CONTENTS:

1 QA development practices 3

2 System model components 5
   2.1 Stratigraphy .......................................................... 5
   2.2 Simple Reservoir ROM ............................................... 5
   2.3 Analytical Reservoir Model ..................................... 5
   2.4 Lookup Table Reservoir Model ................................ 6
   2.5 Generic Reservoir Model ........................................ 6
   2.6 Multisegmented Wellbore Model ................................ 6
   2.7 Cemented Wellbore Leakage Model ............................ 6
   2.8 Cemented Wellbore (Wider Ranges) Model .................. 7
   2.9 Open Wellbore Model ............................................. 7
   2.10 Generalized Flow Rate ROM .................................... 7
   2.11 Hydrocarbon Leakage Model ................................. 7
   2.12 Kimberlina Wellbore Model .................................. 8
   2.13 Seal Horizon Model ............................................... 8
   2.14 Fault Flow Model ................................................ 8
   2.15 Fault Leakage Model ............................................ 9
   2.16 Carbonate Aquifer Model ..................................... 9
   2.17 Deep Alluvium Aquifer Model ................................ 9
   2.18 Deep Alluvium Aquifer (Machine Learning) Model .... 9
   2.19 Alluvium Aquifer Model ....................................... 9
   2.20 Alluvium Aquifer (Low Flow) Model ......................... 10
   2.21 FutureGen 2.0 Aquifer Model ................................ 10
   2.22 FutureGen 2.0 AZMI Model ................................... 10
   2.23 Generic Aquifer Model ......................................... 10
   2.24 Atmospheric Impact Model ................................. 11
   2.25 Plume Stability Model ......................................... 11
   2.26 Chemical Well Sealing ......................................... 11

3 Test Suite 13
   3.1 Execution .......................................................... 13
   3.2 Test Documentation ............................................... 13
   3.3 Contributors ..................................................... 13

Bibliography 15
This is the documentation of the Quality Assurance (QA) for the NRAP-Open-IAM. The NRAP-Open-IAM is an open-source framework for assessing risks associated with geologic carbon storage (GCS).

NRAP-Open-IAM evaluates GCS risk using an integrated assessment modeling approach, where models representing GCS components (e.g., reservoir, wellbore, shallow aquifer, atmosphere) can be linked together into a complete GCS system model. This document provides details of QA for individual components, coupled components, benchmark tests, and describes the process whereby NRAP-Open-IAM maintains QA during development.
NRAP-Open-IAM utilizes the following modern code development practices to ensure QAQC during development:

- Code versioning using Git
- Online development code repository https://gitlab.com/NRAP/nrap-open-iam-dev (private repository for developers)
- Issue tracking using GitLab (https://docs.gitlab.com/ee/user/project/issues/)
- testsuite included with software package
- Continuous integration using GitLab: Installation and test suite are tested on GitLab cloud resources each time developers push code to the development repository. If either one fails, the developer is notified.
- Git branching to allow multiple branches of development prior to merging into the master branch.
SYSTEM MODEL COMPONENTS

The following links document the QA for each NRAP-Open-IAM component containing class documentation, relevant unit tests included in the NRAP-Open-IAM test suite, and any additional QA documentation.

2.1 Stratigraphy

2.1.1 Class documentation

2.1.2 Unit tests

2.2 Simple Reservoir ROM

2.2.1 Class documentation

2.2.2 Unit tests

2.3 Analytical Reservoir Model

2.3.1 Class documentation

2.3.2 Unit tests

2.3.3 Additional QA documentation

The development and testing of the Analytical Reservoir component is documented in the technical report [BBH21] that can be downloaded here.
2.4 Lookup Table Reservoir Model

2.4.1 Class documentation

2.4.2 Unitests

2.5 Generic Reservoir Model

2.5.1 Class documentation

2.5.2 Unitests

2.6 Multisegmented Wellbore Model

2.6.1 Class documentation

2.6.2 Unitests

2.6.3 Additional QA documentation

The development and testing of the Multisegmented Wellbore component is documented in the technical report [BBH21] available for download here.

2.7 Cemented Wellbore Leakage Model

2.7.1 Class documentation

2.7.2 Unitests

2.7.3 Additional QA documentation

The development and verification of the Cemented Wellbore ROM is documented in [HPCG16]. In April 2020, the Cemented Wellbore was updated with significant improvements to its accuracy using a multiple ROM approach. Click here to view a report detailing this update and its QA.
2.8 Cemented Wellbore (Wider Ranges) Model

2.8.1 Class documentation

2.8.2 Unittests

2.9 Open Wellbore Model

2.9.1 Class documentation

2.9.2 Unittests

2.9.3 Additional QA documentation

The verification of the Open Wellbore component is documented in the technical report [BPO21] available for download here. The component was updated with additional lookup lables to improve the accuracy and extend the possible range of input parameters.

2.10 Generalized Flow Rate ROM

2.10.1 Class documentation

2.10.2 Unittests

2.10.3 Additional QA documentation

The development of the model for the Generalized Flow Rate component is documented in the technical report [MSS14] available for download here.

2.11 Hydrocarbon Leakage Model

2.11.1 Class documentation

2.11.2 Unittests
2.12 Kimberlina Wellbore Model

2.12.1 Class documentation

2.12.2 Unittests

2.13 Seal Horizon Model

2.13.1 Class documentation

2.13.2 Unittests

2.13.3 Additional QA documentation

Additional information about the standalone Seal Flux model behind the Seal Horizon component can be found in the model user guide [Lin22] available for download [here](#). In addition to the test mentioned above several scripts and control file examples were developed to compare the standalone code Seal Flux with its integrated version of Seal Horizon component in NRAP-Open-IAM. Although not all results can be recreated in NRAP-Open-IAM: specifically, the ones involving the stochastic simulations, the results of deterministic runs were identical to the ones produced by standalone code. The developed tests did not provide full comparison of the capabilities of both tools as some of Seal Flux capabilities are not fully integrated into NRAP-Open-IAM.

2.14 Fault Flow Model

2.14.1 Class documentation

2.14.2 Unittests

2.14.3 Additional QA documentation

In addition to the mentioned test several scripts and control file examples were developed to compare the standalone code Fault Flo with its integrated version of Fault Flow component in NRAP-Open-IAM. Although not all results can be recreated in NRAP-Open-IAM: specifically, the ones involving the stochastic simulations, the results of deterministic runs were identical to the ones produced by standalone code.
2.15 Fault Leakage Model

2.15.1 Class documentation

2.15.2 Unittests

2.16 Carbonate Aquifer Model

2.16.1 Class documentation

2.16.2 Unittests

2.17 Deep Alluvium Aquifer Model

2.17.1 Class documentation

2.17.2 Unittests

2.18 Deep Alluvium Aquifer (Machine Learning) Model

2.18.1 Class documentation

2.18.2 Unittests

2.19 Alluvium Aquifer Model

2.19.1 Class documentation

2.19.2 Unittests
2.20 Alluvium Aquifer (Low Flow) Model

2.20.1 Class documentation

2.20.2 Unittests

2.21 FutureGen 2.0 Aquifer Model

2.21.1 Class documentation

2.21.2 Unittests

2.21.3 Additional QA documentation

The development and testing of the FutureGen 2.0 Aquifer component is documented in the technical report [Bac21] available for download here.

2.22 FutureGen 2.0 AZMI Model

2.22.1 Class documentation

2.22.2 Unittests

2.22.3 Additional QA documentation

The development and testing of the FutureGen 2.0 AZMI component is documented in the technical report [Bac21] available for download here.

2.23 Generic Aquifer Model

2.23.1 Class documentation

2.23.2 Unittests

2.23.3 Additional QA documentation

The development and testing of the Generic Aquifer component is documented in the technical report [Bac22] available for download here.
2.24 Atmospheric Impact Model

2.24.1 Class documentation

2.24.2 Unittests

2.25 Plume Stability Model

2.25.1 Class documentation

2.25.2 Unittests

2.25.3 Additional QA documentation

The development and verification of the plume stability component are documented in [HOC+19] and [PCM+20].

2.26 Chemical Well Sealing

2.26.1 Class documentation

2.26.2 Unittests

2.26.3 Additional QA documentation

The Chemical Well Sealing model is described in [WDFMC13], [WMDFC14b], and [IWHC17], and was calibrated using experimental data presented in [WDFMC13], [WMDFC14b], and [WMDFC14a].
3.1 Execution

The NRAP-Open-IAM package comes with an automated test suite located in the `test` directory. The test suite can be run from the command line as:

```python
python iam_test.py
```

It is also run automatically after installation when running:

```python
python openiam_setup_tests.py
```

in the `setup` directory. The test suite is also run automatically when developer’s push changesets (upload code) to the GitLab development code repository (refer to qaqc_dev for details).

3.2 Test Documentation

The following provides a description of each test in the test suite.

3.3 Contributors

During the Phase II and/or Phase III of the NRAP the following researchers contributed to the development of NRAP-Open-IAM (listed in alphabetical order with affiliation at the time of active contribution):

- Diana Bacon (Pacific Northwest National Laboratory)
- Seunghwan Baek (Pacific Northwest National Laboratory)
- Pramod Bhuvankar (Lawrence Berkeley National Laboratory)
- Suzanne (Michelle) Bourret (Los Alamos National Laboratory)
- Julia De Toledo Camargo (Pacific Northwest National Laboratory)
- Bailian Chen (Los Alamos National Laboratory)
- Abdullah Cihan (Lawrence Berkeley National Laboratory)
- Dylan Harp (Los Alamos National Laboratory)
- Paul Holcomb (National Energy Technology Laboratory)
- Jaisree Iyer (Lawrence Livermore National Laboratory)


