Big Bay Dam Failure Analysis using DLBreach and WinDAM

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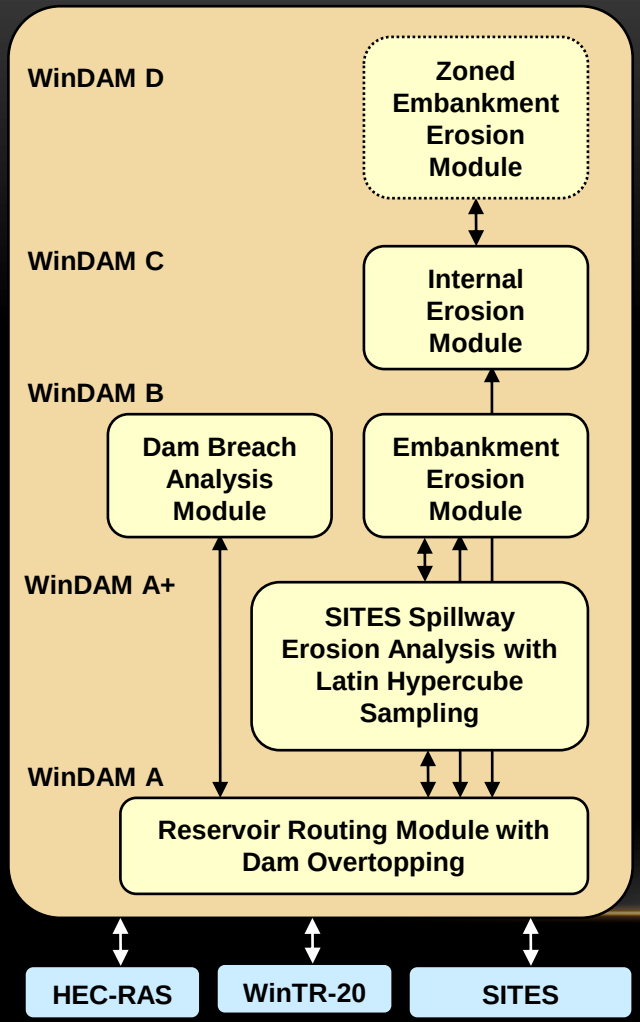
United States Department of Agriculture
Agricultural Research Service
Natural Resources Conservation Service

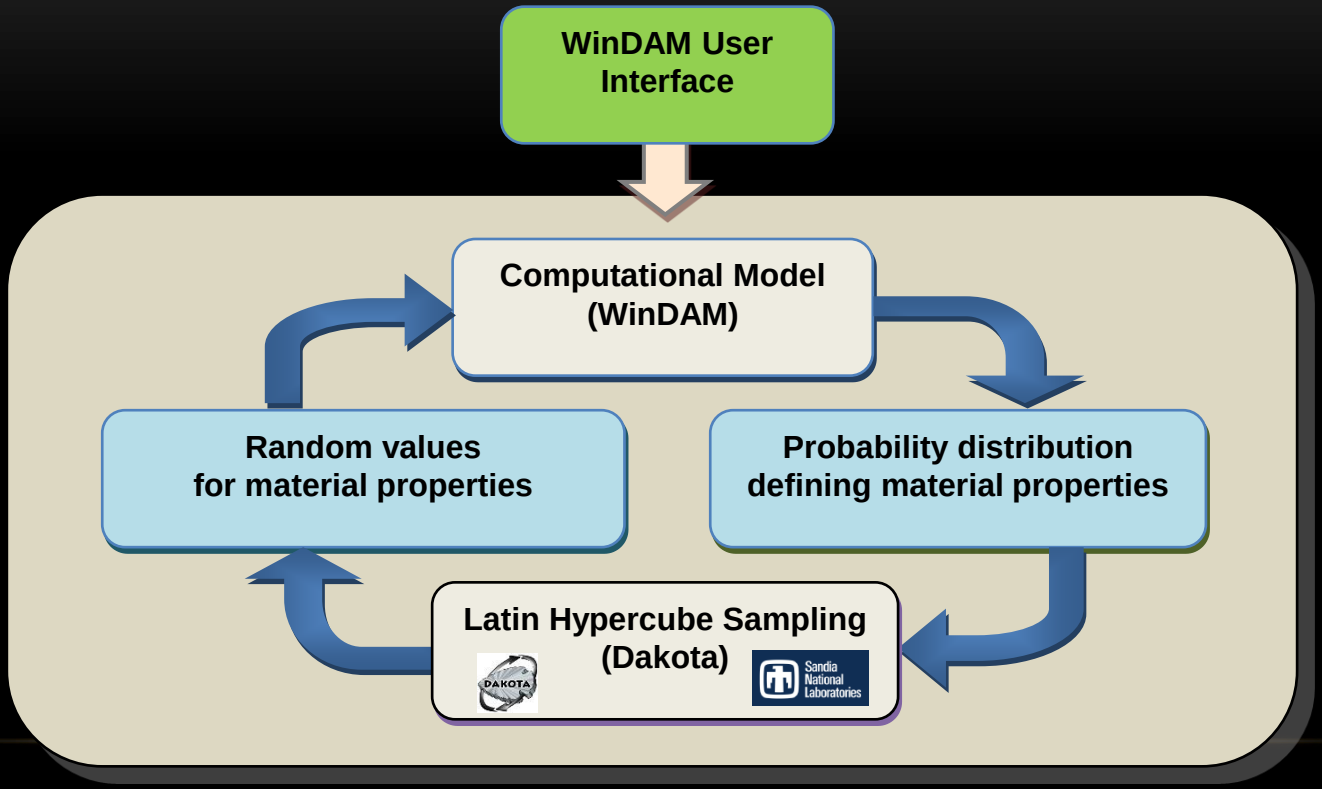
KANSAS STATE UNIVERSITY

Windows* Dam Analysis Modules (WinDAM)

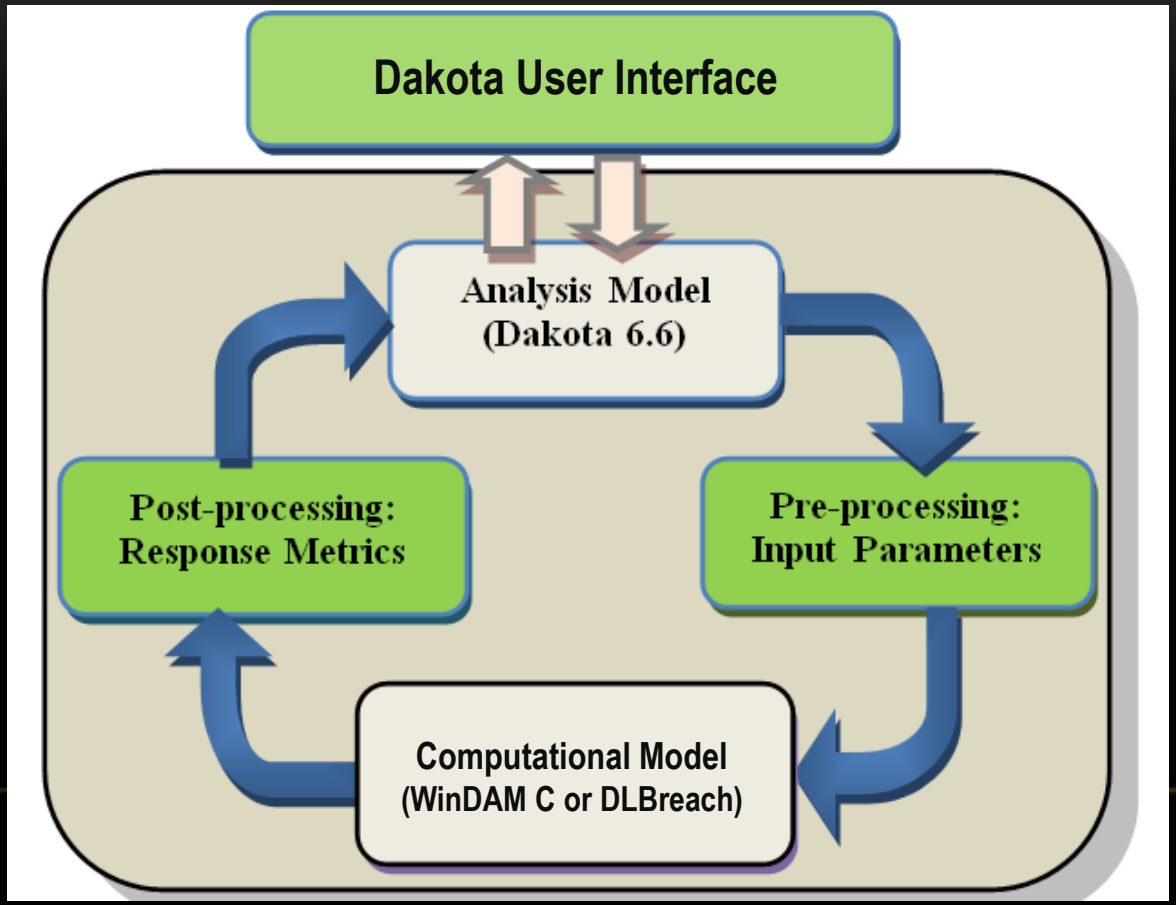
WinDAM is a modular framework for the design and analysis of water control structures (dams).



WinDAM Computational Model



Flip the Paradigm: Use Dakota to Drive the Analysis



Dakota Execution and Information Flow

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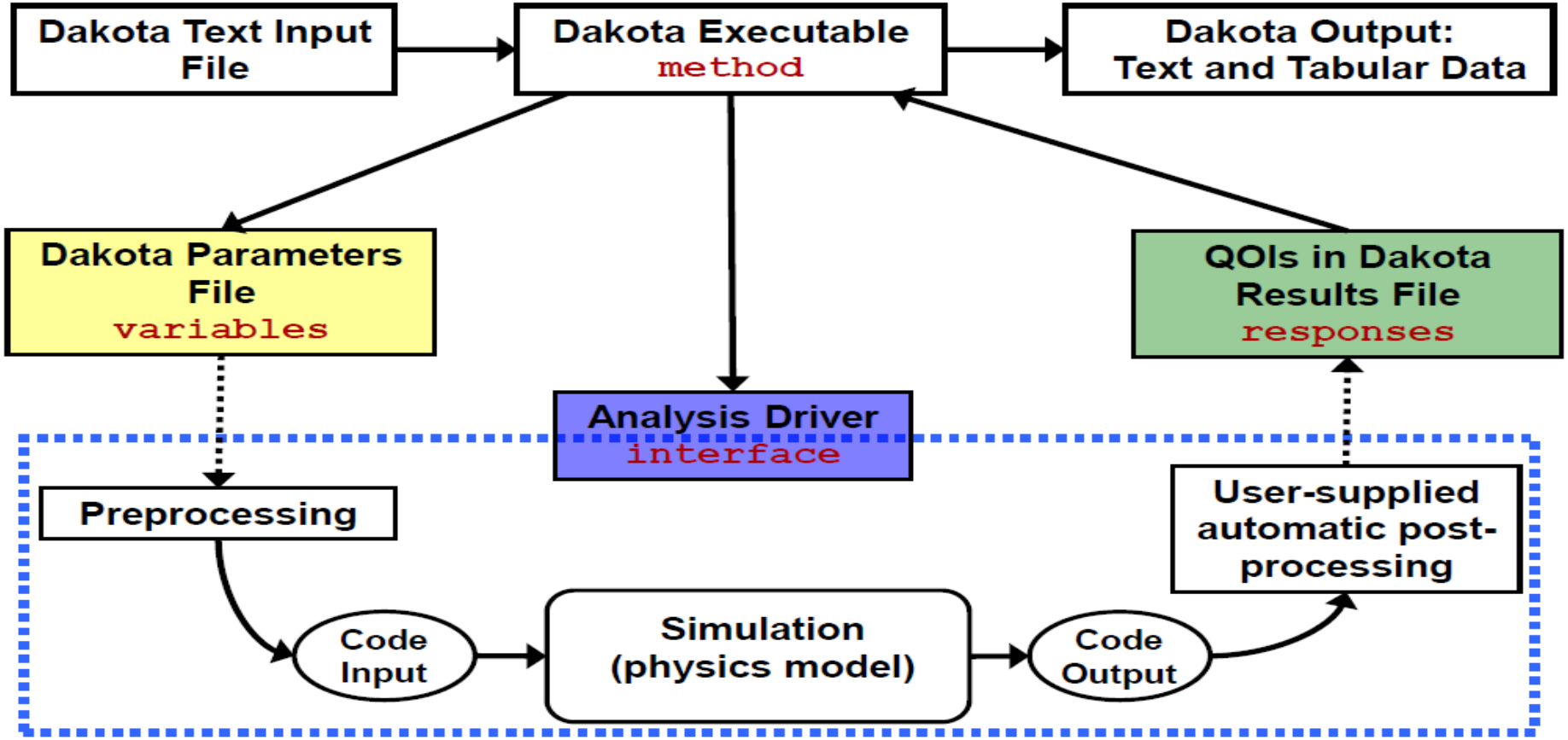
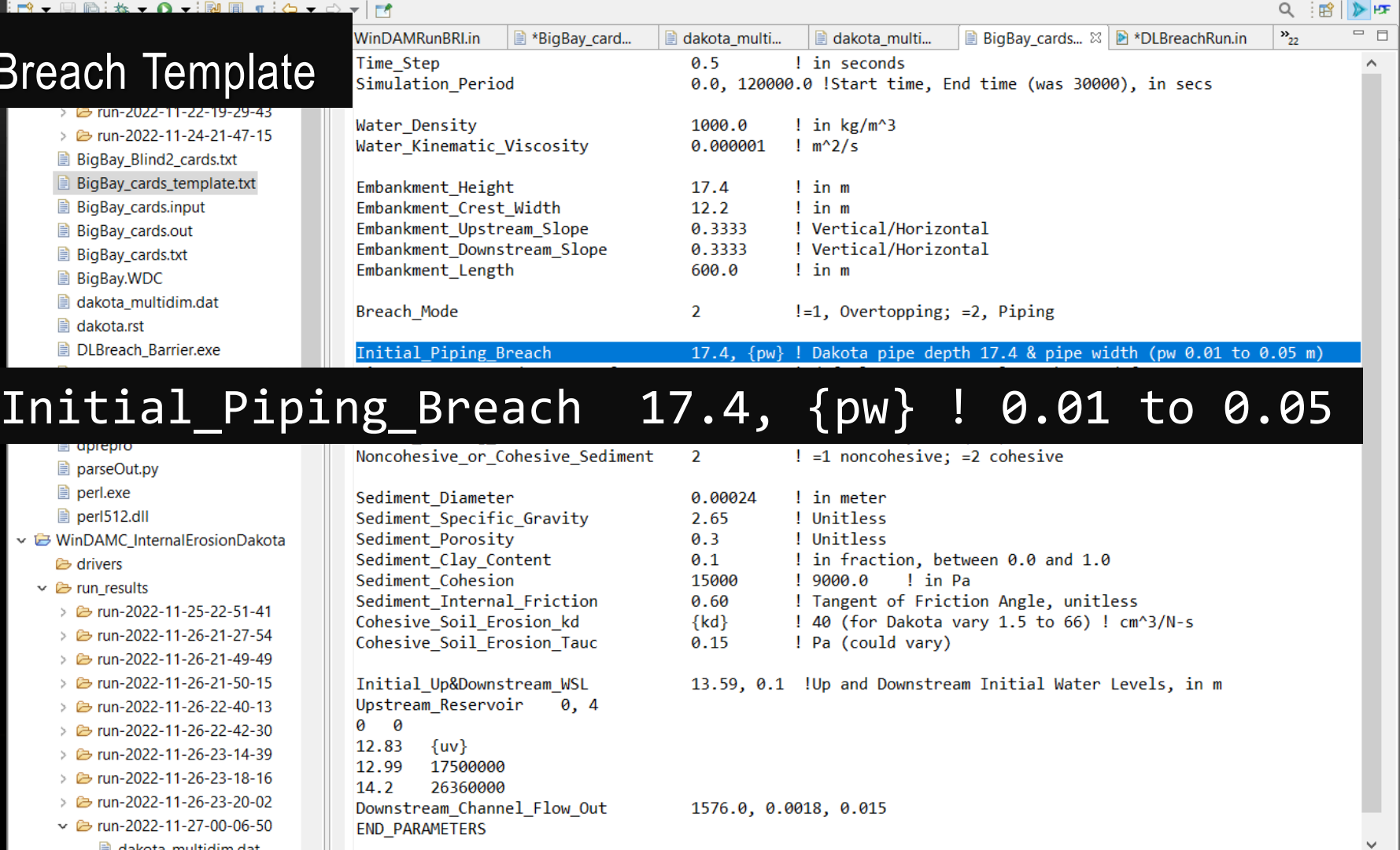
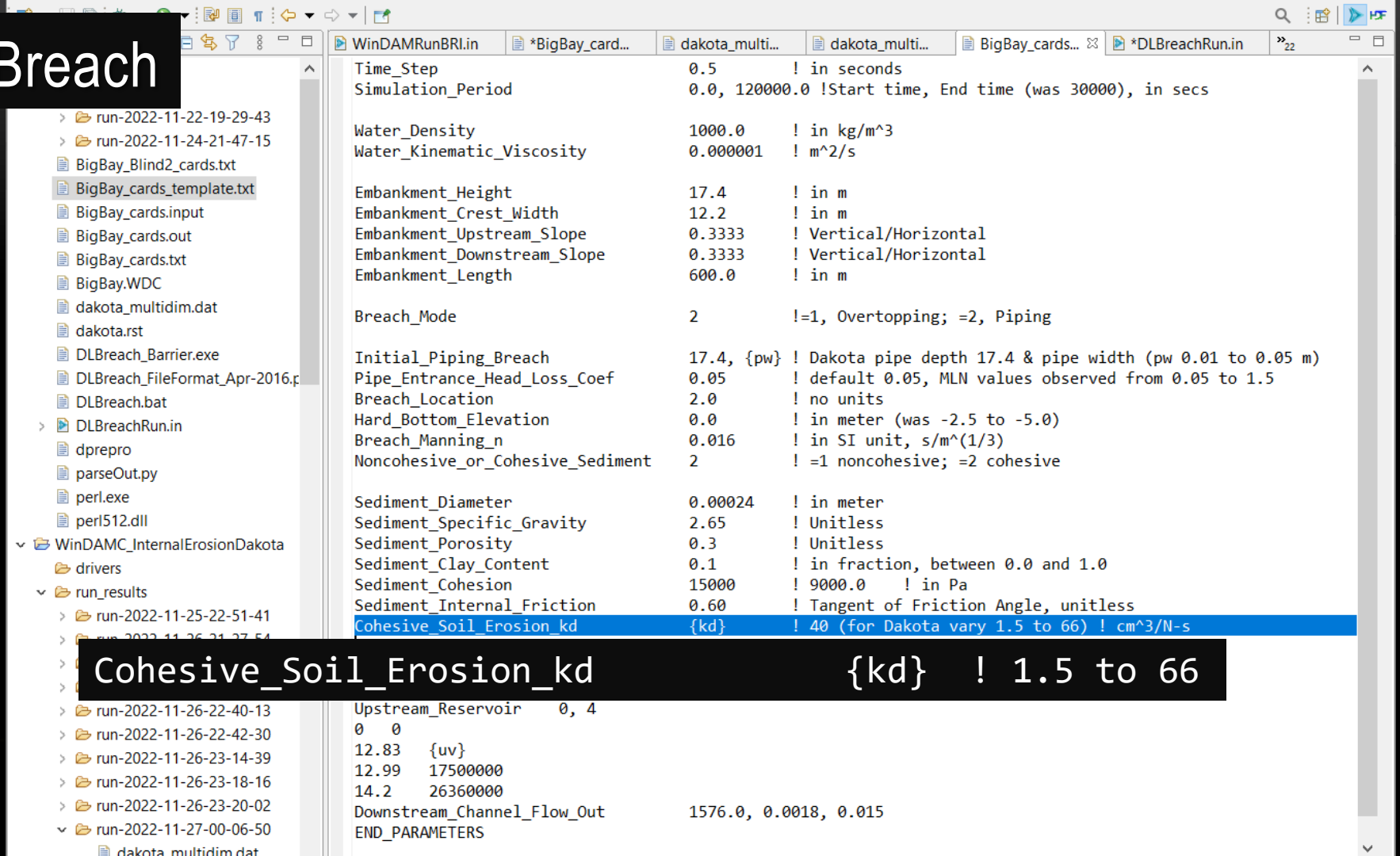


DLBreach Template

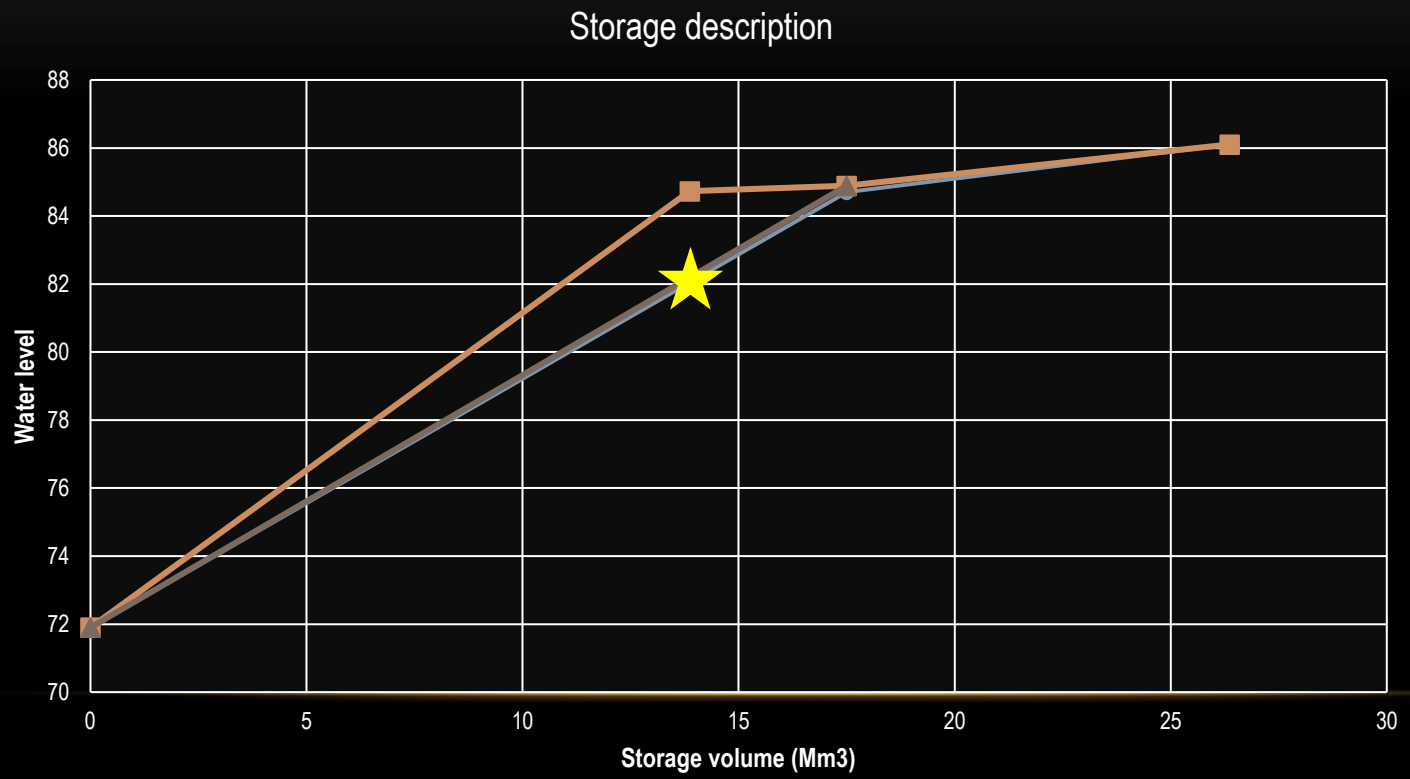


Initial_Piping_Breach 17.4, {pw} ! 0.01 to 0.05

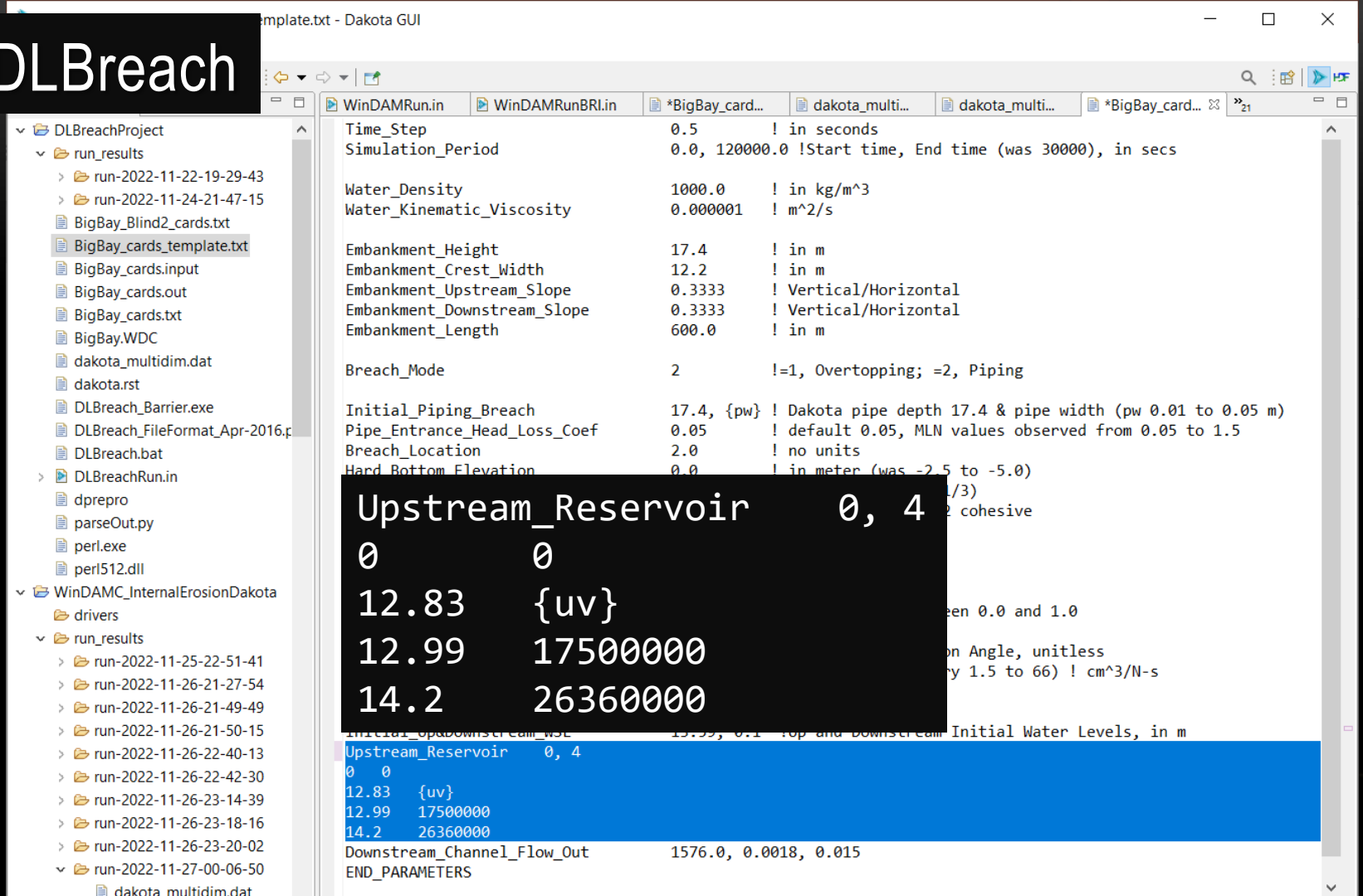
DLBreach


run-2022-11-22-19-29-43
run-2022-11-24-21-47-15
BigBay_Blind2_cards.txt
BigBay_cards_template.txt
BigBay_cards.input
BigBay_cards.out
BigBay_cards.txt
BigBay.WDC
dakota_multidim.dat
dakota.rst
DLBreach_Barrier.exe
DLBreach_FileFormat_Apr-2016.p
DLBreach.bat
DLBreachRun.in
dprepro
parseOut.py
perl.exe
perl512.dll
WinDAMC_InternalErosionDakota
drivers
run_results
run-2022-11-25-22-51-41
run-2022-11-26-22-40-13
run-2022-11-26-22-42-30
run-2022-11-26-23-14-39
run-2022-11-26-23-18-16
run-2022-11-26-23-20-02
run-2022-11-27-00-06-50
dakota_multidim.dat
WinDAMRunBRI.in
*BigBay_card...
dakota_multi...
dakota_multi...
BigBay_cards...
*DLBreachRun.in
Time_Step 0.5 ! in seconds
Simulation_Period 0.0, 120000.0 !Start time, End time (was 30000), in secs
Water_Density 1000.0 ! in kg/m^3
Water_Kinematic_Viscosity 0.000001 ! m^2/s
Embankment_Height 17.4 ! in m
Embankment_Crest_Width 12.2 ! in m
Embankment_Upstream_Slope 0.3333 ! Vertical/Horizontal
Embankment_Downstream_Slope 0.3333 ! Vertical/Horizontal
Embankment_Length 600.0 ! in m
Breach_Mode 2 !=1, Overtopping; =2, Piping
Initial_Piping_Breach 17.4, {pw} ! Dakota pipe depth 17.4 & pipe width (pw 0.01 to 0.05 m)
Pipe_Entrance_Head_Loss_Coef 0.05 ! default 0.05, MLN values observed from 0.05 to 1.5
Breach_Location 2.0 ! no units
Hard_Bottom_Elevation 0.0 ! in meter (was -2.5 to -5.0)
Breach_Manning_n 0.016 ! in SI unit, s/m^(1/3)
Noncohesive_or_Cohesive_Sediment 2 ! =1 noncohesive; =2 cohesive
Sediment_Diameter 0.00024 ! in meter
Sediment_Specific_Gravity 2.65 ! Unitless
Sediment_Porosity 0.3 ! Unitless
Sediment_Clay_Content 0.1 ! in fraction, between 0.0 and 1.0
Sediment_Cohesion 15000 ! 9000.0 ! in Pa
Sediment_Internal_Friction 0.60 ! Tangent of Friction Angle, unitless
Cohesive_Soil_Erosion_kd {kd} ! 40 (for Dakota vary 1.5 to 66) ! cm^3/N-s
Cohesive_Soil_Erosion_kd {kd} ! 1.5 to 66
Upstream_Reservoir 0, 4
0 0
12.83 {uv}
12.99 17500000
14.2 26360000
Downstream_Channel_Flow_Out 1576.0, 0.0018, 0.015
END_PARAMETERS

DAM STORAGE


Storage description
88
86
84
82
80
78
76
74
72
70
Water level
0
5
10
15
20
25
30
Storage volume (Mm3)

DLBreach


mplate.txt - Dakota GUI
DLBreachProject
run_results
run-2022-11-22-19-29-43
run-2022-11-24-21-47-15
BigBay_Blind2_cards.txt
BigBay_cards_template.txt
BigBay_cards.input
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DLBreach.bat
DLBreachRun.in
dprepro
parseOut.py
perl.exe
perl512.dll
WinDAMC_InternalErosionDakota
drivers
run_results
run-2022-11-25-22-51-41
run-2022-11-26-21-27-54
run-2022-11-26-21-49-49
run-2022-11-26-21-50-15
run-2022-11-26-22-40-13
run-2022-11-26-22-42-30
run-2022-11-26-23-14-39
run-2022-11-26-23-18-16
run-2022-11-26-23-20-02
run-2022-11-27-00-06-50
dakota_multidim.dat
WinDAMRun.in
WinDAMRunBRI.in
*BigBay_card...
dakota_multi...
dakota_multi...
*BigBay_card...
Time_Step 0.5 ! in seconds
Simulation_Period 0.0, 120000.0 !Start time, End time (was 30000), in secs
Water_Density 1000.0 ! in kg/m^3
Water_Kinematic_Viscosity 0.000001 ! m^2/s
Embankment_Height 17.4 ! in m
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Embankment_Downstream_Slope 0.3333 ! Vertical/Horizontal
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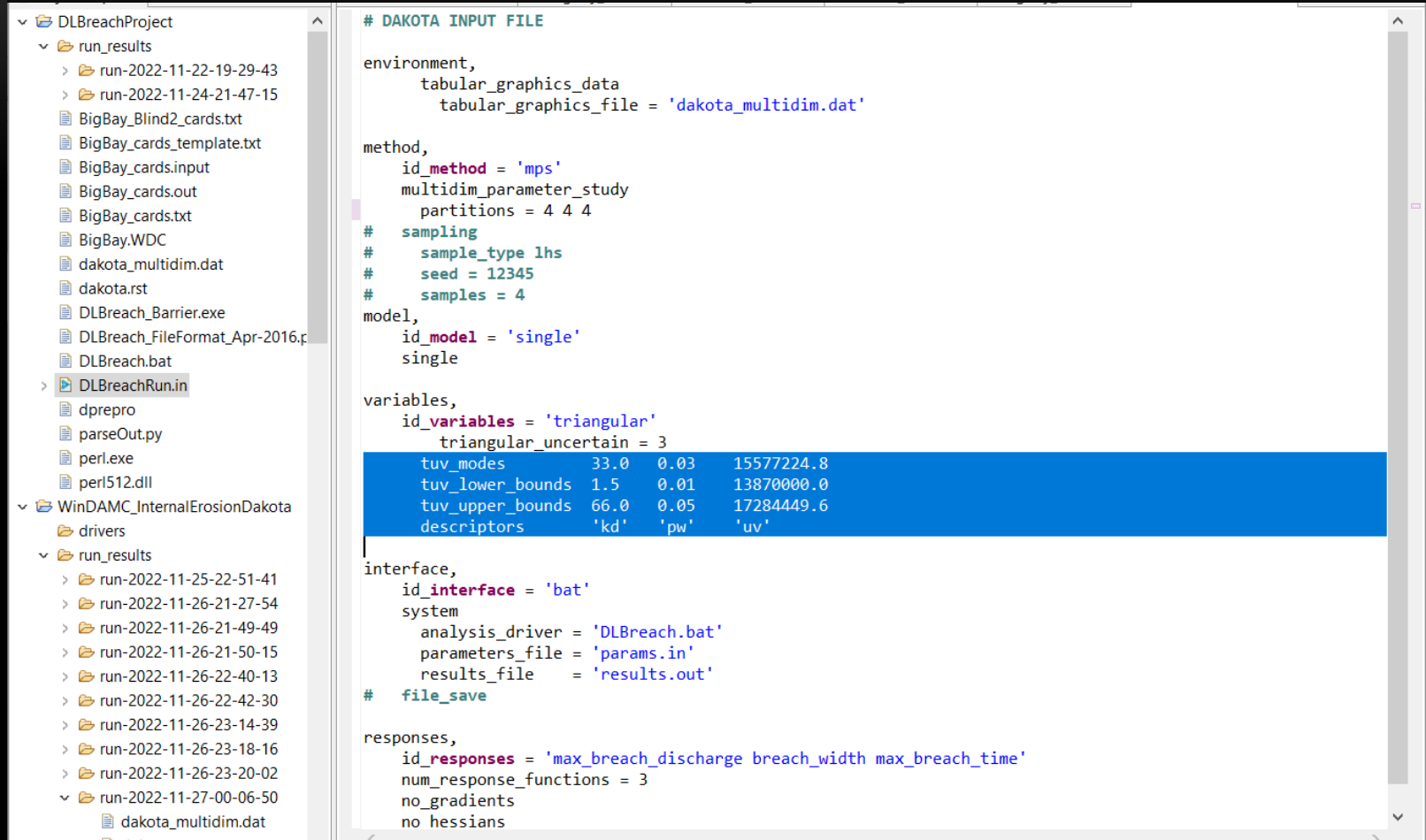
Breach_Mode 2 !=1, Overtopping; =2, Piping
Initial_Piping_Breach 17.4, {pw} ! Dakota pipe depth 17.4 & pipe width (pw 0.01 to 0.05 m)
Pipe_Entrance_Head_Loss_Coef 0.05 ! default 0.05, MLN values observed from 0.05 to 1.5
Breach_Location 2.0 ! no units
Upstream_Reservoir 0, 4
0 0
12.83 {uv}
12.99 17500000
14.2 26360000
Downstream_Channel_Flow_Out 1576.0, 0.0018, 0.015
END_PARAMETERS

DAKOTA DRIVER • DLBreachRun.in

DLBreachProject/DLBreachRun.in - Dakota GUI



DAKOTA INTERFACE – ANALYSIS DRIVER

```
#     seed = 12345
#
mode
    single

variables,
    id_variables = 'triangular'
        triangular_uncertain = 3
      tuv_modes          33.0   0.03    15577224.8
      tuv_lower_bounds   1.5    0.01    13870000.0
      tuv_upper_bounds   66.0   0.05    17284449.6
      descriptors        'kd'   'pw'    'uv'

interface,
    id_interface = 'bat'
    system
      analysis_driver = 'DLBreach.bat'
      parameters_file = 'params.in'
      results_file    = 'results.out'
#   file_save

responses,
    id_responses = 'max_breach_discharge breach_width max_breach_time'
    num_response_functions = 3
    no_gradients
    no hessians
```

Console | Problems

Dakota Console

```
Partial Rank Correlation Matrix between input and output:
```

Dakota Execution and Information Flow

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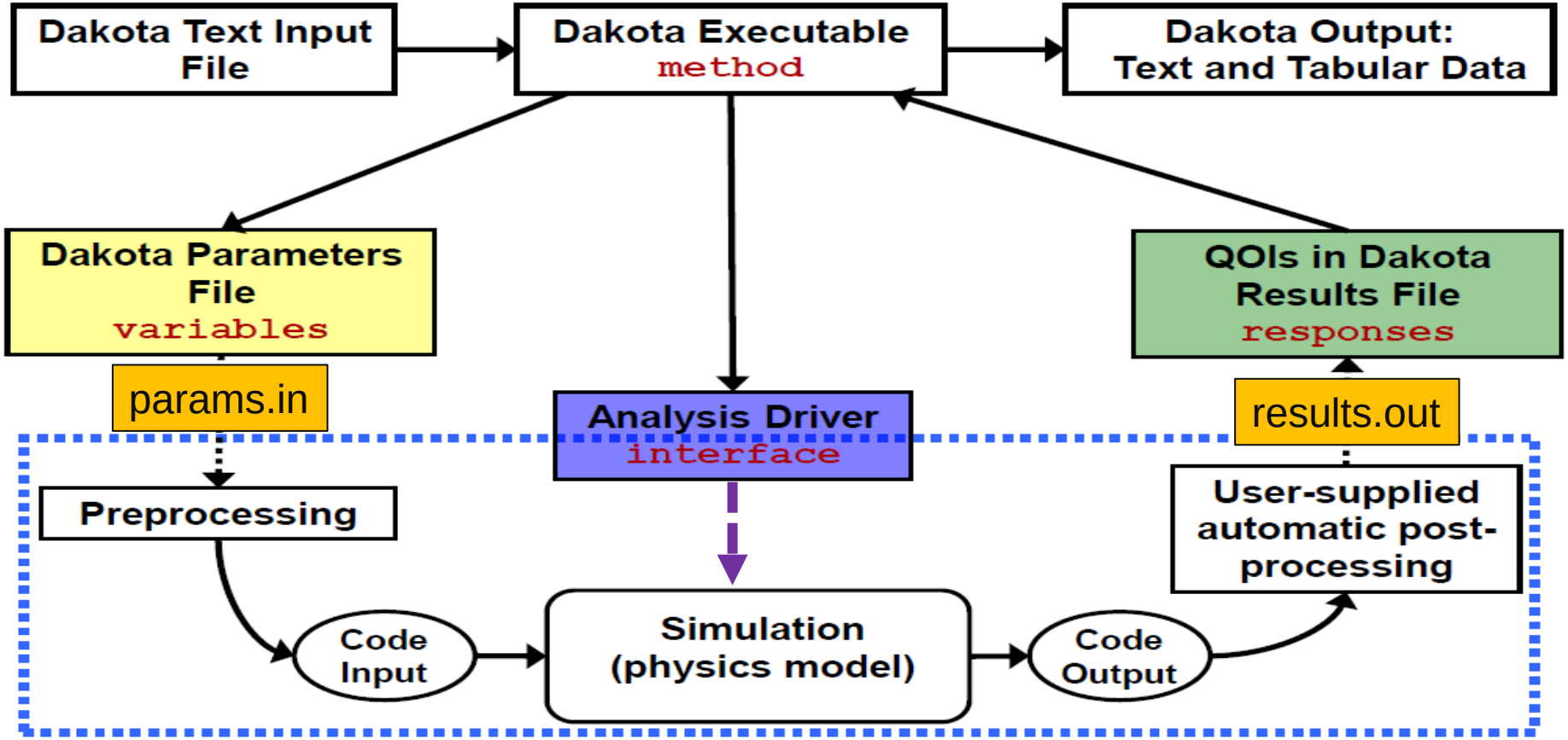


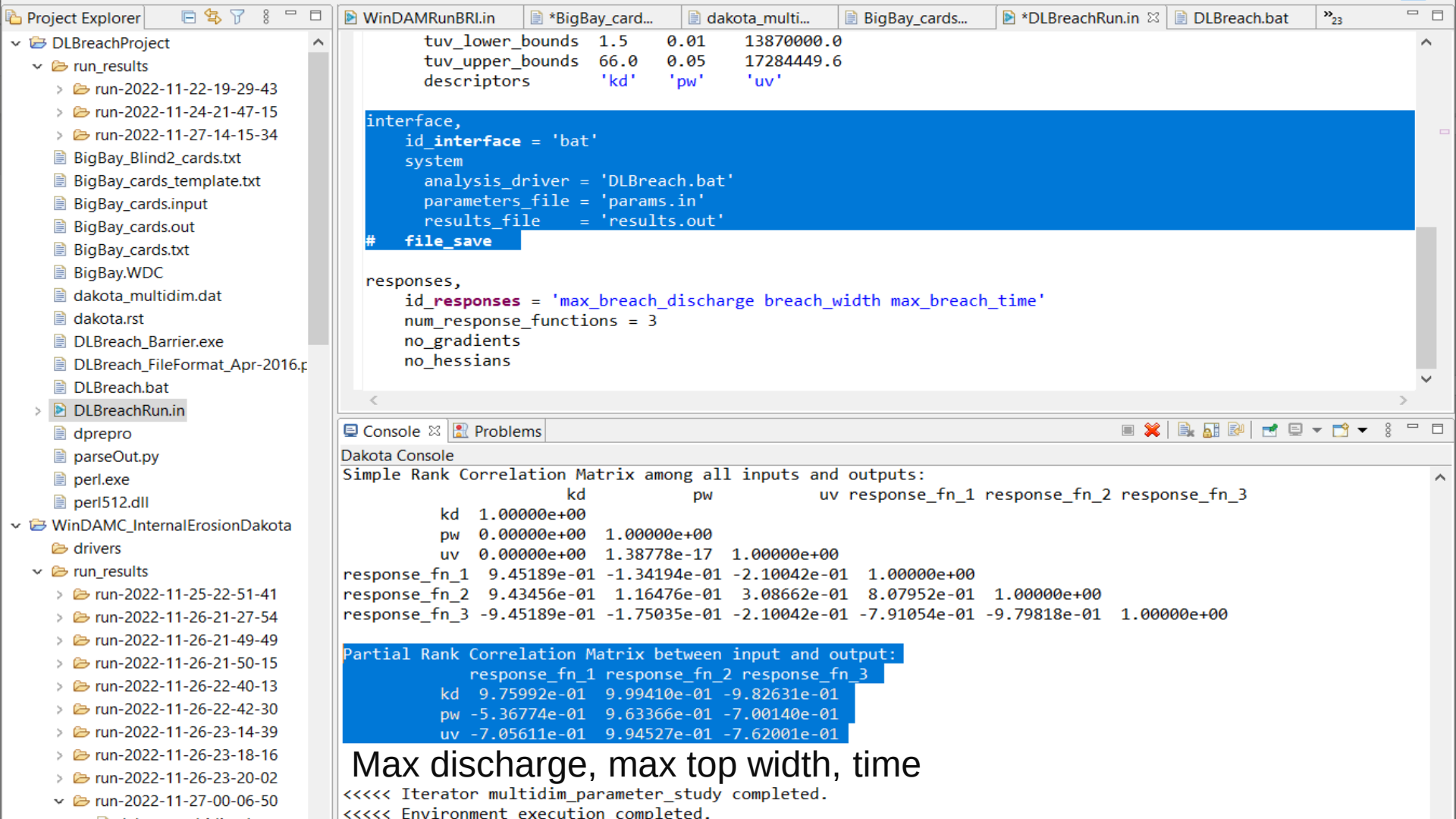
DAKOTA ANALYSIS DRIVER

- DLBreach.bat

```
perl dprepro params.in BigBay_cards_template.txt BigBay_cards.txt
  -- insert parameters in template and output BigBay_cards.txt

echo "BigBay_cards" | DLBreach_Barrier.exe
  -- invoke DLBreach_Barrier.exe to simulate run

python parseOut.py BigBay_cards.out results.out
  -- extract results of interest
```


Project Explorer
DLBreachProject
run_results
run-2022-11-22-19-29-43
run-2022-11-24-21-47-15
run-2022-11-27-14-15-34
BigBay_Blind2_cards.txt
BigBay_cards_template.txt
BigBay_cards.input
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perl.exe
perl512.dll
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drivers
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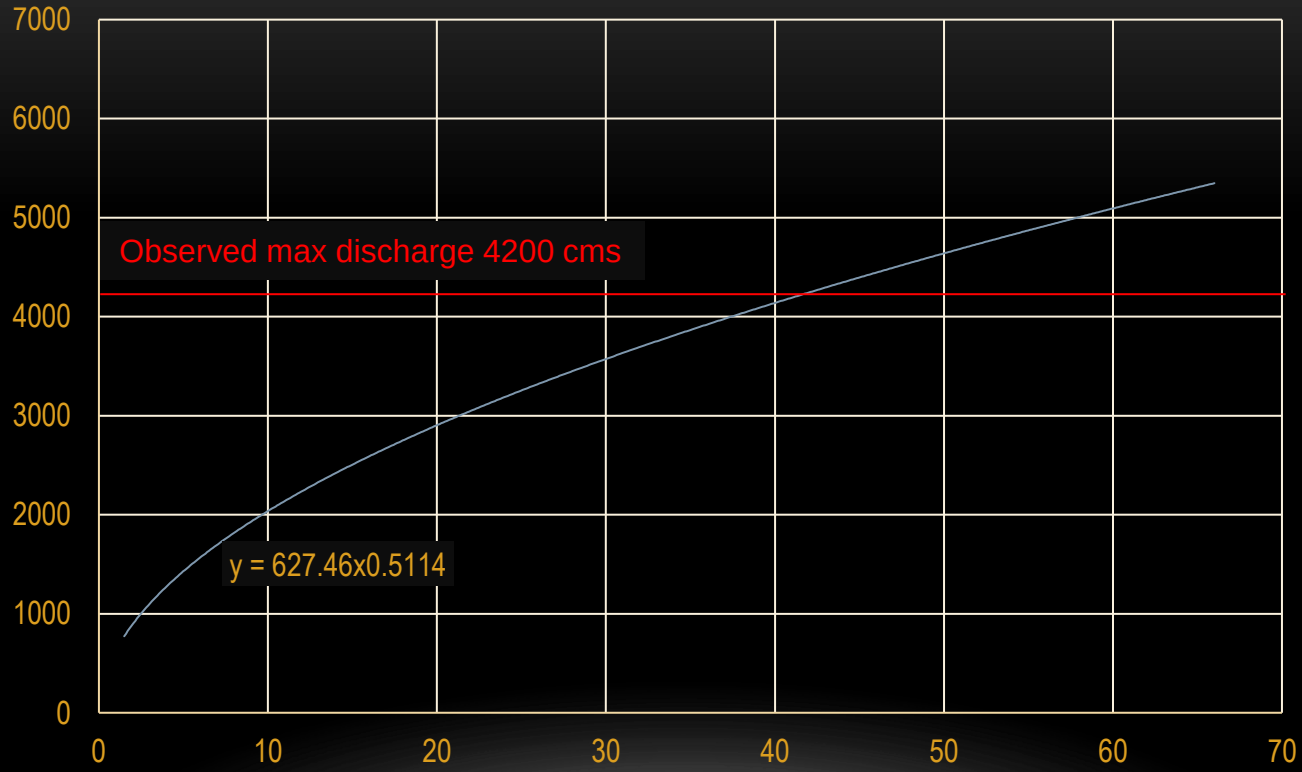
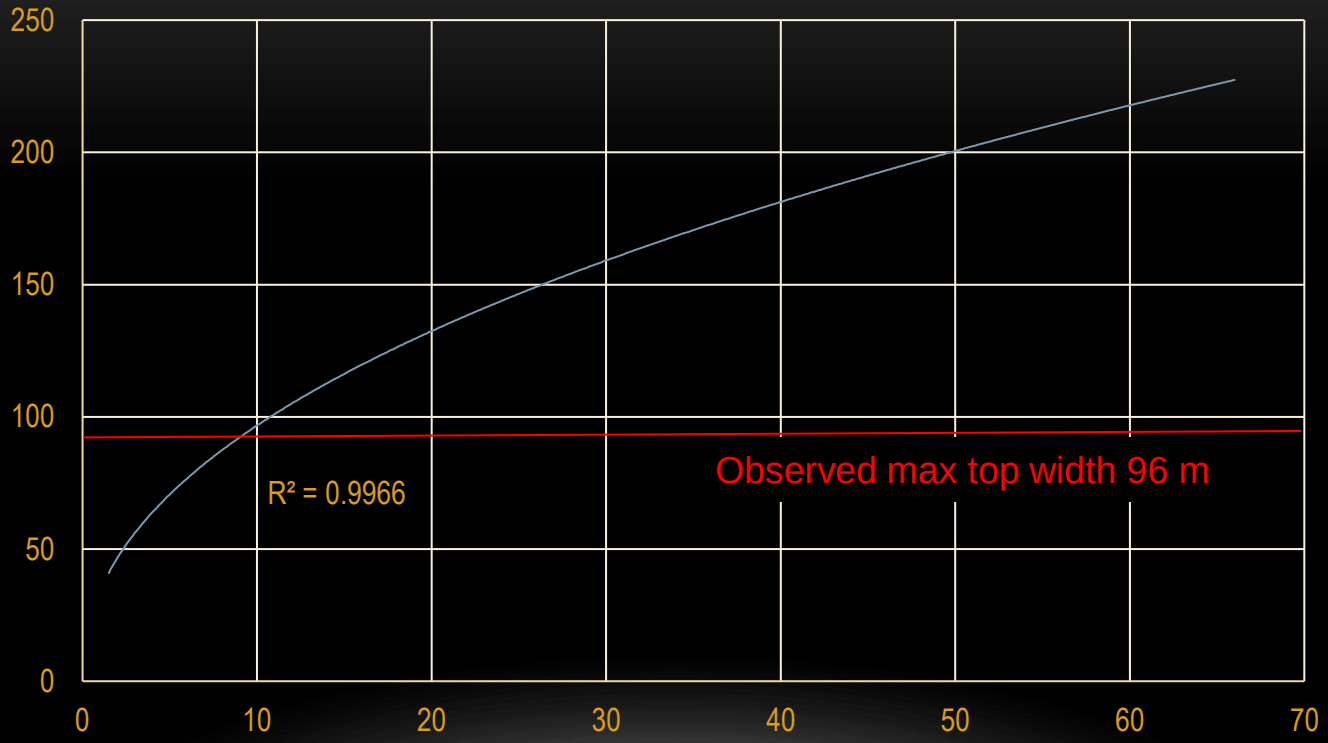
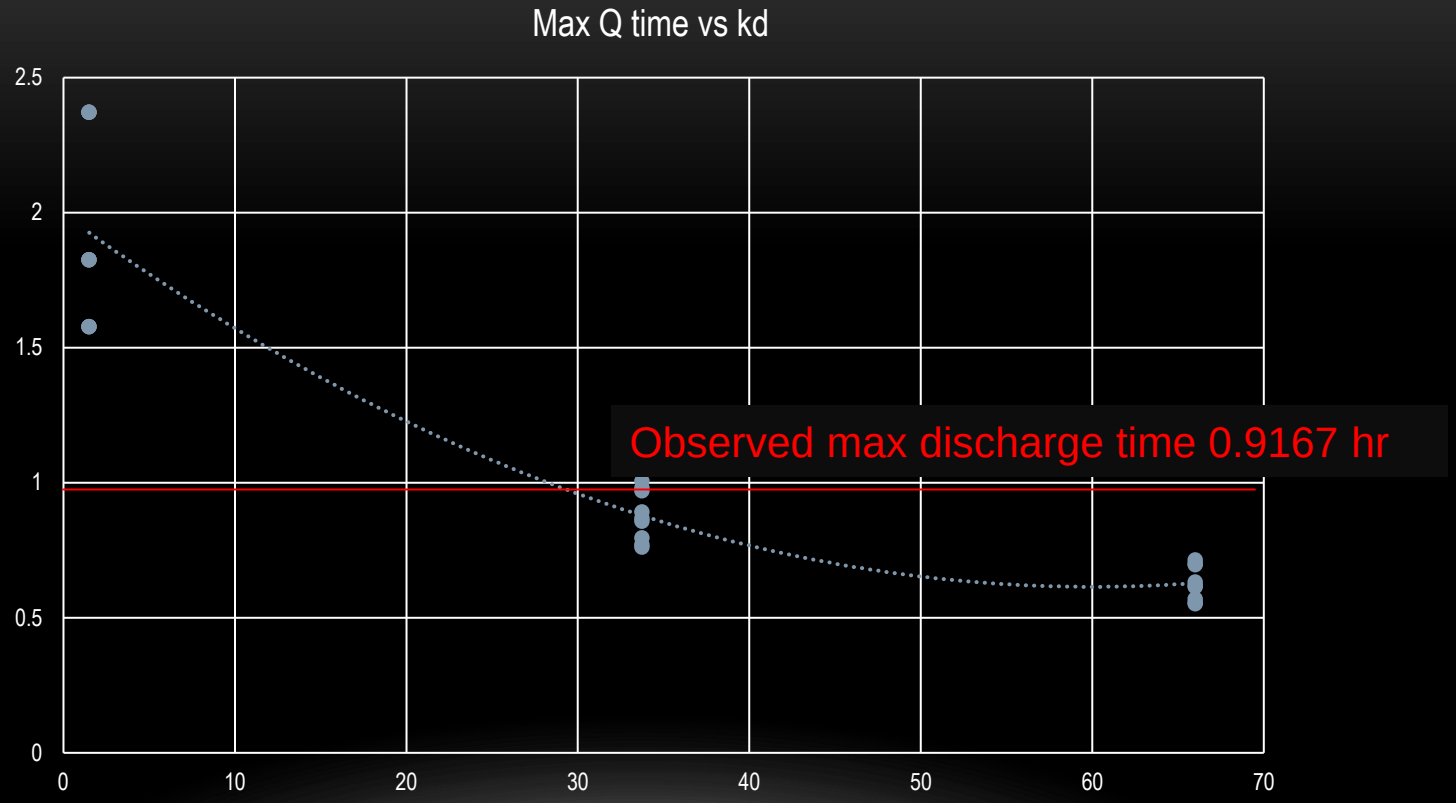
run-2022-11-26-21-49-49
run-2022-11-26-21-50-15
run-2022-11-26-22-40-13
run-2022-11-26-22-42-30
run-2022-11-26-23-14-39
run-2022-11-26-23-18-16
run-2022-11-26-23-20-02
run-2022-11-27-00-06-50
WinDAMRunBRI.in
*BigBay_card...
dakota_multi...
BigBay_cards...
*DLBreachRun.in
DLBreach.bat
tuv_lower_bounds 1.5 0.01 13870000.0
tuv_upper_bounds 66.0 0.05 17284449.6
descriptors 'kd' 'pw' 'uv'
interface,
id_interface = 'bat'
system
analysis_driver = 'DLBreach.bat'
parameters_file = 'params.in'
results_file = 'results.out'
# file_save
responses,
id_responses = 'max_breach_discharge breach_width max_breach_time'
num_response_functions = 3
no_gradients
no_hessians
Console
Problems
Dakota Console
Simple Rank Correlation Matrix among all inputs and outputs:
kd pw uv response_fn_1 response_fn_2 response_fn_3
kd 1.00000e+00
pw 0.00000e+00 1.00000e+00
uv 0.00000e+00 1.38778e-17 1.00000e+00
response_fn_1 9.45189e-01 -1.34194e-01 -2.10042e-01 1.00000e+00
response_fn_2 9.43456e-01 1.16476e-01 3.08662e-01 8.07952e-01 1.00000e+00
response_fn_3 -9.45189e-01 -1.75035e-01 -2.10042e-01 -7.91054e-01 -9.79818e-01 1.00000e+00
Partial Rank Correlation Matrix between input and output:
response_fn_1 response_fn_2 response_fn_3
kd 9.75992e-01 9.99410e-01 -9.82631e-01
pw -5.36774e-01 9.63366e-01 -7.00140e-01
uv -7.05611e-01 9.94527e-01 -7.62001e-01
Max discharge, max top width, time
<<<<< Iterator multidim_parameter_study completed.
<<<<< Environment execution completed.

Max Q vs kd

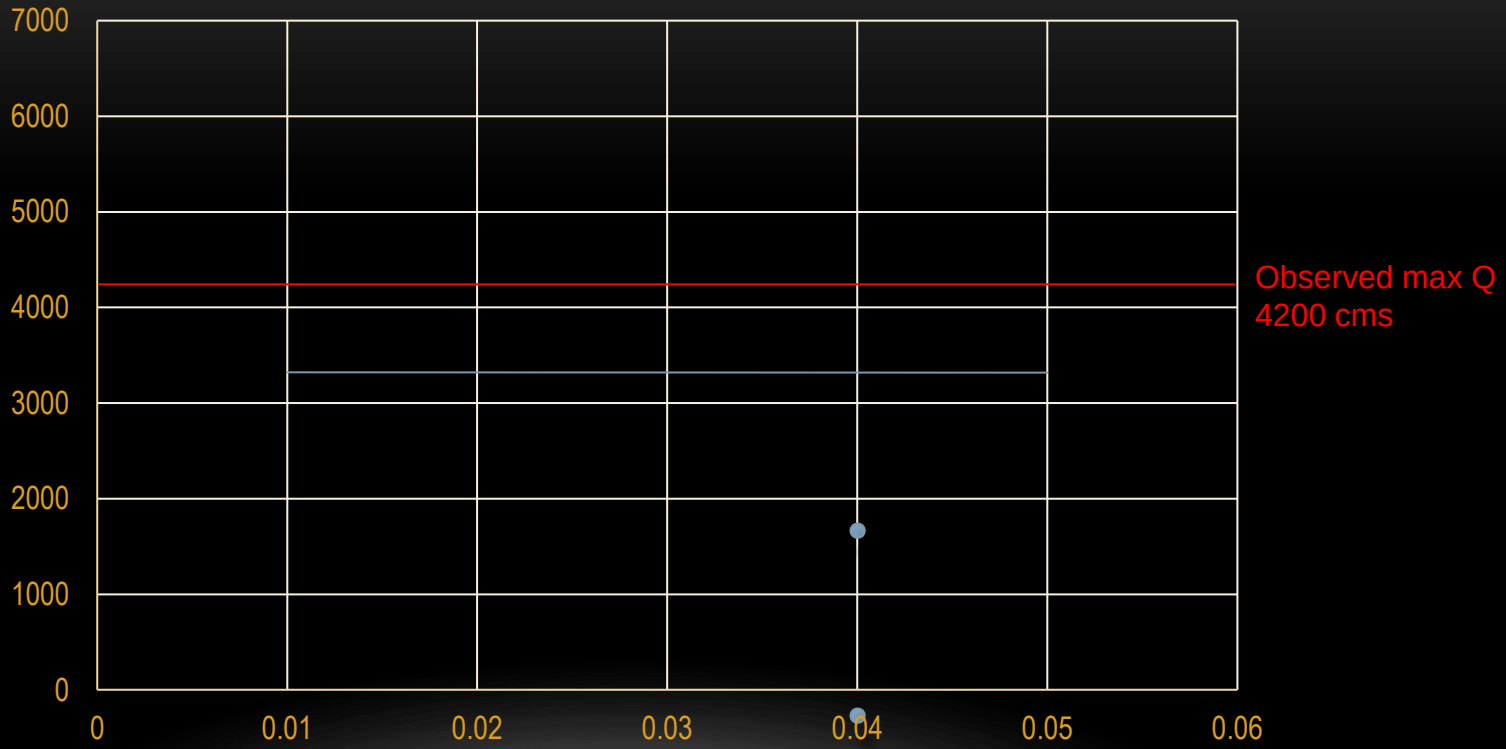

7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60
70
Observed max discharge 4200 cms
y = 627.46x0.5114

Max top width vs kd



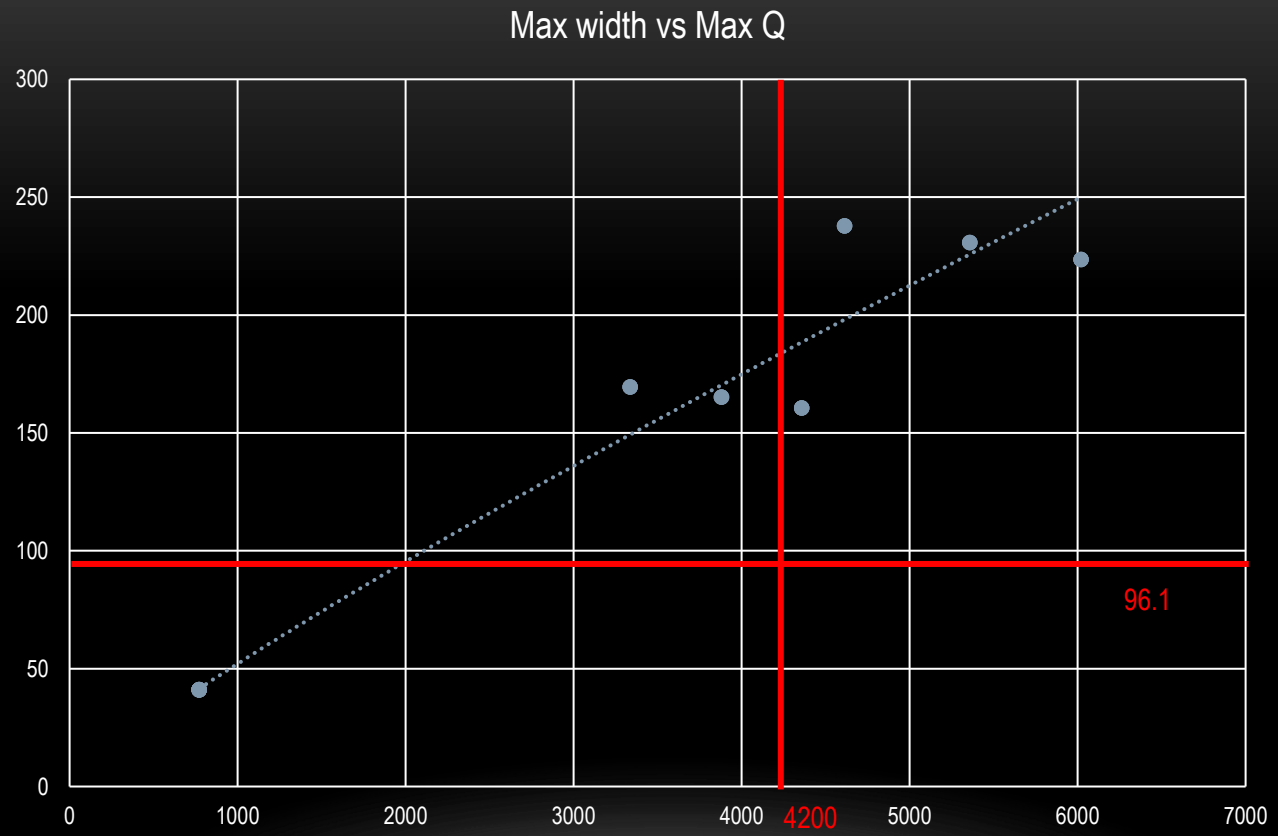

Max Q time vs kd
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
Observed max discharge time 0.9167 hr

Max Q vs pipe width (pw)

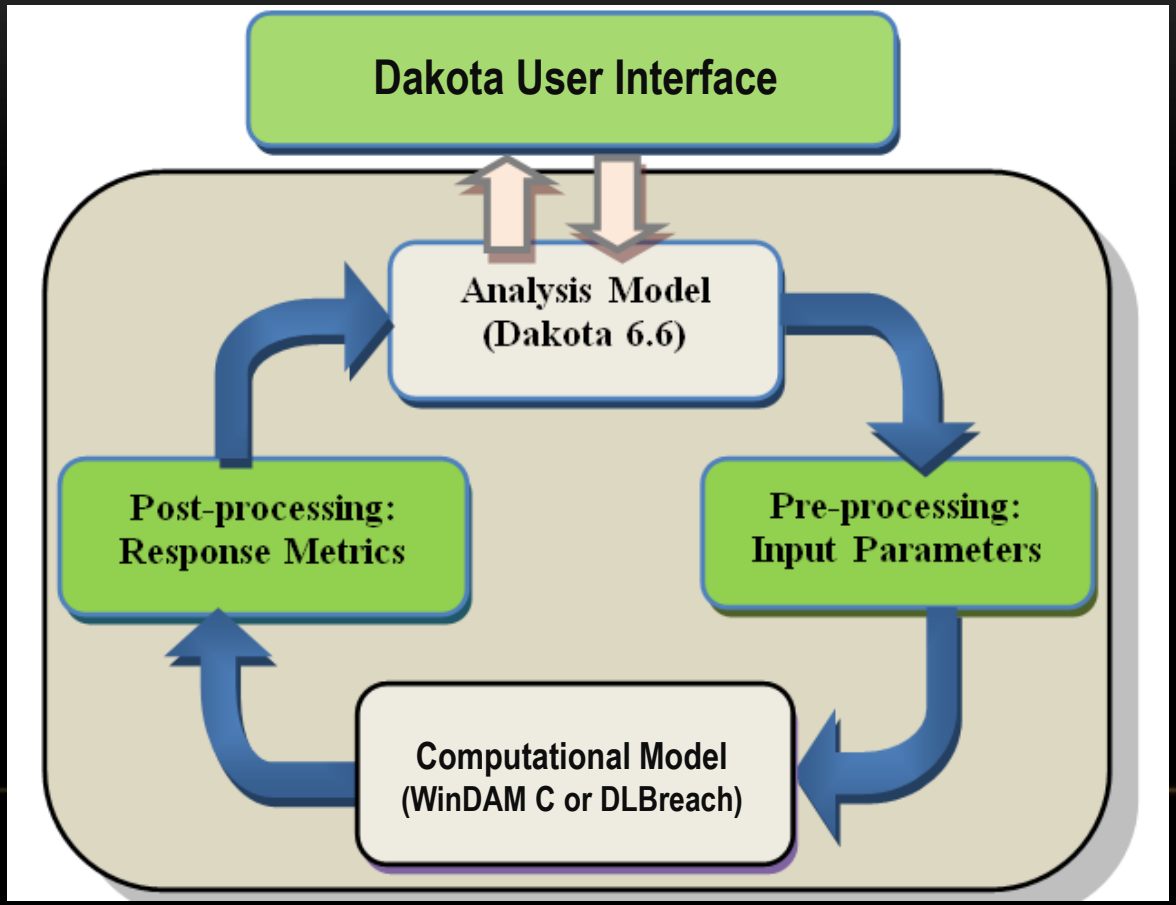


Max Q vs uv


7000
6000
5000
4000
3000
2000
1000
0
Observed max discharge 4200 cms
0
5000000
10000000
15000000
20000000


Max width vs Max Q
300
250
200
150
100
50
0
0
1000
2000
3000
4000
4200
5000
6000
7000
96.1

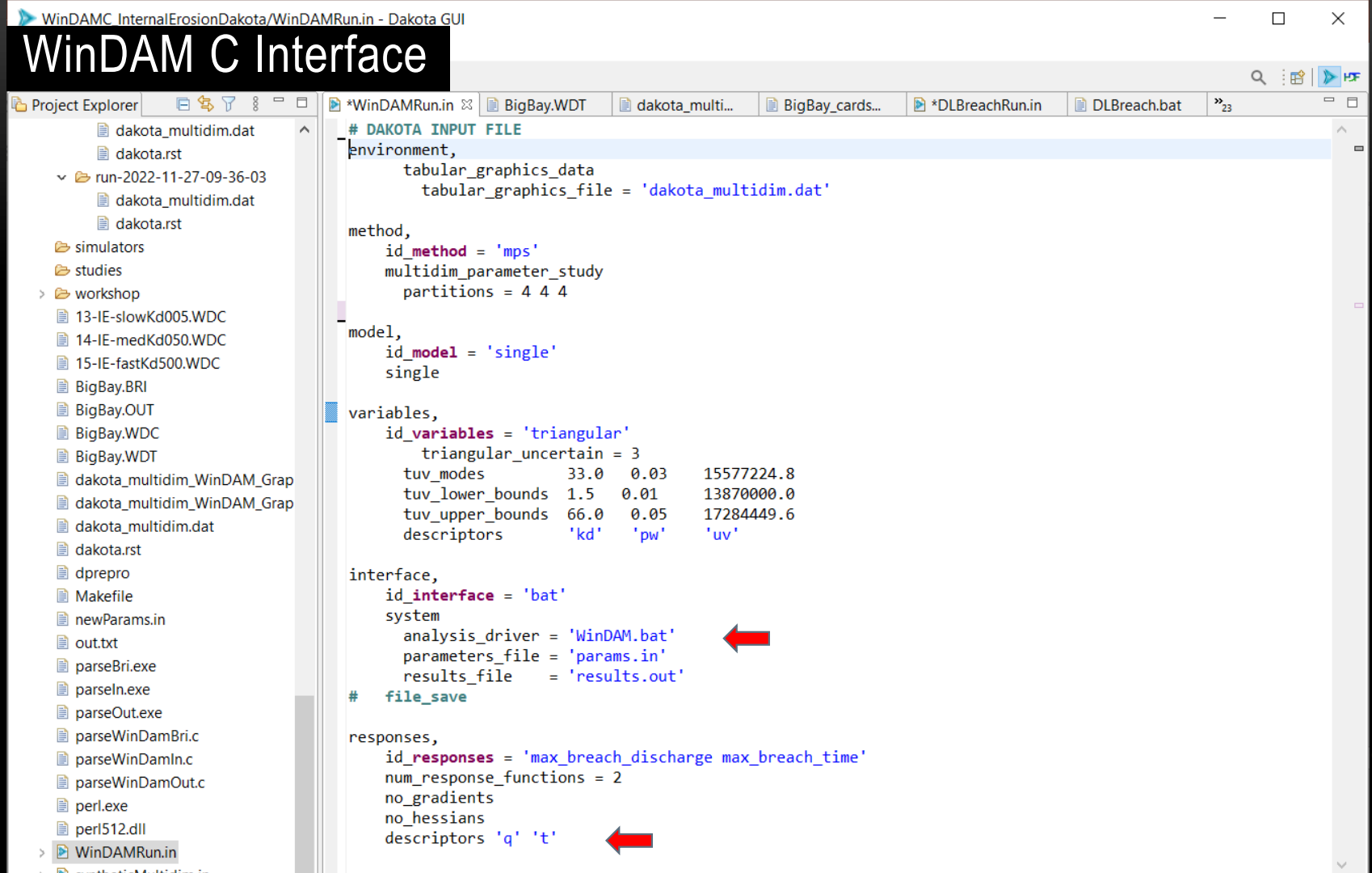
WinDAM C Analysis



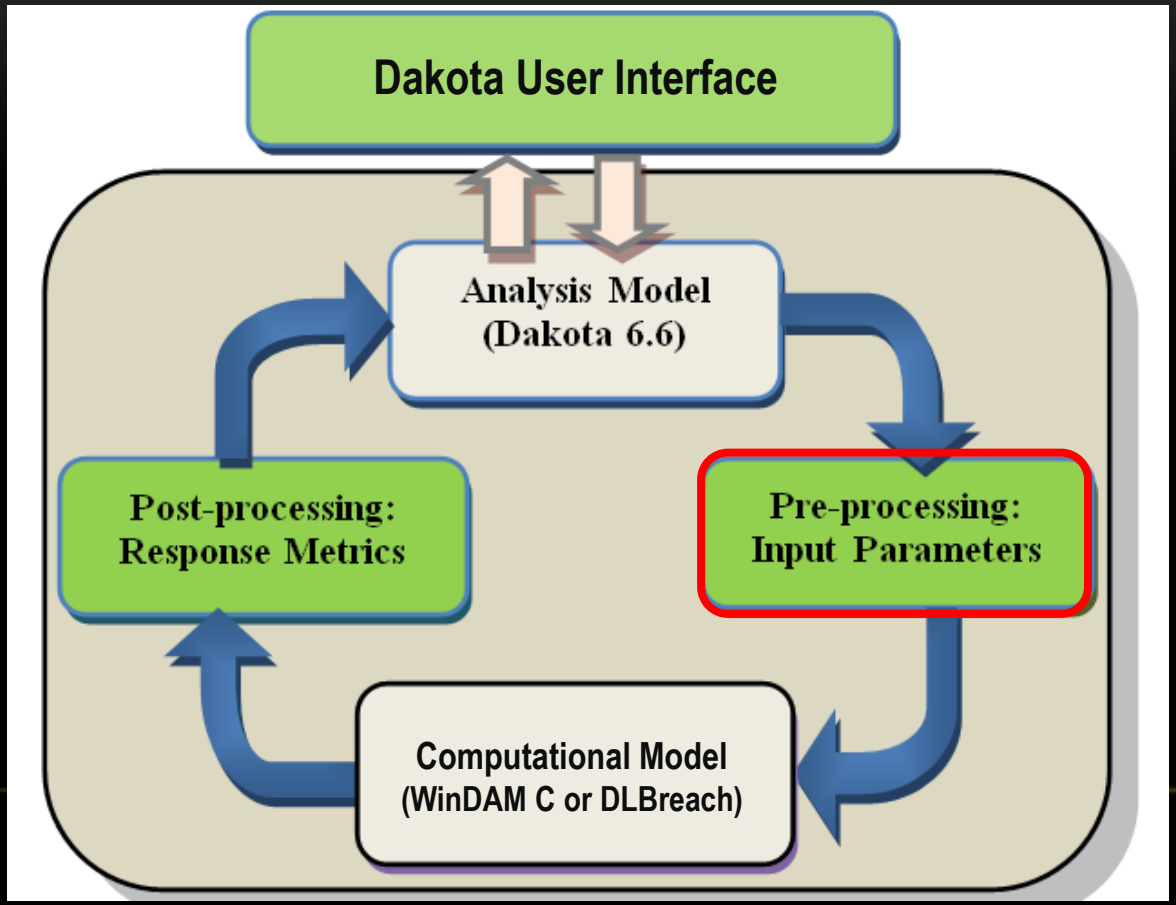
WinDAM Template (BigBay.WDT)

```
WINDAM    10/06/2022IE Models Eval - BigBay
OPTION    SIMPLE    BARESOIL  NOPS      INTERNAL
IEMODEL   2         120.0     {kd       } 100       0.002
HYD                 0.1       0         0C
..
 0
ENDTABLE
CRESTPRFL
          0         57.0866
          1968.5    57.0866
ENDTABLE
STROUTE   44.29     0         ELEV
STRUCTURE BigBay
                    0                   0
                    42.09               {uv}
                    42.62               14187.5
                    46.59               21370.4
ENDTABLE
UPSTREAM  3         0.016
DAMCREST  40        0.016
DWNSTREAM 3         0.016
CONDUIT   {pw       } {pw       } 2         984.25
TAILWATER
ENDTABLE
OUTPUT    ALL
```

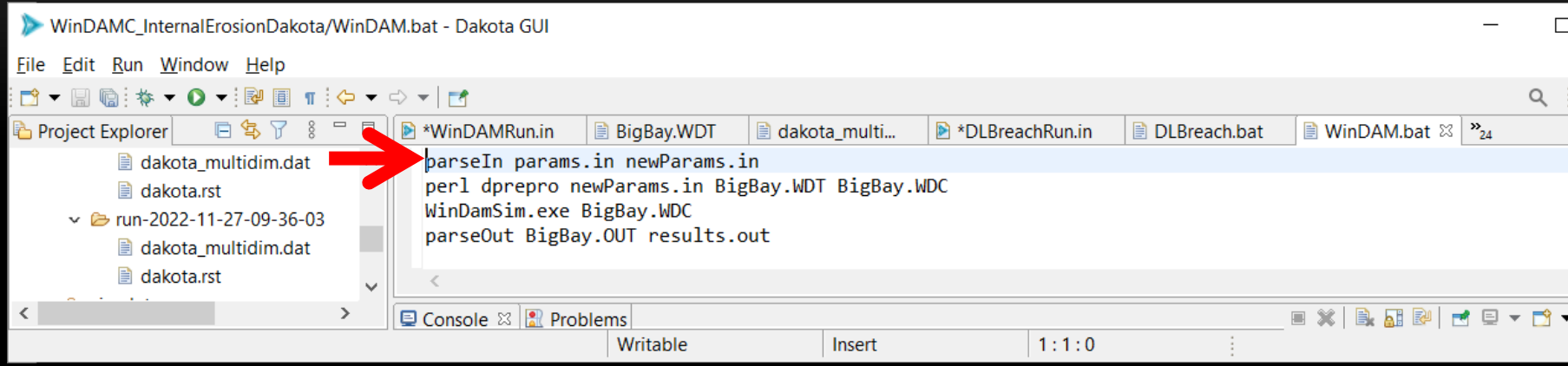
WinDAM C Interface



WinDAM C Analysis



DAKOTA Analysis Driver – WinDAM.bat

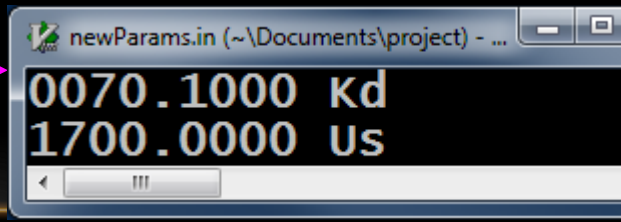


params.in

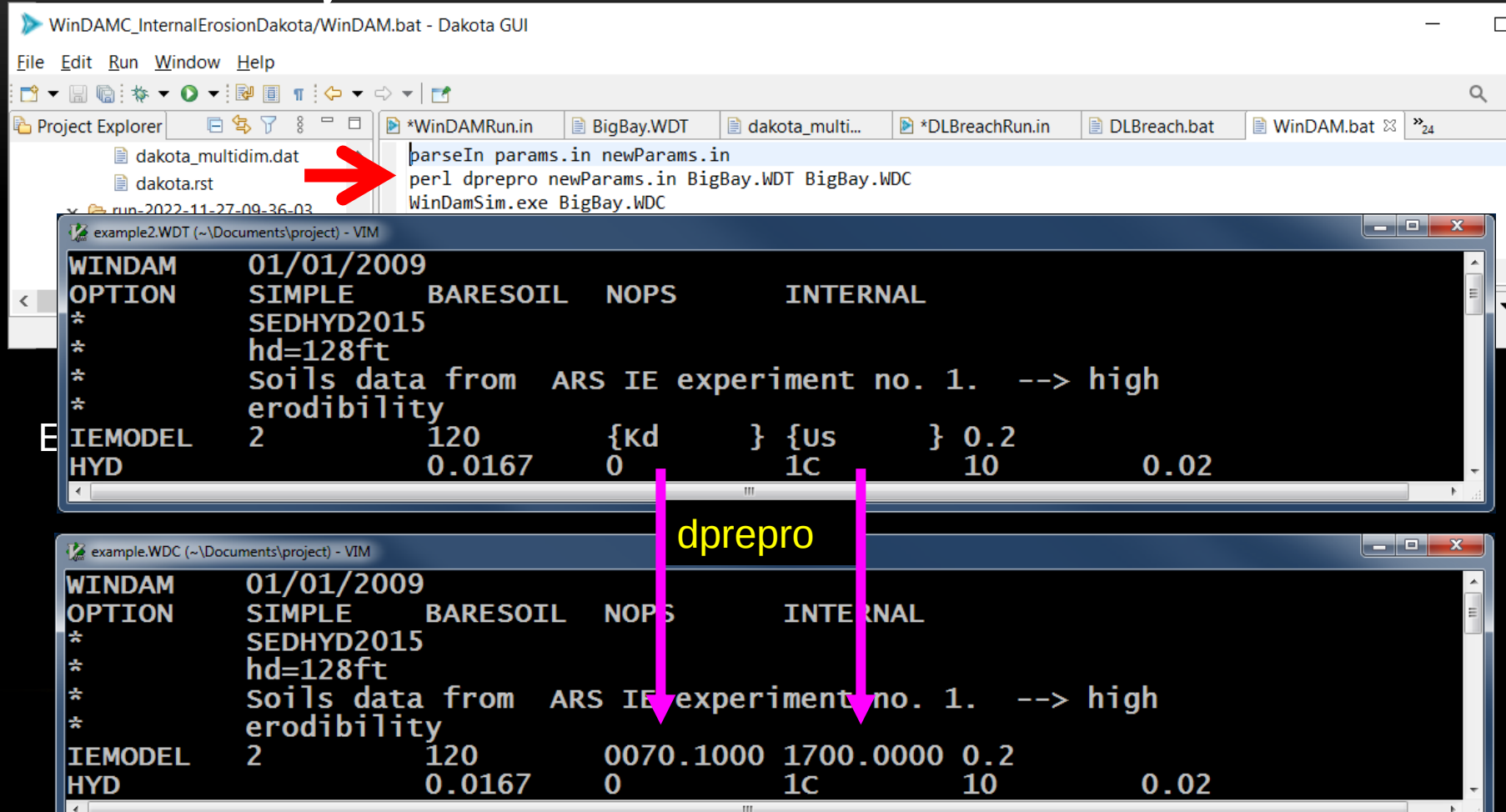
```
                     2 variables
 7.009999999999999e+001 Kd
 1.700000000000000e+003 Us
                     1 functions
                     1 ASV_1:response_fn_1
                     2 derivative_variables
                     1 DVV_1:Kd
                     2 DVV_2:Us
                     0 analysis_components
                   121 eval_id
```

parseIn

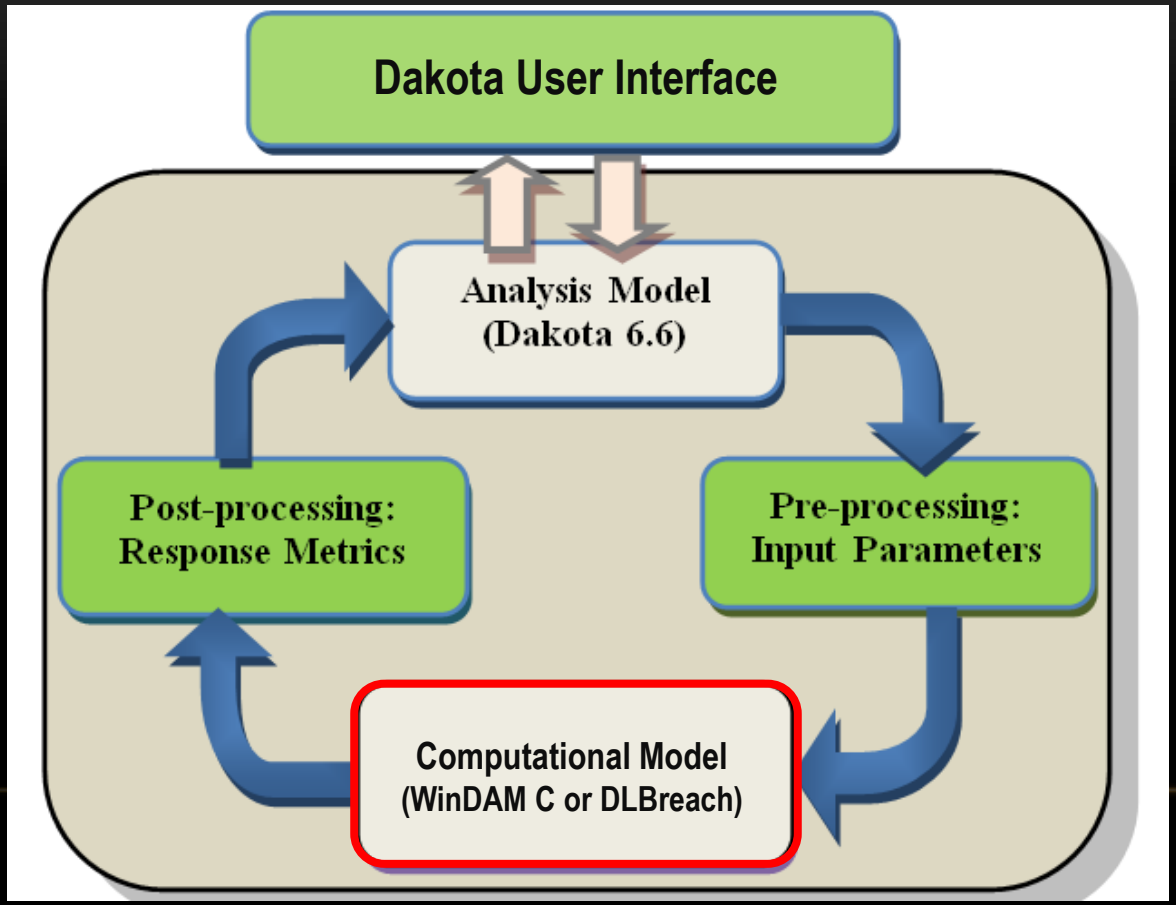
newParams.in



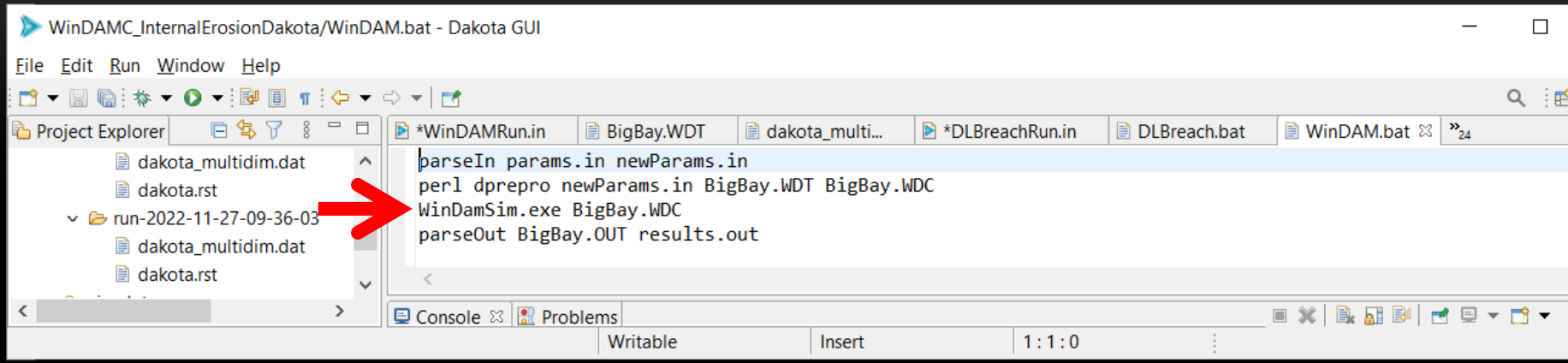
DAKOTA Analysis Driver



WinDAM C Analysis

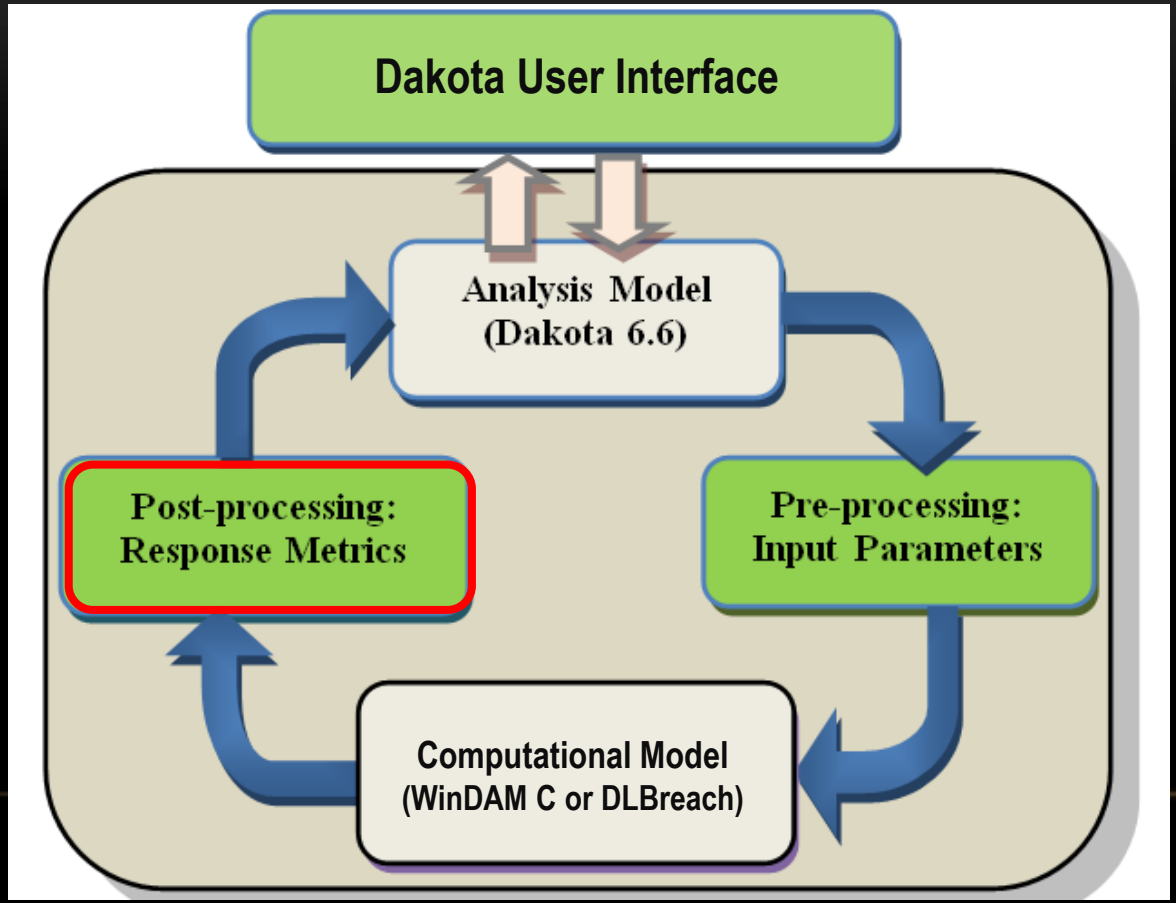


DAKOTA Analysis Driver

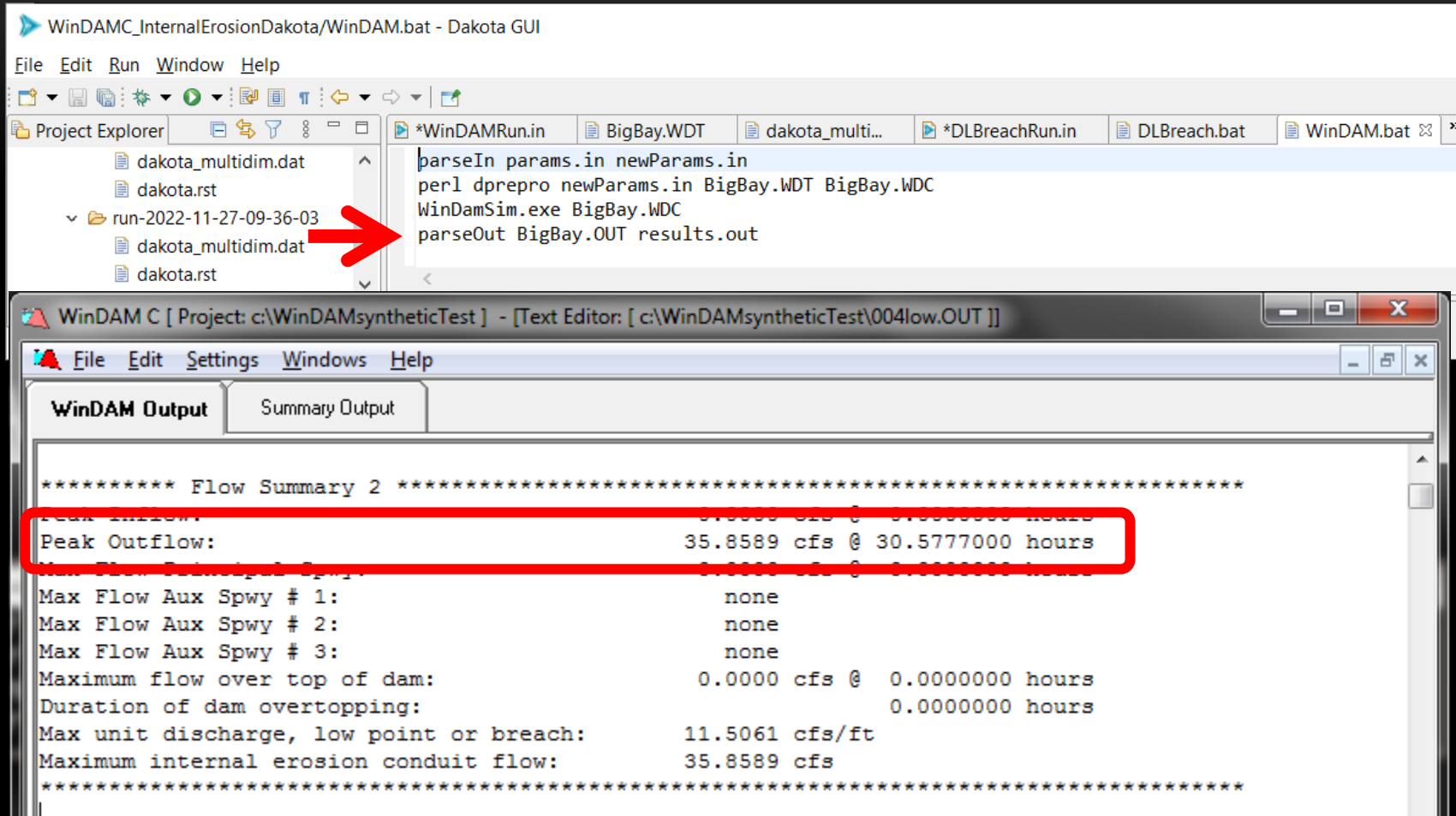


BigBay.WDC → WinDamSim → BigBay.OUT

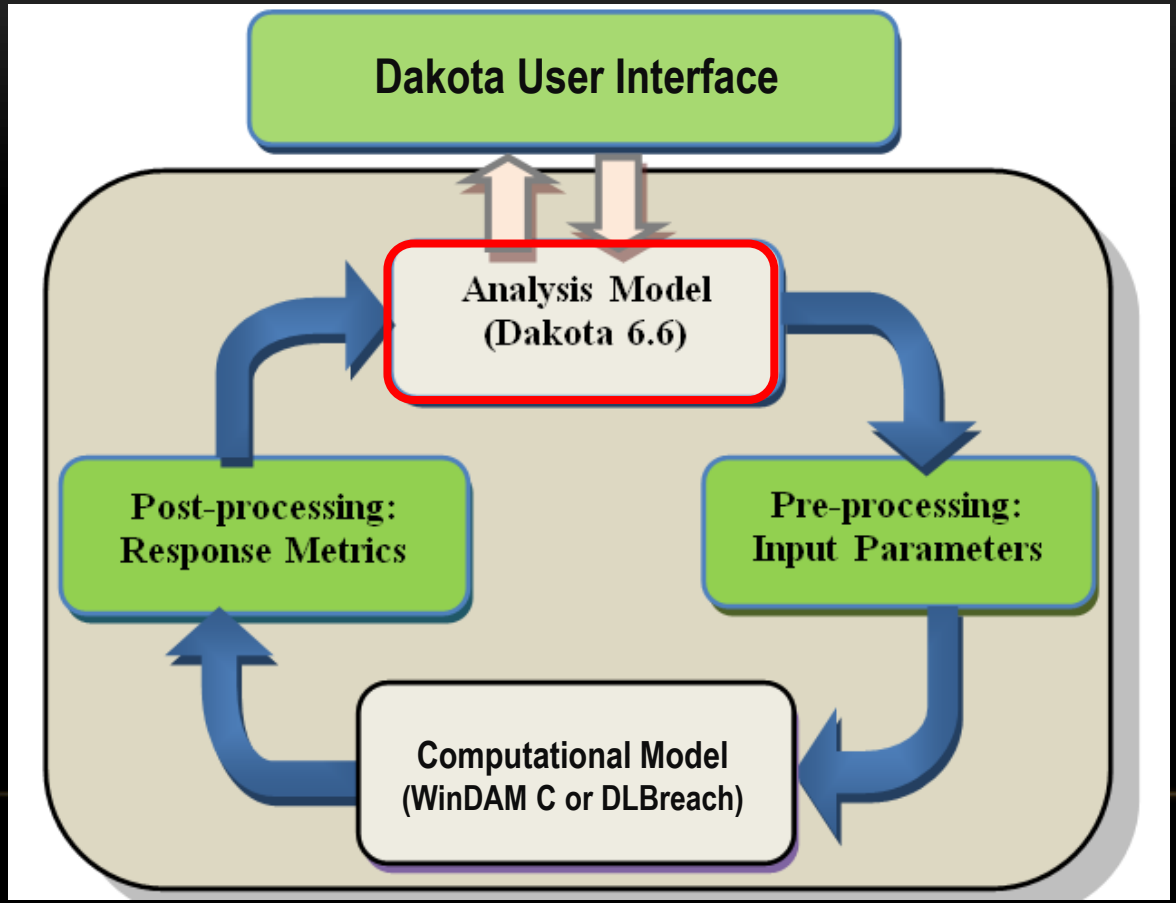
WinDAM C Analysis



DAKOTA ANALYSIS DRIVER



WinDAM C Analysis



DLBreachProject/DLBreachRun.in - Dakota GUI

File Edit Run Window Help

Project Explorer

- dakota.rst
- run-2022-11-27-09-36-03
  - dakota_multidim.dat
  - dakota.rst
- simulators
- studies
- workshop
- ~$dakota_multidim_WinDAM_Gr
- ~$dakota_multidim_WinDAM_Gr
- 13-IE-slowKd005.WDC
- 14-IE-medKd050.WDC
- 15-IE-fastKd500.WDC
- BigBay.BRI
- BigBay.OUT
- BigBay.WDC
- BigBay.WDT
- dakota_multidim_WinDAM_Grap
- dakota_multidim_WinDAM_Grap
- dakota_multidim.dat
- dakota.rst
- dprepro
- Makefile
- newParams.in
- out.txt
- parseBri.exe
- parseIn.exe
- parseOut.exe
- parseWinDamBri.c

*WinDAMRun.in | BigBay.WDT | dakota_multi... | *DLBreachRun.in | DLBreach.bat | WinDAM.bat | »24

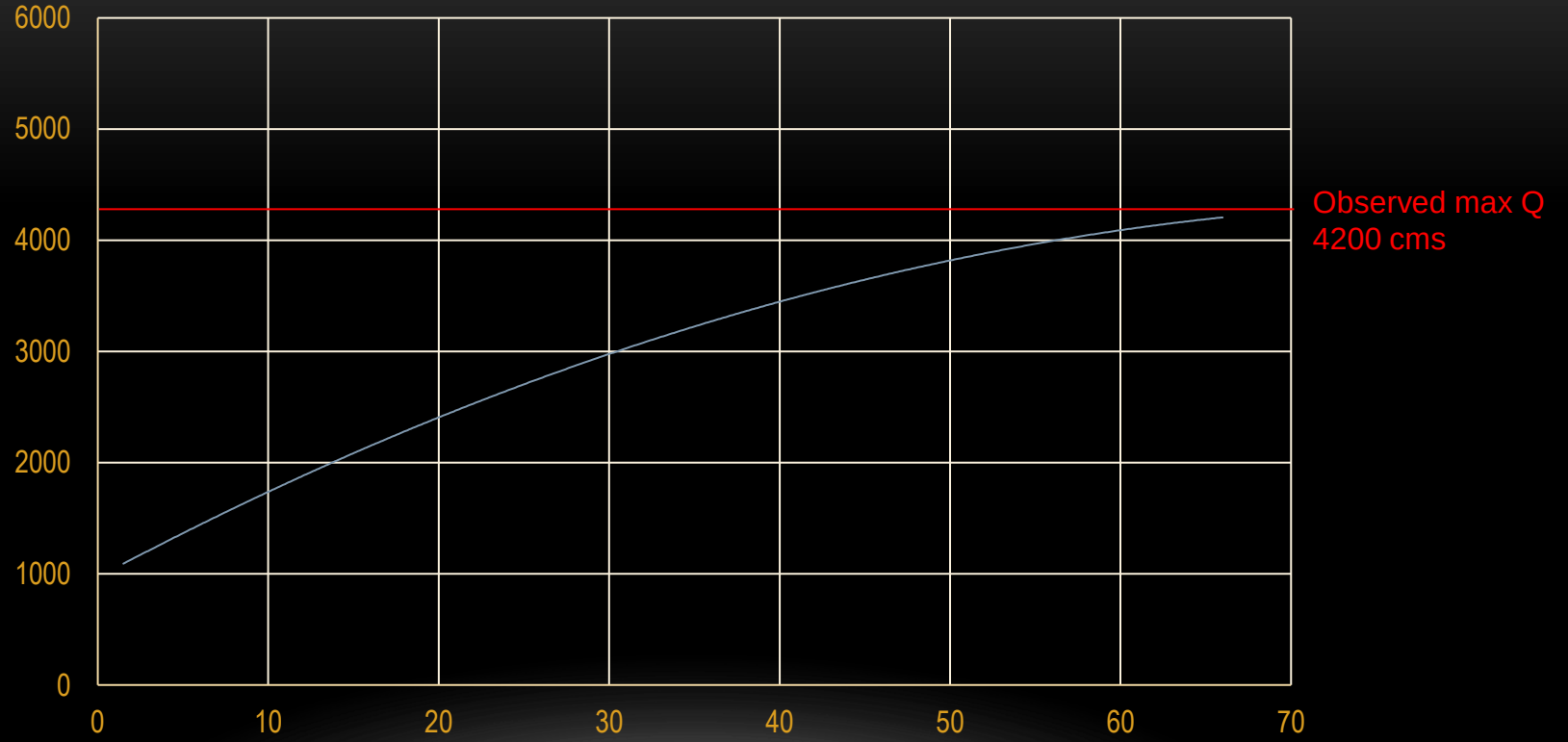
```
#     seed = 12345
#     samples = 4
model,
    id_model = 'single'
    single

variables,
```

Console | Problems

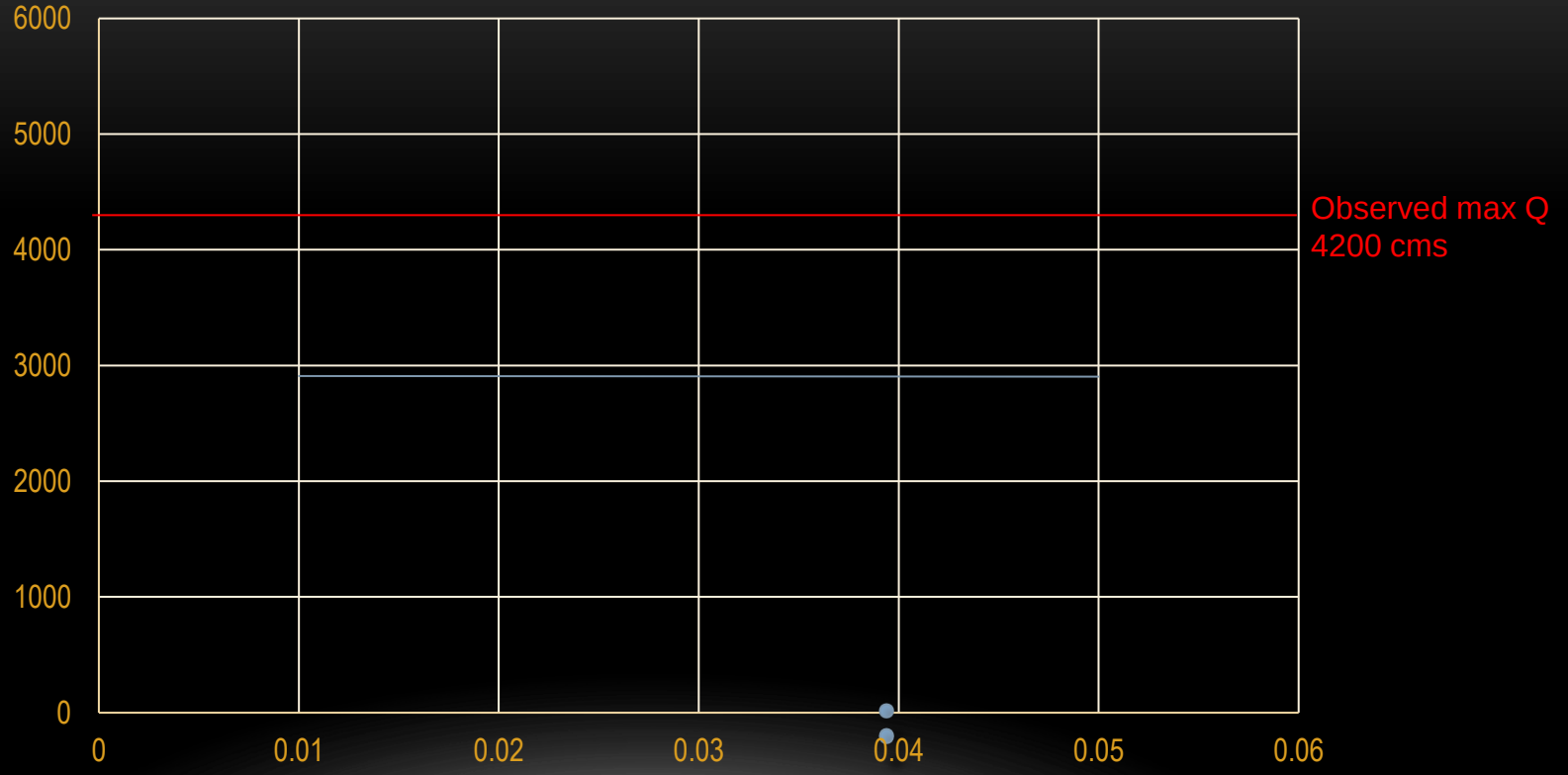
Dakota Console

```
Simple Rank Correlation Matrix among all inputs and outputs:
                kd           pw           uv response_fn_1 response_fn_2 response_fn_3
        kd  1.00000e+00
        pw  0.00000e+00  1.00000e+00
        uv  0.00000e+00  1.38778e-17  1.00000e+00
response_fn_1  9.45189e-01 -1.34194e-01 -2.10042e-01  1.00000e+00
response_fn_2  9.43456e-01  1.16476e-01  3.08662e-01  8.07952e-01  1.00000e+00
response_fn_3 -9.45189e-01 -1.75035e-01 -2.10042e-01 -7.91054e-01 -9.79818e-01  1.00000e+00

Partial Rank Correlation Matrix between input and output:
            response_fn_1 response_fn_2 response_fn_3
        kd  9.75992e-01  9.99410e-01 -9.82631e-01
        pw -5.36774e-01  9.63366e-01 -7.00140e-01
        uv -7.05611e-01  9.94527e-01 -7.62001e-01


<<<<< Iterator multidim_parameter_study completed.
<<<<< Environment execution completed.
DAKOTA execution time in seconds:
  Total CPU        =     335.56 [parent =     335.56, child =          0]
  Total wall clock =    335.561
```

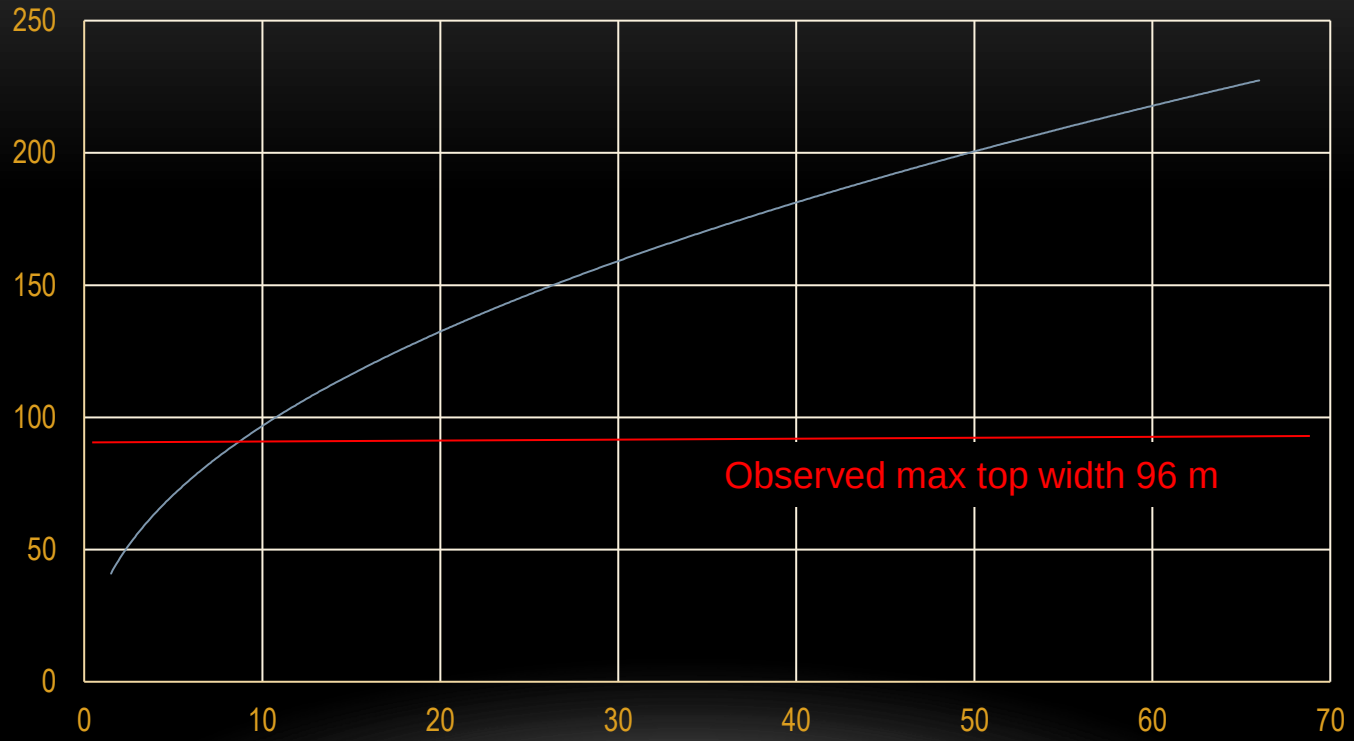
Max Q vs kd

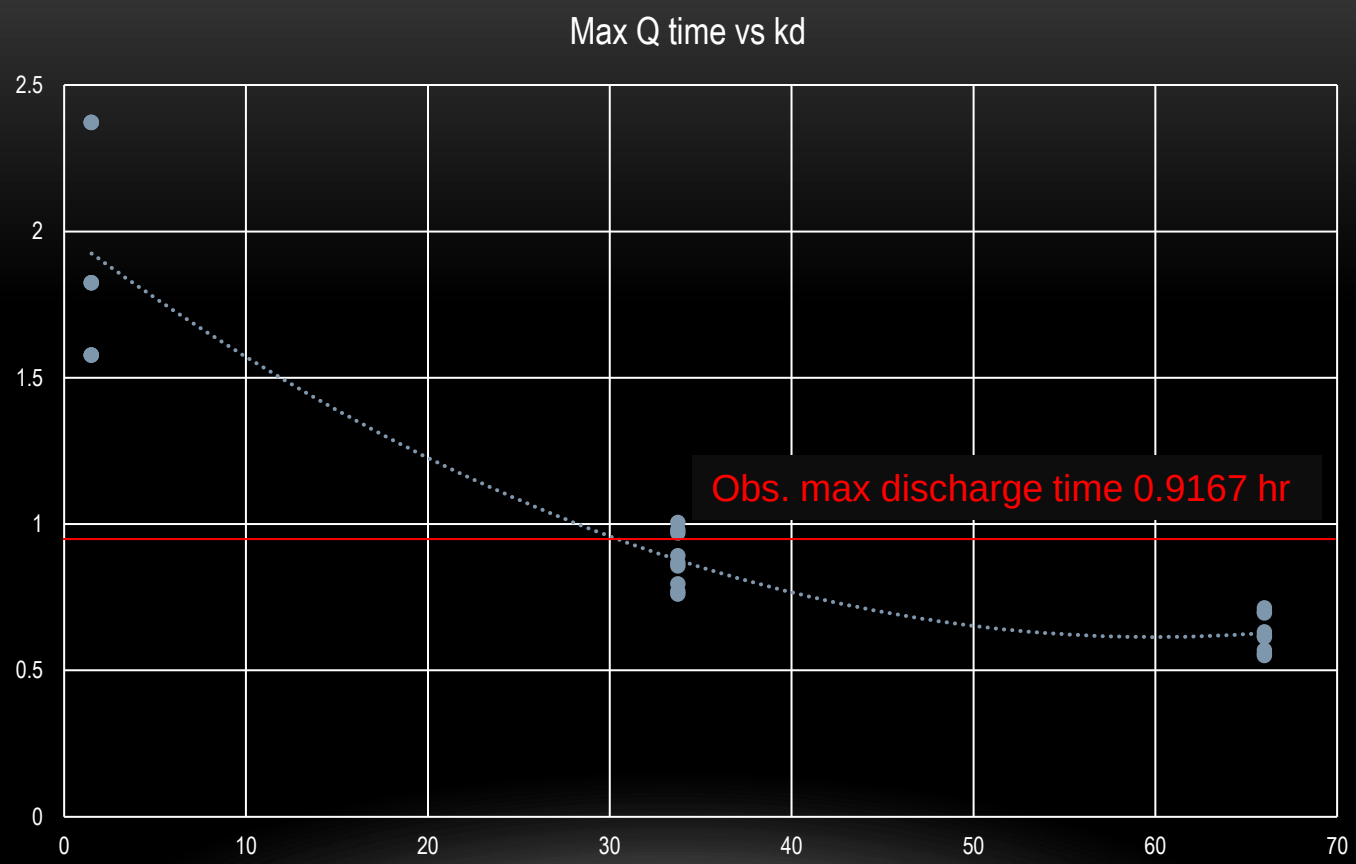

6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60
70
Observed max Q
4200 cms

Max Q vs Pipe Width (pw)

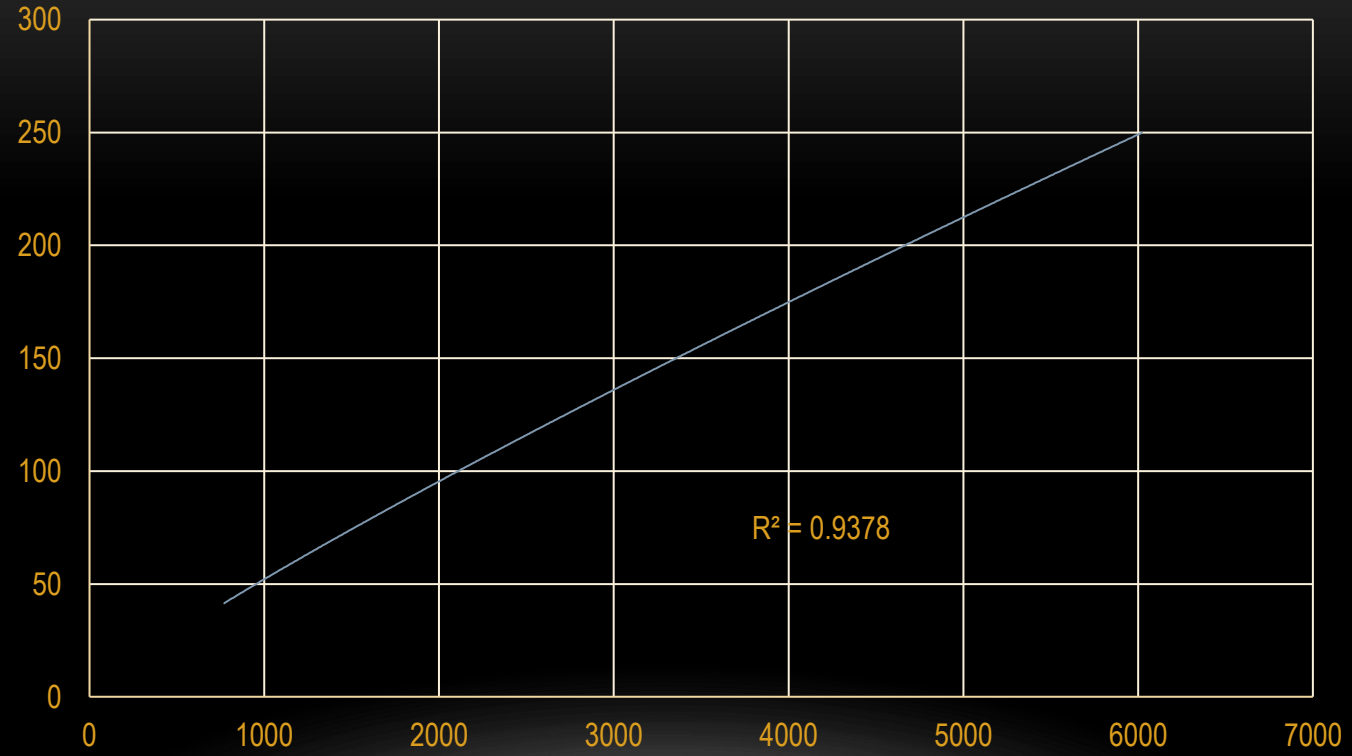


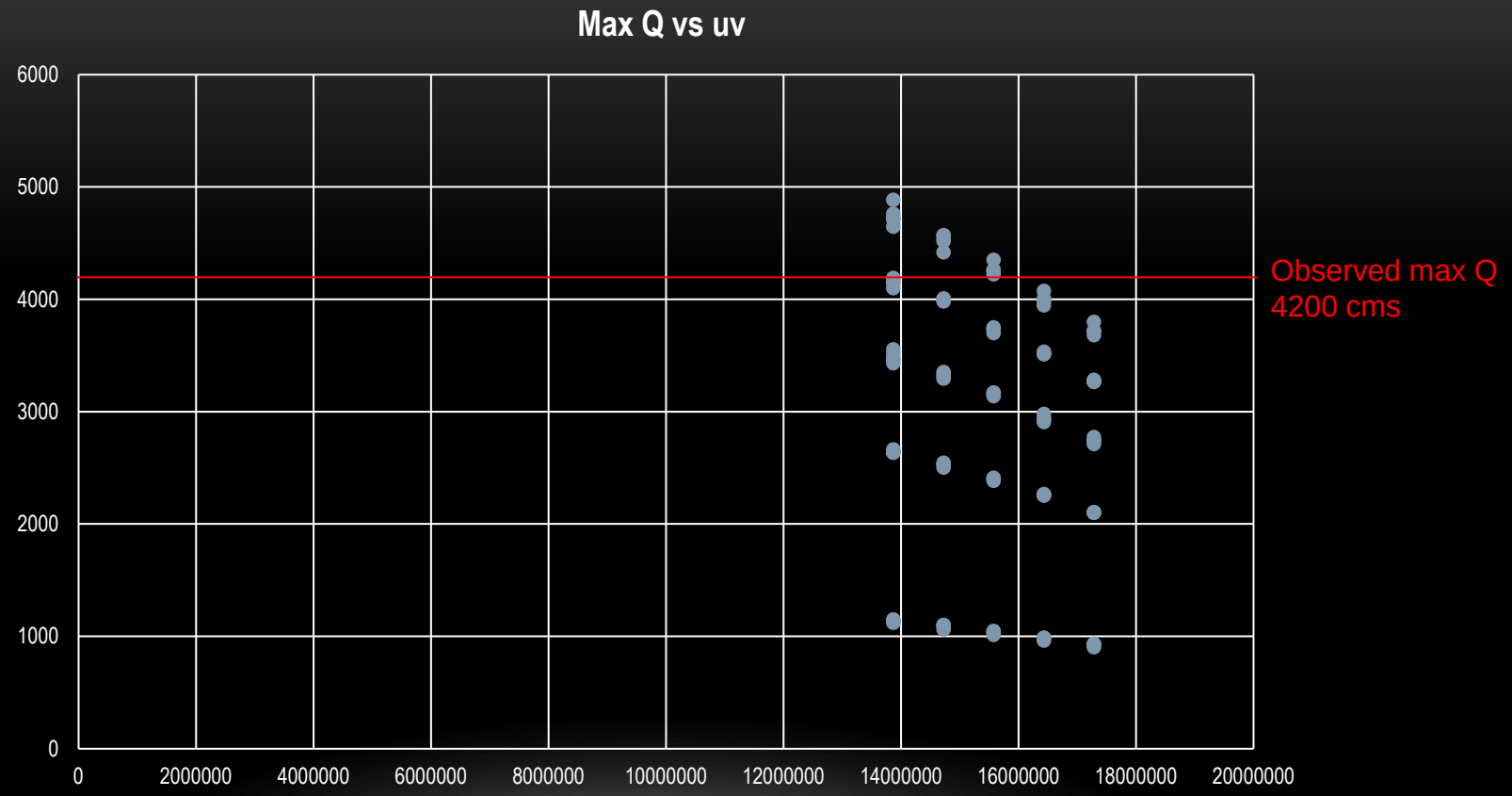
Max top width vs kd

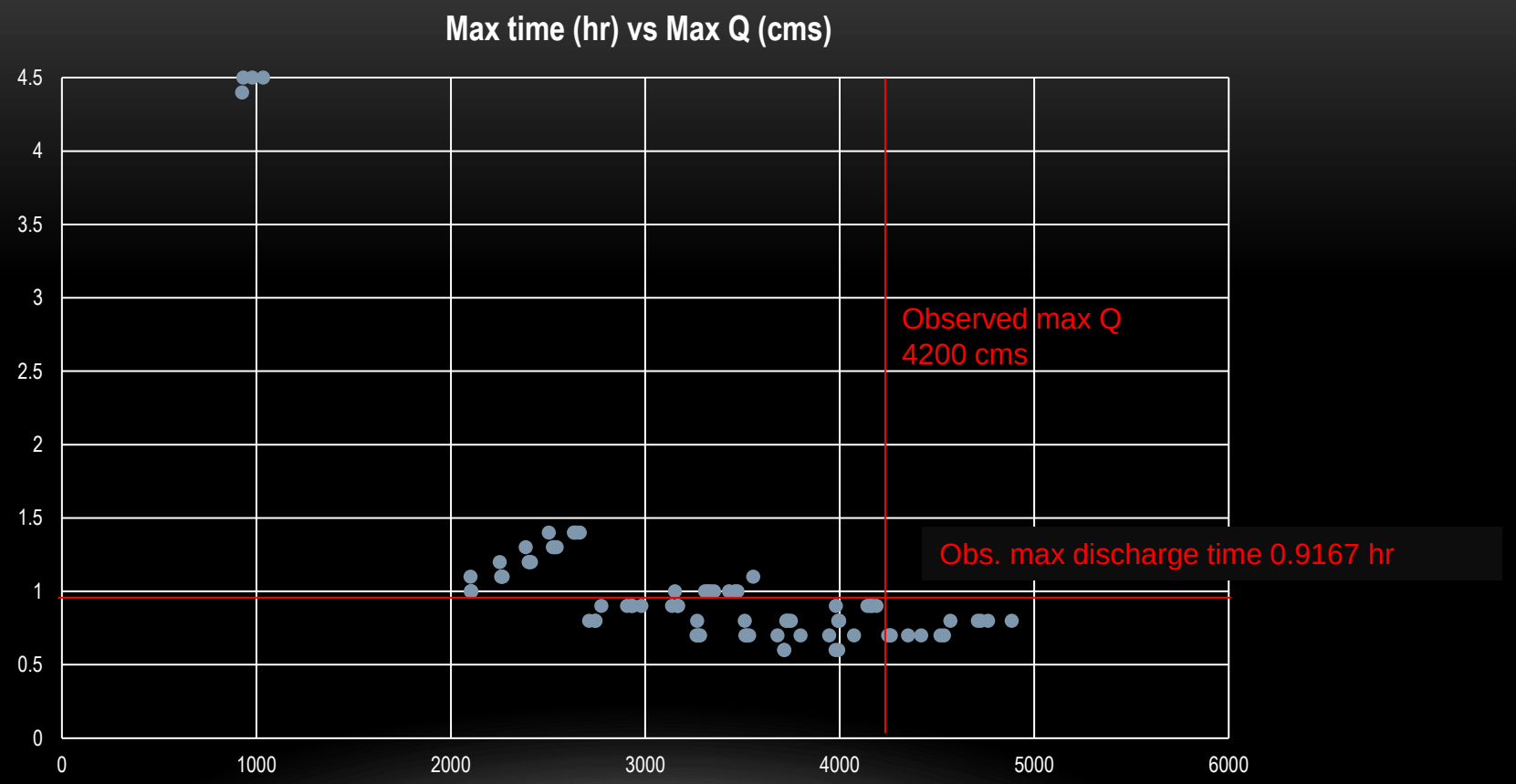



Max Q time vs kd
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
Obs. max discharge time 0.9167 hr

Max width vs Max Q




Max Q vs uv
6000
5000
4000
3000
2000
1000
0
0
2000000
4000000
6000000
8000000
10000000
12000000
14000000
16000000
18000000
20000000
Observed max Q
4200 cms


Max time (hr) vs Max Q (cms)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1000
2000
3000
4000
5000
6000
Observed max Q
4200 cms
Obs. max discharge time 0.9167 hr