U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTATION TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: PRECLOSURE PERFORMANCE ASSESSMENT

PRESENTER: DR. LESLIE JARDINE

PRESENTER'S TITLE AND ORGANIZATION: TECHNICAL PROJECT OFFICER
LAWRENCE LIVERMORE NATIONAL LABORATORY
LIVERMORE, CALIFORNIA

PRESENTER'S TELEPHONE NUMBER: (415) 423-5032

ARLINGTON, VIRGINIA
MAY 20-21, 1991

ELEMENTS OF PRESENTATION

- HISTORY OF REPOSITORY PRECLOSURE PERFORMANCE ASSESSMENTS
- GENERAL METHODOLOGY
- RESULTS OF METHODOLOGY APPLICATION
  - SURFACE FACILITIES
  - SOURCE TERMS
  - FEEDBACK TO DESIGN PROCESS
- OTHER APPLICATION RESULTS
  - UNDERGROUND FACILITIES
  - DOSE UNCERTAINTY ANALYSES
- CONCLUSIONS

SUMMARY OF ACCIDENT ANALYSES PERFORMED TO DATE FOR REPOSITORIES

- PRELIMINARY STUDIES OF POTENTIAL ACCIDENTS AT REPOSITORIES HAVE BEEN PERFORMED BY NUMEROUS ORGANIZATIONS

- ANALYSES HAVE EXAMINED VARIOUS SITES AND REPOSITORY FACILITY DESIGNS INCLUDING TUFF, BWIP, WIPP, SALT (GENERIC), AND SALT (DEAF SMITH)

SUMMARY OF ACCIDENT ANALYSES PERFORMED TO DATE FOR REPOSITORIES

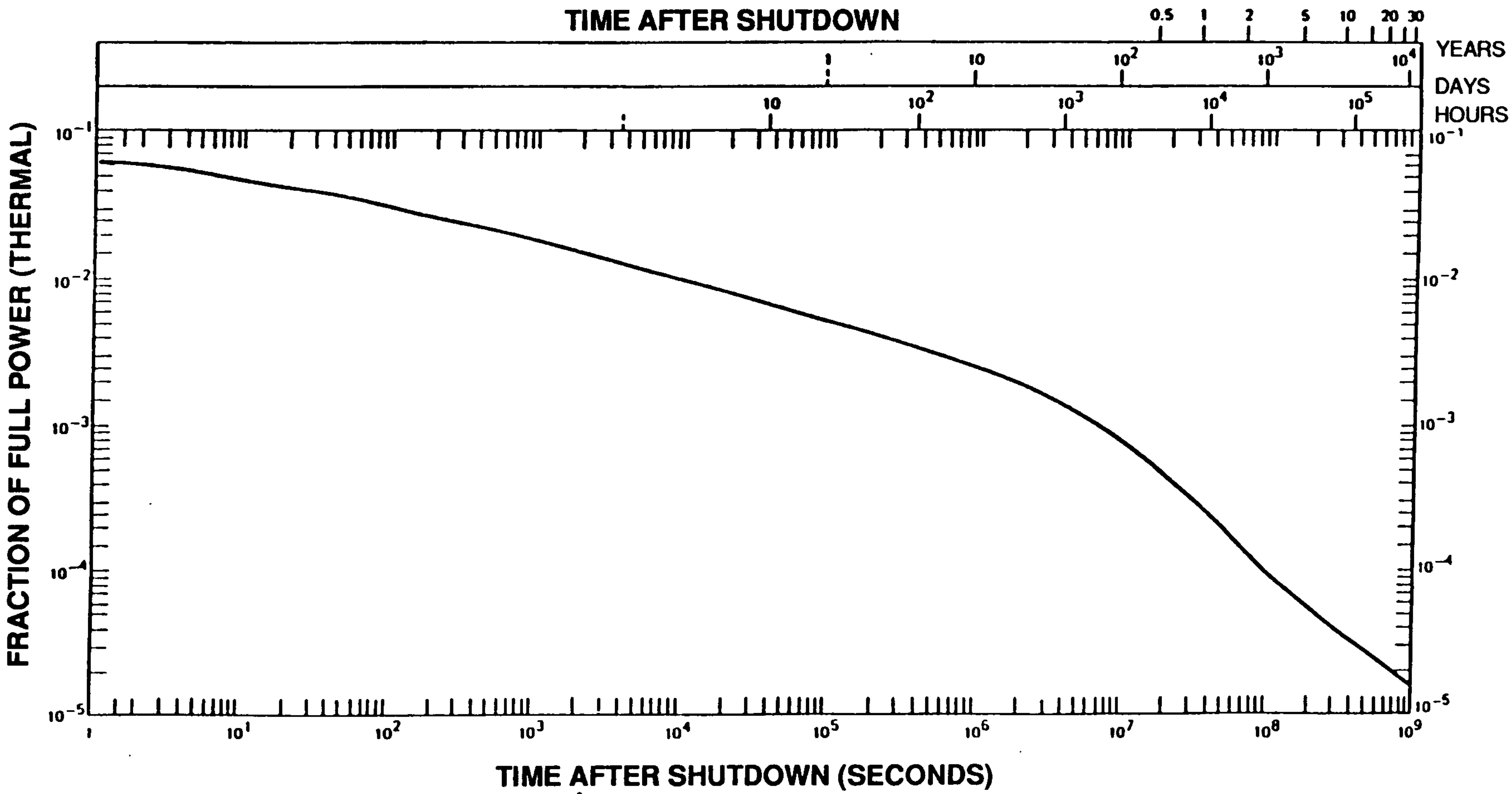
- **A LARGE VARIETY OF POTENTIAL ACCIDENTS HAVE BEEN ASSESSED INCLUDING:**
  - EARTHQUAKES
  - FLOODS
  - TORNADOS
  - AIRCRAFT IMPACTS
  - UNDERGROUND NUCLEAR EXPLOSIONS (UNE)
  - HOIST CAGE DROPS
  - TRANSPORTER COLLISIONS/CRASHES
  - FUEL HANDLING ACCIDENTS
  - CRANE DROPS (CASK, CONTAINER, FUEL ASSEMBLY)

- **ALL CATEGORIES OF EVENTS THAT HAVE SIGNIFICANT CONSEQUENCES HAVE LIKELY BEEN IDENTIFIED**

SUMMARY OF ACCIDENT ANALYSES PERFORMED TO DATE FOR REPOSITORIES

- POTENTIAL OFFSITE DOSE CONSEQUENCES ARE MUCH LESS THAN REACTORS AND REPROCESSING PLANTS DUE TO HANDLING OF AGED SPENT FUEL:
  - LESS DECAY HEAT
  - FEWER SHORT-LIVED, HIGH SPECIFIC ACTIVITY GASES OR VOLATILE ISOTOPES
  - LESS INTRINSIC ENERGY AVAILABLE TO DISPERSE RADIOACTIVE MATERIAL

LWR'S:
FRACTION OF FULL POWER (THERMAL) VS. TIME AFTER SHUTDOWN



LWR'S:
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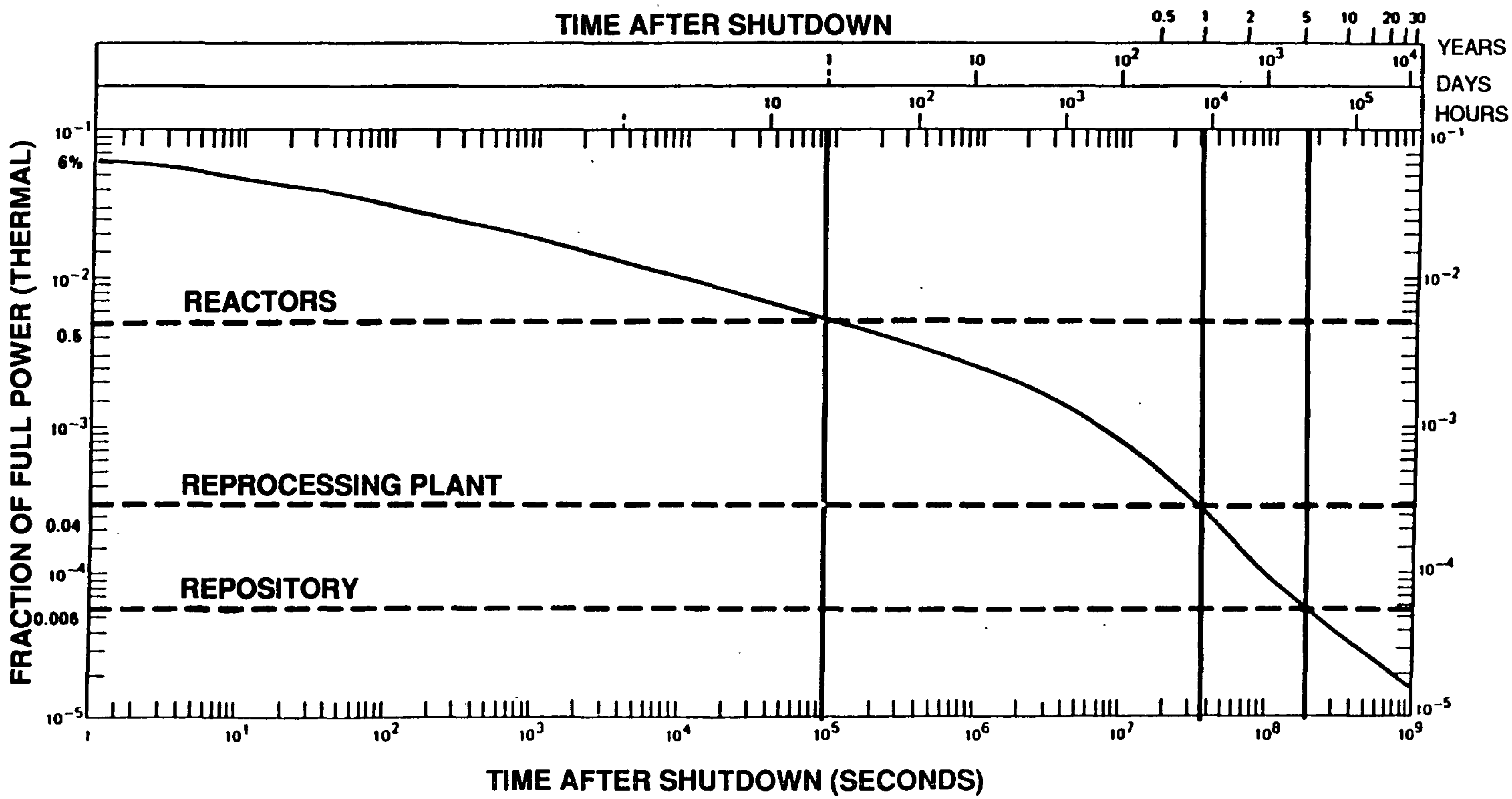

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HISTORY OF YUCCA MOUNTAIN PRECLOSURE PERFORMANCE ASSESSMENTS: ACCIDENTS

1. TOTAL FACILITY: SLTR 86-1005 (6/86)
2. UNDERGROUND FACILITY: SAND 88-7061
3. ESF CONVERSION: SAND 88-7010 (8/88)

4. PRELIMINARY Q-LIST: SLTR 86-1008 (7/86)
5. Q-LIST UPDATE: ESF: SAND 89-7002, SAND 89-7024

6. SEISMIC (SEE NEXT PAGE)

REPOSITORY CONCEPTUAL DESIGN 1985 → 1991

7. AIRCRAFT SCENARIOS/CONSEQUENCES: SAND 90-7051, SLTR 87-7014
8. CRITICALITY EVALUATIONS: SLTR 87-7007 (5/88), SAND 89-7010
9. CONSEQUENCE UNCERTAINTY EVALUATION: SLTR 90-7002 (3/91)
10. PLATE OUT/DRY DEPOSITION: SLTR 87-7020
11. CONTAINER/FUEL ASSEMBLY DROPS: SAND 87-7082

NOTE: REPORTS ONLY

HISTORY OF YUCCA MOUNTAIN PRECLOSURE PERFORMANCE ASSESSMENTS: ACCIDENTS

(CONTINUED)

SEISMIC

1. SEISMIC COST BENEFIT STUDY: SAND 88-1600 (3/89)
2. SEISMIC DESIGN STUDY: SLTR 87-7005 (11/87)
3. UNCERTAINTY ANALYSIS OF SEISMIC COST BENEFIT STUDY: SLTR 88-7012
4. WHB STRUCTURAL CAPACITY FOR FAULT DISPLACEMENTS: SLTR 87-7003 (11/87)
5. SEISMIC DESIGN MARGINS: SLTR 86-1018 (3/87)
6. LOAD COMBINATIONS/ALLOWABLE STRESSES WHB: SLTR 89-7002
7. SEISMIC MARGINS EVALUATION: SLTR 89-7005
8. SEISMIC JOINTS FOR WHB: SLTR 89-7008

REPOSITORY CONCEPTUAL DESIGN 1985 → 1991

9. SEE PREVIOUS PAGE

NOTE: REPORTS ONLY

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- CONCLUSIONS

REPOSITORY DESIGN PROCESS

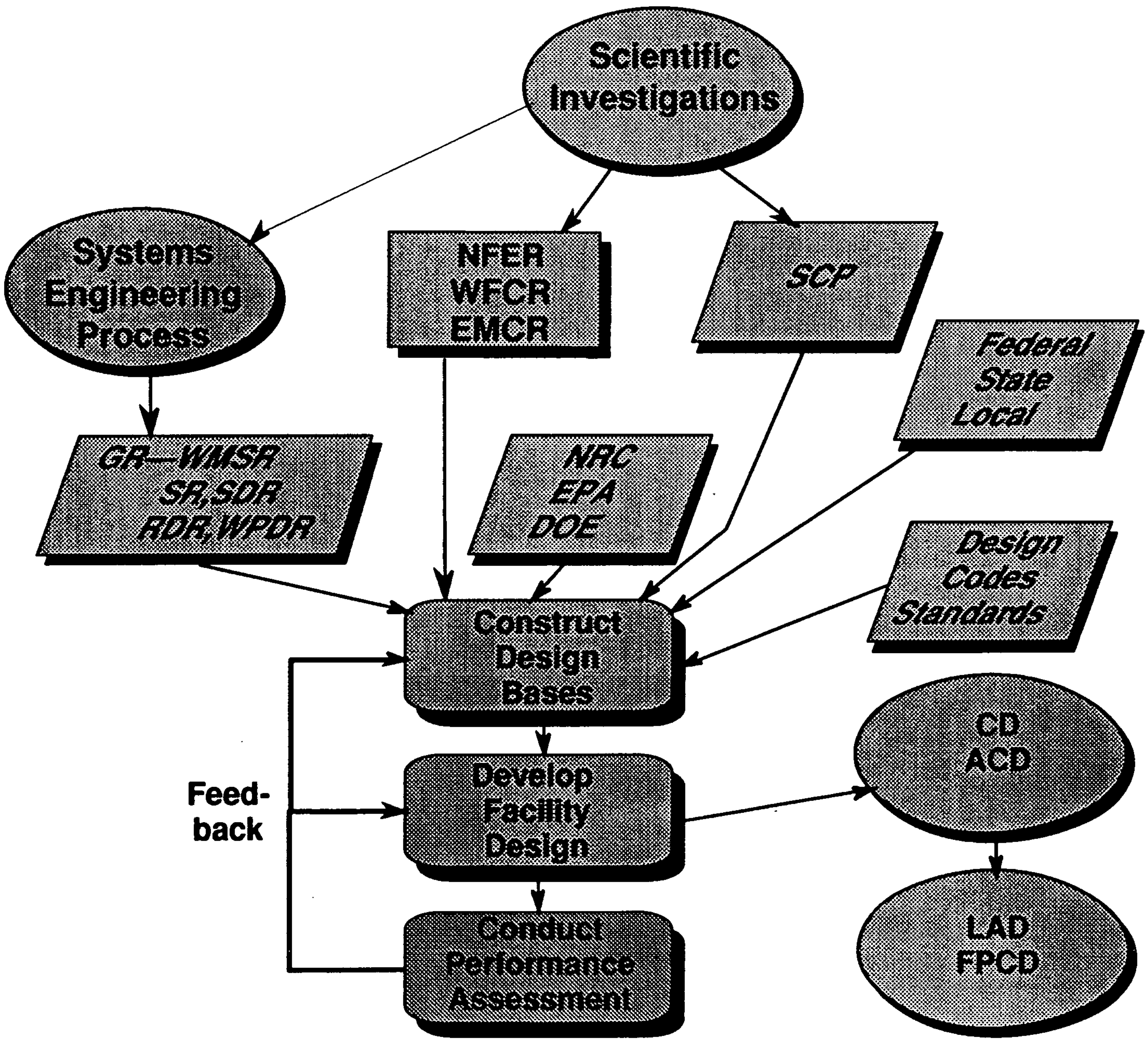
STEP 1: CONSTRUCT DESIGN BASES

STEP 2: DEVELOP FACILITY DESIGN

STEP 3: CONDUCT PERFORMANCE ASSESSMENT

STEP 4: REVISE DESIGN, IF NECESSARY, AND ITERATE

Repository Design Process

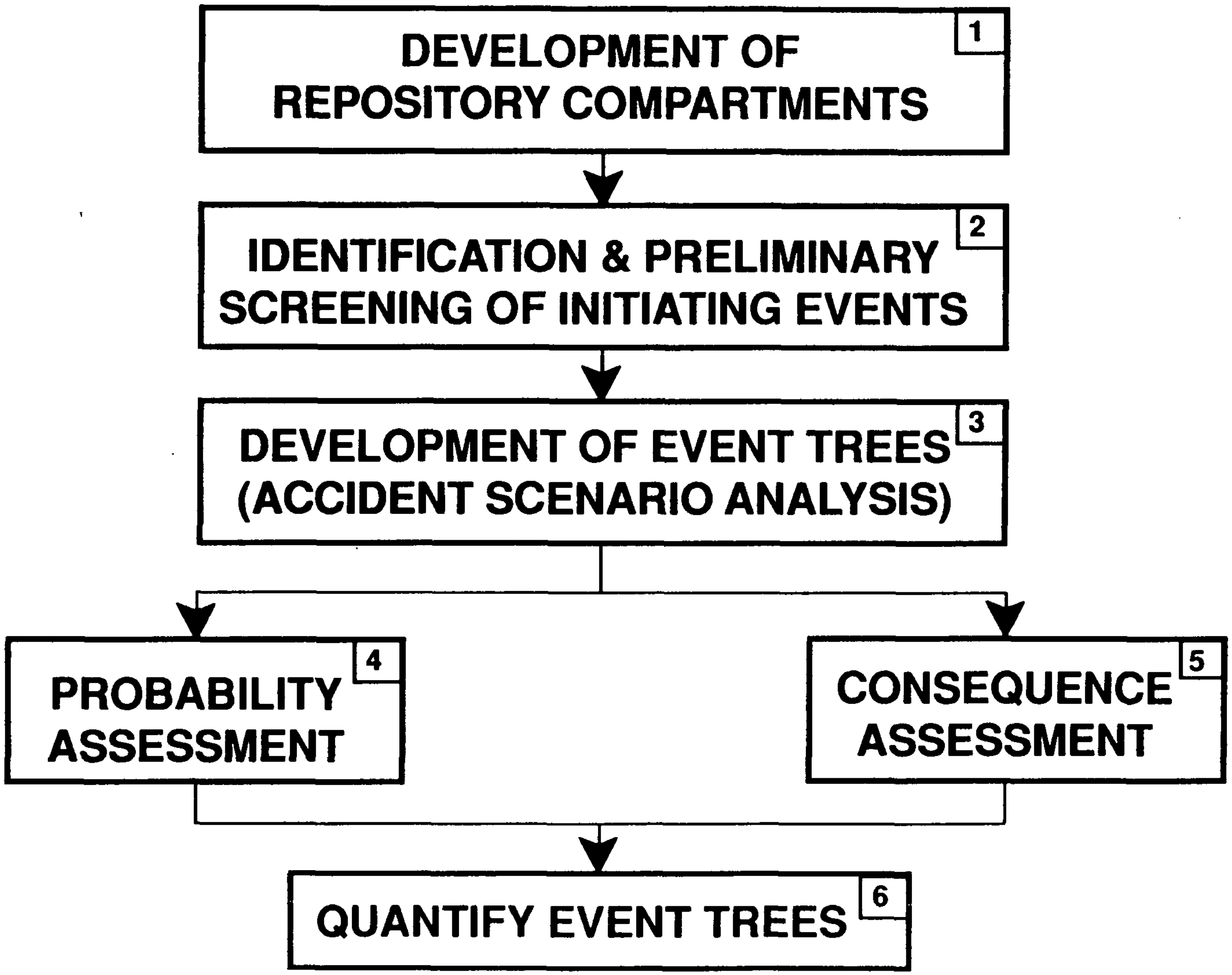


PRECLOSURE PERFORMANCE ASSESSMENT PROCESSES

PERFORMANCE ASSESSMENT

- SYSTEMS MODELING & ANALYSES
- RADIOACTIVE RELEASE ANALYSES
- DOSE CONSEQUENCES ANALYSES
- REGULATORY COMPLIANCE ASSESSMENTS

PRECLOSURE METHODOLOGY



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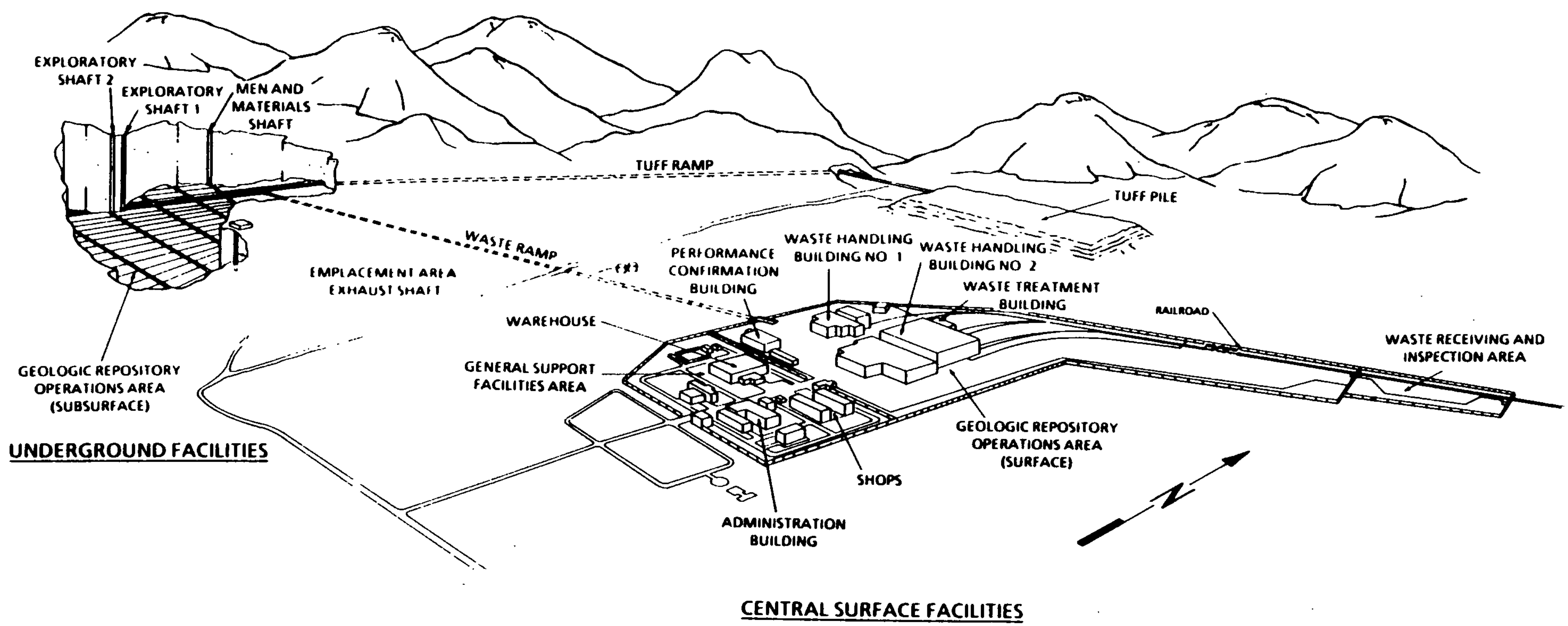
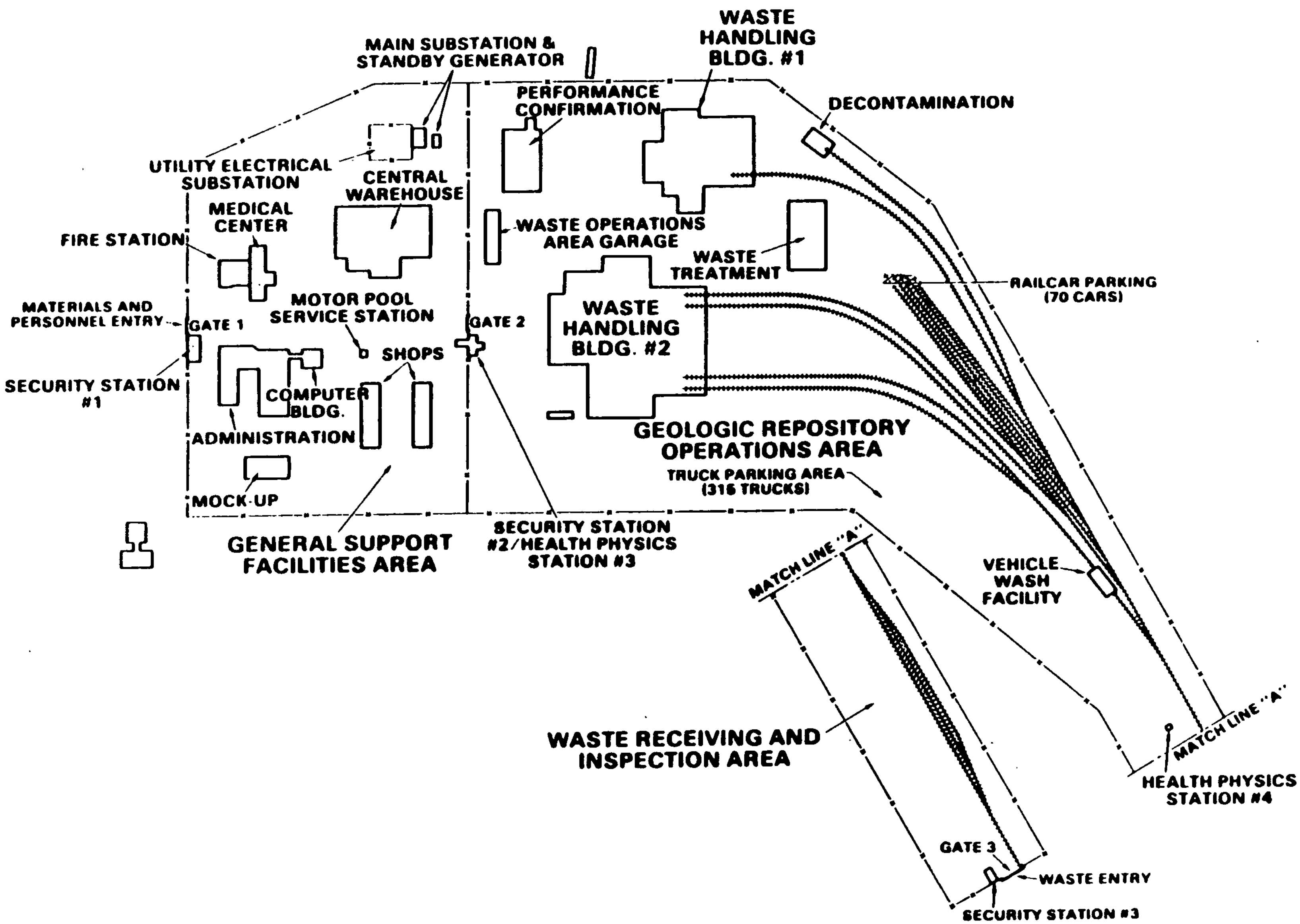
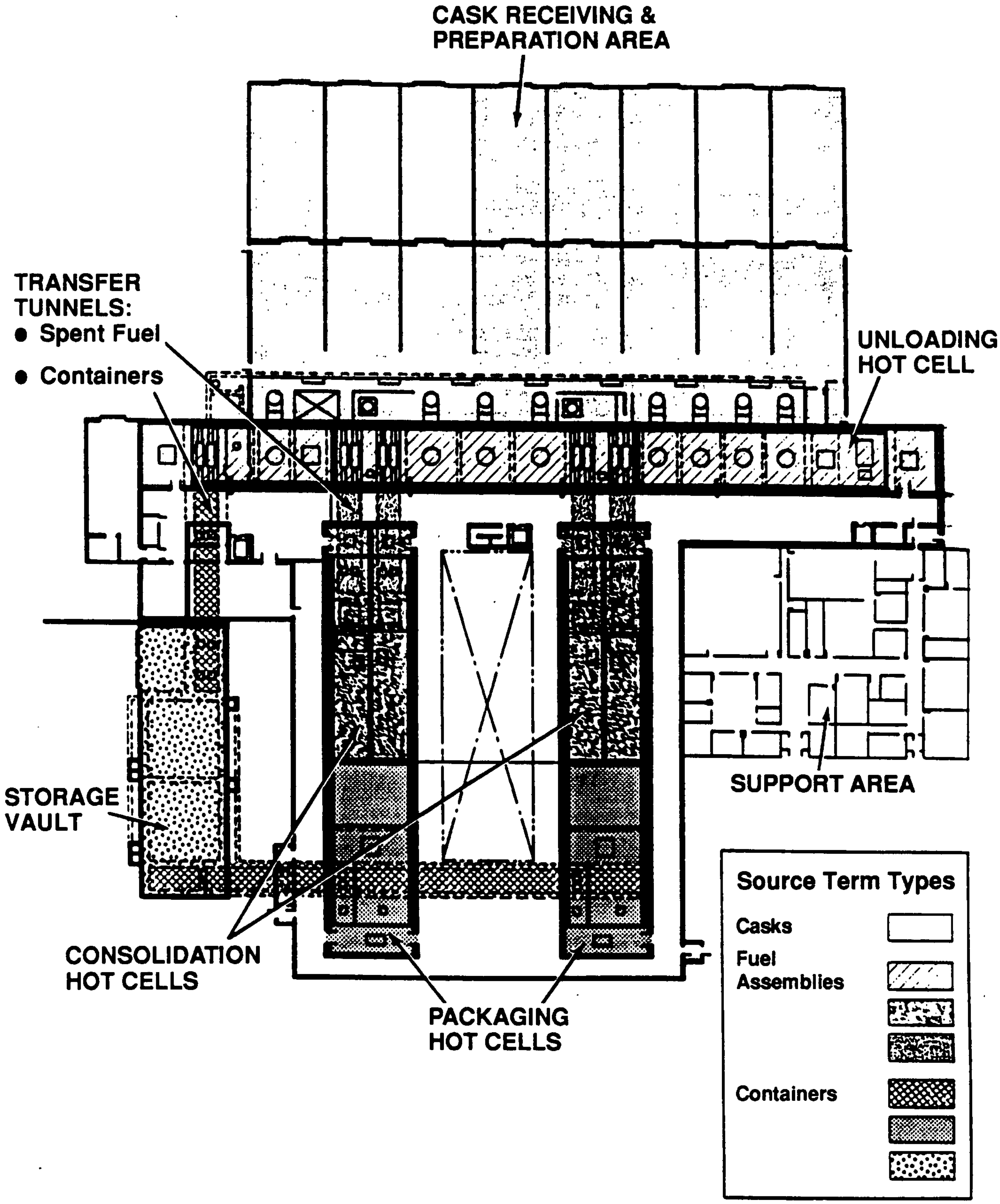
PRELIMINARY DRAWING OF REPOSITORY COMPLEX



CENTRAL SURFACE FACILITIES AREA



COMPARTMENTS: WASTE HANDLING BUILDING #2



DEVELOPMENT OF EVENT TREES AND ACCIDENT SCENARIOS

- **INTERNAL EVENTS**
  - SCREENED OUT 46 INITIATING EVENTS
  - DEVELOPED 12 EVENT TREES INTO 58 SCENARIOS
  - DEVELOPED 16 FAULT DIAGRAMS

- **EXTERNAL EVENTS**
  - SCREENED OUT 45 INITIATING EVENTS
  - ONLY SEISMIC EVENT WAS EVALUATED FURTHER
  - DEVELOPED 9 EVENT TREES INTO 91 SCENARIOS

INTERNAL INITIATING EVENTS DEVELOPED INTO EVENT TREES PART 1

COMPARTMENT AREA	INTERNAL INITIATING EVENT
• ACCESS AREA • RECEIVING & INSPECTION AREA • CASK RECEIVING & PREPARATION • UNLOADING HOT CELL	- TRAIN FALLS OFF BRIDGE - TRAIN COLLISION - CRANE DROPS CASK - CRANE DROPS FUEL ASSEMBLY - CRANE DROPS DHLW CANISTER - CONTAINER CUTTING MACHINE FAILURE
• CONSOLIDATION HOT CELL	- MALFUNCTION OF CONSOLIDATION SYSTEM

INTERNAL INITIATING EVENTS DEVELOPED INTO EVENT TREES PART 2

COMPARTMENT AREA	INTERNAL INITIATING EVENT
• WHB TRANSFER TUNNEL • PACKAGING HOT CELL • SURFACE STORAGE VAULT	- TRANSFER/STORAGE CART ACCIDENT - CRANE DROPS UNSEALED CONTAINER - CONTAINER TRANSFER MACHINE (CTM) DROPS CONSOLIDATED FUEL CONTAINER - CTM DROPS DHLW CONTAINER
• UNDERGROUND EMPLACEMENT AREA	- RUNAWAY TRANSPORTER

REPOSITORY SOURCE TERMS

SPENT FUEL

- RELEASES OF GASES, VOLATILES, AND PARTICULATES:
  - FROM GAP WHEN CLADDING BREACHED
  - FROM PULVERIZATION DURING IMPACTS (BRITTLE FRACTURE)

VITRIFIED HIGH-LEVEL WASTE

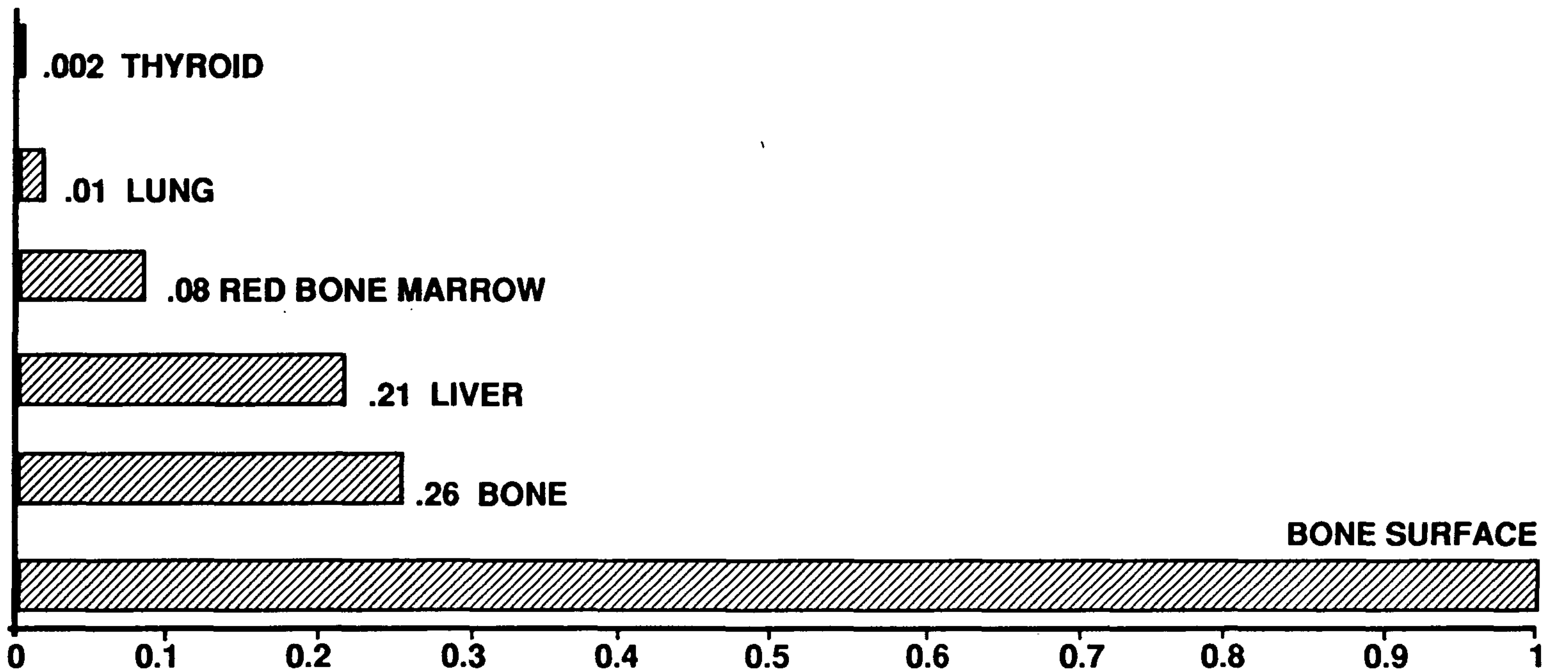
- RELEASES OF PARTICULATES:
  - FROM PULVERIZATION DURING IMPACTS (BRITTLE FRACTURE)
- NO RELEASE OF GASES OR VOLATILES

REPOSITORY SOURCE TERMS: POTENTIAL RADIONUCLIDE RELEASES VIA AIR IMMERSION AND INHALATION DOSE PATHWAYS

GASES	VOLATILES	PARTICULATES: SPENT FUEL & GLASS
Kr - 85	I - 129	Pu - 238, 239, 240, 241
H - 3	Cs - 134, 137	Am - 241
C - 14		Sr - 90
		Cm - 244
		Cs - 134, 137
		Pm - 147

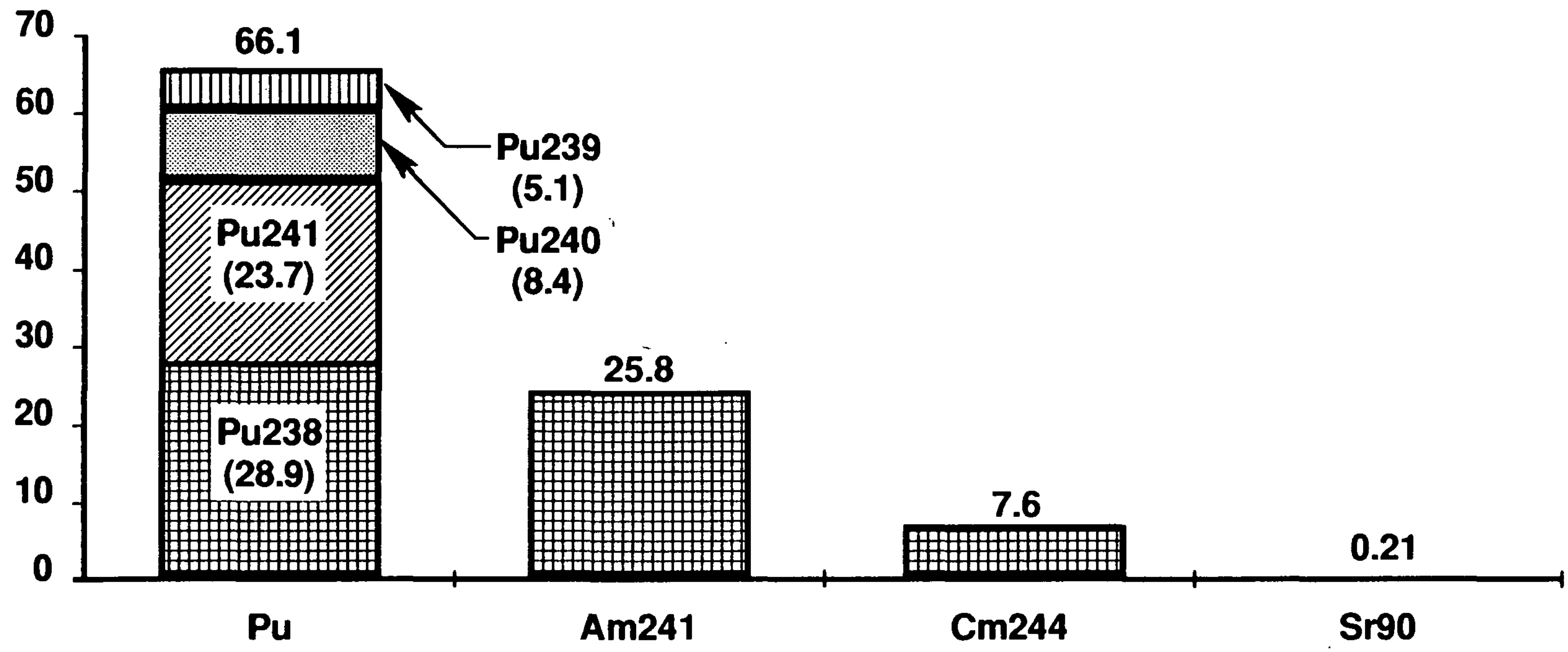
SUMMARY OF YUCCA MOUNTAIN ACCIDENT ANALYSES

RELATIVE RATIO OF DOSE RECEIVED BY CRITICAL ORGANS
NORMALIZED TO THE ORGAN RECEIVING THE HIGHEST DOSE

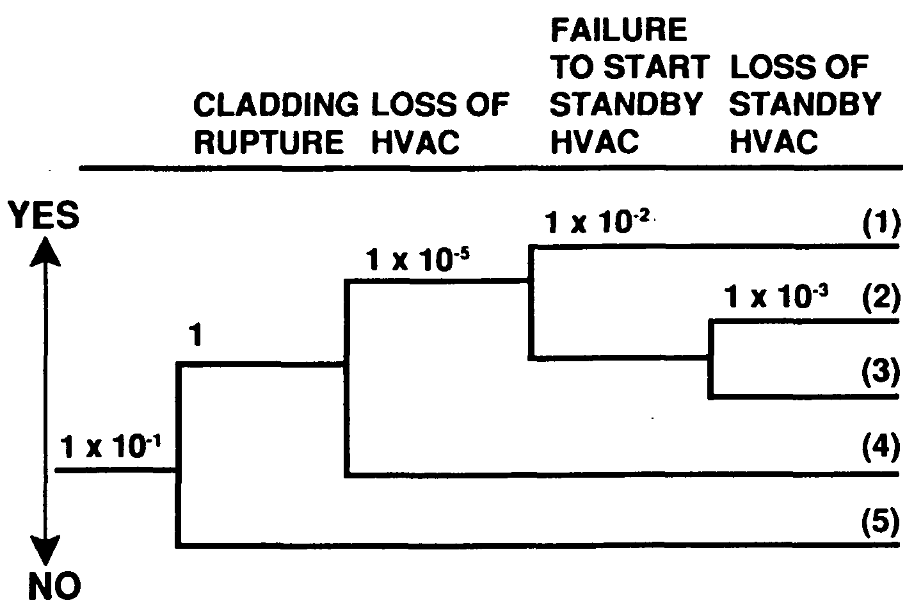


RELATIVE RATIO NORMALIZED TO BONE
SURFACE FOR 10 YEAR SPENT FUEL

PROMINENT ISOTOPIC CONTRIBUTORS TO BONE SURFACE DOSE FOR 10 YEAR AGED PWR SPENT FUEL

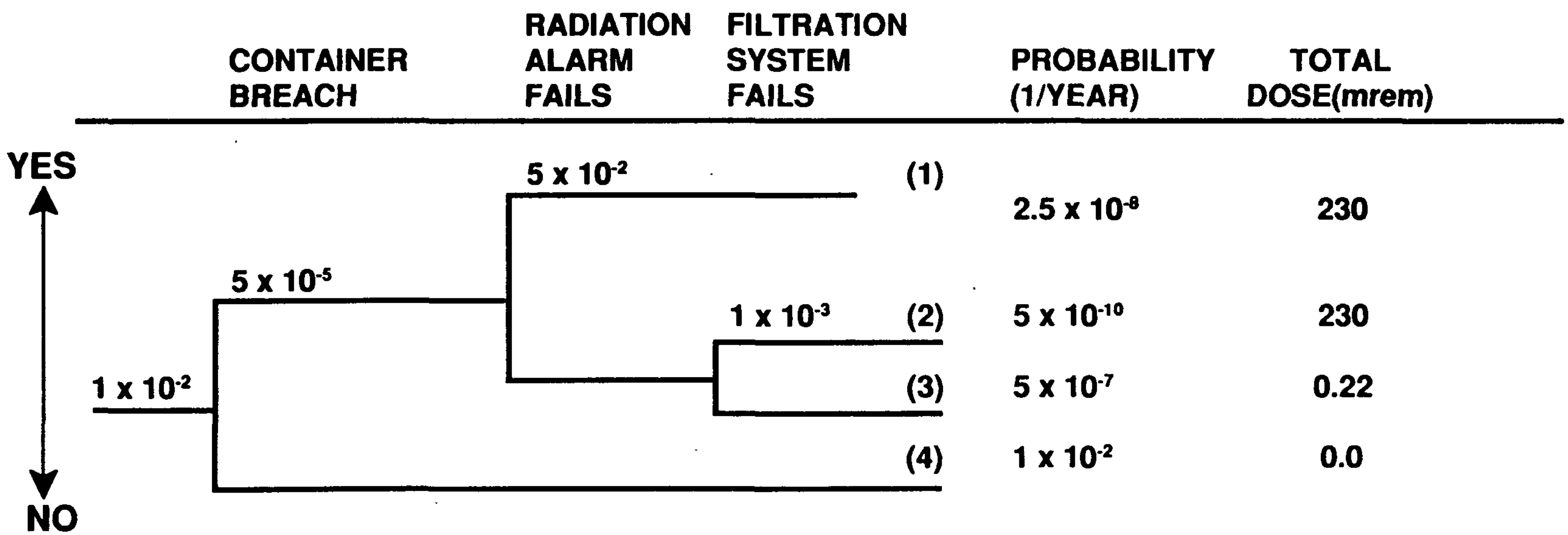


EVENT TREE FOR A CRANE DROPPING A FUEL ASSEMBLY IN THE UNLOADING HOT CELL

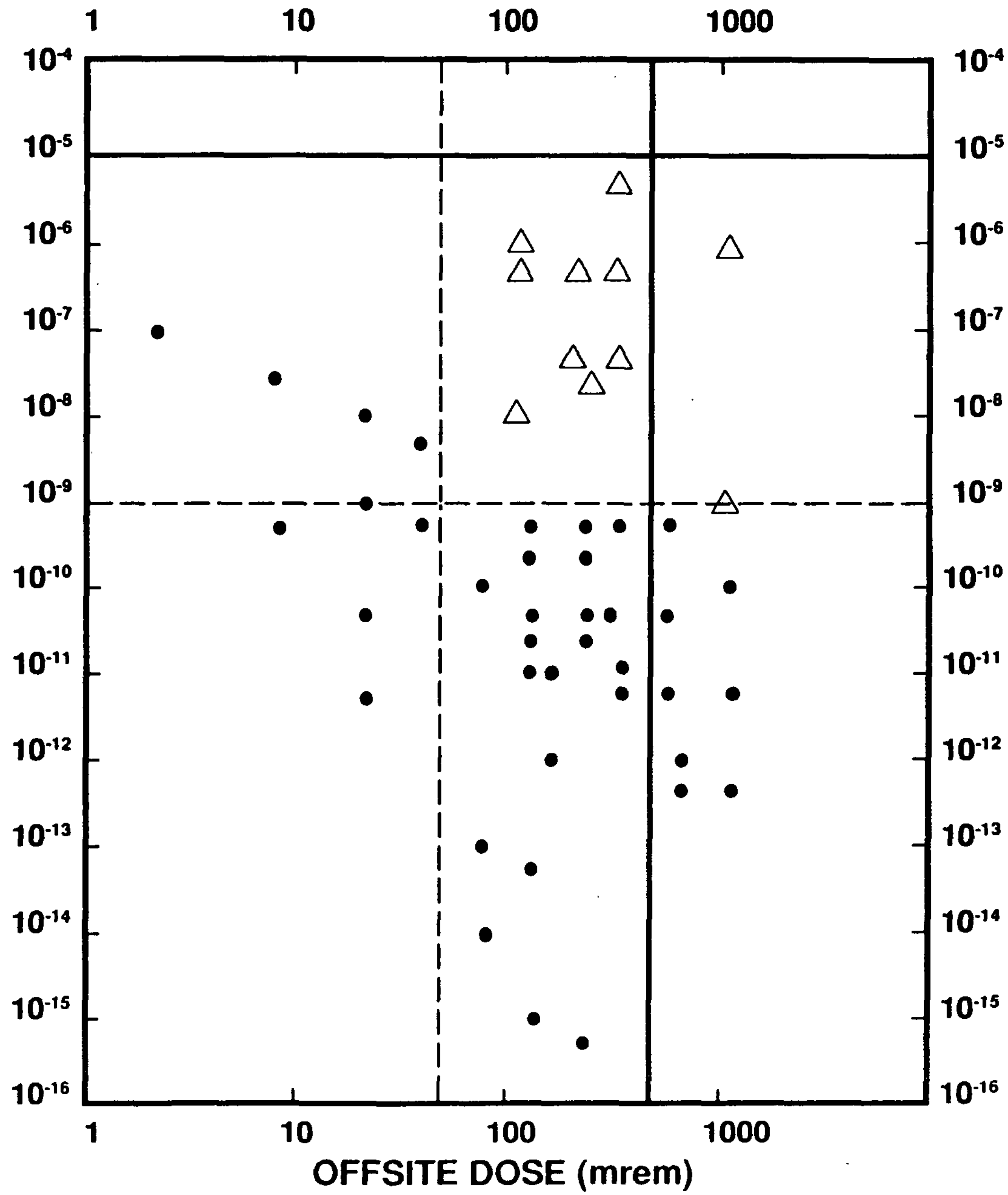


	PROB. ($YEAR^{-1}$)	DOSE(mrem) Kr85	PARTICULATES GAP	PARTICULATES PULV.	TOTAL
(1)	1(-8)	7.4(-2)	4.1(+1)	6.3(+1)	1.1(+2)
(2)	1(-9)	7.4(-2)	4.1(+1)	6.3(+1)	1.1(+2)
(3)	1(-6)	7.4(-2)	4.1(-3)	1.4(-1)	2.2(-1)
(4)	1(-1)	7.4(-2)	4.1(-3)	1.4(-1)	2.2(-1)
(5)	0.0	0.0	0.0	0.0	0.0

SURFACE STORAGE VAULT: CTM DROPS FUEL ROD CONTAINER



ACCIDENT ASSESSMENT RESULTS



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DOMINANT SCENARIOS

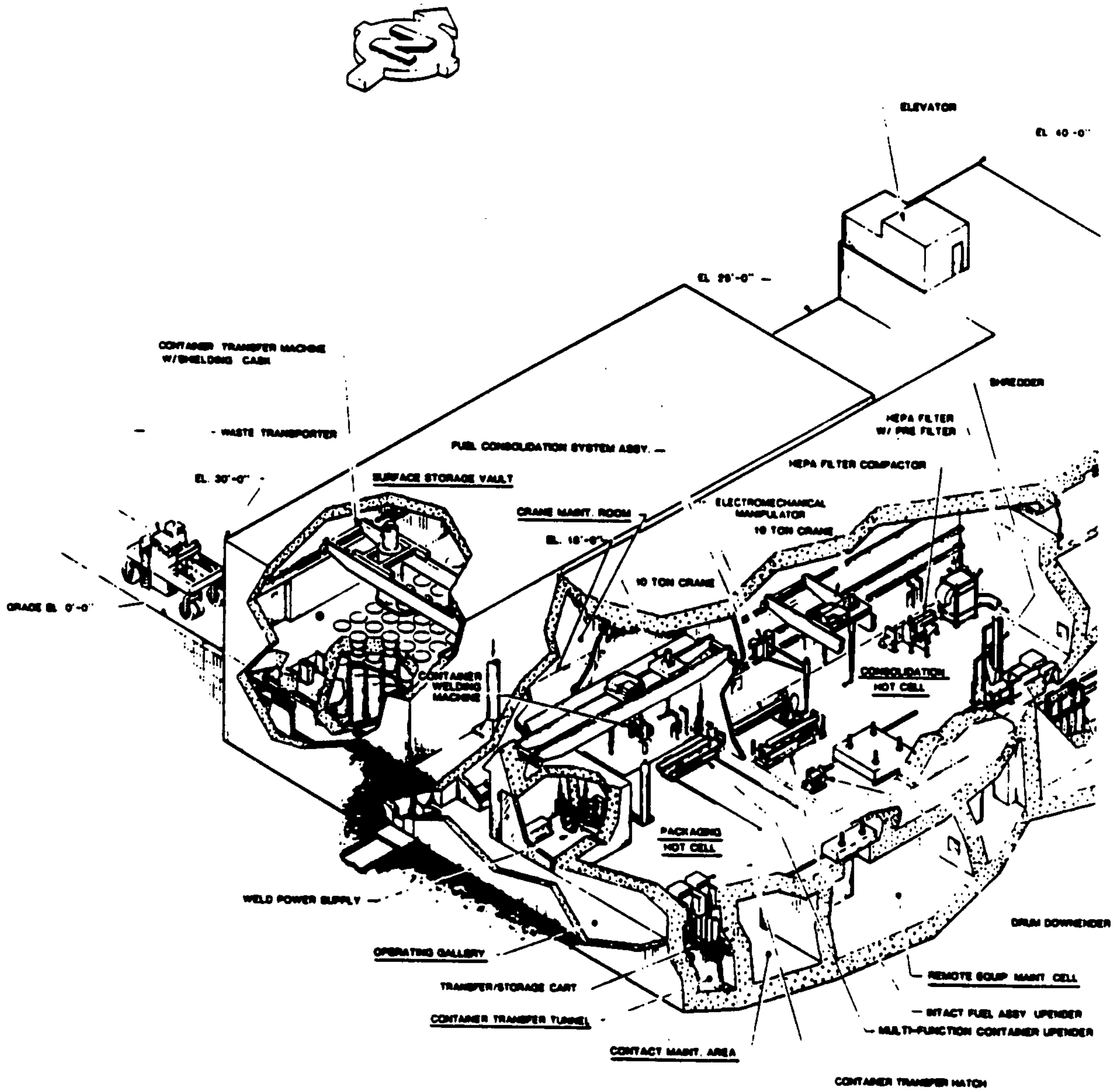
0.1 1 10 100 1000

SYSTEM AREA	PROBABILITY/ YEAR	EVENT
CASK RECEIVING/ PREPARATION	5×10^{-6}	● DROP CASK
	5×10^{-8}	● CRANE FALLS ON CASK
	5×10^{-8}	● CASK FALLS ON CASK
UNLOADING HOT CELL	1×10^{-8}	● DROP FUEL ASSEMBLY
	5×10^{-7}	● STRUCTURE PIECE FALLS ON FUEL
	1×10^{-6}	● EQUIPMENT FALLS ON FUEL
CONSOLIDATION HOT CELL	5×10^{-7}	● STRUCTURE PIECE FALLS ON FUEL
	1×10^{-6}	● EQUIPMENT FALLS ON FUEL
PACKAGING HOT CELL	1×10^{-9}	● DROP UNSEALED CONTAINER
	1×10^{-6}	● EQUIPMENT FALLS ON UNSEALED CONTAINER
	5×10^{-7}	● STRUCTURE PIECE FALLS
HOT CELL TRANSFER TUNNEL	5×10^{-7}	● STRUCTURE PIECE FALLS ON FUEL
STORAGE VAULT	3×10^{-8}	● DROP SEALED CONTAINER

0.1 1 10 100 1000

DOSE CONSEQUENCE (mrem)

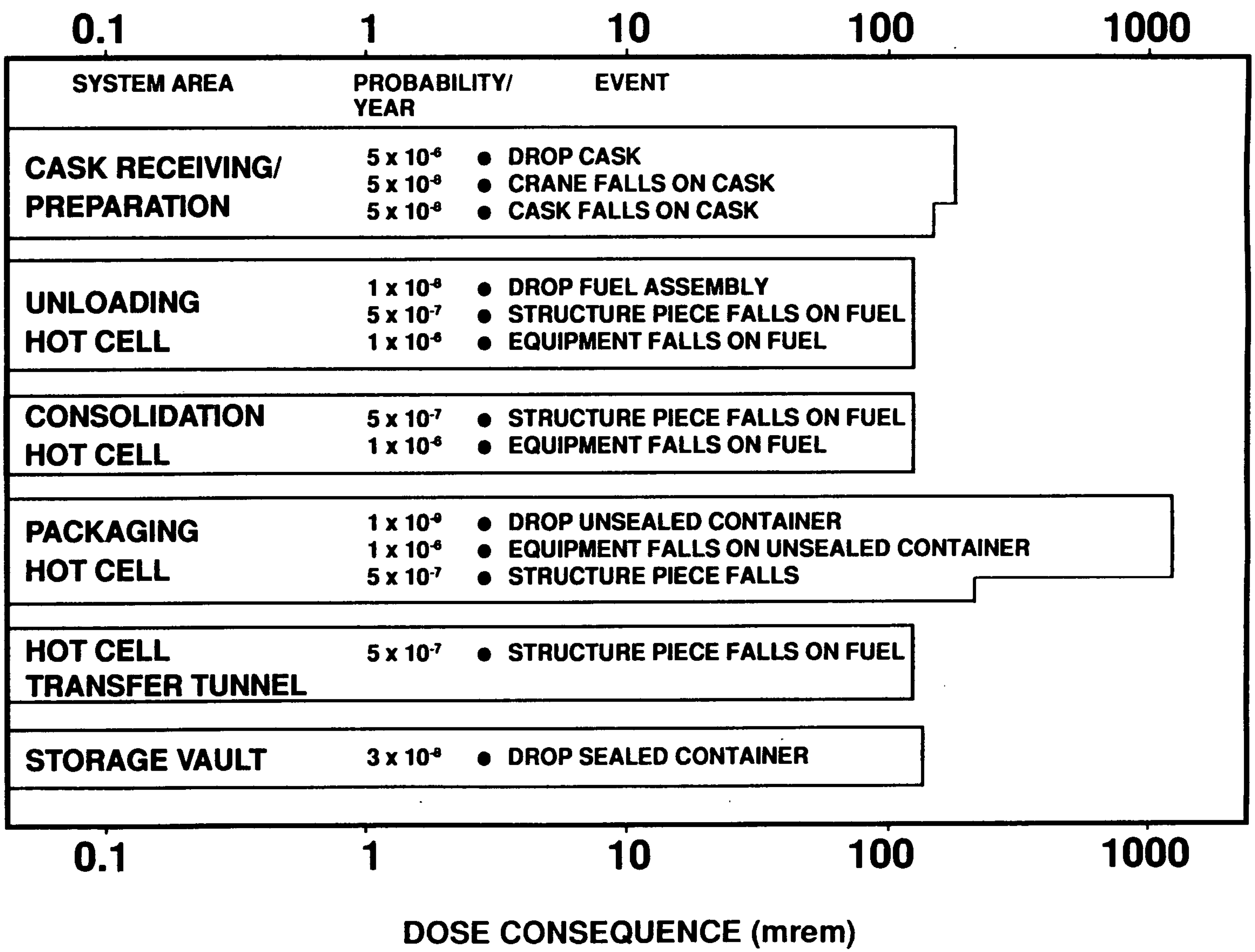
PACKAGING HOT CELL



PACKAGING HOT CELL SCENARIOS

INITIATING EVENT	PROBABILITY (PER YEAR)	OFFSITE DOSE (mrem)
CRANE LOAD DROP	1×10^{-9}	1100
FALLING EQUIPMENT - SEISMIC	1×10^{-9}	1100
FALLING STRUCTURE - SEISMIC	5×10^{-7}	300

DOMINANT SCENARIOS



CASK RECEIVING AND PREPARATION AREA

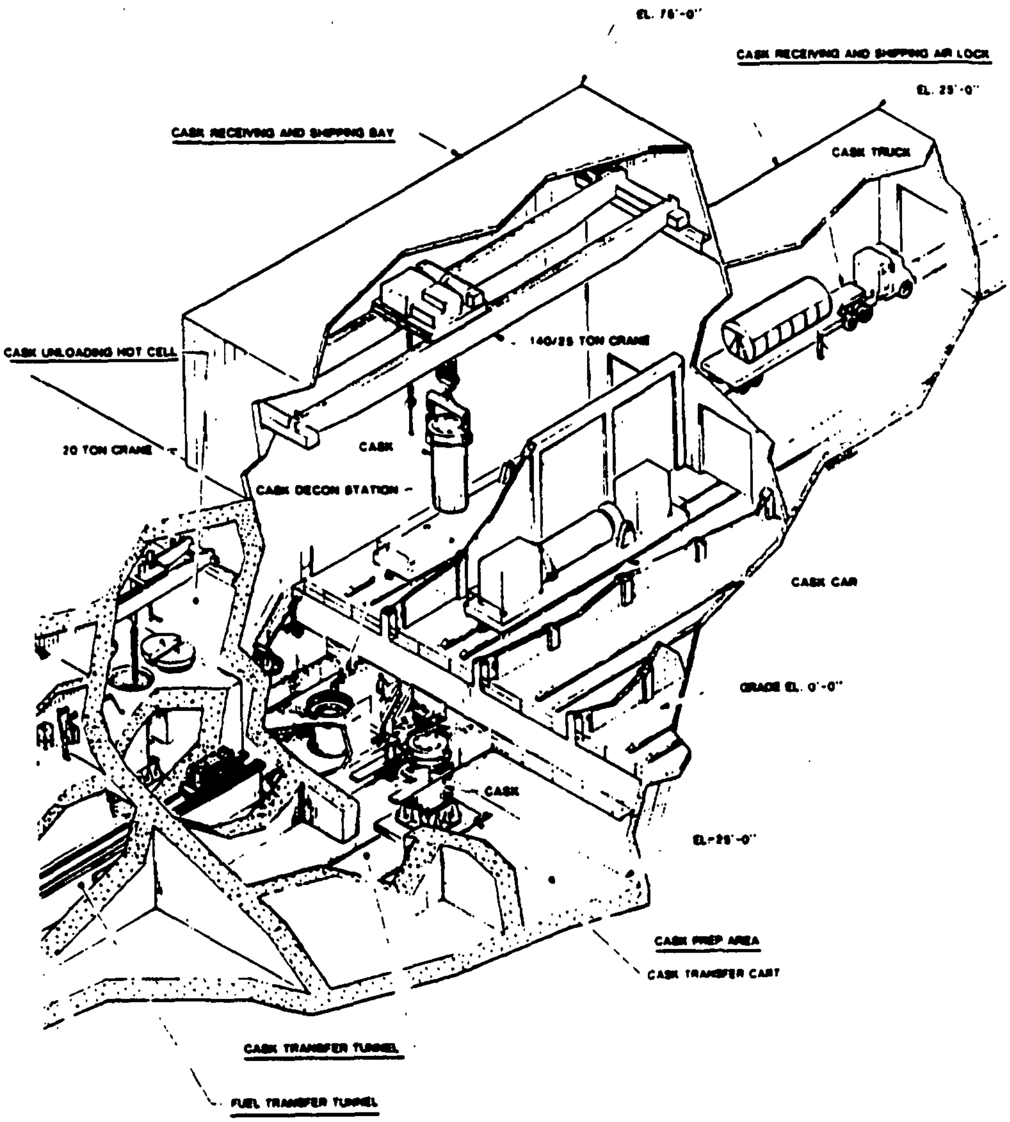


Figure ES-1

TUFF REPOSITORY

WASTE HANDLING BUILDING

ISOMETRIC SKETCH

CASK RECEIVING AND PREPARATION AREA SCENARIOS

INITIATING EVENT	PROBABILITY (PER YEAR)	OFFSITE DOSE (mrem)
CRANE LOAD DROP	5×10^{-6}	300
FALLING EQUIPMENT - SEISMIC	5×10^{-8}	300
FALLING CASK - SEISMIC	5×10^{-8}	300

RECOMMENDATIONS - TO DESIGN PROCESS

- DEVELOP DESIGN ALTERNATIVE TO ROTATING UNSEALED CONTAINER
- DEVELOP PASSIVE DESIGN ALTERNATIVE TO REMOVE 25 FOOT CASK IMPACTS
- CONSIDER POTENTIAL SEISMIC AND FLOOD EFFECTS WHEN SELECTING CASK IMPACT ALTERNATIVES

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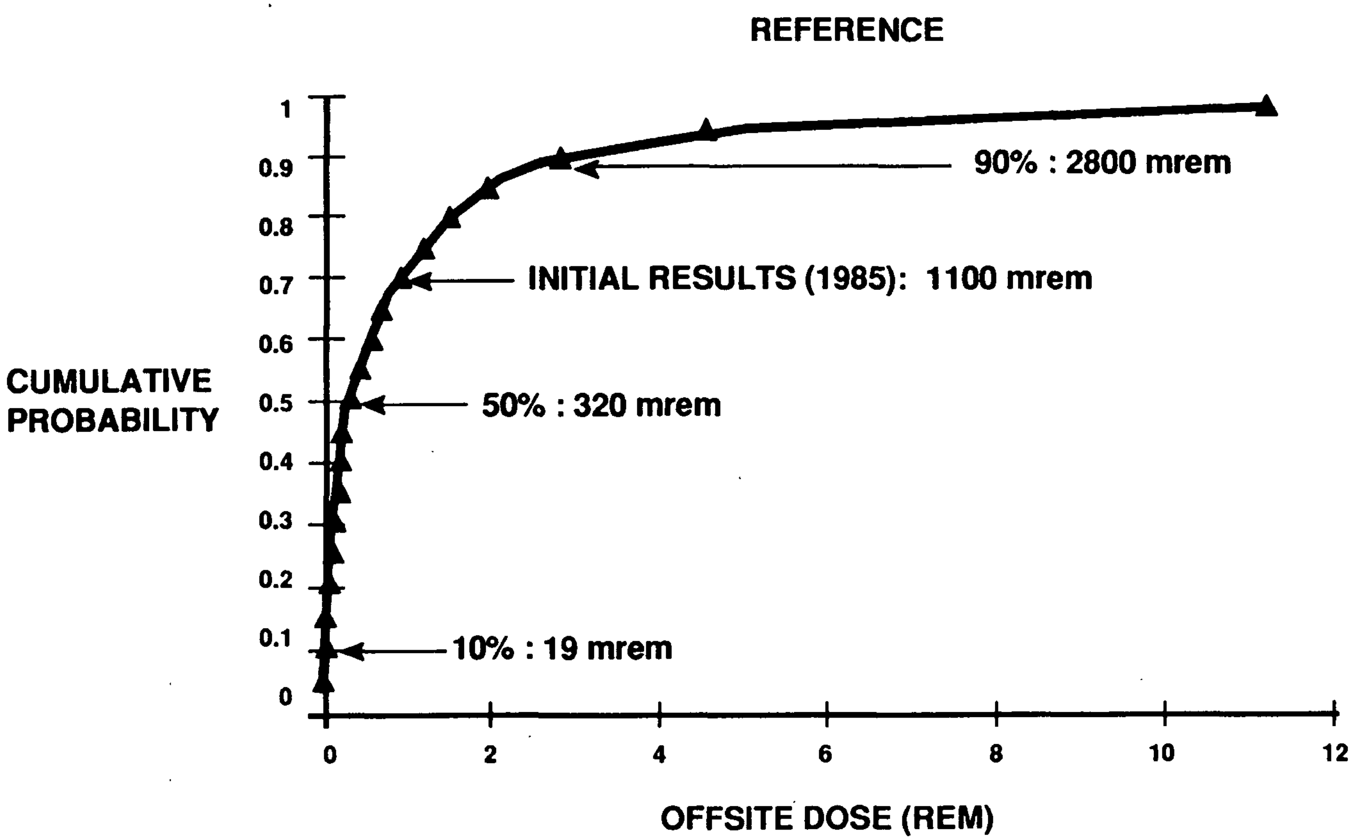
SUMMARY OF UNDERGROUND SCENARIOS WITH OFFSITE DOSE LARGER THAN 100 mrem AND PROBABILITY GREATER THAN 10^{-9}/YR

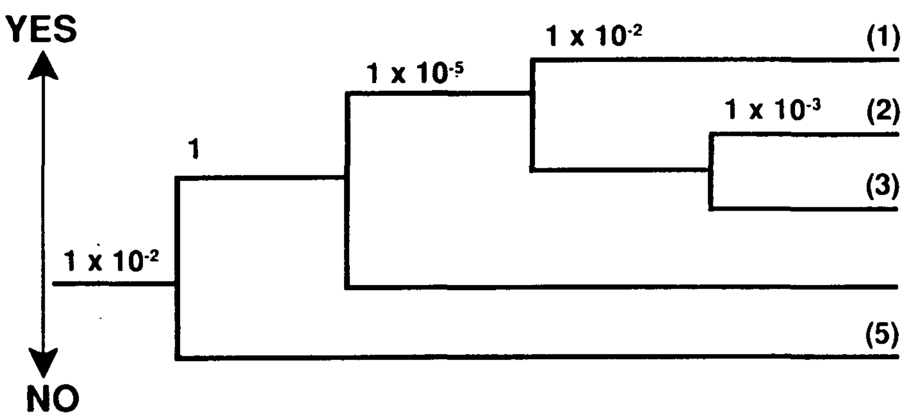
AREA	INITIATING EVENT FOR SCENARIO	PROBABILITY (1/yr)	DOSE (mrem)
UNDERGROUND FACILITIES			
WASTE RAMP	• TRANSPORTER COLLISION WITH FIRE	5×10^{-9}	220
PERFORMANCE CONFIRMATION AREA	• CONTAINER FALLS	5×10^{-4}	110
WASTE MAIN	• TRANSPORTER COLLISION WITH FIRE	5×10^{-9}	220
PANEL ACCESS DRIFT	• TRANSPORTER COLLISION WITH FIRE	5×10^{-9}	220
EMPLACEMENT DRIFT	• TRANSPORTER COLLISION WITH FIRE	5×10^{-9}	220
	• CONTAINER FALLS	5×10^{-4}	110

REFERENCES:
1. PROCEEDINGS OF HLW CONFERENCE, LAS VEGAS, (p. 370), 1990
2. SAND 88-7061

EXAMPLE FROM UNCERTAINTY ANALYSES: CRANE DROP IN PACKAGING HOT CELL



UNCERTAINTY RESULTS FOR CRANE DROPPING A CONTAINER OF CONSOLIDATED FUEL IN THE PACKAGING HOT CELL



	PROB. (PER YR)	PARTICULATE DOSE (mrem) 1985 PRSA	CONFIDENCE INTERVAL 10%	50%	90%
(1)	1×10^{-9}	1×10^{3}	1.9×10	3.2×10^{2}	2.8×10^{3}
(2)	1×10^{-10}	1×10^{3}	1.9×10	3.2×10^{2}	2.8×10^{3}
(3)	1×10^{-7}	2.0	2.8×10^{-3}	1.2×10^{-1}	2.0
	1×10^{-2}	2.0	2.8×10^{-3}	1.2×10^{-1}	2.0
(5)	0.0	0.0	0.0	0.0	0.0

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CONCLUSIONS

- OFFSITE DOSES FROM PRECLOSURE ACCIDENTS AT YUCCA MOUNTAIN ARE NOT LIKELY TO EXCEED THE 500 mrem VALUE USED TO DEFINE IMPORTANT TO SAFETY IN 10 CFR 60.2
- PRA TECHNIQUES CAN BE USED IN A CONCEPTUAL DESIGN PROCESS TO HELP SELECT DESIGN ALTERNATIVES AND IMPROVE SAFETY MARGINS
- CONDUCTING PRAs AT CONCEPTUAL DESIGN STAGE MINIMIZES COST AND SCHEDULE IMPACTS

CONCLUSIONS

(CONTINUED)

- TECHNIQUES FOR APPLYING PERFORMANCE ASSESSMENTS IN SUBSEQUENT, MORE DETAILED DESIGN STAGES REQUIRE DEVELOPMENT

- RESULTS FROM PERFORMANCE ASSESSMENTS ARE USED TO ESTABLISH:
  - DESIGN ALTERNATIVES/MODIFICATIONS
  - DESIGN BASES ACCIDENTS
  - Q-LIST
  - R&D PRIORITIZATIONS/NEEDS
  - NECESSARY SITE CHARACTERIZATION NEEDS
  - REGULATORY COMPLIANCE/STRATEGIES