Simulated $PM_{2.5}$ Health Impacts in California's San Francisco Bay Area

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Introduction

About 7.2 million people live in the San Francisco Bay Area, a major metropolitan region in California. The area attains the national annual $PM_{2.5}$ standard but violates California's annual standard and the national 24-hour $PM_{2.5}$ standard.

The Bay Area Air Quality Management District routinely applies photochemical air quality modeling to study how emission reductions would reduce $PM_{2.5}$ concentrations. As the region makes progress toward meeting national and California standards, local interests have broadened to include understanding the health benefits of reductions in ambient $PM_{2.5}$ levels.

In this preliminary study, **health outcomes were estimated at high spatial resolution** by ***coupling the*** $PM_{2.5}$ ***modeling system with a health impacts model*** (BenMAP; US EPA 2008). The study explores using model predictions, adjusted to measurements, as opposed to using sparse measurements alone, for estimating population health impacts.

Air Quality Modeling

- Four-km horizontal grid resolution
- Emissions inventory development (SMOKE)
- Meteorological modeling (MM5 and WRF)
- Photochemical $PM_{2.5}$ modeling (CMAQ)
- Model performance evaluation for meteorological and air quality models
- Annual average $PM_{2.5}$ levels were estimated as the average of quarterly averages over four seasons. $PM_{2.5}$ levels were explicitly simulated for the highest winter season. As a preliminary estimate, the winter $PM_{2.5}$ spatial distribution was scaled to represent other seasons
- Simulated $PM_{2.5}$ levels were uniformly adjusted such that the 98th percentile of simulated $PM_{2.5}$ matched the observed 2010 design value

Health Impacts Modeling

BenMAP

- Overlays population data onto changes in pollutant levels to estimate health impacts
- Estimates monetary value of health effects for both morbidity and mortality
- Includes the amount people are willing to pay to avoid premature death

BenMAP Inputs

- Simulated $PM_{2.5}$ concentrations (4-km horizontal resolution)
- 2000 US census, projected to 2010

Health Benefit Scenarios

- **Scenario 1: Reducing $PM_{2.5}$ to background**
  - Simulated 2010 $PM_{2.5}$ levels (base year)
  - Assumed natural background levels (90 percent reductions in anthropogenic emissions)
- **Scenario 2: Incremental reductions**
  - Simulated 2010 $PM_{2.5}$ levels (base year)
  - Incremental uniform reductions in $PM_{2.5}$; increments of 1 μg/m^3 from 2010 levels (98th percentile 31 μg/m^3) to 20 μg/m^3

Results – Simulated $PM_{2.5}$

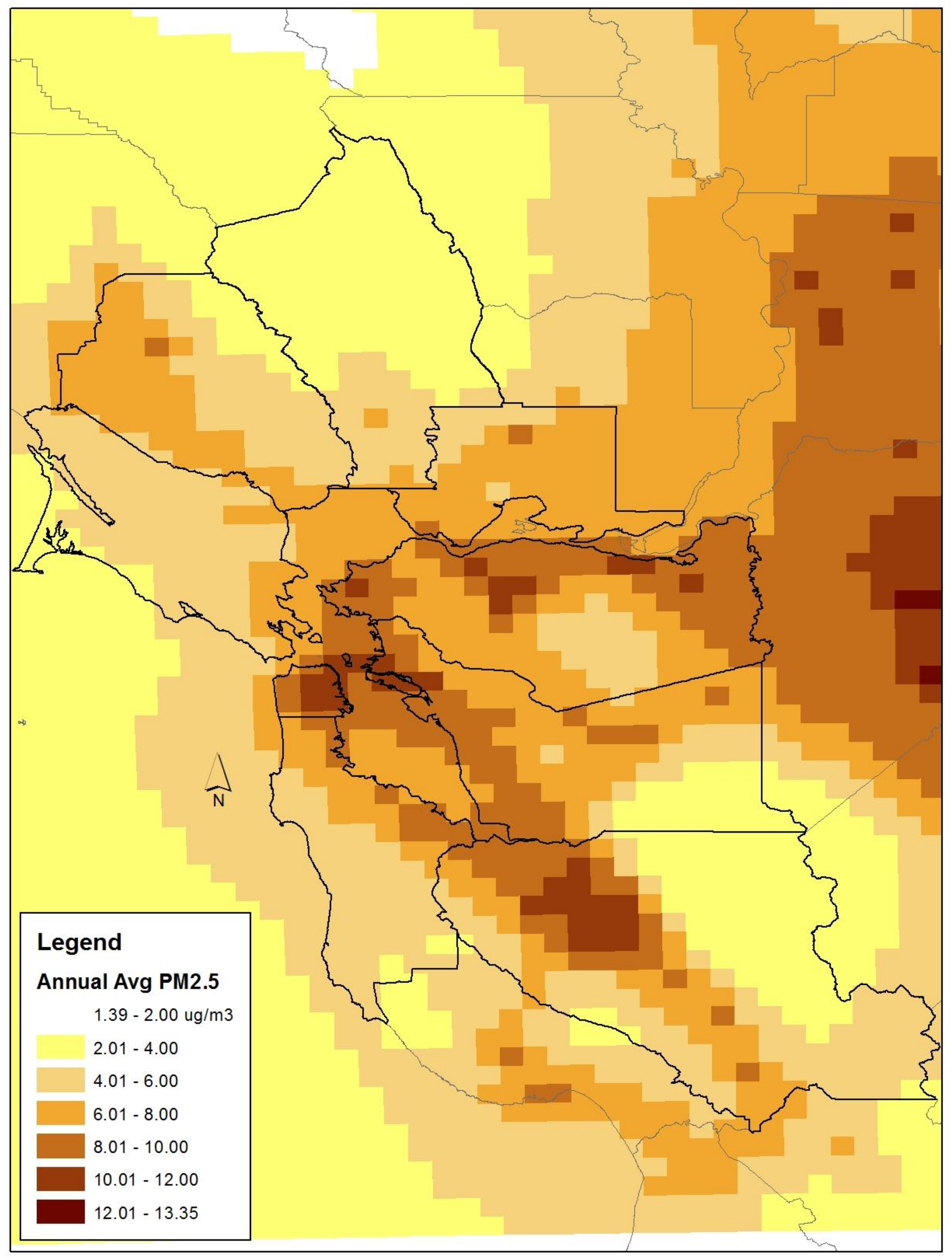

Figure 1. Annual average $PM_{2.5}$ levels were estimated as the average of the quarterly averages over four seasons.

Results - Scenario 1 Health Benefits

Table 1. Benefits of reducing $PM_{2.5}$ levels to background.

Health Endpoint	Total Incidents Reduced
Mortality (all causes)	1,705
Chronic bronchitis	1,446
Heart attacks (nonfatal)	1,569
Emergency room visits, respiratory	1,116
Acute bronchitis	2,723
Acute respiratory symptoms	1,722,345
Work loss days	294,127
Asthma exacerbation	35,363

Results - Scenario 1 Health Benefits

Respiratory symptoms are by far the most common direct health effect attributed to $PM_{2.5}$(Table 1).

Mortality rates from 2010 $PM_{2.5}$ levels were found to be about 300 per million in the Bay area, or approximately 5 percent of the total, non-accident, observed death rate.

The number of children's emergency room visits per unit population varies within the Bay Area. **Areas predicted to have relatively large ER visits have high numbers of asthmatics and high $PM_{2.5}$ concentrations** (Figure 2). While asthma ER visits and hospitalizations are different, we do see significant spatial correlation between predicted ER visits and observed hospitalizations for children (Figure 3).

Monetary benefits (Table 2) of $PM_{2.5}$ reductions are dominated by reductions in mortality. Morbidity values, though lower, include willingness to pay to avoid illness and actual cost of illness and may be less subjective.

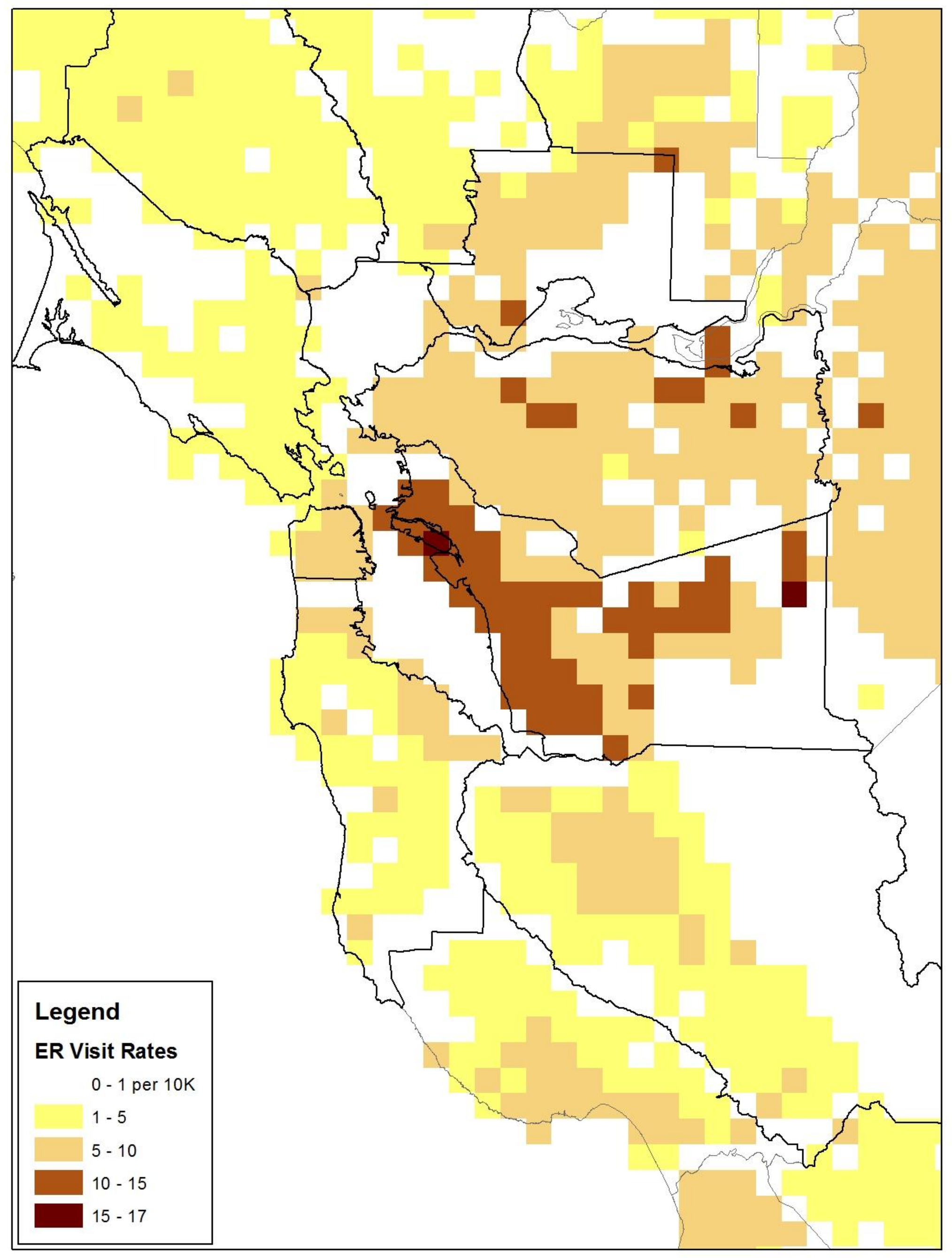

Figure 2. Reductions of asthma-related emergency room visits per 10K population of children under 18.

Table 2. Monetary values associated with health impacts (2006 US dollars).

County	Mortality Valuation (million)	Morbidity Valuation (million)	Total (million)	Mortality Valuation per Capita
Alameda	$2,715	$201	$2,917	$1,751
Contra Costa	$2,206	$154	$2,360	$2,050
Marin	$410	$25	$436	$1,618
Napa	$216	$11	$228	$1,515
San Francisco	$1,893	$119	$2,013	$2,314
San Mateo	$1,000	$69	$1,069	$1,357
Santa Clara	$2,728	$237	$2,965	$1,485
Solano	$614	$44	$658	$1,392
Sonoma	$806	$50	$856	$1,626
Grand Total	**$12,590**	**$915**	**$13,505**	**$1,712**

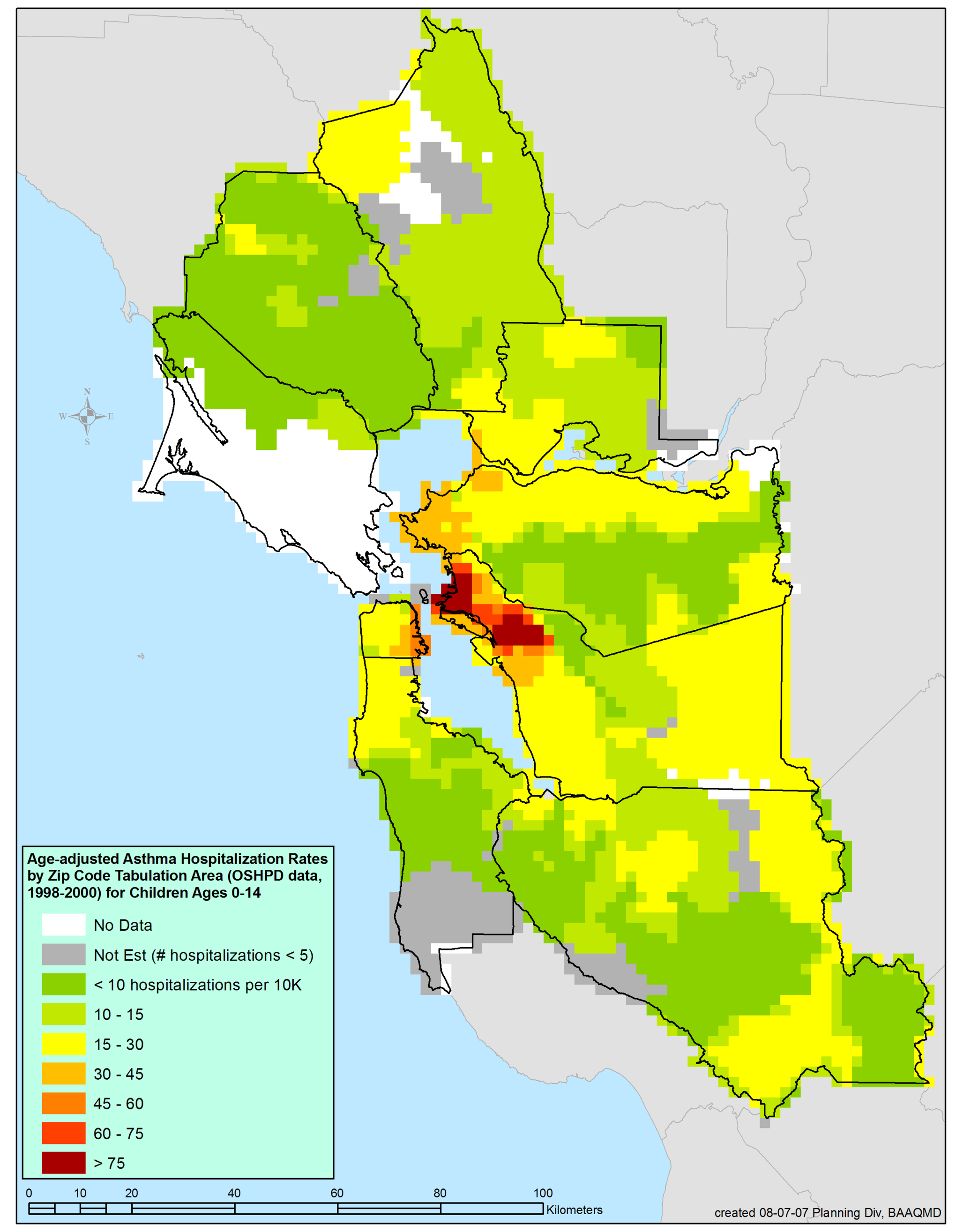

Figure 3. Age-adjusted asthma hospitalization rates, children 0-14, OSHPD data 1998-2000.

Results - Scenario 2 Health Benefits

Table 3. Benefits of per μg/m^3 reduction in $PM_{2.5}$.

Health Endpoint	Total Incidents Reduced
Mortality (all causes)	66
Chronic bronchitis	61
Heart attacks (nonfatal)	71
Emergency room visits, respiratory	46
Acute bronchitis	117
Acute respiratory symptoms	68,348
Work loss days	11,530
Asthma exacerbation	1,362

We estimated 66 avoided deaths annually per μg/m^3 reduction in $PM_{2.5}$ (Table 3) with associated annual benefits of about $500 million per μg/m^3. Annual benefits from morbidity reductions totaled about $37 million per μg/m^3. For the range of concentration differences considered, BenMAP's response was linear for both mortality and morbidity.

Summary, Next Steps

Current pollutant levels contribute significant negative health impacts to the Bay Area's population

Reducing $PM_{2.5}$ can result in half a billion dollars in benefits for every 1 μg/m^3

Next steps include

- PM simulations for each season
- Consistency in comparing to observed health outcomes

For additional information:
http://www.baaqmd.gov/Divisions/Planning-and-Research/Research-and-Modeling.aspx