

Unsteady Flow Modeling for Reservoir Analysis with HEC-RAS

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US Army Corps of Engineers
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Outline

- Boundary Conditions and Computation
- Inline Structures and Gates
- Reservoir Modeling Layout Options



Boundary and Initial Conditions, and Computation Options and Tolerances



Unsteady Flow Data

- External Boundaries required
 - ▶ Upstream and Downstream ends of the river
 - ▶ Typically flow or stage hydrograph upstream
 - ▶ Typically rating or “normal depth” downstream
- Internal Boundaries can be added
 - ▶ Add flow within the river system
 - ▶ Define gate operation
- Initial Conditions - at the start of simulation



Unsteady Flow Data Editor

HEC-RAS 5.0.3

File Edit Run View Options GIS Tools Help

Project: Bald Eagle Creek Example Dam Break Study

Plan: PMF Event No Breach

Geometry: Existing GIS Data Nov 2006

Steady Flow:

Unsteady Flow: PMF Event from HMS

Description: The United States Army Corps of Engineers has granted

Unsteady Flow Data - PMF Event from HMS

File Options Help

Boundary Conditions | Initial Conditions | Apply Data

Boundary Condition Types

Stage Hydrograph	Flow Hydrograph	Stage/Flow Hydr.	Rating Curve
Normal Depth	Lateral Inflow Hydr.	Uniform Lateral Inflow	Groundwater Interflow
T.S. Gate Openings	Elev Controlled Gates	Navigation Dams	IB Stage/Flow
Rules	Precipitation		

Add Boundary Condition Location

Add RS ... Add SA/2D Flow Area ... Add SA Connection ... Add Pump Station ...

Select Location in table then select Boundary Condition Type

	River	Reach	RS	Boundary Condition
1	Bald Eagle Cr.	Lock Haven	137520	Flow Hydrograph
2	Bald Eagle Cr.	Lock Haven	136948	Uniform Lateral Inflow
3	Bald Eagle Cr.	Lock Haven	81454	T.S. Gate Openings
4	Bald Eagle Cr.	Lock Haven	80720	Uniform Lateral Inflow
5	Bald Eagle Cr.	Lock Haven	76865	Lateral Inflow Hydr.
6	Bald Eagle Cr.	Lock Haven	67130	Lateral Inflow Hydr.
7	Bald Eagle Cr.	Lock Haven	66041	Uniform Lateral Inflow
8	Bald Eagle Cr.	Lock Haven	28519	Lateral Inflow Hydr.
9	Bald Eagle Cr.	Lock Haven	1	Lateral Inflow Hydr.
10	Bald Eagle Cr.	Lock Haven	-1867	Normal Depth

Storage/2D Flow Areas

	Boundary Condition
1 193	Lateral Inflow Hydr.

Upstream Boundary Conditions

- Flow Hydrograph
- Stage Hydrograph
- Stage/Flow Hydrograph

Unsteady Flow Data - PMF Event from HMS

File Options Help

Boundary Conditions | Initial Conditions | Apply Data

Boundary Condition Types

Stage Hydrograph	Flow Hydrograph	Stage/Flow Hydr.	Rating Curve
Normal Depth	Lateral Inflow Hydr.	Uniform Lateral Inflow	Groundwater Interflow
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10	Bald Eagle Cr.	Lock Haven	-1867	Normal Depth

Storage/2D Flow Areas

	Boundary Condition
1 193	Lateral Inflow Hydr.

Flow Hydrograph

Flow Hydrograph

River: Nittany River Reach: Weir Reach RS: 60.1

☐ Read from DSS before simulation Select DSS file and Path

File:

Path:

☒ Enter Table Data time interval: 1 Hour

Select/Enter the Data's Starting Time Reference

☒ Use Simulation Time: Date: 08APR 1999 Time: 0000

☐ Fixed Start Time: Date: Time:

No. Ordinates

Hydrograph Data			
	Date	Simulation Time (hours)	Flow (cfs)
1	07Apr 1999 2400	00:00	5179.57
2	08Apr 1999 0100	01:00	5716.45
3	08Apr 1999 0200	02:00	6605.13
4	08Apr 1999 0300	03:00	7836.48
5	08Apr 1999 0400	04:00	9397.87
6	08Apr 1999 0500	05:00	11273.28
7	08Apr 1999 0600	06:00	13443.47
8	08Apr 1999 0700	07:00	15886.16
9	08Apr 1999 0800	08:00	18576.29
10	08Apr 1999 0900	09:00	21486.26
11	08Apr 1999 1000	10:00	24586.21
12	08Apr 1999 1100	11:00	27844.32
13	08Apr 1999 1200	12:00	31227.16
14	08Apr 1999 1300	13:00	34700.03
15	08Apr 1999 1400	14:00	38227.28

Time Step Adjustment Options ("Critical" boundary conditions)

☐ Monitor this hydrograph for adjustments to computational time step

Max Change in Flow (without changing time step):

Min Flow: Multiplier:

- Read from DSS
 - ▶ Select DSS file
 - ▶ Select Pathname
- Enter in Table
 - ▶ Select time interval
 - ▶ Select start date/time
 - ▶ Enter flow data - or cut & paste



Flow Hydrograph

- Min Flow
- Multiplier
- Hydrograph Monitor for Time Slicing

Minimum time step for time slicing (hrs):

0

Maximum number of time slices:

20



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Flow Hydrograph

River: Nittany River Reach: Weir Reach RS: 60.1

☐ Read from DSS before simulation Select DSS file and Path

File:

Path:

☒ Enter Table Data time interval: 1 Hour

Select/Enter the Data's Starting Time Reference

☒ Use Simulation Time: Date: 08APR 1999 Time: 0000

☐ Fixed Start Time: Date: Time:

No. Ordinates Interpolate Missing Values Del Row Ins Row

Hydrograph Data			
	Date	Simulation Time	Flow
		(hours)	(cfs)
1	07Apr 1999 2400	00:00	5179.57
2	08Apr 1999 0100	01:00	5716.45
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15	08Apr 1999 1400	14:00	38227.28

Time Step Adjustment Options ("Critical" boundary conditions)

☐ Monitor this hydrograph for adjustments to computational time step

Max Change in Flow (without changing time step):

Min Flow: Multiplier:

Plot Data OK Cancel

Downstream Boundary Conditions

- Downstream Options:
 - ▶ Normal Depth
 - ▶ Rating Curve
 - ▶ Stage Hydrograph
 - ▶ Flow Hydrograph
 - ▶ Stage & Flow Hydrograph

Unsteady Flow Data - PMF Event from HMS

File Options Help

Boundary Conditions | Initial Conditions | Apply Data

Boundary Condition Types			
Stage Hydrograph	Flow Hydrograph	Stage/Flow Hydr.	Rating Curve
Normal Depth	Lateral Inflow Hydr.	Uniform Lateral Inflow	Groundwater Interflow
T.S. Gate Openings	Elev Controlled Gates	Navigation Dams	IB Stage/Flow
Rules	Precipitation		

Add Boundary Condition Location

Add RS ... Add SA/2D Flow Area ... Add SA Connection ... Add Pump Station ...

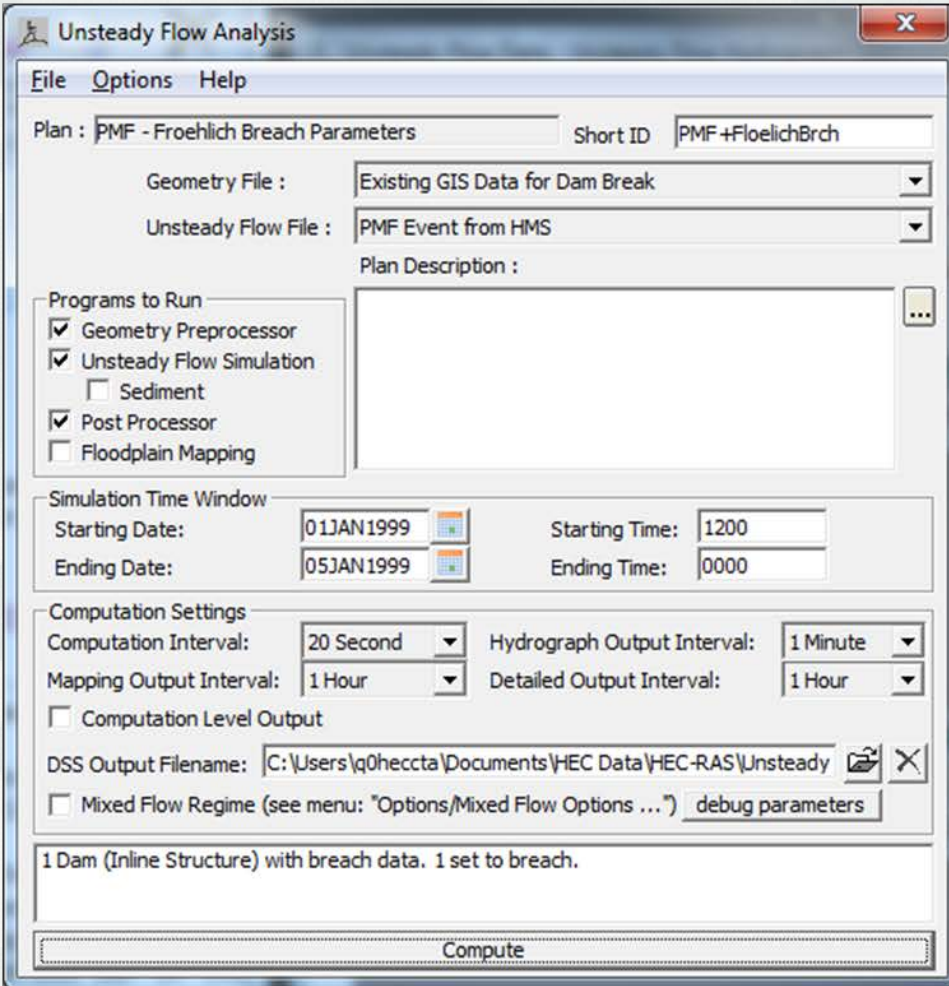
Select Location in table then select Boundary Condition Type

	River	Reach	RS	Boundary Condition
1	Bald Eagle Cr.	Lock Haven	137520	Flow Hydrograph
2	Bald Eagle Cr.	Lock Haven	136948	Uniform Lateral Inflow
3	Bald Eagle Cr.	Lock Haven	81454	T.S. Gate Openings
4	Bald Eagle Cr.	Lock Haven	80720	Uniform Lateral Inflow
5	Bald Eagle Cr.	Lock Haven	76865	Lateral Inflow Hydr.
6	Bald Eagle Cr.	Lock Haven	67130	Lateral Inflow Hydr.
7	Bald Eagle Cr.	Lock Haven	66041	Uniform Lateral Inflow
8	Bald Eagle Cr.	Lock Haven	28519	Lateral Inflow Hydr.
9	Bald Eagle Cr.	Lock Haven	1	Lateral Inflow Hydr.
10	Bald Eagle Cr.	Lock Haven	-1867	Normal Depth

Storage/2D Flow Areas		Boundary Condition
1	193	Lateral Inflow Hydr.

Computation

- Computation Time Step
- Hydrograph Output
- Detailed Output
- Mixed Flow Regime



Unsteady Flow Analysis

File Options Help

Plan: PMF - Froehlich Breach Parameters Short ID: PMF+FloelichBrch

Geometry File: Existing GIS Data for Dam Break

Unsteady Flow File: PMF Event from HMS

Plan Description:

Programs to Run

- ☒ Geometry Preprocessor
- ☒ Unsteady Flow Simulation
 - ☐ Sediment
- ☒ Post Processor
- ☐ Floodplain Mapping

Simulation Time Window

Starting Date: 01JAN1999 Starting Time: 1200

Ending Date: 05JAN1999 Ending Time: 0000

Computation Settings

Computation Interval: 20 Second Hydrograph Output Interval: 1 Minute

Mapping Output Interval: 1 Hour Detailed Output Interval: 1 Hour

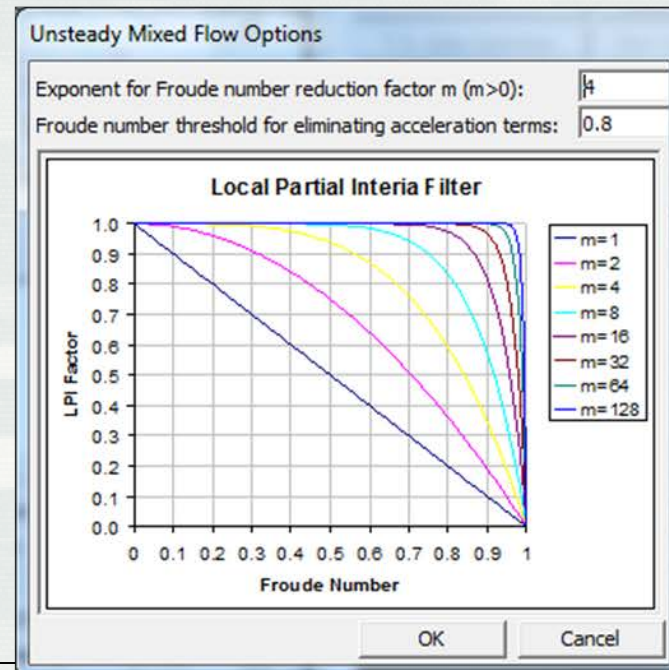
☐ Computation Level Output

DSS Output Filename: C:\Users\q0heccta\Documents\HEC Data\HEC-RAS\Unsteady

☐ Mixed Flow Regime (see menu: "Options/Mixed Flow Options ...") debug parameters

1 Dam (Inline Structure) with breach data. 1 set to breach.

Compute



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Computation Options

HEC-RAS Unsteady Computation Options and Tolerances

General (1D Options) | 2D Flow Options | 1D/2D Options |

Unsteady Flow Options

Theta [implicit weighting factor] (0.6-1.0):	<input type="text" value="1"/>	Number of warm up time steps (0 - 100,000):	<input type="text" value="0"/>
Theta for warm up [implicit weighting factor] (0.6-1.0):	<input type="text" value="1"/>	Time step during warm up period (hrs):	<input type="text" value="0"/>
Water surface calculation tolerance [max=0.2](ft):	<input type="text" value="0.02"/>	Minimum time step for time slicing (hrs):	<input type="text" value="0"/>
Storage Area elevation tolerance [max=0.2](ft):	<input type="text" value="0.02"/>	Maximum number of time slices:	<input type="text" value="20"/>
Flow calculation tolerance [optional] (cfs):	<input type="text"/>	Lateral Structure flow stability factor (1.0-3.0):	<input type="text" value="2"/>
Max error in water surface solution (Abort Tolerance)(ft):	<input type="text" value="100"/>	Inline Structure flow stability factor (1.0-3.0):	<input type="text" value="1"/>
Maximum number of iterations (0-40):	<input type="text" value="20"/>	Weir flow submergence decay exponent (1.0-3.0):	<input type="text" value="1"/>
Maximum iterations without improvement (0-40):	<input type="text"/>	Gate flow submergence decay exponent (1.0-3.0):	<input type="text" value="1"/>
		DSS Messaging Level (1 to 10, Default = 4)	<input type="text" value="4"/>

Geometry Preprocessor Options

Family of Rating Curves for Internal Boundaries

☒ Use existing internal boundary tables when possible.

☐ Recompute at all internal boundaries

1D Equation Solver

☒ Skyline/Gaussian (Default: Faster for dendritic systems)

☐ Pardiso (Optional: May be faster for large interconnected systems)

Number of cores to use with Pardiso solver:

OK Cancel Defaults ...

- **Theta**
1 = Most Stable
- **Water Surface Tolerance**
- **Stability Factors**
1 = Most Accurate
3 = Most Stable

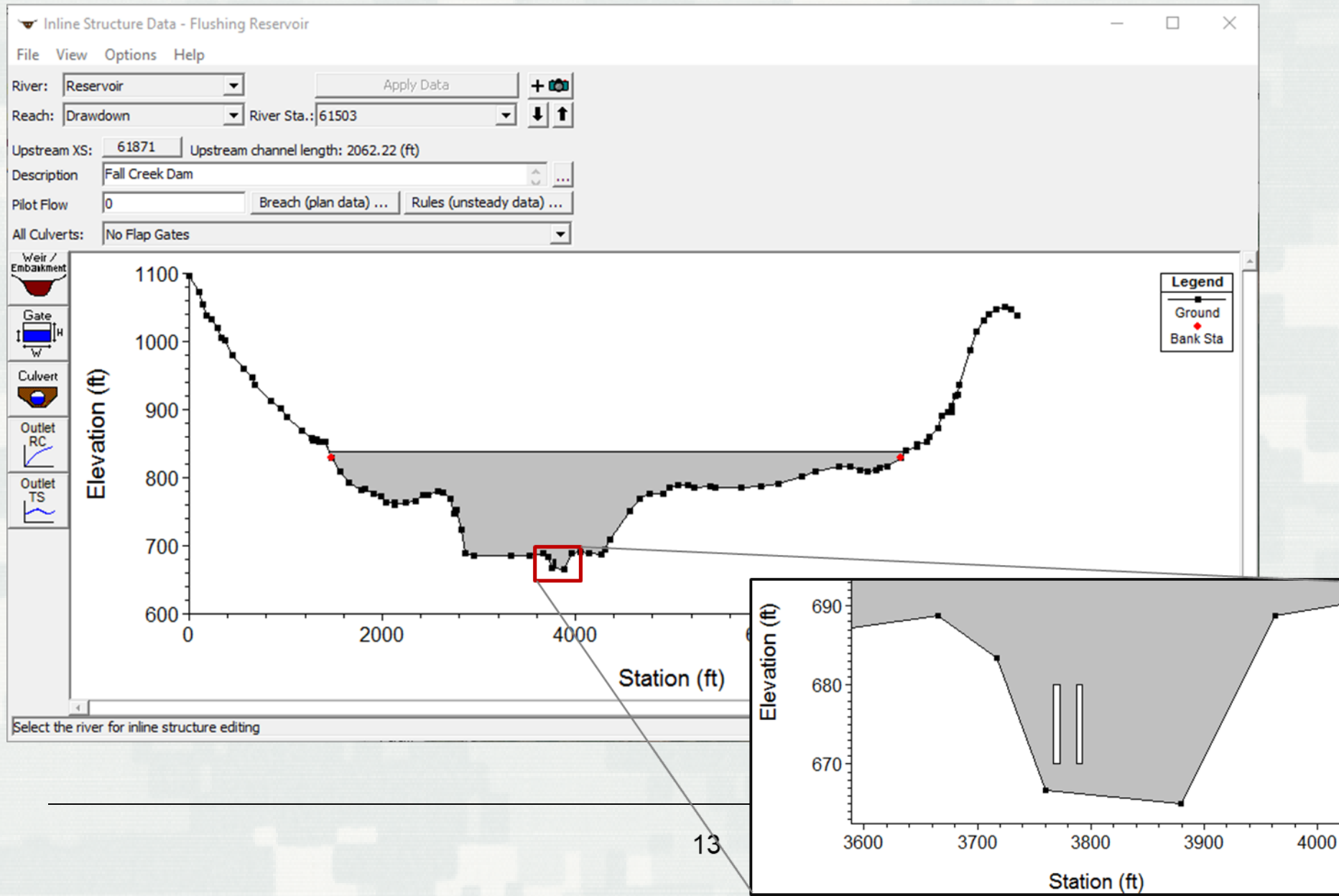


Outline

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- Reservoir Modeling Layout Options



Entering Inline Structure Data



Weir and Embankment Profile

- Distance + Width < U/S XS Reach Length
- Weir include top of dam and spillway
- Weir Coef. used for both dam and spillway

Inline Structure Weir Station Elevation Editor

Distance	Width	Weir Coef
450	25	3.82

Clear Del Row Ins Row Filter...

Edit Station and Elevation coordinates

	Station	Elevation
1	0.	683.
2	1700.	683.
3	1700.	657.
4	2300.	657.
5	2300.	683.
6	6980.	683.
7		
8		

U.S Embankment SS 3.5 D.S Embankment SS 3.5

Weir Data
Weir Crest Shape
☐ Broad Crested
☒ Ogee

Spillway Approach Height: 12
 Design Energy Head: 20 Cd ...

OK Cancel

Enter distance between upstream cross section and deck/roadway. (ft)

Gates

- Sluice
- Radial
- Overflow
- User Defined Curves

Inline Gate Editor

Gate Group: Gate #1

Gate type (or methodology): Radial

Geometric Properties

Height: 15
Width: 7
Invert: 590
Openings: 2

Centerline Stations

	Station
1	5070.
2	5090.
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

Gate Flow

Radial Gate Flow

Radial Discharge Coefficient: 0.65
Trunnion Exponent: 0
Opening Exponent: 1
Head Exponent: 0.5
Trunnion Height: 0

Submerged Orifice Flow

Orifice Coefficient (typically 0.8): 0.8

Head Reference: Center of opening

Weir Flow Over Gate Sill (gate out of water)

Weir Shape: Broad Crested

Weir Coefficient: 3

OK Cancel Help



Gate Settings

- Add the Inline Structure station as a BC location to Specify Gate Settings

Unsteady Flow Data - PMF Event for SA Model

File Options Help

Boundary Conditions | Initial Conditions | Apply Data

Boundary Condition Types

Stage Hydrograph	Flow Hydrograph	Stage/Flow Hydr.	Rating Curve
Normal Depth	Lateral Inflow Hydr.	Uniform Lateral Inflow	Groundwater Interflow
T.S. Gate Openings	Elev Controlled Gates	Navigation Dams	IB Stage/Flow
Rules			

Add Boundary Condition Location

Add RS ... Add Storage Area ... Add SA Connection ... Add Pump Station ...

Select Location in table then select Boundary Condition Type

River	Reach	RS	Boundary Condition
1 Bald Eagle Cr.	Lock Haven	81454	T.S. Gate Openings
2 Bald Eagle Cr.	Lock Haven	80720	Uniform Lateral Inflow
3 Bald Eagle Cr.	Lock Haven	76865	Lateral Inflow Hydr.
4 Bald Eagle Cr.	Lock Haven	67130	Lateral Inflow Hydr.
5 Bald Eagle Cr.	Lock Haven	66041	Uniform Lateral Inflow
6 Bald Eagle Cr.	Lock Haven	28519	Lateral Inflow Hydr.
7 Bald Eagle Cr.	Lock Haven	1	Lateral Inflow Hydr.
8 Bald Eagle Cr.	Lock Haven	-1867	Normal Depth

Storage/2D Flow Areas	Boundary Condition
1 Sayers Res	Lateral Inflow Hydr.

Initial internal water surface elevations set



Gate Boundary Conditions

Gate Openings

River: Nittany River Reach: Weir Reach RS: 41.75

Gate Group: Left Group ↓ ↑

☐ Read from DSS before simulation Select DSS file and Path

File:

Path:

☒ Enter Table Data time interval: 1 Hour

Select/Enter the Data's Starting Time Reference

☒ Use Simulation Time: Date: 08APR1999 Time: 0000

☐ Fixed Start Time: Date: Time:

No. Ordinates Interpolate Missing Values Del Row Ins Row

Hydrograph Data			
	Date	Simulation Time	Gate Opening Height
		(hours)	(ft)
1	07Apr 1999 2400	00:00	3.
2	08Apr 1999 0100	01:00	3.23
3	08Apr 1999 0200	02:00	3.47
4	08Apr 1999 0300	03:00	3.7
5	08Apr 1999 0400	04:00	3.93
6	08Apr 1999 0500	05:00	4.17
7	08Apr 1999 0600	06:00	4.4
8	08Apr 1999 0700	07:00	4.63
9	08Apr 1999 0800	08:00	4.87

Plot Data OK Cancel

Elevation Controlled Gates

River: Nittany River Reach: Weir Reach RS: 41.75

Gate Group: Left Group ↓ ↑

Reference: Based on upstream WS

☐ Upstream WS Elevation Reference

Upstream WS elevation at which gate begins to open:

Upstream WS elevation at which gate begins to close:

Gate Opening Rate: (ft/min):

Gate Closing Rate: (ft/min):

Maximum Gate Opening:

Minimum Gate Opening:

Initial Gate Opening (Optional):

OK Cancel

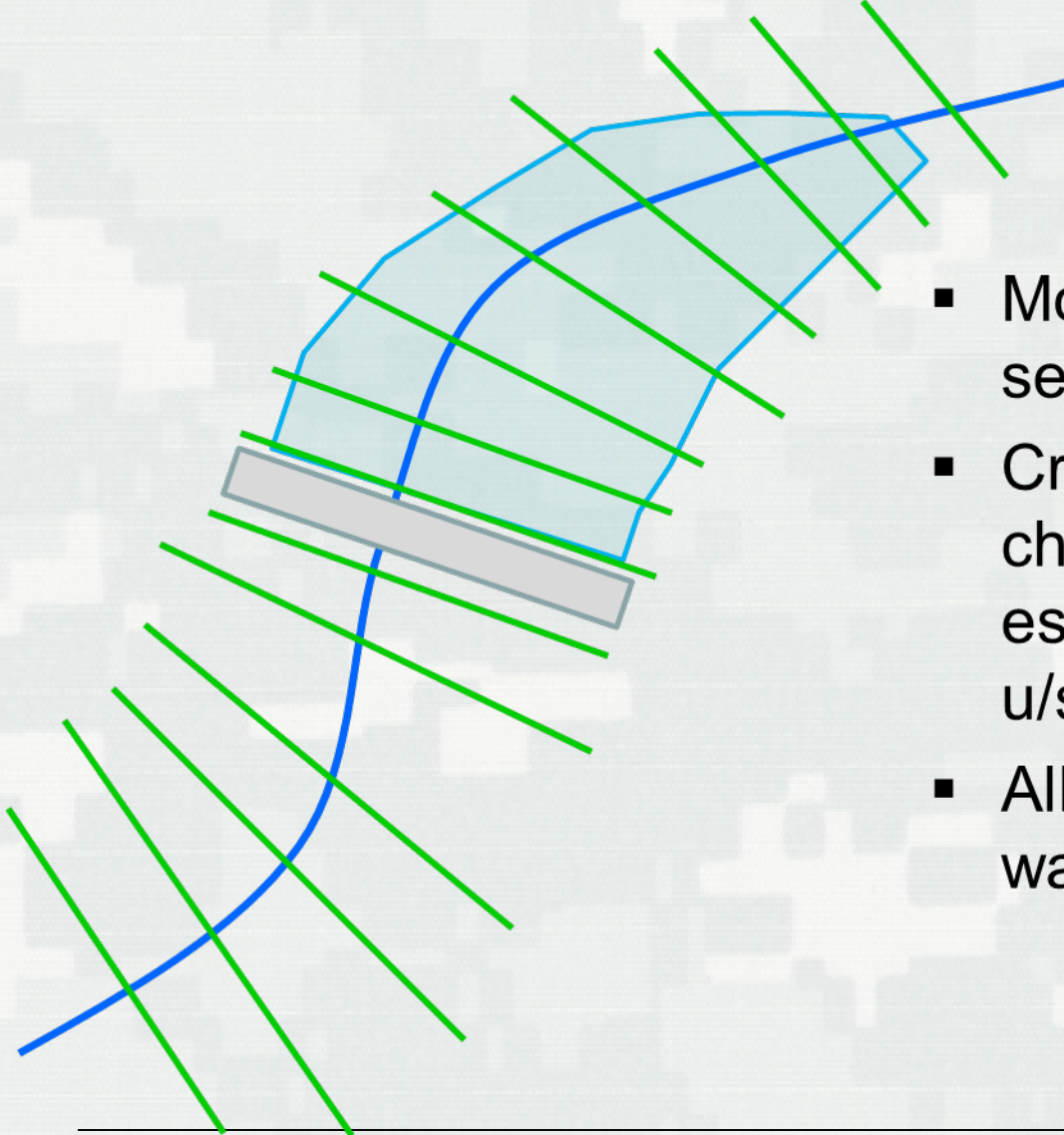


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Reservoir Modeling Option



- Model Reservoir with cross sections
- Cross sections must include channel information, especially around dam both u/s and d/s
- Allows for dynamic routing of water (sloped water surface)



Initial Internal Stages

- Internal RS Initial Stages used to set initial water surface at a XS
- Stage U/S from inline structure is based on a balance of outlet size/gate opening and water surface.

Unsteady Flow Data - Initial Stages

River: Bald Eagle Cr. Delete row(s)... Add Multiple...

Reach: Lock Haven River Sta.: 82303 Add an Initial Stage Location

Locations and Initial Stages				
	River	Reach	RS	Elev
1	Bald Eagle Cr.	Lock Haven	81914	657

Unsteady Flow Data - PMF Event for SA Model

File Options Help

Options menu:

- Delete Initial Flow(s) From Table ...
- DSS Pathname Summary Table ...
- Internal RS Initial Stages ...
- Flow Minimum and Flow Ratio Table ...
- Observed (Measured) Data
- Old River Diversion Adjustment ...

	River	Reach	RS	Elev
1	Bald Eagle Cr.	Lock Haven	82303	1068
2	Bald Eagle Cr.	Lock Haven	81914	1000
3	Bald Eagle Cr.	Lock Haven	-897	6000

Initial Elevation of Storage Areas/2D Flow Areas (Optional)

☐ Keep initial elevations constant during warmup

	Storage Area/2D Flow Area	Initial Elevation
1	190	535
2	191	537
3	192	546
4	193	559.7
5	194	595
6	195	615.6
7	Sayers Res	657

Initial internal water surface elevations set

Operation Rules for Gated Structures

- Unsteady Flow Editor “Rules” boundary condition
 - Inline/Lateral Structures
 - Storage Area Connections
- ## Controls
- ▶ Gates
 - ▶ Weir Coefficients
 - ▶ Min/Max Flow
- Rules are evaluated at every time step

Unsteady Flow Data - Unsteady Flow with ND target 22.65 wro

File Options Help

Boundary Conditions | Initial Conditions | Apply Data

Select Location for Boundary Condition

River: CowHouseCk
Reach: 1 River Sta.: 12500 Add a Boundary Condition Location

Boundary Condition Types

Stage Hydrograph Flow Hydrograph Stage/Flow Hydr. Rating Curve
Normal Depth Lateral Inflow Hydr. Uniform Lateral Inflow Groundwater Interflow
T.S. Gate Openings Elev Controlled Gates Navigation Dams IB Stage/Flow

Rules

River	Reach	RS	Boundary Condition Type
1 CowHouseCk	1	12500	Flow Hydrograph
2 Harney	1	73.3 IS	Rules
3 Hillsborough	1	605400	Flow Hydrograph
4 Hillsborough	1	605101.*	Lateral Inflow Hydr.
5 Hillsborough	1	605100	Lateral Inflow Hydr.
6 Hillsborough	1	604999 IS	T.S. Gate Openings
7 Hillsborough	1	602447.*	Lateral Inflow Hydr.
8 Hillsborough	1	602400	Lateral Inflow Hydr.
9 Hillsborough	1b	601300	Lateral Inflow Hydr.
10 Hillsborough	1h	601050	Lateral Inflow Hydr.

Storage Area and SA Connections: Add a Boundary Condition Location

Storage Area or SA Connection	Boundary Condition Type
1	

Initial internal water surface elevations set
Observed DSS data set

User Defined Rules Editor for Operating Gated Structures

Operation

'PoolElev' = Cross Sections:WS Elevation(Missouri River,Missouri,811.076,Value at current time step)

'Flushing Time' = Time:Hour of Simulation(Beginning of time step)

!

! Set initial 30000 cfs flows for 2 Days

!

Gate.Flow (Desired)(Gates) = 30000

Gate.Flow(Tunnels) = 0

!

! Start draining in 2 Days in

If ('Flushing Time' > 48) Then

! Steve said this was over specified

Gate.Flow (Desired)(Tunnels) = 62000

Gate.Flow (Desired)(Gates) = 0

End If

!

! Close gates 7 days (+warm up and draining) later

If ('Flushing Time' > 312) Then

Structure.Total Flow (Desired) = 5000

If ('PoolElev' >= 1206) Then

Structure.Total Flow (Desired) = 30000

End If

End If

