



# CLIMATE-RESILIENT DAMS AND HYDROPOWER INFRASTRUCTURE INTEGRATING ENVIRONMENTAL SUSTAINABILITY IN PLANNING AND DEVELOPMENT

**Framework for Developing an Effective Early Warning System for  
Dams in compliances to Dam Safety Act 2021 in India**

**By**

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## PIECEMEAL APPROACH –

- Early warning systems (EWS) for dams are often implemented in a fragmented manner.
- Limited coordination between upstream dam operators and downstream communities.

## REACTIVE MEASURES:

- Installation of basic water level sensors:
  - Monitors reservoir levels but lacks predictive capabilities.
  - Alerts are triggered only after critical thresholds are breached.

# Flood Early Warning

WHY

The Dam Safety Act mandates setting up the Flood Early Warning System for all dams

WHOM

Early Warning for whom? Dam operators, government authorities and downstream communities?

WHAT

What should be the components of the Early Warning System?

# Meeting the Challenges

- Manage flood events:
  - Do not allow dam structures to overtop
  - Minimize downstream flooding
  - Warn impacted population around and downstream of the reservoir

# Dam Early Warning (DEW)

- Actively monitor  
current weather (esp. rainfall)  
current reservoir inflows
- Operate reservoirs **individually**  
Assume local inflows  
Assume how the reservoir fills  
Warn downstream population if large releases/spills are imminent



# Advanced Dam Early Warning (ADEW)

- Actively monitor  
current **and forecasted** weather and flows  
**local** reservoir inflows (using models)  
the reaction of the reservoir (using models and  
**prescribed** releases)
- Operate reservoirs **individually**  
Based on local forecasts  
Do not account for impact on downstream reservoirs  
Warn downstream population if large releases are  
imminent





# Integrated Reservoir Operations (IRO)



- Model all inflows and reservoir reactions jointly
  - Feed upstream releases into downstream reservoirs
- Operate reservoirs **jointly**
  - Account for the impact** of upstream releases on downstream reservoirs
  - Manually** tweak prescribed releases to minimize downstream impacts
  - Warn downstream population if large releases are imminent



# Integrated Dam Early Warning (IROP)

Automatically optimize the releases

Account for operations objectives and constraints

Account for optimized releases upstream

Operate reservoirs **jointly**

**Account for the impact** of upstream releases on downstream reservoirs

**Automatically** get releases to minimize downstream impacts

Warn downstream population if large releases are imminent



Integrated Reservoir Optimization

# Comprehensive Early Warning System

Simpler



Forecast  
inflows and  
pool levels

Less Accurate, Less Lead-Time,  
Must assume how reservoir will react



Forecast  
multiple  
reservoirs  
jointly

More Accurate, More Lead-Time,  
Know how individual reservoirs react



Jointly  
optimize  
releases

More Accurate, Maximum Lead-Time,  
Know how all reservoirs react  
Use prescribed releases



More Accurate, Maximum Lead-Time,  
Use automatically optimized releases

More Complex

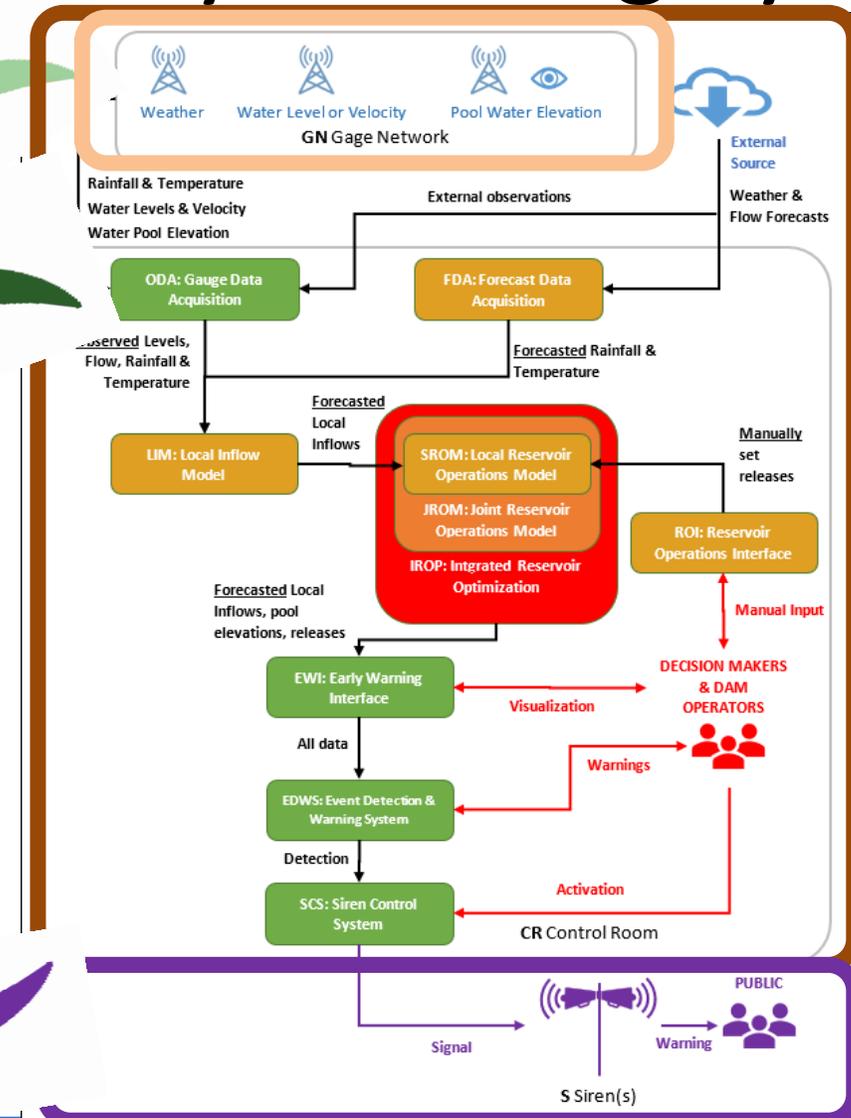
# Main Components of an Early Warning System

## Gage Network

- Sites with *Water Velocity or Level* Sensors
- Weather Stations
- Manual observations (e.g., reservoir pool)

## Control Room & Software

- **ODA:** Collects real-time data from Gage Network
- **FDA:** Collect real-time satellite, forecast, and open data
- **LIM:** Models and forecasts local inflows
- **SROM:** Models and forecasts a single reservoir
- **JROM:** Jointly models and forecasts a group of reservoirs
- **IROP:** Jointly optimizes releases for a group of reservoirs
- **ROI:** Interface to enter manually set reservoir releases
- **EWI:** Interface to present weather, inflow, pool, etc. data
- **EDWS:** Detects worrisome events and send warnings
- **SCS:** Controls sirens



Sirens



**Thank You**