A Curriculum Module Written for
Harpers Ferry National Historical Park

The physical and historical geography of the Harpers Ferry area demonstrates how landscapes shape human history and how human endeavors profoundly affect natural landscapes—a powerful reminder that the actions of today determine the opportunities of tomorrow.

Teacher Guide

Bridging the Watershed

An Outreach Program of the Alice Ferguson Foundation in Partnership with the National Park Service and Area Schools
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<td>Demonstrate changes in settlement patterns as the use of waterpower intensified.</td>
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<td>Predict pollution and other negative consequences of intense over-use of a water resource.</td>
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| Performance Tasks | Predict how life could change when the people in a village move to a site near the creek. | Compose a letter to the 19th-century girl explaining in detail how the turbines at her mill operate. | Complete map/graphic organizers that describe river behavior and write two short essays using the information contained on their map/organizers. Assert and defend a position related to human use of river power. | Perform experiments to assess the Shenandoah River’s impact on Virginius Island and reflect on the location as a future industrial site. | Discuss and evaluate contemporary river use conflicts. |
| Students will: | Describe how waterpower changed several trades in pre-industrial Europe and predict how increased waterpower use could result in future conflicts. | Describe the best place to build a new factory in a hypothetical setting and the rationale for placement. | | Research and present a 21st-century river use conflict. |
| | Design a village that uses water power from a local creek to drive several trades, label point sources of pollution and what the consequences of these might be. | | | |
| | Optional: Demonstrate an ability to integrate recent learning into a scientifically valid narrative of how their imaginary village would be affected by its creek. | | | |
Pre-Industrial WaterPower in Europe

Students will

• Read about and respond to ten questions describing early uses of waterpower.
• Apply their learning by drawing a map of a village that uses waterpower and then color-coding the village’s potential conflicts and pollutants. (see Fig. 1 – “Your Village” student anchor paper).

This lesson is intended to provide students with background knowledge about factors influencing human decisions regarding the use of waterpower. The lesson can function on its own as an ecology or pollution investigation but is intended to lead into the other lessons of the Virginius Island module, including the field study in Harpers Ferry, West Virginia. Important components of this lesson include how pre-industrial Europeans used waterpower and the types of pollution created by early water-powered industries. In addition, students will be asked to design a village that efficiently and effectively uses water-powered industries.

The introductory piece removes students from the present and places them in a European village in the year 1500. Students are asked to speculate regarding how the construction of a new village, otherwise identical to their existing one, will be influenced by the presence of a creek at the new location. The goal of this introduction is to get the students focused on the creek as a resource for their village and to plant in their minds the suggestion that use of this resource may alter it.

The introduction is followed by four paragraphs that provide an overview of the many uses of waterpower by Europeans prior to the industrial revolution. Ten questions are provided that correspond to the reading. The questions start out easy, asking simple recall or identification questions, but quickly become more analytical and evaluative, which may require you to guide students towards possible responses, or at least to allow them to work cooperatively. Seven of the ten questions, if answered properly, will require more than single-sentence responses.

After the class has successfully analyzed the reading, it will be time for them to apply their new knowledge of pre-industrial European waterpower by creating a map of an imaginary village (see Fig. 1c – Student anchor paper of “Your Village”). This map will illustrate the effects of the use of waterpower on the water source, the villagers, the surrounding farms, and the wildlife. The students will also be required to mark on the map and describe on a separate sheet potential conflicts resulting from overuse of waterpower in their village. The map includes forests, wetlands, and crops. The ownership of these resources is defined for students. The intention is that they decide who will own it, who will get to use it, and whether or not those resources are to be sacrificed in the building of the village. Students will most likely want to refer back to both the reading and their written answers as they build their village. In addition, you may want to lead brief discussions regarding each of the facets of the map’s construction and color-coding, especially about the issues of pollution, ownership, and river use conflict.

While the map could well serve as a performance assessment and you could choose to conclude the lesson here, a formal written assessment, which is a re-visiting of the introduction, is also provided for your use. If you choose to employ it, it provides a handy pre- and post-test measuring stick of the students learning.

Possible answers to Pre-Industrial Waterpower in Europe:

1) What kinds of people owned early water-powered mills?

*Common people and farmers owned the early water-powered mills. There were 5,000 water-powered mills being used in England during the 11th century.*
2) How often were these mills used?
   The early mills were used only occasionally when the farmers needed them after a harvest or to mill their neighbor's harvest.

3) What was done with the “products” of these early mills?
   The products of these mills, processed grains, were eaten by the farmers or their animals. They were not sold.

4) How much environmental impact do you think these early mills created? Why or why not?
   I don't think these mills had much environmental impact. They were small, used only occasionally, and probably did not affect the river's flow much even when they were in operation. Furthermore, the mills did not create much pollution, aside from perhaps some floating husks and seeds.

5) Of the many trades which started to use waterpower, which do you think was changed the most? That is to say, which industry had the greatest change in process, quality, or efficiency as a result of waterpower? Why?
   The trade that I think was changed the most was blacksmithing. If people did not have to swing a hammer all day anymore but instead could use waterpower to hammer metals, they could work much longer hours and turn out better products. Also, they could possibly live longer and pass on skills to younger blacksmiths.

6) The title of the section “Easing Labor” suggests that after people started using waterpower they would be less tired, having worked less hard. Do you think waterpower delivered on that promise? Why or why not?
   Yes, people may have been less tired after using waterpower to perform a task, but they would probably just go out and do something else that made them tired. Waterpower probably just made doing other things possible, but the people would go to bed just as sore.

7) Waterpower was described in “Early Use” as being free, and its efficiency was described as being unimportant. Could we, as waterpower’s uses were expanded, continue to make those claims? Why or why not?
   No, all you need to mill grains is turning stones. The other uses, especially moving water out of mines or hammering metal tools, required a lot of force, so efficiency had to be high. Also, if lots of people who did the same thing all lived nearby, then they would compete with each other to offer the lowest prices. That would make the efficiency of the waterpower very important.

8) If you were a farmer living downstream from a town with many waterpower-driven industries, what kinds of complaints might you have? Do you think you would be able to sell your crops to the townsfolk? Could you always guarantee them a good, bountiful harvest? Why?
   If I was a farmer downstream from a town that used waterpower, I probably would not have any water! All of the tradespeople would be diverting it, and there would be none left for me. I don't know if they would buy my crops; it might depend how much they polluted the little water I was able to get. No, I could never guarantee a good harvest because, with little or no water coming down the creek, I would be dependent on rain.

9) If fish caught in the town’s creek were an important part of the townsfolk’s diets, what decisions might they make about the number and type of industries that were powered by the creek?
   If people wanted to keep the fish alive, they should not use all of the water and not pollute it very much. Using a lot of the water to turn looms and then returning it to the creek, might be okay, but not if they also filled the creek with dyes used to color the fabric.

10) Describe two potential conflicts that might occur during a drought. In each case, who should win? Why?
    One potential conflict during a drought could be mills versus carpenters. The mills should win because people need to eat. Another conflict could be miners versus weavers. In this case the miners should win because coal provides heat and allows you to cook food, while you could always wear old clothes until it rained again.
Your Village and Its Water Conflicts

Now that you have a better idea how waterpower was used in pre-industrial Europe, how its use changed settlement patterns and the environment, and how these changes led to conflicts, you are ready to draw your own village and predict how its use of waterpower will affect its residents. Read all of the directions before responding to the instructions so that you will be able to plan your village wisely.

Procedure:

1) Obtain a copy of “Village Site” map (Fig. 1a) and “Your Village” map (Fig. 1b).

2) Take a moment to observe the river, the forests, the fields, and the other features pictured on the “Village Site” map (Fig. 1a). Think about how a pre-industrial village (e.g., homes, farms, shops, roads, wells, and the locations of water wheels) would be situated on this landscape.

3) “Your Village” map (Fig. 1b) is the same landscape with the majority of the natural features removed to give you sufficient workspace to create your village. You may replace as much or as little of the vegetation as you would like as you plan and layout your new village.

4) Determine and draw the direction the stream is flowing. Draw the village. Be as specific as you can within the space provided. If you like, leave the wild spaces such as forests and undeveloped fields in their natural state or build on them and cultivate them. This is your village; you can make it as populous and developed as you like, provided it remains a pre-industrial village.

5) When you have drawn in all of the features, label them. Some will be easy to write right on top of, but others will need to be indicated with the use of arrows. Just try to keep it as neat as possible; this will be graded.

7) Now comes the really interesting part. Using the color code below this paragraph, use colored pencils or markers to indicate along the river’s length where it would probably be polluted by the use of waterpower and the other human activities in the village. Then, trace each color back to its source, be it a mill, a farm, or just a bathroom behind a crowded tavern. Your map, when you are finished, should look something like a thick vein of colors with smaller branches of individual colors coming off of the center.

<table>
<thead>
<tr>
<th>Color</th>
<th>Description of Use</th>
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<tbody>
<tr>
<td>Blue</td>
<td>Dyes and chemicals used to treat fabrics</td>
</tr>
<tr>
<td>Brown</td>
<td>Sawdust and wood chips</td>
</tr>
<tr>
<td>Red</td>
<td>Iron and other heavy metals pumped out of mines as they drain</td>
</tr>
<tr>
<td>Black</td>
<td>Coal dust and dirt washed into the water</td>
</tr>
<tr>
<td>Orange</td>
<td>Flakes of copper, bronze, and other metals used in tools and weapons</td>
</tr>
<tr>
<td>Yellow</td>
<td>Human and animal wastes that have flowed into the river</td>
</tr>
<tr>
<td>Green</td>
<td>Excess plant products dumped into the creek after processing</td>
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8) After you have described the possible pollution sources, identify three points of potential conflict over the river. Using a wide marker or making several passes with your pen or pencil, circle three places on your map where you think there could be conflicts. These could be conflicts between people over access to the river’s water, they could be conflicts between people and animals or plants, or they could be between people and the river itself such as an attempt to change its course.

9) Describe below each of the three potential conflicts you circled by naming who is in conflict, what each side wants, and what the result of each conflict will probably be.

Responses will vary.

0) Finally, return to your map and decide where you would want to live if you were transported back in time to this village. Place an “X,” name one of the buildings “My House,” or otherwise indicate where you would be most comfortable. Be prepared to explain why.
Figure 1c. – Student Anchor Paper of “Your Village”
At the beginning of this lesson, you were asked to imagine that you lived in Europe in the year 1500 and that your village was forced to move to a new location. That new location had a creek running down the middle of it. You were asked to speculate about how that creek would affect your village, how your village would affect it, and how life would be different for the next generation as a result. As a way to demonstrate how much you learned in this lesson, do that exercise again. Use all of your knowledge, including what you learned from the reading, from the map you drew, and from the answers and explanations you provided. Be creative if you like, but be sure to include the key ideas in this unit.

Imagine you live in Europe in the year 1500. Your village has fifty families, most of whom are farmers, but there are also a few tradespeople, including a blacksmith, a carpenter, and weavers. Because of a recent serious event, perhaps a forest fire, an outbreak of disease, or a war, the villagers have decided to move to a new location. The new site, presently undeveloped forest, is similar to the one you’ve abandoned, except that the new village has a fast-flowing creek running through the middle of it.

Possible responses:

1) How might the presence of this creek affect life for you and the other villagers?
   The creek is a resource that we can use. The creek can provide power for mills, it can provide water for our fields, it can remove pollution from the village, and it has fish in it. If we use it properly, it can change our village a great deal.

2) Will it impact the farmers more, less, or differently than it might the tradespeople?
   The tradespeople can and will use it everyday; farmers might use it only a few times a year. The tradespeople may not have to compete with each other for it, but the farmers, since they are consuming the water, might compete among themselves a lot.

3) How might the village change over the next generation because of the creek?
   The village could become larger with more people, more money, and a greater variety of workers.

4) How might the creek change in that time because of the presence of the village?
   The creek could get polluted, it could have its course changed, and it might disappear if we use all of its water for our fields.
Catherine’s Cotton Factory

Students will

- Read a letter from a 19th-century seamstress describing the workings of the cotton mill on Virginius Island, Harpers Ferry, West Virginia.
- Read a technical explanation of how water wheels and turbines powered factories.
- Write a letter in response to the seamstress’ in which the students explain how water wheels and turbines provide power to factories.
- Apply this understanding to a decision-making model in which they have to choose and defend a location for a new mill.

This lesson is intended to follow the lesson on Pre-Industrial Water Power in Europe and continue building the students’ knowledge of and interest in the use of rivers prior to their field study in Harpers Ferry National Historical Park. This lesson centers around one of the ruins on Virginius Island in Harpers Ferry, the cotton factory that was opened in 1848. During their field study, students will have the opportunity to examine these ruins, including the turbine pit and underground canals. In addition, one of the tests they will perform - measuring the river’s speed - will be done along the factory’s southern wall.

The lesson begins with students reading a letter that could have been written by a young 19th century girl who worked at the factory. In the letter, she explains to her cousin how the factory operates, the volume of cotton that it processes, and what her role is. She also expresses confusion about how the Shenandoah River generates enough power to drive all of the factory’s machines. The students will be writing a letter back to this girl explaining how the river’s power is collected and distributed.

Students will then learn all about this specific factory’s power supply, and the technology of 19th-century waterpower in general, by reading a short article. Drawings of the machines will also be available for their use.

At this point, the students will be ready to create their principal product for this lesson, a letter back to our young girl explaining how her factory is powered. Specific instructions are provided, as is an example letter to help you with your grading, to serve as an example for the students, or both. The students will be combining what they learned at the outset in the girl’s letter with the technical information from the article to create a comprehensive picture of how the factory functioned.

An additional assignment is also included, one that could serve as a homework task or an assessment. Students are asked to use a map of an imaginary river to decide where a local town should build its new factory (Fig. 5 – Locating a New Mill). Students will use their newly gained knowledge of how a river generates both horsepower and torque in making this decision, although they may use other justifications as well. Students will then be asked to explain and defend their decision in writing.
My Dearest Family,

It seems like an eternity since I left you all in Springfield. I hope this missive finds you well and in good health. I am sorry I have not written sooner, but life has been a whirlwind with my work at the factory, settling in with the family I am boarding with, and leaving some opportunities for my many suitors. Harpers Ferry is a fascinating village, populated by people from Virginia, Massachusetts and Pennsylvania, many immigrants from England, Ireland and Germany, and black freemen and slaves. The pretty, little town sits between two magnificent rivers and in the shadow of the surrounding hills. With two canals, three turnpikes, and the railroad, the town seems constantly in a bustle. The shops line the streets and all are arrayed with the latest goods and fashions out of the port of Baltimore. I have joined the local Temperance League. I am also busy teaching several of the local girls how to read and write. I am surprised how many girls from good families are unschooled. I hope perhaps to visit Baltimore or Washington City, both only a six-hour journey from here but that will have to wait. This place reminds me of home with its shops and factories. Well, I am sure you want to hear about my work; let me take you on a tour of my cotton factory.

Completed just last year, the factory is the largest in the entire South and competes directly with our factories in Springfield, Massachusetts. It cost $60,000 to build and is four stories tall, all of them brick, complete with a bell tower and a polished tin roof. At night we work by gaslight and in the winter we have steam heat. I work as a spinner, earning $3 a day, minus my room and board. Most of the employees are girls or women, with only a few men to do heavy lifting and maintain the machines. The male employees earn a little more than we do, which seems unfair to me.
What is amazing to me is that the whole factory is powered by the river. The Shenandoah, a little part of it actually, turns these contraptions called turbines down in the basement, and that turning action is translated to axles hung from the roof of the ceiling in each room. These axels in turn drive all of the machines via smaller axles or belts. For the life of me, I cannot understand how that little bit of water drives this entire factory.

Let me officially start your tour. On the first floor is the carding department, where the cotton delivered fresh from the fields by barge, wagon, or train is opened, cleaned, and wound into initial clumpy strands. This is accomplished by two picking machines, eighteen carding engines, and six double roller spreaders, all powered by the river.

On the second floor, where I work, the clumsy, coarse threads are spun into uniform, sew-able threads. There are eighteen frames, each with 132 pairs of spindles and bobbins, and all of them are driven by an overhead axle bringing the river’s power to our work stations. During the day this floor is unbearably noisy, and all of us put cotton into our ears.

The third floor is where the thread is weaved into cloth. There are ninety-seven looms, and on them the cloth is weaved, pressed, and brushed. The whole factory revolves around the weavers. If they work fast one day, the men unloading the cotton and those of us doing the spinning have got to hurry to keep up because, if the looms sit idle, the factory does not make any money. In contrast, if several of the operators get sick (cholera is a constant problem here) or weather forbids them to walk to work, the managers close the whole factory, arguing that the loom operators are the ones that actually make the factory money. If there are not enough of them to pay everyone’s salary, it is cheaper to wait until they return.

The fourth floor is not interesting. Up there the finished cotton bundles are banded, covered for shipping, and tagged for their destinations. I guess I find it uninteresting because the process of creation has ended; the fourth floor is just names and addresses and invoices. The banding machine and the bagger are also powered by the river, however, and require a great deal of energy to handle those huge bundles of tightly woven fabric. I just do not know how the river does it!
There was a big celebration last week with an article in the paper, because the factory shipped 300,000 pounds of cotton the month before, a new record. My friends and I were hoping for bonuses or some recognition, but all of the speeches were reserved for the investors and managers. Oh well, I should not feel too badly – the river did not get any recognition either. I did use the occasion as an excuse to buy a new bonnet, which I wore to both the ceremony and a party afterward. In my next missive, I will write you of my new family and my new friends. The other girls and I are enjoying being surrounded by hundreds of handsome young masons, factorywrights, blacksmiths, carpenters, and soldiers. 

Please write when you get a chance; I can not wait to hear how you all are adjusting to life without me.

With Love,
Catherine

Instructions for writing a letter to Catherine:

Pretend you are Catherine’s cousin Beth or, if you prefer, Beth’s fiancé John. You two have just received Catherine’s letter about the cotton factory where she works, and you want to write back to her. By coincidence, you have also just read an article by a leading engineer in the field of water-driven manufacturing. He described how turbines work and how the power they generate is transferred to machines, and he used as an example of this process the nation’s newest cotton factory, the one in Harpers Ferry, West Virginia. Proud of Catherine and her new job, you want to explain to her how her factory is powered and how those “contraptions called turbines” operate.

Write a letter to Catherine, including

1. The excitement and pride you feel for her and her new job
2. The kinds of power the river creates
3. Why old technologies (water wheels) are insufficient
4. How newer turbines are better than older water wheels
5. The details of her factory’s machinery
6. How you came to learn all of this
Dearest Catherine,

It sounds like you are having a great time in Harpers Ferry. So many kinds of people and so much to do! I am glad the job is going so well, and I hope I can come visit soon.

As it happens, John and I just read an article by one of the leading experts on water-driven industry. All that you were describing made perfect sense to me; perhaps I can explain a bit of it to you. First of all, rivers, your Shenandoah in this case, offer two very different types of power as they rush along. Their speed represents the potential for lots of horsepower, which would allow machines such as the spindles and bobbins to be turned very quickly. And their head, or the number of feet they travel downhill at any particular location, represents potential torque, or the ability to do heavy work. Those machines on the fourth floor, the ones that move the heavy bundles of material, require lots of torque. Luckily, the river has a drop of 14 feet at your Factory, giving you all the torque you need.

The author described your new cotton factory in great detail because he said it uses some of the newest and best technology in America. Older factories are less efficient because they use older water wheels, which are fine but have several problems. They were less efficient, they could get stopped by excess water, and they wasted potential head due to their upright design. You cannot power a four-story factory with old water wheels.

Your factory uses turbines instead, as you mentioned in your letter. Turbines correct all of the disadvantages of water wheels, especially the waste of head. Turbines are water wheels laid flat, so they do not fight gravity, and water comes out of all of their slats at once, which is more efficient. They also require less maintenance and make much more usable energy.

Your factory gets all the power it needs from just two turbines, each almost six feet across. Together they generate 60 to 70 horsepower. The only real problem with the turbines at your factory is that, if something happened to them, you would be out of a job. There is no alternative power system at all.

It is fun when I was reading the article with John. I was quite bored, but now I am so glad I finished it because I got to share all of this excitement with you! It makes me feel like I am right there with you.

Write with more news when you can.

Warmest Regards,

Beth
Locating a New Factory

Throughout the 19th-century, as more and more waterpower was used for manufacturing, decisions had to be made about where to build new factories. Often these decisions were based solely on the river’s head and speed at particular locations, but other times factors such as proximity to towns, impacts on farming, and aesthetics were also considered. Now that you understand how a river’s head and water speed provide power for manufacturing, you are qualified to evaluate the power-producing potential of several possible locations for a new factory. You can also consider other, less mechanical factors if you feel they are important. Carefully study the map of the area where a new factory is going to be built and decide which location is best (see Fig. 5 – Locating a New Mill: Student Map). Once you have picked a spot, write a one-paragraph justification for your choice. In addition, include a second choice in case the first spot cannot be bought by the town. Justify it as well.

A sample response:

I would locate a new factory at site E. Even though the river has very low speed at site E, which would result in low horsepower, it has a lot of head, 9’, which would create a lot of torque. Site E is downstream of the farms and homes, so any environmental effects of the factory would not be felt by our people. Finally, site E is in the middle of a large field, so no trees would have to be cut down to build it.

If site E was not available, I would choose site C, but for different reasons. I would say use site C because it has a medium amount of speed, a lot of head, and roads. Also, because it is sitting between other buildings, it won’t ruin the view of a pretty location. Since that area is developed already, we may as well add to it.

Figure 5 – Locating a New Mill

Note that there are no “right” answers for this assignment. The students should apply what they have just learned about how a river powers a factory, but they can also include aesthetic, health, or other considerations when making their decision.
**Human Impact on River Environments**

Students will
- Work cooperatively to complete a pair of graphic organizers contrasting the behavior during floods of rivers that have been modified by dams and canals with rivers that are unaltered.
- Use those graphic organizers to write paragraph-long evaluations of a flooding river’s impact on its environment.

This lesson is intended to follow the lesson on *Catherine’s Cotton Factory* and continue building the students’ knowledge of and interest in our use of rivers prior to their field study in Harpers Ferry National Historical Park. Using a version of the jigsaw group work technique, the lesson summarizes the behavior of rivers under both normal and flood conditions and contrasts how a river in its natural state behaves compared to one that has had its course modified in order to supply power for human use.

The lesson begins with students reflecting on a river they have visited and considering in what ways the use of that river as a power source may have impacted its appearance. After a brief discussion, the students divided into groups of three and given the combination maps/graphic organizers (Fig. 6) titled, “A River’s Natural Environment Versions A, B, and C,” which describe a river in its natural state. Each of the three students’ maps/organizers has pre-printed information different from that of their partners’, and each has information missing on it that must be filled in. They will need to work with their partners to discuss and share everyone’s information, learning together how the river behaves at different parts of its journey to the sea. After they have copied their teammates’ information and discussed how it all fits into a complete description of the river and its environment, they are to compose a short essay describing how the river reacts to floods.

At this point you may choose to bring them back together as a class and lead a review of the material or instead immediately provide them with the second set of maps/organizers titled (Fig. 7), “A River That Is Being Used As A Power Source Versions D, E, and F,” which describe a river that has been modified to provide power for human use. They are to work as they did before, comparing the information on their organizers and reaching a complete understanding with their teammates before composing a second short essay evaluating the dangers of floods to rivers whose courses have been changed by humans.

The assessment for this lesson is designed to also act as a final preparation for the field study experience. The students are asked to support or oppose the use of river power by humans, and however they argue, they will find evidence for their position on Virginius Island when they visit it. Alternatives are to conduct a debate, poster competition, or other method of having them state and logically defend a position.
A River’s Natural Environment

Figure 6 - Versions A, B, and C

A. Mountains and Forests

1. What will become the river is still many small creeks and streams.

2. During intense rain and/or snow melt, the forest floor absorbs excess water, slowing and reducing the surge of floodwaters.

3. Runoff into the streams and creeks carries leaf matter and other organic materials that “feed” life in the waters.

4. Trees provide shade for the creeks and streams, keeping the water cool, which is important for the life cycles of many insects.

B. The River’s Main Channel and Its Floodplain

1. Silt and organic matter are deposited, creating a habitat and food source for life on the bottom of the river.

2. The water’s surface is warmed by the sun, allowing a greater variety of lifeforms to live in the river.

3. The water slows down the channel, allowing many plants and more delicate animals to live in it.

4. During floods, water runs very fast through the channel, scouring the bottom of its silt, and carrying it downstream.

5. In addition, during flooding, the waters rise to cover the floodplain, fertilizing either crops, natural plants, or both.

C. The River’s Mouth

1. At the mouth, where the river empties into the ocean, healthy, nutrient-rich, cool water creates a mini-ecosystem, separate from that of either the river or the ocean.

2. The constant flow of freshwater from the river mixes with the salty ocean water and keeps it pushed back, creating a unique brackish (mixed fresh and salty) environment for unique species.

3. During floods, the silt scoured from the river’s channel is deposited at the mouth. This material helps to alleviate erosion by tidal action from the ocean.
A River That Is Being Used As A Power Source
Figure 7 - Versions D, E, and F

D. Mountains and Reservoirs

1. Hills that have been denuded of trees do not absorb water; instead, they allow water to quickly rush into streams and creeks, carrying eroded rocks instead of nutrient-rich leaf litter.

2. Water in the reservoir is stagnant and still. Some of it evaporates and is lost, while the eroded rocks settle to the bottom, eventually filling the reservoir.

E. Below the Dam

1. Water slowly trickles over the dam into the shallow channel, depositing any sediment it carries with it.

2. The combination of shallow depth and direct sunlight heats the water, limiting its biodiversity.

3. During flooding, the dam must release more water than normal. When that happens, factories and farms in the floodplain are swamped, resulting in damage and often introducing animal waste and industrial pollution into the river.

F. Canals and the River’s Mouth

1. Water diverted into the canals moves slowly, allowing sedimentation to occur, and the constant filling and emptying of the locks and basins precludes normal plant, fish, and insect lift cycles.

2. Water discharged at the mouth of the river is lifeless, nutrient-poor, slow, and does not “protect” the mouth from the ocean. The unique brackish ecosystem does not occur, or if it does, is much smaller than normal.
Sample Responses

I. During heavy rains, spring melts, or other flood conditions, how do the river and its environment respond? How might the area appear different after a flood than it did before?

During a flood, the creeks and streams carry lots of sediment, mostly leaf matter, down to the river. Not all of the rain or snow melt reaches the river, however, because some of it is absorbed by the soil and plants. When floodwaters reach the river’s main channel, they go very fast and scrub sediment off the river’s bottom. This is important because it keeps the channel from filling up over time. The farmland or natural fields near the river’s banks are fertilized during a flood by the sediment-filled floodwaters. At the river’s mouth, the floodwaters deposit all of the remaining sediment, replenishing material that had been lost to ocean erosion. The flood affects every part of the river.

II. Which condition, normal rainfall or flooding, is more detrimental to the river itself and the wildlife that live in it when a river is being used as a power source? Why?

This question can be answered one of two ways.

Flooding of a river that is being used as a power source is more detrimental. When the factories and farms in the floodplain are swamped, the industrial pollution and animal wastes can poison the river, killing the few species that had managed to live in it.

or

The normal, non-flood state of a river that is being used as a power source is the most detrimental. At those times, the sediment is not being properly distributed, biodiversity is low, and the mini-ecosystem at the river’s mouth is small or nonexistent. At least during floods, the river is able to reclaim some of its previous behavior and course.

III. Rivers can provide enormous amounts of cheap, low-polluting power for generations. However, with the technology presently available, use of river power presents both drawbacks and risks. Defend or criticize the use of river power and provide three reasons in support of your argument.

This answer can be answered either in support or criticism of the use of river power.

Rivers should be used as power sources. They are non-polluting, they provide dependable and virtually continuous sources of cheap power, and they don’t consume any resources.

Rivers should not be used as power sources. In order to harness a river’s power, we have to alter its flow, we drastically change its suitability for animal life, and we will increase the harm done during floods.
Before You Visit the Park

Objective:
- To identify several locations on Virginius Island, Harpers Ferry, West Virginia.

Fig 8 – Virginius Island Trail Guide, is the park’s official map of the area where you will conduct your field study to collect data about the waterpower of the Shenandoah River. Use this map as a guide to locate the following six places. Fill in the blanks with the corresponding numbers from the map.

10  The Shenandoah Canal
7   The Winchester & Potomac Railroad
5   The Shenandoah River
6   The Intake Arches
2   The Water Tunnels
1   The Cotton Factory (Note that you want the larger Cotton Factory that you read about in Catherine’s letter, not the smaller Cotton Mill.)

Figure 8. Virginius Island Trail Guide

1. **Cotton Factory.** In 1848, a four-story “Brick Factory Building, of the most permanent character,” began operation here. The building was fitted with gaslights, heated by steam with pipes, and equipped with the latest cotton machinery. During the civil War, the building served as a Union hospital. After the war, the building was converted into a flour mill and four Leffel Company iron turbines were installed. These turbines remain in the building today. The building was abandoned after the Flood of 1889.

2. **Water Tunnels.** These stone-arched culverts were part of an elaborate underground water supply system that powered the Cotton Factory.
3. **Cotton Mill.** In 1849, a second four-story brick cotton mill was built on Virginius Island. Called “Valley Mills,” a contemporary newspaper account reported that “this factory is capable of manufacturing 400 lbs. of Cotton yarn, 100 lbs of Batting, and 50 lbs of Candle wick per day.” Fire destroyed the building in 1852.

4. **River Wall.** Water drawn from the Shenandoah River was stored in an inner basin here before being distributed to the headraces of the various mills on Virginius Island. A stone wall separated the basin from the river. Silt, deposited by frequent inundation of this area, has filled the old basin.

5. **Shenandoah River.** Hard ledges of Harpers shale, tilted up on end some 230 million years ago, have created a series of rapids here known as “The Staircase.” Over a distance of 1 ½ miles, the river drops 14 feet. This “fall” furnished 19th-century millwrights with the waterpower necessary to drive their machinery.

6. **Intake Arches.** These head gates were originally built in about 1848. Control Gates on the arches regulated the flow of water from the river into the Inner Basin.

7. **Railroad.** On March 31, 1836, the Winchester & Potomac Railroad, opened from Harpers Ferry to Winchester, VA. —a distance of 32 miles. The line served to bolster the economy of Virginius Island, bringing grain and produce from the Shenandoah Valley, and provided a direct link to Baltimore. This railroad still carries freight—the last operating link to the rich history of Virginius.

8. **Shenandoah Pulp Company.** Opened in 1888, this pulp mill was outfitted with ten turbines that together developed more than 2,300 horsepower. These water wheels powered disc-barking machines, shaking screens, wet-press machines, and wood grinders that produced about 40 tons of “Spruce Ground Wood Pulp” daily. The mill operated until 1935.

9. **Hall’s Rifle Works.** In 1820, John H. Hall began assembling his patent breech-loading rifles for the U.S. Government here. Hall was one of the first arms makers to combine mechanized production with the manufacture of interchangeable parts. In 1844, the government began replacing Hall’s frame shops with a new brick Rifle Factory that produced standard U.S. Model Rifles until the Civil War. In 1861, Confederate forces destroyed the factory.

10. **Shenandoah Canal.** Between 1806-1807, the Patowmack Company excavated a 580-yard canal just above Virginius Island. A double-lift lock was erected at the lower end of this canal where the pulp mill ruins now stand. By deepening existing river channels above and below these locks—including the channel in front of you—a waterway over a mile long was created.

11. **Armory Quarry.** In the early 19th century, the U.S. Government quarried rock from these cliffs for use in the construction of Armory buildings.

12. **Iron Foundry.** In 1835, a tannery located here was converted into an iron foundry. Saw, straw cutters, wagon boxes, cast-iron railings, and coal stoves were among the many items produced here.

13. **Herr’s Mill.** In 1840, a large stone flour mill was built here on the site of an earlier grist mill. The building became known as Herr’s Mill following its purchase by Abraham Herr. In 1861, during the first year of the Civil War, Herr invited Federal forces to remove grain from his mill. When nearby Confederates learned of this act, they set fire to the building. The mill was never rebuilt.

14. **Herr/Child House.** In July 18667, Herr sold his Virginius Island holdings to the firm of Child & McCreight. The Child family moved into a sturdy stone house that once stood here. During the Flood of 1870, the Childs were trapped on the second floor. They survived the ordeal, but 42 other local residents perished.

15. **Row Houses.** By 1850, a line of 11 rowhouses extended along the south side of Wernwag Street. These dwellings probably housed workers and their families employed in the mills and factories of Virginius Island.

16. **Wernwag’s House.** A large 3 ½ -story house formerly stood on these foundations. Lewis Wernwag, a nationally recognized builder of long-span wooden truss bridges, formerly lived here. Wernwag operated a nearby sawmill and machine shop.

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**Trail Information:** ¾-mile loop or 1¼-mile loop over a level, partially graded path. Allow about 45 minutes for the shorter loop an hour and fifteen minutes for the long loop.
Plan Wisely for Your Students’ Field Study in the Park

Goal:
- To help students plan and prepare for their field study in a local national park.

Background Information:
It is crucial that all students be prepared for the field study in the park. For many students, working outdoors will be an unusual and challenging experience. The information in this section should be reviewed carefully with the class to help them prepare mentally for the field study and to ensure that they have the appropriate dress and supplies for a meaningful park visit. It may be beneficial to review this information several times before the park visit to be sure all students understand the required preparations and plan well for their visit.

Be Prepared for the Park Visit:
Students need to be dressed appropriately and have adequate food and drink. Expensive clothes and shoes are not appropriate for work in the out-of-doors, and wearing these expensive items makes students reluctant to engage in field studies. Advise students not to wear skirts, shoes with high heels, or sandals.

Park Information:
Students can review information about the park on the Bridging the Watershed web site at <http://www.bridgingthewatershed.org> to gain an understanding of the park’s location and other pertinent information.

Things to Bring
- There will be no place to buy food. Students must bring a bag lunch and plenty to drink, preferably water.
- The hotter the weather, the more students should bring to drink. Have students pack their lunch and drinks in a backpack or bag that they can easily carry into and out of the park study site.
- Keeping in the ecology-minded spirit, suggest that students make their lunch as trash free as possible. Some areas and parks have no trashcans. What is packed in must be packed out. Remember, there is nothing beautiful about trash.
- Make sure that students bring sunscreen and insect repellant.

Park Stewardship
- Remind students that no collecting of any type is permitted.
- Remind students to take only photographs and leave only footprints.

Tips about Clothing
- Students should wear comfortable clothing that allows them to easily move, hike, bend, and climb. Students may have to gather data in a wet and muddy environment, so they should choose clothes they don’t mind getting wet and dirty.
- Dress for the weather. In cool weather, have students wear layers of clothing to keep them warm in the early morning, but that they can remove later in the day or while working. If the forecast calls for possible rain, students should wear a waterproof jacket, hat, and shoes, and bring a plastic bag for materials.
- Even in warm weather, have students wear long pants and a long-sleeved shirt for protection from poison ivy and briars. Students may be in a wooded area or walk through tall grass.
Field Study at Harpers Ferry NHP

Key to Lower Harpers Ferry

1  Information Center
2  The Point
3  Meriwether Lewis Museum
4  John Brown’s Fort
5  Arsenal Square
6  Black Voices Exhibit
7  Storer College Niagara Exhibit
8  John Brown Museum
9  Flagpole
10 Ice Cream Stores
11 Bookstore/Restrooms
12 Shuttle Bus Stop
Field Study at Harpers Ferry NHP

Students will
- perform data collection and analysis related to the Shenandoah River’s effect on the land and industry of Virginius Island.
- compare different groups’ data and evaluate the decision-making processes that led to industry being built on Virginius Island.

This is what all of the hard work and preparation were for – our day in the park.

The day’s agenda will probably include these activities:

1. Disembark bus at the Visitor’s Center and ride the park’s shuttle buses to lower Harpers Ferry.
2. Be greeted by the rangers and BTW staff and move students to the flagpole or perhaps to the grassy area beyond the train tracks.
3. Once there, rangers will orient students regarding the locations of bathrooms, restaurants, safety issues (very important when working on the river), the day’s time table, and any additional issues.
4. Divide the class into groups.
5. Perform the field study.
6. Bring the students back together for a reflection activity.
7. Have lunch (this can happen before, during, or after the reflection).
8. Depart the park via the shuttle buses.

Each student should bring their labeled copy of the Virginius Island Trail Guide (see Fig. 8), a pen or pencil (a clipboard would be nice, too), lunch including water, and a second pair of shoes. The students should not get wet during this field study, but are very likely to get muddy, and if their muddy shoes can be placed into plastic bags before the students visit the bathrooms, bookstore, or ice cream shops, it would be appreciated. Your school bus driver might appreciate it, too.

Field study booklets will be provided at the park.
Contemporary River Use Conflicts

Students will
- Read short descriptions of five 21st-century river use conflicts and classify each according to the nature of the conflict.
- Choose one of the conflicts to study further and create a report describing it for the class.

The lesson begins with an introductory thought exercise that asks the students to reflect on the types of conflicts regarding human use of rivers they have already studied. Students are then asked to forecast what kinds of conflicts might be common in the future and why they believe the way they do.

The class will then be exposed to a list of types of conflicts related to river use, and after reading five short descriptions of ongoing conflicts, they will be asked to place each conflict in the appropriate category. After this introduction to 21st-century conflicts and different ways of thinking about them, the class will be asked to research one specific conflict of their own choosing and report on it to the class. A rubric for grading those presentations is provided. The presentations can easily be converted into writing assignments.

The following analytical rubric can be used to assess quality of work. As with all rubrics, they are best used as a tool to explain your expectations and have been included in the student booklet.

<table>
<thead>
<tr>
<th>Content</th>
<th>5</th>
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<th>2</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Both fully given, with the region well described</td>
<td>Both given, but student failed to fully describe the region</td>
<td>Both given, but with some inaccuracy</td>
<td>Only one given or with substantial inaccuracies in both</td>
<td></td>
</tr>
<tr>
<td>Type of conflict</td>
<td>The conflict is categorized, and the reasons the student chose that category are fully explained</td>
<td>The conflict is categorized, but the reasons the student chose that category are only partially given</td>
<td>The conflict is categorized, but not as well or precisely as it should have been</td>
<td>The conflict is improperly categorized, or the reasons given do not support the decision</td>
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</tr>
<tr>
<td>Most important options</td>
<td>All of the principal options are listed and explained</td>
<td>Most of the options are described, but not fully or equally</td>
<td>Only some of the options are described</td>
<td>Less than half of the options are described, or some are misrepresented</td>
<td></td>
</tr>
<tr>
<td>Environmental impacts</td>
<td>Each option has its environmental impacts fully discussed</td>
<td>All of the options have their environmental impacts discussed, but one is not discussed fully</td>
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<tr>
<td>Recommend one option and explain why it is best</td>
<td>Only one option is described as best, and the student’s reasons are well-considered</td>
<td>Only one option is described as best and reasons are given, but not as accurately or convincingly as they should have been</td>
<td>One option is described as best, but the reasons are unconvincing or partially inaccurate</td>
<td>No option is recommended or two are, or no reasons are given or the reasons are contradictory</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Presentation</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization</td>
<td>Student properly organizes his ideas so that they follow a natural, predictable sequence</td>
<td>Student well organizes his ideas, with occasional errors in sequence or ordering of facts</td>
<td>Larger ideas are well organized, but details are sometimes mismanaged</td>
<td>Little organization is evident to the substantial detriment of the presentation</td>
<td></td>
</tr>
</tbody>
</table>

TOTAL
Contemporary River Use Conflicts

Objectives:
- To categorize five river use conflicts.
- To investigate another conflict of your own choosing.
- To explain that conflict to your classmates.

Throughout this unit, you have been studying human use of river power and the conflicts that arose as a result. Some of the conflicts have been between people with different priorities, some have been between people and the river’s environment, and some have been between the river and the structures or landforms along its banks. What kind of conflict do you think will be the most prevalent in the 21st century? Will most of the issues center around use of the rivers for industry or as a water source or as a recreational opportunity? Will most of the conflicts be between governments of different countries or between business people and environmental activists, or between citizens who want to use the river in more than one way? Make a prediction and explain why you feel the way you do.

River Use Conflict Readings

In this lesson, you will be asked to perform two tasks related to 21st-century river use and the conflicts that have resulted. First, you will read five very short descriptions of conflicts that are occurring today and categorize each by the type of river use conflict it represents. Then, you will research a conflict, either one of the five examples or a different one of your choosing, and write a description of it.

Each of the short readings that follow describes a different kind of conflict related to use of rivers. These five types of conflict are not the only kinds possible, but they represent most of the conflicts in the world today. Read the list of the five types of conflicts on the “River Conflicts that Result from Human Impact” chart, then read the five descriptions and decide which modern conflict falls into which category. Using the chart explain the ways each river’s conflicts fall into each of the categories.

Five River Use Conflicts

1. The Nile River, located in northeast Africa and running north to the Mediterranean, is one of the world’s oldest and most important examples of human use of waterpower. Egyptians have been using the Nile as a source of power, irrigation, transportation, and drinking water for more than five thousand years. Recently, however, many of the countries that are paths for or sources of the Nile’s water have been demanding greater access to it than they are presently allowed. Ethiopia and Kenya in particular want to use Nile-bound water to irrigate their fields and are also considering building dams to provide hydroelectric power. Egypt’s government has refused to discuss the issue with its neighbors; one Egyptian official even went so far as to say that Kenya’s plans, if pursued, would amount to an act of war.
II. **Venezuela** has many rivers and has exploited several of them for the generation of electricity and agricultural uses. One of its rivers, the **Caura**, is an exception in that it is not going to be used for any purpose. The Venezuelan government has decided to leave the Caura, and the region through which it flows, unexploited. The Caura River Basin measures approximately 45,000 square miles and hosts almost 500 species of tropical birds, several hundred fish species, and 2,700 types of plants. The government, utility companies, indigenous peoples, and international environmental organizations all agree that there is no need to use the Caura for any purpose at this time, and that there is substantial benefit in leaving it untouched.

III. **China** is in the midst of a terrible long-term water crisis. A combination of population growth, increased per-capita consumption, inefficient agricultural practices, and poor decision-making concerning the locations of industries have created the crisis, and none of the factors is easily corrected. One of the most severely hit regions is in the dry northeast of the country, where the **Yellow**, **Hai**, and **Hai Rivers** don’t provide enough water for domestic, agricultural, and industrial uses. The government plans to address this problem by cutting three 800-mile long channels from the **Yangtze River** in the south and diverting much of its water north to the Yellow, Hai, and Hai Rivers. Chinese and international environmental organizations fear that the Yangtze cannot provide enough water to the north-east and still satisfy those who have come to rely on it in the south. They also fear that the channels will have detrimental effects on the regions through which they are cut.

IV. In August of 2003, a new dam was completed in the Elfin Forest of **California**, creating a reservoir of freshwater for communities near San Diego. The reservoir, which will use water from the **Colorado River**, is not intended to be a daily source of water but is to be used in emergencies such as earthquakes or severe droughts. The dam was built to survive an earthquake up to 7.2 on the Richter scale, and the reservoir it protects holds enough water for 50,000 homes for one year.

V. In November of 2003, the city of **Richwood, West Virginia** experienced severe flooding. As a result, the mayor of Richwood supported a petition drive that encouraged the construction of a flood-control dam on the **Cherry River**. Many West Virginians opposed the idea on the grounds that it would be expensive and destructive to the environment and that the use of dams to control floods is an old, ineffective idea. Others agreed that something needs to be done to limit the damage done by flooding, but they suggest other methods would be more effective.
<table>
<thead>
<tr>
<th>Conflict</th>
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<tr>
<td>1. Limit the river’s ability to harm them.</td>
<td>Richwood, WV wants to protect itself from the flood waters of the Cherry River.</td>
</tr>
<tr>
<td>2. Insure that the river’s assets are always available.</td>
<td>A new dam was built so that even in the event of a large earthquake, freshwater will still be available.</td>
</tr>
<tr>
<td>3. Continue to use the river’s resources after they have been exhausted.</td>
<td>The Yellow, Haui, and Hai rivers cannot meet all of the Chinese people’s needs</td>
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<tr>
<td>4. Increase their use of the river’s resources by taking some resources away from other people.</td>
<td>Egypt uses most of the Nile’s water now. Ethiopia and Kenya want to use more of it in the future.</td>
</tr>
<tr>
<td>5. Protect the river and its environment for future generations.</td>
<td>The Caura river is being left alone for future generations.</td>
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Prepare a Presentation

Now that you have learned a little about several different types of 21st-century river use conflicts, you are ready to investigate one of them more fully. Either choose one of the examples you just read or pick another conflict you are aware of and consult encyclopedias, journals, or other media sources to find out more. When you have done so, prepare a brief presentation in which you include, at a minimum:

- The location of the conflict and the name of the river
- The type of conflict, using either one of the categories already provided or one of your own invention
- The most important or likely options being discussed by the parties involved
- The environmental impact of each option
- The economic impact of each option
- The human (as opposed to economic – could be moral, aesthetic, political...) impact of each option
- Finally, recommend one of the options and explain why you think it is best.

Use the following rubric to as a guide to help you assess the quality of your work.

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<td>Less than half of the impacts are discussed, or the impacts given are inaccurate</td>
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<tr>
<td>Recommend one option and explain why it is best</td>
<td>Only one option is described as best, and the student’s reasons are well-considered</td>
<td>Only one option is described as best and reasons are given, but not as accurately or convincingly as they should have been</td>
<td>One option is described as best, but the reasons are unconvincing or partially inaccurate</td>
<td>No option is recommended or two are, or no reasons are given or the reasons are contradictory</td>
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<tr>
<td>Presentation</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<tr>
<td>Organization</td>
<td>Student properly organizes his ideas so that they follow a natural, predictable sequence</td>
<td>Student well organizes his ideas, with occasional errors in sequence or ordering of facts</td>
<td>Larger ideas are well organized, but details are sometimes mismanaged</td>
<td>Little organization is evident to the substantial detriment of the presentation</td>
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TOTAL
Introduction to WaterPower

When given a choice, early humans always built communities along the banks of rivers. Sometimes these communities grew into great civilizations, such as those in the Nile River Valley, the Tigris-Euphrates Gulf, or the Indus-Bhramaputra Plain.

Other times, small communities stayed that way as the years and centuries passed, although sometimes invading peoples replaced the original inhabitants. In all cases, the peoples’ relationship with their rivers did not fundamentally change. They used the rivers for washing, for transportation, for irrigation, and for mechanical power. It is that last use, mechanical power, which you will study in this module.

Starting in pre-industrial Europe, and traveling well into our 21st-century future, you will examine how the mechanical power provided by rivers can drive industrial machines, shape human lives, and alter our environment. You will perform a field study among the ruins of factories and homes on Virginius Island, Harpers Ferry, West Virginia. On that field study, you will measure the Shenandoah River’s speed and depth (among other things) and assess its effect on the industries that had been built on the adjacent shore. You will evaluate the decisions made in the 18th and 19th centuries to locate industries and homes along the river, and speculate about how industries and homes might work there today. Finally, you will use what you have learned about using rivers as sources of mechanical power to forecast how well decisions being made today in other parts of the world will succeed.
Pre-Industrial WaterPower in Europe

Objectives:
• To describe early uses of waterpower.
• To demonstrate understanding of a village’s potential water use conflicts.

Imagine you live in Europe in the year 1500. Your village has fifty families, most of whom are farmers, but there are also a few tradespeople, including a blacksmith, a carpenter, and weavers. Because of a recent serious event, perhaps a forest fire, an outbreak of disease, or a war, the villagers have decided to move to a new location. The new site, presently undeveloped forest, is similar to the one you’ve abandoned, except that the new village has a fast-flowing creek running through the middle of it. All of your homes, shops, and farms are within the creek’s watershed, meaning that all of the land area drains into your creek.

As you read the next four paragraphs that describe how the use of water in pre-industrial Europe changed, think about the following:

1. How might the presence of this creek affect life for you and the other villagers?
2. Will it impact the farmers more, less, or differently than it might the tradespeople?
3. How might the village change over the next generation because of the creek?
4. How might the creek change in that time because of the presence of the village?

**EARLY USES:** People have always settled near creeks and rivers to use the water for drinking, bathing, cooking, and transportation. The earliest use of water as a power source in pre-industrial Europe was for milling, which is the grinding and crushing of grains such as wheat or barley between two large stones. The early mills were built around very simple water wheels, which used the power the water exerted as it flowed downstream to turn the mill stones. These small mills were easily built and operated, often used by only one family. In most cases, the mills were only used seasonally after the family’s crops were harvested. The mills processed the grains grown by one family and perhaps their neighbors and were almost never used by farmers who lived far away. These mills were relatively inefficient, at least compared to later designs, but that did not matter since the waterpower was free, and the farmers were milling grains that they or their own animals were going to eat, not producing processed grain for sale. To give you an example of how commonplace these early mills were, there were more than 5,000 in England alone in the 11th century.

**LATER USES:** During the Middle Ages, the use of waterpower expanded to other trades and industries. Weavers used water-driven looms to ease their labor, and leather workers used waterpower in the tanning and brushing of hides. Carpenters used axles turned by water wheels to drill, sand, and saw; in addition, the manufacture of paper was made simpler through the harnessing of waterpower. Even large industries were affected; for instance hydraulic pressure generated by water wheels was used to pump the excess water out of flooded mine shafts, and conveyer belts driven by waterpower were used to carry coal out of mines up to the surface. Perhaps the most important development during this time was the use of waterpower to create much more force than a single person could in order to pound large hammers against cooling metals to create harder, stronger tools and weapons.
EASING LABOR: All of these applications of waterpower allowed work to be done faster, more reliably, and on a larger scale than had been previously possible. For instance, before waterpower was used, weavers turned their looms by continuously pressing a pedal with their foot, a process that inevitably turned the loom at uneven speeds and resulted in the weaver tiring after only a couple of hours of work. Once waterpower was used to turn the looms, these limitations were removed, and the weavers could do a better job for a much longer length of time. For another example of how waterpower allowed work to be done faster and better, ask yourself how coal got out of the mine shafts before there were water-driven conveyor belts or, how heavy is your backpack?

EFFECTS on the ENVIRONMENT: A consequence of work being done faster and better was that instead of one or two families in each village doing all of the weaving or blacksmithing for that village, with another tradesperson laboring similarly down the road in his/her village, the trades became concentrated. Over time, certain villages became known for having many of the same kinds of skilled workers, and if you wanted to purchase a manufactured item, an axe for example, you would travel to a town with many blacksmiths and find exactly the size, shape, and quality of axe you wanted. Often these tradesmen used the same water source for their power, creating conflict over the rights to it and concentrating negative effects such as pollution at these locations. We don’t often think about pre-industrial peoples creating very much pollution, but consider how the dyes used on fabrics or the solutions used to soften and tan leather or the chipped wood from the saw mills would affect the ecology of a stream or river. In addition to concentrating the industries in specific locations, the increased use of waterpower meant that water wheels were being used year-round, often 12 hours a day, six days a week, which constantly disrupted the flow of the water in the stream or creek. In time, the course of the water was permanently changed, and the plant and animal life that depended on the river either adjusted to the change or died. In addition humans have found alternative, faster forms of transportation.

Using what you have just read, answer the following 10 questions:

1) What kinds of people owned early water-powered mills?

2) How often were these mills used?

3) What was done with the “products” of these early mills?

4) How much environmental impact do you think these early mills created? Why or why not?
5) Of the many trades which started to use waterpower, which do you think was changed the most? That is to say, which industry had the greatest change in process, quality, or efficiency as a result of waterpower? Why?

6) The title of the section “Easing Labor” suggests that after people started using waterpower they would be less tired, having worked less hard. Do you think waterpower delivered on that promise? Why or why not?

7) Waterpower was described in “Early Uses” as being free and its efficiency was described as being unimportant. Could we, as waterpower’s uses were expanded, continue to make those claims? Why or why not?

8) If you were a farmer living downstream from a town with many waterpower-driven industries, what kinds of complaints might you have? Do you think you would be able to sell your crops to the townsfolk? Could you always guarantee them a good, bountiful harvest? Why?

9) If fish caught in the town’s creek were an important part of the townsfolk’s diet, what decisions might they make about the number and type of industries that were powered by the creek?

10) Describe two potential conflicts that might occur during a drought. In each case, who should win? Why?
Your Village and Its Water Conflicts

Now that you have a better idea how waterpower was used in pre-industrial Europe, how its use changed settlement patterns and the environment, and how these changes led to conflicts, you are ready to draw your own village and predict how its use of waterpower will affect its residents. Read all of the directions before responding to the instructions so that you will be able to plan your village wisely.

Procedure:

1) Obtain a copy of “New Village Site” map (Fig. 1a) and “Your Village” map (Fig. 1b).

2) Take a moment to observe the river, the forests, the fields, and the other features pictured on the “New Village Site” map (Fig. 1a). Think about how a pre-industrial village (e.g., homes, farms, shops, roads, wells, and the locations of water wheels) would be situated on this landscape.

3) “Your Village” map (Fig. 1b) is the same landscape with the majority of the natural features removed to give you sufficient workspace to create your village. You may replace as much or as little of the vegetation as you would like as you plan and layout your new village.

4) Determine and draw the direction the stream is flowing.

5) Draw the village. Be as specific as you can within the space provided. If you like, leave the wild spaces such as forests and undeveloped fields in their natural state or build on them and cultivate them. This is your village; you can make it as populous and developed as you like, provided it remains a pre-industrial village.

6) When you have drawn in all of the features, label them. Some will be easy to write right on top of, but others will need to be indicated with the use of arrows. Just try to keep it as neat as possible; this will be graded.

7) Now comes the really interesting part. Using the color code below this paragraph, use colored pencils or markers to indicate along the river’s length where it would probably be polluted by the use of waterpower and the other human activities in the village. Then, trace each color back to its source, be it a mill, a farm, or just a bathroom behind a crowded tavern. Your map, when you are finished, should look something like a thick vein of colors with smaller branches of individual colors coming off of the center.

<table>
<thead>
<tr>
<th>Color</th>
<th>Description of Use</th>
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</thead>
<tbody>
<tr>
<td>Blue</td>
<td>Dyes and chemicals used to treat fabrics</td>
</tr>
<tr>
<td>Brown</td>
<td>Sawdust and wood chips</td>
</tr>
<tr>
<td>Red</td>
<td>Iron and other heavy metals pumped out of mines as they drain</td>
</tr>
<tr>
<td>Black</td>
<td>Coal dust and dirt washed into the water</td>
</tr>
<tr>
<td>Orange</td>
<td>Flakes of copper, bronze, and other metals used in tools and weapons</td>
</tr>
<tr>
<td>Yellow</td>
<td>Human and animal wastes that have flowed into the river</td>
</tr>
<tr>
<td>Green</td>
<td>Excess plant products dumped into the creek after processing</td>
</tr>
</tbody>
</table>

8) After you have described the possible pollution sources, identify three points of potential conflict over the river. Using a wide marker or making several passes with your pen or pencil, circle three places on your map where you think there could be conflicts. These could be conflicts between people over access to the river’s water, they could be conflicts between people and animals or plants, or they could be between people and the river itself such as an attempt to change its course.
9) Describe below each of the three potential conflicts you circled by naming who is in conflict, what each side wants, and what the result of each conflict will probably be.

a. 

b. 

c. 

10. Finally, return to your map and decide where you would want to live if you were transported back in time to this village. Place an “X,” name one of the buildings “My House,” or otherwise indicate where you would be most comfortable. Be prepared to explain why.
Figure 1a - “New Village Site”
Figure 1b – “Your Village”
At the beginning of this lesson, you were asked to imagine that you lived in Europe in the year 1500 and that your village was forced to move to a new location. That new location had a creek running down the middle of it. You were asked to think about how that creek would affect your village, how your village would affect it, and how life would be different for the next generation as a result. As a way to demonstrate how much you learned in this lesson, answer those same questions again. Use what you learned from the reading, from the village you planned, and from the answers and explanations you provided. Be creative if you like, but be sure to include the key idea in the unit.

Imagine you live in Europe in the year 1500. Your village has fifty families, most of whom are farmers, but there are also a few tradespeople, including a blacksmith, a carpenter, and weavers. Because of a recent serious event, perhaps a forest fire, or an outbreak of disease, or a war, the villagers have decided to move to a new location. The new site, presently undeveloped forest, is similar to the one you’ve abandoned, except that the new village has a fast-flowing creek running through the middle of it.

1) How might the presence of this creek affect life for you and the other villagers?

2) Will it impact the farmers more, less, or differently than it might the tradespeople?

3) How might the village change over the next generation because of the creek?

4) How might the creek change in that time because of the presence of the village?
Catherine’s Cotton Factory

Objectives:

• To compare the efficiency of water wheels to that of turbines.
• To explain how a 19th-century cotton factory operated.
• To propose a location for a new water-powered mill.

Read the following letter from Catherine, a worker at the cotton factory located on Virginius Island, West Virginia. Then, read the following explanation in order to learn more about the turbines that power her factory and write a letter back to her explaining how they work. Finally, using your knowledge of how turbines convert river power into usable energy for manufacturing, decide where along a river’s path to build a new factory and explain your decision.

February 17, 1850

My Dearest Family,

It seems like an eternity since I left you all in Springfield. I hope this missive finds you well and in good health. I am sorry I have not written sooner, but life has been a whirlwind with my work at the factory, settling in with the family I am boarding with, and leaving some opportunities for my many suitors. Harpers Ferry is a fascinating village, populated by people from Virginia, Massachusetts and Pennsylvania, many immigrants from England, Ireland and Germany, and black freemen and slaves. The pretty, little town sits between two magnificent rivers and in the shadow of the surrounding hills. With two canals, three turnpikes, and the railroad, the town seems constantly in a bustle. The shops line the streets and all are arrayed with the latest goods and fashions out of the port of Baltimore. I have joined the local Temperance League. I am also busy teaching several of the local girls how to read and write. I am surprised how many girls from good families are unschooled. I hope perhaps to visit Baltimore or Washington City, both only a six-hour journey from here but that will have to wait. This place reminds me of home with its shops and factories. Well, I am sure you want to hear about my work; let me take you on a tour of my cotton factory.
Completed just last year, the factory is the largest in the entire South and competes directly with our factories in Springfield, Massachusetts. It cost $60,000 to build and is four stories tall, all of them brick, complete with a bell tower and a polished tin roof. At night we work by gaslight and in the winter we have steam heat. I work as a spinner, earning $3 a day, minus my room and board. Most of the employees are girls or women, with only a few men to do heavy lifting and maintain the machines. The male employees earn a little more than we do, which seems unfair to me.

What is amazing to me is that the whole factory is powered by the river. The Shenandoah, a little part of it actually, turns these contraptions called turbines down in the basement, and that turning action is translated to axles hung from the roof of the ceiling in each room. These axels in turn drive all of the machines via smaller axles or belts. For the life of me, I cannot understand how that little bit of water drives this entire factory.

Let me officially start your tour. On the first floor is the carding department, where the cotton delivered fresh from the fields by barge, wagon, or train is opened, cleaned, and wound into initial clumpy strands. This is accomplished by two picking machines, eighteen carding engines, and six double roller spreaders, all powered by the river.

On the second floor, where I work, the clumsy, coarse threads are spun into uniform, sew-able threads. There are eighteen frames, each with 132 pairs of spindles and bobbins, and all of them are driven by an overhead axle bringing the river’s power to our work stations. During the day this floor is unbearably noisy, and all of us put cotton into our ears.

The third floor is where the thread is weaved into cloth. There are ninety-seven looms, and on them the cloth is weaved, pressed, and brushed. The whole factory revolves around the weavers. If they work fast one day, the men unloading the cotton and those of us doing the spinning have got to hurry to keep up because, if the looms sit idle, the factory does not make any money. In contrast, if several of the operators get sick (cholera is a constant problem here) or weather forbids them to walk to work, the managers close the
whole factory, arguing that the loom operators are the ones that actually make the factory money. If there are not enough of them to pay everyone’s salary, it is cheaper to wait until they return.

The fourth floor is not interesting. Up there the finished cotton bundles are banded, covered for shipping, and tagged for their destinations. I guess I find it uninteresting because the process of creation has ended; the fourth floor is just names and addresses and invoices. The banding machine and the bagger are also powered by the river, however, and require a great deal of energy to handle those huge bundles of tightly woven fabric. I just do not know how the river does it!

There was a big celebration last week with an article in the paper, because the factory shipped 300,000 pounds of cotton the month before, a new record. My friends and I were hoping for bonuses or some recognition, but all of the speeches were reserved for the investors and managers. Oh well, I should not feel too badly – the river did not get any recognition either. I did use the occasion as an excuse to buy a new bonnet, which I wore to both the ceremony and a party afterward. In my next missive, I will write you of my new family and my new friends. The other girls and I are enjoying being surrounded by hundreds of handsome young masons, factorywrights, blacksmiths, carpenters, and soldiers.

Please write when you get a chance; I can not wait to hear how you all are adjusting to life without me.

With Love,
Catherine
How Water Wheels and Turbines Power Factories

Read the following description of how and why water wheels were gradually replaced by turbines, and then use the information to write a letter back to Catherine explaining how her factory works. A list detailing what must be included in the letter is provided below.

Figure 2 – Colvin Water Wheel

Horsepower and Torque

A water wheel is like any kind of engine; it develops two kinds of power – **hors**

epower and **torque**. **Horsepower** is a measure of the **speed** the water turns the wheel and therefore how fast machines connected to the wheel can be turned. The faster the river is rushing downstream, the more horsepower it can provide to the machines connected to the wheel. **Torque** is a measure of the force the water delivers to the wheel and therefore how much weight it can lift or friction it can overcome. This force is determined by how much downhill travel the water is experiencing at that moment, and that travel is called the river’s **head**. **Head** is measured in feet, indicating the difference in elevation between how high the river started and how low it ends up. For example, water pouring off a desk onto the floor has a **head** of about 60 cm, while water poured from your outstretched arm when you are standing would have a **head** of 1.5 to 2 meters. The water you poured while standing would impact a water wheel with more energy than the water from the desk, allowing the water wheel to transfer more torque to its machines and therefore to do more work.

Weaknesses of Water Wheels

Water wheels worked well enough for centuries, but during the industrial revolution as human needs for mechanical power grew, certain drawbacks became apparent. First, the water is only pushing in one direction...
- down. If the wheel has 12 slats, only three or four are being pushed against by falling water at any one time, in the meantime, the other slats are useless. In addition, the force required to turn the un-used slats back up to the top took away energy that could have been turning machines. Second, if the bottom of the wheel gets submerged, the wheel stops turning and becomes useless. There cannot be any depth of spilled water around the wheel; therefore the water must be evacuated quickly. Third, since the pouring water impacts the wheel near its top, much of the water’s head is wasted. It would be better if it could build force before hitting the slats. All of these drawbacks meant that water wheels never exceeded 75% efficiency; that is, they never transferred more than 75% of the river’s power to the machines, and it was often closer to 60%.

A New Technology – Turbines

Turbines were invented in the 19th century specifically to overcome the weaknesses of water wheels. In a turbine, the wheel is placed on its side, and the water is dumped inside it using a pipe. The water wants to exit the wheel, and does so through the hollow slats, turning the wheel as it goes. In this way, the water is pushing against all of the slats at once. In addition, the water is able to fall a greater distance since the turbine lies flat at the bottom of a basin or waterfall. The turbine works underwater, so there is not as pressing a need to evacuate the spilled water, and the turbine is often made of iron, not wood, so it requires less maintenance. The turbine can convert up to 88% of the water’s energy into usable mechanical energy and does so more reliably than water wheels could.

![Water Wheel and Turbine](image)

Figure 3 - A comparison of a traditional water wheel and a mid 19th-century turbine

Catherine’s Cotton Factory and Its Turbines

Catherine’s factory was famous nationwide because it was an example of a factory built in, by, and for the Southern states and because it used all of the newest, most expensive equipment. Prior to the building of this factory, Southern industry had been seen as poor, unsophisticated, and backward. This factory, built in the same town as the very important U.S. government rifle factories, was seen as a first step in changing Southern manufacturing. The factory had two brand-new turbines in its basement, each almost two meters in diameter. The turbines used water brought from the Shenandoah via a specially dug underground Inner Canal and had access to over four meters of head. On average, they generated 60-70 horsepower for the machines, depending on the speed of the river. The turbines were connected to a central axle that traveled straight up through the center of the factory and fed power to secondary axles that ran along the ceiling of each room. The turning motion of these axles was transmitted to the individual machines via smaller axles or leather belts. (see Fig. 4 – Virginius Island Cotton Factory). The machines were completely dependent on the turbines and, therefore, the river. If the river ran dry or the turbines broke, or the central axle malfunctioned, all work stopped. There was no back-up coal, wood, or animal power.
Instructions for writing a letter to Catherine:

Pretend you are Catherine’s cousin Beth or, if you prefer, Beth’s fiancé John. You two have just received Catherine’s letter about the cotton factory where she works, and you want to write back to her. By coincidence, you have also just read an article by a leading engineer in the field of water-driven manufacturing. He described how turbines work and how the power they generate is transferred to machines, and he used as an example of this process the nation’s newest cotton factory, the one in Harpers Ferry, West Virginia. Proud of Catherine and her new job, you want to explain to her how her factory is powered and how those “contraptions called turbines” operate.

Write a letter to Catherine, including

7. The excitement and pride you feel for her and her new job
8. The kinds of power the river creates
9. Why old technologies (water wheels) are insufficient
10. How newer turbines are better than older water wheels
11. The details of her factory’s machinery
12. How you came to learn all of this
Locating a New Factory

Throughout the 19th-century, as more and more waterpower was used for manufacturing, decisions had to be made about where to build new factories. Often these decisions were based solely on the river’s head and speed at particular locations, but other times factors such as proximity to towns, impacts on farming, and aesthetics were also considered. Now that you understand how a river’s head and water speed provide power for manufacturing, you are qualified to evaluate the power-producing potential of several possible locations for a new factory. You can also consider other, less mechanical factors if you feel they are important. Carefully study the map of the area where a new factory is going to be built and decide which location is best (see Fig. 5 – Locating a New Mill: Student Map). Once you have picked a spot, write a one-paragraph justification for your choice. In addition, include a second choice in case the first spot cannot be bought by the town. Justify it as well.
Human Impact on River Environments

Objectives:

- To discuss and explain the differences between a river that has been used as a power source and one that has not.
- To estimate two rivers’ potential to cause damage during floods.
- To place a value on the use of rivers as power sources.

Think about a river you have visited. Perhaps you swam, fished, or rafted in it. At some point in its history, that river has almost certainly been used by humans as a source of power. Do you think that the river, when and where you visited it, looked any different because of that use? In what ways? Why or why not?

Procedure:

1. Each member of your three-member team will use one of three drawings (Fig 6 Version A, B, or C) that shows a river environment and provides some information about a particular part of that environment. Your graphic organizer will have different information pre-printed on it than the organizers of the other members of your team.

2. Each team member will have an opportunity to share information on his/her version while the other members of the team copy the information being shared. This process is repeated until information from all three versions is shared. There is space on the drawing for you to write in information from the other versions.

3. Use your drawing and information recorded to respond to the following short essay question:

   I. During heavy rains, spring melts, or other flood conditions, how do the river and its environment respond? How might the area appear different after a flood than it did before?

4. Each member of your three-member team will be issued one of three drawings (Fig 7 Version D, E, or F) that shows a river being used as a power resource.

5. Each team member will have an opportunity to share information on his/her version while the other members of the team will copy information being shared. This process is repeated until information from all three versions is shared. There is space on the drawing for you to write in information from the other versions.
6. Use your second drawing and information recorded to respond to the following short essay question:

II. Which condition, normal rainfall or flooding, is more detrimental to the river itself and the wildlife that live in it when a river is being used as a power source? Why?

7. Now that you have a better understanding of the effects of human use of river power on the river and its environment, write a response to the following prompt.

III. Rivers can provide enormous amounts of cheap, low-polluting power for generations. However, with the technology presently available, use of river power presents both drawbacks and risks. Defend or criticize the use of river power and provide three reasons in support of your argument.
A River’s Natural Environment

Figure 6 - Version A

A. Mountains and Forests

1. What will become the river is still many small creeks and streams.

2. During intense rain and/or snow melt, the forest floor absorbs excess water, slowing and reducing the surge of floodwaters.

3. Runoff into the streams and creeks carries leaf matter and other organic materials that “feed” life in the waters.

4. Trees provide shade for the creeks and streams, keeping the water cool, which is important for the life cycles of many insects.
B. The River’s Main Channel and Its Floodplain

1. Silt and organic matter are deposited, creating a habitat and food source for life on the bottom of the river.

2. The water’s surface is warmed by the sun, allowing a greater variety of lifeforms to live in the river.

3. The water slows down the channel, allowing many plants and more delicate animals to live in it.

4. During floods, water runs very fast through the channel, scouring the bottom of its silt, and carrying it downstream.

5. In addition, during flooding, the waters rise to cover the floodplain, fertilizing either crops, natural plants, or both.
A River’s Natural Environment

Figure 6 - Version C

A.

B. The River’s Mouth

1. At the mouth, where the river empties into the ocean, healthy, nutrient-rich, cool water creates a mini-ecosystem, separate from that of either the river or the ocean.

2. The constant flow of freshwater from the river mixes with the salty ocean water and keeps it pushed back, creating a unique brackish (mixed fresh and salty) environment for unique species.

3. During floods, the silt scoured from the river’s channel is deposited at the mouth. This material helps to alleviate erosion by tidal action from the ocean.
A River That Is Being Used As A Power Source
Figure 7 - Version D

D. Mountains and Reservoirs

1. Hills that have been denuded of trees do not absorb water; instead, they allow water to quickly rush into streams and creeks, carrying eroded rocks instead of nutrient-rich leaf litter.

2. Water in the reservoir is stagnant and still. Some of it evaporates and is lost, while the eroded rocks settle to the bottom, eventually filling the reservoir.
E. Below the Dam

1. Water slowly trickles over the dam into the shallow channel, depositing any sediment it carries with it.

2. The combination of shallow depth and direct sunlight heats the water, limiting its biodiversity.

3. During flooding, the dam must release more water than normal. When that happens, factories and farms in the floodplain are swamped, resulting in damage and often introducing animal waste and industrial pollution into the river.
A River That Is Being Used As A Power Source

Figure 7 – Version F

D.

F. Canals and the River’s Mouth

1. Water diverted into the canals moves slowly, allowing sedimentation to occur, and the constant filling and emptying of the locks and basins precludes normal plant, fish, and insect lift cycles.

2. Water discharged at the mouth of the river is lifeless, nutrient-poor, slow, and does not “protect” the mouth from the ocean. The unique brackish ecosystem does not occur, or if it does, is much smaller than normal.
Before You Visit the Park

Objective:
- To identify several locations on Virginius Island, Harpers Ferry, West Virginia.

Fig 8 – Virginius Island Trail Guide, is the park’s official map of the area where you will conduct your field study to collect data about the waterpower of the Shenandoah River. Use this map as a guide to locate the following six places. Fill in the blanks with the corresponding numbers from the map.

____ The Shenandoah Canal
____ The Winchester & Potomac Railroad
____ The Shenandoah River
____ The Intake Arches
____ The Water Tunnels
____ The Cotton Factory (Note that you want the larger Cotton Factory that you read about in Catherine’s letter, not the smaller Cotton Mill.)

Figure 8. Virginius Island Trail Guide

1. **Cotton Factory.** In 1848, a four-story “Brick Factory Building, of the most permanent character,” began operation here. The building was fitted with gaslights, heated by steam with pipes, and equipped with the latest cotton machinery. During the civil War, the building served as a Union hospital. After the war, the building was converted into a flour mill and four Leffel Company iron turbines were installed. These turbines remain in the building today. The building was abandoned after the Flood of 1889.

2. **Water Tunnels.** These stone-arched culverts were part of an elaborate underground water supply system that powered the Cotton Factory.
3. **Cotton Mill.** In 1849, a second four-story brick cotton mill was built on Virginius Island. Called “Valley Mills,” a contemporary newspaper account reported that “this factory is capable of manufacturing 400 lbs. of Cotton yarn, 100 lbs of Batting, and 50 lbs of Candle wick per day.” Fire destroyed the building in 1852.

4. **River Wall.** Water drawn from the Shenandoah River was stored in an inner basin here before being distributed to the headraces of the various mills on Virginius Island. A stone wall separated the basin from the river. Silt, deposited by frequent inundation of this area, has filled the old basin.

5. **Shenandoah River.** Hard ledges of Harpers shale, tilted up on end some 230 million years ago, have created a series of rapids here known as “The Staircase.” Over a distance of 1 ½ miles, the river drops 14 feet. This “fall” furnished 19th-century millwrights with the waterpower necessary to drive their machinery.

6. **Intake Arches.** These head gates were originally built in about 1848. Control Gates on the arches regulated the flow of water from the river into the Inner Basin.

7. **Railroad.** On March 31, 1836, the Winchester & Potomac Railroad, opened from Harpers Ferry to Winchester, VA.—a distance of 32 miles. The line served to bolster the economy of Virginius Island, bringing grain and produce from the Shenandoah Valley, and provided a direct link to Baltimore. This railroad still carries freight—the last operating link to the rich history of Virginius.

8. **Shenandoah Pulp Company.** Opened in 1888, this pulp mill was outfitted with ten turbines that together developed more than 2,300 horsepower. These water wheels powered disc-barking machines, shaking screens, wet-press machines, and wood grinders that produced about 40 tons of “Spruce Ground Wood Pulp” daily. The mill operated until 1935.

9. **Hall’s Rifle Works.** In 1820, John H. Hall began assembling his patent breech-loading rifles for the U.S. Government here. Hall was one of the first arms makers to combine mechanized production with the manufacture of interchangeable parts. In 1844, the government began replacing Hall’s frame shops with a new brick Rifle Factory that produced standard U.S. Model Rifles until the Civil War. In 1861, Confederate forces destroyed the factory.

10. **Shenandoah Canal.** Between 1806-1807, the Patowmack Company excavated a 580-yard canal just above Virginius Island. A double-lift lock was erected at the lower end of this canal where the pulp mill ruins now stand. By deepening existing river channels above and below these locks—including the channel in front of you—a waterway over a mile long was created.

11. **Armory Quarry.** In the early 19th century, the U.S. Government quarried rock from these cliffs for use in the construction of Armory buildings.

12. **Iron Foundry.** In 1835, a tannery located here was converted into an iron foundry. Saw, straw cutters, wagon boxes, cast-iron railings, and coal stoves were among the many items produced here.

13. **Herr’s Mill.** In 1840, a large stone flour mill was built here on the site of an earlier grist mill. The building became known as Herr’s Mill following its purchase by Abraham Herr. In 1861, during the first year of the Civil War, Herr invited Federal forces to remove grain from his mill. When nearby Confederates learned of this act, they set fire to the building. The mill was never rebuilt.

14. **Herr/Child House.** In July 18667, Herr sold his Virginius Island holdings to the firm of Child & McCreaight. The Child family moved into a sturdy stone house that once stood here. During the Flood of 1870, the Childs were trapped on the second floor. They survived the ordeal, but 42 other local residents perished.

15. **Row Houses.** By 1850, a line of 11 rowhouses extended along the south side of Wernwag Street. These dwellings probably housed workers and their families employed in the mills and factories of Virginius Island.

16. **Wernwag’s House.** A large 3 ½ -story house formerly stood on these foundations. Lewis Wernwag, a nationally recognized builder of long-span wooden truss bridges, formerly lived here. Wernwag operated a nearby sawmill and machine shop.

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**Trail Information:** ¼-mile loop or 1½ - mile loop over a level, partially graded path. Allow about 45 minutes for the shorter loop an hour and fifteen minutes for the long loop.
Plan Wisely for Your Field Study in the Park

Things to Bring
- There will be no place to buy food. You must bring a bag lunch and plenty to drink, preferably water. The hotter the weather, the more you should bring to drink. Pack your lunch and drinks in a backpack or bag that you can easily carry into and out of your park work site.
- Keeping in the ecology-minded spirit, make your lunch as trash free as possible. Some areas and parks have no trashcans. What you pack in you must pack out. Remember, there is nothing beautiful about trash.
- Bring sunscreen and insect repellant.

Park Stewardship
- While you’re in the park consider how parks can educate, inspire, and provoke thought.
- Remember, no collecting of any type is permitted.
- Take only photographs. Leave only footprints.

Tips about Clothing
- Wear comfortable clothing that allows you to easily move, hike, bend, and climb. You may gather data in a wet and muddy environment, so choose clothes you don’t mind getting wet and dirty.
- Dress for the weather. In cool weather, wear layers of clothing to keep you warm in the early morning that you can remove later in the day or while working. If the forecast calls for possible rain, wear a waterproof jacket, hat, and shoes, and bring a plastic bag for your materials.
- Even in warm weather, wear long pants and a long-sleeved shirt as protection from poison ivy and briars. You may be in a wooded area or walk through tall grass.

A Rewarding Experience
Now that you know the materials to bring, remember to also bring a positive attitude to the experience. Be willing to participate in new adventures and to enter into new things.

Protection of these irreplaceable ruins is your responsibility.
Please leave them undisturbed.
Field Study
Harpers Ferry National Historical Park

Key to Lower Harpers Ferry

1  Information Center
2  The Point
3  Meriwether Lewis Museum
4  John Brown’s Fort
5  Arsenal Square
6  Black Voices Exhibit
7  Storer College Niagara Exhibit
8  John Brown Museum
9  Flagpole
10  Ice Cream Stores
11  Bookstore/Restrooms
12  Shuttle Bus Stop
WaterPower Field Study

Objectives:

- To recall what you learned in the pre-lessons about waterpower and river dynamics.
- To perform experiments on Virginius Island.
- To relate your collected data to your prior learning.
- To estimate the value of Virginius Island as a waterpower location.

WELCOME TO HARPERS FERRY NATIONAL HISTORICAL PARK

The National Park Service administers Harpers Ferry, National Historical Park. Our mission is to commemorate the historic events that occurred at or near Harpers Ferry and maintain and preserve those natural and cultural resources for the benefit and enjoyment of the people of the United States. Education plays a vital role in the accomplishment of our mission.

A variety of educational opportunities facilitate student exploration of the rich tapestry of American Stories found at Harpers Ferry. By using the preserved cultural and natural resources found on this historic landscape, students will hear many significant American stories – from 18th-century pioneering to 20th-century civil rights. Harpers Ferry has been the place in history where many American thoughts and actions took place.

Visiting Harpers Ferry immerses the student in a different time and place. For thousands of years before European settlers arrived, the place now known as Harpers Ferry is thought to have been a sacred location to native peoples who hunted, fished, and traded along the banks of the Shenandoah and Potomac Rivers. Permanent settlements followed the arrival of the Europeans, and the town of Harpers Ferry emerged. When the United States National Armory and Arsenal was established at the beginning of the 19th century, Harpers Ferry was transformed into a thriving, diverse, and vibrant industrial town. When two railroads - the Baltimore & Ohio and the Winchester & Potomac - and a canal - the Chesapeake & Ohio - arrived, Harpers Ferry’s economic prosperity was secured. In the fall of 1859, Harpers Ferry survived John Brown’s Raid only to be decimated by four years of the Civil War. The roots of the African-American experience run deep here: slavery, the struggle for freedom, education, and the early civil rights movement are all a part of the historic fabric of Harpers Ferry. The town today remains a reminder of each of these historic events.

Harpers Ferry National Historical Park offers a variety of curriculum-based educational opportunities, and the interpretive themes at Harpers Ferry include stories that relate to both cultural and natural history. As an extension of your classroom, a field experience at Harpers Ferry will provide your students the unique opportunity to explore many nationally significant events in the place where they occurred.
Anticipatory Questions

*Industry, Transportation, and Investment at Harpers Ferry, West Virginia*

As the park ranger introduces you to the history of the people, factories, and rivers at Harpers Ferry, listen for the answers to these questions. They provide historical background that will help you to both evaluate the decisions that were made at Harpers Ferry and analyze decisions that we may make in the future.

1) What were three types of industries at Harpers Ferry?

2) What were three methods of transportation to and from Harpers Ferry?

3) List three local natural resources that were used by Harpers Ferry’s industries.

4) Name three potential markets for goods produced at Harpers Ferry.

5) Based on these answers, were mid-nineteenth century investors wise to build here?
Harper’s Ferry, WV Student Field Study Map
### Virginius Island Field Study Data Sheet

![Rt 340 Bridge over Shenandoah River](image)

<table>
<thead>
<tr>
<th>River Speed (meters/sec)</th>
<th>Distance (meters)</th>
<th>Time (seconds)</th>
<th>Speed (meters/second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 3</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>River Height (centimeters)</th>
<th>Turbidity (JTUs)</th>
<th>River’s Edge</th>
<th>Between Path &amp; Railroad Tracks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>Trial 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td>Trial 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>Average</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Permeability (sec)</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>River’s Edge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Path &amp; Railroad Tracks</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>River Bank</th>
<th>Bare Soil (%)</th>
<th>Erosion Evident</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 – 10</td>
<td>Stable</td>
</tr>
<tr>
<td></td>
<td>11 – 40</td>
<td>Occasional</td>
</tr>
<tr>
<td></td>
<td>41 - 80</td>
<td>Some</td>
</tr>
<tr>
<td></td>
<td>81 - 100</td>
<td>Severe</td>
</tr>
</tbody>
</table>
Calculating River Speed

Materials:
- compass
- stopwatch
- tape measure
- oranges

Procedure:
1. Walk to the section of Virginius Island between the cotton factory and the Cotton Mill. Find the long stone wall between the two buildings. This is where your group will measure the river’s speed.

2. Station one person where the long wall meets the edge of the Cotton Mill and another person down the wall exactly 10 meters to the east (downstream towards the cotton factory.) These two people will be the spotters.

3. Have each spotter use the compass to select a point on the opposite shore that is due south of their position. They should fix their eyes on a tree, rock, or other landmark that is closest to exactly south and is easy to remember.

4. When the spotters are ready, the third member of the team should throw an orange into the river as hard as he or she can. The orange should land upstream of the first spotter’s line of sight due south. When the orange floats through the first spotter’s line of sight, the spotter will tell the fourth person, who is operating the stopwatch to start timing.

5. The stopwatch will run as the orange floats downstream towards the second spotter’s position. When the orange crosses the second spotter’s line of sight, the stopwatch should be stopped. In this way, you will have timed how long the orange took to float ten meters, which we can assume represents the river’s speed.

6. Record on your data sheet the time it took for the orange to float ten meters.

7. Repeat the experiment two more times, writing down the times and averaging the results. If the oranges always land in the middle of the river, mark their paths on your maps. Similarly, if the thrower could only get the orange a few feet from the shore, draw those paths. This information will make comparisons with other group’s results more meaningful because the middle of the river is usually moving faster than the water close to shore.

8. Divide ten meters by the number of seconds it took the orange to cover that distance and record the speed on your data sheet: 10 meters / ______ seconds = ______ river speed in meters/sec

   Example: 10 meters / 8 seconds = 1.25 mps

9. Average your three trials.
Determining Water Turbidity

**Turbidity** is a measure of water clarity; the greater the turbidity of water, the less clear it is. Turbidity is caused by solids suspended in water that reduce the passage of light through the water. Suspended materials can include many substances such as soil particles (clay, silt, and sand), algae or other forms of plankton, and bacteria. Soil particles range in size from less than 0.004 mm (clay), from 0.004 to 0.063 mm (silt), and from 0.063 to 2.0 mm (sand). High turbidity can damage fish and other organisms and interfere with their ability to find food. In this activity, you will measure turbidity using a test kit that compares the turbidity of a water sample with distilled water. Your results will be measured in **Jackson Turbidity Units (JTUs)**.

**Materials:**

- 1 bottle Standard Turbidity Reagent
- 1 plastic pipette (0.5 mL) with cap
- 2 turbidity columns (marked “Std” and “Sample”)
- 1 stirring rod
- distilled water

**Procedure:**

1. Walk to the section of Virginius Island where the wall west of the Cotton Mill disappears at a little sandy island. You will perform the turbidity, soil type, and soil permeability studies here.

2. Fill the “Sample” turbidity column to the 50-mL line with a sample of river water. If the black dot on the bottom of the tube is not visible when you look down through the water column, pour out half the sample so that the tube is filled to just the 25-mL line.

3. Fill the “Std” turbidity column with an equal amount of distilled water; this is the standard.

4. Look down through the water in each tube to the black dot at the bottom. If the dot is equally clear in both tubes, the turbidity is zero. If the dot in the “Sample” column is less clear than the dot in the “Std” column, continue to Step 5.

5. Vigorously shake the closed bottle of Standard Turbidity Reagent.

6. Fill the pipette (eyedropper) to the 0.5-mL line with Turbidity Reagent and add reagent to the “Std” column.

7. Gently stir the “Std” column to mix the Turbidity Reagent in with the distilled water.

8. Look down into each tube to the black dot. If the “Std” column dot and the “Sample” column dot are equally cloudy, note the total amount (in mL) of Turbidity Reagent added. Use the table on the next page to determine the JTUs. If the “Sample” column dot is still cloudier than the “Std” column dot, continue to Step 9. Remember, you are matching the cloudiness of the water in the two columns, not the color. Ignore color differences between the two columns of water.

9. Add Turbidity Reagent in 0.5-mL increments to the standard (“Std”) water tube. Gently stir the column after each addition. Check turbidity by viewing the black dots in each tube. Continue to add Turbidity Reagent until the clarity of the black dot appears equal in both tubes. Record the amount of Turbidity Reagent added.
10. Use the following table to determine the turbidity in JTUs.

<table>
<thead>
<tr>
<th>No. of Measured Additions</th>
<th>Amount mL</th>
<th>50-mL Gradation JTUs</th>
<th>25-mL Gradation JTUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>1.0</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>1.5</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>2.0</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>2.5</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>3.0</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>7</td>
<td>3.5</td>
<td>35</td>
<td>70</td>
</tr>
<tr>
<td>8</td>
<td>4.0</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>9</td>
<td>4.5</td>
<td>45</td>
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<tr>
<td>10</td>
<td>5.0</td>
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<tr>
<td>15</td>
<td>7.5</td>
<td>75</td>
<td>150</td>
</tr>
<tr>
<td>20</td>
<td>10.0</td>
<td>100</td>
<td>200</td>
</tr>
</tbody>
</table>

11. Record the results on your data sheet. Then average the results of the two trials.

*Watch out for poison ivy!*

### Assessing Riverbank Erosion

One way of assessing the vulnerability of Virginius Island to damage from future floods is to assess the damage done by previous floods. As you work at the shoreline across from the little island west of the cotton mill, pause for a moment and observe the amount of erosion along the shoreline. Then, turn to your data sheet and circle the category of erosion you feel is evidenced. If you are not sure, discuss the options with your teammates and the ranger.
Determining Soil Permeability

Your group will determine soil permeability. Permeability is directly affected by the degree of soil compaction. Compaction occurs when soil is squeezed over and over, such as when it is walked on repeatedly. As air spaces between the soil particles get smaller, the particles pack more tightly and stick together. Soil that is too compacted will not hold water, and plant roots cannot penetrate the soil to grow properly. The other extreme is just as bad. If the soil is too loose, spaces between the particles are so large that water drains out quickly and completely, before plant roots can soak it up. The activity below is one way to test soil permeability.

Materials:
- can with both ends removed
- water
- graduated cylinder
- watch with a second hand

Procedure:

1. Walk to the section of Virginius Island where the path gets narrow and the forest and train tracks are just north of the path. This is where you will perform the soil permeability test.

2. Push and twist the steel can about 2.5cm into the ground just above the river’s edge. If trickles of water are touching the side of the can, that is fine.

3. Measure 100 mL of water. Quickly pour the water into the can, making sure that all of the water is inside the can, that is fine.

4. Remove the can. Replace the soil from the hole, returning the area to the way it was before you began the investigation.

5. Repeat the test on the path, (2) in the woods and (3) near the tracks. Try to find soil of different colors and consistencies. Record the results.

Measuring River Height

Materials: measuring stick calibrated in centimeters

Procedure:

1. Walk to the Intake Arches and find the sycamore tree right next to the low stone wall along the water’s edge. There are two sycamores; you want the one farthest west with many exposed roots (the one pictured on your map). Between this tree and the wall is where you will measure the river’s height.

2. While standing or sitting on the stone wall next to the sycamore tree, slowly lower the measuring stick along the face of the wall until it comes to rest on the bottom. Be careful not to stop too soon by mistaking an edge for the bottom. There is a nice flat area right between the tree’s two root pieces next to the wall.

3. Read the height of the water by having someone either climb out onto the tree’s roots or lean out from the wall. Or if the water is very high, pull the stick out and read the height of the wet mark. Check that you have the highest possible reading at that flat place by lowering the stick a few times. Record your data; then repeat one more time.
Determining Soil Type

After measuring the river’s height, use the beach area under the arches and the lightly forested area near the railroad tracks to get samples of soil you can use to determine soil type. Soil particles range from coarse (sand) to medium (silt) to fine (clay). Use your fingertips to determine what size particles are in your soil sample. When you are finished, record your results.

Start Here

If soil does not form a ball, you have SAND

Place a spoonful of soil in your palm, and add water drop by drop until it is moldable and feels like modeling clay.

If no ribbon forms or it is less than one inch long, you have LOAMY SAND

Place the ball between your thumb and forefinger. Gently push the soil with your thumb, squeezing it upward into a ribbon, allowing it to emerge over the top of your hand until it breaks.

You have formed a weak ribbon less than two inches long

You have formed a ribbon two to three inches long

You have formed a strong ribbon more than three inches long

Wet a pinch of your soil and rub it to feel its texture.

% SAND

SANDY LOAM

Yes

Very gritty?

No

NEITHER GRITTY NOR SMOOTH?

LOAM

Yes

NEITHER GRITTY NOR SMOOTH?

No

SILTY LOAM

Yes

VERY SMOOTH?

No

SANDY CLAY

Yes

Very gritty?

No

NEITHER GRITTY NOR SMOOTH?

CLAY

Yes

NEITHER GRITTY NOR SMOOTH?

No

SILTY CLAY

Yes

Very smooth?

No

SANDY LOAM

High

% CLAY

Low

66
Objectives:

- To categorize five river use conflicts.
- To investigate another conflict of your own choosing.
- To explain that conflict to your classmates.

Throughout this unit, you have been studying human use of river power and the conflicts that arose as a result. Some of the conflicts have been between people with different priorities, some have been between people and the river’s environment, and some have been between the river and the structures or landforms along its banks. What kind of conflict do you think will be the most prevalent in the 21st century? Will most of the issues center around use of the rivers for industry or as a water source or as a recreational opportunity? Will most of the conflicts be between governments of different countries or between business people and environmental activists, or between citizens who want to use the river in more than one way? Make a prediction and explain why you feel the way you do.

River Use Conflict Readings

In this lesson, you will be asked to perform two tasks related to 21st-century river use and the conflicts that have resulted. First, you will read five very short descriptions of conflicts that are occurring today and categorize each by the type of river use conflict it represents. Then, you will research a conflict, either one of the five examples or a different one of your choosing, and write a description of it.

Each of the short readings that follow describes a different kind of conflict related to use of rivers. These five types of conflict are not the only kinds possible, but they represent most of the conflicts in the world today. Read the list of the five types of conflicts on the “River Conflicts that Result from Human Impact” chart, then read the five descriptions and decide which modern conflict falls into which category. Using the chart explain the ways each river’s conflicts fall into each of the categories.

Five River Use Conflicts

I. The Nile River, located in northeast Africa and running north to the Mediterranean, is one of the world’s oldest and most important examples of human use of waterpower. Egyptians have been using the Nile as a source of power, irrigation, transportation, and drinking water for more than five thousand years. Recently, however, many of the countries that are paths for or sources of the Nile’s water have been demanding greater access to it than they are presently allowed. Ethiopia and Kenya in particular want to use Nile-bound water to irrigate their fields and are also considering building dams to provide hydroelectric power. Egypt’s government has refused to discuss the issue with its neighbors; one Egyptian official even went so far as to say that Kenya’s plans, if pursued, would amount to an act of war.
II. Venezuela has many rivers and has exploited several of them for the generation of electricity and agricultural uses. One of its rivers, the Caura, is an exception in that it is not going to be used for any purpose. The Venezuelan government has decided to leave the Caura, and the region through which it flows, unexploited. The Caura River Basin measures approximately 45,000 square miles and hosts almost 500 species of tropical birds, several hundred fish species, and 2,700 types of plants. The government, utility companies, indigenous peoples, and international environmental organizations all agree that there is no need to use the Caura for any purpose at this time, and that there is substantial benefit in leaving it untouched.

III. China is in the midst of a terrible long-term water crisis. A combination of population growth, increased per-capita consumption, inefficient agricultural practices, and poor decision-making concerning the locations of industries have created the crisis, and none of the factors is easily corrected. One of the most severely hit regions is in the dry northeast of the country, where the Yellow, Haui, and Hai Rivers don’t provide enough water for domestic, agricultural, and industrial uses. The government plans to address this problem by cutting three 800-mile long channels from the Yangtze River in the south and diverting much of its water north to the Yellow, Haui, and Hai Rivers. Chinese and international environmental organizations fear that the Yangtze cannot provide enough water to the north-east and still satisfy those who have come to rely on it in the south. They also fear that the channels will have detrimental effects on the regions through which they are cut.

IV. In August of 2003, a new dam was completed in the Elfin Forest of California, creating a reservoir of freshwater for communities near San Diego. The reservoir, which will use water from the Colorado River, is not intended to be a daily source of water but is to be used in emergencies such as earthquakes or severe droughts. The dam was built to survive an earthquake up to 7.2 on the Richter scale, and the reservoir it protects holds enough water for 50,000 homes for one year.

V. In November of 2003, the city of Richwood, West Virginia experienced severe flooding. As a result, the mayor of Richwood supported a petition drive that encouraged the construction of a flood-control dam on the Cherry River. Many West Virginians opposed the idea on the grounds that it would be expensive and destructive to the environment and that the use of dams to control floods is an old, ineffective idea. Others agreed that something needs to be done to limit the damage done by flooding, but they suggest other methods would be more effective.
<table>
<thead>
<tr>
<th>Conflict</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Limit the river’s ability to harm them.</td>
<td>Africa</td>
</tr>
<tr>
<td>2. Insure that the river’s assets are always available.</td>
<td></td>
</tr>
<tr>
<td>3. Continue to use the river’s resources after they have been exhausted.</td>
<td></td>
</tr>
<tr>
<td>4. Increase their use of the river’s resources by taking some resources away from other people.</td>
<td></td>
</tr>
<tr>
<td>5. Protect the river and its environment for future generations.</td>
<td></td>
</tr>
</tbody>
</table>
Prepare a Presentation

Now that you have learned a little about several different types of 21st-century river use conflicts, you are ready to investigate one of them more fully. Either choose one of the examples you just read or pick another river use conflict you are aware of and consult encyclopedias, journals, or other media sources to find out more. When you have done so, prepare a brief presentation in which you include, at a minimum:

- The location of the conflict and the name of the river
- The type of conflict, using either one of the categories already provided or one of your own invention
- The most important or likely options being discussed by the parties involved
- The environmental impact of each option
- The economic impact of each option
- The human (as opposed to economic – could be moral, aesthetic, political...) impact of each option
- Finally, recommend one of the options and explain why you think it is best.

Use the following rubric to as a guide to help you assess the quality of your work.

<table>
<thead>
<tr>
<th>Content</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of conflict &amp; name of the river</td>
<td>Both fully given, with the region well described</td>
<td>Both given, but student failed to fully describe the region</td>
<td>Both given, but with some inaccuracy</td>
<td>Only one given or with substantial inaccuracies in both</td>
<td></td>
</tr>
<tr>
<td>Type of conflict</td>
<td>The conflict is categorized, and the reasons the student chose that category are fully explained</td>
<td>The conflict is categorized, but the reasons the student chose that category are only partially given</td>
<td>The conflict is categorized, but not as well or precisely as it should have been</td>
<td>The conflict is improperly categorized, or the reasons given do not support the decision</td>
<td></td>
</tr>
<tr>
<td>Most important options</td>
<td>All of the principal options are listed and explained</td>
<td>Most of the options are described, but not fully or equally</td>
<td>Only some of the options are described</td>
<td>Less than half of the options are described, or some are misrepresented</td>
<td></td>
</tr>
<tr>
<td>Environmental impacts</td>
<td>Each option has its environmental impacts fully discussed</td>
<td>All of the options have their environmental impacts discussed, but one is not discussed fully</td>
<td>Two or more of the impacts are not fully discussed</td>
<td>Less than half of the impacts are discussed, or the impacts given are inaccurate</td>
<td></td>
</tr>
<tr>
<td>Economic impacts</td>
<td>Each option has its economic impacts fully discussed</td>
<td>All of the options have their economic impacts discussed, but one is not discussed fully</td>
<td>Two or more of the impacts are not fully discussed</td>
<td>Less than half of the impacts are discussed, or the impacts given are inaccurate</td>
<td></td>
</tr>
<tr>
<td>Human impacts</td>
<td>Each option has its human impacts fully discussed</td>
<td>All of the options have their human impacts discussed, but one is not discussed fully</td>
<td>Two or more of the impacts are not fully discussed</td>
<td>Less than half of the impacts are discussed, or the impacts given are inaccurate</td>
<td></td>
</tr>
<tr>
<td>Recommend one option and explain why it is best</td>
<td>Only one option is described as best, and the student’s reasons are well-considered</td>
<td>Only one option is described as best and reasons are given, but not as accurately or convincingly as they should have been</td>
<td>One option is described as best, but the reasons are unconvincing or partially inaccurate</td>
<td>No option is recommended or two are, or no reasons are given or the reasons are contradictory</td>
<td></td>
</tr>
<tr>
<td>Presentation</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td>Student properly organizes his ideas so that they follow a natural, predictable sequence</td>
<td>Student well organizes his ideas, with occasional errors in sequence or ordering of facts</td>
<td>Larger ideas are well organized, but details are sometimes mismanaged</td>
<td>Little organization is evident to the substantial detriment of the presentation</td>
<td></td>
</tr>
</tbody>
</table>

TOTAL