Flooding in Manayunk Neighborhood of Philadelphia

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Introduction

Philadelphia Overview

Philadelphia is the sixth largest city in the United States and most of the city is bordered by two major rivers, the Delaware and Schuylkill (see Figure 1). Many neighborhoods and communities are located on the banks of these two rivers which means they are at risk of flooding during major storms. The communities located along the Schuylkill River have historically been more significantly impacted by flooding compared to those located on the Delaware River. Floods can be deadly naturals disasters that can result in the loss of life and damage to homes, businesses, and infrastructure. Philadelphia has been impacted by many floods since it was founded and Table 1 shows some of the more recent floods. There are two USGS gages on the Schuylkill River that have been identified in Figure 1, which have collected data relevant to this project[1].

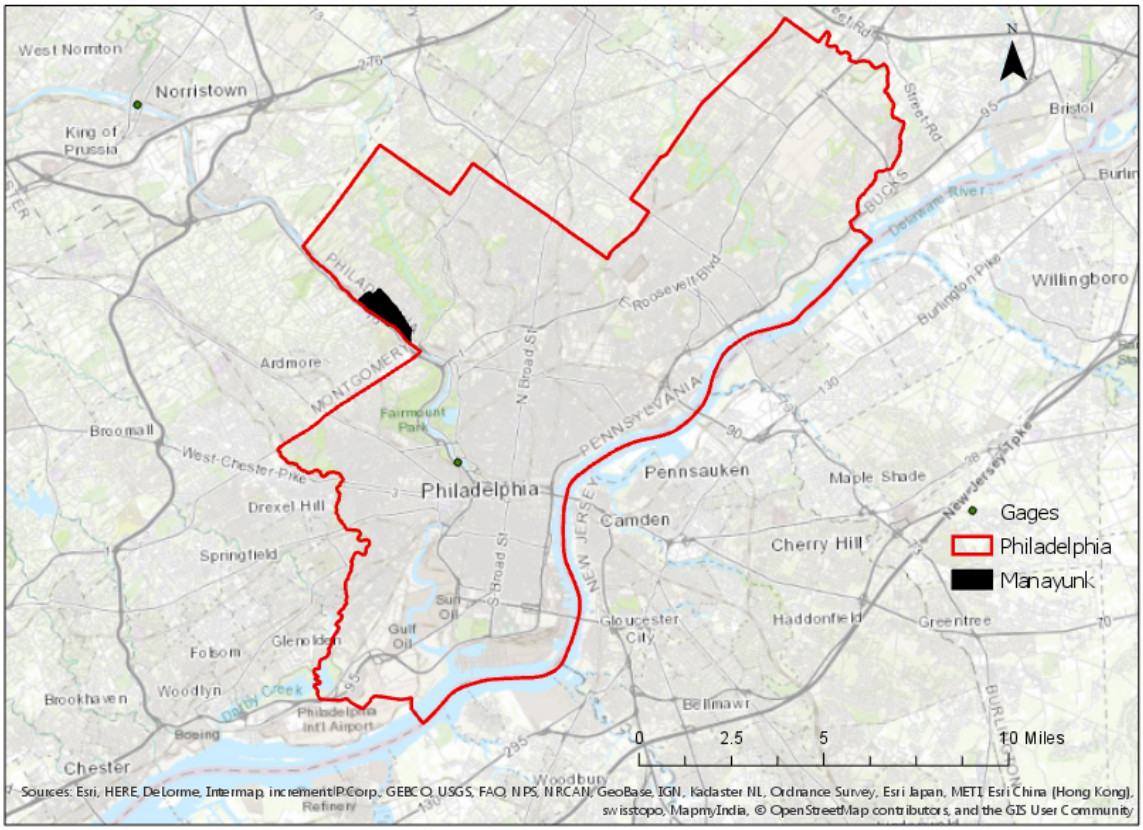

Figure 1: Map of Philadelphia which identifies the Manayunk neighborhoods and location of upstream and downstream gages.

Date of Flood	Crest (ft)	Streamflow (cfs)	Category
9/17/1999	14.10	92,500	Moderate
3/22/2000	11.04	42,700	Minor
6/21/2003	11.43	52,500	Minor
9/18/2004	11.33	51,100	Minor
9/29/2004	11.86	58,500	Minor
4/3/2005	11.74	56,800	Minor
10/9/2005	12.07	61,500	Minor
6/28/2006	12.51	68,100	Minor
4/15/2007	11.34	51,200	Minor
10/1/2010	13.05	76,300	Moderate
3/11/2011	11.03	47,100	Minor
8/28/2011	13.56	83,900	Moderate
9/7/2011	12.01	60,600	Minor
9/8/2011	12.52	68,200	Minor
5/1/2014	13.91	88,300	Moderate

Table 1: USGS flood data for gage located at Schuylkill River at Philadelphia (downstream of Manayunk)[2].

Manayunk Overview

This project focuses on flooding in the Manayunk neighborhood of Philadelphia which is located on the Schuylkill River. Manayunk used to be textile manufacturing hub and in the last couple decades it has gentrified significantly. It has become a residential area for young professionals. My older brother, Ben, is a resident of Manayunk and a business across the street from his apartment, the Manayunk Brewery, was the inspiration for my project. Manayunk Brewery is located directly on the Schuylkill River and has experienced significant damage from floods since it was founded in 1996 (see Figure 2a). On one of the walls inside the brewery they have high water lines for floods that have caused the most damage to the brewery (see Figure 2b). The three flood events shown in Figure 2b are Hurricane Floyd (1999), Hurricane Irene (2011), and the Flash Flood of 2014. The height of the water in the bar for each flood was 79", 48", and 65.5" respectively (measured by my brother). Table 1 identifies each flood as moderate according the National Weather Service. The owner of the Manayunk Brewery did an interview in which she stated that during some of the floods the Schuylkill River reached a height that was 30 feet above the river's normal stage height[3]. Figure 3 shows a map of Manayunk with locations relevant to the analysis done later in this project. The map in Figure 3 was made by importing a Philadelphia neighborhood shapefile and an Excel file with the GPS coordinates of all the bars in Manayunk[4].

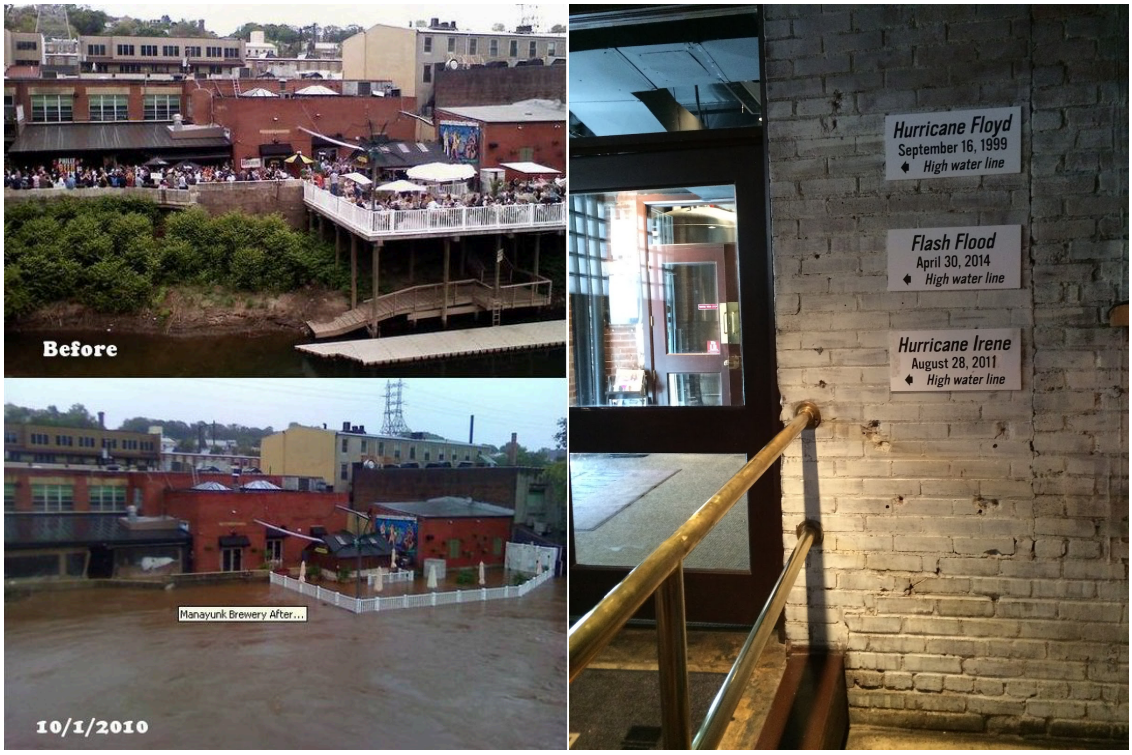

Figure 2: a) Picture of a unflooded and flooded Manayunk Brewery b)Picture of High Water Lines that are marked in Manayunk Brewery

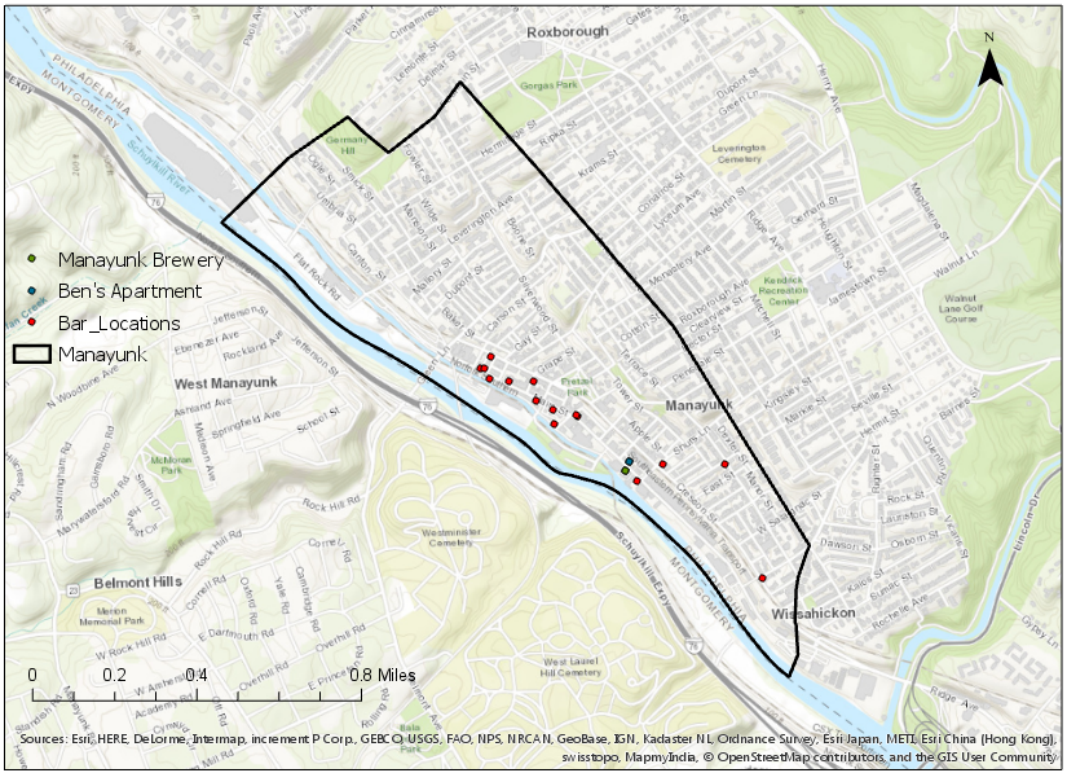

Figure 3: Map of Manayunk neighborhood with Manayunk Brewery, Ben's Apartment and other bar locations identified.

Project Objective

The objective of this project is to use the Height Above Nearest Drainage (HAND) model to gain a better understanding of flooding in the Manayunk Neighborhood of Philadelphia. This achieved by doing the following:

- Determining the stage height for each flood at the Manayunk Brewery by combining the HAND for the bar and the high water lines within the bar for each flood.
- Evaluating how much of Manayunk was flooded during each storm using the calculated stage height.
- Generating a Rating Curve for the Manayunk neighborhood to determine the flow in the Schuylkill River and compare it to the available upstream and downstream gage data.
- Compare results from this project to historical accounts and reconcile any differences.

Methods and Discussion

Stage heights of floods at Manayunk Brewery

The procedure described in lecture and Exercise 5 was used to determine the stage height of each flood. Luckily HAND rasters at the HUC 6 level were already made for the entire US by Yan Liu and the University of Illinois[5]. The HUC 6 which encompassed Philadelphia is shown below in Figure 4. To make this map I imported the available HAND raster for HUC 020402 and adjusted its symbology.

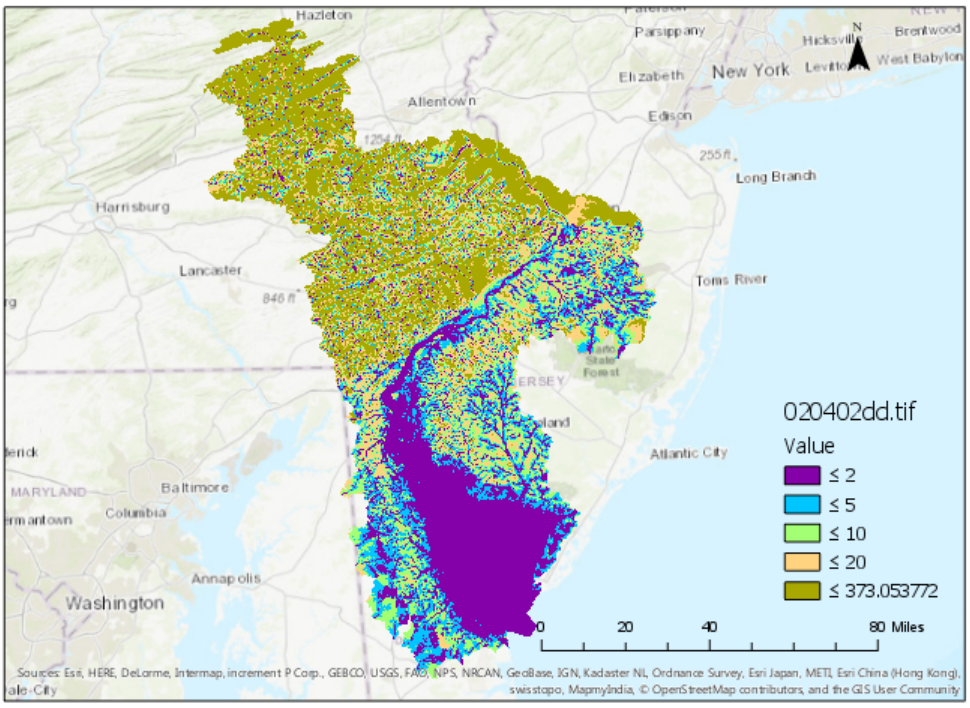

Figure 4: HAND raster of HUC 020402 with height in meters

The Extract by Mask function was then used to create an output raster for just the Manayunk neighborhood. This HAND raster is shown below in Figure 5. It shows that most bars in

Manayunk have a HAND value greater than 10 meters. Manayunk Brewery is one of the few bars that are below 10 meters.

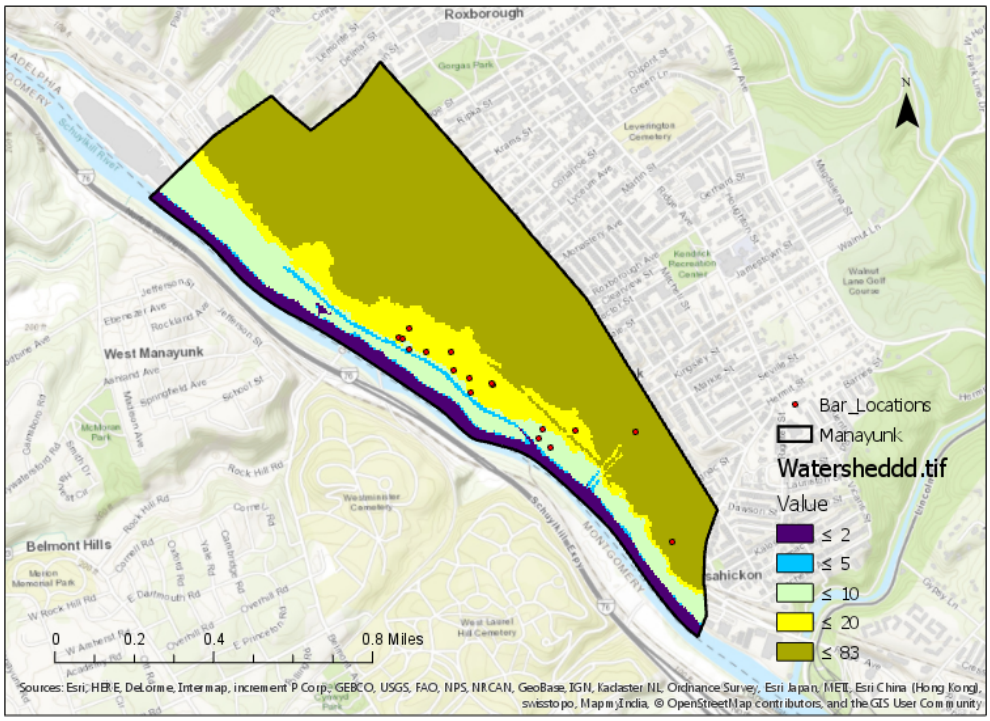

Figure 5: HAND raster of Manayunk with height in meters

To evaluate the flood crest at the Manayunk Brewery I used the Extract Value to Point geoprocessing tool to determine the HAND value for it. I summed the HAND value for the Manayunk Brewery and the height of the high water lines in Figure 1 to determine the crest of each of the floods that have affected the Manayunk Brewery. The estimated crests are shown below in Table 2.

Flood	Date	Crest (ft)
Hurricane Floyd	9/17/1999	29.92
Hurricane Irene	8/28/2011	27.33
Flash Flood of 2014	5/1/2014	28.79

Table 2: Crest achieved by each flood based on HAND model and documented high water line in Manayunk Brewery.

Flooding Impact on Manayunk

The calculated crests for each flood was compared to the HAND value of each bar in Manayunk to determine which would have flooded during each storm. The same four locations were flooded in each storm which are shown in Figure 6. The flooding is centered on the Main Street in the area around the Manayunk Brewery and the rest of Manayunk is relatively safe from flooding. Photographs from some of these storms have been posted on the internet and they

confirm that the flooding is only around the Manayunk Brewery. This verifies the accuracy of this analysis. Some of these photographs can be seen in the Appendix.

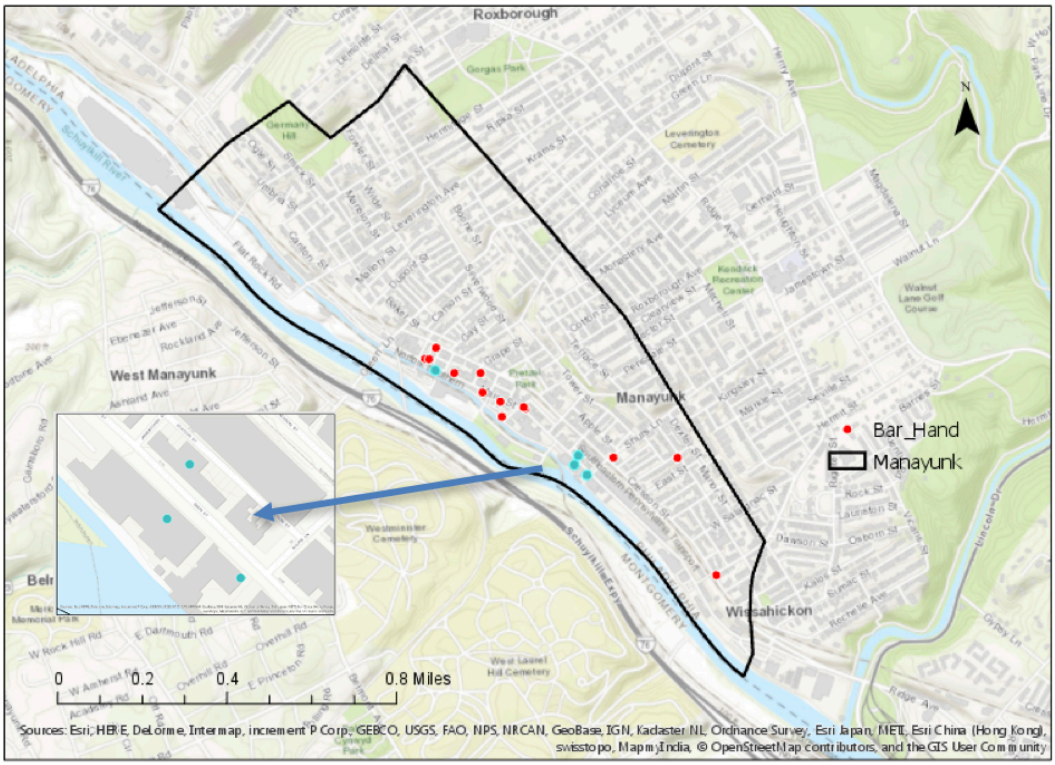

Figure 6: Map of Manayunk bars that are flooded by a 30 foot crest

In the Introduction it was mentioned that the owner of the Manayunk Brewery claimed that the crests for some of these storms were 30 feet higher than the Schuylkill River's normal height. The crest heights calculated in Table 2 were close to 30 feet but none exceeded it so I decided to investigate this claim closer to see if I made an error in my analysis. Conveniently this claim can be checked because a USGS gage was set up in Manayunk in February, 2017. The data from that gage places a normal river level at a height of about 12.5 feet. This means that according to the owner's account the crest during Hurricane Floyd would have reached approximately 42.5 feet. The flooding caused by a 42.5 foot crest is shown in Figure 7. There is significant flooding all along the Main Street of Manayunk and only a few bars would be unaffected by a flood of this magnitude. Comparing this level of flooding to photographs of the Main Street it is apparent that the owner misspoke in the interview. She must have meant to say that flood water "reached a height of 30 feet" not that the Schuylkill River reached a height 30 feet higher than normal.

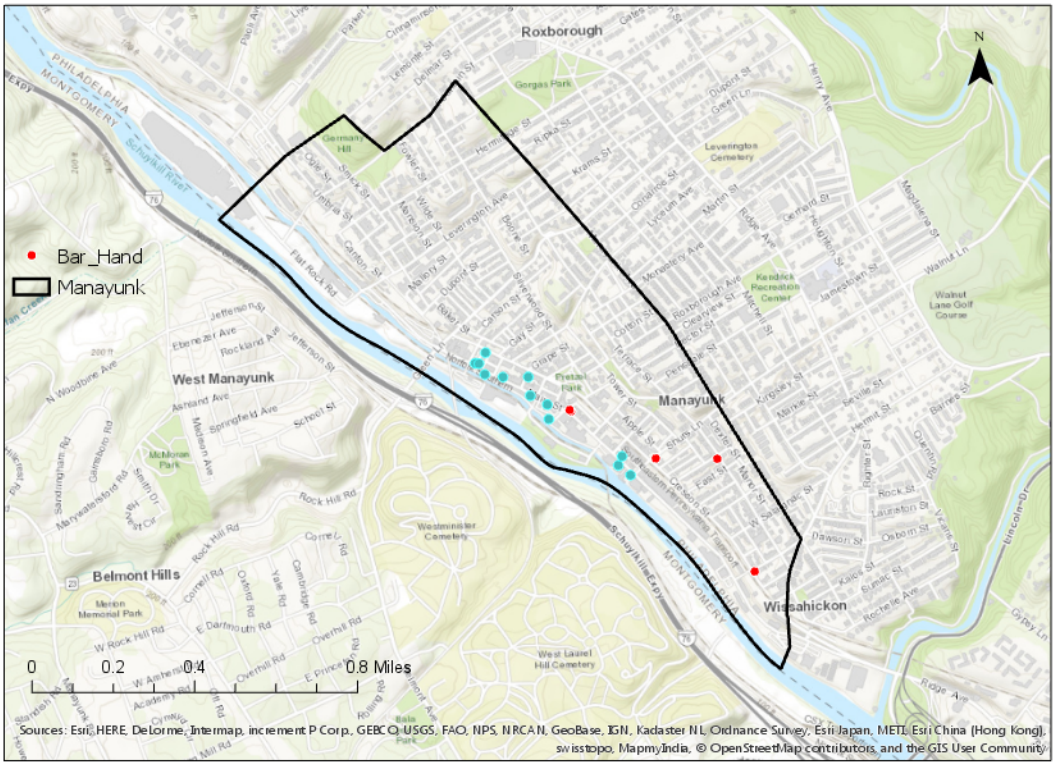

Figure 7: Map of Manayunk bars that are flooded by a 30 foot crest

Rating Curve and USGS Gage Comparison

The procedure in Exercise 5 was followed to generate a Rating Curve for the Schuylkill River by the Manayunk neighborhood. Table 3 below shows the parameters of the Schuylkill River by Manayunk and the calculated parameters used to generate the Rating Curve in Figure 8.

Stage Height (m)	1	6	10	14
As (m2)	66719	276987	1141766	2854414
Ab (m2)	66803	281418	1150900	2867259
V (m3)	47971	900206	3187810	11491871
L(m)	4072	4072	4072	4072
A=V/L(m2)	11.8	221.1	782.9	2822.2
P=Ab/L(m)	16.4	69.1	282.6	704.1
R=A/P(m)	0.719	3.199	2.770	4.008
So	0.001749	0.001749	0.001749	0.001749
n	0.05	0.05	0.05	0.05
Q (m3/s)	7.9	401.4	1291.5	5956.0
Q (ft3/s)	279.6	14170.8	45588.4	210248.0

Table 3: Parameters used to generate Rating Curve

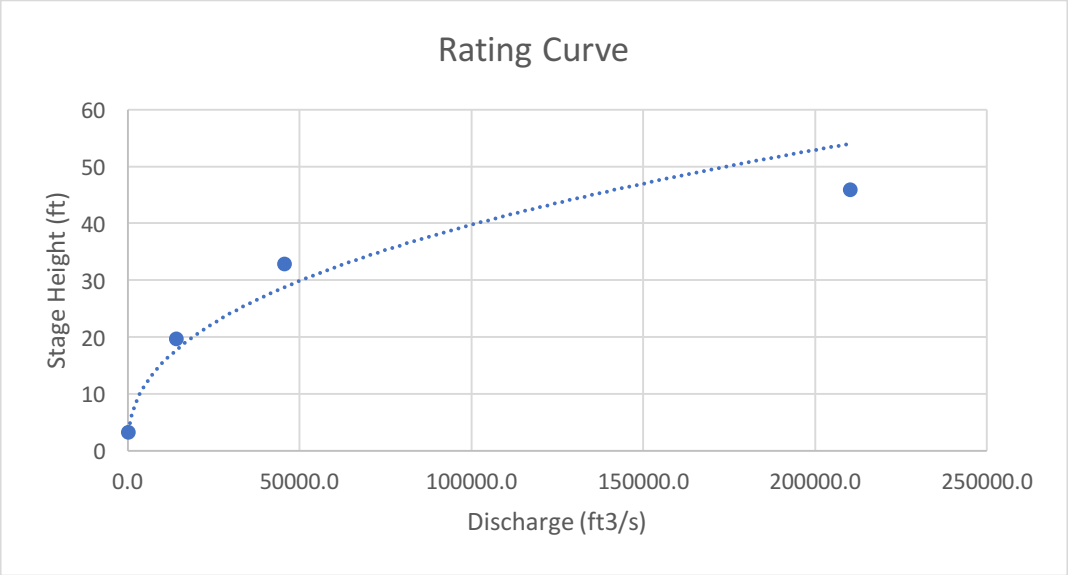

Figure 8: Rating Curve for Manayunk neighborhood

The Rating Curve was then used to determine the discharge flow for each flood based on the calculated crests in Table 2. These flows were then compared to the USGS gages upstream and downstream of Manayunk. The results are shown in Table 4.

Flood	Upstream Gage (cfs)	Downstream Gage (cfs)	Unofficial Manayunk Brewery Gage (cfs)
Hurricane Floyd	-	92,500	77,600
Hurricane Irene	81,400	83,500	67,200
Flash Flood 2014	90,400	83,900	73,000

Table 4: Comparing upstream and downstream gage discharge to the discharge calculated from the Rating Curve

The discharge flows from the Rating Curve are noticeably smaller than both the upstream and downstream flows that were measured. If you refer to Figure 3, 6, or 7 you will notice that there is a stream, the Wissahickon Creek, that meets the Schuylkill River just south of Manayunk. This convergence is well before the downstream gage in Table 4. There is a gage at the mouth of the Wissahickon Creek so I summed the flows from that with the discharges calculated from the Rating Curve. The results are shown below in Table 5. Accounting for the additional flow from the Wissahickon Creek reduced the average difference between the calculated discharge at Manayunk Brewery and the observed downstream gage from 16.2% to 3.3% which is a significant improvement. This approach I used is a basic mass balance and its accuracy suggests that the Rating Curve gives accurate flow discharges for a given stage height and vice versa in Manayunk.

Flood	Downstream Gage (cfs)	Unofficial Manayunk Brewery Gage + Wissahickon Gage (cfs)
Hurricane Floyd	92,500	97,400
Hurricane Irene	83,900	84,300
Flash Flood of 2014	85,300	80,900

Table 5: Comparing downstream gage discharge to the discharge calculated from the Rating Curve and Wissahickon Creek gage

Conclusion

The application of the HAND model in this project was successful in gaining a better understanding of how floods affect the Manayunk neighborhood. I was able to make reasonable estimates for the flood crests in Manayunk where a gage has not been present until recently. With these crest heights and HAND values of bars in Manayunk I was then able to estimate the extent of flooding in Manayunk and compare them to photographic accounts of the floods to confirm my results. Finally, I was able to make a Rating Curve and calculate correct discharges in Manayunk. This robust and light hearted analysis was able to bring greater knowledge about floods in an area that did not have an existing USGS gage. This process can be applied to other locations where there are informal ways to measure flood and sufficient data to do a HAND method evaluation.

References

[1] United State Geological Survey. https://waterdata.usgs.gov/usa/nwis/uv?01474500

[2] National Weather Service. https://www.weather.gov/media/marfc/FloodClimo/SEPA/Philadelphia.pdf

[3] Manayunk Brewer. https://www.manayunkbrewery.com/story

[4] Pennsylvania Spatial Data Access. http://www.pasda.psu.edu

[5] Yan Liu. http://www.cigi.illinois.edu/yanliu/NFIEHAND.pdf

Appendix