Instructor Information:
Activity on Sea Level, Storm Surge, and Flood Risk—a New York City Case Study

Summary
This activity uses Hurricane Sandy as a case study to examine the short-term flood risks and societal costs associated with major storms. It places these risks in the context of long-term, geologic processes, like coastal subsidence and beach erosion, and societal factors, like local development and global sea level rise from pollution-enhanced climate change. This activity is expected to take 60-90 minutes. Instructors are advised to remind students of concepts from Unit 1, found in the Vocabulary of Storms and Storm Systems and in Activity 1: Probability and Risk, especially regarding the magnitude of events and their frequency, recurrence interval and probability. They should have a sense of magnitude of the storm (Hurricane Sandy) and gain understanding about how climate change (through effects on sea level) will impact the magnitude of coastal flooding.

Materials/resources (online)
Coastal resilience 2.0 Tool: http://maps.coastalresilience.org/network/
There is an excellent instructional video for using a coastal defense interactive scenario application (Coastal resilience 2.0): https://vimeo.com/96830721. It includes examples from New York, Puget Sound, Louisiana, etc.
(Optional addition, Sea level rise simulator: http://coast.noaa.gov/digitalcoast/tools/slr)

This activity requires online access, but much of it can be completed offline if necessary by handing out hard copies of these three maps available at cityofnewyork.us

https://data.cityofnewyork.us/Environment/Sea-Level-Rise-Maps-2020s-100-year-Floodplain-/ezfn-5dsb

https://data.cityofnewyork.us/Environment/Sea-Level-Rise-Maps-2050s-100-year-Floodplain-/hbw8-2bah

https://data.cityofnewyork.us/Environment/Sea-Level-Rise-Maps-2050s-500-year-Floodplain-/qwca-zqw3

The online version is highly zoom-able with streets, subways, hospitals, etc. on the maps, which students can use in answering activity questions about flood plain maps and community vulnerability.

While this application is meant for non-scientists and average users, it has many choices, and students may get lost in the details. The module authors recommend that instructors visit the site beforehand to become familiar with the application, and run through the steps to do the exercise to determine any potential pitfalls. The map zoom is very sensitive and will immediately zoom in or out, which might confuse students trying to find a location from which to begin. Instructors should advise students of this sensitivity ahead of time, and build in enough time to the exercise to let students acclimate to using the tools.

The activity also uses an existing InTeGrate activity by David Kobilka on storm surge risk associated with Hurricane Sandy:
http://serc.carleton.edu/integrate/workshops/risk_resilience/case/82138.html
It also uses an online tool created by NOAA for visualizing and identifying coastal hazards: http://www.coast.noaa.gov/floodexposure/ - /map

Rubric for Activity on Sea Level, Storm Surge, and Flood Risk
Case Study: New York City

This activity requires that students effectively navigate and use public tools and databases on flooding and flood risks in New York City. Targeted outcomes include: data retrieval, data application and data interpretation, synthesis and integration with prior knowledge. The first part of the rubric assesses these activity outcomes. The second part of the rubric is a more standard assessment of student responses.

1. Navigation knowledge and application

Student successfully loads and maintains for easy comparison the 100- and 500-year New York City floodplain maps for 2020 and 2050 sea level scenarios. Student is able to locate and open the Coastal Resilience map of New York City, the map style window, and the tool kits for Hurricane Sandy and Coastal Resilience (NY).

- High level - Student succeeds with no instructor assistance, is able to zoom in and out to find and follow features beyond the edge of the map view
- Intermediate level - Student succeeds with some instructor guidance in locating the relevant map views and opening the toolkits.
- Low level - Student needs multiple navigation steps demonstrated, is unable or unwilling to proceed without more guidance.

2. Database application

Student successfully reads New York City maps to locate borough and road names, high population density areas, New York City boundaries, critical infrastructure, areas of high versus low elevation, and flood areas. Student comprehends the differences between the maps and makes appropriate inferences using those differences.

- High level - Student needs no instructor assistance to find the information required for the activity questions. Student makes appropriately validated inferences from the information.
- Intermediate level - Student succeeds with some instructor assistance in locating the relevant data and in utilizing the information in the different toolkits. Student makes some poorly validated inferences from the information, but most inferences are valid.
- Low level - Student needs a lot of assistance in locating the relevant data and in utilizing the information in the different toolkits to answer the activity questions. Student makes many inferences without validation by the data.

3. Database evaluation

Student successfully evaluates the connections between database components, especially about the relationship of risk, geographic vulnerability, infrastructure, and population density.

- High level - Student infers connections between geophysical and social components of the New York City system and can assess how they combine to increase vulnerability or resilience to major storms.
- Intermediate level - Student infers some connections between geophysical and social components of the New York City system but misses one or more important components, or incompletely assesses how they combine to increase vulnerability or resilience to

major storms.

- Low level - Student does not adequately infer connections between geophysical and social components of the New York City system, and so cannot assess how they combine to increase vulnerability or resilience to major storms.

Activity answers:

1) **Where the maps overlap, which of the three scenarios, the 2020 or 2050 100-yr flood, or the 2050 500-yr flood, most closely resembles the flood from Hurricane Sandy?**

The students should recognize that the modern 500-year flood zone is very similar to the projected 2020 100-year flood zone area and that Hurricane Sandy's flood inundation reached those limits and, in some areas, exceeded them. They may also stumble across the storm surge map which shows much greater flooding for Cat 2 and higher storms. FYI: Sandy was a very large Cat 1 extra-tropical storm when it made landfall in New Jersey.

2) **Based on this evidence, in which category would you place Hurricane Sandy for NYC:**

   - **a less than 100-yr flood**
   - **a 100-yr flood - in most (but not all) NYC areas, Sandy exceeded the 100 yr flood zone**
   - **a 500-yr flood**
   - **a greater than 500-yr flood**

Open a new window to see which areas of NYC have the highest population density: ArcGIS map of NYC population density. More detail appears as you increase zoom, to street level.

3) **Make a list of the sections of the city (called boroughs) that flooded in Hurricane Sandy and rank them by density of people in the flood zone (1 = highest number of people affected). It might be helpful to pull up a simple map of NYC to see the borough boundaries.**

   NYC Borough names: Manhattan, Brooklyn, Queens, The Bronx, Staten Island
   1 Manhattan
   2 Brooklyn
   3 The Bronx (note: Brooklyn & The Bronx have very similar population densities)
   4 Queens
   5 Staten Island
   The student should identify at least a few as being both within the flood zone and having some areas of very high population: especially Manhattan, Brooklyn, the Bronx. While Staten Is. had bad flooding, it has the lowest population & population density of all the boroughs.

4) **The population density map is useful but doesn't provide details about the population**

size. Use an internet search to find recent census data for each borough and add the population numbers next to each borough name. Examine your rankings again. If you consider all the people in the borough, and not just the ones in the flood zone, does it change your ranking of greatest number of people impacted?

Total population ranking: Brooklyn, Queens, Manhattan, The Bronx, Staten Island
Yes, considering total borough populations, the impact ranking changes. Brooklyn and Queens had more than two million people (in each borough) affected by the Sandy's outcomes, whereas Manhattan and The Bronx were near 1.5 million each.

5) **One way to find out how the people of NYC were affected is to review the news reports. Do a search of each of the borough names with "Hurricane Sandy". Based on media reports, which boroughs do you think were hardest hit by the storm and in what way? In your response, consider the various environments (natural, cultural, built) that were impacted.**

This will vary depending on the news items that the student locates. Student should cite the news source and source of the population data and explain the rationale for the ranking. Some media reports emphasized the flooded business districts and landmarks, like Coney Island, and ignored the urban residential areas.

6)

- **How does coverage and description of the event by news reports compare to the *Hurricane Sandy Retrospective Analysis*? Describe what you consider as discrepancies between the news reports and the official analysis.**

Students should recognize that the impact was not limited to residents and businesses that were flooded, since power, water supply and transportation was also disrupted over the region. Student responses will vary depending on the news items and boroughs selected.

- **Compare the news reports and photos with the online flood maps and the maps depicted in the *Hurricane Sandy Retrospective Analysis*. Which gives more information about risk useful for city residents? For city planners?**

This question requires that the student compare the modeled flood limits and the actual flooding during Sandy, and to assess whether or not the residents could have perceived the actual amount of flooding from the risk maps. It also brings in the concept of risk communication and how to effectively communicate risk to different stakeholders.

The second part of the question asks students to recognize that planners may be more skilled in using risk maps and may have different knowledge needs for risk mitigation.

7)

- **In the 2020 and 2050 scenarios, in a 100-year flood event, which major roads could you take to go from Brooklyn to somewhere on the mainland(i.e. New Jersey,**

Connecticut, the Bronx or upstate New York)?

The student should determine that all of the roads between Brooklyn and the mainland would be flooded at some point along the roadway. They may conclude that an exit out of the urban area is possible by heading towards the higher topography of northeast Long Island, but this is still on the island.

- **Were any of these routes open once flooding began with Hurricane Sandy? Examine access points for bridges and tunnels and the New York City Hurricane Evacuation Zone Map: http://www.nyc.gov/html/oem/downloads/pdf/hurricane_map_english.pdf. Does this map show an exit route out of the city that does not require crossing any of the evacuation zone areas?**

  No, all roads to the mainland were closed along some part of the route during the flooding.

- **Besides roads, consider other ways that people might try to evacuate from NYC during a flood. Which, if any, of these were accessible during or immediately after Hurricane Sandy?**
  Only the ferries were running; the tunnel access areas were flooded and closed. The tunnels reopened quickly but the subways were closed for weeks.

During Sandy, and for several days afterwards, un-flooded areas of NYC had no electricity or running tap water because parts of those supply systems had flooded. Examine again the population density maps, the escape routes to the mainland, and the flood zone areas.

8) **If you had been in Queens or Brooklyn during the storm, would you have tried to find a way to leave immediately after the storm, or would you have stayed in place to wait for services to return? Describe the things you took into consideration for your answer.**

   Students should consider the risks of travelling along potentially damaged roads versus sheltering in place. They might consider thei own food and water access, medical needs, outside air tempertures and their ability to be sheltered from extremes.

City administrators everywhere struggle to convey information about natural hazards and risks to their residents, and many cities, like NYC, provide online access to floodplain maps. Despite this, many people still choose not to evacuate in response to flood warnings. Do a brief search for news and images of NYC during the Hurricane of 1938.

9) **If people living in NYC in 2012 had been reminded about the 1938 Hurricane, do you think more would have evacuated before Sandy? Explain your answer in a few sentences.**

   Students should consider the value of past example for risk communication.

10) **If you were an administrator in NYC and wanted to convey a message about potential flood risk from a future Sandy-like storm, what information would you communicate to**

the public? Would you use these flood maps? Would you use historical events like the 1938 Hurricane, and Sandy? In your response, consider which aspects of this activity made the greatest impact on you.

While responses to these questions could be quite variable, students should take into consideration their own reactions to these different types of hazard and risk information.

Optional Part B. Leave the maps from Part A open in their own windows but change the Storm Surge map (http://maps.coastalresilience.org/network/) from National Geographic to Shaded Relief (elevation) using the options in the upper right box. Click the storm surge flood layer on and off a few times for comparison of flood area with elevation.

11) **Based on the topography, if the storm surge had been just 1 m higher, which areas would have experienced the greatest amount of additional flooding?**

The region of very flat land around JFK airport, south Brooklyn and south Queens.

12) **Coastal dunes and marshes used to exist all along low-elevation river valleys and beaches in the NYC area until these lands were developed. Give a couple of examples of areas on the map where, prior to development, probably was marshland.**

Responses to this should include areas near existing rivers, and/or areas of low elevation.

In the Map Layers window, leave the Hurricane Sandy Final FEMA Surge Area layer on but also click on the "+" next to Coastal Resilience (NY). Then click the "+" next to Critical Facilities.

13) **Fill in the table by clicking the individual boxes for police, fire, electric and water and, using the map, count the number of facilities in the combined area of Manhatten Island, Queens and Brooklyn. Zoom in to street level and count the number in Sandy's storm surge area. Calculate the <u>proportion</u> and <u>percentage</u> of each type of facility affected by flooding.**

	Total	# Flooded	Proportion Flooded	Percentage Flooded
Police	**77**	**11**	**0.14**	**14**
Fire	**10**	**4**	**0.40**	**40**
Electric	**20**	**8**	**0.40**	**40**
Drinking Water	**4**	**3**	**0.75**	**75**

Note to instructors - depending on how carefully the students pay attentin to the restrictions about the size of the area to survey, these numbers could be very different

14) Which critical facility type suffered the greatest impact from Sandy's storm surge?

From the list above: potable (drinking) water plants, and (tied) electric and fire stations. Students might also note that airports were severely impacted with 3 of 3 flooded.

15) Think about the services offered at each facility. Which categories do you think are the most needed in a crisis like a hurricane? Write down a couple of sentences to explain why these were your choices for most-needed.

Open-ended question, but students should recognize that water is an urgent need, and fire stations, electric facilities and transportation hubs like airports, are all critical.