Air Dispersion Modeling 101

(aka Modeling for Non-Modelers)

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Clean Air Act Permitting Basics

- The New Source Review (NSR) program requires that major new emission sources do not cause a decline in existing air quality
- Air quality defined by the National Ambient Air Quality Standards (NAAQS)
  - Attainment = Good
  - Non-Attainment = Bad
  - Done on a per-pollutant basis
- NSR is separated into two separate regulatory branches:
  - Prevention of Significant Deterioration (PSD) program for sources in attainment areas
  - Non-Attainment New Source Review (NNSR) program for sources in non-attainment areas
- NNSR permit applicants make this demonstration through showing a net decrease in emissions for that pollutant in the area (Emission Reduction Credits or ERC)
- PSD permit applicants make this demonstration through air dispersion models

Ozone Non-Attainment Areas

Class II Ambient Air Quality Standards (Federal)

Pollutant	Averaging Period	Class II SIL (μg/m³)	SMC (μg/m³)	PSD Class II Increment (μg/m³)	Primary NAAQS (μg/m³)
NO_2	Annual	1	14	25[8]	100[4]
NO_2	1-Hour	7.5[1]	-	-	188[6]
CO	1-Hour	2,000	-	-	40,000[4]
CO	8-Hour	500	575	-	10,000[4]
PM_{10}	Annual	1	-	17[9]	Revoked
PM_{10}	24-Hour	5	10	30[8]	150[3]
$PM_{2.5}$	Annual	0.3 [2]	-	4[8]	12[4]
$PM_{2.5}$	24-Hour	1.2 [2]	- [7]	9[8]	35[5]
SO_2	1-hour	7.8[1]	-	-	196[10]
SO_2	3-hour	25	-	512	1,300

1] EPA interim SIL.
[2] $PM_{2.5}$ Class II SILs for preliminary impact analysis were vacated and remanded on January 22, 2013 by the D.C. Circuit Court. However, the SIL can be used for impact analysis with justification and permitting agency approval.
[3] High-sixth-high over five years of concatenated meteorological data; or alternatively the maximum high-second-high from each individual year for a 5-year dataset.
[4] Annual mean averaged over five years.
[5] 98th percentile averaged over five years.
[6] 98th percentile of maximum daily 1-hr concentration per year, averaged over five years.
[7] $PM_{2.5}$ SMC was vacated and remanded on January 22, 2013 by the D.C. Circuit Court.
[8] Highest of each year's second high over five years of meteorological data.
[9] Highest of each year's first high over five years of meteorological data.
[10] 99th percentile of 1-hour daily maximum concentrations, averaged over 5 years.

AERMOD is the current EPA-approved model for modeling demonstrations

Benefits of Using Models

- Offer an efficient analysis of current/future air quality across a large geographic area
- Allows us to see into the future:
  - Will a proposed source cause violations of air quality standards?
  - How will future regulations help achieve or maintain good air quality?
  - How does changing X influence Y?

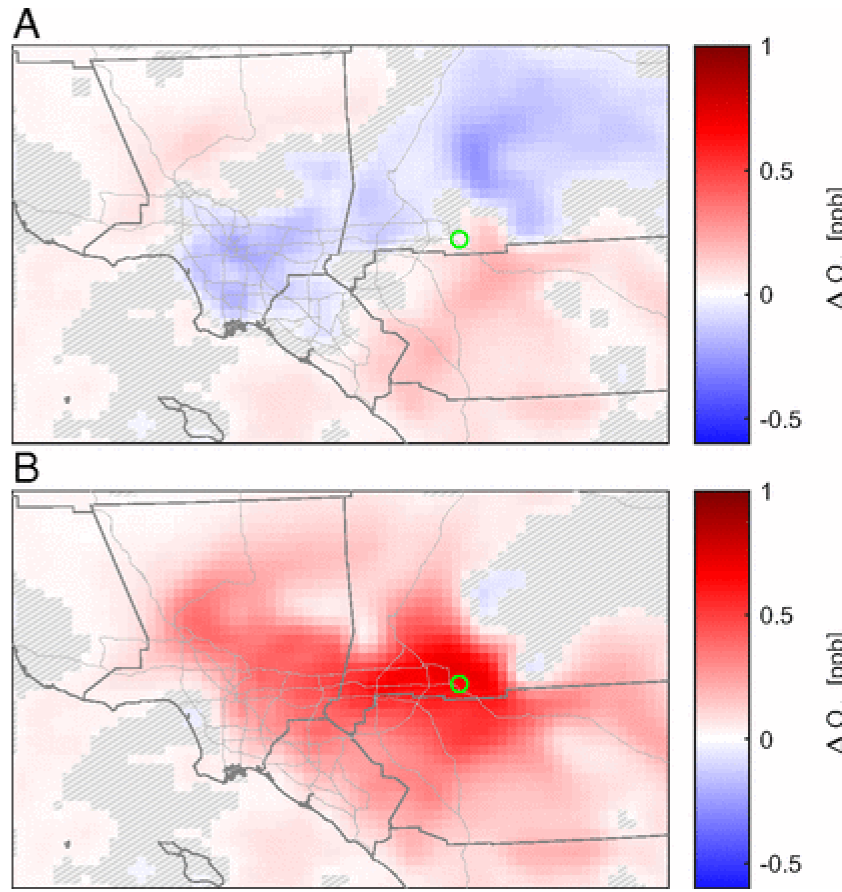
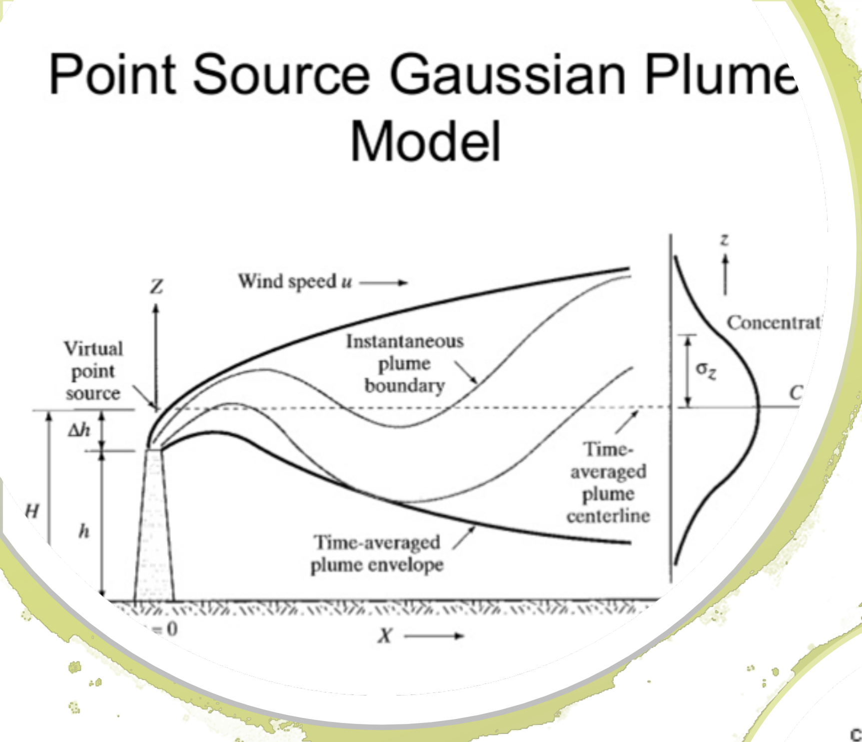


Figure 5 from Air-quality implications of widespread adoption of cool roofs on ozone and particulate matter in southern California (Epstein et al., 2017)

AERMOD Overview

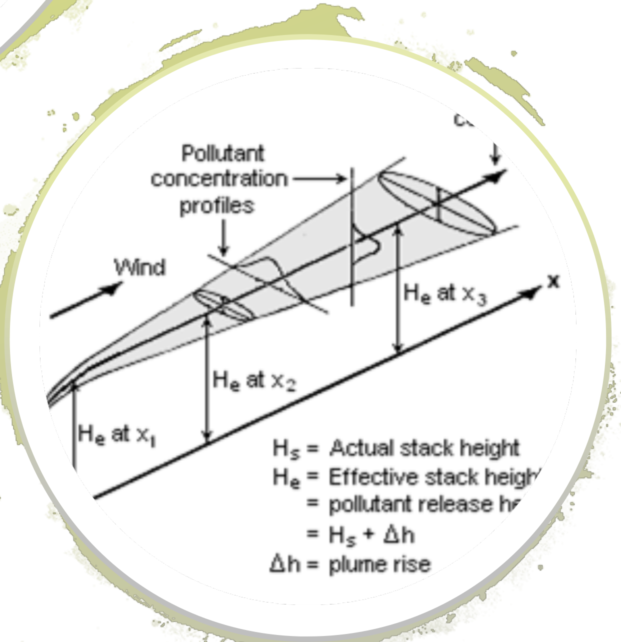
- AERMOD is the EPA-preferred nearfield model
  - Other more advanced models available for long-range transport and chemistry
- Freely available on EPA website
- EPA provides guidance documents on it and related preprocessors
- Regular updates (about once per year) for bug fixes and enhancements
- Requires data for each project site:
  1. Meteorology
  2. Receptors
  3. Local terrain
  4. Buildings and structures dimensions
  5. Emission sources

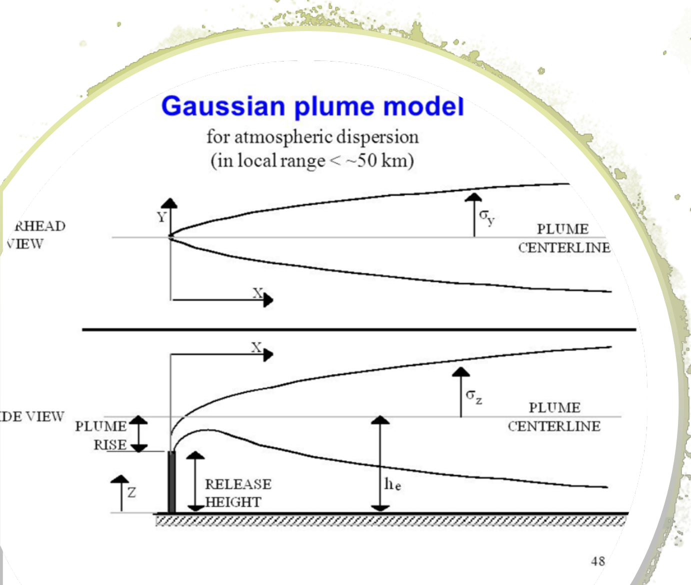


Modeling Theory

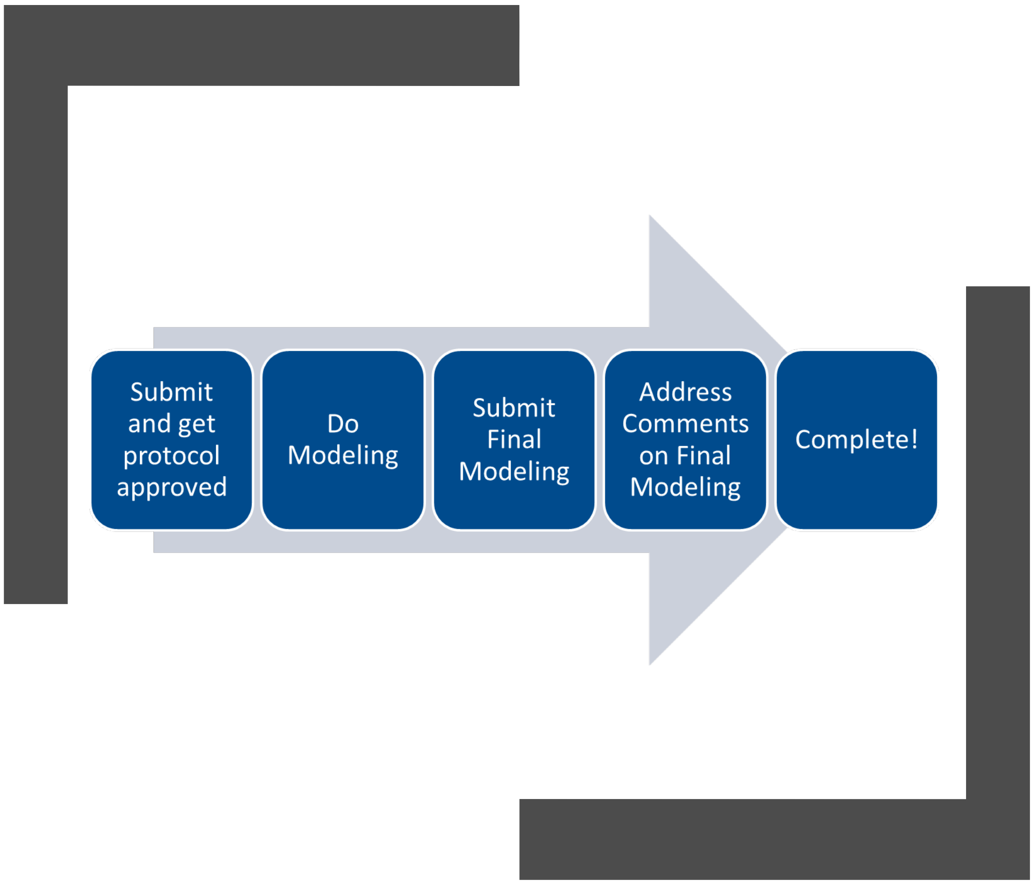
AERMOD uses a Gaussian plume model

- The plume is adjusted for:
  - Wind direction
  - Wind speed
  - Buoyancy
  - Atmospheric stability
  - Downwash effects
  - Surface roughness
  - Other factors





Get the Inputs Right

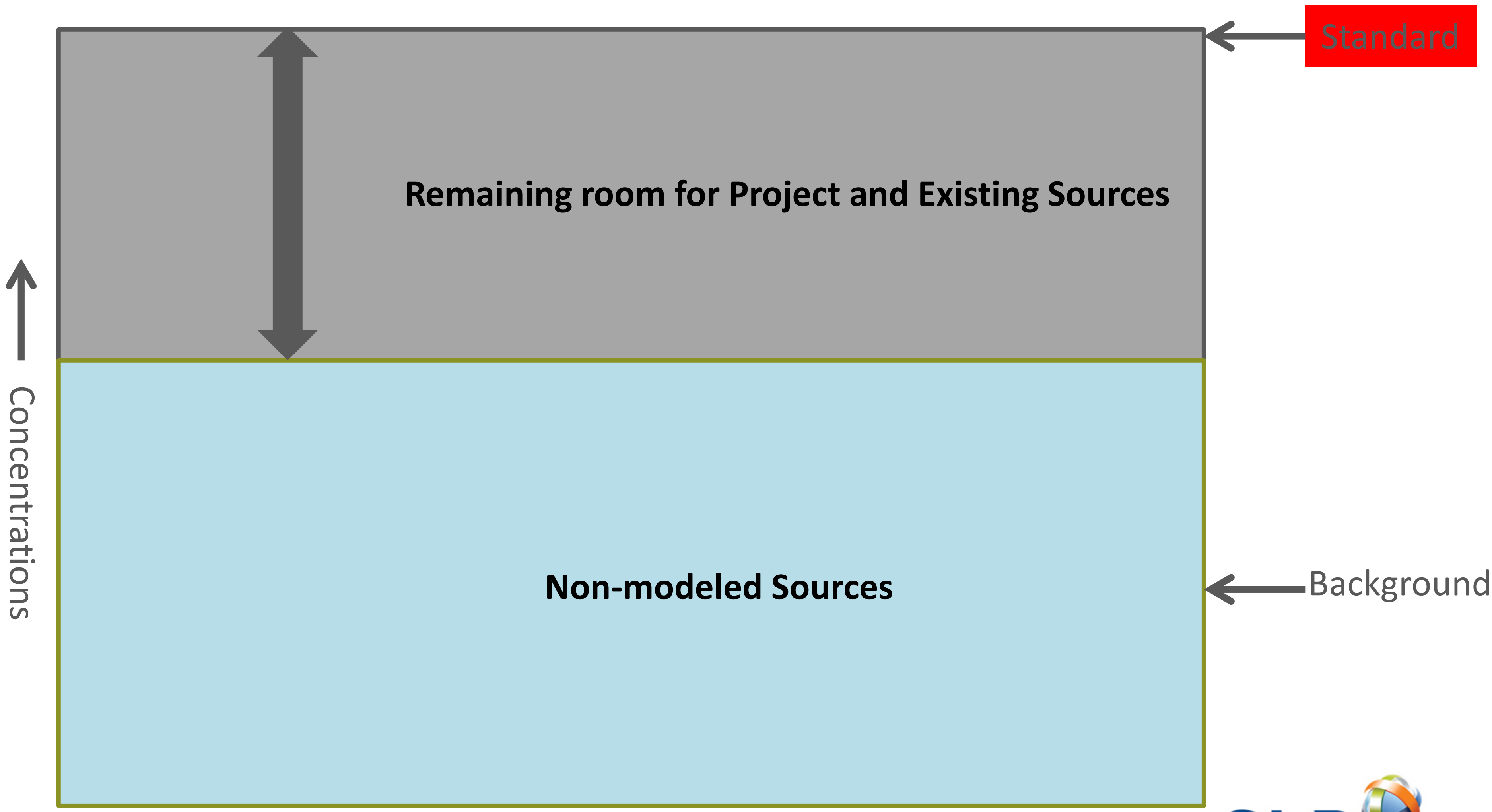


- Models are designed to be protective of human health, so results may be conservative
- A number of assumptions and decisions go into any project, must have a modeling protocol agreed with permit authority
- Refinement of overly-conservative results can be complex and time intensive
- Many decisions and inputs are subjective, so until approved by agency, modeling methodology and results are subject to change

Input 1: Meteorology and Background

- AERMOD requires surface and upper-air met data
  - Onsite measurements (1 year)
  - Airport measurements (5 years)
- Meteorology determines where the plume goes and how much it disperses
- Upper-air stability impacts dispersion and how soon the plume returns to ground-level
- Background concentration data from state monitors or onsite measurement must be included

Background Concentrations



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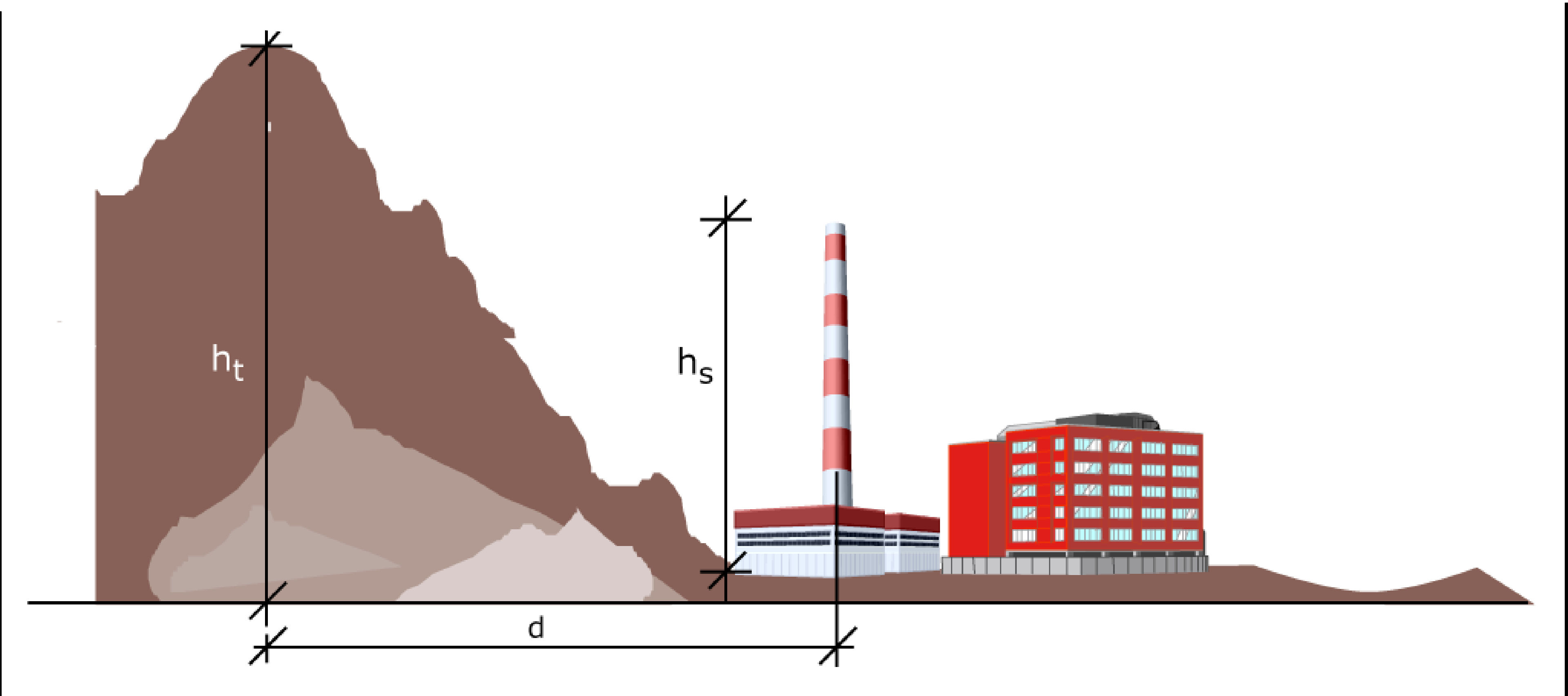
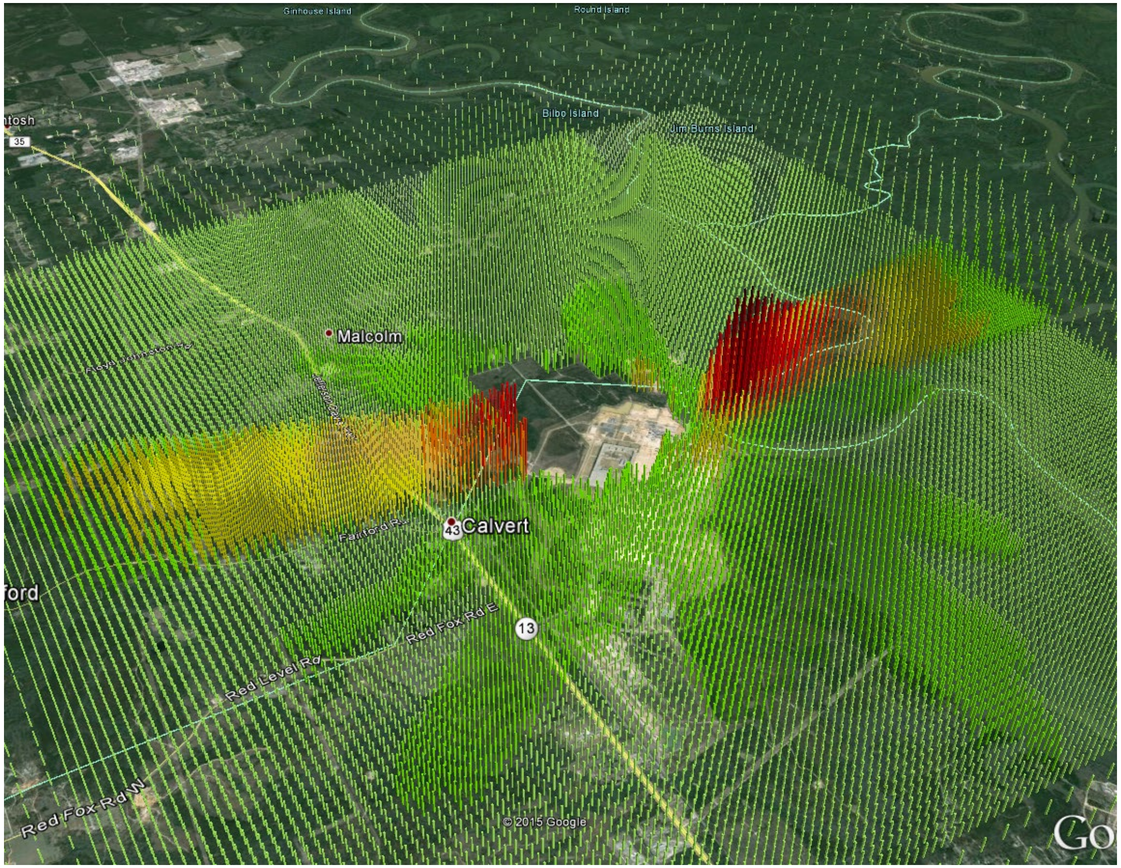
Inputs 2 and 3: Receptors & Terrain

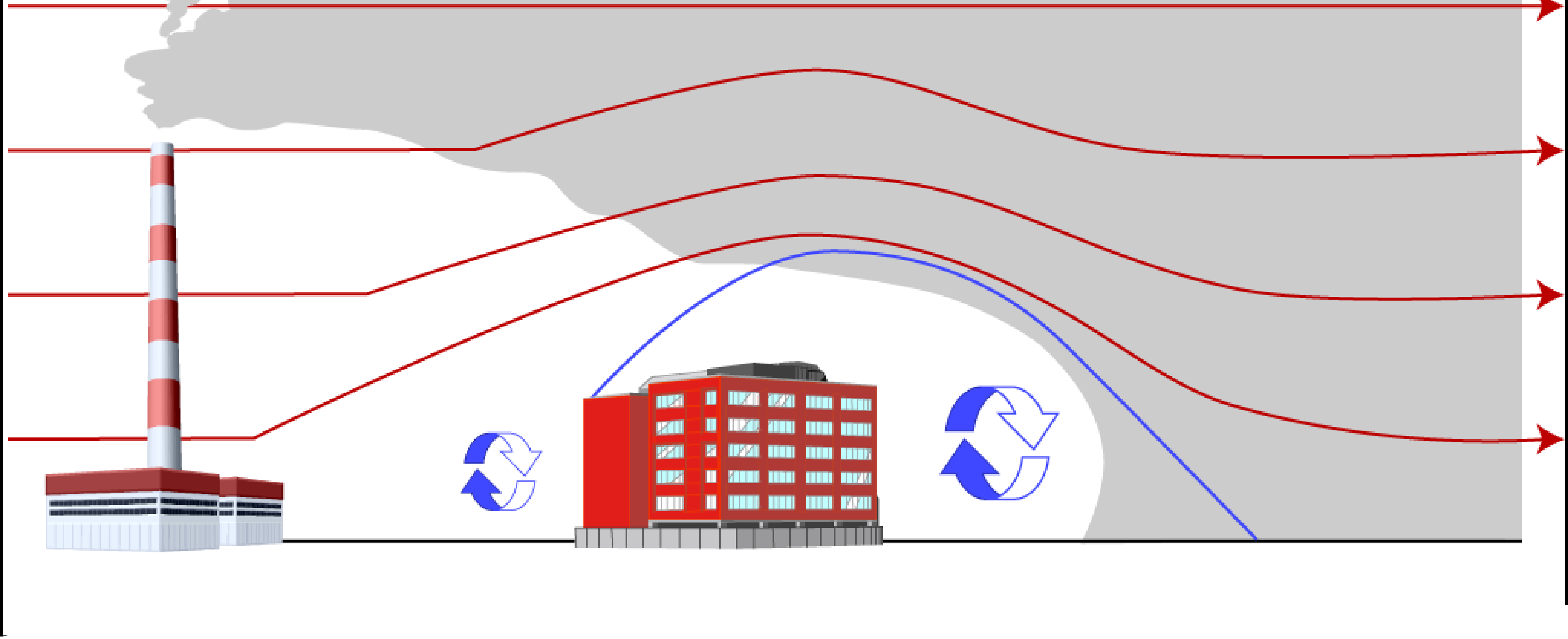
- Receptors have to be placed in “ambient air”
  - Ambient air is anywhere the public can access
  - EPA regulates public air
  - OSHA regulates air quality within facility boundaries
- Usually set at ground level, but may also be “flagpoles” to reflect bridges, etc.
- Plumes can impact high terrain





Receptor Grid

- Receptors are the points where the model calculates impacts
- Tighter spacing between receptors close to the facility
- Outer radius is determined by the *Significant Impact Level (SIL)*
  - Usually set as a percentage of the full standard
  - Model project sources only
- Farthest point showing an impact ≥ SIL sets the *Significant Impact Radius (SIR)*
  - Permit agency will often ask for additional distance beyond the SIR (5 km typical)
- Model the full *Significant Impact Area* (SIA) over the full meteorology set
- Cumulative Modeling: Include off-site sources within the SIA

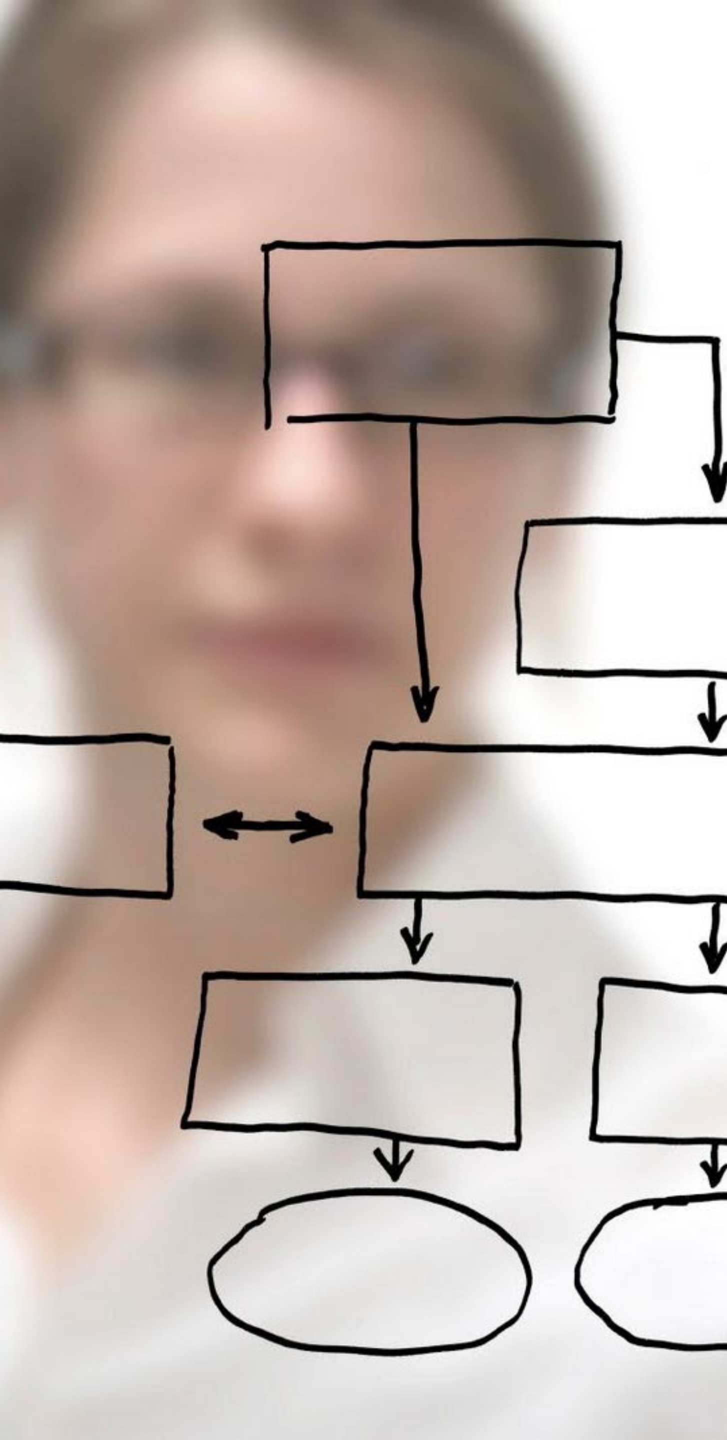


Input 4: Buildings and Structures

- Plume can get captured in complex flow around buildings
- Can greatly increase ground level concentrations near the source
- Buildings taller than two stories should be included
- Structures with a cross-section more than 50% solid should be included
- **This modeling input requires a lot of information from the source being modeled!**

Input 5: Facility Emission Sources

- **AERMOD models both point and fugitive sources**
- **Fugitive source inputs require**
  - Footprint of source (warehouse, shed, pile)
  - Representative release height of emissions
- **Point source inputs require**
  - Stack height
  - Stack exhaust flow (actual)
  - Stack exhaust temperature
  - Stack inside diameter
  - Obstructions or is stack horizontal?
- For cumulative models, must collect and enter all surrounding permitted sources within the SIA
  - Data quality review
  - Increases modeling time



Managing Projects with Modeling

- Modeling cannot show exceedance of applicable standard
- If modeling is needed:
  - Understand applicable modeling guidance
  - Obtain physical data needed from facility (emissions, structures)
  - Obtain model data (meteorology, background, cumulative sources, terrain)
  - Modeling is iterative –many adjustments and runs may be necessary
  - Results of modeling may impact the final project design or operating parameters
  - Confirm agency alignment with expectations in a pre-application meeting
  - Prepare applicant that until the agency reviews and accepts the modeling, part of the analysis may change
  - Have a clear path to favorable modeling before submitting permit application

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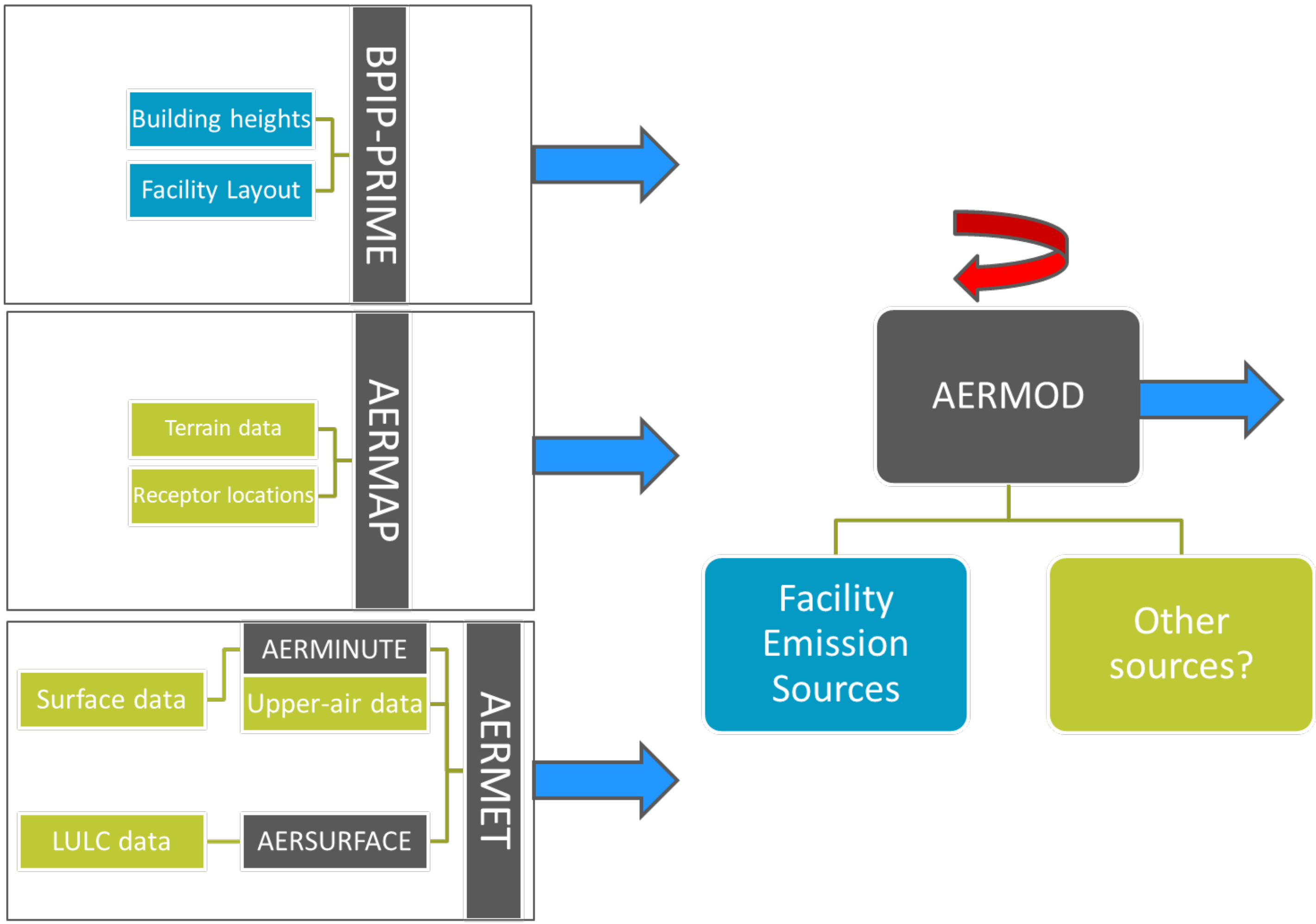
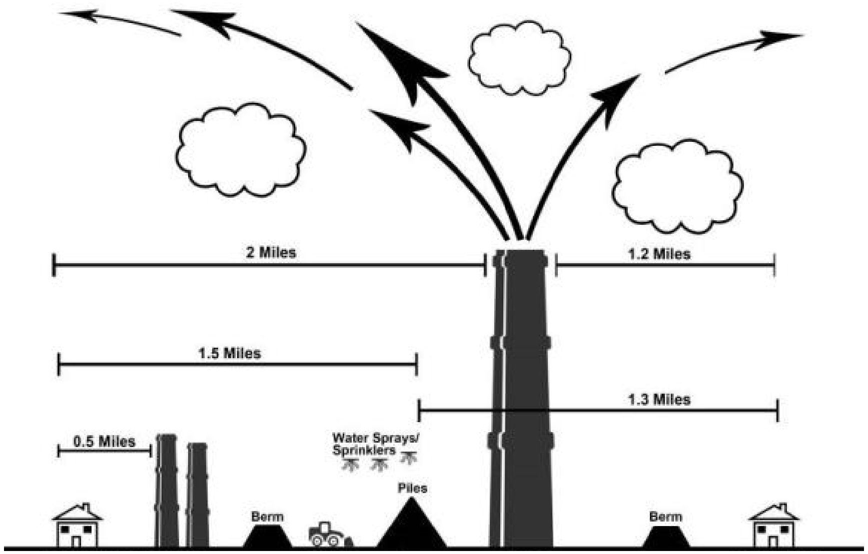
AERMOD Data Elements





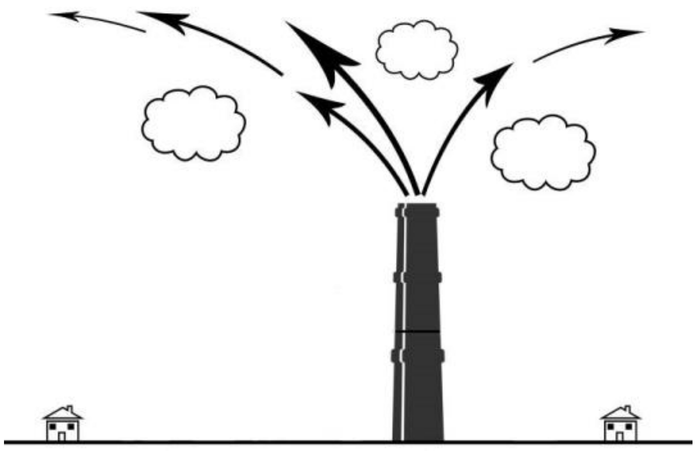
Design Factors for Improved Modeling Results

Stack Parameters and Gas Conditions

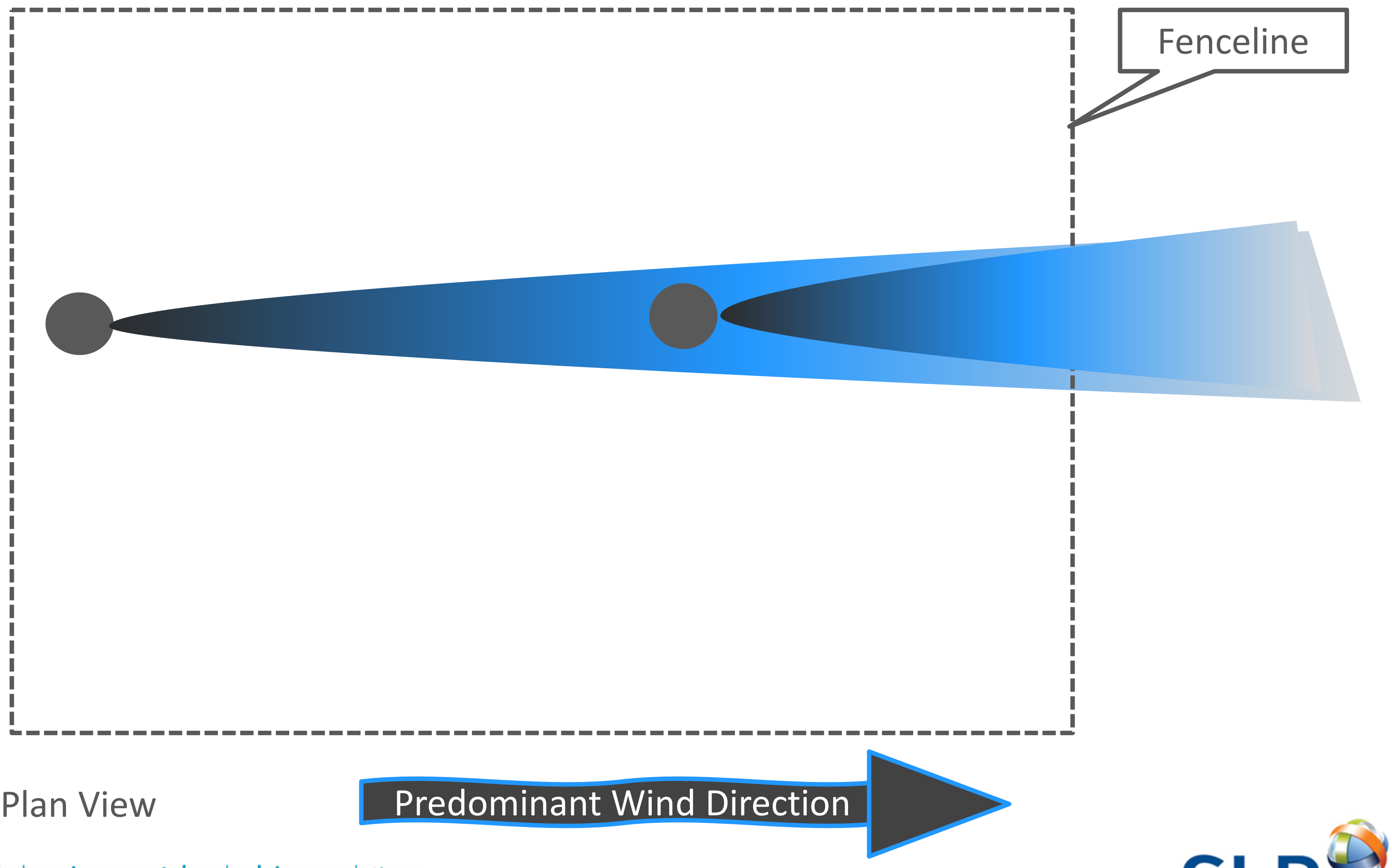
- **Primary Improvement Factors**

Increasing Importance

  - Buoyancy – Higher temp plumes rise higher before sinking back to Earth
  - Exit Velocity – Upward momentum increases dispersion time and distance
  - Diffusion – Spatially separate emissions sources from each other to reduce overlapping impacts
  - Emission Rate – Lowering the hourly mass emission rate of pollutants from the source has a direct impact on modeled results
  - Stack Height – Creates a greater dispersion distance before returning to Earth, geometric influence on modeled results

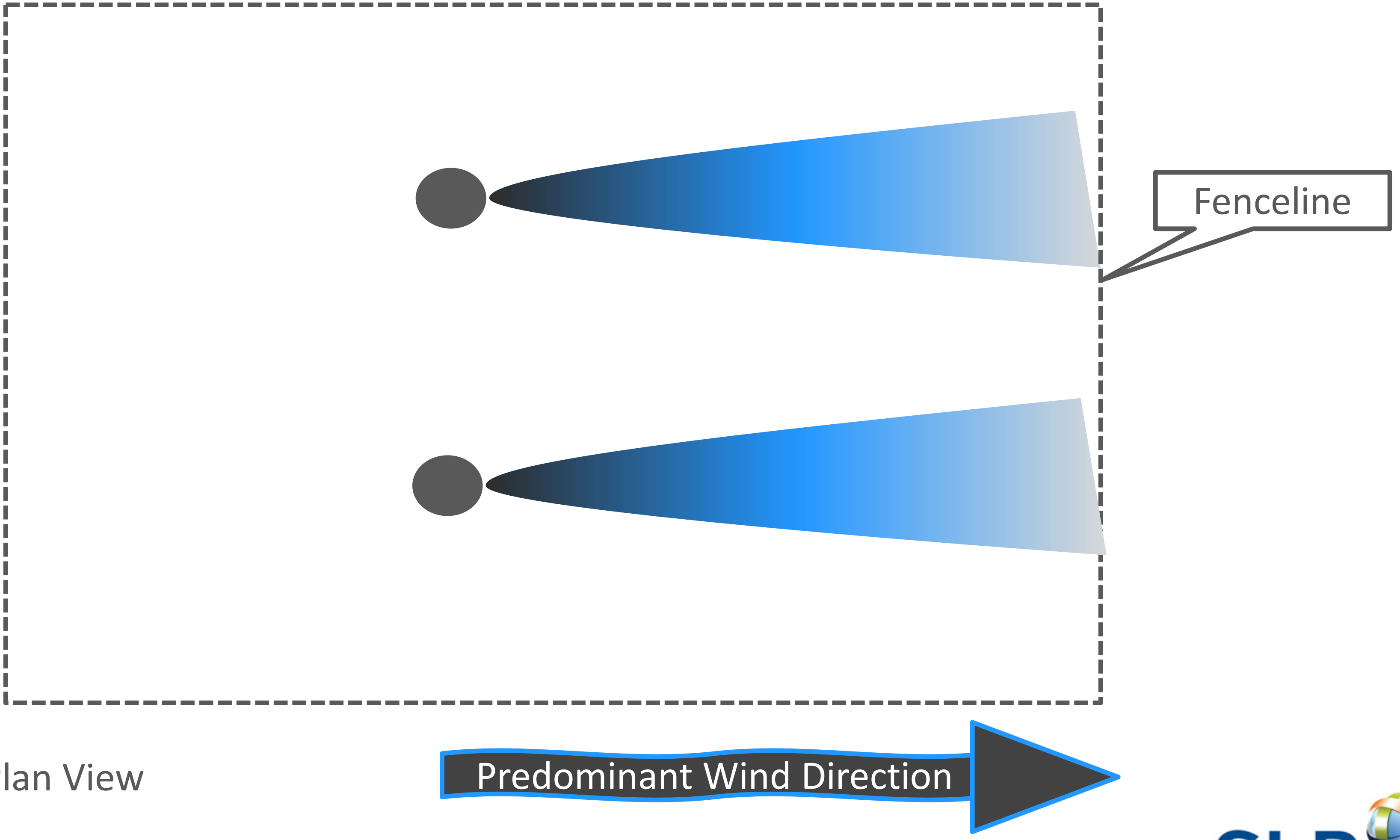


Diffusion Simplified

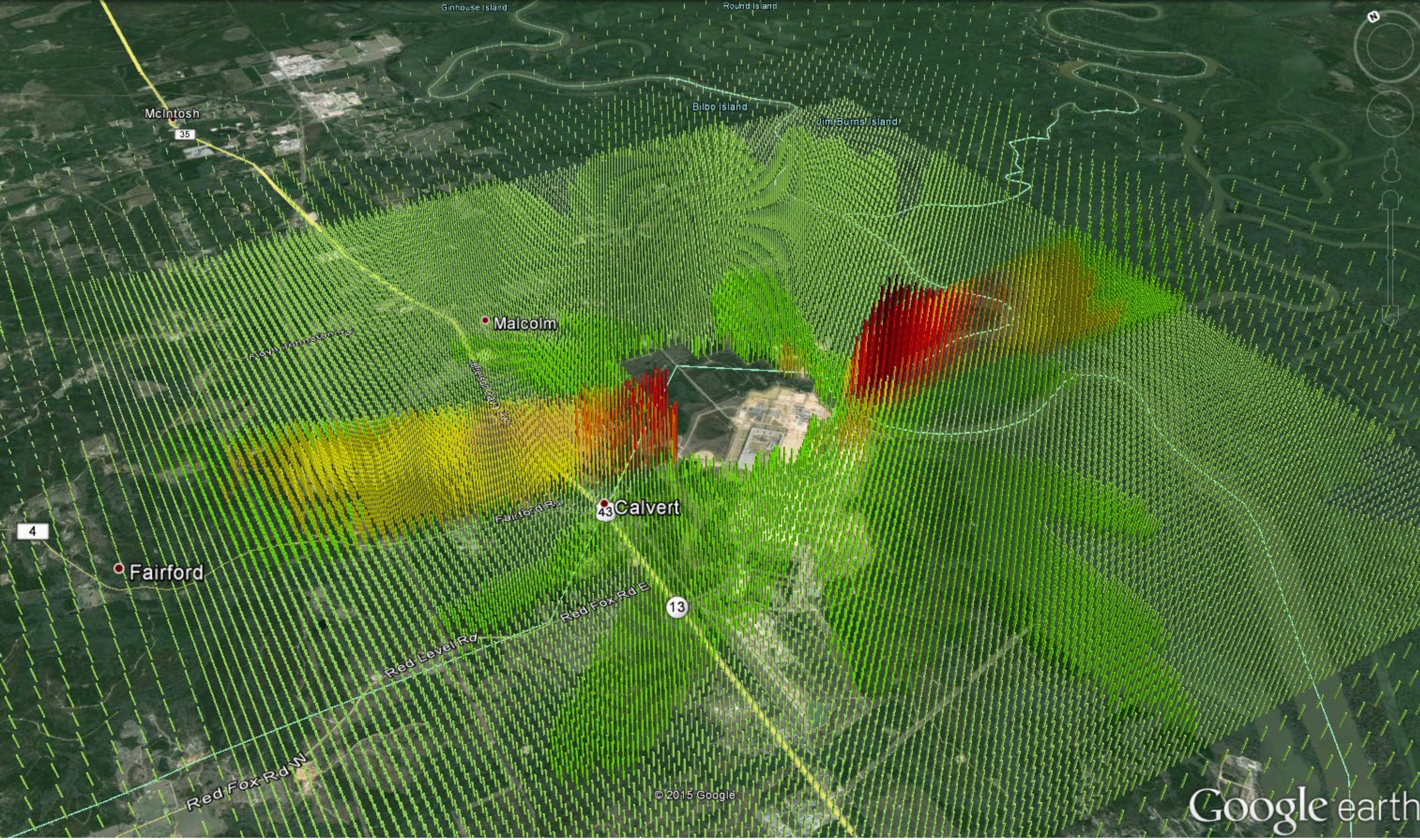


Plan View

Diffusion Simplified



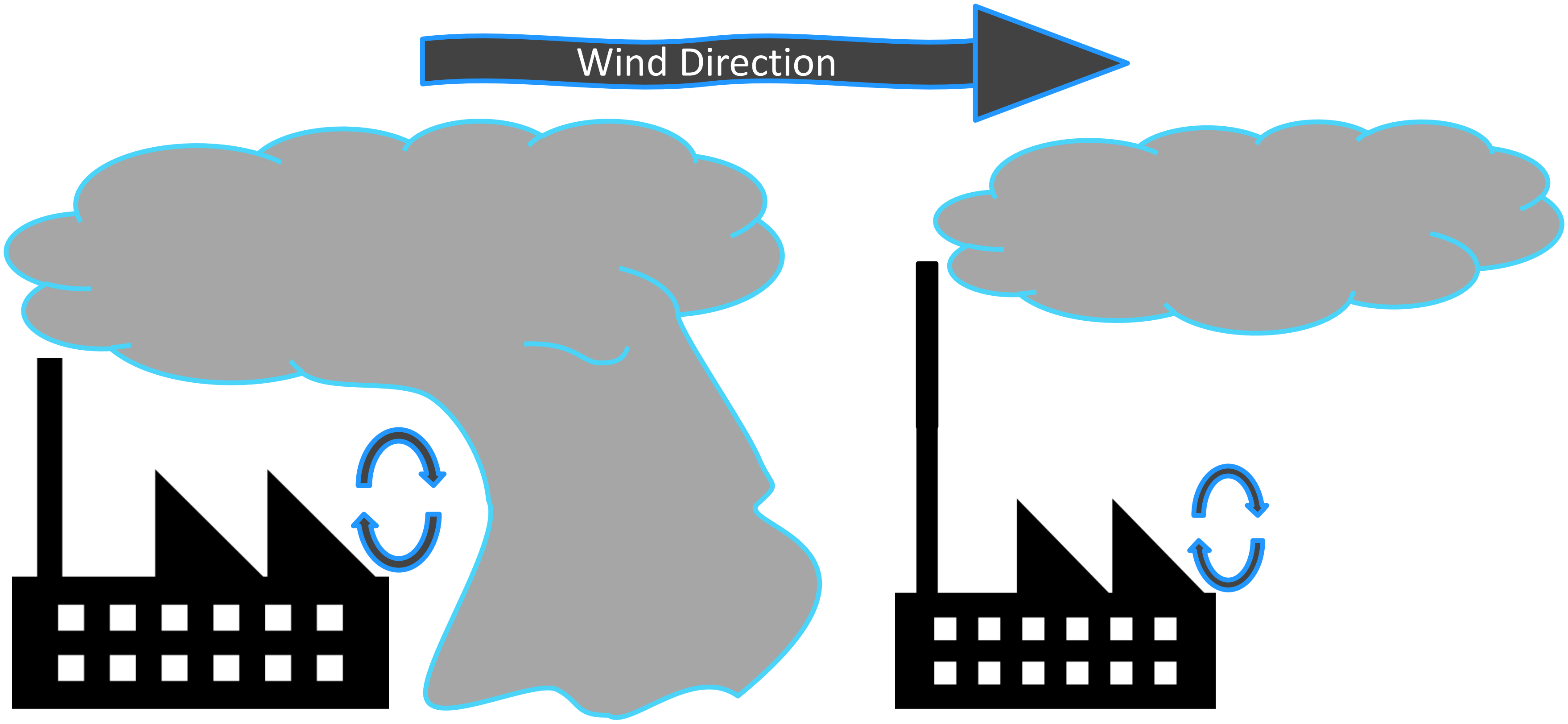
Plan View



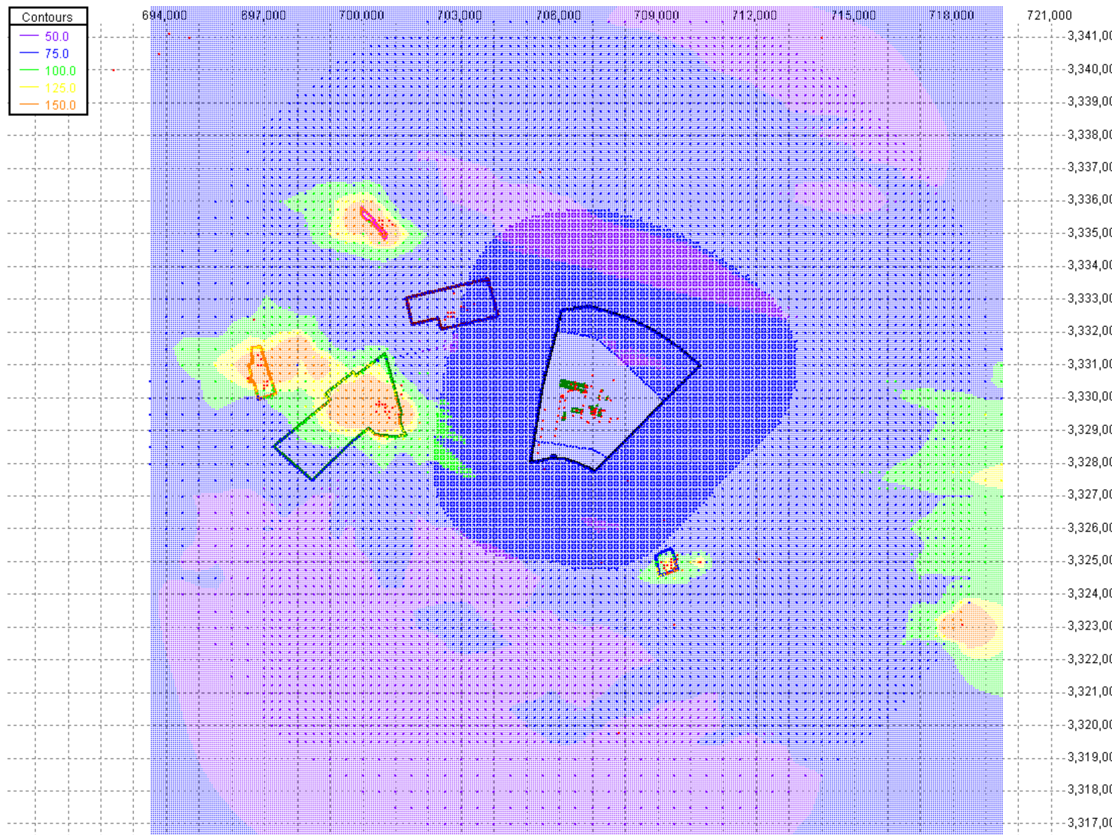
Diffusion Can Get Complicated

Interplay of Stack Heights and Downwash

Higher stack heights can reduce downwash effects

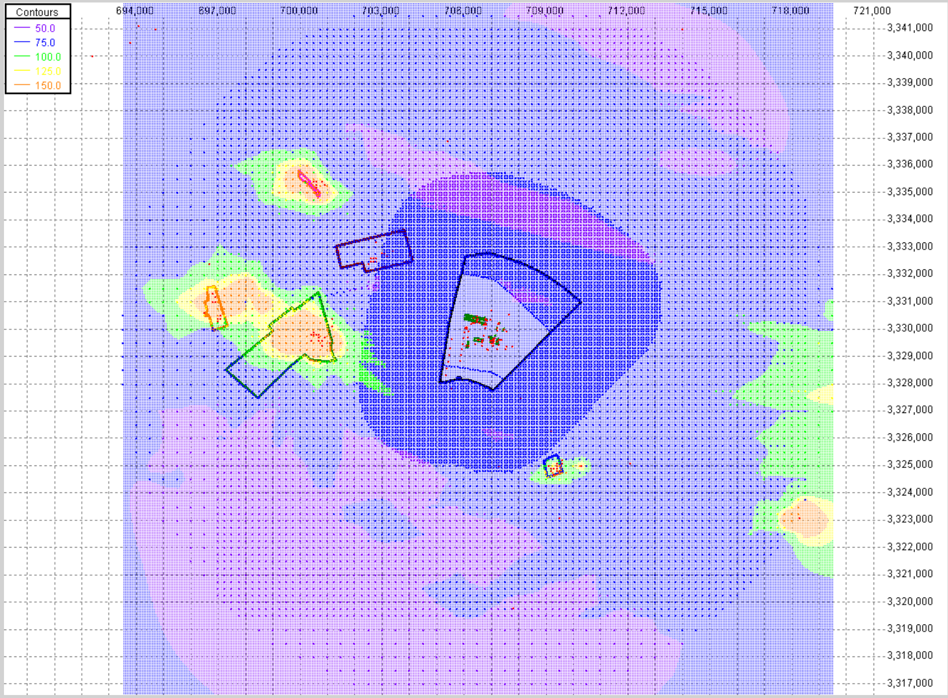


Cumulative Source Model

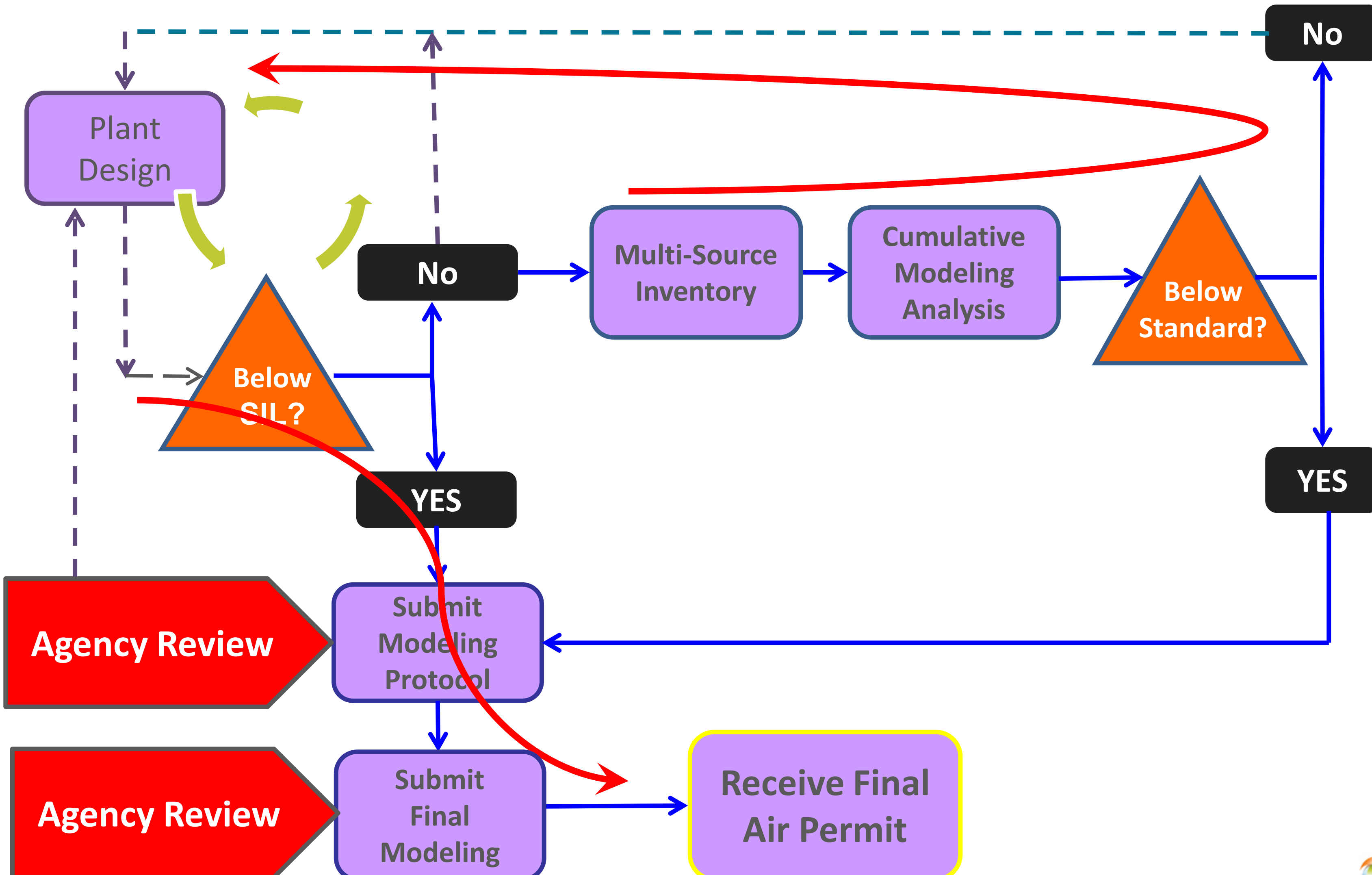


Cumulative Modeling

- Model impacts of stand-alone project against standards
    - If all project impacts < SIL, no further review
    - If any new project impacts > SIL, multi-source analysis required
- Obtain source inventory for all sources in the SIA
    - QA/QC the data!
- Project cannot be significant at a modeled exceedance of the standard
    - Identify culpable sources for any exceedance
    - For large projects, may have to prove insignificance at many receptors

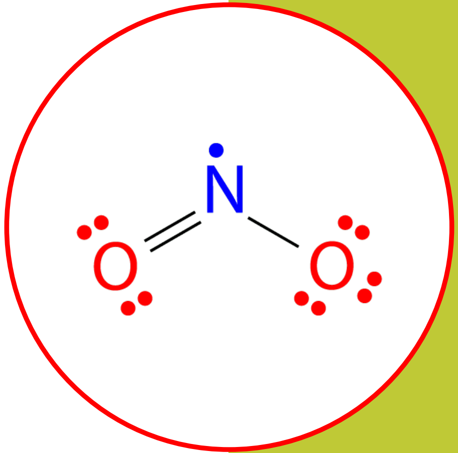


SIL Pathway to Low-Risk Modeling Results



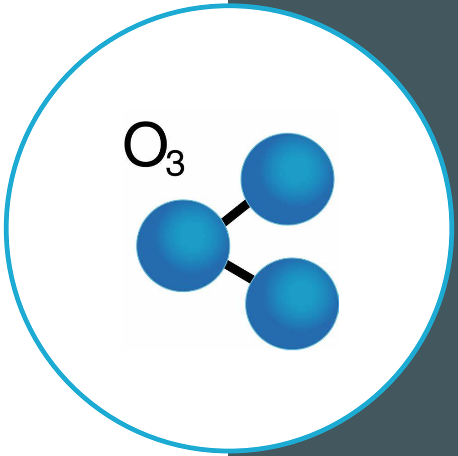
Current Modeling Challenges: 1-Hour NO_2

- Stringent 1-hour standard (2010)
- Sources emit both NO and NO_2 (NO_X), but the NAAQS is for NO_2 only
- NO converts to NO_2 in the presence of ozone
- Need to determine:
  - Which portion is emitted as NO_2
  - What portion of NO converts to NO_2
- EPA has 3 tiers of analysis:
  - Tier 1: Assume all NO_X converts to NO_2
  - Tier 2: Ambient ratio method (ARM2)
  - Tier 3: Ozone-liming method



Current Modeling Challenges: Secondary Formation

- Treatment of secondary formation of $PM_{2.5}$ and ozone for individual projects
- Project NO_X + background ammonia = particulate nitrate
- Project SO_X + background ammonia = particulate sulfate
- Project NO_X + Project VOC + sunlight = ozone
- Full chemical treatment is only handled chemical transport models
- Current approach is to leverage pre-existing EPA platforms to estimate a project's potential for secondary formation



Modeling Project Plan

- ❑ Determine pollutant set most likely to encounter modeling concerns
- ❑ Get the data sets – emissions, met, background, buildings
- ❑ Develop initial SIL models for each pollutant
- ❑ Get multi-source emissions data
- ❑ Identify culpable sources for any exceedance
- ❑ Use results to inform site selection, layout, control technology, general arrangement
- ❑ Pre-application meeting with agency, finalize protocol
- ❑ Refine modeling for final passing results