

# Simple Channel Setup

Dflow-FM-CEC application

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5/1/2024

Current energy converter modeling



# Develop Simple channel with turbines

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**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**

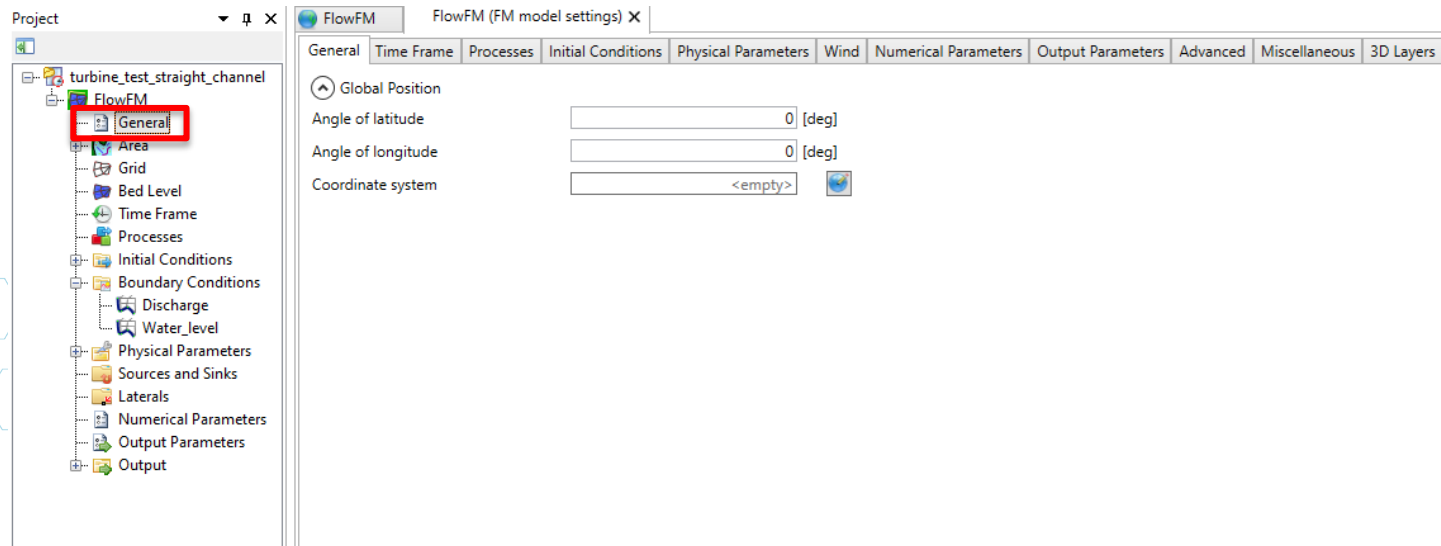
# GUI Walkthrough

1) Menu to access GUI features

The screenshot displays the FlowFM software interface. The top menu bar includes 'File', 'Home', 'View', 'Map', and 'Spatial Operations'. The 'Map' menu is open, showing options like 'North Arrow', 'Zoom Previous', 'Zoom Next', 'Map Coordinate System', 'Export As Image', 'Query Features', 'Query Time Series', 'Show Profile', 'Grid Profile', 'Area', and 'Water Quality'. A callout box labeled '3) Spatial actions menu bar' points to this menu. The main map area shows a grid and features, with a callout box labeled '2) Map showing grid, and features ID'd on right ->'. The right panel shows the 'Map' layer settings, including 'FlowFM', 'Area', 'Boundary Conditions', 'Boundaries', 'Sources and Sinks', 'Laterals', and 'Estimated Grid-snapped features'. A callout box labeled '4) Map Display Layers' points to this panel. The bottom panel shows the 'Messages' window with a list of messages, including 'Project turbine\_test\_straight\_channel saved', 'During import of data from the External Forcing file the following warnings were reported:', 'No spatial operations of type Import, Add or Value found for spatially varying property sand\_channel\_SedConc. Remember to interpolate them to generate the xyz file. Otherwise the model might not run.', 'Saving project turbine\_test\_straight\_channel as C:\Users\smcwilliams74\Desktop\simple\_channel\_turbines\turbine\_test\_straight\_channel.dsp', 'Wall clock "FlowFM": Start time: 15-Apr-2024 14:22:26.', 'Model "FlowFM" has finished in 144 steps.', 'Path used: C:\Program Files\Deltares\DeltaR3D FM Suite 2024.01 HMWQ\plugins\DeltaShell\Dimr\kernels\v64\flowfm\bin\C:\Program Files\Deltares\DeltaR3D FM Suite 2024.01 HMWQ\plugins\DeltaShell.C', 'Running dimr in : C:\Users\smcwilliams74\AppData\Local\Temp\DeltaShell\_Working\_Directory\FlowFM', and 'During import of data from the External Forcing file the following warnings were reported:'. A callout box labeled '5) Messages indicating success, warning, and errors' points to this panel.

# Tabs and menus

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

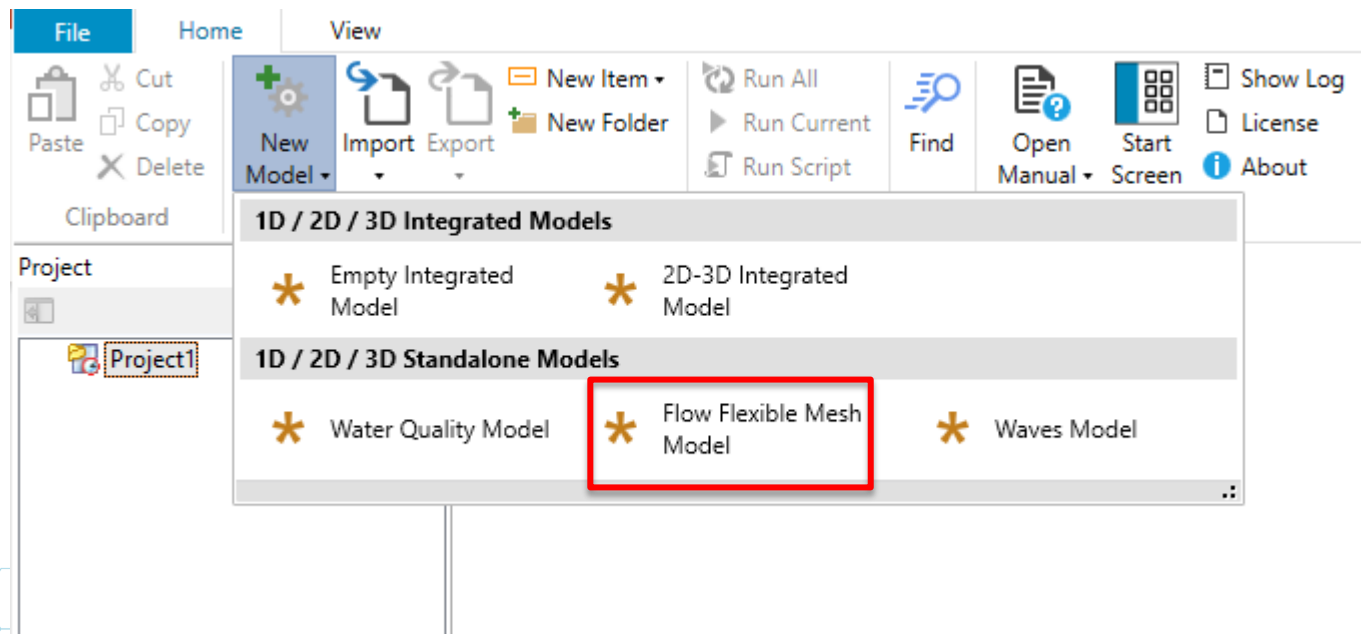


# Building Basic Channel



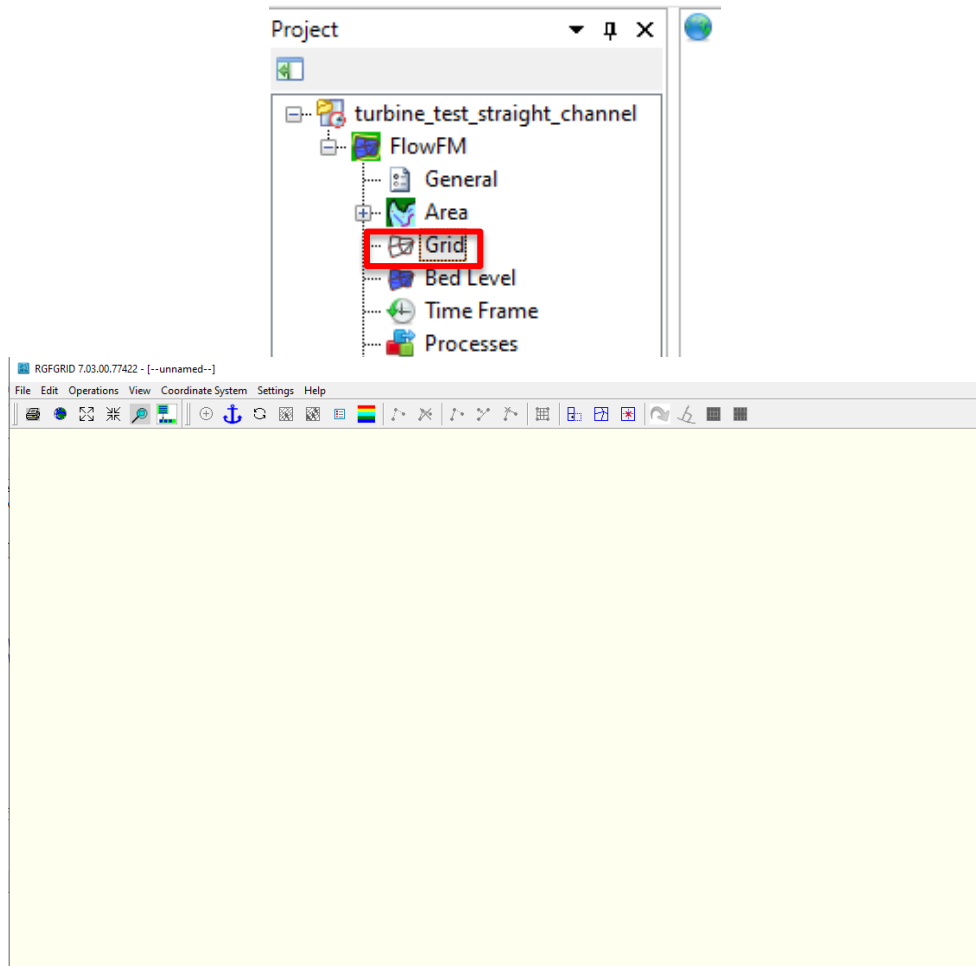
# Start a new model

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



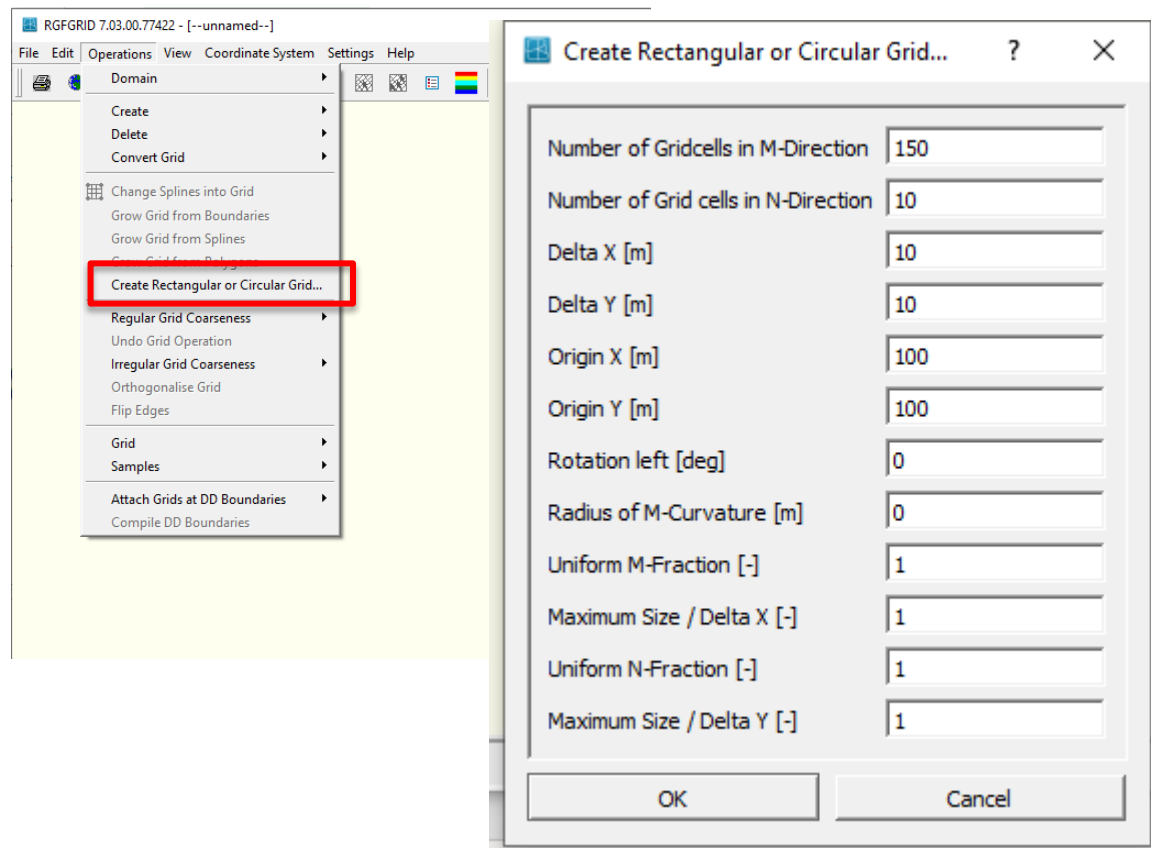
# Grid Development

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



# Generate a simple Rectangular Grid

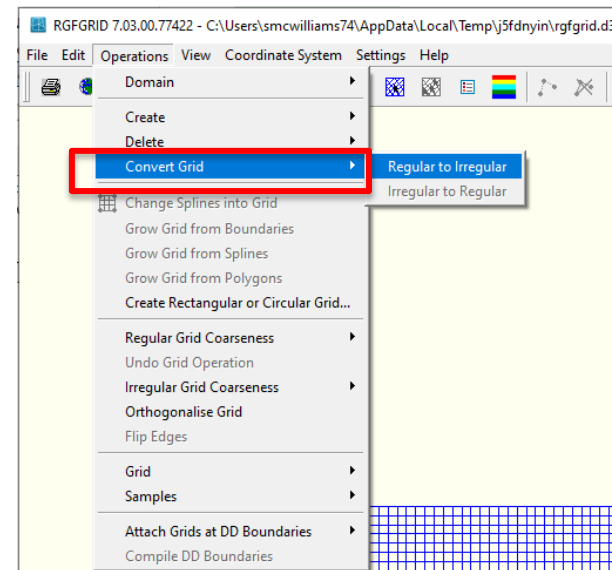
- Simple grids can be generated by defining the number and size of cells.



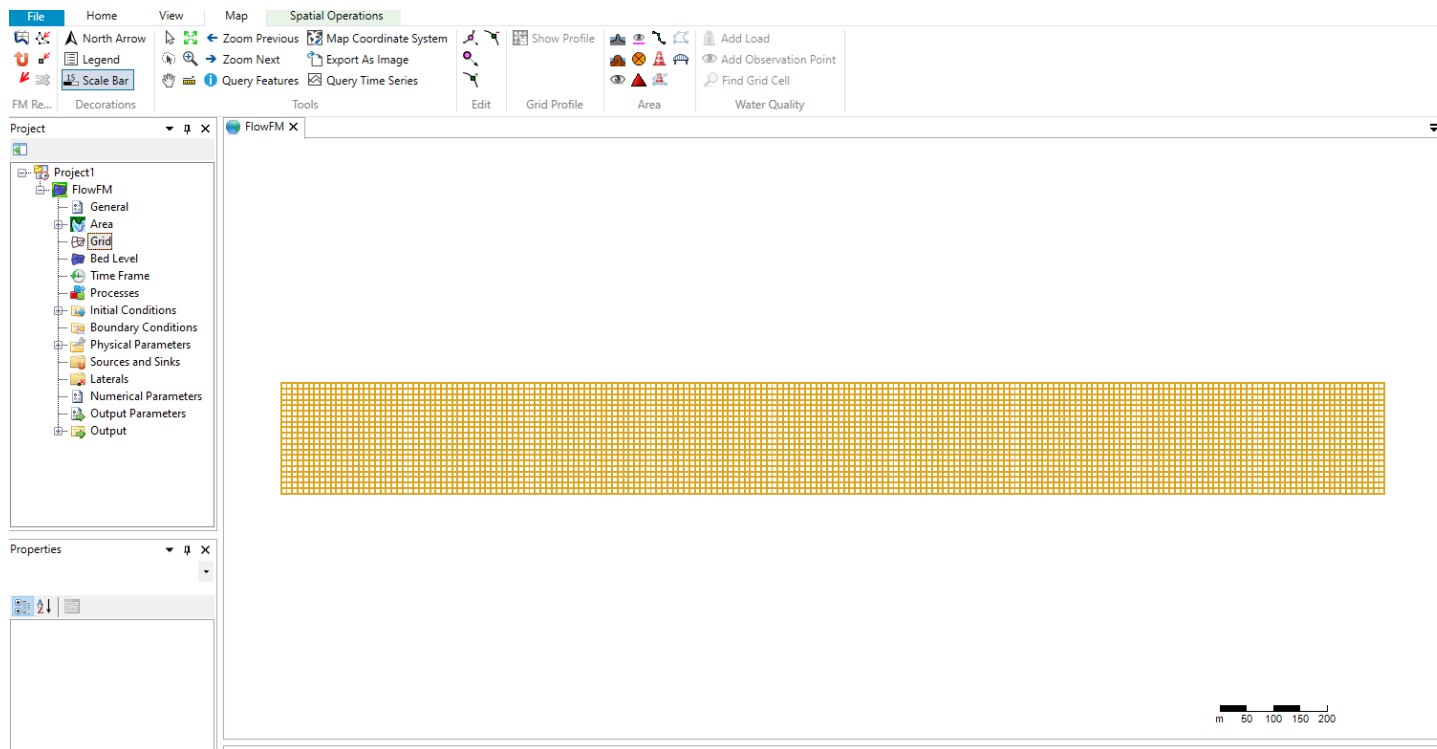


# Convert from a structured to unstructured grid

- 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**



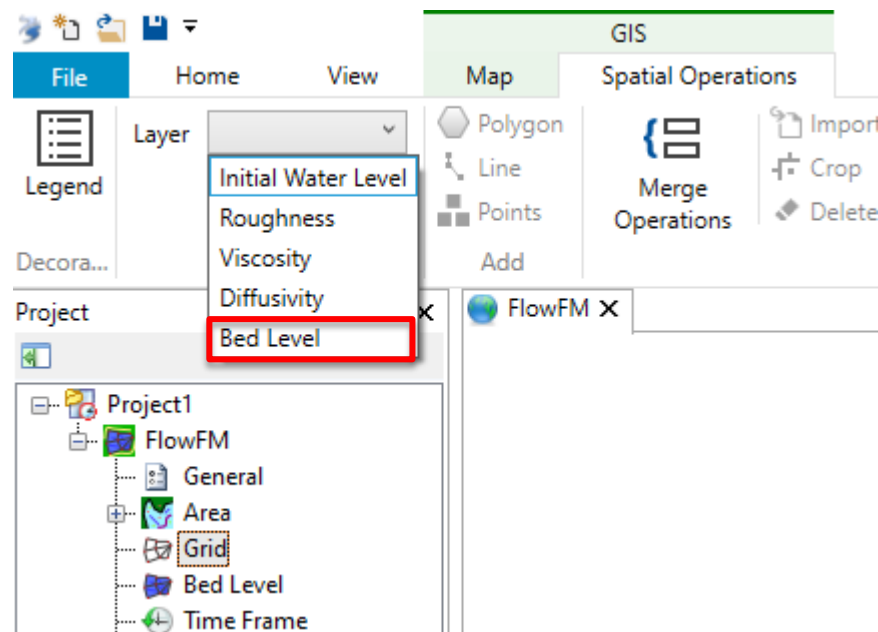
# Grid will appear in Map view of GUI



# 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

The screenshot displays the FlowFM software interface. In the top right, the 'Interpolation operation' dialog box is open, showing 'Value' set to -10 and 'Pointwise operation' set to 'Overwrite'. An arrow points from the 'Set Value' tool in the GIS toolbar to this dialog box. The GIS toolbar is located in the center, with 'Set Value' highlighted. The 'Project' panel on the left shows a tree view with 'FlowFM' and 'General' selected. The main map area shows a grid of yellow squares within a red rectangular boundary. The 'Properties' panel at the bottom left is empty. A scale bar at the bottom right indicates distances in meters (0, 50, 100, 150, 200).

# Bathymetry Application Success

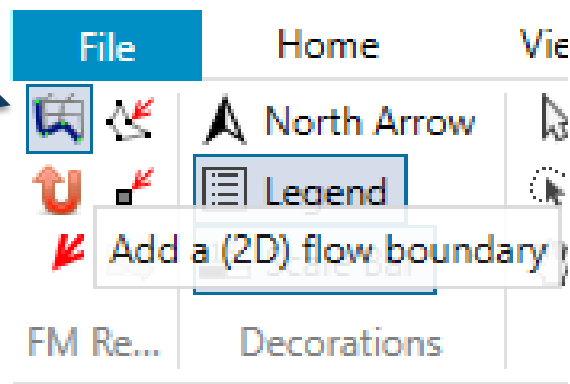
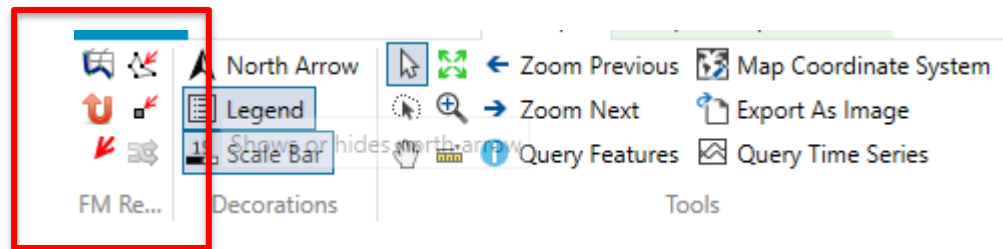
The screenshot displays the Bathymetry Application Success interface. The main map area is a solid blue rectangle. The interface includes several toolbars and panels:

- Top Toolbar:** Contains tabs for File, Home, View, Map, and Spatial Operations. The Map tab is active, showing tools like North Arrow, Zoom Previous, Zoom Next, Export As Image, Scale Bar, Query Features, Query Time Series, Show Profile, Add Load, Add Observation Point, Find Grid Cell, and Water Quality.
- Project Panel (Left):** Shows a tree view of the project structure. The 'FlowFM' folder is expanded, showing sub-items like General, Area, Grid, Bed Level, Time Frame, Processes, Initial Conditions, Boundary Conditions, Physical Parameters, Sources and Sinks, Laterals, Numerical Parameters, Output Parameters, and Output.
- Legend (Top Left):** A legend box for the 'FlowFM' layer, showing 'Bed Level' with a color scale from -10 to -10.
- Map Panel (Right):** A panel showing the map layers. The 'FlowFM' layer is selected, and the 'Initial velocity Y' checkbox is checked. Other layers include Area, Boundary Conditions, Boundaries, Sources and Sinks, Laterals, Estimated Grid-snapped features, Unstructured Grid, Initial Water Level, Roughness, Viscosity, Diffusivity, Initial velocity X, and Bed Level.
- Properties Panel (Bottom Left):** A panel for viewing the properties of the selected layer.
- Scale Bar (Bottom Right):** A scale bar indicating distances in meters (m), with markings for 50, 100, 150, and 200.

# Boundary Conditions

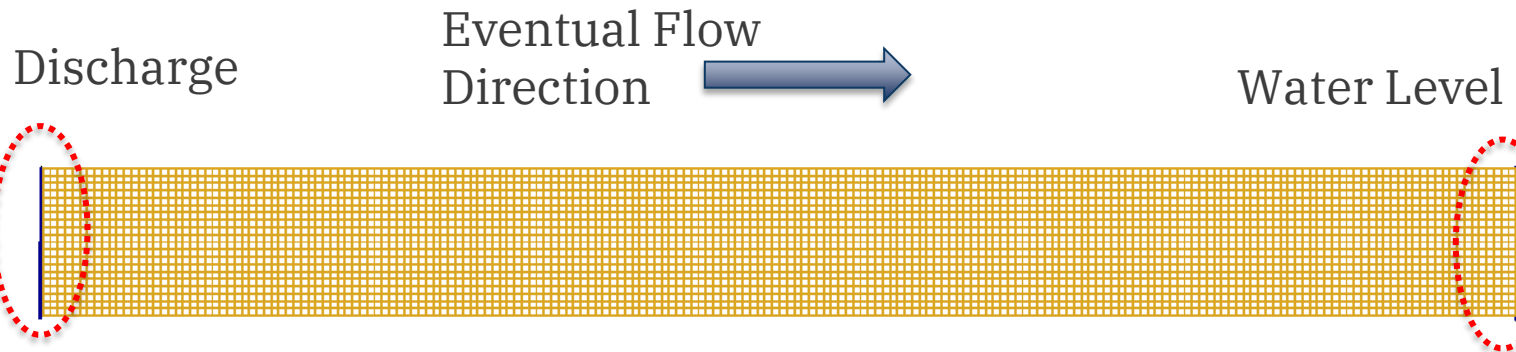
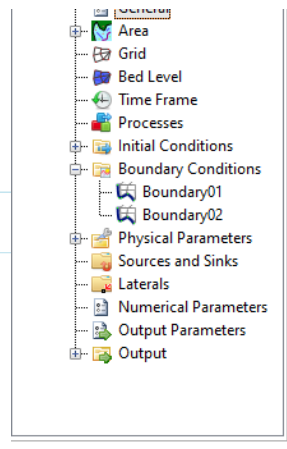
- Multiple boundary types can be applied.
- The 2D flow boundary (highlighted) is applied across grid cells for water level, discharge, or velocity
- Can be defined by drawing lines where boundaries are desired

- Boundaries can have multiple points
- Double click to end



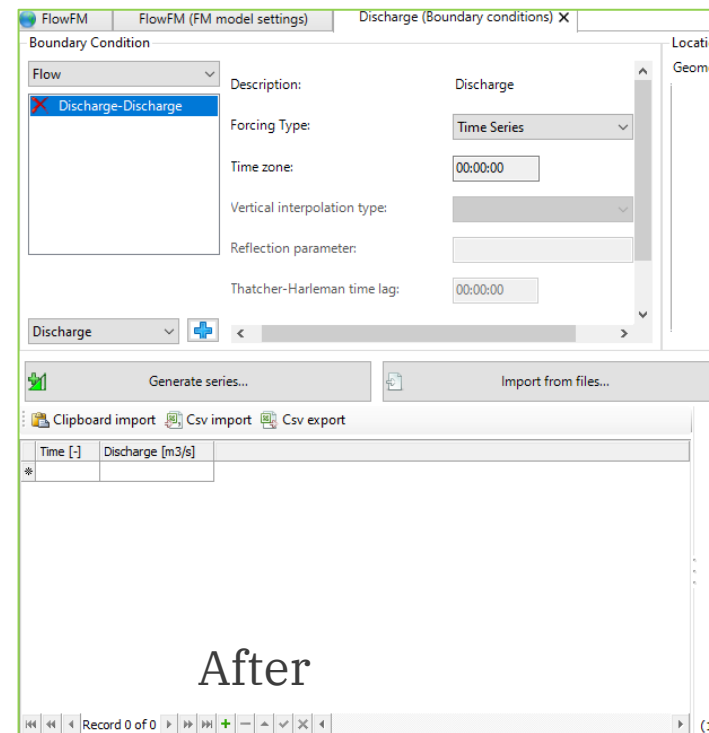
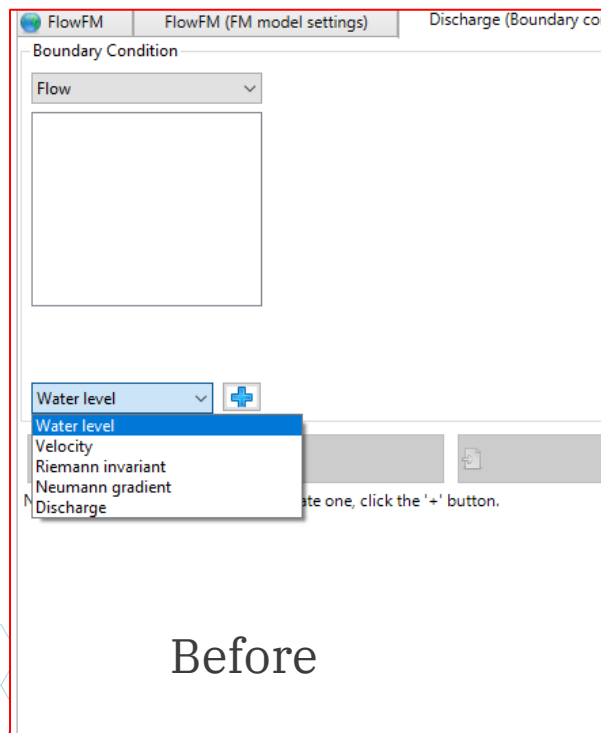
# Boundary Conditions Ctd.

- › 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).

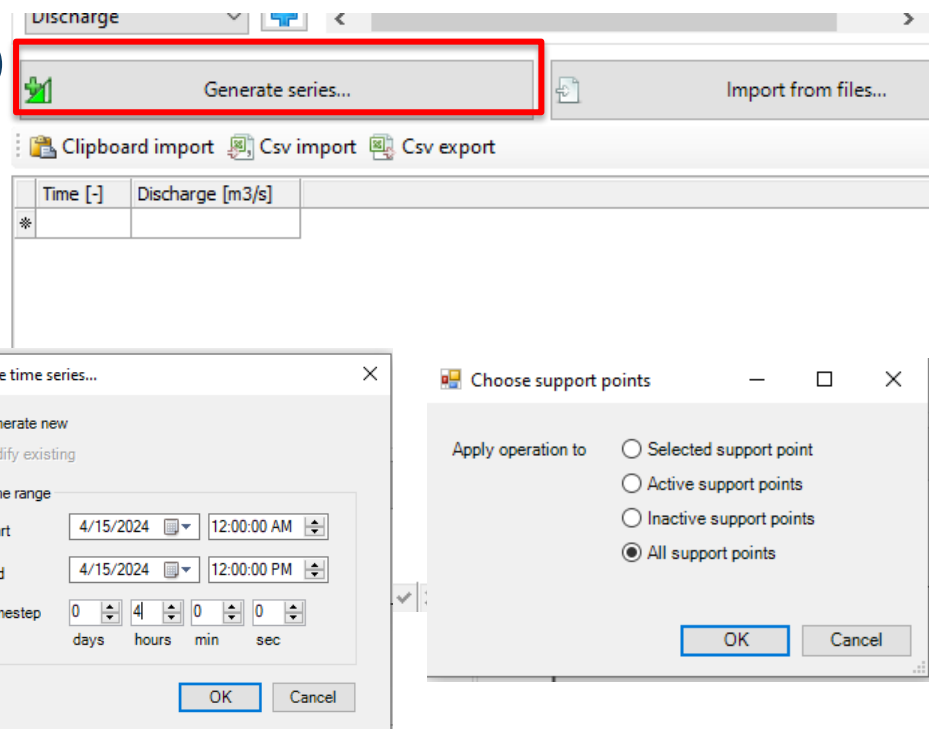
- › Open the first BC
- › Select Discharge from menu and press the +
- › A discharge boundary will provide flow across multiple points





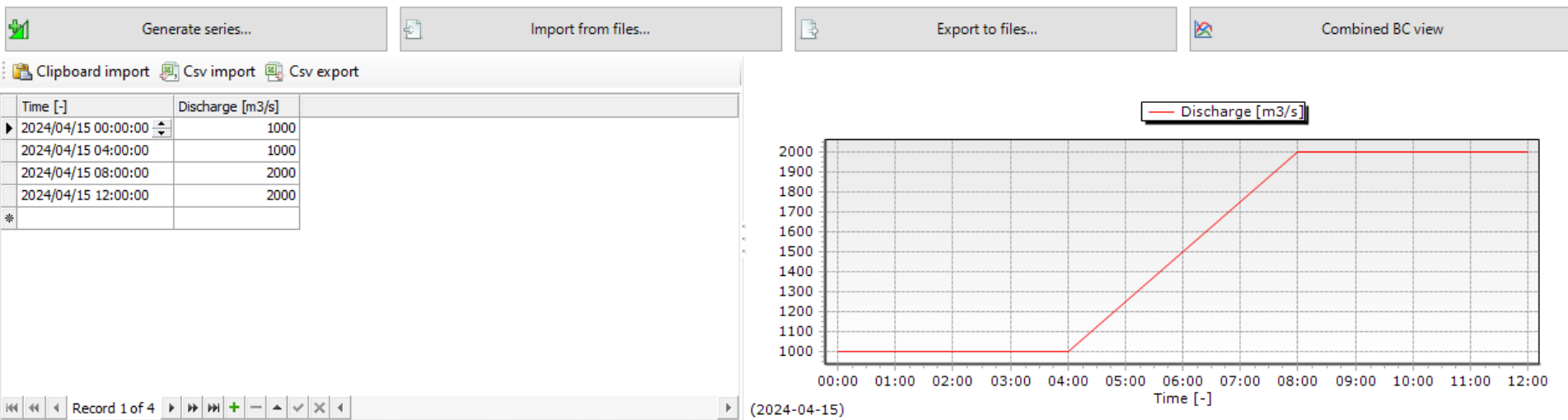
# Discharge Boundary (on left)

- › 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



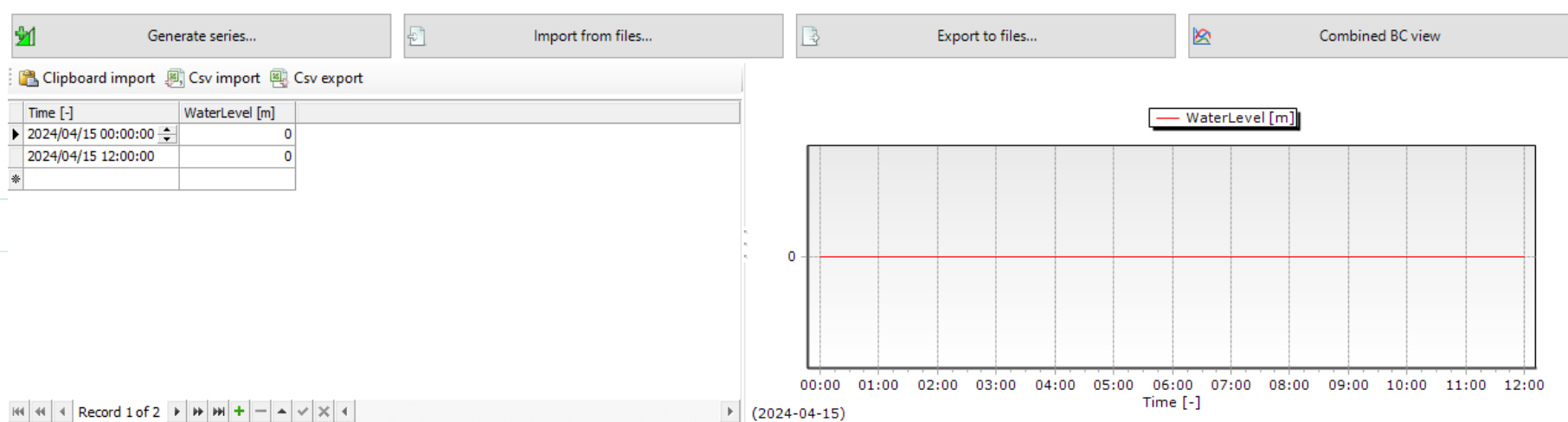
# Discharge BC applied

- › After adding the timeseries you can assign values for discharge.
- ›  $1000 \text{ m}^3/\text{s}$  equals a  $1 \text{ m/s}$  vel and  $2000 = 2 \text{ m/s}$  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

The screenshot displays the FlowFM software interface. On the left is a project tree for 'turbine\_test\_straight\_channel\_n'. The 'FlowFM' folder is expanded, showing sub-items: General, Area, Grid, Bed Level, Time Frame, Processes, Initial Conditions, Boundary Conditions, Discharge, Water\_level, Physical Parameters, Sources and Sinks, Laterals, Numerical Parameters, Output Parameters, and Output. The 'Time Frame' item is highlighted. On the right, the 'Time Frame' tab is active in the settings panel. It contains the following parameters:

Parameter	Value	Units
Max Courant nr	0.7	[-]
Reference date	2024-04-15	
Time zone	0	[-]
User time step	0d 00:05:00.000	
Nodal update interval	0d 06:00:00.000	
Max. time step	30	[s]
Initial time step	1	[s]
Start datetime	2024-04-15 00:00:00	
Stop datetime	2024-04-15 12:00:00	

# Menu Options

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- › 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

General	Time Frame	Processes	Initial Conditions	Physical Parameters	Wind	Numerical Parameters	Output Parameters	Advanced	Miscellaneous	3D La
^ History Write His file <input checked="" type="checkbox"/> His output Interval 0d 00: 05: 00.000 Specify His output start time <input type="checkbox"/> His output start time 2001-01-01 00:00:00 Specify His output stop time <input type="checkbox"/> His output stop time 2001-01-02 00:00:00 Write mass balance totals <input checked="" type="checkbox"/> Write sources-sinks statistics <input checked="" type="checkbox"/> Write general structure parameters <input checked="" type="checkbox"/> Write dam parameters <input checked="" type="checkbox"/> Write pump parameters <input checked="" type="checkbox"/> Write gate parameters <input checked="" type="checkbox"/> Write weir parameters <input checked="" type="checkbox"/> Write k, eps and vicww <input checked="" type="checkbox"/> Write wind velocities <input checked="" type="checkbox"/> Write precipitation <input checked="" type="checkbox"/> Write temperature <input checked="" type="checkbox"/> Write heat fluxes <input checked="" type="checkbox"/> Write salinity <input checked="" type="checkbox"/> Write density <input checked="" type="checkbox"/> Write water level <input checked="" type="checkbox"/> Write water depth <input type="checkbox"/> Write velocity vectors <input checked="" type="checkbox"/> Write upward velocity <input type="checkbox"/>						^ Map Write Map file <input checked="" type="checkbox"/> Map output interval 0d 00: 20: 00.000 Specify Map output start time <input type="checkbox"/> Map output start time 2001-01-01 00:00:00 Specify Map output stop time <input type="checkbox"/> Map output stop time 2001-01-02 00:00:00 Write water levels of previous time step <input checked="" type="checkbox"/> Write water levels <input checked="" type="checkbox"/> Write velocity component of previous time step <input checked="" type="checkbox"/> Write velocity component <input checked="" type="checkbox"/> Write cell-center velocity vectors <input checked="" type="checkbox"/> Write upward velocity component <input type="checkbox"/> Write flow density <input checked="" type="checkbox"/> Write horizontal viscosity <input checked="" type="checkbox"/> Write horizontal diffusivity <input checked="" type="checkbox"/> Write flow flux <input checked="" type="checkbox"/> Write the number of times a cell was Courant limiting <input checked="" type="checkbox"/> Write the shear stress <input checked="" type="checkbox"/> Write the Chezy roughness <input checked="" type="checkbox"/> Write vicww k and eps <input checked="" type="checkbox"/> Write wind velocities <input checked="" type="checkbox"/> Specific Map output times <input type="text"/> [s]				

# 3D Layers

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

FlowFM | Discharge (Boundary conditions) | FlowFM (FM model settings) X

General | Time Frame | Processes | Initial Conditions | Physical Parameters | Wind | Numerical Parameters | Output Parameters | Advanced | Miscellaneous | 3D Layers

Layers

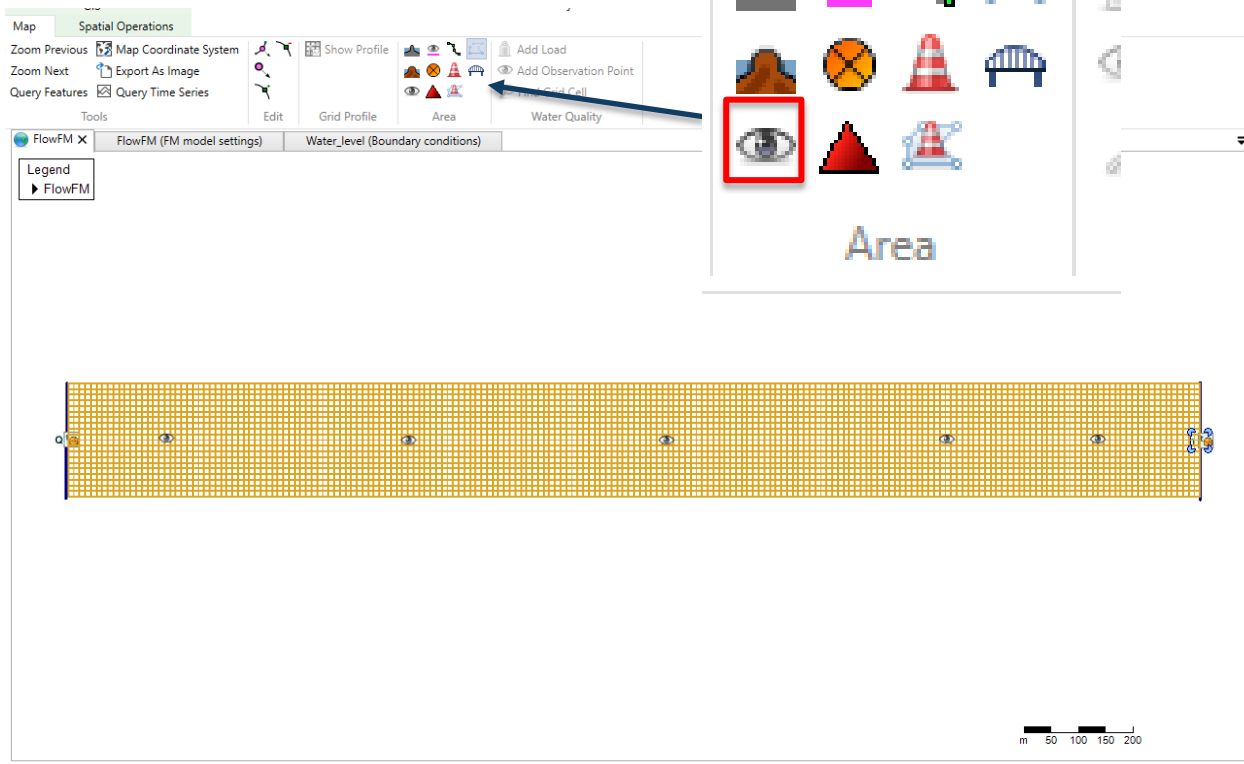
Kmx

Layer type



# 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

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- › 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

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- › 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#
```

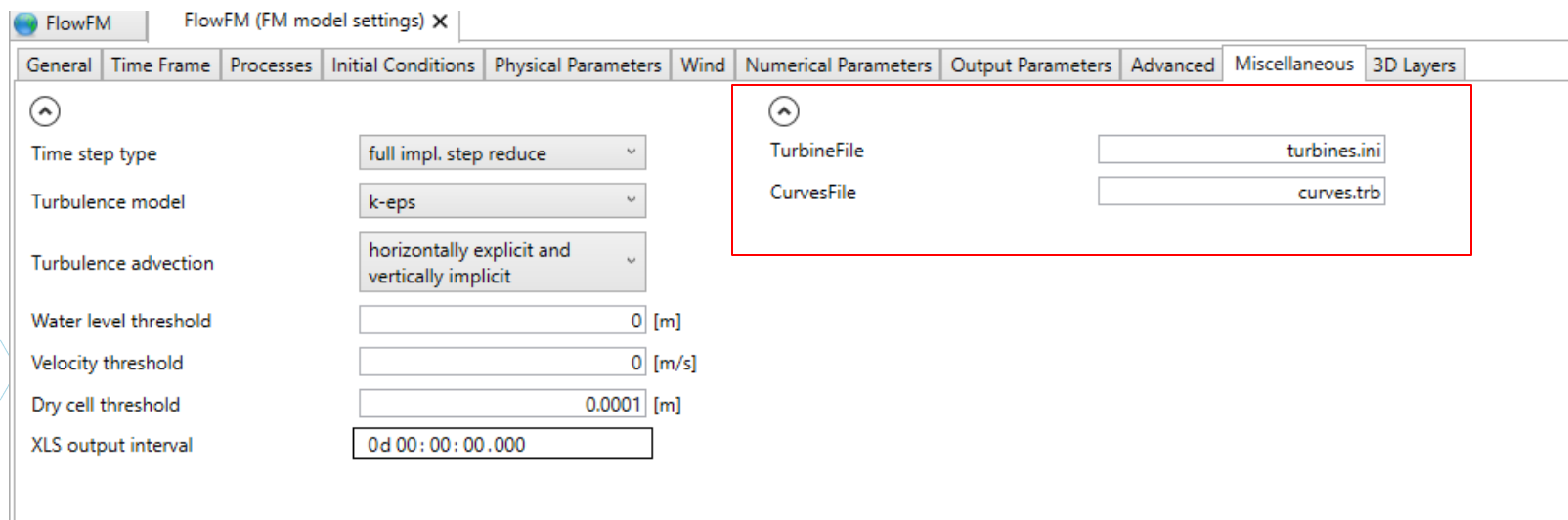
```
NDiaDist4Vel = 0.0
```

```
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	

# 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

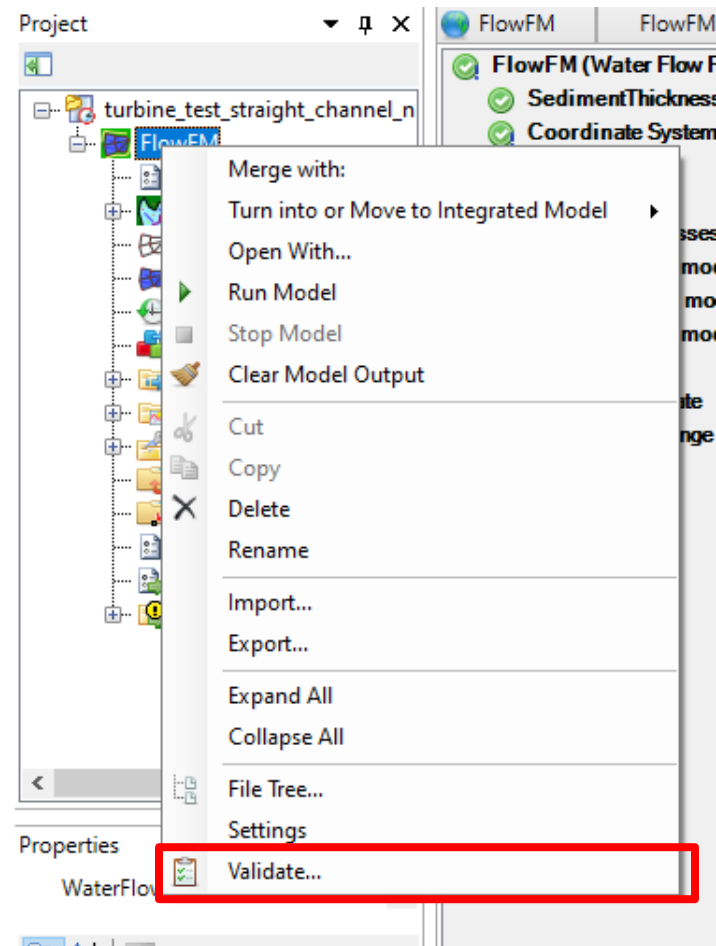


# Run The Model



# Check the Model

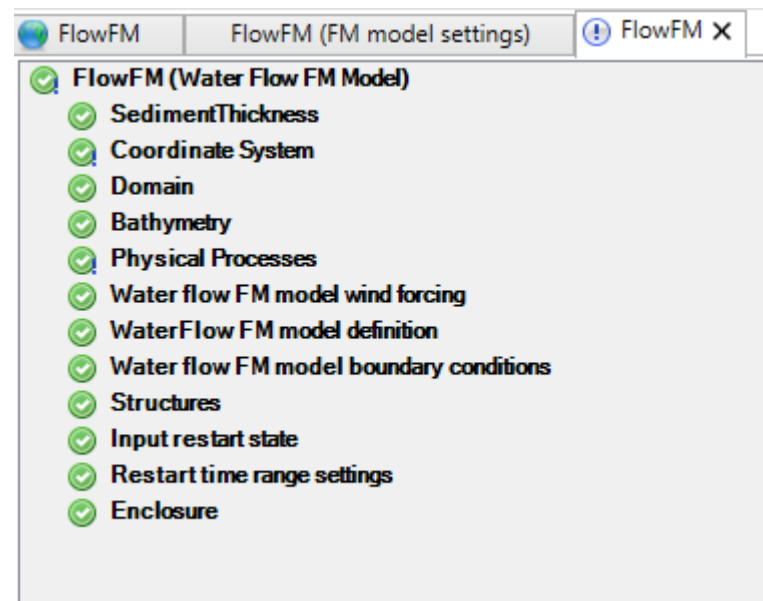
- › We're ready to run the model
- › A good check prior to executing is to “validate” first to make sure all settings are input
- › Right Click on FlowFM and select validate





# Results of Validation

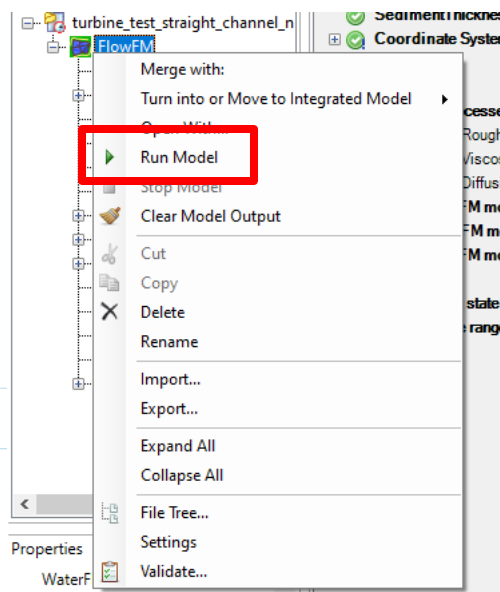
- › All check –boxes should be green
- › Some may show as red if something is not properly set up and it will tell you what those are.
  - Common issues may be inconsistent timing of start/stop and boundary conditions
- › Warnings with ! May also appear and you can select the item to evaluate why



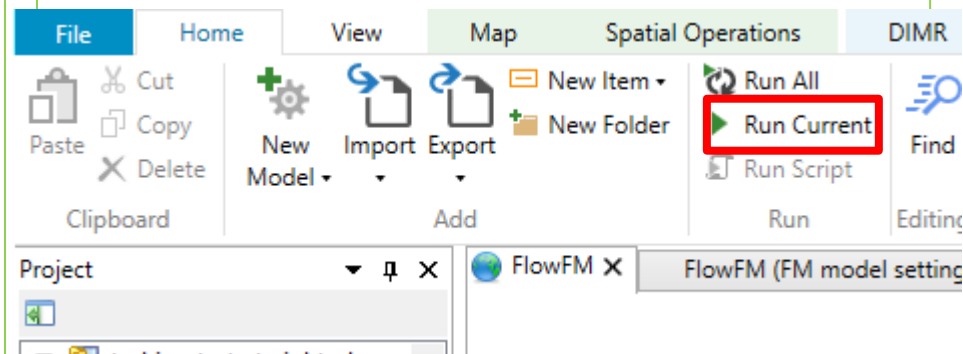
# Run the model

## › 2 Ways to execute

### › Right Click FlowFM and select run

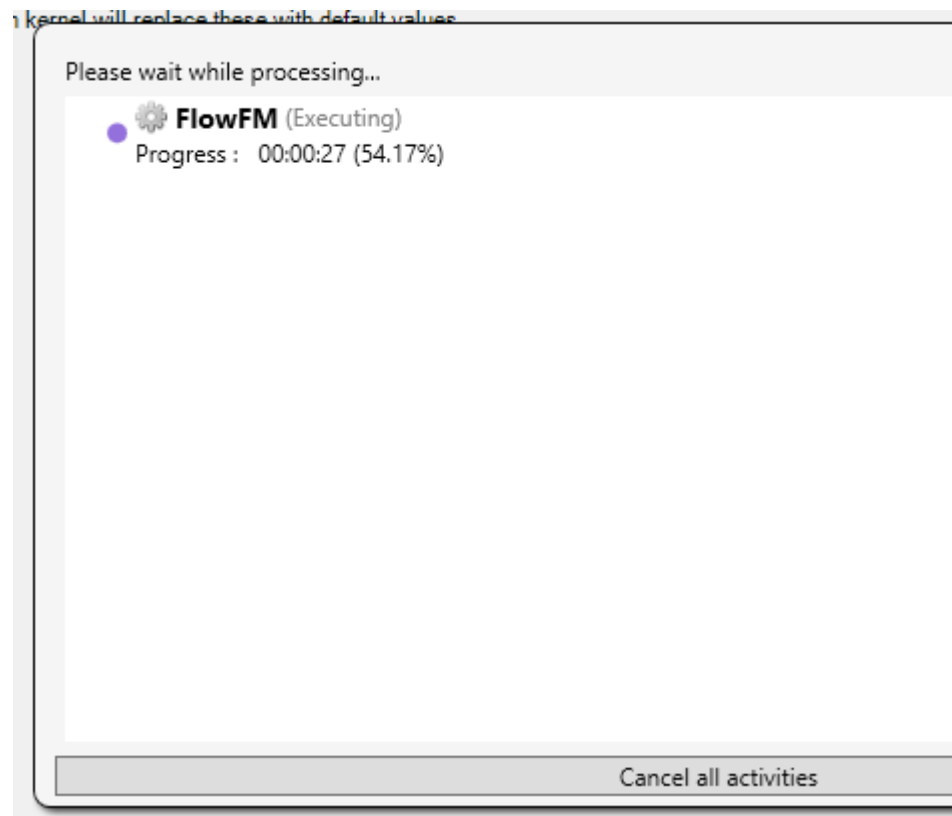


### › In Home Menu select Run Current



# 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.



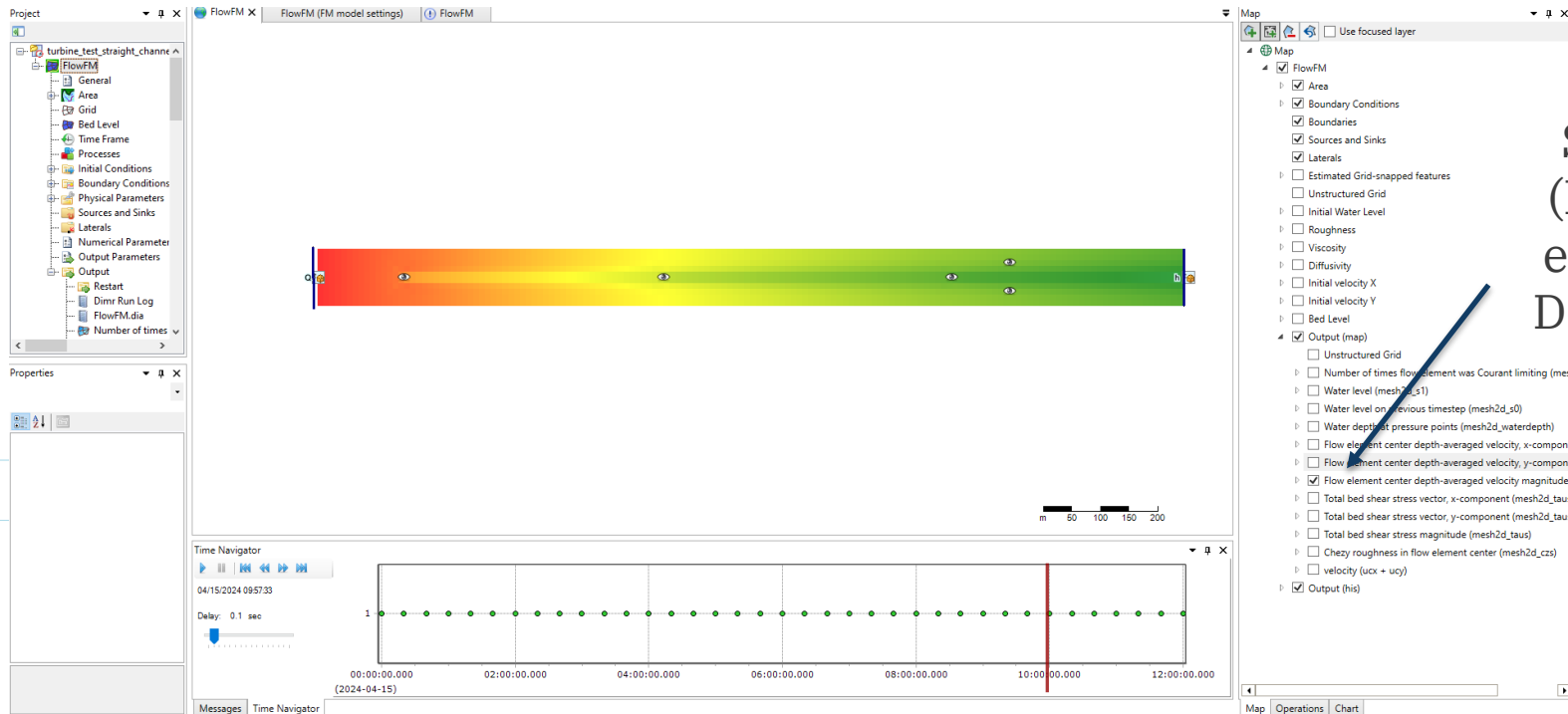
# Success!!

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- › 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



# Influence of Turbines can be seen

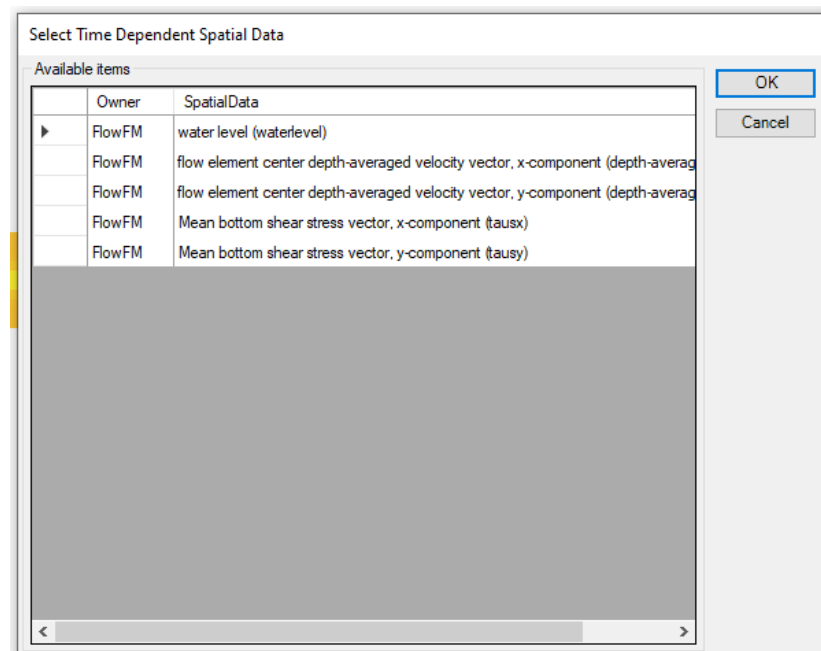
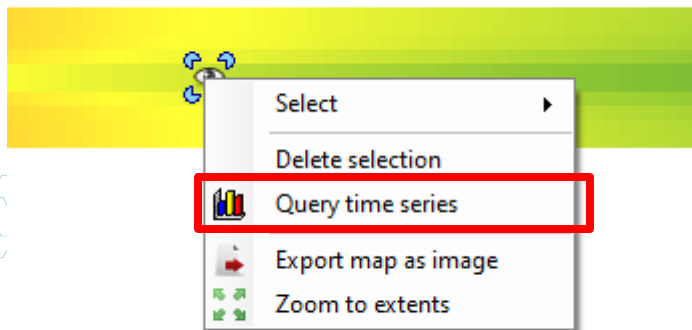


Select Output  
(Map and Flow  
element center  
Depth-averaged  
velocity  
magnitude)

Time Navigator allows user to progress through  
time

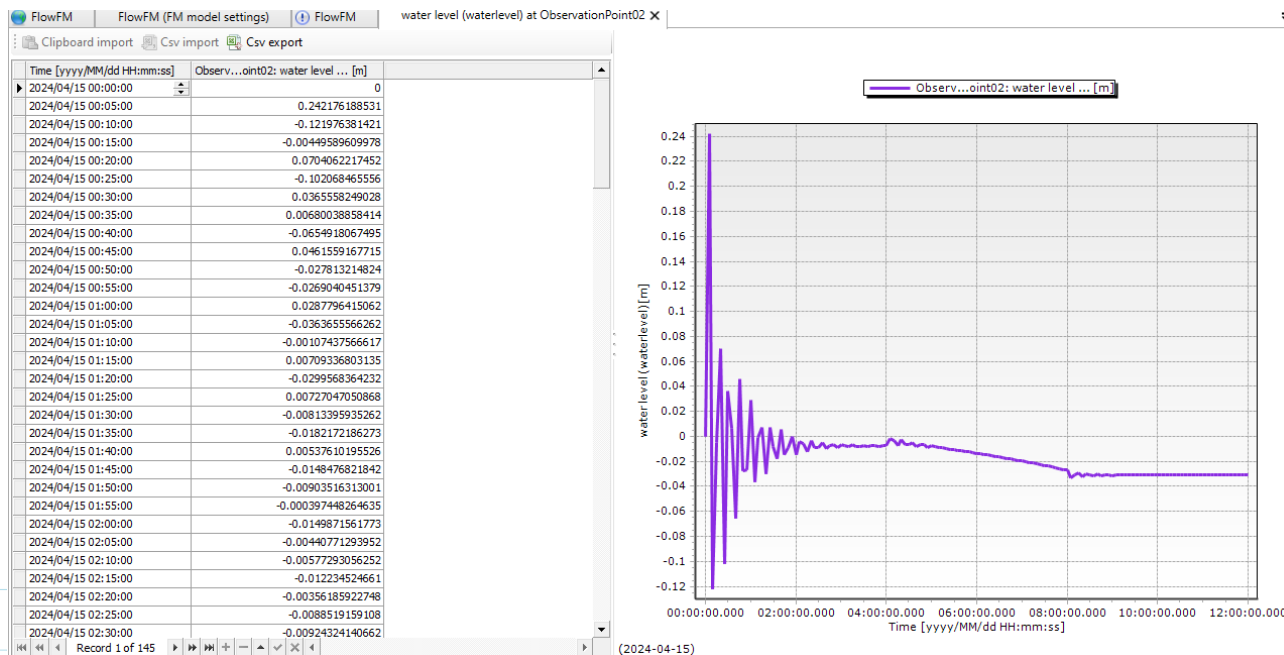
# Observation Point results

- › 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



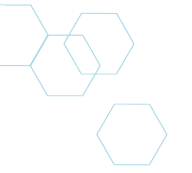
# Water level example





- ▶ 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.



	DATE	TYPE	SIZE
 FlowFM.dia	4/17/2024 8:02 PM	DIA File	80 KB
 FlowFM_his.nc	4/17/2024 8:02 PM	NC File	462 KB
 FlowFM_map.nc	4/17/2024 8:02 PM	NC File	55,233 KB
 Turbine_Power.dat	4/17/2024 8:02 PM	DAT	6,817 KB



# 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

# Next Steps

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- › 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