Small Modular Reactors

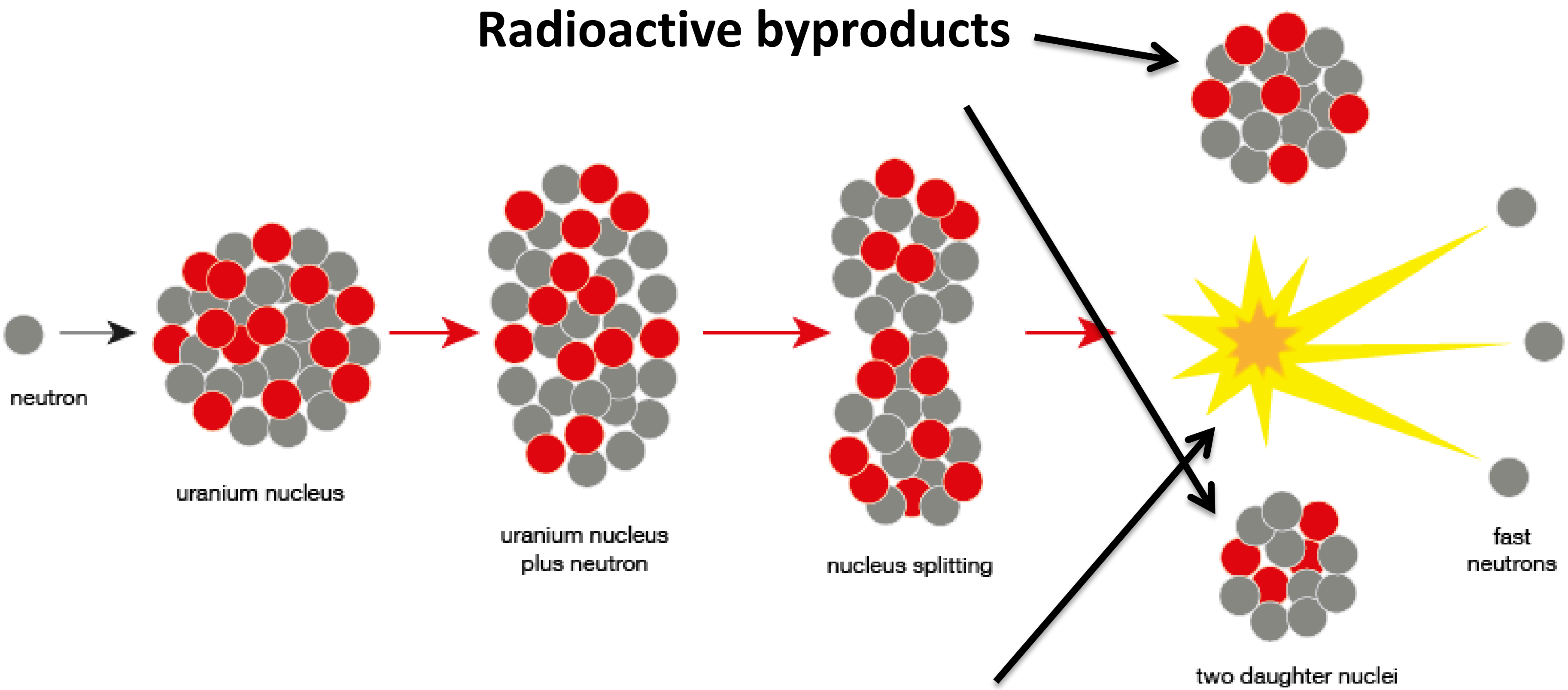
Van Romero PhD
Professor of Physics
Vice President for Research
New Mexico Tech

Small Modular Reactor (SMR) Definition

“Small Modular Reactors (SMRs) are nuclear power plants that are smaller in size (300MWe or less) than current generation base load plants (1,000MWe or higher). These smaller, compact designs are factory-fabricated reactors that can be transported by truck or rail to a nuclear power site. SMRs will play an important role in addressing the energy security, economic and climate goals of the U.S. if they can be commercially deployed within the next decade”

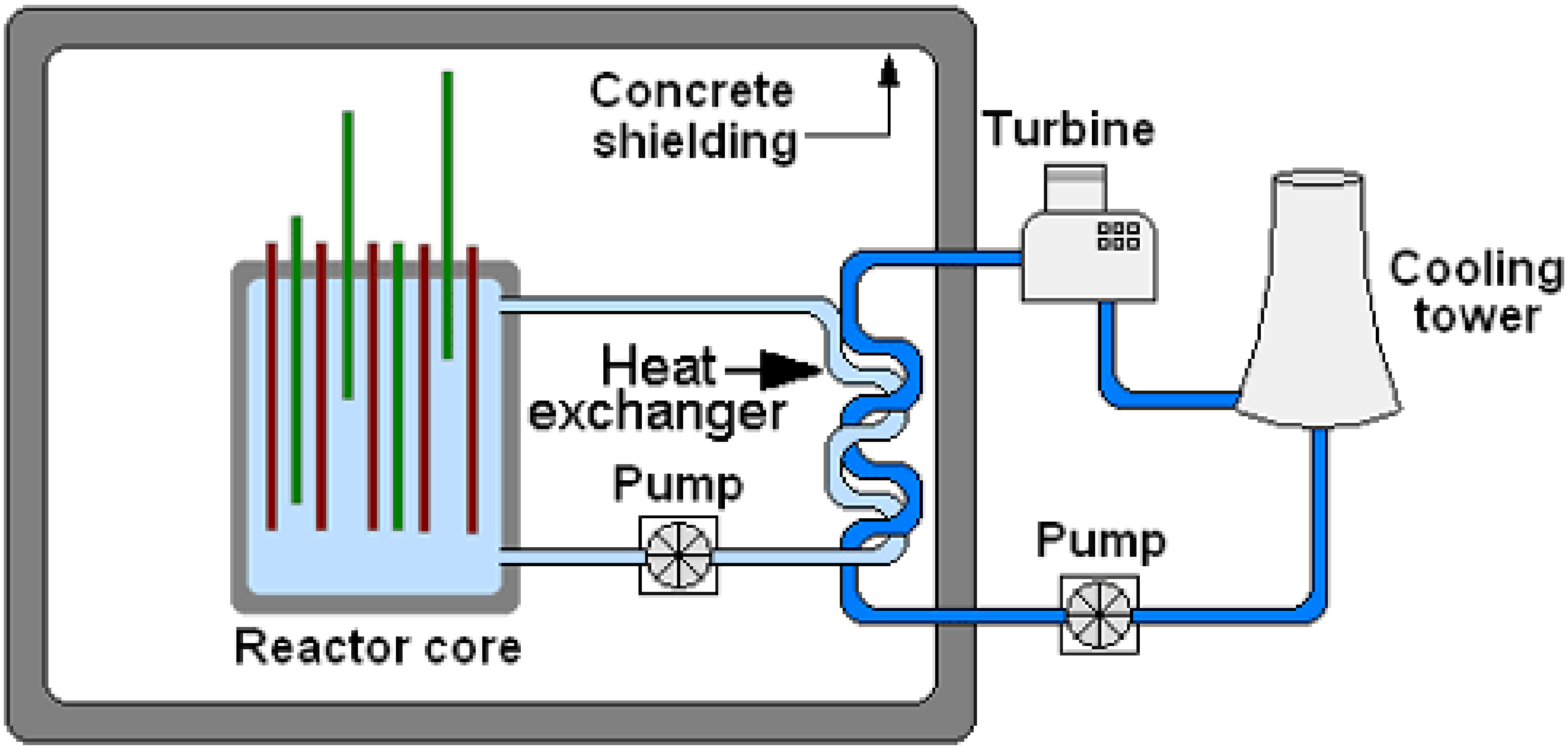
DOE

Fission



$$E=MC^2$$

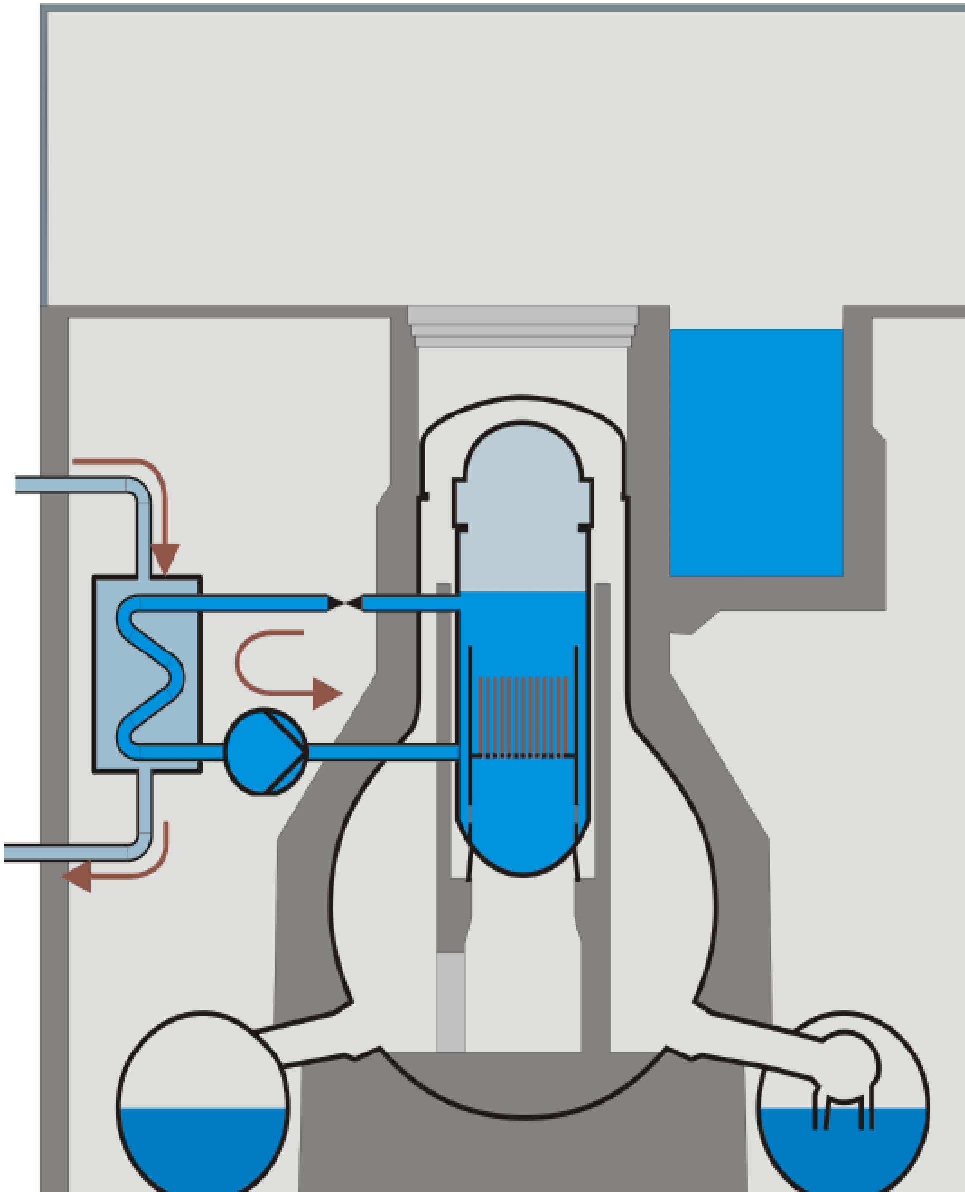
Heat → Electricity




LIVE
17:32 GMT
RT
8.9 QUAKE HITS N.E. JAPAN, TSUNAMI WREAKS DEVASTATION ACROSS REGION
BREAKING NEWS
MS NORTH-EASTERN JAPAN AFTER 8.9 MAGNITUDE

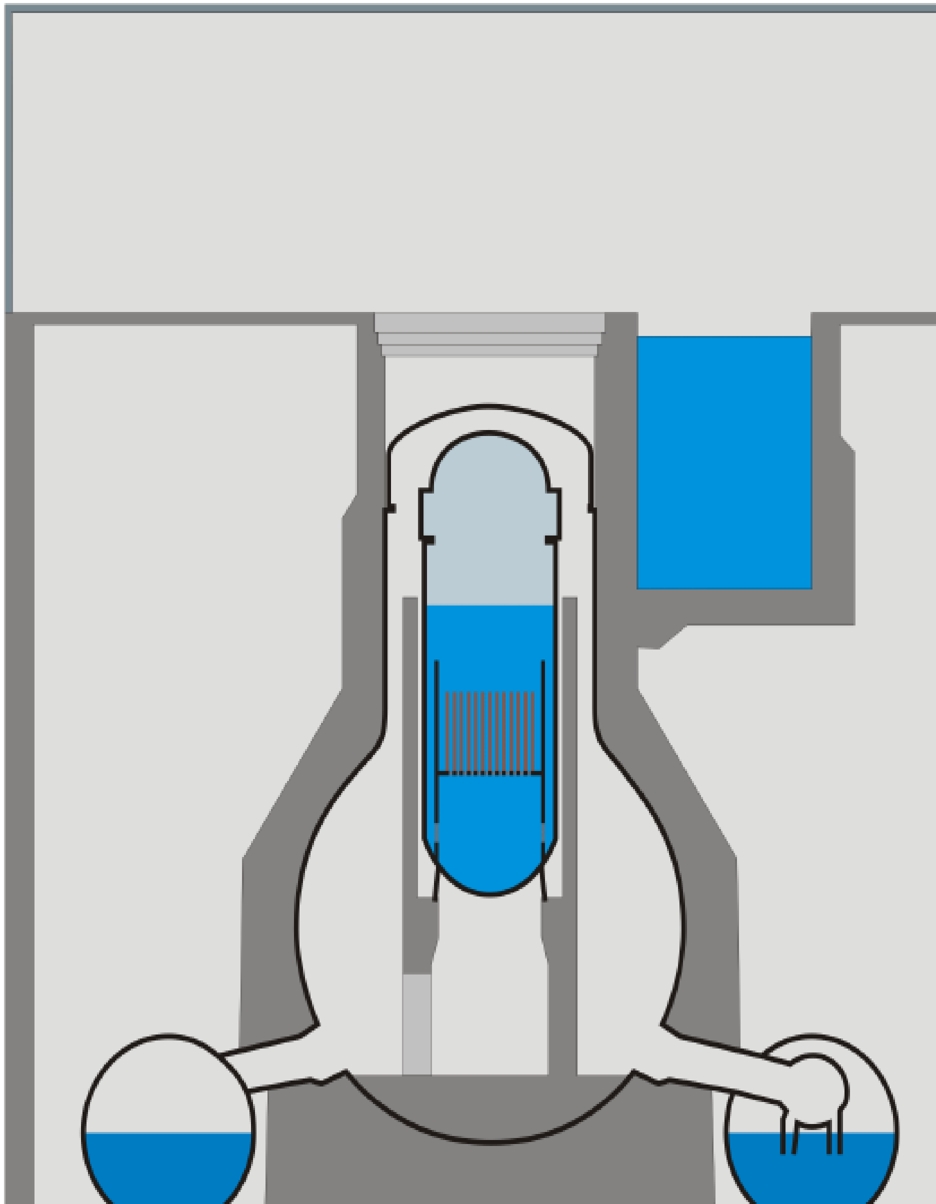
The Fukushima Daiichi Incident
2. Accident progression

- Usual course of action:
  - Cooling reactor by Residual Heat Removal Systems
  - Active spend fuel pool cooling
  - Active containment heat removal
- Necessary
  - Electricity for pumps
  - Heat sink outside reactor building (Service Water)



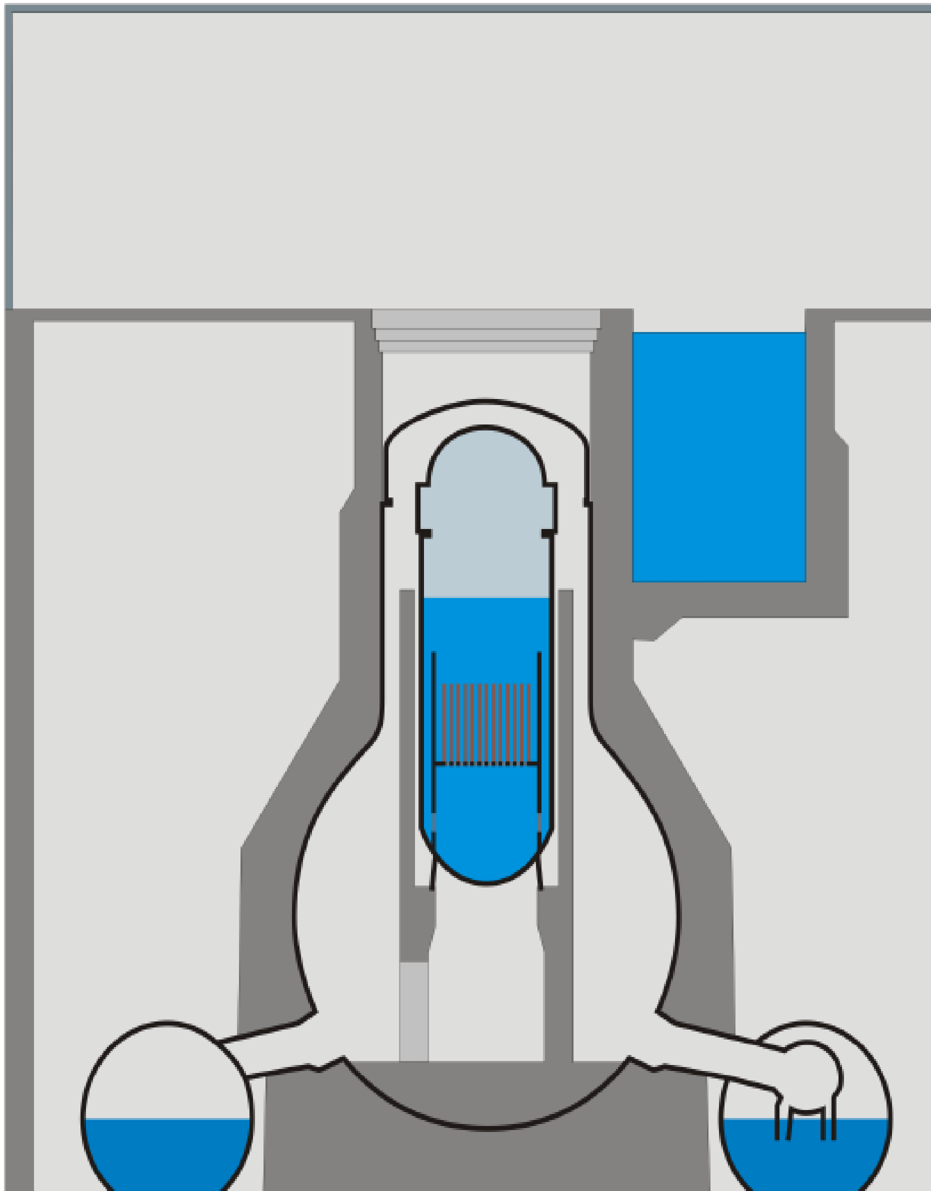
The Fukushima Daiichi Incident
2. Accident progression

- 3/11 15:01(?) Tsunami hits plant
  - Plant Design for Tsunami height of up to 5.7-6.5 m
  - Actual Tsunami height 7-11 m
  - Flooding of
    - Diesel and/or
    - Switchgear building and/or
    - Fuel Tanks and/or
    - Essential service water buildings
- 3/11 15:41 Station Blackout
  - Common cause failure of the power supply
  - Only Batteries are still available
  - Failure of all but one Emergency core cooling system

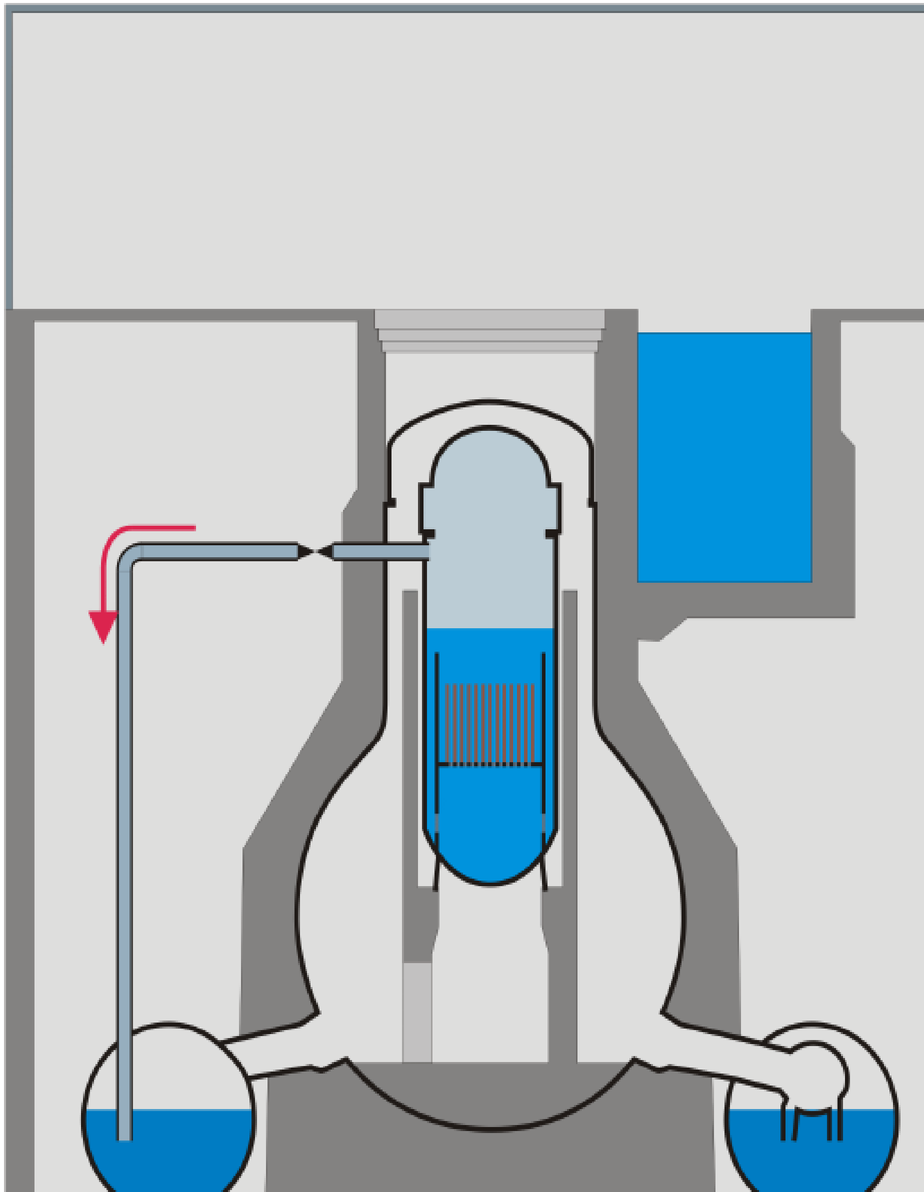


The Fukushima Daiichi Incident
2. Accident progression

- 3/11 16:36 in Unit 1
  - Isolation condenser stops
  - Tank empty(?)
- 3/13 2:44 in Unit 3
  - Reactor Isolation pump stops
  - Batteries empty
- 3/14 13:25 in Unit 2
  - Reactor Isolation pump stops
  - Pump failure
- Consecutively, all reactors are cut of from any kind of heat removal



- Decay heat produces still steam in reactor pressure vessel
  - Pressure rising
- Opening the steam relieve valves
  - Discharge steam into the Wet-Well
- Descending of the liquid level in the reactor pressure vessel



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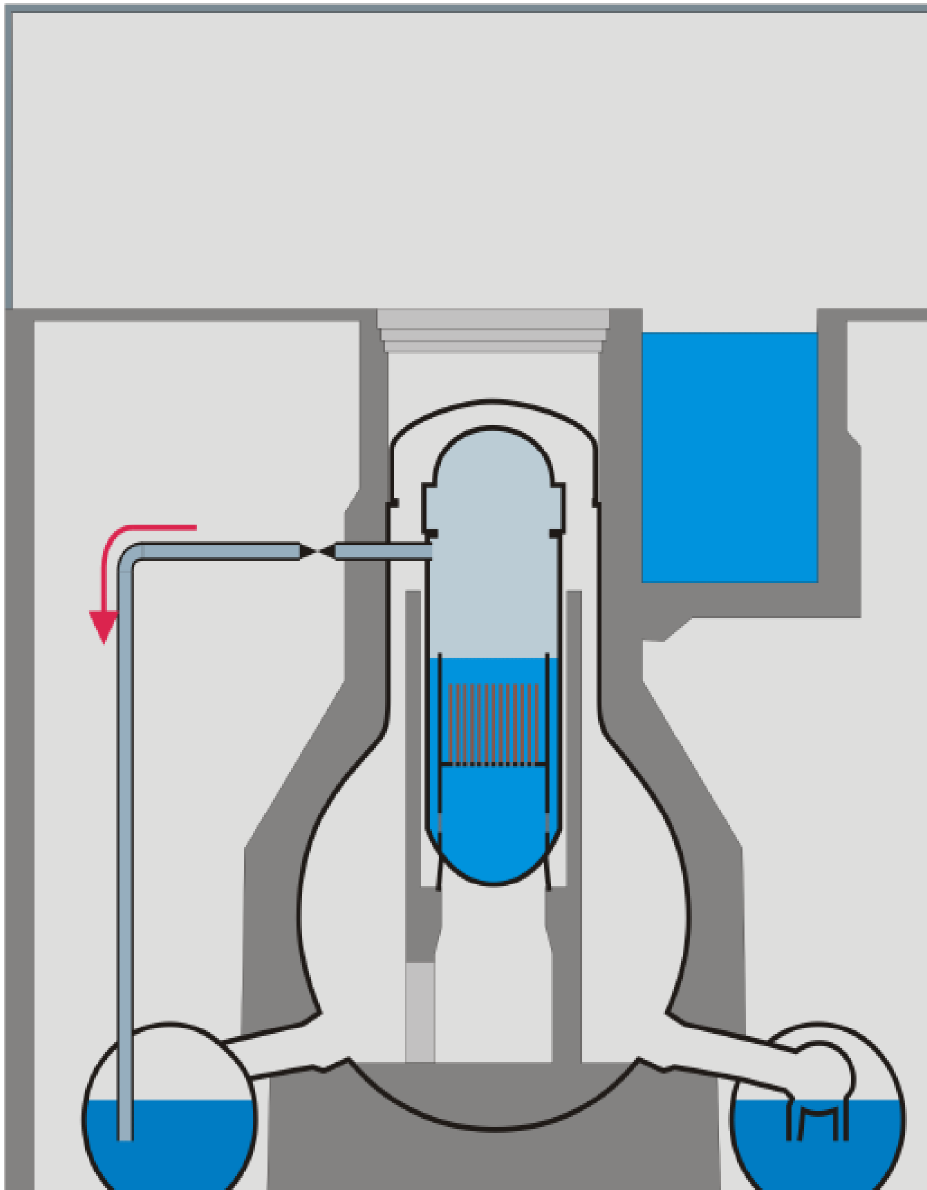

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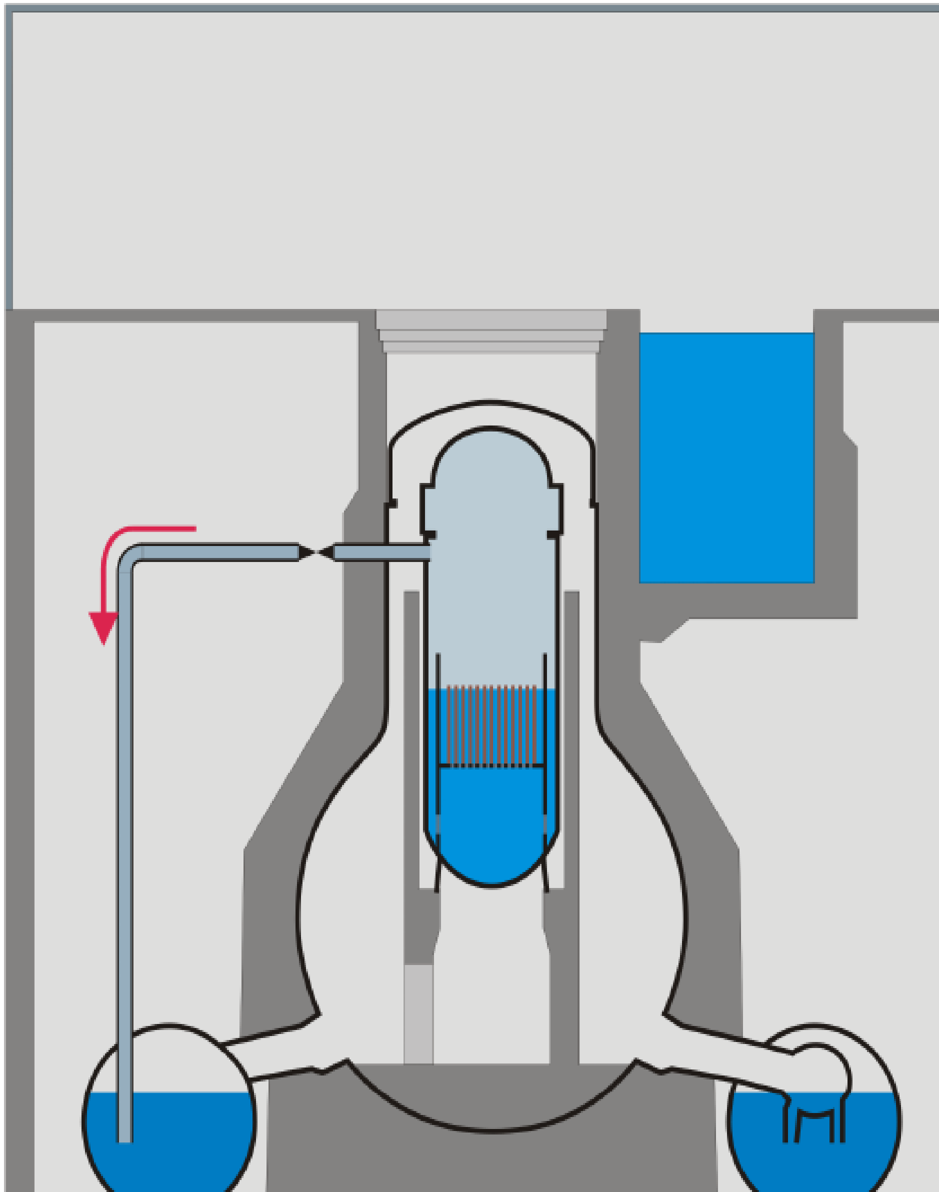

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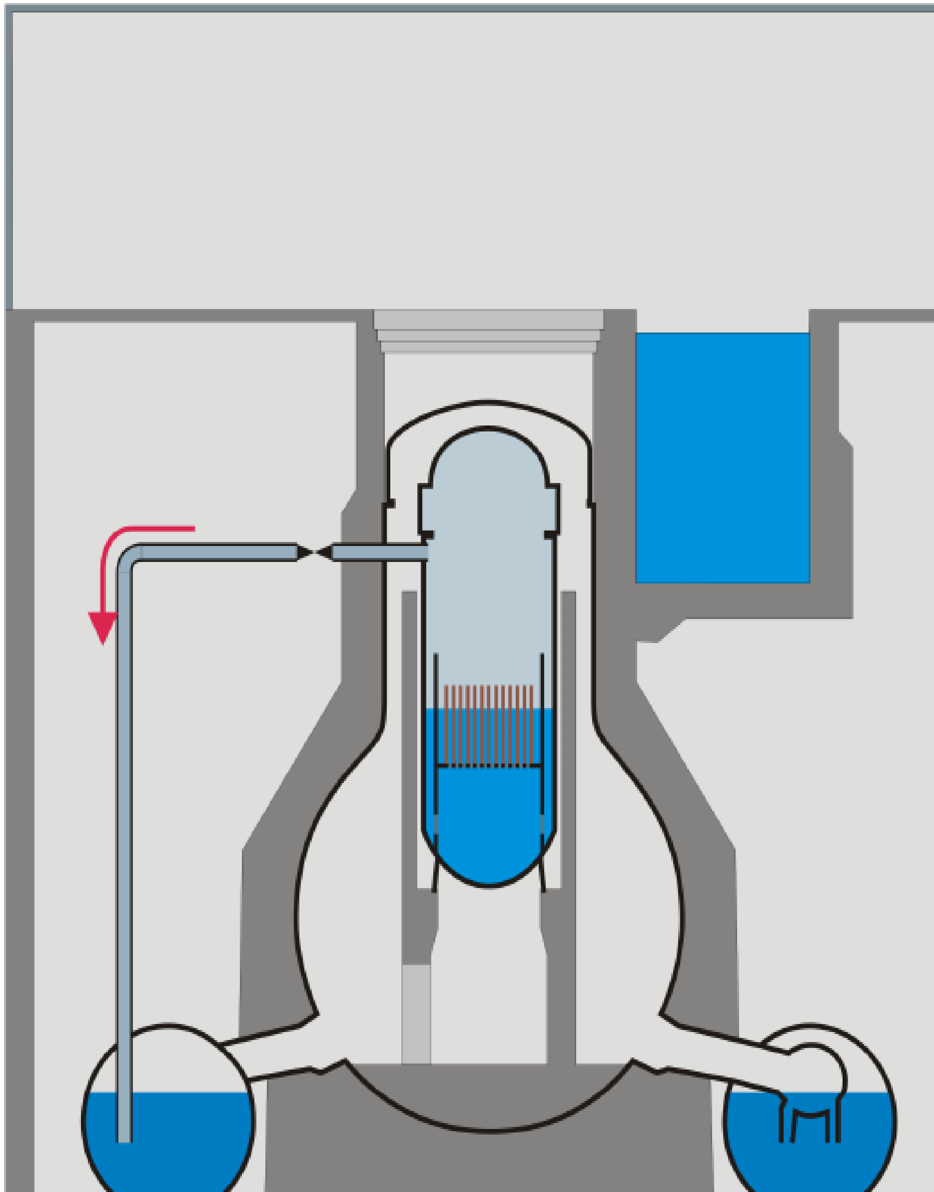
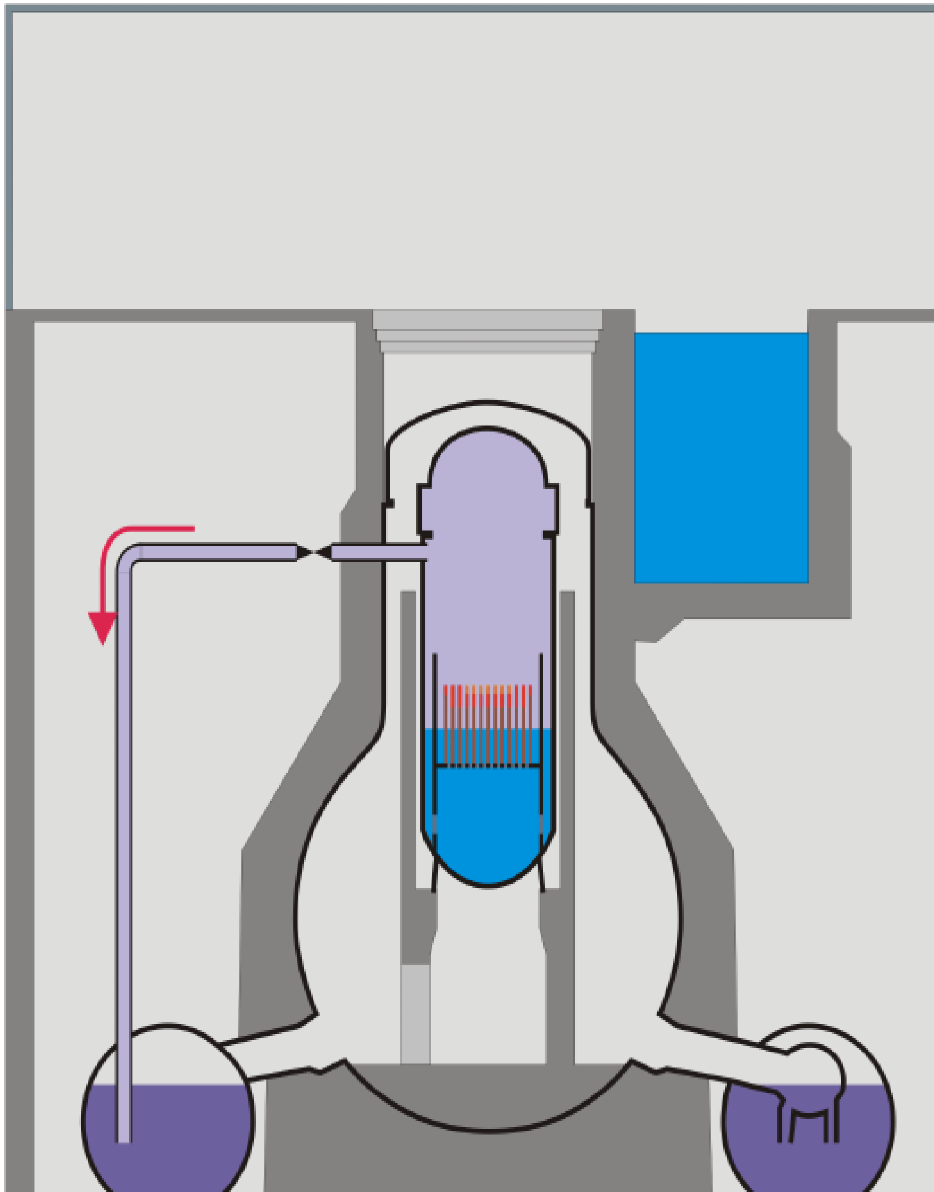


- ~50% of the core exposed
  - Cladding temperatures rise, but still no significant core damage

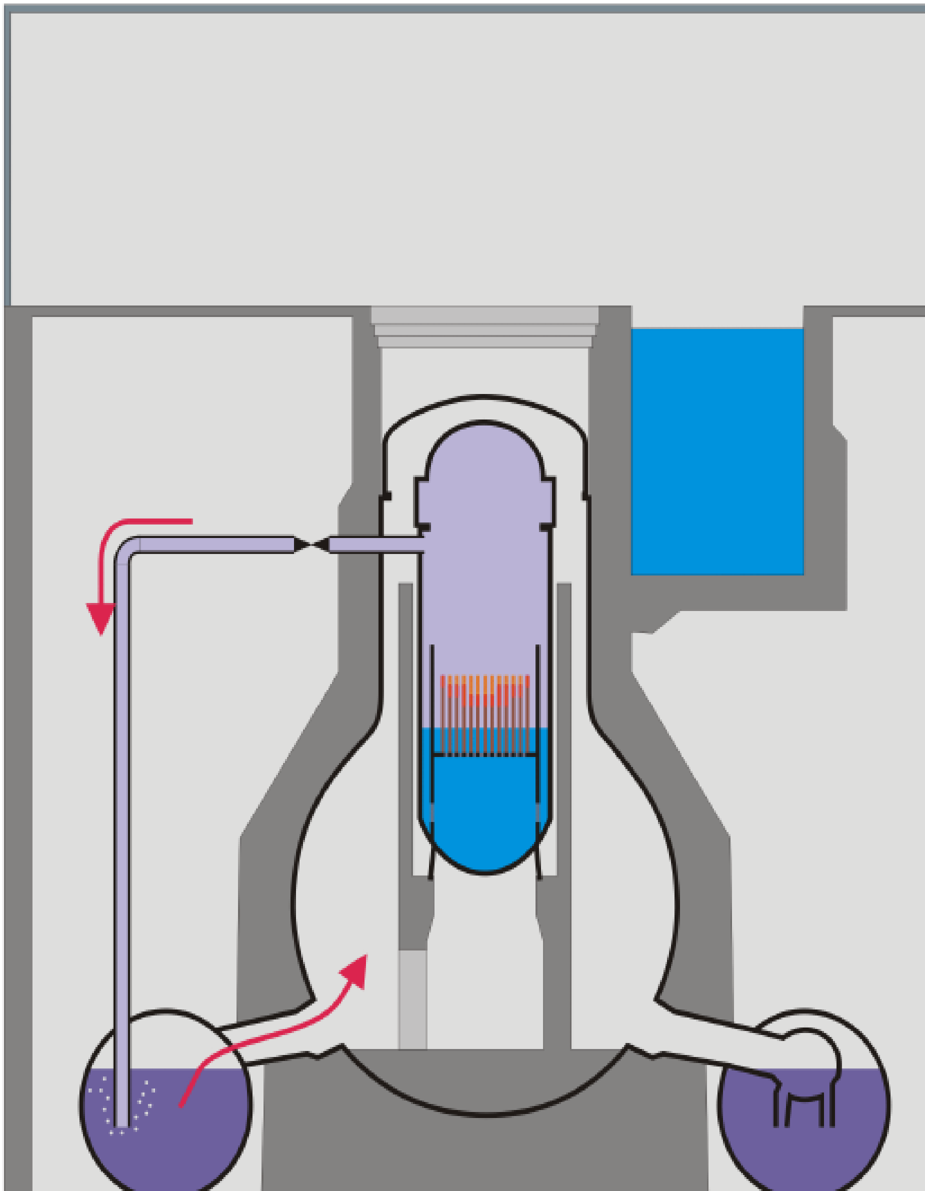
- ~2/3 of the core exposed
  - Cladding temperature exceeds ~900°C
  - Ballooning / breaking of the cladding
  - Release of fission products from the fuel rod gaps

(Measured levels are collapsed level. The actual liquid level lies higher due to the steam bubbles in the liquid)



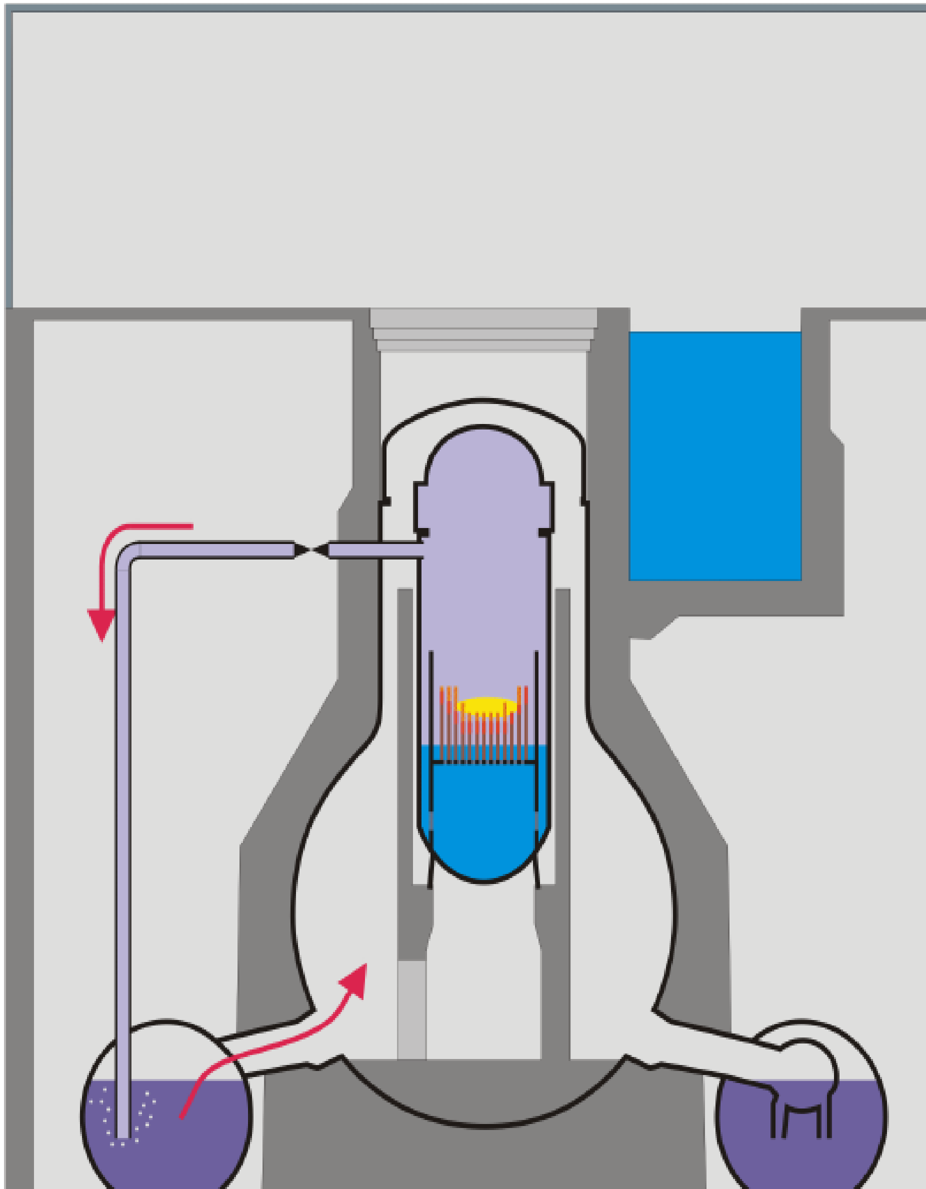
The Fukushima Daiichi Incident
2. Accident progression

- ~3/4 of the core exposed
  - Cladding exceeds ~1200°C
  - Zirconium in the cladding starts to burn under steam atmosphere
  - **$Zr + 2H_20 \rightarrow ZrO_2 + 2H_2$**
  - Exothermal reaction further heats the core
  - Estimated masses hydrogen
    - Unit 1: 300-600kg
    - Unit 2/3: 300-1000kg
  - Hydrogen gets pushed via the wet-well and the wet-well vacuum breakers into the dry-well



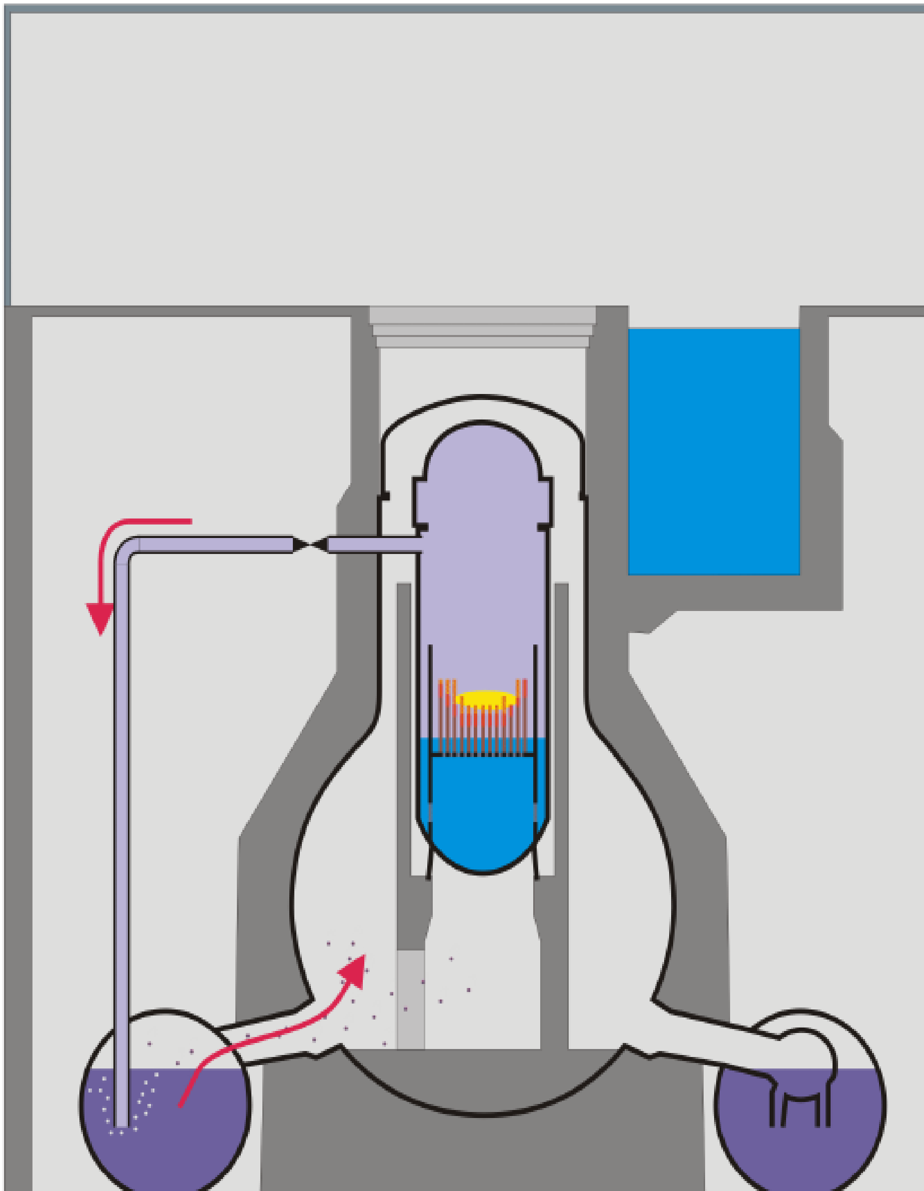
The Fukushima Daiichi Incident
2. Accident progression

- at ~1800°C [expected Unit 1,2,3]
  - Melting of the Cladding
  - Melting of the steel structures
- at ~2500°C [expected Unit 1,2]
  - Breaking of the fuel rods
  - debris bed inside the core
- at ~2700°C [maybe Unit 1]
  - Significant melting of Uranium-Zirconium-oxides
- Restoration of the water supply stops accident in all 3 Units
  - Unit 1: 12.3. 20:20 (27h w.o. water)
  - Unit 2: 14.3. 20:33 (7h w.o. water)
  - Unit 3: 13.3. 9:38 (7h w.o. water)



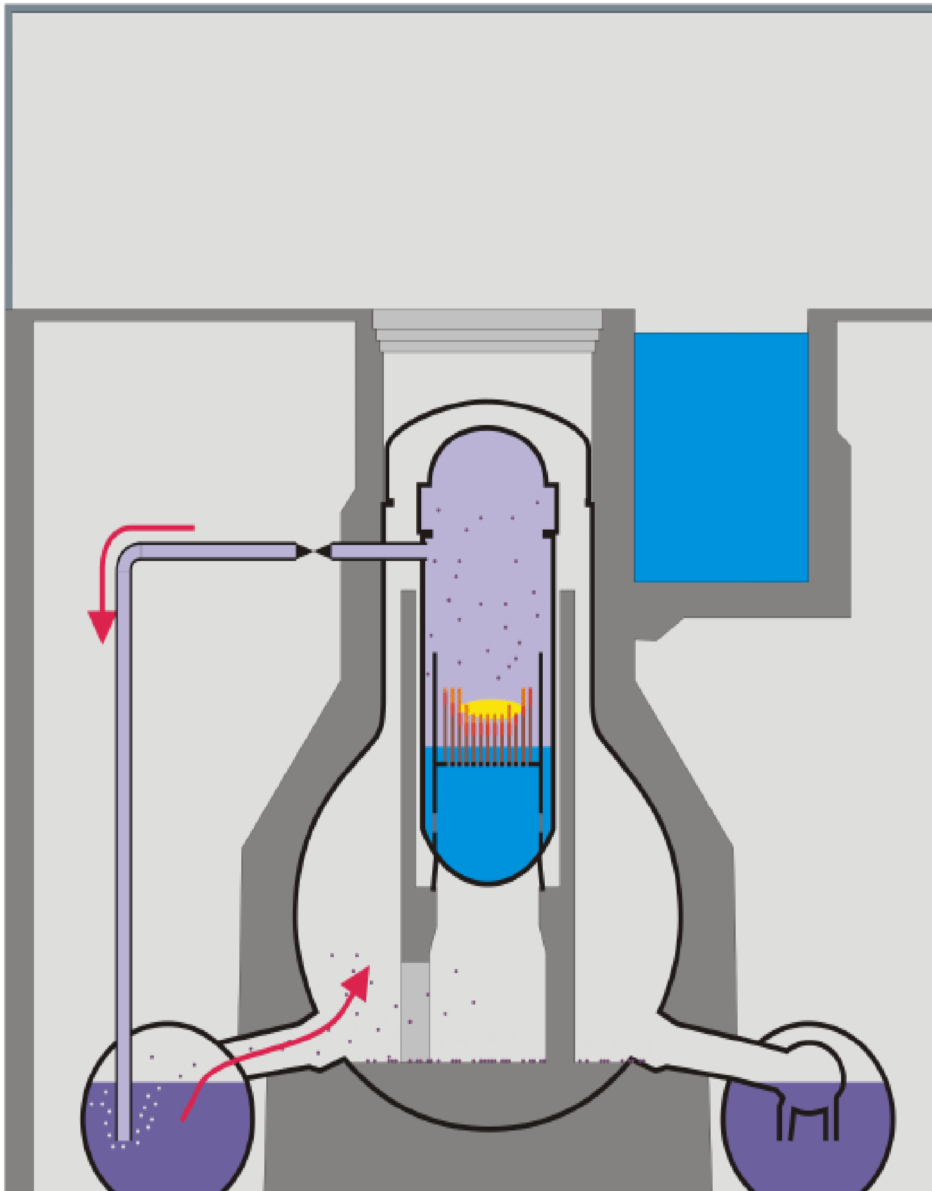
The Fukushima Daiichi Incident
2. Accident progression

- Release of fission products during melt down
  - Xenon, cesium, iodine,…
  - Uranium/plutonium remain in core
  - Fission products condensate to airborne aerosols
- Discharge through valves into water of the condensation chamber
  - Pool scrubbing binds a fraction of aerosols in the water
- Xenon and remaining aerosols enter the Dry-Well
  - Deposition of aerosols on surfaces further decontaminates air



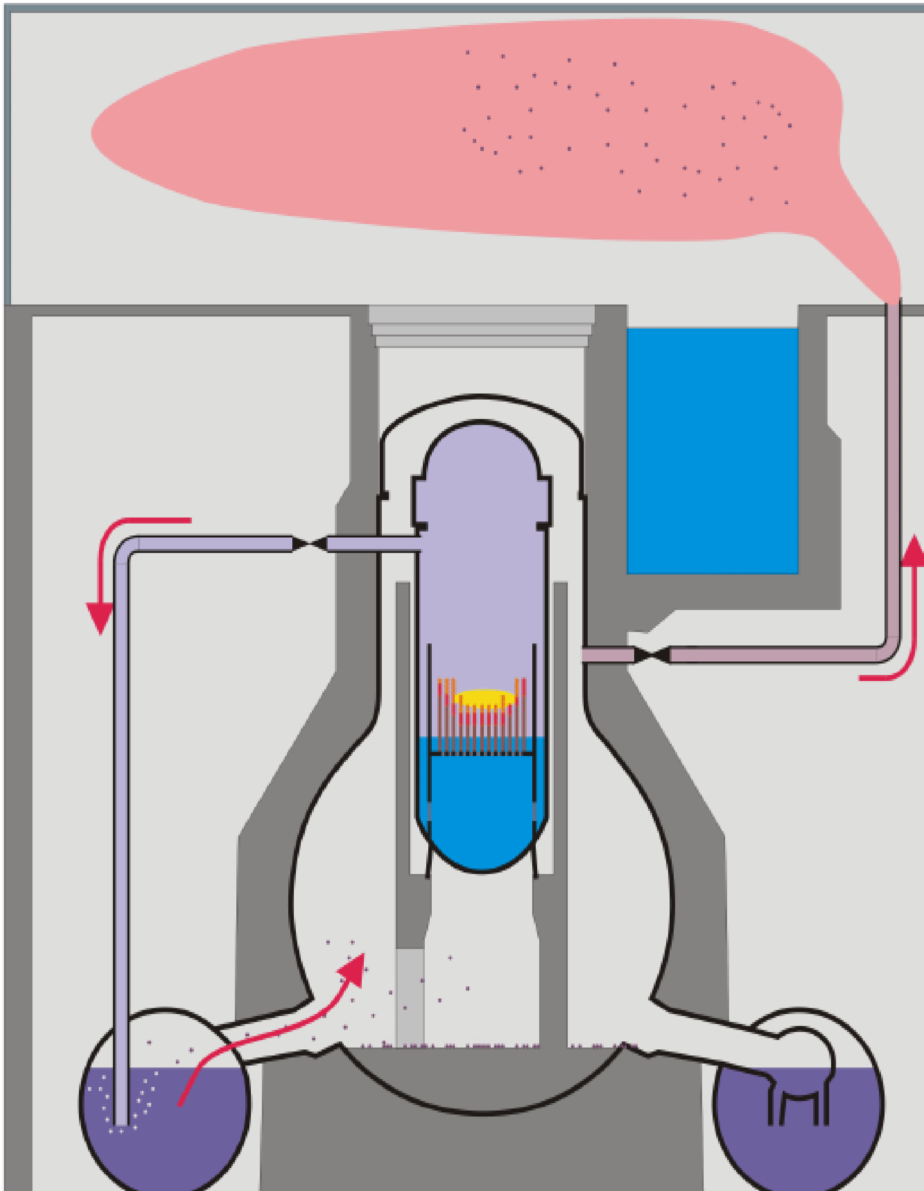
The Fukushima Daiichi Incident
2. Accident progression

- Containment
  - Last barrier between fission Products and environment
  - Wall thickness ~3cm
  - Design Pressure 4-5bar
- Actual pressure up to 8 bars
  - Normal inert gas filling (Nitrogen)
  - Hydrogen from core oxidation
  - Boiling condensation chamber (like a pressure cooker)
- First depressurization of the containment
  - Unit 1: 12.3. 4:00
  - Unit 2: 13.3 00:00
  - Unit 3: 13.3. 8.41



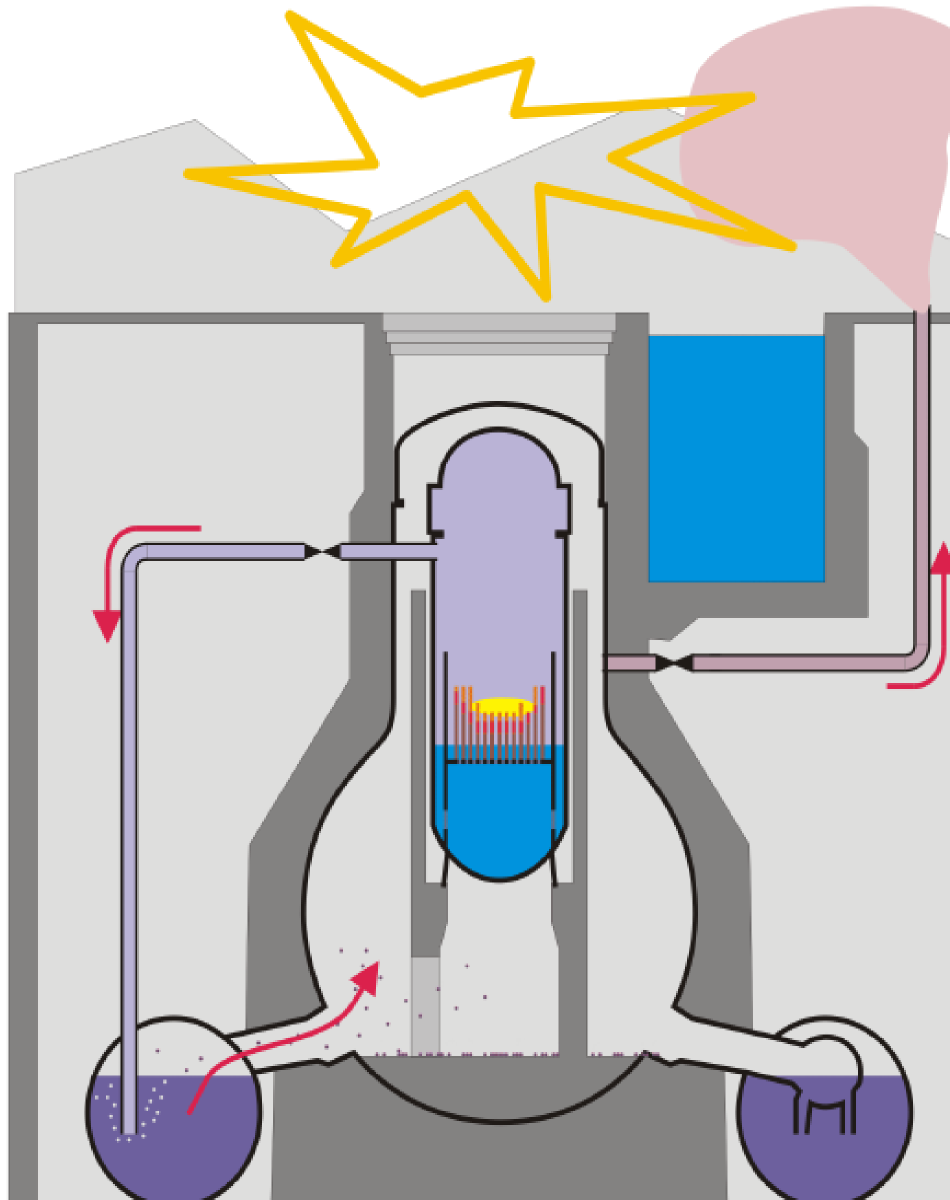
The Fukushima Daiichi Incident
2. Accident progression

- Positive and negative aspects of depressurizing the containment
  - Removes energy from the reactor building (only way left)
  - Reduces the pressure to ~4 bar
  - Release of small amounts of aerosols (iodine, cesium…)
  - Release of all noble gases
  - Release of hydrogen
- Release of unfiltered venting?
- Gas is released into the reactor service floor
  - Hydrogen is flammable

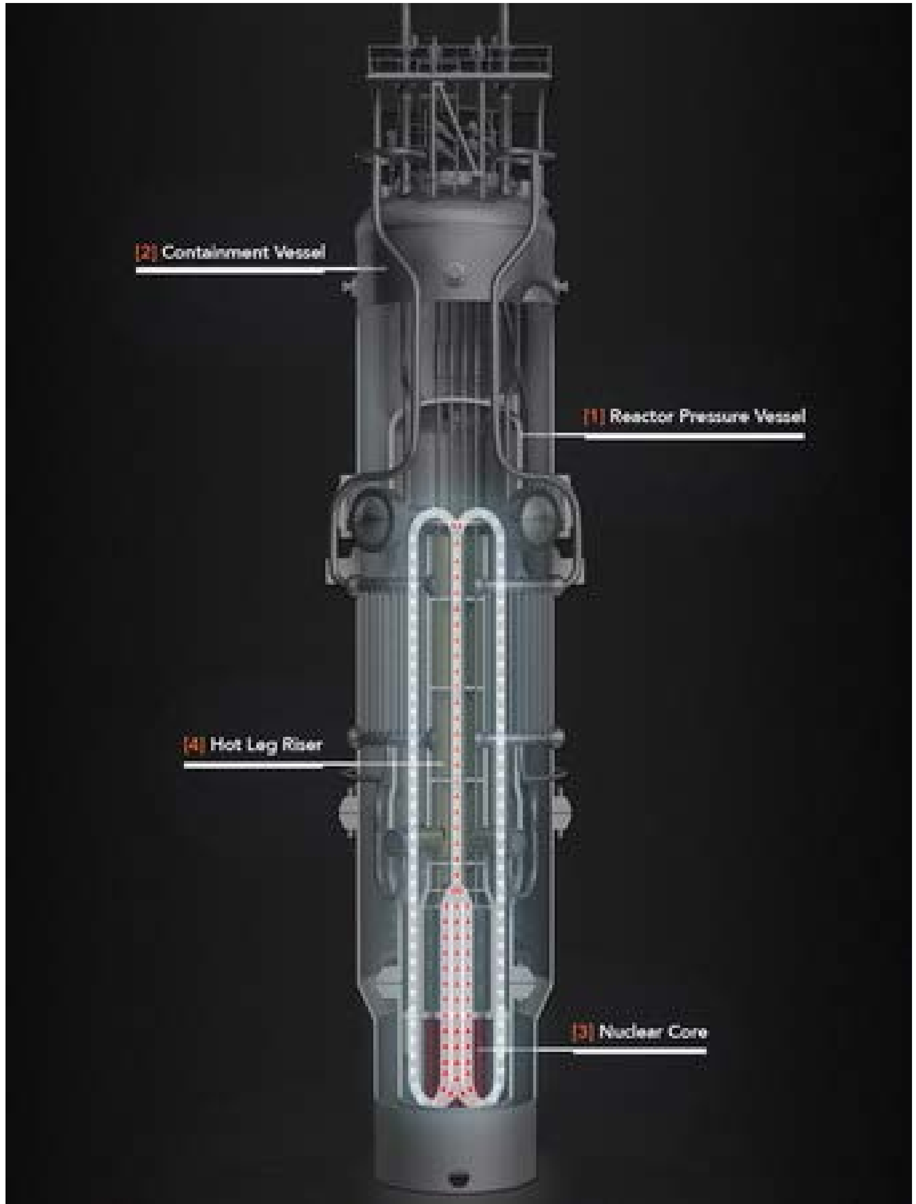


The Fukushima Daiichi Incident
2. Accident progression

- Unit 1 and 3
  - Hydrogen burn inside the reactor service floor
  - Destruction of the steel-frame roof
  - Reinforced concrete reactor building seems undamaged
  - Spectacular but minor safety relevance



Natural Circulation



SMR is not a new idea

Are SMRs
Right For
New Mexico

Energy Minerals & Natural Resources
Department

SMR Pre-Feasibility Study

Figure 8.2: Population Density

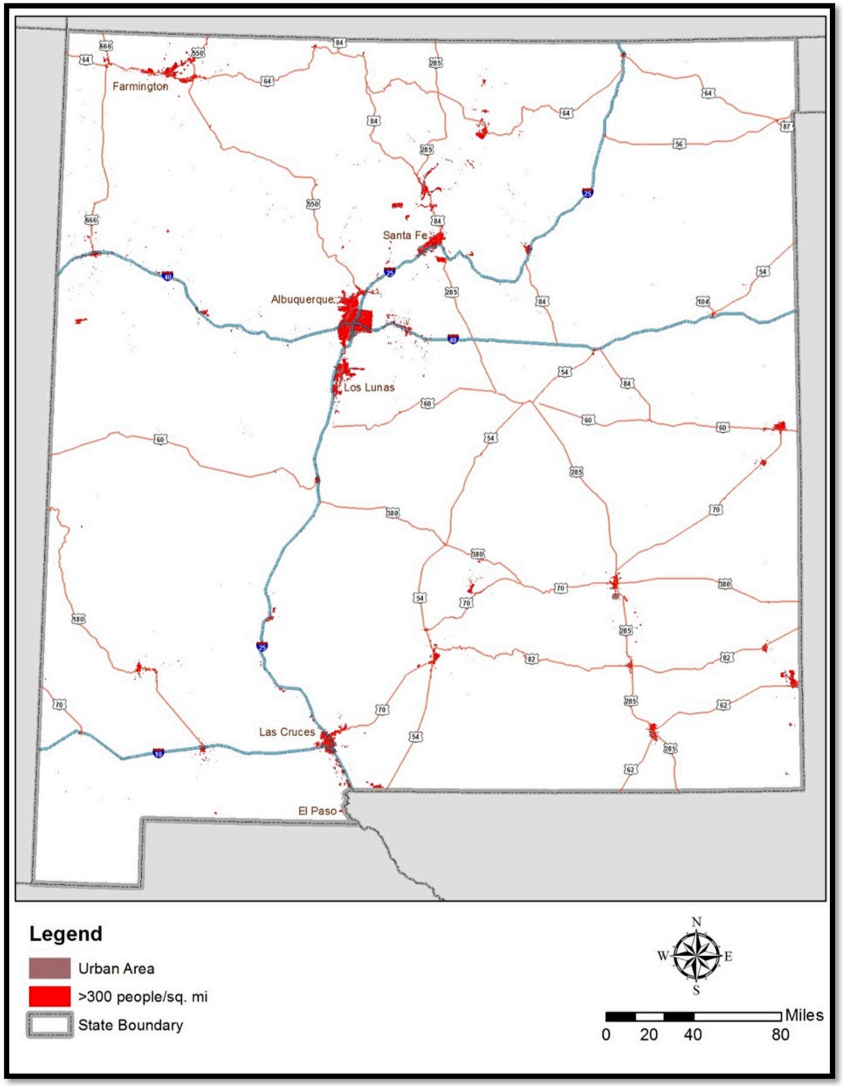


Figure 8.3: Dedicated Land Use

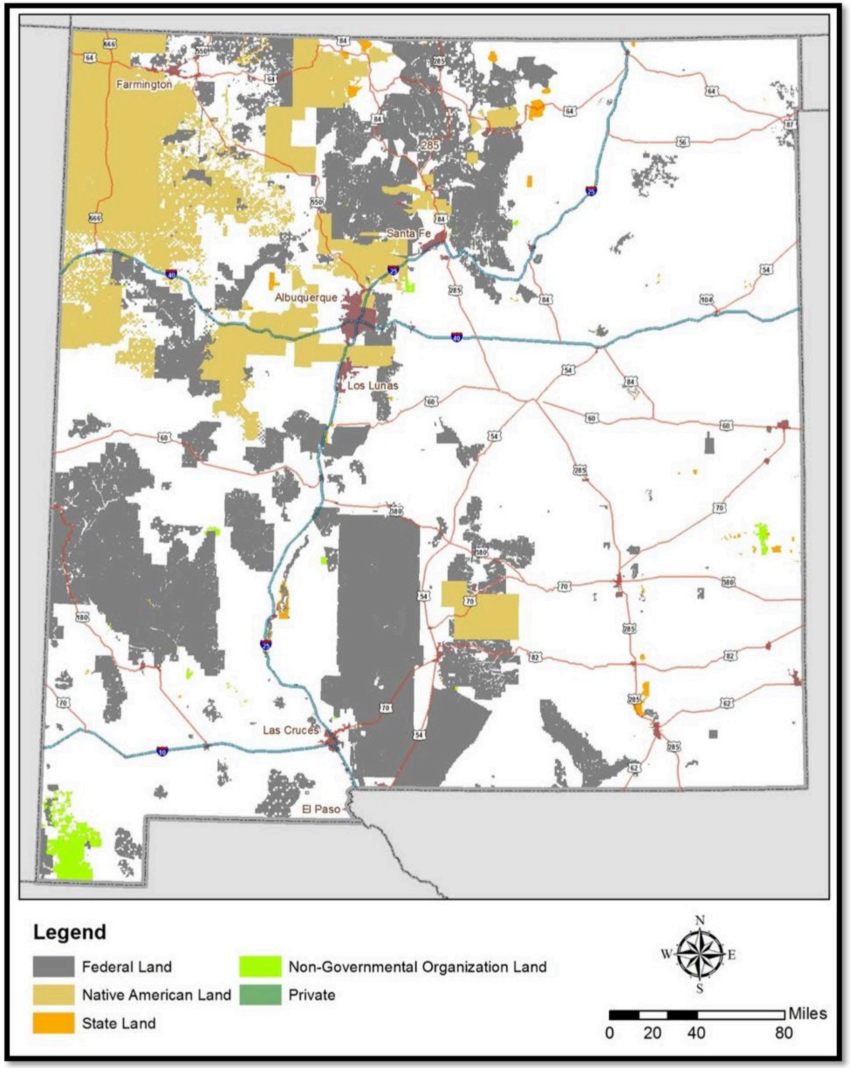


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Figure 8.4: Wetlands

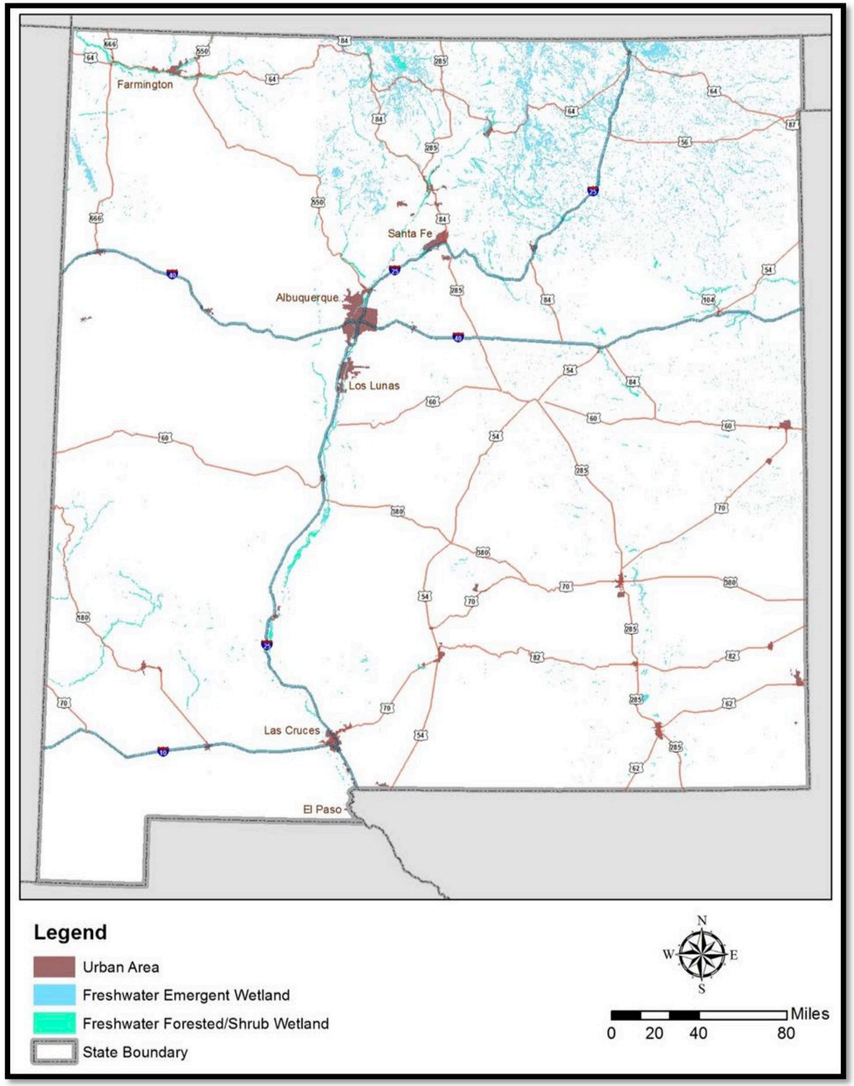


Figure 8.5: Threatened and Endangered Species Mapped Critical Habitat

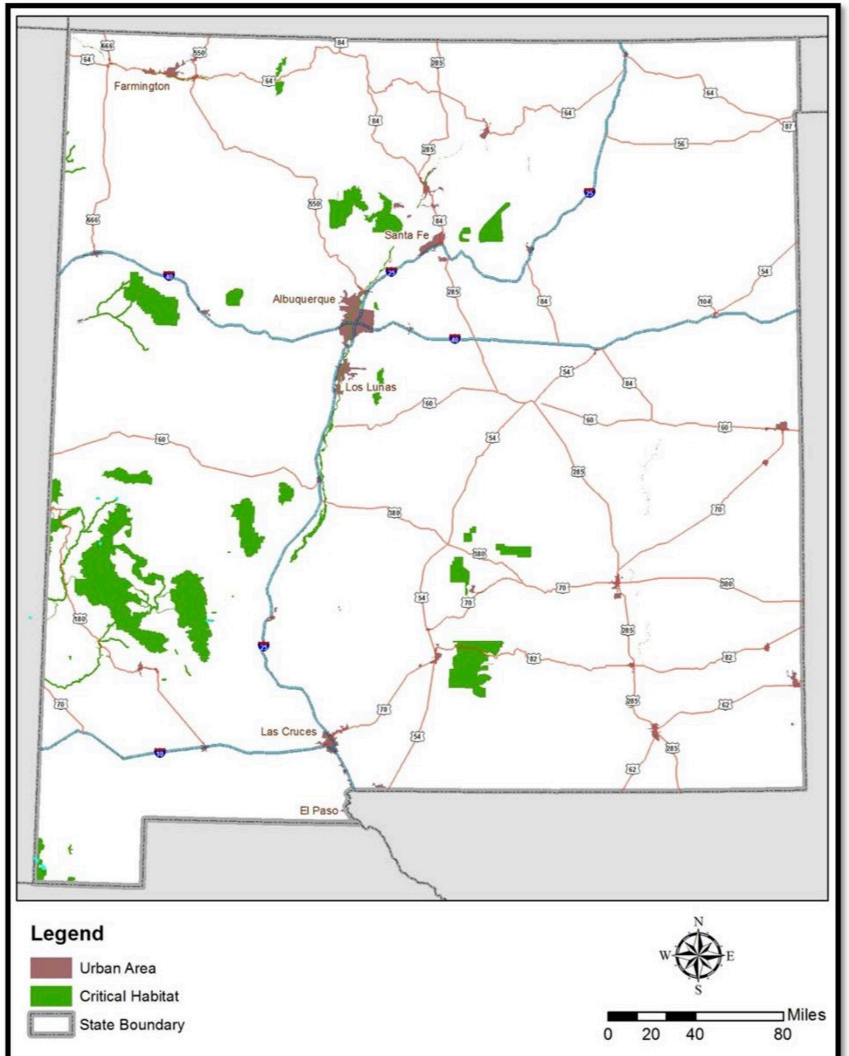


Figure 8.6: Commercial and Military Airports and Heliports

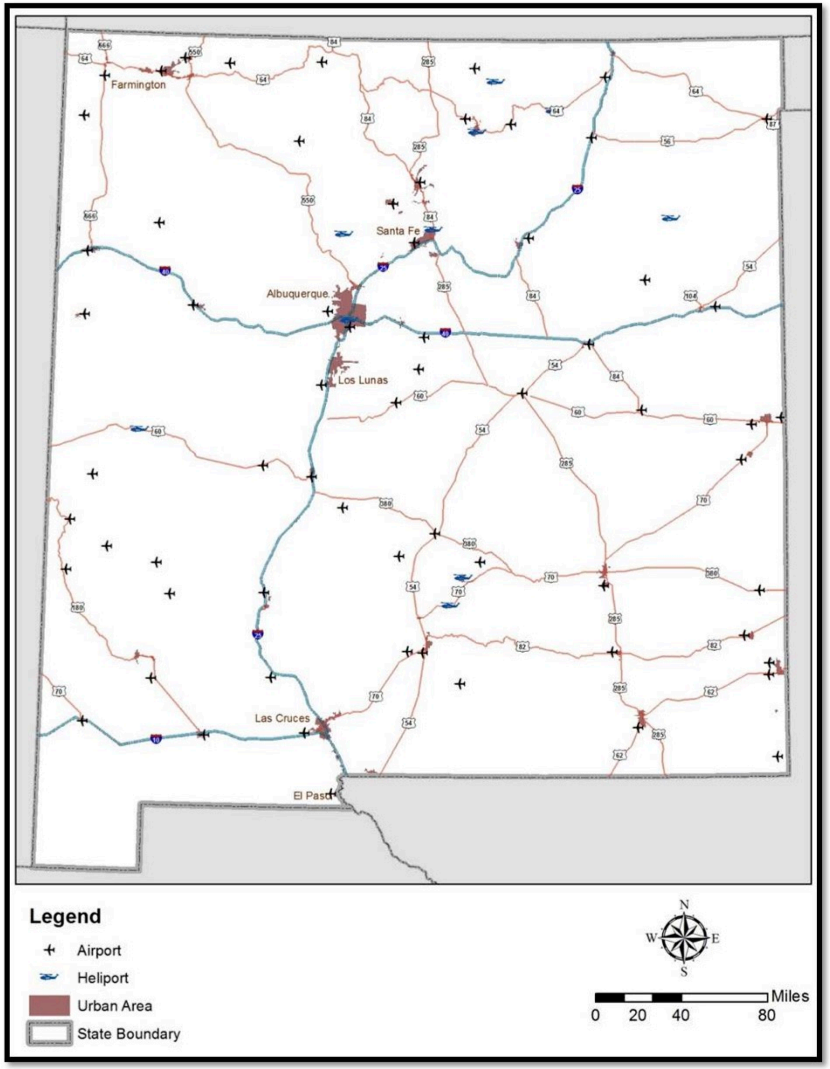


Figure 8.7: Railroad System

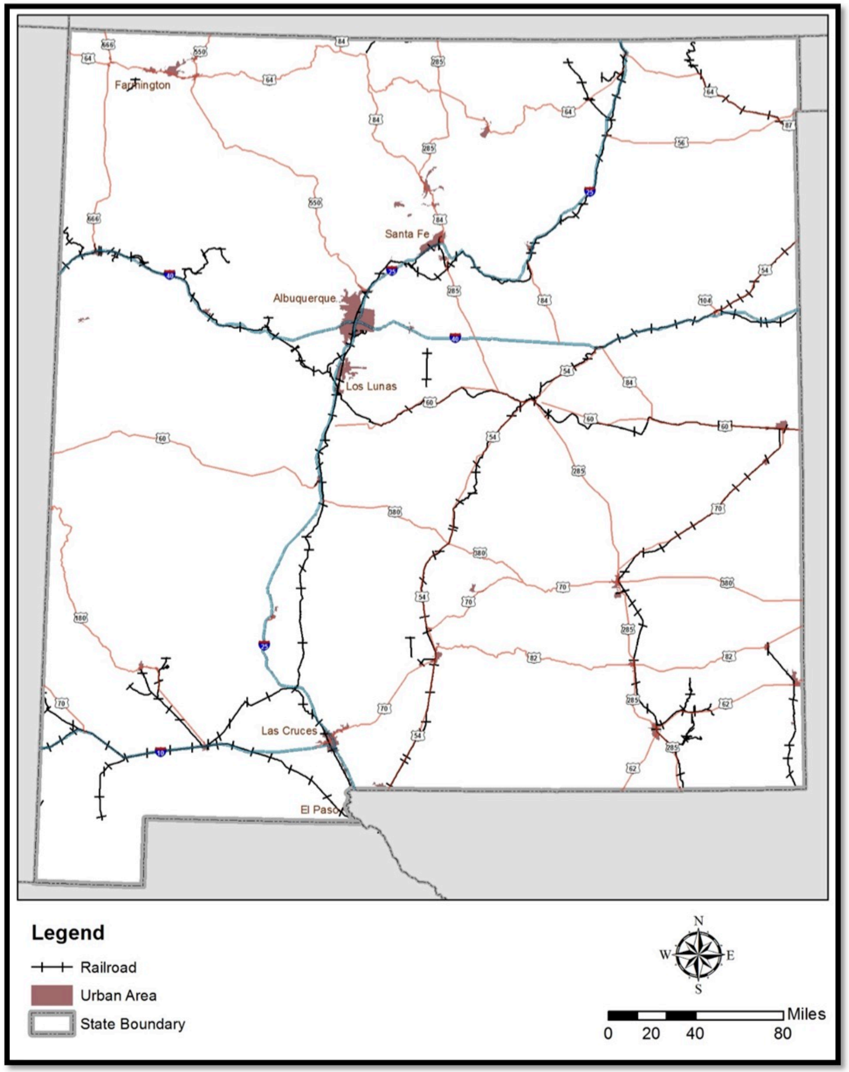
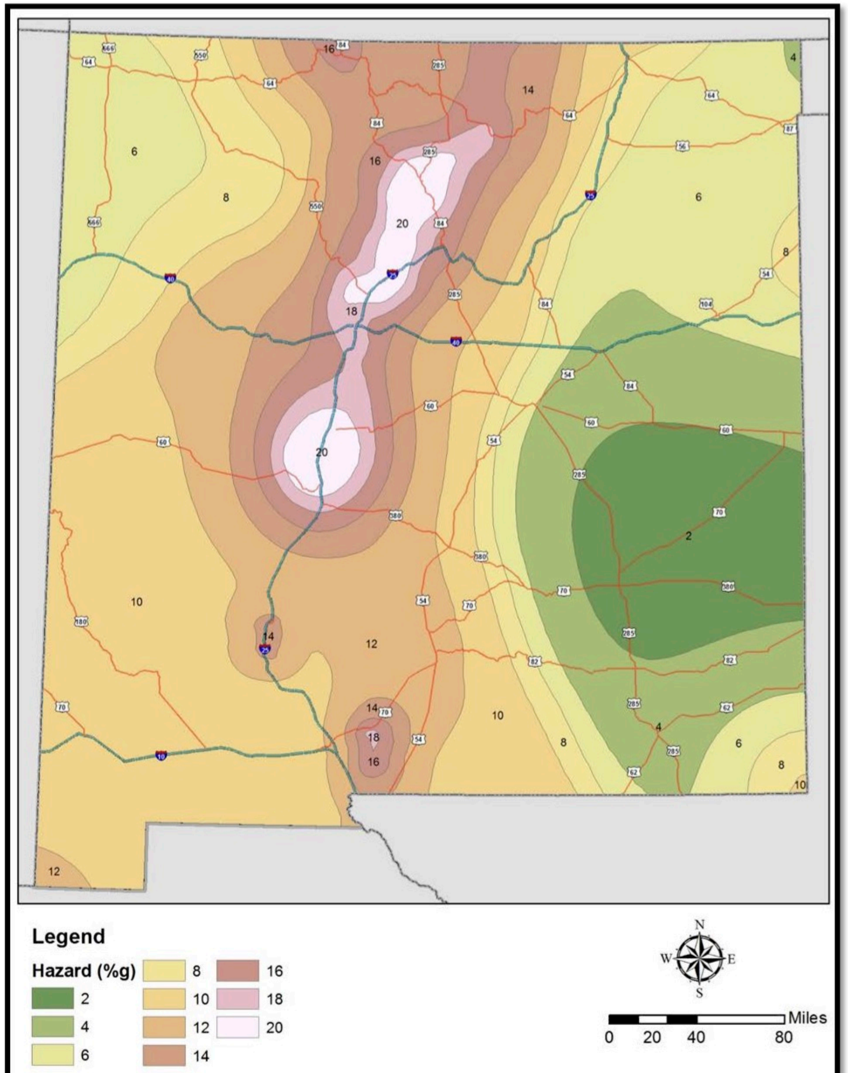


Figure 8.8: Peak Ground Acceleration



The exclusion and avoidance criteria were combined to create a composite layer in the ArcGIS system, as shown in Figure 8.9. These areas, shown as dark grey in the figure, represent land areas that are not considered suitable for siting a new nuclear facility.

Figure 8.9: Exclusion and Avoidance Areas within the ROI

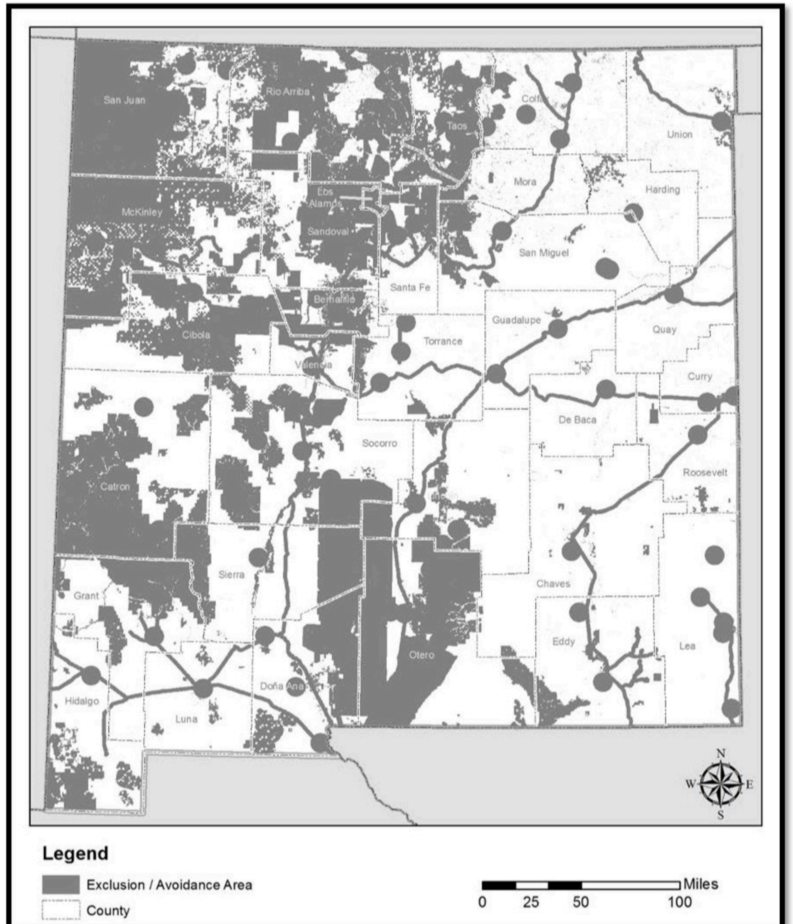


Figure 8.10 Surface Water Sources

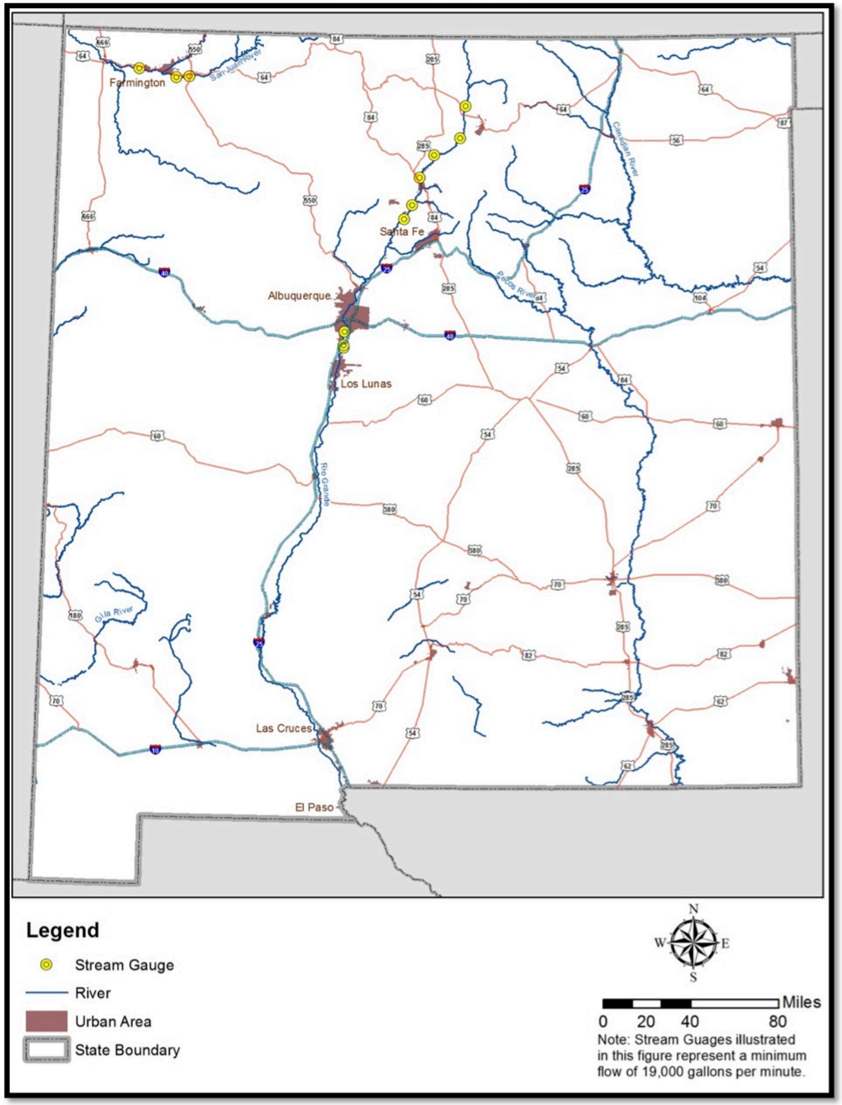


Figure 8.11 Gray Water Sources

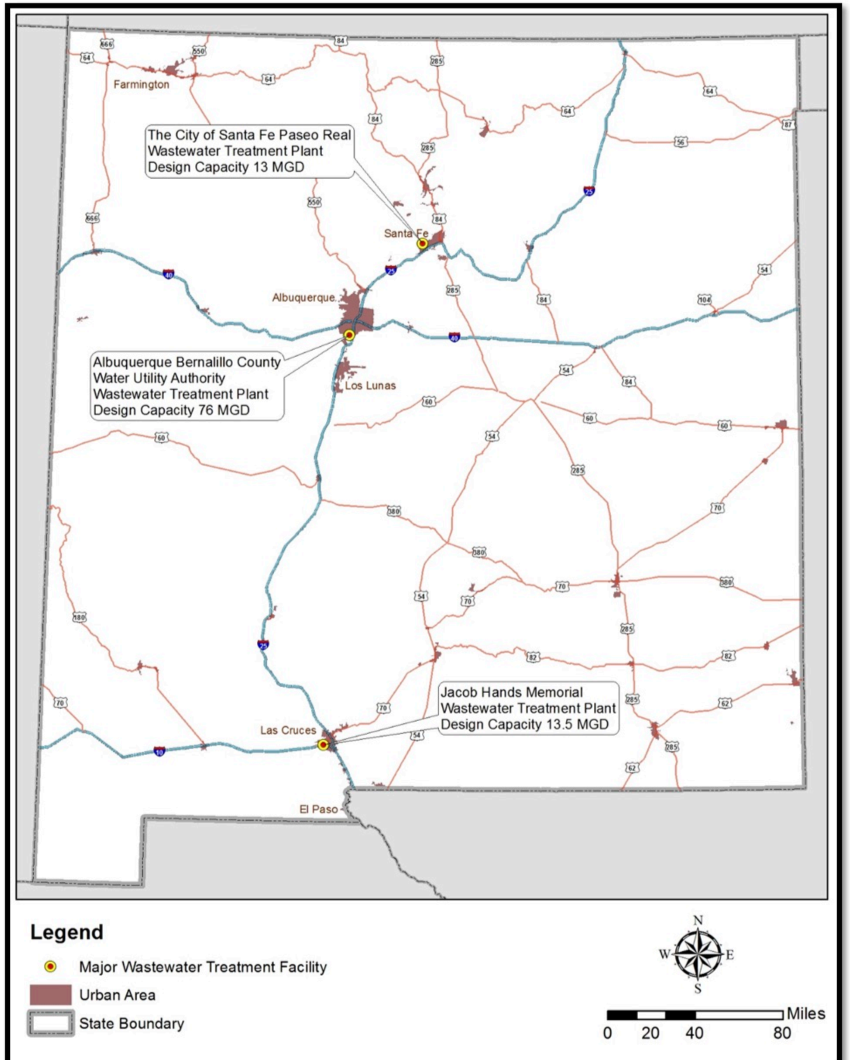


Figure 8.12: Groundwater Sources

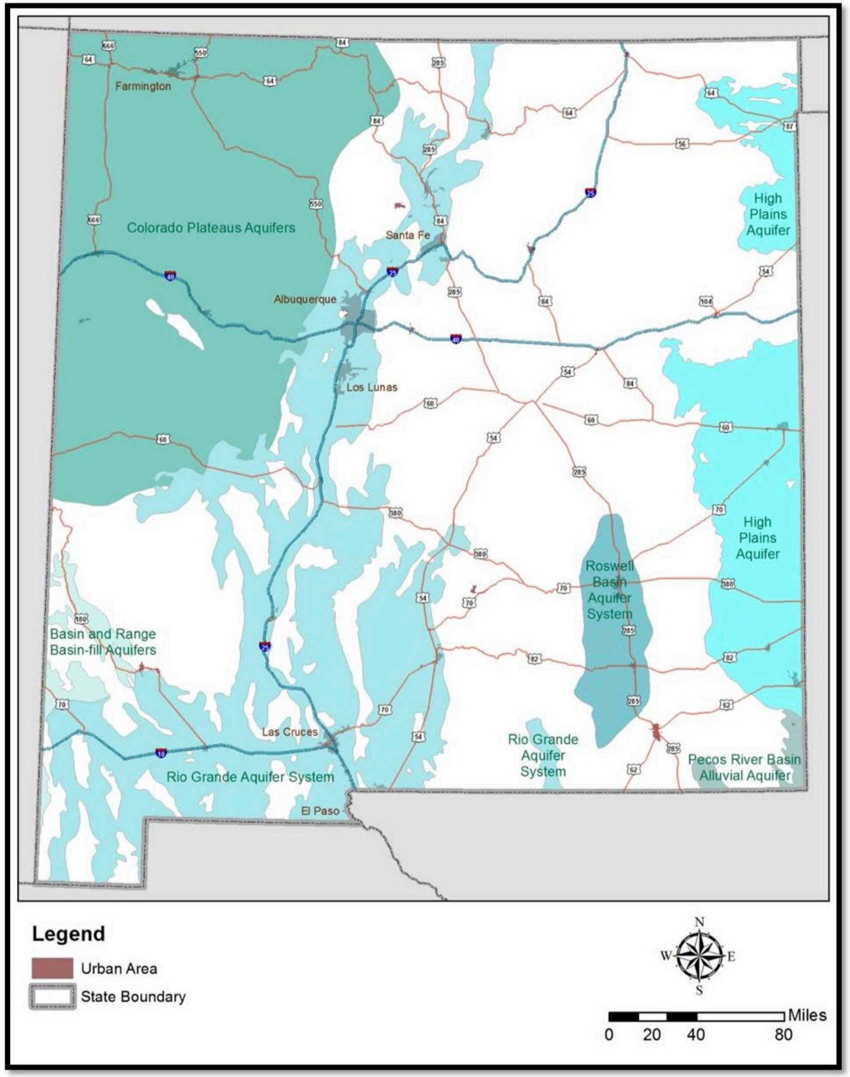


Figure 8.13: Production Water Wells

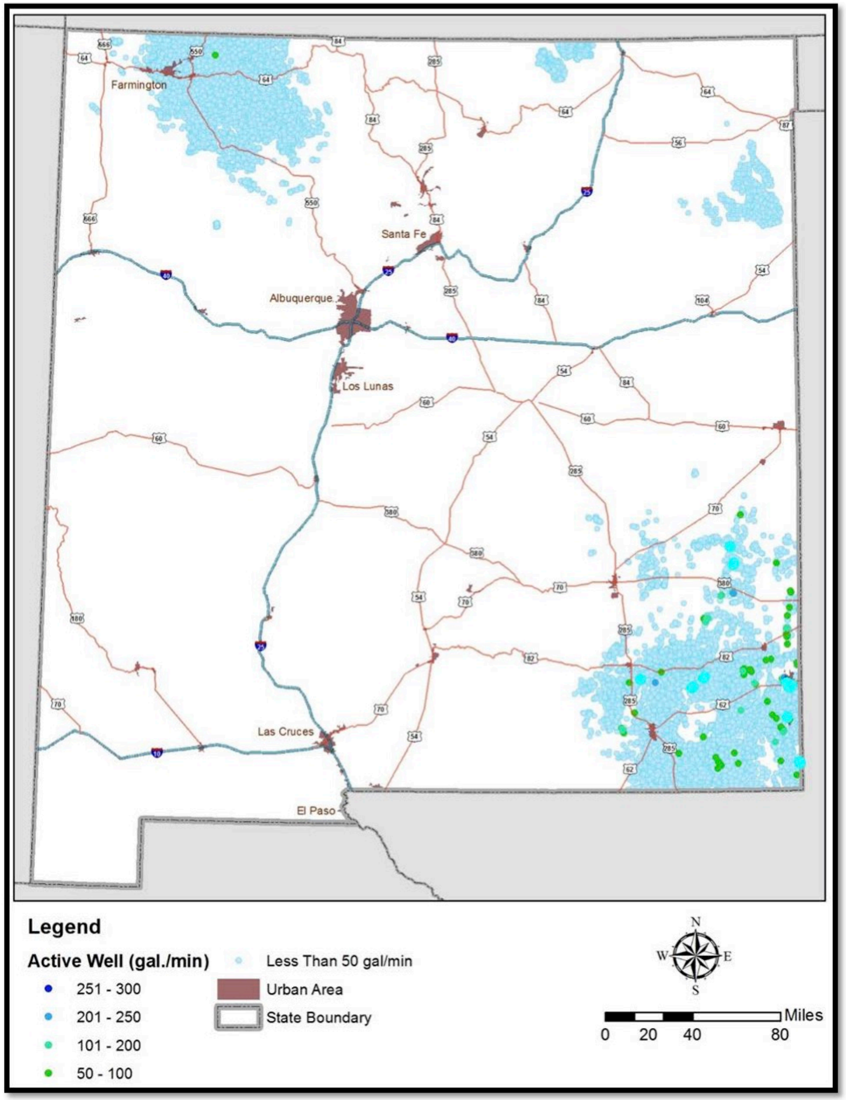


Figure 8.14: National Laboratories

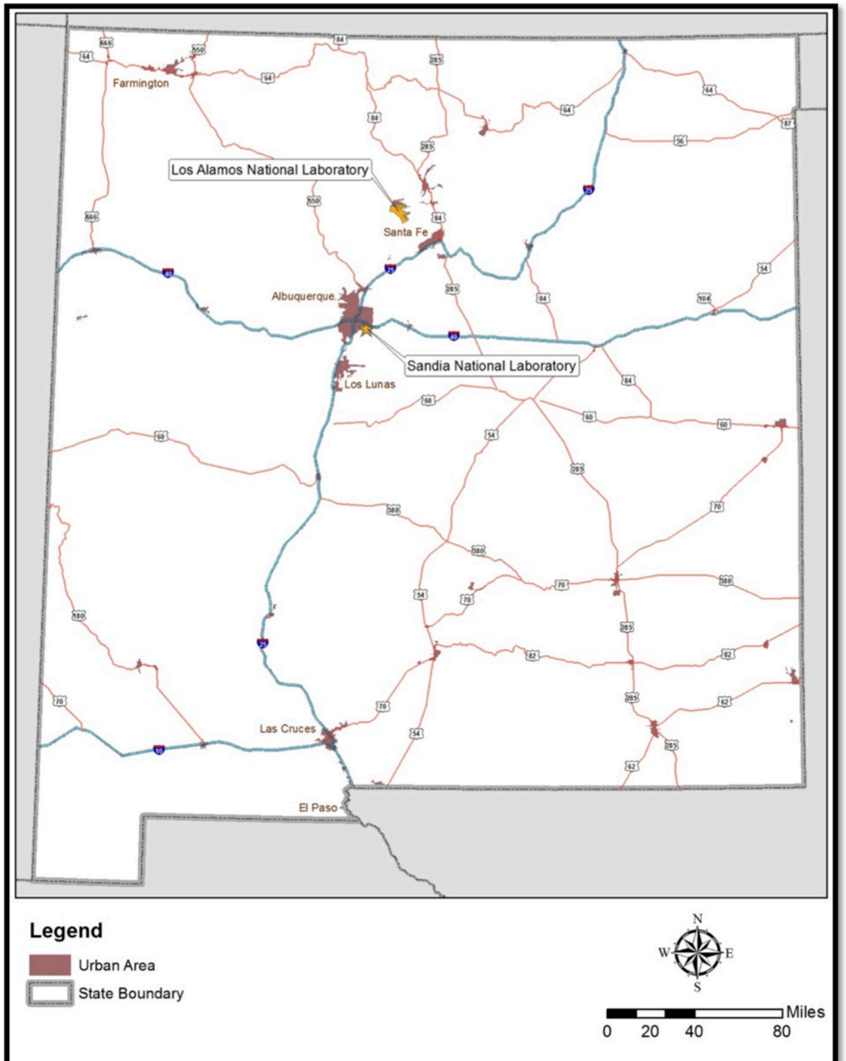


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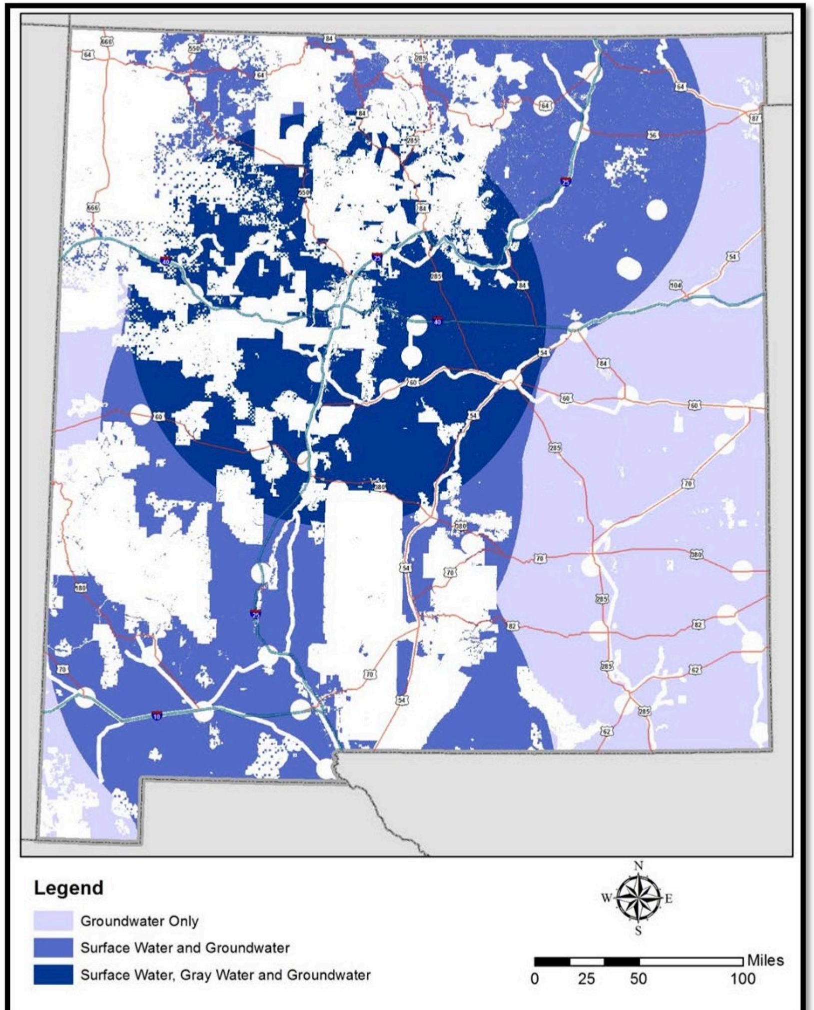
Figure 8.15: Exclusion, Avoidance, and Suitability Screening Result



Conclusion

SMR Pre-Feasibility Study

Will be Issued

December 2016