Risk Management Cone (RMC) — A Three Dimensional Risk Management Concept

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Abstract

Activities in risk management systems are often visualized by means of a two-dimensional risk management cycle. In this concept, the ideal procedure starts with a comprehensive risk assessment, including risk analysis and risk valuation. Based on this assessment, preventive and mitigative measures can be prepared or realized. The emergence of a dangerous process then leads to the stage of event management and finally, the cycle is completed with the regeneration stage. However, activities — or non-activities — in the field of risk management can also lead to an improvement or worsening of the level of risk prevention at a certain point in time. This process can be considered by the further development of the risk management cycle to a three-dimensional risk management cone (RMC). This allows on the one hand the visualization of changes in the level of protection over time. On the other hand, the residual risk can also be illustrated with the RMC. In this study the concept of the RMC will be presented and the implementation in practice will be exemplified by means of three case studies of flood events performed in Switzerland for the villages of Ermatingen and Schwarzenburg and the city of Thun.

Keywords: risk management, natural hazards, floods

Introduction

Natural disasters cannot be prohibited; therefore society has to deal with them (Petrascheck 2004). However, dealing with natural hazards is not the only and rarely the most important working field of society. All the more it is important to ensure effective acting with the funds available. Integral risk management can play a crucial role in this task as it contributes to the allocation of funds for effective risk prevention. So far, activities in risk management systems have often been visualized by means of a two-dimensional risk management cycle (see e.g. Kienholz et al. 2004).

In a risk management cycle (Fig 1), the ideal procedure starts with a comprehensive risk assessment. The assessment includes a scientific risk analysis and a social risk valuation and it is the foundation for every action taken in the risk management system. Based on this, preventive and mitigative measures can be prepared or realized in the risk prevention stage, which is important in order to be well prepared for possible dangerous processes — and to be able to reduce the risks. The aim of preventive measures is to prevent the occurrence of dangerous events, or at least to minimize their frequency. With preparedness the extent of damage can be minimized. The emergence of a dangerous process then leads to the stage of event management. In this stage, coping with the event and immediate taking of measures in the rehabilitation phase take place. In reality, the cycle often starts with an "unexpected event" at this stage (Kipfer 2005). Finally, the cycle is completed with the regeneration stage. This stage includes on the one hand a documentation of the event, which allows learning from former mistakes. On the other hand, the reconstruction of buildings and infrastructure represents the transition to everyday life.

This cycle allows the visualization of actions in a risk management system in a simple way (see e.g. Kipfer and Kienholz 2004). However, there are hardly possibilities to depict changes in the protection system over time. Therefore, this problem was assessed by the further development of the risk management cycle to a three-dimensional risk management cone (RMC).

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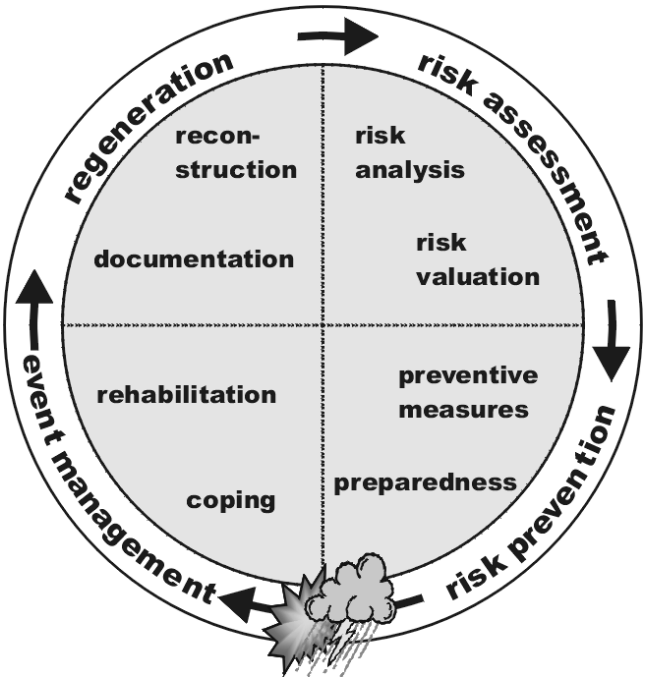

Fig. 1. The risk management cycle (Kienholz et al. 2004)

Risk management cone (RMC)

From the risk management cycle to the risk management cone

A risk management cycle, as presented in the introduction, has two dimensions. However, activities — or non-activities — in the field of risk management can also lead to an improvement or worsening of the level of risk prevention at a certain point in time. This process can be considered by the further development of the risk management circle to a three-dimensional risk management cone (RMC, see Fig. 2) (Kipfer 2005).

Movements on the RMC

The current position on the RMC defines the level of protection in a specific place. The level of protection is relative and related to the area investigated and the time period observed. To facilitate orientation on the RMC, this one is divided into different levels by a spiral line. This allows taking into account that improvements of the level of protection are usually the result of a comprehensive process. For example this is also applicable to the point in time of completion of protection structures — which can lead to a sharp increase of the protection level. This must be seen as a result of a process (risk analysis, risk valuation, evaluation and planning of preventive measures) and not of a single action.

Continuous improvements of the level of protection lead to a spiral movement towards the top of the cone (see Fig. 3, A). If protection remains on the same level, the spiral movement changes into a circular movement (Fig. 3, B). Worsening of the level of protection leads to a spiral or abruptly falling movement towards the bottom of the cone (Fig. 3, C). The desired movement should be determined in the framework of a risk valuation and then be approached consciously.

The shape of the cone makes obvious, that even remaining on a certain level is connected with input of work (see Fig. 3, D). When focusing on a specific location on the cone, every point is located on an inclined plane. This means, that the present location can only be kept, if efforts are undertaken. Without periodical inputs, e.g. by exercising and testing the emergency concept or by checking the protection structures, there will be a movement towards the bottom of the cone (Fig. 3, E). As in general knowledge about emergency planning or the reliability of protection structures are not lost suddenly but rather gradually, a sort of “adhesion” retards this movement at the beginning.

The surface of the cone above the current level of protection symbolizes the residual risk (Fig. 3, F). With the improvement of the level of protection this residual risk can be minimized, but not totally eliminated, as to reach the top of the cone is almost impossible. “Residual risk” stands for all risks, against which no or just limited protection exists. This means that besides emergency planning concepts, which are integrated in

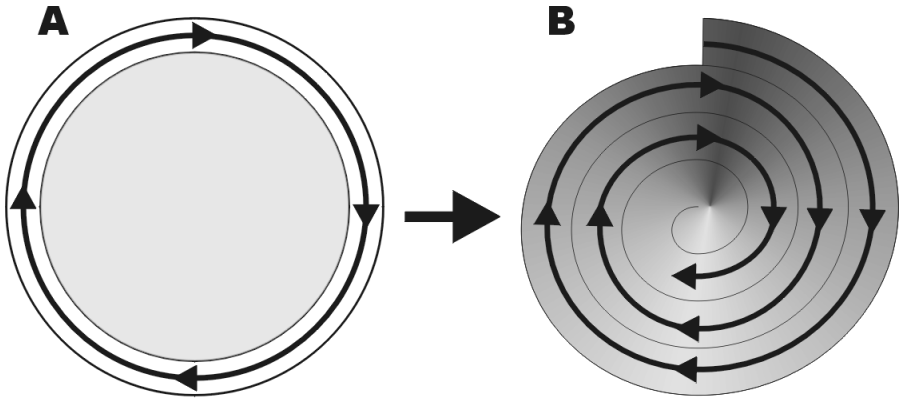

Fig. 2. Further development of the risk management cycle (A) to a three-dimensional risk management cone (B) (Kipfer 2005)

the RMC as protection measures, it has to be assumed that an uncovered residual risk still exists.

Actions on the RMC

The various actions on the RMC in the field of risk management are assigned analogous to those on the risk management cycle. Ideally the movement on the cone starts with risk assessment (see Fig. 4, A).

Obviously, a disastrous event must not necessarily occur to implement an optimization of the protection concept. During every periodical risk assessment (e.g. every 10 years) verification should be performed so as to determine whether improvements are necessary or if the present level of protection is sufficient and satisfactory (see Fig. 4, B). If a next risk assessment shows that the present input is adequate, the level of protection remains on the same level (Fig. 5, A). The remaining risk is accepted as residual risk (Fig 5, B, dark top of the cone).

However, no risk assessment is perfect. Even if the assessment was performed in accordance with the state-of-the-art procedures, it can turn out to be too optimistic or pessimistic. Before this is recognized, a long period of time can pass — and just as well the new assessment can turn out to be "wrong" in reality. In addition, the effect of protection measures can also be under- or overestimated. Therefore, the declaration of the time period considered is important in every RMC.

Implementation of the RMC in practice

The implementation of the RMC in practice can be exemplified by means of three case studies performed in Switzerland for the villages of Ermatingen and Schwarzenburg and the city of Thun. In Ermatingen and Thun a so-called "centennial" flood event of the Lake of Constance (Ermatingen) and the Lake of Thun (Thun) respectively, revealed substantial gaps in the existing flood protection concepts in 1999. The development of the protection concepts including the recurrence of several flood events will be visualized for both locations with the RMC. In Schwarzenburg an extreme flood event of the Dorfbach stroke the center of the village in 1985. Ever since, technical protection measures are under discussion. However, the solutions elaborated were repeatedly rejected by plebiscites. All three case studies are given in detail in Kipfer (2005).

Ermatingen

Ermatingen is located in Switzerland on the southern shore of Lake of Constance (Untersee) near the outflow of the Rhine river (see Fig. 6). The Lake of Constance is well known for its regularly flood events. Ermatingen was affected by six flood events between 1965 and 1987. Therefore, the municipality of Ermatingen was well prepared for flood events.

Visualizing the period between 1965 and the flood event of 1999 on the RMC, a circular movement for six times can be seen (Fig 7, A). Although there were improvements in the flood protection concept after every flood, the preventive measures were not designed for a flood of the magnitude occurring in May/June 1999 — which was about a centennial event (IGKB 1999). Nevertheless, the intervention services have been well trained to cope with frequent flood events. In 1999 they especially benefited from the experiences gained in 1987.

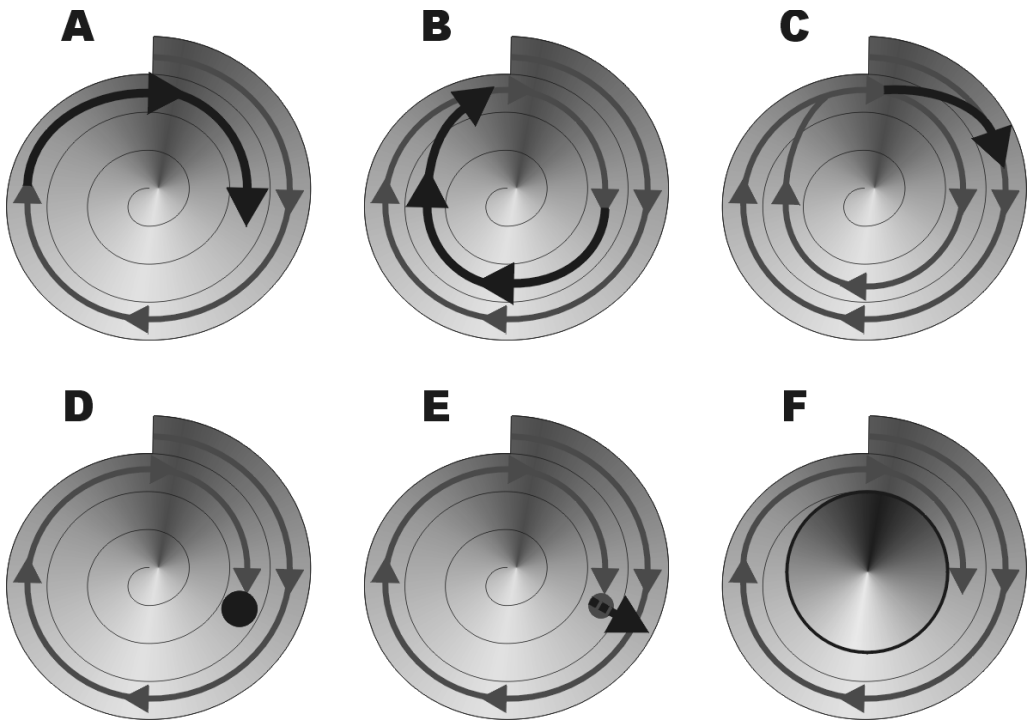

Fig. 3. Movements on the RMC. Improvements of the level of protection lead to a spiral movement towards the top of the cone (A). If protection level remains on the same level the spiral movement changes into a circular movement (B) — as in the risk management cycle. Worsening in the level of protection leads to a movement towards a lower level (C). So as to hold the present position on the inclined plane on the RMC work is needed (D). Otherwise a falling movement towards the bottom of the cone occurs (E). The surface of the cone above the current level of protection symbolizes the residual risk (F), against which no protection exists. (Kipfer 2005)

As the flood of 1999 revealed substantial gaps in the existing flood protection concept, this concept was renewed and the gaps were filled. Measures were especially taken in technical fields (e.g. improvement of power supply and sewage system) and planning (e.g. renewed plans of action and information concept). In addition, "areas with flood protection needed" were inserted in the local building plan. In these areas, a minimum level for openings in buildings is defined for new buildings or substantial renovation works. All these improvements in the protection concept lead to a movement to a higher level on the RMC (Fig. 7, B).

In June 2001, the renewed protection concept passed a first test during a small flood event. Although the water level only rose 4 centimeters above the limit of damage (water level above which damage may occur) press coverage was huge — as the flood of 1999 was still in mind. On the RMC this flood event results in a circular movement (Fig. 7, C).

Thun

The city of Thun (Switzerland) is located at the outflow of the Aare river at the Lake of Thun (Fig 8). Since the late 19th century, gates control the outflow of the lake. There is a regulation, which determines the discharge of the outflow for every water level in each season. Unfortunately the storage capacity of the lake is very limited. Between the lower threshold level of damage (557.00 m a.s.l.), below which the stability of constructions along the lake would be endangered, and the upper threshold value of damage (558.30 m a.s.l.), above which damages at houses or infrastructure around the lake can occur, there is a range of only 1.3 m. In fact, the storage capacity is often even smaller, as the average water level during summer — when most flood events occur — is at 557.85 m a.s.l. In addition, the outflow of the Lake of Thun is a hydraulic bottleneck. Only in periods with high water levels high discharge from the lake can be attained. This means, the lower the water level of the lake, the faster the lake rises.

This limits flood management considerably. At a water level of 557.95 m a.s.l. (35 cm below the upper threshold level of damage) all gates are open. (Kanton Bern 2002b) Between 1892 and 1999, the upper threshold level of damage was exceeded more than 30 times. Before 1999 the highest value measured dated from

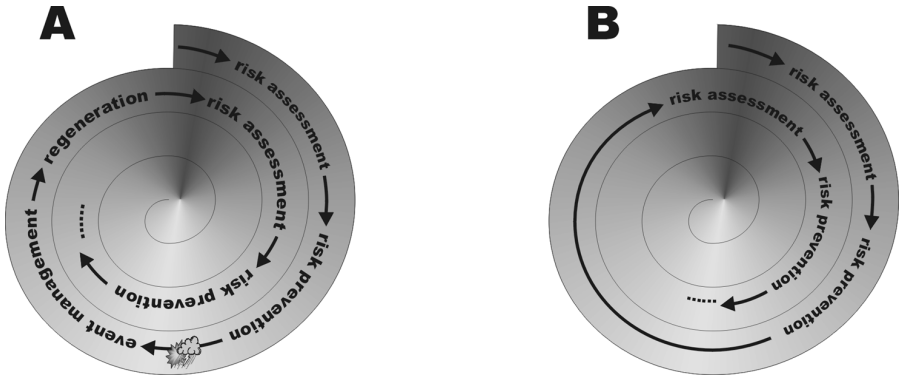

Fig. 4. Ideal risk management cone (RMC) — The movement starts with a risk assessment. Afterwards, in the stage of risk prevention, the appropriate steps are taken. Then, a disastrous event demonstrates where improvements are still necessary (A) or during a periodical risk assessment the need of improvements are detected (B). Gaps will be eliminated in a following risk assessment and risk prevention stage, which are already situated on a higher protection level. (Kipfer 2005)

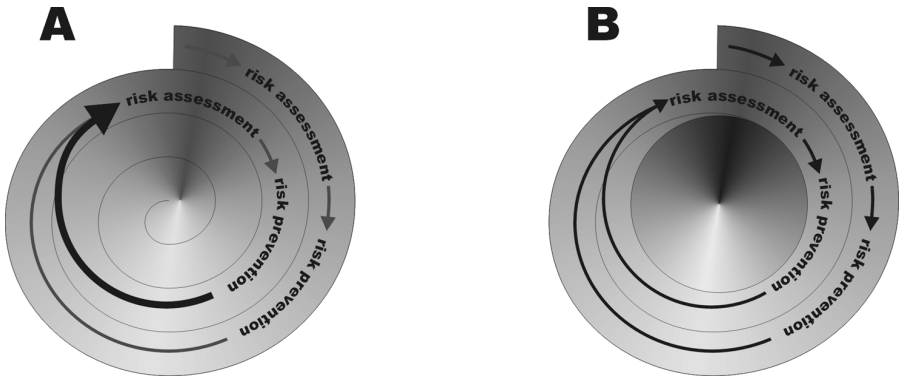

Fig. 5. Actions on the RMC. If a risk assessment shows that the level of protection is in the best possible way at present, remaining on the current level of protection on the RMC should be aimed at (A). The remaining risk (dark top of the cone) is accepted as residual risk (B). (Kipfer 2005)

1910 with a water level of 558.68 m a.s.l. The period since 1979 was without major flood event. However, in May 1999 the lake level rose almost 50 centimeters higher than in 1910. This event occurred due to continuous rainfall in the whole catchment area of the Lake of Thun, which was combined with snow melting in the Bernese Oberland. (BWG 2000) This flood event revealed substantial gaps in the existing flood protection concepts. Thereafter, these gaps were filled. Measures were especially taken in the fields of organization (e.g. information concepts), planning (e.g. creation of a hazard map, setting of long-time alerting plan) and technology (e.g. improvement of power supply and sewage system). Therefore, a movement to a higher level on the RMC can be noticed after 1999 (see Fig. 9, A). So as to improve the outflow conditions of the lake several studies were elaborated. However, divergent interests of the actors affected (navigation, fishery, tourism,...) make it very difficult to find an agreement.

In 2002 (July and August) and 2004 (June) the adapted protection concept was tested during three smaller flood events. These events allowed to slightly adapting the renewed protection concept. Especially the communication and information field proved to be very demanding and thus had to be improved continuously. On the RMC this period results in three circular movements on the same level (see Fig. 9, B). However, it is nearly undisputed, that further technical measures regarding the outflow conditions have to be taken in order to improve risk prevention against large-scale events.

At the end of August 2005, continuous and extensive rainfall occurred in large parts of Switzerland. In the catchment area of the Lake of Thun, rainfall amounted to more than 100 l/m^2 within 48 hours. In addition, the soil was already saturated due to antecedent rainfall (Kanton Bern 2005). On August 24, this caused a rising of the water level of the Lake of Thun to the highest level ever measured, which was 8 centimeters higher than the one during the “centennial” flood in May 1999. The coping with this second “centennial” event within

Fig. 6. Map of Switzerland: Location of Ermatingen

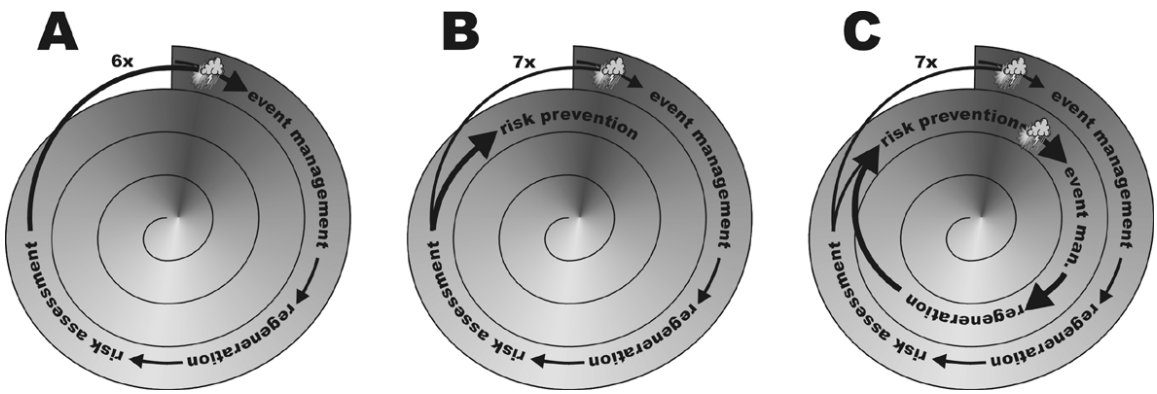

Fig. 7. RMC in practice for Ermatingen. Between 1965 and 1999 six smaller flood events occurred resulting in six circular movements in the RMC (A). In 1999 a "centennial" flood event revealed substantial gaps in the flood protection concept. The concept was renewed and improved afterwards, which lead to a movement on a higher level on the RMC (B). In 2001, the renewed protection concept passed a first test during a small flood event. As no major gaps were detected, a circular movement on the same level on the RMC resulted (C). (Kipfer 2005)

seven years was much better — although still considerable gaps were revealed, especially in the information and alarming concept. In addition, the flood event unmistakably demonstrated the necessity to improve the outflow conditions of the lake. This aim shall be achieved by the construction of a spillway tunnel. This solution allows higher outflow discharges at lower lake levels and therefore eliminates the hydraulic bottleneck. Start of construction is scheduled to the end of 2006 and the beginning of operation to spring 2009 (Kanton Bern 2006).

Schwarzenburg

Schwarzenburg (Switzerland) is located at about 20 km south west of the capital Berne (Fig 10). The Dorfbach brook flows through the center of the village and the catchment area is about 11 km^2. Since the end of the 16th century several severe flood events are known in this region, but mainly in connection with the torrents Sense and Schwarzwasser. The Dorfbach brook is hardly mentioned. However, partial overflows of the Dorfbach occur rather often — at least 6 small flood events are known in the 20th century. (Kanton Bern 2002a) In July 1985 a disastrous flood event stroke the center of Schwarzenburg. A thunderstorm lead to a peak discharge of the Dorfbach in the village of 60 m^3/s, whereas the channel capacity is only designed for 4 to 12 m^3/s. In Kanton Bern (2004) the recurrence interval of the 1985 peak discharge is estimated at about 300 years. The discharge of a centennial flood event is estimated at 30 m^3/s. Due to the topography in Schwarzenburg the area affected was small — about two rows of houses on both sides of the Dorfbach, but the intensity of the event was very high. The municipality and the intervention services were completely unprepared for an event of this magnitude. Therefore, the RMC starts with the event itself (Fig 11, A). After the event everyone agreed with an improvement of the protection level. In the face of the dangerous situation — reaction time is very short and the impact intensity high — technical measures are required.

However, in 1989 a first project for a spillway tunnel was rejected in a plebiscite. Possible reasons

Fig. 8. Map of Switzerland: Location of Thun

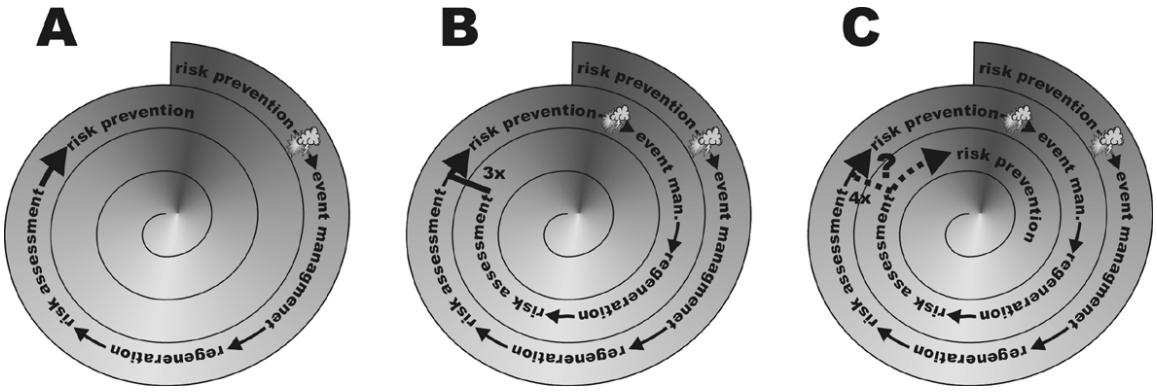

Fig. 9. RMC in practice for Thun. In May 1999 a "centennial" flood event revealed substantial gaps in the flood protection concept. The concept has been renewed and considerably improved afterwards, which lead to a movement on a higher level on the RMC (A). In 2002 and 2004 the renewed protection concept stood the test during three small flood events. As no major gaps were detected, three circular movements on the same level on the RMC resulted (B). However, it is nearly undisputed, that further technical measures have to be taken in order to improve risk prevention against large-scale events. In summer 2005 another "centennial" event unmistakably demonstrated this necessity. As nowadays further measures are in preparation, a movement to a higher level will take place as soon as these measures are implemented (C). (Kipfer 2005)

for this may be — besides the costs — a lack of confidence in the functioning of this construction in case of an extreme event. In 1990, a second project for a spillway tunnel was rejected again — likely due to of the same reasons as in 1989. In 2001 even a third project, comprising 5 retention basins above the village, was rejected. 16 years after the disastrous flood event, doubts about the need of protection measures and the strong opposition of the farmers (because of the impairment of farming land) probably were the main reasons. On the RMC this results in three circular movements on the same level (see Fig 11, B). The level of protection did not change between the flood events in 1985 and 2001 respectively.

Last but not least, in 2002 a team, consisting of local public authorities and opponents of the third project, was formed in order to elaborate a new and well-balanced solution. This process was necessary due to the fact that the pressure of insurance companies and cantonal authorities to raise the level of protection was still very high and the elaboration of a hazard map confirmed the necessity of new protection structures. As a consequence of the experience from former projects the integration of the population in the project planning and the information concept was considerably improved. In 2003 the necessary means for the elaboration of a detailed project were approved by a plebiscite. The new project consists of a retention basin above and channel improvements in the village, which helps to achieve a burden balance between the different stakeholders involved. If the final project is accepted in a plebiscite, which will probably take place in autumn 2006, construction is scheduled to begin at the end of 2006. This would result in a movement towards the top of the RMC (Fig 11, C) — more than 20 years after the beginning of the planning process.

Fig. 10. Map of Switzerland: Location of Schwarzenburg

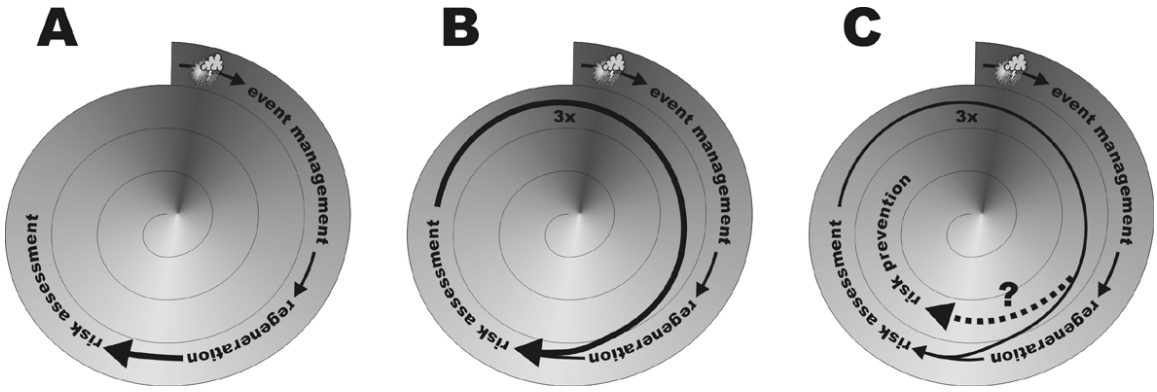

Fig. 11. RMC in practice for Schwarzenburg. In July 1985 an extreme flood event of the Dorfbach brook stroke the center of Schwarzenburg. The need of a movement to a higher protection level was undisputed right after the event (A). However, between 1989 and 2001 three different projects of protection structures were rejected in plebiscites due to various reasons. Thus, the level of protection remained on the same level (B). Nowadays a forth project is in the planning stage, but the necessary means must be conceded in a final plebiscite, which will probably take place in summer 2006. The construction of the protection structures planned (retention basin and channel improvements) would result in a movement towards the top of the cone (C). (Kipfer 2005)

Synthesis

This study demonstrated, that a risk management cycle, as presented e.g. by Kienholz et al. (2004) can be further developed to a three-dimensional risk management cone (RMC). This allows on the one hand the visualization of changes in the level of protection over time. On the other hand, the residual risk can also be illustrated with the RMC. The implementation in practice was exemplified by means of three case studies performed in Switzerland. These examples show that the RMC can be a useful graphical representation so as to receive a general idea about the development of risk management in the area investigated and over the time period observed. However, there is an upper limit for the amount of information that can be provided with the RMC so that the diagram does not become too complex.

Finally, we assume that the RMC cannot only be used in the context of flood events, as presented in the case studies, but for all natural hazards. As risk management itself is a universal concept, the RMC should even be applicable to further research areas, e.g. in chemistry or in transportation planning.

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