Identification of Ordinary Methods in Bavarian Hazard Analysis for Torrents

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Due to law, Bavarian water management authorities have to assess hazard zones caused by torrents for the whole alpine area of Bavaria. To face this demand a special development project was founded. A modern and suitable technical frame or even standard should be created to gain reasonable results in hazard analysis at bavarian torrents and to reach the multiple goals for hazard analysis. A systematic selection process should identify sufficient methods to meet the strict requirements. The identification and adaption of a standard hydrologic method showed suitable results in assessing peak discharges (mean error of 12%). The crucial problem is the lack of data in torrent catchments which causes high uncertainty. The plausibility check should act as an instrument to reduce uncertainty, so that the knowledge won by the plausibility check, can be used to correct the model result. Only an experienced practical application will evaluate the usability of the suggested standard methods. Finally this standard will be further developed in future, regarding new data or new technical evolution.
This paper describes the foreseen way to identify the new standard for hazard analysis. This will be illustrated by the example of hydrology, which is already finished, whereas other aspects like bedload are still in progress.
Key words: hazard analysis, method, administration

1. INTRODUCTION

Hazard analysis is a complex process with many aspects to take into account. Just considering the results, which have to serve multiple, partly counter-rotating goals. Bavaria tries to solve this challenge by working out a modern, transparent and robust standard, which is also suitable in praxis.

In the following we explain the legal, social and technical background for the whole hazard analysis. After that, the foreseen process for identification and introduction of the new standard is described and finally illustrated by the example of hydrology. The work is still going on and changes in future are possible.

2. BACKGROUND

1.1 Legal and Social Situation

Due to law bavarian water management authorities have to assess hazard zones caused by torrents for the whole alpine area of Bavaria. They have to become legally fixed by the responsible legal authority.

Responsible for the torrential hazard assessment is the State of Bavaria, the work is done by the local water management authorities. For this work they can order private engineering consultants, but finally the responsibility stays with the technical authority.

Torrential hazard zones are legally treated like flood areas. Compared with our neighbors (Austria and Switzerland) the legal consequences of flood areas are very strict in Bavaria. A legally fixed flood area implicates a prohibition of building permissions which means a strong interference for land owners. We do not have separate zones, where building is possible with some constraint (“blue zone” like in Switzerland). Nevertheless it is possible to allow exceptions under certain restrictions, but the first consequence implies building ban.

There is no tradition in coping with restrictions of hazard zones in the past, so we face a very skeptical and critical public. The risk awareness and therefore acceptance for restrictions is not very well developed.

Finally this means, that our hazard analysis has to be reliable and effective. Even more it has to bear up legal examination.

2.2. Technical Situation

Flood hazard zones are defined by the spatial distribution of a 100 year flood event. For torrents, the "torrent-typical characteristics" have to be considered as woody debris, bed load or debris flows. The legal and social situation, as well as the technical situation, demands an integrated overall concept for hazard analysis, suitable for the most cases to identify the hazard zones in all the bavarian torrential catchment areas.

Of course we do not start by zero in hazard assessment. The existing working tradition of our authorities and even more the local available data inventory has to be considered.

1.3 Consequence: Elaboration of a Standard Torrential Hazard Assessment Procedure

The above mentioned situation means, that the demand on the hazard assessment procedure is quite high. To face this demand a special development project was founded. A technical frame or even standard should be created to gain reasonable results in hazard analysis at bavarian torrents. This project is delivered at the Bavarian Environment Agency in close cooperation with the local water resources authorities.

A standard method constitutes a clear and defined procedure for users and also allows to educate the own personnel in the water resources administration. A further benefit of the standard concept will be the simplification of the cooperation between authorities and private consultants:

- it provides a basis for ordering engineering consultants
- it assures comparable results by different consultants.

The main goal of the project is to find 'acceptable' methods by choosing already existing ones and adapt them for bavarian conditions. Besides functional questions it is also important to consider traditional experience to win acceptance within the personnel of water resources management authorities.

Following requirements are presented to the standard procedure:

Recognized Rules of Engineering

The standard must represent a modern technical approach which is accepted as state-of-the-art from the majority of experts.

Reproducibility

The standard concept allows reproducibility in the process of hazard mapping. This is essential for quality control of work and helps to improve the argumentation basis for implementation. Especially regarding the cooperation and interaction between technical authorities, legal authorities and consultants, a proper procedure is necessary. For the periodically updates of the hazard assessment the replicability of former results will be helpful.

Comparability

The results of hazard zone mapping for similar catchments must be comparable to be reliable for public.

Effort/ Benefit Balance

The level of accuracy which induces the effort has to be adjusted to the interrogation. The hazard zone map should afford a depiction of single properties which are affected by a torrential hazard and is published in 1:5 000 scale.

Result Quality

Due to the legal consequences of the hazard zones, a sufficient result quality must be ensured. Once it is not possible to evaluate result quality (in almost all cases we don't know how a 100 year event looks like), we assumed that the usage of recognized methods of engineering is effectuating sufficient quality.

3. PROCEDURE FOR CHOOSING RESPECTIVELY ELABORATING A STANDARD METHOD

To meet the requirements mentioned in chapter 1, methods have to be chosen very carefully. Many single processes, which are contributing to the hazard potential, have to be assessed: (1) hydrology, (2) bed load, (3) wood debris and (4) hydraulics are treated separately in assessing their parameters with an appropriate method for the approach of hazard mapping. The interaction of those processes and consequential effects on the spatial flood distribution should be depicted by the hazard zone.

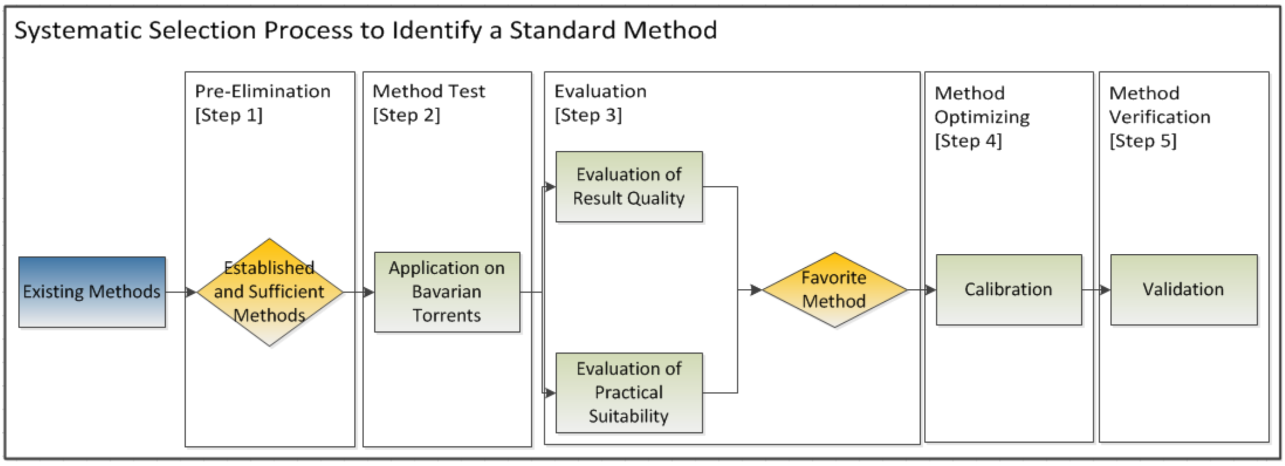

Fig. 1 A schematic depiction of the systematic method selection process which was conducted for the identification of a standard method in bavarian hazard analysis. For each separately assessed torrential process (hydrology, bed load, wood debris, hydraulics) one method was chosen by that concept.

A huge amount of methods exist to assess the parameters of torrential processes. The idea is to use a selection of those existing methods and to adapt them for bavarian boundary conditions, if it is necessary. New developments are only the "last choice".

With a systematic selection process a standard method should be defined to assess the required parameters each torrential process (see figure 1). In the following chapter the elements of the systematic selection process should be declared.

Pre-Elimination

In a first step, existing methods are collected. Therefore the results of 'OptiMeth' (*Rimböck et al.*, 2013) are used. 'OptiMeth' is a working group (consisting of experts from Austria, Germany, Switzerland and Italy), who collects the most common methods, describes and evaluates them. Due to the different backgrounds of the participants and the different circumstances in the countries it is not possible to recommend a single method.

A sample of sufficient methods (2-3), which tend to be useful and suitable for bavarian requirements, are chosen for further detailed investigations.

Application on Bavarian Torrents

As a first step, the sample of sufficient methods are applied on several torrents in Bavaria, whereas the test torrents had to be chosen carefully. The selection should represent a wide range of bavarian torrential conditions and the torrents should be provided with much information (measurements, investigations, event documentations). The application of the method sample focuses the use of the input data from the same data source. This was essential to point out the errors of the method and to exclude other factors which are influencing the errors.

Results and Evaluation

The handling of the methods, as well as their result quality is evaluated in the next step. The aim was to find the best method, related to 'practical suitability` and 'result quality'. 'Practical suitability' was measured in qualitative criteria such as effort to gain input parameters (transform raw data to data the model needs), stability of the results, experience and usability of the related program tool. 'Result quality' was determined by comparing assessed results from the methods with measured data. After the evaluation, one favorite method was specified.

Calibration

The next issue was to optimize the results of the favorite method. This could be done either by calibrating of the input data or the method.

Validation

The lack of measured data was just adequate to conduct calibration. For validation additionally verified results from alternative methods to assess torrential processes were used. Also the data inventory of historical event documentation was suitable either for calibration or validation.

4. EXAMPLE HYDROLOGY

Table 1 Names and identification of the gauges from the test-torrents. MRN is the gauge identification number, A_E the catchment area and I_G the average terrain slope.

Torrent	MNR	Name	A_E [km²]	I_G [%]	Geology
Almbach	18627000	28.5	9.7	62	Ramsaudolomit
Auerbach	18191505	25.0	39.8	45	Hauptdolomit mit Moränen-Überlagerung
Sachenbach	16327504	26.5	2.2	42	Plattenkalk
Traufbach	11416006	23.5	8.3	75	Allgäuschichten
Zeiselbach	18218000	31.0	4.8	42	Flysch

The following chapter describes an example of identifying a suitable standard method to assess rated event hydrographs. The implementation of the concept described in chapter 2 is introduced in the following chapter. A detailed description of the procedure can be found in *Braito et al.* 2014.

Pre-Elimination of Hydrologic Methods

A rated event-hydrograph has to be the result of the hydrology method. Thus a time discretized modelling of the discharge was necessary. Assessing formulas like *Wundt* 1953 are only delivering a peak discharge value. Assessing formulas were dismissed in advance, also because of their weak consideration of occurrence of probability..

Due to aspiration on accuracy and availability of data, deterministic hydrologic models were excreted to be acceptable for the issue of assessing hydrologic parameters for hazard mapping. There are three types of deterministic models:

1. white box model - tries to describe natural processes by physical equations
2. grey box model – tries to describe natural processes by conceptual approach
3. black box model – not based on physical laws but describe cause-effect relationships.

The complex models which are from the types white box and grey box models need many parameters. But only a few parameters are available for small-scale considerations, which is the casein torrent catchments. Thus only black box models are a possibility to meet the requirements in the availability of input data and result quality. With the aid of OptiMeth (*Rimböck et al.*, 2013), references from completed projects and expert knowledge, we chose two models for detailed investigations:

1. The modified runtime-model ZEMOKOST (*Kohl*, 2011), a hydrological model which is based on the 'time concentration' model suggested by Zeller (1974).
2. SCS-unit hydrograph model modified by Caspary (*Maniak*, 1997)

More or less, both models need the same input parameters:

1. **Topographic parameters** were determined in a GIS-program.
2. **Rated rainfall events** (height, duration, rate) which stem from the national heavy precipitation totals in Germany KOSTRA-DWD-2000 (DWD, 2005).
3. **Discharge coefficients** which come from a hydrotope (hydrologic units) map. The whole alpine area of Bavaria was mapped with hydrotopes based on vegetation, land use and soil properties. For each hydrotope a certain discharge coefficient (resp. Curve Number) was determined by heavy rain field simulations (Schauer 2014).

Application of Hydrologic Methods on Bavarian Torrents

To evaluate the model properties they were applied on selected bavarian torrents. Table 1 shows the test-torrents with some characteristics. The test torrents were chosen carefully regarding following aspects:

1. The catchments should represent a sample of a wide range of hydrologic conditions existing in bavarian torrent catchments.
2. Reliable gauge data must be available.

3. The catchments should be almost homogenous to keep the models as simple as possible and to gain comparable results.

Evaluation of Hydrologic Methods

Discharge measurements from the gauges were used to (1) reconstruct (extreme) events from the past and (2) assess the HQ_{100} by extreme value calculation. According to the data quality, assessing HQ_{100} peak discharges from measured discharge time series by extreme value calculation is the method with the lowest uncertainty. The statistical procedure is based on measured discharge data whereas the input parameters of rainfall-runoff models are assessed with uncertainty as well. Thus the results are used as a reference.

The historical event reconstruction was an important reference to evaluate the assessments of the model in terms of discharge volume. Also the rendition of the runoff reaction could be tested. Comparing the modelled HQ_{100} and the HQ_{100} gained by extreme value calculation, the models were evaluated regarding their performance to calculate peak discharges of extreme events. In the following only the results of peak discharge calculations are presented.

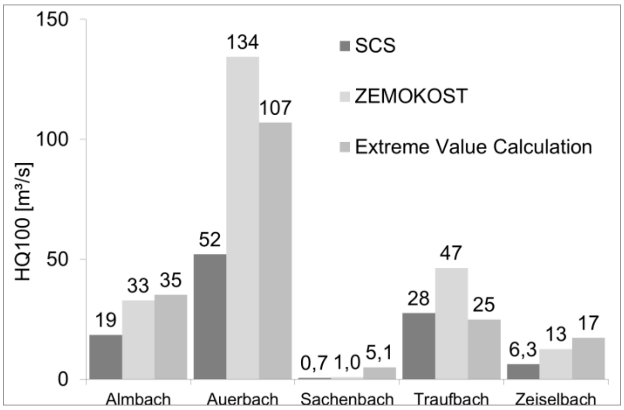

Fig. 2 Results of HQ_{100} peak discharges assessed by the SCS-Method, ZEMOKOST and extreme value calculation.

Figure 2 shows the modeled peak discharges of the 100 year precipitation event for the five test-torrents. Compared to the calculated HQ_{100} by extreme value calculation, the SCS method underestimates the peak discharge in 4 of 5 cases (mean error of 52%). ZEMOKOST is over- and underestimating the peak discharge values of the extreme value calculation (mean error of 45%).

Quantitatively there was no obvious argument prooving that one model delivers better results. Thus, the argument that the model with a consequent underestimation is easier to calibrate lead us to the point that the SCS method is more suitable for the issue. Also the fact that there is already experience in using the SCS method within water resources authority was a reason for the decision.

Calibration of the Most Suitable Hydrologic Method

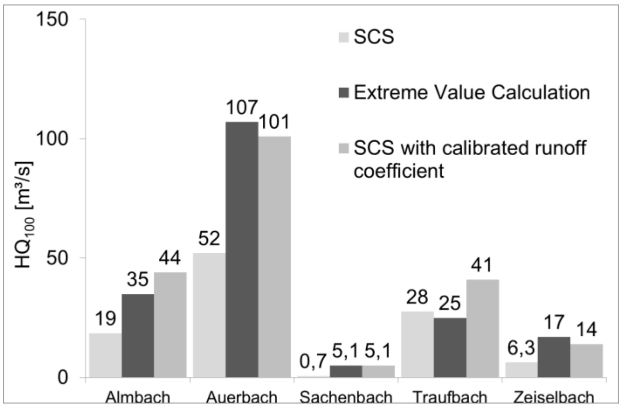

Fig. 3 Results of HQ_{100} peak discharges assessed by extreme value calculation and simulated with and without calibration.

The heavy rain field simulations showed that it is possible to correlate the hydrologic characteristics and thus the runoff coefficient with the parameters vegetation, land use and soil. However due to the high complexity of the interactions between different influences, there is a high variability in space and time. This causes a range of measured runoff coefficients (*Stepanek et al.* 2004). The probable range is an argument to use the runoff coefficient as the calibration parameter. The data source of the runoff coefficient was suitable for the implementation of an adaption.

Thus the runoff coefficients were calibrated to gain best correlation between modelled results and extreme value calculation from gauge data. The best fit was described through a linear regression. With the linear function of the regression, the runoff coefficients of the hydrotope map were adapted. Figure 3 depicts the results of the peak discharges before and after calibration of the runoff coefficients calculated with the SCS method. The deviation to the extreme value calculations from the gauge data should indicate the result quality. A mean error of 12% could be reached. The Traufbach was an outlier because of its specific runoff conditions, that cannot be detected with that kind of simple hydrologic model.

Validation of the Hydrologic Method

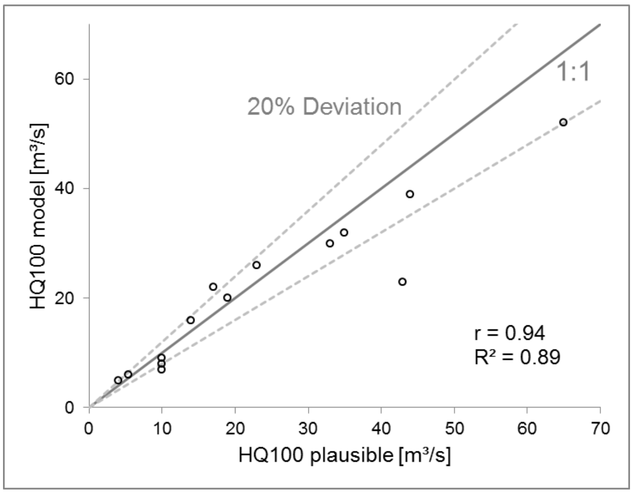

Fig. 4 Comparison of the HQ_{100} results gained from the developed standard method described in this paper with verified HQ_{100} values from already existing hydrologic reports.

Due to missing measured data, validation was done with verified HQ_{100} peak discharges assessed by alternative methods from existing hydrologic reports. Keeping in mind the small sample (N = 15), the validation showed satisfying results on average. The model quality is given by a correlation coefficient of r = 0.94 and a coefficient of determination of R^2 = 0.89 (see figure 4).

Conclusion Hydrology

The investigation showed that the assessment of design flood event with a simple hydrologic model is only possible with relative high uncertainty. The reasons are clearly given in (1) missing data for small-scale considerations (mean area of torrents in Bavaria: 5 km²) and (2) the simplicity of the method. Whereas the missing data is preventing an application of a high sophisticated and thus (in combination with a correct application) more accurate method.

That insight leads us to the point of view, that the application of the model may only be a single task in a comprehensive hydrology procedure. Besides preparatory work and modelling, the plausibility check plays a crucial role in the recommended hydrology procedure. We even postulate, that if the expert discovers reasonable arguments during plausibility check, the modelled HQ_{100} can be corrected to a more plausible one. It is clear, that the plausibility check delivers almost qualitative references, but in combination with the expert knowledge that information can be converted in quantitative assumptions and the model result can be corrected. In general that means if through the obligatory plausibility check no reference could be found that the modeled result is wrong, the value of the model is valid. If there are references that the modeled result differs from reality, the result should be corrected. That loop of review should not only compensate the uncertainty of the model, it also is an opportunity to give the user a chance to influence the result with his experience.

5. WAY TO PROVIDE THE STANDARD METHODS

The final result of the work will be provided by a digital platform where a manual, tools, data and case studies are collected for the personnel within the administration. In future, the document should also be used for placing of orders. The manual will be divided into three parts:

(1) Overview: systematic outline of the working steps (what is to do and where is the information); a checklist for advanced compilers

(2) Manual: Method description in detail; experts should be able to conduct the method with the help of this paper

(3) Details: further explanations, literature, tools, data, case studies etc.

For each torrential process which is to asses there should be a chapter with an identical structure. Documents and data are provided online. The dynamic online format allows a successive preparation of the chapters and an easy actualization in future. A further advantage of the online format the possibility to put links to information (tools, data, and case studies) at appropriate positions in the text of the manual via hyperlinks.

6. CONCLUSION

There is an abundance of methods existing to assess torrential processes. The background of the methods is often very special. They were developed for a certain interrogation or for special cases with a good data basis. An evaluation of usability of existing models for a wide application is difficult especially if the lack of data in torrent catchments is regarded. For these circumstances it is even harder to adapt an existing method to different boundary conditions or input data.

Nevertheless, models are very helpful and in many cases the main basis for assessing torrential processes. But the way how a user is applying it, is significantly influencing the result and its uncertainty. Besides user experience and qualification, a further reason is the availability of high quality input data which is influencing the result uncertainty significantly. The quality of data varies both as spatial and from dataset to dataset. To minimize those influencing factors we want to achieve, that the user should strongly rely on the manual which forces him to gather the input parameters with a standard procedure. According to our guidance, each input parameter has to be checked about its plausibility. This means a constraint degree of freedom for the user. As we have to reckon with a user group who come from different backgrounds, better results in average are expected. Hence, we try to strengthen the importance of plausibility check and make that working step to an essential part of the whole procedure. The plausibility check has the issue to collect entire relevant information for interpretation to validate or even adjust the model result. Thus, qualitative information is used additionally to find the result.

The investigations clearly showed that in many cases only qualitative information is available for assessing processes occurring during extreme events in torrential catchments. But nevertheless this information helps a lot in determining parameters of extreme events. If finally, the plausibility check shows deviations to the model result, the user should correct it. Otherwise the model result is confirmed. By this possibility the user gets a crucial degree of freedom to influence the result by his experience, quasi as counterpart for lost tolerance by a strongly defined method. In common procedures the user can influence the result during a lot of single steps. In our suggested procedure, the user must determine a result properly (obtained from a proved model). That result functioned as a decisional basis and only then the user has the chance to influence the result based on a carefully performed plausibility check.

Using one standard method for a large region like Bavaria could be seen critically. We are aware of the fact and know that every torrent catchment is individual. But we think more trustworthy and especially comparable results are revealed by the suggested standard procedure in average regarding the different wide spectrum of user group which are applying the procedure in such an extensive application. Nevertheless, the application boundaries have to be mentioned carefully.

Already first applications of the standard procedures show, that it is possible to create a standard method to assess torrential processes for a wide range of cases. We hope the methodology will be able to cover at least 70% of bavarian torrents. Only an experienced practical application will evaluate the usability of the suggested standard methods. Finally also this standard will be further developed in future, regarding new data or new technical evolution.

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