	Max cell top: 14.4km, 66.0 max dBz, 108.0 max VIL Tmax YC = 26.6C and no rain. Tmax QF = 26.7C and no rain. Tmax Radar = 25.9C and no rain.	HS4 was launched to a storm approaching Sylvan Lake. They were airborne at 0441Z (08/05) and climbed to cloud base. They began seeding storm #1 with BIP flares and generators at 0454Z (08/05). They seeded the storm until it passed through Red Deer at 0513Z (08/05), and then began patrol for Sylvan Lake. They began seeding storm #2 near Sylvan with acetone generators at 0526Z (08/05). They continued to seed as the storm approached Red Deer and weakened. At 0551Z (08/05) they stopped seeding and RTB, landing at 0558Z (08/05). Flight Summary HS3: 0408Z (08/05)-0623Z (08/05); 196 EJ, 13 BIP; #1 Sylvan Lake through Red Deer, patrol Red Deer, #2 Sylvan Lake, patrol Red Deer. HS4: 0435Z (08/05)-0603Z (08/05); 88 minutes acetone generators, 2 BIP; #1 Red Deer, patrol Sylvan Lake, #2 Sylvan Lake through Red Deer.
August 5, Sunday	Instability persisted today, with very warm temperatures forecast. The ridge was still being flattened by the closed low in the Northwest Territories. A stationary front was positioned in southern AB, near the NE part of the project area. Because of the unstable conditions and clear skies, storms were expected to form along the foothills during the later afternoon and move through the project area. Storms would also form along the stationary front, but would likely remain to the NE. Storms today were expected to be severe, with some supercellular characteristics. There was a chance for elevated thunderstorms as instability persisted overnight. The day began clear, and remained so until the midafternoon when towering cumulus clouds began to develop along the foothills. In the late afternoon, a tall supercell (#1) formed NW of Rocky MH and moved southeastward into the project area tracking through Rocky MH and eventually through Innisfail. Radar data suggested that golf ball sized hail may have fallen 35km NW of Rocky MH. One other strong cell grew within the anvil of the large storm and tracked eastward into Red Deer. Max cell top: 15.1km, 69.0 max dBz, 169.8 max VIL Tmax YC = 28.1C and no rain. Tmax QF = 28.2C and no rain. Tmax Radar = 27.1C and no rain.	HS4 was launched at 2158Z to a large storm NW of Rocky MH. The flight became airborne at 2210Z and patrolled the Rocky MH area for a short time before landing at the Rocky MH airport at 2229Z. HS4 was then launched at 2243Z to the same large storm (#1) that was now beginning to enter into the far northwestern part of the project area. The aircraft became airborne at 2252Z and started seeding storm #1 at 2300Z. The crew was able to find the best inflow along the southern edge of the thunderstorm. The flight continued to seed the storm until it was past Rocky MH. Then at 2358Z, they stopped seeding and RTB. The aircraft landed in YQF at 0013Z (08/06). HS3 was launched at 0038Z (08/06) to the Sylvan area. The flight became airborne at 0100Z (08/06). The crew then started seeding storm #1, W of Penhold, at 0108Z (08/06). Then at 0123Z (08/06) HS3 observed that there was lots of liquid water inside of a localized area with vigorous growth. The flight continued seeding the supercell as it moved over Innisfail. They stopped seeding at 0148Z (08/06), descended for ice, and then RTB at 0155Z (08/06). The aircraft landed in YQF at 0202Z (08/06). HS4 was launched again at 0057Z (08/06) to the same storm (#1) which was now NW of Innisfail. The flight became airborne at 0102Z (08/06). HS4 started seeding storm #1 at

		0110Z (08/06). The crew reported more consistent inflow starting at 0117Z (08/06) and continued to seed the weakening supercell as it moved southeastward over Innisfail. Then at 0148Z (08/06) the crew stopped seeding and RTB to YQF. The flight landed at 0204Z (08/06). Flight Summary HS4: 2204Z-2232Z; no seeding; patrol Rocky MH; takeoff YQF, land Rocky MH. HS4: 2249Z (08/05)-0016Z (08/06); 13 BIP, 116 minutes acetone generators; #1 Rocky MH; takeoff Rocky MH, land YQF. HS3: 0050Z (08/06)-0210Z (08/06); 6 BIP, 105 EJ; #1 Innisfail. HS4: 0057Z (08/06)-0208Z (08/06); 9 BIP, 76 minutes acetone generators; #1 Innisfail.
August 6, Monday	Upper level jet energy stayed far to the north over the Northwest Territories. The mid-levels saw weak ridging during the afternoon hours before an elongated shortwave trough began to push into the area from the SW overnight. 850mb theta-e ridging was centered over AB during the nighttime hours. At the surface, a stationary front was in place just to the NE of the project area. The main trigger for thunderstorm initiation was surface heating along the foothills. Area soundings indicated that the atmosphere was very unstable with weak to moderate speed and directional shear. The morning and early afternoon saw mostly clear skies. In the late afternoon, tall convective cells started forming over the foothills. These cells mainly stayed west of the western project area border. During the evening, storms formed in the northern buffer and moved southward through the project area. Radar data suggested that a very small area may have seen golf ball sized hail west of Sylvan. Max cell top: 13.6km, 68.0 max dBz, 102.2 max VIL Tmax YC = 30.2C and no rain. Tmax QF = 28.4C and 9.2mm of rain. Tmax Radar = 28.6C and 4.2mm of rain.	HS3 was launched to convection west of Rocky MH at 0009Z (08/07). The flight was airborne at 0022Z (08/07). HS3 then started top seeding storm #1 near Rocky MH at 0044Z (08/07). At 0050Z (08/07), the crew stopped seeding and RTB to the Rocky MH airport (YRM). The aircraft landed at 0109Z (08/07). HS3 flew a reposition flight from the Rocky MH airport (YRM) to YQF. The aircraft was airborne at 0234Z (08/07) and then landed at 0252Z (08/07). HS3 was launched for a line of embedded storms in the N buffer at 0342Z (08/07). They were airborne at 0402Z (08/07) and climbed to cloud base. They began seeding storm #2 at 0409Z (08/07) as they approached cloud base. They found high bases with some underlying scud. At 0413Z (08/07), they ascended to cloud top but continued to seed during the climb. They descended to melt ice at 0435Z (08/07), resuming seeding along the eastern side of the storm at 0445Z (08/07). They repositioned further W to seed storm #3 at 0500Z (08/07) as storm #2 moved past any target cities. HS3 continued seeding along a boundary pushing to the SE. They stopped seeding at 0604Z (08/07) and began patrol for Calgary, anticipating development along the boundary. As it became clear the boundary was not producing any threatening storms, HS3 RTB at 0726Z (08/07), landing at 0749Z (08/07). Flight Summary HS3: 0016Z (08/07)-0114Z (08/07); 8 EJ, 1 BIP; #1 Rocky MH; takeoff YQF, land Rocky MH. HS3: 0228Z (08/07)-0258Z (08/07); no

		seeding; Reposition flight; takeoff Rocky MH, land YQF. HS3: 0356Z (08/07)-0756Z (08/07); 222 EJ, 10 BIP; #2 Sylvan Lake, #3 Sylvan Lake through Olds, patrol Calgary.
August 7, Tuesday	An upper level jet streak was expected to start pushing into southern AB during the evening and overnight hours. At the mid-levels, a ridge was over AB. A shortwave trough slowly crept northeastward across the project area during the daytime hours. Moderately strong vorticity advection occurred along the trough axis. A warm front was also over southern AB but was not expected to be a trigger for thunderstorms inside the project area. The 18Z and 00Z area soundings indicated that strong pulse and multicellular storms were possible. The morning hours saw scattered convective rain showers. In the afternoon, several storms formed along the foothills west of Calgary. The strongest storm (#2) of the day formed directly over western Calgary and tracked eastward through the entire metropolitan area. Radar data suggested that golf ball sized hail was possible in southern and eastern Calgary. Pea sized hail was reported in downtown Calgary at 2109Z. 3cm sized hail was also reported in Calgary. A few other thunderstorms formed over northern Calgary, Chestermere, and near Strathmore. Additionally, weaker thunderstorms developed west of Cochrane and west of the Olds-Didsbury area. These storms tracked eastward for a short time before dissipating. Max cell top: 13.6km, 67.5 max dBz, 138.6 max VIL Tmax YC = 26.8C and a trace of rain. Tmax QF = 24.5C and 4.2mm rain. Tmax Radar = 22.8C and a trace of rain.	HS1 was launched to a tall storm west of Calgary at 1939Z. Once the aircraft became airborne at 1956Z, they were redirected to a much stronger storm NW of Turner Valley. HS1 started seeding this storm (#1) at 2014Z. They were then redirected to new growth over western Calgary at 2035Z, and HS1 started seeding this storm (#2) at 2048Z. The crew continued to seed the thunderstorm until it was east of Calgary, and the aircraft was out of flares. The flight stopped seeding and RTB at 2217Z. HS1 landed in YBW at 2231Z. HS2 was launched at 2059Z to a rapidly developing cell directly over western Calgary. The flight was airborne at 2116Z, and the crew started seeding storm #2 over Calgary at 2123Z. HS2 continued to base seed the storm until it was east of Calgary. The aircraft then started seeding another storm (#3) that was tracking towards Strathmore at 2220Z. Next, they started seeding a new cell (storm #5) over northeastern Calgary at 2300Z. HS2 then stopped seeding (2304Z) and RTB. The aircraft landed in YBW at 2320Z. HS3 was launched to two strong thunderstorms over Calgary at 2133Z. The flight became airborne at 2157Z. They then started seeding storm #3 west of Strathmore at 2222Z. Next, the aircraft expedited to another thunderstorm (#4) just to the east of northern Calgary and started seeding at 2242Z. The crew then found explosive growth over northern Calgary, so they began seeding this new cell (#5) at 2248Z. They then stopped seeding (2308Z) and patrolled west of Calgary before starting to seed a weaker cell (#6), just to the W of Cochrane, starting at 2357Z. The aircraft then stopped seeding at 0000Z (08/08) but continued patrolling the same area. They then repositioned to another storm west of Olds and started seeding storm #7 at 0129Z (08/08). The flight stopped seeding and RTB at 0159Z (08/08). The aircraft landed in YQF at 0209Z (08/08). HS2 was launched at 0115Z (08/08) to a storm W of the Olds-Didsbury area. The plane became airborne at 0130Z (08/08). They started seeding storm (#7) at 0152Z (08/08) and continued seeding as the cell inched its way closer to Olds. Then at 0202Z (08/08) the crew was finding only minimal inflow, so they

		stopped seeding and RTB to YBW. The plane landed at 0222Z (08/08). Flight Summary HS1: 1948Z-2233Z; 285 EJ, 22 BIP; #1 Turner Valley, #2 Calgary. HS2: 2108Z-2324Z; 15 BIP, 202 minutes acetone generators; #2 Calgary, #3 Strathmore, #5 Calgary. HS3: 2152Z (08/07)-0216Z (08/08); 140 EJ, 5 BIP; #3 Strathmore, #4 Strathmore, #5 Calgary, patrol W of Calgary, #6 Cochrane, #7 Olds. HS2: 0122Z (08/08)-0228Z (08/08); 20 minutes acetone generators; #7 Olds.
August 8, Wednesday	Conditions today had aligned for a classic severe weather forecast. A jet streak was nosing into S Alberta as the ridge axis moved to the E. Substantial convective inhibition was in place during the morning, with some virga and overcast skies. The cap was expected to erode during the afternoon giving way to a very unstable sounding with good directional and speed shear. Directional shear was best during the early afternoon, but supercell characteristics were expected in any storms that formed. Storms were expected to form along the foothills during the afternoon, triggered by surface heating and upslope flow. The main focus for initiation was during the early evening, when the left exit of the jet streak would produce a lee trough, and the cap would be weakest. Atmosphere was stable by the early morning, with no substantial triggers after the trough had passed. A line of precipitation moved northward through the entire project area during the morning and early afternoon, causing a few thunderstorms in the northern half of the project area. Showers and storms formed over the foothills during the evening, with some severe storms moving through the project area, mainly in the northern half. A few showers occurred overnight with clearing by morning. Grape sized hail was reported east of Penhold and south of Red Deer. A radar tour was held at Olds-Didsbury Radar with 13 people in attendance. Max cell top: 14.4km, 68.5 max dBz, 177.2 max VIL Tmax YC = 28.5C and no rain. Tmax QF = 28.1C and 2.0mm rain. Tmax Radar = 27.4C and no rain.	HS3 performed a PR flight for the radar tour. They were airborne from YQF at 1724Z and landed in Olds-Didsbury at 1740Z. HS4 was launched at 1941Z to a line of quick moving cells extending southwest of Red Deer. They were airborne at 2000Z and climbed to cloud base as they positioned to patrol the SW end of the line. As the storm began to organize and strengthen, they began seeding storm #1 with generators at 2026Z. When the storm was no longer a threat to Red Deer, they RTB at 2051Z. HS4 landed at 2059Z. HS3 was launched to a threatening cell SW of Red Deer at 2020Z. They were airborne at 2034Z and climbed to cloud top. They began seeding storm #1 with BIP flares upon arrival at 2045Z. When the storm was no longer a threat to Red Deer, they stopped seeding and RTB YQF at 2052Z. HS3 landed at 2103Z. HS2 was launched at 2306Z to patrol development along the foothills W of Calgary. They were airborne at 2321Z and climbed to cloud base. They found no developed clouds, and no workable bases or threats of any kind, and began patrol for Calgary. As it became clear all storms would remain to the north, HS3 RTB at 0031Z (08/09), landing at 0040Z (08/09). HS4 was launched to threatening development W of Sundre at 2313Z. They were airborne at 2334Z and climbed to cloud base. A splitting supercell was observed W of Sundre both by pilots and Radar, and HS4 was directed to the right moving cell. They began seeding storm #2 with acetone generators and BIP flares upon arrival at 2356Z. Inflow was very good, and the storm attained a green tint as it intensified and began to hail in the foothills. They seeded the

		storm as it moved past Sundre, then moved S to storm #3. As the cell weakened, they stopped seeding and began patrol at 0053Z (08/09). They resumed seeding storm #2 at 0116Z (08/09) as cells intensified and moved closer to target cities. They once again found very good inflow and seeded with generators and BIP flares as it moved through Red Deer, stopping seeding and RTB Olds-Didsbury at 0208Z (08/09). They landed at 0233Z (08/09). HS3 was launched to storm #2 at 0111Z (08/09) as it approached Red Deer. They were airborne at 0131Z (08/09) and climbed to cloud top. They began seeding storm #2 with BIP flares at 0137Z (08/09) as they continued to climb, beginning EJ flares at 0139Z (08/09). They continued to seed as the storm intensified and passed through Red Deer, stopping seeding and beginning patrol at 0207Z (08/09). They RTB at 0214Z (08/09) when no further threats remained, landing at 0225Z (08/09). HS2 was launched for a threatening cell W of Cochrane at 0228Z (08/09). They were airborne at 0243Z (08/09) and climbed to cloud base. After navigating across a gust front, they started seeding storm #4 with acetone generators and BIP flares at 0245Z (08/09). Although the storm was tall, the structure was disorganized and excessively sheared, and HS2 had trouble finding inflow. As the storm moved past protected cities, HS2 RTB, turning burners off at 0331Z (08/09). They landed at 0342Z (08/09). HS1 was launched to storm #4 at 0244Z (08/09). They were airborne at 0307Z (08/09) after waiting for a gust front to clear the airport. They climbed to cloud top, and were then allowed by ATC to navigate to the cell. They reported a lack of feeders on the cell and glaciation. They began seeding storm #4 with EJ flares at 0332Z (08/09). They continued seeding as the storm moved through all protected cities, stopping seeding and RTB at 0401Z (08/09). They landed at 0420Z (08/09). HS3 was launched to a cell near Sundre at 0300Z (08/09). They were airborne at 0316Z (08/09) and climbed to cloud top. Approaching the cell, they observed a rain free base without noticeable growth, and began patrol. The cell eventually sheared completely apart. At 0329Z (08/09), HS3 RTB, landing at 0345Z (08/09). HS4 performed a reposition flight. They were airborne from Olds-Didsbury at 0313Z (08/09)

		and landed at YQF at 0327Z (08/09). Flight Summary HS3: 1717Z-1744Z; no seeding; PR flight; takeoff YQF, land Olds-Didsbury. HS4: 1952Z-2104Z; 50 minutes acetone generators; patrol Sundre; #1 Red Deer. HS3: 2028Z-2110Z; 1 EJ, 2 BIP; #1 Red Deer; takeoff Olds-Didsbury, land YQF. HS2: 2311Z (08/08)-0043Z (08/09); no seeding; patrol Calgary. HS4: 2325Z (08/08)-0235Z (08/09); 16 BIP, 197 minutes acetone generators; #2 Sundre, #3 Olds, #2 Red Deer; takeoff YQF, land Olds-Didsbury HS3: 0125Z (08/09)-0230Z (08/09); 94 EJ, 2 BIP; #2 Red Deer. Patrol Rocky MH. HS2: 0234Z (08/09)-0345Z (08/09); 2 BIP, 92 minutes acetone generators; #4 Cochrane, HS1: 0256Z (08/09)-0424Z (08/09); 47 EJ; #4 Acme/Linden, HS3: 0311Z (08/09)-0351Z (08/09); no seeding; patrol Sundre HS4: 0308Z (08/09)-0330Z (08/09); no seeding; reposition flight; takeoff Olds-Didsbury, land YQF.
August 9, Thursday	A slight ridge had developed over the project area with cooler, drier air in place. A weak lee trough was expected to develop late in the day causing possible initiation of thunderstorms near the foothills. Instability was modest with very dry air in the mid-levels, but shear was very good. Thunderstorms moving into the project area from the foothills were a possibility, but due to the dry mid-levels, storms were expected to dissipate as they moved eastward. A few showers or weak thunderstorms were possible overnight as the ascent region of a jet streak influenced the area. Skies were clear during the day with pressure dropping and winds shifting to the E during the late afternoon as the lee trough developed. A few showers and weak thunderstorms developed during the evening in the northern buffer zone, slowly moving to the east throughout the night. Max cell top: 9.1km, 53.0 max dBz, 17.6 max VIL Tmax YC = 27.4C and no rain. Tmax QF = 24.5C and no rain. Tmax Radar = 24.5C and no rain.	No aircraft operations.
August 10, Friday	Jet energy was mainly north and south of the area. A weak to moderate midlevel shortwave trough slid eastward across the area during the late evening and overnight. This was the main trigger for thunderstorm development. The low	HS1 was launched at 2300Z for new convective activity NW of Cochrane. They were airborne at 2315Z and briefly patrolled the Cochrane area before RTB to YBW at 2320Z. The aircraft landed at 2325Z.

	levels of the atmosphere were expected to cool and dry during the late overnight hours as the theta-e ridge shifted eastward into Saskatchewan. A surface low was in place over eastern Montana with an inverted trough extending to the northwest into southeastern AB. The surface trough was not expected to be a factor for thunderstorm development. Towering cumulus clouds were first observed along the foothills during the midafternoon. A small cluster of cells then developed into a storm in the late afternoon. This storm moved a short distance into the project area before dissipating northwest of Cochrane. The second storm of the day formed over the foothills SW of Calgary in the early evening. This storm also moved a short distance into the protected area before falling apart. At around midnight, a shortwave midlevel trough pushed into the northern buffer zone resulting in strong convection. These convective cells gradually moved toward the Drumheller area during the overnight hours. Radar data suggested that golf ball sized hail was possible NW of Rocky MH and NW of Lacombe. Max cell top: 12.1km, 68.5 max dBz, 122.3 max VIL Tmax YC = 24.4C and no rain. Tmax QF = 25.1C and no rain. Tmax Radar = 22.5C and no rain.	HS1 was launched for a second time at 0107Z (08/11) to a storm SW of Calgary. The flight became airborne at 0117Z (08/11), and they were directed to fly to southern side of the southern cell. HS1 then patrolled SW of Calgary before RTB at 0153Z (08/11). They landed in YBW at 0200Z (08/11). HS3 was launched to a right turning cell NW of Lacombe at 0704Z (08/11). They were airborne at 0721Z (08/11) and climbed to cloud top. They began seeding storm #1 at 0735Z (08/11) upon arrival at the cell. They found good liquid water and continued seeding until 0753Z (08/11) as the cell track changed and became no factor for Lacombe. They temporarily descended to melt ice and began patrol for Eckville. As all cells dissipated, HS3 RTB at 0823Z (08/11), landing at 0835Z (08/11). <u>Flight Summary</u> HS1: 2307Z-2330Z; no seeding; patrol Cochrane. HS1: 0112Z (08/11)-0203Z (08/11); no seeding; patrol SW of Calgary. HS3: 0714Z (08/11)-0840Z (08/11); 57 EJ, 1 BIP; #1 Lacombe, patrol Eckville.
August 11, Saturday	A midlevel shortwave trough moved through during the morning hours. The rest of the period saw a flat midlevel ridge over the southern half of AB. Another shortwave was expected to push through during the evening. Vorticity advection along the trough axis was weak, so the main trigger for thunderstorms was surface heating along the foothills. The 00Z Calgary thermodynamic sounding indicated that the atmosphere would be moderately unstable. Mostly clear skies were observed through the evening hours. The overnight hours mainly saw convective rain showers, but a few isolated weak thunderstorms formed near the towns of Linden, Three Hills, and Strathmore. Max cell top: 7.6km, 60.5 max dBz, 17.0 max VIL Tmax YC = 21.9C and no rain. Tmax QF = 20.6C and a trace of rain. Tmax Radar = 19.7C and no rain.	No aircraft operations.
August 12, Sunday	Jet energy was not expected to be a factor in thunderstorm development. A moderately	HS3 was launched at 0011Z (08/13) to a supercell W of Sundre. The flight became

	strong shortwave slowly slid W to E across the project area during the late afternoon and evening. Theta-e ridging built back over the southern half of AB during the daytime hours. An organized low level jet was also expected to start forming in the evening, continuing into the morning hours the next day. The thermodynamic soundings for the region showed mixed layer CAPE (convective available potential energy) values near 1100J/kg with moderate speed shear. Directional shear was also present at the low levels of the atmosphere. A large cell formed southwest of Rocky MH during the midafternoon hours and propagated south-southeastward along the foothills before finally pushing into the project area SW of Sundre. As the storm started to move into the project area, it strengthened into a supercell. Then at roughly 0330Z (08/13), the storm started tracking southeastward towards Calgary eventually making its way slowly through most of the metropolitan area from NW to SE. Radar data suggested that golf ball sized hail was possible along much of the storm's (#1) path, especially NE of Cochrane. Radar VIL data showed a pixel of 131.3kg/m^2 over central Calgary at 0440Z (08/13) which is associated with up to golf ball sized hail. Furthermore, storm tops were up to 13.6km (44,000ft) as the cell moved over southeastern Calgary at 0500Z (08/13). VIL numbers over northwestern Calgary were generally less than 70 kg/m^2 indicating that the northwestern part of the metro received less damage than the central and southeastern parts. Golf ball sized hail was reported NW of Cochrane and in downtown Calgary. Larger than toonie sized hail with lots of wind reported in northeastern Calgary. The Weather Network website showed a picture of greater than golf ball sized hail in the Hawkwood neighborhood in northwestern Calgary. Hail damage reports seemed to indicate that the hardest hit areas in Calgary were in isolated pockets rather than a continuous swath of devastation. Max cell top: 13.6km, 67.5 max dBz, 169.0 max VIL Tmax YC = 23.9C and 8.0mm of rain. Tmax QF = 22.8C and 10.6mm of rain. Tmax Radar = 21.8C and a trace of rain.	airborne at 0027Z (08/13). Then at 0043Z (08/13), HS3 started briefly top seeding storm (#1) NW of Cremona. The crew stopped seeding and started patrolling at 0048Z (08/13). HS3 then started seeding the same storm again at 0231Z (08/13). The crew then stopped seeding and descended to shed ice at 0302Z (08/13). HS3 then started seeding again at 0309Z (08/13) and continued seeding the storm until they were out of flares. They then stopped seeding at 0424Z (08/13) and RTB. HS3 landed in YQF at 0448Z (08/13). HS2 was launched at 0232Z (08/13) to the same storm (#1) that HS1 was seeding. The aircraft became airborne at 0251Z (08/13). Upon reaching the storm (#1), the pilots quickly found inflow and started base seeding at 0258Z (08/13). They continued to seed the storm until it was past the Calgary area. At 0512Z (08/13), HS2 stopped seeding and RTB. The aircraft landed in YBW at 0531Z (08/13). HS4 was launched at 0310Z (08/13) to the strong cell NW of Calgary. The flight was airborne at 0329Z (08/13) and expedited to north of Calgary via the western edge of the storm. HS4 started base seeding storm #1 at 0353Z (08/13) as soon as they found viable inflow. The flight continued seeding as the storm moved through the city of Calgary. Then at 0520Z (08/13), HS4 stopped seeding and RTB to YQF. They then landed at 0555Z (08/13). HS1 was launched at 0319Z (08/13) to the same storm (#1) that the other aircraft were working. They were airborne at 0335Z (08/13) and climbed to cloud top south of Calgary. HS1 then moved in to take over for HS3 at top and started top seeding storm #1 at 0358Z (08/13). They continued to seed the cell as it moved southeastward across Calgary. At 0544Z (08/13), the aircraft was out of flares and the cell was exiting the city, so they stopped seeding and RTB. They landed in YBW at 0557Z (08/13). <u>Flight Summary</u> HS3: 0021Z (08/13)-0455Z (08/13); 288 EJ, 23 BIP; #1 Cremona to Calgary. HS2: 0241Z (08/13)-0535Z (08/13); 27 BIP, 268 minutes acetone generators; #1 Cochrane and Calgary. HS4: 0319Z (08/13)-0600Z (08/13); 18 BIP, 178 minutes acetone generators; #1 Calgary. HS1: 0326Z (08/13)-0603Z (08/13); 296 EJ, 22 BIP; #1 Calgary.

August 13, Monday	The upper level jet was nosing into northern AB today as a large scale trough began affecting the area. A surface trough was expected to develop during the afternoon, possibly causing a few showers east of the project area. The best chance for convective initiation was during the evening when a weak shortwave moved through the area. Shear was very strong, but instability was modest. Rain and increasing cloud was expected overnight, with the possibility of a few weak thunderstorms. No severe weather was expected. Skies were cloudy all day. A few weak thunderstorms formed over the project area during the afternoon with no other significant precipitation during the day. Virga and some light rain occurred overnight. Max cell top: 9.1km, 62.0 max dBz, 36.2 max VIL Tmax YC = 27.7C and no rain. Tmax QF = 26.2C and no rain. Tmax Radar = 25.9C and no rain.	No aircraft operations.
August 14, Tuesday	A strong cold front and collocated midlevel trough were expected to move through the project area during the afternoon creating very strong lift. The jet was located over the area giving the sounding a very good shear profile. However, instability was weak and not expected to improve during the day. Showers and a few isolated storms were expected along the cold front, but the severe storm potential was low. Overnight, showers were expected to linger, and substantial cooling was expected to occur. Clearing was expected to begin by morning. The powerful front started to push into the project area during the early afternoon hours. A well-defined line of thunderstorms formed and pushed southward. Out ahead of this line, one individual cell developed W of Sundre and tracked southeastwards. This storm (#2) had supercellular characteristics NW of Airdrie and W of Strathmore. This cell produced quarter sized hail near Airdrie. Calgary received lots of wind damage from storm #3 as it moved towards the southeast through the city. The strongest storm (#4) of the day formed over the foothills W of Calgary and tracked southeastwards through Turner Valley and Black Diamond. This storm also had supercellular characteristics. Golf ball sized hail fell in Turner Valley. Road signs were torn down by the high winds in Calgary, and a window washing crew was forced to break out a window on a high rise building to escape the wind.	HS3 was launched at 1850Z to a moderately strong cell W of Sundre. The aircraft became airborne at 1905Z and was redirected to a line of convection NW of Sundre. HS3 started seeding storm #1 at 1920Z for a short time before expediting to the southern end of a stronger cell NW of Cremona. Upon reaching storm #2, they started top seeding at 1933Z and continued to seed as the storm tracked southeastward through Airdrie, northern Calgary, and Strathmore. The aircraft then repositioned to the storm (#4) northwest of High River and started seeding at 2131Z. The flight then stopped seeding at 2133Z and RTB. They landed in YBW at 2146Z. HS2 was launched at 1939Z to a multicellular line of thunderstorms to the NW of Calgary. Once the flight became airborne at 1956Z, they were directed to the southern and southwestern edge of the line of convection and started base seeding storm #2 at 2008Z. The flight continued to seed the storm as it moved southeastward through Airdrie, northern Calgary, and Strathmore. The aircraft then moved over to the same cell (storm #4) that HS1 was working and started seeding at 2129Z. They continued seeding as the cell moved over High River. Then at 2145Z the crew stopped seeding and RTB. The aircraft landed in YBW at 2223Z. HS1 was launched at 2002Z to the same storm (#2) that HS3 and HS2 were working.

	Max cell top: 12.9km, 69.0 max dBz, 176.0 max VIL Tmax YC = 23.1C and 4.0mm of rain. Tmax QF = 19.0C and 17.8mm of rain. Tmax Radar = 18.5C and 4.5mm of rain.	The aircraft became airborne at 2029Z and was directed to new cellular growth NW of Cochrane. The flight then started base seeding storm #3 near Cochrane at 2034Z. HS1 then expedited to convection SW of Calgary and started top seeding storm #4 for Turner Valley and Black Diamond at 2101Z. The crew reported that the cell had supercell characteristics at 2110Z. They continued seeding the storm as it passed over High River. Then at 2146Z the crew stopped seeding and RTB to YBW. The aircraft landed at 2210Z. HS3 flew a reposition flight from YBW to YQF. The aircraft was airborne at 2218Z and landed at 2245Z. <u>Flight Summary</u> HS3: 1859Z-2149Z; 215 EJ, 20 BIP; #1 Sundre, #2 Cremona to Strathmore, #4 High River; takeoff YQF, land YBW. HS2: 1947Z-2227Z; 14 BIP, 196 minutes acetone generators; #2 Calgary to Strathmore, #4 High River. HS1: 2020Z-2214Z; 222 EJ, 23 BIP; #3 Cochrane, #4 Turner Valley and Black Diamond. HS3: 2211Z-2251Z; no seeding; Reposition flight; takeoff YBW, land YQF.
August 15, Wednesday	An upper level jet streak was along the British Columbia/Alberta border but was not expected to have much of an influence over the project area. At the mid-levels, a large dominant ridge built over the region which capped the atmosphere and inhibited deep convection. Regional soundings showed only a slight amount of atmospheric instability. Furthermore, the soundings showed that the atmosphere was very dry above 10,000ft. The area saw scattered areas of virga during the morning. The rest of the period saw mostly clear skies. Max dBz 34.5 Tmax YC = 17.4C and no rain. Tmax QF = 17.2C and no rain. Tmax Radar = 16.5C and no rain.	No aircraft operations.
August 16, Thursday	A large scale mid and upper level ridge continued to build over AB and BC. 500mb temperatures also warmed by over 1C throughout the forecast period which made the atmosphere capped at the mid-levels. Area soundings showed a dry, stable, and warm thermodynamic profile.	HS4 performed a PR flight for the radar tour. They were airborne from YQF at 1726Z and landed at Olds-Didsbury at 1748Z. HS4 performed a PR flight after the radar tour was completed. They were airborne from Olds-Didsbury at 2207Z and landed at YQF at 2222Z.

	The region saw wispy cirrus clouds during the daytime hours. Other than this, mostly clear skies were observed. A radar tour took place with 15 people in attendance No TITAN cells. Tmax YC = 23.8C and no rain. Tmax QF = 23.3C and no rain. Tmax Radar = 22.9C and no rain.	Flight Summary HS4: 1716Z-1751Z; no seeding; PR flight; takeoff YQF, land Olds-Didsbury. HS4: 2203Z-2228Z; no seeding; PR flight; takeoff Olds-Didsbury, land YQF.
August 17, Friday	The ridge continued to build over the project area, with high pressure as the dominant surface feature. A jet streak was expected to move through the area today, but this was not expected to be a significant feature due to a dry surface and stable atmosphere. High pressure was expected to persist through the forecast period, with no significant weather occurring. The sky was clear all day. No TITAN cells. Tmax YC = 26.1C and no rain. Tmax QF = 25.4C and no rain. Tmax Radar = 24.0C and no rain.	No aircraft operations.
August 18, Saturday	The ridge was still the main feature for the day. It was expected to flatten slightly today, with pressure dropping and a very weak shortwave moving through in the late afternoon. No precipitation was expected, but a few clouds were a possibility. The sky was clear all day. No TITAN cells. Tmax YC = 28.1C and no rain. Tmax QF = 27.4C and no rain. Tmax Radar = 26.8C and no rain.	No aircraft operations.
August 19, Sunday	The ridge was beginning to move to the E of the project area, giving way to a few weak shortwaves during the afternoon. The atmosphere had good instability, but was capped all day, and shear was poor. Storms were expected to form over the foothills, but dissipate as they entered the project area due to inhibition. Showers were expected to persist overnight. Showers and thunderstorms began to form over the foothills during the afternoon. Storms gradually became stronger, but stayed out of the project area until the early evening when a weak thunderstorm entered the southern buffer zone.	No aircraft operations.

	It was not a threat to any target cities. A few showers occurred in the project area throughout the rest of the forecast period. Max cell top: 11.4km, 56.0 max dBz, 22.3 max VIL Tmax YC = 28.1C and a trace of rain. Tmax QF = 27.2C and no rain. Tmax Radar = 25.0C and no rain.	
August 20, Monday	The midlevel ridge remained over AB which kept the atmosphere slightly capped. Several very weak lobes of vorticity were expected to pass over the region during the afternoon, evening, and overnight hours. Nevertheless, the most significant trigger for thunderstorms was just surface heating along the foothills. The atmosphere was moderately unstable with weak to moderate speed shear. Thunderstorms formed along the southern foothills in the early afternoon. These storms dissipated as they tried to move eastward off the foothills. In the late afternoon, thunderstorms were able to start moving into the project area. One storm, southwest of Cremona, became severe for a short time before diminishing. Radar data suggested that golf ball sized hail may have fallen within a very small area southwest of Cremona. Then in the evening, a longer lived storm tracked eastward through the town of Crossfield before dissipating. No significant weather was observed overnight. Max cell top: 12.1km, 65.0 max dBz, 103.7 max VIL Tmax YC = 29.4C and no rain. Tmax QF = 29.2C and no rain. Tmax Radar = 28.1C and no rain.	HS2 was launched to a threatening cell W of Crossfield. They were airborne at 0206Z (08/21) and climbed to cloud base. They were unable to find any inflow on the storm, and at 0218Z (08/21) began patrol for Crossfield. As the storm started to dissipate, HS2 RTB at 0228Z (08/21). They landed at 0246Z (08/21). <u>Flight Summary</u> HS2: 0157Z (08/21)-0251Z (08/21); no seeding; patrol Crossfield.
August 21, Tuesday	An upper level jet streak began to nose its way into southern AB during the late afternoon hours. Two midlevel shortwave troughs passed over the area during the period. The first trough was expected to push into the region in the late afternoon and early evening. The next shortwave moved over the region overnight. At the surface, a low was in place along the border of southern AB and SK. Thermodynamic soundings for the area were fairly unstable with moderate speed shear. The thunderstorms first started to develop along the foothills SW of Cochrane and W of Rock MH. These storms initially moved northward and did not try to move into the project area. In the late evening, several cells formed north of Rocky MH. This convection eventually became	HS1 flew a PR flight from Springbank to Olds-Didsbury airport. They became airborne at 1713Z and landed at 1735Z. After the radar tour concluded, HS1 returned to Springbank. The aircraft became airborne at 2242Z and landed back in Springbank at 2259Z. HS3 was launched at 0610Z (08/22) to a quickly growing cell southeast of Sundre. The flight became airborne at 0632Z (08/22), and after the initial climb to top, they started patrolling the Sylvan area. They also patrolled the Red Deer area. Nothing seedable was observed. They then stopped patrolling and RTB at 0818Z (08/22). The aircraft landed in YQF at 0830Z (08/22). <u>Flight Summary</u>

	stronger, and several cells came together to form a line of thunderstorms extending from Rocky MH to Sundre. Radar data suggested that golf ball sized hail may have fallen to the north and south of Rocky MH. This line moved eastward through the entire northern half of the project area. Max cell top: 12.1km, 67.0 max dBz, 102.3 max VIL A radar tour occurred in the afternoon with 15 people in attendance from insurance companies. There were also 6 additional people attending from Mountain View County. Tmax YC = 26.1C and no rain. Tmax QF = 27.3C and no rain. Tmax Radar = 26.1C and no rain.	HS1: 1707Z-1738Z; no seeding; PR flight; takeoff YBW, land EA3. HS1: 2235Z-2301Z; no seeding; PR flight; takeoff EA3, land YBW. HS3: 0626Z (08/22)-0837Z (08/22); no seeding; patrol Sylvan, patrol Red Deer.
August 22, Wednesday	A weak ridge was expected to build over the project area today with no other significant synoptic features. Temperatures were expected to exceed convective temperature in the later afternoon with storms forming over the foothills and moving into the project area. Clearing was expected overnight. During the afternoon, a few weak thunderstorms formed over the foothills and moved into the project area. The strongest cell formed S of Rocky MH. Skies cleared overnight. Max cell top: 10.6km, 64.5 max dBz, 47.0 max VIL Tmax YC = 25.1C and no rain. Tmax QF = 23.6C and 7.4mm rain. Tmax Radar = 22.7C and no rain.	HS2 performed a recurrency flight. HS2 was airborne at 1556Z and landed at 1649Z. <u>Flight Summary</u> HS2: 1542Z-1656Z; no seeding; recurrency flight.
August 23, Thursday	A closed low was beginning to move through Alberta at the beginning of the forecast period which was expected to provide good upper level dynamics. The first impulse, along a cold front, was expected to begin affecting the project area during the afternoon when the atmosphere was most unstable. Severe storms were expected with this first wave, diminishing to embedded weak storms and rain showers during the evening and overnight. The best dynamics would occur around sunrise the next morning, when very strong vorticity advection would occur in association with the UL jet. Because of very poor thermodynamics at this time, strong thunderstorms were unlikely in the morning hours. A few thunderstorms formed during the afternoon as the cold front moved through the northern part of the project area. Rain showers	HS4 was launched at 2022Z for a threatening storm W of Rocky MH. They were airborne at 2041Z and climbed to cloud base. At 2100Z they repositioned to a cell W of Innisfail and began patrol. As the cell weakened, they repositioned to a storm W of Sylvan Lake at 2146Z. The storm moved N of Sylvan Lake, with HS4 reporting bases progressively lowering. They RTB at 2234Z, landing at 2244Z. HS2 was launched at 2045Z to a threatening cell W of Sundre. They were airborne at 2104Z and climbed to cloud base. They approached Sundre at 2115Z and began patrol. The storm gradually weakened, and they ceased patrol and RTB to Olds-Didsbury at 2159Z. They landed at 2218Z. HS3 was launched at 2233Z to a cell SW of

	continued through the evening and overnight period with a few weak thunderstorms also moving through during the late evening. Max cell top: 12.9km, 68.0 max dBz, 120.3 max VIL Tmax YC = 26.1C and no rain. Tmax QF = 23.9C and 3.4mm of rain. Tmax Radar = 23.4C and 15.5mm of rain.	Lacombe. They were airborne at 2256Z and climbed to cloud top. They began seeding storm #1 with BIP and EJ flares at 2259Z. By 2316Z, the storm weakened below threat criteria, so HS3 stopped seeding and RTB. They landed at 2331Z HS2 performed a reposition flight. They were airborne from Olds-Didsbury at 0046Z (08/24) and landed in YBW at 0105Z (08/24) Flight Summary HS4: 2030Z-2248Z; no seeding; patrol Rocky MH, patrol Innisfail. HS2: 2052Z-2219Z; no seeding; patrol Sundre; takeoff YBW, land Olds-Didsbury. HS3: 2250Z-2337Z; 56EJ, 2 BIP; #1 Lacombe. HS2: 0041Z (08/24)-0109Z (08/24); no seeding; reposition flight; takeoff Olds-Didsbury, land YBW.
August 24, Friday	Southern AB saw weak upper level jet energy. A cold core low continued to move eastward, exiting the area. Lobes of vorticity flowed counter-clockwise around the low. A surface low was positioned over central SK. The main trigger for convection was surface heating. The thermodynamic profile indicated that the atmosphere would be only slightly unstable with weak speed shear. Stratiform rain showers fell during the morning hours. The skies then cleared in the afternoon which allowed surface temperatures to warm. Weak convection formed over foothills. One weak thunderstorm moved into the project area SW of Calgary. Ice pellets were reported from this storm, but there were no significant hail threats. The remainder of period saw isolated to scattered convective rain showers. Max cell top: 8.4km, 52.5 max dBz, 9.0 max VIL A radar tour was conducted, and 14 insurance industry employees were in attendance. Tmax YC = 16.4C and 13.2mm of rain. Tmax QF = 17.3C and 7.2mm of rain. Tmax Radar = 16.1C and 3.2mm of rain.	HS2 flew a PR flight from Springbank to Olds-Didsbury airport. They became airborne at 1734Z and landed at 1758Z. After the radar tour was finished, HS2 returned to Springbank. The aircraft became airborne at 2130Z and landed in Springbank at 2149Z. Flight Summary HS2: 1714Z-1800Z; no seeding; PR flight; takeoff YBW, land EA3. HS2: 2121Z-2152Z; no seeding; PR flight; takeoff EA3, land YBW.
August 25, Saturday	Upper level jet energy was located southeast and east of the area. The main feature was a midlevel ridge which built over the region throughout the period. Surface high pressure was also in place over the area. Area soundings showed that the atmosphere would be just slightly unstable. The northern half of the project area saw shallow cumulus clouds during the morning, afternoon,	No aircraft operations.

	and evening. These clouds occasionally produced virga. There were no hail threats or thunderstorms. 36.5 max dBz Tmax YC = 20.1C and no rain. Tmax QF = 19.3C and no rain. Tmax Radar = 18.2C and no rain.	
August 26, Sunday	Upper level jet energy stayed well to the SW of the area. The midlevel ridge continued to build over the area through the early evening hours. This ridge was expected to shift to the east of the area overnight. Additionally, a low level theta-e ridge was in place over the area overnight. The atmosphere was expected to remain mostly stable throughout the period. The region saw cirrus clouds during the morning, afternoon, and evening. Overnight, weak echoes were observed on radar, but no thunderstorms occurred. 28.0 max dBz Tmax YC = 23.8C and no rain. Tmax QF = 23.0C and no rain. Tmax Radar = 23.0C and no rain.	No aircraft operations.
August 27, Monday	The upper level jet was positioned over Washington and Oregon. The ridge over the region was moving off into Saskatchewan. The atmosphere was moderately unstable above 700mb, but there was a very significant low level cap due to dry low levels. A surface trough was progged to move through just north of the project area during the afternoon. Light stratiform rain showers moved through in the morning and early afternoon with a few shallow embedded convective cells. There were no titan cells, no lightning strikes, and no hail threats. 50 max dBz A tour was conducted at the radar and 12 insurance workers were in attendance. Tmax YC = 30C and no rain. Tmax QF = 27C and no rain. Tmax Radar = 27.7C and no rain.	HS2 flew a maintenance flight. The aircraft was airborne out of YBW at 1409Z and landed in YQF at 1438Z. HS3 flew a PR flight from YQF to the Olds-Didsbury airport. The flight became airborne at 1732Z and landed at 1748Z. After the radar tour ended, the aircraft flew back to YQF. The flight was airborne at 2200Z and landed at 2217Z. HS2 then flew another maintenance flight back to YBW. The flight became airborne at 2255Z and landed at 2326Z. <u>Flight Summary</u> HS2: 1357Z-1443Z; no seeding; MX flight; takeoff YBW, land YQF. HS3: 1726Z-1751Z; no seeding; PR flight; takeoff YQF, land EA3. HS3: 2155Z-2221Z; no seeding; PR flight; takeoff EA3, land YQF. HS2: 2244Z-2331Z; no seeding; MX flight; takeoff YQF, land YBW.
August 28, Tuesday	An upper level jet streak was nosing into AB from the southwest. An upper trough was progged to move through overnight along with a cold front. Low levels were dry over the southern project area while the northern project area had some modest moisture and weak	No aircraft operations.

	instability. A few weak showers were expected in the northern project area, but no hail threats. A few weak convective rain showers developed in the late afternoon and early evening. During the late night hours, a line of weak thundershowers moved through the northern project area. There were no hail threats, but there were some lightning strikes in the Rocky Mountain House area. Max cell top: 7.6 km, max dBz 55.5, max VIL 13.8 Tmax YC = 30C and no rain. Tmax QF = 28.6C and no rain. Tmax Radar = 28C and 1.2 mm of rain.	
August 29, Wednesday	Rain showers were moving through during the morning and at forecast time. The upper jet was positioned over southern AB. Vorticity was shifting east of the area giving way to weak shortwave ridging over the project area. Midlevels were warming, and the sounding showed a significant cap at 500mb. A shallow layer of weak CAPE was present below 16kft. Surface dew points were in the low single digits. No significant convection was expected, just widespread shallow cumulus clouds and some tiny single cell rain showers. A handful of weak isolated single cell rain showers were observed during the day, but the project area was mainly dry. Widespread thin cumulus blanketed the area during the day. There were no lightning strikes as all cells were very shallow. The area was dry overnight. Max cell top: 5.4km, 54.0 max dBz, 7.9 max VIL Tmax YC = 21.9C and 0.2mm of rain. Tmax QF = 20.3C and 1.6mm of rain. Tmax Radar = 20.0C and no rain.	No aircraft operations.
August 30, Thursday	An upper level jet streak was expected to start nosing into central AB during the evening hours. A midlevel closed low lingered over southwestern BC. This low pushed a few weak lobes of vorticity into the area. A weak surface low was over the project area. The Red Deer 00Z sounding suggested that the atmosphere would be slightly unstable. Strong convective inhibition existed over the southern half of the project area. Convective rain showers occurred near Rocky MH during the nighttime hours. No lightning strikes or TITAN cells were observed. The rest of the region saw no significant weather. 40.5 max dBz	No aircraft operations.

	Tmax YC = 21.8C and no rain. Tmax QF = 22.0C and no rain. Tmax Radar = 21.6C and no rain.	
August 31, Friday	Two upper level jet streaks were positioned over southern AB. The midlevel closed low was centered over south central AB. This low continued to push lobes of weak vorticity towards central AB. 850mb theta-e ridging was in place over the area during the evening and overnight, so the atmosphere was expected to remain slightly unstable. At the surface, a weak low formed over southern AB. Soundings indicated that the atmosphere would be capped with moderate instability. The region saw isolated convective rain showers during the evening. No lightning strikes were observed within the project area, but a few lightning strikes were recorded just west of Ponoka. Max cell top: 3.9km, 45.5 max dBz, 3.7 max VIL Tmax YC = 21.4C and no rain. Tmax QF = 18.0C and no rain. Tmax Radar = 17.5C and no rain.	No aircraft operations.
September 1, Saturday	An upper level jet streak slid through southern AB during the day. The midlevel low finally pushed into the region in the afternoon. This low moved eastward through central AB. Vorticity advection was expected to be strongest in afternoon. A surface low was in place along the AB/SK border with a cold front sliding southeastward through the project area. Area soundings suggested that weak to moderately strong thunderstorms were possible. Convection started to develop over the mountains in the morning. During the afternoon hours, TITAN cells formed W and SW of Calgary. A few of these cells tracked through the metropolitan area. At 1954Z, pea sized hail was reported in northern Calgary. This storm eventually tracked towards the town of Irricana, and radar data indicated that this storm may have produced grape sized hail northeast of Calgary. The strongest cell of the day formed N of Sundre and tracked eastward towards Innisfail. Weaker convection then occurred in the evening. Max cell top: 18.5km, 16.5 max dBz, 15.0 max VIL Tmax YC = 18.5C and 0.8mm of rain. Tmax QF = 16.5C and 0.2mm of rain. Tmax Radar = 15.0C and 2.5mm of rain.	No aircraft operations.

September 2, Sunday	Upper level jet energy stayed just south of the area throughout the period. A midlevel low continued to track east of the area. A shortwave trough was expected to push southeastward through the area during the evening. The majority of the energy from this disturbance was expected to stay north and south of the region. At the surface, the low was collocated with the midlevel low. Atmospheric instability was minimal with low surface dew points. A few weak radar echoes developed early in the forecast period over the far northeast project area. It was mostly virga and very light stratus rain. There were no TITAN cells and no lightning strikes. max dBz 38.5 Tmax YC = 21.8C and no rain. Tmax QF = 20.6C and no rain. Tmax Radar = 20.5C and no rain.	No aircraft operations.
September 3, Monday	There was no significant upper jet energy over the region. A deep low pressure system was shifting eastward into Saskatchewan, but a lobe of vorticity was expected to rotate around the low affecting the project area. The region had northwesterly flow aloft and high pressure at the surface. The atmosphere was nearly stable due to cool surface temperatures and very dry low levels. Weak rain showers moved through the area overnight. Some of the showers appeared to be convective in nature, but there were no TITAN cells or lightning. max dBz 50, max VIL 2.5 Tmax YC = 22C and no rain. Tmax QF = 17.1C and no rain. Tmax Radar = 17C and no rain.	No aircraft operations.
September 4, Tuesday	The upper jet was well northeast of Alberta. Weak ridging was expected along with high pressure. Cool, dry surface conditions helped create a stable sounding. Weak rain showers were expected, but no lightning or hail. Weak rain showers occurred in the early morning and late night hours. There were no TITAN cells or lightning, but some of the rain showers were convective in nature. A radar tour occurred in the early afternoon. There were 15 people in attendance from insurance companies.	HS4 performed a PR flight from YQF to EA3 for a radar tour. They took off at 1743Z and landed at 1759Z. After the tour, they returned to YQF. They took off from EA3 at 2200Z and landed in YQF at 2210. <u>Flight Summary</u> HS4: 1735Z-1801Z; no seeding; PR flight YQF to EA3. HS4: 2155Z-2214Z; no seeding; PR flight returning from EA3 to YQF.

	max dBz 45 Tmax YC = 19.6C and 0.8mm of rain. Tmax QF = 18.6C and no rain. Tmax Radar = 18C and no rain.	
September 5, Wednesday	Upper level charts showed a northerly jet streak moving into the Rockies and a potent shortwave pushing into the project area from the north. Ahead of the trough, a frontal system was moving through the area. A cold front was pushing southward through the project area at forecast time. Surface temperatures were not expected to rise enough to make the atmosphere unstable. Rain showers and cloud cover were expected throughout the day, and then decreased clouds overnight. Scattered convective rain showers were observed throughout the period. The northern half of the project area saw more precipitation. Weak thunderstorms occurred just to the north and east of the project area. Max cell top: 7.6km, 58.5 max dBz, 18.5 max VIL Tmax YC = 14.0C and a trace of rain. Tmax QF = 15.3C and 4.8mm of rain. Tmax Radar = 14.0C and 1.4mm of rain.	No aircraft operations.
September 6, Thursday	Upper level jet energy was far to the south of the region. Midlevel dynamics were weak over the area, and a ridge built over the region from the northwest. This feature was part of a much broader ridge over western Canada. At the surface, high pressure also built over the southern half of AB. The atmosphere was expected to gradually stabilize during the afternoon hours. The area saw scattered cumulus, altocumulus, and cirrus clouds through the evening hours. Overnight, a wave of thin midlevel clouds moved eastward through the region. No TITAN cells occurred. Tmax YC = 19.4C and a trace of rain. Tmax QF = 20.2C and no rain. Tmax Radar = 19.3C and no rain.	No aircraft operations.
September 7, Friday	Jet energy remained to the north of the area. Mid and upper level charts indicated that a ridge would continue to build over the area throughout the period. A weak cold front pushed southward through the project area during the evening hours, but the atmosphere was completely stable. Clear skies were observed during the daytime.	No aircraft operations.

	The nighttime hours saw scattered mid and high level clouds. No TITAN cells were observed. Tmax YC = 25.4C and no rain. Tmax QF = 24.2C and no rain. Tmax Radar = 23.3C and no rain.	
September 8, Saturday	The upper level jet remained over the Northwest Territories. The midlevel ridge started to shift eastward during the day, and a weak shortwave trough pushed into the area in the evening. Vorticity advection was also expected to be weak. A surface trough developed along the lee of the Rocky Mountains. Area soundings showed that strong convective inhibition existed. Altocumulus and cirrus were seen over the area during the daytime hours. A wave of stratus clouds moved through the southern half of the project area during the overnight hours. Radar data suggested that these clouds produced virga. max dBz 32.0 Tmax YC = 26.9C and no rain. Tmax QF = 26.8C and no rain. Tmax Radar = 26.6C and no rain.	No aircraft operations.
September 9, Sunday	Jet energy at the upper levels was mainly over the far southern portion of AB. At the mid-levels, a moderately strong shortwave trough slid northeastward across the project area during the late afternoon and early evening. This trough was the main trigger for thunderstorm development. A surface low formed in the lee of the Rocky Mountains and moved eastward. The 00Z Red Deer sounding indicated that the atmosphere would be unstable (800J/kg CAPE) with moderate speed shear. Convection was first seen over the foothills in the midafternoon. The convection eventually strengthened into storms which moved through the project area. The strongest storm of the day formed just south of Cochrane and moved through northwestern Calgary. Pea sized hail was reported in Calgary. Radar data suggested that grape sized hail may have fallen near the Springbank airport. Max cell top: 10.6 km, 62.0 max dBz, 39.3 max VIL Tmax YC = 28.2C and 0.2mm of rain. Tmax QF = 27.7C and 2.0mm of rain. Tmax Radar = 27.0C and 0.8mm rain.	No aircraft operations.
September 10, Monday	The upper jet was pushing into southern Alberta. An upper level trough and associated vorticity	HS4 was launched at 1802Z to a cell W of Rocky MH. They were airborne at 1816Z and

	were progged to affect the project area in the early afternoon. A powerful cold front was expected to move into the project area during the early afternoon creating small hail and cold windy conditions. The project area was expected to stabilize by late afternoon after the front moved through. A line of weak hail storms pushed through the area during the early afternoon creating widespread small hail from Airdrie to Red Deer and damaging winds above 50 knots over much of the project area. The area was very cold and dry during the evening and overnight hours. 0.8mm hail was reported at YQF. 1.0cm sized hail was reported in the Gasoline Alley part of Red Deer. Max cell top: 9.9km, 67 max dBz, 93.8 max VIL Tmax YC = 21.5C and no rain. Tmax QF = 17C and 11mm of rain. Tmax Radar = 17C and 9mm of rain.	climbed to cloud base. The crew patrolled the Rocky MH area for a brief time before RTB at 1837Z. The aircraft landed in YQF at 1850Z. HS3 was launched at 1858Z to new cellular development near Cochrane. The flight became airborne at 1915Z and climbed to top. They patrolled the Didsbury area. Then at 1939Z, HS3 was repositioned to near the Cochrane area. The crew then reported explosive growth W of Crossfield and expedited to this thunderstorm. HS3 started seeding this storm (#1) at 2017Z. At 2028Z, the aircraft was directed to stop seeding, because the storm was now east of the QE2 highway. They then patrolled the same area for a short time before RTB to YQF at 2038Z. The flight landed at 2102Z. <u>Flight Summary</u> HS4: 1808Z-1854Z; no seeding; patrol Rocky MH. HS3: 1909Z-2109Z; 37 EJ, 2 BIP; patrol Didsbury, #1 Crossfield.
September 11, Tuesday	A broad upper trough was draped across western Canada. A cold midlevel low over Saskatchewan was gradually moving away from the project area. Low levels were very cold and dry, but the upper levels were also extremely cold which created a slightly unstable atmosphere in the afternoon. Daytime heating was forecast to produce a few shallow thundershowers throughout the afternoon, but no hail was expected. Scattered light convective showers occurred throughout the day and evening. There were no hail threats and no lightning strikes. Max cell top: 5.4km, max dBz 51.5, max VIL 4.1 Tmax YC = 14.8C and no rain. Tmax QF = 15.1C and no rain. Tmax Radar = 13C and no rain.	No aircraft operations.
September 12, Wednesday	The upper jet was over the project area in the morning, shifting east of the region throughout the period. Upper ridging was occurring. The low levels were dry, and the atmosphere was stable. Clear, dry conditions were forecast throughout the period. Skies were clear throughout the period. There was no precipitation. No TITAN cells. A radar tour was conducted and 15 insurance	HS1 flew a PR flight from YBW to EA3 for a radar tour. They were airborne at 1714Z and landed at 1731Z. After the tour, they returned home. They took off from EA3 at 2153Z and landed at 2211Z. <u>Flight Summary</u> HS1: 1702Z-1734Z; no seeding; PR flight from YBW to EA3. HS1: 2150Z-2215Z; no seeding; PR flight from EA3 to YBW.

	people were in attendance. Tmax YC = 18.8C and no rain. Tmax QF = 17.3C and no rain. Tmax Radar = 17.8C and no rain.	
September 13, Thursday	Upper level jet energy was far to the north of the region. The midlevel ridge continued to be dominant over the area throughout much of the period. Surface high pressure was also expected to stay in place over southern AB. Area thermodynamic soundings were completely stable. The area saw mostly clear skies throughout the period. A few cirrus clouds were observed off and on throughout the day. No radar echoes occurred. Tmax YC = 25.0C and no rain. Tmax QF = 23.8C and no rain. Tmax Radar = 24.0C and no rain.	No aircraft operations.
September 14, Friday	An upper level jet streak was over northern AB. At the mid-levels, a shortwave slid eastward across northern AB. Central and southern AB mainly saw zonal (W to E) flow. The main trigger for convection was a cold front which was progged to push southward through the region during the evening. Altocumulus, cirrus, and cirrostratus clouds were observed inside the project area. Very weak echoes were seen on radar during the early afternoon and early evening hours. Tmax YC = 27.7C and no rain. Tmax QF = 25.6C and no rain. Tmax Radar = 26.5C and no rain.	No aircraft operations.
September 15, Saturday	The upper level jet was expected to stay north and east of the area. At the mid-levels, AB mainly saw northwesterly flow with an embedded shortwave trough pushing southeastward through the project area. The majority of the vorticity energy stayed northeast of the protected area. A weak surface low was centered over southeastern BC with an inverted trough extending northward along the Rocky Mountains. Area soundings were mostly stable. Light stratiform showers passed through the area during the day. There were no significant convective cells. Max cell top: max dBz 39.5 Tmax YC = 19.9C and no rain. Tmax QF = 19.6C and a trace of rain. Tmax Radar = 18.5C and no rain.	No aircraft operations.

Appendix C – Aircraft Operations Summary Table

	HS1	HS2	HS3	HS4
JUNE	18:56	10:41	10:35	16:31
JULY	36:50	46:57	32:25	40:01
AUGUST	8:44	12:34	25:12	12:40
SEPEMBER	0:00	0:00	1:47	0:34

	HAILSTOP 1 - Beech King Air			HAILSTOP 2- Cessna 340A				HAILSTOP 3- Beech King Air			HAILSTOP 4 - Cessna 340A					
STORM DAY	Flight Time	EJ Flares	BIP Flares	Flight Time	EJ Flares	BIP Flares	Gen Time	Flight Time	EJ Flares	BIP Flares	Flight Time	EJ Flares	BIP Flares	Gen Time	No. of Storms	Daily Agl (grams)
JUNE																
2-Jun-12	1:02			1:38			72				2:45			160	3	663
5-Jun-12	2:49	68	14												2	3,460
6-Jun-12	2:11	50	6												2	1,900
9-Jun-12	2:48	236	21					3:37	389	8	0:39				6	16,850
13-Jun-12	2:45	97	9	2:24		6	198				2:41			100	6	5,042
14-Jun-12	1:00	24													1	480
17-Jun-12	1:01	72	7	4:48		1	116	3:18	215	11	5:05		34	432	5	15,256
18-Jun-12	0:17							1:12	23		1:50		5	62	2	1,387
24-Jun-12	2:39	34	7					1:09	100	6	1:23			52	3	4,779
25-Jun-12	1:27		6	1:51		3	84								1	1,590
29-Jun-12								1:19	49		2:08		4	182	2	2,100
30-Jun-12	0:57														0	-
JULY																
1-Jul-12	4:47	407	9	7:20		26	614	5:27	433	14	5:37		18	382	8	29,697
3-Jul-12	2:52	232	21	3:41		12	306	1:52	152	4	1:01	3	2	14	5	14,505
5-Jul-12	2:48	302	4	3:42		26	332	3:14	283	4	4:40		21	140	4	21,299
6-Jul-12	3:03	121	7	3:48		6	166				2:39		16	127	2	7,607
8-Jul-12				0:56											0	-
10-Jul-12				0:34											0	-
12-Jul-12	8:13	225	23	6:05			261				1:06				5	8,696
13-Jul-12	0:09														0	-
17-Jul-12								1:43	40	6					1	1,700
18-Jul-12				2:25		10	50	1:15	100	4	1:53		11	89	1	6,147
20-Jul-12	0:51		8					2:35	219	7					2	6,630
21-Jul-12	0:27														0	-
22-Jul-12	0:43														0	-
23-Jul-12	3:26	49	0	5:56		12	382	4:34	298	21	1:46		12	14	9	14,822
25-Jul-12											3:06		4	102	2	892
26-Jul-12				1:41			96				2:36			210	3	875
27-Jul-12	4:03	179	9	3:13		9	232	2:16	19		3:11		12	234	4	9,792
28-Jul-12	1:22	8		2:12		17	214	3:26	199	11	3:38		20	270	5	12,723
30-Jul-12				1:31		11	106	1:38	150	5	3:11		17	182	1	8,773
31-Jul-12	4:06	296	14	3:53		27	306	4:25	376	10	5:37		26	320	6	26,779

	HAILSTOP 1 - Beech King Air			HAILSTOP 2- Cessna 340A				HAILSTOP 3- Beech King Air			HAILSTOP 4 - Cessna 340A					
STORM DAY	Flight Time	EJ Flares	BIP Flares	Flight Time	EJ Flares	BIP Flares	Gen Time	Flight Time	EJ Flares	BIP Flares	Flight Time	EJ Flares	BIP Flares	Gen Time	No. of Storms	Daily AgI (grams)
AUGUST																
4-Aug-12								1:58	196	13	1:17		2	88	2	6,422
5-Aug-12								1:02	105	6	2:42		22	192	1	6,849
6-Aug-12								4:52	230	11					3	6,250
7-Aug-12	2:35	285	22	2:56		15	222	4:12	140	5					7	15,434
8-Aug-12	1:13	47		2:18		2	92	1:52	95	4	4:12		16	247	4	7,109
10-Aug-12	0:53														0	-
11-Aug-12								1:14	57	1					1	1,290
12-Aug-12	2:22	296	22	2:40		27	268	4:21	288	23	2:26		18	178	1	26,455
14-Aug-12	1:41	222	23	2:27		14	196	3:08	215	20					4	17,850
20-Aug-12				0:40											0	-
22-Aug-12								1:58							0	-
23-Aug-12				1:33				0:35	56	2	2:03				1	1,420
SEPTEMBER																
10-Sep-12								1:47	37	2	0:34				1	1,040

*Flight Time = Air time for Patrol, Seed, and Repositioning missions only.

Appendix D – Flight Summary Table

ALBERTA HAIL SUPPRESSION PROJECT 2012 - Mountain Daylight Time / Project Day

MONTHLY FLIGHT TIME	JUNE	JULY	AUG	SEPT	Season Total
HS1	22:26	41:41	10:55	0:57	**75:59**
HS2	14:13	54:41	18:32	0:00	**87:26**
HS3	14:10	37:11	29:40	2:00	**83:01**
HS4	19:42	48:02	15:17	1:31	**84:32**
					330:58

HailStop #1 - N904DK
HailStop #2 - N457DM
HailStop #3 - N522JP
HailStop #4 - N123KK

	TOTAL TIMI	AIR TIME
Seeding hours:	270:06	245:45
Patrol hours:	29:59	24:05

MONTHLY FLARE USAGE		JUNE	JULY	AUG	SEPT	Season Total
HS1	BIP	70	95	67	0	**232**
	EJECT	581	1819	850	0	**3250**
HS2	BIP	10	156	58	0	**224**
	EJECT	0	0	0	0	**0**
	BURNERS	470	3065	778	0	**4313**
HS3	BIP	25	86	85	2	**198**
	EJECT	776	2269	1382	37	**4464**
HS4	BIP	43	159	58	0	**260**
	EJECT	0	3	0	0	**3**
	BURNERS	988	2084	705	0	**3777**

AHSP 2012 - Local Daylight Time

(Storm-day totals ONLY include flight hours for seed and patrol).

SEASON TOTALS	Flights: 197		Engine Time: 330:58				289:26	7717	914	8090		SEASON TOTALS OF PROJECT DAYS** 269:50		8631	9004	16,721	1,571,009	** Only flares spent for seeding.	116		
Date (MDT)	Aircraft I.D.	Engine On (MDT)	Engine Off (MDT)	Engine Time (h:mm)	Take-Off Time (MDT)	Landing Time (MDT)	Total Air Time (h:mm) All Flights	EJ (#) *used in flight tests	BIP (#) *used in flight tests	Burner Minutes *Test burns	Flight Type	Daily Total Air Time (hh:mm) Seeding & Patrol		Ejectable Flare	Burn-In-Place Flare	Burner Time (Min)	Seed Amount (Per Day, Grams)	Season Seed Accumulation (grams)**	# Storms	Captain	Co-Pilot
												PROJECT DAY TOTALS (06:00 AM to 06:00 AM)									
30-May-12	HS1	17:50	18:40	0:50	18:07	18:32	0:25	*1	*2	0	MX							0	0	MF	JN
30-May-12	HS2	0:03	18:54	0:51	18:26	18:50	0:24	*1	*1	OK	MX							0	0	BM	HK
30-May-12	HS4	19:11	20:04	0:53	19:22	20:00	0:38	*1	*1	OK	FERRY							0	0	MF	JN
31-May-12	HS3	13:35	14:25	0:50	13:50	14:17	0:27	0	*1	0	FERRY							0	0	RT	0
31-May-12	HS2	15:07	16:13	1:06	15:26	16:10	0:44	0	0	0	MX							0	0	BM	HK
31-May-12	HS2	17:33	18:14	0:41	17:40	18:12	0:32	0	0	0	MX							0	0	BM	HK
01-Jun-12	HS4	12:34	13:08	0:34	12:51	13:04	0:13	0	0	0	MX							0	0	JF	AW
02-Jun-12	HS4	12:40	13:20	0:40	12:47	13:12	0:25	0	0	0	CUR							0	0	JF	JZ
02-Jun-12	HS1	14:20	15:35	1:15	14:28	15:30	1:02	0	0	0	PATROL	1:02						0	0	MF	JN
02-Jun-12	HS4	15:10	18:12	3:02	15:22	18:07	2:45	0	0	160	SEED	1:40						0	3	AW	JF
02-Jun-12	HS2	17:16	18:59	1:43	17:18	18:56	1:38	0	0	72	SEED	1:38	5:25	0	232	232	35,463	35,463	0	BM	HK
05-Jun-12	HS1	3:30	05:00	1:30	03:40	04:55	1:15	0	3	0	SEED	1:15	1:15	3	3	3	519	35,982	1	MF	JF
05-Jun-12	HS1	21:04	22:55	1:51	21:17	22:51	1:34	68	11	0	SEED	1:34						35,982	1	JF	HK
06-Jun-12	HS1	3:32	04:21	0:49	03:41	04:16	0:35	0	0	0	REPO		1:34	79	11	79	3,456	39,437	0	JF	HK
06-Jun-12	HS1	9:34	11:30	1:56	09:50	11:26	1:36	50	6	0	SEED	1:36	1:36	56	6	56	2,180	41,617	2	BM	JN
09-Jun-12	HS3	14:06	17:19	3:13	14:14	17:12	2:58	296	5	0	SEED	2:58						41,617	3	RT	MM
09-Jun-12	HS4	14:20	15:08	0:48	14:25	15:04	0:39	0	0	0	PATROL	0:39						41,617	0	JF	JZ
09-Jun-12	HS1	15:13	18:13	3:00	15:23	18:11	2:48	236	21	0	SEED	1:46						41,617	2	BM	HK
09-Jun-12	HS3	18:33	19:25	0:52	18:42	19:21	0:39	93	3	0	SEED	0:39	7:04	654	29	654	19,299	60,917	1	RT	MM
13-Jun-12	HS2	12:01	14:36	2:35	12:08	14:32	2:24	0	6	198	SEED	2:24						60,917	3	MF	JN
13-Jun-12	HS1	12:12	15:17	3:05	12:27	15:12	2:45	97	9	0	SEED	1:49						60,917	1	BM	HK
13-Jun-12	HS4	14:05	16:58	2:53	14:12	16:53	2:41	0	0	100	SEED	2:41	7:50	112	313	410	50,362	111,278	2	JF	JZ
14-Jun-12	HS1	17:47	19:02	1:15	17:58	18:58	1:00	24	0	0	SEED	1:00	1:00	24	0	24	549	111,827	1	BM	HK

17-Jun-12	HS4	13:03	15:26	2:23	13:12	15:22	2:10	0	10	150	SEED	2:10						111,827	2	JZ	MM
17-Jun-12	HS1	13:51	15:02	1:11	14:00	15:01	1:01	72	7	0	SEED	1:01						111,827	0	BM	HK
17-Jun-12	HS2	14:04	15:45	1:41	14:12	15:43	1:31	0	0	0	PATROL	1:31						111,827	0	JF	JN
17-Jun-12	HS2	16:17	17:18	1:01	16:23	17:16	0:53	0	0	0	PATROL	0:53						111,827	0	JF	JN
17-Jun-12	HS3	17:34	21:11	3:37	17:48	21:06	3:18	215	11	0	SEED	3:18						111,827	2	MF	RT
17-Jun-12	HS4	17:50	20:51	3:01	17:53	20:48	2:55	0	24	282	SEED	2:55						111,827	0	JZ	MM
17-Jun-12	HS2	19:05	21:42	2:37	19:13	21:37	2:24	0	1	116	SEED	2:24	14:12	340	601	888	99,488	211,315	1	JF	JN
18-Jun-12	HS4	11:18	11:42	0:24	11:23	11:39	0:16	0	0	0	PR							211,315	0	JZ	MM
18-Jun-12	HS3	10:07	11:03	0:56	10:23	11:00	0:37	0	0	0	FERRY							211,315	0	RT	MF
18-Jun-12	HS3	11:37	11:58	0:21	11:45	11:56	0:11	0	0	0	PR							211,315	0	RT	MF
18-Jun-12	HS4	14:04	16:04	2:00	14:10	16:00	1:50	0	5	62	SEED	1:50						211,315	2	JZ	MM
18-Jun-12	HS3	14:17	15:50	1:33	14:33	15:45	1:12	23	0	0	SEED	1:12						211,315	0	RT	MF
18-Jun-12	HS3	16:16	16:57	0:41	16:31	16:52	0:21	0	0	0	FERRY							211,315	0	RT	MF
18-Jun-12	HS1	19:50	20:18	0:28	19:59	20:16	0:17	0	0	0	PATROL	0:17	3:19	28	67	90	10,867	222,182	0	BM	HK
24-Jun-12	HS1	11:36	13:41	2:05	11:45	13:39	1:54	34	7	0	SEED	1:54						222,182	2	BM	MF
24-Jun-12	HS3	12:15	13:40	1:25	12:26	13:35	1:09	100	6	0	SEED	1:09						222,182	1	RT	JN
24-Jun-12	HS4	12:42	13:48	1:06	12:48	13:46	0:58	0	0	52	SEED	0:58						222,182	0	JZ	MM
24-Jun-12	HS4	15:20	15:54	0:34	15:26	15:51	0:25	0	0	0	PATROL	0:25						222,182	0	JZ	MM
24-Jun-12	HS1	16:32	17:27	0:55	16:40	17:25	0:45	0	0	0	PATROL	0:45	5:11	147	65	199	13,259	235,441	0	BM	HK
25-Jun-12	HS2	12:45	14:05	1:20	13:00	13:58	0:58	0	0	0	TRAINING							235,441	0	JF	JT
25-Jun-12	HS1	13:13	13:41	0:28	13:29	13:39	0:10	0	0	0	FERRY							235,441	0	MF	BM
25-Jun-12	HS1	15:08	16:48	1:40	15:17	16:44	1:27	0	6	0	SEED	1:27						235,441	1	MF	BM
25-Jun-12	HS2	15:15	17:19	2:04	15:24	17:15	1:51	0	3	84	SEED	1:51	3:18	9	93	93	14,396	249,837	0	JF	JT
26-Jun-12	HS1	10:56	11:28	0:32	11:06	11:24	0:18	0	0	0	PR							249,837	0	BM	MF
26-Jun-12	HS1	14:57	15:23	0:26	15:03	15:21	0:18	0	0	0	PR		0:00	0	0	0	0	249,837	0	MB	MF
29-Jun-12	HS4	15:09	17:26	2:17	15:15	17:23	2:08	0	4	182	SEED	2:08						249,837	2	MM	JF
29-Jun-12	HS3	15:46	17:18	1:32	15:54	17:13	1:19	49	0	0	SEED	1:19	3:27	53	186	235	29,632	279,468	0	RT	JZ
30-Jun-12	HS2	17:01	18:13	1:12	17:13	18:10	0:57	0	0	0	PATROL	0:57	0:57	0	0	0	0	279,468	0	JT	BM
01-Jul-12	HS2	11:58	15:36	3:38	12:08	15:32	3:24	0	9	310	SEED	3:24						279,468	1	JT	JN
01-Jul-12	HS1	12:40	15:01	2:21	12:53	14:57	2:04	112	0	0	SEED	2:04						279,468	0	MF	HK
01-Jul-12	HS4	14:25	17:05	2:40	14:30	17:00	2:30	0	2	98	SEED	2:30						279,468	2	JF	MM
01-Jul-12	HS3	15:47	19:11	3:24	15:54	19:05	3:11	214	4	0	SEED	3:11						279,468	1	RT	JZ
01-Jul-12	HS2	17:16	21:23	4:07	17:22	21:18	3:56	0	17	304	SEED	3:56						279,468	2	JT	JN
01-Jul-12	HS4	17:33	20:47	3:14	17:37	20:44	3:07	0	16	284	SEED	3:07						279,468	1	JF	MM
01-Jul-12	HS1	18:20	19:35	1:15	18:30	19:27	0:57	0	0	0	PATROL	0:57						279,468	0	MF	HK
01-Jul-12	HS1	19:55	21:52	1:57	20:02	21:48	1:46	295	9	0	SEED	1:46						279,468	1	MF	HK
01-Jul-12	HS3	21:06	23:33	2:27	21:12	23:28	2:16	219	10	0	SEED	2:16	23:11	907	1063	1,903	183,029	462,497	0	RT	JZ
03-Jul-12	HS4	12:04	13:17	1:13	12:12	13:13	1:01	3	2	14	SEED	1:01						462,497	1	JF	MM
03-Jul-12	HS2	12:00	15:54	3:54	12:10	15:51	3:41	0	12	306	SEED	3:41						462,497	3	JT	JN
03-Jul-12	HS3	12:44	14:36	1:52	12:52	14:33	1:41	152	4	0	SEED	1:41						462,497	0	RT	JZ
03-Jul-12	HS1	12:45	15:50	3:05	12:55	15:47	2:52	232	21	0	SEED	2:52						462,497	1	MF	BM
03-Jul-12	HS3	15:57	16:17	0:20	16:02	16:13	0:11	0	0	0	REPO		9:15	426	359	746	64,502	526,999	0	RT	JZ
04-Jul-12	HS2	11:00	11:34	0:34	11:08	11:32	0:24	0	0	0	PR							526,999	0	JT	JF
04-Jul-12	HS2	15:17	15:49	0:32	15:22	15:44	0:22	0	0	0	PR							526,999	0	JT	JF
05-Jul-12	HS4	15:04	17:14	2:10	15:22	17:10	1:48	0	0	20	SEED	1:48						526,999	1	JZ	JE
05-Jul-12	HS2	16:31	20:26	3:55	16:40	20:22	3:42	0	26	332	SEED	3:42						526,999	1	JT	JN
05-Jul-12	HS1	17:06	19:13	2:07	17:15	19:12	1:57	251	0	0	SEED	1:57						526,999	0	MF	HK
05-Jul-12	HS3	17:17	20:40	3:23	17:21	20:35	3:14	283	4	0	SEED	3:14						526,999	1	RT	MM
05-Jul-12	HS4	17:39	20:41	3:02	17:42	20:34	2:52	0	21	120	SEED	2:52						526,999	0	JZ	JE
05-Jul-12	HS1	19:35	20:34	0:59	19:40	20:31	0:51	51	4	0	SEED	0:51	14:24	640	527	1,112	95,028	622,027	1	MF	JF
06-Jul-12	HS2	11:50	15:51	4:01	12:00	15:48	3:48	0	6	166	SEED	3:48						622,027	1	JT	JN
06-Jul-12	HS1	13:31	16:56	3:25	13:49	16:52	3:03	121	7	0	SEED	3:03						622,027	0	MF	BM
06-Jul-12	HS4	14:22	17:13	2:51	14:31	17:10	2:39	0	16	109	SEED	2:39						622,027	1	JZ	JE
06-Jul-12	HS4	18:48	19:24	0:36	18:55	19:19	0:24	0	0	18	MX		9:30	150	322	443	52,566	674,593	0	JF	JE
08-Jul-12	HS2	16:25	17:37	1:12	16:36	17:32	0:56	0	0	0	PATROL	0:56	0:56	0	0	0	0	674,593	0	JT	HK
10-Jul-12	HS2	18:22	19:10	0:48	18:32	19:06	0:34	0	0	0	PATROL	0:34	0:34	0	0	0	0	674,593	0	JT	JN
11-Jul-12	HS2	7:05	07:51	0:46	07:14	07:46	0:32	0	0	0	MX							674,593	0	JT	JN
11-Jul-12	HS2	12:30	13:07	0:37	12:35	13:04	0:29	0	0	0	MX							674,593	0	JT	JN

12-Jul-12	HS4	11:08	11:45	0:37	11:13	11:40	0:27	0	0	0	FERRY								674,593	0	JF	0
12-Jul-12	HS3	11:08	11:35	0:27	11:19	11:33	0:14	0	0	0	PR								674,593	0	RT	MM
12-Jul-12	HS4	14:15	14:54	0:39	14:35	14:51	0:16	0	0	0	TRAINING								674,593	0	JF	JZ
12-Jul-12	HS2	14:40	17:03	2:23	14:50	16:58	2:08	0	0	108	SEED	2:08							674,593	1	JT	HK
12-Jul-12	HS1	16:08	20:50	4:42	16:15	20:48	4:33	55	14	0	SEED	4:33							674,593	2	BM	MF
12-Jul-12	HS4	16:09	17:28	1:19	16:18	17:24	1:06	0	0	0	PATROL	1:06							674,593	0	JZ	JE
12-Jul-12	HS3	17:01	17:31	0:30	17:05	17:26	0:21	0	0	0	PR								674,593	0	RT	MM
12-Jul-12	HS2	18:42	20:57	2:15	18:50	20:53	2:03	0	0	75	SEED	2:03							674,593	1	JT	HK
12-Jul-12	HS1	22:37	02:30	3:53	22:45	02:25	3:40	170	9	0	SEED	3:40							674,593	1	BM	MF
12-Jul-12	HS2	22:57	01:04	2:07	23:06	01:00	1:54	0	0	78	SEED	1:54	15:24	248	284	509	49,015		723,608	0	JT	JF
13-Jul-12	HS1	11:09	11:36	0:27	11:24	11:33	0:09	0	0	0	REPO								723,608	0	MF	BM
17-Jul-12	HS3	22:43	00:44	2:01	22:52	00:35	1:43	40	6	0	SEED	1:43	1:43	46	6	46	1,951		725,559	1	RT	MM
18-Jul-12	HS4	14:35	16:43	2:08	14:47	16:40	1:53	0	11	89	SEED	1:53							725,559	1	JZ	JE
18-Jul-12	HS2	14:55	16:58	2:03	15:05	16:55	1:50	0	10	50	SEED	1:50							725,559	0	MF	JN
18-Jul-12	HS3	15:24	17:00	1:36	15:37	16:52	1:15	100	4	0	SEED	1:15							725,559	0	RT	MM
18-Jul-12	HS2	18:23	19:10	0:47	18:30	19:05	0:35	0	0	0	REPO		4:58	125	164	264	27,855		753,414	0	MF	JN
20-Jul-12	HS4	11:34	12:00	0:26	11:40	11:56	0:16	0	0	0	PR								753,414	0	JZ	JE
20-Jul-12	HS4	15:26	15:55	0:29	15:32	15:52	0:20	0	0	0	PR								753,414	0	JZ	JE
20-Jul-12	HS1	21:05	22:15	1:10	21:19	22:10	0:51	0	8	0	SEED	0:51							753,414	1	MF	HK
20-Jul-12	HS3	21:48	00:40	2:52	21:57	00:32	2:35	219	7	0	SEED	2:35							753,414	1	RT	MM
21-Jul-12	HS1	0:03	00:44	0:41	00:13	00:40	0:27	0	0	0	SEED	0:27	3:53	234	15	234	7,599		761,013	0	MF	HK
22-Jul-12	HS1	23:41	00:38	0:57	23:50	00:33	0:43	0	0	0	PATROL	0:43	0:43	0	0	0	0		761,013	0	BM	HK
23-Jul-12	HS3	10:07	11:29	1:22	10:20	11:26	1:06	25	3	0	SEED	1:06							761,013	2	RT	MM
23-Jul-12	HS2	10:32	14:48	4:16	10:43	14:43	4:00	0	4	288	SEED	4:00							761,013	2	JT	HK
23-Jul-12	HS1	11:52	14:08	2:16	12:04	14:04	2:00	20	0	0	SEED	2:00							761,013	0	BM	MF
23-Jul-12	HS3	12:58	16:34	3:36	13:02	16:30	3:28	273	18	0	SEED	3:28							761,013	4	RT	MM
23-Jul-12	HS4	13:58	15:39	1:41	14:07	15:36	1:29	0	12	14	SEED	1:29							761,013	0	JZ	JE
23-Jul-12	HS1	14:58	15:27	0:29	15:02	15:24	0:22	0	0	0	PR								761,013	0	BM	MF
23-Jul-12	HS2	15:38	17:44	2:06	15:46	17:42	1:56	0	8	94	SEED	1:56							761,013	1	JT	JN
23-Jul-12	HS1	16:20	17:55	1:35	16:25	17:51	1:26	29	0	0	SEED	1:26							761,013	0	BM	MF
23-Jul-12	HS4	17:23	17:54	0:31	17:31	17:48	0:17	0	0	0	REPO								761,013	0	JZ	JE
23-Jul-12	HS4	18:40	18:59	0:19	18:50	18:55	0:05	0	0	0	MX		15:25	392	441	788	76,242		837,255	0	JZ	JE
24-Jul-12	HS4	13:11	13:56	0:45	13:18	13:53	0:35	0	0	*16	MX								837,255	0	JZ	JE
25-Jul-12	HS4	12:22	13:29	1:07	12:33	13:23	0:50	0	0	*26	PATROL	0:50							837,255	0	JZ	JE
25-Jul-12	HS4	16:43	19:08	2:25	16:48	19:04	2:16	0	4	102	SEED	2:16	3:06	4	106	106	16,283		853,538	2	JZ	JE
26-Jul-12	HS2	15:10	17:09	1:59	15:24	17:05	1:41	0	0	96	SEED	1:41							853,538	2	JT	JN
26-Jul-12	HS4	16:03	18:53	2:50	16:14	18:50	2:36	0	0	210	SEED	2:36	4:17	0	306	306	46,775		900,312	1	JZ	JE
27-Jul-12	HS1	11:25	13:52	2:27	11:38	13:48	2:10	75	5	0	SEED	2:10							900,312	1	BM	MF
27-Jul-12	HS2	12:51	14:06	1:15	13:01	14:01	1:00	0	1	14	SEED	1:00							900,312	0	JT	HK
27-Jul-12	HS4	14:51	18:12	3:21	14:58	18:09	3:11	0	12	234	SEED	3:11							900,312	1	JZ	JE
27-Jul-12	HS2	15:07	17:33	2:26	15:17	17:30	2:13	0	8	218	SEED	2:13							900,312	0	JT	HK
27-Jul-12	HS1	15:18	17:18	2:00	15:22	17:15	1:53	104	4	0	SEED	1:53							900,312	1	BM	MF
27-Jul-12	HS3	15:20	16:30	1:10	15:26	16:21	0:55	0	0	0	PATROL	0:55							900,312	0	RT	MM
27-Jul-12	HS3	18:22	19:56	1:34	18:29	19:50	1:21	19	0	0	SEED	1:21							900,312	1	RT	MM
28-Jul-12	HS1	5:21	06:54	1:33	05:28	06:50	1:22	8	0	0	SEED	1:22	14:05	236	496	702	81,126		981,439	1	BM	MF
28-Jul-12	HS3	11:35	12:49	1:14	11:44	12:42	0:58	0	0	0	PATROL	0:58							981,439	0	RT	MM
28-Jul-12	HS4	12:04	15:38	3:34	12:12	15:36	3:24	0	20	270	SEED	3:24							981,439	3	JZ	JE
28-Jul-12	HS2	13:59	16:24	2:25	14:07	16:19	2:12	0	17	214	SEED	2:12							981,439	0	JT	HK
28-Jul-12	HS3	14:09	16:49	2:40	14:16	16:44	2:28	199	11	0	SEED	2:28							981,439	1	RT	MM
28-Jul-12	HS4	16:02	16:22	0:20	16:05	16:19	0:14	0	0	0	REPO		9:02	247	532	731	86,829		1,068,268	0	JZ	JE
30-Jul-12	HS4	13:41	14:14	0:33	13:51	14:11	0:20	0	0	0	PATROL	0:20							1,068,268	0	JZ	JE
30-Jul-12	HS4	15:43	18:19	2:36	15:47	18:15	2:28	0	17	182	SEED	2:28							1,068,268	1	JZ	JE
30-Jul-12	HS2	16:15	18:01	1:46	16:27	17:58	1:31	0	11	106	SEED	1:31							1,068,268	0	JT	HK
30-Jul-12	HS3	16:20	17:51	1:31	16:27	17:48	1:21	150	5	0	SEED	1:21							1,068,268	0	RT	MM
30-Jul-12	HS3	18:56	19:25	0:29	19:02	19:19	0:17	0	0	0	REPO								1,068,268	0	RT	MM
30-Jul-12	HS4	19:01	19:39	0:38	19:12	19:35	0:23	0	0	0	REPO		5:40	183	321	471	53,156		1,121,424	0	JZ	JE

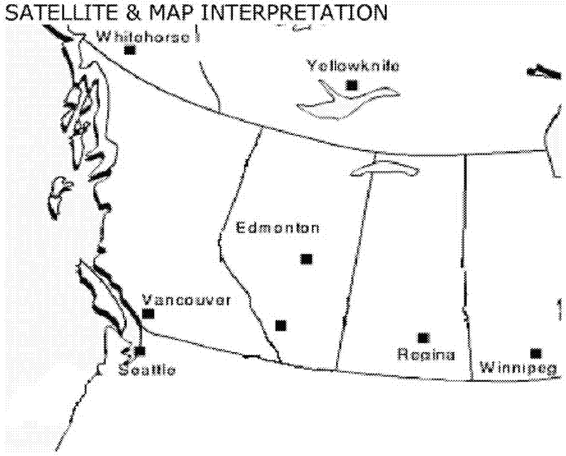
31-Jul-12	HS2	11:13	11:48	0:35	11:23	11:46	0:23	0	0	0	**PR**							1,121,424	0	JT	HK
31-Jul-12	HS4	14:21	16:12	1:51	14:26	16:14	1:48	0	2	24	SEED	1:48						1,121,424	1	JZ	JE
31-Jul-12	HS3	14:19	16:00	1:41	14:24	15:56	1:32	114	7	0	SEED	1:32						1,121,424	1	RT	MM
31-Jul-12	HS2	14:55	18:09	3:14	15:00	18:05	3:05	0	27	306	SEED	3:05						1,121,424	1	JT	HK
31-Jul-12	HS1	15:30	19:52	4:22	15:41	19:47	4:06	296	14	0	SEED	4:06						1,121,424	2	MF	BM
31-Jul-12	HS4	16:40	19:59	3:19	16:45	19:56	3:11	0	24	296	SEED	3:11						1,121,424	0	JZ	JE
31-Jul-12	HS3	18:30	21:32	3:02	18:35	21:28	2:53	262	3	0	SEED	2:53						1,121,424	1	RT	MM
31-Jul-12	HS2	19:15	20:15	1:00	19:22	20:10	0:48	0	0	0	PATROL	0:48						1,121,424	0	JT	HK
31-Jul-12	HS4	20:35	21:23	0:48	20:42	21:20	0:38	0	0	0	**REPO**		17:23	749	703	1,375	124,360	1,245,784	0	JZ	JE
04-Aug-12	HS3	22:08	00:23	2:15	22:13	00:11	1:58	196	13	0	SEED	1:58						1,245,784	2	RT	MM
04-Aug-12	HS4	22:35	00:03	1:28	22:41	23:58	1:17	0	2	88	SEED	1:17	3:15	211	103	299	20,525	1,266,308	0	JZ	JE
05-Aug-12	HS4	16:04	16:32	0:28	16:10	16:29	0:19	0	0	0	PATROL	0:19						1,266,308	0	JZ	JE
05-Aug-12	HS4	16:49	18:16	1:27	16:52	18:13	1:21	0	13	116	SEED	1:21						1,266,308	1	JZ	JE
05-Aug-12	HS3	18:50	20:10	1:20	19:00	20:02	1:02	105	6	0	SEED	1:02						1,266,308	0	RT	MM
05-Aug-12	HS4	18:57	20:08	1:11	19:02	20:04	1:02	0	9	76	SEED	1:02	3:44	133	220	325	36,589	1,302,897	0	JZ	JE
06-Aug-12	HS3	18:16	19:14	0:58	18:22	19:09	0:47	8	1	0	SEED	0:47						1,302,897	1	RT	MM
06-Aug-12	HS3	20:28	20:58	0:30	20:34	20:52	0:18	0	0	0	**REPO**							1,302,897	0	RT	MM
06-Aug-12	HS3	21:56	01:56	4:00	22:02	01:49	3:47	222	10	0	SEED	3:47	4:34	241	11	241	7,159	1,310,056	2	RT	MM
07-Aug-12	HS1	13:48	16:33	2:45	13:56	16:31	2:35	285	22	0	SEED	2:35						1,310,056	2	BM	HK
07-Aug-12	HS2	15:08	17:24	2:16	15:16	17:20	2:04	0	15	202	SEED	2:04						1,310,056	2	MF	JN
07-Aug-12	HS3	15:52	20:16	4:24	15:57	20:09	4:12	140	5	0	SEED	4:12						1,310,056	3	RT	MM
07-Aug-12	HS2	19:22	20:28	1:06	19:30	20:22	0:52	0	0	20	SEED	0:52	9:43	467	264	689	50,909	1,360,965	0	MF	JN
08-Aug-12	HS3	11:17	11:44	0:27	11:24	11:40	0:16	0	0	0	PR							1,360,965	0	RT	MM
08-Aug-12	HS4	13:52	15:04	1:12	14:00	14:59	0:59	0	0	50	SEED	0:59						1,360,965	1	JZ	JE
08-Aug-12	HS3	14:28	15:10	0:42	14:34	15:03	0:29	1	2	0	SEED	0:29						1,360,965	0	RT	MM
08-Aug-12	HS2	17:11	18:43	1:32	17:21	18:40	1:19	0	0	0	PATROL	1:19						1,360,965	0	JT	JN
08-Aug-12	HS4	17:25	20:35	3:10	17:34	20:33	2:59	0	16	197	SEED	2:59						1,360,965	2	JZ	JE
08-Aug-12	HS3	19:25	20:30	1:05	19:31	20:25	0:54	94	2	0	SEED	0:54						1,360,965	0	RT	MM
08-Aug-12	HS2	20:34	21:45	1:11	20:43	21:42	0:59	0	2	92	SEED	0:59						1,360,965	1	JT	JN
08-Aug-12	HS1	20:56	22:24	1:28	21:07	22:20	1:13	47	0	0	SEED	1:13						1,360,965	0	BM	MF
08-Aug-12	HS4	21:08	21:30	0:22	21:13	21:27	0:14	0	0	0	REPO							1,360,965	0	JZ	JE
08-Aug-12	HS3	21:11	21:51	0:40	21:16	21:45	0:29	0	0	0	PATROL	0:29	9:21	164	361	503	58,868	1,419,833	0	RT	MM
11-Aug-12	HS1	17:07	17:30	0:23	17:15	17:25	0:10	0	0	0	PATROL	0:10						1,419,833	0	MF	BM
10-Aug-12	HS1	19:12	20:03	0:51	19:17	20:00	0:43	0	0	0	PATROL	0:43						1,419,833	0	MF	BM
11-Aug-12	HS3	1:14	02:40	1:26	01:21	02:35	1:14	57	1	0	SEED	1:14	2:07	58	1	58	1,476	1,421,308	1	RT	MM
12-Aug-12	HS3	18:21	22:55	4:34	18:27	22:48	4:21	288	23	0	SEED	4:21						1,421,308	1	RT	MM
12-Aug-12	HS2	20:41	23:35	2:54	20:51	23:31	2:40	0	27	268	SEED	2:40						1,421,308	0	MF	JN
12-Aug-12	HS4	21:19	00:00	2:41	21:29	23:55	2:26	0	18	178	SEED	2:26						1,421,308	0	JZ	JE
12-Aug-12	HS1	21:26	00:03	2:37	21:35	23:57	2:22	296	22	0	SEED	2:22	11:49	674	536	1,120	97,081	1,518,389	0	BM	HK
14-Aug-12	HS3	12:59	15:49	2:50	13:05	15:46	2:41	215	20	0	SEED	2:41						1,518,389	3	RT	MM
14-Aug-12	HS2	13:47	16:27	2:40	13:56	16:23	2:27	0	14	196	SEED	2:27						1,518,389	0	JT	JN
14-Aug-12	HS1	14:20	16:14	1:54	14:29	16:10	1:41	222	23	0	SEED	1:41						1,518,389	1	MF	HK
14-Aug-12	HS3	16:11	16:51	0:40	16:18	16:45	0:27	0	0	0	REPO		6:49	494	253	690	49,802	1,568,191	0	RT	MM
16-Aug-12	HS4	11:16	11:51	0:35	11:26	11:48	0:22	0	0	0	PR							1,568,191	0	JZ	JE
16-Aug-12	HS4	16:03	16:28	0:25	16:07	16:22	0:15	0	0	0	PR		0:00	0	0	0	0	1,568,191	0	JZ	JE
20-Aug-12	HS2	19:57	20:51	0:54	20:06	20:46	0:40	0	0	0	PATROL	0:40	0:40	0	0	0	0	1,568,191	0	JT	JN
21-Aug-12	HS1	11:07	11:38	0:31	11:13	11:35	0:22	0	0	0	PR							1,568,191	0	MF	BM
21-Aug-12	HS1	16:35	17:01	0:26	16:42	16:59	0:17	0	0	0	PR							1,568,191	0	MF	BM
22-Aug-12	HS3	0:26	02:37	2:11	00:32	02:30	1:58	0	0	0	PATROL	1:58	1:58	0	0	0	0	1,568,191	0	RT	MM
22-Aug-12	HS2	9:42	10:56	1:14	09:56	10:49	0:53	0	0	0	CUR							1,568,191	0	MF	0
23-Aug-12	HS4	14:30	16:48	2:18	14:41	16:44	2:03	0	0	0	PATROL	2:03						1,568,191	0	JZ	JE
23-Aug-12	HS2	14:52	16:19	1:27	15:04	16:18	1:14	0	0	0	PATROL	1:14						1,568,191	0	JT	JN
23-Aug-12	HS3	16:50	17:37	0:47	16:56	17:31	0:35	56	2	0	SEED	0:35						1,568,191	1	RT	MM
23-Aug-12	HS2	18:41	19:09	0:28	18:46	19:05	0:19	0	0	0	**REPO**		3:52	58	2	58	1,626	1,569,817	0	JT	JN
24-Aug-12	HS2	11:14	12:00	0:46	11:34	11:58	0:24	0	0	0	PR							1,569,817	0	JT	JN
24-Aug-12	HS2	15:21	15:52	0:31	15:30	15:49	0:19	0	0	0	PR		0:00	0	0	0	0	1,569,817	0	JT	JN

27-Aug-12	HS2	7:57	08:43	0:46	08:09	08:38	0:29	0	0	0	MX							1,569,817	0	JT	JN
27-Aug-12	HS3	11:26	11:51	0:25	11:32	11:48	0:16	0	0	0	PR							1,569,817	0	RT	MM
27-Aug-12	HS3	15:55	16:21	0:26	16:00	16:17	0:17	0	0	0	PR							1,569,817	0	RT	MM
27-Aug-12	HS2	16:44	17:31	0:47	16:55	17:26	0:31	0	0	0	MX		0:00	0	0	0	0	1,569,817	0	JT	JN
04-Sep-12	HS4	11:35	12:01	0:26	11:43	11:59	0:16	0	0	0	PR							1,569,817	0	JZ	JE
04-Sep-12	HS4	15:55	16:14	0:19	16:00	16:10	0:10	0	0	0	PR		0:00	0	0	0	0	1,569,817	0	JZ	JE
10-Sep-12	HS4	12:08	12:54	0:46	12:16	12:50	0:34	0	0	0	PATROL	[illegible]						1,569,817	0	JZ	JE
10-Sep-12	HS3	13:09	15:09	2:00	13:15	15:02	1:47	37	2	0	SEED	1:47	2:21	39	2	39	1,191	1,571,009	1	RT	MM
12-Sep-12	HS1	11:02	11:34	0:32	11:14	11:31	0:17	0	0	0	PR							1,571,009	0	BM	HK
12-Sep-12	HS1	15:50	16:15	0:25	15:53	16:11	0:18	0	0	0	PR		0:00	0	0	0	0	1,571,009	0	BM	HK

Appendix E – Forms

WEATHER FORECAST WORKSHEET

SATELLITE & MAP INTERPRETATION



DATE

Forecaster

SYNOPSIS

OPERATIONAL INFORMATION FORECAST:

FCST CDC: Tmax:

Freezing Level: Dew Pt:

-5 C: Tconv:

-10 C:

Max Cloud Top Height:

Cloud Base Height/Temp:

Cell Motion:

Storm Motion:

Outlook CDC:

FORECAST

HAILCAST MODEL FCST Diam. (cm):

ACTUAL WX OBSERVED

CDC

SOUNDINGS:

- LI:
- SI:
- TOTAL TOTALS:
- Precip. Water (in):
- CAPE (J/kg):

WINDS

250 mb

500 mb

600 mb

700 mb

850 mb

Sfc

jet PVA	Insolation
short wave trof	latent instability
thickness advection	loaded gun
wind shear	chinook
upslope flow	cloud cover
frontal lift	gusty winds
night radiation cooling	Dry Slot or Line
morning fog	NE moisture advection
morning ACC or cloud street	Other:

	Summation coverage		Weather nature		Precipitation type		Obscuration type
SKC	nil cloud	MI	Shallow (FG)	DZ	Drizzle	BR	Mist (≥ 5/8 sm)
FEW	≤ 2/8	BC	Patches (FG)	RA	Rain	FG	Fog (< 5/8 sm)
SCT	3/8 to 4/8	PR	Partial (FG)	SN	Snow	FU	Smoke (≤ 6sm)
BKN	5/8 to 7/8	DR	Drifting	SG	Snow grains (never showery)	VA	Volcanic ash (any vsby)
OVC	8/8	BL	Blowing	IC	Ice crystals (≤ 6sm)	DU	Dust (≤ 6sm)
CLR	nil cloud < 10,000' (auto)	SH	Showers	PL	Ice pellets (frozen rain)	SA	Sand (≤ 6sm)
	≥ 6 sm, no CB, no sig wx,	TS	Thunder	GR	Hail	HZ	Haze (≤ 6sm)
CAVOK	nil cld < 5000' or below	FZ	Freezing	GS	Snow pellets (showery)	PO	Dust whirls
	highest min sector	VC	Vicinity	UP	Unknown (auto)	SQ	Squalls
	altitude	FC	Funnel cld			SS	Sandstorm (< 5/8 sm)
		+FC	Tornado/		GRADU >1/2hr TEMPO <1 hr	+SS	Sandstorm (< 5/16 sm)
			Waterspout		RAPID <1/2hr INTER <<1hr	DS	Duststorm (< 5/8 sm)
						+DS	Duststorm (< 5/16 sm)

WMI RADAR OBSERVER LOG

WMI Radar Log
2012 Alberta Hail Suppression Project
Olds-Didsbury Radar Operations Centre

Date (UTC): ____________________

Operator(s): ____________________ Page: ______ of ______

TIME hh:mm (UTC)	**Radar Summary** PPINE, stratus, TITAN cell etc	**Remarks, Action, Decision**	**Carvel Radar***	**Strathmore Radar***

*provide Environment Canada radar summary when Olds-Didsbury radar shows no echoes.

WMI SEEDING AIRCRAFT FLIGHT LOG

WMI Cloud Seeding Flight Log - Alberta 2012			Hobbs Off:		Engine Off:		Landing:		Date: mm/dd @ start of flight, ZULU!	
Dep Airport:		Mission Type:	Hobbs On:		Engine On:		Takeoff:			
REV: 1-2012			Total HOBBS:		Total Engine:		Flight Time:		Page #:	

Pilot:		Copilot:		N-Number:		HS#		All Times in UTC
Time (UTC)	Event No.	Lat. (deg & min)	Long. (deg & min)	Alt. (ft)	Generators On	Generators Off	Flares Ejectable	Flares BIP	Remarks and Observations

(:)	Total Seeding Attempted:				
TOTAL Generator Time (List it above) Both Units! HH:MM	Less Misfires:				
	Total Flares Used:				

Mission Type Categories :	Seeding Flt	SEED	Ferry Flt	FER	Reposition Flt	REPO
	Patrol Flt	PAT	Publicity Flt	PR		
	Maintenance	MX	Currency Flt	CUR		

WEATHER MODIFICATION INCORPORATED

Appendix F – Aircraft Specifications

Several types of aircraft are presently utilized on the project. Though all are twin-engine, the engine type and other performance characteristics make each significantly different from the others. Of the four HAILSTOP aircraft presently used on the project, two are turboprop (prop-jet) aircraft, and the other two are powered by turbocharged, reciprocating piston engines. While the turboprop aircraft are faster and more powerful, they are also more expensive to operate, so the two piston-engine aircraft are used to operate where less performance is needed—at cloud base.

CESSNA 340A AIRCRAFT

Primary mission: cloud base seeding
Power Type, Turbocharged piston twin engine
6290 lbs gross weight
4184 lbs empty weight
1802 lbs useful load
310 hp per engine
280 mph max speed
263 mph rec. cruise
82 mph stall dirty
183 - 203 gals fuel capacity
29,800 feet all engine service ceiling
15,800 feet single engine service ceiling
1650 feet per minute all engine rate of climb
315 feet per minute single engine rate of climb
2175 feet for takeoff over 50 foot obstruction
1615 feet for takeoff ground roll
1850 feet land over 50 foot obstruction
770 foot land ground roll
34 ft 4 in length
12 ft 7 in height
38 ft 1 in wingspan

BEECHCRAFT KING AIR C90

Primary mission: cloud-top seeding
Power Type, Turboprop twin engine
PT6A-21 engines
Full deicing capabilities
9650 lbs gross weight
6382 lbs empty weight
3268 lbs useful load
550 hp per engine
208 kts max speed
185 kts recommended cruise
74 kts dirty stall
384 gals fuel capacity
30,000 feet all engine service ceiling
14,200 single engine service ceiling
1500 feet per minute all engine rate of climb
350 feet per minute single engine rate of climb
3100 for takeoff over a 50 foot obstruction
2250 feet take off roll
1730 feet for landing over 50 foot obstacle
800 foot landing roll
35 ft 6 in length
14 ft 3 in height
50 ft 3 in wingspan

Appendix G – Ground School Agenda

WEATHER MODIFICATION INCORPORATED

Alberta Hail Suppression Project

2012 Ground School – May 28th Calgary, Alberta

MONDAY, MAY 28, 2012

LOCATION Holiday Inn Express - Downtown Calgary Conference Room
1020 8th Ave SW, Calgary AB
Phone – 403.269.8262, Parking Available HIE Lot – See Front Desk Attendant

09:30 Field Personnel Pictures

10:00 WMI Representation and Professionalism
WMI Job Responsibilities/ Duties
Jody Fischer, WMI Chief Pilot & Canada Project Manager
Bruce Boe, WMI Director of Meteorology

10:30 Approved Flight Operations
Aircraft Maintenance Procedures & Pilot Discussion
Aircraft Binders, NAFTA
Aircraft Refueling Procedures
Jody Fischer

11:00 SharePoint Introduction
Paperwork Procedures
Erin Fischer, WMI Project Assistant

11:45 Accounting – Company Expense Reports
Cindy Dobbs, WMI Accounting Manager

12:00 Lunch (On-Site)

13:00 Hands-on SharePoint Session with Field Crew
Erin Fischer

14:30 Cloud Seeding Chemical Inventory & Procedures
Jody & Erin Fischer

14:45 Additional Project Discussion – Q & A

15:15 End of Ground School

Attendance is mandatory for all Weather Modification, Inc. project personnel.

WEATHER MODIFICATION INCORPORATED

WEATHER MODIFICATION
INCORPORATED

Alberta Hail Suppression Project

2012 Ground School – May 29th Calgary, Alberta

TUESDAY, MAY 29, 2012

LOCATION Intact Zone Training Centre – Red Room
12th Floor- Energy Plaza East Tower
311-6th Avenue SW, Calgary AB

08:45 Welcome and Staff Introductions
Mr. Jim Sweeney, WMI Vice President
Dr. Terry Krauss, ASWMS Project Director
Mr. Bruce Boe, WMI Director of Meteorology

09:00 Introduction from the Insurance Industry
Terry Krauss, on behalf of the ASWMS Board

09:15 History of the Alberta Hail Suppression Program
Terry Krauss

10:00 Break

10:15 Hail Program Overview and Status of Hail Suppression Concepts
Bruce Boe

10:45 Overview of 1996-2011 Alberta Operations
Brad Waller

11:30 Severe Weather Forecasting & Daily Forecast Sheet
Dan Gilbert, WMI Chief Meteorologist & Canada Lead Meteorologist

12:00 Lunch (On-Site)

12:45 ATC Controlling Procedures
Scott Young, Supervisor YYC TCU Edmonton Control Center
Calgary Tower Representative (TBA)

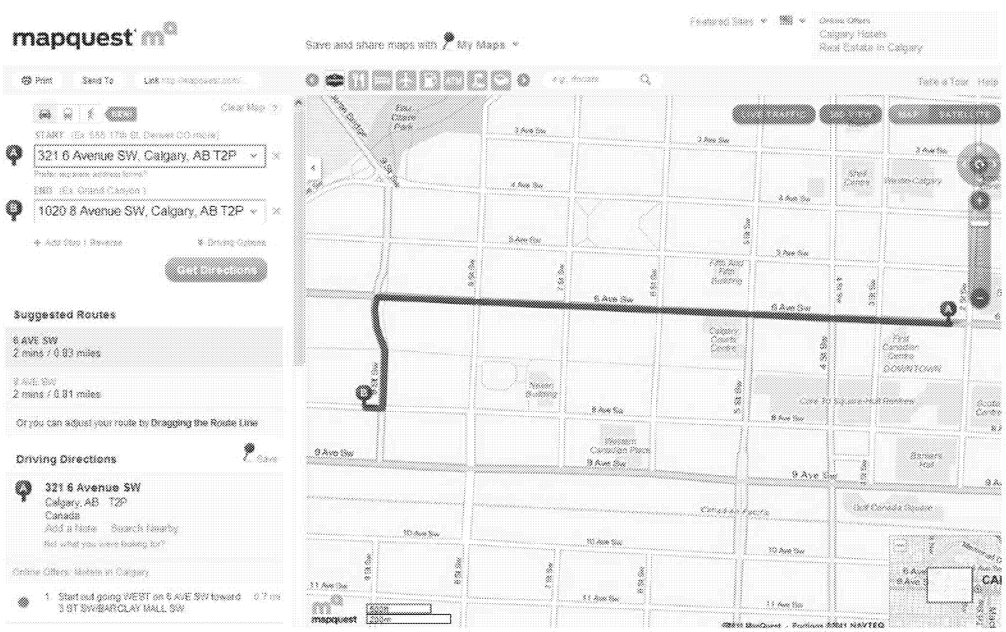
13:30 Job Responsibilities/ Duties
Bruce Boe
Terry Krauss

Attendance is mandatory for all Weather Modification, Inc. project personnel.

14:00	Aviation Weather & Special Procedures Cloud Seeding Aircraft & Equipment Targeting - Seeding Rates Storm Tracking and Directing Jody Fischer, WMI Chief Pilot & Canada Project Manager
14:45	Break
15:00	Alberta Radar Upgrade & Operational Implications CDC Forecast Verification and the Need for Hail Reports Dan Gilbert
15:20	Daily Routines & Procedures Dan Gilbert
15:30	Safety and Emergency Procedures Jody Fischer
16:00	End of Ground School

Directions from Holiday Inn Express Downtown to Intact Training Center:

http://www.mapquest.com/maps?1c=Calgary&1s=AB&1a=321+6+Avenue+SW&1z=T2P&1y=CA&1l=51.047575&1g=114.068296&1v=ADDRESS&2c=Calgary&2s=AB&2a=1020+8+Avenue+SW&2z=T2P&2y=CA&2l=51.046133&2g=-114.084158&2v=ADDRESS



Attendance is mandatory for all Weather Modification, Inc. project personnel.

Appendix H – Airborne Seeding Solution

- Chemical Formulation: 2% AgI - 0.5 NH_4I - 0.1 $C_6H_4Cl_2$ - 1.0 $NaClO_4$
- Recommended Burn Rate: ~2.0 gph
- Nucleation Mechanism: Condensation Freezing
- Total Solution Weight: 33.5 lbs.
- Volume: ~ 5.0 gallons, (20 liters) scale for other amounts
- Seeding Aerosol: $AgI_{0.85}AgCl_{0.15}NaCl$

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

Note: Sodium Perchlorate, anhydrous can be utilized in the formula by adjusting the weight or mass to include 0.34 lb or 158.1 g respectively, although proper handling becomes more difficult. Water amounts should be increased to 1.40 lb or 630 g (0.21 gal).

Note: Use 2.4 urinal pucks (85 gram Paradichloro-benzene) for 205 litre barrel of acetone.

Mixing procedures are as follows:

1.) Combine AgI and acetone in a 5 gallon container and begin stirring;
2.) Combine ammonium iodide, sodium perchlorate and water in another small container and stir until the solution is clear and cool (caution the perchlorate is a strong oxidizer and needs to be done at room temperatures, don't do this in a hot hanger)
3.) Add the ammonium iodide, sodium perchlorate and water mixture to the stirring silver iodide/acetone slurry;
4.) Continue mixing until the solution is clear;
5.) Add the paradichlorobenzene any time after you have added container #2 and the solution is beginning to clear;
6.) Continue mixing for another 10 minutes until very clear; and
7.) Pump the solution into the aircraft generator immediately after mixing or store in an appropriate labeled sealed container. Storage containers can be either stainless or plastic (polypropylene).

Supplier: Solution Blend Service, 2720 7th Avenue N.E., Calgary, AB, T2A 5G6 403-207-9840

Appendix I – Daily Meteorological Forecast Statistics

June 2012

2012 Date	Forecast CDC	Precipitable Water (inches)	0°C Level (kft)	-5°C Level (kft)	-10°C Level (kft)	Cloud Base Height (kft)	Cloud Base Temp (°C)	Maximum Cloud Top Height (kft)	Temp. Maximum (°C)	Dew Point (°C)	Conv Temp (°C)	CAPE (J/kg)	Total Totals	Lifted Index	Showalter Index	Cell Direction (deg)	Cell Speed (knots)	Storm Direction (deg)	Storm Speed (knots)	Low Level Wind Direction (deg)	Low Level Wind Speed (kts)	Mid Level Wind Direction (deg)	Mid Level Wind Speed (knots)	High Level Wind Direction (deg)	High Level Wind Speed (knots)	Observed CDC
1-Jun	-1	0.75	10.2	12.5	15.1	10	0.4	19.4	21	5	20.2	85	51.8	-0.6	0.1	270	23	300	19	250	16	275	35	285	102	-1
2-Jun	1	0.67	8.9	11.3	13.9	7.2	4.6	26.6	17	8	15.3	476	55.8	-2.6	-1.9	255	19	285	12	290	19	230	21	215	56	3
3-Jun	-1	0.56	9.2	11.3	13.9	9.1	0.3	15.7	16	4.5	16.4	70	47.8	2.3	2.6	250	16	280	16	245	10	255	31	255	100	-1
4-Jun	3	0.98	12.8	15.2	17.6	8	8.4	34.8	22	12	20.8	371	52.5	-2.3	-2.1	160	29	210	18	140	21	200	32	210	74	1
5-Jun	3	1.04	12.8	15	17.5	8.6	1.1	36.0	22	13	21	443	51.5	-2.1	-2.2	160	30	190	20	140	19	170	43	160	66	2
6-Jun	3	0.82	11.4	14.3	17.0	4.8	10.7	35.0	15	12.5	12.4	514	48.5	-1.4	-0.2	120	43	155	35	120	26	125	65	125	85	3
7-Jun	-1	0.33	10.5	12.2	14.5	11.9	-4.1	21.8	20	1.5	19.5	65	52.9	-0.6	-0.3	220	23	235	16	210	16	205	28	215	39	-1
8-Jun	1	0.58	8.8	10.6	13.3	8.1	2.2	27.6	15	8	15	518	58.6	-3	-3.1	210	7	240	5	250	12	180	6	200	26	2
9-Jun	1	0.63	8.1	-5	-10.0	2.9	5.0	18.8	15	8	13.6	248	53.7	-1	-0.2	30	13	70	8	360	10	40	11	100	33	3
10-Jun	0	0.69	9.5	12.1	14.8	7.4	4.7	34.0	15	9	15.4	114	51.1	0.1	0.5	340	31	10	20	340	30	330	26	20	27	-1
11-Jun	0	0.65	10.5	12.6	15.8	9.3	3.4	27.5	22	9	21.4	230	51.3	-0.6	0	305	21	330	12	290	17	305	18	305	28	-1
12-Jun	2	0.65	11.2	12.9	15.3	10.4	2.2	34.0	24	7.5	22.3	796	55.8	-3.4	-2.4	275	13	290	6	250	5	255	14	204	14	0
13-Jun	2	0.8	9.6	12.1	14.7	7	7	33.4	19	10	18.8	981	56.9	-3.9	-3.3	240	5	320	1	120	2	250	6	160	12	4
14-Jun	2	0.65	8.5	10.8	13.3	8.4	1.6	34.0	18	6	19	353	52.8	-2	0.6	230	16	270	12	220	12	250	26	240	46	2
15-Jun	2	0.52	8.8	10.7	12.9	8.4	1.4	25.0	17	6	16	393	57.8	-2.6	-2.2	300	23	335	16	300	21	305	26	335	98	-1
16-Jun	-1	0.92	12.5	15.5	17.8	8.3	6.6	11.5	22	11	24	1	48.4	-0.4	0.9	295	25	310	20	290	26	285	31	290	99	0
17-Jun	2	0.63	9.2	11.5	13.9	7.5	4.5	28.0	17.5	7.5	17.2	442	53.1	-2.1	-0.4	280	23	310	15	300	20	270	22	270	36	3
18-Jun	2	0.65	8.8	11.3	14.0	7.1	5.3	31.3	16	7.5	15	959	57.1	-3.6	-2.7	360	9	360	4	10	9	310	7	240	11	2
19-Jun	1	0.60	8.8	11.3	13.9	7.5	4.0	34.0	15	6	15	533	54.7	-1.8	-1.1	340	14	10	10	340	19	340	12	210	2	1
20-Jun	0	0.66	9.8	11.9	14.4	9	2.2	29.2	20	7	17.7	493	56.3	-2.6	-2.1	310	17	340	11	315	13	310	20	305	48	0
21-Jun	2	0.73	10.9	12.8	15.4	9.2	4.8	30.5	23	9.5	20.3	633	55.8	-3.2	-2.6	240	11	270	6	175	8	270	15	290	69	-1
22-Jun	2	0.99	11.7	14.4	17.4	8.6	7.5	35.9	22	11	21.9	785	52.8	-2.6	-1.9	190	12	200	8	150	19	230	5	250	40	1
23-Jun	1	1.06	12.7	15.6	18.1	8.3	7.5	23.3	21	11	21	147	50.2	-0.9	-0.8	160	28	190	18	140	29	180	27	230	62	0
24-Jun	3	0.9	13.9	16.1	18.3	7.3	10.6	39.0	21	14	22	670	53	-2.9	-3.3	210	43	250	30	230	30	210	54	220	86	3
25-Jun	0	0.84	12.4	15.5	17.9	9.4	5.2	13.5	22	9	21.1	26	50.9	-1.1	-0.5	220	43	240	25	175	19	210	53	215	88	2
26-Jun	1	0.81	9.4	12.1	15.5	6.3	8	19.0	17.5	11	17.7	290	46.3	0.2	2.7	170	10	215	10	200	2	180	24	195	51	0
27-Jun	-2	0.55	10	11.9	14.3	9.7	1.0	19.4	19	5	19	154	51.4	-0.4	0.5	280	28	310	18	290	24	270	31	220	19	-1
28-Jun	-3	0.57	12.5	15.4	17.9	10.9	2.8	22.3	24	7.5	24.3	2	49.5	-0.4	0.6	260	26	280	17	250	21	250	30	270	30	-2
29-Jun	2	0.88	11.4	14.2	16.6	8.4	6.2	32.5	22	11.5	22	411	52.5	-1.9	-1.1	280	21	310	14	300	16	270	27	280	33	2
30-Jun	3	0.91	12.2	14.8	17.6	10.1	6.1	35.5	25	12	22.5	848	55.5	-3.5	-3.3	230	20	260	17	220	15	235	32	240	87	0

July 2012

2012 Date	Forecast CDC	Precipitable Water (inches)	0°C Level (kft)	-5°C Level (kft)	-10°C Level (kft)	Cloud Base Height (kft)	Cloud Base Temp (°C)	Maximum Cloud Top Height (kft)	Temp. Maximum (°C)	Dew Point (°C)	Conv Temp (°C)	CAPE (J/kg)	Total Totals	Lifted Index	Showalter Index	Cell Direction (deg)	Cell Speed (knots)	Storm Direction (deg)	Storm Speed (knots)	Low Level Wind Direction (deg)	Low Level Wind Speed (kts)	Mid Level Wind Direction (deg)	Mid Level Wind Speed (knots)	High Level Wind Direction (deg)	High Level Wind Speed (knots)	Observed CDC
1-Jul	2	0.77	11.3	13.7	16.4	9.9	3.7	31.7	22	8	20.5	465	53.9	-2.1	-1.8	255	17	275	13	255	13	240	24	215	63	4
2-Jul	3	0.82	11.4	13.7	16.6	8.5	7	32.0	23	12	23.2	635	55.7	-3.8	-3.2	235	26	260	20	225	16	240	45	240	82	0
3-Jul	2	0.72	9.2	11.4	13.9	7.2	5.8	28.6	18	12	18	903	57.2	-4.4	-2.8	250	21	280	15	260	25	240	18	210	44	3
4-Jul	-1	0.77	9.5	12.2	15.1	6.4	6.2	18.1	16	9.5	16.2	85	49.9	0.1	1.2	290	14	320	11	290	16	260	14	250	46	-1
5-Jul	3	0.76	11.4	13.5	15.8	9.5	5.6	31.0	22.5	10.5	20.6	843	58.3	-5	-4.3	240	28	265	19	215	16	240	38	235	91	4
6-Jul	3	0.78	11.8	14.2	17.1	9.3	6.6	34.0	23	11	23	922	54.8	-3.4	-2.8	270	21	290	14	240	11	270	30	270	47	2
7-Jul	2	0.85	13.5	15.9	18.5	10.7	7.5	34.0	28	12	28	1468	57.0	-4.8	-4.4	270	22	290	11	230	11	270	27	280	25	-1
8-Jul	2	1.06	14	16.3	19.0	10.5	10.1	38.7	30	16	28.1	2057	58.7	-6.9	-5.6	250	14	270	7	210	9	270	13	250	13	3
9-Jul	1	0.87	14.5	16.7	18.9	12.5	4.6	36.6	30	11	30.7	1032	55.5	-3.8	-3.1	270	16	295	9	250	8	270	19	220	26	2
10-Jul	2	0.9	14.3	16.3	18.6	12.5	5.3	37.0	31	12	28.7	1386	58.9	-5.3	-5	295	8	305	7	280	8	265	10	245	24	3
11-Jul	1	0.95	14	16.2	18.7	10.6	8.4	38.0	28	13.5	28.7	1775	57.8	-5.3	-5.1	275	15	285	7	260	12	265	12	270	17	-1
12-Jul	4	1.12	13.6	16	18.6	8.6	11.8	39.2	28	17	27.7	2384	57.8	-6.4	-6	275	18	310	9	280	9	280	17	260	34	4
13-Jul	2	1.11	13.9	16.3	19.0	9.5	9.2	38.3	26	13	26.5	649	52.7	-2.7	-3	270	11	285	6	265	7	275	16	260	21	4
14-Jul	4	1.17	14	16.5	19.2	6.4	15.3	41.5	25	18	23.6	2007	54.3	-6	-5.2	270	2	215	3	140	6	245	6	240	39	2
15-Jul	1	1.46	13.7	16.9	19.8	4.8	15.3	36.7	20.5	17	19.2	743	46.2	-1.9	-0.6	85	6	120	4	40	7	145	6	150	30	0
16-Jul	-1	1.15	14.1	17.3	20.0	7	12.6	33.6	22	15	20.4	814	48.2	-1.7	-1.3	320	8	340	4	340	1	305	13	240	16	-1
17-Jul	2	1.19	13.7	16.5	19.3	7.5	13.2	39.1	24	17	24.4	1645	53.8	-5	-4.2	290	8	275	5	270	7	225	6	235	22	4
18-Jul	2	1.06	12.8	15.4	18.1	7.8	11.3	37.1	24	15	25.5	1324	53.2	-4.5	-3	255	21	290	16	270	16	260	28	235	38	4
19-Jul	1	1.07	14.2	17.6	20.1	7.9	11.8	40.5	24	14.5	24.3	1109	49.5	-2.1	-1.9	275	31	295	16	255	17	270	32	260	38	2
20-Jul	3	1.34	13.9	16.9	19.5	7.5	11.9	39.1	25	16	27.6	923	49.4	-2.9	-1.1	195	23	220	16	185	23	210	27	200	34	3
21-Jul	1	1.15	12.5	15.3	18.1	8.1	9.1	33.9	24	12.5	21.8	596	51.8	-2.6	-1.8	285	30	315	21	295	29	280	32	290	18	0
22-Jul	3	0.97	13.4	15.6	17.9	6.8	10.5	36.6	25	14	25.2	585	52.1	-2.4	-1.7	220	19	235	15	185	15	225	29	230	53	3
23-Jul	3	1.2	12.9	15.4	18.0	5.6	13.5	36.0	21	16.5	20.4	1277	51.4	-4.2	-2.2	175	38	200	26	150	33	185	48	205	63	4
24-Jul	2	0.91	11.8	14.9	17.8	8.6	7.6	33.3	22	10.5	19.5	523	52.2	-2.1	-1.8	325	40	350	28	325	34	320	43	300	50	2
25-Jul	2	0.98	11.8	15	18.0	7.1	10.1	35.6	22	14	22.1	746	50	-1.9	-0.8	330	12	15	7	355	13	320	6	310	6	4
26-Jul	3	0.92	12.5	15.3	17.8	8	10.1	35.2	22.5	13	21.1	1266	55.2	-4.4	-4	255	13	285	7	270	12	250	11	270	19	3
27-Jul	3	0.87	13	15.1	17.6	10.5	6.4	35.2	27	12	26.2	1026	55.9	-4.5	-3.5	270	24	295	14	260	9	265	27	250	41	4
28-Jul	4	0.97	11.7	14.1	16.3	6.5	11	32.8	21	15.5	21.6	1291	56.6	-6.0	-4.2	220	21	255	11	235	14	210	22	220	33	5
29-Jul	1	0.89	12.8	15.3	18.2	9.3	7.7	35.9	26	12.5	25.3	975	53	-2.7	-2.3	280	22	305	11	285	11	275	25	265	30	-1
30-Jul	4	0.88	13	15.5	17.8	9.0	9.5	36.9	27	15	26.9	1780	56	-5.9	-3.6	230	16	255	12	210	9	235	24	225	38	4
31-Jul	3	0.91	11.9	14.4	17.0	8.5	8	35.1	22	12	21.7	1027	55.1	-3.8	-3.2	255	23	280	15	245	14	255	30	245	60	4

August 2012

2012 Date	Forecast CDC	Precipitable Water (inches)	0°C Level (kft)	-5°C Level (kft)	-10°C Level (kft)	Cloud Base Height (kft)	Cloud Base Temp (°C)	Maximum Cloud Top Height (kft)	Temp. Maximum (°C)	Dew Point (°C)	Conv Temp (°C)	CAPE (J/kg)	Total Totals	Lifted Index	Showalter Index	Cell Direction (deg)	Cell Speed (knots)	Storm Direction (deg)	Storm Speed (knots)	Low Level Wind Direction (deg)	Low Level Wind Speed (kts)	Mid Level Wind Direction (deg)	Mid Level Wind Speed (knots)	High Level Wind Direction (deg)	High Level Wind Speed (knots)	Observed CDC
1-Aug	1	0.91	11.8	14.3	17.2	9.5	4.8	24.0	24	10.5	24.2	193	51.4	-1.1	-0.6	275	23	300	14	265	14	275	30	290	47	0
2-Aug	1	0.61	8.6	11	13.6	7.5	3.1	27.4	16	7	15.7	398	55.5	-1.9	-1.0	320	18	340	13	325	20	300	17	285	18	2
3-Aug	-1	0.7	11.5	14.7	17.6	8.1	7	19.7	22	12	22.1	126	48.4	-0.1	0.8	340	18	20	14	345	17	355	21	10	58	-1
4-Aug	2	1.12	13.8	16.4	19.0	9.8	8.1	39.1	28	14.5	27.2	854	52.7	-3	-2.2	285	25	315	15	300	17	285	27	280	44	4
5-Aug	4	1.12	13.8	16.5	19.3	9.7	9.5	40.6	29	15	28.7	1575	54.1	-4.1	-3.3	290	27	315	14	290	15	290	30	300	35	4
6-Aug	3	1.03	14.4	16.7	19.5	11.1	8.4	38.1	30	13.5	29.3	1687	56.9	-5	-4.7	280	14	310	7	270	6	280	15	270	34	4
7-Aug	3	1.26	13.1	15.9	18.8	7.6	12.6	37.7	26	17	25.6	1753	53.8	-5.2	-3.7	5	10	10	4	345	3	335	8	125	2	4
8-Aug	4	1.22	14.4	16.5	18.6	9.2	11	38.6	29	17	29.9	1935	58.5	-6.8	-6	210	34	240	23	210	26	220	42	240	68	4
9-Aug	0	0.81	13.5	16.3	19.0	10.5	6.2	36.2	26	11	26.1	763	51.8	-1.7	-1.5	255	20	280	12	235	14	260	26	260	62	0
10-Aug	3	0.92	13.2	15.6	17.8	7.8	11.0	37.4	23	13.5	22.8	1849	57.4	-5.6	-5.6	255	19	290	10	260	8	250	23	250	37	4
11-Aug	1	0.91	12	14.5	17.4	9.3	6.7	35.3	23	10	20.4	750	54.6	-3	-2.9	295	25	325	14	290	16	290	25	285	39	0
12-Aug	3	0.88	12	14.6	17.2	7.8	9.6	36.4	23.5	13	21.4	1080	54.8	-4.0	-3.4	280	19	295	10	285	9	275	21	275	35	5
13-Aug	2	0.92	13.3	15.8	18.5	11.6	4.8	36.8	28	10	27.4	583	54.7	-3.2	-2.8	285	29	320	17	270	14	300	34	310	56	2
14-Aug	2	0.89	12.5	15.1	18.0	9.1	7.2	26.8	23	11	21.7	346	53	-2.2	-2.4	280	27	310	23	300	21	275	42	275	77	4
15-Aug	-2	0.37	8.5	13.2	16.2	7.5	2.5	10.0	19	5	13	20	43.6	4.3	5.0	10	13	20	13	5	12	350	20	325	79	-2
16-Aug	-3	0.61	12.6	15.1	17.7	10.7	2.3	21.6	25	8	27.4	0	45.2	2.4	3.1	315	28	350	18	315	20	322	35	315	63	-3
17-Aug	-3	0.59	13.6	16.5	19.3	11.8	3.2	12.7	27	8	28.8	0	46.1	1.5	2	330	29	5	19	320	15	335	40	345	40	-3
18-Aug	-2	0.62	15.1	17.8	20.1	11.7	4.5	36.3	28	9	30.7	211	48.5	0.1	0.4	305	10	305	5	290	6	290	10	260	17	-3
19-Aug	1	0.89	14.3	16.6	18.8	11.7	6.5	37.8	28	11	32.1	860	53.5	-3.2	-2.4	280	8	275	5	275	6	250	8	215	22	1
20-Aug	2	0.86	13.8	15.9	18.3	11.6	5.2	37.6	28	11	28.8	994	56.3	-4.1	-3.7	275	17	305	8	275	11	275	14	275	21	4
21-Aug	4	0.89	13.2	15.3	17.6	11	5.5	36.7	28	13.5	29	1336	56.6	-4.6	-3.7	210	14	245	13	225	11	210	28	225	33	4
22-Aug	3	0.88	11.8	14.4	17.3	7.9	8.7	35.0	23	12.5	23.1	812	53.1	-3	-2.3	295	26	330	15	305	19	295	25	290	33	2
23-Aug	4	0.88	10.7	13.2	16.1	6.9	9.8	34.5	21	13	19.8	1266	55.9	-5.1	-3.4	230	18	260	13	220	8	230	33	230	53	4
24-Aug	0	0.47	8.8	10.7	13.0	9	-0.4	25.8	15	3	14.8	266	55.9	-1.6	-1.1	315	27	335	18	310	26	310	25	300	36	0
25-Aug	-1	0.58	10	13.6	15.8	8.2	4.3	13.3	19.5	8	18.7	42	53.5	-1.6	-1	315	25	345	15	315	20	315	20	310	44	-2
26-Aug	-1	0.64	13.1	15.3	17.6	15.6	-5.8	35.1	24	9	29.6	63	50.2	-0.5	0	255	19	270	11	255	14	255	22	270	43	-2
27-Aug	2	0.78	13.6	15.7	17.9	11.5	5.7	42.0	27	12	30.8	578	53.8	-3.2	-1.9	230	25	250	17	210	20	235	28	250	56	-1
28-Aug	-1	0.73	12.4	14.5	16.8	12	1	25.0	26	10	27.7	113	52.6	-1.2	-0.9	225	40	255	28	215	23	235	55	235	99	0
29-Aug	-1	0.55	9.8	11.9	13.9	10	-0.5	16.0	20	5	20.2	109	47.7	2	2.4	285	27	320	18	295	24	295	27	260	55	-1
30-Aug	0	0.65	10.2	12.4	15.1	9.9	0.9	21.0	21	6	20.3	109	52.2	-0.5	-0.1	250	26	270	16	220	9	245	37	250	62	-1
31-Aug	1	0.61	11.8	13.9	16.1	12.1	-0.8	31.0	21	10	25.4	434	55.5	-2.9	-2.5	225	33	250	21	205	20	225	42	235	82	-1

September 2012

2012 Date	Forecast CDC	Precipitable Water (inches)	0°C Level (kft)	-5°C Level (kft)	-10°C Level (kft)	Cloud Base Height (kft)	Cloud Base Temp (°C)	Maximum Cloud Top Height (kft)	Temp. Maximum (°C)	Dew Point (°C)	Conv Temp (°C)	CAPE (J/kg)	Total Totals	Lifted Index	Showalter Index	Cell Direction (deg)	Cell Speed (knots)	Storm Direction (deg)	Storm Speed (knots)	Low Level Wind Direction (deg)	Low Level Wind Speed (kts)	Mid Level Wind Direction (deg)	Mid Level Wind Speed (knots)	High Level Wind Direction (deg)	High Level Wind Speed (knots)	Observed CDC
1-Sep	2	0.48	9.2	10.9	13.0	9.4	-0.6	26.2	16	3	15.7	536	59.3	-3.5	-3	260	26	290	18	270	23	255	27	230	46	2
2-Sep	-2	0.54	10.5	12.3	15.2	11.3	-2.2	15.8	20	2	19	29	50.6	0.5	0.8	300	23	335	15	300	24	295	23	290	22	-2
3-Sep	-2	0.55	8.7	10.7	13.5	11.0	-5.7	14.0	16	2	17	11	42.5	5.6	5.8	295	37	325	25	295	25	295	45	285	52	-1
4-Sep	-1	0.51	9.5	12.4	15.4	9.2	0.7	11.1	18	3	20.4	0	43.7	4.9	5	325	29	355	20	310	24	330	35	330	53	-1
5-Sep	-1	0.78	8.6	11.6	14.4	4.5	8.1	14.0	12	10	12.4	59	50.1	0.4	1.6	310	25	335	16	335	16	290	26	290	59	-1
6-Sep	-2	0.49	9.2	12.9	15.9	7.6	3.8	11.8	19	6	14.9	33	46.8	2.6	2.9	35	12	60	11	355	6	30	21	45	81	-3
7-Sep	-3	0.71	14.8	17.5	19.8	8.8	6.9	9.2	24	10	33.8	0	41.6	2.3	4.4	305	32	345	19	310	25	315	33	320	32	-3
8-Sep	-1	0.65	14.7	17.1	19.3	12.8	3.8	39.7	27	10	33.4	115	47.5	0.4	1.0	225	12	260	11	250	8	235	23	250	30	-2
9-Sep	2	0.87	11.4	13.7	16.2	9.6	5.0	33.0	24	10	24.3	816	52.9	-3.4	-1	235	26	265	19	245	21	230	30	220	54	2
10-Sep	3	0.57	10.9	12.6	14.3	10.6	0.8	30.0	21	5	15.8	817	60.7	-4.7	-4.8	250	28	273	24	260	27	235	39	235	71	3
11-Sep	0	0.27	8.5	10.2	11.9	12.1	-10.6	20.0	14	-6	11.2	126	55.9	-1	-0.9	305	23	245	21	205	23	315	27	300	42	-1
12-Sep	-3	0.47	9.9	12.5	16.4	12.2	-4.7	15.4	18	-2	27.4	0	38.4	7.3	7.4	325	41	355	28	315	24	325	51	345	74	-3
13-Sep	-3	0.6	11.7	14.6	17.3	11.3	0.6	13.7	24	6	25.3	0	48.4	1.3	1.5	280	26	310	16	280	19	290	34	280	31	-3
14-Sep	-1	0.51	16.9	14.4	16.9	12.8	-1.8	31.7	27	5	27.7	304	52.5	-1.1	-0.7	275	31	305	20	280	20	270	38	270	48	-3
15-Sep	-2	0.61	10.9	13	15.2	15.3	-10.3	19.1	19.5	2	22.2	9	52.3	0.0	0.2	280	26	315	15	290	13	285	33	275	53	-2

Average	1	0.8	11.8	14.1	16.6	9.1	5.4	29.6	22.3	10.0	22.3	656.7	53	-2.1	-1.4	254	21.7	262	14.4	253	15.9	259	26.1	246	46.0	1.0
StdDev	2	0.2	2.0	2.7	3.3	2.1	4.9	8.9	4.3	4.3	5.1	571.6	4	2.6	2.6	66	8.9	85	6.5	68	7.3	53	12.1	59	23.8	2.4
Maximum	4	1.5	16.9	17.8	20.1	15.6	15.3	42.0	31.0	18.0	33.8	2384	61	7.3	7.4	360	43.0	360	35.0	360	34.0	355	65.0	345	102.0	5
Minimum	-3	0.3	8.1	-5.0	-10.0	2.9	-10.6	9.2	12.0	-6.0	11.2	0	38	-6.9	-6.0	5	2.0	5	1.0	5	1.0	30	5.0	10	2.0	-3

Appendix J – Project Personnel and Telephone List

ALBERTA HAIL SUPPRESSION PROJECT 2012			
			Last Revised 20 August, 2012
ALBERTA SEVERE WEATHER MANAGEMENT SOCIETY (ASWMS) - CALGARY, ALBERTA			
TODD KLAPAK	ASWMS Board President #1300-321 6th Ave. SW Calgary, AB T2P 0P6	Office: 403-231-1357 Fax: 403-233-2815	todd.klapak@intact.net
CATHERINE JANSSEN	ASWMS Secretary-Treasurer		janssenc@telus.net
TERRY KRAUSS	ASWMS Program Director President, Krauss Weather Services, Inc. 79 Irving Crescent, Red Deer, AB T4R 3S3	Cell: 403-318-0400	twkrauss@gmail.com
WEATHER MODIFICATION, INC. (WMI) - FARGO, NORTH DAKOTA PHONE: 701-235-5500 FAX: 701-235-9717			
BRUCE BOE	Director of Meteorology Weather Modification, Inc. 3802 20th Street North, Fargo, ND 58102	Direct Office: 701-673-3354	bboe@weathermodification.com
HANS AHLNESS	Vice President - Operations Weather Modification, Inc.	Direct Office: 701-373-8834	hahlness@weathermodification.com
ERIN FISCHER	Admin Support Weather Modification, Inc.	Direct Office: 701-373-8829	efischer@weathermodification.com
DENNIS AFSETH	Director of Electronics Weather Modification, Inc.	Office: 701-235-5500 ext. 190/193	dafseth@weathermodification.com
TODD SCHULZ	Electronics Technician Weather Modification, Inc.	Office: 701-235-5500	tm_schulz@yahoo.com
MIKE CLANCY	Director of Maintenance Weather Modification Inc.	Direct Office: 701-373-8841	mclancy@fargojet.com
RANDY JENSON	CFO Weather Modification, Inc.	Office: 701-235-5500 ext. 103	rjenson@weathermodification.com
PATRICK SWEENEY	President/CEO Weather Modification, Inc.	Office: 701-235-5500 ext.107	pat@weathermodification.com
JAMES SWEENEY	Vice President Weather Modification, Inc.	Office: 701-235-5500 ext.102	jim@weathermodification.com
RADAR OPERATIONS CENTER - OLDS-DIDSBURY AIRPORT, ALBERTA			
RADAR FAX: 403-335-8359 RADAR PHONE: 403-335-8359 ADDRESS: 1436, 320 Bergen Rd., Hangar 4, Didsbury, Alberta T0M 0W0 EMAIL: olds@weathermodification.com			
DAN GILBERT	Chief Meteorologist Weather Modification, Inc.		dgilbert@weathermodification.com
BRAD WALLER	Field Meteorologist Weather Modification, Inc.		bwaller@weathermodification.com
JOE PEHOSKI	Field Meteorologist Weather Modification, Inc.		joepeho@gmail.com
PILOT OFFICE - CALGARY, ALBERTA			
PILOT OFFICE: 403-247-0001 ADDRESS: Springbank Aero Services, Inc. 208A Avro Lane, Calgary, Alberta T3Z 3S5 EMAIL: calgary@weathermodification.com			
JODY FISCHER	Project Operations Manager		jfischer@weathermodification.com
BROOK MUELLER	Pilot Weather Modification, Inc. N904DK, N457DM		brookmueller@yahoo.com
MARK FRIEL	Pilot Weather Modification, Inc. N904DK, N457DM		marksfriel@gmail.com
JENNY THORPE	Pilot Weather Modification, Inc. N457DM		jennythorpe@me.com
JENELLE NEWMAN	Co-Pilot Weather Modification, Inc. N904DK, N457DM		jenelle401@hotmail.com
HING KWOK	Co-Pilot Weather Modification, Inc. N904DK, N457DM		hingluenkwok@yahoo.ca

PILOT OFFICE - RED DEER, ALBERTA			
PILOT OFFICE: 403-886-7857 ADDRESS: Hangar #2 Red Deer Ind Airport, Penhold, Alberta, T0M 1R0 EMAIL: reddeer@weathermodification.com			
ROGER TILBURY	Pilot Weather Modification, Inc.		rtilb34292@aol.com
	N522JP		
JOEL ZIMMER	Co-Pilot Weather Modification, Inc.		pro_pilotage@hotmail.com
	N522JP, N123KK		
MATTHIAS MOREL	Co-Pilot Weather Modification, Inc.		matthias.morel@gmail.com
	N522JP, N123KK		
JACOB EEUWES	Pilot Weather Modification, Inc.		jeeuwes@hotmail.com
	N123KK		
ADDITIONAL SUPPORT SERVICES			
SPRINGBANK FUEL TRUCK afterhours		Phone: 403-466-8834	
AIR SPRAY - PERRY DANCAUSE	Director of Flight Ops and Administration	Phone: 403-886-4088 Ext.102 Fax: 403-886-2650	
ATC EDMONTON OSS	Notification to Launch Aircraft	Phone: 888-882-2254	
ATC SHIFT MANAGER EDMONTON		Phone: 780-890-8397 Fax: 780-890-4710	
ATC CALGARY TERMINAL SUPERVISOR		Phone: 780-890-4711	
ATC CALGARY TOWER		Phone: 403-216-7121 Fax: 403-216-7122	
Calgary International Airport	Duty Manager Desk	Phone: 403-735-1200	
STORM WATCH HOTLINE	Severe Weather Desk: 800.239.0484	Phone: 800-66-STORM (800-667-8676)	
RED DEER AIRPORT FLIGHT SERVICE		Phone: 403-886-4547	
SKY WINGS (DENNIS COOPER)	Red Deer Fuel (JET-A)	Phone: 403-886-5191	
HILLMAN AIR LTD (GARY HILLMAN)	Red Deer Fuel (100LL)	Phone: 403-886-4187	
Dave Civil (COMTEL Electric Ltd.)	Radar Technician	Phone: 403-638-6796	comtelelectric@yahoo.com
NOT FOR PUBLIC RELEASE			

ALBERTA HAIL SUPPRESSION PROJECT
FINAL OPERATIONS REPORT 2016

A Program Designed for Seeding Convective Clouds
With Glaciogenic Nuclei to Mitigate Urban Hail Damage
in the Province of Alberta, Canada

by

WEATHER MODIFICATION
INTERNATIONAL

Weather Modification LLC
3802 20th Street North
Fargo, North Dakota
U.S.A. 58102

for the

Alberta Severe Weather Management Society
Calgary, Alberta
Canada

JANUARY 2017

EXECUTIVE SUMMARY

This report summarizes the activities during the 2016 field operations of the Alberta Hail Suppression Project. This was the twenty-first season of operations by Weather Modification LLC, dba Weather Modification International (WMI) of Fargo, North Dakota, under contract with the Alberta Severe Weather Management Society (ASWMS) of Calgary, Alberta. This season was the first season of the latest 5-year contract cycle for this on-going program; WMI has been the contractor since operations began in 1996. The program was again directed for the ASWMS by Dr. Terry Krauss. The program continues to be funded entirely by private insurance companies in Alberta with the sole intent to mitigate the damage to urban property caused by hail.

The cloud-seeding contract with WMI was renewed in 2001, 2006, 2011, and again in 2016. Calgary, Red Deer and many of the surrounding communities have seen significant growth in population and area since 1996. Calgary's population exceeded 1 million in 2006, and property values have more than doubled since the program's inception. In 2008 it was estimated that a hail storm similar to that which caused $400 million damage in Calgary in 1991 would now cause more than $1 billion damage. New record Alberta hailstorms have recently occurred in 2009 and 2010, and in 2012, a severe storm that struck Calgary on August 12 caused more than $500 million dollars damage, indicating that a billion dollar storm within Calgary is certainly now possible.

Springbank Airport (CYBW) continued to be the southern operational base in 2016. The project design has remained the same throughout the period, but a fourth seeding aircraft (Hailstop 4) was added to the project in the summer of 2008 to increase seeding coverage on active storm days. In 2013, a fifth aircraft (Hailstop 5) was added, which is another twin-engine turboprop King Air, the same model aircraft as Hailstop 1 and 3 have been in recent seasons. This fifth aircraft was based in Springbank with Hailstop 1 and Hailstop 2. Hailstop 3 and Hailstop 4 were once again based at the Red Deer Regional Airport (CYQF).

The program was operational from June 1st to September 15th, 2016. Only storms that posed a hail threat to an urban area, as identified by the project's weather radar situated at the Olds-Didsbury Airport, were seeded. The project target area covers the region from High River in the south to Ponoka in the north, with priority given to the two largest cities of Calgary and Red Deer. The project area is shown in Figure 4.

Seven industry-accredited tours of the operations centre located at the Olds-Didsbury Airport were conducted for insurance brokers and insurance company staff. At each, a lecture on the history and science of the hail suppression program was given, the radar facility was explained and demonstrated, and one of the five Hailstop aircraft flew in to provide first-hand observation of the seeding equipment and allow some interaction with a flight crew. A total of 152 attended in the course of the 2016 tours.

Hail was reported within the project area (protected area and buffer area) on 69 days. Larger-than-golf ball size hail was reported on July 3rd in Carseland; the 18th of July east of Rocky Mountain House; July 30th in Calgary; and on August 16th west of Didsbury.

Golf ball size hail was reported or observed by radar signature on June 7th east of Didsbury and on July 1st near Linden.

Walnut size hail was reported or observed by radar signature on June 8th northwest of Ponoka; June 28th west of Calgary and near Okotoks; the 30th of June in Calgary; in Lacombe on July 8th; on the 9th of July northeast of Cochrane; July 12th in Calgary; on July 28th in Calgary; on the 31st of July in Okotoks; and in Calgary on September 2nd.

The weather pattern during the summer of 2016 was less intense than the previous summer, but actually had more days with seeding missions, 35, compared to 26 in 2015. The twenty-one season average is about 31. Of those 35 days, all five Hailstop aircraft flew on six days, and all five aircraft seeded on five of those six days.

In June, 31 seeding missions were flown on 10 days, and an additional six flights flown for patrol on four days. 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.

July was the most active month. Fifty-four seeding missions were flown on 14 days, and 12 more patrol flights on 10 days. The most heavily-seeded day of the season occurred on June 28th when a multicell thunderstorm complex developed as a wave moved off the foothills and into the Calgary area, impacting Calgary and most of the adjacent communities. Storms on July 30th required only slightly less seeding. However, this July storm was even more energetic than the June 28th storm. A number of intense but quasi-isolated cells developed first northwest and later west, of Calgary, before merging into a large convective complex as it passed east of the QE2. A detailed analysis of the July 30th storm is provided in this report.

Activity diminished after the first half of August. A total of 29 seeding missions were flown during the month, all but three on or before August 16th. Three aircraft flew seeding missions on August 31st. The final seeding mission was flown on September 5th; the heavy storms had ended for the season.

There were thunderstorms reported within the project area on 84 days during the summer of 2016, compared with 64 days in 2015. Hail fell on 69 days. During this season, there were 277.1 hours flown on 38 days with seeding and/or patrol operations. A total of 96 storms were seeded during 115 seeding flights on the 35 seeding days. There were 24 patrol flights, and 12 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. The distribution of flight time by purpose is given in Figure 23.

The amount of silver-iodide nucleating agent dispensed during the 2016 field season totaled 294.9 kg. This was dispensed in the form of 6,496 ejectable (cloud-top) flares (129.9 kg seeding agent), 1000 burn-in-place (cloud-base and cloud top) flares (150.0 kg seeding agent), and 246.9 gallons of silver iodide seeding solution (15.0 kg seeding agent).

Five specially equipped cloud seeding aircraft were dedicated to the project. Two Beech C90A King Airs and one Cessna 340A were based in Springbank, and a C90A and another C340A were based in Red Deer. The procedures used in 2016 remained the same as the previous years. The Springbank office and aircraft were at Springbank Aero Services, at that airport. The WMI Red Deer office was again set up in the Air Spray hangar at the Red Deer Regional Airport, as had been done in the five previous seasons.

The aircraft and crews provided a 24-hour service, seven days a week throughout the period. Twelve 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 project manager. The 2016 crew was very experienced. The Red Deer aircraft team was led by Mr. Mike Torris, Ms. Jenelle Newman, and Mr. Kyle Melle, and Mr. Joel Zimmer who has been with the Alberta program for 14 seasons. The Springbank team was anchored by Mr. Jody Fischer and Mr. Brook Mueller. The radar crew was anchored by WMI's Chief Meteorologist, Mr. Daniel Gilbert, now with seven 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 well and there were no interruptions or missed opportunities. A radar calibration prior to the project season ensured that the radar was calibrated correctly for the 2016 operations. Another calibration at season end confirmed that the radar had remained stable throughout the season.

High speed Internet service was once again obtained at the Springbank and Red Deer offices for the pilots so that they could closely monitor the storm evolution and storm motion using the radar images on the web prior to take-off. 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) continued examination of the data set in the off season prior to the 2017 program.

ACKNOWLEDGEMENTS

WMI acknowledges the continuing, kind support of Todd Klapak, Catherine Janssen, Dr. Terry Krauss, and the entire Board of Directors of the Alberta Severe Weather Management Society (ASWMS). The understanding, support, and cooperation of the ASWMS are greatly appreciated.

A number of organizations and people deserve recognition and thanks. The cooperation of these persons and agencies is very important in making the project successful, in positive working environments.

- Edmonton Area Control Center and Calgary Terminal Air Operations. The excellent cooperation by the ATC once again played a very important role in allowing the project pilots to treat the threatening storms in an efficient and timely manner as required, often directly over the city of Calgary.
- For the twenty-first season, special thanks go to Bob Jackson for sharing his office and hangar at the Olds-Didsbury airport, used for the radar and communications control center.
- Sarah Newell (AVIVA Canada) is thanked for organizing the seven informational seminars that were conducted at the Olds radar this summer as part of the Alberta Insurance Council accreditation program.
- Perry Dancause, Dennis Nava, and the staff of Air Spray Ltd are sincerely thanked for providing offices, ramp space, and timely reliable aircraft maintenance this season at the Red Deer Airport.
- Gary Hillman of Hillman Air is thanked for allowing WMI to use his self-serve fuel tank at the Red Deer Regional Airport.
- The staff of Springbank Aero is thanked for providing office space, ramp space, and other operational support to the project at the Springbank Airport.

Weather Modification International wishes to acknowledge the contributions of the staff who served on the project during the summer of 2016: project manager Jody Fischer, meteorologists (Dan Gilbert, Brad Waller, and Adam Brainard), electronics-radar technicians (Barry Robinson and Todd Schulz), pilots in command (Francisco Santana, Brian Kindrat, Andrew Brice, Michael Torris, Brook Mueller, Kyle Melle, and Jenelle Newman); and the co-pilots (Joel Zimmer, Jacob Eeuwes, Christian Avram, Hing Kwok, and Richard Oxlade). The staff performed very well as a team. The support of the WMI corporate head office in Fargo, North Dakota is also acknowledged, specifically, the efforts of Erin Fischer, Cindy Dobbs, Neil Brackin, James Sweeney, Randy Jenson, Hans Ahlness, Bruce Boe, Dennis Afseth, Mike Clancy and Mark Grove are greatly appreciated.

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1. INTRODUCTION

Hail has long been a problem for both agriculture and municipalities in the Province of Alberta. Figure 1 shows the average number of hail days throughout Canada. It is notable that there is a bullseye on the area from Calgary to Red Deer, which also coincides with the greatest population density of the province, which continues to increase. In 1956, under the guidance of the Alberta Research Council, a research program was undertaken that sought to develop and evaluate the effectiveness of cloud seeding from aircraft to mitigate crop-hail damage. Though never "operational", the program continued to research the hail problem and ways to reduce the hail impact on agriculture until 1985, when it was discontinued.

The hail problem did not end with the hail research program, and in 1991 a severe hailstorm caused several hundred million dollars damage in the City of Calgary and adjacent metropolitan areas. This storm, though by no means the first of its kind, was of sufficient magnitude to rekindle interest in hail damage mitigation through cloud seeding.

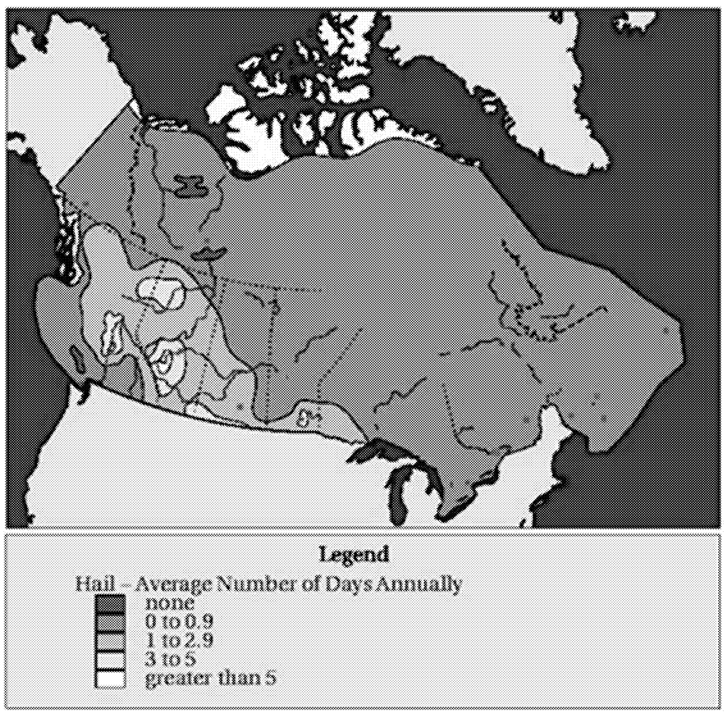


Figure. 1. The hail climatology of Canada, from Etkin and Brun (1999). The average number of hail days per year, based on the 1951-1980 climate normal of Environment Canada (1987).

A consortium of underwriters of property and casualty insurance in Alberta was formed in the wake of the 1991 Calgary storm, and named itself the Alberta Severe Weather Management Society (ASWMS). From its formation, the ASWMS was focused on establishing a renewed Alberta Hail Suppression Program through cloud seeding, but this time, the focus was to be on protecting municipalities, not crops. The necessity for such a program was presented to the Insurance Bureau of Canada (IBC), and though the IBC was encouraging it offered no financial support. The Province of Alberta was itself approached for funding of the program. Though the need was acknowledged by the provincial leaders funding was not forthcoming.

In 1995 the ASWMS developed a protocol through which its members would pay into a common project fund, amount proportional with market share, and the current Alberta Hail Suppression Project finally became possible. An international tender was issued, and Weather Modification, Inc. (WMI) was awarded an initial five-year contract to conduct operations from June 15 through September 15 each summer, beginning in 1996.

The goal of the project from the beginning has been the protection from the ravages of hailstorms to property concentrated in urban areas, to the maximum extent technology and safety will allow. The two largest such areas within the project target area are Calgary and Red Deer, but there are dozens of additional cities and towns that also warrant attention. To do this, the project established a weather radar and Operations Centre at the Olds-Didsbury Airport, approximately halfway between the two largest metropolitan areas. Two aircraft were based in Calgary, a third in Red Deer. At the conclusion of the initial five-year period the contract between the ASWMS and WMI was renewed for a second 5-year period (2001-2005), a third (2006-2010), in 2011, a fourth, and now, in 2016, a fifth.

Seven significant changes have been made to the project scope during the first twenty seasons. Early on (season 2) it was recognized that the hail problem begins earlier in the year than June 15, so since 1998, the project has begun each season on June 1.

Beginning in the 2006 season the protected area was expanded somewhat to the east, to include the town of Strathmore and communities east of Calgary.

The third change did not occur until the 13th season, 2008. The unrelenting expansion of the metropolitan areas within the project area meant increasing risk, and a fourth cloud seeding aircraft was added to the project. This aircraft is based in Red Deer.

The fourth change was the replacement in 2011 of an aging WR-100 weather radar with a new set built by WMI. This radar possessed significantly increased sensitivity which meant that clouds could be detected sooner than they were previously (earlier in their development), and Doppler capability meant that internal storm motions could also be observed.

Figure. 2. An early-season thunderstorm brings rain on the evening of June 8th, 2016. (WMI photograph by Andrew Brice.)

The fifth change was implemented in 2013, with the addition of a fifth aircraft to the project, another King Air, based at the Springbank Airport.

The sixth significant change occurred in 2014, with the replacement of the 2011 Doppler radar with an even-newer Doppler weather radar. This newest Doppler weather radar was installed in May, prior to the 2014 project start. Improvements, in addition to the new transmitter and receiver, included a new antenna pedestal. The pedestal precisely rotates and elevates the radar antenna. This new radar system was developed and is supported by Advanced Radar Corporation (ARC), of Boulder, Colorado. During 2012 and 2013 there were pedestal drive failures that had to be repaired "on the fly", while operations were imminent. Though operations those seasons were not compromised, the upgrade included the new pedestal in part to avoid any further gear failures. Improvements realized from the radar included implementation of the latest version of the TITAN radar software, state-of-the-science radar antenna control, and improved data processing. The last allowed the time required for each volume scan to be decreased from five to less than four minutes, which meant the radar updated 15 times per hour, rather than 12. In addition, the porting of data to the WMI website was also improved.

The most recent and seventh significant modification to the program occurred in 2016, when the northern border of the protected area was pushed north a short distance to include Ponoka in the protected area. Ponoka had previously been in the buffer area, and this modification allows protection without any uncertainty.

This final operations report summarizes, in detail, all the activities during the 2016 field operations of the Alberta Hail Suppression Project, the twenty-first summer of operations.

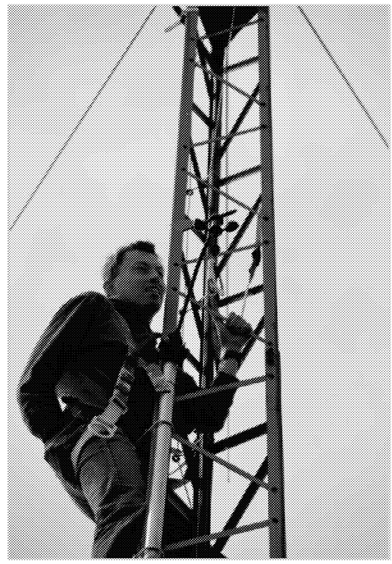


Figure 3. Meteorologist Brad Waller replaces the hail-damaged anemometer cups on the WMI weather station wind sensor on June 24th, 2016. To reduce the effects of surface features, the wind sensor is elevated, affixed to the non-directional radio beacon (NDB) tower at the Olds-Didsbury Airport. (WMI photograph by Adam Brainard.)

2. THE 2016 FIELD PROGRAM

The project conducted operations to mitigate hail storms threatening cities and towns from June 1st through September 15th, 2016. Only those storms posing hail threats to an urban area were treated by the project aircraft. The project target area covers the region from High River in the south to Ponoka in the north, with priority given to the two largest cities of Calgary and Red Deer.

The program utilizes the latest cloud seeding technology available, incorporating several notable improvements over previous projects in the province. These improvements include:

- Fast-acting, high-yield mixtures for the silver-iodide flares and the liquid seeding solution. The flares are manufactured by Ice Crystal Engineering (ICE) of Kindred, North Dakota. The new generation ICE pyrotechnics produce $>10^{11}$ ice nuclei per gram of AgI active at a temperature of -4°C, and produce between 10^{13} and 10^{14} ice nuclei per gram of pyrotechnic active between cloud temperatures of -6°C and -10°C. Colorado State University (CSU) isothermal cloud chamber tests (DeMott 1999) indicate that at a temperature of -6.3°C, 63% of the nuclei are active in <1 min, and 90% active within 68 seconds. This high-yield, fast-acting agent is important for hail suppression since the time window of opportunity for successful intervention of the hail growth process may be less than 10 minutes for each maturing cloud turret.
- Use of the latest GPS tracking and advanced TITAN (Thunderstorm Identification Tracking Analysis and Nowcasting) computer software to accurately display the aircraft locations on the radar displays to improve the controlling of aircraft and facilitate the direction of seeding operations to the most critical regions of the storms.
- Injection of the seeding material directly into the developing "feeder" cloud turrets as the most frequent seeding method.
- Use of experienced meteorologists and pilots to direct the seeding operations.
- Sensitive, state-of-the-science Doppler weather radar.

In 2016, the target area was increased slightly northward to include the town of Ponoka. Five aircraft specially equipped to dispense silver iodide were used. Three aircraft (two Beech King Air C90s and one Cessna 340, or C340) were based in Springbank west of Calgary, and two aircraft (one Beechcraft King Air C90 and one C340) were based in Red Deer. The radar remained located at the Olds-Didsbury airport. The radar coordinates are 51.71 N latitude, 114.11 W longitude, with a station elevation of 1024 m above sea level. The WMO station identifier is 71359, and the ICAO identifier is CEA3. The protected project area dimension is approximately 242 km (N-S) by 97 km (E-W) or 23,474 km^2.

3. PROJECT OBJECTIVES

The project has two main objectives:

- To conduct cloud seeding operations to suppress hail and reduce property damage, and
- To develop a data archive that may eventually be used for the scientific assessment of the program's effectiveness.

The first of these objective is to utilize the five aircraft and experienced pilots and meteorologists to recognize potential threats and react appropriately. The second is being achieved through the operation of a C-band Doppler weather radar with full archival, and the collection of other weather information by project meteorologists. These efforts include the comprehensive archival of all project decision records, as well as a wealth of additional weather data from the internet and other sources.

The project operations area is illustrated in Figure 4. The boundaries of flight operations (actual seeding) are indicated by the broad yellow line, which actually includes the foothills of the Rocky Mountains, west of the protected area. This "buffer" area is very important, for the foothills are an important zone for storm genesis. The broad green line denotes the boundary of the protected area, *i.e.*, storms threatening any of the communities within this area will be seeded, as resources allow, with priority assigned according to population.

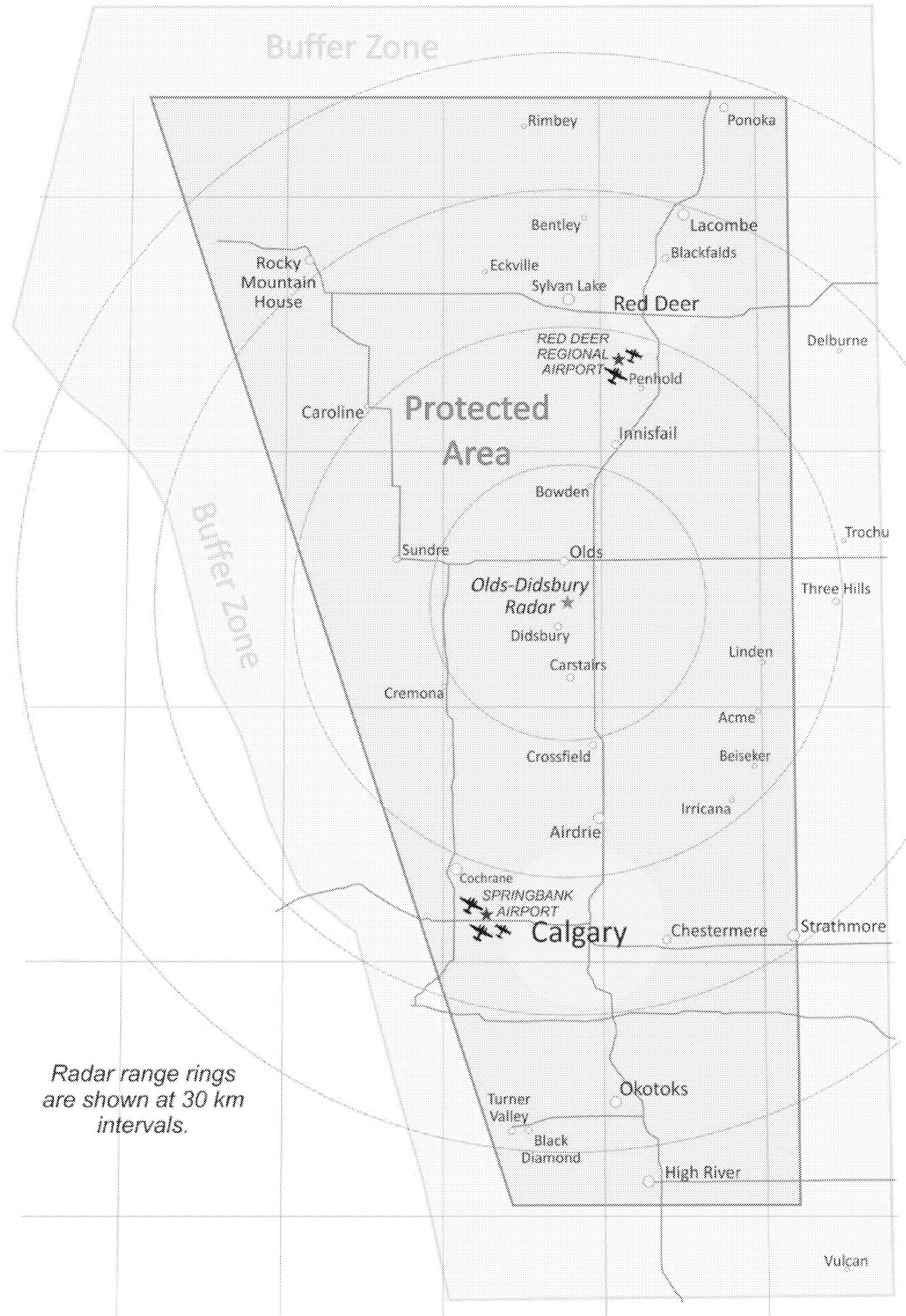


Figure 4. A map of southern Alberta showing the project protected area. The major cities and towns in and near the protected area are shown, along with the location of the Olds-Didsbury Operations Centre (red star). Aircraft bases as shown by aircraft symbols.

4. PRIORITIES

Cities and towns are protected according to priority and proximity of aircraft, with greatest attention given to Calgary and Red Deer. Priority is determined based on rank in population, as shown in Table 1, below.

AHSP Priority List Based on City Population

Priority	City/Town Name	Population as of		Population Change as of 2014		
		1996	2014	From 2011	Since Project Start (1996)	
					Percentage	More People
1	Calgary	767,059	1,195,194	9.0%	55.8%	428,135
2	Red Deer	59,834	98,585	8.9%	64.8%	38,751
3	Airdrie	14,506	54,891	29.0%	278.4%	40,385
4	Okotoks	7,789	27,331	11.5%	250.9%	19,542
5	Cochrane	6,612	20,708	17.8%	213.2%	14,096
6	Chestermere	1,603	17,203	16.0%	973.2%	15,600
7	Sylvan Lake	4,815	13,015	5.6%	170.3%	8,200
8	High River	6,893	12,920	0.0%	87.4%	6,027
9	Lacombe	7,580	12,728	8.7%	67.9%	5,148
10	Strathmore	5,273	12,352	0.4%	134.2%	7,079
11	Olds	5,542	8,617	4.6%	55.5%	3,075
12	Innisfail	6,064	7,922	0.6%	30.6%	1,858
13	Blackfalds	1,769	7,858	24.7%	344.2%	6,089
14	Rocky Mountain House	5,684	7,300	5.3%	28.4%	1,616
15	Ponoka	5,861	6,773	3.0%	15.6%	912
16	Didsbury	3,399	4,957	0.0%	45.8%	1,558
17	Turner Valley & Black Diamond	3,269	4,540	0.0%	38.9%	1,271
18	Carstairs	1,796	3,442	0.0%	91.6%	1,646
19	Crossfield	1,800	2,918	2.3%	62.1%	1,118
20	Penhold	1,609	2,842	19.7%	76.6%	1,233
21	Sundre	2,027	2,695	3.3%	33.0%	668
22	Bowden	936	1,241	0.0%	32.6%	305
23	Irricana	822	1,162	0.0%	41.4%	340
24	Eckville	899	1,125	0.0%	25.1%	226
25	Bentley	930	1,122	4.6%	20.6%	192
26	Beiseker	640	785	0.0%	22.7%	145
27	Linden	563	725	0.0%	28.8%	162
28	Acme	590	653	0.0%	10.7%	63
29	Caroline	452	501	0.0%	10.8%	49
30	Cremona	393	457	0.0%	16.3%	64
	Total Population In Protected Urban Areas	927,009	1,532,562	3.0%	65.3%	605,553

Table 1. AHSP Priority List Based on City Population.

Since 2011 Calgary has grown another 9.0%, Red Deer 8.9%, Airdrie 29.0%, Okotoks 11.5%, Cochrane 17.8% and Chestermere 16%. Most storms are not seeded after they cross the QE II highway, except for storms east of Airdrie and Calgary that might threaten Strathmore. Since the project start in 1996 urban population growth within the protected area has increased by 65.6%.

5. THE SCIENTIFIC BASIS FOR HAIL SUPPRESSION

Hail is formed when small ice particles known as hail embryos are held aloft by strong thunderstorm updrafts within regions of unfrozen supercooled cloud water. This supercooled cloud water is collected by the hail embryos and freezes to them, resulting in growth to hail (greater than 5 mm diameter) sizes. Growth continues until (1) the supporting updraft weakens, (2) the in-storm motion of the growing hailstone moves it to the downdraft side from whence it can fall, or (3) the hailstone grows so large that the updraft can no longer support it. In most situations the subcloud layer is relatively warm (much warmer than 0°C) so hailstones begin to melt during the final portion of their plummet to earth, but in many cases the hailstones are too large for melting to be complete, and hail reaches the ground.

5.1 THE FORMATION OF HAIL

Understanding of the development of hail includes knowledge gained from work in Alberta by Chisholm (1970), Chisholm and Renick (1972), Marwitz (1972a, b, and c), Barge and Bergwall (1976), Krauss and Marwitz (1984), and English (1986). Direct observational evidence from the instrumented aircraft penetrations of Colorado and Alberta storms in the 1970s and early 1980s indicates that hail embryos grow within the evolving main updraft of single cell storms and within the updrafts of developing feeder clouds (the cumulus towers) that flank mature multi cell and supercell storms (see *e.g.* Foote 1984, Krauss and Marwitz 1984). The computation of hail growth trajectories within the context of measured storm wind fields provided a powerful new tool for integrating certain parts of hail growth theories, and illustrated a striking complexity in the hail growth process.

Figure 5. Dan Gilbert, WMI Chief Meteorologist, directs seeding aircraft from the operations centre via VHF radio at 9:39 PM on July 1, 2016. The storm of interest was located just west of the Olds-Didsbury Airport at the time. (WMI photograph by Bradley Waller.)

Some of this complexity is reviewed in the paper of Foote (1985) that classifies a broad spectrum of storm types according to both dynamic and microphysical processes thought to be critical to hail production. Small precipitation embryos that eventually grow into hailstones are called hail embryos.

Hail embryo sources identified by Foote (1985) include the following:

- Embryos from first-ice in a time-developing updraft
- Embryos from first-ice in the core of a long-lived updraft
- Embryos from flanking *cumulus congestus*
- Embryos from a merging mature cell
- Embryos from a mature cell positioned upwind
- Embryos from the edges of the main updraft
- Embryos created by melting and shedding
- Embryos from entrainment of stratiform cloud
- Embryos from embedded small-scale updrafts and downdrafts
- Recirculation of embryos that have made a first pass through the updraft core

Hail embryos grow into hailstones by collecting unfrozen, supercooled liquid water through collisions. This water freezes to the already-frozen embryo, increasing the size, weight, and fall speed, and also the potential for damage at the surface. This growth to large hail is theorized to occur primarily along the edges of the main storm updraft where the merging feeder clouds interact with the main storm updraft (WMO 1995). However, the mature hailstorm most certainly consists of complicated airflow patterns and particle trajectories.

Studies of the internal structure of large hailstones in Alberta and elsewhere have shown that hailstones can have either a graupel (snow pellet) embryo or a frozen drop embryo. The different hail embryos indicate different growth histories and trajectories and illustrate the complexity within a single hailstorm.

5.2 HAIL SUPPRESSION CONCEPTS

The hail suppression conceptual model utilized in the Alberta Hail Suppression Project is based on the results of the former research program of the Alberta Research Council and the experiences of WMI in the USA, Canada, Argentina, and Greece. It involves the use of glaciogenic (ice-forming) materials to seed the developing feeder clouds in the -5 to -10°C zone in the upshear, new growth "propagation" region of hailstorms. The glaciogenic reagents initiate the rapid development of small ice particles through the condensation-freezing nucleation process, and thus produce enhanced concentrations of ice crystals that compete for the available, supercooled liquid water in storms. This helps prevent the growth of large, damaging hail.

Figure 6. This pedestal cloud at the base of a mature cumulonimbus (thunderstorm) was observed from Hailstop 4 on 16 August 2016, at 9:01 PM MST. Pedestal clouds indicate the presence of strong, well-organized storm updrafts, the kind that can grow large hail. (WMI photograph by Jenelle Newman.)

The seeding also stimulates the precipitation process by speeding the growth of ice-phase hydrometeors, initially into snow pellets (also called graupel) which fall from the cloud earlier, melt, and reach the ground as rain, instead of continuing to grow into large ice particles that reach the ground as damaging hail.

The present seeding methodology modifies the graupel embryo hail development process. Frozen drop hail embryos are thought to originate from secondary sources (shedding from large existing hailstones, or via a recirculation process at the edge of the main updraft). Cloud seeding can only reduce the hail that grows from frozen drop embryos if the available liquid water can be reduced to limit their growth, or if the dynamics of the storm can be affected to eliminate the recirculation processes that formed the drop embryo in the first place. Both are extremely complex, and are not the primary focus of the Alberta project.

The governing premise of the Alberta cloud seeding operations is the cloud microphysical concept called beneficial competition. The premise of beneficial competition is that the well-documented natural deficiency of ice nuclei (ice-forming particles) in the atmosphere can be corrected by the release of additional ice nuclei (glaciogenic seeding material) into developing storm clouds. This is done by the combustion of small amounts of reagent and/or solutions containing silver iodide (AgI), either as pyrotechnics (flares) or from wing-borne solution-burning ice nucleus generators (Figure 7). With either method, from 10^{13} to 10^{14} (or from 10,000,000,000,000 to 100,000,000,000,000) ice nuclei are produced for each gram of silver iodide burned, *e.g.*, see Figure 13. This potentially increases greatly the number of precipitation embryos in the cloud. These natural and human-made ice crystals, many of which become precipitation, then "compete" for the available supercooled liquid cloud water within the storm. Because the total amount of supercooled liquid remains essentially unchanged, that same mass is divided among the increased number of embryos, meaning the final maximum size of each individual ice particle is significantly decreased. Hence, the hailstones that form within seeded clouds will be smaller and produce less damage if they should survive the fall to the surface. If they are sufficiently small, they will melt completely in the warmer subcloud layer and reach the ground as rain.

Figure 7. A wing-tip generator on Hailstop 4 produces ice nuclei in the inflow region of a thunderstorm west of Sylvan Lake on 23 June 2016, at 8:44 PM. (WMI photograph by Richard Oxlade.)

Cloud seeding alters the microphysics of the treated clouds, assuming that the existing precipitation process is inefficient due to a lack of natural ice nuclei. This deficiency of natural ice has been documented in the new growth zone of Alberta storms (Krauss 1981). Cloud seeding does not alter directly the energy or dynamics of the storm. Any alteration of the storm dynamics that does occur results as a consequence of the increased ice crystal concentrations and the development of additional precipitation-sized ice particles earlier in the cloud's lifetime. 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, amount, and the extent of the area affected by hail.

A schematic diagram of the conceptual storm model showing the hail origins and growth processes within a hailstorm is shown in Figure 8. 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 or determine by measurements with confidence 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.

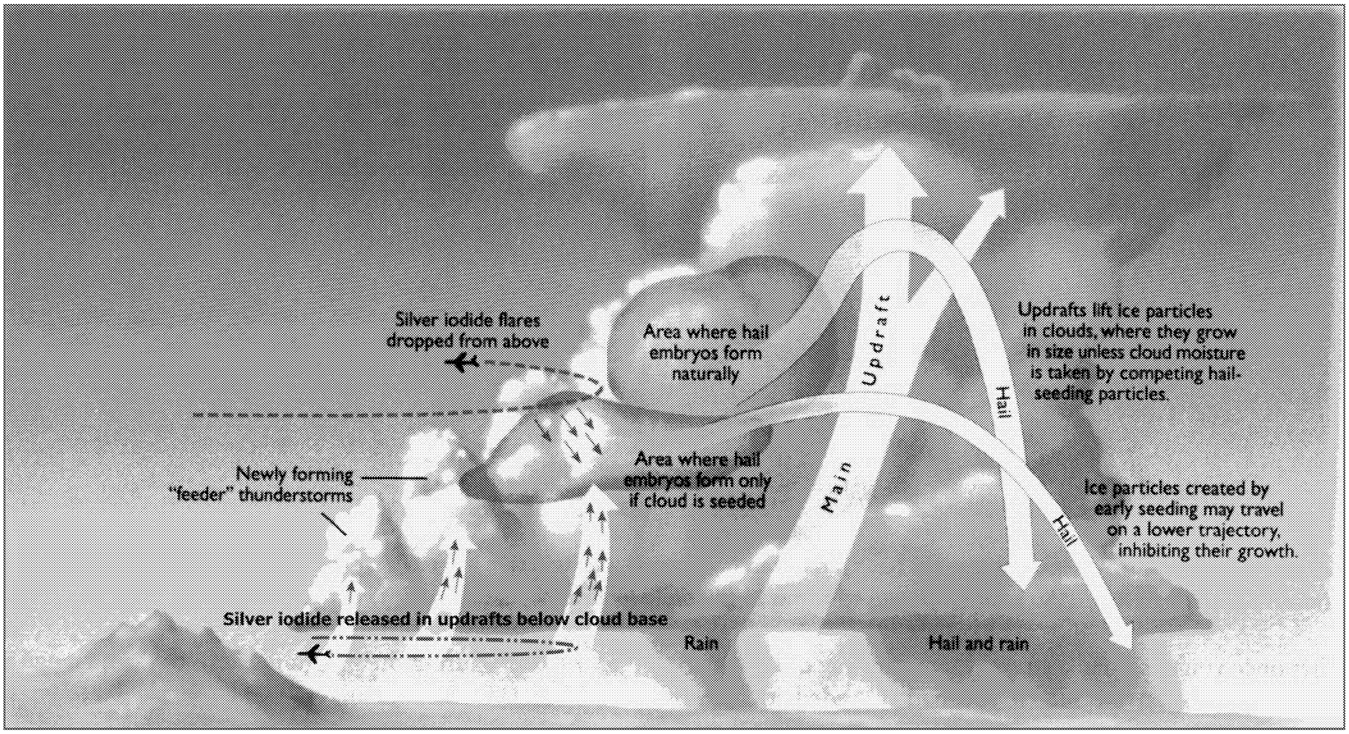


Figure 8. Conceptual model for hail suppression is illustrated graphically, as adapted from WMO (1995). This schematic shows generalized cloud seeding locations at cloud base and at cloud tops, as employed for mature thunderstorms. (Original graphic prepared by Canadian Geographic.)

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. However, such data are considered proprietary and presents obstacles to analyses. (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.

5.3 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 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 9.

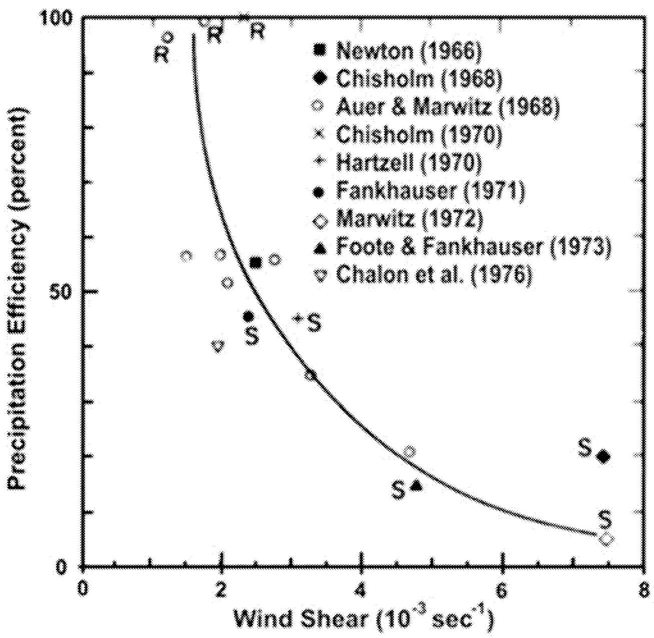


Figure 9. Precipitation efficiency for High Plains thunderstorms, from Browning (1977). Known supercells are labeled "S". Storms that produced only rain are labeled "R". (Copyright American Meteorological Society, Boston, MA, used by permission.)

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 8). 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 to 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 generally 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. THE OPERATIONS PLAN

6.1 *IDENTIFICATION OF HAIL-PRODUCING STORMS*

The height of the 45 dBZ contour (a radar echo-intensity level) was a criterion tested in a 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, beginning in 2015, was set to track any cell having more than 10 km^3 of 45 dBZ reflectivity, extending above 3.5 km altitude (MSL). In all previous seasons the reflectivity threshold had been 40 dBZ, to be "safe", absolutely certain that every cell having even a slight chance of producing hail would be recognized by the radar-processing software as such. The drawback to this was that many, many cells not realistically having much potential for hail were being flagged. With the latest radar upgrade, however, the project radar now has a more sensitive receiver, smaller pulse length, and other radar processing improvements, such that ASWMS Project Manager Dr. Terry Krauss became confident that the 45 dBZ threshold could be used. This decision has been supported by our observations since 2015. As such, 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 within the project boundary (as identified by TITAN with the criteria above) is moving towards and is expected to reach a protected town or city.

The impact on the project was immediate and very helpful. Shallow stratiform rains were no longer identified as TITAN cells. Also, when larger mesoscale convective systems developed the updated reflectivity criterion resulted in far fewer immense, sprawling and complex TITAN cells. In previous seasons it was common to be tracking three or more cells, only to see TITAN merge them into one very large, convoluted entity as their developing anvils merged. Because the cells remain separate longer, this is a significant plus for post-analysis, concentrating on the radar reflectivity volumes associated with hail. That rain showers are no longer identified as cells is not operationally significant.

6.2 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), a 30 minute or greater lead time is generally thought to be advisable.

6.3 CLOUD SEEDING METHODOLOGY

Meteorologists at the Operations Centre (Figure 10) 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.

Figure 10. The radar tower and dome gleam brightly in the evening sun on 3 July 2016 at about 9:00 PM. Everything glistens from the rain generated by the thunderstorm, just passed. (WMI photograph by Adam Brainard.)

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 damaging 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, to avoid collisions and for air traffic control (ATC) considerations only one aircraft can work safely at cloud top for each active thunderstorm complex. If multiple storms develop that are sufficiently spaced, more than one aircraft can work at cloud top simultaneously. Horizontal separation must be sufficient 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 to aid spotting by other Hailstop aircraft. 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 five aircraft to provide uninterrupted seeding coverage (at either cloud-base or cloud-top) and/or to seed multiple 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, and the seeding material would most likely be swept upward into the storm anvil without providing "beneficial competition" to the developing hail zone.

6.4 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 updrafts in the upper regions of developing supercooled cloud towers. Each flare burns for ~37 seconds, while falling a maximum of 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 11).

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.

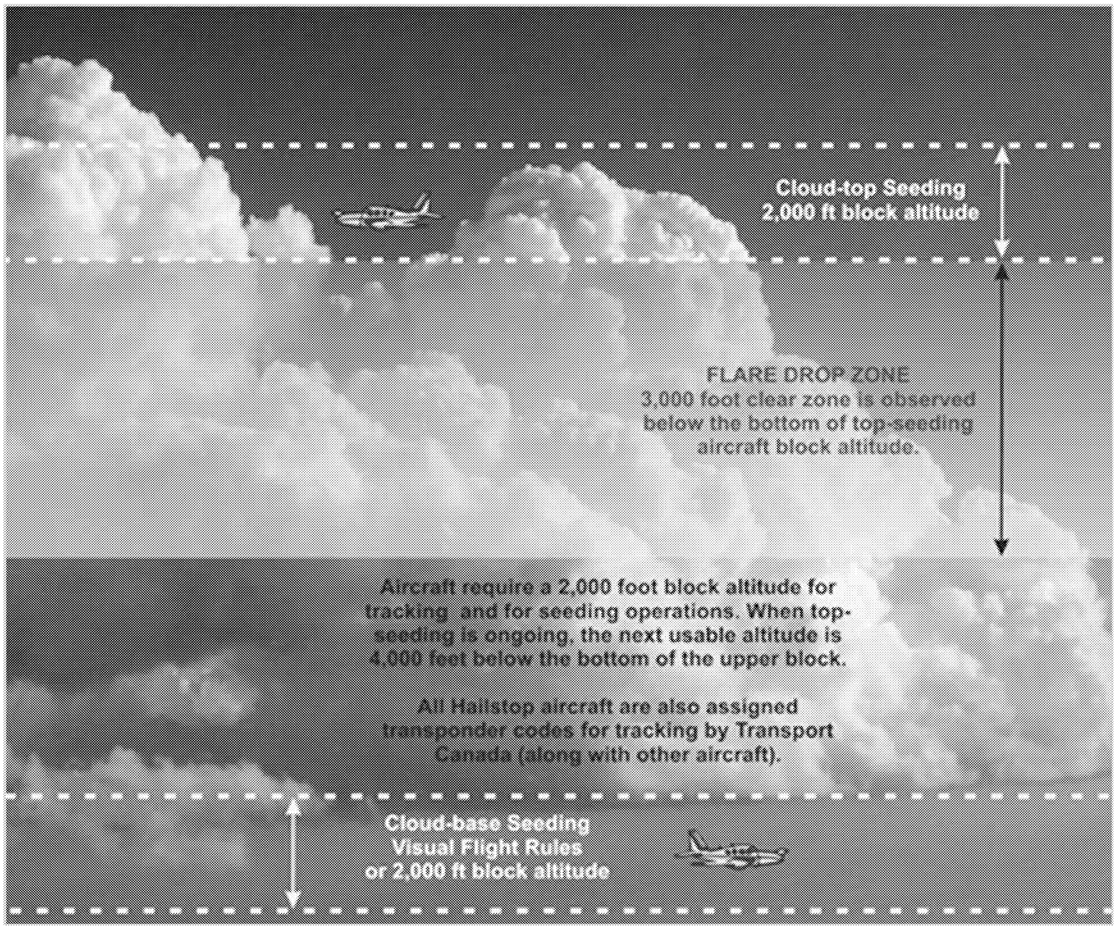


Figure 11. Separation of aircraft by altitude. This diagram illustrates how vertical separation of cloud-base and seeding aircraft is achieved. (WMI graphic.)

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.

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 12. 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.

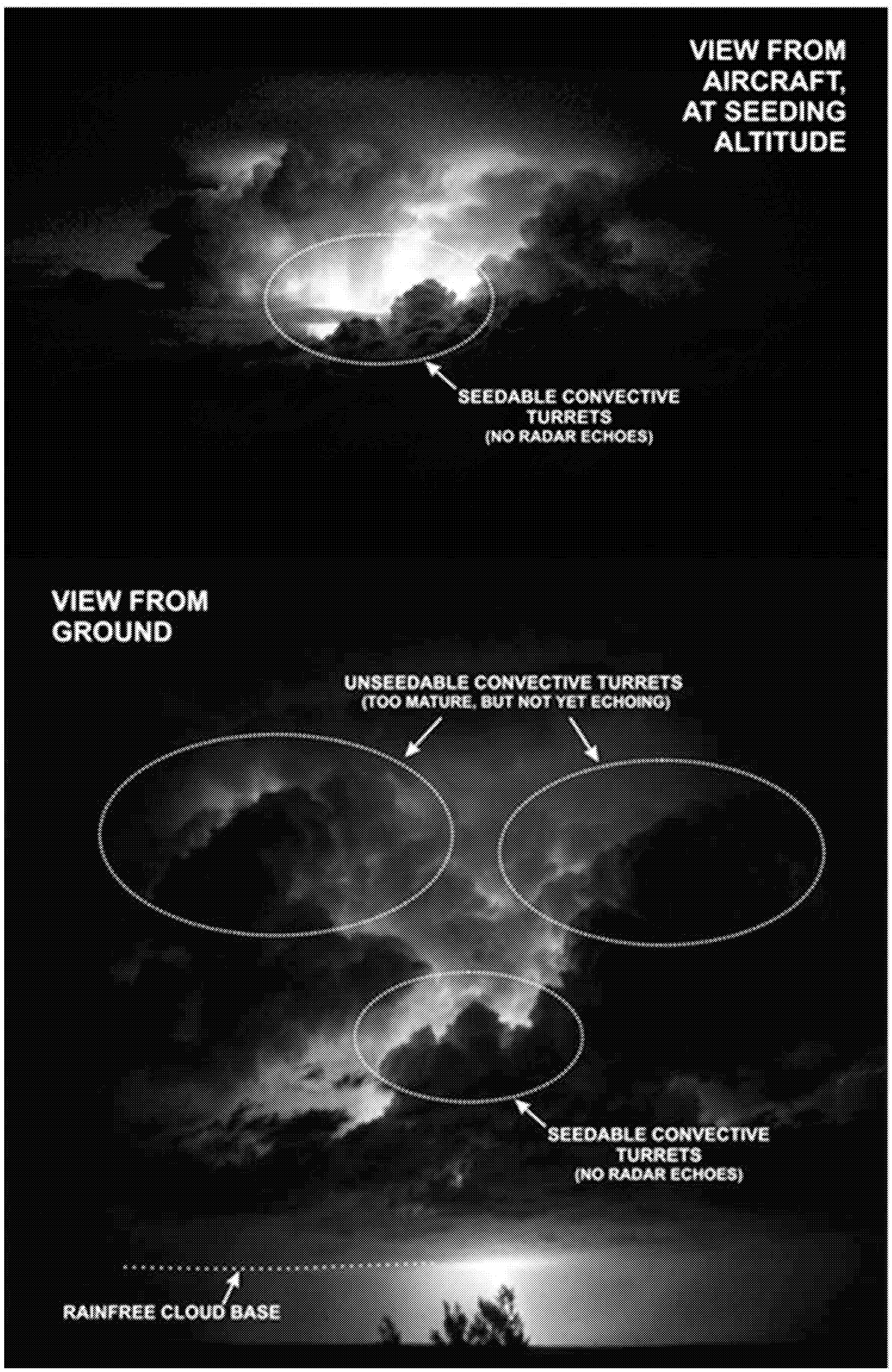


Figure 12. Nocturnal lightning from the ground and from the air.

6.5 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 reflectivity 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.

6.6 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 belly of 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 (*i.e.* 1 flare every 2 to 3 sec) if updrafts are very strong (*i.e.* 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 from consecutive flares is required for the AgI plume 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 intervals (assuming a true-airspeed of 80 m s^{-1}) 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.

6.7 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.

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 13 and are tabulated in Table 2.

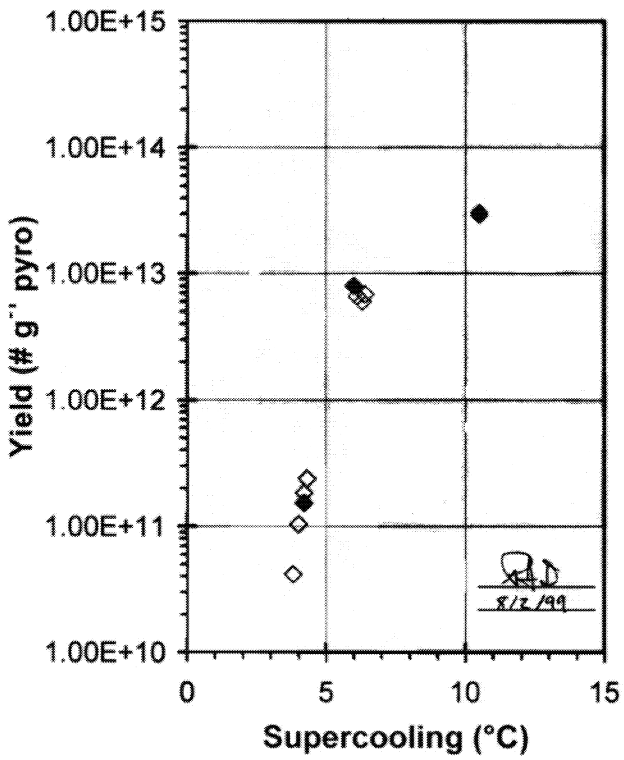


Figure 13. Yield of ice crystals per gram of pyrotechnic as a function of supercooling.

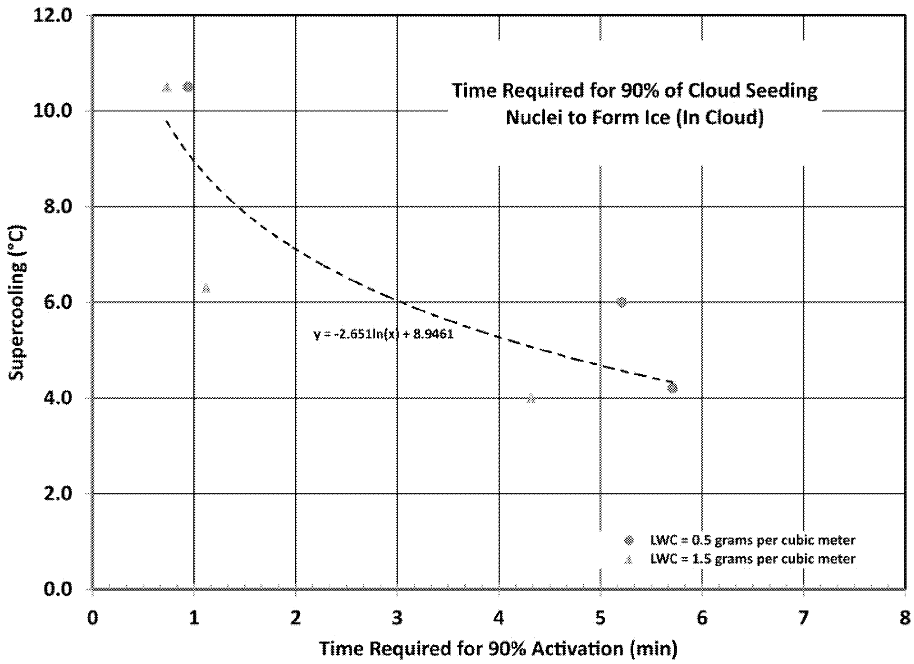
Temp (°C)	LWC (g m^{-3})	Raw Yield (g^{-1} AgI)	Corr. Yield (g^{-1} AgI)	Raw Yield (g^{-1} pyro)	Corr. Yield (g^{-1} pyro)	Yield (per pyro)
-3.8	1.5	$3.72x10^{11}$	$3.87x10^{11}$	$4.01x10^{10}$	$4.18x10^{10}$	$8.36x10^{11}$
-4.0	1.5	$9.42x10^{11}$	$9.63x10^{11}$	$1.02x10^{11}$	$1.04x10^{11}$	$2.08x10^{12}$
-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 2. Yield (per gram) of the ICE Glaciogenic Pyrotechnic (DeMott 1999).

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 14 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 $1x10^{12}$, $5x10^{13}$ and $3x10^{14}$ 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.

Figure 14. The time required for 90% of the seeding agent (nuclei) to form ice, as a function of supercooling. At temperatures colder than about -9°C (9° supercooling), 90% of the seeding agent produces ice in cloud. (Data from DeMott 1999.)



The CSU isothermal cloud chamber tests indicate that, on a per gram basis of pyrotechnic, the output and effectiveness indicate that they are the best available worldwide. 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.

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

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

6.8 SUSPENSION

Criteria are in place that define when seeding should be stopped, or not be conducted. These criteria were developed in accordance with the Weather Modification Association (WMA) statement recommending such criteria be established for all projects. The specifics of the WMA statement can be found by visiting the following link: http://www.weathermodification.org/standards_ethics.php.

The ASWMS suspension guidelines are as follows:

The following criteria and procedures for suspending operations in the face of impending severe weather to avoid contributing to, or appearing to contribute to, damaging weather situations shall be followed:

1. An emergency shutdown of seeding operations can be declared when there is a situation that poses an immediate threat to life and property. A logical criterion would be when a community is under a declared State of Emergency for flooding or tornado.
2. If the field meteorologist has any doubt about whether suspension criteria are met, he or she should order seeding stopped, and then contact the Project Director for clarification.
3. The Alberta Severe Weather Management Society policy of suspension of seeding during severe weather activity is strictly for reasons related to public perception and aircraft safety.
4. Resumption of normal seeding operations would be conditional on the emergency situation no longer posing a reasonable threat, such as a declared State of Emergency being lifted. However, if a storm forecast is of significant threat (3.3 cm diameter hail or greater), the Project Director has the authority to resume operations at any time.

7. PROGRAM ELEMENTS AND INFRASTRUCTURE

7.1 INFRASTRUCTURE

The flow of information within the project is illustrated in block diagram form in Figure 15. 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.

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 International (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.

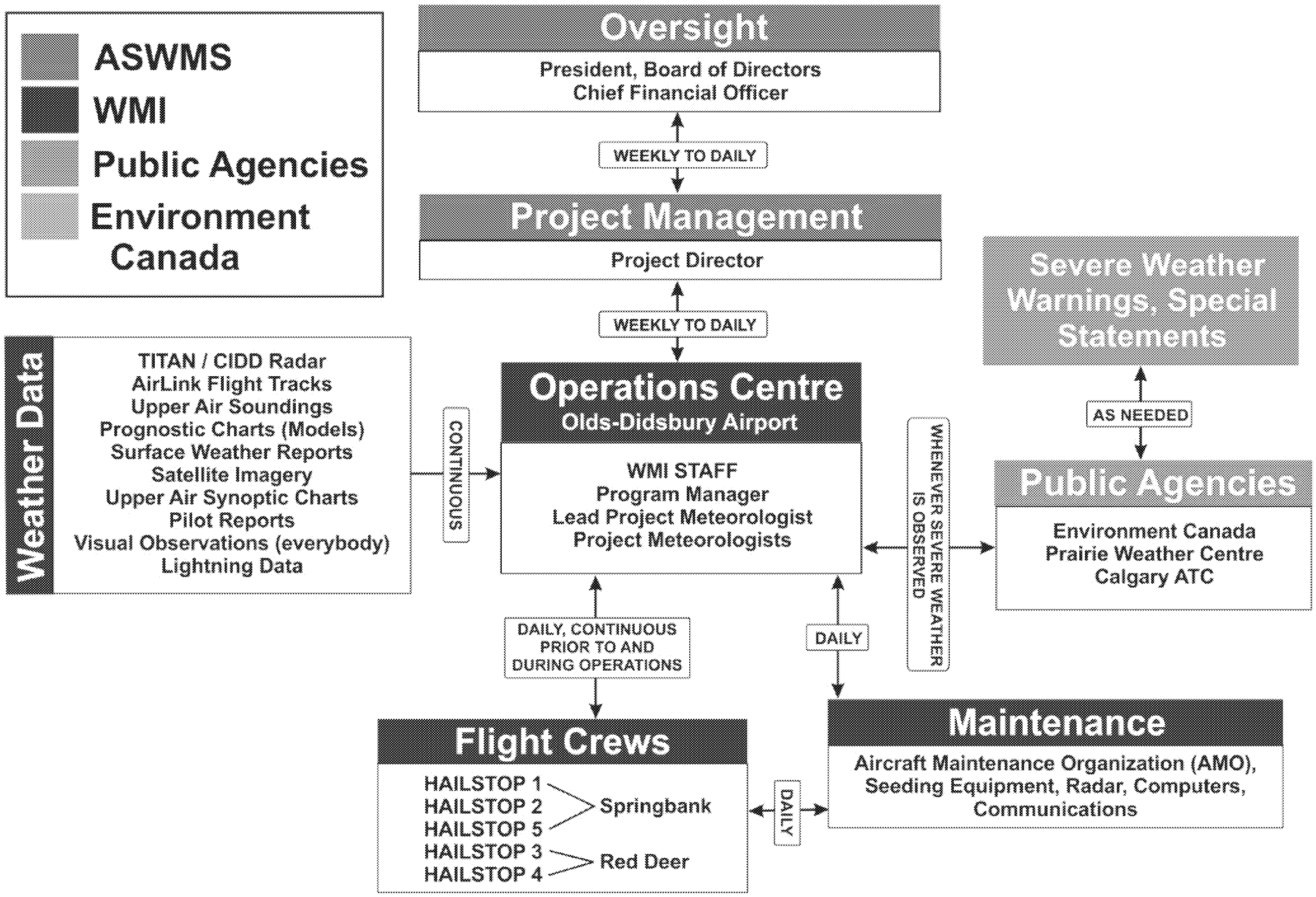


Figure 15. Schematic of Program Infrastructure. Arrows denote direction of information flow. Arrow labels show typical frequency of communications.

7.2 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 4).

An illustrated schematic diagram (Figure 16) 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.

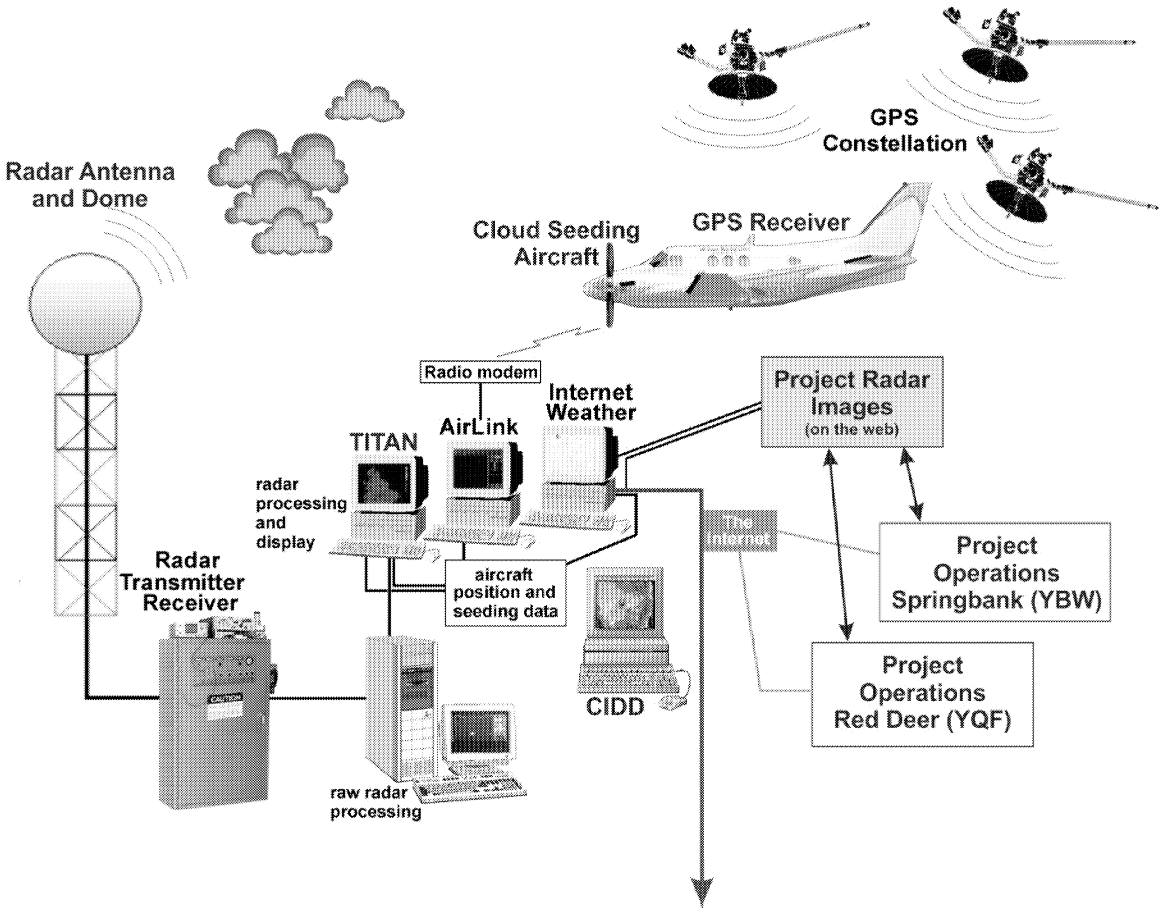


Figure 16. AHSP Operational Elements. The radar and associated equipment shown are all at the Project Operations Centre, located at the Olds-Didsbury Airport, approximately halfway between Calgary and Red Deer.

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 17).

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.

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 four minutes are required for the radar to complete each volume scan.]

7.3 DIGITAL WEATHER RADAR

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.

Figure 17. The glow of the evening sun paints the top of a strong thunderstorm at 9:02 PM on 16 August 2016, as the passing storm finally moves east of the Operations Centre. (WMI photograph by Brad Waller.)

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 radar volume scan. This is done to ensure that the web image is consistent from scan to scan.

7.4 GROUND SCHOOL

A ground school was conducted prior to the commencement of the project field operations on 30 May 2016, for project personnel at the Intact Insurance training room in 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. A representative of NAV Canada's Air Traffic Control Unit for Calgary 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.

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

7.5 PUBLIC RELATIONS

A total of seven groups toured the project Operations Centre at the Olds-Didsbury airport as part of the Alberta Insurance Council accreditation program. Tours were conducted on June 21 and 28; August 10, 16, 22, and 26; and September 1, 2016. In total 152 persons took part in this program, which helps those working in the industry understand the program.

The tours, organized and led by Ms. Sarah Newell (AVIVA Canada), 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 18).

Figure 18. Captain Jenelle Newman (right) explains the seeding equipment on Hailstop 4 to some of the participants in the 10 August 2016 continuing education tour and seminar at the Olds-Didsbury Airport. (WMI photograph by Bradley Waller.)

Recent storms were also replayed on the radar (Figure 19). 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. They also learn how the operations are conducted, hearing the information from the meteorologists and pilots who actually perform the operations.

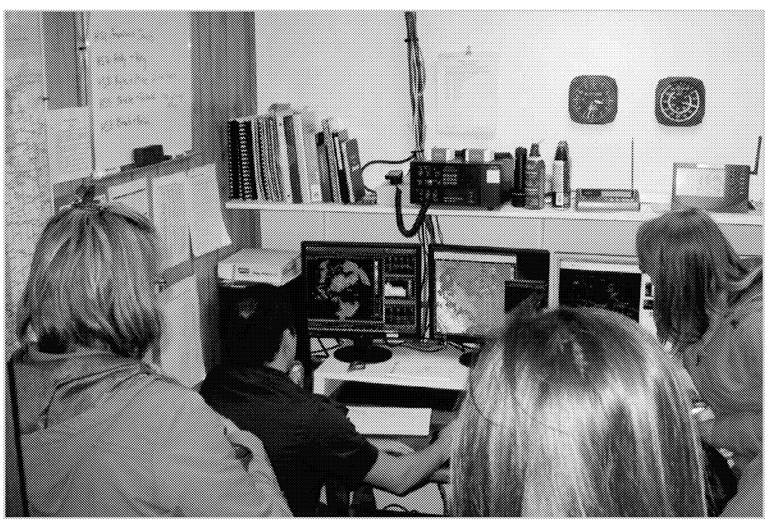


Figure 19. Several members of the 21 June 2016 continuing education tour listen as meteorologist Adam Brainard (seated) explains the morphology of a recent storm. (WMI photograph by Bradley Waller.)

8. FLIGHT OPERATIONS

Five specially equipped cloud seeding aircraft were dedicated to the project. Two Beech C90A King Airs and one Cessna 340A were based in Springbank, and a C90A and another C340A were based in Red Deer. The procedures used in 2016 remained the same as the previous years. The Springbank office and aircraft were at Springbank Aero Services, at that airport. The WMI Red Deer office was again set up in the Air Spray hangar at the Red Deer Regional Airport, as had been done in previous seasons.

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 12).

8.1 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 Springbank, Hailstop 2 for the C340 aircraft (N457DM) based in Springbank, Hailstop 3 for the King Air C90 aircraft (N522JP) stationed in Red Deer, Hailstop 4 for the C340 aircraft (N37356) based in Red Deer, and Hailstop 5 for the King Air C90 aircraft (N518TS) based in Springbank.

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 typically given a ± 1,000 ft altitude clearance (see again Figure 11). This procedure works very well in general. On a few occasions, seeding aircraft are asked to briefly climb to higher altitudes while passing 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.

8.2 CLOUD SEEDING AIRCRAFT

Two different models of twin-engine aircraft were utilized on the project. Hailstop 1, Hailstop 3, and Hailstop 5, the cloud-top seeding aircraft, were Beech King Air C90s, turboprop (propjet) aircraft. Both cloud-base seeding aircraft (Hailstop 2 and 4) were Cessna model 340A aircraft. All five aircraft were 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 one of the Beechcraft King Air C90 (Hailstop 1) is shown in Figure 20. 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 twenty-gram ejectable cloud seeding flares, for an aircraft total of 306 flares.

Figure 20. A King Air model C90, Hailstop 5, awaits a tour group at the Olds-Didsbury Airport on the morning of 16 August 2016. Racks of burn-in-place pyrotechnics are visible aft of the near wing. (WMI photograph by Adam Brainard.)

Each also carried racks affixed to the trailing edges of the wings that held up to forty-eight 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 three turboprop King Air seeding aircraft (Hailstop 1 and 5, 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. 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.

Cessna 340A

The two other seeding aircraft, Hailstop 2 (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 21). Complete specifications for the C340 are given in the Appendix.

The C340 aircraft both carry a 204-position belly rack for twenty gram ejectable flares (used in cloud top seeding, which they also can do very effectively), and wing racks for at least twenty-four 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 21. A Cessna model 340A, Hailstop 2, rests on the ramp at the Springbank Airport, awaiting afternoon thunderstorms on 7 June 2016. (WMI photograph by Andrew Brice.)

9. RADAR CONTROL AND COMMUNICATIONS CENTRE

The project Operations Centre was 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 TV monitor that allows viewing of the main radar display outside the rather small (staff only) operations room (Figure 22). A small refrigerator, coffee pot, and water cooler were also available for staff use.

The project's radar control room contained 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 VHF radio. The controlling duties were led by Dan Gilbert, who was assisted by Brad Waller and Adam Brainard.

The operations room was configured to place all the needed resources within easy reach of the operations director. Project reference and equipment manuals were shelved on the upper left. Telephones were 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 was placed directly in front of the operations director. To the far right was a third computer with dual monitors (Figure 22, I, J), for continuous, dedicated access to internet weather data from other sources. There was ample room for a second meteorologist in the operations room when needed to assist with radio communications, data entry, or general weather surveillance.

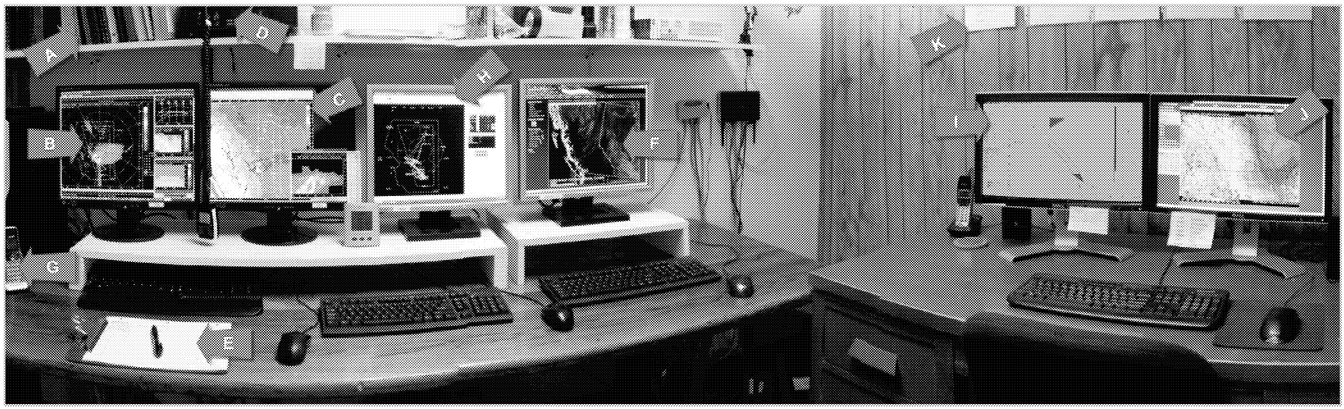


Figure 22. The configuration of the Operations Room. Equipment includes (A) reference manuals, (B) TITAN displays, (C) CIDD, (D) VHF radio for communications with aircraft, (E) radar log, (F) internet data displays, (G) telephone, (H) *AirLink* display, (I and J) forecasting/nowcasting support displays, and (K) radio and radar licenses. (WMI wide-angle photograph by Daniel Gilbert.)

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

A Davis weather station installed at the Operations Centre, with wind sensors affixed to the sub-structure of the airport's non-directional radio beacon (NDB) tower, telemetered temperature, pressure, wind, and humidity into the office, where it was displayed in real-time and recorded. Data from the station were also made available in real-time through the Internet.

9.1 RADAR

The Doppler weather radar was installed in May 2014, prior to the project start. Improvements realized included implementation of the latest version of the TITAN radar software, state-of-the-science radar antenna control, and improved data processing. Volume scans require less than four minutes, which means the radar now updates 15 times per hour, rather than 12 (prior to 2014). In addition, the porting of data to the WMI website was also improved.

A large 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 during the season to ensure functionality for when it is needed. Radar calibration data and system specifications are given in Table 4.

WMI Radar, Olds-Didsbury Airport

CALIBRATIONS	May 2016 (dBm)	
Parameter		
Radar Constant	77.2577	
Noise	-62.6298	
Minimum Detectable Signal	-111.707	
Receiver Gain	49.0772	
Minimum dBZ at 1 km Range	-34.4474	
SYSTEM SPECIFICATIONS		
Frequency (C-band)	5.975	GHz
Peak Power	250	KW
Average Power	150	W
Range Gate (length)	150	m
Pulse Repetition Frequency	600	sec^{-1}
Pulse Width	1.0	µsec
Range	180	km
Beam Width	1.65	deg
Volume Scans	15	per hour

Table 4. Calibrations and Specifications of the Advanced Radar Corporation WMI Radar located at Olds-Didsbury Airport.

9.2 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 storms of July 30, 2016 that struck 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. SUMMARY OF SEEDING OPERATIONS

A brief summary of each day recounting 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 weather pattern during the summer of 2016 was less intense than the previous summer, but actually had more days with seeding missions, 35, compared to 26 in 2015. The twenty-one season average is about 31. Of those 35 days, all five Hailstop aircraft flew on six days, and all five aircraft seeded on five of those six days.

In June, 31 seeding missions were flown on 10 days, and an additional six flights flown for patrol on four days. 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.

July was the most active month. Fifty-four seeding missions were flown on 14 days, and 12 more patrol flights on 10 days. The heaviest-seeded day of the season occurred on June 28th when a multicell thunderstorm complex developed as a wave moved off the foothills and into the Calgary area, impacting Calgary and most of the adjacent communities. Storms on July 30th required only slightly less seeding, however, this July storm was even more energetic than the June 28th storm, as a number of intense but quasi-isolated cells developed first northwest, and later west, of Calgary, before merging into a large convective complex as it passed east of the QE2. A detailed analysis of the July 30th storm is provided as a case study in this report.

Activity diminished after the first half of August. A total of 29 seeding missions were flown during the month, all but three on or before August 16th. Three aircraft flew seeding missions on August 31st. The final seeding mission was flown on September 5th; the heavy storms had ended for the season.

The aircraft and crews provided a 24-hour service, seven days a week throughout the period. Twelve 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 project manager.

Figure 23. Hailstop 4 seeds a strong thunderstorm as it approaches Airdrie at 4:25 PM on 30 July 2016. At the time, the storm had radar-indicated storm tops of 11.4 km, or 37,400 feet. (WMI photograph by Jenelle Newman.)

The 2016 crew was very experienced. The Red Deer aircraft team (Figure 24) was led by Mr. Mike Torris, Ms. Jenelle Newman, and Kyle Melle, and Mr. Joel Zimmer who has been with the Alberta program for 14 seasons. The Springbank team (Figure 25) was anchored by Mr. Jody Fischer and Mr. Brook Mueller.

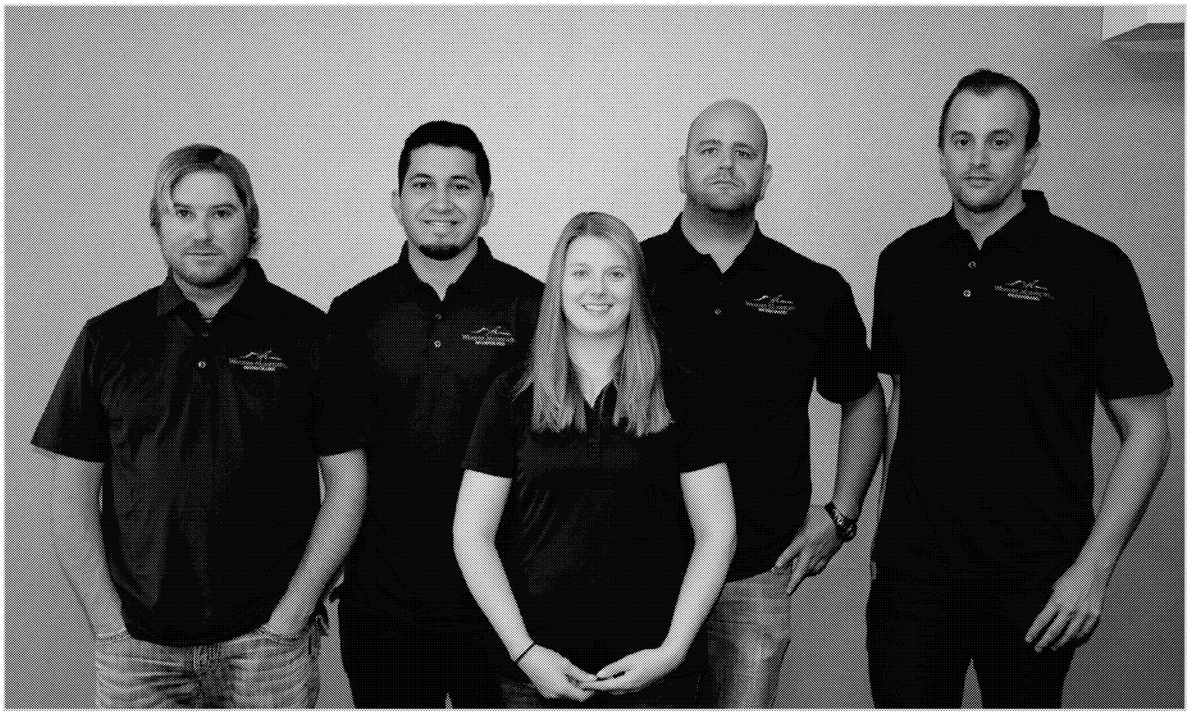


Figure 24. The Red Deer pilots, from left to right: Joel Zimmer, Richard Oxlade, Jenelle Newman, Mike Torris, and Kyle Melle.

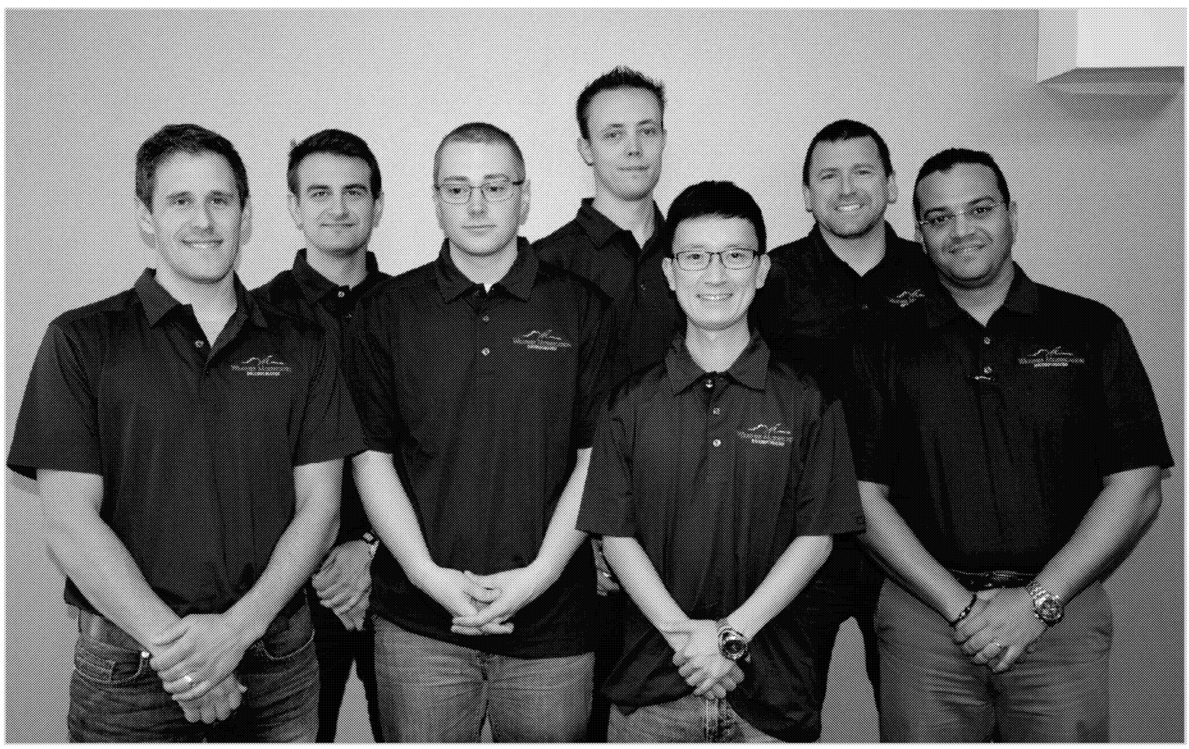


Figure 25. The Springbank pilots, from left to right: Brook Mueller, Cristian Avram, Jacob Eeuwes, Andrew Brice, Hing Kwok, Brian Kindrat, and Francisco Santana.

The radar crew (Figure 26) was anchored by WMI's Chief Meteorologist, Mr. Daniel Gilbert, now with seven seasons' experience in Alberta, in addition to seven seasons' work in a similar capacity on a hail suppression program in North Dakota.

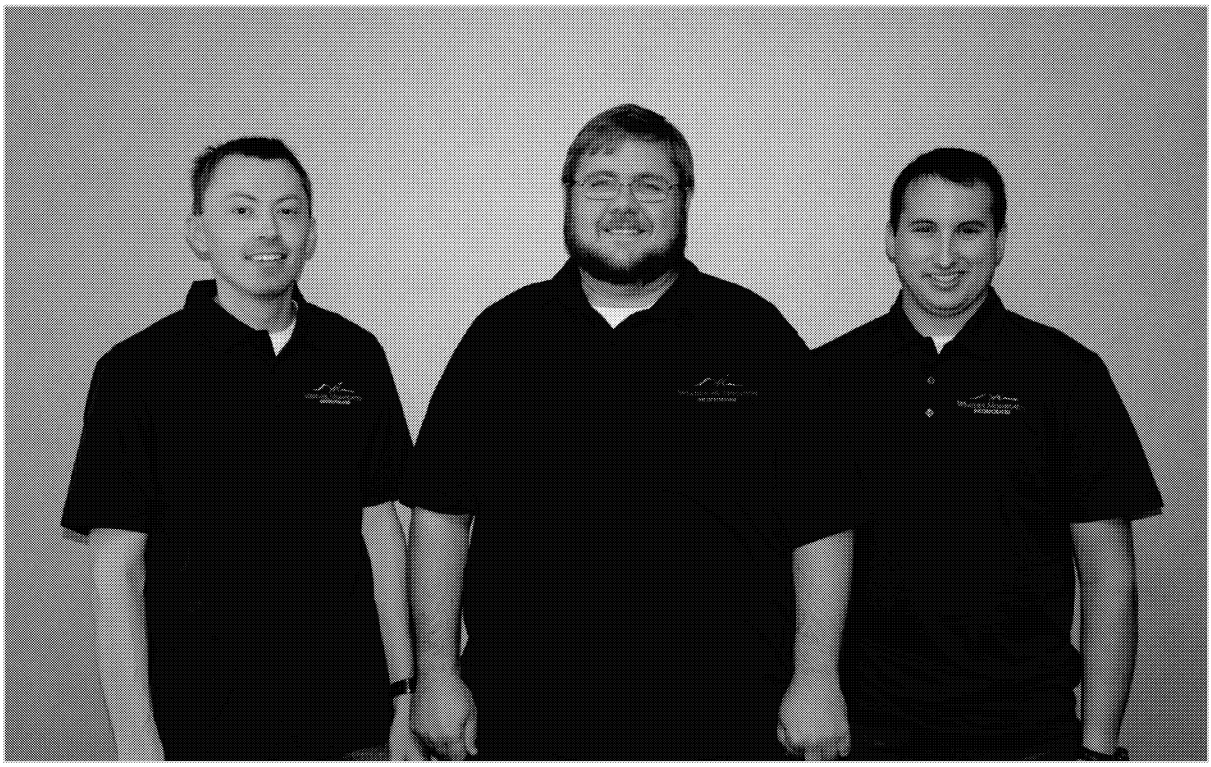


Figure 26. The Old-Didsbury Airport meteorologists that staffed the Operations Centre, from left to right: Bradley Waller, Daniel Gilbert, and Adam Brainard.

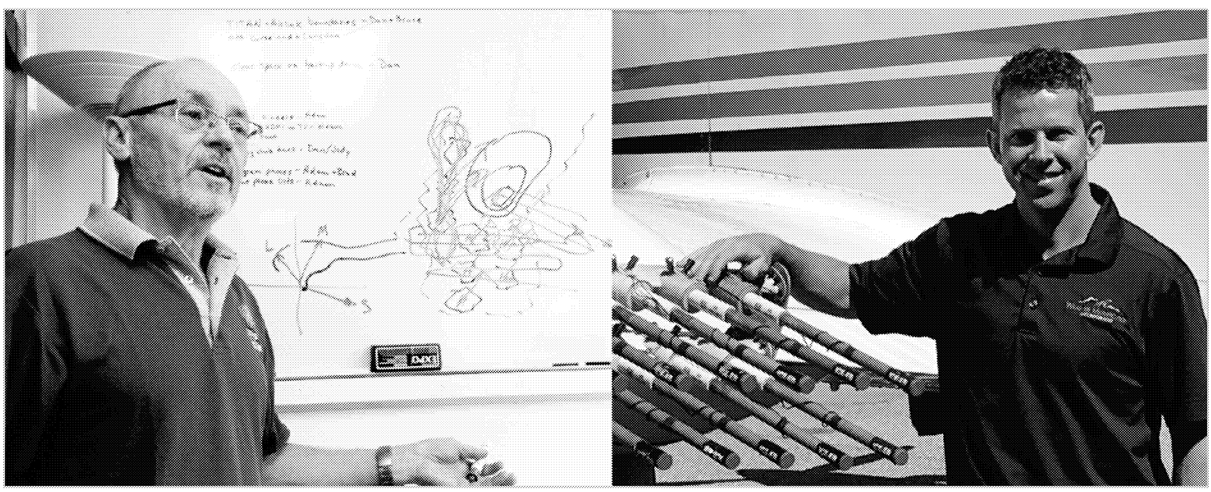


Figure 27. Project administration was overseen by Terry Krauss (ASWMS, left), and Jody Fischer (WMI, right).

Overall, the personnel, aircraft, and radar performed well and there were no interruptions or missed opportunities. A radar calibration at the beginning of the project season ensured that during the 2016 season the radar was calibrated correctly. Another calibration at season end confirmed that the radar had remained stable throughout the season.

High speed Internet service was once again obtained at the Springbank and Red Deer offices for the pilots so that they could closely monitor the storm evolution and storm motion using the radar images on the web prior to take-off. 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) continued examination of the data set in the off season prior to the 2017 program.

10.1 FLIGHTS

There were thunderstorms reported within the project area on 84 days during the summer of 2016, compared with 64 days in 2015. Hail fell on 69 days. During this season, there were 277.1 hours flown on 38 days with seeding and/or patrol operations. A total of 96 storms were seeded during 115 seeding flights on the 35 seeding days. There were 24 patrol flights, and 12 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. The distribution of flight time by purpose is given in Figure 28.

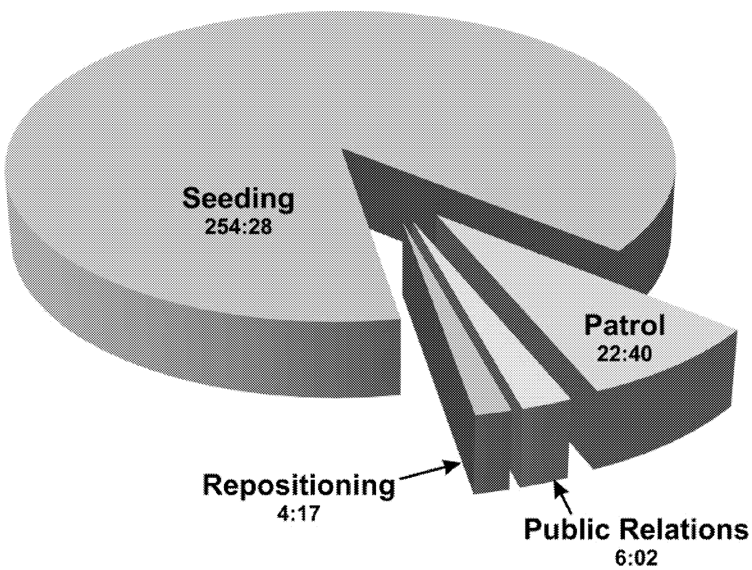


Figure 28. The distribution of flight time during the 2016 season is shown, by purpose. "Public relations" flights were those from the aircraft's base to the Olds-Didsbury Airport on days that insurance industry continuing education training sessions were given.

The distribution of flights (takeoffs and landings) by time of day (Mountain Time) is shown in Figure 29. As was the norm, storm activity, and thus flights, was strongly correlated with the diurnal convective cycle which sees storm development coincide with daytime surface heating, and persistence through the evening hours, but only occasionally, after midnight.

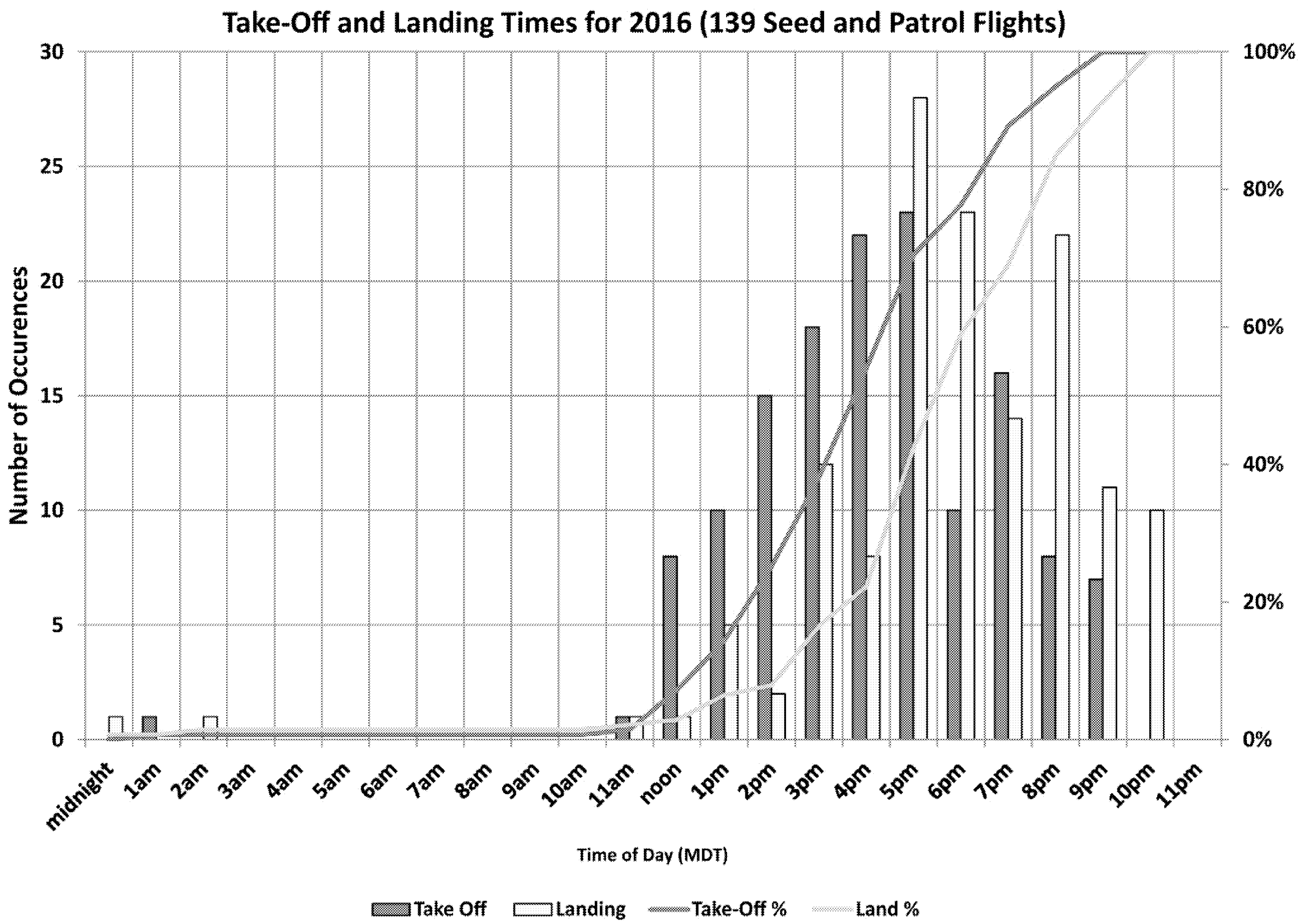


Figure 29. Diurnal variation in takeoff and landings, 2016 (Mountain Daylight Time). The 139 seeding and patrol flights are included. As is the norm, nocturnal flight operations were limited, especially after midnight.

10.2 SEEDING AMOUNTS

The amount of silver-iodide nucleating agent dispensed during the 2016 field season totaled 294.9 kg. This was dispensed in the form of 6,496 ejectable (cloud-top) flares (129.9 kg seeding agent), 1000 burn-in-place (cloud-base) flares (150.0 kg seeding agent), and 246.9 gallons of silver iodide seeding solution (15.0 kg seeding agent).

The amount of AgI dispensed on each day of operations in 2016 is shown in Figure 30. There were 11 days on which more than 10 kg (10,000 grams) of seeding material was dispensed. All of these were days on which at least four of the five Hailstop aircraft flew; on five of those days all five aircraft seeded. The amount of seeding agent dispensed per storm (3.07 kg) was just slightly greater than the project mean (2.50 kg), but significantly less than the 2015 value of 4.42 kg per storm, the highest of any season to date. The benefits of having five aircraft continue to be realized. This is especially demonstrated on those days when convection is widespread; more storms can be effectively treated.

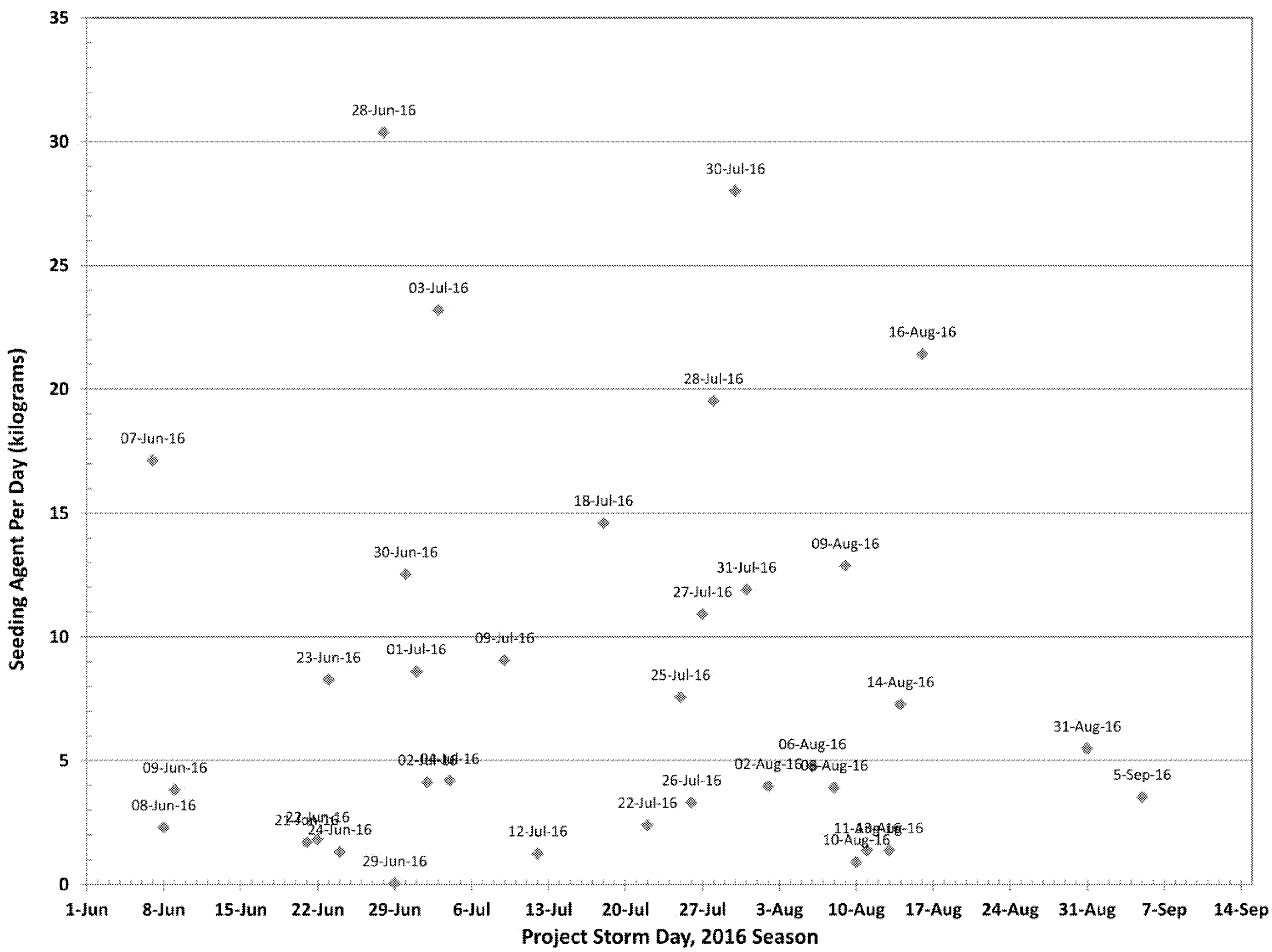


Figure 30. The amount of seeding agent (silver iodide, AgI) dispensed per operational day, 2016.

Table 5 gives a list of the operational statistics for all twenty-one seasons 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. The 2016 summer ranked fifth all-time in terms of activity. Seeding occurred on 35 days [mean is 31 days, record (2011) was 48 days]; 139 project missions were flown for patrol and seeding. The distribution of flights by type and project day is shown in Figure 31.

Season	Storm Days With Seeding	Aircraft Missions (Seeding & Patrol)	Total Flight Time (hours)	Number of Storms Seeded	Total Seeding Agent (kg)	Seeding Agent Per Day (kg)	Seeding Agent Per Hour (kg)	Seeding Agent Per Storm (kg)	Ejectable Flares	Burn-in-place Flares	Seeding Solutions (gallons)	Season Activity Rank
2016	**35**	**139**	**277.1**	**96**	**294.9**	**8.4**	**1.06**	**3.07**	**6496**	**1000**	**246.9**	**5**
Mean	**31.1**	**105.0**	**215.8**	**92.0**	**218.5**	**6.9**	**1.00**	**2.5**	**5242.3**	**682.1**	**166.6**	
2015	26	115	233.3	79	349.2	14.6	1.37	4.42	8127	1138	262.9	8
2014	32	128	259.5	101	382.5	12.0	1.47	3.79	10782	1020	228.6	3
2013	26	103	229.6	70	233.3	9.0	1.02	3.33	6311	636	131.7	11
2012	37	143	300.1	116	314.6	8.5	1.16	2.70	7717	914	260.3	2
2011	48	158	383.0	134	400.1	8.3	1.13	3.00	10779	1020	350.2	1
2010	42	115	271.8	118	263.8	6.3	1.10	2.20	5837	851	227.5	7
2009	20	38	109.3	30	48.4	2.4	0.84	1.60	451	237	56.5	21
2008	26	112	194.7	56	122.9	4.7	1.00	2.20	1648	548	113.5	16
2007	19	76	115.3	41	99.7	5.2	0.90	2.40	1622	413	77	20
2006	28	92	190.2	65	214	7.6	1.10	3.30	4929	703	145.4	13
2005	27	80	157.9	70	159.1	5.9	1.00	2.30	3770	515	94.2	18
2004	29	105	227.5	90	270.9	9.3	1.20	3.00	6513	877	132.7	9
2003	26	92	163.6	79	173.4	6.7	1.10	2.20	4465	518	92.6	15
2002	27	92	157.4	54	124.2	4.6	0.80	2.30	3108	377	80.3	19
2001	36	109	208.3	98	195	5.4	0.90	2.00	5225	533	140.8	10
2000	33	130	265.2	136	343.8	10.4	1.30	2.50	9653	940	141.3	4
1999	39	118	251.3	162	212.7	5.5	0.80	1.30	4439	690	297.5	6
1998	31	96	189.9	153	111.1	3.6	0.60	0.70	2023	496	193.8	12
1997*	38	92	188.1	108	110.8	2.9	0.60	1.00	2376	356	144.3	14
1996*	29	71	159.1	75	163.3	5.6	1.00	2.20	3817	542	80.5	17

**The 1996 and 1997 seasons began on June 15, not June 1, which has been the norm ever since.*

Table 5. Operational statistics for seeding and patrol flights, 1996 through 2016.

The *Season Activity Rank* shown at the far right 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.

AIRCRAFT LEGEND:	C340	CESSNA 340A	C90	BEECH KING AIR C90	CHEY	PIPER CHEYENNE II

hours = flight hours, EJ = ejectable pyrotechnic, BIP = burn-in-place pyrotechnic, gen hr = hours wingtip solution-burning seeding time

SEASON		Hailstop 1		Hailstop 2		Hailstop 3		Hailstop 4		Hailstop 5
		Springbank (Calgary prior to 2012)		Springbank (Calgary prior to 2012)		Red Deer		Red Deer		Springbank
		FLIGHT HOURS, EJ FLARES, BIP FLARES		FLIGHT HOURS, EJ FLARES, BIP FLARES, GEN HOURS		FLIGHT HOURS, EJ FLARES, BIP FLARES		FLIGHT HOURS, EJ FLARES, BIP FLARES, GEN HOURS		FLIGHT HOURS, EJ FLARES, BIP FLARES
2016	C90	63 hours, 2460 EJ, 183 BIP	C340	78 hours, 0 EJ 296 BIP, 82 gen hr	C90	49 hours, 1989 EJ, 164 BIP	C340	54 hours, 0 EJ, 132 BIP, 42 gen hr	C90	59 hours, 2047 EJ, 225 BIP
2015	C90	55 hours, 2798 EJ, 230 BIP	C340	76 hours, 0 EJ, 272 BIP, 76 gen hr	C90	47 hours, 2845 EJ, 208 BIP	C340	61 hours, 0 EJ, 199 BIP, 55 gen hr	C90	46 hours, 2484 EJ, 229 BIP
2014	C90	71 hours, 3554 EJ, 268 BIP	C340	60 hours, 0 EJ, 198 BIP, 57 gen hr	C90	41 hours, 3558 EJ, 207 BIP	C340	64 hours, 90 EJ, 190 BIP, 58 gen hr	C90	72 hours, 3580 EJ, 157 BIP
2013	C90	41 hours, 1149 EJ, 115 BIP	C340	58 hours, 0 EJ, 148 BIP, 37 gen hr	C90	42 hours, 3381 EJ, 166 BIP	C340	48 hours, 0 EJ, 78 BIP, 31 gen hr	C90	40 hours, 1781 EJ, 129 BIP
2012	C90	76 hours, 3250 EJ, 232 BIP	C340	87 hours, 0 EJ, 224 BIP, 72 gen hr	C90	83 hours, 4464 EJ, 198 BIP	C340	85 hours, 3 EJ, 260 BIP, 63 gen hr		
2011	C90	97 hours, 4783 EJ, 239 BIP	C340	105 hours, 244 EJ, 269 BIP, 91 gen hr	C90	99 hours, 5646 EJ, 273 BIP	C340	108 hours, 106 EJ, 239 BIP, 92 gen hr		
2010	CHEY	62 hours, 1612 EJ, 132 BIP	C340	82 hours, 74 EJ, 236 BIP, 53 gen hr	C90	96 hours, 4154 EJ, 200 BIP	C340	68 hours, 2 EJ, 286 BIP, 64 gen hr		
2009	CHEY	22 hours, 250 EJ, 27 BIP	C340	31 hours, 0 EJ, 65 BIP, 6 gen hr	C90	24 hours, 201 EJ, 48 BIP	C340	33 hours, 0 EJ, 97 BIP, 17 gen hr		
2008	CHEY	65 hours, 953 EJ, 88 BIP	C340	44 hours, 0 EJ, 171 BIP, 27 gen hr	C90	51 hours, 695 EJ, 169 BIP	C340	35 hours, 0 EJ, 120 BIP, 19 gen hr		
2007	CHEY	40 hours, 979 EJ, 81 BIP	C340	41 hours, 0 EJ, 155 BIP, 31 gen hr	C90	34 hours, 643 EJ, 177 BIP				
2006	CHEY	54 hours, 3217 EJ, 179 BIP	C340	70 hours, 72 EJ, 248 BIP, 58 gen hr	C90	66 hours, 1640 EJ, 276 BIP				
2005	CHEY	49 hours, 2750 EJ, 169 BIP	C340	45 hours, 0 EJ, 121 BIP, 38 gen hr	CHEY	64 hours, 1020 EJ, 225 BIP				
2004	CHEY	83 hours, 5574 EJ, 359 BIP	C340	62 hours, 0 EJ, 196 BIP, 53 gen hr	C90	82 hours, 939 EJ, 322 BIP				
2003	CHEY	64 hours, 3598 EJ, 250 BIP	C340	54 hours, 0 EJ, 130 BIP, 37 gen hr	CHEY	46 hours, 867 EJ, 138 BIP				
2002	CHEY	57 hours, 1994 EJ, 163 BIP	C340	49 hours, 2 EJ, 73 BIP, 32 gen hr	CHEY	51 hours, 1112 EJ, 141 BIP				
2001	CHEY	62 hours, 3174 EJ, 216 BIP	C340	75 hours, 4 EJ, 215 BIP, 56 gen hr	CHEY	68 hours, 2093 EJ, 102 BIP				
2000	CHEY	90 hours, 4755 EJ, 379 BIP	C340	77 hours, 164 EJ, 193 BIP, 56 gen hr	CHEY	97 hours, 4734 EJ, 368 BIP				
1999	CHEY	91 hours, 3795 EJ, 313 BIP	C340	81 hours, 244 EJ, 197 BIP, 60 gen hr	C340	79 hours, 400 EJ, 180 BIP, 59 gen hr				
1998	CHEY	62 hours, 1880 EJ, 107 BIP	C340	68 hours, 134 EJ, 199 BIP, 29 gen hr	C340	59 hours, 9 EJ, 190 BIP, 48 gen hr				
1997	CHEY	70 hours, 1828 EJ, 62 BIP	C340	58 hours, 264 EJ, 128 BIP, 26 gen hr	C340	60 hours, 284 EJ, 166 BIP, 32 gen hr				
1996	CHEY	62 hours, 2128 EJ, 143 BIP	C340	46 hours, 895 EJ, 192 BIP, 9 gen hr	C340	52 hours, 794 EJ, 207 BIP, 23 gen hr				

Table 6. Cloud seeding pyrotechnic and seeding solution usage by aircraft, through the 2016 season.

A summary of the flare usage, by aircraft, during the past 21 seasons is given in Table 6. The Cessna 340s (Hailstop 2 and Hailstop 4) are used mainly as cloud base seeding aircraft because they have lesser performance

There were no aircraft maintenance issues that impacted operations. Although Hailstop 4 had a damaged propeller (July 4) and was out of service until a new propeller could be ordered, shipped, and installed (July 12), no missions were missed or otherwise affected. At the time, WMI did everything possible to expedite replacement of the propeller; delays occurred that were beyond WMI's control. Ordinarily such a repair would be completed more rapidly.

The best seeding coverage consists of seeding a storm simultaneously using two aircraft; one at cloud base and another at cloud top (-5 to -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 35 days: June 7th, 8th, 9th, 21st, 22nd, 23rd, 24th, 28th, 29th, and 30th, July 1st, 2nd, 3rd, 4th, 9th, 12th, 18th, 22nd, 25th, 26th, 27th, 28th, 30th, and 31st; August 2nd, 6th, 8th, 9th, 10th, 11th, 13th, 14th, 16th, and 31st; and September 5th. All five aircraft were used for operations (seeding and/or patrol) on the following 6 days (local time) this season: June 7th and 28th; July 18th, 28th, and 30th; and August 16th. Patrol flights were flown on June 7th, 23rd, 25th, and 30th; July 2nd, 3rd, 9th, 15th, 18th, 22nd, 25th, 27th, 30th and 31st; and August 2nd, 5th, 10th, 13th, and 16th. No patrol missions were flown in September. Flight operations are summarized in Figure 26.

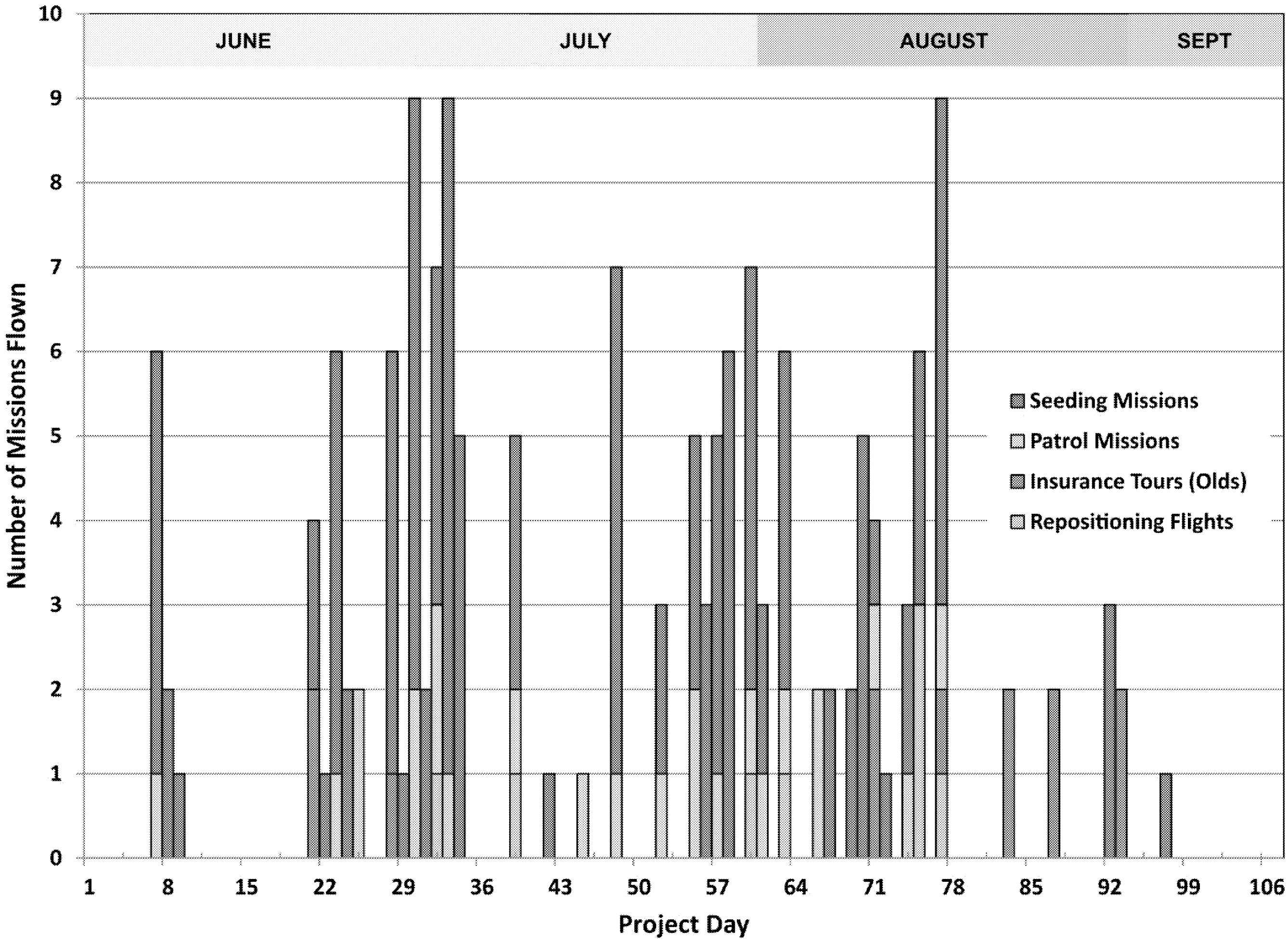


Figure 31. The number of flights, by type, is shown for each project day of the 2016 season. Months are shown at the top of the graphic. The "Insurance Tours" flights were those made to the Operations Centre at the Olds-Didsbury Airport for the seven continuing education training sessions certified by the Alberta Insurance Industry. On two of the seven days, only one flight is shown in this category because weather developed that caused the departing flight to be a seeding or patrol flight.

10.3 STORM TRACKS

A map of all hailstorm tracks (determined by radar) during 2016 is shown in Figure 32. July was the stormiest month, which is the climatological normal. There were thirteen storms that tracked across or within the city limits of Calgary during the 2016 season. Hail damage was reported in isolated neighborhoods of the city on five of these days including June 30th, July 12th, 28th, and 30th, and September 2nd. Unfortunately, the July 30th event resulted in serious damage within portions of northeast Calgary. This storm day is reviewed in detail later in this report.

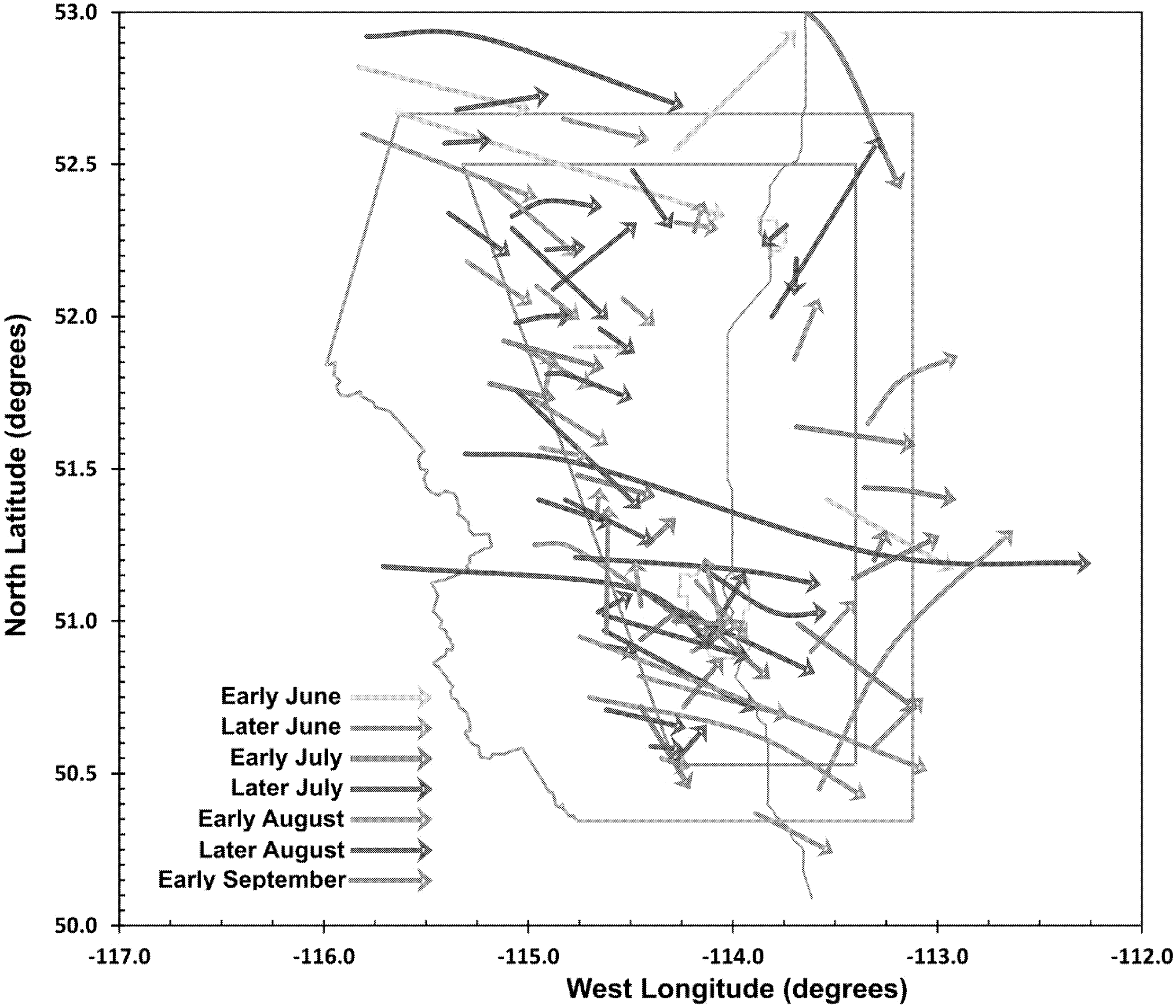


Figure 32. Map of all potential hailstorm tracks within radar coverage during 2016, as indicated by a minimum vertically-integrated liquid (VIL, from the radar) of at least 30 kg/m^2. This map shows all of the 96 storms seeded, plus others of hail potential that did not move near cities or towns. All 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 month, the lighter color denotes storms that occurred during the first half of that month.

The number and distribution of storm tracks during 2016 were similar to previous seasons, with July getting honors for being the most active month. Activity waned sharply after mid-August. Just a single seeding mission was flown in September. The plotted storm tracks shown in Figure 32 include more than just start and end points whenever storms turned appreciably during their lifetimes, giving a better understanding of storm behavior.

Hail was reported within the project area (protected area and buffer area) on 69 days. Larger-than-golf ball size hail was reported on July 3rd in Carseland; the 18th of July east of Rocky Mountain House; July 30th in Calgary; and on August 16th west of Didsbury.

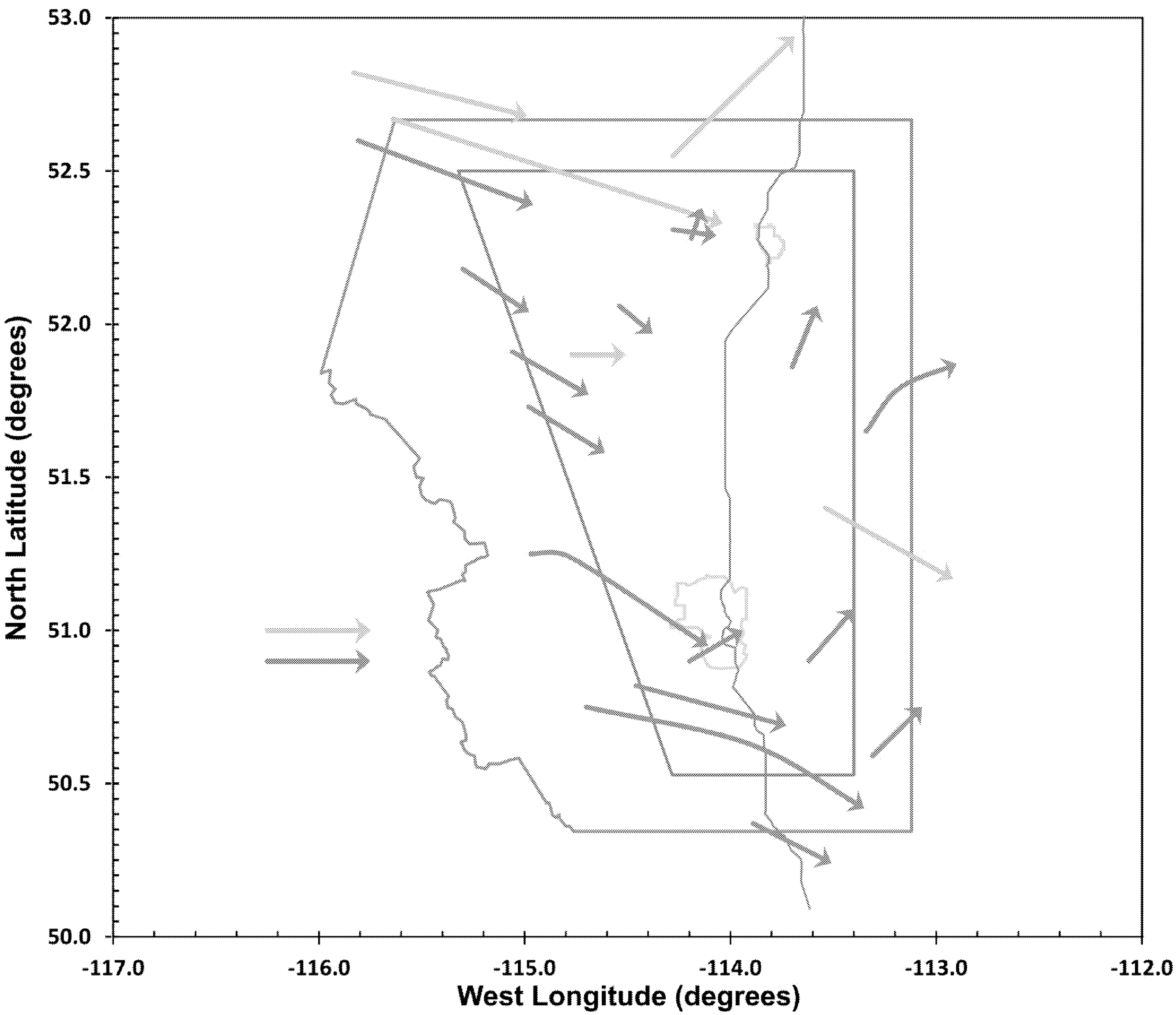


Figure 33. As in Figure 32, but for the month of June 2016.

Golf ball size hail was reported or observed by radar signature on June 7th east of Didsbury and on July 1st near Linden.

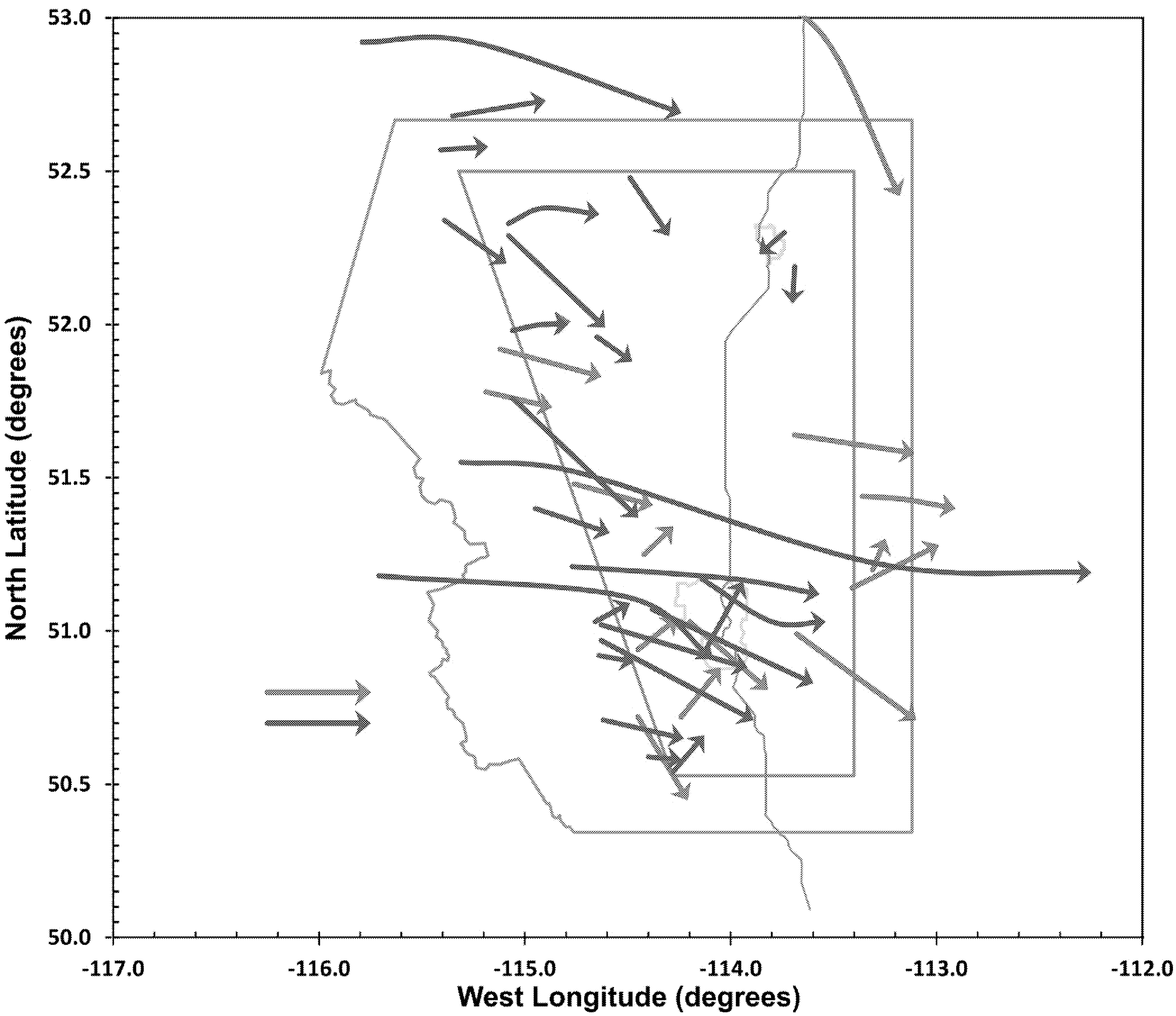


Figure 34. As in Figure 32, but for the month of July 2016.

Walnut size hail was reported or observed by radar signature on June 8th northwest of Ponoka; June 28th west of Calgary and near Okotoks; the 30th of June in Calgary; in Lacombe on July 8th; on the 9th of July northeast of Cochrane; July 12th in Calgary; on July 28th in Calgary; on the 31st of July in Okotoks; and in Calgary on September 2nd.

The weather pattern during the summer of 2016 was less intense than the previous summer, but actually had more days with seeding missions, 35, compared to 26 in 2015. The twenty-one season average is about 31. Of those 35 days, all five Hailstop aircraft flew on six days, and all five aircraft seeded on five of those six days.

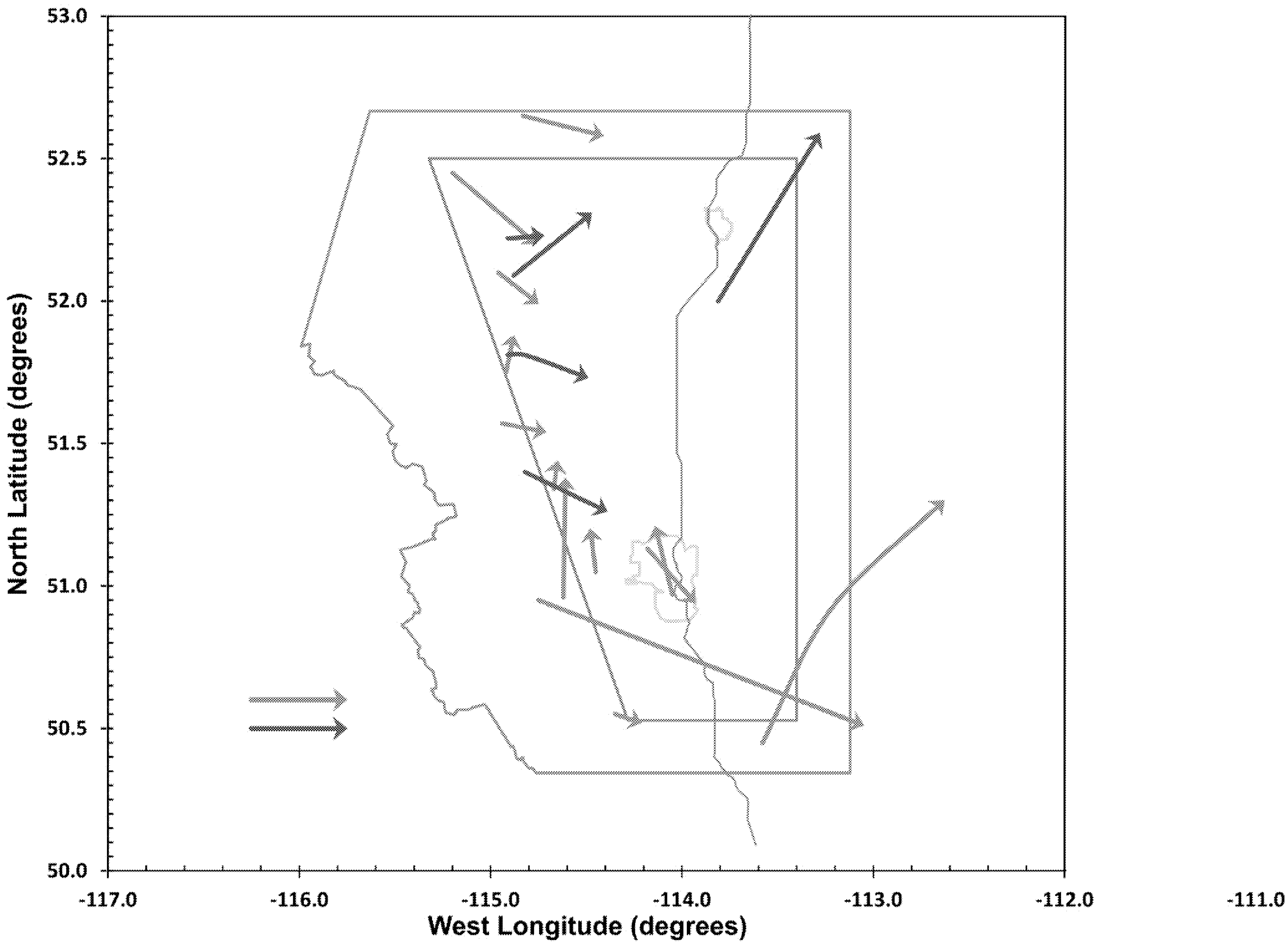


Figure 35. As in Figure 32, but for the month of August 2016.

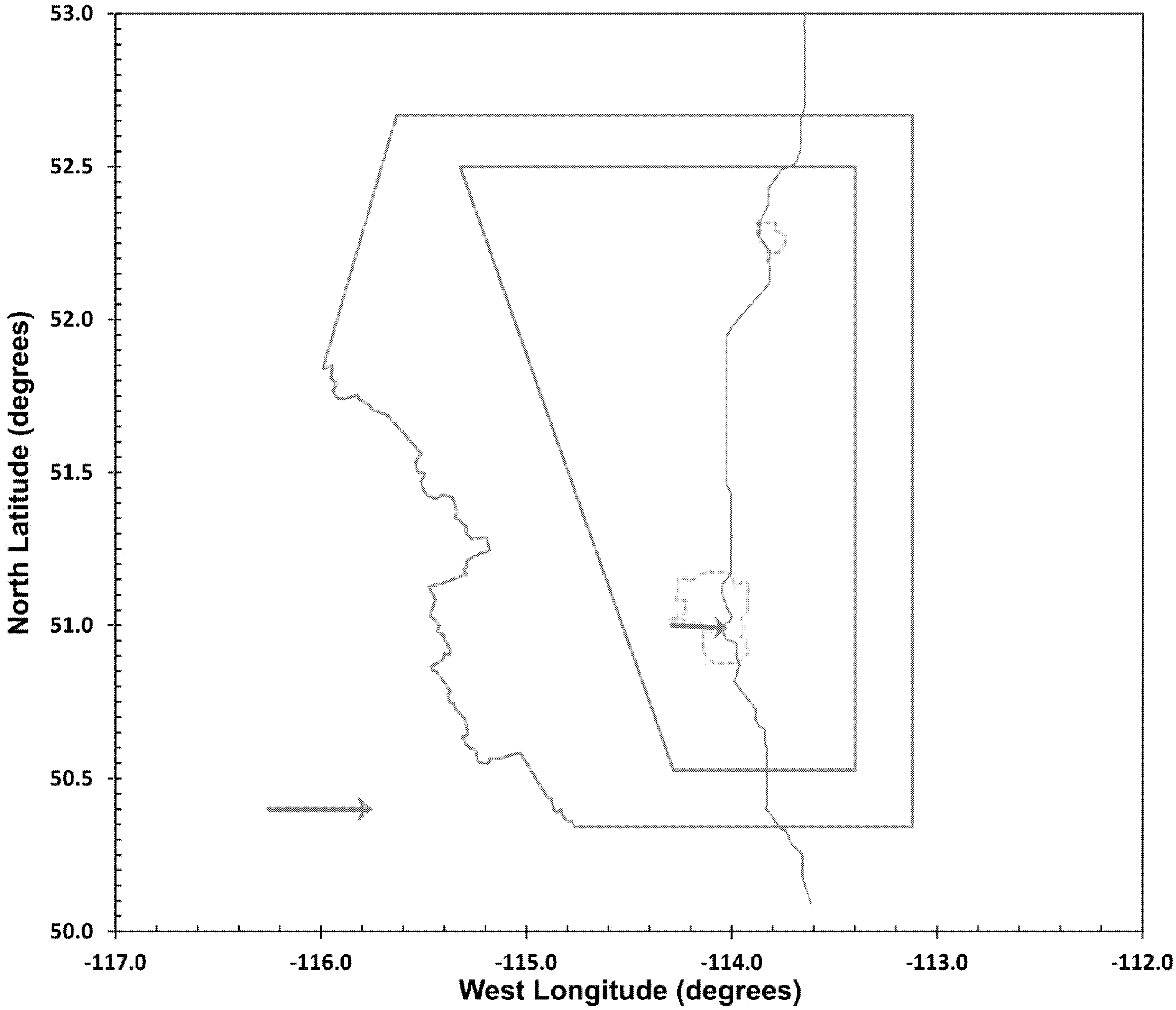


Figure 36. As in Figure 32, but for the first half of September 2016.

11. 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.

11.1 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 can cause 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, for convenience the summary tables are all organized according to the local calendar "storm" day with respect to Mountain Daylight Time.

11.2 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 considered to be 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.

11.3 PROCESS AND DISSEMINATION

Project forecasts were valid from 6:00 AM through 6:00 AM the next day, and also included a day-two outlook. The daily forecast preparation began with an assessment of the current weather conditions. The latest METARs (hourly surface weather reports), 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 (year-month-day) 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 model 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 surface 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 level best reflects the location of the upper jet stream winds, around 35,000 feet altitude. 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 (pressure-wise) 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). The 500 mb charts were examined for temperatures, humidity, wave pattern, and especially vorticity (rotation). Advection of 500 mb vorticity from broad scale troughs, lows, or shortwaves tends to cause air 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 often indicative of 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 Alberta 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, usually near the height of the convective cloud base. The 700 mb charts are most typically used to determine the amount of low level moisture over a region. Lots of 700 mb moisture contributes to unstable atmospheres. Relative humidity, theta-E (equivalent potential temperature), and vertical velocity charts are all useful tools at this level. Shortwave troughs are sometimes evident on 700 mb vertical velocity 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. The 700 mb charts are also be analyzed for the presence of inversions or "caps" that inhibit 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 prognostic 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 were saved, the forecaster created a daily meteorogram. This is a one-page graphic 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 (sounding) 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. The forecaster chose a location and valid time for the daily forecast soundings used in the forecasts. The sounding disseminated with the forecast was the one for 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 around that time, 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 define 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, and was also emailed with the rest of the forecast.

The forecaster then completed the daily forecast as a digital pdf document. Included in the daily forecast were mandatory level charts for the chosen valid time including: 500 mb height analysis for position of any shortwaves or vorticity lobes, surface analysis (including fronts, lows, highs, troughs, and dry lines), position of upper jet streaks at 300 mb, and 850 mb theta-e (equivalent potential temperature) to identify presence of low level moisture. The text body of the forecast was in two main sections including a synopsis of the overall weather features, and a section to describe the expected weather through the next morning. The rest of the forecast thermodynamic parameters included on the forecast were taken directly from the modified sounding and were identical to the forecast sounding diagram that was also included in the forecast. The forecast sheet also included a checklist. The purpose of the checklist is to make sure a forecaster does not inadvertently overlook 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 37). 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 were 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.

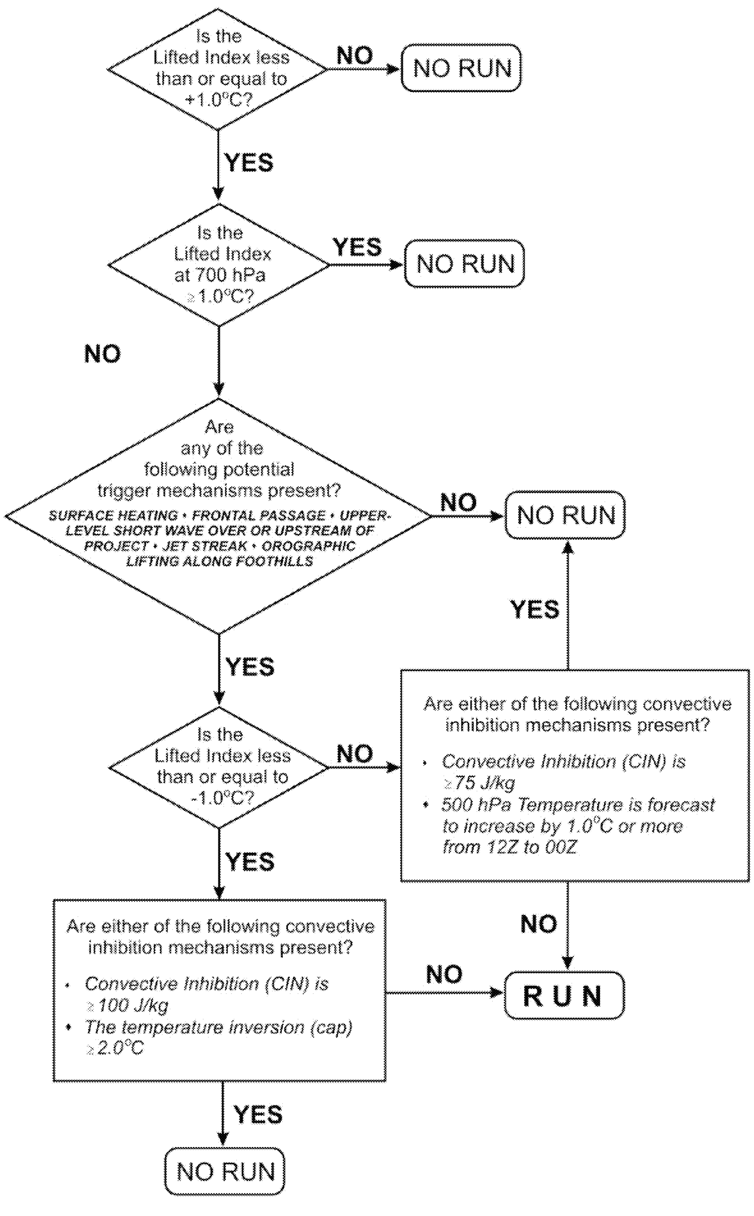


Figure 37. (Left) Hailcast run/no-run flow chart.

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 sounding image to the email and sent it at 10:45 local time, or about 15 minutes prior to the daily briefing.

11.4 DAILY BRIEFINGS

All project staff participated in a "GoToMeeting" visual weather briefing with full video support each day at 11:00 AM (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 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.