Quality Assurance Project Plan

Project 16 – 010
MOVES-Based NO_x Analyses for Urban Case Studies in Texas

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

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Sonoma Technology, Inc. has prepared this QAPP following EPA guidelines for a Quality Assurance (QA) Category III Project: 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: This QAPP includes Project Description and Objectives; Organization and Responsibilities; Model Selection; Model Calibration; Model Verification; Model Evaluation; Model Documentation; Reporting; and References.

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 Quality Assurance Project Plan for Project 16-010: MOVES-Based NO_x Analyses for Urban Case Studies in Texas. The Principal Investigator for the project is Stephen Reid, and the Co-PI for the project is Song Bai.

Electronic Approvals:

This QAPP was approved electronically on September 19, 2016 by Gary McGaughey, The University of Texas at Austin.

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This QAPP was approved electronically on September 19, 2016 by Vincent M. Torres, The University of Texas at Austin.

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This QAPP was approved electronically on September 16, 2016 by Stephen Reid and Song Bai, Sonoma Technology, Inc.

Stephen Reid and Song Bai
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QAPP Distribution List

Texas Air Quality Research Program

David Allen, Director

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1.0 Project Description and Objectives

1.1 Process and/or Environmental System to Be Evaluated

Emissions inventories are an important component of air quality planning and a key input to photochemical grid models that support air quality assessments. Findings from recent studies evaluating ozone concentrations and emissions of ozone precursors suggest that emissions of nitrogen oxides (NO_x) are overestimated in the U.S. Environmental Protection Agency's (EPA) National Emissions Inventory (NEI). This overestimate has generally been attributed to the mobile source sector (Fujita et al., 2012; Anderson et al., 2014; Canty et al., 2015). A previous AQRP-funded project that constrained NO_x emissions over Southeast Texas using an inverse modeling approach estimated that mobile source NO_x emissions in the 2011 NEI should be reduced by a factor of 2 in Houston for 2013 ozone modeling (Choi et al., 2015).

Mobile source emissions estimates are primarily developed using EPA's Motor Vehicle Emissions Simulator (MOVES) model, which includes a default database of county-level input data for the entire United States. EPA recommends that, where possible, these default data be updated with local inputs, such as vehicle miles traveled (VMT), fleet age distributions, meteorological data, and fuel specifications (U.S. Environmental Protection Agency, 2015). Studies evaluating NO_x overestimates in the NEI identified several potential issues with MOVES, including the model's treatment of catalytic converter degradation (Anderson et al., 2014), cold-start activity (Wang, 2013), contributions from super-emitters within the fleet (Liu and Frey, 2015), and reliance on MOVES default data rather than more accurate local inputs (Koupal et al., 2013).

This project will build on the previous NO_x emissions analyses outlined above by using near-road monitoring data to examine MOVES emissions estimates at the local scale. Such comparisons between emissions and ambient data (often called "emissions reconciliation") are used to identify omissions or inaccuracies in an emissions inventory, leading to further investigation and inventory improvement. The results of this work are highly relevant to the recommendations and research priorities outlined in the Texas Air Quality Research Program (AQRP) Strategic Research Plan for 2016-2017, focusing on the investigation and improvement of the accuracy of on-road NO_x emissions estimates.

1.2 Project Objectives

The objectives of this project are to examine MOVES emissions estimates at the local scale using near-road monitoring data and identify which input parameters have the greatest influence on NO_x emissions estimates, using case studies in three Texas metropolitan areas: Dallas-Fort Worth (EPA's AIRS/AQS monitoring site ID 484391053), Houston (EPA's AIRS/AQS monitoring site ID 482011052), and El Paso (EPA's AIRS/AQS monitoring site ID 481410037). The results of this work will support emissions inventory

development and air quality management efforts in Texas by providing information on (1) the accuracy of current MOVES emissions estimates for NO_x, and (2) the MOVES input parameters for which local data collection is most important. This information will help planning agencies in Texas identify potential biases in existing on-road mobile source NO_x emissions estimates and prioritize data collection efforts for future emissions inventory development efforts.

2.0 Organization and Responsibilities

2.1 Project Personnel

This project will be conducted by the STI team, with funding provided by the Texas Air Quality Research Program; the Co-PIs, Stephen Reid and Song Bai, will closely coordinate on all project phases (e.g., data collection, data analysis, and emissions modeling), results reporting (e.g., progress reports and final report), and will have overall responsibility for the research and associated quality assurance. Song Bai will serve as the main point of contact.

This project will be overseen by Air Quality Research Program (AQRP) Project Manager Gary McGaughey and Texas Commission on Environmental Quality (TCEQ) Project Liaison Chris Kite. The scientists working on this project and their specific responsibilities are listed in **Table 2-1**.

Table 2-1. Project participants and their responsibilities.

Participant	Organization	Role	Responsibilities
Stephen Reid	STI	Principal Investigator	Provide technical direction for ambient data analysis aspects of the project
Song Bai	STI	Co-PI	Provide overall technical direction to the project and serve as the primary point of contact with AQRP
Yuan Du	STI	Emissions Modeler	Prepare input data for MOVES analyses, perform MOVES model runs, and post-process model outputs
Ashley Graham	STI	Data Analyst	Acquire, process, and analyze ambient air quality and meteorological data
Annie Seagram	STI	Data Analyst	Support ambient data analyses and comparisons between ambient data and MOVES outputs
Lyle Chinkin	STI	Quality Assurance Lead	Oversee quality assurance reviews for the project
Mary Jo Teplitz	STI	Technical Editor	Edit written deliverables and technical presentations
Jana Schwartz	STI	Technical Editor	Provide a final review of project deliverables
Jenny Narvaez	NCTCOG	In-Kind Support	Provide in-kind support, including the provision of local MOVES inputs for the Dallas-Fort Worth region and review of project findings

2.2 Project Schedule and Main Milestones

The project schedule is presented in **Figure 2-1**. Technical work will not begin until authorization is received from AQRP and TCEQ. The entire project will be completed by August 31, 2017.

Figure 2-1. Project schedule with main milestones by month.

Task	2016						2017							
	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Contract, Scope of Work, QAPP														
1. Emissions Reconciliation Analysis														
2. MOVES Sensitivity Analyses														
3. Reporting and Presentations														
• Quarterly Reports														
• Monthly Technical Reports														
• Monthly Financial Status Reports														
• Draft Final Report; AQRP Review														
• AQRP/TCEQ Presentation														
• Final Report														

Specific work tasks include:

1. Apply emissions reconciliation techniques to compare MOVES emission results with near-road ambient monitoring data for case studies in three Texas metropolitan areas: Dallas-Fort Worth, Houston, and El Paso.
2. Perform sensitivity analyses comparing MOVES emission results, using default vs. local data, to identify which input parameters have the greatest influence on NO_x emission estimates.
3. Submit monthly technical reports and financial status reports each month throughout the project duration; submit a draft final project report and a final project report; and present at the AQRP Workshop.

3.0 Model Selection

The model selected in this project is MOVES, the official mobile source emissions model developed by EPA. MOVES2014a is the latest version of MOVES and will be applied to support the two major objectives of this project: (1) conducting an emissions reconciliation analysis with comparisons between near-road air quality monitoring data and MOVES emission estimates at the local scale, and (2) performing a sensitivity

analysis to assess which input parameters in MOVES have the greatest influence on NO_x emissions estimates. In these analyses, MOVES2014a will be used to provide estimates of on-road emissions (e.g., for NO_x, CO, and $PM_{2.5}$) for different modeling scenarios.

MOVES can provide estimates of on-road emissions at scales ranging from individual roadway segments to large regions. MOVES is a data-driven model – inputs, outputs, default activities, base modal emission rates and all intermediate calculation data are stored and managed in MySQL database (e.g., the MOVES County Data Manager). MOVES model functions query and manipulate MySQL data pursuant to scenario parameters specified in a graphical user interface (under Windows OS). This design provides users with the ability to replace MOVES default data in its MySQL platform with local input data, such as vehicle fleet composition, traffic activities, and meteorological parameters. MOVES outputs, which include emission factors (i.e., gram per mile emission rates) or emission inventories (the total mass of emissions), are functions of modal-based vehicle emission rates and detailed vehicle activities specified for the desired geographic scale.

In this project, local roadway network inputs for MOVES modeling (e.g., hourly traffic volumes and speeds, vehicle age distributions, fleet mix) will be acquired from local agencies, such as the North Central Texas Council of Governments (NCTCOG). Local meteorological data (e.g., wind speed and wind direction) will be collected from representative meteorological monitors for the time periods of interest. The MOVES County Data Manager will be used to incorporate input data for different test cases.

4.0 Model Design

This project applies the EPA's MOVES model directly and does not involve new model development work. Therefore the model design component is not applicable in this quality assurance project plan.

5.0 Model Coding

This project applies the EPA's MOVES model directly and does not involve new model development work. Therefore the model coding component is not applicable in this quality assurance project plan.

6.0 Model Calibration

EPA has adopted MOVES as its official model for developing on-road emissions inventories to support State Implementation Plan (SIP) development and transportation conformity analyses. During the MOVES development process, EPA followed the

Guidance for Quality Assurance Project Plans for Modeling (EPA, 2002) and conducted model calibration, testing, validation, performance checks and documentation. In this project, the project team will directly apply the MOVES model to generate emissions estimates for the reconciliation and sensitivity analyses; no additional model calibration for MOVES is needed.

7.0 Model Verification

The MOVES quality assurance involved the comparison of model-predicted values to in-use data (e.g., vehicle activity, emissions data from portable emission measurement systems, distribution of vehicle emitter types, frequency of air conditioning use, nonroad engine population, and geographic distribution of all sources) for estimating on-road vehicle emission rates and total emissions. Scientific peer review has also been conducted for MOVES, following the EPA's Peer Review Handbook (EPA, 2000).

In this project, the project team will directly apply the MOVES model to generate emissions estimates for the reconciliation and sensitivity analyses; no additional model verification for MOVES is needed. The MOVES modeling data in this project will include default and local inputs for case studies. STI will work with local planning agencies (e.g., NCTCOG) to review and quality-check local vehicle activity data, vehicle age distribution, fleet mix information, and other key modeling input parameters.

The emissions reconciliation analysis will rely on routine near-road air quality data collected by state and local monitoring agencies in 2014–2015 in three Texas metropolitan areas (Dallas-Fort Worth, Houston, and El Paso). The MOVES emission estimates for the reconciliation and sensitivity analyses will rely on default and local data (e.g., vehicle activities, fleet mix data, and meteorological data) for MOVES model runs. Specific quality requirements for ambient air quality monitoring programs are provided in the EPA's *Quality Assurance Handbook for Air Pollution Measurement Systems* (e.g., for regulatory purposes, EPA typically requires 75% of the time periods measured in a year for a site to meet minimum data completeness) (U.S. Environmental Protection Agency, 2013). The monitored air quality data to be used in this project have been previously quality-assured by each air monitoring and reporting agency and meet EPA's quality requirements. For MOVES emissions modeling, general quality assurance practices include confirming model configuration, checking model performance, and assessing model inputs/outputs.

8.0 Model Evaluation

The MOVES output emissions data and analytical results will be assessed through the planned emissions reconciliation and sensitivity analyses, with temporal and spatial variations of modeled NO_x emissions evaluated through data tables and graphics. At

least 10% of the monitored concentration data, MOVES modeling input and output files, and data analysis results (data tables and graphics) will be reviewed for quality assurance purposes by the Co-PIs. Results from the audits will be reported in the final project report.

For the emissions reconciliation analysis, as a quantitative assessment, the MOVES emissions-based pollutant ratios and ambient-based pollutant ratios will be compared by site, season, day of the week, and wind direction. Because of the inherent uncertainties associated with this analysis method, emissions- and ambient-derived ratios that are within approximately 25-50% of each other are considered to be in good agreement (California Air Resources Board, 1997). Larger differences may point to inaccuracies or biases in the emissions inventory; for example, emissions-derived CO/NO_x ratios that are lower than corresponding ambient-derived ratios may indicate that, in the emissions inventory, CO is underestimated, NO_x is overestimated, or both.

For the sensitivity analysis, the assessment will be performed in two ways to ensure that input data are valid for MOVES modeling:
(a) A qualitative approach with in-depth review of the data pattern and ranges; examples include examination of temporal variation in line charts for temperature/humidity and spatial variation in proportions by road type for vehicle miles traveled (VMT).
(b) A quantitative approach with descriptive statistics of data and verification with local agencies for local data that diverge greatly from MOVES default; examples of statistical metrics include VMT-weighted average fleet age (Equation 1), annual average VMT per vehicle by vehicle type (Equation 2), and these metrics will be compared between the local data and MOVES default data to quantify percent differences.

$$WAFA_i = \sum_{j=1}^{30} \left(VAF_{i,j} \times j\right) \qquad \text{Equation (1)}$$

Where,
WAFA = weighted average fleet age
i = vehicle type (source type defined in MOVES)
j = vehicle age (0, 1, 2…, 30)
VAF = vehicle age fraction

$$AAV_i = {}^{AFVMT_i}/_{STP_i} \qquad \text{Equation (2)}$$

Where,
AAV = average annual VMT per vehicle
i = vehicle type (source type defined in MOVES)
AVMT = annual fleet vehicle miles traveled
STP = vehicle population (source type population in MOVES)

The MOVES NO_x emissions outputs associated with various testing cases will be compared and then used to identify which input parameters have larger impact on NO_x emissions estimates.

9.0 Model Documentation

The STI project team will prepare monthly technical reports, a draft project report, and a final project report. These reports will be submitted to AQRP with a summary of modeling approaches, data analysis steps, and quality assurance procedure and results.

9.1 Documentation of Data and Modeling Analysis

For the emissions reconciliation analysis, data processing and modeling analysis will include the following and will be documented in the project report:

- Selecting available hourly measurements for early morning hours (e.g., 6:00 a.m.-9:00 a.m.) to minimize the influence of transported pollutants and chemical reactions on ambient measurements.
- Collecting meteorological data (e.g., wind speed and wind direction) from co-located or nearby meteorological monitors for the time periods of interest.
- Calculating ambient-based pollutant ratios (e.g., CO/NO_x) for each monitoring site and examining variations in these ratios by season, day of the week, and periods when the site is upwind or downwind of the nearby roadway.
- Identifying a "zone of influence" around each monitoring site by using average wind speeds during early morning hours to approximate air parcel travel distance during that time period. This analysis will help determine which roadways and sections of roadways are likely to impact monitored concentrations when winds are from various directions.
- Acquiring local MOVES inputs (e.g., hourly traffic volumes and vehicle speeds, vehicle age distributions, fleet mix) for the road networks within each zone of interest. These data will be used with local meteorological measurements in MOVES to estimate on-road emissions for the road network around each monitoring site.
- Running MOVES2014a to develop emissions estimates and then converting them from mass to molar basis so that pollutant ratios will be comparable to ambient-based ratios.
- Comparing emissions- and ambient-based ratios by site, season, day of the week, and wind direction.

For the MOVES sensitivity analysis, data processing and modeling analysis will include the following and will be documented in the project report:

- Developing MOVES testing cases with default, local data, and other assumed levels of key modeling parameters (e.g., vehicle activities, vehicle age distributions, and fleet mix).
- Using the MOVES County Data Manager to incorporate input data (in CSV data files) for different testing cases, running MOVES2014a for each test case, and assessing how NO_x emissions generated by MOVES change among various cases.

- Re-calculating MOVES-based pollutant ratios for cases involving default input data to see whether those ratios compare more or less favorably with ambient-derived ratios than the MOVES-based ratios developed with local input data.

9.2 Data Storage

The near-road air quality data acquired via the EPA's Air Quality System will be assembled into a database and stored on STI's secure server. The MOVES model inputs and outputs will also be organized and stored on STI's secure server. These project data will be securely archived and backed up through a disk-to-disk-to-tape system during the project. The project data will be transferred to the AQRP in appropriate electronic format and will be maintained for a minimum of five years after the completion of the project. Depending on the size of the project data files, the data transfer will be conducted through STI's secure File Transfer Protocol (FTP) system or an external hard drive.

10.0 Reporting

10.1 Deliverables

AQRP requires certain reports to be submitted on a timely basis and at regular intervals. A description of the specific reports to be submitted and their due dates are outlined below. All reports 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. Report templates and accessibility guidelines found on the AQRP website at http://aqrp.ceer.utexas.edu/ will be followed.

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

Abstract Due Date: Wednesday, August 31, 2016
(STI delivered the Abstract on August 29, 2016)

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.

Table 10-1. Quarterly Report Due Dates

Report	Period Covered	Due Date
Nov2016 Quarterly Report	September, October, November 2016	Wednesday, November 30, 2016
Feb2017 Quarterly Report	December 2016, January & February 2017	Tuesday, February 28, 2017
May2017 Quarterly Report	March, April, May 2017	Wednesday, May 31, 2017
Aug2017 Quarterly Report	June, July, August 2017	Thursday, August 31, 2017

Monthly Technical Reports (MTRs): Technical Reports will be submitted monthly to the Project Manager and TCEQ Liaison in Microsoft Word format using the AQRP FY16-17 MTR Template found on the AQRP website.

Table 10-2. MTR Due Dates

Report	Period Covered	Due Date
Sep2016 MTR	September 1 - 30, 2016	Monday, October 10, 2016
Oct2016 MTR	October 1 - 31, 2016	Tuesday, November 8, 2016
Nov2016 MTR	November 1 - 30, 2016	Thursday, December 8, 2016
Dec2016 MTR	December 1 - 31, 2016	Monday, January 9, 2017
Jan2017 MTR	January 1 - 31, 2017	Wednesday, February 8, 2017
Feb2017 MTR	February 1 - 28, 2017	Wednesday, March 8, 2017
Mar2017 MTR	March 1 - 31, 2017	Monday, April 10, 2017
Apr2017 MTR	April 1 - 30, 2017	Monday, May 8, 2017
May2017 MTR	May 1 - 31, 2017	Thursday, June 8, 2017
Jun2017 MTR	June 1 - 30, 2017	Monday, July 10, 2017
Jul2017 MTR	July 1 - 31, 2017	Tuesday, August 8, 2017

Financial Status Reports (FSRs): Financial Status Reports will be submitted monthly to the AQRP Grant Manager (Maria Stanzione) by each institution on the project using the AQRP FY16-17 FSR Template found on the AQRP website.

Table 10-3. FSR Due Dates

Report	Period Covered	Due Date
Sep2016 FSR	September 1 - 30, 2016	Monday, October 17, 2016
Oct2016 FSR	October 1 - 31, 2016	Tuesday, November 15, 2016
Nov2016 FSR	November 1 - 30 2016	Thursday, December 15, 2016
Dec2016 FSR	December 1 - 31, 2016	Tuesday, January 17, 2017
Jan2017 FSR	January 1 - 31, 2017	Wednesday, February 15, 2017
Feb2017 FSR	February 1 - 28, 2017	Wednesday, March 15, 2017
Mar2017 FSR	March 1 - 31, 2017	Monday, April 17, 2017
Apr2017 FSR	April 1 - 30, 2017	Monday, May 15, 2017
May2017 FSR	May 1 - 31, 2017	Thursday, June 15, 2017
Jun2017 FSR	June 1 - 30, 2017	Monday, July 17, 2017
Jul2017 FSR	July 1 - 31, 2017	Tuesday, August 15, 2017
Aug2017 FSR	August 1 - 31, 2017	Friday, September 15, 2017
FINAL FSR	Final FSR	Monday, October 16, 2017

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: Tuesday, August 1, 2017

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: Thursday, August 31, 2017

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 29, 2017). 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 2017.

10.2 Expected Final Products

An approved final project report will be prepared and submitted by the end of this project. A presentation will be given at the AQRP Workshop to share the findings of the project regarding the accuracy of current MOVES emissions estimates for NO_x and the MOVES input parameters for which local data collection is most important.

11.0 References

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