Significance of reservoir operation during extreme rainfall event in flood mitigation and water demand management in a metropolitan city of India: a case study

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Motivation

Submerged bridge in 2015 floods, Chennai

Source: Wiki

- Increasing water demand and climate change poses a great challenge in managing water resources availability
- Reservoir operation during heavy rainfall events in an urbanized region is crucial in terms of decision making

So, What is the Significance of reservoir operations during an extreme events?

1. Flood mitigation 2. Water storage for future use 3. To avoid socio-economic, ecological problems

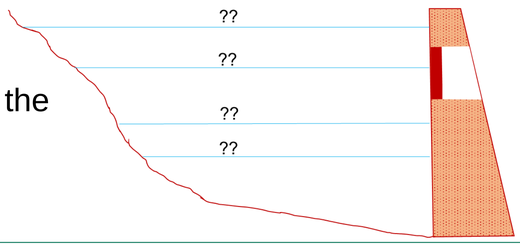
Water supply reservoir in Chennai during 2016

Source: The Hindu

Introduction

- Reservoir operation during extreme hydro-climatic conditions is important i.e. release and storage for flood mitigation and water supply respectively
- Wrong choices on reservoir operation may results in increased flooding or water shortage
- It requires understandings about response of a reservoir system during such extreme events

Initial water level before the event??



Water storage at the end of the event??

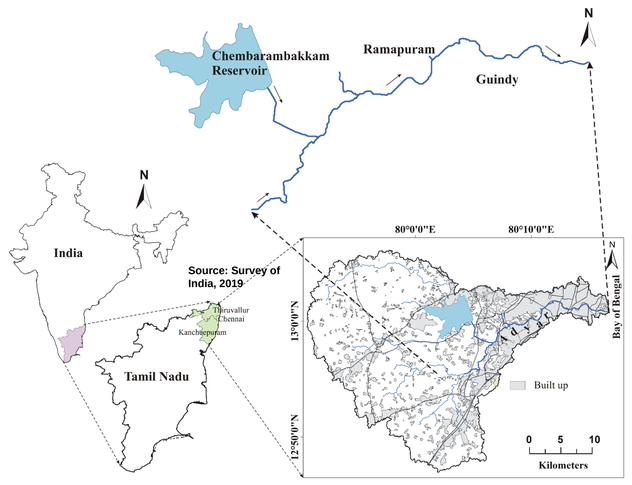
Objective

To assess the significance of reservoir operation during extreme rainfall events on flood mitigation and future domestic water supply

Study area and methodology

Study area

- The Adyar river and Chembarambakkam reservoir in Chennai city, India
- A semi arid, highly populated city in India
- The topography is low lying, flat with gentle slope
- A massive 450 mm rainfall event occurred in 2015 was chosen for the analysis



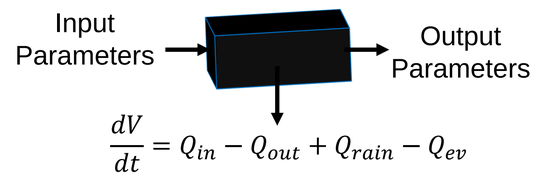
Hydrological modelling

- Inflow to the reservoir was simulated in HEC-HMS
- Runoff volume, runoff-SCS-CN method
- Water movement- Muskingum routing method
- Reservoir operation-Outflow curve method

Box model approach for reservoir operations

- A simple box model for reservoir operations
- Different scenarios were framed to analyze the reservoir operations with storage and release

Box model description:



$$\frac{dV}{dt} = Q_{in} - Q_{out} + Q_{rain} - Q_{ev}$$

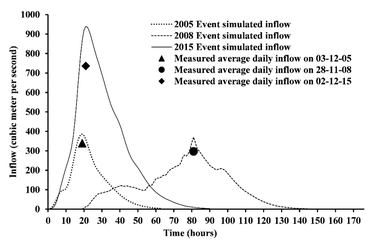
V=the volume of water contained in the reservoir
Q_{in}=inflow (Function of time)
Q_{out}=outflow
Q_{rain}=flow entering the reservoir from rainfall
Q_{ev}=evaporating flow of water

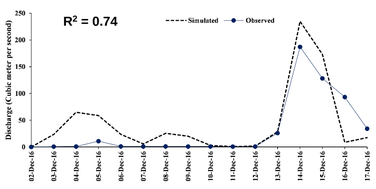
Anandharuban et al. 2019

Results and discussions

Model validation

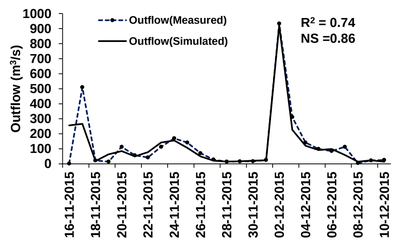
Reservoir inflow simulations

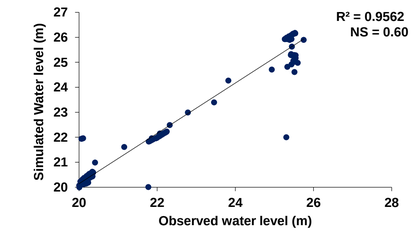




- Hydrological model was validated for 2016 measured inflow and historical peaks at Chembarambakkam reservoir
- The reservoir inflow to reservoir was taken as the main input for the simulations in box model

Reservoir flow simulations in box model



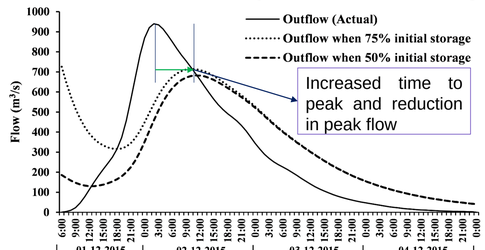


- Box model is validated for the reservoir inflow, storage and water level
- The performance of the box model was assessed with R^2 and Nash-Sutcliffe efficiency

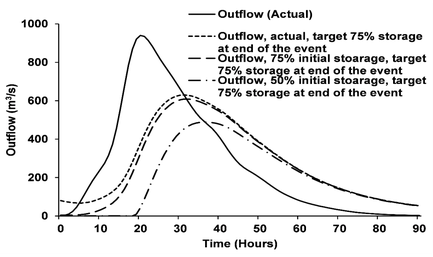
Solutions for flood inundation and water supply

	Scenario	Conditions
1	Reducing the storage before the event and maximum release at early	Reducing the storage to 75%, 50%
2	Actual conditions with target end storage 75%	Reducing the storage to 75%, 50%
3	Increasing the capacities of reservoir gates and storage	Target 75% storage at the end of the event

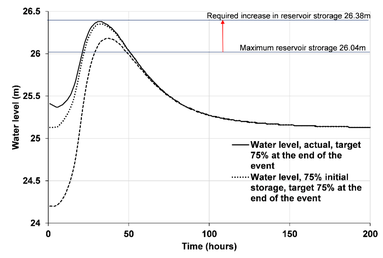
Outflow in actual conditions, early release & reduced storage:



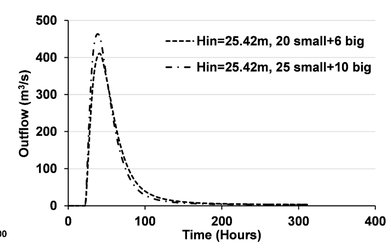
Testing the facilities: Actual conditions, reduced storage & target 75 % storage at the end of the event



Investigation on reservoir storage :



Increasing reservoir storage, gates:



	Scenario	Flood mitigation	Water supply
1	Reducing the storage before the event and maximum release at early stage	Can be increased 1 to 2 hrs	Storage at the end of the event is less for water supply
2	Actual conditions with target end storage	Can be increased 11 to 16 hrs	We can ensure water supply with additional facilities
3	Increasing the capacities of reservoir gates and storage	Can be increased 20hrs	We can ensure water supply with additional facilities

- Early release with actual conditions may help in reducing time to peak only one to two hours. Which may not reduce flooding but affect the water supply
- To target the final storage to 75% at least, it needs additional storage and release facilities
- Increasing storage and releasing facilities are viable solutions for flood mitigation and water supply

Conclusions

- Reducing the reservoir storage in advance and early release will reduce the outflow from 5 to 27% and increase the time to peak by 11 to 16 hours
- Increased storage capacity combined with additional provisions of gates will reduce the outflow by 30% and increase the time to peak by 20 hours
- The developed combined modelling approach can be used to simulate various combinations of reservoir operations to assess the significance of timely decision on release and storage during extreme rainfall events

References

- Anandharuban, P., La Rocca, M. & Elango, L. A box-model approach for reservoir operation during extreme rainfall events: A case study. J Earth Syst Sci (2019) 128: 229. https://doi.org/10.1007/s12040-019-1258-7
- Obringer, R., Nateghi, R. Predicting Urban Reservoir Levels Using Statistical Learning Techniques. *Sci Rep* **8,** 5164 (2018). https://doi.org/10.1038/s41598-018-23509-w
- Raje D and Mujumdar P P 2010 Reservoir performance under uncertainty in hydrologic impacts of climate change; Adv. Water Resour. 33 312–326.

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