Residential Sewage Backups in Baltimore City

Faith C. Ezell

Master of Health Science Candidate

Johns Hopkins Bloomberg School of Public Health

Department of Environmental Health and Engineering

Adviser: Dr. Christopher D. Heaney

April 26, 2019

Table of Contents

Executive Summary

The purpose of this essay is to shed light on the issue of basement backups of raw sewage in the homes of Baltimore City residents. There are many different aspects of this issue that will be addressed including health impacts, climate change, and reimbursement for households. One of the essential parts of addressing this issue starts with identifying areas that are most impacted. This essay features the first known collective maps of residential raw sewage basement backups that occurred in quarters one through four of the fiscal year 2018. This essay also offers insight as to what future projects and actions can be taken to address the needs of the city better.

Introduction & History

The sewer system in Baltimore Maryland was constructed over a century ago. Baltimore City was like many American cities in the 19th century; it was growing rapidly. In 1814, it was the third largest city in America. The rapid growth may have been good for Baltimore's economy, but the amount of sewage people and livestock produced was also growing. If an individual wanted to get rid of waste, it was up to them to dump the waste in nearby streams or rivers. In the early 20th century when most cities had implemented a sewer system Baltimore still did not have a system. In 1905, the city voted to have a sewer system and a treatment plant located near Back River in Baltimore County. Even though Baltimore was initially behind in creating a sewer system they were able to study the plans of other preexisting systems to figure out what best suited the city. In 1911, the creation of the sanitary sewer system, where wastewater and storm water are transported separately, was completed. Much of the structure still exists today. Within the system, the city built structures that allowed for excess sewage to enter the harbor, streams, and rivers. (Baltimore City Department of Public Works, 2015).

These overflows send untreated sewage into waterways which not only pollutes the environment but is a disease threat for any human that comes into contact with the water.

Outflows also produce an odor that is a nuisance and problematic for nearby residents. There are many reasons that these overflows exist, the main contributor being the capacity of the pipes. Sewer pipes are designed based on population size and for storms of a certain magnitude. If the pipes are not the appropriate size, it causes pressure within the system which can cause breaks in the pipes, therefore creating a structure that could relieve that pressure was created.

In 1972, the Clean Water Act made sanitary sewer overflows illegal; this created an issue for many aging cities, such as Baltimore that had many overflow structures (BCDPW, 2018). The city was taken to court for violating the Clean Water Act by the Environmental Protection Agency (EPA). In 2002, a consent decree, which is a legal document that details the agreement that is made between all parties, was created. The Baltimore City Department of Public Works was responsible for identifying and studying the overflows throughout the city. They also completed projects related to the overflows and deactivated 60 of 62 structural overflow points (BCDPW, 2018).

After the signing of the consent decree, the Department of Public Works investigated processes to eliminate these sanitary sewer overflows (SSO). It was discovered that there was a significant hydraulics problem that created a sewage backup in the pipe leading to the Back-River treatment plant. To adequately remedy this collection problem the city plans to install four 1,000 horsepower pumps to replace the hydraulic system and four 1,500 horsepower pumps that will be utilized when there is excess water in the system due to large storms. When massive storms do occur, the excess water can be contained within two storage tanks that can hold up to 36 million gallons (BCDPW, 2017). When there is less water in the system the stored water will be put back into the system. These upgrades are known as the Headworks Project. Once the upgrades and repairs have been made, the city expects that 80% of the present sewage overflow

volumes will be eradicated (BCDPW, 2017). Since the project is a large undertaking compared to what was thought in the consent decree, there was a modified consent decree constructed to accommodate the amount of work that needs to be completed. The original consent decree had a deadline of January 1, 2016 but after review from the U.S. District Court all projects are to be completed by December 31, 2030. The city released a timeline for the actions that are detailed in the modified consent decree. As seen in figure 1, the city has ongoing plans such as educating residents and clearing debris as well as activities that have specific start and end dates like the Headworks project (BCDPW, 2017).

One of the most concerning aspects of the sanitary sewer overflows is the building backups that can occur because of them. Before, when there was too much sewage within the system, it could be released from the structural outflows. Now, with the elimination of such structures that sewage has nowhere to go. These building backups cause raw sewage to overflow into the homes of residents, potentially exposing them to pathogens and property damage. Residents can file for reimbursement for cleaning and disinfection costs through the city's expedited program, but the cleanup is the responsibility of the homeowners (BCDPW, 2017). The city does not provide cleanup personnel nor a list of city certified cleaning agencies. Depending on the amount of sewage that enters the premises the cost of cleanup may be too high for individuals to pay for the cleanup. Therefore, homeowners may decide to take the task of cleaning into their own hands, exposing them and others in the home to hazardous waste.

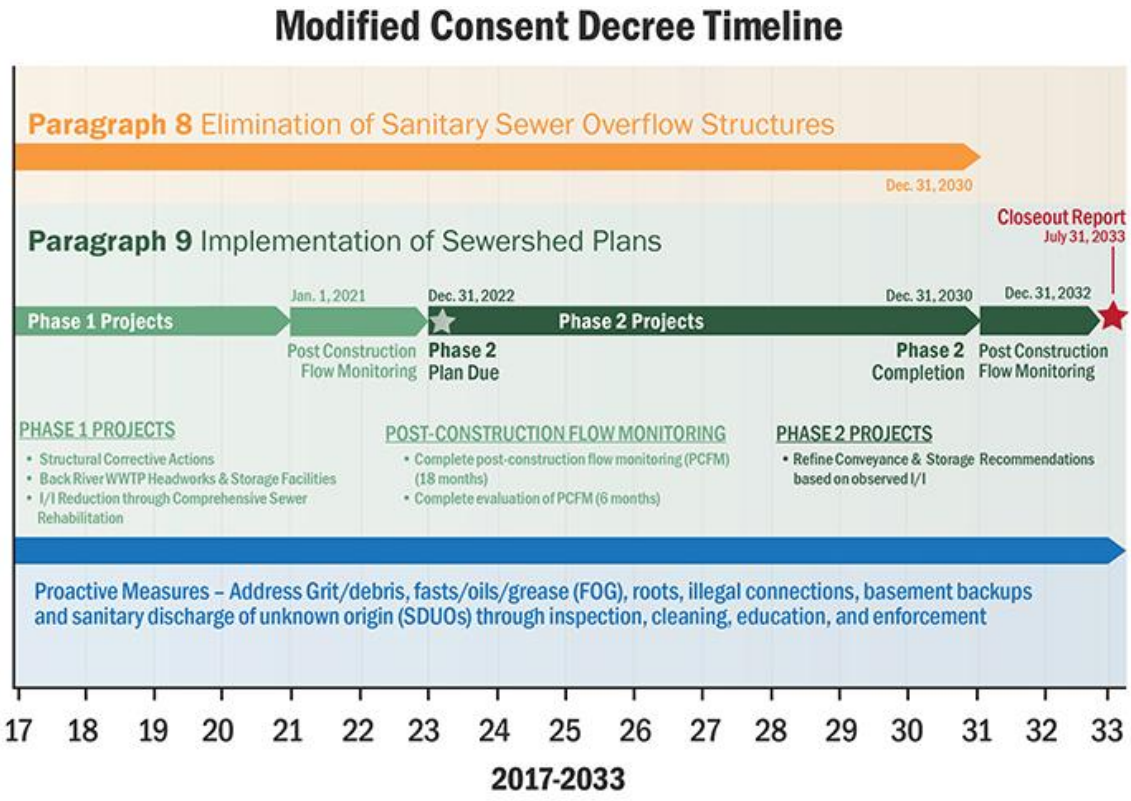


Figure 1. (BCDPW, 2017)

Health Effects

There are many diseases associated with wastewater, specifically those associated with fecal matter. When residents are faced with a building backup, they may not have the funds at the time to seek outside help. Though the city has a reimbursement program, it could be more than sixty days to receive payment after all the appropriate paperwork is filed (BCDPW, 2017).

Due to personal time and money limitations, homeowners may decide to complete the cleanup themselves. Raw sewage contains many pathogens including bacteria, viruses, and parasites (National Academy of Sciences, 1993). Since these pathogens are in the homes of residents, there are many ways that people can be exposed. If residents are not careful, sewage can be transferred from the bottom of shoes to other surfaces on the property. The transfer of sewage can promote different transmission. In addition, if someone is cleaning and does not

sanitize and disinfect the areas impacted by the overflow, they may have sewage on their hands. This could lead to the transmission of a pathogen through touching food prep areas or through touching their face which could result in infection.

Bacteria can be detected in wastewater through the presence of bacteria that is native to the gastrointestinal tract of humans (National Academy of Sciences, 1993). Though these bacteria are generally not harmful to humans, they are used to estimate the amount of disease-causing bacteria that are in the water. The number of *Escherichia coli* is often used as an estimate of the fecal coliform counts which is used as an indicator of fecal contamination in a water supply (National Academy of Sciences, 1993). There are many types of pathogenic bacteria present in human waste; many of them create gastrointestinal illnesses. Cholera and gastroenteritis are two examples that can produce symptoms including: vomiting, diarrhea, abdominal pain, and fever (Environmental Protection Agency, 2004).

Viruses are another class of pathogens that are present in raw sewage and can infect humans. There are over 120 viruses that can be detected in wastewater. Norovirus is a virus that is transmitted through the fecal-oral route and is found in raw sewage. It is responsible for most viral gastrointestinal illnesses in the United States. Someone who comes in contact with raw sewage may ingest some which could result in illness. Hepatitis A is another virus that can be found in raw sewage and has been responsible for outbreaks in contaminated recreational waters (EPA, 2004).

Parasites, like the protozoa Giardia lamblia, are also found in raw sewage and can cause severe diarrhea. The cysts are what infects humans and once ingested, multiply within the host. In the cyst form, they are 10 to 1,000 times more difficult to eliminate through disinfection in comparison to bacteria (Jarroll, 1988).

Several groups may be more susceptible to these illnesses. The first being pregnant women, during pregnancy women have a decreased immune system which could make infections from pathogens like viruses more likely. In addition, it has been found that viral infections could impact the fetus and could be detrimental (Reynolds, 2000). Children may also be more susceptible to diseases found in wastewater because of their underdeveloped immune system (Nwachuku & Gerba, 2004). Infants and children also may be more susceptible because they are more likely to be crawling around the residence and have more hand to mouth contact than adults. Those who are immunocompromised are also more at risk than the average adult. Due to the suppression of their immune system, they may not have the ability to fight infection (Gerba, Rose, & Haas, 1996). Adults with AIDS are especially at risk, and it is estimated that 50 to 90 percent of those with the disease often have diarrheal diseases (Reynolds, 2000). Elderly residents are also more at risk because of the natural decline of their immune system, therefore making them more susceptible (Nwachuku & Gerba, 2004).

Illnesses can also cause a financial burden if individuals have to seek medical care or if residents have to miss days of work. In some cases, individuals could even risk losing their job if they miss too many days of work. The city's expedited reimbursement program does not cover any medical expenses (BCDPW, 2017). Residents could still apply to the general claims program for medical expenses, but it could take months to receive a decision.

An area that has not been well studied is the mental health effects these backups have on residents, especially those who have experienced multiple building backups. The mental stamina needed for dealing with damaged property, potential illnesses, and the smell all are potential stressors. This could be an area for more research in how to best help those in this situation.

Currently, there is no publicly available resource that lists illnesses that may have been caused by building backups in Baltimore City. The incubation period for some illnesses may be long, therefore the collection of this information could be difficult to obtain but could be very useful. If the city added illness information to the expedited reimbursement paperwork that residents fill out, it would help the city understand the magnitude of the burden that is experienced by the public.

A study was conducted in Massachusetts to examine the possible relationship between sanitary sewer overflows and visits to the emergency department for gastrointestinal illnesses. They collected county data and looked at the following time periods: 0-4 days, 5-9 days, ad 10-14 days after county reports of SSO. They used these time ranges because 0-14 days is the normal range for symptoms from gastrointestinal illnesses to occur. Researchers were able to obtain diagnostic information from the Massachusetts ER database. The SSO information was obtained from the Massachusetts Department of Environmental Protection; and there was only information available from four counties in the Northeast section of the state. The study was designed using a case-crossover method. This means that the same case was compared to themselves at a different point in time, either before or after their illness.

Researchers hypothesized that heavy rain events would increase the likelihood of an SSO; they took this into account when looking for possible trends in the analysis. After initial analysis, the odds ratio for the 10-14 day period was most significant. In an analysis that examined heavy rain events, they found the same time period was significant. Though the odds ratio for the 10-14 day window was significant, the degree of significance was not large. The authors state that though the magnitude is not large when looking at the county level it could represent a large number of preventable illness if SSO were reduced or eliminated on a national

scale. In addition, the study assumes that individuals will seek emergency care when infected with gastrointestinal illnesses. The pathogens that infected individuals could have been those with longer incubation periods, therefore making symptoms occur later on. The longer incubation could be due to the route of transmission, whether it was direct contact or from contaminated drinking water or recreational activities (Jagai, DeFlorio-Barker, Lin, Hilborn, & Wade, 2017).

Sewer Infrastructure

Sewers were created to dispose of wastewater and stormwater. When underground sewers were utilized, they reduced waterborne illnesses such as cholera. These sewers purposely fed into streams and rivers, polluting the surrounding water. After World War II, treatment plants became common in many countries, including the United States (BCDPW, 2015).

The performance of sewer systems is crucial and depends on different features of the system such as: type of sewage collected, how sewage is transported, and the size of the system. Sewers can either be combined systems, allowing for wastewater and stormwater to inhabit the same pipes or sanitary sewers. Sanitary sewers use separate pipes for stormwater and wastewater. The transportation of sewage is also an essential feature of sewers and can play a role in blockages if the transportation method is not appropriate. In general, there are two types of transportation methods, gravity sewers and pressure sewers. Gravity sewers use slopes to create flow within the system. In a pressure system, there are pumping stations that contain motor-driven pumps to transport sewage to the wastewater treatment facility. Baltimore's current system is mostly gravity driven; the plans to redesign the sewage collection system for the Back-River treatment plant include pumping stations to relieve a blockage in a pipe leading to the plant (Hvitved-Jacobsen, Vollertsen, & Nielsen, 2013).

The size of a sewer system determines the amount of wastewater and the magnitude of storms the system can handle. Sewer systems work by having smaller pipes feed into larger ones that eventually flow to the wastewater treatment plant. Lateral pipes are often small pipes that lead to residential homes and businesses; they are often connected to larger pipes called main pipes. Cities are divided into sewershed, much like watersheds, where all the pipes within the sewershed lead to a larger pipe or collection of pipes that go to the plant (Hvitved-Jacobsen, Vollertsen, & Nielsen, 2013).

Sewer systems serve thousands of residents and if not used properly, can be the cause for major repairs of the system. Residents and food establishments who pour fats, oil, or grease (FOG) down the drain can contribute to blockages. In 2004, the Environmental Protection Agency reported to congress that FOG in sewer pipes is the number one reason for blockages (EPA, 2004). FOG are known to adhere to the surface of pipes and when enough is present can cause partial or full blockage of pipes. Lateral pipes are more susceptible to these kinds of blockages because residents are dumping them into sinks and toilets which puts them in direct contact with these pipes. Even if FOG is rinsed down the drain with hot water or soap, it can eventually get stuck further down in the system. To clear pipes from FOG high powered water hoses have to be used. Depending on the size of the blockage, it can take hours or days to completely break down the blockage (Nieuwenhuis, Langeveld, & Clemens, 2018).

Similarly, flushing rags, clothing or other debris can get stuck in sewer pipes causing blockages. Even products that claim to break down such as baby wipes can cause problems in the system. Many of those products do not break down immediately and risk getting caught among other debris in the system (Atkinson, 2014). Another major issue for sewer systems is the penetration of tree roots. Pipes that have cracks or small openings large enough for roots to get

inside can obstruct flowing sewage and cause blockages. In the past, roots had to be removed mechanically, and it was challenging to remove roots that were already present in the pipe. Today, chemicals are applied inside the pipe to kill roots growing inside, mechanical clearing of roots near the sewer may still need to be performed (Griffin, 2003).

To keep a sewer system working properly, regular maintenance needs to be performed, especially in urban areas where many people live. By doing routine cleaning of main pipes and treating pipes that could potentially be impacted by nearby tree roots, it helps the city to mitigate adverse impacts that blockages and other sewer damage can have on the community.

The age of Baltimore's sewer system causes a problem because cracks and other damage could have occurred throughout the years. The city is currently working on repairing aging pipes. There are a few methods that the city is using to make these repairs. The first method is called, Cured-In-Place Pipe (CIPP). This method allows for pipes to be repaired without taking them out of the ground. During the process, a treated felt lining is fed through the pipe where it later hardens in place. This creates an inside layer that prevents water and debris from penetrating the pipe (National Environmental Health Association, 2019).

The second method used for lateral pipes is open cut point repair or replacement. This method involves removing the old pipe and either repairing the damage or replacing the pipe altogether. This process is not preferred because it requires streets or sidewalks to be impaired, possibly causing traffic disruptions. In addition, residents would not be able to perform activities in their homes that would typically use the lateral pipe, such as using the toilet or sink (The City of Portland, Oregon, 2019).

Climate Change

Sewer systems are designed to handle sewer flows and storms of a certain magnitude. The Department of Public Works is responsible for monitoring rainfall and putting together a

plan detailing what pipes need to be replaced and how the system can be modified to work during storms. Climate change is a factor that city officials now have to take into account when thinking about future the performance of the sewer system. States such as Maryland are expected to have more rainfall and expect that rainfall to be more intense than rainfall at this present time. In addition, hurricanes are expected to occur more frequently due to warming oceans (EPA, 2017).

The increase and variability in rainfall make it challenging to determine if the sewer upgrades that are being made in Baltimore City are sufficient for centuries to come. One of the city's plans is to create storage tanks for excess storm water that would be reintroduced into the system after the storm has passed. It is difficult to speculate if the water tanks will have sufficient capacity without seeing what models the city is using. If the city is not accounting for these future changes, overflows and breaks in pipes due to pressure in the system may be an upcoming reality. Currently, some pipes are designed to handle two-year storms, which means a rainstorm of that magnitude is expected to occur every two years. The city says that most storms fall into this category, but with climate change, even ten-year storms will become more common (BCDPW, 2018).

Reimbursement Process

The modified consent decree required the city to put a temporary expedited reimbursement program in place. The city must replace it with a permanent program that takes the analysis of the temporary program into consideration. The program does not include commercial properties. The city must have at least two million dollars allocated to the program annually. The program is only designed for building backups that are the result of insufficient sewer capacity during wet weather. Under the program, homeowners can be reimbursed for cleaning cost only and not for the cost of any damages. The maximum a homeowner can receive

for a backup event is $2,500 (United States of America v. Mayor & City Council of Baltimore, Maryland, 2017).

Under the current program residents experiencing a building backup must report it within 24 hours of discovery of the backup to the city's 311 phone or online system. The resident then has 90 days to file a request for reimbursement to the Department of Public Works. They must have clear documentation of cleanup to be considered for reimbursement. The city has 60 days to make a decision. If the resident has homeowner's insurance that covers building backups the city requires the insurance company to be used before any payment from the city can be claimed (U.S.A. v. Mayor & City Council of Baltimore, Maryland, 2017).

It is the responsibility of the city to keep all requests for reimbursements, date of building backups, amount requested, city's determination, date of determination, and explanation of decision. The data must then be reported to the EPA and the Maryland Department of the Environment (MDE) in quarterly reports each year after one year of the program's implementation. After eighteen months the program will be reviewed for effectiveness by the City, EPA, the MDE (U.S.A v. Mayor & City Council of Baltimore, Maryland, 2017).

The expedited reimbursement program was only created for those experiencing building backups due to insufficient sewer capacity in the system because of wet weather. Therefore, any reimbursement request where the backup is attributed to other causes, such as debris blockage, is not covered under this program and the request will be denied. Residents are able to seek reimbursement through Baltimore's General Liability Claims Process and have up to six months after denial to start the process. In addition, the program does not provide reimbursement for property damage, but residents can file a claim with the General Claims process (U.S.A. v. Mayor & City Council of Baltimore, Maryland, 2017).

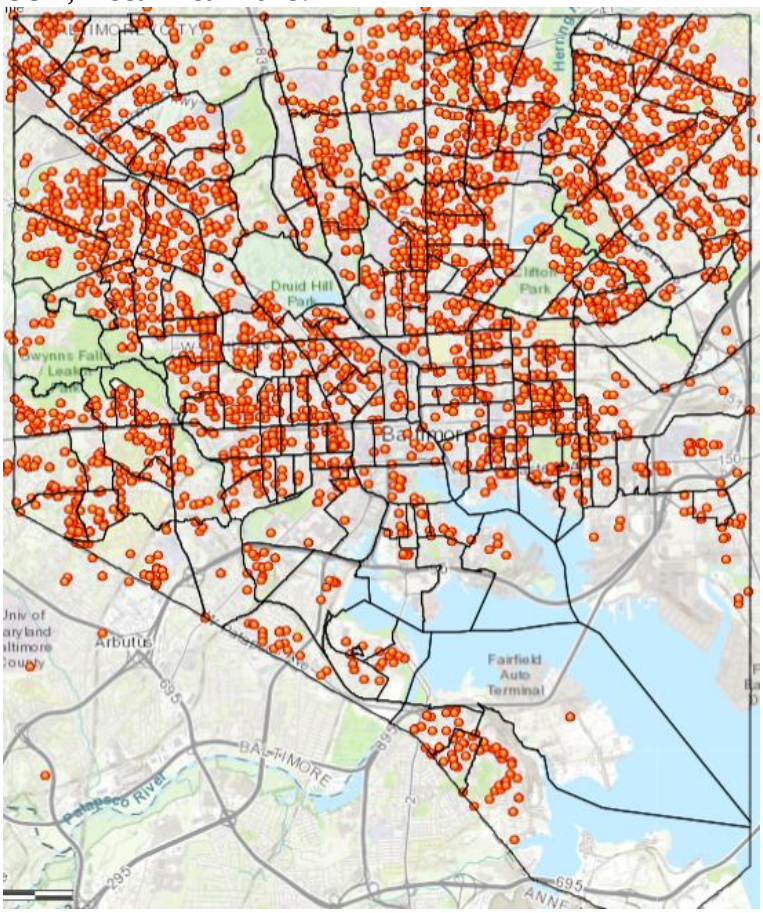
This expedited program was designed to be a temporary program. After three years of the program existences, it will be evaluated so that the long-term program can be as effective as possible. The permanent program will have the same minimum budget requirement as the temporary program and will be in place until the termination of the modified consent decree. The feedback from the temporary program will help determine the strengths and weaknesses through a rigorous review of costs, location of backups, cause of backups, and trends from the program. Once the long term expedited program is approved the city has six months to activate the program (U.S.A. v. Mayor & City Council of Baltimore, Maryland, 2017).

Data and Discussion

The information for locations from quarterly reports are solely from 311 reports made by residents. The Department of Public Works has stated in an August 2017 press release that they would be advertising the expedited reimbursement program, which would include making residents aware that they have to call 311 within 24 hours of discovering the backup (BCDPW, 2017). As can be seen in figure 2 there are census tracts that have more locations than others. This map likely underestimates the true number of basement backups within Baltimore City because it requires residents to call 311 to report the backup. The advertising that is being done by the city may not be enough for all populations. One issue may be those who rent properties and do not receive their water bills directly. If the landlord receives the bill, they would receive the advertising and may not make tenants aware of the program. A future project could include going to community meetings to get a sense of the community member's opinions and knowledge of the city's programs. One challenge with this approach is generally those who attend community association meetings tend to be more involved and therefore may not be representative of the knowledge of the whole community. There also may be member of Baltimore city that do not trust local government and therefore would not call 311 because they

do not want DPW in their homes. It is very difficult to enumerate the number of households that would fall into this category.

Figure 2. All Locations of Basement Backup Reports in Quarter 1-4, Baltimore City, Maryland, USA, Fiscal Year 2018.



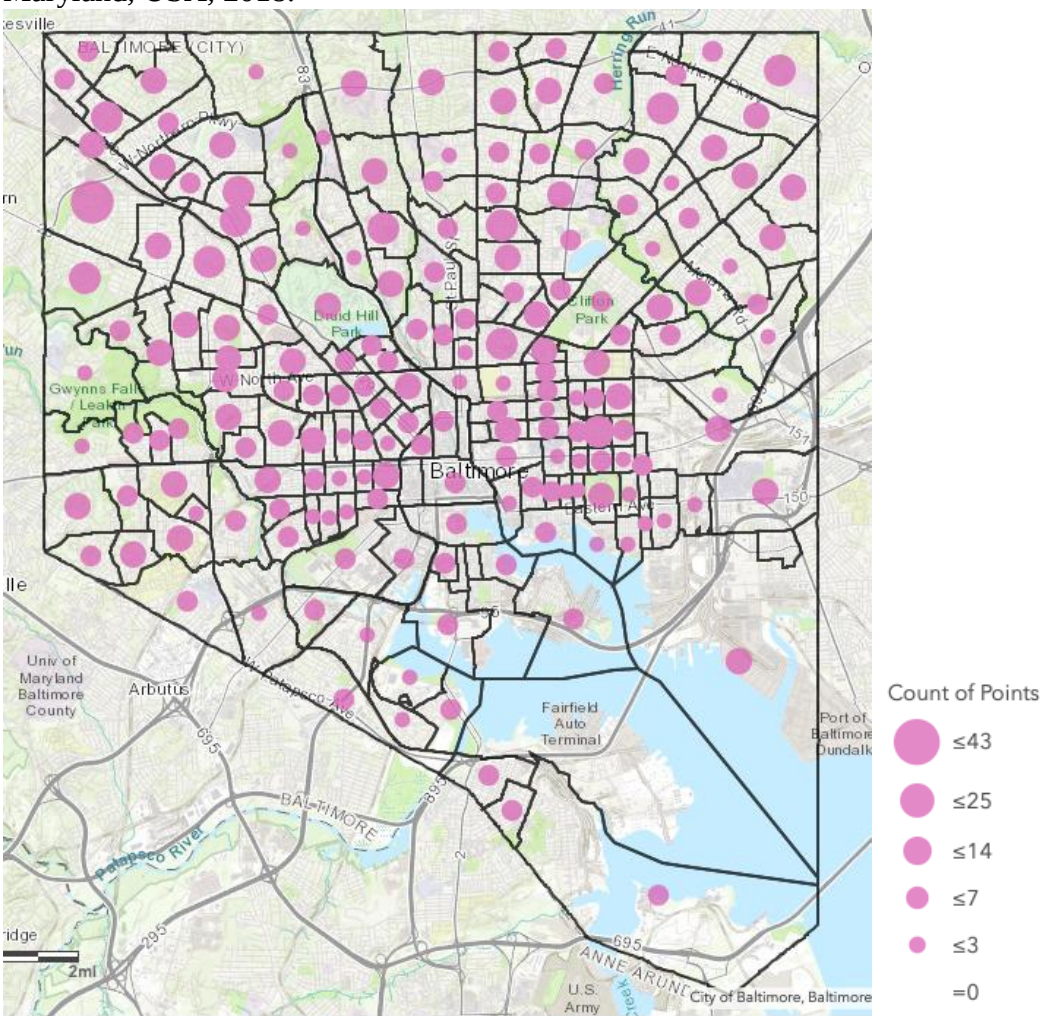
Note. Locations of all basement backup reports in Baltimore City for the 2018 fiscal year quarters 1-4. Lines represent 2010 census tract boundaries. Each point represents a single location of basement backups totaling 5113 locations in the Baltimore City area.

In addition, the collected data was from phone calls and online entries. Due to this method some of the raw addresses were not spelled correctly or had other errors. Some of these errors could be corrected using ArcGIS software and others could not be mapped (information in appendix). There was a location near the Fairfield Auto Terminal, though the quarterly reports only address residential properties, this address was included. From the satellite images it

appears that there are no residential properties at this location. A company could have called and was misclassified to be included in the quarterly reports.

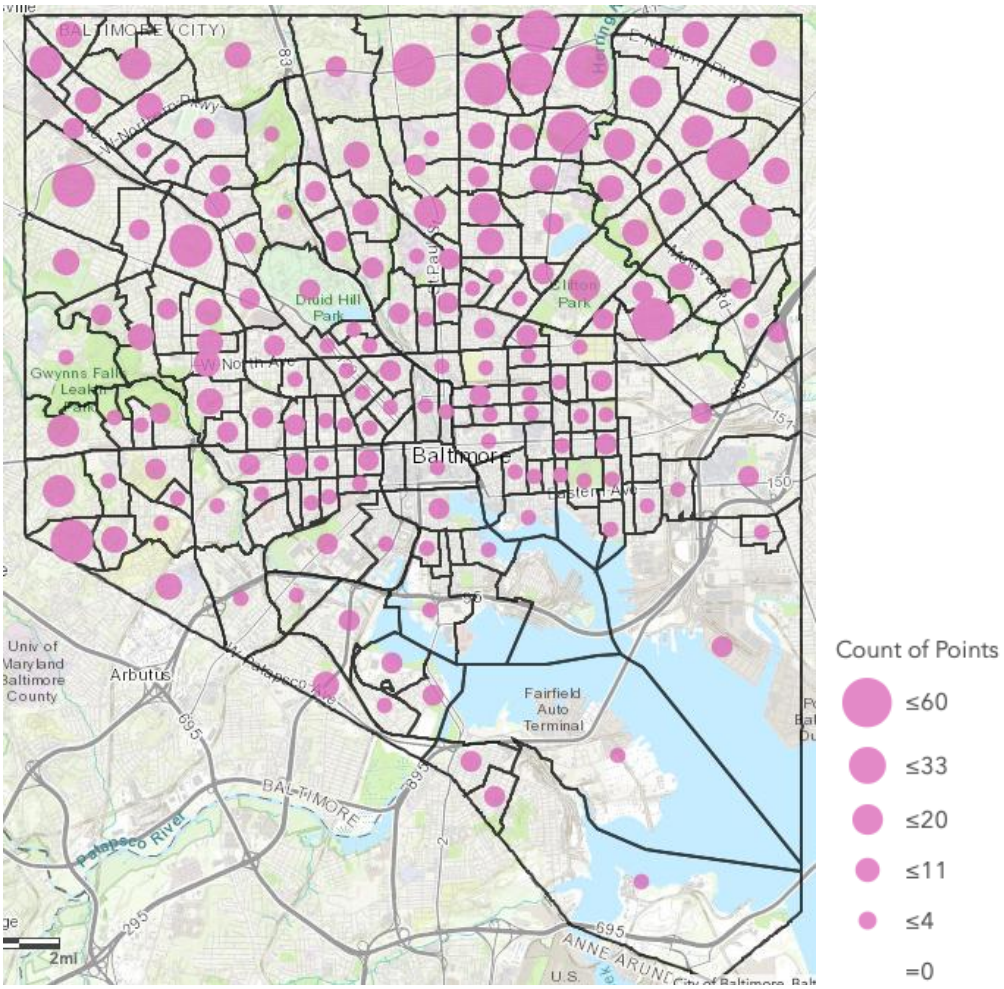
Figures 3 and 4 show the basement backups as caused solely by a mainline or lateral issue. In figure 3 there seems to be a larger number of basement backups caused by a mainline issue in the northwest section of Baltimore in comparison to lateral issues which seem to be more prominent in the upper northeast part of the city. The quarterly reports do not explain what is meant by mainline versus a lateral issue. Some of the issues identified may be due to blockages within those pipes but it is not entirely clear. It is important for the city to be transparent with residents as what the cause of their basement backup was. Technicians are trained to identify how much debris is needed to cause a backup, but residents do not understand how they come to these decisions. It would be ideal for the city to let residents know how much debris needs to be present to warrant a denial from the expediated reimbursement program. If there was a rainstorm as well as a slight blockage within a pipe would the resident be eligible for the expediated reimbursement program? Questions like these are essential in communicating the purpose and effectiveness of the program. Figure 5 shows the breakdown of all basement backups causes. It is even almost amongst all causes including unknown or unidentified. This may speak to the age of all the pipes within the city, and it could also mean that there needs to be better education of what is acceptable to go down drains.

Figure 3.All Locations of Basement Backup Reports Caused by Mainline Only, Baltimore City, Maryland, USA, 2018.



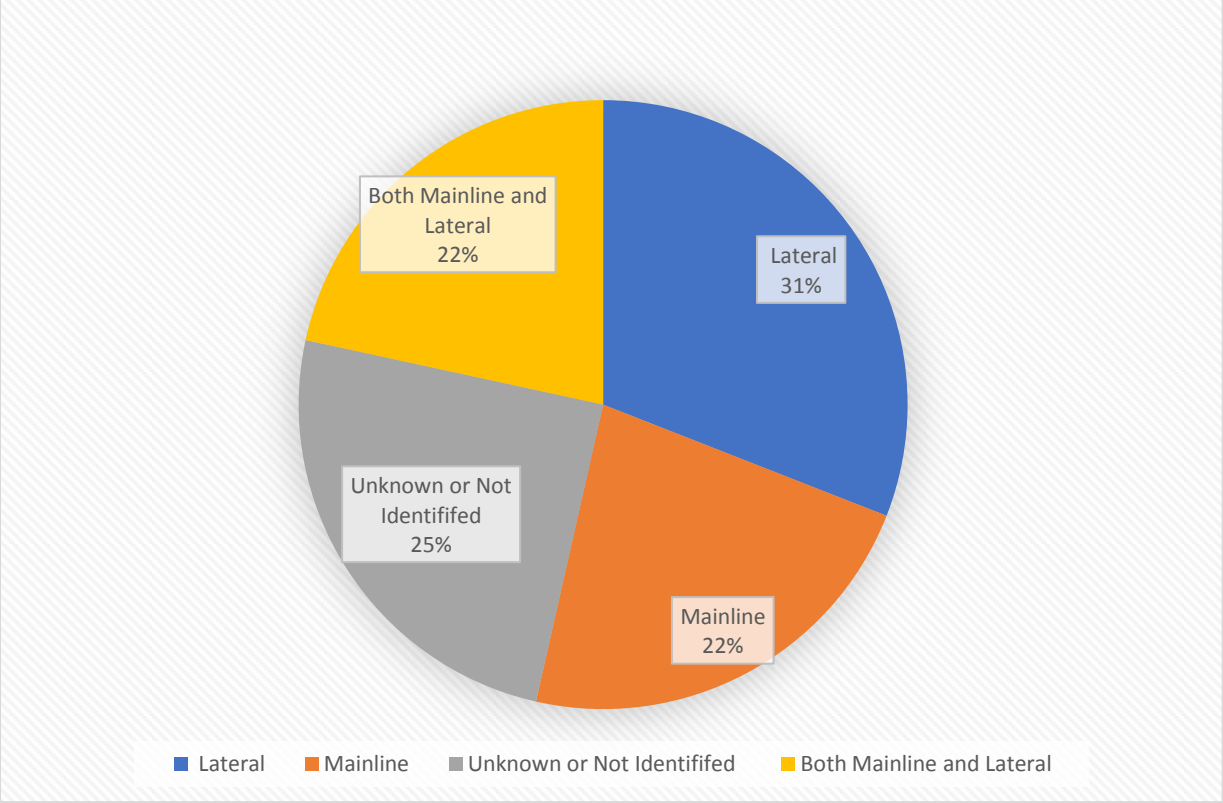
Note. Locations of all basement backup reports in Baltimore City for the 2018 fiscal year quarters 1-4 causes solely by a mainline issue. Each circle is a collection of locations that experienced a basement backup from a mainline issue. Lines represent 2010 census tract boundaries.

Figure 4. All Locations of Basement Backup Reports Caused by Lateral Pipe Only, Baltimore City, Maryland, USA, 2018.



Note. Locations of all basement backup reports in Baltimore City for the 2018 fiscal year quarters 1-4 causes solely by a lateral issue. Each circle is a collection of locations that experienced a basement backup from a mainline issue. Lines represent 2010 census tract boundaries.

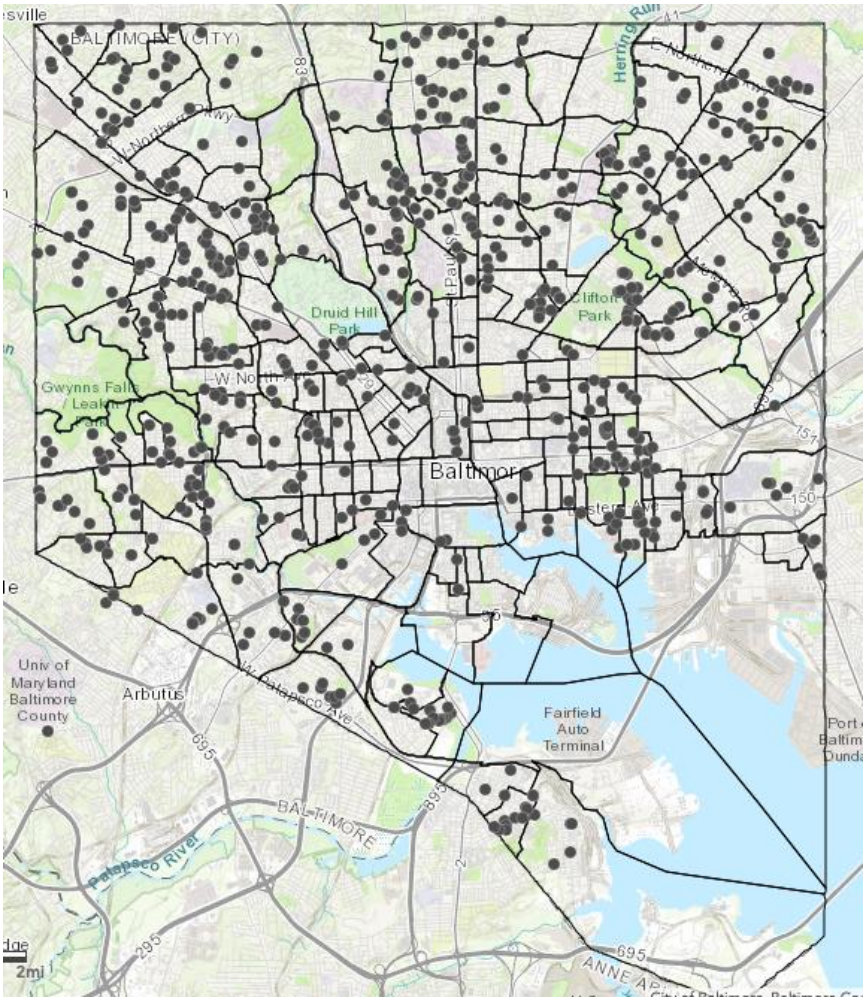
Figure 5. Cause Identification of All Basement Backups, Baltimore City, Maryland, USA, 2018.



Note. This chart shows the breakdown of causes of all basement backups in Baltimore City from quarterly reports 1-4.

Figure 6 shows all locations of preventative measures completed by the city from July 2017 through June 2018. Some of the preventative measures include treating pipes with chemicals to prevent tree root intrusion and main and lateral pipe cleanings. The city prioritized locations based on the number and frequency of issues at locations, some of locations were visited up to six times during this time period (Collection System Operations and Annual Maintenance Report, 2018). There are some census tracts that do not have any preventative cleaning measures though they have a large number of locations. Some of this may be because the time periods do not match up and some backups occurred after the Operations and Maintenance report was released. Also, the preventative measures were determined using data from the past two years which is further back then the quarterly report data goes.

Figure 6. Preventative Actions from DPW FY2018 Quarter 1-4 Baltimore City, Maryland, USA, 2018.

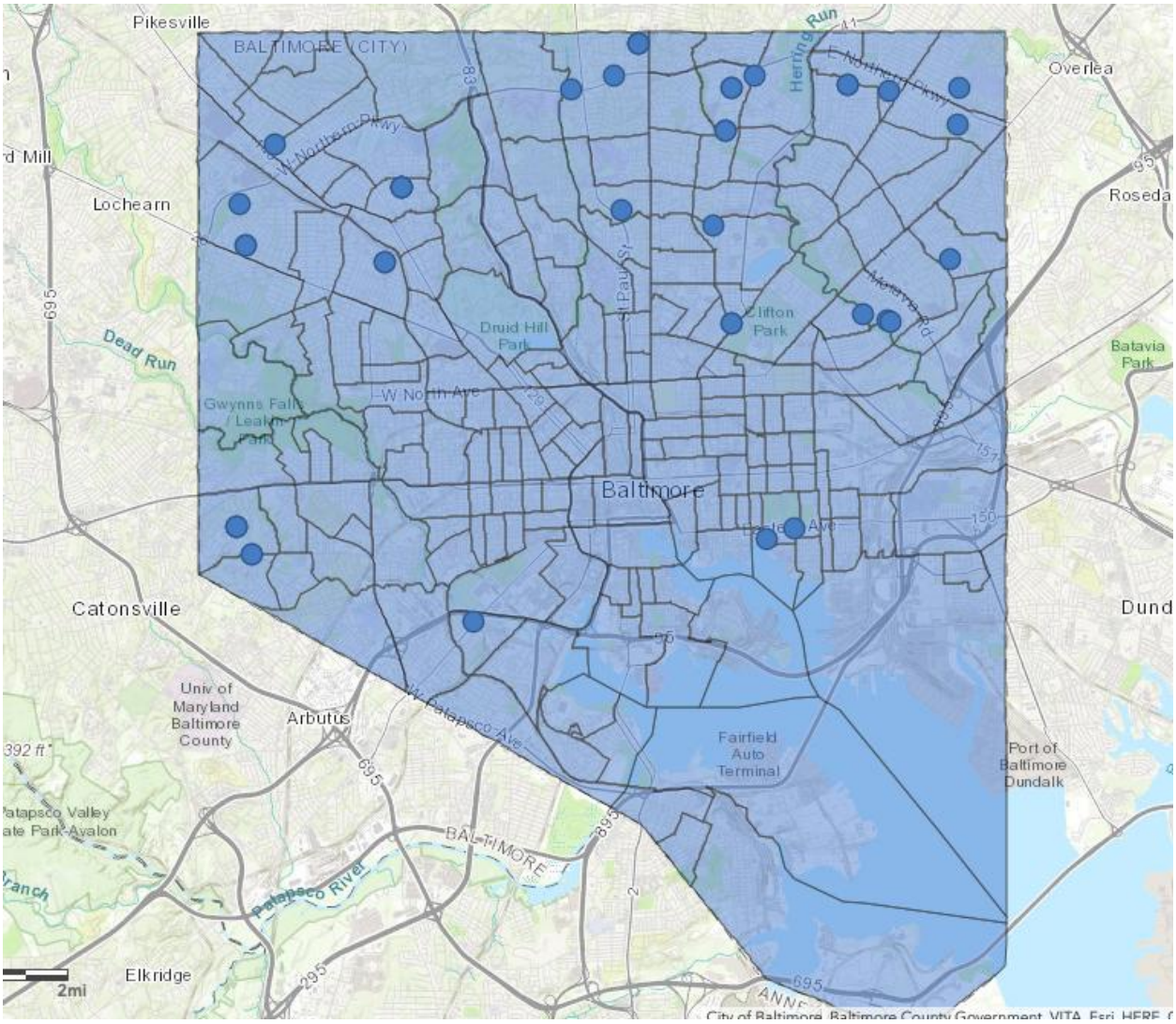


Note. All locations where preventative measures were performed by the city. The map does not show frequency of preventative actions, only locations.

Figure 7 shows the general liability claims that were made by households with a wet weather basement backup. There are only a few blocks where residents have filed general legibility claims. This is a concern because the expedited reimbursement program does not include property damage or hospital costs and only covers up to $2500. There may need to be more education that clarifies the differences and similarities between the two programs. Figure 8 shows that 70% of people with a basement backup did not file a claim. This is a large percentage of people that are not filing a claim, some of this may be because individuals do not understand

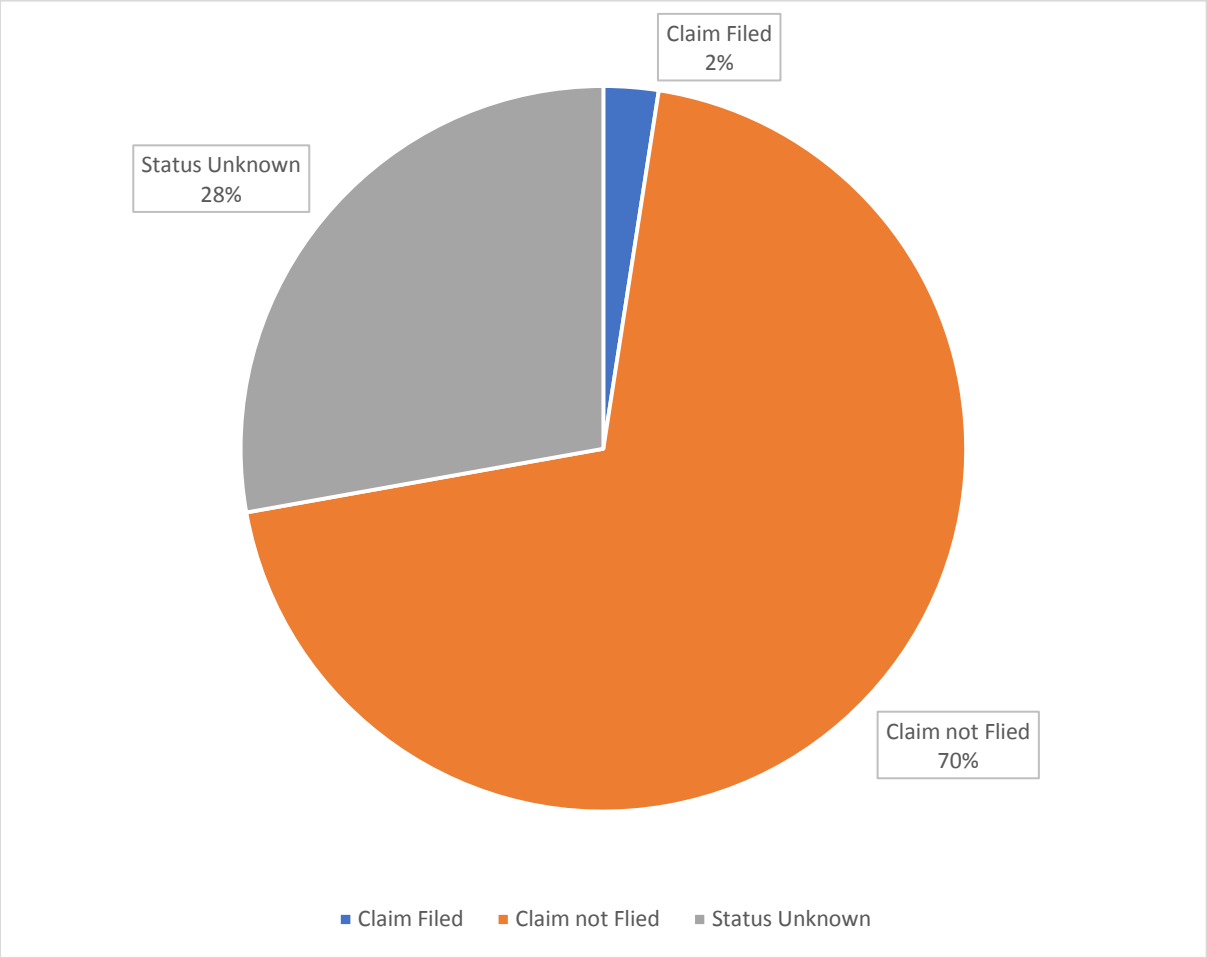
that they can file a claim with the city even if they were denied from the expedited reimbursement program. If there is not clear education of the purpose of the two programs it is easy for residents to get confused or overwhelmed by the process and not file a claim. Since the expedited program is a new program the city was not required to add information on how many residents applied to be considered for expedited reimbursement. Once this information is officially available it will be helpful to know how much of the two million dollars is being spent and what changes could be made for improvement.

Figure 7. General Liability Claims from Wet Weather Basement Sewage Backups, Baltimore City, Maryland, USA, 2018.



Note. The points in the map represent the blocks where at least one general liability claim was filed after a wet weather event (48 hrs. prior to backups).

Figure 8. General Liability Claims from All Basement Backups, Baltimore City, Maryland, USA, 2018.

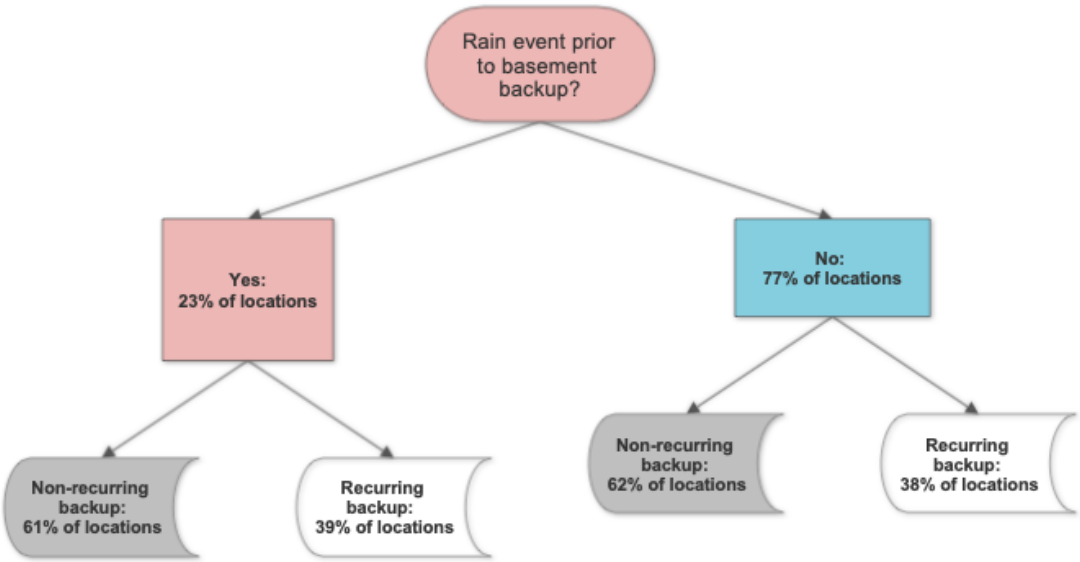


Note. The pie chart shows the percentage of claims that were filed in FY2018 from quarters 1-4.

The association of rain events basement backups is documented in figure 9. Most of the backups were not associated with rain in the past 48 hours or less. This means that a majority of backups are not eligible for expedited reimbursement because the backup was not caused by wet weather. Most of the cases are not caused by wet weather, it may be important for the city to expand the expedited reimbursement program to better accommodate the needs of residents. In

addition, the percentage of recurring backups was not impacted by rain events. In the event that the dry-weather backups are due to blockages, it is crucial that the city educate communities how to properly dispose of materials that are usually flushed or poured down the drain. If the problem is capacity it is essential that the city considers them eligible for the expedited reimbursement program. If the city lacks capacity to properly serve members of the community the city should have to provide reimbursement.

Figure 9. Rain Events and Basement Sewage Backups, Baltimore City, Maryland, USA, 2018.



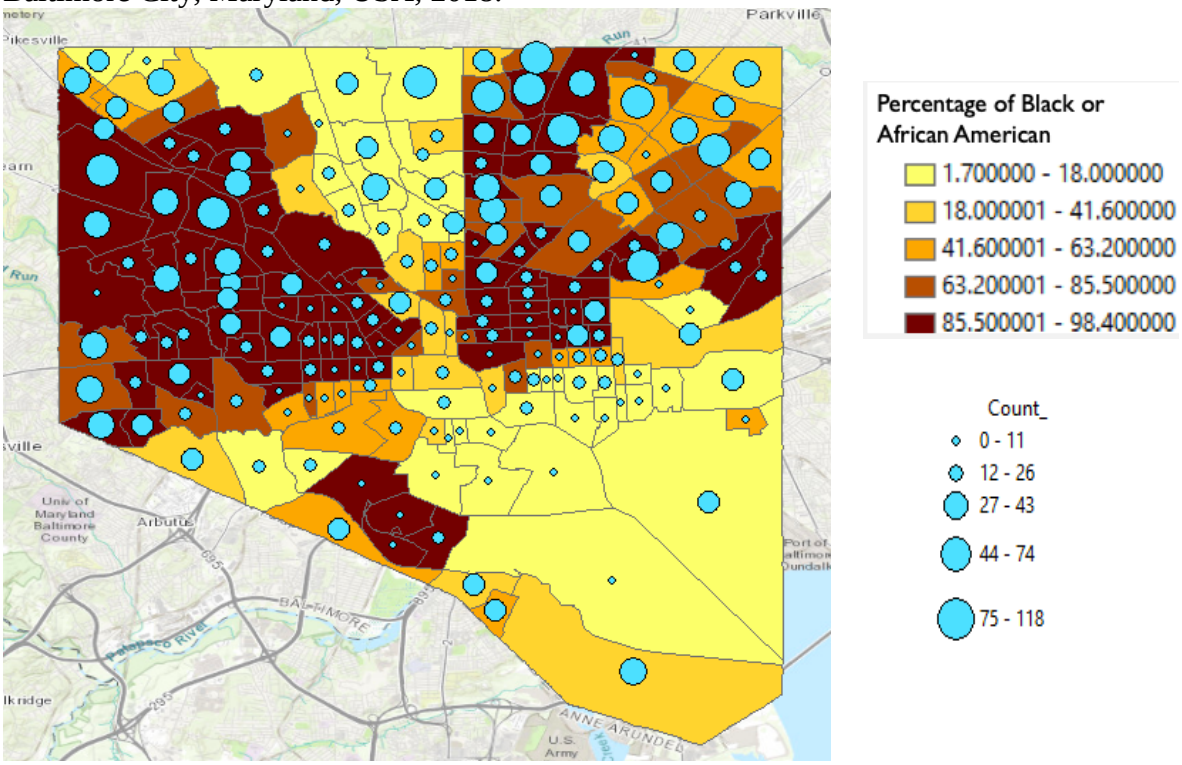
Note. This chart shows the percentage of basement backup reports from quarter 1-4 where there was a rain event that happened 48 hours or less before the backup. The percentage is then divided by recurring or non-recurring backup. Recurring is defined by the Department of Public Works as at least one prior basement backup in the last 18 months.

Figure 10 and table 1 both examine the relationship between basement backups by percentage of African-American or Black population in census tracts. A generalized linear model was created for $\log_{10}$ transformed number of basement backups by census tract and African-American or Black population. It was found that every 10% increase in percent African-American or black was associated with a 1.03 (0.57, 1.48) $\log_{10}$ increase in basement backup reports. The adjusted model took the number of rented properties, education, poverty into

account. It is important that Baltimore City recognize areas that may be more burdened then others and may need to adjust educational material and advertisements to best help this population. Though this finding does not adjust for all factors, it shows that there is a potential need in these communities, and it is important that their needs are met and that their voices are being heard from. Another area of research could also look at stratifying data by biological relevant factors. Some of those factors could include looking at the percentage of children (persons under 18), adults over 65 years of age, and children under 5 years of age by census tracts. Stratifying by these factors could show an increased need in these populations. Additionally, it may be important to stratify the African-American or Black population by mainline and lateral causes for census tracts. This could help identify if increased need in specific communities can be attributed a common cause.

To understand the magnitude of the issue a comprehensive list of the Department of Public Works work orders, preventative measures, and educational/advertising history would need to be compiled to address if the city is responding appropriately.

Figure 10. Basement Backups by Percentage of African-American or Black Population, Baltimore City, Maryland, USA, 2018.



Note. The dots represent the number of locations that experienced a basement backup in FY2018 quarter 1-4. The color represents the by percentage of American-American or Black population in each 2010 census tract.

Table 1. Relation Between Percent African-American or Black and Backups ($1og_{10}$) by Baltimore City 2010 Census Tract FY2018 Quarters 1-4

	Crude: Beta (95% Confidence Interval)	Fully adjusted: Beta (95% Confidence Interval)
Percent A-A or Black Increasing by 10%	0.71 (0.19, 1.22)	1.03 (0.57, 1.48)

Note. The fully adjusted model includes covariates: number of rented housing units and percent of residents within each tract with less than high school education or equivalency.

Methods

All information on location of basement backups in Baltimore city was obtained from the fiscal year 2018 quarterly reports 1-4. Quarter 5 was not available for analysis but is now publicly available on the Department of Public Works website. The city is broken down by 2010 census tracts and characteristics were laid on top of tract boundaries. American Fact Finder website was used to obtain 2010 census tract demographics. The 2010 census tract boundaries TIGER/Line Shapefiles were provided from the U.S. Census Bureau. ArcGIS Online as well as ArcMap desktop were used to geocode addresses. Pie charts were created using Excel, and Smartdraw online tool was used to create the flow chart. After Shapefiles were combined with demographic information, they were included in the census tracts analysis to establish the relationship between percent African-American or black and backups was performed in Stata to get adjusted and crude models using $\log_{10}$ transformed basement backup locations. The basement backups were transformed because they were highly left skewed.

Conclusion

Residential sewage basement backups affected thousands of households in Baltimore City in quarters 1-4 (DPW, 2018). The effects of basement backups are not only physical, but also can affect mental health as well as create an economic burden. It is vital that that Baltimore City provides adequate resources to residents experiencing these issues. As climate change makes weather more variable it is important that the City's actions account for larger storms. The expedited reimbursement program was created to help address this financial burden, and it is imperative that the program be evaluated based on its ability to do so. More research needs to be done to involve the community to assess how well educational efforts made by the city are working as well as assessing how helpful the community thinks the city programs are.

Acknowledgements

I would like to thank Dr. Heaney for introducing me to this project and for introducing me to individuals that helped guide my direction. I would also like to thank Jennifer Kunze and Leah Kelly for helping understand the social implications of this issue. I would like to thank Anne Corrigan who helped me with mapping software. Finally, I would like to thank Dr. Ed Bouwer for allowing me to consult with him on the engineering aspects of this project and for being one of my readers.

References

Atkinson, W. (2014). Clogged arteries. *Pollution Engineering*, *46*(2), 20–24.

Baltimore City Department of Public Works. (2015, December 28). History of Wastewater Removal and Treatment. Retrieved January 17, 2019, from https://publicworks.baltimorecity.gov/pw-bureaus/water-wastewater/wastewater/history

Baltimore City Department of Public Works. (2015). Sanitary Sewer Consent Decree Program. Retrieved January 16, 2019, from https://publicworks.baltimorecity.gov/sewer-consent-decree

Baltimore City Department of Public Works. (2017, November 2). Building Backups. Retrieved January 16, 2019, from https://publicworks.baltimorecity.gov/sewer-consent-decree/building-backups

Baltimore City Department of Public Works. (2017, June 28). Headworks Project Gains City Approval. Retrieved January 16, 2019, from https://publicworks.baltimorecity.gov/news/press-releases/2017-06-28-headworks-project-gains-city-approval-0

Baltimore City Department of Public Works. (2017, August 9). Modified consent decree covers backups into buildings. Retrieved Feb. 19, 2019, from https://publicworks.baltimorecity.gov/news/press-releases/2017-08-09-modified-consent-decree-covers-backups-buildings-0

Baltimore City Department of Public Works. (2018). Collection System Operations and Maintenance Annual Report. Retrieved March 19, 2019, from https://publicworks.baltimorecity.gov/reports

Baltimore City Department of Public Works. (2018). Modified Consent Decree Calendar Quarterly Report 1. Retrieved from https://publicworks.baltimorecity.gov/reports

Baltimore City Department of Public Works. (2018). Modified Consent Decree Calendar Quarterly Report 2. Retrieved from https://publicworks.baltimorecity.gov/reports

Baltimore City Department of Public Works. (2018). Modified Consent Decree Calendar Quarterly Report 3. Retrieved from https://publicworks.baltimorecity.gov/reports

Baltimore City Department of Public Works. (2018). Modified Consent Decree Calendar Quarterly Report 4. Retrieved from https://publicworks.baltimorecity.gov/reports

Environmental Protection Agency. (2004). Report to Congress on Impacts and Control of Combined Sewer Overflows and Sanitary Sewer Overflows, 640.

Gerba, C. P., Rose, J. B., & Haas, C. N. (1996). Sensitive populations: who is at the greatest risk? *International Journal of Food Microbiology*, *30*(1), 113–123. https://doi.org/10.1016/0168-1605(96)00996-8

Griffin, J. (2003). Cities learn value of chemical root control. *Underground Construction*, *58*(1).

Jarroll, E. L. (1988). Effect of disinfectants on Giardia cysts. *Critical Reviews in Environmental Control*, *18*(1), 1.

Hvitved-Jacobsen, T., Vollertsen, J., & Nielsen, A. H. (2013). *Sewer Processes: Microbial and Chemical Process Engineering of Sewer Networks, Second Edition*. Baton Rouge, United States: Chapman and Hall/CRC. Retrieved from http://ebookcentral.proquest.com/lib/jhu/detail.action?docID=1165878

Nieuwenhuis, E., Langeveld, J., & Clemens, F. (2018). The relationship between fat, oil and grease (FOG) deposits in building drainage systems and FOG disposal patterns. *Water Science and Technology*, *77*(10), 2388–2396. https://doi.org/10.2166/wst.2018.173

National Academy of Sciences. (1993). *Managing Wastewater in Coastal Urban Areas*. Washington, D.C.: National Academy Press. https://doi.org/10.17226/2049

National Environmental Health Association. (2019). Cured in Place Piping (CIPP). Retrieved January 17, 2019, from https://www.neha.org/node/59303

The City of Portland, Oregon. (2019). Open Trench Excavation. Retrieved January 17, 2019, from https://www.portlandoregon.gov/bes/article/490269

Nwachuku, N., & Gerba, C. P. (2004). Microbial risk assessment: don't forget the children. *Current Opinion in Microbiology*, *7*(3), 206–209. https://doi.org/10.1016/j.mib.2004.04.011

Reynolds, A., & D, P. (2000). Identifying Populations at Greatest Risk of Waterborne Disease, *42*(3).

United States of America v. Mayor & City Council of Baltimore, Maryland. Modified consent decree. (2017, Civil Action No. JFM-02-1524).

Appendix

From Quarterly Report: 132 could not be geocoded

From Quarterly Report 2: 151 not geocoded

From Quarterly Report 3: 1 not geocoded

From Quarterly Report 4: All geocoded

Locations that were matched: 5113

Total (non-geocoded and geocoded data): 5,397

Able to geocode: 94.74% of data