Logan Airport Health Study

EXECUTIVE SUMMARY

MAY 2014

Massachusetts Department of Public Health

Bureau of Environmental Health

BACKGROUND

Chapter 159 of the Acts of 2000 included a line item directive that stated "*the Director of the Bureau of Environmental Health Assessment* [presently named the Bureau of Environmental Health] *of the department shall conduct an environmental risk assessment of the health impacts of the General Lawrence Logan Airport in the East Boston section of the city of Boston on any community that is located within a 5 mile radius of the airport and is potentially impacted by the airport.*" The 17 communities located either fully or partially within the five-mile radius of the airport include Boston, Brookline, Cambridge, Chelsea, Everett, Hull, Lynn, Malden, Medford, Melrose, Milton, Nahant, Quincy, Revere, Saugus, Somerville, and Winthrop. Based upon this directive the Massachusetts Department of Public Health, Bureau of Environmental Health (MDPH/BEH) designed and conducted the Logan Airport Health Study (LAHS).

In the early stages of design of the LAHS, the MDPH/BEH formed a Community Advisory Committee (CAC) composed of area residents, local health officials and technical experts in the areas of epidemiology, biostatistics, survey design and administration, and air modeling. With input from the CAC, the MDPH/BEH designed and implemented a cross-sectional disease and symptom prevalence study that investigated the associations between opportunities for exposure to airport emissions and adverse health outcomes. Environmental exposure data included noise and air emissions. Air pollution emissions are primarily from aircraft operations, ground service equipment, transportation vehicles on airport property, and the airport power plant. The primary source of noise from the airport is that of aircraft takeoff and landing operations. Three categories of health outcomes were evaluated: respiratory, cardiovascular, and auditory effects.

SURVEYED POPULATION AND HEALTH QUESTIONNAIRE

Following a pilot study aimed to test survey methods initiated in 2002, interviews for the LAHS commenced in 2005. A total of 6,072 eligible residents representing households from the 17 communities that make up the study area were interviewed. These adult respondents also provided information for 2,215 children living in those respective households. Therefore, the results of the LAHS represent information for 8,287 individuals living within five miles of Logan Airport. The telephone interviews, conducted in English and Spanish, collected information on the prevalence of targeted health outcomes as well as relevant demographic and risk factor information. Information was collected for one adult in each of the interviewed households and for any children aged 3-17 years.

Study participants were selected randomly so that the survey results could be considered representative of the study area. A strategy was also employed to oversample residents living closest to the airport to ensure an adequate sample size representing those with the highest potential exposure. Statistical weighting methods were then employed to account for the oversampling.

Modeled after nationally and internationally recognized health surveys, including the Behavioral Risk Factor Surveillance System (BRFSS) and the International Study of Asthma and Allergies in Childhood (ISAAC), the LAHS survey contained questions designed to assess the following categories of asthma and respiratory disease: lifetime asthma, current asthma, current asthma with medication use, probable asthma, asthma hospitalizations, and chronic obstructive pulmonary disease (COPD). Cardiovascular outcomes included non-fatal heart attack, angina, and coronary heart disease. Auditory effects included adult-onset hearing impairment and tinnitus. In addition to assessing the presence of health outcomes, the survey also included questions on risk factors associated with the targeted health outcomes, on potential exposures inside the home and at work, and questions reflecting demographic and socio-economic status. A ten-year residential history was also

taken in order to provide some measure of each respondent's length of residency in the area.

EXPOSURE ASSESSMENT: AIR POLLUTANTS

Air pollutant emissions typically associated with airport operations are largely due to incomplete combustion of fuel from aircraft, ground service equipment, and passenger automobiles on airport property. To estimate potential air pollution exposure specifically from airport-related operations (and thereby exclude possible exposure from non-airport related sources), advanced high-resolution air dispersion modeling (US FAA EDMS model version 5.1.3) was applied to predict ambient concentrations across the study area of five primary air pollutants (CO, NOx, $PM_{2.5}$, SOx, VOCs). The air dispersion modeling was based on 2005 emissions data, meteorological inputs, and aircraft takeoff and landing information for over 350,000 aircraft operations (94% of total 2005 operations). The modeling analysis also estimated emissions along flight paths up to an altitude of 3000 feet for takeoffs and landings. Data on emissions and airport operations were provided by Massport.

Using ArcGIS to map the 6,072 households included in the study, air pollutant concentrations were assigned to each respondent based on inverse-distance weighting of concentrations predicted from the air dispersion modeling. Given the very high correlation of estimated concentrations of the five pollutants across the study area, a combined exposure variable was developed that encompassed all pollutants. Annual average pollutant concentrations were selected for developing cut-points for the creation of three exposure areas estimating lower, medium, and higher potentials for exposure to airport-related air pollution.

EXPOSURE ASSESSMENT: NOISE

MDPH/BEH also evaluated noise exposure across the study area using noise contours from aircraft operations provided by Massport. Using US FAA's Integrated Noise Model (INM),

Massport models noise by considering the number of operations, types of aircraft operating during the day and night, use of runway configurations, and location and frequency of flight paths to and from the runways. Massport produces annual Day-Night Sound Level (DNL) contours that range from 60-75 dBA at five dB increments. The WHO health-based guideline to protect against hearing impairment is 70 dBA. This guideline value indicates that the risk for hearing impairment would be negligible for a cumulative noise exposure below 70 dBA on a daily basis over a lifetime. Review of the 2005 INM noise contours indicated that the 70 dBA contour did not include a sufficient number of respondents to assign as the high noise exposure category. As a result, the 65 dBA contour was selected as the high noise exposure area. The medium noise exposure area was defined by households located in the 60-64 dBA noise contour and the low noise exposure area was defined by households located outside the 60dBA noise contour.

STATISTICAL ANALYSIS

All analyses were conducted using SUDAAN, a statistical package designed for use with complex sampling methodologies, which incorporates weighting and variance calculations associated with the complex random digit dialing (RDD) sample design. Descriptive analyses were conducted separately for adults and children to assess the frequencies (percent of the population) with various socio-demographic characteristics. The prevalence of other potential factors (covariates) that may be associated with each specific outcome among adults and children were also estimated. The prevalence of each health outcome of interest was examined in the total population and among those living in each category of estimated airport-related air pollution or noise exposure.

Multivariate analysis (multiple logistic regression) was used to assess the association between the prevalence of targeted health outcomes and residence in low, medium, or high exposure areas while accounting for the impact of other potentially influential factors (confounders). Controlling for other factors known to be strong predictors of the health outcome being investigated is a statistical method to evaluate the association of interest,

while adjusting for differences across exposure areas for other risk factors such as age, race, smoking status, family history of heart disease, or residential proximity to major roadways.

RESULTS / CONCLUSIONS

The major conclusions of the Logan Airport Health Study are as follows:

- Air dispersion modeling of airport related emissions using a state-of-the-art model indicates that the highest predicted pollutant concentrations associated with airport-related operations are near the perimeter of Logan Airport and fall off rapidly with increased distance. This is a characteristic of the impact of sources that are primarily located near the ground surface.

- Consistent with findings of other airport studies, modeled concentrations of air pollutants are low relative to measured background air pollution concentrations.

- Evaluation of associations between airport-related pollutant concentrations and targeted health outcomes among the study area population detected some elevations in respiratory health outcomes in the high exposure area.

  Specifically:

- Among children, study results identified some respiratory effects indicative of undiagnosed asthma (i.e., probable asthma); children in the high exposure area were estimated to have three to four times the likelihood of this respiratory outcome compared with children in the low exposure area.

- Among adult residents, individuals diagnosed with chronic obstructive pulmonary disease (COPD) were statistically significantly more likely to have lived in the high exposure area for three or more years.

- There were no statistically significant differences in cardiovascular outcomes in the study population across the high, medium, and low exposure areas.

- There were no statistically significant differences with respect to hearing loss in either adults or children for those living in the high exposure area compared to the lowest exposure area.

RECOMMENDATIONS

- The results of this study should be reviewed by Massport and others to determine mitigating steps that can be taken across the study area.

- Massport has undertaken initiatives to reduce air pollution impacts within their control (e.g., providing infrastructure for compressed natural gas (CNG) fuels and electricity charging stations, Alternative Fuel Vehicle Program). Similar initiatives could be considered in consultation with local communities that would serve to further reduce the burden of indoor and outdoor sources of air pollution on residents in closest proximity to the airport.

- Massport has also been working with the East Boston Neighborhood Health Center (EBNHC) to address workforce issues among Massport employees. Massport could expand these efforts with the EBNHC as well as other community health centers to better address respiratory health notably among children in closest proximity to the airport.

- While air dispersion modeling indicates that the contribution from Logan Airport operations across the study area is relatively small, air pollution levels are higher in urban areas. Predicted pollutant concentrations were higher near the perimeter of the airport; thus, any methods that can be implemented to continue to reduce airport-related air pollution should be explored.

- MDPH/BEH should work with communities within the high exposure area (in whole or in part) on initiatives that would serve to further reduce exacerbation of pre-existing respiratory diseases (e.g., asthma and COPD) among residents.

  Specifically:

  - MDPH/BEH will continue to support MassDEP's efforts to reduce motor vehicle emissions including implementation of the Low Emissions Vehicle program and diesel engine retrofit initiatives;

- Upon request MDPH/BEH's Indoor Air Quality (IAQ) Program staff will work with local municipalities to conduct IAQ assessments in schools and public buildings;

- Upon request MDPH will work with local officials to address concerns that may be associated with local development initiatives;

- MDPH/BEH will collaborate with the MDPH Bureau of Community Health and Prevention's Tobacco Cessation and Prevention Program on their efforts to work with local boards of health and tobacco-free community partnerships. These efforts enforce youth access and secondhand smoking laws and provide educational/outreach resources to support smoke-free workplace and housing programs.

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Questions and Answers
Logan Airport Health Study

1. **Q: Why did the Massachusetts Department of Public Health, Bureau of Environmental Health (MDPH/BEH) conduct a health study for Logan Airport?**

   A: The Acts of 2000 originally included a line item directive that "the Director of the Bureau of Environmental Health Assessment of the department shall conduct an environmental risk assessment of the health impacts of the General Lawrence Logan Airport in the East Boston section of the City of Boston or any community that is located within a 5 mile radius of the airport and is potentially impacted by the airport." Despite varying levels of resources and line item directives over the past decade, the MDPH/BEH conducted the Logan Airport Health Study to respond to this directive.

2. **Q: How was community input received in designing the Logan Airport Health Study (LAHS)?**

   A: MDPH/BEH held a number of community meetings to hear health concerns of residents and to share information from the medical literature on health impacts evaluated in other studies involving community environmental concerns associated with living near airports. MDPH/BEH also formed a Community Advisory Committee (CAC) composed of residents, local health departments, and technical experts in epidemiology, biostatistics, survey design and administration, and air modeling. With input from community meetings and the CAC, MDPH/BEH designed and implemented a cross-sectional disease and symptom prevalence study evaluating potential associations between exposure to airport emissions and adverse health outcomes.

3. **Q: What was the overall goal of the LAHS?**

   A: The overall goal of the LAHS was to determine whether residents living in areas with greater potential for airport-related exposures were more likely to experience respiratory, cardiovascular, or auditory effects compared to those residents living in areas with lesser potential for airport-related exposures.

4. **Q: What environmental conditions did the LAHS evaluate?**

   A: MDPH/BEH considered the potential health impacts on local communities of both noise and environmental conditions associated with Logan Airport. Air pollution sources at the airport included aircraft (takeoff, landing, taxiing, and use of auxiliary power units), ground service equipment, passenger and commercial motor vehicle fleets operating and parking on airport property, and the airport power plant. The primary sources of noise from the airport were aircraft takeoff and landing operations.

5. **Q: Who was included in the study?**

   A: Information on more than 8,000 residents (6,072 adults and 2,215 children) was collected in the survey. Residents interviewed were randomly selected so that the survey results could be considered representative of the study area.

6. **Q: How did MDPH/BEH determine exposure opportunities within the 5-mile radius of Logan Airport?**

   A: The study area was geographically categorized into three exposure areas based on the best available data for predicting ambient concentrations of air pollution associated with airport operations and noise associated with aircraft operations.

7. **Q: How did MDPH/BEH determine if residence near Logan Airport was or was not likely to impact the health of nearby residents?**

   A: Results from the survey interviews enabled MDPH/BEH to address the complexity in assessing environmental impacts of airport operations. MDPH/BEH collected data on the prevalence of targeted health outcomes, demographic information, and various risk factor characteristics among residents living in the designated 5-mile radius study area. Statistical analyses were then conducted to determine whether residents living in areas with greater potential for airport-related exposures were more likely to experience the targeted health outcomes compared to residents living in areas with lesser potential for airport-related exposures.

8. **Q: Was the study peer reviewed?**

   A: Yes, MDPH/BEH established an external peer review panel for the LAHS in 2002 to review the study design and statistical analyses protocol for conducting the work. The peer review committee has been involved in review of all activities associated with the LAHS. This included review and comment on the study design, statistical analyses protocol, statistical analyses, as well as the findings and recommendations contained in the report.

9. **Q: Who was on the peer review committee?**

   A: The peer review committee consisted of well-known scientists including Dr. Thomas Burke, Associate Dean for Public Health Practice and Training at the Johns Hopkins Bloomberg School of Public Health; Dr. Thomas Mason, Professor, College of Public Health, Department of Environmental and Occupational Health, University of South Florida; and Dr. Philip Hopke, Bayard D. Clarkson Distinguished Professor, and Director of the Center for Air Resources Engineering and Science, at Clarkson University.

10. **Q: What did the study conclude about environmental exposures related to Logan Airport?**

    A: Modeling indicated that the highest predicted pollutant concentrations associated with airport operations are near the perimeter of the airport and fall off rapidly with increased distance. Consistent with findings with other airport studies, modeled concentrations of the pollutants are low relative to measured background air pollutant concentrations (i.e., combined sources of all air pollution).

11. **Q: What did the study conclude about health?**

    A: Evaluation of associations between airport-related exposures and health outcomes among the study area population revealed some elevations in respiratory health outcomes in the high exposure area (that is, nearest the perimeter of Logan Airport). Specifically, in adults, COPD was statistically significantly higher for residents who had lived 3 or more years in the high exposure area. Children in the high exposure area were estimated to be 3-4 times more likely of having probable asthma (undiagnosed asthma) compared with children in low exposure area. The study did not detect differences in cardiovascular or auditory (hearing loss) effects across the study area. Cardiovascular disease prevalence was lower in the study population as a whole.

12. **Q: What does the study recommend in response to findings?**

    A: Follow-up recommendations of the LAHS include:

    - The results of this study should be reviewed by Massport and others to determine mitigating steps that can be taken across the study area.

    - Massport has undertaken initiatives to reduce air pollution impacts within their control (e.g., providing infrastructure for compressed natural gas (CNG) fuels and electricity charging stations, Alternative Fuel Vehicle Program). Similar initiatives could be considered in consultation with local communities that would serve to further reduce the burden of indoor and outdoor sources of air pollution on residents in closest proximity to the airport.

- Massport has also been working with the East Boston Neighborhood Health Center (EBNHC) to address workforce issues among Massport employees. Massport could expand these efforts with the EBNHC as well as other community health centers to better address respiratory health notably among children in closest proximity to the airport.

- While air dispersion modeling indicates that the contribution from Logan Airport operations across the study area is relatively small, air pollution levels are higher in urban areas. Predicted pollutant concentrations were higher near the perimeter of the airport; thus, any methods that can be implemented to continue to reduce airport-related air pollution should be explored.

- MDPH/BEH should work with communities within the high exposure area (in whole or in part) on initiatives that would serve to further reduce exacerbation of pre-existing respiratory diseases (e.g., asthma and COPD) among residents.

Specifically:

- MDPH/BEH will continue to support MassDEP's efforts to reduce motor vehicle emissions including implementation of the Low Emissions Vehicle program and diesel engine retrofit initiatives;

- Upon request MDPH/BEH's Indoor Air Quality (IAQ) Program staff will work with local municipalities to conduct IAQ assessments in schools and public buildings;

- Upon request MDPH will work with local officials to address concerns that may be associated with local development initiatives;

- MDPH/BEH will collaborate with the MDPH Bureau of Community Health and Prevention's Tobacco Cessation and Prevention Program on their efforts to work with local boards of health and tobacco-free community partnerships. These efforts enforce youth access and secondhand smoking laws and provide educational/outreach resources to support smoke-free workplace and housing programs.

13. **Q: Who should I contact if I have specific concerns about the LAHS?**

A: Please contact:

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A Review of the Logan Airport Health Study (LAHS)
Released May 2014

Conducted For:
The Town of Winthrop, Massachusetts
Noise, Air Pollution and Airport Hazards Committee (WAHC)

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A. Introduction

In May 2014, the Massachusetts Department of Public Health, Bureau of Environmental Health (MADPH/BEH) released their report entitled the Logan Airport Health Study (LAHS). This document, and the research it reports, was required by Chapter 159 of the Massachusetts Acts of 2000, which contained a directive that stated "the Director of the Bureau of Environmental Health Assessment [presently named the Bureau of Environmental Health] of the department shall conduct an environmental risk assessment of the health impacts of the General Lawrence Logan Airport in the East Boston section of the city of Boston on any community that is located within a 5 mile radius of the airport and is potentially impacted by the airport."

The goal of this review of the LAHS is to help the Town of Winthrop, Massachusetts' Noise, Air Pollution and Airport Hazards Committee (WAHC) gain a better understanding of the study design and protocols. This critique will include an assessment of the following aspects of the report, and the adequacy of their documentation presented there:

1. the meteorological and air pollutant measurements (*i.e.*, source emission polluting factors and ambient air quality) data quality objectives, sampling and air pollution analysis methods, the air dispersion model applied, and whether they were appropriate and sufficiently complete to obtain the reported health effect conclusions;
2. the methods applied for setting the number of, and choosing the particular individuals for, the 5,000 plus participants in the telephone survey, and ensure that they were properly sampled from the population within the 5-mile radius of Logan International Airport.
3. the database generation techniques and statistical analysis methods used to assess the public health impacts within the telephone surveyed area.

Based on this assessment, recommendations are provided for possible other future health studies or analyses that could evaluate the effect of airport pollution on adult and children health effects (*e.g.*, respiratory, cardiac, vascular, cancers, and auditory effects [*e.g.*, hearing loss, learning disabilities, sleep disorders, heart attacks and strokes]).

B. Assessment of LAHS Meteorological and Air Pollutant Measurements and Modeling

As presented in the LAHS Report (2014), potential air pollution exposure from airport-related operations, air dispersion modeling (US FAA EDMS, Emissions and Dispersion Modeling System, Model version 5.1.3)* was applied to predict ambient concentrations across the study area of five primary air pollutants (CO, NOx, PM2.5, SOx, VOCs). Atmospheric dispersion modeling was for 2005 emissions data, meteorological inputs, and aircraft takeoff and landing information for over 350,000 aircraft operations. The modeling analysis included air pollution emissions along flight paths up to an altitude of 3000 feet for takeoffs and landings. The input data on airport operations and associated emissions were provided to the study by Massport. The ArcGIS program was employed to map the 6,072 households included in the study, air pollutant concentrations were assigned to each respondent based on inverse-distance weighting of concentrations predicted from the air dispersion modeling. Annual average pollutant concentrations were selected for developing cut-points for the creation of three exposure areas estimating groups of subjects that fell into Low, Medium, and High exposure to airport-related air pollution groups.

While the above choices for air emissions inputs and dispersion modeling cannot be assessed for accuracy without obtaining the raw emissions and meteorological data, inputting them into a dispersion model, and then comparing modeled results with the results presented in the LAHS report, the approach chosen for emissions and modeling appear to be state-of-the art, and should have provided useful estimates for the research conducted. However, since all this work was done to provide estimates for each household, the decision to lump individuals into three exposure groups (Low, Medium, High) is inappropriate, as that approach loses much of the exposure variability information within each group. This is shown in Table 1, taken directly from the LAHS report (2014), which show that the ranges of exposure associated with each group are quite wide, with the maximum $PM_{2.5}$ concentration being up to 6 times the minimum in

* http://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/edms_model/

the "Low" group, up to 3 times the minimum $PM_{2.5}$ concentration in the "Medium" group, and up to 7 times the minimum $PM_{2.5}$ in the "High" group.

Table 1. Range of Modeled Air Pollutant Concentrations Associated with the High, Medium, and Low Pollutant Exposure Categories (Table 4-5, LAHS Report, 2014)

Exposure Level	Number (%) Respondents	Range of Exposure ($\mu g/m^3$)				
		CO	NO_x	$PM_{2.5}$	SO_x	VOCs
Low	3034 (50%)	0.57 - 3.88	0.14 - 0.77	0.005 - 0.03	0.03 - 0.11	0.08 - 0.50
Medium	1834 (30%)	3.88 - 11.4	0.77 - 2.47	0.03 - 0.09	0.11 - 0.34	0.50 - 1.53
High	1204 (20%)	11.4 - 109	2.47 - 15.0	0.09 - 0.65	0.34 - 1.39	1.53 - 11.6

The large geographical areas and the wide range of exposures within a single category are also made obvious by Figures 1a. and 1b. below, with both drawn from the LAHS Report. Figure 1a. shows the wide expanses in and around Boston assumed by the LAHS Report's exposure groupings to have exactly the same exposure (i.e., in the same exposure category, High, Medium, or Low) by the LAHS Report. Figure 1b. (as extracted from Figure 4-3 of the LAHS Report) indicates that, based on the LAHS Report's own modeling, residents near Coleridge Street in East Boston are exposed to an average of about 0.15 $\mu g/m^3$ of airport $PM_{2.5}$ pollution, or nearly triple the level indicated by Figure 1b. to occur near Brookfeld Rd. in Winthrop (at approximately 0.06 $\mu g/m^3$). Despite this approximate 3-fold difference in exposures in these two nearby locales, the LAHS study treats them as having identical exposures, according to Figure 1a. (from Figure 4-5 of the LAHS Report). Thus, the High, Medium, Low subject exposure assessment groupings in the LAHS Report cause these residential exposure differences to be ignored in the study, assigning them the same exposure, resulting in a lowering of the power of the subsequent statistical analyses to detect effects, undermining the ultimate conclusions of the report substantially (see the Statistical Methods discussion below). The report never should have grouped exposures, and instead, should have retained all the exposure information, and utilized the actual residential exposures for each subject in the study analysis.

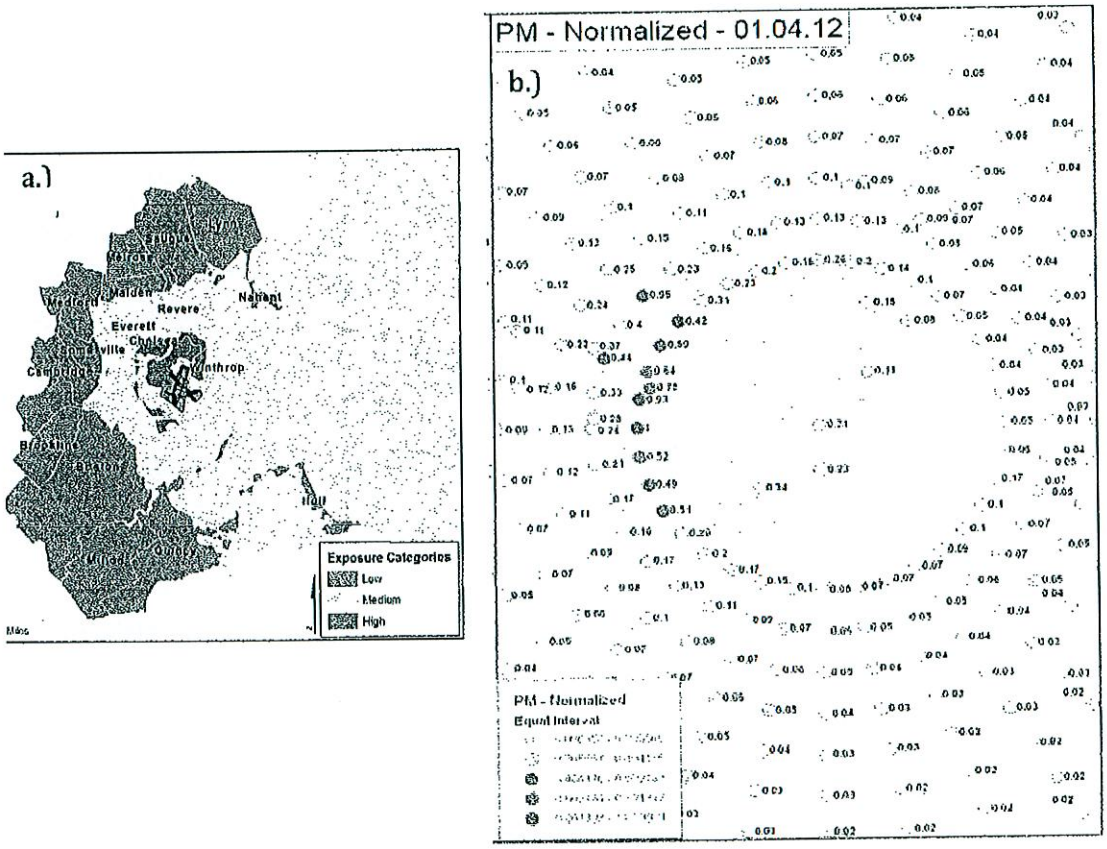

Figure 1. Maps of: a.) Areas Designated High, Medium, and Low Exposure Areas, and; b.) Modeled $PM_{2.5}$ concentrations around Logan Airport (extracted from Figures 4-5 and 4-3 of the LAHS Report, 2014)

C. Methods Applied for Participant Selection

As discussed above, the study population, comprised of roughly 6,000 adults and 2,000 children, was drawn from some seventeen communities surrounding Logan Airport that include a total of more than one million people. Thus, the study cohort population represents less than 1 percent of the actually affected population.

A key aspect of the study population was the decision as to how many subjects to include, which the report says was based upon a Power Analysis[†]. The report states that

[†] The power of a statistical test is the probability that it correctly rejects the null hypothesis (i.e., the hypothesis that there is no effect) when that null hypothesis is really false (i.e., when there actually is an effect). A Power Analysis can be used to calculate the minimum study population size required so that a planned investigation is likely to detect an effect of a given size.

"Based on the power calculation, for the study to have sufficient power (80 percent, α = 0.05) to detect an association between the exposure area of residence and the health outcomes of interest, it was estimated that a total of 6000 participants were required, corresponding to a total of 3000 residents in the "low" exposure area, 1500 in the "medium" area, and 1500 in the "high" area." While such a Power Analysis is an appropriate approach to choose an initial estimate of the necessary cohort size, no information is provided in the report as to the assumptions used to make this calculation on the study population size. For example, a key factor in defining the number of subjects required for a study is the effect size that you wish to detect, with more subjects being required to statistically detect a smaller effect size (i.e., a smaller Odds Ratio[‡], OR), but that study design choice is not noted in the report. That key information should have been provided for evaluation. Indeed, even a cursory examination of the study results now reveal that this was a study designed with inadequate power (insufficient population size) to test the hypothesis it purports to test: whether the air pollution is having a significant adverse effect on the respiratory, cardiac, or auditory health of surrounding residents. Thus, the LAHS study was preordained by its inadequate population sample size to be unable to detect most health effects as statistically significant by the inadequate size of the cohort selected at the start.

The fact that a larger cohort was needed can be shown by some simple analyses. First, a plausible effect size must be assumed to assess power and estimate a necessary population. The American Thoracic Society Statement entitled "What Constitutes an Adverse Effect of Air Pollution (ATS, 2000) states that, "At the population level, any detectable increment in symptom frequency should be considered as constituting an adverse health effect." While this guidance does not give a specific percentage change, the document does state that a "Reduction of the forced expiratory volume in 1 s (FEV1) was graded as mild, moderate, or severe for reductions of less than 10%, 10-20%, and more than 20%, respectively." Conservatively using the high end of this range, we can,

‡ An odds ratio (OR) is a measure of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure (Szumilas, 2010). Thus, an OR = 1.2 represents a 20% increase over expected (i.e., vs. the "Low Exposure" case, in this analysis).

for the purposes of a power analysis, assume an Odds Ratio of OR= 1.2 as an estimate of a minimum risk cut point of an effect size that we would definitely need to be able to detect. Using a power calculation calculator (http://www.dartmouth.edu/~eugened/power-samplesize.php), and assuming a prevalence of 14.8% for current asthma in the LAHS region (as reported in the LAHS Study, page 70), an OR=1.2, and a power of 80% to detect, it indicates that a study cohort population of roughly 13,375 subjects would be required to detect such an effect or larger, vs. the 2,192 (Table 6-4) in the LAHS cohort. Thus, there was never any chance of getting statistically significant effects at levels reasonably considered adverse (e.g., OR = 1.2 or greater) with the number of children in the study. Using the Power Calculator in another way, if we input the 2,192 population in the calculator, then it shows the effect size needed for statistical significance to be achieved in a population of this size would have to be 1.5 or larger for this example health outcome. Thus, the effect of the air pollution from the airport would need to increase asthma prevalence (a major health effect) by more than 50% to be considered statistically significant in the Logan Study cohort. Looking at the results for Current Asthma in Table 6-9 confirms this conclusion, as it shows an OR of 1.2 for Current Asthma, but it is not even close to statistical significance (p=0.52, vs. p-value<0.05 for statistical significance[§]) with this sample size: a sample size roughly 6 times as large would have been required to make this adverse effect become statistically significant in this study. It is therefore very understandable why this study, although it often found Odds Ratios of 1.2 (indicating an adverse effect causing a 20% increase in a disease outcome) or larger, it rarely reported them as statistically significant because of the lack of study power to deem those effects as statistically significant.

A similar analysis for effects among adults comes to the same conclusion: that this study had too few subjects to be able to statistically test the hypotheses that the study purported to test. For example, Table 6-7 reports a 20% increase for the Medium exposure level (OR=1.2), and a 30% increase for High exposure (OR=1.3), in Asthma Hospitalizations, but neither is reported as statistically significant (p =0.63 and 0.56,

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§ The p-value is the probability of an event (in this case of an Odds Ratio) of a given size occurring due to chance alone, so that an OR with a $p < 0.05$ would have less than a 5% chance of occurring by chance alone, and is deemed "statistically significant".

respectively) in the report, despite these large percent increases in disease found with increased airport pollution exposure. Conducting a power analysis as above for children, but with the reported adult Asthma Hospitalization rate of .247 (i.e., 24.7%, from Table 6-3), yields a sample size of 6,403 required to detect an effect at OR=1.2, or 10 times the sample size the study actually had for this health outcome. Thus, while the participant selection and data collection methods may have been appropriate, the sample sizes for both children and adults were insufficient to test the central hypothesis that the study set out to test: whether the airport air pollution was having an effect on the health of the surrounding community or not.

D. Statistical Analysis Methods Employed

As discussed above, the statistical analysis was conducted after grouping the subjects into three groups based on selected ranges of pollution exposures for each group, potentially resulting in people with up to 7 times higher pollution impact as lower exposed individuals in the same group. While this grouping is, as discussed above, a problem from an exposure assessment point of view, the process of grouping is also a large problem with regard to reducing the statistical power of the statistical analysis, beyond that caused by the too small sample sizes. As discussed widely in the published literature, grouping continuous data (such as has been done here for air pollution exposures) is ill advised. As stated by Altman and Royston (2006) in their British Medical Journal Statistics Notes, "much information is lost, so the statistical power to detect a relation between the variable and patient outcome is reduced. Indeed, dichotomising a variable at the median reduces power by the same amount as would discarding a third of the data". Similarly, D.L. Streiner (2002), in his article "Breaking up is hard to do: the heartbreak of dichotomizing continuous data." states: "in conclusion, the one word of advice about turning continuous variables into dichotomous is – don't". Clearly, there was no need for the categorization of the subjects into 3 different exposure groups, and the analysis would have had greater power to statistically detect effects had each subject kept their individual residential exposure estimate, rather than being grouped into High vs. Medium vs. Low exposure groups.

been used include the following:

- Generation of population/community level ambient pollution exposure maps;

- Comparison of benefits across multiple regulatory programs;

- Estimation of health impacts associated with exposure to existing air pollution concentrations;

- Estimation of health benefits of alternative ambient air quality standards.

The third of these above uses could be similarly applied to this Logan health impact analysis to give an alternative means of assessing Logan Airport's health effects on the public living in the study area, allowing health risks not directly studied by the LAHS to also be considered.

F. Conclusions

On the basis of this report, I conclude that the 2014 LAHS was a statistically underpowered study, inadequate to sufficiently assess the full extent and significance of the adverse health effects of air pollution impacting the surrounding communities. In particular, the results as they stand are not adequate to test the statistical significance of the many effects with OR >1.0 from the study, indicating that there is a much wider range of adverse health effects than concluded in the report. Indeed, the very large size of the impact effect estimates found by the report (e.g., many adverse health outcomes with OR ≥1.20) indicate, despite the inability of the study to determine statistical significance, that the airport has a much wider range of important health impacts than was concluded by the LAHS Report (2014). In addition, further Logan Study data re-analyses, including a statistical reanalysis of the available data on a continuous (rather than categorized) exposure basis to increase power, and the application of the US EPA's BenMAP model to the available air pollution impact data, should also be conducted to glean as much useful information as possible from the gathered study data.

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December 26, 2014

Mr. Anthony Majahad, Chair
Winthrop Noise, Air Pollution and Airport Hazards Committee
11 Golden Drive, Apt. 8
Winthrop, MA 02125-1825

Dear Mr. Majahad:

Thank you for providing us with a copy of comments offered by Dr. Thurston on the Logan Airport Health Study (LAHS). As you know, the Massachusetts Department of Public Health, Bureau of Environmental Health (MDPH/BEH) released its final report on the LAHS in May 2014. Although we appreciate the comments offered on this extensive and complex report, it is unfortunate that our offers to either meet with or talk to Dr. Thurston to address any questions were not responded to. Nonetheless, we have provided additional information and noted some inaccuracies in Dr. Thurston's summary review below.

Air Dispersion Modeling

We appreciate the recognition that the modeling used for Logan Airport emissions by MDPH/BEH was based on a state-of-the-art ambient air dispersion model to estimate the impacts of Logan Airport emissions (both from aircraft and airport operations) within the 5-mile radius study area designated in the legislative language. As you know, Dr. Bruce Egan, a world-renowned expert on air dispersion modeling, worked under contract with MDPH/BEH from the earliest days of planning and designing the LAHS to conduct the air modeling work that would ultimately be linked with health data. Appendix A of the report contains detailed descriptions of the model; emissions, meteorological, and other data inputted into the model; quality control measures to ensure accurate and complete data were inputted into the model; validation methods used to test the accuracy of modeled data; and extensive review of the final modeling output data.

Categorical vs. Continuous Exposure Data

It appears that one of Dr. Thurston's main comments focused on our grouping of low, medium, and high exposure categories (i.e., analyzing the exposures as categorical variables). He suggested that because there was variability in estimated air pollution contributions from Logan Airport within each of the exposure categories, that it would be more difficult to detect a health effect from these exposures than it would have been had the exposures of each individual in the study been evaluated (i.e., analyzing exposure as a continuous variable).

In an effort to be thorough and to explore the effects of air emissions from the airport on the study population, MDPH/BEH did in fact conduct analyses using exposure as a continuous variable. These results are contained in Appendix D and briefly discussed on page 97 of the main report. The results from the continuous analyses were consistent with those using categorical exposure and, therefore, did not alter the study conclusions or recommendations.

The LAHS report primarily presented results grouped in exposure categories since the principal goal of the study was to evaluate the risk of residents living closest to the airport. This goal was decided upon through discussions with the community residents and the LAHS Community Advisory Committee (CAC) early in the study design phase. You might be happy to learn that Dr. Brian Dumser, the CAC member representing the Winthrop Noise, Air Pollution and Airport Hazards Committee (WNAAHC), was perhaps the most vocal in providing this advice. While we did conduct continuous exposure analyses, that supported the categorical results, we chose to present most of the results in a manner that would be optimal for the report audience and to answer questions consistent with the legislative directive.

As we believe is evident from the LAHS report, our investigative team took care to approach the categorical analysis responsibly and followed recommended guidelines. Exposure was not dichotomized nor was the categorization based on the median or simple evenly distributed quantiles. Rather, the skewed distribution of the exposure data was evaluated when choosing categories and, to maximize efficiency, cut-points were chosen so that the tail of the distribution was sensibly captured. In fact, the high exposure area, located nearest the airport, actually represented the highest 20 percent of air pollution concentrations from airport operations across the entire study area, thereby capturing the population with the highest risk of exposure to airport operations.

Statistical Methods

Dr. Thurston suggests that there were not enough participants in the study, and thus, he believes that the study did not have sufficient statistical power to detect differences that may have actually existed among the different exposure groups. We disagree with this allegation and offer additional information on how MDPH/BEH calculated the sample size for the study and how we interpreted results of the analyses.

Heart disease was the endpoint chosen to calculate the necessary sample size as it was estimated to have a lower prevalence than asthma (7.8% compared to 10% using data from the 2003 BRFSS and the MDPH 2006 childhood asthma survey). An odds ratio of 1.2 was the effect size

used. To obtain a sample with sufficient power (80 percent, or a type II error rate of 20%) to detect an association between exposure area of residence and heart disease (with an OR of 1.2), it was determined that a total of 6000 completed interviews were required with at least 1500 in each of the high and medium exposure areas. Based on the calculations performed, the LAHS had sufficient power to assess impacts on respiratory and heart disease outcomes that the study was designed to address.

Having said that, MDPH/BEH has never relied exclusively on statistical significance to determine biological significance, or draw meaningful conclusions on health impacts nor did we do so for the LAHS. We recognize that statistical significance is a tool for evaluating epidemiologic study results, and that careful consideration must be given to the role of sample size, and possible confounding (e.g., other risk factors for a given disease) for each of the health outcomes evaluated. In fact, on page 61 of the LAHS report, it states that "borderline statistically significant results are noted particularly in cases where estimates show a consistent effect in one direction or another across several analyses or among similar health outcomes, suggesting a consistent effect." This point is underscored by our recommendation to follow-up on childhood asthma findings despite the fact that rates of current asthma were not statistically significantly higher in the higher exposure areas. Furthermore, we pointed out in our public comments that at the time health data were collected (2005) for the study, universal health care in Massachusetts was not available and had the health care coverage available today been available then, it is likely that we would have observed statistical significance for this outcome. This was one of the primary reasons we asked Massport to provide resources to community health centers to better address this children's health issue.

Dr. Thurston's Recommendations

Dr. Thurston offered three recommendations for additional work. We believe we have addressed the first two with contents offered in response to his specific criticisms. The third recommendation was to use the BenMAP program to estimate the health impacts and economic benefits related to changes in air quality. As he correctly noted, BenMap a tool used by US EPA to assess the impacts of new regulations related to air pollution and human health. It is a computer program developed by EPA to estimate the economic value of air quality changes based on hypothetical estimates of disease. As such, it is a useful tool for regulators, such as EPA, contemplating health, policy, and economic impacts of proposed regulations. The LAHS, on the other hand, was an environmental epidemiological study designed to evaluate the possible relationship between exposure to air pollution from Logan Airport operations and respiratory, cardiac, and auditory health effects. Disease data were generated from surveys conducted for over 6,000 households in the study area (representing more than 6,000 adults and more than 2,000 children) and associations between health and exposure to airport operations were estimated using data specific to Logan Airport. While BenMap is useful for estimating impacts of air quality measures where actual health data are not available, the software would not be an appropriate tool for conducting an environmental epidemiological investigation such as LAHS.

Other Health Outcomes

We were unclear about Dr. Thurston's multiple assertions concerning the inadequacy of the study design to assess health impacts such as learning disabilities and sleep disorders. The LAHS was not designed to assess these outcomes. You may be aware that the design of the study, including choice of specific respiratory, cardiovascular, and auditory outcomes, was done in consideration of the scientific literature and with input from community members, the CAC (including a member of the WNAAHC), local officials, medical and other technical experts, and others from the early stages of the study. We believe that it is inappropriate to criticize the study for not addressing questions it was never designed to answer. These types of comments are both unfair and scientifically inappropriate.

It is perhaps also worthwhile to note that throughout the entire process of designing the study, preparing analytic and other study protocols, conducting air modeling, administering the survey, drafting results of analyses, and preparing the final report, MDPH/BEH worked with its independent scientific peer review committee for continued dialogue and feedback. The peer review committee, critical for any scientific review process, supported the methods, results, and conclusions of the LAHS. In fact, one reviewer noted that exposure assessment is often considered the "Achilles Heel of environmental epidemiology studies, but this was taken to heart by BEH investigators as evidenced by the care with which 'distinct exposure areas' were classified prior to any analysis."

We hope this information is helpful to you. We look forward to continuing to work with residents of LAHS communities and the community health centers to further address the findings of the study and, importantly, to enhance mitigation efforts.

Sincerely,

Suzanne K. Condon, Associate Commissioner
Director, Bureau of Environmental Health

From: George Thurston <gdt1@nyu.edu>
Date: Friday, December 26, 2014 at 4:34 PM
To: "Condon, Suzanne (DPH)"

I am glad to find that a Continuous analysis was also conducted by the MDPH, as I suggested was needed. But the central point of my critique was not the analysis method, but that the study was severely underpowered, and then relied too heavily on statistical significance in making its Conclusions. Those points are still critically relevant. Once again, the details of the referenced Power Analysis conducted by the MDPH are not presented in full so as to allow an evaluation of them (e.g., what effect standard error was employed, and based upon what assumption/reference?). But, in any event, as I noted in my critique, it is made clear from the results printed in the report themselves that there was inadequate power to test an Odds Ratio of 1.2 (i.e., an increase of 20% in the higher exposure area vs. low exposure area) for cardiac events, despite claims that they could detect such an effect. As just one example, looking at Table 6-8 on page 79 of the Report, there is an Odds Ratio of 1.2 (in the lower right hand corner of the table) for Myocardial Infarctions (heart attacks) in the higher exposure area. The p-value given is 0.65, which is not even close to statistical significance (It would need to be <0.05 for that). The size of an effect

(Odds Ratio) to reach statistical significance would need be much larger to be classified statistically significant, or the size of the sample would need to be much larger to detect this size effect, as I noted in my critique. In this case, only an effect roughly three times higher would be statistically significant (or a very large, roughly 60% increase, for an OR of 1.6 , in Myocardial Infarctions), or the study would need to have a number (n) roughly 9 times larger. I stand by my central statement in my report that "Thus, the LAHS study was preordained by its inadequate population sample size to be unable to detect most health effects as statistically significant by the inadequate size of the cohort selected at the start."

Moreover, looking beyond the statistical significance question, at the results themselves as presented in the report, the OR's provided (such as 1.2 for Myocardial Infarctions and Current Asthma) indicate disturbingly large effects on the populations downwind of the airport, even though not statistically significant in this underpowered analysis, and not given sufficient weight in the conclusions. Indeed, the conclusions (on pg. ES-5 of the MDPH Report) about possible cardiac effects merely dismiss them by saying: "There were no statistically significant differences in cardiovascular outcomes in the study population across the high, medium, and low exposure areas.". Similarly, the report concluded "There were no statistically significant differences with respect to hearing loss in either adults or children for those living in the high exposure area compared to the lowest exposure area." Such sole reliance on statistical significance, as clearly made in the report to dismiss certain results, is unwarranted. This is now acknowledged in the letter from Suzanne Condon, dated 12-26-14, and on that we apparently can agree. A reassessment of the report results in that spirit by the MDPH, would be a welcome addition to the review process.

Sincerely,

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P. 20f2

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June 12, 2015

Mr. Anthony Majahad, Chair
Winthrop Noise, Air Pollution and Airport Hazards Committee
11 Golden Drive, Apt. 8
Winthrop, MA 02125-1825

Dear Mr. Majahad,

This letter is in response to comments offered by Dr. Thurston in response to our letter addressing his original comments on the Logan Airport Health Study (LAHS) and its final report. Dr. Thurston's comments continue to demonstrate a lack of familiarity with the LAHS aims and comprehensive findings described in the report. His comments find selective reference to certain tables and narrative without acknowledging others in the report. As you may be aware, our office has a very good track record of working with community advocates to address environmental health issues faced by Massachusetts communities. In the case of the LAHS, we worked closely with the Community Advisory Committee (CAC) for over a decade in the development and implementation of the approaches and scientific methods used in the study. We presented the findings of the study privately at meetings with the CAC and elected officials as well as publicly with over 100 residents in attendance in May 2014. We believe the concerns raised by Dr. Thurston are all fully addressed by the information provided in the LAHS report. We hope that the following will help to further clarify the issues raised.

1. Regarding sample size and statistical power:

   Power calculations for the LAHS study suggested a sample size of at least 6,000 to be adequate. While there were more than 6000 adults in the study, there were significantly fewer children. Nevertheless, the study did find significant effects of probable asthma in the children living closest to the airport, likely because the increased prevalence of this outcome compared to cardiovascular disease (the outcome used in power calculations) required a smaller sample size to detect a reasonable association. Please also keep in mind that the follow-up work underway is further addressing pediatric asthma in the study area. BEH intentionally based its power calculations on the outcome that would require the largest sample, thus ensuring an adequate sample size for the evaluation of other outcomes.

stronger associations between potential airport-related air pollution exposure and most of the targeted respiratory outcomes. These stronger associations reach the level of statistical significance for COPD **and are of borderline significance for current asthma with medication use.**

- From the Conclusions/Recommendations Section: In sub-analyses looking only at residents who lived in their respective exposure areas for longer, COPD was statistically significantly elevated in the higher exposure area and **there was a borderline statistically significant effect for current asthma with medication use, suggesting a possible exacerbation effect.**

4. Dr. Thurston appears to assume that there was an association between cardiovascular disease and airport air pollution in this population and that we simply failed to find it.

   - He states that, "It is made clear from the results printed in the report themselves that there was inadequate power to test an Odds Ratio of 1.2…for cardiac events, despite claims that they could detect such an effect. As just one example, looking at Table 6-8 on page 79 of the Report, there is an Odds Ratio of 1.2 (in the lower right hand corner of the table) for Myocardial Infarctions (heart attacks) in the higher exposure area. The p-value given is 0.65, which is not even close to statistical significance."

   - These statements indicate an assumption that failure to find an association is proof of a lack of statistical power to find such an association, an idea which grossly departs from basic principles of epidemiology. Not finding an association does not automatically imply lack of power. It may mean that no association is present. As Dr. Thurston notes, the p-value for the analysis isn't even close to being statistically significant. It is, essentially, a null finding.

   - Nevertheless, as previously noted, we conducted an additional supplemental analysis of cardiovascular mortality, which also did not support an association with the exposures estimated from Logan Airport.

In conclusion, we reiterate that this study was conducted with every resource available and using the highest scientific standards to answer the questions put to MDPH by the state legislature. The LAHS is one of only a few studies worldwide that have assessed potential health impacts associated with environmental exposures from airport operations. The data were analyzed thoroughly and carefully and, as Dr. Thurston initially overlooked, were evaluated using a continuous exposure measure in addition to the categorical exposure analyses, which became the focus of the report. The results of all analyses were evaluated comprehensively using appropriate epidemiologic principles; and the conclusions drawn are fully supported by the evidence as attested to by our independent and distinguished peer review committee. The study's recommendations reflect the need for increased efforts to address respiratory outcomes in children and adults in the high exposure area. In response, Massport has already worked with us and provided funding to community health centers in the highest exposure area to conduct in-home asthma and COPD interventions.

We appreciate the opportunity to respond to these additional comments. It is our sincere hope that we can work together to focus on the important follow-up that is being conducted as a direct result of the LAHS to better address respiratory health notably among children with asthma and adults with COPD living in closest proximity to the airport.

Sincerely,

Suzanne K. Condon, Associate Commissioner
Director, Bureau of Environmental Health