

**The following presentation,
originally presented at the 2010
NREP Conference (slide 2), has
been slightly adapted for
presentation at an IAEA
Consultancy in June beginning on
slide 3.**



RASCAL 4.0

Radiological Assessment System for Consequence Analysis

National Radiological Emergency Preparedness Conference

March 30, 2010

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RASCAL 4.0

Radiological Assessment System for Consequence Analysis

International Atomic Energy Agency
Consultancy on Developing a Technical Solution for
Assessing the Radiological Consequences of a Nuclear
Accident or Radiological Emergency

June 21 & 22, 2010

Lou Brandon, Nuclear Regulatory Commission

RASCAL 4

- Released beta version March 1st
- Presentation goals:
 - Highlight the big changes
 - Demonstrate new capabilities
 - Discuss the future

A presentation in 4 parts:

1. Data and user interface changes
2. Transport & diffusion, decay, and mixture methods
3. Dose differences & future plans
4. New interface for utilities

Data and User Interface Changes

- What has changed?
- Why was it changed?
- How does the change impact results?

Updated Core Inventory

- Old core inventory – RASCAL 3
 - Taken from NUREG-1228 / WASH-1400
 - Selected for early health effects + likely noble gases
- New core inventory – RASCAL 4
 - Based on normalizes SCALE/ORIGEN run
 - Increased number of nuclides from 33 to 58
 - No longer select for early health effects
- Impact – small changes to source term

Updated Coolant Inventory

- From ANSI/ANS 18.1-1999
- Old inventory (RASCAL 3) excluded:
 - nuclides with half-life < 50 minutes, and
 - noble gases for BWRs
- New inventory (RASCAL 4) includes all
- A more complete set; nuclide number increased from 36 to 63
- Impact – small changes to source term

Improvements to Source Term and Release Path methods

- BWR release pathways
- PWR Steam Generator Tube Ruptures
- Spent Fuel Pool drained

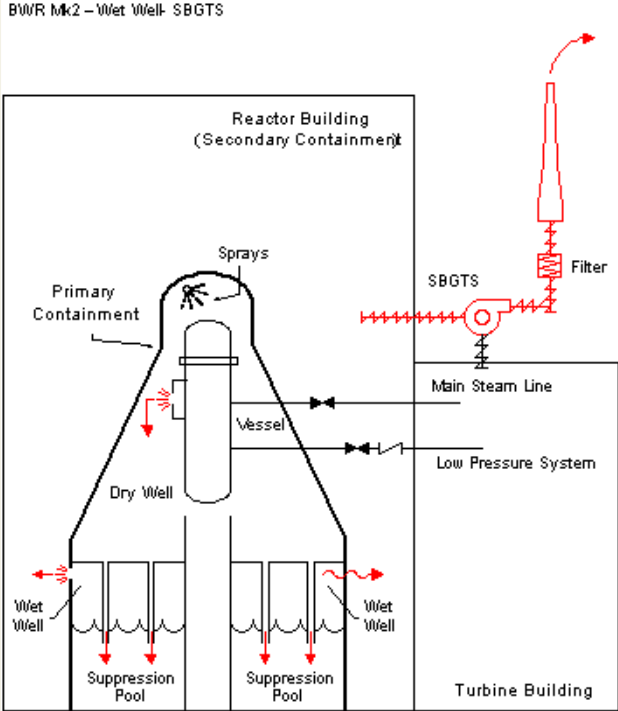
BWR release options

Available release pathways

Pathway from dry well to reactor building (secondary containment)

- ☒ Through the suppression pool
- ☐ Through the dry well wall
- ☐ Bypass reactor building

BWR Mk2 - Wet Well- SBGTS



Reactor Building (Secondary Containment)

Primary Containment

Sprays

Dry Well

Wet Well

Suppression Pool

Vessel

Main Steam Line

Low Pressure System

Turbine Building

SBGTS

Filter

Pathway to atmosphere

- ☒ Via Standby Gas Treatment System (SBGTS)
- ☐ Direct from reactor building or other rapid, unfiltered release

OK

Cancel

Help

Print

SBGTS - filtered and released at stack height

Direct - unfiltered and released at user entered height

SGTR Changes

Steam Generator Tube Rupture

Pathway description: (optional; 60 character max)

Release height: (Stack height: 185 ft)

Release timings: Core uncovered: 2010/02/22 00:00

Leak rate to atmosphere described by:

Leak controlled by 2 flows

Simpler location description

Date	Time	Event	Event setting
2010/02/22	00:00	Leak rate into SG	500 gal/min
2010/02/22	00:00	Rupture location	Above water level
2010/02/22	00:00	Steaming rate	7.5E+04 lb/h
2010/02/22	00:00	Release point	Safety relief valve

Release point can vary with time

Spent Fuel Pool Uncovered

Pool Storage - Uncovered Fuel ✕

Date reactor was shutdown for newest batch of fuel: 2010/02/22 ▾

Total number of spent fuel batches in the pool: 10 ▴ ▾ (3 batches/core)

Fuel uncovered and not cooled: 2010/02/22 ▾ 00:00

Fuel is recovered or cooled by sprays or steam cooling?

☒ No

☐ Yes, at 2010/02/22 ▾ 01:00

OK

Cancel

Help

**Simpler interface
Fewer questions**

Changes in SF Pool

- New version requires only age of newest batch, total batch count, and times for cooling lost and regained
- Assumes a 18 month refuel interval and cladding fire if not cooled for 2 hours
- Release over 24 hours unless recooled
- Impact – generally smaller source terms

Part 2

Transport & diffusion, decay, and mixture methods

RASCAL v4 – The New RASCAL

- What is new?
- Why is it changed?
- What are the implications of the changes?
- Are the changes reasonable?

The Changes

- Radioactive decay scheme
- Monitored mix release type
- Atmospheric dispersion and deposition

Radioactive Decay: What Is New?

- The decay scheme has been revised in the source term, environmental and dose calculations
- The decay scheme uses simplified chains that include short-lived daughters implicitly and are truncated at long-lived daughters
- Decay calculations are made using the Bateman Equations for 0 to 3 daughters and include branching.
- The RASCAL v4 radionuclide library is based on the radionuclide list in Appendix A of Federal Guidance Report 12
- The library lists 800 isotopes; only 15 short-lived isotopes are not Included either explicitly or implicitly.
 - The library also Includes U_{natural} , U_{enriched} , and UF_6

Radioactive Decay

- Why the Change?
 - Consistency
 - RASCAL v3.0.5 uses 3 different decay schemes
 - RASCAL v 4 uses just one
 - Traceability
 - RASCAL v4 decay schemes are documented
 - Appendices in the technical documentation will list the chains, decay parameters and implicit daughters

Radioactive Decay

- What are the Implications of the Change?
 - The changes in decay schemes should not result in any significant changes in dose estimates; however, they significantly alter DRL estimates.
 - Truncation errors have been evaluated and are generally $\ll 1\%$
 - Addition of implicit daughters and simplification of chains that include branching increases doses slightly at short times

Monitored Release

- Assumptions
 - Monitored pathway
 - Monitor capable of distinguishing between particle and noble gas activity
 - Reactor is shutdown with core damage
 - Particles are CsI

Monitored Release

- Assumptions
 - RASCAL v3.0.5
 - Particle activity is 50% Cs-137 and 50% I-131
 - RASCAL v4
 - Particle activity is distributed among all radioactive and stable Cs and I isotopes based on stoichiometric proportions

Monitored Release

- Why the Change?
 - RASCAL 3.0.5 significantly overestimated the long-term consequences of a release by exaggerating the Cs-137 activity
 - RASCAL 3.0.5 significantly underestimated the short-term consequences of a release by minimizing the I-131 activity

Monitored Release

- What are the Implications of the Change?
 - In RASCAL v4, >99.6% of the activity is in iodine isotopes; <0.4% of the activity is in Cesium Isotopes.
 - Doses are also reduced because most of the activity is in isotopes having dose factors that are lower than those for I-131 and Cs-137.

Monitored Release

Monitored Release Particle Activity Fraction

Isotope	RASCAL v3.0.5	RASCAL v4
I-131	0.500	0.115
I-132		0.167
I-133		0.233
I-134		0.258
I-135		0.223
Cs-134		0.00193
Cs-136		0.000613
Cs-137	0.500	0.00134

Atmospheric Dispersion

- What is New?
 - RASCAL v4 has changed from distance-based dispersion parameters to time-based parameters
 - Gone are the Pasquill-Gifford parameters
 - Dispersion is now a function of:
 - time since release
 - wind speed
 - atmospheric stability
 - surface roughness

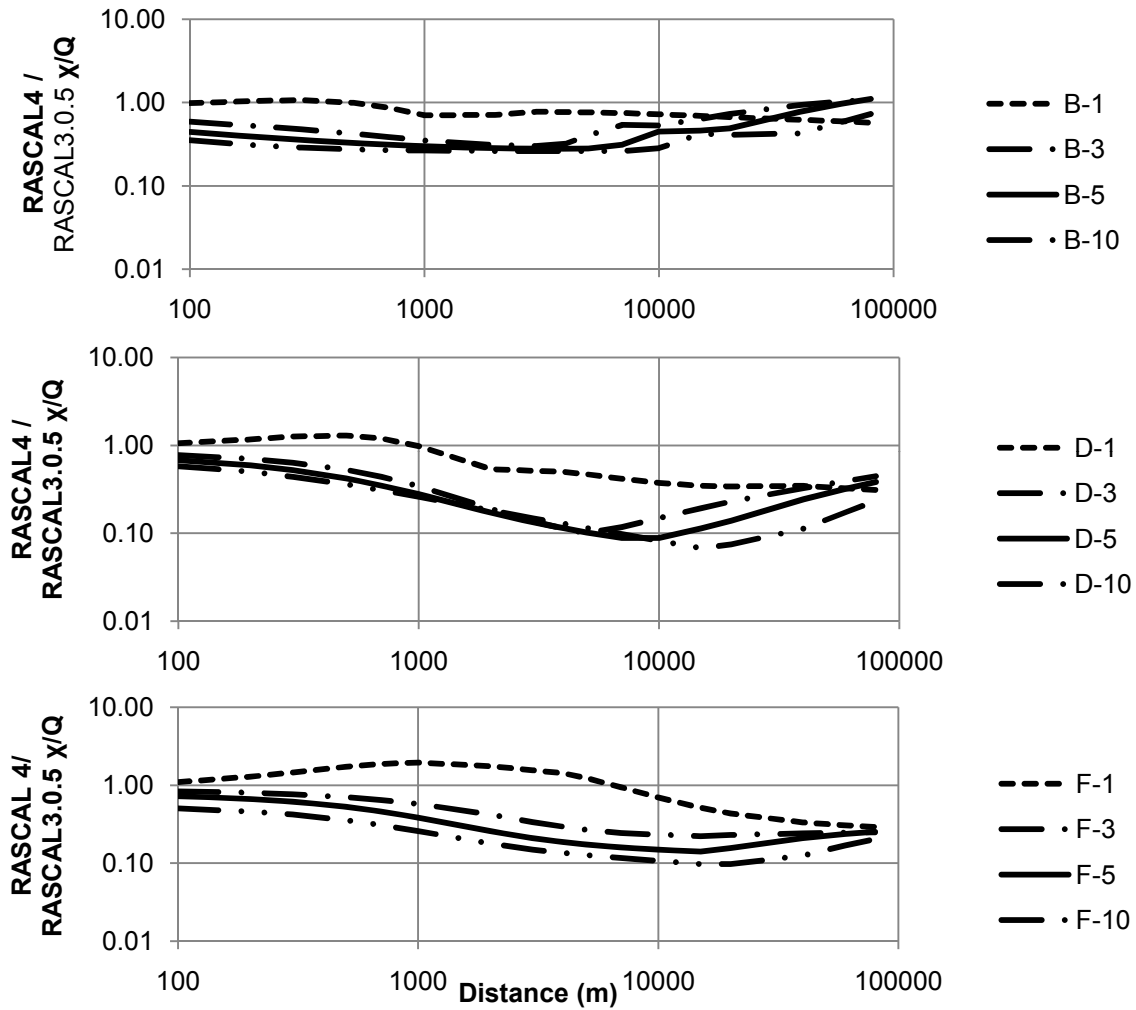
Atmospheric Dispersion

- Why the Change?
 - The Pasquill-Gifford dispersion parameters were based on dispersion experiments in the 1950s.
 - Atmospheric experiments on dispersion and boundary layer processes in the 1960s, 1970s, and 1980s provide better methods of estimating atmospheric dispersion.

Atmospheric Dispersion

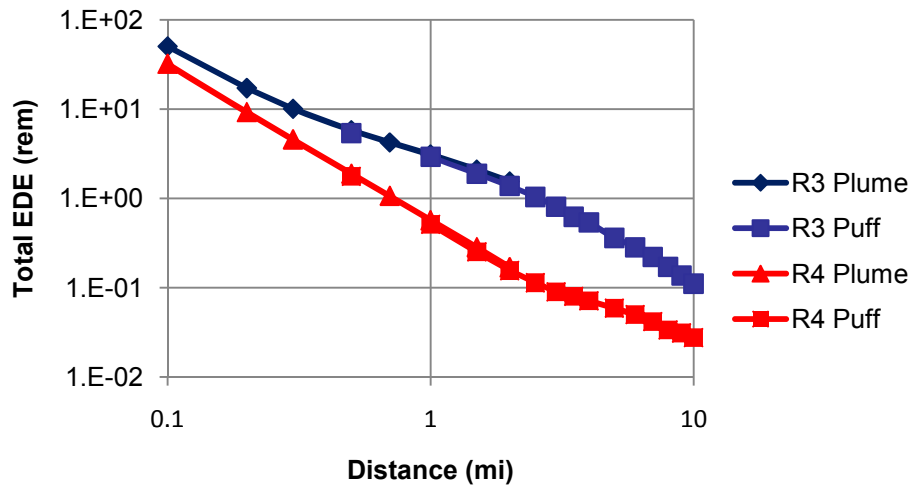
- What are the Implications of the Changes?
 - The RASCAL v4 dispersion parameters tend to be larger than the RASCAL v3.0.5 parameters
 - X/Qs and doses for ground-level releases will tend to be lower
 - X/Qs and doses for elevated releases will tend to be higher near the release point

Atmospheric Dispersion

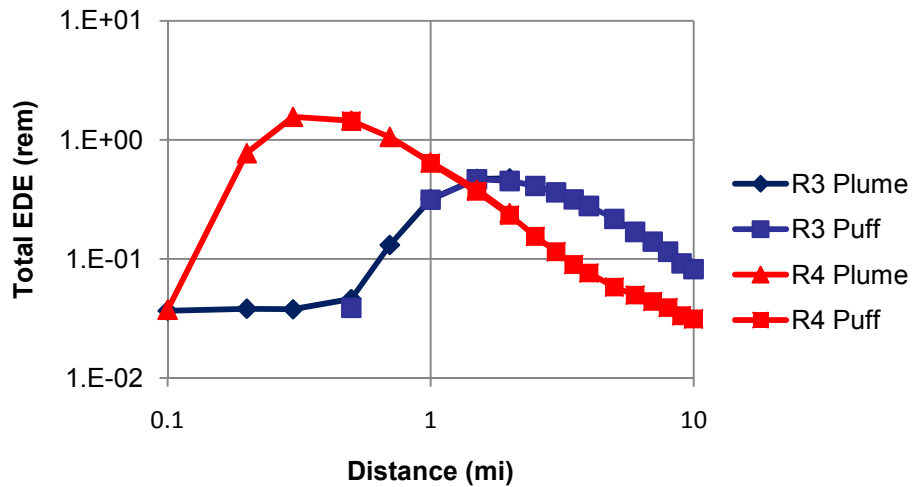


Atmospheric Dispersion

Ground Level,
D Stability, 3 m/s



Elevated,
D Stability, 3 m/s



Atmospheric Deposition

- Why the Changes?
 - The RASCAL v3.0.5 parameters were developed in the 1950s and early 1960s.
 - Research on atmospheric processes in the 1960s, 1970s, and 1980s provide better methods of estimating atmospheric deposition.

Atmospheric Dry Deposition

- What is New?
 - RASCAL v4 has changed from constant dry deposition velocities to dry deposition velocities that are a function of atmospheric conditions including wind speed, stability, and surface roughness.
 - RASCAL v4 treats iodine (halogens) as three species having different deposition characteristics for purposes of calculating deposition (I_2 , particles, and CH_3I)

Atmospheric Dry and Wet Deposition

- What is New?
 - RASCAL v4 iodine speciation is 25% Particles, 30% I_2 , and 45% CH_3I ; CH_3I is assumed not to deposit.
 - RASCAL v4 uses a wet deposition velocity for wet deposition of gases and a washout model for wet deposition of particles. These parameters are functions of wind speed, atmospheric stability, surface roughness, and precipitation rate

Atmospheric Deposition

- What are the Implications of the Changes?
 - The RASCAL v4 deposition parameters, while not constant, tend to be within a factor of 2 of the RASCAL v3.0.5 parameters.
 - RASCAL v4 deposition velocities for iodine tend to be lower than the RASCAL 3.0.5 value in low wind speed conditions and higher in high wind speeds.
 - Deposition of iodine is generally lower in RASCAL v4 because 45% of the iodine does not deposit.

Atmospheric Deposition

Iodine Dry Deposition Velocities (m/s)

	Wind Speed (m/s)				
Stability	1	2	3	5	10
B	0.0023	0.0035	0.0043	0.0055	0.0072
D	0.0018	0.0028	0.0035	0.0046	0.0063
F	0.0014	0.0023	0.0030	0.0039	0.0055

Atmospheric Dispersion and Deposition

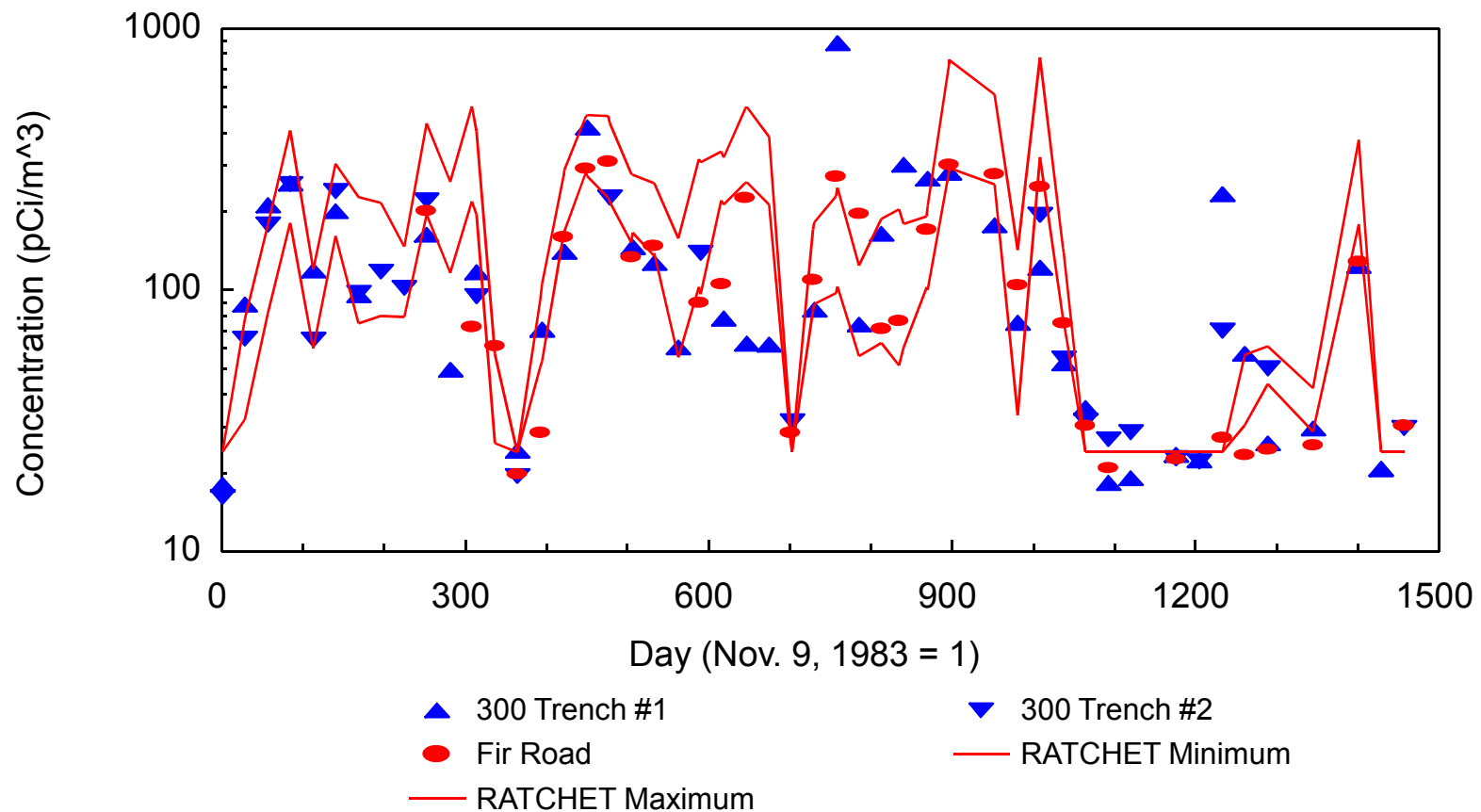
- Are the Dispersion and Deposition Changes Reasonable?
 - The new dispersion and deposition algorithms were developed for environmental dose reconstruction at Hanford in the 1990s
 - The development and application of the new algorithms were extensively reviewed by leading experts including F. Gifford and scientific organizations including the National Academy of Sciences.

Atmospheric Dispersion and Deposition

- Are the Dispersion and Deposition Changes Reasonable?
 - The Hanford Environmental Dose Reconstruction Project included an extensive validation effort
 - The dispersion and deposition algorithms have been used in subsequent dose reconstruction projects (ORNL, INEL, Rocky Flats, and Mayak, USSR)

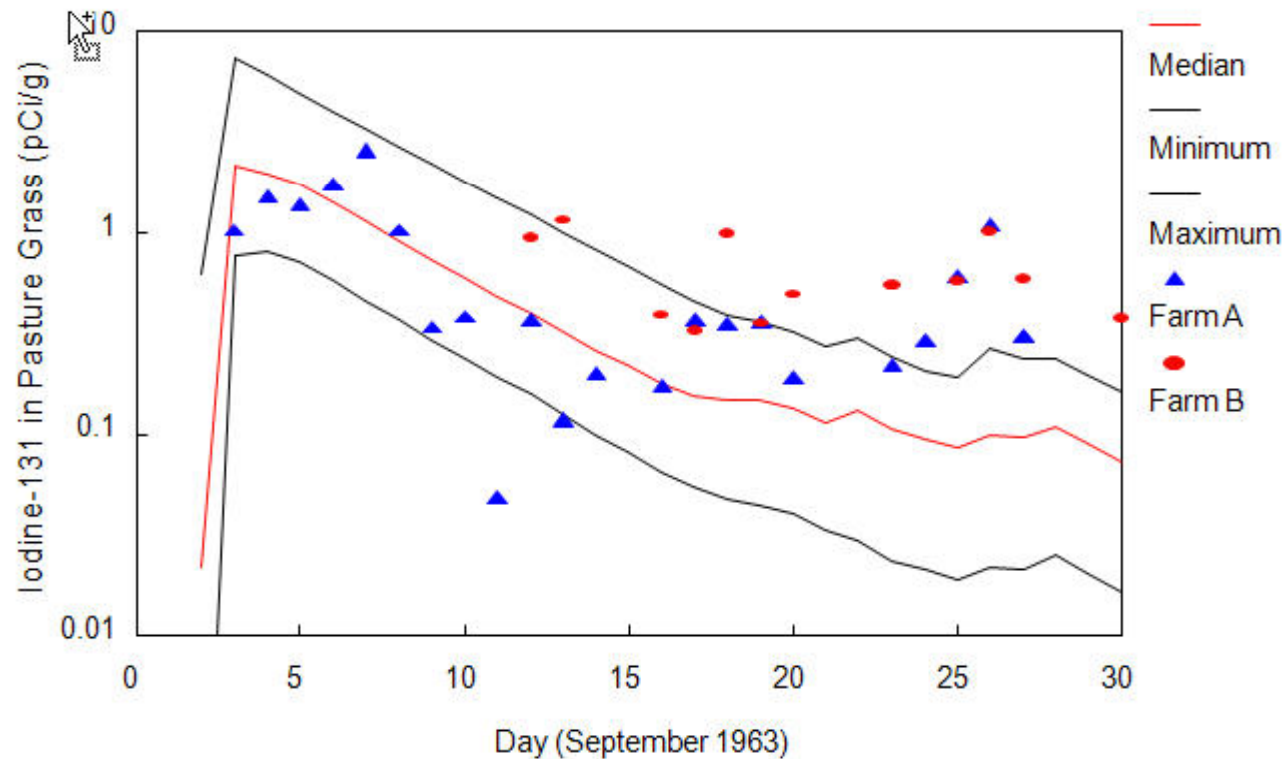
Atmospheric Dispersion

Kr-85 Predictions for Routine Releases at Hanford



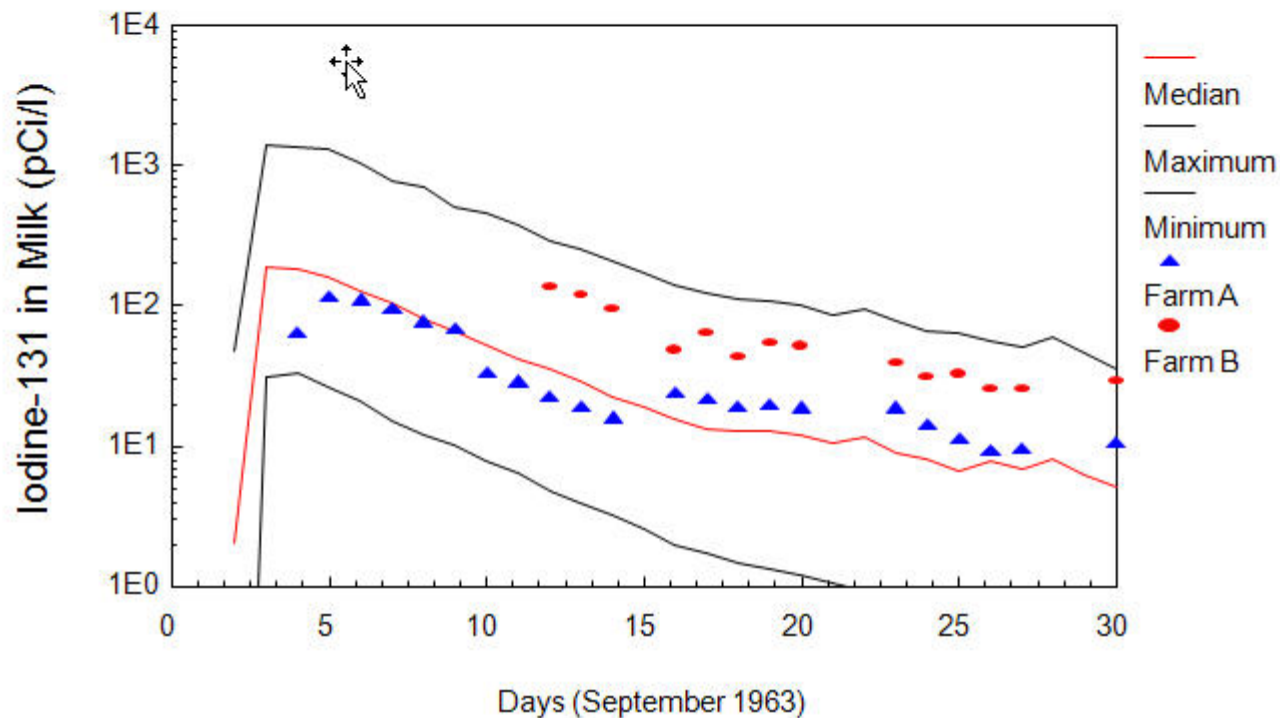
Atmospheric Dispersion and Deposition

Iodine in Grass Following Unintended Release at Hanford (Sept. 1963)



Atmospheric Dispersion and Deposition

Iodine in Milk Following Unintended Release at Hanford (Sept. 1963)



Atmospheric Dispersion and Deposition

The Bottom Line For an Unintended Release at Hanford
(Sept 1963)

	HEDR Median Thyroid Dose Estimate (mrad)	Contemporary Thyroid Burden Estimates (mrad)
Boy	45.3	35
Girl	11.3	9

Part 3

Dose differences, GIS Shape File Export, Future plans

Contrast w/RASCAL 3.0.5

- Highlight new features – new ATD model
- Case Study - Fixed Parameters

Byron NPP, Core uncovered 1 hr

2% release per day, no spray, no filters

activity released – 9.5 E5 Curies 3.0.5

-- 8.9 E5 Curies 4.0

- Case Study – Varying Parameters
Stability Classes B and E
2 & 8 mph wind speeds, no precip

Byron Unit 2: Source Term

The screenshot displays the 'Source Term to Dose - [New Case.STD]' application window. The main interface has a menu bar (File, Options, Nuclide Data Viewer, Site / Facility Data Viewer, Help) and a sidebar with buttons for 'Event Type', 'Event Location', 'Source Term' (highlighted with an orange box), 'Meteorology', 'Release Path', 'Calculate Doses', 'Detailed Results', and 'Save Case'. The main area shows a 'Case Summary' for a 'Nuclear Power Plant' event at 'Byron - Unit 2'. The 'Source Term' tab is active, and two sub-dialogs are open.

Source Term Options for Nuclear Power Plant

Source term based on reactor conditions

- ☒ Time Core Is Uncovered
- ☐ Specified Core Damage Endpoint
- ☐ Containment Radiation Monitor
- ☐ Coolant Sample

Time Core Is Uncovered

Reactor shutdown: 2010/02/20 00:00

Core uncovered? ☒ Yes 2010/02/20 01:00 ☐ No normal coolant activity released

Core recovered? ☒ Yes 2010/02/20 02:00 ☐ No

Buttons: OK, Cancel, Help

Release Pathway

Source Term to Dose - [New Case]

File Options Nuclide Data View

Follow the steps below to define and run a problem

☒ **Event Type**
NPP Reactor

☒ **Event Location**
Byron - Unit 2

☒ **Source Term**
Time Core Is Uncovered

☒ **Release Path**
<undefined>

☐ **Meteorology**
<undefined>

Calculate Doses

Detailed Results

Save Case

Available release pathways

Select the release pathway option to be used in the calculations

☒ **Containment leakage/failure**

☐ Steam generator tube rupture

☐ Containment bypass

PWR Dry Containment – Leakage/Failure

OK

Cancel

Help

Print

Release Pathway Options

PWR - Dry Containment Leakage or Failure

Pathway description: (optional; 60 character max)

Release height:

Release timings: Core uncovered: 2010/02/20 01:00

Leak rate to atmosphere described by: ☒ Percent volume / time ☐ Containment pressure / hole size

Date	Time	Event	Event setting
2010/02/20	01:00	Leak rate (% vol)	2.000 %/d
2010/02/20	01:00	Sprays	Off

Leak Rate as Percent of Volume

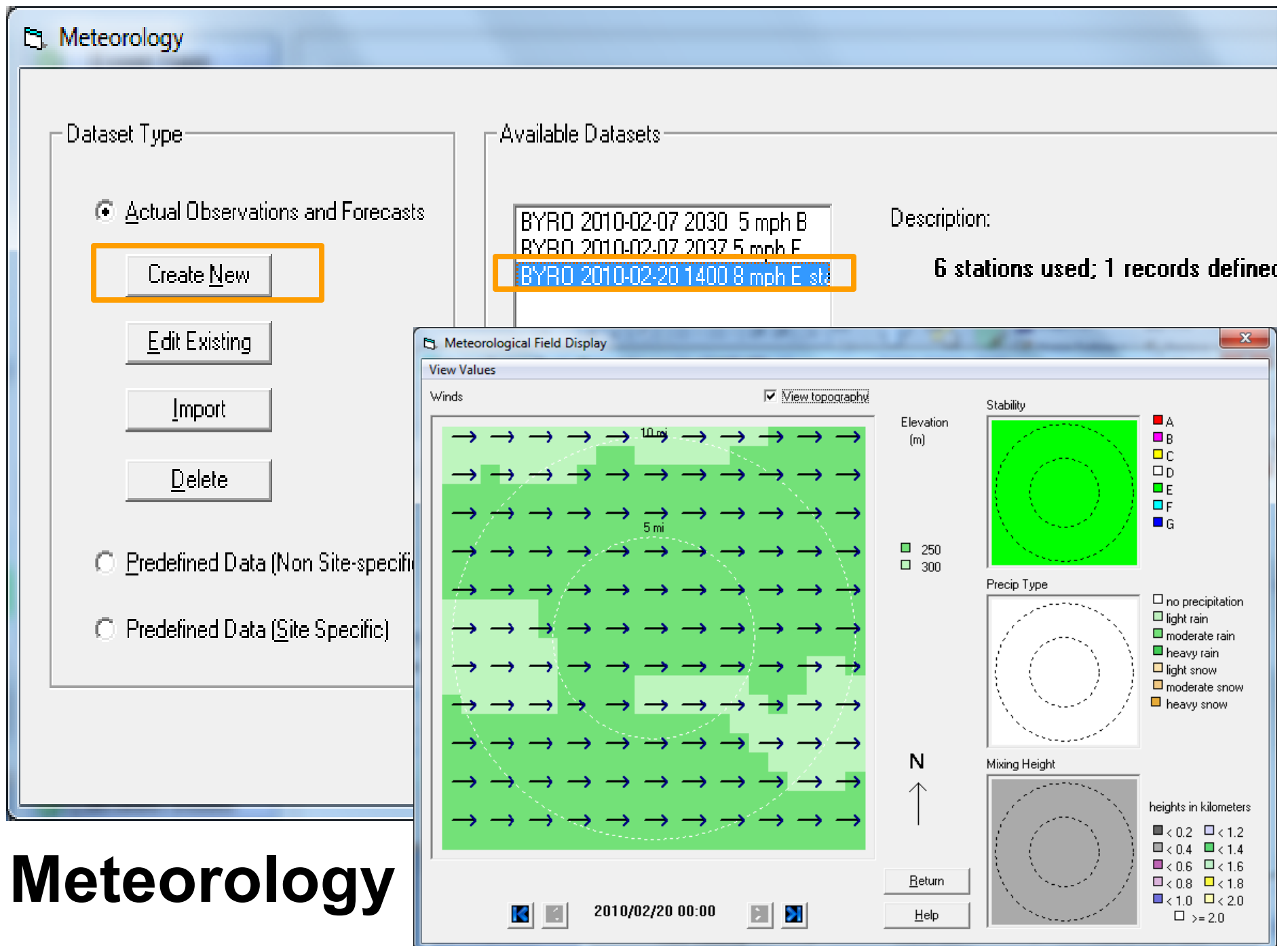
☐ Total Failure (100 %/h) ☒ Percent Volume: % per ☐ Design (0.10 %/d)

OK Cancel Help

Add Row Remove Row Sort Rows Clear All

OK Cancel Help

Minimum 10 m release height is optimum model default



Calculate

The image shows a software interface for calculating doses from a source term. The main window, titled 'Source Term to Dose - [Byron 1 hr uncovered N]', has a menu bar (File, Options, Nuclide Data Viewer, Site / Facility) and a sidebar with several steps: Event Type (NPP Reactor), Event Location (Byron - Unit 2), Source Term (Time Core Is Uncovered), Release Path (PWR Dry), Meteorology (Actual Observations), and Calculate Doses (highlighted with an orange box). Below the sidebar is a 'Case Summary' tab with fields for Name, City, county, Lat / Long / E, Time zone, and Population (2). The 'Calculate Doses' button is highlighted with an orange box. The 'Start the Calculations' dialog box is open, showing options for distance of calculation (Close-in + out to 10 miles (16 km), Close-in + out to 25 miles (40 km), Close-in + out to 50 miles (80 km), Close-in only), using close-in distances in miles (0.1, 0.2, 0.3, 0.5, 0.7, 1.0, 1.5, 2.0), and end calculations at (Start of release to atmosphere plus: 8 hours, User specified time: 2010/02/20 07:00). The 'Case description' field is 'Byron 1 hr uncovered'.

Source Term to Dose - [Byron 1 hr uncovered N]

File Options Nuclide Data Viewer Site / Facility

Follow the steps below to define and run a problem

☒ **Event Type**
NPP Reactor

☒ **Event Location**
Byron - Unit 2

☒ **Source Term**
Time Core Is Uncovered

☒ **Release Path**
PWR Dry

☒ **Meteorology**
Actual Observations

☒ **Calculate Doses**

Case Summary

Case Summary

Event Type

Location

Name:
City, county:
Lat / Long / E
Time zone:
Population (2)

Reactor Param

Reactor power
Average fuel
Containment
Containment
Design press
Design leak r
Coolant mass
Assemblies i
Steam gener

Start the Calculations

Specify options and description for this set of calculations, then OK to begin calculations.

Distance of calculation:

☒ Close-in + out to 10 miles (16 km)
☐ Close-in + out to 25 miles (40 km)
☐ Close-in + out to 50 miles (80 km)
☐ Close-in only

Using close-in distances in miles:
0.1, 0.2, 0.3, 0.5, 0.7, 1.0, 1.5, 2.0

☒ Defaults
☐ User defined

Start of release to atmosphere: 2010/02/20 01:00 (from release pathway definition)

End calculations at:

☒ Start of release to atmosphere plus: 8 hours
☐ User specified time: 2010/02/20 07:00

Case description: Byron 1 hr uncovered (required)

Default 8
hour dose
calculation

Source Term to Dose - [Byron 1 hr uncovered NREP.STD]

File Options Nuclide Data Viewer Site / Facility Data Viewer Help

Follow the steps below to define and run a problem

Use the Tabs below to review information.

Results

☒ **Event Type**
NPP Reactor

☒ **Event Location**
Byron - Unit 2

☒ **Source Term**
Time Core Is Uncovered

☒ **Release Path**
PWR Dry

☒ **Meteorology**
Actual Observations

☒ **Calculate Doses**

☐ **Detailed Results**

☐ **Save Case**

Maximum Dose Values (rem) - To 10 mi

Dist from release miles (kilometers)	3 (4.8)	4 (6.4)	5 (8.0)	7 (11.3)	10 (16.1)
Total EDE	6.9E-01	4.8E-01	3.8E-01	2.5E-01	1.6E-01
Thyroid CDE	<u>1.0E+01</u>	<u>7.1E+00</u>	<u>5.7E+00</u>	3.8E+00	2.4E+00
Inhalation CEDE	4.4E-01	3.1E-01	2.5E-01	1.6E-01	1.0E-01
Cloudshine	4.1E-02	3.0E-02	2.5E-02	1.7E-02	1.1E-02
1 day Groundshine	2.0E-01	1.4E-01	1.1E-01	7.1E-02	4.3E-02
Inter Phase 1st Yr	<u>3.0E+00</u>	<u>2.0E+00</u>	1.6E+00	1.0E+00	6.3E-01
Inter Phase 2nd Yr	<u>1.9E+00</u>	<u>1.3E+00</u>	1.0E+00	6.6E-01	4.1E-01

Notes:

- Doses exceeding PAGs are underlined.
- Early-Phase PAGs: TEDE - 1 rem, Thyroid (iodine) CDE - 5 rem
- Intermediate-Phase PAGs: 1st year - 2 rem, 2nd year - 0.5 rem
- *** indicates values less than 0.1 mrem
- To view all values - use Detailed Results | Numeric Table

Value displayed: ☐ Close-in dose ☒ Doses to 10 miles ☐ Criticality shine dose

Display units: ☒ English ☐ Metric

Definitions Print

Case Summary **Source Term** Maximum Dose Values

New

Check this

m to Dose Model

Viewer Site / Facility Data Viewer Help

Use the Tabs below to review information.

RASCAL 3.0.5

Source Term

Total activity released to atmosphere: 9.5E+05 Ci

Activity Released 6% lower

Nuclide	Ci	Nuclide
Ba-137m	1.1E+03	La-140
Ba-140	1.5E+03	Mo-99
Ce-144	2.0E+01	Np-239
Cs-134	2.2E+03	Pr-144
Cs-135	9.2E-06	Pr-144m
Cs-136	5.1E+02	Pu-239
Cs-137	1.4E+03	Rb-87
Cs-138	1.3E+03	Rb-88
I-129	3.1E-08	Rh-103m
I-131	1.8E+04	Rh-106
I-132	1.8E+04	Ru-103
I-133	3.3E+04	Ru-106
I-134	5.6E+03	Sb-127
I-135	2.3E+04	Sb-129

Notice Cs-137*

Source Term to Dose - [Byron 1 hr uncovered NREP.STD]

File Options Nuclide Data Viewer Site / Facility Data Viewer Help

Follow the steps below to define and run a problem

RASCAL 4.0

Use the Tabs below to review information.

☒ **Event Type**
 NPP Reactor

☒ **Event Location**
 Byron - Unit 2

☒ **Source Term**
 Time Core Is Uncovered

☒ **Release Path**
 PWR Dry

☒ **Meteorology**
 Actual Observations

Source Term

Total amount released to atmosphere: 8.9E+05 Ci

Nuclide	Ci	Nuclide	Ci	Nuclide
Ba-139	2.8E+02	La-142	3.0E+00	Sr-92
Ba-140	1.3E+03	Mo-99	1.7E+02	Tc-99m
Ce-141	3.1E+01	Nb-95	1.3E+01	Te-127
Ce-143	2.6E+01	Nb-97	4.6E-01	Te-127m
Ce-144*	2.5E+01	Nd-147	4.9E+00	Te-129
Cm-242	3.2E-01	Np-239	3.9E+02	Te-129m
Cs-134	1.9E+03	Pm-147	5.7E-04	Te-131
Cs-136	7.5E+02	Pr-143	1.1E+01	Te-131m
Cs-137*	1.3E+03	Pr-144	2.1E+01	Te-132
Cs-138	9.1E+02	Pu-241	2.4E+00	Xe-131m
I-131	1.7E+04	Rb-86	2.7E+01	Xe-133
I-132	1.7E+04	Rb-88	4.0E+04	Xe-133m
I-133	3.1E+04	Rh-103m	1.3E+02	Xe-135

the Tabs below to review information.

RASCAL 3.0.5

s (rem) - Close-In

TEDE (top) & CDE

0.2	0.3	0.5	0.7	1.	1.5	2.
(0.32)	(0.48)	(0.8)	(1.13)	(1.61)	(2.41)	(3.22)
<u>3.5E+01</u>	<u>2.1E+01</u>	<u>1.2E+01</u>	<u>9.2E+00</u>	<u>7.0E+00</u>	<u>5.0E+00</u>	<u>3.9E+00</u>
<u>6.6E+02</u>	<u>3.8E+02</u>	<u>2.2E+02</u>	<u>1.7E+02</u>	<u>1.3E+02</u>	<u>9.1E+01</u>	<u>7.1E+01</u>
<u>2.2E+01</u>	<u>1.3E+01</u>	<u>7.4E+00</u>	<u>5.5E+00</u>	<u>4.2E+00</u>	<u>3.0E+00</u>	<u>2.3E+00</u>
<u>2.9E+00</u>	<u>1.8E+00</u>	<u>1.1E+00</u>	<u>8.8E-01</u>	<u>7.0E-01</u>	<u>5.1E-01</u>	<u>4.0E-01</u>
<u>2.8E+01</u>	<u>1.6E+01</u>	<u>9.5E+00</u>	<u>7.1E+00</u>	<u>5.4E+00</u>	<u>3.9E+00</u>	<u>3.0E+00</u>
<u>8.7E-01</u>	<u>6.3E-01</u>	<u>4.5E-01</u>	<u>3.6E-01</u>	<u>3.1E-01</u>	<u>2.4E-01</u>	<u>1.9E-01</u>
<u>1.4E+00</u>	<u>8.0E-01</u>	<u>4.7E-01</u>	<u>3.5E-01</u>	<u>2.6E-01</u>	<u>1.8E-01</u>	<u>1.4E-01</u>
<u>6.6E+00</u>	<u>3.9E+00</u>	<u>2.2E+00</u>	<u>1.7E+00</u>	<u>1.3E+00</u>	<u>9.1E-01</u>	<u>7.0E-01</u>

underlined.

rem Thyroid (iodine) CDE - 5 rem

Display units: ☒ English
☐ Metric

Definitions

Print

Source Term Summary

Maximum Dose Values

the Tabs below to review information.

4.0

n) - Close-In

0.3	0.5	0.7	1.	1.5
(0.48)	(0.8)	(1.13)	(1.61)	(2.41)
<u>0.1</u>	<u>1.4E+01</u>	<u>6.3E+00</u>	<u>4.1E+00</u>	<u>2.6E+00</u>
<u>0.2</u>	<u>2.0E+02</u>	<u>9.1E+01</u>	<u>5.9E+01</u>	<u>3.7E+01</u>
<u>0.1</u>	<u>8.6E+00</u>	<u>3.9E+00</u>	<u>2.6E+00</u>	<u>1.6E+00</u>
<u>0.1</u>	<u>4.0E-01</u>	<u>2.5E-01</u>	<u>1.8E-01</u>	<u>1.2E-01</u>
<u>0.0</u>	<u>4.6E+00</u>	<u>2.1E+00</u>	<u>1.3E+00</u>	<u>8.5E-01</u>
<u>0.2</u>	<u>6.3E+01</u>	<u>2.9E+01</u>	<u>1.9E+01</u>	<u>1.2E+01</u>
<u>0.1</u>	<u>4.0E+01</u>	<u>1.8E+01</u>	<u>1.2E+01</u>	<u>7.6E+00</u>

Values about 1/3 lower

ed.

Thyroid (iodine) CDE - 5 rem

Year - 2 rem, 2nd year - 0.5 rem

n

Results | Numeric Table

Display units: ☒ English
☐ Metric

Definitions

Source Term

50 Maxim

Detailed Results of Dose Calculations

Result Type

- ☒ **TEDE**
 - ☐ Inhalation CEDE
 - ☐ Cloudshine Dose
 - ☐ 4-Day Groundshine Dose
- ☐ Thyroid CDE
- ☐ 1st year Intermediate Phase TEDE
- ☐ 2nd year Intermediate Phase TEDE
- ☐ 50 year Intermediate Phase TEDE
- ☐ External Gamma Dose Rate (cloudshine + groundshine)
- ☐ Acute Bone Dose Total
- ☐ Acute Bone from Inhalation Only
- ☐ Acute Lung Dose
- ☐ Acute Colon Dose
- ☐ Groundshine Dose Over Defined Time Period
- ☐ Ground Concentration - Total
- ☐ Ground Concentration of: Am-241
- ☐ I-131 Air Concentration

Time Period for Exposure

- ☒ Start of release to end of calculation
- ☐ Cumulative over interval
 - From: 2010/02/20 01:00
 - To: 2010/02/20 09:00
- ☐ Rate at single time
 - 2010/02/20 09:00

Display Format

From 10-mile calculation

- ☐ Footprint
- ☐ Numeric table
- ☐ Special receptors

Define Receptors

From close-in calculation

- ☒ Footprint
- ☐ Numeric table

Display Units

- ☒ English
- ☐ SI

Display Result

Help

Exit

New
options

Check TEDE

Total Effective Dose Equivalent
 Cumulative from 02/20/2010 01:00 to 02/20/2010 09:00
 Byron 1 hr uncovered nrep
 Byron - Unit 2

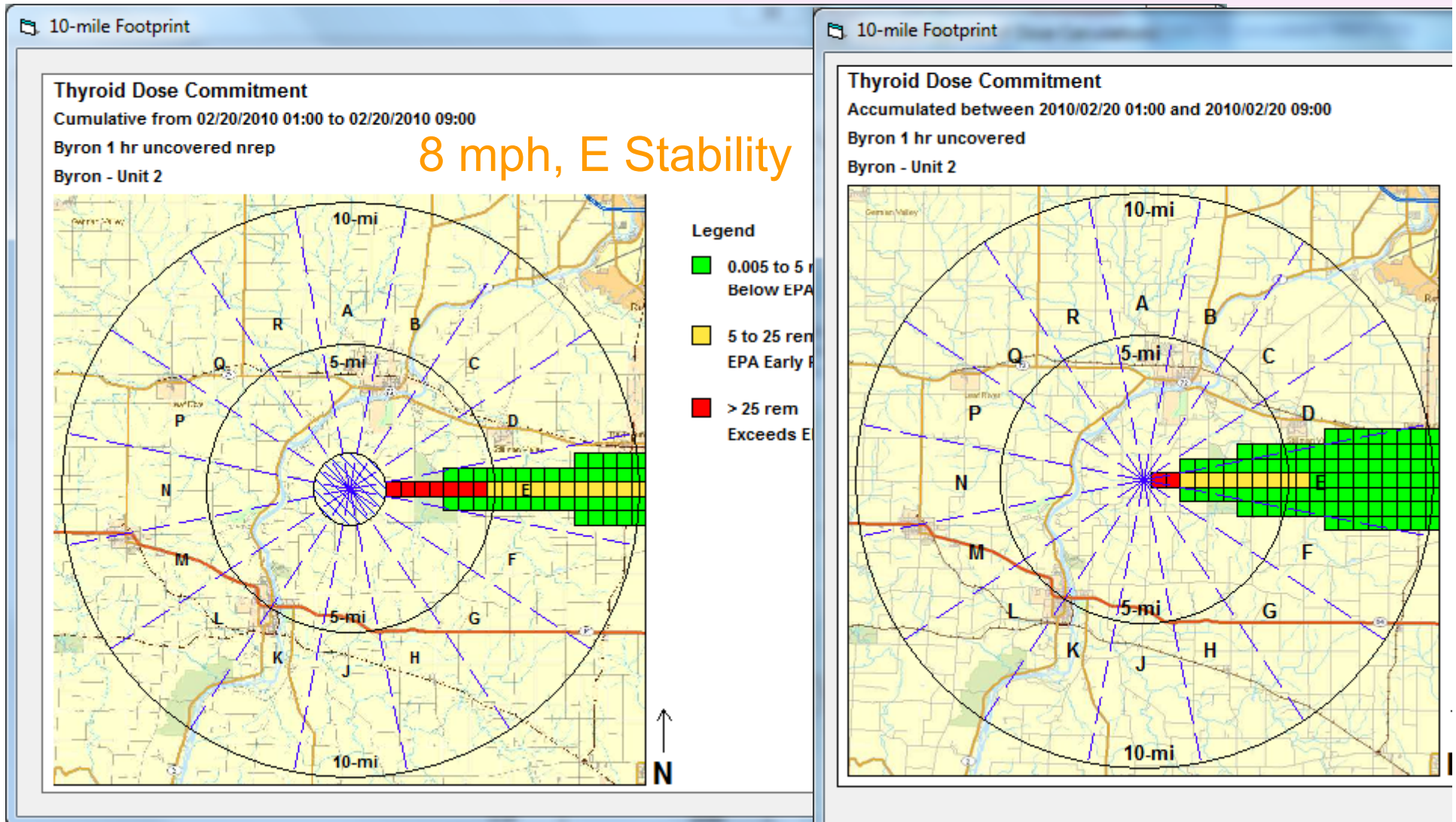
8 mph, E Stability

Legend

- 0.001 to 1 rem
Below EPA R
- 1 to 5 rem
EPA Early PH
- > 5 rem
Exceeds EPA

Total Effective Dose Equivalent
 Accumulated between 2010/02/20 01:00 and 2010/02/20 09:00
 Byron 1 hr uncovered
 Byron - Unit 2

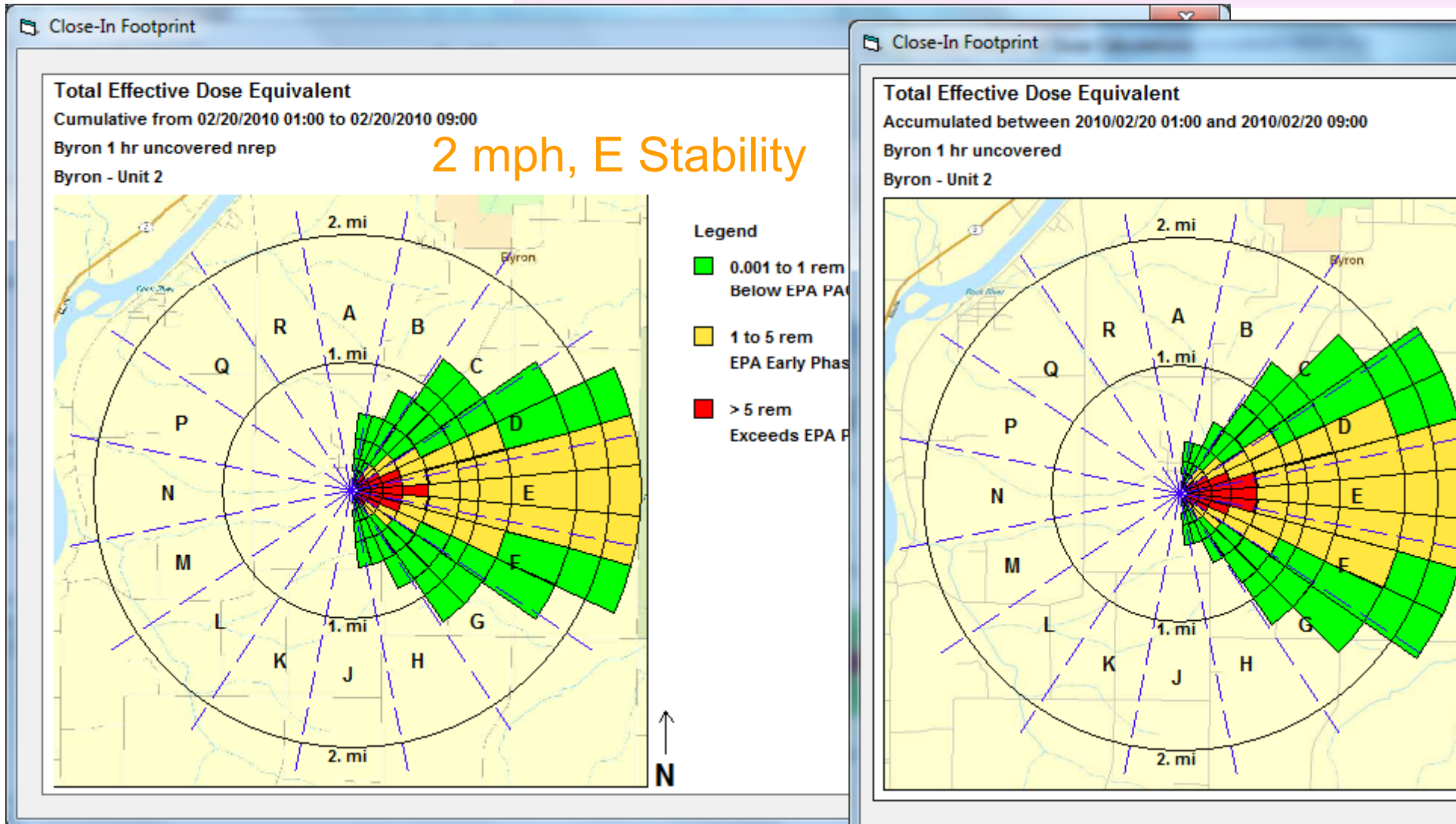
3.0.5 (left) vs 4.0 **Thyroid** 23 rem vs 5.7 rem at 5 mi 8.9 rem vs 2.4 rem at 10 mi



3.0.5 (left) vs 4.0 TEDE

3.3 rem vs 2.3 rem at 2 mi

1.9 rem vs 0.65 at 5 mi



3.0.5 (left) vs 4.0 Thyroid
36 rem vs 13 at 5 mi
15 rem vs 3.2 at 10 mi

10-mile Footprint

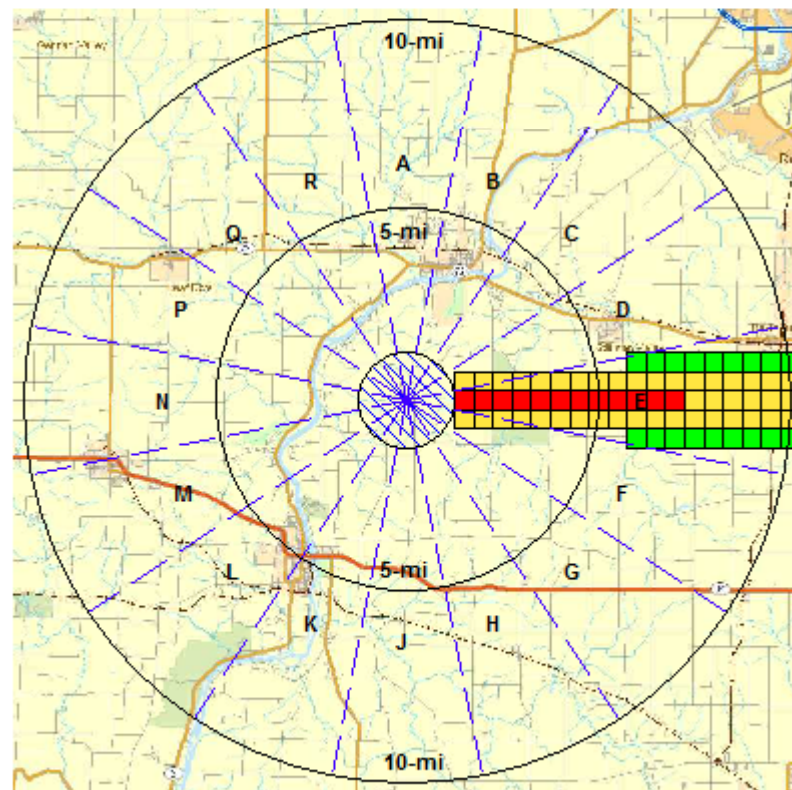
Thyroid Dose Commitment

Cumulative from 02/20/2010 01:00 to 02/20/2010 09:00

Byron 1 hr uncovered nrep

Byron - Unit 2

2 mph, E Stability



Legend

- 0.005 to Below EPA Ear
- 5 to 25 rem
- > 25 rem Exceed

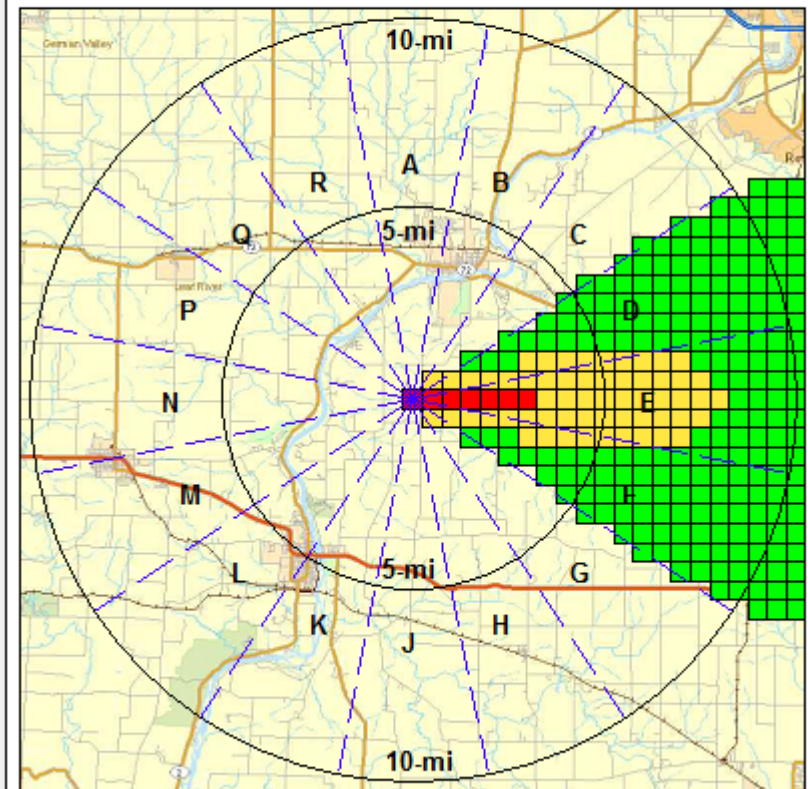
10-mile Footprint

Thyroid Dose Commitment

Accumulated between 2010/02/20 01:00 and 2010/02/20 09:00

Byron 1 hr uncovered

Byron - Unit 2

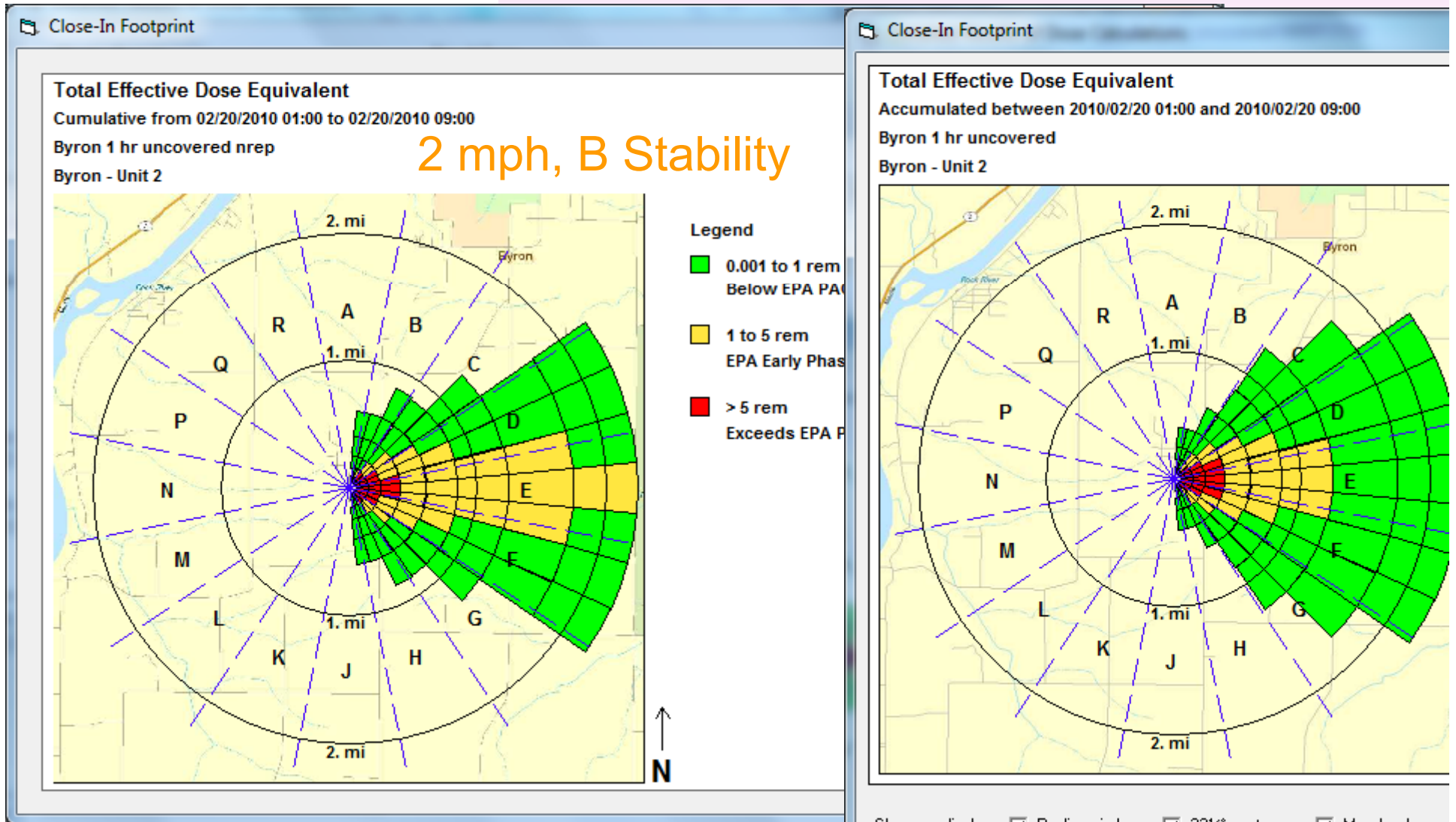


Legend

-
-
-

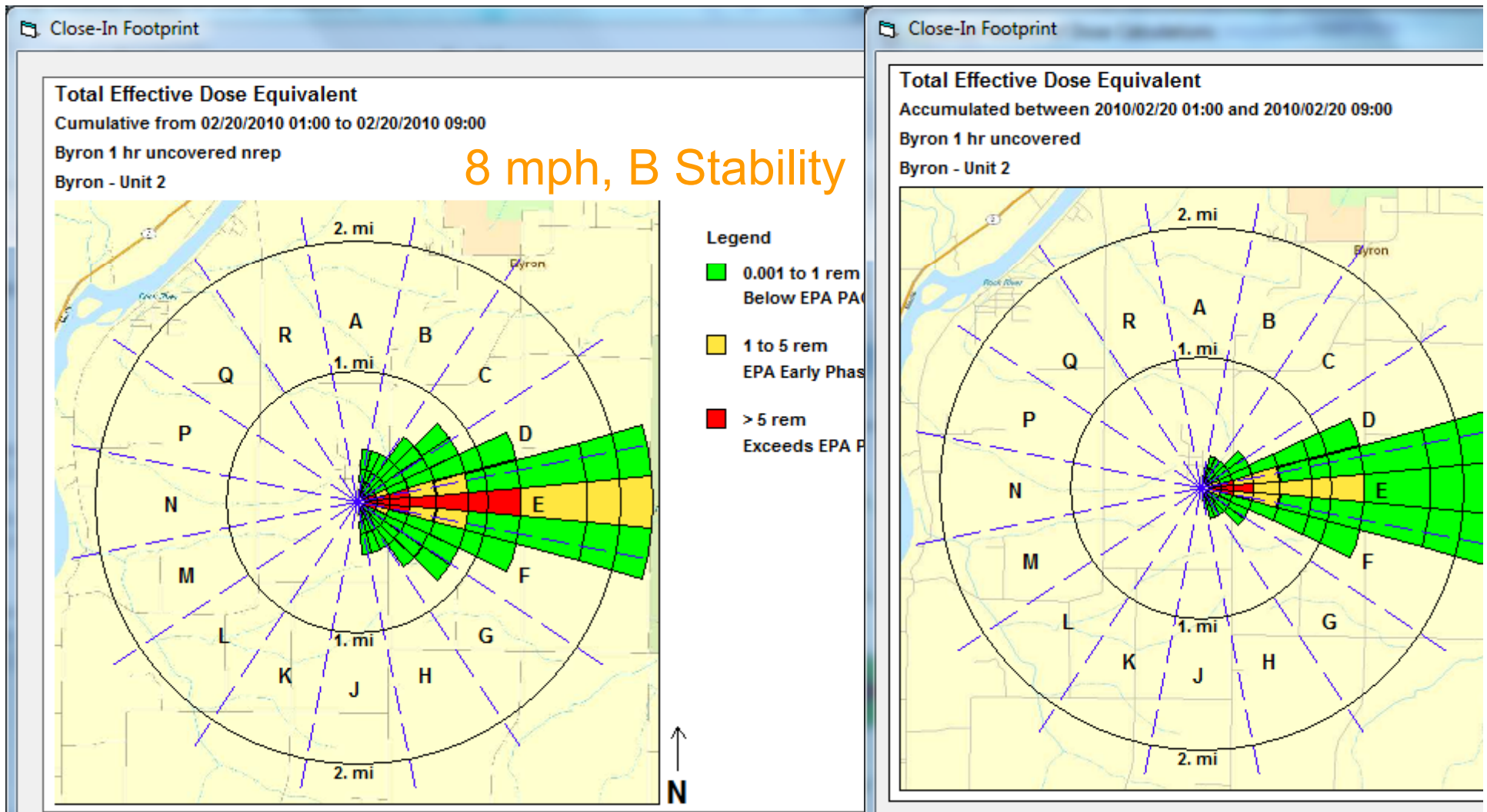
3.0.5 (left) vs 4.0 TEDE

2.1 rem vs **0.44** rem at 2 mi
0.88 rem vs **0.23** at 5 mi

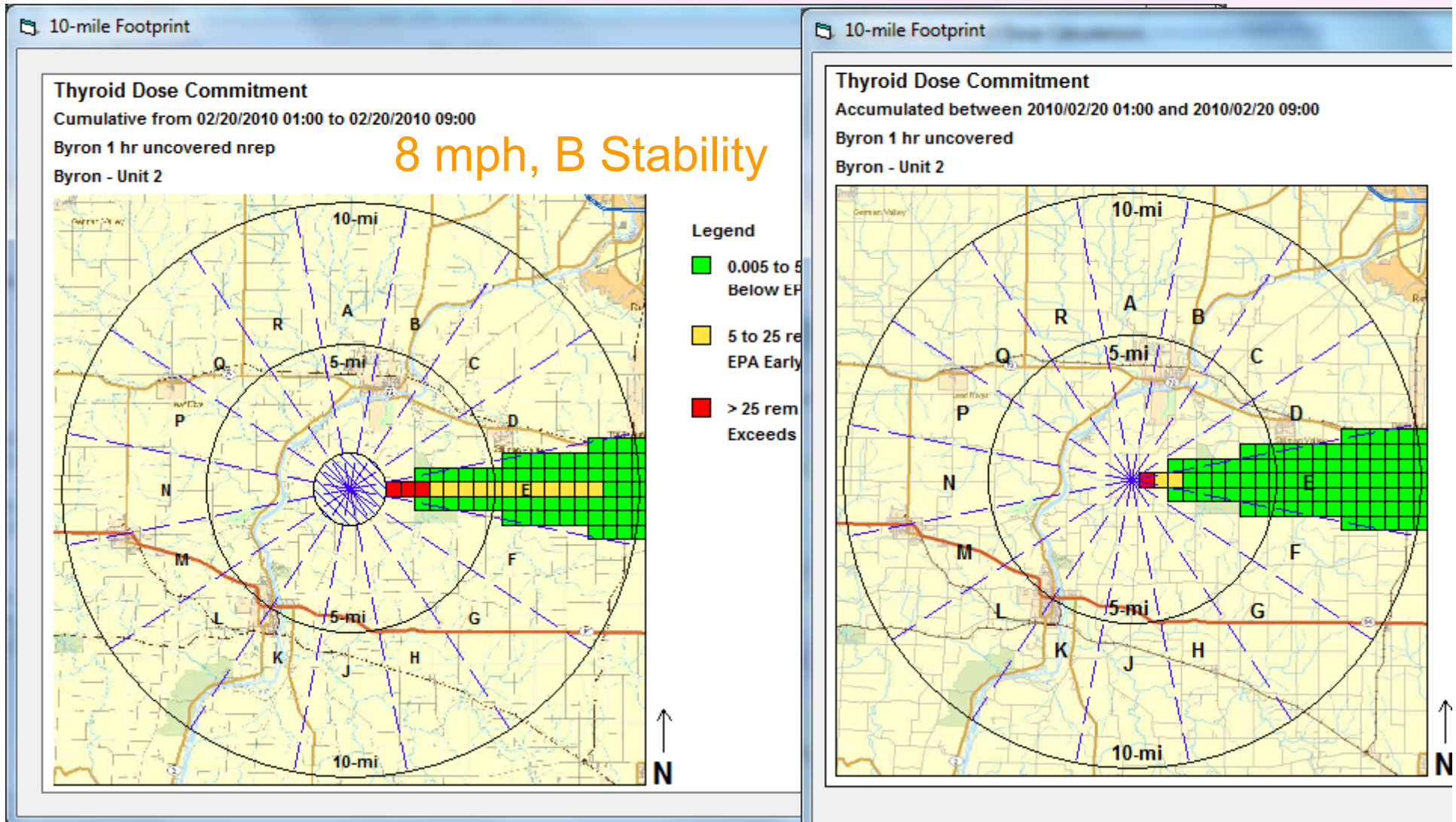


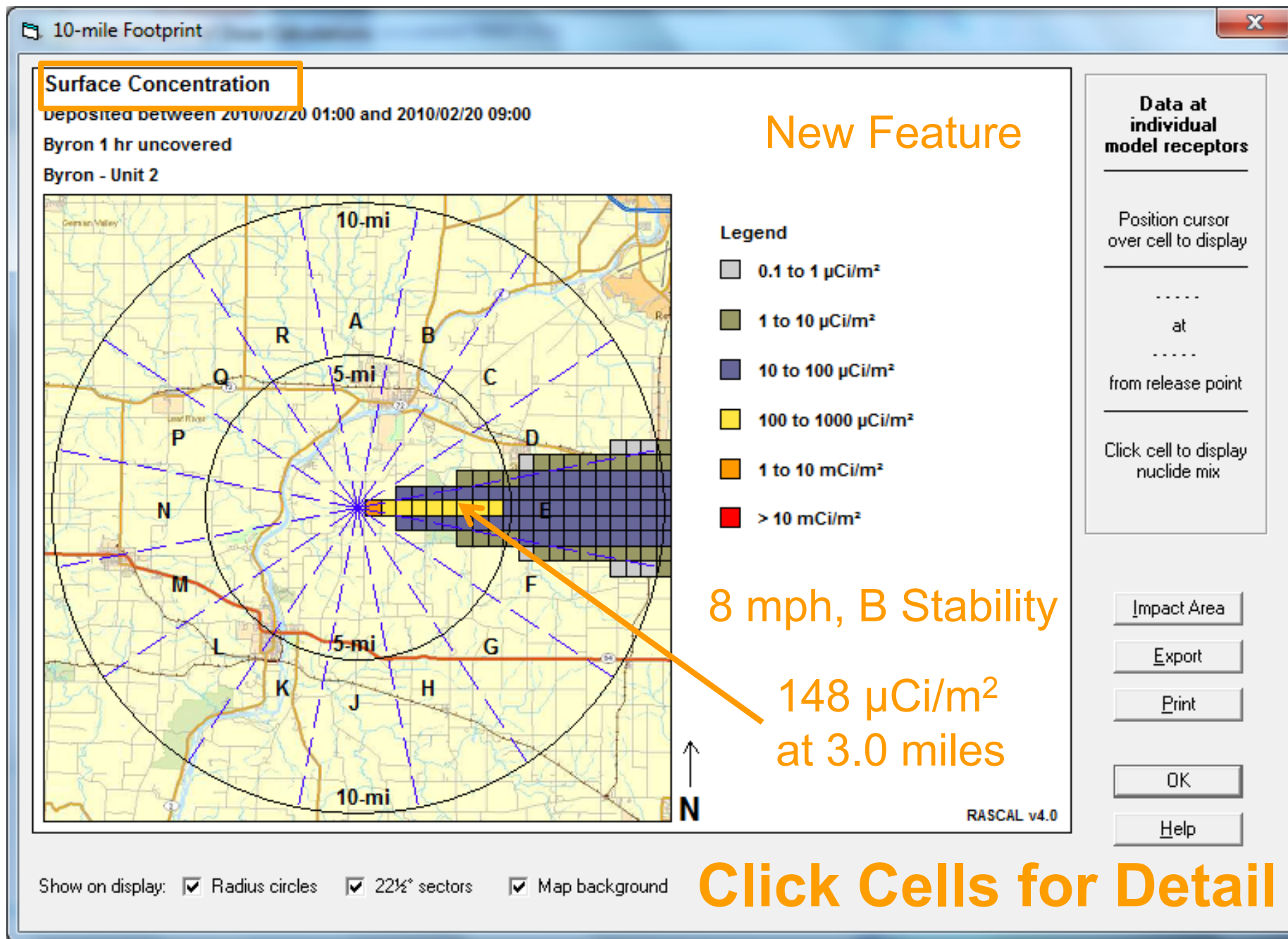
3.0.5 (left) vs 4.0 TEDE

2.4 rem vs 0.33 rem at 2 mi
0.64 rem vs 0.11 at 5 mi



3.0.5 (left) vs 4.0 Thyroid
11 rem vs 1.6 at 5 mi
4.0 rem vs 0.83 at 10 mi





Radionuclide Deposition

Surface Concentration - Radionuclide Mix

Nuclide	$\mu\text{Ci}/\text{m}^2$
I-133	4.67E+01
I-131	3.01E+01
I-135	2.36E+01
Te-132	4.64E+00
Cs-134	3.43E+00
Ba-140	2.46E+00
Cs-137*	2.37E+00
Sr-91	1.59E+00
Cs-136	1.37E+00
Sr-89	1.26E+00
Np-239	6.73E-01
Te-131m	5.81E-01

Deposited between 2010/02/20 01:00 and 2010/02/20 09:00

Bearing / Distance: 90 deg / 3.0 mi (from release point)

Latitude / Longitude: 42.076146° / -89.223617°

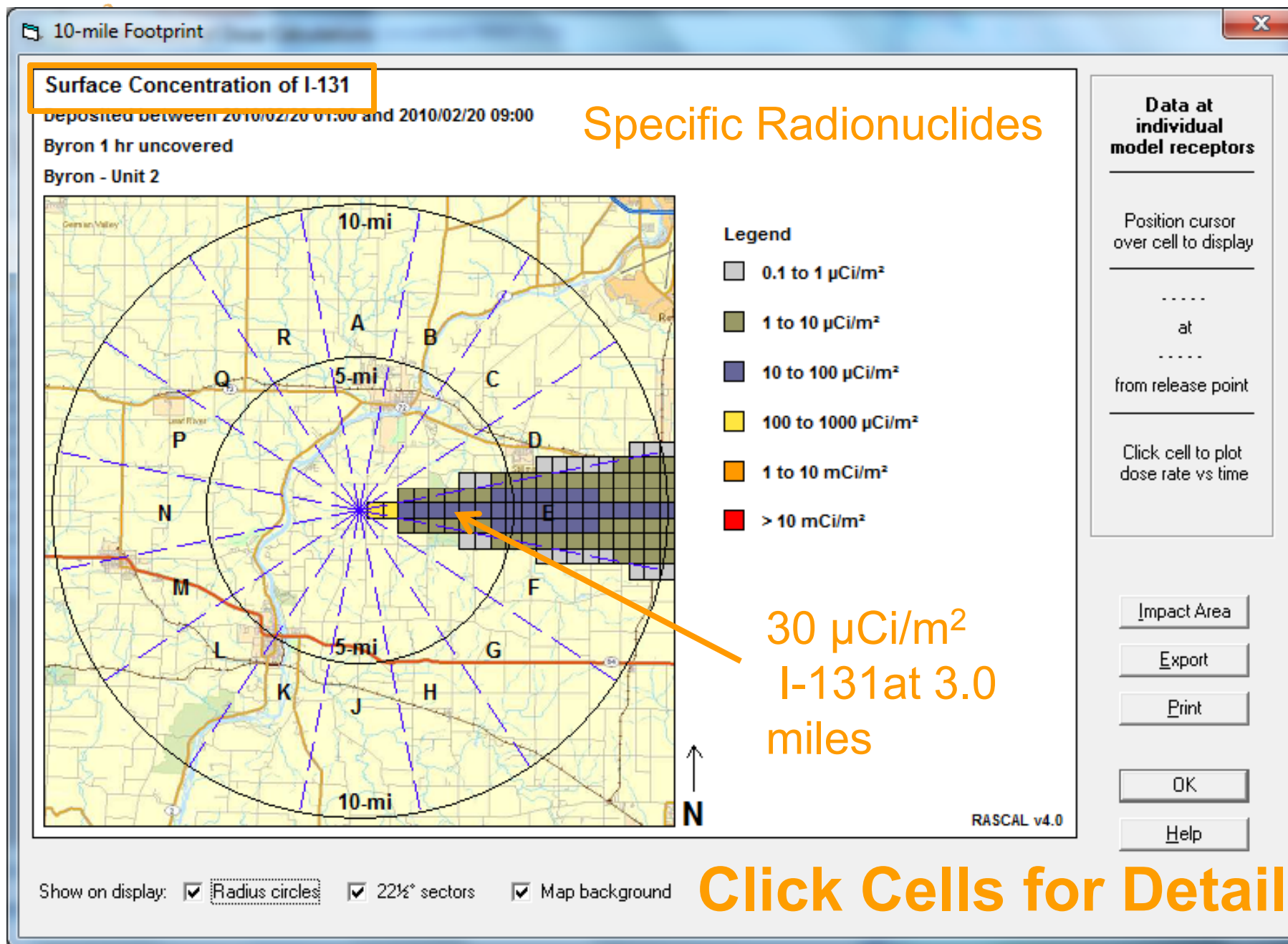
Notes on values displayed:
Activity on the ground is not decayed beyond the end of calculations
Values less than 1.0% of the largest concentration are not shown

Select option for display of nuclide list:

- ☒ All nuclides - sorted by activity
- ☐ Top 10 nuclides by activity
- ☐ Top 10 sorted by contribution to gamma dose rate
- ☐ Top 10 sorted by contribution to beta dose rate
- ☐ Nuclides important for ingestion of food

Sampling required before decision making

OK
Help
Print
Export



Dose vs Time Plot - 10 mile Calculations



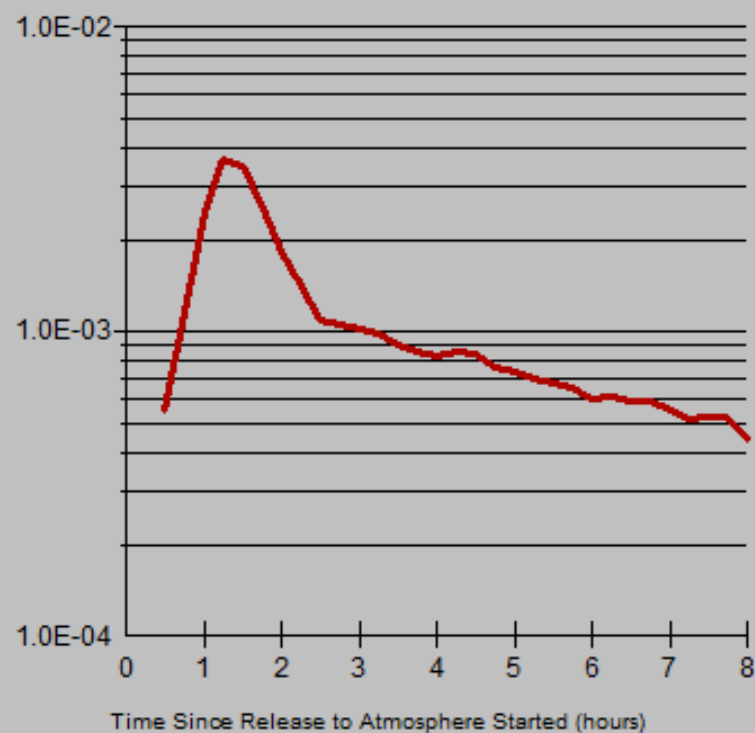
Case description: **Byron 1 hr uncovered**

Start of release: **2010/02/20 01:00**

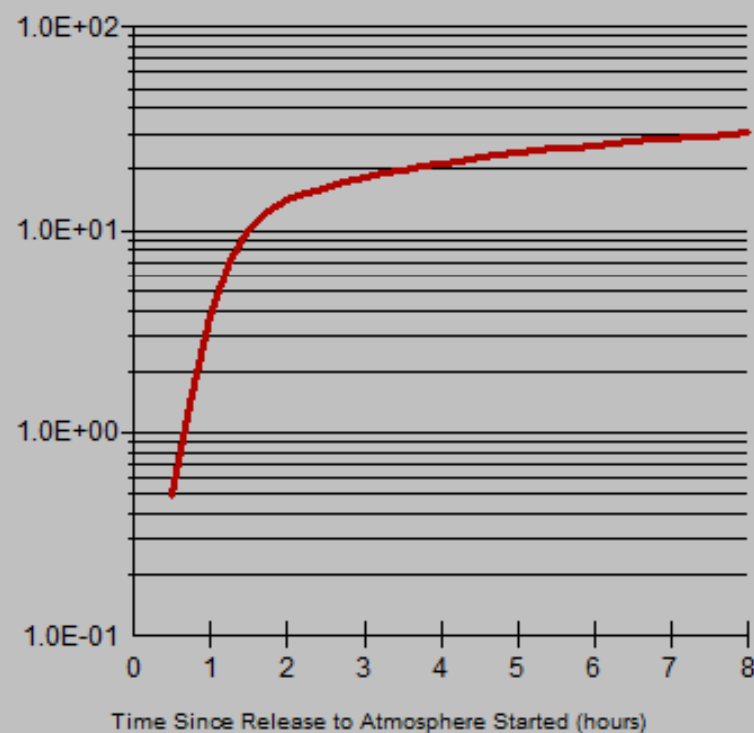
Receptor location: **90 deg, 3.0 mi (from release point)**

Release still in progress but
calculation stopped at 8 hr.

Deposition Rate ($\mu\text{Ci}/\text{m}^2/\text{s}$) of I-131



Surface Concentration ($\mu\text{Ci}/\text{m}^2$) of I-131



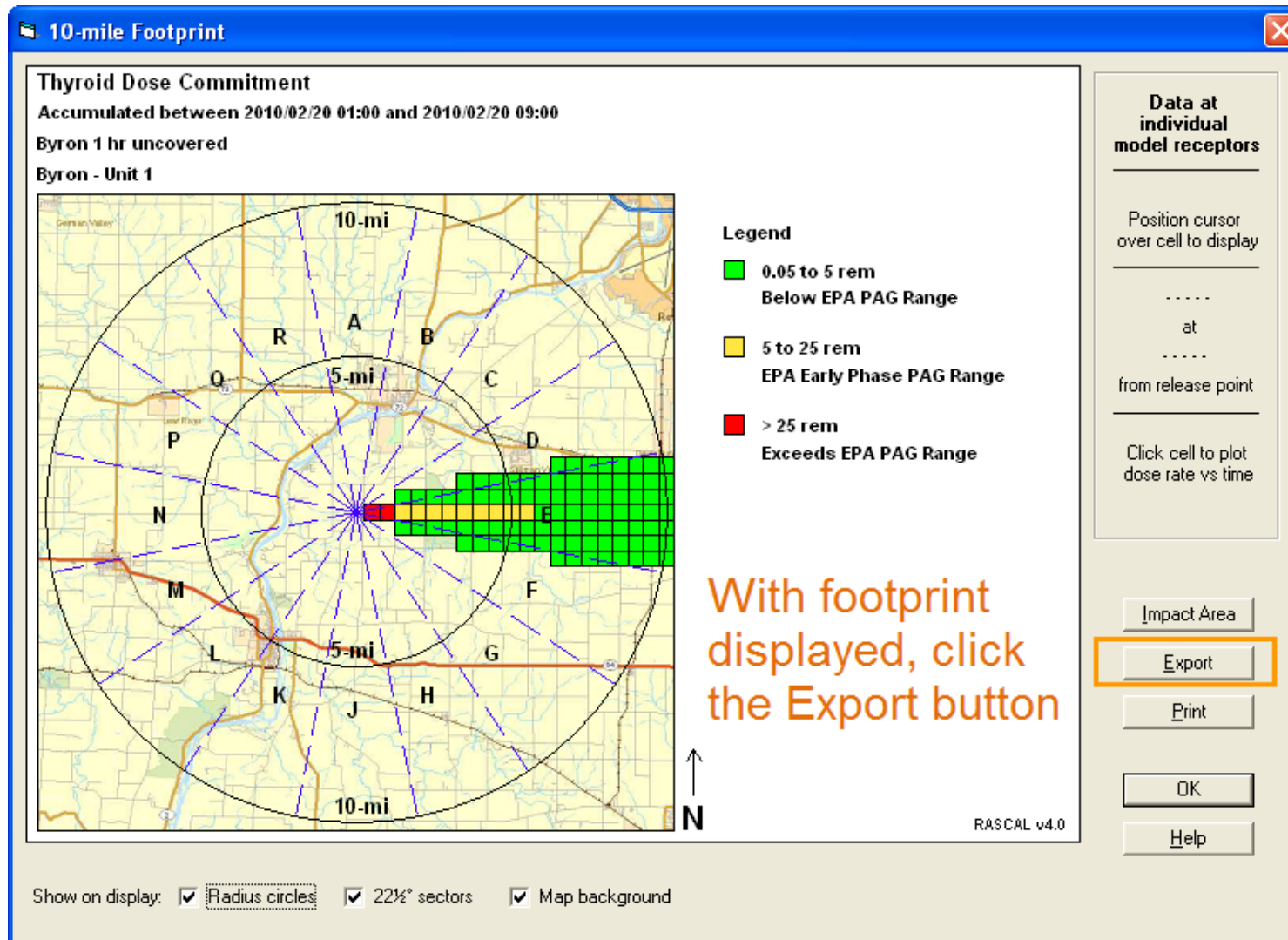
Print

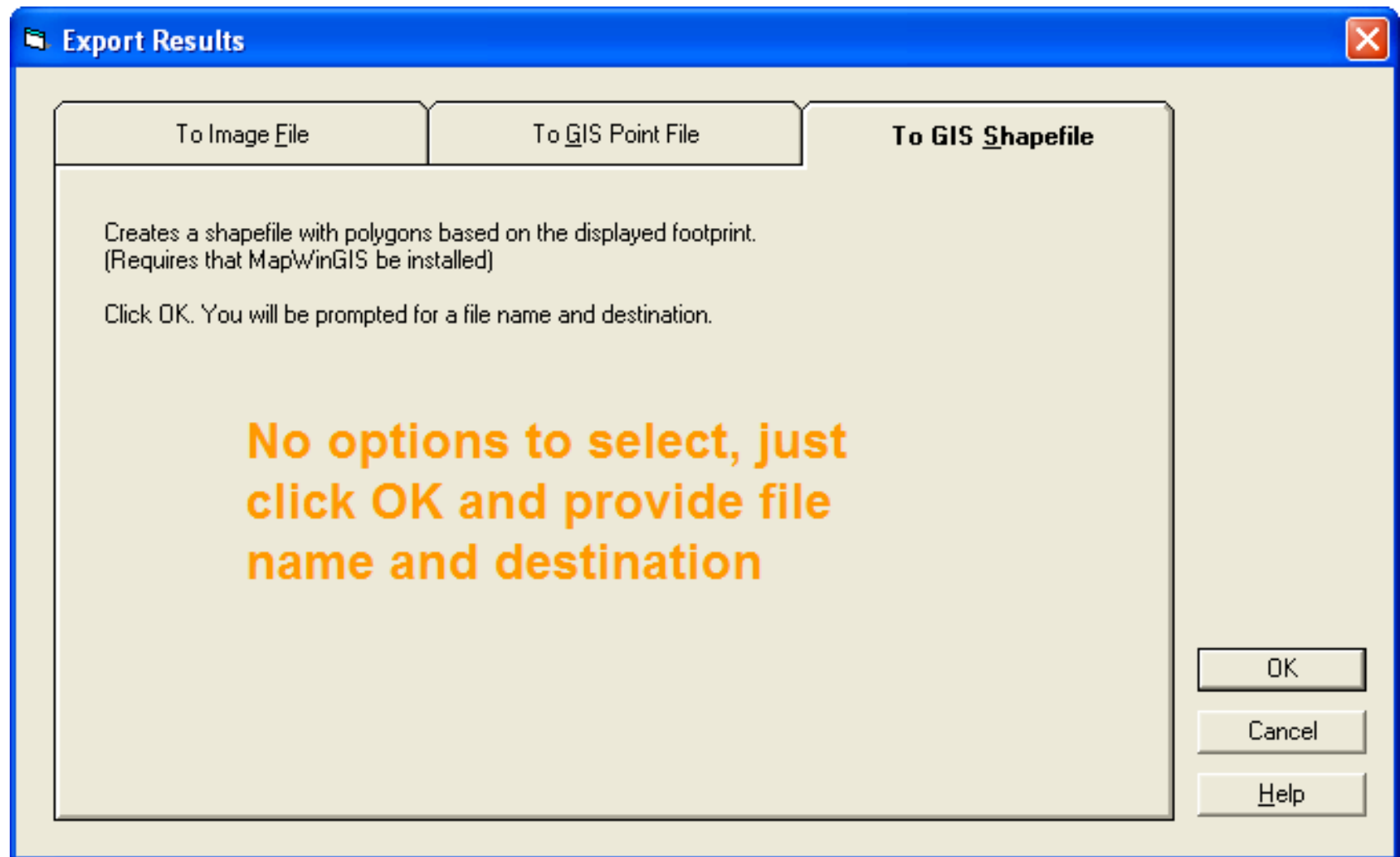
OK

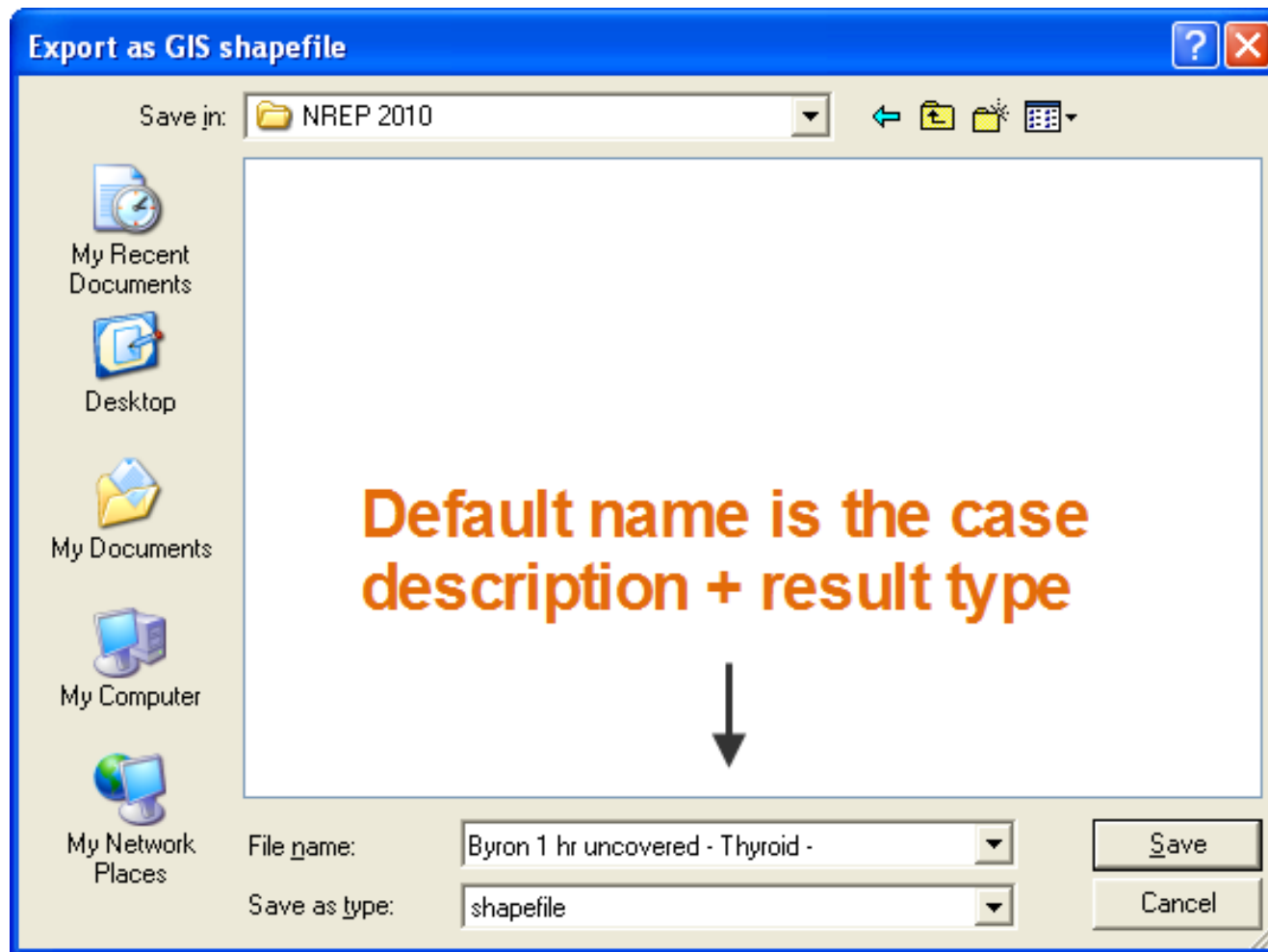
Help

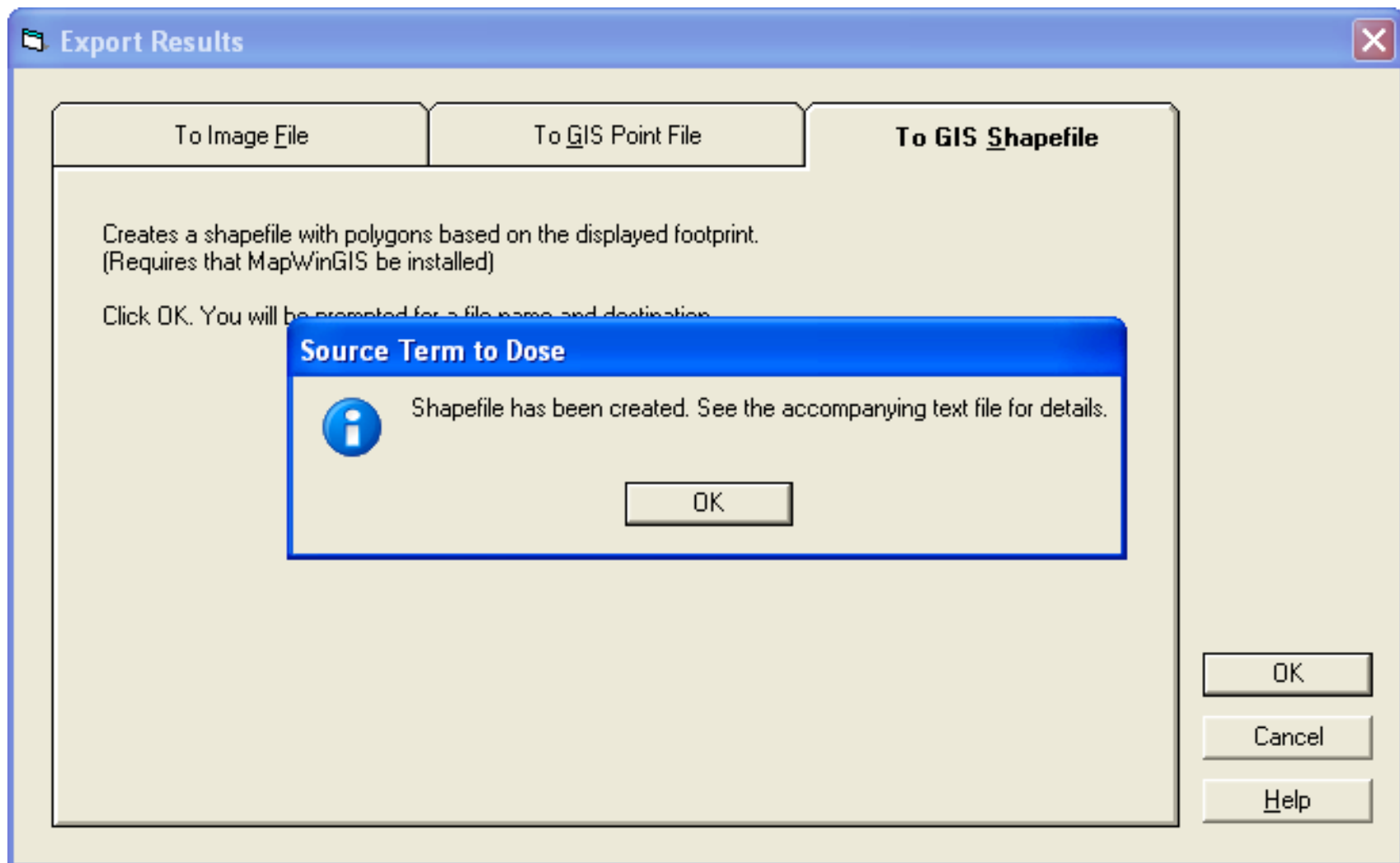
Export Footprint to Shapefile

- Requires the MapWindow GIS open source software
- www.mapwindow.org
- Separate installation required for this feature to work
- Latest installation available with RASCAL installation



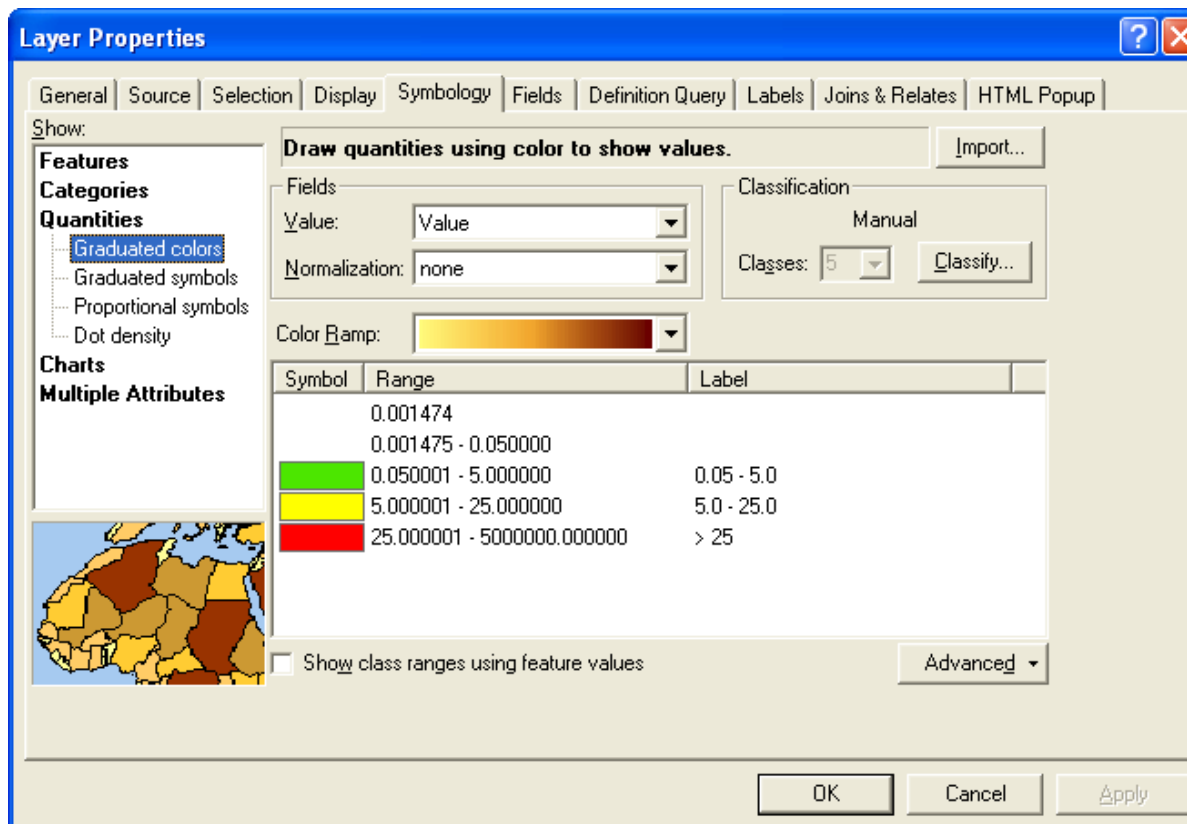




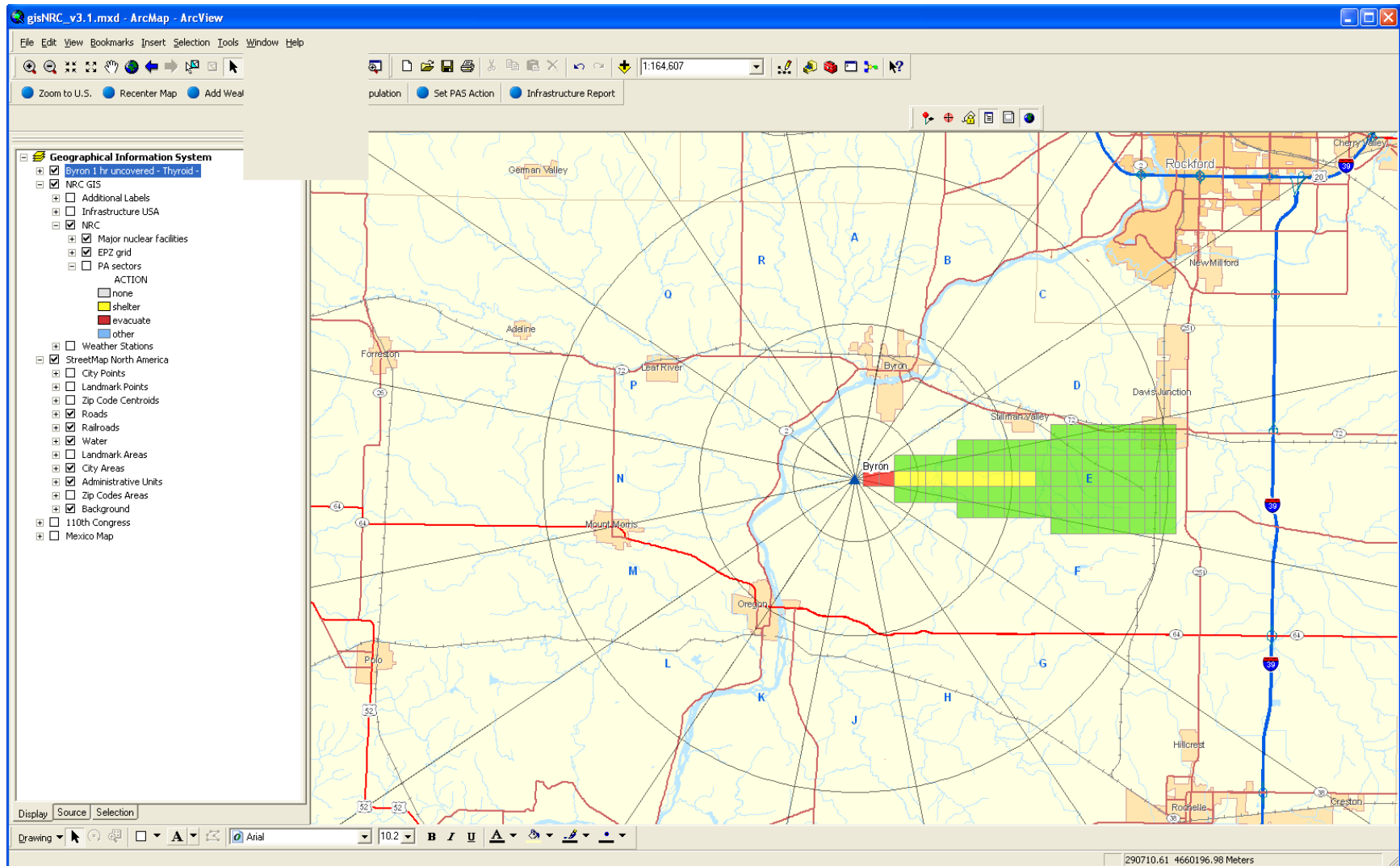




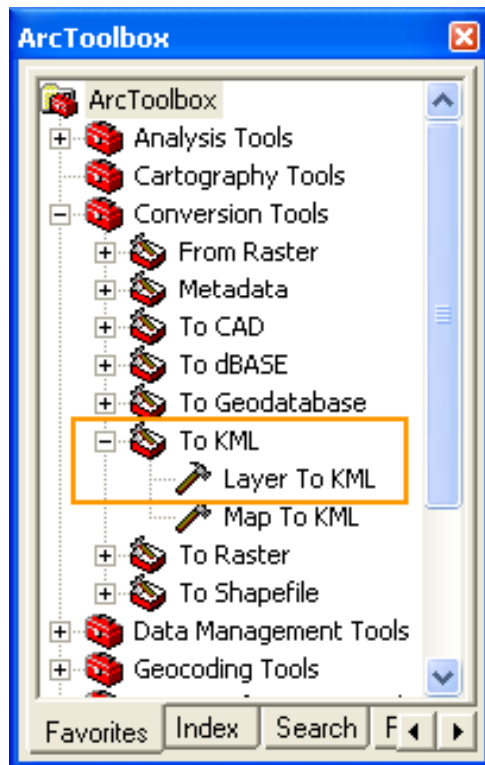
Adjust symbology to match the RASCAL legend



Adjust Transparency

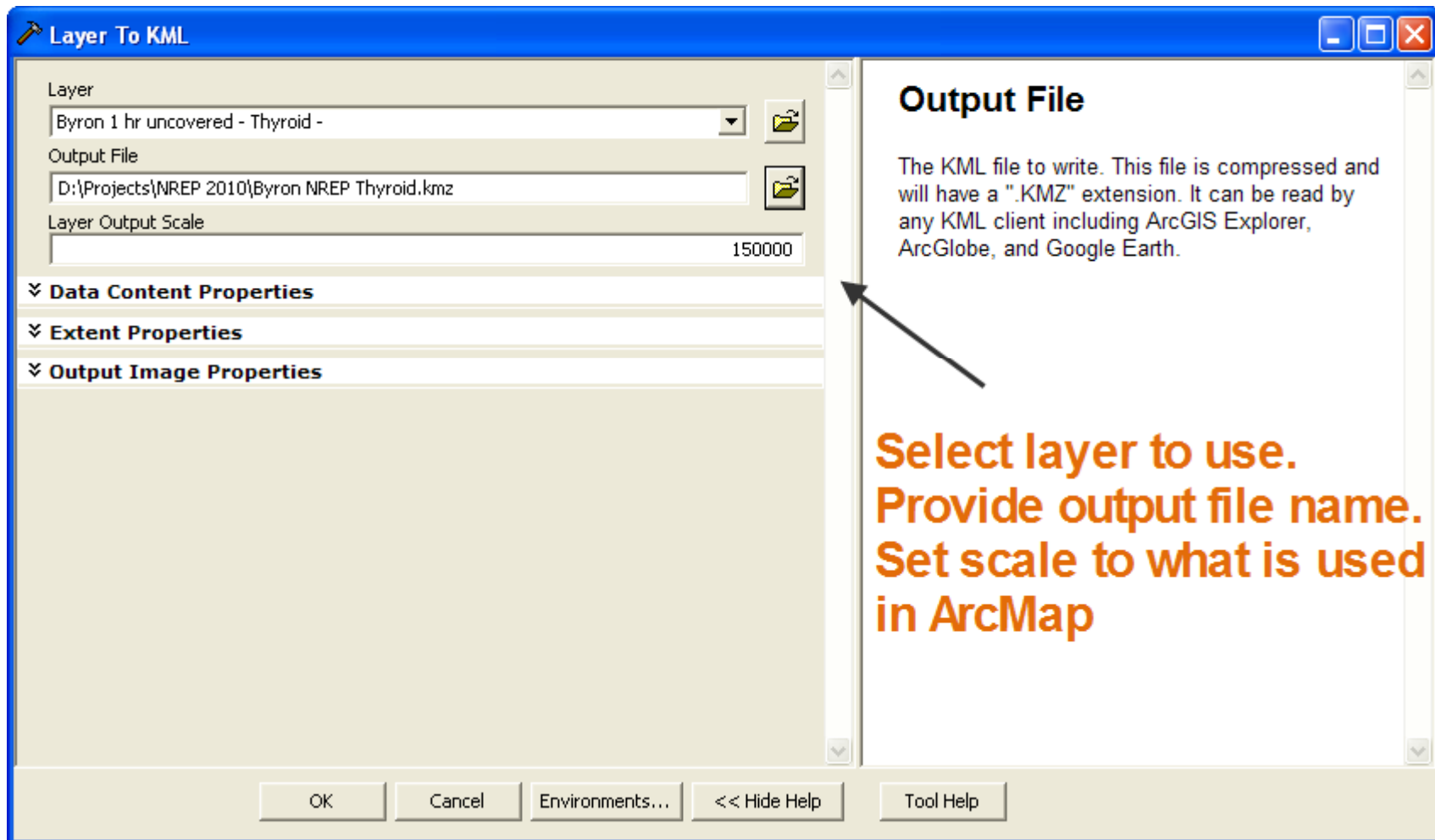


ArcMap to Google Earth

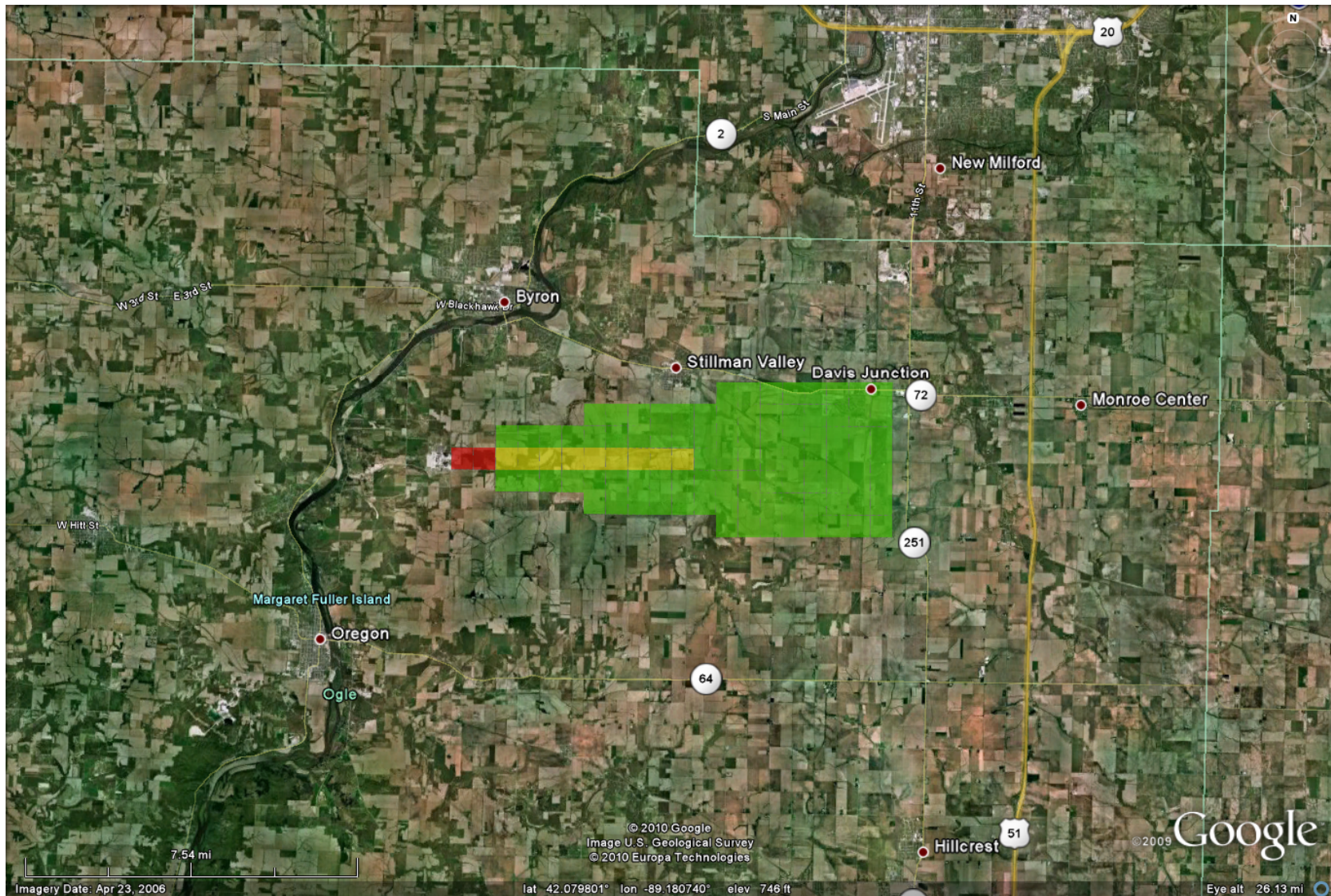


Use the conversion tool
“Layer to KML” in the
ArcToolbox

Layer to KML

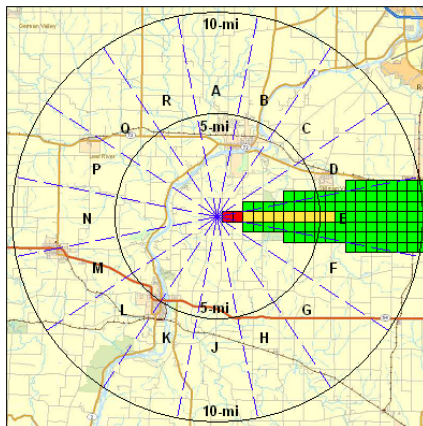


Drag KML into Google Earth

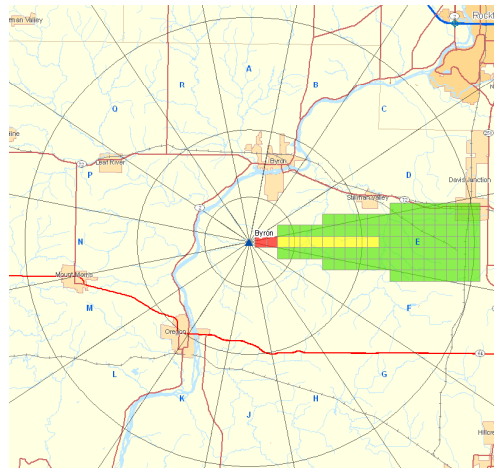


Display Plume in:

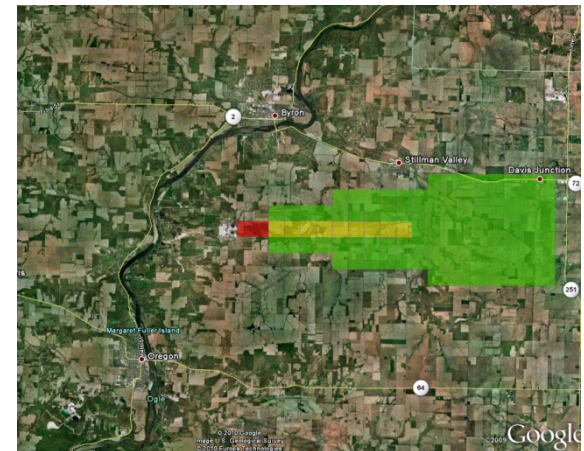
RASCAL



ArcMap



Google Earth



Monitored Mixtures

Source Term to Dose - [Byron 1 hr uncovered NREP.S

File Options Nuclide Data Viewer Site / Facility Data

Follow the steps below to define and run a problem

☒ **Event Type**
NPP Reactor

☒ **Event Location**
Byron - Unit 2

☒ **Source Term**
Effluent Releases - by Mixtures

☐ **Release Path**
<undefined>

☒ **Meteorology**
Actual Observations

Calculate Doses

Detailed Results

Save Case

Case Summary Source Term Maximum Dose Values

Source Term Options

Source term base

☐ Time Core Is Unc

☐ Specified Core D

☐ Containment Rad

☐ Coolant Sample

☐ Air Sample

Source term base

☐ Effluent Release Rates - by Nuclide

☐ Effluent Release Concentrations - by Nuclide

☒ Effluent Releases - by Mixtures

Effluent Releases - by Mixtures

Reactor shutdown: ☐ Yes 2010/02/20 00:00
☒ No

Sample taken: 2010/02/20 01:00

Release rate units: Ci/s

Release rates:

Noble gases 1.00E+03 (Ci/s)

Iodines
☐ Total
☒ I-131 equiv. 1.00E+00 (Ci/s)

Particulates 1.00E-01 (Ci/s)

Can now enter I-131 equivalent release rate

OK Cancel Help

Release Pathway – Monitored, Filtered

Direct to Atmosphere

Release height: 10.0 m

Release timings: Effluent mixture sample taken: 2010/02/20 01:00

Start of release to atmosphere: 2010/02/20 01:00

End of release to atmosphere: ☐ End time 2010/02/20 02:00

☒ Release duration: 0 days 04:00 hh:mm

OK Cancel

Release Path

<undefined>

Meteorology

Actual Observations

Calculate Doses

Detailed Results

Save Case

Reactor Parameters

Reactor power:	3586 MWt
Average fuel burn-up:	30000 MWD / MTU
Containment type:	PWR Dry Ambient
Containment volume:	2.90E+06 ft ³
Design pressure:	61 lb/in ²
Design leak rate:	0.10 %/d
Coolant mass:	2.51E+05 kg
Assemblies in core:	193
Steam generator type:	U-Tube

Print

Case Summary Source Term Maximum Dose Values

2 mph, E Stability, Results

Source Term to Dose - [Byron Mon Mix NREP R4.STD]

File Options Nuclide Data Viewer Site / Facility Data Viewer Help

Follow the steps below to define and run a problem. Use the Tabs below to review information.

Event Type
NPP Reactor

Event Location
Byron - Unit 2

Source Term
Effluent Releases - by Mixtures

Release Path
Direct to atmosphere

Meteorology
Actual Observations

Calculate Doses

Detailed Results

Save Case

Maximum Dose Values (rem) - To 10 mi

Dist from release miles (kilometers)	3 (4.8)	4 (6.4)	5 (8.0)	7 (11.3)	10 (16.1)
Total EDE	<u>1.7E+00</u>	<u>1.1E+00</u>	7.5E-01	<u>4.2E-01</u>	2.1E-01
Thyroid CDE	<u>1.8E+01</u>	<u>1.3E+01</u>	<u>9.3E+00</u>	<u>5.6E+00</u>	3.2E+00
Inhalation CEDE	6.5E-01	4.4E-01	3.1E-01	1.8E-01	1.0E-01
Cloudshine	9.8E-01	6.2E-01	4.2E-01	2.2E-01	1.0E-01
4-day Groundshine	7.0E-02	4.0E-02	2.5E-02	1.2E-02	5.8E-03
Inter Phase 1st Yr	1.1E-01	7.4E-02	5.3E-02	3.1E-02	1.7E-02
Inter Phase 2nd Yr	2.5E-03	1.6E-03	1.1E-03	***	***

Notes:

- Doses exceeding PAGs are underlined.
- Early-Phase PAGs: TEDE - 1 rem, Thyroid (iodine) CDE - 5 rem
- Intermediate-Phase PAGs: 1st year - 2 rem, 2nd year - 0.5 rem
- *** indicates values less than 0.1 mrem
- To view all values - use Detailed Results / Numeric Table

Value displayed: ☐ Close-in dose ☒ Doses to 10 miles ☐ Criticality shine dose

Display units: ☒ English ☐ Metric

Definitions Print

Case Summary **Source Term** Maximum Dose Values

Check this

Event Type
NPP Reactor

Event Location
Byron - Unit 2

Source Term
Monitored Release - Mixtures

Release Path
Direct to atmosphere

Meter
Actual Observations

Calculate

Detailed

Save

Source Term

Total activity released to atmosphere: 1.5E+07 Ci

Nuclide	Ci	Nuclide	Ci	Nuclide	Ci
Cs-137	7.2E+02	I-135	2.4E+04	Xe-131m	2.7E+04
I-131	1.4E+04	Kr-85	1.6E+04	Xe-133	4.7E+06
I-132	1.9E+04	Kr-85m	6.6E+05	Xe-133m	1.7E+05
I-133	2.8E+04	Kr-87	1.3E+06	Xe-135	9.1E+05
I-134	3.1E+04	Kr-88	1.9E+06	Xe-138	4.7E+06

Both
1000
Ci/s
nobles
1 Ci/s
I-131

Source Term to Dose - [Byron Mon Mix NREP.STD]

File Options Nuclide Data Viewer Site / Facility Data Viewer Help

Follow the steps below to define and run a problem
Use the Tabs below to review information.

Event Type
NPP Reactor

Event Location
Byron - Unit 2

Source Term
Effluent Releases - by Mixtures

Release Path
Direct to atmosphere

Source Term

Total amount released to atmosphere: 9.7E+06 Ci

Nuclide	Ci	Nuclide	Ci	Nuclide	Ci
Cs-134	2.8E+00	I-134	1.2E+02	Rb-88	8.5E+05
Cs-136	8.8E-01	I-135	2.7E+02	Xe-131m	3.2E+04
Cs-137*	1.9E+00	Kr-83m	1.4E+05	Xe-133	4.7E+06
Cs-138	3.0E+05	Kr-85	2.4E+04	Xe-133m	1.4E+05
I-131	1.4E+04	Kr-85m	4.1E+05	Xe-135	1.1E+06
I-132	1.5E+02	Kr-87	4.6E+05	Xe-135m	1.3E+05
I-133	3.2E+02	Kr-88	9.7E+05	Xe-138	4.5E+05

Cesiums corrected, only I-131 & I daughters

FM to Dose

RASCAL v4 - Beta Release

Radiological Assessment System for Consequence Analysis

Source Term to Dose

Field Measurement to Dose

Sample Data

Sample ID: (required)

Sample type:

☒ Ground concentrations in units of

☐ Air concentrations in units of

Activity at time of deposition

Nuclide	Gnd Conc (μCi/m²)
I-133	4.67E+01
I-131	3.01E+01
I-135	2.36E+01
Te-132	4.64E+00
Cs-134	3.43E+00
Ba-140	2.46E+00
Cs-137*	2.37E+00
Sr-91	1.59E+00
Cs-136	1.37E+00
Sr-89	1.26E+00
Np-239	6.73E-01
Te-131m	5.81E-01

Event Description

Event name: (required)

Information below is optional. Check a box to include the item in the case file.

☒ Release started:

Information below is optional. Check a box to include the item in the case file.

☐ Sample location

Latitude: degrees

Longitude: degrees

☒ Sample location from release point

Bearing: degrees

Distance:

☒ Sample description

Enter sample data

OK

Cancel

Help

OK

Result

Field Measurements to Dose

File Nuclide Data Viewer Help

☒ Event Description

☒ Sample Data

☒ Calculation Options

☒ Compute Doses

Sample Data

Sample ID: Soil Sample 1

Sample Location: Bearing / Distance 270.0° / 3.0 miles - from release

Sample desc.: Activities from slide 21 - Byron D

Sample type: Ground concentrations

Nuclide	Ground Conc (µCi/m²)
I-133	4.67E+01
I-131	3.01E+01
I-135	2.36E+01
Te-132	4.64E+00
Cs-134	2.42E+00

Source Term to Dose - [Byron 1 hr uncovered NREP.STD]

File Options Nuclide Data Viewer Site / Facility Data Viewer Help

Follow the steps below to define and run a problem

Compare to: Use the

☒ Event Type

NPP Reactor

☒ Event Location

Byron - Unit 2

☒ Source Term

Time Core Is Uncovered

☒ Release Path

PWR Dry

☒ Meteorology

Actual Observations

☒ Calculate Doses

☐ Detailed Results

☐ Save Case

Maximum Dose Values (rem)

Dist from release		
miles	3	4
(kilometers)	(4.8)	(6.4)
Total EDE	1.7E-01	1.7E-01
Thyroid CDE	2.4E+00	2.4E+00
Inhalation CEDE	1.0E-01	1.0E-01
Cloudshine	1.6E-02	1.6E-02
4-day Groundshine	5.3E-02	5.3E-02
Inter Phase 1st Yr	7.5E-01	7.5E-01
Inter Phase 2nd Yr	4.8E-01	4.8E-01

Notes:

- Doses exceeding PAGs are underlined
- Early-Phase PAGs: TEDE - 1 rem, Thyroid CDE - 2.4 rem
- Intermediate-Phase PAGs: 1st year - 2 rem, 2nd year - 0.5 rem
- *** indicates values less than 0.1 mrem
- To view all values - use Detailed Results

Value displayed: ☐ Close-in dose ☒ Doses to 10 miles ☐ Criticality shine dose

Case Summary

Field Measurements to Dose

File Nuclide Data Viewer Help

☒ Event Description

☒ Sample Data

☒ Calculation Options

☒ Compute Doses

Intermediate Phase Doses (rem)

Exposure	1st Year	2nd Year	50 Years
Groundshine	7.43E-01	4.53E-01	5.96E+00
Inhalation	1.15E-04	2.67E-06	1.37E-04
Total	7.44E-01	4.53E-01	5.96E+00

Notes

- 1st year PAG = 2 rem, 2nd year objective = 0.5 rem, 50 year objective = 5 rem
- Total doses exceeding PAGs are underlined
- Doses less than 1E-6 rem (1E-8 Sv) set to zero.

Deposition time

Starts at 4 days

TF values about 80% RASCAL values

Turbo FRMAC

File Tools Help

Turbo FRMAC

Navigation

- New
- Open
- Byon 211 uncovered files
- Predictive Analyses
- Samples
- Air Concentration
- Deposition
- Soil sample - 3 mi east of release
- Exposure Rate
- Food
- Event-Level Items

Paperless FRMAC

Tools

- Analyst Manager
- Radionuclide Mixture Manager
- Radionuclide Viewer

Quick Event View

ICRP Guidance: [ICRP 30](#)

PAG Authority: [Federal Government](#)

Lung Clearance Class: [Maximum](#)

Weathering Correction: [Likhtarev's Method](#)

Resuspension Type: [Time Varying](#)

Resuspension Type: [NCRP 129 Method](#)

Respiratory Protection: [Not Administered](#)

Potassium Iodide (KI): [Not Administered](#)

Radionuclide	($\mu\text{Ci}/\text{m}^2$)
Ba-140	2.46
La-140	2.46
Cs-134	3.43
Cs-136	1.37
Cs-137	2.37
Ba-137m	2.24
I-131	30.1
I-133	46.7
I-135	23.6
Xe-135m	3.63
Np-239	0.673
Sr-89	1.26
Sr-91	1.59
Y-91m	0.919
Te-131m	0.581
Te-131	0.129
Te-132	4.64
I-132	4.64

Using same sample data

release

Event Level Reference Sample... Duplicate... Close Delete... Export

Radionuclide	Activity Concentration
^{140}Ba	2.46
^{134}Cs	3.43
^{136}Cs	1.37

12 parent radionuclides exist in the mixture.

μCi / m^2

Total Effective Dose Equivalent (TEDE)

Calculate Total Effective Dose Equivalent (TEDE)... More Mixture Properties...

Calculation Method

Calculate from Deposition Levels

Dose unit mrem

Filter Options

Age Group: Adult

Organ: Whole Body

Commitment Period: 50 Year

Note

Age Group and Commitment Period not apply to External Dose values

	Early Phase	First Year	Second Year	Fifty Year
Committed Effective Dose Equivalent	3.34E-2	0.118	2.71E-3	0.141
External Dose	32.4	6.22E2	3.45E2	3.11E3
Total Effective Dose Equivalent (TEDE)	32.5	6.23E2	3.45E2	3.11E3

82

Relocation DRLs (mR/h)

Field Measurements to Dose

File Nuclide Data Viewer Help

☒ Event Description

☒ Sample Data

☒ Calculation Options

☒ Compute Doses

Intermediate Phase Derived Response Levels (DRLs)

Reentry Time Days	Gamma dose rate (mR/h) at reentry equal to EPA PAG			Cs-137* surface concentration (μCi/m²) equal to EPA PAG		
	1st Year	2nd Year	50 Year	1st Year	2nd Year	50 Year
0	3.84E+00	8.85E-02	1.14E+00	6.73E+00	2.16E+00	2.00E+00
1	1.70E+00	8.85E-02	4.99E-01	6.84E+00		
2	1.23E+00	8.85E-02	3.56E-01	6.92E+00		
4	9.20E-01	8.84E-02	2.64E-01	7.00E+00		
7	7.66E-01	8.84E-02	2.17E-01	7.08E+00		
10	6.80E-01	8.84E-02	1.91E-01	7.16E+00		
14	5.99E-01	8.83E-02	1.66E-01	7.24E+00		
30	4.41E-01	8.81E-02	1.19E-01	7.43E+00		
60	3.77E-01	8.78E-02	9.91E-02	7.59E+00		
90	3.68E-01	8.75E-02	9.45E-02	7.70E+00		

Notes

- Dose rates are measured at time of reentry
- NC = not calculated; value is a ratio where the denominator is going to zero.

☒ DRL Table

☐ Early Phase Doses

☐ Intermediate Phase Doses

☐ Deposition Exposure Rate DRLs

☐ Marker Nuclide Concentration DRLs

Print

DRL map contours shrink with decay as days pass

On the Horizon...

- Automated weather entry
- Work with DOE – TurboFRMAC consistency
- Work with DTRA – HPAC consistency
- Detailed verification and validation
- State of the Art Reactor Consequence Analysis (SOARCA) source terms
- Create New Reactor models for RASCAL
- Continued progress on future model improvements

SOARCA Station Blackout

- Based on MELCOR run at Sandia
- PWR Scenario – earthquake – no AC power
1st cladding release - 16 h
Containment design leakage increase – 28 h
- BWR Scenario
1st fuel cladding release – 10 h
iodine release exceeds 1% inventory – 20 h
- Scenario ready to incorporate into RASCAL

Part 4

New Interface for Utilities

Exelon and Entergy, using RASCAL source code via Non-Disclosure Agreement, are building interfaces.

Their Goal:

To combine the best features of RASCAL with a site specific front end to create a user friendly interface for the occasional end user.

RASCAL

- Provides many methods for performing dose assessments.
- Has new plume dispersion and deposition models
- Is often times the compared “standard” for licensees.
- Is free to the licensee

RASCAL

- Does not have a direct method allowing the use of licensee's effluent monitors
- Is generically written for all sites in the US
- Can be difficult for the occasional user to run with consistency
- Usually requires more extensive procedures and longer training times

Licensee Dose Assessment Programs

- Typically simplified for the licensee's needs
- Users “recognize” terminology, site specific components, release pathways, etc...
- Allow for the use of effluent monitors direct readings.

Licensee Dose Assessment Program

- Typically requires a third party contractor to maintain
- Will probably require extensive upgrades due to the changes with the new modeling used by RASCAL
- Expensive up keep costs.

Their Goal

- Write a site specific front end the user will be comfortable with and calculate an isotopic release rate
- Use RASCAL's "Effluent Release Rates - by Nuclide" methodology to process the assessment.
- Use RASCAL's meteorological, plume and puff modeling programs to calculate the doses
- Read RASCAL's results files to present the doses in a site specific format.

Results

- Created a very adaptable front and back end to RASCAL which will be utilized at Entergy and Exelon sites
- Integrated the RASCAL processors including the new dispersion and deposition models
- Licensee assessments are very close to RASCAL since the dispersion and deposition models are identical

Long term

- The Licensee maintains control of the interface
- Reduced training costs
- Typically the interface will not need significant upgrades or changes
- If the NRC changes the RASCAL processor programs the licensee won't need to change the interface

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RASCAL webpage for files and updates:
atheyconsulting.com/RASCAL_files.html