GENII Version 2

Pacific Northwest NATIONAL LABORATORY
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Project Manager

Pacific Northwest National Laboratory

PNNL-SA-129753

GENII Version 2
Environmental Radiation Dosimetry Software

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Support from ORNL: Keith Eckerman

GENII Version 2 in FRAMES
Topics to be Discussed

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- GENII
- GENII Development History
- Assessment / Scenario Analysis
- Available Models
  - atmospheric transport
  - surface water transport
  - waste / soil redistribution
  - terrestrial uptake
  - human exposure
  - dose / risk
  - uncertainty / sensitivity

GENII

A set of computer programs for estimation of radionuclide concentrations in the environment and dose/risk to humans from:

- Acute or chronic exposures to
- Releases to surface water or atmosphere, or
- Initial contamination conditions

GENII Development

- 1988 - Version 1 Released
  - ICRP-26/30/48 dosimetry
- 1990 - Version 1.485 stabilized
- 1992 - GENII-S stochastic version
- 2004 - GENII Version 2
  - ICRP-72 age-dependent dosimetry
  - EPA HEAST slope factors
  - Federal Guidance Report 13 risk factors
- 2006/7 – V&V
- 2008 – New features, DOE status

Assessment Question

"What is the assessment question?" - F.O. Hoffman

- Are we compliant?
  - Often, regulatory requirements of facility operations are posed in terms of radiation dose limits
- Design requirements
  - How much material may be released and still meet the criteria?
- Safety Analyses
  - What controls are needed to prevent this event?
- Accident Planning
  - How bad could this event be?

Scenario Analysis

- All of these questions can be answered through the analysis of a *scenario* that considers:
  - Radionuclide inventories,
  - Radionuclide releases,
  - Environmental transport,
  - Environmental accumulation and dilution, and
  - Subsequent human exposure.

Exposure Scenarios

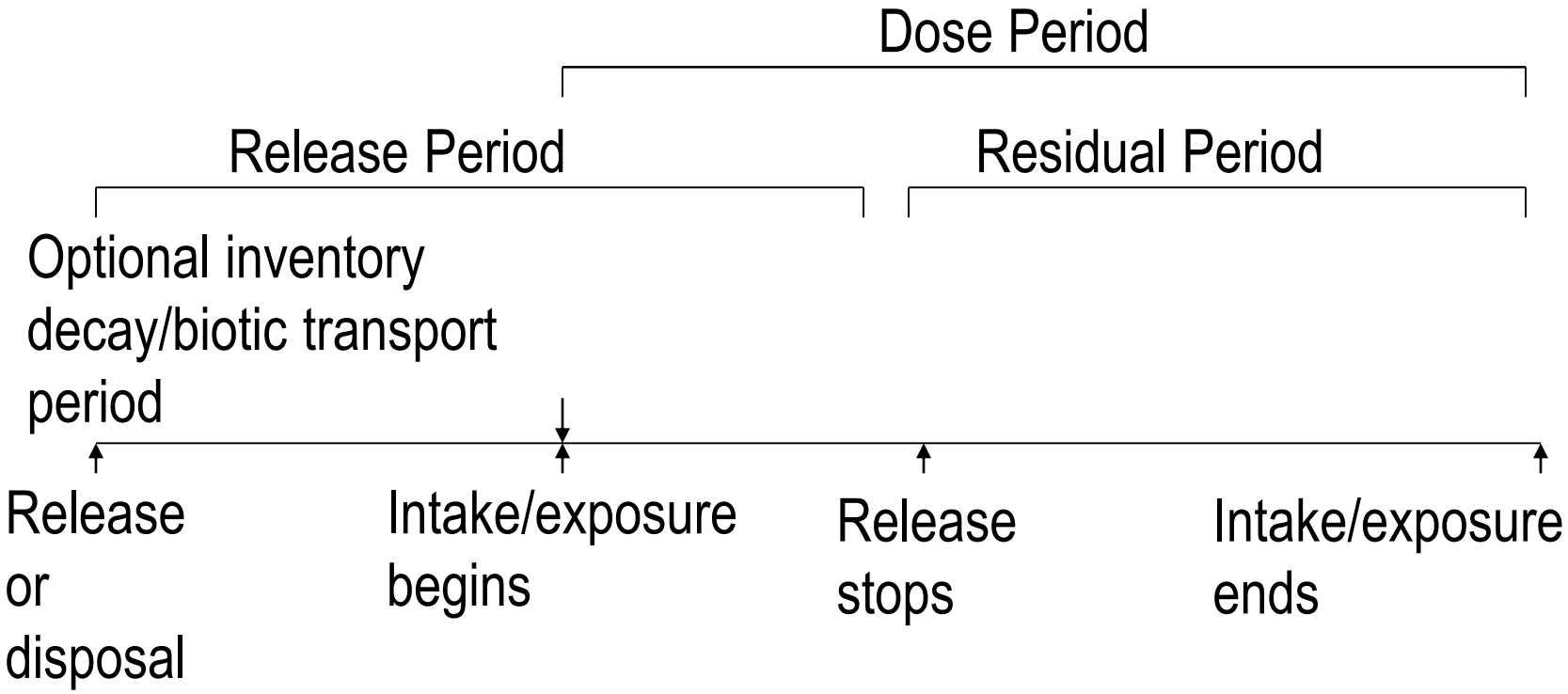
- A scenario is a conceptual model that describes patterns of human activity, events, and processes that result in radiation exposure to people.

- GENII is designed to allow flexible application to most scenarios of interest in a regulatory setting at an appropriate level of detail.

Types of Scenarios

- Far-Field scenarios
  - Atmospheric transport (acute or chronic)
  - Surface water transport (acute or chronic)
- Near-Field scenarios
  - Spills
  - Buried waste
  - (Groundwater use - GW transport modeling is NOT an explicit part of GENII)

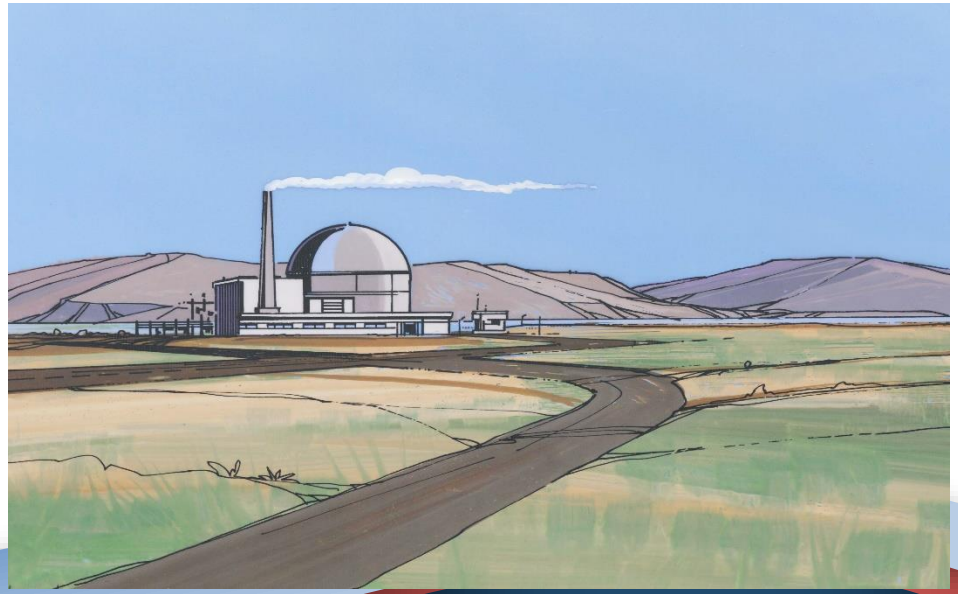
GENII Version 2 Time Line

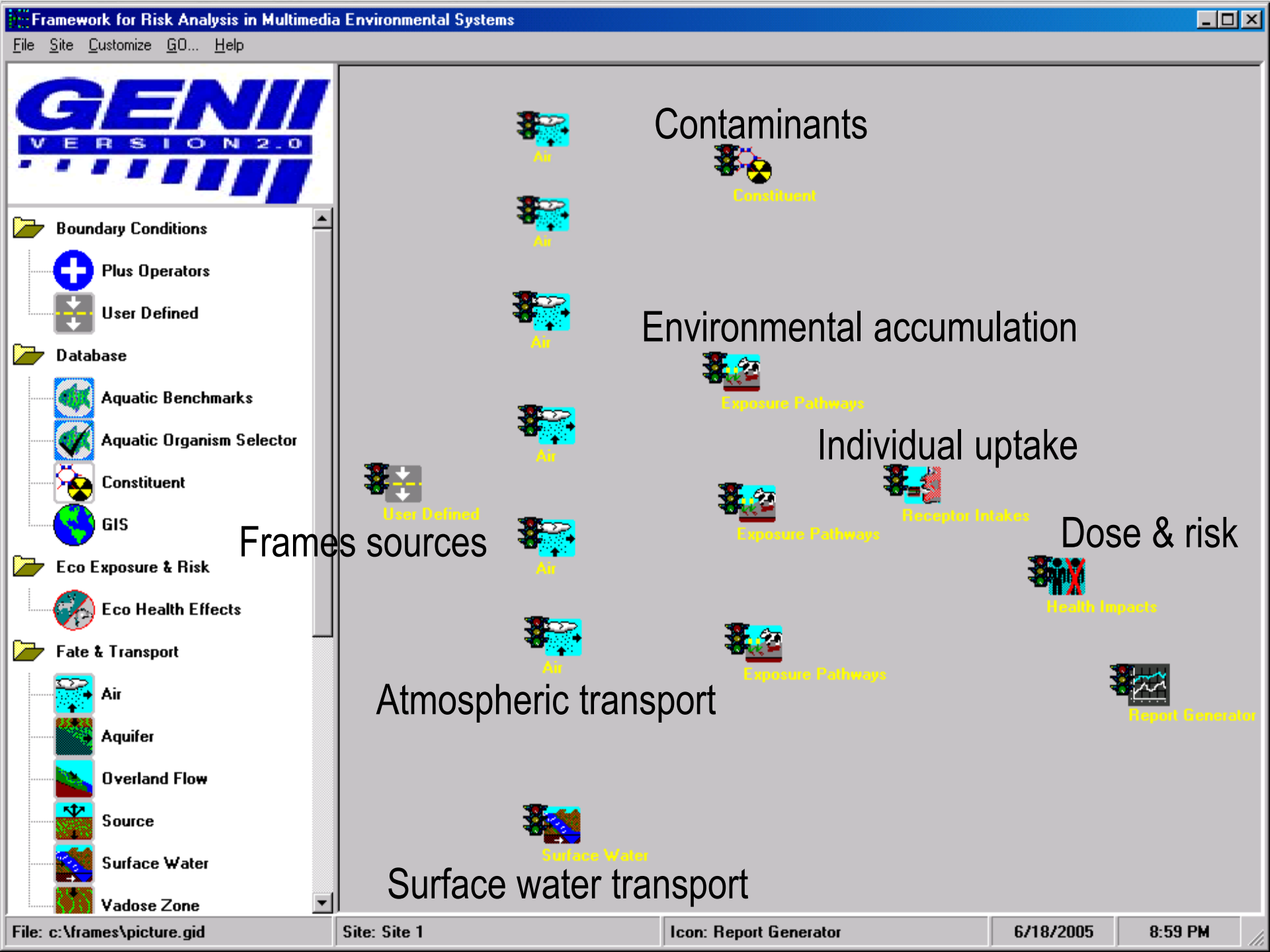


Radionuclides of Interest

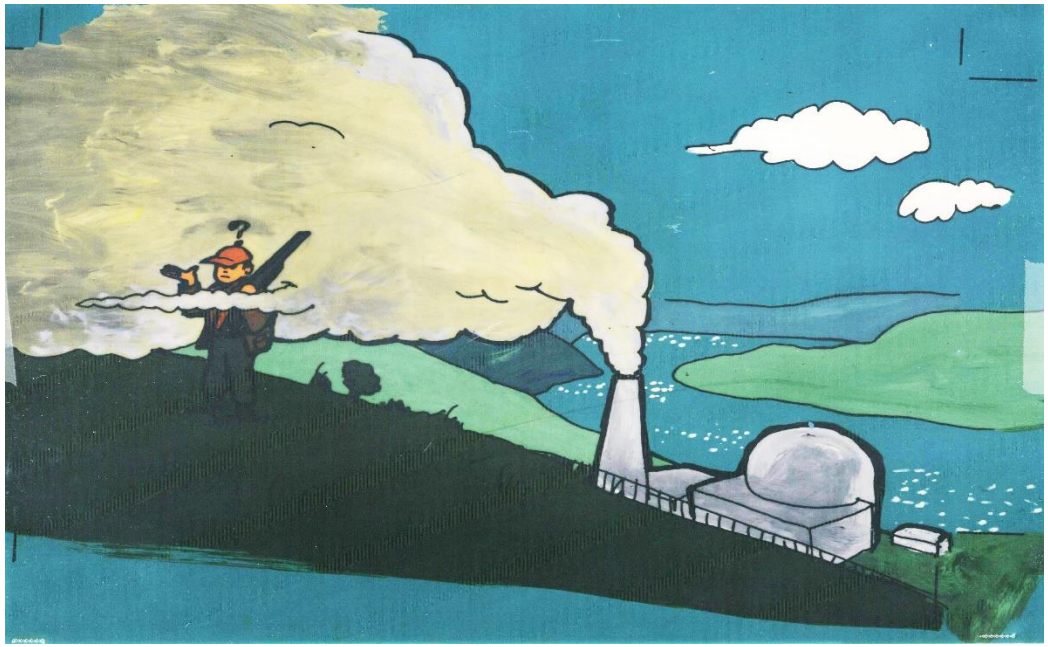
- All those with half-lives greater than 10 minutes*
- All decay progeny of these
  - Some are included “implicitly”

* Except radon progeny




Framework for Risk Analysis in Multimedia Environmental Systems
File Site Customize GO... Help
GENII VERSION 2.0
Boundary Conditions
Plus Operators
User Defined
Database
Aquatic Benchmarks
Aquatic Organism Selector
Constituent
GIS
Eco Exposure & Risk
Eco Health Effects
Fate & Transport
Air
Aquifer
Overland Flow
Source
Surface Water
Vadose Zone
Contaminants
Constituent
Air
Air
Air
Air
Air
Air
Environmental accumulation
Exposure Pathways
Individual uptake
Receptor Intakes
Exposure Pathways
User Defined
Frames sources
Dose & risk
Health Impacts
Atmospheric transport
Exposure Pathways
Report Generator
Surface Water
Surface water transport
File: c:\frames\picture.gid
Site: Site 1
Icon: Report Generator
6/18/2005
8:59 PM

GENII Version 2 Atmospheric Transport Options



- Chronic Gaussian Plume
- Chronic Lagrangian Puff

- Acute Gaussian Plume
- Acute Lagrangian Puff

- Estimation of 95% Dispersion Conditions

- Input of pre-calculated dispersion parameters

GENII Version 2 Chronic Plume Model

- Straight-line sector-averaged Gaussian
  - Runs on hourly observations or joint-frequency data
  - Multiple independent sources
    - Ground level or elevated releases
    - Point or area sources
    - Finite flow correction
  - Sectors by 16 compass points or 10 degrees
  - Radial output grid

GENII Version 2 Chronic Puff Model

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- Lagrangian puff releases based on 1 observation point
  - Hourly time step (variable number of puffs/hour) using hourly observations or quasi-hourly built from joint-frequency data
  - Square grid
- Multiple sources
  - Point or area sources
  - Ground level or elevated releases

GENII Version 2 Acute Plume Model

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- Straight-line centerline gaussian for individuals
  - For short (~2 hour releases)
  - Single source
  - Ground-level or elevated releases
- Radial grid
  - Radial sectors by 16 compass points or 10 degrees
- A specialized module for 95% conditions is now available

GENII Version 2 Acute Puff Model

- Lagrangian puff based on 1 observation point
  - Hourly time step using hourly observations or quasi-hourly inputs derived from joint-frequency data
  - Single source
  - Square grid
  - Ground-level or elevated releases

Parameterizations for Diffusion Coefficients

- Briggs open country
- Briggs urban conditions
- Pasquill-Gifford (ISC-3)
- Pasquill-Gifford (NRC: PAVAN, MESORAD, XOQDOQ, etc.)

Parameterizations Available in All Air Models

- Building wake / low-speed meander
- Buoyancy-induced diffusion
- Plume rise/downwash corrections
  - Momentum
  - Buoyancy
- Diabatic wind profile

GENII Version 2 Atmospheric Deposition Models

- All models have plume depletion / mass balance
- Dry deposition
  - "Resistance model"
  - Includes gravitational settling of larger particles
- Wet deposition
  - Washout dependent on precipitation rate
  - Rain and snow considered

GENII Version 2
Air Submersion Dose Rates

- Infinite plume
  - Based on Federal Guidance Report 13 models
- Finite plume
  - Close to release - array of line sources
  - Intermediate distances - stacked series of infinite planes
  - Long distances - defaults to infinite plume

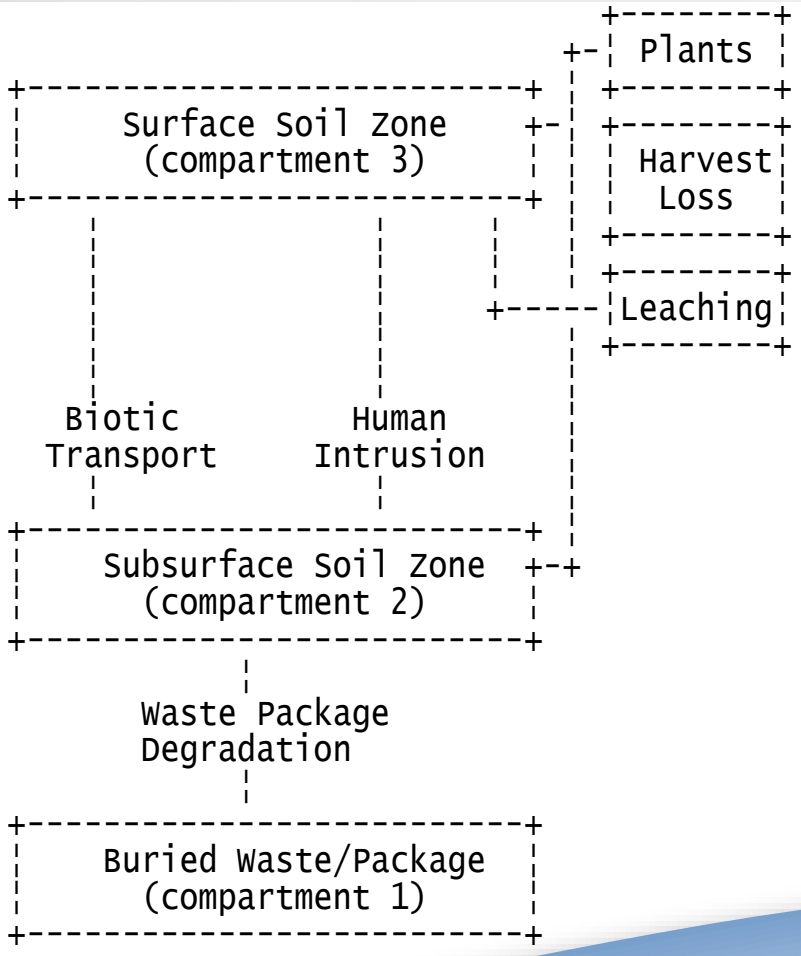
Sources of Data for Atmospheric Models

- Hourly data
  - CD-144 format (National Climatic Data Center)
  - SAMSON format (NCDC)
    - 1st order stations 1961-1990 on 3 CDs, also a later one
  - Precipitation in TD-3240 format (NCDC)
  - (For sites in the US, these are now available online)
  - 10 Years of Hanford Data also now available
- Joint frequency data
  - STAR (ISC-3) [provided for many US sites]
  - GENII Version 1.485

GENII Version 2 Surface Water Transport Models

- Simple models derived from NRC's LADTAP
  - Rivers: analog to atmospheric gaussian plume
    - Constant depth, width, velocity
    - Straight channel
    - Continuous discharge
  - River - dilution volume (well mixed)
  - Acute river (time integral)
  - Lake
    - quasi-steady state wind-driven currents

GENII Version 2 Near-Field Soil Model



GENII Version 2
Near-Field Biotic Transport

- Plant roots - root fraction applied to CR
- Burrowing animals - volume of soil moved versus depth
- Applied to arid, humid, or agricultural conditions

GENII Version 2
Near-Field Human Intrusion

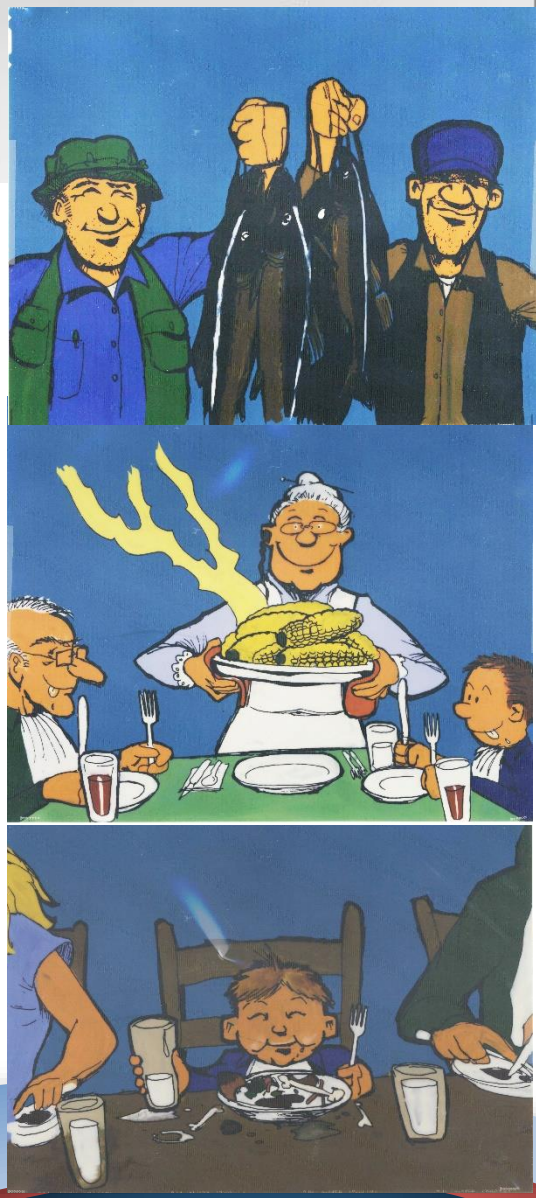
- Buried waste and/or deep soil may be manually redistributed at the start of exposure to the surface soil.
- Process is a step function manual redistribution factor (m^3/m^2)

GENII Version 2 Exposure Pathways

- External
  - Transported air
  - Soil
  - Swimming
  - Shoreline
- Inhalation
  - Transported air
  - Resuspended soil
  - Volatilized indoor air pollutants from water

GENII Version 2 Exposure Pathways

- Ingestion
  - Leafy vegetables
  - Other vegetables
  - Fruit
  - Grain
  - Meat
  - Milk
  - Poultry
  - Eggs
  - Fish
  - Crustaceans
  - Molluscs
  - Water plants
  - Drinking water
  - Shower water
  - Swimming water
  - Soil



GENII Version 2 Crop Contamination

- Plant = Soil * CR + intercepted deposition
  - Concentration ratios (CR) updated/revised
  - Interception function of crop biomass
    - Wet interception
    - Dry interception

GENII Version 2
Animal Product Contamination

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- Animal Product = TF Σ (Crop * Ingestion rate)
  - Transfer factors revised / updated

GENII Version 2
Aquatic Biota Contamination

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- Fish = Water concentration * BF
  - Bioaccumulation factors (BF) revised / updated

GENII Version 2 Tritium Specific Activity Model

- Environmental media assumed to have same specific activity (Bq/kg water) as contaminating medium (water or air)
- Fractional content of both water and non-water portions of the food product is used
- In acute cases, rapid equilibration / de-equilibration is assumed (~8 hours)
- Based on observations at Chalk River

GENII Version 2
Carbon-14 Specific Activity Model

- For atmospheric sources, model is parallel to that for tritium
- For water sources, equilibration is assumed with soil carbon atom ratios
- For acute cases, uptake via photosynthesis is slow, long de-equilibration

GENII Version 2 Human Exposure

- Up to 6 age groups allowed, following ICRP-56, 67, 69

3 months	0-1 year
1 year	1-2 year
5 year	2-7 year
10 year	8-12 year
15 year	13-17 year
20 + year	17- 110 year

GENII Version 2 Acute-Deposition Food Pathways

- GENII Version 2 presents results for 4 seasons (winter/spring/summer/autumn)
- This is a surrogate for a complex set of underlying assumptions about plant growth, weathering, uptake, and time-to-harvest
- Selection of season depends on meteorological input (this is related to the uncertainty capability)
- *This was hard-wired; I made a small change because seasons below the equator are reversed!*

External Exposure - Doses

- Dose rate conversion factors from Federal Guidance Report 12 (FGR 12), provided by Keith Eckerman (ORNL)
  - Air Submersion
  - Water Immersion
  - Soil Plane
  - Soil Volume

Internal Exposure - Doses

- Effective dose equivalent: ICRP-30
  - Adult only
- Effective dose: ICRP-72
  - 6 age groups
  - 24 organs/tissues
  - Inhalation classes F, M, S

Risk Calculations – Slope Factors

- EPA Health Effects Assessment Summary Tables (Currently the same as FGR 13)
  - Ingestion (risk/pCi ingested)
  - Inhalation (risk/pCi inhaled)
  - Ground plane external (risk/year per pCi/g)
- For population exposure = adults

Risk Calculations – Dose-to-Risk Conversions

- ICRP provides estimates of cancer incidence and mortality in relation to effective dose
  - ICRP-30 effective dose
  - ICRP-72 organ dose
- US BEIR VII report supports these values with minor revision
- Risk = Dose (Sv) * Conversion (risk/Sv)

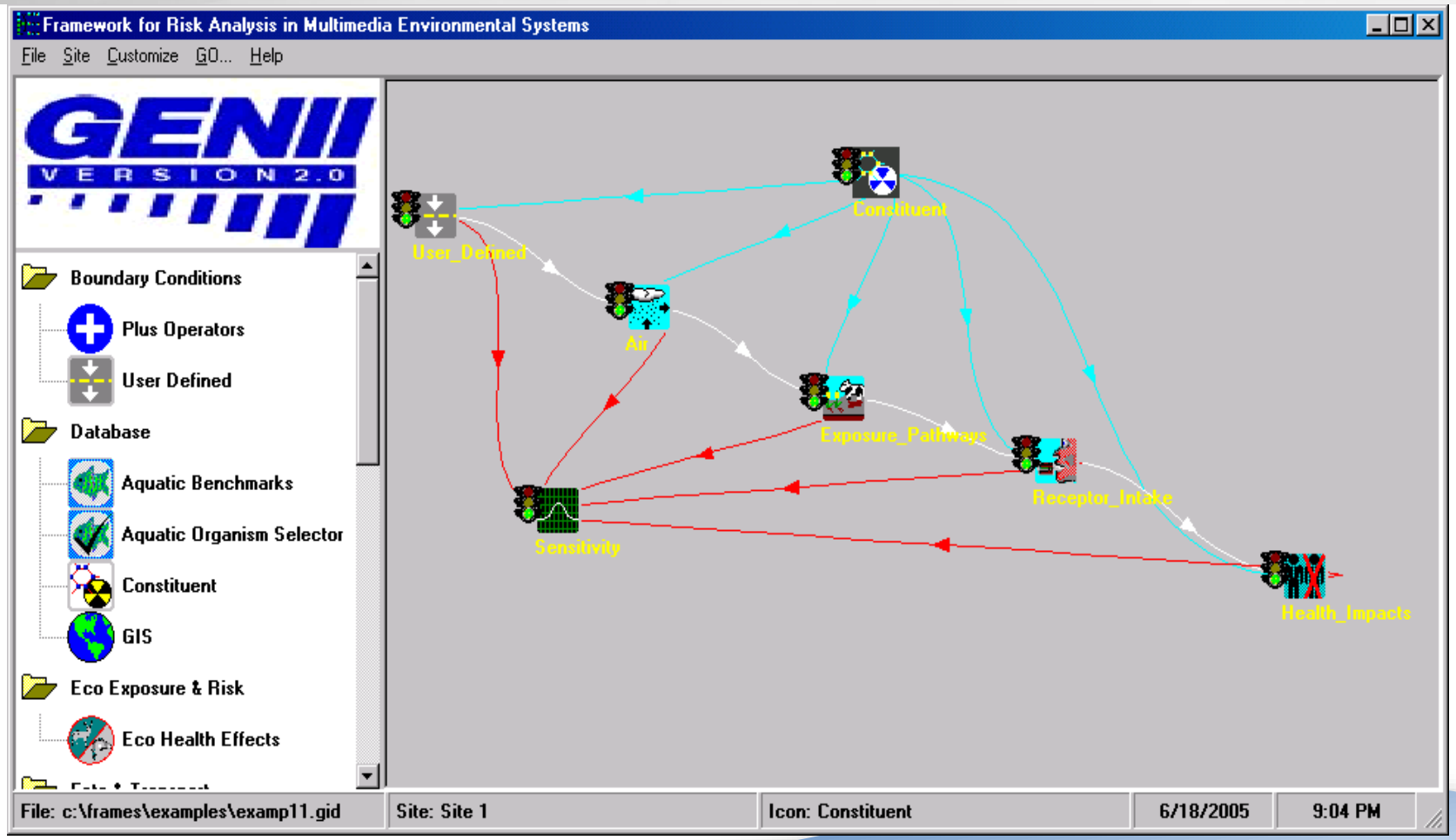
Risk Calculations - FGR 13

- US Federal Guidance Report 13 provides coefficients for 15 cancer sites
  - Inhalation (risk/Bq)
    - Inhalation classes F, M, S
  - Ingestion (risk/Bq)
    - Accounts for different consumption patterns with age
      - Drinking water
      - Food crops

GENII Version 2 Uncertainty Analysis

- Parameter uncertainty and sensitivity may be addressed using the SUM^3 processor in FRAMES.
- All non-control parameters are allowed to be varied, using description files to define 'available' parameters
- Acute atmospheric releases are in important subset. For these, SUM^3 is used to vary start times in the plume or puff models, allowing construction of the location or site cumulative dose/risk distribution function.

Use of SUM^3 to get CDF of Dose



How to get help with understanding and running GENII

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- **A full Users' Guide and a complete Software Design Document are provided electronically with the installation package. The documentation (in Portable Document File – pdf - format) is also available on the GENII website at: http://ramp.labworks.org/GENII/**

- **For software technical support, please contact the software developer, Bruce Napier:**

  Email: Bruce.Napier@pnnl.gov

  Phone: +1 (509) 375-3896

GENII Version 2: A General Purpose Environmental Dosimetry Tool