STACK TESTING OF DIESEL GENERATORS AT MT. SINAI HOSPITAL

Redefining possible.

Case Study of an Alternative Approach to Regulatory Compliance

PRESENTATION OVERVIEW

1. MOECC regulatory compliance requirements for air quality.
2. Project Background
3. Dispersion modelling and early non-compliance result.
4. Early mitigation that was proposed, and subsequently rejected by the MOECC.
5. Stack testing as an alternative to traditional approach to compliance.
6. Conclusions.

1. MOECC Regulatory Compliance for Air Quality

TERMINOLOGY

MOE (Ministry of the Environment)

…now called:

MOECC (*Ministry of the Environment & Climate Change*)

CofA (Certificate of Approval)

…now called:

ECA *(Environmental Compliance Approval)*

Other Common Terms

EASR *(Environmental Activity and Sector Registry)*

POI *(Point of Impingement)*

When Do You Require an ECA?

Under **Section 9** of the Environmental Protection Act (EPA), if you are a facility and you plan to:

- Construct, alter, extend or replace any building, structure, equipment, or thing that may discharge a contaminant into the environment other than water; or,
- Alter a process or rate of production that may alter the rate of discharge of a contaminant.

Although, there are exemptions, *e.g.*:

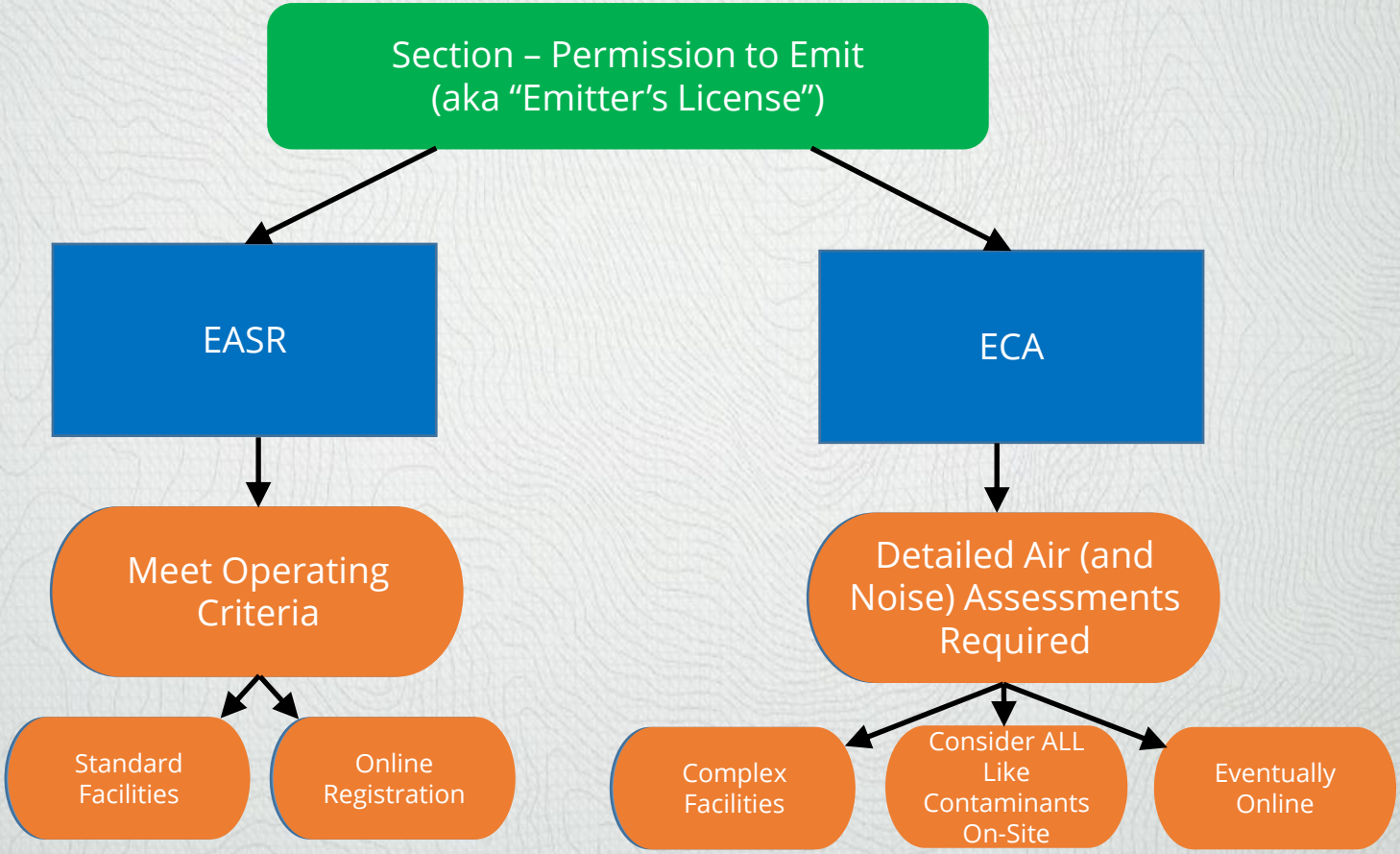
- Residential units
- Construction activities
- Agricultural activities

What and Why?

- Permission to Emit into the Environment
- Ensure that facilities emit within prescribed limits and to reduce environmental and health impacts to the general population
- Proponents must:
  - Conduct dispersion modelling in accordance with the Air Dispersion Modelling Guideline for Ontario (MOECC Guideline A11)
  - Complete an Emission Summary and Dispersion Modelling Report (ESDM) in accordance MOECC Guideline A10
  - Specific requirements outlined in Ontario Regulation (O. Reg.) 419/05: Air Pollution – Local Air Quality

ECA vs EASR?

- Two Routes Through s.9 of EPA

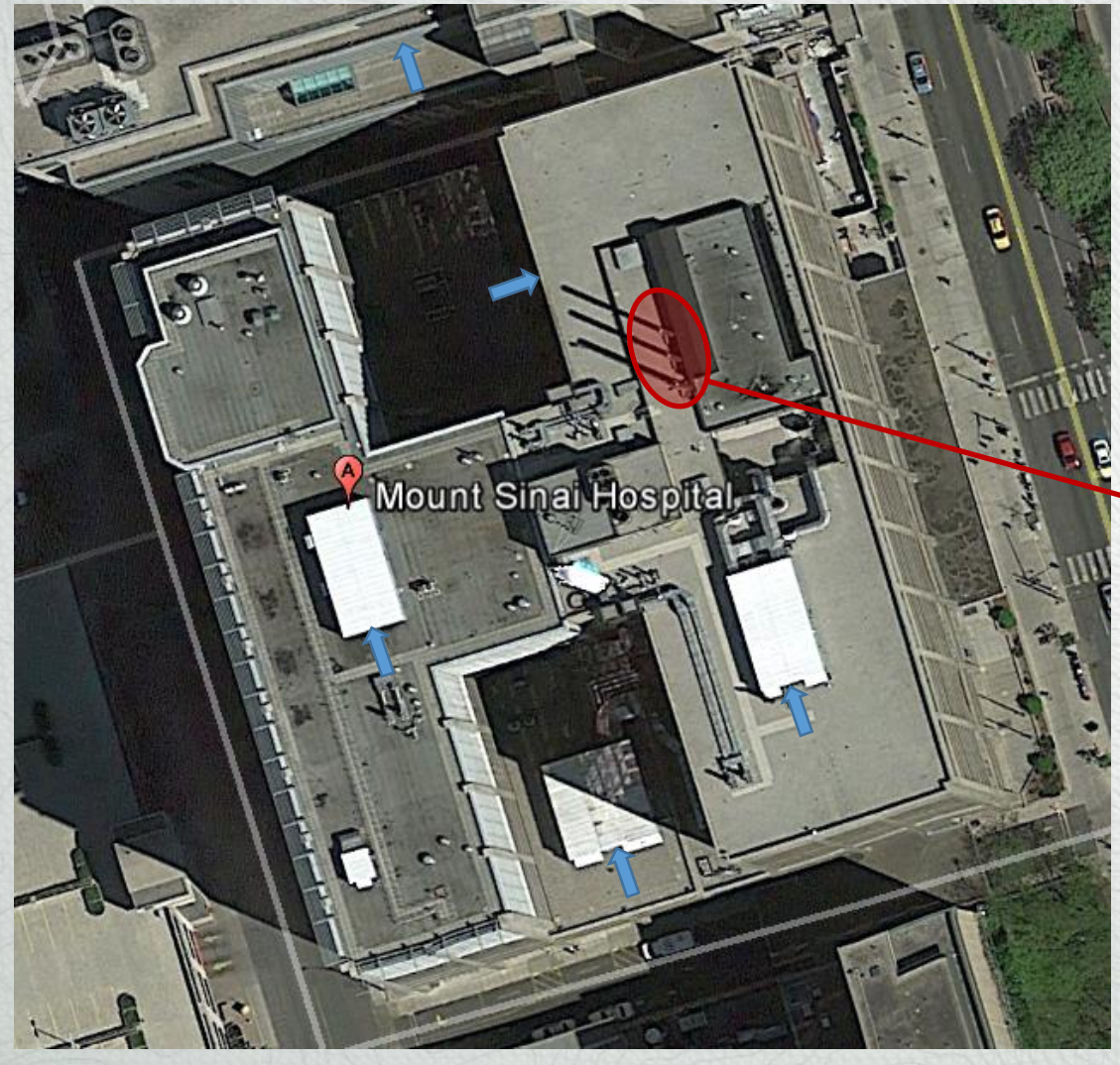


2. Project Overview

Mount Sinai Hospital - Toronto

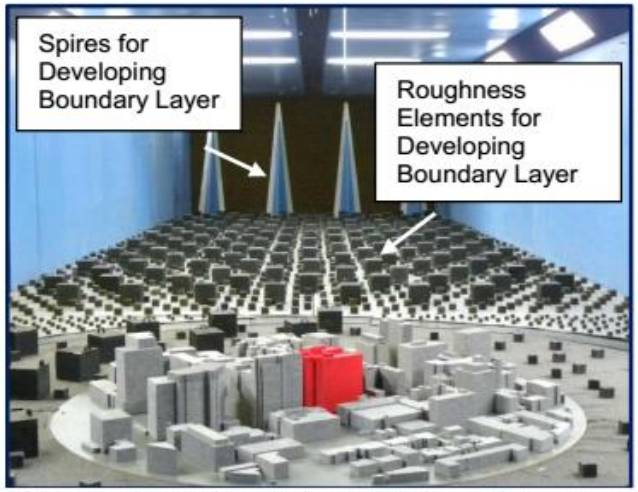
- 3 x 1,500kW Emergency Diesel Generators
- Required C of A (now ECA)
- Numerical modelling showed failures of Point of Impingement (POI) Standards.
- RWDI retained to conduct wind tunnel dispersion modelling to refine results and reduce conservatism.
- MOECC accepts physical modelling as an **alternative** dispersion model. Special approval from the MOECC is required under s. 7 of O. Reg. 419/05.

Mount Sinai Hospital - Toronto

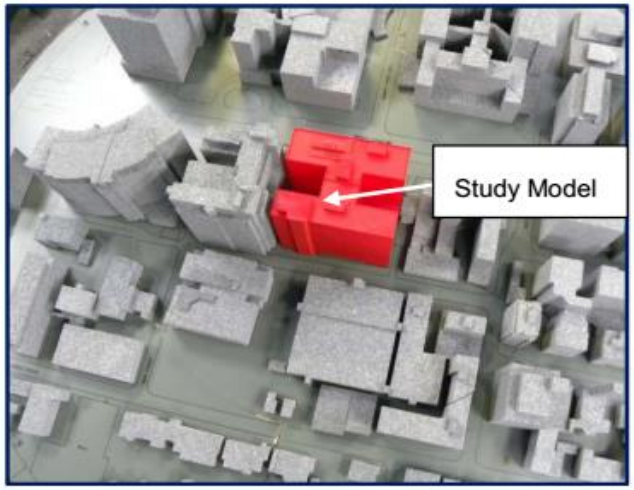


3. Physical Dispersion Modelling

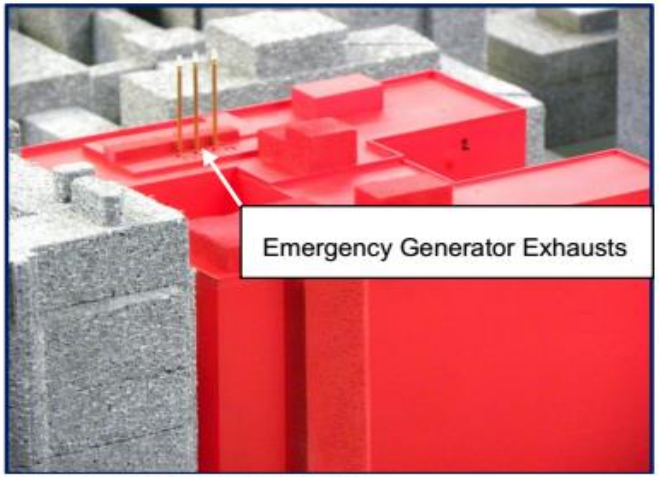
The Physical Model



Scale Model of the Mount Sinai Hospital and Surroundings in one of RWDI's Boundary-Layer Wind Tunnels

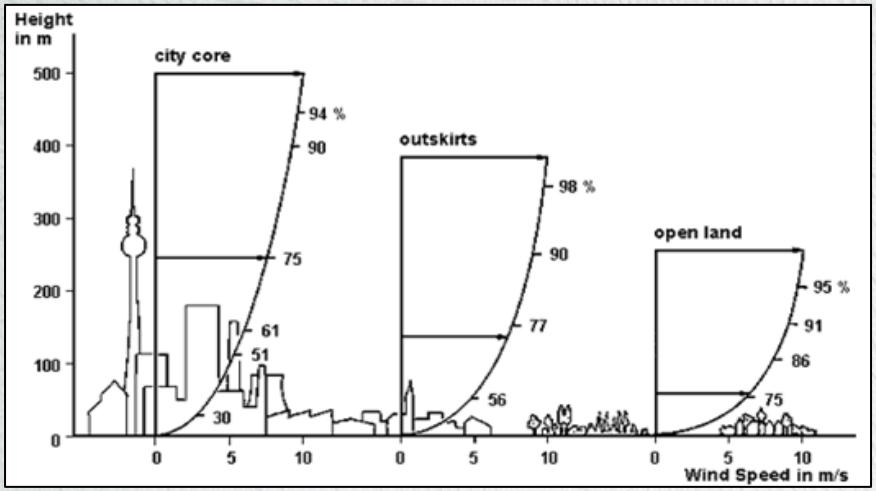


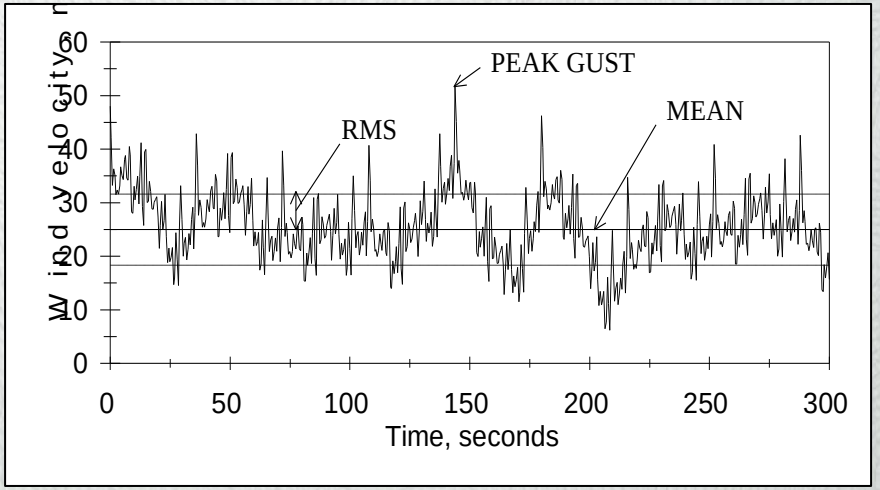
Overhead shot of the Mount Sinai Hospital Scale Model



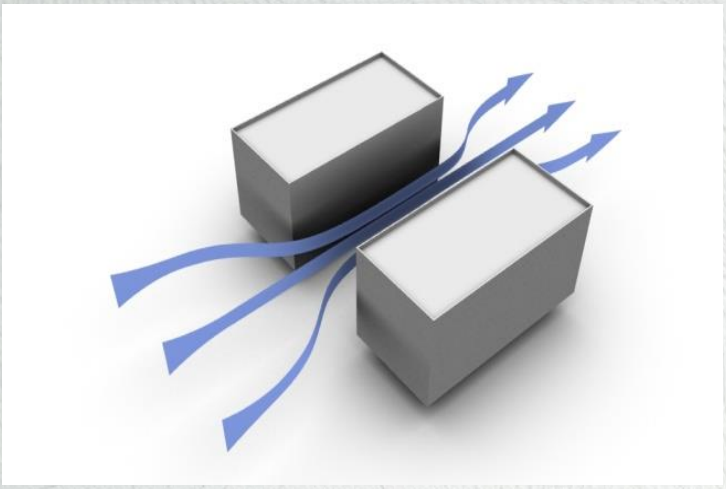
Close-up shots of the Mount Sinai Hospital Scale Model

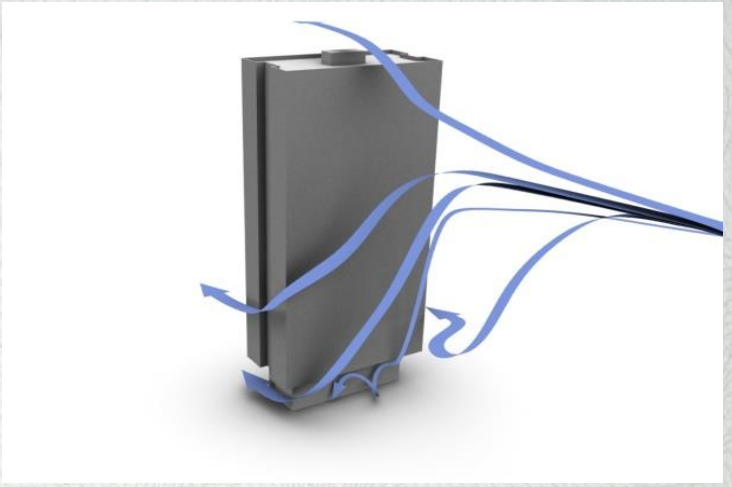
Wind Profile and Turbulence

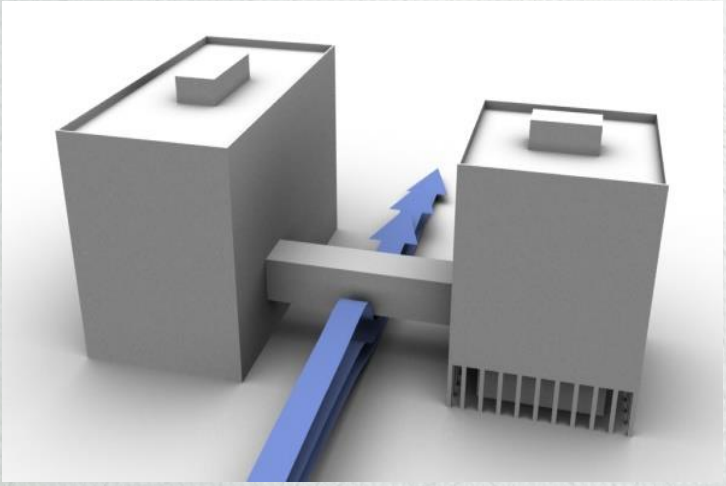


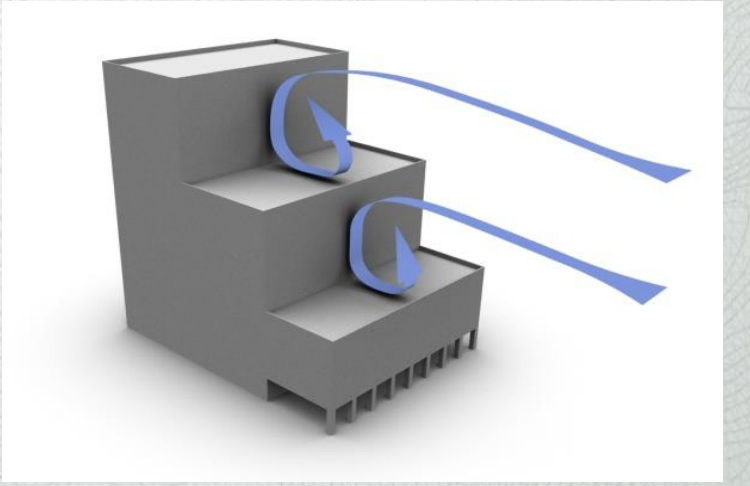


Wind Flow Around Buildings

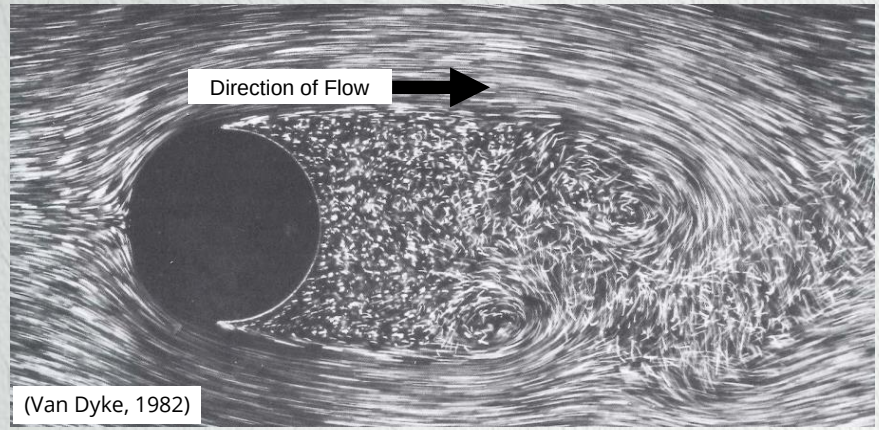




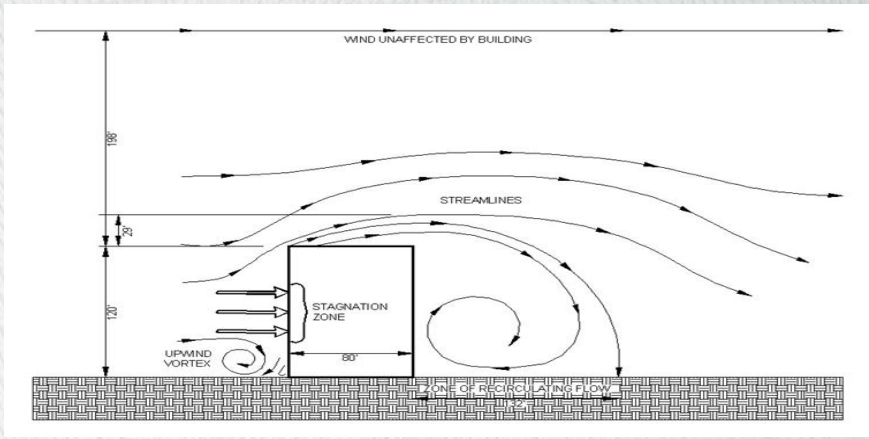


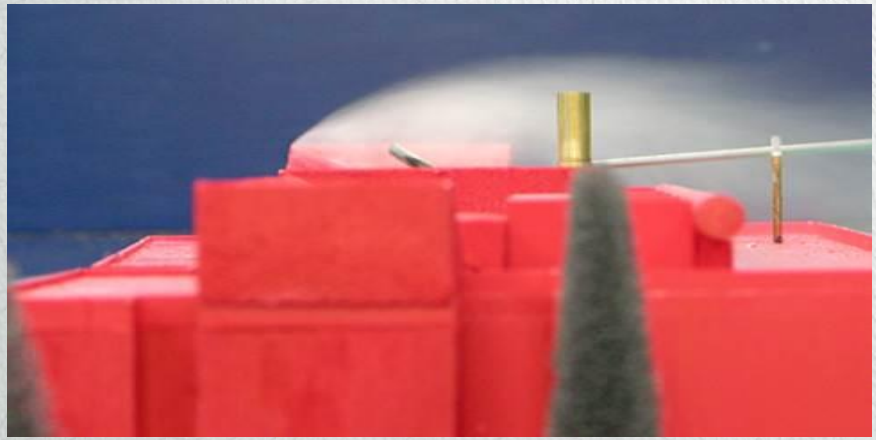


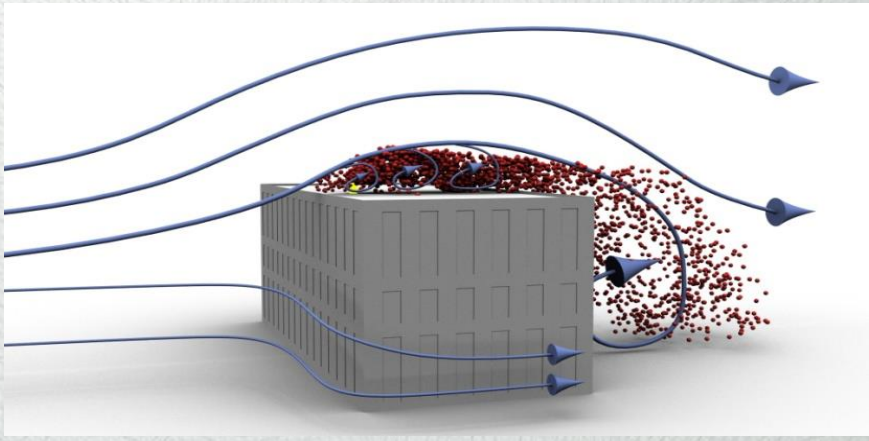
Building Wakes and Turbulence



(Van Dyke, 1982)







Matrix of Data

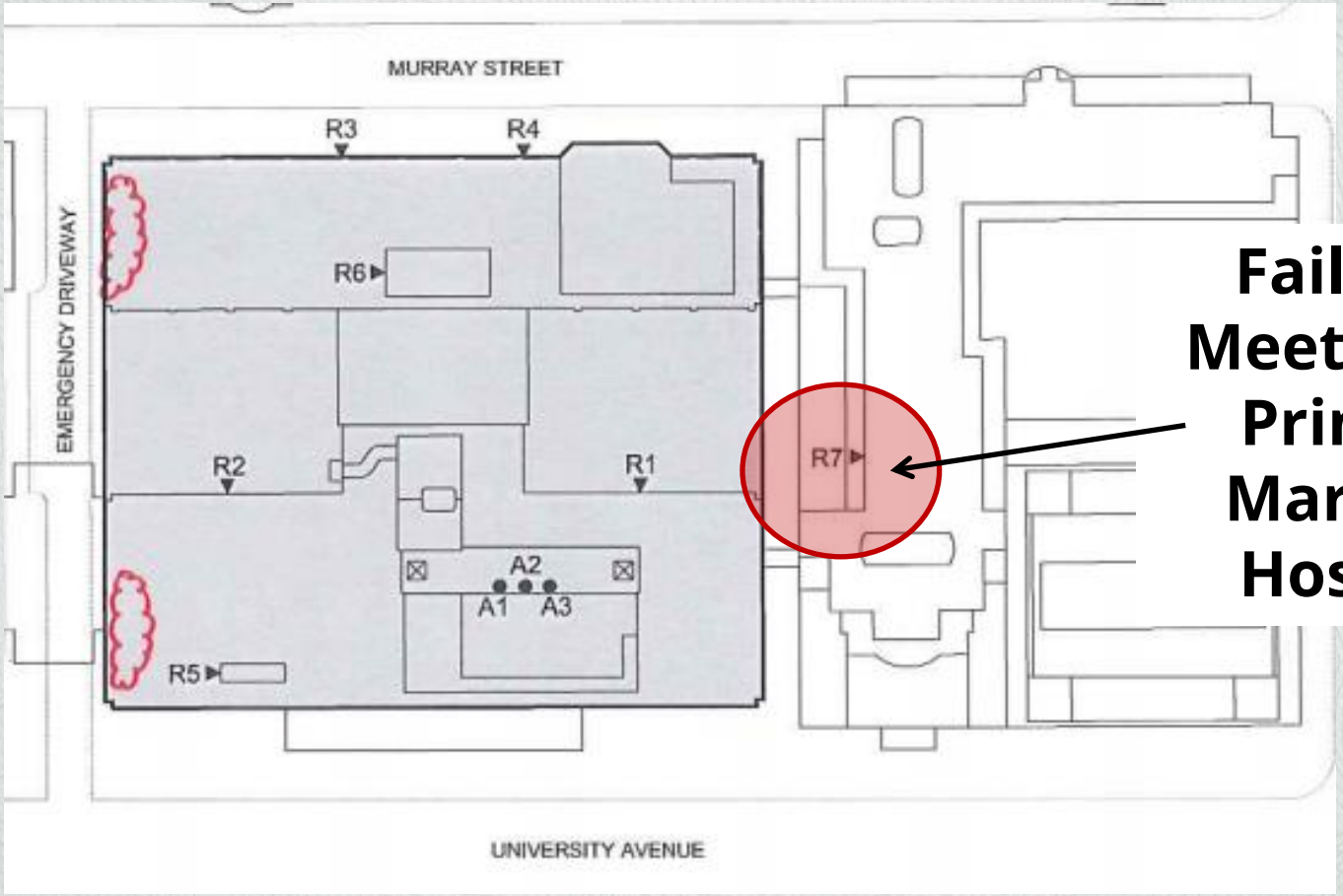
Wind Direction

RECEPTOR LOCATION	WIND (mph)	15	30	NE	60	75	E	105	120	SE	150	165	S	195	210	SW	240	255	W	285	300	NW	330	345	N
7	2	1834	1336	2025	1463	2197	4545	5319	6845	9200	3634	1508	591	327	767	*****	*****	*****	*****	*****	*****	*****	*****	*****	1400
7	5	3628	1429	1904	1614	1918	2571	4322	7375	2215	885	577	374	229	350	*****	*****	*****	*****	*****	*****	*****	*****	*****	4198
7	7	5814	1415	1554	1524	1761	2385	3882	2920	1167	804	702	408	271	325	*****	*****	*****	*****	*****	*****	*****	*****	*****	8711
7	15	*****		1327	1103	1899	2876	3285	1974	1652	1352	1265	782	390	399	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
7	25	*****		1380	915	1605	2536	3174	2149	2670	2073	2008	1099	484	520	8396	*****	*****	*****	*****	*****	*****	*****	*****	*****
8	2	1259	2685	*****	*****	*****	*****	*****	*****	9050	3168	1144	423	227	360	3810	2451	2219	3067	8425	*****	*****	*****	7530	1938
8	5	1314	5552	*****	*****	*****	*****	*****	*****	1925	677	416	255	145	190	2249	1490	1443	1885	4195	*****	*****	*****	*****	5244
8	7	1020	7032	*****	*****	*****	*****	*****	2638	756	519	493	234	147	208	1856	1753	1920	2326	3827	*****	*****	*****	*****	*****
8	15	898		*****	*****	*****	*****	*****	841	574	594	659	323	207	243	1421	2007								
8	25	683		*****	*****	*****	*****	7605	690	663	793	766	365	245	265	1008	1890								
9	2	4733	1956	5219	9009	*****	*****	*****	*****	8110	3654	1431	504	269	586	*****	*****	*****	*****	*****	*****	*****	*****	*****	2950
9	5	*****	2401	6614	7855	*****	*****	*****	*****	2159	892	561	348	186	304	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
9	7	*****	2181	3733	4527	7657	*****	*****	1719	1043	799	667	357	191	323	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
9	15	*****		2424	1783	4625	*****	3656	603	1368	1412	1228	690	291	372	*****	*****								
9	25	*****		1947	1320	2723	6203	2632	578	1927	2186	1991	904	336	382	*****	*****								
31	2	*****	*****	*****	4305	9099	6707	5348	2149	556	382	2845	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
31	5	*****	*****	*****	939	1128	603	1468	875	609	627	3173	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
31	7	*****	*****	6925	964	702	368	686	737	632	693	2636	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
31	15	*****		6394	1607	1262	457	512	678	591	1041	3621	*****	*****	*****	*****	*****								
31	25	*****		*****	2709	2092	845	685	774	806	1504	4417	*****	*****	*****	*****	*****								
42	2	606	1063	529	318	439	2786	5028	3861	1053	398	1721	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	3990	1377	1092
42	5	1326	1227	677	1573	1273	2082	3032	2833	1889	829	2289	4686	*****	*****	*****	*****	*****	*****	*****	*****	*****	6702	5189	3949
42	7	2288	1735	1155	1044	737	891	1344	1714	1774	1003	2097	6840	*****	*****	*****	*****	*****	*****	*****	*****	*****	7072	5900	3517
42	15	5227		1303	498	440	336	526	1051	1060	2338	3733	4946	*****	*****	*****	*****								
42	25	6293		1262	421	353	245	325	708	1101	2576	3849	*****	*****	*****	*****	*****								
48	2	1072	4044	1701	915	1495	3202	3644	9754	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	4936	1607	658	395	833
48	5	1879	4890	1477	1065	1310	1834	3333	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	6196	1197	650	521	761
48	7	2819	4448	1542	1417	1476	1905	3364	7037	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	5910	1328	758	649	1026
48	15	5350		1944	2768	2639	2851	3764	5519	*****	*****	*****	*****	*****	*****	*****	*****								
48	25	6725		2444	4209	4037	4026	5076	7236	*****	*****	*****	*****	*****	*****	*****	*****								
55	2	1051	*****	*****	*****	*****	*****	*****	*****	3481	476	499	1142	717	236	210	249	440	607	559	3027	*****	*****	*****	*****
55	5	8177	*****	*****	*****	*****	*****	*****	*****	8313	790	569	305	274	263	233	652	952	1722	2430	3113	*****	*****	*****	*****
55	7	*****	*****	*****	*****	*****	*****	*****	*****	8606	1000	554	236	200	222	378	857	1076	2014	4454	*****	*****	*****	*****	*****
55	15	*****		*****	*****	*****	*****	*****	*****	*****	2853	1035	354	369	373	1191	1660								
55	25	*****		*****	*****	*****	*****	*****	*****	*****	3292	1263	616	693	764	2025	2309								
57	2	402	7770	*****	*****	*****	*****	*****	*****	2087	414	993	*****	*****	7968	403	255	277	387	361	1111	6752	8251	*****	4907
57	5	1610	*****	*****	*****	*****	*****	*****	*****	*****	1156	2419	3451	2371	974	221	209	235	483	711	612	1415	*****	*****	*****
57	7	2142	*****	*****	*****	*****	*****	*****	*****	*****	1992	2756	2690	1243	414	263	273	395	650	1230	1396	6068	*****	*****	*****
57	15	4097		*****	*****	*****	*****	*****	*****	*****	6402	5516	2966	936	306	650	735								
57	25	5593		*****	*****	*****	*****	*****	*****	*****	8873	6031	3153	1692	410	1199	1203								

Wind Speed

4. Early Results and Mitigation

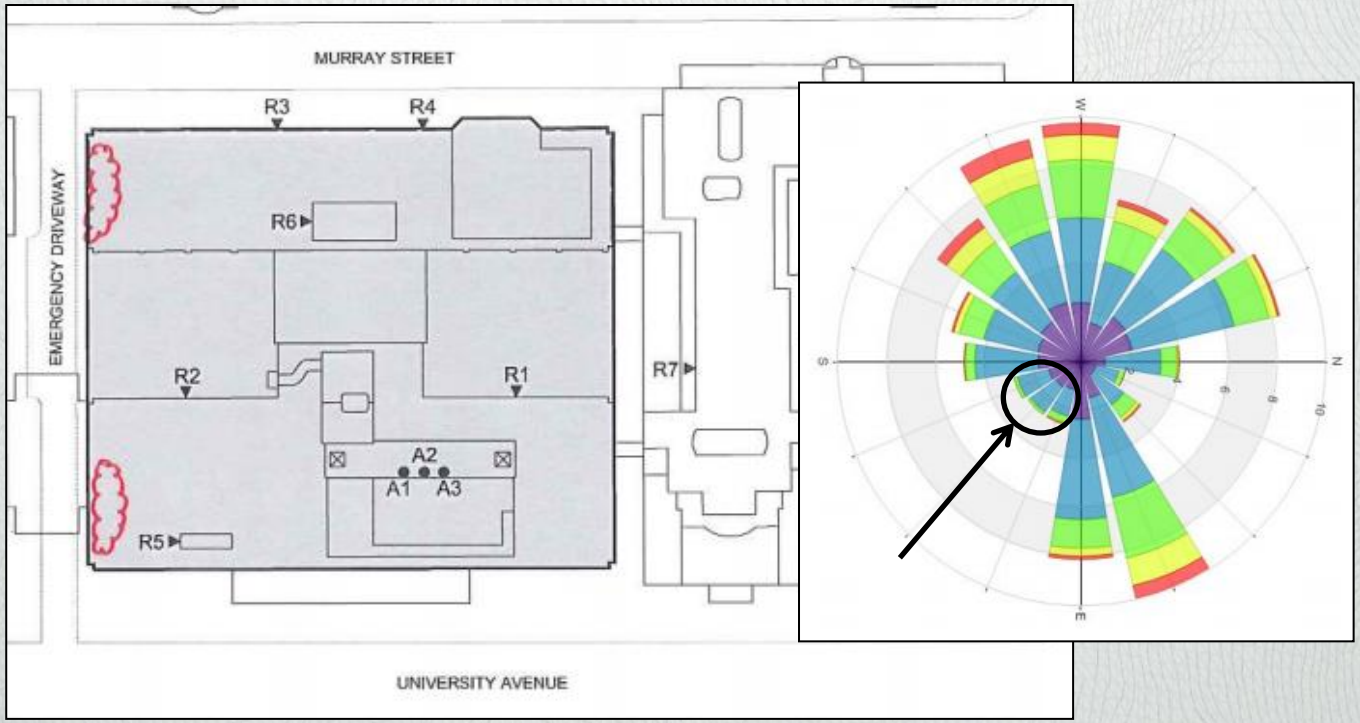
First Results – Failing Criteria!



- 740 mg/m^3 NO_x ***vs*** 500 mg/m^3 standard even with 17m stacks!

Recommended Wind-Based Controls

- Problematic winds occur <1% of the time! Not good enough!
- Schedule generator tests to avoid problem winds. Easy since >99% of winds are good, but need an anemometer.



Anemometer Approach Not Accepted by MOECC

- Although accepted in the past, this approach is no longer considered a feasible solution by the MOECC
- Generally speaking, administrative controls are not acceptable and a design solution is required.

So what to do?

5. Voluntary Emergency Generator Testing Program

Stack Testing

- RWDI conduct a voluntary source sampling program on the exhaust of one of three generators
- Sampling was in support of the ECA application
- Results were used to update emission estimates and thus impacts to address failure of POI.
- Study evaluated:
  - Velocity, flow rate and temperature;
  - Nitrogen oxides (NO_X); and
  - Oxygen (O_2).

Sampling Methodology

OSTC Methods 1 to 4

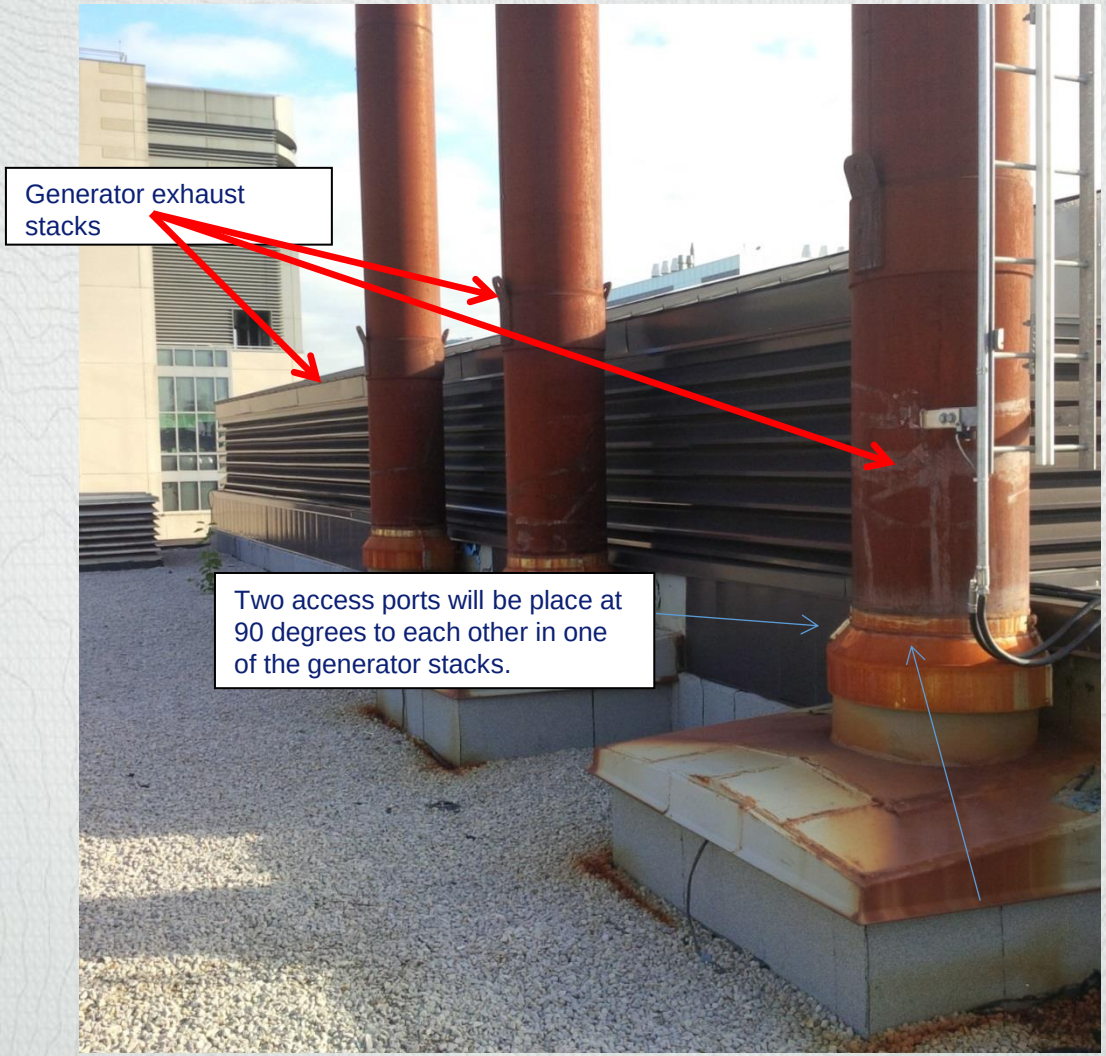
- The exhaust velocities and flow rates were determined following the Ontario Source Testing Code (OSTC) Method 2. Velocity measurements were taken with a pre-calibrated standard pitot tube and incline manometer.
- Volumetric flow rates were determined following the equal area method as outlined in OSTC Method 2. Temperature measurements will be made simultaneously with the velocity measurements and will be conducted using a chromel-alumel type "k" thermocouple in conjunction with a digital temperature indicator.
- The dry molecular weight of the stack gas was determined following calculations outlined in OSTC Method 3A, "Determination of Molecular Weight of Dry Stack Gas". Stack moisture content was determined by direct condensation according to OSTC Method 4, "Determination of Moisture Content of Stack Gas".

Sampling Methodology

US EPA Method 7E

- Testing for NO_X completed with continuous emission monitors (CEM).
- Exhaust gas sample was taken from a single point at the center of the stack using a stainless steel probe. Prior to commencing with the test, a stratification test was completed in order to ensure the gas conditions were consistent across the duct.
- Flue gas was delivered to a heated filter, where particulate matter is removed, and then transferred via a heated Teflon line 120°C (250°F) to a sample conditioner.
- The sample will then be routed to the CEM for measurement. The CEM was a Teledyne chemiluminescence analyzer for NO_x. O_2 and CO_2 analyzers were also used for the determination of molecular weight.
- Prior to testing, sample system bias checks and instrument linearity checks (calibration error) were conducted. In addition, the analysers were calibrated (zeroed and span checked) at the completion of each run. Data acquisition system provided generates one minute averages concentrations
- Three 1-hour tests were conducted while the generator is under maximum load condition

Sampling Locations



Results

Table 3: Sampling Summary - Flow Characteristics

Kohler Generator

Stack Gas Parameter		100 % load			
		Test 1	Test 2	Test 3	Average
Stack Temperature	◦F	796	796	796	796
	◦C	424	424	424	424
Moisture	%	4.1	3.6	4.7	4.1
Velocity	ft/s	93.1	93.2	92.9	93.1
	m/s	28.4	28.4	28.3	28.4
Actual Flow Rate	CFM	9,873	9,881	9,849	9,868
Referenced Flow Rate	CFM	3,282	3,301	3,250	3,278
	m^3/s (Actual O_2)	1.86	1.87	1.84	1.9

Results

Table 4: Measured Parameters - Average Results

GEN901	Test 1	Test 2	Test 3	Average Concentration		Emission Rate	Emission Rate
					Actual O_2		
	(ppm)	(ppm)	(ppm)	(ppm)	(mg/m^3)	(g/s)	(kg/hr)
Nitrogen Oxides, expressed as NO_2 (NO_X)	190.9	188.0	186.8	188.6	354.6	0.66	2.37
Oxygen (O_2) @ stack	(%) 17.4	(%) 17.4	(%) 17.3	(%) 17.4	-	-	-

Notes:

-Sampling followed U.S. EPA Method 3A (O_2), Method 7E (NO_X)

-All referenced concentration values are expressed at 101.3kPa, 25°C

-Emission rate calculated based on average volumetric flow rate measurements

Comparison

Revised Table 2: Emergency Generator Exhaust Parameters used for Wind Tunnel Testing

Source Label	Source Description[1]	Stack Height Above Roof (Grade) [3],[4],[5] [m]	Stack Diameter [m]	NO_x Emission Rate [g/s]	Exit Velocity [m/s]	Flow Rate [m^3/s]	Exhaust Temp. [°C]
Original ESDM Parameters							
A1 - A3	1,500 kW Kohler Emergency Diesel Generators[2]	16.76 (94.64)	0.46	3.38	34.72	5.70	435
Parameters from Stack Testing Results							
A1 - A3	1,500 kW Kohler Emergency Diesel Generators[6]	16.76 (94.64)	0.46	0.66	28.4	4.66	424

Notes:
[1] The proposed generators were modelled as vertical and uncapped stacks.
[2] Original generator specification provided to RWDI by Blumetric (formerly WESA Inc.) on August 29, 2011.
[3] Height of 16.76 m (55 ft) is referenced above local roof. Height is equivalent to 21.49 m (70ft-5in) above level 18a.
[4] Local grade is reference as 0 m.
[5] Heights are based on details shown in drawing M9.13B.
[6] Measurements based on electrical output of 1,350 kW.

- Small change to exhaust parameters but **BIG** change to emissions

End Result

- Lower emissions used to demonstrate compliance at ALL receptors and wind tunnel results accepted by MOECC
- Worst-case changed from 740 mg/m^3 to about 200 mg/m^3 compared to 500 mg/m^3 target.
- Cost Savings!
  - Anemometer System: **$50,000** including siting, testing, commissioning
  - Stack Testing: ~**$10,000**

6. Conclusions

Conclusions

- Dispersion modelling is required by the MOECC for all emergency generators in Ontario.
- Air quality regulations in Ontario are among the strictest, and can result in conservative stack designs
- Required to show full compliance regardless of probability. No more administrative controls!
- Wind tunnel often less conservative than numerical, but did not show compliance in this case.
- Stack testing was used to successfully demonstrate compliance and saved significant $$ compared to the alternatives (taller stacks or anemometer system).
- Stack testing can be used to prove emissions are lower than generic manufacturer statements and result in lower stack, less costly design.

Redefining possible.

THANK YOU!