2-step flood warning system for railways

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1 Introduction

Due to the slope of rivers many railway lines in alpine regions follow the course of rivers. This often turns out to be the only possible way for an economic and reasonable design of railway lines. In case of extreme precipitation not only the danger of flooded or washed out railway tracks has to be kept in mind, but also the possible danger for passengers on a train. In the last years a series of flood events caused the national railway operator ÖBB to close down several tracks: In August 2002 a passenger train was stopped by a flood wave at the Salzach river between Werfen and Golling (Figure 1); in 2005 the railway connection between Tyrol and Vorarlberg had to be closed down for three months due to heavy damage on the tracks caused by floods; in the same year, tracks were flooded along the river March in Lower Austria. These events caused the ÖBB to commission a project to develop a warning system to ensure the safe transport of passengers and goods. The aspired lead time is in the range of 2 to 4 hours. The combination of information from various sources and additional hydrologic and hydraulic analyses shows that warnings can be issued not only for existing forecasting locations but also for other locations which are flood-prone. A warning and monitoring scheme is developed. This 2-step warning system has been implemented at the Westbahn in the Austrian province of Salzburg.

Figure 1 Situation on August 12th 2002, 10 a.m., at Pass Lueg on the river Salzach

2 Analyses

The project "Hochwasserrisikozonierung Austria (HORA)" (*BMLFUW, 2006; Merz et al., 2006; Willems, 2006*) provides information about possible flood inundation zones along rivers in Austria for discharges with a return period of T = 30, T = 100 and T = 200 years. These zones are displayed in aerial pictures. For a first identification of endangered locations the HORA results are combined with informations from the ÖBB concerning track interruptions due to natural disasters like floods, avalanches and debris flow. The information gained from the HORA pictures shows that the location shown in Figure 1 is located within a possible flood inundation zone.
The Hydrographic Service Salzburg runs the forecasting model HYDRIS which provides forecasts for the gauges Werfen and Golling at the river Salzach. The basis of the forecasting model is a river basin model with an updating procedure based on the Kalman-Filter and the Bayes' theorem with an

integrated power plant module (*Gutknecht, 1994; Wiesenegger, 2006*). On August 12, 2002, at 2 a.m. the forecast showed a rapid rise in discharge from around 300 m³/s to 900 m³/s within the next three hours. The actual peak was observed at 9 a.m. with a maximum value of 866 m³/s.
The runoff contribution of the catchment between the gauges Werfen and Golling along the river Salzach is analysed by comparing hydrographs from the two gauges. Steady and unsteady hydraulic simulations are carried out under consideration of the findings of the hydrologic analyses with the 1D model HEC-RAS (*Brunner, 2002a; Brunner, 2002b; Warner et al., 2002*) for the August 2002 event. By means of hydraulic parameters taken from the literature (*Heinemann, 1998*) the simulated waterlevel at Pass Lueg reproduces the observed level well.
The results of the hydraulic simulation show that the forecasts at the gauge Werfen can be extrapolated to any flood-prone location along the river. For Pass Lueg, the location where the train was stopped by the approaching flood wave, it would have been possible to issue a flood warning with the existing forecasts eight hours prior to the incident.

3 Warning and monitoring system

During the project phase a communication system was established between the Hydrographic Service Salzburg and the ÖBB (Figure 2). It is now possible to issue flood warnings for the railway tracks along the river Salzach.
In the case of a critical hydrologic forecast at the gauge Werfen a flood warning is issued by the Hydrographic Service to the ÖBB department *Infra.SERVICE* up to 24 hours ahead of the expected peak discharge. This gives the ÖBB enough time to examine the condition of the tracks at the critical locations in order to be able to evaluate possible damage after the event and organize additional workforce.
Infra.SERVICE receives continuous updates from the Hydrographic Service on the hydrologic situation along the river. If a further rise of the waterlevel can be expected, *Infra.SERVICE* issues a flood warning to the ÖBB department *NETZBETRIEB* two hours before the forecasted critical discharge. A decision is made based on the information from the Hydrographic Service and additional tables and diagrams based on the hydrologic and hydraulic simulations. The warning two hours before the critical discharge/waterlevel is sufficient for the railway operator to organize bypasses of international trains and replacement busses.
Confirmation of the warnings and actions taken are as important as the warning itself. By means of the warning scheme presented in Figure 2 in summer 2006 a flood warning was issued to the ÖBB by the Hydrographic Service Salzburg.
In addition to the expert knowledge from the Hydrographic Service on-site information from flood-prone locations are helpful for the decision makers within the railway company. A possible solution could be the observation of the locations with a network of cameras: Pictures could be broadcasted to the control stations in the case of flood warnings and could be used as assistance in the process of decision making.

4 Conclusions and Outlook

The 2-step warning scheme offers advantages for both parties involved: the ÖBB receives timely and reliable flood warnings, the Hydrographic Service gets additional information from the flooded area. The proposed method can be transferred to railway tracks following rivers with existing forecasting systems. The premises will not always be as good as in Salzburg: in the case of no existing forecasting system hydrographs have to be analyzed regarding discharge prior to the event, precipitation amount, time of concentration, etc. The outcome is a catalogue of scenarios in which the results of the hydrologic and hydraulic analyses are summarized in tables or graphics. This catalogue can serve as a support for the persons in charge within the railway company in deciding whether or not to close down a track.

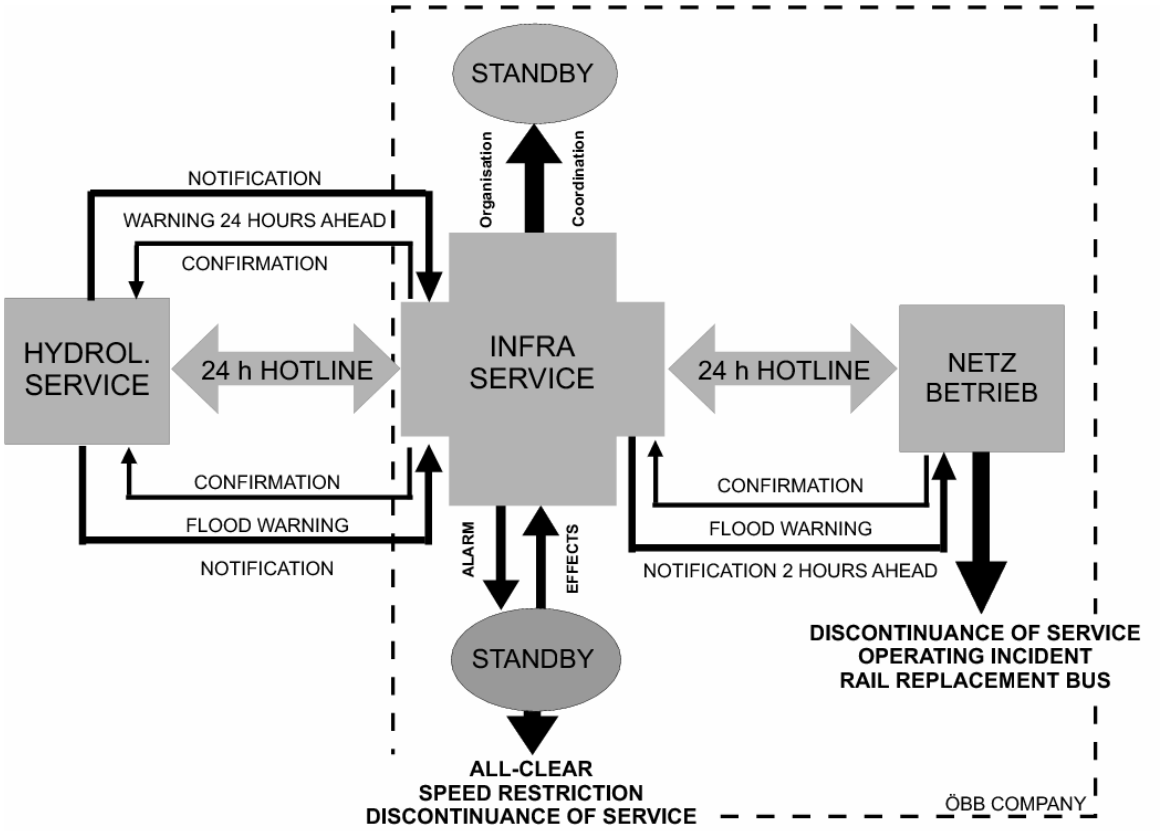

Figure 2 Warning system established between the Hydrographic Service Salzburg and the railway operator ÖBB. Every warning issued has to be confirmed by the receiving authority.

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