QUANTITATIVE RISK ASSESSMENT FOR THE STATE-LICENSED DISPOSAL AREA

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Presented to the
U.S. Nuclear Waste Technical Review Board
Buffalo, New York
April 27, 2011

SDA RISK ASSESSMENT OVERVIEW

- **SCOPE OF THE STUDY**
- **STRUCTURE OF THE MODELS**
- **EVALUATION OF THREATS**
- **QUANTIFICATION OF RELEASE SCENARIOS**
- **SUMMARY OF RESULTS**
- **CONCLUSIONS AND RECOMMENDATIONS**

STUDY SCOPE

- **30-YEAR TIME PERIOD**
  - CURRENT PHYSICAL AND ADMINISTRATIVE CONTROLS
  - ROUTINE SAMPLING, INSPECTIONS, AND MAINTENANCE
  - PLANNED REPLACEMENT OF GEOMEMBRANES
- **RADIATION DOSE TO A MEMBER OF THE PUBLIC**
  - PERMANENT RESIDENT FARMER NEAR THE CONFLUENCE OF BUTTERMILK CREEK AND CATTARAUGUS CREEK
  - TRANSIENT RECREATIONAL HIKER / HUNTER TRAVERSING AREAS ALONG BUTTERMILK CREEK AND LOWER REACHES OF FRANK'S CREEK
- **RADIATION HAZARDS**
  - SOLID WASTES
  - CONTAMINATED TRENCH LIQUIDS
  - WASTE VOLUMES, PHYSICAL FORMS, AND RADIONUCLIDE CONTENTS AT 50-FOOT INTERVALS IN EACH TRENCH DETERMINED FROM 2002 DETAILED REVIEW OF TRANSPORT AND BURIAL RECORDS

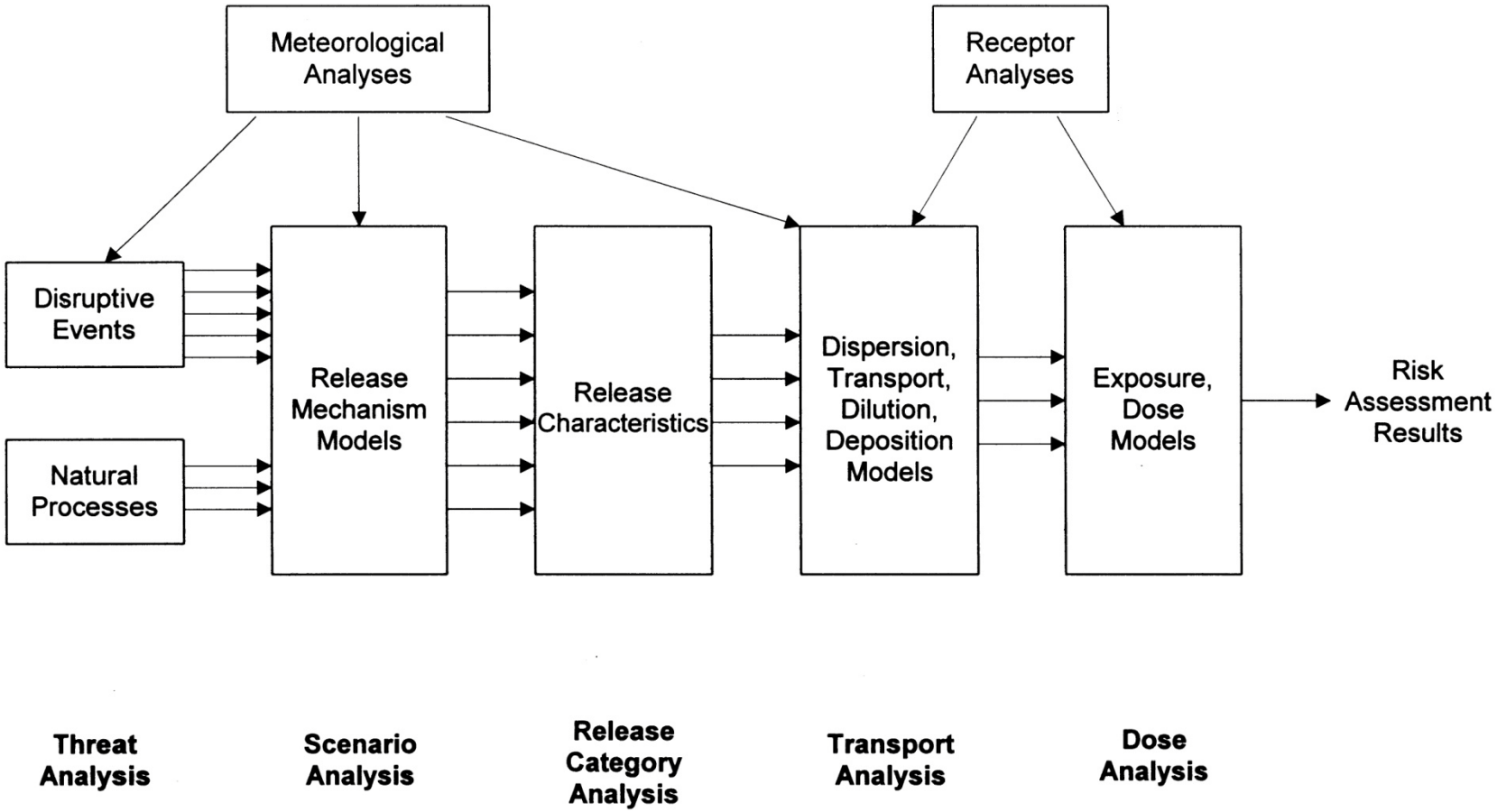
STUDY SCOPE

- **GENERAL THREAT CATEGORIES**
  - **DISRUPTIVE EVENTS: UNEXPECTED EVENTS THAT CAUSE AN IMMEDIATE CHANGE TO THE SITE (e.g., SEVERE STORMS, EARTHQUAKES)**
  - **NOMINAL EVENTS AND PROCESSES: EXPECTED EVENTS AND NATURAL PROCESSES THAT OCCUR CONTINUOUSLY OVER THE LIFE OF THE FACILITY (e.g., GROUNDWATER FLOW, AGING OF ENGINEERED AND NATURAL SYSTEMS)**
  - **STUDY DOES NOT QUANTIFY INTENTIONAL ACTS OF DESTRUCTION, SABOTAGE, OR TERRORISM; SIMPLIFIED SENSITIVITY ANALYSIS FOR POTENTIAL TERRORIST THREATS**
- **TRANSPORT PATHWAYS**
  - **RELEASES OF LIQUID, SOLID, AND GASEOUS MATERIALS**
  - **DISTRIBUTION, DILUTION, AND DEPOSITION OF LIQUID AND SOLID CONTAMINANTS IN ERDMAN BROOK, FRANK'S CREEK, AND BUTTERMILK CREEK**

STUDY SCOPE

- **RESIDENT FARMER EXPOSURE PATHWAYS**
  - **INHALATION**
  - **DIRECT EXPOSURE TO CONTAMINATED SOILS**
  - **CONSUMPTION OF CROPS**
  - **CONSUMPTION OF FOOD PRODUCTS FROM ANIMALS FED CONTAMINATED CROPS**
  - **INCIDENTAL EXPOSURE TO MATERIALS IN STREAM BEDS**
  - **STUDY DOES NOT INCLUDE INGESTION THROUGH DRINKING WATER; BUTTERMILK CREEK IS NOT A SOURCE OF POTABLE WATER**
- **TRANSIENT HIKER / HUNTER EXPOSURE PATHWAYS**
  - **DIRECT EXPOSURE TO CONTAMINATED SEDIMENTS**
  - **INCIDENTAL INGESTION OF SMALL QUANTITIES OF CONTAMINATED SEDIMENTS**

SDA QRA MODEL STRUCTURE



RELEASE MECHANISMS

1. **Liquid releases via groundwater flow through the Unweathered Lavery Till (ULT) and Kent Recessional Sequence (KRS) layers**

2. **Liquid releases via groundwater flow through the Weathered Lavery Till (WLT) layer**

3. **Trench overflow and liquid releases via surface water runoff**

4. **Physical breaches of the trenches and releases of liquids and solid materials**

5. **Extensive physical disruption of the site with airborne releases**

SDA THREAT ASSESSMENT
THREATS EVALUATED AND SCREENED OUT

- **Avalanches**
- **Biological Events**
- **Drought**
- **Erosion**
  - -Coastal/lake shore erosion
  - -River bank erosion
- **Excavation of Contaminated Stream Sediments**
- **Explosions**
- **Extraterrestrial Impacts (involving meteorites greater than 1 meter in diameter)**
- **Extreme Temperatures (heat, cold)**
- **Fires**
  - -Onsite facilities (internal building fires)
- **Flooding Events**
  - -Onsite facilities (internal building flooding)
  - -Dam failure
  - -Site water supply pipe failure
  - -Seiche
  - -Storm surge
  - -Tsunami
- **Fog**
- **Frost**
- **High Tides**
- **Hurricanes**
- **Ice Cover**
- **Lightning**
- **Loss of External Power Supplies**
- **Low Lake or River Water Level**
- **Nearby Facility Accidents**
  - -Industrial
  - -Chemical
  - -Military
- **NRC-Licensed Facility Decommissioning Activities**
  - -Direct accident impacts on SDA
  - -Effects on site grading, surface water runoff, erosion
- **Radiolytic/Chemical Interactions**
- **River Diversion**
- **Seismic Events**
  - -Seismic-induced fires
  - -Seismic-induced flooding (e.g., piping failures)
- **Severe Storms**
  - -Hail
  - -Sand storms
  - -Dust storms
- **Sinkholes**
- **Site Intrusions (direct intrusion into the SDA during the 30-year period of this study)**
- **Toxic Gas Releases**
- **Transportation Accidents**
  - -Rail
  - -Highway
  - -Shipping (by navigable waterway)
- **Volcanic Activity**

SDA THREAT ASSESSMENT
THREATS QUANTIFIED IN THE QRA

Disruptive Events

- **Aircraft Crashes**
  - -Commercial
  - -General aviation
  - -Military
- **Erosion**
  - -Local streams
  - -Trenches
- **Extraterrestrial Impacts**
  - -meteorites less than 1 meter in diameter
- **Fires**
  - -Offsite (e.g., grass fires, forest fires)
- **Flooding Events**
  - -Extreme precipitation
  - -Rapid snow melt
- **High Wind Events**
  - -Extreme sustained winds
  - -Wind gusts
  - -Tornadoes
- **Landslides**
- **Pipeline Accidents**
  - -Site natural gas supply pipe
- **Seismic Events**
  - -Direct seismic failures
- **Severe Storms**

Nominal Events and Processes

- **Corrosion / Deterioration / Decomposition**
  - -Geomembrane covers
  - -Crates, boxes
  - -Steel drums
- **Groundwater Intrusion**
  - -Historic intrusion
  - -Rapid intrusion ("bath-tubbing")
- **Soil Shrink / Swell / Consolidation**

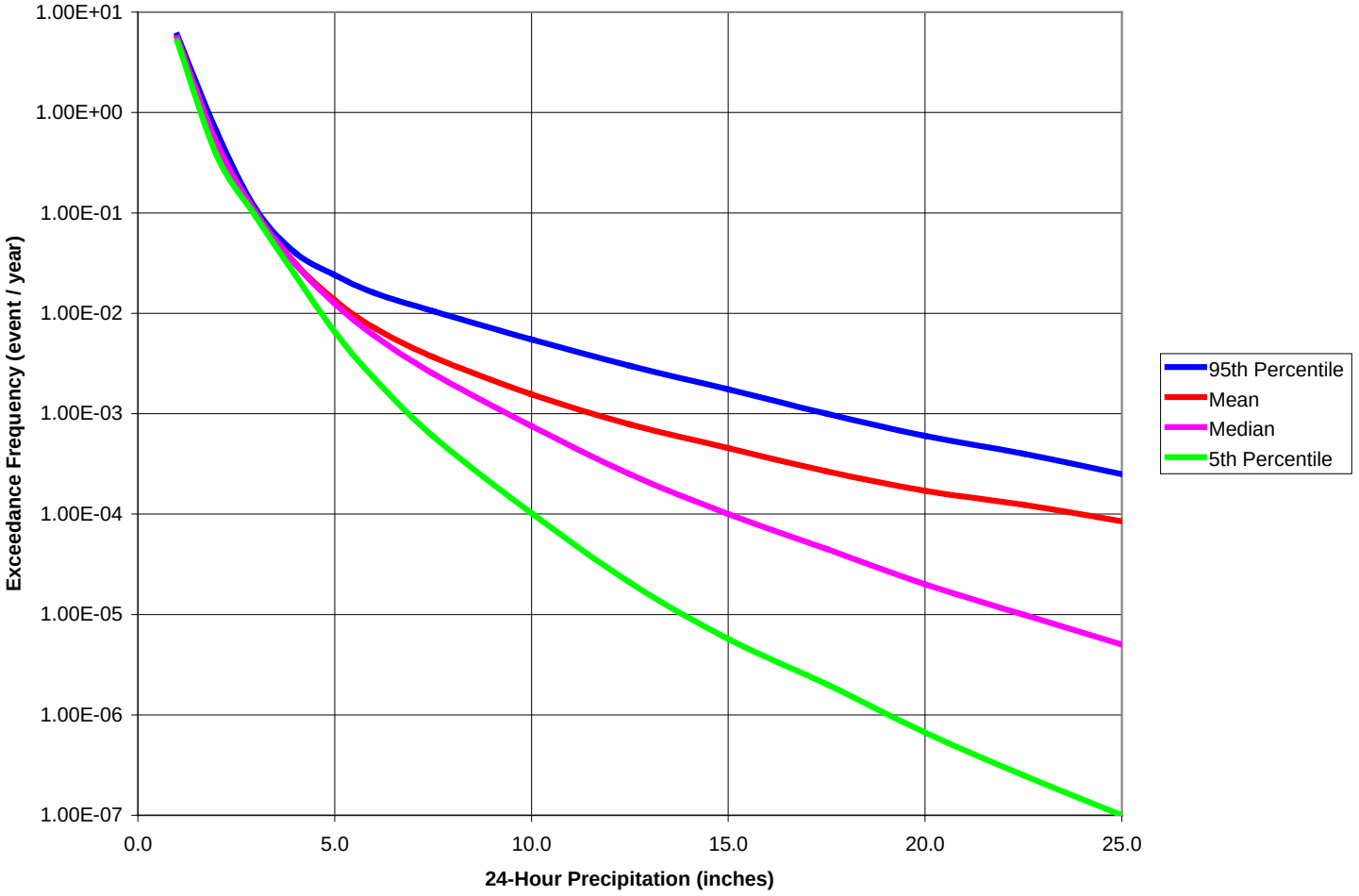
METEOROLOGICAL DATA
PRECIPITATION AND HIGH WINDS

- **BUFFALO NATIONAL WEATHER SERVICE STATION**
  - **34 MILES NORTH OF SITE**
  - **JANUARY 1, 1922 – APRIL 30, 2008 (30,573 DAILY WEATHER RECORDS)**
- **DUNKIRK NATIONAL WEATHER SERVICE STATION**
  - **32 MILES WEST OF SITE**
  - **JANUARY 1, 1926 – APRIL 30, 2008 (28,631 DAILY WEATHER RECORDS)**
- **JAMESTOWN NATIONAL WEATHER SERVICE STATION**
  - **37 MILES SOUTHWEST OF SITE**
  - **SEPTEMBER 9, 1960 – OCTOBER 31, 1962; JANUARY 1, 1973 – APRIL 30, 2008 (11,110 DAILY WEATHER RECORDS)**
- **WEST VALLEY SITE METEOROLOGICAL TOWER**
  - **JANUARY 1, 1991 – DECEMBER 31, 2007 (6,209 DAILY WEATHER RECORDS)**

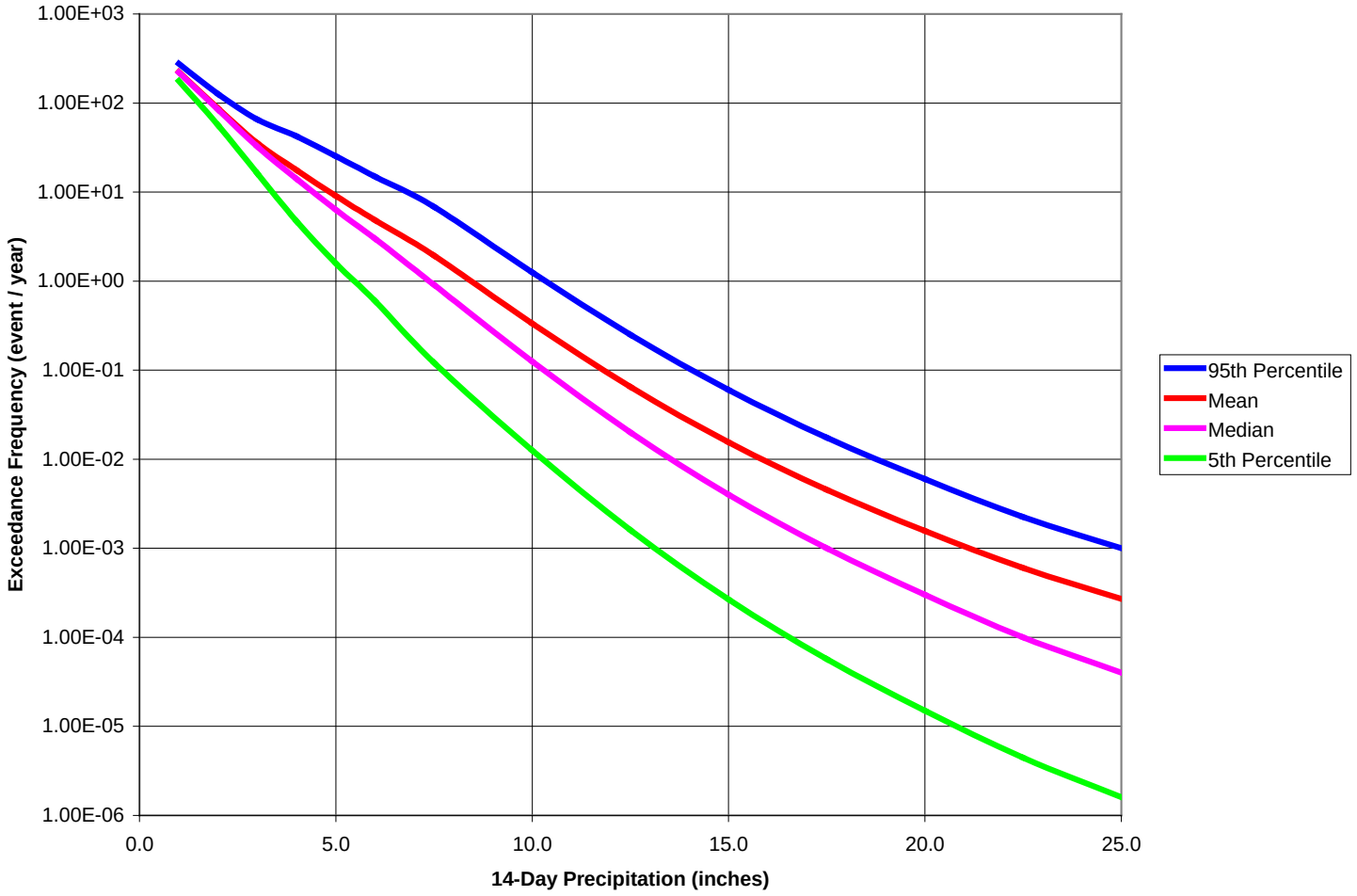
METEOROLOGICAL DATA
PRECIPITATION AND HIGH WINDS

- **SOURCES OF UNCERTAINTY**
  - ANNUAL VARIABILITY IN REGIONAL WEATHER PATTERNS
  - GEOGRAPHIC VARIATIONS IN LOCAL STORM SEVERITIES
  - REPORTING ANOMALIES
- **UNCERTAINTY DISTRIBUTIONS FOR PRECIPITATION EXCEEDANCE FREQUENCIES**
  - BUFFALO DATA USED AS MEDIAN FOR REGION
  - BUFFALO DATA MOST CLOSELY MATCHES WEST VALLEY SITE FOR COMPARABLE REPORTING PERIODS
  - LOGNORMAL UNCERTAINTIES SPAN RANGE OF DATA FROM DUNKIRK AND JAMESTOWN
- **CUMULATIVE PRECIPITATION EXCEEDANCE FREQUENCIES**
  - QRA ANALYSES REQUIRE INFORMATION ABOUT PRECIPITATION RATE AND TOTAL
  - 24-HOUR, 48-HOUR, 72-HOUR, 7-DAY, 14-DAY TIME WINDOWS

24-HOUR CUMULATIVE PRECIPITATION EXCEEDANCE FREQUENCY



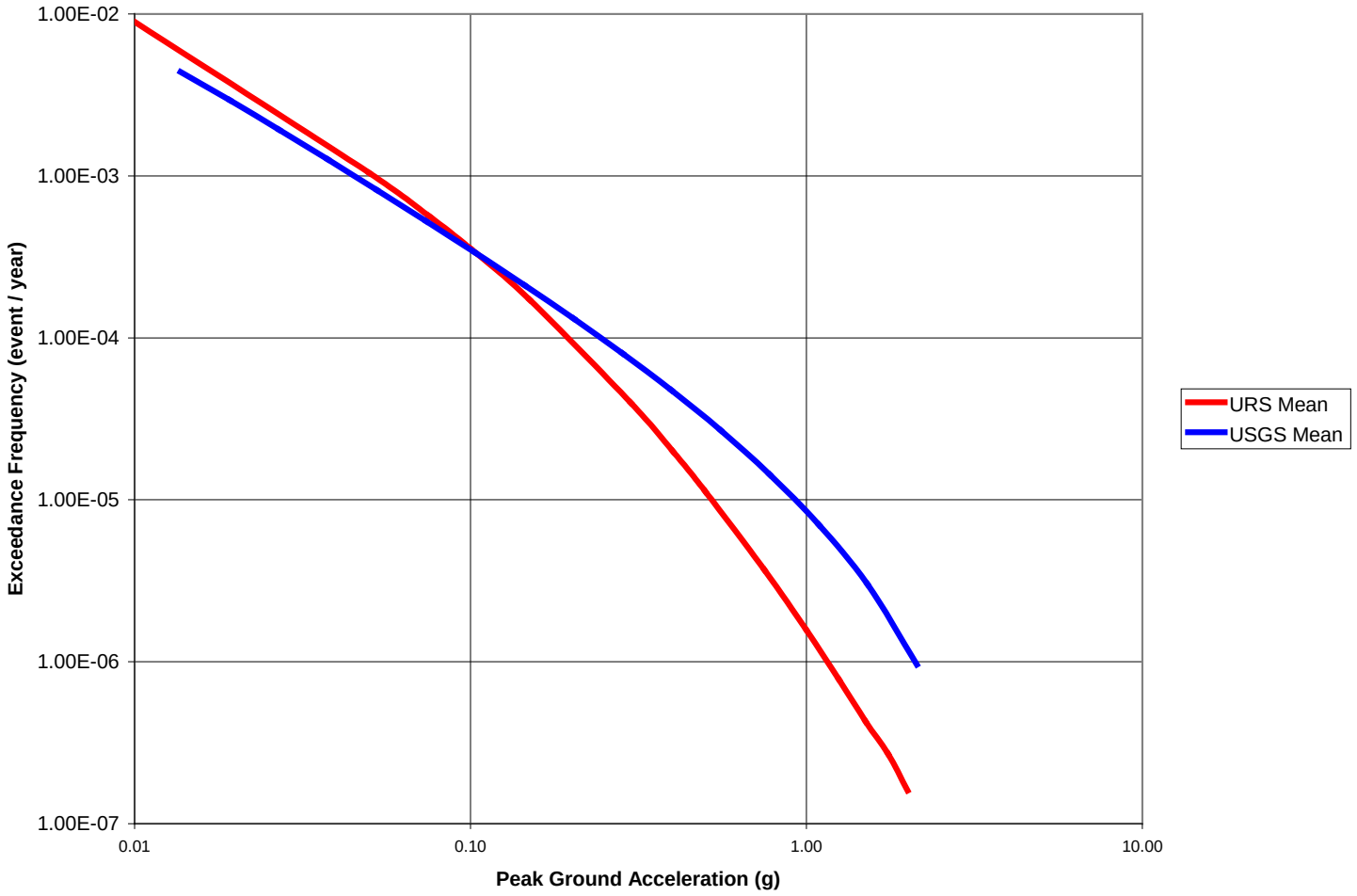
14-DAY CUMULATIVE PRECIPITATION EXCEEDANCE FREQUENCY



SEISMIC HAZARD ANALYSES

- **2004 SITE-SPECIFIC HAZARD ANALYSIS**
  - **URS CORPORATION**
  - **UPDATE OF 1992 DAMES & MOORE ANALYSIS**
  - **BASED ON 1989 EPRI-SOG METHODOLOGY**
  - **LESSONS LEARNED FROM EPRI-SOG APPLICATIONS**
  - **ADDITIONAL SEISMIC SOURCES**
  - **IMPROVED SITE-SPECIFIC SOILS RESPONSE**
- **2008 USGS HAZARD ANALYSIS**
  - **GENERALLY INCREASED SEISMIC HAZARD FOR CENTRAL AND EASTERN U.S. (CEUS)**
  - **ADDITIONAL SEISMIC SOURCES**
  - **UPDATED ANALYSES OF CHARLESTON AND EAST TENNESSEE SEISMIC ZONES**

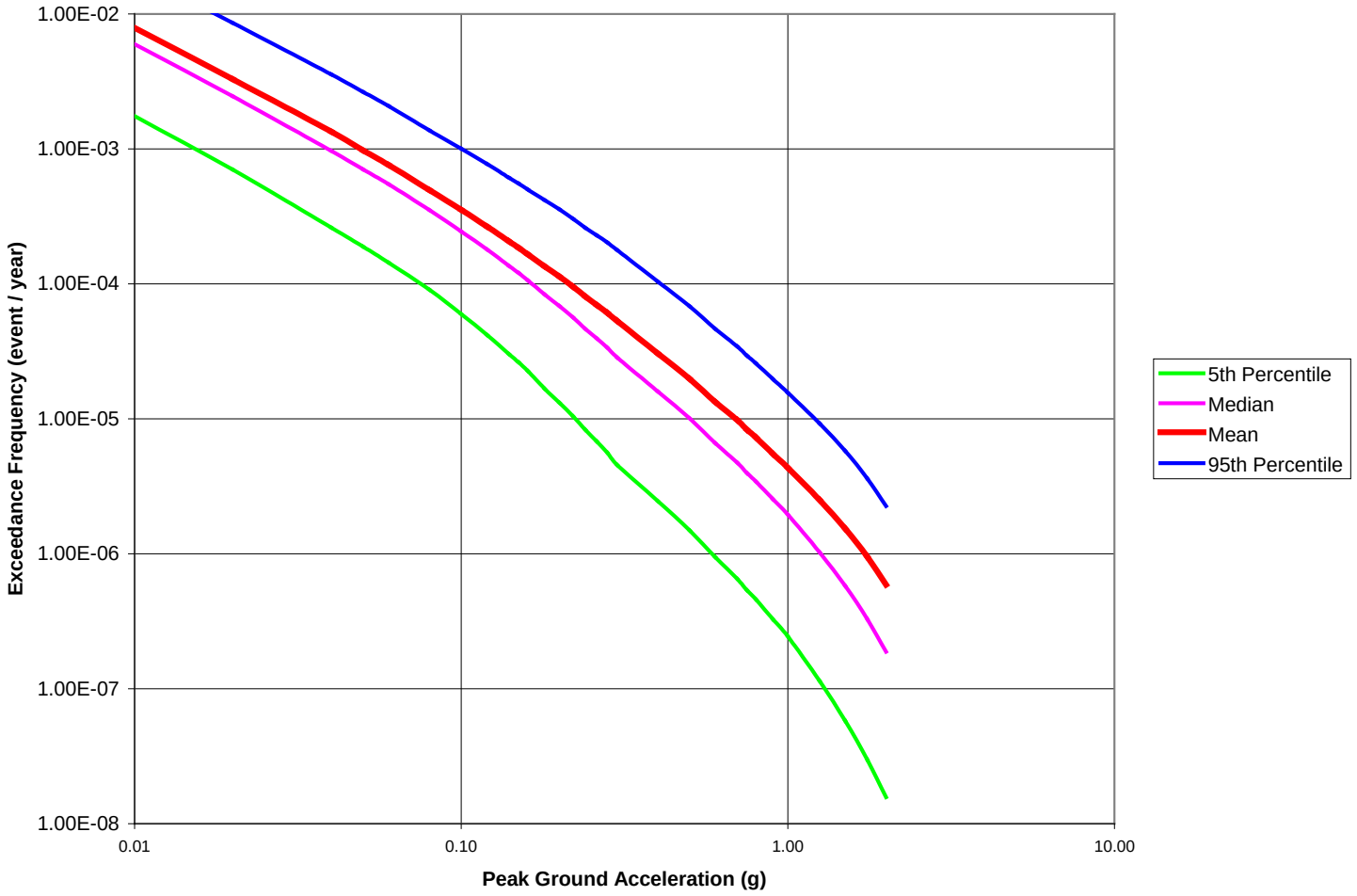
COMPARISON OF URS AND USGS MEAN SEISMIC HAZARD



SDA QRA COMPOSITE SEISMIC HAZARD

- **2004 URS HAZARD**
  - **MEAN EXCEEDANCE FREQUENCIES FROM 0.10 g TO 1.50 g**
  - **LOGNORMAL UNCERTAINTY DISTRIBUTIONS PROVIDE GOOD FIT FOR PUBLISHED ESTIMATES UP TO 0.30 g**
  - **SDA TEAM EXTRAPOLATED UNCERTAINTIES FROM 0.30 g TO 1.50 g, BASED ON TEAM EXPERIENCE FROM OTHER ANALYSES**
  - **ASSIGNED WEIGHT OF 60% FOR COMPOSITE HAZARD**
- **2008 USGS HAZARD**
  - **WEST VALLEY SITE LOCATION**
  - **MEAN EXCEEDANCE FREQUENCIES FROM 0.005 g TO 2.13 g**
  - **SDA TEAM APPLIED LOGNORMAL UNCERTAINTIES CONSISTENT WITH URS HAZARD CURVES**
  - **ASSIGNED WEIGHT OF 40% FOR COMPOSITE HAZARD**

SDA QRA COMPOSITE SEISMIC HAZARD CURVES



TRENCH LIQUID LEVELS

- **IMPORTANT QRA PARAMETER**
  - VOLUME OF LIQUID RADIOACTIVE CONTAMINANTS
  - HYDRAULIC HEAD FOR GROUNDWATER RELEASES
  - TRENCH FREE VOLUME FOR OVERFLOW SCENARIOS
  - SOIL CONDITIONS FOR SEISMIC-INDUCED SLOPE FAILURES AND LANDSLIDES
- **WATER INFILTRATION PATHWAYS**
  - LATERAL INFLOW THROUGH WEATHERED LAVERY TILL
  - SURFACE RUNOFF
  - INCIDENT PRECIPITATION WHEN GEOMEMBRANES ARE NOT INTACT
- **DETAILED ANALYSES OF WATER INFILTRATION MECHANISMS AND CONSEQUENTIAL LEVELS**
  - LEVELS MAY CONTINUE TO DECREASE FROM CURRENT MEASURED CONDITIONS
  - EVENTS MAY CAUSE LEVELS TO INCREASE WITHOUT CAUSING A RELEASE, BUT CONTRIBUTING TO SUBSEQUENT RELEASE SCENARIOS
  - GROUNDWATER FLOWS THROUGH SURFACE WEATHERED LAVERY TILL (WLT) AND DEEPER UNWEATHERED LAVERY TILL (ULT) LAYERS

TRENCH LIQUID LEVELS

- **LEVEL 1**
  - **LEVEL IS BETWEEN THE WLT / ULT INTERFACE AND TOPS OF TRENCHES**
  - **QRA HYDRAULIC ANALYSES ASSUME THAT TRENCHES ARE FULL**
  - **PROBABILITY = 0.12%**
- **LEVEL 2**
  - **LEVEL IS BETWEEN THE CURRENT MEASURED LEVEL AND THE WLT / ULT INTERFACE**
  - **QRA HYDRAULIC ANALYSES ASSUME THAT LEVEL IS AT THE WLT / ULT INTERFACE**
  - **PROBABILITY = 1.37%**
- **LEVEL 3**
  - **LEVEL IS AT THE CURRENT MEASURED LEVEL**
  - **PROBABILITY = 93.51%**
- **LEVEL 4**
  - **LEVEL IS BELOW THE CURRENT MEASURED LEVEL**
  - **QRA HYDRAULIC ANALYSES ASSUME THAT TRENCHES ARE EMPTY**
  - **PROBABILITY = 5.00%**

SDA RISK SCENARIOS
RELEASE MECHANISM 1

- **LATERAL AND VERTICAL GROUNDWATER FLOWS THROUGH UNWEATHERED LAVERY TILL (ULT) AND KENT RECESSIONAL SEQUENCE (KRS) LAYERS**
- **NATURAL PROCESSES**
- **LIQUID RELEASES TO ERDMAN BROOK, FRANK'S CREEK, AND BUTTERMILK CREEK**
- **FOUR SCENARIOS**
  - **TRENCH WATER LEVEL HIGH, LATERAL FLOW THROUGH ULT**
  - **TRENCH WATER LEVEL AT INTERFACE, LATERAL FLOW THROUGH ULT**
  - **TRENCH WATER LEVEL AT CURRENT CONDITIONS, LATERAL FLOW THROUGH ULT**
  - **VERTICAL FLOW THROUGH ULT AND KRS (NOT SENSITIVE TO INITIAL TRENCH WATER LEVEL)**

SDA RISK SCENARIOS
RELEASE MECHANISM 2

- **GROUNDWATER FLOW THROUGH WEATHERED LAVERY TILL (WLT) LAYER**
- **NATURAL PROCESSES**
- **LIQUID RELEASES TO ERDMAN BROOK AND FRANK'S CREEK**
- **ONE SCENARIO**
  - **TRENCH WATER LEVEL HIGH, LATERAL FLOW THROUGH WLT**

SDA RISK SCENARIOS
RELEASE MECHANISM 3

- **TRENCH OVERFLOWS**
- **SEVERE STORMS AND PRECIPITATION**
- **LIQUID RELEASES TO ERDMAN BROOK AND FRANK'S CREEK VIA SURFACE RUNOFF**
- **NINE SCENARIOS – KEY ANALYSIS PARAMETERS**
  - **INITIAL TRENCH WATER LEVEL (HIGH, WLT / ULT INTERFACE, CURRENT)**
  - **GEOMEMBRANE STATUS (INTACT, UNAVAILABLE)**
  - **TRENCH CLAY CAP STATUS (INTACT, DISRUPTED)**
  - **STORM SEVERITY (GEOMEMBRANE DAMAGE, CAP EROSION, CUMULATIVE PRECIPITATION)**

SDA RISK SCENARIOS
RELEASE MECHANISM 4

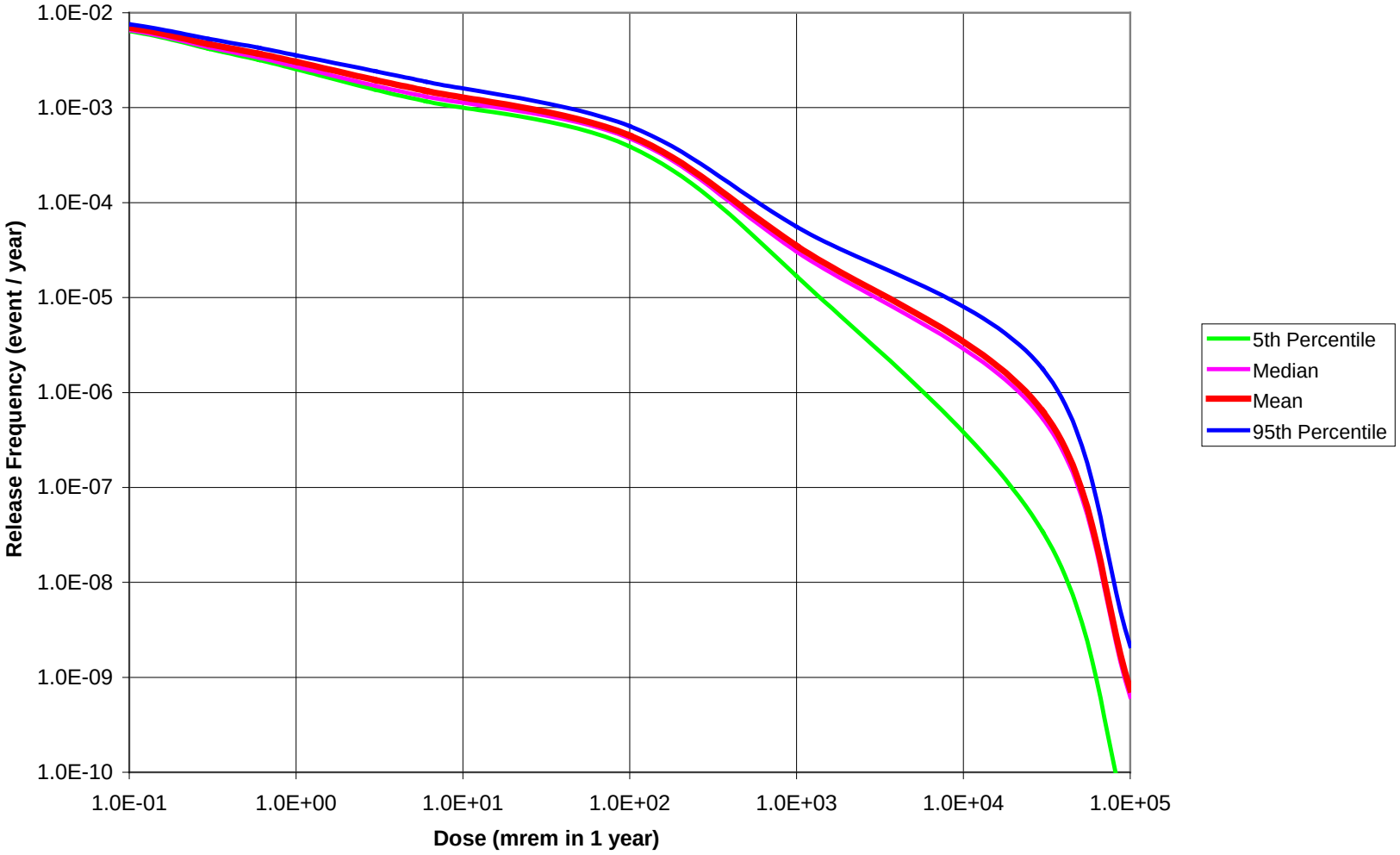
- **PHYSICAL BREACHES OF TRENCH WALLS**
- **EROSION AND GULLYING, SEISMIC EVENTS, NON-SEISMIC LANDSLIDES**
- **LIQUID RELEASES TO ERDMAN BROOK, FRANK'S CREEK, AND BUTTERMILK CREEK; SOLID MATERIAL RELEASES FROM BREACHED SECTIONS**
- **TWENTY SCENARIOS – KEY ANALYSIS PARAMETERS**
  - **INITIAL TRENCH WATER LEVEL (HIGH, WLT / ULT INTERFACE, CURRENT)**
  - **GEOMEMBRANE STATUS (INTACT, UNAVAILABLE – ONLY FOR GULLY EROSION)**
  - **SEISMIC / LOCALIZED LANDSLIDE DAMAGE FOOTPRINT**
    - **CONDITION 1: EAST SLOPE FAILURES INTERSECT TRENCHES 1, 2, 8; AND NORTH SLOPE FAILURES INTERSECT 125 FEET OF THE NORTH ENDS OF TRENCHES 3, 4, 5**
    - **CONDITION 2: EAST SLOPE FAILURES INTERSECT TRENCHES 1, 2, 3, 8, 9; AND NORTH SLOPE FAILURES INTERSECT 250 FEET OF THE NORTH ENDS OF TRENCHES 4, 5**
  - **REGIONAL LANDSLIDE (AFFECTS ENTIRE SITE)**

SDA RISK SCENARIOS
RELEASE MECHANISM 5

- **SEVERE PHYSICAL DISRUPTION OF SITE SURFACE**
- **AIRCRAFT CRASHES, METEORITE IMPACTS**
- **AIRBORNE RELEASES**
- **ONE SCENARIO – THREE CONTRIBUTING IMPACTS**
  - **COMMERCIAL AIRCRAFT CRASH**
  - **MILITARY AIRCRAFT CRASH**
  - **IMPACT OF METEORITE WITH DIAMETER BETWEEN 0.1 AND 1.0 METER**

SUMMARY OF
SDA RISK ASSESSMENT RESULTS

SDA QRA RISK CURVES



SDA QRA RESULTS
WHAT DO THE RISK CURVES MEAN?

- The SDA risk curves represent the combination of all of the analyses of all of the threat conditions, release scenarios, receptors, trench water levels, precipitation events, landslides, earthquakes, tornadoes, fires, floods, aircraft crashes, meteorite impacts, trench overflow events, and general, everyday groundwater transport from the trenches.

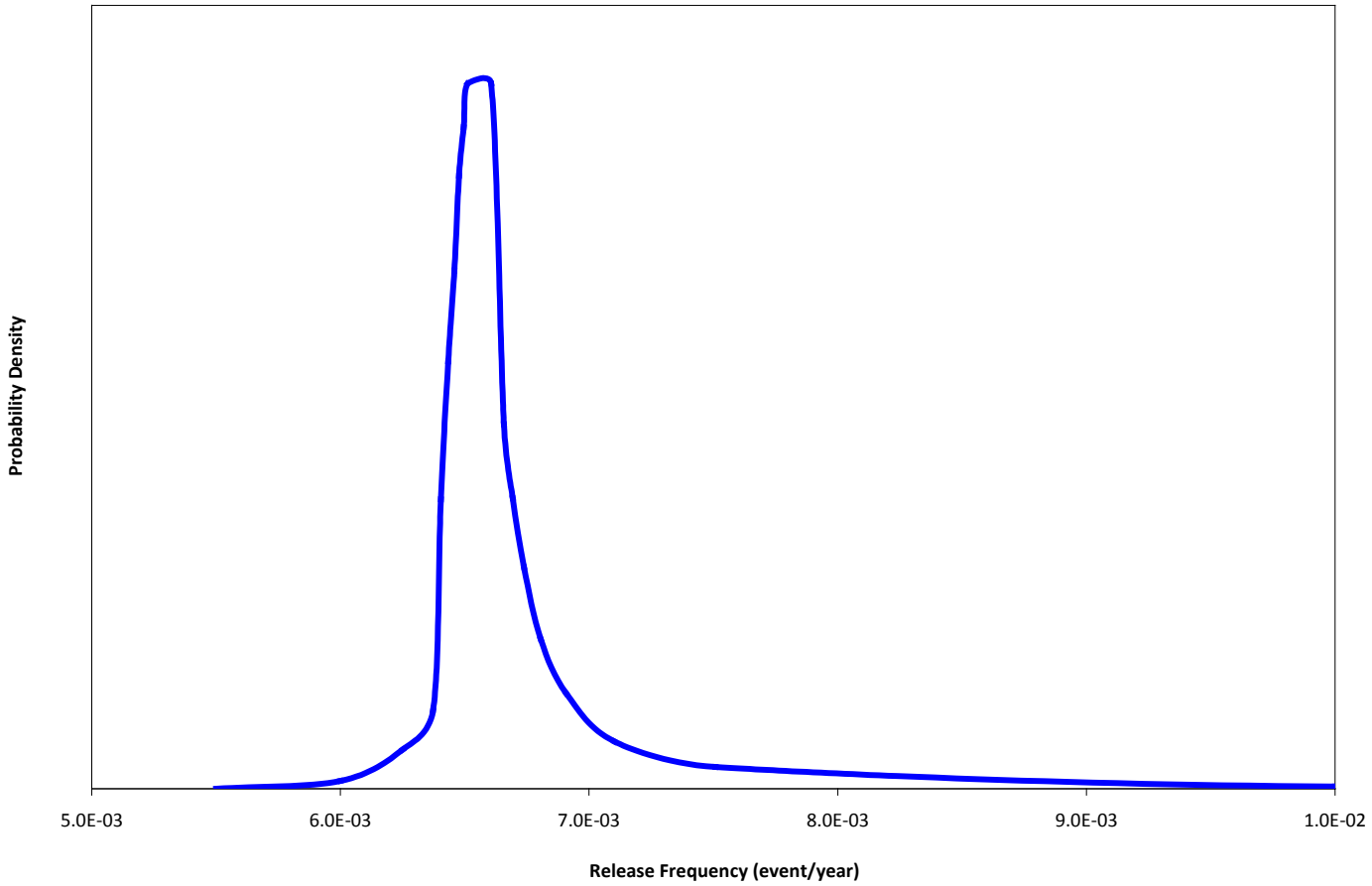
- The risk curves present the potential number of releases per year that result in a particular dose to the public, including explicit treatment of our uncertainty in both the frequency and consequences of those releases.

- The risk curves show that there is a higher frequency of "events" that could cause low doses and a lower frequency of "events" that could cause high doses.

SDA QRA RESULTS
WHAT DO THE RISK CURVES MEAN?

- How many "events" in a year would result in a dose exceeding 0.1 mrem?
- Vertical "slice" through the risk curves at the dose value of 0.1 mrem
- Mean (expected) frequency is 0.0070 event per year (1 event in 145 years)
- 90% confidence range is between 0.0078 and 0.0064 event per year (between 1 event in 130 years and 1 event in 155 years)

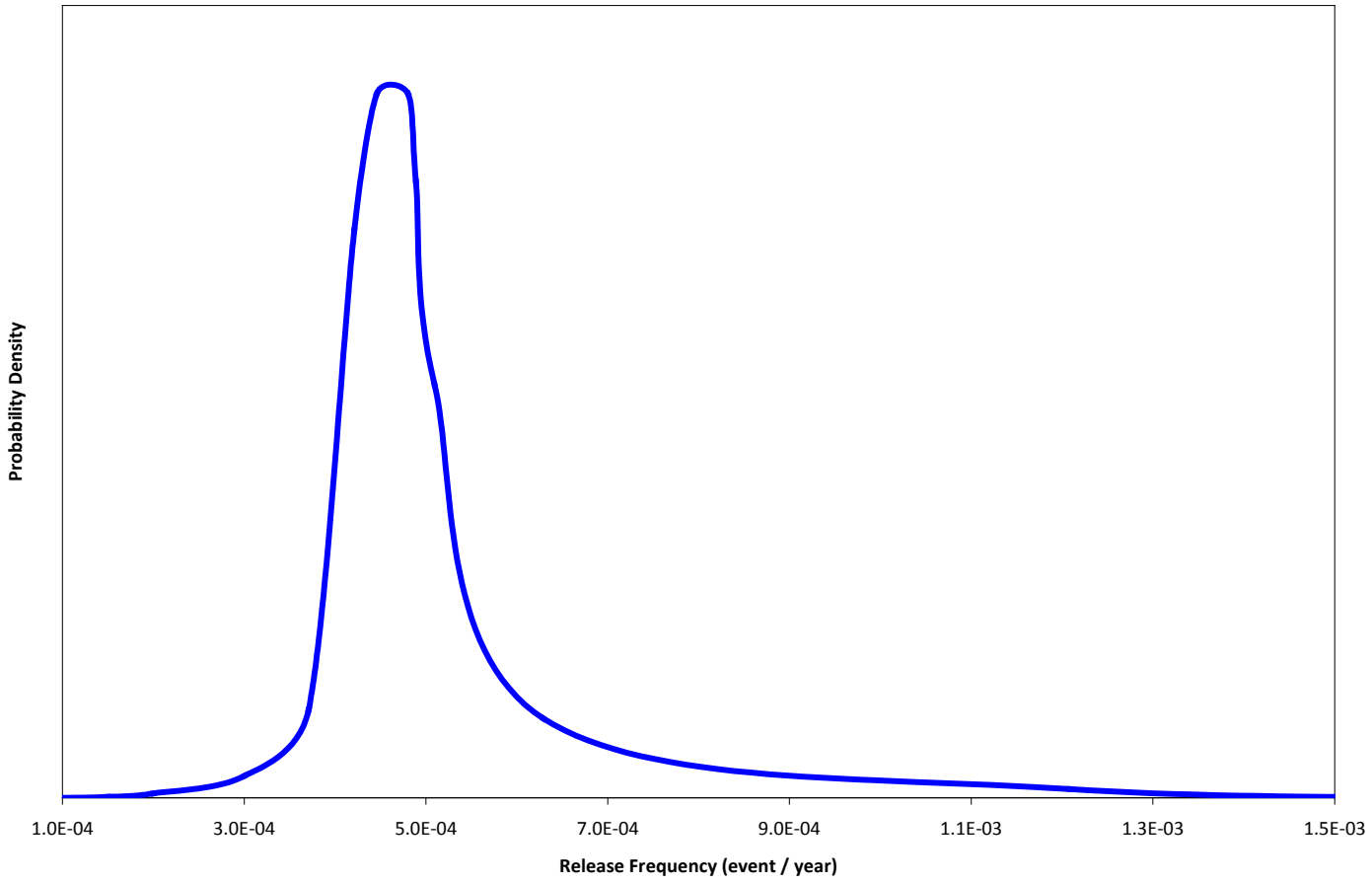
SDA QRA RESULTS
FREQUENCY OF DOSE ≥ 0.1 mrem IN 1 YEAR



SDA QRA RESULTS
WHAT DO THE RISK CURVES MEAN?

- How many "events" in a year would result in a dose exceeding 100 mrem?
- 100 mrem per year limit specified under "Radiation Dose Limits for Individual Members of the Public" in Part 380 of the State of New York Codes, Rules, and Regulations (6 NYCRR Part 380) and in Part 20 of Title 10 of the Code of Federal Regulations (10CFR20)
- Vertical "slice" through the risk curves at the dose value of 100 mrem
- Mean (expected) frequency is 0.00051 event per year (1 event in 2,000 years)
- 90% confidence range is between 0.00064 and 0.00039 event per year (between 1 event in 1,600 years and 1 event in 2,600 years)

SDA QRA RESULTS
FREQUENCY OF DOSE ≥ 100 mrem IN 1 YEAR



SDA QRA RESULTS
RELEASE MECHANISM CONTRIBUTIONS TO RISK

- **RELEASE MECHANISM 1** **45%**
- **RELEASE MECHANISM 2** **10%**
- **RELEASE MECHANISM 3** **9%**
- **RELEASE MECHANISM 4** **36%**
- **RELEASE MECHANISM 5** **< 0.1%**

SDA QRA RESULTS
RELEASE SCENARIO CONTRIBUTIONS TO RISK
(INDIVIDUAL SCENARIOS > 1% OF TOTAL)

- **Lateral groundwater flow through the ULT when trench water levels are at the WLT / ULT interface (30%)**
- **Liquid releases from breached trenches caused by landslides or seismic events when trench water levels are at the current values (23%)**
- **Solid material releases from breached trenches caused by landslides or seismic events (12%)**
- **Lateral groundwater flow through the WLT when trench water levels are at the top of the trenches (10%)**

SDA QRA RESULTS
RELEASE SCENARIO CONTRIBUTIONS TO RISK
(INDIVIDUAL SCENARIOS > 1% OF TOTAL)

- **Lateral groundwater flow through the ULT when trench water levels are at the current values (7%)**
- **Trench overflow when trench water levels are at the WLT / ULT interface (6%)**
- **Vertical groundwater flow downward through the ULT and laterally through the KRS to Buttermilk Creek (4%)**
- **Lateral groundwater flow through the ULT when trench water levels are at the WLT / ULT interface (4%)**
- **Trench overflow when trench water levels are at the top of the trenches (2%)**

SDA QRA CONCLUSIONS

- The QRA results confirm that the public health risk from operating the SDA for the next 30 years is well below widely applied radiation dose limits, such as the 100 mrem per year limit specified in 6 NYCRR Part 380-5.1 and 10CFR20 "Dose Limits for Individual Members of the Public".

- There is extremely high confidence that potential releases of radioactive materials from the SDA which may result in a one-year dose to any member of the public of 100 mrem, or more, will occur much less often than once in 30 years.

- This low level of risk will be maintained only if NYSERDA continues to operate the SDA according to its current physical and administrative controls.

SDA QRA CONCLUSIONS
(continued)

- There is very large uncertainty about several of the most important risk contributors. The three most significant sources of uncertainty are:
  - Models and analyses for the groundwater release pathways
  - Estimation of radionuclide concentrations in the trench leachate
  - Evaluation of SDA slope stabilities and non-seismic slope failures

SDA QRA TEAM RECOMMENDATIONS

- Continue to monitor and, if necessary, actively maintain trench water levels below the ULT / WLT interface level, regardless of the status of the geomembranes and other activities at the site.

- Minimize the amount of time that the geomembrane covers are not intact, and the surface of the trench soil caps is exposed. This includes expedited repairs or replacement of damaged geomembrane sections, and minimizing the time and area of uncovered trench surfaces during planned geomembrane replacements.

- Formalize emergency preparedness plans and guidelines for responses to the types of release scenarios that are evaluated in this study. The risk from specific scenarios is affected significantly by the credit that has been applied for these intervention and mitigation responses.

- Consider the benefits from a program to periodically sample the water in each trench and monitor the concentrations of radionuclide species.