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Smart and Green City: Flooding Prevention & Treatment

1. Background

1.1 What's the Issue?

As a high-density megacity with a population of more than eight million, New York City has always played the role of an economic, foreign trade, fashion, and other center in the United States and the world. As the urban population continues to increase, the urbanization process of cities is also promoted. This leaves New York City vulnerable to severe natural disasters. Arianna is a reporter from Forbes.com; in her article posted on the website, *New York City On Track for Record-Breaking Rainfall And Flooding: Here's How Climate Change Might Play A Role*, she states the reason why the flooding become the most damaging disaster towards to NYC: "90%. That's the percentage of all U.S. natural disasters that happen because of flooding, according to the Department of Homeland Security. Floods account for more economic damage, property damage and loss of life than any other natural disaster (Johnson, 2023¹)." Facts also confirm what Arianna said. New York City has experienced more than two floods in the past few years. Sandy was one of the most damaging hurricanes: "Sandy generated the highest water levels in at least 300 years. In addition to extensive flooding, major power outages, and transportation disruptions, the storm caused 43 fatalities and

¹ Johnson, Arianna. "New York City On Track For Record-Breaking Rainfall And Flooding: Here's How Climate Change Might Play A Role." Forbes.Com, Sept. 2023, p. N.PAG. EBSCOhost, search.ebscohost.com/login.aspx?direct=true&db=bth&AN=172448991&site=eds-live.

an estimated \$19 billion in damages in New York City (Gornitz et al., 2023).² Arianna reported another hurricane,

Due to "extreme rainfall," New York Gov. Kathy Hochul declared a state of emergency [Sep 29, 2023] morning, urging over 8.5 million people to stay safe and avoid traveling on flooded roads...Flooding as a result of the heavy rain has caused road closures, rescue attempts, flooded basements and interrupted subway services as parts of New York experienced a month's worth of rain in just three hours on Friday morning. (Johnson 2023)

Both floods caused considerable damage to New York's municipalities, infrastructure, and economy. At the same time, catastrophes make it difficult for cities to function normally, which is fatal for a world center.

1.2 Causing of the Damage:

The causes of urban flooding can be roughly divided into rainfall and cost. These two factors frequently plague New York City with flooding problems. The city witnesses a substantial annual average rainfall of 1270mm, leading to significant yearly precipitation (Agonafir et al., 2022)³. Moreover, based on geographical measurements, roughly 72% of NYC's land area is characterized by impermeable surfaces (City of New York, 2020a)⁴. Besides the rainfall, the sea level of New York City's coast keeps rising. Keith is a coastal engineer at Barid & Associates. He and his colleagues' work, *Impact of Simulated Twenty-First-Century Changes in Extratropical Cyclones on Coastal Flooding at the Battery, New York City*, posted on the American Meteorological

² Gornitz, Vivien, et al. "Enhancing New York City's Resilience to Sea Level Rise and Increased Coastal Flooding." *Urban Climate*, vol. 33, Sept. 2020. EBSCOhost <https://doi-org.proxy.library.nyu.edu/10.1016/j.uclim.2020.100654>.

³ Agonafir, C., Pabon, A. R., Lakhankar, T., Khanbilvardi, R., & Devineni, N. (2022). Understanding New York City street flooding through 311 complaints. *Journal of Hydrology*, 605. <https://doiorg.proxy.library.nyu.edu/10.1016/j.jhydrol.2021.127300>

⁴ City of New York a. Impact of NYW Bonds. Retrieved from <https://www1-nyc-gov.proxy.library.nyu.edu/site/nyw/investing-in-nyw-bonds/the-impact-of-investing.page>. Accessed 30 Dec. 2020.

Society states that the regulations of the coastal flooding impacted by sea level rising: "Extratropical storms during the cool-season months (November-March) often create coastal flooding along the east coast of the United States, which results in hazardous conditions, coastal erosion, and property damage(Roberts et al. 2017⁵)." In addition to seasonal high tides, the rapidly developing New York City also suffers from the negative impacts of urbanization. Tom Parsons, a research geophysicist in the U. S. Geological Survey, Menlo Park, CA, states that New York City, especially Manhattan, sank as fast as the buildings were built. In the paper which he and his colleagues published, *The Weight of New York City: Possible Contributions to Subsidence From Anthropogenic Sources*, on Bognor Regis, they state that:

A deeply concentrated population of 8.4 million people faces varying degrees of hazard from inundation in New York City...urbanization itself may exacerbate the problem; cumulative pressure applied to the ground from large buildings contributes to subsidence not only from initial primary settlement caused by soil compression and reduction of void space, but also through potential secondary settlement caused by creep in clay rich layers that can continue indefinitely. (Parsons et al. 2023)⁶

Flood problems caused by various reasons make people more in need of solutions to reduce the losses caused. There are various solutions to floods, and people usually start planning solutions before a flood occurs (prevention) and when it occurs (rescue and detection).

⁵ Roberts, Keith J., Brian A. Colle, and Nathan Korfe. "Impact of Simulated Twenty-First-Century Changes in Extratropical Cyclones on Coastal Flooding at the Battery, New York City." *Journal of Applied Meteorology and Climatology*, vol. 56, no. 2, 2017, pp. 415-432. ProQuest, <http://proxy.library.nyu.edu/login?qurl=https%3A%2F%2Fwww.proquest.com%2Fscholarly-journals%2Fimpact-simulated-twenty-first-century-changes%2Fdocview%2F1924691321%2Fse-2%3Faccountid%3D12768>, doi:<https://doi.org/10.1175/JAMC-D-16-0088.1>.

⁶ Parsons, Tom, et al. "The Weight of New York City: Possible Contributions to Subsidence from Anthropogenic Sources." *Earth's Future*, vol. 11, no. 5, 2023. ProQuest, <http://proxy.library.nyu.edu/login?qurl=https%3A%2F%2Fwww.proquest.com%2Fscholarly-journals%2Fweight-new-york-city-possible-contributions%2Fdocview%2F2818932267%2Fse-2%3Faccountid%3D12768>, doi:<https://doi.org/10.1029/2022EF003465>.

2. Possible Solution

2.1 Flood Prevention

In the New York Green Infrastructure Plan, the author mentions that by extending the space of green swales in the urban area, the city is trying to create a "Porous streetscape" that will help to cover runoff and absorb more rainwater (N. R. Mahanta and B. Rajput 2019)⁷. However, as a highly concentrated population city, extending the land for urban rain gardens or wetlands is extremely expensive. Also, as urban natural spaces extend, the worries about the crime rate rise. Nancy is a research ecologist focusing on Baltimore Field Station's social and biological sciences. In the paper that she and her colleagues published, *Fear and fascination: Use and perceptions of New York City's forests, wetlands, and landscaped park areas*, on the Urban Forestry and Urban Greening, they stated what they found in the parks of NYC: "the opportunity for some to act out against social norms in a space that is not prescriptive (sleeping outdoors, taking drugs, lighting a fire) may turn others away from using the space themselves...In particular, natural areas can cause Fear and anxiety for those who feel vulnerable or lack familiarity with these spaces (Sonti, Nancy Falxa, et al., 2020⁸).\" Lack of management of parks will result in park usage being far less than expected, resulting in extreme land waste, especially for a megalopolis like New York City.

Mapping the city's sewer lines has been a solution NYC has been pursuing. However, Sewer information is hard to find and very cryptic, yet crucial to the city's functioning. We want more people to know how the system works and feel

⁷ N. R. Mahanta and B. Rajput, "Landscape Interventions for Resilience and Sustainability in Urban Wetland Parks: a review," 2019 Advances in Science and Engineering Technology International Conferences (ASET), Dubai, United Arab Emirates, 2019, pp. 1-6, doi: 10.1109/ICASET.2019.8714401.

⁸ Sonti, Nancy Falxa, et al. "Fear and Fascination: Use and Perceptions of New York City's Forests, Wetlands, and Landscaped Park Areas." *Urban Forestry & Urban Greening*, vol. 49, Mar. 2020. EBSCOhost, <https://doi-org.proxy.library.nyu.edu/10.1016/j.ufug.2020.126601>.

empowered to improve it (NYC Open Data, 2022).⁹ Exploring the already-built water conservancy system and statistics is a vast project, and this process requires enormous funds to support the advancement of the entire project.

2.2 Flood Detection & Rescue

Existing flood detection methods include the website NYC311, where citizens report flooding conditions on their streets to the government. Agonafir is a Postdoctoral Research Scientist at Columbia Water Center. She and her colleagues learned about the NYC street flooding through NYC311 and published the paper, *Understanding New York City street flooding through 311 complaints*, in the Journal of Hydrology. Even though the website helped them understand flooding data, they pointed out the limitations of the NYC311 citizens' flooding reports: "[NYC street flooding] research may have also been limited by low resident participation. As the study indicates, infrastructural complaints, frequently are in relation with [street flooding] complaints, increasing awareness to residents and visitors of NYC, especially when there is forecasted precipitation, would facilitate modeling endeavors (AGONAFIR, C. et al. 2022)." Also, according to P.M. Wiedemann, a researcher from Monash University, and his colleagues stated in an article published in 2023: selective risk reporting, focusing on selected risk potential but ignoring the full range of the available evidence that does not support risk claims, lead to misleading risk perceptions (Wiedemann et al., 2023).¹⁰

3. Recommendation

3.1 Green Infrastructure & Rain Barrels

Although plans to widen city parks are difficult to implement and may result in a waste of land resources, this does not mean that green infrastructure cannot be

⁹ NYC Open Data <https://opendata.cityofnewyork.us/projects/open-sewer-atlas-nyc/>

¹⁰ Wiedemann, P. M., Freudenstein, F., Lohmann, M., & Böl, G.-F. (2023). Eliminating the effects of reporting bias on risk perception. *Science of the Total Environment*, 874. <https://doi-org.proxy.library.nyu.edu/10.1016/j.scitotenv.2023.162304>

implemented in New York City. Matej is a faculty member of civil and geodetic engineering at the University of Ljubljana. He and his colleagues' paper, the water-management aspect of Blue-green Infrastructure in Cities, introduced the definition of blue-green infrastructure, "Blue-green infrastructure can be defined as natural and semi-natural (hence green) decentralized systems designed to manage urban stormwater (hence blue) while providing a wide range of ecosystem services. Its basic philosophy is to mimic natural hydrological processes (i.e., retention, infiltration, and vapor (transportation) with the aim of managing rainwater locally to prevent generation of runoff and mixing with wastewater (RADINJA 2021)¹¹." In the article, they gave an example of a sponge city in China. They mentioned that China's sponge city plan does not blindly expand urban green spaces but absorbs rainwater by constructing sponge buildings, like roof gardens or rain gardens and rain barrels. At the same time, porous pavement is created by replacing the medians between sidewalks and drive lanes with green plants, and rainwater is collected through these porous structures. This method increases the city's green area without taking up too much public space. At the same time, according to the paper by Barsha, a project engineer from Houston, and his colleagues, Evaluation of land use, climate change, and low-impact development practices on Research in urban flooding shows that the level of flood protection using LID practices is evaluated based on three methods: rain barrels, rain gardens, and a combination of the two. LID plays an important role in slowing water runoff for this particular watershed area, with average reductions of 10%, 21%, and 32% across the three methods, respectively (Neupane et al. 2021)¹².

¹¹ Radinja, Matej, et al. "The Water-Management Aspect of Blue-Green Infrastructure in Cities." *Urbani Izziv*, vol. 32, no. 1, June 2021, pp. 98–110. EBSCOhost, search.ebscohost.com/login.aspx?direct=true&db=edsjsr&AN=edsjsr.27043404&site=eds-live.

¹² Neupane, Barsha, et al. "Evaluation of Land-Use, Climate Change, and Low-Impact Development Practices on Urban Flooding." *Hydrological Sciences Journal/Journal Des Sciences Hydrologiques*, vol. 66, no. 12, Sept. 2021, pp. 1729–42. EBSCOhost, <https://doi-org.proxy.library.nyu.edu/10.1080/02626667.2021.1954650>.

3.2 Flood Detection and Smart City

Professor Charlie Mydlarz is a faculty member from the Center for Urban Science and Progress (CUSP) at New York University (NYU) and a researcher at the New York City flood detection project, Flood Net. The Flood Net introduces the ultrasound detection of floods. According to Professor Mydlarz in our interview, a flood sensor his team utilizes to detect street flooding is a device pointing to the road surface, employing ultrasound technology to gauge the distance between the sensor and the road's surface. A reduction in this distance triggers a response from the sensor. The Flood Net team records the flood profile using the ultrasound data collected, facilitating the identification and analysis of various types of flooding incidents and other relevant factors (Mydlarz, 2023).

Regarding the challenges encountered while installing these sensors, Professor Mydlarz pointed out that while the sensor's functionality is relatively straightforward, it sometimes detects extraneous noise emanating from the road surface, such as a discarded trash bag. To address this issue, the team is diligently visualizing the ultrasound data and utilizing it to differentiate between various surface types. Additionally, privacy concerns emerged as another obstacle. The sensor's microphone or camera-like appearance often raises concerns among the public regarding their privacy. In response, Professor Mydlarz's team has installed informational signs alongside the sensor installations, which educate citizens about the sensors' functions and alleviate concerns regarding collecting video or audio data.

Looking ahead, Professor Mydlarz emphasized that the detection system's modeling will improve as more sensors are deployed throughout the city. With an increased volume of data at their disposal, the machine learning models employed by the team can be trained more effectively. This enhanced capability will assist in profiling and identifying instances of flooding.

In the future, the data collected by the sensors will be integrated with the active signage in the city, providing roadblock information to the public. At the same time, real-time and efficient flood detectors will also serve as the "brain" of the entire city's

green infrastructure, helping to operate and improve green infrastructure. For example, Flood Net's flood detector uses a large amount of data collection and machine learning to predict areas in New York City that are more likely to be flooded and recommends that the government install rain barrels and rooftop rain gardens on buildings in these areas. When floods reach a certain threshold, rain barrels installed on buildings come into play to reduce the risk of flooding.

4. Model Limitation

4.1 Green Infrastructure & Rain Barrels:

Expanding green spaces encounters obstacles due to limited land availability, safety concerns, and potential misuse. The financial burden of blue-green initiatives adds complexity, demanding a delicate balance between cost and benefits. Challenges include managing the perception of expanded green areas and navigating budget constraints.

4.2 Flood Detection and Smart City

The Flood Net's ultrasound detection offers progress, yet challenges persist. False alarms caused by extraneous noise raise concerns about public trust. Privacy issues linked to sensor appearances need ongoing public communication. Ensuring scalability without compromising efficiency is a persistent challenge. Ignatius is a certified information technology auditor. In his paper: *Privacy in the A.I. Era: Navigating Challenges and Safeguarding Data in the Age of Innovation*, he mentioned the challenge when we applied AI technology like machine learning:

organizations must implement robust data governance frameworks, ensuring that data collection, storage, and processing adhere to privacy regulations and best practices. Anonymization techniques, encryption, and secure data storage help protect sensitive information, minimizing the risk of data breaches or unauthorized access. Additionally, privacy-by-design approaches embed privacy considerations into the development of A.I. systems, ensuring privacy is upheld from the early

stages of implementation. (Ravi, 2023)¹³

While integrating flood data with signage aims to enhance public awareness, translating complex information into clear roadblock messages is challenging. Sensor accuracy remains pivotal, as inaccuracies may breed misinformation and erode public trust.

5 Conclusion

In conclusion, the complex challenge of flooding in New York City demands a comprehensive and adaptive strategy that combines preventive and responsive measures. The integration of green infrastructure, guided by the principles of blue-green infrastructure, holds significant promise for flood prevention. This approach leverages natural processes to manage stormwater and addresses concerns related to land use and public safety.

Simultaneously, advancements in flood detection technology, exemplified by Professor Charlie Mydlarz's Flood Net project, showcase the transformative potential of data-driven solutions. By overcoming challenges such as extraneous noise and privacy concerns, these innovations pave the way for a more efficient, accurate, and timely response to flood events.

Looking forward, the synergy of flood data integration with city infrastructure and the evolving capabilities of flood detection systems positions New York City on a trajectory toward becoming a more innovative and resilient metropolis. As more sensors are deployed, and machine learning models improve, the city's ability to proactively identify and address instances of flooding will undoubtedly improve. This enhanced capability safeguards lives and property and establishes a foundation for a more sustainable and adaptive urban environment.

¹³ Ravi, Ignatius. "Privacy in the AI Era: Navigating Challenges and Safeguarding. Data in the Age of Innovation." *ISSA Journal*, vol. 21, no. 10, Oct. 2023, pp. 29–33. *EBSCOhost*,
search.ebscohost.com/login.aspx?direct=true&db=tsh&AN=172769649&site=eds-live.

In the future, the envisioned integration of flood data with city signage and infrastructure presents an opportunity for real-time communication and collaboration. This provides valuable roadblock information to the public and facilitates the swift deployment of response teams to areas affected by floods. The continuous evolution of flood detection technologies promises to play a pivotal role in responding to crises and actively shaping the city's green infrastructure for long-term resilience.

In summary, the journey towards an innovative and green New York City involves harmonizing technological innovation, community engagement, and sustainable urban planning. By embracing these elements, the city can navigate the complex landscape of flooding challenges and emerge as a beacon of resilience in the face of an uncertain climate future.