Flood Mitigation Modeling and Planning

Lesson Summary

Students use a modified version of the West Branch of Herring Run model to test hypotheses about how land cover impacts infiltration and ultimately how much and how quickly water enters a stream after a rain event. Students critique the model and design a flood mitigation plan for the West Branch of Herring Run or their Schoolyard.

Purpose/Objectives

- To model how land use impacts runoff and the shape of stream hydrographs.
- To understand how land use changes can reduce stream discharge and lessen the likelihood of flooding.
- To critique the NetLogo model and identify what the model does well and what it does poorly.
- To design a flood mitigation plan with evidence and reasoning from the Comp Hydro lessons.
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Comp Hydro Learning Goals

C4-5 D5 H7-9

Next Generation Science Standards

HS-ESS-3 HS-ESS3-4 HS-ETS1-2 HS-ETS1-3 HS-ETS1-4

Materials Needed

- Activity 1 Student Pages - Water Loss in Floorlandia
- Activity 2 Student Pages - Land Cover Change in the West Branch of Herring Run
- Activity 3 Student Pages - Critiquing the NetLogo Land Cover Change Model
- Activity 4 Student Pages – Flood Mitigation Plan
- Activity 4 Student Pages- Concluding Reflection
- Computers with Netlogo
- Netlogo files
- Activity 4 Powerpoint Presentation
- Floorlandia with infiltration spreadsheet
- Color Map of the West Branch of Herring Run Watershed
- Color Map of the West Branch of Herring Run Watershed with BMPs
- Colored Pencils
- Tracing Paper
- Masking tape

Agenda

Activity #	*Activity Label*	*Timing*	*Activity Description*
1	Floorlandia with Infiltration	50 min	Students will conduct an urban/rural comparison of the Floorlandia model with infiltration.
2	West Branch of Herring Run NetLogo - Land Cover change	20 min	Explore a new NetLogo model for the West Branch of Herring Run that simulates how land cover change impacts runoff.
3	Critiquing the Netlogo Model	15 min	Use the Claim, Evidence, Reasoning model to critique the Netlogo Landcover change model.
4	Developing a Flood Mitigation Plan	75 min	Teams of students present options to help mitigate impacts of future flooding in the West Branch of Herring Run or their Schoolyard.

Safety Concerns: Be sure to create enough space for students to move smoothly throughout the classroom during the Critique and Inquiry Gallery walk.

2020

Activity One: Floorlandia with Infiltration

Activity Summary

Students will run the Floodlandia activity with an added complexity of water loss in the model. Students will then compare urban and rural watersheds using the Floorlandia model.

Key Vocabulary

Runoff
Runoff Accumulation

Advanced Preparation

Prepare for this lesson by running through the calculations on your own ahead of time. This will help you become familiar with the activity which can seem complicated at first glance.

Materials Needed

- Spreadsheet: Floorlandia with infiltration spreadsheet
  Printouts of tabs:
    - Rural Runoff Grid
    - Rural Runoff Accumulation
    - Urban Runoff Grid
    - Urban Runoff Accumulation
- Activity 1 Student Pages - Water Loss in Floorlandia - 1 per pair of students

Activity Sequence

1. Introduce the activity. Students have learned about surface water runoff, runoff with storage (sponges) and investigated various water pathways in the schoolyard. They will now run Floorlandia again, but this time with water loss.
2. For this activity, consider "water loss" any process that removes water from the surface of a landscape; infiltration, evaporation, plant uptake, etc.
3. Pass out the Rural Runoff Grid. Divide the class into small groups and assign each group 4 or 5 starting cells within the central watershed. Each group should now complete calculations beginning with their starting cell and determining how much of 100 droplets of water will make it to the outlet of the watershed. Students will use multiplication to complete this task.
4. For example: Start in cell C9 with 0.80. 100 x 0.80 = 80 droplets leaving C9 and entering D8. Students should write "80" in cell D8. Then multiply 80 x .7 giving you 56 droplets leaving D8 and entering E8. Students write 56 in cell E8. Students multiply 56 x .6 = 34 leaving and going into cell F7. Students write 34 in cell F7. Students then multiply 34 x 0.6. So you have 20 going into cell G8. Then 20 x .7 is 14 going into cell H8. Then 14 times .8 is 11 going into cell I7. Then 11 x .9 is 10 leaving the watershed.
5. Once students get a feel for this activity, you can pass out the spreadsheet "Rural Runoff Accumulation." Here, the final fractions are identified for the students. They can check their answers on the previous grid using these values.
6. For example, back to our starting cell of C9. We just determined that of 100 droplets starting in cell C9, only 10 make it out of the watershed. Using the "Rural Runoff Accumulation" grid, we can now multiply 100 by the value in cell C9 and determine that indeed, only 10 of our 100 droplets will make it from C9 to the outlet of the watershed.
7. Pass out the Activity 1 Student Pages. Students can now compare a rural watershed to an urban watershed.
8. Begin by asking the students to look at both grids (rural and urban). What differences do they notice? What do the grid values mean?
9. Have students predict which watershed will retain the most water. How do they know?

Continued: Floorlandia with Infiltration

10. Next, students use the two “accumulation” grids to calculate how much water makes it out of each watershed. They should record their data on the worksheet.
11. To make these calculations, students need only add up the values of each cell in each grid based on how many steps away from the outlet each cell is.
12. For example, determine what value(s) are 0 steps away from the outlet. Record this value in the table. Next, determine what value(s) are 1 step away from the outlet. Add up these values and record the sum total in the table. Do the same calculations for all the cells in each grid and record the data in the table.
13. Students should convert their fraction values to % values by multiplying each total by 100.
14. Students should then graph their data on the worksheet.
15. Compare the two watersheds. What are the differences between the urban and rural watersheds and why do we see these differences? Relate these differences to the presence of impervious surfaces in urban watersheds.

Activity 1

Water loss in Floorlandia: Hydrograph

Name: ___________________________ Class:______________ Date:_______

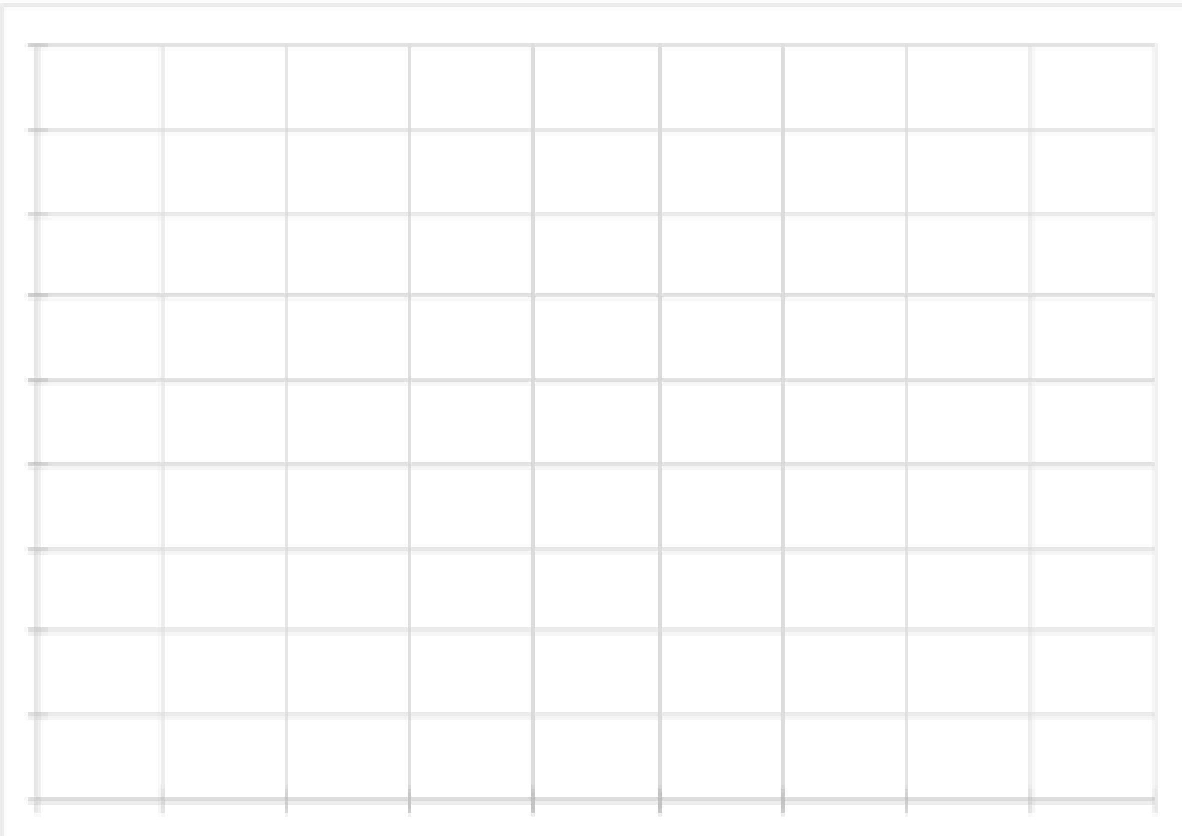
1. Complete this table for the Rural Watershed:

# steps from discharge point	0	1	2	3	4	5	6	7	8	9
List the fraction of water droplets										
% of total water droplets	*0*									

2. Complete this table for the Urban Watershed:

# steps from discharge point	0	1	2	3	4	5	6	7	8	9
List the fraction of water droplets										
% of total water droplets	*0*									

3. Create a graph of the data, labeling your axes. Time is represented on the x-axis (and is the same as the number of steps away from the discharge point) and the total amount of water on the y-axis (same as the number of droplets). These graphs are called a hydrograph.



4. What does your graph tell you about how the model simulates the runoff of water from the rainstorm out of the watershed? How do you explain the shape of the graph?

Activity Two: West Branch of Herring Run Netlogo

Activity Summary

Students will explore the impact of land cover on runoff through the use of NetLogo model simulations. Students will compare forested, industrial and residential scenarios to address strategies to reduce flooding.

Key Vocabulary

Hydrograph
Hyetograph
Runoff

Advanced Preparation

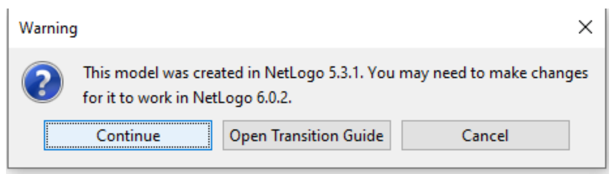
You will need to download and install NetLogo on all student computers before you begin this lesson. Netlogo is free and downloading is easy, but does take time and effort. You should also have all the Netlogo files for lesson four on a flash drive. The files can be downloaded from the shared Google Folder. Do not try to run the model from Google Drive directly. Use the flash drive to place the folder with the files onto each student computer for ease of access. Download Netlogo at https://ccl.northwestern.edu/netlogo/

Materials Needed

- Computers with Netlogo installed
- Netlogo files
- Activity 2 Student Pages - Land Cover Change in the West Branch of Herring Run

Activity Sequence

1. Today students will explore how land cover impacts runoff. Introduce the NetLogo West Branch of Herring Run - Land Cover Change model. Make sure NetLogo is installed on all computers and NetLogo files are accessible.
2. Instruct students to open the NetLogo West Branch of Herring Run - Land Cover Change model. If you see the following message, click “continue.”



3. Student should run the model as follows:
   a. Click on “Setup.” Wait until all the maps are loaded. You should see an aerial image with an orange outline of the WBHR watershed.
   b. Click on “Go.” The model will run and a hyetograph (rainfall) and 2 hydrographs (discharge) will appear to the right. The blue hydrograph is the observed hydrograph from an actual storm in August 2015. The black hydrograph is the graph the model generated using information/data we input into the model.
   c. Change the land cover types to all Forest. Click “Update” and wait for the maps to load. Click “Go”. How did the black hydrograph change? Why did it change?
4. Use the model to compare different land cover scenarios to address strategies for reducing flooding.
   a. All Forested
   b. All Industrial
   c. All Residential
   d. Some combination of the above three
5. Students should complete the Activity 2 Student Pages as they are exploring the model.

Activity 2

Land Cover Change in the West Branch of Herring Run

Name: ___________________________ Class: _____________ Date:_______

You will now have a chance to simulate different land cover scenarios in the West Branch of Herring Run. Complete the table below for at least 3 different scenarios, then answer the Discussion Questions.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Land Cover 1				
Land Cover 2				
Land Cover 3				
Peak Discharge*				

* to get peak discharge, place your cursor over the peak of the hydrograph and read the value on the y-axis

Discussion Questions:

1. Which scenario produced the hydrograph with the lowest peak discharge? What was the peak discharge of this hydrograph (hint: place your cursor at the peak of the hydrograph to read the value on the y-axis)?

2. Which scenario produced the hydrograph with the highest peak discharge? What was the peak discharge of this hydrograph (hint: place your cursor at the peak of the hydrograph to read the value on the y-axis?

3. Which scenario is most likely to result in less flooding in the West Branch of Herring Run? How do you know?

4. Is the scenario you chose for question 3 a realistic land cover scenario for Baltimore City to pursue? Why or why not?

VOCABULARY - Define each in your own words:

● Hydrograph (recall) ● Land Cover ● Hyetograph ● Discharge

Activity Three: Critiquing the Land Cover Change Model

Activity Summary

Students will critique the NetLogo Land Cover Change model and discuss how modeling can be used in multiple professions and through alternative applications.

Key Vocabulary

Computational modeling

Advanced Preparation

None

Materials Needed

- Activity 3 Student Pages - Critiquing the NetLogo Land Cover Change Model

Activity Sequence

1. Use the Student Pages to critique the NetLogo Land Cover Change model.
2. Discuss with your students and help them learn about other modeling approaches used by scientists, engineers and managers.

Activity 3

Critiquing the NetLogo Land Cover Change Model

Name:________________________________ Date:_____________

Identify a claim you can make using outputs from the NetLogo Land Cover Change Model. Hint: How does the stream discharge change when you change the land cover?

Claim:

____

____

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____

Identify the evidence you have to support your claim. Hint: Look at how the shape of the hydrograph changes when you change the land cover in the model.

Evidence:

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____

Identify the reasoning (the scientific explanation) that links your evidence to your claim. Hint: Why does changing the land cover increase or lower the peak of the hydrograph?

Reasoning:

____

____

____

____

Now critique the model.

How do you know if the model output is accurate?

____

____

____

____

What can the model do well? How do you know?

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What does the model not do well? How do you know?

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What information can you give the model, so the output from the model will be more accurate? Why will the information make the output more accurate?

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Activity Four: Developing a Flood Mitigation Plan

Activity Summary

Students become flood consultants for Baltimore City and develop and recommend flood reduction plans and methods for City officials. Students present their plan and budget to the class.

Key Vocabulary

- Flooding
- Runoff
- Watershed
- Best Management Practice (BMP)
- Stormwater management facility
- Bioretention facility
- Curb extension
- Rain garden
- Green roof
- Drainage Area
- Infiltrate

Advanced Preparation

None

Materials Needed

- Activity 4 Powerpoint Presentation – Addressing the Problem of Flooding
- Activity 4 Student Pages – Flood Mitigation Plan
- Activity 4 Student Pages- Concluding Reflection
- Color Map of the West Branch of Herring Run Watershed
- Color Map of the West Branch of Herring Run Watershed with BMPs
- Colored Pencils
- Tracing Paper
- Masking Tape

Activity Sequence

1. In this activity, students in small groups or pairs assess the success of different flood reduction strategies in reducing flooding in the West Branch of Herring Run Watershed
2. Pass out the Best Management Practices (BMPs) map to your students. Explain that the white symbols are stormwater management facilities and the yellow polygons are drainage areas to those facilities. The red symbols are considered “restoration best management practices” and the vast majority of those are rain barrels that control a negligible percent of the watershed drainage area. This would be a good point in the lesson to review the Key Vocabulary terms.
3. Each grid square on the map represents 100,000 square feet of land area.
4. Challenge the students to examine the map and answer the following questions:
    a. Approximately how many square feet is the West Branch of Herring Run Watershed? How did you come to your answer? Why do you think others in the class got different answers? – use this opportunity to reinforce estimation.
    b. Select one of the stormwater management facilities on the map (white circle). Look at the corresponding drainage area (light yellow polygon). Approximately how much land in square feet does the facility treat? How did you come to your answer? Why do you think others in the class got different answers?
    c. Looking at just the yellow polygons, how much of the watershed (in square feet) is treated by stormwater management facilities? Do you think these facilities are sufficient to help reduce riverine flooding in the watershed? Why or why not?
5. The Activity 4 Student Pages has a table of common Best Management Practices for Flood Reduction. The methods work by capturing rainwater close to where the rain lands and slowing the water long enough for it to infiltrate into the ground before reaching the nearest stream. All of these practices are used across Baltimore City to try to control stormwater. You may use the Addressing the Problem of Flooding teacher presentation to review each practice or allow time on computers for students to read about these practices independently. Students may also research practices that are not listed on the table.

Continued: Developing a Flood Mitigation Plan

6. Students should use the Flood Reduction Options table to record information about each Best Management Practice. They must then create their own plan for the West Branch of Herring Run watershed. They can record ideas for their plan in the Flood Mitigation Plan table and/or directly on their map of the watershed. Students should be given a budget of $1 million or another similar sum. This will help them stay focused and limit their ability to “run wild” with their mitigation plan.
7. Students should also complete the section titled “Justification for Remediation Plan” to help them summarize and organize their ideas.
8. Finally, students should compare their Flood Mitigation Plan to that of the actual map of Best Management Practices currently in place in the West Branch of Herring Run. What is the same/different about each plan? Which mitigation practice do they think would be most useful in reducing flooding in the watershed? Why?
9. Have students calculate the square footage of watershed treated by their plan and compare that to the square footage currently treated in the West Branch watershed. Which plan treats more area of the watershed?
10. Conclude this discussion by reminding students that the effort they put into creating their plan could be made easier by using a model. By now, students should be familiar with the pros/cons of using models to simulate real-world scenarios. In this scenario, how could a model make creating a Flood Mitigation Plan easier? What could be more difficult in using a model?
    a. Answers might include:
        i. Easier
            1. Models allow us to make many different designs in a short amount of time
            2. We can do our calculations faster
            3. Models can help us estimate results even if they aren’t 100% accurate
        ii. Difficult
            1. A model does not “match” the watershed exactly so there is always error in the model output
            2. We would have to spend a lot of time designing the model in the first place requiring us to collect and organize data.
11. Use the Concluding Reflection worksheet to help you assess what your students have learned throughout the entire CompHydro Baltimore unit. For a more intensive assessment of student learning, have your students complete the CompHydro Baltimore post assessment.
12. Optional: Teachers may choose have to have students create a culminating project with information from their Flood Mitigation Plan. Projects to consider include:
    a. Students prepare maps of their flood mitigation plan. Maps can be presented in a gallery walk or in front of the class.
    b. Students create a powerpoint presentation and share their plan for flood mitigation with their class. Extension: Since these students are community members they will vote on whether or not each individual proposal should be passed and adopted, or not.
    c. Students can complete a short report or a letter to local government officials with their plan, budget and why these strategies would make a difference to their local environment.

Flood Mitigation Plan

Resources

- Color Map of the West Branch of Herring Run Watershed
- Color Map of the West Branch of Herring Run Watershed with BMPs
- Cost Estimates Table of Flood Reduction Options – See student pages
- Colored Pencils
- Tracing Paper
- Masking tape

Baltimore City has budgeted out $1 million to flood reduction efforts in the West Branch of Herring Run watershed. Baltimore needs flood consultants to help them determine which methods would be more successful. As the consultants, it is your task to help Baltimore City come up with an affordable Flood Mitigation Plan. *Your goal is to minimize the frequency of flooding in the area surrounding the West Branch of Herring Run or your Schoolyard.* With your group, use your knowledge of surface water systems, provided resources, and the guidelines below to evaluate flood reduction methods and design and justify your plan. Prepare a short (5 minute) presentation to your class describing your plan.

To begin, spend some time researching a variety of flood mitigation practices including those listed in Table 1. Use Table 2 to summarize your research. Then, select three methods to use in your Flood Mitigation Plan and complete Table 3 with your chosen methods. Finally, provide a justification for your plan by completing the rest of the worksheet

Flood Reduction Options

Method	How does it work?	How many square feet does this option treat?	How well would this method work to reduce flooding in the West Branch of Herring Run? What evidence do you have?	What are the drawbacks, limitations or negatives of using this method?	Expected cost for this method
Curb Extension					
Rain Garden					
Bio-Retention Facility					
Tree Planting					
Green Roof					

Activity 4

Flood Reduction Plan

Method	Where on the map would you place this method? Note if you would use it more than once.	Square Footage of Surface Treated	Cost
1			
2			
3			

Activity 4

Justification for Remediation Plan

1. On a scale from 1 = Not at all to 10 = Completely, to what extent do you think your remediation plan will address flooding in the West Branch of Herring Run or your Schoolyard?

   Not at all 1 2 3 4 5 6 7 8 9 10 Completely

2. What evidence and scientific rationale are you basing your estimate of effectiveness on?

3. What ideas do you have for how a computer model could be used to predict the effectiveness of your plan?
   a. What would you model and what would the model tell you?

   b. What data would you need to create the model?

c. What do you think would work well and what do you think might be challenging or problematic about using the model you are proposing?

4. What are the pros and cons of your plan for flood reduction?
    a. Pros: What will this plan do well?

    b. Cons: What won't this plan do well?

5. How do you think the stakeholder groups (from Lesson 1) would evaluate your plan and why?
    a. People who live in the effected watershed

    b. Environmentalists & environmental groups

    c. Government agencies such as Baltimore City Department of Public Works

Activity 4

Concluding Reflection

Name: ______________________________ Period: _________ Date: _________

1. In a few sentences, describe the remediation plan your group choose to implement in the West Branch of Herring Run or your schoolyard?

2. What square footage of watershed will your remediation methods treat?

3. How much does your remediation plan cost?

4. What still needs to be considered and/or done in the future?

How have your ideas about the following topics changed since starting this unit? In other words, what have you learned about:

1. Movement of water across the surface of an urban landscape?

2. How computers can be used by scientists?

3. How science can be used to address real world problems?

4. What science can't do (limitations) for addressing real world problems?

5. What's one question related to this unit that you would still like to know more about?

Teacher Resources

1. Storm Water Practices: https://www.epa.gov/greeningepa/stormwater-management-practices-epa-facilities

Green Roof:

http://www.bluewaterbaltimore.org/wp-content/uploads/Green-Roof-BMP-Fact-Sheet-2013.pdf

Blue Water Baltimore's extensive green roof has a variety of sedum plants.

Permeable Pavements:

https://www.baltimoresun.com/business/bs-md-porous-pavement-20140707-story.html

Porous pavement in Baltimore, MD

Bioretention Areas:

https://www.baltimorecityscape.com/projects.html

MedStar Harbor Hospital Green Infrastructure Project, Baltimore, MD.

2. I-Tree Resources: https://www.itreetools.org/
    a. i-Tree Landscape: Accesses human and forest population information; threats to help prioritize areas for tree planting.
    b. i-Tree Canopy: Estimate tree canopy and benefits using aerial photographs
    c. i-Tree Design: Parcel level analysis of current and future tree benefits.
3. USGS Stream Gauge Website (West Branch of Herring Run): https://waterdata.usgs.gov/usa/nwis/uv?01585200
    a. This station managed by the MD-DE-DC Water Science Center Baltimore office and allows users to view multiple parameters, output formats and time periods.

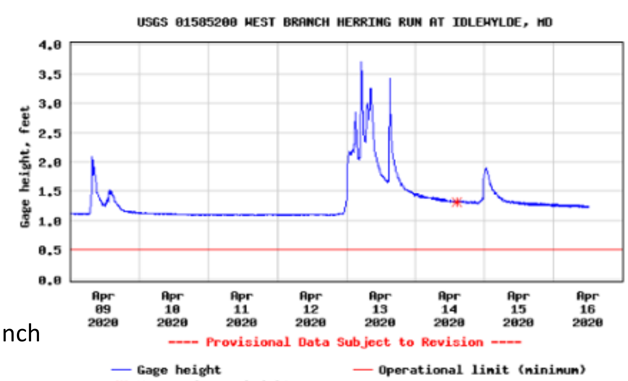
Daily discharge, cubic feet per second -- statistics for Apr 16 based on 53 water years of record more

Min (2002)	25th percen-tile	Median	Most Recent Instantaneous Value Apr 16	75th percen-tile	Mean	Max (2018)
0.64	0.97	1.7	2.36	3	4.1	45.7

Example of daily discharge (cubic feet per second) from West Branch Herring Run at Idlewylde,MD

Gage height, feet

Most recent instantaneous value: 1.23 04-16-2020 12:05 EDT



Example of gage data from West Branch Herring Run at Idlewylde,MD