

DRAFT

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EXAMINATION OF THE POTENTIAL FOR SURFACE CONTAMINATION FROM FUEL DUMPING EVENTS AT GOOSE BAY, LABRADOR

Aim

The aim of this paper is to examine the potential for surface contamination through modeling of the individual fuel dumping/tank jettison events that occurred between 1999 and 2003.

Introduction

Fuel Dumping and tank jettisoning are precautionary procedures carried out to reduce an aircraft's gross weight and facilitate safe landing of the aircraft, should the aircraft experience an in-flight emergency.

Fuel Dumping is the discharge of unburned fuel from the aircraft directly into the atmosphere while the aircraft is in flight, through ports located either on the wing tips or in the tail, designed to maximize the atomization of the fuel.

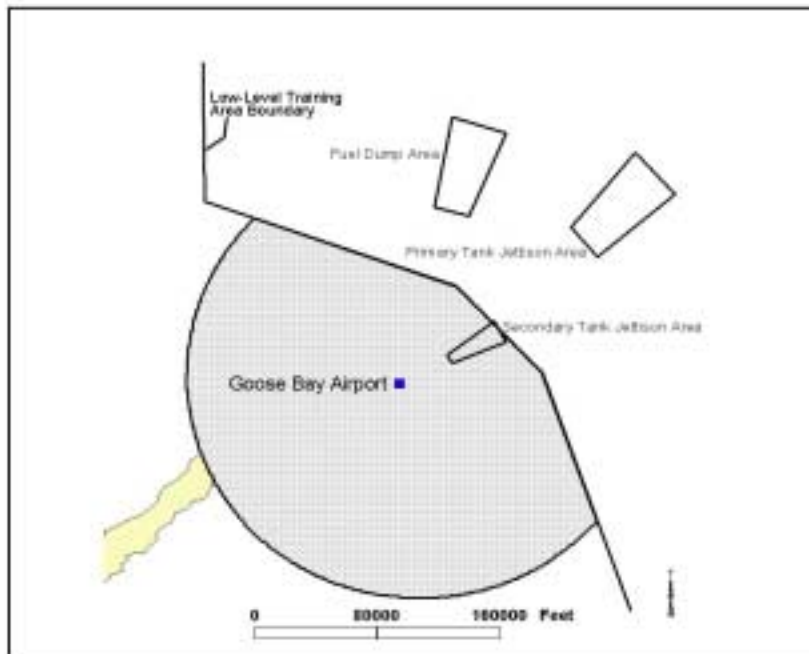
In the event of an in-flight emergency, air traffic control will direct the aircraft to the designated fuel dump area, approximately 20 nautical miles to the northeast of the aerodrome. The fuel dump area is situated close to the aerodrome and just off the approach to the primary runway, yet away from flight routes so the resulting fuel plume will not present a hazard to other aircraft. It is also an area with no permanent human occupancy and no known ecological sensitivity to potential fuel contamination. The dumping altitude is sufficiently high to ensure that most of the fuel discharged from the aircraft dissipates before reaching the ground. If the emergency condition does not permit controlled dumping in the designated dump area, fuel dumping may be carried out prior to landing without regard for position or altitude.

Based on occurrences for this period, four to five events are predicted over the course of a season.

Tank Jettison refers to the jettisoning of external fuel tanks from military fighter aircraft. This usually occurs at take-off. External tanks may contain up to 1000 liters of fuel, and are expected to rupture on impact. They are released under controlled conditions in the vicinity of the aerodrome where impact has the least potential for collateral damage.

Fuel tank jettison is a rare occurrence. Typically, one such incident is anticipated per training season.

The locations of the dumping and jettison areas are shown below.



Applicable Standards Or Regulations

The Canadian Forces Flying Orders establish the minimum altitude for controlled fuel dumping at 5,000 feet, which is the standard for fuel dumping set out in 5 Wing Flying Orders for military aircraft. There are no similar regulations for civilian aviation. However, civil aviation generally operates above 25,000 ft, so it is reasonable to expect that most events involving airliners would, by virtue of their operating altitude, conform to this same standard.

There are no environmental standards or regulations for contamination due to aircraft fuel dumping. The Canadian Council of Ministers of the Environment (CCME) published standards for Petroleum Hydrocarbons (PHC) in soil in May 2001. The most stringent of the CCME Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil, are 30mg/kg for residential/Parkland land use and 130mg/kg for Agricultural Land Use and course-grained soil(Fraction 1). Some of the components of aviation fuel such as benzene, toluene and aromatics which are also components of these CCME standards. Therefore, while these standards are not intended to be applied aviation fuel dump events, the CCME standards would seem to be the most appropriate to apply for guidance.

MITIGATION MEASURES

The Environmental Impact Statement on Military Flying Activities (DND1994) determined that the potential for watershed contamination resulting from fuel dumping events was negligible

when events occurred at sufficient altitude. The EIS further estimated that the total amount of liquid fuel reaching the ground surface ranged from 0.1 to 23.1% of the weight released. It was considered that raw fuel settling over a watershed would mix with the top 10-centimetre layer, resulting in a concentration of less than 0.012 ppm, whereas fuel settling over the ground surface was predicted to have a maximum concentration of 0.1 ppm, assuming that the fuel is retained onto the first centimeter of soil.

Mitigation measures for fuel dump/tank jettison are not designed nor can they prevent the event(s) from occurring. Instead, they attempt to control conditions and to minimize the potential environmental impact at ground surface. For fuel dumps, there is no practical clean-up. The area covered by a plume is extremely large, and as can be seen from the deposition charts, while the deposition is so low that even in the highest concentration areas, it would probably be below detection limits of standard laboratory equipment.

Tank jettison incidents are treated as fuel spill incidents. Whenever possible, these tanks are recovered and the site remediated.

Fuel Dump Modeling

Modeling is essentially a validation process for mitigation measures. Through application of the computer model, the potential risk of surface contamination from each event can be consistently analyzed, potential contamination levels, and localized contamination areas predicted.

Modeling is performed using the commercially licensed Fuel Jettison Simulation Model (FJSIM). This model was developed for the USAF, and incorporates “a Lagrangian approach to track the behavior of each fuel port exit stream through the assumed field flow (modeling aircraft wake and atmospheric effects) by writing trajectory equations of motion and then solving them exactly from step to step”. The FJSIM model incorporates fuel port locations, pump pressures and capacities unique to individual airframes, climatic conditions at altitude and fuel vaporization characteristics into the modeling algorithms. The FJSIM software was adopted as the modeling tool, as it was assessed to have the most rigorous modeling algorithm and was also the most flexible model for examining the “worst case situation”.

Dump events are reported as occurrence reports provided by aircrew following the event. For each event the modeled results are presented at Annexes A and B. Annex A presents a series of four charts for each event as follows:

Deposition: The predicted fuel deposition pattern on the surface is presented in the form of an isopleth. The red arrows indicate wind directions at given altitude(s); the blue arrow represents north, while the black arrow represents the direction of flight of the aircraft and position relative to the surface deposition. The chart also indicates the maximum deposition.

Deposition Cross Section: This chart displays the surface disposition in cross section, viewed in a plane perpendicular to the flight path, as the aircraft flies into the page.

Surface Area Evaporation: This chart plots the persistence of the volume fraction of the deposited material with surface evaporation. Persistence is greatly affected by temperature and fuel type.

Vapor Aloft: This chart plots the effects of evaporation. As the atomized fuel falls through the atmosphere, evaporation removes the more volatile components and increases the vapor volume fraction. The vapor aloft chart indicates what portion of the fuel dumped that does not reach the surface. Typically, greater than 99% of the fuel remains aloft as vapor.

Annex B presents the individual components of fuel (JP8)

Modelling For The Worst- Case Situation

As with any model, there are limitations in the model itself and with the input parameters. Therefore, to establish the worst-case situation, assumptions must be made when information for the event is limited, or when circumstances exceed model parameters. These include:

Circling versus straight-line dumping: An aircraft may be required to circle in order to remain in the fuel dump area. Otherwise, given quantity being pumped out or aircraft speed, the aircraft could not remain within the fuel dump area. FJSIM cannot model multiple passes or circular dumping events. For such events the fuel quantity must be divided by the number of passes, and the circular flight pattern segmented into flight legs. Modeling must then be performed for each pass and flight leg individually. Once the modeling is complete, each flight leg would then need to be treated as a layer with the deposition predicted from the addition of the individual layers. To model such events accurately would require the aircrew to provide detailed data by altitude on the event as well as the start-stop points for each flight leg. To expect this degree of detail during an in-flight emergency is unrealistic. Therefore, it is assumed that the entire quantity of fuel is dumped in one pass at the lowest dumping altitude reported. In doing so, the plume is no longer representative, but the predicted deposition is clearly the worst-case.

Wind: Depending on aircraft altitude, winds between the surface and the aircraft usually change direction and/or speed, affecting both deposition and plume shape and size. Upper altitude climatic information may be limited as it is not gathered locally or at the time of the event. If not available, it must be assumed that the wind is constant from surface to dump altitude.

Changing altitude: Aircraft often reduce altitude during the dump event as the aircraft prepares for landing. For example, in the event of 7 March, the aircraft reduced altitude from 25,000 down to 6,000 feet while dumping fuel. The model does not factor changing altitudes into the algorithm, nor can aircrew provide detailed information on the quantity of fuel dumped as the aircraft passes through altitude blocks. Therefore, to ensure the worst – case situation, the minimum dump altitude is assumed.

Event data: As indicated above, there are a number of factors that go into the model. As these events are emergency procedures, the accuracy and amount of information is secondary to the aircrew's primary responsibility of the safe resolution of the emergency. Aircraft positional data, for example, tends to be limited to a heading and approximate distance from the airfield. Likewise the position of the aircraft at the beginning/end of the dump procedure is approximate.

RESULTS

The amount of fuel that reaches the earth's surface as a result of a fuel dump may be influenced by:

- a. quantity of fuel dumped,
- b. aircraft fuel pumping system: the design and number of orifices as well as their positioning on the tail or wingtips and the pumping pressure directly affects the atomization of the fuel,
- c. dumping procedures: aircraft speed affects the length of the fuel plume, while the release altitude affects the time the fuel is airborne and evaporating. The turbulence of the air resulting by the aircraft passing affects the dispersion of the plume, as does maneuvering the aircraft(race track vs. straight flight), and
- d. atmospheric conditions: fuel evaporation rates and movement of the fuel plume through the atmosphere is affected both by air temperature, wind speed and direction. The warmer the air the faster the fuel evaporates. However air temperature is affected by altitude. Therefore, increasing dumping altitudes may not provide significant benefits due to reduced evaporation rates.

From the vapor aloft charts, the model predicts that, for almost every event, more than 99% of the fuel dumped would evaporate before it reaches the surface. This quantity would continue to evaporate, reducing the surface deposition by approximately one half within 21 days.

During the five training seasons included in this report, a total of 22 fuel dumps involving military fighters occurred with no tank jettison events. This level of occurrence was well below the level reported in the EIS for approximately the same level of flying activity. Six events occurred outside the designated fuel dump area (FDA) and two occurred below the minimum dump altitude of 5000ft. A third event occurred 400 ft below the minimum altitude and was not considered to be below the standard dump altitude. The most significant fuel quantities dumped were not related to military jet activity. For example, the event of 7 March 2002, involving a civilian airliner with a medical emergency, dumped approximately 24,000 litres of fuel. Applying worst-case assumptions, the model predicts that approximately 1864L of fuel might have been deposited at ground surface, covering an area of greater than 30,000 sq ha. However, even under the worst-case situation, a maximum deposition of only .022ml/sqm would have resulted. The next most significant event involved an A340 Airbus that dumped approximately 15,189 litres of fuel on 26 July 2003, with a predicted deposition of .0159ml/sq m. Typically, a military fighter would be expected to dump between 1400 and 5600 litres of fuel, with deposition of less than 100 litres for events occurring during summer. However, deposition increases for events occurring during colder air temperatures.

Although there were no tank jettison events, these appear to be the more significant events, as it may involve dropping a tank (full) of fuel with no opportunity for evaporation. The entire quantity (up to 1000 liters for a full tank) would be spilled on the surface as the tank is expected to rupture on impact. Fuel in external tanks is normally consumed first. Therefore, it can be assumed that aircraft returning to the aerodrome with an in-

flight emergency would have little fuel remaining in these tanks. The potential for contamination in this situation is negligible. However, an in-flight emergency during take-off, when most jettison events occur, as the aircraft reduces its weight to maintain flight, would likely occur west of the primary runway. Wing procedures designate the drop site as the inner basin of Lake Melville, east of the aerodrome. Given the proximity of the main runway to the Lake, it would be appropriate to maintain this area as a secondary drop site. However, it would seem the primary jettison site is misplaced.

Monitoring

As part of the ongoing Monitoring program, National Defence gathered field samples from soil and vegetation in the fuel dump area, and attempted to validate the FJSIM predictions using field samples gathered following a dump event. From the Table, the fuel dump area is the area most heavily used and would be expected to be the area where the highest contaminant levels should be expected. The laboratory analysis of the samples from this area does not support this assumption.

The FJSIM validation proved impractical for the following reasons and was discontinued;

- a. site access cannot be assumed. Access to the LLTA generally requires helicopter support. However the ability to land the helicopter in the area to be sampled is not always possible.
- b. the inability to accurately position the maximum deposition area on the ground as discussed above, and
- c. positioning of the plume on the ground is too coarse. Given the very small target area for the maximum deposition it is unlikely that the sample site will be within the maximum deposition area
- d. the model predicts that even in the highest deposition areas, contamination levels are likely to be below detectable limits using standard laboratory techniques

Conclusions

The frequency of occurrences for both fuel dumps and tank jettison events is well below the levels reported in the EIS

The EIS predicted contaminant levels resulting from a dump event would be negligible. Based on the FJSIM modeling of actual events and the results of laboratory analysis of soil and vegetation samples from the fuel dump area there is no evidence to suggest the EIS prediction is not valid

Table 1

DUMPING OCCURRENCES

Figure	Date	Location	Fuel Dumped(l)	Altitude (ft)	Maximum Deposition (ml/m sq)	Total fuel reaching surface(L)
	1999					
1	20 Feb	5nm east of aerodrome	5062	6,000	.0015	677
2	22 Feb	FDA	5625	6,000	.0029	791
3	1 Apr	FDA	2103	13,000	4.5e-04	32
4	5 May	35 nm east of aerodrome	2250	10,000	2.4E-05	124
	2000					
5	30 Oct	South-West of aerodrome	1690	10,000	.0028	40.7
	2001					
6	24 May	FDA	2250	10,000	1.5E-04	19
7	28 May	F D A	1687	10,000	2.3 E-04	13
8	10 July	South of Aerodrome	2222	4,600	5.4E-04	33
9	31 July	F D A	2025	8,000	1.1E-04	8.0
10	1 Aug	F D A	2481	10,000 >7,000	1.2E-04	13.9
11	3 Aug	F D A	2977	6000	3.14E-04	19.3
12	22 Aug	F D A	1406	6000	2.7E-04	9.6
13	17 Sept	FDA	1687	10,000 >6,000	.0023	26(X2)
	2002					
14*	7 March	North-East of aerodrome	23933	25,000 >6000	.0221	1864
15	19 March	FDA	7,313	5,000	.0020	627
16	19 April	30nm south of aerodrome	1,985	20,000	1.0E-04	51
17	18 May	FDA	3,102	12,000	.0016	173
18	12 June	FDA	2,813	6,000	.0014	37
19	21 June	South of aerodrome	1,688	2,000	1.3E-04	17
20	18 July	FDA	1,688	6,000	6.1E-04	51
21	16 Aug	FDA	1,861	8,000	1.3E-04	10
22	26 Sept	FDA	4,500	5000	.0023	77
	2003					
23*	26 Jul	North of aerodrome	15189	35,000> 10,000	.0159	1332
24	30 Jul	FDA	5625	1000	.016	302
25*	8 Dec	North East of aerodrome	8438	22,500>	.0112	1531

Notes:

1. FDA indicates the event was conducted over the designated fuel dump area,
2. The event of 17 Sept 2001 was related to a North American Air Defence threat response following the 11 September incident. This event resulted in the simultaneous dumping of fuel by two aircraft.
3. The 22 Aug and 17 September events involved CF18 aircraft, while the events of 31 July, 1 Aug 3 Aug were French Mirage. These aircraft are not incorporated into the model, therefore, the Tornado was used for the modeling.
4. The events of 10 July and 21 June occurred outside the FDA. In both events the aircraft was unable to reach the designated dump area.
4. * indicates events involving passenger/transport aircraft

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