Compound Flood Risk from the Combined Effects of Sea Level Rise on Storm Surge, Tidal and Groundwater Flooding, and Stormwater – The Urban Drainage Component

Dr. Valentina Prigiobbe

The interaction between groundwater and sewer network in coastal urban areas is an emerging issue due to sea level rise (SLR), more frequent and intense precipitation events, and the aging of the networks in the country [1]–[3]. The interaction between groundwater and sewer network can manifest itself through processes called infiltration and exfiltration [4].

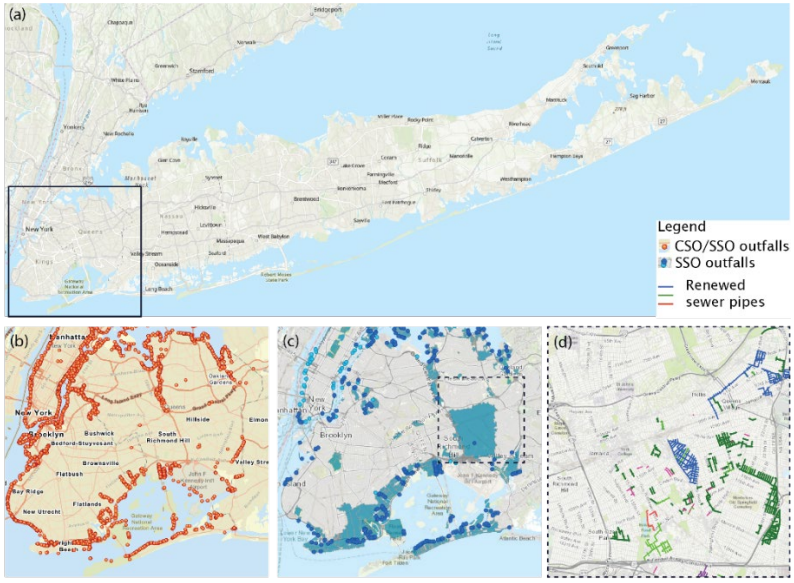

Figure 1. (a) Map of the study region of Long Island with highlighted the neighborhoods of Brooklyn and Queens where the sewer-groundwater interaction will be investigated; (b) sewer outfalls; (c) separated sewer outfalls; and (d) renewed sewer lines.

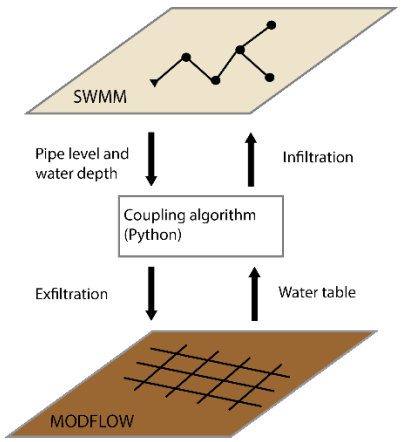

Figure 2. Real-time communication between SWMM and MODFLOW via a coupling algorithm.

Infiltration is due to groundwater entering sewer pipes through cracks or disconnected joints. It reduces the capacity of the sewer network while increasing the flow within the pipes. Moreover, significant infiltration can trigger separated/combined sewer overflows (SSOs or CSOs) and sewer surcharge delivering untreated and uncontrolled amounts of wastewater into surface water bodies [5]. Furthermore, if contaminated sites are present within an urban area, groundwater infiltration may provide a faster route of contaminant migration towards surface water bodies. Exfiltration is due to the leakage of untreated wastewater at damaged locations of the sewer network. It spreads contaminants from the sewer network into the urban soil, possibly contaminating the unconfined shallow aquifer [6]. Considering the aging of water infrastructure and future weather scenarios of more frequent and intense rain

events and SLR [7], [8], groundwater-sewer interaction is going to become an important component of urban hydrology modeling. Current open-source models have the major drawback that they disregard the dynamic interactions between groundwater and sewer network neglecting therefore the risk of more frequent SSOs or CSOs and sewer surcharges.

In this research the objective is to develop a tightly coupled sewer model with a three-dimensional (3D) flow model of groundwater in costal urban areas. The coupled model will help predict the influence of climate change and water infrastructure aging on urban hydrology. Selected sites within the urban areas of Long Island, e.g., the neighborhoods of Brooklyn and Queens, will be used as test cases. With the goal of making the model publicly accessible, the codes will be implemented in the open-source software such as SWMM [2], MODFLOW, and Python. SWMM and MODFLOW are software widely used by hydrologists for stormwater and groundwater modeling. The overall coupled model will be implemented for Brooklyn and Queens, but the framework will be created in a modular manner to be applicable to other sites.

To address this objective, the work will be articulated in tasks comprising: data mining and analysis, development and implementation of the hydrological models and coupling algorithm, validation of the coupled model, and stochastic simulations under future weather scenarios.

Within the three years of the project, the Ph.D. student will gain an extraordinary background on hydrological modeling and programming in Python. The student will have the opportunities to collaborate with the Water Center of USGS (New York, USA), to networking within academia by attending national and international conferences, and to spend up to 6 months in another institution within Europe or the United States as a visiting scholar.

The project is funded by the USGS.

References

[1] R. J. Rossi and L. Toran, “Exploring the potential for groundwater inundation in coastal US cities due to interactions between sewer infrastructure and global change,” Environ. Earth Sci., vol. 78, no. 8, Apr. 2019, doi: 10.1007/s12665-019-8261-9.

[2] T. Liu, M. Beheshti, X. Su, and V. Prigiobbe, “Sewer-Groundwater Interaction in Urban Coastal Areas,” in New trends in urban drainage modelling, UDM 2018, 2019, pp. 771–776, doi: 10.1007/978-3-319-99867-1_133.

[3] S. Thorndahl, J. D. Balling, and U. B. B. Larsen, “Analysis and integrated modelling of groundwater infiltration to sewer networks,” Hydrol. Process., vol. 30, no. 18, pp. 3228–3238, Aug. 2016, doi: 10.1002/hyp.10847.

[4] C. Karpf, S. Hoeft, C. Scheffer, L. Fuchs, and P. Krebs, “Groundwater infiltration, surface water inflow and sewerage exfiltration considering hydrodynamic conditions in sewer systems,” WATER Sci. Technol., vol. 63, no. 9, pp. 1841–1848, 2011.

[5] P. Staufer, A. Scheidegger, and J. Rieckermann, “Assessing the performance of sewer rehabilitation on the reduction of infiltration and inflow,” WATER Res., vol. 46, no. 16, pp. 5185–5196, Oct. 2012, doi: 10.1016/j.watres.2012.07.001.

[6] J. B. Ellis and D. M. Revitt, “Sewer losses and interactions with groundwater quality,” WATER Sci. Technol., vol. 45, no. 3, pp. 195–202, 2002, doi: 10.2166/wst.2002.0079.

[7] W. V Sweet and J. Park, “From the extreme to the mean: Acceleration and tipping points of coastal inundation from sea level rise,” Earth’s Futur., vol. 2, no. 12, pp. 579–600, 2014.

[8] T. Ezer and L. P. Atkinson, “Accelerated flooding along the U.S. East Coast: On the impact of sea-level rise, tides, storms, the Gulf Stream, and the North Atlantic Oscillations,” Earth’s Futur., vol. 2, no. 8, pp. 362–382, 2014.