STATE OF CALIFORNIA

AIR RESOURCES BOARD

MEETING OF THE

RESEARCH SCREENING COMMITTEE

March 28, 2014
9:00 a.m.

Air Resources Board
Research Division
Cal/EPA Building
1001 I Street
Sacramento, CA 95814
(916) 445-0753

State of California
AIR RESOURCES BOARD

Research Screening Committee Meeting
Cal/EPA Headquarters Building
1001 I Street
Conference Room 510, 5th Floor
Sacramento, California 95814
(916) 445-0753

March 28, 2014

9:00 a.m.

AGENDA

I. Approval of Minutes of Previous Meeting: iii - x

January 31, 2014 meeting

II. Discussion of New Research Projects:

1) "Aerodynamic GHG Emissions Reduction Assessment of Non 53-foot Trailers Pulled by Heavy-Duty Tractors," University of California, Riverside, $500,000, Proposal No. 2770-278 1

2) "Evaluation of the Impacts of Emissions Averaging and Flexibility Programs for all Tier 4 Final Off-Road Diesel Engines," University of California, Riverside, $300,000, Proposal No. 2774-278 7

3) "Evaluation of the Feasibility, Cost-effectiveness, and Necessity of Equipping Small Off Road Diesel Engines with Advanced PM and/or NO_X Aftertreatment," University of California, Riverside, $800,000, Proposal No. 2769-278 11

4) "Reducing Formaldehyde Emissions from Home Central Heating and Air Conditioning Filters," Lawrence Berkeley National Laboratory," $350,000, Proposal No. 2771-278 17

5) "Protocol Development for Vehicle Emission Toxicity Testing for Particulate Matter," University of California, Davis, $100,000, Proposal No. 2772-278 23

6) "Improving DNDC Modeling Capability to Quantify Mitigation Potential of Nitrous Oxide from California Agricultural Soils," University of New Hampshire, $199,797, Proposal No. 2773-278 29

III. Discussion of Draft Final Reports:

1) "Central Nervous System Effects of Ambient Particulate Matter: The Role of Oxidative Stress and Inflammation," University of California, Irvine, $309,141, Contract No. 08-306 35

2) "Air Movement as an Energy Efficient Means Toward Occupant Comfort," University of California, Berkeley, $170,000, Contract No. 10-308 41

3) "Construction of a DOAS Instrument for Installation at the California Air Resources Board for the Low Level Measurement of Sulfur Dioxide to Investigate the Relation Between Sulfur Dioxide and Sulfate," University of California, Riverside, $90,004, Contract No. 10-312 45

4) "Improving Regional Biogenic Volatile Organic Compound Emission Estimates Using an Airborne PTRMS EDDY Flux Measurement System," University of California, Berkeley, $400,000, Contract No. 09-339 51

IV. Discussion of Other Business:

1) "Using Feedback from Commercial Buildings to Support Energy-Conserving Behavior," University of California, Berkeley, $184,260, Contract No. 10-310

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Cal/EPA Headquarters Building
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January 31, 2014
9:00 a.m.

MINUTES

RSC Members in Attendance via teleconference

Harold Cota
Forman Williams
Steven Japar
Irva Hertz-Picciotto
Alan Vette
William Eisenstein
Yifang Zhu

The Research Screening Committee (RSC or Committee) convened the meeting at 9:05 a.m. The minutes of the October 18, 2013 meeting were approved.

I. New Research Project

1) "Characterizing the Climate Impacts of Brown Carbon," $452,500, University of California, San Diego, Proposal No. 2768-277

   The Committee expressed overall support for the proposal. The Committee members submitted written comments and discussed three key points:
   - A more concrete understanding of the extent of the data collected to achieve the objectives laid out in Tasks 1 and 2.
   - Characterization of brown carbon regional background levels and how they may affect the field measurement study.
   - How the model would address the internal mixing issue, how well the global and regional modeling studies will be integrated with the other tasks listed in the proposal to be sure to get the best results from this project for California.

   Motion: Move to accept the proposal, subject to inclusion of revisions based on comments from staff and the Committee.

   The Committee approved the proposal.

II. Discussion of a Request for Proposals (RFP)

1) "Evaluation of the Impacts of Emissions Averaging and Flexibility Programs for all Tier 4 Final Off-road Diesel Engines," $300,000, RFP No. 14-301

   Motion: Move to accept the RFP.

   The Committee approved the RFP.

III. Draft Final Reports

1) "Behavioral Responses to Real-Time Individual Energy Usage Information: A Large Scale Experiment," University of California, Los Angeles, $322,003, Contract No. 10-332

   The Committee asked that the report include more context and clarifications on some of the figures. They also asked for further explanation on the variables used in the research and more details on the results and outcomes.

   Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

   The Committee approved the report.

2) "Behavior Strategies to Bridge the Gap Between Potential and Actual Savings in Commercial Buildings," University of California, Davis, $134,981, Contract No. 09-327

   The Committee asked for clarification on the surveys portion of the research. Specifically, they wanted a clarification of survey results, the questions used, and the survey instrument.

   Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

   The Committee approved the report.

3) "Location Specific Systemic Health Effects of Ambient Particulate Matter," University of California, Davis, $285,866, Contract No. 10-302

   Two Committee members commented on the draft final report. Both provided written comments that were briefly summarized for the full Committee, and will be provided to the investigator. One reviewer requested that the investigator add conclusions and a discussion of the implications of the results of the desferroxamine (DFM) experiment to the executive summary and the abstract, and that typos and grammatical errors be corrected in the revised final report. The other member suggested that DFM may be a selective iron chelator, and recommended that the investigator edit the conclusions about the metal chelation

experiment to indicate that the results suggest that iron may have a minimal role, but that other transition metals may still be important. This reviewer also asked that the investigator discuss the possibility that the timing of the measurements may have influenced the results.

Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the report.

4) "Peripheral Blood Gene Expression in Subjects with Coronary Artery Disease and Exposure to Particulate Air Pollutant Components and Size Fractions," University of California, Irvine, $274,931, Contract No. 09-341

The Committee commented that the report was well written and well described. Two Committee members submitted written comments for clarifications to the report. One Committee member had concerns about the multiple comparisons made in the study. The Committee requested that the investigator present a statistical analysis of the data other than the Bonferroni method, or present a comparison of observed vs. expected deviations from the null. The Committee also asked that the author add a figure which presents the results of all gene expression assays for each individual exposure. Staff responded that these concerns will be conveyed to the investigator.

Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the report.

5) "Using Remote Sensing to Quantify Albedo of Roofs in California's Seven Largest Cities," Lawrence Berkeley National Laboratory, $250,000, Contract No. 10-321

A Committee member asked that the 0.2C cooling in Bakersfield for a cool roofs scenario needs to be contextualized so the reader understands if that is too much or too little.

Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the report.

6) "Understanding Primary Organic Aerosol Volatility at Atmospherically Realistic Concentrations for the SIP Analysis," University of California, Davis, $309,769, Contract No. 10-313

A Committee member submitted written comments asking for clarification in a few areas, for example, reducing the number of Figures in the Executive

Summary and formatting the text similar to the Summary and Conclusions, and correcting a few editorial errors along with adding a few new citations.

Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the report.

7) "Three-Dimensional Measurements of Aerosol Mixing State during CalNex Using Aircraft Aerosol Time-Of-Flight Mass Spectrometry," University of California, San Diego, $400,000, Contract No. 09-333

   A Committee member noted several editorial errors.

   Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

   The Committee approved the report.

8) "Extended Analysis of the CARES Aerosol Chemistry Data to Characterize Sources and Processes of Organic Aerosol in the Sacramento Valley of California," University of California, Davis, $155,000, Contract No. 10-305

   One Committee member stated that he was very impressed by the study and that the report is a major contribution to the understanding of aerosol/particle air quality. He and another Committee member submitted comments asking for definitions of nomenclature, addition of an executive summary, and clarification in a few areas.

   Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

   The Committee approved the report.

9) "AMAX-DOAS Trace Gas Column Observations from Research Aircraft over California," University of Colorado, Denver, $549,999, Contract No. 09-317

   Three Committee members submitted written comments asking for clarification in several areas. The members also stated that the strong conclusion in Chapter 3.7 concerning the origin of the reverse weekend effect in the South Coast Air Basin was not supported adequately by observations. Staff agreed with this assessment and stated that the conclusion should be toned down and, if possible, additional measurements of biogenic emissions be added to the report (to strengthen the argument).

   Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the report.

10) "Synthesis of Policy Relevant Findings from the CalNex 2010 Field Study," National Oceanic and Atmospheric Administration, $252,378, Contract No. 10-326

Staff apprised the Committee of four major comments received since the RSC agenda book was sent out to the Committee. These involved improving the characterization of seasonal particulate matter patterns in Figure C2, providing more balance in the discussion of the roles of baseline ozone and anthropogenic controls on ambient ozone concentrations and patterns (Sections D & T), including air quality trends in the San Joaquin Valley in Section E, and correctly labeling an emissions source area in Sections R & S. Most other comments were suggestions by the researchers who made the measurements to improve the nuance of the results.

Staff also responded to Committee comments that were shared before the meeting, noting that: 1) the allusion to additional work in the report was an artifact of an earlier draft and would be deleted and 2) additional caveats regarding the representativeness of the study period would be included in the Executive Summary and the end of the Introduction section. Staff is aware of at least one Committee member who had planned to comment but was unavailable for the meeting. Staff will pursue getting those comments and passing them on to the Principal Investigator.

The Committee was complimentary of the report and suggested that this synthesis approach focusing on policy-relevant findings, should be considered for use in other research areas.

Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the report.

11) "Calibrating, Validating, and Implementing Process Models for California Agriculture Greenhouse Gas Emissions," University of New Hampshire, $249,688, Contract No. 10-309

One Committee member provided written comments, requesting additional graphs on some of the modeling results and the specific URL for the model download. Staff also received comments from the stakeholders at the January 29 N_2O workgroup meeting. One comment was regarding the calculation of net CO_2 equivalent from the agricultural land use. The Principal Investigator (PI) included the change of soil carbon sequestration in the calculation. Stakeholders suggested considering only fluxes of the three greenhouse gases (N_2O, CH_4 and CO_2). Staff will share the comments with the PI to address the issue. Stakeholders also thought that some of the crop acreage data used in the model

may be outdated and provided new data sources. Staff will ask the PI to update the database, rerun the model and revise the report accordingly.

Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the report.

12) "Modeling Optimal Transition Pathways to a Low Carbon Fuel Economy in California," University of California, Davis, $278,356, Contract No. 09-346

Staff reported that the written comments submitted by two Committee members were reviewed by the Principal Investigator who agreed to incorporate into the final report the changes suggested in the comments.

Motion: Move to accept the report, subject to inclusion of revisions based on comments from staff and the Committee.

The Committee approved the report.

The meeting adjourned at 10:26 a.m.

DISCUSSION OF A NEW RESEARCH PROJECT
ITEM NO.: II.1
DATE: March 28, 2014
PROPOSAL NO.: 2770-278

STAFF EVALUATION OF A RESEARCH PROPOSAL

TITLE:	Aerodynamic GHG Emission Reduction Assessment of Non 53-foot Trailers Pulled by Heavy-Duty Tractors
CONTRACTOR:	University of California, Riverside
SUBCONTRACTOR:	Auto Research Center, $200,000
PRINCIPAL INVESTIGATORS:	Kent Johnson, Ph.D. Georgios Karavakalis, Ph.D. Marko Princevac, Ph.D. Kanok Boriboonsomsin, Ph.D. Thomas Durbin, Ph.D.
CONTRACT TYPE:	Interagency Agreement
TOTAL AMOUNT:	$500,000
CONTRACT TERM:	24 months

For further information, please contact Dr. Eileen McCauley at (916) 323-1534.

I. SUMMARY

In order to meet the greenhouse gas (GHG) emission reduction goals specified in California's Global Warming Solutions Act of 2006 (Assembly Bill 32, AB 32), GHG emission reductions are needed from heavy-duty tractors (HDT). The Tractor-Trailer GHG regulation adopted in 2012 was one of the discrete early action measures by the ARB to contribute to the goals of AB 32. The regulation applies to 53-foot or longer box trailers and requires them to be equipped with aerodynamic technologies and low rolling resistance tires, but does not apply to other trailer types. The objective of this project is to investigate potential benefits of extending the regulation to other trailer types (e.g., flatbeds, tankers, etc.) and box trailers shorter than 53 feet. These objectives will be accomplished by: 1) identifying candidate trailer types, and collecting vehicle activity data (e.g., vehicle miles traveled, speed profiles, etc.) for these other trailer types using

fleet-owner surveys, engine computer downloads, and on-vehicle data loggers, and 2) by conducting wind tunnel testing and modeling of aerodynamic technologies, and conducting over-the-road emissions testing. Results will support the development of second-generation GHG control measures for HDT trailers.

II. TECHNICAL SUMMARY

Objective

The objective of this project is to investigate potential benefits of extending the current HDT GHG aerodynamic technologies regulation for 53-foot box trailers to include other trailer types such as flatbeds, tankers, etc., and box trailers shorter than 53 feet in length.

Background

For aerodynamic technologies to work most effectively to reduce aerodynamic drag, vehicle speed is a critical parameter since drag is proportional to the square of the vehicle's speed, and maximum benefits occur at higher vehicle speeds, such as highway cruise operation. Because of this the GHG regulation focused on long-haul trucking operation which accrues high annual vehicle miles traveled at highway speeds.

It is possible that similar benefits may be obtainable from different trailer types such as 'pup' trailers, 48-foot or shorter trailers, flatbed trailers, tankers, etc., but there are little to no data available about the impacts of aerodynamic technologies on HDTs and trailers that operate under non-extended highway cruise conditions. Hence, data is needed to assess the potential benefits of aerodynamic technologies for trailer types and vehicle operating conditions beyond those included in the current GHG regulation.

Project Summary

The project proposal includes five tasks, including: 1) literature review, 2) fleet surveys, 3) on-vehicle data logging, 4) data analyses and test plan development, and 5) testing and reporting (wind tunnel testing, computer and water channel modeling, and in-use data collection).

Task 1 - Literature survey

The objective for this task is to identify all candidate trailer types and aerodynamic technologies, and then select a subset of trailer types and aerodynamic devices for

further study in subsequent tasks, presenting results in a technical summary. This task will be conducted in collaboration with staff from ARB's Mobile Source Control Division.

Task 2 - Fleets survey

This task consists of five subtasks: 1) fleet selection, 2) development of fleet survey, 3) survey administration, 4) survey data analysis, and 5) selection of fleets for data logging, and possibly in-use testing. Results and recommendations will be presented to ARB staff in the form of a summary of fleet results.

Task 3 - Data logging and activity

This task will be accomplished by using on-vehicle Global Positioning System (GPS) data loggers, and driver surveys. CE-CERT will procure data loggers capable of collecting GPS-type data (location, vehicle speed, etc.) and engine electronic control module (ECM; [engine computer]) data collection. These data loggers will be installed on selected vehicles to collect real-time activity data for a time duration, still to be determined, but expected to range between one and six months. In addition, CE-CERT will also download vehicle speed data stored in the engine ECM. CE-CERT will handle data processing, protecting fleet owner identities as necessary, and will address GPS data collection issues such as GPS signal drop out by filtering, data gap filling, and map matching. These data would then be analyzed in Task 4.

Task 4 - Data analysis and test plan

The goal of this task is to analyze the GPS and engine ECM activity data collected during Task 3, summarizing results regarding vehicle miles traveled, vehicle speeds by speed bin, and location of vehicle operation.

Task 5 - Testing and reporting

This task is comprised of three subtasks: 1) wind tunnel testing; 2) University of California, Riverside (UCR) laboratory water channel testing; and 3) in-use testing to measure fuel consumption and emissions.

1) Wind tunnel testing. Wind tunnel testing, per SAE J1252, will be for four and one half days, with 20 runs/day being conducted. Because of cost constraints, CE-CERT recommends studying already-available model types (pup trailers, 48-foot trailers and flatbeds). This task also includes one and one half days of

Computational Fluid Dynamics (CFD) modeling that could supplement the wind tunnel testing. This task will be performed by a subcontractor, the Auto Research Center (ARC).

2) UCR laboratory water channel testing. This task would be performed by Dr. Markov Princevac at UCR, and would involve using UCR's water channel system as an independent test method, subsequent to validation of the water channel system by comparison against wind tunnel testing results.
3) In-use testing to measure fuel consumption and emissions. This subtask would involve testing up to two aerodynamic modifications by conducting over-the-road vehicle-trailer testing using the SAE J1321 Type II procedures, and also using a portable emissions measurement system (PEMS). Results from this task, plus all previous tasks, are reported in the draft final report prepared at the conclusion of Task 5.

III. STAFF COMMENTS

The draft proposal was reviewed by Mobile Source Control Division (MSCD) and Research Division staff. The original proposal needed some work to clarify the technical approach and correct numerous typos, etc. While the revised proposal is responsive to ARB's project goals to collect information and data about additional trailer types that might be added to a second generation of the GHG regulation for HDT trailers, there are remaining issues that need further clarification.

The project elements include in-the-field collection of activity data using surveys and on-board data loggers, and testing of potential aerodynamic technologies using scale modeling approaches (wind tunnel testing with CFD modeling and water channel testing),and in-use, on-board vehicle emissions testing using a portable emissions measurement system (PEMS). These multiple approaches are intended to support a robust data collection effort that will support data analyses and results that could be used for rulemaking purposes. However, it's still unclear if this project has the proper balance of approaches to feed into the regulatory process. ARB's existing regulation for 53' or longer box-type trailers points to U.S. EPA SmartWay-certified technologies. SmartWay uses a modified SAE J1321 procedure, which is a relatively small part of the UCR proposal, and U.S. EPA doesn't seem to require wind tunnel testing. The

EPA/NHSTA Regulatory Impact Analysis documents for GHG emission and fuel efficiency standards for medium- and heavy-duty vehicles already has an extensive comparison of ARC 1/8th scale and NRC-Canada full-scale wind tunnel testing and CFD modeling. So it's not clear is the use of four different approaches to evaluate aerodynamic technologies is the most cost-effective way to reach the regulatory objectives. This will be further discussed with MSCD staff and UCR, and reported back to the Committee.

Drs. Johnson and Durbin have previously conducted HDT-related research projects for ARB, the U.S. EPA, the Engine Manufacturers Association, and other clients, and have developed considerable experience testing HDTs. Most recently (2013), Dr. Johnson successfully completed two off-road diesel equipment emissions test projects for ARB regulatory and emissions modeling staff.

IV. STAFF RECOMMENDATION

Staff recommends the Research Screening Committee approve this proposal for a total amount not to exceed $500,000, subject to any changes and additions specified by the Committee.

DISCUSSION OF A NEW RESEARCH PROJECT
ITEM NO.: II.2
DATE: March 28, 2014
PROPOSAL NO.: 2774-278

STAFF EVALUATION OF A RESEARCH PROPOSAL

TITLE:	Evaluation of the Impacts of Emissions Averaging and Flexibility Programs for All Tier 4 Final Off-Road Diesel Engines
CONTRACTOR:	University of California, Riverside
PRINCIPAL INVESTIGATORS:	Robert Russell, Ph.D. Thomas Durbin, Ph.D. Kent Johnson, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$300,000
CONTRACT TERM:	24 months

For further information, please contact Dr. Eileen McCauley at (916) 323-1534.

I. SUMMARY

California is a participant in the federal Averaging Banking, and Trading (ABT) program and the federal Transition Program for Equipment Manufacturers (TPEM) for criteria pollutant emissions for 2011 and later model-year off-road diesel engines. Both programs are administered at the federal level by the United States Environmental Protection Agency (U.S. EPA), and only national sales data are available. These programs allow higher emitting engines to be sold if these sales are offset by lower emitting engines such that overall fleet-average emissions comply with Tier 4 new engine certification standards. It is possible that a disproportionate number of higher emitting engines may be being sold in California which would have negative impacts on efforts to achieve attainment of ambient air quality standards, and/or could result in public exposure to increased emissions. The objective of this project is to determine the impacts of ABT and TPEM programs on the populations off-road diesel engines sold in California, and if this may have adverse emissions impacts. This will be done using electronic databases, and surveys of California equipment owners. Results will inform

ARB policy makers regarding the impacts of these national programs on California's air quality.

II. TECHNICAL SUMMARY

Objective

The objectives of this project are characterize the national ABT and TPEM off-road diesel engine populations, and the subsets of these populations sold and operating in California, and to assess the emissions impact of these engines in California.

Background

California is a participant in both the ABT and TPEM programs, which are administered at the federal level by the U.S. EPA. California does not have independent ABT or TPEM requirements apart from the federal programs. The ABT program is a permanent component of the off-road regulations that allows engine manufacturers the flexibility of continuing to certify engine families to less-stringent previous-tier standards, as long as the manufacturer also certifies a sufficient number of “counter-balancing” engines below the more-stringent current-tier standard, so that the manufacturer’s entire fleet average is at or below numerical Tier 4 levels. The TPEM program allows equipment manufacturers the flexibility to continue selling a portion of their new equipment with previous-tier engines to ease the transition to the new standards for up to seven years following the introduction of Tier 4 standards. The TPEM program also has a permanent component for providing hardship relief to equipment manufacturers.

These programs are administered only on a national level, so the specific sales fractions of Tier 4 and non-Tier 4 engines in California are unknown, and it is possible that the state or some localities within the state could receive a disproportionate share of higher-emitting engines, and have average emissions from new engines that are higher than the Tier 4 standards. Because California has areas in non-attainment with air quality standards, and has communities adversely affected by poor air quality, it is important for California to receive the benefits expected from the Tier 4 emission standards, and to verify that the ABT and TPEM programs are not adversely affecting either California as a whole, or specific communities in California.

Project Summary

CE-CERT would be the contractor, with Drs. Robert Russell, Tom Durbin, and Kent Johnson acting as co-PIs. The project would focus on three air basins that represent about three quarters of the off-road PM and NO_X emissions inventories: the South Coast Air Basin (AB), the San Joaquin Valley AB, and the San Francisco Bay Area AB.

Tasks

The project consists of three main tasks.

Task 1 Determine and the percentages of ABT and TPEM engines sold nationally and in California - ARB will provide CE-CERT with post-processed copies of the ABT/TPEM national database. CE-CERT will perform additional database processing and then analyze the final database to determine the specific numbers of ABT engines being produced by each engine manufacturer, and by each participating TPEM equipment manufacturer.

For the California determination, and where possible, existing electronic databases from other programs will be used (e.g., the ARB Diesel On-line Off-road Reporting System [DOORS]), but for certain important sectors such as agricultural equipment, surveys will be required to obtain the necessary information and data. CE-CERT proposes a combination of mail, phone and on-site surveys to accomplish this task. Surveys would also be used to supplement any shortcoming of the DOORS data.

Task 2 Determine specific California locations where ABT and TPEM engines have been deployed - this task would be performed in conjunction with Task 1, and this information collected, when the surveys are developed and administered to off-road equipment fleet owners during task 1. Data analyses will be conducted to determine the impact of the ABT/TPEM programs on fleets in locations such as the ports, engines located on transportation refrigeration units (TRUs), and other similar locations with significant public or occupational exposure.

Task 3 Assess the impacts of ABT and TPEM engines or investigate additional source categories and/or regions - in the event that ABT/TPEM program engines are determined to represent a disproportionate fraction of national ABT/TPEM program

sales, the contractor will determine the emissions impact of these engines. In the event that the categories of engines studied are not disproportionately represented in the California off-road fleet, then additional regions would be investigated to make similar determinations regarding the impact of ABT and TPEM program engines.

CE-CERT will prepare 'test plan/technical proposal memos' before beginning each task that will be submitted to ARB staff for approval.

III. STAFF COMMENTS

The project proposal was reviewed by ARB staff from Mobile Source Control and Research Divisions, and has undergone multiple revisions to clarify project tasks, and make editorial corrections.

This project will require collaboration between ARB and CE-CERT staff to deal with confidential data. ARB staff will be providing the contractor with post-processed versions of the ARB's ABT, TPEM, and DOORS databases that have had sensitive and/or confidential information removed.

Staff expects this project to present some challenges given the size and diversity of the in-use off-road population, and the state of ABT and TPEM programs and data - the databases are unsorted and uncharacterized at the present. ARB staff anticipates working closely with CE-CERT during the execution of this project.

Drs. Johnson and Durbin have previously conducted HDT-related research projects for ARB, the U.S. EPA, the Engine Manufacturers Association, and other clients, and have developed experience procuring and emissions testing diesel off-road equipment. Most recently (2013), Drs. Johnson, Durbin and Russell successfully completed an ARB off-road diesel equipment emissions test projects for ARB emissions modeling staff.

IV. STAFF RECOMMENDATION

Staff recommend the Research Screening Committee approve this proposal for a total amount not to exceed $300,000, subject to any changes and additions specified by the Committee.

DISCUSSION OF A NEW RESEARCH PROJECT
ITEM NO.: II.3
DATE: March 28, 2014
PROPOSAL NO.: 2769-278

STAFF EVALUATION OF A RESEARCH PROPOSAL

TITLE:	Evaluation of the Feasibility, Cost-Effectiveness, and Necessity of Equipping Small Off-Road Diesel Engines with Advanced PM and/or NO_X Aftertreatment
PRIME CONTRACTOR:	University of California, Riverside
PRINCIPAL INVESTIGATORS:	Thomas Durbin, Ph.D. J. Wayne Miller, Ph.D. Kent Johnson, Ph.D. Georgios Karavalakis, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$800,000
CONTRACT TERM:	24 months

For further information, please contact Dr. John Collins at (916) 327-8097.

SUMMARY

In 1998, the United States Environmental Protection Agency (U.S. EPA) introduced Tier 1 standards for equipment under 37 kilowatts (kW) (50 hp) and increasingly more stringent Tier 2 and Tier 3 standards for all equipment with phase-in schedules from 2000 to 2008. The Tier 1-3 standards are met through advanced engine design, with no or only limited use of exhaust gas aftertreatment (oxidation catalysts). On May 11, 2004, U.S. EPA signed the final rule introducing Tier 4 emission standards, which are phased-in over the period of 2008-2015. The Tier 4 standards require that emissions of particulate matter (PM) and oxides of nitrogen (NO_X) be further reduced by about 90 percent. Such emission reductions can be achieved through the use of control technologies, including engine modifications and advanced exhaust gas aftertreatment, similar to those used by those meeting the 2007-2010 standards for highway engines. However, off-road diesel engines less than 37 kW are allowed to certify with emissions

at higher levels due to the belief that advanced aftertreatment would severely impact the cost of these smaller engines.

Small off-road equipment are estimated to contribute 22 percent of the total NO_X from off-road equipment and 12 percent of total off-road diesel PM emissions. The proposed study will involve the emissions testing of several small off-road diesel engines representing a cross section of applications in the under-37 kW off-road diesel power category using advanced aftertreatment technologies such as diesel particulate filters (DPF), selective catalytic reduction (SCR), exhaust gas recirculation (EGR) etc. and some will be modified to accommodate operation on alternate fuels, such as natural gas. The research will evaluate the overall emissions impact of this segment of the industry in order to assess the necessity of more stringent standards, and will seek to determine the representativeness of the existing test cycles for these smaller engines. Finally, the investigation will gauge how increasing the cost of control might affect the economic interests of small engine diesel manufacturers, in particular the propensity of consumers to switch from diesel-fueled to gasoline-fueled engines as the relative cost of diesel-fueled engines increases.

The results of this study will be used to determine whether or not small off-road engines less than 37 kW should be subject to more stringent exhaust standards, identify reasonable levels of exhaust control based on costs, and support possible future amendments to the off-road diesel engine regulations.

II. TECHNICAL SUMMARY

Objective

The objective of this study is to evaluate the potential effectiveness, feasibility, and cost effectiveness of implementing regulations on mobile off-road diesel engines with rated powers of less than 37 kW that will require the use of advanced emission control strategies, such as DPFs and SCR. This project will include a comprehensive review of available aftertreatment and other technologies, demonstrate selected aftertreatment technologies on actual engines and verify the emissions performance of these devices through a series of emissions and durability tests, evaluate the cost implications of the added emissions control strategies, evaluate the potential impacts of additional

emissions controls on the emissions inventory, and evaluate the potential impact on the small engine marketplace and consumer choice in that area.

Background

Diesel PM is a known carcinogen and NO_X, as well as being an ozone precursor, is involved in the formation of secondary (or atmospheric) PM. The majority of mobile diesel off-road engines sold as new since 2011 are subject to regulations that require compliance with stringent PM and NO_X exhaust standards based on the use of advanced aftertreatment technologies, such as DPFs and SCR. However, off-road diesel engines less than 37 kW are allowed to certify to less stringent standards, largely due to the belief that advanced aftertreatment would severely impact the cost of these smaller engines. This is especially relevant on a cost-percentage basis as the technological cost component forms a greater proportion of the total product cost for lower-power engines in comparison to average - and higher-power engines in the category. Such were the findings of the U.S. EPA's Regulatory Impact Analysis (RIA) that was conducted in support of the 2004 federal rulemaking for adopting standards that were expected to be met with advanced aftertreatment (i.e., the current Tier 4 standards) for new off-road engines. The RIA estimated the costs of anticipated emission control technologies which were not yet in wide production at the time. However, some of the technologies anticipated in the RIA are now common in both the off-road and on-road diesel sectors. Thus, the "economies of scale" of today's market, as well as the availability of additional exhaust control strategies and techniques not evaluated originally in the RIA, may warrant renewed consideration for adopting more stringent exhaust standards for the under-37 kW sector.

Proposal Summary

Under this project, the Contractor shall:

- Carry out a comprehensive product review of existing and emerging emission control technologies to significantly reduce PM and NO_X that could be employed by off-road diesel engines with power ratings of <37 kW.
- Consider the estimated cost of the control measures to ensure that the technologies are evaluated to be both cost effective and practical for the equipment.

- Develop the test methodology for the emissions and durability testing. This will include selection of engines, selection of test cycles, selection of applications, and preparation of a test plan.
- With cooperation from ARB staff, select and procure at least seven new, current model-year California-certified, off-road diesel engines best representing a cross section of applications from the under-37 kW power category, with particular emphasis on engines less than 19 kW.
- Conduct emissions testing to evaluate the effectiveness of the emissions control systems in terms of PM and NO_X performance at University of California, Riverside (UCR) Vehicle Emissions Research laboratory (VERL).
- In addition to quantifying emissions performance of the modified engines, perform the cost-benefit analysis for putting advanced emissions control technologies on small off-road engines.
- Evaluate the overall emissions impact of the under-37/19 kW off-road power category in order to assess the necessity of California adopting more stringent off-road diesel emission standards in the future.
- Gauge how increasing the cost of controlling NO_X and PM emissions with each of the tested technologies might affect the economic interests of small off-road diesel engine manufacturers and the propensity of consumers to shift from diesel to gasoline powered engines.
- Provide a draft final report and a seminar at the completion of the contract.

III. STAFF COMMENTS

The project proposal was reviewed by ARB staff from Mobile Source Control and Research Divisions, and has undergone multiple revisions to clarify project tasks, and make editorial corrections.

The proposed research affirms investigators familiarity and expertise in evaluating emissions for variety of engines sizes, including small engines, aftertreatment systems for both on-road and off-road equipment and understanding the implications of implementing advanced control strategies on emissions inventories and market place forces. The project will support ARB's effort in assessing whether introduction of aftertreatment technologies on small off-road diesel engines rated less than 37 kW is

feasible and warranted. During the course of the project, the investigators will work closely with the ARB's *Off-Road Diesel Analysis Section* from the beginning of the project to identify technologies to test, arrive at testing protocols/cycles and possibly partner in testing some of these technologies at the ARB Haagen-Smit Laboratory in El Monte, CA. The investigators have conducted a variety of research in the area of vehicle and engine emissions. Tom Durbin, the principal investigator (PI), is a research engineer in the Emissions and Fuels Research group at the UCR and has been the principal investigator for a variety of mobile source related programs. He is presently conducting research in the area of vehicle and engine emissions including studies of advanced and renewable diesel and gasoline fuels, such as biodiesel, natural gas, portable emissions measurement systems (PEMS), particle number and mass emissions, and emissions from off-road equipment. Kent Johnson, one of the co-PI's, has over 15 years of research specifically related to the characterization and performance of diesel engines including development, execution, and design of testing projects; the analysis and interpretation of test results; and the preparation of project specific data for reports and scientific articles. J. Wayne Miller, one of the co-PI's, has more than 30 years of experience in technology planning, new product commercialization, business development and multi-national relationships. For the past twelve years at UCR, his research has concentrated on the physical and chemical nature and impact of emissions from mobile and stationary sources with an emphasis on sources related to goods movement. George Karavalakis, one of the co-PI's is a principal investigator for a variety of mobile source and air quality related programs focused on the use of biomass-derived fuels and on the air quality impacts of vehicle emissions. His primary responsibilities include daily oversight of project testing, the analysis and interpretation of test results, and the preparation of project reports and scientific articles. He was also PI for a small engine emissions study for a private company.

It should be noted that during the course of entire project, the ARB staff will decide whether new regulations are feasible based on the findings from this research. Since the ultimate potential for using aftertreatment devices on small off-road engines is not known at this point, it is understood that the tasks will be staged around decision/evaluation/milestone points, to ensure that feasible technologies are available

for this application. This would allow the contract to be restructured or otherwise modified if less or even no suitable applications for the aftertreatment systems are identified.

IV. STAFF RECOMMENDATION

Staff recommends that the Research Screening Committee approve this proposal for a total amount not to exceed $800,000, subject to any changes and additions specified by the Committee.

DISCUSSION OF A NEW RESEARCH PROJECT
ITEM NO.: II.4
DATE: March 28, 2014
PROPOSAL NO.: 2771-278

STAFF EVALUATION OF A RESEARCH PROPOSAL

TITLE:	Reducing Formaldehyde Emissions from Home Central Heating and Air Conditioning Filters
CONTRACTOR:	Lawrence Berkeley National Laboratory
PRINCIPAL INVESTIGATOR:	Hugo Destaillats, Ph.D.
CONTRACT TYPE:	Standard Agreement
BUDGET:	$350,000
CONTRACT TERM:	30 Months

For further information, please contact Peggy Jenkins at (916) 323-1504.

I. SUMMARY

Formaldehyde is a toxic air contaminant that poses a risk of cancer and other adverse health impacts. Studies have shown that some fiberglass filters used in central heating and air conditioning systems can be sources of formaldehyde. This proposal aims to quantify the indoor contributions of formaldehyde from fiberglass particle filters relative to those from synthetic particle filters, for California homes. The investigators will select at least four types of fiberglass filters that are likely to emit formaldehyde and four types of synthetic filters that, based on prior data, are not expected to have significant emissions, and conduct laboratory testing of formaldehyde emissions across a range of humidity levels, temperatures, and the air velocity passing through filters in typical California homes. The investigators will also estimate the contributions of these filters to indoor formaldehyde concentrations in typical California homes using a mass balance model. It is anticipated that this project will find that use of synthetic particle filters in home central heating and air conditioning systems will result in lower indoor formaldehyde concentrations than use of fiberglass particle filters. This project will help inform decision-makers about whether synthetic particle filters are a part of the solution to reduce indoor formaldehyde exposures.

II. TECHNICAL SUMMARY

Objective

The objective of this project is to quantify the emissions of formaldehyde from fiberglass particle filters relative to synthetic particle filters, and estimate their contributions to indoor concentrations for California homes. The specific objectives are to:

1. measure formaldehyde emission rates from fiberglass particle filters and synthetic particle filters across a range of humidity levels, temperatures and air velocities typical of California homes,
2. estimate the impacts of fiberglass particle filters and synthetic particle filters on indoor formaldehyde levels under typical scenarios in California homes.

Background

Formaldehyde has been classified as a known human carcinogen by the International Agency for Research on Cancer and designated as a toxic air contaminant (TAC) in California by the Air Resources Board (ARB) with no safe level of exposure. Many indoor sources can produce formaldehyde in residences. Based on recent research by Lawrence Berkeley National Laboratory (LBNL), fiberglass particle filters in central heating and air systems may be the single source making the greatest contribution to indoor formaldehyde levels after composite wood products. The formaldehyde apparently is attributable to urea-formaldehyde resins used in fiberglass filters.

In limited laboratory and field studies, fiberglass particle filters produced indoor concentrations that exceeded the Office of Environmental Health Hazard and Assessment's (OEHHA) non-cancer eight-hour and Chronic Reference Exposure Levels (RELs) for formaldehyde (both set at 9 $\mu g/m^3$). LBNL found that emissions of formaldehyde from some fiberglass filters increased with increasing relative humidity (RH). At 50 percent RH, the use of fiberglass filters increased room formaldehyde levels by 18-24 percent, adding an average 4 $\mu g/m^3$ to room concentrations. This is significant because 98 percent of the California population lives in areas where the annual average RH level is 50 percent or higher. At 80 percent RH, room concentrations increased an average of 6 $\mu g/m^3$. For comparison, outdoor formaldehyde concentrations in California average 3.2 $\mu g/m^3$. The LBNL study suggests that changing filter type from fiberglass filters to synthetic filters could reduce indoor concentrations by about 4-5 $\mu g/m^3$ in

homes. This reduction would result in a level that is approximately 50 percent lower than OEHHA's non-cancer eight-hour and cChronic RELs for formaldehyde. However, these preliminary results were based on just a few measurements of emissions from filters used primarily in commercial buildings under limited test conditions. Further study is needed to quantify the contribution of residential fiberglass and synthetic filters to indoor concentrations of formaldehyde under a variety of conditions found in California homes and evaluate the benefits of synthetic filters.

Project Summary

The investigators will convene a small Project Advisory Committee (PAC) to help provide insights on chemical constituents used in the filter manufacturing process and the types of filters most commonly used in California. In consultation with ARB staff and the PAC, the investigators will identify fiberglass particle filters and synthetic particle filters marketed or designed for use in residential central heating and air conditioning systems in California, and test at least four types of fiberglass filters that are likely to emit formaldehyde and four types of synthetic filters that, based on prior data, are not expected to have significant emissions.

The investigators will modify the experimental chamber and ancillary equipment that LBNL used to test formaldehyde emissions from particle filters for commercial buildings in a previous study. The experimental setup will have the capacity of hosting different types of filters and adjusting temperature, RH, and the air velocity passing through the air filters.

Formaldehyde emission rates of fiberglass and synthetic particle filters will be determined in bench-scale and full-scale tests. Bench-scale tests will determine formaldehyde emission rates of filter media under different conditions. A four-inch diameter filter sample cut from each filter will be placed in an air-tight holder. Air from a room-sized chamber will be withdrawn at a constant air flow through filter media. Four parallel sampling lines will be operated to test four filter samples simultaneously. Each filter will be tested across a range of real world conditions observed in California homes, including at least three humidity levels, two temperatures, and three air velocities passing through filters. In total, the investigators will conduct 36 bench-scale tests.

In addition to filter media, filter frames may also emit substantial amounts of formaldehyde. Thus, formaldehyde emission rates of complete filters will be determined in full-scale tests. Ductwork will be used to connect the chamber to a filter holder which can host a complete filter. In consultation with ARB, four filter/condition combinations will be selected and tested in full-scale tests. In addition, a few used filters will be tested to determine if formaldehyde emissions increase with filter loading.

Formaldehyde samples upstream and downstream of the filters will be collected for about one hour using 2,4-dinitrophenylhydrazine (DNPH)-impregnated silica gel cartridges, and then analyzed by HPLC with UV detection, following the EPA TO-11 method. On selected tests, samples will be collected in the chamber and downstream of the filters to evaluate possible off-gassing of volatile organic compounds (VOCs) from filters. VOC samples will be collected on Tenax-TA, Carbotrap or combined sorbent tubes, then analyzed by thermal desorption/gas chromatography/mass spectrometry, following the EPA TO-1 method.

Using the measured formaldehyde emission rates and modeling parameters appropriate for California homes, the contributions of fiberglass particle filters to indoor formaldehyde levels under typical scenarios will be estimated using a mass balance model. The contributions of fiberglass filters and synthetic filters under similar conditions will be compared to quantify the exposure reduction that would likely be achieved by switching to synthetic filters. The results will help quantify the impact of fiberglass filters on formaldehyde exposures in California, and determine the benefits of the use of synthetic particle filters to reduce human exposures to formaldehyde.

III. STAFF COMMENTS

Research Division staff reviewed a draft work plan and provided comments to the investigators, including a request to increase the number of tests on synthetic filters; increase the number of environmental parameters, e.g., RH and air velocity, to be tested; and specify the values for the environmental parameters to be used that are typical of California homes. The investigators developed a draft full proposal accordingly, and they added a few more tests to measure formaldehyde emissions from

used filters. Staff will present additional comments, if any, at the Research Screening Committee meeting.

Staff requested a reduction of indirect costs where feasible. LBNL requested a waiver for the Federal Administrative Charge (Participant's Value Contribution) of $10,500 from the Department of Energy. This amount is not shown in the proposed budget.

The proposed technical plan is sound and focuses on ARB's primary needs, which are to quantify the indoor contributions of formaldehyde from fiberglass particle filters relative to synthetic particle filters, for California homes. The proposed measurement approaches in the laboratory will cover the major variables that are known to affect formaldehyde emission rates and indoor concentrations. The budget for this study is reasonable for the proposed scope of work. The investigators have extensive experience in source characterization, analytical chemistry, indoor air quality modeling, operation of HVAC systems, and the other scientific areas relevant to this project. They have published over 250 scientific papers and reports in the areas of environmental chemistry, advanced analytical methods, source characterization, and indoor air quality and related health impacts. The investigators have recently studied formaldehyde emissions from particle filters used in commercial buildings, and published the results in *Environmental Science & Technology*, which provided hands-on experience on study design, testing protocols and data analysis for this research. They will use LBNL's room-sized experimental chamber, which has unique capabilities needed for this research.

IV. STAFF RECOMMENDATIONS

Staff recommends that the Research Screening Committee approve this proposal for a total amount not to exceed $350,000, subject to any changes and additions specified by the Committee.

DISCUSSION OF A NEW RESEARCH PROJECT
ITEM NO.: II.5
DATE: March 28, 2014
PROPOSAL NO.: 2772-278

STAFF EVALUATION OF A RESEARCH PROPOSAL

TITLE:	Protocol Development for Vehicle Emission Toxicity Testing for Particulate Matter
CONTRACTOR:	University of California, Davis
PRINCIPAL INVESTIGATOR:	Keith Bein, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$100,000
CONTRACT TERM:	24 Months

For further information, please contact Dr. Alvaro Alvarado at (916) 445-4843.

I. SUMMARY

Toxicological testing of particulate samples is an integral aspect of evaluating possible health effects associated with particulate matter (PM) from new engine technology studies and source specific ambient PM. However, there are a multitude of possible standard operating procedures (SOPs) for sample preparation, each with inherent advantages and disadvantages. This is not surprising since all of these procedures require physical and chemical manipulation of the PM sample during isolation which can affect its inherent toxicological properties. The main objective of this study is to systematically investigate these different SOPs and evaluate which procedures can retain of the most toxicologically relevant chemical components of the sample for various toxicological assays while producing the fewest toxicological artifacts. The benefit of this investigation is the establishment of a standard SOP for filter PM sample preparation for future toxicological studies. In addition, knowledge gained from this study can be used to evaluate how previously used sample preparation methodologies may have influenced toxicological results in completed studies.

II. TECHNICAL SUMMARY

Objective

The primary objective of this research is to develop a recommended standard operating protocol (SOP) for the preparation of PM samples collected on filters for toxicological assays. This objective will be accomplished by investigating how different methodologies for isolating PM samples from filters can affect the results in standard toxicological screening assays. To the extent possible, the research will compare the recommended protocol with previously used procedures to assist California Air Resources Board (ARB) in interpreting the toxicity results from past studies. The adoption of an SOP would provide a streamlined methodology for future PM sample preparation for toxicological studies.

Background

ARB evaluated the toxicity of PM in numerous studies from a variety of sources, such as engine emissions, indoor air, and concentrated ambient air pollutant samples. Due to the lack of an SOP, individual researchers used different methodologies for PM sample preparation which can affect the toxicological properties of the sample. Toxicological variations arise from the different physical manipulations and chemical interactions that occur during processing which can preserve some critical PM components, eliminate others, and possibly introduce artifacts that could lead to false positive results. While possibly acceptable for comparison of samples for a particular assay, the different procedures used for PM sample preparations have compromised the ability to directly compare the toxicity of samples from different researchers even for the same PM sample. For example, some researchers use whole PM samples for *in vitro* studies while others use extracts from PM dissolved in either aqueous or organic solvents. It is not certain if any of these methods favor particular PM components or directly introduces toxicological artifacts making result comparisons difficult. Best practices for sample preparation are needed, and there has not been a comprehensive evaluation of the merits of the various procedures. The results will contribute to the scientific baseline in the field of *in vitro* evaluation of PM by being one of the first studies to systematically compare a comprehensive panel of PM preparation methodologies and thus, provide

valid references for other researchers in the field. ARB staff plans to use the study results for standardizing toxicological evaluations in future engine emissions studies. Also, these results may be used to identify possible biased data in previously conducted *in vitro* toxicological studies and allow for reinterpretation of previous results. The knowledge gained and the improved methodology will help ARB in its current Vehicle Emissions Research Programs (VERP). VERP has been ongoing since 1998 and has included toxicological evaluation of PM from different fuels (Biodiesel and renewable diesel research study), and from newer engine technologies (Heavy duty vehicle studies phase I and II and Light vehicle duty studies phase II). This project could impact the interpretation of these studies if it's shown that PM preparation methodology employed may have influenced toxicological results.

Project Summary

This study will evaluate commonly used procedures for preparation of PM samples collected on filters, assess the relative merits of these procedures, and recommend a SOP for sample preparation.

The initial phase of the study will involve a detailed literature review of recent studies which involved the isolation of whole PM and PM extracts for use in toxicological investigations. The evaluation should focus on which procedures are the best at protecting sample chemical integrity, retaining the most toxicologically relevant chemical components of the samples, and producing the fewest false positive toxicological artifacts. The results of this phase of the project will be a document detailing a review of all relevant studies, a summary of various methodologies with a critique on strengths and weaknesses. In addition, this document will outline the experimental protocol including five to six unique sample preparation methodologies to be used for this study.

Upon approval of the study document and experimental protocols, the investigator will be given archived filter samples from a previous dynamometer diesel engine study. To allow direct comparisons of various methodologies, all filters will be from the same test run. In addition, as a control, the investigator will obtain a standard diesel PM sample from the National Institutes of Standards and Technology (NIST) to be used for the study. Both whole PM and PM extract samples will be prepared from both the engine

PM filter and the NIST standard using the methods outlined in the experimental protocol.

The whole PM and PM extract samples along with relevant preparations from blank filters will be used in *in vitro* assays for inflammation, oxidative stress, and genotoxicity, the major physiological impacts related to engine PM health effects. The ability of the samples to elicit inflammatory and oxidative stress markers will be determined by measurement of the production of inflammatory biomarkers, such as COX-2, IL-8, CYP1A1, and HO-1, in a human macrophage cell culture. Oxidative stress potential of the samples will also be determined using a cell-free chemical assay. This will consist of measuring the ability of isolated PM or PM extracts to oxidize the chemical dithiolthreitol (DTT) in an aqueous system. Genotoxicity of the PM sample will be assayed using the standard Ames assay which measures the ability of a sample to cause mutations in a bacterial sample.

Upon completion of the toxicological studies, the results will be analyzed using standard statistical methods in consultation with a staff statistician. The principal investigator (PI), Dr. Keith Bein, will then summarize the results regarding which methodology produced the most optimal results for each toxicological assay. Based on these results the investigator will produce a SOP for sample preparation of PM collected on filters along with a final report detailing the study.

III. STAFF COMMENTS

Research Division staff reviewed the proposal, and the current version adequately addresses the comments raised by staff. OEHHA staff is currently reviewing the proposal and we are awaiting their comments.

Nearly all PM toxicology studies focus on the relationships between ambient and laboratory-generated PM sources and the associated toxicological assay results. However, there is little, if any, discussion on the importance of sample preparation for these assays. This project is among the first to address how different methods of sample preparation may influence *in vitro* toxicological assay results for PM samples, and it should provide a blueprint for establishing an SOP for future studies. The principal

investigator has proposed a systematic and comprehensive approach for preparing both whole PM and PM extract samples to account for the various methodologies currently prevalent in the field. The study is well designed and the investigator has ample experience in the field as demonstrated by his recent work on sample preparation techniques for two ARB-funded toxicological studies. Given his background in PM isolation techniques for both whole PM and PM extract samples, he is well-suited for this study which focuses on both preparation methods using methodologies similar to those he has previously employed. In addition, he has partnered with two investigators who have experience in performing toxicological assays with similar PM sample preparations. Dr. Chris Vogel has published extensively on the *in vitro* inflammatory responses of both ambient PM and PM collected from engine studies and has developed a sensitive cellular model which is ideal for measuring the systemic inflammatory potential of samples. Dr. Norm Kado (a Research Division employee that will be working on the project) has been investigating the carcinogenic effects of both ambient PM and PM from engine emissions for the past twenty years, and his technique for measuring these effects, especially with small sample size, is considered the standard for the field. The completion of this study will greatly enhance the knowledge base for future *in vitro* toxicology and engine PM sample-based studies as well as provide an SOP which can be used by ARB researchers and can be adopted by other agencies.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee approve this proposal for a total amount not to exceed $100,000 subject to any changes and additions specified by the Committee.

DISCUSSION OF A NEW RESEARCH PROJECT
ITEM NO.: II.6
DATE: March 28, 2014
PROPOSAL NO.: 2773-278

STAFF EVALUATION OF A RESEARCH PROPOSAL

TITLE:	Improving DNDC Modeling Capability to Quantify Mitigation Potential of Nitrous Oxide from California Agricultural Soils
CONTRACTOR:	University of New Hampshire, $112,238
SUBCONTRACTOR:	GeoSolutions, LLC. $87,559
PRINCIPAL INVESTIGATOR:	Changshen Li, Ph.D.
CONTRACT TYPE:	Standard Agreement
BUDGET:	$199,797
CONTRACT TERM:	24 months

For further information, please contact Dr. Dongmin Luo at (916) 324-8496.

I. SUMMARY

Agricultural soils are a major source of nitrous oxide (N_2O), a potent greenhouse gas (GHG) contributing to global warming, in California. Because N_2O is produced in soil by microbial activities which are affected by numerous environmental factors, process-based modeling incorporating site-specific conditions is considered a better approach characterizing N_2O emissions from agricultural crop land. Previous studies have indicated that significant mitigation of N_2O emissions from agricultural soils is possible through various management practices; however, a quantitative tool would be required to estimate emission reductions from these practices. The project will develop and deliver to ARB such a tool by further refining the process-based DNDC (DeNitrification-DeComposition) model based on new N_2O emission data obtained from available mitigation studies and new understanding of N_2O emission mechanisms. The improved capability of quantifying N_2O emission reductions under a variety of management practices will bolster the State's ability to develop greenhouse gas mitigation strategies that are essential for meeting long-term climate change goals set forth by Assembly Bill 32.

I. TECHNICAL SUMMARY

Objective

The goal of the project is to develop and deliver to ARB a California-specific modeling tool that can be used to calculate mitigation potential of N_2O emissions from a variety of mitigation practices for major California cropping systems.

Background

Nitrous oxide is a major greenhouse gas contributing to California's GHG inventory. The majority of N_2O in California is produced by microbial-driven processes of nitrification and denitrification from agricultural soils. Therefore, the surface fluxes of N_2O are highly variable, both spatially and temporally, leading to a high degree of uncertainty in the estimation of N_2O emissions and emission reductions. Process-based modeling can be used effectively to capture the emission variability, but requires calibration and validation with site-specific measurements.

Over the past 20 years, the process-based DNDC model has been developed to simulate carbon and nitrogen biogeochemical cycles and trace gas emissions, including N_2O and methane (CH_4), from agro-ecosystems. DNDC has been used successfully in California to simulate these emissions observed in the field, and has been chosen by the American Carbon Registry as a core methodology for calculating emission reductions under prescribed project activities. The model has also several ecosystem-specific versions such as Manure-DNDC, Forest-DNDC and DNDC-Rice, with customized model processes and inputs characterizing unique features of individual ecosystems. Recently, ARB is considering adopting the DNDC-Rice model in its rice offset protocol for methane emissions.

However, given the diverse crop systems and management practices in California, use of the DNDC model to estimate statewide emissions requires extensive calibration and validation with as much California-specific data as possible. A recently completed study provided ARB a validated California-specific DNDC modeling tool, incorporating largely business-as-usual management practices for baseline emission assessment. However, the model needs further development to address changes in management practices designed for GHG mitigation purpose, and to scale up the limited field studies to

estimate emission reduction potential from the California's agricultural soils statewide. This study will expand the current validation efforts to include N_2O emission data from several on-going mitigation studies such as those sponsored by ARB and U.S. Department of Agriculture (USDA).

Successful completion of this study will deliver a rigorous quantitative tool and associated spatial databases on crop yield estimates and GHG mitigation potentials from a set of baseline and mitigation management scenarios, and a process modeling framework and interface for future greenhouse gas emission mitigation estimates at both site-specific and regional levels in California.

Project Summary

The project will build upon the recently completed DNDC modeling system that has been evaluated and validated against California-specific crop growth and N_2O emissions data focusing largely on business-as-usual management scenarios for baseline emission assessment. Additional N_2O emission data are being collected from several key projects investigating mitigation strategies from major cropping systems in California as well as fundamental mechanisms leading to N_2O emissions from soils. The proposed project will refine the DNDC model based on this newly acquired information. The project will consist of the following tasks:

- Collect and review newly emerged literature on N_2O formation mechanisms (such as Zhu et al., 2013) and field N_2O emission data, including an ongoing mitigation study sponsored by ARB and a paired study sponsored by USDA. Both projects are tasked to assess emission mitigation potentials for a variety of mitigation options such as use of nitrification inhibitors, dripping irrigations, cover crops, nitrogen fertilizer types and application methods.
- Improve the flexibility and robustness of the DNDC model in deriving N_2O estimates through additional DNDC model development, calibration and validation for the selected mitigation scenarios to ensure that the model captures the impact of alternative management on crop growth and yields. The new finding of N_2O formation pathways will be incorporated into the model improvement.

- Conduct statistical analysis to assess DNDC model uncertainty. This will entail performing statistical analysis of modeled versus measured residuals and quantifying model uncertainty by using Monte Carlo and Bootstrapping approaches to ensure that model estimates of GHG emissions reduction are realistic and conservative.
- Provide estimates of mitigation potential in terms of CO_2, N_2O and CH_4 reductions for all of California agricultural land using the newly improved DNDC modeling tool, including the updated GIS databases and crop models developed from the recently completed DNDC modeling project.
- Produce a DNDC interface that would facilitate model inputs, including automatic links to the USDA's Soil Survey Geographic database (SSURGO) and climate data from the California Irrigation Management Information System (CIMIS) and other meteorological networks, and post-modeling data processing, for mitigation potential calculations.

III. STAFF COMMENTS

The proposal will further customize the existing geochemical model DNDC for California to more rigorously estimate N_2O and other GHGs emissions and potential emission reductions from California cropland. DNDC is the core methodology used in agricultural offset protocols developed by the American Carbon Registry, and is also the core accounting mechanism proposed by ARB for its rice offset protocol. Dr. Changsheng Li is the original DNDC developer and Dr. William Salas, the subcontractor, has been working with Dr. Li for over a decade in applying the model to various agricultural systems.

DNDC is a processed-based model, which can simulate N_2O and other greenhouse gas emissions from agricultural cropland. The daily or annual spatially distributed outputs of DNDC can potentially serve as *a priori* emission maps for inverse modeling analysis, as well as provide a bottom-up inventory estimate to compare to the top-down results from an ARB-funded project with Lawrence Berkeley National Laboratory utilizing data from ARB's GHG Monitoring Network. The improved DNDC modeling tool is expected to help address the discrepancy of N_2O inventories derived from top-down and bottom-up approaches.

A previous version of the proposal was reviewed by staff from the Research, Air Quality Planning and Science, and Stationary Source Divisions and the current version incorporated staff's comments and addressed critical N_2O program needs that would help achieve the mitigation potential from California agricultural soils. The proposal is currently under review by a large group of external stakeholders. Any additional comments or concerns will be forwarded to the Principal Investigators, reported to the Research Screening Committee, and addressed in the final proposal.

IV. STAFF RECOMMENDATIONS

Staff recommends that the Research Screening Committee approve this proposal for a total amount not to exceed $199,797, subject to any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: III.1
DATE: March 28, 2014
CONTRACT NO.: 08-306
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Central Nervous System Effects of Ambient Particulate Matter: The role of Oxidative Stress and Inflammation
CONTRACTOR:	University of California, Irvine
PRINCIPAL INVESTIGATOR:	Michael Kleinman, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$309,141
CONTRACT TERM:	60 months

For further information, please contact Dr. Alvaro Alvarado at (916) 445-4843.

I. SUMMARY

Numerous epidemiological and toxicological studies have demonstrated that exposure to ambient particulate matter (PM) is associated with increased cardiopulmonary morbidity and mortality; however, little is known about the effects of PM exposure on the central nervous system. The objective of this study was to determine how the biological responses in the brain of genetically modified mice exposed to concentrated ambient fine particulate matter (PM2.5) might depend on the composition of ambient PM emitted from vehicles, power generation, industrial processes and other sources. Mice were exposed in New York City, Sterling Forest, NY, Seattle, WA, East Lansing, MI and Irvine, CA. Exposures were six hours per day, four days per week for 26 weeks (six months). Results of this study suggest that exposure of genetically modified mice to concentrated ambient particles (CAPs) may be associated with inflammatory changes in the brain, and that the sections of the brain that are lower in the signal transducer NF-κB tend to be more susceptible to inflammatory changes. In addition the levels of NF-κB decreased as the animals aged. These results suggest that ambient PM may produce adverse health outcomes in the brain, which should be taken into consideration

when developing future ambient air standards and regulations that will benefit the health of all Californians.

II. TECHNICAL SUMMARY

Objective

The objective of this project was to investigate the potential for inhaled particulate matter to induce adverse effects in the brain and to determine the role of oxidative stress and inflammation in mediating these effects.

Background

Numerous epidemiological and toxicological studies have demonstrated that exposure to ambient PM is associated with increased cardiopulmonary morbidity and mortality. It is known that inhaled ultrafine particles can penetrate the lungs and be deposited in extra-pulmonary tissues; furthermore, there is evidence that inhaled particles can reach the brain. Dr. Kleinman and colleagues have shown that the activities of signaling pathways which mediate inflammatory responses can be up-regulated in the brain of mice exposed to CAPs from the vicinity of heavily trafficked freeways in Los Angeles. Additionally, higher levels of oxidative stress biomarkers and tissue injury in the brain are observed in mice after exposure to CAPs, and may persist for as long as two weeks post-exposure. At present, the extent to which induction of inflammatory markers in the brain of PM-exposed animals may lead to potentially adverse consequences is unknown. Thus, it is important to determine the degree to which adverse effects occur in the central nervous system (CNS), to identify the relationship between these effects and particle dose and composition, and to ascertain whether inflammation, oxidative stress and injury persist after exposure has ended. This study provided a unique opportunity for resource leveraging because the very costly and involved exposure and atmosphere characterization phases were funded by a multimillion dollar HEI grant.

Project Summary

The objective of this project was to determine whether the composition or concentration of ambient PM emitted from vehicles, power generation, industrial processes and other sources would differentially affect biochemical changes in mouse brain tissues. The study was conducted in five locations with different PM2.5 source profiles. Mice were exposed in New York City (NYC), Sterling Forest, NY (SF), Seattle, WA (SEA), East

Lansing, MI (MSU) and Irvine, CA (UCI). NYC is a densely populated urban environment with major impacts from traffic and oil-fired power generation. SF is a rural location with regional source contributions. The SEA location is on a university campus with moderate levels of traffic but there is a strong regional influence of wood burning for space heating during the winter months. MSU is an urban area which is influenced by coal burning sources and is more industrial than the other locations. UCI is a suburban area with major impacts from nearby heavily trafficked roads and regional influence of diesel emissions associated with operations at the ports of Long Beach and Los Angeles.

Genetically modified male six-week-old mice (ApoE-/-) were exposed to filtered air (FA) or $PM_{2.5}$ CAPs for six hours per day, four days per week for 26 weeks at each of the five locations. ApoE-/- mice have reduced ability to metabolize lipids and therefore have very high levels of circulating lipids and cholesterol. Some of the mice were implanted with telemetry devices so that electrocardiographic parameters could be monitored while the mice were exposed. At the end of the 26 week exposure brains were harvested and analyzed for biomarkers of inflammation and oxidative stress. Air samples collected during the exposures were analyzed to provide elemental composition data which were used to apportion the sources of PM2.5 in the five locations. Due to differences in methodology between the NYC and SF locations and the three remaining sites, this report focused primarily on the UCI, SEA, and MSU samples. An additional analysis across different brain regions was conducted on the UCI samples.

The source apportionment analyses agreed with the *a priori* assessments of the key sources that contributed to the PM2.5 at each of the five locations. Exposure of ApoE-/- mice to CAPs was associated with inflammatory changes in the brain and that on a regional basis, the sections of the brain that were lower in the signal transducer NF-κB (which promotes the expression of genes involved in immune responses) tended to be more susceptible to inflammatory changes. In addition, the levels of NF-κB decreased as the animals aged during the six-month study. There also appeared to be an increase in concentrations of biomarkers of oxidative stress that were more prevalent in the sections of the brain with lower NF-κB levels, consistent with a correlation

between inflammation and oxidative changes in the brain. Oxidative changes in the brain were consistently observed in mice exposed at SEA but not in mice exposed at MSU. Mice exposed at UCI showed a pattern of changes that was the same as that seen in SEA mice.

The results of this study suggest that exposure to CAPs from some, but not necessarily all, locations can induce inflammatory changes and oxidative stress in the brains of ApoE-/- mice. Significant effects were seen in the mice exposed at SEA and UCI but not in mice exposed at MSU. The failure to see significant changes in the MSU mice may have been due to a high level of background inflammation and oxidative stress in these mice, since the concentrations of relevant biomarkers were higher for the FA-exposed mice at MSU than at UCI or SEA. For the UCI mice, activation levels of NF-κB increased progressively from the rostral to the mid-brain to the caudal regions, and overall NF-κB levels appeared to decrease as the mice aged. In contrast, protein carbonyl concentrations in brain cytoplasmic fractions of the UCI mice were significantly higher in the rostral sections than in midbrain or caudal regions, in both air- and CAPs-exposed mice. Overall, the findings of this study suggest that exposure of ApoE-/- mice to CAPs may be associated with inflammatory changes in the brain, and that on a regional basis, the sections of the brain that are lower in the signal transducer NF-κB tend to be more susceptible to inflammatory changes.

III. STAFF COMMENTS

Staff reviewers from ARB's Research Division, in addition to one reviewer from the U.S. Environmental Protection Agency, had the opportunity to review the initial draft of this report. The reviewers found the report to be well organized and clearly written. The study provides valuable data regarding the effects of PM2.5 CAPs exposures on the inflammatory and oxidative stress responses in the brain, and how they differ according to regional variation in sources. It also reveals differences in toxicological sensitivity in different brain regions, which could provide a useful starting point for future investigation.

Most of the reviewers' comments were fairly minor, and editorial in nature. These comments were provided to the investigator in the Track Changes feature in the Word

version of the report. Additionally, ARB staff requested a few clarifications for subsequent revisions of the report. These comments were forwarded to the PI, who agreed to address staff concerns in the next draft of his report. Staff felt that the edits would be relatively straightforward to incorporate into the report.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: III.2
DATE: March 28, 2014
CONTRACT NO.: 10-308
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Air Movement as an Energy Efficient Means Toward Occupant Comfort
CONTRACTOR:	University of California, Berkeley
PRINCIPAL INVESTIGATORS:	Edward Arens, Ph.D. Hui Zhang, Ph.D. Wilmer Pasut, Ph.D. Yongchao Zhai, Ph.D. Tyler Hoyt Li Huang
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$170,000
CONTRACT TERM:	36 months

For further information, please contact Dr. Eileen McCauley at (916) 323-1534.

I. SUMMARY

In California, heating and cooling in Commercial Buildings consume roughly 34 percent of the built environment's total energy use. Temperature set points and people's comfort zones are typically not fine-tuned to each other. Significant energy is used without increasing or maintaining occupant comfort. Use of fans, large or small for cooling, and foot warmers for heating is thought to increase occupant comfort while allowing higher set points in summer and lower ones in winter. The investigators examined ceiling fans performance in terms of noise and incorporation into the built environment architecture and, primarily, occupant comfort. Comfort can be provided by fans drawing 2 - 8 watts per person, in settings corresponding to ambient conditions of 30C (86F) and 60 percent RH (relative humidity). Fans can improve and augment the performance of other energy-efficient technologies, such as radiant cooled ceilings and natural ventilation. The documented energy savings for heating and cooling systems can be

substantial (10 - 29 percent). Climate change mitigation policy can make use of fans and other instruments to extract significant energy savings and CO_2 emissions reductions from the built environment.

II. TECHNICAL SUMMARY

Objective

The objective of this study is to encourage broader adoption of fans, into conditioned built environments. To this end, investigators intended to describe low energy use fans, introduce design sensitivity into such adoption, demonstrate occupant comfort with fans and higher temperature set points, demonstrate energy saved through simulations, and work with the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) to establish new standards incorporating energy efficient fan design.

Background

The single largest energy user in California's commercial sector is compressor-based cooling (roughly 15 percent of total electricity consumption, and 5 percent of that of the State as a whole). Building managers often use set points far too low to eliminate occupant complaint and to protect computing resources. Sealed building designs with their low air movement consistently show lower occupant satisfaction than buildings with operable windows. And though buildings with operable windows tend to have warmer interior temperatures than sealed buildings, modest air movement the open windows provide gives them comfort ratings superior to those of sealed buildings.

In a survey and field study of small and medium commercial buildings (which make up 96 percent of all commercial buildings in the nation) conducted for the California Energy Commission and ARB, occupants generally noted the temperature set points for zone conditioning were either too low or too high. In the same study, ventilation air from the outside were often not provided, conditioning systems did not properly function, and air filters were often of improper kind or improperly installed. In short, air ventilation and conditioning often met neither indoor air quality nor occupant comfort.

Buildings, even those constructed without window openings, can be refitted to allow natural ventilation. Natural ventilation has been augmented with fans all over the world as an effective air conditioning. Quantifying, standardizing, and broad adoption of fans in mechanically or naturally ventilated built environments provide an alternative and/or an additional path for air conditioning. Broad fan adoption also has potential for energy savings through higher set points in summer and potential to connect the occupant comfort to air conditioning through micro-fans and other occupant available options.

Project Summary

In this project, the investigators created new product designs and improved performance standards for fans. They evaluated new fan products that are energy efficient and move air effectively and integrated several that are capable of both fixed and oscillating flows in the ceiling of their Controlled Environment Chamber. They conducted a series of human subject tests to evaluate the comfort and perceived air quality effect over a large range of ambient environmental conditions. The investigators tested fan comfort with and without oscillation; characterizing the airflow patterns through physical measurements and proposed a fan evaluation method. They evaluated the sensitivity of current comfort models to the degree of body exposure to fan air movement, effects of clothing, and turbulence intensity of the airflow. They designed two versions of a new occupant-tracking fan system, with patent application currently in progress. They proposed a solution to eliminate the heat transfer blockage of radiant ceilings by suspended acoustical panels, by integrating fans into the acoustical ceiling plane, and evaluated the heat transfer using simulations. They have estimated energy savings of fan systems by EnergyPlus simulations in great detail using the reference building prototypes for commercial buildings. Lastly, they have worked with ASHRAE Standard 55 Committee (‘Thermal environmental conditions for human occupancy’) to remove barriers to fan use. A great deal of this work has now been implemented in the new code-compliant ASHRAE Standard 55-2013. Results are very promising. They show that comfort can be provided by fans drawing 2 - 8 watts per person, up to 30°C (86°F) and 60 percent RH (relative humidity) ambient conditions. They can augment the performance of other energy-efficient technologies, such as radiant cooled ceilings and natural ventilation. Comfort modeling procedures for design, and underlying Standard 55, are robust in spite of the complexity of air flows produced by fans. The

documented energy savings are very substantial. Computer vision and control will enable a new generation of extremely efficient and effective devices for air movement cooling within buildings.

III. STAFF COMMENTS

Staff from ARB's Research Division and the Energy Commission reviewed and provided comments and the principal investigators agreed to all our requests.

Comfort testing conditions for this project included high relative humidity conditions that are atypical of California's environments, leading to the results resembling perhaps a worst case situation for the State. The investigators are seeking federal funding for testing of dry and extremely dry conditions. Aside from some measurements of CO_2 levels, the study lacked ozone or particulate matter (PM) instruments and had to rely on measures of perceived air freshness. The investigators explained that fans can be used to the same effect in both air conditioned and window-ventilated buildings and the thermal comfort of fans are thus independent of whether the air has been mechanically filtered. Further, they explained that in the special case of window-ventilated buildings using fans, the indoor levels of ozone and PM can be higher than in properly functioning mechanical ventilation-filtered buildings. Investigators have incorporated information from an ongoing Energy Commission natural ventilation project, which ran during the same period as this study and is wrapping up in spring 2014.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: III.3
DATE: March 28, 2014
CONTRACT NO.: 10-312
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Construction of a DOAS Instrument for Installation at the California Air Resources Board (ARB) for the Low Level Measurement of Sulfur Dioxide to Investigate the Relation Between Sulfur Dioxide and Sulfate
CONTRACTOR:	University of California, Riverside
PRINCIPAL INVESTIGATORS:	Thomas D. Durbin, Ph.D. John Pisano
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$90,004
CONTRACT TERM:	37.5 months

For further information, please contact Dr. John Collins at (916) 327-8097.

I. SUMMARY

Sulfur is an important component of combustion and lubricant-derived particles. Sulfate levels in vehicle exhaust particulates can be readily measured, but it is important to understand the relative contribution between combustion and oil-derived particles and conversion rates of sulfur dioxide (SO_2) to sulfate (SO_4). Current instruments are not capable of measuring the very low sulfur dioxide concentrations typical of new vehicles. The objective of this research was to construct, test and provide to ARB's Heavy-Duty Emissions Testing Laboratory a differential optical absorption spectrometer (DOAS) that can measure down to 10 ppbV in real time and determine a mass balance between SO_2 and sulfate. During the testing at CE-CERT, the device has been able to measure down to less than 20 ppbV SO_2 at three times the standard deviation of zero gas response although there is interference when ammonia (NH_3) concentration exceeds 11 ppm. The contractors are supplying an update to the DOAS instrument's software and this may minimize the NH_3 interference. Training for ARB's technical staff will be provided as part

of this program so they will be able to properly operate this state-of-the-art instrument independently. This instrument will open testing possibilities for ARB to understand the workings of advanced catalyzed aftertreatment systems and their interactions with the fuel/lube systems, and the potential of those systems to attenuate or produce sulfate particulate matter. This understanding will help ARB understand the impacts of current emission control policies and guide the development of policies to obtain further reductions.

II. TECHNICAL SUMMARY

Objective

The objective of this project is to design, construct, and deliver to ARB an instrument capable of real-time measurements of sulfur dioxide in vehicle exhaust. Further objectives are to install the instrument at ARB's Heavy-Duty Emissions Testing Laboratory and participate in a vehicle measurement test program to demonstrate and verify the instrument performance and to train ARB staff in using the instrument.

Background

Reduction in particulate matter emissions from vehicles is a critical issue for meeting air quality improvement goals. Understanding the composition of particles is important to evaluate their health impacts as well as their formation mechanisms. Sulfur or sulfate is one of the major components of combustion and lubricant-derived particles. Sulfate levels in vehicle exhaust particulates can be readily measured, but it is important to understand the relative contribution between combustion and oil-derived particles and the conversion rates found for SO_2 to sulfate. With the low level of sulfur present in the fuel and oil products used in modern vehicles, detection limits in the ppb range are needed to measure the SO_2 contribution. Previous studies have shown a differential optical absorption spectrometer (DOAS) can be used successfully to make measurements at these levels from raw vehicle exhaust. The goal of this program is to develop a DOAS and apply the technology to exhaust measurements from vehicles at the ARB Heavy Duty Emissions Testing Laboratory in Los Angeles.

Project Summary

During this project, a DOAS instrument was designed, developed and built to measure SO_2 in low concentration in near real-time. The SO_2 measurement goals of this project were achieved by enhancing a UV spectrometer for the range 290-320; by expanding the path length, and by minimizing sample cell volume. The project is composed of seven tasks which included the procurement of the sampling cell and associated components, the design of the DOAS system, system fabrication, and the integration of the DOAS system's individual components.

Prior to installation at the ARB facility, the DOAS for this program was evaluated at the UCR laboratory that is specifically designed for evaluating spectroscopic instruments. The tests document the response of the SO_2 monitor to a range of operating conditions from ambient to those most representative of exhaust gas emanating from vehicle exhaust over concentration levels ranging from 0 to 953 ppbV SO_2. The DOAS was also evaluated over vehicle emissions tests in CE-CERT's light-duty chassis dynamometer laboratory. The results showed no appreciable SO_2 interferences for the tests on the diesel truck, which had very low NH_3 emissions. The two gasoline vehicles, on the other, had higher levels of NH_3, and showed a significant interference, especially when the NH_3 values exceeded 11 ppmV. If it is to be used for vehicles with higher levels of NH_3, an NH_3 scrubber would likely be needed to scrub the level of NH_3 in the exhaust to no greater than 10 ppmV, as well as perhaps some additional updates to the software that are currently being developed.

In March 2014, the DOAS will be delivered and installed at the Heavy-Duty Emissions Testing Laboratory in Los Angeles. Calibration and verification will be conducted along with testing on actual vehicle exhaust from vehicles provided by the laboratory. The vehicle will be tested over a number of different cycle representing surface-street, arterial, and highway driving. (The number of tests will depend on the laboratory scheduling during the period of testing and the number of tests ARB wish to perform to exercise the full range of the instruments capability.) Finally, staff at ARB's Heavy-Duty Emissions Testing Laboratory will be trained in the use and operation of this instrument.

A draft final report has been prepared for ARB incorporating the results up through the testing that was conducted at CE-CERT with the documentation of the delivery and installation at the ARB lab in Los Angeles to be added at a later date.

Final acceptance of the DOAS instrument will be contingent upon the successful delivery, installation, calibration, verification, and evaluation of the DOAS on one ARB-supplied vehicle at the ARB lab, and the training of the laboratory staff.

These tasks were performed over a period of more than 37 months. Two extensions of the contract were required to complete the contract.

III. STAFF COMMENTS

The draft final report has been reviewed by staff in the Research and Mobile Source Control Divisions. The contract specified a minimum detection limit of 10 ppbv SO_2 (at 1 Hz). However, the contractor was unable to attain this concentration. They were able to get as low as 12 to 15 ppbv at 0.2 Hz during the CE-CERT testing.

The draft final report provides the instrument description and performance test results. The report could use additional descriptive information about the spectral retrieval process. We have asked the contractor to provide additional descriptive information such as: details of how the spectrum is obtained from the raw sensor data, methods used to lower spectroscopic noise; and methods used to separate narrow absorption structures from broad structures and high frequency noise.

We expect this information to be available in the final report. There is a significant interference from ammonia when measuring SO_2. The spectral range of the DOAS was narrowed to the 206 nm to 214 nm range, which helped reduce the interference. Also, the DOAS software is being updated to provide a more sophisticated masking of the NH_3 spectral interferent, and we expect this software update to be installed before final acceptance of the instrument and final report.

The DOAS is scheduled for delivery to ARB's laboratory in March; with verification, training, and software update to take place soon after.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: III.4
DATE: March 28, 2014
CONTRACT NO.: 09-339
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Improving Regional Biogenic Volatile Organic Compound (BVOC) Emission Estimates Using an Airborn PTRMS Eddy Flux Measurement Systems
CONTRACTOR:	University of California, Berkeley
PRINCIPAL INVESTIGATORS:	Allen Goldstein, Ph.D. Alex Guenther, Ph.D. Thomas Karl, Ph.D.
CONTRACT TYPE:	Interagency Agreement
BUDGET:	$400,000
CONTRACT TERM:	36 months

For further information, please contact Dr. Eileen McCauley at (916) 323-1534.

I. SUMMARY

Current air quality simulations include the role of isoprene and monoterpene chemistry in tropospheric ozone and aerosol production but the magnitude and spatial-temporal distributions of BVOC emissions in California is a complex issue which would benefit from additional data to constrain emissions estimates. Current biogenic VOC emission models predict significant emissions of isoprene from oak woodlands of the Coast Range and the Sierra Nevada mountains, yet there have been few measurements of BVOC fluxes from California landscapes at a larger spatial scale than individual leaves and branches. To create a regional scale BVOC emissions database for validating emissions estimates, during the summer 2011, the principal investigators deployed an airborne Proton Transfer Reaction Mass Spectrometer and Eddy Covariance (PTRMS-EC) system over key Californian ecosystems. This project found that airborne basal and model land cover emission factors compare favorably. Eucalyptus and oak woodlands were confirmed as critical isoprene emission areas in the state. In Sierra

Nevada oak savanna, agreement between the model and measured flux data is excellent. Generally, average individual ecoregion measured and flux data agree quite well. Isoprene modeling emissions simulations are effective in general and where they differ from airborne data, the issue is likely a combination of discrepancies in the underlying land cover maps, meteorological parameters, or LAI data. This project provides important confirmation of the quality of the biogenic inventory used in ARB's SIP modeling.

II. TECHNICAL SUMMARY

Objective

This project was designed to directly quantify BVOC fluxes across spatial scales relevant to air quality models and to use this information to assess and improve models for regional biogenic emission estimates in California. Additional objectives included improvements to land use maps in the models, a comparison of United States Environmental Protection Agency's (U.S. EPA) simulations with older version models, comparison of isoprene emission factors with our models and U.S. EPA simulations, comparison of temperature, photo-synthetic radiation, and wind data between simulations, and finally comparison of flux data between measurements and simulations.

Background

California's over six hundred different native biomes, as well as exotic species like eucalyptus emit significant isoprene, monoterpenes, and other BVOC. The emitted BVOC react in the presence of NO_X and sunlight to produce ozone and particulate matter. Current models of BVOC emissions for California have uncertainties, and there are very few emission measurements available to validate existing model inventories. In order to assess and improve the model inventories of BVOC emissions for use in air quality State Implementation Planning (SIP), spatially resolved data on BVOC emissions are required.

Prior to this project and over the last 15 years, the Biogenic Emissions Inventory through Geographic Information Systems (BEIGIS) model, developed at ARB and with California-specific inputs, had been used in SIP activities. Comparisons of BEIGIS with

NCAR's model of Emissions of Gases and Aerosols from Nature (MEGAN) prior to and during the early planning for this work produced differences that led to adoption of Moderate Resolution Imaging Spectro-radiometer (MODIS) infra-red database for leaf mass and eventually adoption of a version of MEGAN equipped with California based inputs. Emission factors for agricultural species were also updated through a research project with the same investigators and an assessment of all inputs to the California version of MEGAN improved the simulations significantly.

Due to their high data acquisition rates, mass spectrometer techniques are extremely valuable for the measurement of chemical species in the atmospheric. Chemical ionization mass spectrometers, capable of specificity, have been extensively used to detect atmospheric trace gases for many processes important in the atmosphere. In the last 10 years, INDOEX, TEXAQS2000, TEXAQS2006, ITCT2001, MINOS, NEAQS, MILAGRO, ITCT2004, and BLODGETT studies have all used PTR-MS during various ground and airborne field campaigns for BVOC assessments.

Project Summary

ARB's biogenic emissions modeling predicts significant emissions of isoprene from oak woodlands distributed throughout the foothills of the Coast Range and the Sierra Nevada mountains and significant emissions of terpenes and methyl butenol (MBO) from California's pine forests. These investigators had previously collected the only BVOC flux data from California landscapes at a larger spatial scale than individual leaves and branches at the Blodgett pine plantation. In this project, investigators measured the distribution of isoprene flux across the oak woodland areas of California in order to evaluate and improve the landscape-scale biogenic emission models that are used for regional air quality assessment.

The team of investigators brought unique expertise to the project. They were experienced in both Airborne Eddy Covariance (AEC), an established technique which has been used extensively in the last several decades to measure fluxes directly using an aircraft, and use of a PTR MS, which they had used at the Blodgett pine plantation to produce BVOC flux data. The National Center for Atmospheric Research science team created the MEGAN model. The Center for Interdisciplinary Remote Piloted Aircraft

Study (CIRPAS) airplane crew participated in the CalNex2010 study. The two-engine UV-18A Twin Otter airplane and crew are stationed at the Naval Post Graduate School in northern California.

The investigators successfully completed airborne isoprene eddy covariance measurements, demonstrated that first order chemistry can fully describe the decrease of isoprene flux through the planetary boundary layer, created new algorithms to arrive at spatially resolved isoprene flux data, and, using isoprene flux data, have suggested nuanced approaches for updating land use land cover data. They also suggested that isoprene fluxes are of such reliability as to perhaps be used for calculating free radical fluxes. Observed spatial distribution of airborne fluxes and emission factors match well the emission factors and emission estimates from an ARB implementation of the MEGAN model.

III. STAFF COMMENTS

This project investigated a complex issue of importance to ARB's SIP modeling efforts. The investigators worked closely with ARB staff to develop the flight plans and to share preliminary data. Staff from the Research and Air Quality Science and Policy Divisions provided comments on the first draft, the investigators largely agreed to our requests, and the report was substantially revised.

We made the following suggestions on the first draft: (1) improvement of land use maps; (2) comparison of early MEGAN modeling efforts; (3) comparison of isoprene emission factors inferred from the flux measurements to those from ARB (previously used in BEIGIS) and MEGAN (v2.04 and v2.10); (4) raw concentration, temperature, photosynthetic actinic radiation, and meteorological data used in simulations or flux calculations; and (5) complete instructions for translating input data into flux data. Ten other items were discussed with the investigators ranging from possible comparisons of flux data and resultant emission factors, comparison with flux data from an Ameri-Flux tower in an oak savanna if the data were available, and allusion to possible N_2O, ethanol, and other potential flux data from airplanes in the recommended research section. Most of these items were addressed in the version of the report before the Committee. The data and analyses produced by this project are key to validating ARB's

current BVOC emissions inventory and for evaluating future updates to the BVOC modeling methodology and underlying data sets.

IV. STAFF RECOMMENDATIONS

Staff recommends the Research Screening Committee accept this draft final report, subject to inclusion of appropriate additions and revisions in response to the staff comments and any changes and additions specified by the Committee.