



Methods of Computation of Risk Matrix at City Level (Heavy Rainfall Events)

Nitha .T.S

Scientist –C

Regional Meteorological Centre, Mumbai

India Meteorological Department

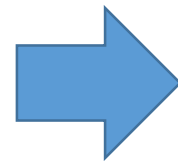
Introduction



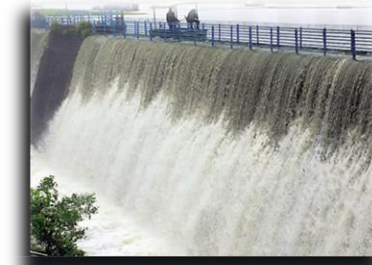
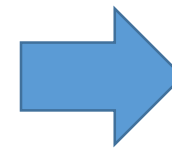
- Mumbai is the economic capital of India. Its one of the most densely populated cities in the world (population of more than 1 crore & daily floating population of few lakhs).
- Mumbai is also one of the most vulnerable cities often affected during monsoon. Urban Flooding in Mumbai especially during extreme rainfall events, almost bring the city to halt, thereby severely affecting its economic and other aspects
- In order to aid the mitigation activities of flood prone Mumbai and to provide early and effective warnings, IMD under the guidance of Ministry of Earth Sciences (MoES), two new initiatives were started during Monsoon 2020.
- **Impact Based Forecasting System (IBF)** along with **Integrated Flood Warning System (I - Flows Mumbai)**

Impact Based Forecasting For Mumbai

Weather forecast for
Mumbai



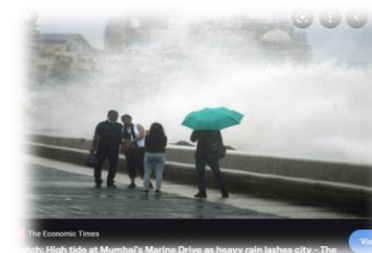
What the forecasted
weather can do over
Mumbai



The Times of India



The Times of India
Landslide in Mumbai: Landslide on Western Express Highway after heavy rain. Traffic movement affected | Mumbai News - Times of India

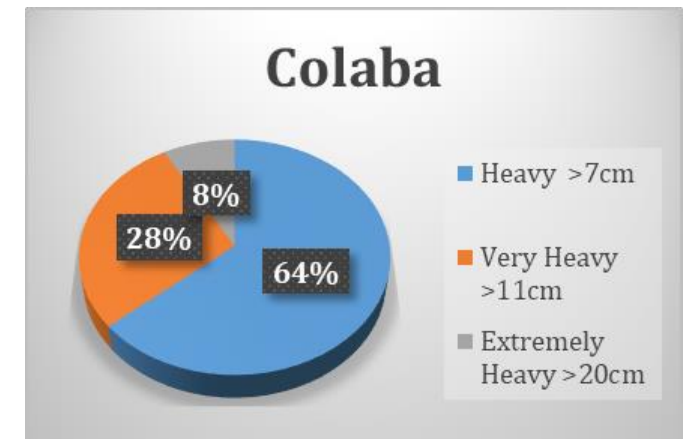
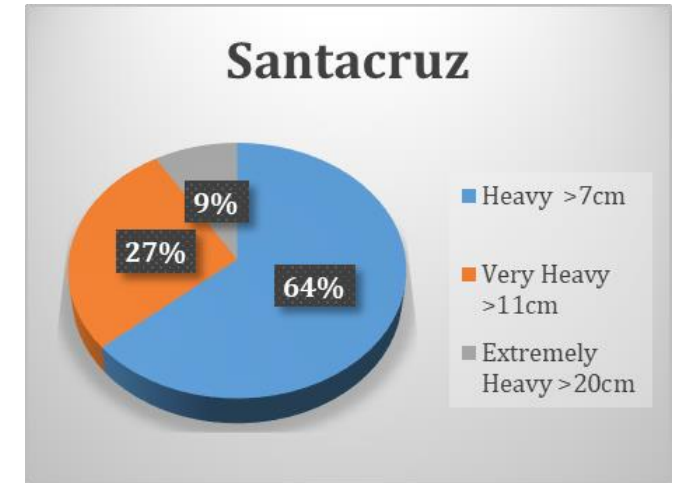
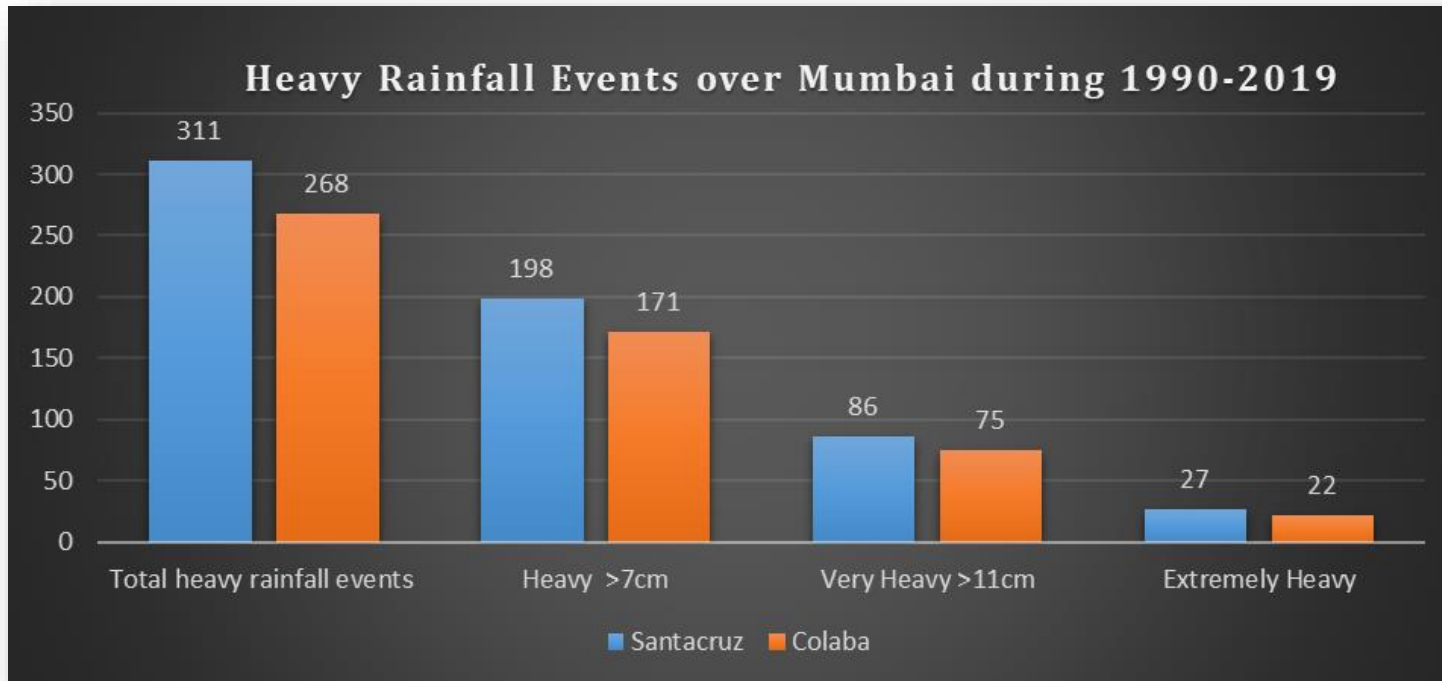


The Economic Times
High tide at Mumbai's Marine Drive as heavy rain lashes city - The Economic Times



Analysis of the Rainfall Data

- Rainfall Data of Mumbai (June – Sept) from past 30 years (1990 -2019) to assess the high impact events.
- Data of **Colaba & Santacruz** stations were considered



Analysis of the Disaster Data

➤ NDMA disaster data (1967-2016), BMC disaster data available and reports from Media during last 10 years were also analyzed

| Duration of the flood & Severity | | | | |
|------------------------------------|----------------------------------|---------------------------|---------------------------|-----------------------------------|
| Total number of major flood events | Flash floods/ 1 day flood events | Floods lasting for 2 days | Floods lasting for 3 days | Floods lasting for 3 days or more |
| 76 | 115 | 30 | 13 | 13 |

➤ Based on analysis of the past events and its severity, the possible impacts were categorized

| Minimal | Minor | Significant | Severe |
|---|--|---|--|
| <ul style="list-style-type: none"> Slippery roads Traffic Congestions | <ul style="list-style-type: none"> Localized flooding/water logging of low-lying areas Traffic Congestions | <ul style="list-style-type: none"> Water logging/ flooding in many parts of low-lying area and river banks Localized and short-term disruption to municipal services (water, electricity, etc.) Major disruption of traffic flow. Major roads/local trains affected. Possibility of danger to very old buildings and unmaintained structures, falling of trees etc | <ul style="list-style-type: none"> Widespread water logging/ flooding in most parts of low-lying area and also on river banks. Major disruption of traffic flow. Major roads/local trains and travel routes severely affected. Inundation of coastal areas coinciding with high tide. Localized and short-term disruption to municipal services (water, electricity, etc.) Possibility of danger to incredibly old and unmaintained structures, falling of trees etc Possibility of local landslides/ landslips in elevated hilly areas |

Correlating the Rainfall data & Disaster data: Threshold Calculation

Cumulative approach as well as individual heavy rainfall days were analyzed

| Year | Month | Date | Santacruz | Rainfall | Date/ Month | Event Type | Location Name District (Area Affected) | Casualties | Intensity | | |
|------|-------|------|-----------|----------|-------------|------------|--|------------|-----------|---|-------------|
| 1990 | 6 | 1 | 22.1 | 11.1 | | | | | | | |
| 1990 | 6 | 2 | 0 | 0 | | | | | | | |
| 1990 | 6 | 3 | 9.2 | 0 | | | | | | | |
| 1990 | 6 | 4 | 0 | 52.9 | | | | | | | |
| 1990 | 6 | 5 | 71.9 | 47.9 | | | | | | | |
| 1990 | 6 | 6 | 0 | 0 | | | | | | | |
| 1990 | 6 | 7 | 0 | 0 | | | | | | | |
| 1990 | 6 | 8 | 1.2 | 77.5 | | | | | | | |
| 1990 | 6 | 9 | 1.3 | 0 | | | | | | | |
| 1990 | 6 | 10 | 3.3 | 4.7 | | | | | | | |
| 1990 | 6 | 11 | 0 | 0 | | | | | | | |
| 1990 | 6 | 12 | 9.8 | 11.1 | | | | | | | |
| 1990 | 6 | 13 | 20.6 | 15.2 | | | | | | | |
| 1990 | 6 | 14 | 1.7 | 0 | | | | | | | |
| 1990 | 6 | 15 | 0.2 | 0.5 | | | | | | | |
| 1990 | 6 | 16 | 150.2 | 421.2 | | | | | | | |
| 1990 | 6 | 17 | 61.9 | 153.9 | | | | | | | |
| 1990 | 6 | 18 | 0 | 6 | | | | | | | |
| 1990 | 6 | 19 | 0.7 | 1.1 | | | | | | | |
| 1990 | 6 | 20 | 0 | 0.8 | | | | | | | |
| 1990 | 6 | 21 | 0 | 0.2 | | | | | | | |
| 1990 | 6 | 22 | 0 | 0.7 | | | | | | | |
| 1990 | 6 | 23 | 1.2 | 2.9 | | | | | | | |
| 1990 | 6 | 24 | 0 | 1.1 | | | | | | | |
| 1990 | 6 | 25 | 2 | 1.4 | | | | | | | |
| 1990 | 6 | 26 | 20.5 | 116.8 | 26.06.1990 | 27.06.1990 | Floods and Heavy Rains | Bombay | 10 | 3 | Heavy rains |
| 1990 | 6 | 27 | 116.3 | 36.9 | 26.06.1990 | 27.06.1990 | Floods and Heavy Rains | Bombay | 10 | 3 | Heavy rains |
| 1990 | 6 | 28 | 105.2 | 86.2 | | | | | | | |
| 1990 | 6 | 29 | 78.5 | 87.5 | | | | | | | |
| 1990 | 6 | 30 | 62.7 | 47 | | | | | | | |
| 1990 | 7 | 1 | 12.9 | 0 | | | | | | | |

| Flood Dates | | Daily Rainfall | | | | | | Cumulative Rainfall |
|-------------|-----|----------------|--------|--------|--------|--------|--------|---------------------|
| | | D-5 | D-4 | D-3 | D-2 | D-1 | D | |
| 26.06.1990 | | 21-Jun | 22-Jun | 23-Jun | 24-Jun | 25-Jun | 26-Jun | |
| | CLB | 0 | 0 | 1.2 | 0 | 2 | 20.5 | 23.7 |
| | SCZ | 0.2 | 0.7 | 2.9 | 1.1 | 1.4 | 116.8 | 123.1 |
| 15.08.1990 | | 10-Aug | 11-Aug | 12-Aug | 13-Aug | 14-Aug | 15-Aug | |
| | CLB | 88 | 20 | 76.5 | 67.5 | 74.4 | 20.5 | 346.9 |
| | SCZ | 54.2 | 12.3 | 126.8 | 0.4 | 259 | 116.8 | 569.5 |
| 17.08.1990 | | 12-Aug | 13-Aug | 14-Aug | 15-Aug | 16-Aug | 17-Aug | |
| | CLB | 20 | 76.5 | 67.5 | 74.4 | 76.7 | 40.9 | 356 |
| | SCZ | 12.3 | 126.8 | 0.4 | 259 | 85.8 | 73.7 | 558 |
| 21.08.1990 | | 16-Aug | 17-Aug | 18-Aug | 19-Aug | 20-Aug | 21-Aug | |
| | CLB | 76.7 | 40.9 | 26.6 | 36.3 | 13.9 | 26.5 | 220.9 |
| | SCZ | 85.8 | 73.7 | 40.8 | 32.6 | 7.5 | 17.2 | 257.6 |

Single day heavy rainfall leading to flooding events increasing in the recent years

Threshold for Mumbai around 6cm

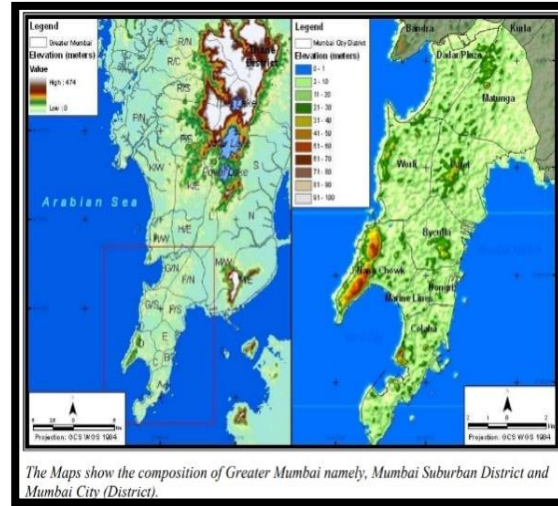
Correlating the Rainfall data & Disaster data : Impact Response Matrix

Single day / 2 consecutive heavy rainfall days leading to high impact events over Mumbai

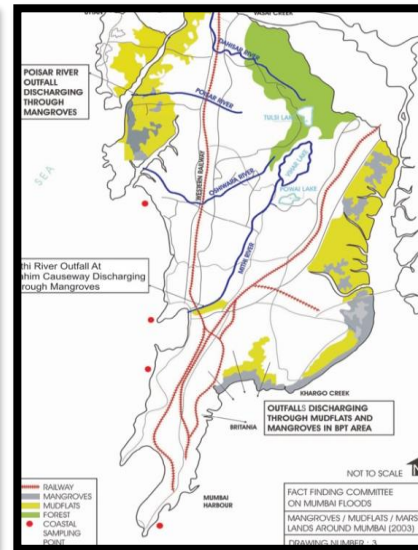
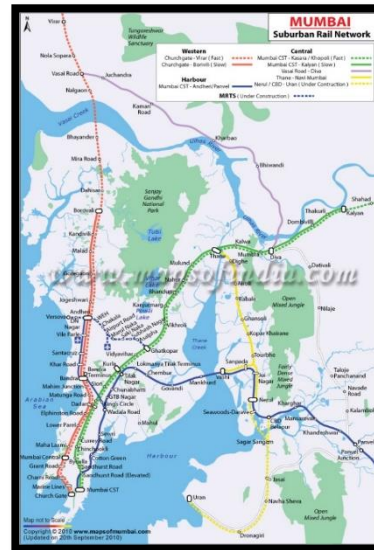
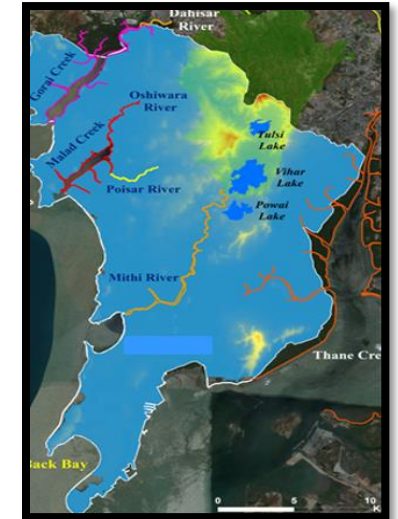
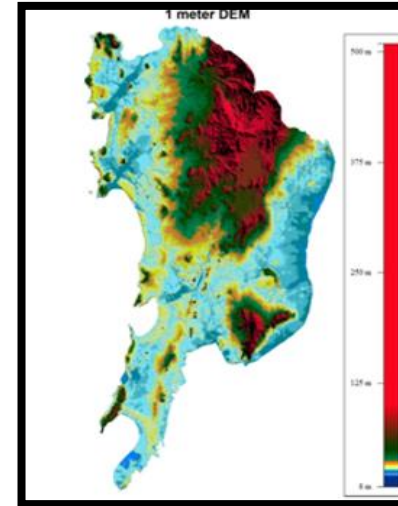
| Rainfall category | Expected Impact | Action Suggested |
|---|--|---|
| Moderate rain (<6cm) | <ul style="list-style-type: none"> ▪ Traffic Congestions ▪ Slippery roads | Nil |
| Heavy rain (7-11cm) with moderate to intense spell | <ul style="list-style-type: none"> ▪ Localized flooding/water logging of low-lying areas ▪ Traffic Congestions | Traffic may be regulated effectively |
| 2 consecutive days of heavy rainfall (>= 12 cm in 48 hours) | <ul style="list-style-type: none"> ▪ Localized flooding/water logging of low-lying areas ▪ Possibility of danger to very old buildings and unmaintained structures | <p>Traffic may be regulated effectively</p> <p>People living in very old buildings and unmaintained structures may take caution</p> |
| Very heavy rainfall (12-20cm) | <ul style="list-style-type: none"> • Water logging/ flooding in many parts of low-lying area and river banks • Localized and short-term disruption to municipal services (water, electricity, etc.) • Major disruption of traffic flow. Major roads/local trains affected. • Possibility of danger to very old buildings and unmaintained structures, falling of trees etc ▪ Closure of roads crossing low water bridges | <p>Traffic may be regulated effectively</p> <p>People living in very old buildings and unmaintained structures may take caution</p> |
| Extremely heavy rainfall (>20 cm) | <ul style="list-style-type: none"> • Widespread and severe water logging/ flooding in most parts of low-lying area and also on river banks. • Major disruption of traffic flow. • Major roads/local trains and travel routes severely affected • Localized and short-term disruption to municipal services (water, electricity, etc.) • Possibility of danger to very old buildings and unmaintained structures, falling of trees etc • Possibility of local landslides in elevated hilly areas • Closure of roads crossing low water bridges | <p>Traffic may be regulated effectively</p> <p>People living in very old buildings and unmaintained structures may take caution</p> |

Collection of Impact Based Data for Mumbai

1. Meteorological Data
2. Geophysical data
3. Physical data
4. Socio-economic data
5. Vulnerability

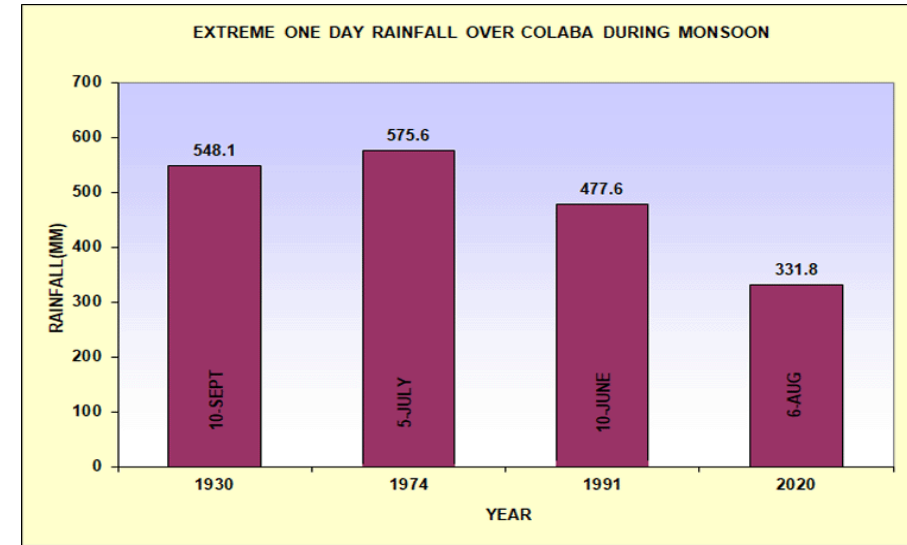


The Maps show the composition of Greater Mumbai namely, Mumbai Suburban District and Mumbai City (District).

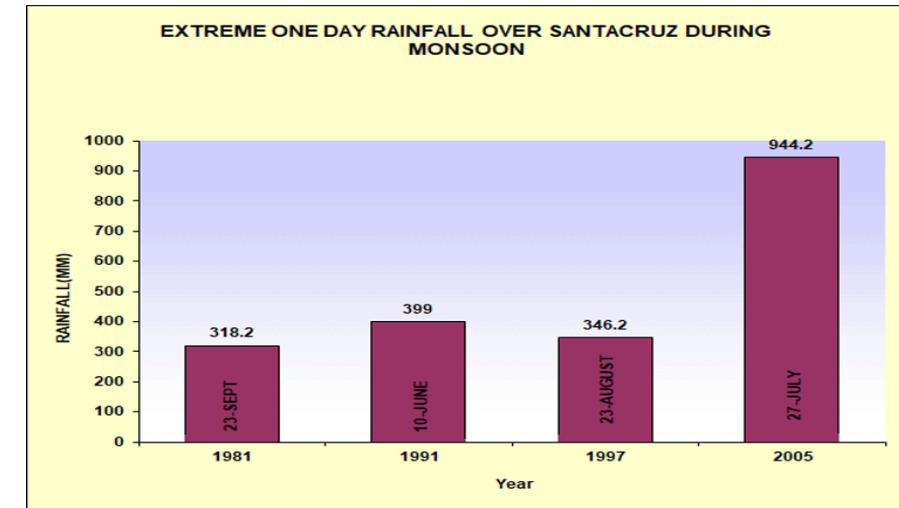


Meteorological Data

| Month | Mean Temperature(°C) | | Mean Total Rainfall (mm) | Mean Number of Rainy Days | Mean Number of days with | | | |
|--------|----------------------|---------------|--------------------------|---------------------------|--------------------------|---------|-----|--------|
| | Daily Minimum | Daily Maximum | | | HAIL | Thunder | FOG | SQUALL |
| Jan | 17.3 | 31.1 | 000.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Feb | 18.2 | 31.3 | 000.4 | 0.1 | 0.0 | 0.1 | 0.1 | 0.0 |
| Mar | 21.4 | 32.8 | 000.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| Apr | 24.2 | 33.2 | 000.1 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 |
| May | 27.0 | 33.6 | 011.3 | 0.8 | 0.0 | 0.5 | 0.0 | 0.0 |
| Jun | 26.6 | 32.4 | 493.1 | 13.6 | 0.0 | 6.1 | 0.0 | 0.5 |
| Jul | 25.5 | 30.4 | 840.7 | 22.9 | 0.0 | 2.9 | 0.1 | 0.4 |
| Aug | 25.1 | 30.0 | 585.2 | 21.5 | 0.0 | 1.4 | 0.0 | 0.2 |
| Sep | 24.8 | 30.7 | 341.4 | 13.9 | 0.0 | 5.7 | 0.0 | 0.0 |
| Oct | 23.8 | 33.4 | 089.3 | 3.4 | 0.0 | 3.1 | 0.1 | 0.0 |
| Nov | 21.3 | 33.7 | 009.9 | 0.6 | 0.0 | 0.7 | 0.0 | 0.0 |
| Dec | 18.5 | 32.4 | 001.6 | 0.2 | 0.0 | 0.0 | 0.1 | 0.0 |
| Annual | 22.8 | 32.1 | 2373.4 | 77.0 | 0.0 | 20.7 | 0.4 | 1.1 |



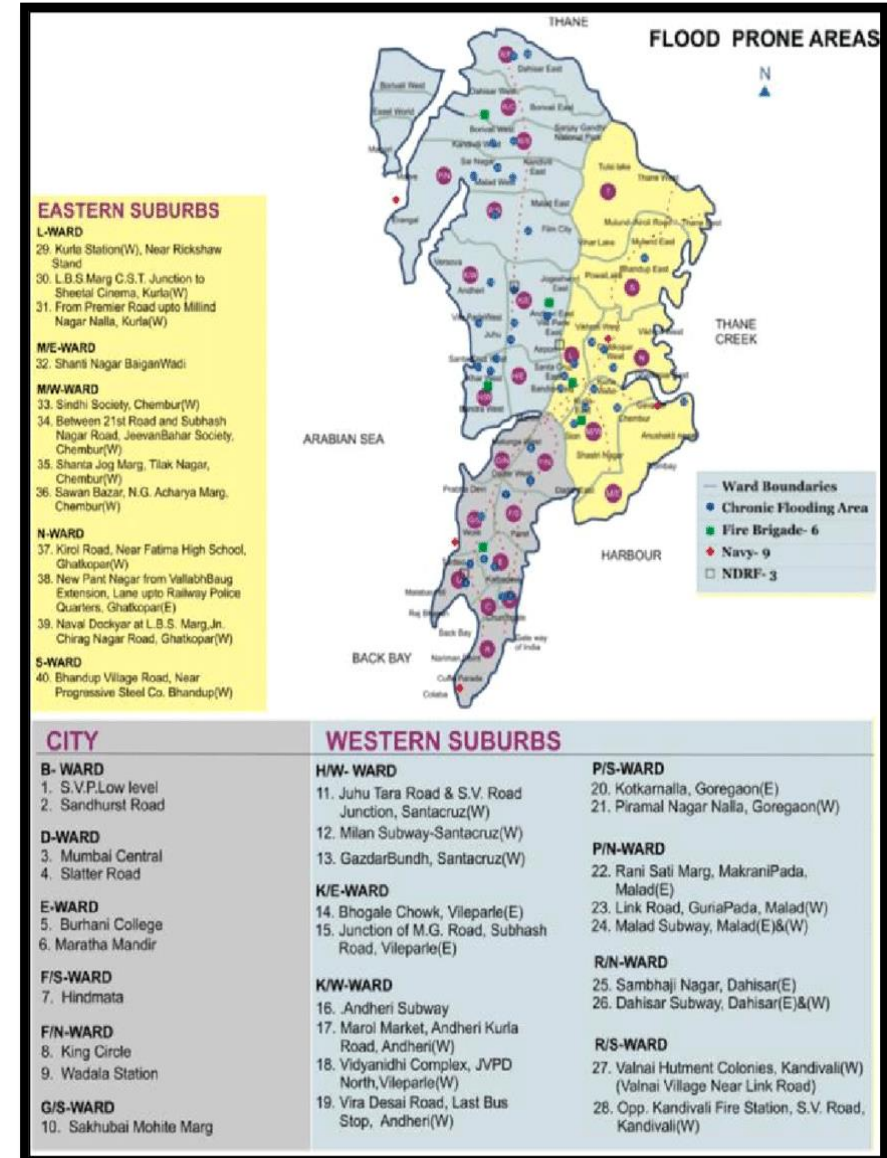
| Stations | 1 day heavy | 2 consecutive days | 3 consecutive days | More than 3 consecutive days |
|----------|-------------|--------------------|--------------------|------------------------------|
| Mumbai | 127 | 39 | 24 | 11 |



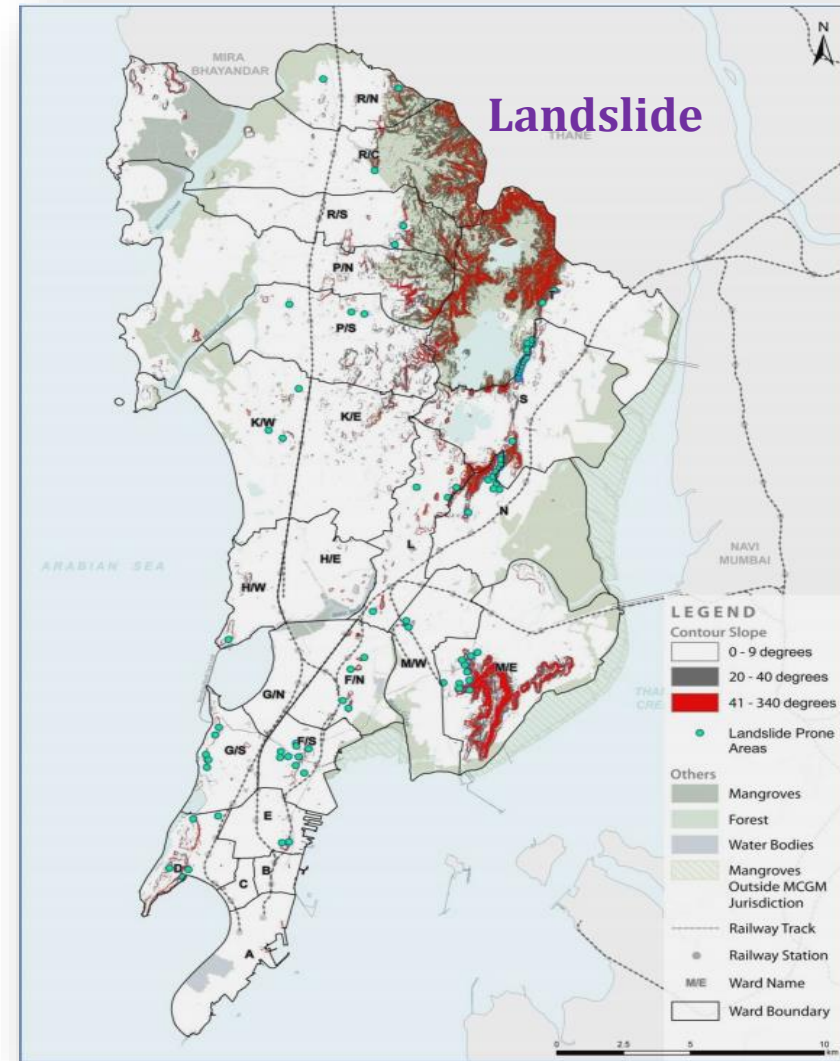
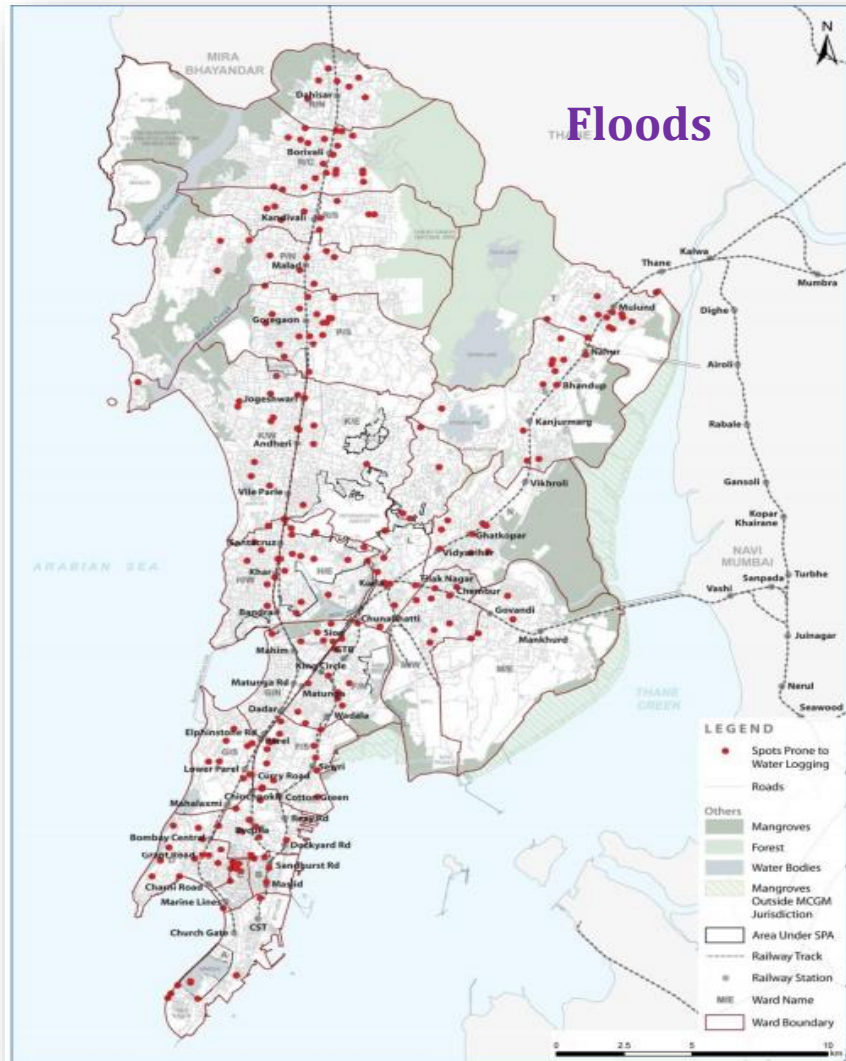
Vulnerability profile of Mumbai

Three different types of flooding are evident in Mumbai:

- **Intense Rainfall taking place in short intervals leading to localized flooding due to inadequate drainage**
- **flooding due to overflows from Mithi River, where settlements have taken place in the flood plains, and**
- **Flooding due to combination of high tides and High River flows.**



Vulnerability profile of Mumbai

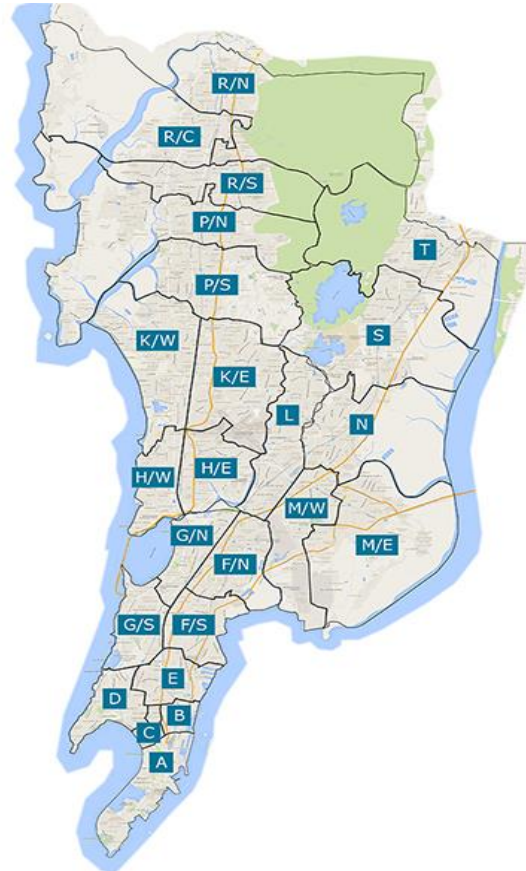


Ward wise Vulnerability profile of Mumbai

Risk Assessment:

WARD VULNERABILITY (2019)

| Sr. No. | Ward | Water Logging Spots | Landslide Spots | Vulnerable Settlements | Dilapidated Buildings in C1* Category (C1* – Complete Demolition) | | | Emergency Assembly Points |
|--------------|------|---------------------|-----------------|------------------------|---|-----------|-----------|---------------------------|
| | | | | | MHADA / Govt | MCGM | Private | |
| 1 | A | 10 | 0 | 7 | 1 | 1 | 2 | 2 |
| 2 | B | 5 | 0 | 0 | 0 | 1 | 0 | 3 |
| 3 | C | 3 | 0 | 0 | 0 | 1 | 2 | 2 |
| 4 | D | 4 | 16 | 10 | 0 | 0 | 13 | 6 |
| 5 | E | 5 | 2 | 10 | 0 | 0 | 6 | 7 |
| 6 | F/S | 7 | 6 | 1 | 0 | 3 | 5 | 5 |
| 7 | F/N | 15 | 4 | 0 | 3 | 2 | 26 | 6 |
| 8 | G/S | 9 | 10 | 5 | 0 | 1 | 1 | 5 |
| 9 | G/N | 7 | 0 | 1 | 0 | 3 | 7 | 5 |
| Total | | 65 | 38 | 34 | 4 | 12 | 62 | 41 |



Risk Assessment:


WARD VULNERABILITY (2019)

| Sr. No. | Ward | Water Logging Spots | Landslide Spots | Vulnerable Settlements | Dilapidated Buildings in C1* Category (C1* – Complete Demolition) | | | Emergency Assembly Points |
|--------------|------|---------------------|-----------------|------------------------|---|-----------|------------|---------------------------|
| | | | | | MHADA / Govt | MCGM | Private | |
| 1 | H/E | 6 | 0 | 0 | 0 | 0 | 23 | 5 |
| 2 | H/W | 10 | 1 | 3 | 0 | 0 | 29 | 3 |
| 3 | K/E | 2 | 5 | 0 | 0 | 0 | 38 | 12 |
| 4 | K/W | 4 | 3 | 4 | 3 | 0 | 48 | 6 |
| 5 | L | 7 | 18 | 13 | 0 | 0 | 23 | 11 |
| 6 | M/E | 8 | 11 | 3 | 0 | 0 | 2 | 3 |
| 7 | M/W | 11 | 1 | 0 | 0 | 0 | 13 | 2 |
| 8 | N | 11 | 32 | 0 | 0 | 30 | 34 | 6 |
| 9 | P/S | 7 | 2 | 0 | 1 | 0 | 13 | 4 |
| 10 | P/N | 12 | 11 | 7 | 0 | 0 | 35 | 8 |
| 11 | R/S | 2 | 4 | 4 | 0 | 1 | 11 | 6 |
| 12 | R/N | 3 | 3 | 1 | 0 | 0 | 11 | 5 |
| 13 | R/C | 9 | 4 | 2 | 0 | 0 | 20 | 6 |
| 14 | S | 12 | 152 | 0 | 0 | 0 | 7 | 10 |
| 15 | T | 11 | 5 | 2 | 0 | 0 | 47 | 6 |
| Total | | 115 | 252 | 39 | 4 | 31 | 354 | 93 |

Updated Impact Response Matrix

| Minimal | Minor | Significant | Severe |
|--|---|---|---|
| <ul style="list-style-type: none"> •Slippery roads •Traffic Congestions •Increased travel times | <ul style="list-style-type: none"> • Localized flooding/water logging of low-lying areas of city, western and eastern suburbs ▪ Traffic Congestions.. ▪ Increased travel times | <ul style="list-style-type: none"> • Water logging/ flooding in many parts of low-lying areas in city, western and eastern suburbs • Flooding/inundation of river banks (especially banks of Mithi River) and other major lakes in suburbs • Major disruption of traffic flow • Major roads and local trains affected. • Flight operations may be affected. • Inundation of coastal areas coinciding with high tides. • Localized and short-term disruption to municipal services (water, electricity, etc.) • Possibility of danger to very old buildings and unmaintained structures. • Falling of trees/branches in gusty winds. • Slum areas along railway track, coastal areas, river banks and drains may be severely affected • Closure of roads crossing low water bridges • Squally weather along the coast and rough Sea conditions | <ul style="list-style-type: none"> • Water logging/ flooding in most parts of low-lying areas in city, western and eastern suburbs •Flooding/inundation of river banks (especially banks of Mithi River) and other major lakes in suburbs. •Severe disruption of traffic flow. •Most roads/local trains and travel routes severely affected. •Flight operations will be affected. •Inundation of coastal areas coinciding with high tides •Localized and short-term disruption to municipal services (water, electricity, etc.) •Possibility of danger to very old buildings and unmaintained structures. •Falling of trees/branches in gusty winds. •Slum areas along railway track, coastal areas, river banks and drains may be severely affected •Closure of roads crossing low water bridges •Squally weather along the coast and rough Sea conditions •Possibility of local landslides in elevated hilly areas of Kurla, Sakinaka, Chembur, Bhandup, Vikhroli, Ghatkopar and Mulund areas. |
| Action suggested | | | |
| <ul style="list-style-type: none"> • Nil | <ul style="list-style-type: none"> • Traffic may be regulated effectively | <ul style="list-style-type: none"> • Traffic may be regulated effectively • People living in very old buildings, unmaintained structures and river banks (specially banks of Mithi river) may take caution and move to safer places. | <ul style="list-style-type: none"> • Traffic may be regulated effectively • People living in very old buildings, unmaintained structures and river banks (specially banks of Mithi river) may take caution and move to safer places. • People in the affected areas may restrict their movement. |

Impact Based Forecast Format




प्रादेशिक मौसम केंद्र, कोलाबा, मुंबई
Regional Meteorological Centre, Mumbai

Dated: 03 Aug 2020 Time of issue: 1300 hrs IST

IMPACT BASED FORECAST FOR HEAVY RAINFALL OVER MUMBAI

| Date | 03 Aug 2020 | 04 Aug 2020 |
|-------------------------------|---|---|
| Forecast & Warning | Heavy to very heavy rainfall at isolated places | Heavy to very heavy rainfall at a few places with extremely heavy rainfall at isolated places |
| Impact Expected | <ul style="list-style-type: none"> Water logging/ flooding in many parts of low lying area and river banks Localized and short term disruption to municipal services (water, electricity, etc.) Major disruption of traffic flow. Major roads/local trains affected. Possibility of danger to very old buildings and unmaintained structures, falling of trees etc Closure of roads crossing low water bridges | <ul style="list-style-type: none"> Widespread water logging/ flooding in most parts of low lying area and also on river banks. Major disruption of traffic flow. Major roads/local trains and travel routes Localized and short term disruption to municipal services (water, electricity, etc.) Possibility of danger to incredibly old and unmaintained structures, falling of trees etc. Possibility of landslides in elevated hilly areas Closure of roads crossing low water bridges |
| Action Suggested | <ul style="list-style-type: none"> Traffic may be regulated effectively People in the affected area may restrict their movement | <ul style="list-style-type: none"> Traffic may be regulated effectively People in the affected area may restrict their movement |

| COLOR CODES | |
|-------------|-------------|
| Very Low | No action |
| Low | Be updated |
| Medium | Be prepared |
| High | Take Action |



प्रादेशिक मौसम केंद्र, कोलाबा, मुंबई
Regional Meteorological Centre, Mumbai

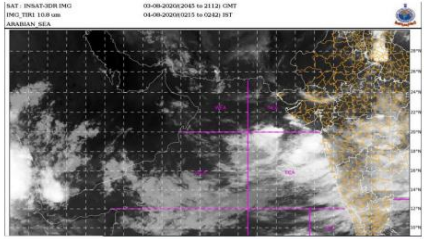
Dated: 04/08/2020 Time of issue: 0230 hrs

IMPACT BASED FORECAST FOR HEAVY RAINFALL OVER MUMBAI

Updates of Ongoing Heavy Rainfall Event

| Date | 04 Aug |
|--|---|
| Rainfall Realised at 0230 hrs of 4 Aug 2020 (from 0830 hrs IST of 3rd Aug) | Mumbai city and suburbs experienced intense spell of rainfall during past 3 hrs. (Map enclosed) |
| Forecast | As per latest satellite and radar observations, Mumbai city and suburbs are very likely to receive very intense spell of rainfall (3-5 cm/hr) during next 3- 4 hrs. |
| Impact Expected | <ul style="list-style-type: none"> Widespread water logging/ flooding in most parts of low lying area and also on river banks. Major disruption of traffic flow. Major roads/local trains and travel routes severely affected. Localized and short-term disruption to municipal services (water, electricity, etc.) Possibility of danger to incredibly old and unmaintained structures, falling of trees etc Possibility of local landslides in elevated hilly areas Closure of roads crossing low water bridges |
| Action Suggested | <ul style="list-style-type: none"> Traffic may be regulated effectively People in the affected area may restrict their movement |

| COLOR CODES | |
|-------------|-------------|
| Very Low | No action |
| Low | Be updated |
| Medium | Be prepared |
| High | Take Action |



MAT: INDIAT-0001.DMG 09:00:00Z(20200804) to 21:00:00Z
INC: IND-1001.WM 04:00:00Z(20200804) to 03:00:00Z
ARABIAN SEA

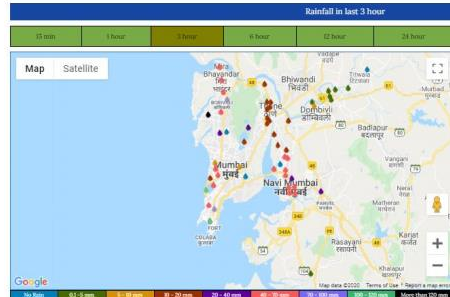
Legends:

| Rainfall Intensity | | | |
|--------------------|----------------|-------------------------|----------------|
| Terminology | Rainfall Range | Terminology | Rainfall Range |
| Light Spell | 1 cm /hr | Very Intense Spell | 3-5 cm/hr |
| Moderate Spell | 1-2 cm/hr | Extremely Intense Spell | 5-10 cm/hr |
| Intense Spell | 2-3 cm/hr | Cloud Burst | >10 cm/hr |

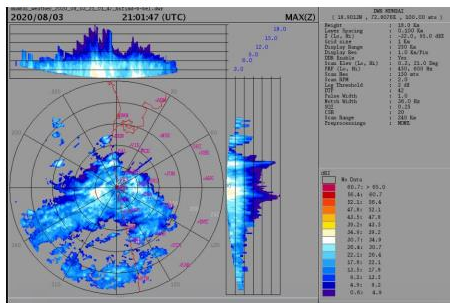
| Rainfall Categories | | | |
|---------------------|------------------|--------------------------|------------------|
| Terminology | Rainfall (in mm) | Terminology | Rainfall (in mm) |
| Very Light Rainfall | Traces - 2.4 | Heavy Rainfall | 64.5-115.5 |
| Light Rainfall | 2.5-15.5 | Very Heavy Rainfall | 115.6-204.4 |
| Moderate Rainfall | 15.6-64.4 | Extremely Heavy Rainfall | >>204.5 |

Regional Weather Forecasting Centre
RMC Mumbai
Phone: +91 022 22150431/22174719/22174735

Rainfall during past 3 hours:

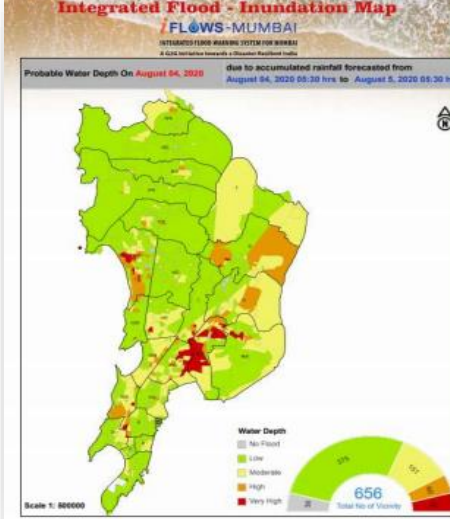


Current satellite & Radar Imageries:



Integrated Flood - Inundation Map
FLOWS-MUMBAI

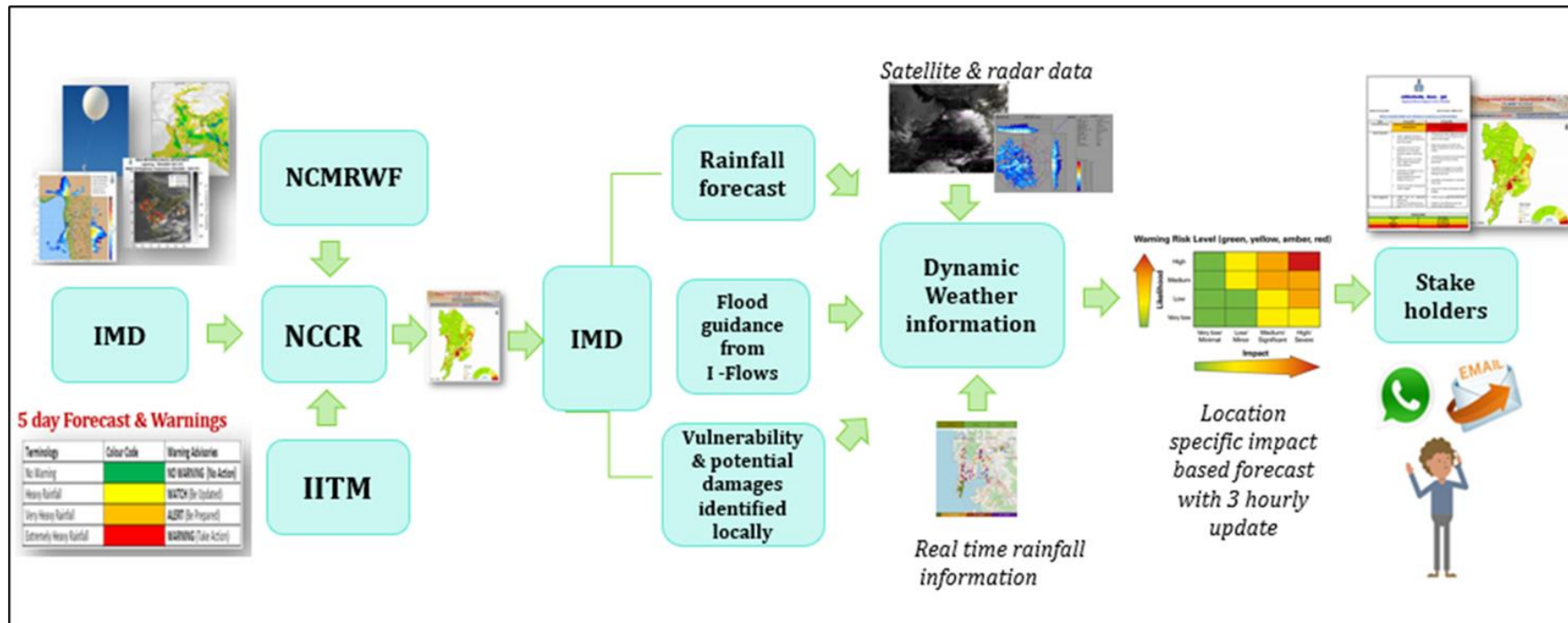
Probable Water Depth On August 04, 2020 due to accumulated rainfall forecasted from August 04, 2020 05:30 hrs to August 5, 2020 05:30 hrs



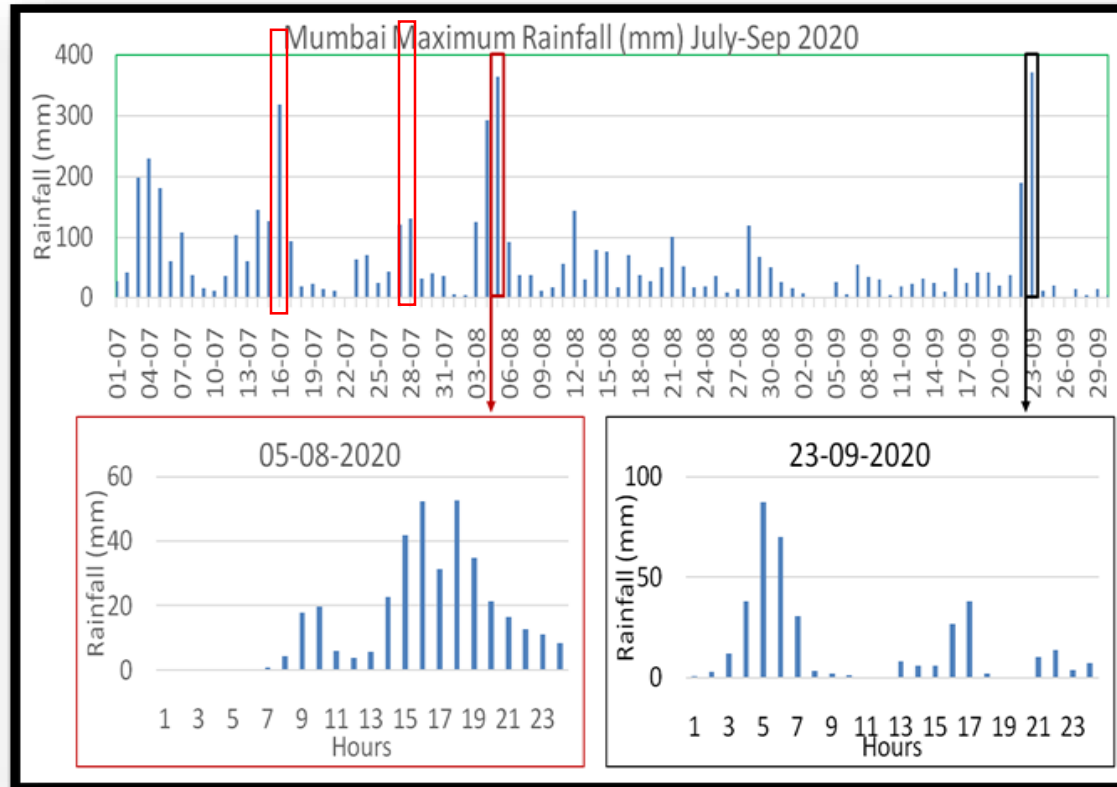
Scale 1: 800000

Impact Based Forecasting Operational Set up

- 5 day district wise warning
 - As per SOP, advisory/ alert 72 hrs prior to stake holders
 - Impact Based Forecast Warning – 24/48 hrs prior
 - 3 hourly IBF update throughout the event
- Based on the rainfall forecast generated by IMD 5 day forecast , if the rainfall is expected to be “heavy” and more flood inundations models are run and ward wise **I – flows flood guidance** are generated by NCCR and sent to IMD.



Evaluation of IBF - Mumbai Monsoon 2020



- 4 high impact events over Mumbai during monsoon 2020
- IBF was issued on all 4 occasions
- 43 Impact Based Forecast bulletins issued

Extremely heavy rainfall event over Mumbai & around 4-6 Aug 2020

With the active monsoon conditions and development of a low-pressure system over North Bay of Bengal, the entire coastal belt of Konkan including Mumbai received an intense rainfall spell during the period 4-6 Aug 2020.

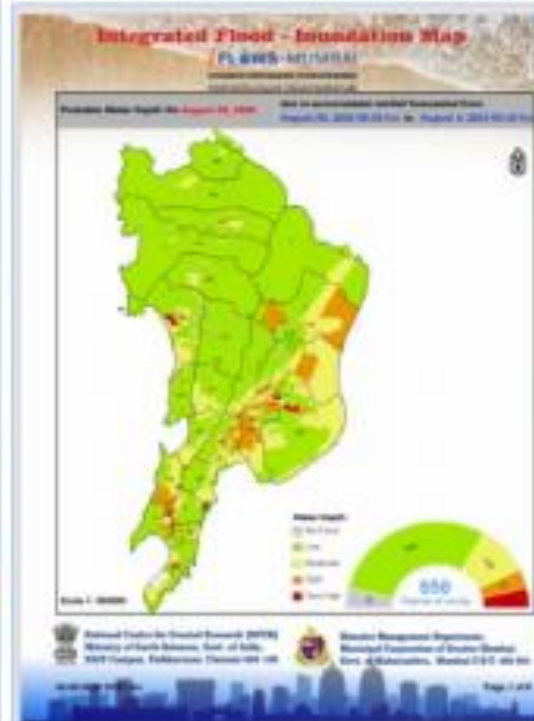
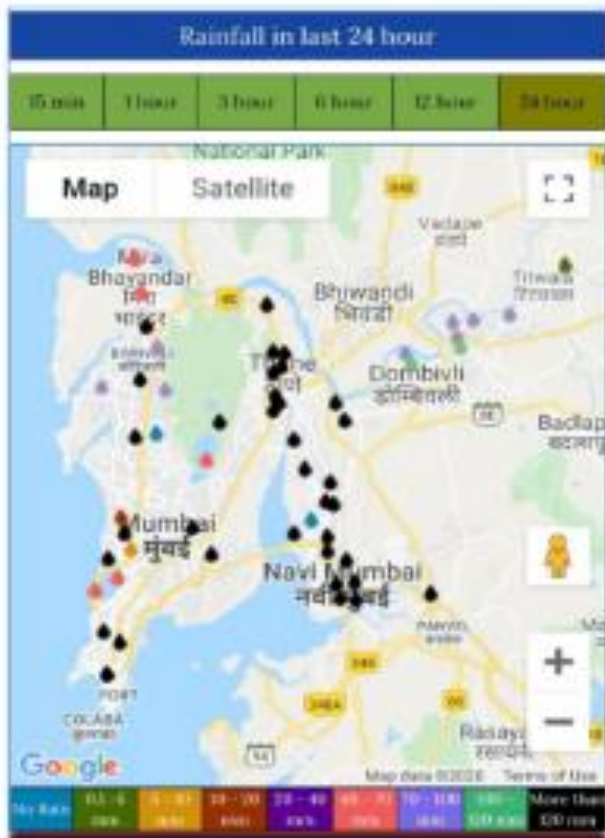
□ **Santacruz** recorded 24 hr accumulated rainfall of **268.6mm, 84.3mm and 162.3mm** consecutively during 4-6 Aug 2020

□ **Colaba** recorded **252.2mm, 53.2mm and 331.8mm** consecutively.



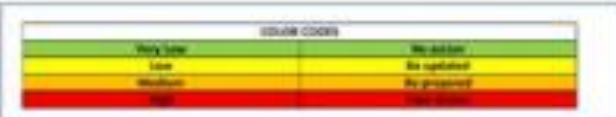
Forecasts and Warnings Issued

Mumbai & around Extremely Heavy Rainfall on 5th -6th Aug 2020 with Flood Guidance and IBF



| Date | 4 th Aug | 5 th Aug |
|--------------------|---|---|
| Forecast & Warning | Heavy rain is expected to continue on 4 th Aug with moderate to heavy rain on 5 th Aug. | Heavy rain is expected to continue on 5 th Aug with moderate to heavy rain on 6 th Aug. |
| Impact Expected | <ul style="list-style-type: none"> Underground water logging/ flooding in most parts of low lying area and also on river banks. Major disruption of traffic flow. Major roads/local trains and travel routes severely affected. Localized and short term disruption to municipal services (water, electricity, etc.) Possibility of danger to incredibly old and unmaintained structures, falling of trees etc. Possibility of local landslides in elevated hilly areas. Closure of roads crossing low water bridges. | <ul style="list-style-type: none"> Underground water logging/ flooding in most parts of low lying area and also on river banks. Major disruption of traffic flow. Major roads/local trains and travel routes severely affected. Localized and short term disruption to municipal services (water, electricity, etc.) Possibility of danger to incredibly old and unmaintained structures, falling of trees etc. Possibility of local landslides in elevated hilly areas. Closure of roads crossing low water bridges. |

| Action Suggested | 4 th Aug | 5 th Aug |
|------------------|---|---|
| | <ul style="list-style-type: none"> Traffic may be regulated effectively. People in the affected area may restrict their movement. | <ul style="list-style-type: none"> Traffic may be regulated effectively. People in the affected area may restrict their movement. |



Forecasts and Warnings issued by IMD

❑ **Impact based bulletins** were also issued as per SOP followed by regular rainfall updates with possible impacts, till the event was over.

❑ **Flood guidance provided from I - flows Mumbai** were also provided to the state and Mumbai disaster management authorities.

प्रादेशिक मौसम केंद्र, कोलाबा, मुंबई
Regional Meteorological Centre, Mumbai

Dated: 03 Aug 2020 Time of issue: 1300 hrs IST

IMPACT BASED FORECAST FOR HEAVY RAINFALL OVER MUMBAI

| Date | 03 Aug 2020 | 04 Aug 2020 |
|--------------------|---|--|
| Forecast & Warning | Heavy to very heavy rainfall at isolated places | Heavy to very heavy rainfall at a few places with extremely heavy rainfall at isolated places |
| Impact Expected | <ul style="list-style-type: none"> Water logging/ flooding in many parts of low lying area and river banks Localized and short term disruption to municipal services (water, electricity, etc.) Major disruption of traffic flow. Major roads/local trains affected. Possibility of danger to very old building and unmaintained structures, falling of trees etc. Closure of roads crossing low water bridges | <ul style="list-style-type: none"> Widespread water logging/ flooding in most parts of low lying area and also on river banks. Major disruption of traffic flow. Major roads/local trains and travel routes. Localized and short term disruption to municipal services (water, electricity, etc.) Possibility of danger to incredibly old and unmaintained structures, falling of trees etc. Possibility of landslides in elevated hilly areas Closure of roads crossing low water bridges |
| Action Suggested | <ul style="list-style-type: none"> Traffic may be regulated effectively People in the affected area may restrict their movement | <ul style="list-style-type: none"> Traffic may be regulated effectively People in the affected area may restrict their movement |

प्रादेशिक मौसम केंद्र, कोलाबा, मुंबई
Regional Meteorological Centre, Mumbai

Dated: 4th Aug 2020 Time of issue: 13:00 hrs IST

IMPACT BASED FORECAST FOR HEAVY RAINFALL OVER MUMBAI

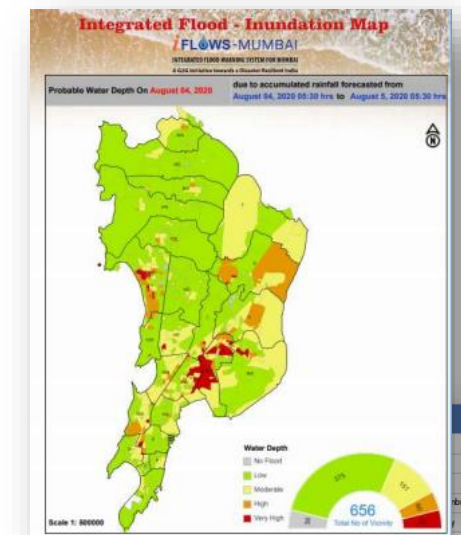
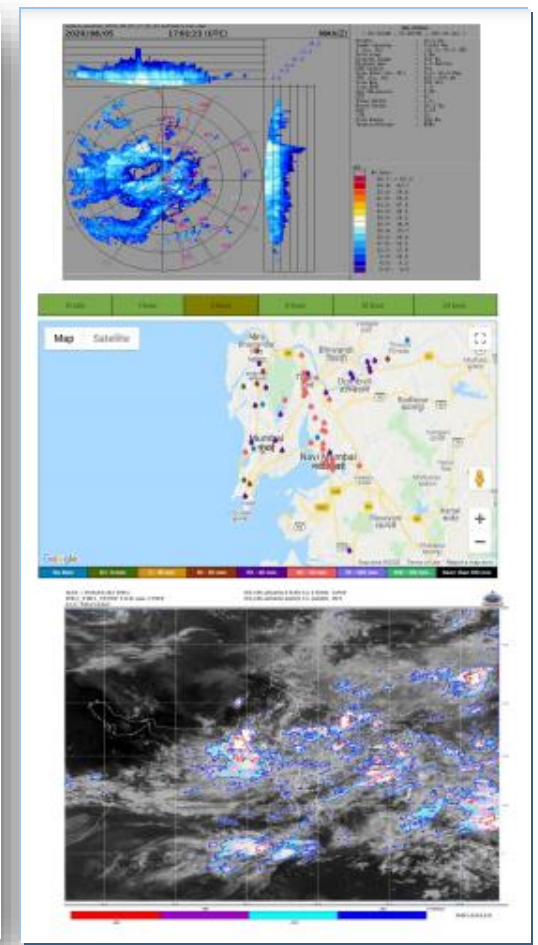
| Date | 4 th Aug | 5 th Aug |
|--------------------|--|--|
| Forecast & Warning | Heavy to very heavy rainfall at a few places with isolated extremely heavy rainfall at isolated places | Heavy to very heavy rainfall at a few places with isolated extremely heavy rainfall at isolated places |
| Impact Expected | <ul style="list-style-type: none"> Widespread water logging/ flooding in most parts of low lying area and also on river banks. Major disruption of traffic flow. Major roads/local trains and travel routes severely affected. Localized and short term disruption to municipal services (water, electricity, etc.) Possibility of danger to incredibly old and unmaintained structures, falling of trees etc. Possibility of local landslides in elevated hilly areas Closure of roads crossing low water bridges | <ul style="list-style-type: none"> Widespread water logging/ flooding in most parts of low lying area and also on river banks. Major disruption of traffic flow. Major roads/local trains and travel routes severely affected. Localized and short term disruption to municipal services (water, electricity, etc.) Possibility of danger to incredibly old and unmaintained structures, falling of trees etc. Possibility of local landslides in elevated hilly areas Closure of roads crossing low water bridges |

प्रादेशिक मौसम केंद्र, कोलाबा, मुंबई
Regional Meteorological Centre, Mumbai

Dated: 05 Aug 2020 Time of issue: 2230 hrs IST

IMPACT BASED FORECAST FOR HEAVY RAINFALL OVER MUMBAI
Updates of Ongoing Heavy Rainfall Event

| Date | 04 Aug 2020 |
|---|--|
| Rainfall Realized at 2230 hrs of 5 Aug 2020 (from 0830 hrs IST of 5 rd Aug) | Mumbai city and suburbs experienced intense spell to very intense spell of rainfall during past 3 hrs. (Map enclosed) Santacruz - 103.00 mm Colaba - 293.8 mm Strong winds with average speed reaching 70-80 kmph were reported at Colaba between around 0830 pm, with maximum wind gusting to 100 kmph. |
| Forecast | As per latest satellite and radar observations, Mumbai city and suburbs are very likely to receive intense spell of rainfall (2-3 cm/hr) during next 3-4 hrs, accompanied with strong winds reaching 70-80 kmph occasionally gusting to 100 kmph hrs. during next 3-4 hrs. Possibility of thunder and lightning in some areas |
| Impact Expected | <ul style="list-style-type: none"> Localized flooding/water logging of low lying areas Widespread water logging/ flooding in most parts of low lying area and also on river banks. Major disruption of traffic flow. Major roads/local trains and travel routes severely affected. Localized and short-term disruption to municipal services (water, electricity, etc.) Possibility of danger to incredibly old and unmaintained structures, falling of trees etc Possibility of local landslides in elevated hilly areas Closure of roads crossing low water bridges |
| Action Suggested | <ul style="list-style-type: none"> Traffic may be regulated effectively People in the affected area may restrict their movement |

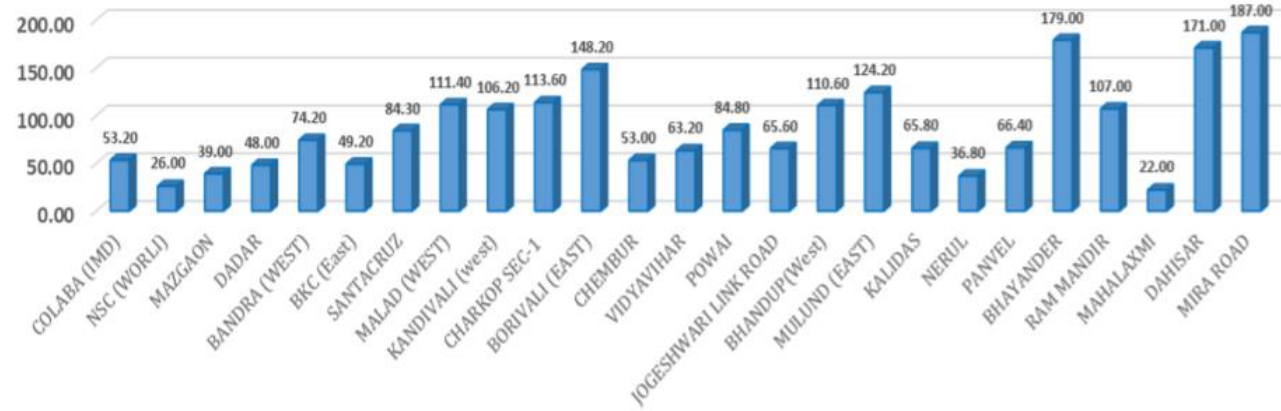


| Sl. No. | Area | First Respondent Number | Vulnerability |
|---------|------|-----------------------------------|---------------|
| 7 | MW | Chembur | VERY HIGH |
| 8 | MW | Chembur | VERY HIGH |
| 9 | ME | Four Bungalows | VERY HIGH |
| 10 | ME | Sanjay Gandhi Nagar | VERY HIGH |
| 11 | ME | Municipal Colony | VERY HIGH |
| 12 | L | Shiv Shakti Nagar (Kurla East) | VERY HIGH |
| 13 | L | Police Colony (Kurla East) | VERY HIGH |
| 14 | KW | Ashok Nagar (Juhu) | VERY HIGH |
| 15 | KW | Four Bungalows | VERY HIGH |
| 16 | KW | Four Bungalows | VERY HIGH |
| 17 | KW | Gulmohar Colony | VERY HIGH |
| 18 | KW | Vihar Nagar (Juhu) | VERY HIGH |
| 19 | KW | Indian Oil Nagar (Four Bungalows) | VERY HIGH |
| 20 | KW | Vallabh Nagar (Juhu) | VERY HIGH |
| 21 | KW | Sainath Nagar | VERY HIGH |
| 22 | KW | Suvarn Nagar (Juhu) | VERY HIGH |
| 23 | KW | Dn Nagar (Four Bungalows) | VERY HIGH |
| 24 | KW | Marish Nagar (Four Bungalows) | VERY HIGH |
| 25 | KW | New Lic Colony (Four Bungalows) | VERY HIGH |
| 26 | HW | Vaishya Nagar (Bandra West) | VERY HIGH |

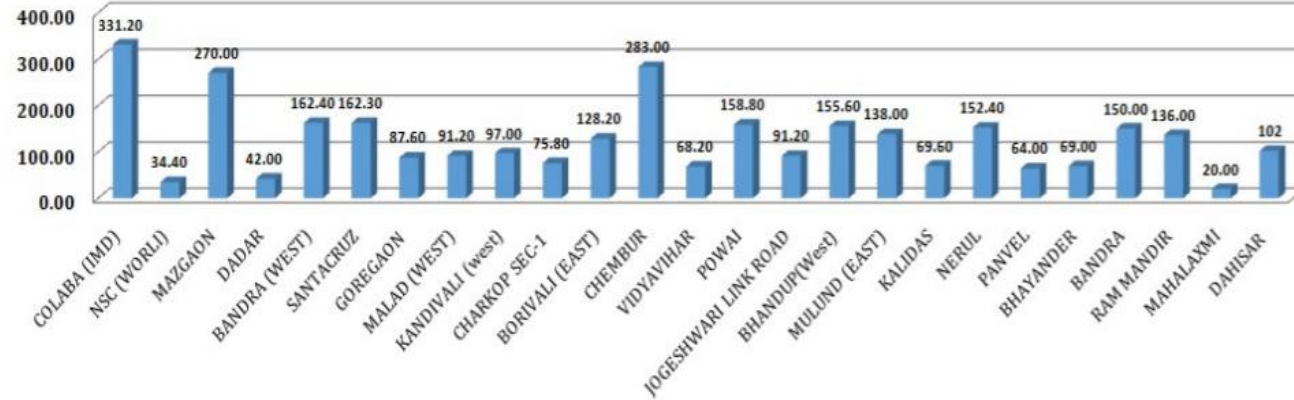
Rainfall Verification

| District | | 3-Aug-20 Mon | 4-Aug-20 Tue | 5-Aug-20 Wed | 6-Aug-20 Thu | 7-Aug-20 Fri |
|-----------|-------------|--|--|---|--|--|
| Thane | Intensity | Heavy to very heavy rain at isolated places. | Extremely heavy rain at isolated places. | Extremely heavy rain at isolated places. | Heavy to very heavy rain at isolated places. | Light to moderate rain |
| | Probability | Very Likely | Very Likely | Very Likely | Likely | Likely |
| Mumbai | Intensity | Heavy to very heavy rain at isolated places. | Extremely heavy rain at isolated places. | Extremely heavy rain at isolated places. | Heavy to very heavy rain at isolated places. | Light to moderate rain |
| | Probability | Very Likely | Very Likely | Very Likely | Likely | Likely |
| Raigad | Intensity | Extremely heavy rain at isolated places. | Extremely heavy rain at isolated places. | Extremely heavy rain at isolated places. | Heavy to very heavy rain at isolated places. | Heavy rain at isolated places. |
| | Probability | Very Likely | Very Likely | Very Likely | Likely | Likely |
| Ratnagiri | Intensity | Extremely heavy rain at isolated places. | Extremely heavy rain at isolated places. | Heavy to very heavy rain at a few places. | Heavy to very heavy rain at isolated places. | Heavy to very heavy rain at isolated places. |
| | Probability | Very Likely | Very Likely | Very Likely | Likely | Likely |

Rainfall (in mm) realised over Mumbai and around at 8.30 hrs of 5th Aug 2020

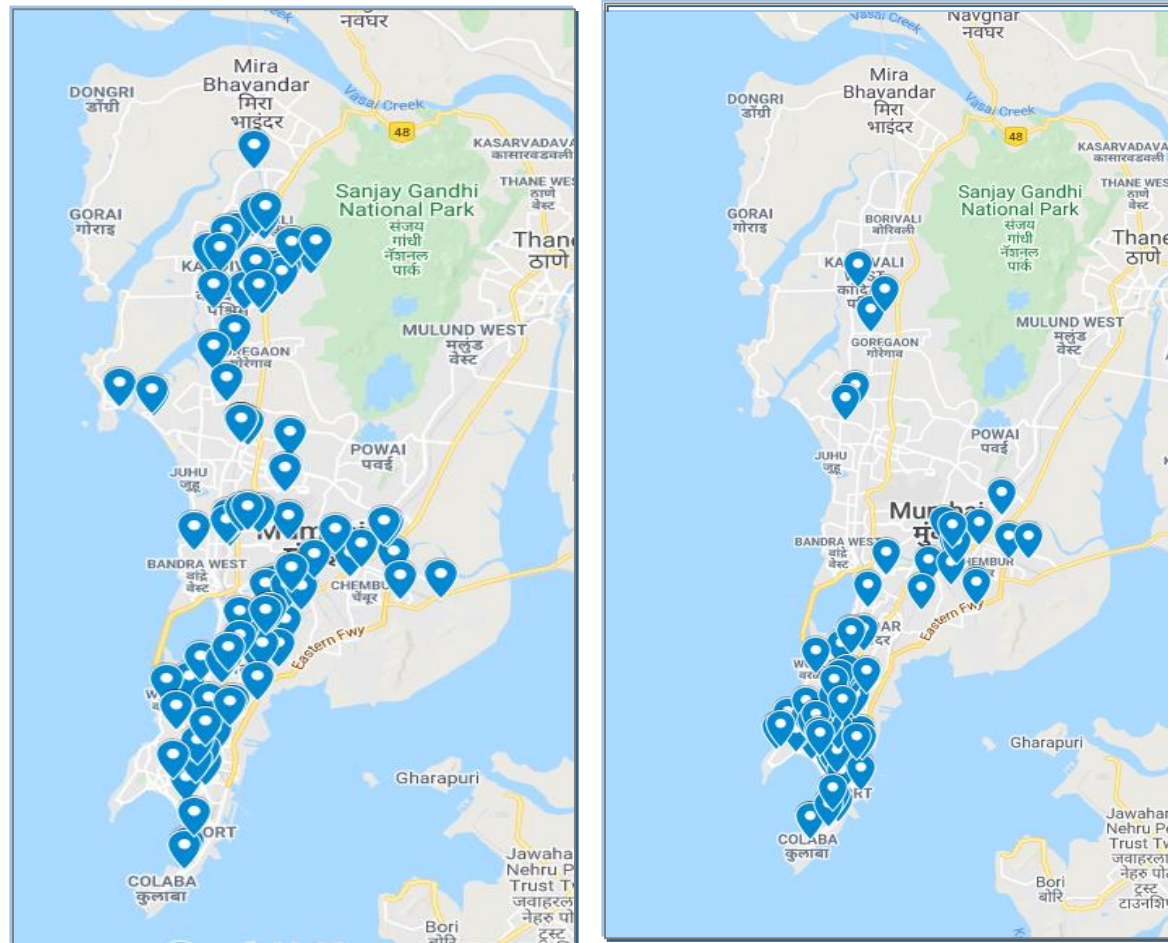


24 hour rainfall (in mm) realised at 8.30 hrs IST of 6th Aug 2020



Validation Based on MCGM Flood Point data

Flood points observed during 4th- 5th Aug 2020 showing extensive floods as indicated in the impact





प्रादेशिक मौसम केंद्र, कोलाबा, मुंबई
Regional Meteorological Centre, Mumbai

Dated: 03 Aug 2020

Time of issue: 1300 hrs IST

IMPACT BASED FORECAST FOR HEAVY RAINFALL OVER MUMBAI

| Date | 03 Aug 2020 | 04 Aug 2020 |
|--------------------|---|---|
| Forecast & Warning | Heavy to very heavy rainfall at isolated places | Heavy to very heavy rainfall at a few places with extremely heavy rainfall at isolated places |
| Impact Expected | <ul style="list-style-type: none"> Water logging/ flooding in many parts of low lying area and river banks Localized and short term disruption to municipal services (water, electricity, etc.) Major disruption of traffic flow. Major roads/local trains affected. Possibility of danger to very old buildings and unmaintained structures, falling of trees etc Closure of roads crossing low water bridges | <ul style="list-style-type: none"> Widespread water logging/ flooding in most parts of low lying area and also on river banks. Major disruption of traffic flow. Major roads/local trains and travel routes Localized and short term disruption to municipal services (water, electricity, Possibility of danger to incredibly old and unmaintained structures, falling of trees etc. Possibility of landslides in elevated hilly areas Closure of roads crossing low water bridges |
| Action Suggested | <ul style="list-style-type: none"> Traffic may be regulated effectively People in the affected area may restrict their movement | <ul style="list-style-type: none"> Traffic may be regulated effectively People in the affected area may restrict their movement |

| COLOR CODES | |
|-------------|-------------|
| Very Low | No action |
| Low | Be updated |
| Medium | Be prepared |
| High | Take Action |

Based on Media Reports



महाराष्ट्र के मुंबई में रविवार यानी कि 5 जुलाई को तेज बारिश हो रही है जिसकी वजह से मुंबई के कई हिस्सों में जल भराव शुरू हो गया है. मुंबई के वडाला एटोप हिल, सांताक्रूज वकोला पुलिस स्टेशन के नजदीकी क्षेत्रों में सड़कों और घरों में भी पानी भर गया है. वहीं शनिवार को मुंबई में काफी बारिश हुई थी और रविवार सुबह से भी मुंबई के कई हिस्सों में बारिश हो रही है. इसी बीच मुंबई में एक बार फिर तेज बारिश शुरू हो गई है. ऐसे में एक फ्लाइट को हैदराबाद एयरपोर्ट पर लैंड कराया गया है.

Widespread water logging in Low lying areas & River banks inundated



Based on Media Reports

| S.No | Ward Name | Vicinity Name | First Respondent Number | Vulnerability |
|------|-----------|---------------------------------|-------------------------|---------------|
| 1 | S | Lake Side Area | 1234567890 | VERY HIGH |
| 2 | S | Mhada Clry 19 | 1234567890 | VERY HIGH |
| 3 | R/N | K/W | 1234567890 | VERY HIGH |
| 4 | MW | Subhas Nagar (Chembur) | 1234567890 | VERY HIGH |
| 5 | MW | Lav Kush Society | 1234567890 | VERY HIGH |
| 6 | MW | Rahul Nagar | 1234567890 | VERY HIGH |
| 7 | M/E | Four Bunglows | 1234567890 | VERY HIGH |
| 8 | M/E | Sanjay Gandhi Nagar | 1234567890 | VERY HIGH |
| 9 | M/E | Municipal Colony | 1234567890 | VERY HIGH |
| 10 | K/W | Gulmohar Colony | 1234567890 | VERY HIGH |
| 11 | K/W | Four Bunglows | 1234567890 | VERY HIGH |
| 12 | K/W | Four Bunglows | 1234567890 | VERY HIGH |
| 13 | H/W | Vaidya Nagar (Bandra West) | 1234567890 | VERY HIGH |
| 14 | G/S | Dighe Nagar (Parel) | 1234567890 | VERY HIGH |
| 15 | G/S | BDD Chawl Lower Parel | 1234567890 | VERY HIGH |
| 16 | E | Siddharth Nagar | 1234567890 | VERY HIGH |
| 17 | E | RBI Staff Colony | 1234567890 | VERY HIGH |
| 18 | A | Mantralaya | 1234567890 | VERY HIGH |
| 19 | A | Church Gate | 1234567890 | VERY HIGH |
| 20 | A | Church Gate | 1234567890 | VERY HIGH |
| 21 | S & MW | Tiak Nagar, Kurla East | 1234567890 | HIGH |
| 22 | S | Vikhroli East | 1234567890 | HIGH |
| 23 | R/S | Samata Nagar | 1234567890 | HIGH |
| 24 | P/S | Cama Indl Eastate-goregaon East | 1234567890 | HIGH |
| 25 | P/N | Gaikwad Nagar | 1234567890 | HIGH |
| 26 | N | Vikhroli East | 1234567890 | HIGH |



Mumbai Rains: RPF teams up with NDRF to rescue around 200 people stranded between Masjid Bunder and Byculla stations

By Swapnil Mishra



Extreme Rainfall Events over Mumbai in 2021



Intense to very intense spells during very short duration
Highly localized activity

Continuous Monitoring with Nowcast updates & Impact Based Forecast Updates



प्रादेशिकमौसमकेंद्र, कोलाबा, मुंबई
Regional Meteorological Centre, Mumbai

Dated: 17 July 2021

Time of issue: 2230 hrs

IMPACT BASED FORECAST FOR HEAVY RAINFALL OVER MUMBAI

Updates of Ongoing Heavy Rainfall Event

| | |
|---|---|
| Rainfall Realised at 2230 hrs (from 0830 hrs IST of 17 July 2021) | Mumbai city and suburbs experienced light to moderate spell of rainfall during past 3 hrs. Santacruz (AWS) – 12 mm, Colaba (AWS) – 4.5 mm, Ram Mandir -19 mm, Juhu Airport – 11.5mm |
| Forecast for next 3-4 hours | As per latest observations, Mumbai city and suburbs are very likely to experience thunderstorm accompanied with lightning, gusty winds and moderate to intense spells of rainfall with during next 3-4 hours. |
| 24 hours Warning for Mumbai (valid from 8.30 hrs of the day to 8.30 hrs of next day) | Heavy rainfall very likely at isolated places. Possibility of thunder/lightning at isolated places. |
| Impact Expected | <ul style="list-style-type: none"> ❖ Water logging in some parts of low lying areas. ❖ Localized and short term disruption to essential municipal services (water, electricity, etc.) ❖ Disruption of traffic flow. Increased travel times. ❖ Possibility of danger to very old buildings and unmaintained structures. ❖ Possibility of cloud to ground lightning. ❖ Traffic may be regulated effectively |
| Action Suggested | <ul style="list-style-type: none"> ❖ People in the affected area may restrict their movement and take caution. |



प्रादेशिकमौसमकेंद्र, कोलाबा, मुंबई
Regional Meteorological Centre, Mumbai

Dated: 18 July 2021

Time of issue: 0100 hrs

IMPACT BASED FORECAST FOR HEAVY RAINFALL OVER MUMBAI

Updates of Ongoing Heavy Rainfall Event

| | |
|--|--|
| Rainfall Realised at 2330 hrs IST of 17 July 2021 (from 0830 hrs IST of 17 July 2021) | Mumbai city and suburbs experienced moderate to intense spell of rainfall during past 3 hrs. Colaba – 64.0 mm, Santacruz -17.0 mm, Juhu Airport-13.5 mm, Mira Road- 10.0 mm, Ram Mandir- 20.5 mm |
| Forecast for next 3-4 hrs | As per latest observations, Mumbai city and suburbs are very likely to experience thunderstorm accompanied with lightning, gusty winds and intense to very intense spells of rainfall during next 3-4 hours. |
| Warning for 24 hours (from 0830 hrs of the day to 0830 hrs of next day) | Heavy to very heavy rainfall at a few places with possibility of thunder/lightning and gusty winds. |
| Impact Expected | <ul style="list-style-type: none"> • Water logging in many parts of low lying areas and river banks • Disruption of traffic flow. Increased travel times • Major roads and local trains affected. • Possibility of danger to very old buildings and unmaintained structures • Occasional gusty winds with speed reaching 45-55 gusting to 60 kmph along and off the coast resulting in possibilities of damage to vulnerable /temporary structures. • Rough Sea conditions along the coast. • Possibility of cloud to ground lightning. |
| Action Suggested | <ul style="list-style-type: none"> • Traffic may be regulated effectively • People staying in vulnerable places may take caution. |



प्रादेशिकमौसमकेंद्र, कोलाबा, मुंबई
Regional Meteorological Centre, Mumbai

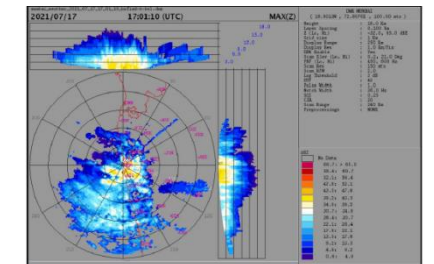
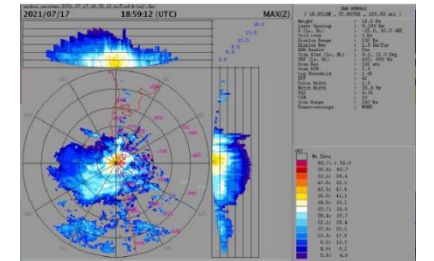
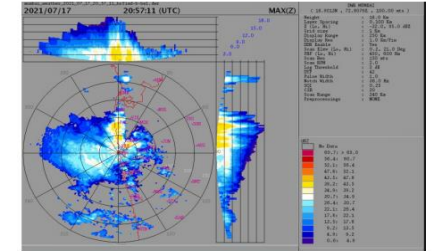
Dated: 18 July 2021

Time of issue: 0300 hrs

IMPACT BASED FORECAST FOR HEAVY RAINFALL OVER MUMBAI

Updates of Ongoing Heavy Rainfall Event

| | |
|--|--|
| Rainfall Realised at 0300 hrs IST of 18 July 2021 (from 0830 hrs IST of 17 July 2021) | Mumbai city and suburbs experienced intense to very intense spell of rainfall during past 3 hrs. Colaba (AWS) –174.5 mm, Santacruz -213 mm, Juhu Airport-197.5mm, Bandra -197.5 mm, Bhayander -164.5mm, Ram Mandir -171.5mm, Mahalaxmi – 154.5mm |
| Forecast for next 3-4 hrs | As per latest observations, Mumbai city and suburbs are very likely to experience intense to very intense spells of rainfall (greater intensity towards northern parts of suburbs) during next 3-4 hours. Possibility of thunder/lightning and gusty winds in some areas. |
| Warning for 24 hours (from 0830 hrs of the day to 0830 hrs of next day) | Heavy to very heavy rainfall at a few places with extremely heavy rainfall at isolated places Possibility of thunder/lightning and gusty winds. |
| Impact Expected | <ul style="list-style-type: none"> • Water logging/inundation in most parts of low lying areas and river banks • Disruption to road, rail, air and ferry transport. Major roads and local trains affected. • Possibility of flash floods coinciding with high tide. • Local disruption of municipal services (Water, electricity etc.) • Flow of water over low-lying roads and bridges. • Possibility of danger to very old buildings and unmaintained structures • Occasional gusty winds with speed reaching 45-55 gusting to 60 kmph along and off the coast resulting in possibilities of damage to vulnerable /temporary structures. • Landslide/Mudslides and rock falls in vulnerable areas. |



| COLOR CODES | |
|-------------|-------------|
| Very Low | No action |
| Low | Be updated |
| Medium | Be prepared |
| High | Take Action |

Evaluation of the IBF issued for Mumbai :

| | |
|--|--|
| Warning for 24 hours (from 0830 hrs of the day to 0830 hrs of next day) | Heavy to very heavy rainfall at a few places with extremely heavy rainfall at isolated places Possibility of thunder/lightning and gusty winds. |
| Impact Expected | <ul style="list-style-type: none"> Water logging/inundation in most parts of low lying areas and river banks Disruption to road, rail, air and ferry transport. Major roads and local trains affected. Possibility of flash floods coinciding with high tide. Local disruption of municipal services (Water, electricity etc.) Flow of water over low-lying roads and bridges. Possibility of danger to very old buildings and unmaintained structures Occasional gusty winds with speed reaching 45-55 gusting to 60 kmph along and off the coast resulting in possibilities of damage to vulnerable /temporary structures. Landslide/Mudslides and rock falls in vulnerable areas. |
| | <ul style="list-style-type: none"> Rough Sea conditions along the coast. Possibility of cloud to ground lightning. |
| Action Suggested | <ul style="list-style-type: none"> Traffic may be regulated effectively People staying in vulnerable places may take caution. |

| COLOR CODES | |
|-------------|-------------|
| Very Low | No action |
| Low | Be updated |
| Medium | Be prepared |
| High | Take Action |

Mumbai rains LIVE: 25 die in multiple incidents, Maharashtra CM calls high-level meeting



Mumbai: Commuters wade through a waterlogged road at Dadar after heavy rains in Mumbai, Sunday, July 18, 2021. (PTI)



Powai lake overflows

Mumbai: Following heavy rains in Maharashtra, Mumbai's Powai lake has started overflowing, the Brihanmumbai Municipal Corporation said on Saturday.

As per the release by BMC, "Powai Lake, one of the most important artificial lakes in the BMC area, has started overflowing at around 3 pm today. The same lake was completely flooded on July 5 last year. Considering this, this year the lake has started filling up and flowing about 24 days earlier than last year."

MUMBAI NEWS

22 dead, several injured in Mumbai landslides after heavy rains

Mumbai reported heavy rainfall overnight especially between 12am to 2am leading to waterlogging in several areas of the city.

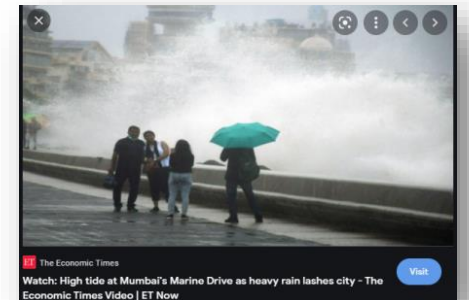
UPDATED ON JUL 18, 2021 01:46 PM IST



Several people were killed after a wall collapsed on some shanties in Chembur's Bharat Nagar area due to a landslide in Mumbai. (HT Photo/Satish Bate)

At least 22 people were killed and several others injured in Mumbai and one of its suburbs after they were trapped under houses that collapsed due to landslides following heavy rains that lashed the city and nearby areas on Saturday night and on Sunday morning, officials said.

Mumbai rain: 25 people died in rain-related incidents as incessant heavy downpour overnight during a major thunderstorm pummeled Mumbai. The Western Railway and Central Railway briefly suspended suburban train services in Mumbai after the heavy rains, and many long distance trains were terminated or regulated at various stations. Seventeen people died as a compound wall came crashing down on some houses located on a hillock after a landslide, a fire official said. The retaining wall of the Bharatnagar locality in Mumbai's Mahul area collapsed at 1 am.



Watch: High tide at Mumbai's Marine Drive as heavy rain lashes city - The Economic Times Video | ET Now

Challenges & Future Scope

❑ IMD has taken up Impact Based Forecasting (IBF) in a big way and i- FLOWS provides a very effective framework for generating IBF for India's megacities

❑ Strengthening of rainfall monitoring network in non representative pockets

❑ Forecast Model consistency during the events. Temporal or spatial shift in the forecast can critically affect IBF issued.

❑ Changing Rainfall Pattern

❑ Precise Mechanism of verification

❑ Receiving disaster data from state govt and continuous feed back

❑ Interactive platform required for sharing the feedbacks even from the general public (***Crowd Sourcing***)

Thank You