column of Table E.3.6. The figures show that there is considerable variability in surface makeup of residential property, with estimates of lawn area ranging from a low of 25 percent to a high of 92.4 percent.

Another source of information was provided by the City of Bellevue, Washington, Storm and Surface Water Utility Department, in the form of a large aerial photograph of a residential area with a corresponding map of properties and structures. A random sample of surfaces was taken from the photograph. The quality of the photograph was such that **it** was impossible to distinguish asphalt from concrete. Therefore, driveways and other paved surfaces were assumed to be concrete. In general, the neigborhood in the photograph appeared to be a fairly new subdivision with larger than average lots and homes. The proportion of lot coverage by the house is probably less than average for urban residential areas.

After excluding observations that happened to land on nonresidential areas such as roads, the results are in Table E.3.7.

TABLE E.3.7. Percentage of Residential Land in Roofs, Lawns and Concrete

| Surface | Percent |
|---|---|
| Roof | 22.3 |
| Other concrete | 9.6 |
| Lawn | 68.1 |

The factor estimates are summarized in Table E.3.8; they are based on all the foregoing information and on the assumption that 80 percent of nonroad pavement is concrete. The factors total more than unity becase of assumed roof overhangs.

The remaining factors are based on the dimensions of a hypothetical representative house. The two basic measures needed are the average floor

TABLE E.3.8. Summary of Factors for Horizontal, Exterior Residential Surfaces

| Factor | Definition | Value |
|---|---|---|
| a | Ratio of roof area to residential land area | 0.26 |
| d | Ratio of other asphalt area to residential land area | 0.01 |
| e | Ratio of other concrete area to residential land area | 0.04 |
| f | Raio of lawn area to residential land area | 0.70 |

space and the average number of floors per home. The number of floors is particularly important for determing the height and, therefore, the area of the

exterior walls. The 1980-82 Statistical Abstract reports that the average number of square feet per household is 1745. According to the Census Bureau and the U.S. Department of Housing and Urban Development, the median-sized home built in 1982 has 1520 square feet of floor space. This was less than in 1980, when the median size was 1550 square feet. While this work is concerned primarily with detached single-family homes, it can be noted that the median-sized apartment built in 1982 contained 925 square feet, compared with 930 square feet in 1981. In general, the typical home seems to be about 1500 to 1700 square feet. Here, a size of 1600 square feet is used.

The National Association of Home Builders provided the information that of the homes completed in 1982, 61 percent were single story, 33 percent were two or more stories, and 6 percent were split level. Assuming that these 1982 figures are not greatly different from those for the housing stock, a weighted average number of floors per house is calculated as follows: Split-level homes are considered to be one story, and homes designated as two or more stories are assumed to be 2.2 stories on average. The relationships for computing the weighted average number of floors are presented in Table E.3.9.

TABLE E.3.9. Computation of Number of Floors per Average Single-Family Residence

| | Percentage Weight | x | Number of Floors | – | Product |
|---|---|---|---|---|---|
| | 61 | | 1 | | 61 |
| | 33 | | 2.2 | | 72.6 |
| | b | | 1 | | 6 |
| Total | 100 | | | | 139.6 |

Average number of floors = 139.6/100 = 1.4

Given a total floor area of 1600 square feet over 1.4 floors, the roof area is:

Roof area = 1600/1.4 = 1143 square feet

This figure is adjusted up to 1200 square feet to account for overhanging eaves. The factor $k$, the ratio of nonbasement floor area to roof area, then becomes

$k = 1600/1200 = 1.33$

The roof with eaves covers 1200 square feet, but without the eaves the area is approximately 1140 square feet. This is consistent with exterior building dimensions of 38 by 30 feet. The total building perimeter is, then, 136 feet. Assuming 10 feet per story, the average exterior wall height is 10 x 1.4 = 14 feet. The total exterior wall area is, therefore, 14 x 136 = 1904 square feet. Factor $h$, the ratio of exterior wall area to roof area, becomes

$h = 1904/1200 = 1.58$

To estimate v, the ratio of interior wall area to roof area, we note first that according to the Census Bureau the average number of rooms per home is 5.1. With a total floor area of 1600 square feet, the area per room is 313.7. The minimum wall length for such a room is about 17.7 feet. If each room has four walls 8 feet high, then total wall area is 2890 square feet. This estimate will be low to the extent that rooms depart from square dimensions and to the extent that closets and hallways are additional to the 5.1 rooms. On the other hand, the estimate could be too high if doorways are large and if there are half walls. Factor v is

$$v = 2890/1200 = 2.40$$

Next we consider basements, focusing first on factor 1, the fraction of homes that have basements. The National Association of Home Builders, in the September 1983 Housing Backgrounder, lists the percentage of new single-family homes built with basements by year. This information is presented in Table E.3.10.

TABLE E.3.10. Percentage of Houses with Basements, by Year

| | 1972 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|
| Houses with full or partial basements | 37% | 44% | 42% | 42% | 36% | 33% | 31% |

The source of the figures in Table E.3.10 is apparently either the Census Bureau or the U.S. Department of Housing and Urban Development. Reference to the 1970 Census of Housing, Vol. 1, Part 1, Table 22, gives additional information about numbers of housing units with basements by region. This is presented in Table E.3.11. These regional figures might serve as a guide for any adjustments to factor 1. Based on the preceding information, 0.48 seems to be an acceptable estimate for 1.

Factor m represents the size of the basement in relation to roof area. Here we have—no firm data and are forced to estimate average basement floor area at 0.70 times the roof area. If the basement has a single room with 8-foot walls, then factor w, the ratio of basement wall area to roof area, is about 0.96.

This completes the estimates of the structure surface areas, but now these must be further disaggregated by type of material. For this task there appears to be little or no government-collected data. What data do exist are generally

TABLE E.3.11. Number of Houses with Basements, by Region

| | Region | | | | |
|---|---|---|---|---|---|
| | U.S. | North East | North Central | South | West |
| Basement | 36,112,009 | 14,398,977 | 14,141,653 | 4,407,897 | 3,163,482 |
| Concrete slab | 14,358,800 | 1,040,632 | 1,971,873 | 6,668,107 | 4,678,188 |
| Other | 17,228,275 | 758,253 | 2,561,706 | 9,807,562 | 4,100,754 |

Source: 1970 Census of Housing, Vol. 1, Part 1, Table 22

commercial marketinq data. There are usually two drawbacks to this information. First, since-it is proprietary, many sources are very reluctant to release it. Second, companies are most often concerned with current sales figures rather than accumulated existing stock. For example, businesses dealing with floor covering materials are less interested in the percentage of total floor area that is carpeted than in the percentage of current sales of floor covering materials accounted for by carpeting.

Roofs of single-family homes are assumed to be of asphalt shingles. This is based on casual observation and on a listing of building materials for a typical 1700 square foot home in the National Association of Home Builders' September 1983 Housing Backgrounder.

In this report we assume that exterior walls of single-family residences are either brick or painted wood. There is apparently no direct quantitative information on the relative usage of brick versus wood siding. The Brick Institute of America did report that 8 to 9 billion bricks per year are sold and, of those, 65 percent are used in single- and multi-family home construction. It is not clear, however, how much of this goes to exterior wall construction. Of the total brick sales, only about 600 million bricks--less than one-tenth of the total--are used west of the Rocky Mountains. This is due in large part to brick's incompatibility with the earthquake hazard. We estimate that 15 percent of exterior walls are brick; the remainder are assumed to be painted wood.

Nonbasement floors are assumed to consist of either wood, linoleum (all resilient floor coverings), or carpet. The floor covering industry seems to be particularly protective of marketing information. However, the Retail Floorcovering Institute did provide its 1983 Management Report. The sales profile data list percentage of sales by type of customer (e.g., residential, contractor, industrial/commercial). Also listed was percentage of sales by product type. Soft surface (carpet) comprised 74.9 percent of sales. Sheet vinyl and resilient tile together accounted for 13.1 percent of sales. Hardwood flooring made up 1.2 percent of sales. Also listed in this publication was the average price per square yard of soft surface products (carpets) sold on a retail basis ($15.66) and the average price per square yard for hard surface products sold

on a retail basis ($20.00). To obtain an idea of the relative areas for different kinds of surfaces, we compare the ratio of percentage of sales to the average cost per yard for both hard and soft surfaces. Total carpet area sold was roughly six times the total hard surface area sold. Hard surfaces include wood, ceramic tile, and resilient floor coverings. Total sales in this group are dominated by sheet vinyl. This material accounts for about two-thirds of sales. Hardwood flooring, considering that its price is much greater than sheet vinyl, accounts for less than one-tenth of the area of vinyl.

Additional information comes from a representative of the Wood and Synthetic Flooring Institute. He estimated that in existing homes wood floors were the second most common following carpeted floors. Vinyl surfaces were third. However, he had no quantitative data to indicate the relative shares of these materials. He also provided information about regional differences. In the South, especially in Florida, homes are often constructed on a concrete slab. These homes have no basements and very seldom have wood floors. In other areas, wood joist construction techniques are used. These homes more often have wood floors and basements. This suggests that the regional basement data provided above might be useful for adjusting the floor covering factors.

The fraction of floor surfaces that is linoleum (n) is estimated to be 0.20. The wood factor (o) is estimated at 0.25, and 0.55 is the estimate for the carpet factor ($k_r$).

All nonbasement interior walls are assumed to be painted wood or plaster, so no special factors applied to interior wall area are necessary. Similarly, basement floors and walls are assumed to be concrete.

As a final note, it should be mentioned that a potential source for data specific to a particular locale may be the local property tax assessment records. These records typically include such information as lot size, structure size, number of floors, number of rooms, construction material, driveway dimensions, and so forth. Unfortunately, this type of information is not normally available in machine-readable format, which would allow one to readily characterize a representative structure.

Commercial Areas. This section describes how the various factors for commercial areas were estimated. As with the factors for residential areas, the first to be estimated are those relating to horizontal, exterior surfaces. Then, factors specifying the dimensions of the representative commercial structure are developed. Finally, the factors dealing with the proportion of specific materials used for floor covering material are developed.

The lack of data for commercial land use areas is even more acute than for residential areas. This is compounded by an even greater variability in land use practices on commercial property compared with those on residential property. A simple example of this variability is illustrated by the fact that areas designated commercial include high-density downtown business areas, small arterial and neighborhood commercial areas, and large suburban shopping centers.

Exterior horizontal surfaces in commercial land use areas include roofs, asphalt parking areas and concrete parking areas. The various runoff reports described in Section E.3.2.2.2 do not help to identify these surfaces, since they are all categorized as "impervious".

The City of Bellevue, Washington supplied an aerial photograph and an accompanying map of a commercial area. However, this area is distinctly a low-density shopping center type and was not felt to be representative of commercial areas in general. The photograph did, however, give a guide as to the lower range for a, the ratio of roof area to commercial land area. Rough estimates place roof—area at no higher than 50 percent of surface area. The low seems to be about 20 percent of land area. Average roof cover, then, would be expected to lie somewhere between 50 percent for low building density suburban shopping center areas and 90 percent or more for high building density downtown business areas. We take 70 percent to be representative.

Commercial areas include parking areas. While multi-level parking garages are generally constructed in concrete, street level parking surfaces are predominantly asphalt. Because street level parking lots comprise a larger share of parking surfaces, we estimate $b_c$, the ratio of asphalt road area to commercial land area, to be 0.20. Factor c, representing the ratio of concrete parking area to commercial land area—is estimated at 0.13. The horizontal, exterior commercial surfaces add to more than unity to account for multi-level concrete parking garages.

Next to be considered are the dimensions of the representative commercial structure. Fortunately, some useful data relevant to this question are available. Of particular interest is Nonresidential Buildings Energy Consumption Survey: Building Characteristics by the U.S. Department of Energy. Table 3A in that publication provides information on numbers of commercial buildings by square footage and function. That information is reproduced here in Table E.3.12. These figures can be used to derive an estimate of the average square footage of commercial buildings. This is done by computing the weighted average floor area of all commercial buildings. To do this, the midpoint of the given size intervals was used except for the two end intervals. For these, values of 750 and 110,000 square feet were used. The ,calculations yielded an average commercial building size of 10,820 square feet. In addition to the overall average commercial building size, average building size for each separate function was also calculated (see Table E.3.13). These figures were used in developing the factor estimates relating to materials used for floor cover.

To obtain the gross exterior dimensions it was next necessary to estimate the number of floors in the representative commercial structure. Table 4A in the DOE publication cited above supplied information useful for this purpose. Figures from that table are presented here in Table E.3.14. The number of floors in the representative commercial building was computed as a weighted average of all types of commercial buildings. This was a straightforward use of the top row of Table E.3.14, except that for the last group, the number of floors was assumed to be 5.5. The result was 1.8 floors per building. Thus, k, the ratio of floor area to roof area, is 1.80.

TABLE E.3.12. Number of Commercial Buildings by Total Square Footage and Function
(Numbers in Thousands)

| Function | Total | Total Square Footage: 1,000 or less | 1,001-5,000 | 5,001-10,000 | 10,000-25,000 | 25,001-50,000 | 50,001-100,000 | Over 100,000 |
|---|---|---|---|---|---|---|---|---|
| Total | 3995 | 655 | 1672 | 745 | 551 | 207 | 101 | 65 |
| Assembly | 448 | 44 | 156 | 131 | 79 | 25 | 8 | 5 |
| Auto sales and service | 401 | 92 | 197 | 78 | 28 | 5 | 1 | 1 |
| Education | 161 | 10 | 33 | 21 | 31 | 30 | 24 | 13 |
| Food sales | 366 | 70 | 207 | 51 | 31 | 5 | 2 | 1 |
| Health care | 44 | 4 | 15 | 9 | 6 | 2 | 4 | 4 |
| Lodging | 101 | 10 | 33 | 22 | 16 | 13 | 4 | 3 |
| Office | 600 | 89 | 259 | 115 | 86 | 27 | 13 | 12 |
| Residential | 347 | 41 | 177 | 45 | 64 | 11 | 6 | 2 |
| Retail/services | 714 | 123 | 292 | 152 | 95 | 31 | 14 | 7 |
| Warehouse and storage | 430 | 79 | 169 | 59 | 64 | 33 | 17 | 10 |
| Other | 237 | 58 | 76 | 38 | 39 | 16 | 5 | 5 |
| Vacant | 147 | 37 | 59 | 24 | 12 | 9 | 2 | 2 |

Note: Data may not sum to totals due to rounding.
Source: U.S. Department of Energy, Nonresidential Buildings Energy Consumption Survey: Building Characteristics March 1981, Table 3A, p. 13.

TABLE E.3.13. Mean Square Footage of Commercial Buildings by Function

| Building Function | Mean Square Footage |
|---|---|
| All Commercial Buildings | 10,820 |
| Assembly | 11,060 |
| Auto sales and service | 5,260 |
| Education | 32,060 |
| Food sales | 5,600 |
| Health care | 23,530 |
| Lodging | 16,520 |
| Office | 10,870 |
| Residential | 8,940 |
| Retail/services | 7,130 |
| Other | 11,660 |
| Vacant | 8,920 |

Dividing the total floor space by the number of floors gave 6000 square feet, which represents average roof area and average square footage per floor.

TABLE E.3.14. Number of Commercial Buildings by Number of Floors and Function (Numbers in Thousands)

| Function | Total | 1 Floor | 2 Floors | 3 Floors | More than 3 Floors |
|---|---|---|---|---|---|
| Total | 3995 | 2322 | 912 | 483 | 279 |
| Assembly | 448 | 195 | 169 | 68 | 16 |
| Auto sales and service | 401 | 326 | 68 | 8 | 0 |
| Education | 161 | 86 | 41 | 22 | 13 |
| Food sales | 366 | 256 | 74 | 28 | 9 |
| Health care | 44 | 16 | 16 | 6 | 6 |
| Lodging | 101 | 44 | 28 | 13 | 16 |
| Office | 600 | 300 | 151 | 88 | 62 |
| Residential | 347 | 55 | 84 | 120 | 87 |
| Retail/services | 714 | 476 | 141 | 71 | 27 |
| Warehouse and storage | 430 | 310 | 74 | 30 | 15 |
| Other | 237 | 163 | 35 | 21 | 18 |
| Vacant | 146 | 96 | 33 | 7 | 10 |

Note: Data may not sum to totals due to rounding.
Source: U.S. Department of Energy, Nonresidential Buildings Energy Consumption Survey: Building Characteristics, March 1981, Table 4A, p. 16.

Approximate dimensions for such a building were assumed to be 55 by 110 feet. The exterior wall area was estimated by multiplying wall height per floor (say, 12 feet) by the average number of floors (1.8) by the total building perimeter (330 feet). This yielded 7130 square feet. The ratio of exterior wall area to roof area was

$$h = 7130/6000 = 1.20$$

Estimation of the percentage of commercial buildings with basements did not have the advantage of direct evidence. A rough approach was to determine a weighted average of buildings with basements by estimating the percentage of each commercial building function likely to have basements. In this procedure, 15 percent of both assembly and automotive sales/service were estimated to have basements. Twenty percent of education, 10 percent of food sales, and 90 percent of health-care structures were presumed to have basements. The corresponding figures for other commercial buildings were: lodging, 10 percent; office, 80 percent; residential, 70 percent; retail/services, 50 percent; and warehouse and storage, 10 percent. This procedure was felt to be an improvement over a single direct estimate of the fraction of commercial buildings with basements because it reflects the distribution of building functions. This weighted average calculation process disregarded the "other" and "vacant" categories. The result was that factor $l$ was 0.40.

Given that a building has a basement, we estimate the size of the basement relative to roof area (m) at 0.90. Basements are presumed to be divided into four large rooms. With a height of 10 feet, basement wall area will be about 6600 square feet, making $w$, the ratio of basement wall area to roof area, equal to 1.10.

Interior wall area will vary greatly from structure to structure. For example, buildings used for assembly, sales, and warehousing purposes will tend to have few but relatively large rooms. On the other hand, lodging buildings and most offices will have the floor segmented into more rooms of smaller size. In order to estimate $v$, a hypothetical 55-foot by 110-foot floor plan was divided up into a number of large and small rooms. These rooms included one large one measuring 55 by 55 feet and several others of various smaller sizes. This yielded a total room perimeter of 740 feet per floor. With 1.8 floors per building and an average interior wall height of 10 feet, total interior wall area is 13,320 square feet. Thus, the ratio of interior wall area to roof area is

$$v = 13{,}320/6{,}000 = 2.22$$

Next to be considered are the materials with which the building walls and floors are constructed. Walls are assumed to be all painted wood or plaster. The factors for floor covering material are developed in Table E.3.15. It is possible to estimate reasonable percentages for different floor covering materials for commercial buildings when the building function is specified. These separate estimates are then multiplied by the aggregate square footage for buildings of that function. This yields the area for different floor covering material by building function. The total concrete, linoleum, and

TABLE E.3.15 Estimation of Floor Covering Material actor

| Building Function | Number of Buildings | Mean Square Footage | Estimated Floor Covering Percent | | | Floor Covering Area | | |
|---|---|---|---|---|---|---|---|---|
| | | | Concrete | Linoleum | Carpet | Concrete | Linoleum | Carpet |
| Assembly | 448 | 11,060 | 80 | 20 | -- | 3,963,904 | 15,855,616 | -- |
| Auto sales/serv. | 401 | 5,260 | 65 | 35 | -- | 1,371,019 | 738,241 | -- |
| Education | 161 | 32,060 | 10 | 80 | 10 | 516,166 | 4,129,328 | 516,166 |
| Food sales | 366 | 5,600 | -- | 100 | -- | -- | 2,049,600 | -- |
| Health care | 44 | 23,530 | -- | 90 | 10 | -- | 931,788 | 103,532 |
| Lodging | 101 | 16,520 | -- | 5 | 95 | -- | 83,426 | 1,585,094 |
| Office | 600 | 10,870 | -- | 15 | 85 | -- | 978,300 | 5,543,700 |
| Residential | 347 | 8,940 | -- | 10 | 90 | -- | 310,218 | 2,791,962 |
| Retail/services | 714 | 7,130 | -- | 60 | 40 | -- | 3,054,492 | 2,036,328 |
| Warehouse, storage | 430 | 13,350 | 100 | -- | -- | 5,740,500 | -- | -- |
| Total | 3,612 | (a) | | | | 11,591,589 | 28,131,009 | 12,576,782 |
| Factor | | | | | | 0.22 | 0.54 | 0.24 |

(a) Total square footage is 52,299,380

carpeted floor area is calculated, and these totals are then divided by total floor area to yield the following factor estimates:

q = 0.22
n = 0.54
p = 0.24

Industrial Areas. As in the preceding two sections, the first factors to be estimated are those having to do with horizontal exterior surfaces. Following that, factors that characterize a representative industrial structure are derived. Finally, those factors that allocate surfaces among specific materials, such as floor area to wood, carpet, concrete, or linoleum material, are estimated.

The horizontal, exterior surfaces in industrial areas consist of roof, asphalt and concrete parking areas, and lawn surfaces. As with residential areas, a starting point could be the runoff studies summarized in Table E.3.6. These studies provide information on the percentage of particular drainage areas that are covered with impervious surfaces such as buildings or pavement. The remaicing pervious area corresponds to the only pervious surface, lawn. Unfortunately, only two of the many drainage areas covered by these studies were characterized by a significantly high proportion of land in industrial use. In "Quality of Runoff From Small Watersheds in the Twin Cities Metropolitan Area, Minnesota - Hydrologic Data for 1980," the Sandburg Road site was described as a light industrial park with partly curbed or guttered streets. The area includes a school and a major industry parking lot. In this area, 5.8 percent of the land was designated as agricultural or idle, 9.6 percent as low-density homes, and 84.6 percent as commercial-industrial. The impervious area was listed as 70.0 percent. If this figure is adjusted by subtracting the agricultural portion from the 30 percent pervious area, we get 74.3 percent of the area as being impervious. In other words, 25.7 percent of the area is pervious lawn.

In "Storm Runoff As Related to Urbanization in the Portland, Oregon-Vancouver, Washington Area," the SE 9th-Madison site is listed as being 19 percent downtown and industrial. In this drainage area, 39 percent is denoted impervious. The remainder - 61 percent - therefore is lawn.

Another source of information is a large aerial photograph of an industrial area supplied by the Storm and Surface Water Utility Department of the City of Bellevue, Washington. As was done with the aerial photograph of a Bellevue residential area, the surfaces at randomly selected points were noted in order to establish an estimate of the relative distribution of exterior horizontal surfaces. However, unlike the residential area photograph in which essentially all of the photograph was of the one land use type, the industrial area photograph included a large proportion of undeveloped land. The sampling area was therefore restricted to the north side of Bellevue-Redmond Road. Within the remaining area there remained some undeveloped parcels. These too were excluded from the sample. The tonal quality of the photograph made it impossible to distinguish between concrete, asphalt, and vacant, except by inference from the use of, and objects on, the surface. In general, it was felt that little or no concrete was used in that area. In instances where the

sample point landed on a vehicle or material in storage on the property, such as lumber, that fact was noted and the surface was recorded as either vacant or asphalt pavement. Also, as with the residential photo, public roads were eliminated from the sample because concrete and asphalt roads are a separate land use category. The results of the sampling process appear in Table E.3.16.

The foregoing information on horizontal, exterior surfaces is summarized in Table E.3.17. From this data we estimated the roof factor at 0.27. The

TABLE E.3.16. Sampling Results for Distribution of Industrial Surfaces

| Surface | Percent |
|---|---|
| Asphalt or concrete road | 47.9 |
| Vacant | 26.0 |
| Roof | 24.7 |
| Lawn | 1.4 |

TABLE E.3.17. Summary of Data on Horizontal Exterior Surfaces in Industrial Land Use Areas

| | Surface | | | | |
|---|---|---|---|---|---|
| Source | Roof | Asphalt Road | Concrete Road | Vacant | Lawn |
| Runoff Study #1 | | 74.3% | | | 25.7% |
| Runoff Study #2 | | 39.0% | | | 61.0% |
| Aerial Photo | 24.7% | 47.9% | | 26.0% | 1.4% |
| Map | 29.3% | | 70.7% | | |

data for asphalt and concrete road surfaces were not as clear. The sum of the roof percentage, plus the two pavement percentages in the first three sources, were 74.3, 39.0, and 72.6 percent, respectively, with an average of 62.0 percent. If we weight the 39.0 percent figure less than the other two in the averaging process - because it seems the most likely figure to be an outlier - a figure of 65.0 percent is obtained, which seems reasonable. Subtracting 27.0 percent for roof area leaves 38.0 percent for the total of asphalt and concrete areas designated as parking areas. The breakdown between these materials is unclear, though it is felt that asphalt will be used more for roads and parking lots while concrete will be used more often for other functions. In general, it is felt that in total, the asphalt area will be about twice that of concrete. Thus, the asphalt factor is estimated at 0.25 and the concrete factor at 0.13.

Accompanying the photograph was a map indicating for several parcels property lines, building outline, and property areas. This map provided enough information so that the building size could be determined by measurement. Thus, roof area as a proportion of lot area could be calculated. These calculations yielded roof area as a percentage of land area, ranging from a low of 15.2 percent to a high of 55.0 percent. The average of the properties measured was 29.3 percent.

The foregoing estimates constrain the estimates for the vacant land and lawn factors to sum to 0.35. We estimate lawn area at 2.0 percent of industrial areas and vacant land at 33.0 percent. These factors are summarized in Table E.3.18.

TABLE E.3.18. Distribution of Exterior, Horizontal Industrial Areas

| Factor | Surface | Estimated Value |
|---|---|---|
| a | roof | 0.27 |
| b | asphalt road | 0.25 |
| c | concrete road | 0.13 |
| f | lawn | 0.02 |
| g | vacant | 0.33 |

The next step is to estimate the dimensions of the representative industrial structure. For this purpose the U.S. Department of Energy publication Nonresidential Buildings Energy Consumption Survey: Building Characteristics is very helpful. Table 3A provides the following information on building square footage. These data are reproduced in Table E.3.19. An average building size was calculated using the same weighted average process described for commercial buildings, yielding a result of 22,400 square feet.

TABLE E.3.19. Numbers of Industrial Buildings by Total Square Footage (in Thousands)

| Total | 1000 sq. ft. or less | 1,001-5,000 sq. ft. | 5,001-10,000 sq. ft. | 10,001-25,000 sq. ft. | 25,001-50,000 sq. ft. | 50,001-100,000 sq. ft. | Over 100,000 sq. ft. |
|---|---|---|---|---|---|---|---|
| 243 | 22 | 58 | 55 | 45 | 30 | 20 | 13 |

Table 4A of the DOE publication listed the number of buildings having one, two, three, or more than three floors. Again, a weighted averaging process as for commercial buildings was used to find the average number of floors at 1.6. This is the value taken for factor k. Dividing total floor area by the number of floors gives an average 14,000 square feet per floor. This figure is also used as the estimate for roof area.

We assume building length and width of 165 by 85 feet with height of 20 feet per floor. With 1.6 floors, this makes the exterior building wall area equal to 16,000. The factor relating exterior wall area to roof area is, therefore:

$$h = 16{,}000/14{,}000 = 1.14$$

The factor for interior wall area was estimated by designing a hypothetical floor plan for a 165 by 85 foot industrial building. The interior walls in such a structure served to set off a small portion of the main floor area while leaving most of the interior open and unobstructed. This plan had a total of 910 linear feet of interior wall, compared with an exterior wall length of 500 feet. The factor relating interior wall area to roof area (v) is 2.00. It is assumed that industrial structures do not have basements.

Exterior walls and interior walls along the perimeter of the building are assumed to be of brick or concrete construction. The remaining interior walls are assumed to be painted wood or plaster. Based on the interior wall dimensions described above, x, the fraction of interior wall area that is painted wood or plaster, is U.45, and $o_i$, the factor for concrete walls, is 0.55.

A representative of the Wood and Synthetic Flooring Institute said that there were no data on industrial floor materials. However, he indicated that concrete was the material in greatest usage with a synthetic resilient flooring the second most common. Carpet would be used in some of the office space. We estimate the factor for concrete floor (q) at 0.80, and 0.15 and 0.05 for linoleum (n) and carpet (p), respectively.

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# APPENDIX F

## STRUCTURE AND USE OF DECON

## INTRODUCTION

The computer program DECON is designed to provide a detailed analysis of site restoration requirements and activities for a radiologically contaminated area. The cleanup criteria are supplied by the user. Decontamination requirements are estimated from the cleanup criteria and from ground concentrations of radionuclides generated by CRAC2. Where the cleanup criteria are expressed in terms of dose or dose commitment, doses throughout the accident site are calculated using CRAC2 models and dose conversion factors.

This appendix provides a detailed description of the structure of DECON and contains instructions on its use.

## PROGRAM STRUCTURE

DECON has a modular design and uses labeled common blocks for the majority of transfers. The primary logic structure is shown in Figure F.1. A hierarchy diagram of the main program and subroutines is shown in Figure F.2.

### COMMON BLOCKS

DECON uses several named common blocks, the contents of which are described below.

#### Common Block PARMS

| Symbol and Dimension | Type | Definition/Value/Units |
|---|---|---|
| IJM | Integer | Number of decontamination methods for all surfaces. The value is determined by the number of methods in the reference data base. IJM is currently 347. It has a maximum value of 350, but it can be increased by redimensioning several variables. A value for IJM is read from PARM.DAT (unit 10). |
| IJS | Integer | Number of decontamination operations for all surfaces. The value is determined by the number of operations in the reference data base. IJS is currently 186, with a maximum value of 200 without redimensioning of variables. A value for IJS is read from PARM.DAT (unit 10). |
| I20 | Integer | Number of exposure (dose, dose commitment, or ground concentration) intervals. The value of I20 is user-specified, but it cannot be greater than 20 without redimensioning of variables. DECON determines in which of up to 20 exposure intervals each grid element falls. Using intervals rather than the actual exposure values can greatly reduce the computational time. A value for I20 is read from PARM.DAT (unit 10). |
| LNDUSE | Integer | Number of land use categories. The value of LNDUSE is currently 11, with a maximum value of 25. The land uses currently implemented are given in Table 3.1, page 3.4. A value for LNDUSE is read from PARM.DAT (unit 10). |
| NGE | Integer | Number of grid elements. The value of NGE is user-specified and has no maximum value. It is read from PARM.DAT (unit 10). |

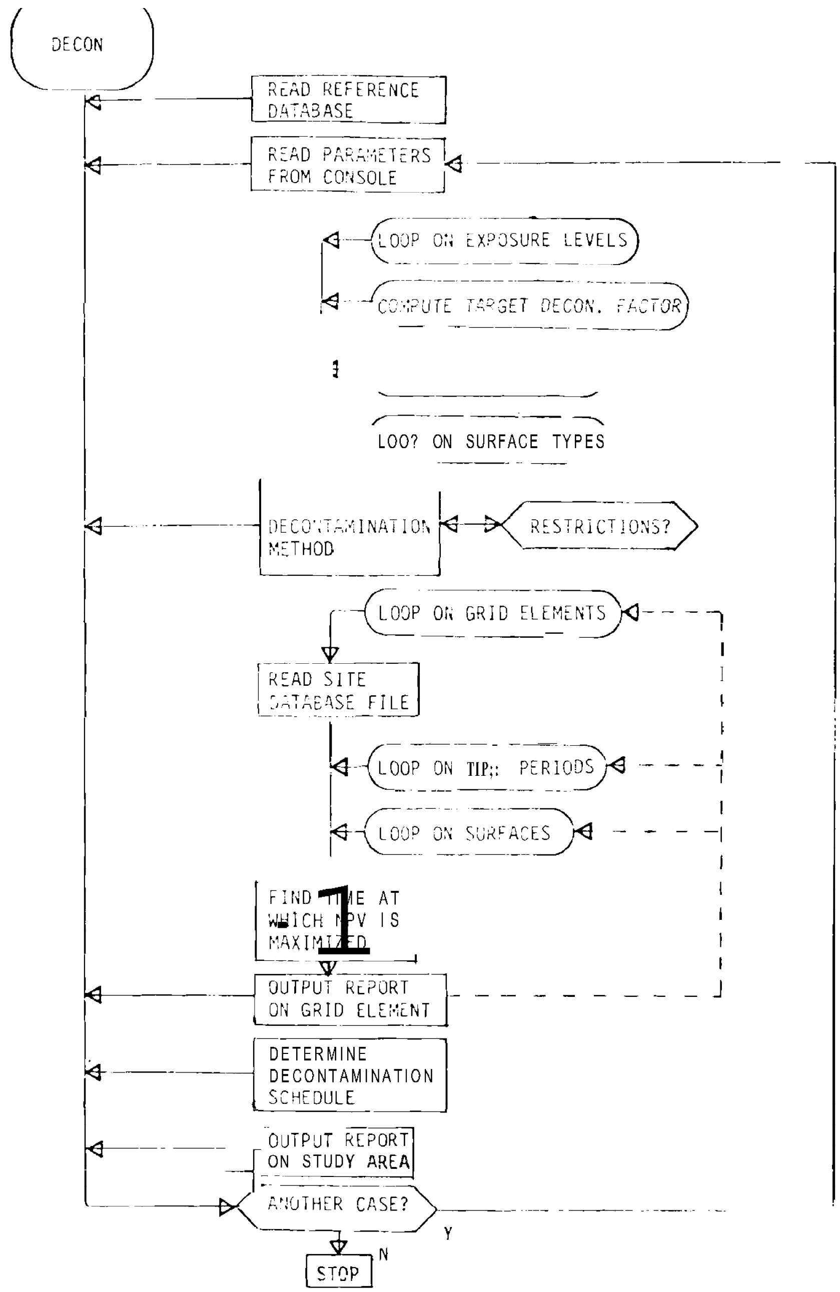


FIGURE F.1. Primary Logic of DECON

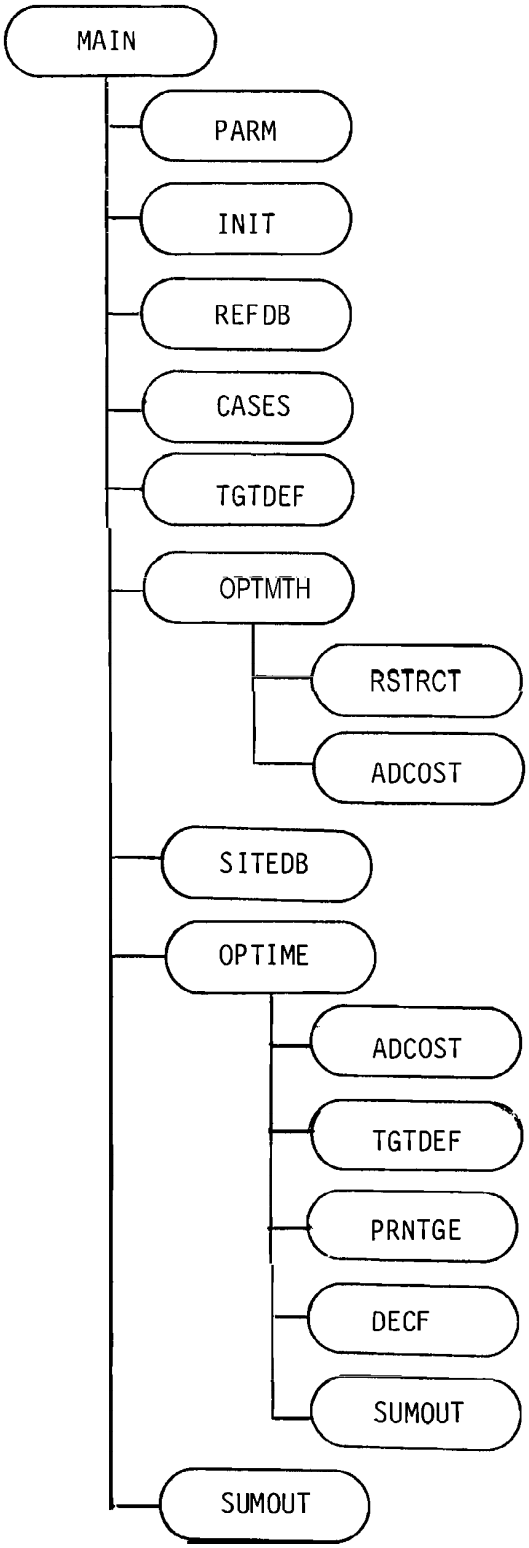


FIGURE F.2. Hierarchy of DECON

| | | |
|---|---|---|
| NPUTS | Integer | Number of factor inputs. The value of NPUTS is currently 90, with a maximum value of 125. It is read from PARM.DAT (unit 10). |
| NSURF | Integer | Number of surfaces. The value of NSURF is determined by the number of surfaces used in the reference data base. NSURF currently has a value of 24; its maximum value is 25. The surfaces currently implemented are given in Table 1.2, page 1.6. (Surfaces 17 and 22 are not currently used.) A value for NSURF is read from PARM.DAT (unit 10). |
| NTP | Integer | Numberoftimeperiods. It can havea valueupto 30 (years) without redimensioning variables. It is user-specified and read from file PARM.DAT (unit 10). |
| P1 | Real | Price adjustment factor for labor. All labor cost estimates are multiplied by this factor. P1 is read from file PARM.DAT (unit 10) and can also be changed by menu selection. |
| P2 | Real | Price adjustment factor for equipment. All equipment cost estimates are multiplied by this factor. P2 is read from file PARM.DAT (unit 10) and can also be changed by menu selection. |
| P3 | Real | Price adjustment factor for materials. All material cost estimates are multiplied by this factor. P3 is read from file PARM.DAT (unit 10) and can also be changed by menu selection. |
| P4 | Real | Price adjustment factor for fuel. All fuel cost estimates are multiplied by this factor. Note, however, that separate fuel costs are not available for all decontamination methods. P4 is read from file PARM.DAT (unit 10) and can also be changed by menu selection. |
| RAINFL | Real | Average daily rainfall in inches. The value of RAINFL is user-specified. It has a default value of 0.1 and can be changed via menu selection. (It is not currently used in any calculations.) |
| RAINPR | Real | Average daily probability of rain. The value of RAINPR is user-specified. It has a default value of 0.32 and can be changed via menu selection. It is used in computing the probability of rainfall prior to the completion of decontamination activities. Rainfall will generally increase the difficulty and cost of decontamination. |

Discount rate. The value of rho is used in computing property losses due to loss of use of property while the property remains contaminated. It has a default value of 0.1 and can be changed via menu selection.

Common Block RFDAT

| Symbol and Dimension | Type | Definition/Value/Units |
|---|---|---|
| CODEM(350) | Integer | Code value for each decontamination method. This variable is used for internal computations. The values for CODEM are read from file CODEX.DAT (unit 5). |
| COST(350) | Real | Cost of each decontamination method, measured in dollars per square meter. The information is contained in the reference data base on file MTHDAT.DAT (unit 8). |
| EFF(700) | Real | Decontamination efficiencies for inhalation pathway (1-350) and external exposure pathway (351-700). This variable is measured in units of percent. The information is contained in the reference data base on file MTHDAT.DAT (unit 8). |
| EXPOS(25) | Real | Exposure factor for each surface. The values for EXPOS are user-specified, with one value for each of the NSURF surfaces (see common block PARM). The default value for the elements of this array is 1.0; other values can be specified via menu selection. Exposure factors are discussed in Section 4.3.5, page 4.11. Their use is illustrated in Section 5.2.6, page 5.16. |
| FICODE(30) | Integer | Code value for factor input. Code values are for internal accounting purposes only. They are read from the reference data base file, MTHDAT.DAT, on unit 8. A maximum of 30 types of factor inputs can be specified for each decontamination method. |
| HAULS(350) | Real | Conversion factor for each decontamination method, relating the cubic meters of radiological waste produced for each square meter of surface area decontaminated. Values for this variable are read from the reference data base file, MTHDAT.DAT, on unit 8. |

| | | |
|---|---|---|
| HDIST | Real | Average hauling distance from decontamination site to disposal site, measured in miles one-way. This variable is user-specified, with a default value of 30.0; it can be changed via menu selection. HDIST is used in computing the cost of hauling radioactive wastes resulting from decontamination. |
| IJM1 | Integer | Variable that equals IJM+1. It is used for internal accounting and denotes that no decontamination is required. |
| IJM2 | Integer | Variable that equals IJM+2. It is used for internal accounting and denotes that adequate decontamination cannot be accomplished with methods available in DECON. |
| ILABOR | Integer | The total number of factor input slots reserved for labor inputs. Used only for internal accounting purposes. |
| INPUTS(30) | Real | Contains the number of each type of factor input required for a specific decontamination method. Values for this variable are read from the reference data base file, MTHDAT.DAT, on unit 8. A maximum of 30 types of factor inputs can be specified for each decontamination method. |
| NMAX | Integer | Maximum number of decontamination methods available for any surface. NMAX is equal to the largest of the NUMSRF. It is used for internal accounting purposes only and is specified in PARM.DAT (unit 10). |
| NUMSRF(50) | Integer | Number of decontamination methods available for each surface. The sum of the NUMSRF must equal the value for IJM. Values for NUMSRF are read from PARM.DAT (unit 10). |
| RATE(350) | Real | Rate of each decontamination method, measured in square meters per hour. The information is contained in the reference data base on file MTHDAT.DAT (unit 8). |
| RCOSTK | Real | Ratio of equipment cost to total cost for current method. The information is contained in the reference data base on file MTHDAT.DAT (unit 8). |
| RCOSTL | Real | Ratio of labor cost to total cost for current method. The information is contained in the reference data base on file MTHDAT.DAT (unit 8). |

| | | |
|---|---|---|
| TREES2 | Real | The present value of orchard trees. This value is lost when decontamination requires removal and disposal of these trees. It is measured in dollars per square meter of orchard decontaminated. The default value is $2.06, and it can be changed via menu selection. |
| TREES4 | Real | The net present value of trees in wooded areas. It equals the present value of the trees if permitted to mature, less the value if harvested in the current period. This net present value is lost when decontamination requires removal and disposal of these trees. It is measured in dollars per square meter of wooded area decontaminated. The default value is currently $4.12, and it can be changed via menu selection. |
| WCUBE | Real | The volume of radiological waste resulting from decontamination operations within any grid element. |
| XWCUBE | Real | The volume of radiological waste resulting from decontamination operations within the study area. |

Common Block RFDATA

| Symbol and Dimension | Type | Definition/Value/Units |
|---|---|---|
| NPTLBL(125) | Alpha | Label for factor input variables. 99 factor input variables are currently defined. The values for NPTLBL are read from file NPTLBL.DAT (unit 7). |
| SRFLBL(25) | Alpha | Label for surface types. There are currently 24 surface types, with types 17 and 22 not being used. The values for SRFLBL are read from file SRFLBL.DAT (unit 6). |
| METH(350) | Alpha | Mnemonic symbol for each decontamination method. The symbols are defined in Table 1.1, page 1.5. The values for METH are contained in the reference data base and are read from file MTHDAT.DAT (unit 8). |

Common Block CONSTS

| Symbol and Dimension | Type | Definition/Value/Units |
|---|---|---|
| RADMIN | Real | The lowest dose, dose commitment or ground concentration that requires surveying and monitoring activities to be conducted. RADMIN has a default of value of 0.1 and can be changed by menu selection. |

| | | |
|---|---|---|
| WEE | Real | An arbitrarily small positive constant. Equals 0.01 and is used only for internal computations. |

Common Block CONSTA

| Symbol and Dimension | Type | Definition/Value/Units |
|---|---|---|
| ANS | Alpha | Variable containing the value 'Y' (yes) or 'N' (no). Used for internal processing only. |
| BLNK | Alpha | Constant containing a blank character. Used for internal processing only. |
| HD | Alpha | Variable containing the value 'Y' (yes) or "N' (no) to indicate whether DECON is loaded onto a hard disk system. |
| | Alpha | Constant containing the value 'N' (no). Used in comparing answers received from terminal when operating in interactive mode. |
| NOMER | Alpha | Variable containing a phrase used in output reports. Value of variable depends on whether DECON is operating in fast mode or normal mode. |
| STAR | Alpha | Constant containing the value '*'. Used as a symbol in output reports. |
| | Alpha | Constant containing the value 'Y' (yes). Used in comparing answers received from terminal when operating in interactive mode. |
| V | Alpha | Constant containing the value 'V'. Used for internal processing only. |
| VV | Alpha | Constant containing the value 'v'. Used to denote that a decontamination method with double vacuuming is used. |

Common Block SITDAT

| Symbol and Dimension | Type | Definition/Value/Units |
|---|---|---|
| AREA | Real | Contains the area of the current grid element. Measured in square meters. The value of area can be 1) set at some constant value, 2) read from file AREA.DAT on unit 11, or 3) defined within a user-supplied subroutine. Selection is made via menu. |

| | | |
|---|---|---|
| CSURF(2,350) | Real | Contains the surface area decontaminated using each method. (Method 349 denotes area requiring no decontamination, and method 350 denotes area that could not be decontaminated with methods in reference data base.) CSURF(2,*) contains above information but with the early vacuuming strategy in effect (see Section 4.3.2, page 4.16). |
| DCOST | Real | Contains the cost of decontaminating the current grid element during the current time period. It is measured in dollars per square meter and is used for internal processing. |
| DEPR(25) | Real | Depreciation factor (for the effects of deterioration and obsolescence) for each land use type. The values for DEPR are user-specified, with one value for each of the LNDUSE land use categories (see common block PARM). The values are read in from PARM.DAT (unit 10), but they can also be specified via menu selection. The default values are: .15, .15, .15, .10, .00, .10, .00, .00, .05, .00, and .20. Depreciation factors are discussed in Section 4.2.1.2, page 4.4. |
| DEPRX | Real | A weighted sum of the depreciation factors DEPR(*). The weights are WTS(I), the percentage of each grid element in the I-th land use. DEPRX is used only for internal accounting purposes. |
| DISC(25) | Real | Discount factor for each land use type. Not to be confused with RHO, the discount rate. The discount factors relate to the diminished property value due to residual contamination remaining after site restoration. The values for DISC are user-specified, with one value for each of the LNDUSE land use categories (see common block PARM). The default values are: .15, .10, .10, .00, .05, .05, .25, .25, .25, .10, and .10; other values can be specified via menu selection. Discount factors are discussed in Section 4.2.1.1, page 4.3. |
| DISCX | Real | A weighted sum of the discount factors DISC(*). The weights are WTS(I), the percentage of each grid element in the I-th land use. DISCX is used only for internal accounting purposes. |
| FINPUT(125) | Real | Used in accumulating the quantity of each factor input that is required to decontaminate the current grid element in the current time period. |

| | | |
|---|---|---|
| | | The exposure level (dose, dose commitment or ground concentration) for the current grid element. The value of GCE is contained in the site data base and is read from file SITEDB.DAT (unit 13). |
| GENPV | Real | Used to accumulate the net present value of all processed property within the current grid element. |
| IDAYS | Integer | The number of days before decontamination can be completed. This variable is user-specified, with a default value of 30. The value is specified via menu selection. IDAYS is used in calculating the probability of rain prior to the completion of decontamination activities. Rain affects decontamination efficiencies and costs. |
| MATIJK(2,30,25) | Integer | Each value of MATIJK contains the code number of the optimal method to use on a particular surface in a given time period, given the exposure level. The first subscript refers to decontamination prior to precipitation (MATIJK(1,*,*)) and after precipitation (MATIJK(2,*,*)); the second subscript refers to the time period (year following release); and the third subscript refers to the type of surface. This variable is used only for internal processing. |
| PBVAL | Real | The pre-accident value of property within the current grid element. Measured in dollars and taken as the market value at the time immediately preceding the radiological release. The value for PBVAL is contained in the site data base and is read from file SITEDB.DAT (unit 13). |
| PDVAL | Real | The post-decontamination value of property within the current grid element. For any particular land use, the post-decontamination value is equal to the pre-accident value multiplied by 1.0 minus the discount factor DISC. For the grid element, PDVAL is the sum of the post-decontamination values for the individual land uses. (See Section 4.2.1.1, page 4.3.) The value for PDVAL is contained in the site data base and is read from file SITEDB.DAT (unit 13). |
| POPS | REAL | The population in the current grid element. The value for POPS is contained in the site data base and is read from file SITEDB.DAT (unit 13). |

| | | |
|---|---|---|
| RADLIM(8) | Real | The radiation limit, exposure limit or cleanup criteria with respect to any of up to 8 body organs. The values are user-specified and are read from PARM.DAT (unit 10). The values can also be changed via menu selection. |
| SCALE | Real | A scale value, usually some power of 10, to enable output values to be expressed in fixed decimal format. The value for scale is user-specified and is read in file PARM.DAT on unit 10. |
| SURF(25) | Real | The square meters of surface area for each surface type within the current grid element. The value for SURF is contained in the site data base and is read from file SITEDB.DAT (unit 13). |
| TPOPS | Real | The population in the study area. TPOPS is equal to the sum of the population, POPS, within each grid element located in the study area. |
| TOTSRF | Real | The total surface area within each grid element that requires decontamination. Measured in square meters of surface area. |
| TXTSRF | Real | The total surface area within each grid element that requires no decontamination. Measured in square meters of surface area. |
| XSURF(25) | Real | For the study area, the total square meters of each type of surface that could not be decontaminated using methods currently in the reference database. |
| WTS(25) | Real | Weights representing the percentage of the area within a grid element that is of each land use type. The weights are contained in the site data base and are read from file SITEDB.DAT (unit 13). |

Common Block CASE

| Symbol and Dimension | Type | Definition/Value/Units |
|---|---|---|
| AREAF | Real | Switch to determine whether the area of each grid element is to be 1) set to some constant value, 2) read from file AREA.DAT on unit 11, or 3) defined within a user-supplied subroutine. Default is for AREA to be set to constant value of 10,000 square meters. Selection is made via menu. |

| | | |
|---|---|---|
| CDOSE | Real | External dose commitment to the resident population of the current grid element. Commitment period begins at time of resettlement following decontamination. |
| DD(20,25) | Real | Contains the total area contaminated, by exposure are and by surface type. The first subscript refers to exposure area and the second subscript to surface type. Used in the single-period, fast mode of analysis. |
| IACT | Integer | Switch to denote whether DECON is to be run in interactive or batch mode. (Batch mode is not currently implemented.) |
| IADD | Integer | Parameter to indicate what special constraints are in effect (e.g., Quick-Vac, operation restrictions, required methods, etc.). Used only for internal processing. |
| IDRSV | Integer | Switch to indicate whether console message is to be written requesting user to change disks in a particular drive. Used when large site database requires multiple diskettes. Used only for internal processing. |
| ING | Integer | Counter used in keeping track of number of paired values used to define subarea boundaries in subarea analysis. (See Section 4.3.1, page 4.9.) Used only for internal processing. |
| IPDQ | Integer | Switch used to indicate whether Quick-Vac option is selected (IPDQ=1) or deselected (IPDQ=0). Default value is zero. Option is made via menu selection. |
| IPRCST | Integer | Print status parameter to indicate what reports are to be produced. Options are:<br>1 - As<br>2 - As + Af<br>3 - As + Af + Aa<br>4 - As + Gs<br>5 - As + Gs + Gf<br>6 - As + Gs + Gf + Ga<br>7 - As + Gs + Gf + Ga + Gd<br>8 - As + Xs<br>9 - As + Xs + Xf<br>10 - As + Xs + Xf + Xa<br>11 - As + Xs + Xf + Xa + Xd |

| | | |
|---|---|---|
| | | where A = Study area<br>G = Grid element<br>X = Exposure area<br>and s = Summary results<br>f = Factor inputs<br>a = Area decontaminated, by surface and method<br>d = detailed surface analysis.<br><br>For example, setting IPRCST equal to 5 produces 1) summary results for the study area, 2) summary results for each grid element, and 3) factor input requirements by grid element. Exposure area results are available only in fast mode, and grid element results are available only in normal mode. A value for IPRCST is requested by DECON when it begins processing. The value can also be changed by menu selection. |
| IPRNT(25) | Integer | Contains numbers of up to 25 grid elements for which detailed analysis is to be provided (equivalent to IPRCST=7, or IPRCST=11). Normally used when there are a large number of grid elements to be processed and detailed results are wanted on only a few of them. Option selected by menu. |
| IQV | Integer | Switch used in connection with Quick-Vac option. Used for internal proocessing only. |
| IQWIK | Integer | Switch used to indicate fast mode of processing. Internally set when number of periods to be analyzed is 1 and IPRCST has a value less than 4 or greater than 7. |
| IRSTF(100) | Integer | One of 4 parameter values set in connection with operation restrictions and/or required methods. IRSTF is the number of the last exposure area to which the restriction/requirement applies. Up to 100 restrictions and/or requirements can be imposed in a single case. (See Sections 4.3.3 and 4.3.4, page 4.10) Note that if restrictions or requirements are to apply to a subarea within the study area, they must be applied to exposure areas rather than grid elements. This option is activated via menu selection. |
| IRSTS(100) | Integer | One of 4 parameter values set in connection with operation restrictions and/or required methods. IRSTS is the number of the first exposure area to which the restriction/requirement applies. Up to 100 restrictions and/or requirements can be imposed in a single case. (See Sections 4.3.3 and |

4.3.4, page 4.10.) Note that if restrictions or requirements are to apply to a subarea within the study area, they must be applied to exposure areas rather than grid elements. This option is activated via menu selection.

| | | |
|---|---|---|
| ISRF(100) | Integer | One of 4 parameter values set in connection with operation restrictions and/or required methods. ISRF defines the surface or surfaces to which the restriction/requirement applies. A value of 99 results in the restriction/requirement applying to all surfaces; otherwise, only a single surface is affected. A positive value indicates a restriction, while a negative value indicates a requirement. Up to 100 restrictions and/or requirements can be imposed in a single case. (See Sections 4.3.3 and 4.3.4, page 4.10.) Note that if restrictions or requirements are to apply to a subarea within the study area, they must be applied to exposure areas, rather than grid elements. This option is activated via menu selection. |
| ISTART | Integer | Switch used to indicate whether the first case is being processed, or subsequent cases. Used for internal processing only. |
| NGF(50) | Integer | One of two parameters used to define the boundaries of a subarea to be analyzed. NGF is the last grid element in the "row" of grid elements to be processed. Up to 50 "rows" of grid elements can be included within the subarea. (See Section 4.3.1, page 4.9.) This option is specified by menu selection. |
| NGS(50) | Integer | One of two parameters used to define the boundaries of a subarea to be analyzed. NGS is the first grid element in the "row" of grid elements to be processed. Up to 50 "rows" of grid elements can be included within the subarea. (See Section 4.3.1, page 4.9.) This option is specified by menu selection. |
| NGSS | Integer | The first grid element in the study area to be processed. NGSS is set equal to NGS(1) unless IPRCST is greater than 7, in which case NGSS=1. Used only for internal processing. |
| NNFF | Integer | The final grid element in the study area to be processed. NNFF is set equal to the last nonzero value of NGF if grid elements are being processed; NNFF is set equal to 120 if exposure areas are being processed. If NGF(1) is zero NNFF is set equal to the number of grid elements in the study area. Used only for internal processing. |

| | | |
|---|---|---|
| NORG | Integer | The number of body organs to be processed in determining target decontamination factor (see Section 4.2.2, page 4.5, and footnote 4 on page 4.7). In the current implementation of DECON, NORG must equal 1. The value for NORG is user-specified. It is read from file PARM.DAT on unit 10. |
| PSAVI | Real | Contains the potential savings from a property buy-out, where the buy-out is made at pre-accident property values. PSAVI will have a nonzero value in circumstances where the cost of decontamination exceeds the pre-accident value of the property. PSAVI provides information that may be useful in determining the cost of providing compensation. The value for PSAVI is internally generated. |
| PSAV2 | Real | Contains the potential savings from a property buy-out, where the buy-out is made at the net present value of the property immediately after the accident. PSAV2 will have a nonzero value in circumstances where the cost of decontamination exceeds the social value of the property. PSAV2 provides information that may be useful in minimizing the social cost of the accident. The value for PSAV2 is internally generated. |
| SAVSRF(25) | Integer | Used internally to optimize processing efficiency. |
| SMCOST | Real | Total surveying and monitoring costs in each grid element. |
| TFNPUT(125) | Real | Used in accumulating the quantity of each factor input that is required to decontaminate the entire study area. |
| TPBVAL | Real | The pre-accident value of property within the study area. Measured in dollars and taken as the market value at the time immediately preceding the radiological release. The value for TPBVAL is the sum of PBVAL for each grid element in the study area. |
| TPDVAL | Real | The post-decontamination value of property within the study area. The value for TPDVAL is the sum of PDVAL for each grid element in the study area. |
| TSMCST | Real | Total surveying and monitoring costs within the study area. |

| | | |
|---|---|---|
| TTCOST | Real | Contains the cost of decontaminating the study area. It is measured in dollars per square meter and is the sum of DCOST for each grid element in the study area. |
| TTTSRF | Real | The total surface area within the study area that requires decontamination. It is measured in square meters of surface area. TTTSRF is the sum of TOTSRF for each grid element in the study area. |
| WDOSE | Real | External dose commitment to decontamination workers within the current grid element. It is measured in man-rem. Commitment period begins in year of decontamination. |
| XGCE(20) | Real | Contains the upper bound of each exposure (dose, dose commitment, or ground concentration) interval. The values for XGCE are user-specified; a maximum of 20 are allowed without redimensioning of variables. DECON determines in which exposure interval each grid element falls. Using intervals rather than the actual exposure values can greatly reduce the computational time. The values for XGCE are read from file PARM.DAT (unit 10). |
| XIT | Integer | Switch to indicate when processing is completed. Program is terminated when XIT equals 1. |
| XNODEC | Real | Contains the total surface area within the study area that requires no decontamination. It is measured in square meters of surface area. XNODEC is the sum of XXNDEC for each grid element in the study area. |
| XPBVAL(20) | Real | The pre-accident value of property within each exposure area. Used only in the fast mode of operation. Measured in dollars and taken as the market value at the time immediately preceding the radiological release. The value for XPBVAL(I) is the sum of PBVAL for each grid element with an exposure level in the I-th exposure interval. |
| XPDVAL(20) | Real | The post-decontamination value of property within each exposure area. Used only in the fast mode of operation. The value for XPDVAL(I) is the sum of PDVAL for each grid element with an exposure level in the I-th exposure interval. |
| XTPOPS(20) | Real | The total population within each exposure area. Used only in the fast mode of operation. The value for XTPOPS(I) is the sum of POPS for each grid element with an exposure level in the I-th exposure interval. |

| | | |
|---|---|---|
| XXNDEC | Real | Contains the total surface area within each grid element that requires no decontamination. It is measured in square meters of surface area. |
| XXXSRF | Real | For the study area, the total surface area that could not be decontaminated using methods currently in the reference database. |
| XCDOSE | Real | For the study area, the external dose commitment to the resident population. The commitment period begins at time of resettlement of the decontaminated areas. |
| XWDOSE | Real | For the study area, the external dose commitment to decontamination workers. XWDOSE is measured in man-rem. Commitment period begins in year of decontamination. |

Common Block CASEA

| Symbol and Dimension | Type | Definition/Value/Units |
|---|---|---|
| SRSTA(100) | Alpha | One of 4 parameter values set in connection with operation restrictions and/or required methods. SRSTA is alphanumeric code for the operation or method that is being restricted. Up to 100 restrictions and/or requirements can be imposed in a single case. (See Sections 4.3.3 and 4.3.4, page 4.10) Note that if restrictions or requirements are to apply to a subarea within the study area, they must be applied to exposure areas rather than grid elements. This option is activated via menu selection. |

Common Block DOSE

| Symbol and Dimension | Type | Definition/Value/Units |
|---|---|---|
| DECAY(30) | Real | Factors used in calculating the exposure levels in the current time period. These factors adjust for radioactive decay and weathering and give the proportion of exposure remaining relative to the exposure level in the first period. A maximum of 30 time periods can be used without redimensioning of variables. The values for DECAY are read from file DOSERATE.DAT on unit 12. This file is created by the dose model (see Appendix E, p. E.l). |

| | | |
|---|---|---|
| DKR(30) | | A maximum of 30 time periods can be used without redimensioning of variables. The values for DKR are read from file DOSERATE.DAT on unit 12. This file is created by the dose model (see Appendix E, p. E.1). |
| DRATIO | Real | The dose rate at time zero. Measured in rem per hour. The values for DRATIO are read from file DOSERATE.DAT on unit 12. This file is created by the dose model (see Appendix E, p. E.1). |
| R2 | Real | The 7-year dose commitment taken 14 days after release. Measured in rem. The values for DRATIO are read from file DOSERATE.DAT on unit 12. This file is created by the dose model (see Appendix E, p. E.1). |
| SHELDI | Real | Shielding factor used for decontamination workers. SHELDI gives the fraction of the total dose received by the decontamination worker. The roughness of the contaminated surface is assumed to give a shielding factor of 0.5 (see USNRC 1975). The use of protective clothing may reduce the shielding factor even further. The value for SHELDI can be modified via menu selection. |
| SHELD2 | Real | Shielding factor used for resident population. SHELD2 gives the fraction of the total dose received by a typical resident of the affected area. The roughness of the contaminated surface is assumed to give a shielding factor of 0.5 (see USNRC 1975). SHELD2 will be further reduced by protective measures (other than decontamination) and/or the shielding effect of materials. The value for SHELDI can be modified via menu selection. |

Common Block HLTH

| Symbol and Dimension | Type | Definition/Value/Units |
|---|---|---|
| NORGUS | Integer | The number of organs considered in establishing the decontamination criteria. The value of NORGUS is constrained to 1 in the current implementation of DECON. |

## DATA FILES

Entry of data into DECON is by console in the interactive mode and from several input files. The input files are:

```
Unit 5 - CODEX    .DAT - codes for decontamination methods
Unit 6 - SRFLBL   .DAT - labels for surface types
Unit 7 - NPTLBL   .DAT - labels for factor inputs
Unit 8 - MTHDAT   .DAT - data from the reference database
Unit 10- PARM     .DAT - parameter values
Unit 11- AREA     .DAT - areas for each grid element
Unit 12- DOSERATE.DAT - data relating to exposure levels
Unit 13- SITEDB   .DAT - site database
Unit 14- SITEDB2 .DAT - extended site database
```

Unit 11 is read only if the user selects to read the area of each grid element from an input file. Unit 14 is read only if the size of the site database is too large to be contained on a single diskette. For a single-sided drive, one diskette will hold the data for 750 grid elements. If unit 14 is required, DECON will prompt the user to mount the second diskette.

A description of each input file and the format in which the data must be prepared is described below. The user of DECON must only prepare the file PARM.DAT; the other files are either pre-prepared as part of the reference database, or they are prepared in other programs requiring user input. These other programs are described in Appendix D. Information supplied to DECON via menu selection is described in a later section.

### Codes for Decontamination Methods; CODEX.DAT - Unit 5

This file is prepared by the program REFDATA, which prepares the reference database (see Appendix D). CODEX.DAT must be on the default drive.

### Labels for Surface Types; SRFLBL.DAT - Unit 6

This file is modified only when changing the number or types of surfaces supported by the reference database. See Appendix D. SRFLBL.DAT must be on the default drive.

### Labels for Factor Inputs; NPTLBL.DAT - Unit 7

This file is modified only when changing the number or types of factor inputs supported by the reference database. See Appendix D. NPTLBL.DAT must be on the default drive.

### Data from the Reference Database; MTHDAT.DAT - Unit 8

This file is prepared by the program REFDATA. It is modified only when adding data to or changing data in the reference database. See Appendix D. MTHDAT.DAT must be on the default drive.

Parameter Values: PARM.DAT - Unit 10

This file is prepared by the user and must reside on the default drive. The variables read and the format in which the variables must appear is described below.

The following 11 variables are read in Fortran format (9I8).

NGE - number of grid elements in the site database

NSURF - number of surface types in the reference database; current value is 24 (numbers 17 and 22 are not currently used).

NMAX - maximum number of decontamination methods available for any surface. The current value is 30.

LNDUSE - the number of land use categories. The current value is 11, and the categories are as follows: 1) residential, 2) commercial, 3) industrial, 4) streets and roads, 5) wooded areas, 6) parking lots, 7) grain crops, 8) vegetable crops, 9) orchards, 10) vacant land and 11) automobiles.

NPUTS - the number of factor inputs. The current value is 90.

NORGUS - the number of body organs to be processed. The maximum value for NORGUS is currently constrained to the value 1.

IJM - the number of decontamination methods in the reference database. The current value is 347.

IJS - the number of decontamination operations in the reference database. The current value is 186.

NTP - the number of time periods to be considered. Any value from 1 to 30, inclusive.

I20 - the number of exposure intervals to be used. Any value from 1 to 20, inclusive.

IACT - Set to 0 if batch processing mode is used; set to 1 if interactive mode at console is used. (Current implementation is only for IACT=1.)

The variable (NUMSRF(I),I=1,NSURF) is read in format (9I8). NUMSRF contains the number of decontamination methods available for each surface. The current values for NUMSRF are: 30, 20, 25, 13, 19, 23, 13, 16, 11, 17, 13, 17, 23, 23, 11, 11, 0, 5, 6, 4, 5, 0, 21, 21.

The variable (RADLIM(I),I=1,NORGUS) is read in format (9F8.2,F7.2). RADLIM contains the radiation limit, exposure limit, or cleanup criterion with respect to NORGUS body organs. RADLIM must be in the same units of measurement as GCE, which is read from the site database. The units of GCE are user-selectable. (The current implementation of DECON requires that NORGUS equals 1.)

The variable (XGCE(I),I=1,I20) is read in format (9F8.2,F7.2). XGCE contains the midpoint of each exposure (dose, dose commitment, or ground concentration) interval. The value of GCE is read for each grid element in the site database, and it is then determined in which of the XGCE exposure intervals GCE falls. The grid element is then processed as though GCE were equal to the value of XGCE for the interval in which it falls. For example, if XGCE(1)=2.5, XGCE(2)=10.0 and GCE=8.1, then GCE will fall in exposure interval 2 and the grid element will be processed as though GCE had equaled 10.0. It is assumed that the lower bound of the first interval is equal to 0.0. All values of GCE greater than the midpoint of the last interval will assume the value of the final XGCE specified.

The variable (DEPR(I),I=1,LNDUSE) is read in format (9F8.2,F7.2). DEPR contains the depreciation rates to be associated with each land use category. This is depreciation due to deterioration and obsolescence of property. The values for the DEPR are expressed as the fraction of the property value lost from one year to the following year. For example, DEPR(3)=0.1 means that property in land use category 3 (industrial) loses 10 percent of its value every year due to deterioration and obsolescence.

The variable (DISC(I),I=1,LNDUSE) is read in format (9F8.2,F7.2). DISC contains the fraction of a property's pre-accident value that is lost because of residual contamination remaining after it has been decontaminated. For example, DISC(9)=0.2 means that property in land use category 9 (orchards) would lose 20 percent of its pre-accident value simply as a result of residual contaniination.

The next set of variables read from PARM.DAT is P1, P2, P3, P4 and SCALE. The format is (9F8.2,F7.2). P1 through P4 are factors that can be used to adjust the costs of labor (P1), equipment (P2), materials (P3) and fuel (P4). These costs are actually adjusted in the program REFDATA, which also uses the file PARM.DAT.

For severe accidents, the costs, areas and hours of labor and equipment are large numbers and need to be scaled down if they are to be expressed in fixed decimal format. The variable SCALE permits the user to scale the output results. SCALE is usually expressed as some power of 10, and is entered in PARM.DAT in scientific notation. For example, the value 1.0E+03 would cause values expressed in dollars, areas, and hours of labor and equipment to be scaled down by a factor of 1000.

The last variable, (EXPOS(I),I=1,NSURF), is read in format (9F8.2,F7.2). EXPOS contains the exposure factors to be associated with each type of surface. Exposure factors are discussed in Section 4.3.5, page 4.11 and illustrated in Section 5.2.6, page 5.16. It is recommended that the values for EXPOS be set to 1.0 for base case evaluations.

Areas of Grid Elements:, AREA.DAT - Unit 11

This file is required only if the user specifies that grid element areas are to be read from a file. AREA.DAT must be on the default drive.

Data Relating to Doses; DOSERATE.DAT - Unit 12

This file contains information relating to doses and dose commitments. It contains 1) the dose rate at time zero in rem per hour; 2) the 70-year dose commitment, taken 14 days after release, measured in rem; 3) the relative decay factors of the 70-year dose commitments; and 4) the relative decay factors of the dose rates. This file is prepared by the dose model and is modified only when a different source term is used. See Appendix E.

Data Relating to the Site Database; SITEDB.DAT - Unit 13

This file, which is prepared by the program SITEDATA, contains all of the information relating to the site database. One random access record is provided for each grid element. Each record contains 1) the record number; 2) the pre-accident value of the property within the grid element; 3) the post-decontamination value of the property (as computed from the variable, DISC); 4) the exposure level (dose, dose commitment or ground concentration); 5) the population; 6) the area of the grid element; 7) the percentage of the grid element in each of land uses one through four; 8) the percentage of the grid element in each of land uses five through eight; 9) the percentage of the grid element in each of land uses nine through 12; and 10) for each surface type, the ratio of the area for that surface type to the total geographic area of the grid element. If DECON is on a hard disk, SITEDB.DAT should be on the default drive. If DECON is run on floppy disks, the default drive is drive A: and SITEDB.DAT is read from drive B:.

Extended Site Database; SITEDB2.DAT - Unit 14

This file is simply an extension of SITEDB.DAT. It is used only when the number of grid elements exceeds 750.

## USER'S GUIDE

This section is a user's guide to DECON. It assumes that all of the input files described above are properly prepared and mounted.

Three diskettes are required to run DECON. Diskette No. 1 contains:

DECON.EXE -- The program "DECON"

Diskette No. 2 contains:

NPTLBL.DAT -- An ASCII file containing labels for the factor inputs
SRFLBL.DAT -- An ASCII file containing labels for the surface types
MTHDAT.DAT -- A random access file containing the reference data set
CODEX.DAT -- An ASCII file containing decontamination method codes
PARM.DAT -- An ASCII file containing parameter values for DECON
DOSERATE.DAT- An ASCII file containing dose decay factors
AREA.DAT -- A random access file containing the area of each grid element

Diskette No. 3 contains the site database; namely:

SITEDB.DAT -- A random access file containing a record of information for the first 750 grid elements of the accident site.

Diskette No. 4 (if needed) contains:

SITEDB2.DAT-- A random access file containing a record of information for grid elements 751 thru 1550 of the accident site.

To run DECON, make Drive A: the default drive and place Diskette No. 2 in this drive. Place Diskette No. 1 in Drive B: and at the console enter B:DECON. DECON will respond with "ENTER OUTPUT CONTROL VARIABLE." The user responds with an integer number, which will control the amount of output, as follows:

| Control Integer | Output Produced | Output Codes |
|---|---|---|
| 1 | As | A = Study area |
| 2 | As + Af | G = Grid element |
| 3 | As + Af + Aa | X = Exposure area |
| 4 | As + Gs | s = Summary results |
| 5 | As + Gs + Gf | f = Factor inputs |
| 6 | As + Gs + Gf + Ga | a = Area decontaminated, by surface and method |
| 7 | As + Gs + Gf + Ga + Gd | d = Detailed surface analysis |
| 8 | As + Xs | |
| 9 | As + Xs + Xf | |
| 10 | As + Xs + Xf + Xa | |
| 11 | As + Xs + Xf + Xa + Xd | |

For example, a control integer of 5 produces 1) summary results for the study area, 2) summary results for each grid element, and 3) factor input requirements by grid element. Exposure area results are available only in fast mode, and grid element results are available only in normal mode. The value of the control integer can also be changed by menu selection.

DECON will operate in FAST mode if a single time period is to be analyzed and the control integer is either less than 4 or greater than 7. The saving in processing time when operating in FAST mode will be particularly significant if a large number of grid elements is to be processed.

The next request by DECON will be a message to "ENTER LINE PRINTER STATUS." If a '0' (zero) is entered, all output will be at the console; if a '1' (one) is entered, reports will be produced at the line printer (device LPT1:).

DECON next asks if a previously generated matrix is to be used. This matrix is contained in file MATIJK.DAT, which must be in Diskette No. 2. It is created by DECON and contains, for each exposure interval, the optimal decontamination method to be used on each surface and at each time period. Using a previously generated matrix will usually shorten processing time by several minutes. However, if any of the following are changed, a new matrix must be generated:

| Description | Name of Variable | File Location |
|---|---|---|
| Number of exposure intevals | I20 | PARM.DAT |
| Value of exposure interval limits | XGOE(*) | PARM.DAT |
| Radiation limit/cleanup standard | RADLIM(*) | PARM.DAT/Menu |
| Restricted operations and/or required methods | ISRF(*) | Menu |
| Exposure factors | EXPOS(*) | PARM.DAT/Menu |
| Radioactive decay factors | DECAY(*) | DOSE.DAT |
| Factor input cost adjustment factors | P1,P2,P3,P4 | PARM.DAT |
| Costs/Efficiencies of Methods | COST(*)/EFF(*) | METHDAT.DAT |

If a previously generated matrix is used, DECON will ask, "DO YOU WISH TO SAVE THE PARAMETER VALUES FROM THE PREVIOUS CASE? (Y/N)." If you answer yes, previous parameter values are saved. However, you will still be permitted to make changes via the menu. If you answer no, then subarea boundary definitions, restrictions on operations, required methods, the Quick-Vac option and detailed printout for selected grid elements will all be deactivated.

The next processing step is to read the reference data base. After doing this, DECON will display the DATA ENTRY MENU, followed by the message "ENTER TASK CODE 1 TO 20, OR -1 TO STOP." The user responds by entering one or more integer numbers. Depending upon the number entered, various options can be selected. They are described as follows:

| Number | Factor | Option Description |
|---|---|---|
| 1 | RAIN PROBABILITY | Enter a value for the daily probability of rain (a value between 0.0 and 1.0). Default value is 0.32. |
| 2 | RAINFALL | Enter a value for the average daily rainfall (a value between 0.0 and 99999.0). Default value is 0.1. |
| 3 | STUDY AREA BOUNDARIES | Enter a pair of values to delimit the set of grid elements to be analyzed. The first value is the number of the starting grid element, and the second value is the number of the ending grid element. A subarea of the study area may be analyzed by using several sets of delimiters to define the boundaries of the subarea. Up to 50 pairs of delimiters can be used. |
| 4 | QUICK-VAC | Enter a value of 1 to activate the Quick-Vac option. Default value is 0. (Not currently implemented.) |
| 5 | DAYS TO COMPLETE DECONTAMINATION | Enter an integer value for the number of days before decontamination is completed. This value is used to calculate the probability of rain prior to the completion of decontamination. |
| 6 | SCALE | Enter a scale factor, normally some power of 10, to enable output values to be expressed in fixed decimal format. The value for scale affects all units measured in dollars, area and man- and equipment-hours. For example, a scale factor of 1.0E+03 will cause all variables measured in dollars, area and man- and equipment-hours to be scaled down by a factor of 1000. |
| 7 | DISCOUNT RATE | Enter a value for the discount rate. Default value is 0.1 (= 10%). |
| 8 | RADIATION LIMIT | Enter values for: 1) the organ number (enter 1 only), 2) the dose commitment period (enter 1 only), and 3) the radiation limit for total dose. |
| 9 | RESTRICTIONS ON OPERATIONS OR METHODS | Enter values for: 1) the starting exposure area, 2) the ending exposure area, 3) the surface number being restricted (see Table 1.2), and 4) the operation or method being restricted (see Table 1.1). A positive value for the surface number denotes that all methods containing the indicated operation are to be excluded. A negative value for the surface number denotes that only the method specified is to be used. To designate all surfaces, enter a 99 for the surface number. The operation/method that is being restricted must be entered within single quote marks. |

Examples:
1,20,3,'W' - for exposure areas 1 through 20 do not use methods containing water on surface 3 (vacant land);
15,15,-15,'CR' - for the fifteenth exposure area, decontaminate roofs using a strippable coating followed by removal and replacement.

| | | |
|---|---|---|
| 10 | OUTPUT OPTIONS | Select from the following: 1) change output control variable, 2) change line printer status, or 3) change grid elements that are selected for microanalysis. If 1) is selected, enter a value for the output control variable; see options above. If 2) is selected enter a value for the line printer status; see options above. If option 3) is selected and if the output control variable is less than 7, enter grid element numbers to obtain detailed analyses of those grid elements. If output control variable is between 8 and 10, enter exposure area numbers to obtain detailed analyses of those exposure areas. Up to 50 grid elements/exposure areas may be specified. NOTE: Use of this option automatically overrides the FAST mode of DECON. |
| 11 | GRID ELEMENT AREA | Enter a value for the size of the grid element in square meters; or designate that areas are to be read from AREA.DAT; or designate that areas are to be obtained from a user-supplied subroutine. Default value for grid element area is 10000 sq. meters. |
| 12 | PROPERTY LOSS FACTORS | Enter a set of values (= to the number of land uses) to indicate the fraction of original property value lost due to residual contamination remaining after decontamination has been completed. Default value = 0.1 (= 10%). |
| 13 | EXPOSURE FACTORS | Enter a set of values (= to the number of surface types) to denote relative human exposure to surface type. Default value = 1.0. |
| 14 | CHANGE X3, #9 OR #10 | Change existing values for selected 1) grid element delimiters, 2) restrictions, or 3) grid elements selected for microanalysis. Change values from those used in previous case, or deactivate by initializing equal to zero. |
| 15 | NUMBER OF TIME PERIODS | Enter a value from 1 to 30 to indicate the number of time periods to be considered in the analysis. Increasing the number of time periods increases the period used in determining the decontamination schedule. |

| | | |
|---|---|---|
| 16 | COST ADJUSTMENTS | Submenu: Enter factors by which to increase or decrease a) labor costs, b) equipment costs, c) costs of materials, and d) fuels costs. Enter a value (in dollars per square meter) for the net present value lost from the income stream caused by premature removal of a) orchard trees or b) forest trees. |
| 17 | HAULING DISTANCE | Enter a value for the average one-way hauling distance between cleanup site and disposal site; default is 30 miles. |
| 18 | SHIELDING FACTORS | Enter a value for the average shielding effect to a) radiation workers; b) resettled population. The default values are 0.5 for both. |

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| NRC FORM 335 (2 841 NRCM 1102 3201 3202 U.S NUCLEAR REGULATORY COMMISSION **BIBLIOGRAPHIC DATA SHEET** SEE INSTRUCTIONS ON THE REVERSE | 1 REPORT NUMBER (Assigned by TIDC add Vol No if any) NUREG/CR-3413 PNL-4790 |
|---|---|
| 2 TITLE AND SUBTITLE<br>OFF-SITE CONSEQUENCES OF RADIOLOGICAL ACCIDENTS: METHODS, COSTS AND SCHEDULES FOR DECONTAMINATION | 3 LEAVE BLANK |
| | 4 DATE REPORT COMPLETED<br>MONTH: November YEAR: 1984 |
| 5 AUTHOR(S)<br>J.J. Tawil, F.C. Bold, B.J. Harrer, J.W. Currie | 6 DATE REPORT ISSUED<br>MONTH: August YEAR: 1985 |
| 7 PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)<br>Pacific Northwest Laboratory<br>P.O. Box 999<br>Richland, Washington 99352 | 8 PROJECT/TASK/WORK UNIT NUMBER<br><br>9 FIN OR GRANT NUMBER<br>B2418 |
| 10 SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)<br>Division of Radiation Programs and Earth Sciences<br>Office of Nuclear Regulatory Research<br>U.S. Nuclear Regulatory Commission<br>Washington, D.C. 20555 | 11a TYPE OF REPORT<br>Technical<br><br>b PERIOD COVERED (Inclusive dates) |
| 12 SUPPLEMENTARY NOTES | |

13 ABSTRACT (200 words or less)

This report documents a data base and a computer program for conducting a decontamination analysis of a large, radiologically contaminated area. The data base, which was compiled largely through interviews with knowledgeable persons both in the public and private sectors, consists of the costs, physical inputs, rates and contaminant removal efficiencies of a large number of decontamination procedures. The computer program utilizes this data base along with information specific to the contaminated site to provide detailed information that includes the least costly niethod for effectively decontaminating each surface at the site, various types of property losses associated with the contamination, the time at which each subarea within the site should be decontaminated to minimize these property losses, the quantity of various types of labor and equipment necessary to complete the decontamination, dose to radiation workers, the costs for surveying and monitoring activities, and the disposal costs associated with radioloqical waste generated during cleanup. The program and data base are demonstrated with a decontamination analysis of a hypothetical site.

| 14 DOCUMENT ANALYSIS a KEYWORDS/DESCRIPTORS | 15 AVAILABILITY STATEMENT |
|---|---|
| decontamination analysis<br>data base<br>radiological waste | Unliniited |
| | 16 SECURITY CLASSIFICATION<br>(This page) Unclassified<br>(This report) Unclassified |
| b IDENTIFIERS/OPEN ENDED TERMS | 17 NUMBER OF PAGES |
| | 18 PRICE |