Eclipse compatible Restart Files in OPM flow

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Outline

- Introduction – background (Why)
- Documentation of Eclipse Restart format
- What does this mean
    - Aquifer example
- How to find unknown restart file parameters for relevant options (Schedule data)
- Implementation
- Status and way forward

Introduction / background

- **OPM flow (Flow) has been implemented in a few Equinor assets for parts of the overall simulation workflow**

- **A prerequisite for the implementation has been a so-called full interoperability between Eclipse 100 (E100) and Flow, which means:**
  - **E100 can restart from Flow**
  - Flow can restart from E100
- **The main reasons for the need for interoperability are:**
  - **Flow lacks generally functionality available in E100** (in particular for prediction runs from a set of history match runs)
  - Need to run E100 models (as restarts) for special processes not available in Flow
  - Need to run Flow restarts from E100 simulations branching out from a set of E100 models
- **Requirement from main stakeholders in Equinor**

Restart support – Fetkovich aquifers example
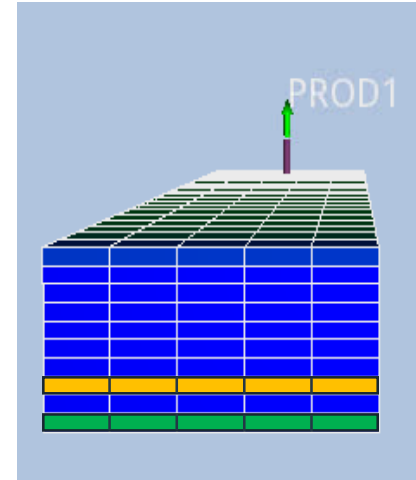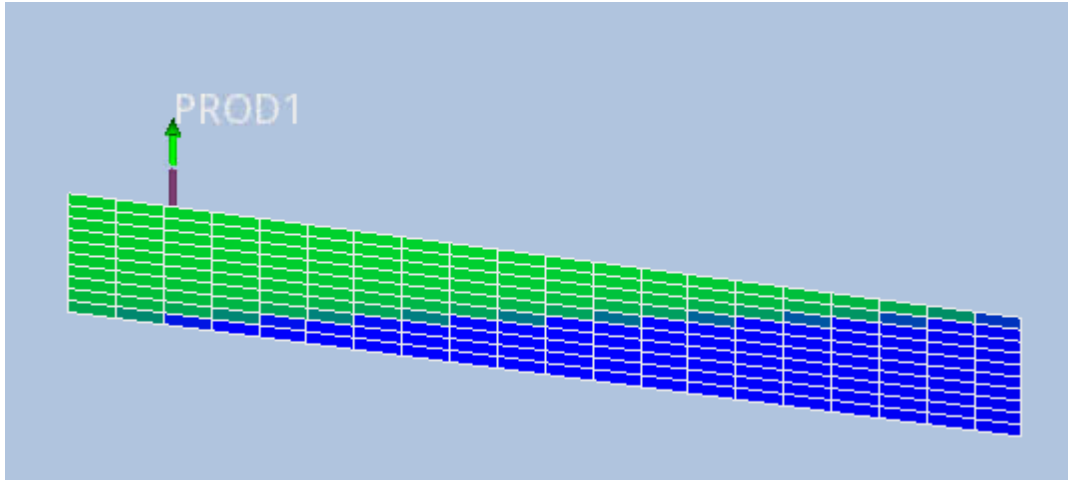
Aquifer ID =1

Aquifer ID =2

```
-----------------------------------------------------------------------
SOLUTION
-----------------------------------------------------------------------

AQUFETP
----  Aqu        depth         Pr       vol       Comp        PI      PVTW
      1        2000.1          250.1    1.23E+7   1.5312E-4   995     1*    /
      2        2000.1          250.1    3.234E+8  1.5312E-4   50      1*    /
/

AQUANCON
--Aqu   I1    I2    J1    J2    K1    K2    face    influx coef.    influx coef. multiplier
    1   20    20    1     5     8     8     'I+'         1*               1*  /
    2   20    20    1     5     10    10    'I+'         1*               1*  /
/
```
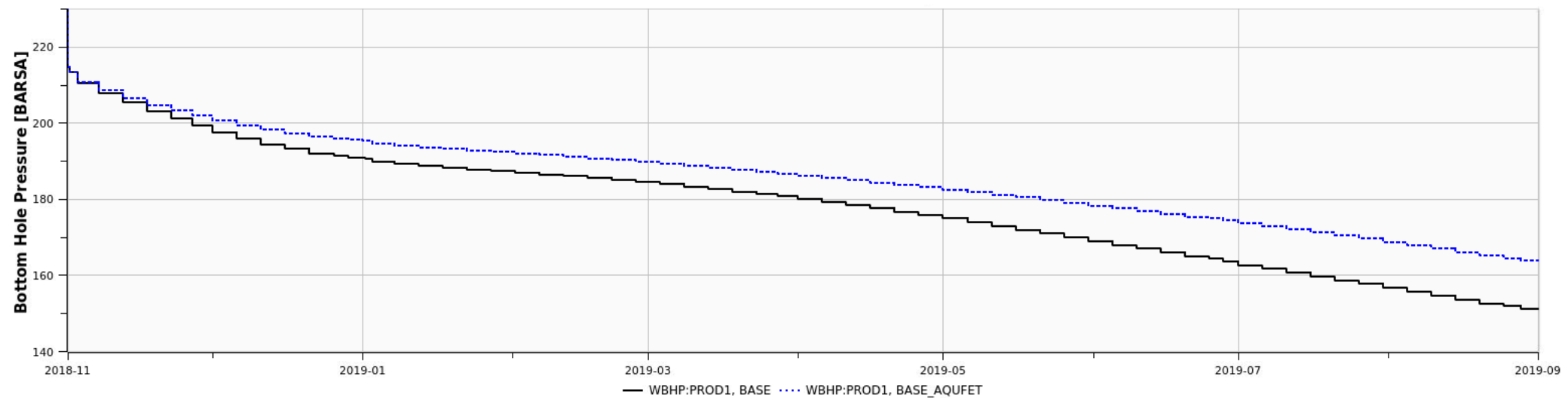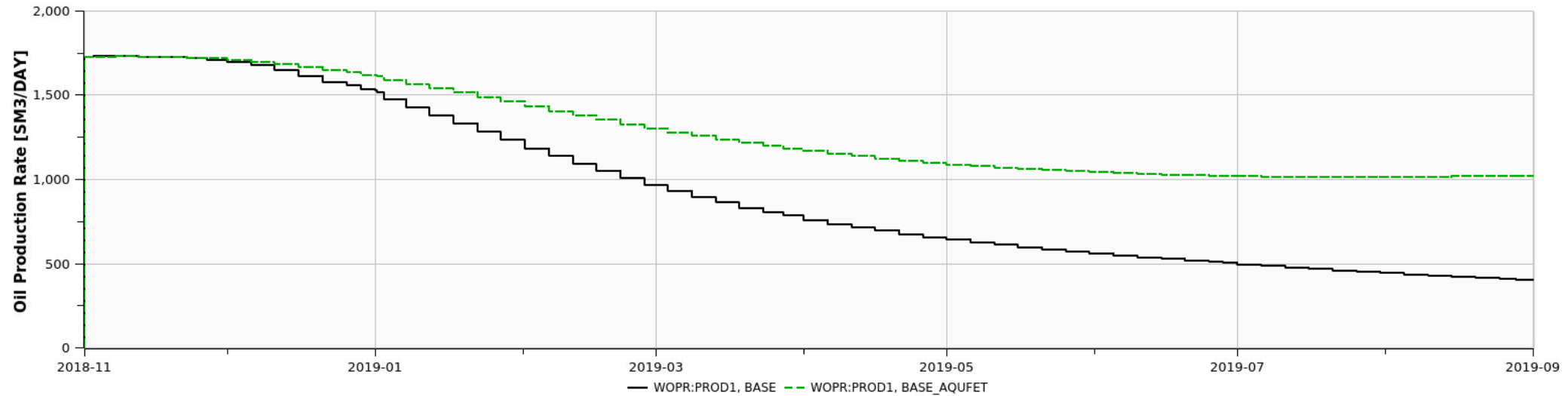
OPM Flow simulations – effect of aquifer support

Restarting flow simulation from 1.1.2019 using Eclipse


```
BASE_AQUFET_RST2_ECLIPSE.DATA - /project/multiscale/OPM/tskille/aquifer/example/test_1511/
File   Edit   Search   Preferences   Shell   Macro   Windows                                  He



-------------------------------------------------------------------------------
SOLUTION
-------------------------------------------------------------------------------


RESTART
 'BASE_AQUFET' 2 /


-------------------------------------------------------------------------------
SUMMARY
-------------------------------------------------------------------------------
```

```
-------------------------------------------------------------------------------
SCHEDULE
-------------------------------------------------------------------------------


TUNING
 0.5 15.0 /
 /
 /

DATES
 01  'APR' 2019 /
 01  'JLY' 2019 /
 01  'SEP' 2019 /
/


END
```
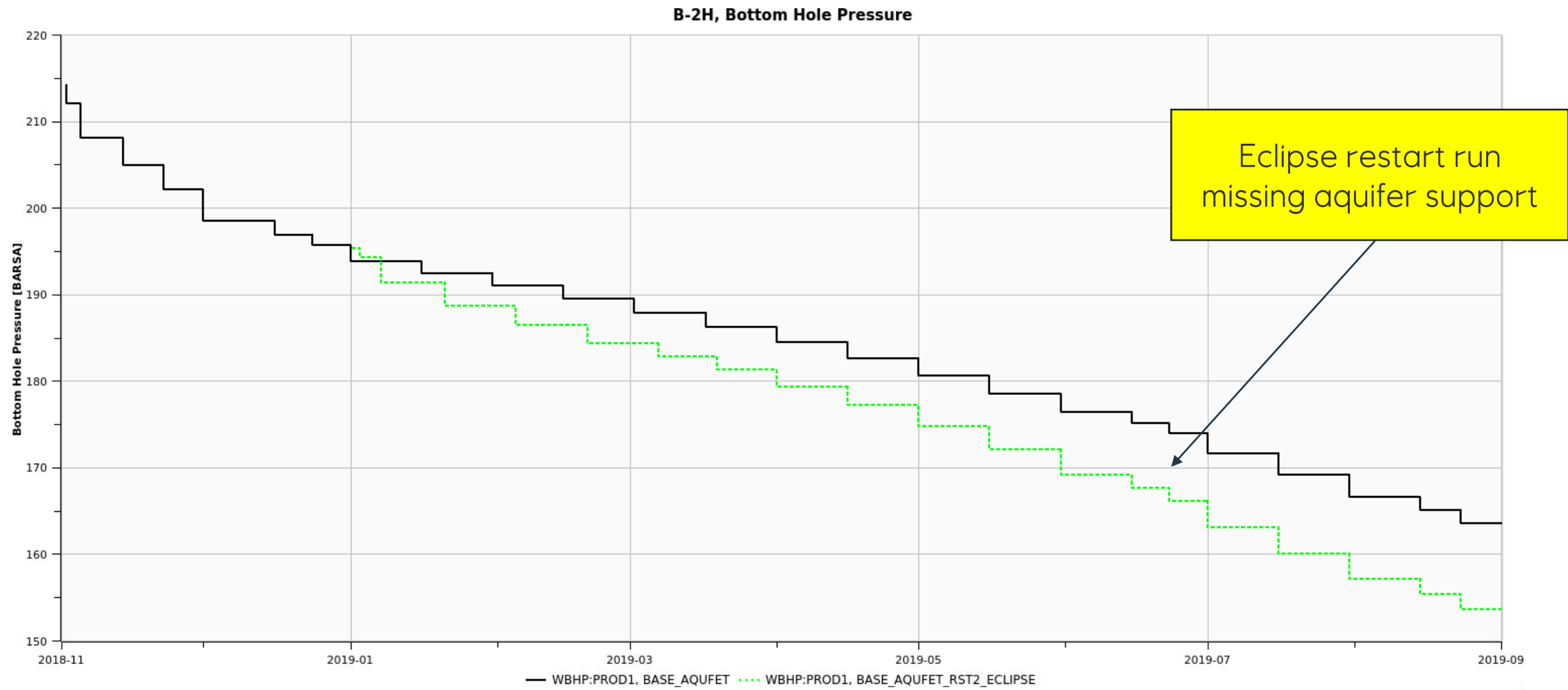
Restarting flow simulation from 1.1.2019 using Eclipse

B-2H, Bottom Hole Pressure

Eclipse restart run missing aquifer support

WBHP:PROD1, BASE_AQUFET — WBHP:PROD1, BASE_AQUFET_RST2_ECLIPSE

Missing array associated with aquifer 1/2

```
'IAAQ     '          36 'INTE'
          5           1          0          0          0          0
          0           0          0          0          0          1
          0           0          0          0          0          0
          5           1          0          0          0          0
          0           0          0          0          0          1
          0           0          0          0          0          0
'SAAQ     '          48 'REAL'
  0.15312000E-03  0.12300000E+08  0.99500000E+03  0.18928401E+01
  0.25010001E+03  0.20001000E+04  0.00000000E+00  0.00000000E+00
  0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
  0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
  0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
  0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
  0.15312000E-03  0.32340000E+09  0.50000000E+02  0.99038019E+03
  0.25010001E+03  0.20001000E+04  0.00000000E+00  0.00000000E+00
  0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
  0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
  0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
  0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
'XAAQ     '          20 'DOUB'
  0.32691946411133D+03   0.23826521301270D+03   0.22289363281250D+05
  0.24991500854492D+04   0.00000000000000D+00   0.00000000000000D+00
  0.00000000000000D+00   0.00000000000000D+00   0.00000000000000D+00
  0.00000000000000D+00   0.57910046386719D+03   0.24970666503906D+03
  0.19477718750000D+05   0.49983001708984D+04   0.00000000000000D+00
  0.00000000000000D+00   0.00000000000000D+00   0.00000000000000D+00
  0.00000000000000D+00   0.00000000000000D+00
```

Missing array associated with aquifer 2/2

```
'SCAQ    '          35 'INTE'
        20           1           8         956           2           0
         0          20           2           8         966           2
         0           0          20           3           8         976
         2           0           0          20           4           8
       986           2           0           0          20           5
         8         996           2           0           0
'SCAQNUM '           1 'INTE'
         1
'SCAQ    '          10 'REAL'
   0.20000000E+00   0.20000000E+00   0.20000000E+00   0.20000000E+00
   0.20000000E+00   0.20000000E+00   0.20000000E+00   0.20000000E+00
   0.20000000E+00   0.20000000E+00
'ICAQNUM '           1 'INTE'
         2
'SCAQ    '          35 'INTE'
        20           1          10         958           2           0
         0          20           2          10         968           2
         0           0          20           3          10         978
         2           0           0          20           4          10
       988           2           0           0          20           5
        10         998           2           0           0
'SCAQNUM '           1 'INTE'
         2
'SCAQ    '          10 'REAL'
   0.20000000E+00   0.20000000E+00   0.20000000E+00   0.20000000E+00
   0.20000000E+00   0.20000000E+00   0.20000000E+00   0.20000000E+00
   0.20000000E+00   0.20000000E+00
```

How to find unknown restart file parameters for relevant options

- Need access to Eclipse simulator
- Run sensitivities on small models
  - With and without options, extra arrays associated with option/functionality
  - Modify values for different items in keywords
    - Observe where these values ends up (restart array, and location in array)

```
AQUFETP
----  Aqu        depth          Pr        vol       Comp          PI      PVTW
   1        2000.1           250.1     1.23E+7    1.5312E-4      995       1*     /
   2        2000.1           250.1     3.234E+8   1.5312E-4      50        1*     /
/
```

Python script - make_fet_unrst.py

BASE_AQUFET.UNRST – STEP 2 (01-JAN-2019)

```
AQUFETP
---- Aqu         depth           Pr        vol       Comp            PI     PVTW
   1       2000.1               250.1     1.23E+7   1.5312E-4        995     1*     /
   2       2000.1               250.1     3.234E+8  1.5312E-4         50     1*     /
/


AQUANCON
--Aqu   I1    I2    J1    J2    K1    K2    face     influx coef.     influx coef. multiplier
   1    20    20     1     5     8     8    'I+'         1*                1*   /
   2    20    20     1     5    10    10    'I+'         1*                1*   /
/
```

MODIFIED.UNRST - modified restart file including Aquifer definitions

Python bindings in opm-common

```python
#!/usr/bin/env python

from __future__ import print_function

import sys
import os
import math
import numpy
import datetime
import argparse
import numpy as np

from opm.io.ecl import EGrid, ERst, EclFile, EclOutput, ESmry, eclArrType

from opm.io.parser import Parser
from opm.io.parser import ParseContext
from opm.io.deck import DeckKeyword
```

Identify arrays which needs to be modified

Eclipse – ok	Flow – not ok	New reference	Modified – ok
SEQNUM	SEQNUM	SEQNUM	SEQNUM
INTEHEAD	INTEHEAD	INTEHEAD	INTEHEAD
LOGIHEAD	LOGIHEAD	LOGIHEAD	LOGIHEAD
DOUBHEAD	DOUBHEAD	DOUBHEAD	DOUBHEAD
STARTSOL	STARTSOL	STARTSOL	STARTSOL
PRESSURE	PRESSURE	PRESSURE	PRESSURE
RS	RS	RS	RS
ENDSOL	ENDSOL	ENDSOL	ENDSOL
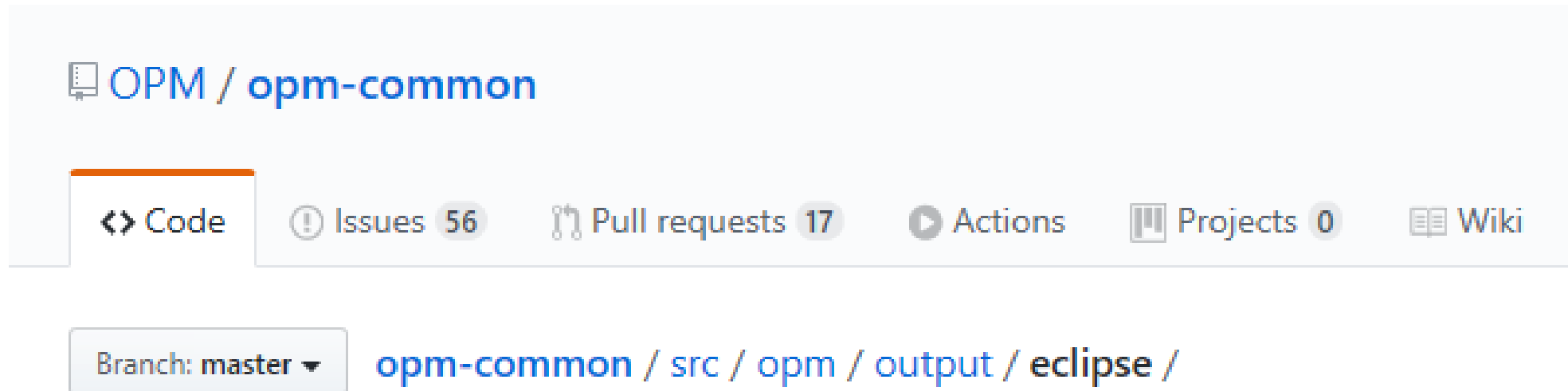
Identify specific items which needs to be modified
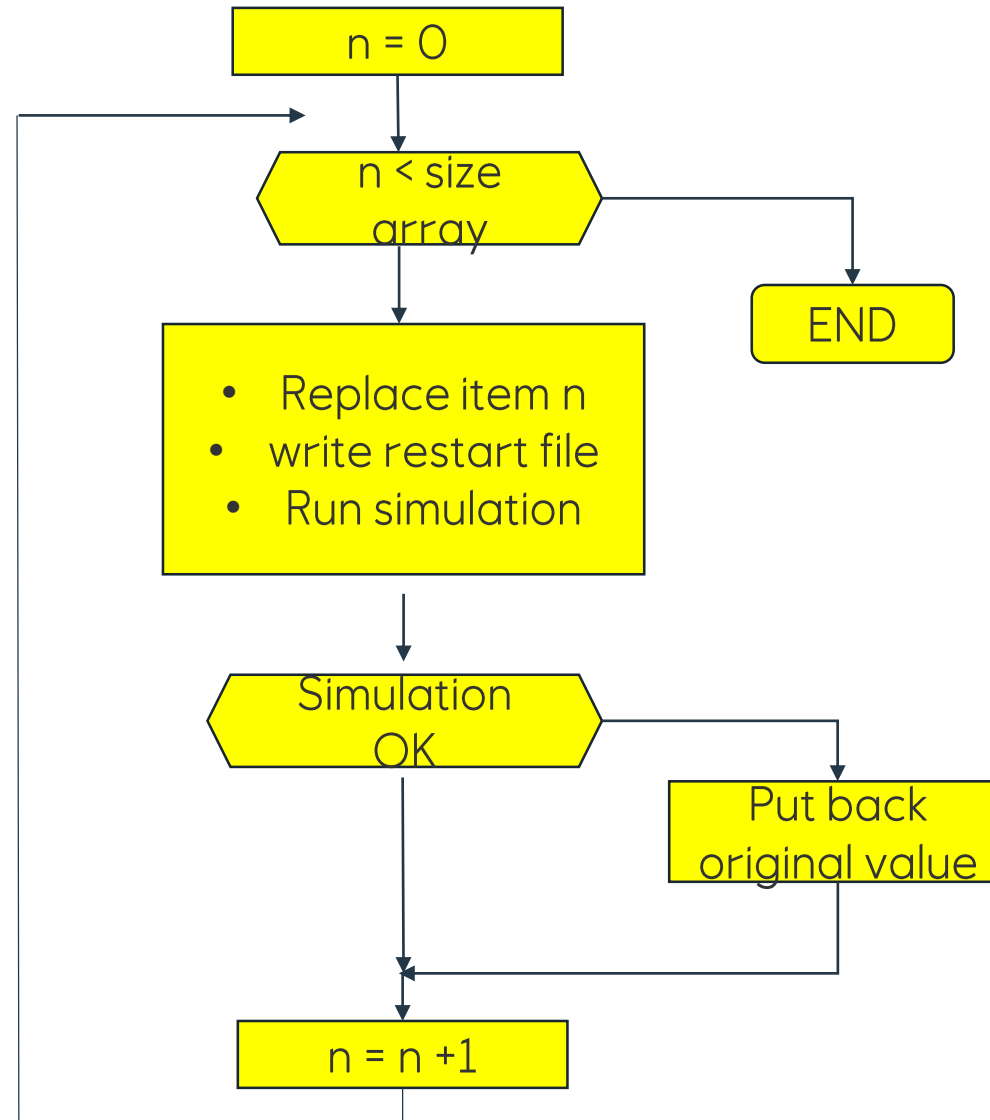
Implementation

- The structure and basic implementation of the restart functionality was presented at the OPM-Summit in 2019 by Bård Skaflestad, SINTEF who is the architect of the restart output code.
  - https://opm-project.org/wp-content/uploads/2019/02/flow-restart.pdf
  - The presentation is recommended for those who would like to have a detailed overview of the restart output and restart load functionality.

Status & way forward

- **Implementations in 2019**
  - Prediction functionality
  - Group control data
  - WSEGSICD, WSEGVALVE
  - Aquifer (Carter-Tracy, Fetkovich, numerical etc.)
  - UDQ – data
  - ACTIONX data

- **New functionality 2020**
  - Group control data – continued.
  - UDQ – ACTIONX data – continued
  - Network – data
  - Aquifer data
  - WSEGAICD

- **Extensions of existing functionality and maintenance**
  - Existing implementation of Restart-file output is generally not valid for all possible data input for a given keyword, e.g. GCONPROD or UDQ/ACTIONX
  - New simulation datasets may require enhancements to the Restart output code to enable E100 restarts from flow simulations
  - Continuous improvement of the Restart-output/functionality is needed
  - Joined effort from OPM community