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Evaluation of Severe Accident Risks: Quantification of Major Input Parameters

MACCS Input

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ABSTRACT

Estimation of offsite accident consequences is the customary final step in a probabilistic assessment of the risks of severe nuclear reactor accidents. Recently, the Nuclear Regulatory Commission reassessed the risks of severe accidents at five U.S. power reactors (NUREG-1150). Offsite accident consequences for NUREG-1150 source terms were estimated using the MELCOR Accident Consequence Code System (MACCS). Before these calculations were performed, most MACCS input parameters were reviewed, and for each parameter reviewed, a best-estimate value was recommended. This report presents the results of these reviews. Specifically, recommended values and the basis for their selection are presented for MACCS atmospheric and biospheric transport, emergency response, food pathway, and economic input parameters. Dose conversion factors and health effect parameters are not reviewed in this report.

5. ECONOMIC PARAMETERS

5.1 Nonfarm Parameters: Recommended Values

Table 5.1 lists the values of nonfarm economic parameters recommended for use in MACCS.

Table 5.1. Economic Parameter Values for MACCS

Variable	(Units)	Site	Value	Range*	Definition
DPRATE	(per yr)	All	0.2	0.1 - 0.3	Property depreciation rate
DSRATE	(per yr)	All	0.12	0.7 - 0.17	Investment rate of return
EVACST	($/day)	All	$27	$25 - $30	Per diem living expenses for evacuees
FRNFIM		All	0.8	0.7 - 0.9	Nonfarm
POPCST	($)	All	$5000	$3500 - $7500	Relocation costs for owners of interdicted property
RELCST	($/day)	All	$27	$25 - $30	Per diem living expenses for relocated population
VALWNR	($)	Grand Gulf	$53K	$43K - $63K	Per capita value of nonfarm wealth
		Peach Bottom	$79K	$69K - $89K	
		Surry	$84K	$74K - $94K	
		Sequoyah	$66K	$56K - $76K	
		Zion	$76K	$66K - $86K	
		US	$80K	$60K - $100K	

* All sampling distributions should be uniform over the stated ranges.

5.2 Nonfarm Parameters: Discussion

Most of the data presented in the following discussion were taken from Statistical Abstract of the United States for 1988. A few figures were taken from Fortune (April 25, 1988) and Forbes (January 11, 1989; June 27, 1988) magazines.

The economic model in the MACCS code treats following costs:

(1) Daily food and lodging costs per person for short-term relocation of people who evacuate or relocate during the emergency phase of the accident (e.g., the first seven days after the accident),

(2) Decontamination costs for property that can be returned to use,

(3) Economic losses incurred while property is temporarily interdicted so that a period of decay following maximum decontamination can reduce yearly doses to acceptable levels (e.g., 5.5 rem in eight years), and

(4) Economic losses from the permanent interdiction of property.

The model divides economic costs into two groups, farm costs and nonfarm costs. Farm costs are always calculated per hectare of farmland (worth of farmland and improvements per hectare, crop worth per hectare). Nonfarm costs are always calculated per person (temporary and permanent relocation costs per person, tangible worth of nonfarm property per person, decontamination costs of nonfarm property per person), where nonfarm property includes residential, commercial, and public land, improvements, equipment, and possessions.

5.2.1 Relocation Costs

Burke [1] estimated per diem relocation costs (housing, food, transportation) per person to be $23.70 in 1982 dollars. Correction to 1986 (1986 CPI = 328; 1982 CPI = 289; ratio = 1.13) gives $26.90 per day per person. Fifty dollars per night for a four-person motel room, and $3.50, $4.50, and $7.00 per person for breakfast, lunch, and dinner plus $1.50 per day for public transportation, gives $29.00 per day per person. Burke estimated that mass care per diem costs would be about half the cost of commercial care (hotels and restaurants) and that about one fifth of all relocated persons would be accommodated in mass care facilities. If per diem costs are $29 per person for 80 per cent of the relocated population and $14.50 per person for the remaining 20 per cent, an average per diem relocation cost of $26 per person results, which agrees well with Burke's result after correction to 1986 dollars. Therefore, a per diem relocation cost of $27 per person is recommended for use in the final NUREG-1150 calculations.

5.2.2 Decontamination Costs

The MACCS decontamination model assumes that for both farm and nonfarm property several (no more than three) decontamination methods will be available. For each decontamination method, the model requires a cost (per hectare for farm property and per person for nonfarm property) and a decontamination factor, F_D, where

$$F_D = C_i/C_f$$

and C_i and C_f are the surface contamination levels before and after the decontamination step. Although the costs of the decontamination methods for farm and nonfarm property need not be the same, the set of decontamination factors used for farm property must be the same as the set used for nonfarm property.

5.2.3 Temporary Interdiction Losses

When property is temporarily interdicted, three costs are incurred for nonfarm property and two for farm property. For nonfarm property, the three costs are lost wages per person moved, lost return on investment on the interdicted property, and the cost of the repairs required to return the property to use once the interdiction period ends. For farm property, the second and third costs apply but the first does not (because only the nonfarm economic model treats people).

Burke [1] examined the relocation costs that would be incurred by a person forced to relocate because his home had been interdicted. Since most of his possessions have been contaminated, Burke concluded that moving costs would be small when compared to lost wages, which he estimated to total about $4000 based on the assumption that each worker relocated would be out of work for 100 to 180 days. Since per capita income in 1986 was $14,600, if 140 days of lost wages are assumed (the average duration of unemployment from 1972 through 1986 was 15 weeks or 105 days, Reactor Safety Study [2] assumed that interdicted businesses would require about six months to reopen in a new location) and lost wages per person relocated would be $5600. Correction of Burke's estimate of $4000 based on 1982 data to 1986 yields $4500. Accordingly, a moving cost of $5000 is recommended for use in the final NUREG-1150 calculations.

Assume that all property (land, buildings, equipment, etc.) can be viewed as an investment that yields a rate of return, r, and depreciates at a rate, p, if left untended for some length of time, t. If, for example, the property is interdicted for t years, then two costs are incurred: (1) lost return on investment and (2) repair costs.

Consider a property composed of land (present value L) and improvements (present value I). The total present value of the property is $L + I = V$, and the fraction of the total present value that is improvements is $I/V = f$. If this property is now interdicted for t years, the lost return on investment is $V_t - V$, where $V_t = V e^{rt}$ and the repair costs that will be incurred at the end of the interdiction period are $I - I_t$, where $I_t = I e^{-pt}$. Therefore,

$$\text{Loss on Investment} = V_t - V = V e^{rt} - V = V (e^{rt} - 1)$$

$$\text{Repair Costs} = I - I_t = I - I e^{-pt} = I (1 - e^{-pt})$$

Let the present values of the lost return on investment and the repair costs be V' and I'. Then

$$V' e^{rt} = V_t - V = V (e^{rt} - 1)$$

$$V' = V (1 - e^{-rt})$$

$$I' e^{rt} = I - I_t = I (1 - e^{-pt})$$

$$I' = I e^{-rt} (1 - e^{-pt})$$

and C', the present value of the total losses incurred during the interdiction period (t), is

$$C' = V' + I' = V (1 - e^{-rt}) + I e^{-rt} (1 - e^{-pt})$$

$$= V - e^{rt} [V (1 - f + f e^{-pt})]$$

which agrees with Burke et al. [1] and with the Reactor Safety Study [2].

To apply the preceding model, values for V, f, r, and p are needed. Since MACCS calculates farm costs on a per hectare basis and nonfarm costs on a per person basis, the values of V needed are the value of farm property per hectare (per acre) and of nonfarm property per person. State and national data for farm property are available from Statistical Abstract of the United States [3] and are discussed in other data packages. A value for the per person worth of nonfarm residential, commercial, and public property can be estimated from the following data, which were taken from Ref. [3]:

Reproducible Tangible Wealth	= $\$1.98 \times 10^{13}$
Urban and Built-Up Land	= 4.64×10^{4} acres
Total Farm Assets	= $\$7.89 \times 10^{11}$
Farm Land	= $\$5.54 \times 10^{11}$
Farm Household Possessions	= $\$3.05 \times 10^{10}$
1987 U.S. Population	= 2.44×10^{8}

Now assuming that nonfarm land costs about $90,000 per acre (typical suburban residential lots are 0.2 acre, land usually constitutes about one fifth of the cost of a house, and the 1986 median value of houses was $92,000), the per person worth of nonfarm residential, commercial, and public property, that is V, is given by

V = [reproducible tangible wealth
+ value of suburban land
- value of farm assets
+ value of farm household possessions]/[U.S. population]

$$= [\$1.98 \times 10^{13} + (4.64 \times 10^{4} \text{ acres})(\$9 \times 10^{4} \text{ acre}^{-1}) - \$7.89 \times 10^{11} + \$3.05 \times 10^{10}]/[2.44 \times 10^{8} \text{ people}]$$

$$= \$7.8 \times 10^{4}$$

Therefore, V is about $80,000 per person.

The value of V is likely to vary significantly by state. This variation can be approximated by multiplying the $80,000 value by the ratio of a state's per capita income to the national per capita income. The pertinent data are given in Table 5.2.

Table 5.2. Value to Region

Reactor	Region	($1000) Per Capita Income	V ($1000)
	US	$14.6	$80
Seq	TN	12.0	66
	AL	11.3	62
Zion	WI	13.9	76
	Chicago	13.2	72
	IL	15.6	85
GG	MI	9.7	53
	LA	11.2	61
PB	PA	14.2	79
	MD	16.9	93
Sur	VA	15.4	84

Since investment property is usually purchased by borrowing money (mortgages, equipment loans), r, the total rate of return on any property must be calculated as the dollar weighted sum of the property owner's rate of return on equity (r_E) and the debt holder's rate of return on debt (r_D). Specifically,

$$r = fr_E + (1-f)r_D,$$

where f = E/V, E is the owner's equity in the property, V is the total value of the property, and V - E = D is the debt on the property (for all manufacturing companies, D/E = 1.8 and thus f = 0.36; for the Fortune 500 companies, D/E = 1.2 and f = 0.45).

Several measures of the rate of return on debt or equity are given in Table 5.3:

Table 5.3. Rates of Return

Measure	Percent
Conventional Mortagage Rate (1970 - 1986)	11.9
Return on Equity	
Forbes Stock Fund Composite (1977 - 1987)	16.4
Standard and Poors 500 (1977 - 1987)	16.9
Fortune 500 (1977 - 1987)	17.2
Fortune 500 (1983 - 1987)	12.8
Fortune 500 (1986)	11.6
Fortune 500 (1987)	13.2
All Manufacturing (1985)	11.6
All Manufacturing (1986)	11.6

These data suggest that 12% is a representative rate of return on both mortagages and equity. Therefore, r equals 12%, which is the value of r used in Reactor Safety Study [2], where r was viewed as the carrying cost (expressed as a percent of value) for interdicted residential property (mortgage rate of 9% plus real estate tax rate of 3%).

Finally, no data on depreciation rates (p) for untended property are available. Reactor Safety Study assumed a value of 20% per year for p after noting that depreciation rates for property that is maintained are typically 3% to 5% per year.

5.3 Farm Parameters: Recommended Values

Table 5.4 gives the recommended values for VALUE and FRFIM.

Table 5.4. Recommended Values for VALWF and FRFIM

Site	VALWF ($/ha)	FRFIM ($/ha)
Grand Gulf (Mississippi)	1824	0.30
Peach Bottom (Pennsylvania)	4469	0.25
Sequoyah (Tennessee)	2708	0.27
Surry (Virginia)	2952	0.25
Zion (Wisconsin)	1754	0.49

VALWF - Value of farm wealth in region (includes all improvements belonging to both public and private sector)

FRFIM - Fraction of farm wealth in region from improvements (includes buildings, equipment, infrastructure (such as roads, utilities, etc.)

5.3.1 Discussion

The total value of farm machinery and implements in 1988 is 84.5 billion dollars according to the U.S. Department of Commerce [4:Table 1086]. Since there are 1002 million acres of farmland in the U.S. [4:Table 1057], the value of machinery and implements per acre is $84.3 or $208.2 per/hectare.

The value of farm land and buildings in 1988 [4:Table 1066] in the states being considered can be summarized as in Table 5.5.

Table 5.5. Value of Farm Land and Buildings (1988)

State	Value of Land & Buildings ($/ha)
Mississippi	654
Pennsylvania	1725
Tennessee	1012
Virginia	1111
Wisconsin	626

The data in Table 5.5 were used to determine the value of the variable VALWF for each of the states considered in Table 5.6.

Table 5.6. Values for VALWF by State

State	Value of Land & Buildings ($/ha)	VALWF($/ha)
Mississippi (Grand Gulf)	1615	1824
Pennsylvania (Peach Bottom)	4261	4469
Tennessee (Sequoyah)	2500	2708
Virginia (Surry)	2744	2952
Wisconsin (Zion)	1546	1754

Based on information from the USDA for 1984 [4:Table 543], Table 5.7 shows the value that was determined for the percentage of the total value of the farm that is accounted for by the buildings for each state being considered.

Table 5.7. Value of Buildings

State	Value of Land and Buildings*	Value of Buildings	Total Value Represented by Buildings (%)
Mississippi	13814	1975	14.3
Pennsylvania	12015	3196	26.6
Tennessee	12743	2829	22.0
Virginia	10192	2140	21.0
Wisconsin	17436	4830	27.7

* in millions of dollars

This percentage was then used with the values derived for VALWF to determine the current value of buildings/acre, as well as the total value of buildings and equipment/hectare as in Table 5.8.

Table 5.8. Value of Buildings per Acre

State	Value of Buildings ($/ac)	Value of Buildings ($/ha)	Value of Buildings & Equipment ($/ha)
Mississippi	138	341	549
Pennsylvania	367	906	1114
Tennessee	211	521	729
Virginia	218	538	746
Wisconsin	265	655	863

The values of FRFIM in Table 5.9 were derived as the fraction of VALWF that is represented by improvements (buildings and equipment).

Table 5.9. Values of FRFIM

State	FRFIM
Mississippi (Grand Gulf)	0.30
Pennsylvania (Peach Bottom)	0.25
Tennessee (Sequoyah)	0.27
Virginia (Surry)	0.25
Wisconsin (Zion)	0.49

REFERENCES

[1] R. P. Burke et al., Economic Risks of Nuclear Power Reactor Accidents, NUREG/CR-3673, Sandia National Laboratories, Albuquerque, NM 1984.

[2] U.S. Nuclear Regulatory Commission, Reactor Safety Study, Appendix VI, "Calculation of Reactor Accident Consequences," WASH-1400, Washington, DC, 1975.

[3] Statistical Abstract of the United States, 1988, U.S. Department of Commerce.

[4] Agricultural Statistics 1984, United States Department of Agriculture, Washington, DC, 1984.