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Decontamination Analysis of the NUWAX-83 Accident Site Using "Decon"

J. J. Tawil

November 1983

Prepared for
the Defense Nuclear Agency
under a Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
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DECONTAMINATION ANALYSIS OF THE NUWAX-83 ACCIDENT SITE USING "DECON"

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Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

This report presents an analysis of the site restoration options for the NUWAX-83 site, at which an exercise was conducted involving a simulated nuclear weapons accident. This analysis was performed using a computer program developed by Pacific Northwest Laboratory. The computer program, called DECON, was designed to assist personnel engaged in the planning of decontamination activities. The many features of DECON that are used in this report demonstrate its potential usefulness as a site restoration planning tool. Strategies that are analyzed with DECON include: 1) employing a Quick-Vac option, under which selected surfaces are vacuumed before they can be rained on; 2) protecting surfaces against precipitation; 3) prohibiting specific operations on selected surfaces; 4) requiring specific methods to be used on selected surfaces; 5) evaluating the trade-off between cleanup standards and decontamination costs; and 6) varying of the cleanup standards according to expected exposure to surface.

The analysis also serves to highlight DECON's flexibility. For example, DECON can analyze virtually any sub-area within the accident site. It can provide summary results for the entire accident site quickly (less than 6 minutes on an IBM PC with floppy disks and under 5 minutes with a hard disk), or it can provide highly detailed results on each grid element.

Other attractive features of DECON which are not been addressed in this report include: 1) the great ease of adding new operations, methods and factor inputs to the reference data base; 2) the relative ease of preparing the site data base; 3) the ability of DECON to handle an accident site with a virtually unlimited number of grid elements; 4) the ability to accommodate grid elements of different size, including--via a user-supplied subroutine--sizes that vary according to distance from the accident site, as in a radial gridwork; 5) the ease of introducing site-specific information during run-time, such as rain probability, expected rainfall, number of days to complete decontamination, and property loss factors related to residual contamination. Finally, DECON has been structured so that additional features and capabilities can be added with minimal changes to the code.

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1.0 INTRODUCTION

In May 1983, the Department of Defense, Department of Energy, and the Federal Emergency Management Agency jointly sponsored an exercise at the Nevada Test Site (NTS) to test the response of military and civilian agencies to a nuclear weapons accident. Called NUWAX-83, the simulated weapons accident caused an area within a mythical town in Virginia--Port Gaston--to be contaminated by Plutonium and Americium. One objective of the exercise was to determine the procedures necessary to restore the site to unrestricted civilian use. This report presents an analysis to support the decontamination of the NUWAX-83 site.

The decontamination analysis was conducted using a computer program developed by Pacific Northwest Laboratory. The computer program, called DECON, was originally designed for planning decontamination activities following a radiological accident at a nuclear reactor. A specially revised version of DECON was prepared for the Defense Nuclear Agency to be used in planning decontamination activities associated with nuclear weapons accidents. The Defense Nuclear Agency version is described in the following section.

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N 751.000 N 750.500 N 750.000 N 749.500 N 749.000 N 748.500 N 748.000

RADCON TRLR.

NAVY STATION BOUNDARY

BEST EASTERN HOTEL

NIGHTENGALE MEMORIAL HOSPITAL

J.D.'S PRODUCE FARM

CYPRESS PARK

GASTON TOWER

HILLVIEW

ANCHOR'S AWAY PAWN SHOP

JEFFERSON COUNTY BLDG.

JEFFERSON COUNTY WEAKLY NEWS

NEPTUNE TATTOO

WSEX RADIO

SEVEN SEAS INVESTMENT BANK

HELICOPTER CRASH SITE

HELICOPTER TAIL SECTION

OCEANSIDE SALVAGE CO.

CAPTAIN NEMO MEMORIAL PARK

CATFISH CABIN CAFE & FISH MARKET

OBSERVATION SITE

WEAPONS SITE

GABE'S MEAT PACKING PLANT

BURKES' FURNACE FILTER CO.

STOCKILLS PLASTIC MEDICAL PRODUCTS CO.

PORT GASTON INDUSTRIAL PARK

SAILORS FAREWELL TRAILER PARK

CORNFIELD

SANDY GROVE CAMPGROUNDS

SYMBOL	Pu(μCi/m^2)
A	<0.2 m
B	0.2-2
C	2-20
D	20-50
E	50-100
F	>100

FIGURE 1.

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2.0 A DESCRIPTION OF DECON

DECON is a computer program that can provide a large amount of useful information regarding the decontamination of large land areas. This information includes:

- the least costly decontamination method that is effective
- the cost of the selected decontamination method
- the effectiveness of the selected decontamination method
- the rate at which the selected decontamination method can be applied, and
- the manpower and equipment needed to complete the decontamination.

DECON requires as input two data bases: 1) the reference data base, which consists of information on the various decontamination methods; and 2) the site data base, which contains information about the site to be decontaminated. The reference data base can be applied without alteration to virtually any contaminated site, while the site data base will vary from site to site.

The reference data base consists of a large number of decontamination procedures, their costs, efficiencies and rates of coverage. A list of the decontamination operations currently implemented in DECON and the codes corresponding to these operations are presented in Table 1. Where more than one operation is given for a code, the correct operation will be apparent from the surface being treated.

In determining what techniques are to be applied to a surface, DECON considers alternative decontamination methods. A decontamination method consists of a combination of one or more decontamination operations. For example, the method VFR consists of the operations: vacuum (V), foam (F), and remove and replace (R). Over 250 decontamination methods are implemented in the current version of DECON.

Additional information on the reference data base is given in (Off-Site Consequences of Radiological Accidents: Methods, Costs and Schedules for Decontamination,, J.J. Tawil et al., (Draft) March 1983) and in (NUWAX Reference Manual, Preliminary Draft, J.J. Tawil and Bold, F.C., September 1983).

TABLE 1. Decontamination Operations

Code	Operation	Code	Operation
V	Vacuum	F	Foam
W	Low Pressure Water	K	Resurface; Repaint Autos
H	High Pressure Water	T	Surface Sealer/Fixative; Tow Car
Q	Very High Pressure Water	C	Strippable Coating
U	Hydroblasting	A	Plow
t	Fixative, Aerial Application	L	Leaching-FeCl
G	Three-Inch Asphalt	E	Leaching-EDTA
R	Remove & Replace; Reupholster	M	Close Mowing
S	Sandblasting	P	Thin Asphalt/Concrete Layer
Y	Deep Plow	B	Vacuum Blast
D	Defoliate; Drive Auto Out	I	Steam Clean
N	Clear; Harvest	Z	Remove Structure
X	Scrape 4"-6"	O	Plane, Scarify; (Radical) Prune
x	Double Scrape	v	Double Vacuum
J	Wash and Scrub	z	Remove Interior and Clean
m	Auto Transport Truck		

The site data base consists entirely of site-specific information, including the type of property (land use) that is on the site, the value of the property, and how severely the property is contaminated. The first step in preparing the site data base is to divide the accident site into a gridwork. In general, the grid element size will depend primarily on the distance between data points from the radiological survey of the accident site. A fine grid will likely give more accurate results, but it will also require the user to provide a larger amount of site-specific information.

The grid for the NUWAX site is shown on the map in Figure 1. Each grid element is of size 50' X 50'. The extent to which each grid element has been contaminated is indicated by the contours of ground concentrations of Plutonium 239. Activity levels of PU^{239} range from less than 0.1 $\mu Ci/m^2$ to over 100 $\mu Ci/m^2$. The activity level of Plutonium 239 is assumed to be 90 percent of the total activity, with Americium 241 making up the remaining 10 percent. Finally, a variety of land uses can be identified on the map, including those listed in Table 2.

An intuitively appealing way of approaching the decontamination problem is to consider the treatment of surfaces. This approach is based on the plausibility of using identical methods to decontaminate similar surfaces that are equally contaminated. Some land uses--e.g., streets, wooded areas and vacant land--can each be thought of as consisting of a single type of surface. Other land use categories--notably residential, commercial and industrial--are

TABLE 2. Land Uses Currently Implemented by DECON

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

best thought of as consisting of a wide variety of surfaces. Such land uses must be decomposed into their constituent surfaces if they are to be made amenable to the "surface" approach being suggested here. The surface types that are implemented by the current version of DECON are listed in Table 3 below.

TABLE 3. Surface Types Currently Implemented by DECON

1. Agricultural Fields
2. Orchards
3. Vacant Land
4. Wooded Land
5. Exterior Walls, Wood
6. Exterior Walls, Brick
7. Floors, Linoleum
8. Floors, Wood
9. Floors, Carpeted
10. Floors, Concrete
11. Interior Walls, Painted
12. Interior Walls, Concrete
13. Streets and Roads, Asphalt
14. Streets and Roads, Concrete
15. Roofs
16. Lawns
17. (Auto Transport)*
18. Auto Exteriors
19. Auto Interiors
20. Auto Tires
21. Auto Engine and Drive Train
22. Not Used
23. Other Paved Surfaces, Asphalt
24. Other Paved Surfaces, Concrete

*Auto transport is not a surface type; it is included because transporting automobiles to decontamination facilities outside of the contaminated area is a necessary step in the decontamination process.

In addition to ground concentration levels and land use information, DECON also makes use of information on property values. DECON compares the value of a property relative to the cost of decontaminating the property. If the decontamination costs exceed the property value, DECON notes that a buy-out and condemnation of the property may be the most attractive alternative.

DECON also permits the user to enter a set of factors--one for each land use--that expresses the fraction of the original property value lost as a result of the accident. The loss in value is the difference between the pre-

accident property value and the value of the property after decontamination has been completed; it is attributed to public perceptions of the health risks associated with the residual contamination. These property losses together with the decontamination costs give a partial estimate of the total accident costs. Other costs not included in the estimate are the costs for surveying, monitoring, medical care, loss of employment, evacuation, and security.

The ground concentrations, the percent distribution of land use categories and property values are supplied for each grid element. This information comprises the site data base. In the next section, DECON is applied to the NUWAX-83 site to demonstrate how it can be used in decontamination planning activities.

3.0 DECONTAMINATION ANALYSIS OF THE NUWAX-83 ACCIDENT SITE

Results on various aspects of the decontamination of Port Gaston, using DECON, are described in this section. First, DECON was run for the entire contaminated area in and around Port Gaston. This run represents the "most likely" scenario, or base case, and is reported in Section 3.1. A variety of different assumptions was then made and the results compared with those from the base case. These are reported in Section 3.2. In Section 3.3 a base case is generated for the residential development Cypress Park. Then the decontamination of Cypress Park is restricted through a ban on the use of operations that use water on exterior surfaces. The results of this scenario are presented in Section 3.4. In Section 3.5 results for a base case scenario for the Port Gaston Industrial Park are presented. These are compared in Section 3.6 with results for the Industrial Park with specific methods being required for certain surfaces. Finally, the last section provides a detailed decontamination analysis for a single grid element.

3.1 PORT GASTON: BASE CASE

For the base case it is assumed that it will be at least 60 days before decontamination can be completed. Thus, the likelihood that precipitation will fall on exterior surfaces prior to this is virtually a certainty. It is also assumed that as a result of decontamination, maximum dose to the lung and bones will not exceed 1.0 and 3.0 millirads per year, respectively. The major results of this run are summarized in Table 4, panel (a). Total costs to decontaminate 391,979 square meters of surface area are $2,119,086, for an average cost of $5.41 per square meter.

Although DECON contains well over 250 decontamination methods at present, 12,272 square meters of surface still could not be adequately decontaminated. The main problem here is that the effect of precipitation on asphalt and concrete surfaces reduces the decontamination efficiencies to the point where even removal and replacement of the surface is inadequate.* One way to solve

*The removal efficiencies used by DECON are based on the contamination originally falling on a surface, even if some of the contaminants subsequently move to another surface. Thus, runoff from rain on paved surfaces will carry contaminants to other surfaces where they will not be removed by removal of the paved surface. However, some of the contamination will be removed when the other surfaces are treated. The removal efficiency estimate is based on a

TABLE 4. Decontamination Results for the NUWAX Site: Base Case

(a) SUMMARY RESULTS FOR EXPOSURE AREA 1 TO EXPOSURE AREA 6

TOTAL DECONTAMINATION COSTS ARE.....	$	2119086.	
TOTAL AREA DECONTAMINATED IS.....		391978.9	SQUARE METERS.
AREA REQUIRING NO DECONTAMINATION IS.....		98109.4	SQUARE METERS.
AREA THAT COULD NOT BE DECONTAMINATED IS.....		12271.8	SQUARE METERS.
PRE-ACCIDENT PROPERTY VALUE IS	$	11570670.	
POST-DECONTAMINATION PROPERTY VALUE IS	$	9835434.	
TOTAL REDUCTION IN PROPERTY VALUE IS	$	1735236.	

(b) TOTAL FACTOR INPUT REQUIREMENTS (MAN/EQUIPMENT HOURS)

COMMON LABOR	19047.21
OPERATOR	23730.81
CRAFTS WORKER	8295.34
SPECIAL LABOR	5.92
LIQUID SPREADER TRUCK	57.61
HAND VACUUM	1722.96
WET VACUUM	1710.82
VACUUMIZED STREET SWEEPER	2.55
DUMP TRUCK	17496.48
TRACTOR	130.92
BACK HOE	22.58
GRADER	126.31
FRONT END LOADER	411.69
HYDROBLAST EQUIPMENT	325.46
SPRAY EQUIPMENT	379.48
NONMOBILE PUMP (HI-PRESSURE WATER)	1904.27
AIR COMPRESSOR AND TOOLS	18.53
CHIPPING MACHINE	136.15
PAVING MACHINE	20.81
ASPHALT PLANT	20.81
ROLLER	48.39
AIRPLANE	3.33
FLOOR SANDING EQUIPMENT	143.14
CEMENT GRINDING EQUIPMENT	54.04
GAS CEMENT FINISH MACHINE	60.51
TANK TRUCK	.13

TABLE 4. (Continued)

(c) TOTAL AREA DECONTAMINATED, BY SURFACE AND METHOD

SURFACE TYPE	METHOD	AREA (SQ. METERS)
AGRICULTURAL FIELDS	WW	15006.
AGRICULTURAL FIELDS	TNxX	388.
ORCHARDS	TDX	5753.
ORCHARDS	TRX	186.
VACANT LAND	WW	51415.
VACANT LAND	TNxX	17786.
VACANT LAND	TNxx	372.
VACANT LAND	NOT DECONTAMINATED	1405.
WOODED LAND	TN	30770.
WOODED LAND	TNX	5446.
EXTERIOR WOOD WALLS	H	6734.
EXTERIOR WOOD WALLS	VTR	712.
EXTERIOR WOOD WALLS	vTR	144.
EXTERIOR WOOD WALLS	TZ	30.
EXTER'R BRICK WALLS	VH	2585.
EXTER'R BRICK WALLS	VO	95.
EXTER'R BRICK WALLS	VTZ	5.
LINOLEUM FLOORS	v	5184.
LINOLEUM FLOORS	VTR	1946.
LINOLEUM FLOORS	vFTR	54.
LINOLEUM FLOORS	NOT DECONTAMINATED	6.
WOOD FLOORS	v	3366.
WOOD FLOORS	vFTR	36.
WOOD FLOORS	VTK	1683.
WOOD FLOORS	vTK	178.
WOOD FLOORS	NOT DECONTAMINATED	7.
CARPETED FLOORS	VTR	12897.
CARPETED FLOORS	vTRJ	393.
CARPETED FLOORS	NOT DECONTAMINATED	108.
CONCRETE FLOORS	v	14145.
CONCRETE FLOORS	vFTK	303.
CONCRETE FLOORS	VH	8500.
CONCRETE FLOORS	NOT DECONTAMINATED	19.
INT'R WOOD/PL WALLS	v	14803.
INT'R WOOD/PL WALLS	J	1545.
INT'R WOOD/PL WALLS	VJ	324.
INT'R WOOD/PL WALLS	vFTR	65.
INT'R CNCRETE WALLS	v	5352.
INT'R CNCRETE WALLS	J	448.
INT'R CNCRETE WALLS	VJ	155.
INT'R CNCRETE WALLS	vFTR	19.
ASPHALT STRTS/ROADS	VP	10364.
ASPHALT STRTS/ROADS	NOT DECONTAMINATED	3910.
CNCRETE STRTS/ROADS	VP	11654.
CNCRETE STRTS/ROADS	NOT DECONTAMINATED	4358.
ROOFS	VW	16870.
ROOFS	CR	9396.
ROOFS	NOT DECONTAMINATED	26.
LAWNS	WW	83474.
LAWNS	XR	46533.
LAWNS	xR	917.
LAWNS	NOT DECONTAMINATED	185.
OTHR PAVED ASPHALT	v	987.
OTHR PAVED ASPHALT	NOT DECONTAMINATED	562.
OTHR PAVED CNCRETE	VP	2962.
OTHR PAVED CNCRETE	NOT DECONTAMINATED	1685.

this problem would be to combine removal and replacement with the operation of scraping. Removal and replacement with scraping would cost about $40 per square meter.

In addition to the problem with the asphalt and concrete surfaces, most of the surfaces contaminated at levels greater than 100 $\mu Ci/m^2$--1,742 square meters--could not be successfully decontaminated with the methods currently available in DECON. Surfaces that could not be decontaminated are identified in Table 4 panel (c), which lists the areas decontaminated by surface type and method used.

It is expected that a major cost of a weapons accident would be a loss in property values even after decontamination has been completed. These losses result because of the perceived health risks associated with the residual levels of contamination. To demonstrate DECON's capability of estimating this effect, a set of property loss factors has been assumed for the base case. These factors are presented in Table 5.0 and give the fraction of the pre-accident property value that has been lost.

TABLE 5. Property Loss Factors from Residual Contamination

Residential	.20	Parking Lots	.05
Commercial	.10	Grain Crops	.25
Industrial	.10	Vegetable Crops	.25
Streets and Roads	.00	Orchards	.25
Wooded Areas	.05	Vacant Land	.10

Because of residual contamination and public perceptions, we estimated that property value losses in Port Gaston amounted to $1,735,236, or an average of 15 percent of the pre-accident property value ($11,570,670). If we add to these property losses the decontamination costs and an estimated $40 per square

Footnote Continued...
judgment regarding the most likely result after the specified method has been used on the specified surface and other likely methods have been used on other surfaces. While there are some difficulties with this approach, we feel it is far superior to the alternative, which would require keeping track of the contaminants and adding and subtracting them from specific surfaces. For example, in the latter approach, land near the edge of a highway or under a roof would have to be processed by DECON differently from other land; furthermore, the additional information required to carry out this approach would be substantial.

meter for surfaces that could not be decontaminated, we arrive at a total damage estimate of $3.4 million. This figure excludes costs for monitoring, security, contaminated waste disposal and other items not explicitly included.

Total factor input requirements--i.e., total hours of labor and equipment--are presented in Table 4, panel (b). Where only a few hours of equipment are specified (e.g., vacuumized street sweeper and tank truck) one should consider the practicality of substituting other equipment that is being used more intensively. Also, it is noted that the cost estimates developed for DECON assume that relatively large areas are to be decontaminated with each of the selected methods. Where this is not the case, a cost premium should be added. This is especially true in circumstances where equipment will have to be thoroughly decontaminated before it can be returned to normal service.

3.2 VARIATIONS ON THE BASE CASE

In this section we consider five variations on the base case. The first utilizes the Quick-Vac option, under which surfaces are vacuumed before rain or snow can carry the contaminated particles onto other surfaces or into inaccessible areas. The second variation assumes that the decontamination can be completed before precipitation falls on exterior surfaces. In the third variation, a ban is placed on decontamination operations that rely on the use of water on exterior surfaces. The fourth variation considers the effect of decontaminating different surfaces to different standards, depending upon the likely human exposure to the various surfaces. The idea here is to determine whether decontamination costs can be decreased without increasing the expected health risks simply by imposing different cleanup standards on different surfaces. Finally, in the fifth case we demonstrate how DECON can be used to generate trade-off relationships between decontamination costs and cleanup standards.

3.2.1 The Quick-Vac Option

The objective of this part of the analysis is to determine whether the Quick-Vac option can produce significant decontamination cost savings. Under this option, exterior surfaces would be vacuumed prior to precipitation, provided it is cost-effective. To exploit this option, state and/or local officials would have to act very quickly to mobilize the necessary manpower and equipment.

Rerunning DECON under the Quick-Vac option shows that savings of over $100,000 could be achieved--total decontamination costs of $2,017,806 vs. $2,119,086 without Quick-Vac (see Table 6, panel (a)). In addition to these savings, about 1500 square meters of surface that could not be decontaminated under the base case could be cleaned up under this option. Panel (c) indicates that the surfaces likely to benefit from the Quick-Vac option are exterior walls, roofs, streets, roads and other paved surfaces.

It is likely that streets and roads in particular could be given a quick pass with street cleaning equipment. Such equipment can achieve an effective coverage rate of 8600 sq. meters per hour. However, the vacuuming of roofs and exterior walls has an effective coverage rate of only 81 and 69 sq. meters per hour, respectively. It is therefore questionable whether much progress could be made on these latter surfaces before it rains or snows, unless large numbers of crews can be quickly mobilized. Finally, we note that DECON selects Quick-Vac only when it is cost-effective; it does not otherwise make a judgment regarding the feasibility of applying Quick-Vac.

In the case of roofs the potential savings might be sufficiently large so that it would pay to cover them with plastic sheeting, thereby protecting them from rain until they can be treated. This protection should result in removal efficiencies equivalent to those associated with decontamination without prior precipitation.

3.2.2 Decontamination Prior to Rain

Generally, precipitation renders most decontamination methods significantly less effective. To measure the effects of precipitation on the decontamination process, DECON was run assuming a 0.0 probability of rain. The results are presented in Table 7.

Total decontamination costs decline to $1.8 million from $2.1 million in the base case. Furthermore, the $1.8 million includes decontaminating about 10,000 square meters of surfaces that could not be decontaminated under the base case. The remaining 1,937 square meters that still can not be decontaminated are almost entirely in areas receiving over 100 $\mu Ci/m^2$ of Pu^{239}.

TABLE 6: Decontamination Results for the NUWAX Site: Quick-Vac Option

(a) SUMMARY RESULTS FOR EXPOSURE AREA 1 TO EXPOSURE AREA 6

*** QUICK-VAC OPTION SELECTED ***		
TOTAL DECONTAMINATION COSTS ARE.....	$ 2017806.	
TOTAL AREA DECONTAMINATED IS.....	393468.2	SQUARE METERS.
AREA REQUIRING NO DECONTAMINATION IS.....	98109.4	SQUARE METERS.
AREA THAT COULD NOT BE DECONTAMINATED IS.....	10782.6	SQUARE METERS.
PRE-ACCIDENT PROPERTY VALUE IS	$ 11570670.	
POST-DECONTAMINATION PROPERTY VALUE IS	$ 9835434.	
TOTAL REDUCTION IN PROPERTY VALUE IS	$ 1735236.	

(b) TOTAL FACTOR INPUT REQUIREMENTS (MAN/EQUIPMENT HOURS)

COMMON LABOR	17273.45
OPERATOR	22660.70
CRAFTS WORKER	7226.74
SPECIAL LABOR	5.92
MOBILE FLUSHER/WATER WAGON	.45
LIQUID SPREADER TRUCK	57.61
HAND VACUUM	1820.31
WET VACUUM	1392.38
VACUUMIZED STREET SWEEPER	2.55
DUMP TRUCK	17422.76
TRACTOR	130.92
BACK HOE	62.29
GRADER	126.31
FRONT END LOADER	411.69
HYDROBLAST EQUIPMENT	30.81
SPRAY EQUIPMENT	359.13
NONMOBILE PUMP (HI-PRESSURE WATER)	1151.54
AIR COMPRESSOR AND TOOLS	18.53
CHIPPING MACHINE	136.15
ASPHALT PLANT	19.86
ROLLER	19.86
HYDRAULIC DEMOLITION HAMMER	39.71
AIRPLANE	3.33
FLOOR SANDING EQUIPMENT	143.14
CEMENT GRINDING EQUIPMENT	30.26
GAS CEMENT FINISH MACHINE	60.51
TANK TRUCK	.13

TABLE 6. (Continued)

(c) TOTAL AREA DECONTAMINATED, BY SURFACE AND METHOD

SURFACE TYPE	METHOD	AREA (SQ. METERS)
AGRICULTURAL FIELDS	WW	15006.
AGRICULTURAL FIELDS	TNxX	388.
ORCHARDS	TDX	5753.
ORCHARDS	TRX	186.
VACANT LAND	WW	51415.
VACANT LAND	TNxX	17786.
VACANT LAND	TNxx	372.
VACANT LAND	NOT DECONTAMINATED	1405.
WOODED LAND	TN	30770.
WOODED LAND	TNX	5446.
EXTERIOR WOOD WALLS	*VW	6734.
EXTERIOR WOOD WALLS	*VH	712.
EXTERIOR WOOD WALLS	*VTR	144.
EXTERIOR WOOD WALLS	TZ	30.
EXTER'R BRICK WALLS	*VW	2452.
EXTER'R BRICK WALLS	*VH	133.
EXTER'R BRICK WALLS	*vH	95.
EXTER'R BRICK WALLS	*VTZ	5.
LINOLEUM FLOORS	v	5184.
LINOLEUM FLOORS	VTR	1946.
LINOLEUM FLOORS	vFTR	54.
LINOLEUM FLOORS	NOT DECONTAMINATED	6.
WOOD FLOORS	v	3366.
WOOD FLOORS	vFTR	36.
WOOD FLOORS	VTK	1683.
WOOD FLOORS	vTK	178.
WOOD FLOORS	NOT DECONTAMINATED	7.
CARPETED FLOORS	VTR	12897.
CARPETED FLOORS	vTRJ	393.
CARPETED FLOORS	NOT DECONTAMINATED	108.
CONCRETE FLOORS	v	14145.
CONCRETE FLOORS	vFTK	303.
CONCRETE FLOORS	VH	8500.
CONCRETE FLOORS	NOT DECONTAMINATED	19.
INT'R WOOD/PL WALLS	v	14803.
INT'R WOOD/PL WALLS	J	1545.
INT'R WOOD/PL WALLS	VJ	324.
INT'R WOOD/PL WALLS	vFTR	65.
INT'R CNCRETE WALLS	v	5352.
INT'R CNCRETE WALLS	J	448.
INT'R CNCRETE WALLS	VJ	155.
INT'R CNCRETE WALLS	vFTR	19.
ASPHALT STRTS/ROADS	*VP	10364.
ASPHALT STRTS/ROADS	NOT DECONTAMINATED	3910.
CNCRETE STRTS/ROADS	*VW	11654.
CNCRETE STRTS/ROADS	NOT DECONTAMINATED	4358.
ROOFS	*VW	16870.
ROOFS	CR	9396.
ROOFS	NOT DECONTAMINATED	26.
LAWNS	WW	83474.
LAWNS	XR	46533.
LAWNS	xR	917.
LAWNS	NOT DECONTAMINATED	185.
OTHR PAVED ASPHALT	*VW	987.
OTHR PAVED ASPHALT	NOT DECONTAMINATED	562.
OTHR PAVED CNCRETE	*VW	2962.
OTHR PAVED CNCRETE	*vR	1489.
OTHR PAVED CNCRETE	NOT DECONTAMINATED	196.

*DENOTES QUICK-VAC OPTION

TABLE 7. Decontamination Results for the NUWAX Site: No Rain

(a) SUMMARY RESULTS FOR EXPOSURE AREA 1 TO EXPOSURE AREA 6

TOTAL DECONTAMINATION COSTS ARE.....	$ 1844056.	
TOTAL AREA DECONTAMINATED IS.....	402313.4	SQUARE METERS.
AREA REQUIRING NO DECONTAMINATION IS.....	98109.4	SQUARE METERS.
AREA THAT COULD NOT BE DECONTAMINATED IS.....	1937.4	SQUARE METERS.
PRE-ACCIDENT PROPERTY VALUE IS	$ 11570670.	
POST-DECONTAMINATION PROPERTY VALUE IS	$ 9835434.	
TOTAL REDUCTION IN PROPERTY VALUE IS	$ 1735236.	

(b) TOTAL FACTOR INPUT REQUIREMENTS (MAN/EQUIPMENT HOURS)

COMMON LABOR	14860.26
OPERATOR	22668.98
CRAFTS WORKER	5378.59
SPECIAL LABOR	5.92
MOBILE FLUSHER/WATER WAGON	.85
LIQUID SPREADER TRUCK	79.79
HAND VACUUM	1474.92
WET VACUUM	1781.18
VACUUMIZED STREET SWEEPER	2.03
SPECIAL VACUUM (SUPER SUCKER, ETC.)	.26
DUMP TRUCK	17420.22
TRACTOR	130.92
BACK HOE	29.66
GRADER	125.54
FRONT END LOADER	411.82
HYDROBLAST EQUIPMENT	13.44
SANDBLAST EQUIPMENT	404.04
SPRAY EQUIPMENT	240.27
NONMOBILE PUMP (HI-PRESSURE WATER)	1062.49
AIR COMPRESSOR AND TOOLS	18.53
CHIPPING MACHINE	136.15
PAVING MACHINE	10.14
ASPHALT PLANT	12.54
ROLLER	25.65
HYDRAULIC DEMOLITION HAMMER	7.08
AIRPLANE	3.33
FLOOR SANDING EQUIPMENT	143.14
CEMENT GRINDING EQUIPMENT	31.58
GAS CEMENT FINISH MACHINE	60.51
ROAD PLANER	.13
TANK TRUCK	.13

TABLE 7. (Continued)

(c) TOTAL AREA DECONTAMINATED, BY SURFACE AND METHOD

SURFACE TYPE	METHOD	AREA (SQ. METERS)
AGRICULTURAL FIELDS	WWW	15006.
AGRICULTURAL FIELDS	TNx	388.
ORCHARDS	TDXW	5753.
ORCHARDS	TRX	186.
VACANT LAND	WWW	51415.
VACANT LAND	TNxX	17786.
VACANT LAND	TNxx	372.
VACANT LAND	NOT DECONTAMINATED	1405.
WOODED LAND	TN	30770.
WOODED LAND	TNX	5446.
EXTERIOR WOOD WALLS	W	6734.
EXTERIOR WOOD WALLS	WJ	144.
EXTERIOR WOOD WALLS	VW	712.
EXTERIOR WOOD WALLS	TZ	30.
EXTER'R BRICK WALLS	W	2452.
EXTER'R BRICK WALLS	VW	133.
EXTER'R BRICK WALLS	VH	95.
EXTER'R BRICK WALLS	vO	5.
LINOLEUM FLOORS	v	5184.
LINOLEUM FLOORS	VTR	1946.
LINOLEUM FLOORS	vFTR	54.
LINOLEUM FLOORS	NOT DECONTAMINATED	6.
WOOD FLOORS	v	3366.
WOOD FLOORS	vFTR	36.
WOOD FLOORS	VTK	1683.
WOOD FLOORS	vTK	178.
WOOD FLOORS	NOT DECONTAMINATED	7.
CARPETED FLOORS	VTR	12897.
CARPETED FLOORS	vTRJ	393.
CARPETED FLOORS	NOT DECONTAMINATED	108.
CONCRETE FLOORS	v	14145.
CONCRETE FLOORS	vFTK	303.
CONCRETE FLOORS	VH	8500.
CONCRETE FLOORS	NOT DECONTAMINATED	19.
INT'R WOOD/PL WALLS	v	14803.
INT'R WOOD/PL WALLS	J	1545.
INT'R WOOD/PL WALLS	VJ	324.
INT'R WOOD/PL WALLS	vFTR	65.
INT'R CNCRETE WALLS	v	5352.
INT'R CNCRETE WALLS	J	448.
INT'R CNCRETE WALLS	VJ	155.
INT'R CNCRETE WALLS	vFTR	19.
ASPHALT STRTS/ROADS	W	10364.
ASPHALT STRTS/ROADS	vR	46.
ASPHALT STRTS/ROADS	vK	142.
ASPHALT STRTS/ROADS	v	3687.
ASPHALT STRTS/ROADS	NOT DECONTAMINATED	35.
CNCRETE STRTS/ROADS	W	11654.
CNCRETE STRTS/ROADS	vFR	144.
CNCRETE STRTS/ROADS	vP	4109.
CNCRETE STRTS/ROADS	NOT DECONTAMINATED	105.
ROOFS	S	8485.
ROOFS	W	16870.
ROOFS	R	911.
ROOFS	NOT DECONTAMINATED	26.
LAWNS	WW	83474.
LAWNS	XR	46533.
LAWNS	xR	917.
LAWNS	NOT DECONTAMINATED	185.
OTHR PAVED ASPHALT	W	987.
OTHR PAVED ASPHALT	vR	11.
OTHR PAVED ASPHALT	vK	53.
OTHR PAVED ASPHALT	v	496.
OTHR PAVED ASPHALT	NOT DECONTAMINATED	2.
OTHR PAVED CNCRETE	W	2962.
OTHR PAVED CNCRETE	vFR	158.
OTHR PAVED CNCRETE	vP	1489.
OTHR PAVED CNCRETE	NOT DECONTAMINATED	39.

3.2.3 Restrictions: Prohibiting the Application of Water

DECON was next applied to determine what the effect would be of prohibiting the use of water while decontaminating exterior surfaces. Contaminated water has the potential of creating major problems. It can penetrate the root systems of plants, crops and trees and contaminate water treatment facilities. The benefits from using water--a cheap and effective way to reduce dosage through the external and inhalation pathways--must therefore be carefully weighed against the costs. The results of running DECON with a ban on operations using water (i.e., operations W, H, Q, U, L and E--see Table 1) are presented in Table 8.

With a ban on the use of water on exterior surfaces, decontamination costs soar to $3.4 million. A comparison of Table 4, panel (c) with Table 8, panel (c) reveals which surfaces account for the increased costs. Agricultural fields, vacant land, roofs and lawns all relied to a major extent on water methods for successful decontamination. With the restriction in effect, agricultural fields and vacant land are fixed, cleared and scraped, roofs are sandblasted and lawns are resodded.

3.2.4 Decontamination Criteria Dependent upon Expected Exposures

Another application of DECON relates to its ability to allow cleanup standards to be adjusted according to the type of surface. The potential usefulness of this feature lies in the fact that human exposure rates to different surfaces varies considerably. Housing interiors, for example, would usually give high exposure rates while highways and wooded areas would tend to offer low exposure rates. The exposure factors are defined as being inversely proportional to the target decontamination factors, and with values in the base case equal to 1.0. Thus, an exposure factor of 2.0 means that the target decontamination factor for the surface will be just half of what it would be with an exposure factor of 1.0. To illustrate this feature, DECON was run with the following exposure factor values:

TABLE 8. Decontamination Results for the NUWAX Site: No Water Methods

(a) SUMMARY RESULTS FOR EXPOSURE AREA 1 TO EXPOSURE AREA 6

TOTAL DECONTAMINATION COSTS ARE.....	$ 3402992.	
TOTAL AREA DECONTAMINATED IS.....	391978.9	SQUARE METERS.
AREA REQUIRING NO DECONTAMINATION IS.....	98109.4	SQUARE METERS.
AREA THAT COULD NOT BE DECONTAMINATED IS.....	12271.8	SQUARE METERS.
PRE-ACCIDENT PROPERTY VALUE IS	$ 11570670.	
POST-DECONTAMINATION PROPERTY VALUE IS	$ 9835434.	
TOTAL REDUCTION IN PROPERTY VALUE IS	$ 1735236.	

(b) TOTAL FACTOR INPUT REQUIREMENTS (MAN/EQUIPMENT HOURS)

COMMON LABOR	38811.44
OPERATOR	32686.80
CRAFTS WORKER	20096.71
SPECIAL LABOR	5.92
LIQUID SPREADER TRUCK	38.90
HAND VACUUM	1514.68
WET VACUUM	2624.80
VACUUMIZED STREET SWEEPER	2.55
DUMP TRUCK	22346.72
TRACTOR	205.95
BACK HOE	22.58
GRADER	392.00
FRONT END LOADER	617.35
HYDROBLAST EQUIPMENT	62.35
SANDBLAST EQUIPMENT	803.35
SPRAY EQUIPMENT	680.86
AIR COMPRESSOR AND TOOLS	18.53
CHIPPING MACHINE	136.15
PAVING MACHINE	20.81
ASPHALT PLANT	20.81
ROLLER	48.39
AIRPLANE	3.38
FLOOR SANDING EQUIPMENT	143.14
CEMENT GRINDING EQUIPMENT	1550.29
GAS CEMENT FINISH MACHINE	1760.50
TANK TRUCK	5.13

TABLE 8. (Continued)

(c) TOTAL AREA DECONTAMINATED, BY SURFACE AND METHOD

SURFACE TYPE	METHOD	AREA (SQ. METERS)
AGRICULTURAL FIELDS	TNx	15006.
AGRICULTURAL FIELDS	TNxX	388.
ORCHARDS	TDX	5753.
ORCHARDS	TRX	186.
VACANT LAND	TNx	51415.
VACANT LAND	TNxX	17786.
VACANT LAND	TNxx	372.
VACANT LAND	NOT DECONTAMINATED	1405.
WOODED LAND	TN	30770.
WOODED LAND	TNX	5446.
EXTERIOR WOOD WALLS	TR	6734.
EXTERIOR WOOD WALLS	VTR	712.
EXTERIOR WOOD WALLS	vTR	144.
EXTERIOR WOOD WALLS	TZ	30.
EXTER'R BRICK WALLS	VO	2680.
EXTER'R BRICK WALLS	VTZ	5.
LINOLEUM FLOORS	v	5184.
LINOLEUM FLOORS	VTR	1946.
LINOLEUM FLOORS	vFTR	54.
LINOLEUM FLOORS	NOT DECONTAMINATED	6.
WOOD FLOORS	v	3866.
WOOD FLOORS	vFTR	36.
WOOD FLOORS	VTK	1683.
WOOD FLOORS	vTK	178.
WOOD FLOORS	NOT DECONTAMINATED	7.
CARPETED FLOORS	VTR	12897.
CARPETED FLOORS	vTRJ	393.
CARPETED FLOORS	NOT DECONTAMINATED	108.
CONCRETE FLOORS	v	14145.
CONCRETE FLOORS	VTK	8500.
CONCRETE FLOORS	vFTK	303.
CONCRETE FLOORS	NOT DECONTAMINATED	19.
INT'R WOOD/PL WALLS	v	14803.
INT'R WOOD/PL WALLS	J	1545.
INT'R WOOD/PL WALLS	VJ	324.
INT'R WOOD/PL WALLS	vFTR	65.
INT'R CNCRETE WALLS	v	5352.
INT'R CNCRETE WALLS	J	448.
INT'R CNCRETE WALLS	VJ	155.
INT'R CNCRETE WALLS	vFTR	19.
ASPHALT STRTS/ROADS	VP	10364.
ASPHALT STRTS/ROADS	NOT DECONTAMINATED	3910.
CNCRETE STRTS/ROADS	VP	11654.
CNCRETE STRTS/ROADS	NOT DECONTAMINATED	4358.
ROOFS	S	16870.
ROOFS	CR	9396.
ROOFS	NOT DECONTAMINATED	26.
LAWNS	R	83474.
LAWNS	XR	46533.
LAWNS	xR	917.
LAWNS	NOT DECONTAMINATED	185.
OTHR PAVED ASPHALT	v	987.
OTHR PAVED ASPHALT	NOT DECONTAMINATED	562.
OTHR PAVED CNCRETE	VP	2962.
OTHR PAVED CNCRETE	NOT DECONTAMINATED	1685.

Agricultural Fields	1.0	Streets/Roads, Asphalt	6.0
Orchards	4.0	Streets/Roads, Concrete	6.0
Vacant Land	10.0	Wooded Land	10.0
Exterior Walls, Wood	1.5	Exterior Walls, Brick	1.5
Floors, Linoluem	0.5	Floors, Wood	0.5
Floors, Carpeted	0.5	Floors, Concrete	1.5
Interior Walls, Painted	0.5	Interior Walls, Concrete	1.5
Roofs	1.0	Lawns	1.3
Vehicle Transport	10.0	Auto Exteriors	2.0
Auto Interiors	0.9	Auto Tires	5.0
Auto Engine/Drive Train	1.6	Other Paved Surfaces/Asphalt	1.0
Other Paved Surfaces/Con.	1.0		

The results of this analysis are summarized in Table 9 panel (a). Total decontamination costs are a little over half of those in the base case: just $1.14 million. More than 180,000 square meters of surface--nearly twice the area of the base case--require no decontamination at all. Finally, only 3,300 square meters could not be decontaminated, versus 12,300 in the base case. Based on this very preliminary result, varying the cleanup criteria according to expected exposure rate has the potential to provide significant cost savings without creating any additional health risk. However, if this option were to be exercised in practice, it would be important to take precautions to ensure that no one would receive high doses from surfaces with large exposure factors (i.e., rated for low exposures).

3.2.5 The Trade-Off Between Cleanup Standards and Decontamination Costs

In this example DECON is used to demonstrate how one can establish the trade-off relationship between cleanup standards and decontamination costs. In the examples up to this point, radiation limits of 1.0 millirad and 3.0 millirads per year have been in effect for the lung and bone, respectively. We now consider corresponding radiation limits of 0.1 and 0.3 millirads; 0.3 and 0.9 millirads; 0.7 and 2.1 millirads; 3.0 and 9.0 millirads; 6.0 and 18.0 millirads; and 12.0 and 36.0 millirads. The results are presented in Table 10. The surface area that could not be decontaminated using methods currently in DECON should be especially noted. Over 65,000 square meters could not be decontaminated with a (0.1,0.3) standard, compared with 12,271 with a (1.0,3.0) standard and just 95 square meters with a (12.0,36.0) standard. Methods adequate for decontaminating these surfaces will be costly, especially in those cases where the cleanup standards are very strict.

TABLE 9. Decontamination Results for the NUWAX Site; Varied Exposure Factors

(a) SUMMARY RESULTS FOR EXPOSURE AREA 1 TO EXPOSURE AREA 6

TOTAL DECONTAMINATION COSTS ARE	$	1136503.
TOTAL AREA DECONTAMINATED IS		318733.3 SQUARE METERS.
AREA REQUIRING NO DECONTAMINATION IS		180294.0 SQUARE METERS.
AREA THAT COULD NOT BE DECONTAMINATED IS		3332.8 SQUARE METERS.
PRE-ACCIDENT PROPERTY VALUE IS	$	11570670.
POST-DECONTAMINATION PROPERTY VALUE IS	$	9835434.
TOTAL REDUCTION IN PROPERTY VALUE IS	$	1735236.

(b) TOTAL FACTOR INPUT REQUIREMENTS (MAN/EQUIPMENT HOURS)

COMMON LABOR	16806.51
OPERATOR	4389.60
CRAFTS WORKER	8454.64
SPECIAL LABOR	.80
MOBILE FLUSHER/WATER WAGON	.85
LIQUID SPREADER TRUCK	22.26
HAND VACUUM	1116.81
WET VACUUM	2289.64
VACUUMIZED STREET SWEEPER	1.87
DUMP TRUCK	2271.52
TRACTOR	130.92
BACK HOE	4.64
GRADER	25.23
FRONT END LOADER	173.06
HYDROBLAST EQUIPMENT	32.49
SPRAY EQUIPMENT	371.56
NONMOBILE PUMP (HI-PRESSURE WATER)	95.63
CHIPPING MACHINE	20.48
PAVING MACHINE	14.86
ASPHALT PLANT	14.86
ROLLER	30.54
HYDRAULIC DEMOLITION HAMMER	3.93
AIRPLANE	.41
FLOOR SANDING EQUIPMENT	129.45
TANK TRUCK	.13

TABLE 9. (Continued)

(c) TOTAL AREA DECONTAMINATED, BY SURFACE AND METHOD

SURFACE TYPE	METHOD	AREA (SQ. METERS)
AGRICULTURAL FIELDS	WW	15006.
AGRICULTURAL FIELDS	TNxX	388.
ORCHARDS	WW	5753.
ORCHARDS	TDXW	186.
VACANT LAND	WW	15429.
VACANT LAND	TNx	2357.
VACANT LAND	TNxX	372.
VACANT LAND	TNxx	1405.
WOODED LAND	TN	5446.
EXTERIOR WOOD WALLS	VW	6734.
EXTERIOR WOOD WALLS	VTR	857.
EXTERIOR WOOD WALLS	TZ	30.
EXTER'R BRICK WALLS	VW	2452.
EXTER'R BRICK WALLS	VH	133.
EXTER'R BRICK WALLS	vH	95.
EXTER'R BRICK WALLS	VTZ	5.
LINOLEUM FLOORS	J	5184.
LINOLEUM FLOORS	VTR	1801.
LINOLEUM FLOORS	vFTR	145.
LINOLEUM FLOORS	NOT DECONTAMINATED	60.
WOOD FLOORS	J	3366.
WOOD FLOORS	vFTR	178.
WOOD FLOORS	VTK	1683.
WOOD FLOORS	NOT DECONTAMINATED	44.
CARPETED FLOORS	VTR	8967.
CARPETED FLOORS	vTR	3930.
CARPETED FLOORS	NOT DECONTAMINATED	501.
CONCRETE FLOORS	V	14145.
CONCRETE FLOORS	vJ	8038.
CONCRETE FLOORS	VH	462.
CONCRETE FLOORS	vH	303.
CONCRETE FLOORS	NOT DECONTAMINATED	19.
INT'R WOOD/PL WALLS	J	14803.
INT'R WOOD/PL WALLS	VJ	1545.
INT'R WOOD/PL WALLS	VTR	324.
INT'R WOOD/PL WALLS	NOT DECONTAMINATED	65.
INT'R CNCRETE WALLS	V	5352.
INT'R CNCRETE WALLS	J	602.
INT'R CNCRETE WALLS	vU	19.
ASPHALT STRTS/ROADS	W	10364.
ASPHALT STRTS/ROADS	vR	142.
ASPHALT STRTS/ROADS	v	3687.
ASPHALT STRTS/ROADS	NOT DECONTAMINATED	81.
CNCRETE STRTS/ROADS	W	11654.
CNCRETE STRTS/ROADS	vR	144.
CNCRETE STRTS/ROADS	vP	4109.
CNCRETE STRTS/ROADS	NOT DECONTAMINATED	105.
ROOFS	VW	16870.
ROOFS	CR	9396.
ROOFS	NOT DECONTAMINATED	26.
LAWNS	WW	83474.
LAWNS	XR	46533.
LAWNS	xR	917.
LAWNS	NOT DECONTAMINATED	185.
OTHR PAVED ASPHALT	v	987.
OTHR PAVED ASPHALT	NOT DECONTAMINATED	562.
OTHR PAVED CNCRETE	VP	2962.
OTHR PAVED CNCRETE	NOT DECONTAMINATED	1685.

TABLE 10. Trade-Off Between Radiation Standards and Decontamination Costs

Radiation Standard (mR to Lung)	Total Cost to Decontaminate	Cost Per Square Meter	Area Not Decontaminated Unable to	Unnecessary to
0.1	$5,067,269	$11.78	65,735.6	6,532.4
0.3	4,075,001	8.56	19,760.4	6,532.4
0.7	3,444,947	7.92	12,747.8	54,642.0
1.0	2,119,086	5.41	12,271.8	98,109.4
3.0	967,310	2.40	781.4	98,109.4
6.0	675,889	1.92	285.6	149,926.3
12.0	297,296	2.61	95.0	388,367.9

3.3 CYPRESS PARK: BASE CASE

DECON can be used to analyze virtually any subarea within an accident site. To demonstrate this capability we have applied DECON to the irregular area that defines the residential development Cypress Park (see Figure 1). Except for the area involved, the other relevant parameters are the same as in the NUWAX base case. The results are summarized in Table 11, panel (a). Total decontamination costs are $323,469 with 77,543 square meters decontaminated, for an average per square meter cost of $4.17. In addition, approximately 19 percent--or about $700,000--of the original property value of $370 thousand was lost because of residual contamination. Nearly 2,500 square meters of asphalt and concrete surfaces could not be decontaminated.

3.4 CYPRESS PARK: BAN ON WATER OPERATIONS

In this example it is hypothesized that the residents of Cypress Park are apprehensive about allowing the contaminants to penetrate into the soil. An analysis is required to determine the additional decontamination costs if methods using water are to be rejected. The results with water methods prohibited are reported in Table 12. Total decontamination costs increase substantially to $567,126, for an average per square meter cost of $7.31. Vacant land is now fixed, cleared and scraped; roofs are sandblasted; and lawns are resodded.

3.5 INDUSTRIAL PARK: BASE CASE

DECON can also provide an analysis where a particular decontamination method is specified. For example, the contamination may have occurred in a foreign country where only minimal equipment or materials are available for the

TABLE 11. Decontamination Results for Cypress Park: Base Case

(a) SUMMARY RESULTS FOR EXPOSURE AREA 63 TO EXPOSURE AREA 416

TOTAL DECONTAMINATION COSTS ARE.....	$ 323469.	
TOTAL AREA DECONTAMINATED IS.....	77543.4	SQUARE METERS.
AREA REQUIRING NO DECONTAMINATION IS.....	21565.3	SQUARE METERS.
AREA THAT COULD NOT BE DECONTAMINATED IS.....	2458.7	SQUARE METERS.
PRE-ACCIDENT PROPERTY VALUE IS	$ 3700920.	
POST-DECONTAMINATION PROPERTY VALUE IS	$ 2997846.	
TOTAL REDUCTION IN PROPERTY VALUE IS	$ 703074.	

(b) TOTAL FACTOR INPUT REQUIREMENTS (MAN/EQUIPMENT HOURS)

COMMON LABOR	3801.24
OPERATOR	2134.44
CRAFTS WORKER	1724.08
SPECIAL LABOR	.41
LIQUID SPREADER TRUCK	1.13
HAND VACUUM	412.64
WET VACUUM	200.11
VACUUMIZED STREET SWEEPER	.50
DUMP TRUCK	1281.73
TRACTOR	31.68
GRADER	1.53
FRONT END LOADER	44.05
HYDROBLAST EQUIPMENT	42.33
SPRAY EQUIPMENT	80.92
NONMOBILE PUMP (HI-PRESSURE WATER)	384.44
CHIPPING MACHINE	10.84
PAVING MACHINE	5.12
ASPHALT PLANT	5.12
ROLLER	10.19
AIRPLANE	.21
FLOOR SANDING EQUIPMENT	36.88

TABLE 11. (Continued)

(c) TOTAL AREA DECONTAMINATED, BY SURFACE AND METHOD

SURFACE TYPE	METHOD	AREA (SQ. METERS)
VACANT LAND	WW	1538.
VACANT LAND	TNxX	255.
WOODED LAND	TN	2453.
WOODED LAND	TNX	430.
EXTERIOR WOOD WALLS	H	1887.
EXTERIOR WOOD WALLS	VTR	32.
EXTER'R BRICK WALLS	VH	339.
LINOLEUM FLOORS	v	985.
LINOLEUM FLOORS	VTR	384.
WOOD FLOORS	v	1231.
WOOD FLOORS	VTK	472.
WOOD FLOORS	vTK	8.
CARPETED FLOORS	VTR	3746.
CARPETED FLOORS	vTRJ	17.
CONCRETE FLOORS	v	3051.
CONCRETE FLOORS	VH	1188.
INT'R WOOD/PL WALLS	v	4090.
INT'R WOOD/PL WALLS	J	68.
INT'R CNCRETE WALLS	v	1169.
INT'R CNCRETE WALLS	J	20.
ASPHALT STRTS/ROADS	VP	2143.
ASPHALT STRTS/ROADS	NOT DECONTAMINATED	946.
CNCRETE STRTS/ROADS	VP	2143.
CNCRETE STRTS/ROADS	NOT DECONTAMINATED	946.
ROOFS	VW	4358.
ROOFS	CR	1697.
LAWNS	WW	30507.
LAWNS	XR	11881.
OTHR PAVED ASPHALT	v	363.
OTHR PAVED ASPHALT	NOT DECONTAMINATED	141.
OTHR PAVED CNCRETE	VP	1090.
OTHR PAVED CNCRETE	NOT DECONTAMINATED	424.

TABLE 12. Decontamination Results for Cypress Park: Ban on Water Operations

(a) SUMMARY RESULTS FOR EXPOSURE AREA 63 TO EXPOSURE AREA 416

TOTAL DECONTAMINATION COSTS ARE.....	$	567126.	
TOTAL AREA DECONTAMINATED IS.....		77543.4	SQUARE METERS.
AREA REQUIRING NO DECONTAMINATION IS.....		21565.3	SQUARE METERS.
AREA THAT COULD NOT BE DECONTAMINATED IS.....		2458.7	SQUARE METERS.
PRE-ACCIDENT PROPERTY VALUE IS	$	3700920.	
POST-DECONTAMINATION PROPERTY VALUE IS	$	2997846.	
TOTAL REDUCTION IN PROPERTY VALUE IS	$	703074.	

(b) TOTAL FACTOR INPUT REQUIREMENTS (MAN/EQUIPMENT HOURS)

COMMON LABOR	8951.85
OPERATOR	3415.34
CRAFTS WORKER	4792.72
SPECIAL LABOR	.41
LIQUID SPREADER TRUCK	.72
HAND VACUUM	358.84
WET VACUUM	420.26
VACUUMIZED STREET SWEEPER	.50
DUMP TRUCK	1423.19
TRACTOR	31.68
GRADER	7.68
FRONT END LOADER	50.20
SANDBLAST EQUIPMENT	207.53
SPRAY EQUIPMENT	150.07
CHIPPING MACHINE	10.84
PAVING MACHINE	5.12
ASPHALT PLANT	5.12
ROLLER	10.19
AIRPLANE	.21
FLOOR SANDING EQUIPMENT	36.88
CEMENT GRINDING EQUIPMENT	203.47
GAS CEMENT FINISH MACHINE	237.63

TABLE 12. (Continued)

(c) TOTAL AREA DECONTAMINATED, BY SURFACE AND METHOD

SURFACE TYPE	METHOD	AREA (SQ. METERS)
VACANT LAND	TNx	1538.
VACANT LAND	TNxX	255.
WOODED LAND	TN	2453.
WOODED LAND	TNX	430.
EXTERIOR WOOD WALLS	TR	1887.
EXTERIOR WOOD WALLS	VTR	32.
EXTER'R BRICK WALLS	VO	339.
LINOLEUM FLOORS	v	985.
LINOLEUM FLOORS	VTR	384.
WOOD FLOORS	v	1231.
WOOD FLOORS	VTK	472.
WOOD FLOORS	vTK	8.
CARPETED FLOORS	VTR	3746.
CARPETED FLOORS	vTRJ	17.
CONCRETE FLOORS	v	3051.
CONCRETE FLOORS	VTK	1188.
INT'R WOOD/PL WALLS	v	4090.
INT'R WOOD/PL WALLS	J	68.
INT'R CNCRETE WALLS	v	1169.
INT'R CNCRETE WALLS	J	20.
ASPHALT STRTS/ROADS	VP	2143.
ASPHALT STRTS/ROADS	NOT DECONTAMINATED	946.
CNCRETE STRTS/ROADS	VP	2143.
CNCRETE STRTS/ROADS	NOT DECONTAMINATED	946.
ROOFS	S	4358.
ROOFS	CR	1697.
LAWNS	R	30507.
LAWNS	XR	11881.
OTHR PAVED ASPHALT	v	363.
OTHR PAVED ASPHALT	NOT DECONTAMINATED	141.
OTHR PAVED CNCRETE	VP	1090.
OTHR PAVED CNCRETE	NOT DECONTAMINATED	424.

cleanup. Alternatively, a method may be preferred if it is not significantly more costly than the method selected by DECON. With this feature of DECON, the alternative method can be checked out to evaluate more fully its relative merits. To illustrate this technique, we first run a base case for the Port Gaston Industrial Park. The results are reported in Table 13. Nearly 25,000 square meters of surfaces are decontaminated at a total cost of about $150,000, or about $6 per square meter. It was unnecessary to decontaminate another 25,000 square meters of surfaces, while 1,350 square meters of surfaces could not be decontaminated with methods currently in DECON. Prior to the accident, property within the industrial park had a market value of $3.25 million. After decontamination has been completed, property losses will amount to $193 thousand.

3.6 INDUSTRIAL PARK: PRE-SPECIFIED DECONTAMINATION METHODS

To illustrate the use of pre-specified decontamination methods, we will require that the following methods be used within the Port Gaston Industrial Park: exterior brick walls - vacuum and scarify; vacant land - fix, clear and scrape as necessary; asphalt and concrete roads - add a thin layer of asphalt; roofs - fix with strippable coating and replace; lawns - scrape as necessary and resod. The results with these restrictions are presented in Table 14.

These restrictions cause decontamination costs to increase from $148 thousand to $272 thousand. The latter figure includes decontamination of 448 square meters of asphalt streets/roads and 895 square meters of concrete streets/roads that were not decontaminated without the restrictions. It is noted that the required method is adopted regardless of whether or not it satisfies the cleanup criteria. In the case of these streets and roads, adding a thin layer of asphalt to the surface will not decontaminate these surfaces to the pre-specified cleanup standard.

3.7 MICRO-ANALYSIS OF THE ACCIDENT SITE

The features of DECON discussed so far are well-suited to planning an overall decontamination strategy. However, for detailed decontamination planning and analysis, one would like to have specific information about each grid element within the contaminated area. DECON has the ability to provide this information, including the quantity of each surface type within the grid element and the most cost-effective decontamination method to use on that

TABLE 13. Decontamination Results for Port Gaston Industrial Park: Base Case

(a) SUMMARY RESULTS FOR EXPOSURE AREA 963 TO EXPOSURE AREA 1181

TOTAL DECONTAMINATION COSTS ARE.....	$	148198.
TOTAL AREA DECONTAMINATED IS.....		24750.7 SQUARE METERS.
AREA REQUIRING NO DECONTAMINATION IS.....		24659.5 SQUARE METERS.
AREA THAT COULD NOT BE DECONTAMINATED IS.....		1355.7 SQUARE METERS.
PRE-ACCIDENT PROPERTY VALUE IS	$	3232682.
POST-DECONTAMINATION PROPERTY VALUE IS	$	3039454.
TOTAL REDUCTION IN PROPERTY VALUE IS	$	193228.

(b) TOTAL FACTOR INPUT REQUIREMENTS (MAN/EQUIPMENT HOURS)

COMMON LABOR	2604.32
OPERATOR	768.22
CRAFTS WORKER	853.04
LIQUID SPREADER TRUCK	1.18
HAND VACUUM	266.69
WET VACUUM	697.80
VACUUMIZED STREET SWEEPER	.23
DUMP TRUCK	202.27
TRACTOR	1.25
GRADER	8.03
FRONT END LOADER	9.28
HYDROBLAST EQUIPMENT	158.78
SPRAY EQUIPMENT	54.27
NONMOBILE PUMP (HI-PRESSURE WATER)	485.86
PAVING MACHINE	1.51
ASPHALT PLANT	1.51
ROLLER	4.54
CEMENT GRINDING EQUIPMENT	38.74
GAS CEMENT FINISH MACHINE	42.64

(c) TOTAL AREA DECONTAMINATED, BY SURFACE AND METHOD

SURFACE TYPE	METHOD	AREA (SQ. METERS)
VACANT LAND	WW	964.
VACANT LAND	TNxX	1338.
EXTER'R BRICK WALLS	VH	1270.
EXTER'R BRICK WALLS	VO	70.
LINOLEUM FLOORS	v	589.
LINOLEUM FLOORS	VTR	457.
LINOLEUM FLOORS	vFTR	25.
CARPETED FLOORS	VTR	522.
CARPETED FLOORS	vTRJ	1.
CARPETED FLOORS	NOT DECONTAMINATED	13.
CONCRETE FLOORS	v	5011.
CONCRETE FLOORS	vFTK	213.
CONCRETE FLOORS	VH	3887.
INT'R WOOD/PL WALLS	v	208.
INT'R WOOD/PL WALLS	J	1.
INT'R WOOD/PL WALLS	VJ	11.
INT'R CNCRETE WALLS	v	1181.
INT'R CNCRETE WALLS	J	7.
INT'R CNCRETE WALLS	VJ	65.
ASPHALT STRTS/ROADS	VP	703.
ASPHALT STRTS/ROADS	NOT DECONTAMINATED	448.
CNCRETE STRTS/ROADS	VP	1280.
CNCRETE STRTS/ROADS	NOT DECONTAMINATED	895.
ROOFS	VW	3275.
ROOFS	CR	2680.
LAWNS	WW	546.
LAWNS	XR	423.
LAWNS	xR	23.

FIGURE 14. Decontamination Results for Port Gaston Industrial Park: Pre-Specified Decontamination Methods

(a) SUMMARY RESULTS FOR EXPOSURE AREA 963 TO EXPOSURE AREA 1181

TOTAL DECONTAMINATION COSTS ARE.....	$	271502.	
TOTAL AREA DECONTAMINATED IS.....		26093.9	SQUARE METERS.
AREA REQUIRING NO DECONTAMINATION IS.....		24659.5	SQUARE METERS.
AREA THAT COULD NOT BE DECONTAMINATED IS.....		12.5	SQUARE METERS.
PRE-ACCIDENT PROPERTY VALUE IS	$	3232682.	
POST-DECONTAMINATION PROPERTY VALUE IS	$	3039454.	
TOTAL REDUCTION IN PROPERTY VALUE IS	$	193228.	

(b) TOTAL FACTOR INPUT REQUIREMENTS (MAN/EQUIPMENT HOURS)

COMMON LABOR	4487.83
OPERATOR	425.43
CRAFTS WORKER	1482.82
LIQUID SPREADER TRUCK	.92
HAND VACUUM	226.26
WET VACUUM	856.58
VACUUMIZED STREET SWEEPER	.39
DUMP TRUCK	301.54
TRACTOR	1.25
GRADER	11.88
FRONT END LOADER	13.14
SPRAY EQUIPMENT	94.20
NONMOBILE PUMP (HI-PRESSURE WATER)	485.86
PAVING MACHINE	2.57
ASPHALT PLANT	2.57
ROLLER	7.72
CEMENT GRINDING EQUIPMENT	356.30
GAS CEMENT FINISH MACHINE	42.64

(c) TOTAL AREA DECONTAMINATED, BY SURFACE AND METHOD

SURFACE TYPE	METHOD	AREA (SQ. METERS)
VACANT LAND	TNx	964.
VACANT LAND	TNxX	1338.
EXTER'R BRICK WALLS	VO	1340.
LINOLEUM FLOORS	v	589.
LINOLEUM FLOORS	VTR	457.
LINOLEUM FLOORS	vFTR	25.
CARPETED FLOORS	VTR	522.
CARPETED FLOORS	vTRJ	1.
CARPETED FLOORS	NOT DECONTAMINATED	13.
CONCRETE FLOORS	v	5011.
CONCRETE FLOORS	vFTK	213.
CONCRETE FLOORS	VH	3887.
INT'R WOOD/PL WALLS	v	208.
INT'R WOOD/PL WALLS	J	1.
INT'R WOOD/PL WALLS	VJ	11.
INT'R CNCRETE WALLS	v	1181.
INT'R CNCRETE WALLS	J	7.
INT'R CNCRETE WALLS	VJ	65.
ASPHALT STRTS/ROADS	VP	1150.
CNCRETE STRTS/ROADS	VP	2175.
ROOFS	CR	5955.
LAWNS	R	546.
LAWNS	XR	423.
LAWNS	xR	23.

surface. Other useful information is provided as well. A complete output for a single grid element is presented in Table 15. The grid element selected is within the residential development of Hillview.

One piece of information in Table 15 requires some additional explanation. In panel (d) there is an item labeled "Total Potential Savings from Property Buy-Out: 1) at Pre-Accident Property Values, and at 2) Post-Decontamination Property Values." If the cost to decontaminate an entire grid element exceeds either the pre-accident or post-decontamination value of the property within that grid element, then the difference between the decontamination cost and the pre-accident/post-decontamination cost is presented. This is the potential savings from compensating the property owner for his losses and then condemning the property (rather than decontaminating it).

Panel (d) at the end of Table 15 repeats information presented in panel (b). However, if a detailed analyis is requested on a group of grid elements, say those within the industrial park, then panels (d) through (e) will summarize the information for all of the grid elements while panels (a) through (c) will provide information on each of the grid elements. Thus, where a group of grid elements is analyzed, the various panels do not duplicate the information presented.

Restrictions on the use of particular methods, the Quick-Vac option and the other special features of DECON noted earlier can also be applied with respect to the micro-analysis. Thus, very detailed strategies can be analyzed and incorporated into the overall decontamination plan.

TABLE 15. Micro-Analysis of a Single Grid Element

(a) SUMMARY RESULTS FOR GRID ELEMENT 778

*** RAIN ***

PROB. OF RAIN/SNOW BEFORE DECONTAMINATING... 1.0000.

SURFACE	AREA	DOSE	ATDF	METH	DF	COST/M**2	TOT. COST	RATE
EXTERIOR WOOD WALLS	31	5.50	5.5	W	6.7	.0095	.30	2200
EXTER'R BRICK WALLS	5	5.50	5.5	W	6.7	.0095	.05	2200
LINOLEUM FLOORS	6	27.50	27.5	vJ	33.3	1.1000	6.93	36
WOOD FLOORS	7	27.50	27.5	vJ	33.3	1.1000	8.66	36
CARPETED FLOORS	17	27.50	27.5	VTR	50.0	24.6800	427.50	3
CONCRETE FLOORS	19	27.50	27.5	vJ	33.3	1.1000	21.46	36
INT'R WOOD/PL WALLS	68	2.75	2.8	V	4.0	.2700	18.44	69
INT'R CNCRETE WALLS	19	2.75	2.8	V	4.0	.2700	5.27	69
ROOFS	27	55.00	55.0	CR	1999.9	21.8800	609.82	26
LAWNS	195	55.00	55.0	XR	333.3	5.0100	977.44	90
OTHR PAVED ASPHALT	2	55.00	55.0	////	********	*********	**********	*****
OTHR PAVED CNCRETE	6	55.00	55.0	////	********	*********	**********	*****

NOTES:
- * = QUICK-VAC
- + = REQUIRED METHOD
- / = RESTRICTED OPERATION(S) ARE IN EFFECT
- //// = UNABLE TO DECONTAMINATE SURFACE
- ---- = UNNECESSARY TO DECONTAMINATE SURFACE

(b) SUMMARY RESULTS FOR GRID ELEMENT 778

TOTAL SURFACE AREA DECONTAMINATED	398.8	SQ. METERS
TOTAL SURFACE AREA NOT DECONTAMINATED	9.3	SQ. METERS
PROBABILITY OF RAIN/SNOW BEFORE DECONTAMINATING	1.0000.	
TOTAL COST OF DECONTAMINATING THIS GRID ELEMENT $	2076.	
PRE-ACCIDENT PROPERTY VALUE OF THIS GRID ELEMENT $	10453.	
POST-DECONTAMINATION PROPERTY VALUE OF THIS GRID ELEMENT $	8362.	

(c) FACTOR INPUT REQUIREMENTS
(MAN/EQUIPMENT HOURS)

COMMON LABOR	28.31
OPERATOR	8.58
CRAFTS WORKER	11.13
HAND VACUUM	2.12
WET VACUUM	.94
DUMP TRUCK	1.04
TRACTOR	.52
FRONT END LOADER	.52
SPRAY EQUIPMENT	.56

TABLE 15. (Continued)

(d) SUMMARY RESULTS FOR GRID ELEMENT 778 TO GRID ELEMENT 778

TOTAL DECONTAMINATION COSTS ARE.....	$	2076.	
TOTAL AREA DECONTAMINATED IS.....		398.8	SQUARE METERS.
AREA REQUIRING NO DECONTAMINATION IS.....		.0	SQUARE METERS.
AREA THAT COULD NOT BE DECONTAMINATED IS.....		9.3	SQUARE METERS.
PRE-ACCIDENT PROPERTY VALUE IS	$	10453.	
POST-DECONTAMINATION PROPERTY VALUE IS	$	8362.	
TOTAL REDUCTION IN PROPERTY VALUE IS	$	2091.	
TOTAL POTENTIAL SAVINGS FROM PROPERTY BUY-OUT			
1) AT PRE-ACCIDENT PROPERTY VALUES.....	$	0.	
2) AT POST-DECONTAMINATION PROPERTY VALUES	$	0.	

(e) TOTAL FACTOR INPUT REQUIREMENTS
(MAN/EQUIPMENT HOURS)

COMMON LABOR	28.31
OPERATOR	8.58
CRAFTS WORKER	11.13
HAND VACUUM	2.12
WET VACUUM	.94
DUMP TRUCK	1.04
TRACTOR	.52
FRONT END LOADER	.52
SPRAY EQUIPMENT	.56

(f) TOTAL AREA DECONTAMINATED, BY SURFACE AND METHOD

SURFACE TYPE	METHOD	AREA (SQ. METERS)
EXTERIOR WOOD WALLS	W	32.
EXTER'R BRICK WALLS	W	6.
LINOLEUM FLOORS	vJ	6.
WOOD FLOORS	vJ	8.
CARPETED FLOORS	VTR	17.
CONCRETE FLOORS	vJ	20.
INT'R WOOD/PL WALLS	V	68.
INT'R CNCRETE WALLS	V	20.
ROOFS	CR	28.
LAWNS	XR	195.
OTHR PAVED ASPHALT	NOT DECONTAMINATED	2.
OTHR PAVED CNCRETE	NOT DECONTAMINATED	7.

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