



Overview of NRC's Probabilistic Flood Hazard Assessment Research Program

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Office of Nuclear Regulatory Research

4th Annual PFHA Research Workshop

NRC HQ, Rockville, MD

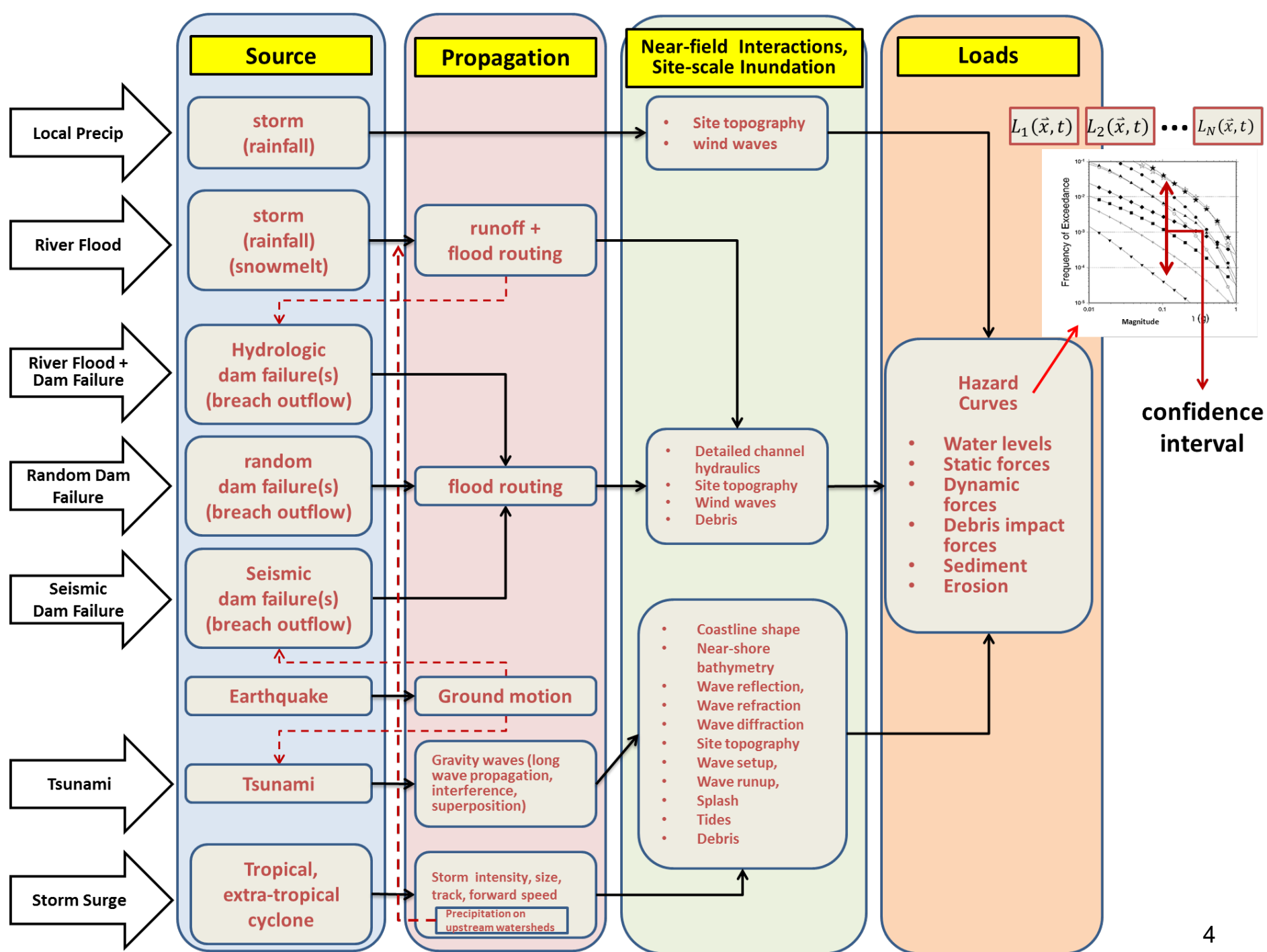
April 30 – May 2, 2019

Outline

- Objectives
- Key Challenges
- Main Research Themes
- Implementation
- Selected Projects
- Future Directions

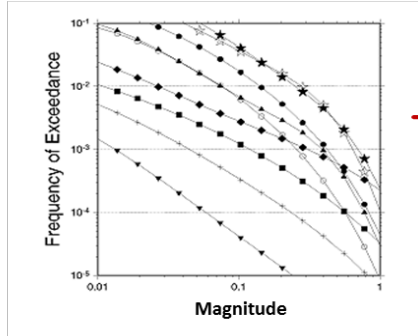
PFHA Research Objectives

- 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



Risk-informed Assessment of Flooding Hazards and Consequences

$$L_1(\vec{x}, t) \quad L_2(\vec{x}, t) \quad \dots \quad L_N(\vec{x}, t)$$

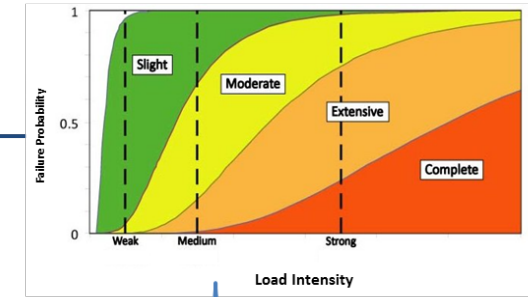


Hazard Curves :
Quantitative probabilistic assessment
of flood hazard(s)

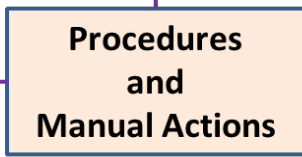
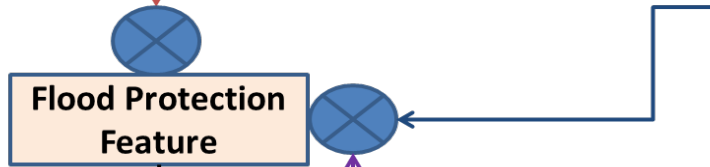
Hazard

$$Fr_1 \quad Fr_2 \quad \dots \quad Fr_N$$

Fragility



Fragility Curves :
Quantitative Reliability of Passive and
Active Flood Protection Features

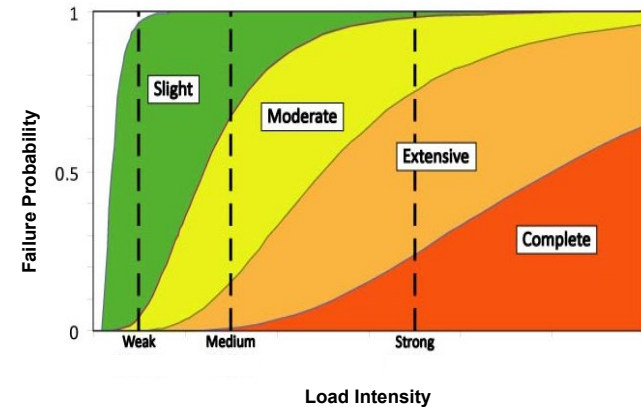
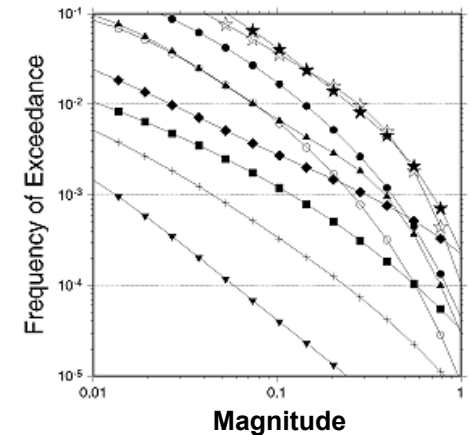


Human Reliability Assessment (HRA) issues with flood protection and/or mitigation procedures



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

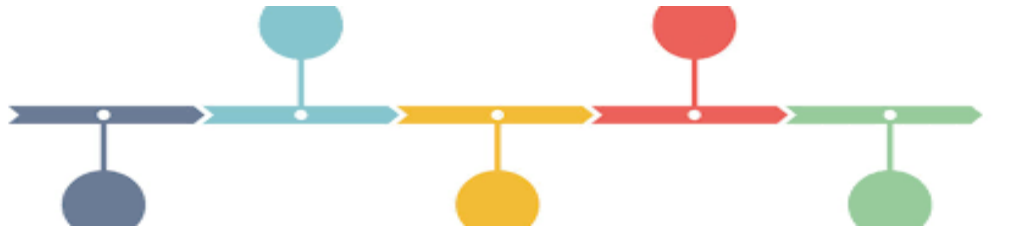




- Leverage available flood hazard information
- Develop PFHA modeling framework for range of flooding scenarios and range of AEPs
- Application of improved modeling techniques for processes and mechanisms associated with flooding
- Assess reliability of flood protection, mitigation, and plant response to flooding events
- Assess potential impacts of dynamic and nonstationary processes on flood hazard assessments and flood protection

Phased Approach

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



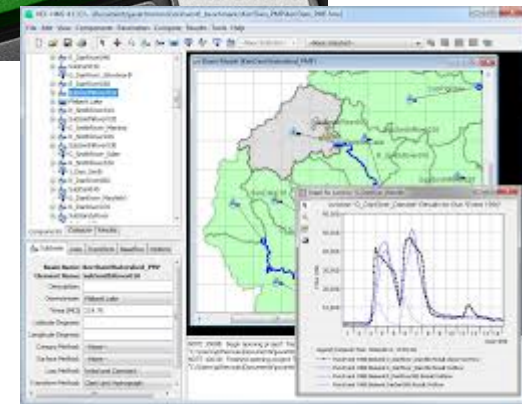
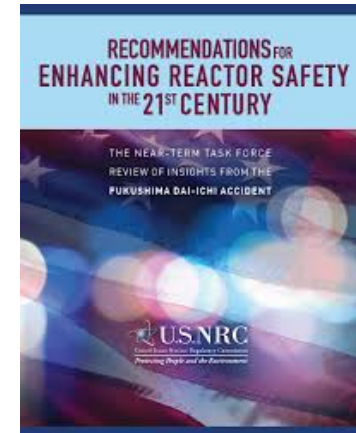
Implementation

- **Internal Collaborations**
 - User offices
 - Other RES divisions/branches
- **External Contract technical support**
 - Interagency Agreements
 - Commercial contracts
- **External Collaborations**
 - MOUs
 - EPRI
 - France Institute for Radiological Protection and Nuclear Safety (IRSN)
 - Federal interagency working groups
 - International working groups



Additional Activities

- Support Agency Post-Fukushima Activities
- Collaboration with other RES and Agency Initiatives
- Training Seminars & Workshops
- Technical Exchanges



Phase 1 (Technical Basis) Projects

Leverage Available Flooding Information

- **Development of Natural Hazard Information Digests for Operating NPP Sites (INL)**
 - *In progress (completion expected FY19)*
- **Application of State-of-Practice Flood Frequency Analysis Methods and Tools (USGS)**
 - <https://pubs.er.usgs.gov/publication/sir20175038>
 - *2nd USGS SIR in publication (expected in FY19)*
- **Extreme Precipitation Estimates in Orographic Regions (USBR)**
 - *NUREG/CR report in publication*
- **Technical Basis for Extending Frequency Analysis Beyond Current Consensus Limits (USBR)**
 - *In progress (expected completion in CY19)*

Leverage Available Frequency Information (Cont.)

- **Eastern US Riverine Flood Geomorphology Feasibility Study (USGS)**
 - *Completed* (<https://doi.org/10.3133/sir20175052>)
- **Eastern US Riverine Flood Geomorphology Comprehensive Study (USGS)**
 - *In progress* (completion expected FY19)
- **Framework for Technical Review of Paleoflood Information (USGS)**
 - *New start* (expected completion FY20)
- **Application of Point Precipitation Estimates to Watersheds (ORNL)**
 - *In progress* (completion expected FY19)

- **Probabilistic Flood Hazard Assessment Framework Development (USACE)**
 - *In progress (completion expected FY19)*
- **Structured Hazard Assessment Committee Process for Flooding (SHAC-F) for LIP & Riverine Flooding (PNNL)**
 - *In progress (completion expected FY19)*
- **Development of SHAC-F for Coastal Flooding (PNNL & USACE)**
 - *New start (completion expected CY19)*

Improved Modeling

- **Numerical Modeling of Local Intense Precipitation Processes (USGS/UC Davis)**
 - *NUREG-CR report in publication*
 - *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 CY19)*
 - *ERDC/CHL SR-19-1 (Literature Review)*
 - <https://erdc-library.erdcdren.mil/xmlui/handle/11681/32293>
- **Erosion Processes in Embankment Dams (USBR)**
 - *NUREG-CR report in publication*
- **Methods for Estimating Joint Probabilities of Coincident and Correlated Flooding Mechanisms for Nuclear Power Plant Flood Hazard Assessments (ORNL)**
 - *New start (completion expected FY20)*

Reliability of Flood Protection

- **Modeling Plant Response to Flooding Events (INL)**
 - *NUREG/CR report in publishing*
- **Effects of Environmental Factors on Manual Actions for Flood Protection and Mitigation at Nuclear Power Plants (PNNL)**
 - *In Progress (completion expected FY19)*
- **Critical Review of the State of Practice in Probabilistic Risk Assessment for Dams (ORNL, UMD)**
 - *In Progress (completion expected FY19)*
- **Performance of Flood Penetration Seals at NPPs (Fire Risk Management)**
 - *NUREG report in preparation*

Dynamic and Nonstationary Processes

- **Regional Climate Change Projections: Potential Impacts to Nuclear Facilities (PNNL)**
 - *YR1 (CONUS) - published as a PNNL report (PNNL-24868)*
 - *YR2 (Southeast US) - published as a PNNL report (PNNL-26226)*
 - *YR3 (Midwest US) - report in review*
 - *YR4 (Northeast US) in progress*

Future Directions

Phase 1 Completion

- **FY19-20**
 - Follow-on Flood Protection Performance Research
 - In discussions w/ ERPI, DOE/INL
 - Identify Selected Draft Guidance Documents
 - White papers
 - Reg Guides

- **FY20-21**
 - LIP flooding scenario(s)
 - Inland (riverine) flooding scenario(s)
 - Coastal flooding scenario(s)
- *Seeking collaboration*
 - *Industry/EPRI*
 - *Other agencies*
 - *International*

Phase 3 (FY22-?)

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

Questions?

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Mark Your Calendar!

5th Annual NRC PFHA Research Workshop
Feb 18-20, 2020
NRC HQ, Rockville, MD

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