EXHIBIT A

SCOPE OF WORK

☒ Contract ☐ Grant

Does this project include Research (as defined in the UTC)? ☒ Yes ☐ No

PI Name: **Jason G. Su**

Project Title: **Assessing Health Impacts of Brake and Tire Wear Emissions in Overburdened Communities of the San Joaquin Valley**

Project Summary/Abstract

This study aims to assess the spatial and temporal distribution of brake and tire wear (BTW) concentrations across the San Joaquin Valley (SJV) and their potential health impacts on vulnerable communities. The research will apply advanced source apportionment algorithms to quantify BTW profiles at various field sampling sites, using methodologies such as Positive Matrix Factorization (PMF) and Multilinear Engine (ME-2) for chemical profiling. Field sampling will involve deploying air quality sensors across 45 sites in the SJV, selected based on a combination of geospatial analysis and traffic modeling, with seasonal variations considered. We will combine road link-level traffic data with EPA's MOVES software to disaggregate EMFAC TBW data into finely spatially resolved emissions estimates. These emissions estimates will then be used as input for the WRF-Chem model to simulate BTW concentrations. This approach will produce high-resolution BTW outputs, capturing spatial and temporal variability in atmospheric processes.

Additionally, oxidative stress analysis will quantify the health risks posed by BTW emissions through assays that measure the oxidative potential of these particles. Health impacts, including emergency department visits, hospitalizations, and pre-term births, will be evaluated using case-crossover designs, while days of hospitalization will be modeled through Poisson or negative binomial techniques, and low-birth weight through logistic regression models. This study will integrate both BTW concentration and PM2.5 data to better understand the health risks associated with BTW exposure. The formation of a Technical Advisory Group (TAG) ensures scientific rigor and community engagement, making the findings highly relevant for public health policy aimed at mitigating BTW-related risks in overburdened communities.

If Third-Party Confidential Information is to be provided by the State:

☐ Performance of the Scope of Work is anticipated to involve use of third-party Confidential Information and is subject to the terms of this Agreement; ***OR***

☐ A separate CNDA between the University and third-party is required by the third-party and is incorporated in this Agreement as Exhibit A7.

Scope of Work

The primary goal of this study is to assess the spatial and temporal distribution of brake and tire wear (BTW) concentrations across the San Joaquin Valley (SJV) and evaluate their potential health impacts on vulnerable communities. The research methodology to achieve such a goal involves several key components. First, a combination of Positive Matrix Factorization (PMF) and the Multilinear Engine (ME-2) will be employed to chemically profile and isolate BTW emissions from other particulate matter sources. Data for source apportionment will be processed through our Fresno site and collected through field sampling - deploying air quality sensors at 45 strategically selected sites across the SJV. These sites will be chosen based on geospatial analysis and traffic modeling, ensuring that they represent diverse traffic patterns and environmental conditions. Sampling will be conducted in two phases: during the dry season (June-July 2025) at 20 sites and the wet season (January-February 2025-2026) at another 20 sites. Additionally, 5 sites will be sampled during both the dry and wet seasons to capture any seasonal variability in BTW emissions. Data from these samples will be used to refine the source profiles for different regions in the valley.

CARB's Emission FACtor (EMFAC) model includes brake wear (BW) and tire wear (TW) emissions, but it focuses on total mass contributions (e.g., $PM_{2.5}$ and PM_{10}) rather than a detailed chemical breakdown. We will leverage EMFAC for total BW and TW emissions estimates and supplement those results with chemical speciation data from laboratory and roadway measurements datasets in California. EPA MOVES software will be used to estimate speciated BTW emissions. The speciated BTW emissions will also be molded through roadway-level traffic data, vehicle types, and environmental factors such as road surface conditions, weather patterns, and vehicle braking behavior throughout SJV. The WRF-Chem model, using spatially resolved BTW emissions as input, will provide a detailed understanding of how BTW concentrations vary across the SJV, contributing to a comprehensive assessment of population exposure. We will estimate BW and TW emissions separately due to their distinct sources and chemical compositions. The health outcome analysis will be conducted in parallel to ensure that the individual contributions of BW and TW to air pollution and associated health effects are appropriately captured. For clarity and simplicity in presentation, we collectively refer to them as BTW.

Oxidative stress assays, specifically measuring reactive oxygen species (ROS) generation, will be employed to assess the health impacts of BTW particles. These assays will focus on oxidative potential in samples collected from high-traffic areas, which are most affected by BTW emissions. In parallel, health impact analyses will be conducted by linking high-resolution BTW concentration data to health outcomes, such as emergency department visits and hospitalizations for respiratory and cardiovascular conditions, and adverse birth outcomes like pre-term births and low birth weights. These analyses will use a case-crossover design to assess short-term impacts, and Poisson or negative binomial models will be applied to evaluate hospitalization duration. Logistic regression models will be used to study preterm birth and low birth weight. Incorporating both BTW exposure and all source PM2.5 concentrations in the modeling process will be used to accurately understand the health risks of BTW exposure.

Potential challenges include accurately isolating BTW concentrations from other sources of particulate matter, variability in traffic patterns and road conditions across different regions, and potential gaps in health data linkage. To mitigate these challenges, the study will employ alternative modeling strategies, such as adjusting input parameters in the WRF-Chem model based on real-world measurements and conducting sensitivity analyses to identify key variables that contribute to uncertainties. Regular validation of model outputs against field measurements will ensure robustness and accuracy. Furthermore, source apportionment at Fresno Garland station will be cross-validated with the field sampling sites to ensure consistency in BTW emission profiles across the valley.

The success of the project will be measured by the accuracy and precision of the source apportionment results, the resolution and reliability of the WRF-Chem simulations, and the strength of the statistical associations found between BTW exposure and health outcomes. The formation of a Technical Advisory Group (TAG) composed of experts and community stakeholders will ensure scientific rigor and community relevance, providing feedback on methodology and data interpretation. Resource-sharing plans will include making the resulting air pollution models and exposure surfaces available to researchers and policymakers to inform future air quality management efforts in the SJV.

In summary, this study will provide actionable insights into BTW exposure and their health impacts in the SJV, contributing to policy development aimed at reducing air pollution exposure in vulnerable populations. By combining advanced modeling, comprehensive field sampling, and robust health analyses, the project aims to bridge critical knowledge gaps and support more effective public health interventions.

Project Tasks

Task 1. Literature Review (UCB)

Recent studies have increasingly recognized the significant contribution of non-exhaust emissions, particularly from brake and tire wear (BTW) to particulate matter (PM) pollution (*1*). Unlike exhaust emissions, which have seen a reduction due to regulatory advances and cleaner vehicle technologies, BTW emissions remain a persistent and under-regulated source of ambient particulate pollution (*2*). These non-exhaust particles, primarily $PM_{2.5}$ and PM_{10}, contain a complex mix of metals such as copper, zinc, and iron, as well as organic compounds, originating from the abrasion of brake pads and tires during vehicle operation (*3*).

Numerous studies have drawn connections between exposure to BTW particles and adverse health outcomes (*4, 5*), emphasizing the role of these particles in promoting oxidative stress (*5, 6*), a biological process linked to inflammatory and degenerative diseases. Oxidative stress occurs when there is an imbalance between reactive oxygen species (ROS) production and the body's antioxidant defenses, leading to cellular damage. Research has shown that BTW particles contribute to localized hotspots of PM pollution, particularly in urban areas with heavy traffic (*7*), thereby increasing the risk of exposure to susceptible populations, such as children, the elderly, and individuals with pre-existing health conditions. Studies have demonstrated that the fine particulate matter from brake and tire wear can trigger oxidative stress in lung tissues (*8*), leading to inflammation and exacerbating conditions such as asthma, bronchitis, and other chronic respiratory diseases. Epidemiological studies suggest that long-term exposure to non-exhaust emissions is associated with cardiovascular diseases, due to systemic inflammation triggered by inhaled particles entering the bloodstream (*9*).

The toxicological impact of BTW particles is closely linked to their chemical composition. For example, high concentrations of metals like copper, iron, and zinc in brake-wear particles have been shown to catalyze ROS production, leading to increased oxidative stress. In areas with elevated concentrations of these metals, studies have found higher rates of respiratory distress and cardiovascular mortality (*4, 10, 11*), further supporting the hypothesis that BTW emissions have a distinct health burden separate from exhaust emissions.

One of the central challenges in addressing BTW-related pollution is accurately quantifying the particles and linking them to specific health outcomes. Recent advancements in air pollution apportionment techniques, including receptor-based models like Positive Matrix Factorization (PMF) and multilinear engine (ME-2) (*12-17*), have allowed for more precise apportionment of BTW particles in ambient air samples. These methods enable the separation of BTW particles from other PM sources, providing a clearer understanding of their contribution to overall air pollution. BTW emissions tend to vary significantly across different environments, with traffic-heavy urban centers experiencing the highest concentrations (*2*). Research has demonstrated that BTW particles can accumulate high near roadsides, leading to higher exposure levels for populations living close to major roadways. These findings suggest the need for localized exposure assessment, particularly in regions like the San Joaquin Valley (SJV), where traffic density and environmental conditions may exacerbate exposure risks. Recent reviews have called for stricter regulations and targeted interventions, such as improving braking materials and developing low-wear tire technologies, to reduce the environmental and health impacts of non-exhaust emissions.

The findings from these studies underscore the importance of our proposed research, which aims to fill critical knowledge gaps in the characterization of BTW particles and their health impacts, particularly in underrepresented communities in the SJV. By leveraging advanced modeling and source apportionment techniques, our research will provide actionable insights for policymakers and public health officials, leading to more effective interventions and policies. Our literature review for the full proposal will build upon this foundation, focusing on several key areas to ensure that our research is informed by the most current findings.

We will conduct a comprehensive review of BTW emissions and their contribution to air quality, expanding to include recent findings on the spatial distribution and variability of these emissions, and modeling techniques to generate such spatiotemporal surfaces. This review will explore the differences in BTW emissions across vehicle activity data (e.g., stop-and-go traffic), vehicle type, road types, and brake characteristics, to understand their relative contributions compared to exhaust emissions. Our literature review will also cover the epidemiological and toxicological literature on BTW particles and their association with specific health outcomes, particularly respiratory and cardiovascular diseases. We will review the most recent advances in oxidative stress research and the role that the chemical composition of BTW particles plays in their varying degrees of toxicity. Studies that explore the heightened risk of exposure for vulnerable populations will be emphasized.

In addition, we will review state-of-the-art techniques for measuring BTW particles, including advancements in receptor modeling, elemental analysis, and real-time monitoring technologies. We will focus on studies that have successfully isolated BTW particles from other PM sources, providing insights into best practices for source apportionment in regions like the SJV. The review will also highlight uncertainty quantification methods in source apportionment studies, identifying gaps in existing methodologies and areas for improvement in our own research. Finally, we will assess current air quality regulations related to non-exhaust emissions, identifying gaps in policy and reviewing case studies from regions that have implemented successful regulatory measures to reduce BTW emissions.

This comprehensive review will ensure that our approach is grounded in the latest scientific findings, providing a strong foundation for our methodology, data collection, and analysis plan, and ultimately supporting CARB's goal of reducing the public health burden from air pollution sources like brake and tire wear, especially for those disadvantaged communities.

Task 2. Development of a Workplan for the Study (UCB)

The central aim of Task 2 is to create a robust and detailed plan that integrates various research components. This plan will guide the evaluation of BTW emissions and concentrations in the SJV, focusing on their spatial and temporal distribution and the health effects BTW has on overburdened communities.

The project will start with an initial kickoff meeting that brings together all collaborating institutions, including UCB, UCLA, UCD, Baylor, CCAC, and CARB. This meeting will solidify project goals, define roles and responsibilities, and set up communication channels to facilitate ongoing collaboration. The team will also establish a detailed project timeline that tracks milestones and ensures timely progress on each task. Regular weekly and monthly updates will help the workplan remain responsive to emerging data and insights, allowing for adjustments as necessary. In addition to the kickoff meeting, CARB will be involved in the development of the project workplan and key decision-making processes. Their input will be integral across various stages to ensure alignment with regulatory needs and enhance the project's impact.

Following the initial planning, UCB will lead the comprehensive acquisition of existing datasets. These datasets, such as CalTrans (California Department of Transportation) PeMS (Performance Measurement System) traffic data, Digital Elevation Models (DEM) data, and road surface condition data from Caltrans, will be essential for identifying key areas where BTW emissions are most significant. Linear mixed models will also be developed to assess the factors influencing BTW concentrations over time and space. This data collection will also enhance source apportionment at Fresno Garland site and field sampling locations and help generate road-link-specific emissions as input for WRF-Chem modeling.

Field sampling, led by CCAC and assisted by UCLA, will involve deploying air quality sensors at 45 sites selected through geospatial analysis, accounting for traffic density, road conditions, and wind direction. Sampling will take place in two seasons—during the dry season (June-July 2025) and the wet season (January-February 2026)—to capture any seasonal variations in BTW emissions.

A significant component of the workplan involves source apportionment, led by UCD, which will be applied to both Fresno Garland and the 45 field sampling sites across the SJV. Initially, aerosol chemistry data acquired from the Fresno Garland site will undergo detailed chemical profiling to identify BTW components using methods like Positive Matrix Factorization (PMF) and the Multilinear Engine (ME-2). These receptor-based models will help isolate BTW emissions from other particulate matter sources. The identified Garland BTW profiles will then inform and constrain source apportionment at the field sampling sites, enabling a more accurate estimation of BTW contributions in different regions. Validation will be achieved by comparing the results between Garland and field sites, ensuring consistent profiles across the region.

In parallel, advanced air pollution modeling will be led by Baylor. The team will integrate traffic data, vehicle types, and environmental factors like road surface conditions and weather patterns to estimate road-link-specific BTW speciated emissions using road link-level disaggregated EMFAC data in EPA MOVES software. The WRF-Chem will then be used to simulate the distribution of BTW concentrations across the SJV at a high spatial resolution.

The oxidative stress analysis, led by UCLA, will quantify the potential health impacts of BTW emissions. Using acellular oxidative potential assays, specifically hydroxyl radical (OH) assays, UCLA will measure the ability of BTW particles to generate reactive oxygen species (ROS) and induce oxidative stress. These assays will be applied to samples collected from high-traffic areas in the SJV, and the findings will help link BTW particle exposure to adverse health outcomes in vulnerable populations.

Health analysis, led by UCB, will link high-resolution BTW concentration data with individual health outcomes such as emergency department visits, hospitalizations for respiratory and cardiovascular conditions, and pre-term birth and low-birth-weight infants. Case-crossover designs and other modeling techniques will evaluate short-term health impacts while incorporating additional air quality data, such as PM2.5, to provide a precise understanding of BTW's health risks.

To ensure scientific rigor and community relevance, the workplan will include the formation of a Technical Advisory Group (TAG). This group will provide feedback on research methods and community engagement, ensuring the integration of both technical and public health perspectives. Community meetings and transparent reporting will further ensure that the research findings are accessible to the public and policymakers, with a focus on mitigating health risks in vulnerable communities.

By integrating source apportionment algorithms, field sampling, advanced modeling, and health impact analysis, this workplan provides a comprehensive approach to understanding the public health impact of BTW in the SJV.

Task 3. Regional exposure assessment and monitoring campaign for $PM_{2.5}$ and PM_{10} linked to BTW emissions (see subtask for responsible institutes)

Task 3.1 Collect ambient BTW pollutants data (CCAC & UCLA)

We plan to deploy air quality sensors at 45 strategically selected sites in the SJV, ensuring these locations complement existing CARB monitoring efforts already established in the SJV. In addition to co-locating two sites with CARB regulatory monitors, the selection of measurement sites will be guided by a combination of criteria, including traffic density, vehicle speed, road conditions (such as the presence of bottlenecks, slope, and surface type), and geographic distribution to ensure coverage across urban, suburban, and rural areas. The intent is to capture a representative sample of conditions that contribute to BTW emissions, both in high-traffic zones and in areas where vehicle wear might be influenced by road characteristics like incline or surface roughness. Additionally, we will consider wind direction and surrounding land uses, such as residential, which may impact the dispersion and accumulation of BTW particles.

To select optimal sites, we will apply a combination of geospatial analysis and traffic modeling, taking into account the traffic flow data and vehicle mix information available through regional transportation models. These models will help identify hotspots for BTW emissions, particularly areas where vehicle braking and tire wear are expected to be elevated due to frequent stops, congestion, or sharp turns. We will also prioritize locations near population centers and sensitive receptors, such as schools, to better understand the potential for human exposure to BTW pollutants.

For this project, sampling will be conducted in two phases: during the dry season (June-July 2025) at 20 sites and the wet season (January-February 2025-2026) at another 20 sites. Additionally, 5 sites will be sampled during both the dry and wet seasons to capture any seasonal variability in BTW emissions. This will provide a more comprehensive understanding of how seasonal variations, including factors like rainfall and dust resuspension, impact the distribution and composition of BTW particles.

At each site, we will measure more than 50 chemical species associated with BTW, including iron (Fe), copper (Cu), zinc (Zn) and barium (Ba), organic carbon (OC) and elemental carbon (EC) which are key indicators of brake and tire wear. Additionally, we will monitor trace metals like lead (Pb), cadmium (Cd), manganese (Mn), chromium (Cr), and nickel (Ni), as well as organic species known to contribute to oxidative stress and adverse health outcomes. The inclusion of these species will allow us to differentiate between different non-exhaust sources and establish a detailed chemical profile of BTW emissions across various environmental conditions and traffic patterns. Stringent quality assurance and quality control (QA/QC) protocols will be applied during the data collection process to ensure data accuracy and reliability.

Task 3.2 BTW profiling through source apportionment (UCD)

Task 3.2.1 Identification of BTW baseline profiles and constraints

We will develop California-specific BTW emission profiles through chemical speciation of locally sourced PM samples. Current literature review and analysis of existing data include:

Schauer (18) study:

The study on brake wear emissions reveals significant contributions of various metals, with iron (Fe) identified as the dominant element, constituting more than 70% of PM emissions across all tests. Notably, barium (Ba) accounts for up to 15%, while copper (Cu) and manganese (Mn) contribute around 5% and 3%, respectively. The average particle size from brake wear emissions ranges from 1 to 3 μm, with some emissions containing larger particles exceeding 10 μm, particularly for elements like calcium (Ca) and titanium (Ti). High acceleration and deceleration scenarios, particularly observed in urban cycle (UC) tests, lead to the production of fine particles, including submicron organic matter through volatilization. Rotor wear significantly contributes to the levels of Fe and Cu found in brake housing dust. The composition of brake emissions resembles brake housing dust more than crushed brake pads, indicating that rotor wear and resuspended dust are major contributors to metal emissions. Emission rates for Fe exhibit the highest levels across all tests, particularly in the UC tests, often exceeding 100 μg/km. Barium also has a high emission rate during the UC test. The overall trend indicates that Fe and Ba are the dominant species in both PM10 and PM2.5 emissions. The UC test conditions tend to produce higher emission rates than the Federal Test Procedure (FTP) test cycles across both vehicles, suggesting that more intense driving patterns lead to increased emissions of these species. In contrast, tire wear emissions are dominated by organic carbon (OC), which accounts for 69% of PM10 and 64% of PM2.5. Metals are largely insignificant in tire wear emissions, with zinc (Zn) comprising only 0.054% of PM10. This stark contrast between the emissions from brake wear and tire wear highlights the dominance of OC and elemental carbon (EC) in the latter. CARB's Haagen-Smit Laboratory (El Monte CA) data was used as part of the study to estimate emissions from BTW using a specialized dynamometer (RL-SHED, model 60000-DRL1, 1995, Webber Engineering and Manufacturing, Ontario California). This facility has a chassis dynamometer in running-loss sealed housing for evaporative determinations.

Lopez, Wang, Chen, Ma, Mendez-Jimenez, Cobb, Frederickson, Fang, Hwang and Shiraiwa (2) study:

The article discusses the methodologies used to assess brake and tire wear emissions and their associated particle size distributions. Calibration of PX-375 units was performed using SRM2783 before field testing, and real-time aerodynamic particle size distributions were measured with a Dekati High-Resolution Electrical Low-Pressure Impactor (HRELPI+). This instrument captured particle size distributions ranging from 6 nm to 10 μm at a sampling rate of 10 Hz. The HRELPI+ utilizes a series of 13 impactor stages as size classifiers, followed by a final filter stage to measure airborne particles. Size distribution data was averaged to hourly intervals for analysis in correlation with other environmental data.

The study integrated various monitoring data, including $PM_{2.5}$ concentrations of 35 μg/m³, wind speeds averaging 5 m/s, and wind directions, to analyze traffic emissions at the I-5 and I-710 highways. Vehicle traffic counts and speeds were sourced from the CalTrans PeMS, which reported peak traffic flow of 5,000 vehicles per hour during morning and afternoon rush hours and reduced flow of 1,200 vehicles per hour in early mornings. To evaluate the statistical relationships among the selected elements, the squared Pearson correlation coefficient (r^2) was calculated, with values ranging from 0.5 to 0.8, providing insights into how well variations in one variable could explain the variability in another.

The findings highlighted elemental concentrations and their differences at downwind and upwind sites, particularly focusing on particulate matter (PM) and elemental abundances. Key elements such as Fe and silicon (Si) were found to be the most abundant in both $PM_{2.5}$ and PM_{10} samples. Specifically, Fe accounted for 40% of the total elemental concentrations measured in $PM_{2.5}$, while Zn, a common marker for tire wear, was present at approximately 5%. Correlation analyses revealed strong relationships among crustal elements, with significant r^2 values of 0.7 for PM_{10}, suggesting common sources. Notably, the study identified moderate correlations between brake wear elements like Fe ($r^2 = 0.55$), titanium (Ti) ($r^2 = 0.52$), copper (Cu) ($r^2 = 0.49$), and other elements after background influences were accounted for, underscoring the complexities of distinguishing between brake and tire wear emissions.

The investigation further revealed challenges in differentiating between brake and tire wear particles, even with background subtraction. The study noted that barium (Ba) had a correlation of $r^2 = 0.25$ with Zn among the brake wear indicators, which could aid in separating contributions from each source. Analysis of $\Delta PM_{2.5}$ Ba concentrations in relation to crosswind speeds indicated variability in concentration tracking, with a correlation coefficient of 0.15. Overall, the article provides a detailed examination of the methodologies and findings related to brake and tire wear emissions, highlighting the significant challenges and insights gained from the data collected at major highways.

We will also incorporate CARB's XRF (X-ray fluorescence) analysis results for brake PM samples into our study to develop California-specific chemical profiles for brake wear emissions.

We will collect and analyze PM samples from both literature and relevant data sources on BTW emissions within California. To develop California-specific chemical profiles across the highway network, we will integrate measured chemical speciation with local space-time traffic data, such as vehicle counts, road types, and braking patterns, along with meteorological factors like wind speed, wind direction, and precipitation. These correlations will be further linked to EMFAC-modeled BTW emissions to ensure that the chemical speciation—such as trace metals (e.g., Cu, Fe, Zn) and organic compounds (e.g., synthetic rubbers)—aligns with CARB's reported emissions. This approach allows us to adhere to CARB's preference for EMFAC while enhancing the model with local chemical profiles, improving the precision of air quality modeling and the accuracy of health impact assessments.

Task 3.2.2 Source apportionment of BTW profiles

We will start the source apportionment process by analyzing aerosol chemistry data collected with a high-resolution soot particle aerosol mass spectrometer (SP-AMS) from the Fresno Garland station during two winter measurement periods (2019-2020 and 2023-2024). These datasets offer detailed chemical profiles, capturing the temporal variability and compositional complexity of aerosol particles. Each SP-AMS mass spectrum reflects the combined contributions of various particulate matter (PM) species, including both BTW components and other species, such as inorganic salts, primary and secondary organic aerosols, and black carbon. The intensity of each ion in the spectrum corresponds to the concentration of its associated chemical species in the sampled air. The high time-resolution of SP-AMS measurements enables more precise tracking of changes in aerosol composition over time, which, when combined with multivariate statistical analysis, enables more effective differentiation between various PM sources and determine their source profiles and contributions. We use the Fresno site for tire and brake wear analysis because real-time SP-AMS measurement data were acquired from this location during specific winter periods. The goal of analyzing the Fresno SP-AMS data is to derive BTW source profiles through factor analysis of ambient aerosol observations. While lab-based brake and tire wear experiments provide valuable insights, analyzing real-world ambient data from Fresno allows us to capture the representative BTW source profiles in a real traffic environment, accounting for variations in driving conditions, vehicle types, tire types, and meteorological factors. This approach provides a more comprehensive and realistic profile of BTW emissions as they occur in the field. The Fresno site also represents an urban environment within the San Joaquin Valley (SJV) that experiences significant vehicular traffic, making it an ideal location for studying emissions from brake and tire wear. The area's traffic patterns and volume are likely to provide meaningful insights into PM emissions relevant to our research. This will facilitate a more robust analysis of the contributions from brake and tire wear to overall PM emissions.

In this project, we will leverage the SP-AMS' laser vaporization mode (laser-on), which is able to measure black carbon and metal species, along with inorganic species and organic matter. We will reanalyze the Fresno SP-AMS laser-on measurement data, focusing on identifying key metals and organic compounds associated with brake- and tire-wear, such as copper, iron, and barium for brake-wear, and zinc, silica, and polycyclic aromatic hydrocarbons (PAHs) for tire-wear. Lab-based experiments will be performed to determine the relative ionization efficiencies (RIE) of various metal species, which will be used to quantify the concentrations of the metal species in ambient air.

After data processing, we will apply source apportionment algorithms such as Positive Matrix Factorization (PMF) and Multilinear Engine 2 (ME-2) to the resulting ion-speciated high-resolution mass spectral matrices. PMF will identify distinct PM sources through a receptor-based approach, isolating factors characterized by metals and organic species specific to brake- and tire-wear. Meanwhile, ME-2 will incorporate prior source profile information, particularly those from Task 3.2.1, to guide and constrain the source apportionment for the Fresno station. These laboratory-validated BTW profiles will provide essential input to the ME-2 algorithm, allowing for more precise identification of BTW sources in the field data. Once source apportionment is completed, we will validate the findings by comparing the BTW source profiles between the two datasets. This step is crucial for determining whether the identified source contributions remain stable or if significant changes have occurred, indicating shifts in local traffic patterns, brake materials, or tire compositions. To further strengthen the analysis, we will estimate uncertainties in source contributions by applying bootstrapping and Monte Carlo simulations within PMF and ME-2 models. These methods will help account for variability in the input concentrations and measurement errors, providing a more robust uncertainty estimate. Additionally, integrating local traffic data, such as vehicle counts, road types, and braking patterns, and meteorological conditions, such as wind speed, wind direction and precipitation, will allow for further refinement of BTW source estimates and minimize associated uncertainties.

For extending source apportionment to 45 locations across the SJV, the same algorithms developed for Fresno data will be applied. PMF will be used to identify source factors, with the expectation that brake- and tire-wear factors will be similar to those observed in Fresno. The validated BTW profiles from laboratory-based SP-AMS data will serve as a reference, allowing for a comparison of factor profiles across different locations. Additionally, ME-2 will be applied using the refined BTW source profiles from Fresno and other data to estimate BTW contributions at each of the new locations. This will ensure that the source apportionment remains consistent across the valley, despite variations in local conditions. The time resolution of filter collections using Harvard samplers can range from several hours to a few weeks, depending on the sampling design. To get enough mass of PM for chemical speciation analysis, we need to collect filter samples for at least two weeks at each site. Those filter samples are meant to generate a wide range of spatial coverage instead of high-temporal resolution. This data set will compliment SP-AMS data analysis and help to validate the modeling results. While this is lower than the real-time data produced by SP-AMS (which typically operates at 2-5 min average), it is still sufficient for performing PMF analysis. PMF works well with time-averaged data if the collection periods capture representative variability in pollutant sources. To bridge the difference in time resolution between filter and SP-AMS data, we can carefully align sampling intervals with expected source variations and environmental conditions. By deploying Harvard samplers strategically—e.g., during dry and wet seasons—we ensure that each sample reflects key emission patterns, making it viable for PMF analysis.

The gold standard for developing chemical profiles involves integrating laboratory-based analyses with real-world monitoring data to ensure a comprehensive understanding of emissions. Laboratory analyses rely on collected samples for detailed chemical characterization using advanced techniques such as SP-AMS, XRF, and inductively coupled plasma mass spectrometry (ICP-MS). These methods provide precise quantification of trace metals (e.g., Fe, Cu, Zn) and organic compounds, including synthetic rubbers, linked to brake and tire wear. Following the chemical analysis, source apportionment is conducted using advanced statistical models like Positive Matrix Factorization (PMF) to disentangle the contributions from multiple sources. This combination of laboratory precision with statistical rigor ensures that the resulting chemical profiles accurately reflect real-world conditions, providing a robust foundation for modeling air pollution sources and assessing their impacts.

To account for spatial variability, site-specific adjustments will be made. Integrating local traffic data, including vehicle counts and braking patterns, will allow for scaling of BTW contributions to reflect the unique traffic characteristics of each site. For example, areas with more stop-and-go traffic may have higher brake-wear contributions. By comparing BTW contributions across all sites, we will assess the spatial consistency of these profiles and use statistical techniques, such as correlation analysis, to determine how similar the factor profiles are to Fresno. Finally, to reduce uncertainty and capture inter-site variability, a Bayesian hierarchical model will be applied. This model will pool data from all sites while accounting for site-specific differences, allowing for more precise estimates of BTW contributions.

Task 3.3 Modeling BTW profiles through linear mixed modeling (UCB)

Task 3.3.1 Collect spatiotemporal data that impact BTW emissions

We will acquire datasets covering the entire SJV to facilitate the WRF-Chem (Weather Research and Forecasting model coupled with Chemistry) modeling and source apportionment adjustments, focusing on understanding brake- and tire-wear (BTW) emissions across space and time. A key dataset is the California Department of Transportation's (Caltrans) Performance Measurement System (PeMS) data, which includes census truck day data that provide detailed insights into the characteristics and behaviors of various trucks on California highways. This dataset, collected through fixed sensor detectors, includes the following information: (1) vehicle class based on their size, weight, and characteristics. Common classifications include light-duty, medium-duty and heavy-duty trucks, including specialized vehicles such as buses and commercial vehicles. (2) vehicle count associated with each vehicle class observed on specific days. (3) vehicle characteristics in each vehicle class, such as gross vehicle weight rating (GVWR), axle configuration, and emissions standards compliance. (4) spatial and temporal attributes such as the location of truck observations on highways (postmile) and temporal attributes such as the time of day, day of the week, and seasonality. The detectors measuring daily truck counts cover ~5% California highway segments. In this study, we will apply spatial interpolation techniques as we implemented in all vehicles across California roadways to derive daily light-, medium- and heavy-duty vehicle traffic for all the San Joaquin highways for the study period.

We also acquired annual “vehicle fuel type count by zip code” data published by the California Department of Motor Vehicles (DMV) for 2018-2022 for California. This dataset contains the vehicle counts broken down by ZIP code, model-year, fuel type, make and duty (light/medium/heavy) of registered vehicles in California with specific as of dates. We also acquired California state fleet of vehicles data from DMV for 2015-2022, which includes, among other information, vehicle type, fuel type, model-year and zip code a fleet vehicle was registered. The individual fleet vehicle data will be aggregated to zip code and compared with the “vehicle fuel type count by zip code” dataset to form an integrated dataset.

Given that surface roughness and pavement type have significant impacts on emissions of pollutants, especially for non-tailpipe vehicle emissions from BTW, we have collected the International Roughness Index (IRI) and surface type data provided by the Highway Performance Management System (HPMS) for all the public roadways in California. IRI is obtained from measured longitudinal road profiles and calculated using a quarter-car vehicle math model, whose response is accumulated to yield a roughness index with units of slope (in/mi, m/km, etc.). California roadways have a mean IRI of 80 in/mi with maximum being 400 in/mi and its pavement surface types include unpaved, asphalt, jointed concrete and continuously reinforced concrete.

We have also acquired the bottleneck data as part of the Mobility Performance Report, a subproject of the Mobility Performance Reporting and Analysis Program (MPRAP) developed by Caltrans. This report provides critical insights into the performance of California's highway system, focusing on congestion and mobility. Caltrans continuously collects vehicle counts and calculates speed data across major metropolitan areas using the PeMS, capturing data throughout the day and week. This extensive dataset allows for the identification of congestion bottlenecks, which are crucial for analyzing the impact of traffic flow on BTW emissions. By pinpointing where these bottlenecks occur, we can better understand how increased stopping and acceleration associated with congestion contributes to higher rates of wear and emissions.

Additionally, we have acquired Digital Elevation Model (DEM) data from the U.S. Geological Survey (USGS) to generate slope and aspect information for the roadways. This data will enable us to assess how the topography of the roads influences vehicle dynamics, such as braking and acceleration patterns, which are directly linked to BTW emissions.

Task 3.3.2 Modeling BTW profiles through linear mixed modeling (UCB)

By integrating real-world traffic, environmental, and vehicle data into a mixed-effects modeling framework, we aim to improve the precision of BTW emission profiles within the WRF-Chem model. This approach will help revise chemical transport model (CTM) inputs, ensuring that BTW emissions are accurately captured across different traffic conditions and geographic regions, thus improving the overall accuracy of air quality simulations. The linear mixed model will allow us to account for both fixed effects, such as vehicle types and road conditions, and random effects, like variations between different geographic locations and time periods. This is especially important for modeling complex interactions between multiple factors while capturing both overall trends and localized variations in BTW emissions. The model will incorporate repeated measures over time, critical given the temporal nature of our traffic and emissions data. Key factors in the modeling process include vehicle-related variables from the CalTrans and PeMS datasets, such as vehicle speed, class, axle configuration, and average weight. These variables are crucial because heavier vehicles with more axles, like trucks, generate more particulate matter during braking and tire wear, while vehicle speed influences the frequency and intensity of braking. Environmental factors, such as road surface roughness, slope, and type (e.g., freeways versus local roads), directly affect friction during travel and impact wear rates. Additionally, weather conditions, including precipitation, temperature, and humidity, will be included, as these can alter wear rates. For instance, wet surfaces may reduce tire friction, while high temperatures increase tire degradation. Traffic patterns, such as bottlenecks and roadway distances from urban centers, will also be incorporated. Bottlenecks lead to congestion and frequent braking, which increases BTW emissions. Meanwhile, roadways closer to urban centers typically experience more stop-and-go traffic, exacerbating wear, whereas rural roads see fewer BTW emissions due to lower traffic density. Temporal factors from PeMS data, which include traffic flow, vehicle composition, and speed at various times of the day, week, and year, will allow us to model BTW emissions dynamically, linking higher emissions to peak traffic hours and seasonal changes in behavior. Driving behaviors inferred from traffic data, such as aggressive braking or frequent accelerations, will also be integrated, as these directly affect braking frequency and intensity, thus influencing BTW emissions.

By incorporating these diverse factors into the linear mixed model, we can develop a comprehensive and detailed profile of BTW emissions across California. This approach ensures that all key variables influencing BTW are accounted for, allowing us to generate accurate, policy-relevant estimates of emissions. Furthermore, the mixed model provides the flexibility to account for localized effects, enabling us to capture the geographic and temporal variability of BTW emissions across different regions and road segments. The model will be applied to areas where BTW profiles have been established and will incorporate new field sampling data to validate and refine the results.

Task 3.4 Extend BTW profiles to the entire SJV through high-resolution WRF-Chem modeling (Baylor)

Task 3.4.1 Conduct link-level TBW emissions estimate using EMFAC BTW in MOVES environment

To conduct a link-level emissions estimate using EMFAC in MOVES, we will leverage the comprehensive set of spatiotemporal and traffic data we have already collected for the SJV. This includes detailed traffic data from CalTrans PeMS, which provides information on vehicle composition, speed, and traffic flow for specific road segments. These road segments, or links, including those through spatial interpolation, will be used for analyzing how emissions vary depending on factors such as vehicle type, speed, and driving behavior. For instance, we have acquired data on vehicle classifications, including light-duty vehicles, trucks, and buses, which are crucial for estimating emissions from brake- and tire-wear as different vehicle types contribute to these non-exhaust emissions at different rates. Additionally, we have collected data on road characteristics, such as road surface conditions, slope, and the International Roughness Index (IRI), which are all factors that influence tire-wear emissions. The detailed traffic flow data includes vehicle speeds and patterns of acceleration and deceleration, particularly important for estimating brake-wear emissions, as frequent braking in stop-and-go traffic can significantly increase these emissions. Using this rich dataset, we will associate this link-specific information with EMFAC to generate BTW $PM_{2.5}$ and PM_{10} emissions estimates tailored to the exact traffic and road conditions of each segment. The BTW $PM_{2.5}$ and PM_{10} emissions estimates at road link level will then be used as input in MOVES software to estimate speciated BTW PM emissions estimates. This process allows us to capture the nuances of vehicle activity on each link, accounting for the variation in emissions from different vehicle types and traffic conditions across the SJV.

Task 3.4.2 Model BTW profiles across the SJV through WRF-Chem modeling

With link-level brake- and tire-wear (BTW) emissions estimated, we will use WRF-Chem to model hourly and daily BTW concentrations across the SJV. WRF-Chem integrates meteorological data with chemical processes to simulate the distribution of pollutants, in this case the non-exhaust sources from BTW emissions. To initiate the process, we feed the link-level BTW emissions data into WRF-Chem by incorporating them as part of the model's emissions inventory. This inventory includes the spatial and temporal variation in emissions derived from our traffic and road condition data, which allows WRF-Chem to account for the fine-scale differences in emissions between road segments.

The model runs in a high-resolution of 100 m, with emissions distributed across the modeled grid based on geographic location, road type, and traffic conditions. WRF-Chem's meteorological component captures how local weather conditions—such as wind, temperature, and humidity—affect the dispersion and transformation of BTW particles in the atmosphere. It simulates the transport of these particles over time, providing outputs of hourly and daily concentration levels for different locations across the valley. The model also simulates the chemical transformation and deposition of particulate matter (PM) from BTW, helping us understand how far particles travel and how concentrations evolve across the region. This is particularly important for assessing how BTW emissions from urban traffic centers affect nearby rural or suburban areas.

To evaluate the performance of the WRF-Chem simulations, we compare the model's predicted BTW concentrations with real-world measurements from field sampling sites. We have field measurements of trace metals and organics at 45 sites. A source apportionment algorithm will be used to analyze BTW at those 45 field sites. By comparing the model outputs to these observed concentrations, we can assess how accurately the model captures the spatial and temporal variation in BTW concentrations.

Uncertainty in the model results will be addressed through multiple approaches. One key method is sensitivity analysis, where we systematically adjust input parameters—such as emissions rates, vehicle activity patterns, or meteorological conditions—and observe how these changes affect the predicted BTW concentrations. This helps identify the variables that introduce the most uncertainty into the model. Additionally, uncertainty estimates can be derived from discrepancies between the modeled and observed concentrations at field sites, which provide a measure of how well the model is performing under real-world conditions. These discrepancies might arise from factors like errors in the emissions inventory, misrepresentation of traffic patterns, or inaccuracies in the meteorological input data.

To reduce uncertainty and improve the accuracy of the model, we will adjust the emissions input based on these performance evaluations. For instance, if we find that the model consistently underestimates BTW concentrations in areas with high traffic congestion, we might revise the emissions estimates for those road links by increasing the weight given to stop-and-go traffic and braking events. Conversely, if the model overestimates concentrations in rural areas, adjustments could be made to reduce emissions associated with low-traffic roadways. We will incorporate more localized traffic data or higher-resolution meteorological data if available, to better reflect the conditions affecting emissions and their atmospheric dispersion.

The iterative process of model validation, uncertainty assessment, and emissions adjustment ensures that WRF-Chem's predictions are as accurate as possible. This process also allows us to refine the input parameters and emissions profiles as more data becomes available, making the model flexible and adaptable to changing conditions or new findings. In the end, this approach not only improves the accuracy of BTW concentration estimates but also informs policy decisions by providing robust, high-resolution data on the distribution of non-exhaust emissions across the region. The ultimate goal is to produce a model that reliably reflects real-world conditions and can be used to inform strategies for reducing air pollution and its health impacts.

Task 4. Exposure analysis for oxidative stress levels (UCLA)

We will conduct a detailed analysis of oxidative stress levels associated with BTW particles to determine their impact on oxidative stress in overburdened communities. A range of acellular oxidative potential assays have been developed to quantify different aspects of PM's ability to generate reactive oxygen species (ROS) and/or induce oxidative stress. In our recent epidemiological studies, the hydroxyl radical (OH) assay clearly outperformed PM2.5 mass (*19*). Thus, we will use our previously developed OH assay (*20*) to analyze samples collected from high-traffic areas and sites, as detailed in Task 3.1. The goal is to quantify the ROS levels in the presence of BTW particles. Following sample analysis, we will apply the PMF source apportionment model to identify and quantify the major sources contributing to the oxidative potential of particles. PMF will be instrumental in isolating the influence of BTW particles from other sources and estimating their relative contribution to the oxidative stress observed. We will correlate these findings with the oxidative stress biomarkers to evaluate how the presence of BTW particles affects oxidative stress levels. Statistical analyses will be performed to determine significant correlations and quantify the strength of the association between BTW exposure and oxidative stress. This approach aims to elucidate the potential health risks associated with BTW particles and provide valuable insights into their exposure-related impacts in the studied communities.

Task 5. Identify and secure health datasets to be linked to exposure data (UCB)

In California, chronic respiratory diseases significantly impact public health, with various estimates reflecting their prevalence. Chronic Obstructive Pulmonary Disease (COPD with ICD-10 code J44), affects approximately 6-7% of adults, equating to about 1.6 million Californians diagnosed with this condition. Chronic bronchitis (ICD-10 code J41), which is often included in COPD statistics, is estimated to affect around 3% of adults. Emphysema (ICD-10 code J43), another component of COPD, has an estimated prevalence of about 2% among adults. Additionally, asthma (ICD-10 code J45) affects roughly 8% of adults and about 10% of children, translating to around 2.6 million individuals in California.

The prevalence of various cardiovascular diseases reflects a significant public health concern in California. Hypertension (High Blood Pressure) (ICD-10 code I10) affects approximately 47% of adults, translating to about 11 million individuals in the state diagnosed with high blood pressure. Coronary Artery Disease (CAD) (ICD-10 code I25.10) has an estimated prevalence of around 6.7%, impacting roughly 1.6 million adults in California. Heart failure (ICD-10 code I50.9) is estimated to affect about 6.2% of the adult population, which equates to approximately 1.5 million Californians. Myocardial infarction (heart attacks) (ICD-10 code I21.9) are estimated to occur in about 7% of adults, with around 250,000 Californians experiencing a heart attack each year. Arrhythmias, including atrial fibrillation (ICD-10 code I48.9), affect approximately 2-3% of the adult population, impacting about 600,000 individuals. Peripheral artery disease (ICD-10 code I73.9) has an estimated prevalence of 4-5%, affecting about 1 million Californians. Finally, stroke (ICD-10 code I63.9) impacts roughly 2% of adults, with about 100,000 stroke events reported annually in the state. Valvular heart disease (ICD-10 code I34.9) affects approximately 2.5% of adults, which equates to about 600,000 individuals in California.

Further, the prevalence of pre-term birth and low birth weight in California is a critical public health issue. Pre-term birth (ICD-10 code O60) affects approximately 9.1% of live births, translating to about 55,000 infants annually. Low birth weight (LBW) (ICD-10 code P07) refers to infants weighing less than 2,500 grams (5.5 pounds) at birth, with about 7.4% of all live births in California classified as low birth weight.

This research will evaluate the impact of TBW on ED visits and hospitalizations from the chronic respiratory diseases and cardiovascular diseases described above. We have previously collected emergency department visit and hospitalization data from the Health Care Access and Information (HCAI) for type 2 diabetes patients under another CARB-funded project and will apply for chronic respiratory and cardiovascular health endpoints for this new study. Additionally, pre-term birth and low birth weight data have been collected from the California Department of Public Health (CDPH) for a separate CARB-funded initiative. To form a control group, all birth data will be requested from CDPH. To integrate these datasets with our exposure data, we will secure permissions and agreements with the state agencies that provide the data, apply for the State Committee for Protection of Human Subjects (CPHS) Institutional Review Board (IRB) approval and the UC Berkeley IRB reliance for health outcome analysis. These datasets will be crucial for assessing the health impacts of non-exhaust emissions and linking them to exposure levels.

Task 6. Analysis of health effects of BTW for the region and overburdened communities (UCB)

To model the impacts of BTW concentrations on ED visits and hospitalizations, we will employ a time-series case-crossover design, utilizing individual-level data where each patient serves as their own control. This methodology is particularly effective for assessing the transient effects of short-term exposures on acute health events, enabling us to clearly examine how variations in BTW concentrations relate to specific health outcomes. We will select cases using individual-level data of patients who experienced ED visits or hospitalizations due to chronic respiratory or cardiovascular diseases. Each case represents a unique health event of interest, allowing us to focus on the direct relationship between BTW exposure and acute health outcomes. To analyze this relationship, we will define specific exposure time windows surrounding each ED visit or hospitalization. For instance, we might consider several lag periods—such as 1 day, 3 days, and 7 days prior to the event—to assess both immediate and delayed health effects. In the case-crossover design, each individual serves as their own control, so we will identify control periods within the same individual's history during which no ED visit or hospitalization occurred. These control periods should be selected from time frames that match the characteristics of the case time period, accounting for seasonal and day-of-week effects. For this, we will select control periods from the same day of the week in the previous week or month to ensure comparability. Estimating individual exposure to BTW concentrations will be accomplished using high-resolution air pollution data modeled through WRF-Chem that can be linked to the specific dates of ED visits or hospitalizations. This linkage allows for the calculation of exposure levels during the defined time windows leading up to each health event, providing a robust assessment of the relationship between BTW exposure and health outcomes.

Statistical analysis will involve the use of conditional logistic regression to analyze the relationship between BTW exposure and ED visits or hospitalization. The model will treat the case and control periods as matched pairs, enabling us to examine the effect of exposure while controlling for individual-level confounding factors. The primary independent variable will be the estimated exposure to BTW concentrations during the specified time windows, allowing us to derive meaningful insights into the acute health risks associated with non-exhaust emissions. To account for health outcome impact from other environmental factors, such as air pollution from traffic exhaust and industrial sources, we will leverage the high-resolution daily air pollution models of PM2.5 with a 100 m resolution generated for the entire state. To isolate the specific effects of BTW, we will include both the BTW concentration estimates and the daily estimates of PM2.5 concentrations in our time-series case-crossover design. In this model, the primary independent variable of interest will be the estimated exposure to BTW concentrations, while the PM2.5 data will serve as a control variable. We can further explore potential interaction effects between BTW exposure and PM2.5 levels, examining whether the health impacts of one are exacerbated by the presence of the other. For instance, higher levels of PM2.5 may enhance the oxidative stress potential of particulate matter from BTW emissions, leading to more pronounced health outcomes. Additionally, we can stratify our analysis based on different PM2.5 exposure levels to examine how the relationship between BTW and health outcomes varies across exposure gradients. This stratification will help identify whether certain subpopulations are at greater risk due to elevated air pollution levels.

To model the number of days in hospitalization as a count outcome, we will employ a statistical framework such as Poisson regression or negative binomial regression. Our main exposure of interest will be the estimated BTW concentration for each individual, along with other relevant air pollution metrics, such as PM2.5 levels derived from our high-resolution air pollution models. In addition to individual-level confounders (age, sex, pre-existing conditions, socioeconomic status, and seasonality), we will incorporate community-level factors such as census tract level CalEnviroScreen score to identify disparities across disadvantaged communities. To incorporate temporal effects, we can include a time variable, such as day of the week or month, or utilize a generalized additive model (GAM) framework to capture non-linear trends over time. We will validate our model using a separate dataset or through resampling methods like cross-validation to ensure that our model generalizes well and is not overfitting the training data. The coefficients obtained from our models will provide insights into how changes in BTW concentrations (and PM2.5 levels) are associated with changes in the expected number of hospitalization days. We will report incidence rate ratios (IRRs) for ease of interpretation, allowing us to estimate relative changes in hospitalization duration associated with unit changes in exposure.

To model pre-term birth and low birth weight, logistic regression will be used as modeling technique. The dependent variable will be coded as 1 for preterm births/low birth weight and 0 for full-term births (≥37 weeks)/birth weight ≥ 2,500 grams. In the logistic regression model, the log-odds of preterm birth/low birth weight can be modeled as a function of BTW concentrations. To model low birth weight, we will also do a sensitivity analysis through a linear regression model by treating birth weight as a continuous variable. In both models, it is crucial to include potential confounding variables that may influence birth outcomes, such as maternal age, income level, access to healthcare, lifestyle factors (e.g., smoking, nutrition) and exposure to environmental factors such as air pollution $PM_{2.5}$. Additionally, it may be helpful to consider interaction terms between exposure and maternal characteristics, as these may reveal more nuanced effects.

By integrating high-resolution PM2.5 models with data on non-exhaust emissions like BTW, we can comprehensively assess the health impacts specific to vulnerable populations, particularly those in disadvantaged communities. Our analysis will explicitly incorporate community-level factors, including CalEnviroScreen score, to distinguish the effects of air pollution exposure in overburdened communities compared to less burdened ones. This will allow us to identify disparities in health outcomes related to BTW exposure and provide targeted insights for public health strategies aimed at mitigating risks. These interventions will focus on improving air quality and health outcomes in communities that face greater environmental and social challenges, thereby ensuring that our findings can inform effective policy decisions and resource allocation.

Task 7. Technical Advisory Group and Community Engagement (UCB)

We will establish a TAG to provide expert guidance and ensure the success of our study on brake and tire wear emissions. The TAG will consist of 5 members, equally divided between community representatives and academic experts specializing in brake and tire wear research. This balanced composition will ensure that both technical expertise and community perspectives are integrated. At the project's inception, the TAG will convene to review and offer recommendations on the study's design, including methodologies for exposure assessment and health analysis. This initial meeting will focus on refining our workplan to align with the study's objectives and ensure robustness in our approach. The TAG will reconvene later in the project to discuss preliminary research findings and provide feedback.

We will collaborate closely with CARB staff to develop and co-create all meeting materials, such as presentation slides, flyers, and speaking notes. This collaborative approach will help accurately represent CARB's policies and ensure that the meetings are informative and aligned with CARB's standards. CARB will participate in these meetings unless otherwise agreed upon, to facilitate effective community engagement and ensure that our research addresses key concerns and priorities.

For community engagement, we will hold two community meetings to facilitate direct engagement with residents. The first meeting will occur at the project's outset to introduce the research objectives, methodologies, and anticipated impacts. This initial gathering will provide an opportunity for community members to voice their concerns and expectations. The second meeting will take place at the conclusion of the project to present the research findings, discuss implications, and gather final feedback. These meetings will serve as platforms for open dialogue, allowing community members to engage meaningfully with the research process. Details of community engagement can be found at "Cultural Competency Statement and Community Engagement Plan".

Task 8. Meeting, reporting, preparation of draft final report (All)

We will ensure effective communication and collaboration with CARB staff through regular interactions and structured reporting. We will conduct monthly meetings with CARB to discuss project progress, review methodologies, and address any emerging issues. The project team will also hold weekly progress meetings. These meetings will facilitate ongoing alignment with CARB's objectives and provide opportunities for feedback and adjustments.

We will submit quarterly progress reports to CARB detailing the project's status, advancements, and any challenges encountered. Six months before the project's conclusion, we will prepare a draft final report, which will be reviewed by CARB for input and revisions. The final report will include a comprehensive section on methodological limitations. Additionally, we will organize a lay-oriented kickoff meeting and a lay-oriented review of findings to engage the community. A lay-oriented fact sheet summarizing the project's findings will also be prepared to ensure clear communication with the broader public. Interim deliverables will be provided annually to track and report on project progress.

Cultural Competency Statement and Community Engagement Plan

Cultural competency is essential in public health research, especially when addressing issues that disproportionately affect specific populations. In this project, we recognize the diverse cultural backgrounds, values, and experiences of the communities impacted by BTW emissions and related health outcomes. Our approach is rooted in an understanding that health disparities are often influenced by social determinants, including socioeconomic status, education, access to healthcare, and systemic inequities. We are committed to fostering an inclusive research environment that respects and honors the voices of all community members, particularly those from historically marginalized and underrepresented groups.

To ensure that our project is culturally competent, we will engage with community stakeholders including those from the Central California Asthma Collaborative (CCAC) and Environmental Justice (EJ) advocates throughout the research process, from the initial design phase to the dissemination of findings. This engagement will involve collaboration with local community-based organizations, public health agencies, and advocacy groups that serve vulnerable populations. By partnering with these organizations, we aim to build trust and establish rapport with community members, ensuring that their insights and concerns are integrated into our research framework. Our plan for integrating community voices including:

Establishing a Technical Advisory Group (TAG): In addition to scientific researchers, a TAG will also consist of community representatives, including individuals who have been directly impacted by air pollution and health outcomes related to BTW emissions. TAG will consist of three local representatives, including those from CCAC and EJ advocates in SJV. The other two will be recruited from academic institutions. This board will meet regularly to provide guidance on project objectives, research methodologies, and data interpretation. Their feedback will be crucial in ensuring that our research questions are relevant and that our approach is culturally sensitive.

Organizing community meetings: We will hold two community meetings to facilitate direct engagement with residents. The first meeting will occur at the project's outset to introduce the research objectives, methodologies, and anticipated impacts. This initial gathering will provide an opportunity for community members to voice their concerns and expectations. The second meeting will take place at the conclusion of the project to present the research findings, discuss implications, and gather final feedback. These meetings will serve as platforms for open dialogue, allowing community members to engage meaningfully with the research process.

By implementing these strategies, we aim to create a research project that not only generates valuable scientific knowledge but also amplifies the voices of community members. Our goal is to foster an equitable research process that empowers communities to influence public health policy and interventions, ultimately contributing to improved health outcomes for all residents affected by air pollution and related health disparities. Through sustained engagement and collaboration, we aim to build a foundation of trust and mutual respect that extends beyond the duration of the project, promoting long-term community resilience and advocacy.

Meetings

A. Initial meeting. Before work on the contract begins, the Principal Investigator and key personnel will meet with the CARB Contract Project Manager and other staff to discuss the overall plan, details of performing the tasks, the project schedule, items related to personnel or changes in personnel, and any issues that may need to be resolved before work can begin.

B. Progress review meetings. The Principal Investigator and appropriate members of his or her staff will meet with CARB's Contract Project Manager at quarterly intervals to discuss the progress of the project. This meeting may be conducted by phone.

C. Technical Seminar. The Contractor will present the results of the project to CARB staff and a possible webcast at a seminar at CARB facilities in Sacramento or El Monte.

CONFIDENTIAL HEALTH DATA AND PERSONAL INFORMATION (OPTIONAL – For projects with Health Data and/or Personal Information)

CARB will not be provided access to and will not receive any confidential health data or other confidential personal information under this contract. Further, CARB will have no ownership of confidential health data or other confidential personal information used in connection with this contract. The entities conducting the research in this contract will follow all applicable rules and regulations regarding access to and the use of confidential health data and personal information, including the Health Insurance Portability and Accountability Act (HIPAA) and requirements related to the Institutional Review Board (IRB) process. CARB will not be a listed entity with authorized access to confidential information pursuant to the IRB process for this contract.

HEALTH AND SAFETY

Contractors are required to, at their own expense, comply with all applicable health and safety laws and regulations. Upon notice, Contractors are also required to comply with the state agency's specific health and safety requirements and policies. Contractors agree to include in any subcontract related to performance of this Agreement, a requirement that the subcontractor comply with all applicable health and safety laws and regulations, and upon notice, the state agency's specific health and safety requirements and policies.

EXHIBIT A1

SCHEDULE OF DELIVERABLES

List all items that will be delivered to the State under the proposed Scope of Work. Include all reports, including draft reports for State review, and any other deliverables, if requested by the State and agreed to by the Parties.

If use of any Deliverable is restricted or is anticipated to contain preexisting Intellectual Property with any restricted use, it will be clearly identified in Exhibit A4, Use of Preexisting Intellectual Property & Data.

Unless otherwise directed by the State, the University Principal Investigator shall submit all deliverables to State Contract Project Manager, identified in Exhibit A3, Authorized Representatives.

Deliverable	Description	Due Date
Racial equity/implicit bias training	The Principal Investigator and key personnel must demonstrate that they have taken, or will take, cultural competency training, implicit bias training, or racial equity training, whichever is administered at their institution. Training certificates or certificates of completion completed within one (1) year prior to the agreement start date will be accepted. If the training has not been completed within one (1) year prior to the agreement start date, then the Principal Investigator and key personnel must demonstrate that they have scheduled the training within 30 days of the agreement start date and shall complete the training within 90 days of the agreement start date.	Within 90 days of the agreement start date.
Initial Meeting	Principal Investigator and key personnel will meet with CARB Contract Project Manager and other staff to discuss the overall plan, details of performing the tasks, project schedule, items related to personnel or changes in personnel, and any issues that may need to be resolved before work can begin.	Month 1
Technical advisory group (TAG) (Task 7: UCB)	Recruit 5 TAG members from community representatives and academic experts specializing in brake and tire wear research.	Q1
Community engagement (Phase 1) (Task 7: UCB)	Introduce the research objectives, methodologies, and anticipated impacts to community members	Q1
Literature review (Task 1: UCB)	Completion of a comprehensive literature review on brake and tire wear (BTW) emissions, health impacts, and source apportionment techniques.	Q4
Acquisition of data impacting BTW emissions (Task 3.3,1: UCB)	Completion of acquiring PeMS traffic data, DEM data, road surface condition data, and vehicle activity data for the SJV.	Q1
Site selection and field sampling (Task 3.1: CCAC, UCLA)	Select and deployment of air quality sensors at 45 sites in two seasons.	Q5

Source apportionment Fresno profiles (Task 3.2.1: UCD)	Completion of source apportionment for Fresno Garland site and other sites using PMF and ME-2 algorithms	Q2
BTW link-level emissions modeling setup (Task 3.4.1: Baylor)	integration of link-level traffic and environmental data with EMFAC to model BTW emissions in MOVES**.**	Q2
BTW profile modeling through linear mixed modeling (Task 3.3.2: UCB)	Through a linear mixed modeling technique to identify key variables influencing BTW and use it to assist more accurate source apportionment and BTW WRF-Chem modeling.	Q4
Exposure analysis for oxidative stress (Task 4: UCLA)	BTW particle analysis for oxidative stress potential.	Q4
Source apportionment (Field sites) (Task 3.2.2: UCD)	Completion of source apportionment for 45 field sampling sites using PMF and ME-2 algorithms, cross-validated with Fresno profiles.	Q4
WRF-Chem modeling (Task 3.4.2: Baylor)	WRF-Chem modeling of BTW profiles for the entire SJV region.	Q4
Identify and secure health datasets (Task 5: UCB)	Application for data on emergency visits, hospitalizations, and birth outcomes from HCAI and CDPH. Seeking approval from State IRB and UCB reliance application.	Q4
Analysis of health effects of BTW exposure (Task 6: UCB)	Analysis of health outcomes using case-crossover, negative binomial and other regression models, including understanding health outcomes in overburdened communities vs. other communities.	Q6
Community Engagement & Dissemination (Task 7: UCB)	Host final community meetings and disseminate results to the public, ensuring transparency and accessibility for overburdened communities.	Q6
Progress Reports & Meetings	Quarterly progress reports and meetings throughout the agreement term, to coincide with work completed in quarterly invoices.	Quarterly
Draft Final Report	Draft version of the Final Report detailing the purpose and scope of the work undertaken, the work performed, and the results obtained and conclusions.	Six (6) months prior to agreement end date.
Data	Data compilations first produced in the performance of this Agreement by the Principal investigator or the University's project personnel.	Two (2) weeks prior to agreement end date.
Technical Seminar	Presentation of the results of the project to CARB staff and a possible webcast at a seminar at CARB facilities in Sacramento or El Monte.	On or before agreement end date.
The following Deliverables are subject to paragraph 19. Copyrights, paragraph B of Exhibit C		
Final Report	Written record of the project and its results. The Final Report shall be submitted in an Americans with Disabilities Act compliant format. The Public Outreach Document, as described in Exhibit A1, Section 2, shall be incorporated into the Final Report.	Two (2) weeks prior to agreement end date.

1. Reports and Data Compilations

A. With respect to each invoice period University shall submit, to the CARB Contract Project Manager, one (1) electronic copy of the progress report. When emailing the progress report, the “subject line” should state the contract number and the billing period. Each progress report must accompany a related invoice covering the same billing period. Each progress report will begin with the following disclaimer:

> *The statements and conclusions in this report are those of the University and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products*.

B. Each progress report will also include:

   1. A brief summary of the status of the project, including whether the project is on schedule. If the project is behind schedule, the progress report must contain an explanation of reasons and how the University plans to resume the schedule.

   2. A brief narrative account of project tasks completed or partially completed since the last progress report.

   3. A brief discussion of problems encountered during the reporting period and how they were or are proposed to be resolved.

   4. A brief discussion of work planned, by project task, before the next progress report. and

   5. A graph or table showing percent of work completion for each task.

C. Six (6) months prior to Agreement expiration date, University will deliver to CARB an electronic copy of the draft final report in both PDF and Microsoft Word formats. The draft final report will conform to Exhibit A1, Section 2 – Research Final Report Format.

D. Within forty-five (45) days of receipt of CARB’s comments, University will deliver to CARB’s Contract Project Manager an electronic copy of the final report incorporating all reasonable alterations and additions. Within two (2) weeks of receipt of the revised report, CARB will verify that all CARB comments have been addressed. Upon acceptance of the amended final report approved by CARB in accordance to Exhibit A1, Section 2 – Research Final Report Format, University will within two (2) weeks, deliver to CARB an electronic copy of the final report in both PDF and Microsoft Word formats.

E. As specified in Exhibit A1, Section 2, Final Report will be submitted in an Americans with Disabilities Act compliant Format.

F. Together with the final report, University will deliver a set of all data compilations as specified in Exhibit A1 – Schedule of Deliverables.

G. University’s obligation under this Agreement shall be deemed discharged only upon submittal to CARB of an acceptable final report in accordance to Exhibit A1, Section 2 – Research Final Report Format, all required data compilations, and any other project deliverables.

2. Research Final Report Format

The research contract Final Report (Report) is as important to the contract as the research itself. The Report is a record of the project and its results and is used in several ways. Therefore, the Report must be well organized and contain certain specific information. The CARB's Research Screening Committee (RSC) reviews all draft final reports, paying special attention to the Abstract and Executive Summary. If the RSC finds that the Report does not fulfill the requirements stated in this Exhibit, the RSC may not recommend release, and final payment for the work completed may be withheld. This Exhibit outlines the requirements that must be met when producing the Report.

Note: In partial fulfillment of the Final Report requirements, the Contractor shall submit a copy of the Report in PDF format <u>and</u> in a word-processing format, preferably in Word – Version 6.0 or later. The electronic copy file name shall contain the CARB contract number, the words "Final Report", and the date the report was submitted.

Accessibility. To maintain compliance with California Government Code Sections 7405 and 11135, and Web Content Accessibility Guidelines, Assembly Bill No. 434, the final Report must be submitted in an Americans with Disabilities Act compliant format. The Final Report will be posted on the CARB website and therefore must be in an accessible format so that all members of the public can access it.

Watermark. Each page of the draft Report must include a watermark stating "DRAFT." The revised report should not include any watermarks.

Title. The title of the Report should exactly duplicate the title of the contract. However, minor changes to the title may be approved provided the new title does not deviate from the old title. These minor changes must be approved in writing by the contract manager. Significant changes to the title would require a formal amendment.

Page size. All pages should be of standard size (8 ½" x 11") to allow for photo-reproduction.

Corporate identification. Do not include corporate identification on any page of the Final Report, except the title page.

Unit notation. Measurements in the Reports should be expressed in metric units. However, for the convenience of engineers and other scientists accustomed to using the British system, values may be given in British units as well in parentheses after the value in metric units. The expression of measurements in both systems is especially encouraged for engineering reports.

Section order. The Report should contain the following sections, in the order listed below:

Title page
Disclaimer
Acknowledgment (1)
Acknowledgment (2)
Table of Contents
List of Figures
List of Tables
Abstract
Public Outreach Document
Executive Summary
Equity Implications Section
Body of Report
References

List of inventions reported and copyrighted materials produced
Glossary of Terms, Abbreviations, and Symbols
Appendices

Page numbering. Beginning with the body of the Report, pages shall be numbered consecutively beginning with “1”, including all appendices and attachments. Pages preceding the body of the Report shall be numbered consecutively, in ascending order, with small Roman numerals.

Title page. The title page should include, at a minimum, the contract number, contract title, name of the principal investigator, contractor organization, date, and this statement:
"Prepared for the California Air Resources Board and the California Environmental Protection Agency"

Disclaimer. A page dedicated to this statement must follow the Title Page:

> The statements and conclusions in this Report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Acknowledgment (1). Only this section should contain acknowledgments of key personnel and organizations who were associated with the project. The last paragraph of the acknowledgments must read as follows:

> This Report was submitted in fulfillment of [CARB contract number and project title] by [contractor organization] under the [partial] sponsorship of the California Air Resources Board. Work was completed as of [date].

Acknowledgment (2). Health reports should include an acknowledgment to the late Dr. Friedman. Reports should include the following paragraph:

> This project is funded under the CARB’s Dr. William F. Friedman Health Research Program. During Dr. Friedman’s tenure on the Board, he played a major role in guiding CARB’s health research program. His commitment to the citizens of California was evident through his personal and professional interest in the Board’s health research, especially in studies related to children’s health. The Board is sincerely grateful for all of Dr. Friedman’s personal and professional contributions to the State of California.

Table of Contents. This should list all the sections, chapters, and appendices, together with their page numbers. Check for completeness and correct reference to pages in the Report.

List of Figures. This list is optional if there are fewer than five illustrations.

List of Tables. This list is optional if there are fewer than five tables.

Abstract. The abstract should tell the reader, in nontechnical terms, the purpose and scope of the work undertaken, describe the work performed, and present the results obtained and conclusions. The purpose of the abstract is to provide the reader with useful information and a means of determining whether the complete document should be obtained for study. The length of the abstract should be no more than about 200 words. Only those concepts that are addressed in the executive summary should be included in the abstract.

Example of an abstract:

A recently developed ground-based instrument, employing light detecting and ranging (lidar) technology, was evaluated, and found to accurately measure ozone concentrations at altitudes of up to 3,000 meters. The novel approach used in this study provides true vertical distributions of ozone concentrations aloft and better temporal coverage of these distributions than other, more common methods, such as those using aircraft and ozonesonde (balloon) techniques. The ozone and aerosol measurements from this study, in conjunction with temperature and wind measurements, will provide a better characterization of atmospheric conditions aloft and the processes involved in the formation of unhealthful ozone concentrations than can be achieved with traditional ground-based monitors.

Public Outreach Document. The public outreach document is a one-page document that will be widely used to communicate, in clear and direct terms, the key research findings from the study to the public. CARB will be translating the document into other languages. This document must adhere to the following guidelines:

- Single space, limited to one-page or about 500 words.
- Use narrative form and active voice.
- Incorporate a graphic that it is easy to interpret and captures the results' central message.
- Avoid jargon and technical terms. Use a style and vocabulary level comparable to that of sixth grade reading level.
- The document should contain a title and the following five sections: Issue/s, Main Question, Key Research Findings, Conclusion/s, and More Information. Guidance on how to write these sections is described below.

  TITLE: Adopt a short, non-technical title to make the topic clear and concise. The title will likely differ from the original title of the contract.

  ISSUE/S: In one to two paragraphs, describe why the project was needed. In this section, identify the problem leading to this study and what the study was set to accomplish to help address the problem. Reference any history that is relevant such as a regulation, legislation, program, law, or other. Without going into detail and disclosing the research findings, mention the methods used in the study and how it informed the results.

  MAIN QUESTION: Present a concise central research question driving this project.

  KEY RESEARCH FINDING/S: This section covers the key research findings. List key points and or findings.

  CONCLUSION/S: In one to two paragraphs, discuss how the results could be used. Mention its relevance to policies, rules, regulations, legislations, or CARB programs. Include suggestions for next steps, additional research, or other actions.

  MORE INFORMATION: In two to three short sentences provide specifics about the study. This section should include the full title of the study, sponsor, authors, and where the full report can be found (the final report will be posted on the CARB website). In addition to a direct contact to gain more information (author and CARB contract manager).

Executive Summary. The function of the executive summary is to inform the reader about the important aspects of the work that was done, permitting the reader to understand the research without reading the entire Report. It should state the objectives of the research and briefly describe the experimental methodology[ies] used, results, conclusions, and recommendations for further study. All of the concepts brought out in the abstract should be expanded upon in the Executive Summary. Conversely, the Executive Summary should not contain concepts that are not expanded upon in the body of the Report.

The Executive Summary will be used in several applications as written; therefore, please observe the style considerations discussed below.

Limit the Executive Summary to two pages, single spaced.

Use narrative form. Use a style and vocabulary level accessible to the general audience. Assume the audience is being exposed the subject for the first time.

Do not list contract tasks in lieu of discussing the methodology. Discuss the results rather than listing them.

Avoid jargon.

Define technical terms.

Use passive voice if active voice is awkward.

Avoid the temptation to lump separate topics together in one sentence to cut down on length.

The Executive Summary should contain four sections: Background, Objectives and Methods, Results, and Conclusions, described below.

THE BACKGROUND SECTION. For the Background, provide a one-paragraph discussion of the reasons the research was needed. Relate the research to the Board's regulatory functions, such as establishing ambient air quality standards for the protection of human health, crops, and ecosystems; the improvement and updating of emissions inventories; and the development of air pollution control strategies.

THE OBJECTIVES AND METHODS SECTION. At the beginning of the Objectives and Methods section, state the research objectives as described in the contract. Include a short, one or two sentences, overview of what was done in general for this research.

The methodology should be described in general, nontechnical terms, unless the purpose of the research was to develop a new methodology or demonstrate a new apparatus or technique. Even in those cases, technical aspects of the methodology should be kept to the minimum necessary for understanding the project. Use terminology with which the reader is likely to be familiar. If it is necessary to use technical terms, define them. Details, such as names of manufacturers and statistical analysis techniques, should be omitted.

Specify when and where the study was performed if it is important in interpreting the results. The findings should not be mentioned in the Objectives and Methods section.

THE RESULTS SECTION. The Results section should be a single paragraph in which the main findings are cited, and their significance briefly discussed. The results should be presented as a narrative, not a list. This section must include a discussion of the implications of the work for the Board's relevant regulatory programs.

THE CONCLUSIONS SECTION. The Conclusions section should be a single short paragraph in which the results are related to the background, objectives, and methods. Again, this should be presented as a narrative rather than a list. Include a short discussion of recommendations for further study, adhering to the guidelines for the Recommendations section in the body of the Report.

Equity Implication Section. The equity implications section should summarize how the research results inform disparate impacts of policies, regulations, or programs on priority communities. [1] This section should summarize how sociodemographic factors were examined in this research. Given the data used or collected, which populations are excluded or overrepresented? How were relevant communities engaged in the research effort and/or how were existing data gaps identified and ground-truthed during the research project? If ground-truthed data were found to not accurately reflect the lived experiences of community members, what future research projects could address this disconnect. The research results should inform existing or future CARB programs and the equity implications section should discuss how the research results may inform programs to close disparities in health outcomes, pollutant exposure or climate adaptation, etc., for priority communities. This section should be limited to a maximum of two (2) pages, single spaced and shall include the following sections.

HISTORICAL ANALYSIS. Provide an overview of the inequities and disparities observed in the existing data or data gathered during the research and how it ties to historic policies. For example, what is the root-cause of the disparity being experienced by the community or population central to this research?

MATERIALS AND METHODS. Describe how this research project examines racial equity. Some methods can include but are not limited to: examining the potential for existing data to address racial inequalities, ground-truthing existing data, engaging priority communities, assessments for racial and ethnic subgroups in the development of data and approaches, identifying data gaps and filling those gaps.

RESULTS AND DISCUSSION. Describe how the results improve our understanding of the equity issues identified or interventions to address those inequalities .

---

[1] Priority communities here encompasses various terms CARB uses such as priority populations[2], communities of concern[3], protected classes[4], or disadvantaged communities[5].

[2] Priority Populations — California Climate Investments

[3] Referenced from the California Public Utilities Commission Environmental and Social Justice Plan an effort resulting from California's Capitol Collaborative on Race & Equity.

[4] Protected Classes | California State Senate

[5] SB-535-Designation-Final.pdf (ca.gov) ; California Climate Investments to Benefit Disadvantaged Communities | CalEPA; CalEnviroScreen 4.0 | OEHHA

Body of Report. The body of the Report should contain the details of the research, divided into the following sections:[1]

INTRODUCTION. Clearly identify the scope and purpose of the project. Provide a general background of the project. Explicitly state the assumptions of the study.

Clearly describe the hypothesis or problem the research was designed to address. Discuss previous related work and provide a brief review of the relevant literature on the topic.

MATERIALS AND METHODS. Describe the various phases of the project, the theoretical approach to the solution of the problem being addressed, and limitations to the work. Describe the design and construction phases of the project, materials, equipment, instrumentation, and methodology.
Describe quality assurance and quality control procedures used. Describe the experimental or evaluation phase of the project.

RESULTS. Present the results in an orderly and coherent sequence. Describe statistical procedures used and their assumptions. Discuss information presented in tables, figures, and graphs. The titles and heading of tables, graphs, and figures, should be understandable without reference to the text. Include all necessary explanatory footnotes. Clearly indicate the measurement units used.

DISCUSSION. Interpret the data in the context of the original hypothesis or problem. Does the data support the hypothesis or provide solutions to the research problem? If appropriate, discuss how the results compare to data from similar or related studies. What are the implications of the findings?

Identify innovations or development of new techniques or processes. If appropriate, discuss cost projections and economic analyses.

SUMMARY AND CONCLUSIONS. This is the most important part of the Report because it is the section that will probably be read most frequently. This section should begin with a clear, concise statement of what, why, and how the project was done. Major results and conclusions of the study should then be presented, using clear, concise statements. Make sure the conclusions reached are fully supported by the results of the study. Do not overstate or overinterpret the results. It may be useful to itemize primary results and conclusions. A simple table or graph may be used to illustrate.

RECOMMENDATIONS. Use clear, concise statements to recommend (if appropriate) future research that is a reasonable progression of the study and can be supported by the results and discussion.

References. Use a consistent style to fully cite work referenced throughout the Report and references to closely related work, background material, and publications that offer additional information on aspects of the work. Please list these together in a separate section, following the body of the Report. If the Report is lengthy, you may list the references at the end of each chapter.

List of inventions reported and publications produced. If any inventions have been reported, or publications or pending publications have been produced as a result of the project, the titles,

[1] Note that if the research employs multiple distinct methods, analyses, etc., the final report can include separate materials/methods, results, and discussion sections to allow for coherent discussion of each set of analyses and findings. However, the executive summary and conclusions sections should synthesize the collective findings of the entire study.

authors, journals or magazines, and identifying numbers that will assist in locating such information should be included in this section.

Glossary of terms, abbreviations, and symbols. When more than five of these items are used in the text of the Report, prepare a complete listing with explanations and definitions. It is expected that every abbreviation and symbol will be written out at its first appearance in the Report, with the abbreviation or symbol following in parentheses [i.e., carbon dioxide (CO2)]. Symbols listed in table and figure legends need not be listed in the Glossary.

Appendices. Related or additional material that is too bulky or detailed to include within the discussion portion of the Report shall be placed in appendices. If a Report has only one appendix, it should be entitled "APPENDIX". If a Report has more than one appendix, each should be designated with a capital letter (APPENDIX A, APPENDIX B). If the appendices are too large for inclusion in the Report, they should be collated, following the binding requirements for the Report, as a separate document.

The contract manager will determine whether appendices are to be included in the Report or treated separately. Page numbers of appendices included in the Report should continue the page numbering of the Report body. Pages of separated appendices should be numbered consecutively, beginning at “1”.

3. Other Deliverables

A. Any other deliverables shall be provided in a mutually agreed upon format unless the deliverable format is already specified in Exhibit A.

EXHIBIT A2

KEY PERSONNEL

List Key Personnel as defined in the Agreement starting with the PI, by last name, first name followed by Co-PIs. Then list all other Key Personnel in alphabetical order by last name. For each individual listed include his/her name, institutional affiliation, and role on the proposed project. Use additional consecutively numbered pages as necessary.

Last Name, First Name	Institutional Affiliation	Role on Project
Principal Investigator (PI):		
Jason G. Su	University of California, Berkeley	Overall project management; collection and modeling spatiotemporal data that impact BTW emissions; collection and modeling of health outcome data; generation of quarterly and final project report.
Co-PI(s) – if applicable:		
Other Key Personnel:		
Tim Tyner	Central California Asthma Collaborative (CCAC)	Field samplers deployment and collection, including BTW elements.
Michael Jerrett, Yifang Zhu and Suzanne Paulson	University of California, Los Angeles	Design of field sampling network; assist CCAC with field sampling; oxidative stress potential analysis.
Qi Zhang	University of California, Davis	Source apportionment on Fresno Garland data and field sampling data collected by CCAC.
Yang Li	Baylor University	BTW emissions estimation and BTW concentration modeling.

EXHIBIT A3

AUTHORIZED REPRESENTATIVES

The following individuals are the authorized representatives for the State and the University under this Agreement. Any official Notices issued under the terms of this Agreement shall be addressed to the Authorized Official identified below, unless otherwise identified in the Agreement.

State Agency Contacts Agency Name: **CARB**	**University Contacts** University Name: University of California, Berkeley
Contract Project Manager (Technical) Name: Address: Research Division 1001 I Street, 5th Floor Sacramento, CA 95814	***Principal Investigator (PI)*** Name: Jason Su Address: Public Health – EHS 2121 Berkeley Way #5302 Berkeley, CA 94720-7360
Authorized Official (contract officer) Name: Alice Kindarara, Branch Chief Address: Acquisitions Branch 1001 I Street, 5th Floor Sacramento, CA 95814 ***Send notices to (if different):***	***Authorized Official*** Name: Angela R. Ford, Executive Director Address: Sponsored Projects Office, UC Berkeley 1608 Fourth Street, Suite 220 Berkeley, CA 94710-1749 ***Send notices to (if different):*** Name: Heidi Gomez, Assistant Director Address: Sponsored Projects Office, UC Berkeley 1608 Fourth Street, Suite 220 Berkeley, CA 94710-1749

Administrative Contact	Administrative Contact
Name: Address: Research Division 1001 I Street, 7th Floor Sacramento, CA 95814	Name: Heidi Gomez, Assistant Director Address: Sponsored Projects Office, UC Berkeley 1608 Fourth Street, Suite 220 Berkeley, CA 94710-1749
Financial Contact/Accounting	***Authorized Financial Contact/Invoicing***
Name: Accounts Payable Address: P.O. Box 1436 Sacramento, CA 95814	Name: Beata Najman, Director Address: Contracts and Grants Accounting UC Berkeley 1608 Fourth Street, Suite 201 Berkeley, CA 94710-1749

EXHIBIT A6

CURRENT & PENDING SUPPORT

University will provide current & pending support information for Key Personnel identified in Exhibit A2 at time of proposal and upon request from State agency. The "Proposed Project" is this application that is submitted to the State. Add pages as needed.

PI: Jason Su

Status (currently active or pending approval)	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
Proposed Project		CARB	Assessing Health Impacts of Brake and Tire Wear Emissions in Overburdened Communities of the San Joaquin Valley	01/01/2025	12/31/2026
Pending	EPA-G2023-STAR-G1	U.S. EPA	Developing Effective Assessment Approaches for Cumulative Impacts and Driving Environmental Health Equity in Underserved Communities	11/01/204	10/31/2027
Active	1RF1NS130659-01	NIH/UCD	Do atmospheric ultrafine particles lodge in the brain and cause cognitive decline leading to Alzheimer's Disease Related Dementias?	09/01/2023	08/31/2025
Active	1R21ES035485-01A1	NIH/Yale	Air Pollution Exposure and Risk for Cerebral Palsy - A Statewide Study	07/01/2024	06/30/2026
Active	22RD010	CARB	Impact of Air Pollution Exposure on Metabolic Outcomes for California Residents	05/01/2023	04/30/2025
Active	22RD011	CARB	Impacts of Air Pollution on Life Expectancy across Multiple Generations: Race, Ethnicity, and Vulnerability Perspectives	06/15/2023	06/14/2025 (NCE: 06/14/2026)
Active	21RD004	CARB/UCLA	Preterm Birth, Term Low Birth Weight, Childhood Autism, Parkinson's, and Alzheimer's Disease and Air Pollution – California Studies	05/01/2022	04/30/2024 (NCE: 04/30/2025)

References

1. R. M. Harrison *et al.*, Non-exhaust vehicle emissions of particulate matter and VOC from road traffic: A review. *Atmospheric Environment* **262**, 118592 (2021).
2. B. Lopez *et al.*, Metal contents and size distributions of brake and tire wear particles dispersed in the near-road environment. *Science of The Total Environment* **883**, 163561 (2023).
3. Q. Zhang *et al.*, Direct measurement of brake and tire wear particles based on real-world driving conditions. *Science of the total environment* **906**, 167764 (2024).
4. N. Stojanovic, J. Glisovic, O. I. Abdullah, A. Belhocine, I. Grujic, Particle formation due to brake wear, influence on the people health and measures for their reduction: a review. *Environmental science and pollution research*, 1-20 (2022).
5. K. O'Sharkey *et al.*, Associations between brake and tire wear-related PM2. 5 metal components, particulate oxidative stress potential, and autism spectrum disorder in Southern California. *Environment International* **185**, 108573 (2024).
6. Q. Meng *et al.*, Ambient exposure to fine particulate matter with oxidative potential affects oxidative stress biomarkers in pregnancy. *American Journal of Epidemiology*, kwae152 (2024).
7. J. Liu *et al.*, Co-kriging with a low-cost sensor network to estimate spatial variation of brake and tire-wear metals and oxidative stress potential in Southern California. *Environment International* **168**, 107481 (2022).
8. K. Arole *et al.*, Impacts of particles released from vehicles on environment and health. *Tribology International* **184**, 108417 (2023).
9. K. Karimova, K. Ismailov, A. Shermukhamedov, S. Yuldashev, in *E3S Web of Conferences*. (EDP Sciences, 2024), vol. 508, pp. 07013.
10. B. Güney, Ö. Ali, Microstructure and chemical analysis of vehicle brake wear particle emissions. *Avrupa Bilim ve Teknoloji Dergisi*, 633-642 (2020).
11. L.-C. Chen, P. Maciejczyk, G. D. Thurston, in *Handbook on the Toxicology of Metals*. (Elsevier, 2022), pp. 137-182.
12. A. Adeyemi, P. Molnar, J. Boman, J. Wichmann, Source apportionment of fine atmospheric particles using positive matrix factorization in Pretoria, South Africa. *Environmental Monitoring and Assessment* **193**, 1-21 (2021).
13. S. Anwar, M. Shameer, H. Alawadhi, N. M. Hamdan, Source apportionment of PM2. 5 and PM10 pollutants near an urban roadside site using positive matrix factorization. *Environmental Advances* **17**, 100573 (2024).
14. D. Srivastava *et al.*, Insight into PM 2.5 sources by applying positive matrix factorization (PMF) at an urban and rural site of Beijing. *Atmospheric Chemistry and Physics Discussions* **2021**, 1-51 (2021).
15. Q. Zhang *et al.*, meteorological impact, source apportionment, and health risks. (2022).
16. Q. Zhu *et al.*, Improved source apportionment of organic aerosols in complex urban air pollution using the multilinear engine (ME-2). *Atmospheric Measurement Techniques* **11**, 1049-1060 (2018).
17. Q. Zhu, Y. Liu, S. Hasheminassab, Long-term source apportionment of PM2. 5 across the contiguous United States (2000-2019) using a multilinear engine model. *Journal of Hazardous Materials* **472**, 134550 (2024).
18. J. Schauer, "Characterization of Metals Emitted from Motor Vehicles," (Research Report 133, 2006).
19. Q. Meng *et al.*, Fine particulate matter metal composition, oxidative potential, and adverse birth outcomes in Los Angeles. *Environmental Health Perspectives* **131**, 107012 (2023).
20. J. Shen *et al.*, Aerosol oxidative potential in the greater Los Angeles area: source apportionment and associations with socioeconomic position. *Environmental Science & Technology* **56**, 17795-17804 (2022).