Floods are a very relevant aspect of dimensioning constructions such as bridges, weirs and dams. As the deterministic prediction of floods is difficult, the probability of flood events is often estimated instead.

Estimations of probabilities on the base of discharge data can be made by two different methods.

- **Direct statistical processing**
  For every year the highest flood peak is identified. Long-term observations need to be available for that. During the direct statistical processing the parameters of an Extreme Value distribution that describes the annual flood series (e.g. Lognormal, Gumbel, Fréchet or Pearson) are estimated from the data. With this probability function predictions of design floods (e.g. a 100-year flood) can be made. However, you have to keep in mind that an extrapolation gets more uncertain the more the return period of your needed design flood differs from the number of observations.

- **Regional statistical processing**
  This method is used, if no discharge data are available for the target catchment or longer time series than the available ones are needed. The background of this regional method is the combination of annual flood series from different catchments to one database. For that purpose every flood peak is divided by the annual mean of the catchment. Through this standardisation one database for a homogenous region is derived from different catchments.

**Assignment:**

The municipality of Davos wants to extend its network of hiking trails to boost summer tourism in the region. To this end it is planned to construct a new bridge over the Dischmabach 100 m upstream of gauge Kriegsmatte.

An engineering consultant has submitted a project proposal that shall be put into practice if it complies with the constraints defined by the canton. The planned bridge is designed for a maximal discharge of 21.3 m$^3$s$^{-1}$. It has to be closed due to safety reasons at higher discharges. Only if this, **statistically speaking, occurs at the most once in 50 years**, the canton is willing to build the bridge.

First part of the assignment will be a direct statistic estimation based on the discharge data from Dischmabach. For the second part data from the catchments of Inn near St. Moritz Bad, Ova da Cluozza at Zernez and Chamuarabach near La Punt are added.
Task 1 (Flood Frequency Analysis / direct statistical analysis)

*Chapters in the script that are of specific use for this task: Chapter V, p. 403ff; VII, p. 65 ff*

In this task you shall apply a direct statistical analysis to evaluate if the proposed project complies with the constraints of the canton and thus can be implemented. Necessary data are available on the course website.

1.1 As a first step, fit the theoretical distributions after Gumbel (EV1) and the Lognormal distribution to the data (sort data, place ranking numbers, estimate distribution parameters, calculate distribution function). Given are the annual flood data of the Dischmabach at gauge Kriegsmatte (1964 – 2008). The distribution functions and the equations for the required parameters are given in the formulary. Compute the distribution parameters (Gumbel: $\mu$ and $\alpha$, Lognormal: $\mu_{ln}$ and $\sigma_{ln}$).

Values of the standard normal distribution are given in the appendix of the formulary.

Remark: Due to the symmetry of Lognormal distribution negative values are not shown, as $\Phi(-z) = 1 - \Phi(z)$.

If you use EXCEL you can directly use the following EXCEL commands to estimate $F(x)$:

- LOGNORMDIST($x$, $\mu$, $\sigma$) (English)
- LOGNORMVERT($x$, $\mu$, $\sigma$) (German)

1.2 Use the Kolmogorov-Smirnov test to evaluate if the annual flood data of the Dischmabach at gauge Kriegsmatte (1964 – 2008) can adequately be characterized by the Gumbel (EV1) or Lognormal distribution.

Compute the empirical cumulative frequency for the dataset using the equation by Gringorten (sort data, place ranking numbers, estimate distribution function).

Apply the Kolmogorov-Smirnov test to both distributions and check if the maximal difference ($T_d$) between $F_{emp}$ and $F_{theor}$ exceeds the test statistic $c$ on a 10% level of significance. If $T_d > c$ you can reject the hypothesis on a 10% level of significance.

According to the results of the Kolmogorov-Smirnov test: Can one or both of the two investigated extreme value distributions adequately characterize the annual flood data of the Dischmabach? Plot both distributions together with the empirical cumulative frequency.

1.3 What is the probability of non-exceedance corresponding to an event with a statistical recurrence period of 50 years?

1.4 a) What is the return period corresponding to the critical discharge of $21.3 \text{ m}^3\text{s}^{-1}$? Is it thus possible to implement the project proposal?

b) What is the return period of the maximum discharge calculated in Assignment 3 ($5.25 \text{ m}^3\text{s}^{-1}$)?

c) Which flood peak corresponds to an annuality of 100 years?

Use the distribution that exhibited a better fit in Task 1.2 for your computation.
Task 2 (Regionalisation)

Chapters in the script that are of specific use for this task: Chapter VII, p. 68 ff

Within this task you should not use the data of Dischmabach – imagine there are no data available for this catchment. In this case the method of regionalisation has to be used to transfer missing information from similar, observed catchments. For this reason, the assumption is made that the catchments of Inn, Ova da Cluozza and Charmuerabach show a similar hydrological response compared to the catchment of Dischmabach. Furthermore, the hydrological response of all catchments is connected to certain catchment characteristics.

If the flood intensity is related to specific catchment characteristics, e.g. catchment area, and the observed catchments show a similar hydrologic response, discharge information can be transferred from one catchment to another.

2.1 Calculate the non dimensional standardised $HQ^*$ for catchments of Inn, Ova da Cluozza and Chamuerabach.

This step is necessary to compare the different data on the same level. It is calculated by division of every value by the mean of the data row. The result will be the standardised $HQ^*$.

2.2 Combine the dimensionless rows of $HQ^*$ from Inn, Ova da Cluozza and Chamuerabach to one dataset. Estimate the parameters of a lognormal distribution $\mu_{ln}$ and $\sigma_{ln}$ for this regionalised data set. Calculate the empiric (Gringorten) and the theoretical distribution (Lognormal) analogous to task 1.1 and 1.2.

Check the fitting of the probability function using the Kolmogorov-Smirnov-Test.

2.3 To connect the mean discharge values and their characteristics with the properties of the catchments a potential approach is used. This relates the mean flood discharge to the area of the catchment.

$$E[HQ] = c \cdot A^n \quad (1)$$

Calculate parameters $c$ and $n$ from the relation of catchment area $A$ and the mean flood value $E[HQ]$ in the catchments of Inn, Ova da Cluozza and Chamuerabach.

The usage of a double logarithmic chart might be helpful.

Remark: $\log E[HQ] = \log c + n \cdot \log A$ linear equation

2.4 Calculate the annual mean flood value of the Dischmabach using its catchment area and the equation from task 2.3.

2.5 Calculate the dimensionless discharge $HQ^*_{100}$ and the discharge of $HQ_{100}$ using the regional statistical approach. Compare this value to the one from task 1.4.
Aufgabe 3 (In practice)

3.1 Imagine you are an engineer and you are supposed to perform a flood analysis in a catchment where only few runoff data exist. Thus, a direct statistical processing is not possible. In addition to the runoff data you have long-time precipitation data from several stations within the catchment.

Explain how you would proceed in this case in order to get an estimate for a flood with an annuality of 100 years.

Remark: Remember the tools and methods you were using in assignment 1, 2 and 3.