Mapping Rising Flood Risk

INSTRUCTIONS FOR COMMUNITIES

This recipe card is one in a series published by FEMA Region 3 to help communities use the GIS data included with FEMA flood mapping products. It focuses on using local elevation data along with National Flood Hazard Layer (NFHL) data to map the areas where flood risk is likely to rise first with climate change.

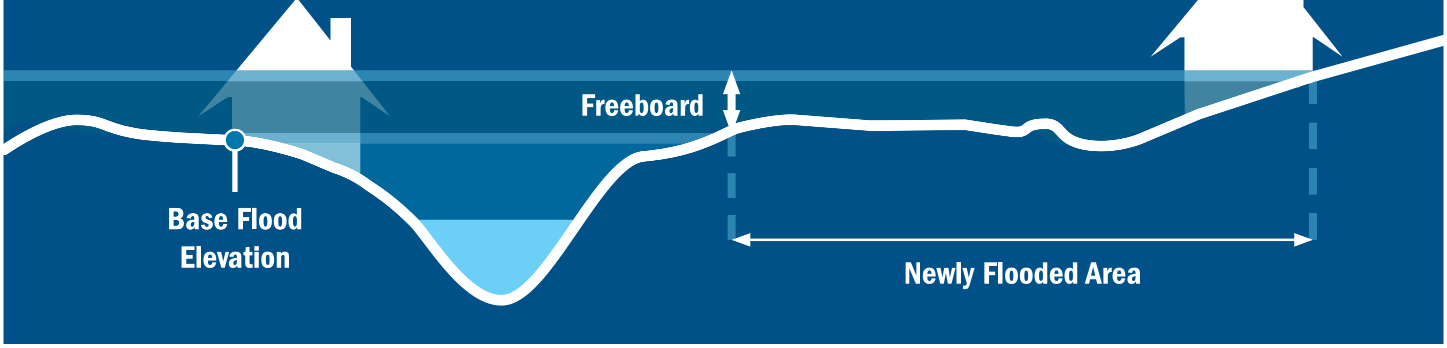
Flood risks are rising across the U.S. This places more people and property in harm's way. Changing rainfall patterns drive some of this changing flood risk. Over the past 25 years, heavy rain has been on the rise across the U.S. The biggest rise has been seen in the Northeast. In the decades to come, climate projections show the Northeast will continue to have more frequent and severe heavy rains, leading to higher flood risk[1].

Communities can use local planning and regulatory tools to adapt to rising flood risk. They can direct future development away from the riskiest areas. They can also require safer buildings in these areas. Identifying the areas where risk is rising, though, is the first step. One way to locate these areas is to use "freeboard." Freeboard is a vertical safety factor that is expressed in feet above a flood height. Many communities add at least 1 foot of freeboard to the 1%-annual-chance flood (base flood) shown on their Flood Insurance Rate Maps (FIRMs). This helps protect homes and businesses from the added flood risk that comes with unknown factors like future development. Freeboard can also be added to minimize risk from predicted climate change.

Figure 1 shows how adding this vertical safety factor creates a wider floodplain. As flood heights rise above the base flood elevation, flood waters will spread beyond the current FEMA 1%-annual-chance floodplain, and new areas will flood. These newly flooded areas are where flood risk will likely increase first with estimated climate change.

These step-by-step instructions describe a simple Geographic Information Systems (GIS) procedure to map the areas newly flooded by 1, 2, and 3 feet of freeboard above the base flood elevation (BFE). This procedure needs either ArcGIS Desktop or ArcGIS Pro. The result will be a series of GIS maps that can inform local action to adapt to potential climate change impacts. The study area for the analysis could be as small as a development site or as large as a community.

FIGURE 1



[1]Northeast - Fourth National Climate Assessment, globalchange.gov

RiskMAP Increasing Resilience Together

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STEP 1. Get the Data

Download terrain and flood hazard data for the study area.

Terrain data are typically gathered at the community, county, or state level. High-resolution, high-accuracy elevation contours are available for most of FEMA Region 3. See page 6 for information on accessing contour datasets in FEMA Region 3. Download the elevation contour data for the study area.

The FEMA Flood Map Service Center (MSC) is the official public source for flood hazard information produced in support of the National Flood Insurance Program (NFIP). Flood hazard data are available for download at the community, county, or state level at https://msc.fema.gov. Download the National Flood Hazard Layer (NFHL) data for the study area.

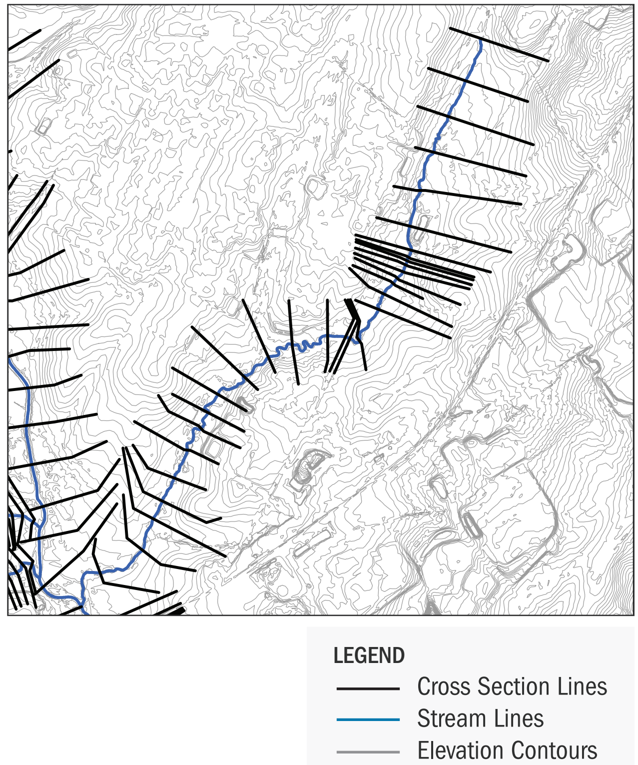
STEP 2. Set-Up the Map

Enable the ArcGIS 3D Analyst extension, add the terrain and flood hazard data, and align the horizontal and vertical coordinate systems.

Enable the ArcGIS 3D Analyst extension to use tools for working with three-dimensional surfaces.

Add the elevation contours to the map. Then, add the following flood hazard layers: cross section lines (S_XS), stream lines (S_PROFIL_BASLN), and flood hazard zones (S_FLD_HAZ_AR).

> **Elevation data can be in units of meters or feet.**
> **Make sure both the contour data and the cross section data use the same units of measurement before continuing. Otherwise, this procedure will not work.**



Use the **Project tool** to convert the cross section layer into the same horizontal coordinate system as the elevation contour layer. FEMA's data are in a geographic coordinate system (i.e., points are referenced by latitude and longitude). That system does not work with all the tools in this procedure. The coordinate system of the elevation contour layer is found in the Layer Properties dialog box. This will vary depending on the data source.

If the vertical datums for the cross section and elevation contour layers are different, use the **Project tool** to convert the elevation contour layer into the same vertical coordinate system as the cross section layer.

STEP 3. Add Freeboard to the Water Surface Elevation Dataset

Add fields to the cross section layer attribute table to show the water surface elevation with 1, 2, and 3 feet of flooding above the 1%-annual-chance flood height.

Add three new fields with Field Type = Float and Precision = Default. Name the fields WSEL_Plus1, WSEL_Plus2, and WSEL_Plus3.

Use the **Field Calculator tool** to add to the water surface elevations shown in the WSEL_REG field. Right click on each of the WSEL_Plus# fields that were just added and use the following equations: WSEL_Plus1= WSEL_REG+1, WSEL_Plus2=WSEL_REG+2, and WSEL_Plus3=WSEL_REG+3.

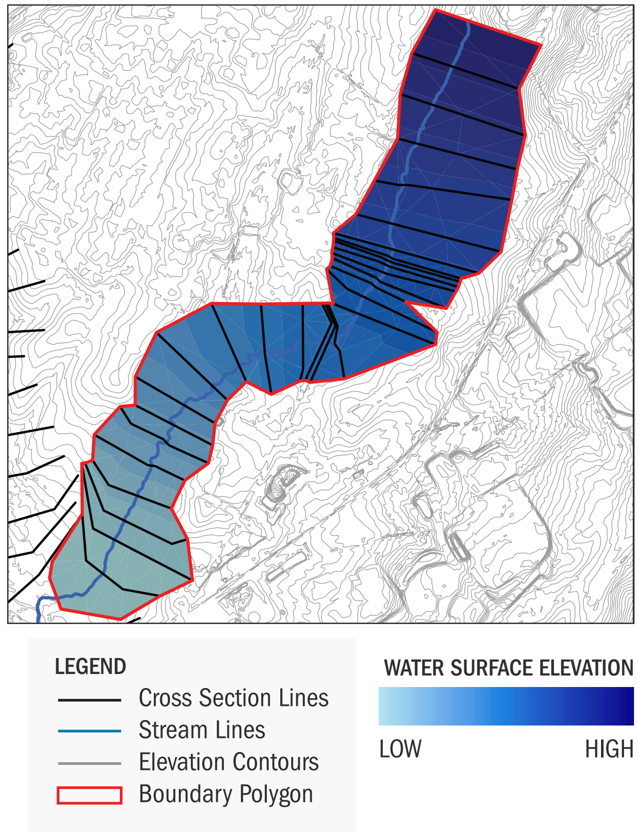
STEP 4. Prepare the Water Surface Elevation TINs

> **A TIN (Triangulated Irregular Network)**
> **is a three-dimensional surface triangulated between various elevation points.**

Create a series of 3D surfaces for the study area showing the 1%-annual-chance water surface elevation with 1, 2, and 3 feet of freeboard.

Create a boundary layer for the water surface elevation data. Create a new polygon shapefile and draw a boundary that snaps to all the cross section endpoints. Use the snapping tool set to endpoint to help create this polygon.

Create a TIN surface for each flood height (WSEL_REG, WSEL_Plus1, WSEL_Plus2, and WSEL_Plus3). Use the **Create TIN tool**. For inputs, add the boundary polygon and the cross section layer. For the boundary polygon, use Soft_Clip as the type. For the cross section layer, use Hard_Line as the type and choose one of the flood heights as the height field. Run the tool once for each flood height: the 1%-annual-chance water surface elevation (WSEL_REG) and each foot of freeboard (WSEL_Plus1, WSEL_Plus2, and WSEL_Plus3).

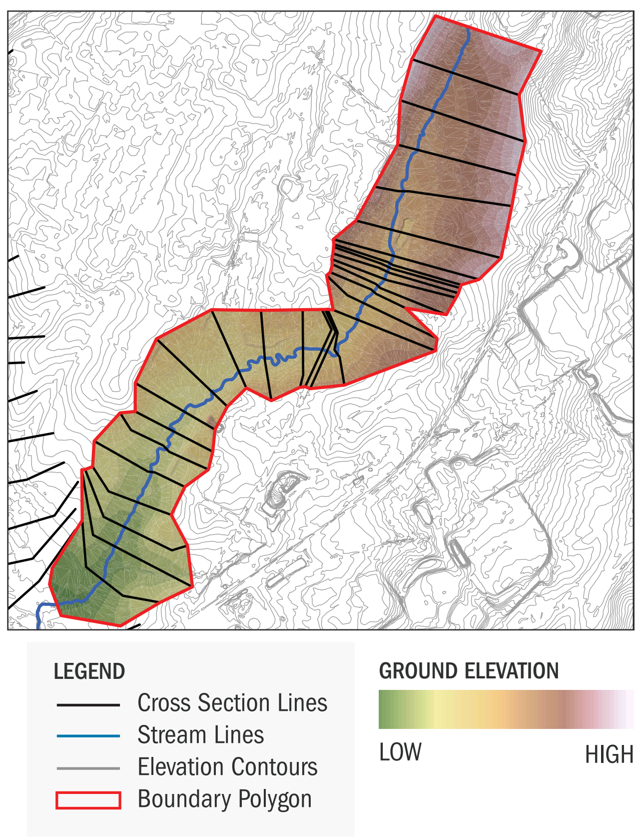


STEP 5. Prepare the Terrain Surface TIN

Create a 3D surface for the area of interest showing the ground elevation.

If the elevation contours for the study area are shown in two or more tiles, use the **Merge tool** to create a single elevation contour layer for the entire study area.

Create a TIN surface for the ground elevation. Use the **Create TIN tool**. For inputs, add the elevation contour layer and the boundary polygon. For the boundary polygon, use Soft_Clip as the type. For the contour layer, use Hard_Line as the type and choose the contour elevation field as the height field.



STEP 6. Identify Areas Where Flood Risk Will Likely Increase First

Identify areas that would be flooded by 1, 2, and 3 feet of freeboard.

A. COMPARE ELEVATIONS

Use the **Surface Difference tool** to calculate the areas that would be flooded. For the Input Surface, add the water surface elevation TIN. For the Reference Surface, add the ground elevation TIN.

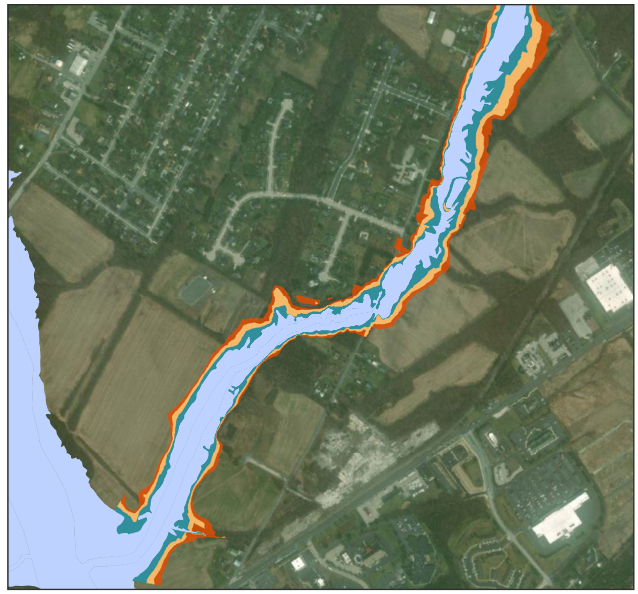
Run the tool one time for each water surface elevation: the 1%-annual-chance water surface elevation (WSEL_REG) and each foot of freeboard (WSEL_Plus1, WSEL_Plus2, and WSEL_Plus3).

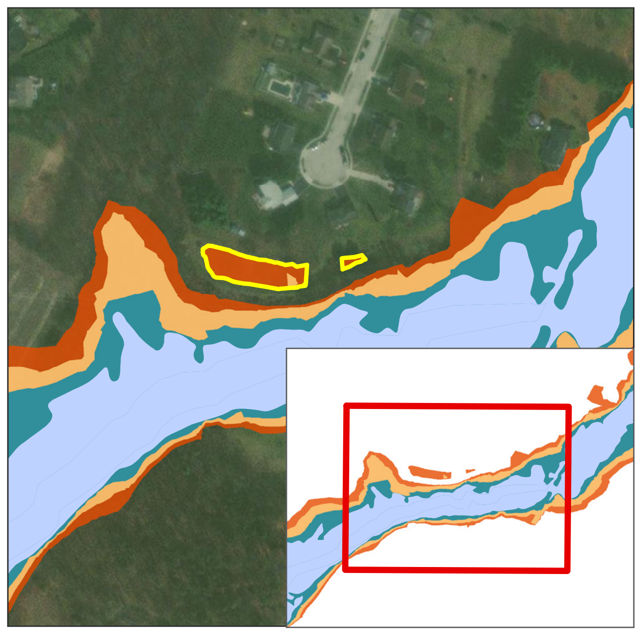
B. DELETE DISCONNECTED AREAS

The Surface Difference tool may identify low spots in the landscape that appear disconnected from the flooding source floodplain. Low spots are areas that are below the water surface elevation but not hydraulically connected to the flood source. If needed, edit the output GIS layer to delete these low spots that are not connected to the main floodplain.

The output will be a series of shapefiles that show where the water surface is above and below the ground surface for each water surface elevation TIN. The areas where the water surface is above the ground are the areas that would be flooded by the base flood and by 1, 2, and 3 feet of freeboard.

The areas beyond the 1%-annual-chance floodplain that would be flooded by 1, 2, and 3 feet of freeboard are the areas where flood risk is likely to increase first with estimated climate change.





LEGEND

- Areas flooded by the 1%-annual-chance flood
- Additional areas flooded by 1 foot of freeboard
- Additional areas flooded by 2 feet of freeboard
- Additional areas flooded by 3 feet of freeboard

STEP 7. Take Action to Protect Your Community

Apply local planning and regulatory tools in the areas identified by this analysis.

LAND USE POLICIES

Communities can direct future development away from the riskiest areas and apply setbacks to counter erosion impacts. This can keep people out of harm's way.

BUILDING REQUIREMENTS

Communities should adopt and enforce the most up-to-date building codes and floodplain management ordinances with standards that go beyond the minimum NFIP requirements. This can keep people who live and work in higher risk areas safe.

SAFETY REQUIREMENTS

Communities can think about higher safety requirements for critical facilities and evacuation routes. This can minimize disruptions to community lifelines like transportation, water and energy infrastructure.

Visit the following websites for information on adopting and enforcing higher floodplain management standards than NFIP minimum requirements and planning for climate change.

Local Government Officials - Floodplain Management Resources
www.fema.gov/floodplain-management/manage-risk/local

Community Rating System (CRS) Coordinator's Manual
www.fema.gov/floodplain-management/community-rating-system#manual

Planning for Future Conditions
www.fema.gov/sites/default/files/2020-09/fema_planning-future-condition.pdf

WHERE TO GET ELEVATION CONTOUR GIS FILES

To explore elevation data available in the area of interest, start with the U.S. Interagency Elevation Inventory. This web application has a comprehensive, nationwide listing of publicly available high-accuracy elevation data for the United States and its territories. Elevation data are also available through state websites. A selection of current state data sources for the jurisdictions in FEMA Region 3 is shown below. Each of these data sources provides high-accuracy elevation contours derived from Light Detection and Ranging (LiDAR) data.

STATE	DATA SOURCE	DATA DESCRIPTION
Delaware	The Delaware Geologic Survey	Statewide 1-foot contours.
District of Columbia	Open Data DC	Districtwide 0.6-meter contours. One dataset is provided for each quadrant.
Maryland	MD iMAP (Data Resources) MD iMAP (LiDAR)	Countywide contours are available through many of the county websites listed on the MD iMAP Data Resources page. LiDAR point cloud datasets are also available through the MD iMAP LiDAR page. These datasets can be converted to contours.
Pennsylvania	Pennsylvania Spatial Data Access (Contours) Pennsylvania Spatial Data Access (PAMAP)	Newer LiDAR-derived contours are available in the following contour datasets: · Pennsylvania Western Lidar 2020 QL1; Contours – North · Pennsylvania Western Lidar 2020 QL2; Contours – North · Pennsylvania Western Lidar 2020 QL2; Contours - South · Pennsylvania North Central Lidar 2019 QL1; Contours · Pennsylvania North Central Lidar 2019 QL2; Contours – North · Pennsylvania North Central Lidar 2019 QL2; Contours – South · South Central Pennsylvania 2017 QL2 LiDAR; Contours · York County - Contours - 2FT (based on 2015 LiDAR) · USGS QL2 LiDAR for Dauphin County, PA 2016 – Contour · Philadelphia 2015 Topographic Contours – 1ft · Philadelphia 2018 Topographic Contours – 2ft · Allegheny County - Contours 2017 For areas without newer data, statewide 2-foot contours from the 2006-2008 PAMAP Program are available in this dataset: PAMAP Program - Topographic Contours (2 ft Interval).
Virginia	VGIN (Locality Geoportals) VGIN LiDAR (Downloads)	Countywide contours are available through many of the county geoportals listed on the Virginia Geographic Information Network (VGIN) page. LiDAR point cloud datasets are available through the VGIN LiDAR Download Application. These datasets can be converted to contours.
West Virginia	West Virginia GIS Technical Center	Statewide 1-foot contours from FEMA/USGS LiDAR projects.