

REDUCING WATER VAPOUR EMISSIONS AND FOG FORMATION AT SAGD FACILITIES

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ABSTRACT

Steam generators at SAGD facilities in the oilsands area of Alberta produce significant amounts of water vapour emissions that can cause visible plumes. Alberta Oil Sands has incorporated novel condenser technology into its SAGD plant design to cost-effectively reduce vapour emissions.

The process uses cold process fluids to cool the steam generator flue gas below its condensing point. The flue gas contains significant water as a product of combustion which is recovered and used in the SAGD process. The system reduces fuel consumption in the boiler and reduces the source water requirements of the project.

The impact of emission reductions on visible plume formation was determined using the CALPUFF dispersion model in PLUME mode which provides statistics on the frequency and characteristics of visible plume. Using meteorological data from five years at the Fort McMurray airport and 70-75% reduction in water vapour emissions, AOS showed that the frequency of plume visibility was reduced from 45% of the time with un-reduced water vapour emissions to 33% of the time. The length of the longest visible plumes was reduced from 3000 to 1300 m. The longest plumes were formed in very cold, stable air and light winds, and most often in winter nights. Visible plumes were not predicted to reach the ground and contribute to surface-based ice fog.

KEY WORDS

Fog, plume dispersion, flue gas condensation, oil sands.

1. Introduction

The proposed Alberta Oil Sands (AOS) Clearwater West Steam Assisted Gravity Drainage (SAGD) Pilot Project

would be situated 1.4 km south of the east end of the runway at the Fort McMurray airport. Plumes from the steam generator have high moisture content, which under certain meteorological conditions, may result in visible plume formation in the area. The remaining two stacks (fractionation boiler and truck flare) contribute reduced water emissions.

The proximity of the proposed development to the Fort McMurray airport and residential areas necessitates an understanding of potential project impact on local visibility. In particular, the goal is to limit the frequency of occurrence and length of visible plumes so that airport operations are not hampered. To assess visibility, modelling using CALPUFF in FOG mode was performed. This paper outlines the modelling approach used, the results of the analysis and references technology proposed to reduced water vapour emissions.

2. Water Vapour Emissions and Plume Modelling Approach

AOS novel condenser technology in its SAGD plant design uses cold process fluids to cool the steam generator flue gas below its condensing point, to cost-effectively reduce vapour emissions. The flue gas contains significant water as a product of combustion which is recovered and used in the SAGD process. The system reduces fuel consumption in the boiler and reduces the source water requirements of the project. The total water emissions from the site are 50 t/d (Table 1) after removing 70% of water from the steam generator exhaust (134 t/d with no removal).

The water vapour content of the flue gas depends in part on the fuel burned, with the largely methane gas used as fuel producing more water vapour than burning straight hydrogen or pure carbon. AOS has included a condensing

economizer in its steam generator design which reduces heat exhausted through the boiler by reducing flue gas temperature and water vapour content. In the AOS design, a portion of the flue gas is routed through a heat transfer chamber into which saturated gas enters. A spray of fine water droplets contacts the flue gas. The gas is cooled below its inlet dew point temperature, condensing all the water used to adiabatically to cool it. The condensed water can be used as boiler feedwater to reduce make-up requirements.

The height, length and frequency of visible plumes from the remainder of the water vapour in the flue gas were predicted using the CALPUFF model [1]. The CALPUFF model requires the input of wind speed, direction, atmospheric stability class, temperature, mixing heights, and relative humidity to assess fogging potential. The first five parameters were extracted from a CALMET dataset developed for 2002 to 2006, using a standard Alberta Environment 3D meteorological dataset. The wind rose from this dataset at Fort McMurray is shown in Figure 1. The relative humidity was obtained from observational data from the nearby Fort McMurray Airport.

Table 1
Steam generator emission parameters

Parameter/Emission	Steam generator	
	70% Reduction	No Reduction
Power Rating (kW)	34000	34000
Power Rating (MMBtu/hr)	116	116
Stack Height (m)	30	30
Stack Diameter (m)	0.6	0.6
Stack Gas Velocity (m/s)	16	16
Stack Gas Temp (°C)	60	177
H ₂ O Emissions (t/d)	36	120

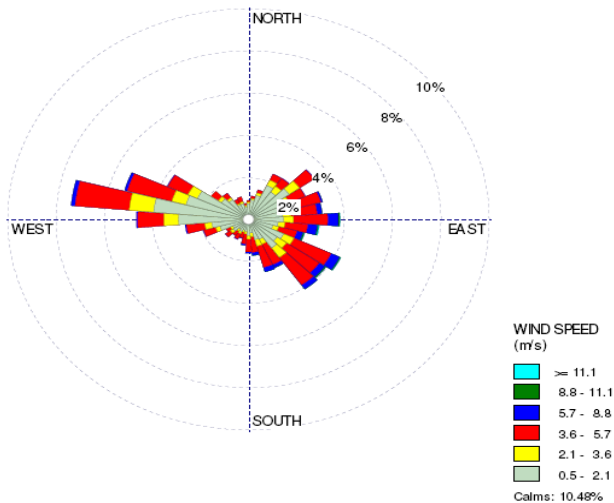


Figure 1 Fort McMurray airport wind rose

3. Assessment of Visible Plumes

Predicted frequencies of visible plume occurrence on an annual basis, including both daylight and night time

hours, are presented in Table 2. With 70% of water vapour removed from the steam generator exhaust, the average frequency of occurrence of a visible plume was 33%, compared to 46% without removal.

Table 2
Predicted visible plume frequencies

Case	2002 (%)	2003 (%)	2004 (%)	2005 (%)	2006 (%)
70% H ₂ O Stripped	37	32	33	33	30
Full H ₂ O Emissions	50	45	46	44	44

With 70% of water vapour removed, the most frequently predicted plume height (Figure 2 top) was 50 to 60 m above ground level, with some below 25 m as a result of diluent fractionator heater and truck flare emissions. The highest predicted plume heights are 90 m, occurring at a maximum frequency of 0.1% over the five-year period modelled. Without stripping, most frequent plume heights are also 50 to 60 m. However, in this case, there were fewer visible plumes below 30 m and no visible plumes below 25 m. The highest predicted plume heights were 130 m, occurring at a maximum frequency of 0.3% over the five-year period modelled.

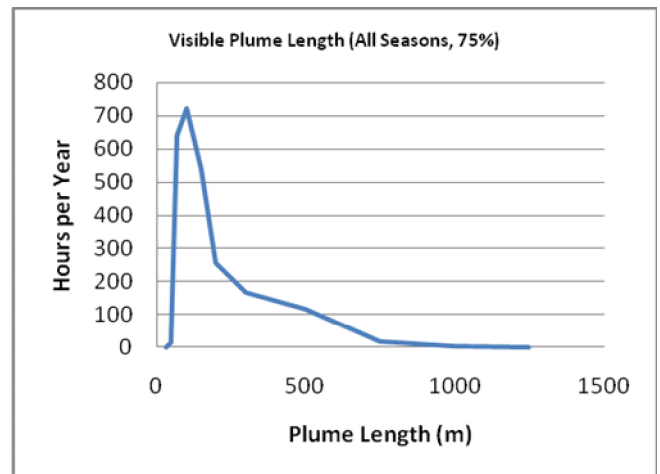
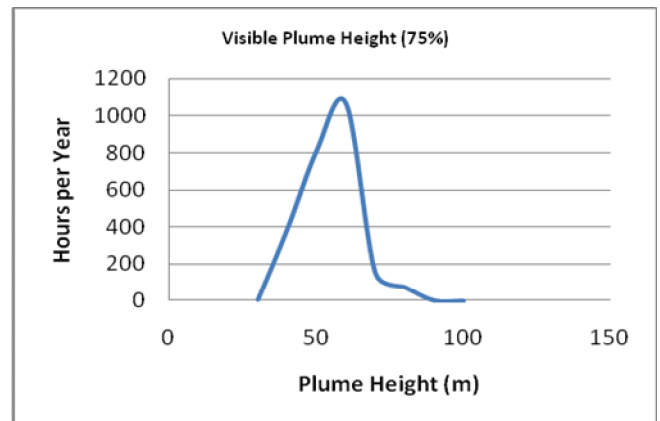


Figure 2 Plume height (top) and length (bottom), 75% water vapour removal

The most frequently predicted plume lengths (Figure 2 bottom) were 50 to 150 m with removal of 70% of water vapour. Plume lengths up to 1250 m (near the end of the airport runway under SE winds) were predicted in three of the five modelled years, at a frequency 0.1% or less. Without vapour reduction, the most frequently predicted plume lengths were 50 to 200 m. The longest predicted plume lengths were up to 3000 m, occurring less than 0.1% of the time. In other words, under SE winds, an untreated steam plume could cover the east end of the runway and airport up to 3.8% of the time (Figure 3).

Additional analysis was completed to understand the seasonal and diurnal impact on visible plume formation. Seasons were defined by Winter (December 2nd to March 1st), Spring (March 2nd to May 1st), Summer (May 2nd to September 1st), and Fall (September 2nd to December 1st). With 70% water removal (Figure 4), 52% of all visible plumes were predicted to occur during the winter period (17% of all hours). Without removal, 43% of visible plumes occurred in winter (20% of all hours). Visible plumes occurred much less frequently in summer.

The model also predicted that most visible winter plumes occurred between sunset and sunrise, the longest plumes at night and the highest plumes in the afternoon. In other seasons, the highest plumes typically occurred around sunrise and the longest plumes occurred at night. Thus, winter nights are the time period during which steam plumes are most likely to affect visibility at the east end of the airport runway.

Ice fog is a concern of the airport authority given its experience that jet engines on the runway can envelope an airport in ice fog for hours. Table 3 indicates the longest predicted plumes occurred in ice fog conditions - most occurred in January in very cold temperatures, early in the morning, under stable conditions. Plume heights were near 60 m and winds were light. None of the plumes were long enough to reach the airport (Figure 5 top). Furthermore, in the stable conditions under which surface-based ice fog occurs, the ice plume does not mix down to the surface (Figure 5 bottom). Thus the elevated ice plume of the steam generator is not predicted to mix with surface-based ice fog to augment the ice fog and lead to reduced visibility.

4. Summary

AOS engineered condensing economizing technology into the design of its steam generator boilers, with the ability to remove 70-75% of water vapour in the fuel gas. Model predictions of plume visibility with 70% of water vapour removed from the steam generator plume indicate:

- Visible plumes occurred more frequently during night time hours, irrespective of season, because plumes dilute less in stable conditions. Visible plumes occurred most often in winter.

- Plume heights most frequently range from 30 to 60 m above ground. These heights are near typical approach heights of aircraft as they pass over the runway threshold on approach.
- Plume lengths near 1300 m were predicted during 4 winter night hours in five years (0.01% of the time). The distance between the facility and the nearest (SE) corner of the runway at the Fort McMurray airport is approximately 1,400 m. Thus, aircraft may see visible plumes on approach or on departure, but should not be affected by them with 70-75% of water vapour removed.
- On average 2/3 of predicted plumes were less than 150 m in length. These plumes are visible to the edge of the AOS facility property line and are not overhead the nearest commercial or industrial facilities, or nearest residences. In the summer months, 95% of predicted plumes are less than 150 m in length.

Without removing water vapour from the steam generator flue gas, maximum predicted visible plume lengths approached 3 km. Visible plumes of that length could reach the eastern end of the runway up to 3.8% of the time, depending on the wind direction, and on average up to 1.7% of the time, and would be at an altitude that could affect aircraft on approach.

The longest plumes occurred in meteorological conditions conducive to the formation of ice fog. Under those conditions, and with 70-75% of the water vapour removed from the steam generator plume, it was not predicted to interact with the surface-based ice fog to further limit visibility at the airport.

Reducing the water vapour content of the steam generator plume by more than 75% proved to be counterproductive, as untreated plumes from the diluent fractionator heater and truck flare became of comparable length.

5. Conclusion

Natural gas is the most common fuel burned in steam generators in SAGD operations in the Alberta oil sands, and a large source of water vapour emissions. AOS incorporated condensing economizers into the design of its steam boilers to reduce emissions of water vapour at its operations near an airport, which reduced the likelihood of visible plumes reaching the airport and industrial and commercial neighbours, and reduced the volume of make-up water needed in its operations.

REFERENCES

[1] Scire, J.S., D.G. Strimaitis, R.J. Yamartino. 2000. A User's Guide for the CALPUFF Dispersion Model. Earth Tech, Concord, MA, January 2000.

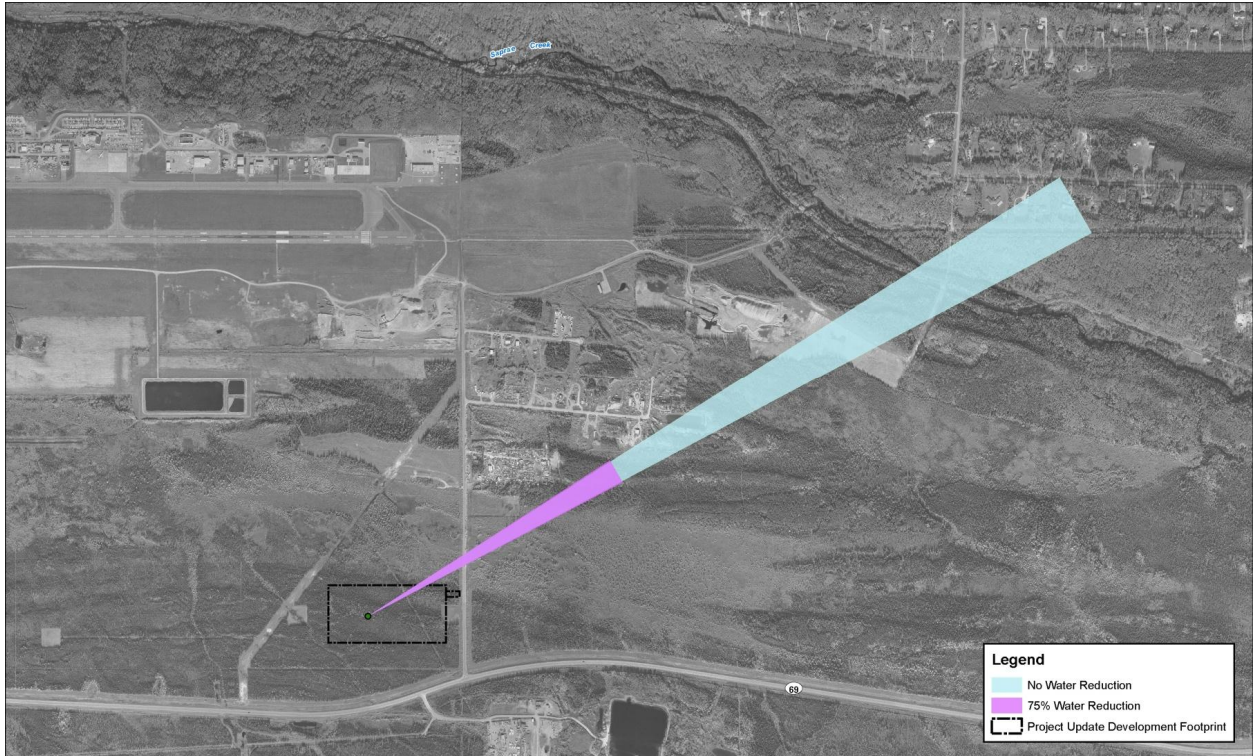
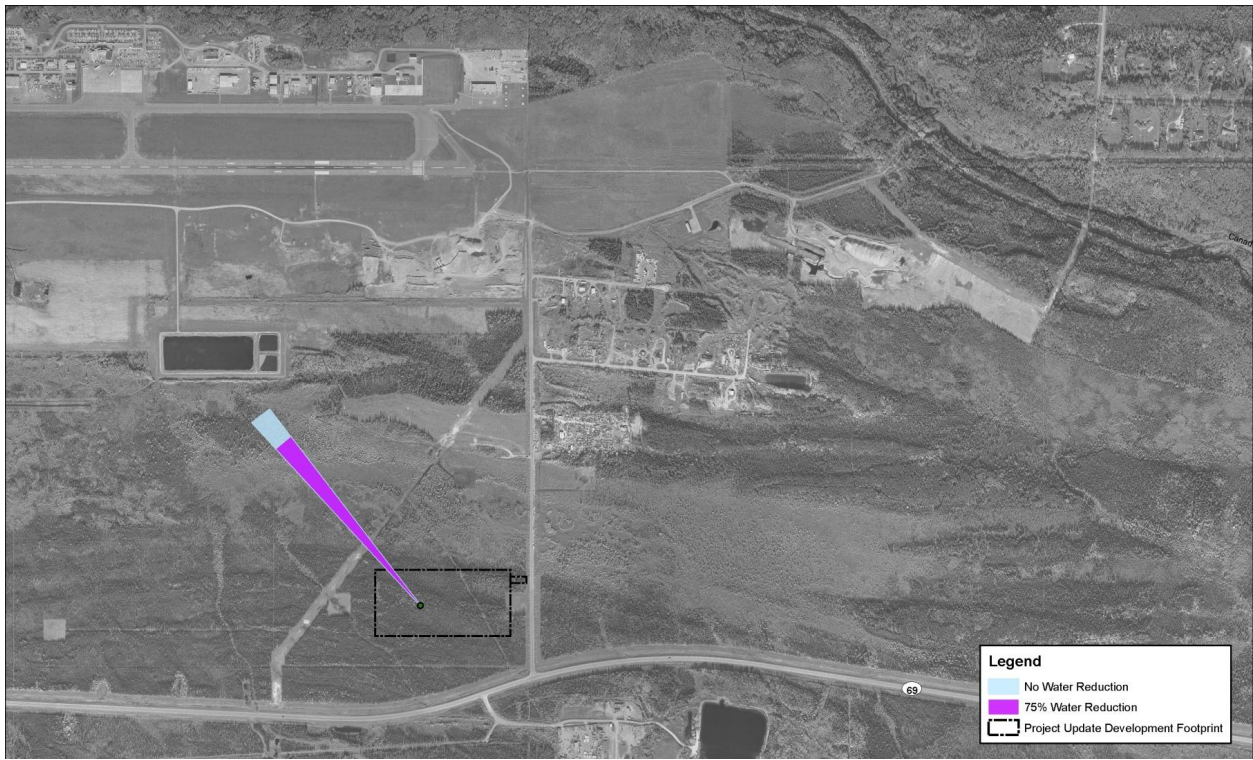


Figure 3 Sample effects of water vapour reduction

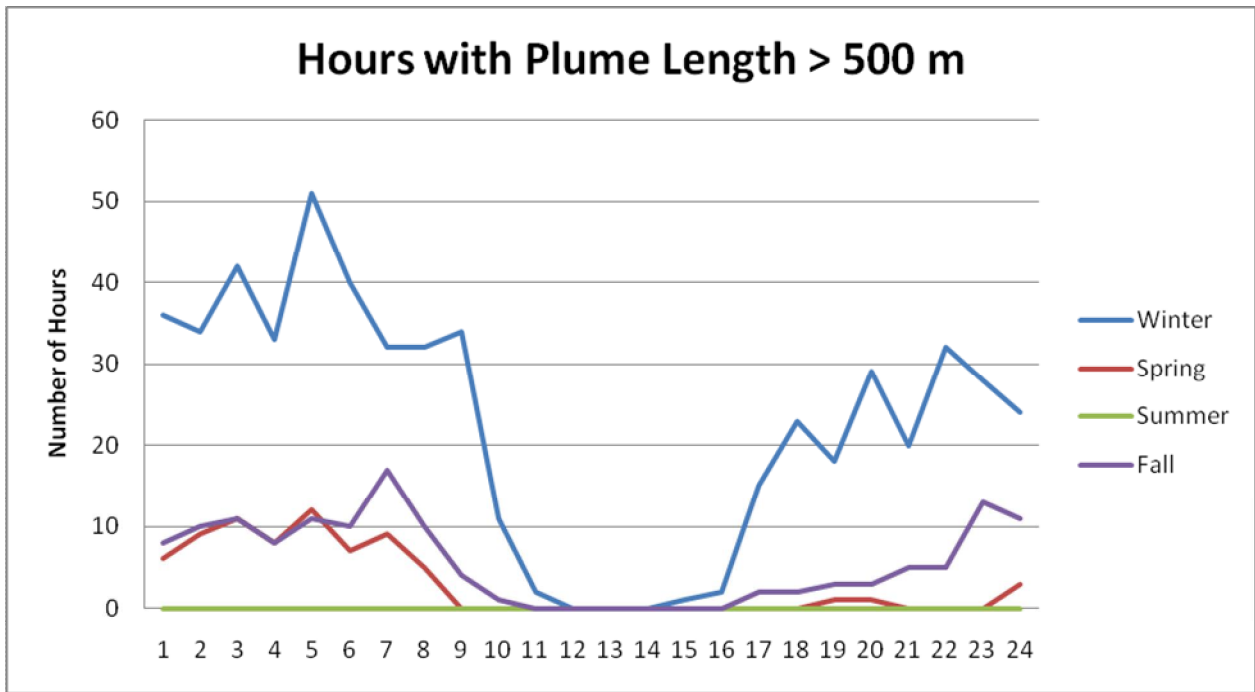


Figure 4 Diurnal and seasonal variations in plume length

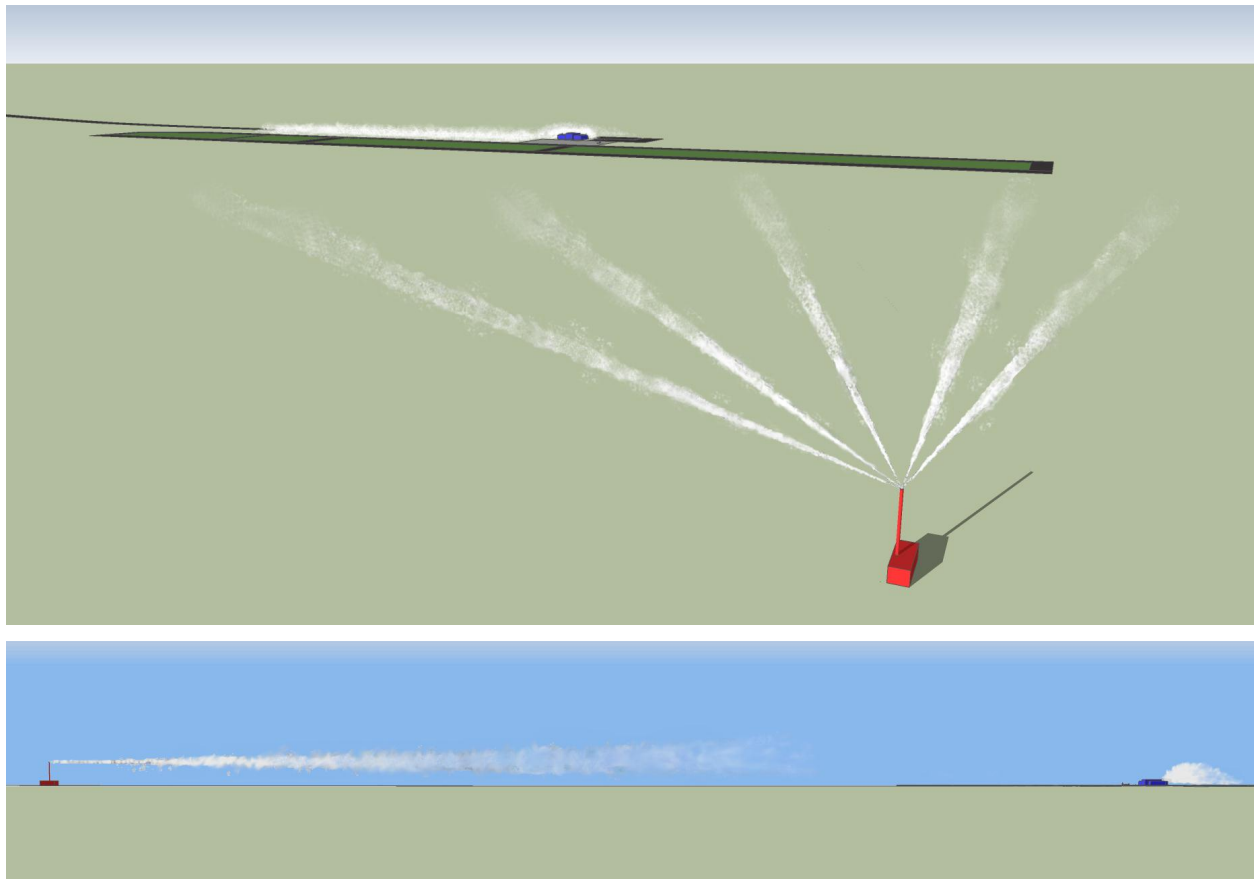


Figure 5 Longest plumes in ice fog conditions ó plan view (top) and side view (bottom)

Table 3
 Meteorological conditions with predicted plume lengths greater than 1000 m ó 70% water removed

Year	Day of Year	Hour of Day	Wind Speed (m/s)	Wind direction (from)	Temperature (°C)	Pasquill-Gifford Stability Class	Mixing Height (m)	Plume Length (m)	Plume Height (m)
2004	27	0900	1.0	WSW	-40	6	50	1,300	60
2004	27	0400	1.0	SSW	-39	6	50	1,300	60
2004	27	0500	1.0	SW	-39	6	50	1,300	60
2004	27	0200	1.0	SSW	-39	6	50	1,300	60
2004	29	0200	1.0	ESE	-38	6	50	1,100	60
2004	29	0300	1.0	ESE	-37	6	50	1,000	60
2005	23	0500	1.0	E	-17	4	50	1,100	75
2003	307	1900	1.0	SW	-22	6	50	1,100	60