

CITY OF TORONTO'S MODELLING STUDIES & NEW DIRECTIONS

AWMA FALL CONFERENCE
AIR DISPERSION MODELLING

OCTOBER 22ND 2013

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Outline

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- First Generation AQ Modelling at AQIB (2000)
 - AQ Improvement Branch & Sweepers
- Improved AQ Model (2006)
- Changed Approach to Address Changed Needs
- Most Recent Results by E&EO (2012)
- Future AQ Directions (AQ Improvements)

Players & Partners & Thank You's

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- **Air Quality Improvement Branch,**
Environmental Services / Technical Services ...
 - RWDI
 - EarthTech / Golder
 - Ortech
 - Spectral Analysis
- **Research & Policy Development,**
Environment Office / Environment & Energy Office
 - Golder
 - RWDI

First Generation AQ Model at AQIB

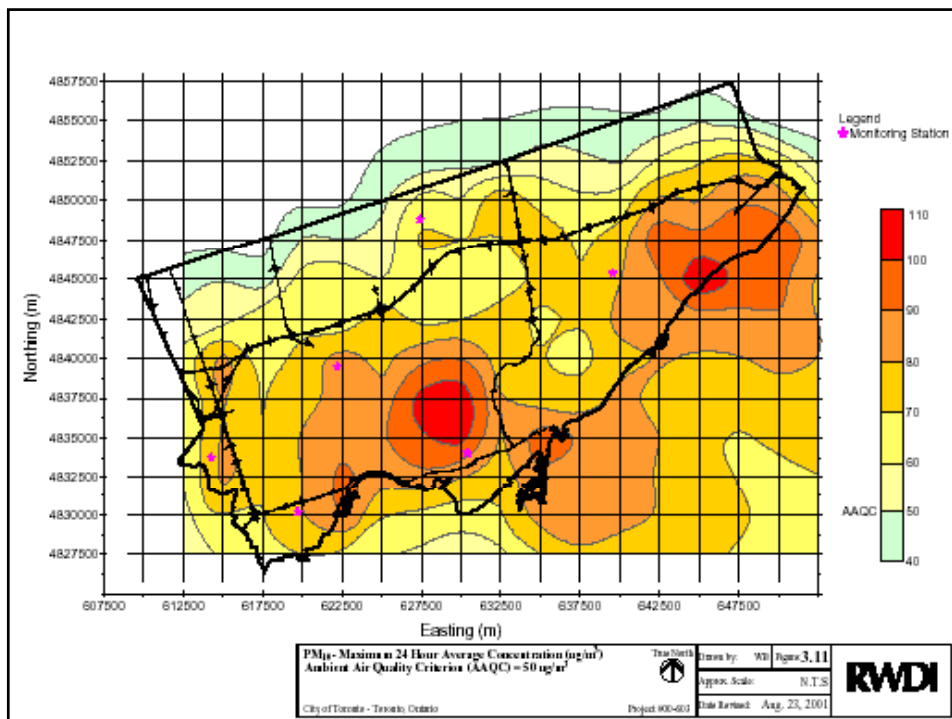
4

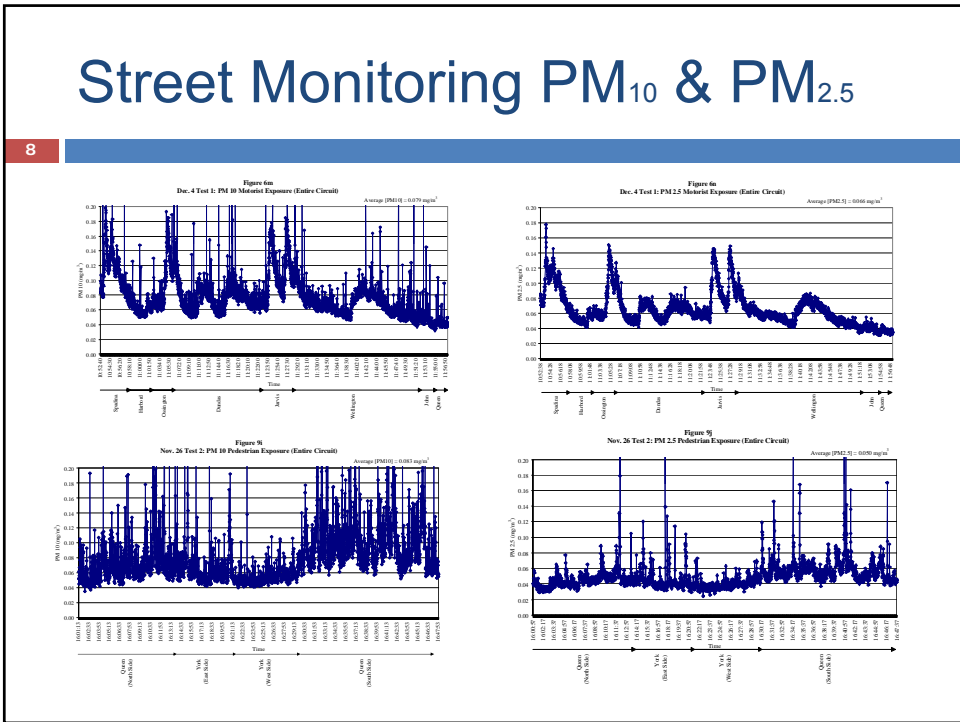
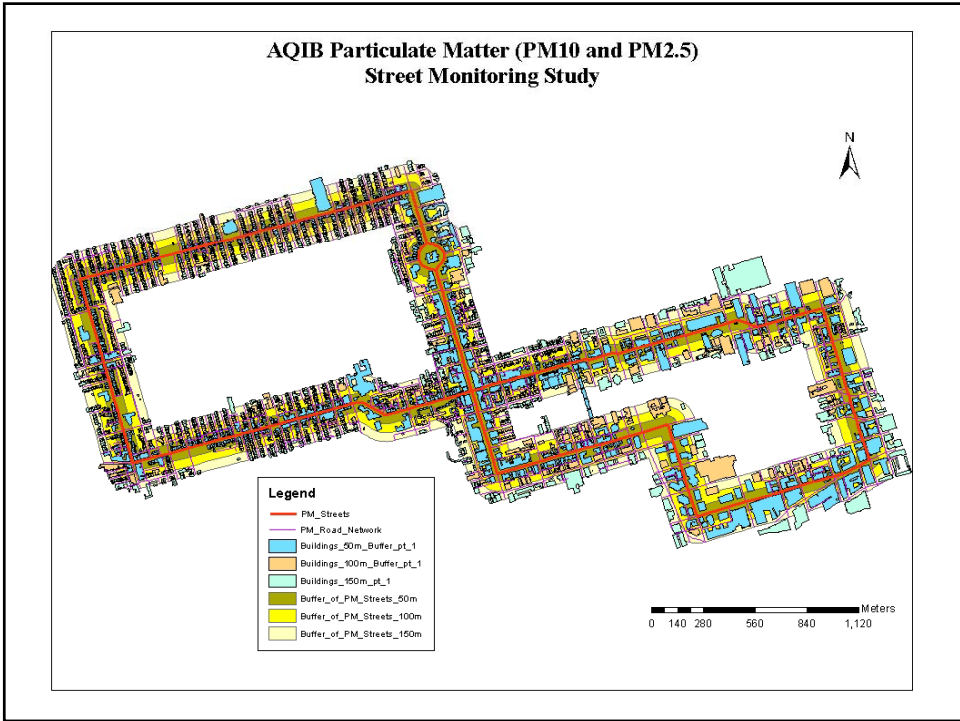
- Role & Responsibility Evaluation (Gap Analysis)**
- MOE “Monitors” at 4 Monitoring Stns in Toronto But
Policy & Action Needs Information re Sources
- → **AQ Modelling Needed re Actions & Policy**
But Not for Compliance Testing
- Engaged RWDI (2000/2001) to evaluate our use of
 - CMAQ (relying completely on others)
 - CALPUFF (relying perhaps on our selves)
- Installed CALPUFF at AQIB based on “local + “top
down data” – a rough & ready early beginning

AQ Improvement Branch & PM₁₀ PM_{2.5}

5

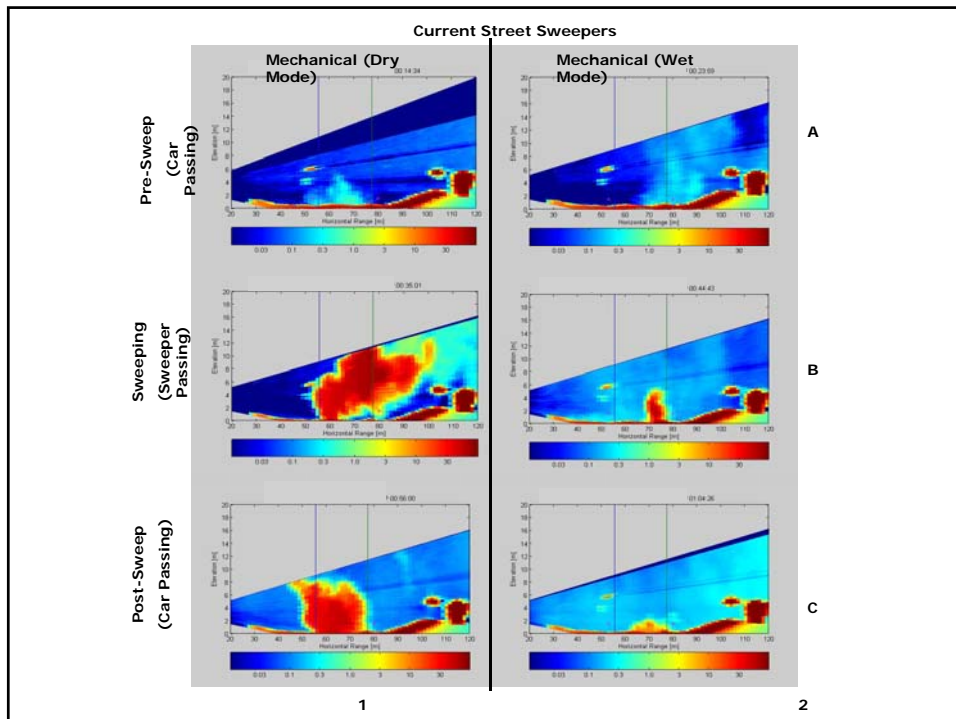
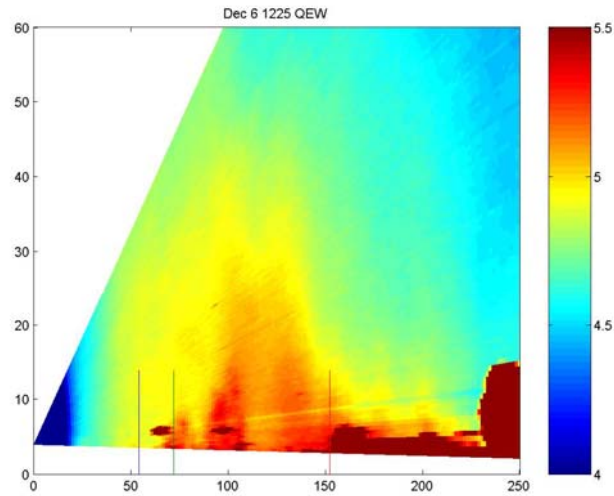
- Though our model system was very limited
- Identified a clear Policy Direction re **PM Problems**
- Street Cleaning is a Municipal Responsibility
 - ▣ Including PM₁₀ & PM_{2.5} on Streets – Need to Do a Better Job
- Rule 1186 re PM₁₀ = Inadequate
- Developed “**Clean Roads to Clean Air**” Program
- Developed a **Testing Protocol**
- Designed & Built a **Testing Facility**
- Tested **All Types of Sweepers** (Mechs. Vacs. Regens etc)
- Toronto **Purchased 50** Regenerative Air Sweepers
- Advised on Their Proper Use
- EC Lic. - Env. Tech. Verification **ETV** Adopted our Protocol

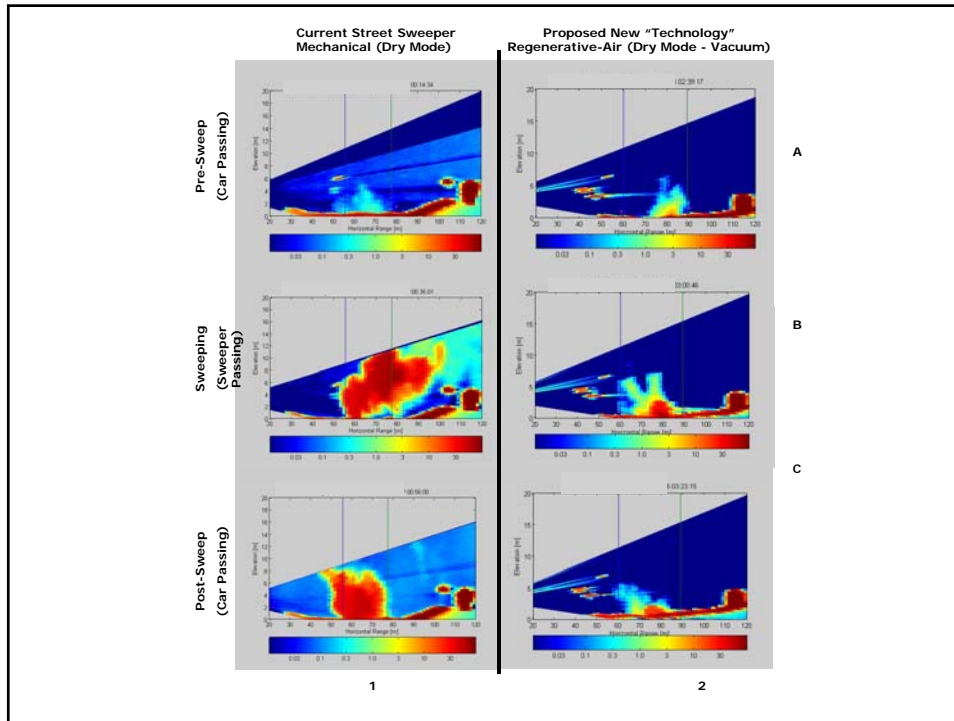




Lidar Evaluation at Street Level

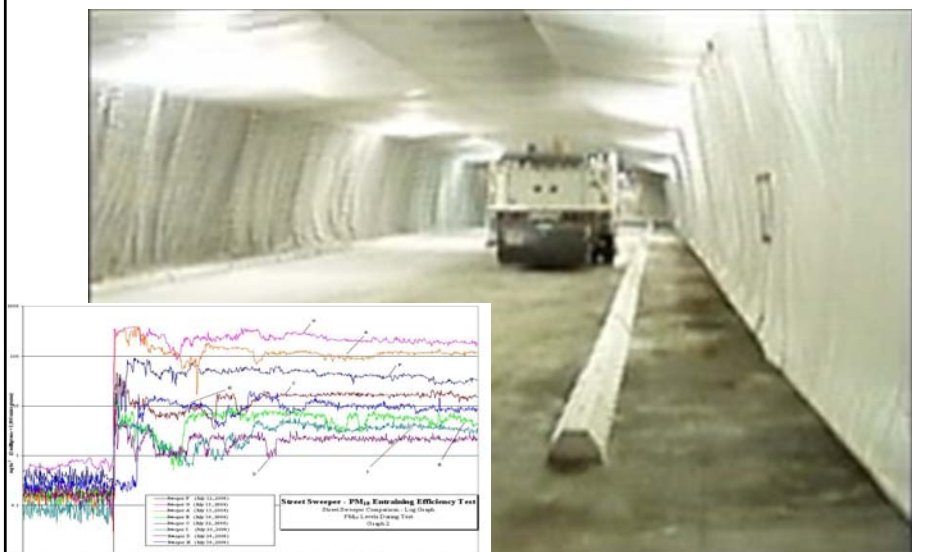
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Disco Sweeper Testing Facility

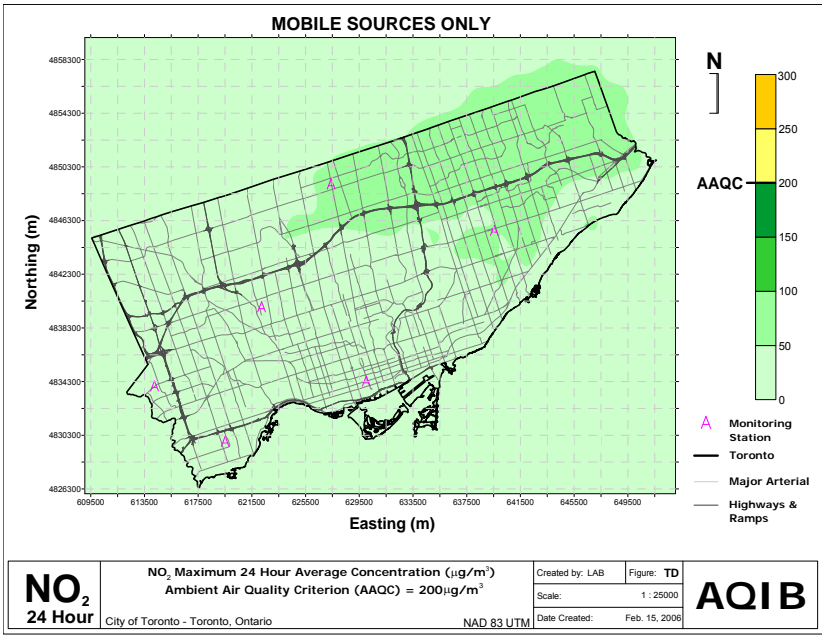
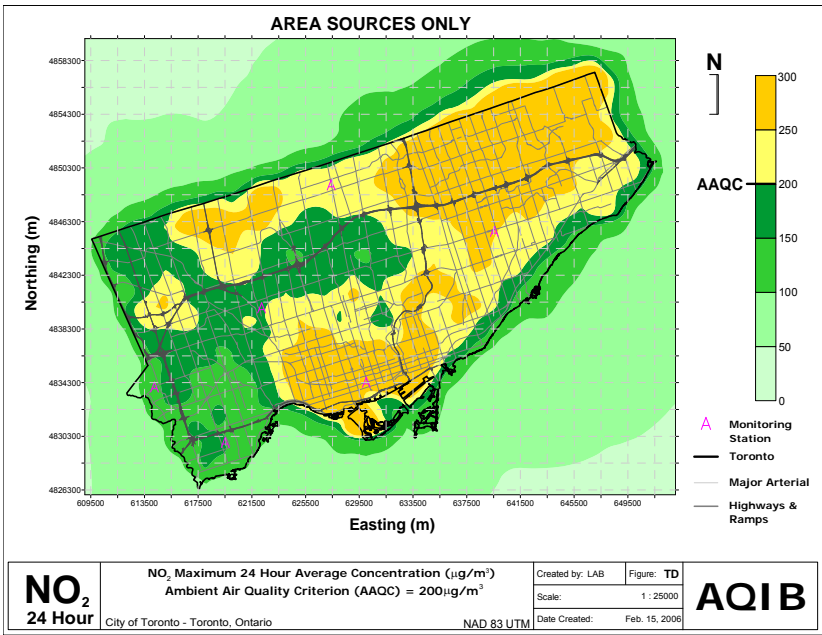
13

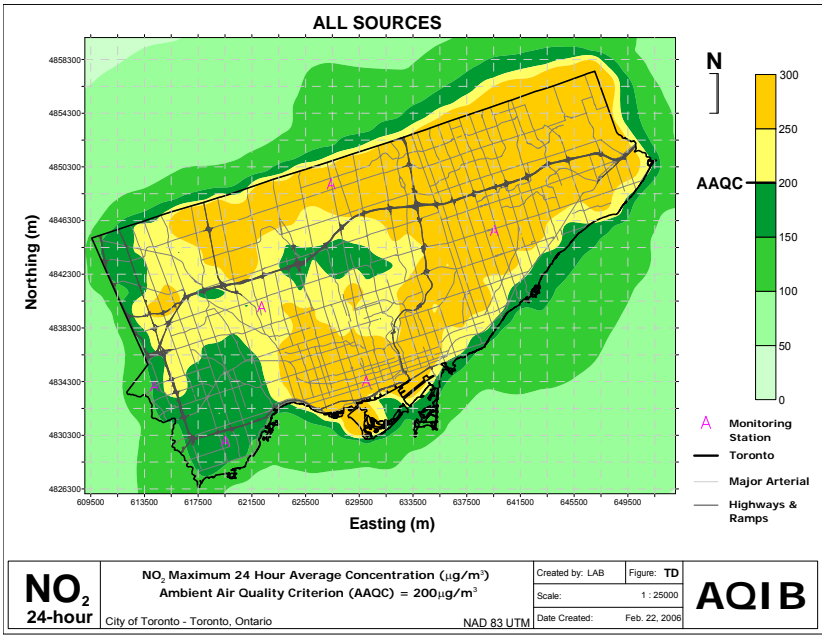
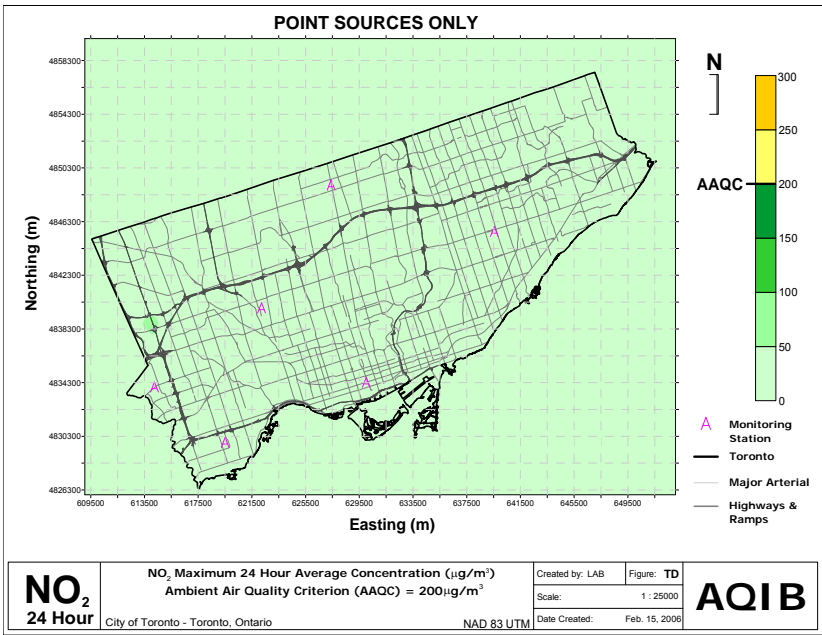


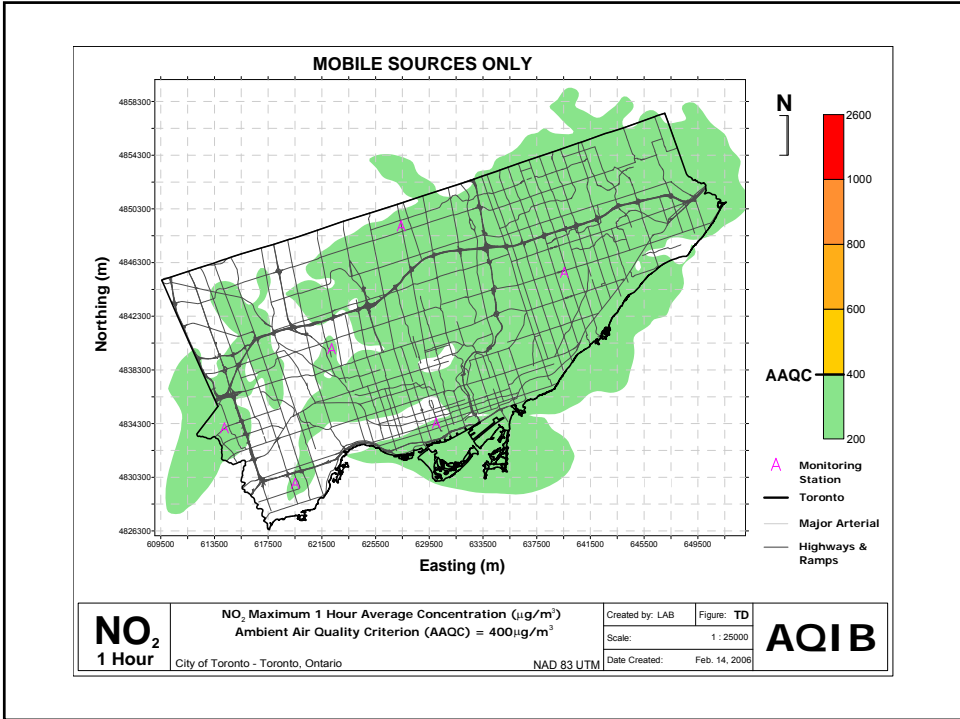
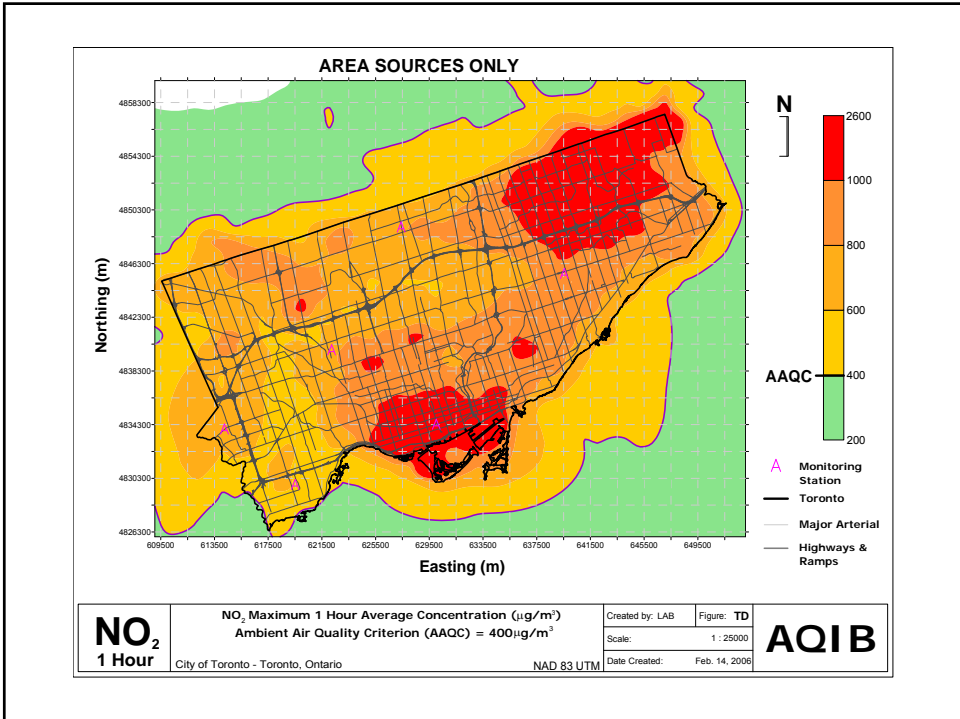
Improved AQ Model (2006)

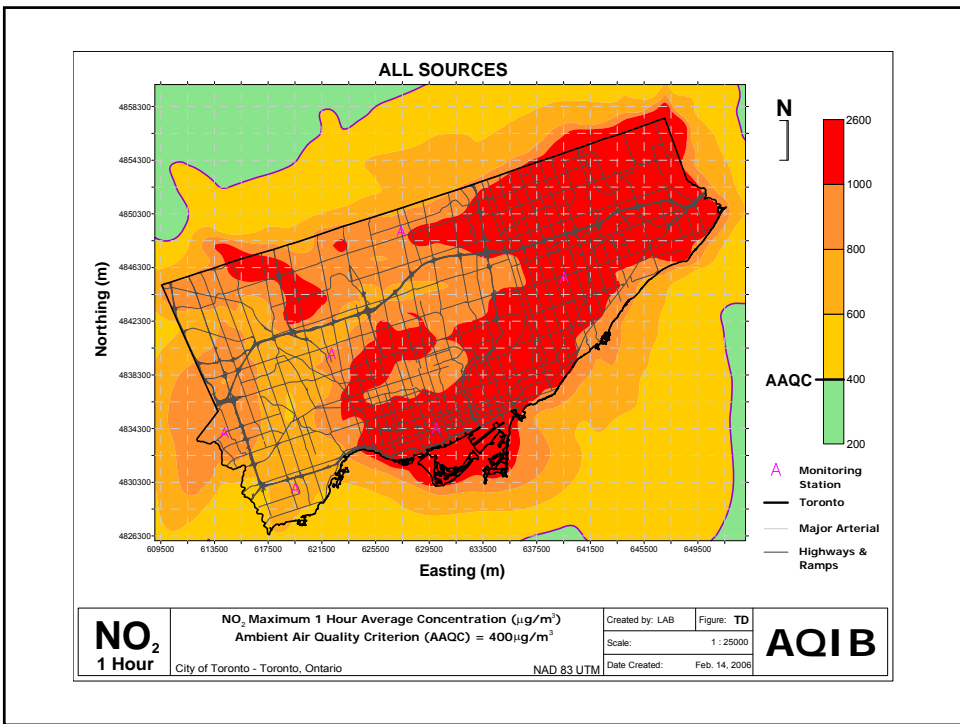
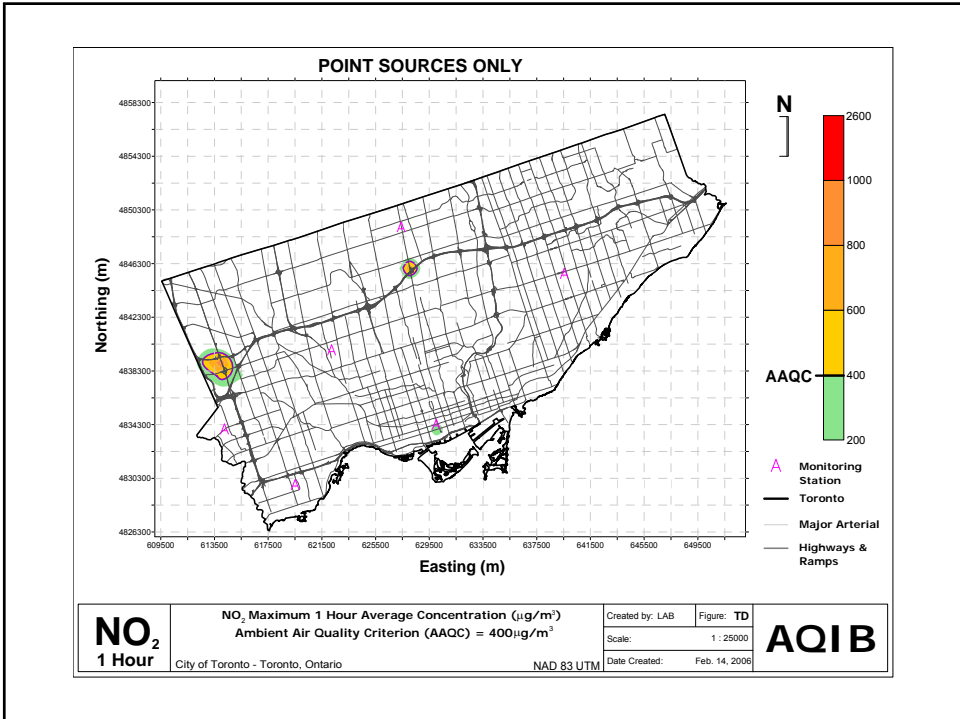
14

- With help from Earth Tech / Golder
- Changed Top-Down to Include more Specific Local Bottom-Up Data (also ensured no double counting)
- Improved Grid Resolution
- We had Better Access to Data and Results
- Improved CAC Maps (including PM) etc
- Mapped CACs by Sources (Points, Lines, Areas & All by Annual , 24 hr, 8 hr and 1hr
- But Still Inadequate Spatial Resolution
- And Still Reliant on Consultants
- And No Trans-boundary Emissions









So - still not making a lot of sense!

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- Obvious significance of missing upwind imports
- Resolution is too coarse to see local details
- Point Sources invisible within uniform areal conc's
- Mobile Concentrations highest in the east
But should be much closer to 401-427 Junction

- Not an adequate basis to develop policy and/or improvement actions

Internal Evaluation (circa 2006-7)

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- Need to Take More Control of our Modelling
- Need to Include TPH's 30 Substances
- Need to Include Chemistry (some or all?) *Deferred*
- Need Upwind Sources
- Need Improved Resolution
- Need Improved Community Outreach
- Need Smaller Local-Specific Models
- And with help from Golder
- We Undertook Ward 5 + Ward 6 LAQ Modelling

Changed Approach to Address Both Our Issues & Our Changed Needs

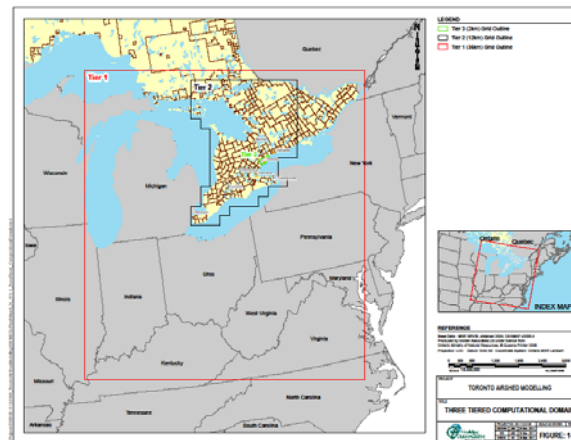
25

Local Area Specific AQ Modelling

- S.Riverdale-Leslieville-Beaches (Wards 30 & 32)
 - History of Concern & Political Pressure/Requirement
- **3 Nested Modelled Areas (Tiers 1,2,3)**
- NE USA (Tier 1 – US EPA TRI)
- Ontario (Tier 2 – NPRI + Major Roads & Area Estimated Sources)
- Toronto Sources (Tier 3 – NPRI + All Road Data + Residential/Commercial Emissions + 3)
- **Ward 5 & 6 Receptors** (561 virtual monitoring stns)

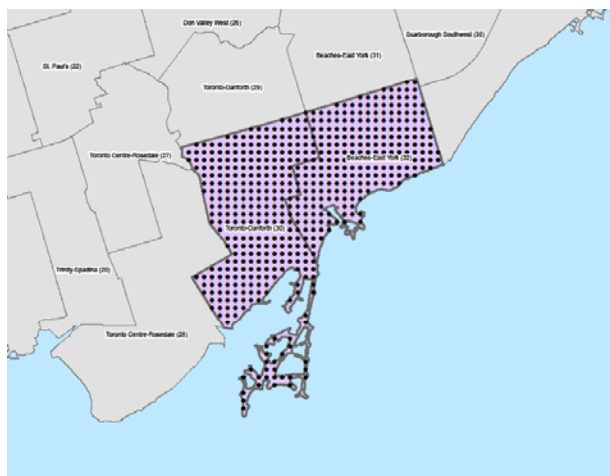
Three “Nested” Model Domains

26



561 Receptors (“Virtual” Monitoring Stations)

27

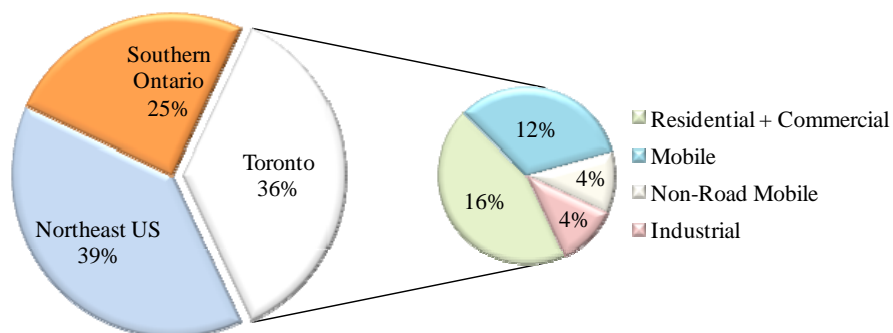


Emissions ≠ Concentrations

28

- Emission by Sources into the Model Domains
 - ▣ US 90%
 - ▣ Ontario 9%
 - ▣ Toronto 1%
- Concentrations by Sources into the Community
 - ▣ US 39%
 - ▣ Ontario 25%
 - ▣ Toronto 36%

Contributions to Local Pollution



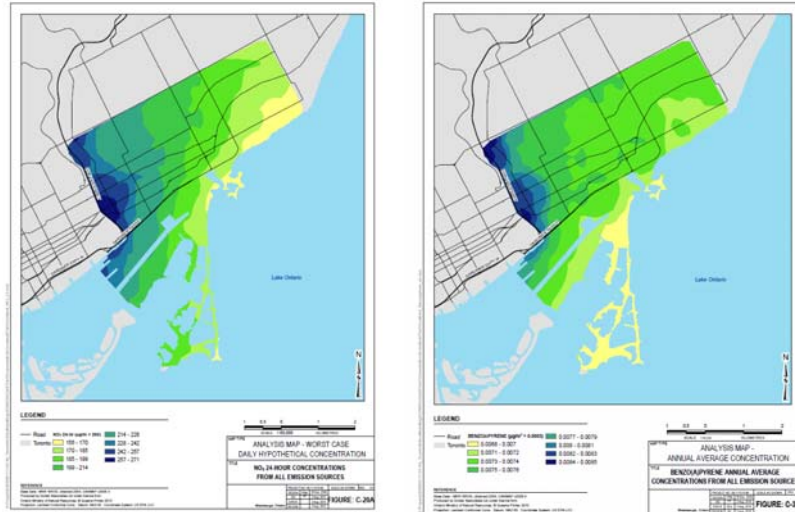
DVP emissions

- Nitrogen Oxides
- Benzo[a]Pyrene
- Benzene
- PM10 and PM2.5
- 1,3 Butadiene
- Acrolein
- Cadmium
- Carbon Monoxide
- Formaldehyde
- Mercury

NO₂ 24 hr

B[a]P Annual

31

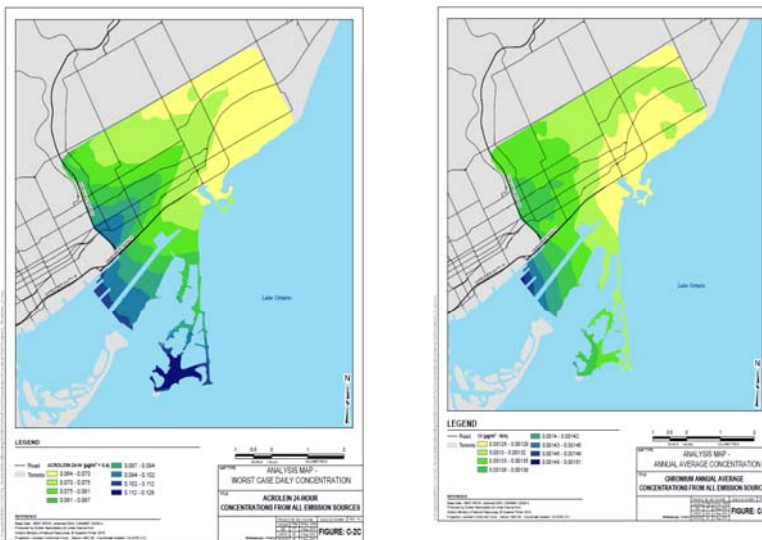


Airport (BBTCA) emissions

- Acrolein
- Chromium
- Acetaldehyde
- Formaldehyde
- Manganese
- Sulphur Dioxide

Acrolein 24 hr Chromium Ann

33



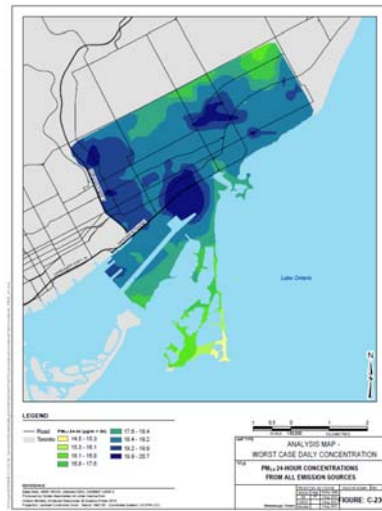
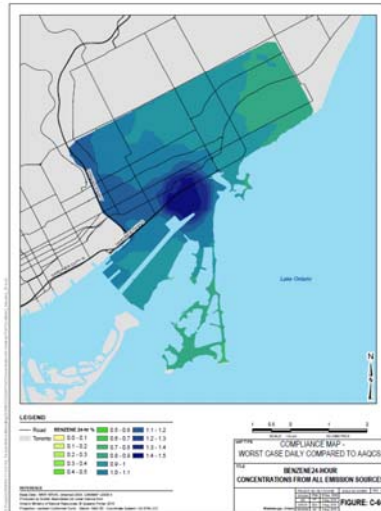
Local "Hot Spot" Emissions

- Benzene
- PM_{2.5}
- Mercury
- Nickel
- Tetrachloroethylene
- Toluene
- Volatile Organ Carbons

Benzene 24 hr

PM_{2.5} 24 hr

35



24-hr Concentration Levels

36

- ❑ **4 PACs exceed** their 24-hr AAQC's
 - ❑ NO_x,
 - ❑ PM₁₀,
 - ❑ PAH (as B(a)P) and
 - ❑ Benzene
- ❑ Exceedances for first **3 PACs are due to traffic** while the exceedance for benzene is from traffic and industrial sources

Annual Concentration Levels

37

- **2 PACs exceed** their AAQC levels
 - Benzene
 - PAH (as B(a)P)

- Over 50% of the annual average benzene level comes from Toronto,
 - 39% is attributed to vehicular activity

- Most of the PAH's (68%) come from sources from beyond the City.

Most Recent Results ... 2013

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- Research & Policy Development (TEO – E&EO) extracted data concerning Etobicoke-Lakeshore (Wards 5 & 6)

- This took an inordinate amount of time on our old & slow workstations – but find we can see & learn more and produce more “public-relevant” maps

- See 18 Local Area Ward Groupings (Later)

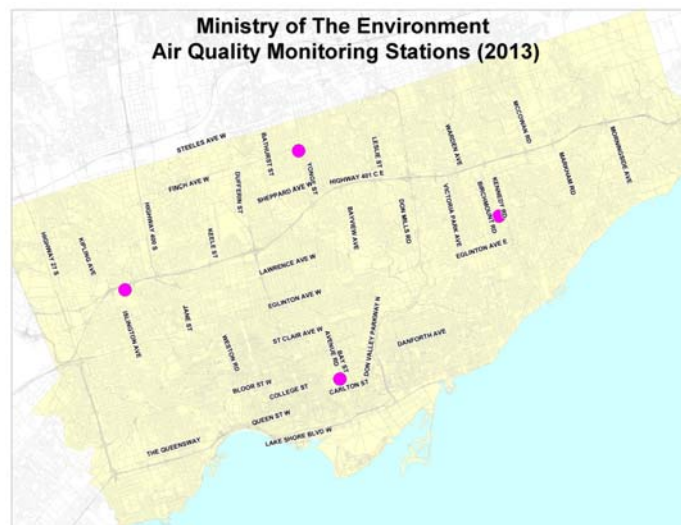
Modelling Areas: Emissions to Concentrations

39



MOE's 4 AQ Monitoring Stations in Toronto

40



Air Quality Contaminants: Concentrations at Virtual Monitoring Stations

41

- ❑ **1048 Virtual Monitoring Stations - 200m apart**
- ❑ Permits fine mapping resolution and detailed local neighbourhood assessment
- ❑ Full Model (Tier 1, 2 & 3) Checked against MOE's 4 Air Quality Stations



MAP TYPES

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- ❑ **COMPLIANCE ASSESSMENT MAPS to show**
 - ❑ Comparison of Modelled Concentrations to “Desirable” AAQCs (Standard)Maps
- ❑ **ANALYSIS MAPS to show**
 - ❑ “Worst Case 24-Hour” Maps
 - ❑ 98th Percentile Maps [re Worst Case]
 - ❑ Annual Average Maps
- ❑ **HEALTH CUMULATIVE RISK MAPS**

List of 30 Priority Air Contaminants

43

1. Acetaldehyde
2. Acrolein
3. Benzene
4. 1,3-Butadiene
5. Cadmium
6. Carbon Monoxide
7. Carbon tetrachloride
8. Chloroform
9. Chloromethane
10. Chromium
11. 1,4-Dichlorobenzene
12. 1,2-Dichloroethane
13. Dichloromethane
14. Ethylene dibromide
15. Formaldehyde
16. Lead
17. Manganese
18. Mercury
19. Nickel compounds
20. Nitrogen Oxides
21. PAHs (as B[a]Ps)
22. PM_{2.5}
23. Tetrachloroethylene
24. Toluene
25. Trichloroethylene
26. Vinyl Chloride
27. PM₁₀
28. Sulfur Dioxide
29. VOCs (Anthro. & Biogenic)
30. Ozone

Ozone (OBM) + VOCs (No AAQC) & 3 WHITE (BLUE) MAPS (0.0¹⁶)

44

1. Acetaldehyde
2. Acrolein
3. Benzene
4. 1,3-Butadiene
5. Cadmium
6. Carbon Monoxide
7. Carbon tetrachloride
8. Chloroform
9. Chloromethane
10. Chromium . But see Health
11. 1,4-Dichlorobenzene
12. 1,2-Dichloroethane
13. Dichloromethane
14. Ethylene Dibromide
15. Formaldehyde
16. Lead
17. Manganese *
18. Mercury
19. Nickel compounds
20. Nitrogen Oxides
21. PAHs (as B[a]Ps)
22. PM_{2.5}
23. PM₁₀
24. Tetrachloroethylene
25. Toluene
26. Trichloroethylene
27. Vinyl Chloride
28. Sulfur Dioxide
29. VOC (Anthropogenic/Biogenic)
30. Ozone

17 YELLOW & 3 GREEN MAPS

45

1. Acetaldehyde *
2. Acrolein *
3. Benzene
4. 1,3-Butadiene
5. Cadmium
6. Carbon Monoxide
7. Carbon tetrachloride
8. Chloroform
9. Chloromethane
10. Chromium .But see Health Map
11. 1,4-Dichlorobenzene
12. 1,2-Dichloroethane
13. Dichloromethane
14. Ethylene dibromide
15. Formaldehyde *
16. Lead
17. Manganese *
18. Mercury
19. Nickel compounds
20. Nitrogen Oxides
21. PAHs (as B[a]Ps)
22. PM2.5
23. PM10
24. Tetrachloroethylene
25. Toluene
26. Trichloroethylene
27. Vinyl Chloride
28. Sulfur Dioxide *
29. VOC (Anthropogenic/Biogenic)
30. Ozone

5 RED MAPS

46

1. Acetaldehyde
2. Acrolein
3. **Benzene**
4. 1,3-Butadiene
5. Cadmium
6. Carbon tetrachloride
7. Chloroform
8. Chloromethane
9. Chromium
10. 1,4-Dichlorobenzene
11. 1,2-Dichloroethane
12. Dichloromethane
13. Ethylene dibromide
14. Formaldehyde
15. Lead
16. Manganese
17. Mercury
18. Nickel compounds
19. **Nitrogen Oxides**
20. **PAHs (as B[a]Ps)**
21. **PM_{2.5}**
22. Tetrachloroethylene
23. Toluene
24. Trichloroethylene
25. Vinyl Chloride
26. Carbon Monoxide
27. **PM₁₀**
28. Sulfur Dioxide
29. VOC (Anthropogenic/Biogenic)
30. Ozone

Highway Emissions

- **Nitrogen Oxides**
- **Benzo[a]Pyrene**
- **PM₁₀**
- **PM_{2.5}**
- **Benzene**
- 1,3 Butadiene
- Acrolein
- Cadmium
- Carbon Monoxide
- Formaldehyde
- Mercury

Airport (BBTCA) emissions

- **Acrolein**
- **Chromium**
- Acetaldehyde
- Formaldehyde
- Manganese
- Sulphur Dioxide

Combination Emissions

- **PM_{2.5}**
- **Benzene**

Local “Hot Spot” Emissions

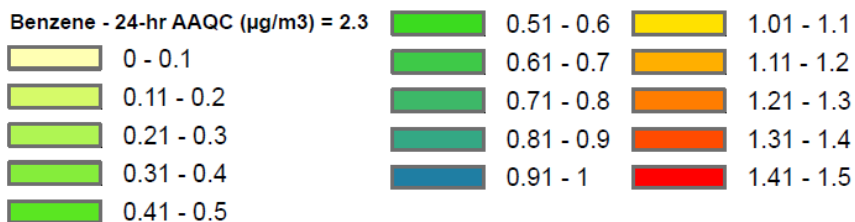
- **PM_{2.5}**
- **Tetrachloroethylene**
- Chromium

- Others ?

Compliance Maps as % of AAQC

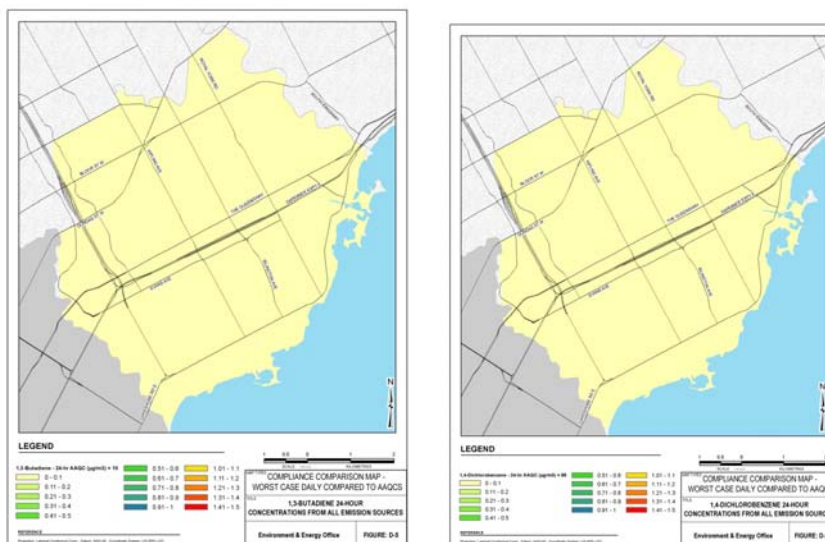
51

LEGEND



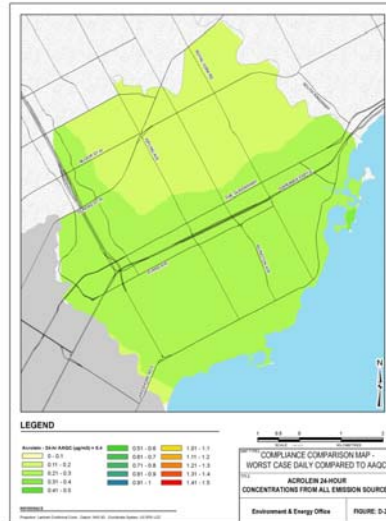
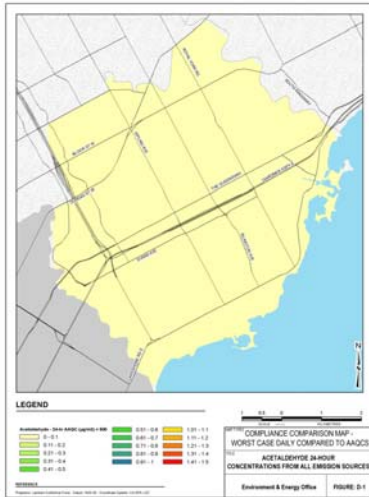
1,3 Butadiene & 1,4 Dichlorobenzene

52



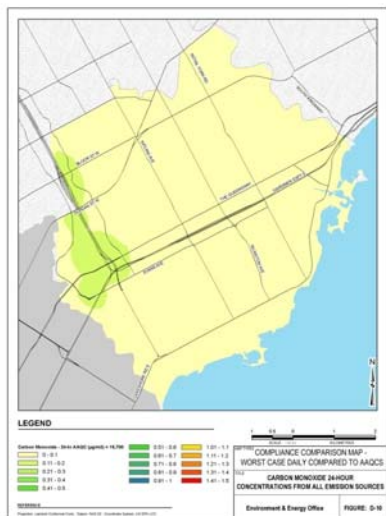
Acetaldehyde & Acrolein

53



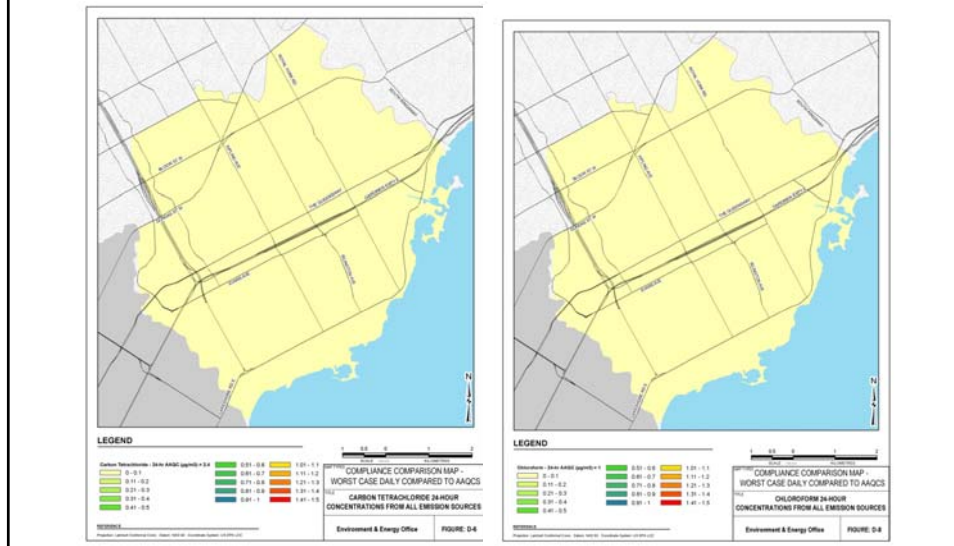
Cadmium & Carbon Monoxide

54



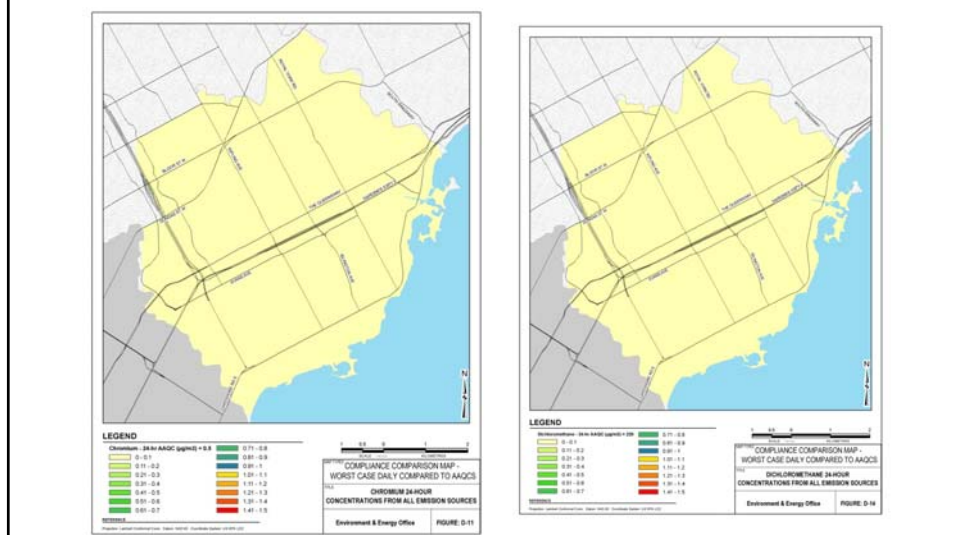
Carbon Tetrachloride & Chloroform

55



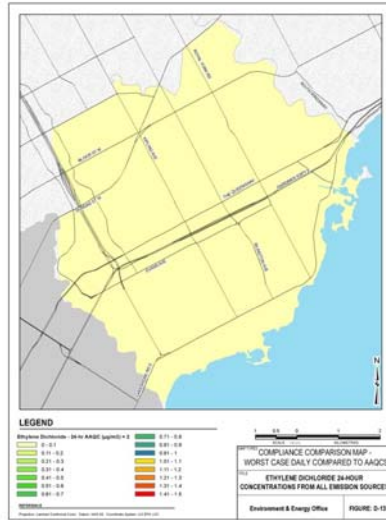
Chromium* & Dichloromethane

56



Ethylene Dichloride & Formaldehyde

57



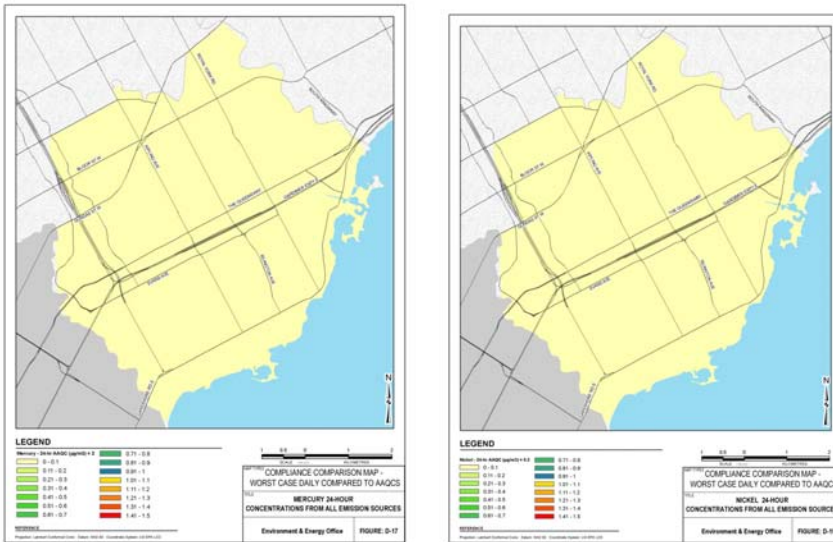
Lead & Manganese

58



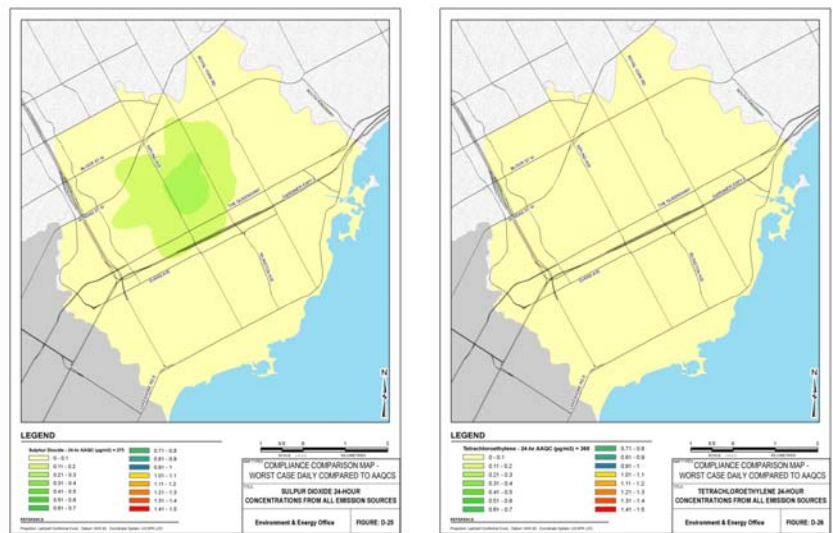
Mercury & Nickel Cmpnds.

59



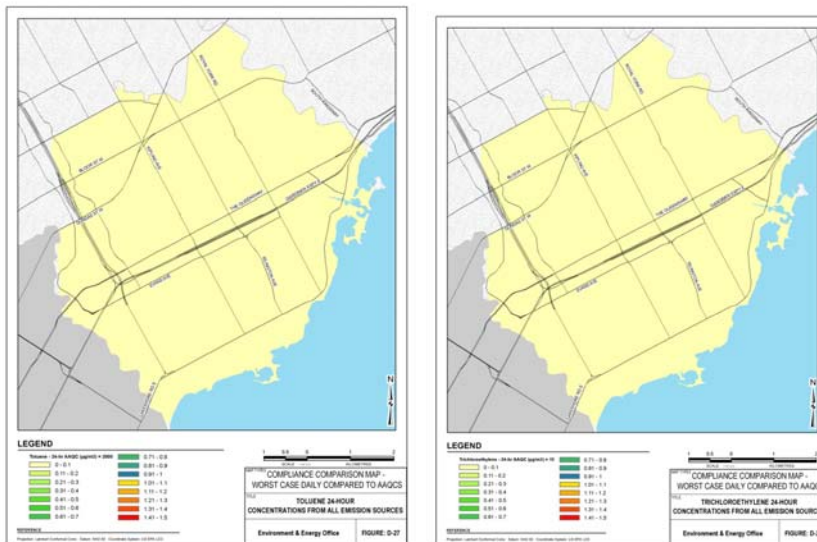
Sulph Dioxide & Tetrachloroethylene

60



Toluene & Trichloroethylene

61



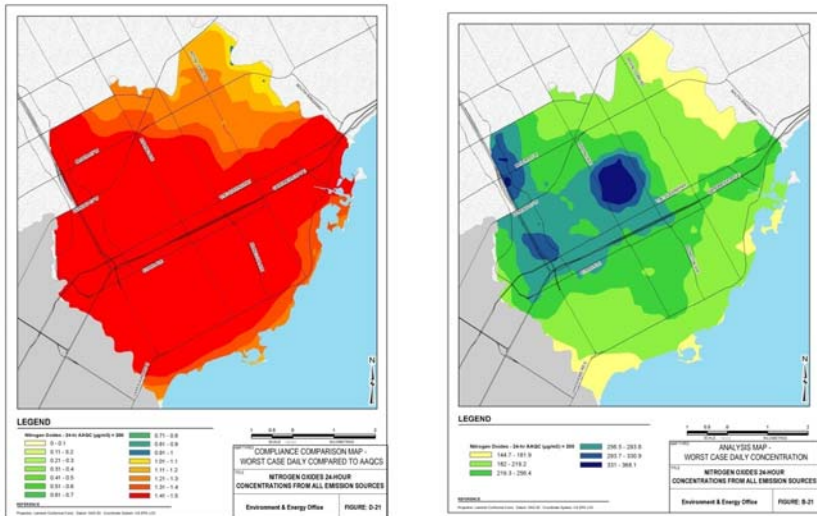
5 RED MAPS

62

1. Acetaldehyde
2. Acrolein
3. **Benzene**
4. 1,3-Butadiene
5. Cadmium
6. Carbon tetrachloride
7. Chloroform
8. Chloromethane
9. Chromium
10. 1,4-Dichlorobenzene
11. 1,2-Dichloroethane
12. Dichloromethane
13. Ethylene dibromide
14. Formaldehyde
15. Lead
16. Manganese
17. Mercury
18. Nickel compounds
19. **Nitrogen Oxides**
20. **PAHs (as B[a]Ps)**
21. **PM_{2.5}**
22. Tetrachloroethylene
23. Toluene
24. Trichloroethylene
25. Vinyl Chloride
26. Carbon Monoxide
27. **PM₁₀**
28. Sulfur Dioxide
29. VOC (Anthropogenic/Biogenic)
30. Ozone

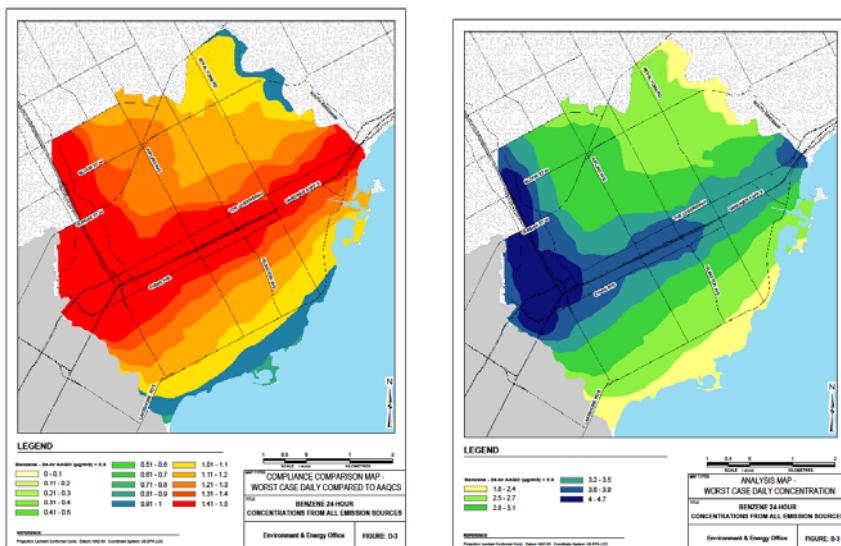
Nitrogen Oxide: Compl. & Analysis

63



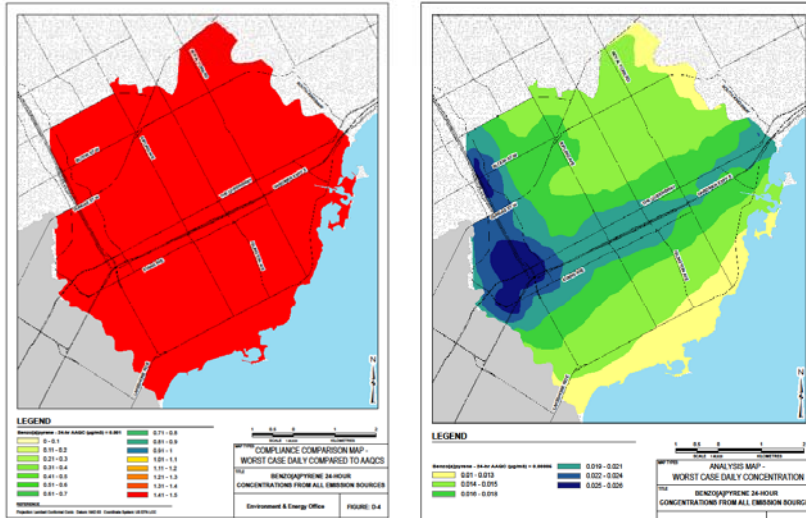
BENZENE Comp & Analysis

64



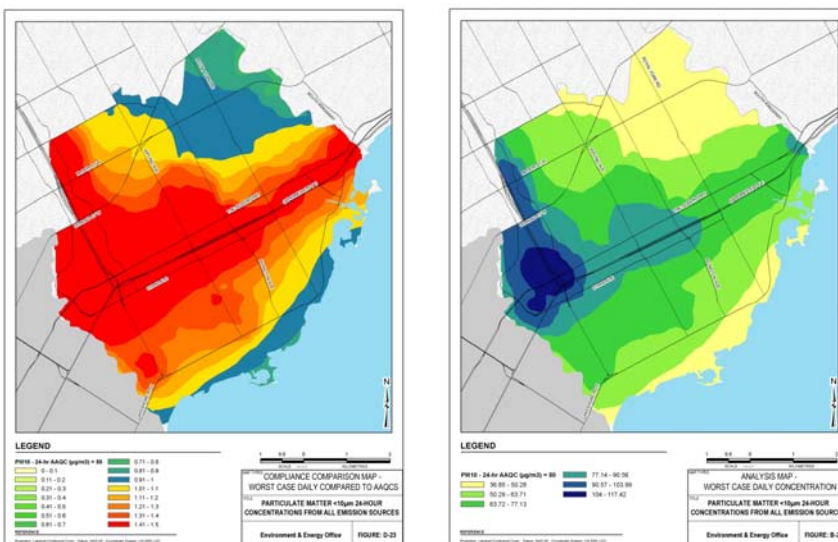
BENZO[A]PYRENE Comp & Anal

65



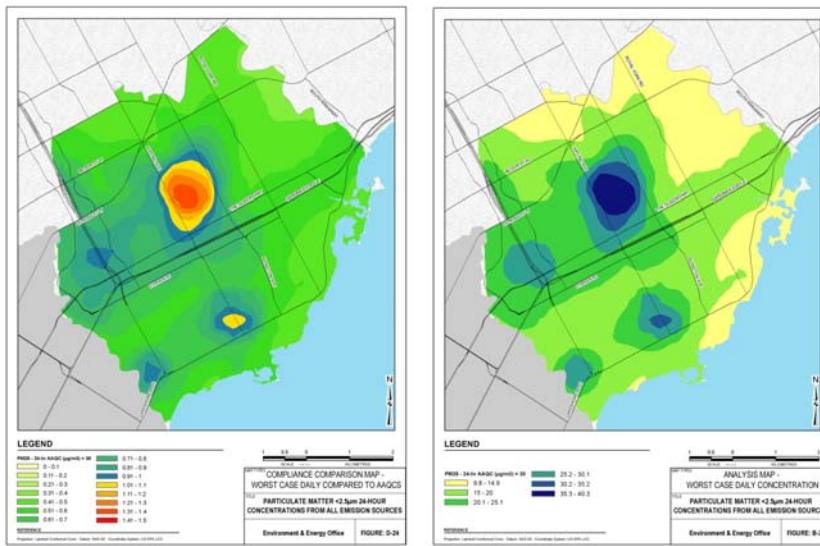
PM₁₀ Compliance & Analysis

66



PM_{2.5} Compliance & Analysis

67



Full Set of Maps: 5x Substance

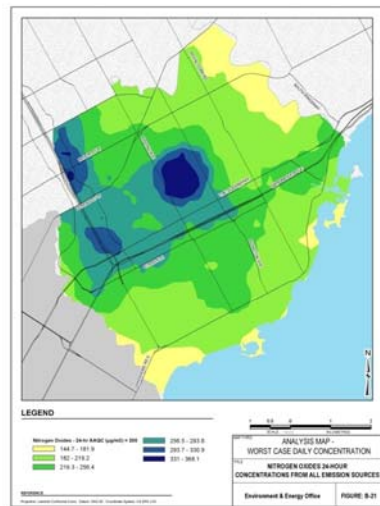
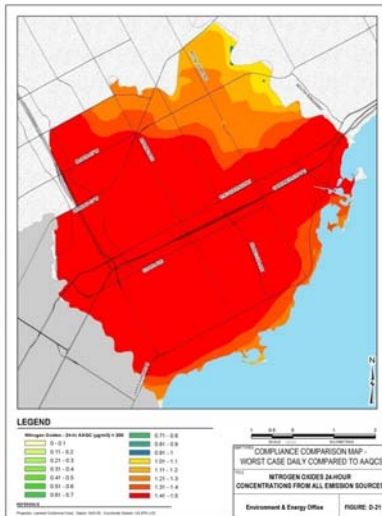
68

- 24 Hour (Worst Case)
- 98th Percentile
- Annual Average
-
- Compliance (cf. with MOE AAQCs)

- TPH Health Risk Values Map

Nitrogen Oxide: Comp. & Analysis

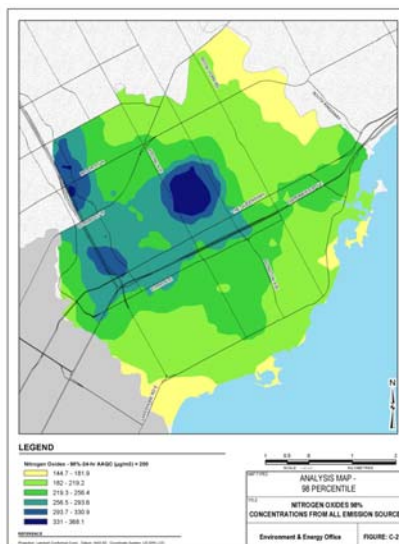
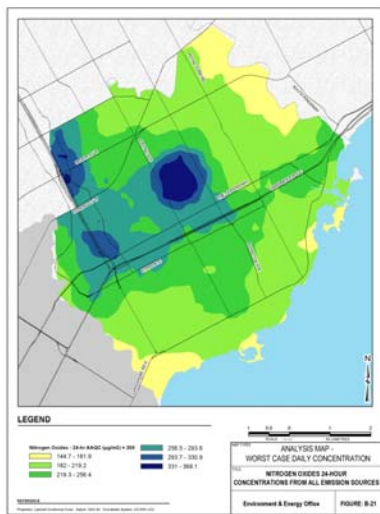
69



NO_x 24 Hour

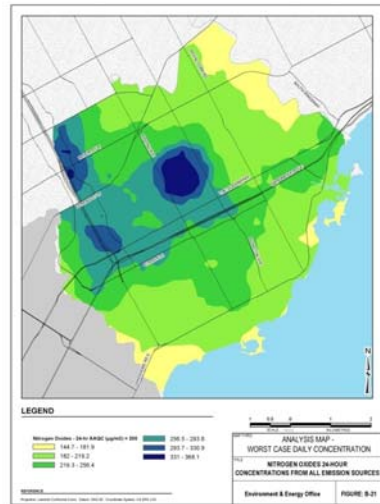
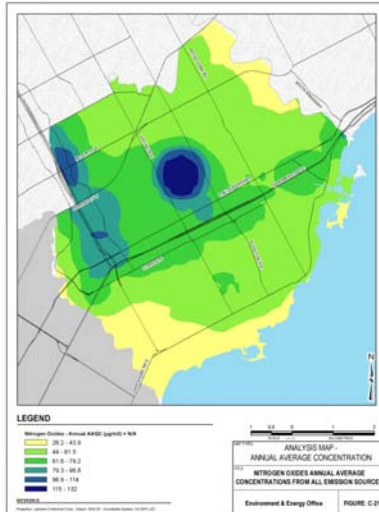
NO_x 98th %

70



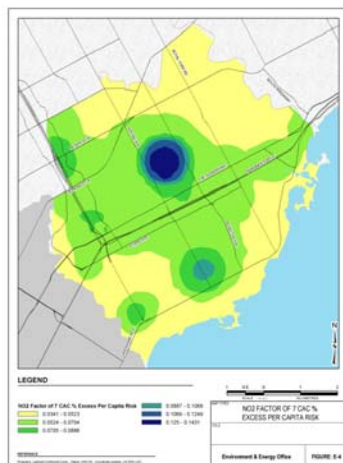
NO_x Annual NO_x “Compliance”

71



NO_x (NO₂) 70% Excess Risk/Cap

72



- 70% because of NO to NO₂ conversion
- Excess Risk per Capita from TPH shows

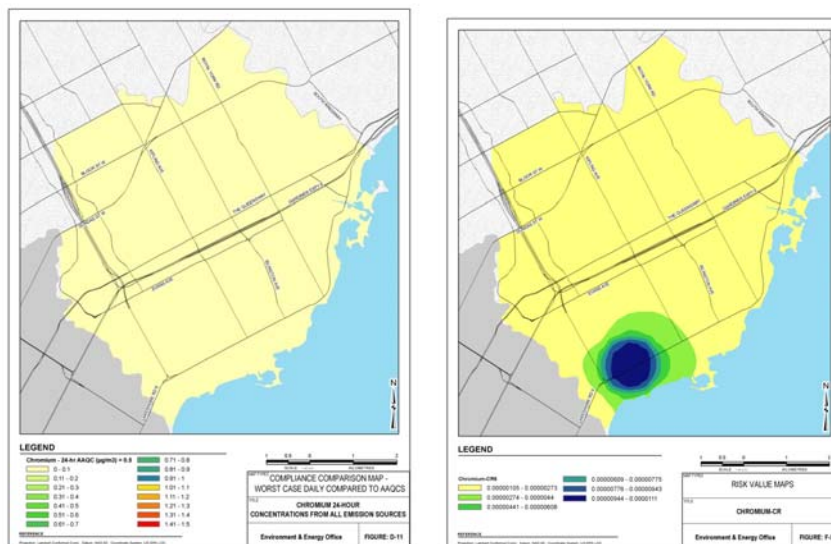
1 RED but MISSING MAP - Cr

73

- | | |
|-------------------------|----------------------------------|
| 1. Acetaldehyde | 16. Manganese |
| 2. Acrolein | 17. Mercury |
| 3. Benzene | 18. Nickel compounds |
| 4. 1,3-Butadiene | 19. Nitrogen Oxides |
| 5. Cadmium | 20. PAHs (as B[a]Ps) |
| 6. Carbon tetrachloride | 21. PM_{2.5} |
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| 11. 1,2-Dichloroethane | 26. Carbon Monoxide |
| 12. Dichloromethane | 27. PM₁₀ |
| 13. Ethylene dibromide | 28. Sulfur Dioxide |
| 14. Formaldehyde | 29. VOC (Anthropogenic/Biogenic) |
| 15. Lead | 30. Ozone |

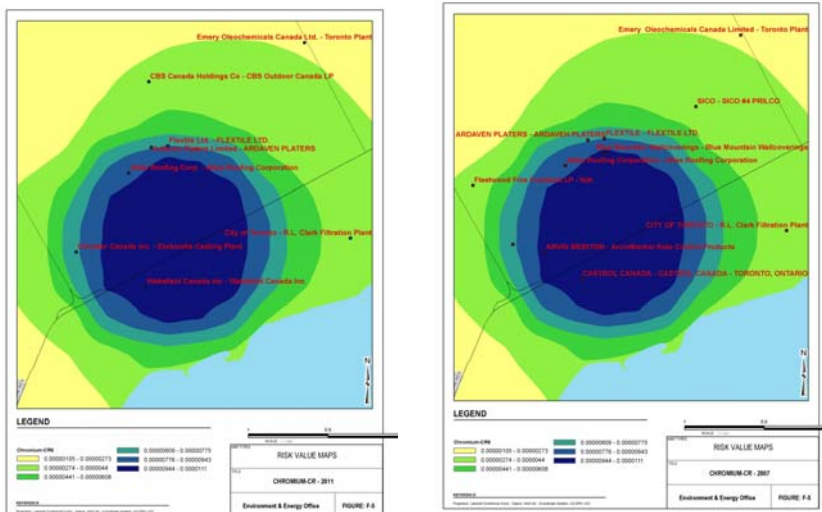
Chromium Compl. & Health Risk

74



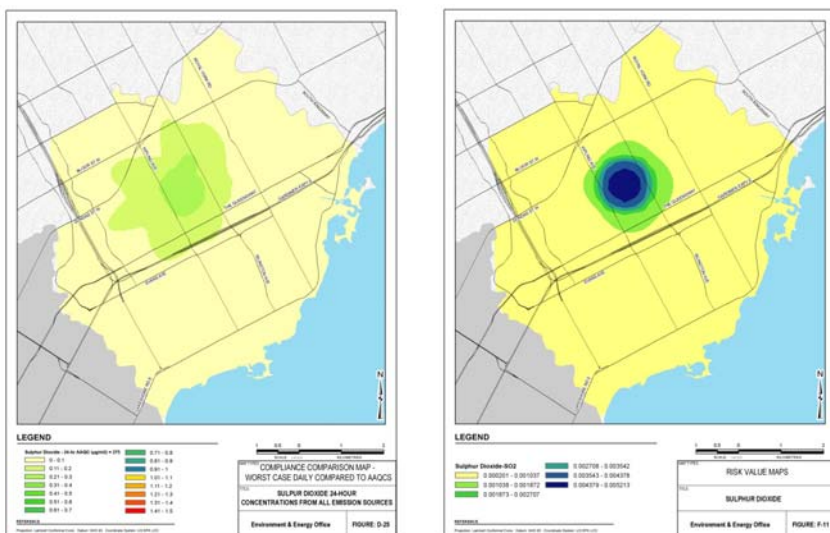
Chromium - 2007 & 2011 NPRI

75



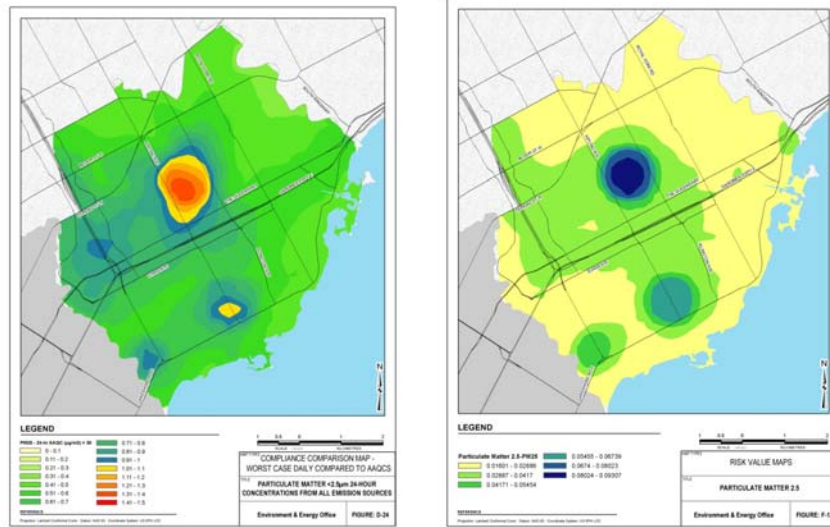
SO₂ Compliance & Health Risk

76



PM_{2.5} Compl. & Health Risk

77



Health Risk Assessment (TPH)

Re: Ward 30 & Ward 32

- Most substances met Ontario's ambient air quality criteria (AAQCs) individually but
- Non Cancerous Toxics - **Cumulative risk** is 0.31, & is below the threshold for concern
- Cancerous - **Cumulative cancer risk** is 83 in 1 million, this is about 2 per cent of the total cancer incidence rate in Toronto
- Criteria Air Contaminants - **Cumulative risk of premature death** is increased by 8.9 percent
-

Cumulative Health Assessment Maps

79



Distribution of cumulative risk from non-carcinogens



Distribution of cumulative risk from carcinogens



Distribution of cumulative risk of mortality from criteria air contaminants

Conclusions from TPH

80

Re: Ward 30 & Ward 32

- Most **carcinogens** are below the one in one million excess cancer risk benchmark & the **cumulative level is very low** compared to the total incidence rate of cancer in Toronto
- The **non-carcinogenic toxics** are **below levels of concern** to health, even when combined exposure taken into account
- **Criteria air contaminants** such as ozone, nitrogen dioxides, and particulate matter contribute to the burden of illness
- Some areas show a higher risk than others
- Current Ontario standards for CACs are not fully protective of health

Remaining Work

81

- ID possible Concentrated Emission Sources
- Verify & Discuss with MOE
- MOE talks with the relevant Industry/ies (if nec.)

- Add in Tier 1 & Tier 2
- Add in TPH Cumulative Risk Maps & Analysis

- Add in ChemTRACK data (all 3 phases)
- Reassess Totals and Local Contributions
- Return to the Community

New Directions (1)

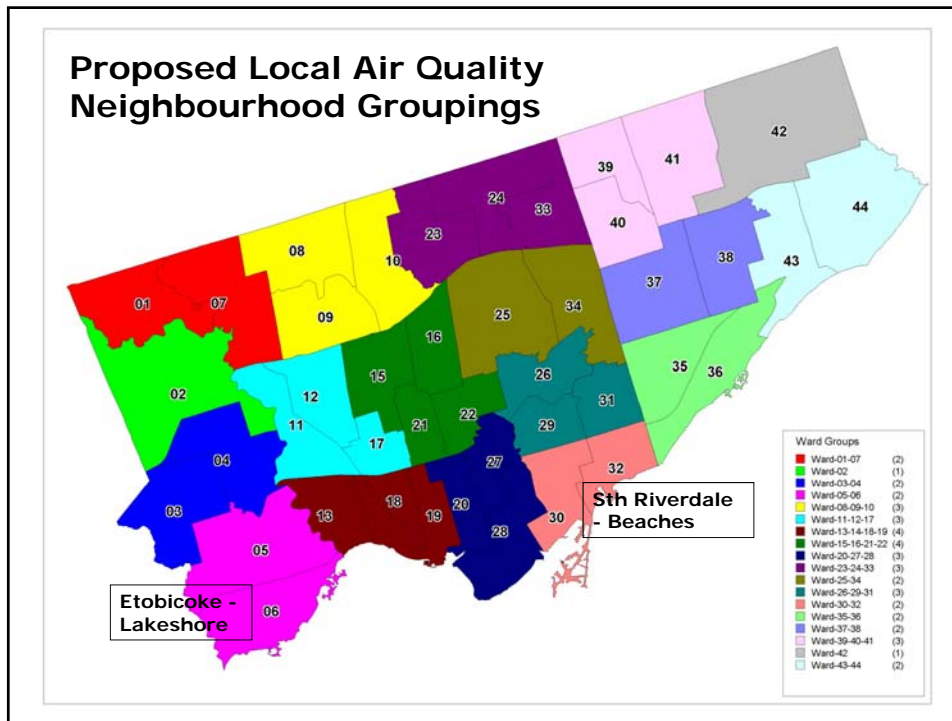
82

18 Local Neighbourhood Groupings

Data Extraction by RWDI

We can do 3 per year - needed faster delivery!

- Add Chem-TRAC Data from TPH (Avoid Double Counting) into Model Layers
- Take the Message to the People (Community Awareness & Outreach)
- Combined Air Quality + Climate Change & Energy Conservation Responses
- Roving Neighbourhood AQ Monitor



New Directions (2)

84

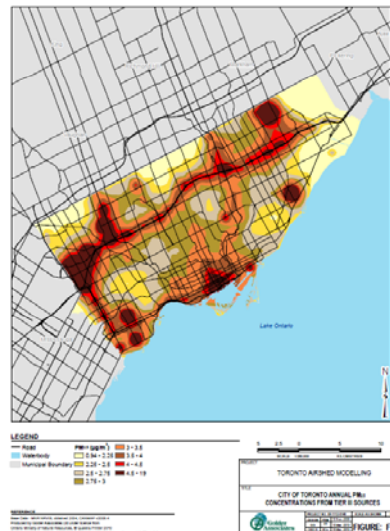
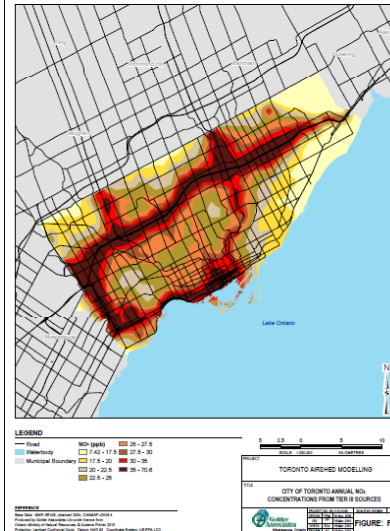
Advocacy (Transportation)

- For Improved Transportation Emissions Standards
 - ▣ Work w TPH re Health Costs
 - ▣ Connect with Other Major Canadian Cities
- Together with Public Health – Work w Ministries of
 - ▣ (i) Environment (ii) Health (iii) Transportation
- Re Trucks Especially
- Re Cars & SUVs etc as well

NO_x Ann

PM_{2.5} Ann

85



New Directions (3)

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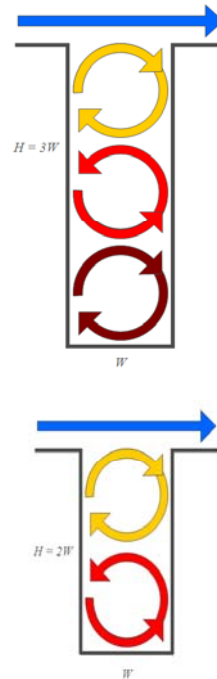
Adaptation (Urban Planning & Urban Design)

- Amend Provincial Policy Statement (PPS) -- done
- Include in City's Official Plan -- done

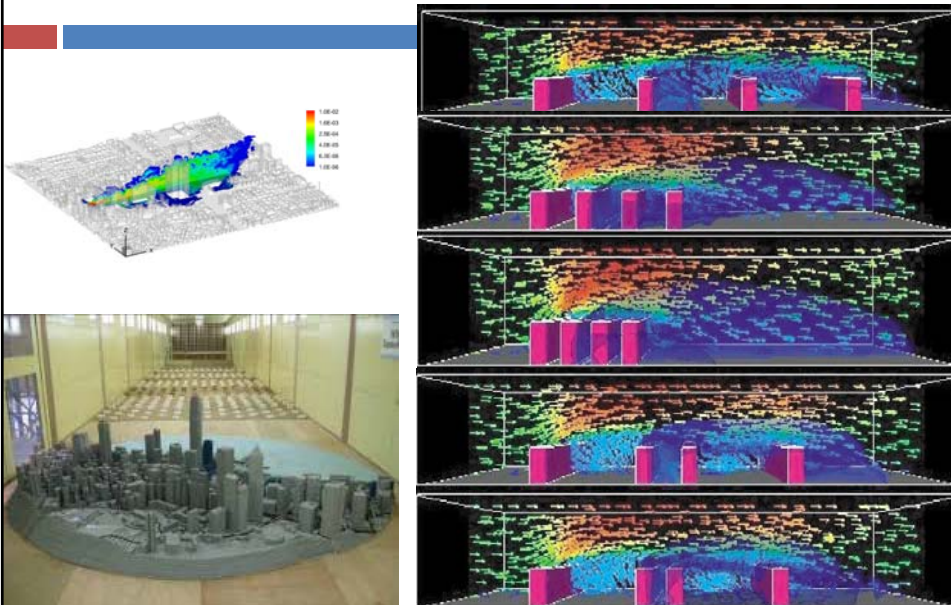
- Tool Kit for Planners (Urban Design) -- in progress
- Test & Develop Concepts → Standard -- in future
 - Develop Appropriate Designs & Configurations from 3-Dimensional AQ Modelling & Technical Analysis of Downtown Tall Buildings & Streets

Urban Canyon Problems

87

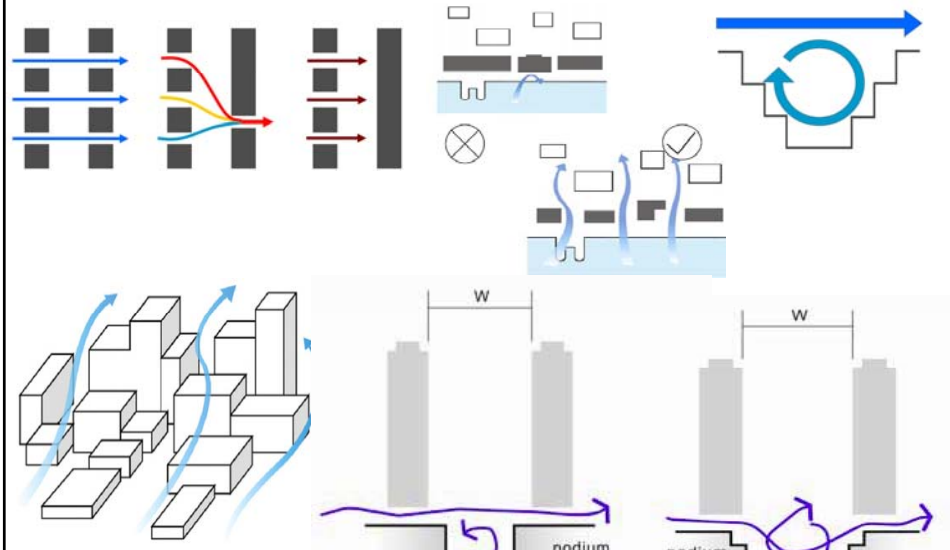


3D Modelling ... Computer + Physical



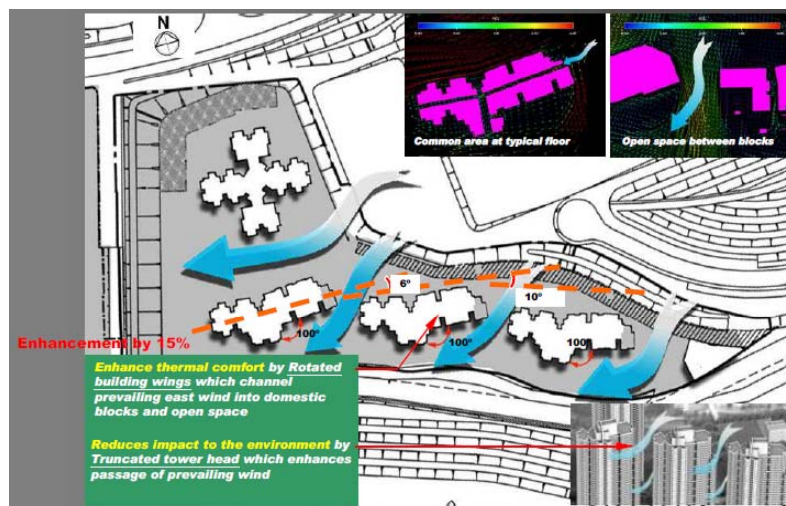
Buildings & Street Design

89



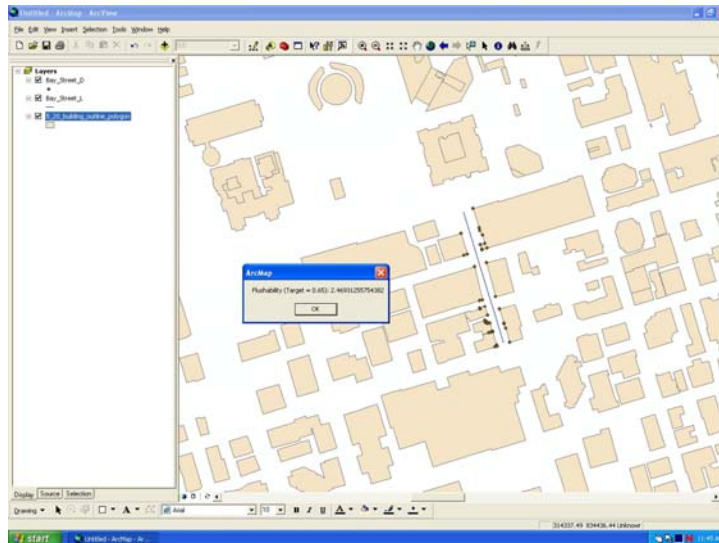
Air Flow Between & Through Buildings

90



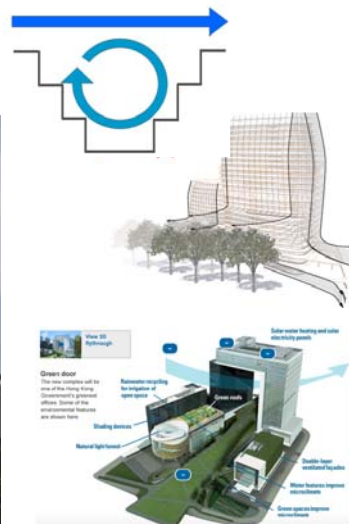
Ventilation Index for Planners

91



Bldg Shape & Orientation

92



New Directions (4)

93

Air Chemistry Improvement (CMAQ)

- To better address smog issues etc
- To better use ChemTRAC data
- To avoid comparative public perception of inadequacies
- Run CMAQ at a high resolution to mimic CALPUFF Tier 1,2, 3 approach
- Rely on Consultants
- Integrate with Continuing CALPUFF Needs

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THE END

QUESTIONS & DISCUSSION ?

Further/Later Questions & Concerns to
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416-392-6903