (06/18) they stopped seeding and RTB back to YYC. They landed at 0337Z (06/18). <u>Flight Summary</u> HS4: 1903Z-2126Z; 150 minutes acetone generator time, 10 BIP; #1 Airdrie, #2 Strathmore. HS1: 1951Z-2102Z: 72 EJ, 7 BIP; #2 Strathmore. HS2: 2004Z-2145Z; no seeding; patrol

		Cochrane to Okotoks. HS2: 2217Z-2318Z; no seeding; patrol Okotoks. HS3: 2334Z (06/17)-0311Z (06/18); 215 EJ, 11 BIP; #3 Rocky MH, #5 Bowden. HS4: 2350Z (06/17)-0251Z (06/18); 282 minutes acetone generator time, 24 BIP; #3 Rocky MH to Innisfail. HS2: 0105Z (06/18)-0342Z (06/18); 116 minutes acetone generator time, 1 BIP; #4 Carstairs, patrol Airdrie, #3 Innisfail.
June 18, Monday	The day began with a cirrostratus layer and moist soil from the previous day's rain. The upper level jet was south of the area with a surface trough extending from west to east across southern Alberta. An upper level trough existed over the entire province which was expected to deepen slightly throughout the day. Associated with this trough was a large region of vorticity which was the main weather feature for the day. Clearing was expected in the early afternoon, allowing temperatures to rebound. With a moist boundary layer, there was a great deal of instability in the atmosphere. Wind shear was poor, which was expected to limit severe convection. The forecast was for showers and thunderstorms to occur throughout the day beginning in the early afternoon with the most severe storms occurring in the later afternoon. Focus was on the southern half of the area where dewpoints were slightly higher and the strongest vorticity maxima were expected. With strong capping, no overnight convection was expected. Storms began in the early afternoon forming along a line about parallel with the foothills. A few cells became strong but did not persist for long. The later afternoon consisted of mainly rain showers with a few thunderstorms near and just south of Calgary. The early overnight period saw some convective rain showers with clearing later in the overnight period. Ice pellets were reported in NE Calgary by project pilots. A tour took place at the Olds-Didsbury radar. There were 14 people in attendance from Intact. The radar was inoperative from the beginning of the forecast period until 2252Z. Max cell top: 11.4km, 60.0 max dBz, 50.3 max VIL Tmax YC = 17.2C and 7.2mm of rain. Tmax QF = 14.5C and 0.8mm of rain. Tmax Radar = 15.2C and 0.5mm of rain.	HS4 took off from YQF at 1723Z for a PR flight to the radar. They landed at the Olds-Didsbury airport at 1739Z. HS3 took off at 1623Z for a ferry flight from YQF to YYC to refuel due to the YQF Jet-A fuel truck being inoperative. They landed at YYC at 1700Z. After fueling, HS3 took off from YYC at 1745Z for a PR flight to the radar. They landed at the Olds-Didsbury airport at 1756Z. HS4 was launched to cloud base for development NW of Olds at 2000Z. They were airborne from the Olds-Didsbury airport at 2010Z and began seeding storm #1 W of Olds with acetone burners and BIP's at 2016Z. They repositioned to W of Strathmore at 2038Z. They began seeding storm #2 with acetone generators at 2058Z. At 2100Z, they reported their right burner was inoperative. As the cell lost strength, they were directed to stop seeding and RTB YQF at 2108Z. They landed at 2200Z. HS3 was launched to cloud top for development NW of Olds at 2015Z. They were airborne from the Olds-Didsbury airport at 2033Z and reported no significant targets. They were directed to reposition W of Strathmore at 2046Z and began seeding with ejectable flares upon arrival at the cell at 2108Z. They stopped seeding and began patrol at 2121Z. At 2134Z, they RTB YYC for fuel. They landed at 2145Z. After fueling, HS3 took off for a ferry flight from YYC to YQF. They were airborne at 2231Z and landed at 2252Z. HS1 was launched to cloud top for development over the city of Calgary at 0137Z (06/19). They were airborne at 0159Z (06/19) and began patrolling Calgary. The cell quickly diminished, and nothing seedable was found. They RTB YYC at 0204Z (06/19) and landed at 0216Z (06/19).

		Flight Summary HS4: 1718Z-1742Z; no seeding; PR flight YQF to Olds-Didsbury. HS3: 1607Z-1703Z; no seeding; ferry flight YQF to YYC. HS3: 1737Z-1758Z; no seeding; PR flight YYC to Olds-Didsbury. HS4: 2004Z-2204Z; 62 minutes acetone generator time; 5 BIP; #1 Olds, #2 Strathmore; takeoff Olds-Didsbury, land YQF. HS3: 2017Z-2150Z; 23EJ; #2 Strathmore, patrol Strathmore; takeoff Olds-Didsbury, land YYC. HS3: 2216Z-2257Z; no seeding; ferry flight YYC to YQF. HS1: 0150Z (06/19)-0218Z (06/19); no seeding; patrol Calgary.
June 19, Tuesday	The upper level trough persisted over our area, and with a few shortwaves passing through the project area, unsettled conditions were expected. Cold air advection was expected to occur throughout the day cooling the mid and upper troposphere but also inhibiting major instability at the low levels. Wind shear was poor, so thunderstorms were expected to be short lived and not severe hail threats. The best chance for thunderstorms was in the afternoon when thermodynamics were best and a shortwave was progged to move through the area. Showers were expected to linger into the overnight period, but with ridging beginning by sunrise, the next morning was expected to have no severe threat. Convective cells were observed mainly moving southeastward through the project area. The strongest thunderstorm of the day formed southeast of Strathmore before tracking east of the region. Radar data indicated that this storm may have produced pea sized hail within the eastern buffer zone. Mostly clear skies were then observed during the late evening and overnight. Max cell top: 9.1km, 57.0 max dBz, 21.8 max VIL Tmax YC = 16.8C and 0.2mm of rain. Tmax QF = 16.3C and 3.4mm of rain. Tmax Radar = 15.3C and a trace of rain.	No aircraft operations.
June 20, Wednesday	The upper level jet was concentrated south and east of the area. A weak midlevel ridge slowly built over BC and AB during the day and overnight. Nevertheless, the 00Z Red Deer sounding indicated the atmosphere would be moderately unstable with weak speed shear. No vorticity advection was expected. Low level	No aircraft operations.

	moisture gradually diminished during the evening and overnight hours. Surface high pressure was in place for most of the day. The only trigger mechanism for thunderstorms was insolation. Scattered convective rain showers occurred in the morning, afternoon, and early evening. Isolated short-lived thunderstorms were observed in the afternoon and early evening. The skies then became mostly clear in the late evening. No significant weather occurred overnight. Max cell top: 7.6km, 55.0 max dBz, 10.9 max VIL Tmax YC = 18.1C and 0.2mm of rain. Tmax QF = 19.5C and no rain. Tmax Radar = 17.8C and no rain.	
June 21, Thursday	A weak midlevel ridge built over the region during the daytime hours. Surface dew points were expected to stay relatively high due to a southeasterly low level jet advecting moisture from the Great Plains of the US. The main triggers for thunderstorms were surface heating and vorticity advection. The 00Z soundings for Red Deer and Calgary showed an instability and wind profile conducive with long lived moderately strong thunderstorms. Multiple TITAN cells formed over the foothills during the afternoon hours, but only a few convective rain showers were observed just within the western project area boundary. Max cell top: 6.0km, 40.5 max dBz, 2.2 max VIL Tmax YC = 21.6C and no rain. Tmax QF = 22.9C and no rain. Tmax Radar = 20.6C and no rain.	No aircraft operations.
June 22, Friday	The day began with haze and high surface dewpoints. A closed low was stationary off the coast of the PACNW and was expected to send mid-level disturbances through Alberta over the next several days. Surface moisture was expected to remain good throughout the day, and with warm temperatures, instability was very good and conducive to long lived hail producing storms. The wind had an easterly component, giving a chance of orographically triggered storms. However, the cell motion was not conducive for moving thunderstorms off the foothills and into the project area. Airmass thunderstorms were also unlikely, despite the high instability, due to persistent cloud cover throughout the day and limited insolation. A shortwave moving through the area around 00Z	No aircraft operations.

	was thought to be the best chance for storms, which would likely occur after peak heating and in a more stable regime. There was a possibility for overnight rain showers. A few rain showers occurred during the afternoon, triggered by surface heating. More extensive rain coverage began during the evening and occurred throughout the overnight period. Max cell top: 8.4km, 59.0 max dBz, 28.0 max VIL Tmax YC = 21.2C and 2.2mm rain. Tmax QF = 23.4C and no rain. Tmax Radar = 20.6C and no rain.	
June 23, Saturday	Rain showers occurred during the early hours of the forecast period. Surface dewpoints were expected to be high, and high temperatures limited due to persistent cloud cover. While wind shear was good, instability was poor, even at peak heating. Upper level divergence was expected to occur throughout the daytime period, producing showers. Overnight, a low level jet was expected to advect warm moist air into southern Alberta. There was a chance of thunderstorms during the last few hours of the forecast period, and a forecast for severe storms during the next forecast period. Stratiform rain occurred throughout the entire project area in several waves throughout the day. Rain continued into the overnight period with clearing occurring during the last few hours of the forecast period. Max cell top: 8.4km, 54.5 max dBz, 14.1 max VIL Tmax YC = 18.6C and 10.0mm rain. Tmax QF = 21.6C and 0.2mm rain. Tmax Radar = 19.0C and 8.2mm rain.	No aircraft operations.
June 24, Sunday	Fog and low cloud cover occurred in southern Alberta during the morning. The placement of a jet streak was expected to cause substantial enough subsidence that no convection would occur during the early afternoon despite very moist conditions. A mid-level shortwave trough was expected to pass through the area in the later afternoon, which would be the main focus for severe convection. It was also possible, due to unstable conditions, that surface heating could cause convective initiation in the project area. Due to expansive cloud cover, these storms would only occur in clear slots. Strong speed shear indicated storms producing moderate sized hail were possible. No activity	HS1 was launched at 1730Z for development near Calgary. They were airborne at 1745Z and began top seeding storm #1 over western Calgary at 1804Z. At 1809Z, they repositioned northward and then began seeding storm #2 near the radar at 1813Z. They top seeded from Olds to YQF until 1909Z and then RTB back to YYC. They landed at 1939Z. Pilots reported their radar was not functioning properly throughout the flight. HS3 was launched at 1802Z for development near Innisfail. They were airborne at 1826Z and began top seeding storm #3 from Sylvan

	was expected overnight. Thunderstorms formed along the front during the late morning and moved northwards through the project area very quickly. By the early afternoon, the main threat had passed, and only a few showers lingered. Cool temperatures and cloudy skies prevailed through the rest of the day with all precipitation ending by the early evening. Overnight, skies cleared with fog forming during the early morning hours. Pea sized hail 3 miles W of Sundre was reported at 1817Z. Max cell top: 12.1km, 66.0 max dBz, 77.9 max VIL Tmax YC = 18.4C and 13.6mm rain. Tmax QF = 19.8C and 4.6mm rain. Tmax Radar = 17.4C and 2.2mm rain.	to Red Deer at 1838Z. At 1914Z, they shifted to an adjacent cell and seeded #2 Red Deer. Shortly after that, at 1917Z, they stopped seeding and RTB as all activity moved off to the east. They landed back in YQF at 1935Z. HS4 was launched at 1831Z and airborne at 1848Z heading toward Innisfail. They began base seeding storm #2 at 1859Z upwind of Red Deer. They seeded the storm until it moved past Red Deer. At 1925Z, they stopped seeding and headed toward Rocky MH. Shortly after that, all activity diminished and they RTB at 1932Z. They landed in YQF at 1946Z. HS4 was launched again at 2108Z and airborne at 2126Z heading for patrol over Red Deer. Nothing seedable developed, and they RTB at 2142Z. They landed back in YQF at 2151Z. HS1 was launched at 2215Z for patrol W of Calgary. They were airborne at 2240Z and began patrol at 2249Z. Nothing seedable developed and they were directed to RTB at 2308Z. They landed back in YYC at 2325Z. <u>Flight Summary</u> HS1: 1736Z-1941Z; 34 EJ, 7 BIP; #1 W Calgary, #2 Olds/Didsbury to Red Deer. HS1 experienced radar problems through the entire flight. HS3: 1815Z-1940Z; 6 BIP, 102 EJ; #3 Sylvan Lake to Red Deer, #2 Red Deer. HS4: 1842Z-1948Z; 52 minutes acetone generators; #2 Red Deer, patrol Rocky MH. HS4: 2120Z-2154Z; no seeding; patrol Red Deer. HS1: 2232Z-2327Z; no seeding; patrol W Calgary.
June 25, Monday	The upper level jet started to push into southern AB from the southwest. A midlevel shortwave trough was expected to move over the area during the late afternoon or early evening with weak vorticity advection. The closed low over the Pacific northwest morphed into a trough as it began to move northeastward towards southern AB. At the surface, a stationary front was in place just to the southeast of the project area. The Red Deer and Calgary soundings showed that the atmosphere would be slightly unstable with strong speed shear. During the midafternoon hours, a line of strong convection tried to push into the southern half of the project area from the west. The strongest cell along this line moved into the southern buffer zone before moving northeast across the	HS2 conducted a training flight in the early afternoon over the southern half of the project area. They were airborne from YYC at 1900Z, and landed in YBW at 1958Z. HS1 performed a ferry flight to the new base at YBW. They were airborne from YYC at 1929Z and landed in YBW (Springbank) at 1939Z. HS1 was launched to top at 2059Z to patrol threatening storms in the SW buffer. They were airborne at 2117Z. They reported that their aircraft weather radar was malfunctioning, and relied on meteorologist radar guidance for the rest of the flight. IMC conditions were prevalent through most of the flight. At 2200Z, they began seeding storm #1

	project area. Radar indicated that grape sized hail may have fallen north of High River. Max cell top: 12.9km, 60.5 max dBz, 47.1 max VIL Tmax YC = 22.7C and 1.0mm of rain. Tmax QF = 21.7C and a trace of rain. Tmax Radar = 20.1C and 0.5 rain.	with BIP flares, and descended to 18kft. At 2217Z, they descended to cloud base on the SE end of the cell. At 2226Z, they resumed seeding with BIP's at cloud base. With the storm no longer a threat to any target cities, HS1 RTB YBW at 2230Z. They landed at 2244Z. HS2 was launched at 2104Z to patrol threatening storms in the SW buffer. They were airborne at 2124Z. At 2150Z, in moderate inflow, HS2 began seeding storm #1 near High River with acetone generators. At 2206Z, as the storm intensified and approached High River, HS2 was directed to begin using BIP flares. They seeded storm #1 as it moved past High River. HS2 stopped seeding at 2232Z and continued patrolling the storm SW of Strathmore. They RTB YBW at 2255Z and landed at 2315Z. <u>Flight Summary</u> HS2: 1845Z-2005Z; no seeding; training flight YYC to YBW. HS1: 1913Z-1941Z; no seeding; ferry flight YYC to YBW. HS1: 2108Z-2248Z; 6 BIP; patrol SW YYC, #1 High River. HS2: 2115Z-2319Z; 84 minutes acetone generators, 3 BIP; patrol SW Calgary, #1 High River, patrol Strathmore.
June 26, Tuesday	Upper level jet energy was weak over the region. A midlevel low moved northeastward through southern AB during the day. Vorticity advection was the main trigger mechanism for thunderstorms. Similar to the previous day, the atmosphere was more unstable to the east and south of the project area. The Red Deer 18Z sounding suggested that the atmosphere would be moderately unstable and capped at the mid-levels. Speed shear was weak. Stratus rain with areas of embedded convection began in the afternoon and continued through the forecast period. A tour took place at the Olds-Didsbury radar. There were 17 people in attendance. Max cell top: 6.9km, 57.5 max dBz, 13.3 max VIL Tmax YC = 14.2C and 5.6mm rain. Tmax QF = 19.4C and 9.6mm rain. Tmax Radar = 14.6C and 21.0mm rain.	HS1 flew to the Olds-Didsbury airport for a radar tour. They were airborne from YBW at 1706Z and landed at the Olds-Didsbury airport at 1724Z. HS1 flew back to YBW after the radar tour was finished. They were airborne from Olds-Didsbury airport at 2103Z and landed in YBW at 2121Z. <u>Flight Summary</u> HS1: 1656Z-1728Z; no seeding; PR flight YBW to Olds-Didsbury. HS1: 2057Z-2123Z; no seeding; PR flight Olds-Didsbury to YBW.
June 27, Wednesday	The closed low was east of the project area, with northwest winds in southern Alberta. Due to cold air advection, dewpoints were expected to drop	No aircraft operations.

	during the forecast period, and temperatures would remain cool. Upper level ridging was occurring, and the jet was to the E. A weak shortwave was expected to move through the area at 00Z (06/28), creating the risk of a rain shower, but no severe weather was expected due to poor thermodynamics. Clearing was expected overnight. Some virga was observed at the beginning of the forecast period. No significant weather was observed through the rest of the period. There were no TITAN cells. 46.5 max dBz Tmax YC = 20.0C and 6.0mm rain. Tmax QF = 21.3C and 1.0mm rain. Tmax Radar = 19.8C and no rain.	
June 28, Thursday	Mid and upper level ridging continued. The ridge axis was expected to move through W Alberta after sunset with no substantial triggers following its passage. The lower and mid troposphere were dry throughout the period, precluding precipitation and substantial cloud cover. Clear skies were expected overnight, producing strong convective inhibition. Mostly clear skies were seen through most of the period. Nevertheless, a few light stratiform rain showers were observed on radar during late nighttime hours. 34.0 max dBz Tmax YC = 21.6C and no rain. Tmax QF = 22.1C and no rain. Tmax Radar = 20.1C and a trace of rain.	No aircraft operations.
June 29, Friday	No upper level jet energy was expected over the region. Midlevel charts showed a shortwave trough moving through the area during the late afternoon and early evening hours. Weak vorticity advection was expected along the trough. A weak surface low was also expected to move west to east across southern AB during the afternoon hours. The main triggers for thunderstorms were vorticity advection and differential surface heating. The 00Z Red Deer sounding suggested that moderately strong pulse thunderstorms were possible. Thunderstorms started forming along the foothills west of Sundre during the midafternoon hours. These cells eventually made their way off the foothills and tracked east-southeastward over the towns of Olds, Didsbury, and Carstairs. Radar data suggested that grape sized hail may have fallen just to the southeast of Sundre. In the evening, a cluster of TITAN cells moved eastward inside the northern buffer zone. Mostly	HS4 was launched at 2057Z and airborne at 2115Z. They began base seeding storm #1 near Olds at 2129Z. At 2220Z, they repositioned for storm #2 headed for Carstairs while burners remained on. They began seeding #2 Carstairs at 2224Z. At 2300Z, they stopped seeding and patrolled for a brief time. They RTB at 2307Z and landed back in YQF at 2323Z. HS3 was launched at 2133Z for convection near Sundre. They were airborne at 2154Z and began top seeding storm #2 west of Carstairs at 2211Z. At 2225Z, they stopped seeding and patrolled the same storm. They then descended to shed ice while patrolling. At 2259Z, the cell dissipated and HS3 RTB. They landed back in YQF at 2313Z. Flight Summary HS4: 2109Z-2326Z; 4 BIP, 182 minutes acetone generator time; #1 Olds, #2 Carstairs.

	clear skies occurred in the late evening and overnight. Max cell top: 10.6km, 63.5 max dBz, 38.4 max VIL Tmax YC = 24.6C and no rain. Tmax QF = 22.5C and 0.2mm of rain. Tmax Radar = 21.0C and 1.4mm of rain.	HS3: 2146Z-2318Z; 49 EJ; #2 Carstairs.
June 30, Saturday	The left exit region of an upper level jet streak was positioned directly over the area. A shortwave trough with weak to moderate vorticity advection was expected to push through the region in the late afternoon and early evening. The triggers for thunderstorm development were surface heating, a stationary front, vorticity advection, and the jet streak. The sounding showed a moderately unstable atmosphere with both speed and directional wind shear. A theta-e ridge was present during the overnight hours, but stable conditions were expected. Thunderstorms formed over the Calgary metropolitan area during the late afternoon hours and moved northeastward. Thunderstorms also formed NW of Rocky MH for a short time before dissipating. Max cell top: 8.4km, 57.5 max dBz, 16.1 max VIL Tmax YC = 24.7C and 2.2mm of rain. Tmax QF = 25.1C and no rain. Tmax Radar = 23.1C and no rain.	HS2 was launched to cloud base at 2251Z to patrol weak cells over the Calgary area. They were airborne at 2313Z. They patrolled Calgary, Strathmore, and Irricana finding no significant inflow or hail threats. They were directed to RTB at 2355Z (06/30) and landed back at YBW at 0010Z (07/01). <u>Flight Summary</u> HS2: 2301Z (06/30)-0013Z (07/01); no seeding; patrol Calgary, Strathmore, and Irricana.
July 1, Sunday	A broad upper level trough was over British Columbia and Alberta. Weak lobes of vorticity were moving through during the afternoon, evening, and overnight. A surface low with an associated cold front was in place along the AB/SK border. Surface and low level winds were expected to become more southeasterly during the evening and overnight hours advecting moisture from the Great Plains of the US. Additionally, a theta-e ridge was in place over the area during the overnight. The thermodynamic sounding indicated that moderately strong, long lived thunderstorms were possible. At around 18Z, convection quickly developed SW of Calgary and eventually moved through the metropolitan area. During the early afternoon, a cluster of cells developed from Rocky MH to Sundre and moved eastward across the entire project area. Another cluster of cells formed near the towns of Olds and Didsbury before tracking eastward. One centimeter hail fell at the Olds-Didsbury airport (2144Z) for approximately 5 minutes. Over the northern part of the project area, the storms	HS2 was launched at 1753Z for weak cells developing southwest of Calgary. They were airborne at 1808Z and began base seeding storm #1 near Calgary at 1819Z. They continued seeding with generators and BIPs until the cell moved east of Calgary at 2054Z. They then patrolled east of Calgary as the cell was moving toward the Strathmore area. They were replaced at cloud base by HS4 and RTB at 2111Z. They landed in YBW at 2132Z. HS1 was launched at 1830Z for developing cells southwest of Calgary. They were airborne at 1853Z. They began patrolling at cloud top at 1903Z. At 1948Z storms began intensifying and HS1 began top seeding storm #1 near Calgary with EJs. The storm moved east of Calgary, and HS1 stopped seeding and RTB at 2043Z. They landed at YBW at 2057Z. HS4 was launched at 2007Z for convection in the southern project area. They were airborne at 2030Z and began patrol between Calgary and Strathmore at 2111Z. They began base seeding storm #2 near Calgary at 2134Z.

	became more severe the further eastward they moved. Severe thunderstorms were observed between Red Deer and Three Hills. Radar indicated that golf ball sized hail may have fallen to the north of the towns of Linden and Three Hills. In the evening, strong cellular development occurred north of Cochrane and west of High River. The storm near Cochrane eventually moved through northern Calgary and Strathmore. Marble sized was reported in northwestern Calgary. The tallest storm of the day occurred west of High River. Radar data suggested that golf ball sized hail may have fallen over a small area to the southwest of High River. Max cell top: 13.6km, 69.5 max dBz, 188.8 max VIL Ping pong sized hail was reported 30km E of Olds. Tmax YC = 22.8C and 2.4mm of rain. Tmax QF = 21.6C and 15.2mm of rain. Tmax Radar = 20.5C and 12.5mm of rain.	They stopped seeding #2 at 2152Z and repositioned to Sylvan. They started base seeding #3 west of Sylvan at 2220Z. At 2251Z, they RTB to YQF for a quick turn around and immediate launch as soon as possible. They landed in YQF at 2300Z HS3 was launched at 2135Z for activity west of Sylvan. They were airborne at 2154Z and began patrol at cloud top near Sylvan at 2201Z. They patrolled as a storm cell barely missed Sylvan heading toward Red Deer. They then began seeding storm #3 west of Red Deer at 2322Z. At 2355Z, they stopped seeding #3 as it dissipated. They descended to shed ice at that time. They climbed back to cloud top and immediately began top seeding #4 west of Bowden at 0008Z (07/02). They RTB at 0057Z (07/02). HS2 was launched for a second flight at 2308Z for towering cumulus near Airdrie. They were airborne at 2322Z and began patrol. They began seeding storm #2 west of Bowden at 0001Z (07/02). At 0041Z (07/02) they stopped seeding and repositioned near Sundre. At 0106Z (07/02) they began seeding #5 Sundre with only one functioning generator. At 0114Z (07/02) both generators were functioning and seeding continued. At 0132Z (07/02), they repositioned to near High River leaving generators running during transit. They began base seeding #7 High River at 0155Z (07/02) with intermittent Airlink coverage. At 0302Z (07/02) they were running low on fuel and RTB to YBW. They landed at 0318Z (07/02). HS4 was launched again 2315Z after quickly replenishing fuel and chemical. They were airborne at 2337Z and began base seeding #3 near Red Deer at 2337Z immediate as they climbed out of YQF. At 2349Z, they shifted southward and began base seeding #4 near Innisfail. At 0109Z (07/02), they stopped seeding and repositioned to west of Acme. They began seeding #6 Acme at 0118Z (07/02). At 0143Z (07/02) they stopped seeding and repositioned west of Olds. They began seeding #5 near Olds/Didsbury at 0154Z (07/02). At 0227Z (07/02) the storm moved east of the highway and HS4 RTB. They landed back in YQF at 0244Z (07/02). HS1 was launched for a second flight at 0009Z (07/02) and airborne at 0030Z (07/02). They patrolled near Sundre and Bowden for a brief time, but nothing seedable was found. They RTB at 0113Z (07/02) and landed in YBW at 0127Z (07/02).

		HS1 was launched again at 0146Z (07/02) for a third flight shortly after landing. They were airborne at 0202Z (07/02) and headed toward High River. They began seeding #7 at 0215Z (07/02). At 0255Z (07/02) they repositioned near Springbank for storms approaching Calgary. They began seeding #8 at 0306Z (07/02). At 0335Z (07/02) HS1 was out of flares and RTB. They landed in YBW at 0348Z (07/02). HS3 was launched at 0252Z (07/02) and airborne at 0312Z. They headed for Calgary and began top seeding #8 for Calgary at 0335Z (07/02). They descended to shed ice once at 0402Z, dragging BIPs while they melted off ice. They seeded the same storm from Calgary to Strathmore until it moved out of the project area. Seeding ended at 0506Z (07/02) and they RTB. HS3 landed in YQF at 0528Z (07/02). Flight Summary HS2: 1758Z-2136Z; 9 BIP, 310 minutes acetone generators; #1 Calgary, patrol SW Calgary. HS1: 1840Z-2101Z; 112 EJ; #1 Calgary, patrol Calgary. HS4: 2025Z-2305Z; 2 BIP, 98 minutes acetone generators; #2 Calgary, #3 Sylvan, patrol Strathmore. HS3: 2147Z (07/01)-0111Z (07/02); 214 EJ, 4 BIP; #3 Red Deer, #4 Bowden. HS2: 2316Z (07/01)-0323Z (07/02); 17 BIP, 304 minutes acetone generators; #4 Bowden, #5 Sundre, #7 High River, patrol Airdrie; brief temporary burner failure. HS4: 2333Z (07/01)-0247Z (07/02); 16 BIP, 284 acetone generator time; #4 Innisfail, #6 Acme, #5 Didsbury and Olds. HS1: 0020Z (07/02)-0135Z (07/02); no seeding; patrol Bowden and Sundre. HS1: 0155Z (07/02)-0352Z (07/02); 295 EJ, 9 BIP; #7 High River, #8 Calgary. HS3: 0306Z (07/02)-0533Z (07/02); 219 EJ, 10 BIP; #8 Calgary to Strathmore.
July 2, Monday	Weak jet positive vorticity advection was possible during the evening hours. The upper levels saw diffluent flow. At the mid-levels, a shortwave trough was expected during the evening hours. A surface low and cold front were expected to move eastward across AB during the late afternoon and evening hours. The majority of the severe weather was expected to stay just to the north of the project area. The majority of thunderstorm activity was just to	No aircraft operations.

	the north of the project area during the daytime hours. Inside the project area, several towering cumulus clouds were observed near Red Deer. Overnight, a couple of weak thunderstorms were observed near High River and Vulcan. Max cell top: 7.6km, 52.0 max dBz, 13.3 max VIL Tmax YC = 23.3C and no rain. Tmax QF = 23.3C and no rain. Tmax Radar = 21.3C and no rain.	
July 3, Tuesday	Cyclogenesis was occurring in N Alberta, and a cold front was moving through the eastern project area. The area was under a deep mid/upper level trough, which was expected to deepen slightly throughout the day. The trough axis was expected to move through the project area around the time of peak heating. This was expected to be the main focus for storms during the day. Wind shear was poor with instability improving throughout the day, indicating embedded, marginally severe thunderstorms. A few rain showers were expected overnight. Storms began in the late morning, forming along the foothills and moving swiftly eastward. Some of the cells were severe with a maximum hail size report of marble size in the city of Red Deer. Radar data indicated that walnut sized hail may have fallen northeast of Rocky MH and just to the east of Three Hills. Max cell top: 12.1km, 64.5 max dBz, 92.6 max VIL Quarter (25mm) sized hail was reported 20km W of Olds close to the town of Harmattan. Tmax YC = 21.3C and 0.2mm of rain. Tmax QF = 17.8C and 11.0mm of rain. Tmax Radar = 21.1C and 0.7mm of rain.	HS2 was launched at 1750Z for patrol W of Calgary. They were airborne at 1810Z. At 1833Z, they began base seeding storm #2 Calgary. As the storm passed over Airdrie at 1914Z, they were told to extend their line to W of Didsbury, seeding for storm #3 Olds. At 2010Z, they shifted north and began seeding storm #5 near Innisfail, continuing seeding as the storm moved through Red Deer. At 2106Z, they stopped seeding and were directed to RTB. They landed back in YBW at 2151Z. HS4 was launched at 1754Z for a line of convection in the northwest project area. They were airborne at 1812Z. They reported difficult base seeding conditions, so they were instructed to climb to cloud top. At 1837Z, they began top seeding storm #2 for Rocky MH with ejectable flares, BIPs and acetone generators at the -3C level in embedded conditions. At 1849Z, they stopped all seeding and began patrolling Rocky MH. HS4 RTB at 1856Z, landing in YQF at 1913Z. HS3 was launched for a line of storms threatening Sundre at 1831Z. They were airborne at 1852Z and climbed to cloud top. At 1907Z they began top seeding storm #3 W of Olds. They reported very strong growth and good SLW. At 1942Z, they descended to melt ice. They resumed seeding storm #3 at 1953Z as they climbed to top. At 2018Z, they stopped seeding and repositioned to W of Calgary for patrol. At 2022Z, they determined that there were no threats W of Calgary, and they were directed to RTB Olds-Didsbury to wait for storms near YQF to clear. They landed at Olds-Didsbury at 2033Z. HS1 was launched for storms W of Calgary at 1835Z. They were airborne at 1855Z and climbed to cloud top. They began top seeding storm #1 for Airdrie with EJ's and BIPs upon arrival at 1905Z. At 1920Z, as the storm passed over Airdrie, HS1 was directed to move to the front of the line and seed along the NE edge of storm #4 for Acme/Linden/Beiseker. At 1944Z, as the storm

		moved over the towns, HS1 stopped seeding and repositioned NE to patrol Red Deer. At 2015Z, they began seeding storm #5 Red Deer. At 2105Z, they stopped seeding and flew NW around the storm to RTB YBW. They landed at 2147Z. HS3 performed a ferry flight to reposition from the Olds-Didsbury airport to their base at YQF. They took off from Olds-Didsbury at 2202Z and landed at YQF at 2213Z. Flight Summary HS4: 1804Z-1917Z; 2 BIP, 3 EJ, 14 minutes acetone generators; #2 Rocky MH, patrol Rocky MH. HS2: 1800Z-2154Z; 12 BIP, 306 minutes acetone generators; patrol Calgary, #1 Calgary, #3 Olds. HS3: 1844Z-2036Z; 152 EJ, 4 BIP; #3 Olds, Patrol W. Calgary; YQF to Olds-Didsbury. HS1: 1845Z-2150Z; 21 BIP, 232 EJ; #1 Airdrie, #4 Beiseker, patrol Red Deer, #5 Red Deer. HS3: 2157Z-2217Z; no seeding; ferry flight Olds-Didsbury to YQF.
July 4, Wednesday	An elongated upper level jet streak was along the US/Canada border. At the mid-levels, the closed low from the previous day continued to move northeastward over Saskatchewan. 500mb temperatures warmed during the period which made the atmosphere capped at midlevels. Surface winds were expected to gradually decrease during the late afternoon and evening hours. Stratiform rain showers occurred over the northern part of the project area during the morning hours. The afternoon saw cumulus and altocumulus clouds which produced mainly virga. In the evening, a few convective cells produced light rain showers over Calgary. Max cell top: 6.1km, 47.0 max dBz, 4.6 max VIL A tour was conducted at the radar and 17 insurance industry representatives were in attendance. Tmax YC = 19.4C and a trace of rain. Tmax QF = 16.9C and 3.2mm of rain. Tmax Radar = 16.6C and no rain.	HS2 performed a PR flight for the Olds-Didsbury Radar tour. They were airborne from YBW at 1708Z and landed at Olds-Didsbury airport at 1732Z. HS2 performed a PR flight after the Olds-Didsbury Radar tour. They were airborne from Olds-Didsbury at 2122Z and landed in YBW at 2144Z. Flight Summary HS2: 1700Z-1734Z; no seeding; PR flight; takeoff YBW land Olds-Didsbury. HS2: 2117Z-2149Z; no seeding; PR flight; takeoff Olds-Didsbury land YBW.
July 5, Thursday	Upper level jet energy was weak over the area. A midlevel open wave trough was over the northern BC and AB border for much of the day. A shortwave trough was expected to push through the project area during the afternoon. At the surface, a low was progged to form along the southern AB/Montana border. 850mb theta-e	HS4 was launched at 2051Z for development west of Sundre. They were airborne at 2122Z and began patrolling near Sundre. At 2251Z, they began base seeding storm #1 Sundre. At 2301Z, they stopped seeding and headed to Olds-Didsbury for fuel. They landed at 2310Z and fueled quickly to be launched again as

	ridging was expected overnight. Soundings showed a significant amount of atmospheric instability with strong speed shear and also directional shear. The veering winds with height suggested that supercells were possible. Convection first started to form to the west of Sundre during the midafternoon hours. These thunderstorms gradually moved through the northern part of the project area and passed through the towns of Sundre, Olds, and Innisfail. In the late afternoon convection started to form over the foothills west of Calgary. These cells eventually developed into a supercell which tracked eastward through northern Calgary and Strathmore. Radar indicated that golf ball sized hail was possible over the northern Calgary area. Overnight, another thunderstorm moved eastward through Calgary. Max cell top: 11.4km, 68.0 max dBz, 118.5 max VIL Loonie and walnut sized hail were reported in northwest Calgary along with drifts of pea size hail over much of northern Calgary. Tmax YC = 21.3C and 26.4mm rain. Tmax QF = 21.7C and 9.0mm rain. Tmax Radar = 20.2C and 1.3mm rain.	soon as possible. HS2 was launched at 2220Z for storms forming west of YBW. They were airborne at 2240Z and began patrolling west of Calgary. They began base seeding storm #2 Calgary at 2300Z. They seeded a supercell as it moved through Calgary and Strathmore. Both of their generators ran dry at 0146Z (07/06). They continued seeding with BIPs until all were expended. They were out of chemical and RTB at 0158Z (07/06). They landed back in YBW at 0222Z (07/06). HS1 was launched at 2255Z for development west of Calgary. They were airborne at 2315Z and began top seeding storm #2 Calgary at 2322Z. They continued seeding the same storm as is pushed through Calgary and Strathmore. At 0100Z (07/06), they stopped seeding and RTB as they were replaced by HS3. They landed back at YBW at 0112Z (07/06). HS3 was launched at 2305Z. They were airborne at 2321Z and began top seeding storm #3 near Red Deer at 2331Z. At 2345Z, they stopped seeding #3 and repositioned further south to cells approaching Olds. They began seeding storm #1 Olds at 2354Z. At 0007Z, they were iced up and descended to melt ice. They resumed seeding storm #1 at 0018Z. At 0038Z, they stopped seeding and repositioned southward to take over for HS1 west of Strathmore. They descended to shed ice while in transit. They began seeding storm #2 between Calgary and Strathmore at 0100Z (07/06). Once the storm moved out of the project area, HS3 RTB to YQF at 0201Z. They landed at 0235Z (07/06). HS4 was launched at 2321Z from Olds-Didsbury after a quick refueling. They were airborne at 2342Z and began base seeding #1 west of Olds at 0005Z (07/06). At 0019Z (07/06) they reported one generator was not functioning but continued to seed with the other functioning generator. At 0036Z (07/06), they began shifting southward toward Calgary and began seeding #2 west of Strathmore at 0055Z (07/06). They stopped seeding at 0208Z (07/06) and repositioned to Didsbury for patrol. Nothing seedable was found near Didsbury and HS4 RTB at 0213Z (07/06). They landed back at YQF at 0234Z (07/06). HS1 was launched for top seeding at 0126Z (07/06) for convection approaching Didsbury. They were airborne at 0140Z (07/06) and began seeding storm #4 Didsbury at 0151Z

		(07/06). They stopped seeding at 0209Z (07/06) as the cell weakened. At 0218Z (07/06) nothing seedable was left and they RTB. They landed back at YBW at 0231Z (07/06). <u>Flight Summary</u> HS4: 2104Z-2314Z; 20 minutes acetone generators; Patrol Sundre, #1 Sundre. YQF to Olds-Didsbury. HS2: 2231Z (07/05)-0226Z (07/06); 26 BIP, 332 minutes acetone generators; #2 Calgary. HS1: 2306Z (07/05)-0113Z (07/06); 251 EJ; #2 Calgary. HS3: 2317Z (07/05)-0240Z (07/06); 4 BIP, 283 EJ; #3 Red Deer, #1 Olds, #2 Calgary. HS4: 2339Z (07/05)-0241 (07/06); 21 BIP, 120 minutes acetone generators; patrol Red Deer, #3 Red Deer, #1 Olds, #2 Calgary; left burner malfunction. Takeoff Olds-Didsbury, land YQF. HS1: 0135Z (07/06)-0234Z (07/06); 51 EJ, 4 BIP; #4 Didsbury, patrol Didsbury.
July 6, Friday	A shortwave trough was moving through central Alberta, with its influence remaining to the north of the project area. Southwest winds had developed a dry line extending through the project area and southern Alberta. A very unstable airmass existed over southern Alberta, with strong speed shear and some directional shear. Storms were expected to form along the dryline throughout the afternoon, moving west into the project area. No significant weather was expected after midnight due to midlevel warming. A few storms formed along the foothills during the early afternoon and moved through Calgary and Didsbury. They produced small hail and some heavy rain. A few popup showers persisted into the evening, and skies cleared overnight. Max cell top: 10.6km, 62.0 max dBz, 37.2 max VIL There was a report of up to "marble or moth ball" sized hail falling in Didsbury for 10 minutes. Tmax YC = 21.1C and 9.6mm rain. Tmax QF = 23.3C and no rain. Tmax Radar = 20.3C and 2.4mm rain.	HS2 was launched at 1741Z to patrol development W of Calgary. They were airborne at 1800Z and climbed to cloud base. They patrolled the storm until 2010Z when they began seeding storm #1 with acetone generators and BIP flares. At 2049Z, HS2 ceased BIP flares and continued with acetone generators. They resumed BIPs at 2118Z, continuing until they began to run low on fuel. At 2133Z they RTB YBW, landing at 2148Z. HS1 was launched at 1921Z to patrol development W of Calgary. They were airborne at 1949Z and climbed to cloud top. As the storm strengthened, they began seeding storm #1 at 2014Z using EJs in good feeders on the SE side of the storm. They continued seeding as the storm passed through Calgary and into Strathmore. HS1 stopped seeding and RTB at 2232Z as the storm passed through Strathmore. They landed at YBW at 2252Z. HS4 was launched to a threatening cell W of Didsbury at 2011Z. They were airborne at 2031Z and climbed to cloud base. They began seeding storm #2 upon arrival at the cell at 2043Z with both acetone generators and BIP flares. At 2050Z, they reported a malfunction with their left acetone generator. After the storm passed through Didsbury at 2124Z, they stopped seeding and repositioned to storm #1 for Calgary and Strathmore. They began seeding storm #1 with BIPs and acetone generators at 2136Z. As the storm weakened, HS4 ceased using BIP flares at 2201Z. They

		RTB to YBW at 2237Z, landing at 2310Z. HS4 performed a maintenance flight to test repairs on the left acetone generator. They were airborne at 0055Z (07/07) and landed at 0119Z (07/07). <u>Flight Summary</u> HS2: 1750Z-2151Z; 6 BIP, 166 minutes acetone generators; patrol Calgary, #1 Calgary. HS1: 1931Z-2256Z; 121 EJ, 7 BIP; #1 Calgary to Strathmore. HS4: 2022Z-2313Z; 16 BIP, 109 minutes generator time; #2 Didsbury, #1 Calgary to Strathmore; left burner malfunction. HS4: 0048Z (07/07)-0124Z (07/07); 18 minutes acetone generators; Maintenance flight.
July 7, Saturday	Ridging continued today, suppressing upper level triggers but producing clear skies and very unstable conditions. High surface moisture and temperatures produced an excellent sounding with a cap persisting most of the day. The level of free convection was quite high. Due to a lack of focused triggers, storms were possible but unlikely. A stationary front was located along the southern border of Alberta which had a chance of moving N as a warm front in SE flow. There was weak upslope flow and a weak trough oriented along the foothills. Storms were possible later in the day, forming along the foothills and moving east. They were expected to be short lived, and isolated in coverage. Storms were possible but unlikely overnight due to persistent elevated instability. Skies remained clear over the project area with a few towering cumulus over the mountains. During the evening, a few rain showers occurred in the project area. Max cell top: 4.6km, 47.0 max dBz, 3.8 max VIL Tmax YC = 25.7C and no rain. Tmax QF = 26.7C and no rain. Tmax Radar = 24.4C and no rain.	No aircraft operations.
July 8, Sunday	Conditions were expected to be very hot and very humid, with a great deal of instability. Some convective inhibition was in place during the early afternoon, but this was expected to erode under clear skies and very warm temperatures. The area was under a midlevel ridge, and there were no surface triggers. A midlevel shortwave moving through during the late afternoon was expected to be the main focus for convective initiation with storms forming over the foothills and moving into the project area. Storms had	HS2 was launched at 2210Z for development W of High River. They were airborne at 2236Z and climbed to cloud base. As they approached the storm, they found that all growth was on the W edge of the storm over the foothills, and began patrolling the SE side. As the storm moved into the project area, it was just dissipating stage convection. HS2 RTB 2322Z and landed at 2332Z. <u>Flight Summary</u>

	severe potential. Due to a weak shear profile, they were not expected to be long lived. A few storms formed over the foothills during the afternoon. These storms were very severe, but moved SE along the range. Any storms which strayed into the project area quickly dissipated, and no severe weather threatened cities in the project area. Radar data indicated that walnut sized hail may have fallen west of Cremona. Max cell top: 12.9km, 66.5 max dBz, 86.8 max VIL Tmax YC = 26.9C and no rain. Tmax QF = 29.1C and no rain. Tmax Radar = 26.7C and no rain.	HS2: 2225Z-2337Z; no seeding; patrol W Cremona.
July 9, Monday	No upper level jet energy was expected over the region. An upper level ridge remained over the area for much of the day, and vorticity advection was minimal. An 850mb theta-e ridge was expected during the overnight hours. At the surface, a weak lee trough developed over the project area in the afternoon. The 00Z soundings showed a fairly unstable atmosphere, but thunderstorms were expected to remain over the foothills due to convective inhibition. The convection remained over the foothills during the afternoon hours. In the evening, a tall and potentially severe thunderstorm made its way off the foothills and into the southern buffer zone before dissipating south of High River. Radar data suggested that grape sized hail may have fallen southwest of High River, inside the southern buffer zone. Overnight thunderstorm activity stayed south and east of the project area. Max cell top: 13.6km, 58.0 max dBz, 48.0 max VIL Tmax YC = 30.5C and no rain. Tmax QF = 31.0C and no rain. Tmax Radar = 28.7C and no rain.	No aircraft operations.
July 10, Tuesday	An upper level ridge gradually shifted eastward during the day and overnight. At the mid-levels, two shortwaves were expected to pass over the region, one in the afternoon and the other in the evening. The first shortwave was expected to move through the far southern part of the project area with moderate positive vorticity advection. 850mb theta-e ridging was in place again during the overnight hours. A surface trough was positioned just to the east of the project area. The 00Z Calgary sounding showed that strong pulse thunderstorms were possible. Skies remained clear excluding a few upper level clouds and some cumulus over the	HS2 was launched at 0015Z (07/11) for threatening development NW of Rocky MH. They were airborne at 0032Z (07/11) and climbed to cloud base. While the aircraft was enroute to the storm, the radar indicated total dissipation. HS2 RTB YBW 0047Z (07/11) and landed at 0106Z (07/11). Flight summary HS2: 0022Z (07/11)-0110Z (07/11); no seeding; patrol Rocky MH.

	mountains. During the late afternoon, a few intense thunderstorms formed over the mountains, but weakened as they moved E into the project area. Overnight, some storms occurred in the N buffer zone with a rain shower over the city of Red Deer. Skies cleared by sunrise. Max cell top: 13.6km, 64.0 max dBz, 70.3 max VIL Tmax YC = 29.1C and no rain. Tmax QF = 29.6C and no rain. Tmax Radar = 28.2C and no rain.	
July 11, Wednesday	Unstable but capped conditions persisted. Temperatures were expected to remain below convective temperature. With no significant synoptic features, severe weather was not expected in the project area. Storms were forecast to form over the mountains during the later afternoon, but would weaken as they moved into the project area. Skies were clear throughout the day. During the late evening, some rain showers were observed N of Rocky MH. Max cell top: 6.1km, 51.5 max dBz, 9.4 max VIL Tmax YC = 27.1C and no rain. Tmax QF = 27.2C and no rain. Tmax Radar = 25.4C and no rain.	HS2 performed a flight to YQF for routine maintenance. They were airborne from YBW at 1314Z and landed YQF at 1346Z. HS2 performed another maintenance flight to return home. They were airborne from YQF at 1835Z and landed YBW at 1904Z. Flight Summary HS2: 1305Z-1351Z; no seeding; maintenance flight; takeoff YBW land YQF. HS2: 1830Z-1907Z; no seeding; maintenance flight; takeoff YQF land YBW.
July 12, Thursday	A surface trough was causing convergence over the province. Instability was significant with little to no cap during the afternoon. There was moderate shear and cell motion toward the east potentially allowing storms to move off the foothills into the project area. The main focus for storms would be in the N half of the PA as a moderate shortwave moved through during the early evening. Overnight, a cold front was expected to move through the area. Convective cells started forming along the southern foothills in the late morning. These storms dissipated as soon as they tried to move eastward off the foothills. In the early afternoon, activity was also seen along the northern foothills. Then in the late afternoon a strong storm developed northwest of Cochrane before tracking towards Calgary. This storm also struggled to survive once it began to move into the project area. In the late evening, a large severe storm developed northwest of Cochrane. This storm was slow moving and gradually tracked south-southeastward before dissipating just to the southwest of the Calgary metropolitan area. The severe thunderstorm activity continued through the late nighttime hours. Radar data indicated that golf ball sized hail may	HS4 (N234PS) performed a ferry flight from YYC to YQF. The aircraft had just cleared customs after arriving from Fargo to replace N123KK. They were airborne from YYC at 1713Z and landed in YQF at 1740Z. HS3 performed a PR flight from YQF to Olds-Didsbury. They were airborne from YQF at 1719Z and landed in Olds-Didsbury at 1733Z. HS4 performed a training flight with the new HS4 airplane. They were airborne from YQF at 2035Z and landed in Olds-Didsbury at 2051Z. HS2 was launched for patrol NW Cochrane at 2032Z. They were airborne at 2050Z and climbed to cloud base. They patrolled the storm until it began to move into the project area, and then began seeding storm #1 for Cochrane at 2152Z. The cell began to dissipate at 2245Z, so they stopped seeding and RTB. They landed in YBW at 2258Z. HS4 was launched out of Olds-Didsbury airport at 2157Z for storms threatening Rocky MH. They were airborne at 2218Z and climbed to cloud base. They patrolled near RMH, but the storm posed no threat. They RTB YQF at

	have fallen NW of Rocky MH and SW of High River. A radar tour took place in the early afternoon hours. There were 13 people in attendance. Max cell top: 16.6km, 68.0 max dBz, 197.5 max VIL Tmax YC = 27.3C and 0.4mm rain. Tmax QF = 27.3C and no rain. Tmax Radar = 25.1C and 1.8mm rain.	2250Z, landing at 2324Z. HS1 was launched at 2202Z for storms NW of Cochrane. They were airborne at 2215Z and climbed to cloud top. They began seeding storm #1 for Cochrane with EJs and BIPs at 2232Z. They stopped seeding at 2240Z after losing liquid water and feeders, and began patrolling Cochrane. At 0027Z (07/13), they repositioned to S Calgary. As the storm intensified, they began seeding storm # 2 for Calgary with EJs and BIPs at 0041Z (07/13). They found difficult flying conditions, and continued seeding until 0115Z (07/13), when the storm had weakened. At this time they began patrolling Calgary. At 0143Z (07/13), HS1 repositioned to patrol W of Okotoks. At 0215Z (07/13), they began seeding storm #4 as the storm approached High River. As the storm moved past High River, HS1 stopped seeding and RTB at 0225Z (07/13). They landed in YBW at 0248Z (07/13). HS3 performed a PR flight from Olds-Didsbury to YQF. They were airborne from Olds-Didsbury at 2305Z and landed YQF at 2326Z. HS2 was launched at 0031Z (07/13) for storms near S Calgary. They were airborne at 0050Z (07/13) and climbed to cloud base. They began seeding storm #2 at 0100Z (07/13) with acetone generators. They found difficult flying conditions with lots of cloud debris. They stopped seeding at 0117Z (07/13). At 0125Z (07/13), they began seeding storm #3 with acetone generators. At 0145Z (07/13), as the cell dissipated, they stopped seeding and began patrolling Calgary. They then repositioned to High River, and began seeding storm #4 with acetone generators at 0206Z (07/13). They ceased seeding and began patrol at 0226Z (07/13) as the bases began breaking up and inflow was lost. Pilots reported problems with their right generator during the flight. They RTB at 0230Z (07/13), landing at 0253Z (07/13). HS1 was launched at 0430Z (07/13) for storms W of Calgary. They were airborne at 0445Z (07/13) and climbed to cloud top. They began seeding storm #5 at 0501Z (07/13), and continued seeding as the storm developed. They stopped seeding and began patrol at 0546Z (07/13). They began seeding storm #5 again at 0743Z (07/13). They stopped seeding and began patrol at 0748Z (07/13), and RTB 0802Z (07/13). They landed at 0825Z (07/13) in YYC due to convection surrounding YBW. HS2 was launched at 0404Z (7/13) for storms

		W of Calgary. They were airborne at 0506Z (07/13) after encountering some problems with their aircraft. They climbed to cloud base, and began seeding storm #5 at 0519Z (07/13) with acetone generators. They stopped seeding and began patrol at 0558Z (07/13). They RTB at 0646Z (07/13), landing at 0700Z (07/13). Flight Summary HS4: 1708Z-1745Z; no seeding; ferry flight; takeoff YYC land YQF. HS3: 1708Z-1735Z; no seeding; PR flight; takeoff YQF land Olds-Didsbury. HS4: 2015Z-2054Z; no seeding; training flight; takeoff YQF land Olds-Didsbury. HS2: 2040Z-2303Z; 108 minutes acetone generator time; #1 Cochrane. HS1: 2208Z (07/12)-0250Z (07/13); 55 EJ, 14 BIP; #1 Cochrane, #2 Calgary, #4 High River, patrol Okotoks and Calgary. HS4: 2209Z-2328Z; no seeding; patrol Rocky MH; takeoff Olds-Didsbury, land YQF. HS3: 2301Z-2331Z; no seeding; PR flight from Olds-Didsbury back to YQF. HS2: 0042Z (07/13)-0257Z (07/13); 75 minutes acetone generator time, #2 Calgary, #3 Calgary, #4 High River; right generator failure. HS1: 0437Z (07/13)-0830Z (07/13); 170 EJ, 9 BIP; #5 Calgary; takeoff YBW, land YYC. HS2: 0457Z (07/13)-0704Z (07/13); 78 minutes acetone generator time; #5 Calgary.
July 13, Friday	A midlevel shortwave trough with moderate vorticity advection was expected to move eastward across the project area during the afternoon hours. At 850mb, a theta-e ridge was in place during the entire period. A weak surface trough was positioned over the area. The Red Deer and Calgary soundings showed a moderately unstable atmosphere with convective inhibition (CIN) at the low levels. The thunderstorm development was mainly along the mountains and foothills. One single strong thunderstorm formed SW of the Calgary metropolitan area, and radar data showed that golf ball sized hail may have fallen during this time. This storm dissipated before reaching an urban area. The rest of the project area saw no thunderstorm activity. Max cell top: 12.9km, 66.5 max dBz, 116.3 max VIL Tmax YC = 25.6C and 0.2mm of rain. Tmax QF = 27.0C and no rain. Tmax Radar = 25.1C and no rain.	HS1 departed YYC for a reposition flight back to YBW. They were airborne at 1724Z and landed at 1733Z. Flight Summary HS1: 1709Z-1736Z; no seeding; reposition flight YYC to YBW.
July 14, Saturday	Upper level jet energy continued to be north of the area. A potent midlevel shortwave trough	No aircraft operations.

	was expected to push northward through the project area during the afternoon hours. 850mb theta-e ridging continued through the overnight hours. At the surface, a low formed over Montana before pushing northward into western Saskatchewan during the overnight hours. The 18Z Red Deer sounding showed a fairly unstable sounding with weak speed and directional shear. Overall, the sounding showed that strong multicellular pulse storms were a possibility. The region saw scattered pulse thunderstorms during the afternoon, evening, and overnight. These storms were very short lived and a minimal hail threat. Radar data suggested that grape sized hail may have fallen north of the town of Sylvan during the early evening hours. Max cell top: 10.6km, 63.0 max dBz, 61.9 max VIL Tmax YC = 21.4C and a trace of rain. Tmax QF = 23.7C and a trace of rain. Tmax Radar = 23.8C and no rain.	
July 15, Sunday	Upper level jet energy remained over the Northwest Territories. A midlevel cutoff low remained quasi-stationary over the state of Washington. A broad trough extended northeastward from the cutoff low and weak to moderate vorticity advection was possible along the trough axis. At the surface, a low was in place over the project area. The upslope flow was expected to be stronger over the northern part of the project area. Area soundings indicated that scattered weak thunderstorms were likely. The region saw scattered rain showers with embedded convection throughout the period. A few lightning strikes were observed near Red Deer. Max cell top: 7.6km, 55.0 max dBz, 15.7 max VIL Tmax YC = NA. Tmax QF = 19.2C and NA. Tmax Radar = 18.7C and 14.5mm of rain.	No aircraft operations.
July 16, Monday	A weak trough collocated with a warm front was producing thick cloud and drizzle over southern AB. Both were expected to move off during the day, with cloud cover becoming broken by nightfall. Midlevel temperatures remained steady with no disturbances in the project area. The sounding showed some instability, but shear was weak. Due to the lack of triggers, no thunderstorms were expected. Drizzle ended in the early afternoon, and skies	No aircraft operations.

	cleared by nightfall. There was no precipitation overnight. Max cell top: 6.1km, 51.5 max dBz, 10.6 max VIL Tmax YC = 19.4C and 0.8mm rain. Tmax QF = 19.9C and 12.0mm rain. Tmax Radar = 18.7C and 0.5mm rain.	
July 17, Tuesday	A low pressure system to the north produced a weak trough with surface convergence over most of Alberta. Low morning overcast was expected to clear during the afternoon, but high clouds would keep temperatures down slightly. Thunderstorms were expected in the evening as a vorticity lobe moved N through Alberta, possibly continuing into the overnight period. Significant surface moisture allowed for a very unstable sounding, but poor shear indicated storms would be short lived. Storms began forming over the foothills during the afternoon, but none moved into the project area. More threatening cells formed during the evening and moved through the northern part of the project area weakening by morning. Max cell top: 14.4km, 65.5 max dBz, 115.7 max VIL Tmax YC = 23.0C and a trace of rain. Tmax QF = 24.4C and no rain. Tmax Radar = 23.3C and no rain.	HS3 was launched at 0428Z (07/18) for a cell W of Rocky MH. They were airborne at 0452Z (07/18) and climbed to cloud top. They reported a structured storm with good feeders, but a very low cloud base. Upon arrival at 0515Z (07/18), they began seeding storm #1 with BIP and EJ flares. The cell provided vigorous updrafts. They stopped seeding at 0542Z (07/18) and began patrol. They RTB at 0615Z (07/18), landing at 0635Z (07/18). <u>Flight Summary</u> HS3: 0443Z (07/18)-0644Z (07/18); 6 BIP, 40 EJ. #1 Rocky MH, Patrol Rocky MH.
July 18, Wednesday	An upper level jet was located over northern British Columbia. At the mid-levels, a shortwave trough moved west to east across central AB during the afternoon hours. This shortwave was the main trigger for thunderstorms. Nevertheless, vorticity advection from this trough was expected to be weak over the project area, so there was a chance that the thunderstorm activity would stay north of the region. The 18Z Red Deer sounding showed a moderately unstable atmosphere with moderate speed shear. The southern half of the project area was capped. Shortly after 18Z, explosive towering cumulus clouds were observed forming along the western border of the project area. The strongest cluster of cells developed NW of Rocky MH. This convection quickly strengthened into a large storm which moved southeastward into the project area. This thunderstorm eventually tracked through the town of Lacombe. Radar data indicated that golf ball or larger sized hail may have fallen in the northern buffer zone, 15km southwest of Ponoka. 2.5cm sized hail	HS4 was launched at 2023Z for convection in the northern buffer zone. They were airborne at 2047Z. They began base seeding storm #1 west of Lacombe at 2104Z using generators and BIPs. Pilots reported a malfunction of the left side generator. They lost inflow as the cell weakened near Blackfalds. They stopped seeding at 2228Z. They RTB at that time and landed in YQF at 2240Z. HS2 was launched at 2044Z for convection near Sylvan Lake. They were airborne at 2105Z. They reached the cells and began base seeding storm #1 near Blackfalds with HS4 at 2140Z. Pilots reported a right side generator malfunction, but they seeded with one generator and BIPs. As the storm weakened north of Red Deer, they stopped seeding at 2230Z and then RTB to YQF at 2234Z. They landed at 2255Z. HS3 was launched at 2115Z for development in the northern buffer zone. They were airborne at 2137Z and began top seeding storm #1 with EJs and BIPs at 2148Z. They

	was reported in the town of Rimbey. Max cell top: 15.1km, 70.0 max dBz, 217.7 max VIL Tmax YC = 27.8C and no rain. Tmax QF = 27.9C and 0.2mm of rain. Tmax Radar = 27.3C and no rain.	accumulated airframe icing rapidly and descended to shed ice at 2226Z. The storm weakened at that time and HS3 began patrol near Sylvan Lake. No further hail threats developed and HS3 RTB at 2241Z. They landed in YQF at 2252Z. HS2 took off from YQF to reposition back to YBW. They were airborne at 0030Z (07/19) and landed at 0105Z (07/19). <u>Flight Summary</u> HS4: 2035Z-2243Z; 11 BIP, 89 minutes acetone generator; #1 Lacombe; left side generator malfunction. HS2: 2055Z-2258Z; 10 BIP, 50 minutes acetone generator; #1 Blackfalds; right side generator malfunction; takeoff YBW, land YQF. HS3: 2124Z-2300Z; 100 EJ, 4 BIP; #1 Blackfalds. HS2: 0023Z (07/19)-0110Z (07/19); no seeding; reposition from YQF to YBW.
July 19, Thursday	Upper level jet energy was north and south of the region. The midlevels saw ridging for much of the day and 500mb temperatures warmed which made the atmosphere slightly capped. 850mb theta-e ridging rebuilt over the area during the evening and overnight hours. The main trigger for thunderstorm initiation was elevated surface heating along the foothills. Towering cumulus and TITAN cells were observed over the foothills during the late afternoon and evening hours. This convection quickly dissipated as it tried to move into the project area. Overnight, a wave passed over the area which triggered a few thunderstorms east of Olds and Innisfail. Max cell top: 9.1km, 61.0 max dBz, 33.0 max VIL Tmax YC = 23.7C and no rain. Tmax QF = 23.1C and a trace of rain. Tmax Radar = 21.2C and no rain.	No aircraft operations.
July 20, Friday	High pressure and a substantial cap existed during the morning. A substantial midlevel trough was progged to move through the project area during the overnight period, beginning cyclogenesis during the early morning. This trough was preceded by a strong shortwave expected to move through during the late afternoon, which was expected to be the main focus for thunderstorm initiation today. The atmosphere was capped, but unstable with strong speed shear. Storms were only expected to initiate over the foothills. Overnight, rain	HS4 performed a PR flight for the radar tour. They were airborne from YQF at 1740Z and landed at Olds-Didsbury at 1756Z. HS4 performed a PR flight after the radar tour. They were airborne from Olds-Didsbury at 2132Z and landed at YQF at 2152Z. HS1 was launched at 0257Z (07/21) to a line of storms moving into the southwest corner of the project area. They were airborne at 0319Z (07/21) and climbed to cloud base. They

	showers were expected with a few weak thunderstorms. During the afternoon, the shortwave caused some storms over the Rockies, but only virga in the project area. During the evening a line of storms associated with the main trough moved northeastward through the project area. Some storms were capable of large hail. During the morning, some showers moved into the N part of the PA. A radar tour took place in the afternoon with 14 people in attendance. Max cell top: 15.1km, 66.5 max dBz, 82.2 max VIL Tmax YC = 22.9C and 1.8mm rain. Tmax QF = 23.0C and a trace of rain. Tmax Radar = 22.2C and a trace of rain.	began base seeding storm #1 for Calgary with BIP flares at 0323Z (07/21). They were restricted to the W side of the cell by ATC. They continued seeding the storm until 0359Z (07/21). They RTB to Olds-Didsbury at 0403Z to wait for the line of storms to pass, landing at 0410Z (07/21). HS3 was launched at 0335Z (07/21) to a line of storms moving through the southern project area. They were airborne at 0357Z (07/21) and climbed to cloud top. They began seeding storm #2 for Airdrie at 0418Z (07/21) with EJs and BIPs. HS3 stopped seeding and began patrol at 0433Z (07/21). They patrolled until 0520Z (07/21) when they began seeding storm #2 for Bowden through Red Deer. They stopped seeding and began patrol at 0606Z (07/21) as the storm weakened. They RTB at 0615Z (07/21), landing at 0632Z (07/21). HS1 performed a reposition flight back to YBW. They were airborne from Olds-Didsbury at 0613Z (07/21) and landed at YBW at 0640Z (07/21). Flight Summary HS4: 1734Z-1800Z; no seeding; PR flight; takeoff YQF land Olds-Didsbury. HS4: 2126Z-2155Z; no seeding; PR flight; takeoff Olds-Didsbury land YQF. HS1: 0305Z (07/21)-0415Z (07/21); 8 BIP; #1 Calgary; base seeding; takeoff YBW land Olds-Didsbury. HS3: 0348Z (07/21)-0640Z (07/21); 7 BIP, 219 EJ; #2 Airdrie, patrol Crossfield, #2 Bowden to Red Deer. HS1: 0603Z (07/21)-0644Z (07/21); no seeding; reposition; takeoff Olds-Didsbury land YBW.
July 21, Saturday	Rain, associated with the low pressure system that had formed overnight in central Alberta, persisted during the morning. It was expected to continue into the afternoon in northern Alberta with a slight chance of weak thunderstorms over the region. The low was expected to move east by the evening giving way to ridging and providing clearing overnight. After the morning showers ended, cloud cover persisted until evening. Skies cleared overnight. Max cell top: 9.1km, 55.5 max dBz, 16.1 max VIL Tmax YC = 25.6C and no rain. Tmax QF = 23.2C and 6.0mm rain. Tmax Radar = 23.5C and no rain.	No aircraft operations.

July 22, Sunday	High pressure and a mid-level ridge were in place in the morning, and these were expected to persist throughout the daytime period for an uneventful afternoon. A very strong closed low was progged to move into the PA during the overnight period, with heights beginning to fall during the early evening. Strong storms were expected beginning around midnight, continuing into the next forecast period. Fair weather cumulus prevailed during the afternoon. Around midnight, a few elevated storms moved very quickly through the S half of the PA. After these storms subsided, rain showers continued through the rest of the night. Max cell top: 12.9km, 69.5 max dBz, 76.6 max VIL Tmax YC = 24.8C and no rain. Tmax QF = 25.3C and no rain. Tmax Radar = 23.9C and 0.5mm rain.	HS1 was launched to cells SW of Cochrane at 0532Z (07/23). They were airborne at 0550Z (07/23) and climbed to cloud top. As they reached cloud top, they reported that the cell was dissipating, which was confirmed by radar. They RTB at 0614Z (07/23) and landed at 0633Z (07/23). <u>Flight Summary</u> HS1: 0541Z (07/23)-0638Z (07/23); no seeding; patrol Cochrane.
July 23, Monday	The left exit region of an upper level jet streak was in place over the region. A deep closed low with strong vorticity advection pushed into the project area from the west during the afternoon hours. 500mb temperatures cooled by around 4C during the daylight hours which helped to exacerbate the already unstable atmosphere. At the surface, a low with associated cold and warm fronts was in place over the project area. The surface low gradually shifted northeastward. Scattered thunderstorms began to form over the area during the early morning hours. The convection continued for the rest of the morning due to a cold front creeping eastward. In the early afternoon, the thunderstorms became more severe over the northern half of the project area. One cluster of strong development, which initially formed west of Okotoks, moved northwards through Calgary, Airdrie, Olds, Innisfail, and Red Deer. The strongest storm of the day formed west of Sundre before moving northwards through Caroline and Rocky MH. Radar data suggested that golf ball or larger sized hail may have fallen to the northwest of Rocky MH. Dime sized hail was reported in Airdrie, and grape sized hail fell at the Red Deer airport. A radar tour was conducted where 11 people were in attendance. Max cell top: 13.6km, 70.0 max dBz, 175.7 max VIL Tmax YC = 23.2C and 5.4mm of rain. Tmax QF = 22.9C and 15.6mm of rain.	HS3 was launched at 1551Z for convection in the northern project area. They were airborne at 1620Z and climbed to cloud top. They began seeding storm #1 near Sylvan at 1629Z, but they stopped seeding after only a few flares and repositioned to near Blackfalds. They began seeding #2 Blackfalds at 1638Z. They stopped seeding again at 1650Z and patrolled near Red Deer. At 1708Z, HS3 RTB to the Olds-Didsbury airport intending to take part in a radar tour. They landed at EA3 at 1726Z. HS2 was launched at 1620Z for convection southwest of Calgary. They were airborne at 1643Z and began patrol near Turner Valley. At 1739Z, they began base seeding storm #3 southwest of Calgary. At 1917Z, they repositioned to near Innisfail with their generators on in transit. At 1934Z, they began seeding storm #5 for Red Deer and Innisfail. They RTB at 2003Z and landed in YBW at 2043Z. HS1 was launched at 1743Z for activity southwest of Calgary. They were airborne at 1804Z and began patrol at cloud top at 1821Z. At 1858Z, they began top seeding storm #3 near Calgary. They stopped seeding at 1918Z and resumed patrol. They RTB to Olds-Didsbury at 1934Z. They landed at EA3 at 2004Z to take part in the radar tour. HS3 was launched at 1855Z from Olds-Didsbury for convection near Olds. They ascended to cloud base and began base seeding storm #4 near Olds at 1903Z. They

	Tmax Radar = 22.0C and 19.0mm of rain.	observed cold air funnels at that time. At 1934Z, pilots reported poor bases and climbed to cloud top. They shifted north near Red Deer in the climb. They began top seeding storm #6 near Red Deer at 1943Z. At 2103Z, they repositioned near Sundre. They began top seeding #7 Sundre at 2116Z. At 2141Z, they repositioned to Innisfail. They began briefly seeding #8 Innisfail at 2212Z. At 2216Z, HS3 was low on fuel and flares and RTB to YQF. They landed at 2230Z. HS4 was launched at 1950Z and airborne at 2007Z. They started base seeding storm #6 over Red Deer at 2018Z. At 2024Z, they reported a blown circuit breaker and both generators inoperative. They continued seeding with BIPs only. At 2103Z, they stopped seeding and began patrol near Red Deer. At 2118Z, they RTB to Olds-Didsbury to troubleshoot the generators. They landed at 2136Z. HS1 took off from Olds-Didsbury to return home after the radar tour had concluded. They were airborne at 2102Z and landed in YBW at 2124Z. HS2 was launched for a second seed flight at 2130Z. They were airborne at 2146Z and headed toward Red Deer. They began base seeding storm #9 over Red Deer at 2212Z. At 2259Z, they lost all inflow and RTB. They landed back in YBW at 2342Z. HS1 was launched at 2208Z for development near Rocky MH. They were airborne at 2225Z and climbed to cloud top. They began top seeding storm #9 near Rimbey at 2255Z. As the cell weakened, they stopped seeding and began patrol at 2305Z. They RTB at 2327Z and landed back in YBW at 2351Z. HS4 took off from EA3 after troubleshooting their generators. They repositioned back home to YQF. They were airborne at 2331Z and landed at 2348Z. They tested the generators in flight and still had problems with them. HS4 took off from YQF for a maintenance flight after more troubleshooting of their generators. They were airborne at 0050 (07/24) and landed back in YQF at 0055Z (07/24). <u>Flight Summary</u> HS3: 1607Z-1729Z; 25 EJ, 3 BIP; #1 Sylvan, #2 Blackfalds; takeoff YQF, land EA3. HS2: 1632Z-2048Z; 4 BIP, 288 minutes

		acetone generator time; #3 SW Calgary, #5 Red Deer. HS1: 1752Z-2008Z; 20 EJ; #3 Calgary, patrol Crossfield; takeoff YBW, land EA3 for radar tour. HS3: 1858Z-2234Z; 273 EJ, 18 BIP; #4 Olds, #6 Red Deer, #7 Sundre, #8 Red Deer. HS4: 1958Z-2139Z; 12 BIP, 14 minutes acetone generators; #6 Red Deer; left and right side generator failure. HS1: 2058Z-2127Z; no seeding; PR return flight from EA3 to YBW. HS2: 2138Z-2344Z; 8 BIP, 94 minutes acetone generators; #8 Red Deer, #9 Red Deer. HS1: 2220Z-2355Z; 29 EJ; #9 Rimbey to Sylvan; patrol Sylvan. HS4: 2323Z-2354Z; no seeding; reposition from EA3 to YQF. HS4: 0040Z (07/24)-0059Z (07/24); no seeding; maintenance flight.
July 24, Tuesday	Jet energy was concentrate along the southeastern side of a closed low which was along the AB/SK border. Lobes of vorticity rotated counter-clockwise around the low and were the main trigger for thunderstorm development. Low level moisture continued to wrap around the low. Winds at the surface were expected to be northwesterly and gusty. Area soundings showed a moderately unstable atmosphere with strong speed shear. In the late morning, a line of weak thunderstorms formed just to the north of Red Deer before moving southward. This line briefly became stronger south of Red Deer before continuing to the southeast. Radar data indicated that grape sized hail may have fallen to the southeast of Red Deer. The rest of the period saw isolated to scattered convective rain showers. Max cell top: 8.4km, 65.0 max dBz, 50.1 max VIL Tmax YC = 20.9C and 1.2mm rain. Tmax QF = 19.1C and 18.6mm rain. Tmax Radar = 16.6C and 3.6mm rain.	HS4 performed a maintenance flight to test their generators. They were airborne at 1918Z and landed at 1953Z. <u>Flight Summary</u> HS4: 1911Z-1956Z; 16 minutes acetone generators; maintenance flight.
July 25, Wednesday	Rain showers and some towering cumulus were occurring during the morning. Some remnant vorticity and midlevel divergence from the closed low, now well to our east, were providing modest lift over the project area. This was expected to continue throughout the day. With a moderately unstable atmosphere but poor shear, some weak thunderstorms were expected in the late afternoon. No significant weather was expected overnight.	HS4 was launched to patrol threatening development near Rocky MH at 1814Z. They were airborne at 1833Z and climbed to cloud base. As they approached the cells, they saw that the clouds had minimal vertical development and no new growth. They RTB at 1859Z and landed at 1923Z. During this flight, they conducted an extended test of the acetone generators, but no actual storms were seeded.

	Showers formed over the entire project area during the early afternoon. During the later afternoon, a few showers became intense and reached hail criteria. Showers ended during the evening, and no significant weather occurred overnight. Max cell top: 13.6km, 66.5 max dBz, 107.7 max VIL Tmax YC = 22.8C and 1.0mm rain. Tmax QF = 22.6C and 2.0mm rain. Tmax Radar = 20.4C and 5.6mm rain.	HS4 was launched at 2232Z for a storm near Rocky MH. They were airborne at 2248Z and climbed to cloud base. As they approached the Rocky MH cell, they were repositioned back east near Olds. At 2338Z, they began seeding storm #1. At 2350Z, they repositioned to N of Innisfail, and at 0001Z (07/26) began seeding storm #2. As it became clear the storms would miss all major cities, they turned burners off at 0028Z (07/26) and began patrolling Didsbury. They RTB at 0039Z (07/26), landing at 0104Z (07/26). <u>Flight Summary</u> HS4: 1822Z-1929Z; no storms seeded; patrol Rocky MH; 26 minutes acetone generator time for equipment testing. HS4: 2243Z (7/25)-0108Z (7/26); 4 BIP, 102 minutes acetone generators; #1 Olds, #2 Innisfail, patrol Didsbury.
July 26, Thursday	A moist boundary layer and a shortwave indicated that strong storms were possible. Lack of wind shear would limit the severity of the storms, making them mostly a heavy rain threat. Storms were expected to begin during the afternoon due to surface heating, and continue into the evening as a shortwave moved through the project area. Showers were expected overnight, with the possibility of a thunderstorm due to a continued unstable atmosphere. Showers began during the early afternoon, mainly over the foothills. A few storms moved off the foothills during the afternoon, slowly moving through the project area until the early evening. Rain showers persisted overnight. Max cell top: 12.1km, 65.5 max dBz, 77.9 max VIL Tmax YC = 22.8C and no rain. Tmax QF = 23.3C and no rain. Tmax Radar = 22.1C and 0.5mm of rain.	HS2 was launched at 2105Z for a storm moving W of Cremona that was moving off the foothills. They were airborne at 2124Z and climbed to cloud base. They found a shelf and good inflow on the storm and began seeding storm #1 with acetone generators at 2133Z. They seeded the storm until 2151Z when they repositioned to a more threatening storm over Okotoks. Enroute, they discovered some towering cumulus in NW Calgary, and began seeding storm #2 with acetone generators at 2205Z. They were restricted by ATC from moving further E, and as the cell failed to develop into a threat, they turned burners off at 2221Z and began patrolling near Okotoks. They were then repositioned to Cochrane at 2230Z, then to Airdrie at 2247Z, to inspect growth seen visually. Finding no developing threats. They RTB 2256Z, landing at 2305Z. HS4 was launched at 2154Z to a storm W of Carstairs. They were airborne at 2214Z and climbed to cloud base. They began seeding storm #1 at 2232Z, reporting modest inflow and ice pellets. They continued to seed the storm as it passed through Carstairs, then repositioned to development W of Airdrie. They began seeding storm #3 for Airdrie at 2324Z. They continued to seed this storm as it developed further S, stopping seeding at 0016Z (07/27) as they lost all inflow. They were then repositioned to patrol near Spring Bank, but no threats were observed. They RTB 0024Z (07/27), landing at 0050Z (07/27). <u>Flight Summary</u> HS2: 2110Z-2309Z; 96 minutes acetone generators; #1 Cremona, #2 Calgary, patrol Cochrane, patrol Airdrie.

		HS4: 2203Z (07/26)-0053Z (07/27); 210 minutes acetone generators; #1 Carstairs, #3 Airdrie, patrol YBW.
July 27, Friday	The mid-levels saw weak ridging through the early evening hours. The main trigger for thunderstorms was a shortwave trough during the late afternoon and early evening. Weak to moderate vorticity advection was expected with the shortwave. Overnight, a theta-e ridge was in place along with vorticity advection from the southwest. The thermodynamic soundings indicated that the troposphere would be moderately unstable with moderate speed shear. Convection started to form over the mountains and foothills in the early morning and continued into the afternoon hours. At around 19Z, explosive growth occurred south of Turner Valley. This convection quickly turned into an intense storm which tracked southeastward. Radar data indicated that golf ball sized hail may have fallen southeast of High River inside the southern buffer zone. The rest of the afternoon saw scattered thunderstorms. The second major storm (#2) formed west of Calgary and moved southeastward towards southern Calgary and Okotoks. Another storm (#3) formed near Cremona and moved eastward through Crossfield. The fourth storm began to push into the project area southwest of Sundre at around 00Z. This storm pulsed up and down several times before dissipating north of Cremona. During the late overnight hours another wave of thunderstorms moved through the area. Max cell top: 16.6km, 67.0 max dBz, 149.7 max VIL Tmax YC = 28.1C and no rain. Tmax QF = 26.7C and no rain. Tmax Radar = 25.4C and a trace of rain.	HS1 was launched at 1716Z to convection W of Calgary. The flight became airborne at 1738Z and patrolled SW of Calgary. The crew was then redirected to patrol the Rocky MH area at 1817Z. HS1 was redirected toward new growth NW of High River at 1836Z. The aircraft started seeding storm #1 at 1900Z. The crew reported explosive growth along the southern edge of the storm at 1916Z. Then at 1928Z the aircraft was directed to stop seeding and RTB to YBW. The flight landed at 1948Z. HS2 was launched at 1842Z to explosive growth NW of High River. The aircraft became airborne at 1901Z. At 1923Z, the crew started seeding storm #1 as it tracked towards High River. Then at 1928Z, HS2 patrolled YBW for a short time before RTB to YBW at 1950Z. The aircraft landed at 2001Z. HS4 was launched at 2034Z to a storm NW of Rocky MH. They became airborne at 2058Z and redirected to a new storm W of Calgary. HS4 started seeding storm #2 west of Calgary at 2136Z. The aircraft continued to seed the storm as it moved over southern Calgary. Then at 2322Z, the flight was redirected towards a storm (#3) west of Linden and Acme. Seeding started at 2327Z. The crew seeded this storm for a short amount of time before stopping seeding and RTB at 2346Z. The aircraft landed at 0009Z (07/28). HS3 was launched at 2049Z to cells W of Innisfail. The aircraft became airborne at 2126Z and headed toward Rocky MH. The crew did not see anything seedable, so the aircraft RTB to CYQF at 2153Z. The flight landed at 2221Z. HS2 was launched at 2055Z to a strong storm (#2) W of Calgary. The flight became airborne at 2117Z and started seeding #2 at 2121Z. Then at 2207Z, the crew extended their line to near Turner Valley and Black Diamond. The aircraft continued to seed as the storm moved over southern Calgary and Okotoks. At 2310Z they stopped seeding and RTB to YBW. The aircraft landed at 2330Z. HS1 was launched at 2105Z to the same storm that HS2 was seeding. The flight became airborne at 2122Z and was redirected to strong growth W of Crossfield. HS1 started seeding storm #3 at 2152Z. The crew

		continued to seed the storm until it was past Airdrie. Then at 2251Z, HS1 stopped seeding, and at 2303Z the aircraft RTB to YBW. They landed at 2315Z. HS3 was launched at 0007Z (07/28) to explosive growth near Cremona. The aircraft became airborne at 0029Z (07/28), and at 0047Z (07/28) started seeding storm #4 as it moved east-southeastward towards Cremona. HS3 stopped seeding at 0052Z (07/28) and continued to patrol the storm as it moved towards Didsbury. At 0126Z (07/28), the crew was only finding minimal growth, so the aircraft RTB to YQF. The flight landed at 0150Z (07/28). HS1 was launched at 1100Z (07/28) for a solitary cell SW of Strathmore. They were airborne at 1128Z (07/28) and climbed to cloud top. As they approached the cell, they encountered very embedded conditions, and found some new growth on a cell further to the S. They began seeding storm #5 at 1158Z (07/28), finding some growth and generally good liquid water. As the cell passed through Strathmore at 1206Z (07/28), they stopped seeding and continued patrol. Several more cells formed SW of Strathmore, but they were not hail threats. HS1 RTB at 1236Z (07/28) and landed at 1250Z (07/28). <u>Flight Summary</u> HS1: 1725Z-1952Z; 75 EJ, 5 BIP; patrol SW of Calgary, patrol Rocky MH, #1 High River. HS2: 1851Z-2006Z; 1 BIP, 14 minutes acetone generators; #1 High River, patrol CYBW. HS4: 2051Z (07/27)-0012Z (07/28); 12 BIP, 234 minutes acetone generators; #2 Calgary. HS2: 2107Z-2333Z; 8 BIP, 218 minutes acetone generators; #2 Calgary and Okotoks. HS1: 2118Z-2318Z; 104 EJ, 4 BIP; #3 Crossfield. HS3: 2120Z-2230Z; no seeding; patrol Rocky MH. HS3: 0022Z (07/28)-0156Z (07/28); 19 EJ; #4 Cremona, patrol Didsbury. HS1: 1121Z (07/28)-1254Z (07/28); 8 EJ; patrol Strathmore, #5 Strathmore.
July 28, Saturday	The upper levels saw diffluent flow during the early afternoon hours. A midlevel shortwave trough slid W to E across the project area during the afternoon hours with strong vorticity advection. A small ridge was expected to start building over the region in the evening. The 850mb theta-e ridge shifted eastward into Saskatchewan during the daytime hours, so no significant weather was expected overnight. The	HS3 was launched at 1726Z to a cluster of TITAN cells W of Rocky MH. The flight became airborne at 1744Z and patrolled the Rocky MH area before RTB at 1819Z. The aircraft landed at 1842Z. HS4 launched at 1752Z to a growing cell west-northwest of Sundre. The aircraft became airborne at 1812Z. HS4 quickly found good

	soundings indicated that the atmosphere was fairly unstable with decent speed shear. The first cluster of strong convection started developing west of Rocky MH during the late morning hours as a midlevel trough began to push into the region. Starting in the afternoon, the convection spread further south along the foothills. The strongest storm of the day formed southwest of Sundre and tracked southeastward through Cremona, Airdrie and Crossfield. A tornado touched down near Cremona. There was a report of larger than golf ball size hail 11km south of Irricana near Kathyrn. Walnut sized hail was reported in southeastern Airdrie. In the late afternoon, another storm (#4) strengthened west of Sylvan and Lacombe. These storms tracked east-northeastward through Lacombe and Ponoka. Max cell top: 13.6km, 67.5 max dBz, 166.5 max VIL Tmax YC = 25.0C and 0.8mm of rain. Tmax QF = 22.2C and no rain. Tmax Radar = 20.0C and a trace of rain.	inflow and started base seeding storm #1 NW of Sundre at 1838Z. Then at 1917Z the flight started seeding a quickly intensifying storm (#2) W of Cremona. HS4 then repositioned to near Springbank due to new echoes west of Calgary. They started seeding storm #3, W of Calgary, at 1940Z. The crew only reported minimal inflow, so the flight was redirected back up north to the Crossfield storm (#2). Seeding resumed on #2 at 2003Z, and HS4 continued seeding this very strong storm until it was well east of Calgary. The aircraft RTB to CEA3 for a quick turnaround at 2122Z, and landed at 2136Z. HS2 was launched at 1953Z for cells forming over Calgary. The flight became airborne at 2007Z. They began seeding #3 Calgary at 2014Z. HS2 continued to seed storm #3 until it was east of Calgary and was then redirected to storm #2 at 2105Z to replace HS4. They began seeding #2 NW of Strathmore at 2112Z. HS2 RTB at 2201Z as the cell was no longer threatening Strathmore. The aircraft landed in YBW at 2219Z. HS3 was launched to large cell W of Crossfield at 1957Z. They were airborne at 2016Z. Then at 2029Z, they started seeding storm #2 near Crossfield. HS3 reported explosive growth and started seeding aggressively over Airdrie. At 2151Z the aircraft was redirected to the Red Deer area. HS3 seeded storm #4 west of Lacombe for a short amount of time before RTB at 2226Z. The aircraft landed in YQF at 2244Z. HS4 flew a reposition flight from CEA3 to CYQF. The aircraft was airborne at 2205Z and landed at 2219Z. <u>Flight Summary</u> HS3: 1735Z-1849Z; no seeding; patrol Rocky MH. HS4: 1804Z-2138Z; 20 BIP, 270 minutes acetone generators; #1 Sundre, #2 Cremona Crossfield and Airdrie, #3 Calgary. HS2: 1959Z-2224Z; 17 BIP, 214 minutes acetone generators; #3 Calgary, #2 Calgary to Strathmore. HS3: 2009Z-2249Z: 199 EJ, 11 BIP; #2 Crossfield, #4 Lacombe. HS4: 2202Z-2222Z; no seeding; reposition flight CEA3 to CYQF.
July 29, Sunday	Upper level jet energy continued to stay south of the international border. A midlevel ridge remained over the area for most of the day. No vorticity advection was expected, so the main trigger for thunderstorm initiation was elevated	No aircraft operations.

	surface heating along the foothills. A surface high was centered along the southern AB/SK border. Stronger convective inhibition existed over the southern part of the project area. Fair weather cumulus occurred over the area during the forecast period. A few isolated rain showers were observed in the northern part of the project area during the early morning. No TITAN cells, 44.5 max dBz, 2.8 max VIL Tmax YC = 25.8C and no rain. Tmax QF = 25.5C and no rain. Tmax Radar = 24.4C and no rain.	
July 30, Monday	High pressure and a moist boundary layer were prevalent during the morning and early afternoon. A strong shortwave trough was expected to move through the project area, causing substantial lift. The sounding was very unstable with very good speed shear and some directional shear. Severe storms were expected to begin during the afternoon, continuing into the evening. Large hail was a good possibility. Due to the sounding profile, high winds and possible bowing storms were also possible. After the shortwave passed through, no severe storms were expected. A few showers could linger into the overnight period. A few high topped storms were observed over the Rockies shortly after noon. A strong storm formed over the NW foothills during the afternoon, and moved E through the central project area. The storm weakened slightly as it passed through Bowden, but there were a few reports of hail. A funnel cloud 1 mile E of Olds was reported by HS4. Golf ball sized hail was reported near Sundre. Pea sized hail was observed at the Bowden golf course. Max cell top: 15.1km, 66.5 max dBz, 127.3 max VIL Tmax YC = 29.3C and no rain. Tmax QF = 27.1C and 3.2mm rain. Tmax Radar = 26.4C and a trace of rain.	HS4 was launched for patrol at 1919Z. They were airborne at 1951Z and were directed towards Rocky Mountain house. There were no threats near the project area, so HS4 landed at Rocky MH to await severe weather. Touchdown time was 2011Z. HS4 was launched at 2131Z to patrol a storm NW of Sundre. They were airborne from Rocky MH at 2147Z and climbed to cloud base. They began seeding storm #1 at 2156Z. They continued seeding the storm as it passed through Bowden. They seeded continuously until 2333Z, when they stopped seeding and repositioned to patrol Airdrie. At 2338Z, they RTB to refuel, landing in YBW. Touchdown time was 0015Z (07/31) HS2 was launched to a very strong storm W of Bowden at 2208Z. They were airborne at 2227Z and climbed to cloud base. They began seeding at 2241Z. They found very good inflow, and seeded continuously until 2327Z. At this time, they stopped seeding and began patrol N of Spring Bank. After encountering severe turbulence along the front, they RTB Spring Bank at 2347Z, landing at 2358Z. HS3 was launched to a very strong storm W of Bowden at 2212Z. They were airborne at 2227Z and climbed to cloud top. They began seeding storm #1 with EJs and BIPs at 2240Z. HS3 stopped seeding and descended to melt ice at 2314Z, resuming seeding with BIPs and EJs at 2329Z. They stopped seeding at 2336Z. They RTB at 2338Z to Olds-Didsbury due to weather over YQF, landing at 2348Z. HS3 performed a reposition flight after weather had cleared YQF. They were airborne from Olds-Didsbury at 0102Z (07/31) and landed in YQF at 0119Z (07/31). HS4 performed a reposition flight after

		weather had cleared YQF. They were airborne from YBW at 0112Z (07/31) and landed in YQF at 0135Z (07/31). Flight Summary HS4: 1941Z-2014Z; no seeding; patrol Rocky MH; takeoff YQF, land Rocky MH. HS4: 2143Z (07/30)-0019Z (07/31); 17 BIP, 182 minutes acetone generators; #1 Caroline through Bowden, patrol Airdrie; takeoff Rocky MH, land YBW. HS2: 2215Z (07/30)-0001Z (07/31); 11 BIP, 106 minutes acetone generators; #1 Bowden. HS3: 2220Z-2351Z; 5 BIP, 150 EJ; #1 Bowden; takeoff YQF land Olds-Didsbury HS3: 0056Z (07/31)- 0125Z (07/31); no seeding; reposition flight; takeoff Olds-Didsbury, land YQF. HS4: 0101Z (07/31)-0139Z (07/31); no seeding; reposition flight; takeoff YBW, land YQF.
July 31, Tuesday	The atmosphere was capped during the morning with some virga and increasing cloud moving in over the mountains. A weak stationary front was located in central Alberta, mainly E of the project area. The weak midlevel shortwaves causing precipitation were expected to cause severe storms in the project area closer to peak heating, as the inhibition eroded. During the afternoon, the atmosphere was expected to be moderately unstable with good speed shear. The main forcing this forecast period was expected to be during the evening when a more substantial shortwave trough moved through the area. Storms moved off the foothills during the early afternoon, continuing to form and move through the area throughout the day. Some storms were severe with large hail, heavy rain, and funnel clouds. During the evening, storms diminished in intensity until they were only showers after midnight. Radar data suggested that up to golf ball sized hail may have fallen over southwestern Calgary and near Three Hills. 30mm sized hail was reported in southwest Calgary. A radar tour took place with 10 in attendance. Max cell top: 13.6km, 69.0 max dBz, 134.4 max VIL Tmax YC = 25.0C and 0.8mm of rain. Tmax QF = 22.6C and 7.4mm of rain. Tmax Radar = 21.4C and 21.0mm of rain.	HS2 performed a PR flight for the radar tour. They were airborne from YBW at 1723Z and landed at Olds-Didsbury at 1746Z. HS4 was launched at 2006Z to a cell W of Sundre. They were airborne at 2026Z and climbed to cloud base. HS4 began seeding storm #1 at 2039Z. They stopped seeding at 2051Z and patrolled near Sundre and Springbank. HS4 RTB at 2143Z landing in Olds-Didsbury to refuel. Touchdown time was 2214Z. HS3 was launched at 2009Z to a cell W of Sundre. They were airborne at 2024Z and climbed to cloud top. They began seeding storm #1 at 2042Z. At 2058Z, they repositioned further north to seed storm #2. At 2107Z, they repositioned back to storm #1. They descended to melt ice at 2135Z. After they descended, they RTB to YQF as the storm moved past any protected cities. The crew landed at 2156Z. HS2 was launched out of Olds-Didsbury for storm #2 at 2049Z. They were airborne at 2100Z and climbed to cloud base. They began seeding with generators at 2102Z. They repositioned to storm #1 at 2136Z. At 2153Z, they stopped seeding and repositioned further to the SW near Cremona. They began seeding storm #3 at 2203Z. HS2 RTB to YBW at 2345Z, landing at 0005Z (08/01). HS1 was launched to cells W of Turner Valley. They were airborne at 2141Z and climbed to cloud top and began patrol. At 2240Z, the crew was redirected to new development W of

		Sundre. At 2300Z, they began seeding Storm #4 with EJs and BIPs. The crew continued to seed the storm as it passed over Sundre and the Olds-Didsbury area. At 2357Z the crew visually observed new explosive growth W of the Calgary area, so the aircraft was redirected there. The crew started seeding storm #5 at 0009Z. Once HS3 moved into the area, HS1 dropped down to base to seed at 0104Z (08/01). At 0128Z (08/01) HS1 was out of chemical, so they RTB. They landed in YBW at 0147Z (08/01). HS4 was launched out of Olds-Didsbury at 2230Z. The aircraft became airborne at 2245Z (08/01) and moved toward the Sundre storm (#4). The flight started seeding at 2254Z and continued seeding as the storm moved through Sundre and the Olds-Didsbury area. HS4 was then redirected to a new intensifying cell W of Calgary and started seeding this storm at 0027Z (08/01). The crew continued to base seed this storm as it passed over the southern Calgary metropolitan area. They then RTB to YBW at 0139Z and landed at 0156Z (08/01). HS3 was launched to explosive growth W of the Calgary area at 0015Z (08/01). The flight became airborne at 0035Z (08/01) and expedited to southern Calgary. The crew started top seeding storm #5 aggressively over southern Calgary at 0059Z (08/01). Next, HS3 stopped seeding and started patrolling the Strathmore area (0139Z). The aircraft was then redirected to southern Calgary and started seeding storm #6 at 0208Z (08/01). They then expedited to storm #5 and started seeding for Strathmore at 0239Z (08/01). HS3 then patrolled for a short time before RTB at 0256Z (08/01). They landed in YQF at 0328Z (08/01). HS2 was launched at 0113Z (08/01) to a tall storm (#6) just to the W of Cochrane. The crew became airborne at 0122Z (08/01) patrolling Cochrane, Airdrie, and Calgary before RTB at 0203Z (08/01). The flight landed in YBW at 0210Z (08/01). HS4 flew a reposition flight. The crew took off from Springbank at 0242Z (08/01) and landed in Red Deer at 0320Z (08/01). <u>Flight Summary</u> HS2: 1713Z-1748Z; no seeding; PR flight takeoff YBW, land Olds-Didsbury. HS4: 2021Z-2212Z; 24 minutes acetone generators, 2 BIP; #1 Sundre, patrol Springbank; takeoff YQF, land Olds-Didsbury.

		HS3: 2019Z-2200Z; 114 EJ, 7 BIP; #1 Sundre, #2 Bowden. HS2: 2055Z (07/31)-0009Z (08/01); 27 BIP, 306 minutes acetone generators; #2 Bowden, #1 Olds, #3 Cremona; takeoff Olds-Didsbury, land YBW. HS1: 2130Z (07/31)-0152Z (08/01); 296 EJ, 14 BIP; patrol Turner Valley, #4 Sundre, #5 Calgary. HS4: 2240Z (07/31)-0159Z (08/01); 24 BIP, 296 minutes acetone generators; #4 Sundre, #5 Calgary; takeoff Olds-Didsbury, land YBW. HS3: 0030Z (08/01)-0332Z (08/01); 262 EJ, 3 BIP; #5 Calgary, patrol Strathmore, #6 Calgary, #5 Strathmore. HS2: 0115Z (08/01)-0215Z (08/01); no seeding; patrol Cochrane, Airdrie, and Calgary. HS4: 0235Z (08/01)-0323Z (08/01); no seeding; reposition flight; takeoff YBW, land YQF.
August 1, Wednesday	An upper level closed low was in place over northern BC during the daytime hours. This low moved southeastward towards Edmonton overnight. At the mid-levels, a shortwave trough was expected to slide eastward across the area during the evening hours. Additionally, a cold front was expected to push into the project area from the northwest during the evening hours. The Red Deer 00Z and 06Z soundings indicated that the atmosphere would be slightly unstable with moderate speed shear. The late morning, afternoon, and early evening saw several towering cumulus clouds, but no radar echoes were observed during this time. Weak thunderstorms formed just north of the area during the evening and eventually made their way into the northern half of the project area during the overnight hours. Several lightning strikes were observed. Max cell top: 9.1km, 56.5 max dBz, 19.1 max VIL Tmax YC = 23.3C and 1.8mm of rain. Tmax QF = 23.5C and no rain. Tmax Radar = 22.4C and 3.0mm of rain.	No aircraft operations.
August 2, Thursday	An upper level jet streak was just to the west of the region and may have provided weak lift for thunderstorm development. A mid and upper level closed low was centered just to the east of the region and continued to dig southeastward throughout the period. The surface cold front pushed southward through the project area during the morning hours. Clouds ceilings were expected to stay fairly low during the day. The Red Deer 00Z sounding indicated that the	No aircraft operations.

	atmosphere was moderately unstable with weak speed shear. A line of heavy convective rain showers pushed southward through the project area during the morning hours. A relatively strong cold front was the trigger for this convection. The afternoon and early evening hours saw a few weak thunderstorms over the northern half of the area. Scattered convective rain showers then occurred during the rest of the period. Max cell top: 9.9km, 62.0 max dBz, 30.4 max VIL Tmax YC = 14C and 5.4mm rain. Tmax QF = 17.6C and 4.2mm rain. Tmax Radar = 14.3C and 2.2mm rain.	
August 3, Friday	Substantial ridging was expected as the trough moved to the east. Cool, dry conditions persisted through most levels of the atmosphere, producing a sounding that indicated convective rain showers were likely. A surface trough was approaching the project area during the evening and expected to be the main focus for the day. Due to ridging, no severe hail was expected. Some showers occurred in the early morning with gradual clearing afterwards. No additional precipitation was observed through the remainder of the forecast period, and skies were clear by early morning. Max cell top: 4.6km, 49.0 max dBz, 4.3 max VIL Tmax YC = 21.0C and 0.4mm rain. Tmax QF = 21.5C and no rain. Tmax Radar = 20.1C and no rain.	No aircraft operations.
August 4, Saturday	The ridge persisted throughout the forecast period, producing clear skies during the morning. The atmosphere was expected to become unstable during the day with good speed shear. A weak shortwave was expected to initiate thunderstorms during the early evening, but they were expected to stay mainly over the foothills. During the late overnight period, a cold front was progged to move through the area. This feature was expected to produce only some rain showers, with the chance of a weak thunderstorm. Storms formed in the late afternoon along the cold front as it approached the project area from the north. Some severe storms occurred in the northern part of the project area, diminishing to rain showers after midnight. Skies cleared overnight.	HS3 was launched to a cell NW of Sylvan Lake at 0351Z (08/05). They were airborne at 0413Z (08/05) and began the climb to cloud top. They reported very frequent lightning and good growth. HS3 began seeding storm #1 with BIP flares at 0419Z (08/05) as they continued to climb, with EJ flares beginning at 0421Z (08/05). They continued seeding, finding very good targets as the storm moved through Sylvan Lake and Red Deer. They stopped seeding at 0507Z (08/05). At this time, they also descended to shed ice, and began patrol for Red Deer. They climbed to top again for a cell approaching Sylvan Lake, and began top seeding storm #2 with BIPs and EJs at 0526Z (08/05). They stopped seeding at 0547Z (08/05) as the cell weakened, continuing patrol over Red Deer. They RTB at 0600Z (08/05), landing at 0611Z (08/05).