



Overview of NRC's Probabilistic Flood Hazard Assessment Research Program

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Outline

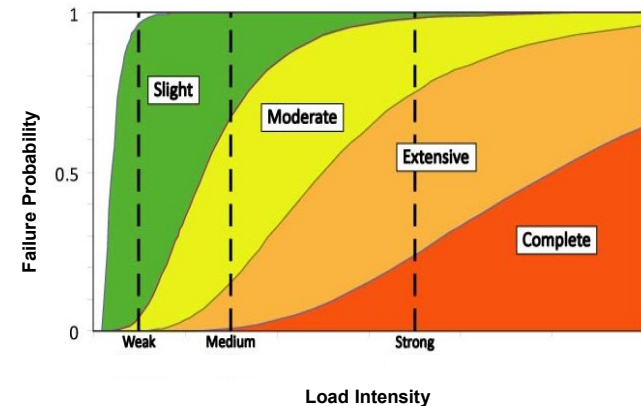
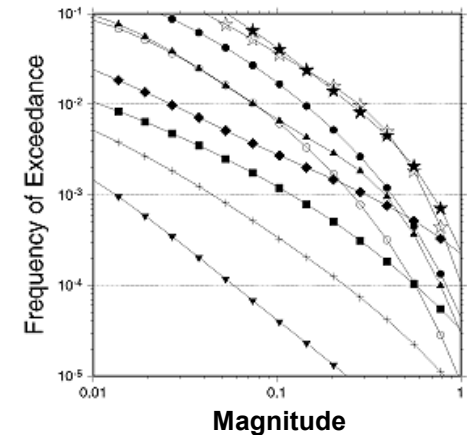
- Objectives
- Key Challenges
- Research Approach
- Selected Projects
- Future Directions

PFHA Research Objectives

- Address significant gap in technical basis for guidance for probabilistic assessment of external hazards
 - Probabilistic: seismic, high winds
 - **Deterministic: flooding**
- Develop resources, tools and selected guidance
 - Support risk-informed licensing and oversight activities associated with flooding hazards and consequences
 - Licensing and oversight in operating reactor program
 - Design basis flood hazard assessments for new facilities
 - Readiness for licensing of advanced reactors

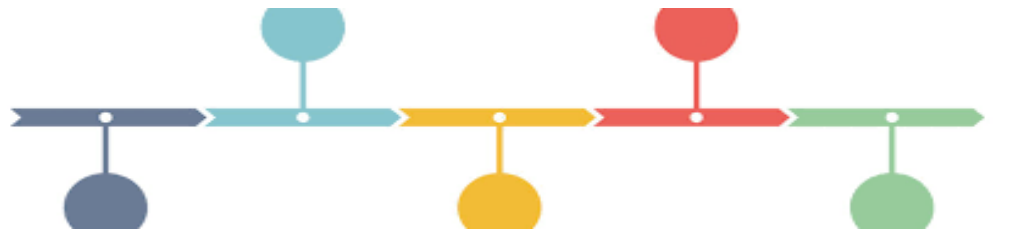
Key Challenges

- Hazard Curve Development
 - Range of annual exceedance probabilities (AEPs)
 - Moderately rare to extreme floods
 - Multiple flooding mechanisms
 - Coincident and correlated mechanisms
 - Uncertainty characterization and estimation
 - Aleatory (e.g. storm recurrence rates)
 - Epistemic (e.g. model structure, parameters)
- Fragility Curve Development
 - Information on reliability of flood protection features and procedures is sparse
 - Cliff-edge effects



Phased Approach

- Phase 1 (FY15-FY19)
 - Technical basis research
- Phase 2 & 3 (FY20-FY22)
 - Selected draft guidance documents
 - Perform pilot studies
 - Finalize guidance



Phase 1 Technical Basis Projects

Leverage Available Flood Information
PFHA Modeling Frameworks
Improved Modeling
Reliability of Flood Protection
Dynamic and Nonstationary Processes

Phase 1 Technical Basis Projects

**Leverage Available
Flood Information**

PFHA Modeling
Frameworks

Improved Modeling

Reliability of Flood
Protection

Dynamic and
Nonstationary
Processes

Leverage Available Flooding Information

- **Development of Natural Hazard Information Digests for Operating NPP Sites (INL)**
 - **Completed** (*continue with updates/maintenance*)
- **Application of State-of-Practice Flood Frequency Analysis Methods and Tools (USGS)**
 - **Completed – USGS Scientific Investigation Report**
 - <https://pubs.er.usgs.gov/publication/sir20175038>
 - *2nd USGS SIR in publication*
- **Extreme Precipitation Estimates in Orographic Regions (USBR)**
 - **Completed - NUREG/CR report in publication**
- **Technical Basis for Extending Frequency Analysis Beyond Current Consensus Limits (USBR)**
 - *In progress (completion expected in FY20)*

Leverage Available Flooding Information

- **Eastern US Riverine Flood Geomorphology Feasibility Study (USGS)**
 - **Completed – USGS Scientific Investigations Report**
 - (<https://doi.org/10.3133/sir20175052>)
- **Eastern US Riverine Flood Geomorphology Comprehensive Study (USGS)**
 - *In progress (completion expected FY20)*
- **Framework for Technical Review of Paleoflood Information (USGS)**
 - *In progress (completion expected FY20)*
 - *Workshop summary: ML19200A281*
- **Application of Point Precipitation Estimates to Watersheds (ORNL)**
 - **Completed (NUREG/CR report in publication)**

Phase 1 Technical Basis Projects

Leverage Available
Flood Information

**PFHA Modeling
Frameworks**

Improved Modeling

Reliability of Flood
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PFHA Modeling Frameworks

- **Probabilistic Flood Hazard Assessment Framework Development (USACE)**
 - *In progress (completion expected FY20)*
- **Structured Hazard Assessment Committee Process for Flooding (SHAC-F) for LIP & Riverine Flooding (PNNL)**
 - *In progress (completion expected FY20)*
- **Development of SHAC-F for Coastal Flooding (PNNL & USACE)**
 - *In progress (completion expected FY20)*
- **Methods for Estimating Joint Probabilities of Coincident and Correlated Flooding Mechanisms for Nuclear Power Plant Flood Hazard Assessments (ORNL)**
 - *In progress (completion expected FY20)*
 - *Task 1 (Literature review) completed*
 - *Task 2 (Critical Assessment of Selected Methods and Approaches) Completed.*

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- **Numerical Modeling of Local Intense Precipitation Processes (USGS/UC Davis)**
 - **Completed - NUREG-CR report in publication**
 - **Peer-reviewed papers: Mure-Ravaud, et al. (2019a,b)**
<https://www.sciencedirect.com/science/article/pii/S0048969719306734>
 - <https://www.sciencedirect.com/science/article/pii/S0048969719306291>
- **Quantifying Uncertainties in Probabilistic Storm Surge Models (USACE)**
 - *In Progress (completion expected FY20)*
 - **Task 1 (Literature Review) Completed. ERDC/CHL SR-19-1**
 - <https://erdc-library.erdc.dren.mil/xmlui/handle/11681/32293>
 - **Task 2 (Storm Recurrence Rate Models) Completed. ERDC/CHL TR-19-4**
 - <https://apps.dtic.mil/docs/citations/AD1073835>
- **Erosion Processes in Embankment Dams (USBR)**
 - **Completed - NUREG-CR report in publication**
- **Convection-Permitting Modeling for Intense Precipitation Processes (NCAR)**
 - *In Progress (completion expected FY21)*

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Reliability of Flood Protection

- **Modeling Plant Response to Flooding Events (INL)**
 - *Completed. NUREG/CR report in publishing*
- **Effects of Environmental Factors on Manual Actions for Flood Protection and Mitigation at Nuclear Power Plants (PNNL)**
 - *Completed. NUREG/CR report in publication process*
- **Critical Review of the State of Practice in Probabilistic Risk Assessment for Dams (ORNL, UMD)**
 - *Completed. ORNL report available at <https://www.osti.gov/biblio/1592163-current-state-practice-dam-safety-risk-assessment>*
- **Performance of Flood Penetration Seals at NPPs (Fire Risk Management, Inc.)**
 - *Completed. NUREG report in publication process*
- **Flood Barrier Testing Strategies (INL/ISU)**
 - *In Progress. Public workshop to be held March 12 - 13*

Phase 1 Technical Basis Projects

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Dynamic and Nonstationary Processes

- **Regional Climate Change Projections: Potential Impacts to Nuclear Facilities (PNNL)**
 - **Year 1 (CONUS) – Complete**
 - *published as a PNNL report (PNNL-24868)*
 - **Year 2 (Southeast US) - Complete**
 - *published as a PNNL report (PNNL-26226)*
 - **Year 3 (Midwest US) – Complete**
 - *published as a PNNL report (PNNL-27452 Rev1)*
 - **Year 4 (Northeast US) – Complete**
 - *published as a PNNL report (PNNL-29079)*

Future Directions for PFHA



Future Directions for PFHA



Phase 2 Pilot Studies

Objective: Synthesize results from technical basis research

- Multiple flooding mechanism contribution to hazard curves
- Quantify key aleatory variabilities and epistemic uncertainties

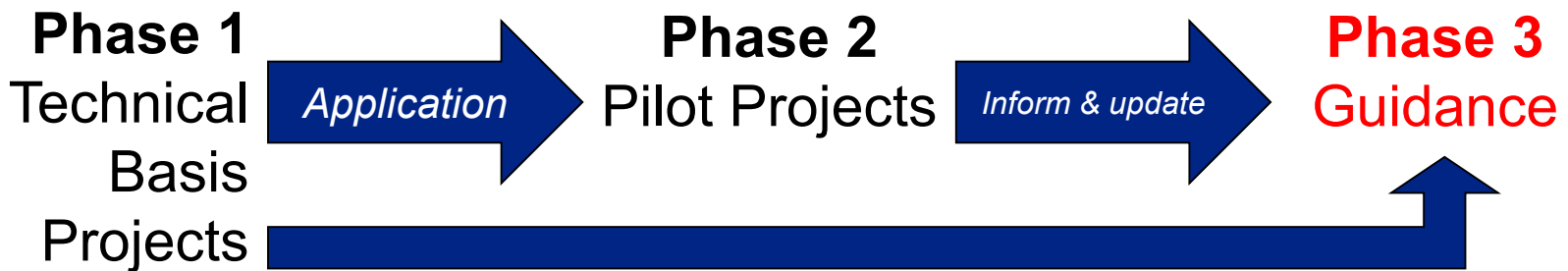
LIP Flooding PFHA Pilot (PNNL)

- Pilot study to inform development of guidance for probabilistic assessment of flooding hazards at NPPs due to local intense precipitation events

Riverine PFHA Pilot (USACE/HEC)

Coastal Flooding Pilot PFHA Pilot (USACE/ERDC)

Phase 3 (FY22-?)



- Revise guidance documents based on pilots
- Stakeholder & Public Interactions
- Finalize guidance

Questions?

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