Extreme Torrential Flooding at Simbach on June 1st, 2016 - Key Findings of a Detailed Event Analysis -

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In 2016 an extreme flood event occurred in Simbach, Germany, which caused enormous damages and also 5 fatalities. Some characteristics of the event were unexpected such as a very quick rise of the water level to an extreme height. Additionally a street dam upstream of the city and a dyke in the settlement area got overflown and both broke.
To better understand the event and its processes a detailed event documentation and analysis were initiated. In addition to the collection of lots of photos and videos the event was reproduced in a hydrologic model. Further a hydraulic model was built up to simulate the flow patterns. Finally the peak discharge could be reconstructed by all these calculations and analyses of the photos. It was far more than the design flood, a 100years flood. Additionally the main questions about the processes could be answered by this analysis.
Thereby we learned a lot about such extreme events and could draw first conclusions. So this highlights the necessity of a sound event documentation and analysis. But also many of the questions need further analyses of more events. Nevertheless also further discussion and societal consensus about the strategies how to handle remaining risks is necessary.

Key words: Simbach, event analysis, dam failure, hydrologic modeling, hydraulic modeling

1. OVERVIEW SIMBACH CATCHMENT

In the town of Simbach the torrent Simbach flows into the Inn river. The catchment comprises around 33 square kilometers. Already during the 1950s torrent control measures with state of the art techniques were installed in the Simbach. After the flood events in 1991 and 1999 the flood protection of the town Simbach was further improved. The Simbach is primarily fed through the Antersdorfer Bach (catchment of 13 square kilometers) and the Kirchberger Bach (15 square kilometers), which merge into the Simbach north of the town. The Simbach is crossed by the Schulstraße and subsequent by the heavy frequented federal road B12. At both road embankments the river passes the road via a culvert. The culverts are designed for a 100 years flood event (assessed at time of construction). Between the both junctions a sawmill is situated right near the channel of the Simbach.

Subsequently the torrent flows for around 500 meters along a stretch without control measures before passing through a funnel-shaped inlet structure into a rectangular channel just above Passauer Straße. The gauge Simbach is situated in this developed stretch. In the lower reach flood protection dykes run along the Simbach up to the mouth into the Inn. The channel of the Simbach in the town was designed for a discharge of 60 cubic meters per second plus freeboard.

In the south the town is differentiated from the Inn through levees (= flood protection dyke Inn). As a result the polders Simbach (in the west) and Erlach (in the east) are formed which are drained through pumping stations.

2. EVENT ON JUNE 1st, 2016

On June 1st, 2016 heavy rainfall caused a sudden and extreme flood event in the torrent Simbach. The culvert in the street dam Schulstraße was not able to drain the huge discharge. Therefore the dam was overflown and eroded. The channel of the Simbach in the town could not keep the mass of

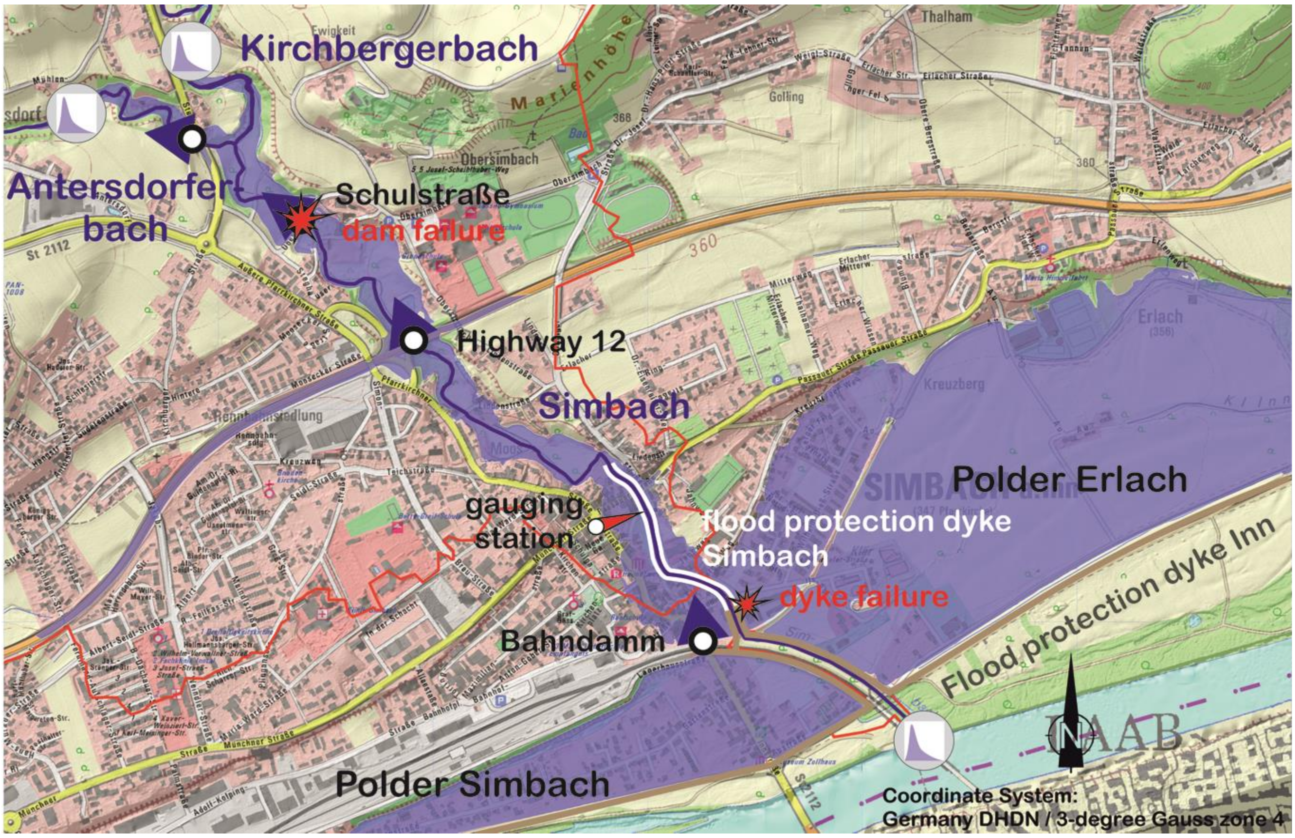

Fig. 1 General map of the town of Simbach (BOKU Vienna)

water. As a result large quantities of water were flowing through the center of Simbach. The dykes along the torrent were overflown and the left one to the Polder Erlach (at Wilhelm-Dieß-Straße) eventually breached. More than two million cubic meters water accumulated in both polders together (**Fig. 1**). Due to the levees along the Inn the water could not drain into the receiving stream, which at that time was not prone to flooding. The pumping stations were overburdened by the extreme amounts of water. To relief the polder Erlach a levee was opened temporarily (**Fig. 2**). In addition mobile pumps were used.

At the gauge in Simbach the channel depth is around three meters. The maximum water level during the event was more than five meters – determination of discharge through the rating curve was not possible.

The event caused very high damages. Besides the high damage to property five casualties were to be mourned. A lot of people had to be evacuated or rescued from acute danger to life. Several citizens could not return to their homes due to danger of collapse. Fresh water supply and waste water disposal was limited and partly broken down. Important traffic routes were interrupted causing major traffic problems (**Fig. 3**).

Fig. 2 Artificial levee breach (Source: VERBUND Innkraftwerke GmbH)

Fig. 3 Flooded federal road B12 (Source: Polizei Niederbayern)

3. MOTIVATION FOR DETAILLED EVENT DOCUMENTATION AND ANALYSIS

Such an extreme event should always be a reason to critically evaluate currently used protection strategies. It also helps to deepen the knowledge about natural processes and also to scrutinize established models. An important prerequisite is a prompt event documentation and therefore collection of valuable data. For that reason the Bavarian Environment Agency (LFU) commissioned the University of Natural Resources and Life Sciences, Vienna (BOKU) for a detailed event analysis.

The discharge pattern in Simbach was complex. Important elements were the backwater at intersecting structures, the failure of the street dam at Schulstraße, the dyke failure at Wilhelm-Dieß-Straße and numerous log jams. For experts as well as persons concerned the course of events raised numerous questions.

According to the EU Floods Directive areas prone to flooding were calculated in three scenarios (frequent, medium and extreme flood) before 2016. These calculations showed correct tendencies for the cases of overload. But the event in 2016 was even more extreme (**Fig. 4**).

After the event the search for someone/something to blame immediately started in the media. It was especially focused on the overloaded culvert at Schulstraße – together with the failure of the street dam – and was seen as the central cause for the catastrophe.

Other headlines such as “Maize and the century flood” targeted agriculture as main cause for the flooding. One aspect certainly is the increased surface runoff on compacted cropland, which is only slightly covered at the start of the vegetation period. In addition soil erosion is playing an important role during heavy rain. During the event on 1st of June 2016 large quantities of fine sediment were transported. After the retreat of the flood these sediments covered wide areas of the town.

The large quantity of press releases with various theories regarding this exceptional event in Simbach shows that many aspects need to be taken into account.

Through an elaborated event analysis the University of Natural Resources and Life Sciences tried to reconstruct discharge patterns on the basis of Data, measured values, photos, videos and interviews.

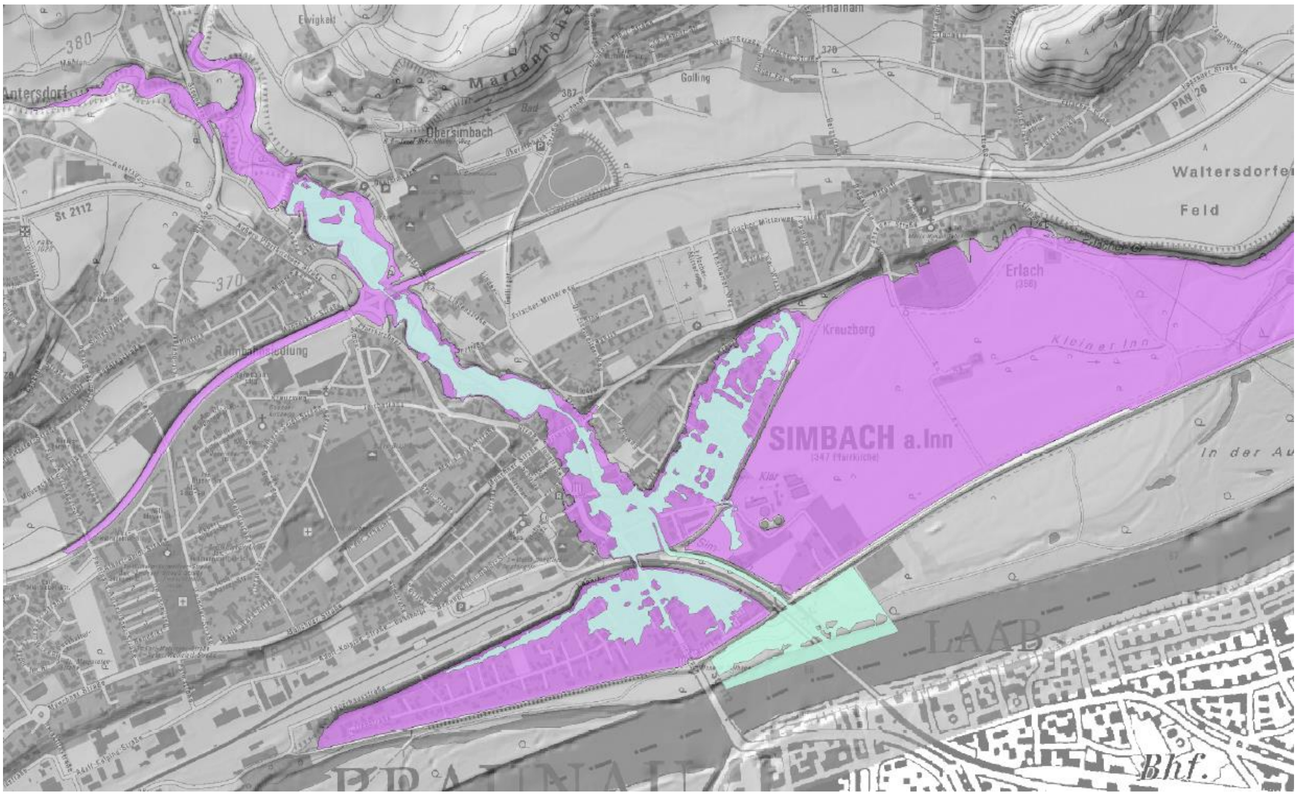

Fig. 4 Comparison of the flooded area on June 1st (purple) and the hydraulic simulation for an extreme event (cyan)

4. INVESTIGATIONS AND RESULTS

The investigations should help to answer the following questions:

- What would have happened, if no failures of structural measures would have occurred?
- How much did the dam failure influence the hydrograph and the flooded area?
- What would have happened, if the dyke would not have failed?

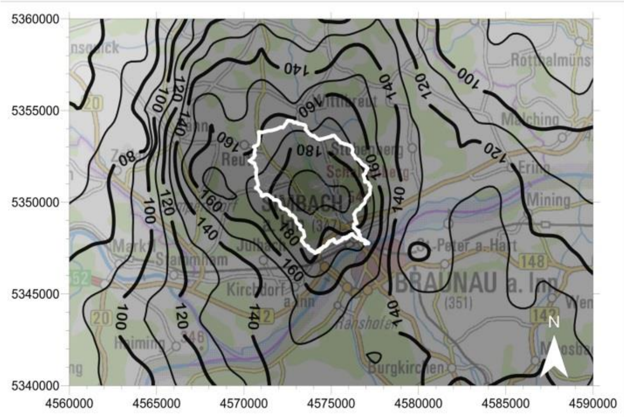

Fig. 5 Areal precipitation for the period from May 31st 07:00 to June, 2nd 00:00. The black lines indicate the calculated isohyetes, the white line the boundary of the Simbach catchment.

The first questions aim for the definition of a “natural” hydrograph, which is subsequently adapted to the failure situations. This means to combine a hydrological model with a hydraulic model, because downstream of the junction of the two tributaries two road embankments are situated, each crossed by a corrugated steel pipe arch, which caused remarkable retention effects. In addition, the hydraulic model should facilitate the simulation of the inundation areas to compare the flooding areas according to the research questions.

The first objective of the detailed analysis was to reconstruct the triggering rainfall and the maximum discharge during the event. Therefore, data of recorded rainfall at the observation stations in Bavaria and Austria were used to calibrate the weather radar data from the Germany's National Meteorological Service (**Fig. 5**). The water height was monitored by a gauging station within the town. The recorded water level was far above a proven rating curve, therefore the rating curve had to be expanded from 2.6 to more than 5 meters. With this upgraded rating curve and using 1D and 2D hydraulic simulations of the area around the gauging station, the hydrograph of the flood event was derived. However, this hydrograph represents the “natural” event, including the retention effects of the dams, the breach surge, and, after the depletion of the retention areas, the natural runoff of the catchment. To get more insights into the flood dynamics at different sites and to detect the time of dam failures, nearly thousand photos and more than 60 videos were analyzed and the time record of the pictures determined by individual inquiry (**Fig. 6**). Additional water marks were surveyed in the flooded areas to ascertain the flow height at different locations and to later compare these values with the results of the hydraulic simulation.

The second objective was to set up a conceptual hydrological model and to calculate the natural runoff at the junction of the two tributaries. Spatial distributed data of soil types and their hydraulic properties, vegetation and land use were applied as input data as well as the derived time and space distributed rainfall. The model was than calibrated with several minor flood events of the last decades. The resulting hydrograph was used as input for the 2D hydraulic simulation. The hydraulic model has to cover all the flooded areas. The topographical model was based on a one meter grid and the channel geometry on a detailed survey. The culverts and bridges were implemented as boundary condition. Because of the clogging of some of these structures, different scenarios were calculated.

Fig. 6 Discharge at the upper end of the channel through the town about 120 meters upstream of the gauging station. Natural runoff (left) just before the arrival of the breaching surge (right) (Source: Köck)

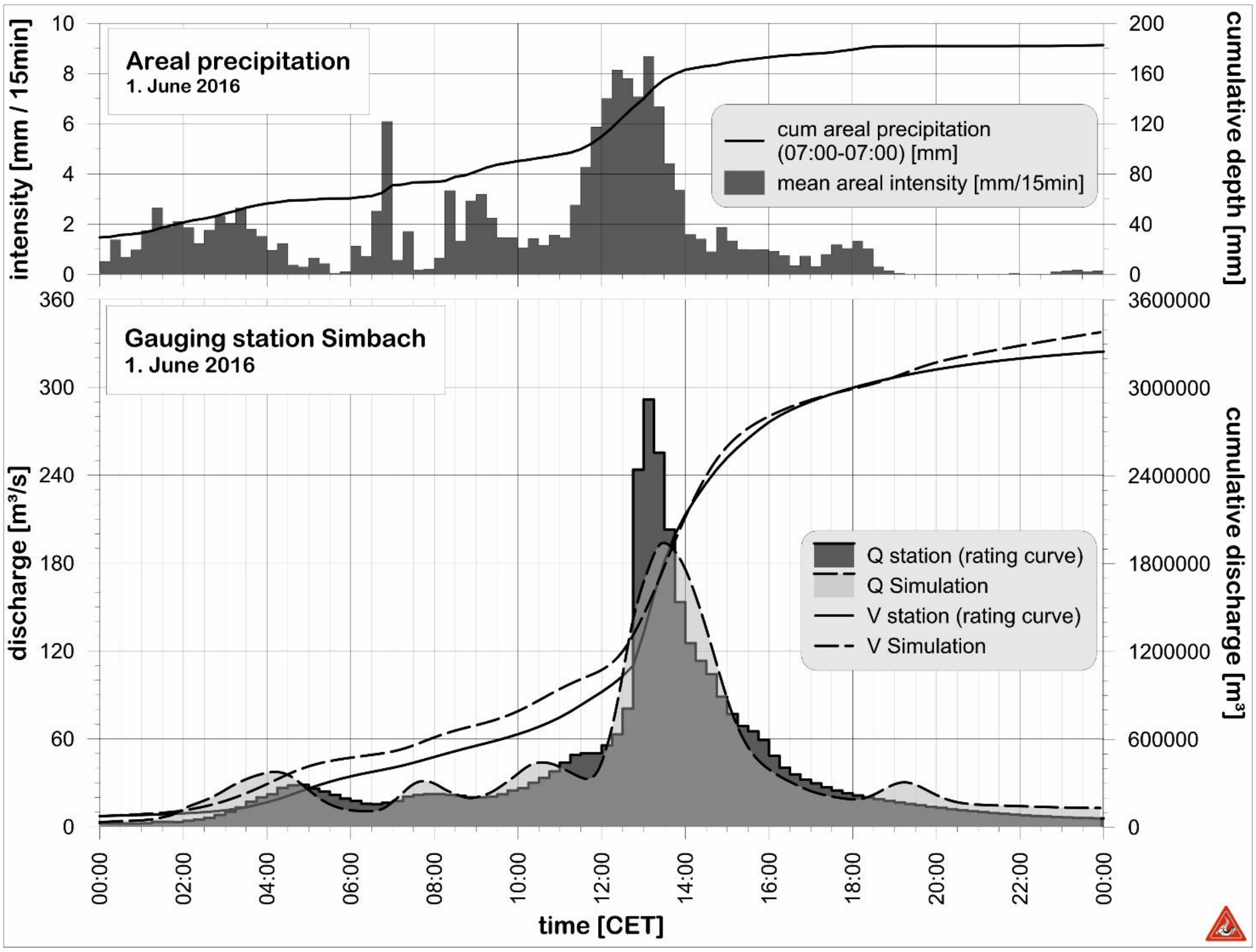

Fig. 7 Areal daily precipitation for the Simbach catchment and observed discharge at the gauging station compared with the hydrological simulation results for the „natural" runoff.

Roughness coefficients were assessed according to the land use. Buildings were identified as no-flow areas. With these input data the flooding area of the "natural" flood was simulated.

The third objective was to identify the effect of the dam failure in the upstream area and the dyke failure within the town of Simbach. Therefore, the failures of the street dam and the dyke were implemented into the hydraulic model. Different scenarios were defined, varying the model parameters like breaching time and opening width development. The flooding areas were then calculated and a resulting hydrograph at the gauging site compared with the recorded one. Additionally the flow heights at the locations with water marks were compared with the simulation results.

The analysis estimated the maximum discharge of about 280 cubic meters per second at the gauging station during the event. This value resulted from the superposition of the natural runoff with the breaching discharge (**Fig. 7**). The natural peak discharge was estimated with 180 cubic meters per second, meaning a specific discharge of 6.6 m³/s·km². This very high runoff resulted from:

- the high amount of rainfall, corresponding to an aerial daily precipitation depth of more than 180 mm. The return period of this daily rate exceeds 100 years.
- the cell of the shower moved downstream from the headwater.
- the shape of the hyetograph. Considering the period from May, 31st 07:00 to June, 1st 19:00 the hyetograph shows, that 50 percent of the precipitation fell within 20, or 40 percent in about 10 percent of this period, more or less concentrated at the end of the rainfall period.
- the development of a dense system of rills and small gullies on agricultural areas and the use of paths, tracks and roads as flow paths that led to a short time to peak.

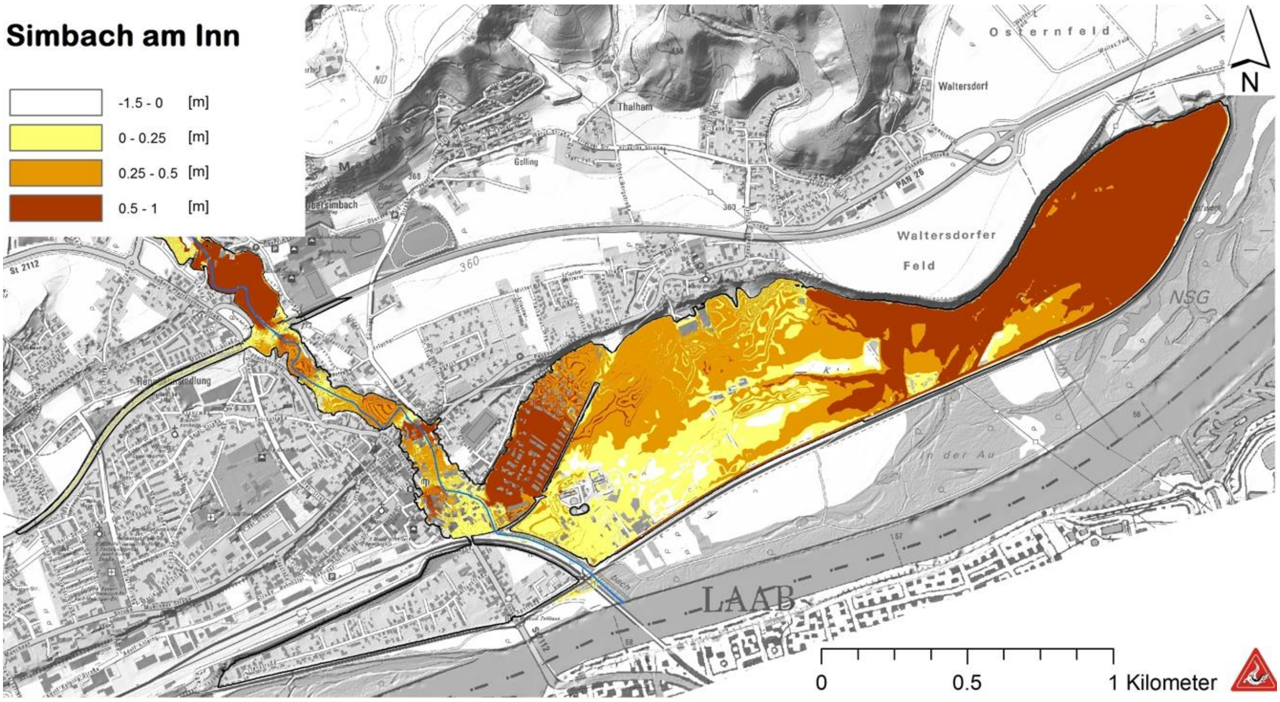

Fig. 8 Difference of flow heights in the flooded area of Simbach by comparing the results of the flood under "natural" conditions versus the results of the flood including the effects of the failures of the structures.

The calibration of the hydrological model was quite difficult, because the already recorded peak discharges were quite smaller. Utilizing long time series of rainfall and runoff a peak discharge of only 95 cubic meters per second could be calculated. Therefore, the model parameter (esp. retention parameter for surface runoff and interflow) were adjusted to get more plausible simulation results. A comparison with the peak rate factor, which is implemented in the HEC-HMS model, yields to a doubling of the suggested value of 484 [-].

The dam breaching resulted in an increase of the discharge of more than 120 cubic meters per second downstream of the dam (~350 cubic meters per second) and diminished along the channel down to the gauging site. Comparing the flooded area of the natural runoff and the scenario including the dam and dyke failure, it can be stated that the flooded area was not considerable enlarged by the breaching hydrograph, but the flow height increased about 0.5 meters in the town (**Fig. 8**).

The scenario without the dam and dyke failure lead to a peak discharge of about 180 cubic meters per second at the gauging stations, the polder Simbach is filled up with 0.6 million cubic meters, whereas the polder Erlach is charged with approximately 0.15 million cubic meters. Assuming the discharge with dam and dyke failure, the polder Simbach gets a surplus of 0.35 million cubic meters and the polder Erlach 0.75 million cubic meters. This means, that the structural failures changed the charging behavior of the polders by the flood.

5. INSIGHTS FROM SIMBACH

The event on 1st of June 2016 in Simbach and the following event analysis provides valuable and important findings with regard to dealing with extreme events in the future. It also showed possible conflicts in the course of flood risk management.

5.1 Technical recommendations

The calibration of a hydrological model with time series without flood events of medium to low probability may lead to an underestimation of a calculated peak discharge for an extreme flood. The Simbach example shows, that a rainfall with a return period of about 300 years lead to a peak discharge that is more than twice of a one hundred years flood. Therefore, hydrological critical spatio-temporal rainfall conditions have to be considered.

Extreme events do not behave in a regular way. Hydraulic critical conditions usually lead to failures of structural measures, drastically modifying the hydrograph and the extent of flooded areas.

5.2 Strategic consequences for the management of extreme events

5.2.1 Preparation for extreme events

After a flood event the question arises, how to prepare for events in the future at the best. The risk management cycle, which is also positioned in the

Bavarian flood protection program „AP2020plus“, provides several aspects in this context. In the following two examples are explained:

1.) Take necessary time for in-depth planning: Immediately after an event the reconstruction starts. The authorities in charge have to repair damaged infrastructure facilities and protection works as fast as possible. A balanced mixture of urgent measures and an in-depth planning is essential in practice. On the one hand legal obligations have to be fulfilled. Otherwise an economic and in every respect optimized solution should be strived.

Structural protection measures are usually expensive. Therefore an in-depth and detailed planning should be taken as basis for every measure. Even if wide-ranging researches take up a lot of time and occasion additional costs, the gained information help to save expenses in the execution of construction work.

2.) Prepare for phase of reconstruction: In many villages the settlement area moved steadily closer to the streams within the years. Riverine zones, which would provide enough space for structural protection measures or sufficient discharge sections, are rare. After a flood event the authorities in charge should try to acquire land along the waterbodies. People concerned recently are more likely to allocate a part of their property for protection measures or even resettle in a more secure area.

But the timeframe for this bargain is only short. Even serious events vanish into oblivion surprisingly fast.

In this context it is necessary to be prepared for (extreme) flood events and at least consider possible cases of overload. So in-depth considerations before the event can lead to a reasonable reaction (“build back better”). It is also a necessary prerequisite to reach a real improvement and to better cope with such events.

5.2.2 Necessary discussion: how society wants to deal with extreme events

For a lot of questions regarding extreme events there are currently not yet clear answers respectively not yet a societal consensus on how to deal with them.

For example, events such as the one in Simbach raise questions up to which level technical flood protection for a recently affected municipality should be designed. Affected persons frequently demand that „such an event may never happen again“ (implying a desire for a higher protection level). A (fair) statewide consistent approach requires fair and comparable calculation of design events.

In both cases a residual risk will remain. Central questions are: How do we want to deal with this residual risk? Accept it? Reduce it by (cost-effective) measures such as alert strategies and emergency plans? Or transfer the risk to others such as insurances?

Flood risk management is a collective task where many parties are to be involved – from state to municipality as well as individuals. The role of the state is established up to the design event. To what extent the state is in duty to care for protection above the design event? Can the responsibility for personal provision be expected by the citizen or is this expectation too much for the individual? Does the state in the field of residual risk need to take action additionally to increasing hazard awareness in municipalities and the society through continuous and targeted risk communication?

The relatively young approach of integral flood risk management has to be filled with life in the future. Through this the impacts of natural events on livelihoods, environment, cultural heritage and economy can be further reduced. On this occasion aspects of extreme events need to be incorporated.

6. CONCLUSION

Extreme events like the one in Simbach show that these are no theoretic scenarios but can become real quite quickly. Society has to deal with these risks. In addition to it discussions are needed which risks can be accepted and how to deal with residual risks. Risk dialogue in an integrated risk management offers an ideal platform. Though many existing measures for risk reduction have to be adapted for extreme events or further developed.

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