RIMAROCC

RISK MANAGEMENT FOR ROADS IN A CHANGING CLIMATE

Case study – *Structure scale* National Road RV90, Väja Sweden

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1 Foreword

"ERA-NET ROAD – Coordination and Implementation of Road Research in Europe" was a Coordination Action funded by the 6th Framework Programme of the EC. The partners in ERA-NET ROAD (ENR) were United Kingdom, Finland, Netherlands, Sweden, Germany, Norway, Switzerland, Austria, Poland, Slovenia and Denmark (www.road-era.net). Within the framework of ENR this joint research project was initiated.

This report is part of the RIMAROCC project with the objective to develop a common ERA-NET ROAD method for risk analysis and risk management with regard to climate change for Europe. The project is led by a Project Management Group with representatives from all partners SGI, Bo Lind (co-ordinator); EGIS, Michel Ray; Deltares, Thomas Bles; NGI, Frode Sandersen. Additional funding to the RIMAROCC project has been provided by all participating partners. We would like to thank KNMI, Meteo France and SMHI for their input on climate change and critical climate factors.

The Project Steering Group from the ERA-NET Board, Åsa Lindgren (Project Manager), SRA, Sweden; Alberto Compte and Eva Ruiz-Ayucar CEDEX, Spain and Geoff Richards and Dean Kerwick-Chrisp, HA, UK, have in a constructive way contributed to the project together with other persons from the ERA-NET organisations and other co-workers - they are all gratefully acknowledged.

The study was conducted to implement the RIMAROCC framework for risk analysis. The RIMAROCC method is developed to fit different geographical scales including structure, section, network and territorial scale. This case study is on the structure scale which means risk analysis of a specific structure or a specific point in the road network.

The authors also wish to acknowledge Mikael Ånäs at the Swedish Transport Administration whose time and effort have made this case study possible, and Håkan Nordlander at the SRA for his support.

2 Comments on structure scale analysis

Risk analysis of a specific structure is usually made when some risk exposure to the structure already has been identified. This may be the result of previous damages (as in the case of this study) or by an analysis on a wider structure or network scale. The structural scale does not look at other parts of the road than the specific structure or object. Other critical structures may exist that has not yet been identified or taken care of.

3 The RIMAROCC method

The RIMAROCC framework is a cyclic process to continuously improve the performance and capitalise on the experiences. It starts with an analysis of the general context where risk criteria are established and ends up with a reflective step where the experiences and results are documented and made available for the organisation. The RIMAROCC steps are presented in Table 1.

Table 1: Summary of the RIMAROCC method.

Main steps	Sub-steps
1. Context analysis	1.1 Establish general context 1.2 Establish appropriate context for particular scale 1.3 Establish risk criteria and indicators adapted for each particular scale
2. Risk identification	2.1 Identify risk factors 2.2 Identify vulnerabilities 2.3 Identify possible consequences
3. Risk analysis	3.1 Risk analysis : qualitative aspects 3.2 Establish risk scenarios 3.3 Determine impact of risk 3.4 Evaluate occurrences
4. Risk evaluation	4.1 Evaluate quantitative aspects with appropriate analysis (CBA or others) 4.2 Compare climate risk to other kinds of risk 4.3 Determine which risks are acceptable
5. Risk mitigation	5.1 Identify options 5.2 Appraise options 5.3 Negotiation with funding agencies 5.4 Elaborate action plan
6. Implementation of action plans	6.1 Develop action plan at each level of responsibility 6.2 implement adaptation action plans
7. Monitor, re-plan and capitalize	7.1 Regular monitoring and review 7.2 Re-plan in case of new data or delay in implementation 7.3 Capitalization of return of experience on both climatic events and progress of implementation
Communication and gathering of information	

CASE STUDY

Step 1 Context analysis

By establishing the context, the organization articulates its objectives and defines the external and internal parameters to be taken into account when managing risk, and sets the scope and risk criteria for the remaining process.

Step 1.1 Establish general context

Väja is a small village in the inland of mid-Sweden along the road Rv90. The flooding or possible collapse of a small dam close to the road has been identified as a potential risk. The Rv90 is an essential national road for the inland traffic in northern Sweden with an average daily traffic of about 5000 vehicles/d. A closing at Väja may cause a 10-20 km alternative route on small roads (depending on route).

In year 2000 the road was flooded after a period of heavy rain and the road was damaged and totally closed for a short period of time.

The general prerequisites of the project are summarised in “Internal context” and “External context” and listed in Table 2, Table 3 and Table 4.

Internal context

The internal organisation for risk management within the Swedish Road Administration is part of the overall organisation for road operation – specific the maintenance.

Table 2: General internal context

The site	Road Rv90 at Väja, coordinates: X 6986560, Y1596338. Parallel road- and railroad embankments downstream an old dam.	
Studied structure	Road embankment damaged by high flows and erosion in 2000. Identified as risk object 2007-06-04 in the general overview by SRA.	
Documents	Oral information: Stefan Johansson, Vectura: Old timber floating-dam with a temporary flume dike crossing the road and railroad. Maps, photos. Object is identified in risk inventory, SRA Risk Analysis nr 717.	
Purpose/goal	Evaluate risks and suggest cost-effective actions to mitigate damages. ***Only the road*** is included in the study.	
Responsibilities	Road embankment	Swedish Transport Administration
	Railway embankment	Swedish Transport Administration
General information	Road region	Region Mitt
	Municipality	Kramfors
	County	Västernorrland
	Road number	RV90
	Traffic load	YDT 4830 (Heavy traffic 416)

Table 3: Individual responsibilities

Role	Responsibility	Person	Contact information
Risk management group	In response to internal needs	SRA Board	Risk management policy
Risk Manager, SRA Region mitt	Receiver of risk report, Financial responsibility	Anders Silén	(omitted from report)
Project leader, Risk management	Prioritise needs and report to SRA regional Board	Peter Rehnman	(omitted from report)
Contact person – risk inventory, SRA	Geotechnical Field inventory and report to Risk manager	Mikael Ånäs	(omitted from report)
Project leader; Maintenance	Order maintenance and construction works after priority from Risk manager	Joakim Melander	(omitted from report)
Vectura – external consultant	Geotechnical Field inventory	Stefan Johansson	(omitted from report)
Dam owner		Owner unknown	(omitted from report)
Process leader risk analysis	RIMAROCC	Bo Lind and Stefan Falemo	Bo.lind@swedgeo.se Stefan.falemo@swedgeo.se

External context

The external context is focusing on general as well as site-specific aspects and steering documents.

Table 4: External context including regulations and directions

Aspect	Responsible	Documents	Timing / About
Climate scenarios	SMHI	Scenario maps	2007
Climate risk factors	RIMAROCC	Table- overview	2010
National climate policies	Government	*Sweden and climate change* (SOU 2007:60)	Adaptation to CC
VVFS – SRA's Code of Statutes	Swedish Transport Administration	Documents, regulations, directions	Stability requirements
Stakeholders	Industry owner Swedish Transport Administration (rail dep.) Land owners Dam-owner County Administrative Board		

Step 1.2 Establish general context for particular scale

The case study site is located along road Rv90 at Väja, a small village in the inland of mid-Sweden (Figure 1). Upstream of the road the flooding of an old timber floating dam close to the road has been identified as a potential risk (Figure 2). In year 2000 the road was flooded following such a dam flooding, damaging the road and railway downstream (Figure 3). Elements at risk are the road, a railway track and a paper and pulp industry. The dam and neighbouring road are in focus in this structure scale risk management case study. The dam is watered from Grössjön, and downstream of the dam the water runs along the road for about 100 meters before running into a tunnel leading to the coastal inlet Bollstafjärden.

Figure 1: Map of the Väja site, with marked critical section. The timber floating dam is the small dam within the red circle.

Figure 2: Old timber floating dam critical to collapse (Photo, SGI).

Figure 3: The road was flooded and damaged during a period of heavy rain in year 2000. (Photo, SRA).

Step 1.3 Establish risk criteria and indicators adapted for structure scale

The definition of risk criteria is an important step. This may be seen as a "one-time" job, since the criteria may be used in many different studies at the same geographical scale. The criteria for Climate risk; Exposure; Vulnerability (sensitivity); Consequences and Probability are listed in Table 5. It should be noted that it is important to set the criteria in relation also to available data. It should be verified that required data are available and relevant for the actual study.

Table 5: Risk criteria

Criteria to assess the climate event	**Indicator unit**				
H1 Frequency of key climate conditions / past extreme events	x times per year				
H2 Predicted amount of climate change compared to 1961-1990 period	-- Substantial decrease	- Some decrease	+/- No change	+ Some increase	++ Substantial increase

Exposure indicators	**Exposure level**			
	Low (1)	**Medium (2)**	**High (3)**	**Critical (4)**
E1 Exposure duration	Hours	Days	Weeks	Months
E2 Exposed area	<0,1 ha	0,1 – 0,5 ha	0,5 – 1,0 ha	> 1 ha
E3 Exposed people	<5 people	5-50 p	50-100 p	>100 p
Objects	Road only	Road & rail		Large number

Vulnerability indicators	**Vulnerability level**			
	Low (1)	**Medium (2)**	**High (3)**	**Critical (4)**
S1 Speed of occurrence / forecast time	> 3 days accurate predictions possible	½ to 3 days accurate predictions possible	< 12 hours accurate predictions possible	< 5 hours accurate predictions possible
S2 Amount and type of information to road users	Matrix boards available	Good radio coverage	Little road information	No road information
S3 Amount of knowledge of a hazard with related consequences	Detailed insight in occurrence of hazard	Only insight in trends	Little knowledge of hazard	No knowledge of hazard
S4 Used design standards and type of maintenance	Used design standards have an age of less than 5 years	Design standards 5 – 25 years	Design standards older than 25 years - good maintenance	Design standards older than 25 years - poor maintenance

Consequence indicators	**Consequence class**			
	Minor (1)	**Moderate (2)**	**Major (3)**	**Catastrophic (4)**
C1 Persons *(Loss of safety due to event)*	Light injuries	1 - 3 serious injuries	1-5 deaths	> 5 deaths
C2 Property *(Direct costs; costs for reconstruction)* (MSEK)	< 0,1	0,1 – 1	1-20	> 20
C3 Environment *(Impact on the environment)*	Temporary minor	Temporary serious	Permanent minor	Permanent serious
C4 Financial *(Unavailability of the road, Indirect costs)* (MSEK)	< 0,1	0,1 – 1	1-20	> 20
C5 Intangible *(Loss of confidence / image / prestige / political consequences)*	No consequence	Local image consequence	Regional political cons.	National political cons.

Probability of event			
Very low (1)	**Low (2)**	**High (3)**	**Reliable (4)**
< 1/1000 yrs (less than once in 1000 years)	1/1000 - 1/100 yrs	1/100 - 1/10 yrs	> 1/10 yrs (more than once in 10 years)

Step 2 Risk identification

Risk sources, events and their causes are identified in this step. Risk scenarios are formed and their potential consequences are assessed.

The primary risk scenario is high flows with flooding of the dam that cause erosion and damage to the road and railroad embankments. ***Only the road*** is included in the study.

Step 2.1 Identify risk sources

The studied structure was identified due to earlier flooding and damages in year 2000. Critical structures may also be identified from studies on section – territory scale.

The list of climate parameters imposing risks to the road infrastructure (Table 1 in Guidebook) was discussed; seasonal and annual average rainfall as well as extreme rainfall events were considered relevant for Väja. In addition snowfall causing flooding due to snow melt was considered an important climate risk variable.

The predictions and intensity for change of the identified critical climate parameters was estimated from the summary-table of present knowledge (Table 2 in Guidebook). In a perspective of 2071-2100, the average amount of rainfall is very likely to increase significantly (++) in winter and the intensity of extreme rainfall events is likely to increase moderately (+). The snowfall is virtually certain to decrease moderately (-). The intensity of the spring flood depends on snow depth, temperature and precipitation. This information is summarised in Table 6. It was concluded that extreme rainfall events, including heavy showers and long rain periods, was the most important climate factor to consider but also the possible problems with flooding from melting snow.

Contextual site factors that were identified in the case study are summarised in Table 7.

Table 6: Climate factors threatening the road structure are presented along with expected amount of change and likelihood of the prediction. Change is predicted for the period 2071-2100.

Climate factor	Change	Likelihood
Winter rainfall amount)	++	Very likely
Intensity of extreme rainfall	+	Likely
Snowfall	-	Virtually certain

Table 7: Contextual site factors surrounding the road structure

Contextual site factors	Comments
Deforestation within catchment area	Unknown
Small dam upstream of road	Dam is in poor condition. Can be flooded or collapse.
Creek upstream of road	Undersized
Pipe under private road upstream from road	Undersized

Step 2.2 Identify vulnerabilities

Contextual site factors and infrastructure intrinsic factors were identified using experience from the flooding in year 2000 along with findings from the site inspection. Vulnerabilities were scored with good help from information about the earlier flooding. The results are summarized in Table 8.

Table 8: Summary of climate factors, contextual site factors and infrastructure intrinsic factors. The vulnerability scores are marked in bold figures.

Climate factors	**Vulnerability to climate change** 1-4 (low-critical)						
	E1 Duration	E2 Area	E3 People/Object	S1 Speed	S2 Information	S3 Knowledge	S4 Standard
Extreme rainfall events (heavy showers and long rain periods)	Days **(2)**	0.1-0.5 ha **(2)**	Road and rail **(2)**	< 5 hours accurate predictions possible **(4)**	Good radio coverage **(2)**	Detailed insight in occurrence of hazard **(1)**	Used design standards have an age of less than 5 years **(1)**
Spring flood from snow melt	Days **(2)**	0.1-0.5 ha **(2)**	Road and rail **(2)**	½ to 3 days accurate predictions possible **(2)**	Good radio coverage **(2)**	Detailed insight in occurrence of hazard **(1)**	Used design standards have an age of less than 5 years **(1)**
Contextual site factors	**Comments**						
Deforestation within catchment area	Unknown						
Small dam upstream of road	Dam is in poor condition. Can be flooded or collapse.						
Creek upstream of road	Undersized						
Pipe under private road upstream from road	Undersized						
Infrastructure intrinsic factors	**Comments**						
Road foundation	Subject to erosion if flooded						
Dimension of bridge crossing creek	Sufficient						
Ditch along road	Undersized						

Factors used to identify risk scenarios and consequences

Using the risk factors and vulnerabilities above, four risk scenarios were identified. These are presented together with their assessed consequences in Table 10.

Step 2.3 Identify possible consequences

From the summary of climate factors, contextual site factors and infrastructure intrinsic factors in Table 8, possible consequences were identified. Simultaneously, four different scenarios were formulated; they are presented in step 3.2.
Both direct (e.g. damage of the road) and indirect (e.g. human injuries) were discussed and the following possible consequences listed:

- Material damages on infrastructure and vehicles
- Human injuries and fatalities
- Economic consequences from damages and reduced traffic capacity
- Environmental consequences due to erosion of contaminated soil
- Loss of confidence (intangibles).

Step 3 Risk analysis

This step consists in individual analysis of risks listed in step 2. This analysis is based on the use of criteria and indicators defined in step 1. For application in this case study steps 2 and 3 were to a large extent executed simultaneously.

Step 3.1 Risk analysis: semi-quantitative aspects

It was underlined that the study was focusing on the road, which is the responsibility of the SRA, however, the identified hazards are also affecting the railroad and the environment.

Step 3.2 Establish risk scenarios

This step was carried out simultaneously with steps 2.3 and 3.2. Four different risk scenarios were identified using the climate, site and infrastructure intrinsic factors in Table 8. These are presented in Table 9 below.

Table 9: Risk scenario descriptions.

Risk scenario	**Description**
R1	Extreme rainfall event cause flooding of dam; high flows in creek and flooding of the road.
R2	Extreme rainfall event cause neighbouring dam to collapse; rapid and high flows in creek, flooding and severe erosion of the road.
R3	Spring flood cause flooding of dam; high flows in creeka and flooding of the road.
R4	Spring flood cause neighbouring dam to collapse; rapid and high flows in creek, flooding and severe erosion of the road.

Risk chronology was discussed informally. SRA does not monitor precipitation measurements, so there is no formal alert sign before the first consequence occurs: the water start flooding the road. However, the road maintenance contractor is aware of the flood risk and can pay attention to weather conditions to get an idea of the current risk situation.

Step 3.3 Determine impact of risk

This step was carried out simultaneously with step 2.3 and 3.2, following the normal procedure for NRA. Consequences are divided into five consequence categories, or indicators. The consequences of the risk scenarios are scored from 1-4 for each indicator as shown in Table 10.

It is known that the financial damage of a disruption of the road system often gives rise to the greatest costs. Thus, analysis of the consequences of road closure is crucial. The SRA has developed a tool to estimate the economic costs of traffic stoppage on different type of roads, see Figure 4. This diagram applies to a national road/primary road, <11.5 m wide, 90 km/h, where the bypass has the same standard as an ordinary road stretch.

The estimated costs in this actual case study are based on the costs of the flooding of this structure in year 2000. The numbers are therefore considered reliable. Costs are presented along with consequence classes in Table 10. The consequence for C4 "Financial" was calculated according to SRA – tool for societal cost from closing of roads with varying traffic load (including, traffic, alternative road length, type of damage and estimated repair time).

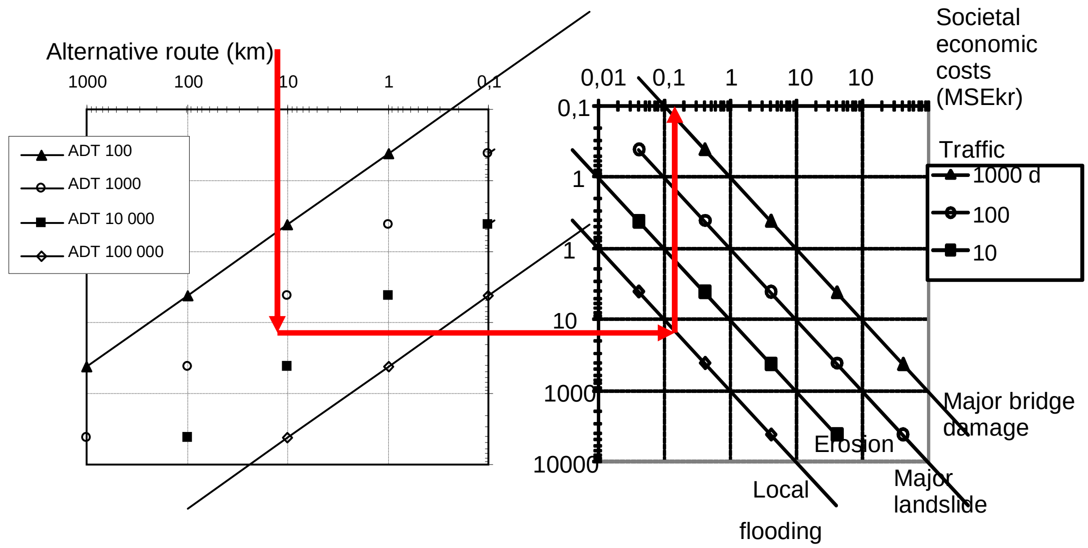

Figure 4: SRA-model for public economy costs of traffic interruption. ADT is average annual daily traffic.

Table 10: The identified risk scenarios are presented along with their respective consequence indicator values (black) and estimated costs (blue).

Risk scenario	Description	Consequences: Indicator value 1 - 4 (low – high) Estimated cost (MSEK)				
		Persons C1	Property C2	Environ. C3	Financial C4	Intangible C5
R1	Extreme rainfall event cause flooding of dam; high flows in creek and flooding of the road.	2 / 1	3 / 1,5	1 / 0	1 / 0,1	1 / 0
R2	Extreme rainfall event cause neighbouring dam to collapse; rapid and high flows in creek, flooding and severe erosion of the road.	3 / 2	3 / 2	1 / 0	2 / 0,5	1 / 0
R3	Spring flood cause flooding of dam; high flows in creek and flooding of the road.	2 / 1	3 / 1,5	1 / 0	1 / 0,1	1 / 0
R4	Spring flood cause neighbouring dam to collapse; rapid and high flows in creek, flooding and severe erosion of the road.	3 / 2	3 / 2	1 / 0	2 / 0,5	1 / 0

Step 3.4 Evaluate occurrences

Four risk scenarios have been identified and are summarised in Table 8 below, along with occurrences of climatic events and the calculated probability for each scenario. The scenarios feature two climatic events: extreme rainfall and spring flood.

The frequency of an extreme rainfall event powerful enough to flood the dam is estimated to 1 per 10 years. With climate change, extreme rainfall is predicted to occur more often (+; ++). Given this event occur, the probability for flooding of the road with moderate damages is estimated to p=1.0 (it is certain that the road will be flooded). The probability for dam collapse and severe erosion is estimated to p=0,2. Since the dam is in bad condition and not maintained, the probability for dam collapse will increase with time, causing a slight decrease in probability for R1 and increased probability for R2. However the climate change contribution is considered more important, resulting in an increased probability also for R1 in the future. The probability for R2 is 0,02 year^{-1} (0,1 x 0,2) and will increase with time, due to more frequent extreme rainfall events and a higher risk for dam collapse.

Spring flood is considered a risk in today's climate. Large amounts of snow melt rapidly following a temperature rise, sometimes in combination with rain. Based on past events a spring flood intense enough to flood the dam is calculated to occur around 1 per 10 years. In this region of Sweden, precipitation in winter is expected to increase (+ +), but will fall as rain to a greater extent. Consequently the risk for spring flood is expected to decrease in the future. The decreasing probability for spring flood is considered to even out the increasing probability for dam collapse (due to aging). So, the probability for risk scenario R3 is 0,1 $year^{-1}$ and decreasing with time, while the probability for R4 is 0,02 and is not expected to change.

It is assumed that there is a risk for dam collapse only when the dam is flooded (i.e. is exposed to the maximum load). A study of the catchment area and calculation of flows would improve the estimation of probability of occurrences of the described events.

Table 11: Risk scenarios, occurrence of climatic events (c.e.), probability for dam collapse given a climatic event, probability for risk scenario and expected risk change with time.

Risk Scenario	**Description**	**p(c.e.) $year^{-1}$**	**p(risk scenario given that c.e. happens)**	**p(risk scenario) $year^{-1}$**	**Future probability for scenario**
R1	Extreme rainfall event cause flooding of dam; high flows in creek and flooding of the road	0,1	0,8	0,08	Increasing
R2	Extreme rainfall event cause neighbouring dam to collapse; rapid and high flows in creek, flooding and severe erosion of the road.	0,1	0,2	0,02	Increasing
R3	Spring flood cause flooding of dam; high flows in creek and flooding of the road	0,1	0,8	0,08	Decreasing
R4	Spring flood cause neighbouring dam to collapse; rapid and high flows in creek, flooding and severe erosion of the road.	0,1	0,2	0,02	No change

Step 4 Risk evaluation

This step aims to evaluate the risks and prioritize which risks need proper attention. The consequence indicators are weighted and the resulting risk scores are visualized in a risk matrix. The risks are compared to other kinds of risk and it is determined if they are acceptable or not.

Step 4.1 Risk prioritization

In this case study, the estimated economic loss in each consequence indicator is used to assess the consequences. Another way to prioritize risks is to weight them against each other. Weighting was done by relating consequence indicators to each other as shown in the handbook:

0 = not important related to the other criterion
1 = of minor importance but still attributes
2 = of major importance
3 = absolutely of major importance related
 to the other criterion

The weighting results and the calculated standardized indicator weights are displayed in Table 12. This prioritization should be carried out thoroughly once for the road organisation, then the same standardised indicator weights can be used for all future road risk analyses.

Table 12: Indicator matrix for consequences. In each row scores are summed from left to right. The standardised indicator weight is obtained by dividing the sum of each consequence criterion with the total sum (30).

	Persons C1	**Property C2**	**Environ. C3**	**Financial C4**	**Intangible C5**	∑	Standardised indicator weight
Persons C1		3	3	3	3	12	0,4
Property C2	1		1	2	2	6	0,2
Environ. C3	0	1		2	2	5	0,17
Financial C4	0	1	1		2	4	0,13
Intangible C5	0	1	1	1		3	0,1
						30	1

In Table 13 the consequence indicators are weighted by multiplying the consequence scores from step 3.3 with the indicator weights from Table 12. The total consequence score C_{Tot} is calculated as the sum of the weighted scores. Economic value (C_{value}) is the sum of loss estimates from step 3.3. The probabilities were calculated in Table 11.

Table 13: Summary of probabilities and consequences for the identified risk scenarios.

Risk	**Probability for risk scenario (year^{-1})**	**Consequence (indicator value*indicator weight)**						**Economic value**
		Persons C1	**Property C2**	**Environ. C3**	**Financial C4**	**Intangible C5**	C_{Tot}	C_{value} (MSEK)
R1: Extreme rain + flooding	0,08	0,8	0,6	0,17	0,13	0,1	1,8	2,6
R2: Extreme rain + collapse	0,02	1,2	0,6	0,17	0,26	0,1	2,3	4,5
R3: Spring flood + flooding	0,08	0,8	0,6	0,17	0,13	0,1	1,8	2,6
R4: Spring flood + collapse	0,02	1,2	0,6	0,17	0,26	0,1	2,3	4,5

The results are displayed in a risk matrix. C_{value} is the consequence measure chosen for display in Figure 5. One could also have used the Consequence class value C_{Tot}.

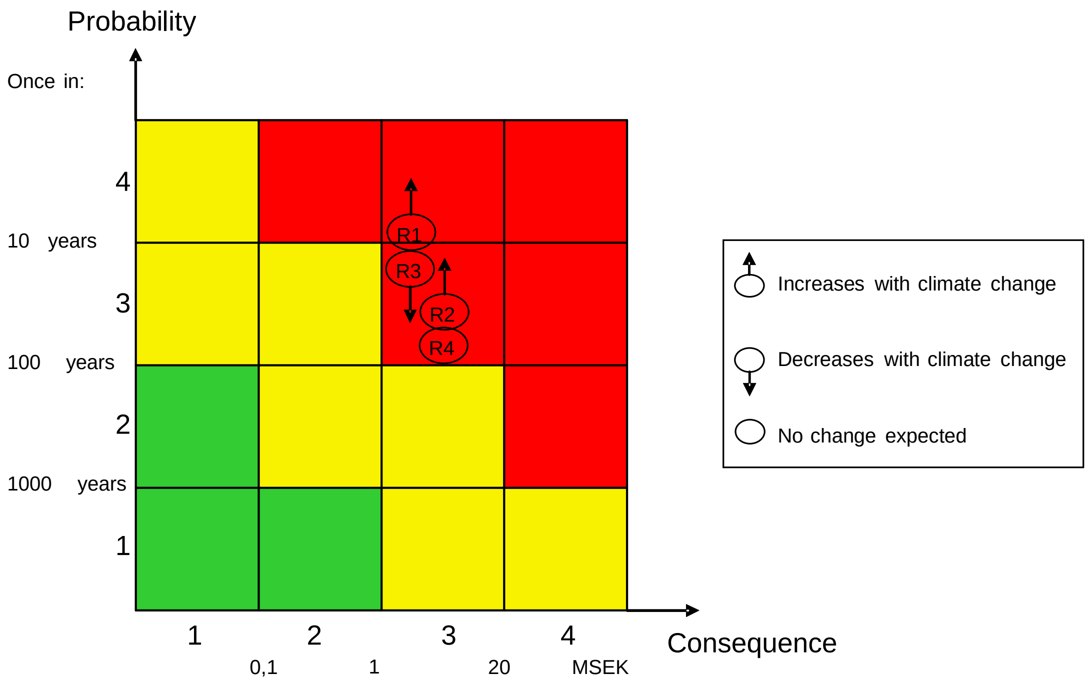

Figure 5: Risk matrix with probability and consequence indicated for all four risk scenarios. Arrows indicate how the risk is expected to evolve with climate change; the arrow shows the direction of movement of each risk in the matrix.

Step 4.2 Compare climate risk to other kind of risk

The risk was not compared to other types of risk. However it will be compared to other risks threatening the road network in order to obtain maximum value for money regarding risk reduction investments. The risk with the highest value for money will be treated first.

Step 4.3 Determine which risks are acceptable

None of the risk scenarios are acceptable without further investigations. It was concluded that in a long time climate perspective the R2 scenario, with extreme rainfall and a collapse of the dam, will become very likely to occur (high probability) and will have the most severe consequences. This was regarded as the most prioritised non-acceptable risk. The risks including flooding of the dam has less costly consequences for the road owner however, an overall evaluation of the risk matrix pointed out also these risk scenarios as not acceptable. This was even more obvious when considering the consequences beyond the responsibilities of the road owner, e.g. for the railroad.

Step 5 Risk mitigation

Risk mitigation involves identifying, appraising and selecting one or more options for modifying the non-acceptable risks. It also includes securing financing as well as documenting in an action plan how the chosen adaptation measures will be implemented.

Some examples of risk treatment options are: changing the likelihood of the risk scenario, changing the consequences and sharing the risk through risk financing.

Step 5.1 Identify options

Do minimum: Monitoring. SRA:s head of maintenance ask road maintenance operator to keep an eye on the dam and water levels when weather conditions are unfavourable.

Retro-fit: Build erosion protection in road embankment. Demolish the dam (time-consuming process; owner unknown, permission from water-rights court is required). Widen ditch and clean drums/pipes (may require permission from water-rights court). Replace drum under private road with larger drum (requires landowner's permission).

Contingency plan: Maps for redirecting traffic are ready to use. A crisis management group will assemble in extreme weather situations.

Future proof designs: Demolish the dam and replace with a steel net to prevent rocks and vegetation from clogging pipes and ditches. The net could be cleaned from a vehicle via a service road.

Research: Control owner situation. Control water management and environmental laws. Flow calculations to improve probability assessment.

In a seminar the risk scenarios were mapped on a white board and the possible mitigation options were discussed. The following options were identified;

- protection against erosion
- secure drainage by cleaning up and check dimensions of ditches and piping
- remove the dam
- protect against mudflows

Options including discussions and co-operation with other stakeholders were discussed.

Step 5.2 Appraise options

It was concluded none of the identified risk management options would solve the problem alone. A package of measures that are expected to reduce the risks for future flooding of the road is presented in Table 14. It is expected to allow for higher flows without flooding, eliminate the risk for dam collapse and reduce the risk for clogged pipes, drums and ditches.

The residual risk after taking these measures can be estimated from the new probability situation. No such calculations were done in this case study but it can be noted that risk scenarios R2 and R4 (including dam collapse) can no longer occur. It is estimated that the probability of scenarios R1 and R3 are lowered one class (one square in the matrix).

Table 14: Estimated costs for identified options.

Measure	Estimated cost (kSEK)
Erosion protection along road embankment -crushed rock, 1*1*150 m -widen ditch	50
Clean culvert under main road	-
Demolish dam	800
Construct steel net.	200
Replace drum under private road	10
Sum	**1060**

Step 5.3 Negotiation with funding agencies

SRA will fusion with Swedish Rail Administration before these measures are implemented, so benefits and costs will most likely be divided between the two fields. Another possible funding partner is the County administration board.

Step 5.4 Elaborate action plans

The SRA is not the owner of the dam or the watercourse and can not act as a single actor. The dam is old and the owner is not known.

It was identified that a collapse of the dam will have severe consequences also for the environment – as there is an industrial area and a lake downstream, and for the railroad. Thus there should be also other parties interested in reducing the risks.

Action plan

1. Contact the County Administrative Board (ongoing work). It is the responsibility of the County Administrative Board to contact land owner, downstream industry and the Railroad agency. Set up a meeting with all partners to present the risk analysis and discuss common actions. Note that the identified options together will solve the problem for all Risk scenarios.
2. Inform the maintenance contractor

Step 6 Implementation of action plans, and Step 7 Monitor, re-plan and capitalize

Within the time schedule of the RIMAROCC project, it was not possible to go through steps 6 and 7 in this case study.

4 Conclusions

The results from the case study have been evaluated together with the whole RIMAROCC project. It is already noted that the RIMAROCC-method can bring value to the existing routines. A plan for implementation in the organisation is an important step.

Steps 2.3, 3.2 and 3.3 need to be addressed together. Identifying consequences and formulating risk scenarios are dependent on each other. This procedure has been improved and clarified in the RIMAROCC guidebook.