A Large Scale Gridded Application of the CALINE4 Dispersion Model

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Introduction

- Atlantic Steel is a major downtown Atlanta urban redevelopment project (with freeway access) that will significantly increase the number of trips generated and attracted to the local area and vehicle miles of travel on local arterials and freeways
- For federal agency approvals to be issued, the project must not create a violation of the ambient air quality standards for carbon monoxide
- CALINE4 dispersion modeling was performed for large scale project area, using hundreds of links and receptors to prepare a gridded worst-case CO analysis

Methodology

- Employed MOBILE5a emission rate model to develop regional emission rates
- Employed CALINE4 line source dispersion model with local meteorological parameters
- GIS, PERL, and FORTRAN scripts link 4-step travel demand and traffic simulation model outputs with CALINE4 (activity data provided by Hagler Bailly, Moreland Altobelli, Inc., Georgia DOT, ARC, and GT)
- Input files created and standard models called and run for desired conditions (hundreds of links and receptors)
- Outputs captured, processed, and integrated to predict and display worst-case pollutant concentrations throughout the project region

Microscale CO Impact Assessment

- Performed for worst-case traffic and meteorological conditions in the area of transportation projects
- Ambient air quality standards are expressed in units of concentration over an averaging time
  - 35 parts per million of CO over a one-hour period
  - 9 parts per million of CO over an 8-hour period
- Examine concentrations expected over 1-hour and 8-hour periods in areas where the population is expected to work, rest, or play for periods in excess of one hour
- If analyses do not show air quality violations under worst case conditions, the transportation system is not expected to yield violations under normal conditions

CALINE4 DISPERSION MODEL

- Line source air quality dispersion model predicts pollutant concentrations downwind from a road system
- Based on the Gaussian diffusion equation
- May be used in Environmental Impact Statement (EIS) modeling and in conformity modeling (provided the region has employed the model in the past)
- CAL3QHC is the EPA regulatory-preferred model
  - The research team prefers CALINE4
    - Improved dispersion parameters
    - Better match with average speed emission rates
  - EPA can grant permission to use CALINE4

CALINE4 vs.CALINE3

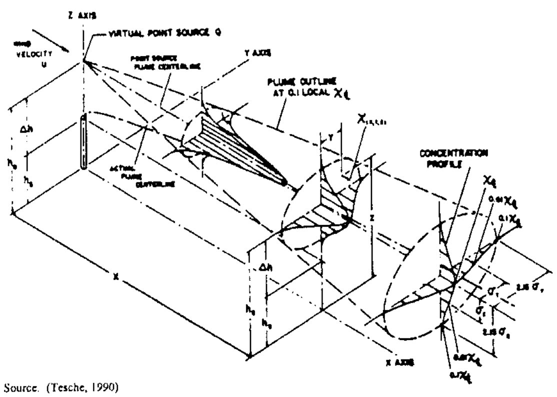
- Incorporation of additional new dispersion data measurements improve dispersion parameters (sigmas)
- Allows wind speed of 0.5 m/s (still recommend 1 m/s)
- Algorithms enhance initial mixing due to buoyancy effects, but plume is still assumed to remain at the surface
- Finer worst case wind angle search algorithm

- Note: The CALINE4 intersection modeling mode is out of date and should not be used because emission rate modifiers are based upon 1970's technology vehicles

CALINE4 vs. CAL3QHC

- CALINE4 allows a reactive pollutant component
  - NO, NO_2, O3
- CALINE4 improved the CALINE3 dispersion algorithms included in CAL3QHC
- CAL3QHC includes queuing algorithms
  - However, given the nature of average speed relationships in MOBILE5a, the average speeds used in CALINE runs better reflect emission rate assumptions and are more theoretically sound

Double Gaussian Distribution

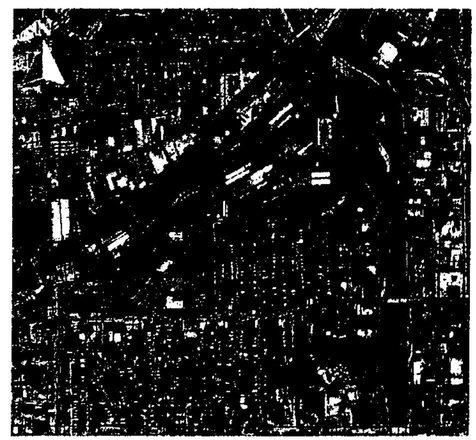


Source: (Tesche, 1990)

CALINE4 MODEL INPUTS

- CALINE4 input variables are divided into 6 groups:
  - Run time & miscellaneous program variables
  - Pollutant variables
  - Roadway and receptor geometry
  - Emissions & traffic variables
  - Intersection variables
  - Meteorology variables

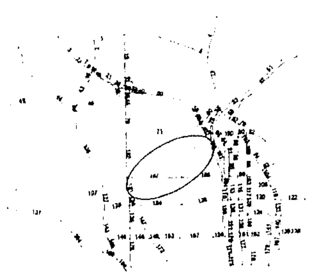
Atlantic Steel Redevelopment Site



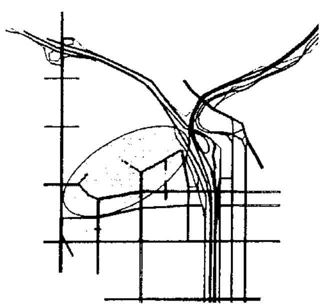
Transportation Network

- The transportation network was obtained from the GDOT roadway database (new roadways associated with the project were added)
- Road network includes the project and all relevant major roadways (included in travel demand modeling) that are likely to have an impact on the region surrounding the site
  - Approximately 8 square miles (1.6% of Atlanta metropolitan area)

TRANPLAN and CORSIM



TRANPLAN
4-Step Travel Demand



CORSIM
Simulation Model

TRANPLAN Processing

- Convert binary loaded-network files to ASCII and import to ARC/INFO (GIS product by ESRI)
- Conflate the network to the GDOT road database and develop roadway widths
- Convert daily traffic volumes to peak hour volumes using ARC peak hour factors
- Verify links, speeds, capacities, and daily volumes using field measurements and ATMS data (freeway volumes at capacity were underestimated as were speeds)
- Write link attributes to CALINE pre-processor
  - x, y coordinates, link capacity, daily and peak hour traffic volume, peak hour average speeds, and roadway width for about ~320 links

CORSIM Processing

- FHWA's CORridor SIMulation (CORSIM) microscopic traffic simulation model used by Moreland Altobelli, Inc. to evaluate the Atlantic Steel project
- CORSIM simulates vehicle interaction with network controls (signal timing) and other vehicles (using driver behavior, car following, and lane changing theory)
- CORSIM employs a coded spatial representation of the network (initial boundary conditions for network traffic volumes came from 4-step model outputs)
- PERL scripts pull from CORSIM outputs and drop data into CALINE pre-processor to create input files

Link Geometry

- Link coordinates (X1, Y1), (X2, Y2)
- Link height (-10m to +10m)
- Link width
  - Width of lanes plus 3 meters on each side (mixing zone assumption)
- Link type (at grade, depressed, fill, bridge, parking lot, intersection)
  - Distance to right canyon or bluff wall
  - Distance to left canyon or bluff wall

Receptor Site Selection Criteria

- Analyses should include enough receptor sites to insure that the worst case condition is analyzed
- The location of all receptors should be clearly located on a project map
- Sites nearest the right of way where the general public has continuous access are selected (these include residential yards, playgrounds, buildings, etc.)
- All sensitive receptors such as schools hospitals, day care centers, retirement home, convalescent homes, should be included in the analysis even if they are not immediately adjacent to the right-of way

(Caltrans, 1988)

Atlantic Steel Receptor Sites

- A grid of 400 receptor sites was created
  - Some receptors will lie in the freeway right-of-way (these do not count in NAAQS assessment)
- Selected 17 additional locations that anticipate highest CO concentrations (for 1-hr and 8-hr averaging)
- Modeling not performed for building air intakes
- Receptor height was set to 1.5 m (human nose) for outdoor exposure, referenced to terrain level

Conventional Analysis

Atlantic Steel 17 Receptor Sites

Emissions Rates

- MOBILE5a input files for the metropolitan area were provided by the EPA Region IV office
  - Fleet mix, I&M program, fuel composition, etc.
  - Assumed old I&M program to provide safety factor
- Prepared MOBILE5a CO emission rate matrices by calendar year and average speed in 2.5 mph increments
  - Composite fleet emission rates (grams/vehicle-mile)
  - Morning and evening runs differed by temperature

Worst Case Meteorological Parameters

- January
- Realistic "near worst case" meteorological parameters
  - Wind speed and direction
  - Temperature
  - Mixing height
  - Background CO (2ppm)
- Employ data from the best available source to represent local conditions
  - Proximal data sources, whenever possible
  - Extrapolations account for seasonal differences or differences in topography between the sampling site and the property in question

Wind Conditions

- Mean Wind Speed
  - 1995 to 1999 data from two urban PAMS in Atlanta (within 20 km of Atlantic Steel), localized data from Georgia Tech campus (~3 km south of the site)
  - Georgia Tech data show slightly lower mean and median wind speeds compared to PAMS sites
- Wind speeds are at or below 1 meter/sec for more than 10 % of the time during the January period
- 1.0 m/s is best match for dispersion assumptions

Wind Direction

- Wind direction is input automatically into each sequential CALINE analysis (measured data from the PAMS site are not employed)
  - 18 degree increments were used due to processing time (link screening will allow refined wind angles)
- Wind Direction Variability taken from the Tucker PAMS site for January 1995 and January 1997 (when high time resolution data are available)
  - The standard deviation of wind direction was calculated at 27.4 degrees for a five-minute averaging period based on one-second data
  - Since this is quite close to the default value or 25 degrees, the default value was used

Temperature

- NOAA climatological data for "mean coldest January day" for Atlanta, GA, scaled to the mean diurnal temperature profile recorded at the Tucker PAMS site and rounded to the nearest degree

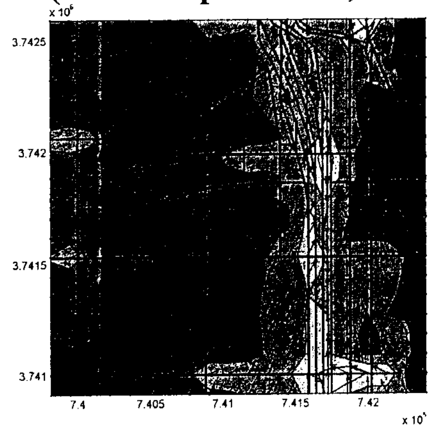
Time	Temperature
01:00	-10 C
07:00	-10 C
13:00	-3 C
19:00	-5 C

Dispersion Mixing Height

- Estimated from Southern Oxidants Study data
- Approximately 65 complete tethersonde profiles of wind, temperature and dew point 3 km south of the site (8-9/1991, 7-8/1992, 9/1995, and 7-8/1996)
- Low inversions, with mean boundary layer breakup by about ~8:30 am and 80% of full boundary layer height achieved by about ~ 10 am in January

Time	Temperature
1:00	20 m
7:00	22 m
13:00	160 m
19:00	36 m

Gridded Worst-Case Analysis 2005am (400 Receptor Sites, 320+ Links)



Top 10 Concentrations for 400 Receptor Grid

On the Freeway ROW
19.0
17.6
17.4
16.4
15.8
15.3

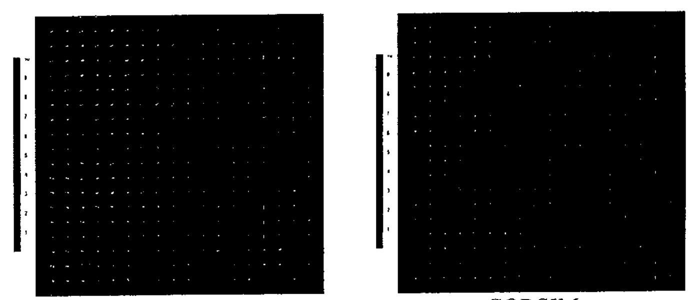
Valid 1-Hour Receptors
15.0
14.7
14.2
13.7

Top Concentration for the 17-Receptor Sites
14.8 ppm

Arrows point toward wind source under worst case conditions

TRANPLAN vs. CORSIM

Differences in CALINE4 CO Levels



TRANPLAN
4-Step Travel Demand

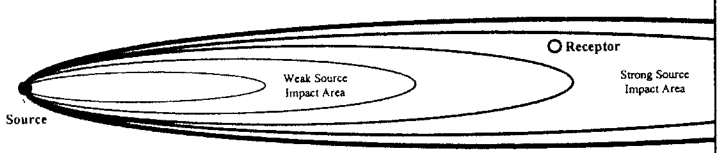
CORSIM
Simulation Model

Be Careful:
TRANPLAN (accurate volumes, congested speeds biased low)
CORSIM (accurate current speeds, volumes biased low)

Computationally and Disk Intensive

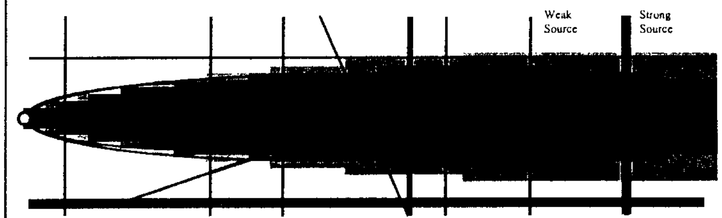
- Atlantic Steel runs with 400 receptors, 320+ links, and 20 wind angle increments yields 2.6 million calculations
- Each gridded run takes about 30-40 hours to complete
- Processing time is primarily associated with program calls and will drop dramatically when CALINE4 code is integrated directly
- Screening links from the analysis will also significantly reduce computational time
  - Roadway links that do not contribute significantly to the concentration at a receptor should not be included in the CO analysis for that receptor

Significance of Downwind Impacts



- The impact of a point source on receptor concentration is a function of source strength, distance to receptor (x, y, z), and dispersion relationships (by stability class)
- The concentration at the above receptor is not significantly impacted by weak source strengths but is affected by strong source strengths
- Ignore weak sources in predicting concentrations

Link Screening



- Develop dispersion impact zones to identify links that will contribute significantly to receptor concentration (link strength, orientation, and distance to receptor)
- Retain links (black) that cross a dispersion impact zone when the link source strength exceeds the zone threshold
- Retain long "in-line" links (dashed), based upon link strength and orientation of roadway to wind angle

Conclusions

- Worst case gridded analysis provides striking visual output that can be employed in planning to identify potential CO hot spots and focus new development
- Gridded regional dispersion analysis can be performed on an ongoing basis (by running the application in background on DOT computers)
  - Integrate new plans, programs and facilities as activity data are developed in traffic impact studies
- Analyses can be linked with real-time (or average) vehicle activity and meteorological data and with hydrocarbon speciation data to perform toxic air contaminant exposure assessment studies