

Reduction of flood risk by optimizing reservoir operation using real time flood forecast

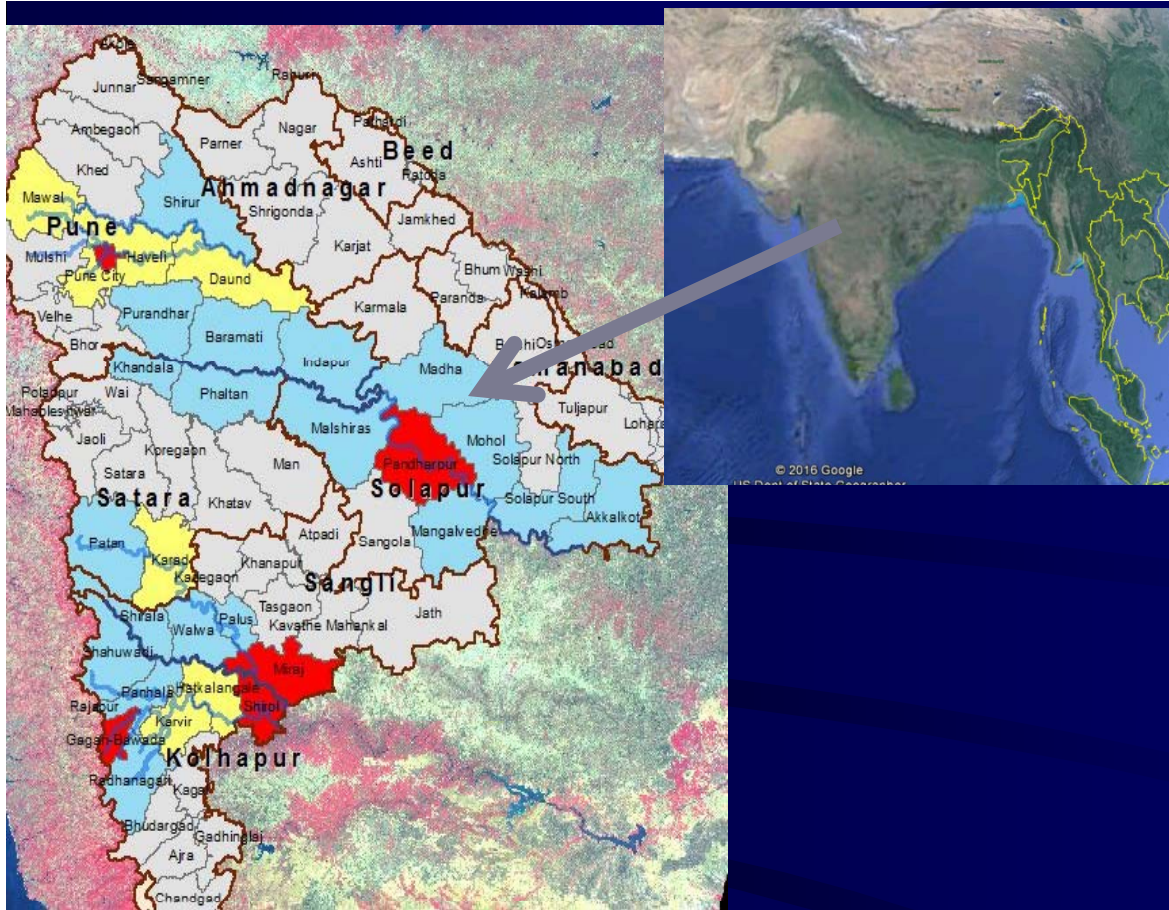
Guna Paudyal

Senior Flood Risk Management Expert

Presentation Objectives:

To share findings from a study in Maharashtra, India: Reservoir inflow forecasting and optimized operation to reduce downstream flood

Flood disasters in Maharashtra, India



Widespread Floods In Maharashtra, 30 Cars Submerged In Pune

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Uploaded by IndiaTV on Jul 20, 2011
More than 30 cars were submerged in flash flood in this city on Tuesday, as 19,000 cusecs water was released in Mutha river from the Khadakvasala

Maharashtra
Krishna-Bhima
basins floods
2005-2006

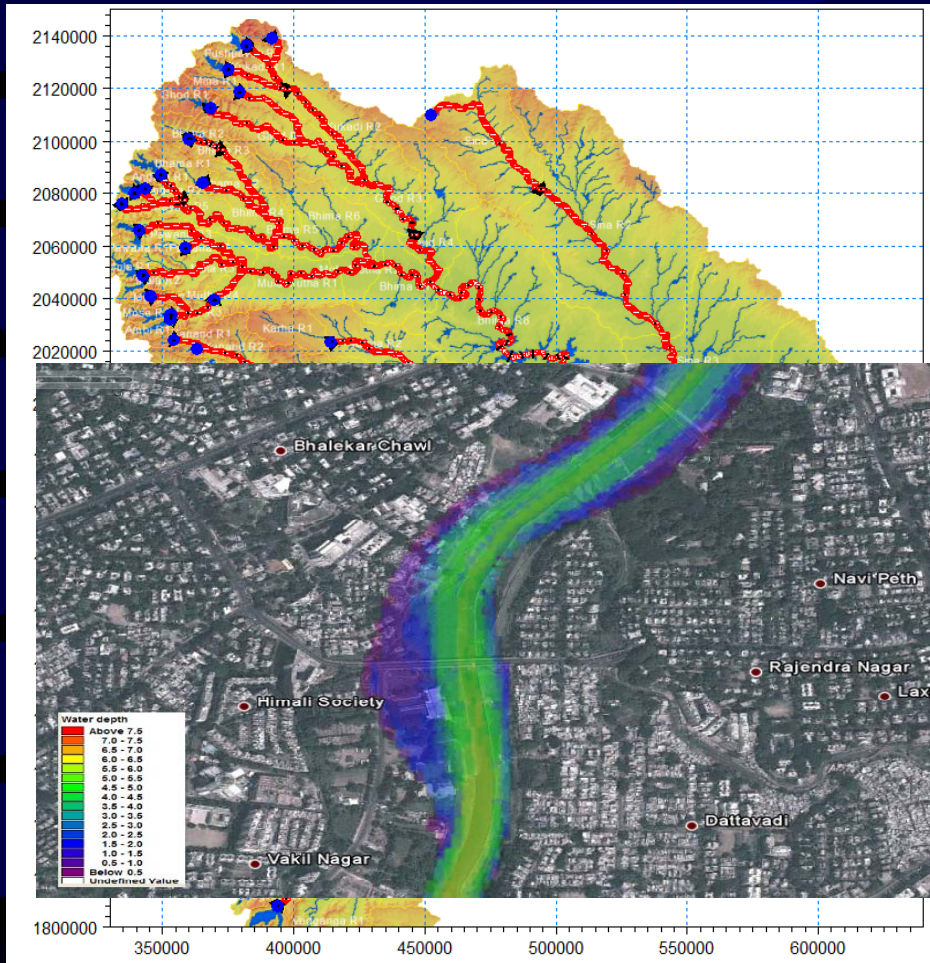


Krishna Basin

Flood losses in one year (2006), Million Rupees

District	Crops & Infrastructure		Land/ Structure Damages	Horticulture		Total
	Farmers	State		Crops	Govt. Nursery	
Satara	329.3	2.3	63.7	152.9	0.5	548.7
Sangli	744.4	3.5	148.2	98.6	0.4	995.1
Kolhapur	2080.5	26.8	125.7	152.0	1.3	2386.3

District	Human Losses		Cattle Losses	
	2005	2006	2005	2006
Satara	11	23	156	239
Sangli	13	19	224	23
Kolhapur	26	26	236	80



In the Krishna Basin

46 major and medium reservoirs
 Operated with rigid operational rule
 curves: **keep the reservoirs full
 towards the end of rainy season.**

**But when heavy rain occurs in
 catchments, then the reservoirs are
 operated releasing sudden floods
 downstream with disastrous effects.**

High Level Government commission:

Floods of 2005 and 2006 were devastating, strong needs of specific forecasts and early warning were felt. Reservoir operations should consider downstream flooding more explicitly.

Reservoirs of Maharashtra

The reservoirs in Maharashtra are multipurpose - hydropower, irrigation, domestic and industrial water supply.

Though these reservoirs are not specifically provided with flood cushion, they can moderate flood peaks to considerable extent by proper reservoir operations.

Reservoirs are operated with rigid rules as single entities based on the historical hydro-meteorological data and experience gained.

These methods are often not adequate for establishing optimal operational decisions, especially where integrated operation of multiple reservoirs for flood management is contemplated.

A Real time monitoring and forecasting system was developed in 2012-13. about 300 telemetry stations were installed.

Flood Bulletin

The interface displays real-time data for the Krishna-Bhima system. Key components include:

- Mobile Phone Display (Left):** Shows three instances of the system's mobile application. Each screen displays a map of the region and a discharge graph for station 1013 Karad/Krishna. The graphs show discharge levels over time, with a legend indicating 'Normal' (< MQ) and 'Warnings' (Yellow, Orange, Red).
- Desktop Map (Middle):** A geographical map of the Krishna-Bhima basin, showing various stations and reservoirs. A legend on the right indicates different discharge levels.
- Discharge Bulletin Table (Right):** A detailed table titled 'Krishna-Bhima Discharge Bulletin'. It lists various stations and reservoirs, their current discharge levels, and forecasted levels for the next 24 hours. The table includes columns for 'Warning Level', 'Hours after Time of Forecast', and 'Maximum'.

Station / Reservoir	Warning Level	Hours after Time of Forecast	Maximum
1001 Krishna Bridge (Dangam Mahuli/Krishna)	1200	100	1200
1002 Navarasta (Dangavadi Bridge/Koyna)	1200	2000	3000
1003 Shingori/Koyna	1000	1000	1000
1004 Nitavade/Koyna	800	1000	1200
1005 Bhalga/Bhigavadi	800	1000	1200
1006 Wananga/Panohanganga	1500	2000	2500
1007 Ishakarangi/Panohanganga	1500	2000	2500
1008 Shivade/Krishna	1200	2000	2500
1009 Sangli/Bhaskar/Krishna	1500	2000	2500
1010 Ankali Bridge/Krishna	1500	2000	2500
1011 Mhasalk/Krishna	1800	2000	2500
1012 Shilakba (Alphal Aqueduct)/Yerala	50	100	150
1013 Karad/Krishna	1500	3800	4500
1014 Kunwad/Krishna	2000	4000	5000
1015 Shirur/Ghod	400	800	1100
1016 Ambabadi/Ghod	400	800	1100
1017 Koraganj/Bhima/Bhima	1500	2000	2500
1018 Nigoh/Indrayani	500	1000	1500
1019 Pimpri/Bhima/Pawane	200	300	400
1020 Paud/Mula	200	300	400
1021 Dattawadi/Mutha	800	2000	3000
1022 Kalyan nagar Bridge/Mula Mutha	1500	3000	4000
1023 Khargapur/Mula Mutha	1500	3000	4000
1024 Pargan/Bhima	2000	5000	8000
1025 Keshid/Ghod	500	1000	1500
1026 Panchapur/Bhima	2000	4000	5000
1027 Tali/Bambur/Bhima	500	1000	1500
1028 Siddhewadi/Agram	100	200	300
1029 Dausdi/Bhima	1500	3000	4000
1030 Wasah/Bhima	800	1500	2000
1031 Nira/Nandipur/Nira	1500	3000	4000
1032 Limbe/Kausur/Kanand	300	500	800
1033 Lake/Nira	800	1500	2000
1034 Ambahar/Nira	400	800	1100
1035 Subnai/Krishna	2000	4000	5000
1036 Dev Navarasta/Bhima	1500	4000	5000
2001 Dhoni/DHOM RESERVOIR	500	1000	1200
2002 Dhoni/Balkavadi/DHOM BALKAWADI RESERVOIR	100	200	300
- SMS & E-mail alerts (Bottom Right):** A section for configuring alerts. It includes a 'Send SMS' button, an 'Email Warning Message' form with a subject line 'Warning Message from Flood Control Center in Pune', and lists of 'SMS Receivers' and 'Email Receivers'.

SMS Receivers:

Name	Number
Chief Engineer	9999999999
Executive Engineer	8888888888
Director	7777777777
Receiver n	6666666666

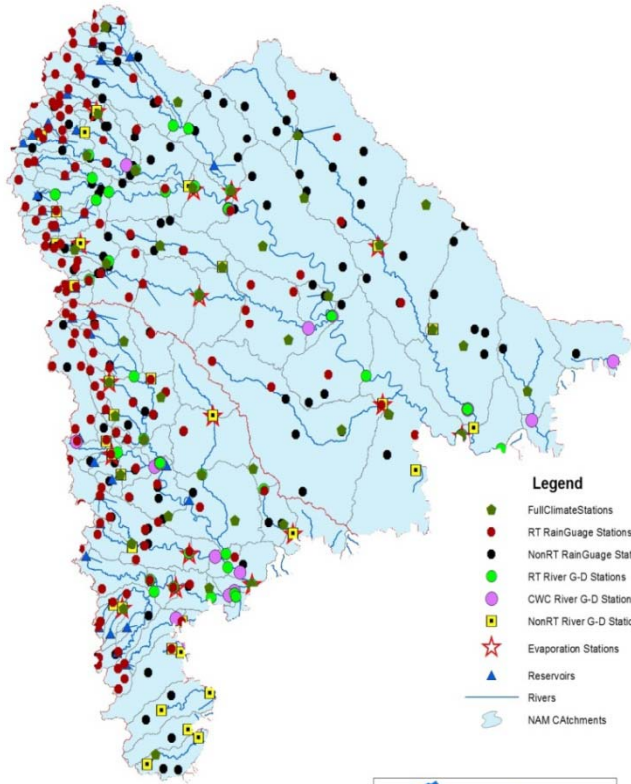
Email Receivers:

Name	Email
Receiver 1	email1@gmail.com
Receiver 2	email2@gmail.com
Receiver n	emailn@gmail.com
- Discharge Graph (Bottom Left):** A detailed graph for station 1013 Karad/Krishna. The Y-axis represents discharge in m³/s, ranging from 0 to 5000. The X-axis shows time from 00:00 on 2006-07-29 to 00:00 on 07-30. The graph shows a rising discharge curve that crosses the warning levels (Yellow, Orange, Red) and reaches a peak of approximately 4500 m³/s.

Real Time Data Acquisition System (RTDAS)

RTSF & ROS for Krishna & Bhima Basins in Maharashtra

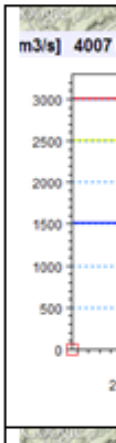
NAM Catchments with Hydro-met Stations



DHI

Forecasting of inflows and floods

Koyana

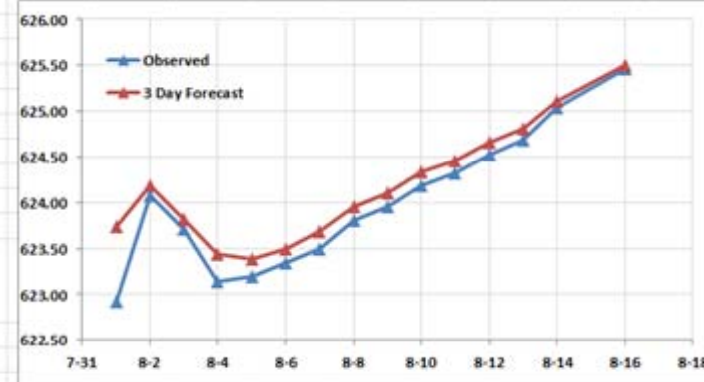
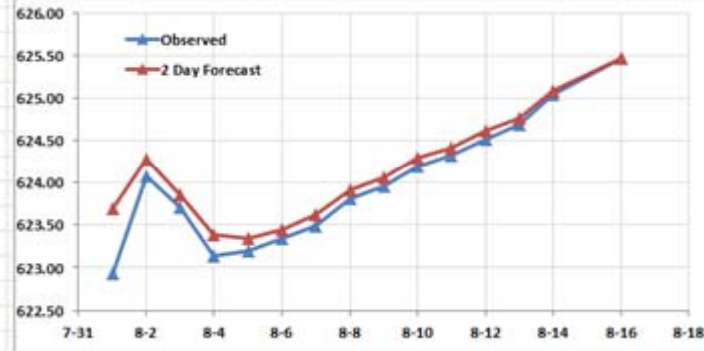
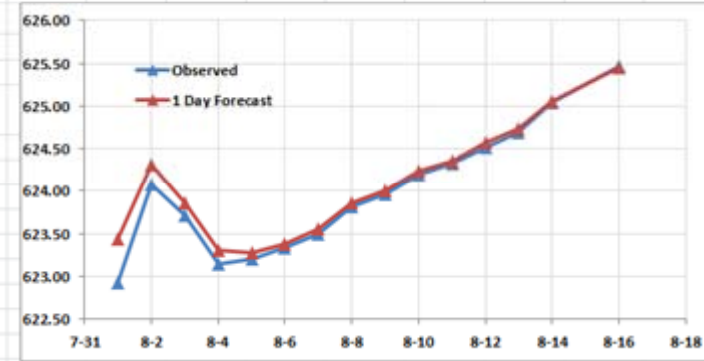


Date	Observed	1 Day Forecast		2 Day Forecast		3 Day Forecast	
		Forecasted	Difference	Forecasted	Difference	Forecasted	Difference
01-08-2013	622.93	623.44	-0.51	623.70	-0.77	623.74	-0.81
02-08-2013	624.08	624.31	-0.23	624.28	-0.20	624.18	-0.10
03-08-2013	623.71	623.86	-0.15	623.86	-0.15	623.82	-0.11
04-08-2013	623.14	623.31	-0.17	623.39	-0.25	623.44	-0.30
05-08-2013	623.20	623.28	-0.08	623.34	-0.14	623.39	-0.19
06-08-2013	623.34	623.38	-0.04	623.44	-0.10	623.50	-0.16
07-08-2013	623.49	623.55	-0.06	623.62	-0.13	623.69	-0.20
08-08-2013	623.81	623.86	-0.05	623.91	-0.10	623.96	-0.15
09-08-2013	623.96	624.00	-0.04	624.06	-0.10	624.11	-0.15
10-08-2013	624.19	624.24	-0.05	624.29	-0.10	624.34	-0.15
11-08-2013	624.32	624.36	-0.04	624.41	-0.09	624.46	-0.14
12-08-2013	624.52	624.57	-0.05	624.61	-0.09	624.66	-0.14
13-08-2013	624.69	624.73	-0.04	624.77	-0.08	624.81	-0.12
14-08-2013	625.04	625.05	-0.01	625.08	-0.04	625.11	-0.07
16-08-2013	625.46	625.45	0.01	625.46	0.00	625.50	-0.04

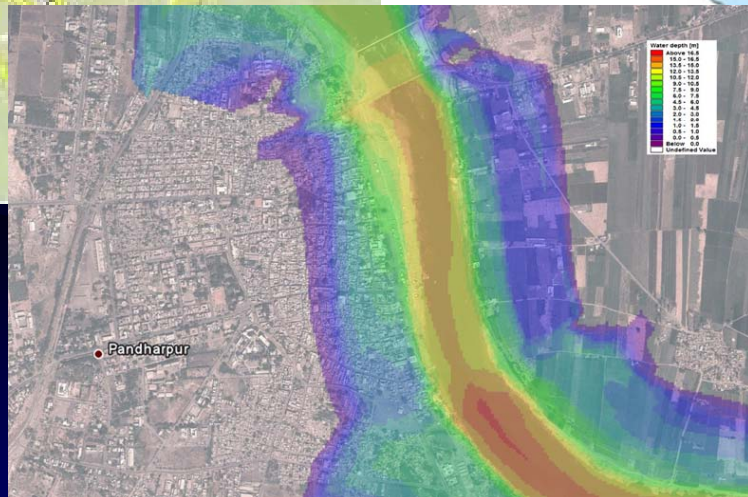
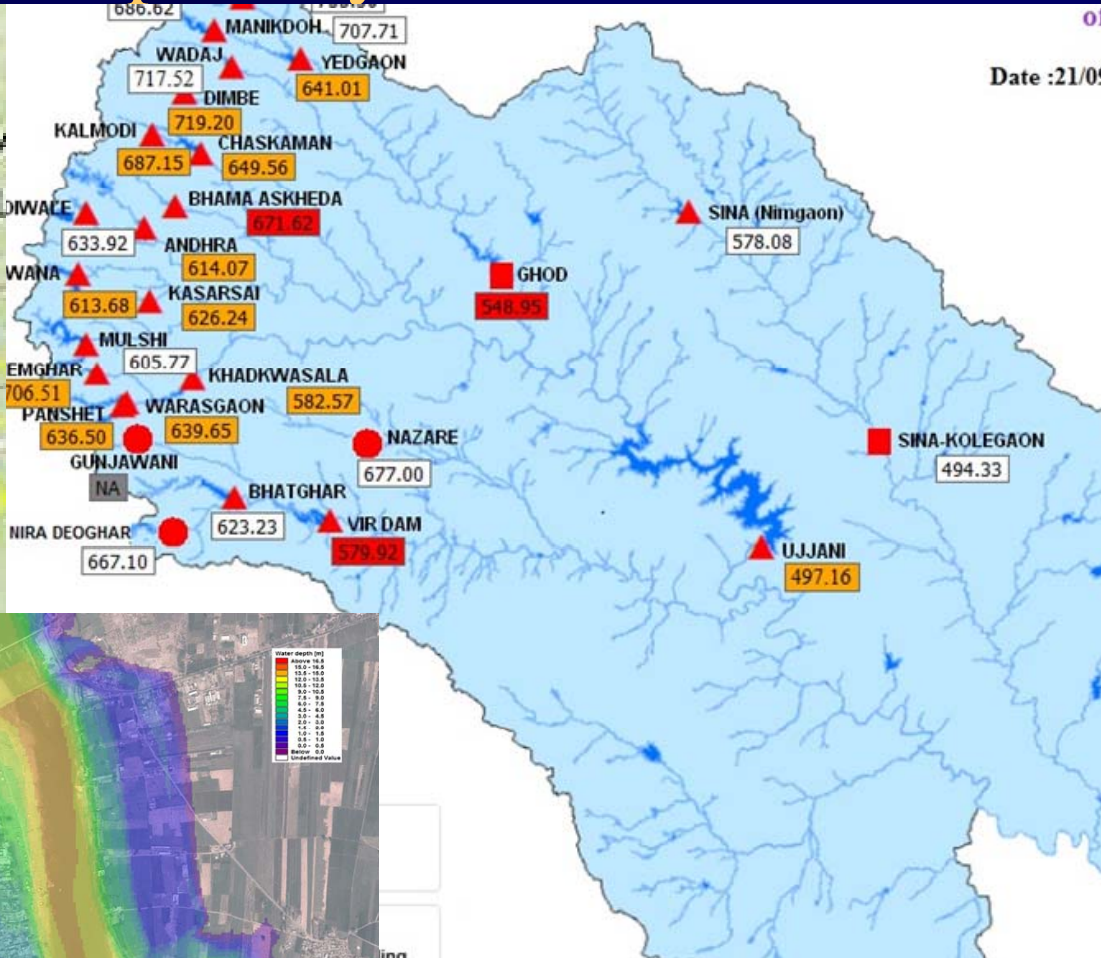
Count	15	15	15	
Mean	623.59	624.09	624.15	624.18
bias	-0.101	-0.156	-0.189	
RMS	0.161	0.234	0.258	
BI	-0.0002	-0.0003	0.000	
SI	0.000	0.000	0.000	
r (Correlation Coefficient)	0.85	0.84	0.84	

Operational Forecast since 2013

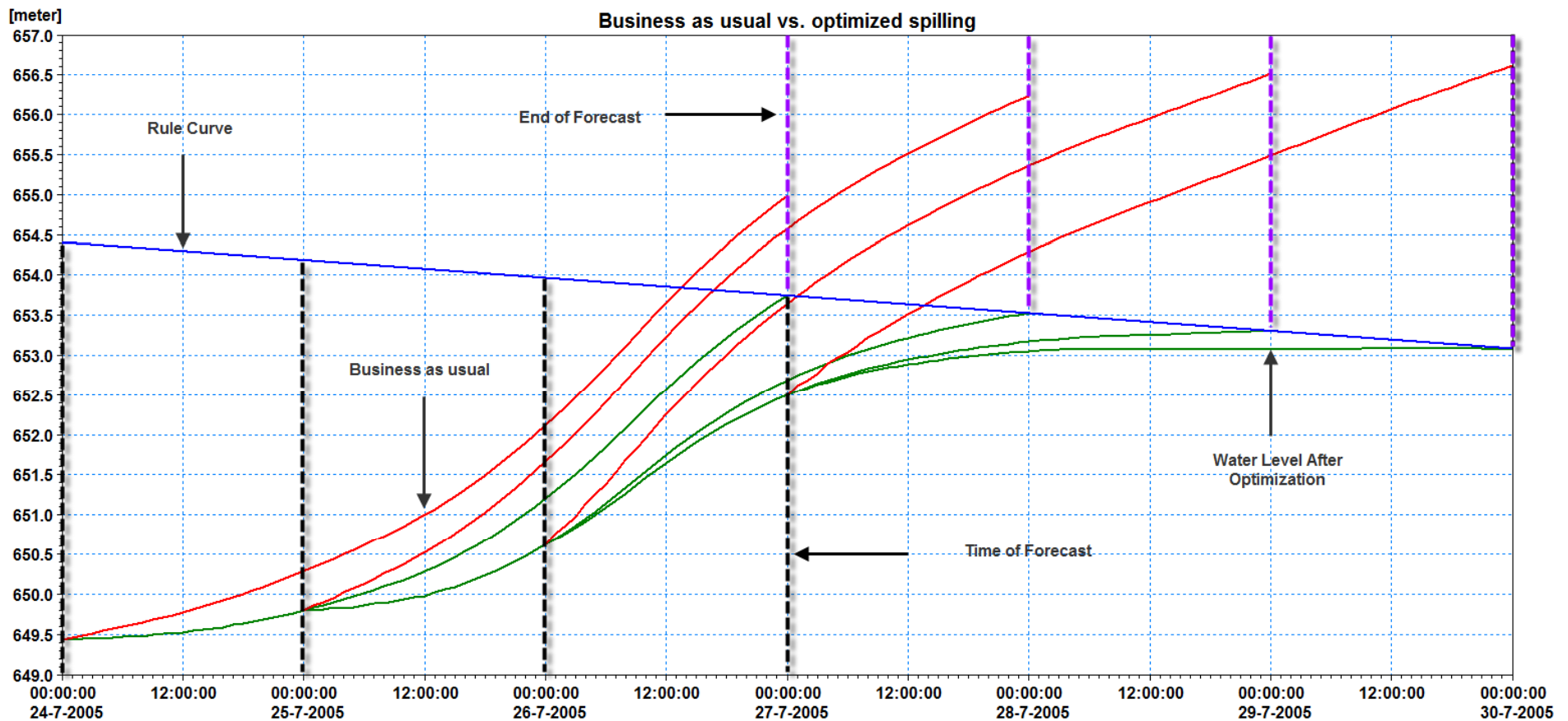
Note: Correlation coefficient varies between -1 to +1 depending upon rising or falling nature of water level. +1 and -1 signifies perfect match mean accurate result. Zero mean poor match.



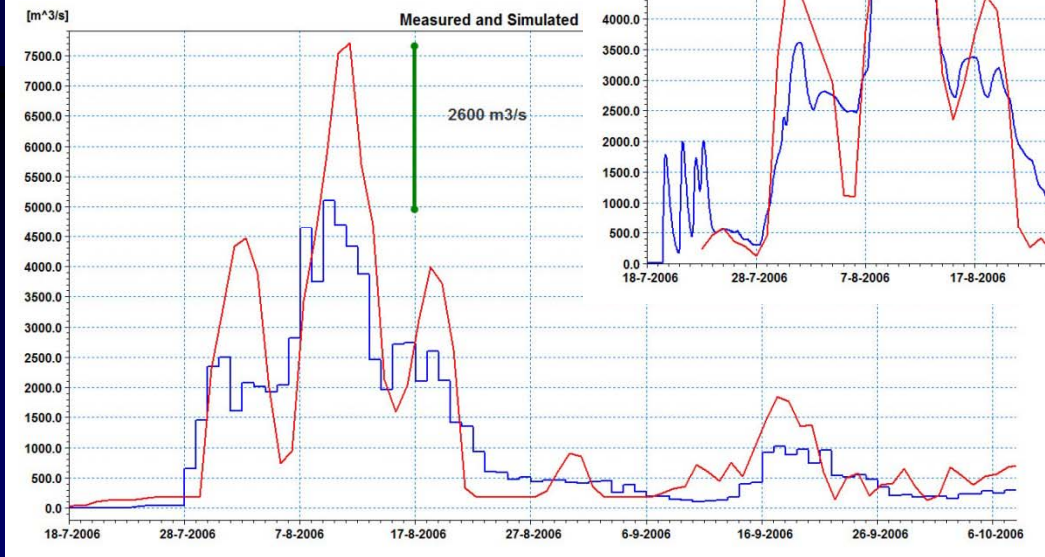
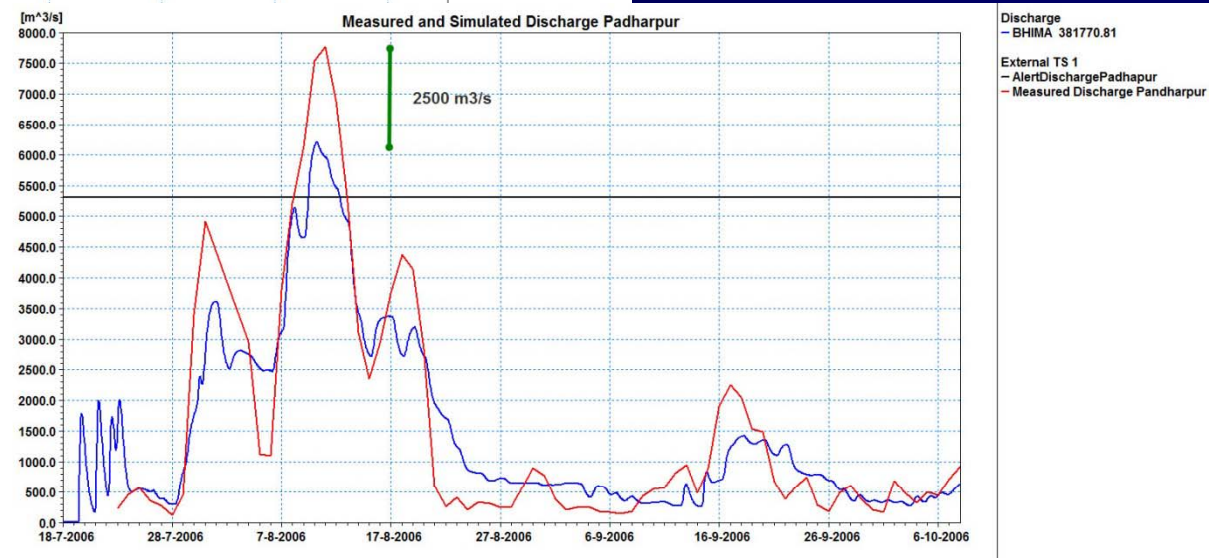
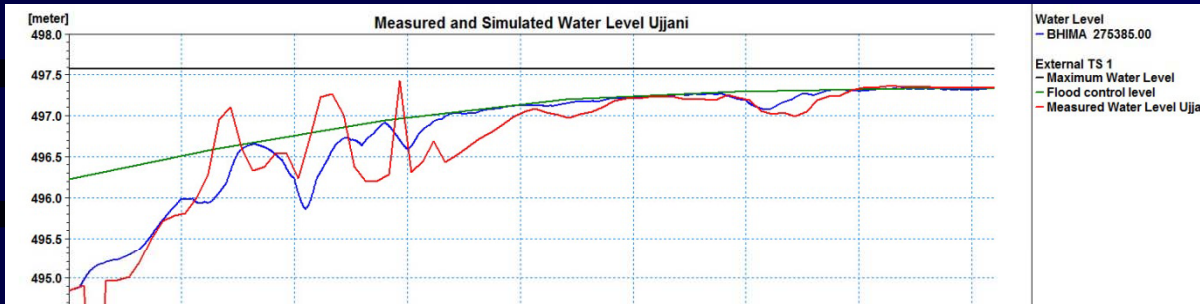
The Case of Ujjani Reservoir and flooding of Pandharpur city



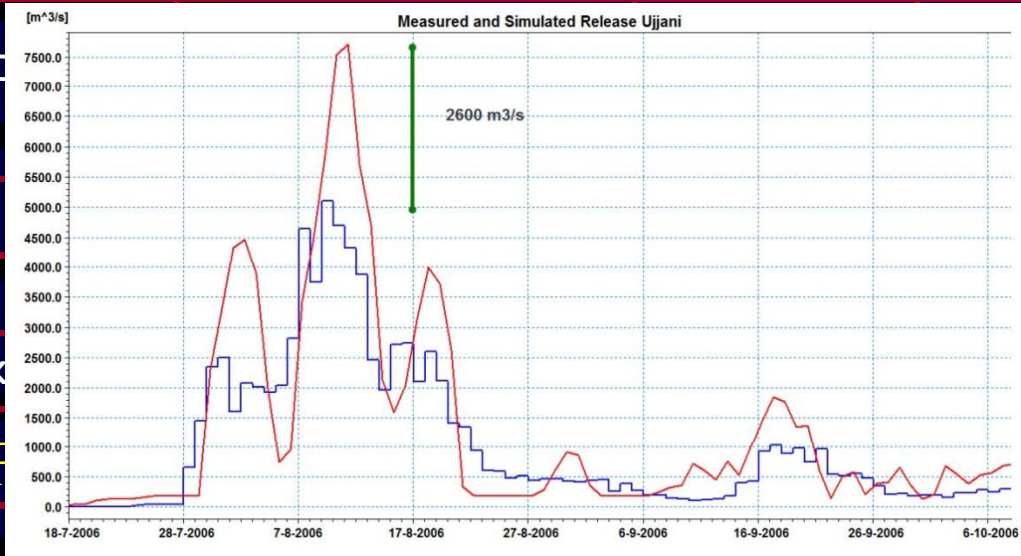
Optimized Operation of the reservoir based on 3-day inflow forecast



Ujjani reservoir operation during Moonsoon 2006



Optimized reservoir operation during flood emergencies



Discharge	Total
BHIMA 275575.00	
External TS 1	
Measured Release Ujjani	
0.5	548.7
0.4	995.1
1.3	2386.3

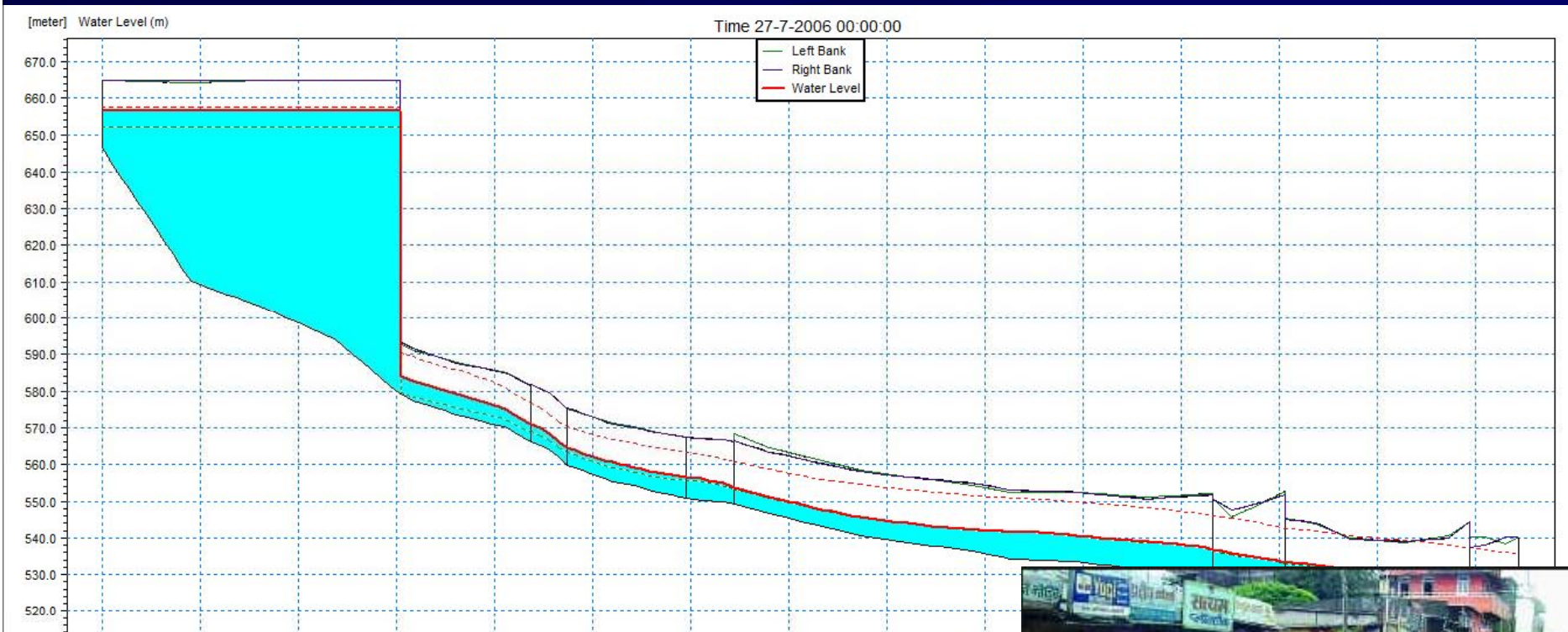
Rs. 2386 mil / yr.

These losses could have been avoided

	2006	2005	2006
	23	156	239
	19	224	23
	26	236	80

Cost of setting up RTDAS (telemetry 300 stations) = Rs. 230 mil
 Cost of forecasting system incl., software, datatbase, capacity bldg.,
 (completed in 18 months + 2 years support = Rs. 82 million
TOTAL= Rs.312 million

Reservoir Operation must consider downstream floods



Joy for some, trouble for many !

Over 20,000 evacuated in flood-hit Vadodara

Reservoir Water Raises River Level

TIMES NEWS NETWORK

Vadodara: The menacing Vishwamitri brimmed over in Vadodara, leaving several areas of the city in waist-deep water. Over 20,000 people were evacuated to safer locations across the district due to the flash floods.

While the city and district hardly received any rainfall since Tuesday night, the water released from Ajwa reservoir till early on Wednesday morning lead to the flooding of Vishwamitri. The river reached a level of 34 feet in Vadodara on Wednesday morning.

While the 62 gates of Ajwa reservoir were closed at



People shift from a flooded locality after heavy rains in Vadodara

5.30am, waters in Vishwamitri refused to recede. Till 8pm, the water level was stagnant at 34 feet and was expected to recede only in the night.

VMC commissioner Manish Bhardwaj said that the water level did not go down through the day as the Dhadhar river, into which the Vish-

wamitri flows into, was also in spate. "Dhadhar was at a level of 35.6feet and it was unable to accommodate the flow from Vishwamitri," said Bhardwaj. Ajwa reservoir was 213.8 feet on Wednesday night, down from Tuesday's 215.5 feet. Bhardwaj said that 15 to 20 per cent of the city

Crocodiles flow into city with Vishwamitri water

When firemen reached Siddharth Bungalows on Sama-Savli Road to rescue stranded residents on Tuesday night, the last thing they expected was crocodiles. It was one of the scariest rescue operations carried out by the fire brigade personnel in Vadodara. When water from the Vishwamitri gushed into the residential colony on Tuesday, about five crocodiles too flowed in.

The reptiles also caused delays in the evacuation process that was on at around 2am on Wednesday. "When we were rescuing people from the colony, I spotted a crocodile swimming near our boat. It was risky as we had to ensure that people don't step into the water. Also, we couldn't tell people about the crocodiles as they would have panicked and put lives of others in the lifeboat at risk," said Om Jadeja, a fire brigade officer.

"The crocodiles were following our rescue boats all the time. About six came in the colony after the wall of EME got washed away on Tuesday. The crocodiles didn't have any exit route from the colony so they kept moving around inside. However, they did not interfere with our operations," Jadeja told TOI. Pinal Parikh, a resident of Siddharth Bungalows, too spotted crocodiles. "I saw some crocodiles and two snakes swimming near my house. We were too scared to come out."

There are close to 204 crocodiles in the Vishwamitri and the incident has refreshed memories of 2005 floods when the reptiles had entered several homes. TNN

was waterlogged due to the floods when Vishwamitri reached 34 feet.

In Vadodara city, 12,761 were moved to safer areas while 9,528 from villages were relocated. National Disaster Response Force and EME Corps of the Indian Army also joined the rescue efforts.

The city was divided into two parts with the western parts cut off from the rest of the city. Waters from the Vishwamitri river that runs through the city had inundated approaches to major bridge crossing it. A heavy traffic jam was witnessed on the newly constructed Ako-

ta-Dandia Bazaar link in the morning. But the approach of the link on the Akota side got inundated later in the day and it had to be closed.

The flash flood here comes at a time when the nation has put all efforts for rescue and relief of victims of the worst-ever floods in J&K.

Vadodharaa city flooding in 2014.

CHENNAI | KILLING THE DRAIN

No. of waterbodies in the 1980s

AIRPORTS ON LAKES, RUNWAYS ON RIVERS

LIFE ON THE EDGE

ES 27
MUMBAI 36.5 s
LOST BET

CHENNAI TO Babu-nexus cities

W hat happens easily happens. Those responsible for the chaos in India's cities are trapped in files and implementation or thoughtless. The truth: Most man-made. So when the Tamil Nadu climate experts wore a told-you-so look of government intent to stop about call a halt to mindless concretisation, air waterways and drainage channels.

Truth is, while extreme weather conditions their manifestation on our cities is worsened slugs — faulty legislation, lack of will to enforce human greed. Politicians, bureaucrats and builders to chop and change urban plans and legislate have legalised unauthorised colonies on the Like Chennai, where suicidal developers crowded neighbourhoods such as Mudichur and Ilkkanani coming up on wetlands and 500 wet ecological tensions are building up in other ment policy and corruption allow lowland which receive the runoff from torrential r plotted out for 'development'.

Take Bengaluru. While the city's built-up area exponentially between 2000 and 2014, veget an Indian Institute of Science study, has sh water bodies is worse. None of this would h out politicians, babudom and the bulldozing caluots. Shockingly, Hyderabad, which lakes, has only a few left now.

LAW AND DISORDER them. That brings us to the q We don't have a dearth ably fall short on impleme administrations are complaceny sets the better ad of

about 5,000 cases into the Adyar," said a highly placed areal In-

METROS SLIP ONE BY ONE

At least five of India's metros have battled floods since 2000 resulting in extensive loss to life and property. Since 2005, the frequency of such urban disasters has increased, Mumbai experiencing flood-like situations almost every year. The impact of these freak weather events has been compounded because of urban mismanagement. Lax implementation of laws, civic bodies bending regulations and bypassing of Masterplans in the name of development have worsened matters. Here is how...



3 PROPOSALS: FILEBOUND, DILUTED, IGNORED

1 RIVERS IN RED TAP
Rivers are openly preyed upon by governments that put convenience ahead of caution. Reason why a 2002 proposal for river-protection is still a mere draft.
► A River Regulation Zone (RRZ) was proposed in 2002, as legal protection for floodplains from encroachments and to ensure no river-zone land is diverted.
► Draft RRZ bill is still with government.
► RRZ is drafted on the lines of the Coastal Regulation Zone.
► Current Status: Draft RZR notification vetted by law ministry, awaits green ministry's nod.

2 WETLAND RULES 2010 DILUTED
Rules protect only those wetlands with area of over 500 ha or any other wetland the Central Wetland Regulatory Authority (CWRA) suggests.
More than 90% wetlands are smaller ones, which now have no legal protection.

3 MASTERPLANS IGNORED: In metros like Chennai and Delhi, Masterplans clearly caution and detail water bodies and floodplains to be protected zones where development cannot be allowed. Chennai's Pallikaranai marsh an instance, as are the encroachments on Delhi's Yamuna. But is anyone listening? Totally not.

CITY AFTER CITY, SAME MISTAKES

What happens when planners value only land, and not water? When it rains, cities drown. Builders eat up water bodies with govt consent. Every major metro has followed the same route, making all cities sitting ducks

NCR | LIVING ON THE FLOODPLAINS

► Delhi state website lists 1,011 waterbodies but the majority have a remark alongside showing it has disappeared, is encroached upon or is being used as dumping grounds

YAMUNA: CAPITAL POLLUTION

Home to over 25 million, Delhi constitutes only 2% of Yamuna's catchment area but is responsible for 80% of the river pollution

DDA parcelled out land in the eco-sensitive zone, starting with the Akshardham temple, then for CWG Village, slum resettlement colonies like Khadar, even bus depots

► Poor sewerage leads to sewage discharged into these drains, from where it finds its way to the river. Yamuna has seldom been dredged

19 drains open into the Yamuna. At one time, these carried rainwater

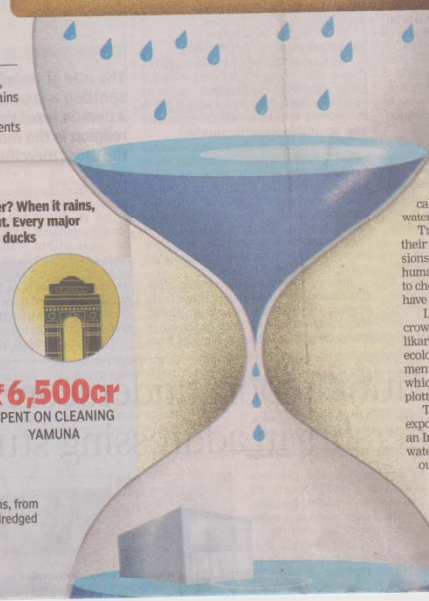
► 22 Haryana industrial units, 42 Delhi ones and 17 in UP dump effluents into the river

tion of Delhi checked building stability in east Delhi in 2010, it found most riddled with serious structural defects. But the alarming findings didn't change mindsets. Today, civic agencies don't even have a count of Delhi's dangerous buildings.



₹6,500cr
SPENT ON CLEANING YAMUNA

AS EXTREME WEATHER EVENTS RISE IN FREQUENCY...



- Zone I (Least Dangerous)
- Zone II
- Zone III
- Zone IV
- Zone V (Most Dangerous)

Sources: CSE, nsc for inputs from Chennai, Hyderabad, Bengaluru, Delhi, Mumbai and Kolkata

1 to 5. Has government learnt lessons? Not really, if one were to consider plans for a new airport at Navi Mumbai. The Rs 15,000-crore project involves cutting hillocks and diverting the Ulwe River, while reclaiming marshy land.

CHENNAI
600 WATERBODIES IN 1980S DOWN TO 27

Slums on stormwater pipes, malls on lakes, roads over drains — blind concretisation has brought cities to a tipping point. When it rains, cities drown, miseries pile

CHennai Ba ne ci



MITHI GETS BITTER

The river is nothing more than a sewage drain now — 93% of Mithi is domestic sewage and 7% industrial waste

► In 2005 floods, the clogged Mithi instead of flowing downstream into Arabian Sea, spewed flood water and gallons of waste, onto Mumbai's streets
► River was clogged with plastic, garbage and sewage
Mumbai authorities have taken 9 years and missed two deadlines to desilt a mere 6km of the 17.8-km long river

₹1,770cr

SPENT ON CLEANING MITHI

► Project cost up nearly Rs 209cr — almost 70% of the initial estimate
► The Brihanmumbai Municipal Corpn responsible for the rest of the river stretch has managed about 73% of the de-silting work. Industry continue to dump waste, oil, sludge into the river



₹405cr

SQUANDERED SINCE 2001 TO SEND TREATED WATER INTO MUSI

► Hyderabad's Musi river is a cesspool of sewage and monia smell

...MINDLESS CITY PLANNING TURNS THEM INTO D

BENGALURU WETLANDS TO BUILDINGS

No. of lakes in the 1960s

280

183

No. of lakes today, most in bad shape



125% increase in built-up area 2000 to 2014

62% decrease in vegetation cover

85% water bodies destroyed

54% lakes built over illegally

66% are sewage dumps

14% are surrounded by slums

RAMSAR CONVENTION

INDIA HAS ONLY 26 SITES LEFT THAT ARE DESIGNATED WETLANDS OF INTERNATIONAL IMPORTANCE. UK, A MUCH SMALLER COUNTRY, HAS 169 SITES

► Water's colour ranges from dull grey to black; polythene packets and animal carcasses float on the surface

Musi among India's top 15 most polluted rivers

► Two rubber dams were set up by the Greater Hyderabad Municipal Corporation for Rs 50cr. But the dams only benefited breeding mosquitoes

In February 2015, state govt attempted to divert industrial effluents from the Kukatpally nala into Musi to facilitate the emptying of Hussainsagar as part of its clean-up

Real time flood warning- Gives you time to act

