



NRC PFHA Research Program

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Outline

- PFHA Research Program
 - Research objectives
 - Main themes
 - Implementation
- Overview of current projects
- Plans for future projects

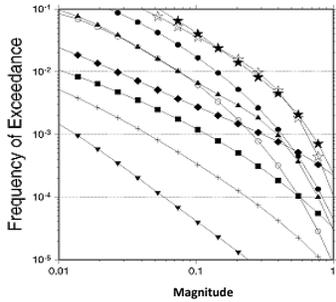
PFHA Research Plan

- **FY2014 Research Program Plan developed**
 - Detailed plan developed in close consultation with licensing offices
 - Office of New Reactors (NRO)
 - Office of Nuclear Reactor Regulation (NRR)
 - Condensed version provided to Commission
 - Publicly Available in ADAMS (*ML14296A442*)
 - Google “nrc pfha research plan”
- **FY2015 Initiated implementation**
 - Phased approach

PFHA Research Objectives

- Support development of risk-informed licensing and oversight guidance and tools for assessing flooding hazards and consequences
 - Addresses significant gap in probabilistic basis for external hazards
 - Seismic and wind hazard assessments currently have probabilistic basis
- Support both NRO's new reactor licensing and NRR's oversight of operating reactors
 - Design basis flood hazard assessments for new facilities
 - 10 CFR Part 50 - traditional construction permits and operating licenses
 - 10 CFR Part 52 - early site permits (ESPs), combined operating licenses (COLs)
 - Operating reactor oversight program (ROP)
 - Significance determination process (SDP) analyses for evaluating deficiencies related to flood protection at operating facilities

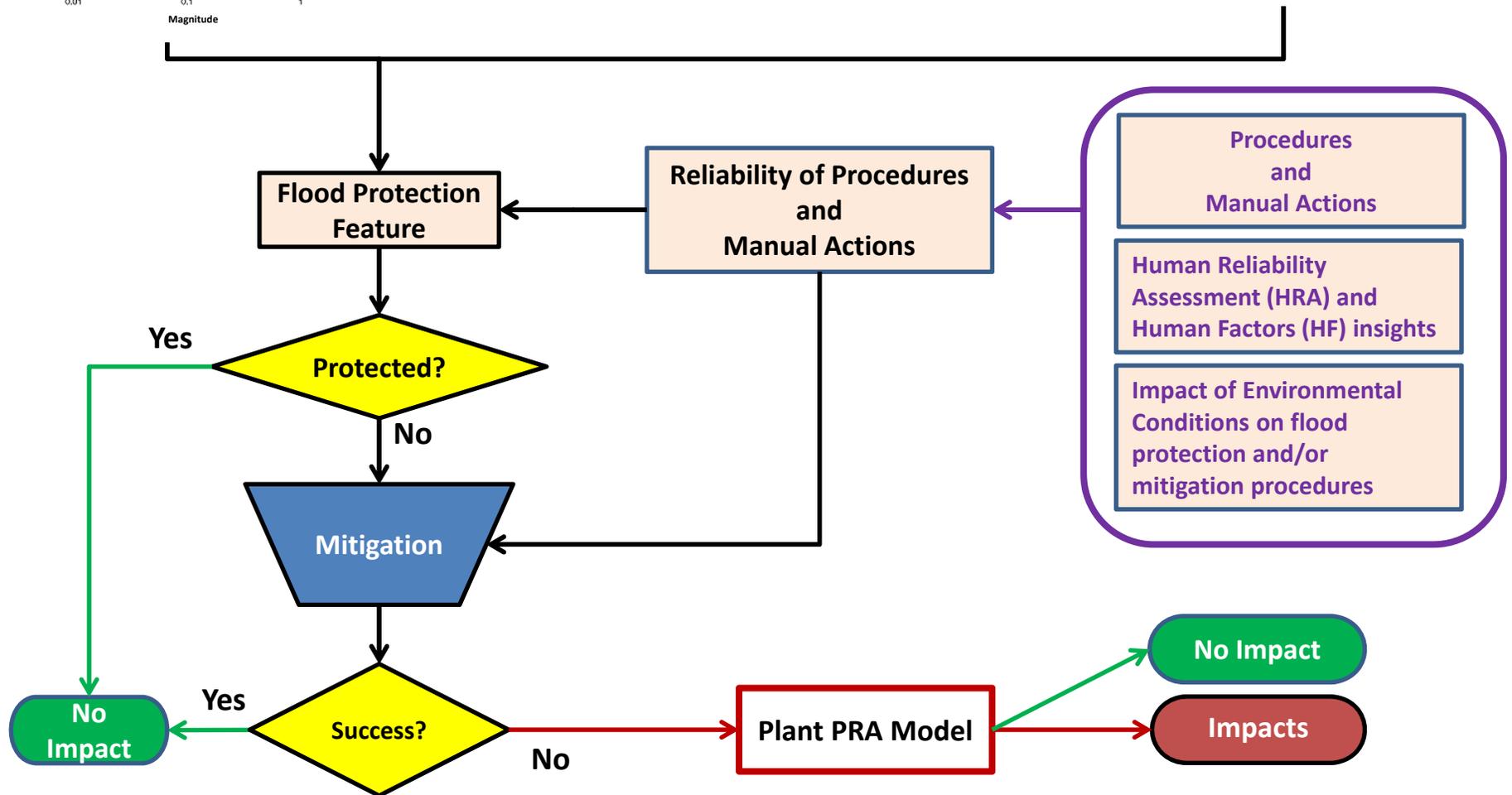
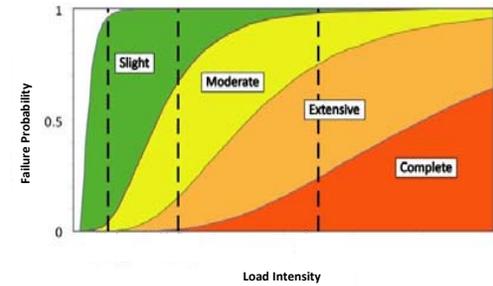
$L_1(\bar{x}, t)$ $L_2(\bar{x}, t)$... $L_N(\bar{x}, t)$

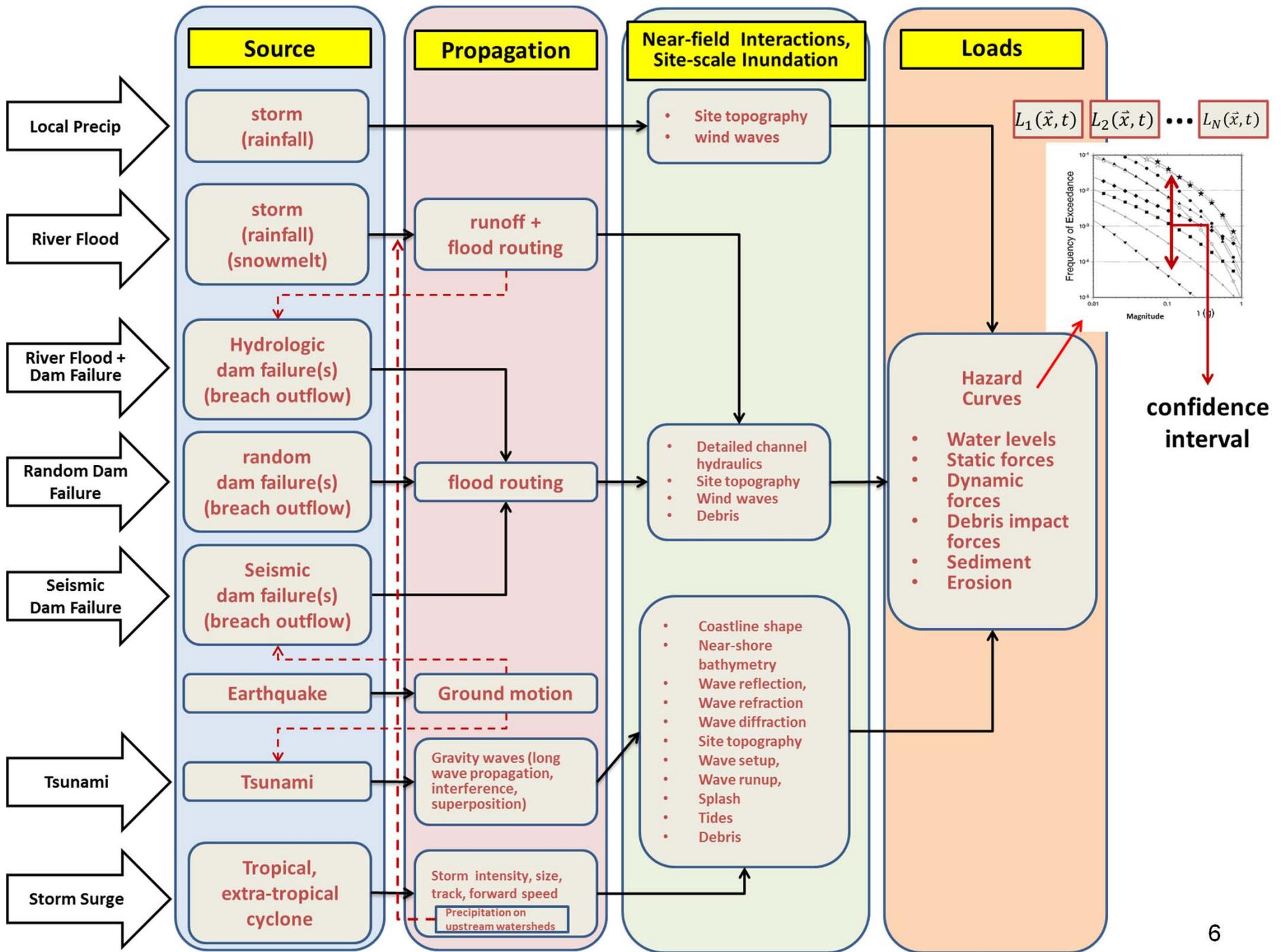


Hazard Curves :
Quantitative
probabilistic
assessment
of flood hazard(s)

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

Fr_1 Fr_2 ... Fr_N





Key Challenges

- Full hazard curves needed
 - Interested in range of annual exceedance probabilities (AEPs) from moderately rare to extreme floods
 - Right hand tails, AEPs in the range 10^{-4} to 10^{-6} desired
 - Aleatory and epistemic uncertainties need to be characterized and propagated
- Complexity
 - Multiple flood causing mechanisms
 - Mechanisms can combine/co-occur
 - Associated effects
- Component fragility and human reliability information is sparse
- Flooding impacts are nonlinear
 - Cliff-edge effects
 - Rates and duration may be important
- Large uncertainties
 - Sensitivity analysis
 - Which uncertainties can be reduced? How?



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Protecting People and the Environment

Research Plan Main Themes

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

Implementation

- **Phased Approach**
 - Phase 1 (Technical basis, draft guidance) ~ 5 years
 - Phase 2 (Pilot studies) } ~ 2 years
 - Phase 3 (Finalize guidance) }
- **Contract technical support from other agencies**
 - DOE Laboratory Contracts (PNNL, INL)
 - Interagency Agreements (USACE, USGS, USBR)
- **Communication**
 - Internal Technical Advisory Group, Research Seminars
 - Annual PFHA Research Program Workshop
 - NRC staff, contractors, selected external invitees
 - NRC Regulatory Information Conference (RIC)
 - Professional meetings & conferences
 - Interagency working groups (e.g. AQWI/SOH)
- **External Collaborations**
 - Electric Power Research Institute (EPRI)
 - French Institute for Radiological Protection (IRSN)



Overview of Current Projects

Current Projects

- **Leveraging Available Flooding Information**
 - Guidance on Application of Frequency Analysis Methods (USGS and USBR)
 - Guidance on Application of State-of-Practice Flood Frequency Analysis Methods and Tools (USGS)
 - Technical Basis for Extending Frequency Analysis Beyond Current Consensus Limits (USBR)
 - Development of Flood Hazard Information Digest (INL)

Leverage Available Flooding Information (Cont.)

- **Guidance on Application of State-of-Practice Flood Frequency Analysis Methods and Tools**
 - *USGS (Tim Cohn, William Asquith, Julie Kiang)*
 - Focus on best practices for characterizing the full uncertainty in flood frequency estimation using current methods
 - Provide guidance on judging the validity of extrapolating hydrologic hazard curves developed using current, widely-used methods

Leverage Available Frequency Information (Cont.)

- **Technical Basis for Extending Frequency Analysis Beyond Current Consensus Limits**
 - *USBR (Joseph Knight)*
 - Develop guidance for extending frequency analysis methods beyond current consensus limits for riverine flooding applications
 - Focus on describing alternative methods for integration of the characterizations from multiple approaches to estimate rainfall and floods with AEPs 1×10^{-5} to 1×10^{-6} .
 - Expand on the streamflow-based statistics methods and rainfall-runoff methods used at USBR
 - Uncertainty characterization and hydrologic risk concepts developed at USBR

Leverage Available Flooding Information

- **Development of Flood Hazard Information Digests for Operating NPP sites**
 - *INL (Kellie Kvarfordt, Curtis Smith)*
 - Organize flooding information and build database of currently available site-specific flood hazard information

Current Projects (Cont.)

- **PFHA Framework Development**
 - Technical Basis for Probabilistic Flood Hazard Assessment – Riverine Flooding (PNNL)
 - Probabilistic Flood Hazard Assessment Framework Development (USACE)
 - Structured Hazard Assessment Committee Process for Flooding (PNNL)

- **Technical Basis for Probabilistic Flood Hazard Assessment – Riverine Flooding**
 - *PNNL (Rajiv Prasad, Philip Meyer)*
 - Critical review of the state of practice in PFHA modeling for riverine flooding (absent dam failure)
 - Compare data-driven and simulation approaches

- **Probabilistic Flood Hazard Assessment Framework Development – LIP, Riverine**
 - USACE (*Aaron Byrd, Brian Skahill*)
 - Develop PFHA Framework for range of flooding scenarios and annual exceedance probabilities (AEPs)
 - Rigorous logical and mathematical framework for combining information types
 - Initial focus on local intense precipitation (LIP) and riverine flooding

- **Structured Hazard Assessment Committee Process for Flooding (SHAC-F)**
 - *PNNL (Rajiv Prasad, Philip Meyer) and Coppersmith Consulting (Kevin Coppersmith)*
 - Develop a Structured Hazard Assessment Committee process for Flooding (SHAC-F)
 - Assess need for a hierarchy of study complexity to address range of flooding issues
 - Develop example applications of framework
 - Local intense precipitation (LIP), riverine flooding
 - Virtual workshops

Current Projects (Cont.)

- **Application of Improved Modeling Techniques for Processes and Mechanisms Associated with Flooding**
 - Numerical Modeling of Local Intense Precipitation Processes (UC Davis)
 - Estimating Precipitation-Frequency Relationships in Orographic Regions (USBR)
 - Quantifying Uncertainties in Probabilistic Storm Surge Models (USACE)



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Improved Modeling Techniques

- **Numerical Modeling of Local Intense Precipitation Processes**
 - *UC Davis (Levent Kavvas, Kei Ishida, Mathieu Mure-Ravaud)*
 - Assess capability of regional numerical weather simulation models to accurately simulate extreme precipitation events
 - Mesoscale convective systems
 - Tropical cyclones and/or remnants
 - Extratropical cyclones
 - Use models to investigate impact of climate change on extreme precipitation events

Improved Modeling Techniques (Cont.)

- **Estimating Precipitation-Frequency Relationships in Orographic Regions**
 - *USBR (David Keeney, Kathleen Holman)*
 - Critical review of historical precipitation analysis with focus on applicability to orographic regions
 - Orographic storm analysis methods
 - Regional precipitation-frequency analysis
 - Recent applications of methods in USBR dam risk studies
 - Extension of USBR methods

Improved Modeling Techniques (Cont.)

- **Quantifying Uncertainties in Probabilistic Storm Surge Models**
 - *USACE (Norberto Nadal-Caraballo, Victor Gonzalez, Mary Cialone, Jeff Melby, Chris Massy)*
 - Fully quantify epistemic and aleatory uncertainties inherent in probabilistic storm surge modeling.
 - Assess propagation of uncertainties in joint probability analyses of storm surge hazard

Current Projects (Cont.)

- **Reliability of Flood Protection and Mitigation**
 - Performance of Penetration Seals (FRM)
 - Erosion Processes in Embankment Dams (USBR)
 - Effects of Environmental Factors on Manual Actions for Flood Protection and Mitigation at Nuclear Power Plants (PNNL)

Reliability of Flood Protection and Mitigation (Cont.)

- **Performance of Penetration Seals**
 - *Fire Risk Management Inc. (Mark Cummings)*
 - *Subcontractors: Alion, Nuvia*
 - Develop standard testing procedures, acceptance criteria, and protocols to assess effectiveness and performance
 - Testing of selected penetration seal designs

Reliability of Flood Protection and Mitigation

- **Erosion Processes in Embankment Dams**
 - *USBR (Tony Wahl)*
 - Study dam breach processes through physical hydraulic model tests
 - Construct 2 zoned physical models of rockfill dams with clay cores and filter zones.
 - One model to be tested with overtopping flow, and the second to be tested with internal erosion through a designed embankment defect (piping)
 - Post-test data analysis will include the development of correlations between measured variables, comparison to established relationships from previous research on this topic, and comparison of test results to predictions made with breach erosion computer models.

Reliability of Flood Protection and Mitigation

- **Effects of Environmental Factors on Manual Actions for Flood Protection and Mitigation at Nuclear Power Plants**
 - *PNNL (Rajiv Prasad, Kristi Branch, Garill Coles, Angela Dalton, Nancy Kohn)*
 - *Subcontract with Alvah Bitner*
 - Consider environmental factors (EFs) and environmental conditions (ECs) that can occur during flooding events and the manual actions taken to prepare/respond
 - Develop a framework for assessing impact of ECs on manual actions
 - Review and apply current literature to assess impacts to performance

Plant Response to Flooding Events

- **Modeling Total Plant Response to Flooding Events**
 - *INL (Curtis Smith, Zhegang Ma)*
 - Dynamic analysis approach that depict scenarios through simulation methods
 - Combination of margins analysis, mechanistic physics-based modeling, and probabilistic risk assessment approaches
 - Use LIP as example application

Dynamic and Nonstationary Processes

- **Regional Climate Change Projections: Potential Impacts to Nuclear Facilities**
 - *PNNL (Ruby Leung, Rajiv Prasad, Lance Vale)*
 - Annual review of climate science and modeling research and assessments of potential impacts to NPPs
 - Hydrological and non-hydrological impacts

Projected FY16 New Starts*

- Critical review of State of Practice in Probabilistic Risk Assessment for Dams
 - Failure mode identification and fragility characterization
 - System modeling approaches
 - Operational and HRA/HF issues
 - Regulatory confidence as a function of available information
 - Planned start Q1 FY16
- Application of Land Use/Land Cover Change Models for Assessing Potential Changes in Watershed Flooding Risks
 - State of practice in modeling biophysical landscape change and human activity
 - Assess capability to model changes in hydrological processes and flood risks
- Eastern U.S. Paleoflood Hydrology Study
 - Candidate reach: Tennessee River Gorge below Chattanooga
 - Planned NRC/EPRI/TVA collaboration, (potential USACE and USBR)
 - Feasibility study first
 - short timeline
 - modest cost
 - Detailed study if feasibility study is successful

*** Subject to availability of funding**

Projected FY17-19 Work*

- Further Development of SHAC-F
 - Coastal flooding mechanisms
- Probabilistic treatment of combined processes/events
- Assess probabilistic tsunami modeling methods
- Develop Pilot Test
 - Work with Industry, other Agencies
 - Inland location, coastal location

* **Subject to availability of funding**



Questions?
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