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CONFERENCE PROCEEDINGS

FLOOD RISK IN MUMBAI—CONSULTATIVE STAKEHOLDER WORKSHOP

A workshop for framing urban flooding issues through analytical methods and data, ethnographic research, catalogs of personal experiences, and available financial toolkits

Executive Summary

Brihanmumbai Municipal Corporation (BMC) hosted a two-day consultative stakeholder workshop, with support from WRI India as the knowledge partner, to engage with stakeholders who have analyzed the flooding issue from various perspectives. The goal of the workshop was to scope the problem and develop an informed, comprehensive, and transparent roadmap to make Mumbai flood-resilient, in light of new constraints and available innovative solutions.

The workshop participants comprised experts in flood risk assessment, meteorology and hydrology, social sciences and community organizations, urban design, architectural and development policy; BMC officials from the Storm Water Drainage Department and Disaster Management and Mumbai Metropolitan Region Development Authority (MMRDA); citizens impacted by Mumbai's floods; C40 Cities; and the Asian Development Bank.

The consultative discussion dove into the issues that are key to assessing and adapting to the emerging flood risk in Mumbai, such as the changing demands on storm water drainage due to various types of flood risk (coastal inundation, perennial risk to low-lying areas, terrain close to previously natural drainage channels, and concretization) and outlined the added risk for vulnerable communities, which was highlighted by first-person accounts from citizens impacted by Mumbai's floods.

28-29 APRIL, 2022

FLOOD RISK IN MUMBAI—CONSULTATIVE STAKEHOLDER WORKSHOP, MUMBAI

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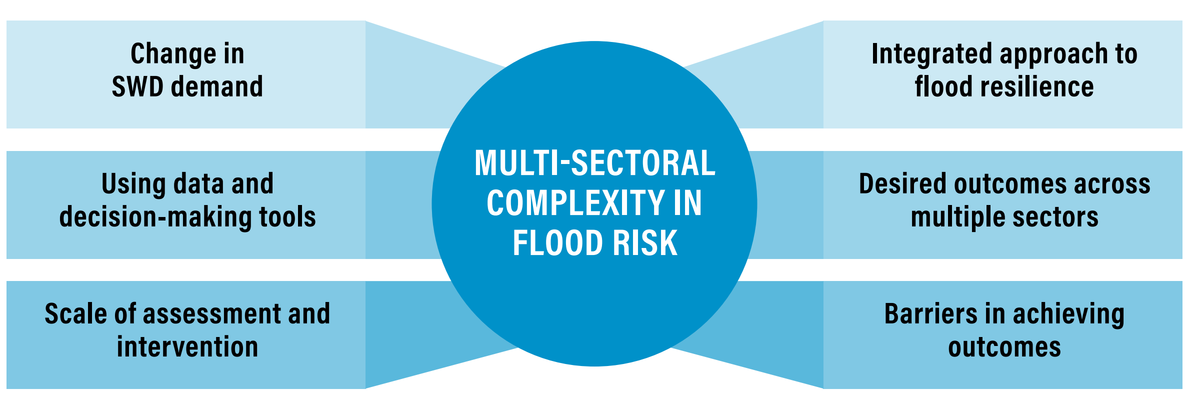
People Crossing the Road in the Evening. Source: zeber2010

The workshop provided an opportunity for stakeholders to learn about initiatives taken by BMC's Storm Water Drainage and Disaster Management departments and MMRDA to manage flood risk and response. Finally, C40 Cities conducted an interactive session on financing mechanisms for flood risk management using nature-based solutions, with examples of self-financing projects.

The workshop shone a light on the need for interdepartmental and agency coordination, and further planning development for flood resilience to support innovative engineering solutions to resolve this complex issue.

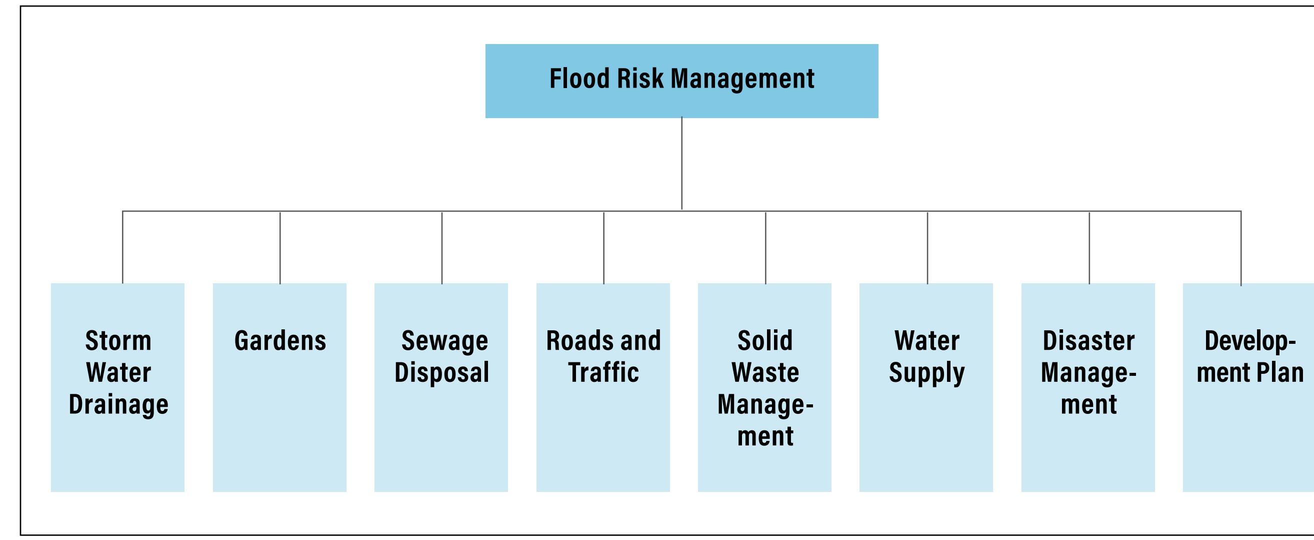
Figure 1 | Flood Risk Management For Mumbai



Source: Flood Risk in Mumbai - Consultative Stakeholder Workshop. Note: SWD = Storm Water Drainage.

Figure 2 | Interdepartmental Coordination For Flood Risk Management In Mumbai

NEED FOR INTERDEPARTMENTAL COORDINATION



Source: Flood Risk in Mumbai - Consultative Stakeholder Workshop. Note: SWD = Storm Water Drainage

The workshop was inaugurated by former Hon. Minister of Tourism, Environment and Protocol, Mr. Aaditya Thackeray, with BMC's Additional Municipal Commissioner–Projects, Mr. P. Velrasu. The workshop comprised six sessions to allow multisectoral stakeholders to provide insights and inputs. The workshop format was discussion-oriented with short presentations by the panelists at the beginning of each session. Mr. Jairaj Phatak (IAS retired, Former Municipal Commissioner, Brihanmumbai Municipal Corporation) and Mr. Ajoy Mehta (IAS retired, Former Chief Secretary, Government of Maharashtra) addressed the closing session of the workshop on Day Two.

Global Highlights

The consultative workshop highlighted several potential directions to increase flood resilience for Mumbai. The overall takeaways of the workshop are described below.

Consultative process and interagency coordination

The workshop was a unique platform for multiple stakeholders to provide inputs and insights and share information on the flood risk in Mumbai. It is important to examine the role of each stakeholder and department and understand their function in an integrated way. An ongoing consultative dialogue among stakeholders should be established to address flood risk, particularly with the increasing demand on storm water drainage.

Flood risk cannot be mitigated by storm water drainage initiatives alone, as several factors exacerbate it, such as access to and compliance with effective solid waste management and sewage disposal and increased concretization and development in flood-prone zones. Thus, mitigating flood risk in Mumbai requires coordination between BMC departments such as Development Planning, Solid Waste Management, Roads and Traffic and external agencies.

People Walk through a Flooded Street during Heavy Rains in Mumbai. Source: Manoej Paateel

Vulnerable communities

- It is essential to mainstream the protection of vulnerable communities while addressing flood resilience. Flood risk in Mumbai is not only a technical problem but also an administrative and socio-economic issue.
- Flood resilience for highly vulnerable communities is an intersectional issue across multiple sectors such as storm water drainage, solid waste management, water supply, and housing and development. Lack of coordination in providing access to these facilities increases the flood risk to vulnerable communities.
- The complex development of the city poses an additional challenge to flood disaster management. Adaptive capacities and resilience in communities in flood- and landslide-prone areas need to be augmented and exploited. We need to empower citizens and build capacity with citizen groups. This will help prevent disasters and decentralize disaster management for improved preparedness, enabling a first response to be mounted prior to the government response. Awareness of preventive measures such as efficient solid waste management and infrastructure protection can help prevent disasters in vulnerable communities.

Reimagining solutions for flood resilience

- The scope of storm water drainage needs to be changed to storm water management. It also needs to be expanded beyond engineering measures to encompass social and development aspects aspects by viewing all projects and measures through a climate lens. It is crucial to create structures that incorporate climate and social filters and climate tests in all projects.
- The flood-prone zones of the city are not identified in the proposed land-use maps of Development Plan 2034. Key clauses in the Development Control Regulations (DCR) need to be addressed for improving flood resilience, as the objectives of the Development Plan (DP) and climate-resilient flood risk management conflict with each other.
- In addition to increasing concretization, Mumbai is experiencing higher variability in both spatial and temporal precipitation intensity. Reducing flooding by relying solely on draining the city is not the solution, as the city has additional challenges in the form of low-lying areas and coastal surges. Building a storm water drainage system for 100% runoff is not practical, and business-as-usual scenarios could exact a heavy toll in the form of intense flood damage and economic losses due to flood-prone days. To delay runoff and reduce the overall volume of water flowing into the already strained storm water drains, the demand on storm water systems must be reduced, the key to which is minimizing concretization.
- The existing storm water drainage needs to be supported to reduce—or at least delay—runoff inflow to the system. Natural areas such as green or open spaces, mangroves, water bodies, rivers, and adjoining areas act as shock absorbers in case of intense precipitation, thus retaining runoff and reducing the strain on storm water drainage. It is essential to document the geography of the city, including the natural areas, for a holistic flood management plan. Naturalizing the existing drainage channels will augment the storm-water-carrying capacity of the city through increased percolation and provide buffer spaces for rivers to retain flood waters.
- For flood resilience in Mumbai, natural spaces must be integrated into the storm water management system. Mumbai needs to prioritize blue-green infrastructure where possible to support the storm water system capacity, and gray infrastructure where only conservative engineering measures can mitigate the flood risk. Due to the complex nature of urban flooding in Mumbai, catchment-based analyses are necessary to plan, design, and adopt effective solutions, be they nature-based solutions, gray infrastructure, administrative or multisectoral interventions, or land-use and development planning. The degree of hybridization between nature-based and gray infrastructure can be based on both the contextual requirements and the scope of the intervention needed to address the flood issue.

Constructive data usage for decision-making

- To effectively capture chronic and critical flood hotspots and resolve flooding on a citywide scale, it is essential to fill key data gaps. For example, an accurate contour map and tidal gauges are crucial for assessing precipitation and tidal impacts on flooding, especially in low-lying areas.
- Data must be validated with on-ground observations to plan flood control measures effectively. Simultaneously, multiple data sets need to be integrated to meaningfully assess flood risk. Good-quality data can empower smaller agents, enabling them to help solve urban flooding issues for both communication and usage.

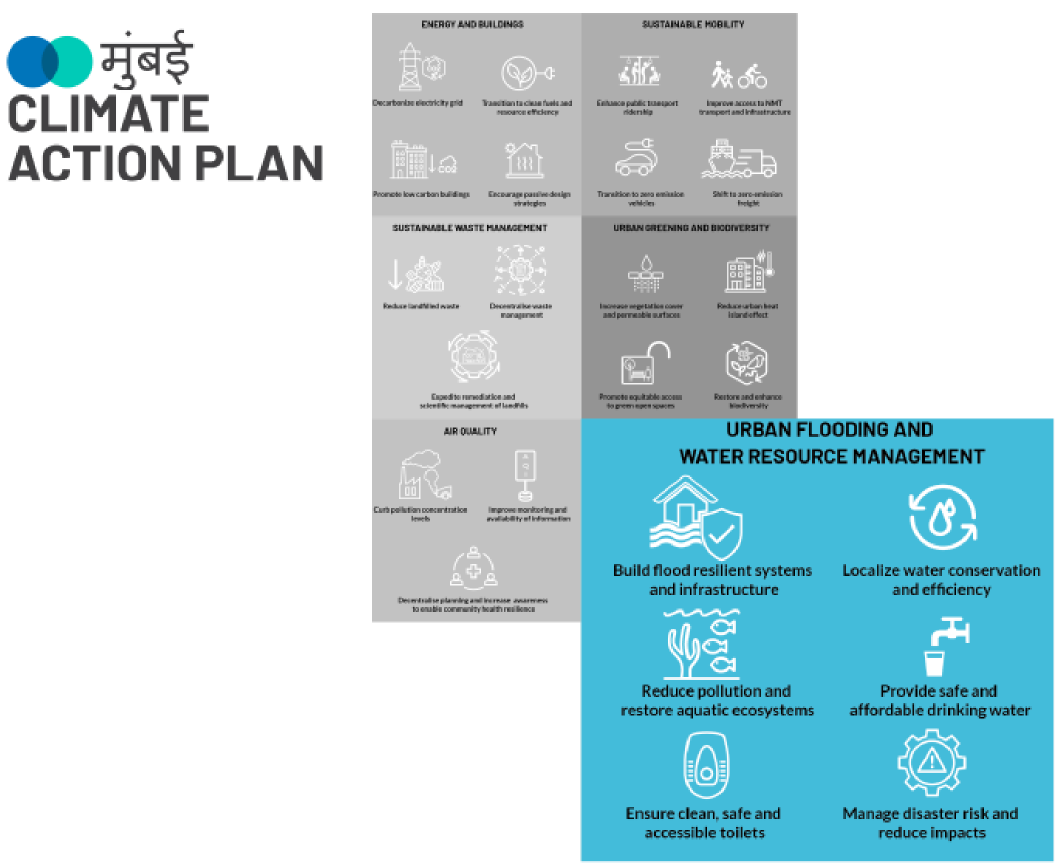
Background and motivation

The increase in urbanization and concretization have increased the overall runoff to Mumbai's storm water drainage by inhibiting the delay, detention, and infiltration capacity of storm water in the city. Further, climate change impacts continue to increase the frequency of intense storms, testing the storm water drainage system in an unprecedented manner.

The Mumbai Climate Action Plan acknowledges the growing flood risk to Mumbai by highlighting Urban Flooding and Water Resource Management as one of the six key action areas. Further, due to Mumbai's unique hydrology and topography, an increased storm surge, especially with sea level rise, is anticipated to strain the storm water drainage system further, as it relies on draining storm water runoff to the sea in low tide periods.

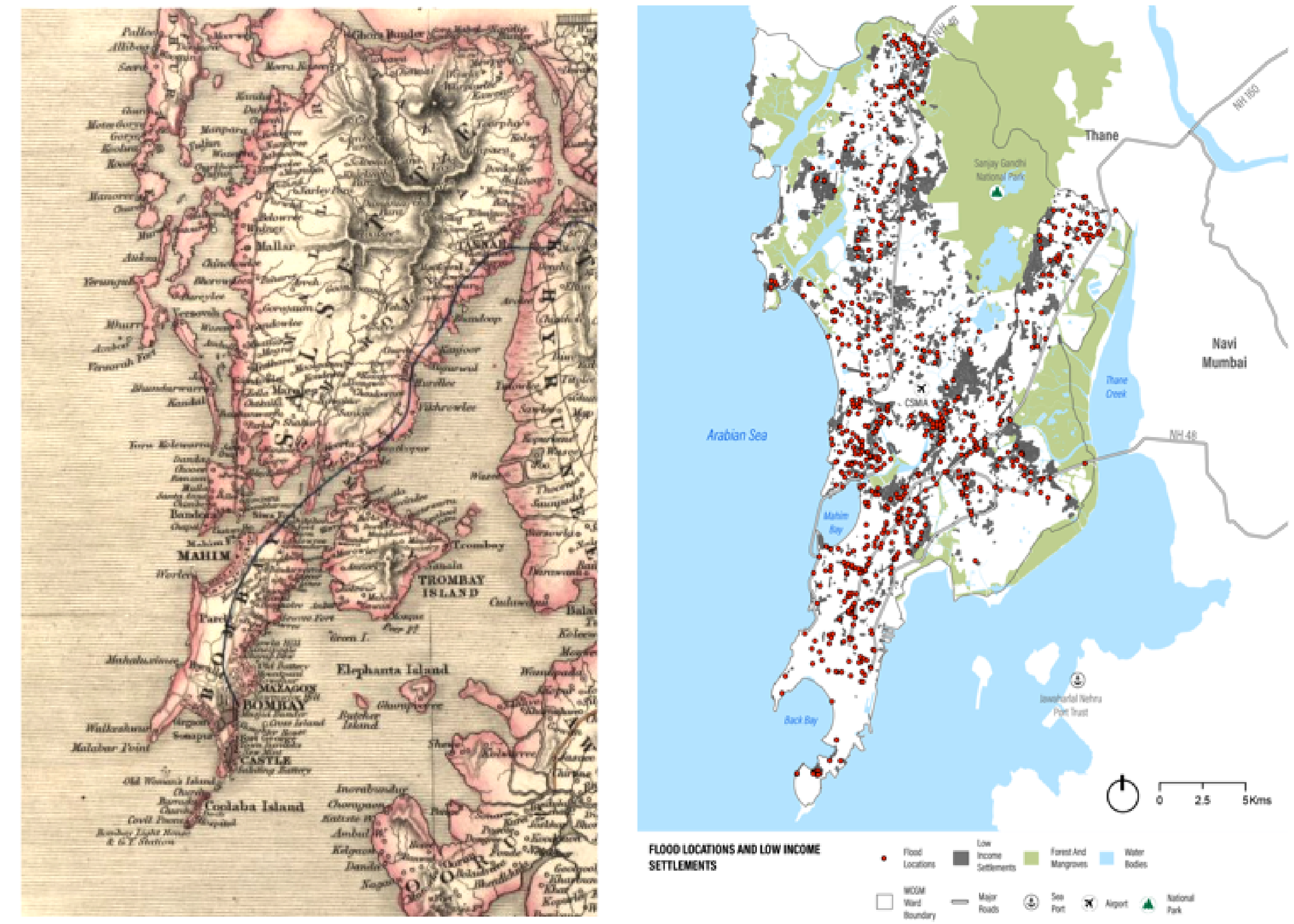
The increasing strain on the storm water drainage over the past decades has escalated the already severe threat to citizens, especially vulnerable communities, and critical infrastructure. The city needs a more comprehensive understanding of the impact of urban flooding and waterlogging events on vulnerable communities. The barriers to formulating a flood risk mitigation strategy for such communities can be understood only through the lens of how such communities are put at risk.

Figure 3 | Mumbai Climate Action Plan – Highlighting 6 Action Tracks Related To Water Sector From 24 Overall Priority Action Tracks



Source: Mumbai Climate Action Plan, Brihanmumbai Municipal Corporation (BMC).

Figure 4 | Historic Map of Mumbai (Left), Flood Hotspots with Low-Income Settlements from Mumbai Climate Action Plan (Right)



Source: (Left) Tate, W. A. 1854. Plan of Islands of Bombay and Salsette, British Library. (Right) Mumbai Climate Action Plan, Brihanmumbai Municipal Corporation (BMC).

It is evident that the urban flooding issue will require solutions in the form of interventions integrated with the existing storm water infrastructure, to delay, detain, and infiltrate storm water while revisiting development planning to mitigate flood risk. Simultaneously, green spaces that counter the urban heat island effect and provide several co-benefits such as enhanced public spaces, quality of life, and biodiversity need to be prioritized. Nature-based solutions for flood management can delay storm water runoff to the storm water drainage system, thus increasing the overall capacity of the storm water drainage of the city, while providing critical co-benefits that the city needs in the face of climate change impacts, increasing urbanization, and population density.

Opening Address

The “Flood Risk in Mumbai” consultative stakeholder workshop started with an opening presentation by honorable Additional Municipal Commissioner, Projects, of Brihanmumbai Municipal Corporation, Mr. P. Velrasu. It was critical for setting the premise of the discussions over the ensuing two days and highlighting the key aspects of the challenges faced by Mumbai city and their specificity. The city’s vulnerability is associated with its high population density, its geographic setting of an estuary with historical land reclamation creating natural low-lying areas that are below mean sea level, and the increasing intensity of rainfall over shorter durations, with almost 40 to 50 percent of the annual rainfall experienced within a day or two. Mr. P. Velrasu highlighted the gravity-based nature of Mumbai’s storm water drainage system, which poses challenges during high tide situations as out of 186 storm water outfalls along the coast of the city, only 6 are located above the high tide level, 135 outfalls are located between the mean sea level and high tide level, and the rest are below mean sea level.

Despite these geographic limitations, the department has managed to overcome these challenges by incorporating the store–delay–discharge strategy, which involves building infrastructure such as holding tanks and pumping stations. However, these are short- and mid-term measures, and a long-term strategy is needed that considers not only the existing demands on the storm water infrastructure system but also envisions building capacity, given the rise in storm surges and cyclones. In conclusion, Mr.P. Velrasu observed that there is immense knowledge and understanding in the field of rainfall prediction and forecasting, but it also suffers from limitations due to certain data gaps. It is crucial to refine these prediction models and make their information actionable to plan for imminent extreme weather events.

The workshop was inaugurated by the guest of honor, former Cabinet Minister of Environment, Climate Change, Tourism and Protocol, Government of Maharashtra, and Guardian Minister, Mumbai Suburban, Mr. Aaditya Thackeray, who shared his thoughts on the flood risk in Mumbai.

He highlighted a very important point about the declining absorption and infiltration capacity of the city caused by the reduction in the mangrove cover, open spaces, and vegetation cover and the increase in concrete surfaces, which raises the question of “where will the water percolate?” Mr. Thackeray emphasized that climate change is not a future risk anymore, but that we are living in it. Extreme weather phenomena such as a record drop in temperature during winters, extreme warm temperatures and series of heat waves during summers, and the increasing intensities of short-duration rainfall events along with frequent cyclones or storm surges are now common in Mumbai. This highlights the need to develop political sensitivity toward climate change mitigation and adaptation measures, resilience capacity, and include vulnerable communities in the process.

> “There is immense knowledge and understanding when it comes to rainfall prediction and forecasting, but it has its limitations due to certain data gaps. It is crucial to refine these prediction models and make this information actionable to plan for imminent extreme weather events.”
>
> **–Mr. P. Velrasu,** Additional Municipal Commissioner Projects of Brihanmumbai Municipal Corporation

> “If Mumbai is facing climate change, the methods of city administration’s operations should also change. Hence there is a need to establish a single planning authority for the city which won’t be planning for the next five years alone but will be strategizing for at least the next 50 years.”
>
> **–Mr. Aaditya Thackeray,** former Hon. Minister of Tourism, Environment and Protocol, Government of Maharashtra

Mr. Thackeray stressed that it is important to apply a climate test to every project that is taken up in the city. Multiple agencies manage the city and provide utilities and services to its citizens. An immense degree of coordination is required among these agencies even while planning and executing the smallest of projects such as constructing a footpath. As Mumbai is facing climate change, how the city is administered should also change. Hence Mr. Thackeray noted that there is a need to establish a single planning authority for the city that will not be planning for the next 5 years alone but will be strategizing for at least the next 50 years.

Session 1 - Updating Technical Considerations For Flood Management In Mumbai

Constructive data usage for decision-making

- The geographic setting of Mumbai is estuarian with a varying gradient characterized by steep upstream hilly terrain and flatter terrain at the foot of these hills and near the coast. Due to this setting, the impact of tidal movement on the city is significant; hence, in technical terms, hydraulic modeling of the entire region as one system is not ideal. There are also data gaps in tide information, bathymetry, and even the flood footprint in terms of volume, extent, and duration; further, much of the topographic information is outdated.

- About 60 automated weather stations installed across the city capture precipitation, humidity, temperature, wind, and other parameters daily, throughout the year at 15-min intervals. However, 27 of these were installed in 2006 and 33 in 2011. Thus, there are no data to understand the trends over the past 20 to 30 years. Yet, these automated weather stations do capture the spatial variability that the city experiences with respect to the intensity of rainfall; for instance, the Kurla area might experience a rainfall event of 20 or 30 cm, while at the same time it might be dry in the Colaba area.

- Robust frameworks for data collection and methods to assess and validate these data sets must be developed, with a focus on climate resiliency. Moreover, it is essential to make these data publicly available, not only for information dissemination but also for utilization by researchers and academicians in data analytics and modeling. Such a push toward accurate analytics will improve planning and adaptive decision-making in the city. Although flood models and forecasting systems may not be the solutions, they can serve as enablers for potential solutions.

Reimagining solutions for flood resilience

- Besides the extreme weather events and geographic setting of the region, the urbanization pattern is another important factor that increases urban flood risks. The concretization of the city has resulted in near-zero infiltration capacity with the runoff coefficient being as high as 1. This not only creates waterlogging but also adds pressure on the city’s storm water drainage system. To add to this, it is conjectured that there is sufficient water in the borewells of the city as they are used regularly by communities, but this water is brackish and non-potable. This is mainly due to low freshwater ingress, which is also a result of concretization, as it hinders fresh rainwater recharge into the ground.

- The city is currently managing to drain out the storm water using engineering solutions such as pumping stations, holding tanks, and drain capacity augmentation. However, there needs to be a shift from short-term forecasts and project planning to long-term strategizing. The cost of converting already scarce spaces in a dense city such as Mumbai to a single use—holding storm water seasonally—is prohibitive. Hence, experimenting through design thinking and re-establishing trust in an approach geared toward multipurpose, adaptive, and flexible use is critical.

- An engineering approach is usually designed around the tipping point of the system. However, significant financial resources are needed for a risk-free solution associated with an extreme event, creating large lock-in periods on this sum, which depreciates over time due to the nature of the operations and the maintenance needs of the associated infrastructure. On the other hand, a nature-based solution or even a hybrid gray-green solution reduces the cost of ownership while addressing the same issue and adding co-benefits to the system. Land being a challenge in Mumbai, planning for multifunctional use of spaces taking into account the economic value of ecology and the environment and factoring in the flexibility of such an approach while assessing the costs and benefits of risks and their solutions is crucial.

- A larger landscape strategy is needed that respects hydrological catchment dynamics and where open spaces are converted into infrastructure to improve public health and the environment. Existing instruments such as the floor space index (FSI) and transfer of development rights (TDR) can be explored to develop financial models that make such approaches feasible.

- It is not feasible for an extremely urbanized city such as Mumbai to rely completely on gray infrastructure or even nature-based solutions to tackle urban flooding. Hybrid approaches can be used; however, establishing desired goals on a short-, medium-, and long-term basis is necessary, and a permanent platform for a consultative process is crucial to aid its planning.

Session 2 - Assessing Vulnerability to Flooding in Mumbai

Vulnerable communities

- Assessment of vulnerability relates to the susceptibility of people to the flooding risk, and their coping and adaptive capacity. It is essential to mainstream protection of vulnerable communities while addressing flood resilience by encouraging a behavioral change from reactiveness to proactiveness to solve the problem at the community level. Whether vulnerability should always be established based on formal eligibility for city services, flood resilience planning, and infrastructure is a question that needs to be discussed.

- The impact on civic provision and infrastructure systems associated with storm water drainage, solid waste management, water supply, and housing during urban floods is highest within vulnerable communities. Acknowledging and working toward this intersectional issue across multiple sectors is important for addressing this vulnerability.

Reimagining solutions for flood resilience

- Existing adaptive capacities and resilience in communities in flood- and landslide-prone areas must be documented, augmented, and exploited.

- Flood management is not only a technical subject but also concerns social science and the environment. The municipal corporation tackles urban flood issues using engineering and technical expertise. It is important to consider the new frameworks of social aspects and vulnerability assessment for long-term city planning.

- Social aspects cannot be mechanically layered onto the engineering approach; engineering solutions must be imagined differently when social and environmental concerns. are taken into consideration.

Session 3 - Implementation of Flood Mitigation Interventions for Mumbai

Development control regulations and planning policy

- The city development plan is not only about the construction and building potential but also about the conservation, preservation, and integration of natural areas. About 700 km of watercourses run through Mumbai, which include rivers, creeks, and major nullahs. According to several reports, buffer zones must be provided along these watercourses. Converting these buffer zones into public spaces would lead to networks of linear parks and micro urban forests that can accommodate the swelling of these watercourses during extreme rainfall events, thus reducing the strain on storm water drainage. Natural areas are the city's shock absorbers, which need to be recognized, surveyed, and protected.

- According to the Maharashtra Regional and Town Planning Act, it is necessary to earmark flood-prone zones within the development plan of the city. The city can then formulate separate regulations for development and building codes that account for the possibility of flooding in these zones and minimize its impact by accommodating for flood-resilience in the planning process or by de-densifying the zones to reduce their vulnerability.

- Reducing concretization within the city, which will also reduce the runoff coefficient by increasing the extent of permeable surfaces, can be achieved by making amendments within the development control regulations (DCR) that incentivize or mandate plot-level interventions. Simultaneously, it is important to treat open spaces as infrastructure for flood mitigation and adaptation, and lay down guidelines for multipurpose use of such spaces within the DCR. Correlating the FSI with the population density in flood-prone zones while assessing the capacities of the storm water drainage infrastructure is important for understanding the stress and tipping point of the infrastructure and planning accordingly.

A systems-thinking approach and interagency co-ordination

- It is important to understand the system to optimally design an intervention, to ensure that the intervention is not overdesigned, which would make it extremely expensive; or under-designed, which would not fulfill the purpose of the intervention. Floods are not only a technical problem but also an urban design problem, which makes data and system understanding key to decision-making. The central guiding principle is implementing blue-green where possible and gray where needed, thereby taking into account the uncertainties and keeping interventions adaptive.

- Urban plans and departments managing the city are siloed and divided. In many cases, interconnected issues are handled by different departments. However, water is always mixing across these different departments: nullahs hold sewage, rivers hold storm water, the sea enters rivers and wetlands, and leaking pipes are recharging our aquifers. These different waters need to be read as a single interconnected waterscape system of the city; they cannot be effectively administered separately.

- Due to the complex setup of the city, catchment-based analyses are necessary to plan, design, and adopt effective solutions, whether these are based on blue-green or gray infrastructure, administrative restructuring, or amendments within development plans and polices. It is important to prioritize blue-green infrastructure where possible to support and reduce the stress on the existing storm water drainage system, and prioritize gray infrastructure where only conservative engineering measures can mitigate flood risks. The degree of hybridization of the infrastructure can be decided based on the characteristics of the system and its requirement and scope.

Session 4 - Flood Management Initiatives By City Administration

Vulnerable communities and disaster response

- The community living in vulnerable conditions is the first line of response in disaster management. Even if the disaster management department responds quickly to a disaster, reaching the location is typically a challenge due to the topography, and narrow and steep lanes within densely populated neighborhoods.

- In addition, communities need to be prepared for, and sensitized to, the risk associated with their habitation. They should be educated regarding the preventive measures to follow so that the risk is not exacerbated.

Constructive data usage and reimagining solutions

- Efficient systems management, forecasting cloud formation and precipitation, and forecasting tidal situations are critical for minimizing the impact of a disaster in terms of volume or duration. It is not possible to completely prevent a disaster, but being prepared for it and having a response plan is important.

- An immense amount of data is available, and app-based information dissemination protocols are in place. However, the data sets are not correlated and explored; they do not talk to each other. Making the data available in the public domain is another crucial aspect of how researchers and academics can utilize this data and develop some interesting insights for the city's decision-makers.

- In spite of the large data sets in place, some critical gaps are present that must be filled if the system is to be understood. Satellite images and models suggest that Mumbai is not only a coastal city but also a sediment sink. This could be significant for addressing the city's flood risk, but there is no data set that validates the suggestion. Understanding the overall geology, tidal movement, and bathymetry of water bodies is critical while planning flood mitigation for a coastal city such as Mumbai. The current deepening of the Mithi River, especially at the mouth, where there is tidal activity, can impact the bed of the river because of headward erosion caused by the lack of any dampening effect, thereby pushing the extent of the tidal effect further upstream. The runoff coefficient considered for designing storm water infrastructure needs to be rechecked, especially to assess whether the city's soil has the capacity to absorb water, given the land use and development changes that the city has witnessed.

- Disaster management is considered to manage discrete events, but the perpetual disaster within the city is pollution of water and soil that impacts the health of its citizens. Pollution has worsened the risk of floods and complicated the implementation of flood mitigation measures.

Session 5 - Citizen and City Stories

Vulnerable communities

- The city comprises both its citizens and the city administration, and hence the responsibility for resilient and sustainable development must be shared by both. It is equally important to empower citizens, use their existing capacity, and build it further to decentralize disaster management and preparedness, as the citizens are the first respondents in a disaster. To establish this responsibility and leverage this capacity, a constant dialogue between the administration and citizens is crucial.

- Rehabilitation of vulnerable communities within the time stipulated by the High Court is a challenge due to various factors such as fragmented land ownership, the involvement of various government departments (city and state), and the legal status of the settlement, leading to gaps in protecting project-affected people. Hence, a comprehensive and consultative post-disaster rehabilitation plan needs to be considered where citizens are not treated as project-affected people but as project-invested people.

Reimagining solutions for flood resilience

- The urban population in India is expected to grow at a much faster rate in the coming decades, mainly due to migration. The migrants may not be able to afford land in the city. This trend is an opportunity to rethink cities as incubators or employment opportunity creators.

- Communicating to the citizens the efforts put in by the city administration in addressing flood risk issues is critical, as many actions and considerations behind those actions are not visible.

Session 6 - Financing Flood Mitigation Interventions And Measures

Case studies of financing flood mitigation interventions

- Sources of finance for flood mitigation projects vary depending on their scale. The possible sources are central government funds, funds from taxes levied by the municipal corporation, green bonds or commercial banks, or even international development funds. The session provided examples of these methods:

  Municipal-corporation-led financing instrument – Austin introduced storm water drainage charges on the land parcels along with its property taxes. Based on the infiltration capacity of the land parcel, a storm water management discount was sanctioned to the landowners.

  Pool of funds – Tokyo introduced the concept of green bonds to attract investments for climate-change-related initiatives, with 44% of the proceeds earmarked for flood impact reduction projects.

  Public-private partnership (PPP) – Bilbao partnered with the landowners of an industrial area to redevelop the site, thereby financing the flood mitigation project.

  The session also featured a group exercise in which participants from Mumbai's agencies and departments, academia, urban planners and designers, and civil society organizations discussed possible ways to raise finance for the strategies proposed in the Mumbai Climate Action Plan. The main takeaways from the discussions are as follows:

- **Preferred sources of finance:** Most of the stakeholders suggested using the Municipal Budget of Mumbai for financing, but some also highlighted PPPs (a proven model in India) and corporate social responsibility (CSR) funds.
- **Critical enabling factors and stakeholders:** Participants also mentioned that the involvement of communities, politicians, and real estate developers is important.
- Participants mentioned that the critical barriers to implementing flood mitigation measures are (1) encroached areas, especially on the banks of rivers and natural drainage systems; (2) the capacity of local authorities to undertake nature-based solutions; and (3) compact development and the lack of open spaces. These aspects delay the overall implementation and finances as well.
- Involving landscape architects/urban planners in all the project preparation phases, including in engineering projects.
- Enhancing private sector involvement and policy interventions for the transfer of development rights/open plots to protect flood plains.

Closing Note

The workshop was concluded by the former Municipal Commissioner, Brihanmumbai Municipal Corporation, Mr. Jairaj Phatak (IAS retired) and the former Chief Secretary, Government of Maharashtra, Mr. Ajoy Mehta (IAS retired). In his concluding note, Mr. Phatak highlighted some important points about how urban floods differ significantly from rural floods, where the urbanization itself increases the peaks of floods from 1.8 to 8 times, as there is not enough space for water to recede. Moreover, Mumbai and Singapore both receive 2,500 mm of rainfall, but Singapore experiences this volume spread across the year, whereas Mumbai receives it within a span of four months. The drainage capacity that must therefore be designed to accommodate these volumes over such short durations will be active for only four months and subject to abuse from encroachment or dumping of waste the rest of the year. Typically, a city can cope with around 10 percent of its annual rainfall in a day. For an extreme rainfall event, preparing a system and investing to increase the capacity to meet a 1 in a 100 year event is not rational. A city can plan to control and mitigate the possibility of a flood, but it cannot nullify its impact, said Mr. Phatak .

Mr. Ajoy Mehta emphasized that urban flooding is a human-made disaster that requires a human-made solution. There is a dilemma within the city administration about budget expenditure, especially for tackling urban floods, as several sectoral demands compete for the same funds. A huge economic loss is associated with floods, but a large portion, or rather the larger economic impact, is borne by the urban poor as it impacts their living conditions and their livelihoods. Mr. Mehta highlighted four dimensions of failures in adapting to flood risk: (1) planning disaster, when flood plains, flood-prone areas, and demographic and socioeconomic impacts are not taken into consideration in the planning process; (2) execution disaster, when there is a failure in the plan due to lack of local level understanding, sub-standard execution, and poor project management; (3) operational disaster, when the system fails due to lack of operation and maintenance checks; and (4) perception disaster, when critical infrastructure such as transport, power, and communication are not treated as must-run systems. He further emphasized that flood control is fundamentally a joint effort that spans a wide range of capabilities, from the person preparing the development plans to the person operating the pump in the waterlogged location. It has to be innovative and equally an on-ground exercise for successful execution.

"A city can cope with around 10 percent of its annual rainfall in a day. For an extreme rainfall event, preparing a system and investing to increase the capacity to meet the standards of 1 in a 100-year event is not rational. A city can plan for controlling and mitigating the possibility of the flood, but it cannot nullify the impact of its occurrence."

–Mr. Jairaj Phatak
IAS retired, former Municipal Commissioner, Brihanmumbai Municipal Corporation

"Flood control is fundamentally a joint effort; it encompasses both the person preparing the development plans and the person operating the pump at the waterlogged location. It has to be innovative and equally an on-ground exercise for successful execution."

–Mr. Ajoy Mehta
IAS retired, former Chief Secretary, Government of Maharashtra

APPENDIX: 1

Synopsis Compilation

Dr. Subhankar Karmakar

Professor and Head of the Environmental Science and Engineering department, faculty member at DST-Centre for Excellence in Climate Studies and the Centre for Urban Science and Engineering, Indian Institute of Technology, Mumbai

BIO: *Dr. Subhankar Karmakar is currently a Professor and Head at the Environmental Science and Engineering Department, and associated faculty member in the DST-Centre of Excellence in Climate Studies, and the Centre for Urban Science and Engineering at Indian Institute of Technology Bombay. He obtained his PhD from the Indian Institute of Science, Bangalore, India. He worked as a Post-Doctoral Fellow at the University of Western Ontario, Ontario, Canada. Further, he received a BOYSCAST Fellowship from the Government of India to pursue research on Ecological Modelling at Duke University, North Carolina, USA. His primary research interests are in Environmental Systems Analysis, Uncertainty Modelling, and Risk-Vulnerability Analysis to Climate-induced Natural Hazards. Some of his recent research contributions include understanding the dependence of Indian summer monsoon rainfall extremes on temperature, mapping disaster vulnerability for densely populated coastal urban areas, mapping agricultural vulnerability at a national scale, and developing lifecycle-based decision support tools for selecting wastewater treatment alternatives. He has published over 100 international journal papers, 6 book chapters, and several international conference proceedings. He received the Professor S. P. Sukhatme Excellence in Teaching Award and Research Excellence Award at IIT Bombay in 2019 and 2020, respectively.*

Synopsis

Coastal regions worldwide are those regions that not only house complex transitional ecosystems but are also significantly threatened by changing climate conditions. These regions are increasingly facing twin challenges related to water and flood management. In the context of rising floods and other water-related disasters, mainly due to rapid urbanization and climate change, we propose adopting a socio-technocratic approach to sustainable adaptation and management. This is a holistic approach to water and flood management driven by community ecosystem-centered planning and development. Among coastal cities, India's densely populated Mumbai city experiences a deluge of floods almost every year. The vulnerability to floods is severe due to its location in the southwest monsoon belt and the western coast, exposing it simultaneously to extreme monsoon rainfall and high tide impacts. Moreover, expanding urban sprawl, slum encroachments, lack of drainage systems, and lackadaisical implementation of flood management strategies have aggravated flood-associated problems. The water-related risk in Mumbai has been identified through the DPSIR (Drivers–Pressures–States–Impacts–Responses) framework. Following this, a Programme of Measures (PoM) has been recommended that is aligned with the United Nations' Sustainable Development Goals (SDGs), the Sendai Framework for Disaster Risk Reduction (SFDRR), and the National Water Mission (NWM). The measures include blue-green infrastructure, urban water, sanitation and hygiene (WASH), and slum rehabilitation, which may be implemented successfully through strong water governance.

The recommendations proposed include a periodic update to hazard, vulnerability, and risk mapping (as defined by AR5 & 6 of IPCC, 2014 & 2022) along with multiple positive interventions for blue-green infrastructure, WASH, and slum rehabilitation managed by strong water governance. The outcomes of the studies conducted at IIT Bombay may help stakeholders and policymakers formulate and implement sustainable water and flood management plans for improved disaster resilience over coastal and transitional ecosystems. The overall aim of the workshop is to bring to the table thought-provoking insights to potential future researchers and water professionals.

Dr. Tune Usha

Scientist-G at National Centre for
Coastal Research (NCCR),
Ministry of Earth Sciences (MoES)

BIO: *Dr. Tune Usha has been working as Scientist-G in National Centre for Coastal Research (NCCR), Ministry of Earth Sciences (MoES) and in MoES since 1999. Previously she worked in the Institute for Remote Sensing, Institute for Ocean Management, Anna University. She has 25 years of experience in the fields of geoinformatics, satellite data processing, coastal zone management, coastal hazards and vulnerability mapping & modeling, and capacity building. Dr. Usha has contributed significantly toward developing applications and tools with societal and ecological implications such as GIS-based information systems for critical habitats, multi-hazard decision support systems for coastal areas, modeling and mapping coastal hazards such as tsunamis, storm surges, oil spills, climate change, operational flood warning systems, and marine spatial planning. These tools are being used by state governments in their disaster mitigation and management operations.*

Synopsis

As extreme precipitation events, driven by warming temperatures and changes in the monsoon, are on the rise in India, and in line with the country's commitment and the need of the hour, the Ministry of Earth Sciences (MoES) and BMC have developed the state-of-the-art Integrated Flood Warning System (IFLOWS) for Mumbai to enhance its resilience.

The capital of the state of Maharashtra, Mumbai, a megapolis and the financial capital of India, has been experiencing floods at regular intervals, including the recent floods of August 29, 2017, that brought the city to a standstill in spite of its extensive natural and storm water drainage systems. The date July 26, 2005, is probably etched in the memory of every Mumbai citizen; on that day, the city received 94 cm of rainfall, a 100 year high, in a span of 24 hours, which paralyzed the city completely. Anticipating floods before they occur allows for precautions to be taken and people to be warned so that they can be prepared in advance for flooding conditions. In a bid to aid the mitigation activities of the flood-prone city, the MoES along with BMC decided to develop IFLOWS-Mumbai, using the in-house expertise available in the MoES institutes: India Meteorological Department (IMD), Indian Institute of Tropical Meteorology (IITM), National Centre for Medium Range Weather Forecasting (NCMRWF), and National Centre for Coastal Research (NCCR).

I-FLOWS is an innovative approach to flood risk mapping based on the Sendai Framework for Disaster Risk Reduction, leveraging weather models, field data, numerical flood modeling, and Web GIS technologies. I-FLOWS comprises seven modules, and as elevation and river bathymetry are essential datasets for accurately capturing the terrain conditions, extensive bathymetry data collection was undertaken in the Mithi, Dahisar, Oshiwara, Poisar, and Ulhas rivers, lakes, and creeks. The system incorporates weather models from NCMRWF and IMD, field data from the extensive rainfall network stations set up by IITM, thematic layers on land use, infrastructure, etc. Based on inputs from weather models, hydrologic models are used to transform rainfall into runoff and provide inflow inputs to river systems. Hydraulic models are used to solve equations of fluid motion to replicate the movement of water to assess flooding in the study area. Hydrodynamic models and storm surge model are used to calculate the tide and storm surge impacts on the model domain.

The system houses flood inundation models that operate in forecast (3 days in advance) and now cast mode using field datasets. The system works in near-real-time mode using actual rainfall data collected from the field instrumentation. A Web-GIS-based decision support system has been built to calculate the vulnerability and risk of elements exposed to flood. The beta version of the system was tested by BMC in the monsoon of 2020. The system is presently in operational mode and will be handed over to BMC and maintained at IMD-Mumbai.

Following this, a programme of measures (PoM) has been recommended that is aligned with the UN Sustainable Development Goals (SDGs), the Sendai Framework for Disaster Risk Reduction (SFDRR), and the National Water Mission (NWM). The various measures include blue-green infrastructure, urban water, sanitation and hygiene (WASH), and slum rehabilitation that may be implemented successfully through strong water governance.

Mr. Ravindra Punde
Architect and Urban and Regional Planner, Founder Trustee and Director of the School of Environment and Architecture, Mumbai, co-founder of the Landscape and Planning Practice Design Cell.

BIO: *Ravindra Punde is an Architect and an Urban and Regional planner. He studied architecture at the Academy of Architecture, Mumbai, and urban and regional planning from the School of Planning and Architecture, New Delhi. He is the co-founder of the landscape and planning practice Design Cell, which works from Gurgaon and Mumbai. Ravindra has extensive experience in master planning, landscape, and urban projects. He has successfully led several national and international competitions for Design Cell, which under his leadership has maintained a strong commitment to environmentally and culturally sensitive designs. His practice extends in many parts of India, where he has led teams to design and execute large and complex projects. He has taught at the School of Planning and Architecture, Delhi, and been the Principal of the Academy of Architecture, Mumbai. He is a Founder Trustee and Director of the School of Environment and Architecture, Mumbai.*

Synopsis

Of Land or Water

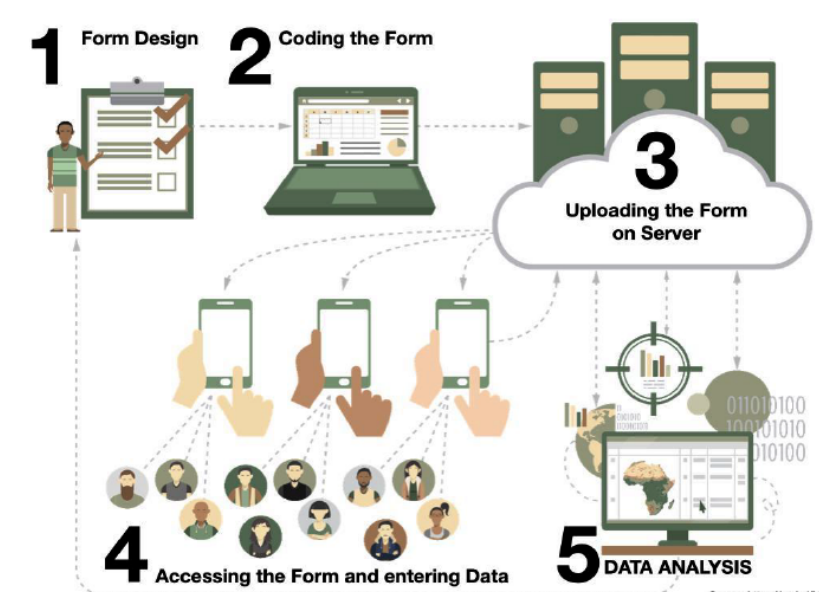
The city of Mumbai rests on a ground shaped by the actions of the water and land over millennia. Human occupation has "reclaimed" and transformed this landscape along its generous coastline since prehistoric times, and this is witnessed along the rivers in the city as well—or what remains of them today. The current form of practice of city-making along with an increase in the intensity of rain, tidal action, and the ever-looming climate change have made our cities and settlements along the coastal belt more vulnerable to natural and man-made disasters. The IPCC report quantifies the rising sea level for the year 2050 as 1 meter higher than the current mean sea level. With the current practices and urban systems as they are, the issues of flooding due to heavy rains and tidal action will worsen in the times to come. In the face of these emerging environmental conditions, the School of Environment and Architecture (SEA) in Borivali aimed to sensitize students toward, and help them develop an understanding of, the complexity of climate, terrain, and built form. It conducted a studio that dwelled on this phenomenon of flooding in and around the "R ward" and what kind of resilient urban form should emerge out of a city that faces extreme vulnerability owing to tidal action, ground water, flooding, and rising sea levels.

Method

Methodologically the studio began with manually understanding the on-site natural and man-made conditions of flooding in the area. In order to understand terrain, students were introduced to and worked with a Geographic Information System (GIS) software; the QGIS software was used to map attributes including contours, built form, infrastructure, soil type etc. A careful study of the unaltered terrain that QGIS generated brought into focus the lowermost contours in various micro-zones, which would be ideally expected to take the water towards the creek. The identification of the major 'ridges' and 'valleys' formed by the terrain opened up the discussion around the various watershed systems.

Simultaneously, the studio engaged in ethnographic fieldwork to identify and verify flooding spots acquired datasets from the Urban Design Research Institute (UDRI), to understand the phenomenon of flooding by interacting with the people who inhabit these spaces. Human-centric measurements of 'ankle, calf, knee, waist and shoulder' level of flooding along a certain duration of time ranging from an hour to two days along the span of the last two decades was used to piece together this phenomenon over time. The ongoing fieldwork data overlaid on terrain data indicated points of conflict, and man-made interventions that did not allow the water to run off, thus causing flooding. This required factoring in of the existing water infrastructure of the city including drain capacities, outfall data, highest rainfall, tidal action, change in the mean sea levels, and the alterations done to the natural topography of the site became the main parameters along with the type of settlements in these sites and the age and type of construction of the buildings. Some of the narratives and observations from the site identified issues of inadequate storm water drainage capacity, swelling of the river in lower contours thus flooding the settlements around, concretization of the rivers, incorrect camber of the roads, new roads built incrementally on top of each other hence housing societies going lower than the road, blocking of the river due to construction debris and garbage etc.

Figure 5 | Methodology of Data Collection and Analytics



Source: School of Environment and Architecture, Mumbai.

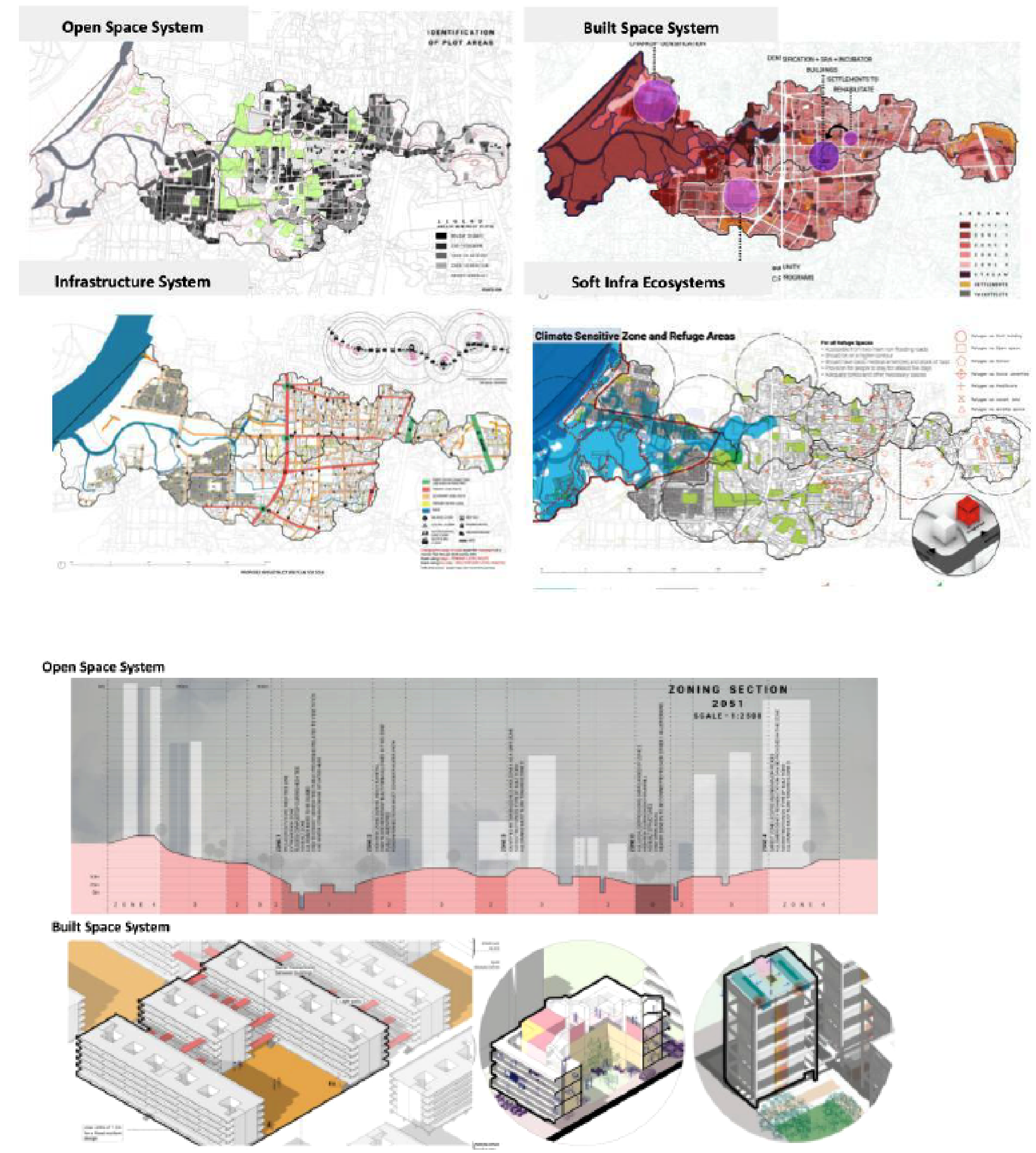
Figure 6 | Analysis of Flooding using Ethnographic Documentation and GIS Datasets

Source: School of Environment and Architecture, Mumbai.

Simultaneously, to study built form, students georeferenced historical maps and traced the transformation of the ways of the river and the history of occupation and habitation along with policies that generated the specific urban form. Various stakeholders from the field were invited to the studio, including locals, architects and urban planners, administrators (R ward corporators), and politicians to understand how each of these groups looked at the problem of flooding, and to open up discussions on any strategies that they had undertaken or that were in the pipeline. Here, through presentations and directed questions, the needs of these citizen groups and administrative bodies were tallied against their aspirations. Larger questions that then emerged from these interactions were based on the diverse aspirations of the citizen groups vs. the elected representatives vs. the administrators.

Ideas such as notions of justice for all, equal rights and access, access to development, scales at which the infrastructural interventions of the city are envisioned, alternate systems of water management, and draining emerged during the discussions. Further negotiating with the vulnerability caused by water and what are the varied imaginations of the urban form of a resilient city that responds to all the concerns were put as questions to the participants.

Figure 7 | Some of the Proposed Short-Term, Mid-Term, and Long-Term Spatial Design Strategies



Source: School of Environment and Architecture, Mumbai.

Figure 8 | Stakeholder Discussion and Dissemination Workshops

Source: School of Environment and Architecture, Mumbai.

Outcomes

The studio proposed short-term, mid-term, and long-term spatial design strategies for built form, open spaces, and infrastructure and suggested policy changes that would address the question of a resilient urban form. These strategies focused on the following:

- Open space systems that could percolate, hold, and create a route for the water.
- Built form strategies depending on the vulnerability index of the location of living and working spaces. The strategies of densification by rehabilitation and relocation were explored in order to release pockets of low-lying, flood-prone, vulnerable parcels of land.
- Infrastructure strategies as a whole to create a network that would allow right of way for water.
- Soft infra ecosystems to operationalize and set out policy frameworks for the new urban form of the city.

Mr. Raj Bhagat
Senior Program Manager
(Geo Analytics for Sustainable Cities & Transport Program) at WRI India

BIO: *Raj Bhagat works as a Senior Program Manager - Geo Analytics for Sustainable Cities & Transport program at WRI India, based in the Bangalore office. He supports projects associated with Urban Development, Water, and Transport. Prior to joining WRI, Mr. Bhagat worked as a freelancer for projects related to GIS, remote sensing, statistical modelling, and web development with multiple clients. Mr. Bhagat holds a B.E in Civil Engineering from St. Xavier's Catholic College of Engineering (affiliated to Anna University) and an M.Sc. in Geo-Informatics and Earth Observation from the Indian Institute of Remote Sensing (Indian Space Research Organization) and the University of Twente, The Netherlands. Apart from work, Mr. Bhagat immerses himself in multiple research areas like big data, artificial intelligence, GPU computing, and geophysical phenomena like plate tectonics and gravitational anomalies.*

Synopsis

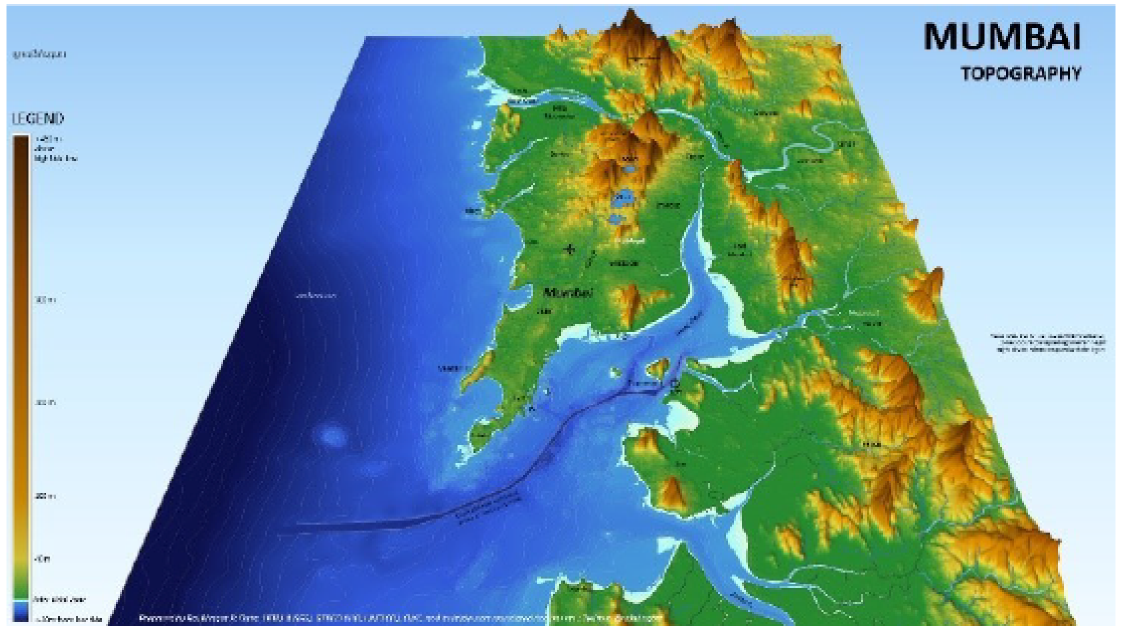
Introduction

Mumbai, because of its unique topography and extreme amount of rainfall faces lots of urban flooding. Being the financial capital of India, Mumbai's built-up area rapidly grew while reclaiming the seas and inter-tidal zones that were once surrounding it. These have aggravated the issue of flooding the city. Though there have been very specific severe incidents of flooding like in 2005, the city faces stagnation and minor flooding almost every year. Many flood simulation models exist in both open and proprietary domain. Though these have been widely used in the academic circle, its level of application has been relatively lesser in India. The application of such models has also been limited to short-term flood forecasting rather than planning. If cities like Mumbai have to solve issues around flooding, they need to apply flood simulation models to build not just different rainfall and tide scenarios but also incorporate different solutions into the models so that their effectiveness could be examined.

Flood Models

One of the biggest difficulties in applying flood models at urban scale in the Indian context is with data. If a model has to be successfully built and run, it will require a lot of data related to topography, built environment, tide-related information, natural landscapes, natural and artificial storm water drains, rainfall information, ground water data, information related to design specifications of buildings, and adoption of various measures in campuses etc. In many cities across India, these datasets have been scarce, and it has always been difficult to make them talk to each other as they are typically created by different agencies for different purposes. A model's success is largely dependent on these datasets, and it becomes imperative that we need to build these datasets initially.

Figure 9 | Virtual Mumbai, A Topographic Illustration



Source: Raj Bhagat.

Agencies that build successful models should not limit them to short-term flood forecasting. With respect to its limitations as well as applications, short-term flood forecasting might not be a wise idea. Such models are heavily dependent on the success of the forecasts provided by weather models, which themselves have quite a bit of errors and might not be reliable all the time. On top of the error related to weather forecasts, data-related errors and assumptions in the hydrological and hydraulic components of the models would further complicate the results. Even if models do get short-term forecasting right, it would have limited application, such as evacuation or other emergency-oriented actions. For a city, it does not matter whether it would flood in July or August, it should be prepared for either event in terms of the quantity and intensity.

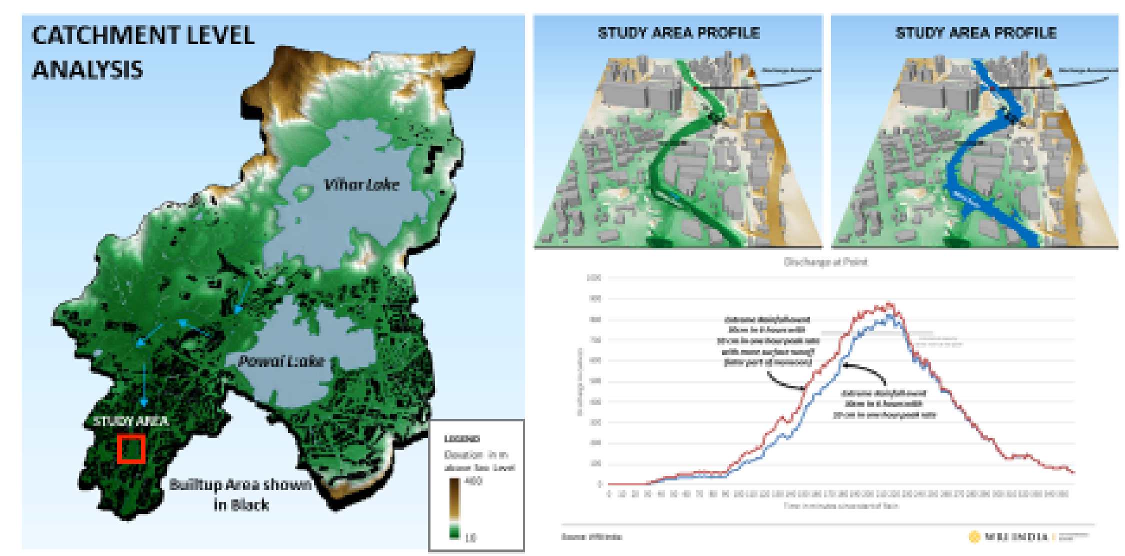
This means that the city should focus on flood hazard mapping for planning purposes and build scenarios that assess the existing infrastructure, its ability to help in flood issues, and the effectiveness of the newly proposed interventions. Flood simulation models should integrate precipitation scenarios, tide and storm surge scenarios, soil saturation information, and the groundwater scenario. They should also integrate business-as-usual gray infrastructure situations and the proposed interventions into them. Flood hazard maps with different return periods should be used for zoning and other regulations. Street side and other storm water drain designs should integrate catchment-level assessments while designs are being built rather than adopting arbitrary rainfall rate numbers.

Way Forward

Mumbai should start building a strong database so that its own topography and geophysical processes associated with the city can be studied. This implies that it should build more accurate and updated topography maps; add more sensors to measure tide, rainfall, water flow in rivers, and ground water levels; and conduct regular assessments of buildings, roads, and other forms of built-up areas. The datasets thus created should also be open to the public.

It is unlikely that only a select few institutions would be able to provide the solutions that the city needs. Solutions might come from anywhere, and the city should encourage and enable such possibilities. Considering that the city faces six heavy rainfall events, five very heavy rainfall events, and four extremely heavy rainfall events every year, the city and institutions interested in helping it should focus on scenario-building for different amounts of precipitation (spatiotemporal combinations) rather than on short-term flood forecasting.
The streets of the city and every other solution or intervention should be assessed and designed with the help of insights obtained both at granular and catchment levels. Though the current scope of flood models has been largely limited to the engineering, hydrological, and financial dimensions of floods, institutions should also integrate and assess the social aspects of proposals and interventions.

Figure 10 | Catchment Level Analysis for the Section of Mithi River



Source: Raj Bhagat.

Ms. Kavitha Iyer
Author, Independent Journalist

BIO: *A journalist for 22 years, Kavitha Iyer has spent most of her career writing about Indians living on the margins: slum dwellers, landless laborers, small farmers, indigenous communities, and women. Her first book, Landscapes of Loss: The Story of an Indian Drought, was published in 2021 by HarperCollins and won the Tata Literature Live Best First Book 2021 award in the nonfiction category. Ms. Iyer was a 2021 fellow of the Logan Nonfiction Program and is currently reporting and writing her second book, tentatively scheduled for a summer 2023 release.*
As an independent journalist, Ms. Iyer writes for Article-14, People's Archive of Rural India, and other publications.

Synopsis

In my very first year as a reporter, in July 2000, I found myself stuck on LBS Marg, in Kurla, not far from the Kalpana Talkies junction that you might remember from news photographs taken in 2019 of children hurling themselves off the top of a BEST bus to swim on the flooded road.

In 2000, the BEST bus I was traveling in could go no further; the water level was too high. After waiting for a futile hour, I alighted with everyone else and walked about a kilometer on the raised median or divider, holding the soaking wet shoulder of the stranger ahead of me for support, flood waters swirling around my waist.

I now live just off LBS Marg, in Kurla. This last monsoon, I found myself stuck in my car one rainy day on this memorable stretch of road. I was at more or less the very same place where I had walked as a terrified cub reporter, and more or less the same place famously photographed in 2019. This time, waist-high flood waters swirled around some yellow-black barricading erected by the BMC. This is one of the dozens of points on this arterial road that remain mysteriously barricaded for months on end.

In 22 years as a reporter, I have on numerous occasions walked through a flooded stretch of LBS Marg, in Kurla, to post social media updates. I remember what senior planner Sulakshana Mahajan told me, in 2017, that the only solution for Mumbai is to put all of its infrastructure and operations in the hands of experts—"like a patient in an ICU where nobody but the most qualified doctors are allowed to touch any part of the patient's body"—remove political interference and politically expedient decision-making entirely, and work step by step on a masterplan that will hold good for the next 50 years.

Any Mumbaikar would wager a pretty penny that such radical ideas would never materialize, I wrote cynically. Seen from the vantage point of a reporter, there is a persistent lack of accountability in urban governance in general and with flood proofing or mitigation plans in particular. The same spots flood year after year, additional spots have been added to that list, and nobody is willing to concede that mitigation plans that cost crores need to be honestly reassessed.

Every Project Must Be Honestly/Fairly Audited and Assessed

In my years as a city reporter, I wrote extensively on various agencies' projects that were meant to improve the city's flood resilience. After the 2005 deluge, all of us began to report on Brimstowad, which was at the time delayed by 12 years. A project design document originally dated 1993 was to be updated and implemented. Elements of this project, now recalibrated and referred to as envisioned in 2005, were being constructed even in 2021. When I last checked, in the summer of 2021, a contractor was being finalized for the Mogra suburban pumping station.

This prompted me to check on other things I had reported on: a micro tunneling solution to connect a storm water drain with a larger sewer line at various locations, the grand Mithi River rejuvenation project, extensive recommendations to protect the Sanjay Gandhi National Park from further construction activity, retention basins for flood water, contour maps for a flood modeling system, a Mumbai Watershed Council. My findings were incredible: Many, too many, of these proposals and plans remained incomplete, and/or were never assessed and audited for efficacy.

That this lack of accountability persists in the year 2022 boggles the mind—for urban flood management is no longer about looking at rising concretization and rising runoffs, but increasingly it is about rising seas, unpredictable climate patterns, and more extreme climate events. Today, to sit back and split hairs over whether predictions made about the rising seas are precisely true or only vaguely true is just hubris.

How Floods Affect the Most Vulnerable

As we prepare to estimate the size, significance, or magnitude of urban flooding, we must also see the effects of flooding beyond the immediate loss of life and property. A humane and inclusive plan for the coming years must look at business losses for the poor whose livelihood may be impacted by flooding and impacts on health/sanitation for the most vulnerable communities living in informal housing.

In 2000, my editors asked me to locate Mumbaikars worst affected by the flood that day. It would be my first visit to the slum we now know to visit each time it floods: Kranti Nagar's residents will be evacuated from home to their school. In later years, I had the opportunity to become very familiar with fellow Mumbaikars from slums across the city: Wadala, Mankhurd, Kurla, Chembur, Kandivali, and Malvani. The floor in some houses would be pockmarked with wet bubbles when the swamp below was too damp, there were accounts of inaccessible toilets during a flood, all manner of disease in weeks after a flood, water contamination, loss of schoolbooks and schoolbags, and worse.

I find less and less news coverage of these communities' lived experience of flooding, but the impact that floods have on them is not limited to the physical waterlogging and drainage issues.

Those Just Outside Mumbai Are Stakeholders Too

The same lack of accountability has also begun to haunt Mumbai's satellite towns. The townships along the Kalu, Ulhas, Waldhuni, and Bhatsa rivers are all populated by Mumbaikars.

Nobody calls themselves a *Vithalwadi-kar* or a *Titwala-kar*. The Mumbaikars who live in these dormitory towns are witnessing the same things I wrote about Mumbai in 2002, 2003, 2004, 2005, 2006: a spurt in construction activity, the urban rivers ravaged by unplanned urbanization, encroachments, illegal sand dredging, dumping of effluents, and construction activity on their floodplains.

It is inconceivable to me that it can be business as usual in municipal offices in Mumbai and any of these cities. Mumbai's flood mitigation plans to my mind must obviously include plans for the satellite towns.

Ms. Sucharita Roy
Urban and Regional Planner, Development Expert, and Independent Consultant

BIO: *An urban and regional planner and a development expert, Ms. Roy has experience of working in research and for philanthropic and international implementation agencies operating in the inclusive sustainable development domain. She is passionate about finding innovative, people-centered solutions for improving quality of life and accelerating climate action on the ground. She has expertise in strategic planning and advisory services, impact assessment, action research, and program management and has worked in sectors such as climate adaptation, decarbonization, disaster risk reduction, green affordable housing, water and sanitation, livelihoods, poverty alleviation, and migration.*

Synopsis

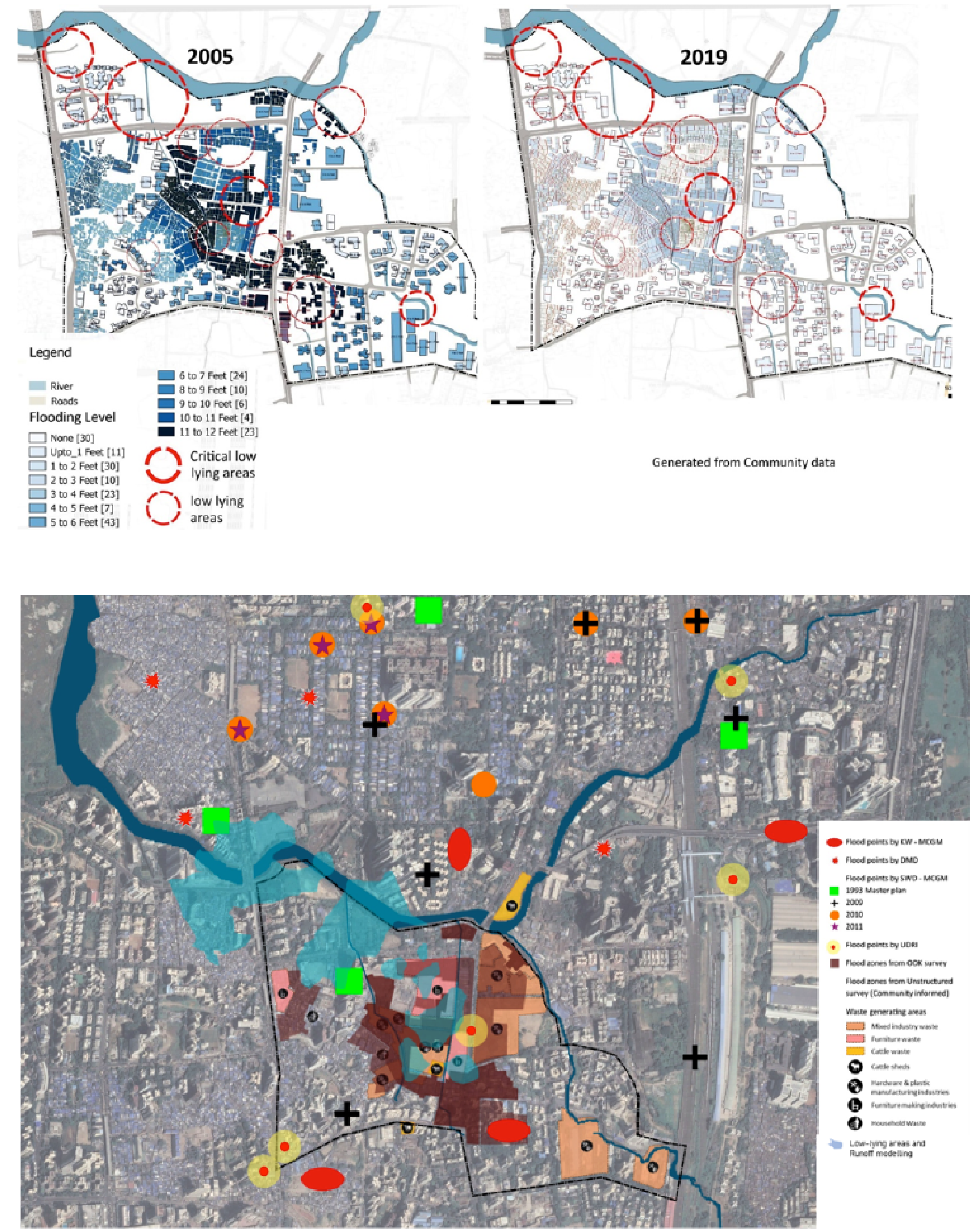
Urban Flooding: Assessment of the Vulnerabilities and Risks and Role of Citizen Groups

Urban floods have today become one of the most significant disasters impacting many cities in South Asia and across the globe. While a disaster is defined as a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability, and capacity, complex urban-scale assessments often fail to capture the learnings from the ground or the inherent capacities of the local communities and the ecosystem to cope with the disaster.

A microlevel study of an electoral ward 62 in the K West administrative ward of a suburban district of Mumbai is a case which proves the complexities of a typical burgeoning urban area. The study was undertaken to assess the hazard, vulnerability, and risk in the identified ward and identify the preemptive, mitigative, and restorative measures which can help in reducing the risk for the affected communities. An electoral ward was chosen over an administrative ward to explore opportunities to develop a roadmap for local management of urban floods through aggregation of locality improvement funds.

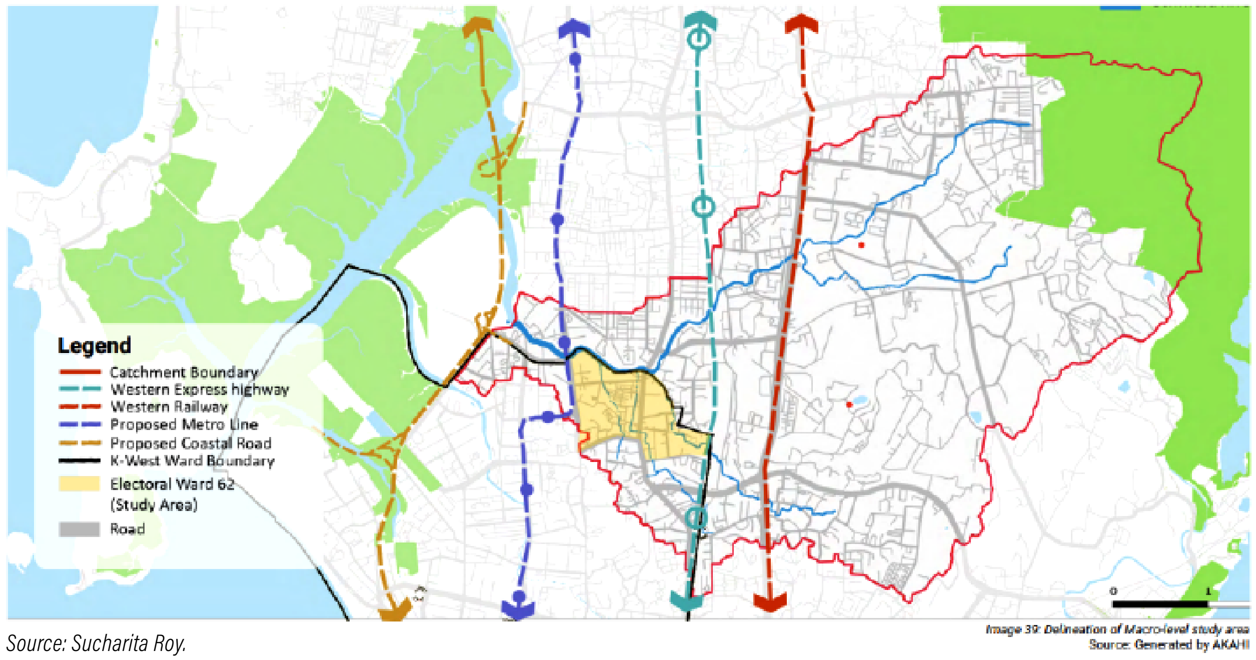
The study was undertaken at two scales to assess both the macro and micro parameters which could be contributing to and aggravating the flooding in the ward. At the macro scale, remote sensing data and analytics were used to investigate the state of the environment and ecology including the watershed and riparian region, topography, land use land cover, vegetation, built-up surface model, runoff, and flood-prone zoning. Secondary studies and data were relied on for information on the rainfall patterns, tidal movement, flooding incidents, water quality, demography, infrastructure, development plans, and policies with respect to the environment, coastal regulations, urban and regional development, etc. Consultations with experts from academia, industry, and the administration were undertaken to understand and develop a preliminary perspective on issues related to flooding in the area.

Figure 11 | Flood Spots and Flooding Levels in Electoral Ward 62 in Mumbai



Source: Sucharita Roy.

Figure 12 | Macro- and Micro-Level Study Boundaries



Source: Sucharita Roy.

An attempt to identify the historical flood spots in the area through various secondary sources showed wide variations in locations/flood spots at the macro and micro scales, establishing the need to source more sensitized locale data. Flood spots, when mapped through citizen groups, were mostly found at locations away from the river, and within residential areas.

The preliminary issues identified through consultations and visual inspections established the need for a structured real-time locality-level assessment of the causes of flooding at a local level. This was undertaken through transect walks, stakeholder consultations, primary surveys, focus group discussions, traffic studies, infrastructure surveys, and expert consultations. To capture social learning, the citizen groups and stakeholder observatories were comprised of residents from formal and informal settlements, representatives from local industrial and commercial enterprises, and political and social institutions. The citizens and stakeholders were further classified based on their roles during floods as rescuer or rescued, resident or business owner, etc., and on their awareness of flooding-related issues. Various tools were developed for undertaking and recording surveys, focus group discussions, and freewheeling conversations. Participatory mapping of the flood spots, built footprint, ecosystem features, state of the physical infrastructure, and crowdsourced photos and real-time information on flooding during the monsoon season through social media applications such as WhatsApp were used to get accurate real-time data on status of flooding, status of infrastructure, and response to the flooding by various stakeholders including local administrations, citizen groups, local leaders, and business houses. The roles played by various stakeholders within the communities, their perceptions and engagement with the immediate environment, vulnerabilities, and coping mechanisms and awareness of issues related to the environment, flooding, and climate change were captured through focus group discussions and surveys.

An ecosystem approach was adopted to collate and analyze the information gathered, and an impact matrix was generated which captured the vulnerabilities and risks each parameter exerted on the other. The broad parameters were classified as follows: Environment and Ecology; Community, Stakeholders and their Activities; Administration and Governance; Provision of Services and Infrastructure; and Urban Development. Each parameter was further subclassified into its variable factors. The interrelationship between the various parameters was examined through a simple matrix where a red color suggests a strong relationship between variables (i.e., a change in one can impact the other and thereby increase the vulnerability of the community and the risk of flooding).

The study clearly established that there is a need to ensure that real-time urban assessments can be undertaken to aid data-driven agile administration, management, and governance to build systemic resilience. This can be undertaken through empowered citizen groups and the use of simple participatory assessment tools, digital informatics platforms, and social media platforms.

Ward-level flood management plans for the flood-prone wards should be based on real-time hazard, vulnerability, and risk assessment at the local level by the disaster management department. Capacities shall have to be enhanced for officials to engage in regular assessments and real-time mapping through citizen observatories and the use of remote sensing and sensor-based technologies.

Agile and integrated administration and governance will require vertical and horizontal integration of policies and plans. Integration can also minimize overlap in mandates and actions and facilitate cost-effective planning (Sendai Framework). A comprehensive ecosystem management framework at the macro scale and flood management and mitigation plans for vulnerable wards at the local level can be integrated into the development planning process to ensure an integrated approach to planning.

Flood management and mitigation plans should focus on nature-based, blue-green solutions which are less capital-intensive and can be implemented by the communities themselves. Fund mobilization at the ward level by aggregating corporate social responsibility funds from local business houses, local area development funds from corporators, and funds mobilized through locality management groups can enhance local-level awareness of flooding, ownership, accountability of all stakeholders for their actions and responsibilities, and real-time governance of flood infrastructure and management plans.

Enhancing the capacities of vulnerable citizens groups to respond to flooding can go a long way in building resilience within urban communities to flooding and other emerging urban hazards.

Mr. Rohit Mujumdar
Urban Planner and Architect, and Faculty Member at the School of Environment and Architecture

BIO: *Rohit Mujumdar is an Urban Planner and Architect, and teaches at the School of Environment and Architecture in Mumbai. His current research focuses on exploring the potentials of democratizing climate action by attending to household and local state experiences, responses, and innovations to the monsoon's everyday wetness and its extreme events in coastal cities.*

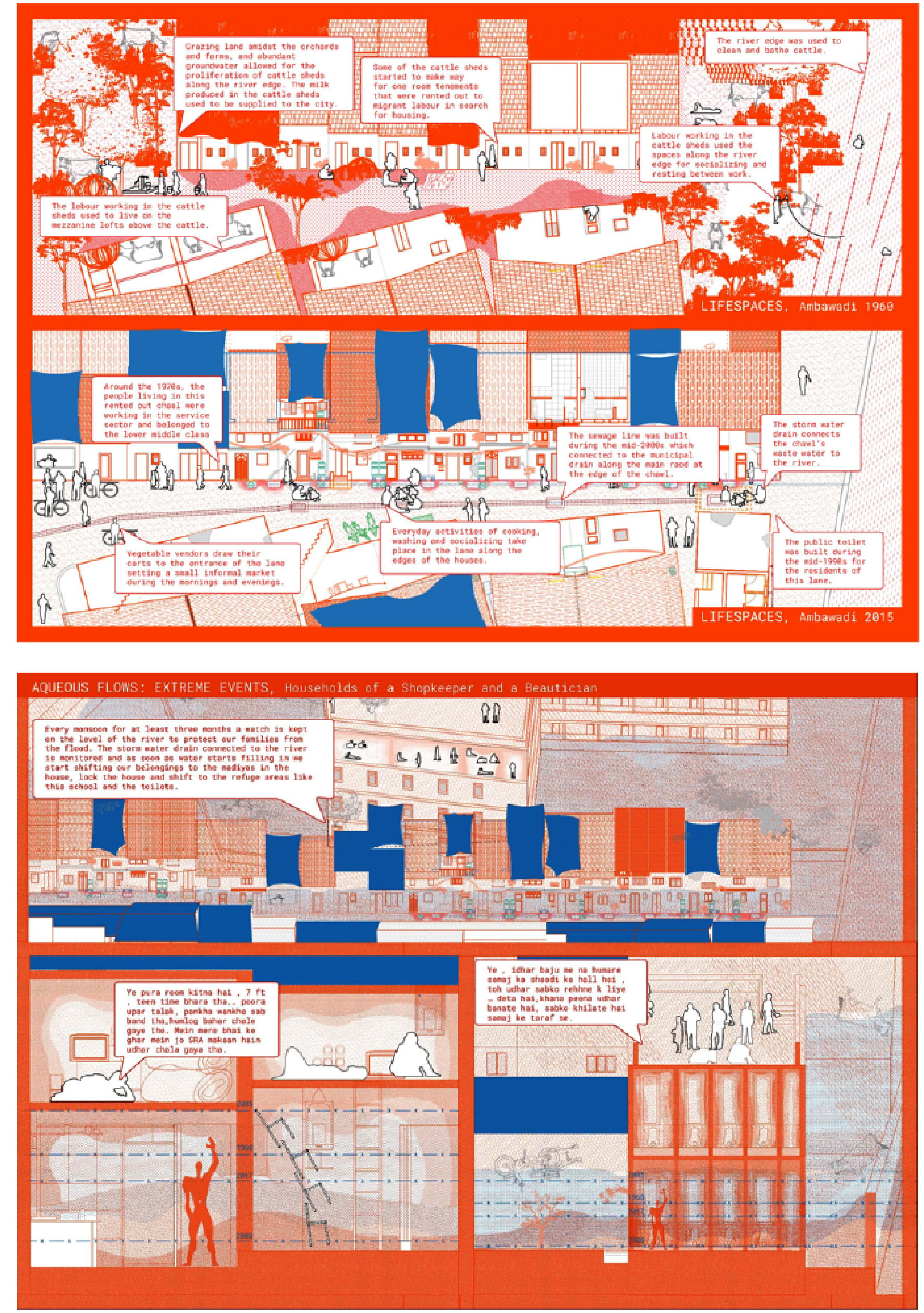
He is also engaged in articulating the new housing questions that emerge from the emerging contexts of urbanization in second cities in South India. His earlier research has focused on examining the spatial and cultural politics of collaborative action in establishing Special Economic Zones in Maharashtra.

Synopsis

In thinking about flooding risk, infrastructural interventions at large attempt to contain and channelize the flow of monsoonal waters. During the last two decades, protagonists of Mumbai's climate conversations have proposed four kinds of actions in response to sea-level rise projections for 2050: first, infrastructures in the form of widening water courses and constructing tall, concrete retaining walls along their edges; second, "slum" demolitions along water courses to increase capacities for draining monsoonal waters; third, en masse city relocation and resettlement on a higher ground; and fourth, post-apocalypse scenarios of a submerged city for leisure activities. Such actions fail or intensify social harm by either shifting the problem elsewhere or they weaken and even dislocate the claims of the majority of households in the present in attempting to futureproof the city for a post-weather tipping point. But in the meantime, how do most households experience, respond to and innovate in the process of inhabiting monsoon's everyday wetness and its extreme events in Mumbai? Delving into this question to discuss household vulnerabilities to flooding alongside Mumbai's Dahisar river, this presentation advances a different tack by drawing attention to three aspects.

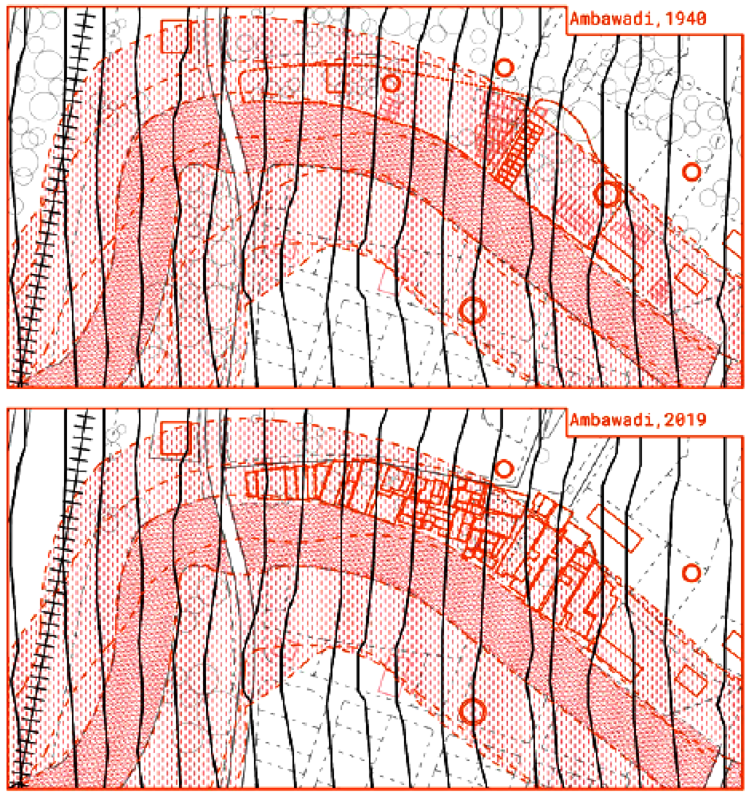
First, along Dahisar river, a majority of households across different income classes, and in particular those occupied by low income groups, are engaged in a series of practices and measures to live with, endure and mitigate monsoonal wetness by adapting their built form through housing repairs and retrofits. Practices and measures of housing repairs and retrofits are not only far more widespread across a range of income groups than those of housing redevelopment but could also prove to be more financially as well as socially appropriate, sustainable and just in the long run. Expert thinking needs to find a way to expand their expertise by understanding and engaging with such defacto practices and occupancies

Figure 13 | Representative Images from Architecture of (Ex)foliation



Source: Mujumdar, Rohit, Vastavikat Bhagat, and Shreya Kothawale. 2020. Architectures of (Ex)foliation. Unpublished research report available with the School of Environment and Architecture, Mumbai.

Figure 14 | Representative Images from Architecture of (Ex)foliation



SETTLING
There were orchards like Khirkeecha Pada and Ambe Pada along the Dahisar River. On the eve of independence, the land in Ambe Pada, now known as Ambawadi, was settled by members of a North Indian community who reared cows in cattle sheds. Many cattle shed owners along Dahisar River anticipated a demand for housing as the state established a milk cooperative during the 1970s. They built and rented single room tenements to low-income migrants. Pratibha Nagar Chawl in Ambawadi was one such chawl built by a such cattle shed owner who rented single room tenements to low-income migrants.

Source: Mujumdar, Rohit, Vastavikat Bhagat, and Shreya Kothawale. 2020. Architectures of (Ex)foliation. Unpublished research report available with the School of Environment and Architecture, Mumbai.

wherever possible to adapt built form so that households can live by accommodating monsoonal wetness. I term these lay practices and measures as architectures of (ex)foliation due to the ways in which they adapt built form.

Second, such measures of adaptation to monsoonal wetness will require a commitment to develop strategies that work at the intersection of municipal line departments and cannot be considered the sole responsibility of the Storm Water Drainage Department. Addressing flooding risks, for instance, will require new imaginations of urban infrastructures to hold and soak monsoonal waters in the ground. This calls for the municipal line departments such as Storm Water Drainage, Sewerage, Solid Waste, Parks and Gardens, and MHADA's Building Repairs and Reconstruction Board to develop spatial, technical, financial, and regulatory strategies in conversation with one another. Such conversations with several state actors could be facilitated through workshops such as the one we are currently participating in.

And third, rather than beginning from a blanket regulatory or institutional approach for the entire city of Mumbai, I suggest that it might be worthwhile to begin with a few retrofitting-based housing and landscape adaptation projects that could demonstrate their potential for climate adaptation for the public at large. Such interventions could be scaled up into policy or program depending upon their success.

Ms. Avinash Kaur
Architect, Program Manager
Tata Institute of Social Sciences

BIO: *Avinash Kaur is an Architect, currently working as a Program Manager with Transforming M Ward Project, Tata Institute of Social Sciences. She has a master's degree in Architecture in Urban Design. She has been involved in researching issues related to water and sanitation infrastructure in urban poor communities in M East Ward. Her interests are in climate adaptive planning and design for vulnerable urban poor communities.*

Synopsis

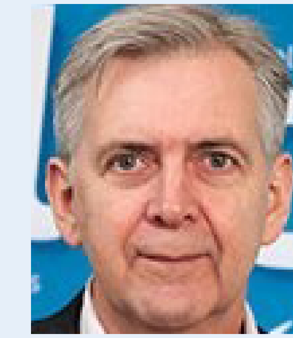
Total indifference toward the existing land topography remains one of the main reasons for flooding. Along with concretization of most surfaces and climatic changes, the existing storm water drain systems and related sewer drains have an interdependent relationship where the lack or inadequacy of one is fulfilled by another. Flooding needs to be viewed as a multifaceted issue concerning the existing water and sanitation infrastructure with the historical topography and hydrological conditions that existed within the area of concern.

Cheeta Camp, Trombay, is an excellent example of why we need to look at the water and sanitation infrastructure together with these topographical and hydrological conditions if we plan to help mitigate and moderate the possibility of flooding in Mumbai. Cheeta Camp, a resettlement colony settled in the 1970s, is situated on land that was marshy at the time. The community was given individual plots by the BMC (one toilet block and one standpost connection per sector was provided by the BMC) in exchange for the land in Janta Colony where BARC is now located. The marshes were filled with debris to make land for construction of the houses. The area also had estuaries connecting the swamps and mangroves of the Thane creek. These estuaries are now part of the existing storm water drain network, which runs around each of the 11 sectors of Cheeta Camp. The settlement gradually runs 10 meters below the main access road as we move toward the mangroves near Thane creek. The community is also dependent on the freshwater wells, which have deteriorated over the years, for their water needs.

The sectors of Cheeta Camp are surrounded by the storm water drains on its periphery. Gallis have their own drains (nalli) centrally located in the lane which are connected to the household wastewater discharge serving households on both sides of the galli, connected to the storm water drains at the sector periphery. The construction of sewer lines in the settlement is long overdue. Sewer lines laid in smaller sections in two sectors still remain disconnected from the main sewers. This has forced the community to opt for septic tanks as the only available option for their sanitary needs. The houses are so tightly bound between the gallis that in many cases septic tanks are located right below the household with their overflow connected to the centrally located drains. The groundwater table is high due to its historical hydrology, which is why we can find water as we dig even 3–4 ft. Heavy rains cause the groundwater table to rise and fill the septic tank with water. In cases where the household is closer to the peripheral storm water drain, the outflow of the toilet sewerage is directly let into this drain. Eventually most of this untreated water and sewerage is let into the mangroves. Interconnection of drains and nullahs and sewage malfunctions with even minor rain events cause internal gullies to flood.

Flooding for the community in Cheeta Camp is an unsolvable issue. Reconstruction of gullies and internal nullahs is seen as the only available option. Desilting drains is not enough. Cleaning and maintaining drains is difficult due to multiple infrastructures like water lines, cables, and overflow outlets connected in the existing drains. There are times when citizens, especially women from the community, have undertaken the job of cleaning the drains after multiple calls to the municipal corporation went unheard. Will an integrated approach to deal with water, waste, and sewerage bring a viable solution? Can Cheeta Camp be undertaken as a pilot for this approach?

Mr. Tjitte Nauta
Regional Manager Asia, Deltares'



BIO: *Mr. Nauta has 35 years of specialist consultancy experience as Strategic Advisor at the Deltares applied research institute in Delft, the Netherlands. His experience includes water quality and integrated flood risk management, master planning and IWRM / ICZM studies for inland and coastal water systems in numerous countries worldwide. In Asia these include Thailand, Philippines, Myanmar, Indonesia, Vietnam, India, China, Singapore, Taiwan and a number of Pacific Islands. In many of these projects Mr. Nauta was either the Team Leader or Project Director. As Deltares' Regional Manager for Asia, Mr. Nauta is responsible for the coordination and development of research and specialist consultancy studies in the Asian region.*

Synopsis

Development of an Integrated Flood Resilience Strategy—Example of Yangon

The impacts of natural hazards in Asian cities, especially recurrent pluvial (rainfall related), fluvial (river related and most problematic during the monsoon season), and coastal flooding (caused by high tides and periodic storm surges), are expected to be exacerbated by climate change and sea level rise. Flooding is associated with damage to properties and assets, disruption of economic activity, and health problems. The proposed Integrated Flood Resilience Strategy (IFRS) for Yangon, which can be considered illustrative for other Asian Coastal Cities, provides a conceptual framework for identification of priority flood resilience investments in response to the challenges the city is facing with regard to the frequent flooding of parts of the city. The IFRS comes with an investment package (Program of Measures) consisting of structural and non-structural interventions that aim to prevent floods expected to occur with a specific frequency, and to mitigate the impact of more extreme floods that are expected to occur less frequently. The investments have been selected to address concrete objectives to create a more flood-resilient Yangon by 2040.

Status of Flood Risk in Yangon City

There are several causes of flooding in Yangon City. Coastal surges, which coincide with high (spring) tides and high river levels during the monsoon season from May to August, were found to be the most dominant flood driver, leading to the highest inundation depths in Yangon City. The city's existing drainage capacity was found to be inadequate for serious rainfall events, leading to widespread resultant pluvial flooding in low-lying areas. This causes extensive traffic jams, and consequential business disruption, particularly in the Central Business District. During the monsoon season, parts of Yangon face regular flooding caused by the combination of seasonal high river levels and spring tides. High river water levels also hamper free gravity drainage, thereby prolonging and exacerbating flooding in low-lying areas that arises from rainfall. Clogging of drains by illegal dumping of solid waste is a further cause of flooding.

Yangon's flood risk is projected to rise as a result of increasing urbanization (with a population growth of approximately 1.5–2% per year); accelerating sea level rise (estimated at 20 cm by 2040); and land subsidence (especially notable in the north-eastern area of Yangon and estimated to be up to 2 cm/year).

Building a Vision to Reduce Flood Risk by 2040

The following vision statement for a flood-resilient Yangon was formulated during the preparation of this IFRS: "A Flood Resilient Yangon City that has an appropriate standard of flood protection and the ability to relieve and recover from flooding, in a way that minimizes social and economic disruption to an acceptable level so that all residents have equal opportunities for a prosperous future in a safe, healthy and attractive living environment."

Program of Measures: A Balanced Investment Plan for 2021-2040

The Program of Measures was formed by selecting the most appropriate measures from a Catalog of Measures developed under this assignment that combine structural and non-structural aspects as outlined above. A preliminary qualitative assessment was done of the extent to which the various measures contribute to reaching the flood resilience objectives. This provided insight into how effective individual and combined measures would be in tackling local flood challenges. From the structural perspective, they range from i) Large Scale Infrastructure Investments, which are relatively expensive but will have a wide-ranging impact on the entire city and ii) Local-Scale Infrastructure Investments including SUDS Measures and local scale traditional infrastructure such as drainage improvements and pumps, which are less costly and will deliver significant and importantly visible benefits at the local/township, block, and plot level. The non-structural aspects of the measures have been designed to complement the specific structural activities to ensure that the broad aims of the objectives are fully achieved.

Local-Scale Infrastructure Improvements and SUDS Measures

- **Township Level:** Drain improvements to increase capacity and structural integrity, moderately sized pumping capacity to increase discharge at all tidal states, and tidal gate rehabilitation, often in combination with the construction of a river embankment to prevent overtopping of river water.
- **Industrial/port areas:** Infiltration fields/strips, drainage infiltration transport drains (DIT), green roofs, ditches, and permeable pavements.
- **Commercial areas:** Green roofs, bioswales, permeable pavers, and rain barrels/tanks.
- **Residential areas:** Bioswales, infiltration fields, rain barrels, and DITs.
- **Public areas:** Rain gardens, bioswales, and infiltration fields.
- **Green areas:** Surface water, rain gardens and infiltration fields.

Although SUDS measures (ranging from green roofs, infiltration measures, and small retention ponds) are individually small, taken together, they can have a significant effect on reducing pressure on existing drainage infrastructure by slowing down or reducing the flood water and as such limiting the extent and duration of flooding. A Yangon Resilient Cities Toolbox was developed to evaluate the applicability and effectiveness of SUDS measures in four distinct pilot areas. These pilots, which are representative of the range of townships throughout Yangon, revealed that SUDS measures could make a cost-effective contribution, not only to flood resilience but also to improvement in the quality of life of city residents. SUDS measures alone are not a full solution to flood alleviation. It was found that they could, when applied to the space available, contribute on average up to 20% of overall flood resilience requirements. This means that traditional drainage infrastructure measures such as local retention, increased drainage capacity, and where necessary pumping are required to provide the full capacity necessary to attain the flood risk objectives. By adopting low-cost SUDS measures, the life of existing drainage infrastructure may, with some modest investment in rehabilitation, be prolonged, thereby postponing the need for expensive new investments. SUDS can also play a very important non-structural role by increasing awareness among residents that they can all play an important role in contributing to a safer and healthier Yangon City.

Although flood protection is a collective, or public good, there are some opportunities for the private sector to step in (e.g., land reclamation and green roofs may qualify for innovative financing opportunities) by taking the lead in formulating standards, requirements, and specifications.

Dr. NIKHIL ANAND
Environmental Anthropologist
University of Pennsylvania

BIO: *Nikhil Anand is an Environmental Anthropologist whose research focuses on cities, infrastructure, state power, and climate change. He addresses these questions by studying the political ecology of cities, read through the different lives of water. His award-winning first book, Hydraulic City: Water and the Infrastructures of Politics in Mumbai (Duke University Press, 2017), examines the everyday ways in which cities and citizens are made through the everyday management of water infrastructure. His new book project, Urban Seas, is supported by grants from the National Science Foundation, the Wenner-Gren Foundation, and the Penn Global Inquiries Fellowship. Based on field research with fishers, scientists, and planners as they work in the sea, the book decenters the grounds of urban planning by drawing attention to the ways in which climate-changed seas are remaking coastal cities today. Urban Seas also contributes to work in two collaborative research initiatives, Rising Waters and Inhabited Sea, in which Dr. Anand serves as the Principal Investigator.*

Synopsis

Introduction: The Problems of Concrete and Climate

Mumbai's climate has changed. The cyclones, cloudbursts, and very heavy rain days of recent monsoons have made clear that human-caused climate change is already part of our everyday environment. No one knows this better than the engineers in the Storm Water Drainage department. Following the catastrophic floods of July 26, 2005, the Chitale Committee Report pointed out that the rain event was an exceedingly rare, one-in-a-hundred-year event and that expanding the city's existing storm water infrastructure would ensure that the network would work during normal times.

But normal times are a thing of the past now. The extremely heavy rainfall of July 2005 has happened several times since, including this last year. Rainfall intensity no longer meets our historical expectations. Not just in Mumbai, but everywhere. The city of Houston, for example, experienced three one-in-500-year flood events in the span of just two years!

Given this situation, it simply not possible to "dewater" the city using concrete and steel. This is because floods are not a technical problem, they are a design problem. As architect and designer Dilip da Cunha has put it, floods are declared when water crosses a line that humans draw (and then fill with concrete). Technical experts (such as engineers) are hired in to put water in pipes, drains, and across the coastline, into the sea. But water will not permanently stay within the lines humans demarcate for it. It never has. The floods that have regularly visited the city from its earliest days are a direct consequence of the concretization of Mumbai's wetlands over the last 200 years. Every year, rain and tidal waters simply return to occupy the same grounds that were once wetlands, khadi (creek), or talab (pond). As a result, the city's residents have long been accustomed to living with regular floods.

Despite significant work by the BMC in expanding Mumbai's storm water drainage network (it can now handle 50 mm of rain per hour at low tide), the floods have only gotten worse. Flooding is more widespread because both climate and concrete construction have intensified. It has gotten worse because the solution to flooding has often been more concretization!

Flooding now occurs in parts of the city that never used to flood. The city's near future depends on how it plans to regulate and adapt to the persistent and increasing presence of water in the city. Climate change has revealed important blind spots in traditional urban planning and infrastructure projects, not just in Mumbai, but in many parts of the world. Where do we go from here?

Reimagining Flood Expertise

First, urban plans and city administrations are siloed and divided. They are top-down initiatives that divide up complex and interrelated urban processes into the work of different departments. In Mumbai, for instance, storm water drains, sewage, and roads are all managed by different departments in the city. Yet, the water in these infrastructures is always mixing: nalas hold sewage, rivers hold storm waters, the sea enters rivers and wetlands, and leaking pipes recharge aquifers. These different waters are part of a single interconnected urban waterscape. They cannot be effectively administered separately.

For example, the design capacities of storm water drains depend on the coefficient of runoff in the city, currently estimated at 100%. The work of drainage would be complemented by reducing the coefficient of runoff in the city, but this can only be achieved in coordination between the Departments of Roads, Gardens, and Buildings. They can make the city more permeable. Storm water needs to be addressed by different departments.

Relatedly, storm water drains also depend on different water bodies in the city to work: the wet and dry weather flows of rivers, talabs, and nalas; the level of the water table; and the permeability of the intertidal regions in the city. These need to be better understood and integrated into flood infrastructures and not considered as different systems. Rather than trying to dewater the city—an impossibility—officials need to understand and support existing infrastructures that effectively hold water for some part of every day, month, or year. Fortunately, the city still has a wealth of these natural infrastructures which provide considerable service to the city.

Green infrastructures (or nature-based solutions) are generally more cost-effective. They can (and already do) complement costly engineering solutions such as storm water drains and water retention tanks. Natural infrastructures are also more spatially efficient and flexible. In wet seasons, they work as green infrastructures. In dry seasons, they can be used as open spaces in the city.

Of course, just saying we need to have nature-based solutions is not enough. Like storm water infrastructures, they need to be designed and integrated with existing gray infrastructures in the city. Accordingly, flood plans also need to be developed in concert with other experts who understand the city; in particular, landscape architecture expertise and social expertise are needed in the design of its flood infrastructure. Understandings of landscape or social equity need to be considered in the very design of flood infrastructures like storm water drains, and not added as a topping to technical systems.

Second, although the BMC has some critical in-house engineering expertise, this is not the only relevant kind of expertise. First, in the last fifty to sixty years, new social and environmental fields of urban expertise have arisen that the city needs to incorporate in infrastructure design and maintenance. Fortunately, much of this expertise resides in the city's world-class universities. Expertise around managing floods also lives in its neighborhoods. Residents of Mumbai have tremendous understanding and capacity, which is put into action every year to deal with floods at Mumbai's many flooding locations. How can these knowledges and experiences be taken into planning processes?

Changing Failures: Reimagine and Unblock Flows

The Storm Water Drains (SWD) Department is aware that the storm water improvements made in the last 10 years are already insufficient for rain which frequently exceeds 50 mm/hour (the new normal). The city cannot be drained, and engineers know this. In the everyday culture of the institution, however, there are disincentives to take risks. There are disincentives to working with the participation of civil society/NGOs. It is much easier for engineers to keep doing what they are doing, knowing that the city will flood. But now, more than ever, we also know that efforts to manage the city's rains in the present and future, based on 100-year-old technologies of storm water management, will fail, more so because we are living in climate-changed times, times in which the city is increasingly concretized. Flood damage will be even The city cannot afford to do nothing new. If Mumbai is to have a chance, existing infrastructures need to be supported by new, well-designed nature-based solutions.

Building a future city that lives better with increasing rainfall intensity and higher tides will need a difference in management and vision. First, the city needs to recognize floods as a more technical phenomenon. For floods to be fully addressed, the collaboration of different departments and civil society actors is required. These kinds of partnerships need to be encouraged by the city administration. For instance, the Additional Municipal Commissioner's (AMC's) office might consider how to mobilize resources for pilot projects that are socially, technically, environmentally innovative, and that do not depend on further concretization. They may consider instituting awards for innovative projects that collaborate across departments and stakeholders. This requires a fundamentally different vision of, and approach to, flooding in the city. Flooding is not just a technical issue; it is primarily a social one, and an administrative one. As such, flood infrastructure projects need to be designed by working not just with engineers in other departments (Gardens, Roads, Buildings), but also in a participatory manner with communities, landscape architects, and social experts.

A gray-green flood infrastructure will only succeed if it reduces the vulnerability of social groups in the city. For this, the public in Mumbai have to be treated not as project-affected persons but as project-invested persons. Currently it is not just floods that harm vulnerable groups but also flood infrastructures. New infrastructures (gray or green) often displace communities without due process or compensation. Flood control projects placed on the homes of informal communities, displacing them, will fail. It will produce more vulnerability. Projects that build and improve quality of life on the ground—that support existing ways of living—will succeed.

The different organizations in the room have described very strong experiences in working in communities which the BMC needs to listen to and treat as expertise.

Conclusion

Cities around the world are experimenting with these new integrations of social, natural, and technical expertise to address the climate crisis. It is not about adding social and environmental masala to technical projects; it is about building flood infrastructure that integrates these approaches from its very inception.

In the last two years, Mumbai has been recognized around the world not for the coastal road; it has been recognized for its Mumbai Climate Action Plan (MCAP). Unlike the coastal road, the MCAP is a planning paradigm that is not based on 20th century dreams of urban connectivity, but on 21st century designs of urban livability. Our existing modes of managing floods are failing. We have nothing to lose. Instead, by trying new approaches promised by green infrastructure, we might make a city that wins.

Mr. Mahesh Narvekar
Director, Disaster Management Department,
Brihanmumbai Municipal Corporation (BMC)

BIO: *Mahesh Narvekar has done his post-graduation diploma in Disaster Management. Prior to being the Director of BMC's Disaster Management Department, he was the Protocol & Liaison Officer, Dy. Chief Officer for Disaster Management, Director of Information Technology, and Director of the Municipal Co-Operative Bank. He has managed various natural disasters like floods, cyclones, and landslides as well as manmade disasters like terrorist attacks, bomb blasts, and building collapses in the last 10 years. He has been instrumental in developing the City Institute of Disaster Management with Educational Gallery, Post-Graduation Diploma in Disaster, Fire & Industrial Management, GIS-based Disaster Management; a state-of-the-art Emergency Operations Center and a Decision Support System; and preparing comprehensive District Disaster Management Plan & SOPs. Mr. Narvekar submitted papers for the Sasakawa Award in 2010 and in 2011 presented papers to UNISDR and received the Role Model Reorganization for Urban Flood.*

Synopsis

The Disaster Management Department scopes out 10 potential flood-induced hazards for the city of Mumbai which are either direct or indirect impacts during and post monsoon: cyclone, urban floods, landslides, lightning, tree falls, electrocution, short circuit, building collapse, epidemics, and chemical spills. To elaborate, in the past few years Mumbai has experienced multiple cyclones, and the impact is evident with almost 2,500 tree falls. Mumbai experiences landslides at least once or twice every year during the monsoons. Electrocutions and short circuits are frequently reported in vulnerable neighborhoods with low-income communities. The Disaster Management Department has identified about 380 dilapidated buildings in the C1 category which need to be pulled down. After floods, health issues like malaria or leptospirosis need attention.

Non-engineering Measures of the Department

The Disaster Management Department mainly focuses on non-engineering measures, in the form of efficient communication and response to mitigate risks. There is a continuously operational, state-of-the-art administrative, control, and communication system at the BMC headquarters, further supported by ward-level units, to reach out to citizens.

Other than high-end technological support and ground-stationed systems for quick response, an important tool of the Disaster Management department is the Disaster Management Act, 2005, which overrides local conflicting laws during a disaster, not only for response but also for prevention and mitigation. For instance, certain sections of the act can be invoked to restrict media communication to prevent the spread of misinformation. The planning and response protocols for the department are formulated based on GIS-based disaster management, where all the relevant data are collected, and specific scenarios of rainfall events or cyclones are simulated to identify the most-impacted and vulnerable locations. An early warning system and predictive analysis are crucial for disaster preparedness. The estimated death tolls, spatial impact, and associated time stamp are identified, and protocols to minimize the impact are formulated in collaboration with experts from IIT Bombay.

Evacuating citizens impacted during a disaster, identifying the evacuation routes, and shifting these citizens to shelters are key to the disaster management protocol. Mobilizing transport and medical aid is mapped in the GIS-based system and fed into the response protocol.

Mobilizing Response Resources

After the 2005 deluge, the goal is to minimize the response time to mobilize resources. For instance, there are three teams of National Disaster Response Force stationed in Mumbai near the chronic flooding spots. Moreover, Navy and Fire Brigade teams are also pre-positioned in potential vulnerable locations to minimize the overall response time in the face of a disaster.

Citizens Are the First Respondents

Awareness among citizens is important for disaster management; moreover, citizens are the first respondents. Training citizens to prevent a disaster and later act during a disaster is as important as the government response. A Disaster Management Institute has been established in Mumbai to train citizens and sensitize them to the risks they are exposed to and how to respond to disasters. All citizens who have undergone the training are given the title of "Apada Mitra" in accordance with the National Disaster Management Authority's guidelines.

Mr. Prashant Ramugade

Designated Officer (Mithi River), Storm Water Drainage Department, Brihanmumbai Municipal Corporation (BMC)

BIO: *Prashant Ramugade is working in the BMC's storm water drain department as Designated Officer for the Mithi River. He completed his master's degree in civil engineering from VJTI and MBA from Mumbai University. He has two research papers published in the Indian Concrete Journal on the application of predictive tools such as Multiple Regression Analysis and Artificial Neural Networks.*

Mr. Mayur Kshatriya

Sub-Engineer, Storm Water Drainage Department, Brihanmumbai Municipal Corporation (BMC)

BIO: *Mayur Kshatriya is working in the BMC's storm water drainage department as a sub-engineer. He completed his bachelor's degree in mechanical engineering from VJTI and has an MBA from Mumbai University. He has extensive experience of 9 years working on the storm water drainage system of Mumbai city.*

Synopsis

Urban drainage systems capture storm water runoff and prevent flooding. During storm events, the volume of runoff flowing into drainage systems and the ability of these systems to manage runoff depend on a variety of site-specific factors, such as the imperviousness of the land area in the drainage basin.

The purpose of an urban storm water drainage system is to collect, transport, and dispose of water, mainly rainfall, which collects on the ground surface before it accumulates at depths and locations that cause damage. There are three basic routes through which the storm water can be transported:

- Over the surface
- In open channels
- In closed conduits

Methods of collection of storm water depend upon the transport method adopted. Transport methods can include the use of pumps, and storage can also be incorporated in the system. In general, storm water is transported by gravity systems. The disposal can be into river systems, into coastal waters, onto flood plains, or into underground strata.

In a coastal city surrounded by open tidal water, all surface water drainage ultimately discharges into coastal waters. Some, however, is routed through short river systems, all of which are influenced by tides.

Causes of flooding

- Siltation in inter-tidal zone
- Encroachments along banks
- Insufficient holding ponds
- Low-lying areas
- Outfalls below mean sea level
- Garbage dumping into the storm water drains
- Diversion of natural course
- Obstructions of utilities
- Gravity-based storm water drainage system
- Ingress of sewerage into storm water drains
- Need to augment the existing drains
- Climatic change and high-intensity rainfall

Vision 2030: Probable Future Solutions

Aquifer/Groundwater Recharge Wells: Aquifer recharge wells will be constructed to infiltrate the storm water into the ground through the gravity or pumping method. The water recharging an aquifer can be reutilized through lift irrigation for city water supply.

Percolation Pits: The Chennai Metropolitan Development Authority (CMDA) introduced regulation of Rain Water Conservation (Annexure 19) for effective measures in each premises for conservation of rainwater and installation of rainwater-harvesting structures.

For Buildings up to Ground + 1 Floor: Percolation pits of 30 cm diameter and 3 m depth, constructed at distance of 3 m center to center, filled with broken bricks (or pebbles) for 2.85 meters and the top covered with perforated Reinforced Concrete Cement (RCC) slabs.

Special Buildings, Group Developments, Multi-story Buildings, Industries, and Institutional Buildings: Pebble bed of 1 meter width and 1.5 meter depth all around the building and filled with rounded pebbles 5 cm to 7.5 cm size.
(A dwarf wall of 7.5 cm height is built across the entry and exit).

Underground Discharge Channel: The discharge channel is a mechanism to drain water from flooded residential areas into gigantic vertical shafts built below the ground and then discharge it into rivers through an underground tunnel connecting the shafts.

Sponge City: Rainfall will flow into its corresponding sponge, i.e., Low Impact Development (LID) facilities like pervious pavement, green roof, surface flow constructed wetland, rain garden, and eco parking lot. Excessive rainfall will flow into the municipal drainage system. This will help to reduce the surface runoff of stormwater.

Mithi River Development, Pollution Control, and Rejuvenation Project:

In response to the unprecedented deluge on July 26, 2005, the Government of Maharashtra vide its Government Resolution dated August 19, 2005, formulated a dedicated Authority, the Mithi River Development and Protection Authority (MRDPA) under the Chairmanship of the Honorable Chief Minister with the objective of resolving the issues related to the flooding of Mithi River. In accordance with the suggestions of the Central Water & Power Research Station (CWPRS) and the Fact Finding Committee, the works of widening, deepening, and construction of the retaining wall/service road were initiated.

Up to 2019, 95% of the widening and deepening and 80% of the construction of the retaining wall of Mithi River was completed, whereas the remaining works of widening, deepening, and construction of retaining wall/service road have been incorporated in the Mithi River Pollution Control Project.

In 2017, BMC had appointed the Consultant, M/s. Frischmann Prabhu (I) Pvt. Ltd., to suggest short-term and long-term measures to control the pollution of the Mithi River under the Mithi River Pollution Control Project. After a survey and study, the consultant had proposed short-term works and long-term works in four different packages to divert the dry weather flow (DWF) of about 285 million liters per day discharging into the Mithi River to the municipal sewer system. The details are given below.

Package I It comprises providing and laying sewer line of 1.65 km length along the banks of the Mithi River from Filter Pada to WSSD Garage at Powai, construction of influent pumping station, effluent pumping station, and 8 MLD sewage treatment plant at WSSD Garage, and construction of service roads along the banks of the Mithi River. The time period for the Package-I works is 18 months (including the monsoon). The work is underway and presently 85% of it is complete. The work is likely to be completed by May 2022.

Package II (from WSSD Garage to CST Bridge) works are located in the non-tidal influence zone. It includes 8.07 km length of sewer line, 3.325 km length of retaining wall, 9.375 km length of service road, and the construction of 102 minor interceptors to divert the DWF from minor nallas to the municipal sewer network system. Presently, the contractual agencies have been appointed. The time period for the Package-II works is 24 months (including the monsoon). The work is underway, and presently 15% of the work has been completed. The works are scheduled to be completed by December 31, 2023.

Package III (from CST Bridge to Mahim Causeway including Vakola River) works are located in the tidal influence zone. It includes training of the river (construction of retaining wall and service road), sewage pumping stations, interceptions and diversion works for diverting the DWF of various outfalls/nallas into nearby existing municipal sewer networks along with gate pumps and beautification including promenades and allied works.

It comprises sewer line work (7.61 km), retaining wall (1.775 km), service roads (4.961 km), 28 interceptors, 26 gate pumps, 3 sewage pumping stations, and 12.04 km of beautification of the river including promenades with their operations and maintenance for 10 years. The process of draft tender preparation is underway, and the tender will be invited shortly. The time period for the Package-III works is 36 months (including the monsoon).

Package IV This work comprises the construction of a tunnel for diversion of the intercepted DWF from Bapat Nalla and Safed Pool Nalla to the proposed Waste Water Treatment Facility at Dharavi.

The diameter of the proposed sewer tunnel is 2.6 m, and its length is about 6.5 km. Presently, the contractual agencies have been appointed, and the work is underway. About 10% of the work has been completed. The time period for the Package-IV works is 48 months (including the monsoon), and it is expected to be completed by September 2025.

Mr. S. C. Deshpande
Chief of Town and Country Planning Division, Mumbai Metropolitan Region Development Authority (MMRDA) and Project Director and Member Secretary, Mithi River Development & Protection Authority (MRDPA)

BIO: *S. C. Deshpande has completed his master's degree in civil engineering with a special focus on town and country planning. Further, he has done his postgraduation in urban and regional planning from Rotterdam University in the Netherlands. He is currently pursuing his PhD from IIT Bombay. Mr. Deshpande has been involved in (and worked as in-charge of) the Mithi River Development Project, transit-oriented development policies, overseeing regional planning of MMR, and working on urban design and infrastructure planning and design for the Bandra-Kurla Complex. He was involved in the inception of Line-1 Metro, has regulated urban development along the Metro and tackled issues related to land, and worked on rental housing projects and landscape of roads in Mumbai.*

Synopsis

Mumbai Flood: July 26, 2005

After the unprecedented deluge in Mumbai on July 26, 2005, with rainfall of 944 mm in 24 hours coinciding with the highest high tide of 4.48 m., the Mithi River in Mumbai became the cynosure of the country. Mumbai lost 698 lives, and property worth crores of rupees was lost/damaged.

Action Taken by the State Government

To look into the reasons for the floods in Mumbai and its surroundings and recommend mitigation measures to overcome such natural disasters, the Government of Maharashtra appointed a fact-finding committee in 2005 under the Chairmanship of Dr. Madhavrao Chitale. Also, via Government Resolution dated August 19, 2005, the Government formed the Mithi River Development and Protection Authority (MRDPA) under the Chairmanship of the Honorable Chief Minister. The MRDPA acts as a coordinating agency between the Mumbai Metropolitan Region Development Authority (MMRDA) and the BMC for the Mithi River works.

The MMRDA appointed the Central Water and Power Research Station (CWPRS) of the Ministry of Water Resources, Government of India, as the expert institution in the field of river hydrology to recommend the deepening and widening widths of the river. The institution submitted its report, based on mathematical models and hydrological studies, to the MMRDA.

The MMRDA has also appointed IIT Bombay as the expert institution in the field of environment and also carried out an independent Environmental Impact Assessment study through the National Environmental Engineering Research Institute (NEERI).

Characteristics of Mithi River and Vakola Nalla

The Mithi River with a catchment area of 7,295 ha originates from spillovers of Vihar and Powai lakes and traverses Mumbai's suburban areas—Santa Cruz Electronic Export Processing Zone (SEEPZ), Marol, and Andheri—and then flows below the runway of the international airport before meandering through the areas of Bail Bazar, Kurla, and the Bandra-Kurla Complex and meeting the Arabian Sea at Mahim Bay after flowing below 15 bridges over a length of 17.84 km. Out of this length,11.84 km is under the jurisdiction of the BMC (Planning Authority as Local Authority), and 6 km is under the jurisdiction of the MMRDA (Special Planning Authority for BKC) for carrying out the Mithi River improvement works.

Works Executed

On the basis of the reports submitted by the Chitale Committee, IIT Bombay, and CWPRS, works such as deepening, widening, rock excavation, retaining wall, service road, and beautification work have been completed in the respective areas of the MMRDA and BMC, during which 9,477 out of 11,248 encroachments were removed. Also, 5,077 project-affected people have been rehabilitated, and they have been allotted accommodation in accordance with government policy. Up to now, the MMRDA and BMC have completed 95% of the work.

The major challenges faced during the execution of the work were

i. Encroachments removal and

i i. Court cases related to land acquisition.

Benefits of the Project

- Increase in water holding capacity 2.0 times
- Increase in river discharging capacity 3.0 times
- Bed slopes resulted in increased flushing activity
- Decreased water pollution, increased dissolved oxygen
- Reduction in siltation due to retaining wall, economical cross section, increase in velocity of flow
- Embankment protected due to the retaining wall
- Encroachments restricted due to the retaining wall
- Service road facilitates periodic maintenance work
- No major flood has occurred in the Mithi River since 2005

Other Initiatives by MMRDA

The MMRDA has signed an MoU with Marine Debris Partnership for the Mithi River Clean-Up Project. Marine Debris Partnership is a partnership between the United Nations Technology Innovation Labs (UNTIL), the VTT Technical Research Centre of Finland, River Recycle Oy of Finland, and Earth5R Environmental Services Private Limited, Mumbai, India. The technology operates on the principle of concentrate and collect. The solution concentration modules powered by the river flow collect the floating waste from the river and feed it to the collector module. The collected waste is then led up a conveyor belt powered by a water turbine to remove the plastic/floating waste from the water.

Mr. Sitaram Shelar
Founder Member and Director of
Centre for Promoting Democracy

BIO: *Sitaram Shelar is the Founder Member and Director of Centre for Promoting Democracy. He has been actively involved in various social justice movements in the city, and intervenes in issues of urban poverty, participatory governance, and planning and the built environment.*

He was instrumental in the formation of the people's campaign "Hamara Shehar Mumbai Abhiyan," which engaged in the revision of the Development Plan of Mumbai 2014-2034. The campaign was able to create a space for dialogue between the State, the Planning Department of BMC, and citizens who will be affected by the plan. He initiated the 51 Mumbaikar campaign toward the implementation of ward committees as mandated by the 74th Constitutional Amendment Act. Mr. Shelar is a well-known water rights activist, a founder member and Convenor of the Pani Haq Samiti, which won a landmark judgment from the Bombay High Court in 2014 that water is a fundamental right of all citizens.

He has been actively working with the BMC Water Department for universalization of water access. He has authored the book Mumbaicha Paani (Mumbai's Water). He is a visiting faculty at DY Patil College of Architecture and Kamla Raheja Vidyanidhi Institute of Architecture.

Synopsis

At midnight on July 1, 2019, following an unremitting downpour, a 2.3 km boundary wall that ran alongside Ambedkar Nagar and Pimpripada in Malad collapsed at two places on the homes of the residents. The Malad area in Mumbai received as much as 183 mm of rainfall in a short span of 3 hours between 10 pm on June 30 and 1 pm on July 1. The mayhem and confusion caused by the collapse were compounded by a sluggish relief response by the authorities. The disaster claimed at least 32 lives and left about 130 injured.

Our team members shared their lived experiences of this disastrous incident. They also described how the BMC and the Forest Department responded to rescue, relief, and rehabilitation and their experiences of approaching the elected representatives and their responses to the pleadings for justice. Our team members also shared their individual family experiences of dealing with this disaster and the 26-year wait for rehabilitation.

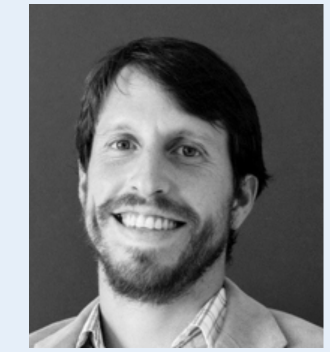
Yogesh Bole is a community activist living in Ambedkar Nagar, Malad. He is engaged with the Samyak Social group and runs free support classes for children in the area. He is also an active member of Pani Haq Samiti. He works with the Center for Promoting Democracy (CPD) on the Entitlements for Homeless initiative.

Ashish Yadav is a resident and community leader from the Navdurga Chawl Committee, Ambedkar Nagar. He is exploring a career in the film industry. He is following up this cause for justice with courage and commitment. He also works for the Ghar Bachao Ghar Banao Andolan campaign, which has been striving for 26 years for the rehabilitation of all people on forest land.

Munni Ramakant Gaud is a homemaker who contributes to the family's income with earnings from making imitation jewelry. She lost her young son in this human-made disaster. She also consistently engages with the administration for her family's right to rehabilitation and justice for her lost son.

Mr. Pedro Ribeiro

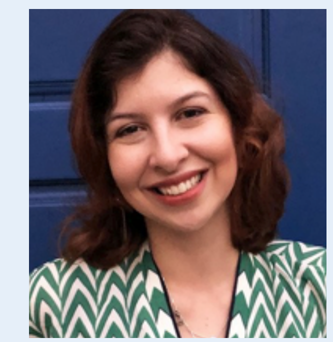
Adaptation Senior Manager, C40 Cities



BIO: *Pedro Ribeiro manages the Urban Flooding Network at C40 and works as the Acting Technical Lead for Urban Flooding, advising the C40 Climate Action Plan Programme. He supports a network of global cities, helping them to identify, plan, and implement projects to increase resilience to urban flooding impacts. The network is focused on four work streams: Governance and Holistic Water Management; Measuring and Monitoring Urban Floods; Flood Operations and Response; and Flood Reduction.*

Ms. Barbara Barros

Adaptation Senior Finance Manager, C40 Cities



BIO: *Barbara Barros is the Senior Adaptation Finance Manager for the C40 City Finance Programme, and is responsible for helping C40 cities take tangible action to overcome the financing challenges they face in delivering the infrastructure necessary to become more resilient to the impacts of climate change. Previously, she served as City Adviser for Rio de Janeiro, Brazil, as part of C40 Climate Action Planning Programme, where she had a key role in delivering the city's Sustainable Development and Climate Action Plan. In addition, she also worked to support the City of Rio de Janeiro in mainstreaming the climate lens in the City's Master Plan and in the Municipal Capital Plan (Strategic Plan).*

Mr. Akira Matsunaga

Principal Urban Development Specialist, Asian Development Bank

BIO: *Akira Matsunaga works primarily on urban and water service infrastructure programs in India. Prior to the ADB, he worked as the energy sector division director of the Japan International Cooperation Agency. He holds master's degrees in Law from Stanford University and Development Policy from the University of Wisconsin in Madison.*

Synopsis

Contributing to the discussion on how to support the implementation of the adaptation actions of the Mumbai Climate Action Plan, C40 Cities and WRI India organized the workshop session "Financing Flooding Mitigation Measures Focused on Nature-Based Solutions," and with the special participation of the Asian Development Bank, brought case studies on how cities are financing the implementation of their adaptation measures focusing on flood reduction, especially through nature-based solutions.

The session aimed to broaden the understanding of financing sources for projects focused on flood reduction in order to stimulate the adoption of innovative financing mechanisms. For example, the City of Austin is funding programs and activities to implement nature-based solutions for flood reduction through a municipal revenue instrument called drainage charge. On the other hand, neighborhood-scale projects or large interventions in watersheds require more financial resources. In these cases, other sources of financing—such as concessional loans by development banks (see the highlighted case study below), public-private partnerships, or green bonds—may be more viable.

Highlighted Case Study: Integrated Urban Flood Management for the Chennai-Kosasthalaiyar Basin Project

Led by the Greater Chennai Corporation (GCC) and the ADB, the project aims to strengthen climate and disaster resilience. The flagship project uses both structural and non-structural measures, bringing multiple social-environmental and inclusivity benefits to local communities. It will demonstrate nature-based solutions to enhance flood retention in the Kadapakkam Lake through ecosystem restoration, mitigate environmental degradation, and enhance biodiversity. The project financing includes an ADB concessional loan and a Global

Figure 15 | Illustrative Image of the Integrated Urban Flood Management for the Chennai-Kosasthalaiyar Basin Project

Source: Asian Development Bank (ADB).

Takeaways of group discussions

- Sources of financing for flood mitigation projects can vary based on the scale of the project; it could be central government funds, funds from taxes levied by the municipal corporation, green bonds or commercial banks, or even international development funds.
- The Austin example of introduction of stormwater drainage charges and stormwater management discount on those charges based on the infiltration capacity of the property.
- The Tokyo example of green bonds where 44% of the procedures are utilized for flood impact reduction projects.
- The Bilbao example of public-private partnership to finance a flood mitigation project during redevelopment of an industrial area.

Group Exercise

The session also featured a group exercise in which participants from the City of Mumbai's agencies and departments, academia, the third sector, and civil society organizations discussed possible ways of finance or raise funding for strategies proposed in the Mumbai Climate Action Plan.

The main takeaways from the discussions are as follows:

- **Preferred sources of finance:** Most of the stakeholders suggested using the Municipal Budget of Mumbai for financing nature-based solutions, but some also highlighted PPPs (a proven model in India) and corporate social responsibility funds.
- **Critical enabling factors and stakeholders:** Participants also mentioned that the involvement of communities, politicians, and real estate developers is important.
- **Critical barriers to flood mitigation measures mentioned by participants:** Encroached areas, especially on the banks of rivers and natural drainage systems; the capacity of local authority to undertake nature-based solutions; and c) compact development and the lack of open spaces. These aspects delay the overall implementation and finances as well.
- Involving landscape architects/urban planners in all the project preparation phases, including engineering projects.
- Enhancing the private sector's involvement and policy interventions for transfer of development rights/open plots to secure flood plains.
- Integrating nature-based solutions with disaster management and data dissemination for further research needs to be considered by the city authority.

APPENDIX: 2

List of Participants

1. National Centre for Coastal Research
2. Indian Institute of Technology Bombay
3. Indian Institute of Tropical Meteorology
4. School of Environment and Architecture
5. Tata Institute of Social Sciences
6. Youth for Unity and Voluntary Action
7. P K Das and Associates
8. StudioPod
9. Urban Center, Mumbai
10. Deltares
11. Kamla Raheja Vidyanidhi Institute of Architecture
12. University of Pennsylvania
13. NDTV
14. Pani Haq Samiti
15. Environment Department, BMC
16. Town and Country Planning Division, MMRDA
17. Disaster Management Department, BMC
18. Storm Water Drainage Department, BMC
19. Gardens Department, BMC
20. Mumbai First
21. Indian Express
22. Sponge Collaborative
23. Fluid Robotics
24. Ludwig Maximilian University, Munich
25. Individual Citizens from Flood-Impacted Communities
26. C40 Cities
27. Asian Development Bank
28. World Resources Institute, India

APPENDIX: 3

Agenda of workshop on Flood Risk in Mumbai

DAY 1: APRIL 28, 2022	
10 to 10.45 am	**Inauguration and Opening Address** Former Honorable Cabinet Minister of Environment, Climate Change and Tourism, Government of Maharashtra, and Guardian Minister Mumbai Suburban, Shri. Aaditya Thackeray, and Honorable Additional Municipal Commissioner Projects, Brihanmumbai Municipal Corporation, Shri. P. Velrasu, IAS
10:45 to 11 am	**Tea Break**
11 to 1 pm	**Updating Technical Considerations for Flood Management in Mumbai** Moderator: Dr. Kartiki Naik (World Resources Institute, India) ● Dr. Subhankar Karmakar (Indian Institute of Technology, Mumbai) ● Dr. Roxy Mathew Koll (Indian Institute of Tropical Meteorology) ● Dr. Tune Usha (National Centre for Coastal Research, Ministry of Earth Sciences) ● Mr. Ravindra Punde (School of Environment and Architecture) ● Mr. Raj Bhagat (World Resources Institute, India) **Followed by discussion**
1 to 2 pm	**Lunch**
2 to 3:30 pm	**Assessing Vulnerability to Flooding in Mumbai** Moderator: Dr. Amita Bhide (Tata Institute of Social Sciences) ● Ms. Kavitha Iyer (Author, Freelance Journalist, formerly with the Indian Express) ● Ms. Sucharita Roy (Independent Consultant, Urban Designer) ● Mr. Rohit Mujumdar (School of Environment and Architecture) ● Ms. Avinash Kaur (Tata Institute of Social Sciences) ● Ms. Roshni Nuggehalli (Youth for Unity and Voluntary Action) **Followed by discussion**
3:30 to 3:45 pm	**Tea Break**
3:45 to 5:45 pm	**Implementation of Flood Mitigation Interventions for Mumbai** Moderator: Ms. Lubaina Rangwala (World Resources Institute, India) ● Mr. P K Das (P K Das and Associates) ● Ms. Mansi Sahu (StudioPOD) ● Mr. Tjitte Nauta (Deltares, Netherlands) ● Mr. Pankaj Joshi (Principal Director, Urban Centre Trust) ● Mr. Aneerudha Paul (Kamla Raheja Vidyanidhi Institute for Arch. and Env. Studies) ● Dr. Nikhil Anand (University of Pennsylvania) **Followed by discussion**
5:45 to 6 pm	**Wrap-up – Day 1**

APPENDIX: 3

Agenda of workshop on Flood Risk in Mumbai

DAY 2: 29 APRIL, 2022	
10 to 10:15 am	**Recap and Day Two Overview**
10:15 to 11:45 am	**Flood Management Initiatives by Government** Moderator: Mr. Sahil Kanekar (World Resources Institute, India) ● Mr. Mahesh Narvekar (Director, Disaster Management, BMC) ● Mr. Ashok Mistry (Chief Engineer, Storm Water Drainage Department, BMC) ● Mr. S C Deshpande (Chief, Town and Country Planning Division, MMRDA) **Followed by discussion**
11:45 to 12 pm	**Tea Break**
12 to 1 pm	**Citizen and City Stories** Moderator: Mr. Sitaram Shelar (Pani Haq Samiti) ● Ms. Ashwini Desai (Resident of flood-affected area) ● Mr. Simpreet Singh (Tata Institute of Social Sciences) ● Mr. Ashish Yadav (Resident of flood-affected area) ● Mr. Yogesh Bole (Resident of flood-affected area) **Followed by discussion**
1 to 2 pm	**Lunch**
2 to 3:30 pm	**Financing Flood Mitigation Interventions and Measures** Moderator: Nikhil Kulkarni (C40 Cities) ● Pedro Ribeiro, Adaptation Senior Manager, C40 Cities ● Barbara Barros, Adaptation Senior Finance Manager, C40 Cities ● Akira Matsunaga, Principal Urban Development Specialist, Asian Development Bank ● Exercise: Mapping finance sources for Mumbai CAP's flood resilience actions **Followed by discussion**
3:30 to 3:45 pm	**Summarising the workshop**
4 to 4:45 pm	**Closing Address** Mr. Jairaj M. Phatak, IAS retired, Former Municipal Commissioner, Brihanmumbai Municipal Corporation Mr. Ajoy Mehta, IAS retired, Former Chief Secretary, Government of Maharashtra.

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