NRC RAMP Fall 2020 Users Group Meeting

RESRAD Session

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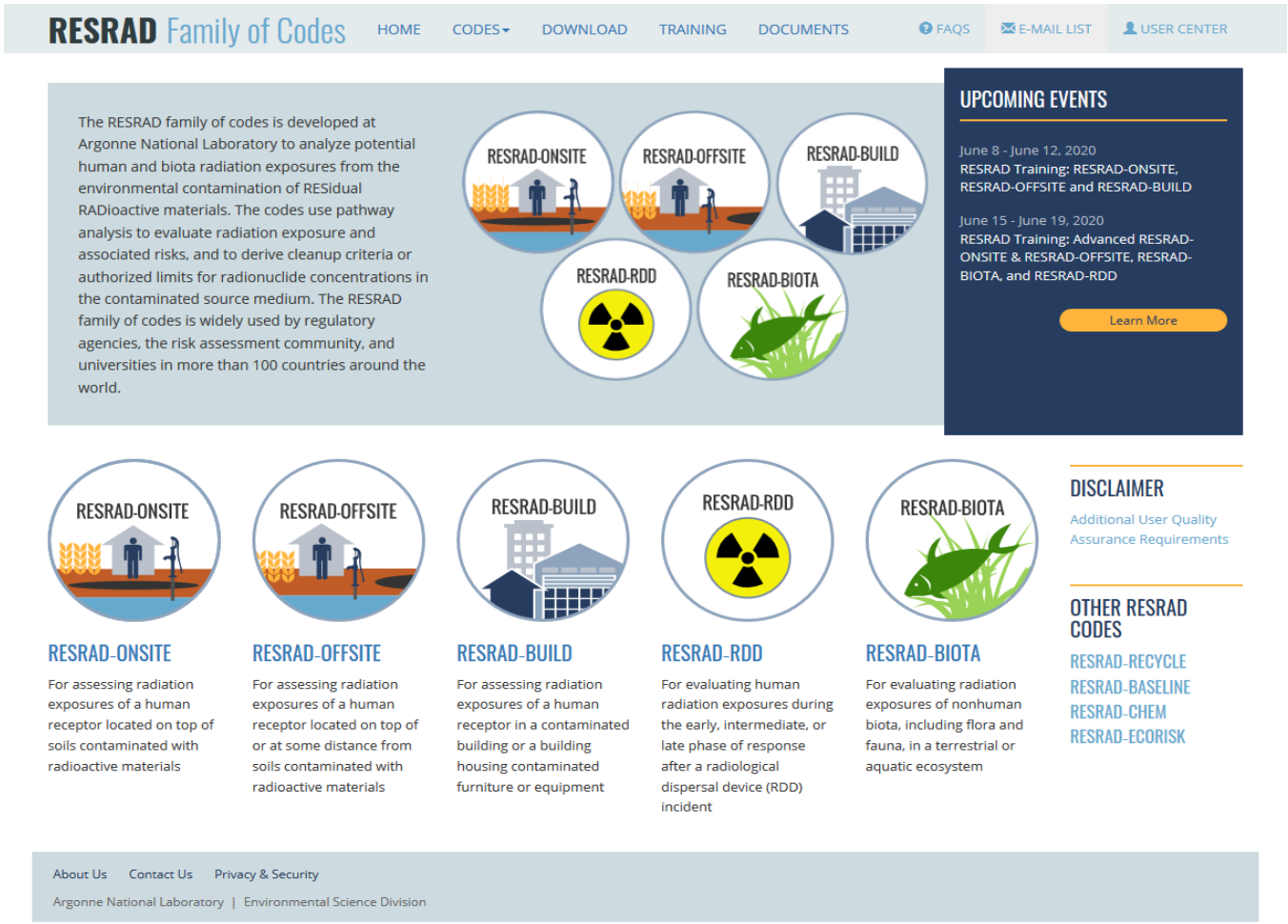
Environmental Science Division

RESRAD Family of Codes Update

RESRAD Family of Codes Can be Used to Conduct Radiological Dose Assessment



More Info at RESRAD Web Site:

https://resrad.evs.anl.gov

Email: resrad@anl.gov

Update to RESRAD Family of Codes

- RESRAD-ONSITE Version 7.2
  - New User's Guide (ANL/EVS/TM-18/1)
  - New RESRAD-ONSITE deterministic graphics program (using DevExpress)
  - Improved probabilistic graphics program (using MSChart control)
  - Improved Non-circular Shape Factor for external exposure pathway
  - NUREG/CR on parameter default values and distributions (NUREG/CR-7267, ANL/EVS/TM-20/1)

Update to RESRAD Family of Codes (Cont'd)

- RESRAD-OFFSITE Version 4.0
  - New RESRAD-OFFSITE deterministic graphics program
  - Updated "Simulate RESRAD-ONSITE Code" option and "Onsite Scenario Template File" option
  - New source term models for waste disposal evaluation
    - Delayed release (waste form, waste in container, institutional control, etc.)
    - Diffusion-controlled release
    - Solubility-limited release
  - New surface water model
  - NUREG/CR on parameter default values and distributions
  - New User's Manual and User's Guide (NUREG/CR-7268, ANL/EVS/TM-19/2, Vol. 1 & Vol. 2)

Update to RESRAD Family of Codes (Cont'd)

- RESRAD-BUILD Version 3.8 beta
  - Updated QA files (included in the installation package)
  - Added 90+ radionuclides to the database to calculate dose coefficients (DCs) for IND scenario
  - Fixed dose contribution allocation to decay progeny
  - Listed external DCs in the text report
  - NUREG/CR on parameter default values and distributions (NUREG/CR-7267, ANL/EVS/TM-20/1)
  - Version 4 will have ability to model more than 3 rooms and other advanced features

Update to RESRAD Family of Codes (Cont'd)

- RESRAD-RDD Version 1.7 (and 2.0 Beta)
  - Incorporated dose coefficients for 90+ radionuclides calculated with RESRAD-BUILD
  - Rewriting User Interface for RESRAD-RDD&IND
  - Modified the code to correctly retrieve data from previous input file and save file before calculation
  - Added Water PAG as Group H Water Consumption in RESRAD-RDD (and RESRAD-IND)
  - Incorporated new resuspension model
  - Implemented analytical time-integration combining resuspension, weathering, and decay & ingrowth

Update to RESRAD Family of Codes (Cont'd)

- RESRAD-BIOTA Version 1.8 (and 1.9 Beta)
  - New installation file for RESRAD-BIOTA 1.9.0.6 Beta
  - Compiled sediment Kd data
  - Fixed the code on grid data display for Win 10
  - Improved deterministic and probabilistic graphics program
  - Revised the method of saving allometric input parameters for different organisms
  - Improved the input parameter report
  - Saving input data in memory until user instructing to save in a file
  - New DOE STANDARD--A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota (DOE-STD-1153-2019)

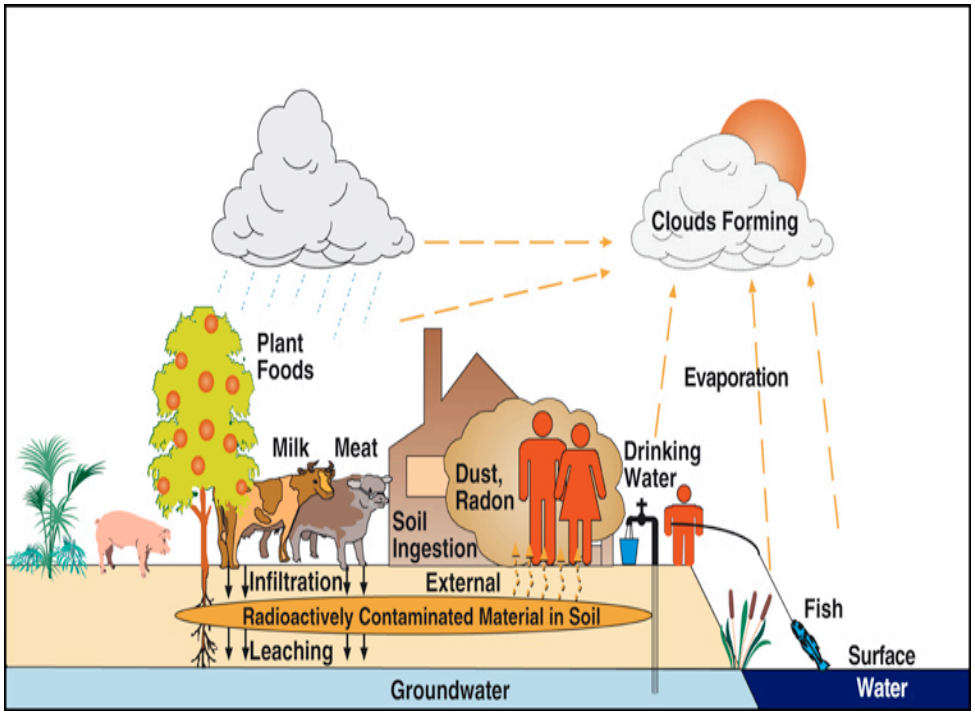
One Hundred Twenty-One (121) Countries Downloaded RESRAD Family of Codes (seven (7) new countries: Burundi, Cuba, Dominican Republic, Jamaica, Lebanon, Nepal, and Uruguay)

Algeria	Burkina Faso	Czech Republic	Ghana	Kazakhstan	Moldova	Norway	Singapore	Thailand	Vietnam
Argentina	Burundi	D.R. of the Congo	Greece	Kenya	Monaco	Pakistan	Slovakia	Togo	Yemen
Armenia	Cameroon	Denmark	Hungary	Kuwait	Mongolia	Peru	Slovenia	Tunisia	Zambia
Australia	Canada	Djibouti	India	Latvia	Montenegro	Philippines	South Africa	Turkey	Zimbabwe
Austria	Chad	Dominican Republic	Indonesia	Lebanon	Morocco	Poland	South Korea	Uganda	
Azerbaijan	Chile	Egypt	Iran	Libya	Mozambique	Portugal	Spain	Ukraine	
Bangladesh	China	Estonia	Iraq	Lithuania	Namibia	Puerto Rico	Sudan	United Arab Emirates	
Belarus	Colombia	Fiji	Ireland	Macedonia	Nepal	Qatar	Sweden	United Kingdom	
Belgium	Congo	Finland	Israel	Madagascar	Netherlands	Romania	Switzerland	United States	
Bosnia & Herzegovina	Cote D'Ivoire	France	Italy	Malawi	New Zealand	Russia	Syria	Uruguay	
Botswana	Croatia	Gabon	Jamaica	Malaysia	Niger	Saudi Arabia	Taiwan	Uzbekistan	
Brazil	Cuba	Georgia	Japan	Mauritius	Nigeria	Senegal	Tajikistan	Vanuatu	
Bulgaria	Cyprus	Germany	Jordan	Mexico	North Korea	Serbia	Tanzania	Venezuela	

Overview of RESRAD-ONSITE

RESRAD-ONSITE – A Regulatory Tool for Determining Allowable RESidual RADioactivity in Site Cleanup

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



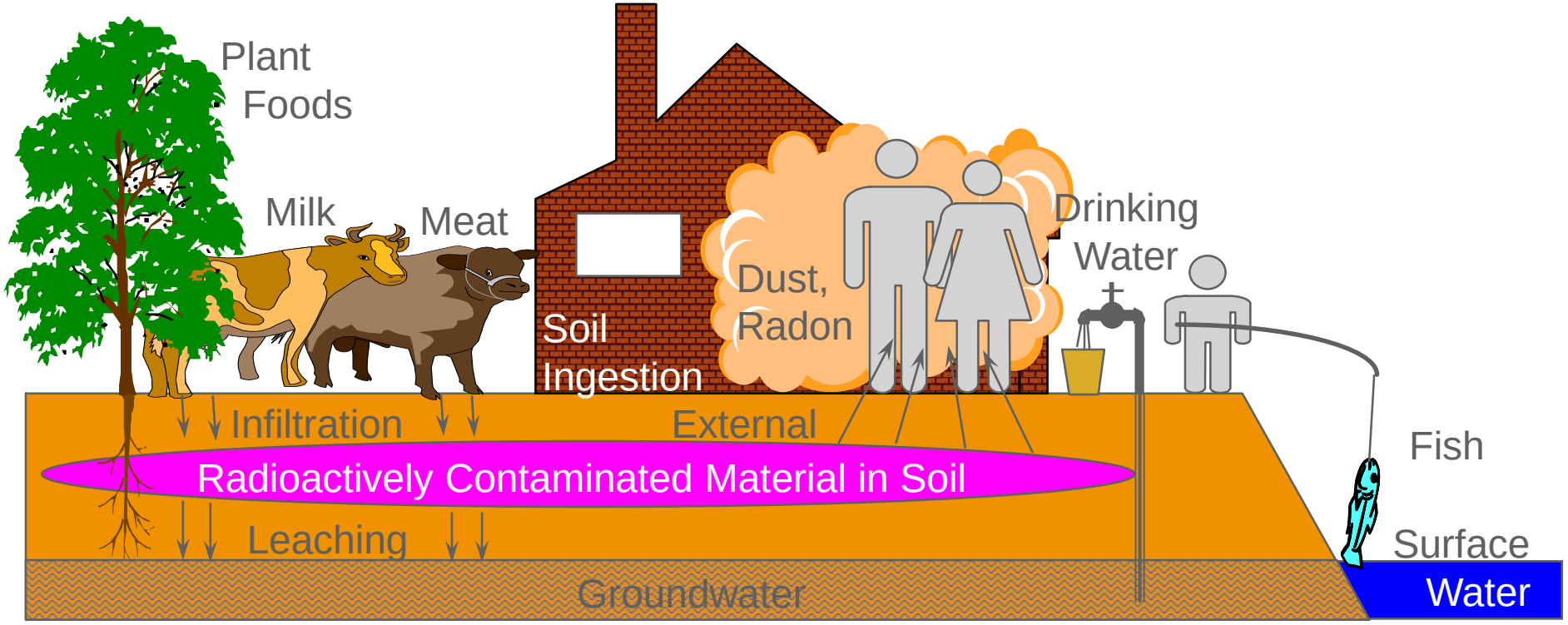
Accepted for use by government regulatory agencies

- DOE (Designated by Order 5400.5 and 458.1)
- NRC (NUREG-1757)
- EPA
- State agencies

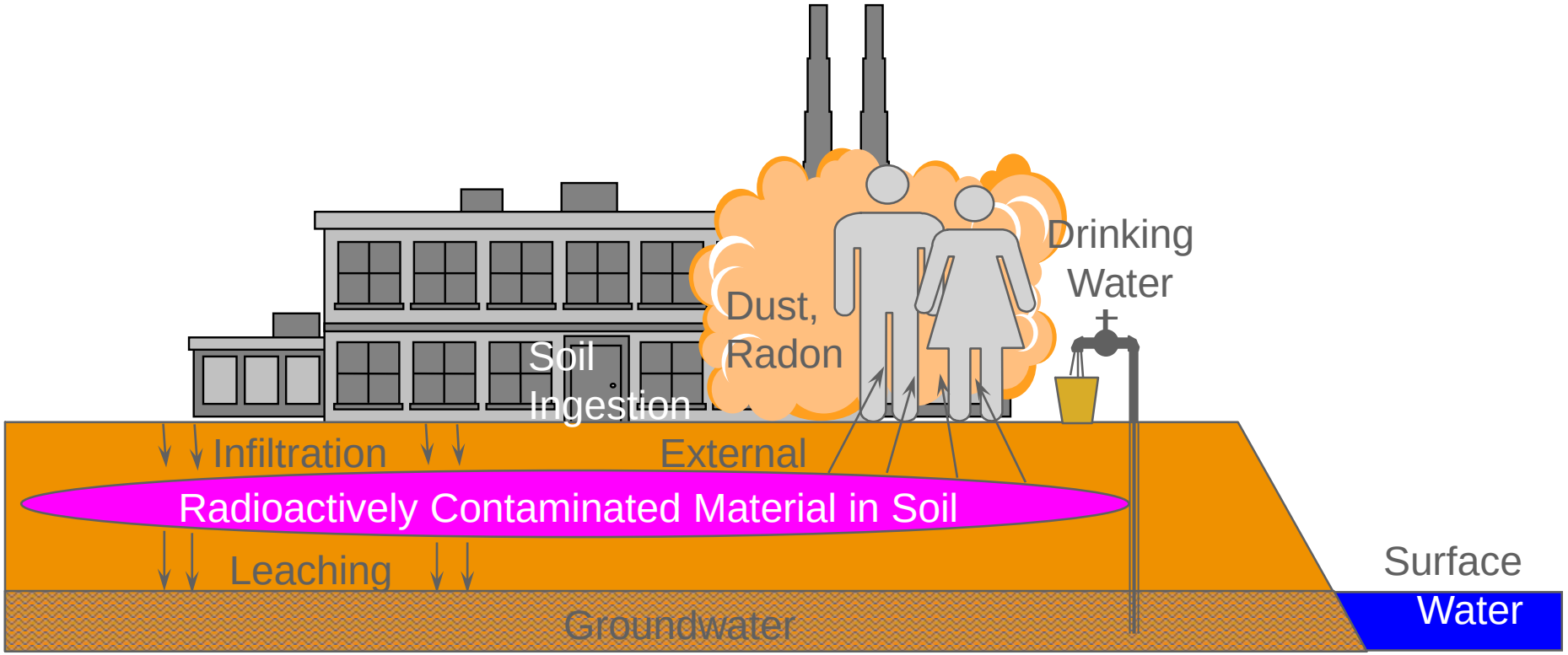
In use for more than 30 years

- Evaluation of over 300 cleanup sites including many DOE/EM sites
- More than 150 training workshops
- International recognition (IAEA multilingual version and training)

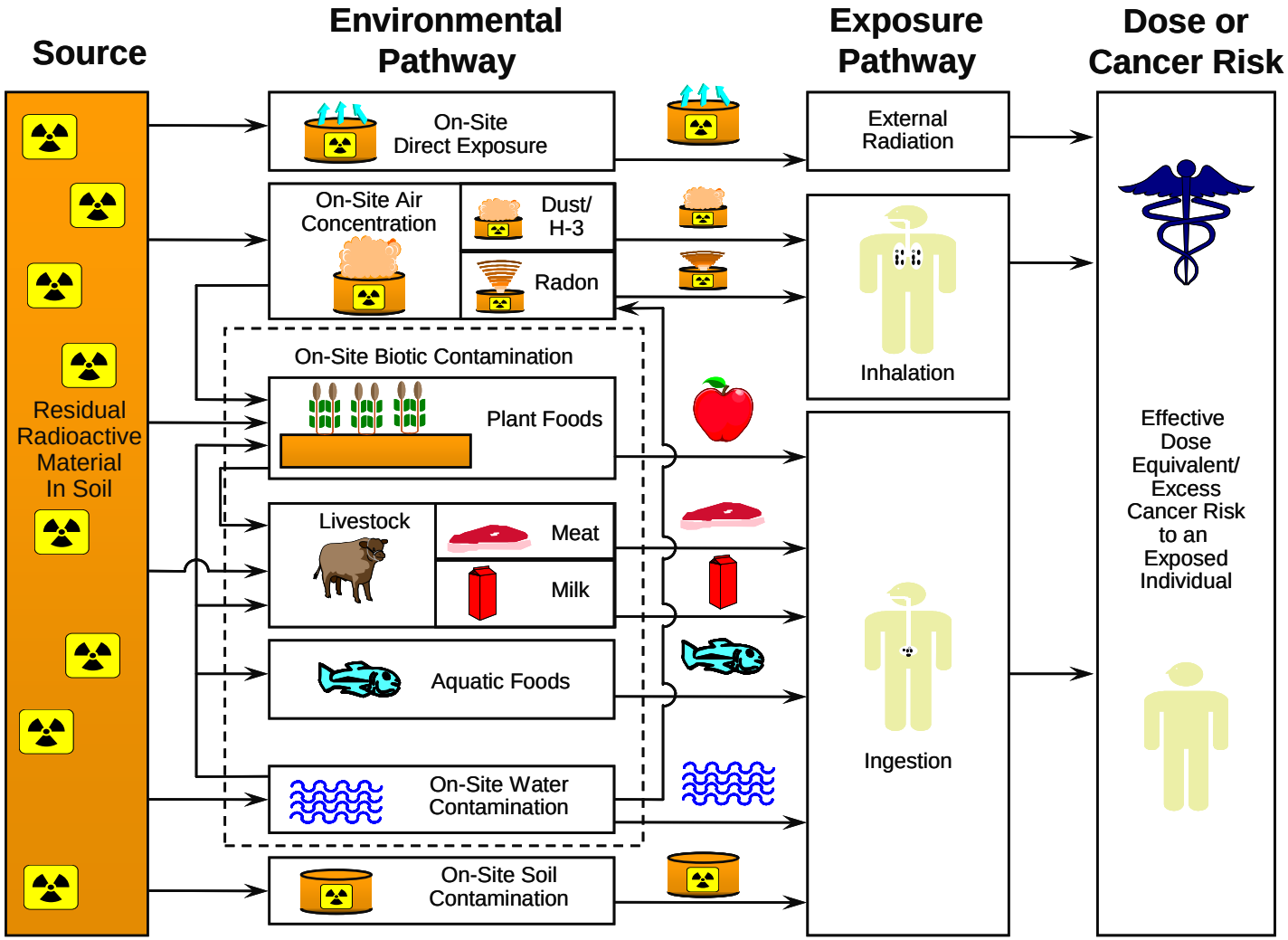
Exposure Pathways Considered in RESRAD-ONSITE: (Resident Farmer Scenario)



Exposure Pathways Considered in RESRAD-ONSITE: (Industrial Use Scenario)



RESRAD Contains An Array of Parameters for Pathway Analysis in Performing Comprehensive Risk Assessment



Major Categories of Input Parameters for RESRAD

- Contamination
  - Physical size, concentration, nuclides of concern
- Environmental Release and Transport
  - Release: leaching, particulate air release, erosion, root uptake
  - Transport: groundwater, air, radon gas, food chain
- Exposure Pathways (related to land use scenario)
  - External
  - Inhalation (particulates and radon),
  - Ingestion (plant, meat, milk, water, soil, aquatic foods)
- Consideration of Health Impacts
  - Annual dose or lifetime risk
  - Use of different coefficient to convert exposure to impact (dose, risk)

Use RESRAD-ONSITE for Dose/Risk Estimates or Determining Cleanup Criteria

- Forward: Input final/measured residual radioactive material **concentrations**
  - Concentration → Environmental Pathways → Dose or Risk

- Backward: Input **dose limit** to estimate residual radioactive material concentrations so that the dose to an individual is below the dose limit (***DCGL = D****erived* ***C****oncentration* ***G****uideline* ***L****evel*)
  - Dose Limit → Environmental Pathways → Concentration
    - Derived separately for each radionuclide based on its maximum dose
    - Requires the use of the "Sum of Fractions" if multiple radionuclides or sources are present

RESRAD-ONSITE Has Many Conservative Default Assumptions

- All activities occur on the contaminated land
- The well is placed at the contamination edge where the water concentration would be the highest
- Default distribution coefficients and other parameters are often selected to be conservative
- The range of peak annual dose can occur anywhere in the 1,000 years (or the specified time frame)
- The default scenario is subsistence farmer (half of plants, half of meat and milk, all water from contaminated land)
- Internal Dose Coefficients are the largest of the set considering lung clearance class and gastrointestinal fraction
- Food transfer factors are for sensitive organisms
- 1-D transport to the groundwater table and 2-D in groundwater aquifer, no dispersion

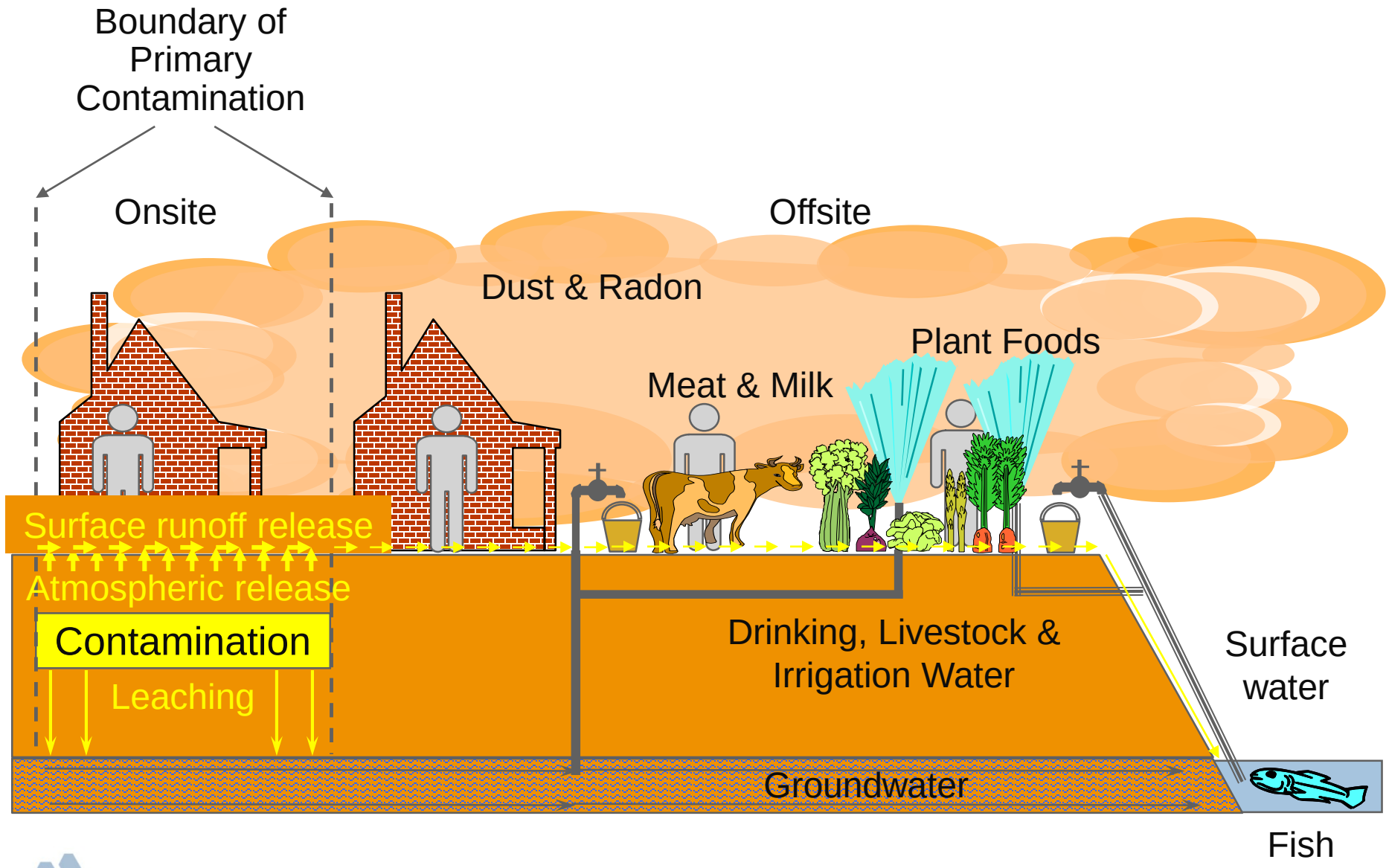
Note that users can overwrite these assumptions by modifying input parameters and by turning pathways on or off.

Demonstration of RESRAD-ONSITE Code

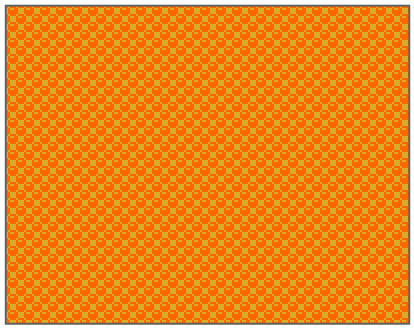
Break / Q&A

Overview of RESRAD-OFFSITE

Environmental Pathways and Exposure Locations

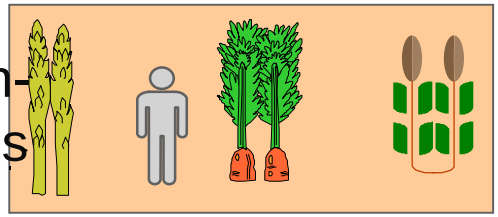


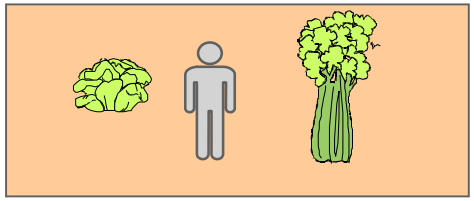
Areas of Secondary Contamination – RESRAD-OFFSITE



Primary contamination

Fruit, grain, non-leafy vegetables

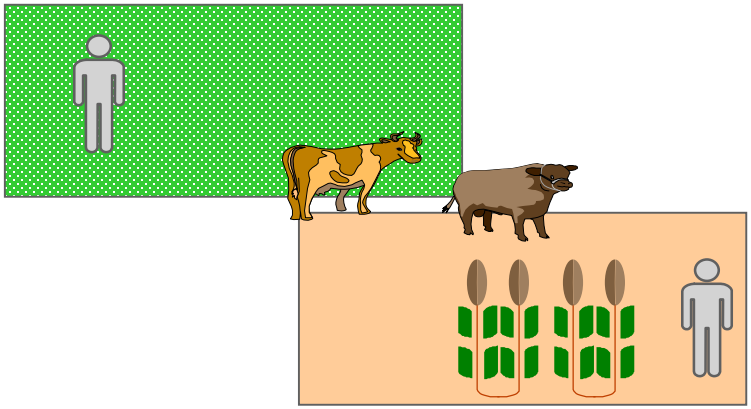




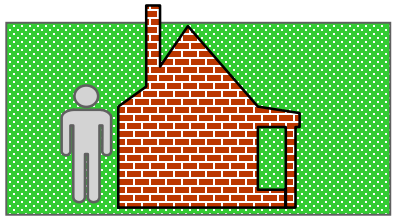
Leafy vegetables

Well

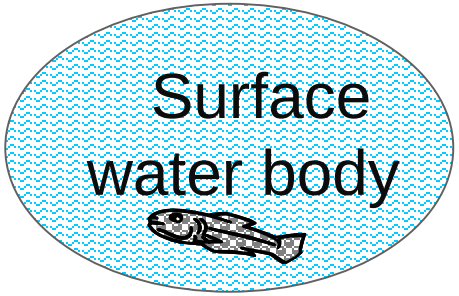
Pasture



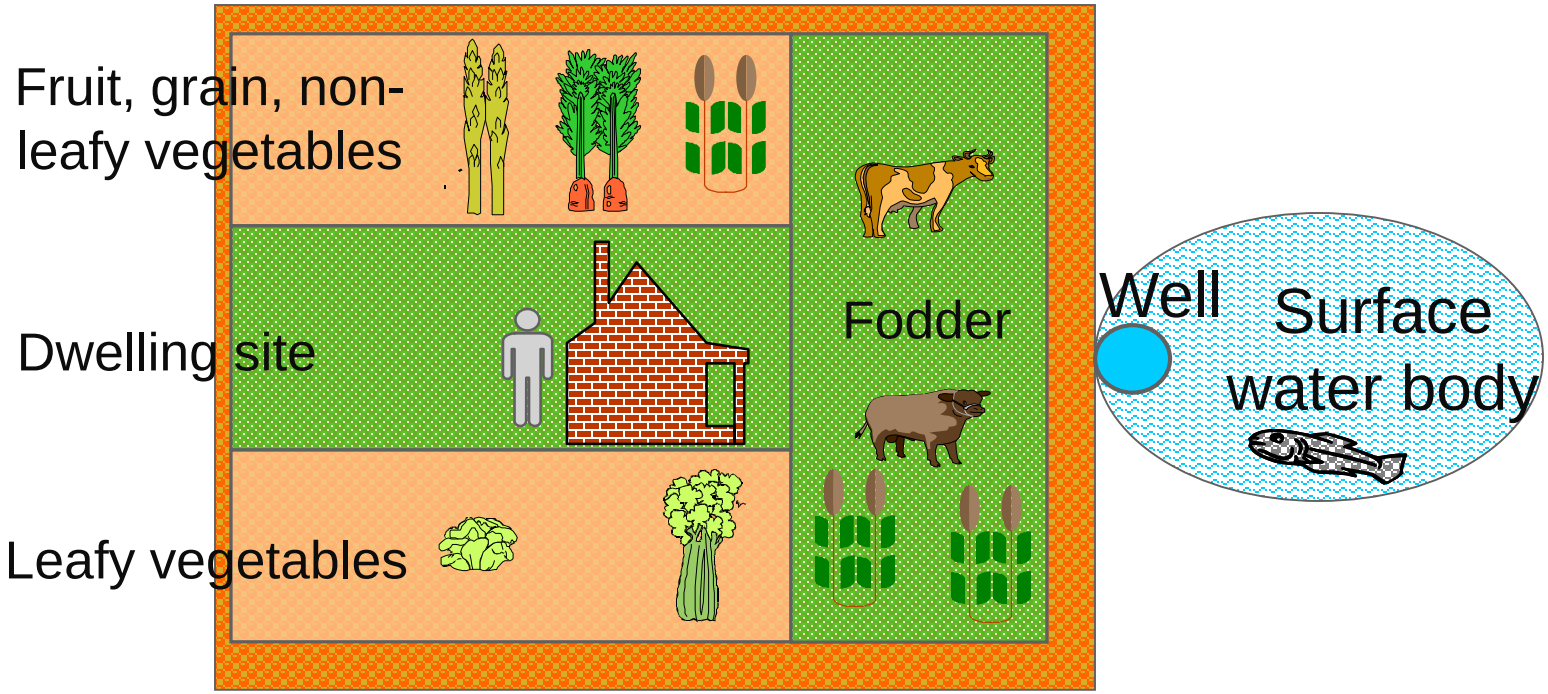
Livestock grain



Offsite dwelling

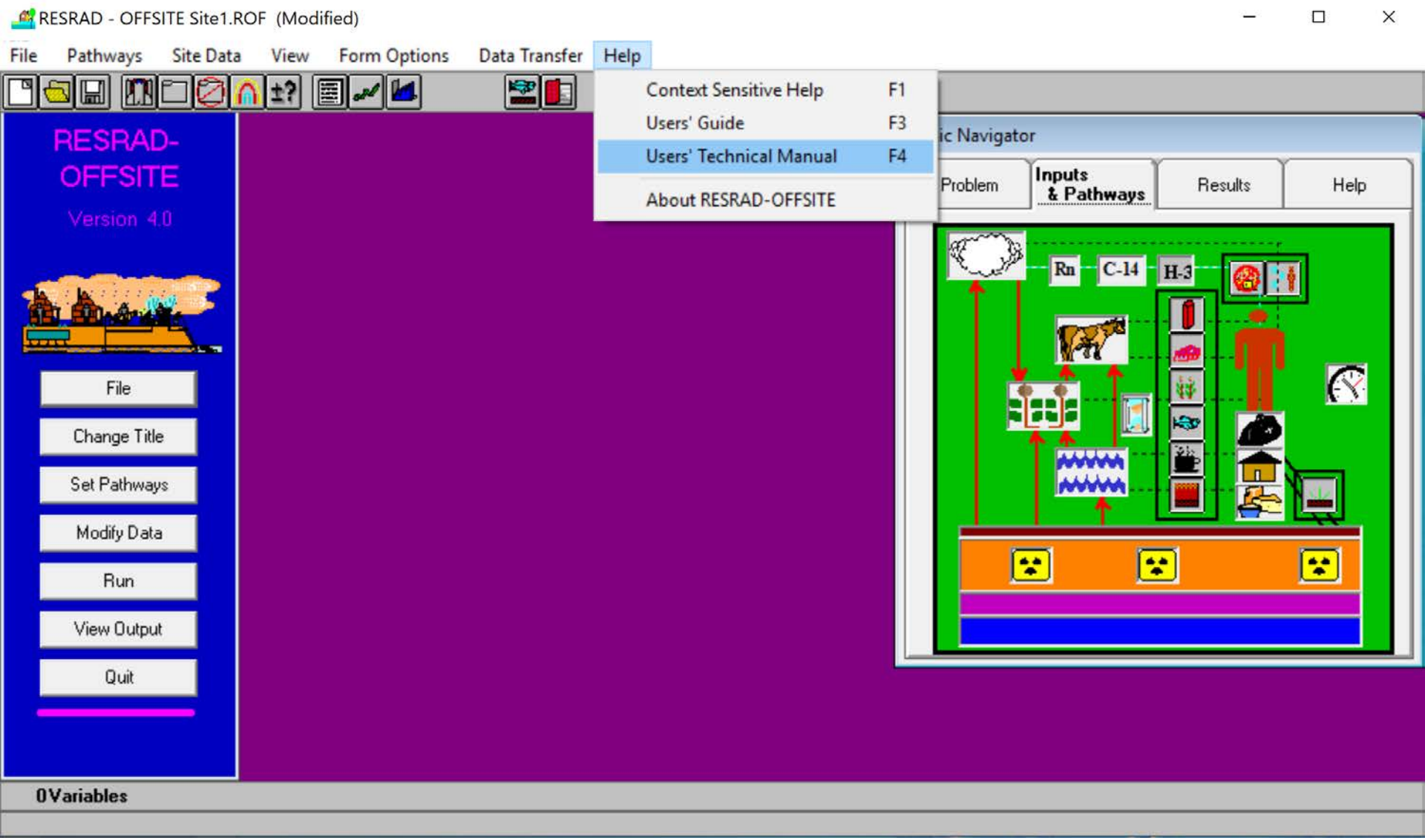


Areas of Secondary Contamination – RESRAD-ONSITE

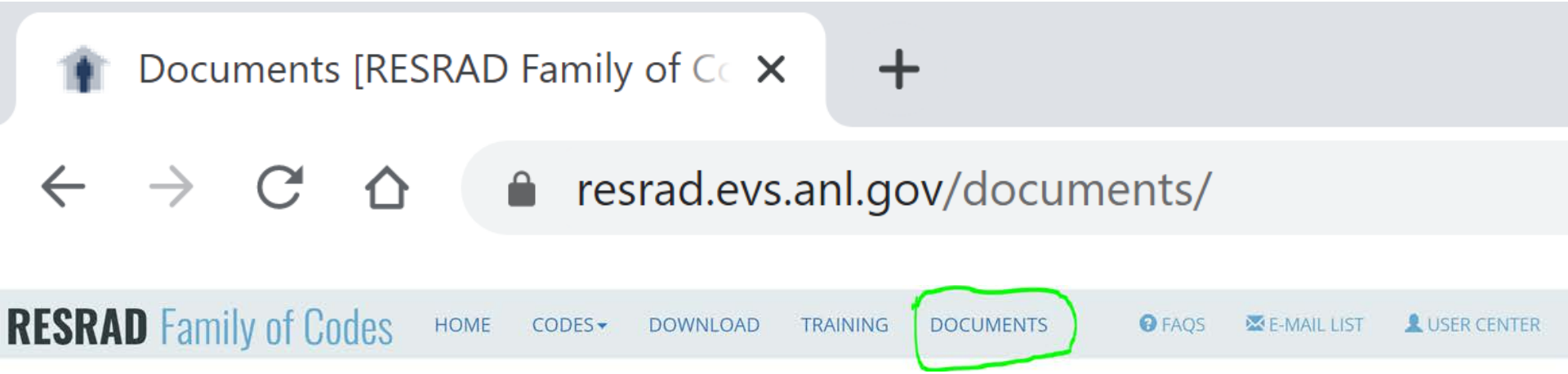


Appendices K and L of the manual

User's Manual accessible from the code



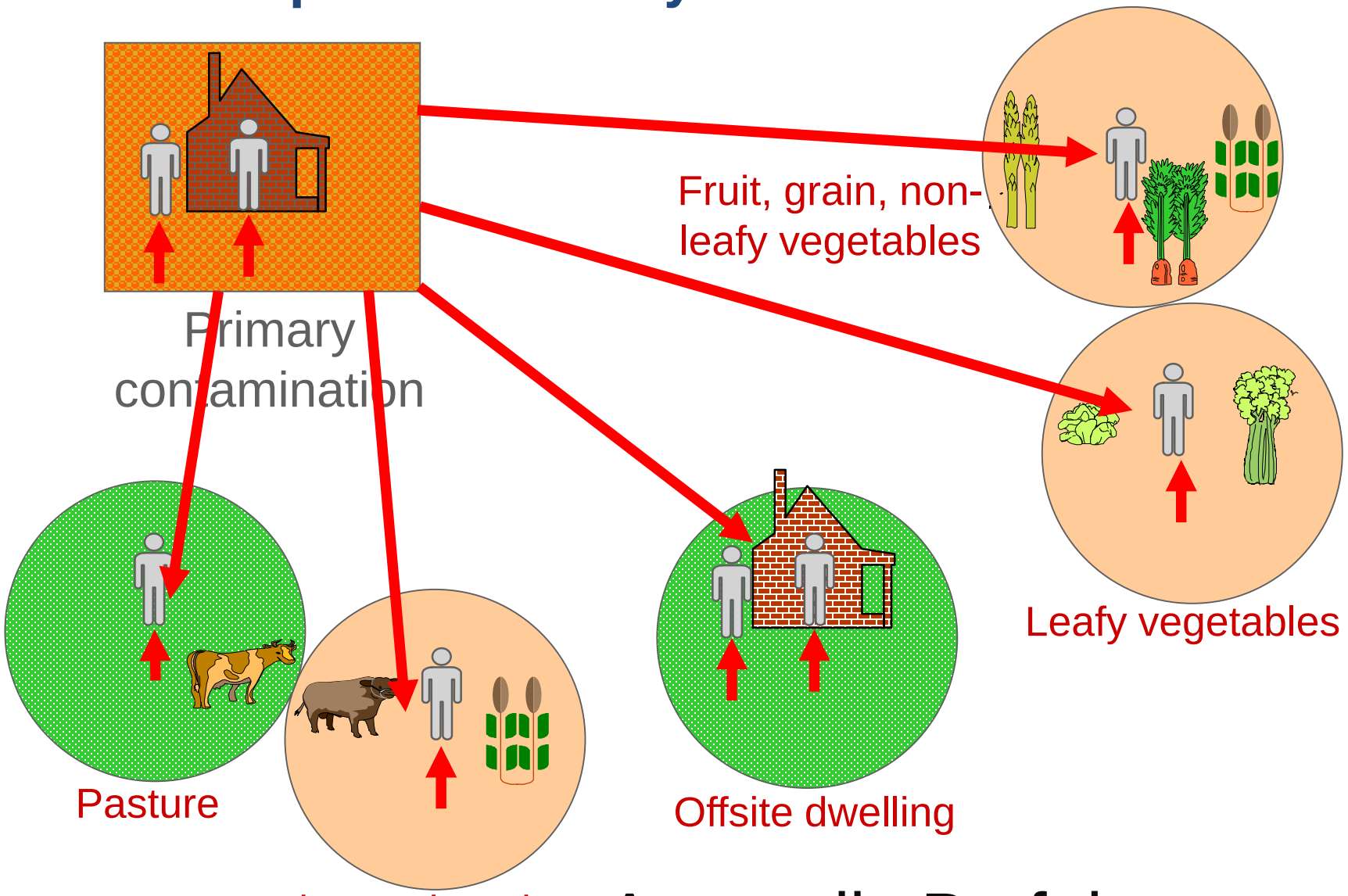
User's Manual accessible from the web



RESRAD-OFFSITE

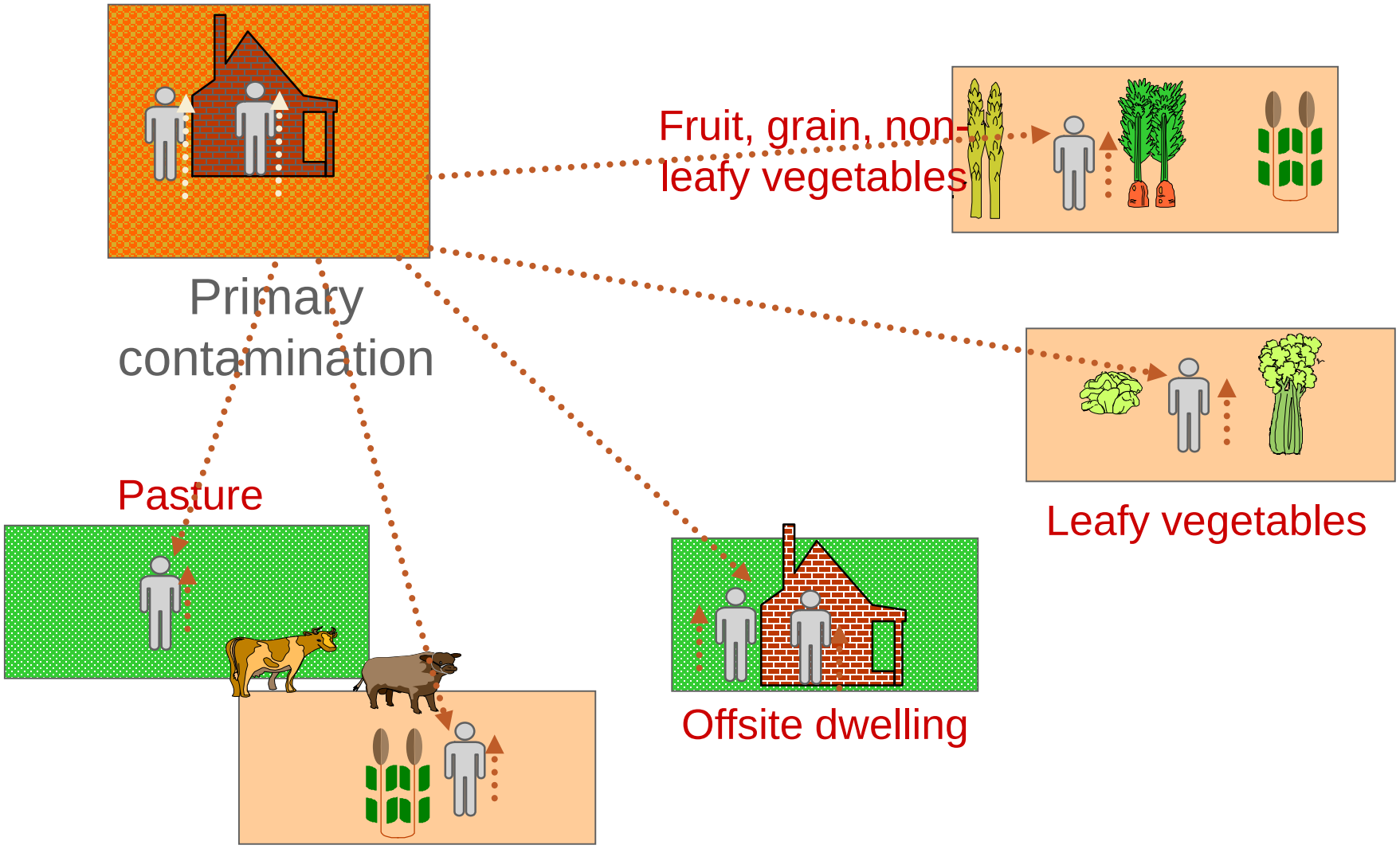
- User's Manual Volume 1: Methodology and Models Used in RESRAD-OFFSITE Code (NUREG/CR-7268, February 2020) 20 MB
- User's Manual Volume 2: User's Guide for RESRAD-OFFSITE Version 4 (NUREG/CR-7268, February 2020) 3.9 MB

Direct Exposure Pathways



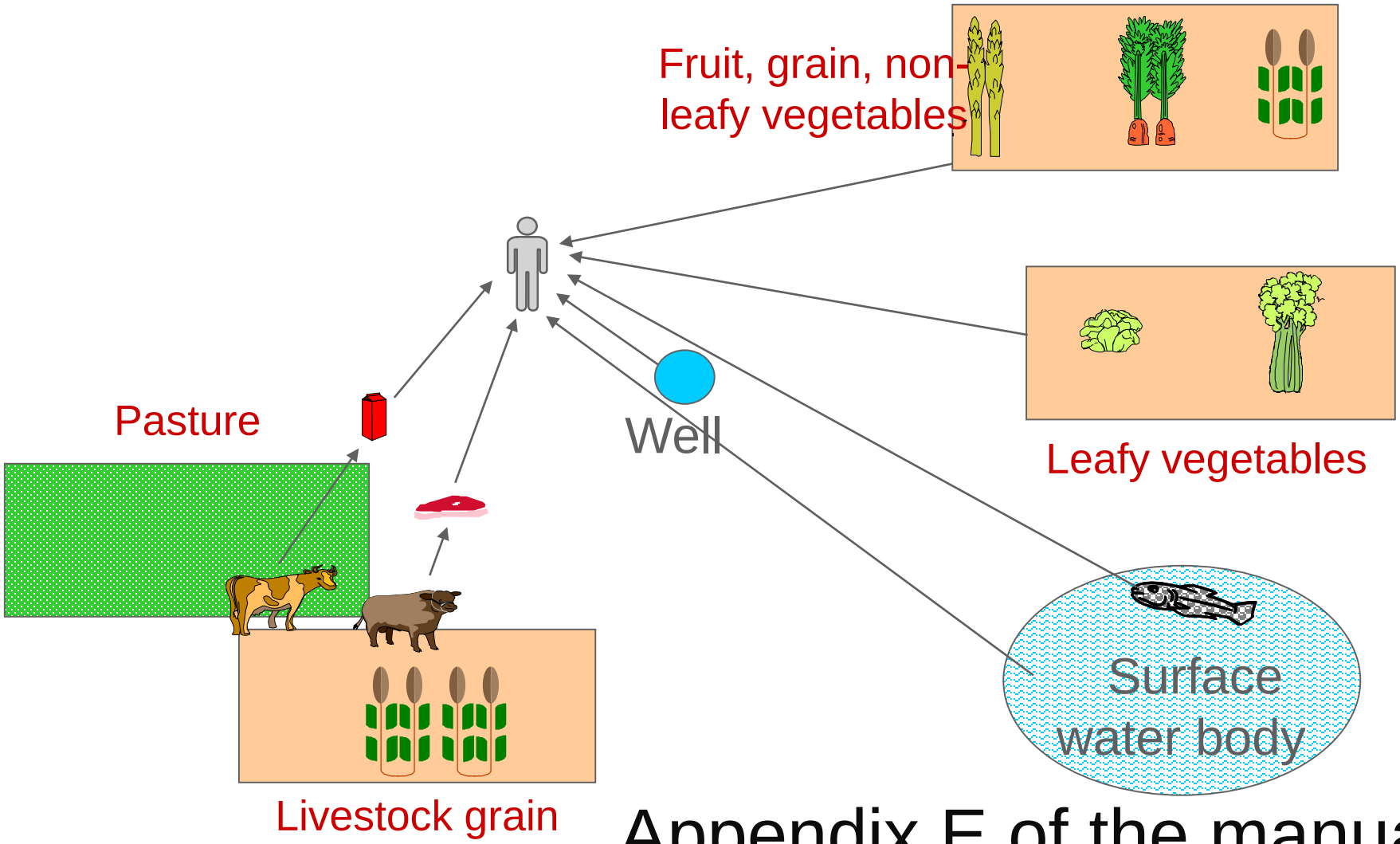
Appendix B of the manual

Inhalation Exposure Pathway – Particulates



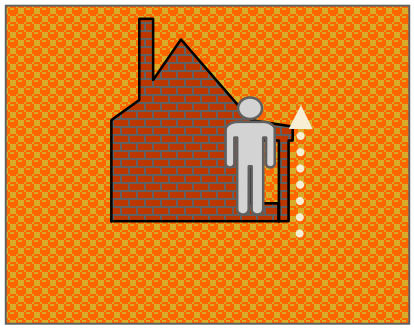
Appendix C of the manual

Ingestion Exposure Pathway – Food and Water



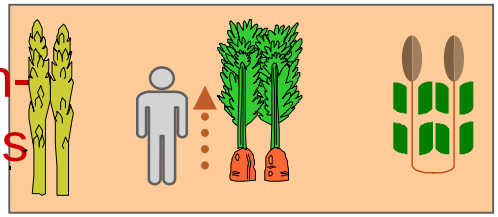
Appendix E of the manual

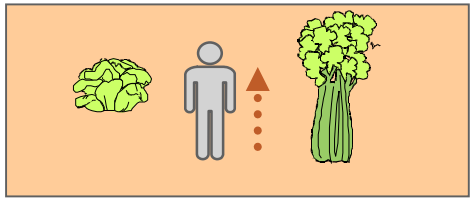
Ingestion Exposure Pathway – Soil



Primary contamination

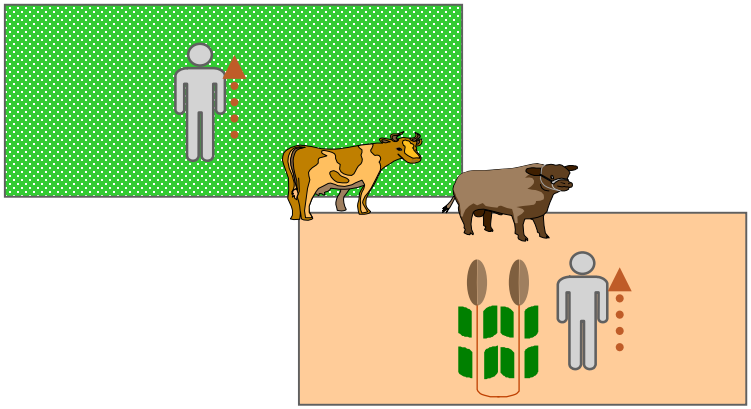
Fruit, grain, non-leafy vegetables



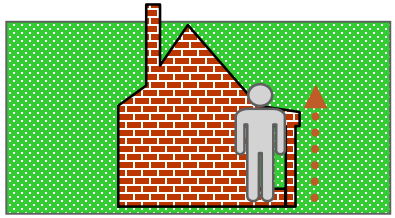


Leafy vegetables

Pasture

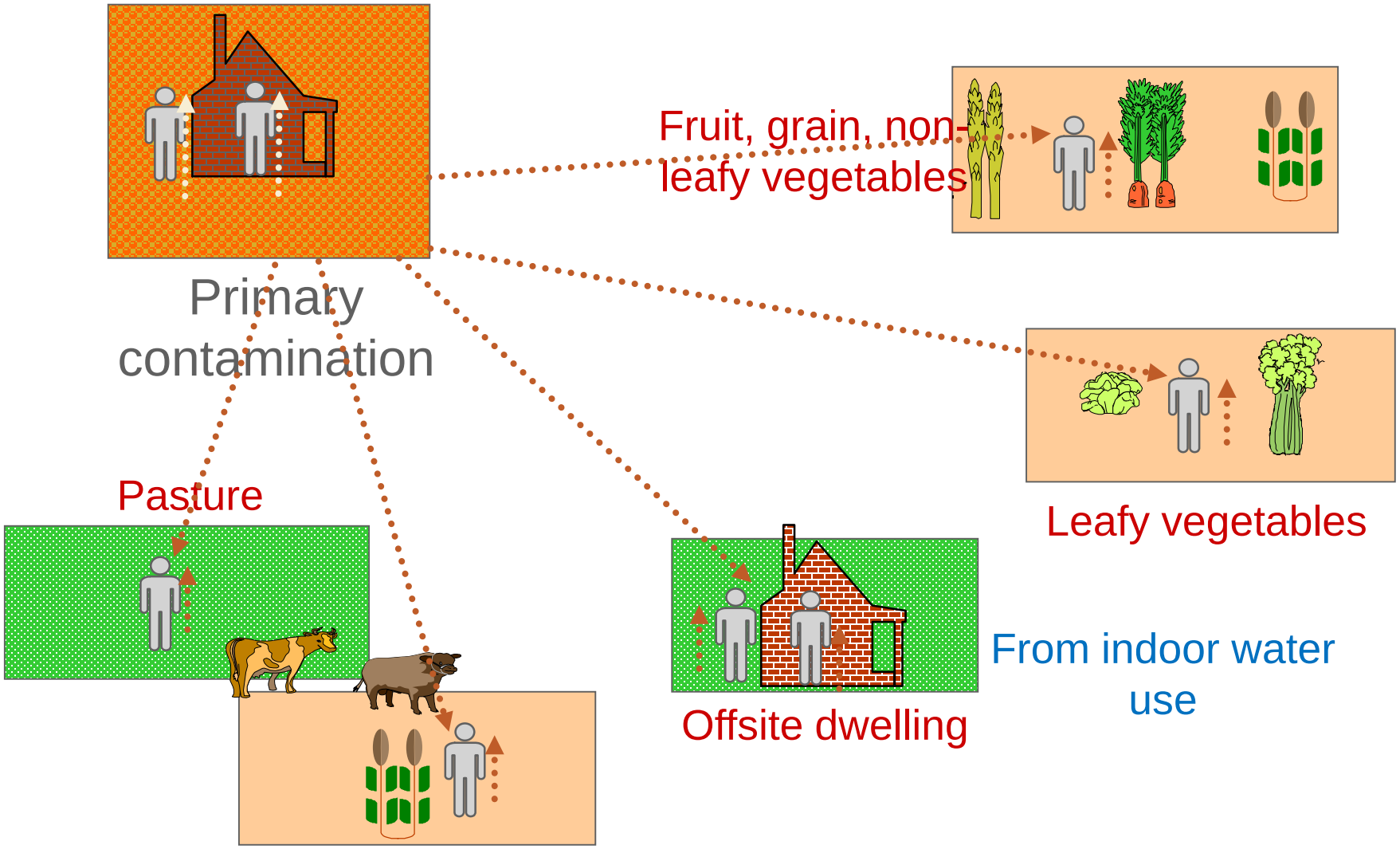


Livestock grain



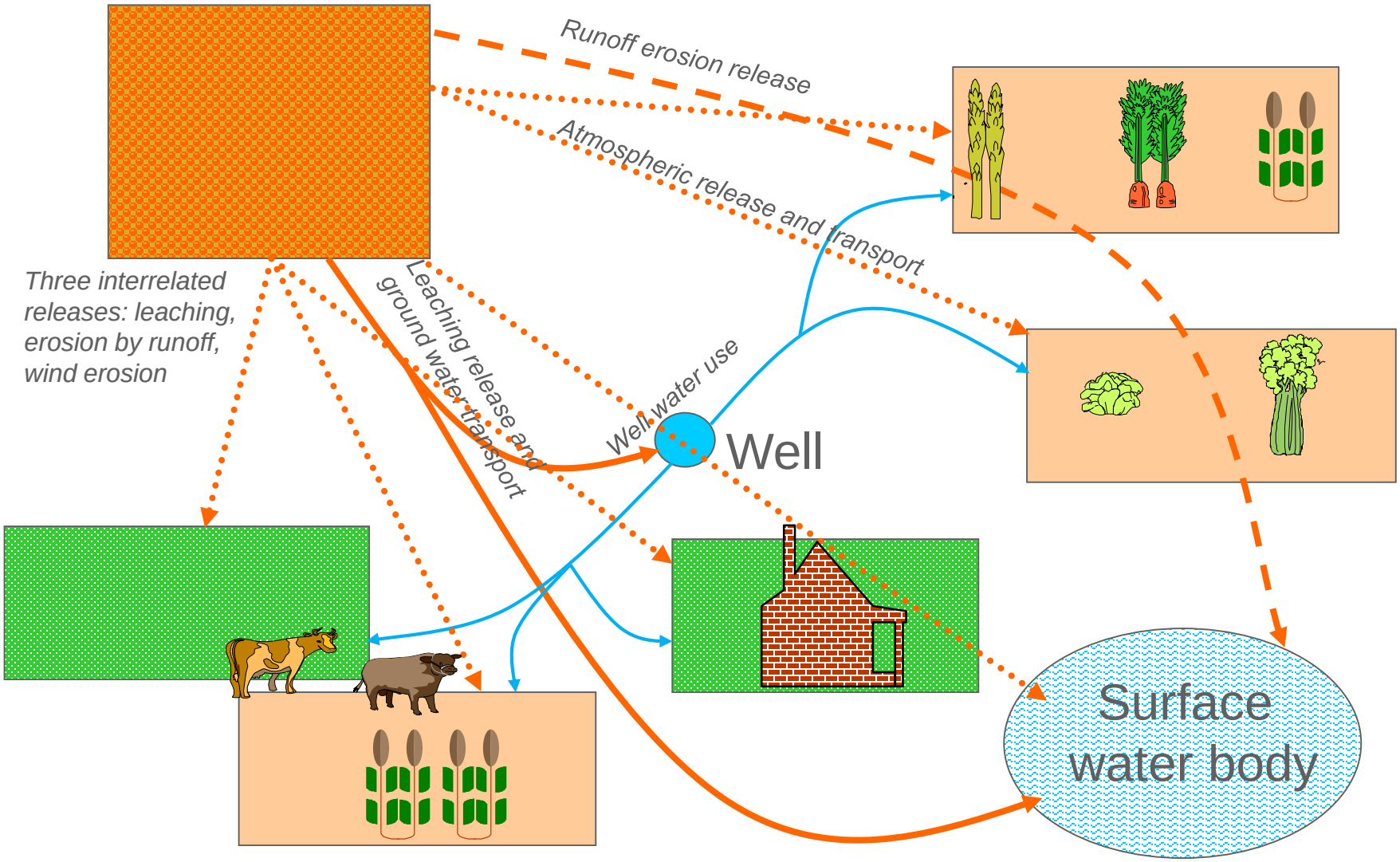
Offsite dwelling

Inhalation Exposure Pathway – Radon

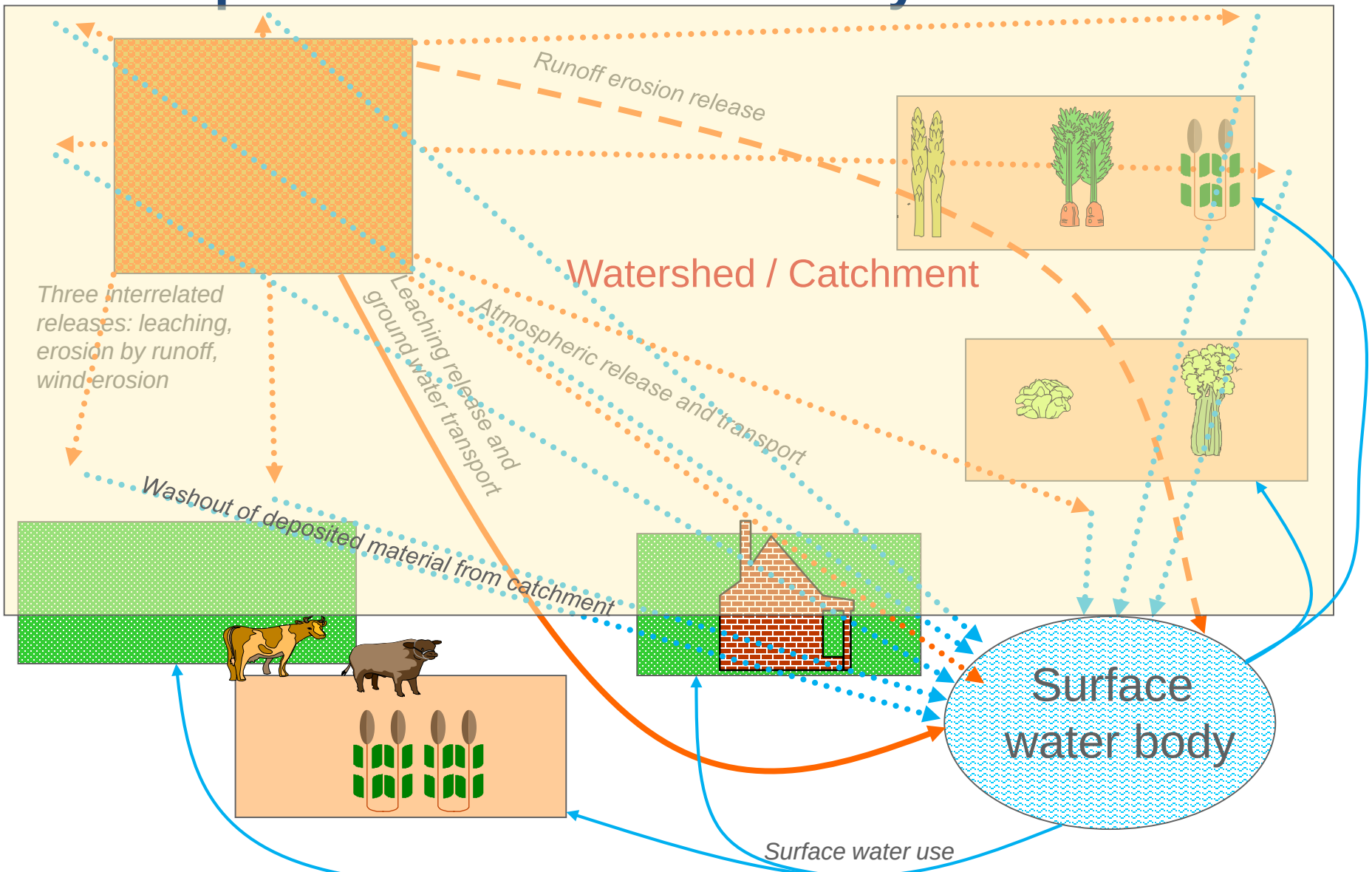


Appendix D of the manual

Transport to Areas of Secondary Contamination

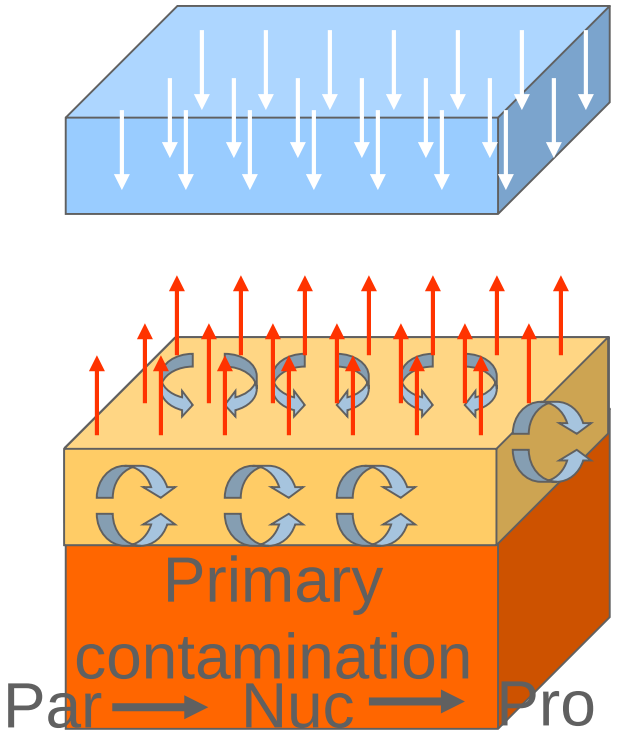


Transport to Surface Water Body



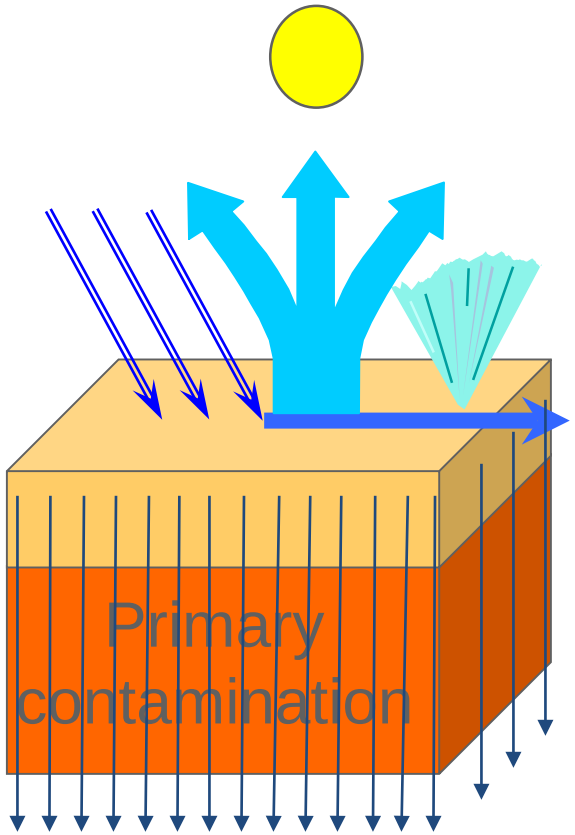
Processes modeled in the Primary Contamination (1)

- Radiological transformations
- Mixing of the surface layer
- Exchange of particulates between the surface layer and the atmosphere
  - Release of gases for ^{3}H, ^{14}C, ^{220}Rn and ^{222}Rn



Processes modeled in the Primary Contamination (2)

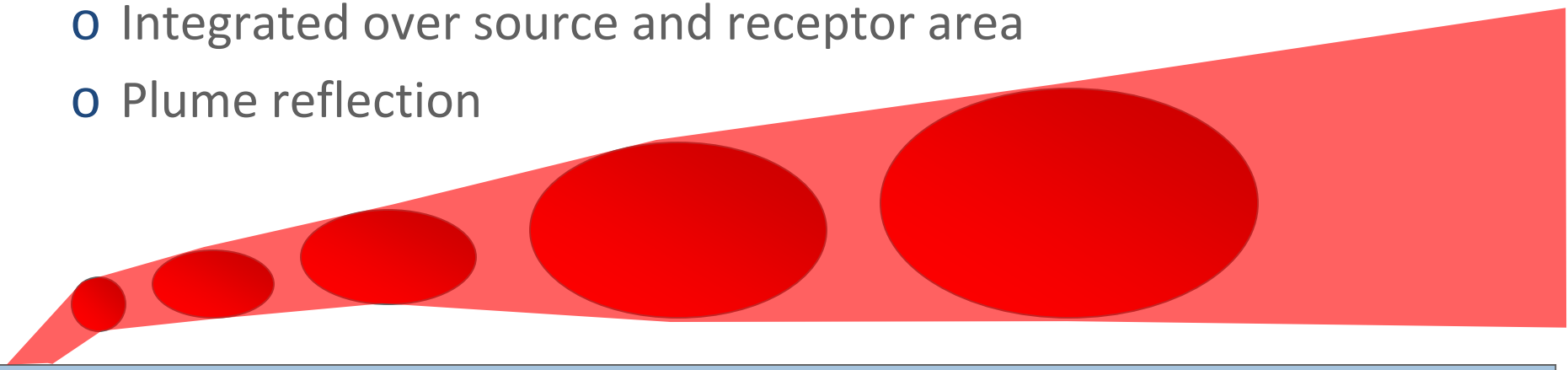
- Removal of particulates by water runoff
- Removal of radionuclides by infiltrating water
- Failure of Engineered Barriers over time



Appendix G of the manual

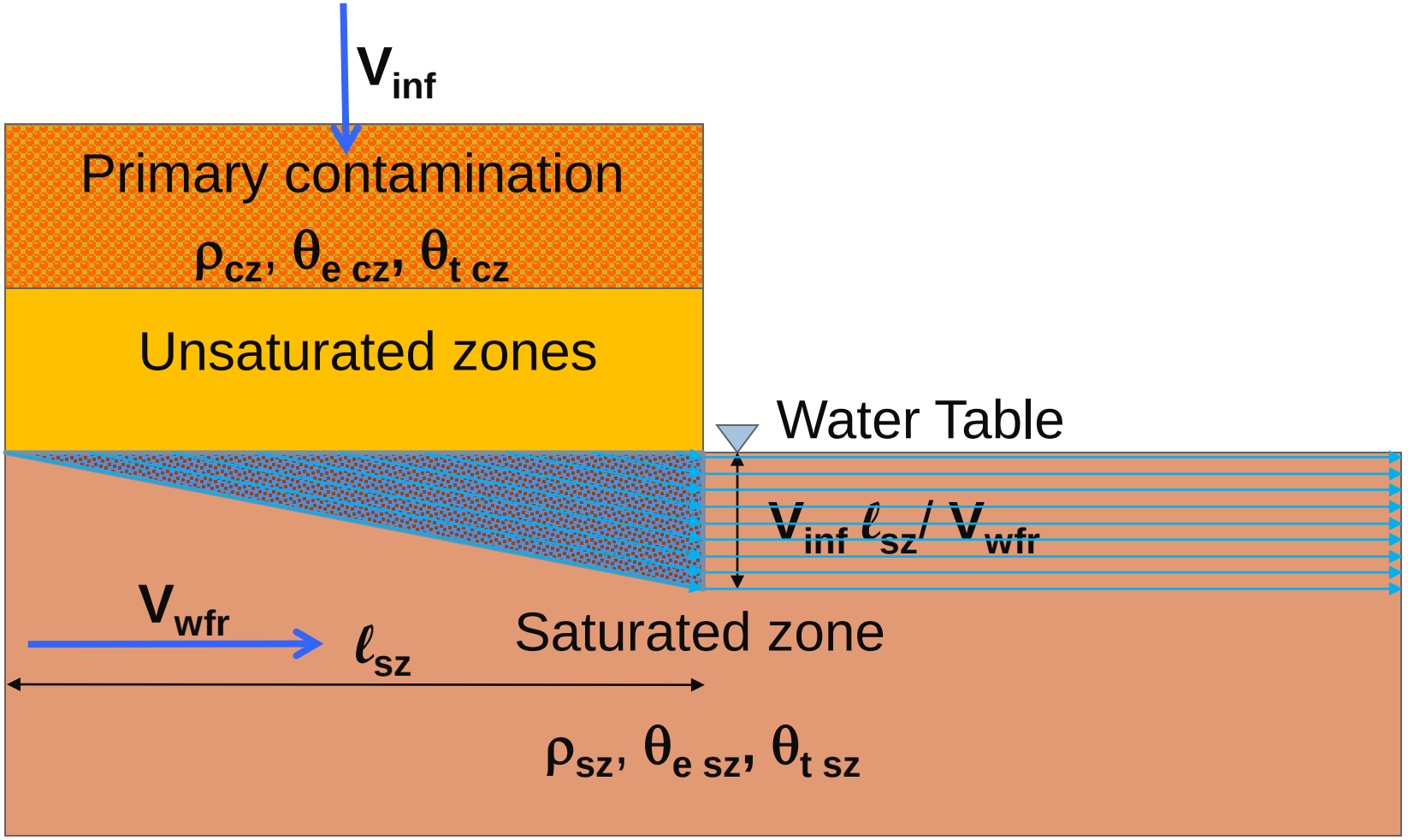
Gaussian Puff

- Chronic Gaussian plume area source
  - Based on discrete puff point source
  - Plume depletion
    - Dry and wet deposition
    - Conservation of mass
  - Sector average time-integrated air concentrations
  - Integrated over source and receptor area
  - Plume reflection



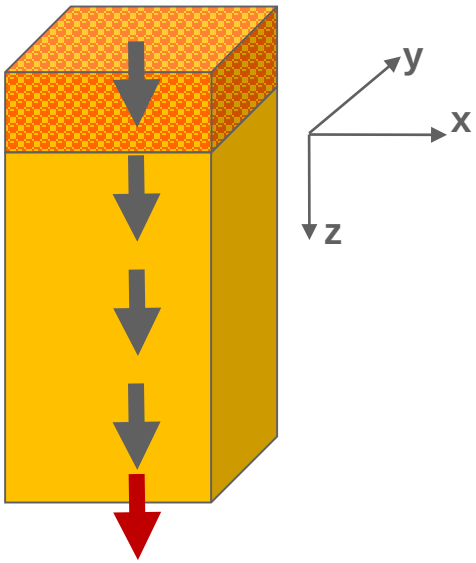
Appendix I of the manual

Conceptualization for Groundwater Transport
Unsubmerged Primary Contamination



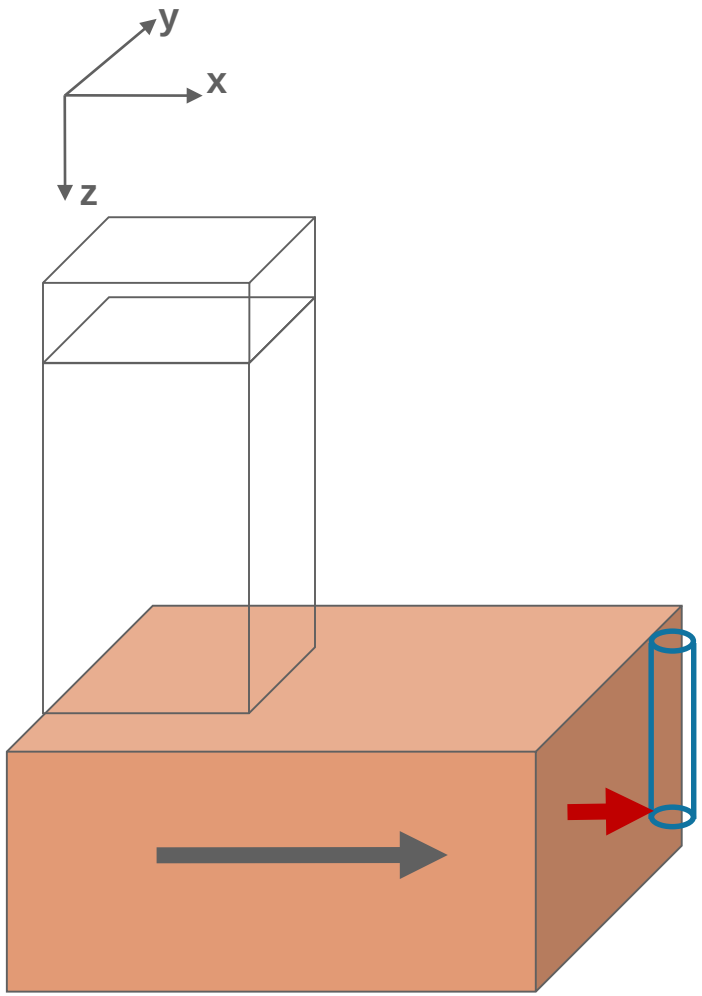
Appendix H of the manual

Processes Modeled for Vertical Transport in the Unsaturated Zones



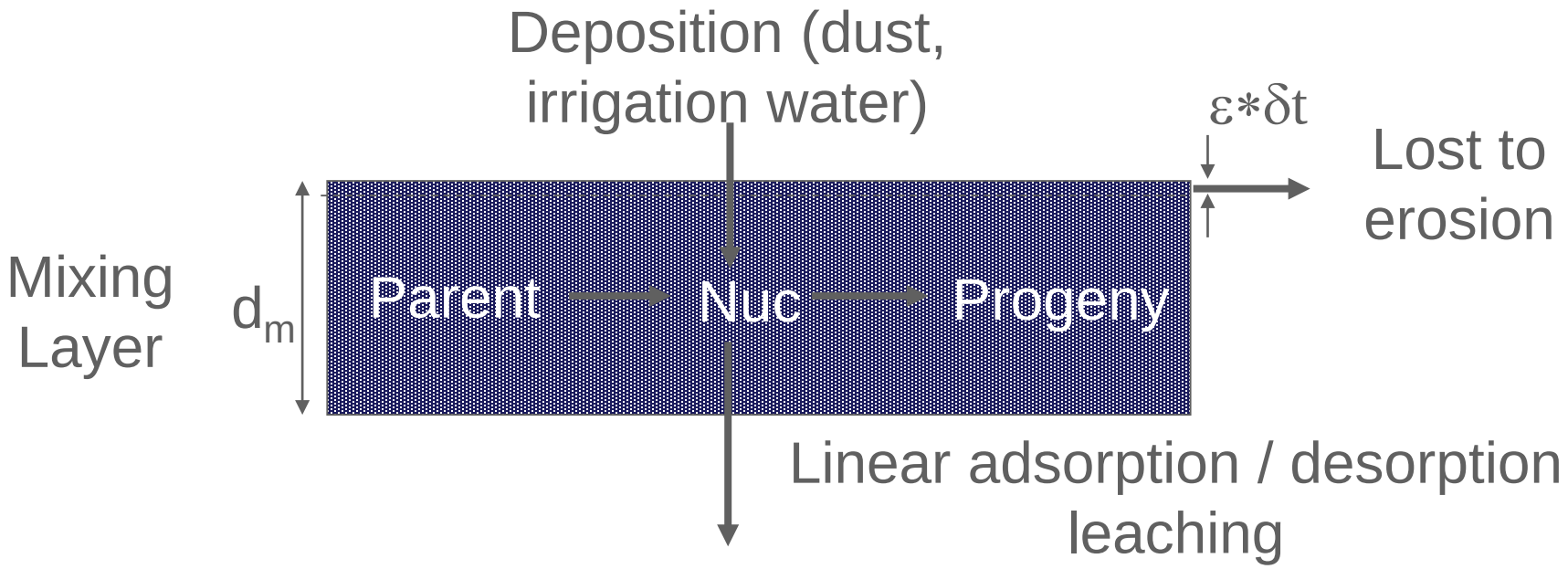
- Vertical transport
  - Longitudinal (z) advection
  - Longitudinal (z) dispersion
  - Transformations during transport
  - Nuclide specific solute-soil interaction
    - Transport rate
    - Concentration in water
- Areally integrated flux to water table

Processes Modeled Saturated Zone Transport



- Longitudinal (x) advection
- Longitudinal (x) dispersion
- Nuclide specific solute-soil interaction
- Transverse (y, z) dispersion
- Areally integrated flux to surface water body
- Concentration in well water
- Uniformly spaced computation time points require smaller execution time

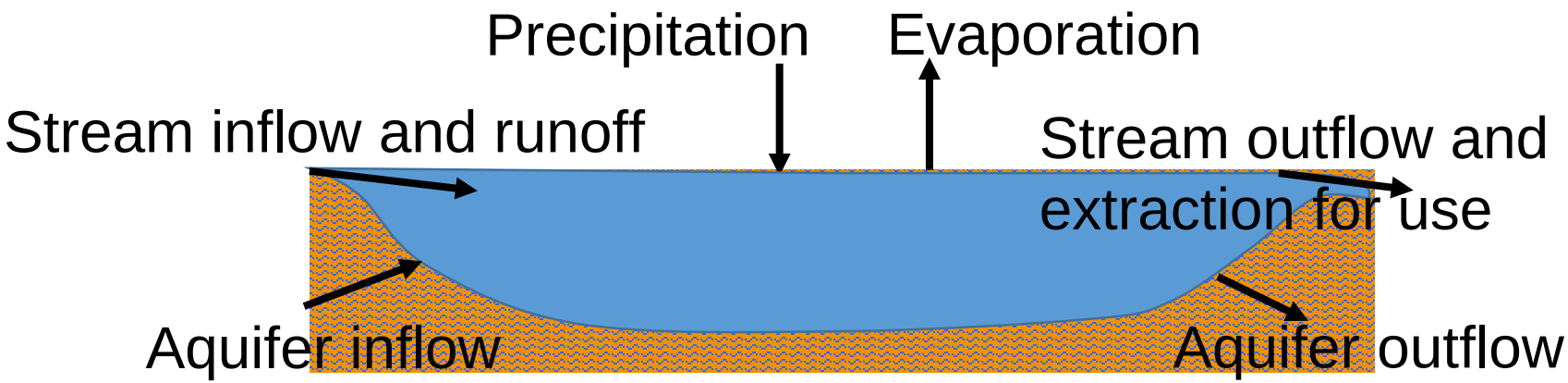
Process Modeled for Accumulation in Offsite Soil



- Process modeled
  - Uniform mixing within mixing layer
  - Loss due to surface erosion
  - Linear adsorption desorption
  - Radiological transformations
  - Time dependent deposition

Appendix J of the manual

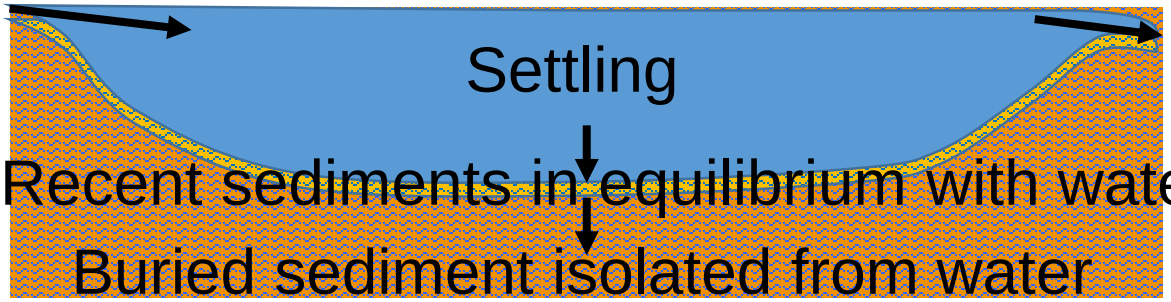
Process Modeled for Surface Water Body - Water Balance



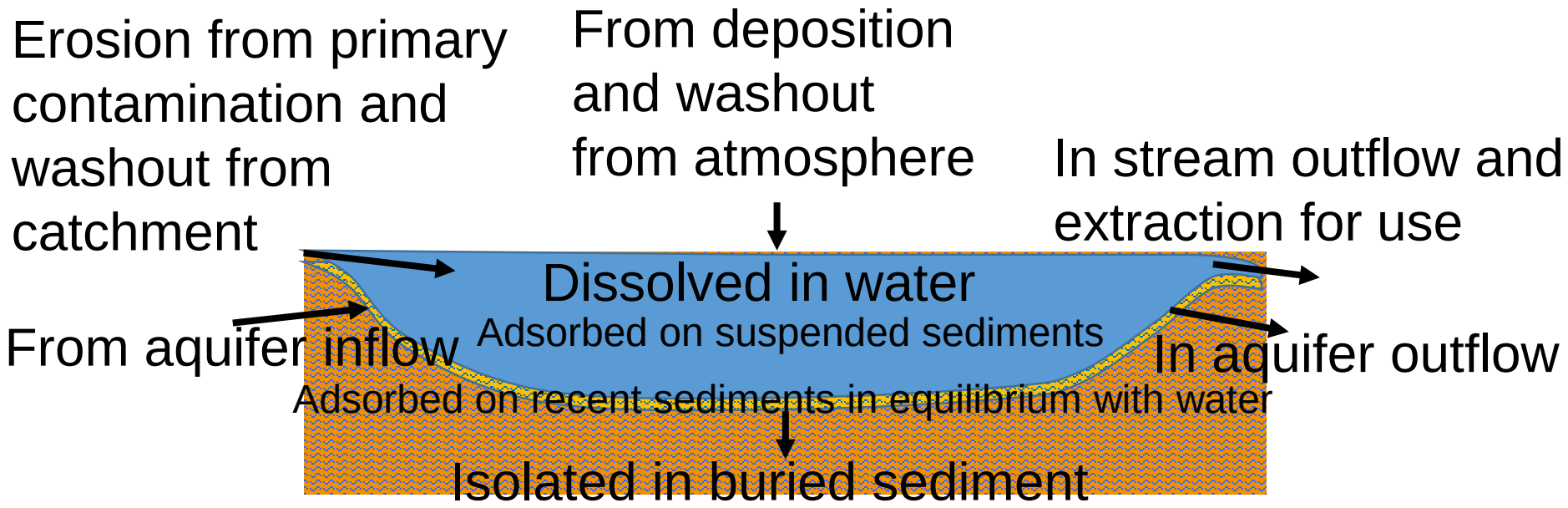
Process Modeled for Surface Water Body - Sediment/particulate Balance

Erosion from catchment

In stream outflow and extraction for use

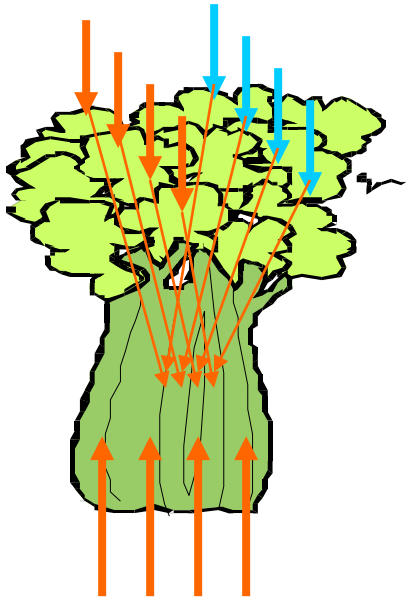


Process Modeled for Surface Water Body - Nuclide Balance



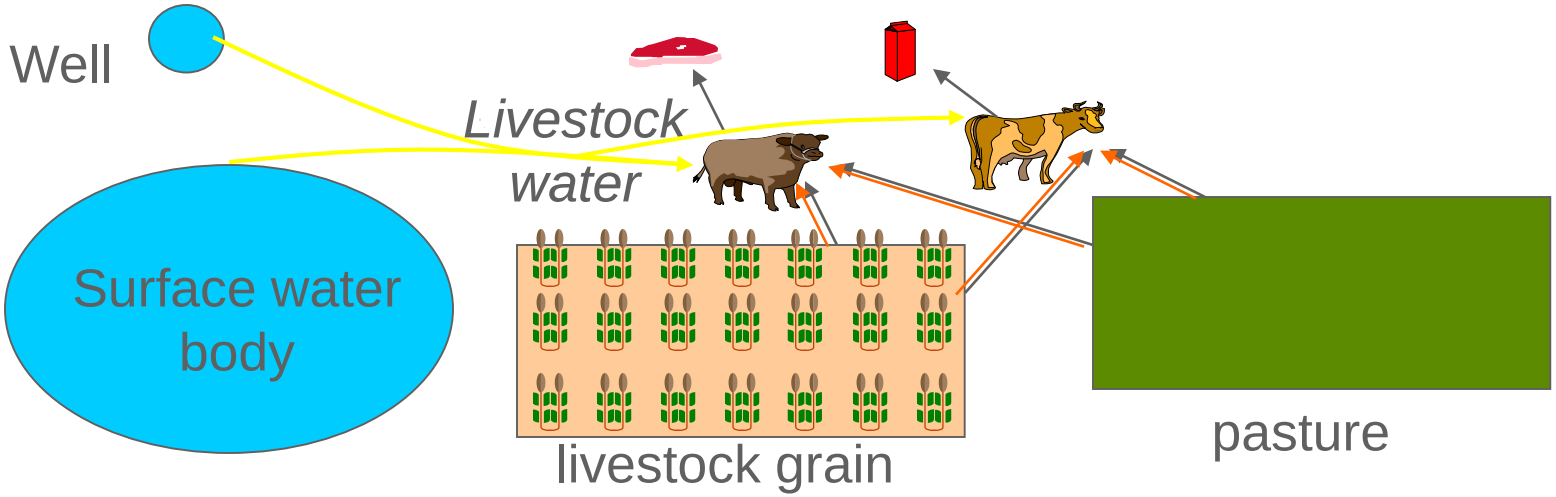
Process Modeled for Contamination of Plant Food

- Root uptake from soil
- Foliar interception of contaminated dust
- Foliar interception of contaminated irrigation
- Translocation of intercepted contamination to edible part of plant



Contamination of Meat and Milk

- Ingestion of contaminated feed (grain, grass)
- Ingestion of soil with feed
- Ingestion of contaminated water
- Transfer to milk or accumulation in meat



Argonne NATIONAL LABORATORY

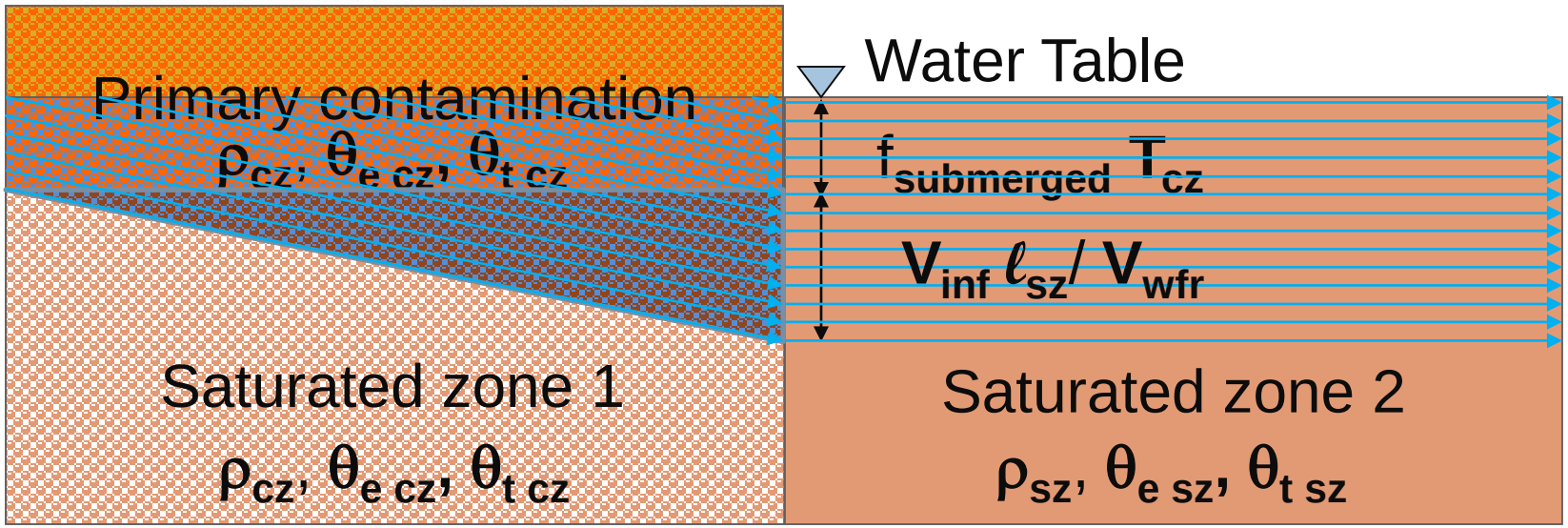
Demonstration of RESRAD-OFFSITE Code

U.S. DEPARTMENT OF ENERGY

Conceptualization of Primary Contamination

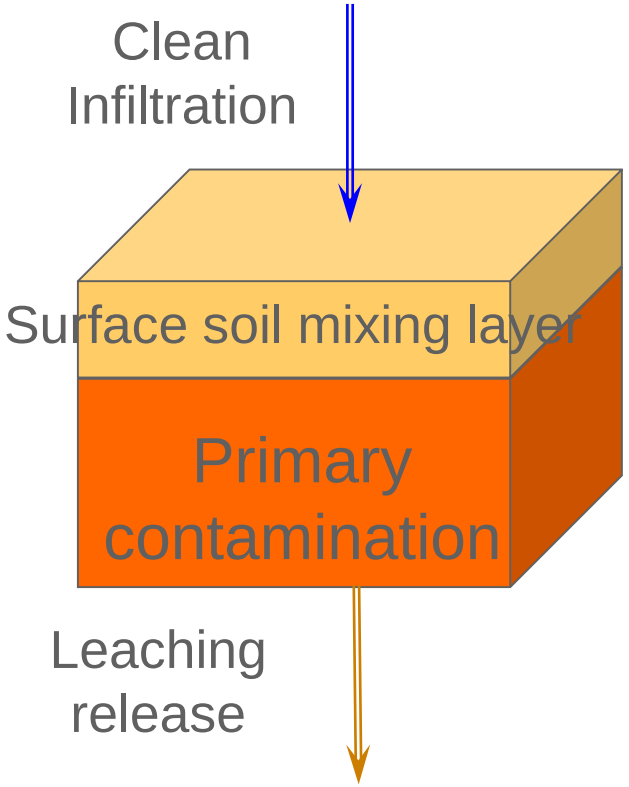
- Is a layer of “soil”
  - Uniform thickness
  - Homogeneous
    - Uniformly contaminated
- There may be a layer of clean cover above it
- Can be located
  - above the water table
  - straddling the water table
  - just below the water table
    - with top of primary contamination at the water table

Conceptualization for Groundwater Transport
Partially Submerged Primary Contamination



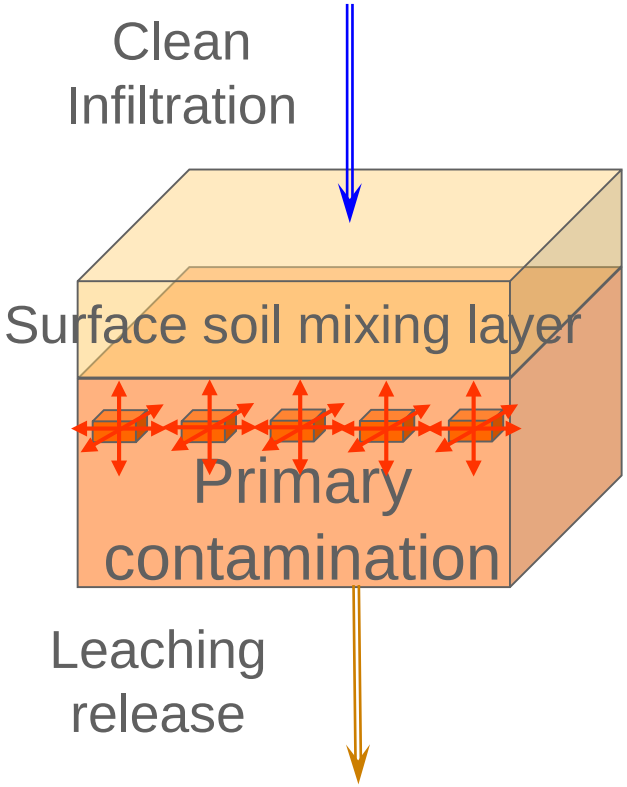
Leaching Release to Infiltration

- Equilibrium release options
  - Adsorption – desorption
    - Distribution coefficient of **isotope**
    - $cm^3\ g^{-1}$ (≡ 0.001 $m^3\ kg^{-1}$)
  - Precipitation – dissolution
    - Total soluble concentration of **element**
    - g atomic weights in a liter
    - g/L ÷ atomic weight (g)
- Rate controlled release option
  - Leach rate of **isotope**
    - 1/year



Diffusive Release to Infiltration

- Negligible infiltration through contaminated media
  - Infiltration is through the surrounding soil
- Adsorption – desorption equilibrium of radionuclides between the solid phase and the moisture in the contaminated media
  - Distribution coefficient of **isotope**
- Diffusive transport out of contaminated media into surrounding soil
  - Diffusion coefficient of **isotope**
    - m^2/year



Dispersion Coefficients

- Pasquill-Gifford stability classes (A through F)
- Pasquill coefficients (ground-level release)

$$\sigma_z' = ax^b + c$$

- Briggs coefficients (rural or urban)

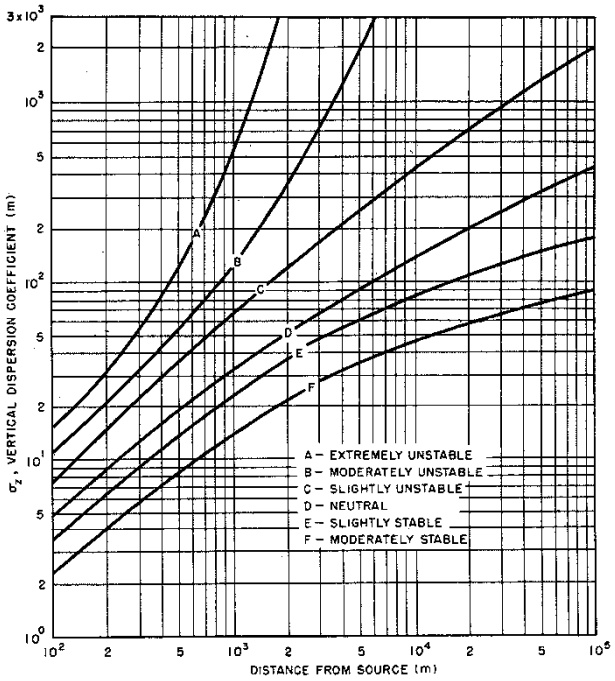
$$\sigma_z' = ax(1+bx)^c$$

- Buoyancy induced dispersion

$$\sigma_{zb} = \frac{\Delta h}{3.5}$$

- Final form

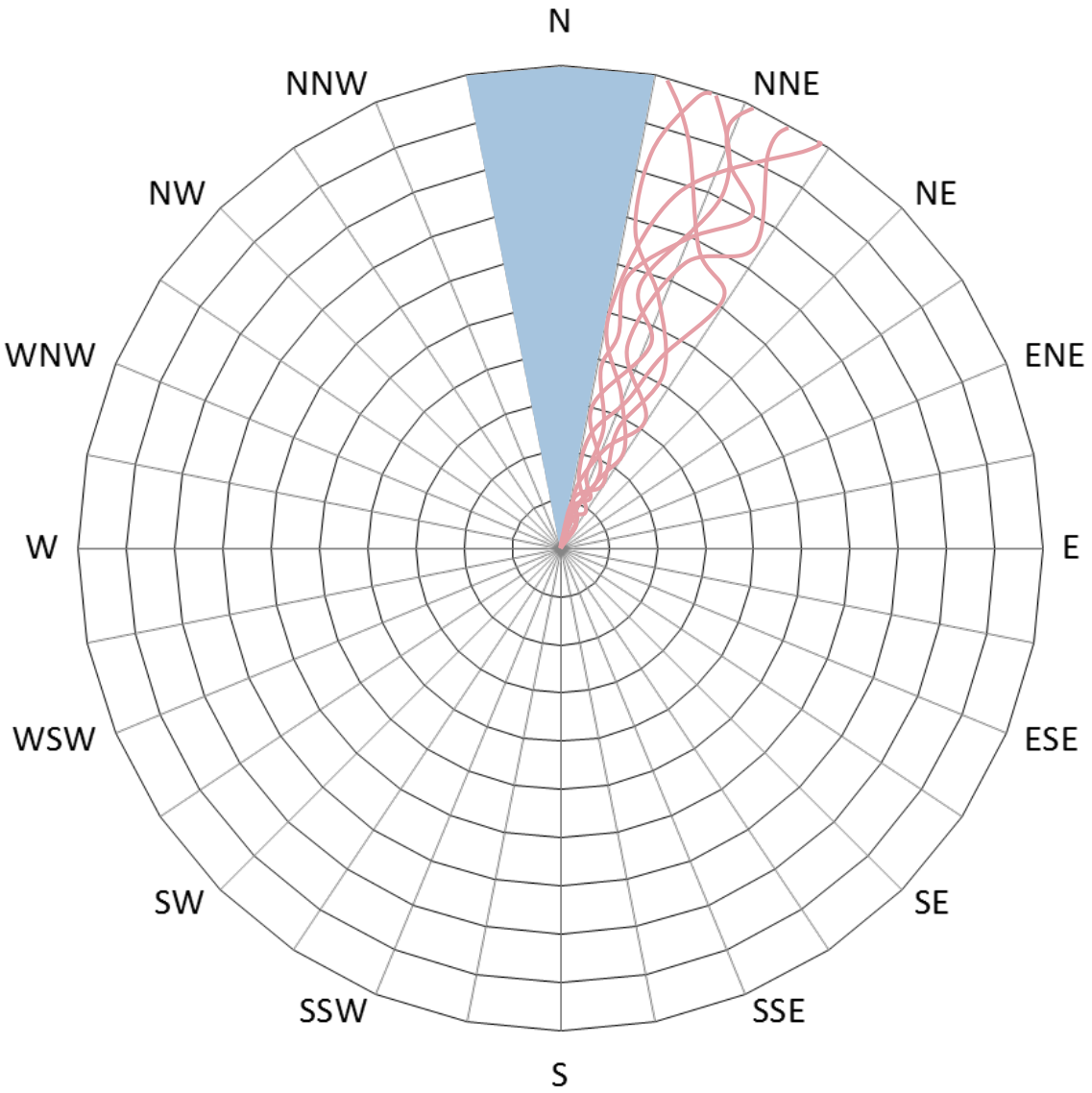
$$\sigma_z = \left(\sigma_{zb}^2 + \sigma_z'^2\right)^{1/2}$$



Meteorology and Atomic Energy 1968
Air Resources Laboratories
U.S. Dept. of Commerce, 1968

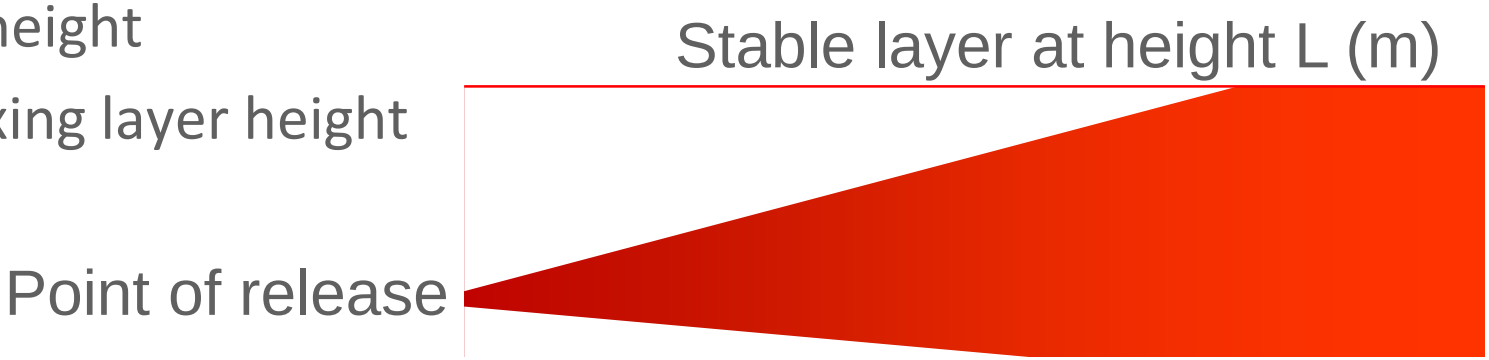
Meteorological Data Grid

- 16 directions
- 22.5º sectors
- Sector averaged



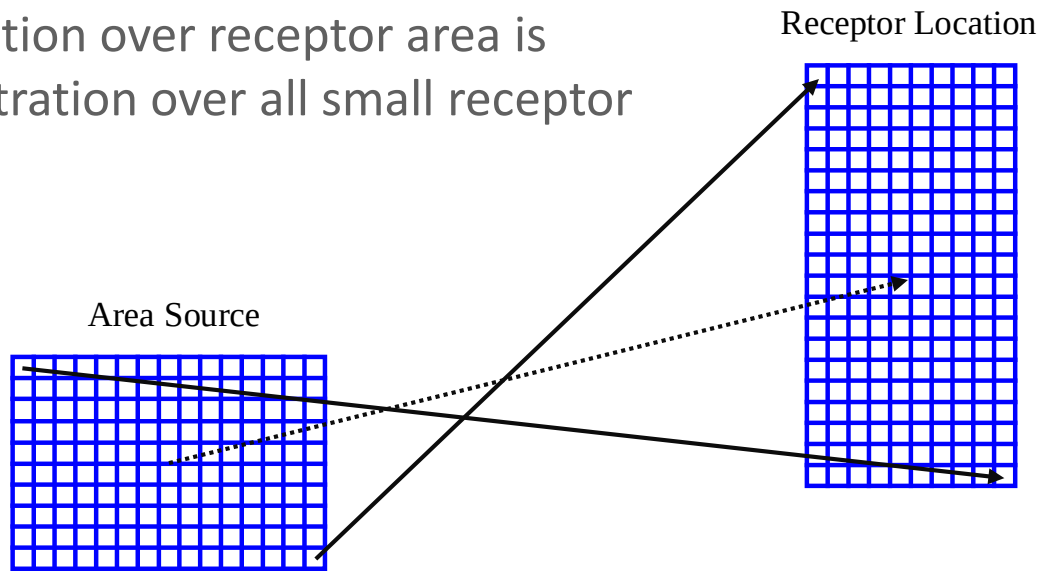
Plume Reflection

- Plume may become confined by a stable layer
  - lid height
  - mixing layer height



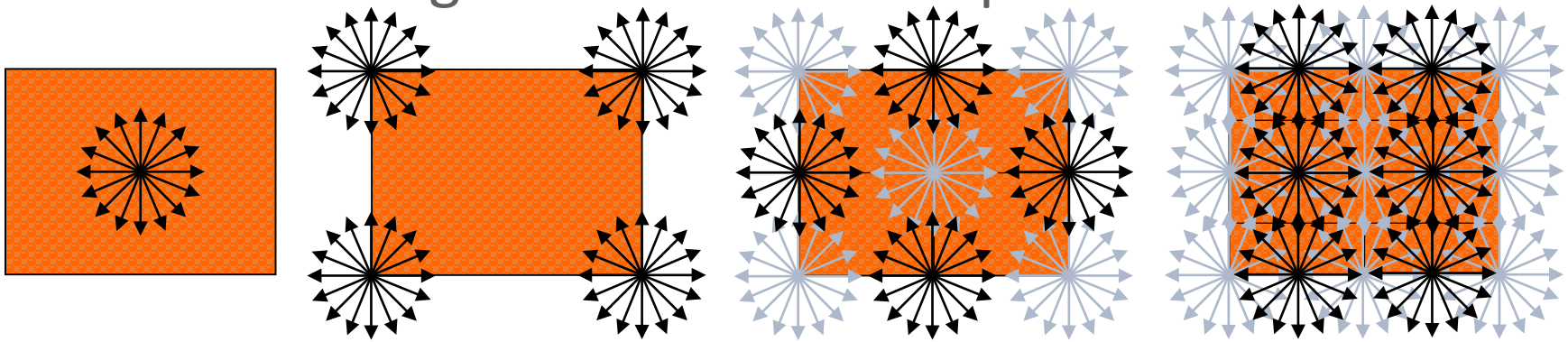
Area Source Model

- Source and receptor areas segmented by uniform grids into smaller rectangles
- Point-to-point dispersion estimates from center of source rectangles to center of receptor rectangles
- Air concentration over small receptor rectangle point is the sum of contributions from all small source rectangles
- Average air concentration over receptor area is average of air concentration over all small receptor rectangles



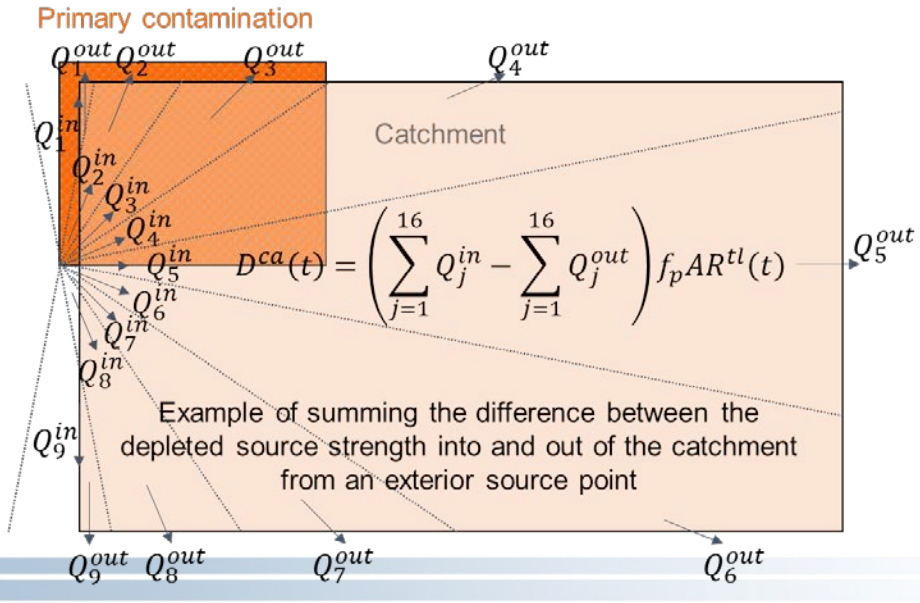
Wet and Dry Deposition over the Catchment

- Use increasing number of source points

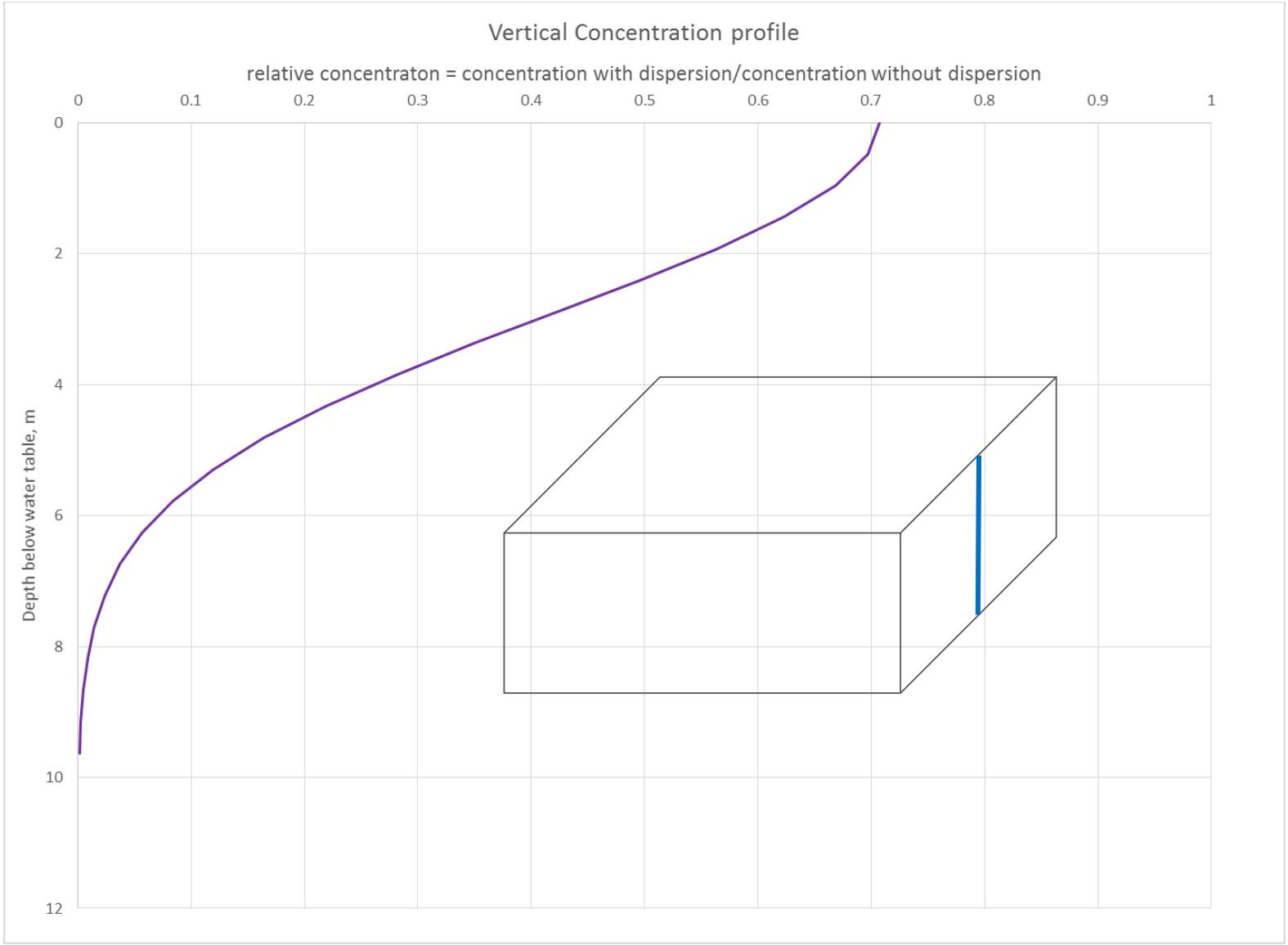


1 point 2 x 2 points 3 x 3 points 5 x 3 points

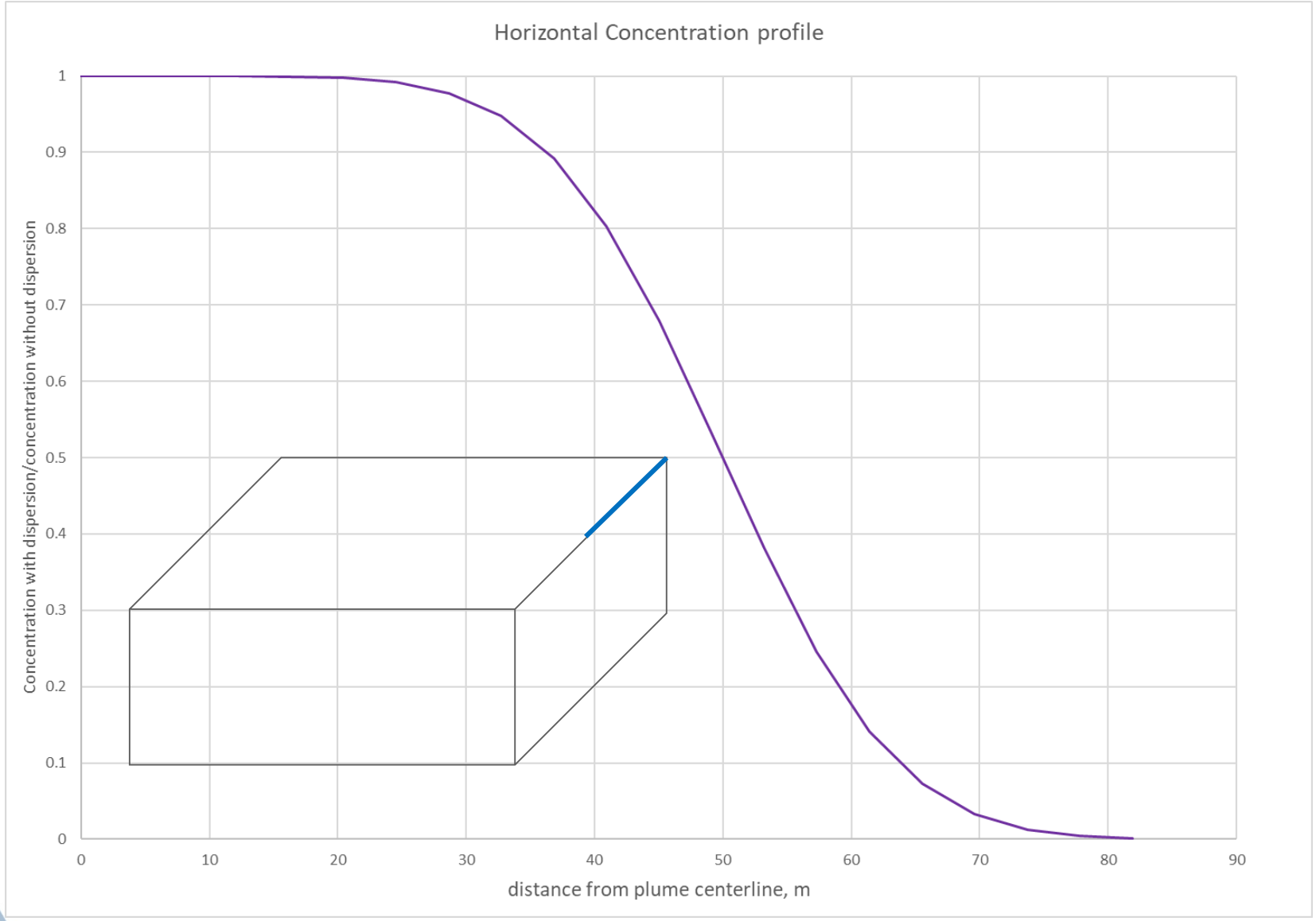
- Calculate deposition over catchment from each source point



Vertical Concentration Profile in Aquifer

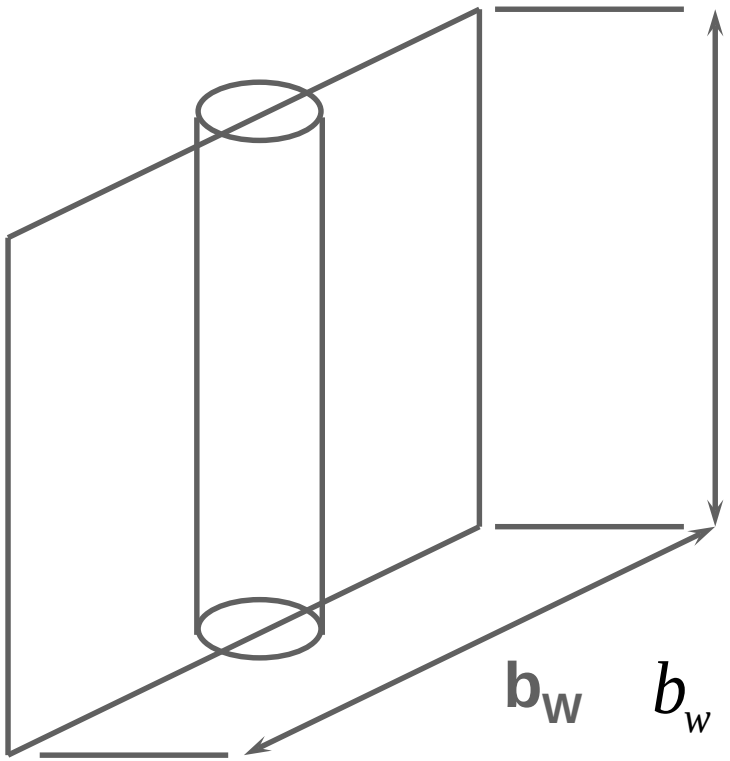


Horizontal Concentration Profile in Aquifer



Concentration in Well Water

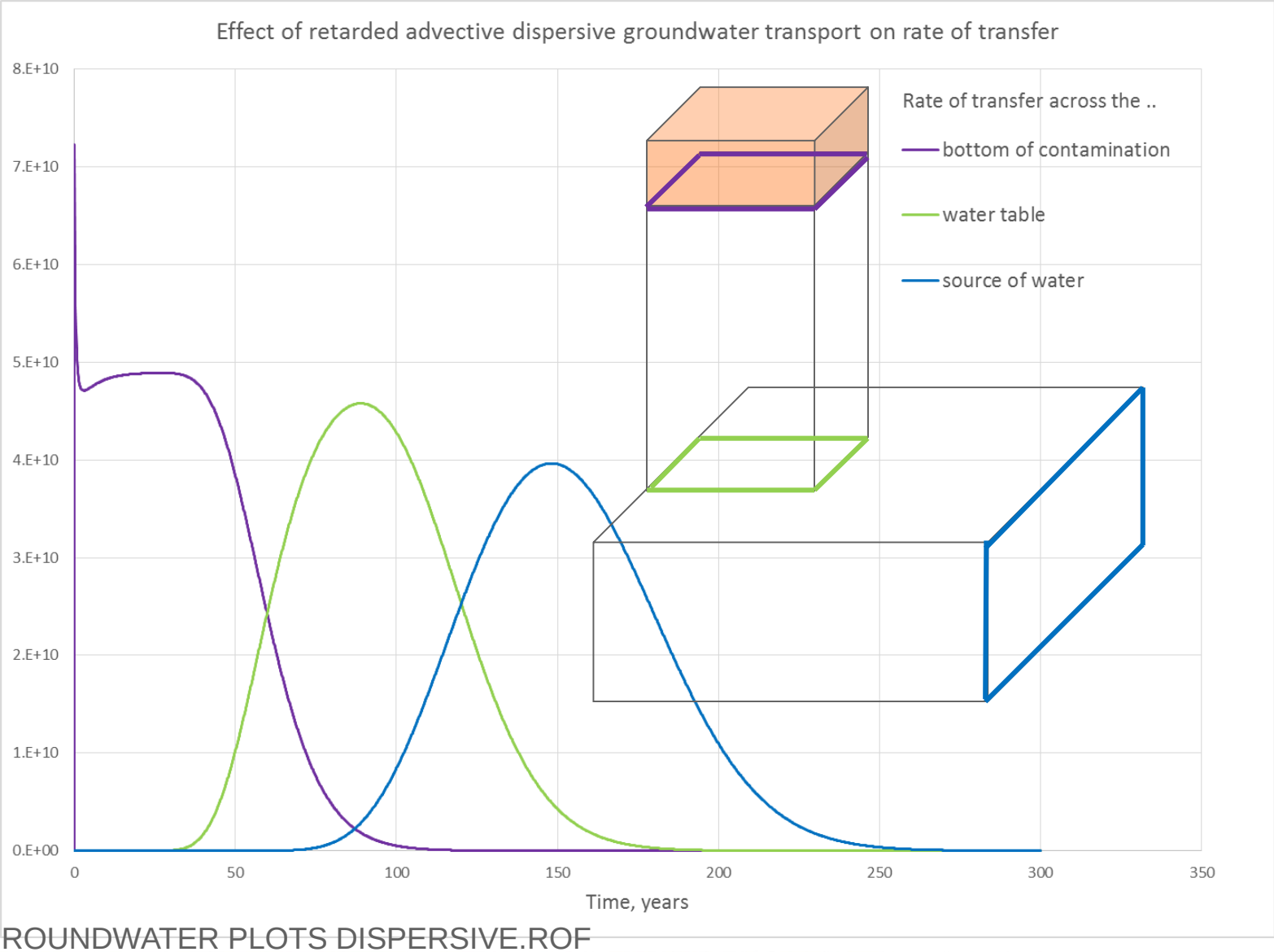
- Average of concentration over the area of the aquifer contributing to the well



$$c_w(t) = \frac{\int_0^{d_w}\int_{-r_w}^{r_w} c_{aq}(x,y,z,t)\,dy\,dz}{2d_w r_w}$$

$$b_w = \frac{U_w}{V_d d_w} \qquad r_w = \frac{b_w}{2}$$

Retarded Advective Dispersive Transport in Groundwater



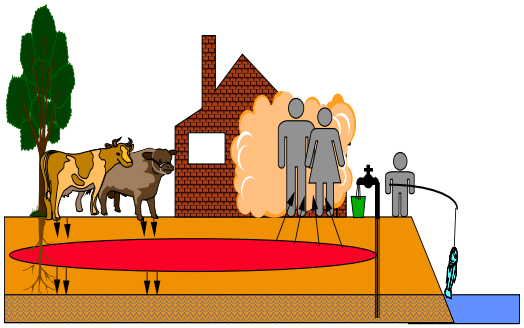
GROUNDWATER PLOTS DISPERSIVE.ROF

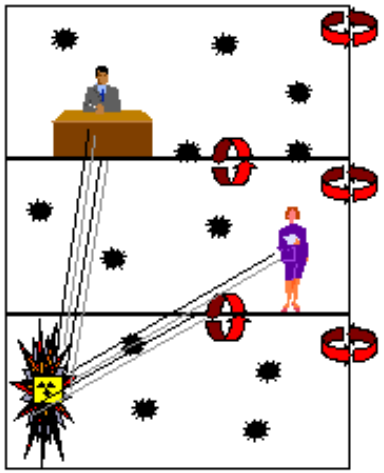
Break / Q&A

Overview of RESRAD-BUILD

Comparison of RESRAD-ONSITE and RESRAD-BUILD

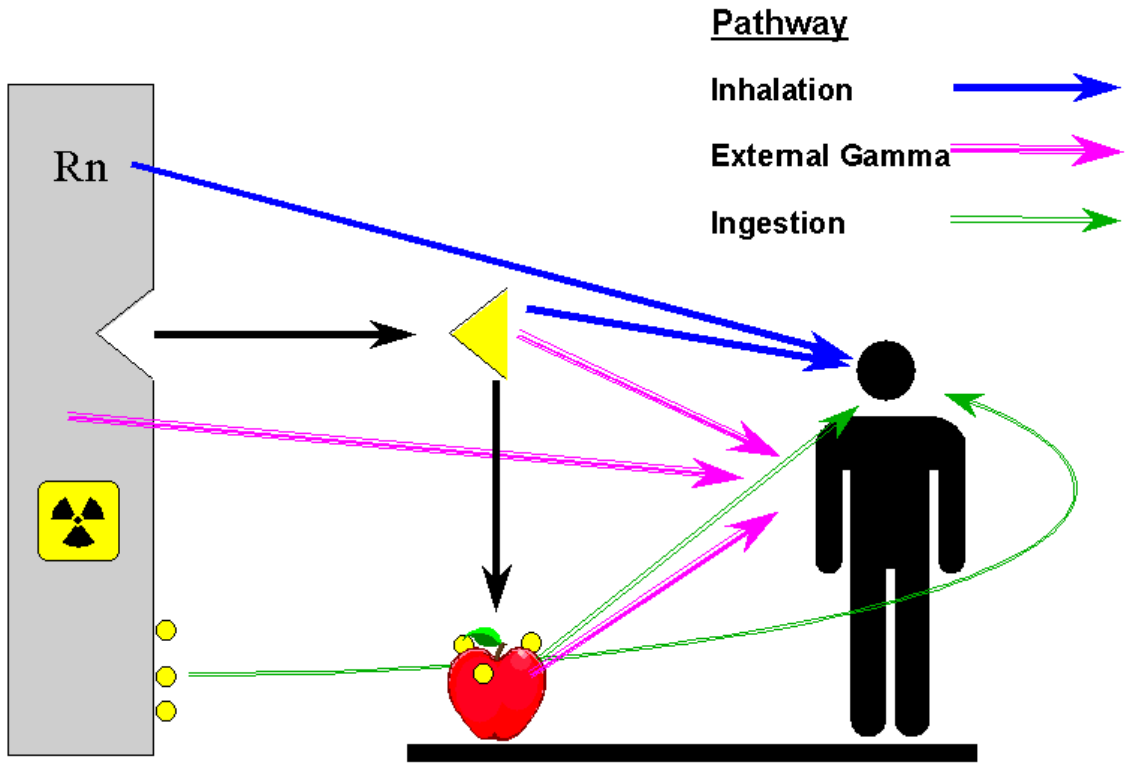
- RESRAD-ONSITE (soil) and RESRAD-BUILD (building) codes address different contamination sources and uses:
  - Soil contamination which might lead to foodstuffs and water contamination through movement by natural processes
  - Building contamination in man-made products and air-flows which might lead to exposure during normal building occupancy and/or D&D activities





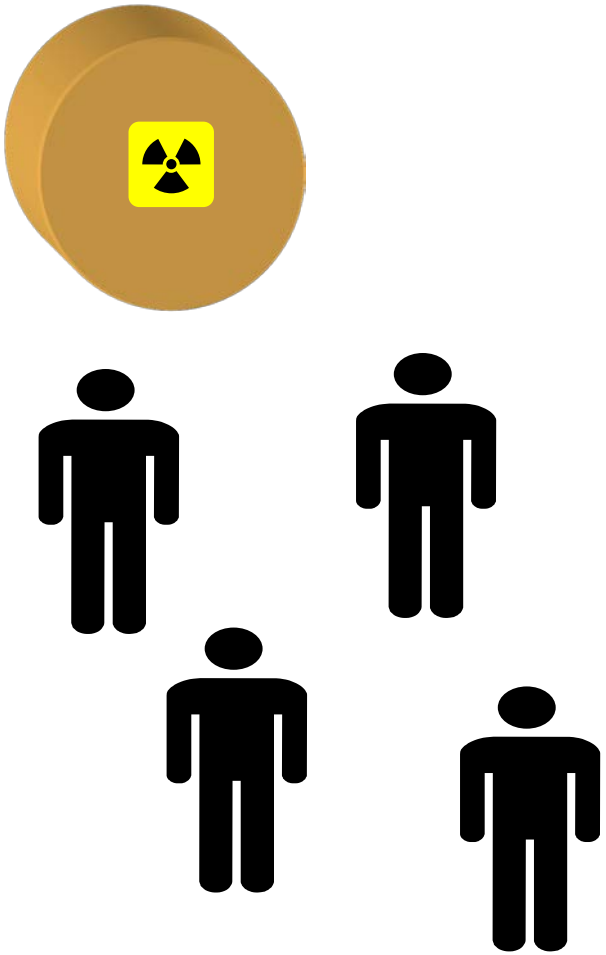
Pathways Considered in RESRAD-BUILD

- Inhalation
  - Airborne
  - Resuspension
- Ingestion
  - Direct
  - Deposition
- External
  - Direct
  - Deposition
  - Immersion
- Radon



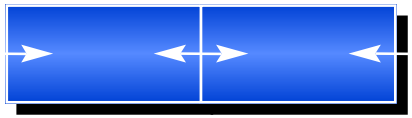
Sources and Receptors Considered

- Four distinct source types
  - Point
  - Line
  - Area
    - Circular
    - Rectangular
  - Volume
    - Circular
    - Rectangular
- Ability to co-locate sources
  - Area source above a volume source
  - Hot-spot in an area source
- Up to 10 sources in a single run
- Up to 10 receptors in a single run

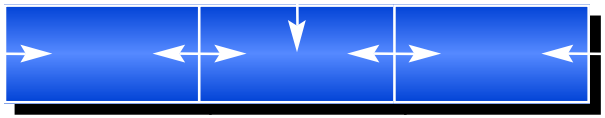


Building Geometry in RESRAD-BUILD (Version 3)

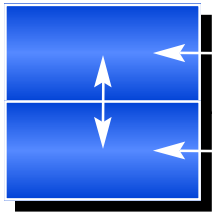
1-Room Warehouse



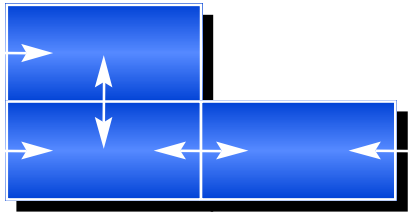
2-Room House



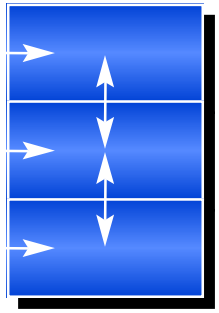
3-Room House



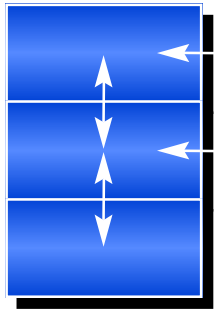
2-Story House



2-Story Building with 2 Rooms on the First Floor

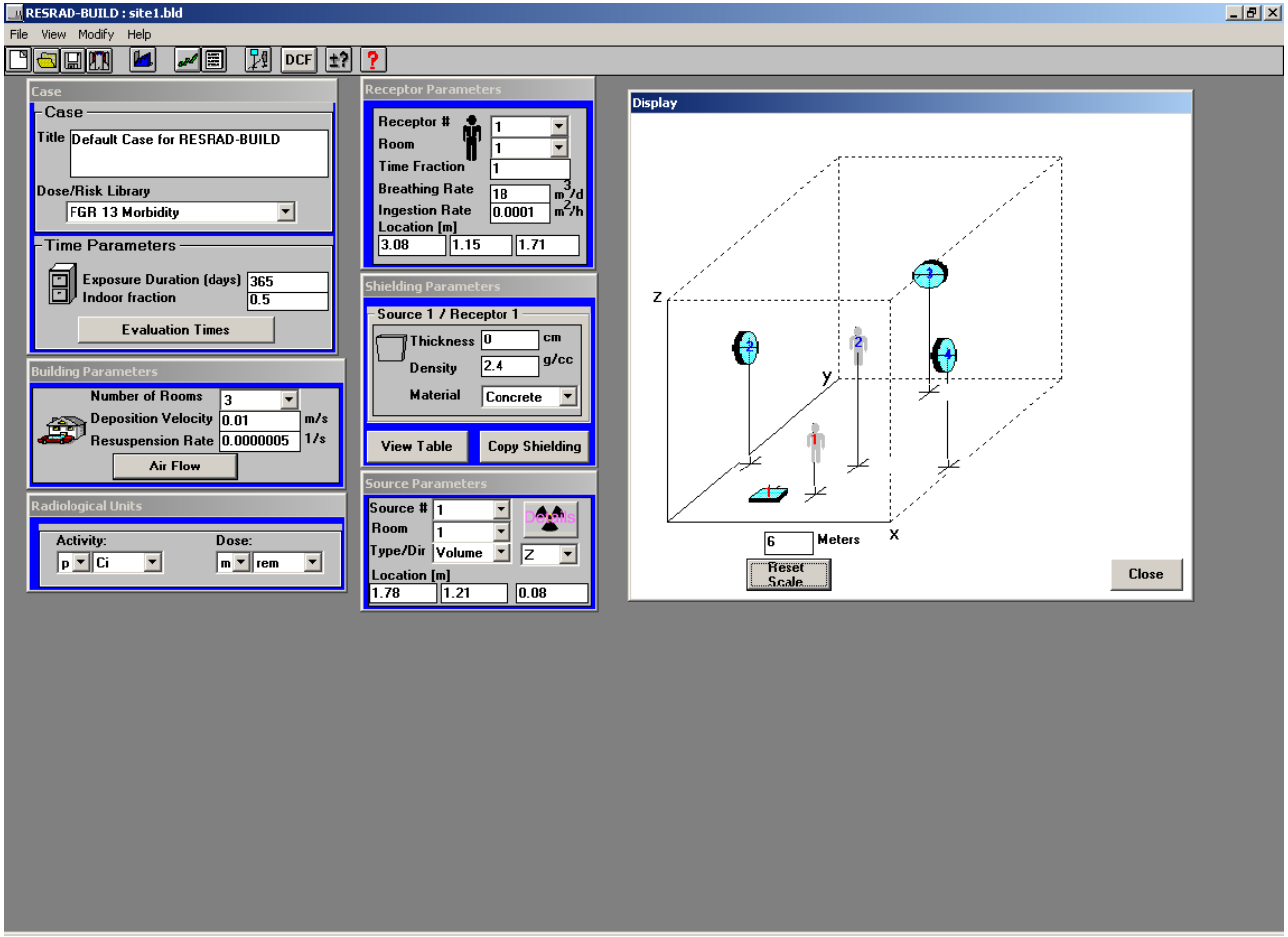


3-Story House



2-Story House with Basement (No air exchange between basement and outdoors)

RESRAD-BUILD User Interface



RESRAD-BUILD One Room Air Flow Model

$$V\,dC/dt = I - QC - \lambda VC + \lambda VC_P - \lambda_D VC + \lambda_R \lambda_D VC / (\lambda_R + \lambda)$$

Change of Activity in the room

Exchange with outside

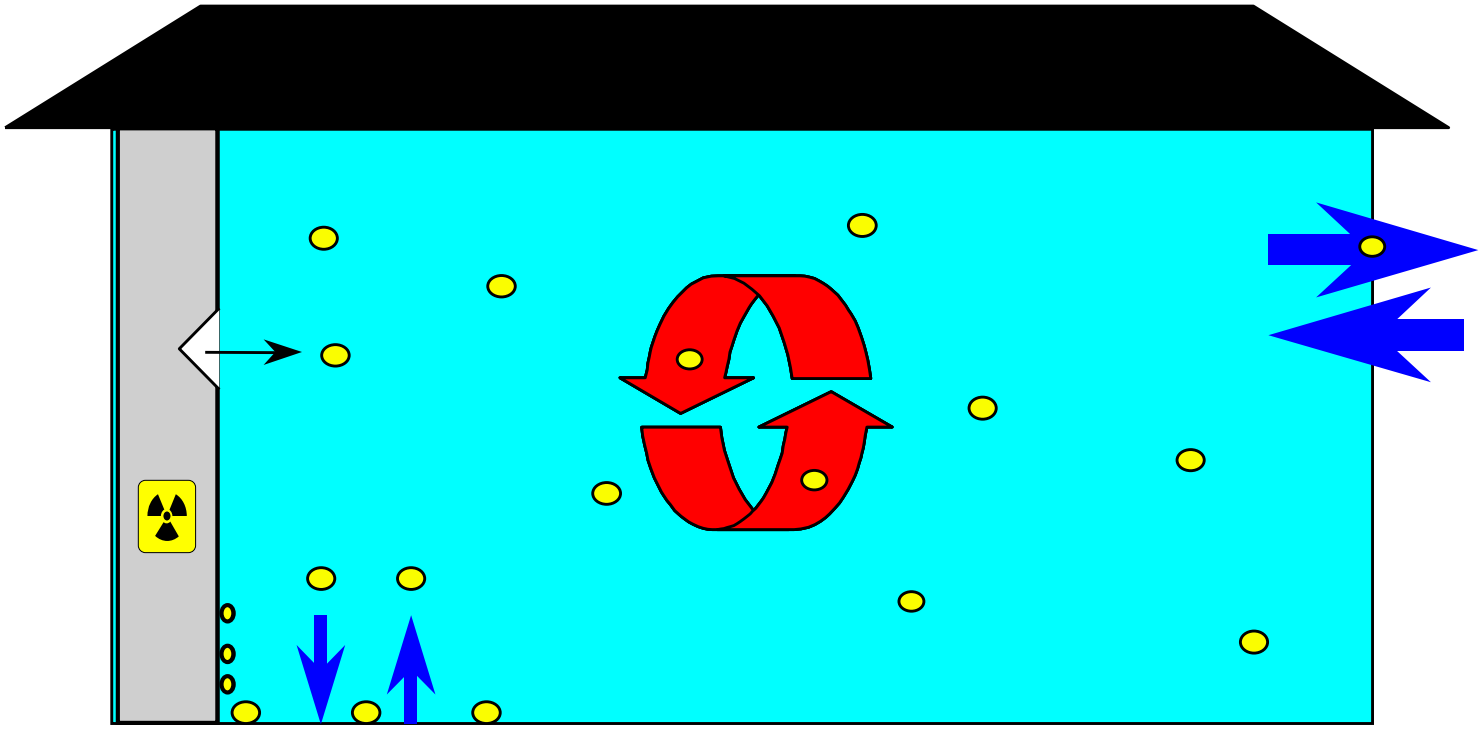
Decay of parent in Air

Resuspension

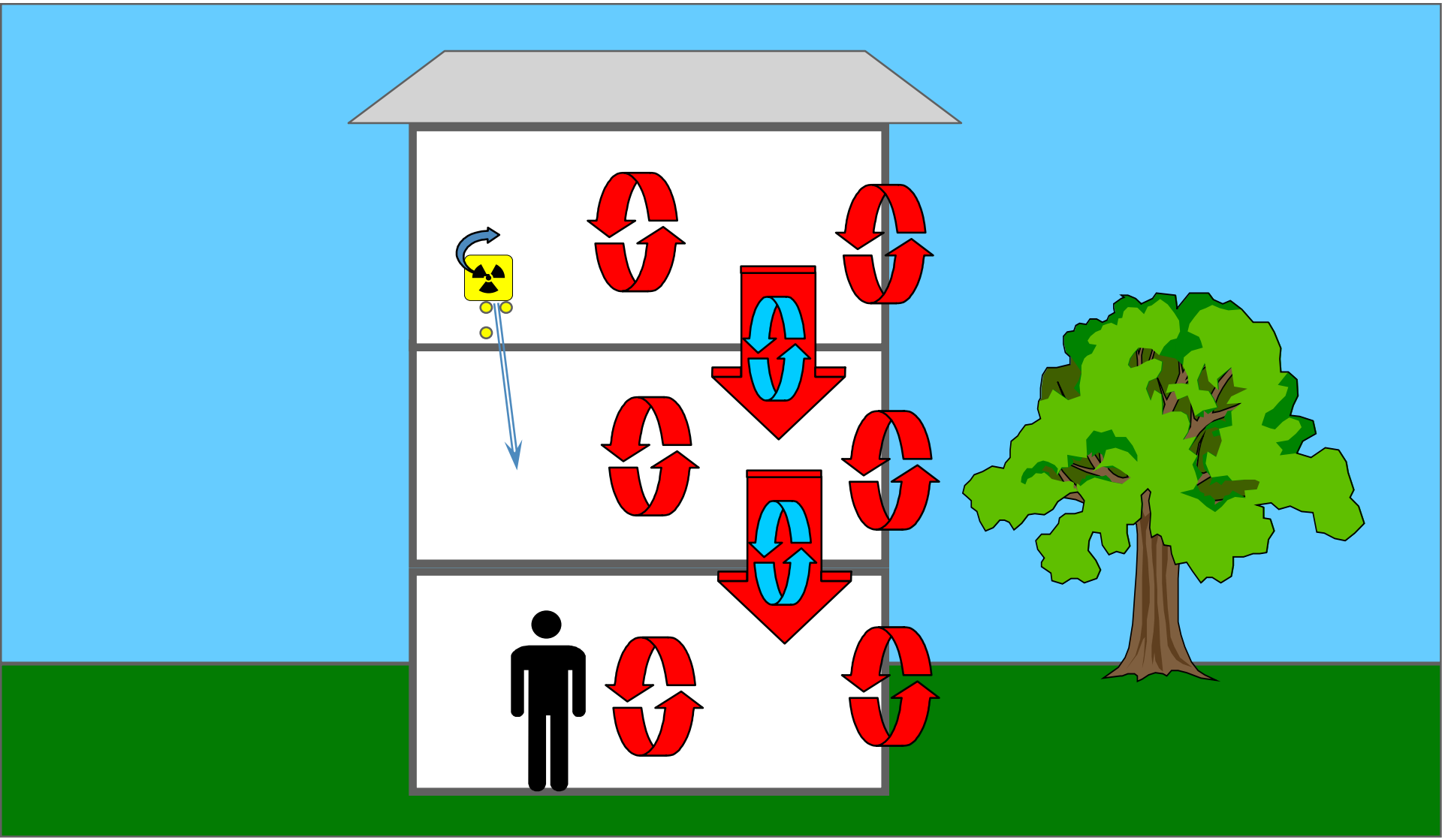
Injection Rate

Decay in Air

Deposition



Three-room Air Flow Model



Guideline Development

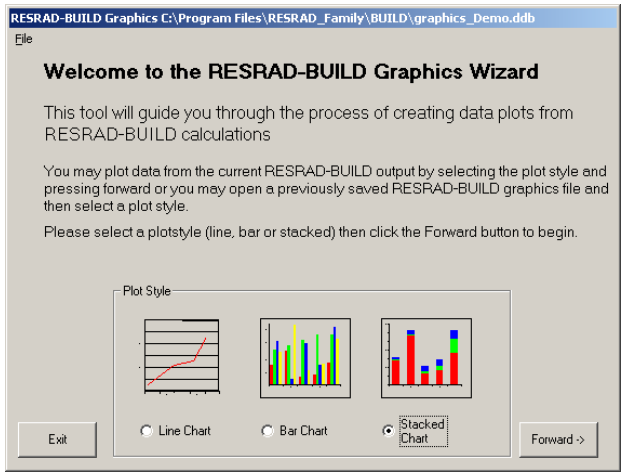
- Users must develop guideline values for each source type
- Guideline values are in units of Concentration over
  - mass (Volume Source)
    - pCi/g or Bq/g
  - area (Area Source)
    - dpm/m^2
  - length (Line Source)
    - pCi/m or Bq/m
  - pCi or Bq (Point Source)
- Use RESRAD-BUILD to develop $DSR_i(t)$

$$G_i(t) = \frac{H_E}{DSR_i(t)}$$

$G_i(t)$ Single Radionuclide Guideline
H_E Dose Limit (0.25 mSv/yr)
$DSR_i(t)$ Dose-to-Source Ratio (mrem/yr / Unit Concentration)

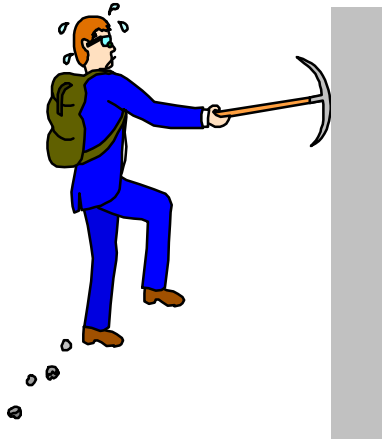
Output Results

- RESRAD-BUILD provides users with graphical- and text-based results
  - Summary report provides
    - Parameter used
    - Source term
    - Dose
  - Detailed report
    - Intermediate calculations involving airflow
    - Injection rates
    - External dose parameters
  - Graphical results
    - Interactive plotting



Building Occupancy vs. Building Renovation

- Building Occupancy Scenarios
  - Low release over a long period of time
  - Material that is more likely to become airborne
  - Exposure duration is typically one year
- Building Renovation
  - Large release over a short time
  - Airborne fraction lower than building occupancy
  - Exposure duration usually short (e.g., 30 to 90 days)



Argonne NATIONAL LABORATORY

Demonstration of RESRAD-BUILD Code

U.S. DEPARTMENT OF ENERGY

Q&A / Poll

Adjourn