

# HEM4 QA/QC Report

Quality Assurance / Quality Control Testing  
During Development of the  
Human Exposure Model 4 for Single and Multiple Facility  
Exposure and Risk Modeling

Open-Source Version 1.0

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## **Disclaimer**

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## 1.0 Introduction and Overview

Quality assurance/quality control (QA/QC) practices are based on the guidance and requirements for quality documentation, as specified by the US Environmental Protection Agency (EPA) and by the Quality Management Plan (QMP) of the EPA's Office of Air Quality Planning and Standards (OAQPS).

In compliance with QA/QC practices the HEM4 model was thoroughly tested throughout its development. The quality assurance (QA) activities performed help to deliver consistent results through a set of standardized procedures. More specifically, quality control (QC) activities helped scrutinize the data quality of the end products (output files) to ensure that the data generated by the model faithfully reflects user-specific inputs and that the model produces reasonable and reliable predictions prior to public release. When assessing HEM-4 inputs and outputs the quality objective was to ensure that HEM4 maintains or exceeds the functionality of HEM-3, faithfully generates and transfers the inputs to AERMOD, and faithfully translates the AERMOD outputs into HEM4 concentration and risk predictions.

A combined approach of computerized/automated and manual testing activities were used to assess HEM4's overall performance. While the HEM4 model itself was tested for functionality, the model's data/outputs were assessed for reliability, representativeness and completeness. The accuracy of HEM4's outputs were ascertained by ensuring the unit concentrations produced by AERMOD were faithfully and reliably transformed by HEM4 to multi-pollutant concentrations, cancer risk estimates, noncancer hazard quotient and hazard indices. (Note: The accuracy of the AERMOD dispersion model has been rigorously tested and reviewed, including AERMOD's concentration outputs.) This QA/QC with respect to AERMOD involved both automated scripts and reports, as well as manual review and comparison of outputs by SC&A staff.

SC&A's QA/QC also included rigorous testing of HEM4's error handling. SC&A model developers designed HEM4 with numerous internal checks in the model's code that automatically cross-reference the input files provided by the user, including the modeling parameters chosen, for consistency and reasonableness. In cases where information entered in one or more of these files is missing, invalid or nonsensical, HEM4 is designed to notify the user, or when appropriate modify or correct the input data – e.g., utilize a default value assigned to a field. Forced-error testing was one approach used to ensure these notifications occurred as expected and provided the user with instructive error messages.

QA/QC testing was performed by qualified, experienced QA testers. SC&A's QA testers represented a range of knowledge and familiarity with respect to HEM4 – from experienced users of HEM4 to beginner modelers – to better reflect the range of public stakeholders who will run HEM4. This range of perspective ensured that HEM4 operation was intuitive and suitable for the beginner through the advanced user.

QA testers were tasked with checking all the essential features of the HEM4 model. As different inputs were created, test parameters run, and different outputs reviewed, these QA activities were recorded in a Master QA Excel™ workbook of spreadsheets. SC&A testing staff organized all QA activities in this Master QA workbook and updated it on a continuous basis since January 2020. Changes made to this workbook were documented with the tester's initials and test date

and automatically saved via Microsoft's AutoSave feature. A complete history of all QA workbook versions is archived and available through Microsoft's version history feature. **Note:** This Master QA spreadsheet workbook has been provided to the EPA under separate cover.

Beginning in February 2020, issues that arose during the development of the HEM4 model were also recorded on github.com (<https://github.com/>), a cloud-based Git repository hosting service. SC&A staff used the HEM4 github site to post issues/bugs identified by SC&A's QA testers, prioritize fixes by SC&A programmers, track the status of reported issues/bugs and their fixes, and report the final resolution, retesting and closure of the identified issue/bug in HEM4. SC&A's QA/QC approach, including the use of the Master QA spreadsheet and the github repository site, are discussed in more detail below.

## 2.0 Quality Assurance Objectives and Design

Ensuring the stability and soundness of HEM4's underlying code is a necessary precursor for meaningful and effective QA/QC activities. Steps taken to maintain the model's integrity during HEM4 development and testing included:

- Using the Github code repository system to ensure code integrity and avoid "versionitis";
- Establishing a uniform set of Python packages (libraries) and their version numbers required to build the HEM4 application, thereby ensuring each developer/programmer is working from the same code base;
- Standardizing of the variable names associated with output file fields; and
- Building-in a Python unit test module to confirm that after every code change, HEM4 produced results that exactly match a standard set of outputs.

### 2.1 Model Components and Attributes Tested

Performing QA/QC testing is time- and labor-intensive. To ensure resources allocated for the QA portion of the HEM4 development process were used efficiently and effectively, SC&A staff organized QA/QC testing around the following HEM4 components and attributes:

- Graphical User Interface (GUI) elements;
- Required (standard) input files;
- Optional (non-standard) input files;
- Additional (risk summary and output analysis) modeling options;
- Forced-error testing; and
- Concentration comparisons of outputs.

A description of each HEM4 component and attribute category tested is provided below.

HEM4 Component/Attribute	Description
GUI	A stable and reliable GUI is necessary for correct model functioning. GUI functionality tests were designed to identify and address common GUI problems, such as menu button functionality and searching/browsing and opening/retrieving of input files. QA/QC tests and re-tests were recorded and tracked in a GUI-specific spreadsheet within the Master QA spreadsheet workbook*.

HEM4 Component/ Attribute	Description
Required (standard) Input Files	HEM4 will fail to run or run improperly if one or more of the required (standard) input files is missing or incorrectly populated. Rigorous QA testing of all three (3) HEM4 required input files – the Facility List Options, HAP Emissions, and Emissions Location files – ensures a user can successfully edit and upload the required files; that the model notifies the user, when appropriate, of missing or incomplete data; and that the model produces expected outputs reliably based on user-specific field selections. QA activities are recorded and tracked on individual spreadsheets specific to each required input file, within the Master QA workbook*.
Optional (non-standard) Input Files	HEM4 prompts for additional (non-standard) input files based on modeling options indicated by the user in the required input files. QA testing was performed using variations of the following optional input files: Polygon Vertex, Buoyant Line Parameter, Deposition and Depletion input files (Particle Data, Land Use, Month to Seasons), Building Dimensions, User-Defined Receptors, Emissions Variation, Alternate Receptors and Census Update files. QA testing results for most optional input files were recorded together in a combined spreadsheet within the Master QA workbook*. Emission variation tests and deposition and depletion tests were assigned their own spreadsheet(s), due to the complexity of possible user input selections/combinations and therefore assessments.
Additional Modeling Options	HEM4's Summarize Risks and the Analyze Outputs functions were tested to confirm that the model was able to accurately generate all nine risk summary reports and allow the user the ability to view and/or analyze facility-specific as well as run group-wide outputs. QA testing results for these additional modeling options were jointly documented on a spreadsheet within the Master QA workbook*.
Forced-Error Testing	Tests that created conditions causing errors in the model were used to identify possible user input mistakes and conditions that were improperly handled by the model, or not detected at all. QA testing included but was not limited to examining model selections and input mistakes which commonly resulted in errors in HEM-3 (based on past experience). Although some of these tests were analyzed as part of one or more model component/feature, a separate spreadsheet* highlighting error testing for the three required input files was used.
Output Concentration Comparison	The detailed evaluation of outputs files is required to determine and verify that HEM4 is performing as designed – i.e., generates outputs that are comparable to HEM-3 outputs and, more fundamentally, faithfully and reliably delivers inputs to and reports outputs from AERMOD. HEM4:AERMOD and HEM4:HEM-3 tests were performed that evaluated and compared output concentrations for standard, acute, and deposition and depletion runs. The interpretation and analysis of these resulting comparisons were documented in multiple spreadsheets within the Master QA workbook*.

**Figure 1. QA Testing Categories During HEM4 Development**

\* SC&A has submitted the HEM4 QA workbook and included spreadsheets to EPA under separate cover.

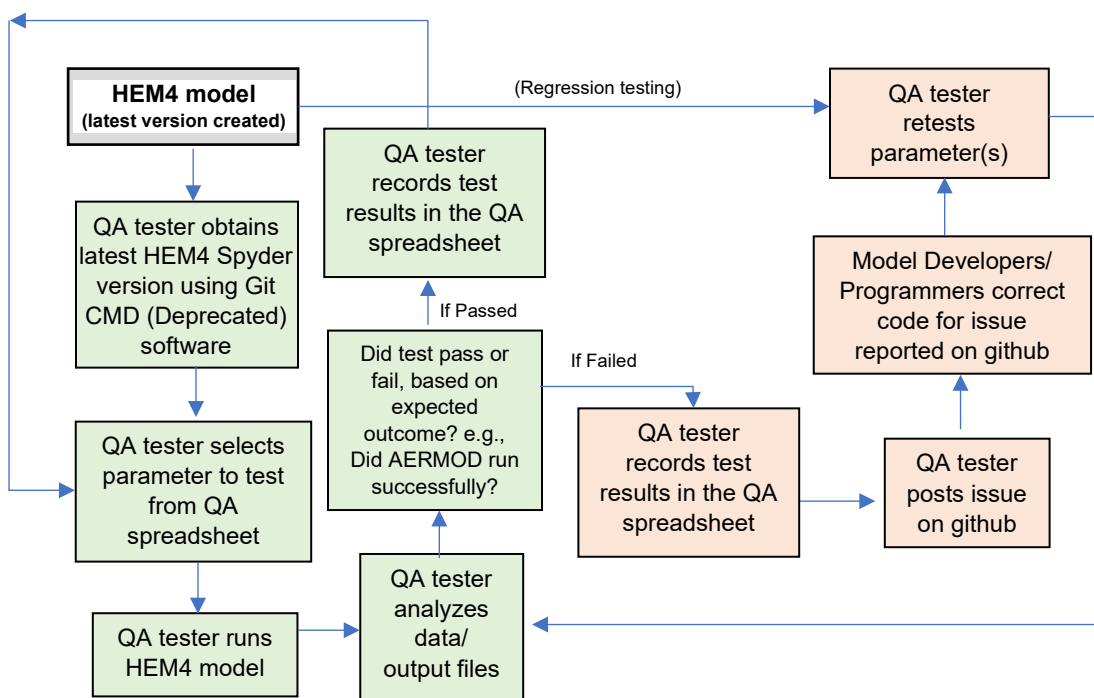
## 2.2 Quality Assurance / Quality Control Process

The QA/QC process during HEM4 development was iterative. QA testers tested a feature or parameter of HEM4, working through the universe of features and parameters listed in the spreadsheets of the Master QA workbook (discussed in more detail in Section 2.3). SC&A developers/ programmers made changes to the HEM4 code throughout development via Python's Spyder platform, as issues with functionality and reliability were identified by SC&A QA

testers. As corrections, improvements and updates were made to a model version, the HEM4 developers/ programmers created a new Spyder version of HEM4 on github.com (discussed in more detail in Section 2.4) for QA testers to run, including retesting of previously identified issues for which the programmers implemented fixes, as well as retesting of basic functionality. Using the most recent model version on the HEM4 Github site, QA testers were tasked with (a) ensuring the recent code change fixed the specific issues/errors it was intended to fix and (b) performing regression testing to ensure no adverse side effects to other model functionality occurred as a result of the code change/fix. QA testers repeated a suite of tests to verify both (a) and (b) to ensure the model performed as expected, before moving on to test additional features and parameters listed in the Master QA workbook.

When model issues were identified through QA testing, the issues were uploaded/posted to the Github repository site where the developers/programmers were able to review and then amend code as necessary. Each iteration of amendments to the model code required testers to repeat QA testing procedures (i.e., perform regression testing) to ensure the integrity and functionality of each version of HEM4.

Below is a flow chart of the basic approach used to test and QA the HEM4 model during development, including the github.com process of reporting an issue.



**Figure 2. HEM4 QA Testing Flow Chart**

A set of standardized inputs or test template files were created for each standard and additional/ optional input file used for HEM4. These templates were used by QA testers to ensure consistency in testing procedures and outputs. A standard format for inputs files minimizes user errors by the QA tester and also maximizes efficiency of the overall testing regime. These templates were updated as needed based on the parameter being tested or when major or

significant updates to the model were done – e.g., the addition or removal of an input field (i.e., column header in an input file).

After a HEM4 model run was completed, QA testers analyzed the data/output files for accuracy (compared to an AERMOD run), representativeness (based on inputs), and completeness (based on modeling options chosen) and documented the results in the applicable spreadsheet of the Master QA workbook. For example, depending on the specific modeling options indicated in the input files, a QA test's outputs were deemed accurate, representative and complete if for a given modeled facility the following facility-specific files were produced and contained the expected data values (compared to a previously verified run through AERMOD with the same inputs, as discussed in Section 2.5):

- facilityID\_acute\_bkdn.xlsx
- facilityID\_acute\_chem\_max.xlsx
- facilityID\_acute\_chem\_pop.xlsx
- facilityID\_all\_inner\_receptors.csv
- facilityID\_all\_outer\_receptors.csv
- facilityID\_all\_polar\_receptors.csv
- facilityID\_block\_summary\_chronic.csv
- facilityID\_cancer\_risk\_exposure.xlsx
- facilityID\_incidence.xlsx
- facilityID\_input\_selection\_options.xlsx
- facilityID\_maximum\_indiv\_risks.xlsx
- facilityID\_maximum\_offsite\_impacts.xlsx
- facilityID\_noncancer\_risk\_exposure.xlsx
- facilityID\_ring\_summary\_chronic.csv
- facilityID\_risk\_breakdown.xlsx
- facilityID\_source\_risk.kmz
- AERMOD\_P.inp
- AERMOD\_V.inp
- aermod\_P.out
- AERMOD\_V.out
- plotfile\_p.plt
- plotfile\_v.plt
- maxhour\_p.plt
- maxhour\_v.plt

### 2.3 Master Quality Assurance Workbook of Spreadsheets

The Master QA workbook, submitted to the EPA under separate cover, is comprised of multiple individual spreadsheets representing the testing categories described above in Section 2.1 and outlined in Figure 1. Each QA spreadsheet contains numerous test parameters regarding HEM4's user interface, input files and fields, internal databases, intentional user errors, and output comparisons with HEM-3 and AERMOD.

Each QA test was run as defined by the test parameters listed in the spreadsheets of the Master QA workbook. HEM4 has retained and exceeded all the functionality of the earlier HEM-3 version, and many of the basic QA test parameters used to review and cross-check the model



were originally prepared, approved and used to evaluate HEM-3. However, because of HEM4's enhanced capabilities including additional input fields compared to HEM-3, SC&A added and modified testing parameters accordingly, to reflect HEM4's new input capacities and updates. More than 500 test parameters were used to analyze the general testing categories shown in Figure 1 of Section 2.1. A more detailed sample list organized by general category of the QA test parameters used, along with expected outcomes, is provided in Table 1 of Section 3.0.

Each of the test parameters were defined in the spreadsheets of the Master QA workbook along with the expected outcome, whether the initial test passed or failed, the output file name if applicable, the date tested, and the initials of the tester. A list and description of the fields (column headers) that are included in the QA spreadsheets are provided below in Figure 3. Sample spreadsheets are provided in Tables 2 through 6 of Section 3.0.

**Figure 3. HEM4 QA Testing Spreadsheet Fields**

Field	Description
Test Parameter	Characteristic/standard being tested
Test Procedure / Expected Outcome	A brief description on how to check if the model ran successfully and/or a description of anticipated outcomes
Test - Pass/Fail	The actual results of the test based on expected outcomes
Date Tested (or re-tested)	The date when the test was initially performed or when a re-test was completed
Initials of Tester	SC&A QA staff member's initials responsible for executing the test
Test Run Output File	The file name of the failed or passed test
Error Message	A copy and paste of the AERMOD.out generated model error message, or if not available, a brief description of the error identified
Github Error Entry	Issues posted on the github site are automatically assigned a number. This number was recorded in the QA spreadsheet and used to track the progress of model developers/programmers in addressing the issue(s).
Resolution Taken	A brief description of the action(s) taken to correct the identified issue(s); this field also records when a github entry has been closed
Notes	Used to expand upon identified issues, and/or provide additional information deemed useful for model developers/programmers
Facility ID*	Name of the facility modeled
Source ID*	Name of the Source ID modeled
Source Type*	Identifies the source type modeled – i.e., point, area, volume, polygon, line and buoyant line
Pollutant Name*	Name of the pollutant modeled
Rundir*	The output file from HEM4 run
HAPemis_path*	The HAP Emissions file from HEM4 run
Acute*	"Y" or "N" identifies whether acute concentrations were modeled
Runtype*	Identifies the deposition type chosen for HEM4 run

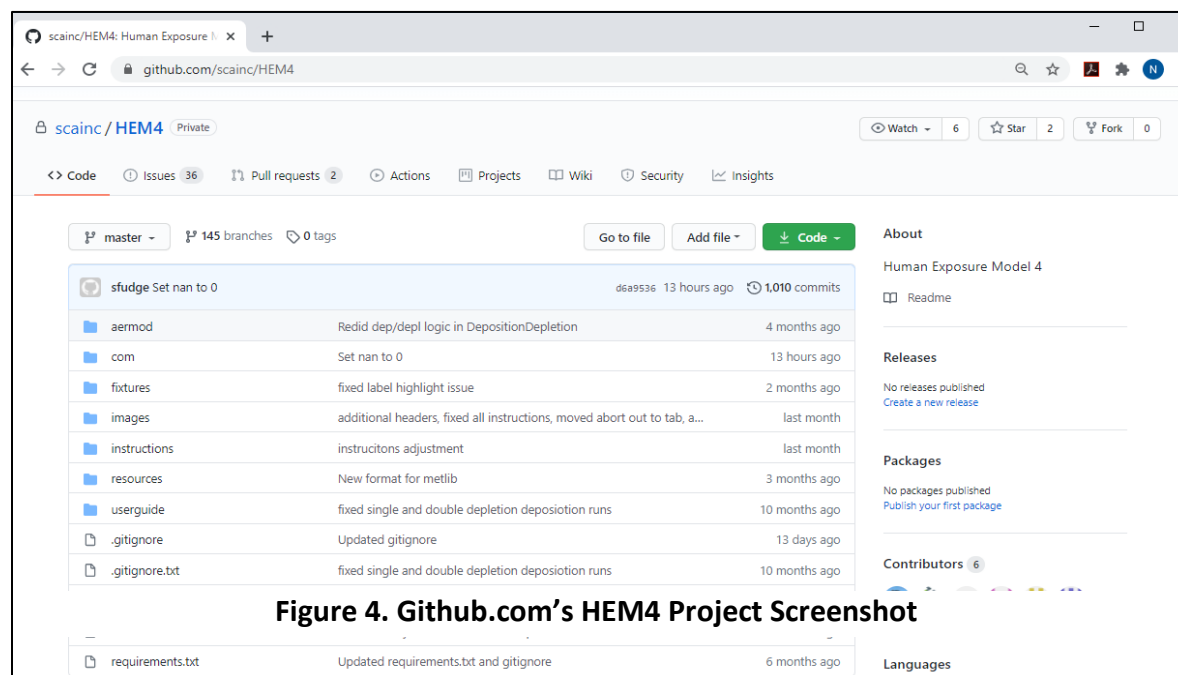
Field	Description
Emistype*	P (particle), V (vapor), or C (combined) emission types; also identifies the type plot file produced by HEM4 run
% Difference*	Provides the percentage difference (if any) between HEM4 output concentrations and AERMOD plot file output concentrations
Deptype*	Indicates whether wet or dry depletion was modeled
File Location*	Location (file directory) of HEM4 output files used for comparison
Diff_acute_bkdn*	The percentage difference between HEM4 and HEM-3 acute output files titled, Acute Bkdn
diff_acute_chem_max*	The percentage difference (if any) between HEM4 and HEM-3 acute output files titled, Acute Chem Max
diff_acute_chem_pop*	The percentage difference (if any) between HEM4 and HEM-3 acute output files titled, Acute Chem Pop
diff_all_inner_receptors*	The percentage difference (if any) between HEM4 and HEM-3 inner receptor files titled, All Inner Receptors
diff_all_outer_receptors*	The percentage difference (if any) between HEM4 and HEM-3 outer receptor files titled, All Outer Receptors
diff_all_polar_receptors*	The percentage difference (if any) between HEM4 and HEM-3 polar receptor files titled, All Polar Receptors
diff_block_summary_chronic*	The percentage difference (if any) between HEM4 and HEM-3 block summary files titled, Block Summary Chronic
diff_maximum_indiv_risks*	The percentage difference (if any) between HEM4 and HEM-3 max risk files titled, Maximum Individual Risks
diff_ring_summary_chronic*	The percentage difference (if any) between HEM4 and HEM-3 ring summary files titled, Ring Summary Chronic
diff_risk_breakdown*	The percentage difference (if any) between HEM4 and HEM-3 risk breakdown files titled, Risk Breakdown
Depo only = Standard run*	The results of a comparison of concentrations from the "all_inner_receptor" file for deposition only (no depletion) test runs to concentrations from a standard run (no deposition, same inputs)
Depo + Depl = Depl only*	The results of a comparison of concentrations from the "all_inner_receptor" file for deposition plus depletion test runs to concentrations from a depletion only test run (same inputs)
Depl only < Depo only*	The results of a comparison of concentrations from the "all_inner_receptor" file for depletion only test runs to concentrations from a deposition only test run (same inputs)
Depo + Depl < Depo only*	The results of a comparison of concentrations from the "all_inner_receptor" file for deposition plus depletion test runs to concentrations from a deposition (no depletion) test run, with the same inputs
Depo + Depl < Standard run*	The results of a comparison of concentrations from the "all_inner_receptor" file for deposition plus depletion only test runs to concentrations from a standard run (no depo/depl, same inputs)

\*Field included in concentration comparison spreadsheets only.

**Figure 3. HEM4 QA Testing Spreadsheet Fields**

## 2.4 Github Repository Site

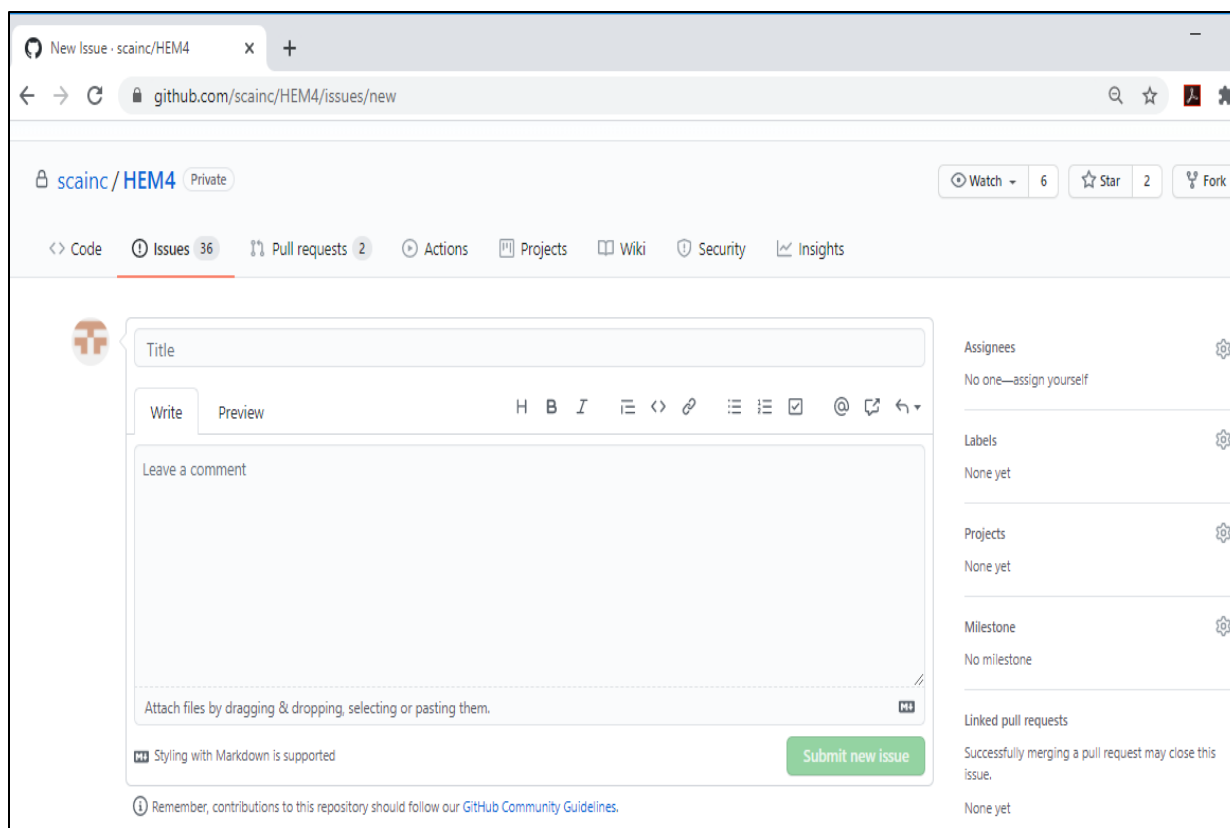
Github.com is a cloud-based software development platform. HEM4 developers/programmers used this Git repository hosting service to develop, manage and review code and to ensure code integrity by avoiding “versionitis”. Github also allowed SC&A’s QA process and code updates/revisions to be safely and efficiently managed, tracked and controlled by HEM4’s developers/programmers. Using github.com, SC&A’s developers/programmers and QA testers collaborated on the HEM4 project from any location and the user-friendliness of github’s interface allowed programmers and non-programmers to safely use it. These attributes will also prove helpful as support for HEM4 continues, as well as when future HEM4 versions are developed. A screenshot of the github.com site for the HEM4 project is provided in Figure 4.



**Figure 4. Github.com’s HEM4 Project Screenshot**

The github platform’s “Issues” feature provided a central location for SC&A’s QA testers to flag and catalog HEM4 issues in real-time, including details related to the error or malfunction and specific changes needed to address the issue. On the Issues page, the QA tester described the issue or error found and included a copy and paste of the model code’s error notice, as well as the specific file(s) used to test the parameter that resulted in the issue/error. This allowed SC&A’s HEM4 developers/programmers to reproduce the problem and efficiently begin the debugging process to address the problem and correct the issue.

Issues reported on github can be searched or filtered by author, label type (e.g., bug, question, duplicate, etc.) and project, as well as other filters. HEM4’s developers/programmers as well as all SC&A QA testers automatically receive email notifications regarding activity on the project-specific github site, including when a new issue is posted by a tester. Each issue posted on github is rendered an “issue number” that is used to track the progress of model developers/programmers in correcting the identified problem. The issue number is also recorded by the QA tester who submitted the issue on the appropriate spreadsheet in the HEM4 Master QA workbook. A screenshot of the “Issues” page is provided in Figure 5.



**Figure 5. SC&A’s HEM4 Issues Page on Github.com**

## 2.5 Concentration Comparisons

Another important testing aspect to SC&A’s QA process was reviewing, analyzing, and comparing HEM4 output concentrations in three different ways. First, HEM4 concentrations under one modeling run scenario were compared to HEM4 concentrations under a different run scenario. This kind of comparison was used primarily to ensure that deposition and depletion modeling options were being fed to AERMOD correctly and that HEM4 was reporting reasonable results under the various modeling scenarios. In addition, HEM4 concentrations were compared to concentrations generated by HEM-3, using the same inputs, to determine if HEM4’s predictions were in line with what HEM-3 would have predicted. Finally, and perhaps most importantly, HEM4 concentrations were compared to “raw” concentrations output by AERMOD in plot files to ensure HEM4 was faithfully delivering inputs to and retrieving concentrations from AERMOD. These 3 methods of reviewing, analyzing, and comparing concentrations are explained further below.

### HEM4 Deposition and Depletion Concentration Comparisons

To ensure HEM4 was handling deposition and depletion modeling options properly and conveying those options reliably to AERMOD, SC&A QA testers reviewed and compared concentrations from the “all\_inner\_receptor” file for deposition and/or depletion test runs with

concentrations from a “standard run” (wherein neither deposition nor depletion was modeled) with the same inputs. Over 80 different combinations of deposition and/or depletion scenarios were tested and analyzed for more than 20 different pollutant source type combinations (e.g. wet and dry deposition with wet depletion only for particles; dry deposition only with no depletion for vapor; etc.). The following guidelines were used when comparing concentrations to determine if there was an issue that required investigation by SC&A’s developers/programmers model (in which case the issue was posted to HEM4’s github.com repository site):

- The sum of concentrations for deposition only runs is approximately equal (=) to the concentration sum for a standard run.
- The sum of concentrations for deposition plus depletion runs is equal (=) to the sum of concentrations for depletion only runs.
- The sum of concentrations for depletion only runs is less than (<) the sum of concentrations for deposition only runs.
- The sum of concentrations for deposition plus depletion runs is less than (<) the sum of concentrations for deposition only runs.
- The sum of concentrations for deposition plus depletion runs is less than (<) the sum of concentrations for a standard run.

See Table 3 in Section 3.0 for an example of the QA spreadsheet used to review and compare deposition and depletion concentrations. **Note:** The completed deposition and depletion concentration comparison spreadsheets in the Master QA workbook have been provided to EPA under separate cover.

#### HEM4 to HEM-3 Concentration Comparisons

To ensure HEM4 produced an AERMOD input file identical to that created by HEM-3 and also producing concentrations that reasonably matched HEM-3 concentrations, SC&A QA testers performed numerous HEM4 and HEM-3 runs using the same inputs. With each of these runs, the SC&A QA testers then meticulously calculated the percentage difference between the HEM4 and HEM-3 concentrations. To achieve this objective, a Python comparison tool was designed by SC&A that analyzed and provided results showing any differences in HEM4 concentrations compared to HEM-3 concentrations. Over 50 HEM4 to HEM-3 concentration comparison tests were performed and the following differences (“diff”) were computed for each run involving standard and optional facility-specific output files:

- diff\_acute\_bkdn;
- diff\_acute\_chem\_max;
- diff\_acute\_chem\_pop;
- diff\_all\_inner\_receptors;
- diff\_all\_outer\_receptors;
- diff\_all\_polar\_receptors;
- diff\_block\_summary\_chronic;
- diff\_maximum\_indiv\_risks;
- diff\_ring\_summary\_chronic; and
- diff\_risk\_breakdown.

Comparisons that demonstrated a substantive difference between concentrations – i.e., showed a >10% difference between HEM4 and HEM-3 concentrations – were flagged by SC&A's QA tester on HEM4's github.com repository page. For these flagged differences, the HEM4 developers/programmers thoroughly investigated the cause of the difference to determine if a code fix was needed.

See Table 6 in Section 3.0 for an example of the QA spreadsheet used to review and compare HEM4 concentrations to HEM-3 concentrations. **Note:** The completed HEM4 to HEM-3 concentration spreadsheets in the Master QA workbook have been provided to EPA under separate cover.

#### HEM4 to AERMOD Plot File Concentration Comparisons

Finally, SC&A QA testers compared HEM4 concentrations to “raw” AERMOD plot file concentrations using a Python tool designed by SC&A to quickly run these comparisons. This QA testing was conducted to ensure the HEM4-modeled concentrations and outputs produced were within a 1% difference to the AERMOD plot values for numerous standard test runs, as well as for deposition/depletion test runs. More than 200 test runs for each test group (standard and deposition/depletion runs) were conducted using various modeling options/parameters.

Comparisons that demonstrated >1% difference between the HEM4 concentrations and AERMOD's plot file concentrations were flagged by SC&A's QA tester on HEM4's github.com repository page. For these flagged differences, the HEM4 developers/programmers thoroughly investigated the cause of the difference to determine if a code fix was needed.

See Tables 4 and 5 in Section 3.0 for an example of the QA spreadsheets used to review and compare HEM4 concentrations to AERMOD plot file concentrations, for standard runs and for deposition/depletion runs, respectively. **Note:** The completed HEM4 to AERMOD concentration spreadsheets in the Master QA workbook have been provided to EPA under separate cover.

### 3.0 Quality Assurance Testing Parameters and Sample Spreadsheets

This section provides a detailed sample of the fields and parameters tested (Table 1) and sample QA spreadsheets (Table 2 through Table 6). For brevity, not all fields and parameters tested and present in the Master QA workbook are listed here. The full and completed Master QA Excel™ workbook with individual testing spreadsheets has been submitted to EPA under separate cover.

**Table 1. Sample List of Test Parameters**

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
The Graphical User Interface (GUI)	AERMOD	AERMOD version	Checked that HEM4 runs using AERMOD version 19191
	Title Page	Screen titles/information	Check that titles are spelled and used correctly
		RUN HEM4 (tab)	Check that button opens new window/program
		CENSUS (tab)	Check that button opens new window/program
		SUMMARIZE RISKS (tab)	Check that button opens new window/program
		ANALYZE OUTPUTS (tab)	Check that button opens new window/program
		LOG (tab)	Check that button opens new window/program
		HEM4 User's Guide link	Check that link directs you to the most recent version of the User's Guide
		AERMOD User's Guide link	Check that link directs you to the most recent version of the User's Guide
		Usability	Are additional directions/instructions needed? If so, add in "notes" column
	Run HEM4 (tab)	Click Use U.S. Census receptors	Confirm radio button works
		Click Use alternate receptors	Confirm radio button works
		Click Use alternate receptors	Confirm that the request for CSV file appears
		Unclick Use alternate receptors	Confirm that the request for CSV file goes away
		Name Run Group (option)	Make sure that model allows you to enter a name
		Hover over "Please select a Facilities List Options file"	Informational box appears and is accurate
		Hover over "Please select a HAP Emissions file"	Informational box appears and is accurate
		Hover over "Please select an Emissions Location file"	Informational box appears and is accurate
		Select "Please select a Facilities List Options file"	Check that browse window pops up and allows you to browse/select a file
		Select "Please select a HAP Emissions file"	Check that browse window pops up and allows you to browse/select a file

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
The Graphical User Interface (GUI)	Run HEM4 (tab)	Select "Please select an Emissions Location file"	Check that browse window pops up and allows you to browse/select a file
		Hover over "Please select an Emissions Variation file"	Informational box appears and is accurate
		Hover over "Please select associated Polygon Vertex file"	Informational box appears and is accurate
		Hover over "Please select associated Building Dimensions file"	Informational box appears and is accurate
		Select button to run model	Confirm that model begins and redirects user to Log page.
		Select button to stop model run	Confirm that model asks if you want to abort and aborts when selected.
HEM4 (Required) Input File: Facility List Options	Met Station	Test that met_station file names longer than 20 characters are supported.	Check AERMOD.out file for name of metfile used, substitute copy of metfile with arbitrarily long filename, add matching entry to metlib_AERMOD.xlsx, and be sure model still runs properly.
		Test facility center	Open kml file via GoogleEarth. Facility center should match the facility center entered.
		Run facility with met_station blank.	Run completes successfully. Check the Facility_max_risk_and_hi.xlsx file to make sure the met station selected is within 100 km of the facility center (Exceptions for facilities in AK or TX).
		Run facility with the met_station field contains a .sfc file that is in the metlib_aermod.xlsx file.	Check AERMOD.out file to make sure the met station used is the one specified.
		Run facility with the met_station field contains a .sfc file that is in the metlib_aermod.xlsx file.	Check AERMOD.out file to make sure the met station used is the one specified.
		Edit the metlib_aermod.xlsx file and add a new met station near the facility to be modeled. Make sure the modified metlib_aermod.xlsx file is in the "Reference" subfolder. Run the facility with the new met station in the metlib_aermod.xlsx file.	Check AERMOD.out file to make sure the met station used is the one specified.
		Run the facility where the met_station field contains a .sfc file NOT in the metlib_aermod.xlsx file.	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.



Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
HEM4 (Required) Input File: Facility List Options	Rural/Urban "R"/"U"	Run 2 facilities, one with a default urban environment and one with a default rural environment.	Check the AERMOD.out file to make sure the correct environment is selected. For the urban environment, make sure the CO URBANOPT line is included. Check the population number for the URBAN facility to make sure it is the correct value from the state census file is used in the URBANOPT line.
		Run the 2 facilities with the rural_urban field populated with "R" and "U". For "U" also enter a value greater than 100,000 for the Urban_pop field.	Check the AERMOD.out file to make sure the environment specified is used for the runs. For "U" make sure the population specified is correct.
		Run a facility with the environment set to "U". Enter various values in the Urban_pop field (e.g. 10,000 to 10 million)	Check the AERMOD.OUT file to make sure the population specified is correct in the CO URBANOPT line.
	Max Domain Distance	Run a facility with the Max_dist field blank.	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Run a facility with the Max_dist field set to a value Greater than 50,000.	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Run a facility with the Max_dist field set to a value Less than 50,000.	Check the "RE GRIDPOLR polgrid1 DIST " line in the AERMOD.out file to make sure the last number is the value entered
	<b>Note: additional Facility List Options fields tested but not shown here include the modeling domain distance, radials, circles, overlap distance, hours, elevation, polar ring distance, acute, user receptor, building downwash, Fastall, annual and period fields. See Master QA Workbook.</b>		
HEM4 (Required) Input File: Emissions Locations	Point Sources Only	Test 3 types of Points In same Facility (P,C,H)	Check all output files are created including the kmz file. Open the kmz file to make sure the source types are correctly identified
		Test Points (P) source type only	Check all output files are created including the kmz file. Open the kmz file to make sure the source types are correctly identified
		Test Capped Points (C) source type only	Check all output files are created including the kmz file. Open the kmz file to make sure the source types are correctly identified
		Test Horizontal Points (H) source type only	Check all output files are created including the kmz file. Open the kmz file to make sure the source types are correctly identified

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
HEM4 (Required) Input File: Emissions Locations	Area Sources Only	Test Area (A) source type only	Check all output files are created including the kmz file. Open the kmz file to make sure the source types are correctly identified
		Test Area (A) source type with x-length and y-length less than 1 and a release height less than 1 meter.	Check all output files are created including the kmz file. Open the kmz file to make sure the source types are correctly identified
		Test Area (A) source type with y-length less than 1 and a release height of 1000.2 meters.	Check all output files are created including the kmz file. Open the kmz file to make sure the source types are correctly identified
	Line Sources Only	Test Line (N) source type only	Check all output files are created including the kmz file. Open the kmz file to make sure the source types are correctly identified
		Test Line (N) source type with length less than 1 and a release height of 1000.3 meters.	Check all output files are created including the kmz file. Open the kmz file to make sure the source types are correctly identified
		Test Line (N) source type with release height less than 1 and a length of 1000.4 meters and a narrow width.	Check all output files are created including the kmz file. Open the kmz file to make sure the source types are correctly identified
		Test Line (N) source type with values entered in columns not used for a line source type.	Check all output files are created including the kmz file. Open the kmz file to make sure the source types are correctly identified
	<b>Note: additional Emissions Locations fields tested but not shown here include volume sources, polygon sources, buoyant line sources, various combined sources, all sources, the method field, the mass fraction field, the particle diameter field, and other miscellaneous input tests. See Master QA Workbook.</b>		
HEM4 (Required) Input File: HAP Emissions	Source ID	Use a HAPEmis file where the Source ID does not match a Source ID in the Emissions Locations file.	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Facility ID	Use a HAPEmis file where the Facility ID does not match a Facility ID list in the Emissions Locations file.	Model should only run facilities common to Faclist, HAPEmis, and Emissions Locations
	Pollutant Name	Use a HAPEmis file where the name of a pollutant is spelled incorrectly.	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Fraction Emitted as Particulate Matter	Enter negative value for Fraction emitted as particulate matter (%)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should use default value

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
HEM4 (Required) Input File: HAP Emissions	Fraction Emitted as Particulate Matter	Enter a value greater than 100 for Fraction emitted as particulate matter (%)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should use default value
	Other	Use a HAPEmis file where the 2 records matched (duplication)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Use a HAPEmis file where the pollutant listed is not listed in the Dose-Response Lib	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	<b>Note: Additional other tests involving user errors in the HAP Emissions file were tested but not shown here. See Master QA Workbook.</b>		
HEM4 (Optional) Input File: Polygon Vertex	Facility ID	Test Polyvertex file with missing Facility ID(s)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Source ID	Test Polyvertex file with missing Source ID(s)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Coordinate System	Test Polyvertex file with invalid coordinate system	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Longitude	Test a Polyvertex file with longitude out of range (-180 < lon < 180)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Latitude	Test a Polyvertex file with latitude out of range (-80 < lat < 85)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	UTM Zone	Test a Polyvertex file with malformed UTM zone	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Test a User Receptor file with inappropriate zone value (1 < zone < 60)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Number of Polygon Vertices	Test a User Receptor file with inappropriate number of verticies (3 <= numvert < 20)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Area with Polygon	Test a Polyvertex file with an area < 0	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
HEM4 (Optional) Input File: Polygon Vertex	Other	Test a Polyvertex file with polyvertex that have not been assigned to a facility in the Facility List Options file	All sources and facilities should appear in HEM4 log. Extra polyvertex should be ignored
		Run a test using an emission_loc file with a polygon source type so the model would prompt the user for the additional input file.	Check that the model accepts file or notifies the user of missing information
HEM4 (Optional) Input File: Buoyant Line Parameter (BLP)	Facility ID	Test BLP file with missing Facility ID(s)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Average Building Dimensions – Length, Height, Width	Run a test where one or more dimensions is blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Run a test where one or more dimensions is set to 0	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Avg Line Source Width	Run a test where one or more dimensions is blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Run a test where one or more dimensions is set to 0	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Avg Building Separation	Run a test where one or more dimensions is blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Run a test where one or more dimensions is set to <0	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Avg Buoyancy	Run a test where one or more dimensions is blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Run a test where one or more dimensions is set to 0	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Other	Run a test using an emission_loc file with a buoyant line source type so the model would prompt the user for the additional input file.	Check that the model accepts file or notifies the user of missing information.

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
HEM4 (Optional) Input File: Particle Data	Facility ID	Use a particle_data file where the Facility ID does not match a Facility ID used	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Use a particle_data file where a field is left blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Source ID	Use a particle data file where the Source ID does not match a Source ID in the HAPEmis file	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Particle diameter	Run a test where particle diameter is less than or equal to 0, or is left blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Mass Fraction	Use a particle_data file where a field value is outside of range (mass fraction does not add up to 100)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should use default value
	Particle density (g/cm <sup>3</sup> )	Use a particle_data file where the particle density value is <0	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should use default value
	Other	Run a test for deposition and/or depletion that would require the additional input file	Check that the model accepts file or notifies the user of missing information.
HEM4 (Optional) Input File: Land Use	Facility ID	Use a landuse file where the Facility ID does not match a Facility ID used	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Land Use Code	Use a landuse file where a field value (land use code) is outside of range	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Other	Use a landuse file where a field is left blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Use a landuse file with missing column	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
HEM4 (Optional) Input File: Land Use	Other	Run a test for deposition and/or depletion that would prompt the additional input file	Check that the model accepts file or notifies the user of missing information.
HEM4 (Optional) Input File: Month-to-seasons	Facility ID	Use a month-to-seasons file where the Facility ID does not match a Facility ID used	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Use a month-to-seasons file with duplicate Facility IDs	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Assigned Season	Use a month-to-season file with invalid value (e.g. where a field value is blank or outside of range)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Month (M01-M12)	Use a month-to-season file with missing column	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
HEM4 (Optional) Input File: Building Dimensions	Facility ID	Use a bldg. dimension file with a missing Facility ID	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Pathway Section	Run a test where the Pathway /Section field is blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should default to SO.
		Run a test where the Pathway /Section field is listed in lowercase and uppercase	Confirm that model reads both formats
	Keyword	Run a test where the Keyword field is blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Run a test where the Keyword field is misspelled or lowercase	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information; lowercase is accepted
	Source ID	Use a bldg. dimension file where the Facility ID does not match a Source ID used (e.g., in HAPEmis file)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Use a bldg. dimension file where the Source ID is missing	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
HEM4 (Optional) Input File: Building Dimensions	Values	Run a test where one or more values cells are blank.	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	<b>Note: additional Building Dimensions tests were run but not shown here. See Master QA Workbook.</b>		
HEM4 (Optional) Input File: User receptor	Facility ID	Use a user receptor file with a missing Facility ID	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Coordinate System	Run a test where the coordinate system field is blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Longitude / Latitude	Run a test where values entered are switched, i.e., lat values entered under long and vice versa	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Run a test where lat/long fields are blank, but L was entered under coordinate system	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	UTM Zone	Enter a UTM zone greater than 60	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should default to 60
		Enter a UTM zone less than 1	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should default to 1
		Run a test where UTM zone field is blank, but U was entered under coordinate system	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Run a test where UTM zone field is missing 'hemisphere'	No error message should appear. Model should default to "N"
	Elevation	Run a test where elevation field is blank	No error message should appear. Review output file.
	Type of receptor	Run a test where type of receptor field is blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Receptor ID	Run a test where receptor ID field is blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Hill Height	Run tests with ranging hill heights	Review model outputs

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
HEM4 (Optional) Input File: User receptor	Other	Use a urec file with missing column	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	<b>Note: additional User Receptor tests were run but not shown here. See Master QA Workbook.</b>		
HEM4 (Optional) Input File: Emissions Variation	Temporal input	Test temporal variation HROFDY input file	Check AERMOD.out to confirm that the model correctly modeled the selected file
		Test temporal variation HRDOW7 input file	Check AERMOD.out to confirm that the model correctly modeled the selected file
		Test temporal variation HRDOW input file	Check AERMOD.out to confirm that the model correctly modeled the selected file
		Test temporal variation SEASON input file	Check AERMOD.out to confirm that the model correctly modeled the selected file
		Test temporal variation MONTH input file	Check AERMOD.out to confirm that the model correctly modeled the selected file
		Test temporal variation WSPEED input file	Check AERMOD.out to confirm that the model correctly modeled the selected file
		Test temporal variation SEASHR input file	Check AERMOD.out to confirm that the model correctly modeled the selected file
		Test temporal variation SHRDOW input file	Check AERMOD.out to confirm that the model correctly modeled the selected file
		Test temporal variation SHRDOW7 input file	Check AERMOD.out to confirm that the model correctly modeled the selected file
		Test temporal variation MHRDOW7 input file	Check AERMOD.out to confirm that the model correctly modeled the selected file
		Test temporal variation MHRDOW input file	Check AERMOD.out to confirm that the model correctly modeled the selected file
		Test temporal variation of multiple variations in one input file	Check AERMOD.out to confirm that the model correctly modeled the selected file
	Facility ID	Use an emissions variation file with a missing Facility ID	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Source ID	Use an emissions variation file with a missing Source ID	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Variation	Use an emissions variation file with an invalid variation value	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information



Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
HEM4 (Optional) Input File: Emissions Variation	Other	Test various fields with improper out-of-range values	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	<b>Note: additional Emissions Variations tests were run but not shown here. See Master QA Workbook.</b>		
HEM4 (Optional) Input File: Alternate Receptors	Alternate Receptors input (part of the GUI QA Testing)	Click "Use alternate receptors" radio button	Request for CSV file should appear. Check that the model accepts file
		Unclick "Use alternate receptors" radio button	Request for CSV file should go away
	Receptor ID	Test alternate receptors file with missing receptor ID(s)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Coordinate system	Test alternate receptors file with missing coordinates	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Longitude	Test alternate receptors file with out of range longitude (outside $-180 < \text{lon} < 180$ )	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Latitude	Test alternate receptors file with out of range latitude (outside $-90 < \text{lat} < 90$ )	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	UTM	Test alternate receptors file with malformed UTM zone	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
		Test alternate receptors file with invalid UTM zone (outside $1 < \text{zone} < 60$ )	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Population	Test alternate receptors file with missing population values	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Receptor type	Test alternate receptors file with invalid receptor type (not P, B, or M)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information
	Other	Test alternate receptors file with duplicate records	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
HEM4 (Optional) Input File: Census Update	Census Update file <i>(part of the GUI QA Testing)</i>	Click "Please select a census update file:"	Check that model allows user to browse, select output folder
		Test "Revise Census" option	Check that model updates census file successfully
		<b>Note: additional tests and analyses were performed on the Census Update option but are not shown here.</b>	
Additional Modeling Options: Summarize Risks	Summarize Risk Option <i>(evaluated separately and part of the GUI QA Testing)</i>	Test "Select output folder"	Check that model allows user to browse, select output folder
		Test radio buttons for each of the 11 risk summary options	Check that user is allowed to select and deselect option
		Run record for Max Risk Summary	Check that model runs report successfully
		Run record for Cancer Drivers	Check that model runs report successfully
		Run record for Hazard Index Drivers	Check that model runs report successfully
		Run record for Risk Histogram	Check that model runs report successfully
		Run record for Incidence Drivers	Check that model runs report successfully
		Run record for Acute Impacts	Check that model runs report successfully
		Run record for Multipathway	Check that model runs report successfully
		Run record for Type Risk Histogram	Check that model runs report successfully
		Usability	Are additional directions/ instructions needed? If so, add in "notes" column
		<b>Note: additional tests and analyses were performed on the Risk Summary Outputs but are not shown here.</b>	
Additional Modeling Options: View & Analyze Outputs	View & Analyze Outputs Option <i>(evaluated separately and part of the GUI QA Testing)</i>	Test "Open a facility or a summary output table"	Check that model allows user to browse, select output folder
		Test "Open a chronic or acute risk map"	Check that model allows user to browse, select chronic or acute risk map
		Test "View summary graphical outputs in web browser"	Check that model allows user to browse, select outputs to view
		<b>Note: additional tests and analyses were performed on the View &amp; Analyze Output maps and charts, but are not shown here.</b>	
Deposition and Depletion	Deposition Only Run <i>(Note identical parameters were tested for Depletion only runs and runs that included both Deposition and Depletion)</i>	Wet Particle Only Test Run	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., wdep nowetdplt
		Dry Particle Only Test Run	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., ddep nodrydplt
		Wet & Dry Particle Only Test Run	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., wdep ddep nowetdplt nodrydplt
		Wet Gaseous Only Test Run	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., wdep nowetdplt
		Dry Gaseous Only Test Run	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., ddep nodrydplt

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
Deposition and Depletion	Deposition Only Run (Note identical parameters were tested for Depletion only runs and runs that included both Deposition and Depletion)	Wet & Dry Gaseous Only Test Run	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., wdep ddep nowetdplt nodrydplt
		Wet & Dry Particle & Gaseous Combined	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., wdep ddep nowetdplt nodrydplt (particle & gas)
		Wet Particle & Gaseous Combined	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., wdep nowetdplt wdep nowetdplt
		Dry Particle & Gaseous Combined	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., ddep nodrydplt ddep nodrydplt
		Wet Particle & Dry Gaseous Combined	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., wdep nowetdplt ddep nodrydplt
		Dry Particle & Wet Gaseous Combined	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., ddep nodrydplt wdep nowetdplt
		Wet & Dry Particle & Wet Gaseous Combined	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., wdep ddep nowetdplt nodrydpl wdep nowetdplt
		Wet & Dry Particle & Dry Gaseous Combined	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., wdep ddep nowetdplt nodrydpl ddep nodrydplt
		Wet Particle & Wet & Dry Gaseous Combined	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., wdep nowetdplt wdep ddep nowetdplt nodrydpl
		Dry Particle & Wet & Dry Gaseous Combined	Check AERMOD.out line "CO MODELOPT" that the correct is shown – i.e., ddep nodrydplt wdep ddep nowetdplt nodrydpl
Note: additional tests and analyses were performed on the Deposition and Depletion functioning and outputs that are not shown here. See Master QA Workbook.			
Forced-Error Testing	FacList file	Run a facility with the Acute field set to "Y", the Multiplier field set outside of range	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should use default value
		Run a facility with the Acute field set to "Y", the hours field set outside of range	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should use default value
		Run a facility with Annual set to N and Period blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should use default value

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
Forced-Error Testing	FacList file	Run a facility with Period start and end times/dates switched	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Run a facility with Annual set to Y and Periods entered	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Run a facility with the Circle field set outside of range	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should use default value.
		Use a FacList file where the Met Station entered is not included in the met.lib file	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Ran a facility where facility center lat/long are switched	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Run a facility with the Max Dist field set outside of range	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should use default value.
		Run a facility with Urban/Rural field set to "U" and Urban pop field left blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Run a facility with the Overlapping Dist field set outside of range (set to 0)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should use default value.
		Run a facility with the Overlapping Dist field set outside of range (greater than 30)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should use default value.
		Run a facility with the Radials field set outside of range	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information. Model should use default value.
		Run a facility with the Ring Dist field set outside of range (set to 0)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Run a facility with the Ring Dist field set outside of range	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
Forced-Error Testing	FacList file	Use a FacList file where the Facility ID does not match a Facility ID used	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Use a FacList file with missing column	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
	HAPEmis file	Use a HAPEmis file where the name of a pollutant is spelled incorrectly.	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Use a HAPEmis file where the Source ID does not match a Source ID in the Emissions Locations file.	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Use a HAPEmis file where the Facility ID does not match a Facility ID list in the Emissions Locations file.	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Use a HAPEmis file where the 2 records matched (dupl entry)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Enter negative value for Fraction emitted as particulate matter (%)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Enter a value greater than 100 for Fraction emitted as particulate matter (%)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Enter a HAPEmis file with missing column	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
	EmisLoc file	Run a facility with the angle field set outside of range	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Use a FacList file where the Facility ID does not match a Facility ID used	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Use a FacList file with missing column	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information .

Category	Field Tested	Parameter	Test Procedure/ Expected Outcome
Forced-Error Testing	EmisLoc file	Use a FacList file where the Source ID field is blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Run a facility with Lat/Long selected but with blank lat/long fields	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Run a facility with Source Type field blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Run a facility with UTM zone field blank	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
		Run a facility with MassFrac field is out of range (Method 2 only)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information Model should use default value.
		Run a facility with MassFrac and Partdiam field entered but Method field blank (Method 2 only)	Error message should appear (as a popup box or in the Log tab or AERMOD.out) notifying users of missing or invalid information.
<b>Note: additional forced user error tests were performed that are not shown here. See Master QA Workbook.</b>			

**Note:** The above table is only a sample of the QA testing performed by SC&A staff on the HEM4 model. The Master QA Workbook, submitted to the EPA under separate cover, includes additional testing, dates of testing, results of testing, and other information. In addition to the QA testing captured in the Master QA Workbook, other frequent testing during HEM4 development was performed by SC&A programmers/ developers, SC&A management staff, and EPA staff outside the official SC&A QA testing regimen. Any issues or errors identified through this additional testing were cataloged on the HEM4 Github site during code development.

**Table 2. Sample QA Testing Spreadsheet**

Test Parameter (Note: Use the same facility for all 3 tests)	Test Procedure / Expected Outcome	Initial Test						
		Initial Test - Pass/Fail (✓/ X)	Test Run Output File Name	Date Tested [mm/dd/yy]	Initials of Tester	Error Message	Github Error Entry	Resolution(s) Taken [enter a brief description]
Run a facility with the Max_dist field blank	Popup box will appear notifying user of missing information	✓	GUIv3_Test_Run_2	06/17/20	NA			
Run a facility with the Max_dist field set to a value Greater than 50,000	Popup box will appear notifying user of missing information	✓	GUIv3_Test_Run_4	06/17/20	NA			

Table continued ....

Test Re-Run							Notes [include date]
re-Test Pass/Fail (✓/ X)	Test Run Output File Name	Date(s) re-Tested [mm/dd/yy]	Initials of Tester	Github Error Entry	Date Passed [mm/dd/yy]	"Passed" Run Output File Name	
✓	GUIv3_DefaultRU_Test1	07/23/20	CC				
X	GUIv3_Max_distField_Test3	07/23/20	CC	#294			model 'stopped' mid-way; log tab indicates default value [7/23/2020] RE GRIDPOLR polgrd1 DIST line still used default values

**Table 3. Sample Deposition and Depletion QA Testing Spreadsheet**

<b>Pollutant Source Type</b>	<b>Test Parameter (to Assets Conc.)</b>	<b>Depo only = Standard run</b>	<b>Date Tested</b>	<b>Depo + Depl = Depl only</b>	<b>Date Tested</b>	<b>Depl only &lt; Depo only</b>
		<b>Failed Test</b>	<b>Passed Test</b>	<b>Failed Test</b>	<b>Passed Test</b>	<b>Failed Test</b>
Particle Only	Wet	April 2020	5/5/2020, 5/8/2020, 7/31/2020		April 2020, July 2020	
Particle Only	Dry	April 2020	5/5/2020, 5/8/2020, 7/31/2020		April 2020, July 2020	
Particle Only	Both Wet & Dry	April 2020	5/5/2020, 5/8/2020, 8/4/2020		April 2020, August 2020	
Gaseous Only	Wet	April 2020	5/5/2020, 5/8/2020	August 2020	April 2020, August 2020	August 2020
Gaseous Only	Dry		5/11/2020, 8/3/2020		April 2020, August 2020	
Gaseous Only	Both Wet & Dry		5/11/2020, 8/4/2020		April 2020, August 2020	

Table continued ....

<b>Date Tested</b>	<b>Depo + Depl &lt; Depo only</b>	<b>Date Tested</b>	<b>Depo + Depl &lt; Standard run</b>	<b>Date Tested</b>	<b>Notes</b>
<b>Passed Test</b>	<b>Failed Test</b>	<b>Passed Test</b>	<b>Failed Test</b>	<b>Passed Test</b>	
April 2020, July 2020		April 2020, July 2020	April 2020	July 2020	For depletion runs involving particles, the final concentrations may be higher than that of the same facility modeled without deposition or depletion due to the nature of the model.
April 2020, July 2020		April 2020, July 2020	April 2020	July 2020 (see notes)	
April 2020, August 2020		April 2020, August 2020	April 2020	August 2020	
April 2020, August 2020	August 2020	April 2020, August 2020	August 2020	April 2020, August 2020	
April 2020, August 2020		April 2020, August 2020		April 2020, August 2020	
April 2020, August 2020		April 2020, August 2020		April 2020, August 2020	



**Table 4. Sample QA Spreadsheet Used for HEM4 to AERMOD Plot File Concentration Comparisons**

Facility ID	Source ID	Source Type	Pollutant Name	rundir	hapemis_path	acute	runtype	emistype	% Diff.
Fac1-NC	RW000001	N	Acrolein	C:/Users/ccook/Documents/HEM4_git_repository/HEM4/output/GUIv3_wdep_ddep_Test1	rundir + "/Inputs/hapemis.xlsx"	Y	3	P	0
Fac1-NC	CV000001	C	Indeno[1,2,3-c,d]pyrene	C:/Users/ccook/Documents/HEM4_git_repository/HEM4/output/GUIv3_wddepp_wdepv_Test1	rundir + "/Inputs/hapemis.xlsx"	N	3	v	0

Table continued ....

Test Run				Github Error Entry	Resolution(s) Taken [enter a brief description]	Retest Run			
Initial Test - Pass/Fail (✓ / X)	Test Run Output File Directory	Date Tested	Initials of Tester			re-Test Pass/Fail (✓ / X)	Date(s) retested [mm/dd/yy]	Date Passed [mm/dd/yy]	"Passed" Run Output File Name
✓	C:\Users\ccook\Documents\HEM4_git_repository\HEM4\output\GUIv3_wdep_ddep_Test1\Fac1-NC	7/24/2020	CC						
✓	C:\Users\ccook\Documents\HEM4_git_repository\HEM4\output\GUIv3_wddepp_wdepv_Test1\Fac1-NC	7/24/2020	CC						

**Table 5. Sample QA Spreadsheet Used for HEM4 to AERMOD Plot File Concentration Comparisons for Deposition and Depletion Options**

Test Parameters									
Facility ID	Source ID	Source Type	Pollutant Name	rundir	hapemis_path	acute	runtype	emis type	dep type
Fac1-NC	FU000001	A	Mercury (elemental)	C:\Users\ccook\Documents\HEM4_git_repository\HEM4\output\GUIv3_ddepdeplpv_wdepdeplp_ddepdeplv_Test1	rundir + "/Inputs/hapemis.xlsx"	N	3	P	W
Fac1-NC	HV000001	H	1,2,3,7,8-Pentachlorodiben zofuran	C:\Users\ccook\Documents\HEM4_git_repository\HEM4\output\GUIv3_ddepdeplv_wddepdeplv_Test1	rundir + "/Inputs/hapemis.xlsx"	Y	1	V	D
Fac1-NC	HV000001	H	1,2,3,7,8-Pentachlorodiben zofuran	C:\Users\ccook\Documents\HEM4_git_repository\HEM4\output\GUIv3_ddepdeplv_wddepdeplv_Test1	rundir + "/Inputs/hapemis.xlsx"	Y	1	V	W

Table continued.....

% Diff.	Initial Test - Pass/Fail (✓ / X)	Test Run Output File Directory	Date Tested	Initials of Tester	Github Error Entry	Resolution(s) Taken [enter a brief description]	re-Test Pass/Fail (✓ / X)	Date(s) re-Tested [mm/dd/yy]	Date Passed [mm/dd/yy]	"Passed" Run Output File Name
0	✓	C:\Users\ccook\Documents\HEM4_git_repository\HEM4\output\GUIv3_ddepdeplpv_wdepdeplp_ddepdeplv_Test1\Fac1-NC	7/30/20	CC						
0	✓	C:\Users\ccook\Documents\HEM4_git_repository\HEM4\output\GUIv3_ddepdeplv_wddepdeplv_Test1\Fac1-NC\DepComparisons	7/30/20	CC						
0	✓	C:\Users\ccook\Documents\HEM4_git_repository\HEM4\output\GUIv3_ddepdeplv_wddepdeplv_Test1\Fac1-NC	7/30/20	CC						

**Table 6. Sample QA Spreadsheet Used for HEM4 to HEM-3 Concentration Comparisons**

File Location	Facility ID	diff_acute_bkdn	diff_acute_chem_max	diff_acute_chem_pop	diff_all_inner_receptors
<b>ALL SOURCES</b>					
C:\HEM4_v12\output\ QA_Test_Run_2_ ALL\Fac1-NC	Fac1- NC	Chloroform, rv000002, 48%, -2.31E-11% xylenes (mixed), rv000002, 48%, -2.82E-10% acetaldehyde, rw000001, -31.7%, -13.2% acrolein, rw000001. -31.7%, -13.2% hydrofluoric acid, rw000001. -31.7%. -13.2% trichloroethylene, rw000001, -31.7%, -13.2%	*Large differences in some concentrations Pollutant: acetaldehyde Conc(ug/m3): -13.2% Pollutant: acrolein Conc(ug/m3): -13.2% Pollutant: hydrofluoric acid Conc(ug/m3): -13.2% Pollutant: trichloroethylene Conc(ug/m3): -13.2%	*Large differences in some concentrations Pollutant: chloroform Conc(ug/m3): 48% Pollutant: xylenes (mixed) Conc(ug/m3): 48% Pollutant: acetaldehyde Conc(ug/m3): -31.7% Pollutant: acrolein Conc(ug/m3): -31.7% Pollutant: hydrofluoric acid Conc(ug/m3): -31.7% Pollutant: trichloroethylene Conc(ug/m3): -31.7%	*Large differences were attributable to comparison of miniscule numbers inflating the percentage difference
<b>EMISSIONS LOCATION</b>					
C:\HEM4_v12\output\ QA_Test_Run_2_ AllPoints\Fac1-NC	Fac1- NC	*Large differences were attributable to comparison of miniscule numbers inflating the percentage difference	*No substantive differences	*No substantive differences	*Large differences were attributable to comparison of miniscule numbers inflating the percentage difference

Table continued.....

diff_all_outer_receptors	diff_all_polar_receptors	diff_block_summary_chronic	diff_maximum_indiv_risks	diff_ring_summary_chronic	diff_risk_breakdown	Notes
<b>ALL SOURCES</b>						
*No substantive differences present	*Large differences were attributable to comparison of miniscule numbers inflating the percentage difference	*No substantive differences present	""Most substantive difference occurs in respiratory hi (values compared are in the tens decimal place)	*No substantive differences present	*Large differences were attributable to comparison of miniscule numbers inflating the percentage difference	*No substantive differences present
<b>EMISSIONS LOCATION</b>						
*Large differences were attributable to comparison of miniscule numbers inflating the percentage difference	*Large differences were attributable to comparison of miniscule numbers inflating the percentage difference	*Large differences were attributable to comparison of miniscule numbers inflating the percentage difference	*No substantive differences	*No substantive differences	*Large differences were attributable to comparison of miniscule numbers inflating the percentage difference	