Using Data to Study Rivers and Flash Flooding

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Introduction: This 5-day lesson sequence uses the phenomenon of flash flooding—focusing on a specific flash flooding event in Ellicott City, Maryland—to engage fourth-grade students in learning science using real-world data. The core standard addressed in these lessons is **NGSS 4-ESS3-2**, which states that students will be able to, "Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans."

Flooding is a common natural hazard for which people need to implement mitigation strategies and is also a phenomenon for which there is a substantial amount of accessible data that can be used in the classroom. There are places within the lessons that can be tailored to relate flooding and mitigation strategies to any region. Resources have been produced and compiled to help with accessing and processing local data. Included in the resources are the slides and student handouts, which are referenced throughout the lesson. Each lesson is designed to take 45 minutes.

Within the lessons, directions to the teacher are in normal text, while questions meant to be asked to students are italicized. "Focus questions" within the lessons are important for transitioning from one activity to the next. "Leading questions" are intended to guide classroom discussion.

Individual activities and lesson plans within this sequence have been field tested. Components of lessons can be used independent of this sequence or can be used to illustrate other concepts.

Please feel free to comment on these lessons by contacting Lindsay Mossa, AGI Education Specialist: **lmossa@americangeosciences.org**

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USING DATA TO STUDY RIVERS AND FLASH FLOODING — DAY 1 OF 5

Key Question: How does water move around us?

Grade / subject: 4th grade science

LESSON OBJECTIVE(S)

- Explore a hydrograph by building the graph, acting out the graph, and matching pictures to the graph to understand that river height changes and can be measured.
- Explore how water moves near a model of a river to see water can move as groundwater and surface water.

NGSS PERFORMANCE EXPECTATION

- **4-ESS3-2.** Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

NGSS SCIENCE AND ENGINEERING PRACTICES

- (2) Developing and using models
- (4) Analyzing and interpreting data
- (7) Engaging in argument from evidence

MATERIALS

- Day 1 slide deck
- 4 images of St. Mary's River for Card Sort activity, 1 set per pair of students
- Wavy blue borders, 1 per student
- Tall staff gauge ranging from 7′ to at least 14′
- Handout of the St. Mary's hydrograph with 4 points labeled, 1 per student
- Exit Ticket, 1 per student

INTRODUCTIONS [2 MIN]

[Slide 1]
- Introduce unit topic and learning outcomes.

ENGAGEMENT [5 MIN]

[Slide 2]

- Images of different rivers starting with rivers in more natural settings and progressing to rivers in cities.

  - **Leading Question:** *What are some things that you can do at or in a river? What are some problems that can happen at a river?*

[Slide 3]

- Hook: Show Ellicott City video

  - **Leading Question:** *What do you notice? Why did it happen?*

  - **Focus Statement:** *We need to understand some things about rivers to see if we can come up with ways to mitigate flooding.*

EXPLORATION # 1—HOW WATER CHANGES IN A RIVER [10 MIN]

[Slide 4]

- For only the top image, use visual thinking strategies to facilitate conversation and introduce vocabulary.

  - **Leading Question:** *What are some things you notice about the river?*

  - **Focus Question:** *Do you think the river always looks like this? How could the river change?*

[Slide 5]

- Display images of staff gauges. Explain that gauges usually start at 0 at the riverbed so river height can be measured and recorded.

[Slide 6]

- Map of country with Fort Wayne highlighted, which is where we will study the St. Mary's River.

[Slide 7]

- Hand out the 4 images of the St. Mary's River to each pair of students.

  - **Leading Question:** *Look at all four images: Talk with your partner first about your ideas.*

  - *What do you notice about the images? Do you wonder anything about the images?*

  - *How are the banks similar and different? How might this have happened?*

  - *Which of the changes are about the river, and which are about the area around the river?*

  - **Focus Question:** *We notice the river is at different heights. What does that mean? Why does it matter?*

EXPLANATION #1—HOW WATER CHANGES IN A RIVER [10 MIN]

[Slide 8]

- Introduce baseflow, the usual height of the river. An estimate of St. Mary's baseflow is displayed.
- Explain axes: Date along bottom in the year 2021. Each vertical line is one day. Gauge height in feet along Y axis.

[Slide 9]

- Since there is so much blank space between 0 and 7, we will start the graph at 7.

[Slide 10]

- Hand out blue wavy border to each student. Let's look at some real data.
  - ► *Here is an enlarged staff gauge, which is what is used to measure rivers. Usually, they start at 0 at the riverbed. This one starts at 7 to match our graph. Imagine there is 7 feet of water below the floor.*
  - ► *We're going to "be" the river. The top of the river will be our wavy blue border.*
- Have students stand up so they can see the staff gauge and move up and down as the data appears.
- The data table fills in and points are graphed as the slide is advanced. Click through the red points and have students hold their wavy blue line at the same height, aligned with the staff gauge. Optional: have students come up and graph the data on the board. Can incorporate as time allows.
  - ► **Focus Statement:** *Imagine your movements—as we go from one point to another, there is actually a connection. We can connect the points with a line.*

[Slide 11]

- Brief class discussion sharing initial thoughts.
  - � **Leading Question:** *What do you notice about the graph?*
  - ► *There's data we didn't see because we only looked at data initially from certain points in time.*
  - � **Focus Question:** *What does this actually look like in a real river? Let's look at four points.*

ELABORATION #1—HOW WATER CHANGES IN A RIVER [10 MIN]

[Slide 12]

- 4 Card Matching: Hand out hydrograph with 4 points labeled.

[Slide 13]

- Have students work in pairs to examine the river height in the images and match the pictures with the labeled points on the hydrograph. Students should draw the shape from one card around the corresponding number on their hydrograph. Students will talk to each other and **share their evidence with each other** as they match before discussing as a class.

    - ***Which picture goes with data point 1? What evidence did you use to make your decision? Was there something in the hydrograph that you saw to help you make that decision? Continue with data point 2...***

- As students make decisions and match the shapes with the numbers, draw them on the board.

    - Answer Key: 1. Star 2. Square 3. Diamond 4. Triangle

- Let's discuss what you found as a class.

    - **Leading Question:** *What did you notice about the hydrograph?*

    - **Focus Question:** *What do you think happened here and here (point to peaks). Why do you think the river height changes?*

    - **Focus Question:** *What could cause the river height to rise so suddenly?*

    - **Focus Statement:** ***A flood is when the river goes over the banks.*** *Which image do you think may be closest to being a flood?*

- Let's look at the picture with the triangle. While discussing the image and the questions below, demonstrate how to describe that it is the image closest to being a flood by using evidence versus using process of elimination.

    - **Focus Question:** ***Is this a flood? Explain why or why not***. *(Note: This image shows the river 1 ft under flood stage for the St. Mary's River.)*

    - *What do you think would happen if there was more precipitation?*

    - *Is there any other information you'd like to know to understand the river better?*

EVALUATION—HOW WATER GETS TO A RIVER [3 MIN]

[Slide 14]

- Exit Ticket

    - *At which point do you think the river appears to be near baseflow?*

    - *If you were standing at the river, how might it look different on July 11 (A) compared to July 17 (B)?*

USING DATA TO STUDY RIVERS AND FLASH FLOODING — DAY 2 OF 5

Key Question: What factors impact how water moves in a natural environment?

Grade / subject: 4th grade science

LESSON OBJECTIVE(S)

- Read hydrographs and experiment with stream tables to discover the concept of lag time between a precipitation event and maximum river height.

NGSS PERFORMANCE EXPECTATION

- **4-ESS3-2.** Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

NGSS SCIENCE AND ENGINEERING PRACTICES

- (2) Developing and using models
- (4) Analyzing and interpreting data
- (7) Engaging in argument from evidence

MATERIALS

- Day 2 slide deck
- Handout of Pocomoke hydrograph, 1 per student
- Awesome Aquifer© kit, 1 per group
- Stream table station materials (per station/group):

ENGAGEMENT [5 MIN]

[Slide 1]

- Review of the previous day and introduction of today's lesson.

 Leading Question: *What did we talk about yesterday?*

 ► *Today we are going to look at the Pocomoke River and further explore how water gets to a river. We also talked about rain, and we will continue that discussion today.*

EXPLORATION # 1—HOW WATER GETS TO A RIVER [10 MIN]

[Slide 2]

- Discuss how students think water gets to a river.

  - **Focus Question:** ***Where do you think the water comes from? How do you think the rainwater gets to the river?***

- Hand out Awesome Aquifer Kits. Identify banks, riverbed, etc. in the kit. Discuss the limitations to using this particular model.

  - **Leading Question:** *If we add water at the top, what do you think will happen?*

  - *How will water move through the model? We'll use colored water so we can see how the water moves more easily.*

[Slide 3]

- Class Discussion of Awesome Aquifer Kit results.

  - **Leading Question:** *How did the water move when you added it at the top? Describe the pathway it took.*

  - As students describe groundwater flow and surface water flow, introduce the new vocabulary words and diagram them on cross section.

  - *Did all the water make it to the river? What evidence do you have?*

  - **Focus Question:** ***What would a flood look like in this model?***

  - *In what ways is the model like a real river? In what ways is it different?*

EXPLANATION—HOW WATER GETS TO A RIVER [3 MIN]

[Slide 4]

- Google Earth video 'flying' from the school to the Pocomoke River.

[Slide 5]

- Satellite image of Pocomoke River and the surrounding area.

  - **Focus Question:** ***What do you notice about this image—green and grey areas. What are those?***

  - *How would you describe the area around the Pocomoke River?*

  - *Most of the area around the river is green space. Water can go into the ground of a green space; we call this pervious.*

  - *Water doesn't go through the houses or roads (grey areas). We call these impervious surfaces.*

[Slide 6]
- Satellite image of area around the Pocomoke.
  - ► *The river is colored so we can see it—that is not really what the river looks like.*
  - ► *Let's look at a comparison of how much pervious green space there is compared to roads and buildings and other impervious surfaces.*
- Animation with the pie chart of amount of coverage (green vs grey) will appear upon clicking.
  - ► *This graph shows us that most of the surroundings are covered in grass, trees, and other natural ground cover. There might be some impervious surfaces we cannot see due to being covered by trees.*
  - ► *Let's take a look at how the Pocomoke River changes using a hydrograph.*

EXPLORATION # 2—HOW WATER CHANGES IN A RIVER [10 MIN]

[Slide 7]
- Pocomoke River Hydrograph—Hand out the Pocomoke hydrograph. *What does this type of graph show us again?*
- Think, pair, share annotating the hydrograph.
  - ► Annotate the graph—Circle and/or put arrows and/or label anything that you notice, have questions about, changes are occurring, or that you think is interesting. *You can write words anywhere on the page. Tell why you marked different features or areas of the graph.*
- Class discussion. Ask guiding questions and probe for evidence as students lead the conversation.
  - � **Leading Question:** *Why do you think the river rises at certain times? What is happening when the graph is going down?*
  - � **Focus Question:** ***Where does this water come from? Why do you think so? What additional information would you need to know for sure?***
  - ► *If you were standing right next to the river during this time, describe what may be happening.*
  - ► *When do you think it rained for the river to change like this?*

[Slide 8]
- Re-explain that the X axis is time in the real world. Each day is the start of a new day.
  - ► Students make predictions on their hydrograph. *Put shading on the X axis where you think it rained.*
  - � **Leading Question:** *Can you make any inferences about the rain? Was it the same each time it rained? What is your evidence? Why do you think so?*

- Animation

  - ► *This bar will move through the graph—**it is important to watch it once first to observe what happens in the graph, then we will watch it again to focus on specific details about what it shows.***

  - ► *We're going to play this again. This time, raise your hand when you think it was raining. Put your hand down when you think it wasn't raining.*

- Play animation while students raise and lower their hands according to their predictions.

  - **Focus Question:** ***What led you to raise and lower your hands? What evidence did you use to decide?***

  - ► *We actually have the rain data. Let's take a look at it.*

[Slide 9]

- Show the precipitation graph and briefly discuss it. Be careful to not describe the quantity of the rain, but rather the intensity. The height of the rain line shows the intensity of the rain at a specific time.

  - **Leading Question:** *What do you notice about the rain? What are similar and different about these rain events?*

  - ► *What rain event would you consider to be more intense? ("Intense" could be different things to different people.) What about it makes you think one or another is more intense?*

  - ► *How do you think these affected the river?*

[Slide 10]

- Display dual hydrograph. Discuss things you notice with your partner.

  - ► *Compare your predictions (the shaded areas that you made) about when it rained to the precipitation graph. Did it rain earlier or later than you thought? Did it rain for a longer or shorter time than you thought?*

  - **Leading Question:** *What do you think is going on in the river?*

  - **Focus Question:** ***What relationships do you notice between river height and rain events?***

- Click to have the red box appear around a portion of the graph.

  - ► *It may help us to look closer at the data. Let's examine what happened with the rain and the river between May 26 and May 29.*

[Slide 11]

- Zoomed in dual plot from May 26 to May 29

  - ► *Take a moment to examine the graph. Talk with your partner about what you notice about the rain and the river.*

[Slide 12]

- Rain and staff gauge animation—**Watch a couple times**.
  - ► *Talk to your neighbor about what you notice.*
  - After a few moments, ask the pairs of students to discuss: ***What relationships do you notice between river height and rain events?***
- Class discussion
  - � **Focus Question:** ***What can you say about when the rain starts and when the river starts to rise?***
  - ► *Compare the peak precipitation intensity to the when the river is at peak height. How do the times they occur relate to one another?*
  - � **Focus Question:** *The rain ends before river goes back to base height.* ***What's your evidence?***
  - � **Focus Question:** ***Why do you think the river keeps rising after the rain stops? Why does the river stay higher even if the rain stops?***
  - � **Leading Question:** *What else do you notice?* Elicit student ideas and deep thinking about the dual plot.
  - ► *A model may help us understand what is going on with this data. We'll be modeling the Pocomoke River on the stream table.*

EXPLANATION # 2—HOW WATER CHANGES IN A RIVER [10 MIN]

[Slide 13]

- Stream Tables with green space and low intensity rain (only 2 holes exposed in rain bottle). Give students time to explore the stream tables and make observations.
- Explain the stream table and describe pros and cons of using it as a model. Explain the differences between what the stream table and the hydrograph show—stream tables show water flowing or not, whereas hydrographs display the height of the river that is always flowing. **Stream table has no baseflow.**
- Animation of pie chart of area around the Pocomoke.
- Explain the procedure and roles—rain maker, river watcher, timer, water watcher:
  - The rain maker should put water only in the top half of the green stream table using the rain bottle. Stop the rain when the river flows enough to move the sawdust.
  - The river watcher observes the river the whole time, before/during/after the rain. Does the river keep flowing after the rain stops?

- The timer starts the stopwatch when the rain starts and stops it when the river begins to move the sawdust.

- The water watcher observes how the rainwater gets to the river.

- Brief class discussion of stream table results.

  � **Leading Question:** *What observations did you make while exploring the stream table? What did you notice about the rain and the river?*

EVALUATION—EXIT TICKET [3 MIN]

[Slide 14]

- **Hand out Exit Slip.**

  ► *What do you think the hydrograph looked like after June 6? Examine the data and draw what you think the hydrograph of the Pocomoke River looked like.*

  ► *Tomorrow, we are going to look at hydrographs and use the stream tables to understand how the ground cover could impact the water in a river and flooding.*

USING DATA TO STUDY RIVERS AND FLASH FLOODING — DAY 3 OF 5

Key Question: What factors impact how water moves in a natural environment?

Grade / subject: 4th grade science

LESSON OBJECTIVE(S)

- Collect data on how water travels through pervious surfaces to describe how ground water and surface water flow affect a river.
- Investigate the effects of the intensity of rain on how a river flows to explain how multiple factors can affect a river.
- Compare two areas that differ in surface type to predict how the amount of pervious vs. impervious surfaces affect a river.

NGSS PERFORMANCE EXPECTATION

- **4-ESS3-2.** Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

NGSS SCIENCE AND ENGINEERING PRACTICES

- (2) Developing and using models
- (4) Analyzing and interpreting data
- (7) Engaging in argument from evidence

MATERIALS

- Day 3 slide deck
- Stream table station materials (per station)
- Handout of Exit Ticket

ENGAGEMENT [5 MIN]

[Slide 1]

- Review of the previous day and introduction of today's lesson.

    - **Leading Question:** *What did we do and learn yesterday?* Remind students about the Pocomoke River and hydrographs. *Do you think all rivers are alike?* Discuss ways they are different.

    - ► *Let's take a look at another river near us.*

EXPLORATION # 1—HOW GROUND COVER AFFECTS WATER MOVEMENT [15 MIN]

[Slide 2]

- Stream Tables with green space and low intensity rain (only 2 holes exposed in rain bottle).
- Repeat the procedure for using the stream tables as in Day 2. Collect quantitative data.
- Click to have the pie chart of the area on the stream table appear.
- Explain the procedure and roles—rain maker, river watcher, timer, water watcher:
  - The rain maker should put water only in the top half of the green stream table using the rain bottle. Stop the rain when the river flows enough to move the sawdust.
  - The river watcher observes the river the whole time, before/during/after the rain. Does the river keep flowing after the rain stops?
  - The timer starts the stopwatch when the rain starts and stops it when the river begins to move the sawdust.
  - The water watcher observes how the rainwater gets to the river.
- Brief class discussion of stream table results.

  � **Leading Question:** *Think about how this would look in a real river.*

[Slide 3]

- Class discussion and making a class data table.

  � **Leading Question:** *How long did it take for the river to start flowing after it started raining? Why did the water not make it to the river immediately?*

  � **Leading Question:** *Why didn't the river start flowing immediately?*

  ► *Where did the water go? How does the water make it to the river?* Diagram flow on the cross section by adding arrows for groundwater flow infiltrating the ground and surface water flow over the ground. The size of the arrows you draw can help indicate relative amounts of water in each type of flow. Discuss the meaning of the terms groundwater and surface water as they come up.

  � **Focus Question:** *Why do we all get different times?* **Discuss variables that can exist between stream tables as well as antecedent conditions**. *What could affect how long it takes for the water to get to the river?*

  ► *When did the river stop flowing? Why does the river keep flowing even after we stop adding water?*

- **Key things for students to note: 1) There is a lag between when it started raining and the river started flowing. 2) The river continued to flow after the rain stopped.**

  ► *Let's use what we learned in this model and apply it to the Pocomoke River.*

ELABORATION #1—HOW GROUND COVER AFFECTS WATER MOVEMENT [10 MIN]

[Slide 4]

- Dual plot of Pocomoke hydrograph and precipitation.

  � **Leading Question:** *Think about how the water moved on the stream table with a lot of green space. How do you think the water moved to the Pocomoke River? What evidence for this can we see on the hydrograph?*

- Discuss the graph as a class:

  � **Leading Question:** *What do we notice?*

  ► *Thinking about what we saw on the stream table, why does this lag make sense?*

  � **Focus Question:** *Knowing how the water moved on the stream table with a lot of green space, how do you think the water moved to the Pocomoke River? What evidence can we use from the hydrograph to support our ideas? Talk to your partners and your group.*

  ► **Focus Statement:** *It took a little time for the first water to get to the river. The rising limb is only a few hours later.*

  ► **Focus Statement:** *It took a longer time for most of the water to get to the river—Peak flow is about 1.5 days later.*

  ► **Focus Statement:** *The water kept moving to the river for a long time after the rain stopped.*

  � **Leading Question:** *What do you notice about the graph of the rain?*

  ► *How could we represent a higher intensity rain event in our model? Uncover more holes on the rain bottles or use more than one rain bottle.*

EXPLORATION # 1—EFFECTS OF RAIN INTENSITY (OPTIONAL) [15 MIN]

[Slide 5]

- Return to the stream tables and have students repeat the procedure with more holes open on the rain bottle to simulate a higher intensity rain.

  ► *What observations did you make while testing a higher intensity rain? What reasons can you give for the river behaving differently than it did with low intensity rain? Both the intensity and the conditions of the sand will likely make the river begin to flow more quickly.*

[Slide 6]

- Class discussion of results of stream table.

  � **Leading Question:** *Think about how the higher intensity rainfall move to the river. How was this different from the lower intensity rainfall?*

- Click to have the Pocomoke hydrograph appear. Click again to show the question.

  ► *How did different rain events impact the Pocomoke River? Use evidence from the hydrograph.*

EXPLANATION #1—HOW GROUND COVER AFFECTS WATER MOVEMENT [15 MIN]

[Slide 7]

- Satellite image showing where Ellicott City, Maryland is.
  - Remind students of the Ellicott City flood video and that this event occurred near the Patapsco River.

[Slide 8]

- Satellite images comparing the area around the Pocomoke River to the area around the Patapsco River.

  � **Leading Question:** *How do these two areas differ?*

[Slide 9]

- Satellite images with the pie charts estimating the amount of pervious and impervious surfaces in each area.

EVALUATION—CLASS DISCUSSION [8 MIN]

[Slide 10]

- Class Discussion:

  ► *How do you think water moves to a river surrounded by mostly green space?*

  ► **Formative Assessment:** *How do you think water would move to a river near a city?*

USING DATA TO STUDY RIVERS AND FLASH FLOODING — DAY 4 OF 5

Key Question: What factors impact how water moves in an urban environment?

Grade / subject: 4th grade science

LESSON OBJECTIVE(S)

- Read hydrographs and experiment with stream tables to understand how impervious surfaces affect lag time between a precipitation event and maximum river height.
- Analyze and compare two hydrographs and make inferences about the environments near the rivers.

NGSS PERFORMANCE EXPECTATION

- **4-ESS3-2.** Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

NGSS SCIENCE AND ENGINEERING PRACTICES

- (2) Developing and using models
- (4) Analyzing and interpreting data
- (7) Engaging in argument from evidence

MATERIALS

- Day 4 slide deck
- Handout of the Patapsco River hydrograph, 1 per student
- Stream table station materials (per station)
- Large square sticker to draw city, 1 per student (about 17–18cm square)
- Handout of the side-by-side graphs
- Individual whiteboard or similar and marker, one per pair (laminated cardstock works—check markers)
- Handout of side by side River A and B hydrographs, one per pair

ENGAGEMENT [5 MIN]

[Slide 1]

- Review of the previous day and introduction of today's lesson.

  Leading Question: *What did we do and learn yesterday? (*Reminders of Pocomoke River and hydrographs*) Do you think all rivers are alike? (*Discuss ways they are different*)*

  ► *Let's take a look at another river near us.*

[Slide 2]

- Satellite image comparison of area around Pocomoke River and the Patapsco River including the pie charts of grey and green space.

    - **Leading Question:** *What do you see in the images? What is similar? What is different?*

    - *Is grass pervious? Can water move through it? What did we see on the stream tables that supports your answer?*

    - *What are some other examples of pervious surfaces? What about impervious surfaces?*

    - *Let's look at these overhead images of the two cities and see which has more pervious materials.*

    - *How would you describe the data that is shown in the graph?*

    - **Focus Question:** *How could these surfaces affect the water in the river? Do you think the hydrographs would look different?*

EXPLORATION # 1—HOW GROUND COVER AFFECTS WATER MOVEMENT [15 MIN]

[Slide 3]

- Stream Tables, Adding impervious surfaces. Lay down the impervious sheet on top of the green space. Review the procedure for the data collection.

    - *Let's model an extreme version of the area surrounding the Patapsco River on the stream table.*

    - **Leading Question:** *What do you think will happen to the river now that we added this impervious sheet? Where do you think the water will go? What will the river do? Talk about your prediction with your partner.*

[Slide 4]

- Discuss the stream table results as a class.

    - *How is this model like and unlike the real thing? Work in a discussion of the pros and cons of the model, and how it could be improved.*

    - **Leading Question:** *How did the water move to the river? How does the way the water moved compare to when the stream table was covered with all green space?*

    - *How long did it take for the river to start flowing? Compare to pervious. Use evidence to justify.*

    - *How did the impervious surface affect how the water got to the river?*

    - *Let's use what we learned in this model and apply it to the Patapsco River.*

- **Focus Question:** *How do you think the way the water moved will affect the changes in the river?*

- **Focus Question:** *How do you think the way the water moved will show on the hydrograph?*

EXPLANATION #1—HOW GROUND COVER AFFECTS WATER MOVEMENT [15 MIN]

[Slide 5]

- Hand out the Patapsco Hydrograph. Think, pair, share with the hydrograph.
  - **Leading Question:** *What do you notice?*
  - ► *Remember we talked about the "normal" flow on a hydrograph? What height is baseflow here?*
  - ► *What does this shape on the hydrograph tell us?*
  - ► *What does this actually look like at a river?*
  - ► *Think about how much the river is changing at some of these events. What do you think may be some effects of the river rising this high? What would this look like if you were down by the river? [connect to flooding]*
- Animation
  - ► *When do you think it rained?* Have students shade the x axis to show their prediction on the hydrograph.
  - ► *If the river height increased at this time (point to a specific peak), when do you think the rain occurred?*

[Slide 6]

- Display dual hydrograph/precipitation plot. Talk with your partner first, then share answers as a class.
  - ► *Compare your prediction to this graph that shows the rainfall? Did it rain earlier or later than you thought?*
  - ► *What do you notice about the rain events? How would you describe them? How are they similar and different?*
  - **Focus Question:** *How are the rain and the river height of the Pocomoke River related?*
  - **Leading Question:** *Look at the rain event on May 27. What do you notice? How would you describe this event in real life? What do you think this looked like?*
  - **Leading Question:** *How does the rain event on May 27 compare to the rain event around June 3?*
  - ► *Why do you think the river stays high so long? Why does the river stay higher even if the rain stops?*

- ► *What else do you notice?* [elicit student ideas and deep thinking about the dual plot]

- Animation of red box around May 26–May 29.

  - ► *Let's look closer at this section of the graph to help us more clearly see what's going on.*

[Slide 7]

- Zoomed in dual plot from May 26–29.

  - **Leading Question:** *What do you notice about the timing of the rain compared to when the river started rising? What about when it reached its peak height? Do the peak of the precipitation events and the peak river height happen at the same time?*

  - **Leading Question:** *How does the river respond to the rain? What is your evidence on the hydrograph?*

  - ► *Why do you think the river rose so quickly?*

- If students note peak on May 28, let them discuss. Ask about when we've seen the river respond more slowly after the rain event? Discuss groundwater flow.

[Slide 8]

- Pocomoke and Patapsco River hydrographs side by side, zoomed in on May 26–29 data.

  - **Focus Question:** *Why do you think the responses are different? What evidence from the hydrographs can you use to back up your explanation?*

  - **Leading Question:** *What do you notice about the timing of the rain compared to when the river started rising? What about when it reached its peak height?*

  - **Focus Question:** *Knowing how the water moved on the stream table with a lot of impervious surfaces, how do you think the water moved to the Patapsco River? What evidence can we use from the hydrograph to support our ideas?*

[Slide 9]

- Side by side of Pocomoke and Patapsco, longer date range

  - NOTE the differences in shapes of the hydrograph which is a result of the effects of pervious vs. Impervious surface.

EVALUATION—ANALYZING HYDROGRAPHS [10 MIN]

[Slide 10]

- What information can be determined from a hydrograph?

- Two options: white board activity or written evaluation.

USING DATA TO STUDY RIVERS AND FLASH FLOODING — DAY 5 OF 5

Key Question: What factors impact how water moves in an urban environment?

Grade / subject: 4th grade science

LESSON OBJECTIVE(S)

- Discuss and model mitigation strategies to make an argument about how they could be implemented in your local area.

NGSS PERFORMANCE EXPECTATION

- **4-ESS3-2.** Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

NGSS SCIENCE AND ENGINEERING PRACTICES

- (2) Developing and using models
- (4) Analyzing and interpreting data
- (7) Engaging in argument from evidence

MATERIALS

- Day 5 slide deck
- Satellite image of your town or a nearby city, 1 per student
- Dark colored markers
- Handout of Exit Ticket

ENGAGEMENT [5 MIN]

[Slide 1]

- Review of the previous day and introduction of today's lesson.

    � **Leading Question:** *What did we do and learn yesterday?*

[Slide 2]

- Patapsco hydrograph dual plot. Click to show arrow to highlight the May 27 event.

[Slide 3]

- Ellicott City May 27, 2018 Flooding video

    � **Leading Question:** *What did you notice? Introduce the term flash flood as students define the new vocabulary. This is different than the type of flooding we have been talking about—which is called a "river flood"*

    ► *What types of surfaces did you see around Ellicott City? Were they pervious or impervious? How was the water flowing on or around these surfaces?*

    ► *The Patapsco River is at the bottom of the hill. What do you think is happening down there?*

    ► *Do you think this flash flood could have been avoided? How?*

    ► *What evidence could you use to support the position that Ellicott City needs more surface water flow mitigation? Could we use any evidence from the hydrograph or precipitation data?*

    ► *What do you think could be done to help manage the surface flow? Talk with your partner about your ideas.*

[Slide 14]*

- *Alternate slide- in case you do not have internet access, use this slide to show images of flooding.

EXPLANATION #1—SURFACE WATER MITIGATION [15 MIN]

[Slide 4]

- Introduce vocabulary—Surface Water Flow Mitigation Strategies.

    � **Leading Question:** *What could be done to increase the amount of water that goes into the ground? This is called infiltration.*

- Share a couple of best practices and relate them back to the student ideas as appropriate.

    ► *Do you know of any areas around your school or town where these practices are implemented?*

    ► *Can you think of a place around your school or town where you think mitigation is most needed?*

- ► *Why do you think these practices haven't been implemented already?*

- ► *What other issues can you think of that could be caused by surface water flow over impervious surfaces?*

[Slide 5]

- Students use the stream tables to test out how water moves through or around each of the three types of surface water mitigation strategies. Set up two stream tables for each of the three mitigation strategy and have the student groups rotate through each of the strategies to test how they affect water movement.

[Slide 6]

- Review the students' results for the stream table with a Detention Ponds/Infiltration Basin before discussing how this strategy works and could be used in an actual city.

  - **Leading Question:** *How did the water move with this strategy? How was this different that when the stream table was entirely covered with impervious surface?*

  - ► *Where in a city would this strategy be most effective?*

[Slide 7]

- Review the students' results for the stream table with Porous Pavement before discussing how this strategy works and could be used in an actual city.

  - **Leading Question:** *How did the water move with this strategy? How was this different that when the stream table was entirely covered with impervious surface?*

  - ► *Where in a city do you think this strategy would be most effective?*

[Slide 8]

- Review the students' results for the stream table with added Vegetation before discussing how this strategy works and could be used in an actual city.

  - **Leading Question:** *How did the water move with this strategy? How was this different that when the stream table was entirely covered with impervious surface?*

  - ► *Where in a city do you think this strategy would be most effective?*

[Slide 9]

- Class Discussion

  - **Leading Question:** *Do you think areas around our school or town need surface water flow mitigation? Why do you think that? What evidence could you use to support your thoughts?*

  - ► *What else would you need to support your thoughts?*

[Slide 10]

- Pervious vs. impervious data—display map with pie chart of Patapsco and Pocomoke.

- ► *Remember that we discussed the amount of pervious and impervious space around both the Pocomoke and Patapsco Rivers.*

[Slide 11]

- Teacher-generated slide with satellite image and pie chart of impervious vs pervious surfaces for the area around their town or a nearby city (if possible, include your school in the image). The satellite image should cover an area less than 25 km^2 in order to have a high enough resolution.

  - **Leading Question:** *How do you think the water will move across the areas around your school? What about around the city?*
  - ► *Now that we have the pervious and impervious surface data, do you think our school needs surface water flow mitigation? What about our town or city?*
  - ► *Why do you think mitigation strategies aren't already in place?*

EXPLORATION # 1—MITIGATING YOUR CITY [15 MIN]

[Slide 12]

- Hand out the satellite image of the town or city. Students work individually.
  - ► *What areas on the map would benefit from a surface water flow mitigation strategy? Students should circle these areas on the map.*
- Students work in groups to agree on one area they agree is most in need of mitigation. Students should use a different color to indicate group decisions.
  - ► *Identify on the map where the mitigation strategy would be built. Draw it in.*
  - **Focus Question:** *Which strategy or strategies would you choose? Why would you choose this/these over the other options?*
- Each group shares their idea with the whole class.

EVALUATION—EXIT SLIP [10 MIN]

[Slide 13]

- Exit slip
  - ► *Which strategy that you included on your map do you think would work the best?*
  - ► *Which strategy did you hear from others might you want to include on your map?*
  - ► *How could you check if your strategies work?*