Methodology developed for the Belgian External Flooding PSA

25/02/2021

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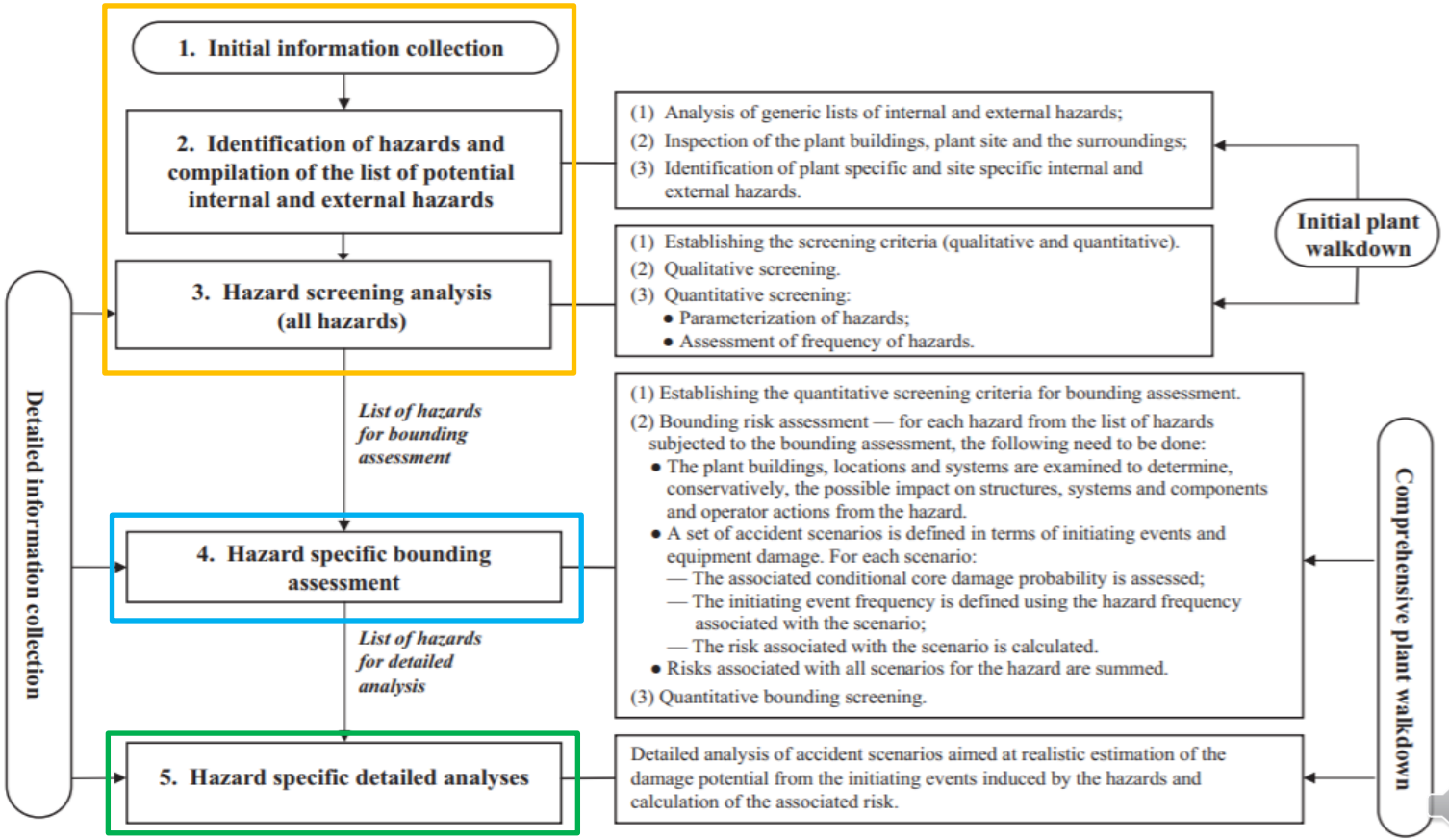
Introduction

Introduction



Tihange site

Tihange Site

General assumptions

Scope, assumptions and limitations

- Applicable equally to Reactor or Spent Fuel Pool PSA
- Level 1 PSA methodology
- Based on the available internal events PSA
- Site-level response: isolation of the peripheral wall
- Single unit system modelling (except for the flex/ultimate means, for which cross unit back-up is credited)

Scope, assumptions and limitations

- Reflection the operator’s strategy
- Two optimal safe shutdown states
  - Power operation => Intermediate shutdown
  - Outage => Shutdown for refuelling

Task descriptions

Task 1 : Hazard curve characterisation

Instrumental Hydrology:

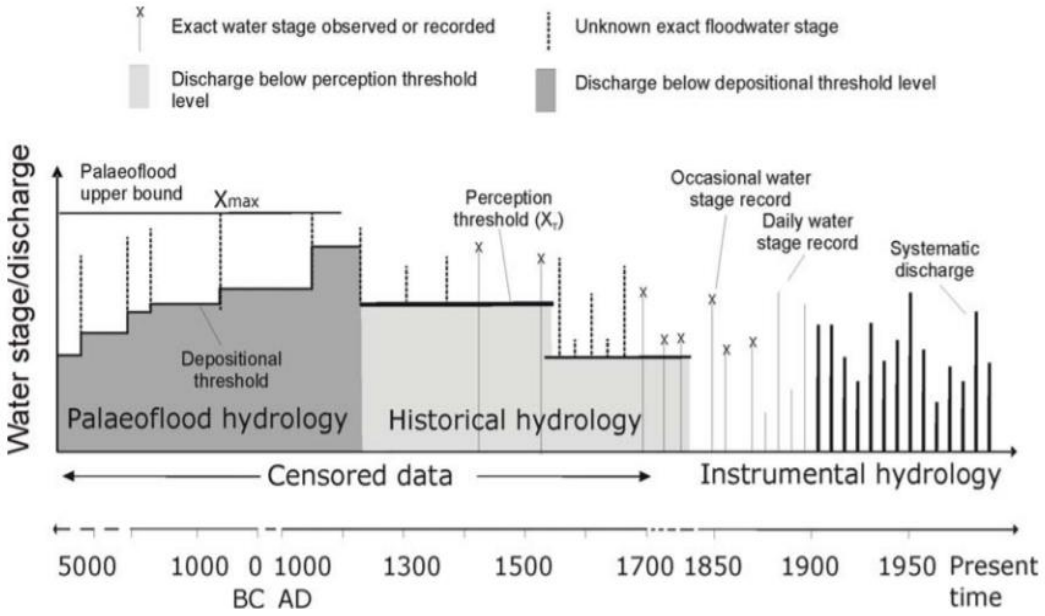
- Some 60-70 years

Historical flood doc sources :

- Newspapers
- Flood mark on a house
- Personal correspondence

Palaeoflood indications :

- Scars on trees
- Flood deposit



Task 1 : Hazard curve characterisation

- Converted into PSA compatible form
- Estimation of uncertainty
- Goals:
  - Define the discrete intervals to analyse
  - Assess and reduce the epistemic uncertainty

Task 2 : SSC Identification

- Modelling for external flooding
  - Existing reactor PSA model
  - SFP model
  - Input data : functional descriptions, P&IDs, logical diagrams and maintenance records.
- Examination and adaptation of existing internal events PSA fault trees

Task 3 : Site walkdown data collection

- Complete topographical models of the site with and without the anti-flooding wall exist
- When additional details are needed :
  - Request from the site – for clarifications
  - Site walkdown to be organized – for significant amount of details
- An interview with the site personnel

Task 4 : Peripheral wall reliability model

- Detailed characterisation of the wall :
  - Wall elements
  - Actions to isolate the wall
  - Maintenance procedures
- Sources of data for failure probabilities :
  - Site specific empirical experience
  - Empirical experience from other plants
  - Generic industry data or failure probabilities
  - Engineering judgement

Goal : Determine the reliability of the wall by FT analysis

Task 5 : Water level correlations (optional)

- Calculation of onsite water levels and propagation inside buildings
- Task 5 inputs : from Tasks 1, 2, 3, and 4
- Map the relationship between the critical hazard parameters for an external flooding PSA
- Optional:
  - Depends on the extent, to which the methodology will be applied

Task 6 : Human reliability analysis (HRA)

- River flooding is a predictable hazard, HRA is focused on :
  - Pre-emptive human actions (close the wall and install barriers, bring plant to safe state)
  - Post initiating event human actions
- Flood monitoring and warning system has an essential role to trigger pre-emptive actions that should be included in the model :
  - Principles of implementation and equipment used for monitoring the Meuse river flow
  - Ability to detect the on-going flooding
  - Ability to ensure sufficient time during warning phase
  - Successive warnings phases

Task 6 : HRA - Post-initiating event human actions

- Re-quantification of existing HEPs can be performed by using penalizing factors to account for the additional stress and organizational workload

Task 7 : Additional system analysis

- Internal events PSA model will be expanded with the modelling of critical systems required to cope with external flooding events
- Ultimate Means System
  - Make-up to the primary, SG, SFP
  - Diesel generator
- Detailed fault trees will be developed
- Extension of the modelling of other systems

Task 8 : PSA consequences definition

- External flooding event trees development
- Task 8 outputs :
  - Relevant function events
  - Definition of scenario sequences
  - Consequences defined for each sequence
  - Assignment of boundary condition sets
- Same success criteria as internal events PSA
  - Success
  - Induced accident
  - Core damage

Task 9 : PSA model integration

- External flood PSA quantification
  - Sequence/consequence analysis
  - CCDP estimation per interval
  - CDF Quantification
- Risk quantification consider :
  - Flooding induced failures
    e.g. loss of the safety systems when the water reaches a certain height
  - Non flooding failures : random failures, human actions, etc.;
    e.g., a pump fails to start, CCF.

Task 10 : Sensitivity, uncertainty and importance analysis

Parameters for the interpretation of the results :

- Uncertainty : confidence interval
- Importance analysis : evaluate the importance of basic events
- Sensitivity analysis : re-quantification of the analysis using alternative assumptions

→ To assure robustness of further decisions based on PSA and provide important inputs to any recommended design or procedure changes

Task 11 : Presentation of the results

Technical note with final result, includes :

- Numerical value of the core damage frequencies
- Split of the results per plant operating state
- Dominant sequences
- List of top minimal cut-sets
- HSS basic events
- Sensitivity results
- External flood vulnerabilities
- Insights and recommendations

Conclusion

Conclusion

- Methodology for the external flooding detailed probabilistic safety analysis was developed
  - High level: describes the overall philosophy
  - Ad hoc adaptations possible
  - Based of literature review, benchmarking
  - Lessons learnt from the bounding analysis
- CDF quantification, Error Factor and identification of the potential vulnerabilities


Thank you for your attention!