Dispersion Modelling and Air Quality Management

Peter L. Jackson

and the PGAIR Research Working Group

Acknowledgements

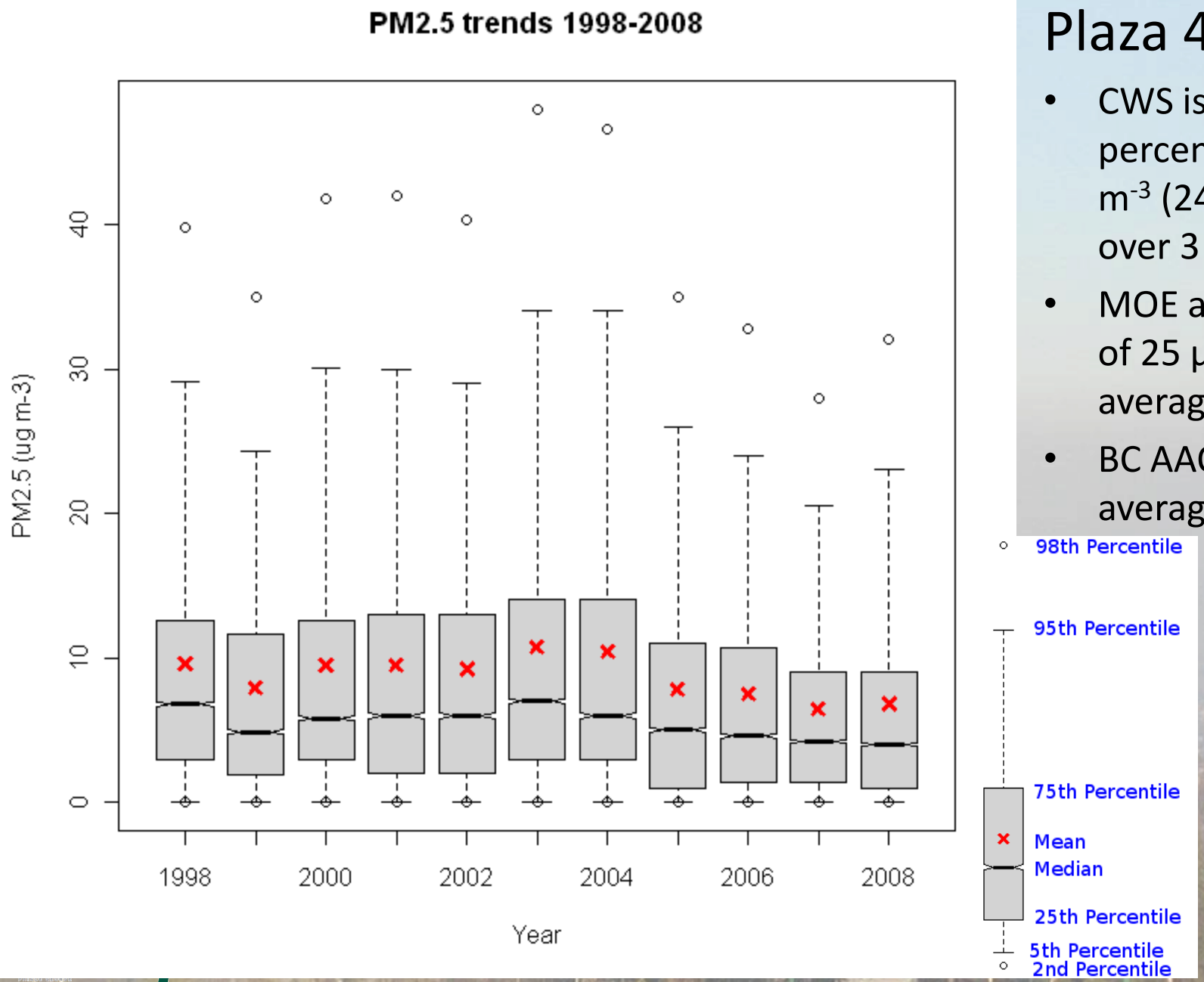
- STANTEC especially John Spagnol
- PGAIR-RWG members, especially Dennis Fudge and Dave Sutherland

Outline

1. Background
   - AQ issue
   - Source attribution and AQ management
   - Source attribution methods
2. Dispersion Modelling
   - What it is, what it can do
   - Strengths and limitations
3. Prince George Dispersion Modelling Study
   - Rationale and history
   - Current results
   - Comparisons with other studies
   - Strengths and limitations
   - Next steps

Prince George Air Quality

- PG has two main air quality issues:
  - Elevated particulate matter levels (PM_{10} and $PM_{2.5}$) due to health concerns
  - Elevated total reduced sulphur (TRS) levels which is mainly a nuisance/odour issue
- Most of the work to-date, including AQ management has concerned PM



Plaza 400

- CWS is 98th percentile of 30 µg m^{-3} (24 h average) over 3 years
- MOE advisory level of 25 µg m^{-3} (24 h average)
- BC AAQO annual average of 8 µg m^{-3}

It's not all about size…it's about impact

Sources → Atmosphere → Receptors

All must be considered!

Most AQ issues are complex and solutions that work can be challenging

What we care about are impacts on Receptors (i.e. people)

- In managing AQ to protect health, we care about **ambient** air quality where people live and work

Air Quality Management

- Goal is to lower **ambient** levels of particular pollutants to a level sufficient to protect health, environment and quality of life
- To do this effectively we need to attribute the contribution of each source to ambient levels – in order to rank sources and be able to estimate the result of source reduction

Types of Source Attribution Studies

1. Receptor Modelling
   - based on **ambient AQ data**
   - wind sector analysis (Fudge et al, BCMOE)
   - chemical mass balance (CMB) – associates source chemical source profiles to ambient data (EC/BCMOE/STI study)
   - PCA / PMF (EC/BCMOE/STI study) - lets the ambient data "speak for themselves" and infers source profile
2. Dispersion Modelling
   - based on **source emission inventory,** meteorological data
   - validated by ambient data and can determine contributions of individual sources at any receptor in the airshed
   - Many "levels" of modelling
   - Several past studies by gov't / industry
   - Current comprehensive study using Calpuff (Spagnol et al, UNBC – PGAQIC – Research Working Group)

Source Attribution

- None of the methods are perfect – all have strengths, weaknesses and limitations
- Receptor modelling and wind sector analysis can give general guidance, but can't draw a direct link from a specific source or emitting unit to ambient levels at a point in the airshed
- Dispersion modelling can make the specific connection between sources and ambient levels making it the preferred tool for ranking and prioritizing sources

Dispersion Modelling

Dispersion models have three components:

1. An **Emission Inventory** that lists, locates, quantifies and characterizes all emissions in an airshed
2. A **Meteorological Model** that characterizes the atmospheric environment by quantifying wind, temperature, turbulence and stability each hour across an airshed
3. A **Dispersion Model** that places emissions from #1 into the atmosphere characterized by #2, and calculates how the emissions are diluted and transported to predict the ambient concentrations at specified points (receptors) in the airshed

Dispersion Modelling – cont'd

- The link between source and ambient concentration at receptors is maintained
- The model can therefore account for and rank the contributions of all modelled sources at all receptors
- This information is exactly what is needed in air quality management, to prioritize sources for reduction, and to estimate the expected improvement in ambient levels due to source reductions

Dispersion Modelling and AQ Management

- In order to use dispersion model results, we have to believe the model predictions are essentially correct and understand the limitations
- Expert review of the model and its results are done to ensure that all components were done without serious error, and using appropriate methods and scientific judgement
- Comparison of model predictions with observed ambient levels is also done to see how well the model predicts what is measured

Dispersion Model Uncertainties

- Each of the three components of the modelling system has uncertainty and error
- For particulate matter, the emission inventory is especially problematic due to the large number of sources, that can be poorly characterized
- Only some of these sources are measured (e.g. industrial emissions)
- Others must be estimated using emission factors that relate activity to emission amounts
- Emission amounts have a **direct impact** on ambient levels → therefore if an emission estimate is 50% too large, then the ambient levels resulting from that emission will also be 50% too large

Prince George Dispersion Modelling Study

- In order to guide phase III air quality management planning, the PGAIR-RWG proposed a dispersion modelling study in 2005
- The study goals were to
  - Identify the relative contribution to ambient air quality of all important sources of PM_{10} and $PM_{2.5}$ in the airshed
  - Examine scenarios for source reduction to most efficiently reduce ambient levels

PG Study Strategy

- Most dispersion modelling studies are conducted to assess the impact of a single facility on ambient AQ (e.g. a proposed new facility) – this requires a relatively simple emission inventory
- We recognized at the outset that modelling all PM sources would require iteration and extensive interaction with RWG members to refine the modelling to an acceptable accuracy
- Therefore, in the initial stages we hired a modeller, rather than contracting the work to a consultant

PG Dispersion Modelling History

- Project started in 2006 with funding from BCMOE, EC, City of PG, Northern Health, and CANFOR
- John Spagnol was hired as a post-doctoral fellow at UNBC to work with the RWG on the emission inventory and to conduct the modelling
- A 3rd party review of the early modelling results was conducted mid-stream
- An interim report was produced in early 2008 that was reviewed by a 3rd party consultant that made recommendations for further improvement to model settings and emission inventory
- STANTEC consultants were contracted by PGAIR and BCMOE in late 2009 to work with the RWG and implement improvements, producing and publicly presenting their draft report in March 2010 and delivering the final report in October 2010 (available on the PGAIR website after December 1)

History - continued

- At each stage of the modelling study, new refinements were identified and made, especially to the emission inventory
- This was expected from the start, due to uncertainties in the emissions of many sources
- If uncertain sources were shown by modelling to be potentially significant contributors to ambient levels, then more work was done to improve their emission estimates
- For example, the interim report (2008) found locomotives were very significant downtown, so RWG effort was spent to more accurately estimate their emissions – resulting in lower predicted ambient contributions in the current results

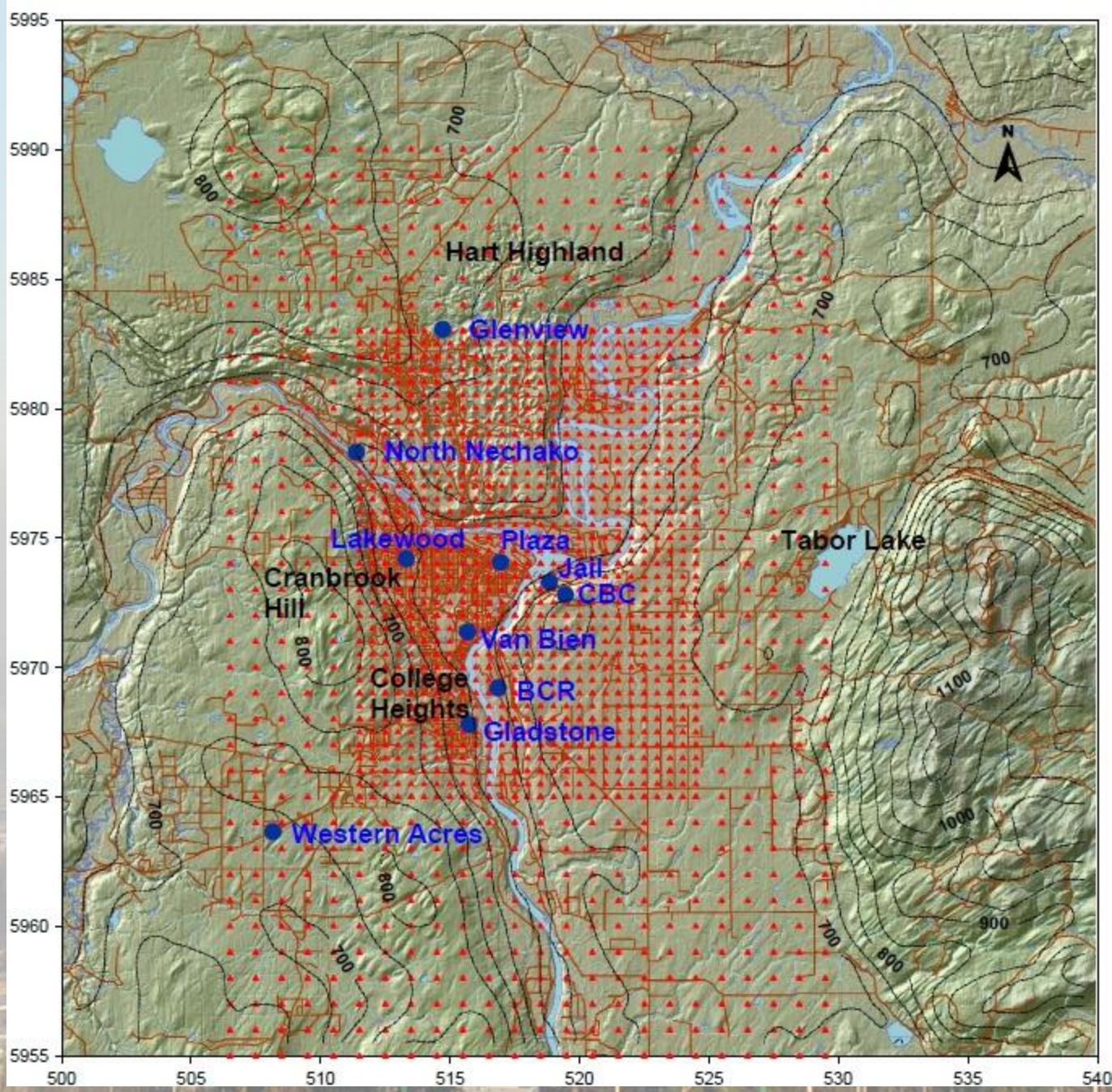
Dispersion Model Results

- The current model predictions are the best information to-date characterizing the contributions of specific sources on ambient levels in the Prince George airshed
- Ongoing review of the report by RWG members as well as limitations identified by STANTEC indicate further refinements are needed for some source categories

Model Domain

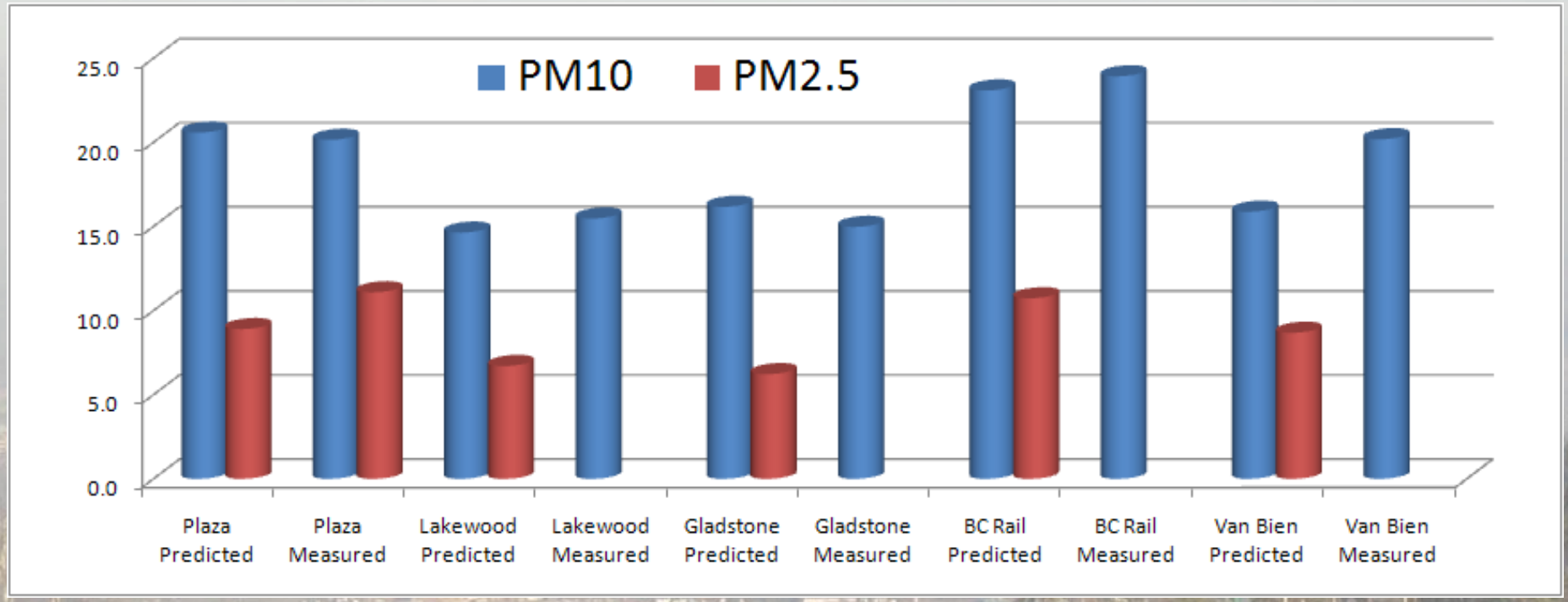
- There were 1883 receptors where ambient pollutant levels were calculated (red dots)
- Every hour between 2003-2005 was modelled
- About 1500 individual sources were modelled, as point, area or lines
- 33 permitted (industrial) sources with about 350 emitting units

Source: Stantec (2010)

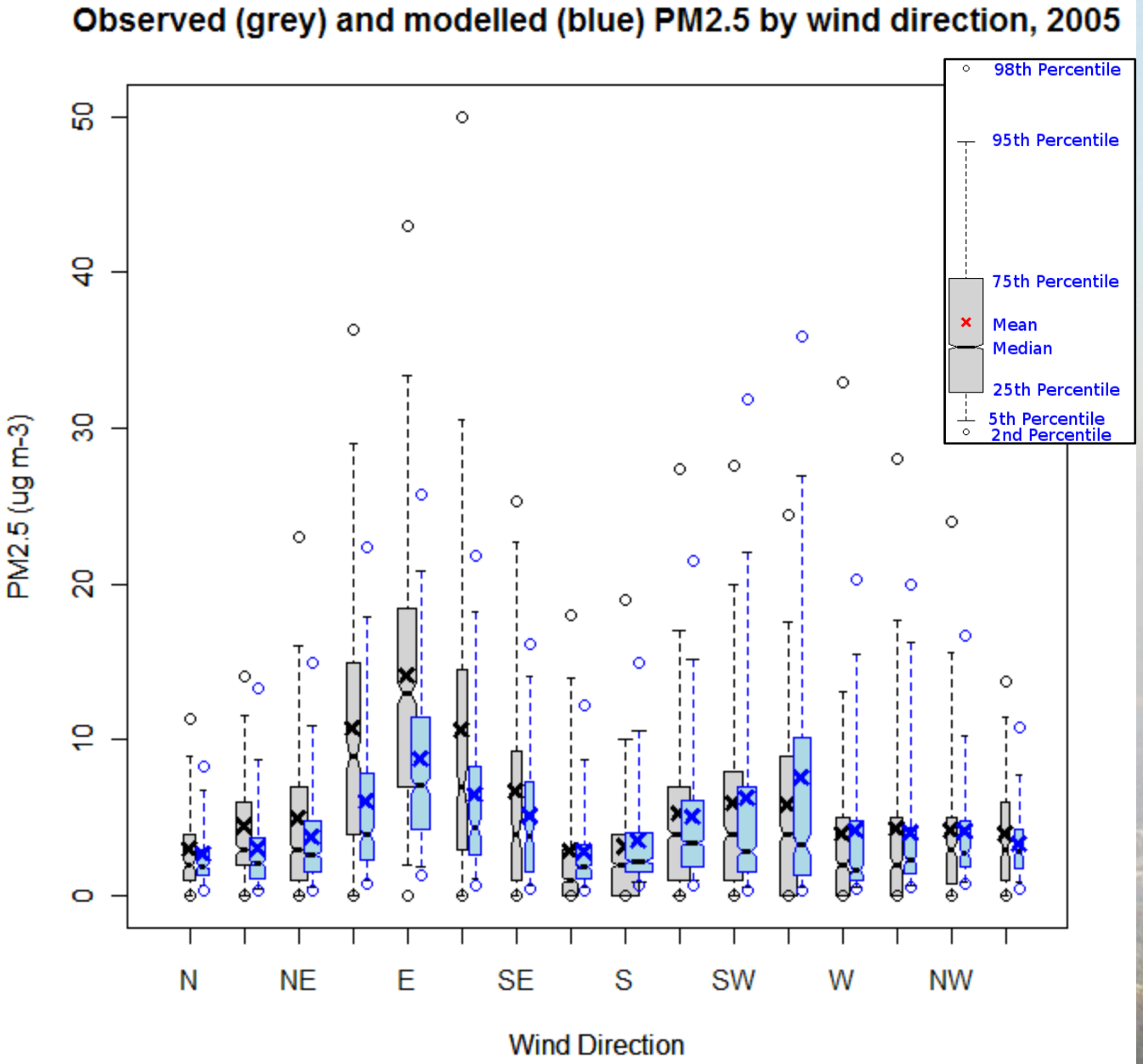


Model Performance

- 2003-2005 Average Predicted vs Measured PM_{10} & $PM_{2.5}$
- The mean is reasonably well predicted at most locations



Source: Stantec (2010)



Plaza **observed** and **modelled** $PM_{2.5}$

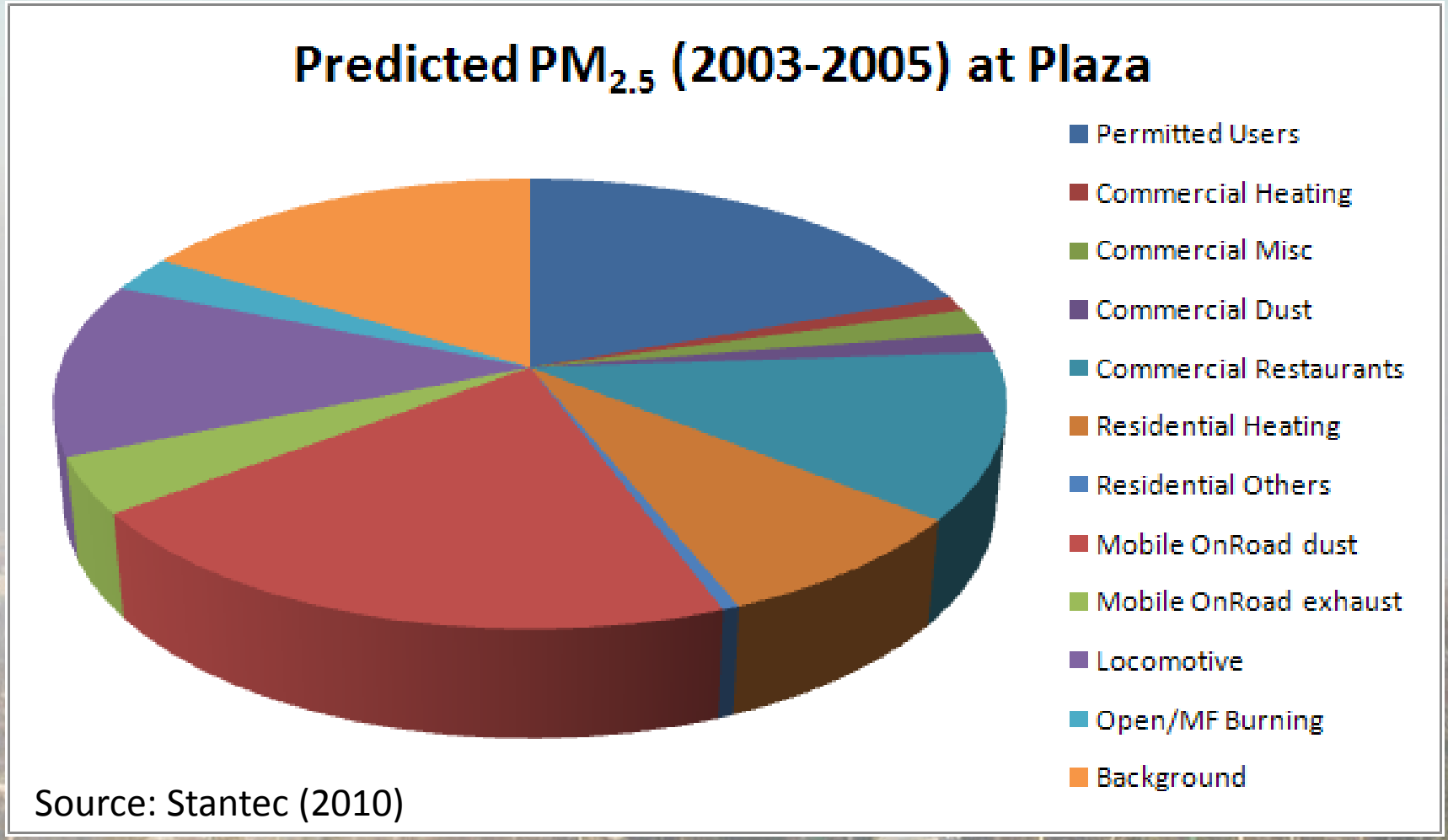
- Model under-predicts from the easterly quadrant
- We think this is a model windfield issue
- Could also be underestimating the sources in the industrial sector (e.g. condensable PM, secondary PM, fugitive dust)

Model Performance

- These results show that the model is generally performing well, at times over predicting but usually under predicting.
- There appears to be an under-predicting bias downtown with winds from the east and northeast
- Some uncertainty results from use of background values derived from measurements taken some 300 km to the east of Prince George, and in different years.
- There is also uncertainty in the measured concentrations.

Monitoring Site Receptor Results

Predicted $PM_{2.5}$ Contributions by Source Category at the Plaza Site



Source: Stantec (2010)

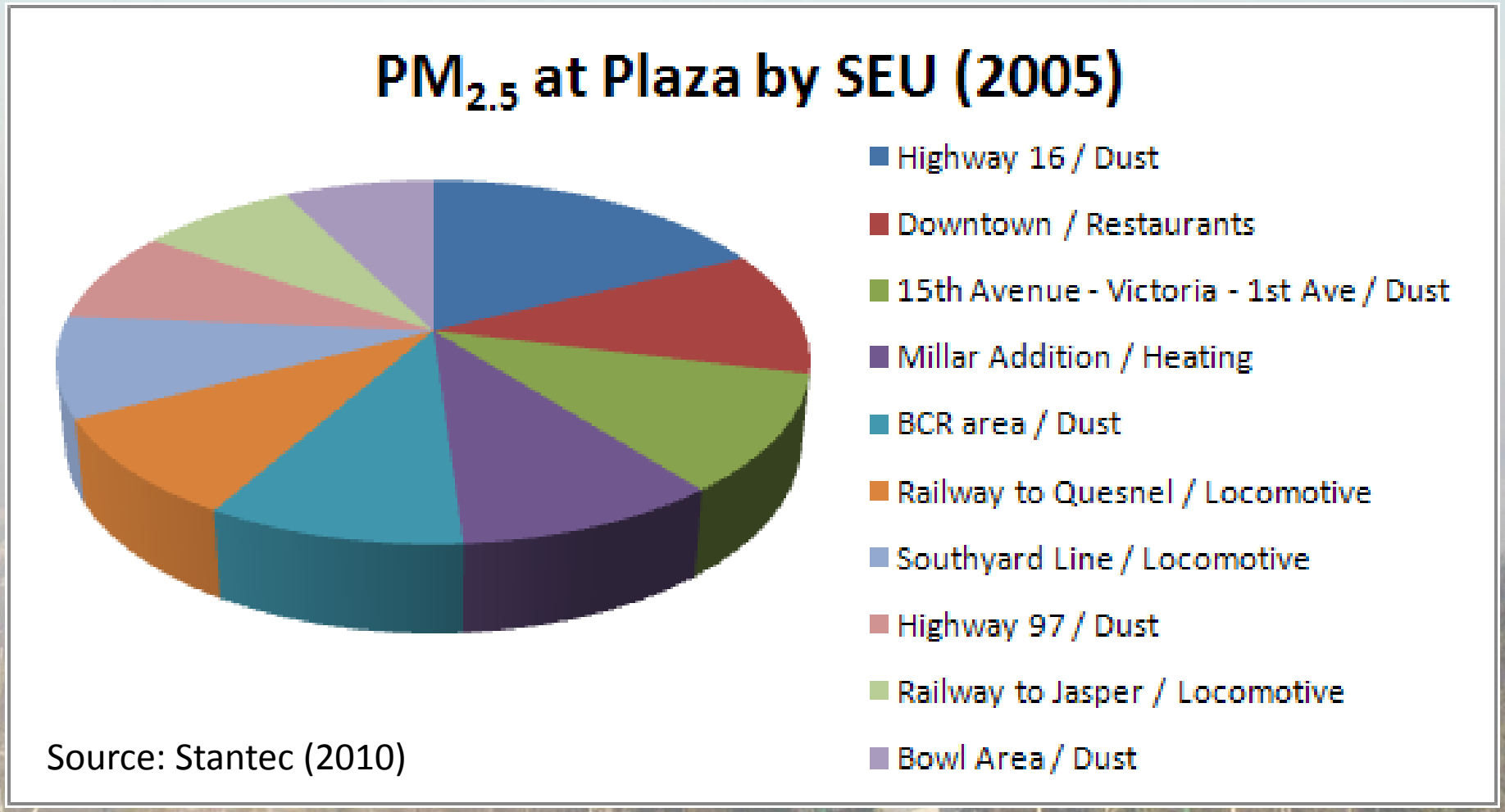
Table 6.7: Ranked Contributions to Predicted Annual Average $PM_{2.5}$ and PM_{10} Concentrations at the Plaza Site by Sub-Source Category: Year-2005 (cont'd)

Plaza	Sub Source Category	2005 PM_{10} ($\mu g/m^3$)	2005 $PM_{2.5}$ ($\mu g/m^3$)	2005 PM_{10} (%)	2005 $PM_{2.5}$ (%)
#3 Primary and Secondary PM Predictions Background is added as a line Item in this table	Permitted users	2.74	1.83	14.61%	20.67%
	Locomotive	1.40	1.34	7.45%	15.15%
	Background	5.1	1.3	27.20%	14.67%
	On-road dust	5.70	1.24	30.40%	13.96%
	Commercial restaurants	1.13	1.04	6.01%	11.78%
	Residential heating	0.82	0.82	4.37%	9.20%
	On-road mobile	0.66	0.53	3.52%	5.99%
	Open/MF Burning	0.30	0.28	1.58%	3.18%
	Commercial miscellaneous	0.20	0.19	1.07%	2.19%
	Commercial dust	0.55	0.12	2.91%	1.35%
	Commercial heating	0.08	0.08	0.45%	0.96%
	Residential others	0.08	0.08	0.43%	0.91%

Source: Stantec (2010)

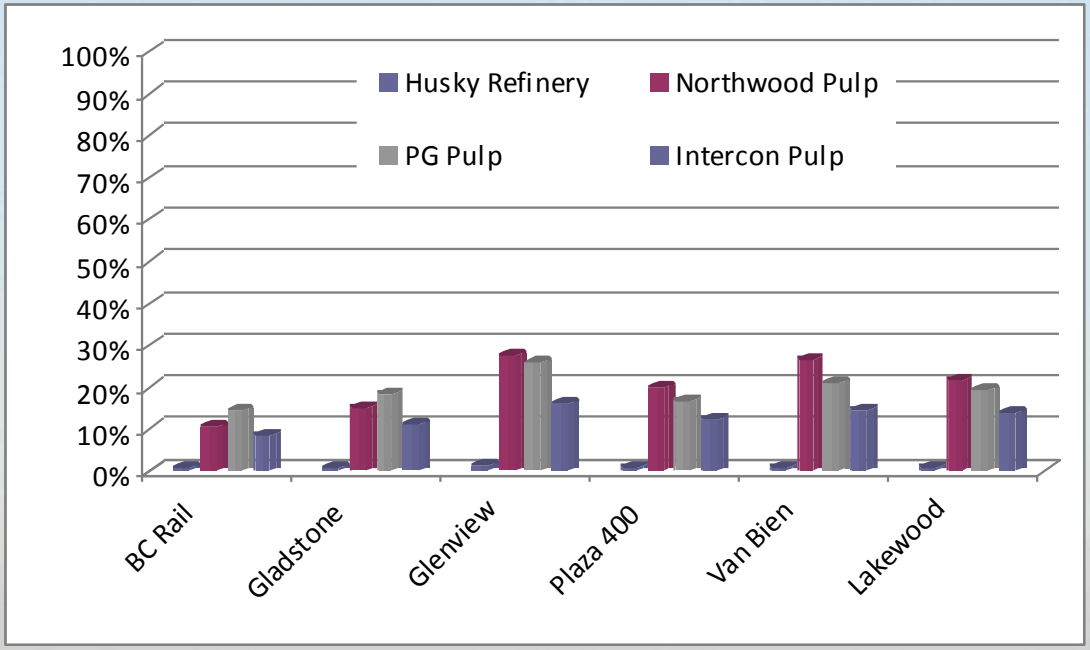
Monitoring Site Receptor Results

Top 10 Source Emitting Unit Ranked Contributions to $PM_{2.5}$ at Plaza Site dominated by line and area sources



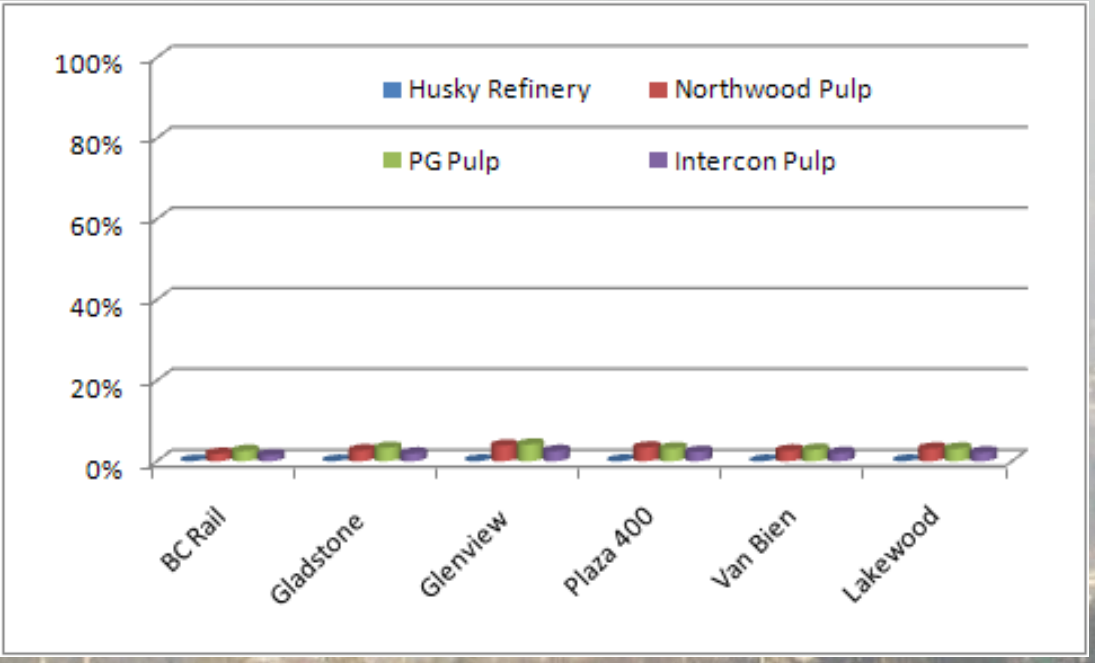
Source: Stantec (2010)

Monitoring Site Receptor Results



Pulp & Refinery $PM_{2.5}$ Contributions as a % of Permitted Users* (2003-2005)

* 4 of 33



Pulp & Refinery $PM_{2.5}$ Contributions as a % all source Categories (2005)

Source: Stantec (2010)

Comparison between STI source apportionment of $PM_{2.5}$ and Calpuff dispersion modelling for Plaza 2005

STI categories	CMB STI (2008)	PMF STI (2008)	Calpuff Stantec (2010)	Stantec Categories
Pulp Mill	25 %	24%	21%	Permitted
Burning	26%	18%	25%	Restaurants Res. Heating Open Burning Res. Other
Carbon (HDDV, LDGV, OC)	24%	22%	22%	Locomotives, On-road mobile, Com. heating
Soil	5%	10%	30%	On-road dust Com. dust Background
Other	20%	26%	2%	Com. misc.

Calpuff Summary

- The predicted PM_{10} and to a lesser extent, $PM_{2.5}$ concentrations are heavily influenced by dust emission sources, especially on-road vehicles.
- For downtown, the predicted concentrations attributed to restaurants ranked higher than expected – Dennis Fudge has been re-evaluating the emission inventory (emissions could be two-times too large) and dispersion model settings (results mostly neutral so far).
- Permitted users emissions do not appear to dominate the predicted PM_{10} and $PM_{2.5}$ concentrations except near the facilities
  - However the model is under-predicting ambient levels at Plaza when winds are from the east, so there may be a bias
  - These conclusions may differ had *fugitive dust* emissions from industrial yards and storage piles been included in the dispersion modelling.
  - As well, *condensable PM* emissions were ignored, perhaps leading to an under prediction in permitted users emissions and secondary particulate matter formation.

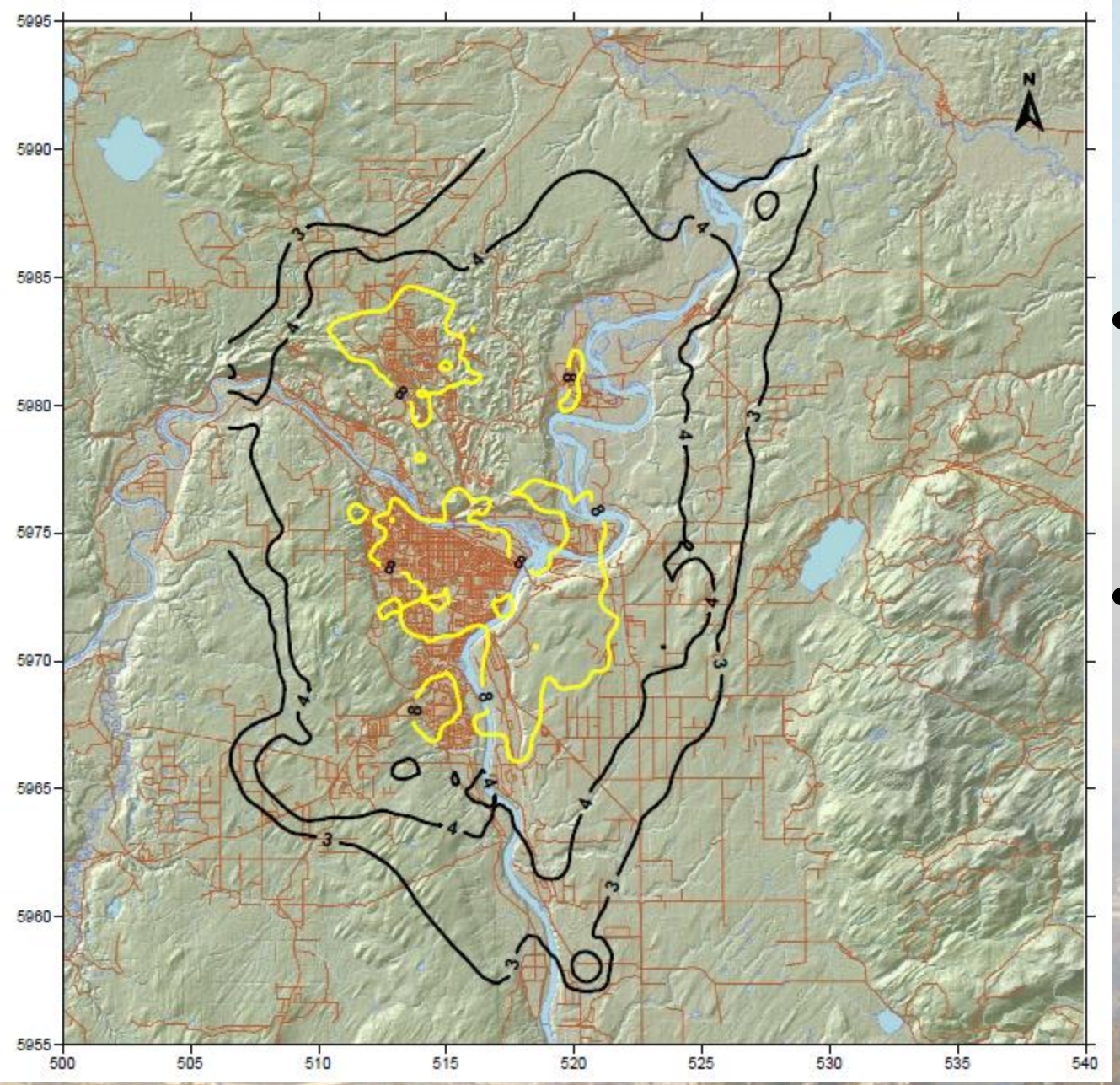
What does it all mean?

- The results are the best information to-date to guide AQ Management decision making
- No model or method is perfect
- The current results with interpretations and adjustments can be a basis for ranking sources for reductions
- Restaurant emissions and area sources (e.g. dust, fugitive dust, road dust), as well as secondary particulates and background levels need to be examined more closely moving forward

Immediate Research Needs and Plans

- Clarify area sources, especially restaurant emissions
  - underway with D. Fudge conducting preliminary investigations, also a BC CLEAR application for funding has been submitted
- Make the model results easily available so that emission reduction scenarios can be tested
  - STANTEC did some scenarios in STANTEC (2010), also a BC CLEAR application has been submitted to develop a web-based graphical tool to query the model result database

Questions?



- PM2.5 2005 annual average
- 8 µg m^{-3} is the BC AAQO

Source: Stantec (2010)