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Status of Volcanic Hazards Analyses for the Proposed Kemmerer, WY Site

a TerraPower & GE-Hitachi technology

NATD-LIC-PRSNT-0023

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Goals

- Ensure alignment on interpretations of guidance in RG 4.26 for volcanic hazards analyses
- Volcanological overview including the summary of ongoing investigations of Quaternary volcanic systems in the site region
- Present current approaches for the practical implementation of RG 4.26 guidance in conducting volcanic hazards analyses
  - Initial results of characterization and screening

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Presentation Outline

- Natrium™ reactor overview
- Volcanological overview of the proposed Natrium site region.
- Planned approach to implementing guidance in RG 4.26 for the volcanic hazards analyses
  - Initial results of characterization and screening
- Questions and discussions

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Natrium Reactor Overview

- Regulatory Engagement Plan was submitted 6/8/2021
- Construction Permit Application submittal planned for 8/2023
- Pre-application interactions are ongoing, intended to reduce regulatory uncertainty and facilitate the NRC's understanding of the Natrium advanced reactor and its safety case
- The Natrium Reactor is demonstrating the ability to design, license, construct, startup and operate the Natrium reactor within a seven-year timeframe

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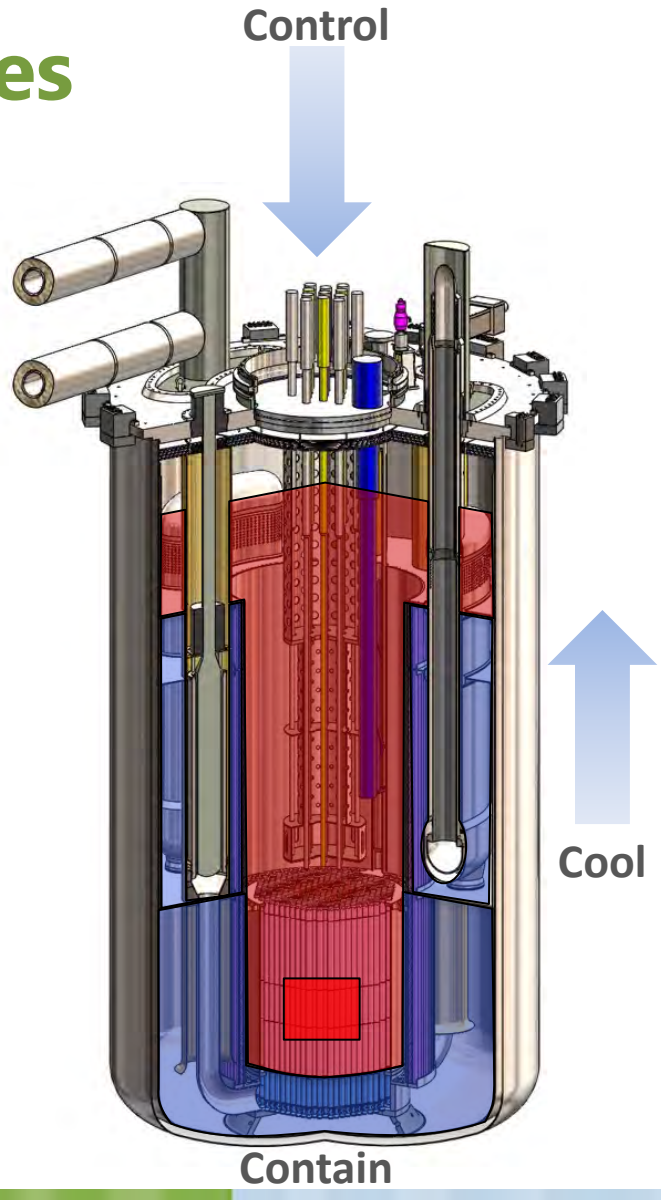
Natrium Safety Features

- Pool-type Metal Fuel SFR with Molten Salt Energy Island
  - Metallic fuel and sodium have high compatibility
  - No sodium-water reaction in steam generator
  - Large thermal inertia enables simplified response to abnormal events
- Simplified Response to Abnormal Events
  - Reliable reactor shutdown
  - Transition to coolant natural circulation
  - Indefinite passive emergency decay heat removal
  - Low pressure functional containment
  - No reliance on Energy Island for safety functions
- No Safety-Related Operator Actions or AC power
- Technology Based on U.S. SFR Experience
  - EBR-I, EBR-II, FFTF, TREAT
  - SFR inherent safety characteristics demonstrated through testing in EBR-II and FFTF



Control

- Motor-driven control rod runback
- Gravity-driven control rod scram
- Inherently stable with increased power or temperature

Cool

- In-vessel primary sodium heat transport (limited penetrations)
- Intermediate air cooling natural draft flow
- Reactor air cooling natural draft flow – always on

Contain

- Low primary and secondary pressure
- Sodium affinity for radionuclides
- Multiple radionuclides retention boundaries

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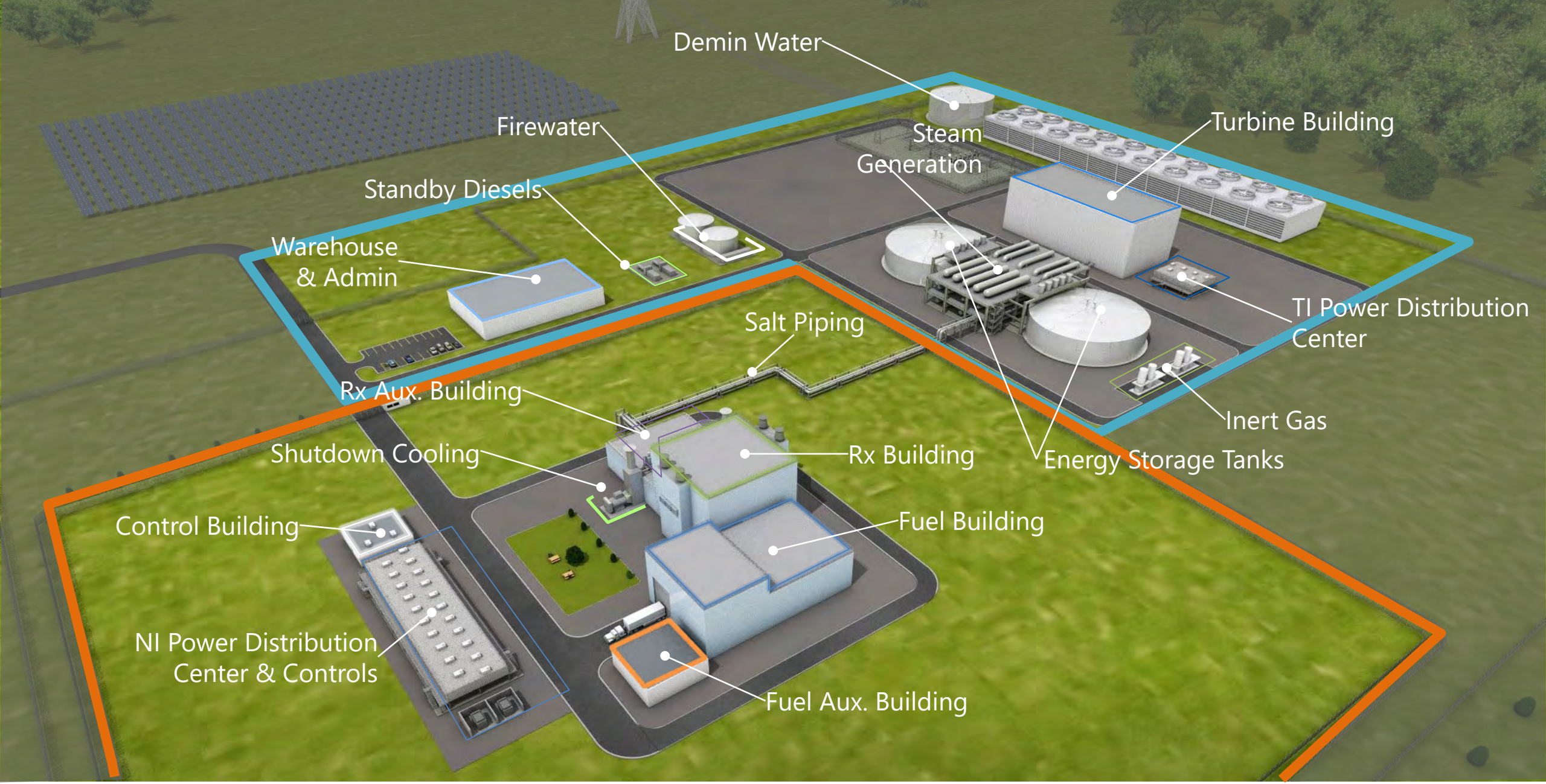

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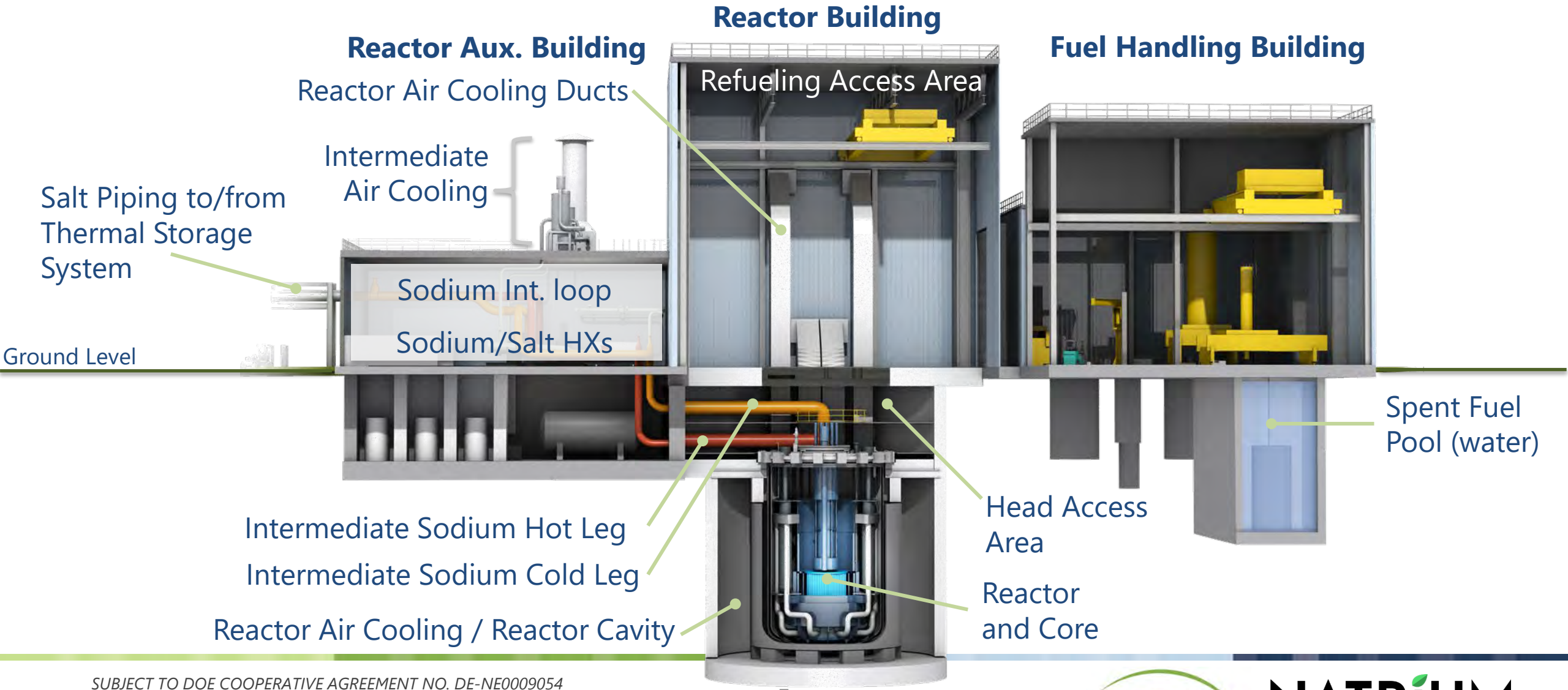
Plant Overview



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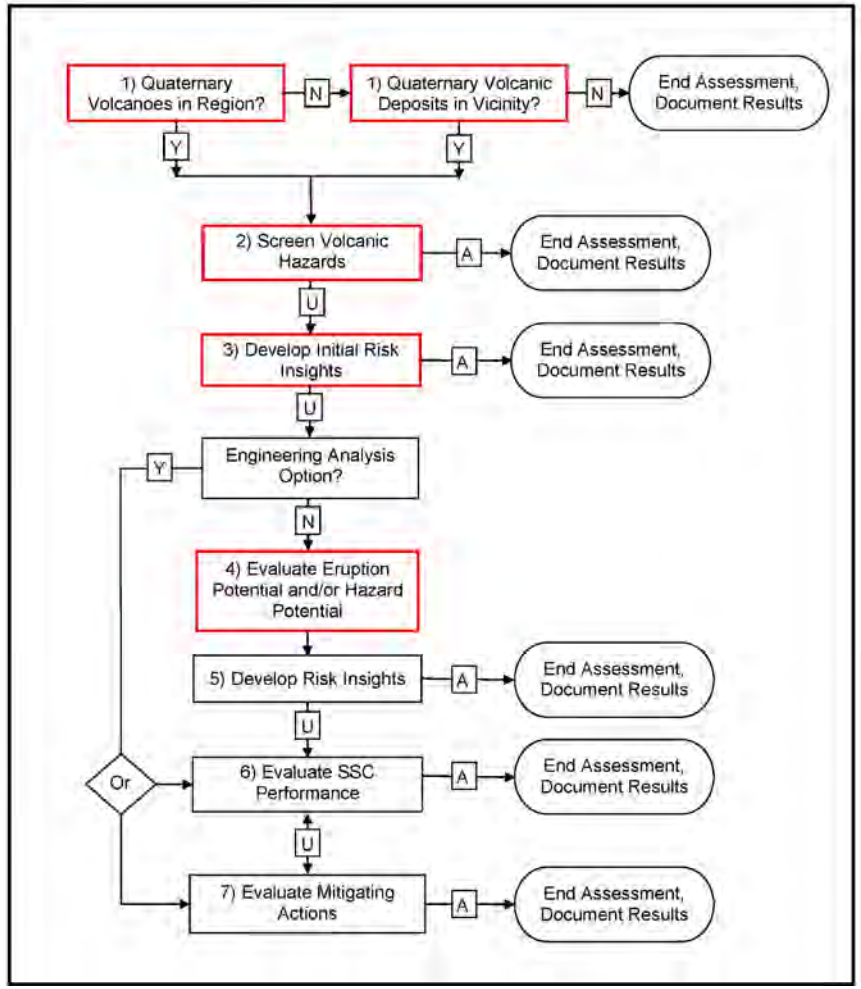
Volcanic Hazards Analysis Guidance in RG 4.26



- The volcanic hazards analysis will follow the approach in RG 4.26.
- Deterministic screening analysis.
  - Information from regional and analogue systems.
- Probabilistic hazards analyses (P_H with P_E bounds, if necessary).

Today's discussion focuses on status and approaches for Steps 1–4.

  - All information from published sources.

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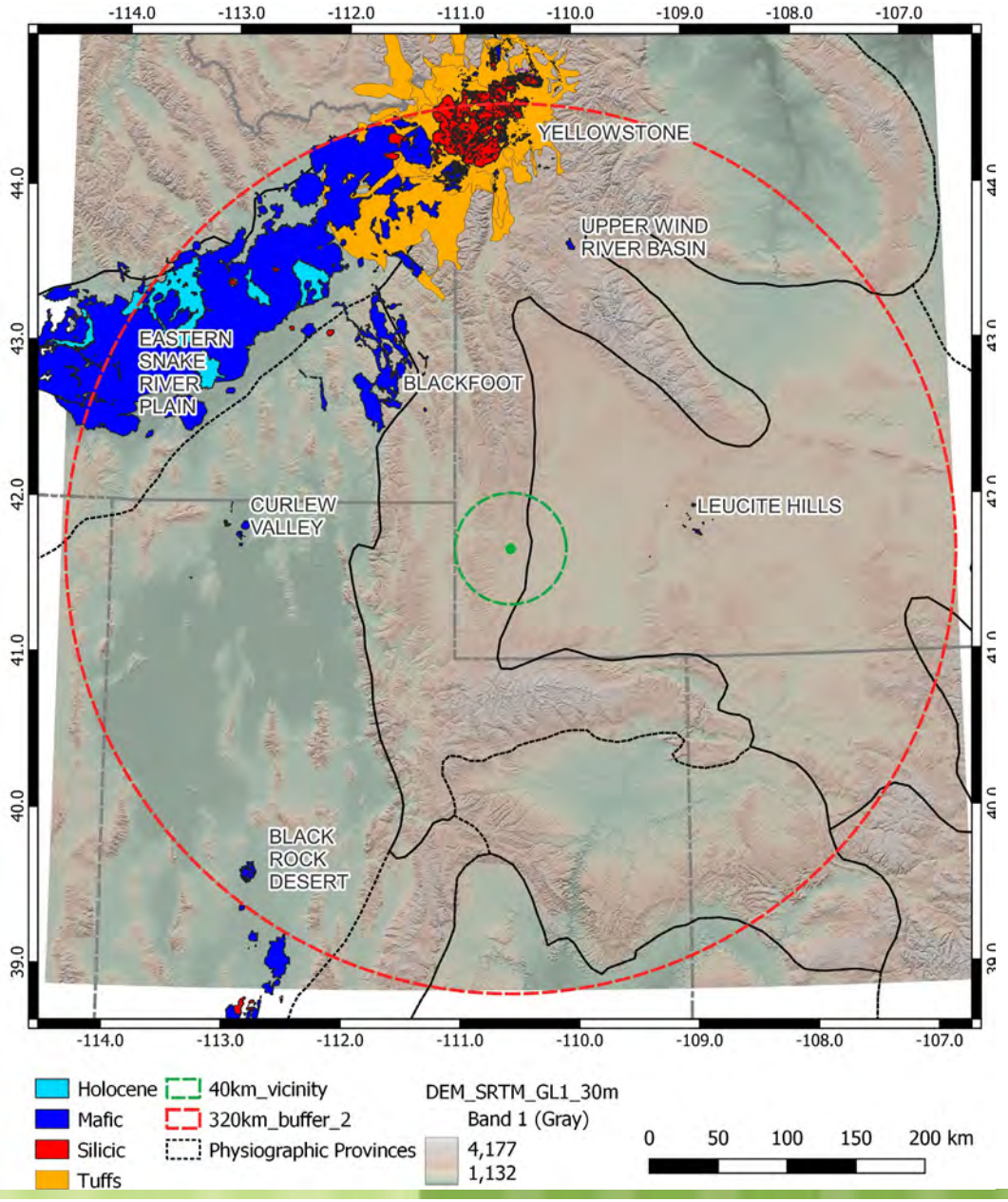

Geologic Setting

- Proposed site located in the Sevier Overthrust belt of the central Rocky Mountain tectonic province.
  - Sevier = 60-120 Ma orogeny.

- 7 Quaternary volcanic systems within 320 km (region) of the proposed site.
  - 320 km = NRC RG 4.26.
  - 40 km = site vicinity.
  - Nearest volcanic system is ≈100 km east in the Leucite Hills.

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RG 4.26 Step 1a: Characterization of Volcanoes

- Identify all Quaternary-age volcanoes in the site region (<320 km).
- Determine characteristic phenomena for each volcano.
  - Lava flows, pyroclastic flows, tephra falls, etc.
- Develop maximum-magnitudes for each characteristic phenomena to support screening decisions in Step 2.

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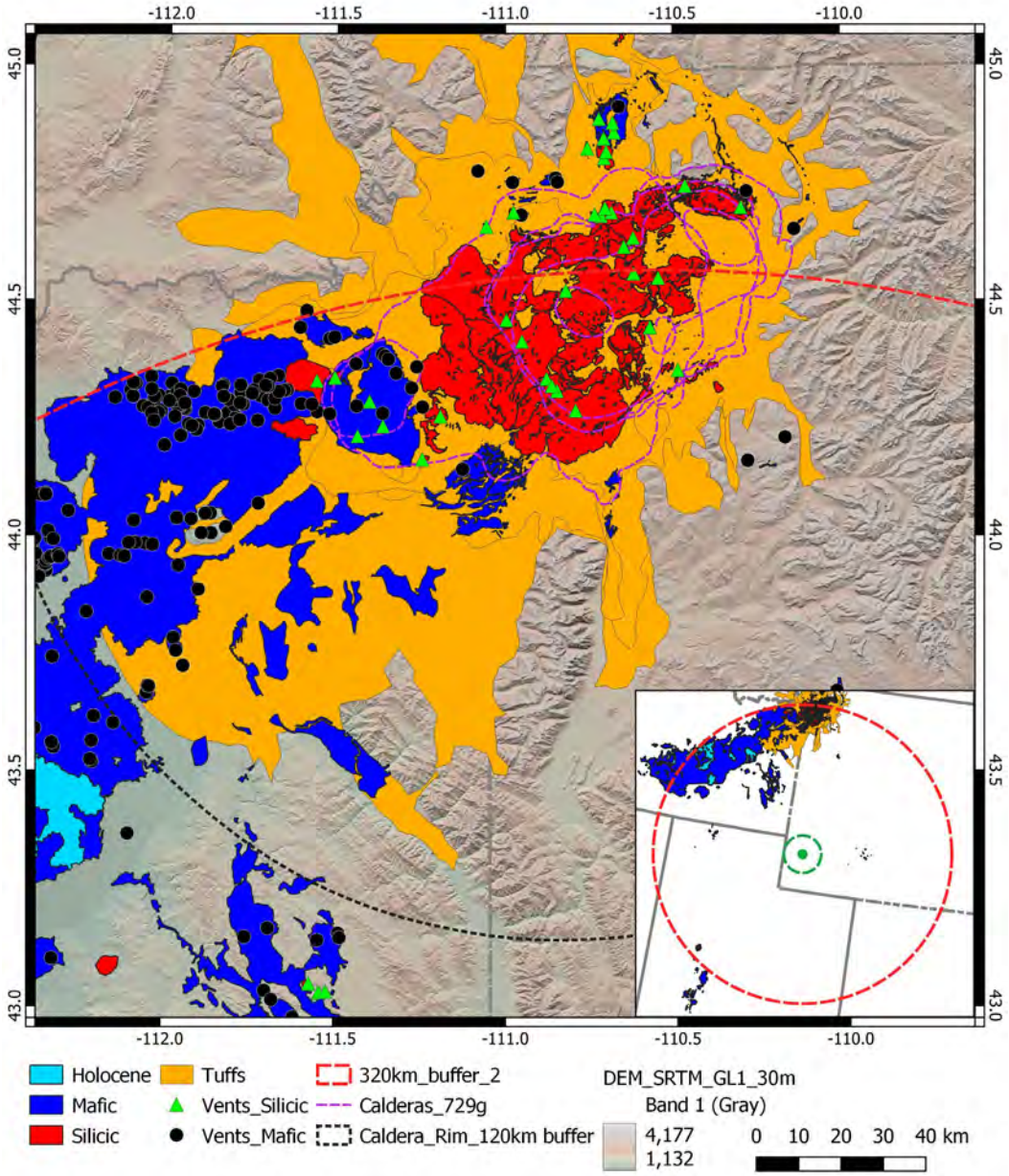

Yellowstone Volcanic System

- 3 major caldera eruptions, each with pyroclastic flows <120 km long:
  - Lava Creek (0.64 Ma, 1000 km^3).
  - Mesa Falls (1.3 Ma, 280 km^3).
  - Huckleberry Ridge (2.1 Ma, 2450 km^3).
- 35 rhyolite vents (18 in site region).
- 21 basaltic vents in site region.
- Total of 59 Quaternary vents.

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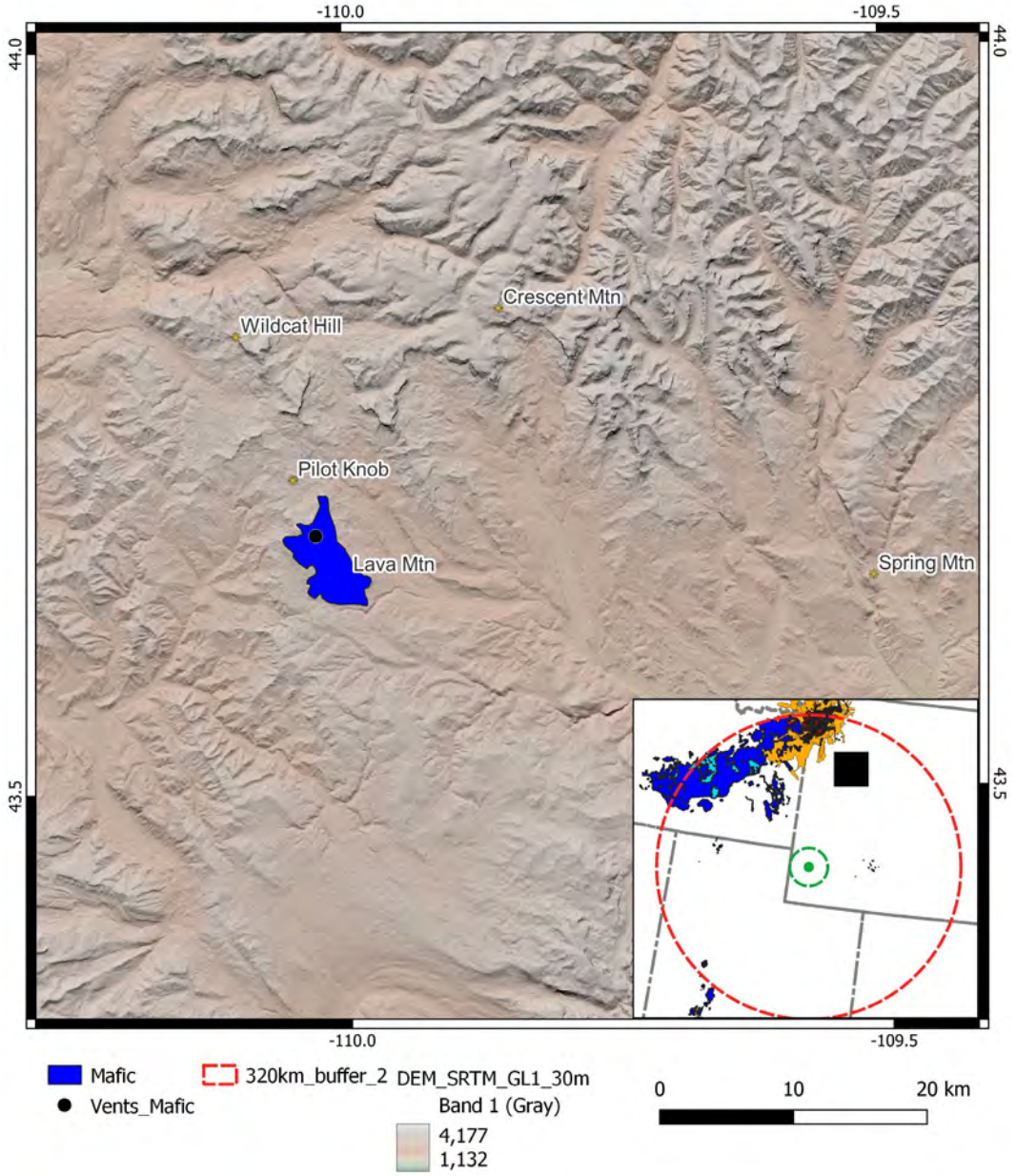

Upper Wind River Basin, WY

- Broad area of mafic volcanism since ~9 Ma from Jackson Hole to Wind River area.
  - 4 volcanoes 2.6-5 Ma shown on figure.

- Lava Mountain: 0.43±0.09 Ma scoria cone, 29 distinct flows.
  - Basaltic andesite to dacite.
  - Model as single event with compositional variability.

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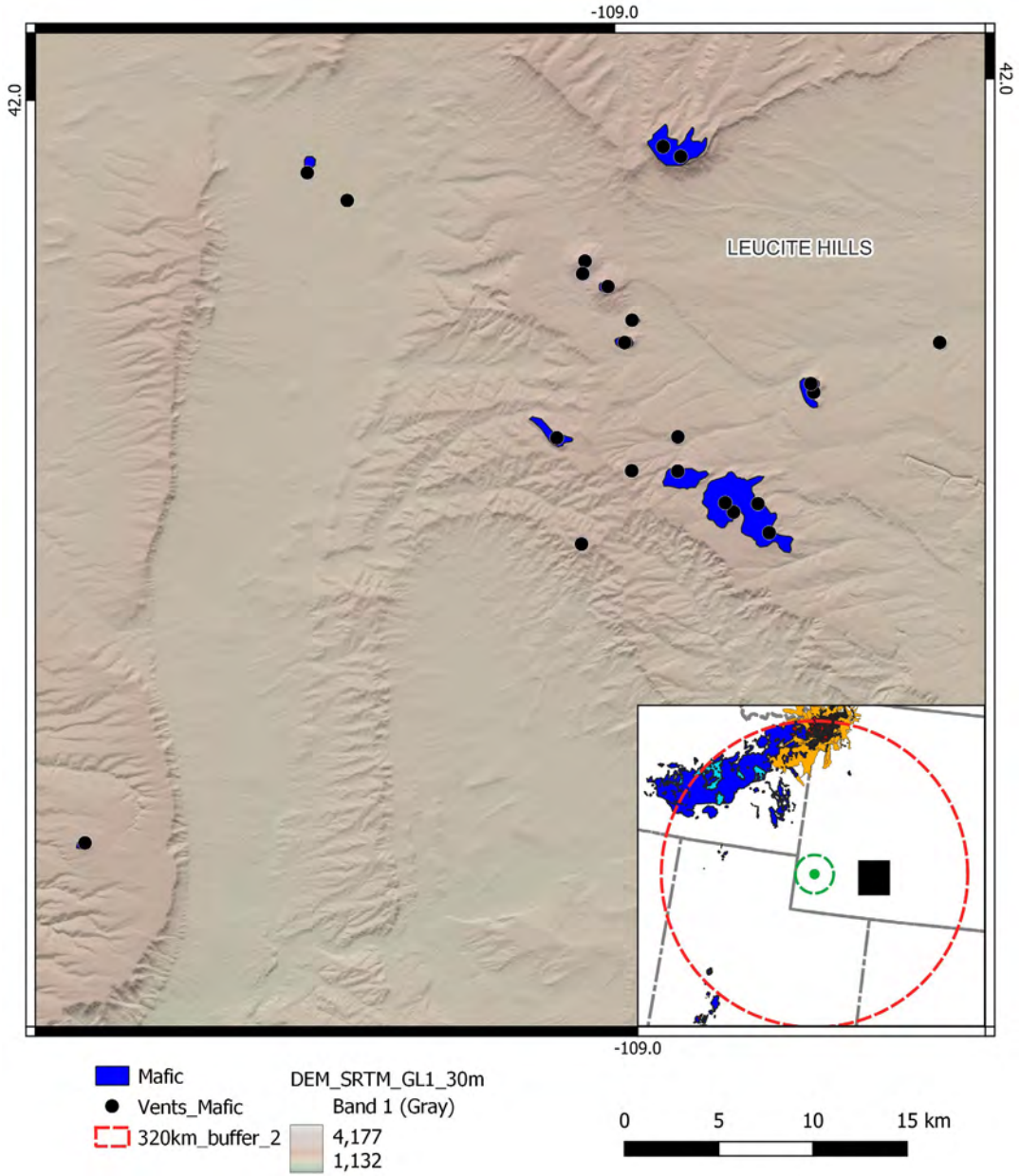

Leucite Hills, WY

- NE shoulder of Rock Springs anticline (Laramide age) in Green River/Wyoming basin.
- 21 small, distributed scoria cones, lavas, and subvolcanic intrusions.
- Activity 0.89-3 Ma, 90% occurring 0.89-0.94 Ma.
- Lamproite (Hi-K basalt) magmas, high volatility contents.

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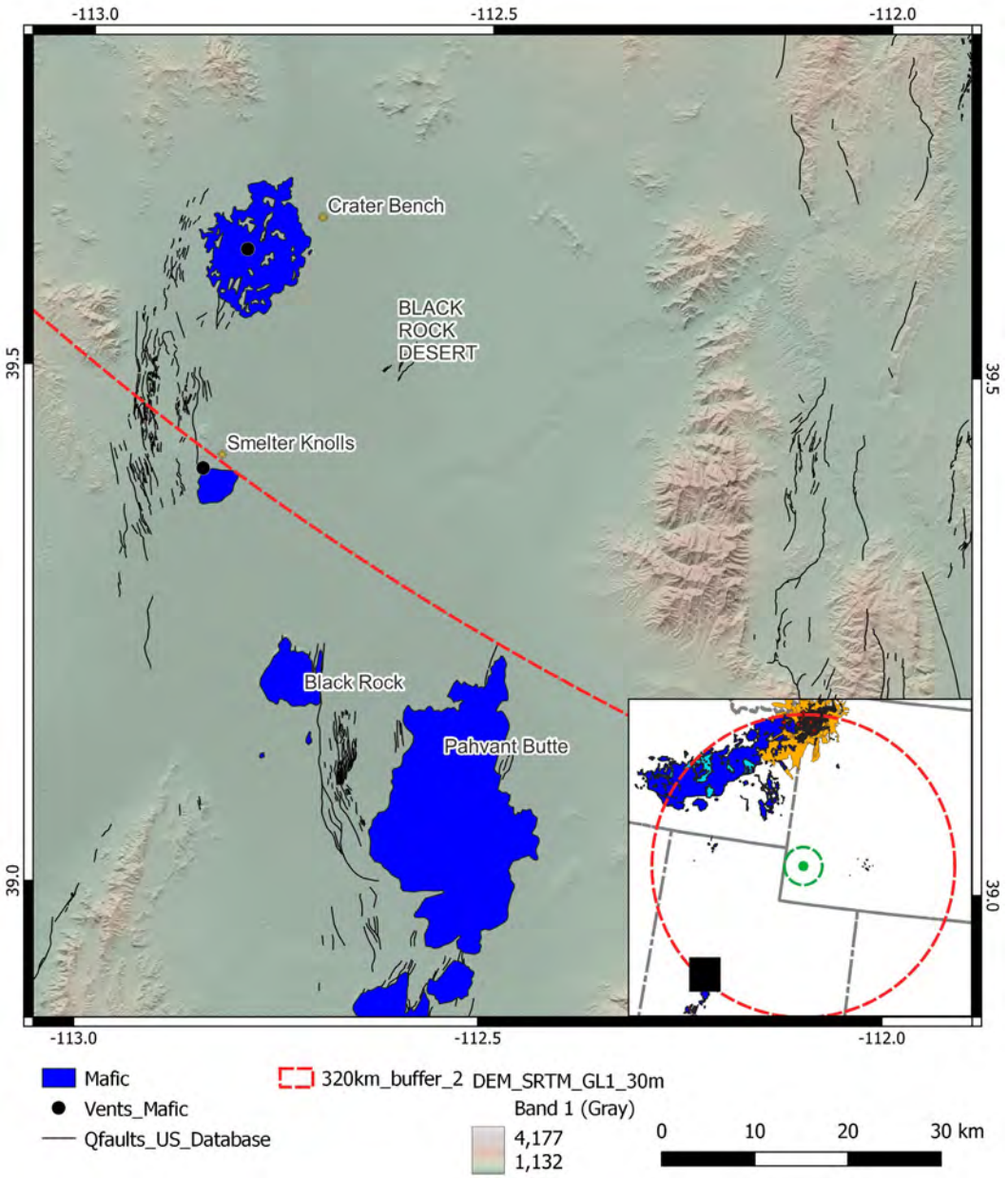

Black Rock Desert, UT

- Eastern Basin & Range tectonic province.
- Northern end of the Quaternary Black Rock Desert volcanic field (mostly outside of the <320 km site region).
- Two ≈1 Ma small basaltic scoria cones and lava flows in the site region.

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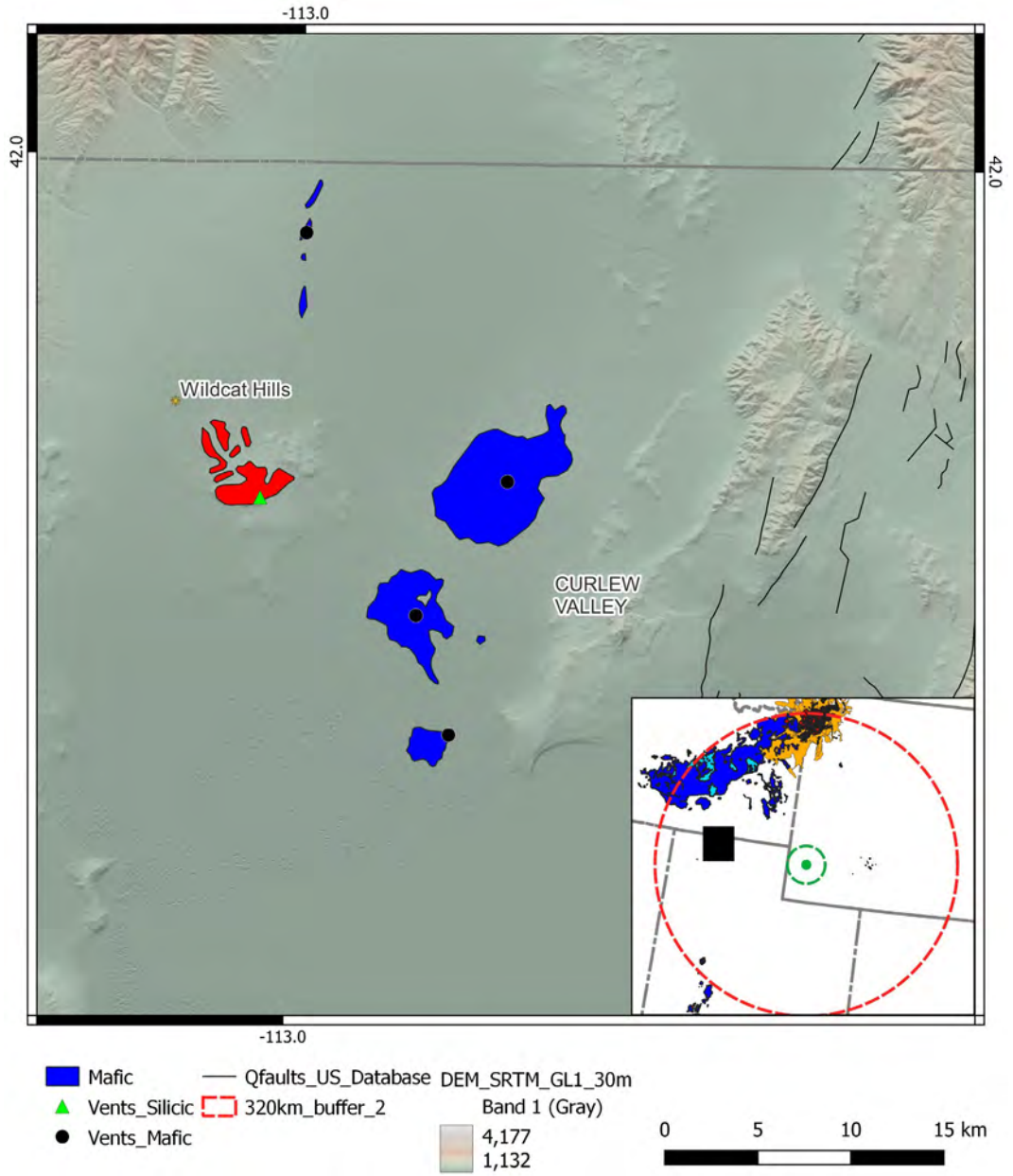

Curlew Valley, UT

- Eastern Basin & Range tectonic province.
- Rhyolitic flow-dome and basaltic fissure vents (NW cycle), 2.1-2.2 Ma.
- Four isolated basaltic scoria cones and lavas (SE cycle), 0.44-1.16 Ma.

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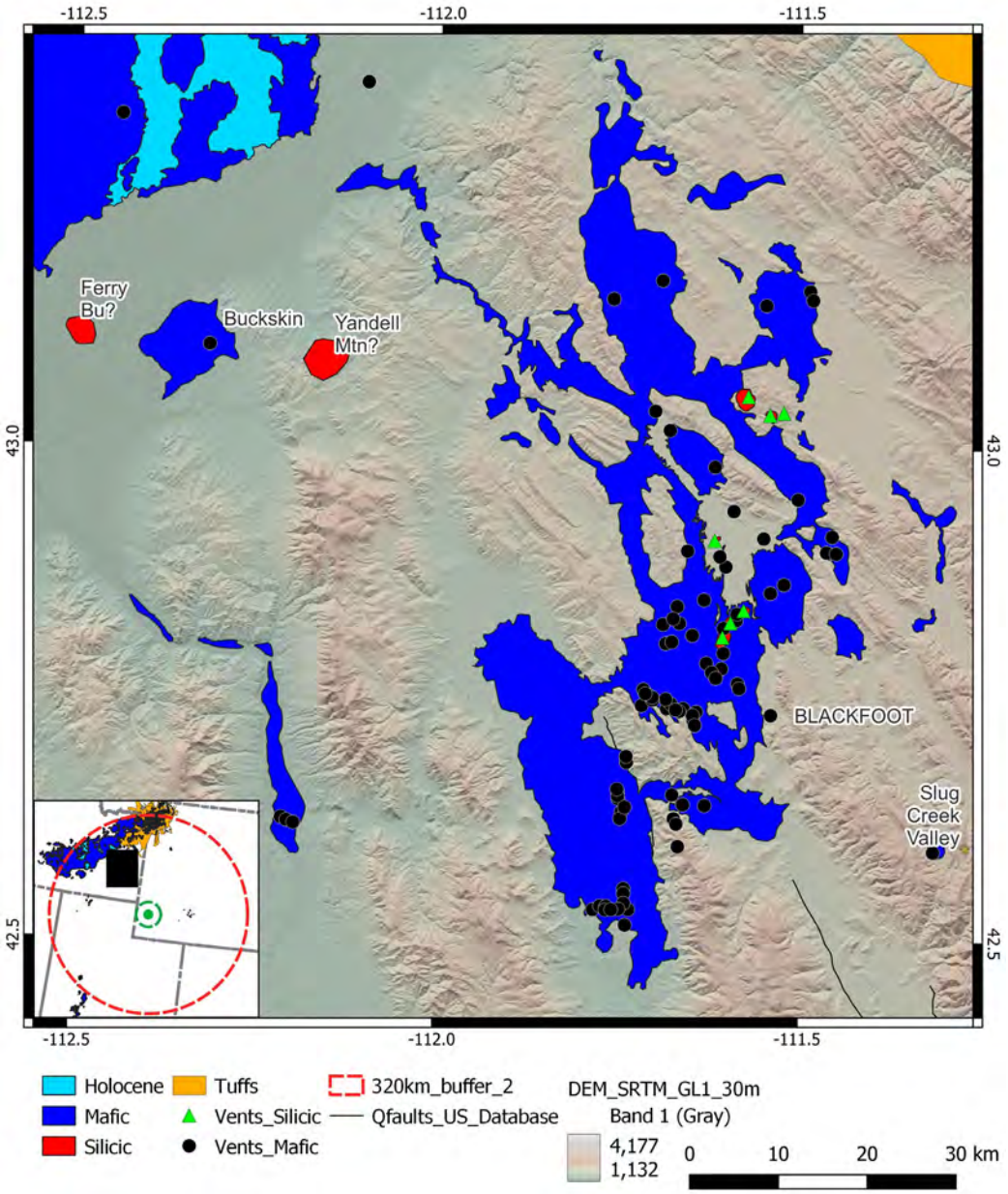

Blackfoot Volcanic Field, ID

- NE Basin & Range tectonic province.
- 87 basaltic scoria cones & fissures, most with lava flows.
  - Poor age constraints; 2 dates of 0.5 Ma and 2.4 Ma.
- 7 small rhyolite domes, 1.4 to 1.6 Ma (N) and ≈50 ka (S).
  - Shallow silicic intrusions(?) at Ferry Butte & Yandell Mtn.

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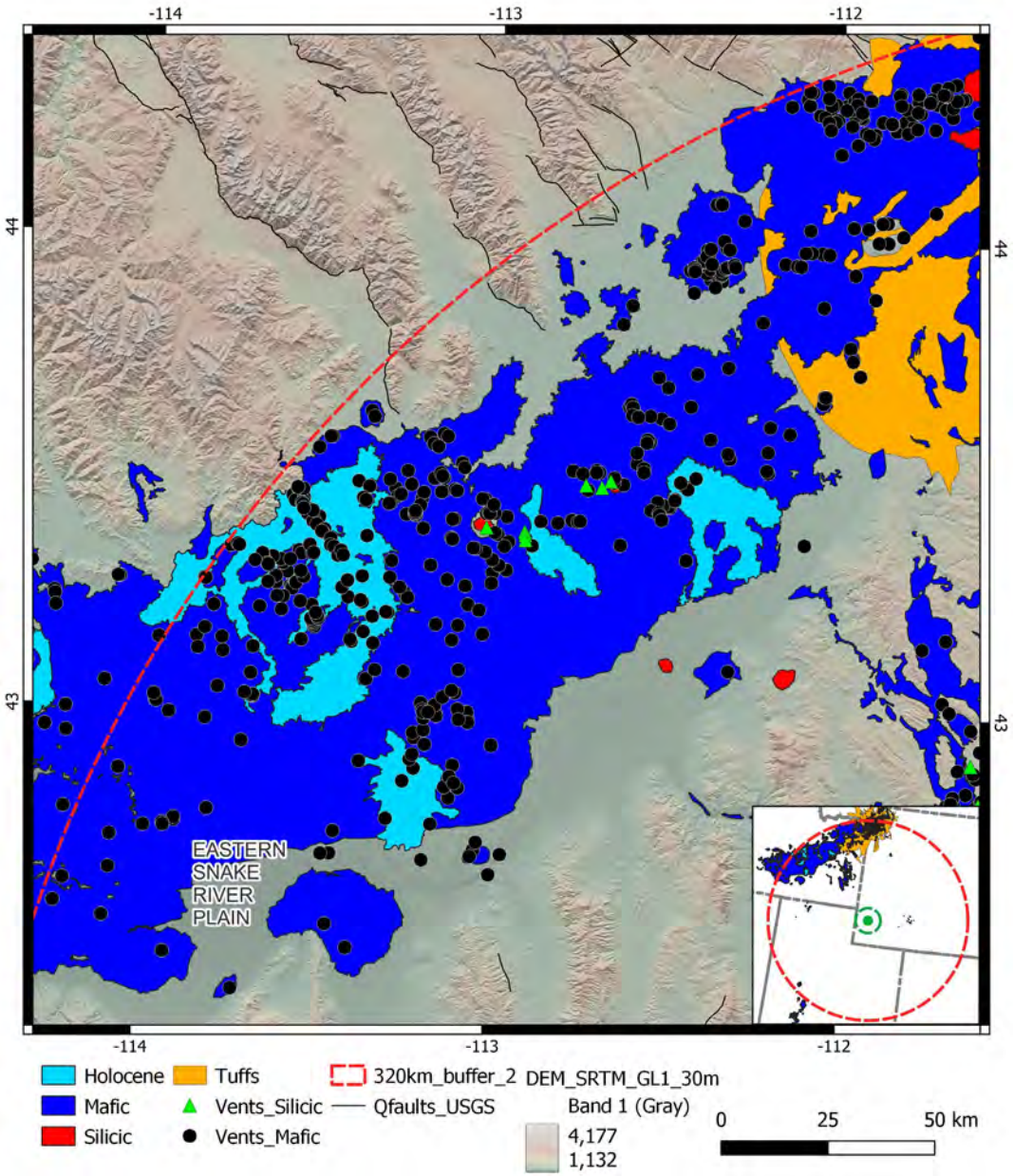

Eastern Snake River Plain, ID

- Distributed volcanic field with 433 basaltic fissures and spatter cones in site region.
  - Surface flows 5-400 ka.
- 28 intermediate composition scoria cones at Craters of the Moon, 2-15 ka.
- 7 rhyolite domes 0.3-1.6 Ma.

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Summary of Characteristic Volcanic Hazards

Volcano Type	Count	Opening Of New Vents	Proximal Hazards	Lava Flows	Pyroclastic Density Currents	Tephra Falls
Mafic & Intermediate Scoria Cones	598	X	X	X		X
Silicic Domes	30	X	X	X	X	X
Silicic Calderas	3				X	X
Volcanic sources >320 km from site	4					X

- 631 Quaternary volcanoes in site region.
- Volcanic sources >320 km:
  - Long Valley CA
  - Valles, NM
  - Cascades, WA
  - Mazama, OR

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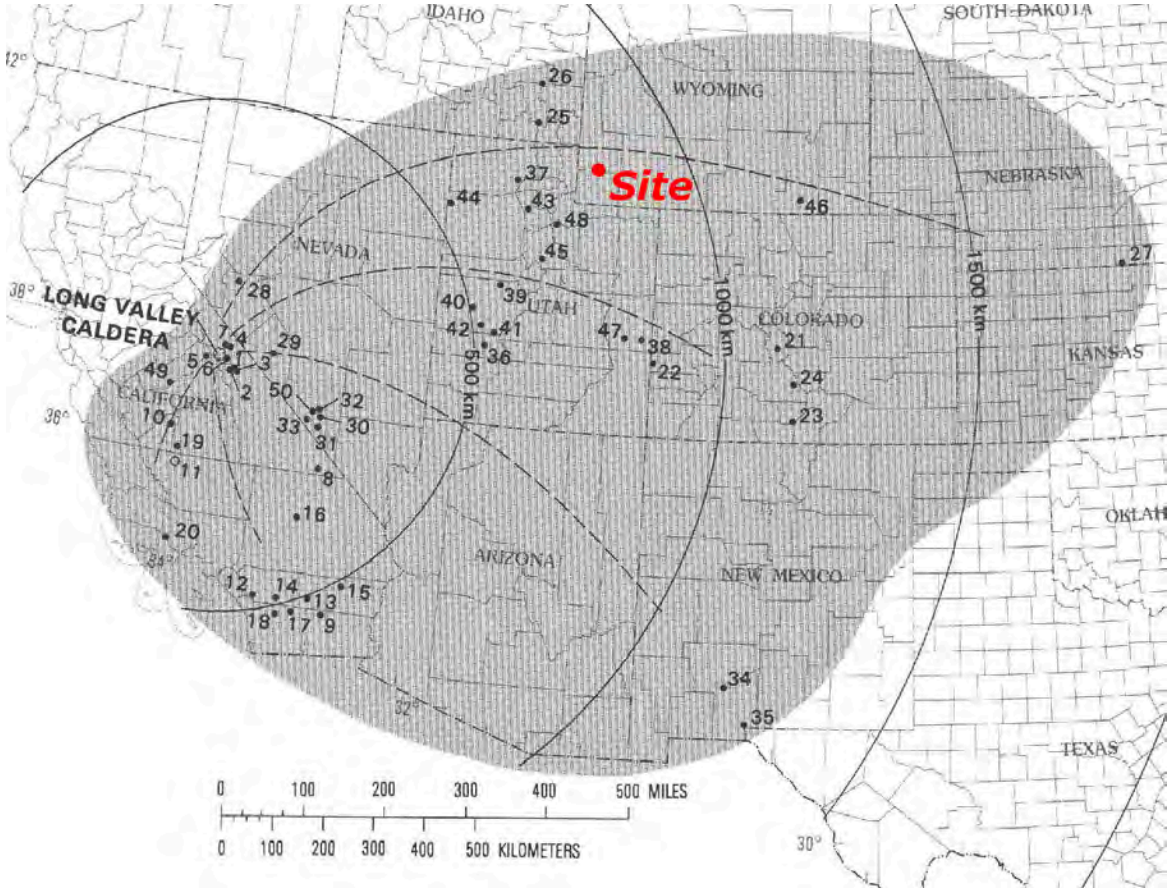
RG 4.26 Step 1b: Characterization of Distant Sources



Izett et al. (1988) USGS B-1675, Fig. 1

- Any ash deposits from volcanoes >320 km away within 40 km of the proposed site (RG 4.26)?
  - Bishop ash, nearest actual deposit 100 km from site.
  - No Valles tephra fall within 100 km of site.
  - No Mazama/Cascades tephra-falls within 40 km of site.
- Conservative screening: distal fall hazards will be less than potential hazards from Yellowstone and other volcanoes in the region.

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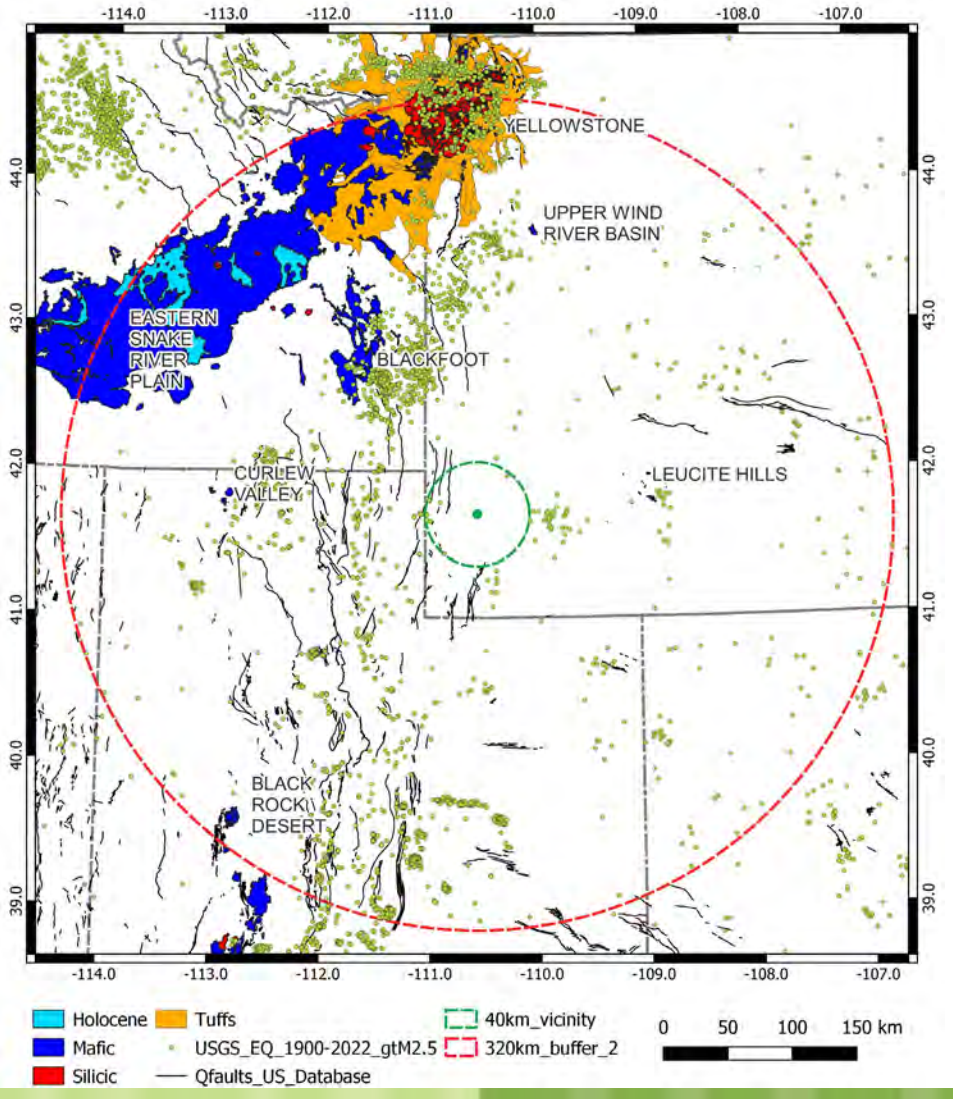
RG 4.26 Step 2a: Tectono-magmatic Model



- Rational framework to consider potential for future volcanism at or near the proposed site.
- Proposed site is in Sevier Overthrust belt of central Rocky Mountain tectonic province:
  - East of Basin & Range faulting and seismicity.
  - West of Laramide-age basin tectonics.
  - South of Yellowstone-ESRP hot-spot tectonics and seismic "parabola."
- Anticipate that the model will contrast the tectonic characteristics of the site to those of volcanic fields in the region, to help inform screening decisions for new vent openings.

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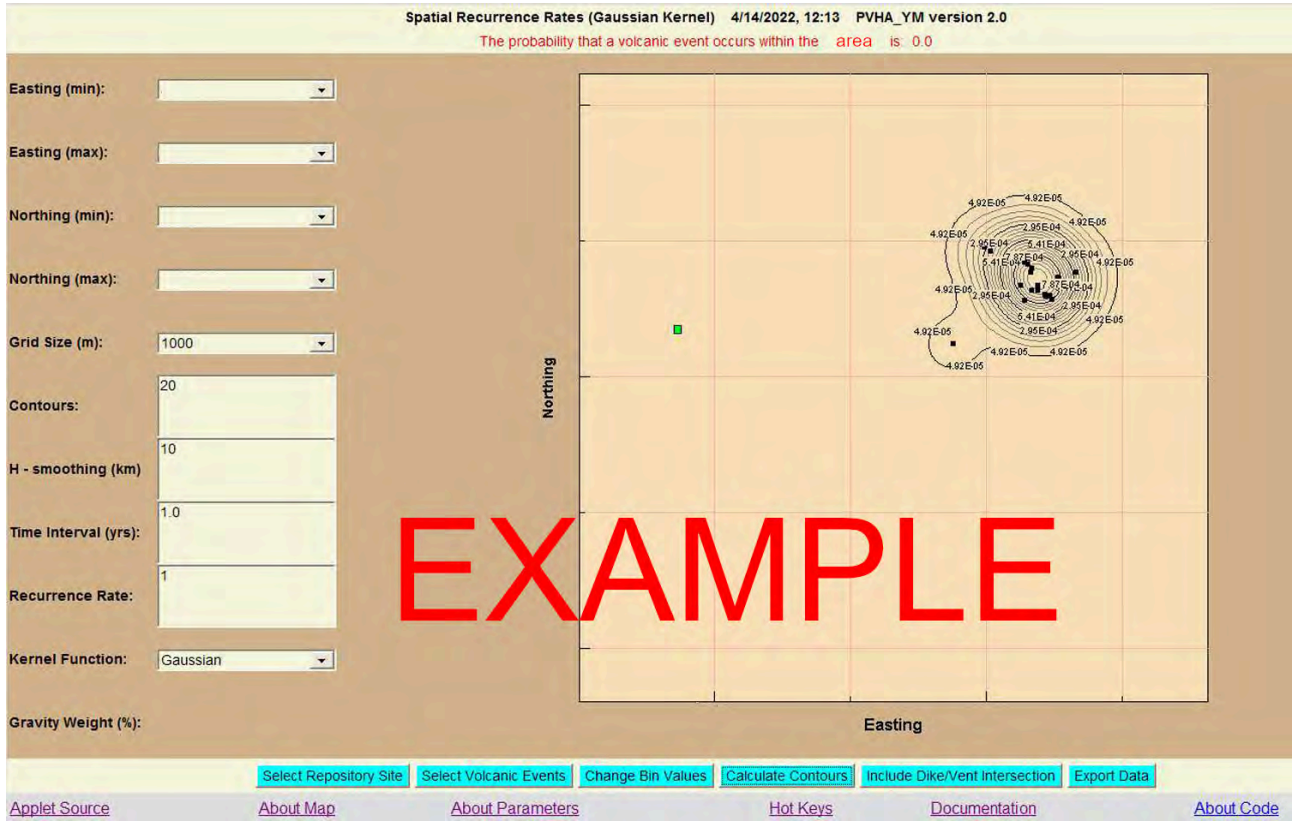
RG 4.26 Step 2b: Screening Analysis



PVHA_YM Version 2.0, NRC ADAMS No. ML033640083).

- Opening of new vents
  - Insights from tectono-magmatic model.
  - PVHA_YM for spatial clustering using kernel density functions.
    - Meets Parts 50 & 63 QA.

- Proximal hazards
  - Initial investigations show opening of new vents is not a hazard at the proposed site.
  - If verified, proximal hazards can be screened from further analysis.

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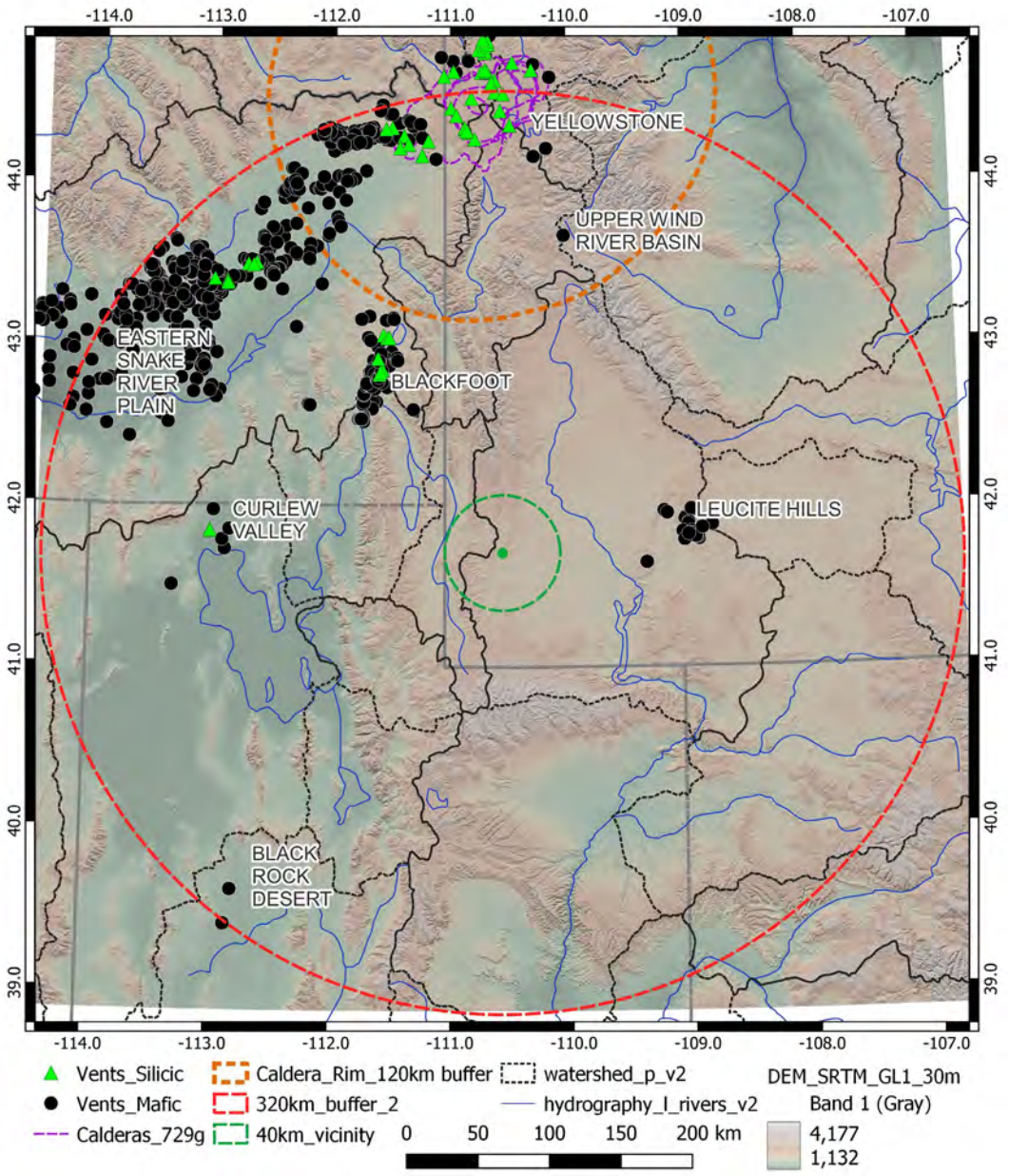

RG 4.26 Step 2b: Flow Screening

- Flow phenomena, evaluate:
  - Maximum flow lengths.
    - Yellowstone pyroclastic flows traveled <120 km.
    - Other flows <100 km.
  - Consider topography between site and potential vent locations.
  - Intrabasin drainage (Green River) traps potential flows from Leucite Hills.
  - Other volcanoes in separate drainage basins from proposed site.
  - Volcanic flows physically cannot reach the proposed site.

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RG 4.26 Step 2b: Tephra-fall Screening

- Potential sources of future tephra falls in site region:
  - Yellowstone caldera eruption.
  - Yellowstone silicic dome eruption.
  - Scoria cones with intermediate compositions (e.g., Leucite Hills, Craters of the Moon).
  - Basaltic scoria cones with evidence of violent strombolian activity.

- Basaltic fissure vents, shield volcanoes, and spatter cones likely screen-out based on limited transport distances shown at analogue volcanoes (<100 km dispersal).

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RG 4.26 Step 2b: Preliminary Screening Analysis

Volcano Type	Count	Opening Of New Vents	Proximal Hazards	Lava Flows	Pyroclastic Density Currents	Tephra Falls
Mafic & Intermediate Scoria Cones	598	Out; T-M model, distance	Out; new vent >40 km	Out; distance, topography		IN
Silicic Domes	30	Out; T-M model, distance	Out; new vent >40 km	Out; distance, topography	Out; distance, topography	IN
Silicic Calderas	3				Out; distance, topography	IN
Volcanic sources >320 km from site	4					Out; no deposits <40km

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RG 4.26 Step 3: Initial Risk Insights

- Screening analysis gives maximum-magnitude event.
- Consider whether a maximum-magnitude event might affect performance of Structures, Systems, and Components important to safety.
- Risk insights guide the need to develop in Step 4 either:
  - Hazard curves that are conditional on eruption occurrence (P_H).
  - Probabilistic hazard curves with eruption likelihoods (P_E x P_H).

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RG 4.26 Step 4: Tephra-fall Hazard Analyses

- Caldera eruptions from Yellowstone mostly form pyroclastic flows.
- Tephra-fall deposits from past eruptions are poorly preserved and inadequate to constrain potential hazard.
- Plan to use analyses in Mastin, et al. (2014; doi:10.1002/2014GC005469) as maximum-magnitude event for a conditional tephra-fall hazard, based on past eruption volume.
  - Represents a conservative upper bound on future tephra-fall volume.
- Bound the likelihood of a future caldera-scale eruption at $<10^{-6}$/yr.
  - "The probability of another major caldera-forming Yellowstone eruption, in the absence of strong premonitory indications of major magmatic intrusion and degassing beneath a large area of the caldera, can be considered to be below the threshold of useful calculation." USGS Open-file Report 2007-1071, p. 4.

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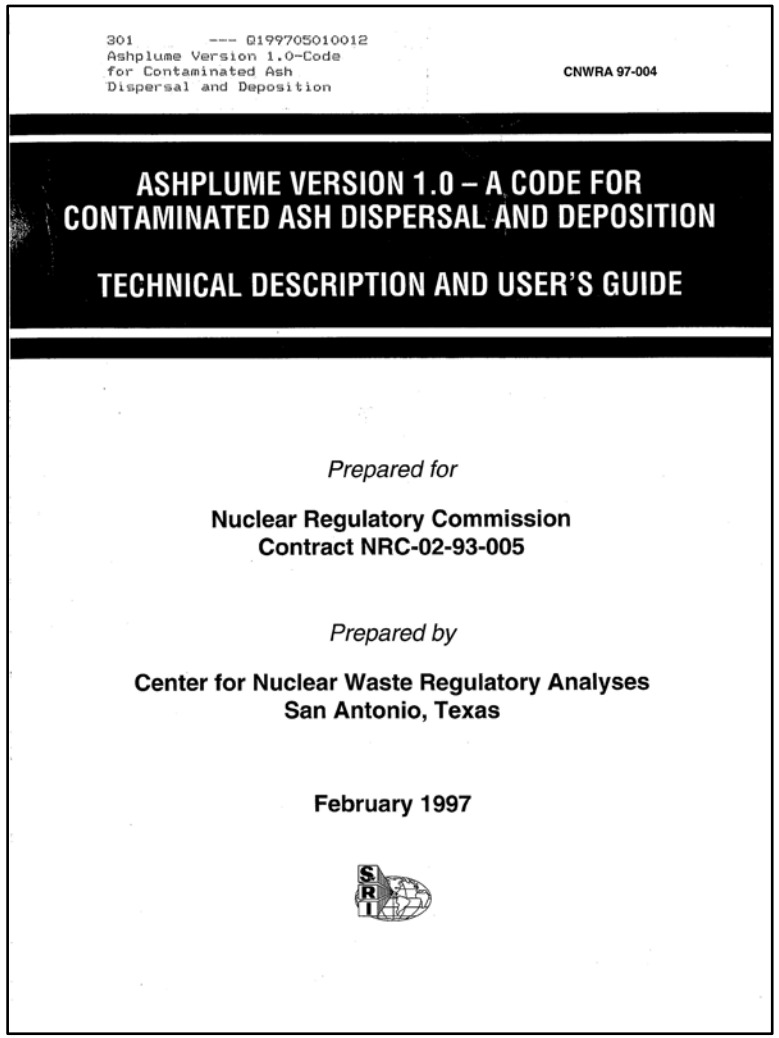
RG 4.26 Step 4: Tephra-fall Hazard Analyses



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Ashplume Version 1.0-Code
for Contaminated Ash
Dispersal and Deposition

CNWRA 97-004

ASHPLUME VERSION 1.0 – A CODE FOR CONTAMINATED ASH DISPERSAL AND DEPOSITION

TECHNICAL DESCRIPTION AND USER'S GUIDE

Prepared for

Nuclear Regulatory Commission
Contract NRC-02-93-005

Prepared by

Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas

February 1997

- Silicic dome and scoria-cone tephra falls, all vents >100 km from the proposed site.
- Analyze using ASHPLUME code (NRC ADAMS No. ML040200038).
  - Meets Parts 50 & 63 QA.
- Eruption parameters from analogue systems.
  - Fall deposits in region eroded away.
  - Develop cone:fall relationships.
- Direct plume towards site, sample characteristic wind speeds.
- Bound probability of eruption occurring (P_E), if necessary.

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Key Points

- ~630 Quaternary volcanoes are located within 320 km of the proposed site near Kemmerer, WY.
- The proposed site, however, is located **>100 km away** from the nearest Quaternary-age volcano.
- Initial screening analyses suggest **tephra fall is the only potential volcanic hazard** of concern for this site.
- The PVHA_YM and ASHPLUME codes meet NRC Part 50 Quality Assurance requirements and appear suitable for use in these hazard analyses.
- Information from analogue volcanoes must be used to conduct the tephra-fall hazard evaluations.
- Plan to evaluate conditional tephra-fall hazards by **directing plume towards the proposed site**, and sampling representative wind speeds and eruption parameters.
- If warranted by risk insights, eruption probabilities might need to be bounded.

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Acronyms

- ka – Thousand years ago
- LMP – Licensing Modernization Project
- Ma – Million years ago
- NRC – U.S. Nuclear Regulatory Commission
- P_E – Probability of Eruption (RG 4.26)
- P_H – Probability of Hazard (RG 4.26)
- RG – Regulatory Guide
- QA – Quality Assurance

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