Quality Assurance Project Plan

Project# 20–007
Texas urban vegetation BVOC emission source inventory

Prepared for
Texas Air Quality Research Program (AQRP)
The University of Texas at Austin

Prepared by

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June 16, 2020
Version #3

Ramboll has prepared this QAPP following EPA guidelines for a Quality Assurance (QA) Category III and IV composite Project: Secondary Data and Research Model Development and Application. It is submitted to the Texas Air Quality Research Program (AQRP) as required in the Work Plan requirements.

QAPP Requirements: The QAPP describes the project description and objectives, project organization and responsibilities, scientific approach, quality metrics, data analysis, sampling procedures, measurement procedures, quality checks, data analysis, model design, model coding, model calibration, model verification, model evaluation, and reporting procedures, as prescribed in the applicable NMRL QAPP Requirements template (https://www.tceq.texas.gov/airquality/airmod/project/quality-assurance).

QA Requirements: Technical Systems Audits - Not Required for the Project
Audits of Data Quality – 10% Required
Report of Findings – Required in Final Report

Approvals Sheet

This document is a Category III & IV Quality Assurance Project Plan (QAPP) for the Texas urban vegetation BVOC emission source inventory project. The Principal Investigator for the project is Tejas Shah and Co-PI is Alex Guenther.

Electronic Approvals:

This QAPP was approved electronically on 06/08/2020 by

Elena McDonald-Buller
Project Manager, Texas Air Quality Research Program
The University of Texas at Austin

This QAPP was approved electronically on 6/17/2020 by

Vincent M. Torres
Quality Assurance Project Plan Manager, Texas Air Quality Research Program
The University of Texas at Austin

This QAPP was approved electronically on 6/16/2020 by

Tejas Shah
Principal Investigator, Ramboll

QAPP Distribution List

Texas Air Quality Research Program
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Elena McDonald-Buller, Project Manager
Vincent M. Torres, Quality Assurance Project Plan Manager

Texas Commission on Environmental Quality
Miranda Kosty, Project Liaison

Ramboll
Tejas Shah, Principal Investigator

Alex Guenther, Co-Principal Investigator

1. Project Description and Objectives

Emissions of reactive gases from the earth's surface drive the production of ozone and aerosol and other atmospheric constituents relevant for regional air quality. Volatile organic compound (VOC) emissions from trees and other vegetation (biogenic emissions; BVOC) are the dominant source of VOC for Texas urban areas. BVOC emissions are highly variable and their atmospheric concentrations can vary more than an order of magnitude over spatial scales of less than a km and time scales of less than a day. This makes estimation of these emissions especially challenging and yet accurate quantification and simulation of these fluxes is a necessary step towards developing air pollution control strategies and for attributing observed atmospheric composition changes to their causes. The purpose of this project is to improve the spatial representation of biogenic emissions by using high resolution satellite imagery. This activity will benefit the Texas air quality simulation by improving the accuracy of the biogenic emission inventory for urban areas.

Urban areas are the most challenging for BVOC emissions estimation, due to heterogeneity and a lack of vegetation information, and yet they continue to be the least studied. Recent ground surveys of urban tree inventories and increasingly higher resolution remote sensing data products have substantially improved the potential for characterizing the landcover inputs required for biogenic emission models. This will be accomplished by developing an urban Leaf Area Index (LAI) and high BVOC tree fraction inventory for Texas by synthesizing ground survey data with aerial and satellite imagery. Our approach will capture spatial variation in urban biogenic emissions with ~1 km resolution. These data will then be used to compile suitable input datasets for both MEGAN and BEIS biogenic emissions models.

The project comprises three major tasks:

1. To quantify high resolution (8 day, 10 m) LAI and vegetation cover fraction data for three major Texas urban areas: Houston, San Antonio, Austin.
2. To quantify high resolution (10 m) vegetation distributions of high BVOC emitting trees (e.g., live oaks, deciduous oaks, sweetgum, palms, pines, juniper) in the three major Texas urban areas.
3. To compile and assess vegetation characteristics input data for both MEGAN and BEIS models, update MEGAN Emission Factor Processor to improve processing of urban and other landcover data and investigate sensitivity of Texas urban biogenic emissions to landcover inputs.

2. Organization and Responsibilities

This project is being conducted by Ramboll, Wildland Solutions, Alex Guenther, and Chris Geron team under a grant from the Texas Air Quality Research Program (AQRP). The project Principal Investigator (PI) is Mr. Tejas Shah, who will assume overall

responsibility for the research and overall responsibility for quality assurance. Dr. Alex Guenther and Dr. Greg Yarwood will serve as a technical advisor for all tasks. Other staff members instrumental to the technical work include Dr. Ling Huang of Ramboll, Mr. Keith Guenther of Wildland Solutions and Mr. Chris Geron. Mr. Chris Geron will lead the development of BELD biogenic emissions landcover database. The personnel working on this project and their specific responsibilities are listed in Table 1.

The project will be overseen by AQRP Project Manager Dr. Elena McDonald-Buller and TCEQ Project Liaison Miranda Kosty. They will review the project deliverables and documentation.

Table 1. Project participants and their key responsibilities.

Participant	**Key Responsibilities**
Tejas Shah (Ramboll)	Principal investigator, lead Ramboll's effort for compiling MEGAN input data, updating MEGAN3.1 EFP and source code, develop and review reports and presentations, and overall quality assurance.
Greg Yarwood (Ramboll)	Project technical advisor
Dr. Alex Guenther (Independent Consultant)	Lead researcher, technical lead for Task 1 and 2 compile high resolution urban LAI and high BVOC tree fraction inventory, contribute to reporting, and reviewer
Chris Geron (Independent Consultant)	Lead the development of BELD biogenic emissions landcover database and contribute to reporting
Keith Guenther (Wildland Solutions)	Lead image processing for landcover characterization, technical consultant, and contribute to reporting
Dr. Ling Huang	Assist with developing input data for MEGAN3.1, carrying out modification to the MEGAN3.1 EFP and source code.
Jean Guo	Assist with various data analysis tasks.

An overall schedule of project activities by task is shown in Table 2. The schedule assumes a start date during June 2020 and end date of August 31, 2021.

The planned duration of the project is 15 months (June 2020 – August 2021). An overall schedule of project activities by task is shown in Table 2. The schedule assumes a start date during June 2020 and end date of August 31, 2021.

Table 2. Schedule of project activities (tasks are bolded).

ID	Task	2020							2021							
		J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
	Kickoff Meeting	X														
1	High resolution LAI and vegetation cover fraction		X	X	X	X										
2	**BVOC emitting tree distributions**															
2.1	Training and evaluation areas				X	X	X	X								
2.2	Supervised classification of raster pixels								X	X	X					
3	**MEGAN and BEIS input data, processors and results**															
3.1	MEGAN input data, updated EFP and meteorological input data											X	X	X		
3.2	Integrate Texas urban vegetation data into BELD											X	X	X		
3.3	Assess and compare MEGAN and BEIS sensitivity to Texas urban vegetation data													X	X	
5	Monthly Progress Reports	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	Quarterly Progress Reports		X			X			X			X			X	
5	Draft Final														X	
5	Final															X
	AQRP Workshop															X

3. Scientific Approach

This project will undertake two complementary activities that together will improve landcover data for the three major Texas urban areas. First, we will develop high resolution (8-day, 10-m) LAI and vegetation cover fraction for urban Texas. We will use the Simplified Level 2 Product Prototype Processor (SL2P) to estimate LAI and total vegetation cover fraction (TVCF) from Sentinel-2 satellite Multispectral Instrument (S2/MSI) 10 m resolution data. The S2/MSI satellite data will be accessed from the Copernicus Open Access Hub (https://scihub.copernicus.eu/). The SL2P uses a neural network approach trained with a globally representative set of simulations from the PROSAILH canopy radiative transfer model (Weiss and Baret, 2016). Second, we will develop BVOC emitting tree distributions for the three major Texas urban areas. We will utilize a Texas urban tree inventory database that contains over 200,000 geolocated and identified individual trees. We will use tree inventory database to train, extrapolate and assess BVOC emitting tree cover distributions. We will use the i-Tree Canopy application (see https://canopy.itreetools.org/), a state-of-the-art, peer-reviewed software developed by the USDA Forest Service for urban forestry analysis, to quantify urban

vegetation type cover fractions within targeted areas. We will investigate the performance of at least three machine learning classification approaches (e.g., Random Forest, Support vector machine, Deep learning) and a classical supervised classification technique to determine the best approach for classifying BVOC emission types in each urban area. We will assess the performance using a confusion matrix (a comparison of observed and predicted landcover) generated with the ARCGIS Accuracy Assessment tool (see https://pro.arcgis.com/en/pro-app/help/analysis/image-analyst/accuracy-assessment.htm) using accuracy assessment points (identified landcover) that have not been used in the training areas. We will consider both the overall classification accuracy and also BVOC emission categories i.e. if a high emitter is classified as another high emitter that might lower the overall accuracy but not greatly impact BVOC emission estimates. We will choose the approach that provides the most accurate distribution of BVOC emitters.

4. Quality Metrics

The S2/MSI data processing includes radiometric and geometric correction using ground control points and a digital elevation model to correct for parallax error. The Sen2Cor processor will be used for cloud and shadow removal and to convert Sentinel-2 level 1 (MSIL1C) data to atmospherically corrected top-of-canopy reflectance data. We will select relatively cloud free images and will use the Sen2Cor scene classification map to mask any remaining cloudy pixels in the imagery. Each image will be visibly inspected to assess quality and geolocation errors.

The existing urban tree inventory data is a valuable resource but is not a sufficient basis for characterizing Texas urban areas because it does NOT 1) include trees on private property, 2) all Texas urban areas, and 3) provide cover fraction. We will use tree inventory database to train, extrapolate and assess BVOC emitting tree cover distributions.

5. Data Analysis, Interpretation and Management

5.1. Data Reporting

Data reporting procedures will be documented in the project final report as discussed under Section 10.

5.2. Data Validation

Data validation procedures are discussed under Section 8.

5.3. Data Analysis Procedures

ARCGIS will be used to aggregate and map the 10-m vegetation cover developed for Task 2 onto the 30 second (~ 1km) resolution of the MEGAN preprocessor. We will also integrate the Texas urban vegetation cover data into the BELD database to enable use

with BEIS. We will assess the sensitivity of MEGAN and BEIS results to Texas urban landcover by comparing landscape average BVOC emission factor distributions generated with 1) current BEIS, 2) current MEGAN, 3) revised BEIS, 4) revised MEGAN. Emissions generated with the four approaches will be investigated for each of the three Texas urban areas. The impact of the new MEGAN vegetation type distributions and the new MEGAN LAI data will be assessed both individually and in combination. We will compare BVOC emissions estimated using all four models for the summer 2013 scenario (June 1-July 15, 2013 period) for the TCEQ 12 and 36 km domains. We will focus on isoprene and monoterpenes to assess model sensitivity to urban landcover change. We will compare domain totals and emissions by US state and review spatial plots and emission difference plots.

5.4. Data Storage

Data generated for this project will be securely archived during the project on portable hard drives and stored for a period of at least three years following the completion of the project. All data obtained for this project will be stored in electronic format.

6. Model Design

The project will use a widely-used biogenic emissions model called the Model of Emissions of Gases and Aerosols from Nature (MEGAN; Guenther et al., 2012), which is designed to provide inputs of all significant biogenic VOC emissions on the temporal and spatial scales required for regional air quality and global earth system models. The model considers all BVOC emissions regardless if they occur in natural ecosystems or managed landscapes including urban areas. The current version, MEGAN3.1, is updated from MEGAN3.0 to include Texas-specific isoprene, monoterpene and sesquiterpene emission factors and an improved soil NO emission approach. The MEGAN model has been used for numerous biogenic emission modeling studies in Texas[1].

Isoprene and monoterpene emissions in Texas have previously been estimated using the Global Biosphere Emissions and Interactions System (GloBEIS; Yarwood et al., 2002), which was developed as a more flexible alternative to the USEPA BEIS model that was previously the only widely used tool for biogenic emission modeling. GloBEIS is no longer being developed or supported. The flexible framework and key features of GloBEIS have been incorporated into the MEGAN model, which has been used for biogenic emission modeling in Texas. These features include the ability to 1) use landcover data developed for the state of Texas, 2) account for environmental conditions prevalent in Texas (e.g., drought), and 3) update emission factors and other model components as new information becomes available.

[1] https://www.tceq.texas.gov/assets/public/implementation/air/sip/dfw/dfw_ad_sip_2015/AD/Adoption/DFW_SIP_Appendix_B_060315.pdf

6.1. Model Data

The current MEGAN inputs, including emission factors, landcover (growth form fractions, ecotype, LAI), weather (PAR, temperature, wind speed, humidity, soil moisture) and atmospheric composition (CO2, ozone W126 index) will continue to be used in this project although the landcover will be updated to incorporate high resolution LAI, vegetation cover and type data, and tree inventory data. Per requirements for Category III projects, more than 10% of the improved landcover data will be audited, i.e., reviewed visually and assessed for reasonableness. We will perform quality assurance checks to ensure that the updated landcover data are processed correctly for input to MEGAN3.1. The visual inspection of model inputs will be performed by a member of the team who did not participate in the development of the model inputs. Finally, model outputs will be evaluated as outlined in the next paragraph below.

The MEGAN3.1 and BEIS3.61 models with updated landcover data will be run and thoroughly evaluated. More than 10% of the output data generated will be compared to the output from the models with the original landcover to ensure that landcover changes result in expected outcomes. More than 10% of the sensitivity results will be evaluated visually using graphical systems to identify and report the impact of the landcover changes. The assessment of updated model results will be reviewed by a project team member who did not participate in the model inputs development.

7. Model Calibration

The MEGAN model emission factors will be based on emissions data in MEGAN3.1. These data were obtained from literature and recent Texas Air Quality Research Program (AQRP) Project 18-005 (Guenther et al. 2019). The resulting landscape average emissions have been constrained with comparisons to aircraft flux measurements and satellite observations using chemical transport models for three Texas Air Quality Research Program (AQRP) Projects 14-016 (Yu et al., 2015) and 16-011 (Guenther et al., 2017) and 18-005 (Guenther et al. 12019). Although limitations were identified, earlier versions of the model perform within reason for U.S. forested regions and are within the uncertainties of other models, such as BEIS model (Warneke et al. 2010). The differences between BEIS and MEGAN isoprene emissions in forested regions have been further reconciled and the agreement with aircraft and satellite observations is well within the observational uncertainties (AQRP 18-005, Guenther et al. 2019). No further calibration of the MEGAN model will be performed as part of this project.

8. Model Validation

We will carry out emissions sensitivity modeling to evaluate the sensitivity of Texas urban biogenic emissions to landcover inputs by a comparison of the datasets developed for this project with existing datasets currently used for TCEQ's BVOC emission modeling. Sensitivity studies will systematically examine how Texas urban

landcover modifications to the MEGAN and BEIS models influence estimates of biogenic VOC relative to the baseline configuration. Spatial mapping and descriptive summaries will be created for this project to facilitate the detection of anomalies and evaluation of reasonableness. The team members have extensive experience with the development of the MEGAN model, its application, and evaluation of uncertainties surrounding the model inputs. They will apply expert judgment in the calibration of the model investigating in particular how updates to model input parameters or use of alternative input datasets affect emissions estimates relative to the baseline configuration. In cases where an expected directional change in model predictions is inconsistent with changes in input data resources or anomalously small or large emissions estimates are evident, further investigation of discrepancies will be conducted and reconciliation approaches will be pursued.

9. Model Evaluation

A minimum of 10% of the data used in this study will be audited through visualization of MEGAN and BEIS output emissions. Ramboll staff will carry out quality assurance / quality control (QA/QC) procedures for MEGAN and BEIS emissions modeling by carefully reviewing log files for error messages, domain total emissions and spatial plot of output emissions. All error records reported during processing will be reviewed and resolved. Results of all QA/QC procedures and a report of the data quality audits will be discussed in the Final Report.

10. Reporting

As required, monthly technical, monthly financial status, and quarterly reports as well as an abstract at project initiation and, near the end of the project, the draft final and final reports will be submitted according to the schedule below. Mr. Shah or his designee will electronically submit each report to both the AQRP project manager and the TCEQ liaisons and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources (http://aqrp.ceer.utexas.edu/). A representative from the project will present at the AQRP Workshop. Draft copies of any planned presentations (such as at technical conferences) or manuscripts to be submitted for publication resulting from this project will be provided to both the AQRP and TCEQ liaisons per the Publication/Publicity Guidelines included in Attachment G of the subaward. Final project data and associated metadata will be prepared and submitted to the AQRP archive. Each deliverable and required deadline for submission are presented below.

Abstract: At the beginning of the project, an Abstract will be submitted to the Project Manager for use on the AQRP website. The Abstract will provide a brief description of the planned project activities, and will be written for a non-technical audience.

Abstract Due Date: Friday, July 31, 2020

Quarterly Reports: Each Quarterly Report will provide a summary of the project status for each reporting period. It will be submitted to the Project Manager as a Microsoft Word file. It will not exceed 2 pages and will be text only. No cover page is required. This document will be inserted into an AQRP compiled report to the TCEQ.

Quarterly Report Due Dates:

Report	Period Covered	Due Date
Quarterly Report #1	May, June, July 2020	Friday, July 31, 2020
Quarterly Report #2	August, September, October 2020	Friday, October 30, 2020
Quarterly Report #3	November, December 2020, January 2021	Friday, January 29, 2021
Quarterly Report #4	February, March, April 2021	Friday, April 30, 2021
Quarterly Report #5	May, June, July 2021	Friday, July 30, 2021

Monthly Technical Reports (MTRs): Technical Reports will be submitted monthly to the Project Manager and TCEQ Liaison in Microsoft Word format using the AQRP FY20-21 MTR Template found on the AQRP website.

MTR Due Dates:

Report	Period Covered	Due Date
Technical Report #1	Project Start - June 30, 2020	Friday, July 10, 2020
Technical Report #2	July 1 - 31, 2020	Monday, August 10, 2020
Technical Report #3	August 1 - 31, 2020	Thursday, September 10, 2020
Technical Report #4	September 1 - 30 2020	Friday, October 9, 2020
Technical Report #5	October 1 - 31, 2020	Tuesday, November 10, 2020
Technical Report #6	November 1 - 30, 2020	Thursday, December 10, 2020

Technical Report #7	**December 1 - 31, 2020**	**Friday, January 8, 2021**
Technical Report #8	**January 1 - 31, 2021**	**Wednesday, February 10, 2021**
Technical Report #9	**February 1 - 28, 2021**	**Wednesday, March 10, 2021**
Technical Report #10	**March 1 - 31, 2021**	**Friday, April 9, 2021**
Technical Report #11	**April 1 - 30, 2021**	**Monday, May 10, 2021**
Technical Report #12	**May 1 - 31, 2021**	**Thursday, June 10, 2021**
Technical Report #13	**June 1 - 30, 2021**	**Friday, July 9, 2021**

Financial Status Reports (FSRs): Financial Status Reports will be submitted monthly to the AQRP Grant Manager (RoseAnna Goewey) using the AQRP 20-21 FSR Template found on the AQRP website.

FSR Due Dates:

Report	Period Covered	Due Date
FSR #1	**Project Start - June 30**	**Wednesday, July 15, 2020**
FSR #2	**July 1 - 31, 2020**	**Friday, August 14, 2020**
FSR #3	**August 1 - 31, 2020**	**Tuesday, September 15, 2020**
FSR #4	**September 1 - 30 2020**	**Thursday, October 15, 2020**
FSR #5	**October 1 - 31, 2020**	**Friday, November 13, 2020**
FSR #6	**November 1 - 31, 2020**	**Tuesday, December 15, 2020**
FSR #7	**December 1 - 31, 2020**	**Friday, January 15, 2021**
FSR #8	**January 1 - 31, 2021**	**Monday, February 15, 2021**
FSR #9	**February 1 - 28, 2021**	**Monday, March 15, 2021**
FSR #10	**March 1 - 31, 2021**	**Thursday, April 15, 2021**

FSR #11	**April 1 - 30, 2021**	**Friday, May 14, 2021**
FSR #12	**May 1 - 31, 2021**	**Tuesday, June 15, 2021**
FSR #13	**June 1 - 30, 2021**	**Thursday, July 15, 2021**
FSR #14	**July 1 - 31, 2021**	**Friday, August 13, 2021**
FSR #15	**August 1 - 31, 2021**	**Wednesday, September 14, 2021**
FSR #16	**Final FSR**	**Friday, October 15, 2021**

Draft Final Report: A Draft Final Report will be submitted to the Project Manager and the TCEQ Liaison. It will include an Executive Summary. It will be written in third person and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources. It will also include a report of the QA findings.

Draft Final Report Due Date: Monday, August 2, 2021

Final Report: A Final Report incorporating comments from the AQRP and TCEQ review of the Draft Final Report will be submitted to the Project Manager and the TCEQ Liaison. It will be written in third person and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources.

Final Report Due Date: Tuesday, August 31, 2021

Project Data: All project data including but not limited to QA/QC measurement data, metadata, databases, modeling inputs and outputs, etc., will be submitted to the AQRP Project Manager within 30 days of project completion (September 20, 2021). The data will be submitted in a format that will allow AQRP or TCEQ or other outside parties to utilize the information. It will also include a report of the QA findings.

AQRP Workshop: A representative from the project will present at the AQRP Workshop in the first half of August 2021.

Presentations and Publications/Posters: All data and other information developed under this project which is included in **published papers, symposia, presentations, press releases, websites and/or other publications** shall be submitted to the AQRP Project Manager and the TCEQ Liaison per the Publication/Publicity Guidelines included in Attachment G of the Subaward.

11. References

Anderson, D.C., Pavelec, J., Daube, C., Herndon, S.C., Knighton, W.B., Lerner, B.M., Roscioli, J.R., Yacovitch, T.I. and Wood, E.C., 2019. Characterization of ozone production in San Antonio, Texas, using measurements of total peroxy radicals. Atmospheric Chemistry and Physics, 19(5), pp.2845-2860.

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Warneke, C., de Gouw, J. A., Del Negro, L., Brioude, J., McKeen, S., Stark, H., Kuster, W. C., Goldan, P. D., Trainer, M., Fehsenfeld, F. C., Wiedinmyer, C., Guenther, A. B., Hansel, A., Wisthaler, A., Atlas, E., Holloway, J. S., Ryerson, T. B., Peischl, J., Huey, L. G., and Hanks, A. T. C.: Biogenic emission measurement and inventories determination of biogenic emissions in the eastern United States and Texas and comparison with biogenic emission inventories, J Geophys Res-Atmos, 115, -, Artn D00f18, Doi 10.1029/2009jd012445, 2010.

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