WPS7481

Policy Research Working Paper 7481

Shock Waves: Managing the Impacts of Climate Change on Poverty

Background Paper

The Exposure, Vulnerability, and Ability to Respond of Poor Households to Recurrent Floods in Mumbai

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WORLD BANK GROUP
Development Economics
Climate Change Cross-Cutting Solutions Area
November 2015

Policy Research Working Paper 7481

Abstract

This paper examines poor households in the city of Mumbai and their exposure, vulnerability, and ability to respond to recurrent floods. The paper discusses policy implications for future adaptive capacity, resilience, and poverty alleviation. The study focuses particularly on the poor households, which tend to have greater exposure and vulnerability to floods and limited ability to respond given the constraints on physical and financial resources. The study seeks to understand the implications of the fact that poor households are more likely than non-poor households to be located in flood-prone areas. The study used the land use maps for the selected flood-prone areas to determine the extent and spread of poor and non-poor households and other types of assets and activities in areas with chronic and localized flooding. Primary data were obtained through detailed household surveys to understand the vulnerability and impacts of the extreme floods of July 2005, recurrent floods and the ability of households to respond and cope. The study examined the option of relocation to flood-free areas and identified factors that influence families' decisions regarding relocation. The study finds that a significantly large proportion of poor households are located near areas with chronic and localized flooding. These households are either below the poverty line or have low incomes and reside in informal settlements or old and dilapidated structures. Future climate risks are likely to put greater burden on the poor and push them further into poverty unless well directed efforts are made to protect them.

This paper was commissioned by the World Bank Group's Climate Change Cross-Cutting Solutions Area and is a background paper for the World Bank Group's flagship report: "Shock Waves: Managing the Impacts of Climate Change on Poverty." It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at archana.patankar09@gmail.com.

The Exposure, Vulnerability, and Ability to Respond of Poor Households to Recurrent Floods in Mumbai

Archana Patankar[1]

Keywords: floods, household survey, urban poverty, disaster risk management
JEL: Q54, I32, I38, Q56

Acknowledgements

I am indebted to Stephane Hallegatte and Mook Bangalore for their ideas, valuable inputs and support in completing the case study. I am also grateful to Prof. Anand Patwardhan, University of Maryland, for his inputs and feedback at each stage of the work. Special thanks to Ms. Sravanthi Rallabandi of MP Ensystems Advisory Pvt. Ltd. for preparing the GIS maps to understand flood exposure. I would also like to thank Saurabh Dani, World Bank, for an in-depth review of this paper, Bernice Van Bronkhorst, World Bank, for providing valuable inputs during the workshop held in Feburary 2015, and Laura Bonzanigo, World Bank for useful comments on a previous version of this paper. Dr. Potdar, Ms. Madhura Palnitkar and their entire team from the Centre for the Study of Social Change (CSSC) need a special mention here for successfully carrying out the field work in Mumbai. I am also grateful to Mr. Mahesh Narvekar, Chief Officer, Disaster Management Cell, MCGM and his entire team for their immense support for the research work on Mumbai, timely inputs in understanding flood exposure and vulnerability and carrying out the required field work.

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Contents

1. Introduction

Urbanization is inevitable and essential for future economic growth. What happens in cities and towns, particularly in the developing world, will determine the global economic growth, poverty alleviation, environmental sustainability and quality of life. Today, urban areas regularly experience increasing population, inadequate infrastructure, poverty, growth of informal settlements and environmental degradation, which do not pose a good picture for future sustainable development. In addition to these challenges, many cities across the globe are hotspots of vulnerability due to climate change and variability and are at risk from extreme and recurrent weather events. Recent decades have seen extreme weather events, such as the floods in Mumbai in July 2005, which have led to massive damages and loss of life and property, and adversely affected economic and social life. Such events have adverse consequences for economic development and poverty alleviation and can potentially alter the development trajectory of the city and surrounding areas. Accompanied by physical, economic and social vulnerabilities in such cities is the low adaptive capacity with constraints on physical, financial and human resources. It is, therefore, critical to assess the vulnerability of cities to extreme and recurrent weather events and their ability to respond in order to determine the future adaptation interventions.

The empirical study carried out in Mumbai aims to examine the exposure, vulnerability and ability to respond of households to recurrent floods and brings out policy implications for adaptive capacity. The study focuses particularly on the poor households in the city, who tend to have greater exposure and more vulnerability to hazards like floods and have limited ability to respond and adapt. Greater Mumbai, with a population of 12 million as per Census 2011 figures (GoI, 2011), is a megacity and an important financial center. However, the city is vulnerable to climate risks due to its flood-prone location and the landmass composed largely of reclaimed land. The most vulnerable sections of the city are the residents in informal settlements known as slums, who comprise about 41% of the city's households (GoI, 2011). Therefore, Mumbai is an important case study to understand the vulnerability of poor households to recurrent weather events and examine their ability to respond. The findings of this study have wider and significant policy implications.

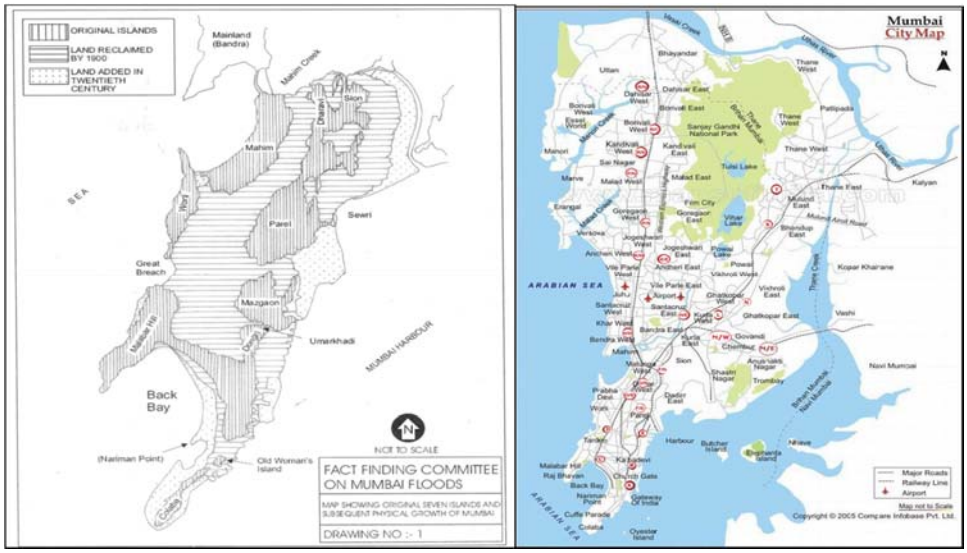
The case study is structured as follows. The next section describes the city profile, rainfall pattern and the nature of recurrent floods. Methodology and data sources are outlined in Section 3 followed by the discussion on the findings on exposure, vulnerability and ability to respond in Section 4. Section 5 brings out the policy implications of the study followed by the summary and conclusions in Section 6.

2. Mumbai city: Profile, rainfall pattern and recurrent floods

Mumbai (formerly known as Bombay) is currently the sixth largest urban agglomeration in the world with the population of 20 million (United Nations, 2014). The city is the financial capital of India with a large commercial and trading base. It plays host to a number of industries, multinational companies

and important financial institutions. The city is also an important international sea port and strategic from the defense perspective. Mumbai is located on the western seacoast of India on the Arabian Sea and was originally a cluster of seven islands as seen in Figure 1 below. Since the 17th century, these islands have been joined through drainage and reclamation projects as well as construction of causeways and breakwaters to form the modern day one landmass (MCGM, 2014).

Figure 1: Original seven islands and subsequent growth of Mumbai



Source: MCGM, 2006; MCGM, 2015

The Greater Mumbai Region (referred to as Mumbai in this paper) occupies an area of 458.16 square kilometers (sq. km.), of which 415.05 sq. km. area (Groupe SCE, 2012) is under the jurisdiction of the local government, Municipal Corporation of Greater Mumbai (MCGM) and the remaining are the Special Planning Areas (SPA).[2] The primary agency responsible for governance is the MCGM. The city is divided into different administrative zones known as ***'wards'*** to ease the day-to-day functioning of the civic authority. The civic body is responsible for the provision of civic amenities including urban planning, water supply, sanitation, drainage, solid waste and roads, along with services like education, public health, art and culture and heritage conservation. Other key parastatal agencies also have an important role to play in the provision of infrastructure and planning of the city. They include the Mumbai Metropolitan Region Development Authority (MMRDA),[3] Maharashtra Housing and Area Development Authority (MHADA)[4] and Slum Rehabilitation Authority (SRA).[5] Multiple agencies with multiple mandates at times create challenges of coordination and jurisdiction and are

[2] Special Planning Areas (SPAs) include Backbay Reclamation, Bandra Kurla Complex, Dharavi, SEEPZ, MIDC, Aiport, etc. which are not under the jurisdiction of MCGM and are governed by other agencies or parastatals.
[3] MMRDA was set up in 1975 as the planning and coordinating agency for the Mumbai Metropolitan Region. It brings together central and state government to jointly fund urban development and works with municipal corporations and municipal councils in the region.
[4] MHADA is a state government body working for providing cheaper housing and building repairs and maintenance in coordination with municipal corporations.
[5] SRA was set up in 1995 to survey the slum areas and formulate and implement schemes for slum rehabilitation.

known to affect the pace of many infrastructure and developmental projects implemented in the city.

The total population of Mumbai has grown steadily from 3 million in 1951 to 8 million in 1981 to 12.43 million in 2011 with population density of 28,404 persons per sq. km. (MCGM, 2014). About 55-60% of the population resides in informal settlements or hutments known as slums, which occupy 33% of the total residential area (MCGM, 2014a) and almost all the population increase in the city over time has been absorbed in these settlements (Annez et al., 2010). The majority of the people living in slums belong to low-income segments of the population. Yet, Mumbai is the economic powerhouse of the country, contributing 33% of income tax collections nationwide, 60% of customs duties collection and 40% of foreign trade (MCGM, 2014a). The per capita income at current prices has increased from USD1,089 (1USD=INR60)[6] in 2006-07 (GoM, 2007) to USD4,058 in 2013-14 (GoM, 2014). However, the household income distribution shows acute inequalities with 20% earning less than USD167 per month, 50% below USD330 per month and top 10% earning USD2,000 per month (Annez et al., 2010). These acute inequalities in income distribution reveal acute poverty in the city and also explain more than 50% population living in informal slum settlements.

On the weather front, the city experiences a heavy southwest monsoon rainfall and is also prone to cyclones and gusty winds. Historically, Mumbai has been receiving an annual rainfall of about 2,200 millimeters (mm) during the monsoon season between June and September. Since 2004, the average annual rainfall has been more than 2,400mm, with variations in rainfall from the lowest of 1,274mm recorded at Colaba weather station in 2002 to a maximum of 3,378mm recorded at Santacruz weather station in 2010[7] (MCGM, 2014). There are a number of days every year when rainfall exceeds 65mm or 135mm per day. Rainfall of 200mm or more per day is also not uncommon during the onset of monsoon. Heavy precipitation and resultant flash floods are, therefore, a regular event in Mumbai.

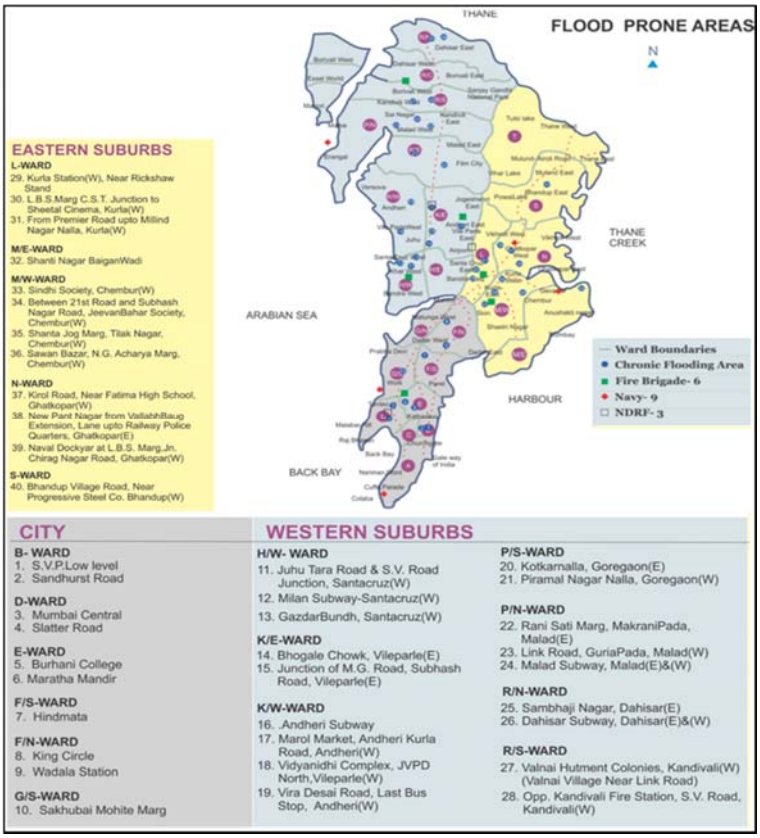
Flooding is a chronic and recurrent problem during monsoon. The key reasons for flooding are tidal variations, flat gradients and mud flats causing excessive siltation (MCGM, 2014a). Many low-lying and reclaimed areas across the city get flooded, especially when heavy rains combine with high tide or storm surges, with the added difficulties due to unsanitary methods of solid waste and sewage disposal and problems with the drainage systems (Sherbinin et al., 2007). Other contributing factors to flooding are manmade inappropriate levels of outfalls, loss of holding ponds due to land development, increase in the run-off coefficient, encroachments on drains and obstructions due to crossing utility lines (MCGM, 2014a). Mumbai's vulnerability to extreme precipitation was demonstrated on ***26 July 2005*** when ***944mm*** rainfall occurred in the suburban district in the 24-hour period. About 200km of road length and the airport was submerged in flood water. Local train services, bus services and air traffic came to a complete standstill. Around 2 million people were

[6] The conversion rate of **1US Dollar = Indian Rupees 60** used throughout this paper.
[7] Floods occurred in 2010 after this maximum rainfall and have occurred every year since the 2005 event.

stranded in transit and another 2.5 million had their houses under water for hours together. Property and assets worth billions of rupees were lost or damaged.

This extreme precipitation event brought about changes in the way floods are reported and dealt with in the city. The Disaster Management Cell (DMC), set up at MCGM, has installed 54 rain gauges across the city to record rainfall at 15-minute interval. Warnings are issued to ward offices when rainfall exceeds 40mm per hour. The database of flood instances between the year 2000 and 2008 shows an average of 76 instances of flooding annually in the island city, 57 instances in the Eastern suburbs and 129 flooding instances in the Western suburbs.[8] Further, based on the experience of recurrent floods, MCGM has identified 40 chronic flooding spots (low-lying areas) as seen in Figure 2. In addition to these, there are over 200 localized flooding spots, where waterlogging is due to inadequate drainage and/or changes in the topography with changing land use. While these recurrent floods are less intense in terms of magnitude (for instance, compared to the 2005 floods), they nevertheless increase the vulnerability of people living in these chronic flood spots. As discussed below, a large percentage of the population living in chronic flood zones are amongst the poorest with low levels of adaptive capacity.

Figure 2: Chronic flooding spots in Mumbai



Source: Disaster Management Cell, MCGM. http://www.mumbaimonsoon.com

[8] Data obtained from Disaster Management Cell, MCGM.

3. Methodology and data sources

As discussed, Mumbai is acutely vulnerable to recurrent floods. Given the acute income inequalities and 50% population residing in informal settlements, it is critical for the city to examine how recurrent floods impact the households and how do they cope with them. The aim of this study is to examine the ***exposure*** of the households to recurrent floods, ***vulnerability*** in terms of direct and indirect impacts of floods and their ***ability to respond***. The study lays special emphasis on the ***poor households*** to understand their location in the flood-prone areas vis-à-vis the non-poor households, estimate the losses suffered by them on account of floods and examine the extent to which they can adapt to floods and have the ability to respond.

Table 1 describes the research questions, methodology and sources of primary and secondary data used in this study. To determine the ***exposure to flooding***, the study seeks to understand the extent and spread of poor and non-poor households located along the chronic and localized flooding spots. For this purpose, extensive database of the Planning Department of MCGM has been used. The Planning Department released Existing Land Use (ELU) maps (MCGM, 2015) as part of the exercise for creating the new development plan for the city. We have selected nine most flood-prone wards and superimposed the chronic and localized flooding spots on the ELU maps using the GIS-based platform. The chosen wards – F South, F North, K East, K West, H East, H West, L, M West and P North – represent three types of flood-prone areas - low-lying areas, areas in the Mithi river flood plain and reclaimed areas. The demographics for these wards are given as Annexure A.1 and the maps showing land use in chronic and localized flood spots are given as Annexure A.2. The study has used 500 meter (m) buffer zone around the chronic spots and 200m zone around the localized spots to identify the vulnerable households in the flood-prone areas.

In order to understand the ***vulnerability and impacts of floods*** as well as the ***ability to respond***, the study has used detailed household surveys in the flood-affected wards. Most damage assessment methods use insured exposure analysis to calculate the direct losses. This is particularly true for the developed world, where the coverage of insurance is very high. However, such methods are not able to capture losses suffered by the poor households, especially in developing countries, since they do not have the means to insure themselves. Yet, they are the most vulnerable sections to hazards like floods (Herweijer et al., 2009). Further, empirical studies for flood-related economic damage assessment focus at macro or meso level and spatial aggregation of the affected assets is done over the whole administrative area using land use and hazard exposure maps (Merz et al., 2010). There are very few studies that try to assess the damage to single risk elements, such as, houses by carrying out detailed household surveys, e.g., Dutta et al., (2003), Khandlhela and May, (2006), Brouwer et al., (2007), Sales (2009) and Rabbani et al., (2013). For Mumbai, household surveys have carried out by Hallegatte et al. (2010) to examine the impact of the July 2005 extreme floods on marginalized population and informal economy: the economic impacts on assets and business losses for marginalized populations totaled USD $245 million. But this is likely an underestimate, as health

impacts and out-of-pocket health expenditure were not included in the estimate but were likely to be high.

For the present study, data from two detailed household surveys carried out in six wards have been used as seen in Table 2. The first survey of 1168 households focused on the losses due to the extreme weather event of July 2005 (Patankar et al., 2012). Detailed information was obtained on flood-specific impacts and costs of repairs/replacements of household assets and equipment. Similarly, the second survey of 200 households (carried out in 2014 as part of the present study) focused on the impacts of recurrent floods and ability to respond. Under this survey, questionnaires were used to understand more about vulnerability and impacts of recurrent floods and ability to respond, including the possibility of relocation to another area to escape recurrent floods. The questionnaire focused on (a) household income, expenditure and assets, (b) household characteristics, (c) exposure and impact of recurrent floods, (d) preparing for floods and (e) relocation as an option.

In addition to the above surveys, we have also used the data obtained from 30 housing societies[9] in order to understand the adaptation options exercised by households collectively, source of finance for such measures and the decision-making process involved therein (Patankar et al., 2015).

Table 1: Methodology and data sources for the study

	Research questions	Methodology	Data Sources
Exposure	• Who and what is exposed to recurrent floods	• Examine demographics of flood-prone wards	• Census 2011 data on Mumbai • Ward-wise data obtained from planning department of MCGM on residential, commercial and other land uses
	• What is the extent and spread of poor and non-poor households around flooding spots	• Land use identified in 500m buffer zone around chronic flooding spots and 200m zone around localized spots	• Existing Land Use (ELU) maps of planning department of MCGM • GIS based land use maps created for buffer zones around chronic and localized flood spots
Vulnerability	• What have been the impacts of extreme weather event of July 2005	• Sampling for households in flood-affected wards • Administering questionnaires to sample	• Primary data collected from 1168 households under 2010 household survey

[9] A housing society is a group of housing units, whose object is to provide its members with the open plots of land, dwelling units or apartments and common amenities and services. Member households elect representatives who take decisions on their behalf and look after the common services and their maintenance.

		households to capture impacts	
	• What is the asset and income loss associated with recurrent floods?	• Sampling for households in flood-affected wards • Administering questionnaires to sample households to capture asset and income loss	• Primary data collected from 200 households as part of 2014 household survey
	• Are the impacts heterogeneous	• Examine the impacts on poor and non-poor households separately • Examine welfare impacts such as health, productivity and savings in asset that get exposed to floods easily	• Census 2011 data on Mumbai households • Primary data collected from 200 households for the 2014 household survey
Ability to respond	• What are the adaptation options at the household level	• Identify household adaptation options, their costs, source of finance and decision-making process	• Primary data collected from 1168 households under 2010 household survey • Primary data collected from 30 housing societies under 2014-2015 housing society survey
	• What is the role of government in facilitating private adaptation	• Role of local government in facilitating private adaptation • Community organizations working with local government	• Secondary data and reports from MCGM
	• To what extent can households respond effectively to floods and what are the barriers to adaptation	• Short to medium term effectiveness of household adaptation • Factors restricting the ability to cope	• Primary data from 30 housing societies under 2014-2015 housing society survey • Primary data from 2014 household survey

Table 2: Details of household surveys[10]

Wards	Type of area	Population	Chronic flooding spots	Localized flooding spots	Flooding Depth (feet)	Sample households	
						2010 household survey (N=1168)	2014 household survey (N=200)
K East	Reclaimed area	823,885	2	7	1.0-3.6	241	30
H East	River flood plain	557,239	0	14	0.8-6.0	176	36
F North	Low lying area	529,034	2	9	1.0-3.0	177	29
F South	Low lying area	360,972	1	8	2.0-4.0	103	35
L Ward	River flood plain	902,225	3	13	1.0-4.0	231	35
P North	Reclaimed area	941,366	3	6	1.0-2.6	240	35

4. Results and discussion

This section discusses the findings based on the primary and secondary data to understand the exposure of poor and non-poor households to recurrent floods, direct and indirect impacts on them and their ability to respond to such events.

4.1 Exposure to floods

In order to understand the nature of exposure of poor and non-poor households to recurrent floods in Mumbai, the study has examined the demographics and land use pattern in nine administrative wards that are prone to floods every monsoon. The details of the chosen wards are given as Annexure A.1. Also provided in are the tables showing the flood exposure and demographics in each of the 9 selected wards in Annexure A.1. These wards represent three types of flood-prone areas – low-lying areas, reclaimed areas and areas in the Mithi River flood plain, as seen in Table A.1.1. The information on the total ward population, slum population and the number and location of flooding spots has been obtained from the Disaster Management Cell (DMC) of the MCGM. All the selected wards experience recurrent floods and have a number of chronic and localized flooding spots located within. As seen in Table A.1.1, each ward has a large residential density and also a significantly high percentage of the residents living in slums. For instance, F North, L Ward, M West and P North have more than 50% people residing in slums followed by K East, where the slum population is 49% and H East, where it is 42%.

[10] Information on ward population, chronic and localized flooding spots and average depth of flooding obtained from Disaster Management Cell, MCGM.

In the aftermath of the extreme flooding event of July 2005, the DMC has mapped the locations of chronic and localized flooding spots. Using the Quantum GIS Software and the Existing Land Use (ELU) maps developed by the Planning Department of the MCGM, we have determined the extent of direct exposure of residents around the flooding spots. In addition to the flooding spots, the number of people located near the landslide prone areas has also been estimated in our analysis. This gives us an added dimension to understand the vulnerability of residents.

The types of land uses and number of slum and non-slum residents located in the 500m buffer zone of the chronic flooding spots, 200m buffer zone of the localized flooding spots and 100m buffer zone of landslide prone areas, where applicable, have been estimated through the exposure maps developed by us (seen in Annexure A.2). The assumption for calculating the numbers in Table A.1.1 is that the residential density will be the same across the entire ward. Hence, for each flooding spot, the total residential area covered around the buffer zone of the flooding spot is multiplied by the residential density to arrive at the total number of vulnerable people. Across the flood-prone wards, more than 20% residents are exposed to recurrent floods as they reside in either chronic or localized flooding spots. In M West, more than 47% population is exposed to floods followed by 30% population in F North and L Ward.

In order to understand more about the residents living in flooding spots, the study has used the different types of residential land uses is provided in the ELU maps. Their respective percentages as provided in the ELU maps have been used to determine the number of people in each type of residential land use around the flooding spot using the given residential density. Table A.1.2 gives details of the different types of residences located in the flooding spots, such as, slums, chawls,[11] apartments, government housing and individual housing. Slums and chawls are mostly occupied by poor or low-income households. Apartments and government housing usually have a mix of low and middle-income families. High rise apartments and individual houses are occupied by higher middle income and rich households. We see sizable slum population in the selected wards getting exposed to floods, as seen in Table A.1.2. For instance, in L Ward, M West and H East, more than 30% of the slum population is directly vulnerable to recurrent floods. In P North and F South, sizable population of chawl residents is vulnerable. Similarly, percentage of apartments belonging to low-income and middle-income households with direct exposure to recurrent floods is very high across all wards.

Besides the types of residences located near the flooding spots, we have analyzed the types of other land uses to get better understanding of the asset exposure to recurrent floods. As seen in Table A.1.3, all the selected wards have a number of retail shops, markets, office blocks and industrial units

[11] Chawls are large buildings divided into many separate and often single-room rental tenements offering cheap and basic accommodation. Such buildings were constructed in Mumbai many years back to provide housing to textile mill workers and other labourers who migrated into the city. Many of these buildings are in poor and dilapidated conditions now.

in flood-prone areas. For instance, L Ward and M West have a large number of retail shops and markets located near the chronic flooding spots. Similarly, L Ward, K East, K West and F North have a number of industrial units located near chronic and localized flooding spots. In addition, there are educational amenities, including schools, which are located near flooding spots in almost all the selected wards. Among the medical facilities, the key public hospitals are located at the chronic flooding spot in F South. Similarly, a number of medical facilities are located near chronic spots in M West, L Ward and P North. Social amenities like places of religious worship or community centers are also in large numbers all along the flooding spots in the selected wards. Besides the other services and amenities, there are a large number of public utilities located in flood-prone areas. These include electric transmission and receiving stations, power lines, water pumping stations, sewage pumping stations, public sanitary facilities, solid waste disposal sites, fire brigade, storm water pumping stations, etc.

The key findings from the flood exposure analysis are:

- A large number of households reside nearby and are directly exposed to chronic and localized floods across the flood prone wards in the city.
- The percentage of slum dwellers located near the flooding spots is quite high. These are the most vulnerable sections of the population and are directly exposed to flood waters due to their location on the roadsides or in low-lying areas.
- Besides slum households, other poor, low and middle income households residing in chawls and apartments are exposed to recurrent floods in large numbers.
- Apart from the households residing in and near the flooding spots, people transiting through the areas for work or to use services and amenities are also directly and indirectly exposed to floods.
- The direct exposure of population in transit happens when they use the services and amenities located near the flooding spots. There are a number of shops, markets, educational and medical facilities, social amenities and public utilities which are located near these spots.
- The nature of all the land uses around the chronic and localized flooding spots highlights the significant amount of asset and wealth exposure to recurrent floods.

4.2 Vulnerability and impacts of floods

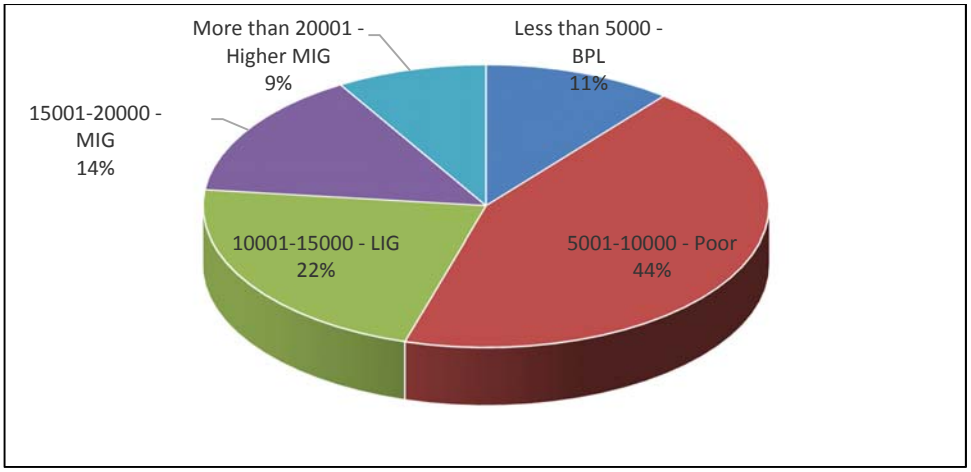
This section explores the vulnerability and impacts of recurrent floods on the households in Mumbai through the surveys carried out in six flood-prone wards as described in the methodology section. The analysis focused on the socio-economic profile of surveyed households, multiple stressors faced by them, vulnerability to recurrent floods, impacts of the extreme weather event of July 2005 and subsequent impacts of recurrent floods.

4.2.1 Socioeconomic profile

For the 200 households surveyed across six wards for this study, Figure 3 shows their socio-economic status. Among the sample households, 11% have monthly income less than Indian Rupees (Rs.) 5,000.

Based on the Poverty Line estimates using Tendulkar Method, the All India Urban Poverty Line is Rs. 1,000 per person per month (GoI, 2013). Since the average family size in slums is 5 as per Census 2011 and Below Poverty Line (BPL) households reside mainly in Mumbai slums, the households with income less than Rs. 5,000 per month are classified here as BPL households. Incomes between Rs. 5,000 and 10,000 are also poor households, but just above the poverty line. Ministry of Housing and Urban Poverty Alleviation (MHUPA) recognizes Rs. 15,000 or less as Low Income Group (LIG) households and above Rs. 15,000 as Middle Income Group (MIG) households. We have further classified Rs. 20,001 and above as Higher MIG households. Based on this classification of households into BPL, poor, LIG, MIG and Higher MIG, most of the households (77%) in our sample are BPL, poor and LIG households. This corresponds with the overall income distribution in Mumbai (Annez et al., 2010).

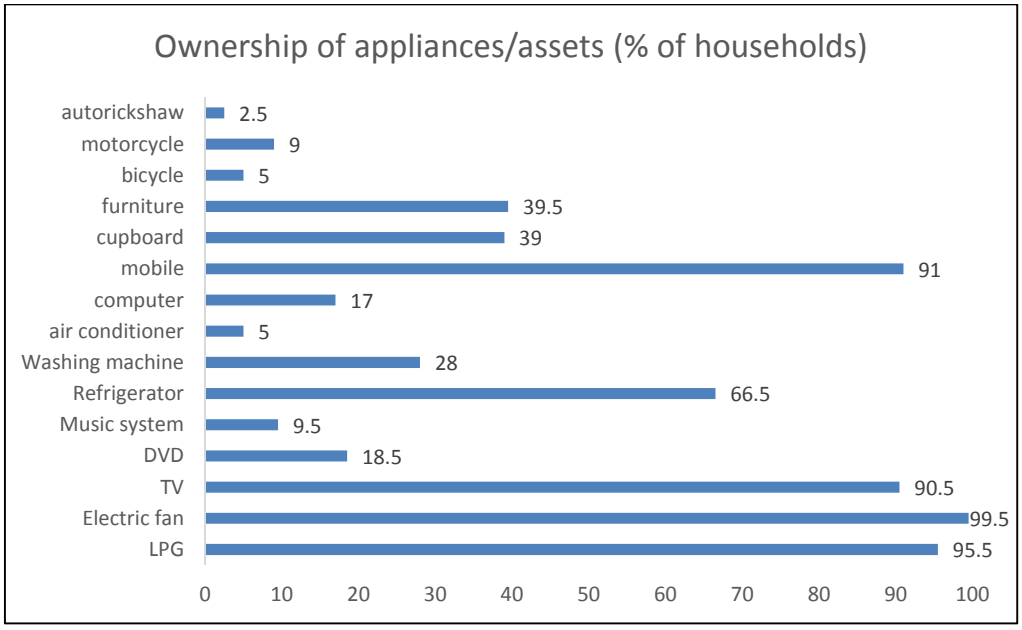
Figure 3: Income distribution of sample households



The average family size is 6 members, with 4 adults and 2 children and mostly only one earning member. Education and occupation of head of the household is a good indicator of the socioeconomic status of the family. In our sample, the average level of education is matriculation (10^{th} grade, 33%) followed by higher secondary (10+2, 26%) and graduation (20%). Not many are educated beyond graduation or have professional degrees. The occupation, in accordance with education, is either private service or small retail business. 23% of respondents also work as skilled or unskilled labor. Average expenditure further corroborates the income levels reported by the families. They spend on an average Rs. 3,000 on groceries, Rs. 250 on water, Rs. 1,000 for electricity and Rs. 850 for transportation per month. The medical expenses are Rs. 850 and repairs or maintenance expenses are about Rs. 1,000. Only 15% families have reported saving some money in the bank every month and the average savings are about 10% of monthly incomes. The penetration of banking is actually quite high in Mumbai (86% of households) based on Census 2011. However, given the lower incomes, the households may not be able to keep a large part of their incomes as savings in a bank.

Figure 4 depicts the ownership of appliances or assets that the sample households own. More than 90% families own a television set, mobile phone and electric fan. Almost all houses use LPG cylinder for cooking. More than 66% families also own a refrigerator. Expensive durable appliances, such as, air conditioner or washing machine are owned by fewer households. Another important finding is that 90% families own the house they live in. Although housing in slums is considered illegal, the families purchase houses through the informal networks operating in these areas. The implication of this finding is that poor and low income households invest in the house and durables and appliances; the very assets that are most affected during floods.

Figure 4: Ownership of appliances/assets in sample households

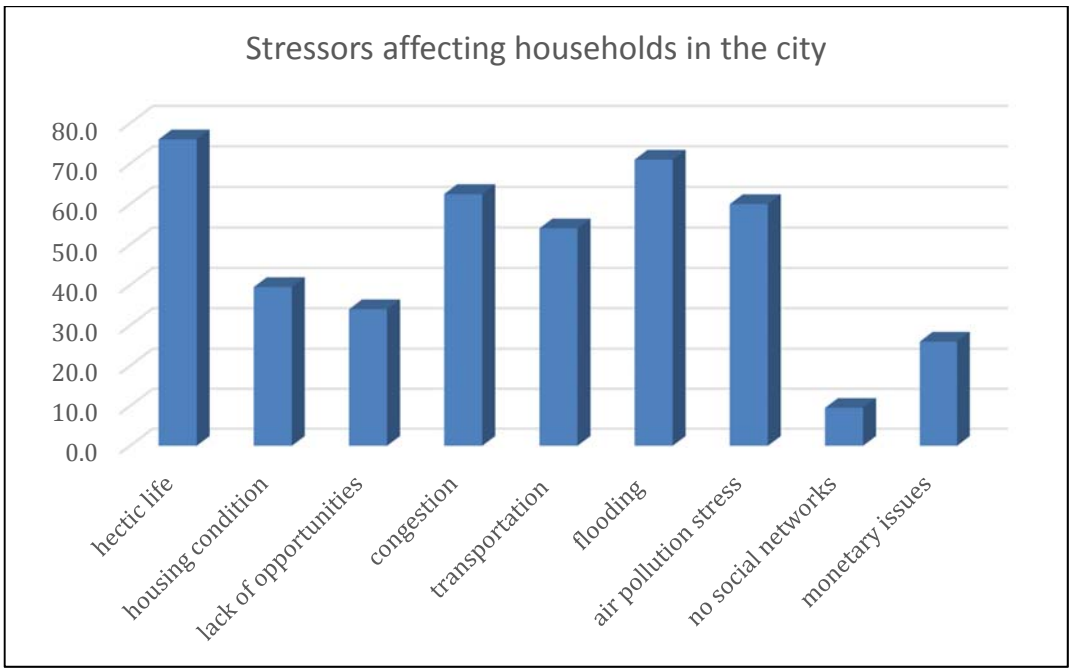


Most surveyed families live in older buildings with average 30 years since construction. 72% are living in slums or chawls and the average size of the dwelling is 200 sq. ft. Families usually carry out maintenance and repair work every 2-3 years, for which each house contributes about Rs. 500 per month. More than 60% houses have rated the quality of drinking water and sanitation as fair and 27% have rated it as good. Same is true with the reliability of electricity with 61% rating it as fair. Almost all households have some medical services nearby in the form of general practitioners, municipal health centers, hospitals or specialist health clinics. 90% of the families live and work in the same area. The same area would basically mean a workplace within the city limits, since the average time spent by them for traveling to work every day is about 1.5 hours. The mode of transportation is multiple, which is typical for Mumbai. About half of the families use the suburban railway network followed by buses and 35% also walk to work.

The majority of the families have been living in the same area for a long time (average 45 years) and 51% have migrated from rural areas 38-40 years back. 66% reveal that they feel less stressed in the

city compared to how they were in the rural area. However, there are a number of stressors that families associate with city life as seen in Figure 5. 71% households have reported flooding as a critical stressor, which is the second highest stressor after hectic life. Other important stressors are congestion, air pollution and transportation.

Figure 5: Multiple stressors affecting households in the city



4.2.2 Impacts of the July 2005 extreme event

Most households living in the suburbs of Mumbai were affected directly or indirectly during the extreme precipitation of 26 July 2005. The city administration was caught off guard and the deluge brought the city to a virtual standstill. It took almost a week for the public utilities and services to return to normalcy. The worst hit by the unprecedented floods were the poor and low income households, who do not have any form of insurance or social protection. As mentioned in the methodology section, the household survey in 2010 (funded by the Asia Pacific Network or APN) interviewed 1,168 households across six flood-affected wards to understand the magnitude and nature of losses suffered by them. The monetary impact on the households, as analyzed by the 2010 household survey, is depicted in Table 3. The most important impact in terms of the amount spent on repair or rebuilding the house. This amount has exceeded the average monthly incomes of the respondent households across all surveyed wards. Other losses are due to damage to household appliances, assets or vehicles.

Table 3: Impacts on households during July 2005 extreme event

	K East	H East	F North	F South	L Ward	P North
	(Figures in bracket as % of average household monthly income)					
Income loss due to floods	10474 (69.8)	8543 (57.0)	5164 (25.8)	8323 (41.6)	22578 (112.9)	14894 (74.5)
Amount spent on repair/rebuilding of house/premises	22270 (148.5)	26191 (174.6)	34335 (171.7)	42967 (214.8)	22457 (112.3)	27118 (135.6)
Losses due to damage to household appliances (TV, refrigerator, washing machine, etc.)	13190 (87.9)	15469 (103.1)	13442 (67.2)	10081 (50.4)	11325 (56.6)	23923 (119.6)
Losses on account of damage to household assets (Furniture and utensils)	9735 (64.9)	11061 (73.7)	11756 (58.8)	6602 (33.0)	7121 (35.6)	10417 (52.1)
Losses due to damages to vehicles (Car, Motorcycle, Bicycle)	12974 (86.5)	9153 (61.0)	11833 (59.2)	1250 (6.3)	5478 (27.4)	7232 (36.2)

Source: Patankar et al., 2012

Table 4 further looks at these impacts across different income categories. Similar income classification of BPL, LIG, MIG and Higher MIG is used here depending on the income ranges originally used in the study. The table shows how the poor and low income houses suffered relatively far greater magnitude of losses compared to their earnings. For instance, BPL houses suffered losses of Rs. 37,000 on average, which is more than six times their monthly income. But for LIG families, losses are 4-5 times their monthly income, thrice for the MIG households and twice for the higher MIG families. Hence, the poor and low income households with limited or no ability to bear the losses have suffered more during the extreme floods compared to their better-off counterparts.

Table 4: Impacts distributed across income categories (2005 floods)

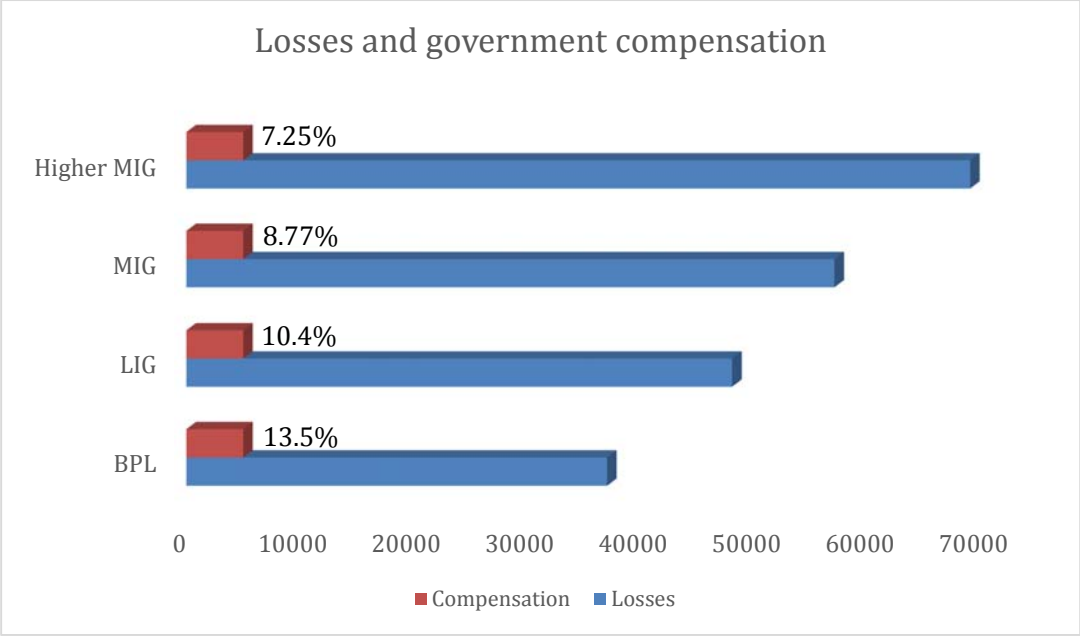
Category	Income loss	Damage to appliances	Damage to assets	Amount spent on house repairs	Damage to vehicles	Average losses
Less than 5000 (BPL)	5000	11000	6700	15000	6500	37000
5000-15000 (LIG)	5000	13000	7000	22000	9000	48000
15000-30000 (MIG)	14000	14000	10000	30000	10000	57000
Above 30000 (Higher MIG)	12000	17000	13000	45000	-	69000

Source: Calculations based on data obtained from 1168 households

When we consider the nature of assets in which poor families invest, such as house, durables and appliances, these are the very assets which suffer the most damage during floods. This is a very important finding that has critical policy implications in terms of specifically directing the adaptation interventions towards poor. The losses suffered by the poor households in the city are uninsured and therefore, there is a need to develop an effective insurance or social security mechanism that can protect the only assets owned by the poor from floods and other hazards in future.

The government provided some assistance to the affected families after extreme floods. Among the surveyed households, about 47% reported receiving the monetary help from the government of maximum Rs. 5,000. This amount, termed as the Gratuitous Relief Assistance (GRA) has been predetermined by the Standing Orders (1983) of Government of Maharashtra (GoM, 2006). This assistance is supposed to take care of the immediate requirements of food, clothing and utensils. Therefore, it has no correlation with the actual amount of losses reported by the families. We find the correlation coefficient of -0.18 between the losses suffered by the surveyed households and compensation offered by the government. This suggests that the compensation mechanism is not sufficient and effective in targeting the poor. The amount of the compensation seems to have been decided arbitrarily by an order passed in 1983 and an update of the provision to better reach the poor and more adequately offer compensation should be a priority.

Figure 6: Losses and government compensation for different income groups



Source: Calculated based on the survey of 1168 households

As shown in Figure 6, the government assistance of Rs. 5,000 on average for each income category can cover only up to 13.5% of the losses suffered by the BPL families and 10.4% of losses of low income households. Further, the amount of compensation on average is Rs. 5,000 but some families

have reported receiving less than this amount. If we divide the amount of compensation with the number of family members, the per capita compensation is about Rs. 1,000 for the BPL families (average 5 members) and Rs. 1,250 for others (average 4 members). Thus, the absolute amount of the compensation may seem pro-poor in relative terms, but as poor households are typically larger, the compensation per capita seems to be in favor of families who are not below poverty line.

4.2.3 Impacts of recurrent floods

July 2005 precipitation is a 1-in-200 year event that had a devastating impact on the city households. However, they suffer regularly, albeit in lesser degree, on account of recurrent floods that occur every monsoon season. With this in view, we have gathered information from the 200 households in the present study on the impacts of recurrent floods. The households have been asked specific questions pertaining to the number of days and average depth of flooding every year, problems faced by the families during floods, workdays lost and health impacts after floods.

The average depth of flooding in the surrounding compound, as reported by the households, is about 1.5 feet with the range of 0.5-4.5 feet and water remains between 0.5 and 8 hours depending on the area. 42% of the households have reported that flood waters enter their house every year during monsoon. The average depth of flooding inside the house is 1.3 feet with the range of 0.5 to 3.5 feet and the houses remain flooded for average 2 hours. The maximum depth experienced by the surveyed families was in July 2005 when the compound and the houses were flooded up to 5 feet and 4 feet respectively. Almost all families have said that the intensity and depth of flooding has reduced since 2005, which is not surprising since July 2005 was an extreme and a rare event.

Most households reported damages to structure, electrical wiring, appliances, furniture, plumbing, utensils and vehicles in 2005. Such damages have not been reported since then. During recurrent floods, families face problems of non-availability of transportation, disruption in power supply and non-availability of food and other supplies. Once in 2-3 years, they also face problems of non-availability of drinking water and shortage of fuel during floods. Thus, we can infer that extreme floods cause significant monetary damage to the households, whereas recurrent floods cause inconvenience and indirect impacts due to recurrent problems.

Another important consequence of recurrent floods is the loss of workdays every year, which causes loss of income as well as productivity. On an average, households have reported losing about 2.5 workdays per year. The range is from 1 to 6 days and this would vary every year depending on the intensity of precipitation during monsoon. The reasons for lost workdays are mainly flooding of the road outside offices or houses and non-availability of transportation.

Perhaps the most critical impacts of recurrent floods are the health effects experienced by them in the immediate aftermath of floods every year. Vector-borne and water-borne diseases have a strong link with heavy precipitation and floods. Every year, during monsoon, areas which get flooded

experience an increased incidence of malaria, dengue, diarrhea and jaundice. Wading through the flood waters is also known to be the cause of Leptospirosis. Table 5 gives the significantly high incidence of health impacts experienced by the households every year. The most prominent are chronic cold and cough, viral fever, malaria, diarrhea, typhoid and dengue. This is supported by secondary data from public health department of the MCGM, which has recorded a 217% increase in the incidence of malaria during the last decade and identified unhygienic living conditions in slums and water accumulation during monsoon as the factors responsible for it.[12]

Table 5: Health impacts experienced by households every year after floods

Health impact	% of households
Malaria	64.5
Dengue	29.0
Typhoid	34.5
Jaundice	25.0
Diarrhea	39.5
Viral fever	86.5
Leptospirosis	4.0
Asthma attack	7.5
Chronic cold and cough	92.0

Source: Calculations based on data obtained from 200 households

The responses obtained from the households, thus, show how recurrent floods continue to impact the households year after year. Although the intensity of the impacts is not the same as those during the deluge of 2005, poor households continue to suffer on account of floods. Health impacts and workdays lost also involve direct monetary burden that includes cost of treatment and loss of productivity. Therefore, it is not just the low probability high consequence events like July 2005 that have a significant impact on the households but even high probability low consequence events like recurrent floods that involve recurrent and significant impacts.

4.3 Ability to respond

From the preceding discussion on exposure, vulnerability and impacts, it is clear that the poor and low income households are acutely vulnerable to floods and bear significantly high burden of the impacts. The monetary losses suffered by them during an extreme event are far greater than their incomes. During the recurrent floods, there are impacts and losses on account of lost workdays and non-availability of basic services. Further, there are indirect losses due to the unavailability of services like water supply, electricity and transportation, which cannot be quantified easily. The important issue is to assess the vulnerability and impacts in view of the ability of the poor households to respond

[12] Data obtained from the Public Health Department of the MCGM.

to floods. This section tries to capture different aspects of this ability of poor, short to long-term responses as a function of this ability and the feasibility of the relocation option.

The ability of the households, poor or non-poor, would depend on factors, such as, financial resources at their disposal, early warning systems about floods, responsive administration, training given to households to enhance their coping capacity and resources to prepare for and respond to floods. Some of these aspects are shown in Table 6 below, where the sample households have been classified under three categories, Below Poverty Line (BPL) with monthly incomes below Rs. 5,000, Poor households with incomes of Rs. 5,000-15,000 and Non-Poor households with incomes of Rs. 15,001 and above. For the BPL and poor households, their ability to respond to floods is already limited due to lack of financial resources. Coupled with this are other factors, captured through this survey, which determine their ability to respond and cope.

Table 6: Factors determining the ability of households to respond to floods

Question	Response	BPL (%)	Poor (%)	Non-poor (%)
Aware of nearby shelter	Yes	10.0	8.2	7.0
Have you ever shifted to shelter	yes	5.0	10.1	7.0
Official warning about floods	Yes	10.0	6.6	7.0
How do you receive warning	Community alarm	56.0	64.9	52.6
	Cell phone	11.0	2.7	-
	cable network	-	5.4	10.5
	Radio and TV	33.0	27.0	36.8
How long in advance do you get warning	Less than 15 mins	50.0	66.7	44.4
	Less than 1 hour	33.3	33.3	44.4
	12 hours before	16.7	-	11.1
Whom do you contact in case of floods	Ward office	-	3.3	2.3
	Disaster control room	-	-	2.3
	Local corporator	25.0	20.5	9.3
Training to cope with floods	some training	25.0	16.1	21.4
	no training	75.0	83.9	78.6
Who has provided the training	MCGM	25.0	81.8	83.3
	NGO	50.0	18.2	16.7
	Academic institute	25.0	-	-
Whom do you take loans from after floods	Family and friends	36.4	56.0	37.2
	Informal money lender	9.1	5.0	7.0
	Bank	54.5	47.0	48.8
	Microfinance or NGO	-	1.0	2.3
	Government	-	2.0	2.3

Source: Calculations based on data obtained from 200 households

As seen in the table, across the three categories of households, more than 90% are not aware of nearby shelters. Even during the extreme floods of July 2005, these households did not move to shelters. More than 90% also do not receive any warning about floods. Mumbai does not have an effective early warning system and the only warning households get is through the community alarm and radio and television network. Community alarm simply means the network within the community who spreads information on the impending floods. The households mostly get flood warning 15 minutes prior. When floods occur, poor households approach only the local corporator (elected representative with the local government) since they are known to provide formal and informal support to slums and other poor communities. Some of the non-poor households either approach the MCGM ward office or the disaster control room. Majority of the poor and non-poor households have not received any training on coping with floods. Among those who have received some form of training, it has been organized mainly by NGOs and academic institutions for BPL families and MCGM and NGOs for others.

As regards the financial support and loans in the aftermath of floods, both poor and non-poor households approach banks and/or family and friends. Banks are the major source of support for all since the penetration of banking in the city is very high. It must also be noted that the poor usually do not approach the scheduled commercial banks for loans but the local cooperative banks or chit funds. All these sources have been clubbed together under the heading of loans from banks to indicate that the sources are organized in nature.

4.3.1 Short-term responses

The poor and non-poor households have a limited ability to respond to recurrent floods since they do not have adequate financial resources or access to a formal early warning system and training. With the limited ability, the households, both poor and non-poor, undertake various measures every year on the onset of monsoon through their own initiative and funding. Some of these measures are given in Table 7. All these measures are recurrent with recurrent costs and put financial burden on the poor families. The BPL families have to undertake repairs for roofs and houses in larger numbers than the non-poor, simply because their houses are constructed poorly or might be temporary structures.

Table 7: Recurrent measures undertaken by households in the pre-monsoon period

Measures taken by HHs	BPL (%)	Poor (%)	Non-poor (%)	Cost per HH (in Rs.)
Cleaning house surroundings	70.0	55.7	68.2	200
Cleaning nullah (canal or gutter)	50.0	48.4	56.8	200
Repairing roof	50.0	35.2	25.0	1300
Overhauling vehicle	5.0	5.7	4.5	600
Repairs inside house	35.0	22.1	13.6	800

Source: Calculations based on data obtained from 200 households

Despite the pre-monsoon measures, when the flooding happens every year, the families have to undertake immediate responses in terms of shifting assets to higher elevation, protecting durable assets, documents, jewelry, furniture, etc. As seen in Table 8, the non-poor households shift assets and protect durables and jewelry in more numbers than the poor families since their ownership would be more among the non-poor.

Table 8: Immediate response to floods (% of households)

	BPL	Poor	Non-poor
Shift assets to higher elevation	75.0	77.0	83.7
Protect durable assets	80.0	91.8	95.3
Protect documents	90.0	94.3	95.3
Protect jewelry	85.0	79.5	90.7
Protect vehicles	25.0	17.2	18.6
Protect small furniture and utensils	60.0	64.7	62.8

Source: Calculations based on data obtained from 200 households

4.3.2 Structural responses

After the floods of July 2005, many households have also undertaken structural measures to protect their assets from floods. Some of the responses on structural measures obtained from the survey of 1,168 households are listed in Table 9 below. The poorest households have had to undertake major repairs and reconstruction work after the damage done by July 2005 floods. Further, the measures have been undertaken with the hope that they will provide effective long-term solutions to protect against floods or reduce the impacts of floods. Most of these households have reported obtaining loans to undertake these measures, in the absence of insurance or other compensation mechanisms.

Table 9: Measures undertaken by households after July 2005 event

Measures after 2005 floods	BPL (< Rs. 5000)	LIG (Rs. 5000-15000)	MIG (Rs. 15001-30000)	Higher MIG (> Rs. 30000)
Increasing height of surrounding plot	57.5	52.9	59.4	73.3
Reconstruction within the house/parking	14.5	12.2	12.1	6.7
Repairing & elevating electrical meters	45.1	30.1	34.7	26.7
Repairs inside house to elevate furniture	45.1	40.2	54.0	80.0
Repairs inside house to elevate electronic gadgets	44.6	32.6	37.1	26.7
Repairing/ modifying toilets	8.3	5.3	11.3	13.3

Source: Calculations based on survey of 1168 households

Besides household efforts, cooperative housing societies have also undertaken structural measures as shown in Table 10. Many poor and most non-poor households in Mumbai organize themselves into housing societies. A typical housing society has a number of families residing in apartments and

they make monthly contribution to the funds raised by the society for repairs and maintenance. The structural measures are financed through the monthly or yearly contribution that member families have to make. Out of the 30 housing societies surveyed in flood-affected areas of Mumbai (Patankar et al., 2015), majority have increased the height of the surrounding plot. Many have relocated the electrical meter rooms or have shifted individual electrical meters on the higher floors. For some societies, the local corporators (elected representatives) have used their official funds to put paver blocks in the compounds to increase the height of the surrounding plot. Most of the measures are financed by the members' monthly or annual contribution and in some cases through the society corpus, which is also the members' contribution at the time of forming a society.

Table 10: Long-term measures undertaken by housing societies

Measure	% of HHs undertaking measure	Average cost in Rs.	Source of finance
Increase the height of the surrounding plot	43.3	13000	Members' contribution/Society corpus
Reconstruction within the building and/or parking	13.3	50000	Members' contribution
Relocating electric meter room	26.7	9000	Members' contribution/Society corpus
Relocating/ Elevating water pump room	30.0	12000	Members' contribution
Elevating electric meters to a higher level	20.0	10000	Members' contribution
Modifying/repairing water supply network inside premises	30.0	5000	Members' contribution
Paver blocks	13.3	NA	Elected representative

Source: Patankar et al., 2015

The structural measures undertaken by individual households and housing societies are essentially private efforts financed through individual resources. There are some critical points about these efforts that need to be mentioned here. Although the structural measures are believed to provide long-term protection against flooding, almost half of the housing societies and individual households do not believe that they measures will be effective if another event like July 2005 strikes the city. Further, most of the households and even housing societies have not taken professional help to assess the technical specifications of the work undertaken. The decisions are purely based on what the households decide, individually or collectively. Further, technical and financial assistance from the local government or other entities is limited. Given that the decision-making regarding the responses and measures is driven by individual needs with little guidance on what is appropriate, cost effective and beneficial in the long-term, they may not be technically and financially the best possible solutions. Further, there is a strong possibility of mal-adaptation given that the measures

are designed and financed by private stakeholders with limited focus on individual premises. This has been experienced in many parts of the city where individual housing societies have increased the heights of their plots, thus flooding the road or nearby premises. As there is no regulation on the measures undertaken by the private stakeholders, resilience in these areas to future risks may be compromised.

4.3.3 Relocation as an option

As flooding in Mumbai is recurrent and the poor households bear the brunt of the impacts every year, relocation to a flood-free area might be one of the solutions, especially for those who reside in chronic flood spots. Therefore, we asked our sample of 200 households specific questions about relocation as a possible option and factors they would consider important while accepting relocation to a flood-free area.

As seen in Table 11, half of the BPL households have considered moving out the flood-prone area after the experience during July 2005 floods. However, the BPL as well as poor households have not moved out for a number of reasons. For the BPL families, main consideration is the existing strong social network, which is often the source of support while living in informal settlements with little access to amenities and public utilities. These families feel that they will not be comfortable in new locations where such networks are not present. Another important consideration is that such families do not have enough financial resources to move to a better location. For the other poor and non-poor households, the decision not to move out of the flood-prone areas is proximity to the work place and strong social networks.

Table 11: Reasons cited by households for not moving out of flood-prone areas

	BPL	Poor	Non-poor
Have you considered moving out			
Yes	50.0	24.8	23.3
No	50.0	75.2	76.7
Reasons for not moving out			
Not enough financial resources	35.0	34.4	27.9
Can't avail of loans for another house	15.0	18.9	16.3
Work place is nearer	25.0	45.9	48.8
School/college is nearby	10.0	4.1	7.0
Access to public transportation is good	20.0	19.7	16.3
Do not feel comfortable about new location	45.0	42.6	44.2
Transportation will be costly	10.0	2.5	2.3
Water, electricity or maintenance will be costly	10.0	2.5	0.0
Have strong social network	45.0	47.5	41.9

Source: Calculations based on the data obtained from 200 households

Further, Table 12 shows that majority of the households below poverty line and non-poor households would not want to consider relocation as an option in future. Only among the poor households, more than half are willing to consider this option. For all the households put together, irrespective of their income category, the most important factors for relocation seem to be (in the order of importance) clean surroundings, access to medical facilities, people from the same community living nearby, cheaper transportation, access to schools and good social networks. For the BPL families, important factors are people from same community living nearby, access to schools, medical facilities, cheap transport and clean surroundings. For the other poor households, clean surroundings and access to medical facilities are important. For the non-poor, access to medical facilities and schools, clean surroundings and good social networks are important considerations.

Table 12: Factors considered important for relocation by poor and non-poor households

	BPL	Poor	Non-poor
Will you consider relocation as an option			
Yes	35	53.7	39.5
No	65	46.3	60.5
Factors important for relocation			
Job opportunities	25	26.2	16.3
Same cost of living	20	12.3	7
Access to transport	20	18.9	16.3
Cheaper transport	55	44.3	39.5
Access to schools	45	43.4	44.2
Access to medical facilities	70	51.6	46.5
Clean surroundings	65	67.2	41.9
Good social networks	25	36.1	41.9
People with similar backgrounds	20	32	27.9
People from same community	75	49.2	32.6

Source: Calculations based on the data obtained from 200 households

Finally, all surveyed households have acknowledged the fact that they can do something themselves to reduce the extent of flooding. Although almost all of them believe that MCGM must take the primary responsibility to reduce the flood risk, even individuals are responsible for the same. Some important suggestions from households regarding individual efforts are cleaning the nearby gutters, stopping the encroachment on nullahs and gutters, stopping dumping garbage and reducing the use of plastic bags that clog the drains. There are instances of initiatives taken up mainly by the MCGM to clean up the areas. But individual efforts seem to be lacking in this regard and households mainly rely on the local government departments to take steps to reduce the flood risks.

5. Policy implications

Poor households in Mumbai support a large share of the cost of extreme and recurrent floods. Further, they are vulnerable to floods due to limited resources and have inadequate infrastructure and access to facilities thus limiting their capacity to respond to floods. Therefore, it is important for

Mumbai's planners and policy makers to have well-directed adaptation planning and programs. They need to initiate specific plans or programs that target areas where poor people reside and are vulnerable to floods. Efforts to reduce the extent of flooding in the city have implications for poverty alleviation. A number of policy recommendations emerge:

- **Departmental coordination.** There appears to be a lack of an integrated approach and various departments of the local government, which seem to work in silos. Departments like solid waste, water and sanitation and public health do not have a coherent strategy for dealing with floods. Recurrent floods are the result of not just the inadequacy of the current storm water drainage system to carry the rainwater out to sea but also the inability of the solid waste machinery to keep the roads and nullahs free of garbage. This is apparent from the feedback received from the households. What is needed is a well-coordinated effort in MCGM that will bring all the departments together to chalk out a common program for dealing with recurrent floods.

- **Drainage upgrades.** The upgrading of the storm water drainage system in Mumbai has not been completed on time and there have been significant cost over-runs. The main challenges are the clearances required from various authorities within the city, such as, railways, airport, traffic police and port trust as well as lack of access to many sites due to encroachment by slums or issues related to land ownership. Governance and implementation of such schemes in Mumbai becomes difficult since there are a number of land owners and multiple planning authorities. The land owners include MCGM, Mumbai Metropolitan Region Development Authority (MMRDA), Urban Development and Housing Departments, District Administration, Special Planning Authority and other Para-statals. As these institutions have diverse agendas, it makes it difficult to implement plans and programs in the city.

- **Household measures.** In case of structural measures initiated by households, the decision-making is driven by individual needs with little guidance on what is appropriate, cost effective and beneficial in the long-term. The measures undertaken privately may not be the best solutions, technically and financially, as professional help is often not sought, and financial incentives from the government to invest in risk reduction are lacking. Further, even if the households are making efforts to protect themselves against recurrent floods, there is very little awareness about future climate risks. There is a greater need for more awareness and capacity building to prepare them for future risks. The focus needs to shift from engineering solutions to community measures that provide benefits by improving the solid waste management, cleanliness of the surroundings, and hygiene practices. The solutions should also aim at behavioral changes among households.

In combination with structural changes, a number of non-structural policy recommendations also come forward from the analysis:

- **Insurance.** The monetary burden of losses as well as responses taken by poor households brings into focus the need to have an effective insurance mechanism to provide protection against such losses and finance the response measures as and when the need arises. But even if insurance products are designed to protect households from floods, the premiums are unaffordable for the poor households. Therefore, a public-private partnership approach is required to provide insurance and reinsurance facilities in order to induce insurance companies to provide appropriate and affordable products for flood related damages. In most of the flood areas in Mumbai, people have small-scale industries that are sometimes badly hit and are uninsured. A combined asset/small business insurance as well as medical insurance (typhoid and other water-borne diseases are a big concern) will go a long way towards strengthening communities.

- **Compensation.** The compensation mechanism of the government is not sufficient and effective as it is not directed specifically at poor households and those below poverty line. In fact, in per capita terms, compensation offered in the aftermath of July 2005 event seems to be higher for non-poor rather than poor households. Therefore, a mechanism that can have targeted social protection provided to the poor should be a priority for the government. If non-poor households can access insurance products against floods and other risks, the government may be able to concentrate their resources on helping the poor and non-insured. This would ensure more efficient utilization of government funds for relief and rehabilitation.

- **Household rainfall monitoring**. Developing an application for hourly monitoring of rainfall that households (including the poorest) can access can assist households in making their own decisions in terms of evacuation and protecting assets, rather than waiting for wards or the local government to sound the alarm. The Disaster Management Cell of MCGM has developed a mobile application (Disaster Management Mobile Application) to give ward-wise 15-minute interval data on rainfall, wind speed, and tidal information. However, this application is not widely used since awareness is very low. Given that early warning access is a paltry 10% in the surveyed sample, awareness building about the mobile phone application will help reach the poorest to make better-informed decision-making at the household level.

While some characteristics of this case study are specific to Mumbai, many issues related to flood vulnerability outlined in this paper are applicable to many cities in South Asia, as identified by a recent World Bank study on urbanization in the region (World Bank, 2015).

Between 2000 and 2011, South Asia's urban population expanded by 130 million people and is poised to grow by 250 million more by 2030. Almost 80 percent of these major South Asian cities are exposed to floods, with exposure increasing not only due to a higher population living in risky areas but also climate change.

Many of these cities should follow Mumbai's lead and develop hazard and land-use mapping to improve knowledge on risk information for land-use planning. But as outlined through our household survey, land-use planning can realistically function only if accompanied by investments in transport and other infrastructure to make it possible for people to settle in safe places while maintaining access to the same (or comparable) jobs and services. And infrastructure investments in general will reduce the long-term vulnerability of the population only if they serve poor people and only if new infrastructure designs remain efficient in spite of changes in climatic and environmental conditions.

In addition, ex-ante grants targeted to low-income households can incentivize investment in flood protection. Increased penetration of insurance through public-private partnerships can hasten recovery by lowering out-of-pocket expenses after a flood. But such schemes may not be applicable for the poorest population. For this group, ex-post compensation is necessary. The ad-hoc schemes after the Mumbai floods in 2005 and the Bangkok floods in 2011 (Noy and Patel, 2014) are insufficient and not targeted to this segment of the population; adapting these schemes to be more systematic, better-funded, and better-targeted should be a priority to support the most vulnerable after a flood hits.

6. Summary and Conclusion

To summarize, this study has been carried out to examine the exposure, vulnerability and ability to respond of households in the city of Mumbai to recurrent floods and bring out policy implications for future adaptive capacity and resilience. Given the large presence of informal settlements and acute income inequalities in the city, the study has specially focused on the poor households. The study seeks to understand how poor households may be located in the flood-prone areas vis-à-vis the non-poor households, understand the losses suffered by them on account of floods and examine the extent to which they have the ability to respond to floods. The key findings and conclusions from the study are as below:

- It is apparent from the flood exposure maps and land uses in the chronic and localized flood spots that the poor families are directly exposed to recurrent floods in the city. Most vulnerable families are living in slums or old dilapidated structures known as chawls. Flood waters regularly enter their premises and damage their assets and durables.
- The extreme precipitation on 26 July 2005 imposed a huge monetary burden on the poor on account of income loss, damage to structure of the house or premises, damage to household assets and appliances and damage to vehicles. Families below poverty line as well as poor and low-income households suffered relatively greater magnitude of losses compared to their relatively better off counterparts.
- Poor households who suffer during floods are also uninsured. The insurance penetration levels are negligible among households in India. There is limited social safety nets as well. In the absence of insurance or social security, money spent on repairs and replacements are strictly out-of-pocket expenses borne by families regardless of their income levels. With low

incomes and low savings potential, poor families are the worst hit when such losses are incurred during floods.

- The poor households suffer losses on account of damaged assets, such as, the house or durable appliances and furniture. The poor invest their earnings in these assets, which suffer the most damages during floods. This shows how the asset base of the poor is threatened due to floods.
- During recurrent floods, there are no specific damages to assets but there are indirect impacts due to non-availability of transport, power, drinking water, food and essential supplies. These cause direct and indirect losses that are difficult to measure in monetary terms. The most significant impact of recurrent floods are the recurrent health effects. Vector and water borne diseases are experienced by a large number of households in the aftermath of floods every year. The incidence of malaria, dengue and water borne diseases goes up during monsoon significantly. There is monetary burden of the health impacts in terms of cost of treatment and loss of productivity.
- The compensation offered by the government after the floods does not cover losses of more than 10-15% for poor as well as non-poor households. Further, there is no correlation between the actual losses and the assistance provided. Not all affected families have received this assistance and those who received it have been chosen randomly in the affected areas. There is, thus, a clear problem in targeting the compensation and making it pro-poor.
- The poor households have very limited technical and financial resources to cope with floods. There is no early warning mechanism in the city and the various departments of the local government are not very responsive to the needs of the poor families. The households have to resort to financial assistance from family/friends or banks to cope with impacts of floods which puts additional burden on their already limited resources.
- There are some short-term measures that households undertake on the onset of monsoon every year to reduce the intensity and depth of flooding in their premises. These recurrent measures with recurrent costs put financial burden on the poor families. After the event of July 2005, many households, including the poor, have undertaken structural measures by spending their own resources to find a long term solution. However, there is no technical or financial support and guidance offered by the government to undertake such structural measures and there is a strong possibility of mal-adaptation.
- Despite the vulnerability to floods, relocation to better and flood-free area is not considered by most households, poor as well as non-poor. They would prefer to remain in the same area as they have a good social network. They also do not have the financial resources to make such a move.

To sum up, this study has effectively demonstrated how poor households are exposed and vulnerable to risks from recurrent flooding. It is the poor households who face a significantly large monetary burden of the flood impacts and have very limited capacity to respond or cope given the constraints on their resources. Therefore, well-directed adaptation efforts with focus on the poor are required

in order to protect them from future climate risks. Mainstreaming adaptation into the larger developmental processes will help the city achieve economic growth as well as assist in poverty alleviation.

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Annexure

A.1 Flood exposure and demographics in the 9 selected wards

Table A.1.1: Demographics of the selected wards and number of vulnerable residents

Ward	Type of area	total area in sq. km.	Area for residential use in sq. km.	Population	Slum population as % of total	Residential density per sq. km.	No of flood spots		Number of people			Total population exposed to floods and landslides	% of ward population
							Chronic	Localized	Chronic spots	Localized spots	Landslide spots		
F South	Low lying	9.79	2.34	360972	26.4	154380	1	7	36093	50000	9960	96053	**26.61**
F North	Low lying	12.28	4.03	529034	58.3	131411	2	11	76068	79749	5127	160944	**30.42**
K East	River flood plain	23.96	6.85	823885	49.0	120200	4	6	154025	38728	0	192753	23.40
K West	Low lying	24.55	8.25	748688	14.5	90739	4	11	92015	73927	1096	167038	22.31
H East	Reclaimed	12.42	2.83	557239	42.1	197085	0	14	0	115318	0	115318	20.69
H West	Reclaimed	9.03	4.22	307581	38.5	72935	3	8	40169	34241	1903	76313	24.81
L Ward	River flood plain	15.68	5.45	902225	54.4	165573	3	14	164615	106956	2051	273622	30.33
M West	Low lying	17.4	3.92	411893	52.7	105094	4	5	164598	27992	2248	194838	**47.30**
P North	Reclaimed	46.72	10.27	941366	53.6	91645	3	10	138292	50302	0	188594	20.03

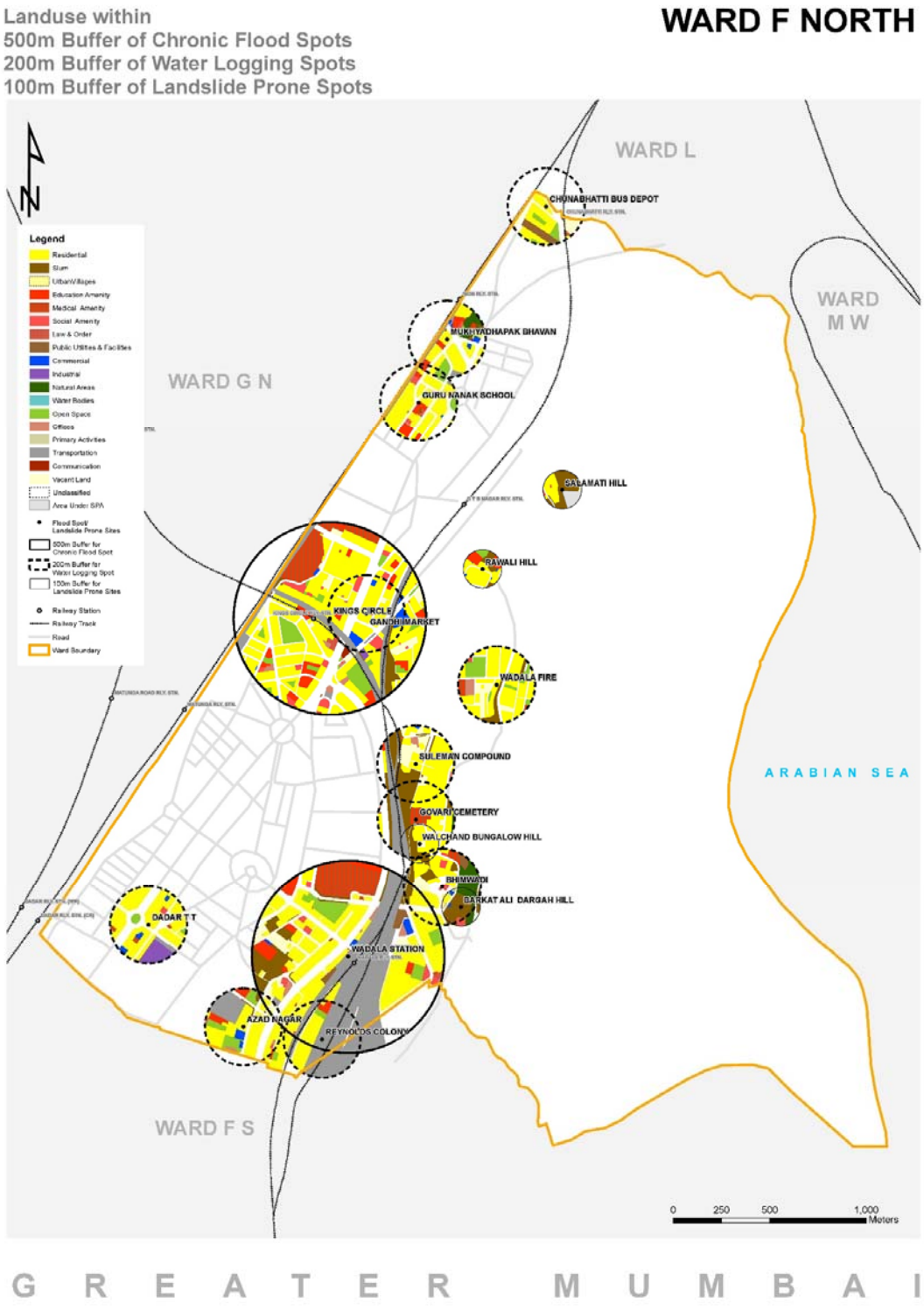
Table A.1.2: Types of residential uses in the flooding spots

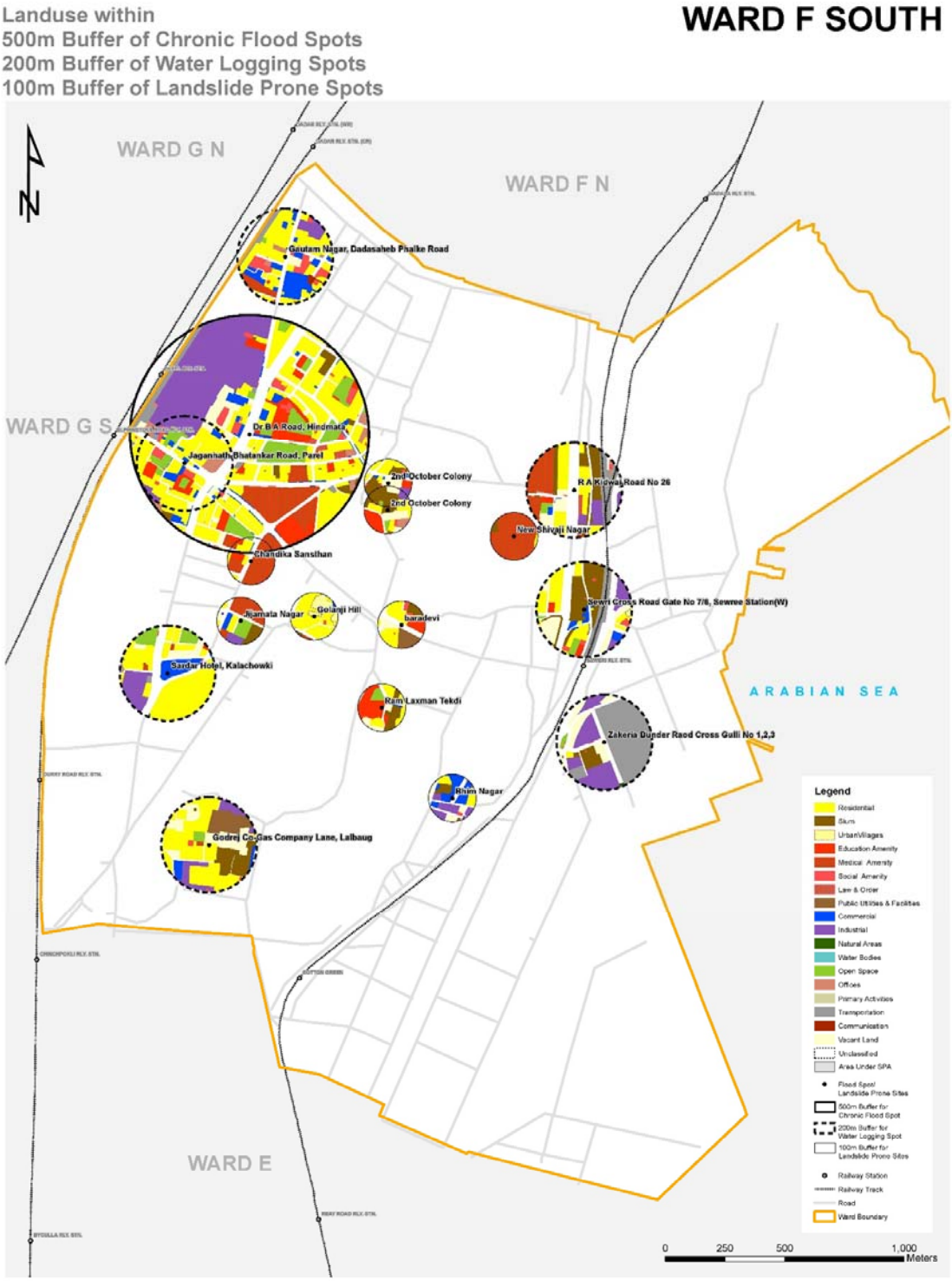
Ward	Total population	Total population exposed to floods	% of exposed population to total	Slums		Chawls		Apartments		Government housing		Individual houses	
				Number	% of exposed population	Number	% of exposed population	Number	% of exposed population	Number	% of exposed population	Number	% of exposed population
F South	360972	86093	23.9	11630	13.5	6571	7.6	43820	50.9	23763	27.6	310	0.4
F North	529034	155817	29.5	19429	12.5	5355	3.4	88823	57.0	40298	25.9	1913	1.2
K East	823885	192753	23.4	30154	15.6	3896	2.0	145487	75.5	9468	4.9	3748	1.9
K West	748688	165942	22.2	25103	15.1	4235	2.6	120438	72.6	4269	2.6	11897	7.2
H East	557239	115318	20.7	38578	33.5	979	0.8	56402	48.9	17393	15.1	1966	1.7
H West	307581	74410	24.2	10954	14.7	514	0.7	54927	73.8	2731	3.7	5284	7.1
L Ward	902225	271571	30.1	106092	39.1	8777	3.2	141839	52.2	7862	2.9	7001	2.6
M West	411893	192590	46.8	67945	35.3	1169	0.6	84628	43.9	19159	9.9	19689	10.2
P North	941366	188594	20.0	40970	21.7	26979	14.3	88346	46.8	2823	1.5	29475	15.6

Table A.1.3: Other land uses in chronic and localized flooding spots

Ward	No of flood spots		Shops and markets	Offices	Industrial	Educational amenities	Medical services	Social amenities	Public utilities
			Number of blocks/buildings						
F South	Chronic	1	53	15	3	17	5	31	7
	Localized	7	47	15	19	9	6	31	10
F North	Chronic	2	12	16	1	22	8	35	11
	Localized	11	21	9	2	17	9	19	7
K East	Chronic	4	92	17	13	34	8	52	9
	Localized	6	21	6	8	6	1	10	5
K West	Chronic	4	84	6	16	17	8	25	8
	Localized	11	52	7	8	13	3	33	7
H East	Chronic	0							
	Localized	14	59	7	6	13	5	26	12
H West	Chronic	3	60	9	4	10	6	22	8
	Localized	8	39	6		8	5	22	3
L Ward	Chronic	3	162	15	22	28	12	62	24
	Localized	14	58	10	22	20	1	35	14
M West	Chronic	4	138	21	1	31	24	96	33
	Localized	5	3	2	2	3	1	14	6
P North	Chronic	3	99	7	9	21	12	72	14
	Localized	10	43	4	1	13	1	30	6

A.2 Ward land use maps





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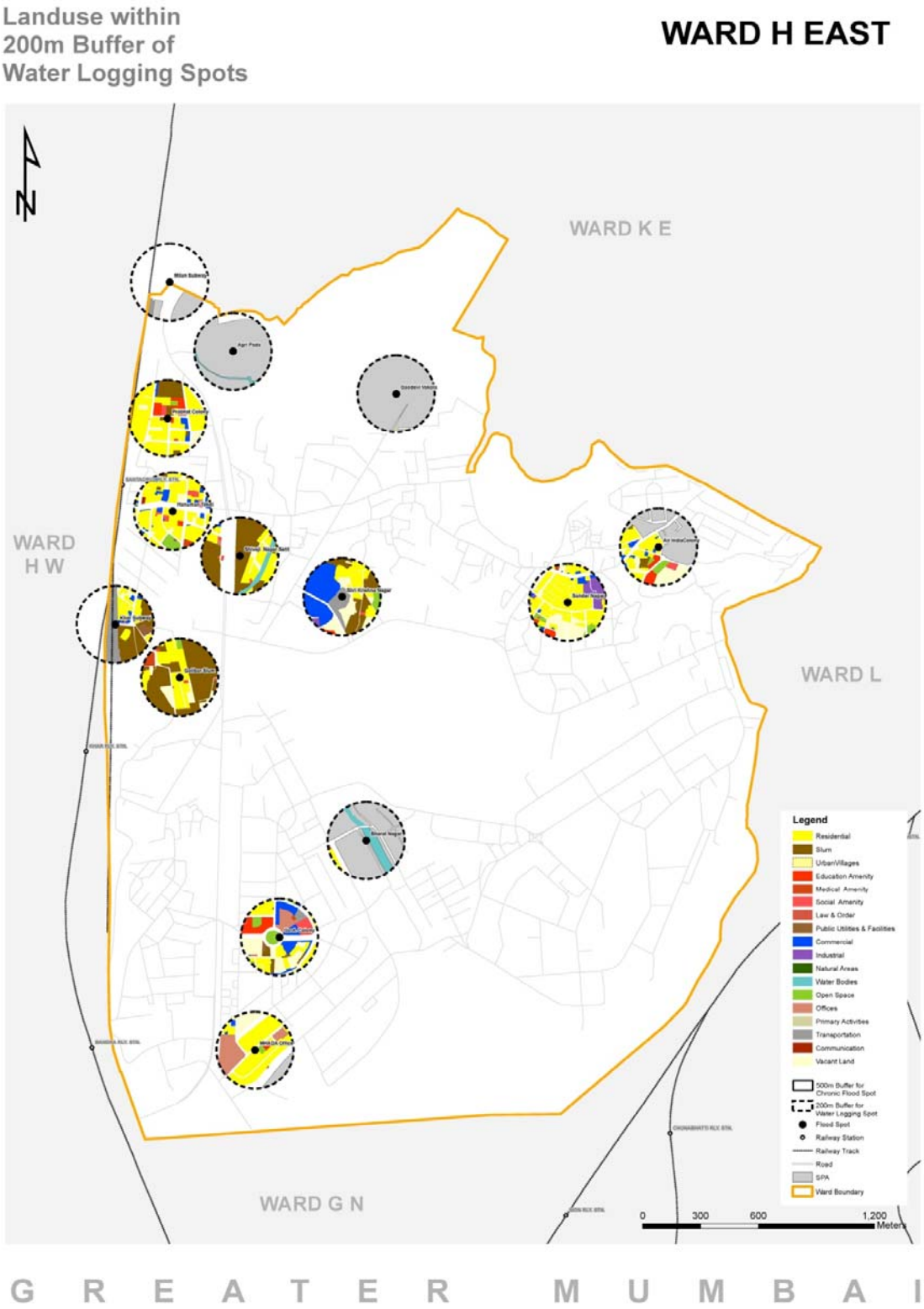
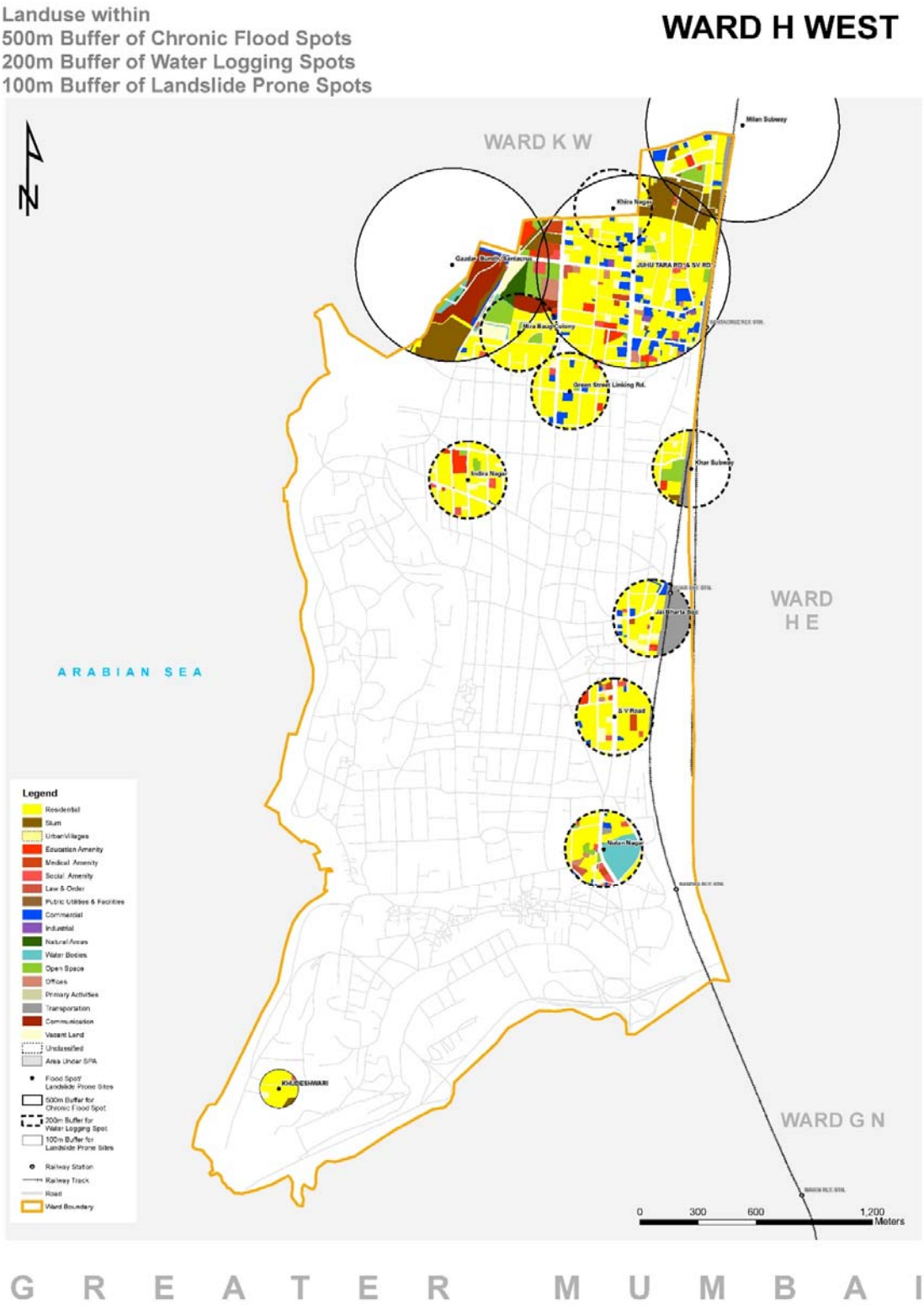
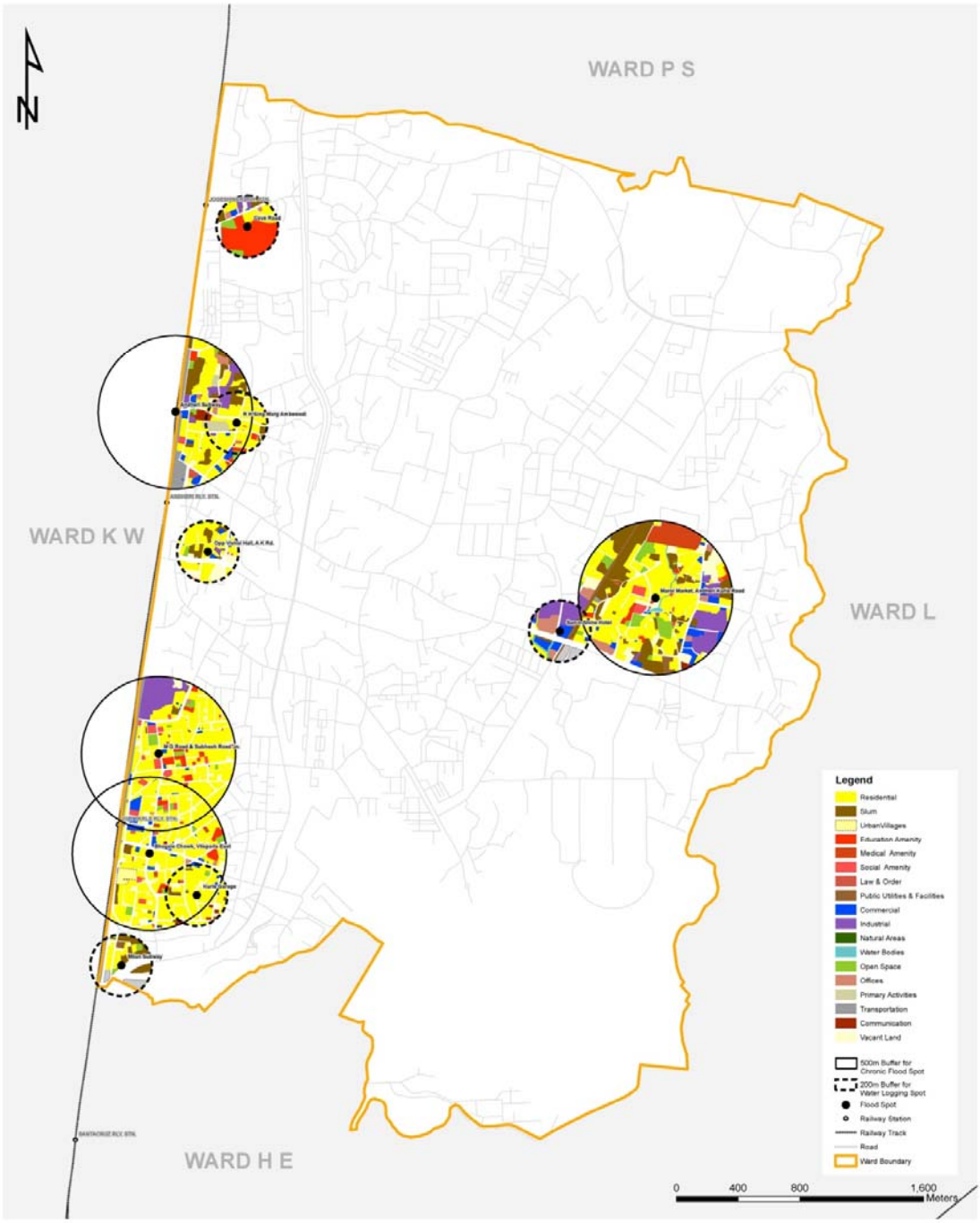

Landuse within
200m Buffer of
Water Logging Spots
WARD H EAST
N
WARD K E
WARD
H W
WARD L
WARD G N
Legend
Residential
Slum
UrbanVillages
Education Amenity
Medical Amenity
Social Amenity
Law & Order
Public Utilities & Facilities
Commercial
Industrial
Natural Areas
Water Bodies
Open Space
Offices
Primary Activities
Transportation
Communication
Vacant Land
500m Buffer for Chronic Flood Spot
200m Buffer for Water Logging Spot
Flood Spot
Railway Station
Railway Track
Road
SPA
Ward Boundary
0
300
600
1,200
Meters
G R E A T E R M U M B A I



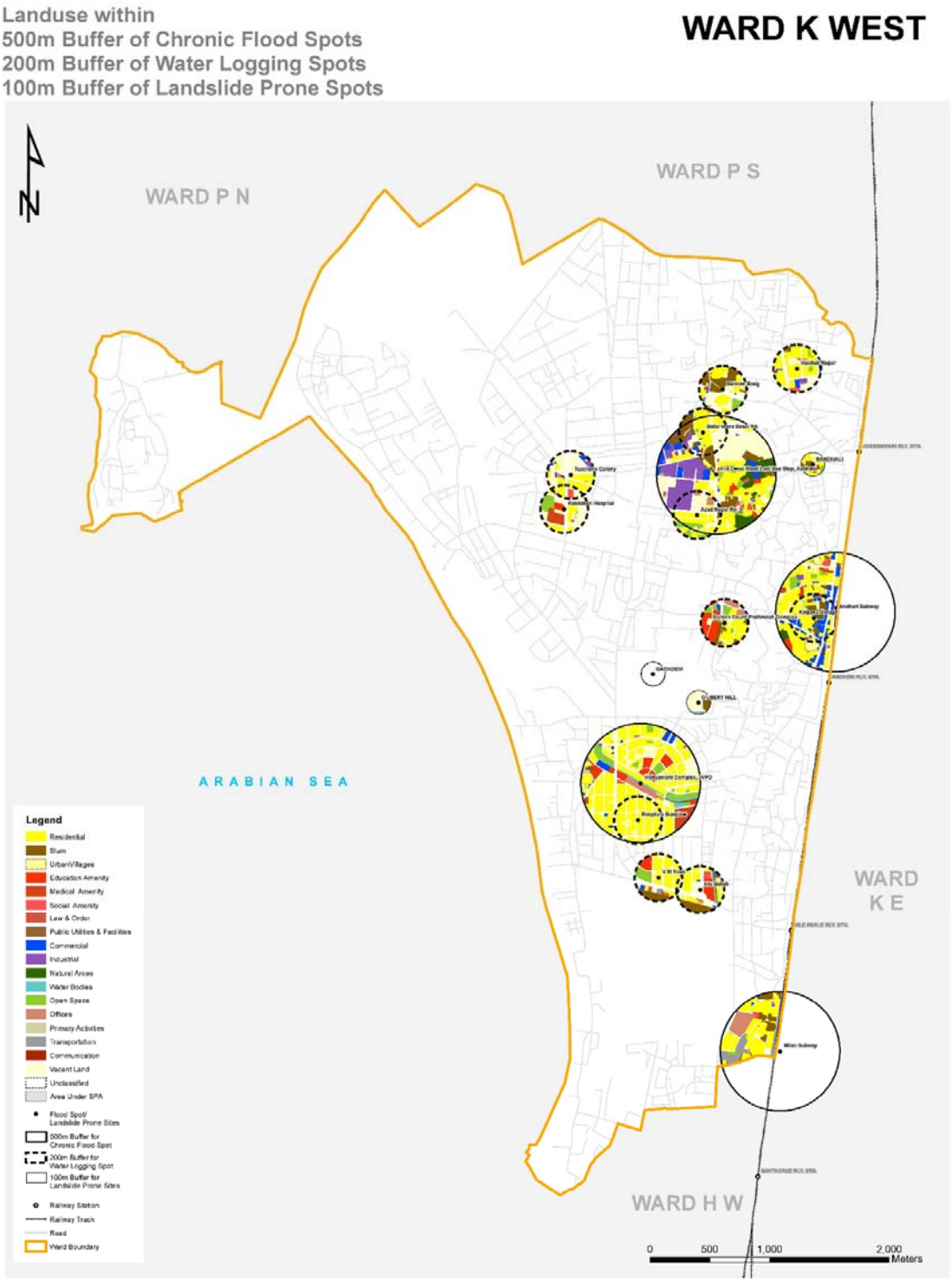
G R E A T E R M U M B A I

Landuse within
500m Buffer of Chronic Flood Spot
200m Buffer of Water Logging Spots

WARD K EAST



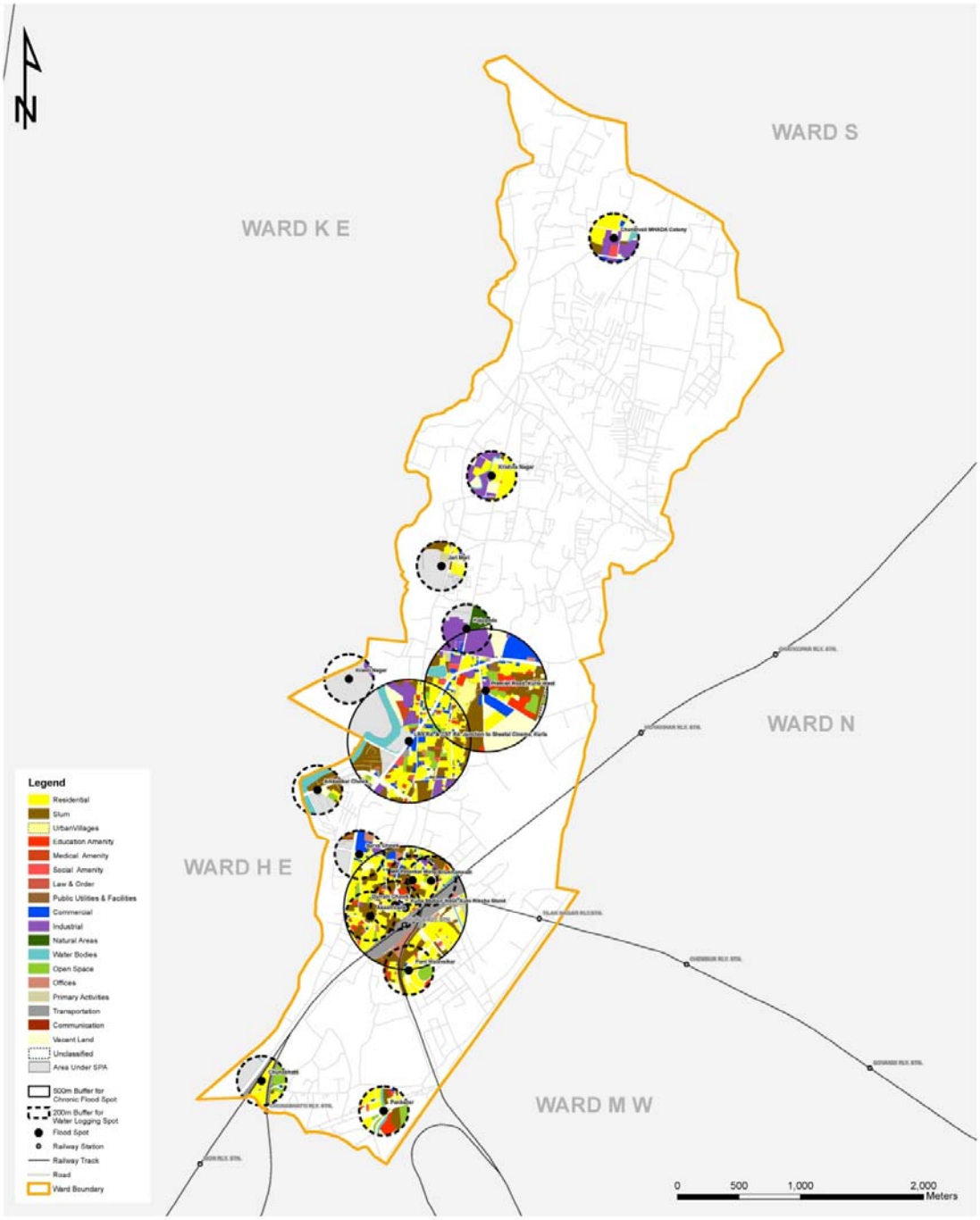
G R E A T E R M U M B A I



G R E A T E R M U M B A I

Landuse within
500m Buffer of Chronic Flood Spot
200m Buffer of Water Logging Spots

WARD L



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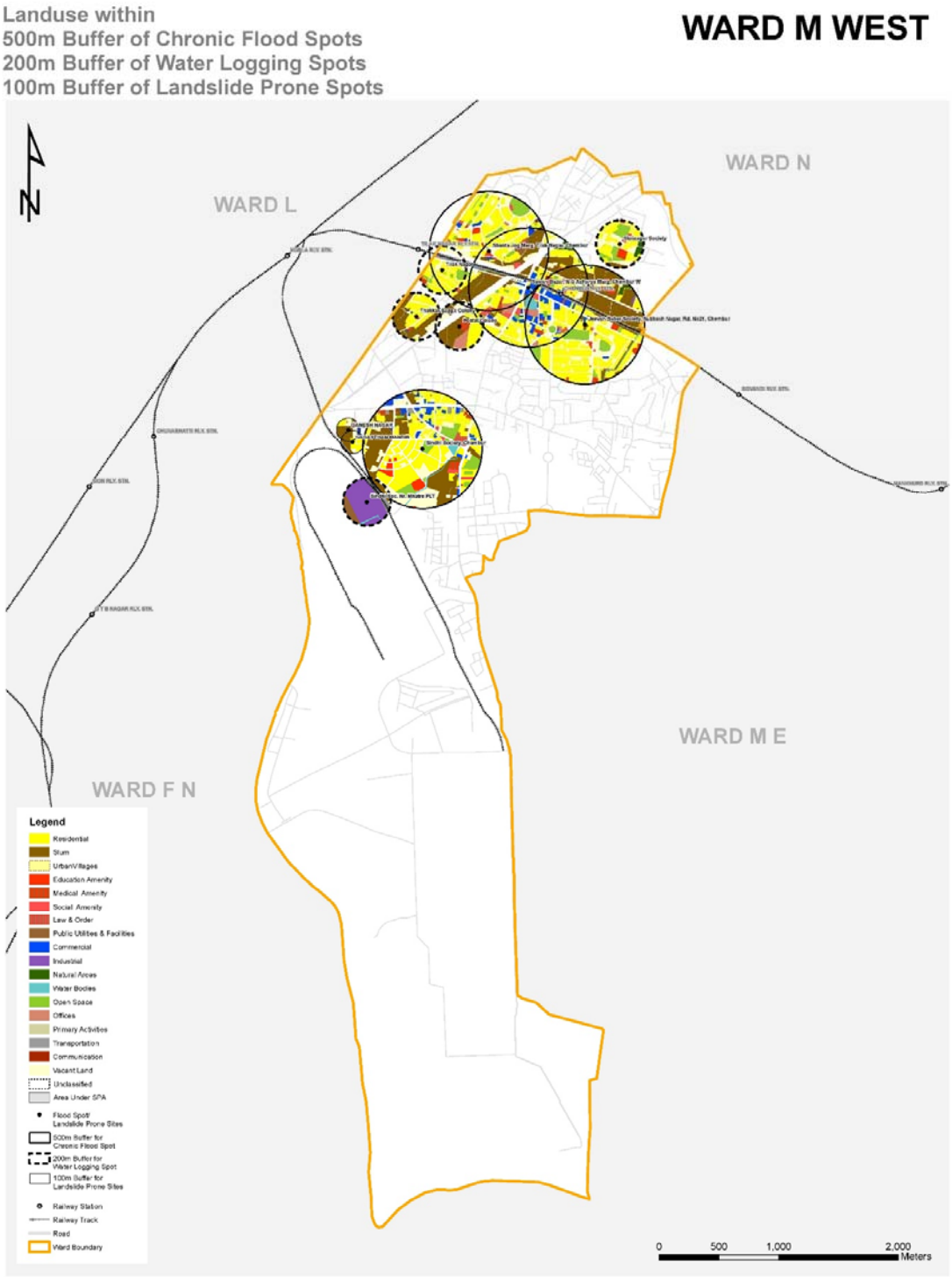
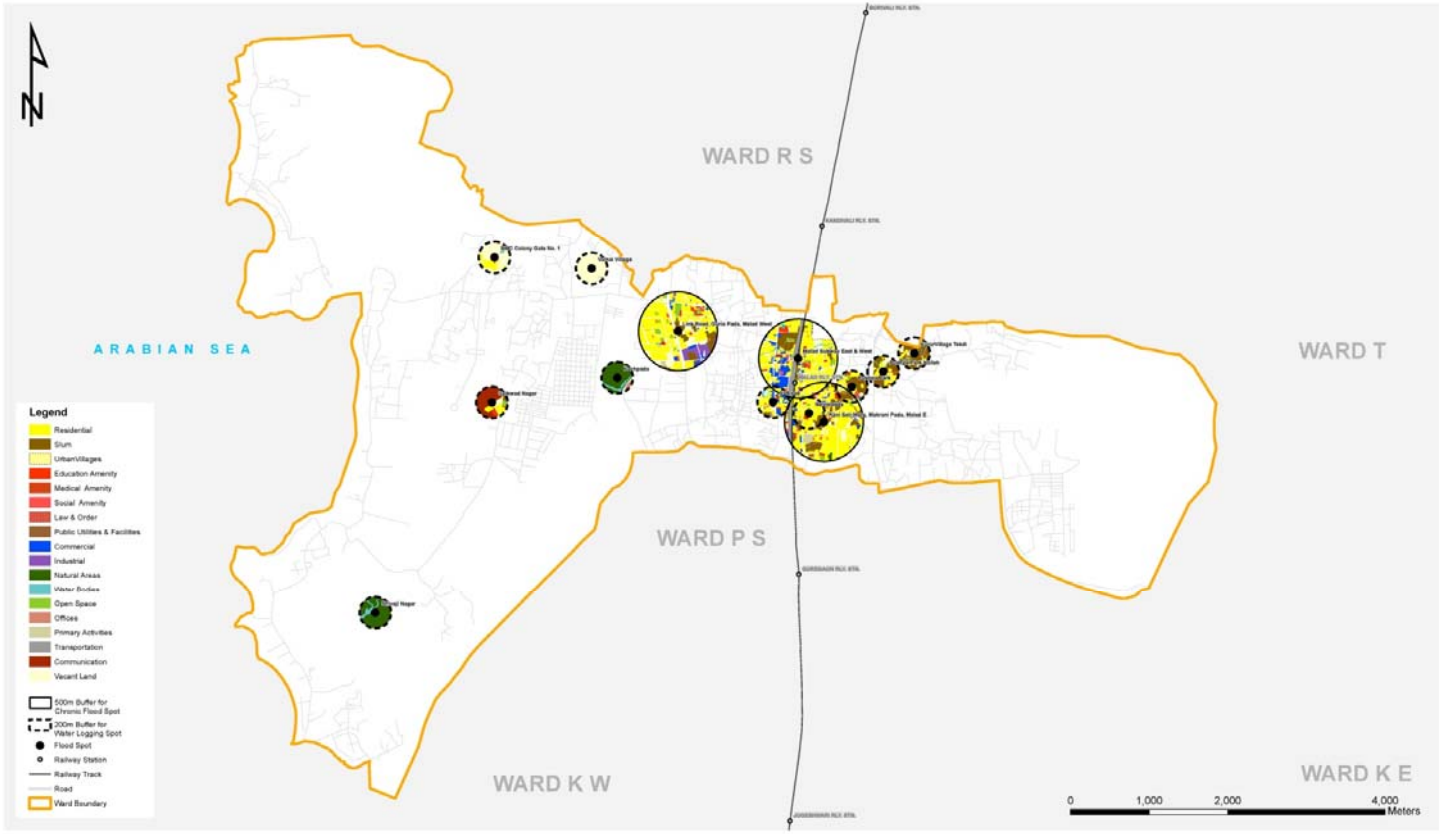


G R E A T E R M U M B A I

Landuse within
500m Buffer of Chronic Flood Spot / 200m Buffer of Water Logging Spots

WARD P NORTH



G R E A T E R M U M B A I