Activity Summary
In this activity, students investigate a large watershed, look for sources of pollution in the watershed, and study the impacts of a rain storm on a watershed and estuary, without going on field trip. Students begin by examining the San Francisco Estuary using Google Maps (Part 1), identifying possible sources of pollution and contamination along the major rivers that feed into the estuary (Part 2). Students also examine graphs of water quality data from the estuary and identify changes that occur due to a storm event (Part 3).

Learning Objectives
Students will be able to:
1. Demonstrate a more complete understanding of watersheds.
2. Identify and articulate connections between land-use in the watershed and water quality in rivers and estuaries.
3. Analyze and interpret water quality graphs to understand how a storm impacted water quality in San Francisco Estuary.

Grade Levels
6-12

Teaching Time
4 (55 minute) class sessions + homework

Organization of the Activity
This activity consists of 3 parts which help deepen understanding of estuary systems:
Part 1: Exploring the San Francisco Watershed
Part 2: What’s Upstream Comes Downstream
Part 3: Water Quality at the Mouth of the Watershed

Background
San Francisco Bay is an extensive and shallow estuary that drains approximately 40% of the land in California. Ninety percent of the water flowing into the bay comes from the Sacramento and San Joaquin rivers, whose headwaters are in the Sierra Nevada Mountains. Both rivers flow into the Delta, a vast network of channels, agricultural lands and fresh water wet-
lands, and then into San Francisco Bay where they mix with salt water from the Pacific Ocean.

Northern California’s climate has a distinct wet and dry season, with nearly all of the rain coming in the winter months, often during large storms. These distinct seasons makes it an ideal estuary and watershed for an introduction to how rainfall in a watershed changes water quality in an estuary.

San Francisco Bay National Estuarine Research Reserve includes China Camp State Park on the north-west shore of the estuary. China Camp State Park was the site of a Chinese shrimp-fishing village where some 500 people lived in the 1880s. The water quality data in this activity were collected from a monitoring station on this historic pier that was part of the village.

Materials

**Students**

- Need to work in pairs, small groups, or individually at computer with internet access
- Copy of Student Reading Part 1: Exploring the San Francisco Watershed
- Color Copy of Student Worksheet Part 1: Exploring the San Francisco Watershed
- Copy of Student Worksheet Part 2: What's Upstream Comes Downstream
- Copy of Student Worksheet Part 3: Water Quality at the Mouth of a Watershed
- Copy of Student Data Sheet 1 Part 1: Exploring the San Francisco Watershed
- Copy of Student Data Sheet 2 Part 3: Water Quality at the Mouth of a Watershed
- Dark colored markers

**Teachers**

Optional Resources:
- Part 1: Computer and Projector with Google Maps, satellite or “earth” view on and centered on Golden Gate Bridge in San Francisco, California
- Part 3: Descriptions of water quality parameters, available on the [NERRS Estuary Education](#) Science at Data page.

Preparation

Read the Student Reading for more background information.

Connect to the internet and find China Camp State Park in San Rafael, CA on Google Maps, satellite view.
**Procedure**

**Part 1 — Exploring the San Francisco Watershed**

1. Ask students what, if anything, they know about watersheds. If possible, walk outside your classroom, observe and discuss your local watershed with students. Where does the water that passes through gutters, ditches, creeks, or streams near your school go? (Note: If your students need an introduction to watersheds, you may want to complete first exercise in Estuaries 101 Activity called “Oil Spill: The Rest of the Story”.)

2. Hand out the Student sheets (*Reading, Worksheet and Data Sheet*) for Part 1: Exploring the San Francisco Watershed and markers.

3. Have the students read the *Student Reading, Part 1: Exploring the San Francisco Watershed*.

4. Have students (preferably in pairs) follow the directions for question #1 on the *Student Worksheet, Part 1: Exploring the San Francisco Watershed* to outline the general limits and confines of the watershed of San Francisco Estuary. Check that the students recognized that there are sub-watersheds within the huge area outlined on their image that makes up the entire estuary’s watershed.

5. Have students move to computers with internet access, start Google Maps and select “Earth” (or satellite) view. Show students their starting point (Golden Gate Bridge) on Google Maps and have them finish the rest of the questions in Part 1 of the *Student Worksheet*.

   If students are new to using Google Maps, show them how to zoom in and out to change viewing altitude and move around the image. You may want to start with a view that is familiar (like your school) for the initial orientation.

6. Review and discuss the tasks and questions in Part 1 of the *Student Worksheet*.

**Part 2 — What’s Upstream Comes Downstream**

1. Have students complete Part 2 of the *Student Worksheet—What’s Upstream Comes Downstream* choosing one of the two rivers and taking a Google Map trip to identify areas and man-made features that may be potential sources of pollutants and contaminants.

2. Review and discuss the Part 2 tasks and questions. Have students report their findings to the class.

**Part 3 — Water Quality at the Mouth of a Watershed**

1. Ask students what might happen to the salinity and turbidity in the San Francisco Estuary after a rainstorm. Go over the other water quality factors students will be analyzing, too.

2. Have students complete Part 3 of the *Student Worksheet—Water Quality at the Mouth of a Watershed*.

3. Review and discuss the Part 3 tasks and questions.

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**Next Generation Science Standards**

This lesson uses the following Practices:

1. Asking questions (for science) and defining problems (for engineering)
2. Analyzing and interpreting data
3. Using mathematics and computational thinking
4. Constructing explanations (for science) and designing solutions (for engineering)
5. Engaging in argument from evidence

Extension ideas connect this lesson with HS—LS2, HS-ESS2, and HS-ESS3.
Check for Understanding

1. Discuss the following:
   - What watershed do you live in? Is there more than one right answer to that question?
   - Would an estuary with a small watershed that was entirely forested respond to a rain storm differently than the San Francisco Estuary did? How might graphs of water-quality after a storm in that type of watershed and estuary look different than the ones you examined?

2. Project a satellite image of the Chesapeake Bay and its watershed (or your local watershed). Ask students to identify major urban areas around Chesapeake Bay (or your local bay or water body) and major rivers that drain the watershed. Ask students to identify areas of potential pollution.

Optional Extension Inquiries

1. Investigate your own watershed! Have students locate possible sources of pollution and contamination in your local watershed (as in Parts 1 and 2).
2. Establish a water-monitoring program at a stream or river near your school to study how your watershed responds to rain storms.
3. Is there a National Estuarine Research Reserve close to you? Your students can create their own graphs of water quality data to look for storm impacts in “their” estuary. Graphs are easy to make at coast.noaa.gov/SWMP.
4. Connect to NGSS Standards HS-LS2 and HS-ESS3 by designing solutions to limit pollution running off into estuary during storms.
5. Connect to NGSS Standards HS-ESS2 by using stream tables before this lesson to explore the impacts of runoff.
Part 1 — Exploring the San Francisco Watershed

1. **Answer:** Lines drawn on the image will vary, but should follow the peaks of the mountain ranges, including the Sierra Nevada Mountain in the far east of the image. There is a small watershed near the bottom of the image that flows into the Pacific Ocean, rather than the Estuary. The key aspect of this section is that the students demonstrated an understanding of watersheds and sub-watersheds.

2a. Fly around the bay in a clockwise direction, identify the rivers that empty into the bay, and list the name of the river (if you can find a label) or the closest labeled landmark to where the river meets the bay.

*Answer:* The Petaluma River (Black Point, Green Point, Sears Point are all near here), Napa River, Carquinez Straight (students may record this as San Joaquin River and Sacramento River, or Suisun Bay if they explored upstream), Alameda Creek (near Coyote Hills Regional Park), and Coyote Creek. Depending on their observation and attention, students may identify many smaller rivers.

2b. Describe what kinds of human activity or evidence of man-made changes you see along the shore of the estuary.

*Answer:* Variety of answers, including cities, bridges, ships, salt ponds (these are the brightly colored areas at the south end of the estuary), landfills, and sewage treatment plants.

2c. What is the most interesting thing you saw along the shoreline? What do you wonder about it?

*Answer:* Variety of answers.

2d. List at least five interesting features you noticed on the journey back to the estuary.

*Answer:* Variety of answers, including several large “lakes” or reservoirs, farmland, big curves in the river, natural (protected) areas, changes in color of the water (an artifact of piecing together satellite images taken on different day or at different times of day), and the City of Sacramento.

2e. How is the land that the San Joaquin River travels through different from that of the Sacramento River?

*Answer:* Variety of answers, including more snowy, more mountainous, more agriculture. It is harder to follow the San Joaquin River.
Part 2 — What’s Upstream Comes Downstream

2a. List ten possible sources of pollutants or contaminants along the river. Record the source and a place name or latitude and longitude coordinates for each site.

*Answer: Student responses will vary, and may include:*

**Napa River:**
1. Shipyards (Mare Island)
2. Salt ponds
3. Golf course
4. Urban streets
5. Agricultural fields (mostly growing wine grapes)
6. Wineries
7. Ponds of wastewater
8. Landfill (Clover Flat Landfill)
9. Sewer treatment ponds (just south of Calistoga)
10. Reservoir/lake at Kimball Canyon

**Coyote Creek:**
1. Salt ponds
2. Wastewater treatment facility
3. High-tech industry plants (Cisco Systems, etc.)
4. Golf course
5. Urban streets
6. Zoo
7. Commercial businesses (malls, Costco, etc.)
8. Freeways/roads
9. PG and E facility
10. Agricultural fields
11. Reservoir/boating at Anderson Lake

*Answers may spark conversations about types of pollution and contaminants. For example, students may list wetlands, or tidal salt marshes, as sources of pollution because they are often muddy. If so, this can lead to discussion about role of marshes in filtering out sediments from the water. Could something be both a source and a sink for pollution?*
2b. What do you think is the most likely source of pollution and contamination along the river you investigated?

*Answer:* Student answers may vary, but could reasonably include any of the answers they listed in 2a.

2c. Can you see any evidence that contaminants are being released into the river?

*Answer:* Students may be able to see sediment plumes at various places, notice differences in water color in treatment ponds, or may see (or infer) other evidence. Or they may not see any evidence. The important aspect of this question is to start looking for actual evidence, rather than making assumptions.

2d. How could you collect evidence of pollution or contaminants?

*Answer:* Students could collect water samples and test them for pollution. They could also look at data collected by professional scientists.

2e. Did you see any natural or manmade features that might clean the water before it enters the river or estuary?

*Answer:* Students should notice tidal wetlands where both rivers meet the estuary, and may notice other wetlands along the waterway. There are forested/natural/wild areas along both waterways. On the Napa River, there are riparian forests (trees) along the banks of the river in most places that keep it cleaner and create habitat.
Part 3 — Water Quality at the Mouth of a Watershed

3a. Predict how this event would affect these water quality factors in the estuary:

*Answer:* Student answers will vary.

3b. Consult the *Student Data Sheet 2 — Water Quality Data*, look for evidence of a major storm event that occurred in 2017. When did the storm occur? What evidence did you use to determine when it occurred?

*Answer:* A major rain and storm event appears to have begun on January 7th or 8th. The best evidence for this is a significant drop in salinity. If they students did not reach this answer, you may need to review estuaries being a mix of fresh and salt water, and how the salinity at any given location changes with the tide, season, and amount of rainfall. Students could use turbidity data as evidence and decide the storm started January 7th; this could be correct too. The factor to look for is that they interpreted the graphs correctly and used evidence from the graphs to make their determination.

3c. Look at the graphs and record what happened to each of the water quality parameters in response to the storm. Did the parameter increase, decrease or stay the same? Describe patterns or changes you notice.

*Answer:* Student answers may vary but most typical are listed below. These answers could lead to further investigations.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Change Description</th>
<th>Patterns/Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Temperature</td>
<td>Decreased, then increased</td>
<td>Temperature warmed up after storm</td>
</tr>
<tr>
<td>pH</td>
<td>Decreased after storm</td>
<td>Bigger spikes after storm</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>Accept variety of answers; difficult to summarize</td>
<td>Spikes at start of storm, general increase after storm, more restricted daily range immediately after storm</td>
</tr>
<tr>
<td>Salinity</td>
<td>Decreased after storm</td>
<td>Changes daily, more restricted daily changes after storm, drops almost to 0.</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Increased at start/before storm, Spikes</td>
<td>Very high spikes beginning with storm and continuing after</td>
</tr>
</tbody>
</table>
3d. How well did your predictions match what actually happened during the storm event? For any predictions that didn’t match, explain why your original reasoning may or may not have been correct.

Answer: Answers will vary based on their original predictions, but should center around the idea that the storm meant lots of freshwater was flowing through the estuary. At China Camp, where the water is typically a mix of freshwater from the watershed and saltwater from the Pacific Ocean, the storm meant that there was proportionally more freshwater. More information about each of the water quality parameters can be found in the “Science and Data” section of the NERRS education website (coast.noaa.gov/estuaries). The intent of this question is to promote careful observation of graphs and practice arguing from evidence.

Temperature: This could be evidence of the storm bringing warmer weather or of freshwater coming down the estuary being warmer than saltwater from the Pacific Ocean.

pH: The pH of saltwater is higher than the pH of freshwater, so the decline in pH indicates that there is proportionally more freshwater at China Camp after the storm.

Dissolved oxygen: This graph is more difficult to interpret and explain. Perhaps the storm was preceded by wind that added oxygen into the water through waves? It might be interesting to discuss this graph further and to compare it with graphs from other storms to see if the pattern is consistent (other similar storm: December 25, 2005 through January 5, 2006;).

Salinity: This is the most clear of the graphs. Salinity drops because there is more freshwater flowing down the estuary. The up-down oscillation is caused by the tide.

Turbidity: Turbidity (or murkiness of the water) begins to spike as the storm starts. This is the strongest indicator of muddy flood waters coming down the estuary from its’ watershed.