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Memorandum

To:	Karl Russek, University of Pennsylvania Water Center
From:	AKRF, Inc.
Date:	April 1, 2022
Re:	PWSA Strategic Plan for Stormwater - Impervious Area Analysis

Introduction:

A high-level impervious area analysis for the City of Pittsburgh was conducted by AKRF as part of the Pittsburgh Water and Sewer Authority (PWSA) Strategic Plan for Stormwater. The analysis was performed to provide a base understanding of the sources of stormwater generation by using impervious area as a surrogate for stormwater runoff. Generally, the quantity and quality of stormwater runoff in urban areas is directly proportional to the quantity of impervious surface area. Understanding the spatial distribution of impervious area across the City, as well as the types of impervious areas (i.e. impervious area located in the public right-of-way versus impervious area on private land), provides a base understanding of the sources of stormwater which can then inform long-term strategic planning efforts.

Methodology:

As part of the PWSA Strategic Plan for Stormwater, AKRF was provided a geodatabase file titled "StormwaterPlan.gdb" containing the following relevant datasets for the purposes of the impervious area analysis:

- "Transportation" - Polygon feature class representing ground level impervious transportation features (roads, sidewalks, driveways, parking lots)
- "Buildings" - Polygon feature class representing building footprints
- "Other" - Polygon feature class representing other types of ground level impervious features such as courtyards, small pads, patios, and swimming pools.
- "Sewersheds" - Polygon feature class representing City of Pittsburgh sewershed boundaries
- "Bridges" - Polygon feature class that was not used for this analysis as upon visual inspection this layer is already included within the "Transportation" polygon layer referenced above.

Figure 1 depicts the Transportation, Buildings, and Other impervious area features provided by PWSA.

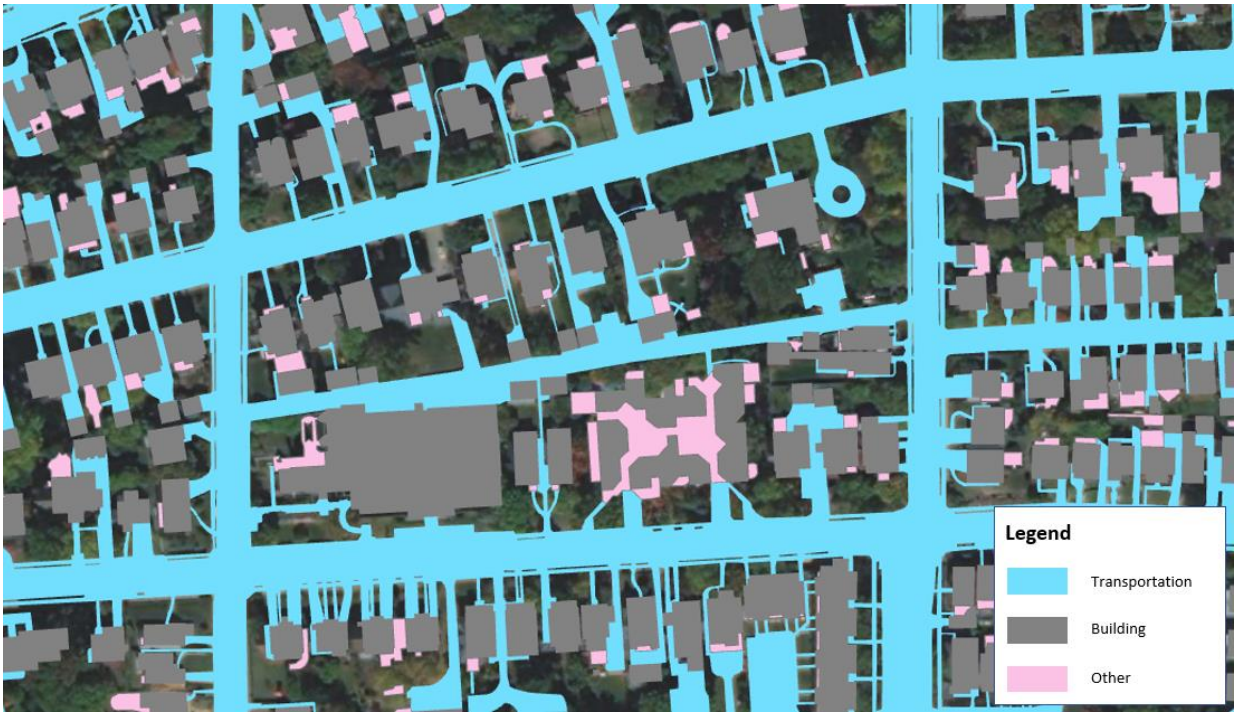


Figure 1. PWSA Transportation, Building, and Other Impervious Data Layers

In addition to the impervious area files in the "StormwaterPlan.gdb" file, AKRF obtained the publicly available "2022 - Allegheny County Parcels" polygon boundary shapefile data from the Pennsylvania Spatial Data Access (PASDA) Geospatial Data Clearinghouse. The Allegheny County parcel polygon GIS data was used to determine the approximate limits of the public right-of-way. A planning level assumption was made that any area not within a designated Allegheny County parcel boundary is to be within the public right-of-way. It is understood that the exact limits of the public right-of-way may extend onto some parcel boundaries, however the exact survey limits of the public right-of-way for the City of Pittsburgh were unavailable at the time of this study. For the purposes of this analysis, the parcel data provides the best available option for calculating an estimate of the amount of impervious area that can be managed solely within the public right-of-way. Figure 2 depicts the Allegheny County parcel data intersected with PWSA's impervious data layers from the previous image in Figure 1.

Figure 2. PWSA Transportation, Building, and Other Impervious Data Layers Intersected with Allegheny County Parcel Data to Estimate ROW Impervious

The impervious area layers were then intersected in GIS by the Allegheny County Parcel data to separate impervious area features by right-of-way and non-right-of-way impervious area to determine the amount of impervious area in the public realm.

In addition to the right-of-way impervious area analysis, the impervious area stats were summarized by the PWSA "Sewersheds" layer provided in the "StormwaterPlan.gdb" file. The impervious area values then summed across the entire city as well as for each of PWSA's 289 sewersheds to understand the distribution of impervious area types across the city as well as individual sewersheds.

Results:

City-Wide Impervious Results

The total impervious area in the City of Pittsburgh by impervious data type is shown in Table 1. Results are provided as total impervious area, total impervious in ROW, and total impervious in parcels (not in ROW). Total impervious area is the summation of the total impervious in ROW and total impervious in parcels.

Table 1. City-Wide Total Impervious Area by Impervious Area Type

Impervious Type	Total Impervious (sq mi)	Total Impervious in ROW (sq mi)	Total Impervious in Parcel (sq mi)
Transportation	14.72	7.45	7.28
Buildings	7.57	0.00	7.57
Other	1.32	0.01	1.31
Total Impervious	**23.61**	**7.45**	**16.15**

The total area results in Table 1 were then calculated as a percentage of the total city area (55.76 square miles) and total city impervious area (23.61 square miles) to determine the percentage contribution from each impervious area type. The percentage results are shown in Table 2.

Table 2. City-Wide Percentage of Impervious Area by Impervious Area Type

Impervious Type	Percent of Total City Area	Percent of City Total Impervious Area
Transportation (Total)	26.40%	62.36%
Transportation (ROW)	13.35%	31.54%
Transportation (Parcel)	13.05%	30.82%
Buildings (Total)	13.57%	32.06%
Buildings (ROW)	0.00%	0.00%
Buildings (Parcel)	13.57%	32.06%
Other (Total)	2.36%	5.58%
Other (ROW)	0.02%	0.04%
Other (Parcel)	2.35%	5.55%
Total Impervious	**42.34%**	**100.00%**
Total Impervious in ROW	**13.37%**	**31.58%**
Total Impervious in Parcels	**28.97%**	**68.42%**

As shown in Table 2, the city is roughly 42% impervious with approximately 13% of that located in the right-of-way. When looked at from the perspective of the percentage of the total impervious area, 62% of the impervious area is within the transportation layer which includes roads, parking lots, sidewalks, and driveways. 32% of the total impervious area is from building rooftops with the remaining 6% classified as "other". Assuming all "transportation" and "other" impervious areas are ground level impervious, roughly 68% of the impervious area in the city is located on the ground surface level, with the remaining 32% coming from building rooftops. Finally, 32% of the total impervious area in the city is estimated to be in the right-of-way with nearly all of this area classified as "transportation."

Individual Sewershed Impervious Results

The impervious area statistics were also calculated by sewershed boundary. There are 289 individual PWSA sewersheds in that file that intersect the City of Pittsburgh municipal boundary. Various statistical analyses on the sewersheds as well as choropleth heat maps were generated to understand the spatial distribution of impervious area for the sewersheds. These results are summarized below.

Sewershed Results By Total Impervious Area:

The distribution plot of the total impervious area in acres across all 289 sewersheds is shown in Figure 3. The mean and mean values of total impervious area are 49.5 acres and 15.0 acres, respectively.

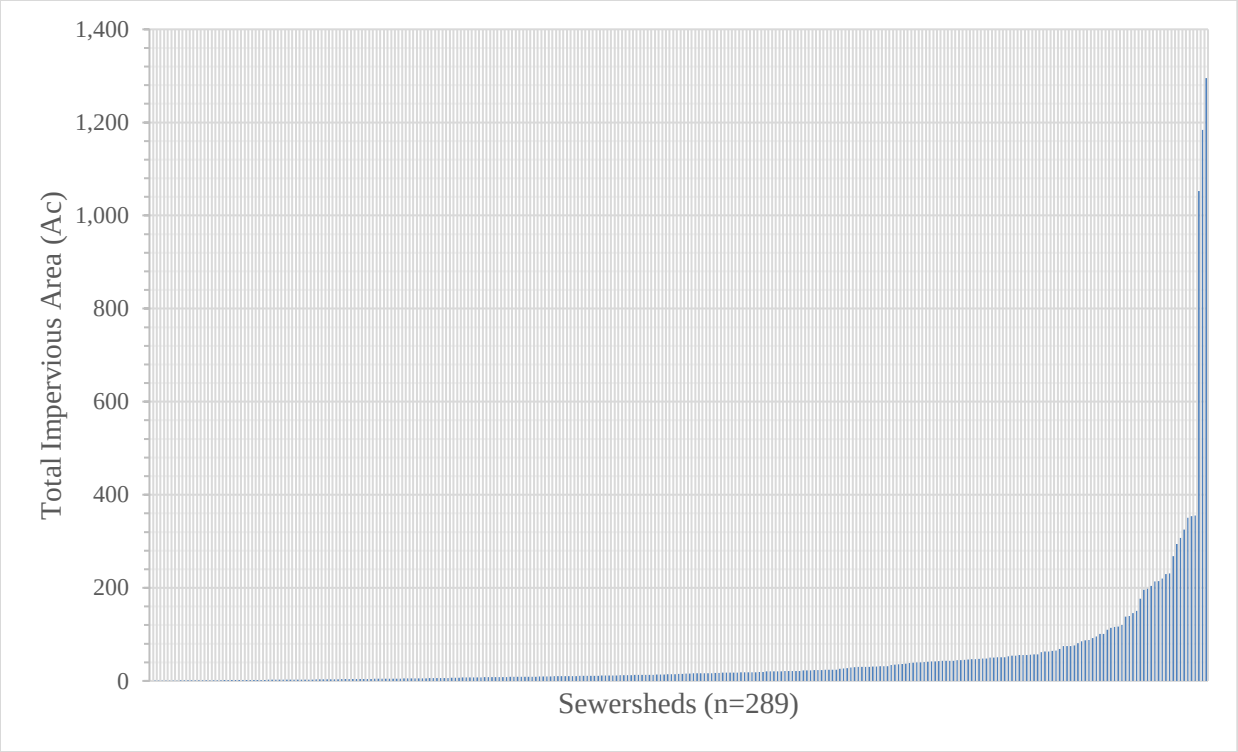


Figure 3. Total Impervious Distribution by Sewersheds

Another way to visualize total impervious area is by creating a scatter plot of cumulative fraction of impervious area on the y-axis and cumulative fraction of sewersheds on the x-axis. The purpose of this type of plot is to understand how the impervious area is concentrated spatially within the sewersheds. This plot is shown in Figure 4. Examples are drawn in blue and red on the plot for help in interpreting the results using either the x-axis or the y-axis. The blue arrow (using the x-axis) indicates that in 50% of the sewersheds, there is only approximately 16% of the total impervious area. Likewise, using the red arrow (y-axis) this indicates that 40% of the total impervious area is contained within 82% of the sewersheds; or inversely the red arrow example could be thought of as 60% of the total impervious area is within 18% of the sewersheds. This is not entirely surprising given that there are many large sewersheds with large quantities of impervious area. The top three sewersheds in terms of total impervious area are: A-42 (1295 Ac), M-29 (1183 Ac), and A-22 (1053 Ac). These large sewersheds contain the largest quantities of impervious area within the city. Choropleth sewershed maps depicting total impervious area results are provided in Appendix Map A-1.

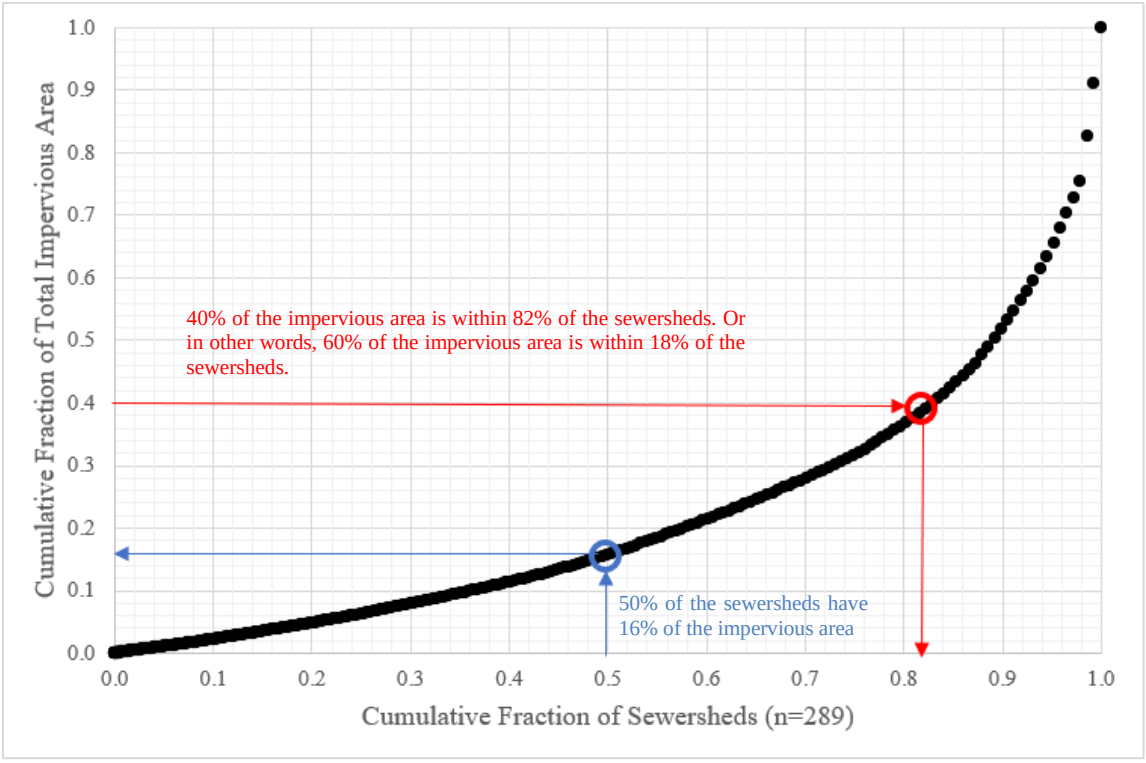


Figure 4. Total Impervious Area Cumulative Fraction Distribution

Sewershed Results by Impervious Area Type:

In addition to the total imperviousness of each sewershed, the impervious area type (Transportation, Building, Other, and Right-of-Way) were analyzed. For each sewershed the following was calculated for each impervious data type:

1. The percentage of each impervious type by total sewershed area, and
2. The percentage of each impervious type by total sewershed impervious area.

Box and whisker plots were generated for each impervious area type to observe the statistical variation of the results. The percent of total sewershed area by impervious area type box and whisker plots are shown in Figure 5. The percent of total sewershed impervious area by impervious area type box and whisker plots are shown in Figure 6. A box and whisker plot a simple way of visualizing probability density of a large dataset around a statistical value, in this case impervious area percentage. On the graph X represents the mean value, the middle line of the box is the median, the outer edges of the box represent the 25th and 75th percentiles, the whisker edges outside of the box represent the “maximum” and “minimum”, and values outside of the whiskers represent outliers in the dataset. It should be noted that a handful of sewersheds have small slivers that cross into the city and are the sources of many of the outlier data points. For example, there are sewersheds with ROW impervious area upwards of 100% of the total area and were confirmed to be small slivers of sewersheds that intersect the city boundary. Choropleth sewershed maps of the results shown in Figures 3 and 4 are provided in Appendix Maps A-2 through A-5.

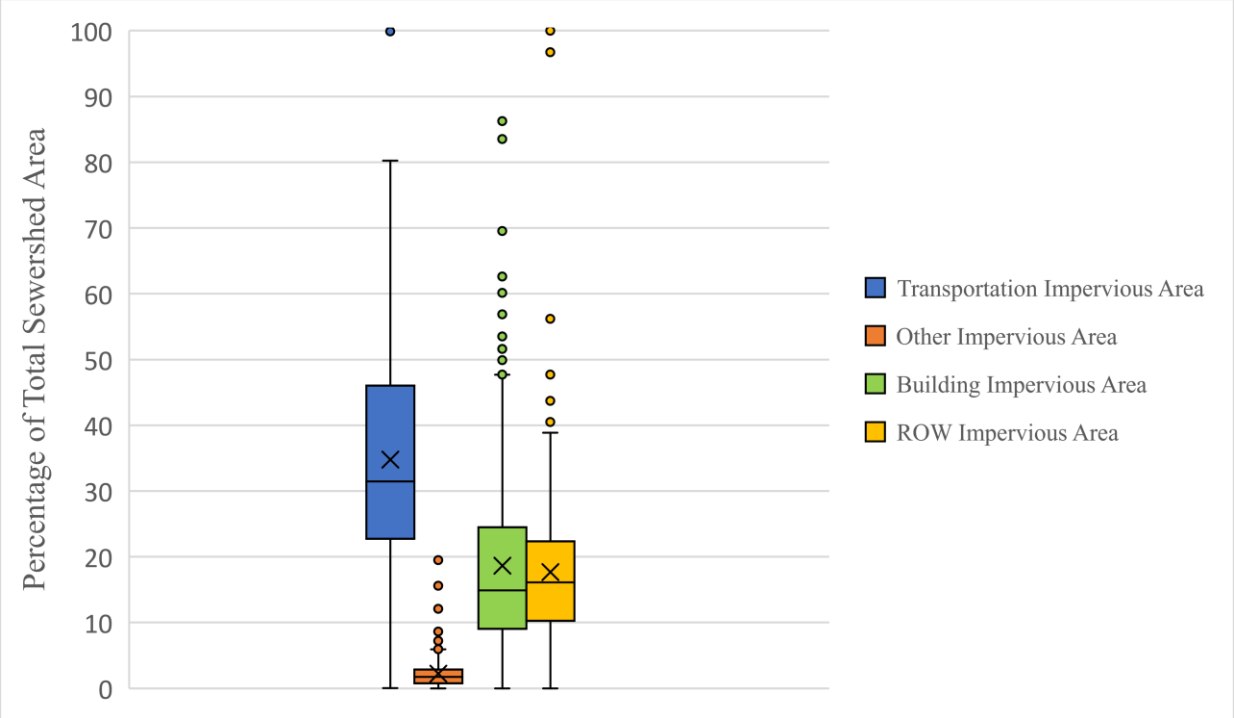


Figure 5. Percentage of Total Sewershed Area by Impervious Area Type for Sewersheds (n =289)

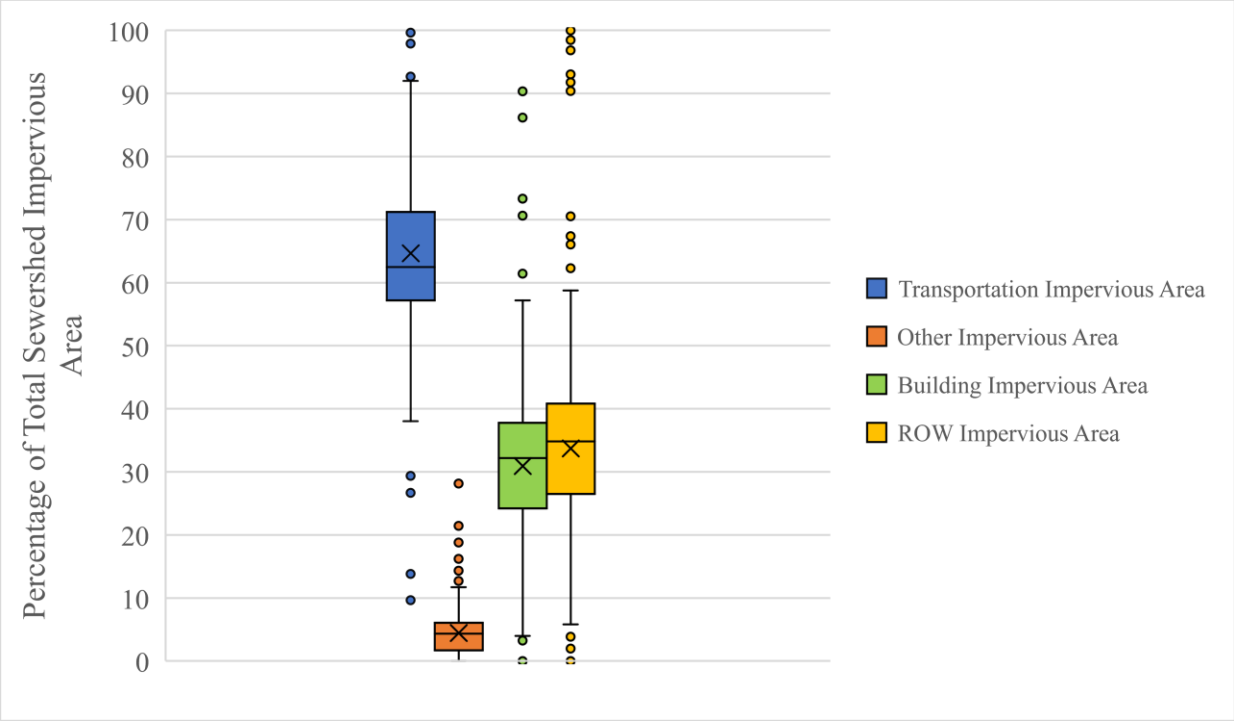


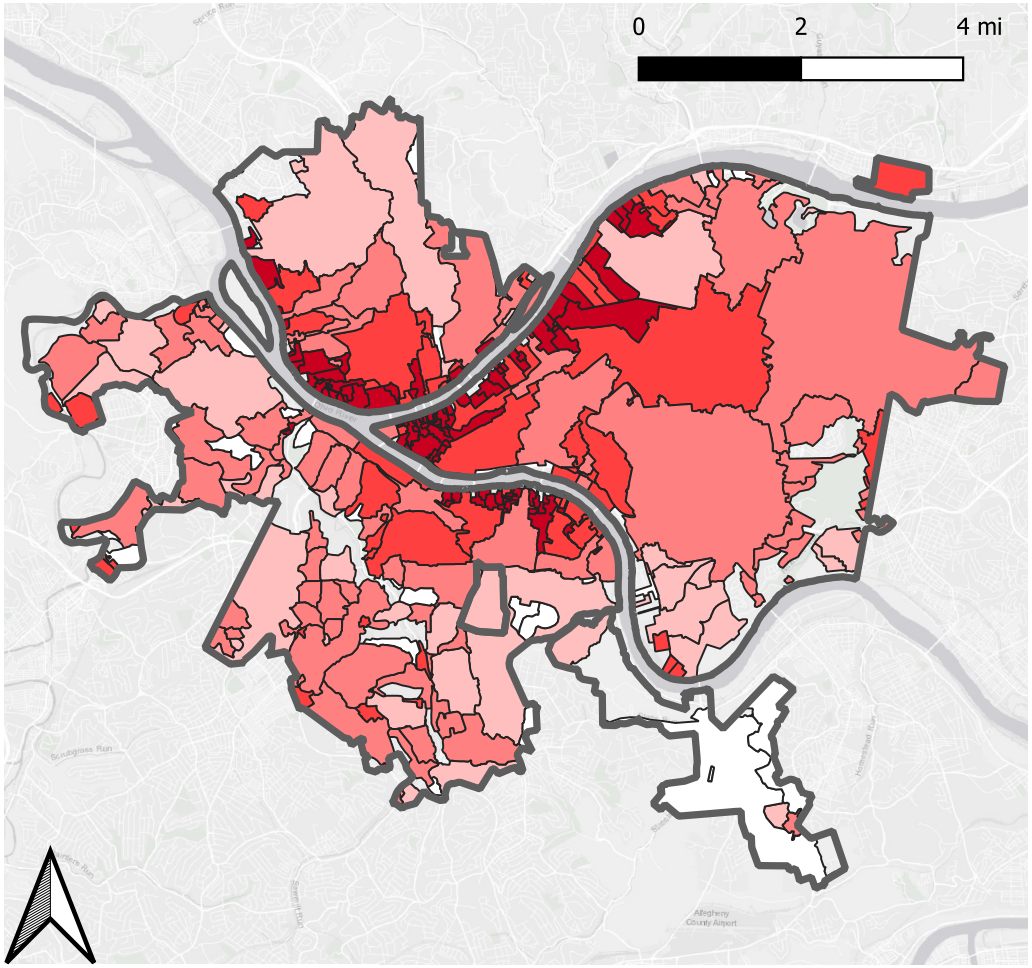
Figure 6. Percentage of Total Sewershed Impervious Area by Impervious Area Type for Sewersheds (n =289)

Conclusions and recommendations:

Based on the results of the impervious area analysis, the following are several key conclusions and recommendations for consideration as part of PWSA's Strategic Plan for Stormwater:

1. The city is approximately 42% impervious with the area distributed between transportation (26.4%), buildings (13.6%), and other impervious (2.0%).
2. Of the total impervious area in the city (23.61 acres), only 31.5% is located approximately in the right-of-way indicating that future stormwater mitigation will likely need to consider on-parcel sources of impervious stormwater generation in addition to right-of-way impervious. Private stormwater incentive programs should be explored along with leveraging the city's fee-in-lieu stormwater trust fund from private development stormwater permits.
3. The vast majority (+99%) of the right-of-way impervious is in the transportation impervious area layer. Stormwater mitigation efforts from right-of-way transportation impervious will need to consider coordination with the Department of Mobility and Infrastructure (DOMI). Stormwater agreements that establish stormwater "ground rules" between PWSA and DOMI should be explored and developed, including working towards a common understanding on stormwater design standards and cost sharing agreements.
4. 32% of the total impervious area are from building roofs. This indicates that private downspout disconnection strategies from buildings need further development and consideration. Strategies, incentives, and public education around private downspout disconnections and on-parcel stormwater management should be explored as part of PWSA planning projects where feasible.
5. Over 60% of the total impervious area is in 20% of highest ranking sewersheds in terms of total impervious area. These are concentrated in the large sewersheds primarily in the East End portion of the City (See Map A-1 right panel).
6. The highest concentrations of Transportation impervious are in Downtown, Northside, South Side, Uptown and Strip District areas (See Map A-2 right panel). However, many of these are small sewersheds and in dense neighborhoods where stormwater management may be difficult.
7. Percentages of other impervious areas are very small across most sewersheds (<10% of the total sewershed area). Just about all this area is located on parcels.
8. Buildings make up the highest percentages in downtown as well as East End sheds (A-22, M-29). Of the total impervious area, values are upwards of 40 to 50% in these sewersheds (See Map A-4 left panel).
9. Right-of-way impervious rarely exceeds 45% across all sewersheds. However, it is highest in A-41 and A-42 as well as in Saw Mill Run (roughly 40% of the total impervious area - See Map A-5 left panel). Strategies targeting right-of-way stormwater management should be explored in these areas and coordinated with future DOMI capital investments.

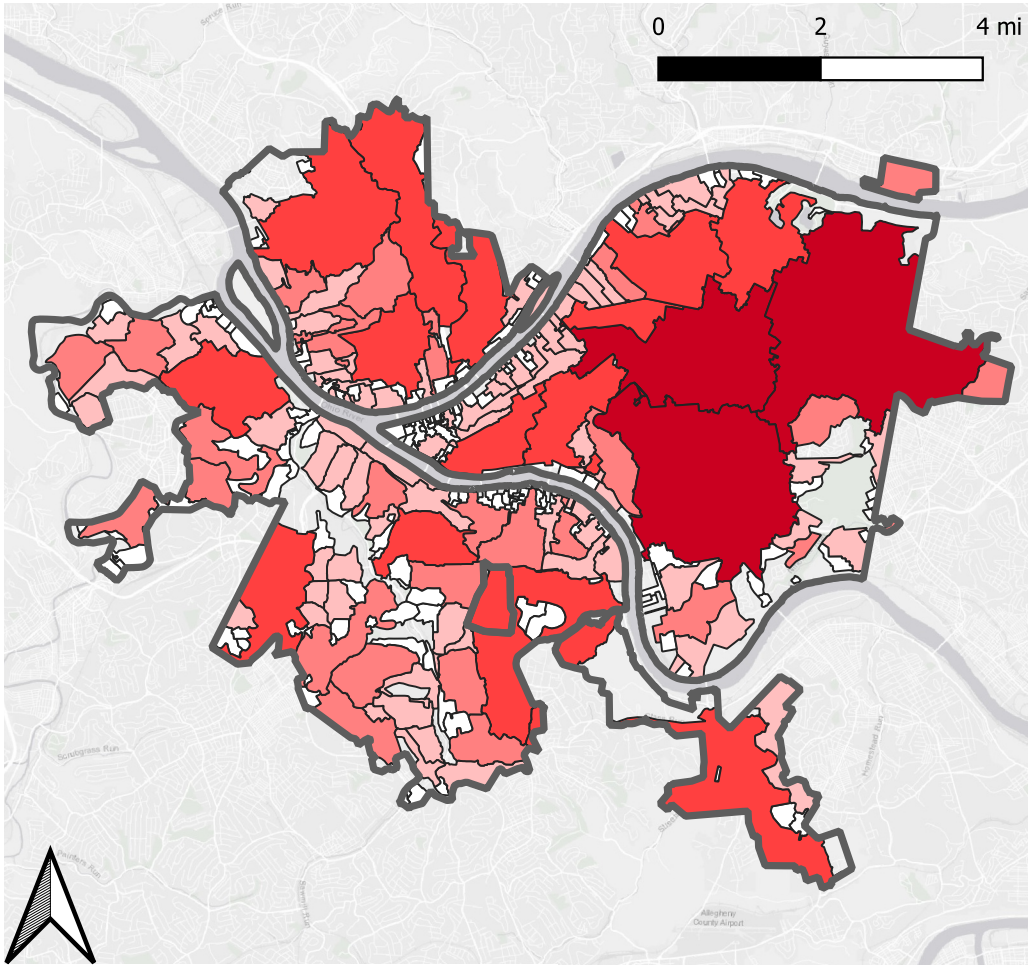
Percent Impervious Area In Sewershed



Percent Impervious Area

- 0 - 25
- 25 - 35
- 35 - 55
- 55 - 75
- 75 - 100

Total Cumulative Fraction of Total Impervious Area

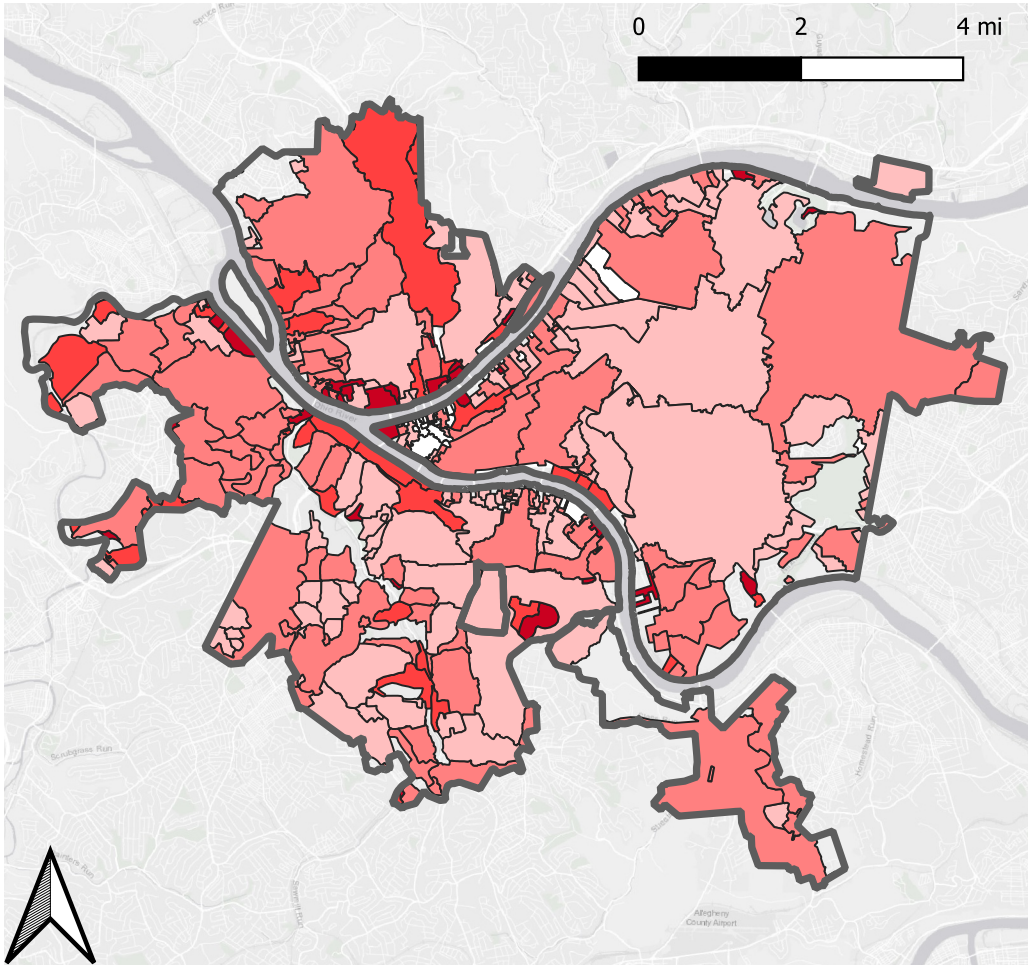


Total Impervious Cumulative Fraction

- 0 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1

Map A-1. Total Impervious Area

Percent of Transportation Impervious Area In Sewershed as Percentage of Impervious Area in Sewershed

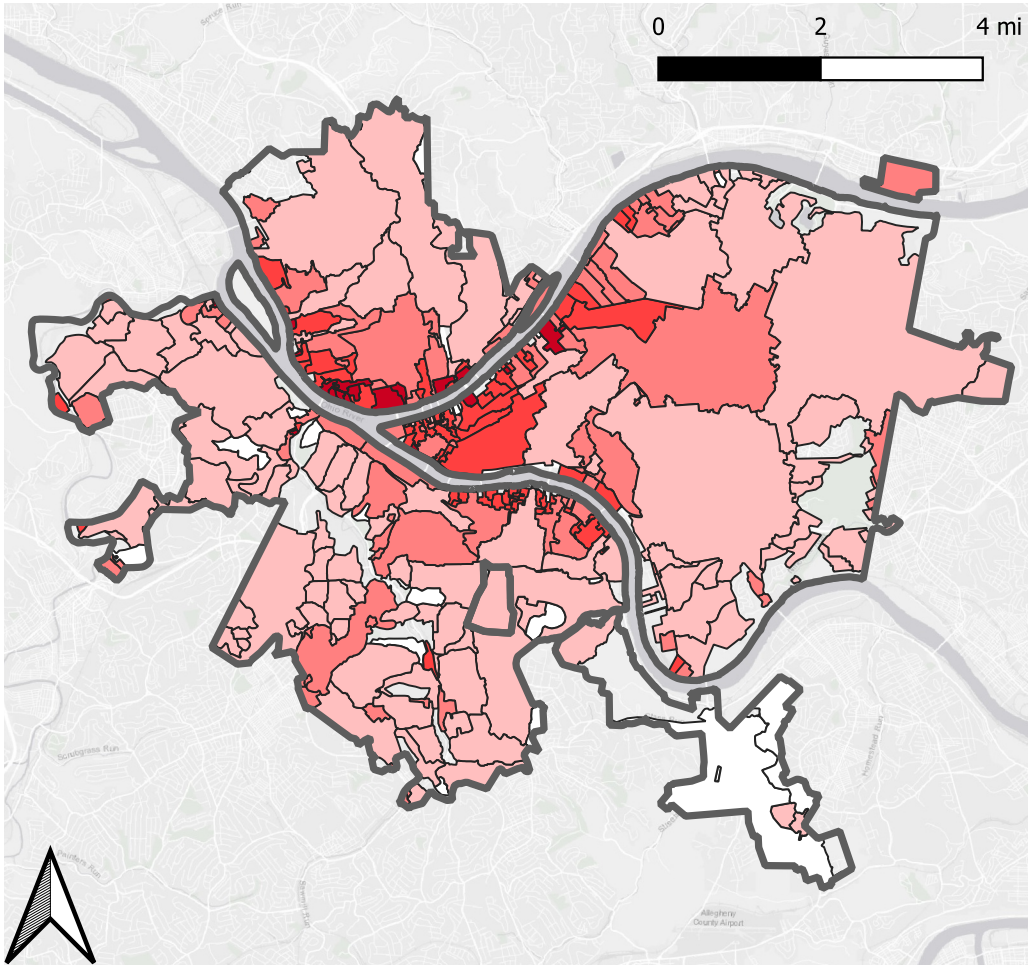


Percent of Total Impervious

Percent Transportation Impervious

- 9.6 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 100

Percent of Transportation Impervious Area In Sewershed as Percentage of Total Area of Sewershed



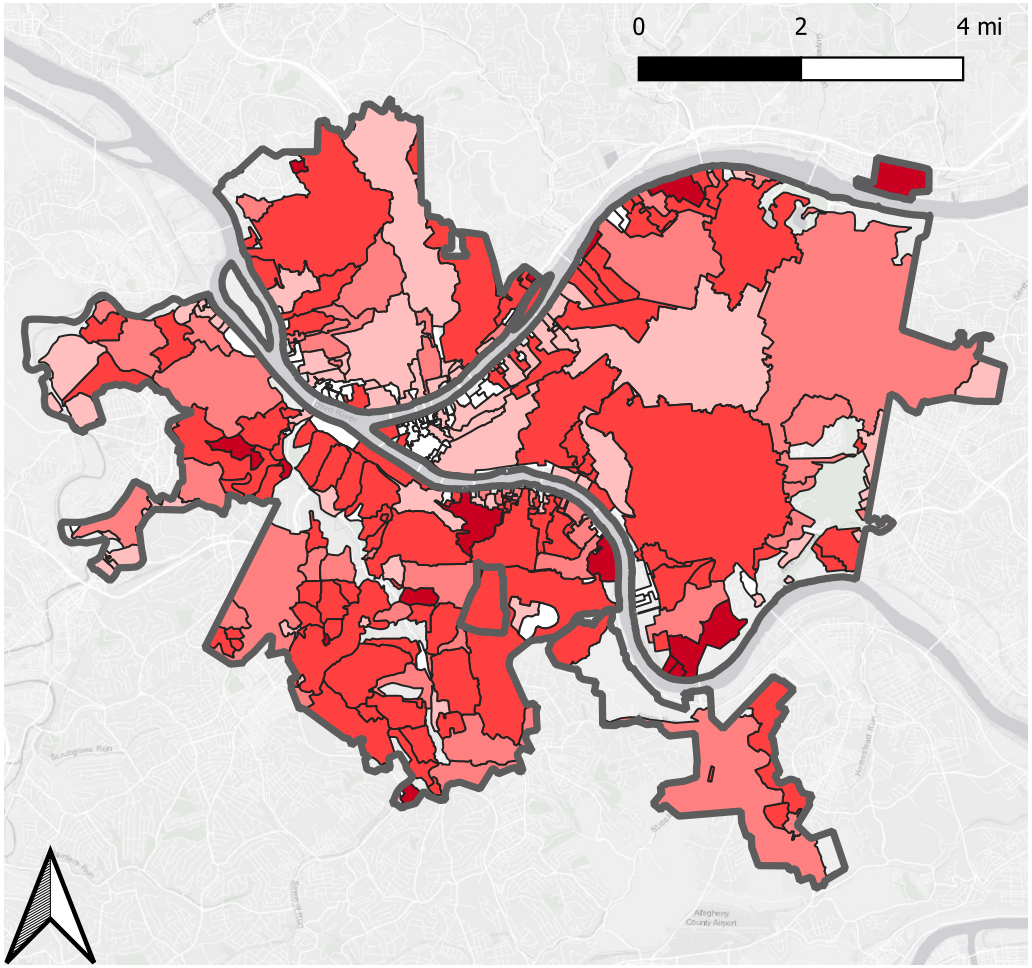
Percent of Total Area

Percent Transportation Impervious

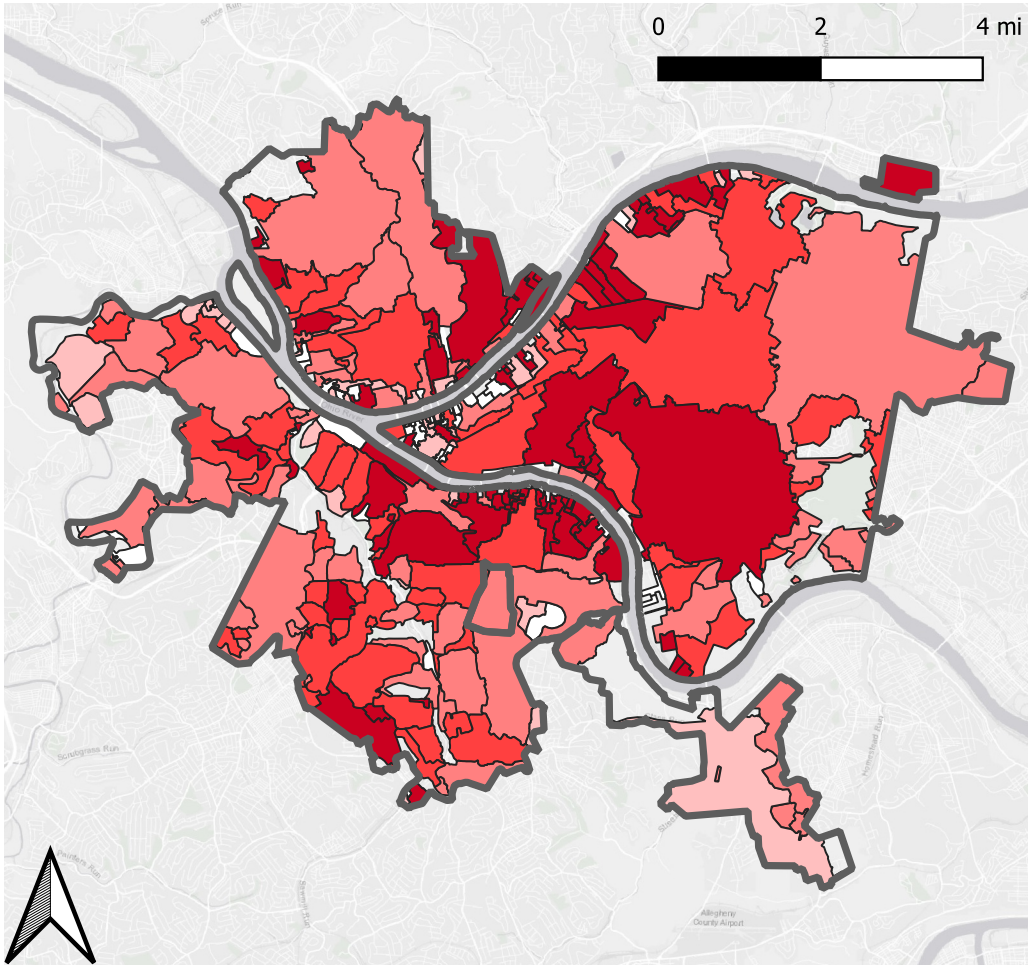
- 0 - 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 100

Map A-2. Transportation Impervious Area

Percent of Other Impervious Area In Sewershed as Percentage of Impervious Area in Sewershed



Percent of Other Impervious Area In Sewershed as Percentage of Total Area of Sewershed



Percent of Total Impervious

Percent Other Impervious

- 0 - 1
- 1 - 4
- 4 - 5
- 5 - 10
- 10 - 28.17

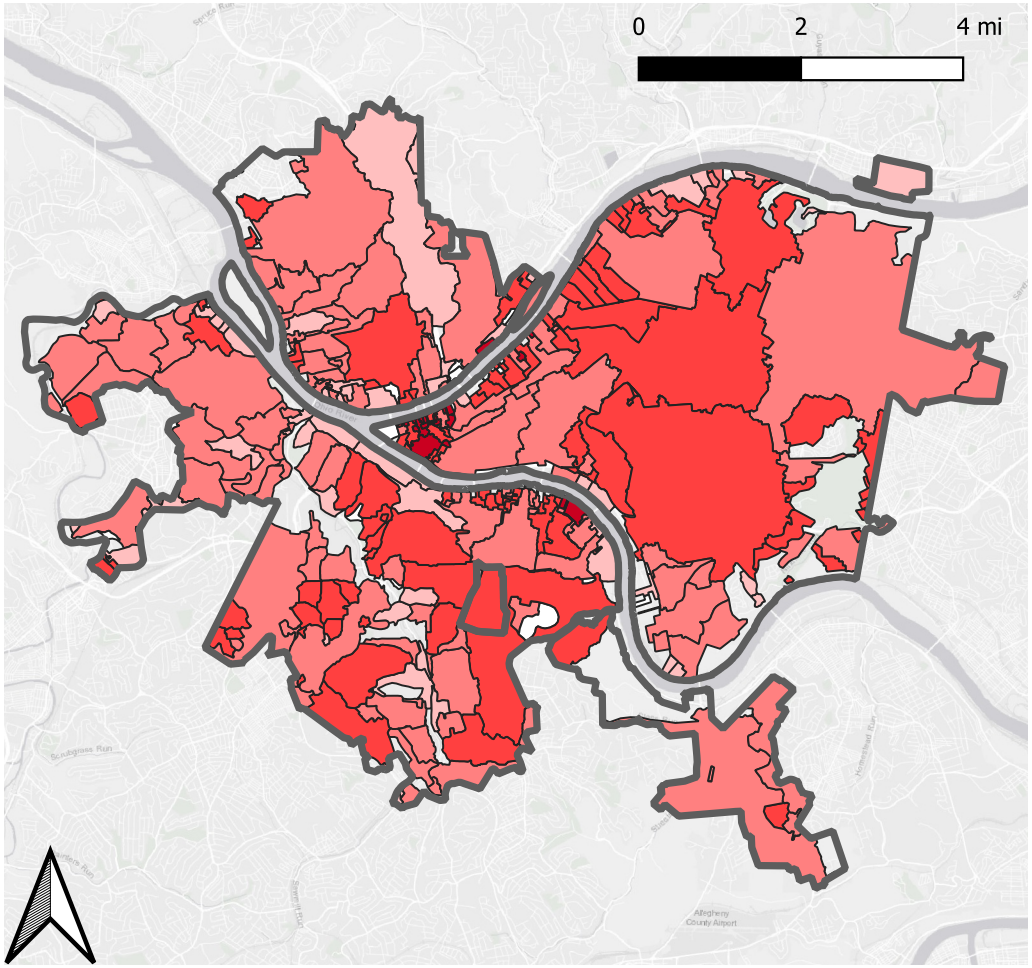
Percent of Total Area

Percent Other Impervious

- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 19.47

Map A-3. Other Impervious Area

Percent of Building Impervious Area In Sewershed as Percentage of Impervious Area in Sewershed

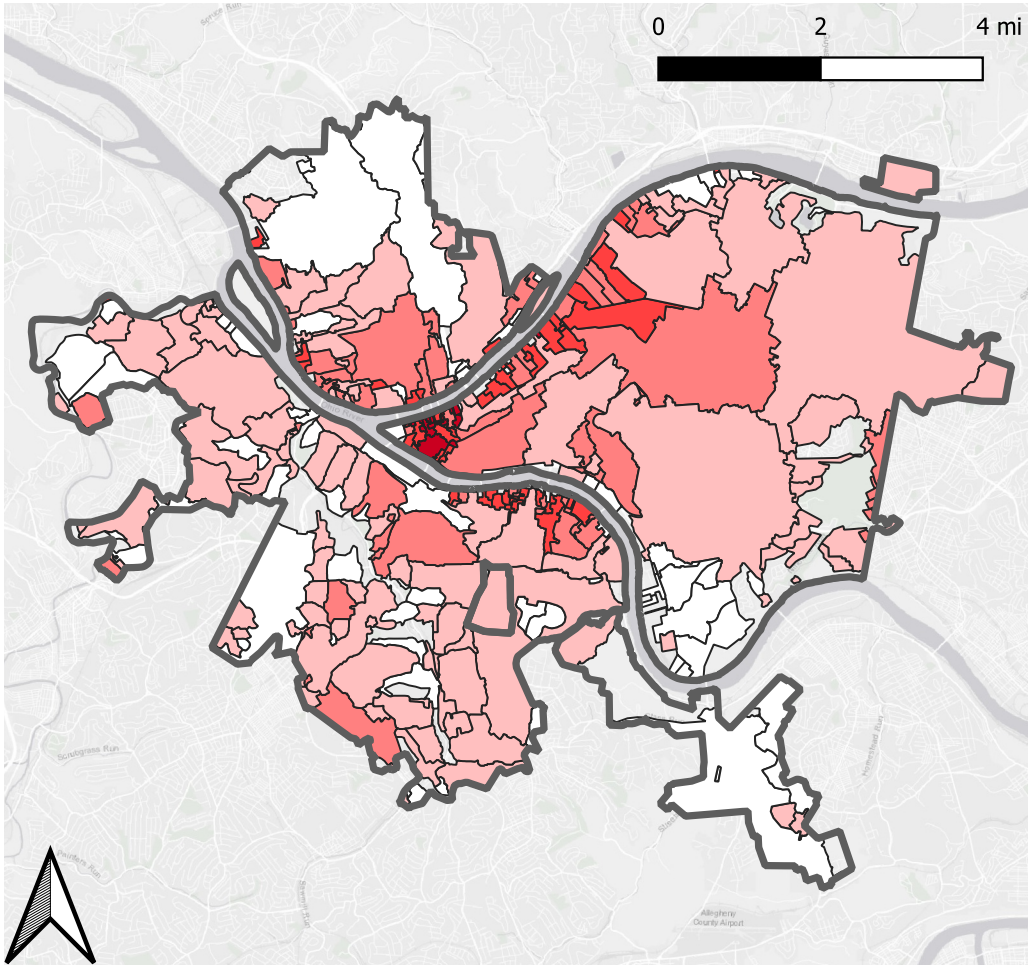


Percent of Total Impervious

Percent Building Impervious

- 0 - 10
- 10 - 25
- 25 - 35
- 35 - 50
- 50 - 90.4

Percent of Building Impervious Area In Sewershed as Percentage of Total Area of Sewershed



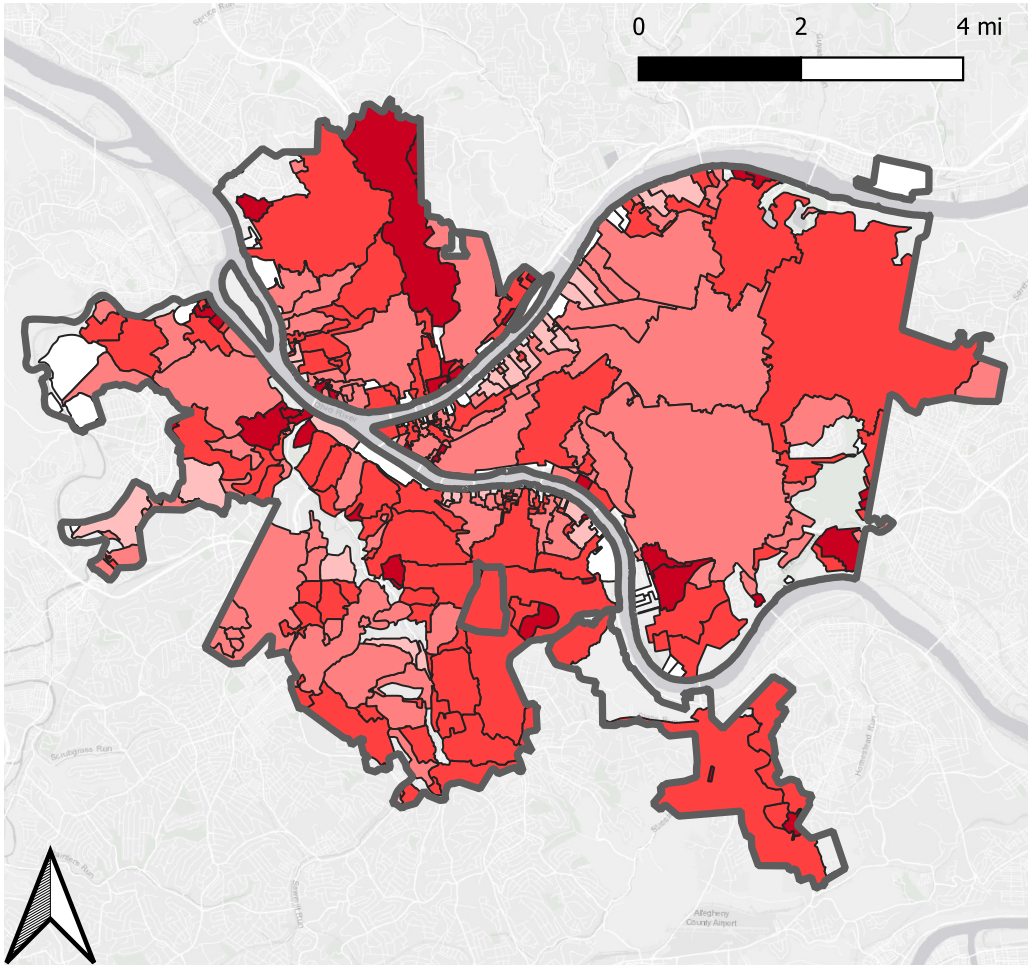
Percent of Total Area

Percent Building Impervious

- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- 50 - 86.3

Map A-4. Building Impervious Area

Percent of Right of Way Impervious Area In Sewershed as Percentage of Impervious Area in Sewershed

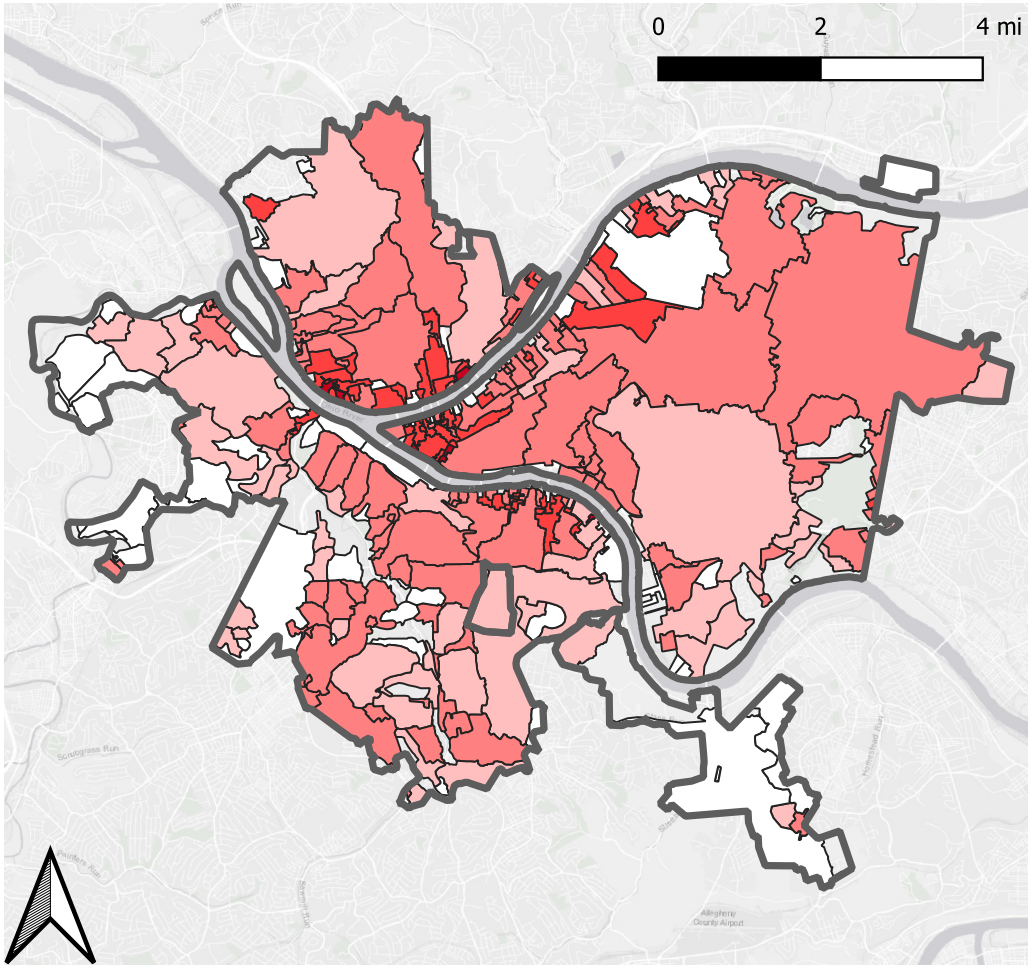


Percent of Total Impervious

Percent ROW Impervious

- 0 - 15
- 15 - 25
- 25 - 35
- 35 - 45
- 45 - 100

Percent of Right of Way Impervious Area In Sewershed as Percentage of Total Area of Sewershed



Percent of Total Area

Percent ROW Impervious

- 0 - 10
- 10 - 15
- 15 - 25
- 25 - 40
- 40 - 100

Map A-5. Right of Way Impervious Area