Kennis voor Klimaat

Deltares
Enabling Delta Life

How robust is Oologah Lake water supply for droughts?

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AGWA

Overview

1. What is system robustness analysis?
2. Application on drought risk systems
    1. System definition
    2. Introduction to Oologah Lake
    3. Drought impact model
    4. Drought event characterisation and selection

3. Robustness of Oologah water supply system
4. Discussion

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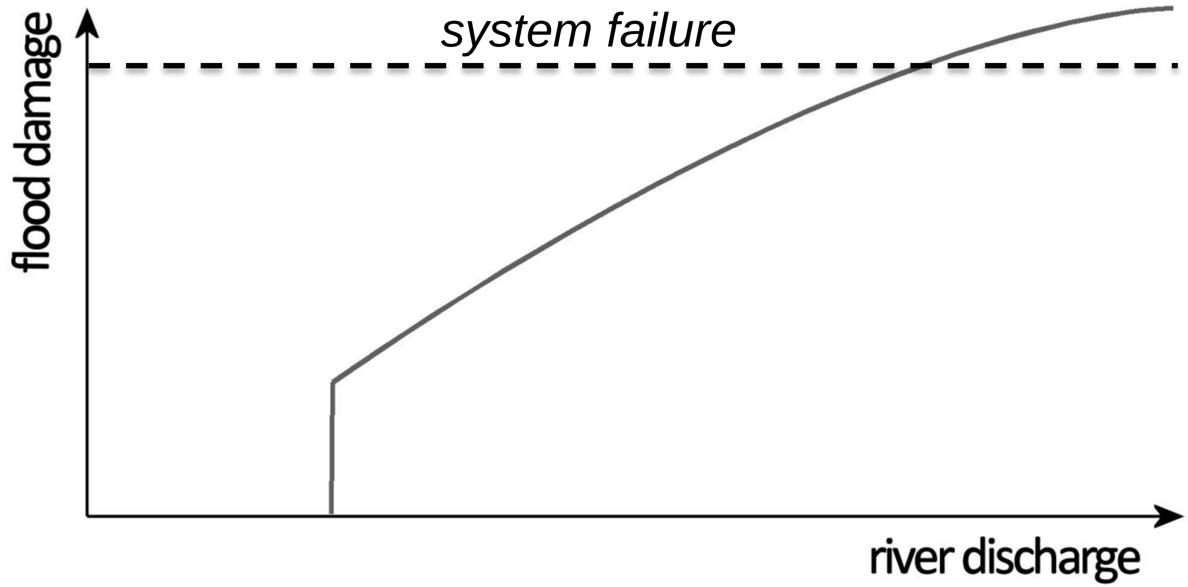
1. What is system robustness analysis?

Robustness analysis

Robustness = ability to remain functioning during a range of disturbance magnitudes

failure of one element ←→ failure of entire system



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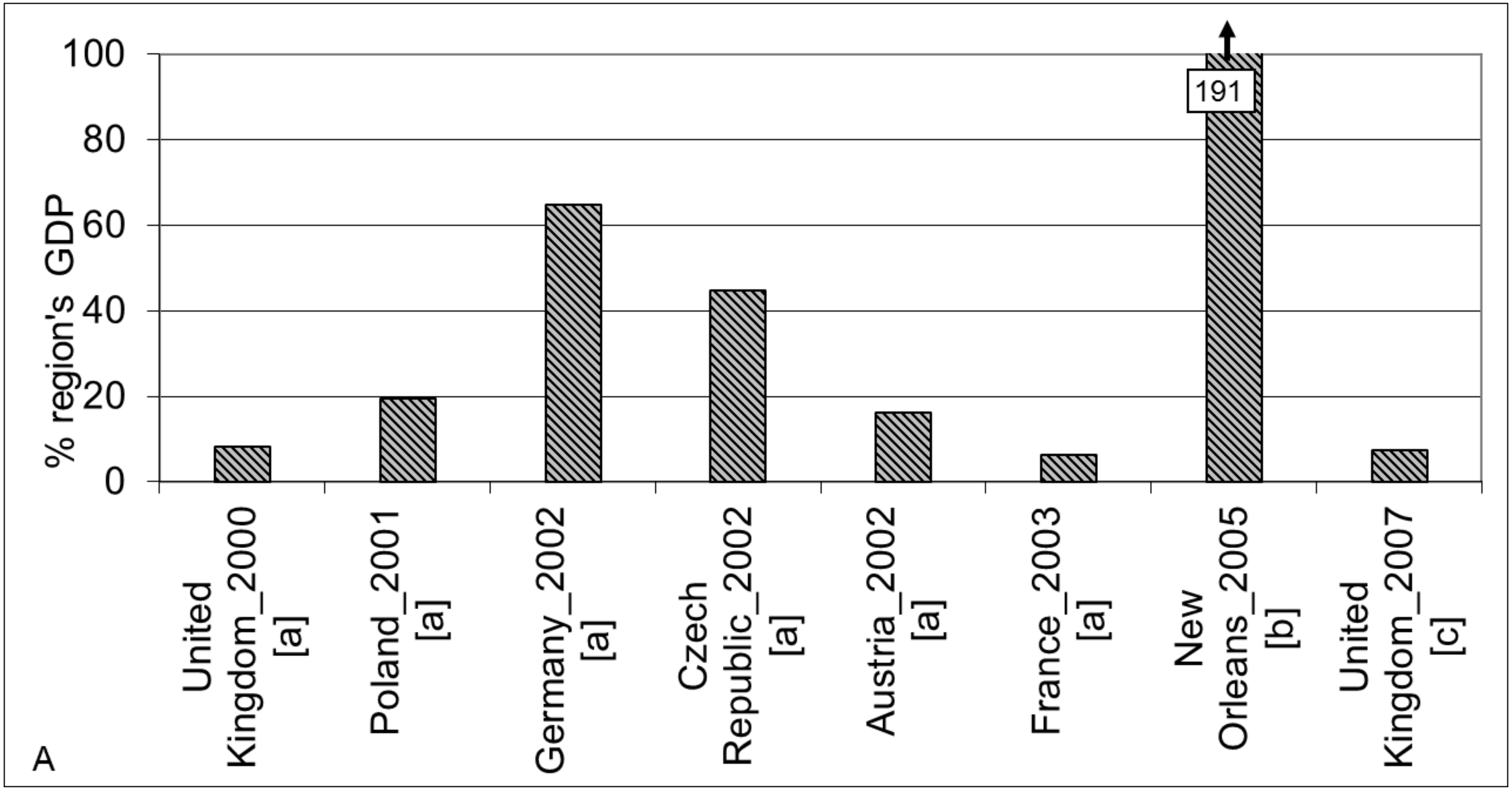
Unacceptable consequences



‘Great catastrophe’ (Munich Re): impact > 5% GDP

[A] Mens and Klijn (under review) The added value of system robustness analysis for flood risk management. *Natural Hazards and Earth System Sciences*.

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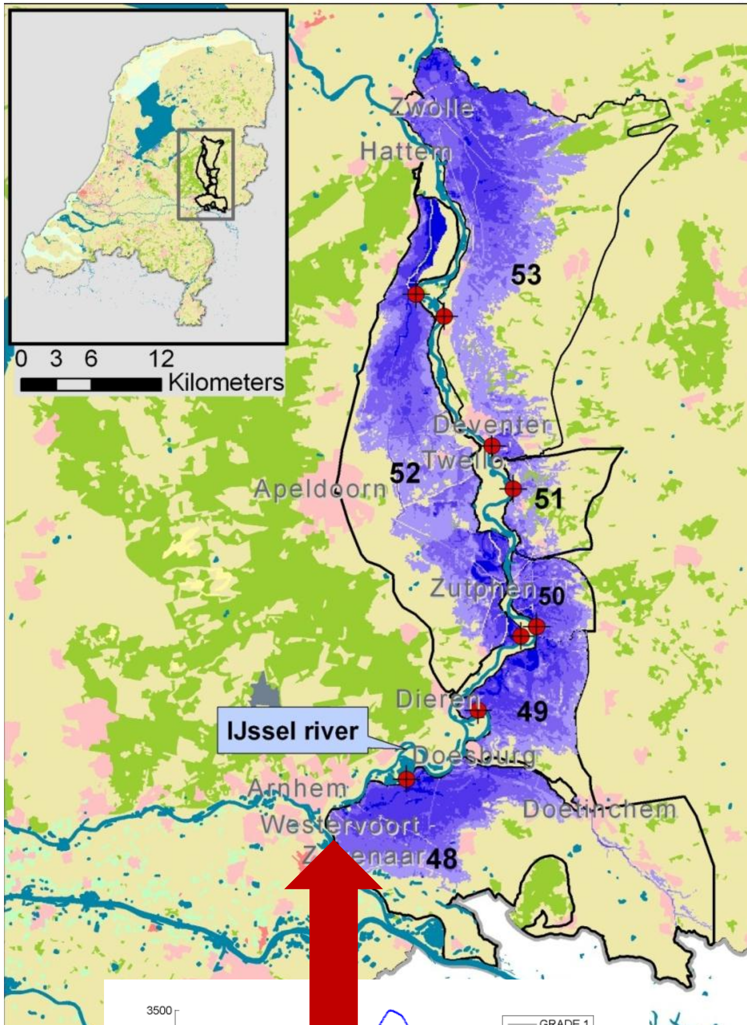
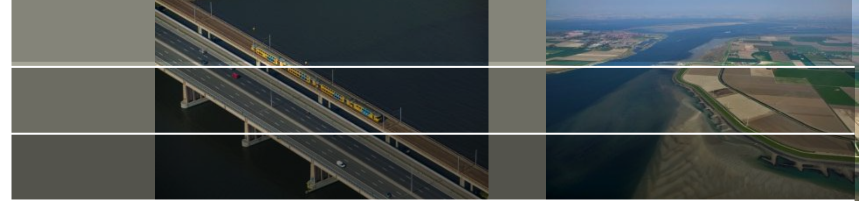
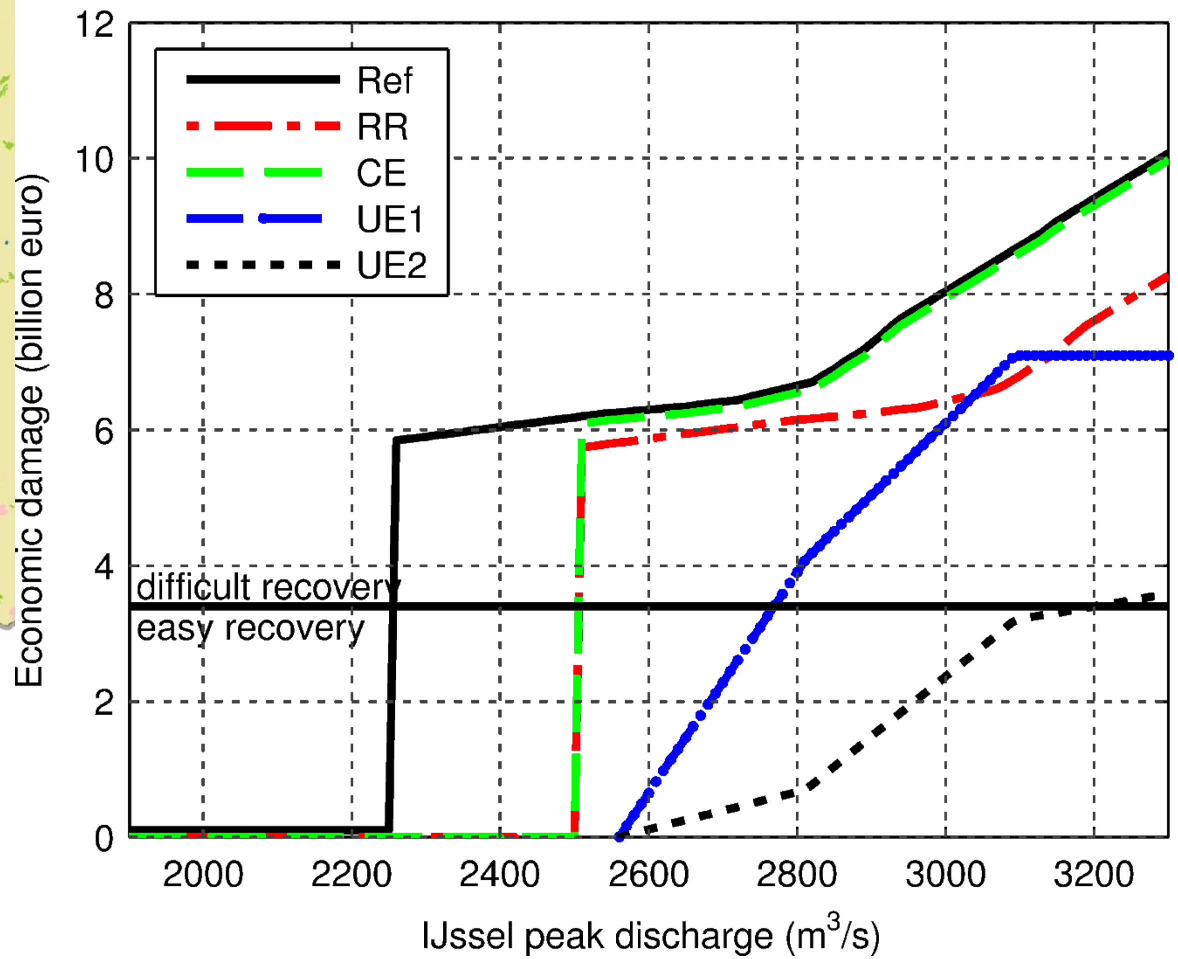
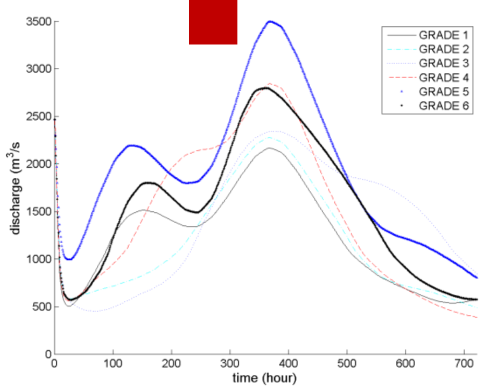

Zwolle
Hattem
53
0 3 6 12
Kilometers
Deventer
Twello
Apeldoorn
52
51
Zutphen
50
Dieren
49
IJssel river
Doesburg
Arnhem
Westervoort
Doetinchem
Zevenaar
48
Legend
Breach locations
53 Dike-ring areas
Dutch border




Ref
RR
CE
UE1
UE2
difficult recovery
easy recovery
Economic damage (billion euro)
IJssel peak discharge (m³/s)
0
2
4
6
8
10
12
2000
2200
2400
2600
2800
3000
3200


GRADE 1
GRADE 2
GRADE 3
GRADE 4
GRADE 5
GRADE 6
discharge (m³/s)
time (hour)

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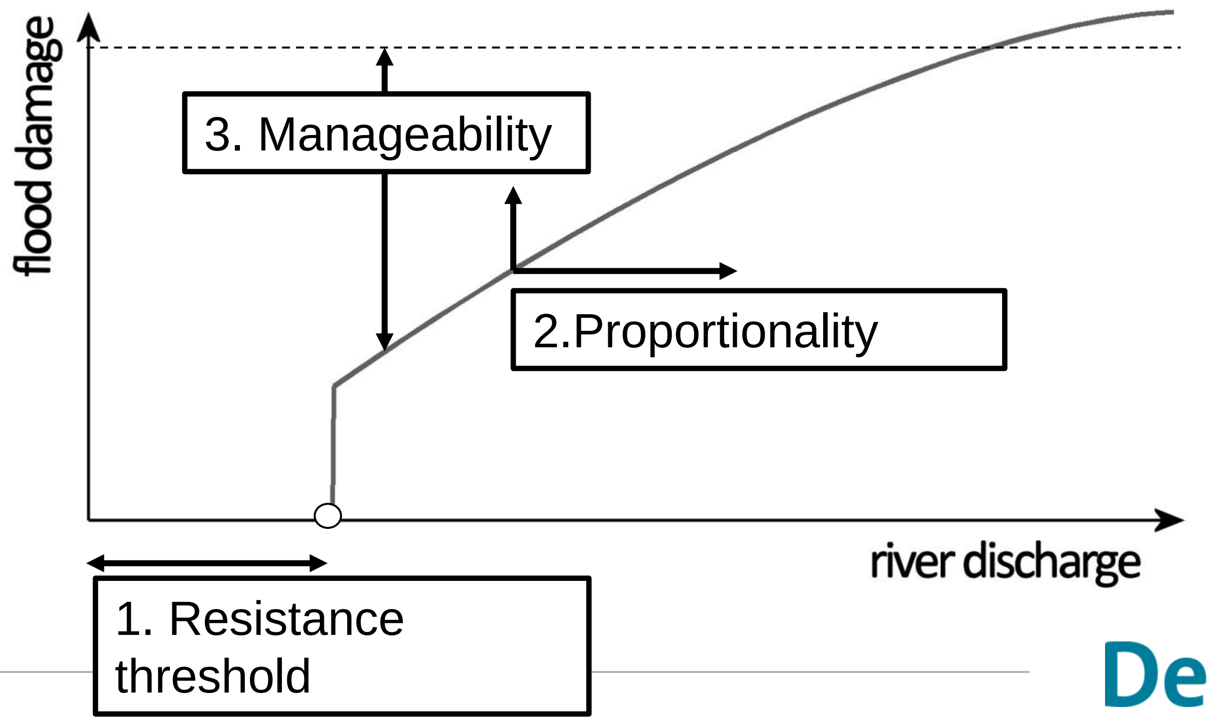
Quantifying system robustness

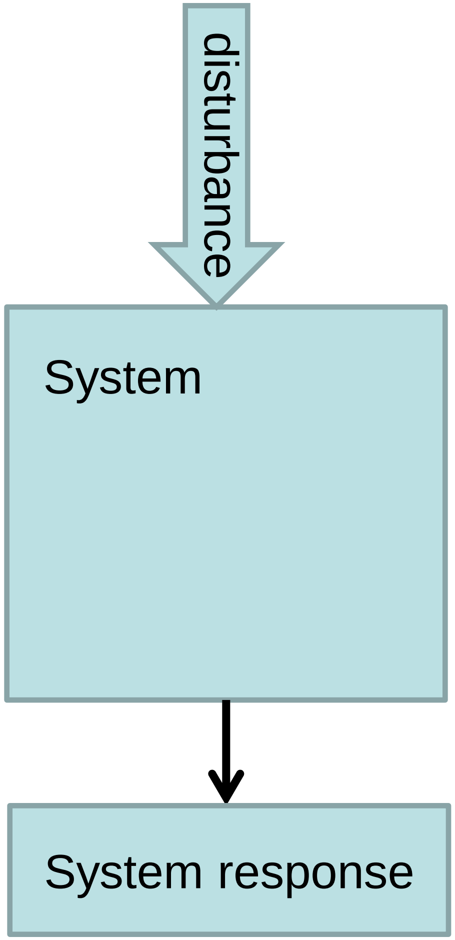
Criteria:

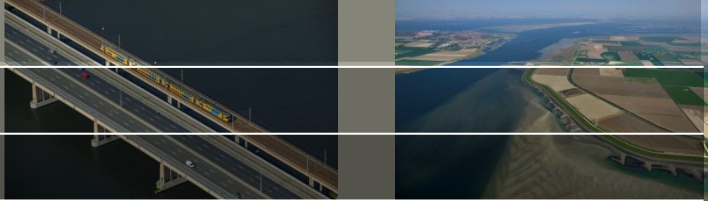
1. Resistance threshold
2. Response proportionality
3. Severity / Manageability



2. Application to drought risk systems

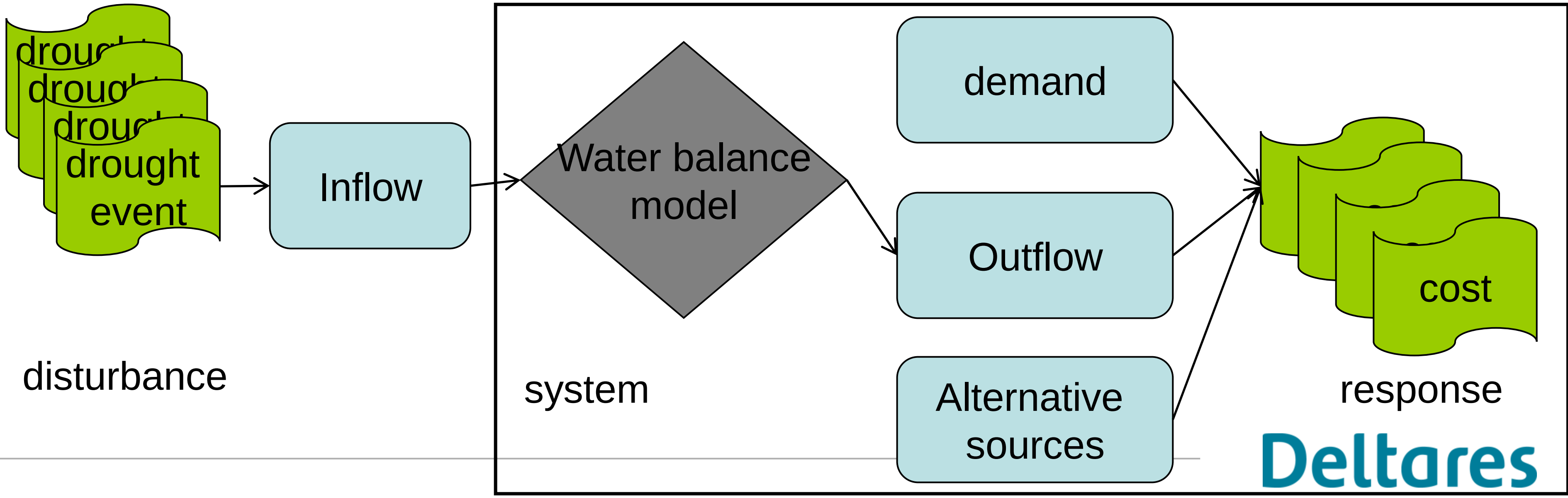
- **System definition**
- Introduction to Oologah Lake
- Drought impact model
- Drought event characterisation





System definition

1. Disturbance — Drought events
2. System — Water users, operating rules, cost of water shortage
3. Response — Economic impact of drought events



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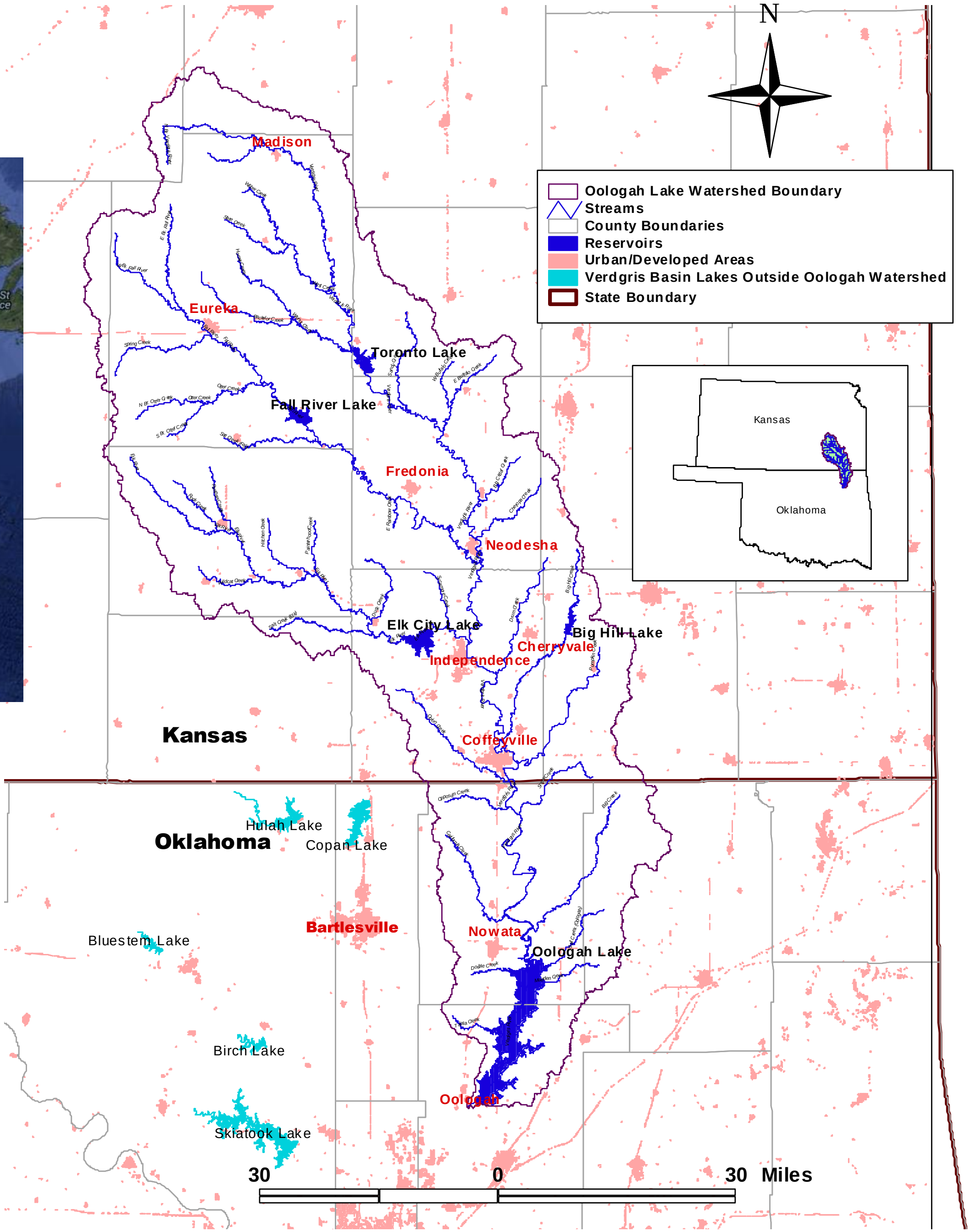
2. Application to drought risk systems

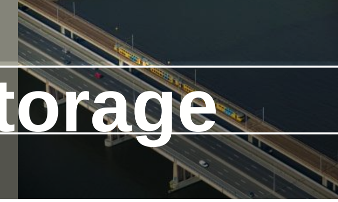
- System definition
- **Introduction to Oologah Lake**
- Drought impact model
- Drought event characterisation

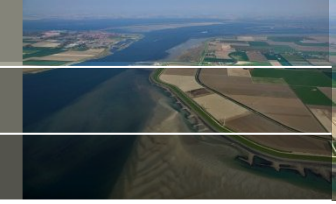
Oologah Lake



Three pools in a reservoir

Oologah Lake conservation storage





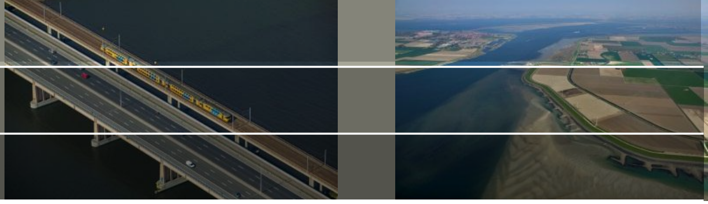
Water supply contract	Storage (Acre-Feet)	yield(MGD)	Yield (ft^3/s)
Rogers County RWD #1	1590	1	1
Public Service Co. of Oklahoma	30355	14	21
Rogers County RWD #3	5960	3	4
Nowata County RWD #1	200	0	0
City of Collinsville	6670	3	5
Tulsa Metropolitan Water Authority	285450	128	199
City of Claremore	6675	3	5
Washington County RWD #3	4170	2	3
Town of Chelsea	1530	1	1
Not Under Contract	0	0	0
water supply storage	342600	154	238
environmental flow			93
Navigation	168000	81,3	126
Conservation storage	510600	235	457

Firm yield = 457 cfs ~ 13 m^3/s

2. Application to drought risk systems

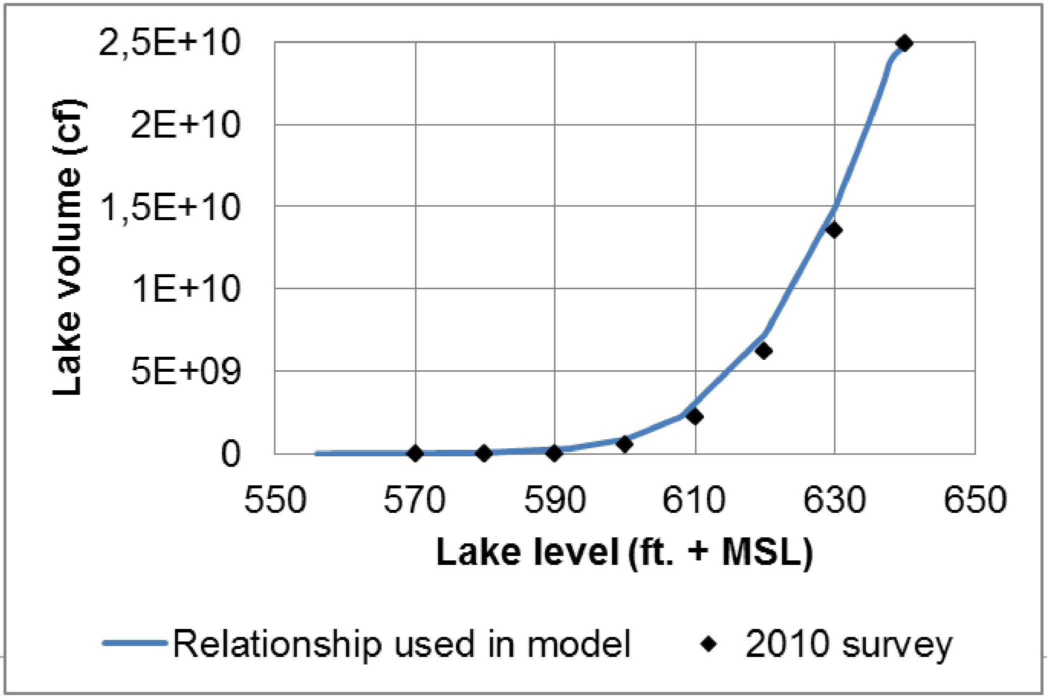
- System definition
- Introduction to Oologah Lake
- **Drought impact model**
- Drought event characterisation

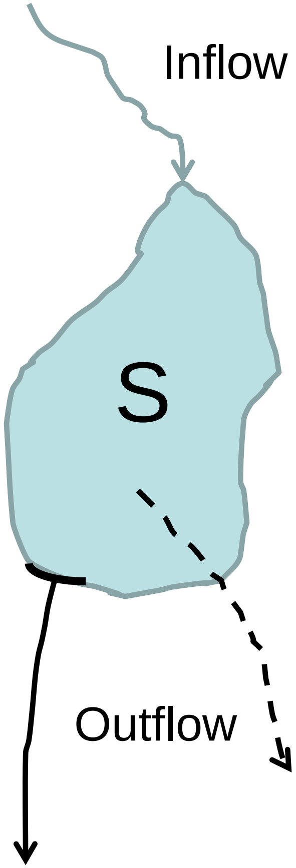
Water balance model



Water balance model:

- S(t) = S(t-1) + Inflow(t) – Outflow(t)
- Lake level = f{S}
- Start @ top conservation pool





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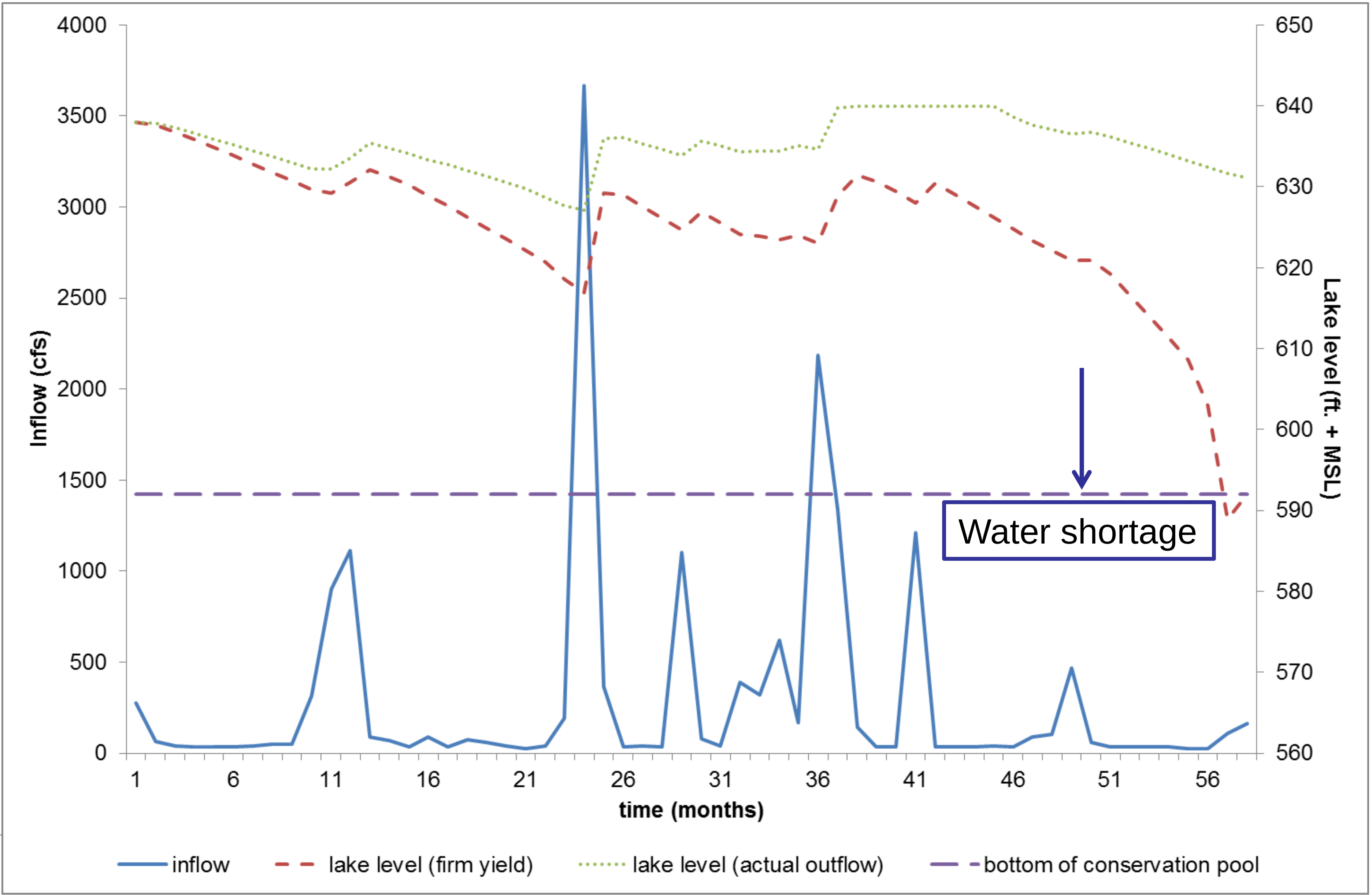
Example inflow and lake level



Cost of water shortage

Municipal water (City of Tulsa and many small counties)

Recreation on the lake

Industrial water

Power supply (cooling water)

Navigation

Cost of trucking in water from Kaw reservoir:

- 0.086 USD /m^3/km
- Distance = 290 km roundtrip
- = 25 USD / m^3

2. Application to drought risk systems

- System definition
- Introduction to Oologah Lake
- Drought impact model
- **Drought event characterisation**

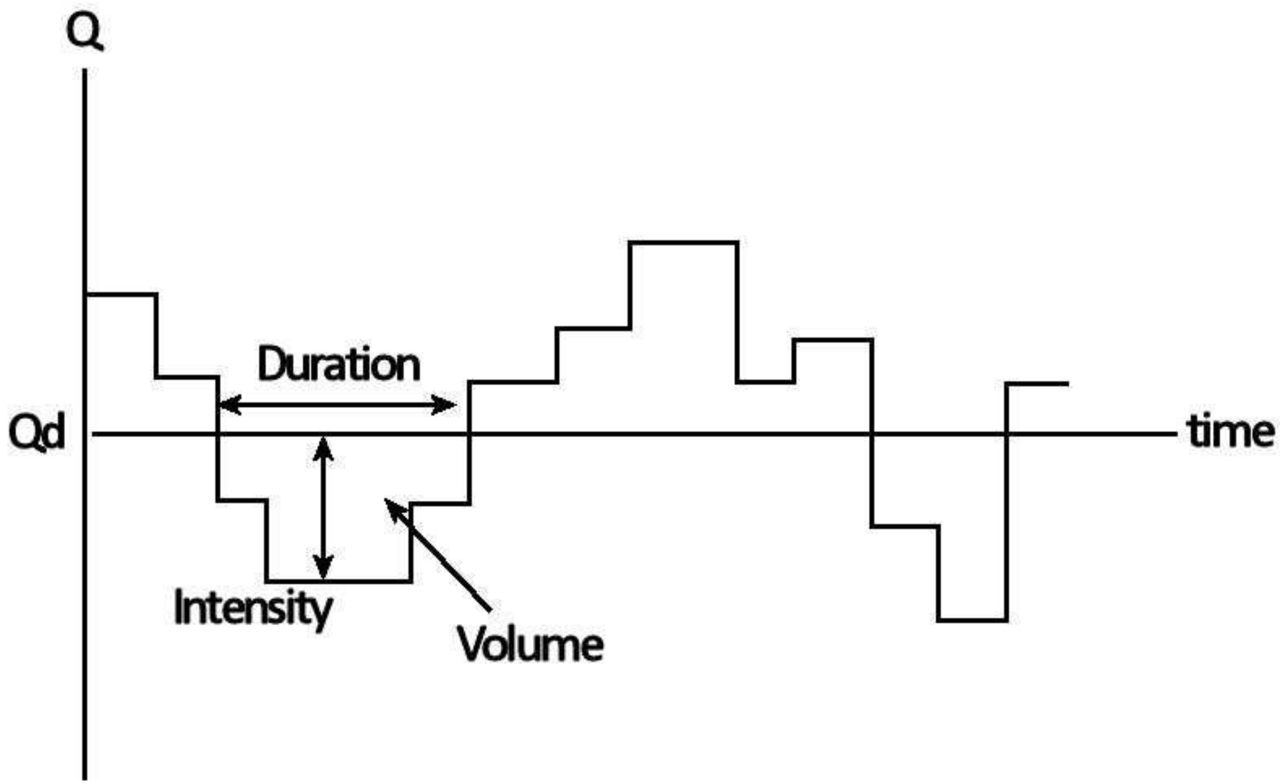
Drought events

Aim: to provide a range of drought events with varying characteristics

- Characterizing droughts
- Selecting droughts
    - Historical drought
    - Future droughts
    - Theoretic droughts

Definition of droughts

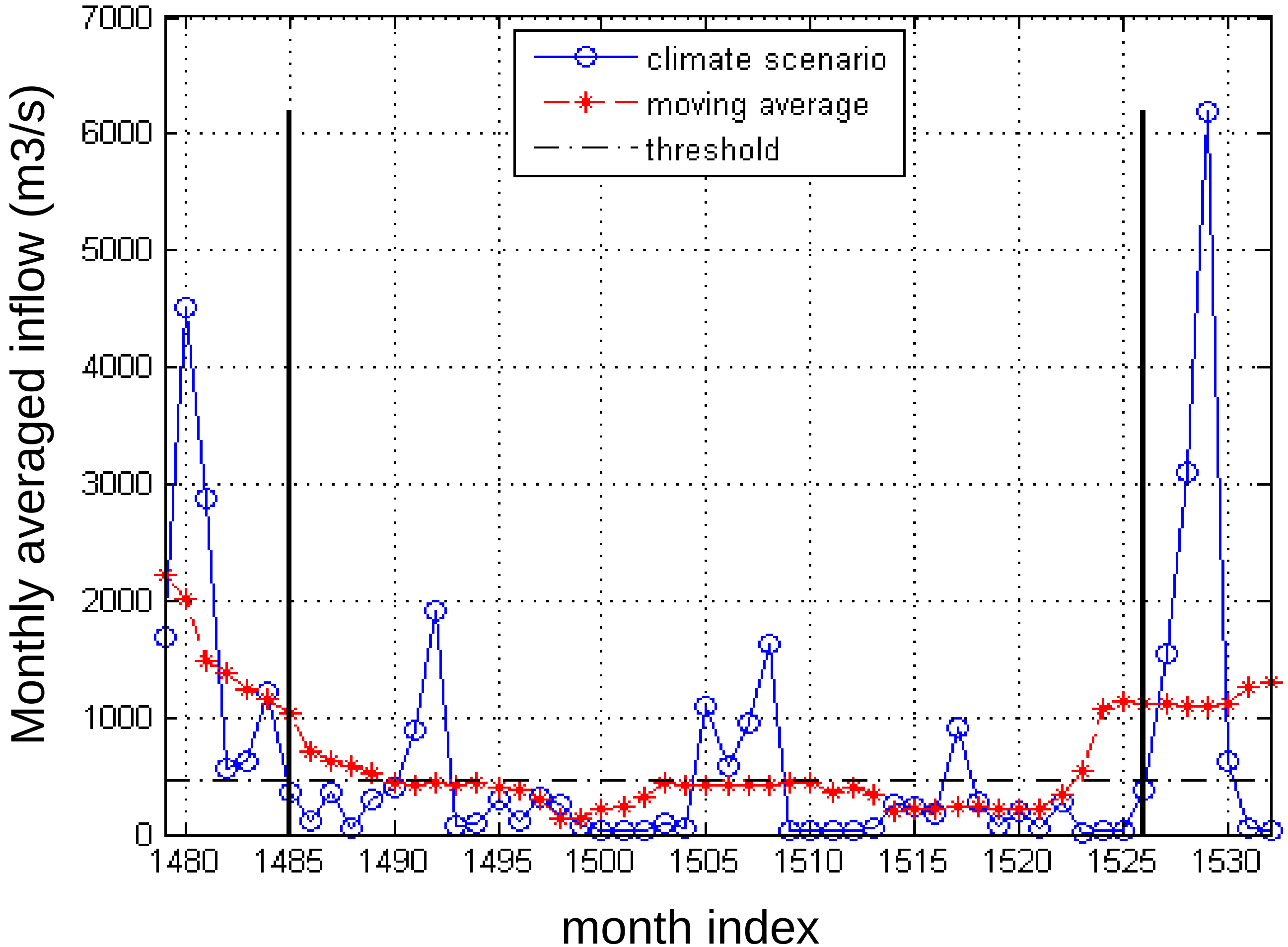
Duration, Severity, Volume and Intensity



Severity = Volume/Duration

Example drought selection

Criteria: Inflow < threshold OR Inflow_{MA} < threshold



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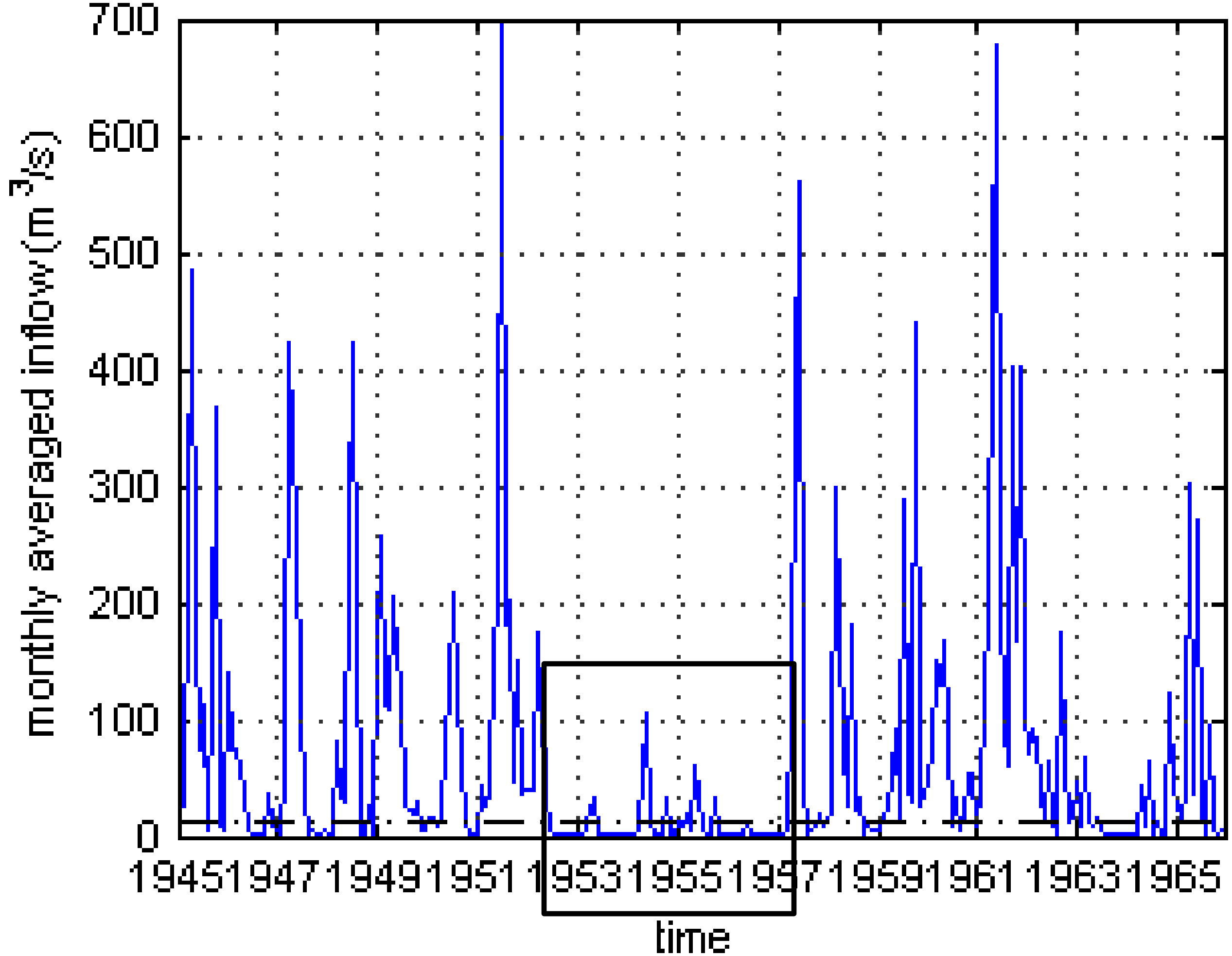
Example: historical drought

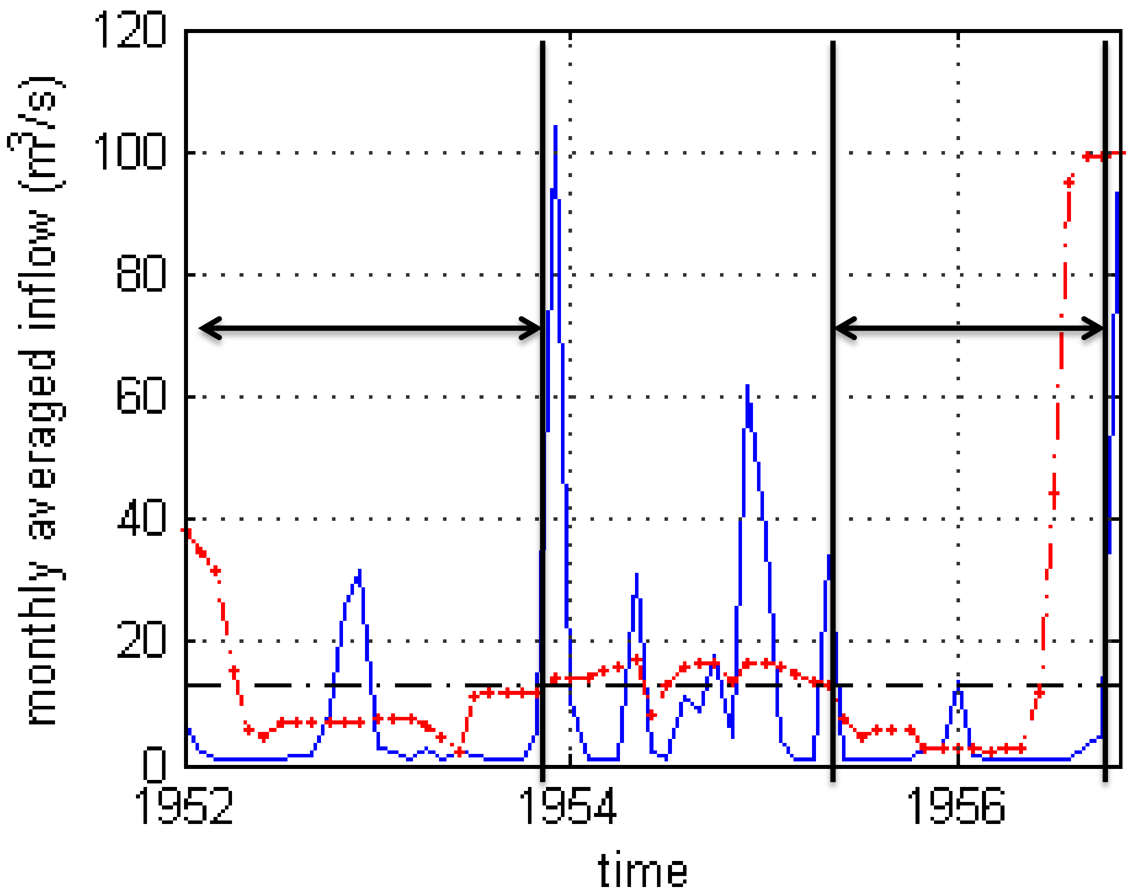
- Design drought of 1952-1957
- Threshold = 13 m^3/s

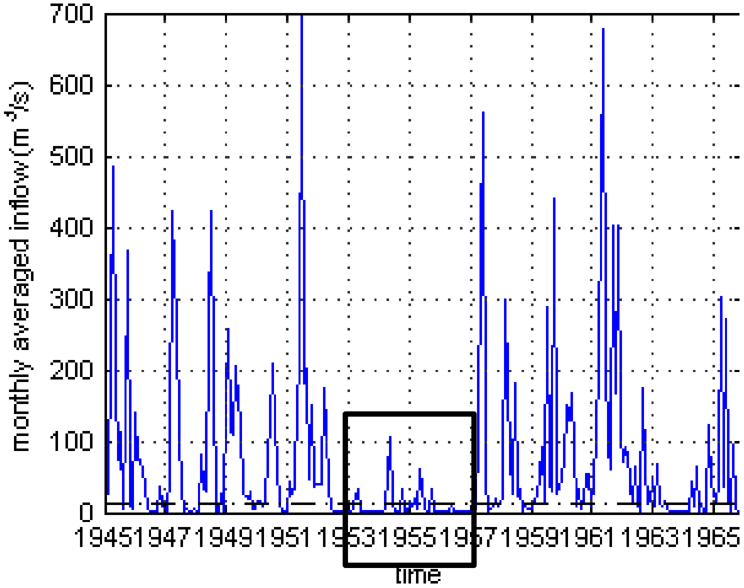


Example: historical drought

- Design drought of 1952-1957
- Threshold = 13 m^3/s
- Average inflow = 8.2 m^3/s

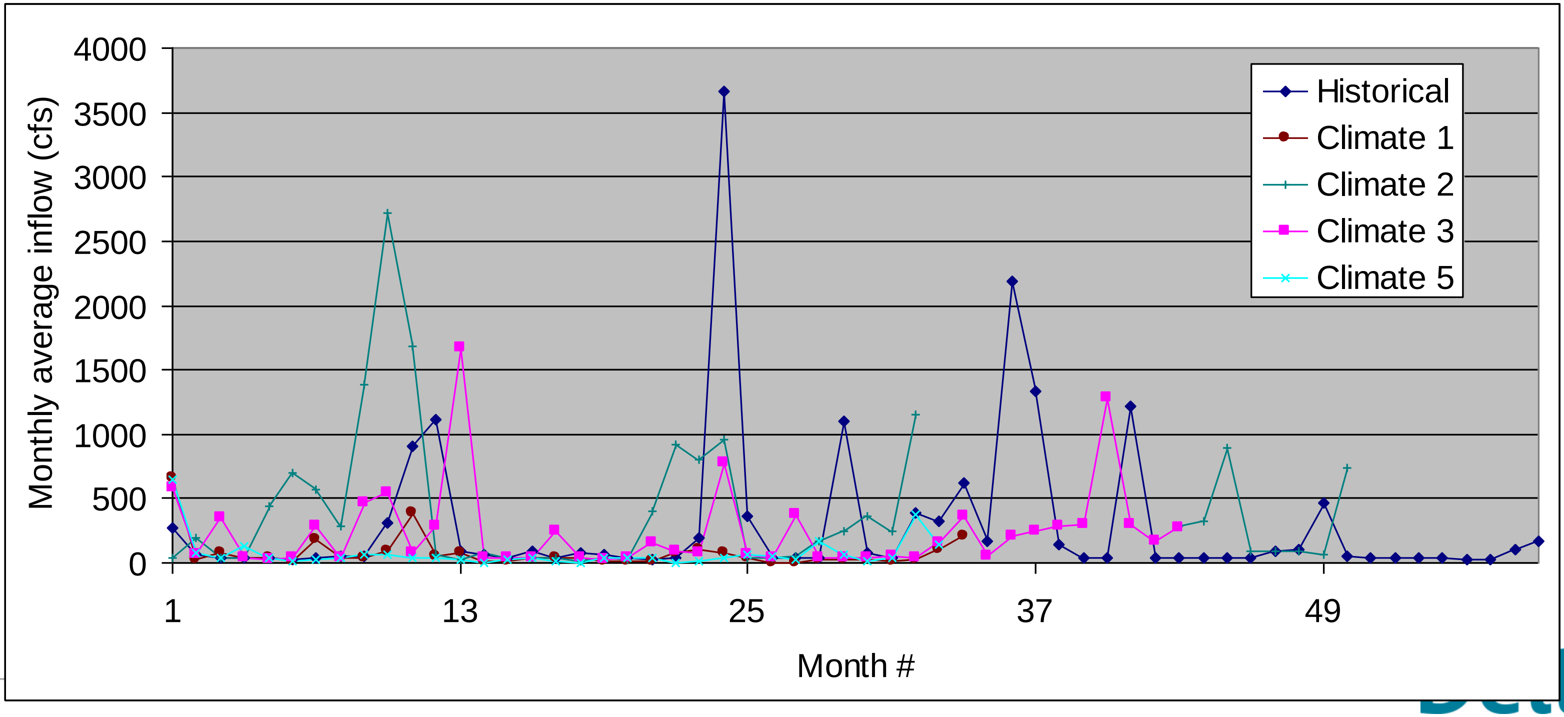
Duration	= 58 months
Severity	= 4.8 m^3/s
Intensity	= 13 m^3/s
Volume	= 0.7 10^9 m^3





Selection of future droughts

- Data: 112 inflow time series, each 150 years
- Selection criteria:
  - Inflow < 13 m^3/s OR $Inflow_{MA}$ < 13 m^3/s
  - Duration > 12 months



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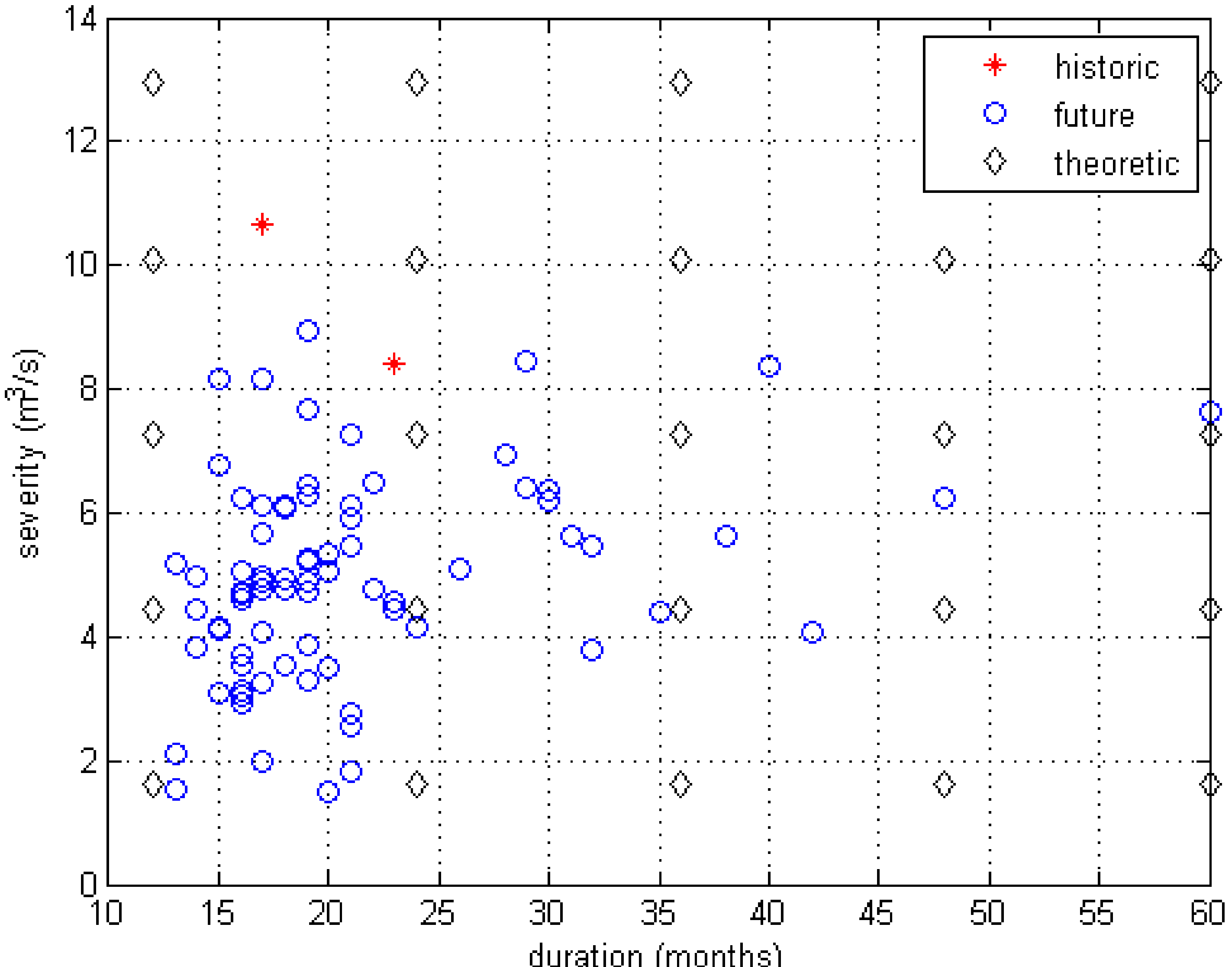
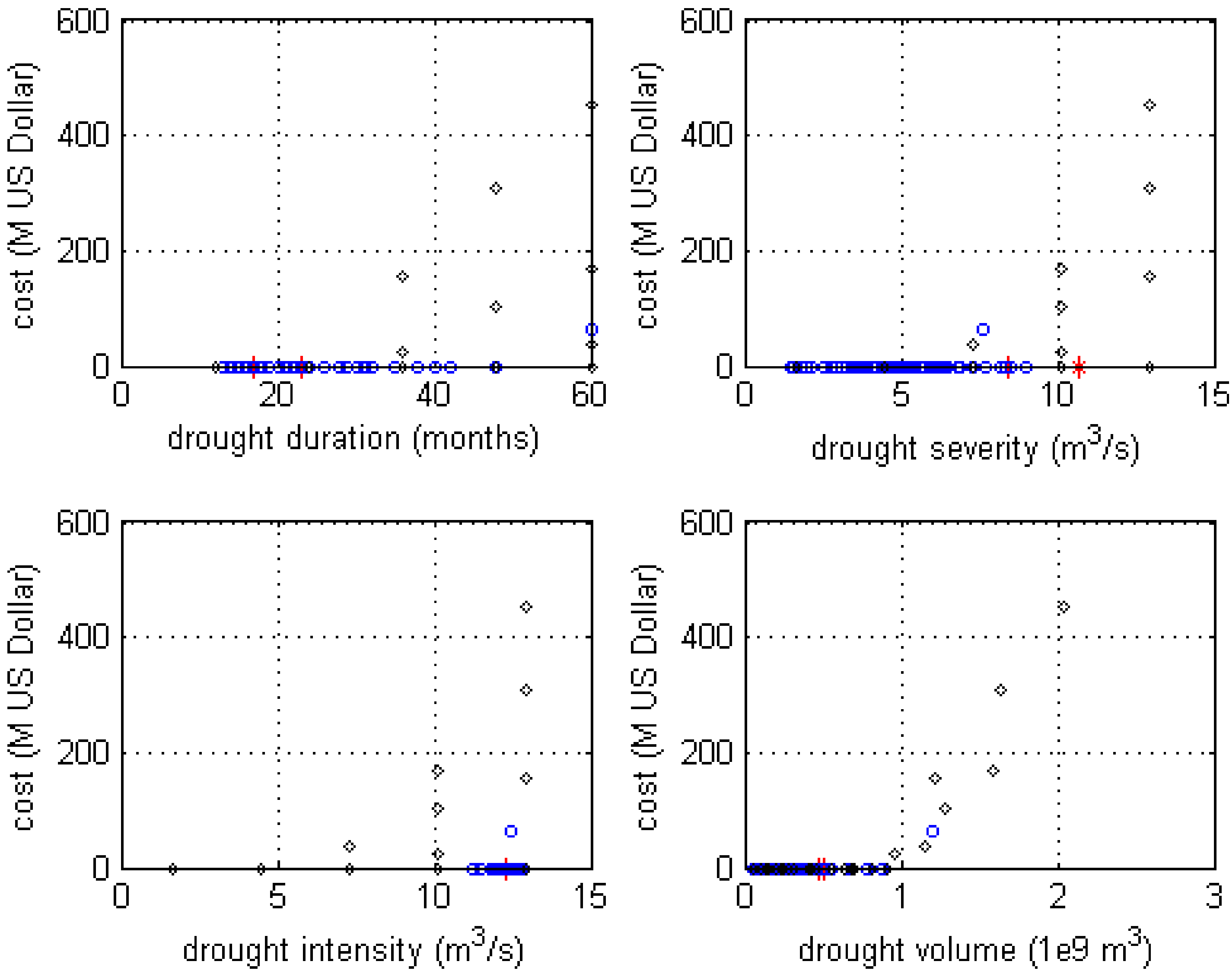


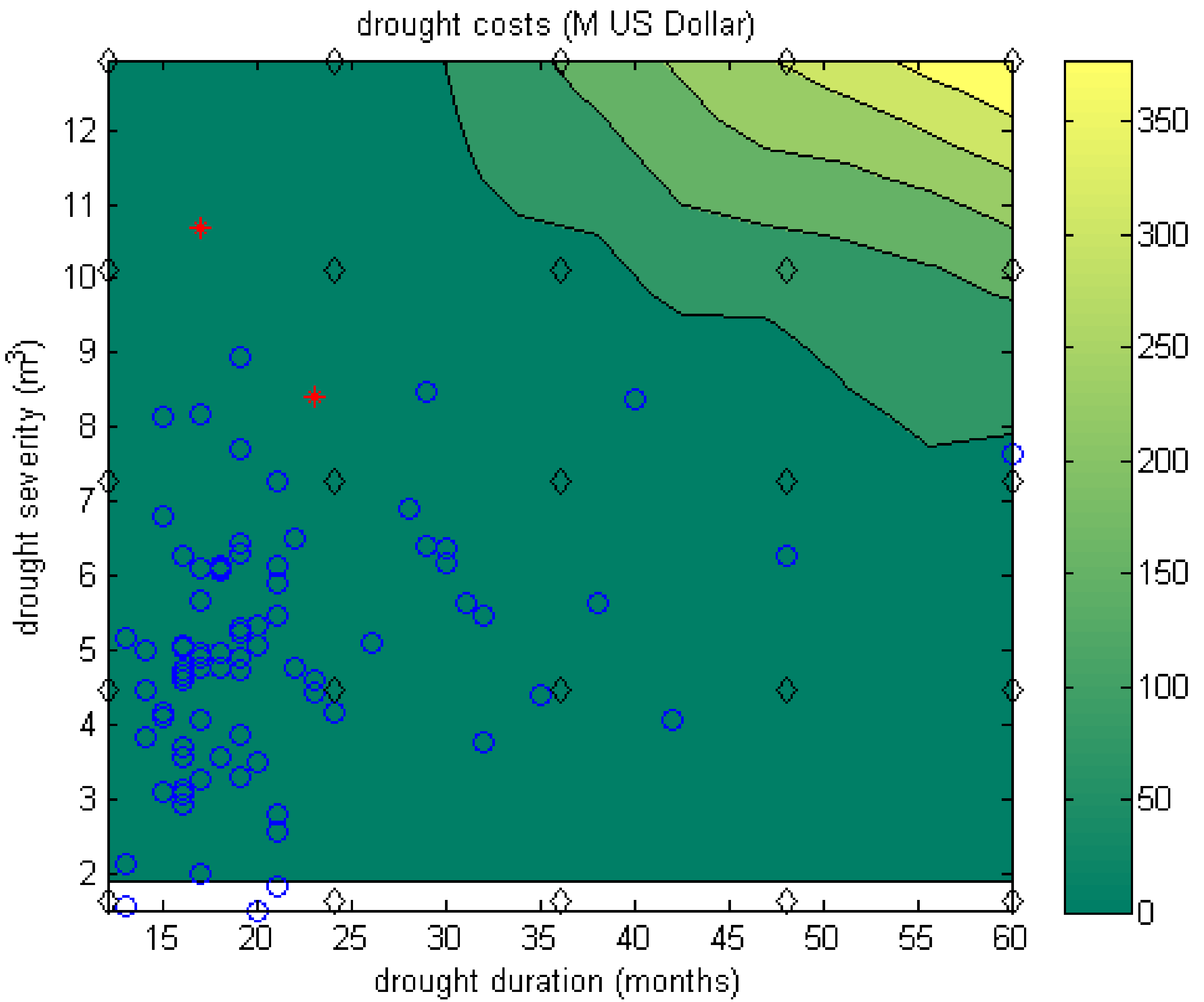
historic
future
theoretic
severity (m^3/s)
duration (months)
0
2
4
6
8
10
12
14
10
15
20
25
30
35
40
45
50
55
60

3. Robustness of Oologah water supply system



cost (M US Dollar)
600
400
200
0
0
20
40
60
drought duration (months)
cost (M US Dollar)
600
400
200
0
0
5
10
15
drought severity (m3/s)
cost (M US Dollar)
600
400
200
0
0
5
10
15
drought intensity (m3/s)
cost (M US Dollar)
600
400
200
0
0
1
2
3
drought volume (1e9 m3)

Results


drought costs (M US Dollar)
drought severity (m3)
drought duration (months)
12
11
10
9
8
7
6
5
4
3
2
15
20
25
30
35
40
45
50
55
60
350
300
250
200
150
100
50
0

Drought impact reduction

Build pipeline (Tulsa Water Authority)

Restrict personal water use during drought

Prioritize among user types during drought

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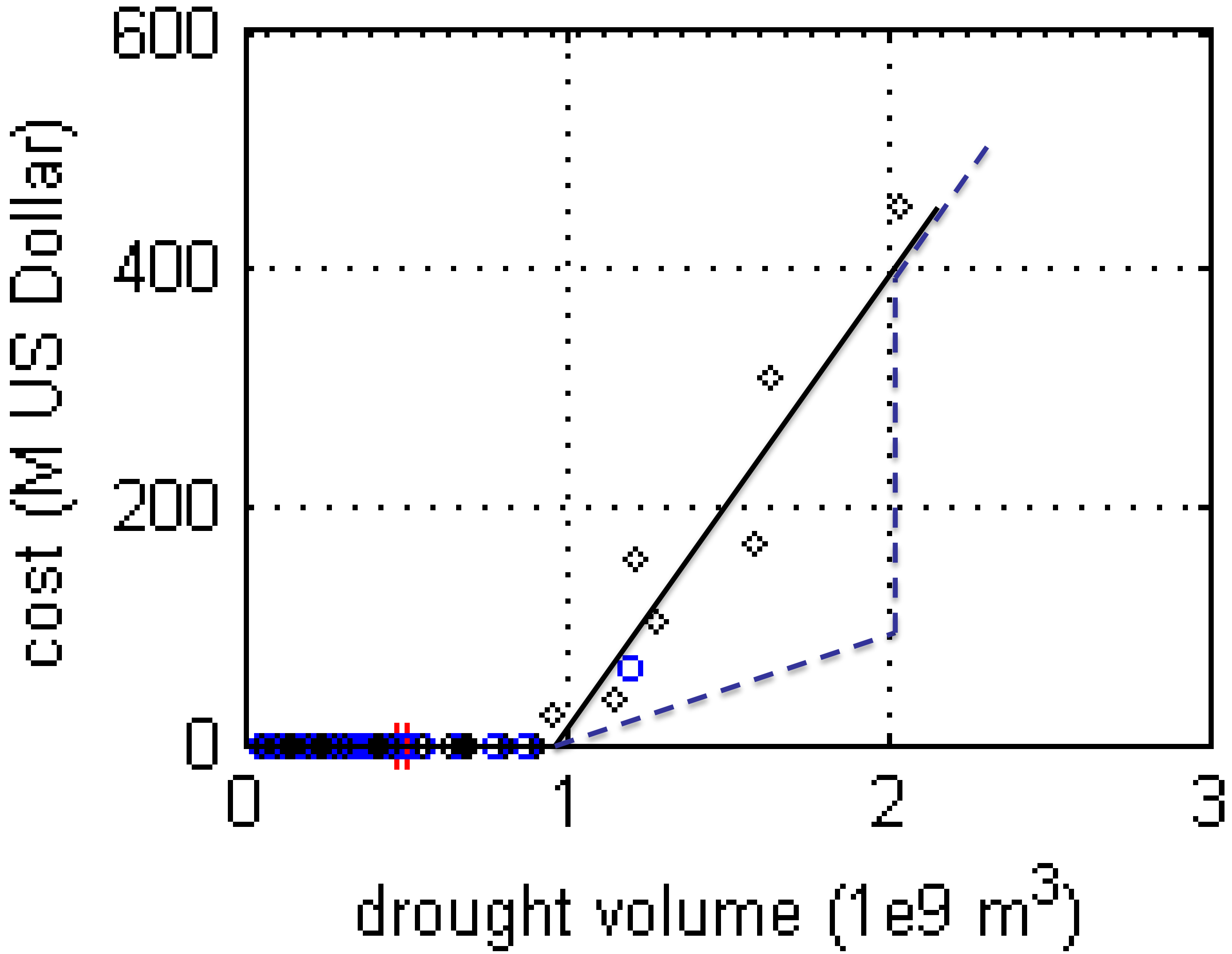
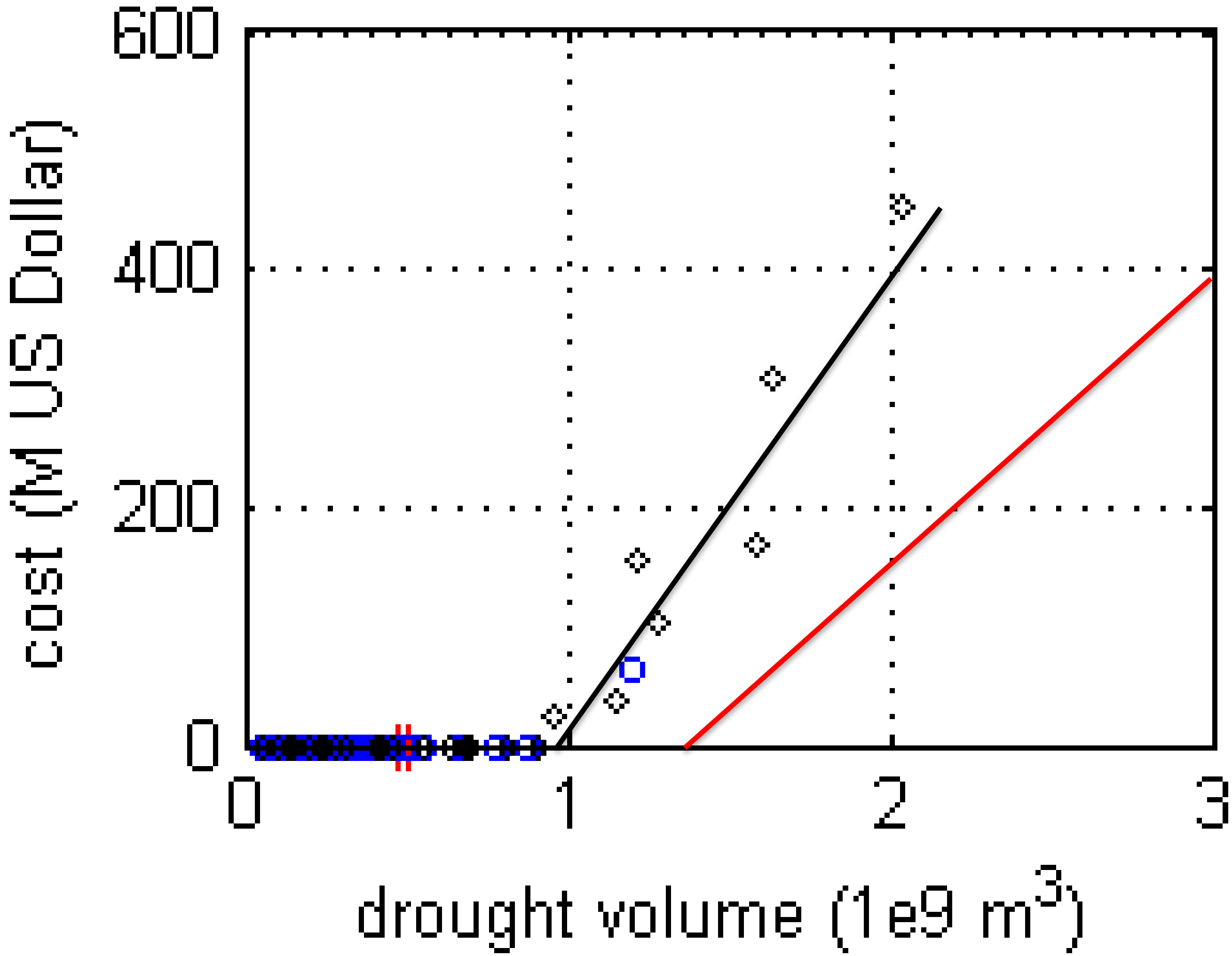
Effect of impact reduction - pipeline



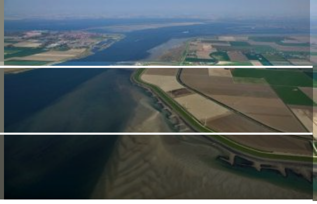
Effect of impact reduction -restrictions



Insights

Robustness criteria:

- Resistance threshold
  - > Duration > 3 years (36 months)
  - > Severity of >8 m^3
  - > Volume of >1 m^3
- Proportionality of the response
  - Gradual increase, but quite steep
- Manageability/recovery threshold
  - ? (depends on economic capacity of the region)



Insights

Mechanisms behind resistance threshold:

- Storage capacity of the reservoir
- Actual use is less than issued in contracts
- Restrictions? → room for increasing resistance threshold

Mechanisms behind proportionality:

> Tulsa water authority has alternative source of supply

> Smaller communities don’t

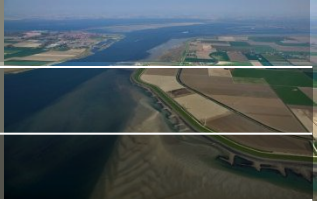
Conclusions and follow-up

Conclusions:

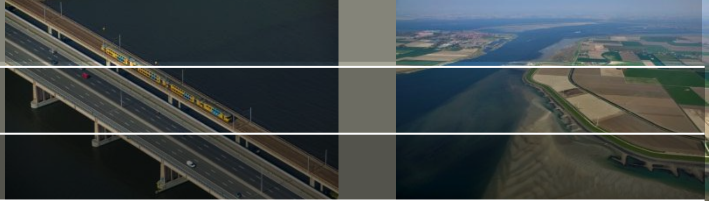
- Theoretic events provide a way to find the resistance threshold
- This threshold can best be expressed in terms of drought volume
- There is room for increasing robustness → more research needed

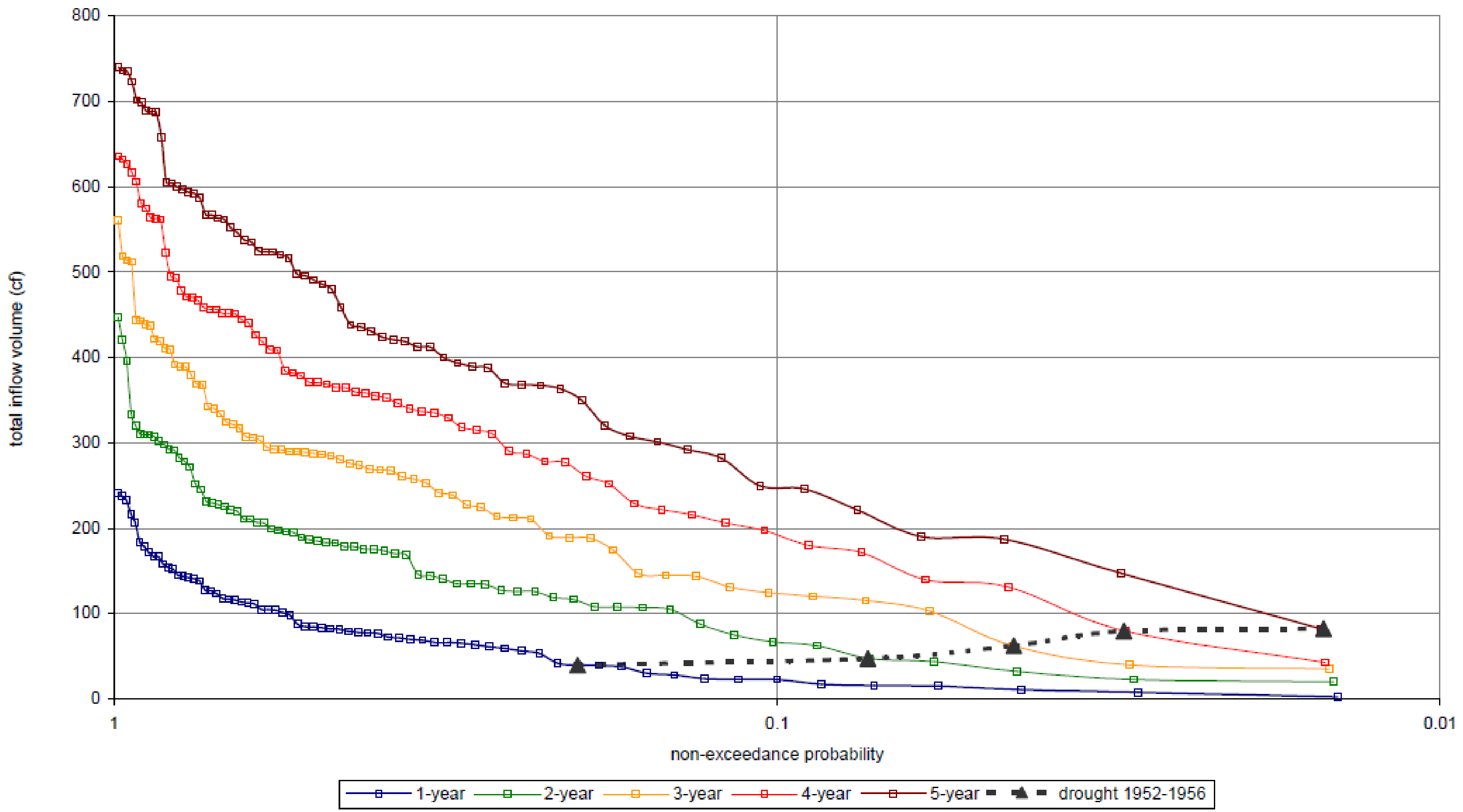
Follow-up:

- Cost for lack of cooling water
- Capacity of pipeline
- Statistics: to determine relevant range of drought events
- Recovery thresholds and economic capacity:
  - When would people move to another area?
  - What level of impact is unacceptable?
- Options to prioritize among users
  - Cost of navigation

Thanks for your attention!





800
700
600
500
400
300
200
100
0
total inflow volume (cf)
1
0.1
0.01
non-exceedance probability
1-year
2-year
3-year
4-year
5-year
drought 1952-1956