Adapting Successful Hazard Analysis Approaches to New Hazards at the Nuclear Regulatory Commission

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U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Outline

- Statutory role of NRC
- Regulatory requirements for new reactor applications
- Success Stories
  - Applying SSHAC to Volcanic Hazards
  - Incorporating Engineering Judgement in Flooding Analyses

NRC Mission

The NRC licenses and regulates the Nation's civilian use of radioactive materials to provide reasonable assurance of adequate protection of public health and safety and to promote the common defense and security and to protect the environment.

Regulatory Requirements

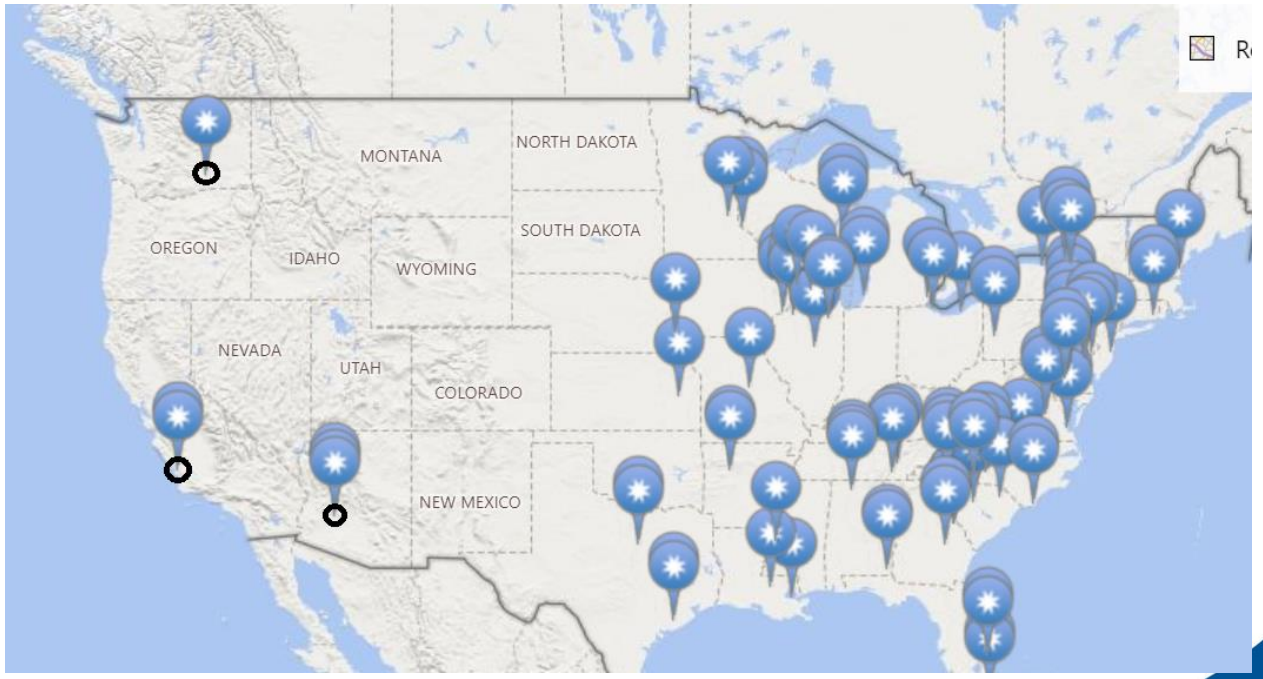
- 10 CFR Part 50, Appendix A, “General Design Criteria for Nuclear Power Plants,” General Design Criterion 2
  - Must consider the effects of natural phenomena without loss of capability to perform their safety function
  - Consider the most severe phenomena that have been historically reported for the site and surrounding area.
- 10 CFR 100.23(c), “Reactor Site Criteria”
  - investigate all geologic and seismic factors (for example, volcanic activity) that may affect the design and operation of the proposed nuclear power plant

Applying SSHAC to Volcanic Hazards

Endorsing a successful seismic hazard approach for another hazard

SSHAC Overview

- Senior Seismic Hazard Analysis Committee (SSHAC) approach to guide expert elicitation of hazard information to develop a probabilistic hazard assessment
- Considers the Center, Body and Range of the Technically-Defensible Interpretations (CBR of the TDI)
- NRC guidance on the process
  - NUREG-2213



SSHAC Essentials

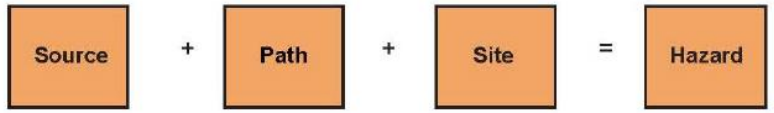
1. Clearly defined roles
2. Objective evaluation of existing data and models
3. Integration to capture the best estimates and the range of uncertainty
4. Clear and transparent documentation
5. Independent participatory peer review

Additional information provided in NUREG-2213

SSHAC Study Levels

Table 3-1	Attributes of SSHAC level studies from Level 1 to Level 3*			
	Level 1	Level 2	Level 2 Augmentation Options	Level 3
Peer Review	At least two reviewers; Communication with PPRP during evaluation and integration	Two or more reviewers; Feedback on preliminary models	One or more PPRP representative(s) observes working meetings, TI Team interactions with external experts, and/or workshops	Ideally five reviewers; Engagement during evaluation and integration process; PPRP briefing of final model
Technical Integration Team	Small TI Team (depending on nature and complexity of issues)	Small TI Team; possibly multiple teams (e.g., seismic source characterization and ground motion characterization)	Larger TI Team	Five or more TI Team members
Evaluation	Sensitivity analysis to identify significant issues; Systematic review of literature	Outreach to proponents and resource experts (e.g., phone interviews)	Add Workshop #1, #2, or hybrid that includes resource experts and/or proponents	Two workshops with resource expert and proponents; Data summary tables
Integration	Develop models that capture the CBR of TDI	TI Team interaction and hazard feedback during model-building	Add Workshop #3 with feedback from PPRP	One workshop to discuss preliminary models; PPRP briefing
*All attributes are additive, moving from left to right on the table; Level 4 is essentially the same as Level 3 with respect to these attributes.				

- Determined by scope of review and available information
- Level 2 can be used for site specific project relying on regional SSHAC Level 3 studies.
- Higher level studies can have greater regulatory assurance and longevity.
- Levels 3 and 4 differ in project organization, not outcome



	How Big How Often Where	Dispersion Attenuation	Location Site Characteristics Size	Time Exceedance of Intensity Measure
Ground Motion Hazard (seismic)	• M_{MAX} • Recurrence • Fault Geometry • Faulting Style	• Attenuation • Kappa • Q • Source Model	• V_S Profile • Damping • G/G_{MAX}	Annual Probability of Exceeding Spectral Ground Motion Level
Ash Fall (Volcanic)	• Volcano Type • Eruption Rate • Intensity • Distance • Particle Size	• Atmospheric Conditions	• Facility Location • Site Area	Annual Probability of Exceeding Ash Fall Depth
Tsunami	• Location, Size, and Frequency of Submarine Earthquakes • Location, Size, Velocity, and Frequency of Submarine Landslides	• Wave Propagation • Inundation • Bathymetry	• Site Topography • Land-Use Configuration • Infrastructure	Annual Probability of Exceeding Wave Height or Run-Up Height
Faulting	• Magnitude • Recurrence • Fault Geometry • Faulting Style	• Model for the Decay of Displacement with Distance	• Bedrock Type • Soil and Soil Profile • Site and Facility Configuration	Annual Probability of Exceeding Fault Displacement Level
Earthquake-Induced Liquefaction	• Magnitude • Recurrence • Duration • Depth	• Attenuation • Kappa • Q • Source Model	• Water Table • Soil Strength • V_S Profile • Damping	Annual Probability of Liquefaction Susceptibility

Figure 1-2 **Basic framework model for natural hazards that includes the source, path, and site. Characterizing these basic elements and quantifying the epistemic uncertainties in each can be implemented using a SSHAC approach.**

SSHAC as a Framework Model for Multiple Hazards

Incorporating Engineering Judgement in Flood Hazard Analyses

Modifying the approach for volcanic hazards to assess flood hazards at advanced and small modular reactor sites

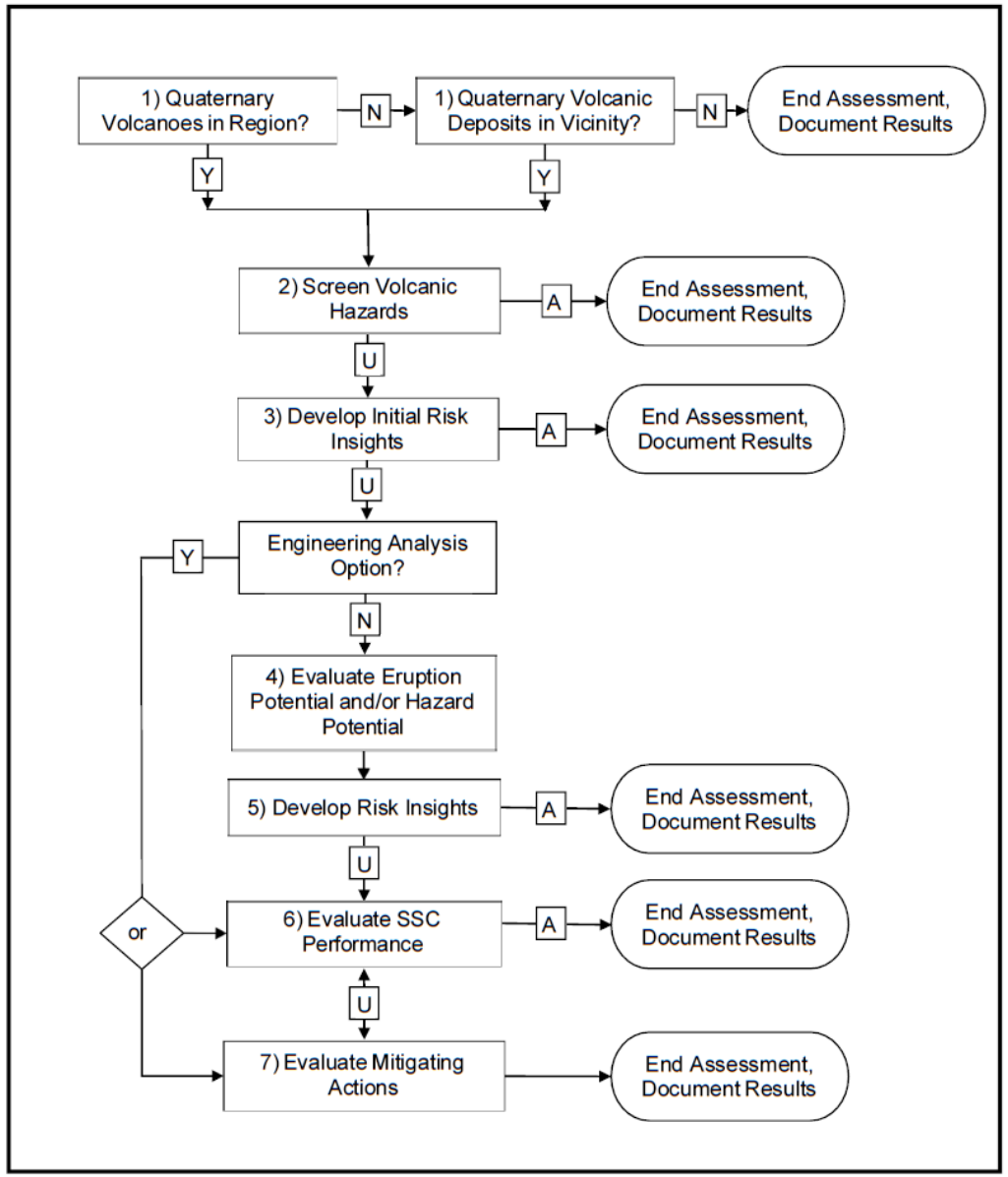


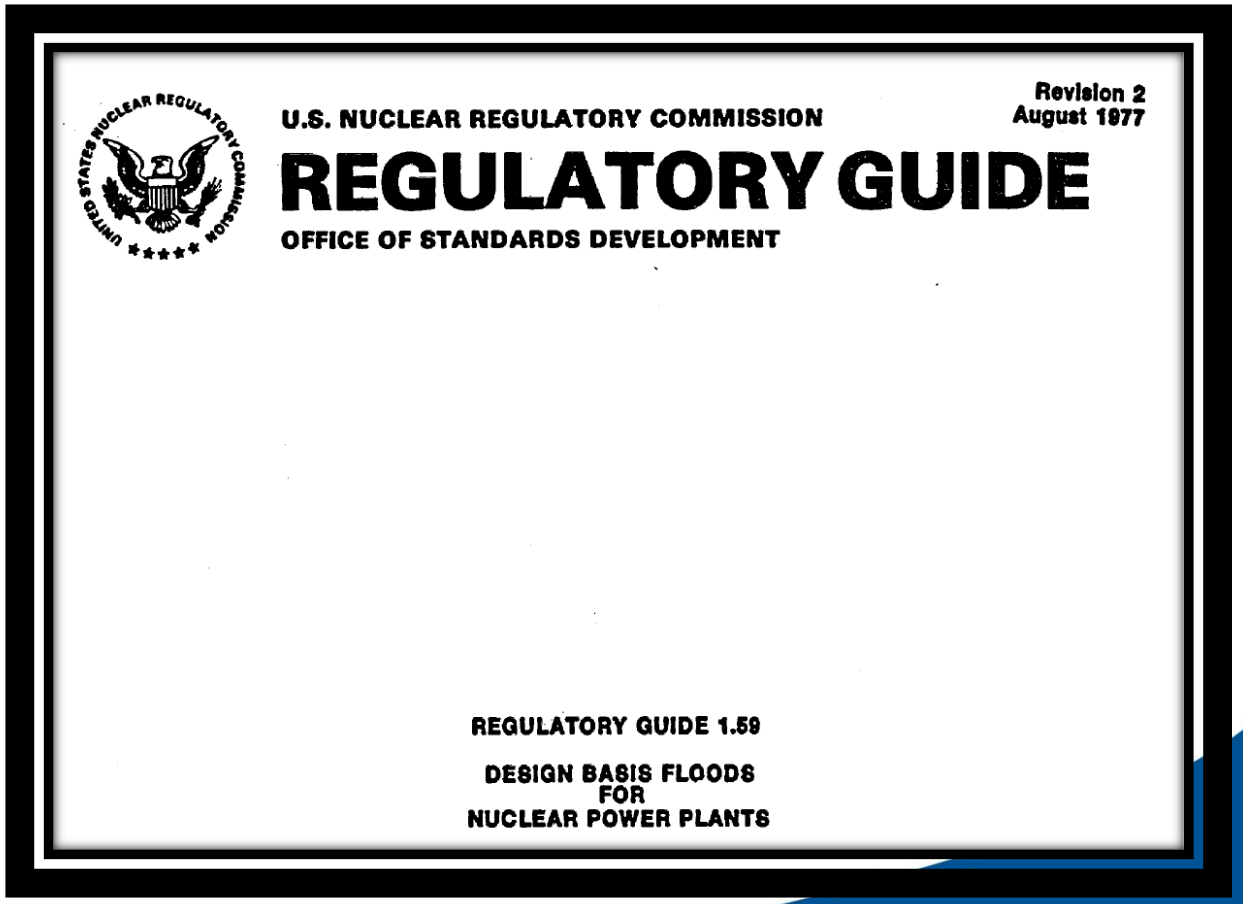
Figure 1 Flowchart for an acceptable volcanic hazards assessment

("Y" = Yes, "N" = No, "U" = Unacceptable performance, A = "Acceptable performance)

Regulatory Guide 4.26, "Volcanic Hazards Assessment for Proposed Nuclear Power Reactors

RG 1.59, Design Basis Floods for Nuclear Power Plants

- RG 1.59, Revision 2, issued in 1977
- Revision 3 initially issued for public comment as DG-1290 in 2022, reissued for public comments July 15, 2024
- Appendix K adapts methodology from RG 4.26 for advanced reactor and small modular reactor applicants.


U.S. NUCLEAR REGULATORY COMMISSION

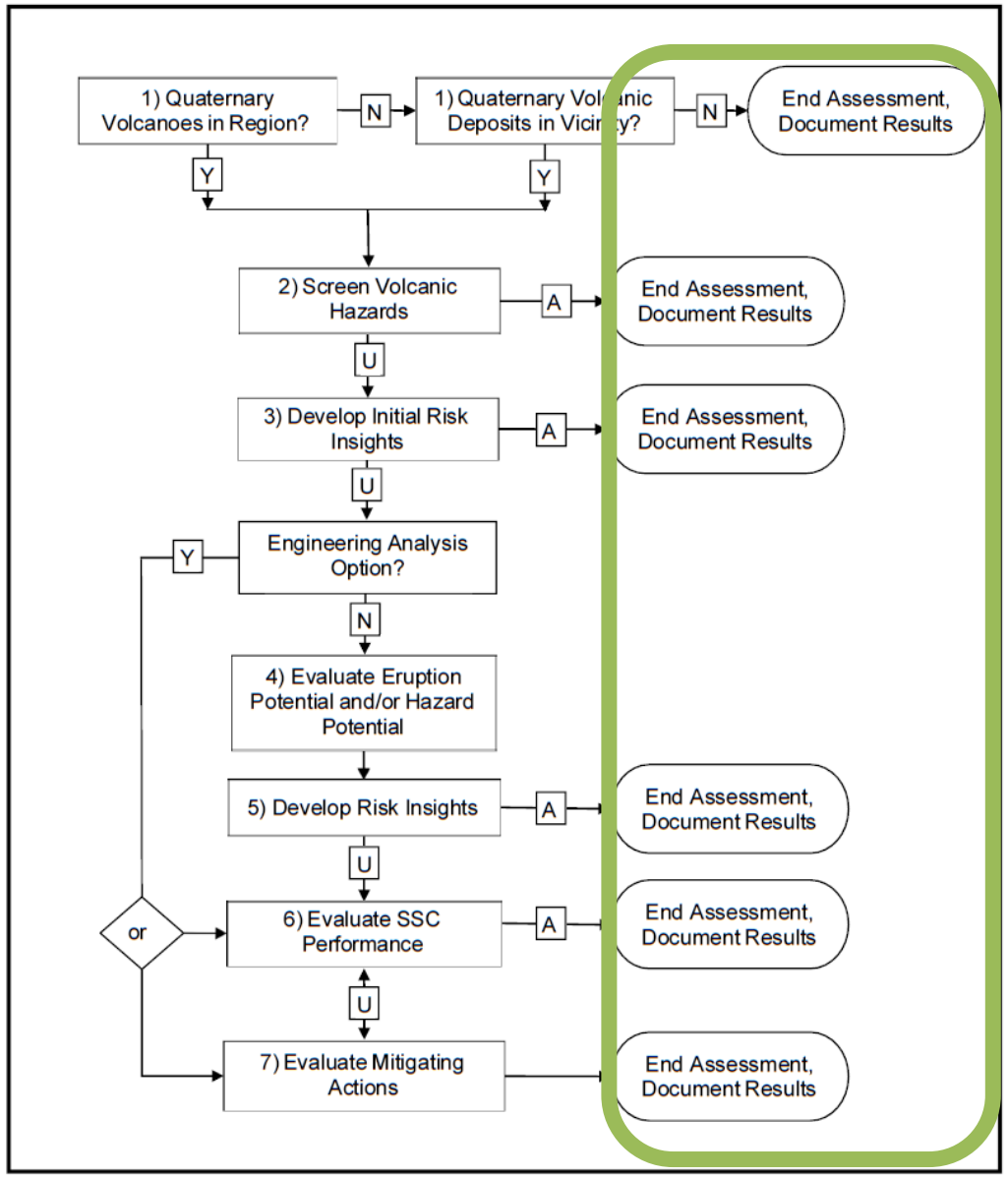
Revision 2
August 1977

REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

REGULATORY GUIDE 1.59

DESIGN BASIS FLOODS
FOR
NUCLEAR POWER PLANTS



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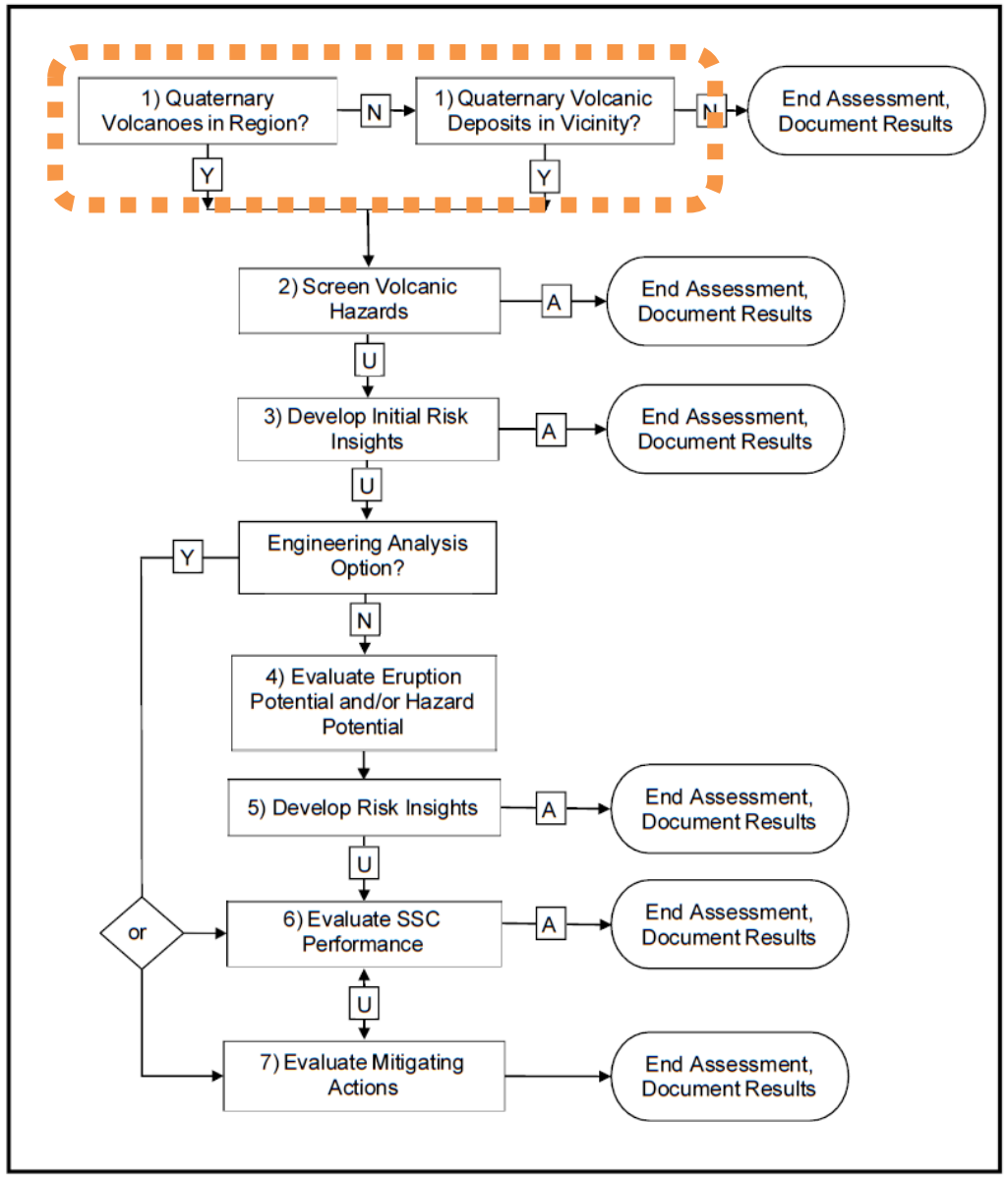
What can we adapt from RG 4.26?

- **Flexible, stepwise approach with multiple off-ramps**



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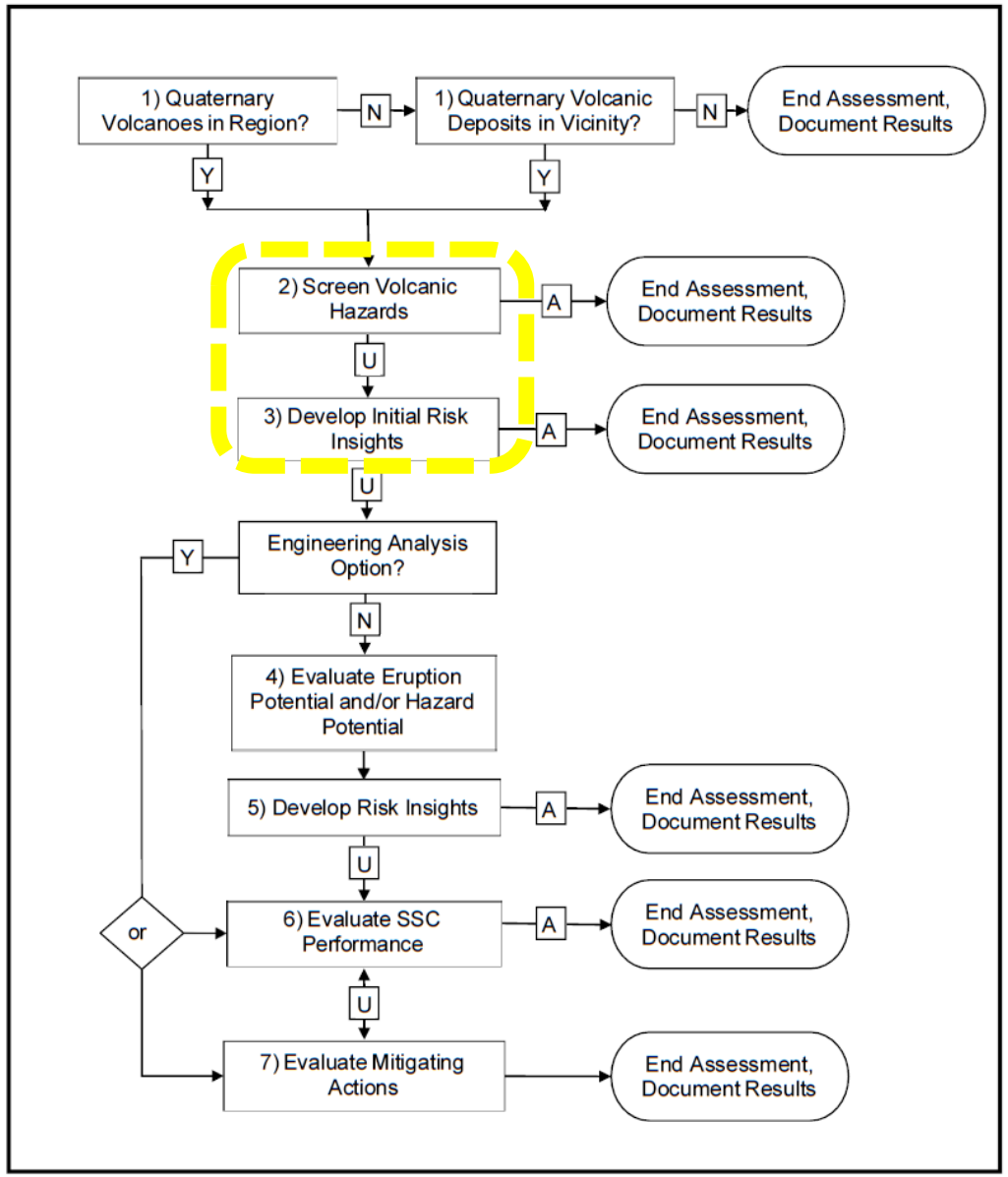

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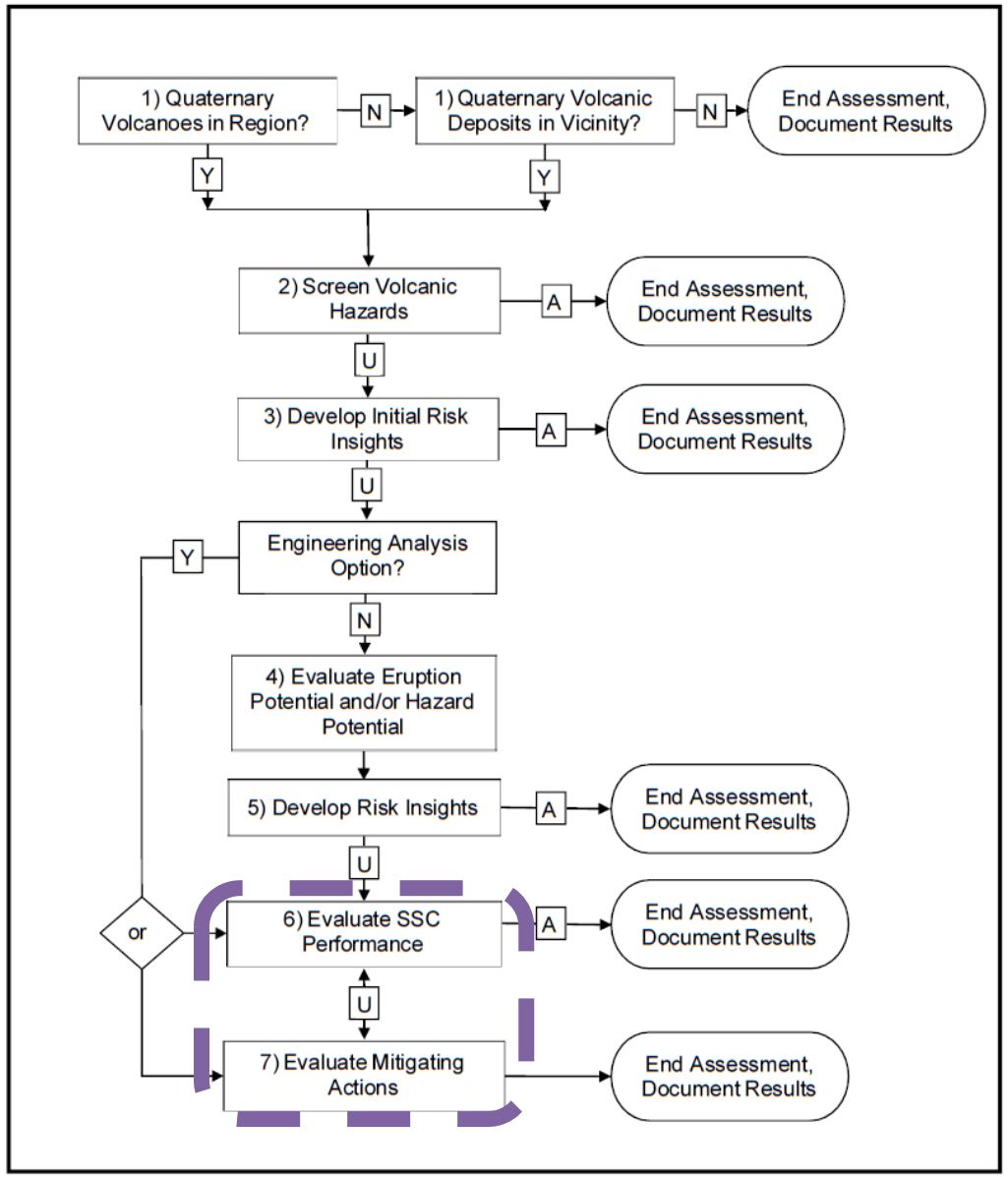

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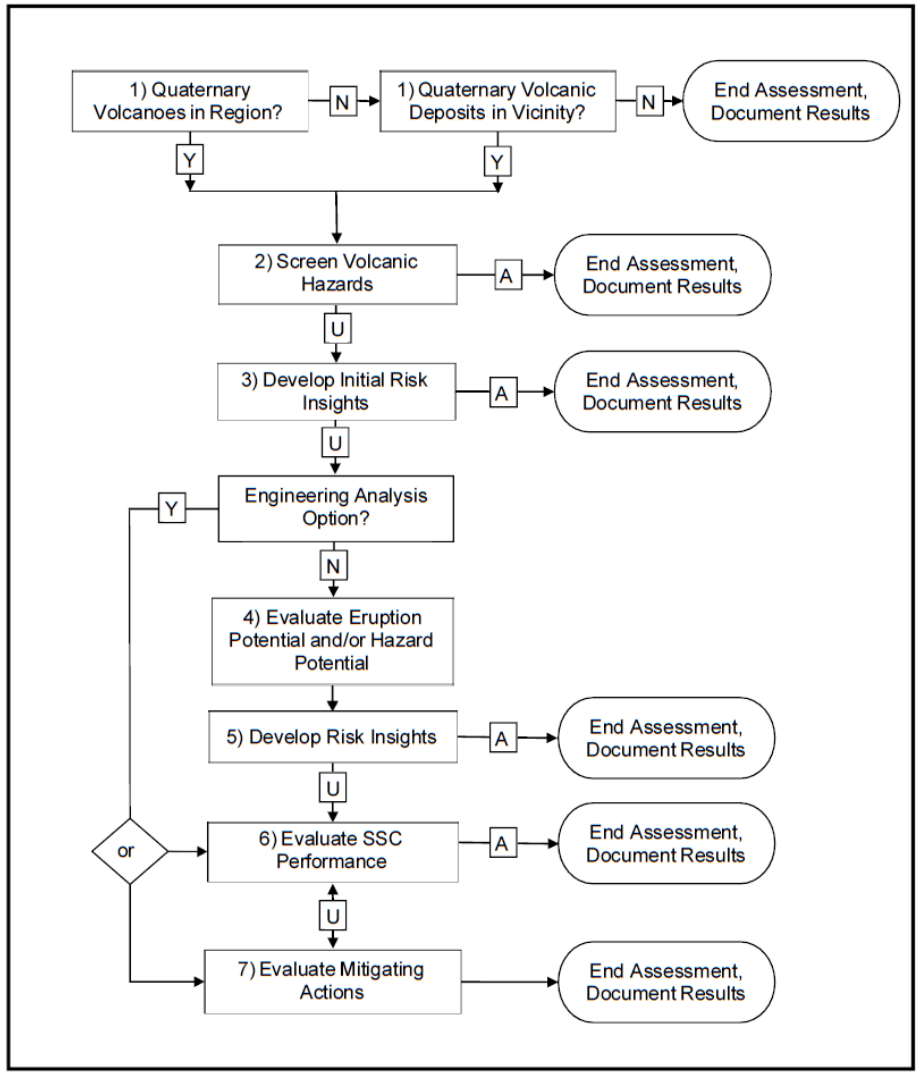
What can we adapt from RG 4.26?

- Flexible, stepwise approach with multiple off-ramps
- Leverage existing site characterization information
- Screen hazards and consider risk insights
- **Evaluate SSC performance and mitigating actions in addition to or in place of detailed hazard analysis**

From RG 4.26 to DG-1290



RG 4.26, Figure 1

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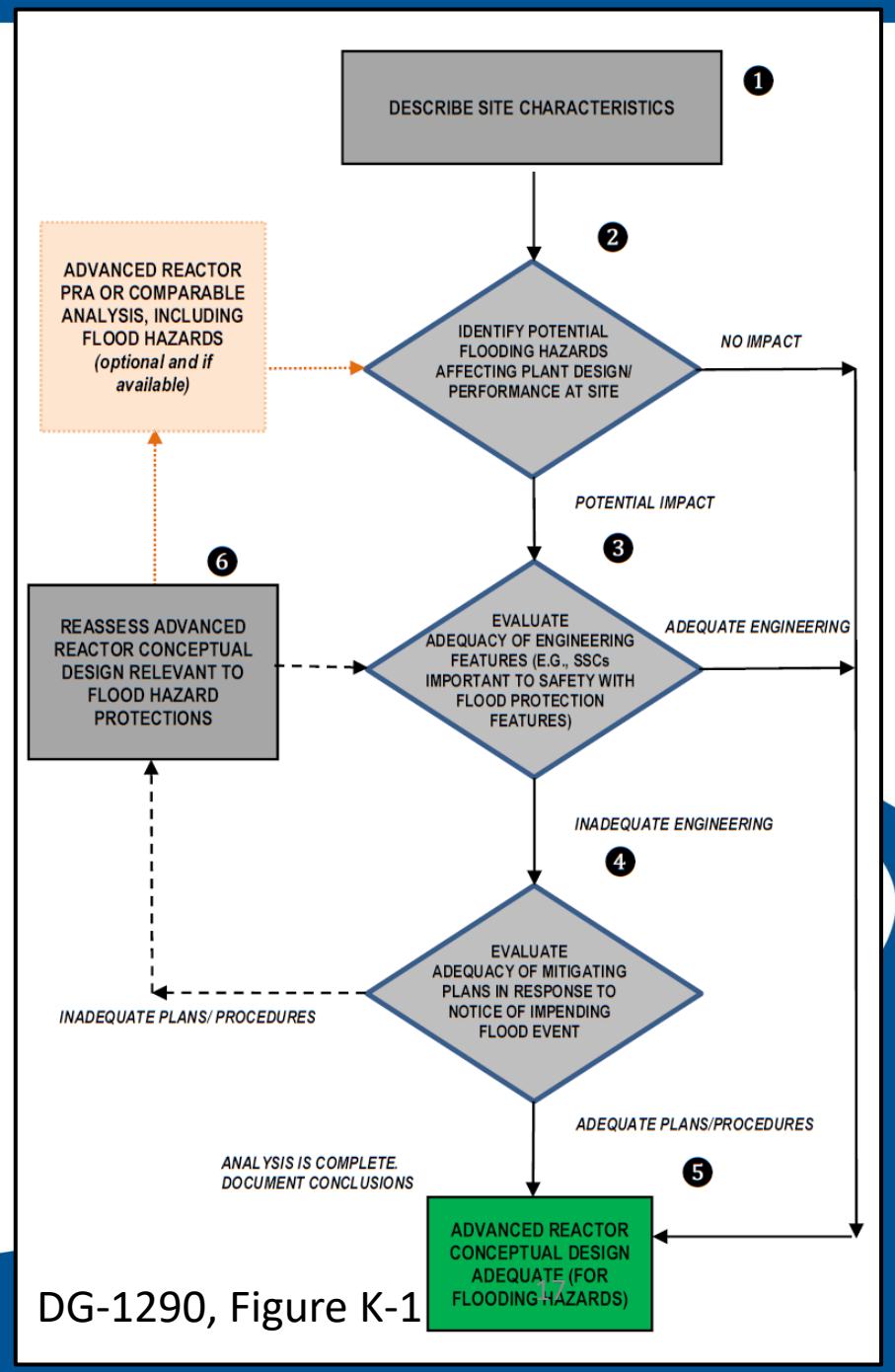
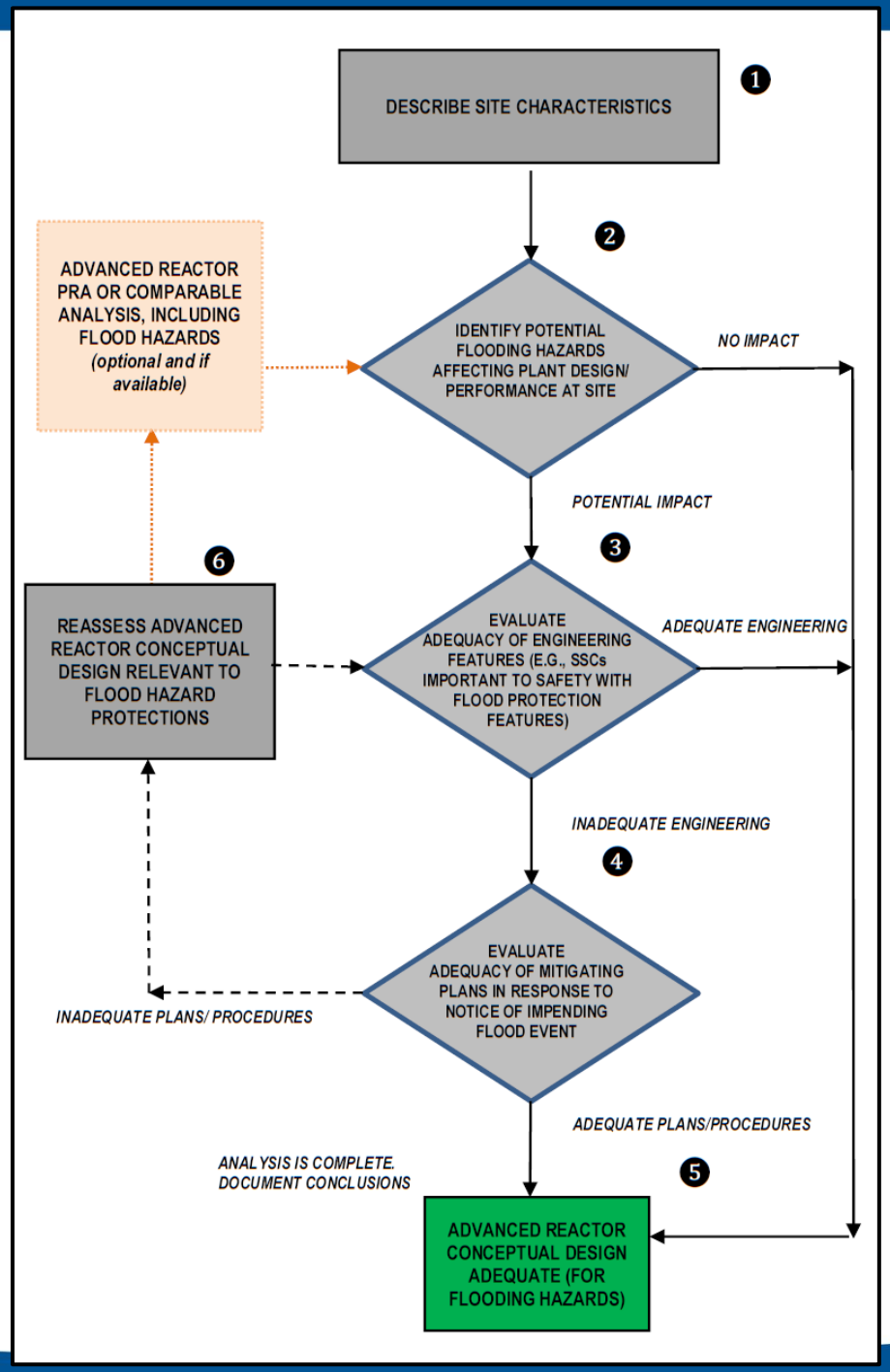


DG-1290, Figure K-1

Appendix K Flowchart



- Step 1 – leverage site characterization information
- Step 2 – determine which, if any, flood-causing mechanisms affect plant performance
- Step 3 – determine if there is adequate engineering for SSCs to withstand the hazard
- Step 4 – evaluate mitigating actions for adequacy
- Step 6 – reassess design features and/or consider PRA
- Step 5 – assessment complete and results documented

Figure K-1, DG-1290, Rev. 1

Appendix K Summary

- **End the flood evaluation at the earliest possible point in the process.**

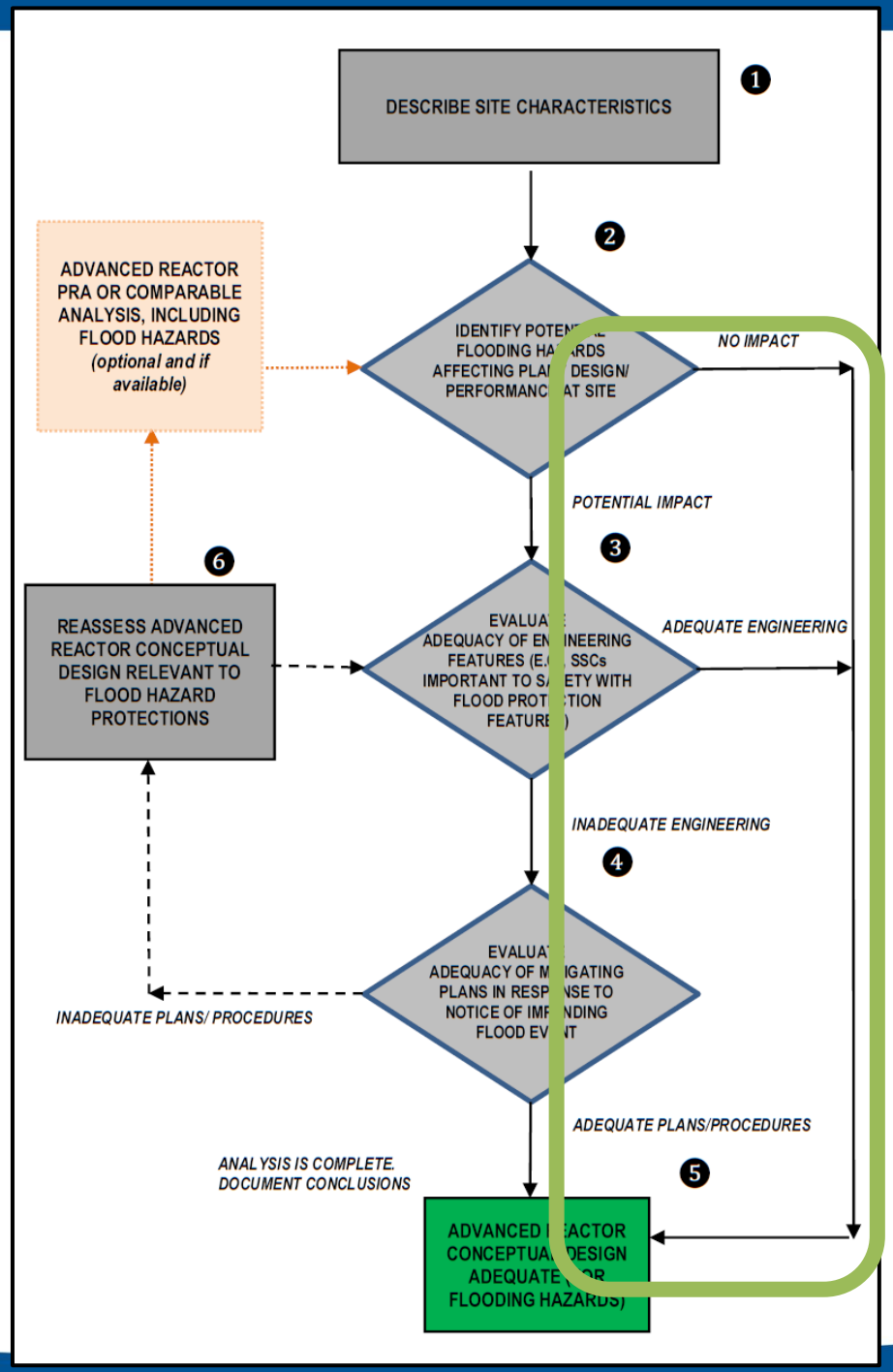
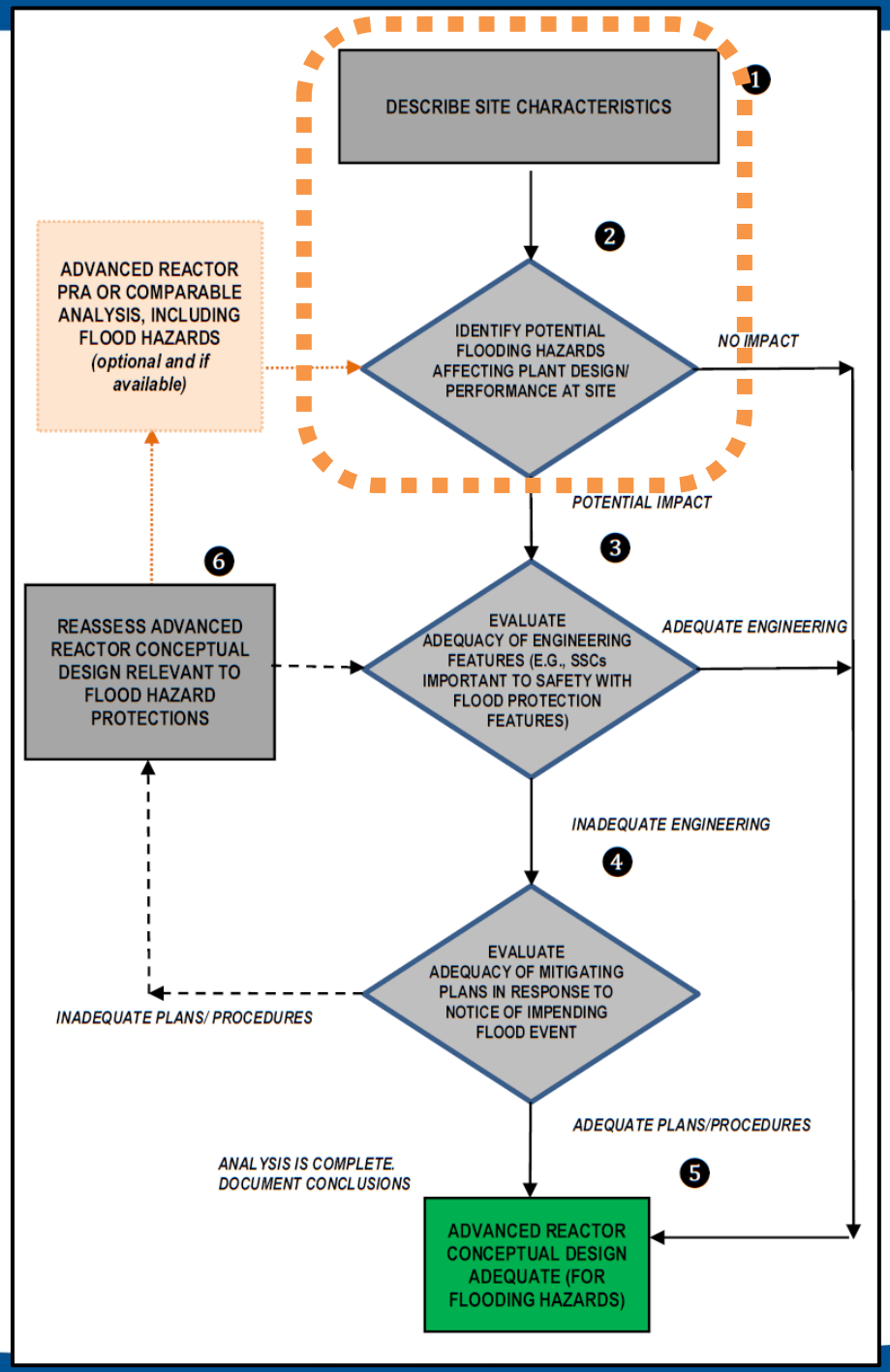


Figure K-1, DG-1290, Rev. 1

Appendix K Summary

- End the flood evaluation at the earliest possible point in the process.
- **Focus on flood causing mechanisms of importance to the design**



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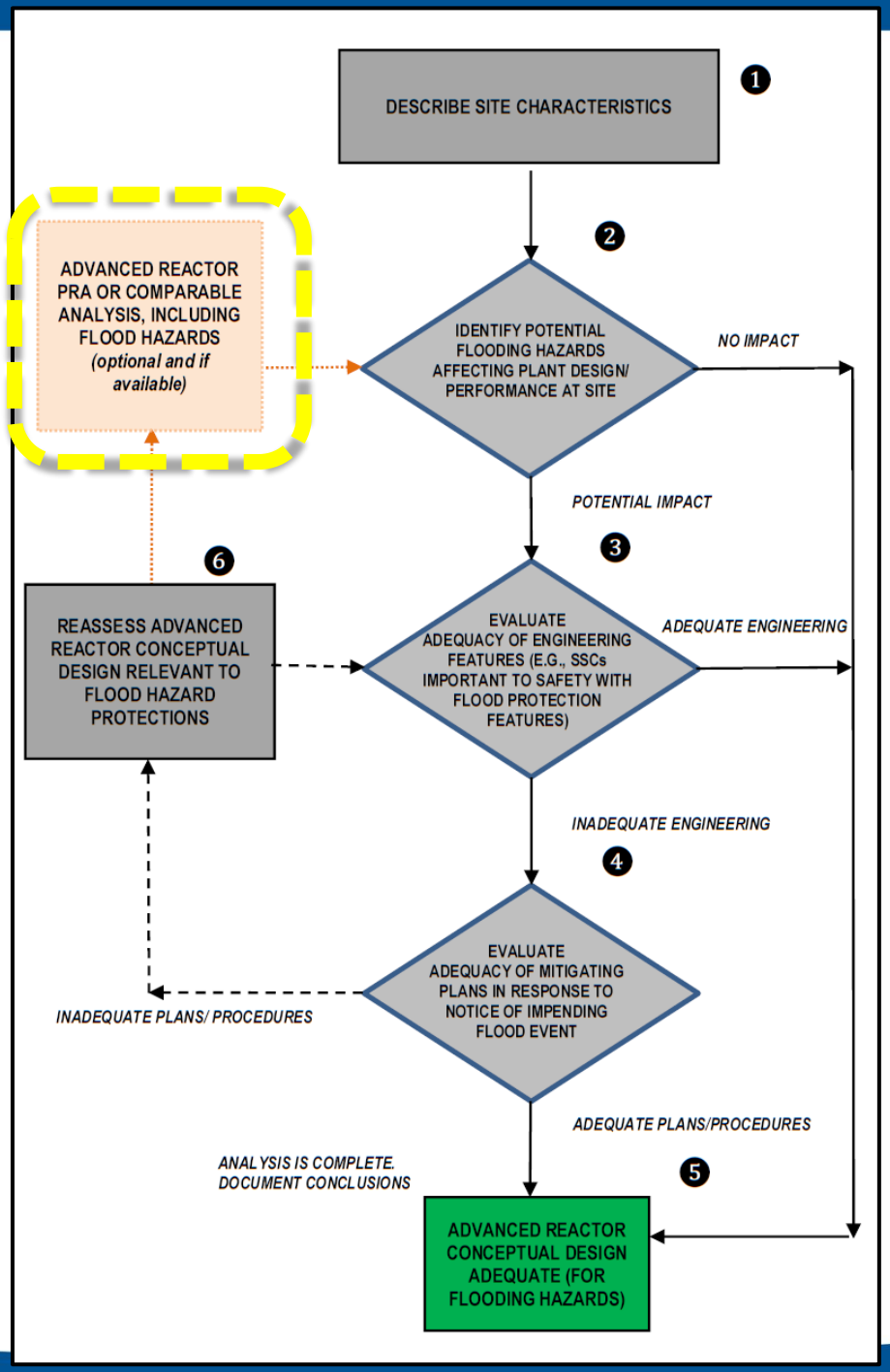

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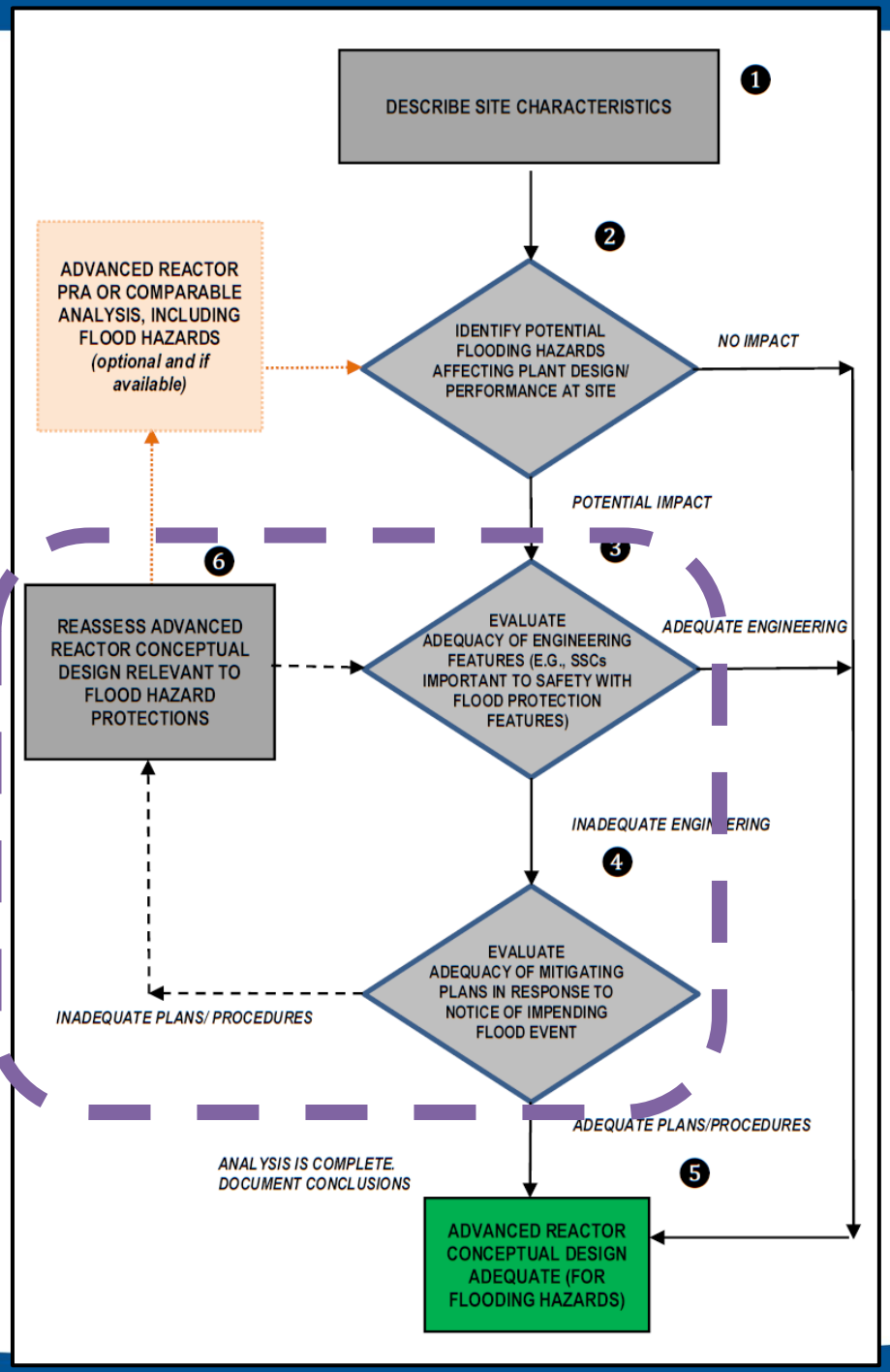
- End the flood evaluation at the earliest possible point in the process.
- Focus on flood causing mechanisms of importance to the design
- **Consider PRA or comparable analysis**



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- End the flood evaluation at the earliest possible point in the process.
- Focus on flood causing mechanisms of importance to the design
- Consider PRA or comparable analysis
- **Iterate between evaluation of SSCs performance and mitigating actions and design reassessment to achieve satisfactory result.**

Figure K-1, DG-1290, Rev. 1

What comes next?

Volcanic Hazards

- First-of-a-kind V-SSHAC results used to inform NRC permit or license application
- Revision of RG 4.26 to clarify use of SSHAC.

Flooding Hazards

- DG-1290 Public Comment period closes September 13, 2024
- Public comments will be dispositioned
- RG 1.59, Revision 3 will be published

Applying similar approaches to external hazard reviews for advanced reactors, small modular reactors and microreactor applications.