The flood warning service of the Austrian Federal Railways

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ABSTRACT

According to Austrian legislation, the Austrian Federal Railway Infrastructure Company (OEBB Infra) is responsible, on one hand, for the safety and on the other hand for the high availability of the national and transnational railway tracks in Austria. To fulfil these high demands different countermeasures against natural hazards are necessary. Beside a high range of technical protection measures also organisational measures such as flood warning services are very important. On the basis of experiences a 3-phase warning service was developed. With the incoming weather forecasts the Early Warning Phase of the OEBB Flood Warning service starts and preliminary analyses of the expected development of the flood event are initiated. The most important step during the event phase is to initiate the required emergency measures. The end of a flood event is the beginning of the next event. An accurate event documentation is very helpful to improve the warning processes and to plan optimal countermeasures.

KEYWORDS

Railway infrastructure; flood warning service

INTRODUCTION

Since natural hazards have impact on the safety, availability and economy of railway infrastructures, therefore the protection of transported people, the railway staff and goods must be the top priority of natural hazard management. Regarding the fact that damage on railway infrastructure can be substantial and hindering, the Austrian Federal Railway Infrastructure company (OEBB Infra) is continuously improving its services and fully liable for safety issues.

Floods, especially those with a large spatial extent, cause enormous costs for recovery of the railway infrastructure such as train stations, tracks, bridges or catenaries. The flood events on the Arlberg in 2005 and the flood event on the March River in 2006, as examples, generated total costs of 80 Million Euro for infrastructure recovery. Following the risk circle (Figure 1) there are different possibilities to reduce the risk of natural hazards. Risk maps, as a valuable support for planning preventive measures, help to identify flood-prone areas. Technical countermeasures such as flood protection dams in Austria are designed by using flood events with a 100-year return period and neglecting larger events. Warning services, contingency

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planning and –training as organisational measures support the handling of disasters. As pointed out by Rudolf-Miklau (2009), measures, if applied in optimal chronology and functional order, are likely to achieve their intended effect.
However, the hazard itself cannot be avoided, thus the main objective of organisational counter measures is to protect lives. The early observation of natural hazard events through the use of warning systems is crucial, especially in the case of failure of technical counter-measures. Therefore, OEBB Infra is intensively working on the development of comprehensible and robust systems to predict meteorological and hydraulic events.

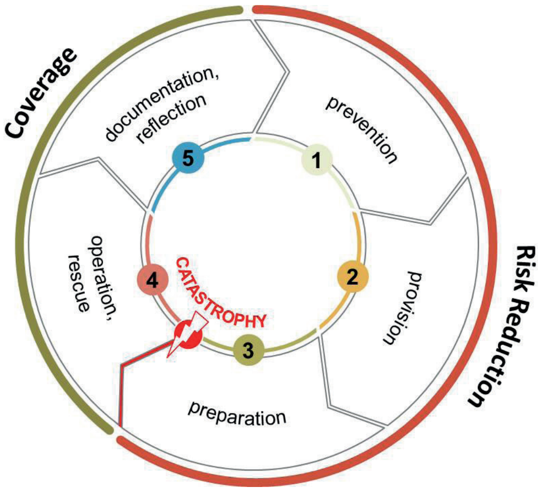

Figure 1: OEBB Infra - Risk Cycle

STRATEGIES AND TOOLS

Natural Hazard Management aims at reducing risk specifically by following the phases of the Risk Cycle. When it comes to floods, infrastructure operators have various means for the protection of technical facilities as well as for the absolute safety of their customers and employees. Primarily, there are technical safety measures such as flood protection dams or mobile flood protection walls alongside the endangered track. By creating flood risk maps, endangered hot spots of the railway can easily be identified and thus contribute to preventive measures as best as possible. In the phases of provision and preparation, organisational measures are included, such as emergency trainings which are executed on a regular basis to ensure a well prepared and skilled staff. Furthermore, alarm plans are elaborated for specific railway sections and warning levels. The OEBB Infra operates its own weather information- and warning system called "infra:wetter". This includes Austrian-wide weather forecasts, real time weather radar data as well as customised warning levels for defined rail sections. Additionally, the web page supplies all users with specific information about fire- and avalanche risk and gale warnings. It provides those responsible for the affected area standardised and replicable weather warnings for the assigned parts of the railway network via text message and e-mail. These customised warnings are crucial to the preparation of organisational countermeasures against extreme weather conditions. Nevertheless, it does not offer hydrological and hydraulic information about rivers relevant to the railway network.

Due to gathered experiences at the last events it became clear that the earlier one knows about possible flood events the better organisational countermeasures can be taken, such as:
- Constant observation of the flood-prone hot spots
- Closing of the affected tracks in advance
- Evacuation of flooded areas

METHODS AND IMPROVEMENTS

In extension to the former approach, which was exclusively based on weather and precipitation forecasts, the flood risk warnings also incorporate the analysis of historic flood event data as well as flood forecasts and the expertise of hydrological warning services. The utilised flood risk maps also include three-dimensional spatial analyses which take into account railway structures such as bridges and culverts instead of the flooded areas along the track only.
A fundamental value of information lies in the height of the railway facilities referred to the considered water level (so called 'warning sections'). The inclusion of as much existing data and information as possible (for example administrative hydrological warning systems and the expertise of Federal Hydrographic Services) is just one crucial improvement of the flood warning service. –. Through well-established hydrological models of the Hydrographic Services, flood level forecasts (depending on the size of the observed river catchment) can be provided several hours in advance. In addition, the Natural Hazard Management of the OEBB Infra together with the hydrologists of the federal services determine on certain water gauges which are of particular interest for the flood warnings for the railway tracks. In case of an announced flood event, the water levels of the selected water gauges will be included in the flood report of the Federal Hydrographic Services and thus help to further improve the local flood warnings.

ASSESSMENT OF FLOOD POTENTIAL FOR RAILWAY INFRASTRUCTURE IN AUSTRIA

The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMFLUW) holds a complete dataset of flood-prone areas, water depths and flow velocities in Austria. This dataset is a collection of all available data from the technical departments of Austria's nine provinces, the Austrian service for torrent- and avalanche control as well as the Federal Ministry. It covers three scenarios in form of the return periods of 30, 100 and 300 years and serves as a valuable, nationwide overview of the flood situation and offers a good basis for the assessment of the flood potential for the railway infrastructure in Austria.

FLOOD WARNING LEVELS

A first step for the detection of flood affected areas was a spatial intersection between the railway network and the available flood scenarios. To emphasise the relevance of the data basis, a distinction between the various classes of data origin was displayed as separate maps. In a later stage, the accomplishment of a delineation of relevant areas for the warning process which would take into account three-dimensional flood height information from a digital elevation model was a top priority. The combination of distance to the rails and the height difference between the water level and the top of the railway embankment is classified in three warning levels:

- Orange warning section: marks flooded areas close to the railway track with significant height differences and thus rails are unlikely to be affected by a flood.
- Red warning section: identifies flooded areas close to the railway track with little height differences and thus rails are likely to be affected by a flood.
- Purple warning section: reveals intersections between flood areas and railway tracks.

A detailed explanation is given in Figure 2. The warning sections visualise the potential extent of flood scenarios for three different return periods. This information represents different cases in a static way, whereas the dynamic part is included by incorporating incoming (hydrographic) warnings. Depending on the forecasted warning, the most appropriate case is used to identify areas where measures have to be taken. The spatial classification

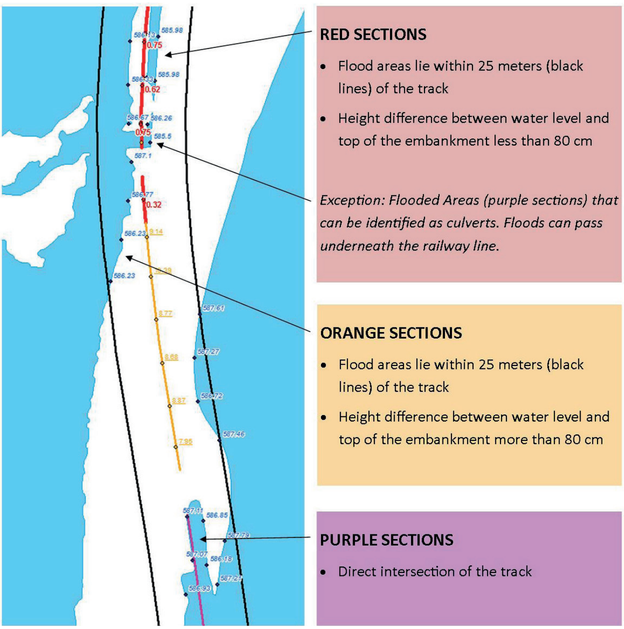

Figure 2: Classification of Warning Sections

of warning sections for flood events is designed in a way that is consistent with the warning levels of the weather warning system already in use. This enables an implementation into the existing internal web GIS and provides the users with an already familiar classification scheme.

PROCEDURE OF THE FLOOD WARNING SERVICE

The Flood Warning Service is divided into three different phases, using the available data basis to achieve the best possible result (Figure 3). Furthermore, the on-call availability of a service operator providing this service, as well as the involvement of several key figures guarantee a successful, smooth and especially continuous performance of the Flood Warning Service.

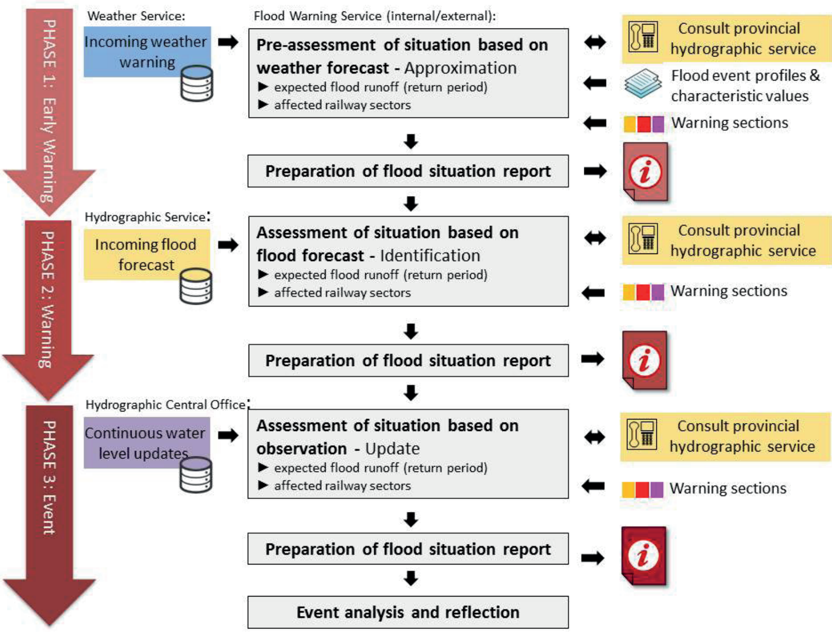

Figure 3: Procedure of the Flood Warning Service of the OEBB Infra

PHASE 1: EARLY WARNING

With the incoming weather warning from the above mentioned internal weather warning system(usually 3 to 5 days prior to the forecasted event), the 'Early Warning Phase' starts together with the initiated preliminary analyses of the expected development of the flood event. These analyses use characteristic values and summarised flood profiles of known historic flood events in the affected regions and river basins. The flood event profile aims at giving a clear overview of each individual historic flood event. It contains detailed information about the hydro-meteorological system state, the precipitation, the runoff and a textual description of the event.

By comparing weather forecasts to historic flood events, a rough estimation of the scale of the expected flood (return period) is attempted. The responsible federal Hydrographic Services are consulted in this early phase of the warning system for the characteristics of the catchment. The next step is to approximately identify the affected railway sectors according to the warning level classification. The periodic flood situation report summarises all crucial information, which was collected, analysed and prepared by the Flood Warning Service during the Early Warning Phase. It supports the Natural Hazard Management of OEBB Infra in taking decisions and initiating measures in the emergency planning.

PHASE 2: WARNING

The Warning Phase is initiated as soon as specific flood forecasts are provided by the Provincial Hydrographic Services. The flood forecasts are the result of hydrological models and are interpreted by experts with comprehensive regional knowledge. Thus, the preliminary analysis can be updated due to this additional data. On the basis of hydrological modelling, the estimation of the expected flood (return period) ensures a rather accurate identification of affected railway sectors.

Furthermore current water gauge levels are published by the Hydrographic Central Office. Subsequently, predefined threshold values are monitored for each identified railway sector. As before, all crucial information for the support of the emergency planning is summarised in the flood situation report. The warning phase lasts from when flood forecasts are available until certain water level thresholds are exceeded.

PHASE 3: EVENT

With the observation of the water gauges, once again, the expected event scale can be updated and the identification of affected railway sectors can be derived. The most important measure during the event phase is the initiation of the required emergency measures, which means that an incident command is installed and the general management decides about temporary mitigation measures such as constant observation, mobile flood protection or railway closures. Additionally, constant communication between the involved authorities (OEBB, the Flood Warning Service and the Hydrographic Services) is highly important.
The flood situation reports are generated in shorter intervals and focus on the temporal course of the event. As soon as the water gauges show a decreasing in water level, the general management decides on the end of the alarm.
Shortly after the flood event, analysis is carried out and the possibility for reflection among the involved experts to gain fundamental experience and to improve the Flood Warning Service with every event is given.

FLOOD SITUATION REPORT

The Flood Situation Report (Figure 4) is the core element of communication between the Flood Warning Service and the OEBB. It summarises current information on potential flood risk in a catchment. It supports the Natural Hazard Management of the OEBB Infra by providing important professional advice for the decision making and initiate mitigation measures during the emergency planning. More specifically, it contains the following parts:

- River catchment
- Description of meteorological and the hydrological situation
- Characterisation of the system's state (soil moisture, snow fall, snowmelt, zero degree line)
- Estimation of expected runoff (scale of flood event as return periods)
- Identification of affected railway sections
- Summarised experts' opinion

1	**River basin**
	Main river + relevant tributaries

2	**Meteorologic and hydrologic situation**
	Summary of weather forecast and expertise knowledge of regional hydrographic services

3	**System State**					
	Soil moisture state	☐ dry	☐wet	**Snow melt**	☐ influence	☐ no influence
	Base flow	☐ low	☐ high	**Zero degree line**	☐ snowfall	☐ no snowfall

4	**Estimation of scale of flood (return period)**				
	Basis	☐ Analysis of historic flood event		☐ flood forecast	☐ flood observation
	Water gauges	A - Name	☐ estimation not possible		
			☐ << HQ30		
			☐ HQ30		
			☐ HQ100		
			☐ > HQ100		
	Occurence of event (peak discharge)	☐ in 72 - 48 hours	☐ in 24 - 12 hours	☐ in 6 - 3 hours	
		☐ in 48 - 24 hours	☐ in 12 - 6 hours	☐ in 3 - 0 hours	

5	**Flood potential** (affected railway sections)													
	Route (VZG) and junction stations	**Associated Water Gauge**		**warning sections**	**HQ30**			**HQ100**			**HQ300**			
	Name	Name	A	map number 1	X			X			X	X		
				map number 2	X	X	X	X	X	X	X	X	X	

6	**Expert opinion**
	Summary and conclusion

Figure 4: Structure of the Flood Situation Report

Including the expertise of Provincial Hydrographic Services, the system's state is characterised by a qualitative assessment on whether soil moisture or snowmelt are likely to influence the flood development. The approach to estimate the expected runoff depends on the warning phase and available data. The pre-assessment is based on historic flood events, later on specific flood forecasts which are published by the Hydrographic Services and can be used to update the estimation. To supply those responsible for the emergency planning with crucial information, the identification and display of the affected railway sections for the return periods of 30, 100 and 300 years (orange, red and purple sections in Figure 2) are highly important and count as final steps.

CONCLUSIONS

According to Austrian legislation, the Austrian Federal Railway Infrastructure Company (OEBB Infra) is, on one hand, responsible for the safety and, on the other hand, for the high availability of national and transnational railway tracks in Austria.

To fulfil these high demands, different countermeasures against natural hazards are necessary. Beside a high range of technical protection measures like dams, barriers or fences, organisational measures such as warning systems, training, and contingency plans are equally important.

There are three major reasons for the utilisation of organisational measures. First of all, technical countermeasures are not always possible due to natural, technical and legal reasons. Secondly, the planning, approval and construction of technical measures take very long – often years. Thirdly, technical countermeasures are planned by using design events: if a natural hazard event exceeds the design event, organisational measures help to protect human life. Warning systems are inexpensive and can be well adapted to resist influences from climate change.

The accurate discharge models of the different catchment areas build the basis for planning countermeasures against flood events. In Austria, these discharge models are calculated by nine different federal countries. For a nationwide infrastructure operator, it is challenging to combine and interpret the different data.

The quality of weather forecasts is very high, since the prognosis of the amount and the spatial position of precipitation concerning larger catchment areas, for example, are very accurate three days prior to an expected event. Because of the limited local resolution of prognosis models, it is very difficult to make forecasts for small catchment areas.

Before, during and after a flood event, information and communication are crucial for a well-functioning warning system. The major principle of the flood warning system of the OEBB is the utilisation of existing information. The delivery of expert knowledge by the warning centres of the federal countries in Austria and the punctual contact with the Hydrographic Services serve as a fundament for taking decisions. Large infrastructure operators (18.000 employees at the OEBB Infra) need a well-functioning communication system, which includes an early conveyance of information to boot up the emergency organisation. Also, it is very important to communicate the timely all-clear.

The end of a flood event is the beginning of the next event, thus, an accurate event documentation is very helpful to improve the warning processes and to optimally plan countermeasures.

Even though warning systems, as organisational countermeasures, help to protect human life and to optimise the disposability of traffic, they are not able to reduce damage on infrastructure.

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