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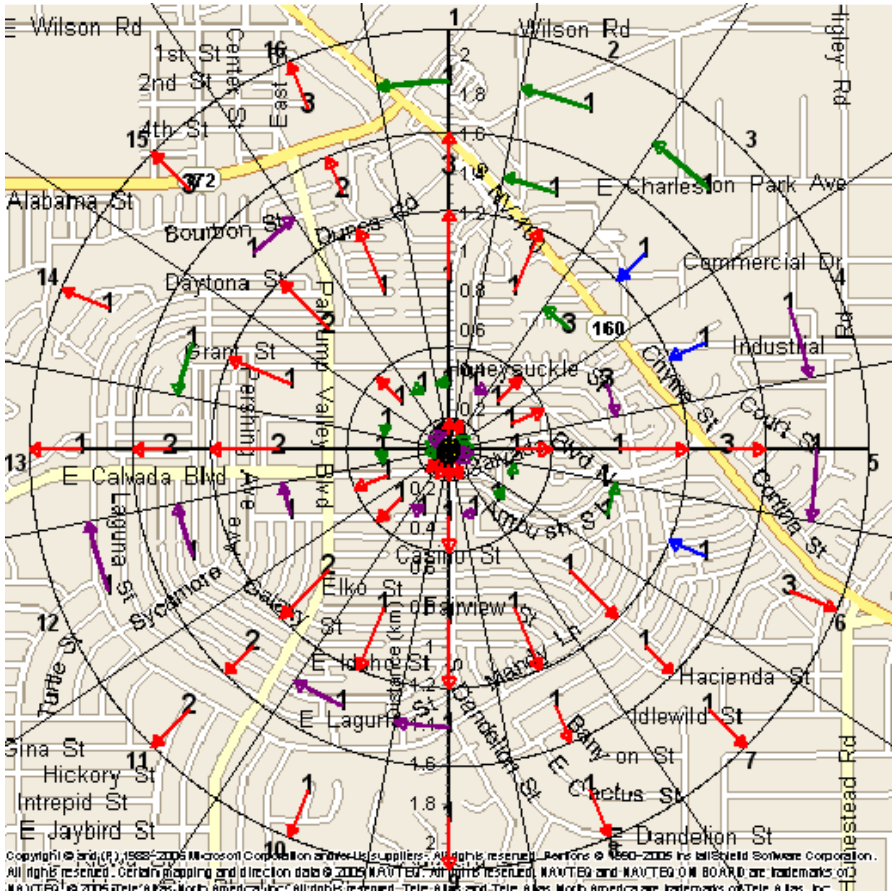

Emergency Response and EARLY Cohort Definition

Nate Bixler
Sandia National Laboratories

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U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration

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Objectives

- Learn how emergency response is modeled
- Learn how to define emergency-phase cohorts
- Differentiate the portions of the inputs that are site or accident-scenario specific and those that are not

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Introduction to Protective Measures

- Mitigative actions are protective measures designed to reduce exposures and health effects
- Mitigative measures in MACCS are divided into three phases (as defined by the EPA) with different protective actions possible in each phase
  - Emergency phase – from 1 to 40 days from the beginning of an accident
  - Emergency-phase protective actions are called emergency-response (ER) actions
    - Evacuation
    - Sheltering
    - Relocation

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Introduction to Protective Measures (cont.)

- Intermediate phase - begins immediately after the emergency phase and extends up to 1 year
  - Continuation of temporary relocation when projected dose exceeds the user specified limit
- Long-term phase - follows the intermediate phase
  - Mitigative actions attempt to reduce long-term health effects
    - Decontamination*
    - Temporary interdiction*
    - Condemnation*
    - Crop disposal
    - Restricted crop production

* Long-term exposure is based on groundshine and resuspension inhalation

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MACCS Modeling of Phases

- The Emergency Phase is modeled by EARLY.
  - Duration is specified by user
  - Extends up to 40 days after the arrival of the first plume at a spatial location
- EARLY can model up to twenty emergency-phase cohorts.
- CHRONC models intermediate and long-term phases.

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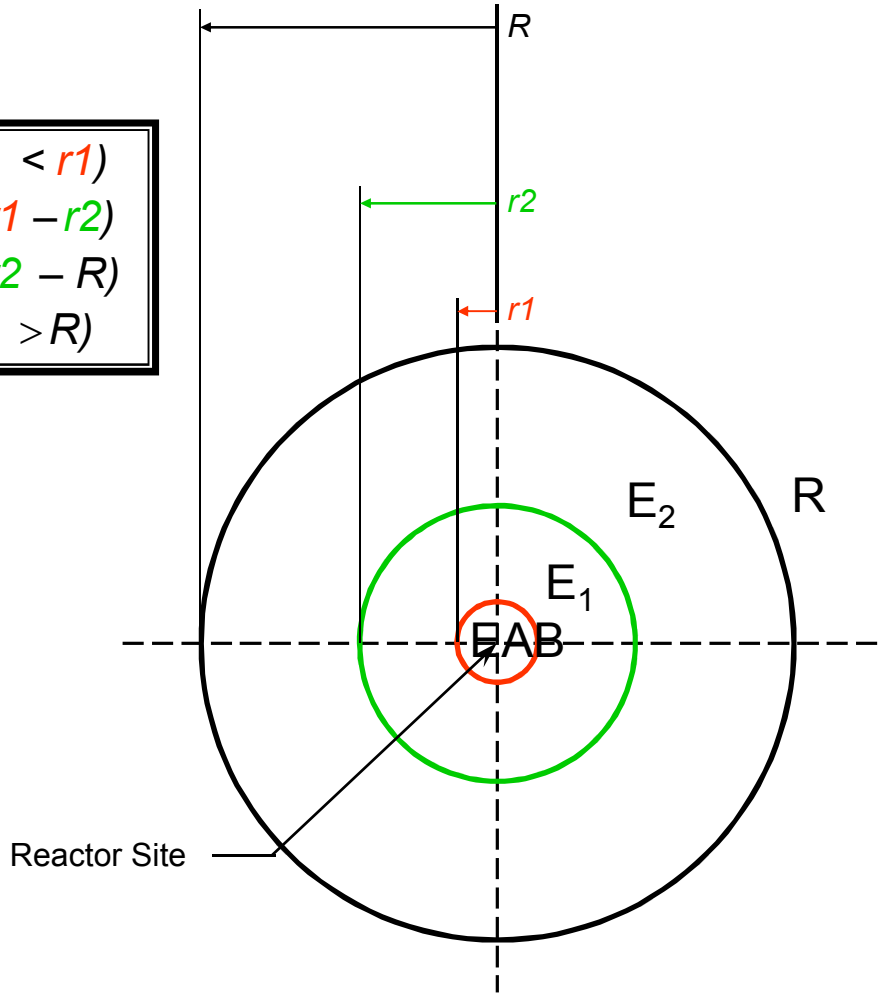
Emergency Response Zones

Exclusion Area Boundary	(< *r1*)
↗ E_1: Emergency Planning Zone (EPZ)	(*r1* – *r2*)
↗ E_2: Shadow Evacuation Zone	(*r2* – *R*)
↗ R: Relocation Zone	(> *R*)

- The exclusion area boundary is bounded by *r1*.
- Evacuation and sheltering generally occur within the EPZ.
- Shadow or ad hoc evacuation may occur beyond the EPZ.
- Relocation applies to all of the population that does not evacuate.



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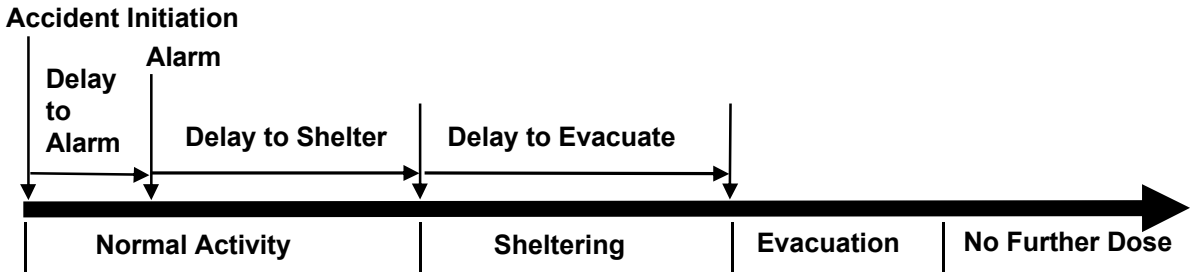
Shielding Factors

- Specified for each of three groups
  - Evacuees
  - People taking shelter
  - People continuing normal activity
- Shielding factors are multipliers in dosimetry calculations for each pathway and activity
  - Cloudshine
  - Groundshine
  - Inhalation
  - Skin deposition
- Typical relationship

  1.0 ≥ SFs for evacuees ≥ SFs for normal activity ≥ SFs for sheltering ≥ 0.0

Sheltering and Evacuation

- First period: Delay time prior to sheltering (user-specified for each zone)
  - Normal activity (and normal activity shielding factors) assumed
  - Delay time is from off-site alarm time
- Second period: Delay time prior to evacuation (user-specified for each zone)
  - Shielding factors for sheltering are used
  - Delay time is from beginning of sheltering



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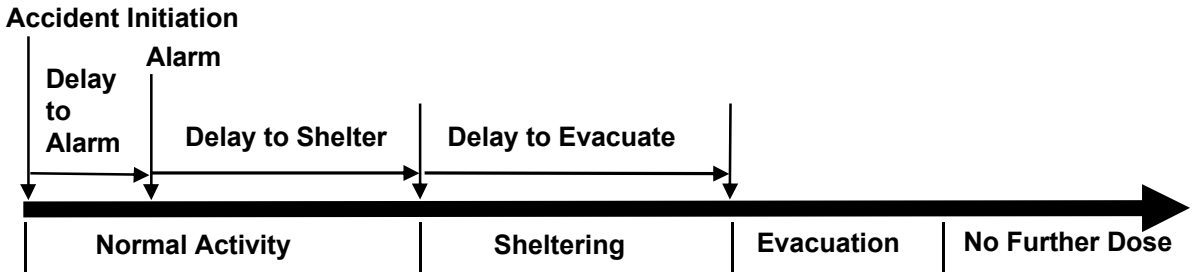
Sheltering and Evacuation (cont.)

- Third period: Evacuation
  - Speeds are user specified and can vary with
    - Three subphases
    - Weather
    - Grid element
  - Evacuation is to (user-specified) distance from reactor site
  - Evacuating shielding factors apply
  - Exposure to plume depends on location relative to front and back of plume
- Fourth period: After evacuation
  - Following evacuation, evacuees avoid further exposure in EARLY



Sheltering and Evacuation (cont.)

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- Fifth period: After end of Emergency Phase
  - Evacuees move back to original spatial element if dose criterion is satisfied.
  - Any additional exposures are from intermediate and long-term exposure pathways.

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Intermediate Phase

- The Intermediate Phase begins at the end of the Emergency Phase
- Extends for a user-specified interval of time up to 1 year
- Optional (duration can be set to zero)
- Relocation is the only mitigative action during intermediate phase
- Relocation criterion parameters
  - Dose limit
  - Critical organ
  - Dose-projection period

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Long-Term Phase

- Initiation
  - End of intermediate phase
  - At the end of the emergency phase if there is no intermediate phase
- Mitigative actions depend of the following:
  - Projected doses
  - Cost-effectiveness of the action
- Decontamination worker doses are calculated for
  - Farmland
  - Non-farm properties

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Decontamination and Temporary Interdiction

- Habitability criterion
  - Based on dose projection over a user-specified time period
  - Land is habitable when projection is less than dose limit
  - Population is present for rest of long-term phase when habitability criterion is met
  - Mitigative actions are considered in order when the habitability criterion is not met
    - Decontamination (up to three levels of increasing effectiveness)
    - Period of interdiction following maximum decontamination
      - Atomic decay
      - Weathering
    - Condemnation of land

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Long-Term Ingestion Doses

- Three mitigative actions are modeled for farmland.
  - Removal of farmland from production when uninhabitable
  - Removal of farmland from production when too contaminated to grow crops (not farmable)
  - Disposal of milk and/or crops during growing season
- The user specifies the maximum allowable food doses.
  - Short-term milk dose
  - Short-term food dose (other than dairy)
  - Long-term dose from all food

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Long-Term Ingestion Doses (cont.)

- Farmland is condemned if
  - Land cannot be restored to habitability and farmability
  - Costs of decontamination and interdiction exceed farm value
- User-specified limits affect
  - Milk disposal during year of accident
  - Crop disposal during year of accident
  - Ability to farm in subsequent years

Cohort Models and Parameters

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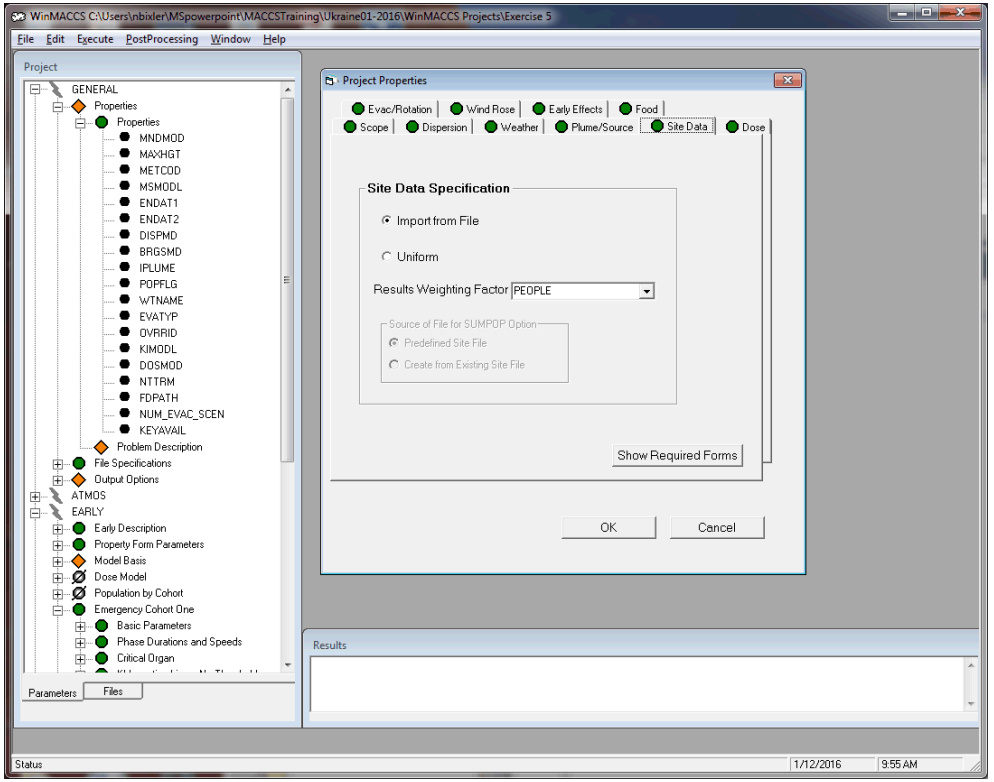
- Population distribution
- Type of evacuation
- Basic parameters
- Phase durations and speeds during evacuation
- KI ingestion
- Boundaries
- Shielding and exposure parameters
- Response delays
- Network evacuation parameters (advanced feature)
- Keyhole parameters (advanced feature)

Defining Population Distributions

- Uniform population and other site data can be used when metrics are limited to
  - Individual doses
  - Average health-effect risks
- Site file containing population and other site data should be used when metrics include
  - Population doses
  - Number of health effects
  - Population-weighted health-effect risks
  - Land contamination areas
  - Economic losses



Site File Contents

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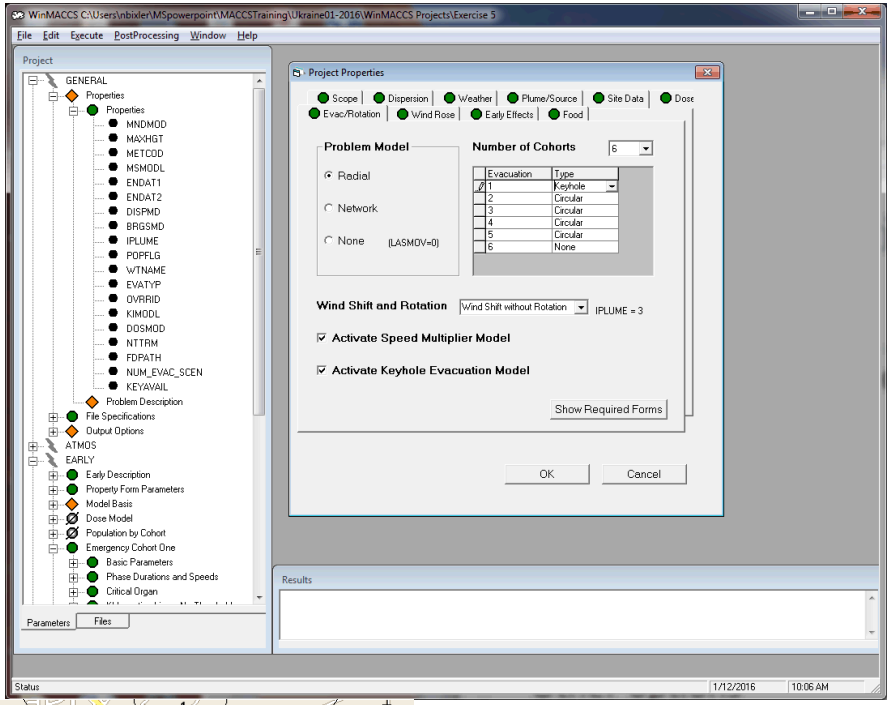
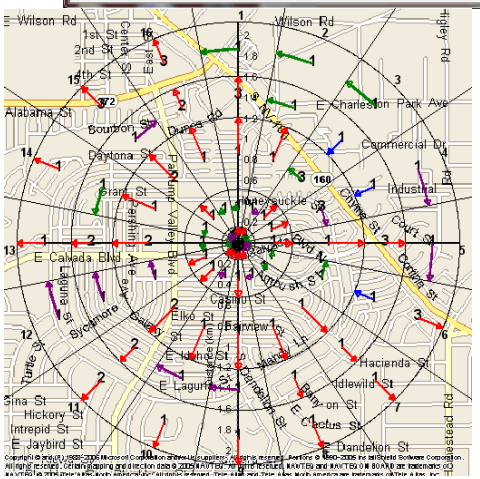
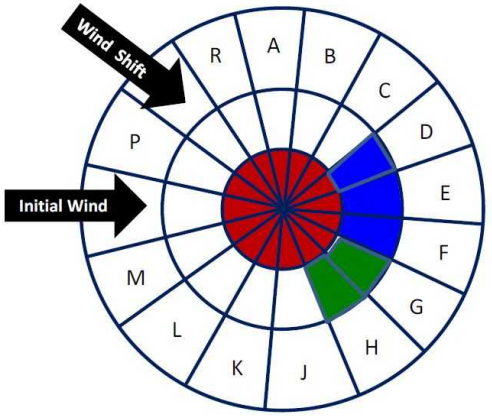
- Format is defined in NUREG/CR-6613 Vol. 1
- Contents include
  - Grid definition
  - Population by grid element
  - Land fractions by grid element
  - Economic region index by grid element
  - Watershed index by grid element
  - Crop season and share data
  - Watershed definitions
  - Regional economic data
- Site files are usually created by SecPop

Types of Evacuation

- Two types of evacuation model choices
  - Radial or network
  - Evacuation shape
    - None
    - Circular
    - Keyhole
- Other options
  - Activate speed multiplier model (advanced option)
  - Wind shift and rotation

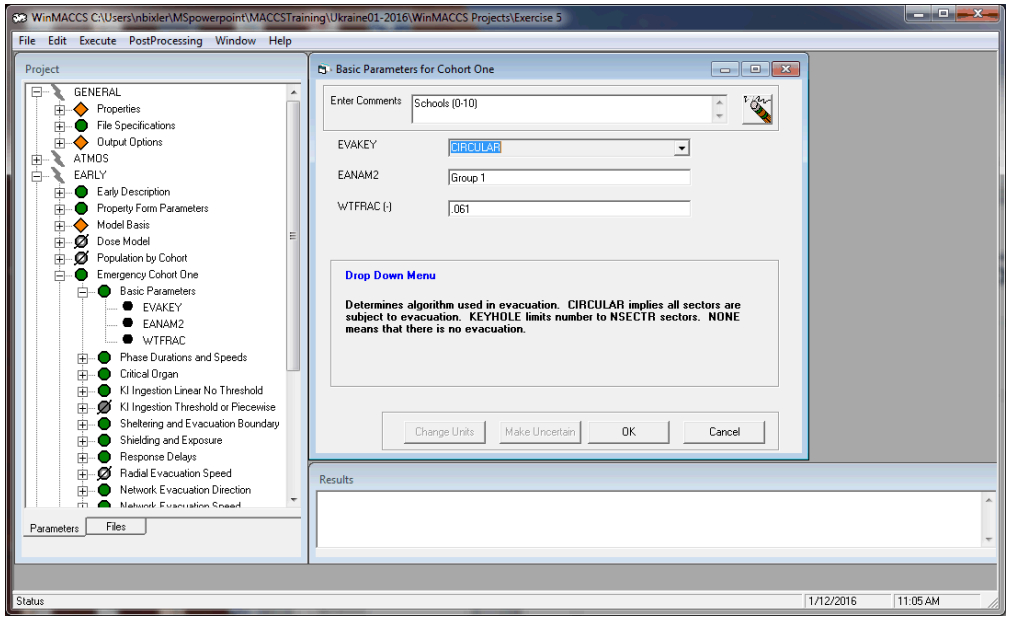






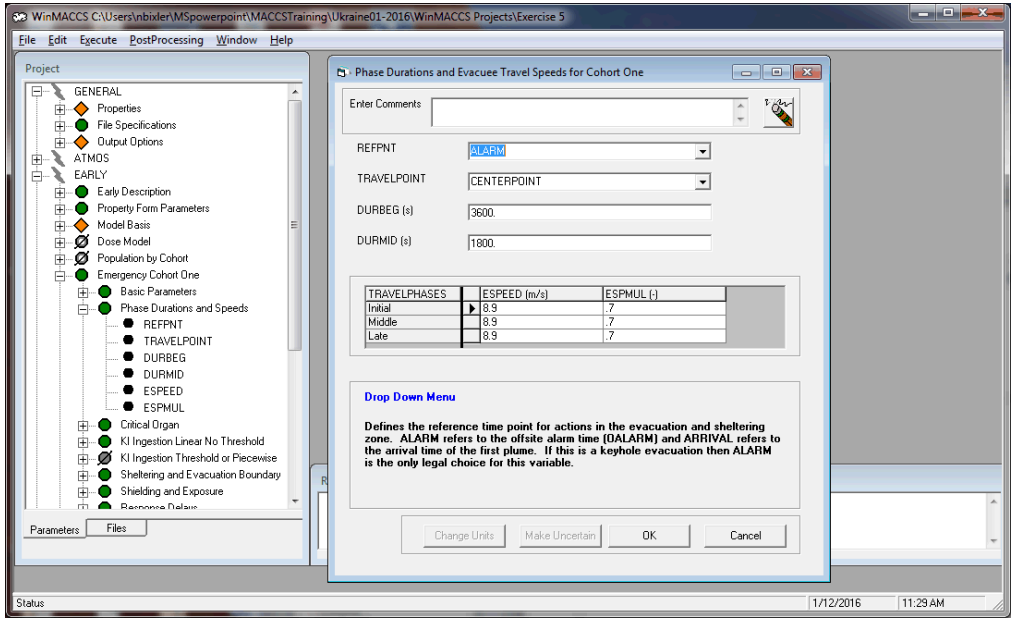
Basic Parameters

- Evacuation shape for cohort (read only)
- Cohort name
- Population fraction
  - Fraction of population in cohort
  - Fraction of population in cohort is uniform over entire grid
  - A more advanced feature allows a nonuniform distribution over the grid (SUMPOP)



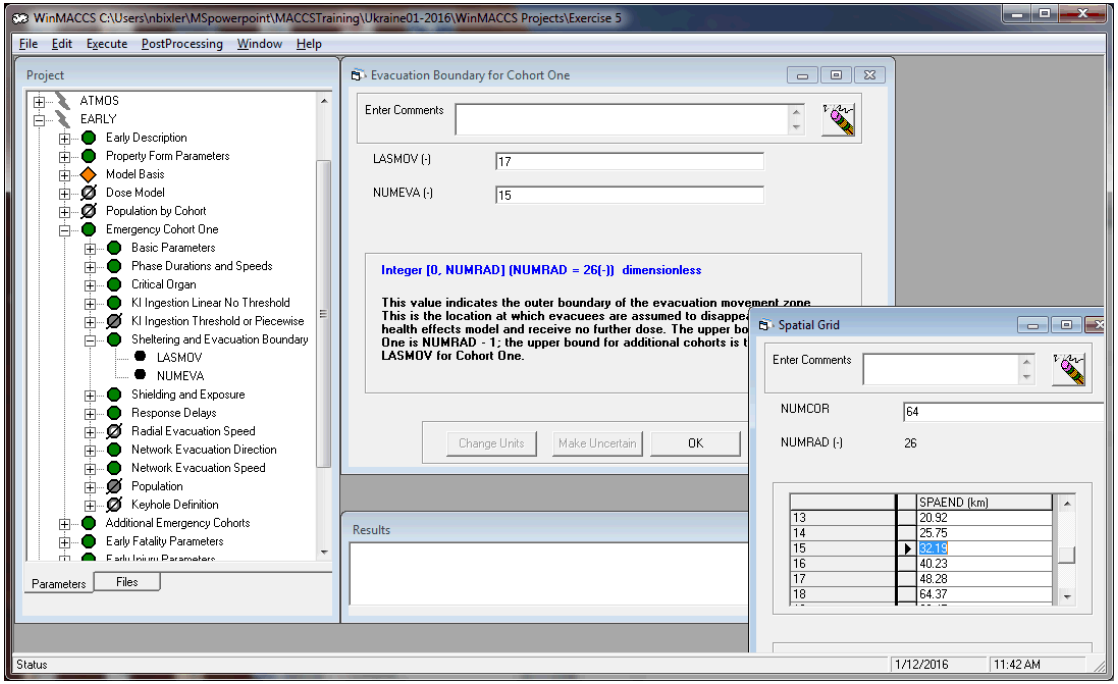
Phase Durations and Speeds

- Reference point for emergency actions: alarm or plume arrival
- Location where evacuee moves to next grid element
- Duration of beginning and middle subphases of evacuation
- Evacuation speeds
- Multiplier during precipitation events



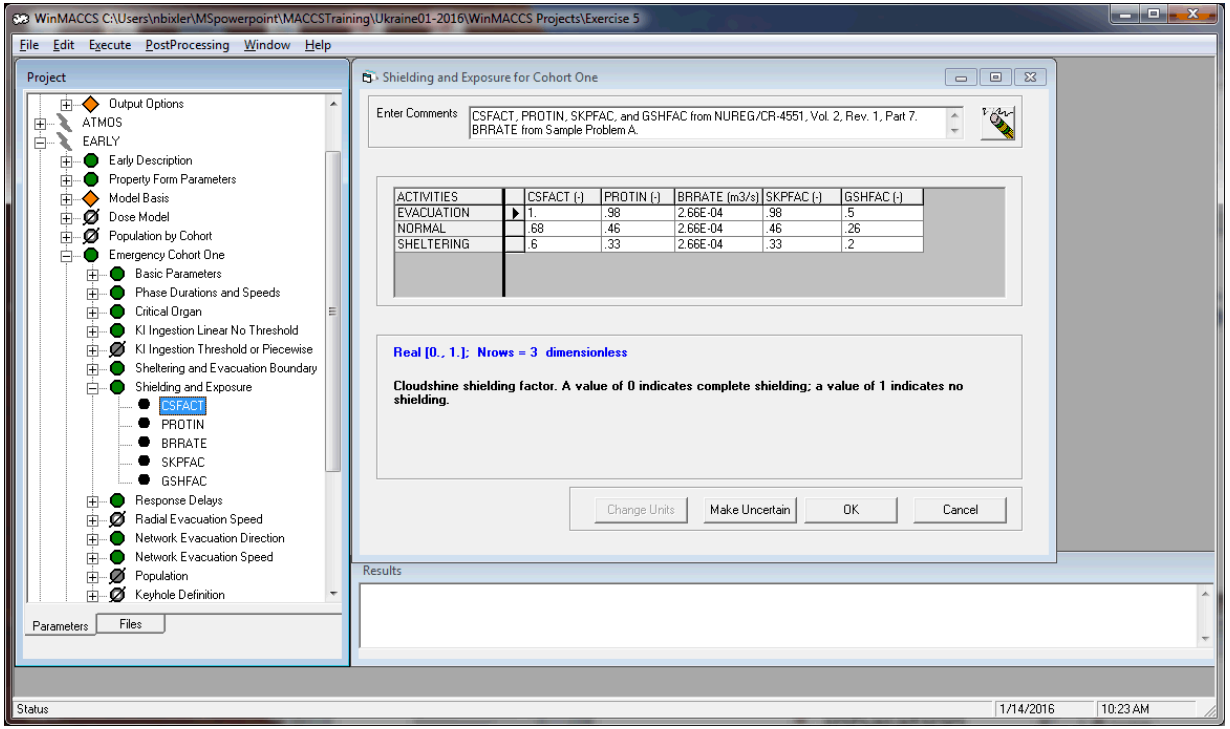
Evacuation Boundaries

- First boundary is the index (referenced to spatial grid definition) of the outer boundary for evacuation
- Second boundary is the index of the distance at which evacuees no longer receive a dose during the emergency phase



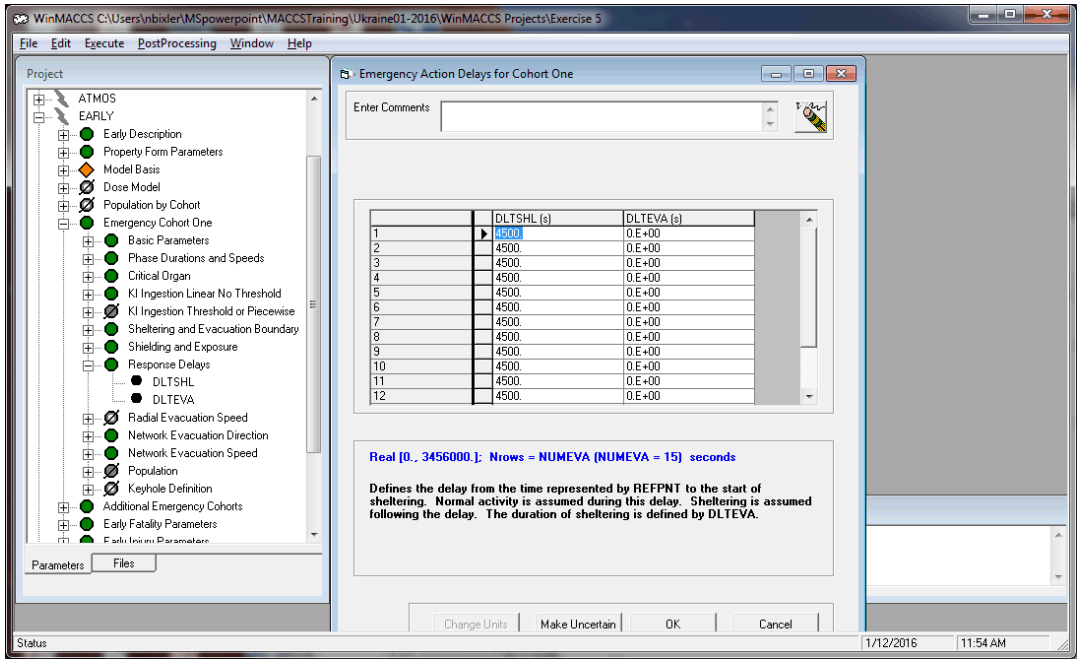
Shielding and Exposure

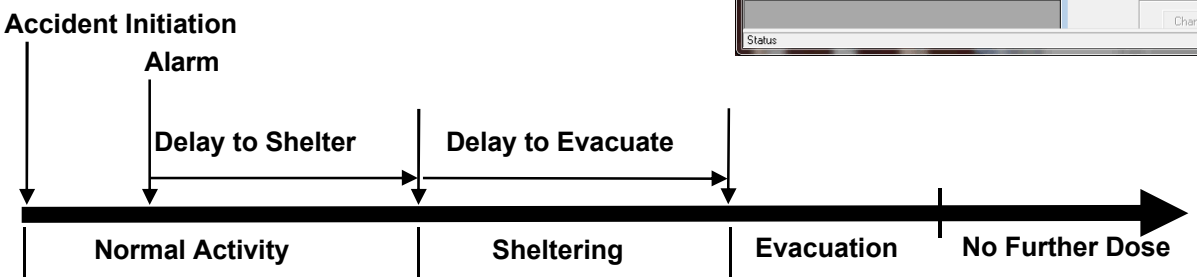
- Shielding and protection factors define the dose fraction received by
  - Dose pathway
    - Cloudshine
    - Inhalation
    - Skin
    - Groundshine
  - Activity
    - Evacuation
    - Normal
    - Sheltering
- Breathing rate



Response Delays

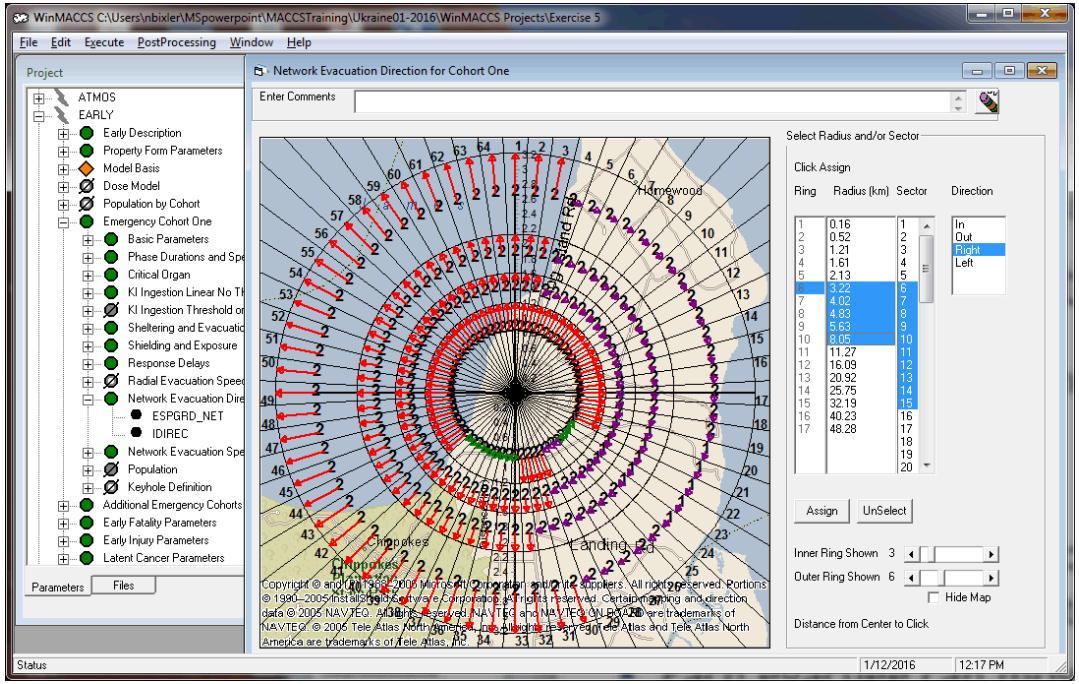
- Delays are specified for each ring within the evacuation zone
  - Delay to shelter
  - Delay to evacuation
- Delays are generally different for each cohort





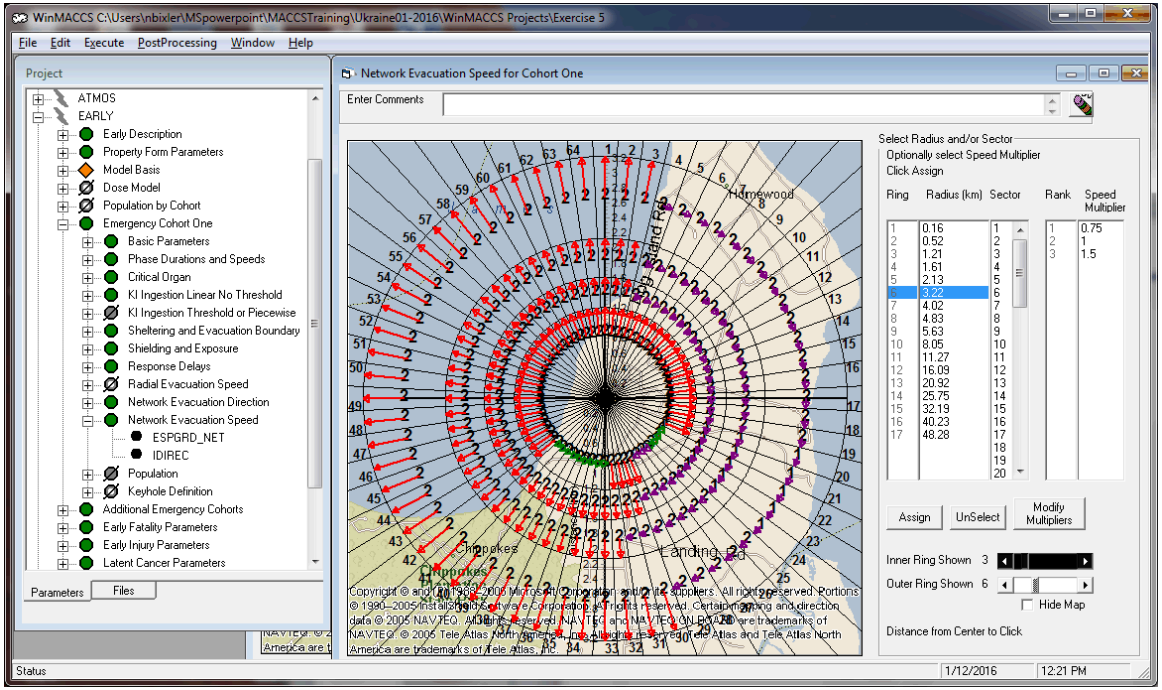
Network Evacuation Direction

- Radial evacuation is the basic model
- Network evacuation allows model to mimic actual evacuation routes
- Each evacuee can move in one of four directions
- Model disallows
  - Infinite loops
  - Travel through center of grid (site)



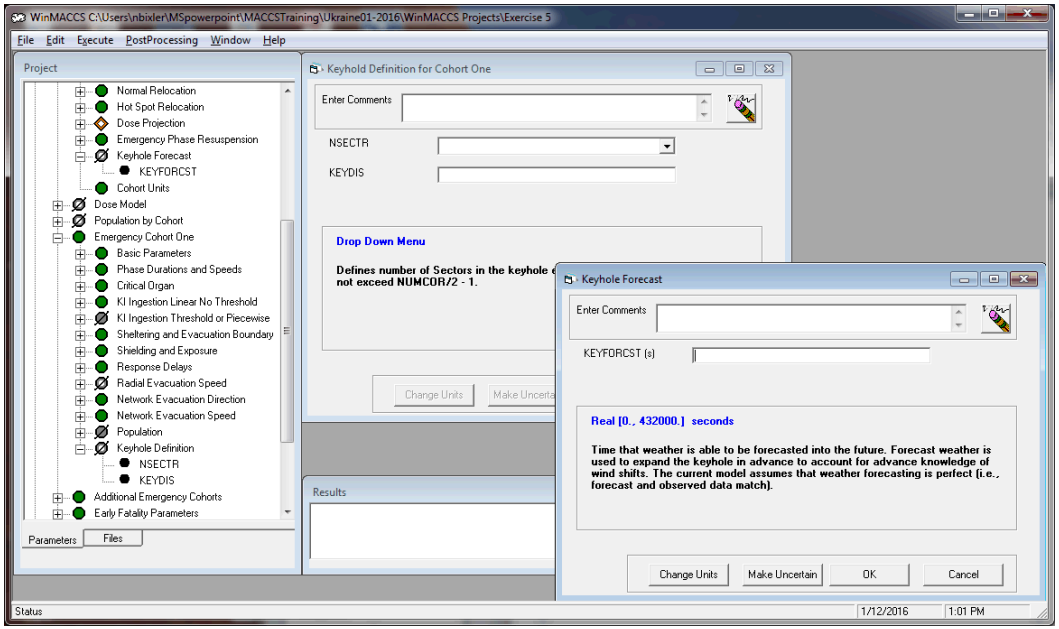
Network Evacuation Speed

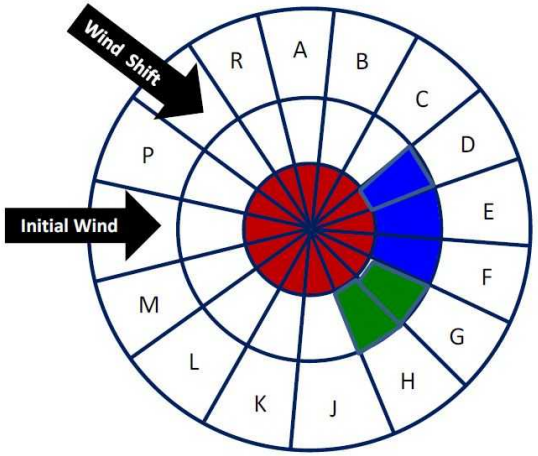
- Radial or network evacuation options support grid-level speed multipliers to account for
  - Type or road or highway
  - Traffic bottlenecks
- Multipliers modify basic speed on Phase Duration and Speed form



Keyhole Definition

- Three parameters define keyhole evacuation
  - The number of sectors in the outer portion
  - The number of rings in the circular portion
  - The number of hours reliable weather data are available to forecast wind shifts





Summary

- MACCS models all of the relevant dose pathways
- Essentially all of the cohort parameters depend on the site and accident sequence and need to be considered for each consequence analysis