integral INSIGHT FOR AN EVOLVING WORLD

Sandia National Laboratories

# Simple Channel Setup

## Dflow-FM-CEC application

Chris Chartrand
Craig Jones
Jessica Nguyen

**5/1/2024**

**Current energy converter modeling**

# Develop Simple channel with turbines

**Module will highlight the following:**

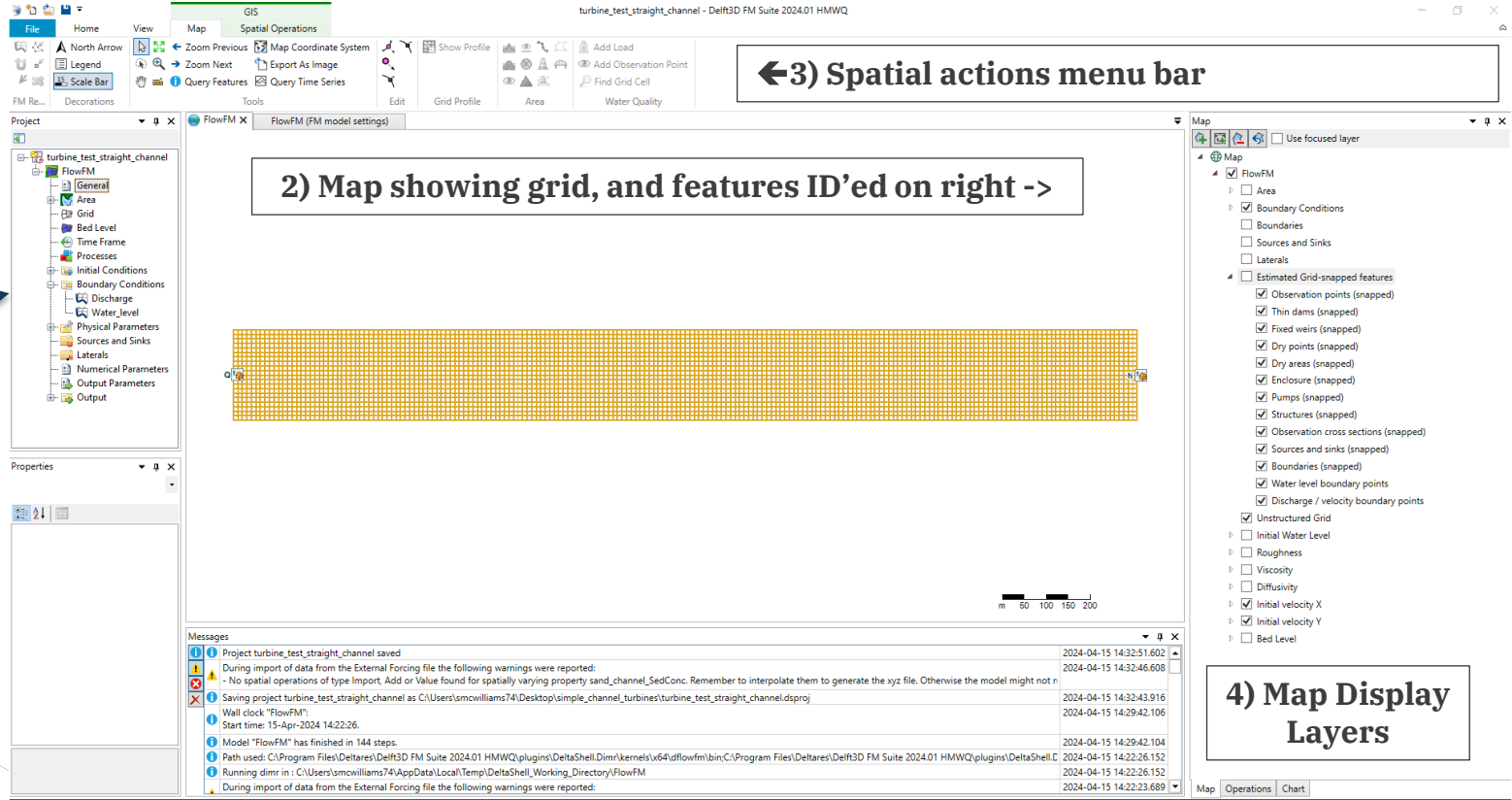
- **Develop Grid in RGF-Grid**
- **Apply bathymetry and boundary conditions**
  - **Simple Discharge and water levels**
- **Set up output locations**
- **Develop Turbine inputs**
- **Execute model**
- **View Results**

integral

Sandia National Laboratories

# GUI Walkthrough

1) Menu to access GUI features




2) Map showing grid, and features ID'ed on right ->

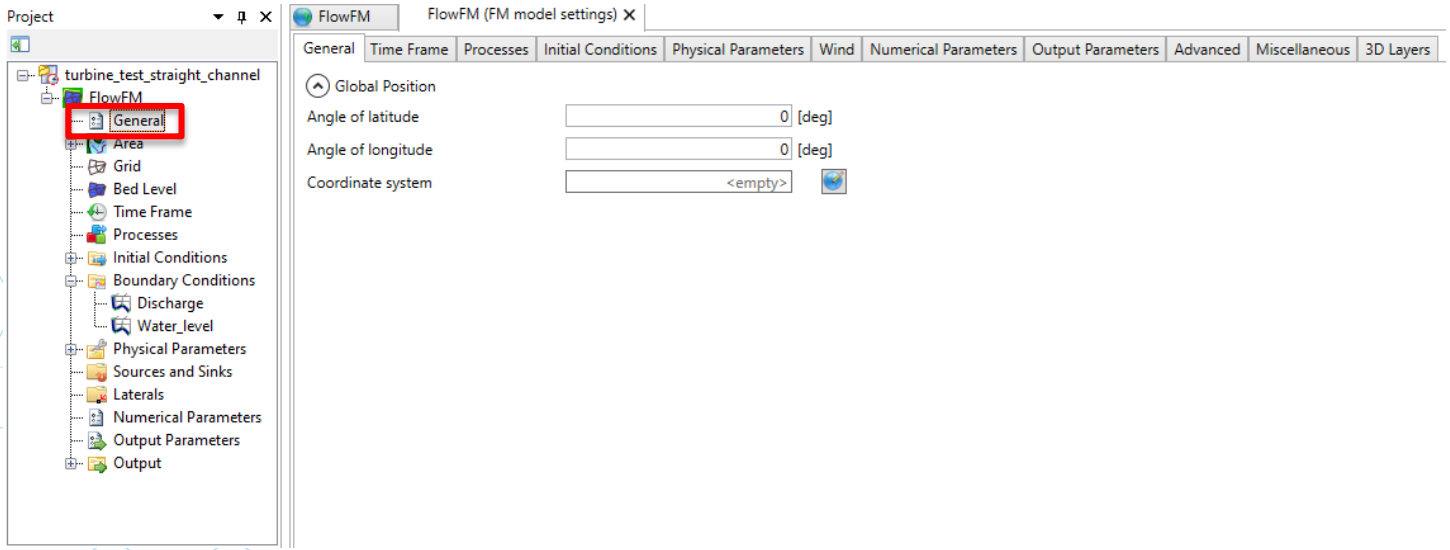
←3) Spatial actions menu bar

4) Map Display Layers

5) Messages indicating success, warning, and errors

# Tabs and menus

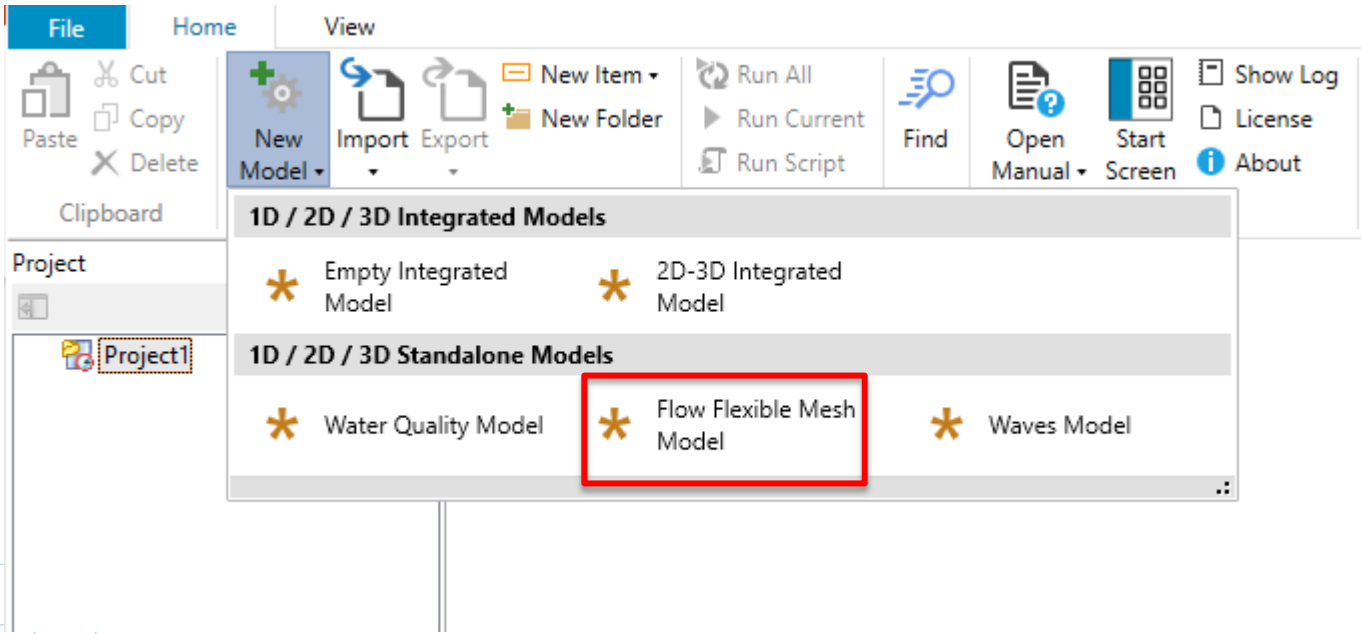
The General tab opens access to the tabs seen across the top. These follow similar inputs to the structured Delft3D-Flow.



# Building Basic Channel

# Start a new model

- Start a new flexible mesh model as shown on the right

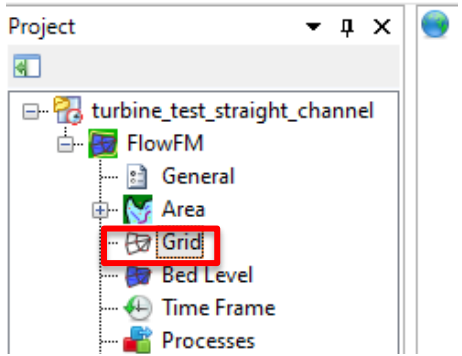


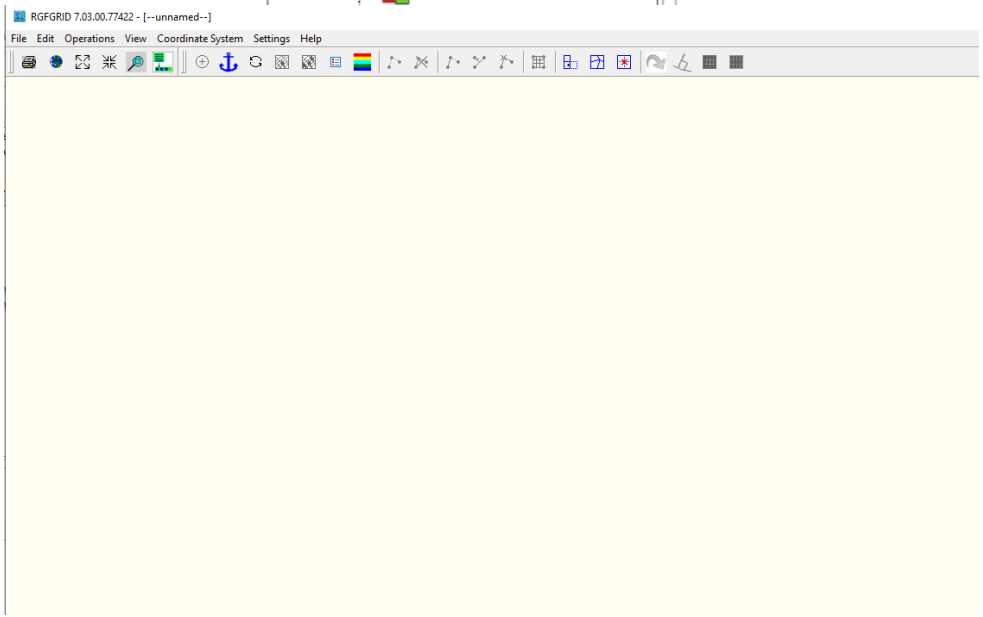

integral

Sandia National Laboratories

# Grid Development

- Double click on Grid to open RGF Grid.
- New window will appear
- Program is used to build rectilinear, curvilinear, and unstructured grids.



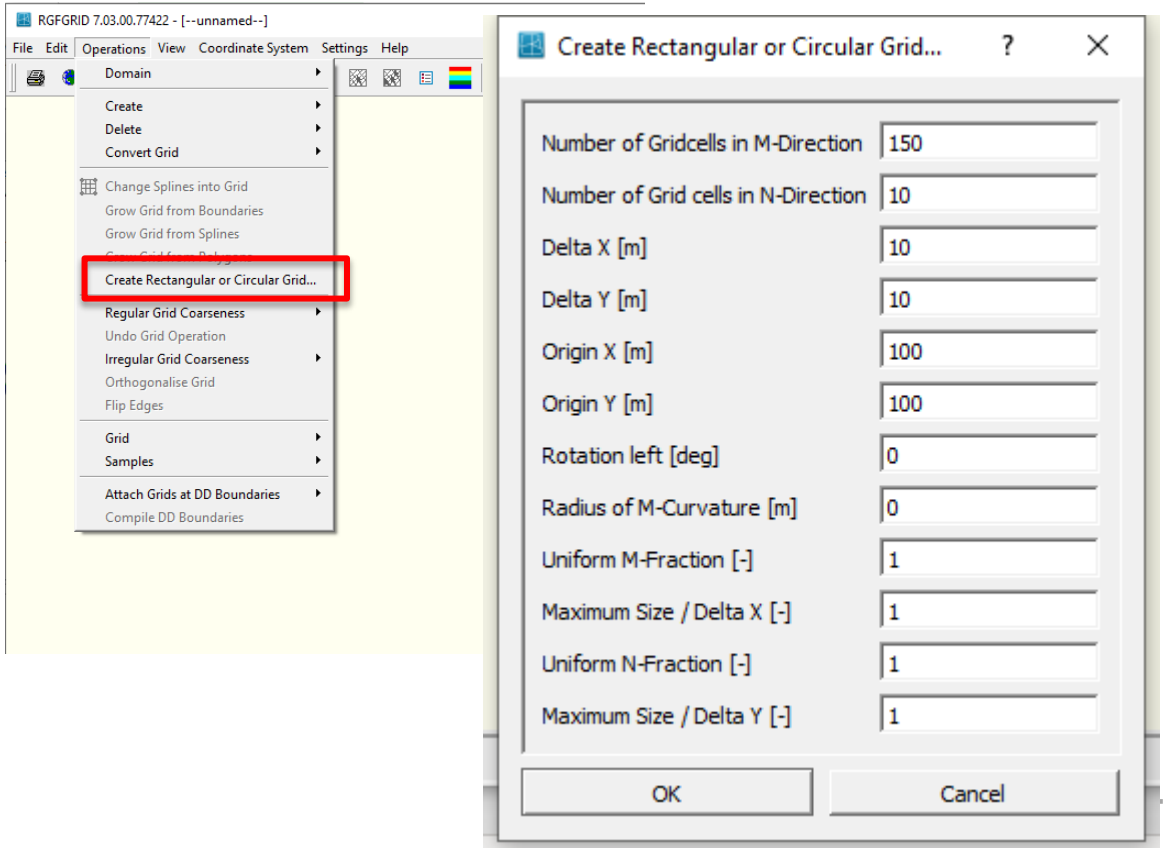




integral

Sandia National Laboratories

# Generate a simple Rectangular Grid

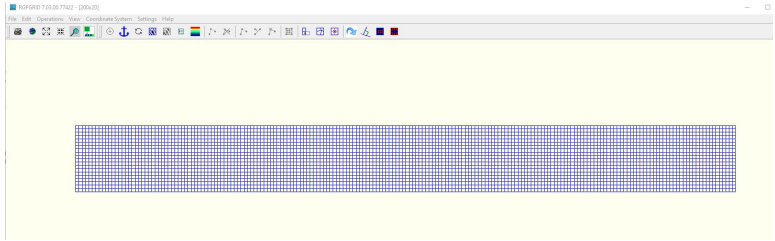
- Simple grids can be generated by defining the number and size of cells.

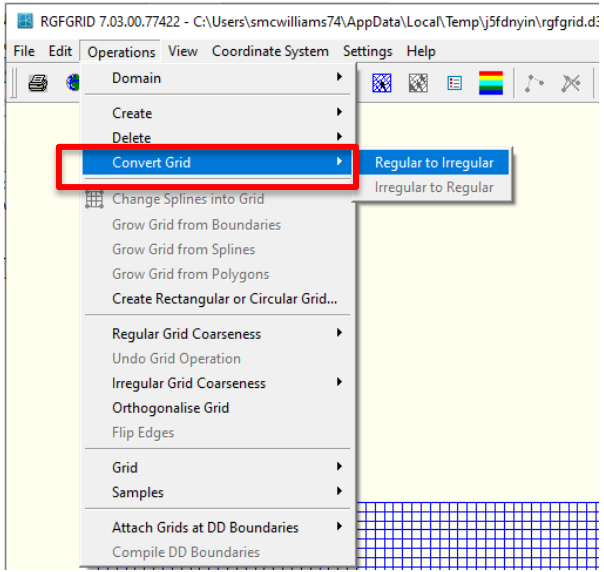



integral Sandia National Laboratories

# Convert from a structured to unstructured grid

- Basic  Structured Grid is developed.
- 
- Convert from Regular to Irregular
  - **Key step for flexible mesh grid.
  - **Grid links should change from dark to light blue!**
- **File-> Save Project and exit**

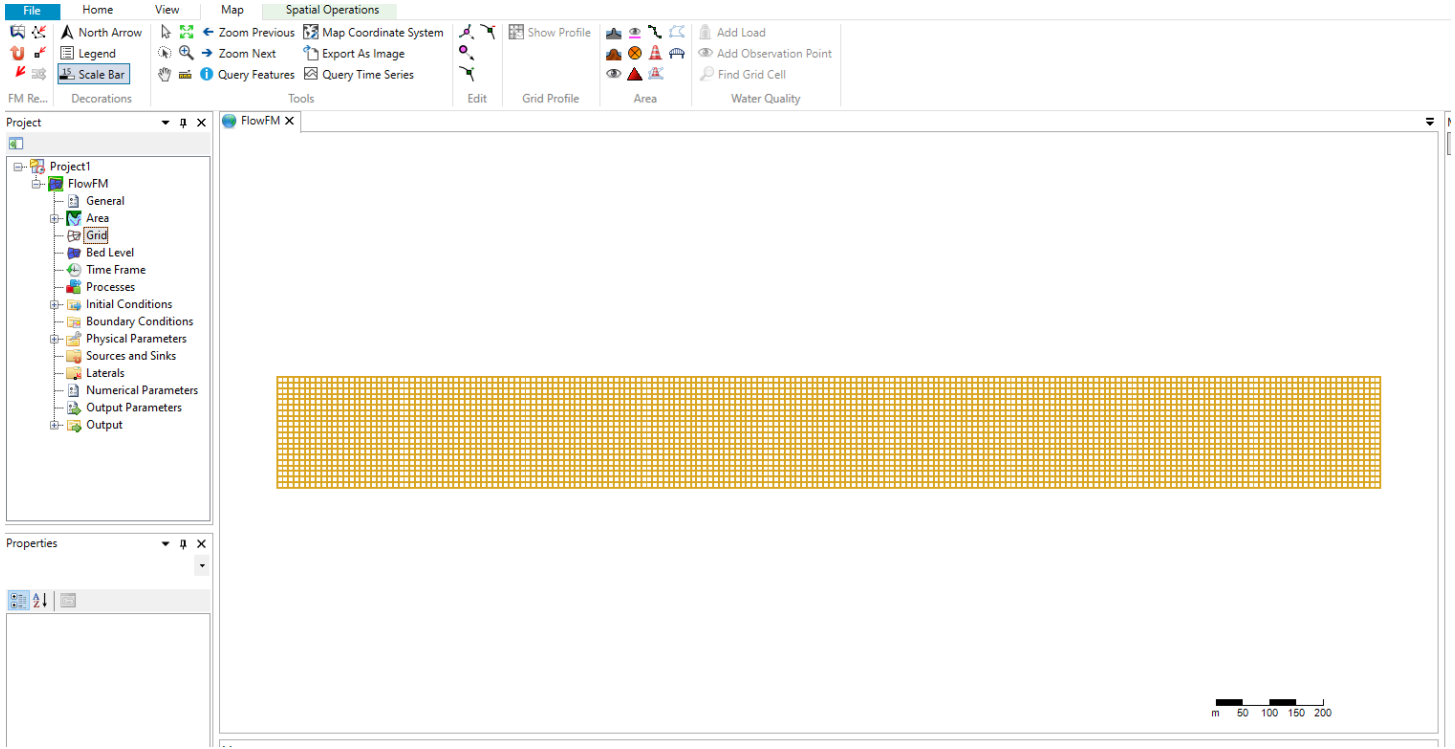





integral

Sandia National Laboratories

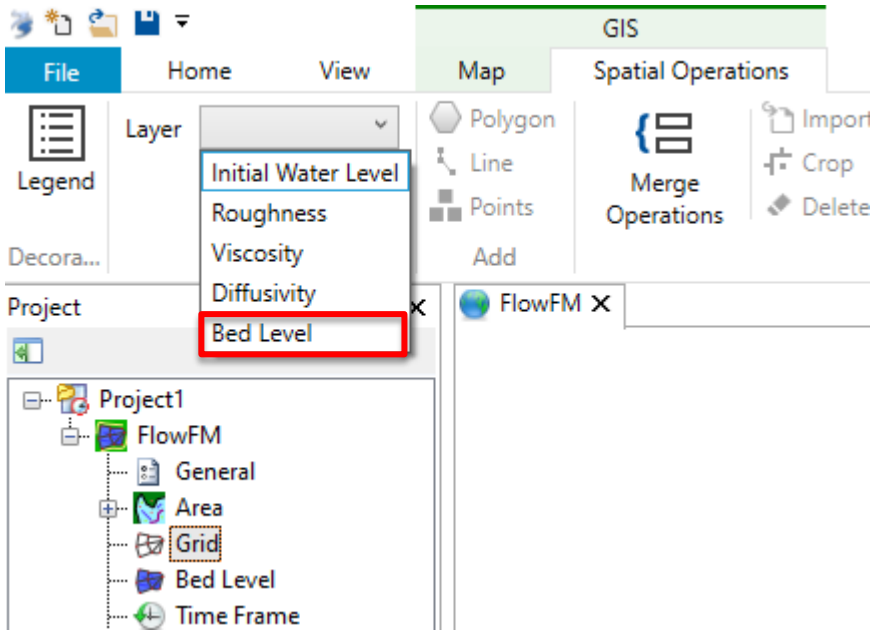
# Grid will appear in Map view of GUI



# Bathymetry

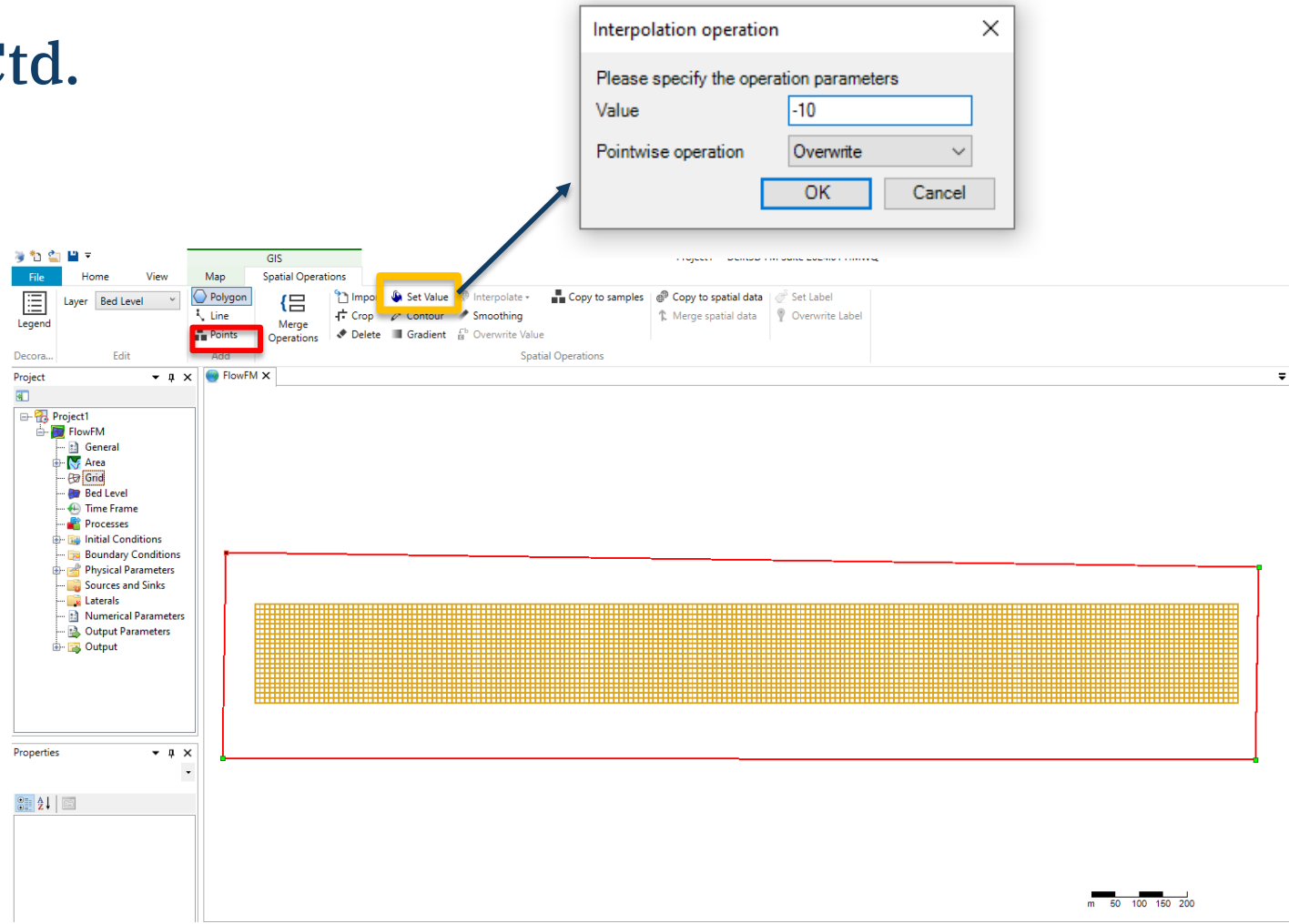
- Add bathy to the grid
- Select the bed level layer in the spatial operations menu
- This menu allows you apply spatial data to grid from an xyz file or assign bulk values across regions.

**Bathymetry is applied in the GIS Spatial Operations Menu!!!**



# Bathymetry Ctd.

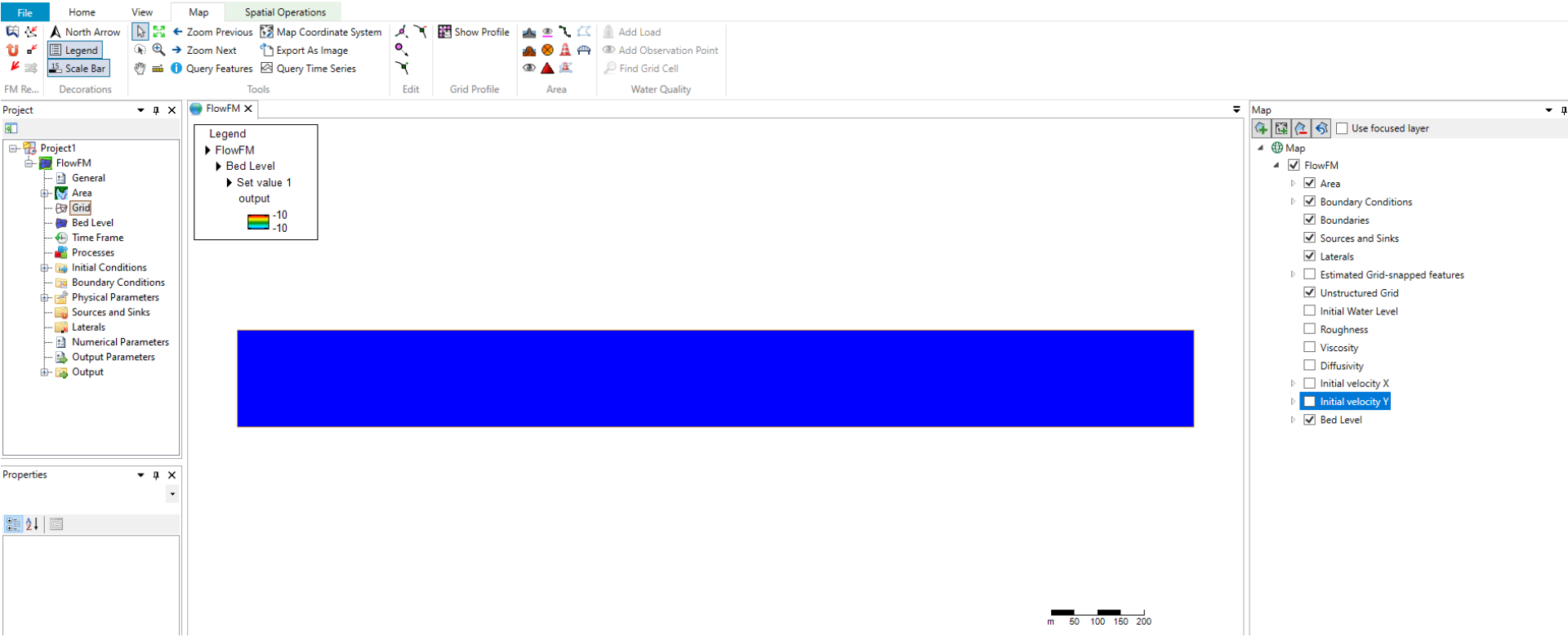
- Draw a polygon around the grid-
- Select Set Value
- Enter -10 to set a depth of 10 m everywhere inside the polygon
- Depths are relative and are negative. i.e. you can relate depths to a datum like NAVD88 or MSL




integral

Sandia National Laboratories

# Bathymetry Application Success

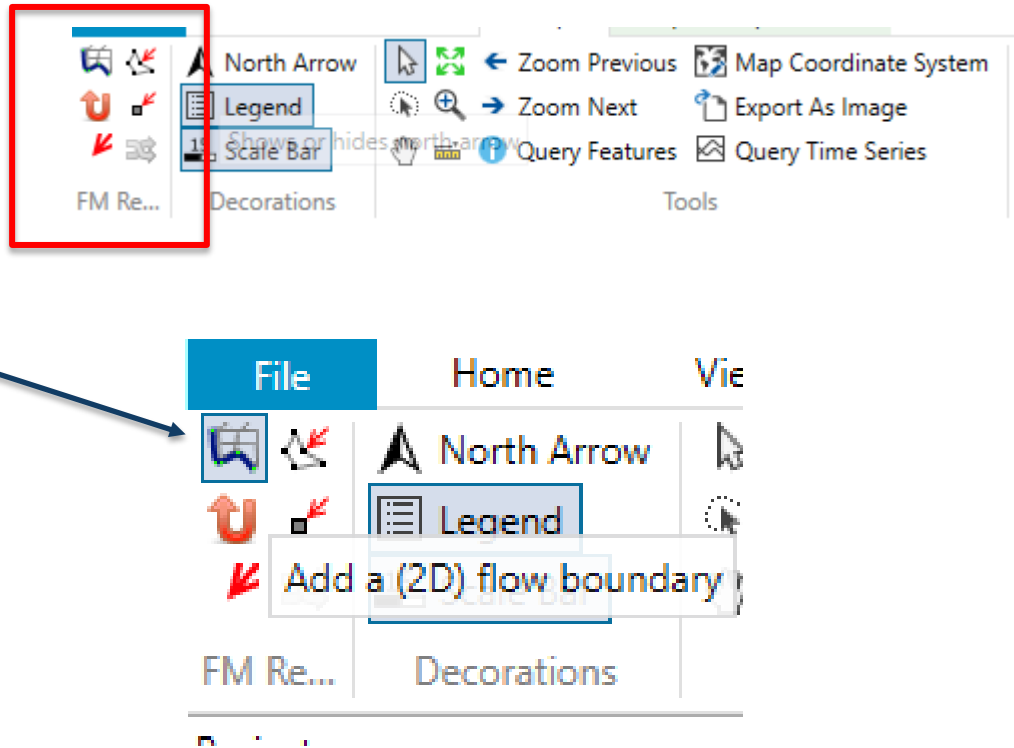



integral

Sandia National Laboratories

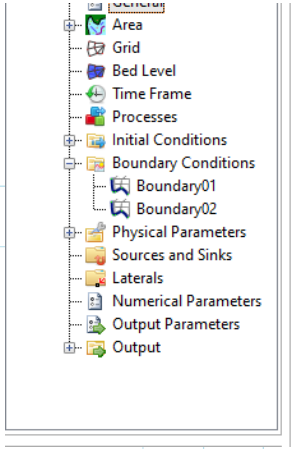
# Boundary Conditions

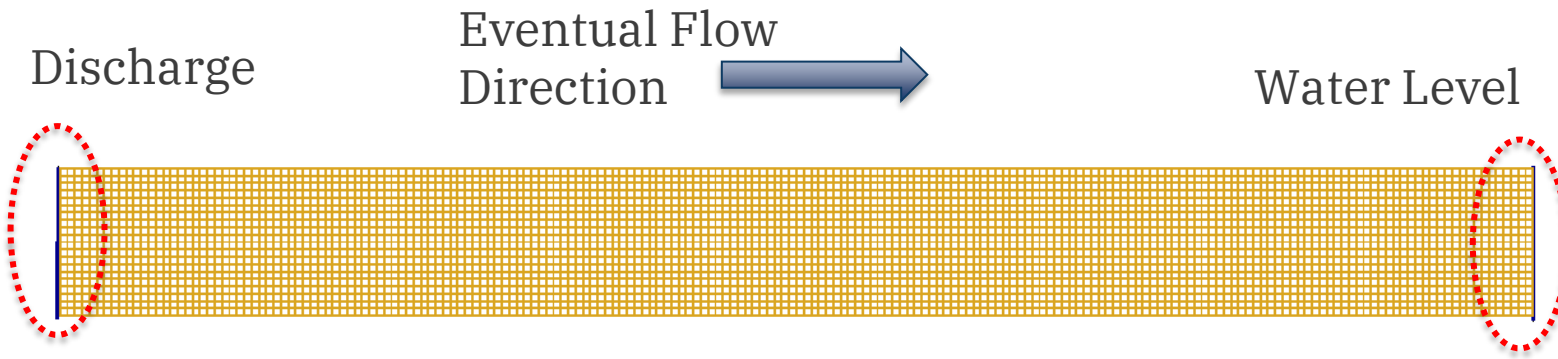
- Multiple boundary types can be applied.
- The 2D flow boundary (highlighted) is applies across grid cells for water level, discharge, or velocity
- Can be defined by drawing lines where boundaries are desired
  - Boundaries can have multiple points
  - Double click to end



# Boundary Conditions Ctd.

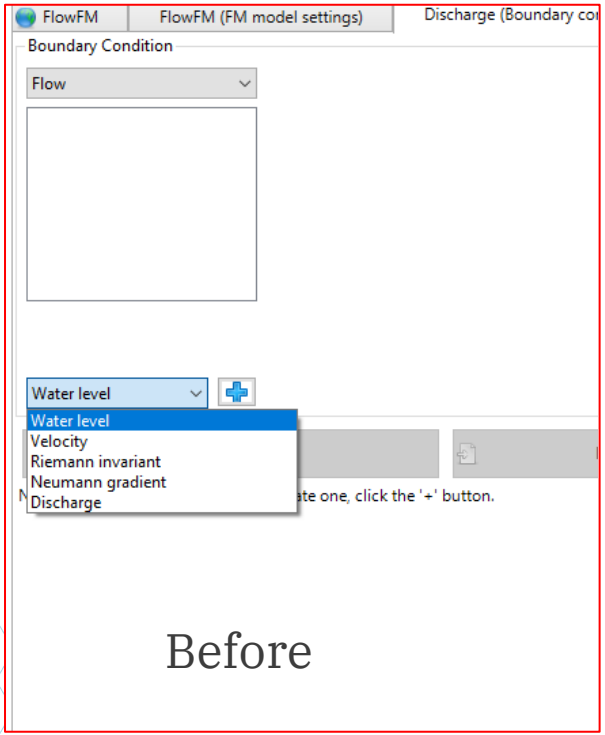
- Draw BCs along edges at left and right extents
  - They should be close but the program will snap them into place along grid edge
- Two entries in the left menu will appear (Boundary01 and Boundary02)



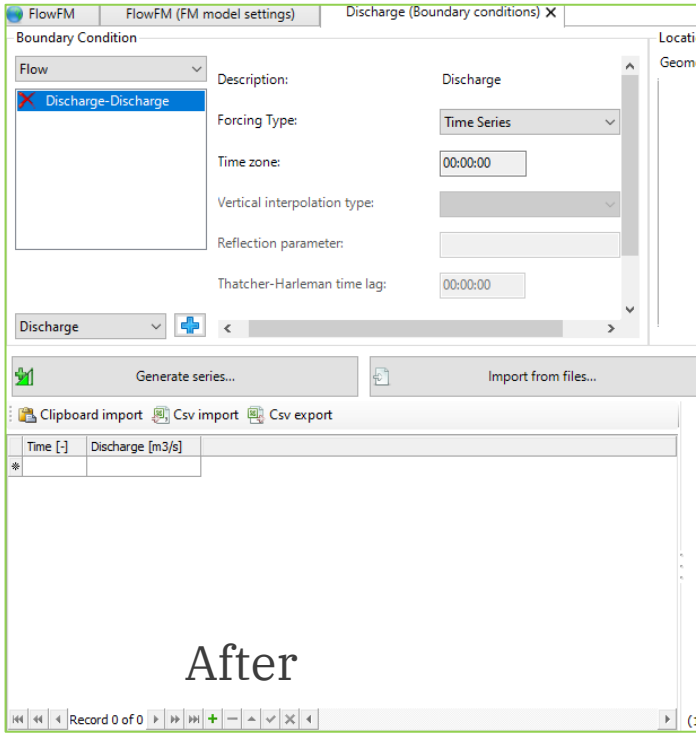



# Discharge  Boundary ( on Left).

- Open the first BC
- Select Discharge from menu and press the +
- A discharge boundary will provide flow across multiple points



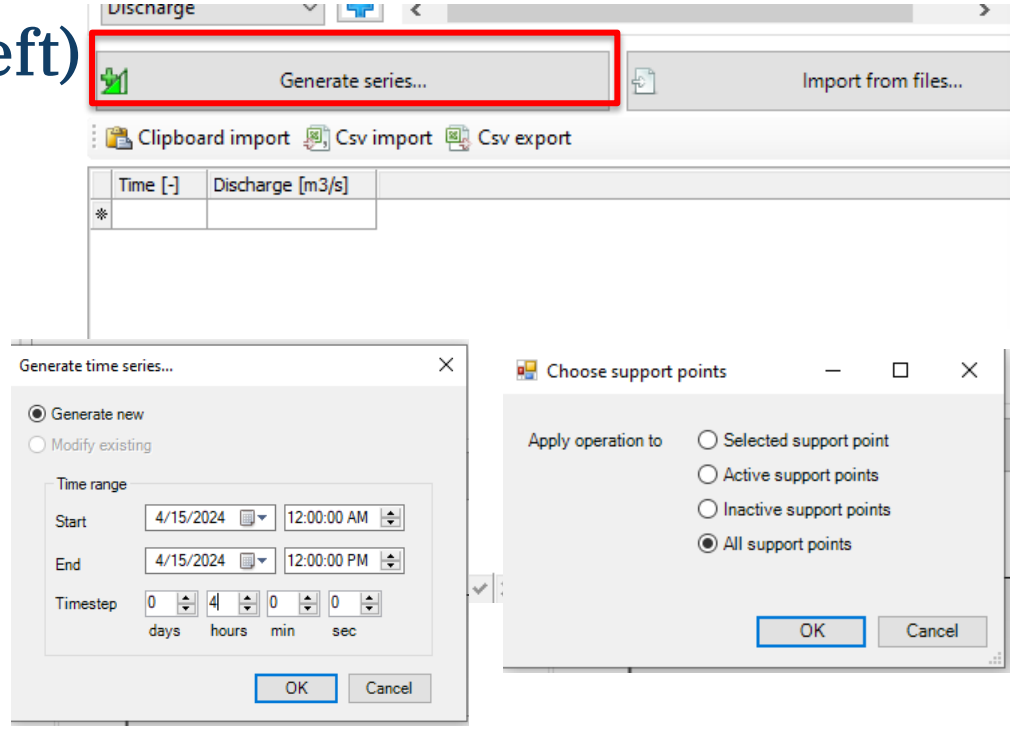

Before




After

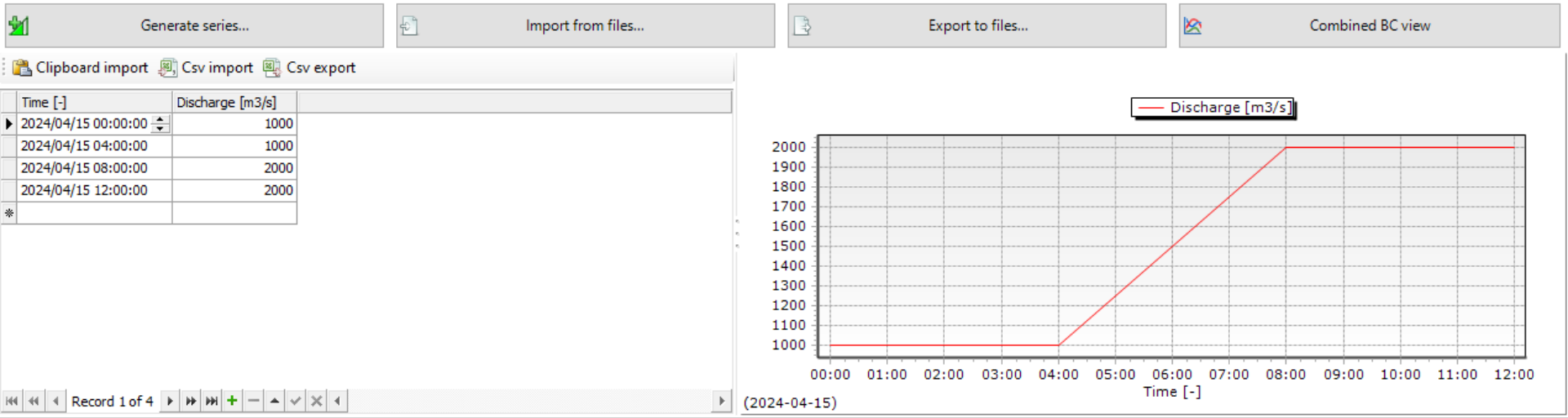
# Discharge Boundary (on left)

- A timeseries can be manually developed or imported from a file
- Generate a timeseries for 12 hours with 4 hour intervals.
- Select all support points to apply across entire boundary



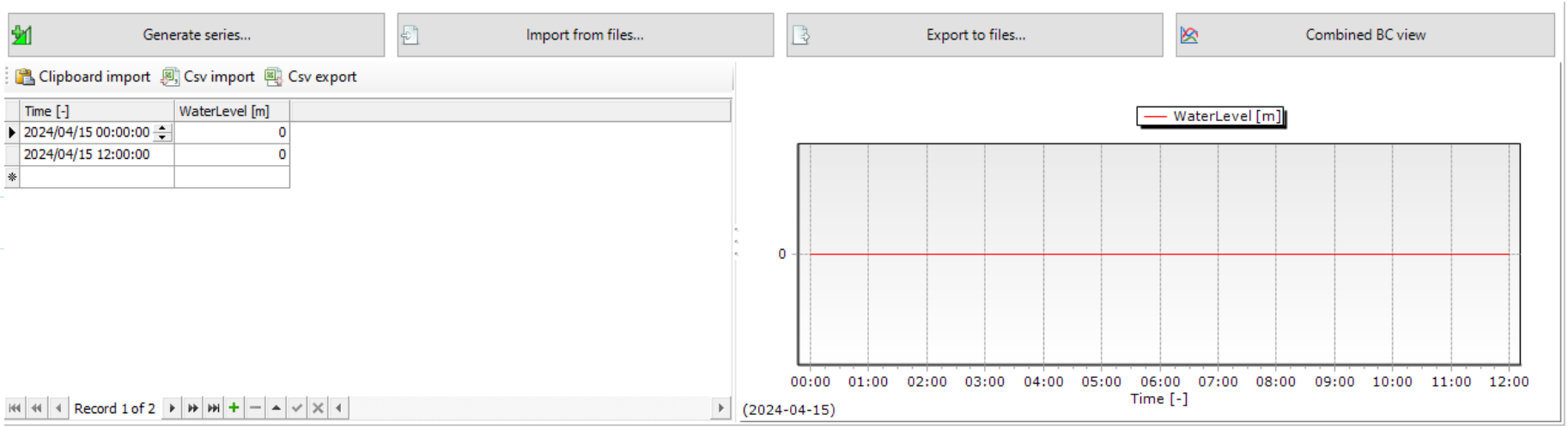
# Discharge BC applied

- After adding the timeseries you can assign values for discharge.
- 1000 m^3/s equals a 1 m/s vel and 2000 = 2 m/s vel in the channel



# Water Level BC

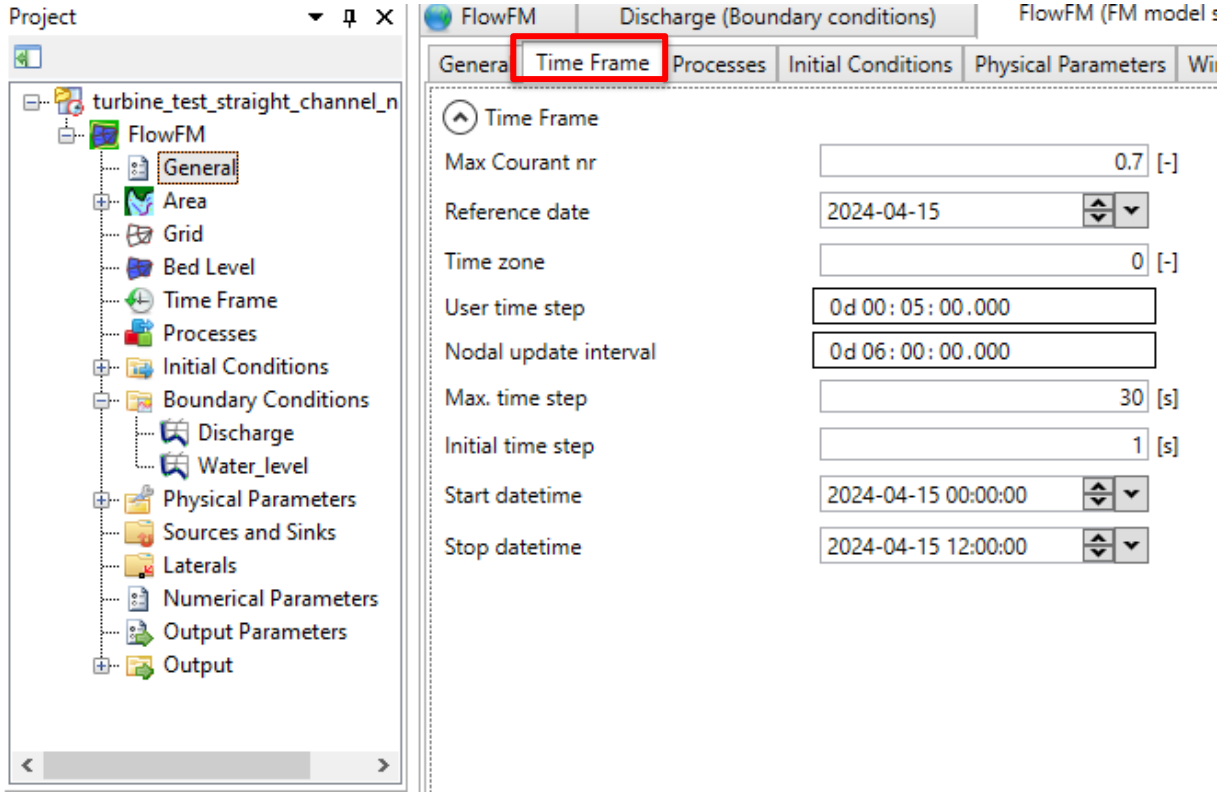
- Repeat the process on the downstream BC but select water level instead of discharge
- Set the water level to 0 for the duration of the model run.



# Model Settings

# Time Frame

- Set reference dates and start and stop
- Solver is dynamic and will select a timestep at each computation based on Courant threshold to maintain stability
  - This means the model run-time can be variable and slow down/speed up




integral

Sandia National Laboratories

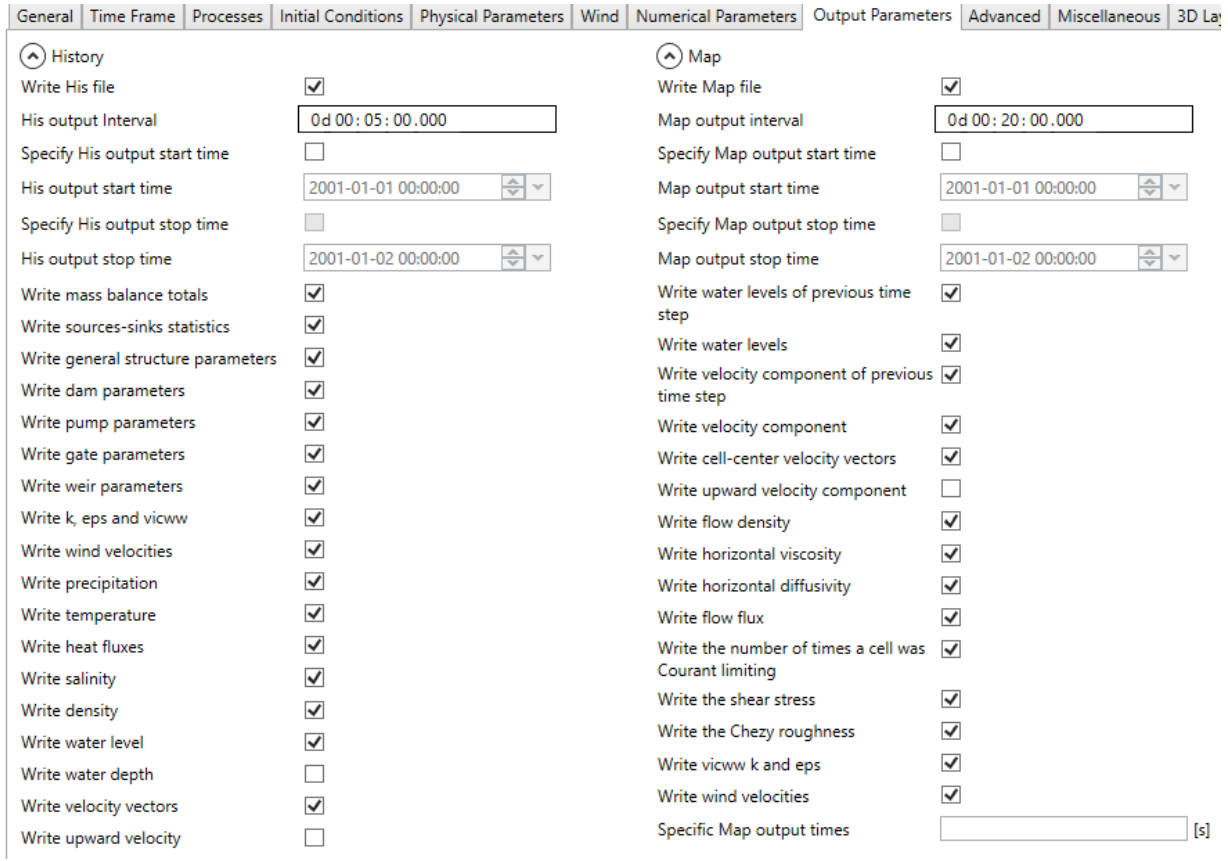
# Menu Options

- We can skip Processes, Initial Conditions, Physical parameters, and Numerical Parameters for now.

- However, each have key parameters for setting up sediment transport, global roughness, and initial water levels.

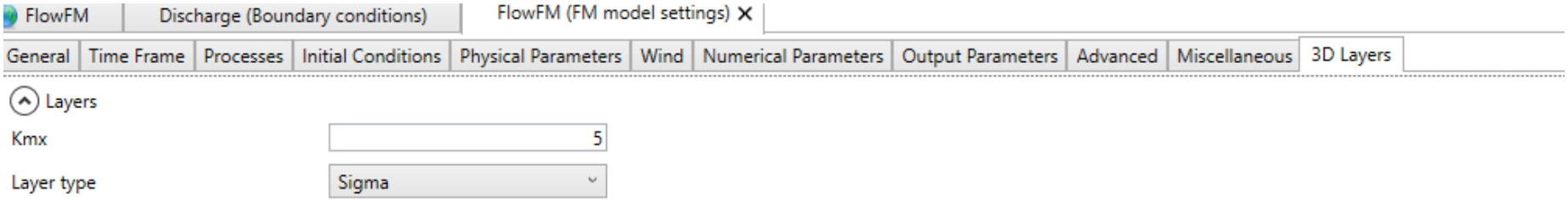
# Output Parameters

- Outputs are in NetCDF format
- His files are point or cross section locations (well define later)
- Map files are across entire grid
- Map files can get large so be mindful of what you are outputting



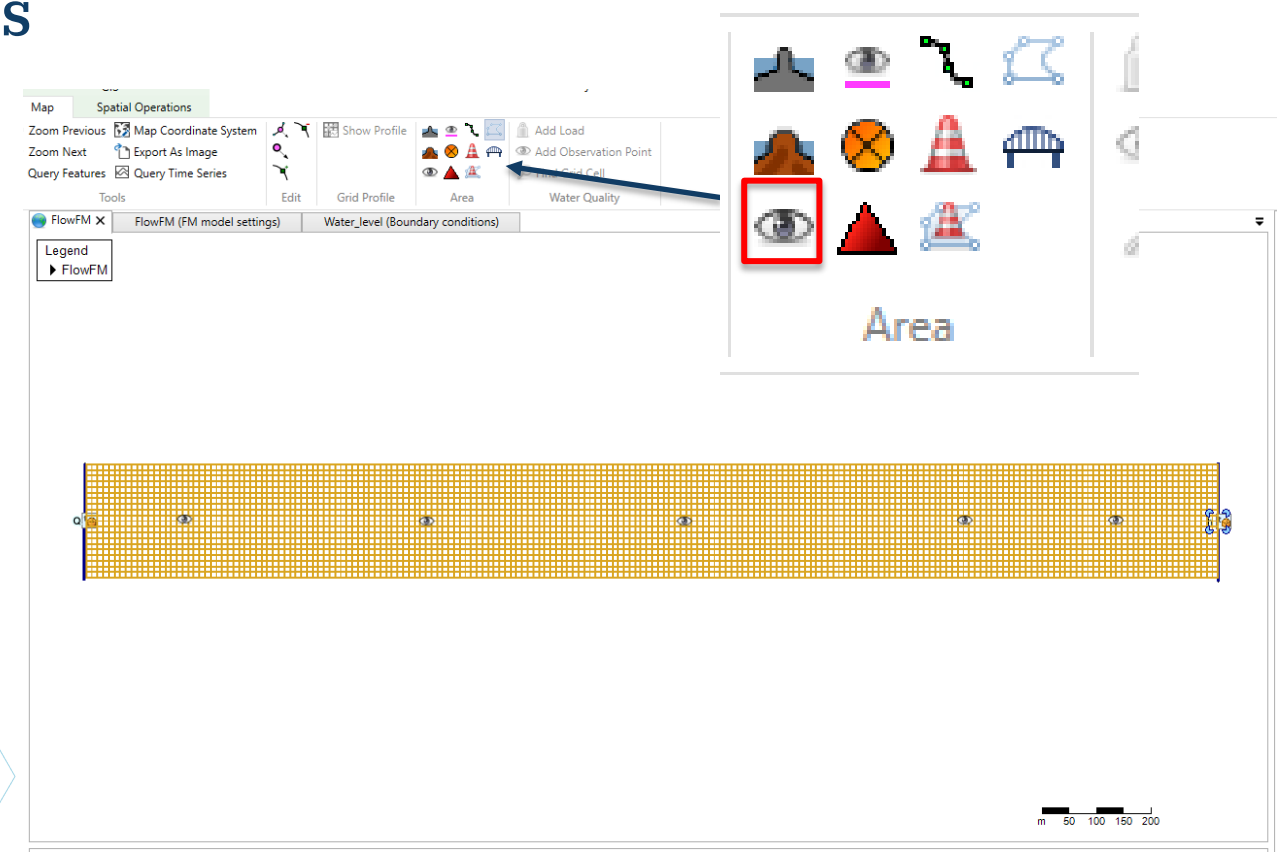
# 3D Layers

› Set the number of Sigma layers to 10. The turbine module will interact only with the layers it overlaps.



# Observation points

- Add observation points to determine where you want to see history file outputs
- We can use these as proxies for turbine locations later.



# Model is now set up to run without turbines

- The steps outlined above get us to a base model with relevant components
  - Unstructured grid
  - Basic bathymetry
  - Boundary conditions
- Save model in File-> Save as
  - Select a save location and check to make sure it created
    - .proj file
    - Project folder and a subfolder called FlowFM and in that a subfolder called input

# Turbine Application Procedures

- Requires two descriptor files for turbines
  - Curves.trb
  - Turbines.ini
- Copies should be provided in documentation
- Requires modification of .mdu file
  - .mdu file is master definition file for dflow-fm model runs
  - Found in project folder

# Modify .mdu file with turbine reference files

- The .mdu file is the master definition file for unstructured grids
- Open the file from the input folder in a text editor and copy

```
[Turbines]

TurbineFile = turbines.ini

CurvesFile  = curves.trb
```

- The two reference files contain the description of a basic set of turbines and a generic rating curve

```
230  WaterdepthClasses                = 0.0
231  ClassMapInterval                 = 0
232  StatsInterval                    =
233  TimingsInterval                  =
234  Richardsononoutput               = 1
235
236  [Turbines]
237  TurbineFile                      = turbines.ini
238  CurvesFile                       = curves.trb
```

# Turbine files

› Copy Turbines.ini and curves.trb into input directory

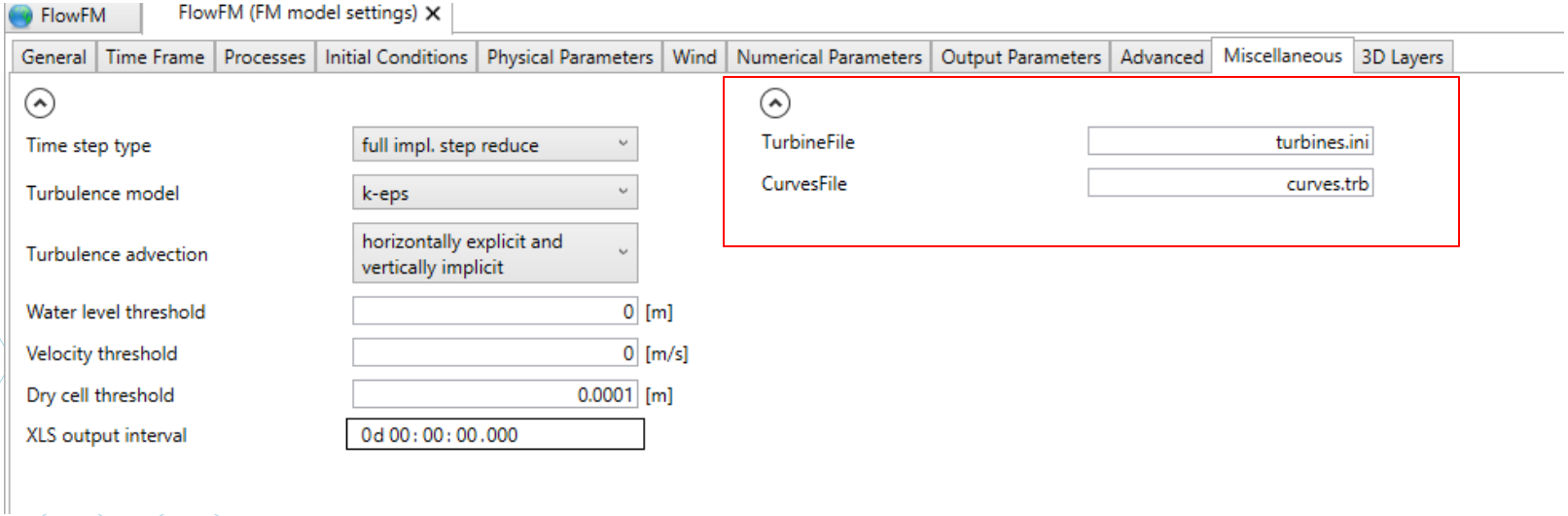
```
[TurbineFileInformation]
  FileVersion  = 01.00
[General]
  CurvesFil    = #curves.trb#
[Turbine]
    Name          = #Turbine1
    Turbtype      = 1
    Width         = 5
    Height        = 5
    XYLoc         = 250, 150
    Orientation   = 0
    VertPos       = #fixed#
    AxisLevel     = -5
    ThrustCurve   = #Turbine Type 1#
    PowerCurve    = #Turbine Type 1#
    NDiaDist4Vel  = 0.0
    TurbineModel  = 1
```

```
table-name          'Turbine Type 1      '
parameter           'velocity            '                    unit '[m/s]'
parameter           'thrust coefficient  '                    unit '[ - ]'
parameter           'power coefficient   '                    unit '[ - ]'
0.0     0.84    0.37
0.5     0.84    0.37
1.0     0.84    0.37
5.0     0.84    0.37
```

integral Sandia National Laboratories

# Reload model

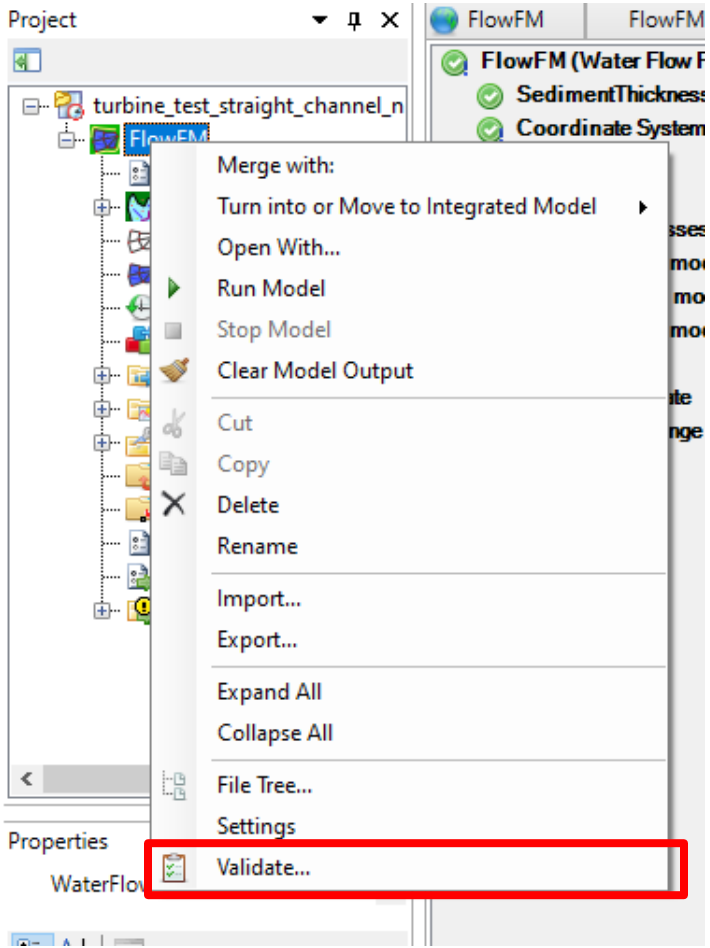
- Reloading the model will make sure the modification are included
- You can check that those files were included in the GUI in the Miscellaneous tab



# Run The Model

# Check the Model

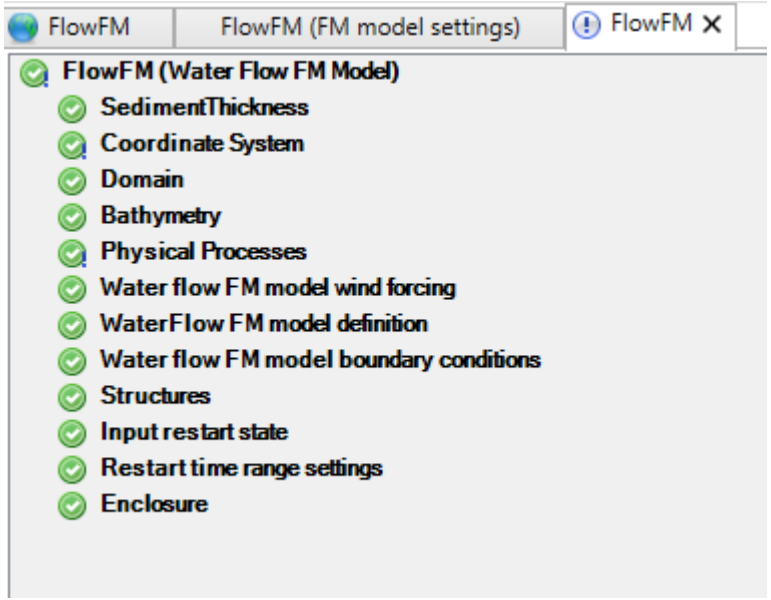
- We're ready to run the model
- A good check prior to executing is to "validate" first to make sure all settings are input
- Right Click on FlowFM and select validate




integral Sandia National Laboratories

# Results of Validation

- All check –boxes should be green
- Some may show as red if something is not properly set up and it will tell you what those are.
  - Common issues may be inconsistent timing of start/stop and boundary conditions
- Warnings with ! May also appear and you can select the item to evaluate why



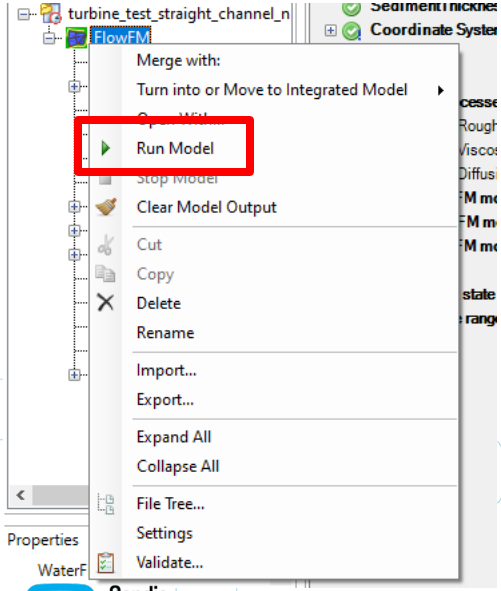

integral

Sandia National Laboratories

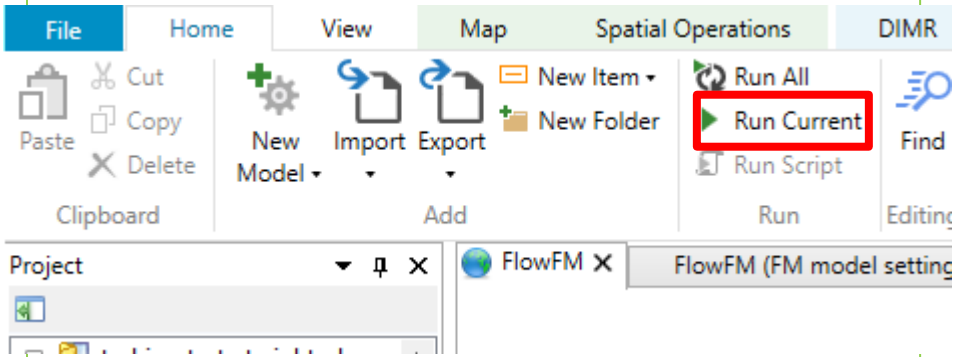
# Run the model

› 2 Ways to execute

› Right Click FlowFM and select run

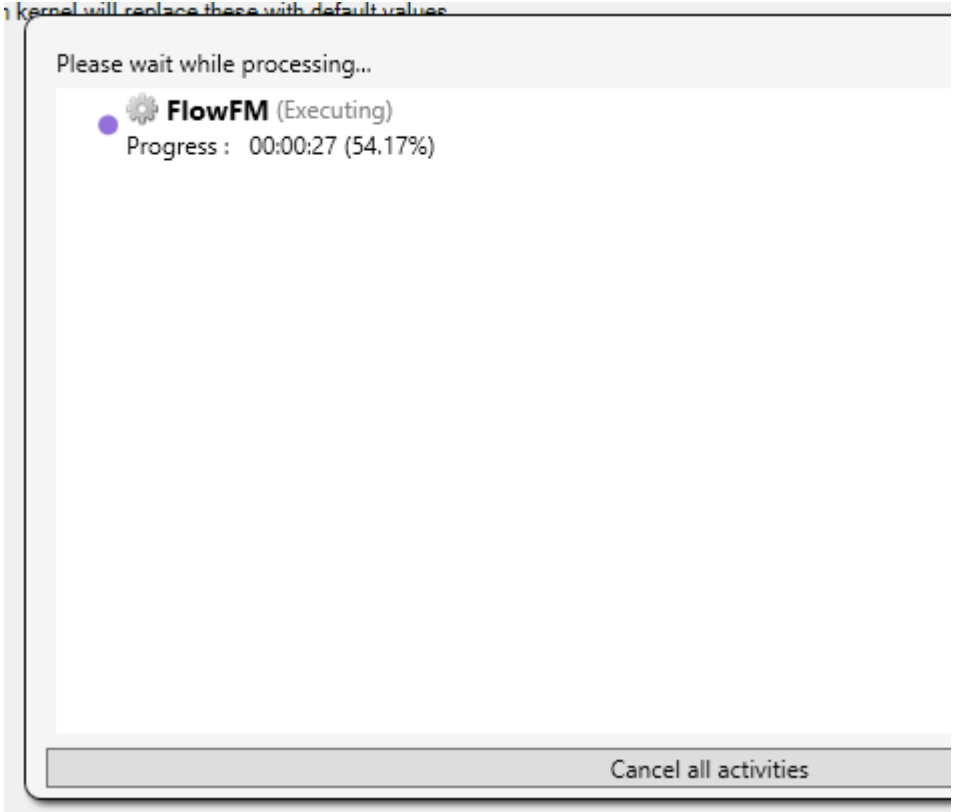



› In Home Menu select Run Current



# Model running

- If model is run from the GUI a box will appear showing progress
- NOTE: This is not the only way to run these models
- Models can be run with bash scripts, on linux, or other means.



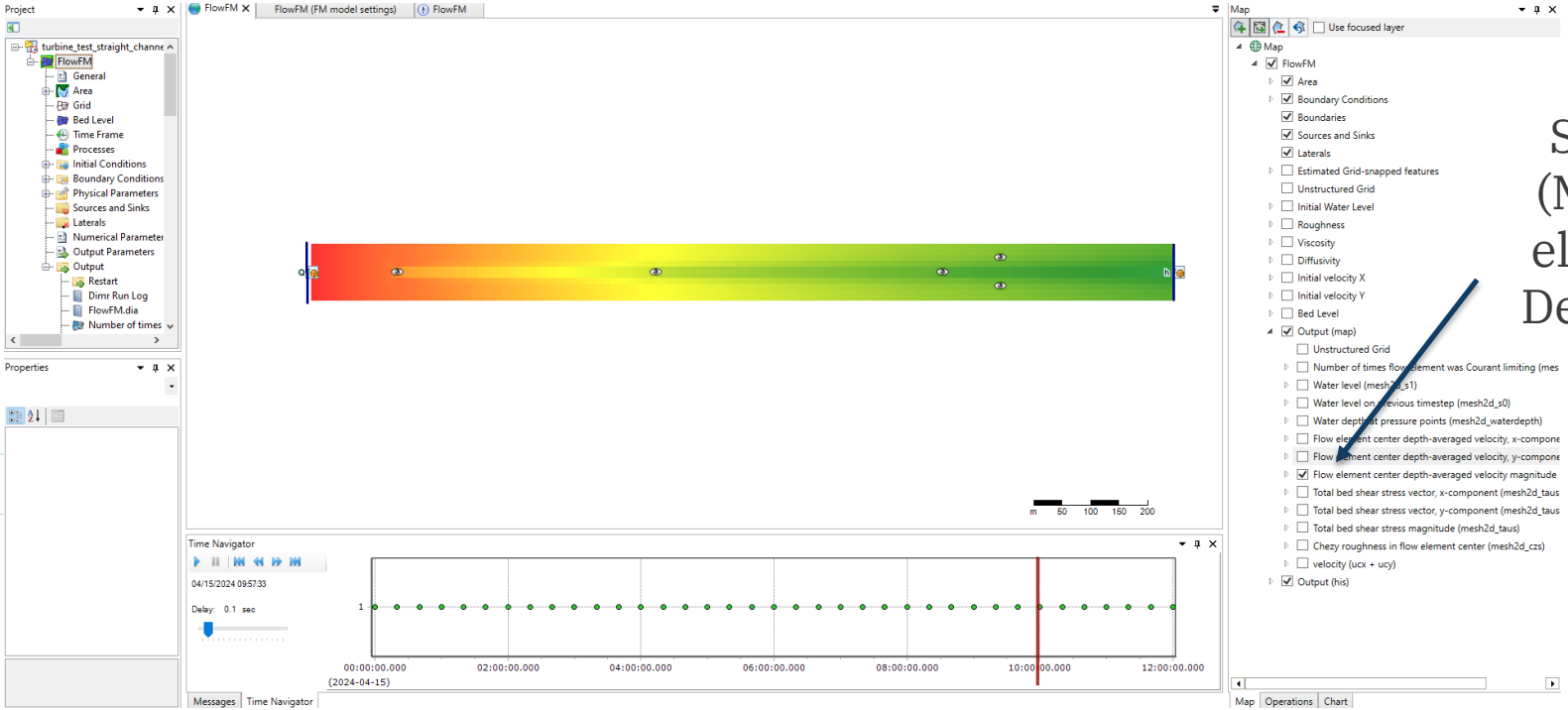

integral Sandia National Laboratories

# Success!!

- Model run was successful and results are displayed in GUI.
- Save model and results will be saved to an output folder in same location as the input folder

integral Sandia National Laboratories

# Influence of Turbines can be seen

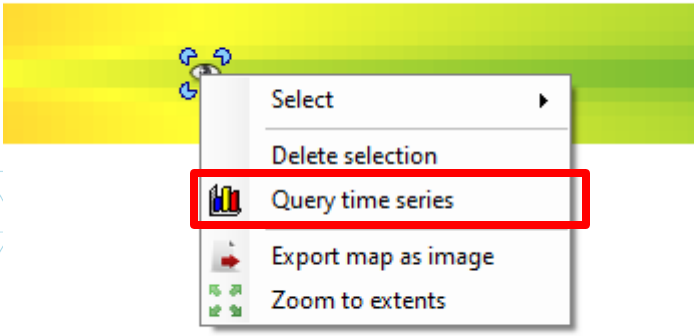


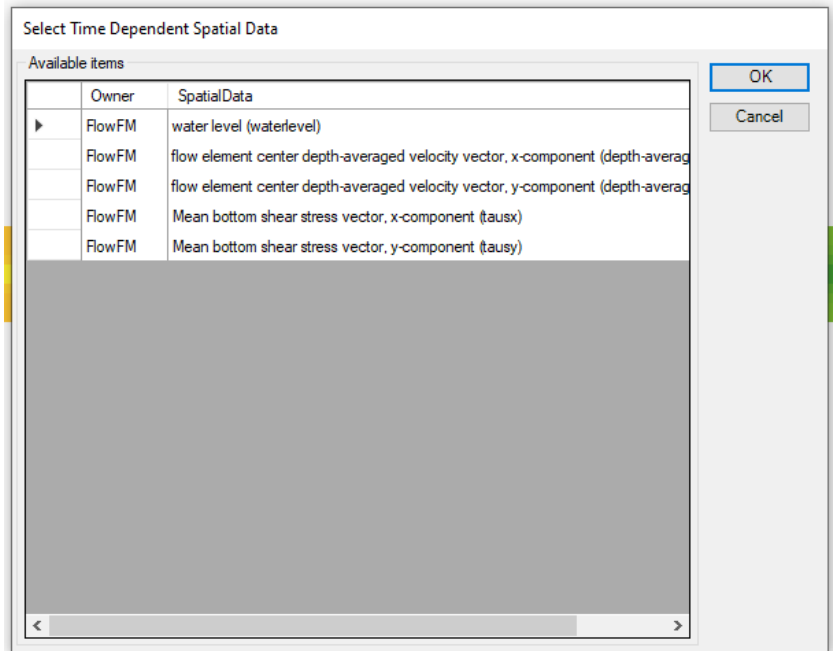

Select Output (Map and Flow element center Depth-averaged velocity magnitude

Time Navigator allows user to progress through time

# Observation Point results

- You can right click on an observation point to query a timeseries
  - Turbine data is not included in these but velocity, water levels, etc. are available

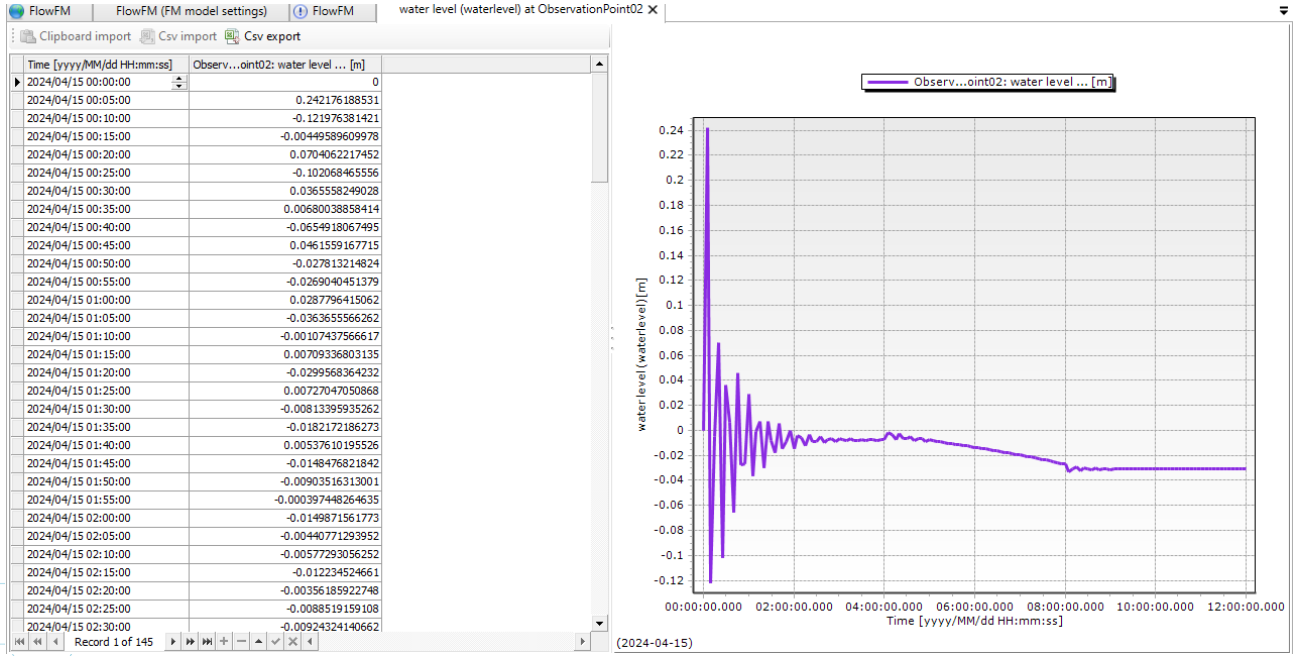



integral Sandia National Laboratories

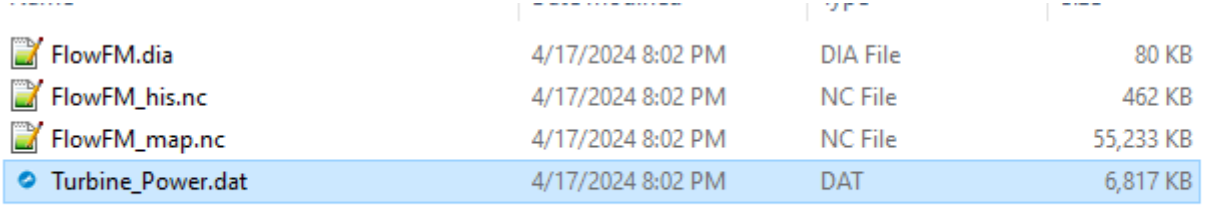
# Water level example

- Timeseries are available to see
- Note the instability in the beginning that may indicate the need for a ramp-up time



# Alternate Visualization methods

- The GUI is limited to only displaying depth-averaged results
- To show layers programs like Quickplot, or processing scripts in matlab or python are required
- Model outputs are in NETCDF and turbine power is recorded in a Turbine_Power.dat file that can be easily manipulated.




integral Sandia National Laboratories

# Power output for each turbine

- Power from each turbine at each timestep is recorded in the Turbine_Power.dat file

| Turb# | Time | Thrust | Power | Uref | Wetted Area | Ct | Cp |
|---|---|---|---|---|---|---|---|
| 1 | 0.0000000000000000 | 0.0000000000000000E+00 | 0.0000000000000000E+00 | 0.0000000000000000E+00 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 2 | 0.0000000000000000 | 0.0000000000000000E+00 | 0.0000000000000000E+00 | 0.0000000000000000E+00 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 3 | 0.0000000000000000 | 0.0000000000000000E+00 | 0.0000000000000000E+00 | 0.0000000000000000E+00 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 1 | 0.0000000000000000 | 0.0000000000000000E+00 | 0.0000000000000000E+00 | 0.0000000000000000E+00 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 2 | 0.0000000000000000 | 0.0000000000000000E+00 | 0.0000000000000000E+00 | 0.0000000000000000E+00 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 3 | 0.0000000000000000 | 0.0000000000000000E+00 | 0.0000000000000000E+00 | 0.0000000000000000E+00 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 1 | 1.0989010989010990 | 0.9929573077815315E-21 | 0.1345004238924315E-33 | 0.3075180688119970E-12 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 2 | 1.0989010989010990 | 0.7044709696428799E-81 | 0.8037526912410779E-124 | 0.2590221482794896E-42 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 3 | 1.0989010989010990 | 0.4826488871886338E-150 | 0.1441367589367935E-227 | 0.6779864355916849E-77 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 1 | 2.3041474654377883 | 0.7288121352469331E-17 | 0.8457678677300453E-28 | 0.2634590661703009E-10 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 2 | 2.3041474654377883 | 0.5330134699143993E-72 | 0.1672765508392501E-110 | 0.7124828953097413E-38 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 3 | 2.3041474654377883 | 0.4608265053531002E-135 | 0.4252398576888710E-205 | 0.2094951994797427E-69 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 1 | 3.6272401433691757 | 0.1075278869301762E-13 | 0.4793022366085397E-23 | 0.1011965964655297E-08 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 2 | 3.6272401433691757 | 0.3161212682897435E-64 | 0.7640263940759601E-99 | 0.5486965231907894E-34 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 3 | 3.6272401433691757 | 0.1806895247951000E-122 | 0.3301621257210782E-186 | 0.4148316064496762E-63 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 1 | 5.0800477897252092 | 0.5524133399341607E-11 | 0.5581154240685581E-19 | 0.2293704302638940E-07 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 2 | 5.0800477897252092 | 0.3885944572465936E-57 | 0.3292855636454163E-88 | 0.1923772229975446E-30 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 3 | 5.0800477897252092 | 0.7448999057350654E-111 | 0.8739260146785238E-169 | 0.2663509867923232E-57 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 1 | 6.6742096935645323 | 0.1219908625167943E-08 | 0.1831549840888055E-15 | 0.3408544760238868E-06 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 2 | 6.6742096935645323 | 0.1229536017357804E-50 | 0.1853274163749406E-78 | 0.3421968268698452E-27 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |
| 3 | 6.6742096935645323 | 0.8099135095142526E-100 | 0.3133182940110177E-152 | 0.8782631721399819E-52 | 0.2500000000000000E+02 | 0.8400000000000000E+00 | 0.3700000000000000E+00 |

integral Sandia National Laboratories

# Next Steps

- Try to manipulate the inputs
  - Boundary condition discharge rate/ water level
  - Turbine parameters-turbines.ini
  - Number of turbines –turbines.ini
  - Modify power curve – curves.trb

integral

Sandia National Laboratories