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Air Dispersion Modeling Basics for EHS Managers

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Agenda

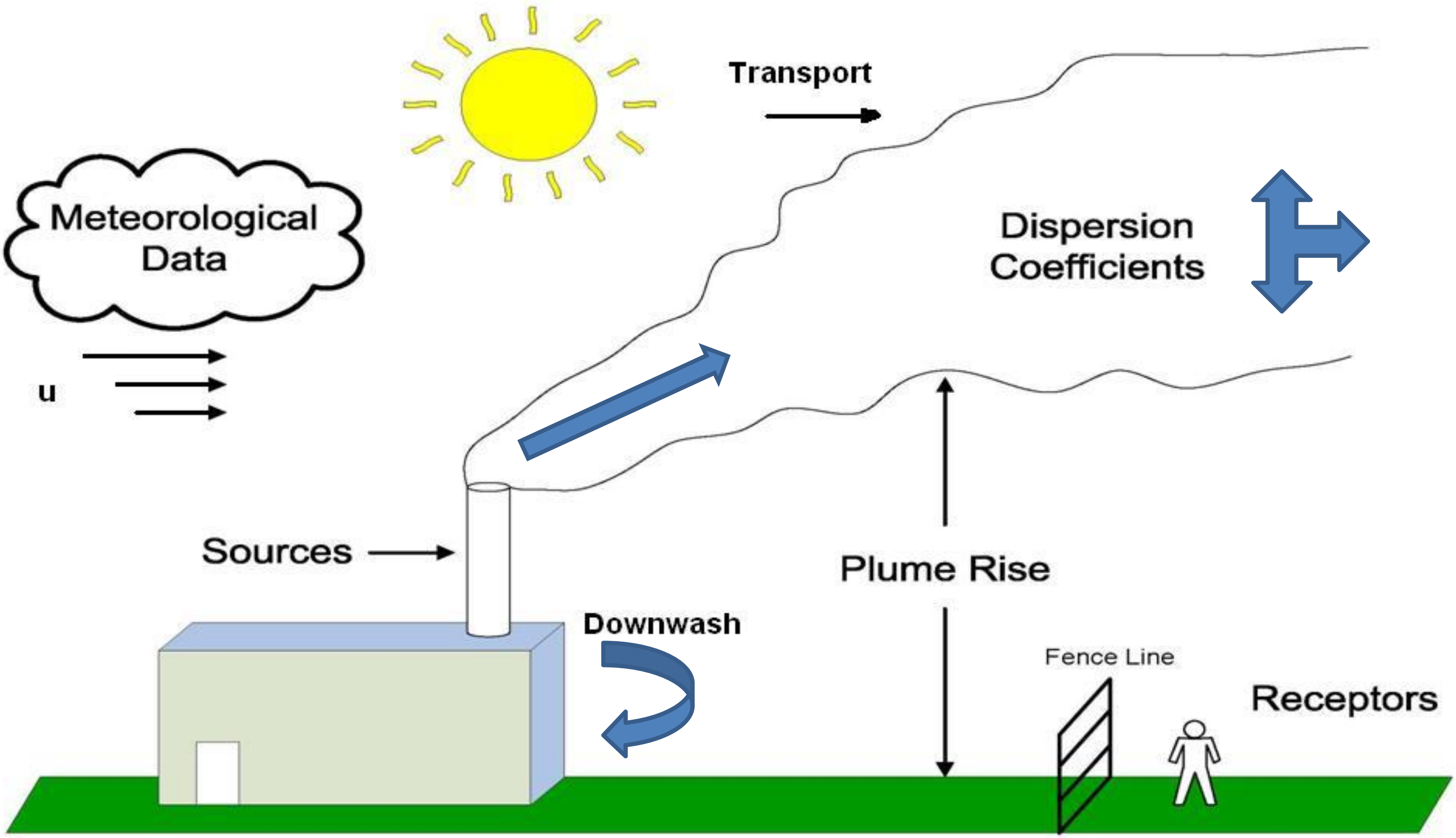
- What is Modeling?
- When are Models Needed?
- Modeling Basics
- Modeling Considerations and Tips

What is Modeling?

Modeling - a definition

Modeling is the combined mathematical simulation of atmospheric processes which gives a convenient and physically meaningful way of relating sources/emissions to ambient air impacts.

Visual Orientation of Modeling



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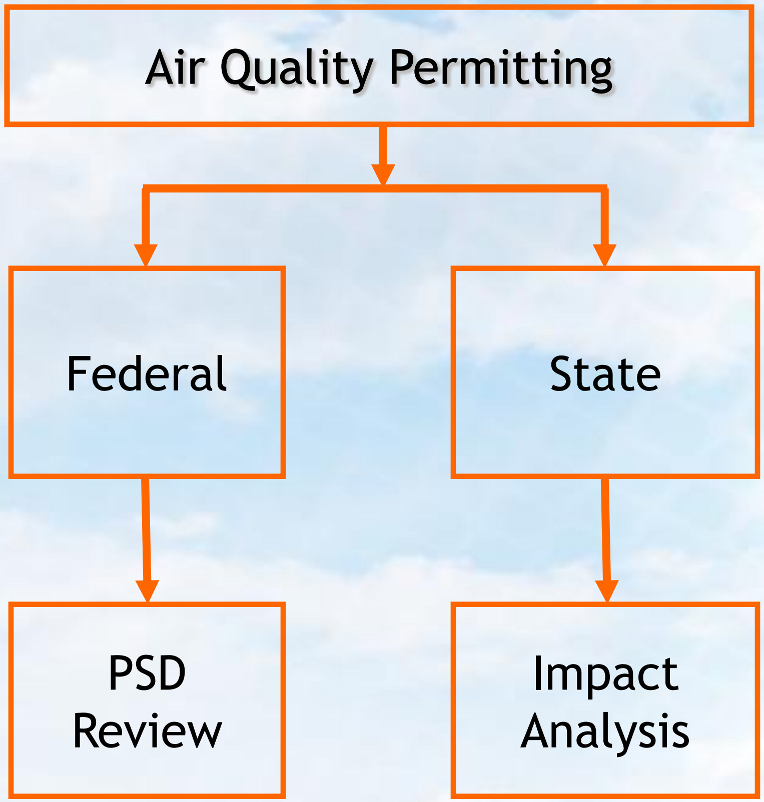
When are Models Needed?

- **Regulatory** - to determine air quality impacts due to existing, new, or modified sources of air emissions to determine compliance with existing air quality standards
- **Engineering** – to discern viable control and mitigation options in terms of the net change in air quality
- **Health** – to estimate risk and acute effects
- **Ecological** – to calculate effects on soils & vegetation
- **Litigation** – to determine who is contributing what

When is Modeling Required for Regulatory Purposes?



** For projects that do not trigger a Federal review, modeling for criteria pollutants (NAAQS) may be requested by State or County agency*

Main Parts of a PSD Application Requiring Dispersion Modeling

1. Control Technology Review (BACT)
2. Air Quality Analysis – Class II Areas
   - SIL
   - NAAQS
   - PSD increments
3. Additional Impacts Analysis
   - Visibility
   - Soils & vegetation
   - Visibility in Class I
   - Growth
4. Class I Area Analysis
5. Additional assessments may be required:
   - Endangered Species Act
   - Coastal Zone Management Act
   - National Historic Preservation Act
   - Magnuson-Stevens Fishery Conservation and Management Act

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Class II PSD Modeling Steps

- Step 1 – Significance Analysis
  - Significance Analysis – Determining if new project has a "significant impact"
  - PSD SIL – Significant Impact Levels
- Step 2 – NAAQS and Increment Analysis
  - If the Step 1 impacts (the impacts of the project only) are over the SILS, proceed to Step 2, a full review of compliance with the NAAQS and Increments, include regional sources.
    - Use Significant Impact Area (SIA) (or Radius of Influence (ROI)) from Significance Analysis to determine the inventory of sources to include
      - SIA = Maximum distance at which the pollutant exceeds the SIL (Note, there can be a different ROI for each pollutant)

  *If the Step 1 impacts are under the SILs, no additional modeling is required.

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NAAQS Modeling

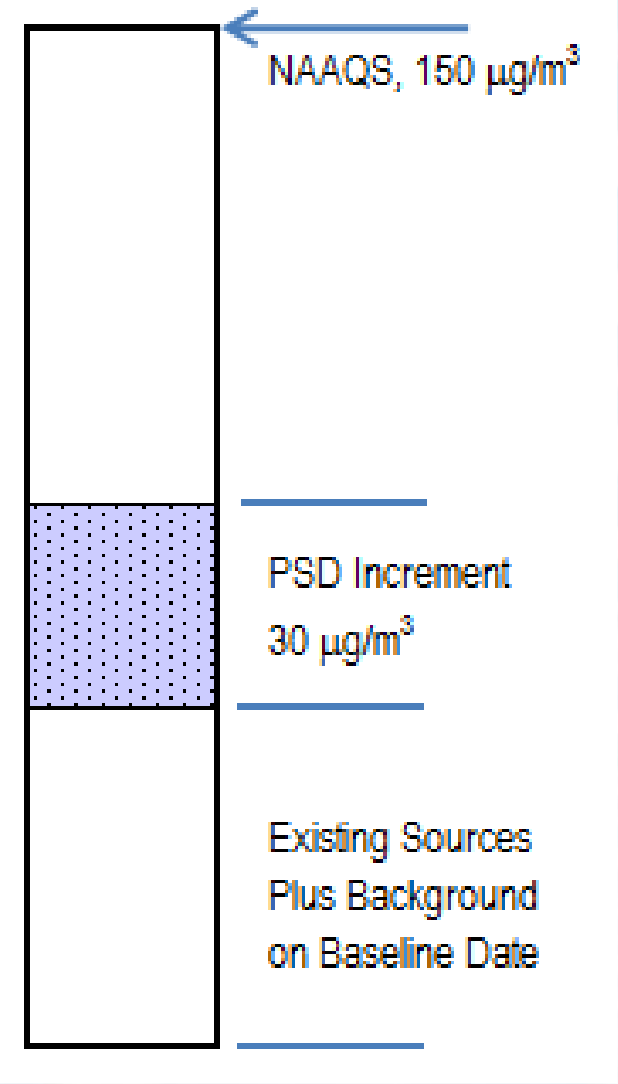
- NAAQS Modeling
  - Model all sources at your facility as they will exist after project
  - Model regional inventory sources
  - Add a background concentration
    - Obtained from nearby monitors
  - Compare to the NAAQS

Increment Modeling

- Increment Modeling (SO_2, NO_2, PM_{10}, $PM_{2.5}$)
  - Model increment-affecting sources at your facility as will exist after project
  - Model increment affecting regional inventory sources
  - Increment-affecting
    - (+) Actual emissions increases from major sources after major source baseline date
    - (+) Actual emissions from minor sources after minor source baseline date
    - (-) Actual emissions from units shut down (or reduced) that were in existence prior to the baseline date
  - Compare to the Increment

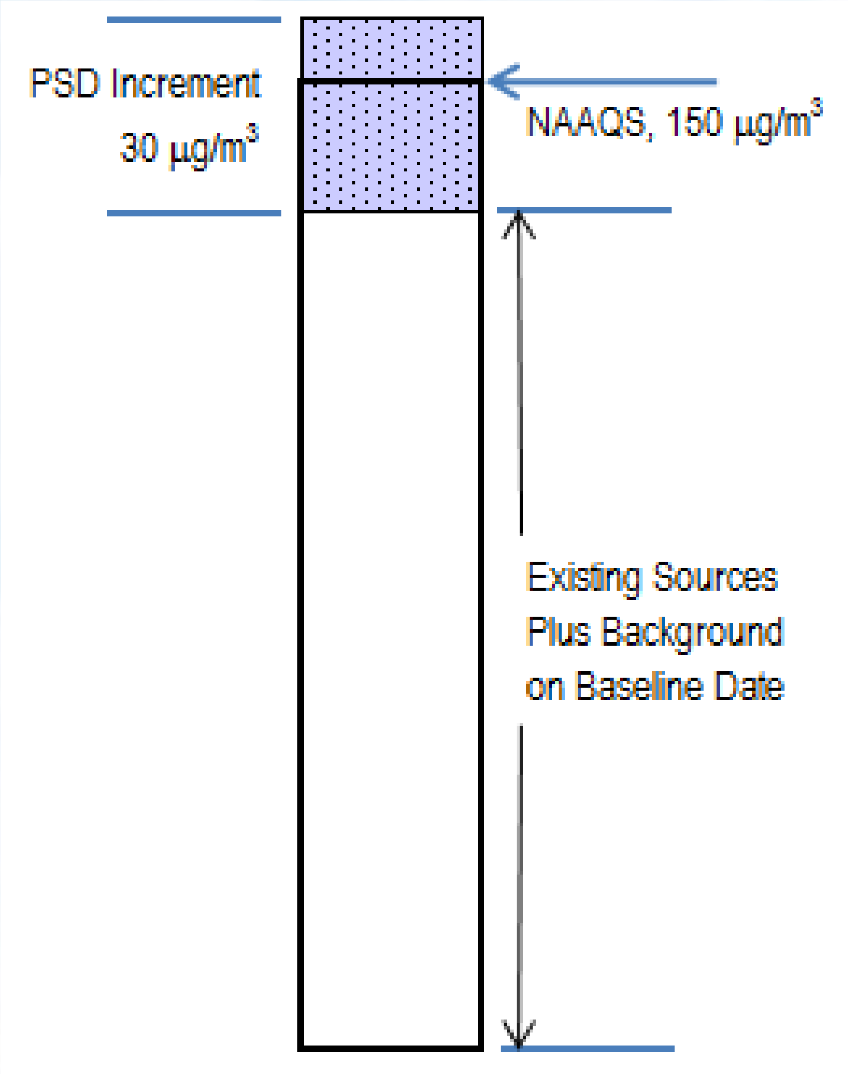
Case 1: PSD Increment Limited Area

PM_{10} 24-hour NAAQS



Case 2: NAAQS Limited Area

PM_{10} 24-hour NAAQS



Regulatory Standards

PSD Significant Emission Rates (SERs), Significant Monitoring Concentrations (SMCs), Significant Impact Levels (SILs),
PSD Increments and National Ambient Air Quality Standards (NAAQS) – Page 1 of 2

Pollutant	Averaging Period	PSD Significant Emission Rates (SERs)[a] (tons/year)	Significant Monitoring Concentrations (SMCs) ($\mu g/m^3$)	Significant Impact Levels (SILs) ($\mu g/m^3$)	PSD Increments ($\mu g/m^3$) Class		National Ambient Air Quality Standards (NAAQS)[b]				
							Primary		Secondary		Form (i.e., How Standard is Applied)
					I	II	($\mu g/m^3$)	(ppm)	($\mu g/m^3$)	(ppm)	
PM_{10}	Annual	15[c]	--	1	4	17	~~50[d]~~	~~--[d]~~	~~50[d]~~	~~--[d]~~	~~Annual arithmetic mean, averaged over 3 years[d]~~
	24-hour		10	5	8	30	150	--	150	--	Not to be exceeded more than once per year on average over 3 years
$PM_{2.5}$	Annual	10 of $PM_{2.5}$ 40 of SO_2 40 of NO_X[e]	--	~~0.3[f]~~	1	4	12	--	15	--	Annual arithmetic mean from single or multiple monitors, averaged over 3 years
	24-hour		0[f]	~~1.2[f]~~	2	9	35	--	35	--	98th percentile of concentrations in a given year, averaged over 3 years
SO_2[g]	Annual	40	--	1	2	20	~~(80)~~	~~0.03~~	--	--	~~Annual arithmetic mean~~
	24-hour		13	5	5	91	~~(365)~~	~~0.14~~	--	--	~~Not to be exceeded more than once per calendar year~~
	3-hour		--	25	25	512	--	--	(1,300)	0.5	Not to be exceeded more than once per calendar year
	1-hour		--[h]	--[h]	--[h]	--[h]	(196)	0.075	--	--	3-year average of the 99th percentile of the annual distribution of daily maximum 1-hour concentrations
NO_2	Annual	40 of NO_X	14	1	2.5	25	(100)	0.053	(100)	0.053	Annual arithmetic mean
	1-hour		--[h]	--[h]	--[h]	--[h]	(188)	0.1	--	--	3-year average of the 98th percentile of the annual distribution of daily maximum 1-hour concentrations
Ozone[i]	8-hour	40 of VOC or NO_X	VOC or NO_X emissions increase > 100 tpy	--	--	--	(147)	0.075	(147)	0.075	3-year average of annual 4th highest daily maximum 8-hour concentrations
	~~1-hour~~		--	--	--	--	~~(235)~~	~~0.12~~	~~(235)~~	~~0.12~~	~~Not to be exceeded more than 3 times in 3 consecutive yrs.~~
CO	8-hour	100	575	500	--	--	(10,000)	9	--	--	Not to be exceeded more than once per calendar year
	1-hour		--	2,000	--	--	(40,000)	35	--	--	Not to be exceeded more than once per calendar year
Lead[j]	~~Calendar Quarter~~	0.6	--	--	--	--	~~1.5~~	--	~~1.5~~	--	~~Maximum arithmetic mean~~
	Rolling 3-month avg.		0.1	--	--	--	0.15	--	0.15	--	Maximum arithmetic mean

a. Lower SERs apply in certain nonattainment areas for nonattainment new source review. Sources within 10 km of Class I areas can trigger PSD if impacts exceed 1 $\mu g/m^3$ (24-hour average).

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Modeling Requirements for Non-PSD Projects

- Criteria Pollutants
  - A number of states require modeling for non-PSD projects
- Air Toxics
  - Vary by state/local
  - Use modeling versus acute and chronic health risk
  - Derive maximum ground-level pollutant concentrations using screening model; If screening model fails, use refined model

Modeling Triggers for Region 7 States

State	Major (PSD) Construction Permitting[1]	Minor Construction Permitting[2]	Toxics
Kansas	X		
Missouri	X	X	X
Nebraska	X	X	
Iowa	X	X (Refer to Form MD)	

[1]NAAQS and increment modeling is required if project triggers major PSD construction permitting for NO_x, PM_{10}, $PM_{2.5}$, SO_2, CO, VOC, or Pb. In Missouri, this is referred to as a Section 7 permit.

[2]NAAQS and increment modeling is required if project triggers minor construction permitting for NO_x, PM_{10}, $PM_{2.5}$, or SO_2. In Missouri, this is referred to as a Section 6 permit.

Missouri Toxics Modeling

- If trigger a toxics risk analysis under either Section 5, 6, or 7 permitting
  - MDNR maintains a list of toxics where each toxic has an annual Screen Modeling Action Level (SMAL) and one or more risk assessment levels (RALs)
  - If the annual Emission Increase from a physical change or change in the method of operation exceeds the SMAL for a Section 5, 6, 7, or 8 permit, an application for a construction permit must demonstrate that the ambient air impact of the toxic emissions is either
    - Less than 4% of the RAL(s) for the project by itself
    - Less than the RAL(s) when plant-wide potential emissions of the toxic are considered

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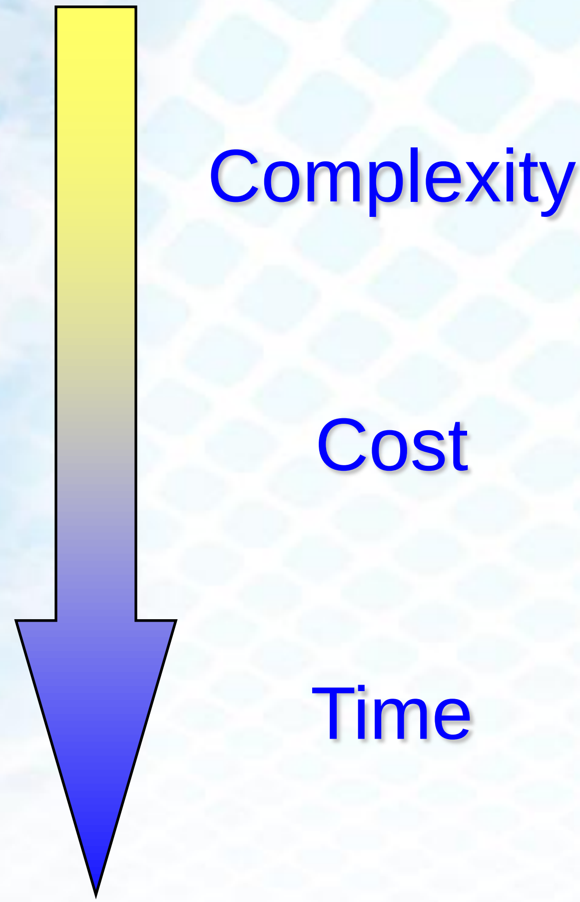
Iowa - Form MD Modeling Determination for Minor Projects

- IDNR Modeling Determination Guidance
  - Emissions increase > equivalent PSD SER on lb/hr basis: requires modeling
  - Emissions increase < equivalent PSD SER on lb/hr basis : stack exempt from modeling provided previous facility-wide modeling results were at least one SIL or more below the NAAQS
  - Note emissions increase can account for project net decreases and can exclude certain types of sources
- Previous requirements related to stack heights and distances from the property line no longer considered for automatic modeling

Hierarchy of Air Models

- Look-up tables/Monitored Values
- AERSCREEN (formerly SCREEN3)
    - Fast, conservative “screening model”
    - Run by regulatory agency/applicant
    - Typically used for small projects
- AERMOD, BLP
    - Short range regulatory model (< 50 km)
    - Run by applicant
- CALPUFF
    - For visibility and long-range impacts
    - Run by applicant
    - Usually for Federal projects only
- CMAQ, CAMx
    - Numerical, regional, photochemistry



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Elements of a Dispersion Model

- Emission sources and characteristics
- Building downwash
- Receptors and terrain
- Meteorology
- Chemical and physical transformations
- Outputs and averaging

Structure of a Dispersion Model

For Each Source

- Physical Height
- Pollutant Emission Rate
- Coordinates
- Stack Diameter
- Stack Gas Velocity
- Stack Gas Temperature
- Building Dimensions Used to Characterize Wake Effects

Meteorology

- Stability
- Wind Direction
- Wind Speed
- Mixing Height
- Ambient Temperature

For Each Receptor

- Coordinates
- Ground level Elevation
- Height Above Ground

Simulation of Atmospheric Physics – The Black Box

Estimates of Air Pollutant Concentrations at Receptors

Adapted from Turner, 1994

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Typical Modeling Procedures

- Develop a scaled site plan, including sources, structures, and property boundary
- Define modeling domain and receptor locations
- Develop emission inventory of all point and fugitive emission sources
- Characterize source types (e.g., point, area, volume)
- Input and analyze building data
- Obtain and process representative meteorological data
- Obtain and process terrain data
- Develop model input files and select processing options
- Run model and analyze results

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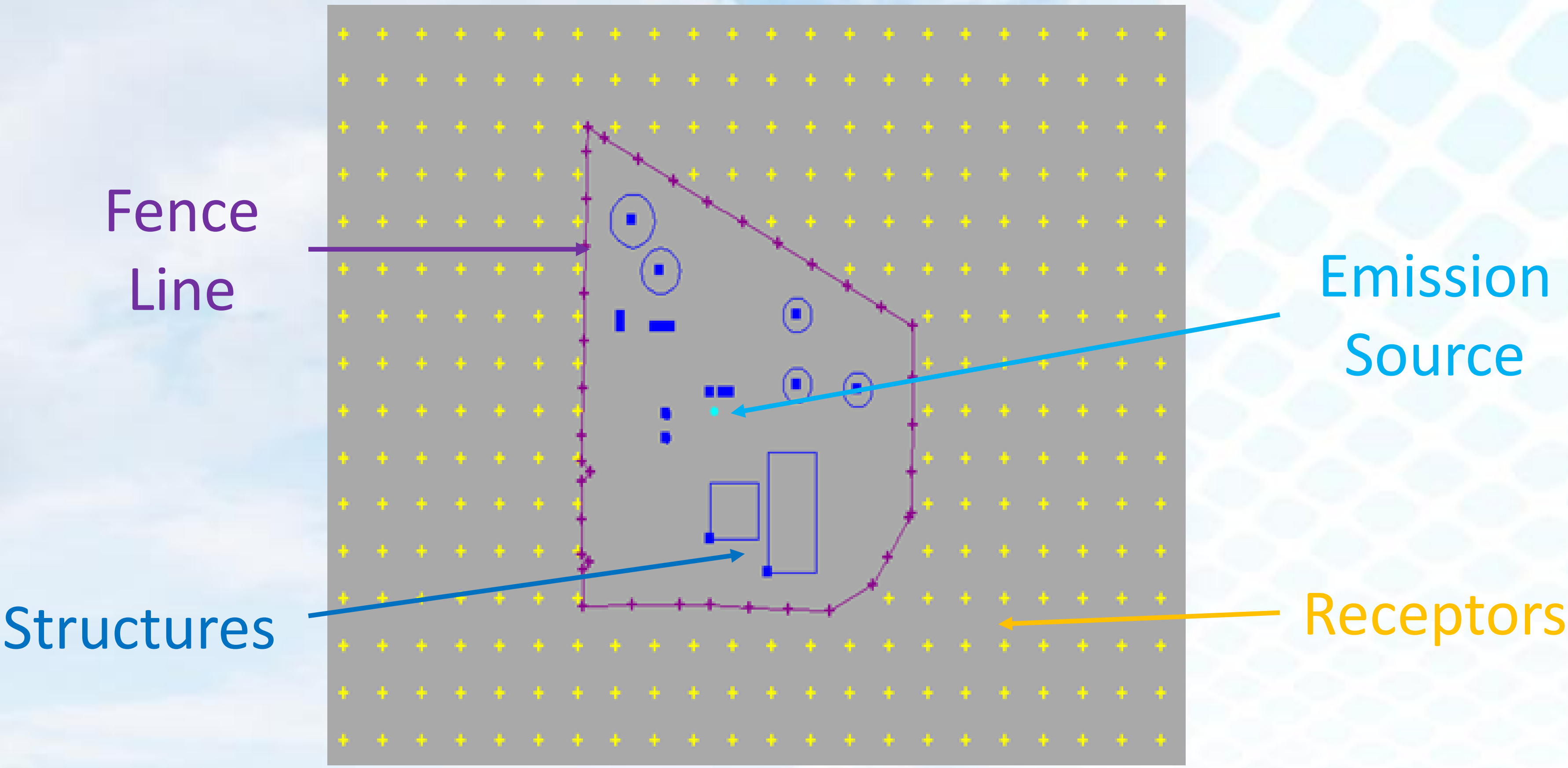
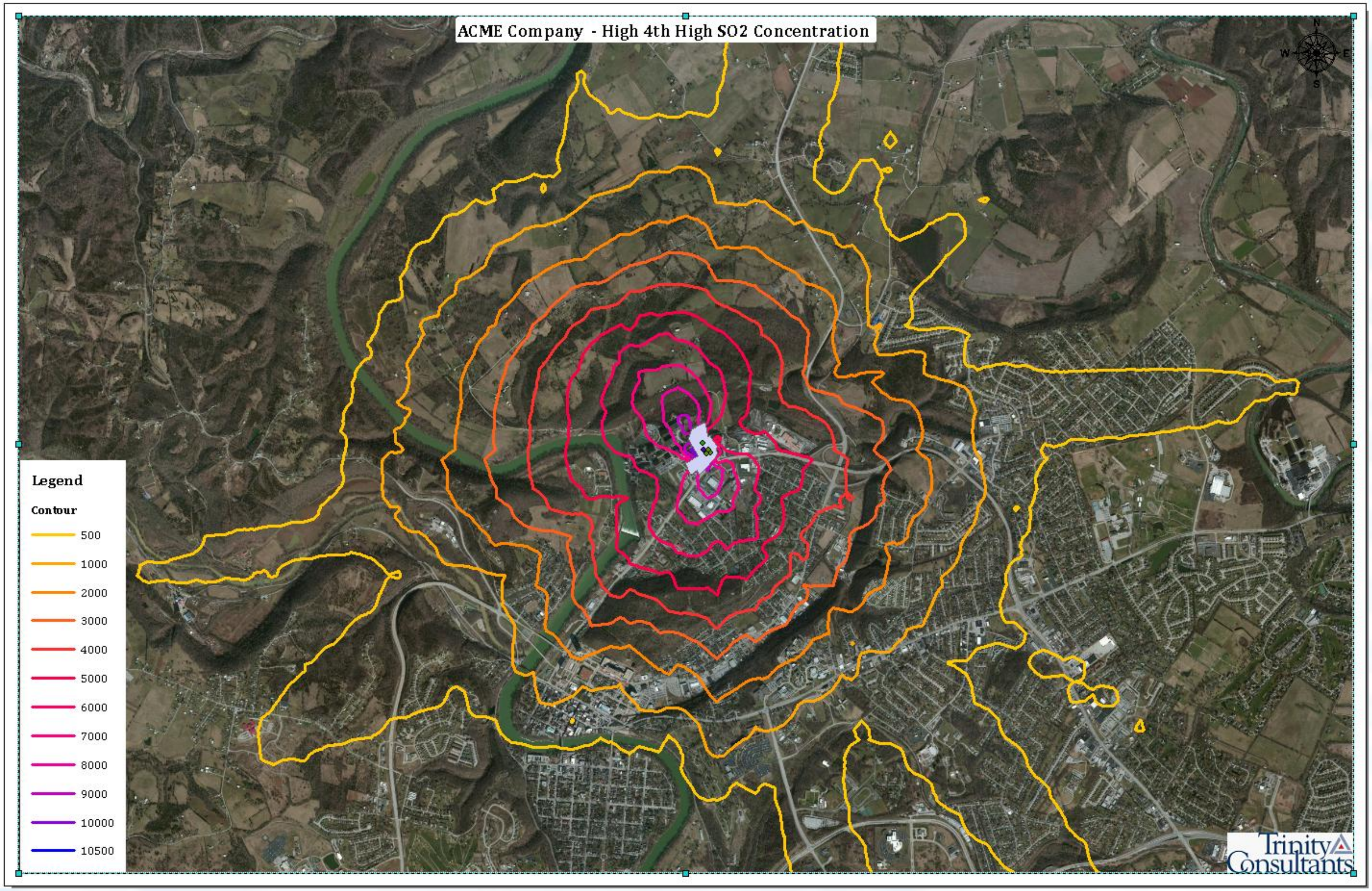
Putting It All Together



Model Output - Isopleths

Model Output - Contours



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Sources of Emissions

- Common dispersion models allow for emissions sources to be represented as…
  - Point sources, area sources, volume sources, line sources
- Characteristics of emissions source dictate which representation is most appropriate
  - **Point** – Emission rate; Inside stack-tip diameter; Exit velocity or flow rate (ACFM); Exit temperature; Height above grade; Horizontal/obstructed release
  - **Area** - Emission rate per area; Coordinates and elevation; Release height above ground; Dimensions, shape, orientation
  - **Volume** - Emission rate; Coordinates and elevation; Release height above ground of volume center; Initial Lateral (s_y) and Initial Vertical dimension (s_z)
- Fugitive sources (roads, piles, transfers) add a layer of complexity
  - Derivation of emissions
    - Number of data inputs
    - Multiple components – e.g., storage pile has emissions from load in/out, vehicle activity, wind erosion
  - Parameters required for modeling
  - Can present compliance challenges
    - Sources are low lying and don't disperse well; Results in local impacts often along fenceline

Emission Quantification: PM_{10} versus $PM_{2.5}$

- Need to know $PM_{2.5}$ emissions better
  - Filterable and condensable
- $PM_{2.5}$ background concentrations very high compared with NAAQS – modeling demonstrations become very complex
- Using PM_{10}=$PM_{2.5}$ is a strategy that is being phased out on multiple levels
  - PM_{10} emission factor can be several orders of magnitude greater in some cases

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Receptors/Ambient Air

- Only concerned with ambient air
  - The portion of the atmosphere, external to buildings, to which the general public has access (40 CFR §50.1(e))
    - November 9, 2018 draft memorandum, “Revised Policy on Exclusions from ‘Ambient Air’” expands the number of measures that may be considered in determining where the “ambient air boundary” is located
      - Draft policy states that it is appropriate to exclude *"the atmosphere over land owned or controlled by the stationary source, where the owner or operator of the source employs measures, which may include physical barriers, that are effective in deterring or precluding access to the land by the general public.“*
- Receptors are typically placed on *grids* and in *discrete* locations
- Objective is to place receptors in such a way as to capture maximum impact on 100-meter spaced grid

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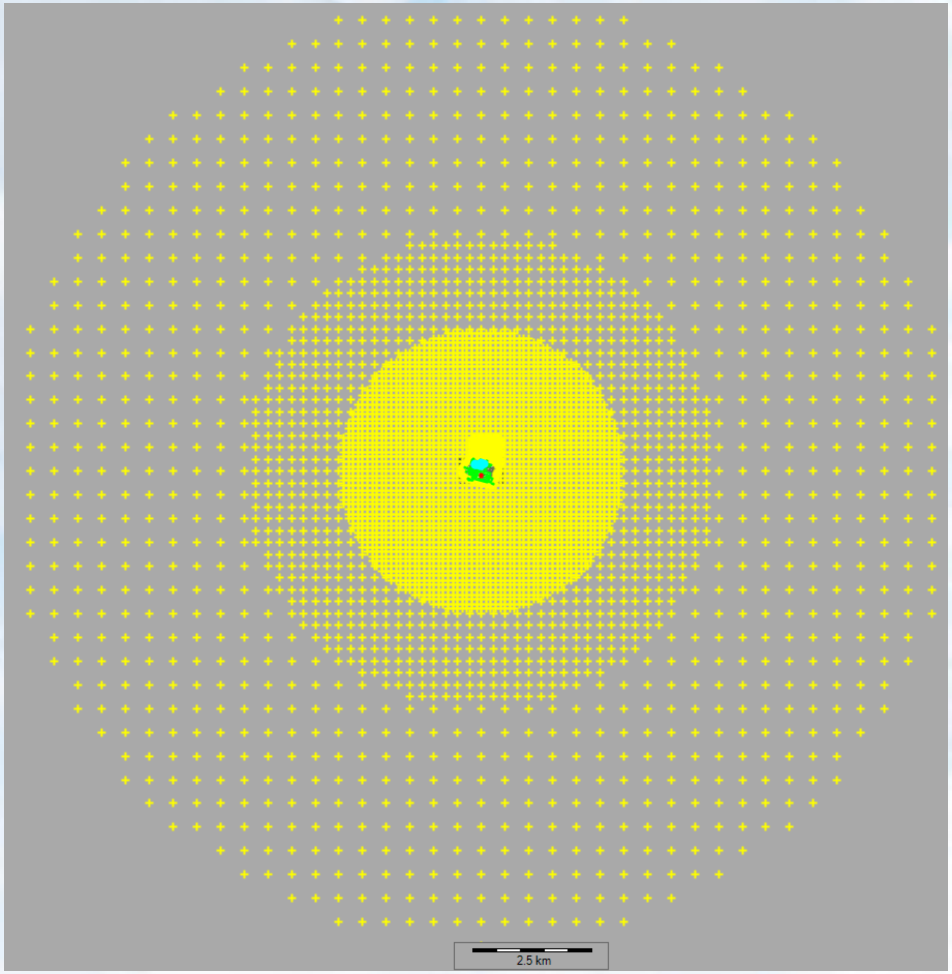
Typical Receptor Grids



Additional Modeling Considerations

- State specific guidance?
- Communication is key
  - Comprehensive understanding of emissions and processes
- Visualization is important
  - Plot, plot, plot

Common Errors

- Compare to correct standards?
- Incorrect stack and building locations
- Unit errors (mass, time distance, speed, energy…..)
- Coordinate system errors
- Incorrect receptor placement
  - Fenceline vs. property line
  - Need to include any public access – railways, roads
- Units!!! – g/s vs lb/hr vs tpy
- Short term vs. long term emission rates
  - Review emissions summary input calculations
- Incorrect value for comparison
  - HH, 1st high, HSH, 2nd high, H8H, 98th percentile?
- Incorrect or outdated data sets
  - Updates to AERMINUTE, AERMAP, AERMET and AERSURFACE require new data

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Summary

- Modeling is a key piece of permitting to demonstrate project will not adversely impact air quality
- Requirements include significance, NAAQS, Increment, and Class I
- Review model inputs and assumptions
- Visualization and communication

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