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Probabilistic Flood Hazard Assessment

Storm Surge

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Initiating Event Frequency Determination

- A Probabilistic Risk Assessment (PRA) requires an estimate of the frequency of an initiating event
  - For an at-power PRA, an initiating event is an event that causes or demands the immediate shut-down (SCRAM) of a nuclear power plant
- A Probabilistic Flood Hazard Assessment (PFHA) is used to estimate the frequency of external flooding hazards

Extrapolation

- Historical records are limited to a few hundred years at best
- Extrapolation to extremely low frequencies is required to assess risk to nuclear power plants
  - PRA models assess risks down to a frequency of 10^{-7}/yr or lower
  - The PFHA may be required to assess the hazard frequency down to 10^{-6}/yr – equivalent to an Annual Exceedance Probability (AEP) of 10^{-6}
- Design basis analyses use the concept of a Probable Maximum Flood (PMF), but make no attempt to calculate the frequency of occurrence of such a flood

Frequency Analysis as Part of a PFHA

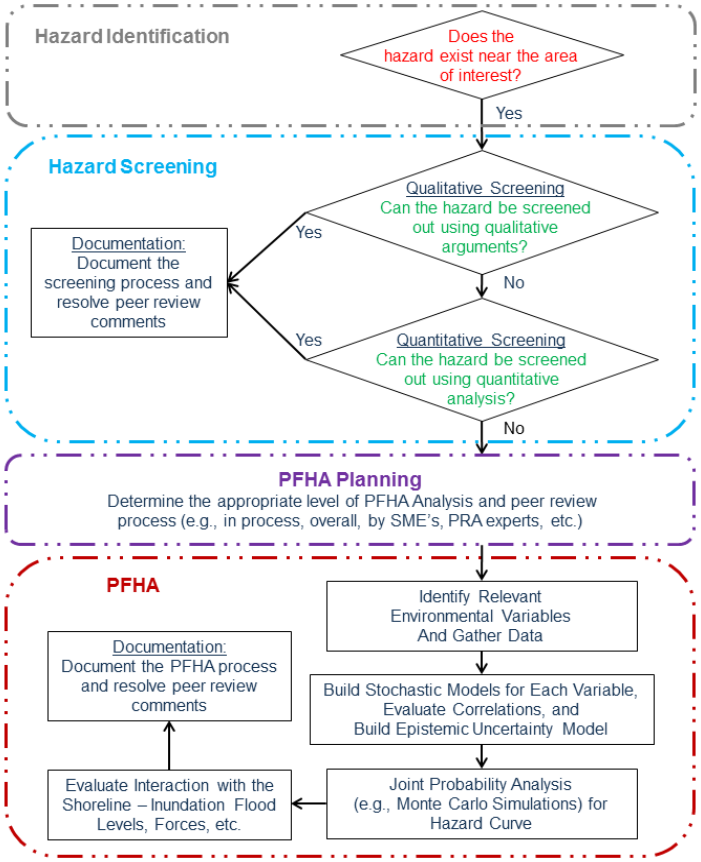
- Extrapolation beyond twice the historical record is not considered to be credible
- A variety of methods are used to extend the effective historical record
  - Use of independent, but applicable measurements (e.g., rain gauges)
  - Transposition of observed storms from one location to another
  - Development of synthetic storms to simulate flooding impact with Monte Carlo analysis
  - Use of paleo (i.e., outside of the historical observation) evidence to inform the data
- All of these techniques involve uncertainty, so it is important to characterize the uncertainty
- Independent peer reviewers lend credence to the analysis

EPRI Report on Storm Surge

- ERPI report 3002008111, Probabilistic Flooding Hazard Assessment for Storm Surge with an Example Based on Historical Water Levels
- Provides generic PFHA process as applied to Storm Surge
- Available data and storm type that leads to storm surges for site of interest determines the simulation approach
  - Controlling storm is a hurricane: atmospheric parameters such as central pressure deficit, radius of maximum wind, and maximum wind speed as well as tidal levels can be modeled in the Monte Carlo simulation
  - Controlling storm is not hurricane: historical water levels can be utilized to determine mean sea level or average lake level, storm surge level, and wind-wave effects using Monte Carlo simulation techniques

Probabilistic Flood Hazard Assessment (PFHA)

- A PFHA is used to assess a potential external flooding hazard to a site
- Steps of the process include:
  - Hazard identification – Which hazards are applicable to a site?
  - Hazard screening – Can the hazard be screened from analysis?
  - PFHA planning (e.g., determine the appropriate approach)
  - Conducting the PFHA



Hazard Identification

- Any hazard that can occur in the vicinity of a nuclear plant is included in the hazard identification
- Only hazards that cannot occur at the site are excluded at this step
  - For example, a riverine site in Illinois would not identify a tsunami as a hazard applicable to that site
  - A storm surge is a plausible event for all coastal sites

Hazard Screening

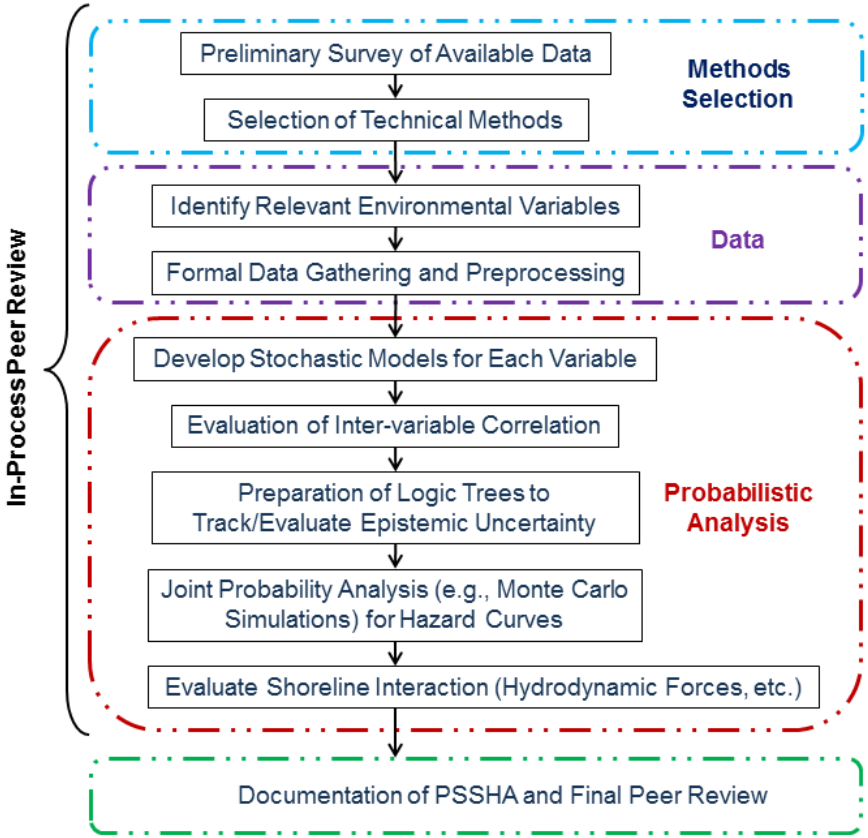
- Qualitative or quantitative screening approaches can be used to eliminate a hazard from further consideration
- Qualitative arguments must provide confidence that the hazard could not impact the site
- Quantitative screening can be based on deterministic or probabilistic arguments

PFHA Planning

- Determine PFHA approach
  - For storm surge, the analysis could be based on synthetic modeling of the controlling storm (typically a hurricane) or based on the use of historical water levels to generate probability density functions for use in Monte Carlo analysis
- Determine peer review participation
  - Involving a peer review team throughout the process can prevent significant re-work if they find an issue that invalidates the analyses at the end

Performing the PFHA

- Create the statistical model
  - Correlation of variables
  - Treatment of uncertainty
- Perform the analysis
- Generate the hazard frequency curve
- Validate the analysis with independent peer review



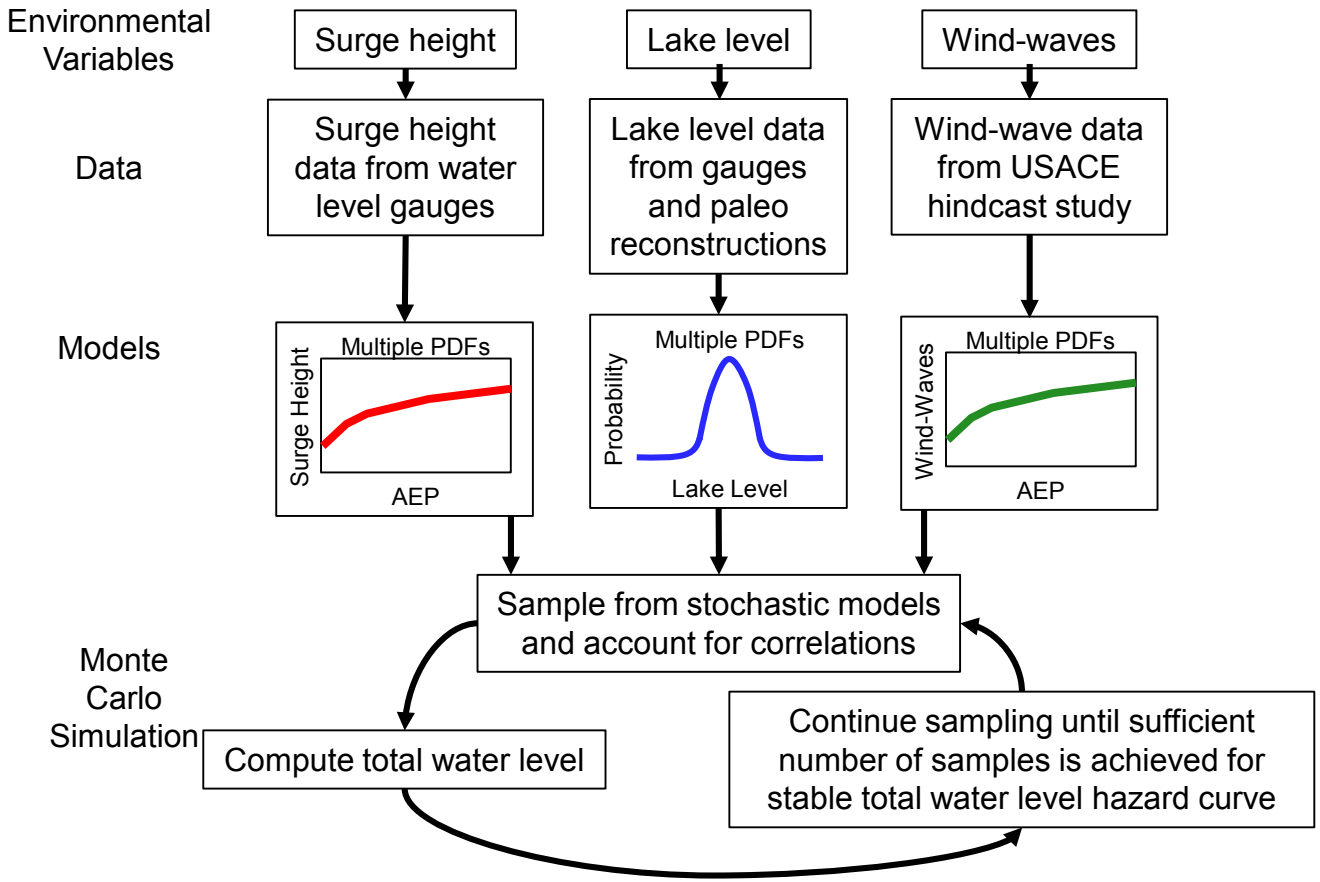
Example Probabilistic Storm Surge Hazard Analysis

- Site located on one of the Great Lakes
- Site is not subject to fully formed hurricanes, so using a Joint Probability Method that models the atmospheric parameters is not appropriate
- Long history (greater than 100 years) of lake levels is available including paleo data that can extend the record to 4000 years
- Lake buoys provide water level data
- Wave height, period, and direction determined by U.S. Army Corps of Engineers hindcast datasets

Monte Carlo Simulation for Storm Surge

- Probability density functions (PDFs) created to represent:
  - Initial lake level
  - Storm surge height
  - Wind-wave parameters
- It is not always obvious which PDF provides the best fit to the existing data and which data source is most applicable
  - Logic trees used to weight alternative PDFs and data sources to each parameter
  - Process is similar to what is used by the Senior Seismic Hazard Analysis Committee (SSHAC)
- Monte Carlo simulations used to develop still water level hazard curve and total water level (including wave run-up) hazard curve
  - Sensitivity studies can be run to determine the sensitivity of the analysis results to particular assumptions

Probabilistic Storm Surge Hazard Assessment Example



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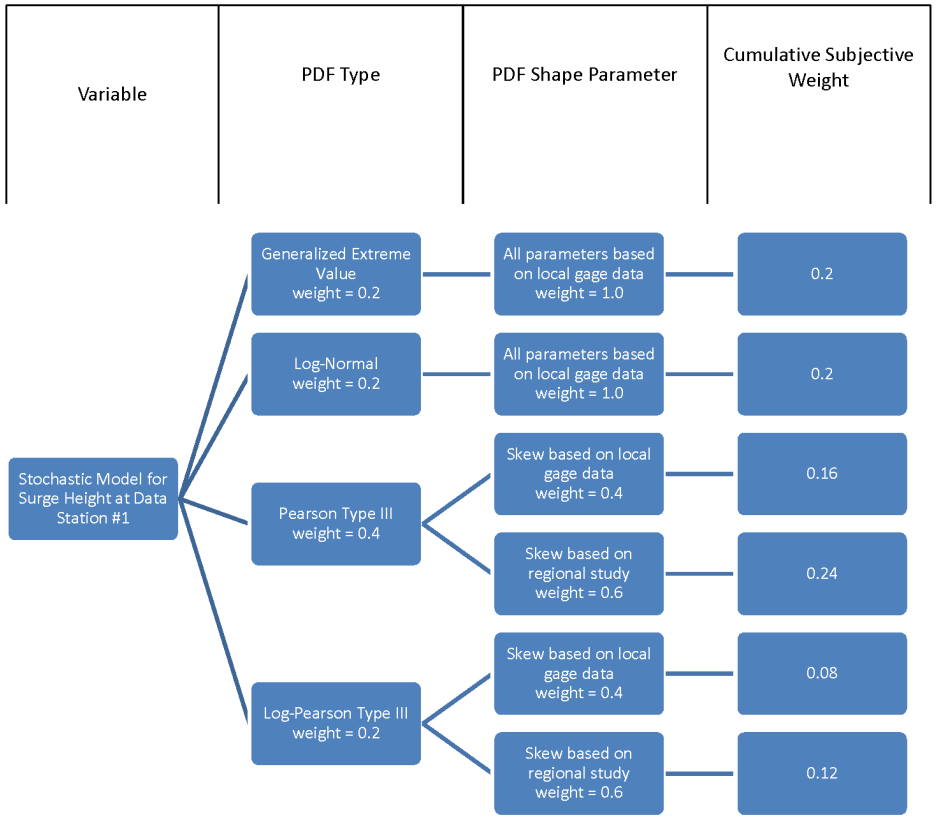
Example Logic Tree to Determine Weighted PDF



Expert judgement and objective criteria used to set weighting parameters

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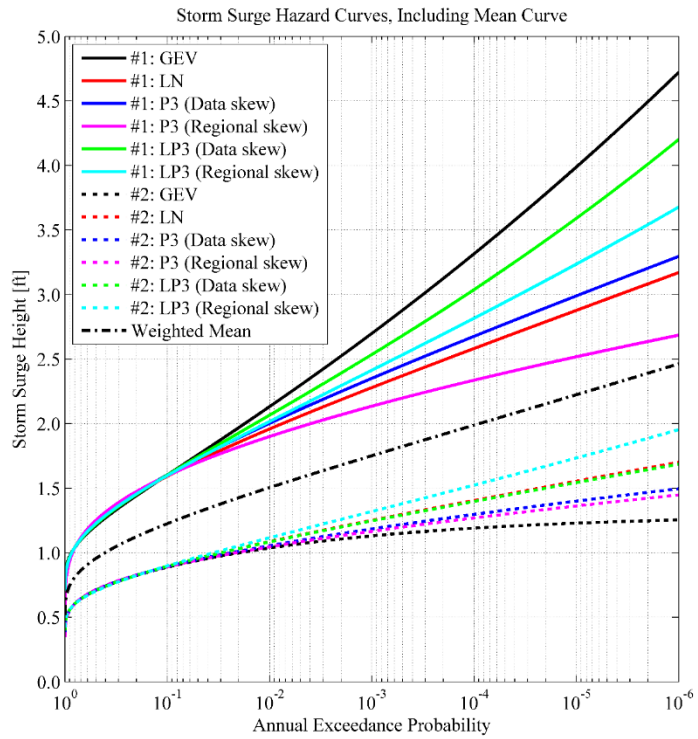
Example of Storm Surge Height Weighted Mean



Mean level determined after applying the logic tree's weighting factors

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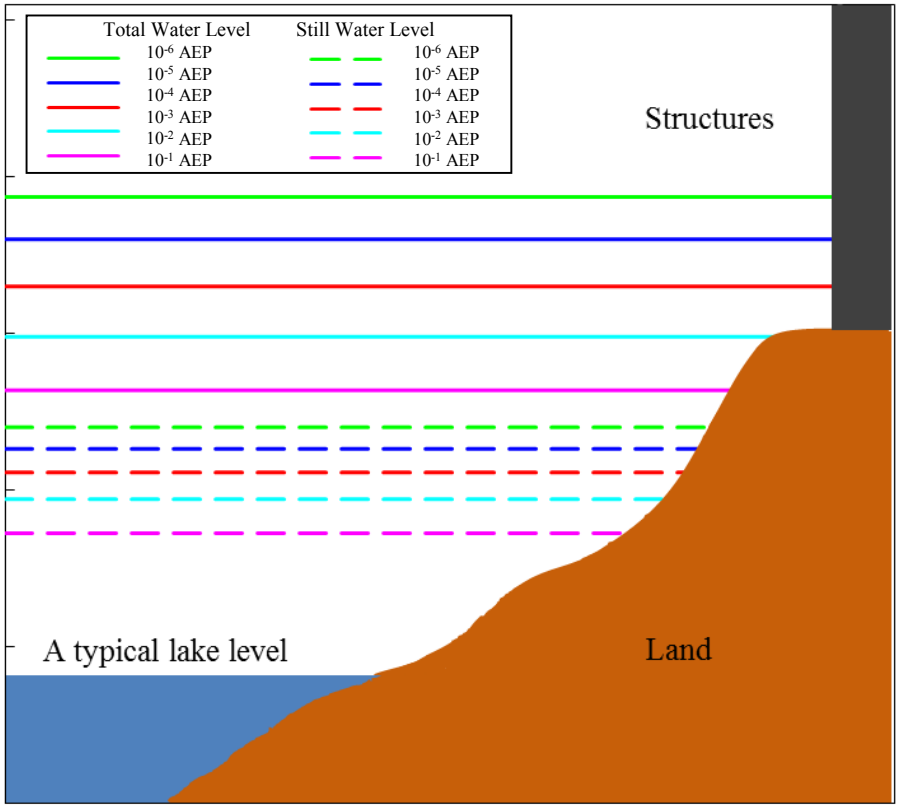
Example Still Water and Total Water Levels



Structures may be impacted by waves at a frequency of about $1X10^{-3}$/year

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Uncertainty and Peer Review

- Two important aspects of a PFHA are uncertainty analysis and peer review
- Uncertainty analysis attempts to characterize the range of uncertainty in the analysis
  - Logic trees and sensitivity studies are techniques to control and characterize the uncertainty
- Peer reviews lends credibility to the analysis by getting independent experts to provide comments and findings
  - Engaging a peer review team early and often in the PFHA process helps prevent significant re-work if the peer review team identifies an important issue that needs to be resolved

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