



# *Characterization of Water Reclamation Plant Influent: An Application of Cluster Analysis*

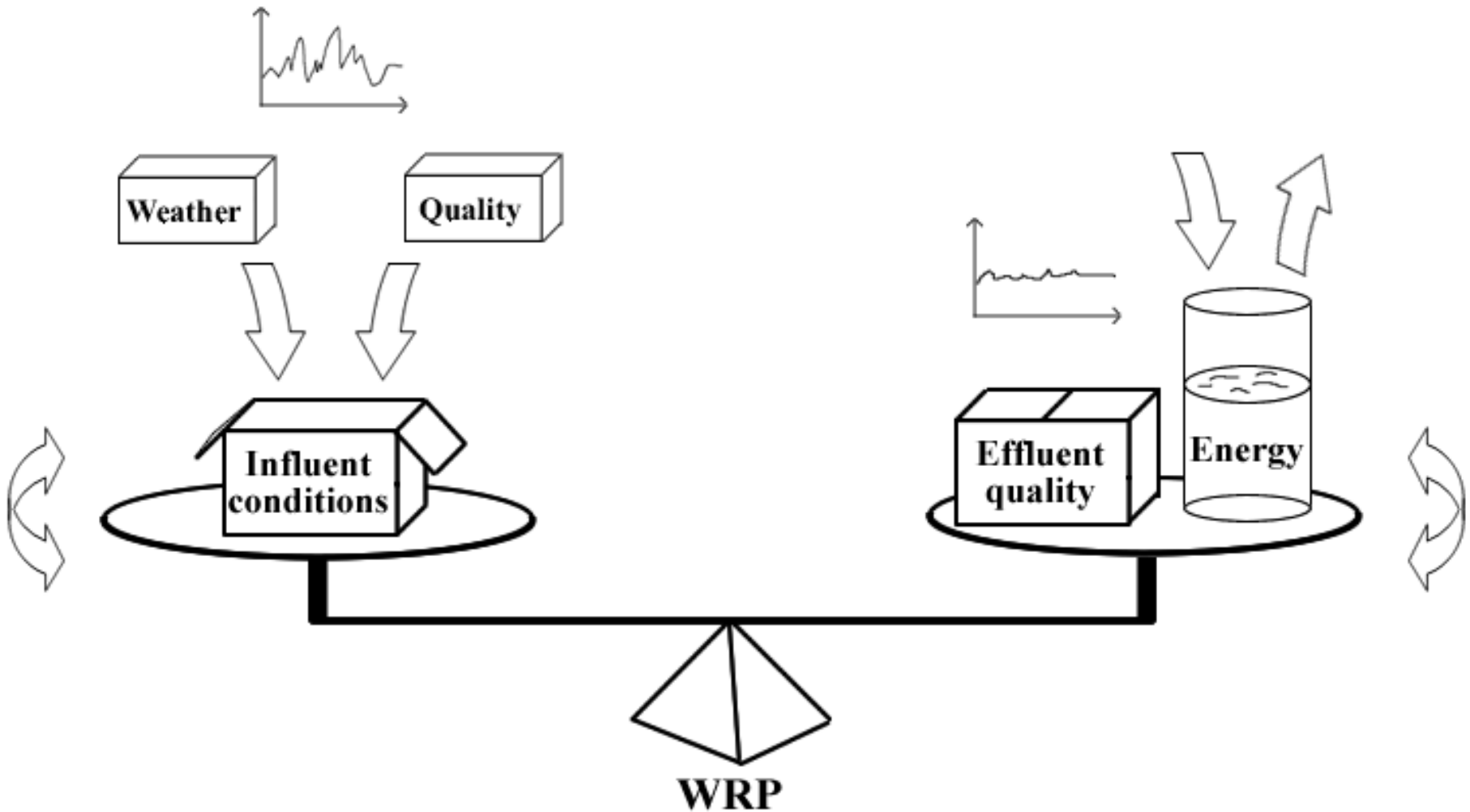
**Jun-Jie Zhu and Paul R. Anderson - Illinois Institute of Technology**  
**Javier Segovia - Universidad Politecnica de Madrid**

# Cyber-physical systems (CPS)



- Managing loosely-coupled networked control systems with external disturbances
  - Funding: National Science Foundation (NSF)
  - Collaboration: Metropolitan Water Reclamation District of Greater Chicago (MWRDGC)
- Goals for an aging infrastructure
  - Satisfy effluent standards
  - Reduce aeration costs
  - Maintain process resilience
- This investigation
  - Characterize Calumet Water Reclamation Plant (WRP) influent

# Managing influent fluctuations

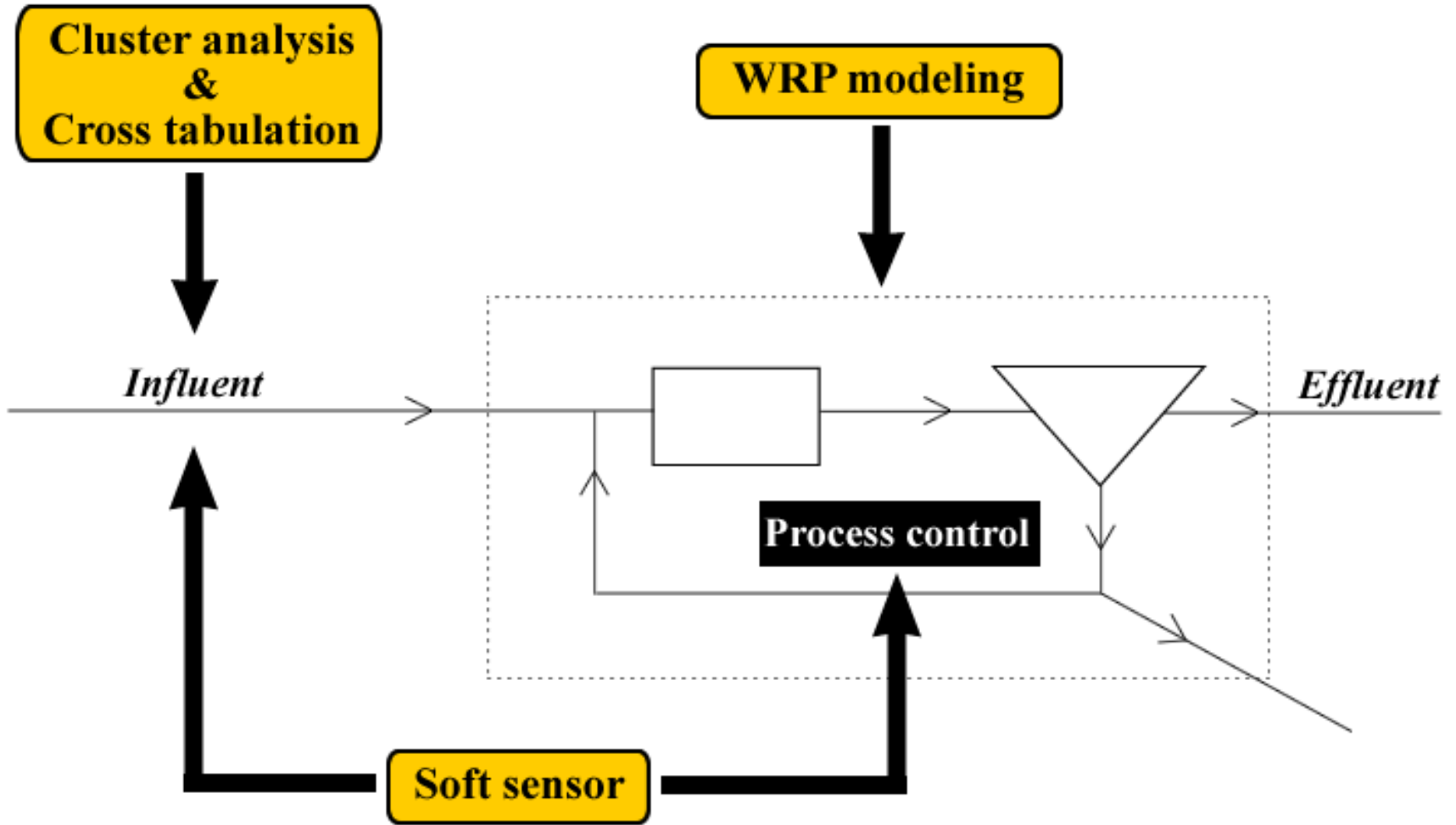


# Benefits of influent characterization

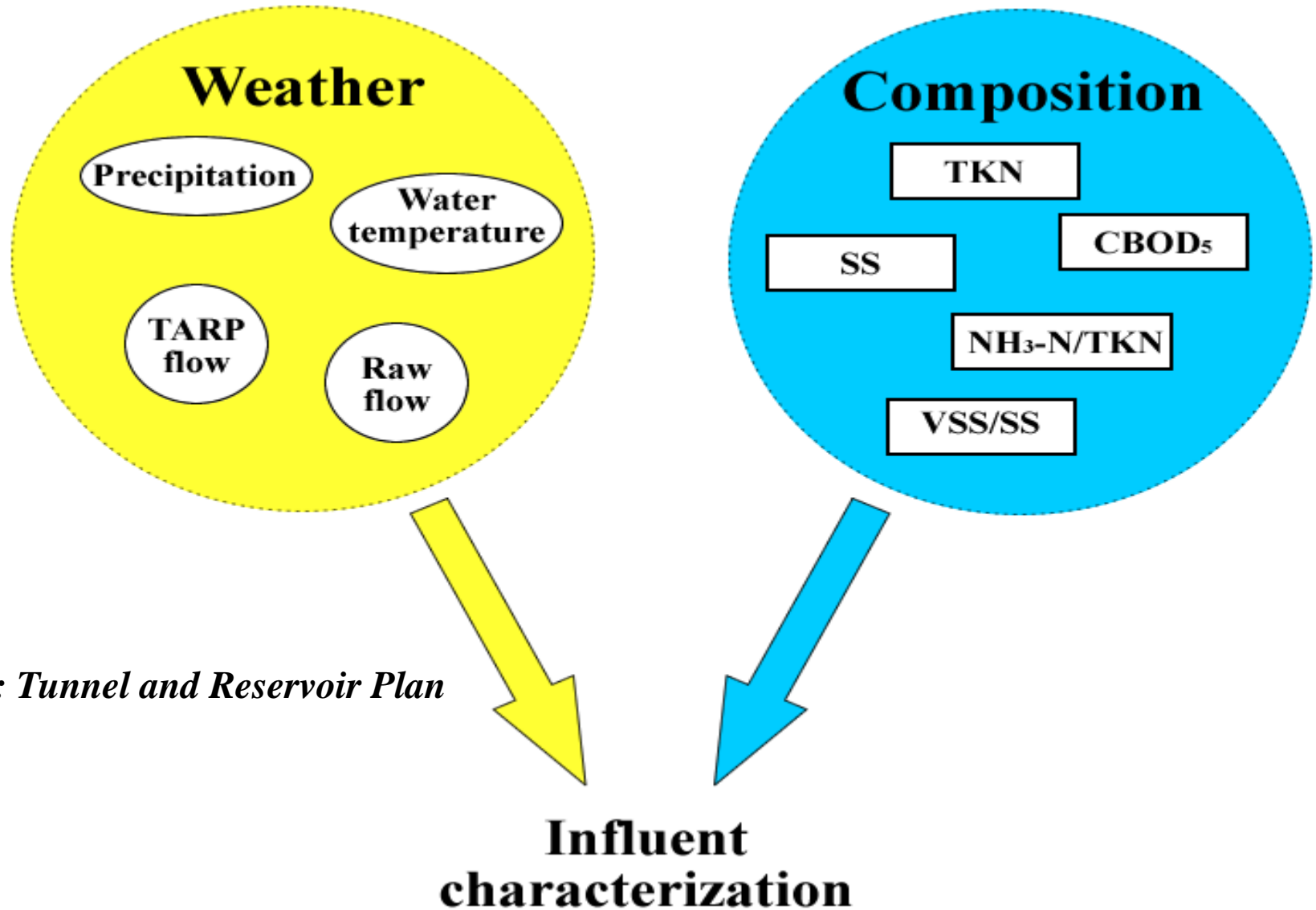


- Identify challenging conditions
- Prepare for future events
- Develop suitable control strategies
- Assess energy-savings options
- Understand WRP resilience

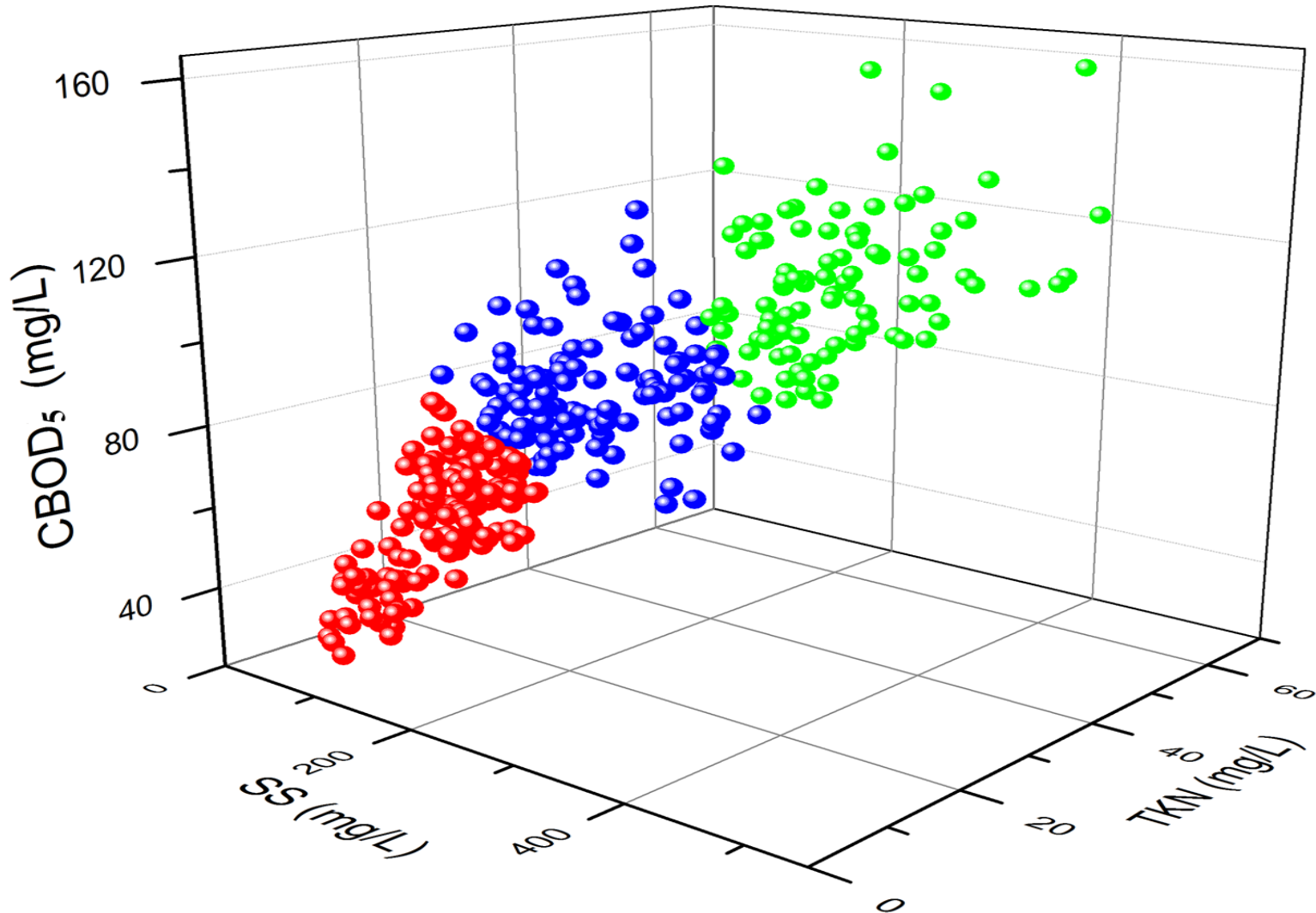
# Tools for scenario analysis



# Important influent variables



# Influent data clusters



# Five weather scenarios



*Precipitation*

**Normal storm  
in cold weather**

**Dry & warm weather  
& high TARP flow**

*TARP  
flow*

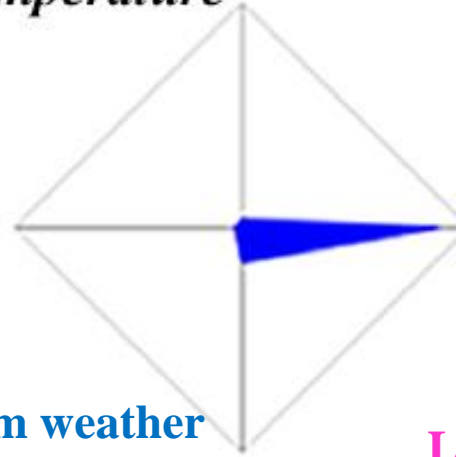
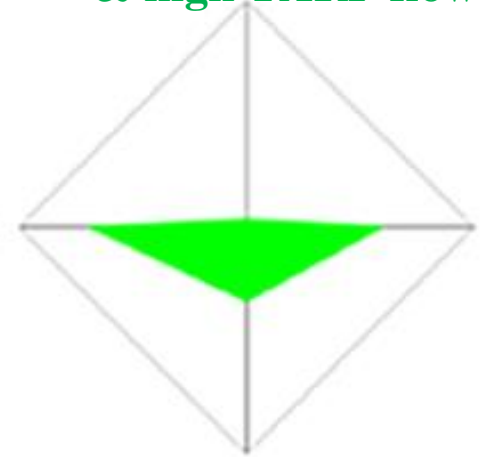
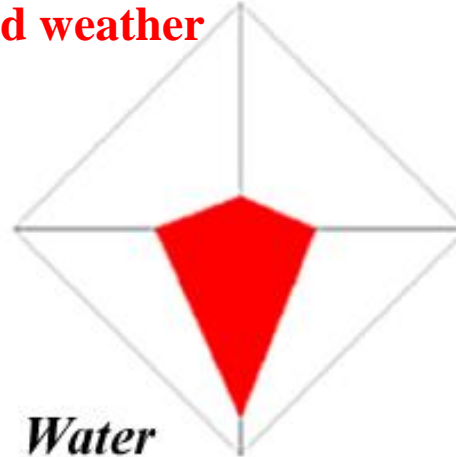
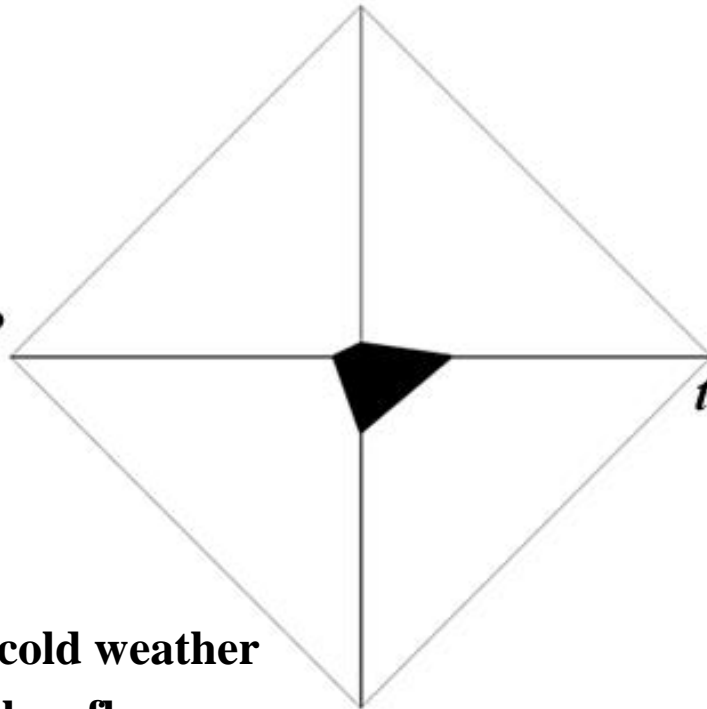
*Water  
temperature*

**Dry & cold weather  
& low flow**

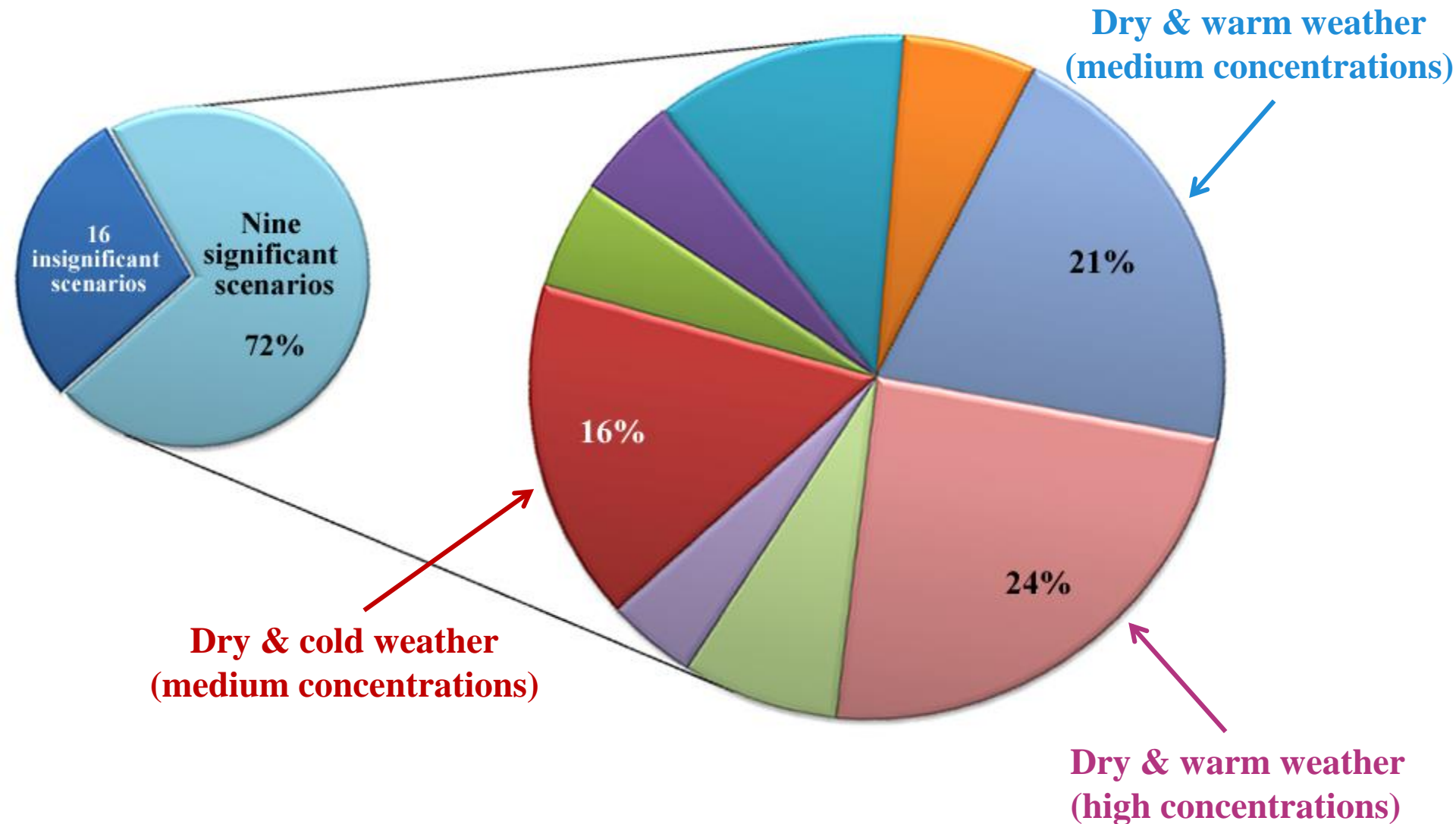
*Raw flow*

**Dry & warm weather  
& low flow**

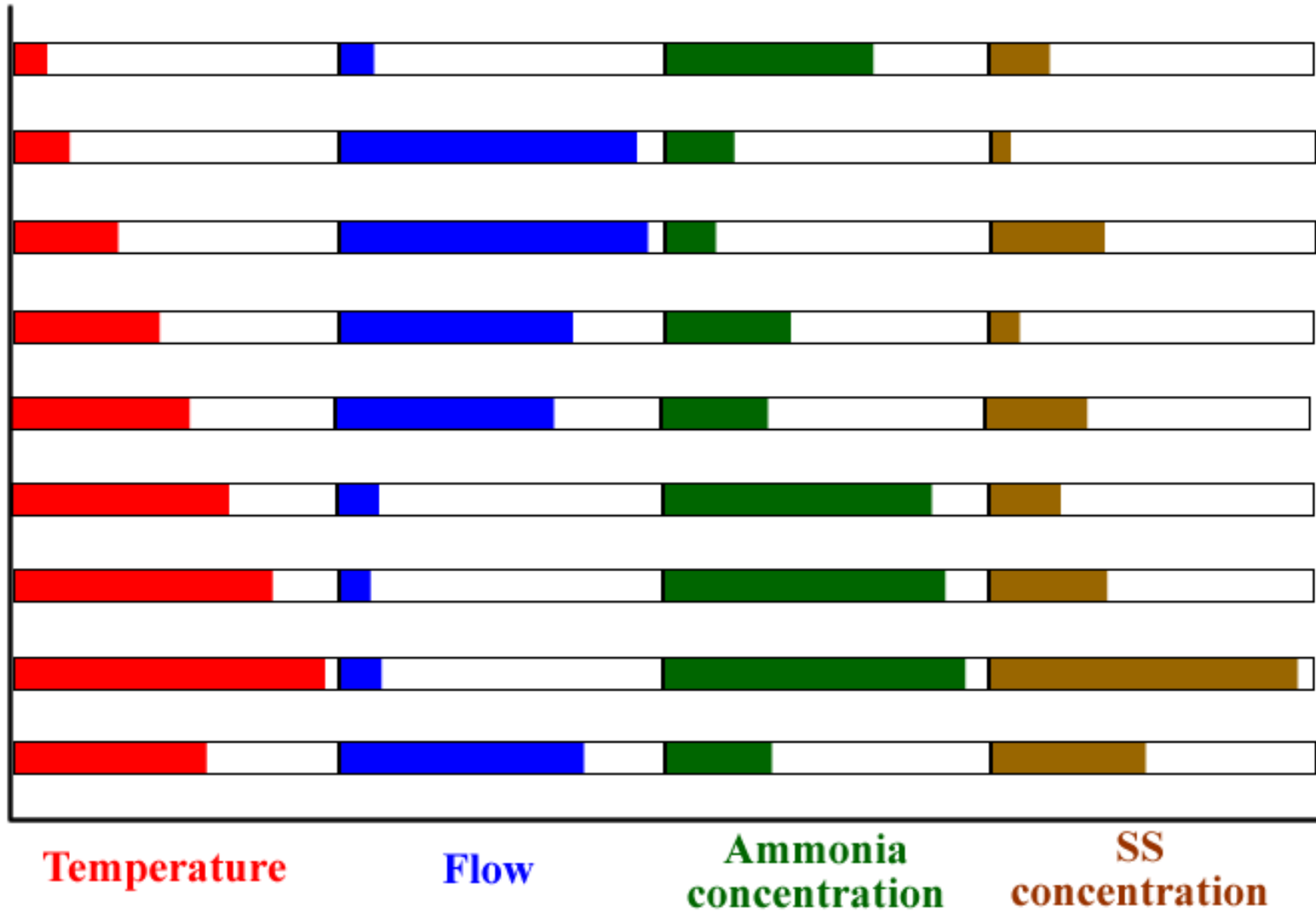
**Large storm  
in warm weather**



# Three influent scenarios dominate



# Characteristics of nine scenarios



Dry & cold weather

Large storm in warm weather

Temperature

Flow

Ammonia concentration

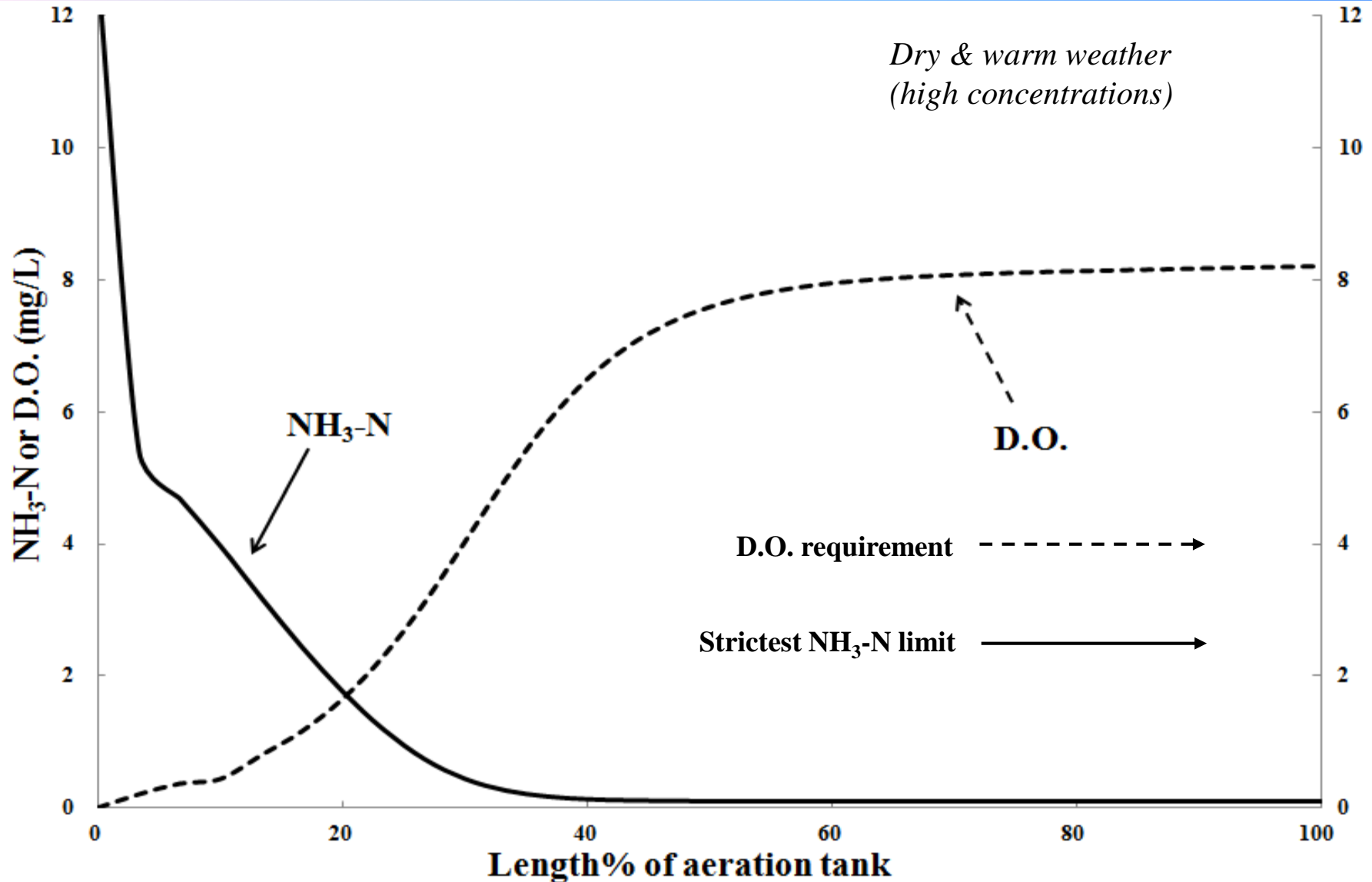
SS concentration

# Scenario summary

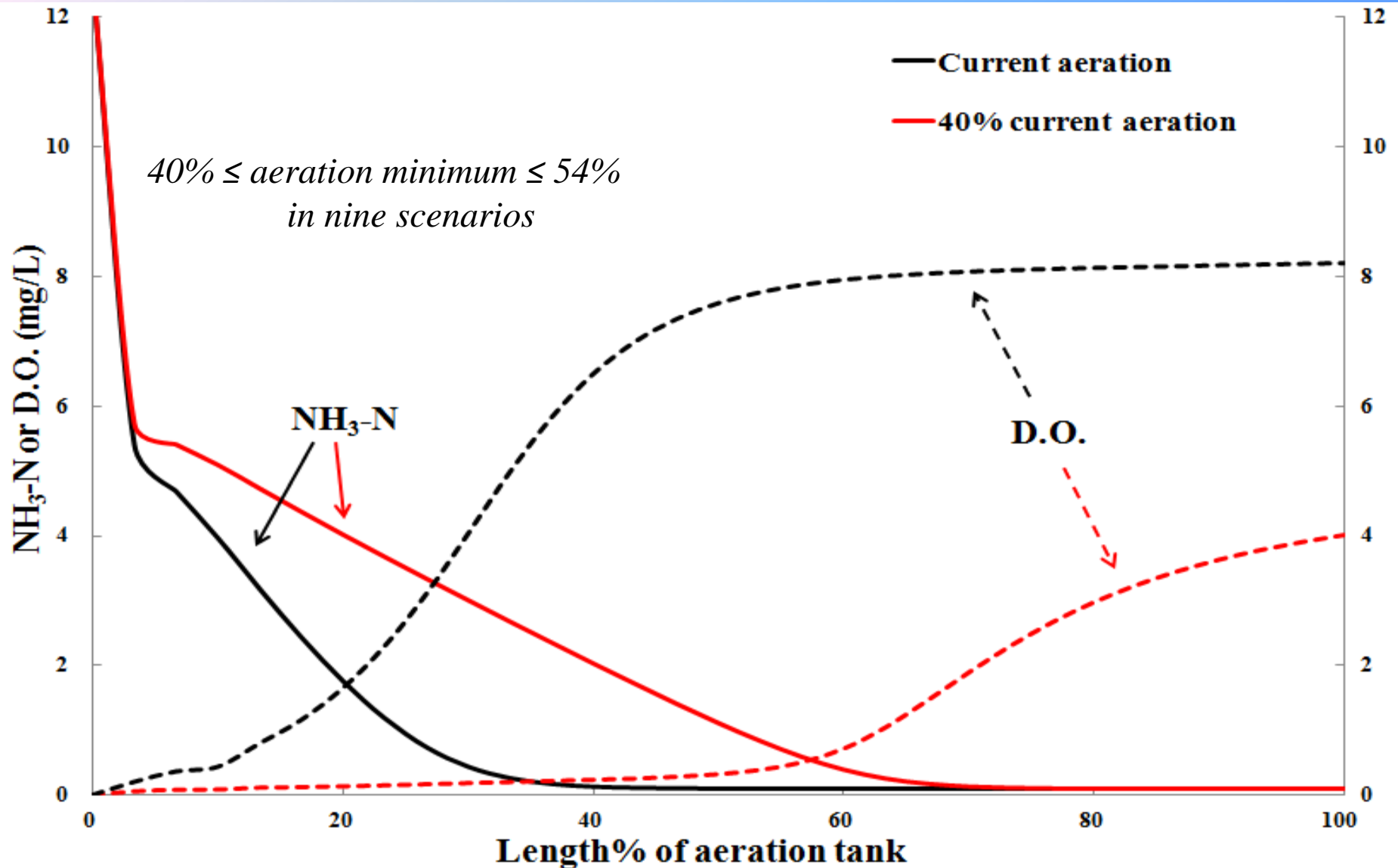


- Most frequent scenario
  - Warm, dry weather & high concentrations
- Warm weather characteristics
  - More variable concentrations
  - Higher volume storm events
- Cold weather characteristics
  - Average volume storm events

# Treatment often exceeds requirements



# Minimum aeration requirement?

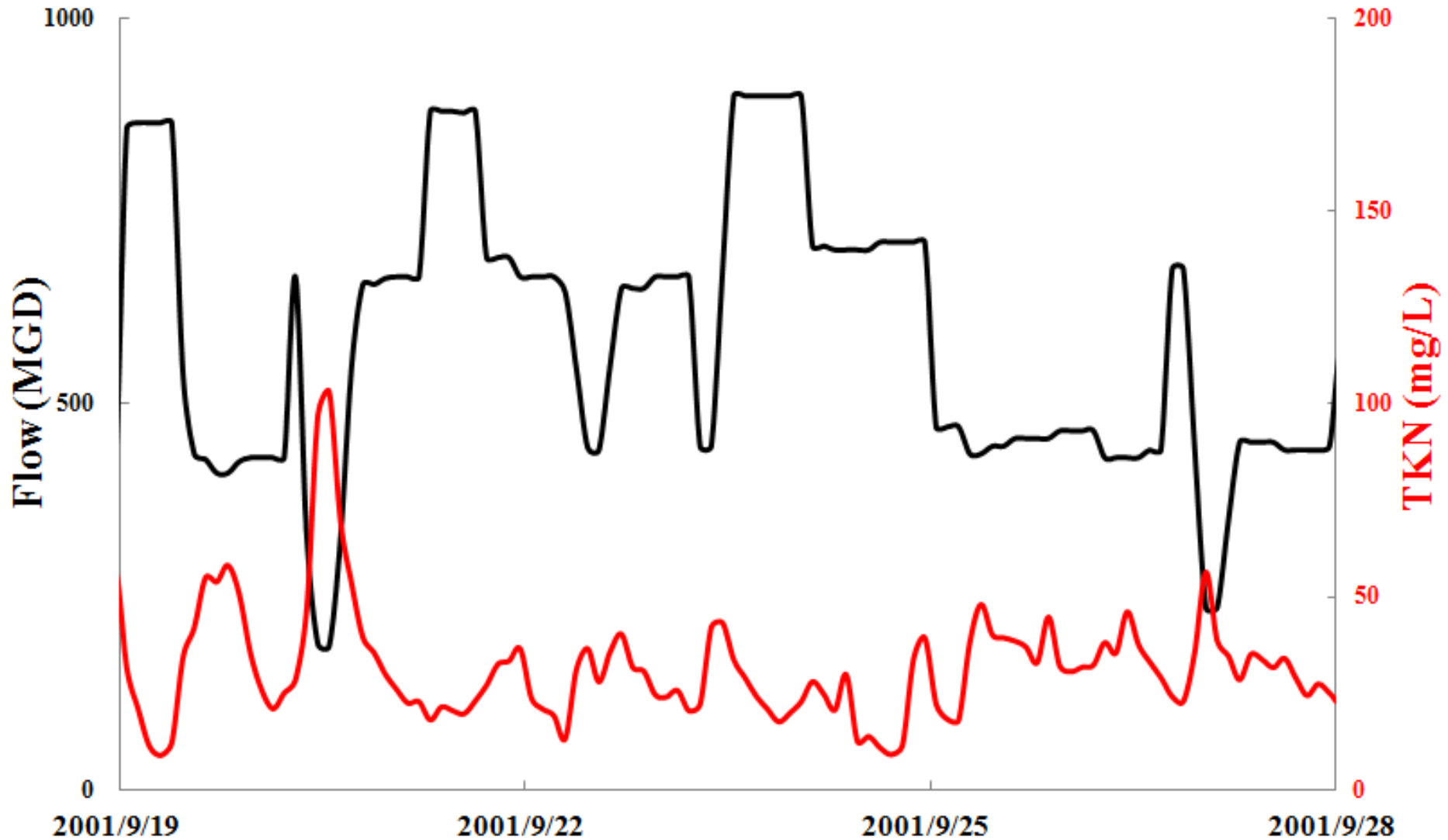


# What about influent perturbations?

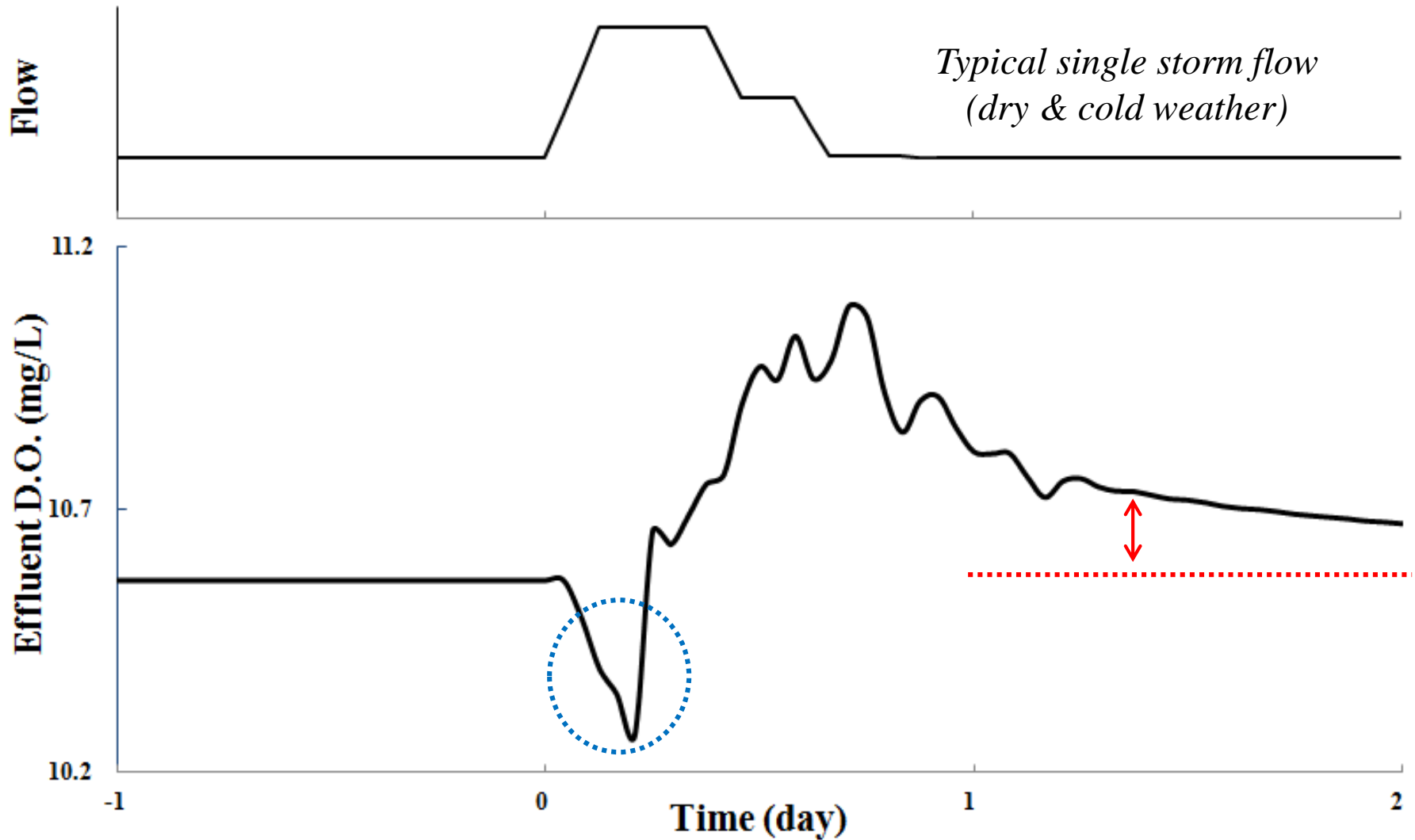


- Steady-state describes “average” conditions
- Each scenario features characteristic perturbations
- How do perturbations affect the treatment process ?

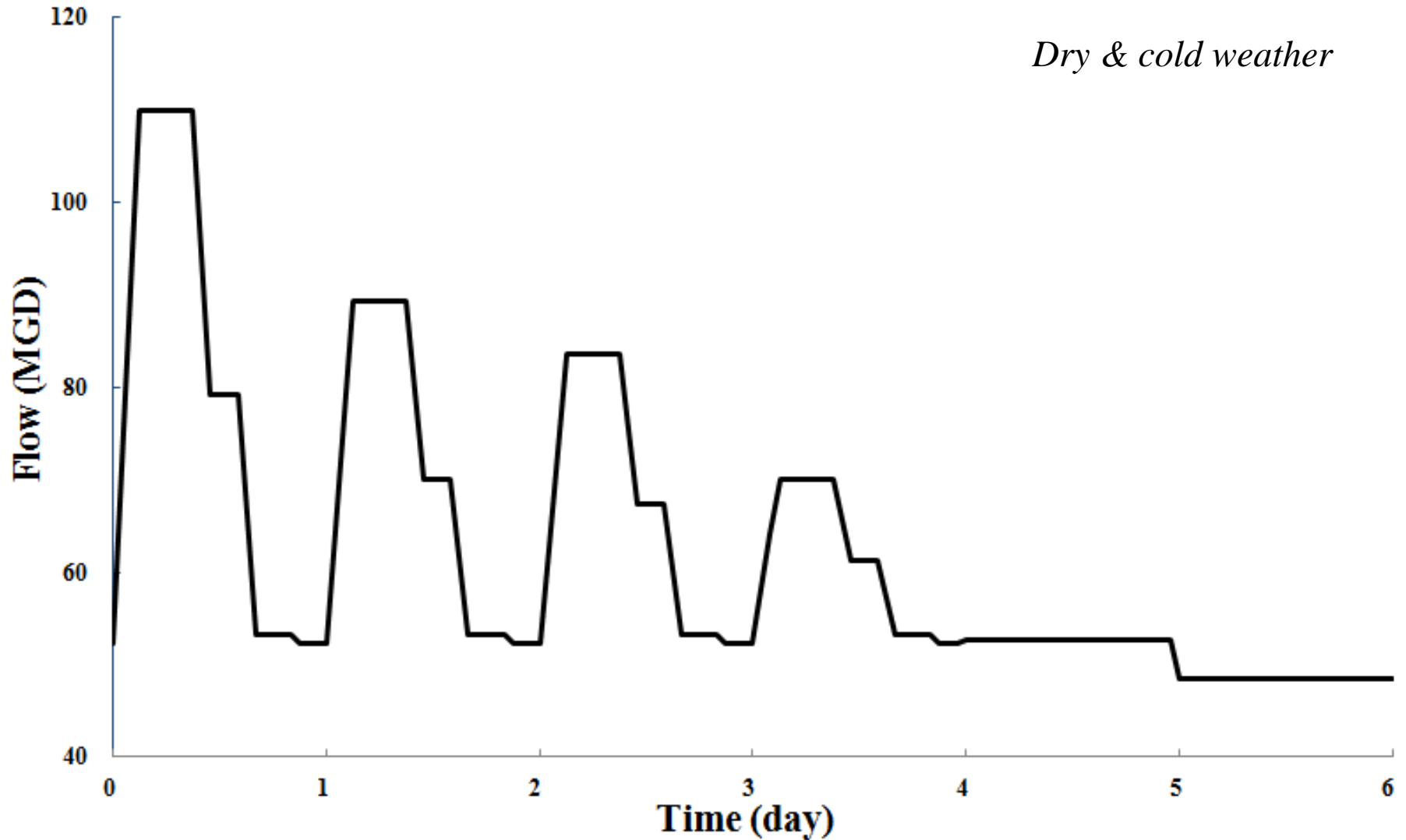
# Example influent perturbations



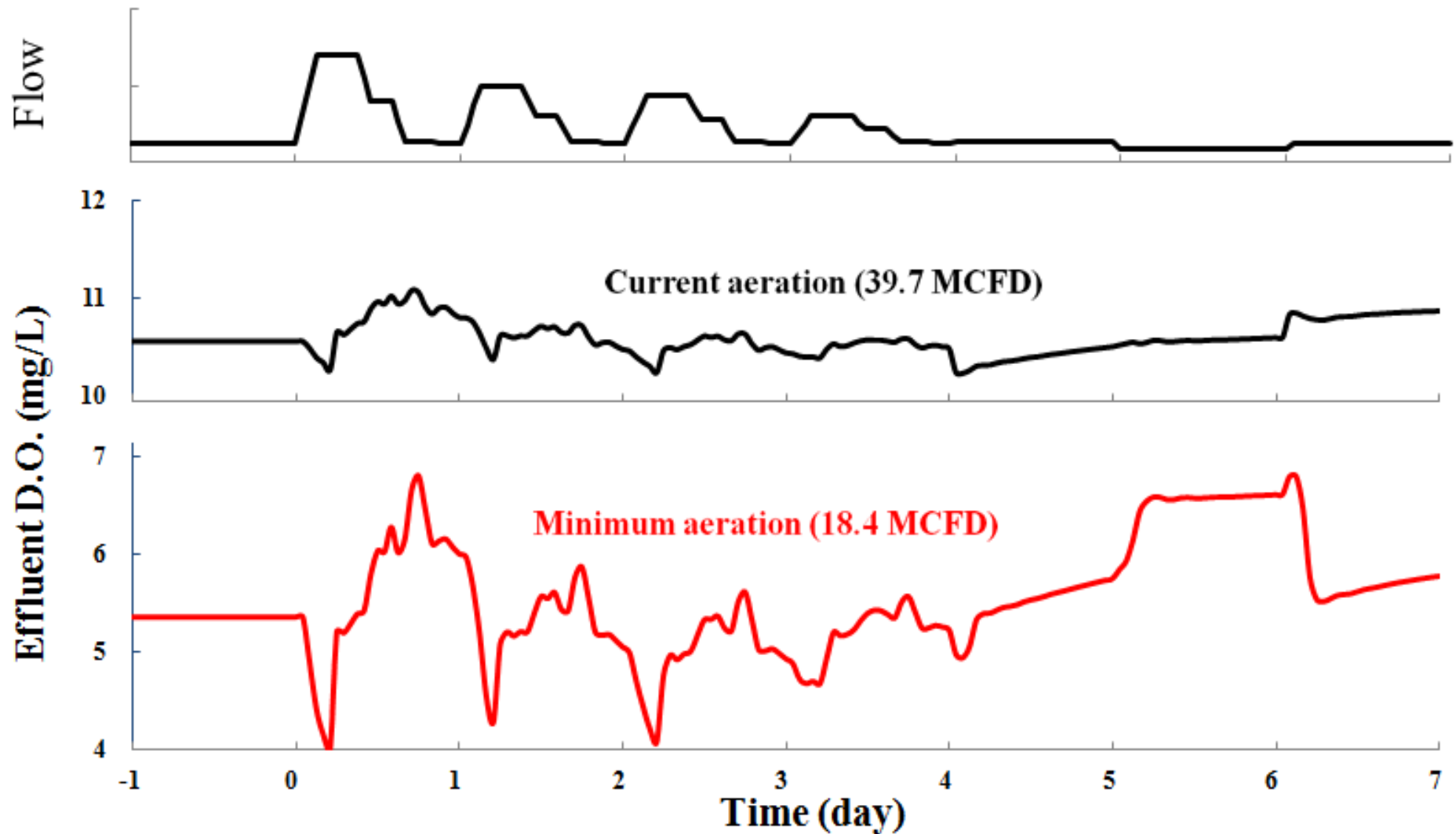
# Effluent response to perturbations



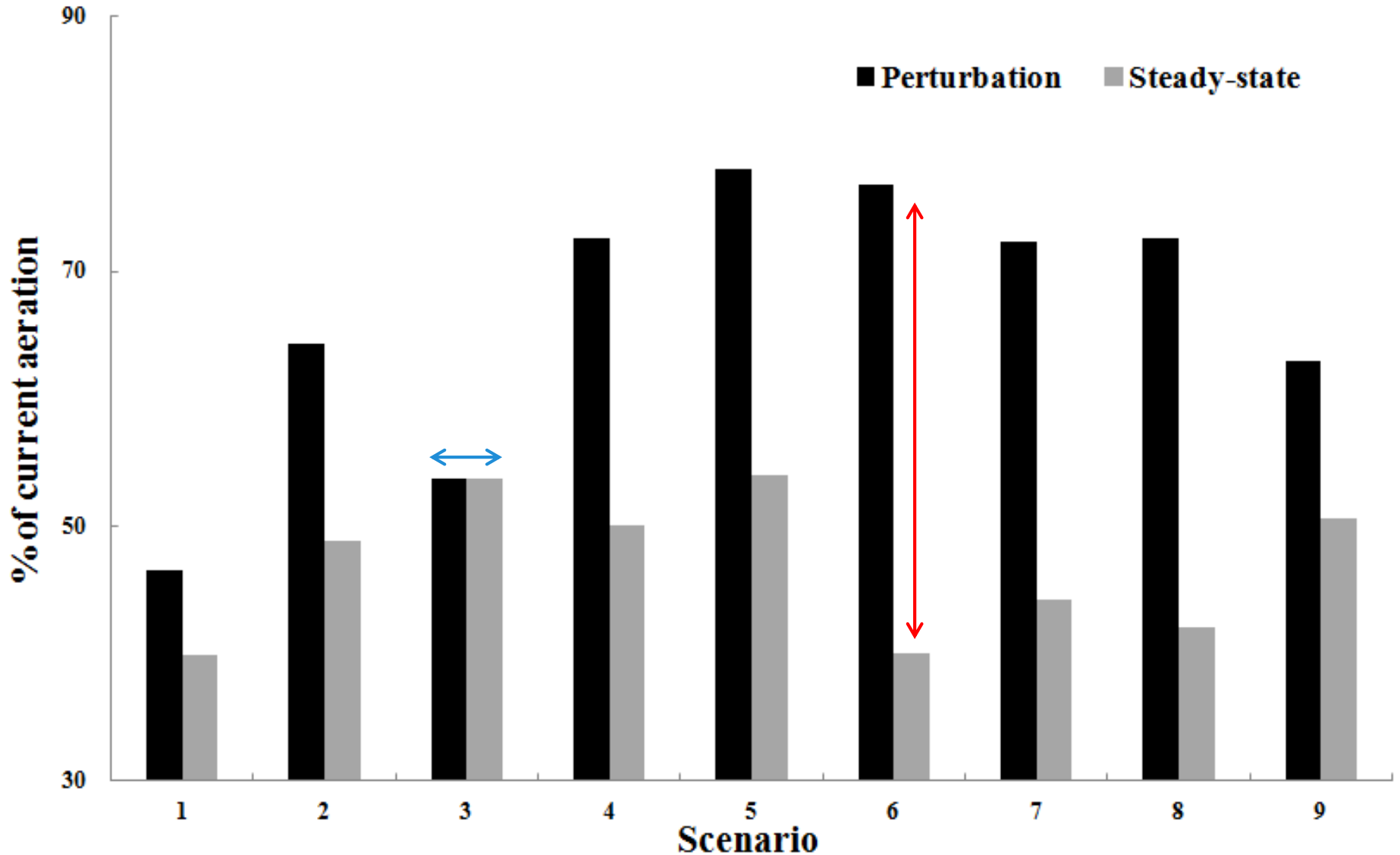
# A synthetic influent perturbation



# Aeration affects process resilience



# Scenario aeration requirements



# Conclusions



- Influent conditions occur in characteristic clusters
- Monitoring & process control could lower aeration costs
- Under steady-state conditions aeration could be cut by 50%
- Influent perturbations require management
  - Cold-weather perturbations are typically not challenging
  - Warm & dry-weather perturbations can require increased aeration

# Some uncertainties...



- Low probability scenarios were neglected
- Synthetic perturbations
- Process model uncertainty
- Process control options are not included

# REC 2014 thoughts...



- Infrastructure is more than “structure”
- Consider water resources management uncertainties
  - Wastewater, water supply, stormwater
- How do these methods apply?
  - Life-cycle robustness
  - Interval analysis
  - Imprecise probability
  - Targeted random sampling
  - Reliability analysis
  - Polymorphic uncertainty models
  - Time-dependent conditional probability