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# ***Development and Applications of RESRAD-OFFSITE***

*Presented At*

***PA Community of Practice Technical Exchange***

***Richland, WA***

*April 14, 2010*

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Argonne National Laboratory*



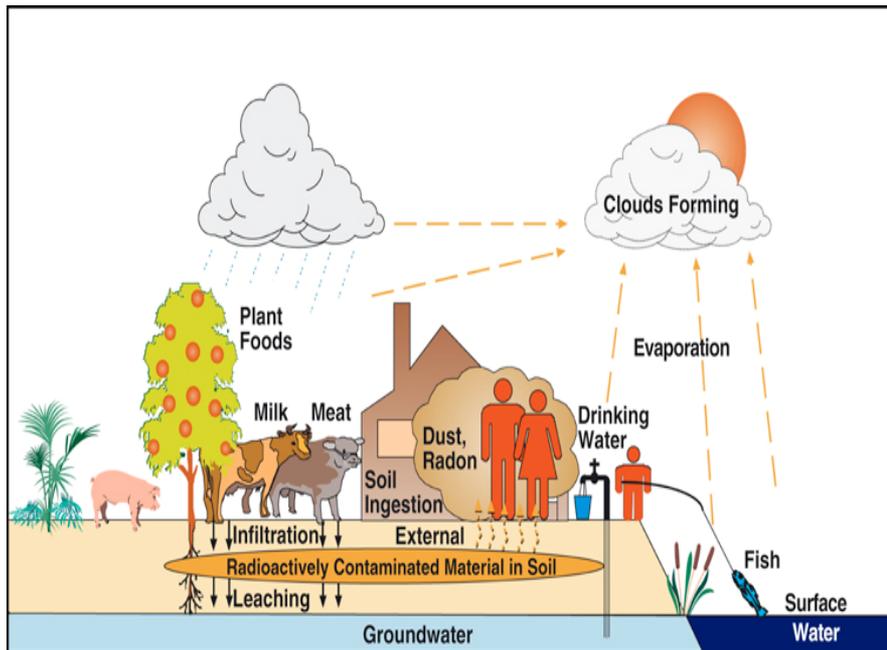
U.S. Department  
of Energy

UChicago ►  
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# RESRAD – A Regulatory Tool for Addressing Site Cleanup Issues

*RESRAD, an internationally utilized model, successfully addresses the critical question "How clean is clean enough?"*



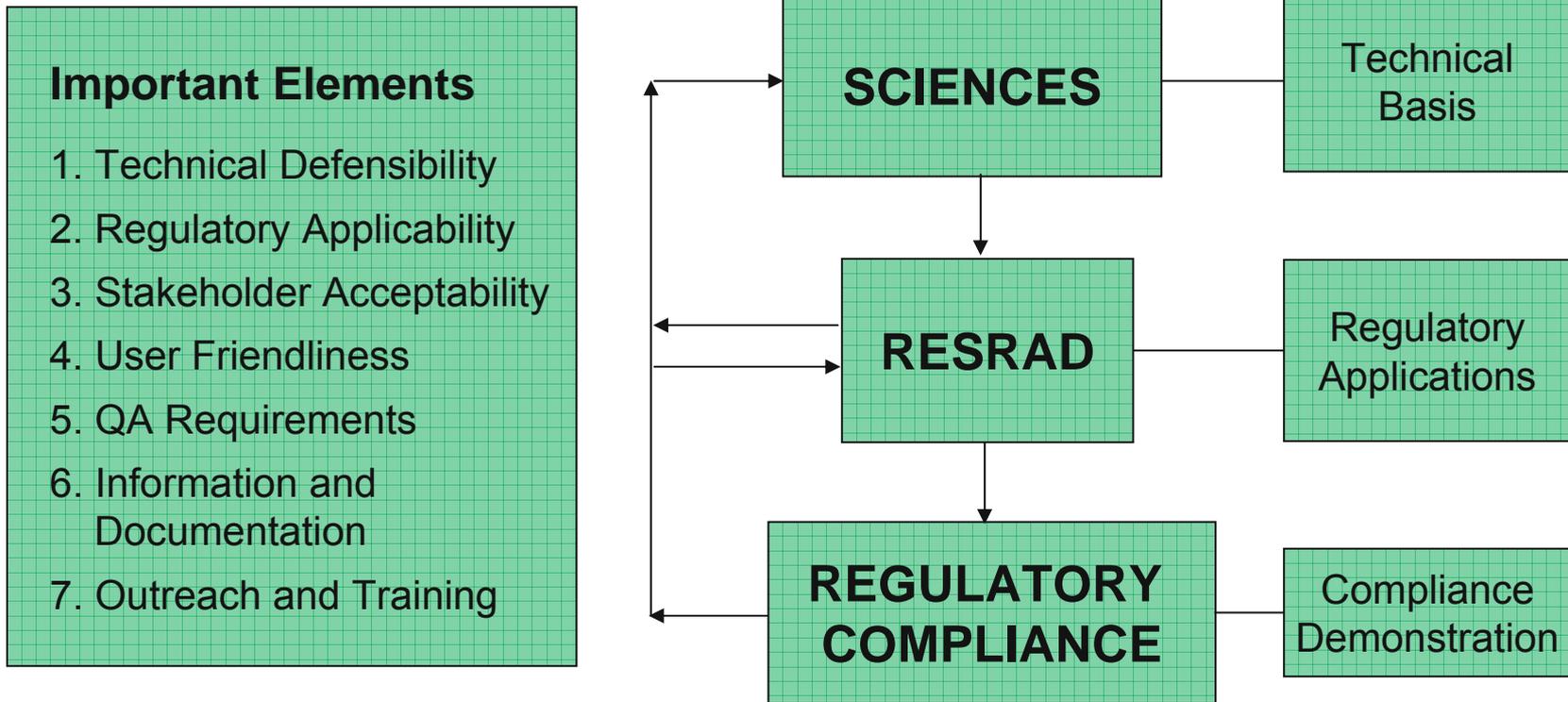
**Supports government  
regulatory endeavors in cleanup**

- DOE (Designated by Order 5400.5)
- NRC (License Termination Rule; 10 CFR 20 Subpart E; NUREG/1757)
- EPA (CERCLA)
- State agencies

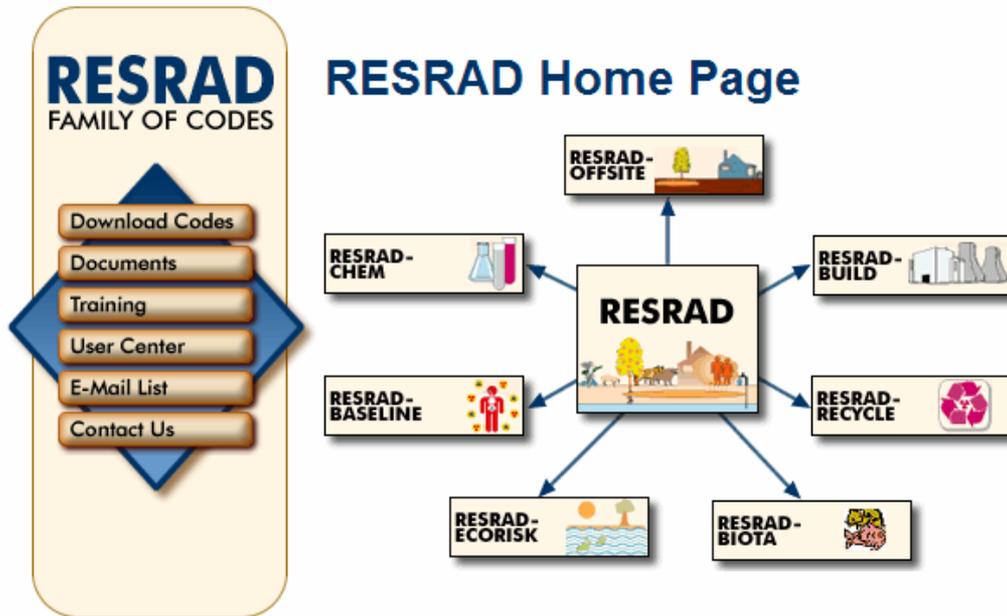
**In use for about 30 years**

- Evaluation of more than 300 cleanup sites
- Over 100 training workshops
- International (e.g., IAEA) recognition

# Development Philosophy : Bridging Science with Regulatory Compliance



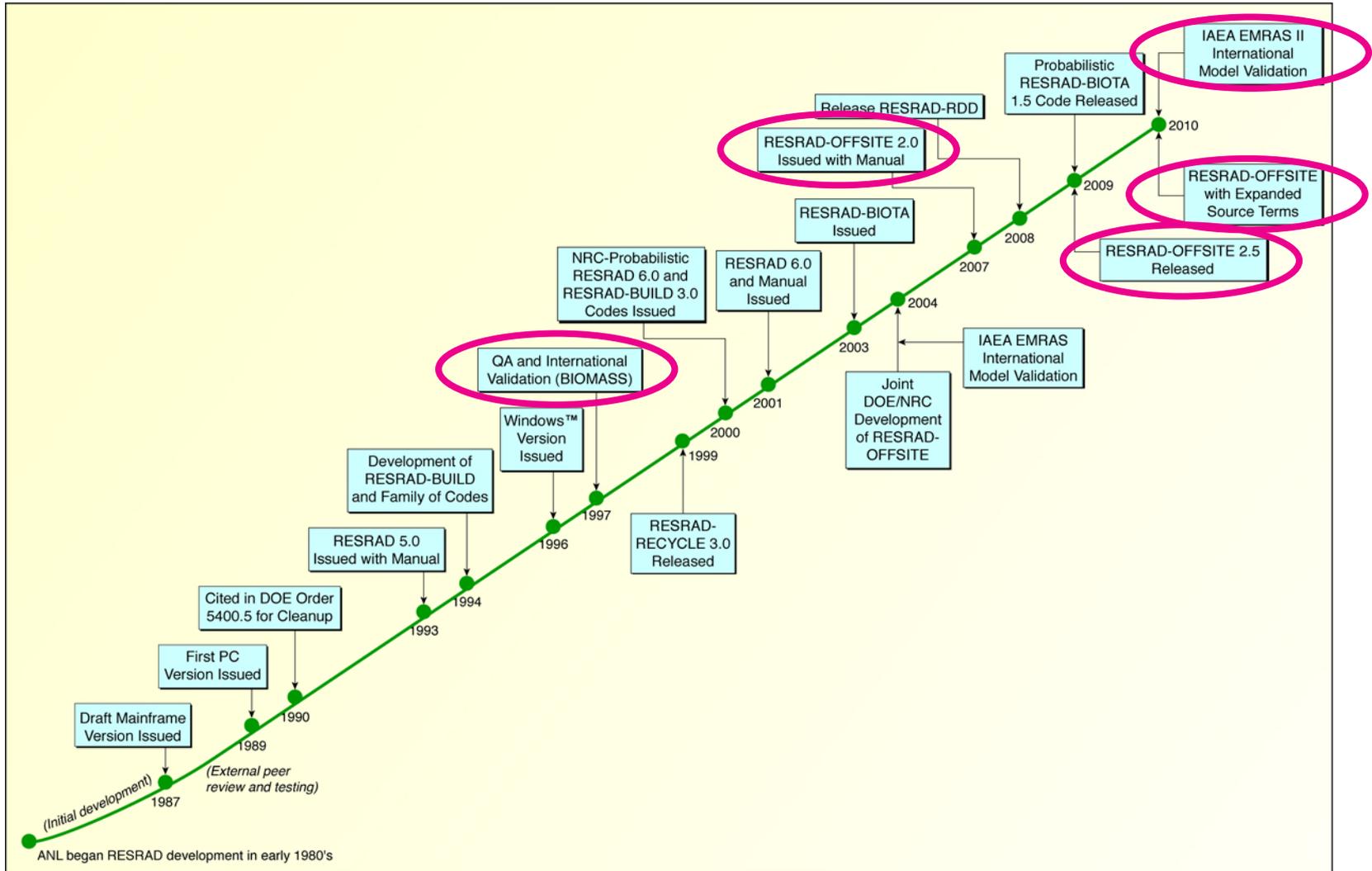
# RESRAD Family of Codes Support National Cleanup Efforts



- Software Download
- Supporting Documentation
- Update News
- Training Events
- User Feedback

<http://www.evs.anl.gov/resrad>

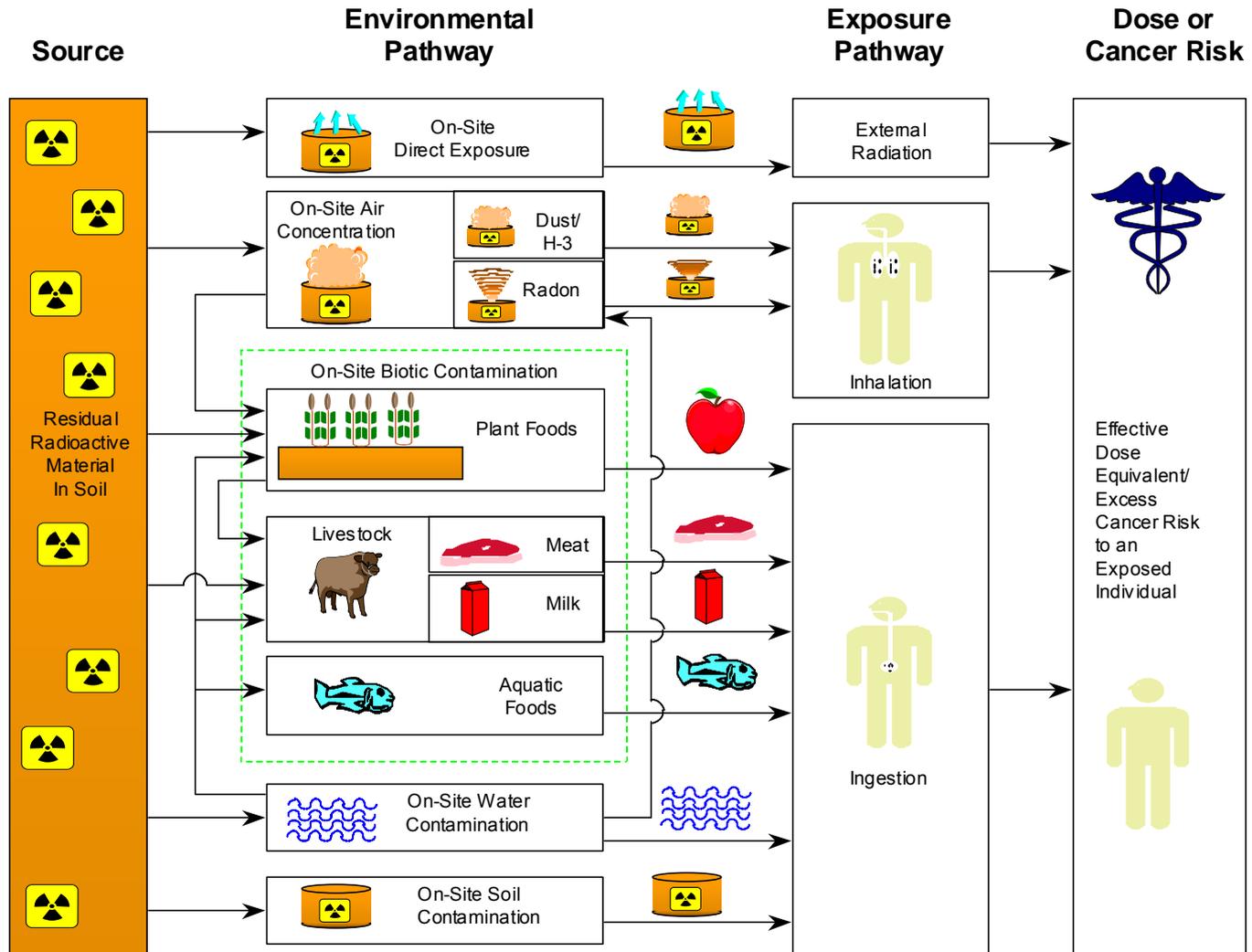
# Development History Since Early 1980s



# *An Integrated, Risk-Based Approach to Environmental Modeling*

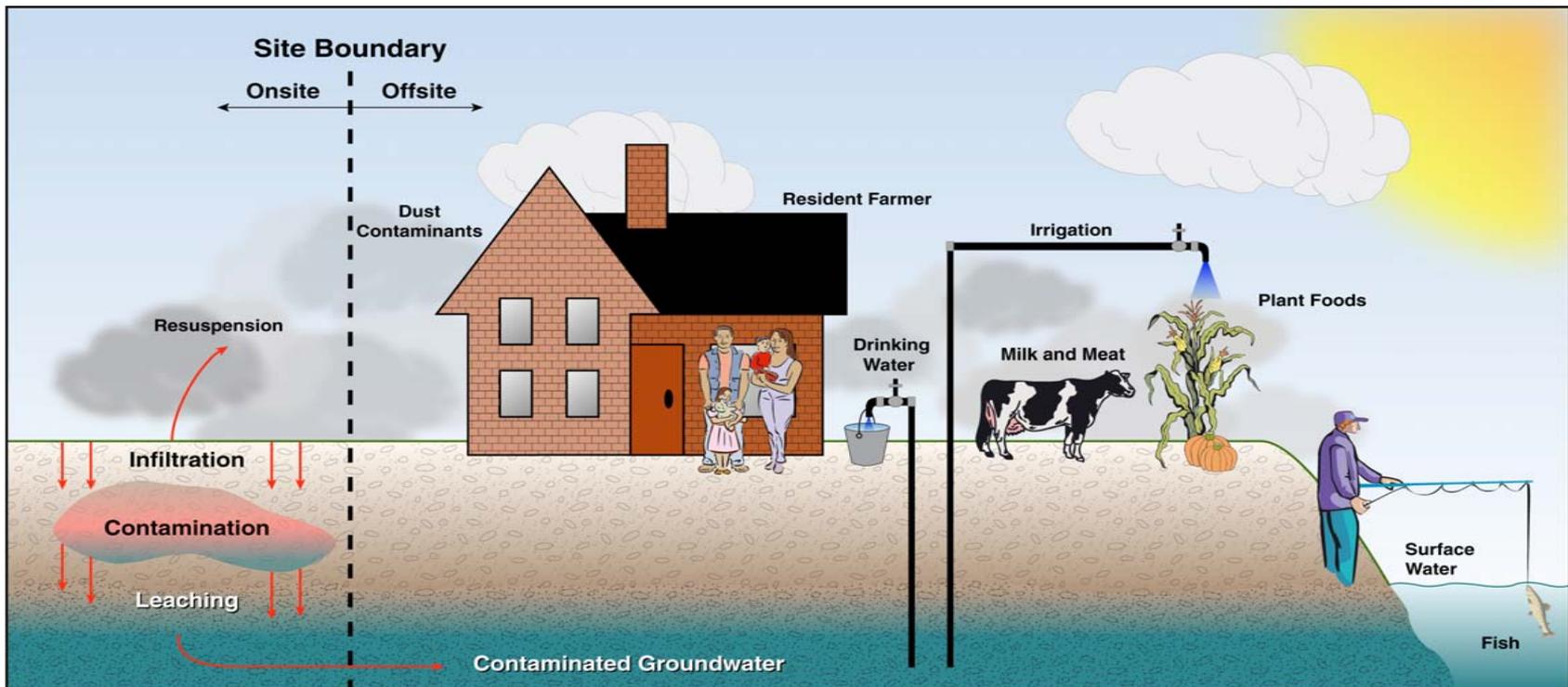
- Environmental settings
- Source term characterization
- Contaminant surface transport
  - Resuspension & emanation → atmospheric transport
  - Soil erosion → surface water transport
- Contaminant subsurface transport
  - Geochemical properties
  - Hydrogeological properties
  - Groundwater flow properties
- Contaminant transfer and uptake via food chains
- Human exposure mechanisms
- Radiation dose and risk estimation

# Comprehensive Exposure Mechanisms



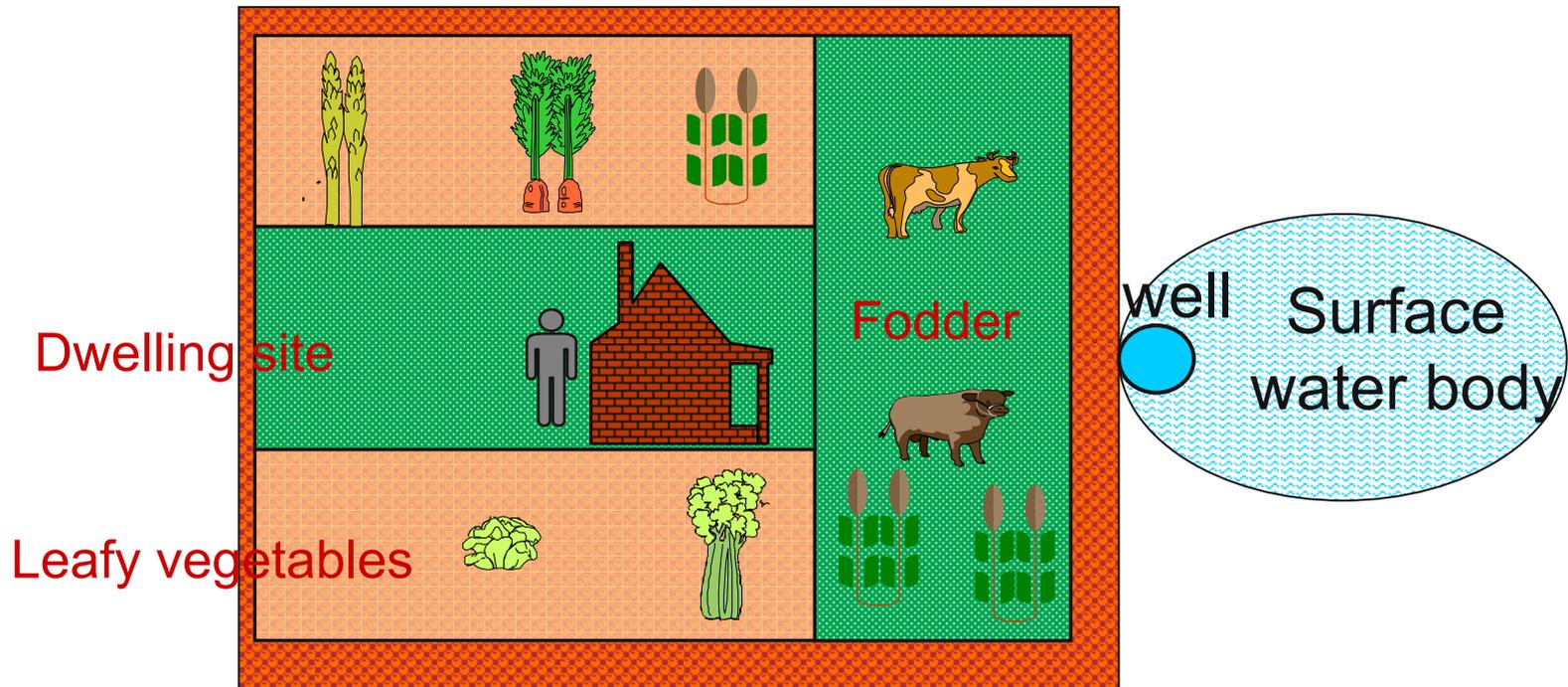
# RESRAD-OFFSITE – Extending the Analysis to Address Complex Sites Issues

Provide offsite assessment for: (1) more realistic analysis, (2) partial site release, (3) complex site conditions



# Area of Primary Contamination

Fruit, grain, non-leafy vegetables

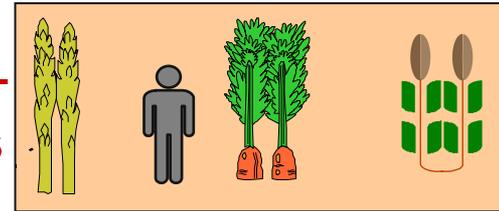


Primary  
contamination

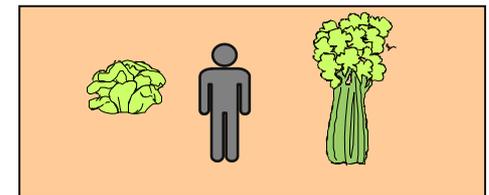
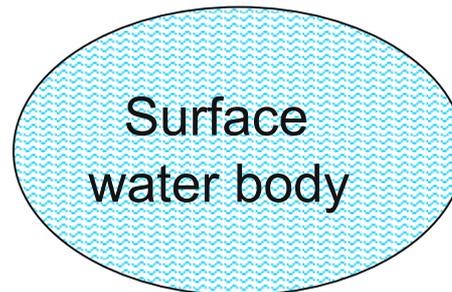
# Areas of Secondary Contamination

Primary contamination

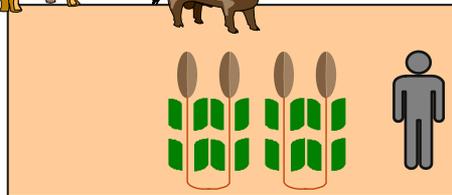
Fruit, grain, non-leafy vegetables



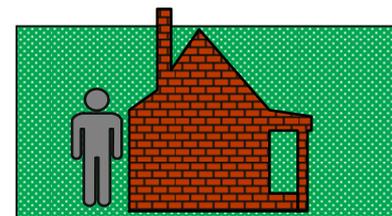
Well



Leafy vegetables

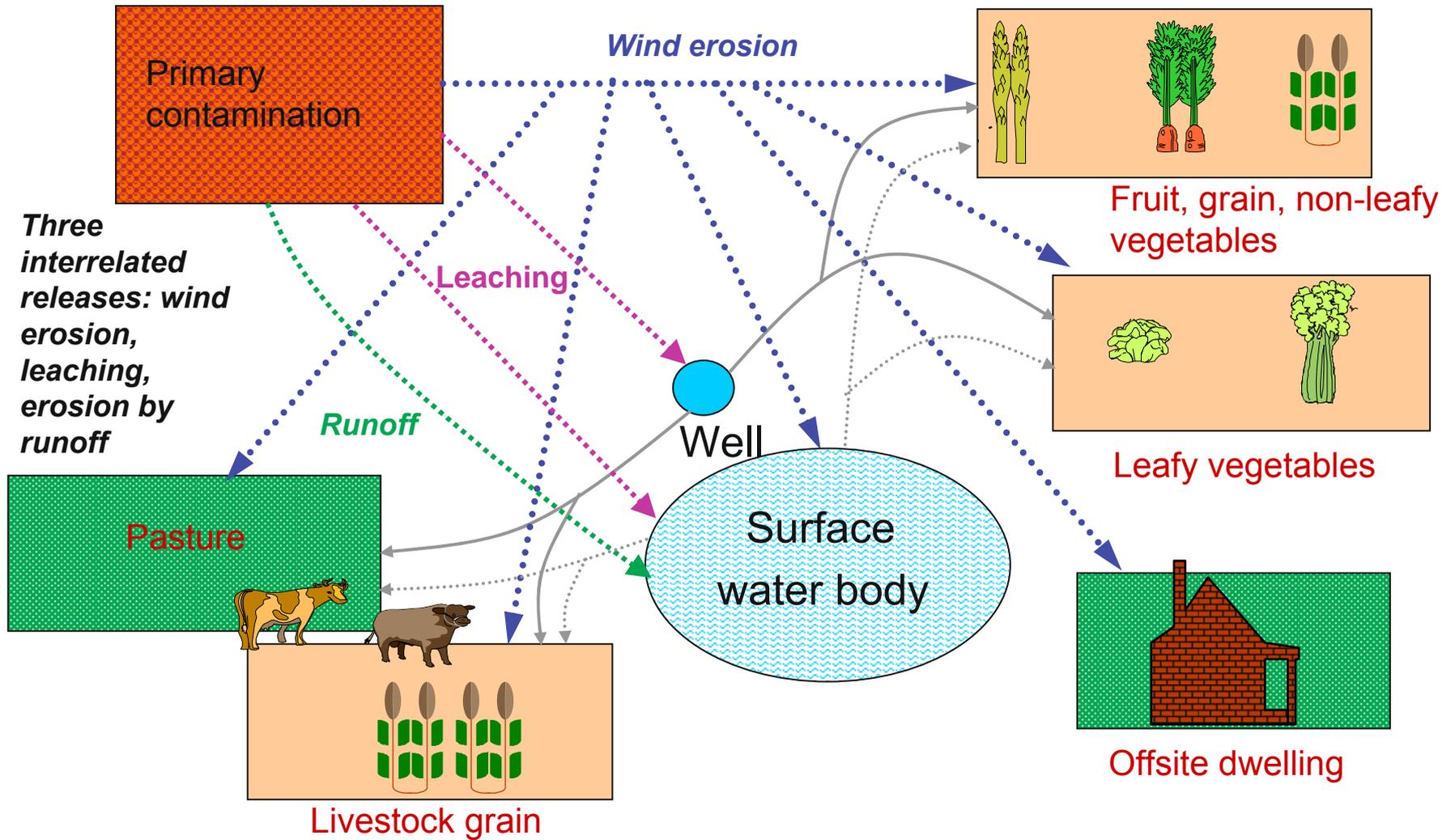


Livestock grain



Offsite dwelling

# Transport to Areas of Secondary Contamination



# Major New Models/Features in RESRAD-OFFSITE

## ■ Transport Pathways

- Air dispersion (Gaussian Plume) model
- Groundwater transport model
  - *1-D advective, 1-D dispersive transport in unsaturated zone*
  - *1-D advective (straight or curved flow path), 3-D dispersive transport in saturated zone*

## ■ Additional impacted areas

- Choice of 2 dwelling locations (onsite, offsite)
- 4 agriculture areas
- Well and surface water body can be at different locations
- Accumulation in offsite soil and surface water body

## ■ Improved User Interface

- Graphical map user interface
- Both deterministic and probabilistic analysis

# Computational Scheme

- Maintain mass balance for the source term
  - Calculate release rates (fluxes) at a series of time
- Develop analytical expressions for transport and accumulation
  - Track radioactive decay and ingrowth of progenies
  - Allow for different transport rates between parent and progenies
- Evaluate some of the analytical expressions with numerical formulations
  - Allow subdivision of each transport zone to increase precision

# *Input of Intermediate Contaminant Fluxes and Concentrations*

- RESRAD-OFFSITE can be flagged to read in:
  - Releases and inventory of the primary contamination (deterministic run)
    - *Flux to ground water*
    - *Flux to atmosphere*
    - *Flux to surface water*
    - *Inventory remaining in the primary contamination and mixing layers*
  - Concentrations in surface water and well
  
- This feature allows the application of RESRAD-OFFSITE to various contamination situations, e.g.
  - From waste disposal,
  - Emissions from effluent stacks, or
  - Discharges from wastewater pipelines

# Application of RESRAD-OFFSITE – Sewage Sludge Dose Assessment

- Argonne assisted the Interagency Steering Committee on Radiation Standards (ISCORS) in analyzing the potential transport of radioactive materials from sewage sludge generated by publicly owned treatment works (POTWs) into the environment and the subsequent exposure of humans
- Seven exposure scenarios were analyzed under three management and processing practices
  - Land application
    - *Onsite resident*
    - *Recreational user*
    - *Nearby town resident*
  - Waste disposal / incineration
    - *Landfill neighbor*
    - *Incinerator neighbor*
  - Occupational exposure
    - *Application worker*
    - *POTW worker*

# Application of RESRAD-OFFSITE (Cont.)

- Probabilistic analyses with Latin hypercube sampling technique were conducted using RESRAD-OFFSITE for three of the seven scenarios
- Dose-to-source ratios for different percentile values were obtained and used with source concentrations to obtain dose results
- Dose report was reviewed by
  - EPA's Science Advisory Board,
  - A Committee of Expert Peer Reviewers selected by ISCORS, and
  - Interested organizations and members of the general public
- The reviews were generally positive and supportive
- The overall results suggest that at the levels of radioactive materials found in the sewage sludge and ash samples of the survey, radiation exposure to the public and to POTW workers is generally very low, and not likely to pose a health risk

## References:

*ISCORS 2005, ISCORS Technical Report 2004-03; EPA832-R-03-002A; NUREG-1783; DOE/EH-0670.*

*Wolbarst et al. 2006, Health Physics, 90(1), pp: 16-30.*

*Bachmaier et al. 2007, International Journal of Environment and Waste Management, 1(2/3), pp 113-127.*

# Application of RESRAD-OFFSITE – Demonstrating Compliance with NRC’s License Termination Rule (10 CFR 20, Subpart E)

- RESRAD is accepted for demonstrating compliance
  - Methodology described in NUREG 1757 on Decommissioning Guidance
  - Site-Specific vs. screening dose analysis
  - Has been applied in many license termination applications
- RESRAD-OFFSITE has been benchmarked with RESRAD for onsite exposure
  - Consistent results in almost all areas

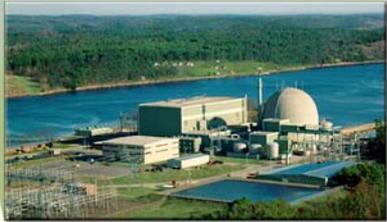
ANL/EAD/TM/04-03, Rev. 1

Training Course

## Evaluation of Dose Modeling for Compliance with Radiological Criteria for License Termination

Prepared by the  
Environmental Assessment Division  
Argonne National Laboratory

for the  
U.S. Nuclear Regulatory Commission



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 Office of Science  
U.S. Department of Energy

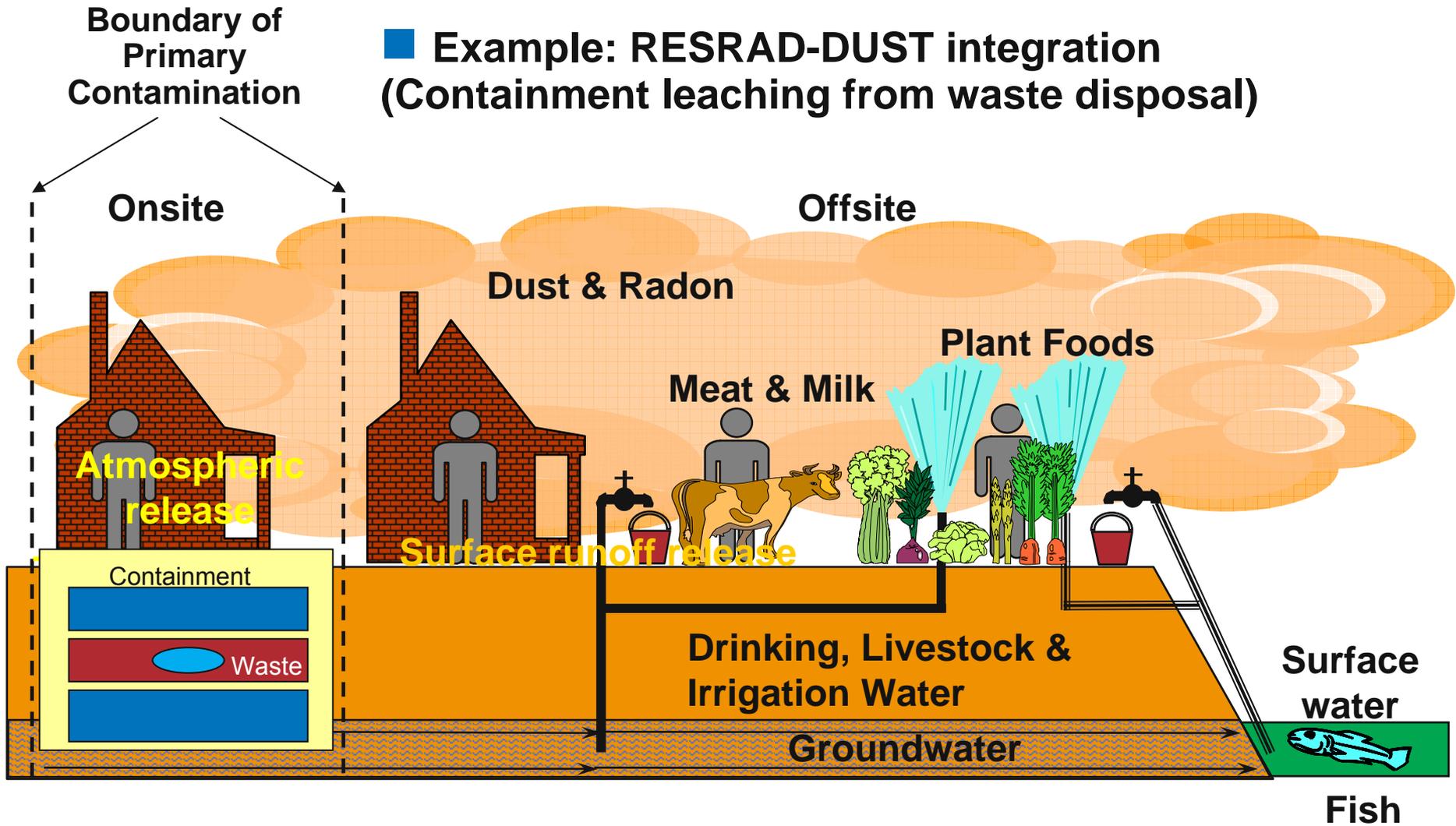
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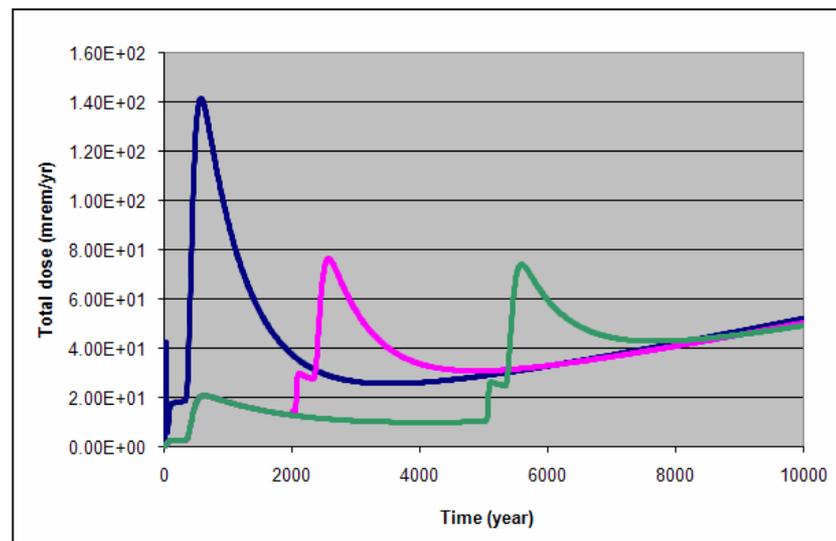
# Application of RESRAD-OFFSITE – Used with Other Source Term Model

■ Example: RESRAD-DUST integration (Containment leaching from waste disposal)



# Application of RESRAD-OFFSITE – An Example Using the Input of Flux Feature

- RESRAD-OFFSITE accept input of flux to groundwater, atmosphere, or surface water
- The flux can be calculated with other computer code or methodology to account for a variety of releases from different sources
- The following graphic shows the dose results based on specified input of flux as a function of time



# *Application of RESRAD-OFFSITE – Other Examples*

- RESRAD-OFFSITE has been used by the IAEA EMRAS and EMRAS II Program NORM and Legacy Sites Working Group for model comparison study of several scenarios and sites contaminated with NORM and other radionuclides.
- RESRAD-OFFSITE is used in the RDD Operational Guidelines report in derivation of Group F-4 operational guidelines for contaminated soils and lands.
- RESRAD-OFFSITE has been used by EPA to study NORM contamination problems in the US.
- RESRAD-OFFSITE was used in the IAEA BIOMASS Program to analyze probabilistic scenarios containing uranium mill tailings.
- Many other applications by authors around the world (do a Google search and you'll find a lot)

# *Moving Toward Performance Assessment – NRC Sponsored Effort*

- Tasked by NRC to expand the source term model in RESRAD-OFFSITE
- The objectives are
  - Provide more release mechanisms for the user to choose from, and allow specification of the fraction of inventory that will be released by each mechanism,
  - Provide mechanisms for future modeling situations where the initial contamination is in containers, in addition to the current assumption of soil contamination
  - Maintain consistency among all RESRAD calculations
- After the expansion of the source term model, RESRAD-OFFSITE can be applied directly to
  - Model the long-term performance of waste disposal facilities
  - Evaluate different disposal methods

# Expansion of the Source Term Model

- Methodologies for calculating source release rates in the DUST and BLT codes were evaluated
  - Degradation of containers
    - *General failure*
    - *Localized failure*
  - Release mechanisms
    - *Solubility-limited*
    - *Surface wash-off subject to partitioning*
    - *Diffusion*
    - *Uniform release (e.g., dissolution)*
- Compatibility with and preserving the RESRAD-OFFITE features were considered
- Benefits and disadvantages of linking vs. including an external code were assessed
- Stay tuned for subsequent development

# ***RESRAD Team Actively Supports DOE/EM ASCEM Program***

- RESRAD team is an active member of the ASCEM (Advanced Simulation Capability for Environmental Management) team
- Share lessons learned and regulatory experiences
- Offer an integrated, risk-based systematic philosophy and approach
- Shorten the overall “Learning Curve”
- Introducing the problem solution with graded complexity

# Summary and Conclusions

- RESRAD is an established regulatory tool that has been extensively applied in cleanup activities over the past three decades
- The wide acceptance of RESRAD has been based on a combination of factors that include good science, rigorous QA, clarity and ease of use, plus extensive stakeholder outreach
- RESRAD has been constantly improved to respond to feedback from users, change of hardware/software environment, and emerging issues
- With the support from NRC and DOE, the use of RESRAD is gradually transitioned to the use of RESRAD-OFFSITE
- With support from NRC and DOE, RESRAD-OFFSITE is being incorporated with new capabilities to address performance assessment (PA) issues
- The RESRAD team actively supports DOE/EM's ASCEM Program for advanced modeling simulation effort in environmental research and applications

***Thank You !***

***We would like to hear your comments and suggestions, please contact –***

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