Return period vs. Probability of failure: which concept to choose for decision-making in flood risk management.

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Academic background

- 2006 : Hydraulic Engineering Diploma, ENSH (Algeria)
- 2010 : Hydrologic Engineering Master, ENSH (Algeria)
- 2020 : Doctorate ès Science in Hydraulic, ENSH (Algeria-France)

Professional background

- 2006 - 2012: hydraulic and hydrologic engineer (Algeria)
- 2012 – 2021: University lecturer/ consulting engineer (Algeria)
- 2021 – 2023 : Postdoctoral fellowship, university of Sherbrooke, QC (Canada)
- 2023 – present : professional in science, Stantec, Québec (Canada)

The concept of return period "T" in hydraulic design

Design storm/flood application:

- Dam and spillway
- Culvert and bridge
- Drainage network
- Detention basin
- Flood control structures
- Inundation map, etc.

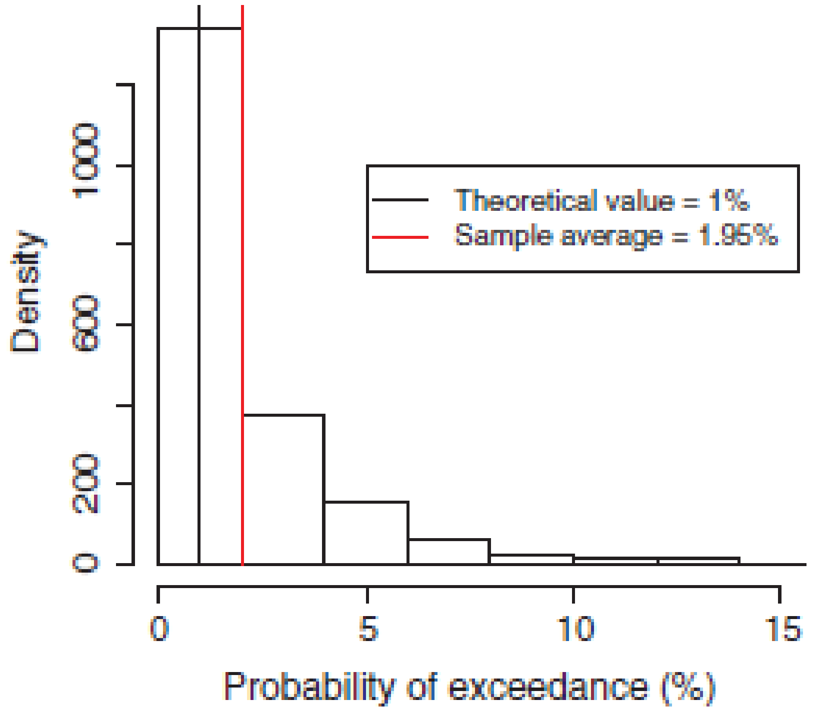
What is a return period?

- Despite its name, this is not a periodic process
- Several definitions
- Each T event is independent from previous one.
- A concept that characterizes the magnitude of the largest probable event over a period of T year.

Assessment of the T-year quantile

- Historical observation
- Statistical inference
- Design value has an expected probability of exceedance = 1/T
- Design value for return period of T is affected by uncertainties.

Why should we use probability of failure design value instead T-year quantile



- **Distribution of exceedance probabilities of the 100-year estimated quantiles for 2,000 samples of 30 values drawn from the GEV parent distribution**
- **Black vertical line : theoretical value of 100yr (1%) quantile**
- **Red vertical line: 100yr quantile samples average to 2% probability of exceedance (50yr).**

Probability of failure

Probability of failure :

- Return period
- Structure lifetime

Formulation :

$$P_{failure} = 1 - (1 - p)^{Nc}$$

- $P_{failure}$: probability of failure
- p : probability of exceedance, p = 1/T
- Nc : lifetime of the structure

Examples :

Drainage network :

- A structure with lifetime of 30yr
- Design value: T=10yr
- $P_{failure} = 96\%$

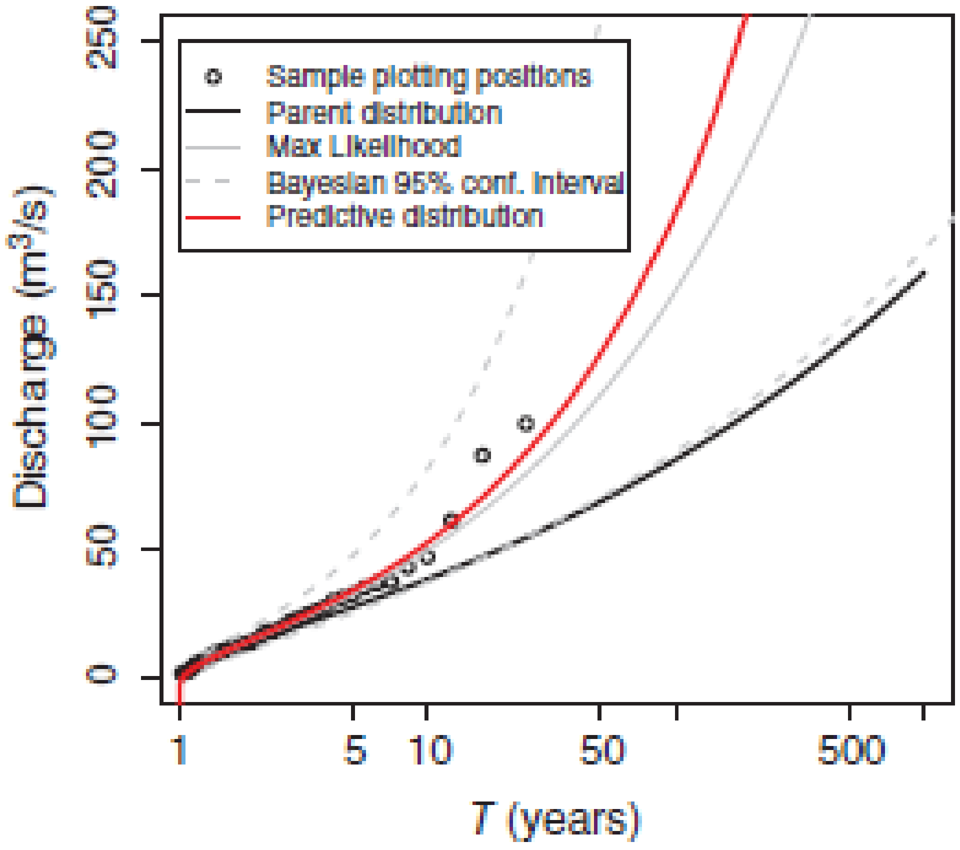
Culvert :

- A structure with lifetime of 50yr
- Design value: T=50yr
- $P_{failure} = 64\%$

Probability of failure : the predictive distribution

The predictive distribution:

- <u>**The distribution of possible unobserved values conditional on the observed values**</u>
- **Unknown mathematical formulation**
- **Unknown density function**
- **Numerical construction to jump from 30,40, 50 values of observed hydrological variable to a dataset of millions of values.**



Bayesian perspective and MCMC inference

Bayes Law:

$$p(\boldsymbol{\theta}|\boldsymbol{D}) = \frac{l(\boldsymbol{D}|\boldsymbol{\theta})p(\boldsymbol{\theta})}{p(\boldsymbol{D})}$$

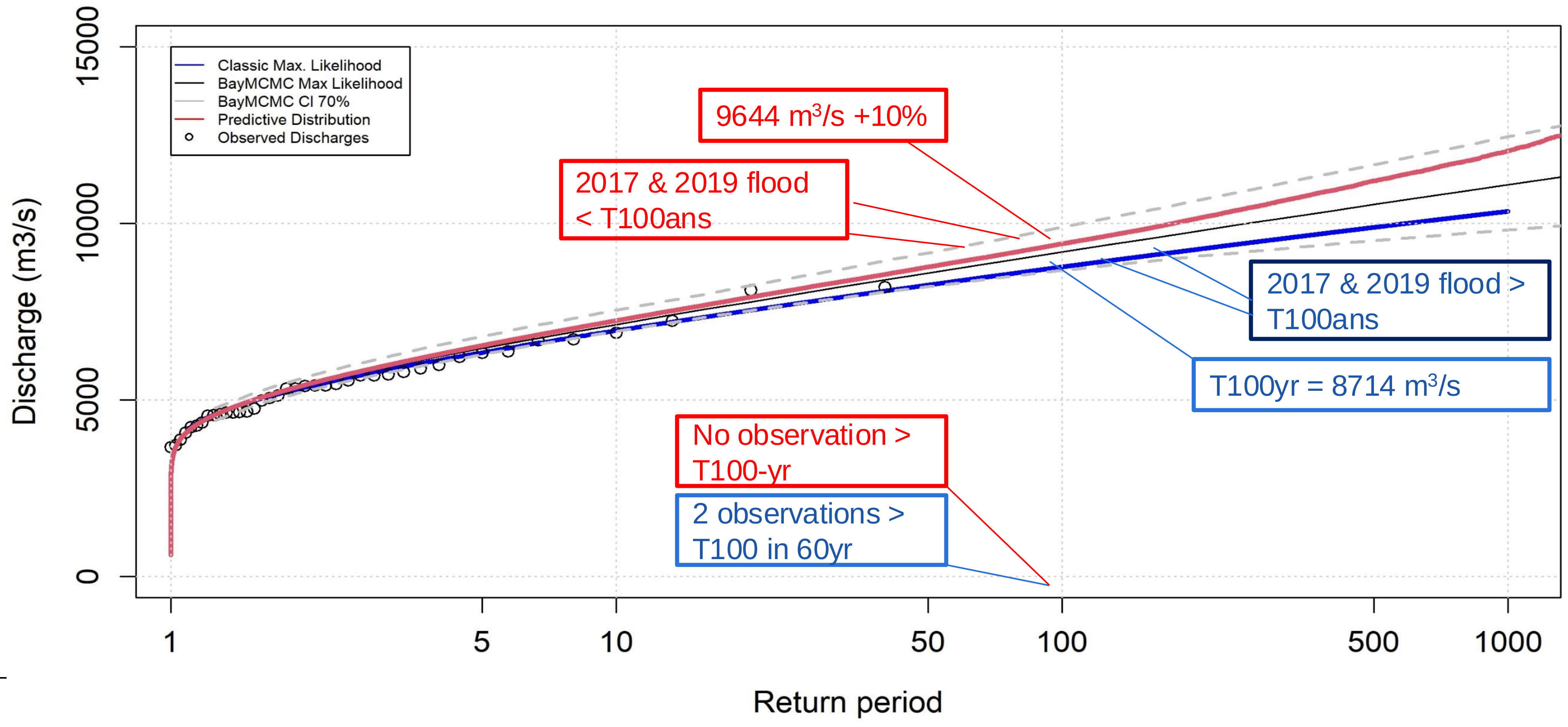
- $p(\boldsymbol{\theta}|\boldsymbol{D})$: Marginal probability density of the
- parameter vector θ given the data set D (i.e., posterior distribution)
- $l(\boldsymbol{D}|\boldsymbol{\theta})$: Vraisemblance de l'échantillon D
- $p(\boldsymbol{\theta})$:a priori or alternative knowledge on the distribution of θ (Prior distribution of θ)
- $p(\boldsymbol{D})$: is the probability of the sample D which is unknown

Bayesian framework

- MCMC algorithms combining random walk Monte Carlo methods with Markov Chains: allows sampling from multivariate random distributions efficiently.
- Integration of uncertainties in the statistical inferential process
- Integration of historical information
- Reduction of credibility interval
- Draw samples for each parameter's data set of the posterior distribution for numerical construction of the predictive distribution.
- nsRFA package on R (Viglione et al., 2024)

Example : Ottawa River at Carillon Dam Station 02LB024

Annual maximum daily flow fitted to GEV distribution – Available recording period (1962-2002)
2017 and 2019 flood events outside the observation range (used as historical information)



Conclusion

- Risk (probability) of failure is a more realistic measure of the risk for design purposes.
- Stationary models and a suitable assessment of the uncertainty accounting for possible temporal persistence should be retained as more theoretically coherent and reliable options for practical applications in real-world design and management problems;
- A clear understanding of the actual probabilistic meaning of stationary return periods and risk of failure is required for a correct risk assessment and communication.

Thank you