2 FUNDAMENTALS OF MATHEMATICAL RIVER FLOW MODELLING

A solid understanding of the underlying mathematics is needed in order to be able to judge the adequacy of a mathematical method and its application limits. This knowledge helps to analyse how precisely the flow is described mathematically, which simplifying assumptions were made, and how they affect the result of the calculation. To help satisfying this need, the theoretical foundations of the two most common fundamental model approaches in engineering practise, the one-dimensional water level model and the two-dimensional shallow water model, will be discussed in detail in the following chapters.

2.1 ONE-DIMENSIONAL WATER LEVEL CALCULATIONS

The easiest mathematical method for calculating the flow situation in rivers is the water level calculation. It reduces the multi-dimensional real-world flow processes to a one-dimensional problem by assuming the flow cross-section and the flow velocity at a certain water level or, depending on the used approach, parts of the cross-section to be constant. The complex flow situation in the river is thus condensed to be a simple one-dimensional stream tube.

2.1.1 DEVELOPMENT OF A WATER LEVEL MODEL

To build a one dimensional flow model initially basic data are to be collected. Basically, preliminary considerations to the challenge and the goal of the modelling have always to be put in front of any data acquisition.

The structure of a classic 1D model runs in five steps:

1) Gathering all the input data.
2) Configuration of the 1D model.
3) Calibration of the 1D model.
4) Calculation/ Simulation for the design flood or other scenarios.
5) Evaluation and monitoring of the results.

At the gathering of all the input data it can be reverted to cards, literature, surveys and measurements.

- Number, location and extent of the profiles to be recorded
- Recording of the profile geometry
- Location and level data of inflows / outflows
- Grain size and structure of the river bed
- Structure and use of the floodplain
- Embankments, shore grouting and specialties
- Vegetation density, vegetation height, vegetation type and vegetation distance on the floodplain
- Gauge data of HQ, NQ and MQ – events with associated water levels
- Geometry, location and characteristics of bridges, culverts and weirs

While the configuration of the 1D model, all input data have to be transferred on the desired flow model and, where appropriate, assessments and simplifications have to be taken into account. These include the mapping of the cross sections, including the hydraulic parameters, the definition of the water course through the profiles, the definition of runoff events as well as the determination of all calculation settings such as simulation variants, flow-resistance act, parameters, etc.

As part of the calibration, which is usually carried out at first for the water bed under mean water and later for the floodplain under floodwater, the hydraulic parameters have to be calibrated. Here initially roughness, vegetation and hydraulic parameters are elected from past experience or references. After

an initial calculation the hydraulic parameters can be adjusted in a physically meaningful interval comparing the calculated results with the measurement. This calibration process will continue for as long as the results of calculating simulate the measurements as accurately as possible.
For the calculations of scenarios or design floods, the calibrated 1D model is the basis and (mostly) a reference state for studies. A steady control of the results by hand rough invoices or plausibility checks is recommended for each calculation. For this purpose especially the visualization of the results in a map and in the longitudinal section is suitable.

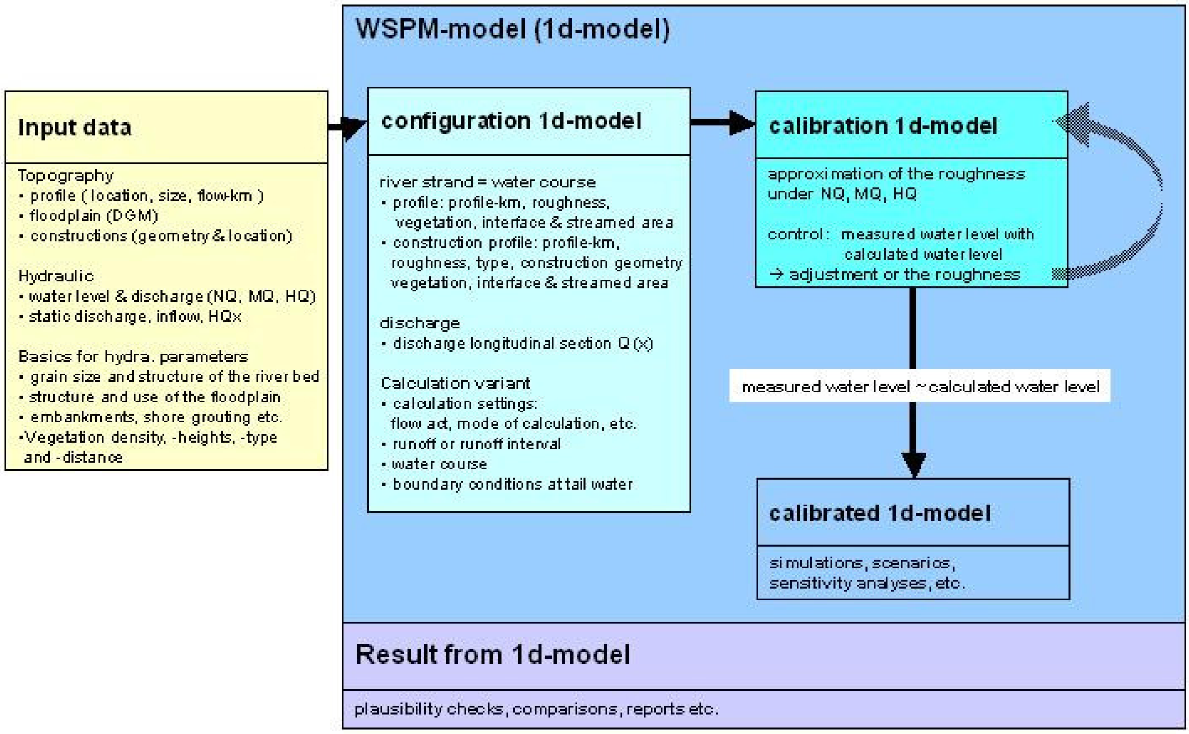

Figure 2-1: Development of an 1D-model for the calculation engine Kalypso 1d

2.1.1.1 SUPPLEMENTAL TERMINOLOGY

In the following the basic data of the one-dimensional water level calculation are defined and their significance is described.

Profile

A water profile is defined by the profile name (stations-km, profile state), about which the profile is referencable. A profile contains all the geometric and hydraulic data, which describe a cross section. Their content varies depending on the profile type (e.g. normal profile, bridge profile, weir profile). Regardless of the profile type, each profile contains the description of the land- or building geometry (in the y-z-level). This purely geometric description of the profile is supplemented by the hydraulic parameters such as bed roughness, vegetation, interface and floating zones, such as streamed part and the bankfull point.
The **growth parameters** ax, ay, and dp of the water profile after LINDER / PASCH will be additionally overlaid by the bed roughness. Hereby the growth parameters are defined as follows:

- ax = vegetation distance in the direction of flow,
- ay = vegetation distance crosswise to the direction of flow,

- dp = equivalent vegetation diameter (for trees equivalent to the trunk diameter, but for bushes much bigger).

For choosing the right parameters the BWK-bulletin 1, the DVWK-bulletin 220/1991 and other literature provide tables with growth parameters of different vegetation.
With the establishment of two interfaces per profile the so-called interface roughness between floodplain and river tube is considered after PASCH. The interfaces describe the momentum exchange between the floodplain and river tube and define the boundaries between the water flow in the water course and the significantly reduced water flow on the floodplain. Here the interface is also applied in the hydraulic calculation as a wall resistance between the river bed and floodplain. The interfaces have to be located at the transitions between extreme leap of roughness and/or increase of the ground level elevation. Basically, the two interfaces have to be arranged at the transition to the relevant roughness deprivation.
The streamed area indicates the area where the principle of linear momentum is applied. All areas outside the streamed area do not go in with a hydraulic calculation. The streamed area is to be defined in that manner that no distortion of the actual flow forces in the water course occurs. For example, troughs and branches adjacent to the stream course are not to be included in that area. Ideally, the streamed area should end at the outermost highest ground elevation point.

River strand
The consecutiveness of profiles along the water course is defined through the river strand. It also corresponds to the order of execution in the water level calculation. Moreover, the distances between the profiles in the river bed and on the floodplain are defined. The profile distances result from the user-entered values of the single stations. Also for each river strand a list of all the state's profiles is deposited. The order of the profile declaration is defined by the calculation direction opposite to the direction of the flow direction. The stationing direction is not fixed. However, it is basically recommended to fix the stations from the estuary in the direction of spring.

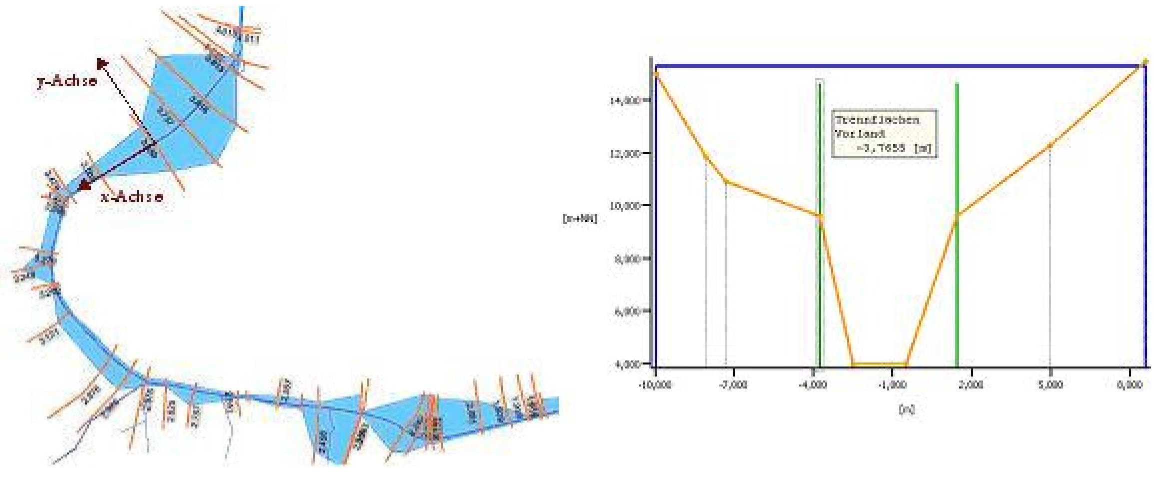

Figure 2-2: Left: river strand with water profiles in the plan view. Right: profile with interfaces (green) and streamed area (blue)

Discharge event
For a water level calculation the discharge has to be defined as a boundary condition. For this serves the discharge data set. Initially, a discharge data set is independent from the river strand and is only assigned to the river strand in the calculation variant. In this data set, the discharge can be established relative to a profile or even between two profiles. However, only those flow- kilometres have to get an discharge definition, where a discharge change occurs compared to the previous profile. Every discharge data set stand for exactly one discharge event. While the water level calculation the user can select the desired flow condition.