Environmental Crises: Accident Reconstruction and Plume Modeling

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Seveso Accident, 1979

- The **Seveso disaster** was an industrial accident that occurred around 12:37 pm July 10, 1976, in a small chemical manufacturing plant approximately 15 km (9.3 mi) north of Milan in the Lombardy region in Italy.
- It resulted in the highest known exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in residential populations which gave rise to numerous scientific studies and standardized industrial safety regulations.

Bhopal, 1984

- A leak of methyl isocyanate gas and other chemicals from the plant resulted in the exposure of hundreds of thousands of people.
- The official immediate death toll was 2,259 and the government of Madhya Pradesh has confirmed a total of 3,787 deaths related to the gas release.
- Others estimate 3,000 died within weeks and another 8,000 have since died from gas-related diseases.
- A government affidavit in 2006 stated the leak caused 558,125 injuries including 38,478 temporary partial and approximately 3,900 severely and permanently disabling injuries.

Chernobyl disaster, 1986

- The **Chernobyl disaster** (was a catastrophic nuclear accident that occurred on 26 April 1986 at the Chernobyl Nuclear Power Plant in Ukraine (then officially Ukrainian SSR), which was under the direct jurisdiction of the central authorities of the Soviet Union.
- An explosion and fire released large quantities of radioactive contamination into the atmosphere, which spread over much of Western USSR and Europe.
- It is widely considered to have been the worst nuclear power plant accident in history

Air Pollution Accidents

- Accident will happen, mostly due to unexpected multiple failures
- When accident happen, we need:
  - Emergency preparedness (difficult)
  - Emergency response (very difficult – timescale!)
  - Post-accident reconstruction and investigation (not easy)

Accidents and Litigation

- More and more often, especially in the US, accidental releases – even minor ones - are litigated in court
- Even with a good record of regulatory compliance, the industry can be sued
- The cost of litigation (and the potential penalties if the case is lost in court) are very high – and growing…

Cont.

- Litigation requires technical experts and litigation support
- The attorney and the scientist – an interesting interaction!
  - Different culture
  - Different skills
  - Different goals
  - Different language

Post-Accident Investigations

- One of our major consulting activities
- Multi-disciplinary
  - Industrial / chemical / combustion engineering
  - Atmospheric physics and chemistry
  - Computer modeling and GIS
  - Adverse Effects:
    - Toxicology
    - Environmental / Ecological / Material Damages
    - Economic damage

Post-Accident Technical Work

The Accident

Technical Tasks

1. Accident Reconstruction
2. Emission Characterization
3. Meteorological Characterization
4. Plume/Puff Modeling
5. GIS Visualization
6. Adverse Effects

1. Accident Reconstruction

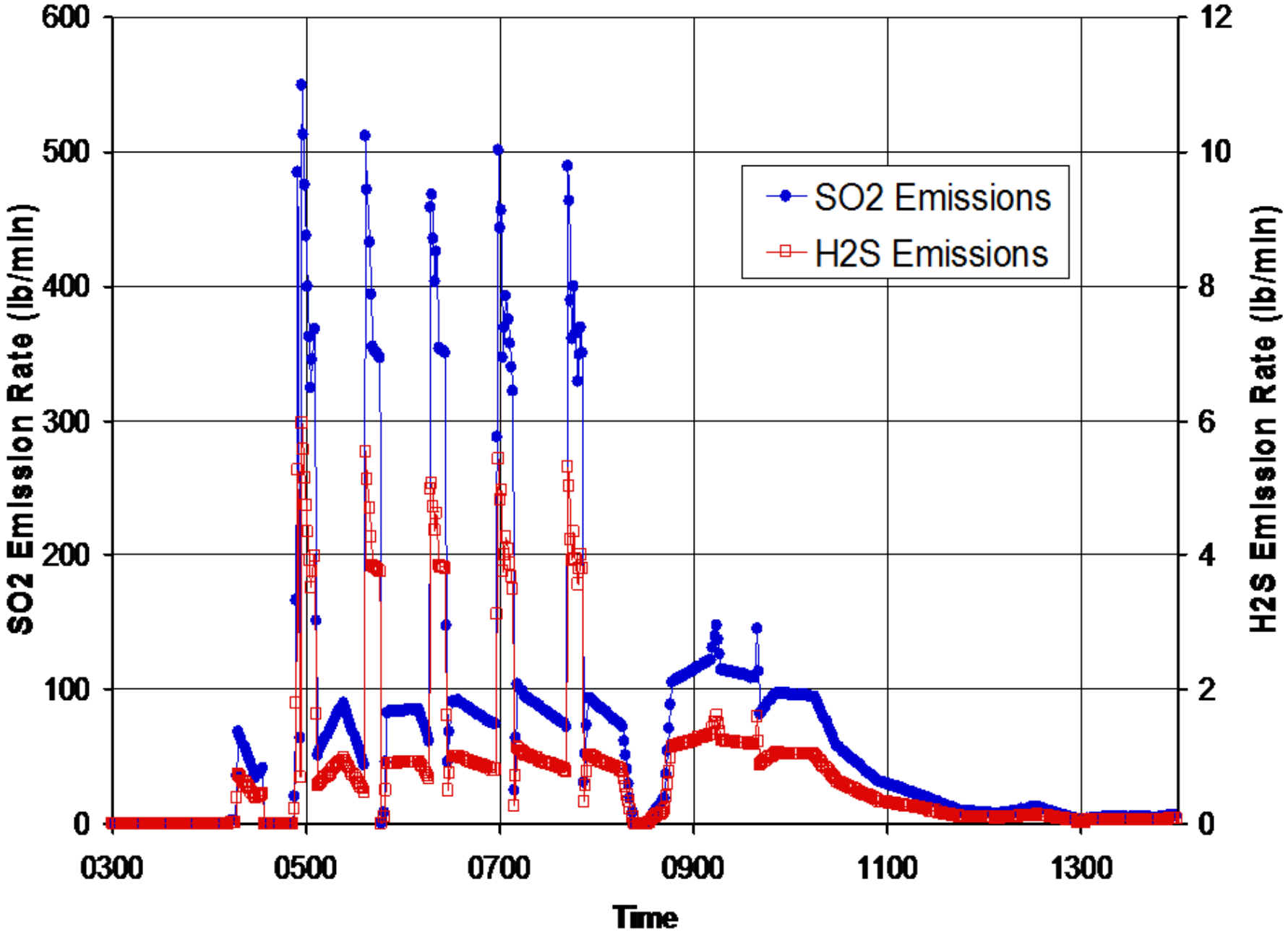
- Review of industrial monitors
- Timeline of events
- Mass balance calculations
- Review of testimony, pictures, videos
- Uncertainty analysis

2. Emission Characterization

- Average release rate and parameters
- Minute-by-minute estimates

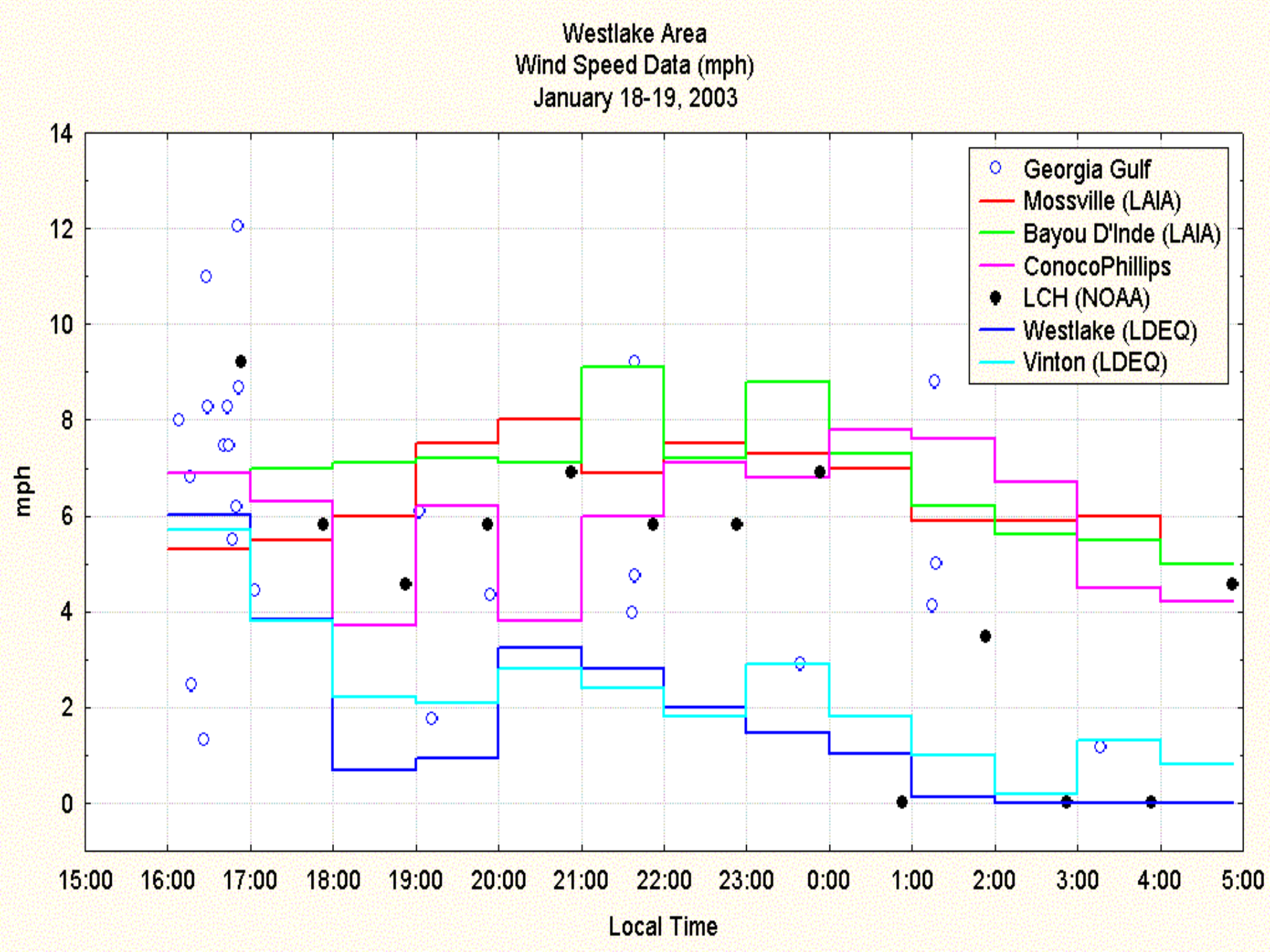
- E.g., a flaring incident (1990s)

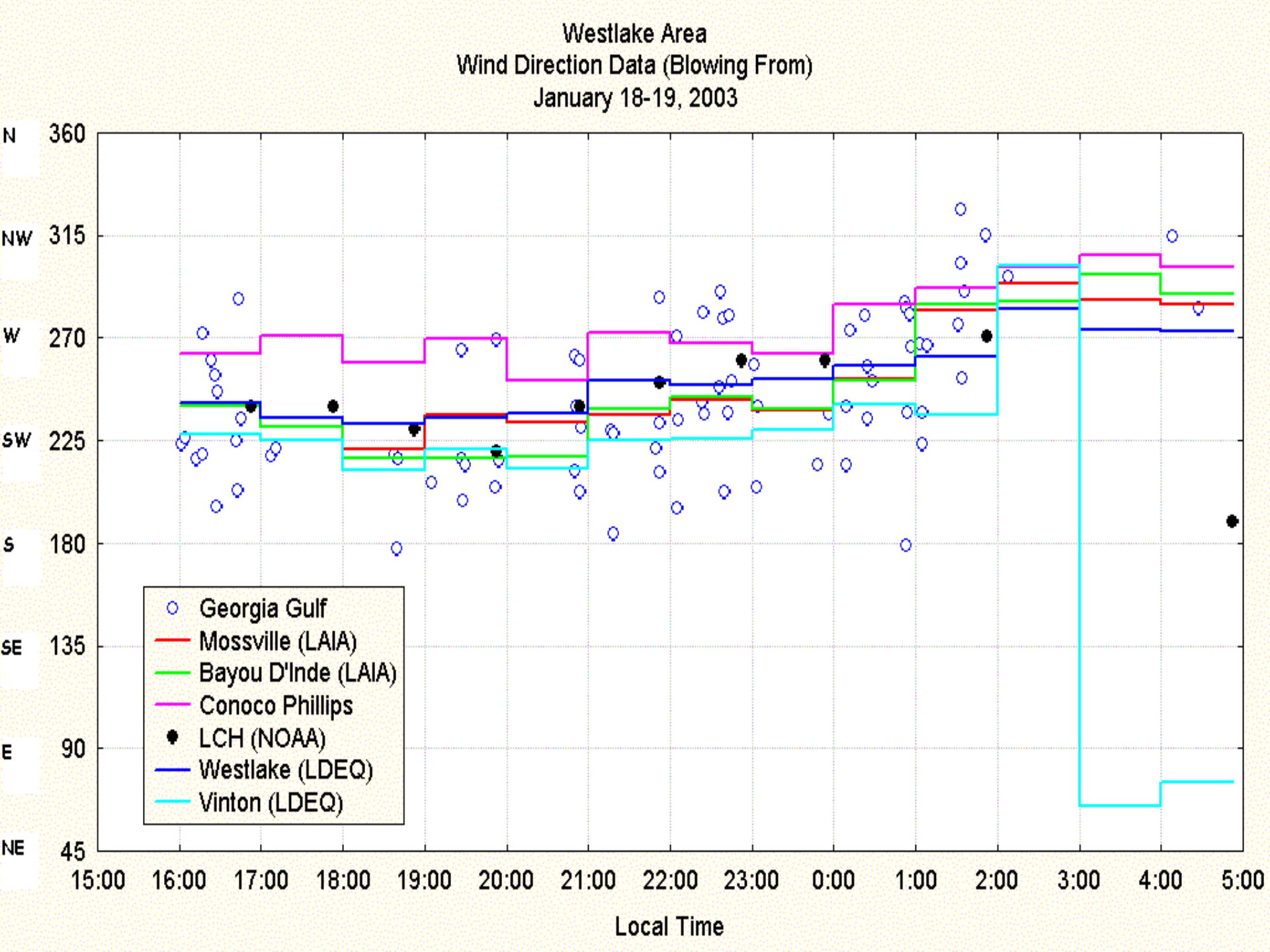

FreeFoto.com


SO2 Emissions
H2S Emissions
SO2 Emission Rate (lb/min)
H2S Emission Rate (lb/min)
Time
600
500
400
300
200
100
0
12
10
8
6
4
2
0
0300
0500
0700
0900
1100
1300

3. Meteorological Characterization

- Collect available meteorological and weather data during the accident
- Review and select relevant information


Westlake Area
Wind Speed Data (mph)
January 18-19, 2003
Georgia Gulf
Mossville (LAIA)
Bayou D'Inde (LAIA)
ConocoPhillips
LCH (NOAA)
Westlake (LDEQ)
Vinton (LDEQ)
mph
14
12
10
8
6
4
2
0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
Local Time


Westlake Area
Wind Direction Data (Blowing From)
January 18-19, 2003
N
NW
W
SW
S
SE
E
NE
360
315
270
225
180
135
90
45
Georgia Gulf
Mossville (LAIA)
Bayou D'Inde (LAIA)
Conoco Phillips
LCH (NOAA)
Westlake (LDEQ)
Vinton (LDEQ)
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
1:00
2:00
3:00
4:00
5:00
Local Time

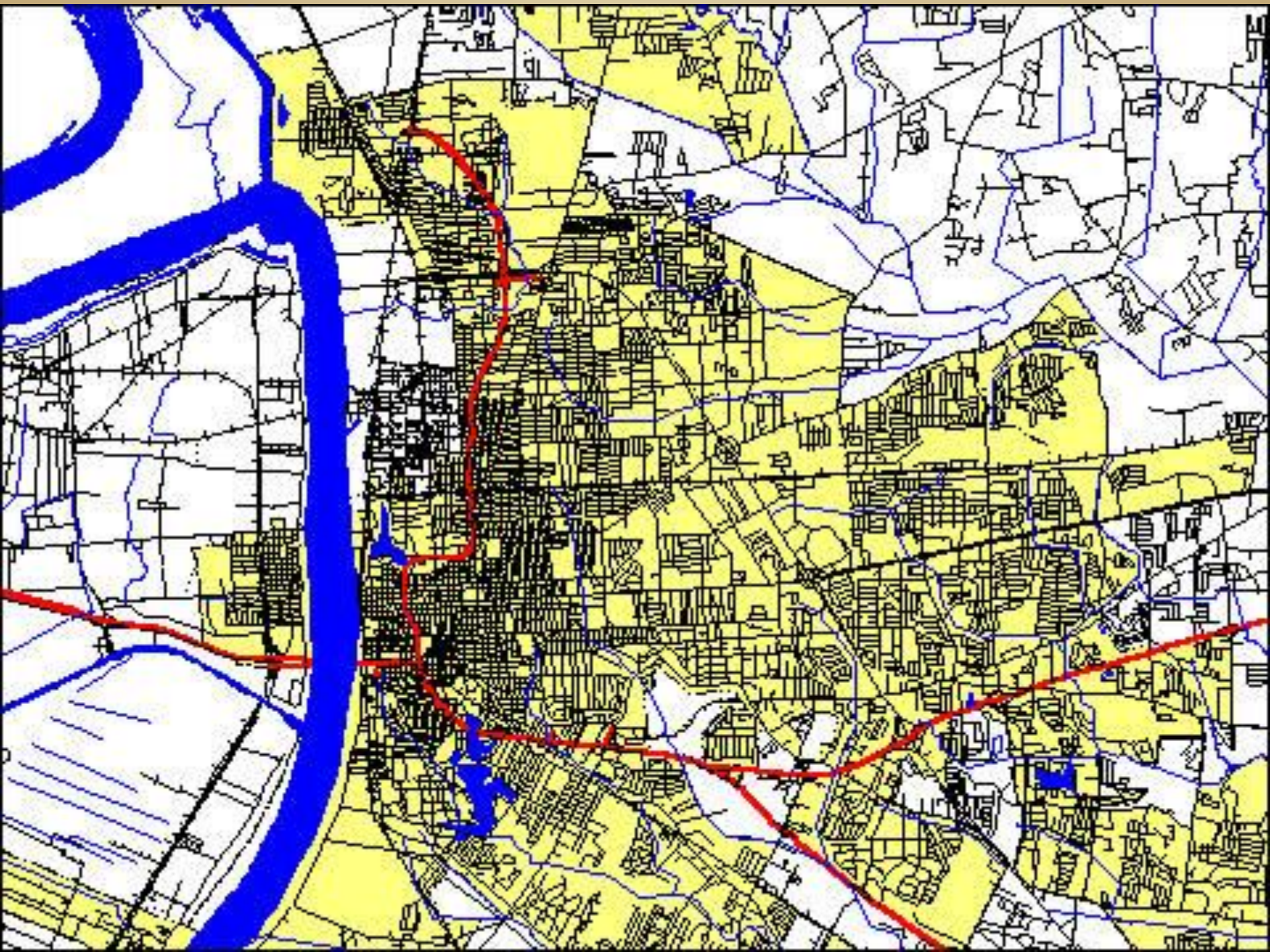
4. Plume/Puff Modeling

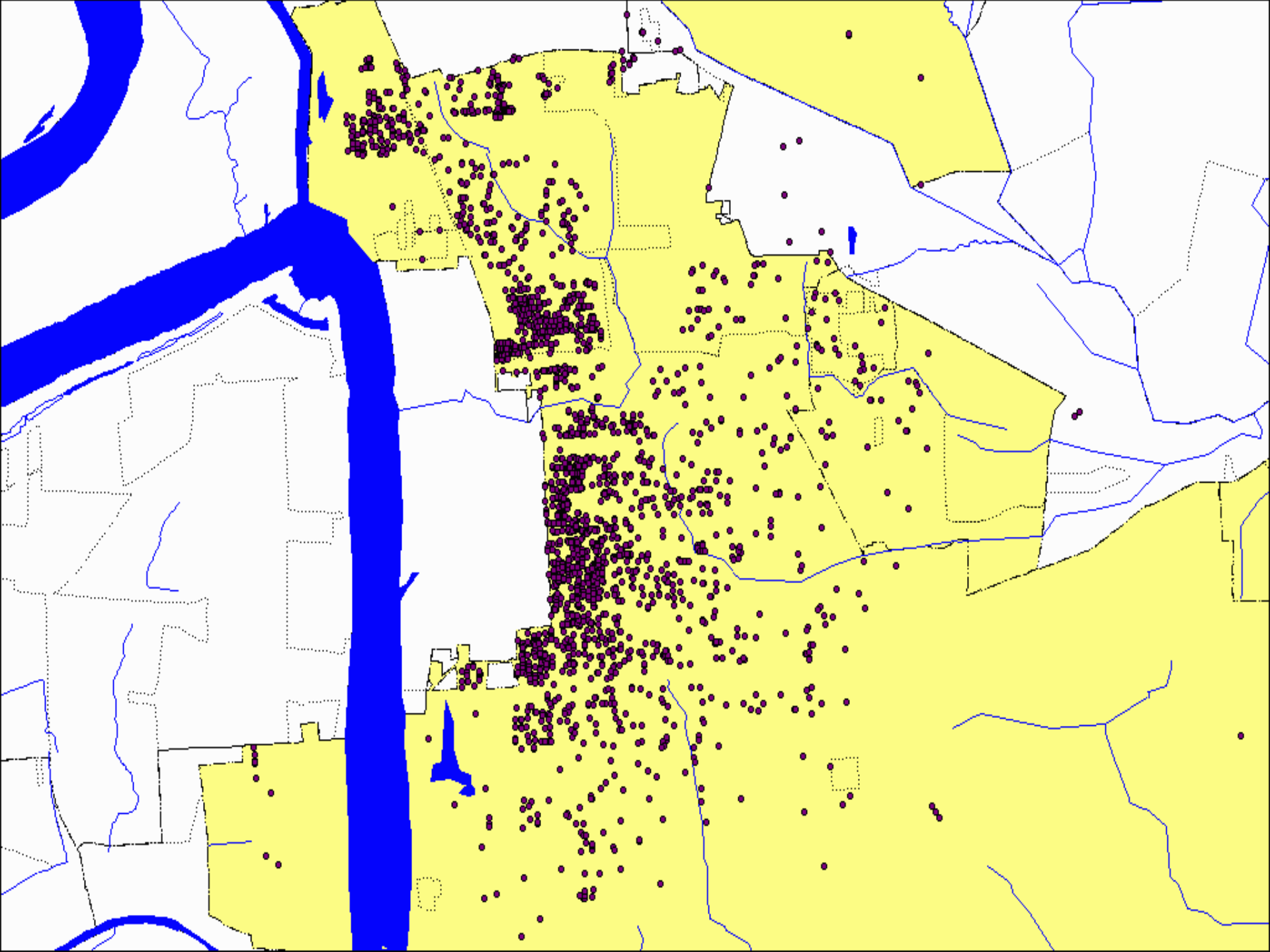
- EPA models vs. other models
- Simple models (e.g., a steady state Gaussian Plume model) vs. complex models (e.g., a dynamic puff model)
- Example of application of MONTECARLO (20 y ago)
- Today's animation capabilities – M case

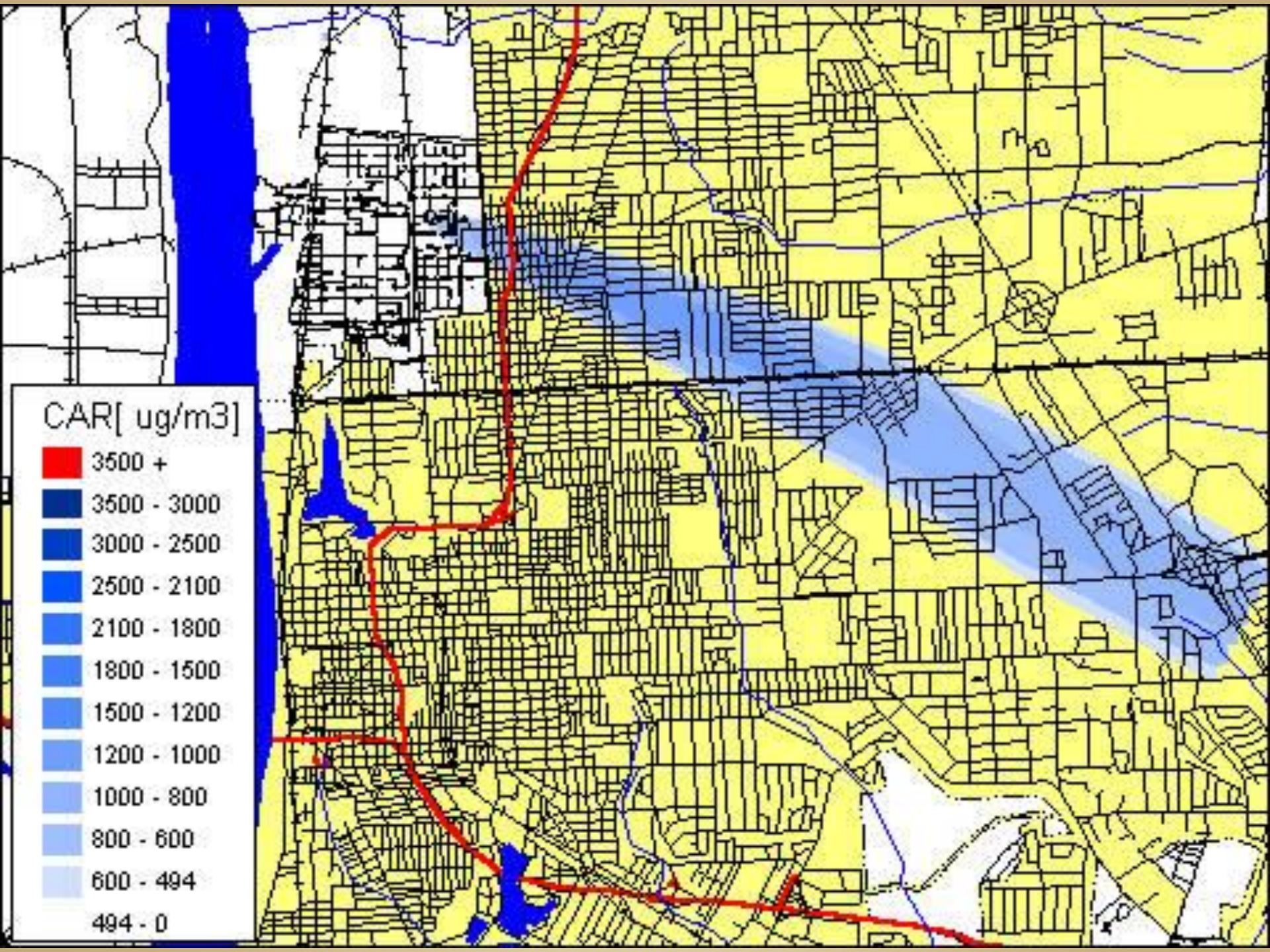
5. GIS Visualization

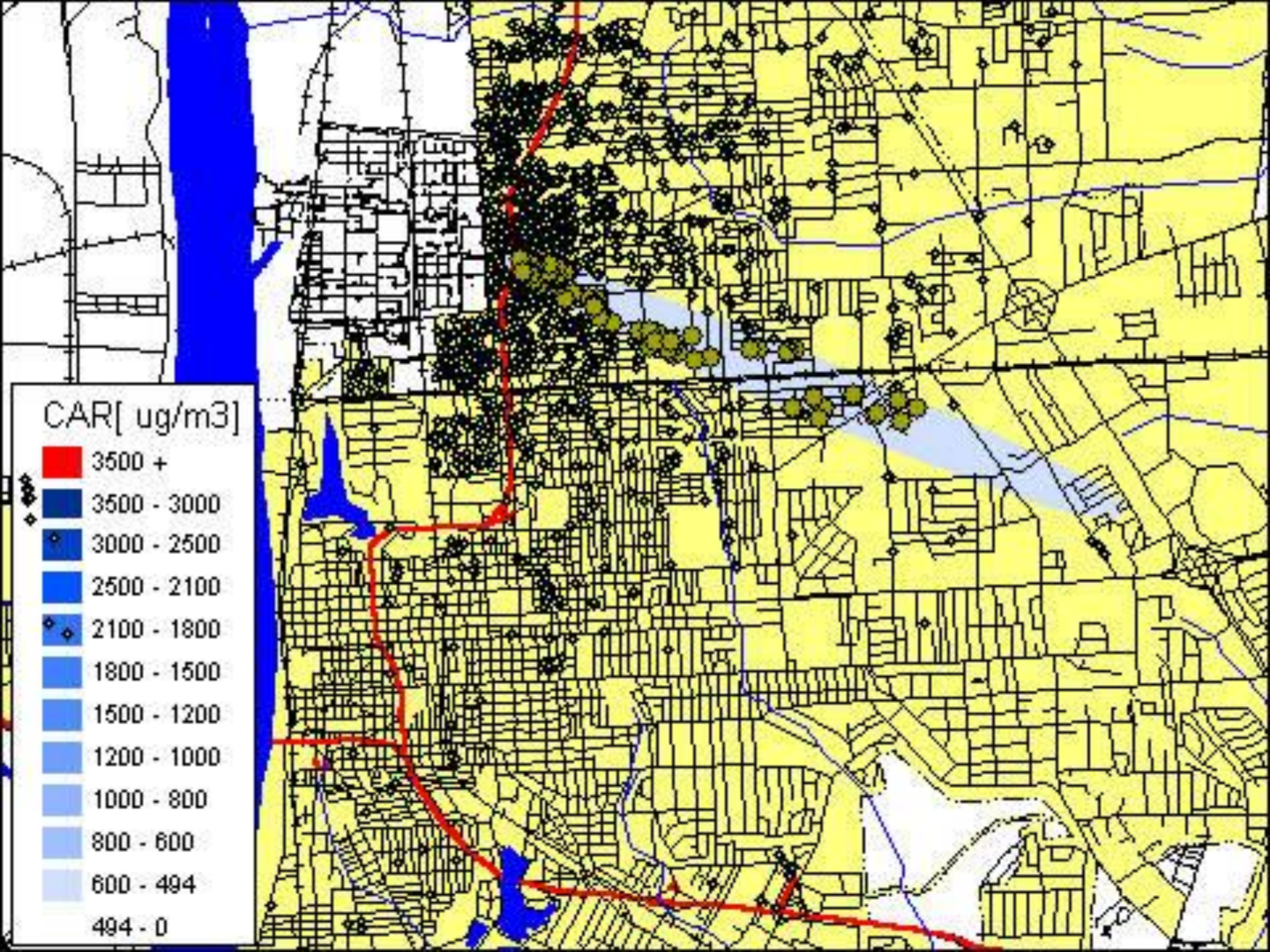
- Visualization of results:
  - Plume
  - Plaintiffs locations
  - Other geographic features
- The use of a GIS is indispensable
  - Different layers of information
  - Easy to change
  - Automatic geocoding of addresses

  ➔ example (20 y ago)

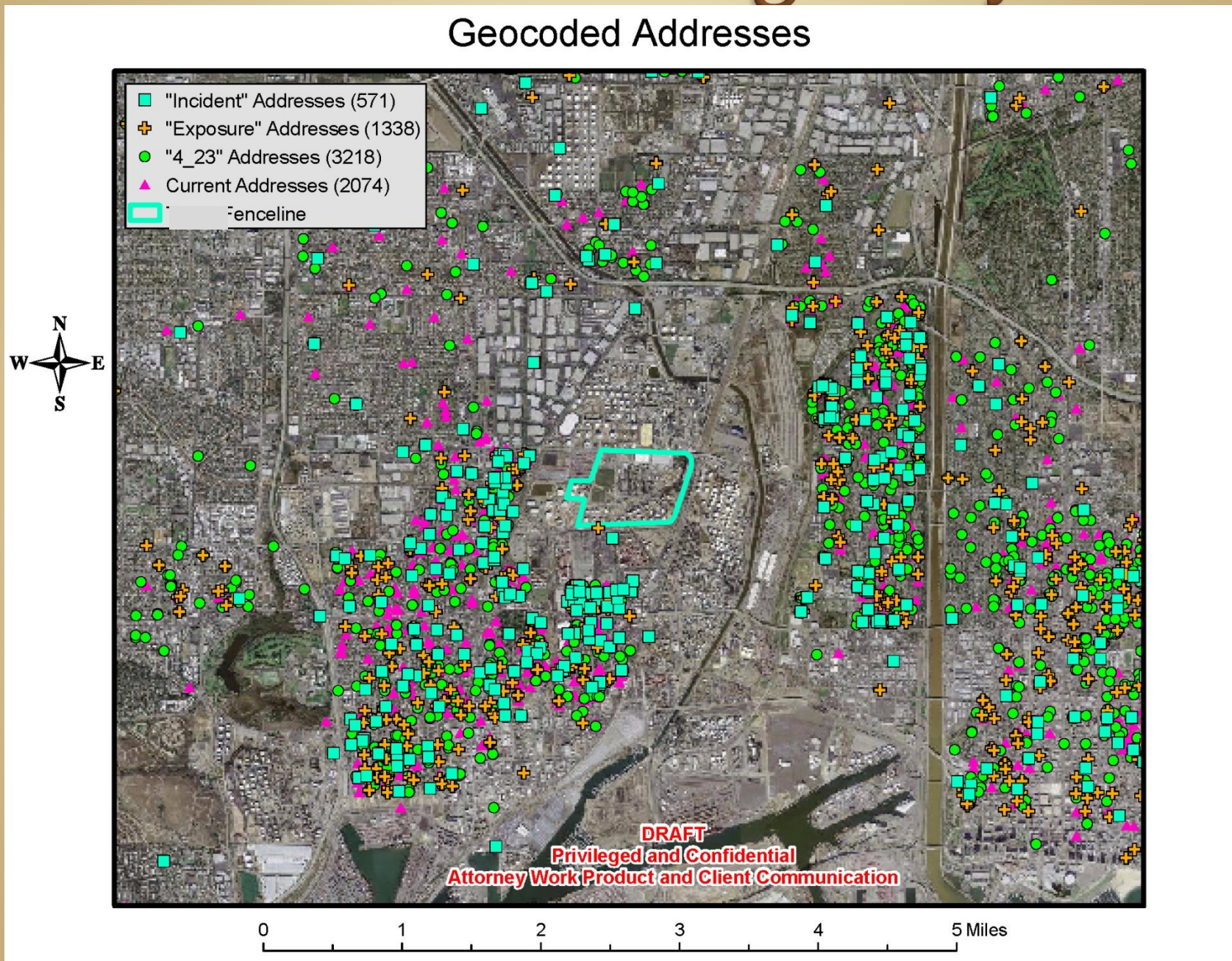




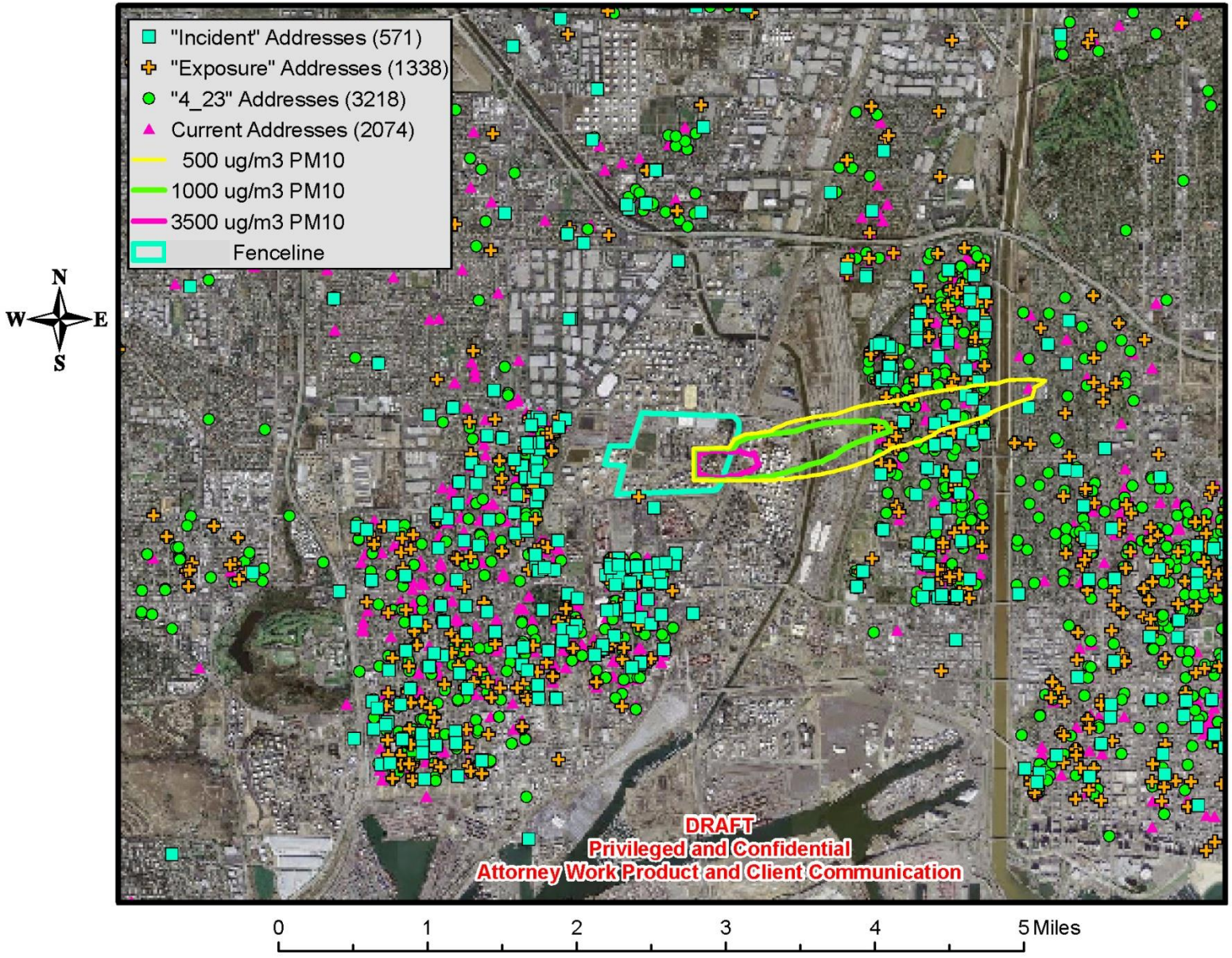

CAR[ug/m3]
3500 +
3500 - 3000
3000 - 2500
2500 - 2100
2100 - 1800
1800 - 1500
1500 - 1200
1200 - 1000
1000 - 800
800 - 600
600 - 494
494 - 0


CAR[ug/m3]
3500 +
3500 - 3000
3000 - 2500
2500 - 2100
2100 - 1800
1800 - 1500
1500 - 1200
1200 - 1000
1000 - 800
800 - 600
600 - 494
494 - 0

GIS + Geocoding today



1-Hour Maximum Pointwise PM10 Concentrations and Geocoded Addresses



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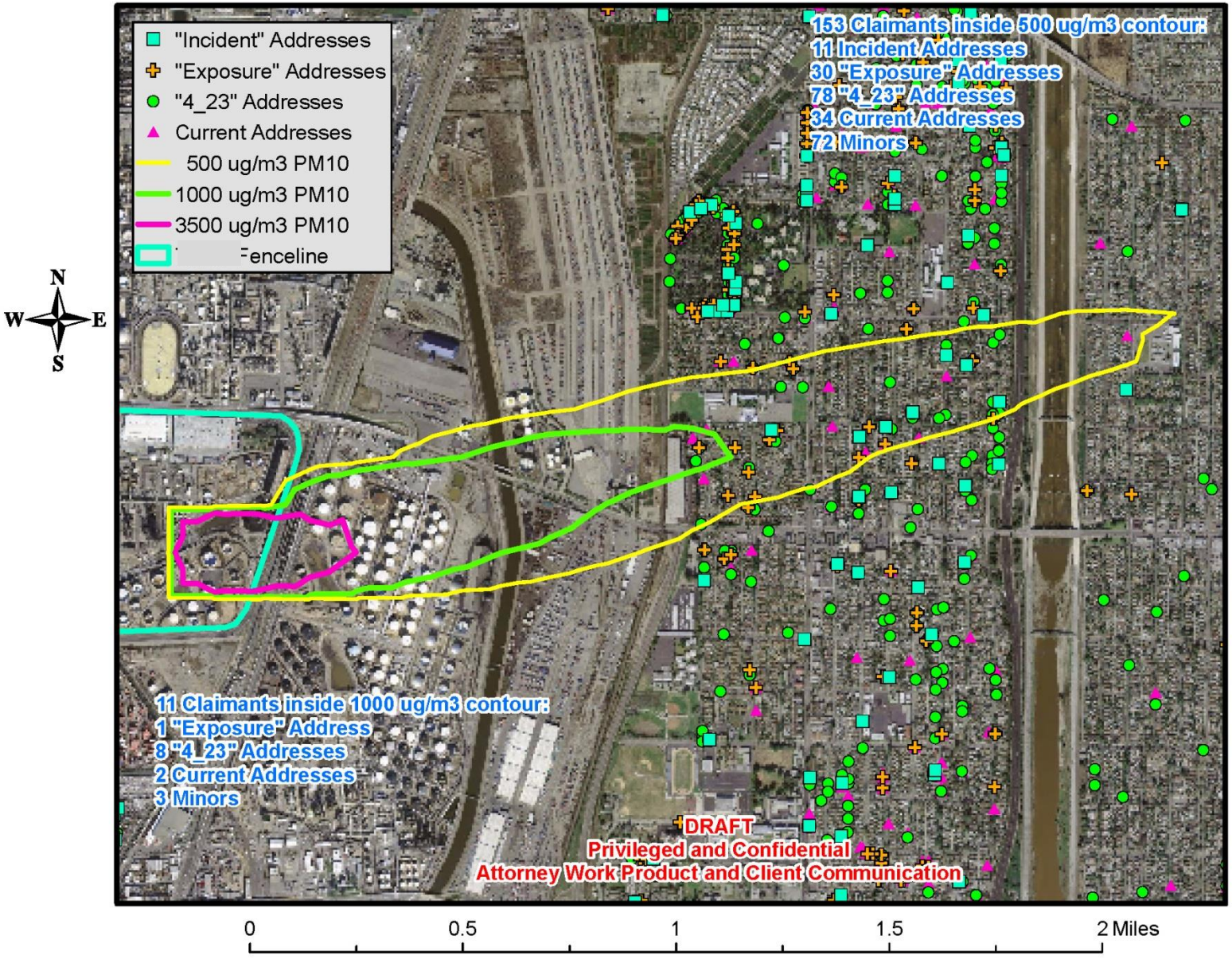


6. Adverse Effects

- Human Health
  - Comparison of simulated concentrations with established Levels of Concern (LOCs) http://orise.orau.gov/emi/scapa/chem-pacs-teels/aegls-erpgs-teels.htm
- Odor Nuisance
  - Comparison of simulated concentrations with odor thresholds

  http://www.lbl.gov/ehs/chsp/html/OdorThresholds-3MRespiratorSelectionGuide.pdf
- Damage to materials and surfaces (e.g., paint)
- Reduction in property value

Computer Tools

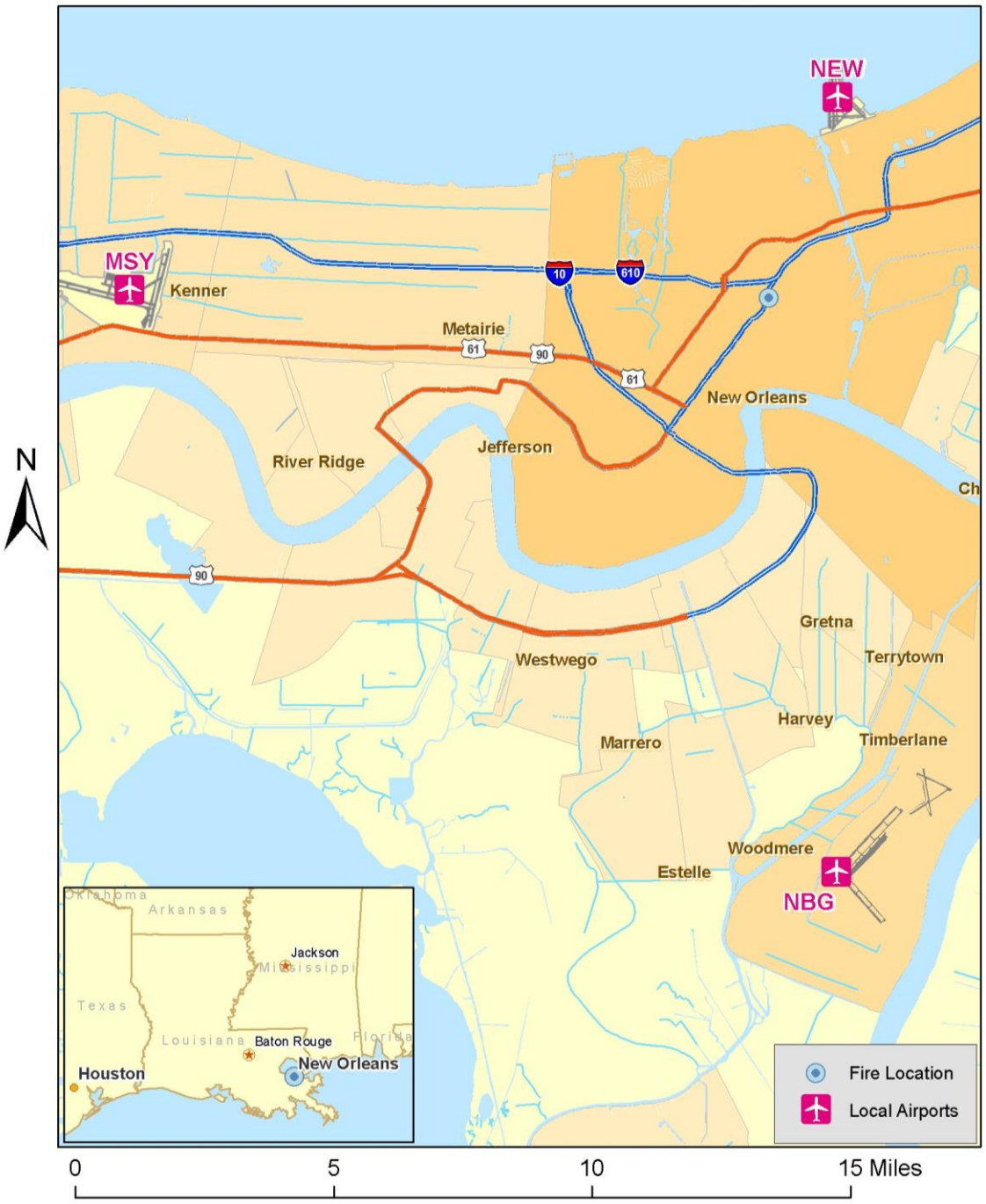
- Visualization of Events
- Accident Reconstruction
  - Short Term Releases
  - Long Term Emissions (unplanned)
- Meteorological Characterization
- Modeling of Transport and Fate of Chemicals
- Modeling of Adverse Effects

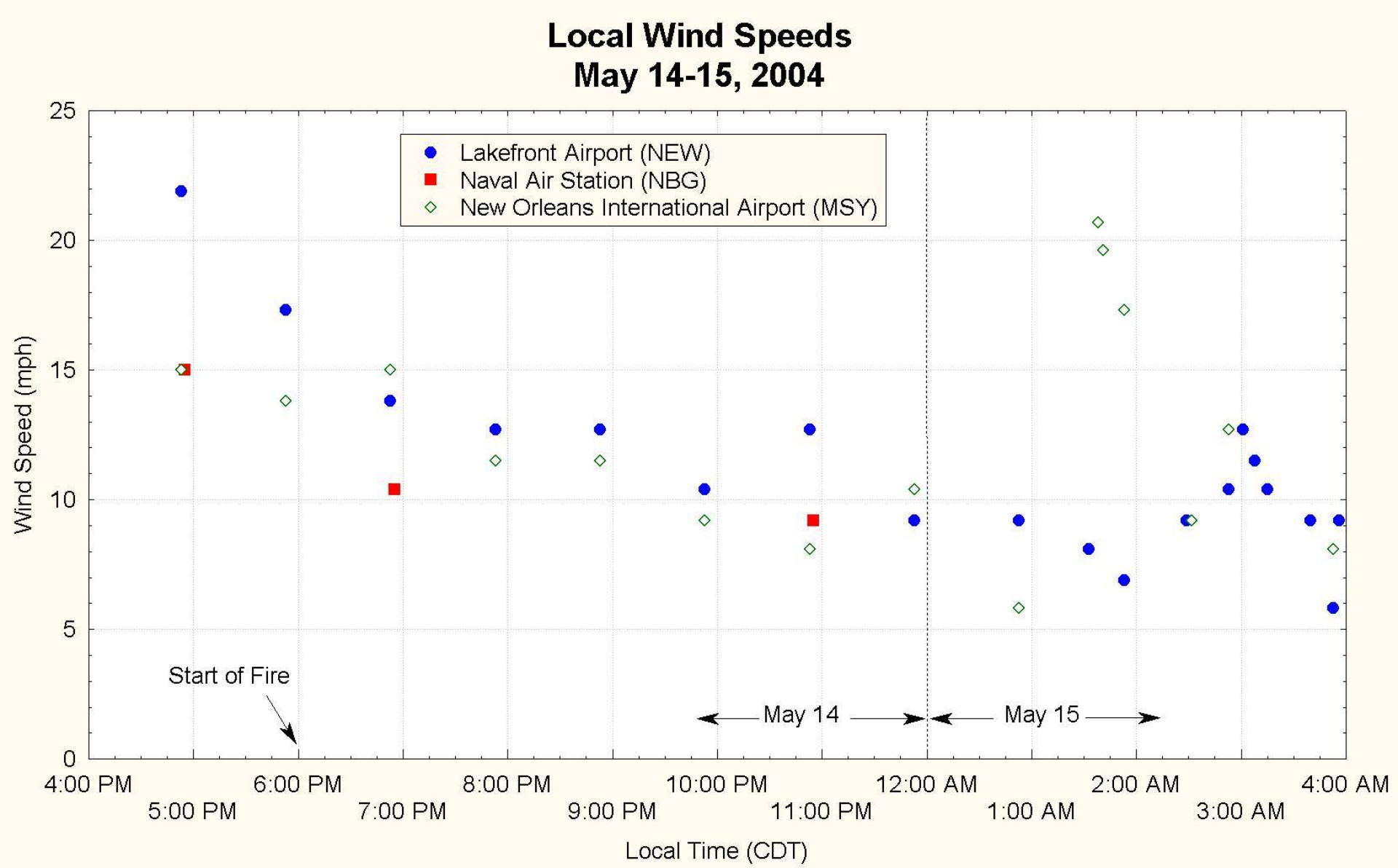
CASE STUDY

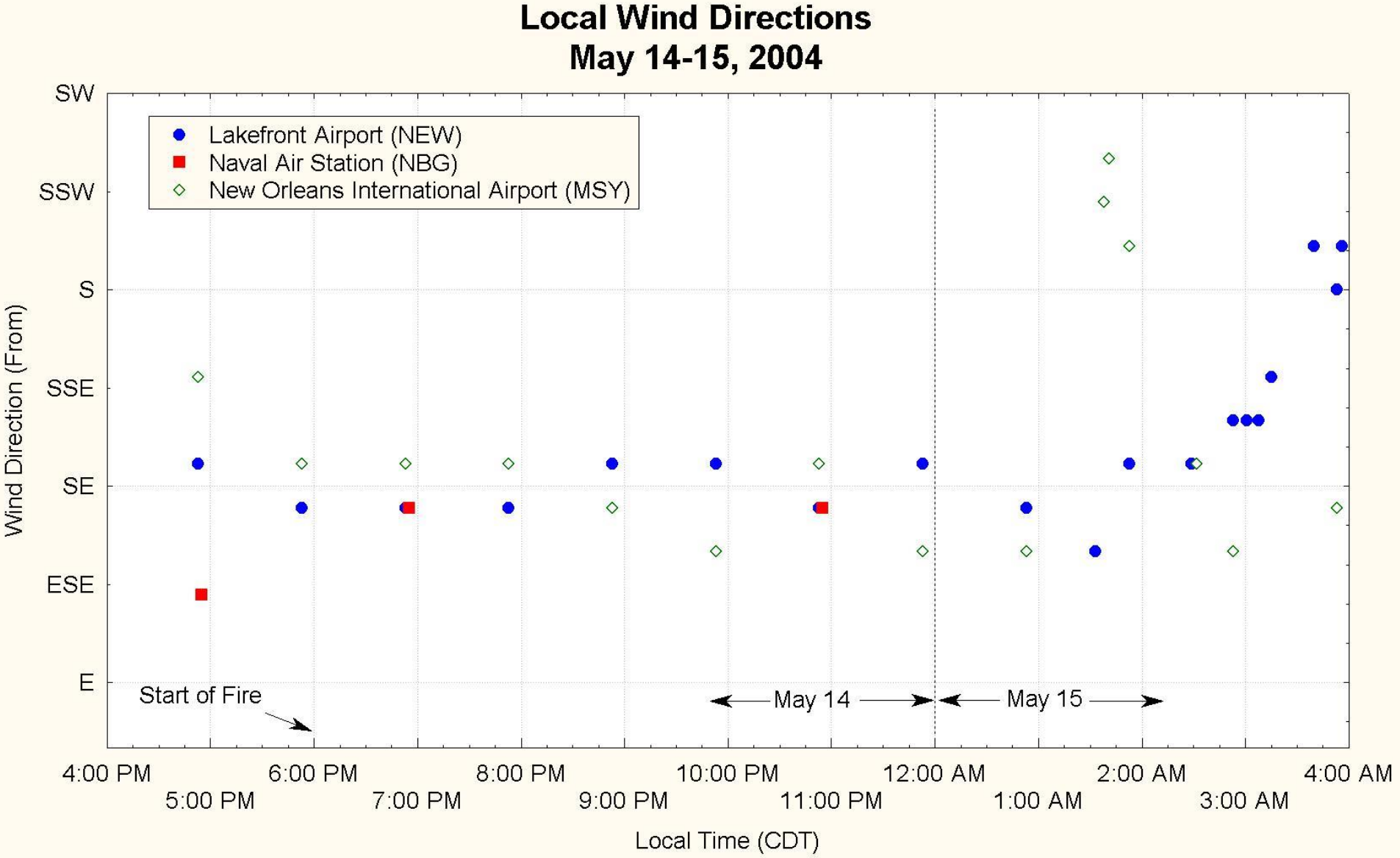
Fire at a facility in New Orleans, Louisiana

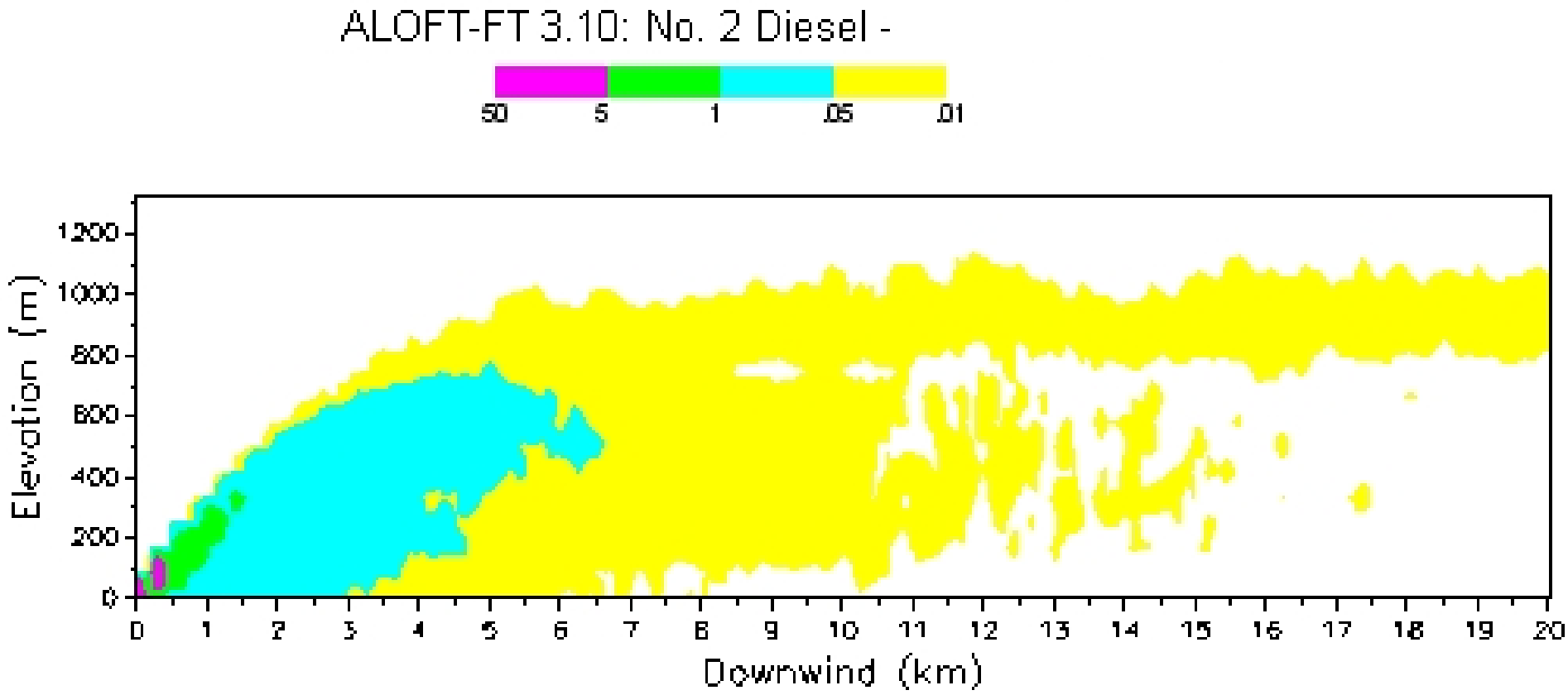
Video

Fire Location and Local Airports

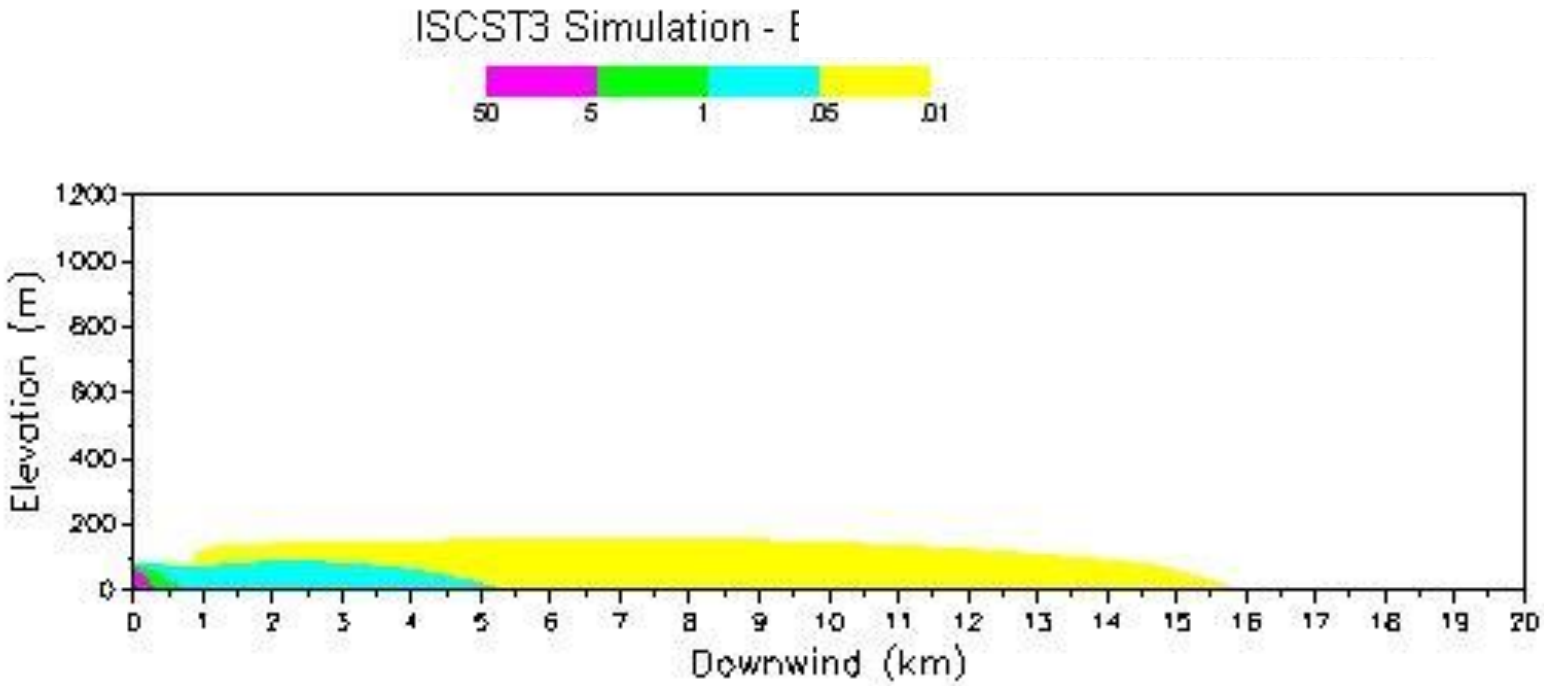



Local Wind Speeds
May 14-15, 2004
Lakefront Airport (NEW)
Naval Air Station (NBG)
New Orleans International Airport (MSY)
Wind Speed (mph)
25
20
15
10
5
0
Start of Fire
May 14
May 15
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
Local Time (CDT)


Local Wind Directions
May 14-15, 2004
Lakefront Airport (NEW)
Naval Air Station (NBG)
New Orleans International Airport (MSY)
Wind Direction (From)
SW
SSW
S
SSE
SE
ESE
E
Start of Fire
May 14
May 15
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
Local Time (CDT)

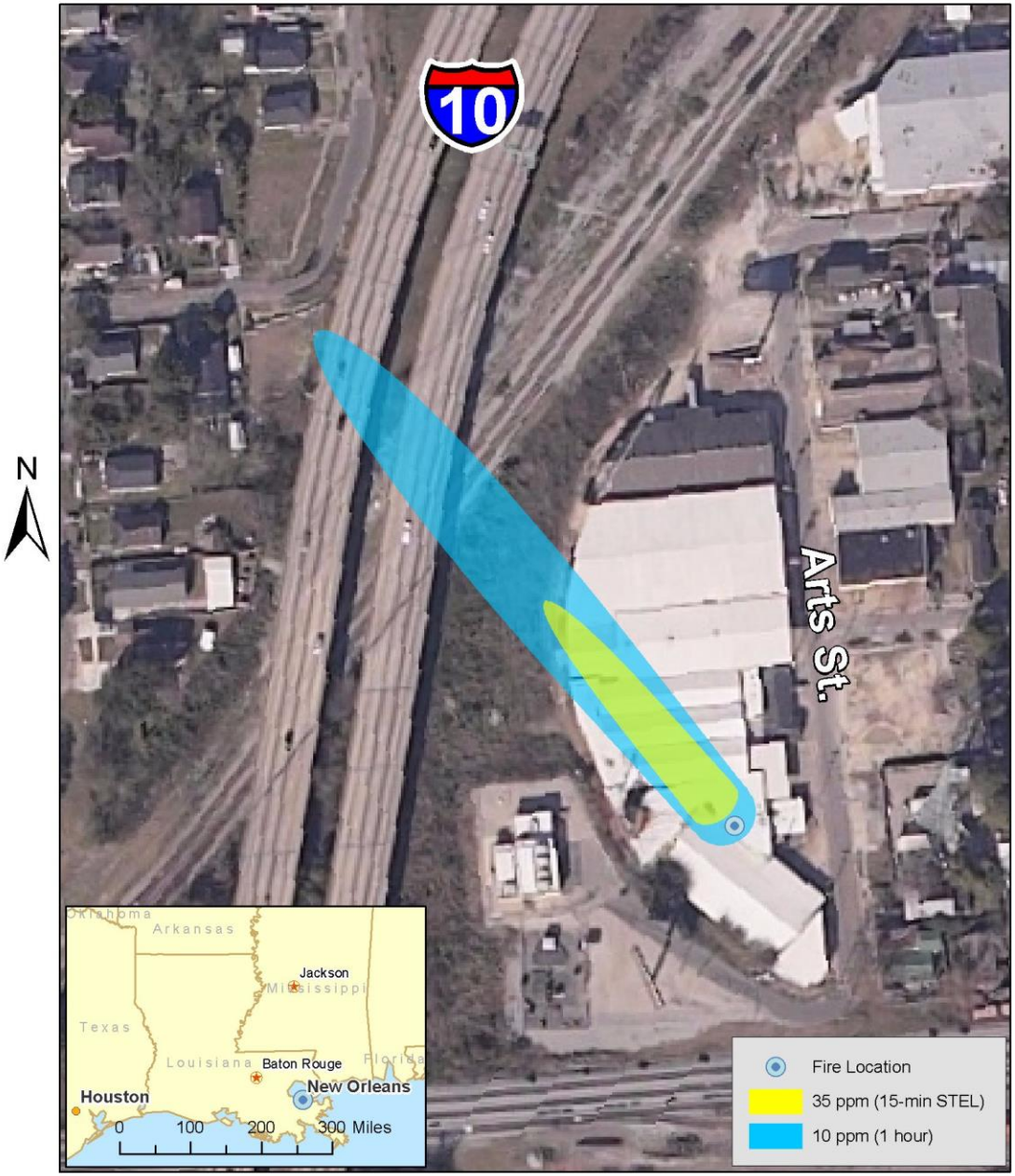


Ammonia Concentration (ppm - one hr avg) Vertical Plane, 0 m Crosswind



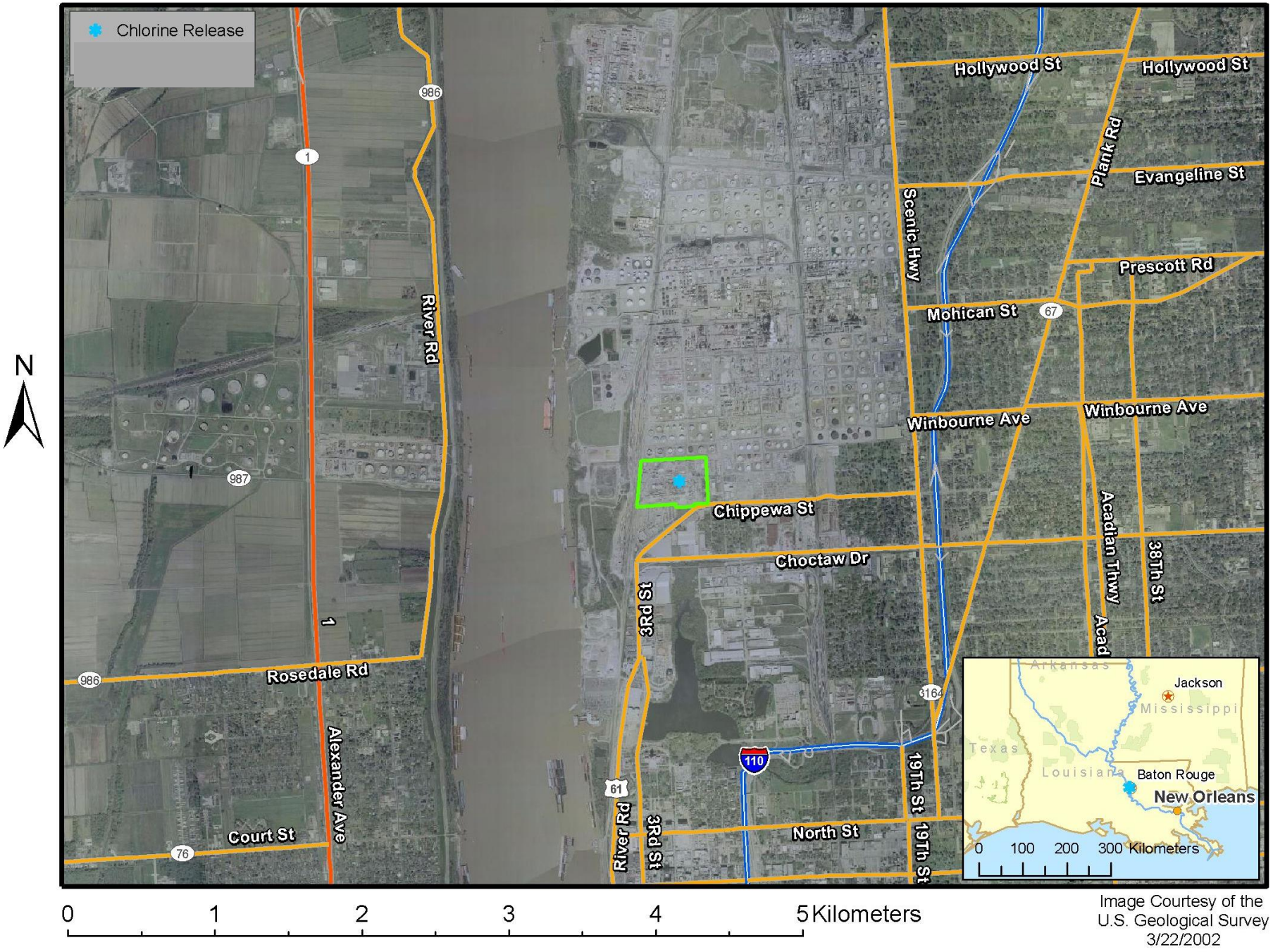
Ammonia Concentration (ppm - one hr avg) Vertical Plane, 0 m Crosswind

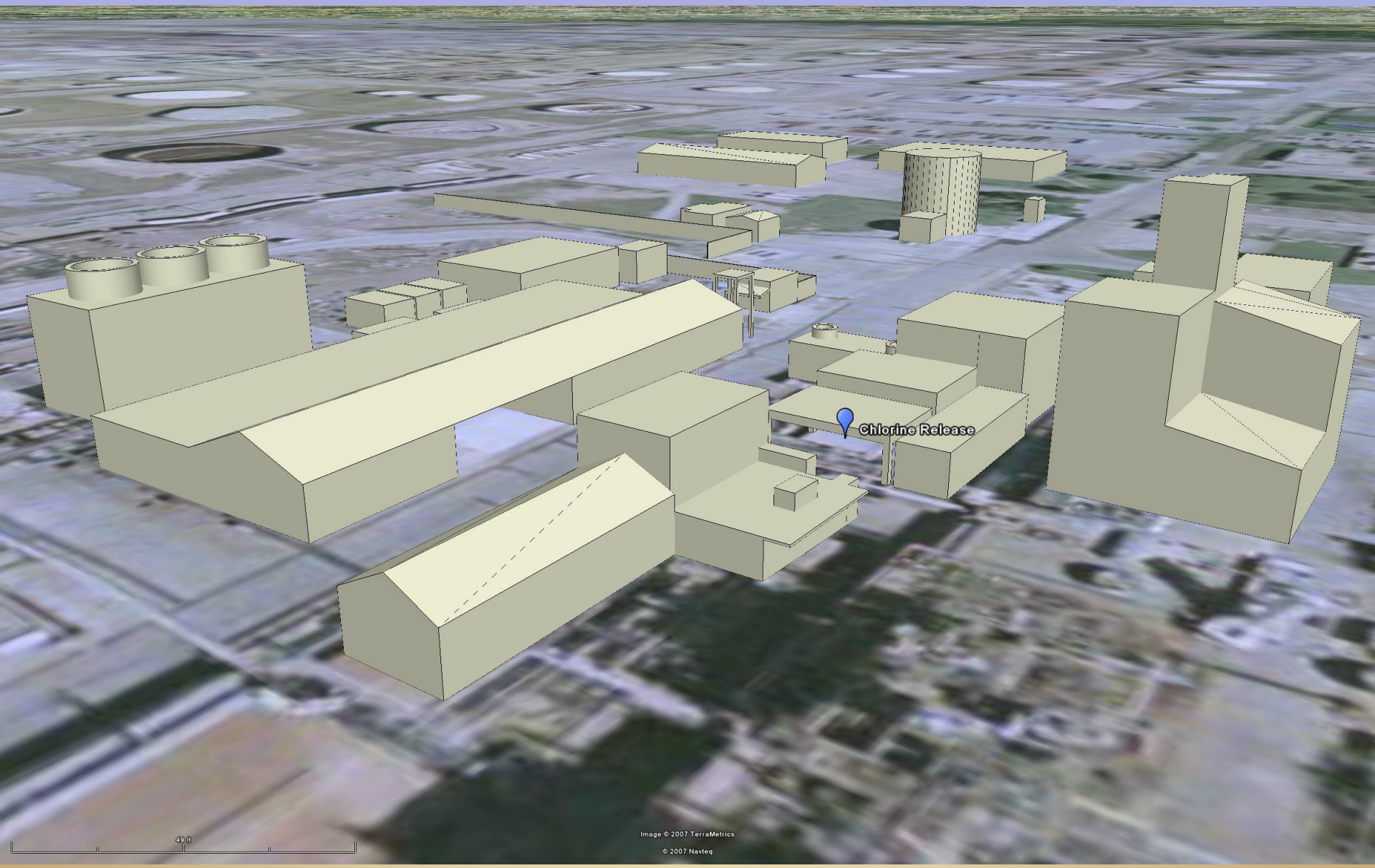
ISCST3 Simulated Ammonia Concentrations



CASE STUDY

Chlorine Release in Baton Rouge, Lousiana


Chlorine Release
N
Hollywood St
Hollywood St
Plank Rd
Evangeline St
Scenic Hwy
Prescott Rd
Mohican St
67
River Rd
Winbourne Ave
Winbourne Ave
Chippewa St
Choctaw Dr
3Rd St
Acadian Thwy
38Th St
986
1
987
Rosedale Rd
Alexander Ave
Court St
76
3164
110
61
River Rd
3Rd St
North St
19Th St
19Th St
Arkansas
Jackson
Mississippi
Texas
Louisiana
Baton Rouge
New Orleans
0 100 200 300 Kilometers
0 1 2 3 4 5 Kilometers
Image Courtesy of the
U.S. Geological Survey
3/22/2002


Chlorine Release
Image © 2007 TerraMetrics
© 2007 Navteq

ISCST3 Simulation of Chlorine Release

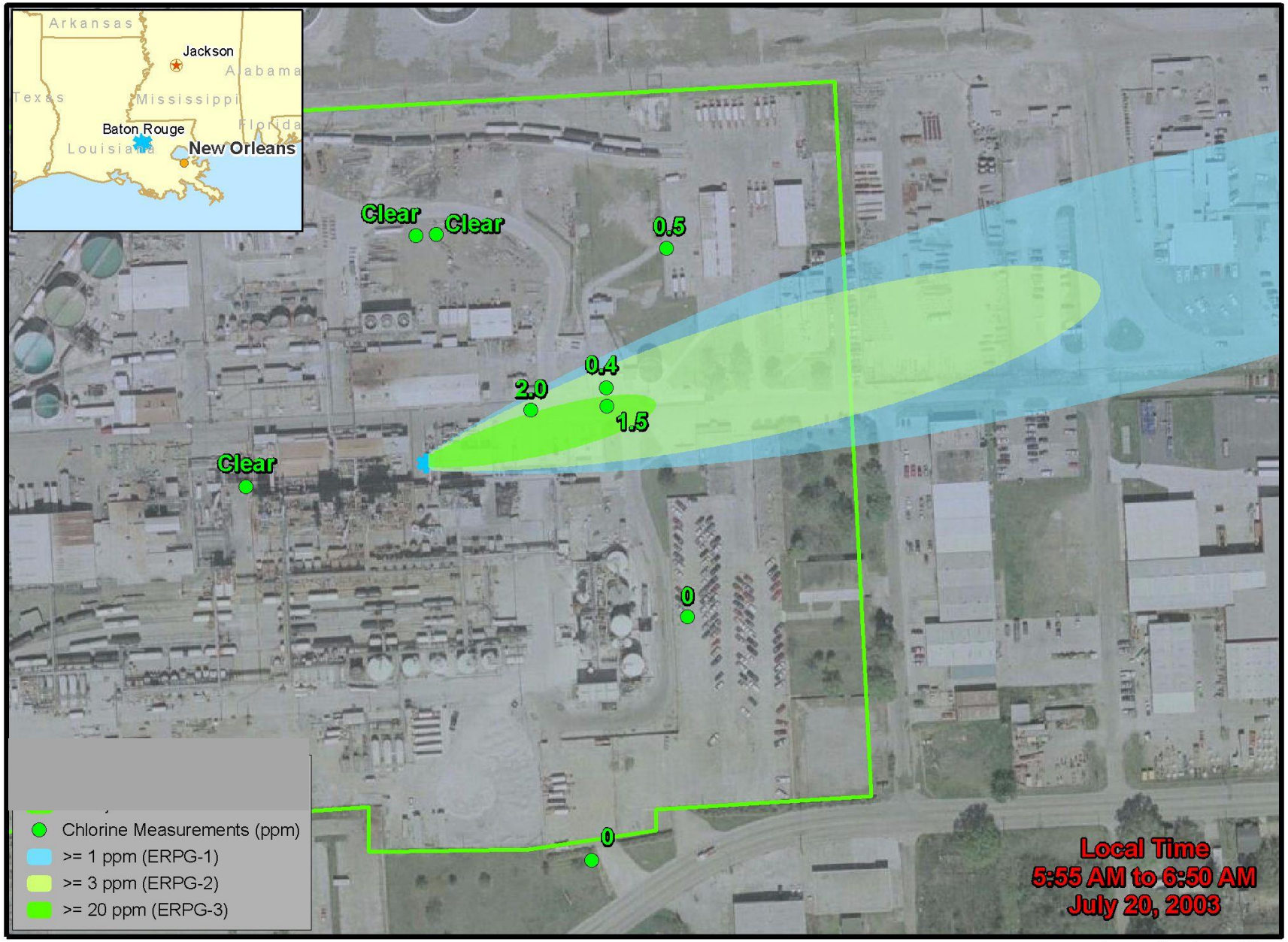


Image Courtesy of the U.S. Geological Survey 3/22/2002

Simulations of Release with Chlorine Measurements

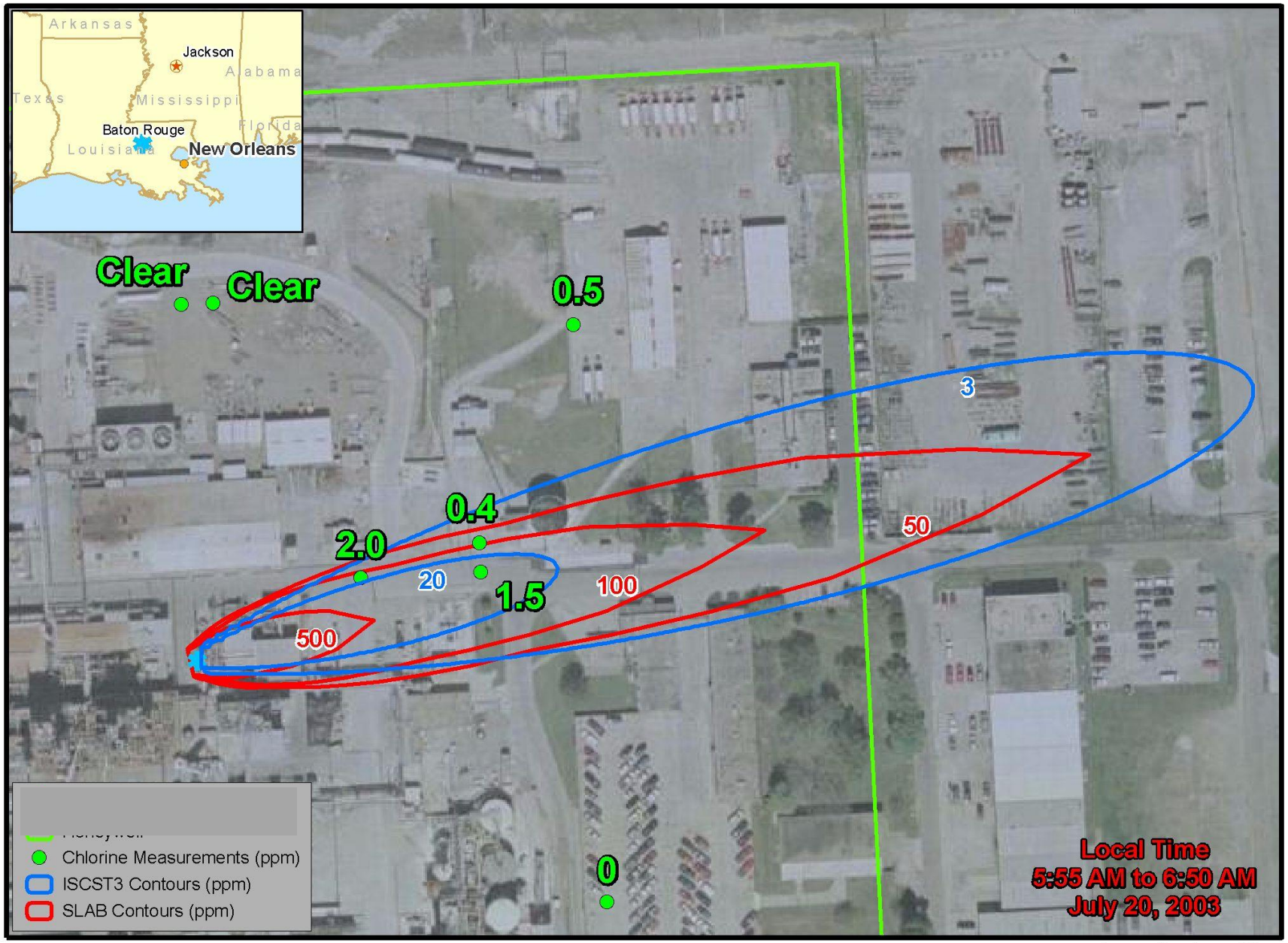


Image Courtesy of the U.S. Geological Survey 3/22/2002

CASE STUDY

Rubio Incident

Thanks!

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