A.1.9 Lawns

Lawns present particular difficulties for decontamination, largely as a result of the surface texture. There are three general ways to remove radiation from lawns. The first is to lift the material out of the lawn by vacuuming or close mowing. The second is to drive the contaminants down below the surface by watering or using a chemical leaching agent. The third is to remove the radioactive particles by removing the whole lawn and replacing it with a new lawn. These approaches are discussed below.

A.1.9.1 Vacuuming

There are a variety of ways in which lawns could be vacuumed. These include using standard home vacuums, using portable vacuums which can be strapped on one's back, using the large push-type vacuums which are often used for parking lot cleanup, using standard mobile vacuumized street sweepers, or using the very high-powered, truck-mounted vacuums described in Section A.1.5.1. Comparative decontamination efficiency data are not available to guide the choice of equipment. However, from the information available, it would seem that the Power-Master type truck-mounted vacuum would be too powerful for this job, while home vacuums and back-carried vacuums are too small and lack sufficient power for this sort of work. Because of capacity, power, and mobility, we assume that vacuumized street sweepers, using existing hose intakes fitted with several feet of hose and an intake nozzle, would be the best option for this operation.

Referring to the vacuumized street sweeping data presented in Table A.1.5.1.11, we can calculate the cost per hour of operating this equipment by multiplying the cost per sq meter by the number of sq meters per hour. Doing this gives an hourly labor cost of about $18.00 for labor and $19 for equipment for a total of $37.00 per hour. This operation would require an extra worker per truck which is estimated at $24.95 per hour, the Means billing cost for a medium equipment operator. This raises the total hourly labor cost to $43.00. Additional equipment including hoses and fittings should add about $1.00 per hour to equipment charges, raising total equipment charges to $20.00 per hour. The total hourly cost is, then, $63.00 per hour.

We assume an average of 4000 sq feet of lawn per house and a productivity rate of 4000 sq feet of lawn vacuumed per hour. Adjusting this figure for one hour in eight being lost to radiation control measures brings the average hourly coverage to 3500 sq feet, or 326 sq meters. Dividing this into the cost per hour yields $0.19 per sq meter. The inputs' respective shares of total cost are $0.13 per sq meter for labor and $0.06 per sq meter for nonlabor inputs. Since vacuuming lawns involves less vehicle movement than vacuuming streets, fuel costs may be somewhat lower than in street sweeping operations.

A.1.9.2 Water

Under some conditions, driving radiation into the soil may be an acceptable method of mitigating the radiation hazard. One way this can be accomplished is by watering the lawn. This strategy will be more attractive when

there is no important underground water source which might be contaminated and when it is unlikely that the radioactive material will travel a significant distance through the soil.

The simplest and most economical way to accomplish this is for a worker to move from house to house, turning on existing sprinklers. For houses without a sprinkler system, the worker would set up hoses with ordinary lawn sprinklers attached. Any necessary watering equipment could be dropped from a large pickup or stakebed truck at various intervals along streets. After this initial equipment distribution, the hoses and so forth would probably be most efficiently moved without any motor vehicles. After setting up the water sprinkling equipment on one lawn, the water would be left running while the person moved to the next lawn. This would continue until enough time had passed so that a sufficient amount of water had been applied to the first lawn. The person would return to that lawn, shut off the water, and move any equipment to the next unwatered lawn.

For an operation such as this, there is no information based on experience. Unit cost and rate estimates are based on assumption. The hourly labor cost used is \$17.45, the billing cost for common building laborers as reported in Means' Building Construction Cost Data 1981. To this is added \$1.50 per hour for equipment. For a lawn of 4000 sq feet, we estimate 15 minutes of labor time. This is an average, considering that for some lawns all that will be necessary would be to turn the existing sprinkler system on and off. For other lawns it will be necessary to bring sprinkler equipment, set it up, turn it on, and remove it after turning it off. Using this estimate, we have a cost per shift of:

$$8 \text{ hr/shift} \times (17.45/\text{hr} + 1.50/\text{hr}) = \$151.60/\text{shift}$$

Since there will be only seven productive hours during the eight shift hours, total coverage during a shift will be seven times the average hourly coverage of 16,000 sq feet. This works out to 10,416 sq meters per shift, or 1302 sq meters per shift hour. The cost per unit area is

$$\frac{\$151.60/\text{shift}}{10{,}416 \text{ m}^2/\text{shift}} = \$0.014/\text{m}^2$$

This method is obviously very labor intensive. Labor comprises 92 percent of the cost (\$0.013 per sq meter).

A.1.9.3 Leaching

The action of moving the contaminants down into the soil with water can be greatly accelerated by the use of any of a number of chemical leaching agents such as ferric chloride ($FeCl_3$), EDTA (ethylenidiaminetetraacetic acid), or

OAGI0001550_00306

calcium chloride. These have the ability to solubilize contamination particles so that they are more readily carried down into the soil.

The most efficient way to handle treatment of lawns with water and leaching agents such as ferric chloride seems to be to apply a concentrated chemical solution to the lawns from a tanker truck equipped for spraying. This would be followed with a water treatment as described in the previous section (Section A.1.9.2). Several sources reported effectiveness data for 0.3-inch application of water with ferric chloride. The original study to which these sources refer used a solution of one-percent ferric chloride by weight (Dick and Baker 1967). Percentages by weight are about equal to percentage by volume for this material. Presumably precise control of the mixture is not extremely important. The amount of leaching agent used would be determined primarily by the type of soil. Another consideration is whether it is desirable to attempt to limit the depth to which the contaminant is moved.

Ferric chloride is sold in powder form, but more frequently it is sold in a 40-percent aqueous solution. To apply enough of this solution so that there would be sufficient ferric chloride for a one-percent solution of 0.3-inch total coverage, one gallon of the 40-percent solution should be applied to every 21 sq feet. This is calculated in the following way:

$$\frac{231\ \text{in}^3\text{/gal} \times 0.40\ \text{fraction FeCl}_3}{0.01\ \text{fraction FeCl}_3\ \text{coverage desired} \times 0.3\ \text{in coverage}}$$

$$= \frac{92.4\ \text{in}^3\ \text{FeCl}_3\text{/gal}}{0.003\ \text{in FeCl}_3\ \text{coverage desired}}$$

$$= 30{,}800\ \text{in}^2\ \text{covered 0.003 in deep with 100 percent FeCl}_3\text{/gal}$$

$$\frac{30{,}800\ \text{in}^2\ \text{covered/gal}}{144\ \text{in}^2\text{/ft}^2} = 213.9\ \text{ft}^2\ \text{covered/gal}$$

$$213.9\ \text{ft}^2\text{/gal} \times 0.093\ \text{m}^2\text{/ft}^2 = 19\ \text{m}^2\ \text{covered/gal}$$

Various sellers of ferric chloride were contacted. The prices for a ton of ferric chloride on a 100 percent basis for large volume shipments are shown in Table A.1.9.3.1. Prices differ largely because of volume, packaging, and shipping factors. On the basis of these figures, we used a price of $200 per ton of ferric chloride. This is equivalent to $0.10 per pound. Further, Conservation Chemical and C.P. Hall reported that a 55-gallon drum of

OAGI0001550_00307

TABLE A.1.9.3.1. Prices of Ferric Chloride by Various Suppliers for Large Volume Shipments

Supplier	Price (1982 $/ton)
Conservation Chemical	200
DuPont, Chemicals, Dyes & Pigments Dept.	176
C.P. Hall	260
Chemwest	200

40 percent solution weighs 600 lbs. Thus, a gallon weighs about 11 pounds which means there are about 4.4 pounds of material per gallon; therefore, the cost is about $0.44 per gallon.

Including an allowance for shipping and so forth brings the cost to about $0.50 per gallon. The cost of ferric chloride per sq meter is:

$$\frac{\$0.50/\text{gal}}{19\text{m}^2/\text{gal}} = \$0.0263/\text{m}^2$$

A hydroseeder, as described by a source with the Washington State Department of Transportation (see Section A.1.9.5), would provide an effective means of applying the concentrated leaching agent solution. This machinery can easily spray surfaces within a radius of 100 feet. The reported average coverage rate of this equipment is in excess of an acre per hour at 0.4 gallons per sq yard. This is equivalent to an average pumping rate of 32 gallons per minute. These figures include time for refilling. It is possible that metal surfaces on the hydroseeder may have to be coated to prevent corrosive action of the leaching agent.

The Washington State Department of Transportation reported that the hydroseeder entails a labor cost of $60 per hour for two workers plus $135 per hour for the equipment. The application rate of one gallon for 19 sq meters is probably too thin to be done with much uniformity of coverage. Therefore, we assume that the solution is partially diluted before applying. If the ferric chloride is diluted, say, four parts water to one part of the solution as purchased, then one gallon of this mixture should be applied over an area of about 3.8 sq meters. The pump rate of 32 gallons per minute for the hydroseeder multiplied by the coverage of 3.8 sq meters per gallon gives an output of 122 sq meters per minute. Coverage per shift-hour would be

$$122\ \text{m}^2/\text{min} \times 60\ \text{min/hr} \times 7/8\ \text{adj} = 6400\ \text{m}^2/\text{hr}$$

OAGI0001550_00308

Dividing this into the hourly costs gives $0.009 per sq meter for labor and $0.021 for equipment. The total cost of operating the hydroseeder apart from the leaching agent is $0.03 per sq meter.

Once the chemical is applied to the surface, an application of water is used to carry it through the soil. The costs of applying the water are explained in the previous section.

Table A.1.9.3.2 summarizes the cost of leaching. Combining the different procedures so that the overall rate equals the rate of the most costly step requires that 4.92 watering crews be used for every application crew.

TABLE A.1.9.3.2. Summary of Leaching Cost and Productivity Data

Item	Rate (m^2/hr)	Cost (1982 $/$m^2$)			
		Total	Labor	Equipment	Materials
Ferric Chloride	--	0.026	--	--	0.026
Application of Chemicals	6400	0.030	0.009	0.021	--
Watering	1302	0.014	0.013	0.001	--
Total	6400	0.07	0.022	0.022	0.026

A.1.9.4 Close Mowing

Close mowing of contaminated lawns is another method of reducing the radiation hazard from that surface. Because the total lawn surface will be broken down into numerous small, odd-sized parts, and because some lawns will have only limited access, large mowers would be too cumbersome for efficient use. Smaller riding mowers seem to be the most attractive option. Besides mowing, the workers must also see that lawn cuttings are carefully bagged for later removal. Mowers with a vertical axis cutting blade would be used since they would pick up particles with a vacuum action.

Three sources supplied cost and rate estimates for this operation. Since the equipment specifications did not change much from source to source, the major areas of difference were in wage rates and productivity rates. An allocation of about $2.00 per hour appears to be adequate to cover the costs of the mower, maintenance, and fuel. We estimate that 15 minutes of time per lawn for labor and a pickup truck is sufficient for pickup and disposal of bagged clippings.

According to Means' Building Construction Cost Data 1982, the monthly rent for a pickup truck is $275, and the hourly operating cost is $4.24. With 336 working hours per month (2 shifts per day), the hourly cost for the truck is:

OAGI0001550_00309

$$\frac{\$275/mo}{336\ hr/mo} + \$4.24/hr = \$5.23/hr$$

Using Means' billing rate cost for a common laborer of $17.45, the total hourly cost for the pickup of lawn cuttings is

$$\$5.23 + \$17.45 = \$22.68/hr$$

Based on the estimate of 15 minutes pickup time per 4,000 sq foot lawn, total coverage during the seven working hours of an eight hour shift would be 112,000 sq feet or 10,416 sq meters. Dividing this figure by eight hours per shift gives the average coverage per shift hour as 1302 sq meters. The cost per sq meter can be calculated by dividing the cost per hour by the coverage per hour:

$$\frac{\$22.68/hr}{1302\ m^2/hr} = \$0.017/m^2$$

The Administrative Services Department of the Spokane Community College in Spokane, Washington said that for large, flat, unobstructed areas a large mower such as a Toro Lawn Master with a 4.5 foot mowing width can mow one acre in 15 minutes. However, using a small riding mower for mowing the front and back lawns of a standard 50 foot width lot, this source estimates that 45 minutes are required. To this should be added time for bagging the clippings. This translates into about one hour for 4000 sq feet, or 372 sq meters. With an hour per shift lost to special protective measures necessitated by the radioactivity, the average hourly production would be 7/8 of this amount--326 sq meters per hour.

Using Means' common laborer billing rate of $17.45 per hour for the labor cost, the total hourly cost would be $19.45 when the equipment cost is included. The cost per sq meter is:

$$\frac{\$19.45/hr}{326\ m^2/hr} = \$0.060/m^2$$

Labor would account for:

$$\frac{\$17.45}{326\ m^2/hr} = \$0.054/m^2$$

OAGI0001550_00310

American Maintenance Systems in Seattle, Washington, provided a similar estimate - 45 minutes to an hour to mow 4500 sq feet. Adding the time for bagging, this comes to an hour and fifteen minutes. Adjusting for an average of one hour per shift lost due to radiation control measures, gives

$$\frac{4500\ \text{ft}^2}{1.25\ \text{hr}} \times 0.093\ \text{m}^2/\text{ft}^2 \times 7/8\ \text{adj} = 293\ \text{m}^2/\text{hr}$$

Again, using \$17.45 per hour for labor and \$2.00 per hour for capital and dividing by the hourly production yields a cost per sq meter of \$0.0664.

The Craft and Operation Services Department of Battelle, Pacific Northwest Laboratories in Richland, Washington estimated 10 to 12 hours for 20,000 sq feet. This is much slower than the other estimates in part because specific consideration was given to time necessary for the bagging of cuttings and for the slower mowing rate necessitated by cutting the grass as close to the ground as possible. Using a time of 11 hours for 20,000 sq feet, the production during an average hour of mowing would be

$$\frac{20{,}000\ \text{ft}^2}{11\ \text{hr}} \times 0.093\ \text{m}^2/\text{ft}^2 = 169\ \text{m}^2/\text{hr}$$

Adjusting this figure for an hour lost per shift for radiation control measures, the average hourly production becomes

$$169\ \text{m}^2/\text{hr} \times 7/8\ \text{adj} = 148\ \text{m}^2/\text{hr}$$

With a labor cost of \$20.00 per hour plus \$2.00 per hour for equipment, the average cost per sq meter is

$$\frac{\$22.00/\text{hr}}{148\ \text{m}^2/\text{hr}} = \$0.1486/\text{m}^2$$

Table A.1.9.4.1 presents the foregoing data. It is clear that the cost estimate for mowing from Battelle is much higher than the estimates from the other two sources. The reason for this is the explicit consideration given by the source at Battelle for the special actions which must be taken in this case: mowing as close to the ground as possible and careful bagging of the cuttings. Because of these explicit considerations, the representative figures for this procedure are taken as very close to the Battelle figures.

OAGI0001550_00311

TABLE A.1.9.4.1. Summary of Cost and Productivity Data for Close Mowing of Lawns

Item and Source	Rate (m^2/hr)	Cost (1982 $/m^2$) Total	Labor	Equipment
Mowing				
Spokane Comm. Coll.	326	0.060	0.054	0.006
Amer. Maint. Sys.	293	0.066	0.059	0.007
Battelle PNL	148	0.149	0.136	0.013
Pickup				
Means	1302	0.017	0.013	0.004
Representative				
Mowing	150	0.130	0.116	0.014
Pickup	1302	0.017	0.013	0.004
Total	150	0.147	0.129	0.018

The total cost for the whole operation is the sum of the mowing cost plus the removal cost - $0.147 per sq meter. The overall rate is geared to mowing, the more costly step. This means that 150 ÷ 1302 = 0.115 pickup crews would be required for every mowing crew.

A.1.9.5. Fixative

A sticky, penetrating type of fixative might be the most appropriate for use on lawns, though hydrophilic and solid membrane types could also be used. According to the Washington State Department of Transportation, the first step of coating the lawn surfaces with a fixative could be done with a hydroseeder. This is a tanker truck equipped to spray liquids of varying viscosity to surfaces within a 100 foot radius. With a coverage of, say, 0.4 gallons per sq yard, this equipment can deliver liquids at a rate sufficient to cover an acre per hour. This implies a pumping capacity of 32 gallons per minute. The hydroseeder requires two workers - a driver and someone to operate the spraying mechanism. The reported cost of operating the hydroseeder is $60 per hour for the two workers plus $135 for the equipment. The equipment charge includes allowance for capital, depreciation, maintenance, fuel, and so forth. These costs work out to a total of $1560 per shift. The hydroseeder's coverage rate of an acre per hour is equivalent to 4,051 sq meters per productive hour. During the seven productive hours of a shift, the total production would be 28,357 sq meters. Thus, the unit cost would be

$$\frac{\$1560/\text{shift}}{28{,}357\ m^2/\text{shift}} = 0.055/m^2$$

OAGI0001550_00312

Labor's share of the cost is

$$\frac{\$60/\text{hr} \times 8 \text{ hr}}{28{,}357 \text{ m}^2/\text{day}} = \$0.017/\text{m}^2$$

Equipment accounts for the remaining $0.038 per sq meter. The average production per shift-hour is

$$\frac{28{,}357 \text{ m}^2/\text{shift}}{8 \text{ hr/shift}} = 3{,}545 \text{ m}^2/\text{hr}$$

Referring to Section A.1.1.2, the cost of a fixative appropriate for use on lawns covers a broad range. Here we assume that a fixative like road oil would be used with a unit cost of $0.31 per sq meter. This brings the total cost of fixative and application to $0.365. Table A.1.9.5.1 summarizes the cost and productivity data for the application of a fixative to lawns. It is clear that selection of a lower cost fixative would have a significant impact on the total cost.

TABLE A.1.9.5.1. Summary of Cost and Productivity Data for Applying Fixative to Lawns

Item	Rate (m^2/hr)	Cost (1982 $/$m^2$)			
		Total	Labor	Equipment	Material
Fixative	--	0.310	--	--	0.310
Application	3545	0.055	0.017	0.038	--
Total	3545	0.365	0.017	0.038	0.310

A.1.9.6 Removal and Replacement

A relatively effective but costly method of reducing radiation contamination in lawns is to take the direct approach of removing the lawn and replacing it with new sod. To be sure that the radioactive matter is fixed to the lawn to be removed, removal should be preceded by application of a fixative. That step is not included in removal and replacement as described here.

Sod removal and replacement are normally done by the same business and, therefore, the cost is frequently given for the combined procedure. A source at the American Institute of Architects provided a cost estimate of $4.12 per sq yard for removal and replacement of sod on flat terrain and $4.53 on a slope. These are figures for the East Coast which should be higher than the national average. Apparently, these data are taken from a Means construction cost publication. Using the average of the figures for level and sloped

OAGI0001550_00313

surface, the cost can be converted to a cost per sq meter basis. The following shows this calculation and adjusts for one hour per shift with no production:

$$\frac{\$4.12/yd^2 + \$4.53/yd^2}{2} \times 0.836\ m^2/yd^2 \times 8/7\ adj = \$4.13/m^2$$

C&M Landscaping of Richland, Washington, charges $0.50 per sq foot for lawn removal and replacement. This can be converted to a cost per shift-hour in the following way:

$$\frac{\$0.50/ft^2}{0.093\ m^2/ft^2} \times 8/7\ adj = \$6.14/m^2$$

Means' Building Construction Cost Data 1982 (p. 56) indicates that the crew for sodding requires one outside foreman ($22.25 per hour billing cost), four building laborers ($19.40) and one light-equipment operator ($23.70). The total hourly labor cost is $123.55. Necessary earthwork equipment has an hourly cost of $19.86. The total hourly cost on level ground is

$$470\ yd^2/day \div 8\ hr/day \times \$3.98/yd^2 = \$233.83/hr$$

Subtracting the hourly labor and equipment costs gives the hourly material cost, which can be converted to a dollars-per-sq-meter basis with the following calculations:

$$\$(233.83 - (123.55 + 19.86)) = \$90.42/hr \text{ for material}$$

$$\frac{\$90.42/hr}{58.75\ yd^2/hr \times 0.836\ m^2/yd^2} = \$1.84/m^2$$

The rate given for sodding on level ground is 470 sq yards per day, and the rate for slopes is 405 sq yards per day. We base our calculations on the average of these two rates - 438 sq yards per day. Converting to sq meters and accounting for one hour per day lost to radiation control measures, we have:

$$438\ yd^2/day \div 8\ hr/day \times 7/8\ adj \times 0.836\ m^2/yd^2 = 40\ m^2/hr$$

OAGI0001550_00314

Dividing the hourly coverage rate into labor and equipment costs gives those costs on a dollars-per-sq-meter basis:

$$\text{Labor: } \frac{\$123.55/\text{hr}}{40\ \text{m}^2/\text{hr}} = \$3.09/\text{m}^2$$

$$\text{Equipment: } \frac{\$19/86/\text{hr}}{40\ \text{m}^2/\text{hr}} = \$0.50/\text{m}^2$$

Adding the labor, equipment, and material cost gives the total cost as $5.43 per sq meter.

The costs given here are different from those given by the American Institute of Architects (AIA), despite the fact that the AIA stated that its source was a Means publication. It appears that the AIA may have used an earlier edition.

Partial information was also supplied by Elite Sod Farm, Richland, Washington. The cost of laying new sod near this business was $0.16 to $0.22 per sq foot. This does not include removal of existing lawn. These costs are equivalent to $1.72 to $2.36 per sq meter without adjustment for the special radiation measures affecting costs and production rates. Averaging these two amounts together and adjusting for an hour per shift lost due to special conditions imposed by radiation, we get $2.33 per sq meter.

Table A.1.9.6.1 presents the foregoing information. The various costs for removing and installing sod, while not in perfect agreement, seem to be mutually consistent. The representative cost was taken as the Means data.

A.2 WATER BODIES

A.2.1 Reservoirs

Specification of the decontamination procedures to be applied to reservoirs is complicated by the difficulty in defining a "standard" reservoir. For example, reservoirs are found in a wide range of physical configurations. Some cover an area of hundreds of sq miles, while small distribution reservoirs within a city may occupy less than an acre. These small reservoirs are frequently concrete lined, while large reservoirs may be hundreds of feet deep if located over a steep-sided canyon.

In addition to physical structure, reservoirs vary in other ways that can affect the designing of a decontamination program. One is the degree of reliance placed on the reservoir as a local water supply. If the reservoir accounts for a relatively large portion of an area's water supply, then the necessity to supply water might interfere with carrying out the decontamination

OAGI0001550_00315

TABLE A.1.9.6.1. Summary of Cost and Productivity Data for Removing and Replacing Lawns

Source and Rate	Rate ($\$/m^2$)	Cost (1982 $\$/m^2$) Total	Labor	Equipment	Material
Amer. Inst. of Archs Remove and resod	--	4.13	--	--	--
C&M Landscaping Remove and resod	--	6.14	--	--	--
Means Remove and resod	40	5.43	3.09	0.50	1.84
Elite Sod Farm Resod Only	--	2.33	--	--	--
Representative	40	5.43	3.09	0.50	1.84

measures. On the other hand, if the reservoir can be taken out of service, with other water sources substituting, then some operations, such as draining the reservoir, become more attractive.

Another consideration is the character of the downstream release flow. If the stream or river fed by the reservoir has significant agricultural, recreational, or consumptive uses, or if the river flows through a populated area, it may be desirable to reduce or curtail outflow of contaminated water. Conversely, if there is little potential risk or damage as a result of contaminated outflow, draining the reservoir may provide a very attractive decontamination alternative.

The type and extent of existing water treatment facilities are also relevant, since these facilities can be used in some decontamination operations, notably those that treat the water before it enters into a distribution system.

Apart from the characteristics of the water, the nature of the contaminants is also an important issue. A reservoir is likely to become contaminated via two pathways: directly from atmospheric fallout, and indirectly from runoff from other surfaces within the watershed served by the reservoir.

Once in the reservoir, radionuclides will remain in either of three states: mixed with sediment at the bottom of the reservoir, suspended as solids in the water, or in solution with the water. Each of these states may require a different type of treatment. For example, removing contaminants in solution would most likely be done by treating the water as it leaves the reservoir and passes through a treatment system. This method would have no effect on materials that had settled to the bottom of the reservoir. Dredging is an option for removing contaminants from the lake bottom, but it would have no removal effect on materials suspended or in solution.

OAGI0001550_00316