Since scraping is a relatively common operation, there are a variety of techniques and equipment available. For example, the basic scraping equipment could be either a crawler tractor, a bottom-dump scraper, or a grader. While all these seem to be reasonably effective, information from sources experienced in scraping as a decontamination procedure indicated a preference for the grader and front-end loader. The grader scrapes earth into windrows and a front-end loader loads the windrows into dump trucks. This is the principal technique used by REECo at the Nevada Test Site where it has been engaged in scraping and removing soil contaminated in weapons tests. This source reported that where soil is particularly hard they use a crawler tractor instead. The procedure in this case is for the tractor to drive over the soil first with rear-mounted shallow ripper shanks in a lowered position. After scarifying the soil, the tractor raises the shanks, backs up, lowers the front scoop and proceeds to push the earth into rows or piles. These piles are later picked up by a front-end wheel loader and loaded into a dump truck.

Joseph M. Hans, Jr., of the U.S. Environmental Protection Agency, was involved with the decontamination of a uranium mill site. In this work he gained a familiarity with the effectiveness of earth-moving equipment. He found that common problems include equipment actually driving the contamination below the surface and soil spillage. He reports that equipment needs vary from site to site and that push bottom-dump scrapers were inefficient because they removed too much soil.

In reviewing scraping practices as used in decontamination projects and as used in ordinary earth-moving work, it appears that a grader working with one or more front-end loaders in the manner described above constitutes a fairly effective and efficient technique for soil removal.

Those doing decontamination work found that, in addition to the actual scraping, periodic wetting of the soil prevented dust. Application of water was done either with a water wagon or a hydroseeder (see Section A.1.9.5). Using a hydroseeder to spray water may permit wetting the contaminated soil from a decontaminated area. This reduces disturbances to the contaminated area. Occasionally a small amount of detergent is added to the water to improve wetting.

A final element in the scraping operation is the transporting of contaminated soil to a dump site. The cost of dumping will depend in large part on the distance to the dump site. At least one source envisions a dump site for every sq kilometer (Julin et al. 1978). At another extreme, soil would be transported to one of the few national nuclear-waste dumps. Such hauls could be over 1,000 miles. Another possibility is that a dump site would be created in or adjacent to any permanently interdicted area.

Relying on Means, an estimate of scraping costs can be developed. The basic piece of equipment is a grader. A 30,000 pound grader costs $51.34 per hour. Operating with the grader are two wheel-mounted front-end loaders, each with a 2.25 cubic yard capacity and each costing $50.79 per hour. The total equipment cost is $152.92 per hour.

The labor requirements are three medium-equipment operators at $24.95 per hour each, one building laborer at $19.40 per hour, and one foreman at $22.25 per hour. The total labor cost comes to $116.50 per hour. Adding the labor and equipment costs together, we get the total hourly cost of $269.42.

The rate is more difficult to estimate. Apparently, the limiting factor is the speed at which the front-end loaders can load the windrows into dump trucks. The front-end loaders are listed as having a 2-1/4 cubic yard capacity with a loading rate of 100 cubic yards per hour. With a scraping depth of about six inches, about five sq meters are covered for every cubic yard. Therefore, each front-end loader can cover about 500 sq meters per hour. The second loader brings the production rate to 1000 sq meters per hour. Adjusting this for the time necessary for personnel and equipment decontamination reduces the rate to 875 sq meters per hour. This figure appears to be within reason when compared with those reported by other sources. For example, Doolittle Construction estimated a rate of 146 sq meters per hour. This was with a smaller crew and only one loader. REECo indicated that its rate is about an acre a day or about 500 sq meters per hour. The rate derived from McGraw-Hill's Dodge Guide was a little over 4000 sq meters per hour. It should also be noted that these estimates are for scraping vacant land, which would normally take longer than scraping agricultural fields.

Dividing the hourly production rate into the hourly costs gives the cost in dollars per sq meter. The total is $0.31, labor is $0.13 and equipment comes to $0.18 per sq meter. Total costs per sq meter reported by other sources were:

Doolittle Construction	$0.34
Julin et al. (1978)	0.16
REECo	0.24
McGraw-Hill	
Loose soil	0.26
Broken rock	0.61
Battelle (1978)	0.47
World Excavating	0.23

A.1.1.6 Plow

Both by mixing and turning the soil, plowing is an effective method of reducing radiation hazards from external exposure and inhalation. Since plowing is a relatively common operation for which much data have been collected, there is a considerable amount of information about plowing. Farm advisors and publications of agricultural extension services are good sources. For the present report, additional sources were contacted, including farm management consultants and academic sources.

There are various types of plowing operations, including chisel plowing, heavy discing, and mouldboard plowing. Mouldboard plowing is particularly

appropriate for the purposes at hand because it turns the soil more than cutting it. This would be the most effective plowing technique to move surface-level contamination below the soil. Most plowing operations operate to depths of eight to ten inches, though some plowing is done to depths of 18 inches and 12-inch deep plowing is not uncommon. For plowing to greater depths - three feet deep and more - see the next section, A.1.1.7, concerning deep plowing.

The University of California, Division of Agricultural Sciences publication Custom Rates for Farm Applications (1979) gives the cost of plowing at \$10.00 to \$12.50 per acre in 1978 dollars. In 1982 dollars this amounts to \$15.75 to \$17.20 per acre, using the gross national product implicit price deflator to adjust to 1982 price levels. Using the upper end of this range and adjusting for an hour per shift for radiation control measures, we find the cost per sq meter as

$$\frac{\$17.20/\text{ac}}{4046.7\ \text{m}^2/\text{ac}} \times 8/7\ \text{adj} = \$0.0049/\text{m}^2$$

The indicated rate is about 1.8 acres per hour. This implies a coverage rate of

$$1.8\ \text{ac/hr} \times 4046.7\ \text{m}^2/\text{ac} \times 7/8\ \text{adj} = 6374\ \text{m}^2/\text{hr}$$

Iowa State University Cooperative Extension supplied results from 1983 Iowa Farm Custom Rate Survey which shows that mouldboard plowing averages about \$10.70 per acre (in 1982 dollars). The cost ranges from \$9.00 to 12.40 per acre. At \$10.70 per acre, the adjusted cost per sq meter is \$0.0030. The approximate breakdown of these costs is 25% for labor, 55% for equipment and 20% for fuel. These figures were confirmed by King Management Company, a farm management concern in Des Moines, Iowa. This source added information about related operations. Chisel plowing to a depth of 12 inches costs about \$0.0024 per sq meter, and heavy discing to a depth of 12 to 18 inches costs about \$0.0022 per sq meter.

From this information, we take as representative a total cost of \$0.004 per sq meter. This is comprised of \$0.001 for labor, \$0.002 for equipment, and \$0.001 for fuel. The hourly rate is 6374 sq meters.

A.1.1.7 Deep Plow

Deep plowing here refers to plowing to a depth of about 36 inches, though there are procedures for plowing any depth up to 36 inches and deeper. In addition, there are a number of different techniques and terms associated with deep plowing, including ripping, subsoil, and slip plowing. Most deep plowing operations involve pulling one, two, or three shanks through the soil with a large tractor. Agristruction, Inc. operates a rig with seven shanks, over a

16.5-foot width, that rip to a depth of 32 inches. Some operations turn 36 inches of soil using a large mouldboard plow. For hard soil it is sometimes necessary to use a second tractor pushing or pulling the first. One source (Agristruction, Inc.) uses 14-foot shanks weighing a ton each to rip very hard soil up to five feet deep.

Deep plowing is not a particularly common farm operation. One region in which deep plowing is not uncommon is the Southern San Joaquin Valley in California. In this area deep plowing is used to break up a layer of hard pan below the surface in order to facilitate root penetration. Most deep plowing is done by custom farming companies that specialize in this type of work.

Because equipment, soil conditions, procedure, and plowing depth differ from source to source, cost estimates vary considerably. The lowest is equivalent to \$0.008 per sq meter, while the highest figure is \$0.20 per sq meter. Table A.1.1.7.1 summarizes the data collected. The figures are adjusted for radiation control measures.

The representative rate and cost are taken as 5000 sq meters per hour and \$0.06 per sq meter. The labor cost is figured at \$0.005 per sq meter based on an hourly operator billing cost of about \$25.00 per hour.

However, there are some covers that could. For example, corn at or near full growth could certainly pose an obstacle to other treatment measures.

Corn was, in fact, used as the representative crop to be cleared. For corn and for other crops, it appears that farm machinery offers the best possibility for the lowest-cost way to clear the crop. Clearing may therefore entail harvesting the crop. Conversation with a representative of the U.S. Department of Agriculture in Seattle, Washington indicated that for the purposes of clearing corn a swather may be the best option. A swather will bale the stalks to facilitate removal. The average cost per acre for this procedure is \$94.28. This is broken down into \$10.80 for baler twine, \$21.42 for machinery and fuel, \$25.89 for maintenance and repair, \$2.95 for interest on equipment, and \$33.22 for labor. Combining the non-labor costs under equipment, we get \$61.06 per acre.

$$0.15 \text{ ac/hr} \times 4046.7 \text{ m}^2\text{/ac} \times 7/8 \text{ adj} = 543 \text{ m}^2\text{/hr}$$

Dividing the hourly cost figures by this hourly production rate yields the cost of swathing on a per-sq-meter basis. The total is \$0.026. Labor accounts for \$0.009 per sq meter, and equipment \$0.017.

TABLE A.1.1.7.1. Deep Plowing Cost Data Summary

Source and Procedure	Rate (m^2/hr)	Cost (1982 \$/m^2)
Univ of Calif. Coop Exten, "Costs to Estab. and Produce Walnuts"		
Shallow subsoil	--	0.0141
Univ of Calif. Coop Exten, "Custom Rates for Farm Operations"		
Subsoil (36")	7588	0.0082
Rip (6')	--	0.0194
Agristruction, Inc.		
Rip soft soil (5')	5311	0.1130
Rip hard soil (5')	1328	0.1412
Can-Do Custom Farming		
Slip plow (18")	2479	0.10
Slip plow (36")	2833	0.20
Moorehead and Idell		
Slip plow (36")	4249	0.03
Battelle (1978), "Estimate of Potential Costs..."		
Plow (1 m)	--	0.06
Dave Price		
Slip plow (6')	2656	0.10
Mouldboard plow (52")	1770	0.11
Braden Farms		
Rip	6551	0.015
Valley Tractor Co.		
Plow (36")	6374	0.047
Plow (52")	3541	0.11
Valley Agricultural Consultants		
Slip plow	2479	0.022

A.1.1.8 Cover

This operation involves covering the ground with six inches of uncontaminated soil. This may be done to replace soil which has been removed as a radiation treatment measure, or the contaminated ground may be covered by the new soil. However this operation fits into a decontamination program, the soil cover will help reduce resuspension and external exposure.

The first step in this operation is the excavation of the earth that is to be spread in the treatment area. This excavation might be coupled with contaminated-material disposal. If a pit is to be dug for disposing of contaminated soil or other materials, the removed soil might be usable for covering. The excavated soil would be hauled to the decontaminated site, dumped there, and spread by a front-end loader.

Means' Building Construction Cost Data 1982 (p. 29) lists several ways to accomplish bulk excavation. The least costly is to use a large (five cubic yard capacity) wheel-mounted front-end loader. This equipment can excavate and load 1480 cubic yards per day of medium soil. Noting that each cubic yard of soil will cover six sq yards six inches deep, the hourly coverage rate is

$$\frac{1480\ yd^3/day}{8\ hr/day} \times 6\ yd^2/yd^3 \times 0.836\ m^2/yd^2 \times 7/8\ adj = 812\ m^2/hr$$

Means calls for one medium-equipment operator at \$24.95 per hour billing cost and half a building laborer at \$19.40 per hour as the labor input. This totals \$34.65 per hour. The front-end loader costs \$100.38 per hour. The total hourly cost is \$135.03. Dividing these figures by the hourly production rate gives costs in terms of dollars per sq meter: total, \$0.166; labor, \$0.043; equipment, \$0.123.

The cost of hauling is handled separately since it depends on the distance (see Section A.6.2).

Means (p. 32) also supplies data for estimating the cost of spreading and grading the new soil. The inputs for this step are similar to the excavation step. The labor inputs are the same, but instead of a front-end loader, a 200-horsepower bulldozer is called for. The cost for this equipment is \$78.04 per hour. The listed rate of 1000 cubic yards per day can be converted to sq meters per hour with the following calculations.

$$\frac{1000\ yd^3/day}{8\ hr/day} \times 6\ yd^2/yd^3 \times 0.836\ m^2/yd^2 \times 7/8\ adj = 549\ m^2/hr$$

Dividing this hourly rate into the hourly cost yields dollars per sq meter.

Table A.1.1.8.1 summarizes the foregoing results and shows the combined costs for excavation and spreading. Spreading is the more costly step, and, as a result, 549/812 = 0.68 excavation crews would be used for every spreading crew.

TABLE A.1.1.8.1. Summary of Excavation and Grading Cost Data for Soil Cover

Procedure	Rate (m^2/hr)	Cost (1982 $\$/m^2$) Total	Labor	Equipment
Excavate	812	0.166	0.043	0.123
Spread and grade	549	0.205	0.063	0.142
Total	549	0.371	0.106	0.265

A.1.2 Orchards

Orchards possess two important characteristics affecting decontamination operations. The first is that orchards include ground, leaves, and branches, all of which would become contaminated. Since treatment of one of these may or may not have an adverse effect on another, decontamination of orchards can be more complex than other types of areas. Second, the trees necessarily limit vehicular mobility and will completely preclude the use of large trucks.

A.1.2.1 Water

This operation involves applying water to orchard soil using existing flood irrigation equipment. Water will tend to drive soil contamination down below the surface, helping to reduce hazards due to resuspension and external exposure. It should be pointed out that some orchards have no irrigation system in place, while others may use some other type of irrigation such as drip or center-pivot sprinkling. Any irrigation involving sprinkling has the added advantage of moving some of the radioactive matter from the trees and foliage to the ground.

The sources of information for this operation are various cooperative extension publications including "Costs of Establishing and Producing Prunes," "Almond Production Costs on Class I Soils in Sacramento Valley, 1981," "Almond Production Costs on Class II and Class III Soils in Sacramento Valley, 1981," and "Costs to Establish and Produce Walnuts," all by the University of California Cooperative Extension. Another source was "Cost of Producing Apples in Central Washington," prepared by the Cooperative Extension, College of Agriculture, Washington State University. The information provided in these pamphlets is not always complete. For example, the third publication listed gives the total yearly costs for irrigation but does not indicate how many times the orchard was irrigated. In general, however, all the sources seem to be consistent with the information in the first pamphlet, which indicates about one man-hour of labor required for irrigation for each acre for each application. The cost of this labor was listed at five dollars per hour. Thus, the cost per sq meter is

$$\frac{\$5/\text{ac} \times 1 \text{ ac}}{4046.7 \text{ m}^2/\text{ac}} \times 8/7 \text{ adj} = \$0.0014/\text{m}^2$$

The hourly coverage rate is

$$1 \text{ ac/hr} \times 4046.7 \text{ m}^2\text{/ac} \times 7/8 \text{ adj} = 3541 \text{ m}^2\text{/hr}$$

A.1.2.2 Fixative - Aerial Application

Orchards pose a problem of how to apply liquid treatments such as water or a fixative to both the tree foliage and the ground. One technique is to apply these liquids from an airplane or helicopter. In general, however, any fixative, regardless of the method of application, will have reduced effectiveness when the trees are in full leaf. It is essentially impossible to reach every surface with an even application. For this reason it may be advisable to defoliate the trees before applying tne fixative (see Section A.1.2.4).

There are also some important considerations with respect to the choice of fixative. If the area is to be decontaminated, and the existing trees are to be saved, then a non-toxic material should be used. On the other hand, the difficulty in achieving an even covering of fixative suggests that it may be desirable to use a material that remains sticky for a long time. This would tend to capture particles dislodged by wind or other means. Road oil and diesel oil remain sticky for a long time, but they would be damaging to the orchards themselves. A fixative that might prove appropriate is lignosite. This is relatively inexpensive, and it is non-toxic. However, it may not remain sticky for a sufficient length of time. (See Section A.1.1.2 for a discussion of fixatives and their characteristics and requirements for application.)

Because leaves and branches raise the total surface per gross land area, we increase the amount of fixative to be applied by 50%, bringing the application rate to 0.75 gallon per sq yard. Increasing the amount of material by 50% per unit area also entails a 50% increase in the cost per sq meter. As shown in Section A.1.1.2, the cost per sq meter of lignosite at normal application rates is $0.06 per sq meter. At the higher application rate the cost rises to $0.09 per sq meter.

The cost of application is based on costs developed in Section A.1.4.1. The rate of application is estimated at 14,000 sq meters per hour for an application of 0.4 gallon per sq yard. Increasing the amount of fluid applied to 0.75 gallon per sq yard will increase the application time by a factor of 0.75/0.4 = 1.875. The new application rate is

$$14,000/1.875 = 7467 \text{ m}^2\text{/hr}$$

Hourly labor and equipment costs can be found in the discussion of aerial application of fixatives in Section A.1.4.1. Multiplying the rate (14,000 sq

meters per hour) by the unit labor cost ($0.01 per sq meter) and the unit equipment cost ($0.14 per sq meter) gives the hourly costs for these input categories. They are $140 per hour for labor and $1960 for equipment. Dividing these hourly costs by the new application rate gives the adjusted unit labor and equipment costs:

$$\text{Labor: } \frac{\$140/\text{hr}}{7467 \text{ m}^2/\text{hr}} = \$0.019/\text{m}^2$$

$$\text{Equipment: } \frac{\$1960/\text{hr}}{7467 \text{ m}^2/\text{hr}} = \$0.262/\text{m}^2$$

Adding the costs of these two inputs to the material cost gives a total cost per sq meter of $0.371.

A.1.2.3 Fixative - Ground Application

In the previous section, aspects of applying a fixative to orchards were discussed. In this section, the procedure and costs of applying a fixative from the ground are presented.

Normal orchard farming procedures include activities that involve application of liquids to the ground and to the trees. For example, ground surfaces are often sprayed with herbicides for weed control using a seed sprayer. A blast sprayer applies chemicals to the tree foliage by spraying a very fine mist into the air. These two sprayers could be used for application of fixative.

In addition to various cooperative extension publications, information was obtained from California and Washington State cooperative extension farm advisors specializing in orchard crops. According to the orchard farm advisor in Butte County, California, costs relating to prune orchards are reasonably representative of orchard costs in general.

The University of California Cooperative Extension publication "Cost of Establishing and Producing Prunes" provides cost and rate data for prune production operations for a 100-acre orchard. For spraying the ground twice with herbicide, the total cost is $30.65 per acre. Subtracting the cost of materials ($24) and dividing by the total acres sprayed (one acre sprayed twice is equivalent to two acres) gives $3.325 per acre. This is comprised of $1.75 for labor and $1.575 for fuel and repairs. Converting these figures to a cost per sq meter can be done as follows:

$$\text{Labor: } \frac{\$1.75/\text{ac}}{4046.7 \text{ m}^2/\text{ac}} \times 8/7 \text{ adj} = \$0.000494/\text{m}^2$$

$$\text{Fuel: } \frac{\$1.575/ac}{4046.7\ m^2/ac} \times 8/7 \text{ adj} = \$0.000445/m^2$$

These cost figures are relatively low primarily because a typical application of herbicide is only 50 gallons per acre as compared with a fixative application in the range of 0.2 to 0.5 gallon per sq yard. The application of 50 gallons per acre is equivalent to

$$\frac{50\ gal/ac}{4840\ yd^2/ac} = 0.01033\ gal/yd^2$$

To adjust the cost figures to a level appropriate for fixative, the costs will have to be multiplied by

$$\frac{0.4\ gal/ac}{0.01033\ gal/ac} = 39$$

Thus, the labor cost becomes $0.0193 per sq meter, and the fuel cost is $0.0174.

The equipment cost is estimated differently, using the time to treat a unit area of land. The time to spray one acre once with 50 gallons of herbicide is 0.35 hours. The time required for a 0.4 gallon-per-sq-yard coverage would be 39 times longer, and with the adjustment for personnel and equipment decontamination the time would be

$$0.35\ hrs/ac \times 39 \times 8/7 \text{ adj} = 15.6\ hr/ac$$

The hourly cost of the weed sprayer is $0.50, and the cost of the 30-horsepower tractor to tow the sprayer is $4.00 per hour. The total hourly cost is, therefore, $4.50. The equipment cost per acre is

$$\$4.50/hr \times 15.6\ hr/ac = \$70.20/ac$$

The cost per sq meter is

$$\$70.20/ac \div 4046.7\ m^2/ac = \$0.0173/m^2$$

Adding the labor cost ($0.0193/m^2$), the equipment cost ($0.0173/m^2$), and the fuel and repair cost ($0.0174) gives the total application cost per sq meter of $0.054. The 15.6 hours per acre time requirement is equivalent to a production rate of

$$\frac{4046.7\ m^2/ac}{15.6\ hr/ac} = 260\ m^2/hr$$

Similar calculations using data in "Cost of Producing Apples in Central Washington," released by the Cooperative Extension, College of Agriculture, Washington State University, generated a total cost of $0.061 per sq meter for application. Of this total, labor accounts for $0.016 per sq meter, equipment and repair $0.034 per sq meter, and $0.010 for fuel.

These cost figures can be compared to the cost of fixative application using a large distributor tank truck as described in Sections A.1.1.1 and A.1.1.2. The cost data in A.1.1.2 show the cost for applying fixative at 0.75 gallon per sq yard to be about $0.0161 per sq meter, excluding the cost of the fixative.

The cost of using the orchard spray equipment is considerably higher than that of using the large distributor tank truck because the former is designed for lower-volume applications in areas with restricted access. Since somewhat larger capacity equipment may be usable in some instances, we can view the cost with orchard spray equipment as an upper bound and the cost with the large distributor tank truck as a lower bound.

The pamphlet "Costs of Establishing and Producing Prunes" also provides information on the cost of spraying the trees using a blast sprayer. The time required to spray an acre twice is one hour. The labor cost is $5.00, and fuel and repairs cost $10.00. The amount of material applied is 350 to 400 gallons per acre per application. In addition, the sprayer and tractor together cost about $7.00 per hour. Performing the same calculations as done on the ground spraying data, we get a cost of $0.00976 per sq meter for labor, $0.01367 for equipment, and $0.01953 for maintenance and repairs. The implied rate is 512 sq meters per hour.

Similar calculations were performed using data from the Cooperative Extension, College of Agriculture, Washington State University publication "Cost of Producing Apples in Central Washington." The resulting labor cost is $0.0082 per sq meter. The equipment cost is $0.0252 per sq meter, and the cost of fuel is $0.0318 per sq meter. The coverage rate is 610 sq meters per hour.

Table A.1.2.3.1 summarizes the results of these calculations and presents representative costs and rates. The representative figures were calculated in four steps. The first was to convert the costs as shown to a dollars-per-hour basis by multiplying the rate by the cost per sq meter. Second, the average

TABLE A.1.2.3.1. Summary of Data for Spraying Orchards from the Ground, Excluding Material Cost

Source and Procedure	Rate (m^2/hr)	Cost (1982 $/m^2) Total	Labor	Equipment	Fuel
Univ. of Calif.					
Spray ground	260	0.054	0.019	0.017	0.017
Spray trees	512	0.043	0.010	0.014	0.020
Total	260	0.097	0.029	0.031	0.037
Wash. State Univ.					
Spray ground	305	0.060	0.016	0.034	0.010
Spray trees	610	0.065	0.008	0.025	0.032
Total	610	0.125	0.024	0.059	0.042
Representative					
Spray ground	280	0.058	0.018	0.027	0.013
Spray trees	560	0.055	0.009	0.020	0.026
Total	280	0.113	0.027	0.047	0.039

rate and the average cost per hour for both steps were calculated from the two data sources. Third, the average dollar per hour figure was divided by the average rate to yield the representative dollars per sq meter. Finally, the costs for the two steps were added to find the total cost per sq meter. The representative combined rate was set equal to the rate of the more costly procedure - spraying the ground. This means that for every operator-tractor-weed sprayer crew there will be one-half of an operator-tractor-blast sprayer crew.

Finally, there is the cost of the fixative to be applied. Aspects bearing on the choice of the fixative were discussed in the previous section, and following the reasoning there it is assumed that the fixative chosen is lignosite. Because of the increased total physical surface area per sq meter due to tree foliage, the foregoing calculations relating to application assumed that more than the usual amount of fixative per sq meter would be required. Those calculations assumed that spraying the ground and spraying the trees would each require about 0.4 gallon per sq yard. At this application rate, the material cost for each spraying procedure would be about $0.05 per sq meter. For the two procedures combined the cost would be $0.10 per sq meter. This raises the total cost for the combined spraying operation to $0.213.

A.1.2.4 Defoliate

According to the Cooperative Extension orchard farm advisor in Butte County, California, orchard defoliation is seldom done intentionally any more. The only time it is done is when very heavy wind is expected. Defoliation is a last step to prevent the trees from being blown down.

Defoliation is accomplished by spraying a zinc sulfate solution on the trees. The solution is prepared by mixing eight to ten pounds of zinc sulfate per 100 gallons of water. About 350 gallons of solution are applied per acre. The Cooperative Extension, College of Agriculture, Washington State University publication "Cost of Establishing on Apple Orchard, Columbia Basin, Central Washington" lists the price of zinc sulfate at $1.35 per pound.

Mixing nine pounds per 100 gallons and spraying 350 gallons per acre means that 31.5 pounds of zinc sulfate are being applied per acre. The cost per sq meter for the chemical is

$$31.5 \text{ lb/ac} \times \$1.35/\text{lb} \div 4046.7 \text{ m}^2/\text{ac} = \$0.0105/\text{m}^2$$

Table A.1.2.4.1 summarizes the data from the University of California Cooperative Extension publication "Cost of Establishing and Producing Prunes" and the Cooperative Extension, College of Agriculture, Washington State University publication "Cost of Producing Apples in Central Washington." These are the same data used in the previous section for calculating the cost of applying fixative to trees. As shown, the hourly labor, equipment, and fuel costs are averaged along with the time to spray one acre with 350 gallons. This average time is converted to a rate in terms of sq meters per hour and adjusted for one hour per shift lost to radiation control measures. This is done as shown:

$$4046.7 \text{ m}^2/\text{ac} \div 0.425 \text{ hr/ac} \times 7/8 \text{ adj} = 8331 \text{ m}^2/\text{hr}$$

Dividing this rate into the hourly cost figures gives the labor, equipment, and fuel cost per sq meter. Adding the material cost brings the total to $0.0333 per sq meter.

A.1.2.5 Leach

The general aspects of leaching are described in Section A.1.9.3, which addresses the leaching of lawns. As in the case of leaching lawns, it seems the appropriate method for leaching orchards is first to apply a concentrated solution of the leaching agent to the soil and to follow this with an application of water. Following Section A.1.9.3, we base the calculations on ferric chloride being used as the leaching agent. Dick and Baker (1967) used this material in a 1% solution in their tests at the Nevada Test Site. Other chemicals could be used, notably EDTA.

The cost of applying ferric chloride is estimated here using the representative cost of applying fixative to the ground, which was developed in Section A.1.2.3. This cost is adjusted to account for the different amount of material applied.

TABLE A.1.2.4.1. Summary of Data for Applying Defoliant to Orchard Trees

Source	Time or Rate	Cost (1982 $/m^2)					
		Units	Total	Labor	Equipment	Material	Fuel
Univ. of Calif.	0.5 hr/ac	$/hr:	--	5.00	7.00	--	10.00
Wash. State Univ.	0.35 hr/ac	$/hr:	--	5.00	18.43	--	23.29
Average	0.425 hr/ac	$/hr:	--	5.00	12.72	--	16.64
Representative	8331 m^2/hr	$/m^2:	0.0146	0.0006	0.0015	0.0105	0.0020

Ferric chloride is normally sold in a 40% solution. One gallon of this mixture will cover 19 sq meters to produce a 1% solution when 0.3 inch of water is applied to the soil. One gallon for 19 sq meters is equivalent to 213 gallons per acre. Fixative application, at 0.4 gallon per sq yard, is equivalent to 1936 gallons per acre. Thus, applying the leaching agent involves a fraction of the cost and time that applying a fixative does:

$$213 : 1936 = 0.110$$

Adjusting the application rate with this factor gives 2545 sq meters per hour. The labor cost is $0.00198 per sq meter, and the equipment and fuel costs are $0.00297 and $0.00143 per sq meter, respectively.

In addition to the cost of applying the leaching agent, there is also the cost of the leaching agent itself. This was calculated as $0.026 per sq meter in Section A.1.9.3. Finally, the cost of applying water was estimated in Section A.1.2.1. The various costs for leaching are summarized and combined in Table A.1.2.5.1.

A.1.2.6 Scrape Without Tree Removal

This operation involves removing the top four to six inches of orchard soil without removing or damaging the trees. The requirement to work around the trees makes this operation significantly different from scraping agricultural fields (A.1.1.5) or vacant land (A.1.3.3). There are four principal ways in which scraping will be affected by the presence of trees. First, any earthmoving equipment used will have to be fairly small to fit between the trees. Second, such equipment will be limited in movement by the trees. Third, dump trucks will not always be able to get close to the spot where the scraping is being done. Fourth, shallow roots and the base of the trunk will require careful equipment operation if damage to the trees is to be avoided.

TABLE A.1.2.5.1. Summary of Leaching Data

Item	Rate (m^2/hr)	Cost (1982 $\$/m^2$)				
		Total	Labor	Equipment	Material	Fuel
Ferric chloride	--	0.026	--	--	0.026	--
Application of ferric chloride	2545	0.0064	0.0020	0.0030	--	0.0014
Application of water	3541	0.0014	0.0014	--	--	--
Total	2545	0.0338	0.0034	0.0030	0.026	0.0014

A workable procedure for scraping appears to be to have two laborers shovel soil from the base of the trees toward the center of the lanes between the tree rows. These would be followed by a small (0.75 cubic yard capacity) wheel-mounted front-end loader. The front-end loader would scrape up the top surface of the soil and remove the soil to a dump truck waiting at the end of the lane.

Means' Building Construction Cost Data 1982 provides data useful for estimating the cost of this operation. The hand shoveling would require two building laborers at $19.40 per hour each. A medium-equipment operator at $24.95 per hour and 0.5 building laborer are specified for operating the front-end loader. Total hourly labor costs (including fringe benefits) are $73.45. The front-end loader costs $24.00 per hour.

Estimating the rate is more conjectural. Means lists the output of the small front-end loader as 45 cubic yards per hour for bulk excavation of medium soil. As mentioned earlier, the orchard places severe limitations on the equipment's productive efficiency. On the other hand, the soil is likely to be relatively soft and light, and the terrain fairly flat and free of excess brush and weeds. Based on these considerations, we estimate the (unadjusted) production rate at 75% of that listed by Means. The coverage in terms of sq meters per hour can be calculated as follows:

$$45\ yd^3/hr \times 0.75\ eff.\ adj \times 6\ yd^2/yd^3 \times 0.836\ m^2/yd^2 \times 7/8\ adj = 148\ m^2/hr$$

In comparison, Ed Doolittle of Doolittle Construction Co. supplied data indicating a faster rate. This faster rate is largely the result of his specifying a larger-capacity front-end loader. He estimated that a front-end loader with a three cubic yard capacity could load a scoopful into a dump truck once every three minutes. This is equivalent to one cubic yard per minute or 60 cubic yards per hour. This is one-third more than the full rate given by Means for the smaller loader. Converting the Doolittle figure to sq meters per hour, we get

$$60\ yd^3/hr \times 6\ yd^2/yd^3 \times 0.836\ m^2/yd^2 \times 7/8\ adj = 263\ m^2/hr$$

Here we use the rate calculated from the Means data since the smaller equipment seems more appropriate in this situation. Further, the rate can be adjusted with better information simply by changing the efficiency adjustment factor from 75% to a different level.

Dividing the hourly rate into the hourly labor and equipment costs generates their respective costs in terms of dollars per sq meter: $0.496 and $0.162. The total cost per sq meter is $0.658.

A.1.2.7 Plow

Section A.1.1.6 provides a general description of plowing as a decontamination technique. In an orchard, however, plowing will be hampered by the presence of trees. Also, according to the Cooperative Extension orchard farm advisor in Butte County, California, unless the orchard has been cultivated on a regular basis, roots may be so shallow that any plowing-type operation may be impossible without severe permanent damage to the trees.

This source indicated that the particular plowing-type operation appropriate for orchards is called disc and float. This mixes more than turns the soil, and it limits damage to the root structure. A standard ten-inch disc harrow will mix the soil well to a depth of four to five inches. Floating does little more than level out the ridges left by the disc. The cost information provided indicated that normal orchard operations entail expenditures of about $100 per acre per year for discing and floating. The procedure is performed five times per year. The rate given was 2.2 acres per hour, but as will be explained, this is probably an inadvertent error and the rate is more likely 2.2 hours per acre.

In the University of California Extension publication "Costs to Establish and Produce Walnuts," the time required for disc and float five times is 2.2 hours per acre. This same rate is repeated elsewhere in the publication. The estimate of 2.2 hours per acre for performing the operation five times is equivalent to 0.44 hours to disc and float one acre once. The farm advisor's 2.2 acres per hour for five treatments implies one fifth of an hour to disc 2.2 acres once. In other words, the hourly coverage rate is 11 acres. This seems unreasonably high. Further, the publication-listed rate of 2.2 hours per acre is consistent with the listed labor cost of $11 per acre. This works out to $5.00 per hour, which is the normal agricultural labor wage rate.

At 2.2 hours per acre for disc and float five times, the rate in sq meters per hour is

$$\frac{5}{2.2 \text{ hr/ac}} \times 4046.7 \text{ m}^2\text{/ac} \times 7/8 \text{ adj} = 8047 \text{ m}^2\text{/hr}$$

For comparison, the rate for plowing agricultural fields is 6374 sq meters per hour.

"Costs to Establish and Produce Walnuts" lists the labor cost for discing and floating as $11.00 per acre and the fuel and repair costs as $15.75 per acre. In addition, a 60-horsepower wheel-mounted diesel tractor costs $7.00 per hour to operate, and the disc and float equipment cost $1.15 and $1.00 per hour, respectively. It is not clear if these figures include the cost of ownership, but since purchase price, depreciation, and interest are listed separately, it appears that the hourly operation costs do not include these other items. The cost of the tractor is $20,000 and that of both the

associated implements is $5,000, for a total of $30,000. This $30,000 comprises about 13.9% of the total $216,200 farm equipment investment. This source gives the depreciation and interest per acre for the total equipment investment as $216.00 and $151.34, respectively. Taking 13.8% of these figures as the share for discing and floating equipment, we get a depreciation cost of $30 per acre per year and $21 per acre per year for interest. The total of these two costs is $51.00. However, since this equipment is used for other farming activities besides discing and floating, only a fraction of this cost can be ascribed to that procedure, and, unfortunately, this source does not provide sufficient information to determine that fraction.

Another approach is to refer to Means' Building Construction Cost Data 1982. This source (p. 10) lists the monthly rent for a 65-horsepower wheel-mounted tractor equipped as an earthloader. Assuming that the additional five horsepower and the loader equipment are roughly equivalent in cost to the disc and float equipment, we take the monthly ownership cost to be $1875. Dividing by 336 hours per month, we get an hourly equipment ownership cost of $5.58. Total equipment cost is, therefore, the sum of this figure and the operation costs. The total is $14.73 per hour.

Dividing the hourly costs by the coverage per hour gives $0.006 per sq meter for labor, $0.0018 per sq meter for equipment, and $0.0020 per sq meter for fuel and repairs. Adding these gives a total cost of $0.0044 per sq meter.

A.1.2.8 Remove and Replace

The most costly orchard decontamination operation is removing and replacing the trees. This operation has three cost components. They are removal of trees, ground preparation and planting of trees, and the trees themselves. This operation might be done in conjunction with soil scraping. If this were the case, the appropriate stage for the scraping to be done would be after tree removal, but before ground preparation. Soil scraping with the trees removed is listed as a separate operation (see Section A.1.2.12).

Not included in the cost estimates here are the loss in income from unrealized crop sales. It is assumed that if orchard removal and replacement were necessary, the crop would not be safe for use. Another consideration is that the newly planted trees will not yield a marketable crop for several years. This loss in income, as well as the necessary post-planting orchard care costs, are not counted as part of the removal and replacement operation cost.

Orchards differ considerably among themselves due to local conditions as well as the type of crop being raised. The two main factors which affect removal and replacement costs are the number of trees per acre and the cost of the trees.

The Cooperative Extension, College of Agriculture, Washington State University publication "Determining the Costs of Removing and Replacing Dead or Damaged Commercial Fruit Trees" is the primary source of information about the removal of trees. The cost data were adjusted from 1977 to 1982 price levels.