Schuylkill River Flood in Philadelphia, PA

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Introduction

Philadelphia flood

Philadelphia is the largest city in the state of Pennsylvania in the northeastern United States. It is located at the confluence of the Delaware and Schuylkill rivers.

In this city, water is prone to be collected to cause flooding. Floods tend to increase with severe weather events such as hurricanes and storms. In addition to extreme weather, heavy precipitation, there are many reasons led to this situation. Urban areas lack vegetation that can capture water from precipitation. Urban areas with large population and urban facilities increase discharge in the stream. And original channel would be replaced or narrowed with development activities.

As can be seen from Table 1, 35 floods occurred in the past 35 years (1980-15), 10 from 1980 to 1999, and 14 from 2000 to 2015.

Date of Flood	Category	Date of Flood	Category
4/16/83	Minor	9/18/04	Minor
12/13/83	Minor	9/29/04	Minor
5/30/84	Minor	4/3/05	Minor
7/7/84	Minor	10/9/05	Minor
12/5/93	Minor	6/28/06	Minor
3/9/95	Minor	4/15/07	Minor
1/19/96	**Moderate**	**10/1/10**	**Moderate**
10/19/96	Minor	3/11/11	Minor
12/14/96	Minor	**8/28/11**	**Moderate**
9/17/99	**Moderate**	9/7/11	Minor
3/22/00	Minor	9/8/11	Minor
6/21/03	Minor	**5/1/14**	**Moderate**

Table 1. Historical Floods: Schuylkill River in Philadelphia, PA

Schuylkill River Watershed

Philadelphia contains seven major sub-basins. This project concentrates on a sub-basin - Schuylkill River Basin.

The Schuylkill River is an important river in central and eastern Pennsylvania. It completes its journey, joining Delaware after flowing through Philadelphia.

There are some facts about it:
Area: drains approximately 2,000 miles2;
Stream Miles: approximately 135 linear miles;
Population: approximately 1.5 million population;
County / City: Covering 11 counties, including Schuylkill, Berks, Montgomery, Chester, Philadelphia, Carbon, Lehigh, Lebanon, Lancaster, Bucks and Delaware.

The Schuylkill River Watershed's Hydrologic Unit Code is 02040203. There are 61 of the HUC-12 Subwatersheds that lie within the Schuylkill River basin shown on Figure2.

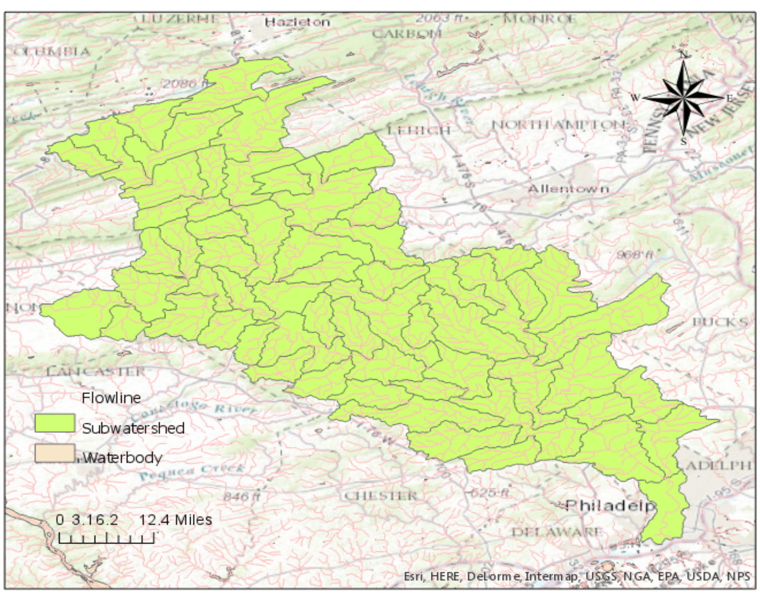

Figure 2.Schuylkill River Watershed with HUC_12 Subwatersheds

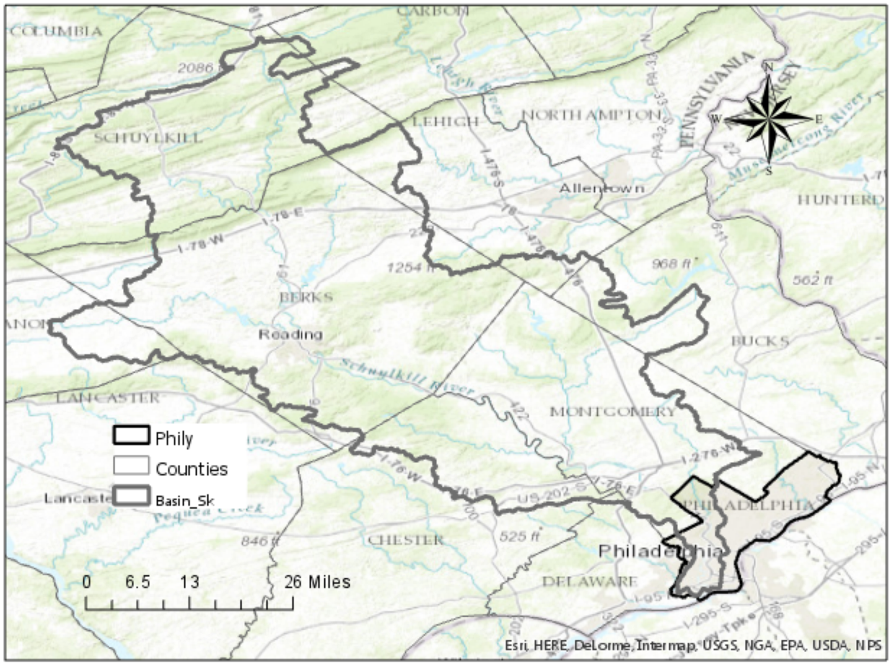

Figure 3. Schuylkill River Watershed, Counties and Philadelphia City

Objective

The objective of this study is to learn the flood information in one of the Philadelphia's watersheds—Schuylkill river watershed to the city. In order to gather the information, the FEMA Flood Risk Area, the Landcover, Population Density, City Facilities would be considered.

Methods and Discussion

Schuylkill River Watershed and Philadelphia

Define the watershed of the Schuylkill River use the data from the ArcGIS Online map of Water Resource Region 12 using this link: http://arcg.is/1JW0DBm. Because the river goes through Pennsylvania, we click on the Mid-Atlantic region. Go to **Watersgeo** website to find The HUC_8 as 02040203 for the watershed. Then use **Dissolve** tool to merge all of the HUC_10 and HUC_12 subwatersheds with the same HUC_8 together.

Then add "Pennsylvania Counties" Layer to delineate the boundary of Philadelphia.
Figure 2 shows the Schuylkill River Watershed, counties and Philadelphia City. The watershed has a gray border and Philadelphia's borders are black.

Philadelphia Gage

There are many gages within the watershed. But focused on the Philadelphia gage, because the project focuses on the watershed effect of Philadelphia.

The latitude is 39° 58'04"and longtitude is 75° 11'20". It is located at the "right bank of the Fairmount Dam 150 meters upstream, the bridge is 1,500 feet upstream and 8.7 miles upstream of Spring Garden Street in Philadelphia."

Defined and input a table in .cvs containing the location information from the **USGS** Site. Display the XY Data and there shows the dot needed. Changed the dataset to GSC_North_American_1983, changed every time when the dataset coordinate system is not NAD 1983.

Philadelphia gage is shown in Figure 4, which is the red dot in the end of the flowline shown.

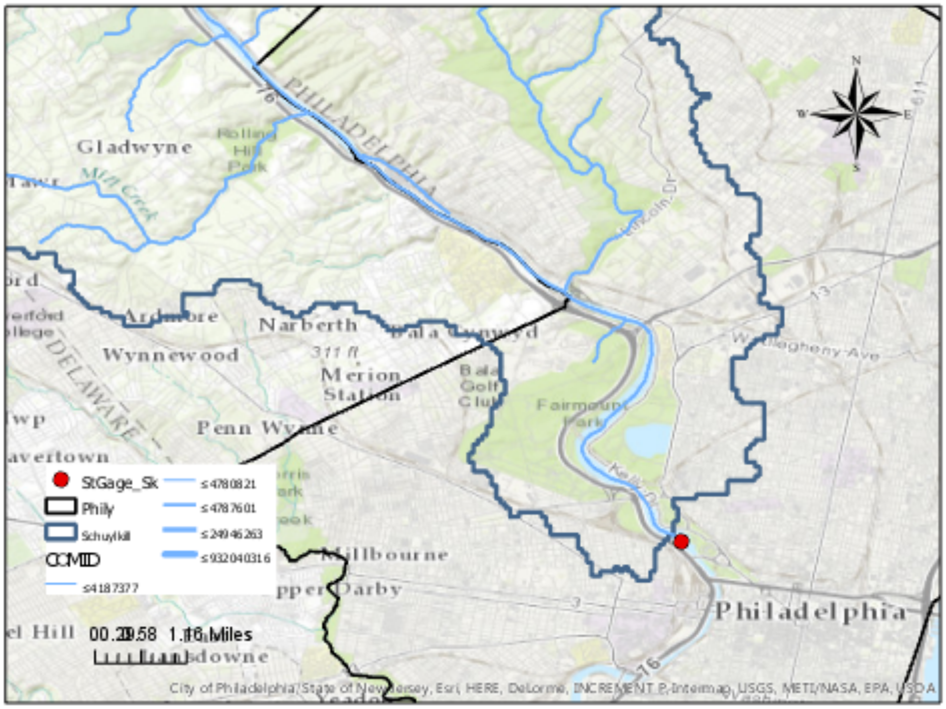

Figure 4.Philadelphia Gage

Study Area

With Dr. Maidment's guidance, the Schuylkill watershed is updated according to gage location. Cut a portion of the watershed after the gage location to the entrance of Delaware River. It is because there are frequent exchange streams that might affect the analysis. Figure 5 shows updated map, where the streamline ends earlier than the original one.

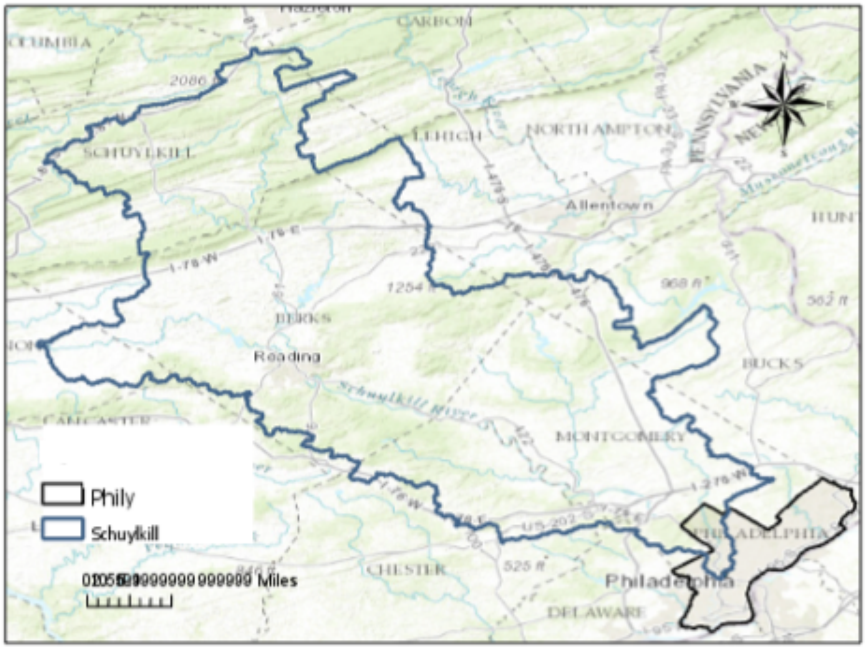

Figure 5. Corrected Schuylkill River Watershed

For further study, consider the watershed area as a part of the city which is the black area shown in Figure 6.

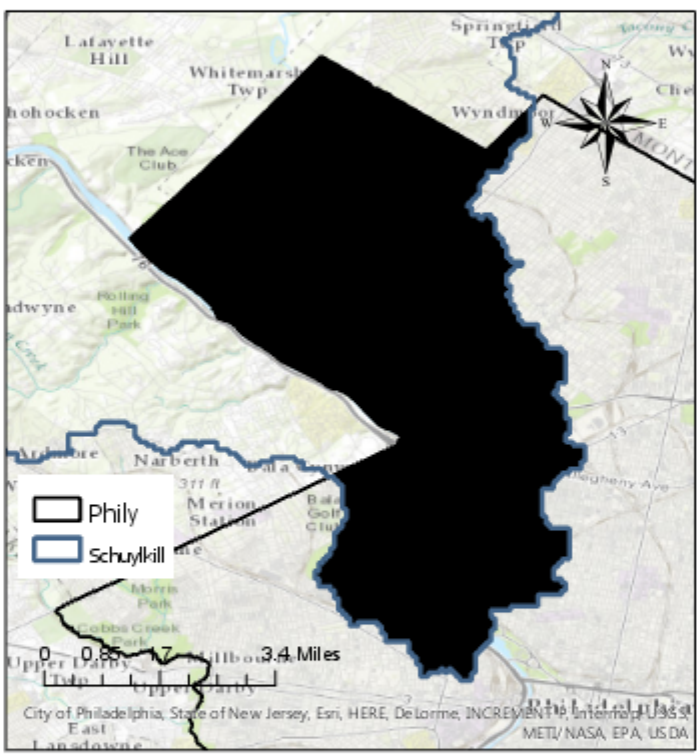

Figure 6. Study Area of the Project

FEMA Flood Risk

I added the “FEMA’s National Hazard layer”, which was created to determine the locations related to the flood hazard information. From the digital map, the potential flood areas are estimated. From the map, we see the purple flood zone, which means that the probability of flooding every year is 1%. It appears that the left part of the study area is prone to flooding.

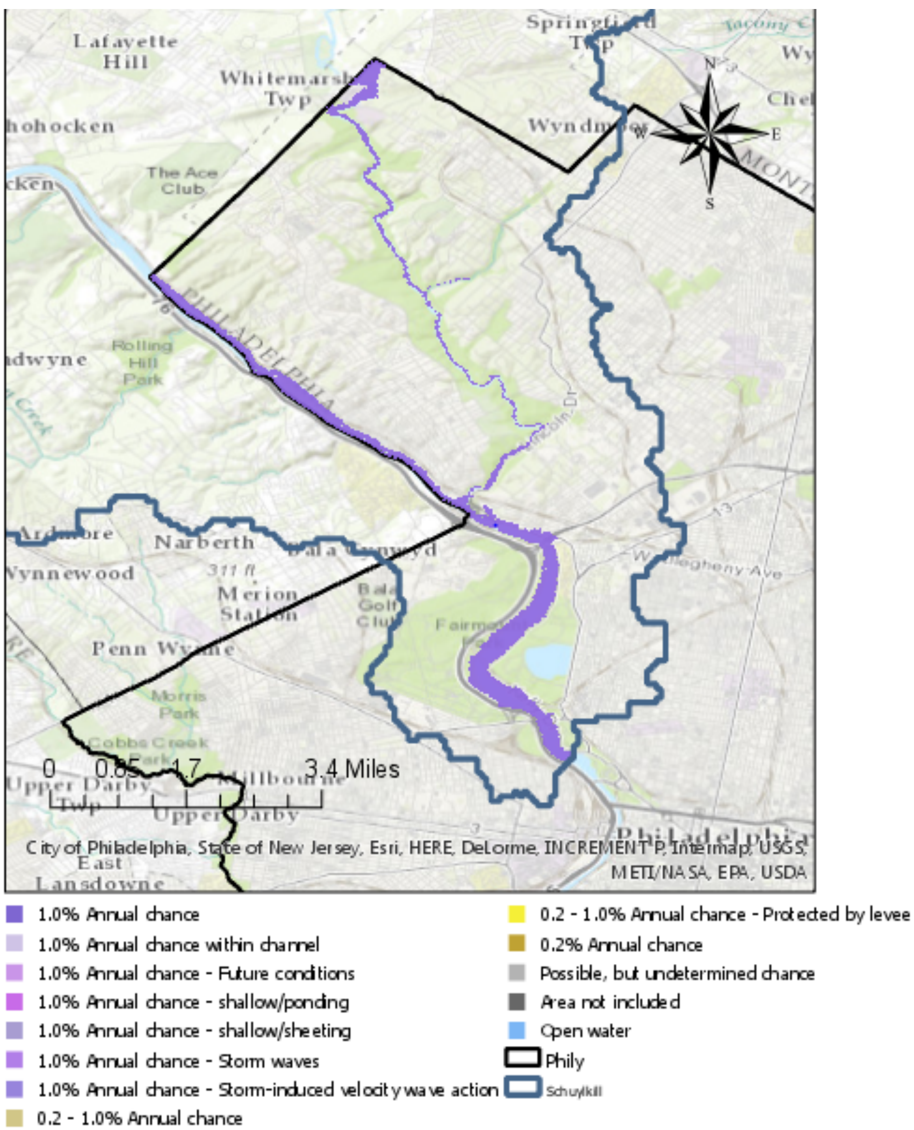

Figure 7. FEMA Flooding Risk Map

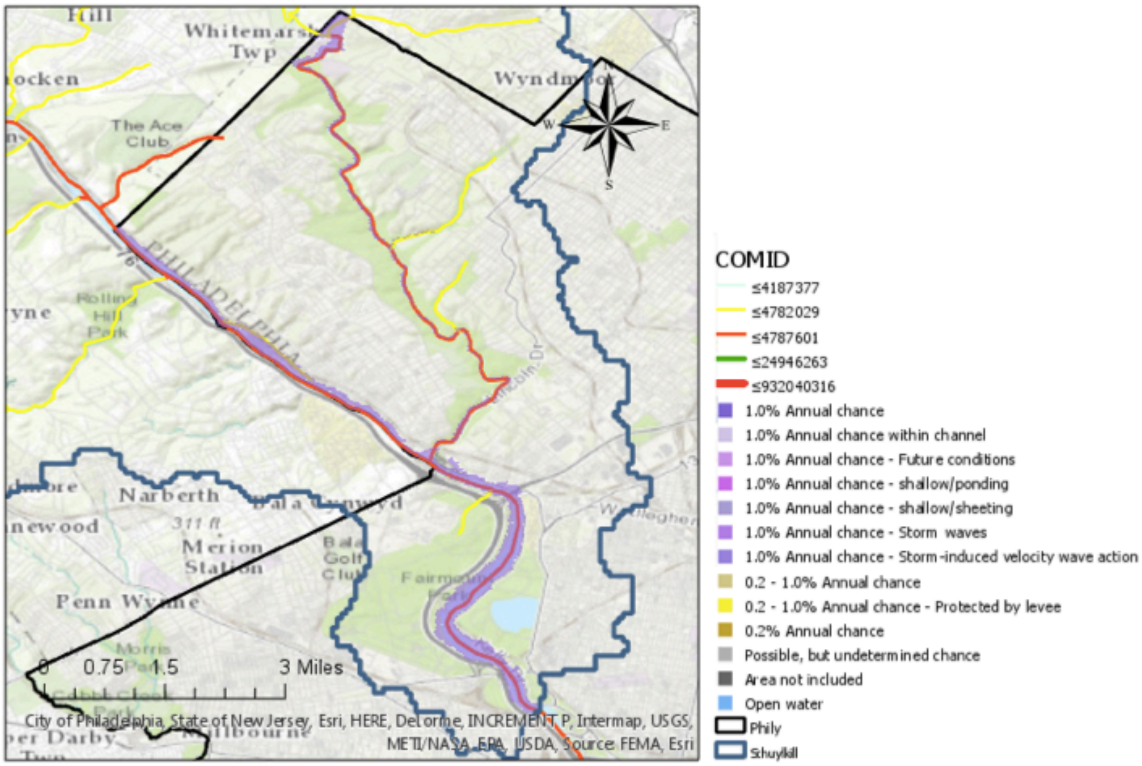

Figure 8. Flowline in Flooding Risk Area

Then I add the flowline data from **NFIEGeo_12.gdb** and change the symbology of the flowline in the Schuylkill tributaries. Most of the streamlines covered by the flood hazard zone are orange. As shown, these stream discharge range from 4782029 cfs to 4787601 cfs. And a small fraction of the flow is less than 4787601 cfs with the risk of flooding. In this region, the discharge in the range of 4782029cfs to 4787601cfs is the maximum discharge value. Therefore, it appears that a flow with a larger flow will have a higher risk of flooding.

Landcover

After creating the flooding map, I added landcover dataset and displayed a landcover map in the study area. In Figure 9, the red part representing the development class includes the main land in the area.

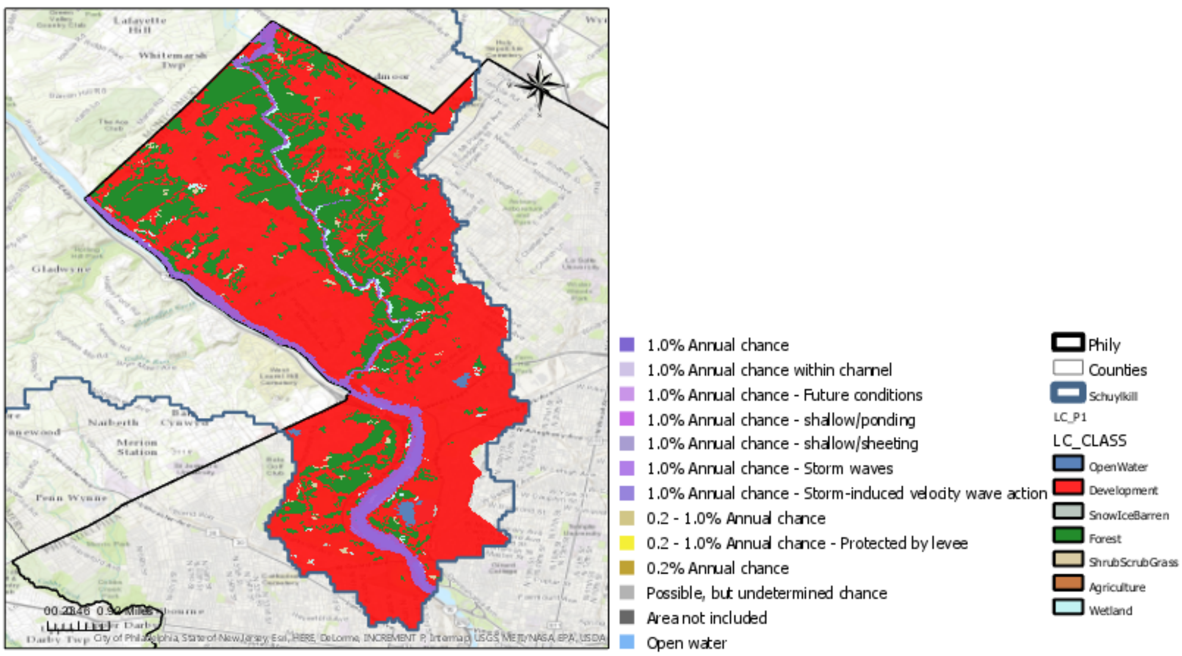

Figure 9. Part watershed Landcover

After summarizing and exporting the table of land cover maps, I created a pie chart for direct understanding. According to the Pie chart, the development of river basin cover contributes over 70 percent of land cover, and forest accounts for a quarter of the land. In addition to the open water on the map, the left purple flood area flows through the development zone.

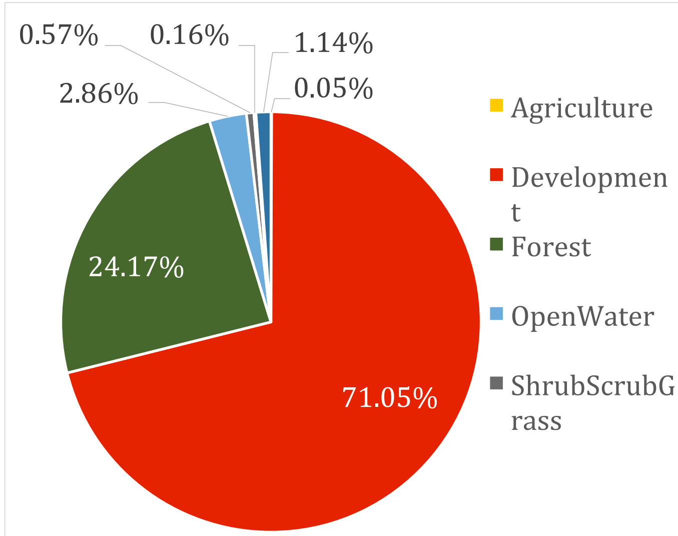

Figure 10. Pie Chart of Landcover

The flooding area landcover generated after extracted the Landcover by Flooding area mask data.

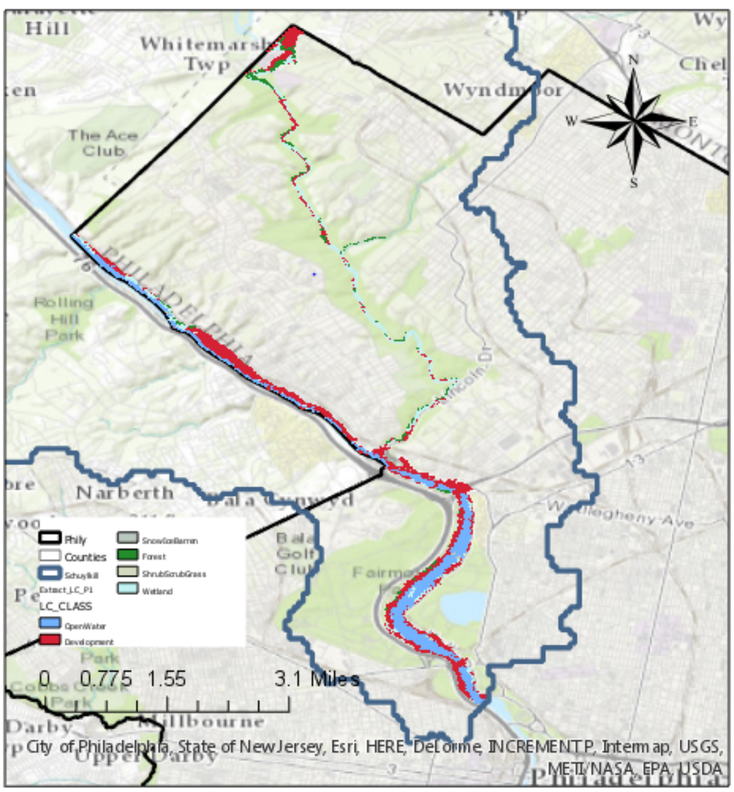

Figure 11. Flooding Area Landcover

Make sure that it is a raster with 30m x 30m cells per grid. Exported the summary Table again and calculated the area affected by the flood. The area of each land cover category can be determined by multiplying the count number by 900 m^2 /grid. And the data were included in the Table 2.

LC_CLASS	Area,m2	SUM_COUNT	Percentage
Development	**1638900**	**1821**	**44.24%**
Forest	278100	309	7.51%
OpenWater	1286100	1429	34.72%
ShrubScrubGrass	7200	8	0.19%
SnowIceBarren	12600	14	0.34%
Wetland	481500	535	13.00%

Table 2. Landcover in Flooding Risk Area

In the flood under the influence of the development of nearly 1.6 square kilometers of land, accounting for 44.24% of the total area of affected land. 7.51% and 13.00% are forests and wetlands, respectively.

Population Density

The population density was also considered in this project related to flood casualties. Similarly, the population density map was generated using the **2015_Population_Density** in the Servers' folder. The main part of the study area is Urban class, which mean "Density ranges from 1,909 to 16,978 people per square kilometer. 53% of all people(worldwide) live at this level of density or higher." The class descriptions are included in Table 3.

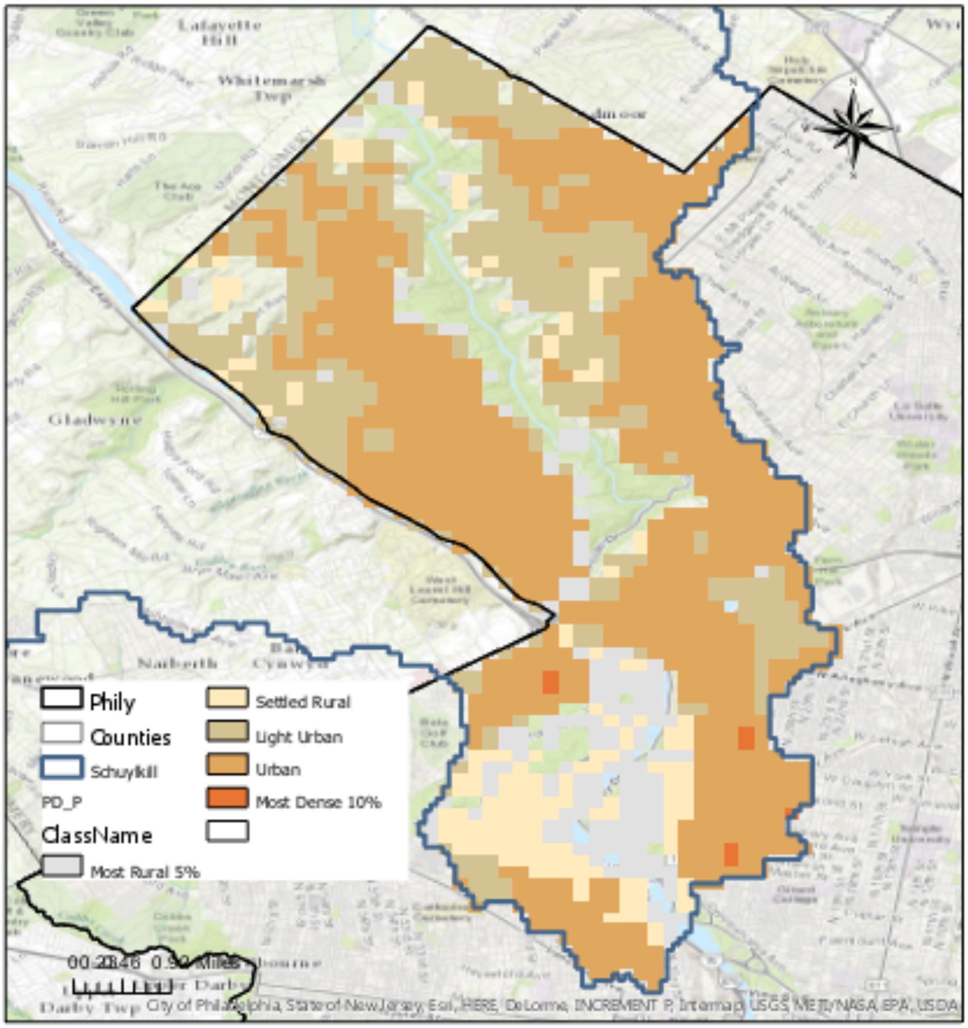

Figure 12. Population Density Map in Study Area

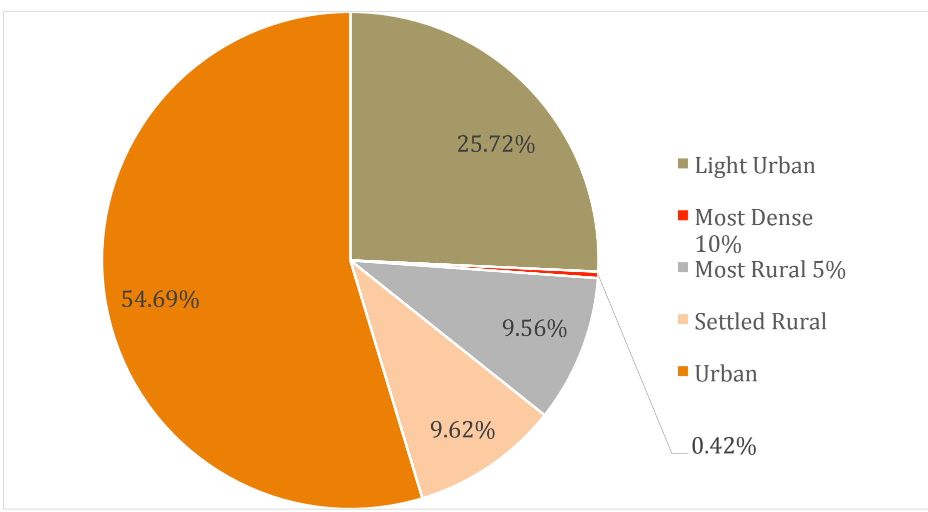

Figure 13. Pie Chart of Population Density

ClassName	MAX_Description
Most Rural 5%	Density ranges from 1 to 99 people per square kilometer. 5% of all people live at this level of density or less.
Settled Rural	Density ranges from 100 to 400 people per square kilometer.
Light Urban	Density ranges from 400 to 1908 people per square kilometer. 82.9% of all people live at this level of density or higher.
Urban	Density ranges from 1,909 to 16,978 people per square kilometer. 53% of all people live at this level of density or higher.
Most Dense 10%	Density ranges from 16,979 to 26,331 to people per square kilometer. 10% of all people live at this level of density or higher.

Table 3.Description of Class in Population Density

The pie chart was created in the same way mentioned before. It shows the percentage of the different density classes in this area. Obviously, the distribution of Urban and Light Urban is respectively 54.69% and 25.72%. Besides, Most Rural and Most Dense both make up around 9.5% of total amount. The density level in this part of the urban area is between 400 and 1908 or higher (light city, city and densest 10%), with a density of 80.83%, compared with 82.9% documented. In addition, the percentage of Most Rural in the map is greater than the standard as 5%. In this way, we can not say that this area is a region with a high population density.

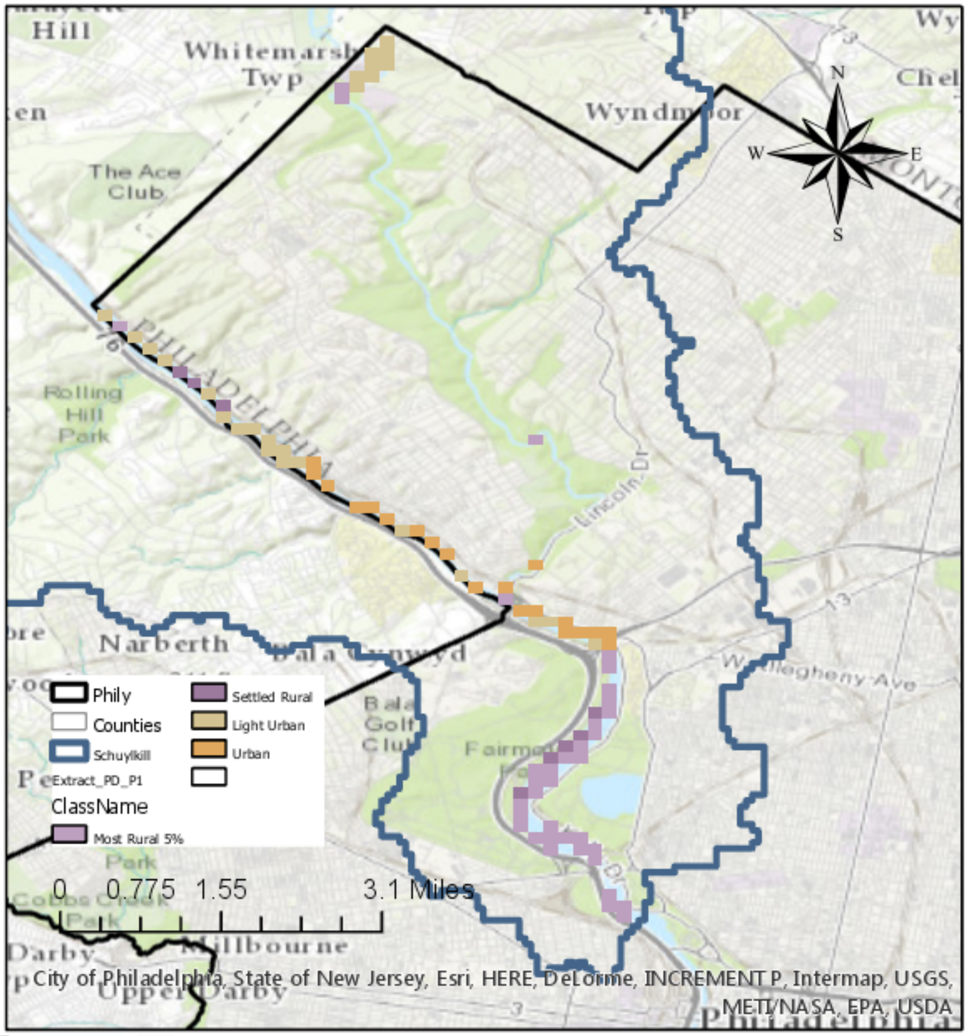

Figure 13. Flooding Population Density map: Population Density in the Flooding Risk Area.

Reduce the map to the Flooding Population Density map shown above. We can see that there is almost no population density in the upper right flood area. But there has population density on the left.

The coordinator system was corrected to NAD 1983. Thus, the grid size was 30 m x 30 m. Aggregate the Attribute Table and move to excel. The actual area and population are then analyzed to calculate the area using the same method as the Landcover analysis. And the results are included in Table 4.

ClassName	Area,m2	SUM_Count	Percent	Population	*AveDen,Cap/km2
Light Urban	1379469	1533	28.89%	1592	1154
Most Rural 5%	1910035	2122	40.00%	96	50
Settled Rural	424452	472	8.89%	106	250
Urban	1061130	1179	22.22%	10021	9443.5

Table 4. Summary Data of Population Density

*AveDen: Average Population Density, assume it is the mean of the density level,

Example:AveDen(Most Rural)=(1+99)/2=50 Capital/km^2

It is good news that floods will not affect the region's most urbanized areas. But flooding need to be considered, because the Urban and Light Urban areas contains 2.44km^2 with 11,613 population are flood-affected. Rural area should also improve focus on flood risk.

City Facilities

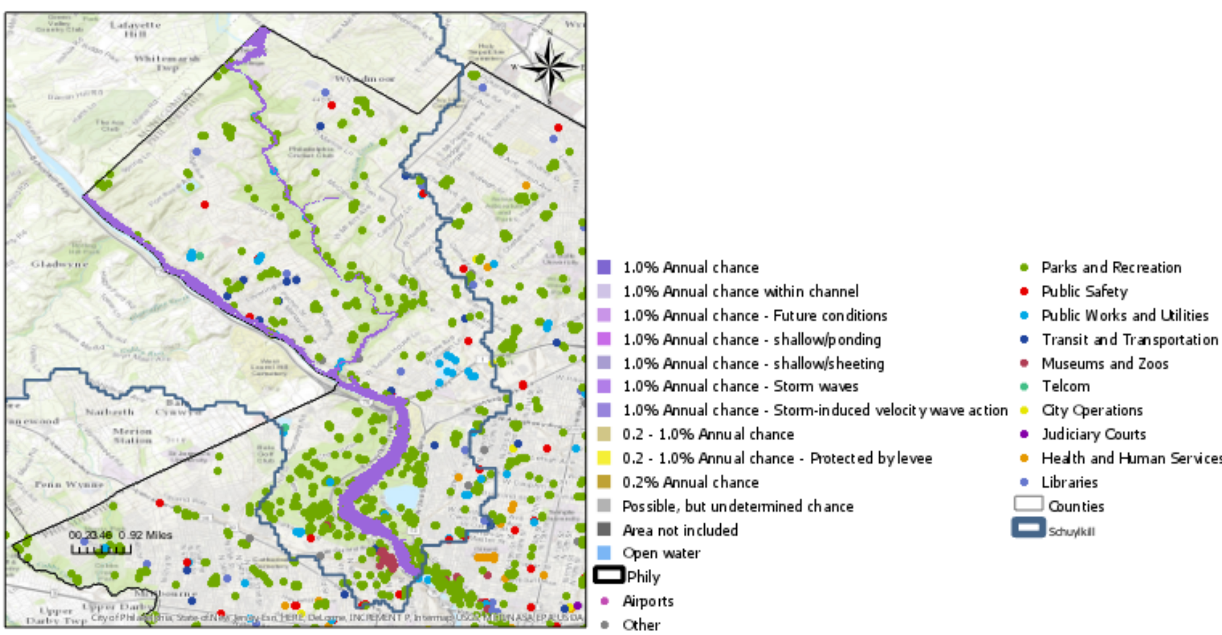

Figure 14. City Facility in Philadelphia

In addition of human casualties, Economic losses should be considered as well. So the public facilities and utilities information is a concern in the project.

Create the City Facility Map with documented data. Figure 14 shows the Flood Risk area covered the City Facilities. The most affected facilities in this region are the green dots -Park and Recreation alongside the river. And after counting, there are 27 green dots and 2 light blue dots covered by the potential flood.

Precipitation Flowline

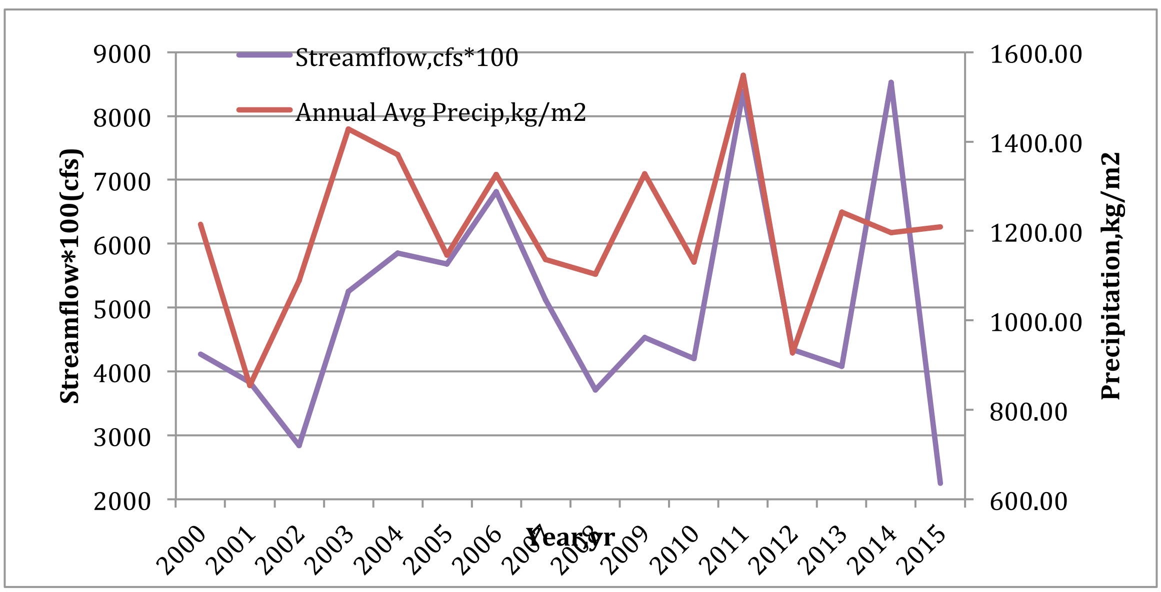

Figure 15. Annual Mean Streamflow and Precipitation at Philadelphia Gage

Studies were made trying to determine the relation between runoff and precipitation. The streamflow discharge and precipitation data from the Philadelphia gage set at beginning. With the data form USGS and Data Rods Explorer App, the graph of Precipitation and Streamflow during the period from 2000 to 2015 was generated.

As seen in Figure 15, the changing trend of Streamflow and Precipitation are similar from 2000 to2013. While the relation changed from 2012 to 2015. This may be because urban discharge changed activity during this time.

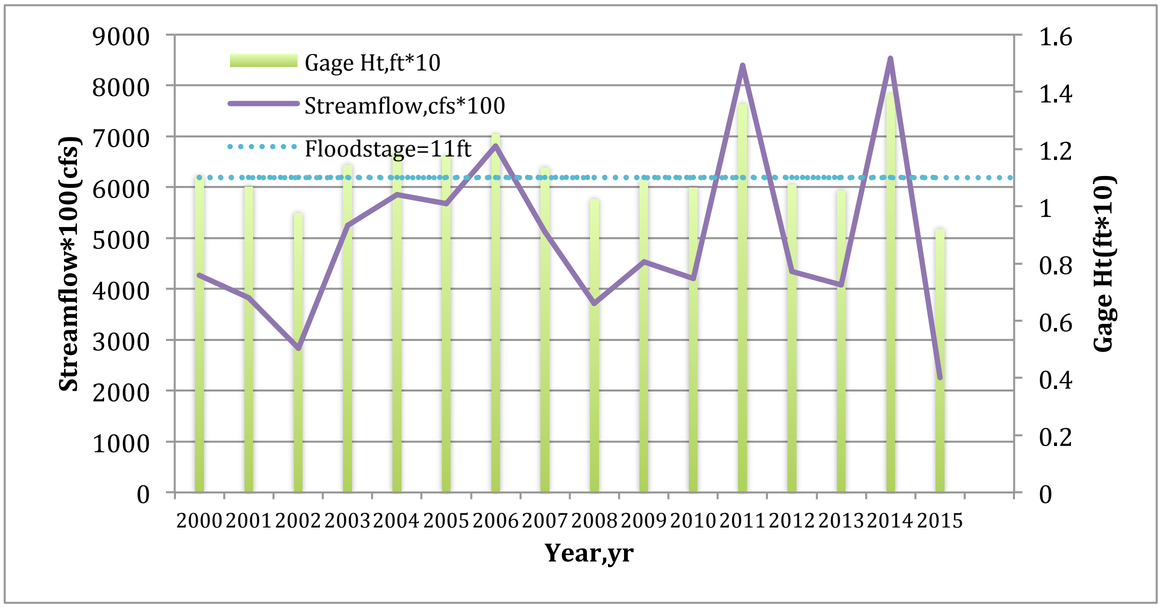

Figure 16. Streamflow and Gage at Philadelphia Gage

Figure 16 shows the relation between Streamflow and Gage Height. And the floodstage is also generated in the Figure. The variation of the gage height is highly correlated with the change of the discharge.

Conclusion

A series of information on the flood impact of the Philadelphia from the Schuylkill River Basin were considered in the report. The relationship between precipitation and streamflow is analyzed. The relationship between streamflow and gage height is also analyzed. Use Landcover maps, population density maps and public facilities maps to analyze potential loss to the city caused by the predicting flooding. According to these maps, appropriate planning about stream discharge, building reinforce and evacuation should be considered in order to reduce economic losses and casualties during the potential flood.

The Further study could consider the change in urban occupancy of the city in Philadelphia. The same research can be applied to the other six watersheds.

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