SHAPED BY WATER:
The lexicon of built elements as a cause of changing water in the case of Dharavi and Kanpur

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ABSTRACT

Water plays a lead role in shaping urban waterfront territories. They are generally located in the central part of the cities and are burdened with environmental challenges. Climate change is expected to increase extreme weather events with a larger volume of change in water. Sea level rise, high tides, storms, and floods enhance the vulnerability of such areas along the water. Waterfront territories are more vulnerable to changing water as they occupy the low-lying marshy land. How humans respond to flooding is one of the most challenging questions. The response involves using various built elements embedded in the urban morphology of waterfront territories. The objective of the paper is to identify, systematize and categorize the built elements that exist as a cause of changing water in urban waterfront territories, in the case of Kanpur riverine area and Dharavi, Mumbai. The methodology, exploratory and investigative in character, involve assessment by direct observations and interpretation from the sites, collected images and literature review from the previous published research. The cases from two different territories; formal and informal, enable findings and lessons that contribute to research into the lexicon of built elements necessary for addressing floods.

Keywords: *Adaptation; Floods; Built elements; Urban morphology*

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Thematic block: *1. City and project: Urban morphology, 2. City and environment: Environment, landscape, resilience, and climate change, 3. Urban Dynamics: Informal neighborhoods.*

1. Introduction

1.1 Urban waterfront & changing water

Water presents significant risks, with settlements along the river being more vulnerable. Coastal informal settlements are particularly more vulnerable to changing water levels due to limited capacity to prevent and absorb the water induced risks. As a direct cause, the physical location of such settlements makes them at a greater risk (Goyal, A., & Pereira, J., 2022, p.80) as they occupy the low-lying land. Furthermore, water plays a lead role in shaping urban waterfront territories. Here, 'waterfront' identifies the urban area in direct contact or proximity with water. Urban waterfronts serve as places connecting the water and the land that naturally attract people (Zhang, 2002). These are vibrant places generally located in the significant part of the cities and are connected to places of historic and natural importance (Petrtýlová, R. & Matej, J., 2022) burdened with environmental challenges. Historic waterfront areas are rich in culture and built heritage, as they contain structures that are a result of both the formal strategic decisions and local transformation by the people who occupy such areas over the years. This space undergoes a long process of transformation and their function, design and uses are shaped in close relationship with its proximity with water. According to the function that they serve, various categories of the waterfront suggested, in the previous research, are '*cultural waterfront'* having cultural, educational and scientific activities, *environmental waterfront* that seeks to improve environmental quality, *'historical waterfront'* in the form of development towards historical building conservation, '*mixed-used waterfront'* in the form of a combination of housing, offices, trade or culture, '*recreational waterfront'* that provides recreational facilities, '*residential waterfront'* is a residential area, and '*working waterfront'* is in the form of heavy industrial area and port function (Aulia et al., 2019). Urban waterfronts have been attractive space for creating settlements in both formal and informal territories. It delivers many unique elements, natural or artificially created, that provide for risk reduction towards the changing water levels. The architectural structures are integrating into the urban and natural landscape with varying degrees of approximation to water (Dal Cin et al., 2021). In this context, water presents a significant role in shaping the built environment of waterfront territories. Changing water refers to the cyclical behavior of river water to vary in its levels, flows, and courses, in dry and wet seasons. This being the primary aspect in influencing the human response towards creating the built elements in waterfront territories.

1.2 Flood risk and vulnerability of waterfront territories

Climate change is expected to increase extreme weather events with a larger volume of change in water. Sea level rise, high tides, storms, and floods enhance the vulnerability of such areas along the water. Flood is the most common hazard that continued to affect the largest number of people, 35.4 million people in 2018 (UNISDR, 2019) with an equally large proportion currently living on land below the high tide line. The IPCC 2014 report states that about 70 percent of the coastlines worldwide are projected to experience sea level change within 20 percent of the global mean (Pachauri et al., 2014, p. 60) and notes that coastal systems and low-lying areas will increasingly experience submergence, flooding, and erosion throughout the 21st century and beyond, due to sea level rise (Pachauri et al., 2014, p. 74). UN Habitat recently noted, at least 136 megacities - the port cities with +1 million people in 2005, will be affected by flood in the next two decades. Preparedness and city resilience strategies are essential (UN Habitat, 2018). Further, from 2000 to 2030, globally, the amount of urban land within the low-elevation coastal zone is projected to increase by 230 percent (Güneralp et al., 2017). When risks related to river and coastal floods are combined with population increase and rapid urbanization, an increasing number of communities are being placed at risk (Verwey, Adri et al. 2017). India presents the greatest population, 4.84 million (WRI, 2015), exposed to river flood risk and are most vulnerable to climate change.

The challenge posed by climate change, particularly the changing water, has forced the dwellers to adapt and cope. How humans respond to flooding is one of the most challenging questions. Particularly for informal settlements, formal measures provide less towards the risk and vulnerability of urban poor and in developing countries with higher percentage of slums, addressing floods depend on the ability of slum dweller to respond, physical factors such as protection from water leakages, efficiency of drainage systems and natural typological situations (Goyal, Anubhav, 2021, p.19). The excess of water seen as a treat, is progressively being seen as an opportunity with learning how to live in constant adaptation. Adaptation at local level from slum dwellers is very crucial in the present scenario due to multiply causes and impacts of flooding. Reducing the risk and vulnerability depends on the water management in the river catchment area (Goyal, Anubhav, 2021, p.19). The response and flood adaptation involves using various built elements embedded in the urban morphology of waterfront territories.

1.3 Study area profile

We selected waterfront territories with similar water-based typography in different types of urban spaces: formal and informal. Formal waterfront territories represent build elements that are the result of government-based waterfront re-development projects. In contrast, informal waterfront territories present vernacular local built elements for flood adaptation developed indigenously by the slum dwellers in the absence of adequate formal interventions. Formal waterfront territories in Kanpur riverine area and informal waterfront territory in Dharavi, Mumbai in India, *(Fig. 01)*, are assessed to identify such build elements and further systematized that lead to holistic findings and lessons that contribute to research into the lexicon of built elements necessary for addressing floods.

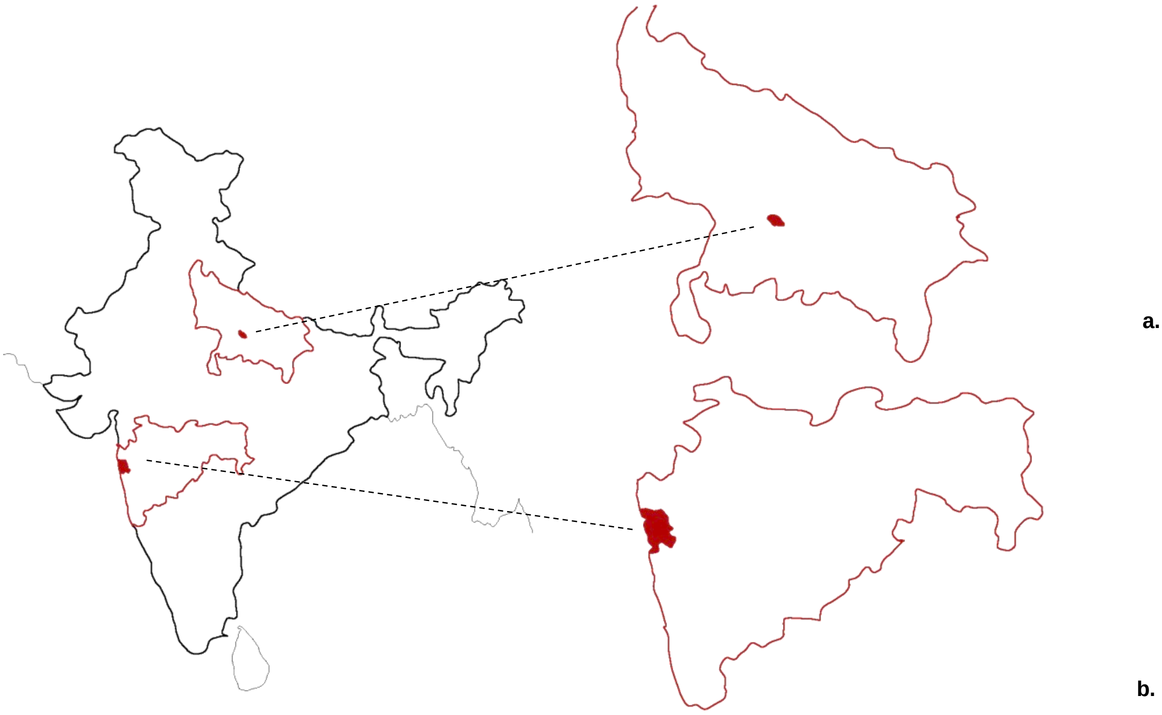

Fig. 01 The location of assessed cases. Left: assessed cases in India. Right: (a) Kanpur in Uttar Pradesh and (b) Mumbai in Maharashtra respectively. Red: Assessed cases (Author).

1.4 Intend of the study

The objective of the paper is to identify, systematize and categorize the built elements that exist as a cause of changing water and perform towards the response to floods in urban waterfront territories.

The paper is divided in following three main parts. In the initial part *(2. Material)* the case of Dharavi slum in Mumbai and Kanpur riverine area are overviewed with collected images and literature review from the previous published research. The applied methodology, results and discussion from the assessment based on fieldwork and direct observations, interpretative sketches, cross-sections, and collected images are presented in the second section *(3. Interpretation)*. In third section *(4. Conclusions)* conclusions drawn from the assessment and closing remarks are noted.

2. Material

2.1 Dharavi

From being a small informal settlement of early fishermen community, *the kolis,* in the 18th century along the Mithi River, Dharavi host a population of more than a million (WEF, 2016). This informal waterfront settlement on the low-lying neglected marshy swamp, once in the suburbs of Mumbai Island, now exist in the center of the Mumbai metropolitan area. Over the years, Dharavi transformed into a large informal territory with close relationship with changing water. The physical location *(Fig. 04)* of Dharavi being a low-lying marshy site in proximity to river leads to higher vulnerability towards the floods in monsoon seasons. Here the slum dwellers have adopted local community led adaptation measures to deal the intensity of the monsoons. Such measures in the case of Mumbai and other coastal urban slums in India are presented through a framework in previous publication (Goyal, Anubhav, 2021) and are crucial in reducing the risk and vulnerability towards floods in the absence of adequate government interventions. The informal and organic urban morphology of Dharavi represents a repository of history and water-based local adaptation to live in harmony with water. The slum is noted as a complex urban system in motion where urban structures reveals the presence of recurrent traits and cycles marked by certain necessities, recognizable and order-able that structure the existence (Zappulla, C. et al. 2014, p.257). Despite of lack of infrastructure and formal government interventions, the slum morphology of Dharavi is embedded with built elements that provide resilience against the changing water.

The following images *(Fig. 02, 03)* are collected from waterfront territories within Dharavi slum during the dry season in the month of February.

Fig. 02 Waterfront territories in Dharavi slum, Mumbai. Images collected from fieldwork in February 2023 (Author).

Fig. 03 Waterfront territories in Dharavi slum, Mumbai. Images collected from fieldwork in February 2023 (Author).

Fig. 04 Left: The location of Dharavi slum in Mumbai. Right: Dharavi slum along the Mithi River. Red: Mithi River (Author).

2.2 Kanpur Riverine Area

Kanpur is situated on the southern bank of the Ganga River *(Fig. 05)*. With the oldest four riverine settlements being created during the Oudh Empire (Ali, S. A., 1970), Kanpur, which was originally a village called *'Konha'*, became a British military cantonment in 1778. After thereafter, Kanpur developed into a civil city with several thriving enterprises.

Since the later decades of the twentieth century, this city has been documenting changes in the natural environment and human population because of the industrial revolution (Paarcha et al., 2023). Kanpur, also called the commercial capital of the state, developed in a linear form along the river and thus has a unique waterfront character. The Kanpur riverine area assessed in the study is situated in the oldest part of the city with enormous temporal changes in relation with water. It is composed of many morphological layers embed with built elements as a cause of changing water (Maheshwari, S., 2011).

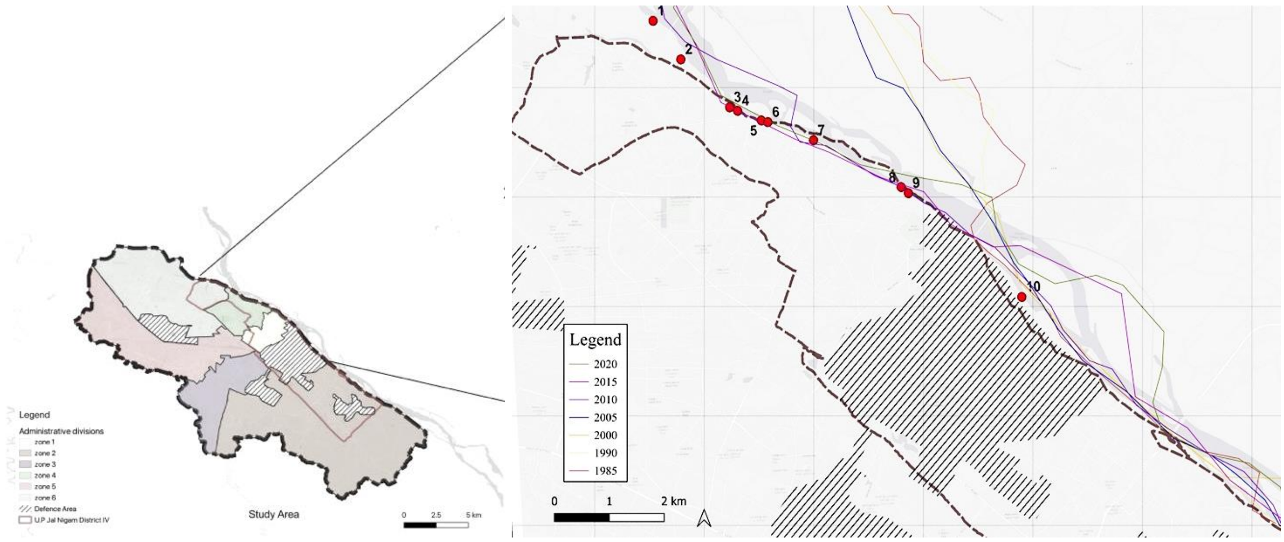

Fig. 05 Left: The location of Old Riverine area from Nawabganj to Jajmau. Right: Identified sites on the strip along with the temporal change in the river course between 1985 – 2020. Grey: Ganges River (Author).

The character of the built elements that are present on the riverine edge is governed by the main functions being administrative, industrial, and religious. As a result, along the river, it is easy to see the related constructed built elements such as watchtowers, drains, embankments, and *ghats*. The historic riverine area (riverside strip stretching from *Nawabganj* to *Jajmau* via cantonment), which has been chosen as the study area, comprising the ten sites: *1.* Kanpur's Boat Club, *2. Atal Ghat*, *3. Bhairon Ghat*, *4.* Magazine *Ghat, 5. Sisamau* Drain, *6.* Overhead tank like structure near Elgin Mills, *7. Parmat* Temple and *Ghat, 8. Sarsaiya Ghat*, 9. District Magistrates Bungalow and *10. Satti Chaura Ghat (Fig. 06)*, has undergone significant morphological changes.

Fig. 06 Waterfront territories in Kanpur riverine area. Image collected from fieldwork: 1. Atal Ghat, 2. Kanpur boat club, and 3. Sarsaiya Ghat (Author).

As the city grew in a liner pattern along the changing river course *(Fig. 07)*, interventions to control flood and changing water levels are seen in the form of *ghats* and retaining walls all along the river. However, *ghats* are the most common built elements that address the changing waters. They act as a protective structure that address the changes both in the river course and the water levels.

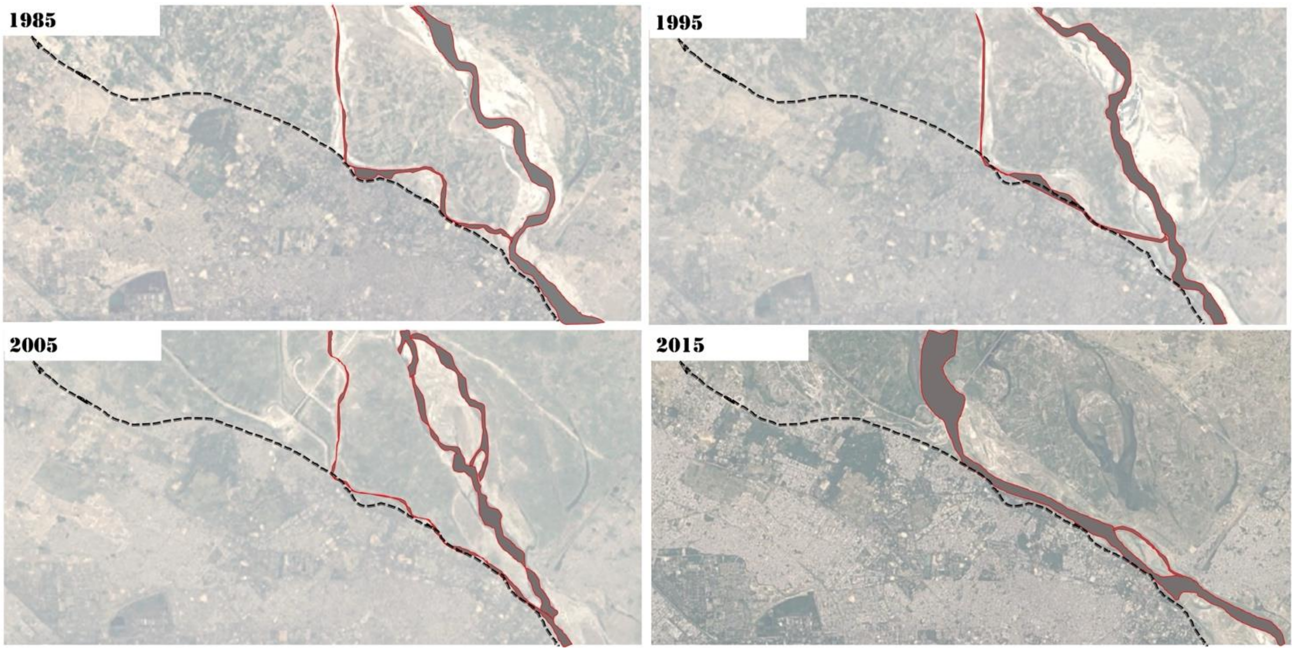

Fig. 07 Change in the river course between 1985 – 2015, within the assessed area. Derived from google earth time-lapse images and QGIS software for Geo-referencing (Author).

The effects of rapid urbanization are affecting the environment. The use of the built elements is impacted by the cyclical water level and changing river course. The government stepped in to address the needs of urbanization and water-induced risks following the building of the barrage in 2006, which led to a change in the river's course. Riverfront development projects and formal construction of built elements were undertaken with redevelopment of *Atal ghat* in 2019 and Kanpur boat club in 2021 being the most recent.

3. Interpretation

3.1 Methodology

The methodology has an exploratory and investigative character *(Fig. 08)*. Built elements that exist within the urban morphology of the areas are assessed by direct observations from the sites, through interpretation from collected images and literature review from the previous published research aiming to present a framework of built elements that provide for building flood resilience. The waterfront territories in Dharavi slum, Mumbai was assessed in the month of February 2023, during the dry season, with the objective to observe the local flood adaptation measures and built elements in the informal context. In formal context, waterfront territories of Kanpur riverine area were assessed in March 2023 and previously in 2011. Kanpur riverine area was assessed at sites of Kanpur boat club, *Atal ghat*, *Bhairon ghat*, *Magazine ghat, Sisamau* drain, *Elgin* mills, *Parmat* temple *ghat*, *Sarsaiya ghat*, district magistrate bungalow and *Massacre ghat.* The collected images are interpreted to identify the built elements that exist as a cause of changing water and perform towards the response to floods in both informal and formal urban territories. This enables holistic findings, systematization, and categorization of built elements for flood adaptation based on the parameters of context, conceptualization, and control.

The result of the research signifies the role of water in shaping urban morphology, in particular the built elements in waterfront territories that provide for flood resilience and an urban character, illustrated through the cross-sections *(Fig. 12)* derived from the assessed sites. The identified built elements are then systematized and categorized in a framework based upon the parameters of context, conceptualization, and control *(table 01)*.

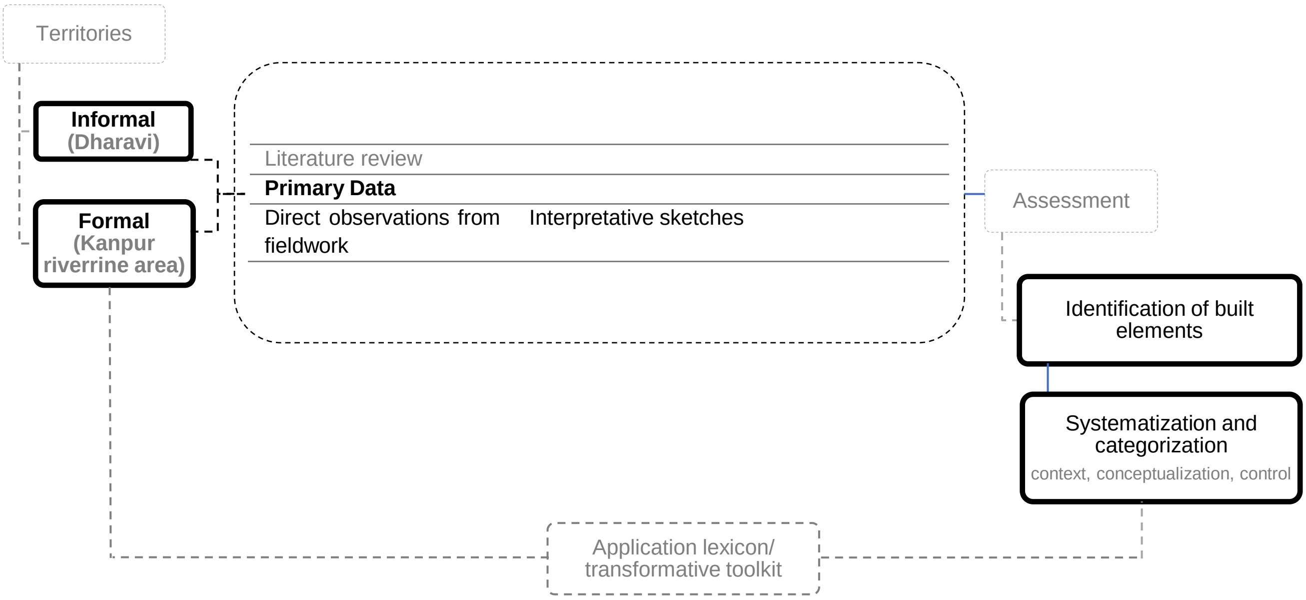

Fig. 08 Research map for assessment of the built elements that exist as a cause of changing water in urban waterfront territories (Author).

3.2 Result and discussions

The interpretation involved identification of built elements from the assessed cases. The built elements as identified are marked in red in the sketches derived during the fieldwork *(Fig. 09, 10, 11).* Further these are systematized and categorized based upon the parameters of context: formal and informal, conceptualization: individual and community, and control: temporary and permanent *(table 01)*. In scope of the research, formal built elements are those elements which exist because of government interventions and waterfront re-development projects. Informal built elements are created at local level, mostly with vernacular techniques and materials, directly by the dwellers. Such elements require less time and expense in the erection. These mostly provide effective temporary flood risk reduction in the absence of government interventions. Conceptualization is presented into individual and community levels which is the scale of formulation of the built element. Furthermore, the parameter of control presents the nature of protection or risk reduction i.e., temporary, and permanent, by a specific built element. In the case of Kanpur riverine area, the built elements in the waterfront territory are developed by the government interventions in the process of redevelopment of the space for the primary usage for recreation, religion, and tourism purposes in close relationship with changing water levels. While in Dharavi slum, the waterfront is occupied in informal manner without planning interventions, occupied for residential and small-scale industries.

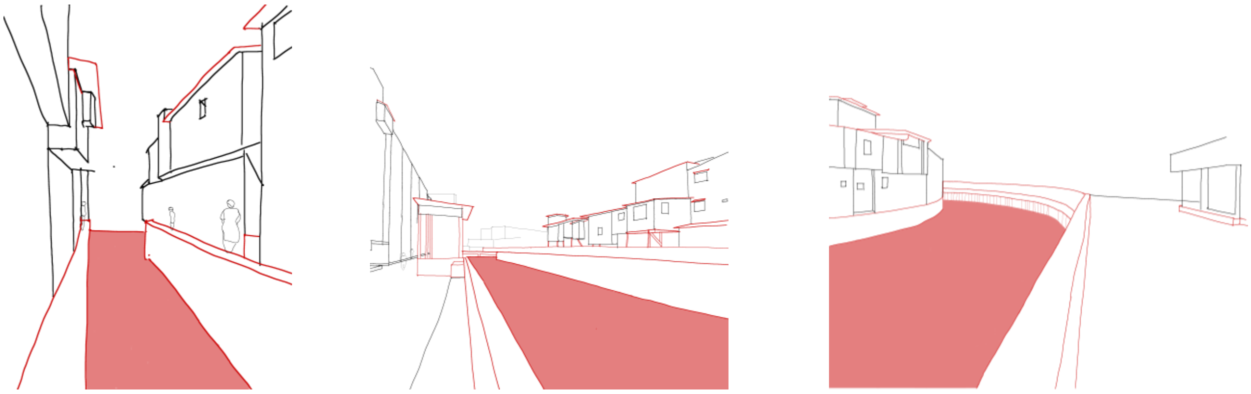

Fig. 09 Interpretative sketches derived from the fieldwork in Dharavi slum, Mumbai. Red: water and built elements that exist as a cause of changing water levels and provide for flood resilience (Author).

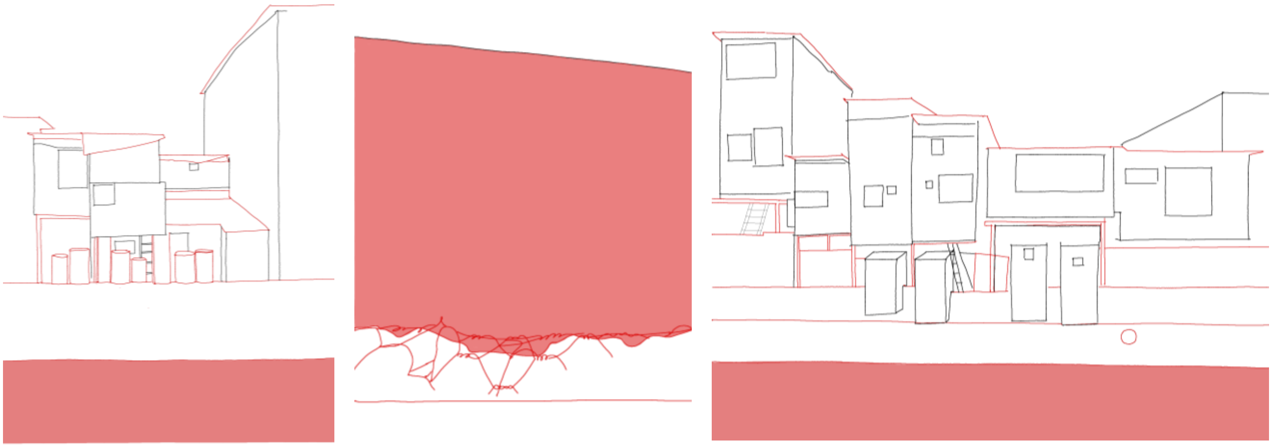

Fig. 10 Interpretative sketches derived from the fieldwork in Dharavi slum, Mumbai. Red: water and built elements that exist as a cause of changing water levels and provide for flood resilience (Author).

The common built elements observed in the case of Dharavi are water retaining structures like wall, barriers created in permanent manner with materials such as stones, bricks and also in temporary manner with concrete blocks, sand bags, plastic sheets and drums. These are mostly created locally at individual and community levels. The dwelling units along the water are mostly two-storied structures with upper level being raised on metal or wooden stilts. Such construction primarily serves as protection against flooding. The lower level or space under the residential space of upper level is used for work during the dry season. The tin metal roofs are projected and pitched towards the water channel. Gabion walls raised plinths and platforms, door barriers etc. are some of the other built elements that provide for flood resilience in informal contexts as illustrated in the sketches derived from fieldwork in Dharavi slum *(Fig. 09, 10)*.

The built elements observed in Kanpur riverine area which exist because of formal government interventions mostly provide for permanent or long-term control towards the changing water levels. These are conceptualized and formulated to serve larger scales. The interpretative sketches *(Fig. 11)* derived from the fieldwork illustrates the built elements such as water promenade, embankments, *ghats* etc. on the waterfront territory of the selected riverine sites in Kanpur.

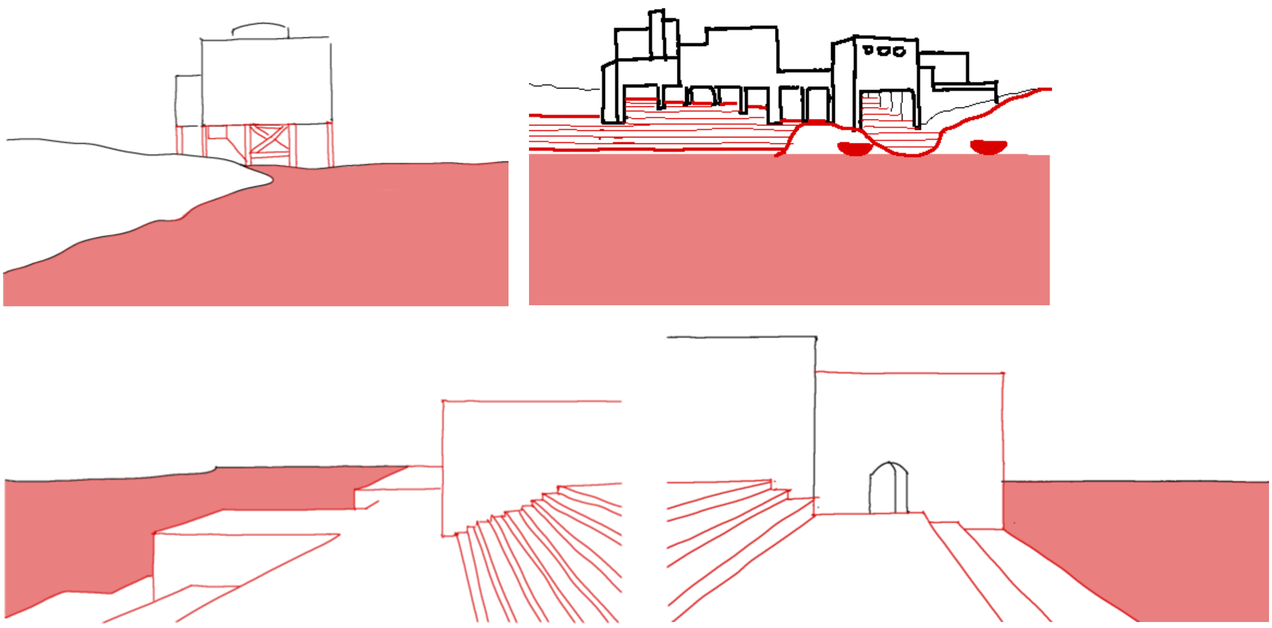

Fig. 11 Interpretative sketches derived from the fieldwork in Kanpur riverine area. Red: water and built elements that exist as a cause of changing water levels and provide for flood resilience (Author).

The site of Kanpur boat club *(Fig. 06)* shows a series of steps, referred as *ghats*, approaching the deck from the river promenade along with a continuous embankment on the river edge that are constructed in relation with changing water levels. Ghats such as *Atal ghat, Bhairon ghat, Magazine ghat, Sarsaiya ghat* provide for space for religious purposes as ritual platforms and act as barriers towards the water rise. Furthermore, continuous embankment and bastion along the *Massacre ghat* were identified from the assessed site.

The following table *(table 01)* presents the systematization and categorization of the identified built elements from the cases.

Table 01 Systematization and categorization of built elements from the assessed cases (Author).

Assessed Cases		**Built elements**	**Context**		**Conceptualization**		**Control**	
			Formal	**Informal**	**Individual**	**Community**	**Temporary**	**Permanent**
Dharavi		Embankments	x	x		x		x
		Retaining walls	x	x	x	x		x
	Barriers	Sandbags		x	x		x	
		Plastic drums		x	x		x	
		Tin sheets		x	x		x	
		Stone barriers		x	x		x	x
		Brick barriers		x	x		x	x
		Concrete blocks		x	x		x	
	Stilts	Wooden stilts		x	x			x
		Metal stilts		x	x			x
		Cantilevers		x	x		x	x
		Gabion wall	x	x		x		x
		Raised plinths		x	x			x
		Platforms	x	x		x	x	
		Open retention tanks	x	x		x		x
Kanpur Area	**Riverine**	Promenade	x			x		x
		Embankments	x	x		x		x
		Ghats (series of stairs)	x			x		x
		Deck	x			x	x	x
		Bastion	x			x		x
		Concrete Stilt structures	x	x	x	x		x

Drains	x			x		x
Ramps	x			x		x
Retaining walls	x	x	x	x		x
Tanks	x	x		x		x
Pavilions	x			x		x
Concrete tripods	x			x	x	

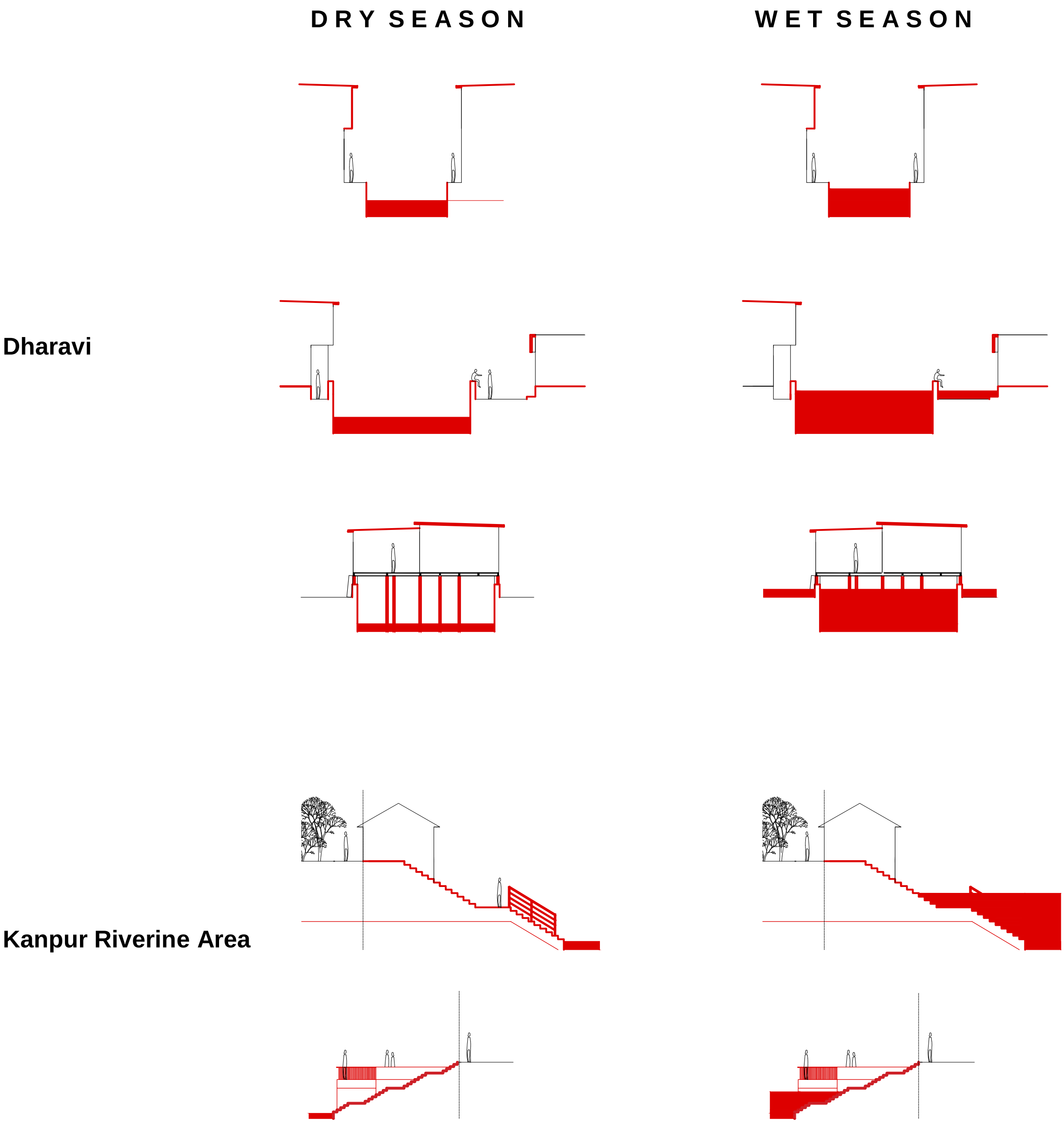

Fig. 12 Cross-sections derived from informal waterfront territories in Dharavi slum and formal waterfront territories in Kanpur riverine area, illustrating the functioning of identified built elements in time: dry and wet seasons that provide for flood resilience. Red: built elements and changing water level (Author).

4. Conclusions

The paper substantiates the argument that water plays a lead role in shaping the urban waterfront territories both in formal and informal sites. *'We share the fate with river'.* Over the years, with changing climate and water levels, dwellers along the waterfront territories have adapted and learned to survive. While interpreting the complex set of built elements as ensembles consisting of buildings and shared spaces in riverine area it is realized that water is the contributor towards shaping the built environment. In this process of respond towards floods, the embedded built elements that are categorized in their context, conceptualization, and control, provide for water induced risk reduction and in shaping the urban character.

Some built elements that exist in both the contexts of formal and informal may vary in other parameters of conceptualization and control. Same built elements in different contexts also vary in their materials. Furthermore, there exist some built elements in the formal context, conceptualized at larger community scale and provide for permanent control which does not serve the purpose of risk reduction in informal context. It is also concluded; formal sites have mostly achieved desired scale and permanency of flood protective built elements while a lot is still to be achieved in the informal sites as such sites are mostly neglected and uncovered under the government redevelopment plans and interventions. The study summarizes the identified built elements for flood adaptation and adds to the understanding of how adaptive capacity at the local level can be supported and enhanced through the combination of built elements at both formal and informal contexts. In informal sites, vernacular locally created built elements play the major role in addressing floods in the absence of adequate formal government interventions for dwellers in informal sites. Thus, the risk paradigm should shift from institutional top-down to more local built elements of addressing floods with community participation of those at risk in coastal informal settlements.

The research contributes further towards the creation of a lexicon of built elements or a transformative toolkit necessary for addressing floods particularly for coastal informal settlements.

5. Author contributions

The presented research idea is conceived by the first author who also developed the theory and wrote the manuscript. Further, the first author conducted the fieldwork, collected images, derived interpretative drawings and observations in the case of Dharavi slum. The second author conducted the fieldwork and collected images at the Kanpur riverine area. Both the authors prepared interpretative drawings in the case of Kanpur riverine area and contributed to formulation of the framework derived from respective cases.

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