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Modeling of Carbon Monoxide Dispersion from Vehicle Exhaust in a Partially Enclosed Roadway

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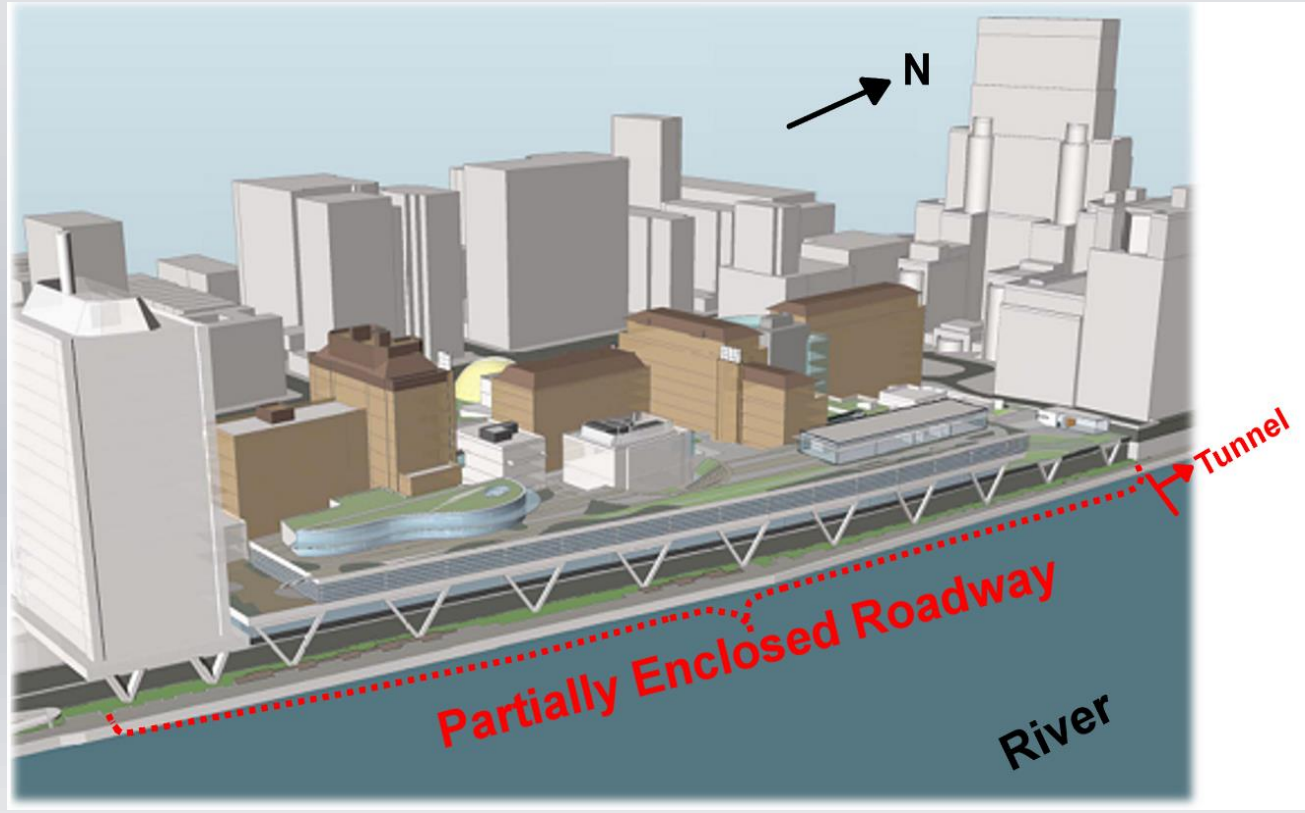
BACKGROUND

Proposed building will partially enclose a 900 ft long section of a six lane roadway over approximately 900 ft

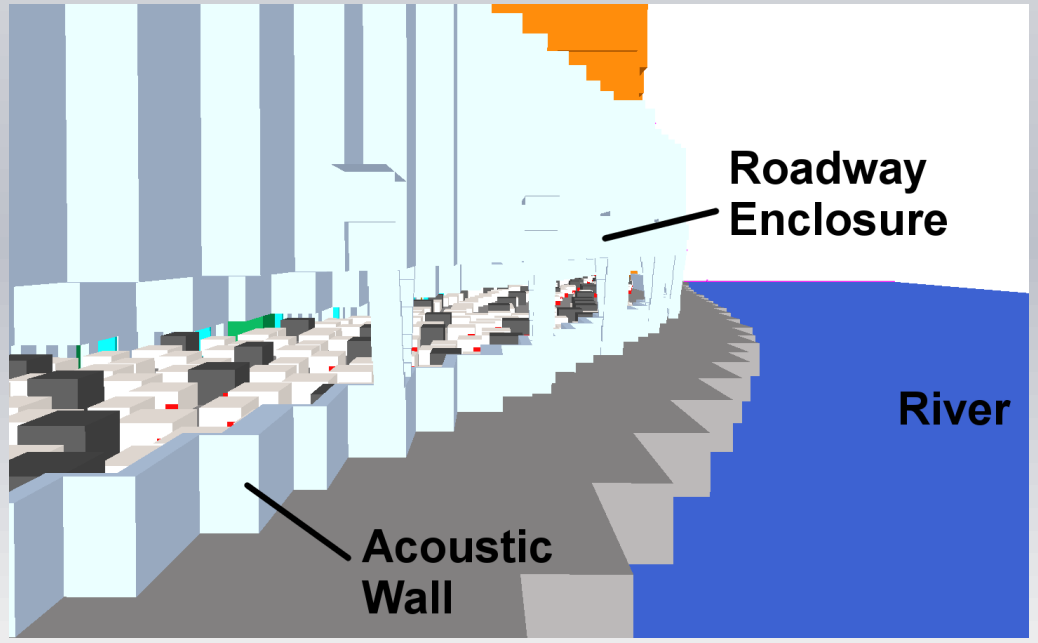


BACKGROUND

Concerns were raised regarding potential for accumulation of dangerous levels of carbon monoxide

Due to:

- Stalled traffic
- Adverse wind conditions



BACKGROUND

Federal Highway Administration (FHWA) and Environmental Protection Agency (EPA) set limits on the levels of pollutants

Timeframe	CO Limit	Applies at
1 hour	35 ppm	Esplanade
8 hour	9 ppm	Esplanade
15 min	120 ppm	Tunnel

FHWA

ANALYSIS APPROACH

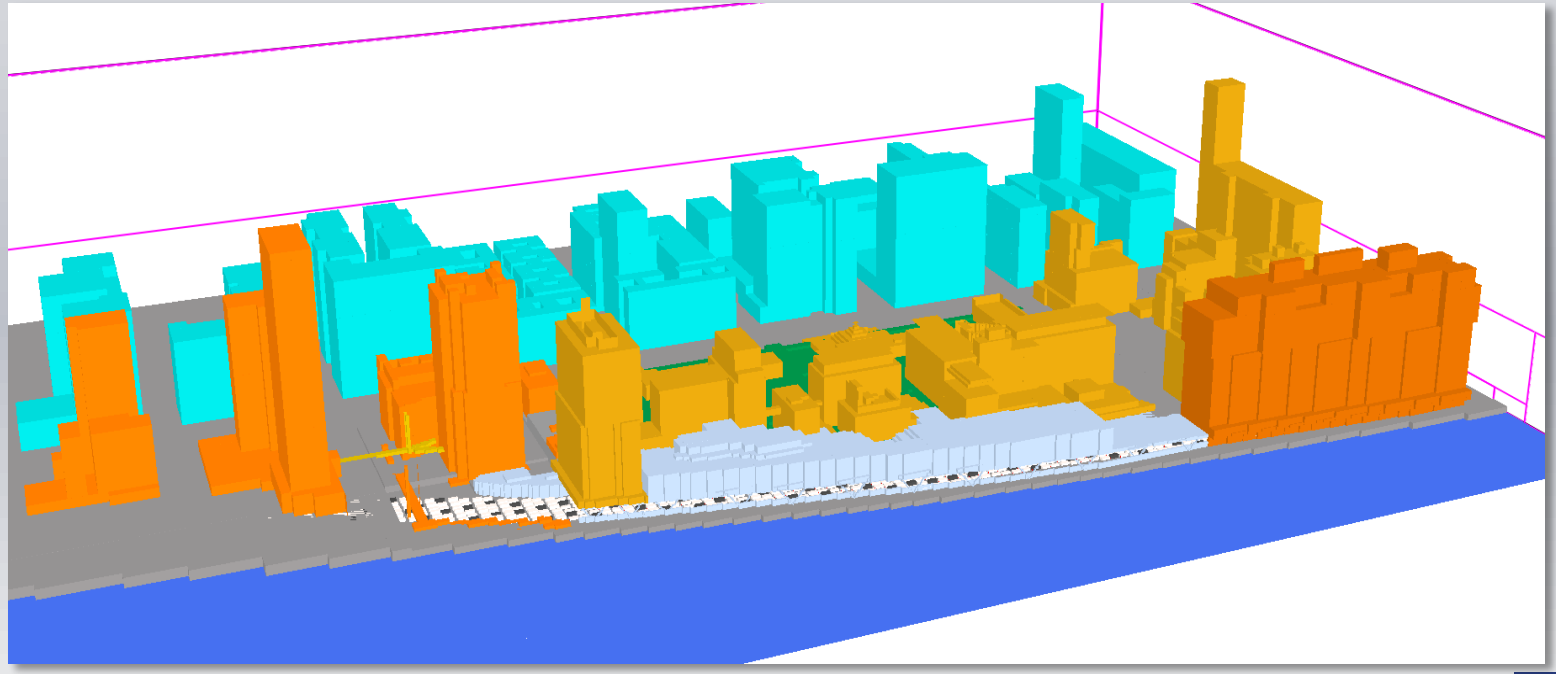
Interaction of wind, vehicles, buildings and partially enclosed roadway is highly complex

- Fire Dynamics Simulator (FDS) used to predict carbon monoxide concentrations under different scenarios
- Peak concentrations compared to the FHWA and EPA criteria
  - Maximum 15-minute average of 120 ppm

MODEL SETUP

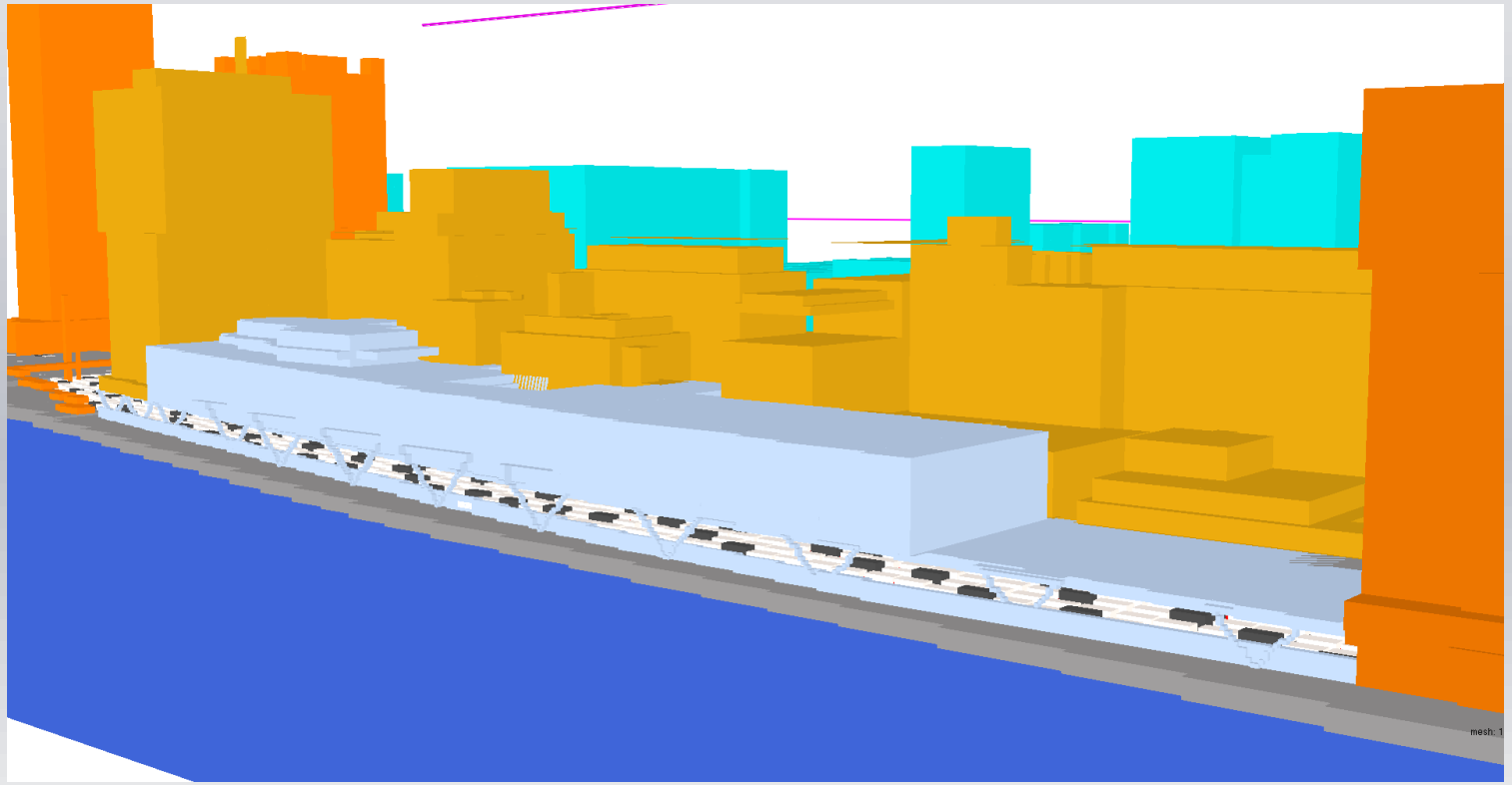
Fire Dynamics Simulator model constructed for a 0.4 km^2 region around roadway section

- Captured wind flow around tallest buildings and major obstructions upstream and downstream of roadway



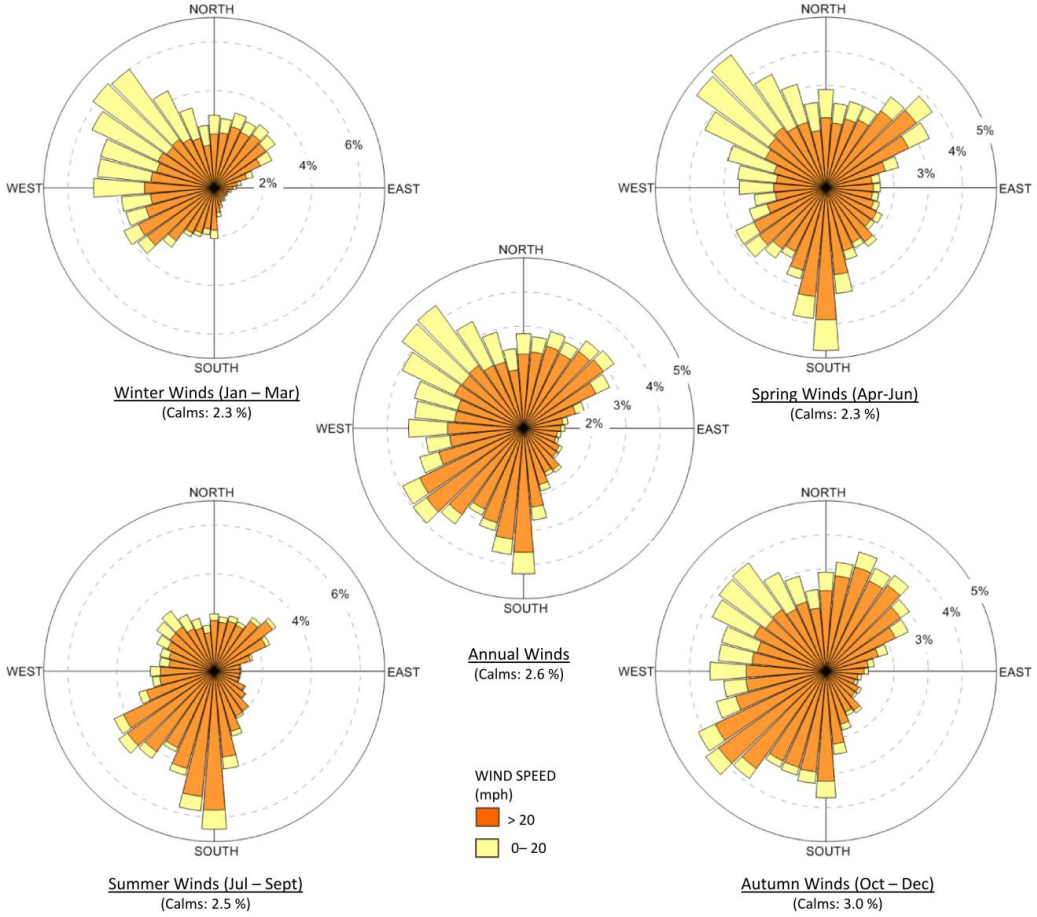
MODEL SETUP

- Over 4 million cells
- 0.5 m to 4.5 m cell size



WIND DATA

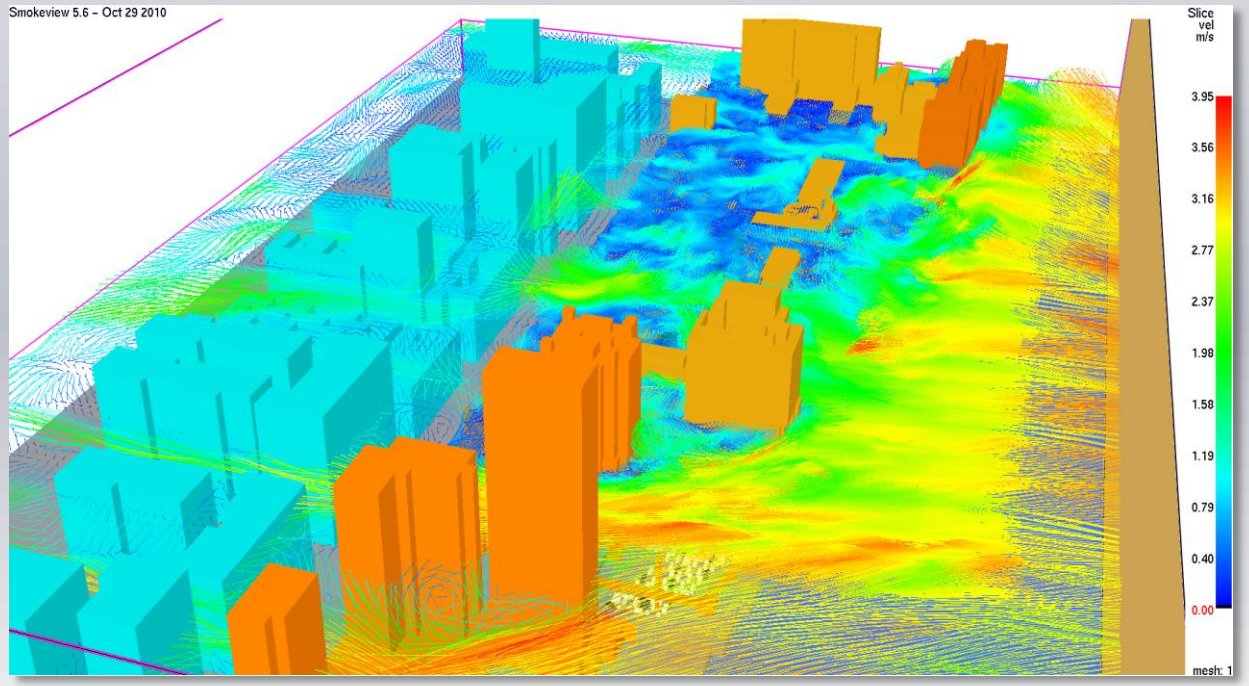
Seasonal wind data for nearby locations was collected by third party for pedestrian wind study



WIND DATA

Typical wind directions and velocities evaluated in the FDS model

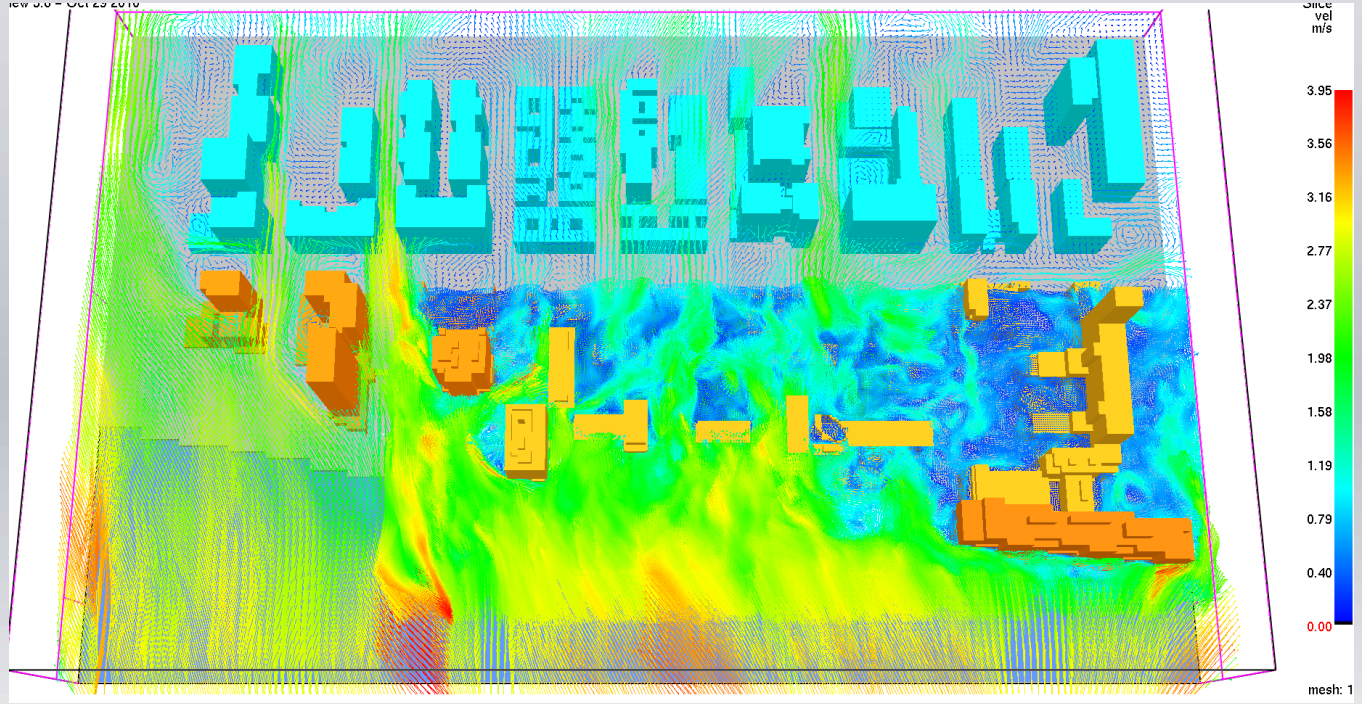
- Wind speeds 0 – 22 mph (0 - 10 m/s)
- Four wind directions
- Summer and winter temperatures



WIND DATA

Preliminary simulations showed:

- Lower wind speeds gave higher CO concentrations
- Little difference between summer and winter temperatures

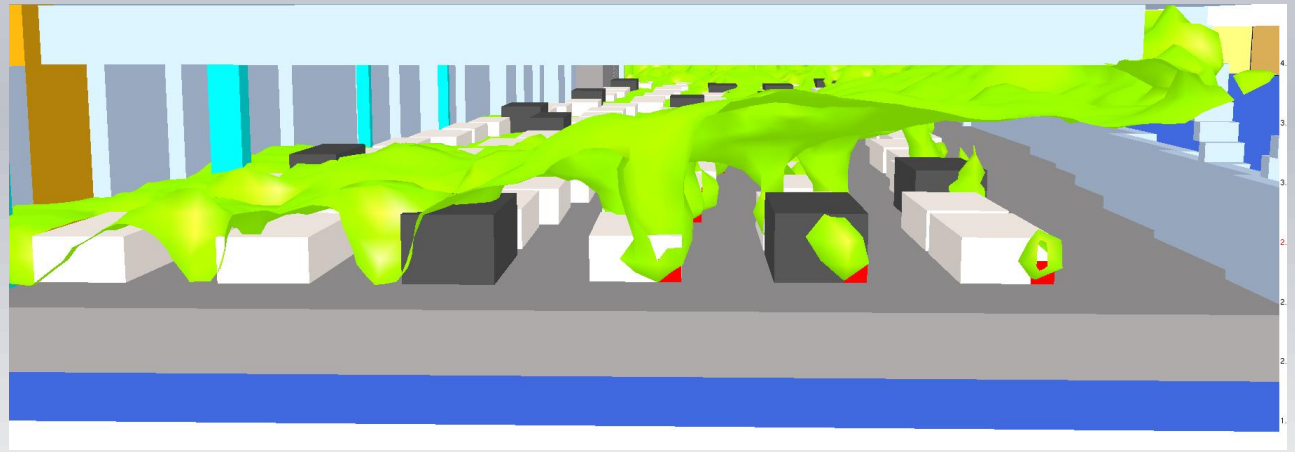


TRAFFIC CONDITIONS

Worst case traffic conditions assumed

- Stalled traffic in both directions
- ~ 2 ft distance between cars
- Mix of sedans and SUVs (No large trucks are allowed)

- Per EPA emission factor, CO release is 46.9 g/hr/vehicle
- Exhaust assumed to be only CO and air



TRAFFIC CONDITIONS

- Typical fuel use while idling is 0.5 gallon/hr (1.9 L/hr)
- Assuming a stoichiometric air-to-fuel ratio of 14.7 gives total mass exhaust rate and mass fraction of CO

$$\dot{m}_{total} = \dot{m}_{CO} + \dot{m}_{air} = 5.81 \ g/s$$

- The total mass release in FDS is prescribed as:

$$\dot{m}_{total} = \chi_{CO}\dot{m}_{total} + \chi_{air}\dot{m}_{total}$$

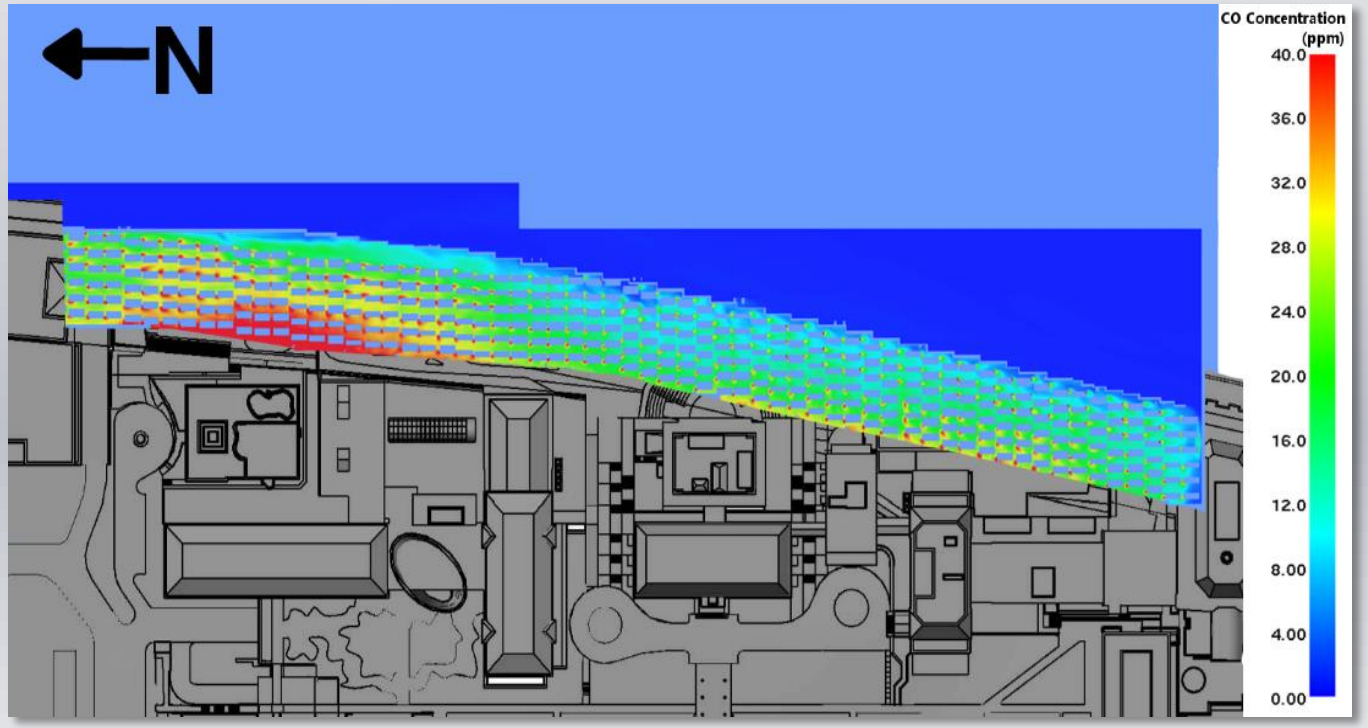
RESULTS

- A series of nine final simulations evaluating different wind and temperature conditions
- Peak 15-minute average CO evaluated above the roadway
- Maximum CO levels remained never exceeded 120 ppm

Scenario	Wind Direction	Wind Speed	Ambient Temperature	15-min Max CO
1	North-East	5 m/s	29° C	24 ppm
2		1 m/s		48 ppm
3	South	5 m/s	29° C	26 ppm
4		1 m/s		33 ppm
5	East	5 m/s	29° C	41 ppm
6		1 m/s		30 ppm
7	South-West	5 m/s	29° C	33 ppm
8		1 m/s		32 ppm
9	Calm	-	29° C	27 ppm

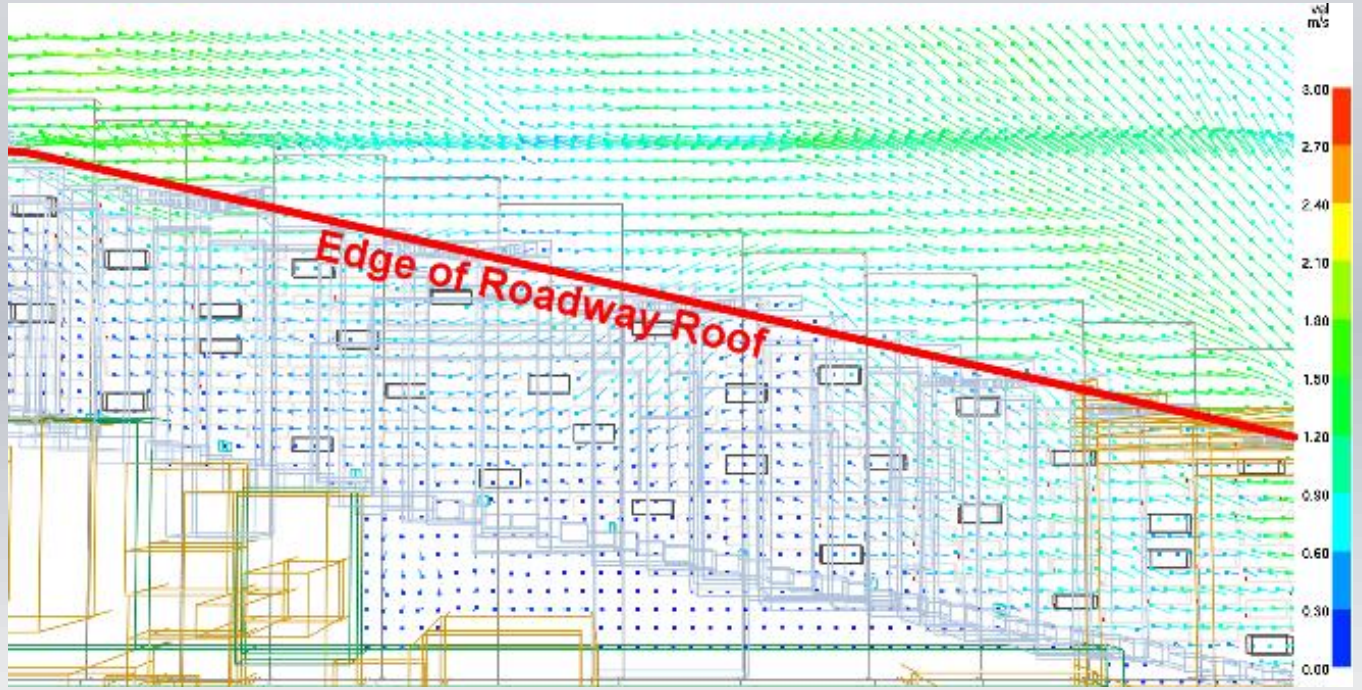
RESULTS

- 15-minute average CO concentration at 5 ft above roadway
- Evaluated as time-averaged slice fire (SLCF)



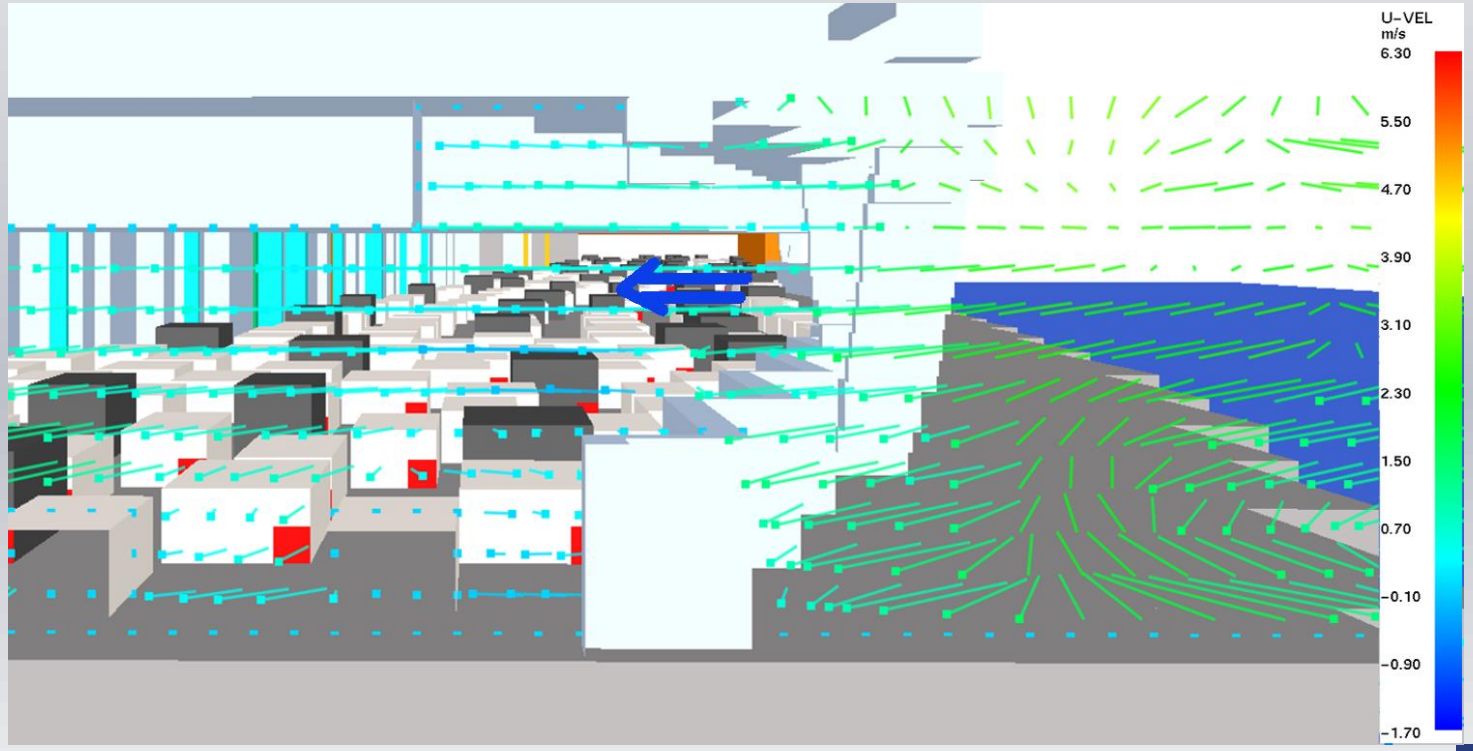
RESULTS

- FDS results showed flow of wind through partial enclosure under different scenarios
- Use to determine worst-case configurations warranting further study



RESULTS

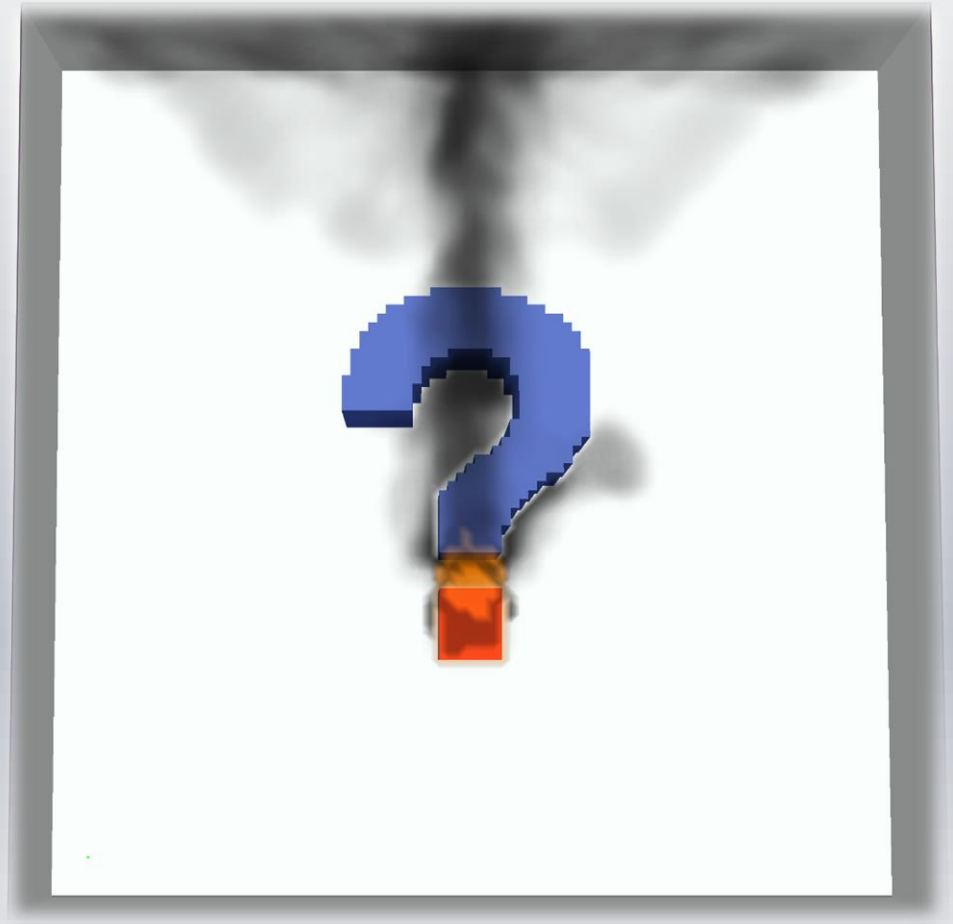
- Wind flow at enclosure openings evaluated with vertical vector slices
- Showed how acoustic wall prevent outflow



CONCLUSIONS

- Extremely complex system with hundreds of vehicles, tall buildings and complex wind flow required large FDS model to accurately evaluate
- Multiple wind scenarios could be evaluated simultaneously
- Federally mandated limits for CO concentrations were not exceeded during worst-case conditions
- The client was able to avoid the cost of installing additional tunnel ventilation

QUESTIONS



THANK YOU

For More Information Contact:

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