ICFR 2013
BREACH RISK EVALUATION OF
THE RAILWAY EMBANKMENT
BETWEEN ARLES AND TARASCON

Mark CHEETHAM (Projets Système Ingénierie - SNCF)
Breach Risk Evaluation of the Railway Embankment between Arles et Tarascon

- **Description**
  - **Location**
    - Line 830 PARIS – MARSEILLE
    - Upstream limit – Km 764.800 (RD 99)
    - Downstream limit – Km 773.420 (Ouvrage CNR)
  - **Construction**
    - Embankment constructed in the 1840s
    - Material taken from borrow pits either side of structure
  - **Geometry**
    - Crest width = 14m (Double track)
    - Embankment height = 2-6m
    - Embankment slopes = 3H/2V
  - **Traffic**
    - 200 trains/ day
      - 150 trains with passengers (including 10 TGV trains)
      - 50 freight trains
    - Maximum speed = 200 km/h
Breach Risk Evaluation of the Railway Embankment between Arles et Tarascon

- History
  - Regulatory context
    - EU requirement – obligation to separate management of railway infrastructure and train operations

Since 1997

Réseau Ferré de France

Infrastructure manager
Owner and manager of the railway infrastructure in France

Train operator
Delegated infrastructure manager
Management and maintenance of the railway infrastructure on behalf of RFF
Breach Risk Evaluation of the Railway Embankment between Arles et Tarascon

History

- Rhône flood of December 2003
- Legislation of 25 August 2010 (Arrêté préfectoral): obligations relating to the operation, maintenance and monitoring of the railway embankment

« Due to the impact for the security of the population who are at risk in the event of its rupture or disfunction, the railway embankment requires the undertaking of studies and the application of rules in relation to its maintenance, operation and monitoring…»

- Obligations
  - Structure specific document
  - Description of the organisation to meet the obligations
  - Operations organisational document
  - Operations annual report
  - Annual detailed inspection
  - Flood resistance evaluation study
  - Breach and flood risk evaluation
  - Review of the flood resistance
Breach Risk Evaluation of the Railway Embankment between Arles et Tarascon

- **Risk identification and evaluation**
  - Risk analysis: Generalised method (ISO 31010)
    - Quantitative approach?
    - Qualitative approach?
    - Mixed approach?
**Breach Risk Evaluation of the Railway Embankment between Arles et Tarascon**

- **Risk identification and evaluation**
  - Generalised method
  - Risk analysis: Adopted method
    - Preliminary risk assessment (APR) – Identification of key scenarios
    - Detailed risk analysis – Bow-tie method (Method developed by ICI and Royal Dutch Shell)
Breach Risk Evaluation of the Railway Embankment between Arles et Tarascon

- **Risk identification and evaluation**
  - Functional analysis of the structure and its environment
    1. System of protection (regional scale)
    2. Analysis of the structures making up the system between Tarascon et Arles
    3. Railway embankment and its component parts
      - **Railway infrastructure**
        - Earth embankment
        - Railway bridges
        - Hydraulic structures
        - Track (rails, sleepers, ballast)
        - Catenary system
        - ...
      - **Services**
      - **Defects**
      - ...

![Diagram of railway infrastructure and components](image)
Risk identification and evaluation

- Principles for the prevention of accidents and the management of security of the structure (SGS)

General Infrastructure Management Plan
- Security of the infrastructure and train operations
- Numerous actors (RFF, EPSF, DCF, SNCF, …)
- Organisation at a local level
- Infrastructure monitoring
- Specific monitoring (in case of adverse weather, incidents, …)
- Definition of methods for intervening
- …

Rail operations during flood events
- Security of the infrastructure and train operations
- Numerous actors (Railway + Local services…)
- Coherence between the railway infrastructure emergency plans and those of the local communities
- Setting of threshold levels
- Defining the method of alert
- Methods for monitoring during Rhône flood events
- Defining methods for intervening
- …
Breach Risk Evaluation of the Railway Embankment between Arles et Tarascon

- Risk identification and evaluation
  - Research of historical examples
    - SNCF archives
      - Incidents in the study zone (2003 flood)
      - Incidents on the national rail network
    - Historical lower Rhône floods/defence breaches
    - Other documented breaches (national/international)
Breach Risk Evaluation of the Railway Embankment between Arles et Tarascon

- Risk identification and evaluation
  - APR – Selection of the principal breach scenarios (ERC)
    - Located in an area which:
      - Leads to the maximum level of flooding in the protected zone
      - Is most probable
      - Is the most vulnerable in terms of public security
    - 9 ERC retained
Breach Risk Evaluation of the Railway Embankment between Arles et Tarascon

- **Risk identification and evaluation**

  - ERC – Fault tree analysis
    - Identification of initiating events (IE)
    - Estimation of the probability of occurrence of each EI
    - Identification and evaluation of the efficiency of barriers which can influence the probability of the breach occurring

  - ERC – Event tree analysis
    - Interpretation of the results from 2D hydraulic modelling in terms of danger levels of each breach scenario (adaptation of the FLOODsite method)
    - Identification and evaluation of barriers which can reduce the seriousness of the breach
Breach Risk Evaluation of the Railway Embankment between Arles et Tarascon

- Risk identification and evaluation
  - ERC – Bow-tie diagrams
Breach Risk Evaluation of the Railway Embankment between Arles et Tarascon

- Risk identification and evaluation
  - Risk evaluation
    - Evaluation of the ERC
      - Public domain
      - Railway system

<table>
<thead>
<tr>
<th>Probability</th>
<th>Danger threshold</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (\text{annual probability of occurrence} &gt; 0.1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B (\text{annual probability of occurrence} 0.1 - 0.02)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C (\text{annual probability of occurrence} 0.02 - 0.004)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D (\text{annual probability of occurrence} 0.004 - 0.001)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E (\text{annual probability of occurrence} &lt; 0.001)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Context → Risk appreciation → Risk Identification → Risk Analysis → Risk Evaluation → Risk Reduction → Monitoring and Experience
Discussion

- Risk analysis – Bow-tie method
  - The bow-tie risk analysis method allows the presentation of complex reasoning in a clear and concise manner for both specialists and non-specialists.
  - The actions which lead to a reduction in risks are easily identifiable in the diagrams (barriers) and the evaluation of their effectiveness easily traced.

- Problems encountered
  - Defining acceptable levels of risk in the evaluation of each breach scenario is difficult for the infrastructure owners, particularly when the risk to a population is integrated into the analysis.
  - The evaluation of risks at a structure level can introduce problems of coherence between different studies when considering the protection system as a whole.
  - A quantitative risk analysis approach is highly subjective and agreement between « experts » is not always straightforward.
  - The tools used in breach modelling remain in the early stages of development and require further testing to ensure results are realistic.