Appendix A.1: Exposure and Health Equity Assessment for Rule 6-5

2021-05-19: *Promoted to final from interim draft.*

2021-03-25: *Minor revisions to version 2021-01-27, to reflect reordering and renumbering of Appendices within Appendix A.*

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Contents

I. Overview

This Appendix provides technical details regarding the exposure and health equity assessments presented in Section V. Starting from block-level population estimates (Appendices A.2 and A.3) and model-estimated, incremental fine particulate matter ($PM_{2.5}$) concentrations (Appendices A.4 and A.5), this appendix documents the calculation of:

1. Block-level, source-specific incremental $PM_{2.5}$ concentrations; and
2. Population-stratified, source-apportioned residential impacts ("exposures").

Unless otherwise noted, all computations and data transformations were carried out using the R programming language, version 3.6.

II. $PM_{2.5}$ Concentrations and Study Area

A. *Input Data*

CALPUFF output (Appendices A.4 and A.5) consists of modeled incremental concentrations assigned to the cells of a raster (that is, a regular grid) at 100m resolution. Figure 2, below, depicts the raster values for the "baseline" scenario. The outermost contour represents a contribution of +0.1 µg/m3, which as an order-of-magnitude is approximately 1% of the total ambient concentration within the general area.

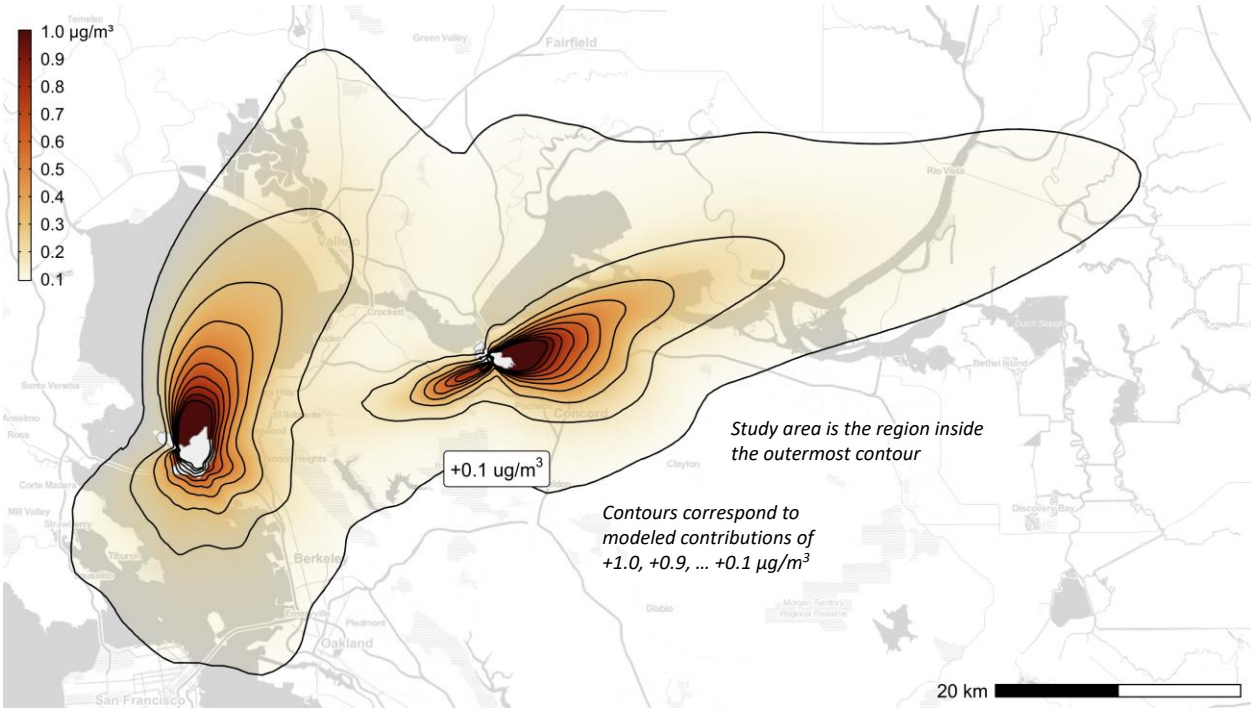

Figure 1. *Contributions of modeled baseline emissions to ambient $PM_{2.5}$. The outermost contour represents a contribution of +0.1 µg/m^3, which is approximately 1% of ambient $PM_{2.5}$ within the vicinity. Contributions less than +0.1 µg/m^3 (i.e., beyond the study area) are not shown. In this figure, all contributions larger than 1.0 µg/m^3 are shown using the same color—that is, the color scale is clamped to 1.0—but actual values were never clamped when computing exposures.*

B. *Study Area*

The +0.1 µg/m^3 contour illustrates the basis for the "study area", which scoped the subsequent population and exposure estimates. To be precise, the study area was taken to consist of all Census blocks for which the block-average $PM_{2.5}$ contribution (see next section) from all modeled baseline emissions combined was exactly 0.1 ug/m^3 or greater.[1]

[1] GIS operations were not used to intersect the contour with block polygons. The contour does encompass the set of block polygons that comprise the study area, but it also intersects some block polygons with an average concentration less than 0.1 ug/m3, which were omitted from the "study area".

III. Block-Level Average $PM_{2.5}$ Contributions

Let the cells of the CALPUFF raster be indexed by r, the blocks by i, and the contributing sources of $PM^{2.5}$ by k. Then the modeled "block-average" incremental concentration for block i, from source k, may be denoted X_{ik}. We calculated each X_{ik} as an area-weighted average[2] of the values assigned to raster cells X_{rk} as follows:

$$X_{ik} = \sum_{r} A(r,i) \cdot X_{rk}$$

… where $A(r,i)$ is the area-of-overlap function: zero if block i and cell r are non-overlapping, and otherwise equal to the fraction of block i that overlaps with cell r.[3] We operationalized this by using the *exactextractr* R package[4] to overlay the CALPUFF raster with Census-block polygons, creating these block-level averages. Raster cells within the facility boundaries (for both Chevron and PBF) were omitted from the overlay operation.

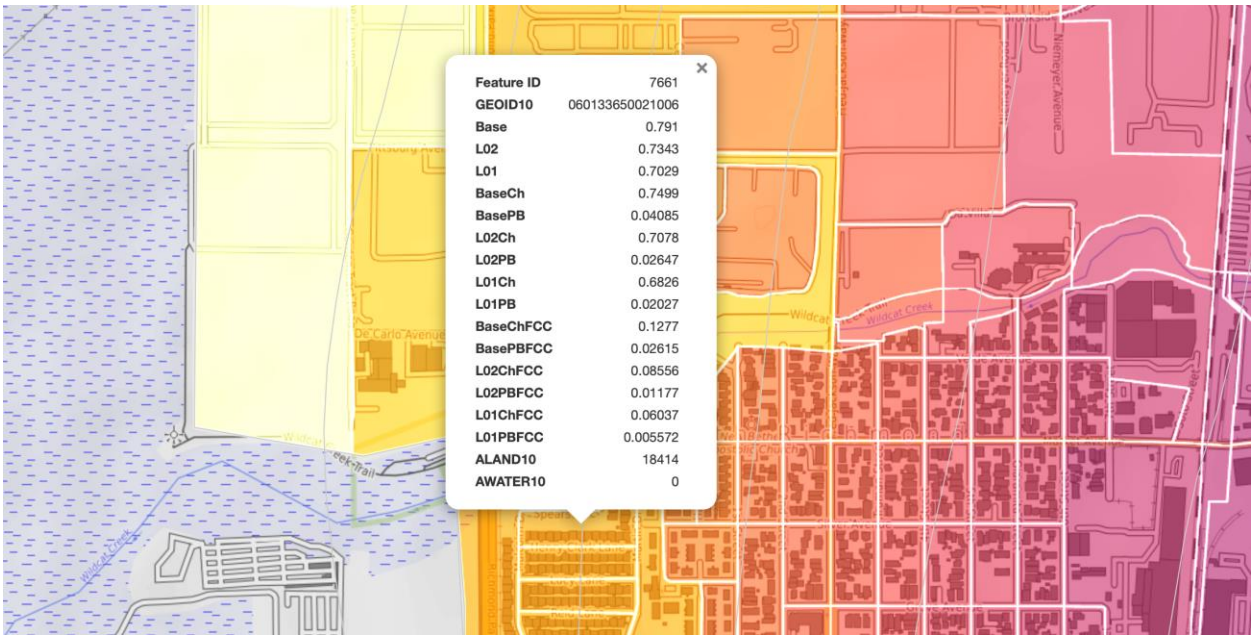

Figure 2. *Example: block-level averages of modeled contributions to ambient $PM_{2.5}$ for a randomly selected block in the vicinity of Henry Clark Ln (North Richmond neighborhood). Block boundaries, drawn in white, are from US Census (TIGER/LINE) data. Attributes beginning with `Base`, `L02`, and `L01` are block-level $PM_{2.5}$ averages assigned to the selected block for a given scenario (Base = Baseline; L02 = Scenario A; L01 = Scenario B). Attributes suffixed with `Ch` or `Pb` are specific to Chevron or PBF, while those suffixed with `FCC` represent contributions specifically attributed to FCCU emissions. Colors in this figure correspond to values of `Base`.*

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[2] This method effectively treats each X_{rk} as constant across cell r.

[3] Since the cells are non-overlapping, $\sum_r A(r,i) \leq 1$ for each and every block i. For the blocks that comprise the "study area" ($i \in I$; see text) $\sum_r A(r,i) = 1$ for all i.

[4] https://cran.r-project.org/web/packages/exactextractr/index.html

IV. Block-Level Populations

Block-level population estimates were created using PopGrid, a tool that is part of the US EPA BenMAP platform. (See Appendices A.2 and A.3 for details.) These were imported into R and joined, at the block level, to the PM2.5 averages described in the previous section.

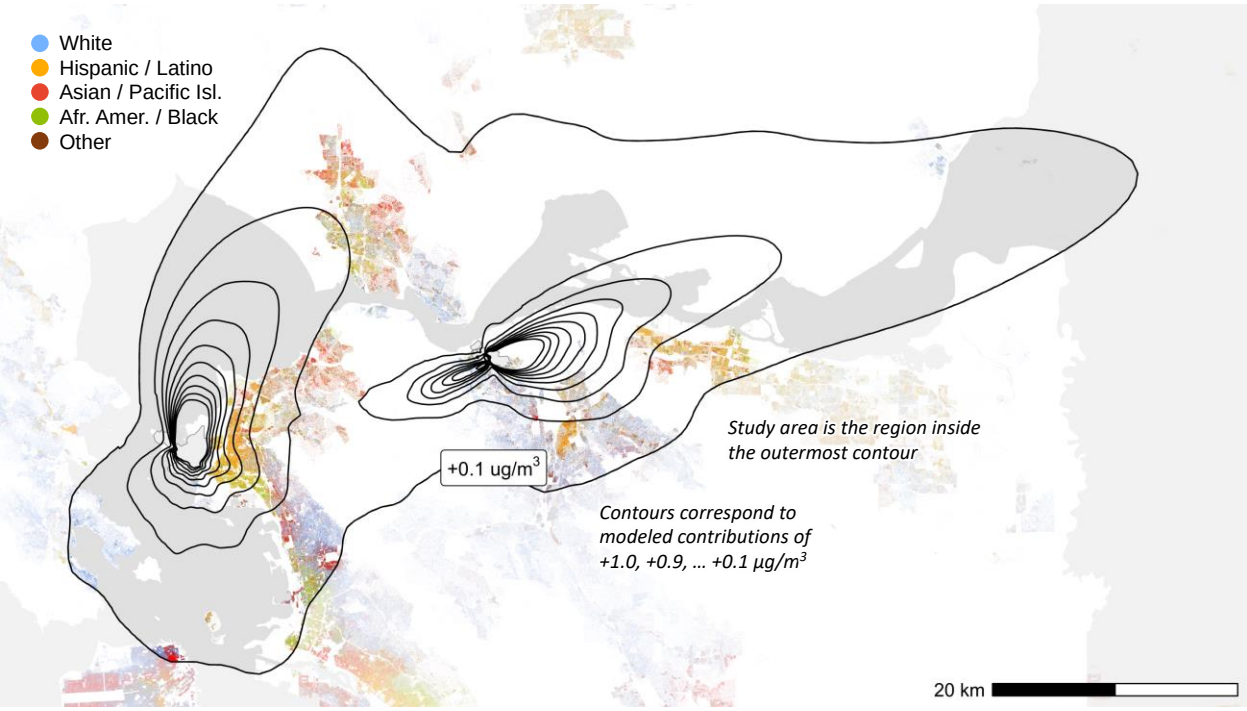

Figure 3. *Each dot corresponds to one resident; colors correspond to US Census race/ethnicity categories. Approximately 1 million people reside in the study area.*

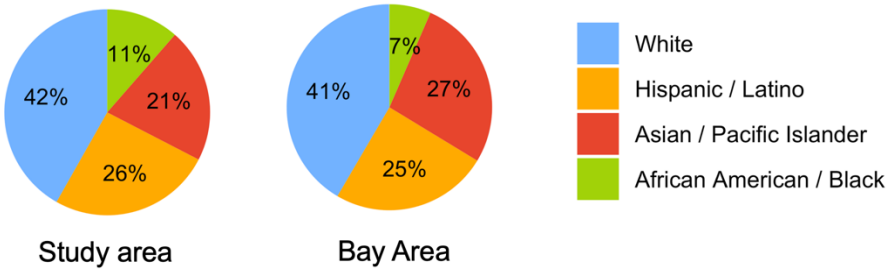

Figure 4. *Demographics. Not shown: 0.3% Native American / Alaska Native (both charts).*

V. Exposure by Race/Ethnicity

A. Population Exposure

For each combination of {Scenario, Facility, Source, RaceEth, Block}, we computed the product of population and average $PM_{2.5}$, and then summed these across blocks. This yielded estimates of population exposure (person-μg/m³) for the entire study area, indexed by {Scenario, Facility, Source, RaceEth}, as depicted in the figure below.

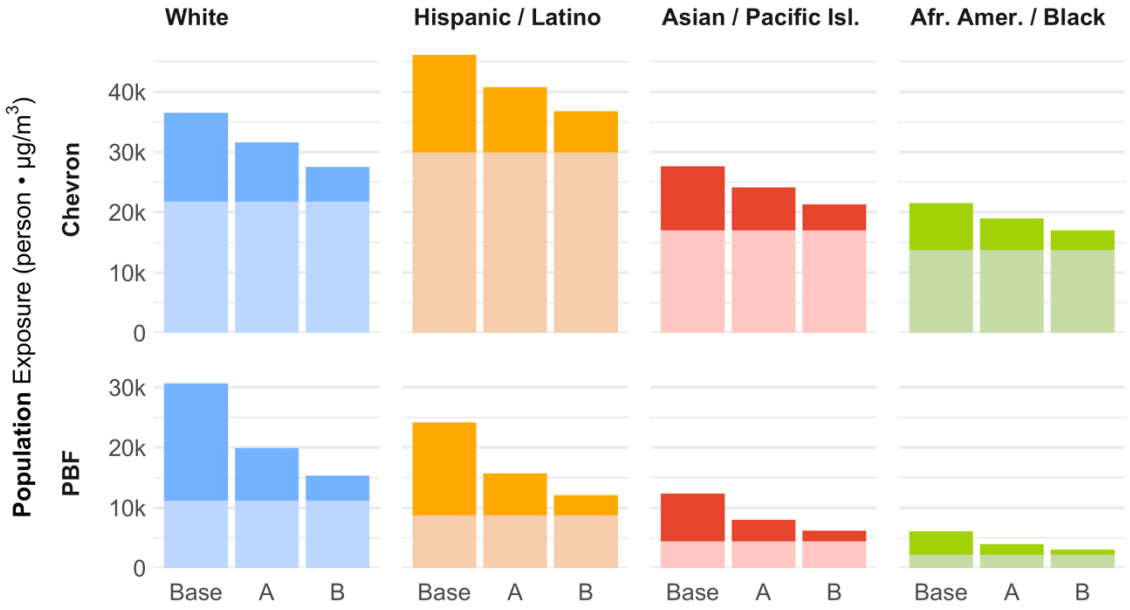

Figure 5a. *Modeled estimates of total population exposure (residential impact) within the study area. Within each of the eight panels, there are three bars. The leftmost bar corresponds to the baseline scenario. The middle and rightmost bars correspond to scenarios where emissions from the FCCU have been reduced. Bar heights correspond to total impacts from all modeled sources; the darker portions of the bars correspond to the shares of those impacts that are specifically attributed to FCCU emissions.*

B. Exposure "Per Capita"

For each combination of {Scenario, Facility, Source, RaceEth}, we also calculated population-weighted averages of block-level $PM_{2.5}$ estimates, using block populations (specific to a particular RaceEth category) as the weight. This yielded "average" or "per capita" exposure intensities indexed by {Scenario, Facility, Source, RaceEth}, depicted in the figures below. Estimates specific to source but not facility—that is, aggregating the two facilities together—were computed by the same operation, but omitting Facility from the set of indexing (i.e., grouping) variables.

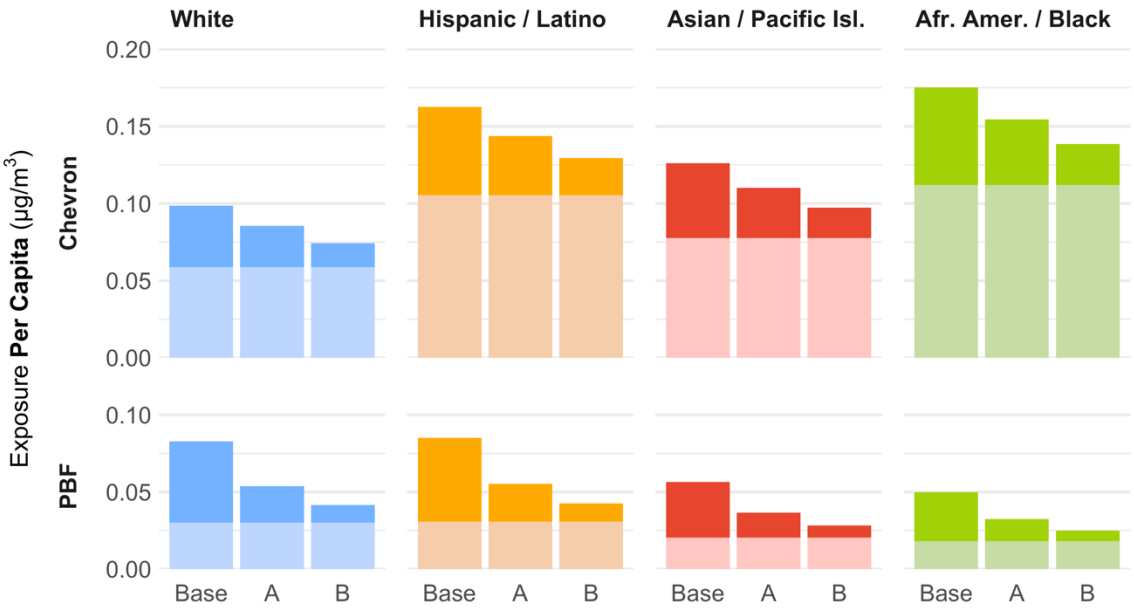

Figure 5b. *Same as previous, except that the y-axes have been normalized by population, yielding bar heights that correspond to average (that is, "per capita") impacts.*

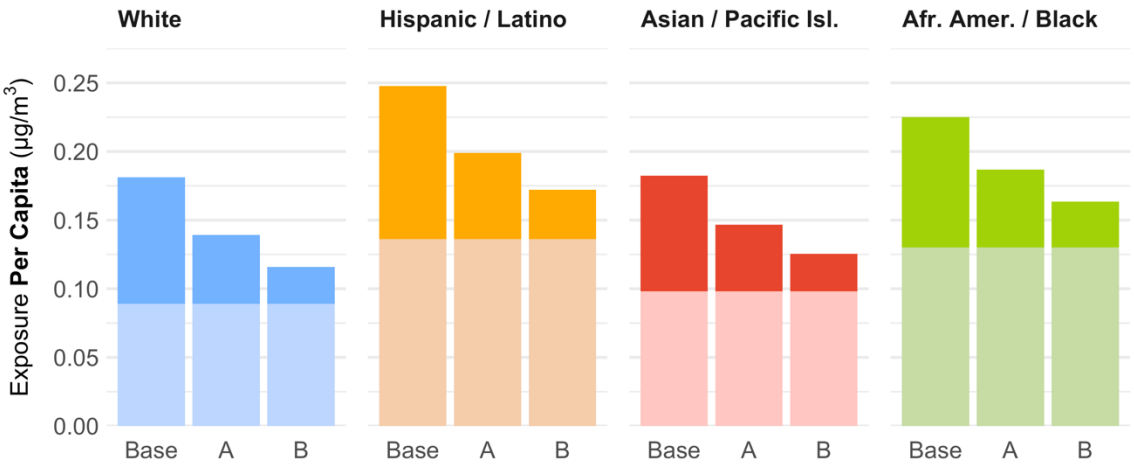

Figure 5c. *Same as previous, except that impacts from both facilities have been combined.*