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

Offsite Consequence Analysis Modeling Approaches for NRC Site Level 3 PRA

International MACCS User's Group
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NRC Site Level 3 PRA

Project Objectives

- Develop a contemporary Level 3 PRA that:
  - Addresses risk contributors not previously considered.
  - Reflects technical advances since NUREG-1150 study, including application of methods developed by the State of the Art Reactor Consequence Analyses (SOARCA) project within a full risk context.
- Extract new risk insights to:
  - Enhance regulatory decision making.
  - Help focus limited resources on issues most directly related to NRC's mission to protect public health and safety.
- Enhance NRC staff's PRA capability and expertise.

NRC Site Level 3 PRA

Background

- Reference site: Vogtle Electrical Generating Plant, Units 1 & 2
  - Two Westinghouse 4-loop PWRs with large, dry containments
  - Units 3 and 4 not within scope
- Radiological sources
  - Reactor cores
  - Spent fuel pools
  - Dry cask storage
- Project scope
  - All reactor modes of operation (e.g., at power, low-power/shutdown)
  - All internal and external hazards (excluding malevolent acts)
  - Level 1, 2, and 3 PRA (full consequence analysis)
  - Integrated site risk

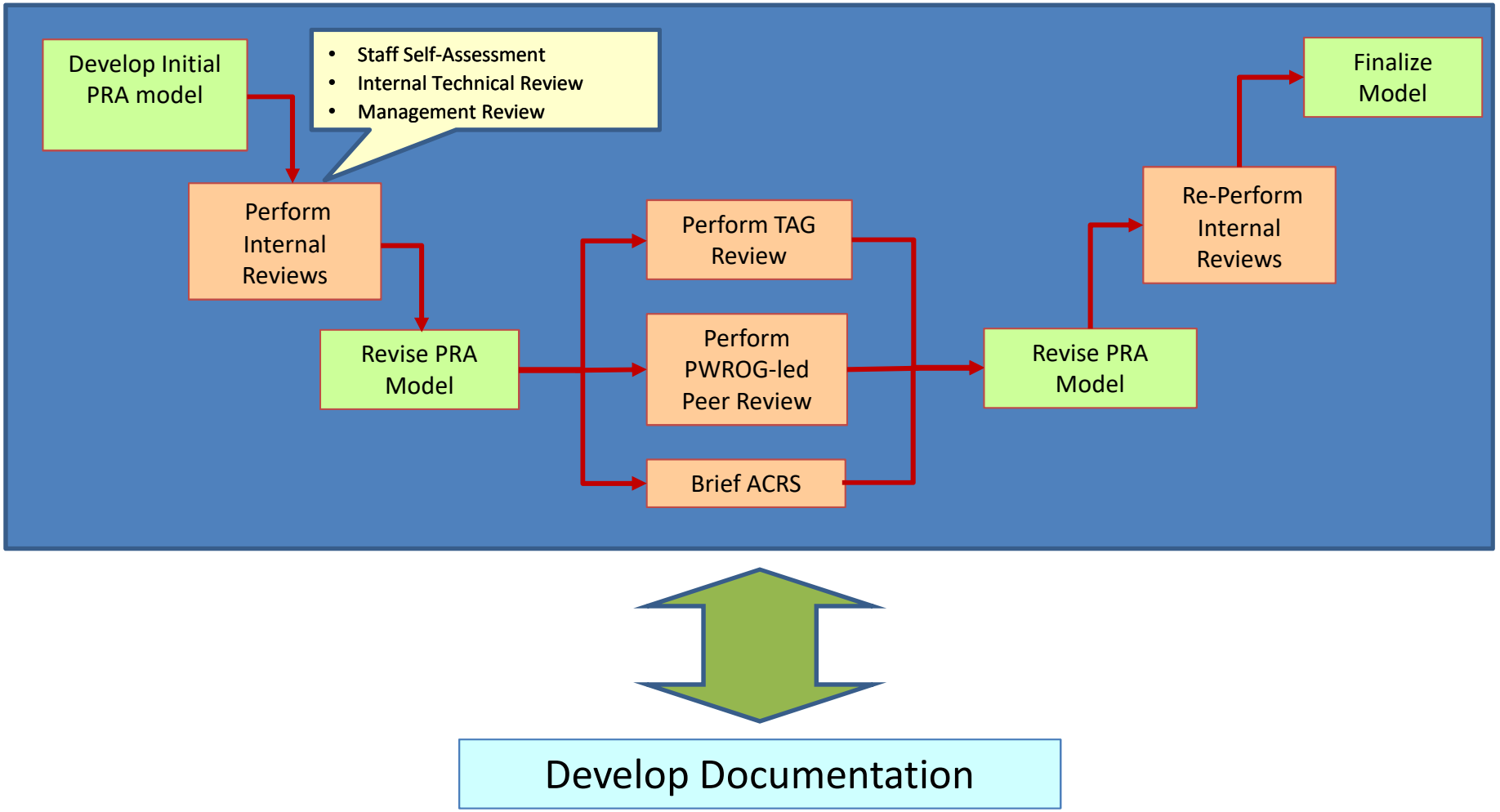
NRC Site Level 3 PRA

Potential Uses

Described in SECY 12-0123:

- Enhancing the technical basis for the use of risk information
- Improving the PRA state-of-practice
- Identifying safety and regulatory Improvements
- Supporting knowledge management

Generic Process for PRA Model Development



MACCS Code Development Work

- MELMACCS (2.0.2)
  - Multi-source releases (multiple units, spent fuel pools, and combinations of both)
- WinMACCS (3.10)
  - Capability to model multiple source terms
  - Capability to model of prolonged releases
  - Capability to model user-specified dose projection period
  - Enhanced reporting of population evacuation and relocation results

Environmental Setting

Population

Population centers within 50 miles
(*adapted from VEGP ESP ER Figure 2.1-2*)

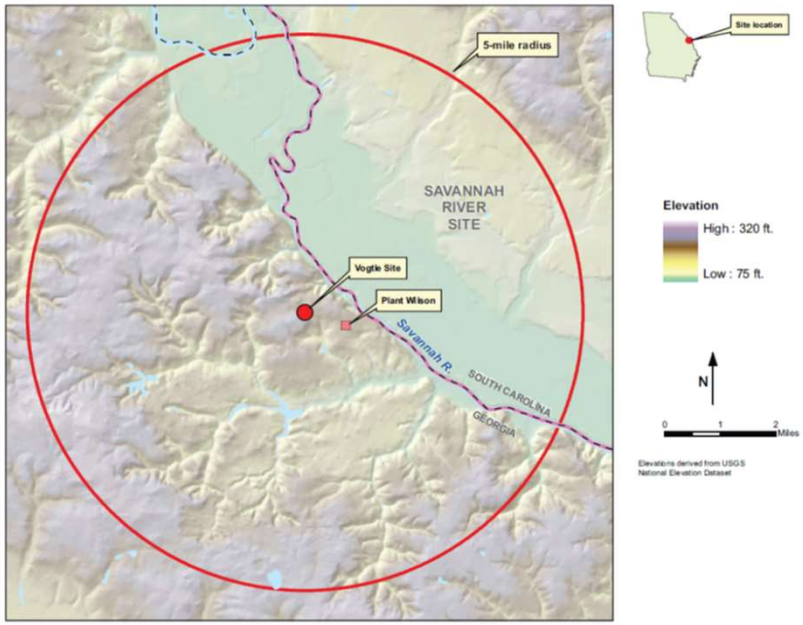
Very low population within a few miles of site

Distance (mi)	Cumulative General Public Population*
1.75	25
2	29
3	67
4	292
5	592
10	3,226
15	15,902
20	42,961
25	133,099
50	746,243
100	3,350,283

**SecPop 4.3 results escalated to 2015*

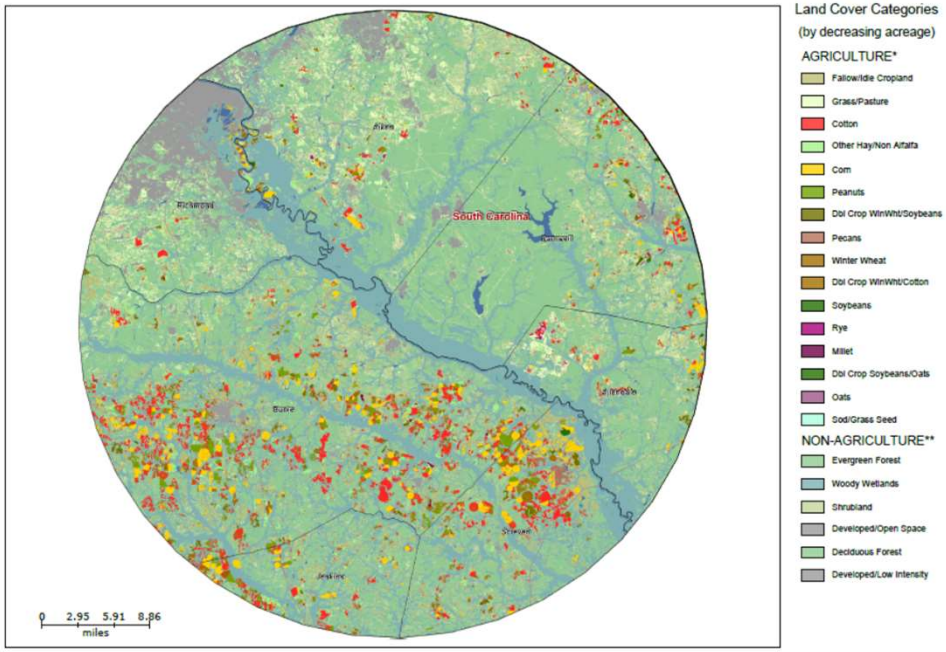
Environmental Setting

Topography and Land Cover



Topographic features within five miles

(adapted from ESP ER Figure 2.7-14)



2013 land cover categories within 25 mi

(*http://nassgeodata.gmu.edu/CropScape*)

Documentation of MACCS Input Parameters

- Technical Discussion
  - Identification of analysis assumptions
  - Description of conceptual models based on MACCS model description documents (NUREG/CR-4691 V2, NUREG/CR-6613 V1, and draft WinMACCS user manual)
  - Discussion of technical bases for input parameters reflecting state of practice analysis
  - Technical bases drawn from site specific information and SOARCA best practice recommendations such as those documented in NUREG/CR-7009
  - Identification of uncertainties and recommended sensitivity analyses to address potentially significant uncertainties

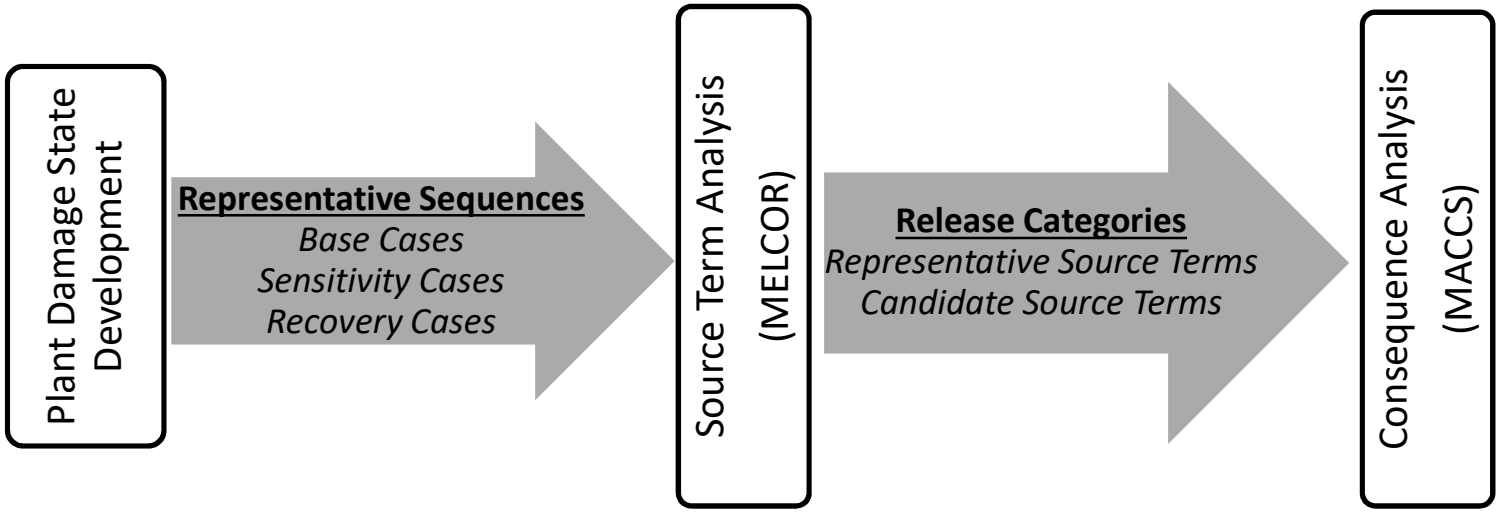
- Tabular summary of input parameters
  - References to applicable discussion section for traceability

Overview of MACCS Input Model

- Radionuclide Release (RE)
- Meteorology (ME)
- Atmospheric Transport and Deposition (AT)
- Protective Actions, Site Data, and Economic Factors (PA/EC)
- Dosimetry (DO) and Heath Effects (HE)
- Output Control

MACCS Input Model

Radionuclide Release (RE)



- Release categories include:
  - Bypass events (ISLOCA, SGTR)
  - Early/intermediate/late containment failure (e.g., by steam explosion, hydrogen combustion, or overpressure
  - Containment isolation failure
  - Basemat melt-through
  - No containment failure (normal containment leakage)

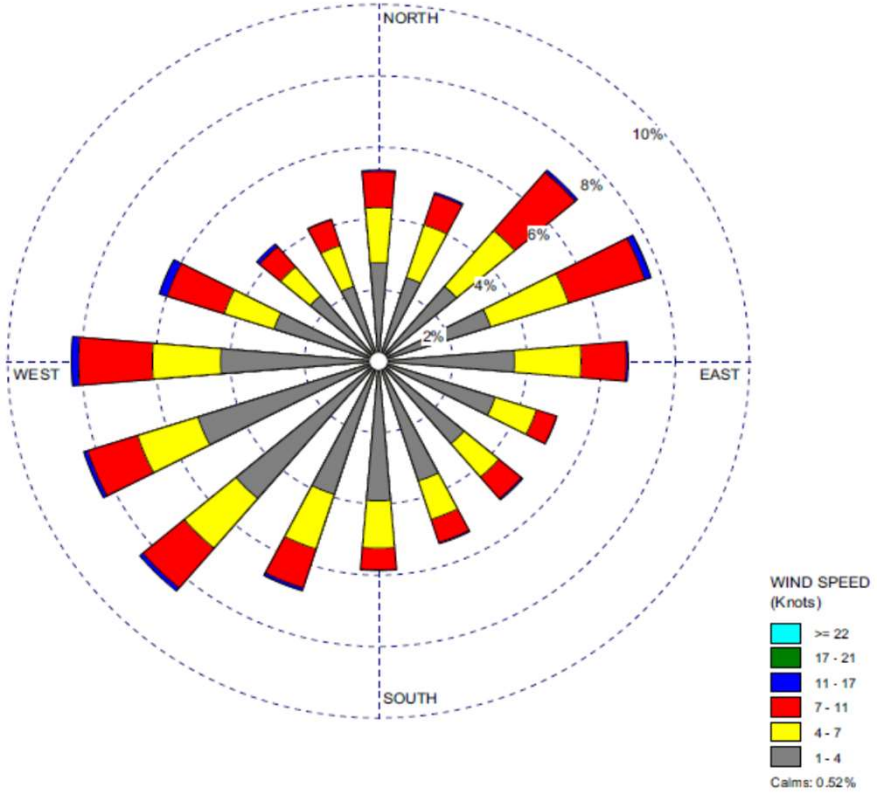
MACCS Input Model

Radionuclide Release (RE)

- MELMACCS development efforts for generation of composite sources for multisource releases
- Radionuclide selection based on earlier studies
- Core inventory based on same ORIGEN runs used for Level 2 analyses
- Release height and building dimensions consistent with MELCOR flowpaths

MACCS Input Model

Meteorology (ME)



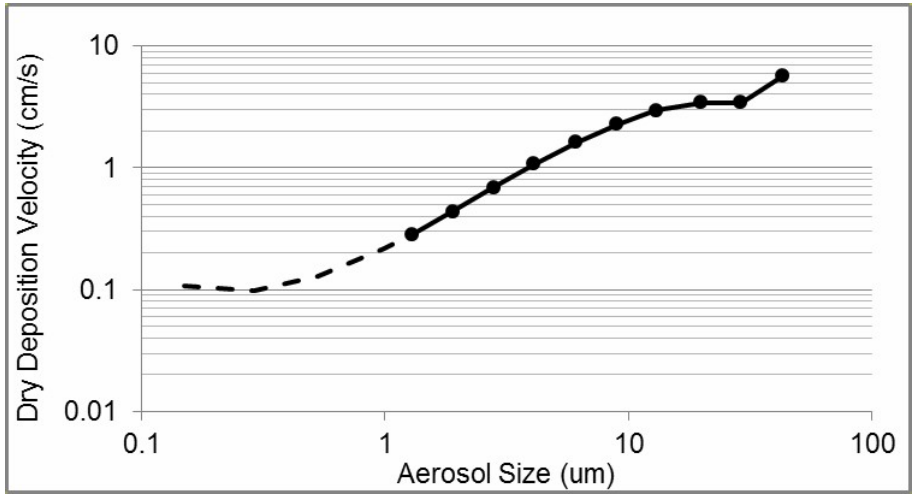
Annual wind rose at the 10-m measurement level based on 1998-2002 data

(*adapted from ESP ER Figure 2.7-2*)

- 1998-2002 meteorological data available from Vogtle early site permit (ESP) application
- Extensive discussion of site meteorology from ESP environmental report and environmental impact statement
- 1998 data selected as representative weather year
- MACCS meteorological file reviewed by NRC staff meteorologists
- Weather bin sampling scheme

MACCS Input Model

Atmospheric Transport and Deposition (AT)



Dry deposition velocities based on:
Updated NUREG/CR-7161 median value interpolation
2.3 m/s windspeed, 100 cm roughness length

- Used SOARCA dispersion parameterization based on NRC-CEC expert elicitations
- Alternate dispersion parameterizations may be explored as sensitivity analyses
- Implementing time-based dispersion model per Hanna (2002)
- Surface roughness and dry deposition modeling

MACCS Input Model

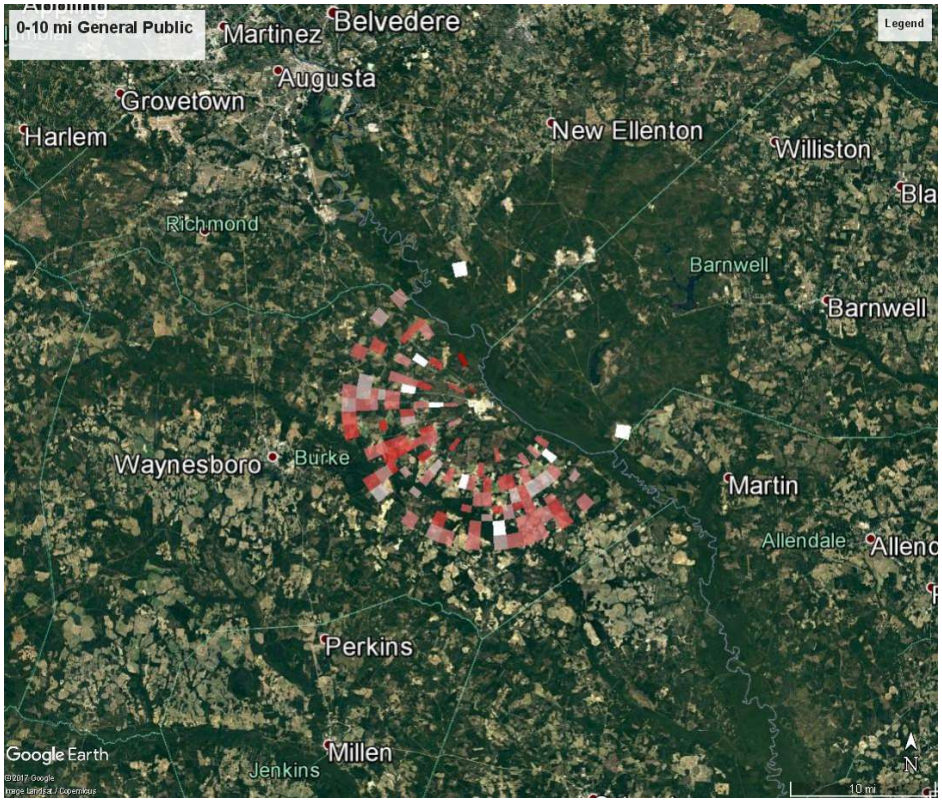
Protective Action Parameters and Other Site Data (PA) & Economic Factors (EC)

- Based on work carried out at Sandia National Laboratories (SNL)
- Protective Actions Considered
  - Sheltering followed by evacuation
  - Early phase relocation of non-evacuating population based on EPA emergency phase PAGs of 1-5 rem over four days
  - Intermediate phase relocation based on 2 rem EPA intermediate phase PAG for the year of the accident
  - Recovery phase decontamination and interdiction based on 500 mrem EPA intermediate phase PAG for year following the accident
  - Reoccupancy based on 500 mrem EPA intermediate phase PAG for years following the accident
- Use of evacuation time estimates for 0-10 mile, 10-15 mile, and 15-20 mile regions

MACCS Input Model

Protective Action Parameters and Other Site Data (PA) & Economic Factors (EC)

- Site demographic characteristics based on 2010 census data projected to 2015
- Supplemented by information from site visits and review of evacuation time estimate (IEM, 2012)
- Cohorts:
  - General public (4 cohorts each) (0-10 mi, 10-15 mi, 15-20 mi)
  - Shadow evacuees (10-15 mi, 15-20 mi, 20-25 mi)
  - SRS workers
  - Schools within 10-15 miles
  - Non-evacuees



0-10 Mile General Public, First Cohort (1GP1)

- Very sparse population within a few miles of site
- Non-evacuees are the majority of the population beyond 20 miles

MACCS Input Model

Protective Action Parameters and Other Site Data (PA) & Economic Factors (EC)

- Exposure and Shielding Parameters
  - Based on processing data from NRC-CEC expert elicitations
- Food and Water Ingestion
  - COMIDA food model coupled with agricultural countermeasures based on FDA recommendations for adults and infants
- Economic Factors (EC)
  - Economic factors based on updated 2007 BEA and USDA databases in SECPOP and best practice default values for non-site-specific parameters
  - Leveraging ongoing work to update parameters for decontamination plan and economic factors

MACCS Input Model

Dosimetry and Health Effects (DO/HE)

- Dosimetry and health effects models same as SOARCA
  - Dosimetry based on models from FGR-13
  - Deterministic health effects based on expert elicitation data (NUREG/CR-6545, NUREG/CR-7161)
  - Stochastic health effects based on FGR-13/BEIR V
- Updated documentation

Consequence Quantification

- Input parameter development based on consequence measures that may be selected for reporting
- Consequence reporting considerations include
  - Analysis objectives (typically linked to application-specific requirements or questions)
  - Stakeholder interests and Technical Advisory Group guidance
  - Standards requirements or state-of-practice
  - Insights from previous studies and lessons learned from operational experience
  - Potential future uses of results and insights
  - Capabilities and limitations of models and analytical tools
  - Schedule and resource constraints

Consequence Quantification
MACCS Output Capabilities

- Concentration of individual radionuclides in air (Bq/m^3) and on ground surface (Bq/m^2)
- Variety of dosimetric measures for individuals and populations, by cohort and overall
- Collective and individual health effects resulting from accumulated doses, by cohort and overall
- Extent of land area and population affected by radionuclide deposition and/or protective measures
- Costs associated with protective measures
- Contribution of weather bins to output measures
- Results as mean/median values or as distributions across weather trials

Current Status

- Initial offsite consequence analysis for reactor at-power internal events and internal floods completed in 2015
- PWROG peer review of consequence analysis completed in 2015 using then-draft version of ASME/ANS Level 3 PRA standard
- Initial offsite consequence analysis for dry cask storage systems completed in 2016
- Revised consequence analyses for reactor at-power internal events and internal floods underway

Acronyms and Definitions

ACRS	Advisory Committee on Reactor Safeguards
ANS	American Nuclear Society
ASME	American Society of Mechanical Engineers
BEA	Bureau of Economic Analysis
ESP	Early Site Permit
ER	Environmental Report
ISLOCA	Interfacing systems LOCA
LPSD	Low power and shutdown
PRA	Probabilistic risk assessment
PWR	Pressurized-water reactor
PWROG	PWR Owners Group
SGTR	Steam generator tube rupture
SOARCA	State of the Art Reactor Consequence Analysis
TAG	Technical Advisory Group
USDA	U.S. Department of Agriculture
USNRC	U.S. Nuclear Regulatory Commission