Isensee and Jones (1975) also used a laboratory-scale, aquatic ecosystem to study TCDD bioaccumulation in mosquito fish, fingerling channel catfish, algae, duckweed, snails, and water fleas. TCDD was adsorbed on soil which, when equilibrated with the water, resulted in TCDD concentrations in water ranging from 0.05 to 1,330 ppt. Concentrations in excess of 200 ppt exceed the limits of water solubility for TCDD and prevent meaningful interpretation of those bioaccumulation data.

In experiments where the water concentration was less than 200 ppt, Isensee and Jones (1975) reported bioaccumulation ratios (the ratio of the concentration of TCDD in the organism to the concentration of TCDD in the water) ranged from 2×10^3 to 63×10^3. They found a strong, positive correlation between the concentration of TCDD in tissue and concentration of TCDD in water for all organisms. Isensee recalculated these data from a dry weight basis to a fresh weight basis in order to make the data more comparable to other studies. He reported the average degree of bioaccumulation ranged from 2 to 7×10^3 times the water concentration of TCDD. The total amount of TCDD accumulated was directly related to the water concentration. Equilibrium concentrations in tissues were reached in 7 to 15 days. He reports TCDD bioaccumulates to about the same magnitude as many of the chlorinated hydrocarbon insecticides in model aquatic ecosystems.

These results from laboratory studies indicate that organisms exposed to TCDD in their diet or in aquatic ecsosytems will bioaccumulate TCDD. The degree of bioaccumulation which occurs from the use of TCDD-contaminated herbicides in natural ecosystems depends on the magnitude and duration of organism exposure. In laboratory studies, organism exposure is assured through regular addition of TCDD to the food (for feeding studies) or (in aquatic ecosystems) from a substantial reservoir of TCDD adsorbed on sand or soil which continuously releases small quantities of TCDD to water.

In the natural environment, several processes operate to reduce or eliminate TCDD exposure to organisms and thereby minimize the opportunities for bioaccumulation. Crosby and Wong (1977) report TCDD in herbicide formulations disappears rapidly from vegetation and soil when exposed to sunlight. This mechanism would markedly reduce or eliminate organism exposure through dermal contact with or ingestion of contaminated vegetation. In the aquatic environment, the likelihood of 2,4,5-T and TCDD entry to aquatic systems is slight, but if it does occur, chemicals in the water are rapidly diluted and carried downstream with streamflow. TCDD which adsorbs on sediments provides a reservoir of TCDD in the aquatic environment similar to that provided in the model aquatic ecosystem studies. However, in real stream systems, TCDD liberated from the sediments would be quickly moved downstream with streamflow. The opportunity is minimal for bioaccumulation by a particular organism.

ENVIRONMENTAL MONITORING

The third approach to evaluating TCDD bioaccumulation is to look directly for evidence of bioaccumulation in the field. Several efforts have been made, but with markedly different sophistication and sensitivity of analytical methods. For instance, Woolson et al. (1973) analyzed samples of eagle tissues from various regions in the United States. No TCDD was detected. The minimum detection limit, however, was 50 ppb which is not adequate to properly evaluate bioaccumulation of TCDD, considering the inherent toxicity of the molecule.

Young et al. (1976) studied the behavior and bioaccumulation of TCDD in animals from the Elgin Air Force Base site used for equipment development and testing for application of herbicides in Vietnam. The study area received massive applications (1,000 pounds per acre) of 2,4,5-T, much of which contained TCDD in excess of 1 ppm. Analysis of soil from the test site shows TCDD residue levels in the range of 10 to 1,500 ppt. Analysis of rodents, reptiles, birds, fish, and insects shows the presence of TCDD in tissues of at least some of the organisms involved in this test program. The results of this test substantiate the physical-chemical data and the data from laboratory tests which indicate that if TCDD is available to organisms in the field, it will be bioaccumulated. The degree to which herbicide used at Elgin test site was contaminated with TCDD and the massive rates of application, however, make these data not directly applicable to the use of herbicides for any registered purpose in the United States. They are useful to indicate TCDD does have a potential for bioaccumulation.

Other studies done in connection with the registered uses of 2,4,5-T for vegetation control have found relatively little TCDD in biological samples. In 1973-74, the Environmental Protection Agency, cooperatively with the USDA Forest Service, conducted a monitoring program for TCDD in tissues of animals from several areas which had been recently treated with 2,4,5-T in western Oregon and Washington. The analytical methodology employed however, was not adequate to establish the presence of TCDD in those environmental samples. It was adequate to determine which samples did not contain TCDD in the low-to-middle part per trillion range.

Results of the monitoring program showed approximately 84 percent of the samples did not contain detectable levels of TCDD. The remaining samples are described by EPA as "minutely suggestive" for TCDD. In 1976, five of these "possible positive" samples were reanalyzed by two laboratories (participants in the dioxin monitoring program); two samples did not contain detectable TCDD. EPA described the results of analysis of the other three as follows: "Some of the samples analyzed in 1973-74 still appear positive for TCDD. Unfortunately, the results from the two laboratories participating in the confirmation vary widely. The confirmation analysis, therefore, still does not give a precise quantification of the amount of TCDD present. It does appear, however, that from a qualitative standpoint TCDD was present in a small percentage of the forest samples collected in 1973." Assuming three out of five samples (60%) which were possible positives in the 1973-74 analysis are, in fact, qualitative for TCDD, then 9.6 percent of the

1973 samples were positive for TCDD and 90.4 percent did not contain detectible resides.

The EPA beef fat monitoring program which was initiated in 1974, has been completed. Samples of beef fat (85) and liver (43) have been analyzed for TCDD. Approximately 25 percent of these samples are from animals not exposed to areas sprayed with 2,4,5-T. EPA reported in a Draft Dioxin Position Document that one sample showed a positive TCDD level at 60 ppt, and two at 20 ppt; five samples appeared to have TCDD in the range of 5 to 10 ppt. EPA stated, "The analytical method is not valid below 10 ppt, alhtough a recent dioxin implementation plan meeting statement set 9 ppt as the minimum detectable level." Of the 43 liver samples analyzed, one sample may contain TCDD, but the level is too close to the sample detection limits for quantification. A fat sample from the same animal showed no TCDD residue. The results of the EPA beef fat monitoring study indicate bioaccumulation of TCDD in grazing animals is not sufficient to result in regularly detectable levels of TCDD greater than 10 ppt in beef fat and liver.

Newton and Snyder (1978) reported on the analysis of livers from mountain beavers captured 2 months after a forested area in western Oregon was treated with 2,4-D and 2,4,5-T. Analysis of the tissues showed no detectable levels of TCDD with a minimum detection limit of less than 10 ppt. Mountain beavers normally consume large quantities of vegetation, thereby affording them substantial exposure to herbicide-treated plants. In addition, they are a burrowing animal which will put them in intimate contact with herbicide and TCDD present on the soil surface.

Shadoff et al. (1977) looked for accumulation in animals due to the use of 2,4,5-T in the mid-western United States. They did not detect any TCDD (detection limit about 10 ppt) in samples of fish, water, mud, and human milk from areas in Arkansas and Texas. An extensive survey for TCDD residues (with a detection limit of 10 ppt) in aquatic organisms in currently in progress by the USDA Forest Service Pacific Northwest Forest and Range Experiment Station. Organisms are from streams flowing from Oregon forests with a recent history of 2,4,5-T use. The study will be completed by December 1, 1979.

Meselson and O'Keefe (1977), in a preliminary report to Oregon Congressman Weaver, indicated some samples of human milk from areas in which 2,4,5-T is used contained detectable levels of TCDD. They reported three samples out of six from Texas, and one sample out of five from Oregon contained detectable levels of TCDD. The levels detected were at the limits of detection, and were substantially below the 10 ppt level established by EPA in the beef fat monitoring program as the minimum acceptable, reportable level.

The results of these various tests indicate that, if TCDD is present in the environment in a form which is available to organisms, then bioaccumulation will occur if organisms are exposed. This concept is supported, both from an examination of the physical-chemical properties of TCDD, as well as by studies of its behavior in anmals exposed through feeding studies or in laboratory model aquatic ecosystems. The degree to which bioaccumulation of TCDD occurs in the field is dependent not only on the physical-chemical properties of the compound, but also on the persistence and availability of TCDD in the environment. Mechanisms of degradation and dilution which operate in the natural environment reduce the opportunities for organisms to be exposed, and thereby reduce the degree to which bioaccumulation might occur.

Monitoring for TCDD residues in animal samples from areas where 2,4,5-T is used at normal rates of application tend to show little or no detectable bioaccumulation of TCDD. In the beef fat monitoring study, for instance, only three samples out of 63 (exposed group) contained TCDD at levels within the range at which the analytical method is valid quantitatively. The EPA monitoring for TCDD in animal samples from western forests conducted prior to June 1974, showed about 90 percent of the samples did not contain detectable levels of TCDD.

The study of TCDD residues in livers of mountain beavers from areas treated with 2,4,5-T showed no detectable levels of TCDD, with minimum detection limit of less than 10 ppt. A widescale monitoring of water, sediment, fish, beef, and human milk from areas in the midwestern United States where 2,4,5-T has been applied also showed no detectable TCDD residues at minimum detection levels which averaged 10 ppt. These monitoring efforts indicate that substantial bioaccumulation of TCDD (sufficient to produce residue levels in excess of 10 ppt TCDD in the majority of the population) is not occurring in animals in or near areas treated with 2,4,5-T in current operational programs.

This conclusion is not in conflict with recently reported findings of TCDD in fish from the Titawabasee River downstream from the Dow chemical manufacturing plant at Midland, Michigan (Dow 1978a). The residues in the fish, whether they are from plant discharge water or are from the products of combustion (Dow 1978b), did not result from the use of 2,4,5-T as an herbicide.

THERMAL CONVERSION OF 2,4,5-T TO TCDD

It is possible to produce TCDD on heating or burning of 2,4,5-T or 2,4,5-T treated materials in laboratory tests. The conditions of combustion and herbicide concentration are crucial. The tests reported by Baughman and others show TCDD formation when 2,4,5-T is heated in a closed container under alkaline conditions such that the sodium salt of trichlorophenol is a significant degradation product. The amount of herbicide employed in these tests was very high. Langer et al. (1973) showed control of the decomposition reaction to produce trichlorophenol was necessary since heating above the decomposition point (300°C) produced no TCDD. Concentration of herbicide is very important because the formation of TCDD is apparently a bimolecular reaction; that is, it requires the joining together of two molecules of sodium 2,4,5-trichlorophenate. If conditions of heat and alkalinity are conducive to the condensation of the phenol to form TCDD, then the extent of condensation varies with the number of molecules available to interact with one another.

Experiments like those of Baughman and others are useful only to show that thermal production of TCDD is chemically possible. Experiments which use closed systems and high concentrations of 2,4,5-T drastically overestimate the levels of TCDD which might be produced in burning situations in the field because (a) the concentrations of herbicide are several times greater than the levels of 2,4,5-T which occur in the field, and (b) heating is prolonged and uniform, but combustion does not actually occur. Temperatures at which thermal decomposition of TCDD occurs (800°C) are not attained in these test situations. Actual burning, of course, will result in temperatures near those used in laboratory tests only briefly. As temperatures approach 800°C, thermal decomposition of TCDD will also occur. When combustion can take place with a free exchange of air, temperatures above 1,200°C are common. Under these conditions we expect complete oxidation of 2,4,5-T, trichlorphenols, TCDD, and similar chemicals.

There are only limited experimental data on how much TCDD is produced when 2,4,5-T is burned. Watts and Storher (1973) noted burning and heating of such 2,4,5-treated products as vegetation, meat, and fat did not produce detectable TCDD. Sensitivity of their analysis was not adequate to detect environmentally important quantities of TCDD. Present metholdology with sensitivities approaching 10 ppt is sufficient.

The most pertinent data come from a laboratory experiment in which grass treated with 2,4,5-T at 12 pounds per acre was burned under conditions somewhat resembling those which might occur in the field (Stehl and Lamparski 1977). Their study showed an approximate 0.00016 percent conversion of 2,4,5-T to TCDD. This involved a semi-closed system, however. Thus, any TCDD which might normally have been lost to the air as vapor or adsorbed on smoke particles in forest burning was captured and retained in this system.

The amount of TCDD produced is dependent on the concentration of 2,4,5-T in the vegetation. Norris et al. (1977) determined the persistence of 2,4,5-T in Oregon forests. Calculated levels of TCDD which might be produced by burning, assuming the conversion ratio reported by Stehl and Lamparski (1977) are in table 9.

Clearly, the amount of TCDD produced depends to a major degree of when burning occurs after treatment. 2,4,5-T is occasionally used to desiccate brushfields prior to burning. Burning may take place from 1 to 3 months after the application resulting in the possible TCDD levels of 14 and 0.2 parts per trillion, respectively. In some brush types, burning is delayed for 12 months or more. Immediately after application the level of TCDD present on the vegetation is approximately 10 parts per trillion, assuming the 2,4,5-T contained 0.1 parts per million TCDD. Research of Getzender and Hummel (1975) and Crosby and Wong (1977) indicates the TCDD orginally applied will be largely gone within 1 month of the application. Therefore, the levels of TCDD which might be produced by burning are not expected to substantially exceed TCDD levels present as a result of the original application of herbicide.

Preliminary research results from the Dow Chemical Company indicates several dioxin isomers may be formed in trace amounts during the combustion of many substances (not contaminated with or associated with 2,4,5-T). Fossil fuels, automotive exhaust, trash burners, cigarette smoke, and charcoal-grilled meats have all been found to produce or contain minute quantities of various dioxin isomers, including in some cases the 2,3,7,8-tetrachloro isomer (Dow 1978b). The validity of this research remains to be substantiated, but in any case, these sources of dioxins are not associated with the registered uses of 2,4,5-T as an herbicide in any way.

Table 9--2,4,5-T residues on vegetation (measured) and TCDD (calculated) that might be produced by burning vegetation

Months after application	2,4,5-T	Possible TCDD level if burning occurs at time indicated
	ppm	ppt
0	95	152
1	9.1	14
3	0.10	0.16
6	0.07	0.11
12	0.01	0.02

a/ From Norris et al. (1977).

b/ Percent conversion is 0.00016% (Stehl and Lamparski 1977).

PART 4: ANALYSIS OF EXPOSURE-NONAPPLICATORS

EXPOSURE VIA AIR

Bamesberger et al. (1966) indicated 2,4,5-T was found infrequently and in low concentrations in air-sampling studies in Washington state. In high use areas, however, one might expect concentrations similar to 2,4-D as reported by Adams et al. (1974). Average concentrations of the ester of 2,4-D in air in Washington during the spraying season was 0.1 $\mu g/m^3$. Assuming a person would inhale 30 cubic meters of air per day, the exposure would be 0.003 mg per day. The threshold limit values in air adopted by the American Confernece of Governmental Hygienists in 1977 were 10 mg/m^3 for 2,4-D or 2,4,5-T (Anonymous 1977b).

A medical evaluation was made of 64 men engaged in the manufacture of 2,4,5-T in the Dow Chemical Plants (Johnson 1971). No adverse effects in human health or clinical results were found when compared to 4,600 men not exposed to 2,4,5-T. Some workers were exposed to 2 to 8 mg (inhalation) daily of 2,4,5-T for >960 days (total of 10,000 mg 2,4,5-T).

The highest concentration of phenoxys in air probably occurs during application. Russian workers (Fetisov 1966) found concentrations of the sodium salt of 2,4-D up to 22.4 mg/m^3 after spraying. Akesson (1978) however, has shown a maximum of 20 $\mu g/m^3$ of herbicides downwind from typical aerial application sprays. TCDD has not been measured in the air in spray areas, but possible levels can be calculated based on an assumed 2,4,5-T:TCDD ratio of $1{:}1x10^{-7}$ and the levels of herbicide above.

EXPOSURE VIA FOOD

No research data or reports were found on suicidal attempts or accidental ingestion of large amounts of 2,4,5-T. Three reports on the fate of 2,4,5-T in man taken orally in moderate amounts indicated a majority of the 2,4,5-T is eliminated unchanged in the urine a few hours after ingestion (Gehring et al. 1973, Kohli et al. 1974, Matsumura 1970). Doses as high as 150 mg (2.2 mg/kg) were taken (Matsumura 1970). No detrimental effects were noted. Oral intake of these proportions, however, would be uncommon.

Measurable amounts of 2,4,5-T were found only in two food samples in FDA market basket surveys in 1966-1967 and one sample in 1967-1968. No 2,4,5-T has been found in food since 1968 in the FDA studies. A total of over 2,000 samples were collected and analyzed. Highest 2,4,5-T concentration in the 1966-1967 samples was 0.19 ppm. Only two residues of silvex were found. These occurred in dairy products collected in 1965-1966 and were 0.018 and 0.029 ppm (EPA 1978). Therefore, based on FDA market basket surveys, the amount of phenoxy herbicides in food is virtually undetectable.

The most direct exposure of man to 2,4,5-T through food products is probably via plants. However, research has shown that phenoxy residues in forage and agronomic crops usually disappears rapidly. Since most weeds in crops are treated in early spring, residues disappear by harvest time. Devine (1970) analyzed 27 samples of rough rice from Texas, Arkansas, and Louisiana for residues of 2,4,5-T at intervals from 50 to 84 days after application of 2,4,5-T for weed control. No detectable residues (0.01 ppm) were found. Rice straw contained residues which varied from <0.01 ppm to 1 ppm. In the case of pasture and rangeland plants, which may intercept relatively high amounts of phenoxy herbicides (up to 200 ppm), residues can be avoided in meat and milk products by deferring grazing for milk cows on the treated area a few days to a few weeks and removing meat animals from treated pastures two weeks before slaughter. These restrictions appear on current product labels.

Even when wildlife species or livestock graze on pastures immediately after spraying, only small amounts of phenoxy herbicide may appear in meat or milk. It disappears after a few days due to rapid loss of the herbicides from forage and by normally rapid excretion from the grazing animal. Klingman et al. (1966), in actual field grazing trials with cattle, found 0.01 to 0.09 ppm of 2,4-D in milk the first two days after spraying 2,4-D 2 lb/A and lower amounts thereafter. No residues of 2,4,5-T were found in milk from cows put into pastures four days after spraying. Bjerke et al. (1972) found no residues of 2,4-D, 2,4,5-T or MCPA, or their corresponding phenols greater than 0.05 ppm in milk from cows exposed to 30, 300, or 1,000 ppm 2,4,5-T in their feed level. Residues of silvex were found only at the 1,000 ppm feeding level. Clark et al. (1975) concluded residues of phenoxy herbicides or phenolic metabolites in meat of sheep or cattle are unlikely under normal patterns of 2,4,5-T use.

In field studies, Newton and Norris (1968) found that blacktail deer did not accumulate large amounts of 2,4,5-T grazing browse that had been treated with 2 lb/A. Concentrations in tissue rarely reached detectable levels and the ruminant was able to degrade and eliminate the herbicide soon after ingestion. Obviously game animals may graze in treated areas immediately after spraying, but in most cases spray areas are substantially smaller than the home range of large game animals thus exposure is not continuous. Game animals are likely to constitute a vanishing small proportion of the average human diet in the U.S., but may be an important component in the diet of a few individuals.

Fish and other aquatic organisms are also important components of the diet of man. Occurrence of significant amounts of phenoxy herbicides in the FDA market basket survey in fish products was not indicated. Research shows that most fish do not accumulate large amounts of the phenoxy herbicides (<1 ppm), even when the herbicide is applied directly to water surrounding the fish. Degradation of phenoxys occurs in water sources. Fish also have the capability to eliminate and degrade the phenoxys.

Bioaccumulation of TCDD in aquatic ecosystems under experimental conditions has been demonstrated (Isensee and Jones 1975), but in the natural environment they remain largely undetected (see bioaccumulation of TCDD in Part 3 of this chapter).

EXPOSURE VIA WATER

Residues of phenoxy herbicides, tend to remain in upper soil layers and are rapidly degraded. It is unlikely that groundwater would be polluted from current registered uses of phenoxy herbicides, thus exposure is considered zero.

Surveys of surface waters by the U.S. Geological Survey program of major rivers in the western United States over a period of years indicated that the highest concentration of a phenoxy herbicide was 0.00097 ppm 2,4-D. Researchers have found that even in streams adjacent to aerial spraying operations in the forest, concentrations of 2,4-D, 2,4,5-T, or other herbicides seldom exceed 0.01 ppm. After application, concentrations of the herbicide rapidly diminish by dilution, The preponderance of stream water samples from operational monitoring programs in forest land have not contained detectable residues of 2,4,5-T. Even when ditch banks were sprayed directly so spray fell into the stream, the maximum 2,4,5-T found after applications at 2 lb/A was 0.04 ppm. Herbicide could be found only in the treated area, but none 1 mile downstream.

Therefore, considering that only small and intermittent portions of the total land area are treated, the risk of exposure of the general population in the U.S. to significant levels of the phenoxy herbicides in water is remote. The greatest potential for exposure occurs if domestic water is taken from very small streams in or immediately downstream from treated areas. An extensive research base shows: (1) such exposure would be infrequent because most small watersheds are never treated, and those that are seldom yield water contaminated with herbicides, and (2) when contamination does occur it is low (less than 0.1 ppm, usually less than 0.01 ppm 2,4,5-T) and transitory (less than one hour to a few days).

PART 5: EXPOSURE ANALYSIS - APPLICATORS

The Environmental Protection Agency RPAR notice (Position Document 1 or PD-1) for pesticide products containing 2,4,5-T reported six rebuttable presumptions against registration (or presumptions of risk). In all but one, scenarios regarding spray practices involving 2,4,5-T were used to establish assumptions for calculating a presumed level of application exposure. When these levels of exposure were compared with estimated no adverse effect levels (for reproductive and fetotoxic effects), EPA concluded ample margins of safety did not exist. The assumptions used in the scenarios in PD-1 substantially over estimate exposure resulting in calculations of margins of safety which over estimate risk.

Calculation of accurate margins of safety is dependent equally on correct identification of no-adverse-effect-levels and correct determination of the nature, magnitude and duration of exposure. The purpose of this section of the report is to provide information on the nature, level, and duration of exposure applicators (or those in or near spray operation areas) receive from spray practices currently in use. This section contains three major sections: (1) description of the exposure situations which result from spray practices currently in use in each of the four major commodity areas (timber, range and pasture, rights-of-way, and rice), (2) an analysis of exposure in which various exposure assumptions are used in a factorial approach to calculate adjusted levels of exposure and margins of safety, and (3) an estimation of maximum exposure based on direct measurement and expressed in absolute terms.

PRESUMPTIONS OF RISK AND METHODS FOR EVALUATING EXPOSURE

The Environmental Protection Agency Notice of Rebuttable Presumption Against Registration and Continued Registration of Pesticide Products Containing 2,4,5-T contains the conclusions that the following rebuttable presumptions against registration or presumptions of risk arise:

1. TCDD alone and 2,4,5-T containing 0.05 ppm TCDD can produce oncogenic effects in mammalian species (EPA 1978, page 17128).

2. The difference between the no-adverse-effect-level and the calculated dermal exposure level of a back-pack sprayer for both 2,4,5-T and TCDD do not constitute an ample margin of safety with regard to teratogenic effects (EPA 1978, page 17139).

3. The difference between the no-adverse-effect-level and the calculated dermal exposure level of a sprayer using tractor-mounted, low-boom equipment for both 2,4,5-T and TCDD does not constitute an ample margin of safety with regard to teratogenic effects (EPA 1978, page 17140).

4. The difference between the no-adverse-effect-level and the calculated dermal exposure of persons exposed directly beneath the spray plane for only 2,4,5-T does not constitute an ample margin of safety with regard to teratogenic effects (EPA 1978, page 17140).

5. The difference between the no-adverse-effect-level and the calculated (inhalation) exposure level of persons exposed directly beneath a spray plane for only 2,4,5-T does not constitute an ample margin of safety with regard to teratogenic effects (EPA 1978, page 17141).

6. The difference between the no-adverse-effect-level and the calculated cumulative exposures of oral, dermal, and inhalation exposure level for both 2,4,5-T and TCDD does not constitute an ample margin of safety for those instances that single route exposures had exceeded ample margins of safety (EPA 1978, page 17141).

Appendix 3 contains extracts from PD-1 showing the exposure scenarios, assumptions, dose levels, and no-adverse-effect levels for presumptions of risk two through six.

Presumption of risk no. 1 (oncogenic effects) is based solely on the toxicology of 2,4,5-T and TCDD. The EPA PD-1 does not include an analysis of exposure in relation to a no-adverse-effect-level for oncogenic effects. The USDA policy on conduct of activities of joint Pesticide Assessment Teams precludes consideration of the toxicology associated with presumptions of risk. Therefore this assessment team report does not comment on presumption of risk no. 1.

The other five presumptions of risks (two through six, listed above), include both elements of toxicology and an analysis of exposure (to determine exposure or dose level). The toxicological basis for these five presumptions is identified in PD-1 and is based on "reproductive and fetotoxic" effects or teratogenicity. The exposure levels consistent with "no-adverse-effect" for teratogenicity were determined in the PD-1 as 20 mg/kg/day for 2,4,5-T and 0.03 μg/kg/day for TCDD. These no-adverse-effect levels are an integral part of the exposure scenarios from which the presumptions of risk arose. For the reason stated above, the Assessment Team does not evaluate these no-effect-levels. This report does evaluate exposure in these and alternative scenarios.

There are two major methods for reviewing the exposure analyses: the factorial method and the absolute method. The factorial method starts with the exposure scenarios as presented in PD-1. It identifies both the overt and hidden assumptions in a particular scenario, presents an alternate or modified set of assumptions, and develops a set of correction factors by which the exposure level should be multiplied in order to adjust for the modified assumptions. This is particularly useful in demonstrating the effect of various exposure assumptions on the calculated margin of safety. A range of assumptions can be evaluated quickly; for instance, if a particular scenario uses a 40 lb/100 gal. concentration of spray and 8 hours of exposure per day but the reader wishes to determine the effect of a 10 lb/100 gal spray and a 4-hour exposure day. The "correction factor" of 0.25 x 0.5 = 0.125 can be applied to either the previously calculated level of exposure (0.125 x exposure) or margin of safety (1/0.125 x safety margin) to obtain an adjusted value.

The absolute method is used by the EPA in the PD-1. It calculates de novo in stepwise fashion the estimated exposure for a particular exposure situation based on a series of assumptions. We have used the absolute method by keying preliminary data derived from one experiment involving exposure of human to 2,4,5-T with estimates of dermal contact based on field-use experience.

A third approach, which would be a modification of the absolute method could be considered. The absolute method as used herein and in the PD-1 tends to rest largely on single-source documents for a given scenario. It may be more valid to derive exposure potentials from the large body of data on drift from various kinds of equipment and calculate the dermal and inhalation interception of drift for persons in various dress at various distances. This could easily be accomplished jointly by persons involved in drift and exposure research and those involved in regulatory and hazard-evaluation work. Some efforts along this line have already been initiated (Akesson 1978) Although this approach has much to recommend it, it was beyond the scope of this assessment team.

Included in this report are calculated "margins of safety." The EPA PD-1 presents the data necessary for the calculations of the margin of safety (the no-adverse-effect-level divided by the calculated dose level) but does not explicitly state what consititutes an "ample margin of safety." Both the set of conditions or assumptions and the applicable acceptable safety margin associated with a presumption of risk should be clearly stated along with all statements of risk. This would enable all interested parties (including non professional groups) to assess the applicability of particular assumptions and margins of safety to their own circumstances.

An exposure analysis involves three types of exposure - environmental, consumer, and occupational; and three routes of exposure - oral, dermal, and inhalation. Although environmental exposure has been the principal focus of citizens' groups opposed to the use of 2,4,5-T and other chemicals, it was concluded by EPA that the present evidence shows this to be inconsequential with regard to the no-adverse-effect-levels which were identified in the PD-1 (EPA 1978). Consumer exposure was also shown to be inconsequential but was added to the total in the cumulative calculations that resulted in the assumption of unacceptable level (EPA 1978, page 17138). The other presumptions of risk (Nos. 2,3, 4, and 5) all involved occupational exposures primarily through dermal or inhalation routes. In judging any risks from occupational exposure, higher levels of presumptive exposure are acceptable because of its voluntary nature. Potential for over-exposure in any given situation can also be reduced through special protective measures.

Data on exposure for numerous exposure situations are needed. The scenario process involves making certain reasonable assumptions pertinent to the scenario being analyzed. In the absence of hard data, it is necessary to use the judgment of qualified, experienced individuals.

It is vital to the credibility of any hazard analysis to present the assumptions on which it rests as clearly as possible. These were not all explicitly stated in EPA's Position Document No. 1. Hidden assumptions can seriously mislead inexpert persons as to the applicability of the conclusions. There are several steps in hazard analysis which must be exposed to public judgment as part of the process of identifying whether the assumptions are reasonable or absurd. Other steps characterize an adverse effect as a "reasonable" or an "unreasonable" effect (which under FIFRA is the basis for EPA action). The use of "worst case" assumptions (particularly when several worst case assumptions are multiplied in sequence) can lead to unreasonable or improbable conclusions. The assumptions, reasonableness of adverse effects, and the use of worst-case situations in estimating risk need critical scrutiny.

Actual exposure time to a pesticide during the work day and work year is less than it would first appear. The information needed to compute exposure times is in 14 calculation summaries at the end of each commodity group portion in the "Exposure of applicators according to use pattern" section in Part 5 of this chapter. A summary table is at the end of the section.

Some confusion may exist in terminology. In this report the following definitions are used. The time spent at the treatment site is called "application time"; the time the sprayer is actually operating is called "nozzle time;" the portion of the nozzle time during which the worker intercepts the spray drift is called "drift time." For example, the typical back-pack sprayer on rangeland has 6 hours per day of application time, but because of the distance between stems (targets), the nozzle time is 6 seconds per minute and the walking and searching time is 54 seconds per minute. The sprayman works at spraying for 2 days per week over a 5-week period and does other ranch chores the balance of the week. Aircraft application results in the least exposure to field workers because the workers are upwind and at least one swath width away, while foliar application with power hand guns have the greatest exposure time. For most application situations, the application of 2,4,5-T is incidental to other activities and the worker will operate in only one or a few sites, but in rights-of-way and helicopter crews there are a number of commercial applicators applying the chemical for several months each year.

EXPOSURE OF APPLICATORS ACCORDING TO USE PATTERN

FORESTS

Aerial Application

Formulation and Containers

2,4,5-T is available for use in rehabilitation, site preparation, and release in forestry aerial applications as low-volatile emulsifiable esters (butoxyethanol, 2-ethylhexyl, propylene glycol butyl ether, and isooctyl esters) containing 4 or 6 lb ae per gallon. Several mixtures of 2,4,5-T with other herbicides are also used. Tordon 155 (1 lb ae picloram and 4 lb ae 2,4,5-T as the isooctyl ester), brushkiller (2 lb ae each of 2,4-D and 2 lb ae 2,4,5-T as low-volatile esters), and Banvel 310, 320, 510, and 720 (dicamba with 1 or 2 lb of 2,4,5-T per gallons as esters or amine salts). Invert drift reducing formulations of 2,4,5-T containing 1 or 2 lb ae alone or in combination with 1 or 2 lb ae of 2,4-D are also available. Containers are 1 or 5 gallon cans and 30 or 55 gallon steel drums.

Several adjuvants may be used to increase either viscosity or surface tension and reduce droplet drift. These include: bifluid invert emulsifiers, Norbak, Lo-Drift, Nalco-Trol, and foaming agents.

Method of Application

Helicopters such as the Bell G3B, Hiller 12E, Llama Allouette, or Bell 206 are usually used to aerially apply 2,4,5-T in forestry. A few applications are made with Bell 205 and larger helicopters. The most common conventional application equipment consists of a 36 to 40-foot spray boom equipped with 18 to 22 flat fan, hollow core straight stream (jet), or Raindrop nozzles operated at 20 to 45 psi pressure. Nozzles are oriented on the boom from straight down to directly back along the airstream; an angle of 30° to 45° from the horizontal and directed back is common.

Satisfactory results from phenoxy herbicides require a deposit of 72 droplets per square inch of plant surface (Behrens 1957). Spray equipment used in aerial applications requires nozzles which provide sufficient droplets to meet this requirement and retain enough size to reduce movement from the spray target area by drift. A D6-46 hollow cone nozzle produces a range of droplets with a volume mean diameter (VMD) of 300 to 400 microns and deposits 70 to 90 percent of the spray within 96 to 130 feet when applied at 50 feet in elevation in a 6 mph wind. If the D6-46 nozzles are directed straight back, VMD is increased to 400 to 600 microns and deposits of 85 to 98 percent of the spray volume are deposited within 6 to 96 feet when applied at 50 feet in elevation in a 6 mph wind. D8 jet nozzles with drift-reducing additions produce droplets with a VMD of 800 to 1,000 microns and a deposit of 95 to 98 percent with no drift when applied at 50 ft. elevation in a 6 mph wind (Akesson and Yates 1978, USDA Forest Service 1978). Specialized spray equipment is less commonly used to apply high viscosity drift-reducing sprays, or foam sprays. For maximum drift control near sensitive crops, a Microfoil Boom is quite often used.

The average spray tank holds 120 gallons with up to 400 gallons on larger helicopters. Actual spray loads average 60 to 80 gallons on the smaller helicopters (Bell 3GB or Hiller 12E) due to safety considerations related to air density effects. The spray system is calibrated to apply 1 to 20 gallons of spray mix per acre in 1 or 2 passes in a 55- to 100-foot spray swath. Sprays are applied at 40 to 60 MPH (up to 90 MPH with larger helicopters) at a height of 30 to 50 feet above the vegetation.

Rate and Timing of Application, Carrier and Operating Conditions

2,4,5-T is applied during one of four spray seasons: Budbreak or dormant (Feb.-Mar.), early foliar (May-July), late summer foliar (mid-July mid-August), and late foliar (mid-Sept. - early Oct.) (table 10).

Chemical is applied to the treatment area at a rate of 3/4 to 4 lb of a.e. per acre. The average rate is slightly more than one pound per acre, reflecting widespread dilution with 2,4-D. When 2,4,5-T is used alone, 2 lb/acre is the most commonly used dosage in 5 to 10 gallons total spray, with 10 gallons prevalent in the Northwest and 5 gallons in the East.

2,4,5-T is diluted and suspended in one of three kinds of carriers -- oil, water, or oil-in-water emulsions. Oil is used for dormant or budbreak sprays in the spring on deciduous species. Water carriers are used for foliar sprays during the growing season. Emulsions are used for evergreen brush species or when leaves of deciduous species have fully developed and conifers are inactive.

Aerial spray operations are normally conducted when winds are less than 6 MPH, temperatures are less than 70°, relative humidity is above 50 percent, and when vegetation is free of excessive moisture or ice. Precipitation must not be falling or about to fall, and air turbulence must be calm enough so as to avoid disrupting normal spray patterns. Conditions suitable for treatment may exist for only a short period of time each day and may not occur at all on some days. Usually only about 1 to 4 hours of proper conditions exist in any day to permit spraying. From 50 to 80 acres are treated per hour of actual operation depending on amount of mixture per acre and distance from treatment area to helispot. Each hour of operation involves about 10 minutes of nozzle time (table 11).

Time Required for Treatment and Number of Applications

Aerial application companies that do most of their business with agricultural crops are also used for forestry. Most aerial spraying in the forest is done by contract application. Most forest operations

Table 10--Timing and purpose of aerial applications of 2,4,5-T in forestry by geographic section

Section	Rehabilitation and site preparation	Release
NORTH	mid-July - mid-August	mid-July - mid-August
SOUTH	April - July	April-July
ROCKY MOUNTAINS	June - July	Feb.-Mar. mid-July - mid-August
PACIFIC COAST	Feb.-Mar. - May-July	Feb.-Mar. May-June late July - Sept.

Table 11--Helicopter horsepower, chemical load and working speed for aerial application of 2,4,5-T in forestry

Model	Horse-power	Chemical load[a]	Working speed
		pounds	mi/hr
Bell 47G-3B1	270	800	80
47G-3B2	280	1,000	88
Hiller UH 12E	305	1,050	90
Hughes 300	180	700	60
300-C	190	1,025	99
500 (Turbo)	317	1,400	90
Alouette II	360	1,320	112
SA-341	600	1,660	152

[a] Chemical load under restricted agriculture category.

require a pilot (to apply chemical and ferry ship from area to area) and one or two ground personnel. Ground personnel are responsible for helicopter servicing, operating equipment, mixing the formula to be applied, loading helicopters with the herbicide mixture, and moving vehicles between helispots.

The landowner may also supply a chief inspector and one or more observers to properly monitor application. An additional person is sometimes required to keep application records and to monitor and record weather conditions.

Treatment units vary in size from 1 to 700 acres but average about 30 acres. It may take 10 to 30 minutes to treat 30 acres, depending on volume of spray per acre and travel distance between helispot and treatment area. A helicopter using a Microfoil Boom and a 55-foot swath width treats 6.6 acres per minute at 60 MPH and 4.95 acres per minute at 45 MPH.

The following time is required to treat each acre:

1. Fill or refill 30 seconds (50 to 80 gallon load).

2. Travel to and from treatment site - 30 to 90 seconds.

3. Alignment with prior treatment swath - 30 to 60 seconds (where flagmen are not used).

4. Application - 2 to 4 minutes (50 to 80-gallon loads). Half of this is nozzle time, half is in turns. Additional time is usually spent in reconnaissance and pilot-orientation flights prior to treatment).

The application sequence may include one site-preparation spray applied after harvest and before planting, followed by one or more release sprays at 2 or 3 year intervals for a total of one to three treatments (rarely four or five) during the first 15 years in a 25 to 120-year rotation. Most of acreage presently treated by aerial methods is in the South and on the Pacific Coast, but there is a large potential in the North.

Exposure During Application

Personnel exposure on aerial spray operations is variable depending on job and conditions. The most common aerial spray crew organization is pilot, loader (who also mixes the spray), contract supervisor, and one or two observers. Of these, only the pilot and loader have direct contact with the spray solution. The pilot sits in an enclosed, but not airtight, cockpit when spraying. He may occasionally be exposed to the herbicide at the loading site. Return flights through the previous spray cloud do not usually occur because the large droplet formulations used settle quickly. Ground personnel are exposed only during the actual mixing and loading operations. About 10 minutes per spray day is spent in formulating the batch mix, plus about 10 minutes in loading aircraft. The mixing tanks and loading devices are closed systems. The mechanic-mixer-loader is the only person who handles the herbicide concentrate. PD-1 did not show an exposure scenario for mechanic-mixer-loaders. Use of gloves when handling any mixing or loading functions will reduce exposure to near zero as noted in later sections. Persons other than pilot and mechanic, such as contract administrators, inspectors, and timekeepers do not participate directly in the operation and so receive only incidental exposure. Helicopter crews normally maintain safety procedures consistent with the much more toxic insecticides which is part of their normal experience.

Nozzle time is about one hour per spray day. Helicopters do not apply material directly over people. Flag persons are not used in aerial applications in the West; they are used in some Microfoil Boom operations in the South. Flag persons must move to a new position before the helicopter reaches the spot at which they were initially positioned in order to be in position for the next spray swath. They continually move upwind and into the unsprayed area. Flag persons are also normally positioned off the treatment area, out beyond the application cutoff point. Direct contact with spray droplets is minimal. On still days, the "tail" of the adjacent swath will occasionally result in limited exposure. Persons doing environmental sampling are required not to contaminate themselves by visiting the spray operation or traveling through the treated area. About 75 percent of the total forest acres treated annually with 2,4,5-T is done by aerial application (table 12).

Additional Exposure Possibilities

No re-entry is necessary immediately following aerial treatments. Areas sprayed for site preparation are usually planted 3 to 4 months after treatment. Exposure to people using the forest areas for dispersed recreation or hunting could occur, but odors from the oil and phenol residues and the wilting and browning of foliage forewarn visitors to the area that treatment has taken place. Because 2,4,5-T and TCDD degrade rapidly in the environment, exposure diminishes rapidly following treatment.

The average tree-planting crew size is about 10 people. Each planter will plant 1 to 2 acres per day. The maximum amount of treated area that one planter would normally plant during a season or year is about 100 acres. Exposure of planters therefore is negligible.

Protective Equipment

Pesticide users must read the label of the particular herbicide they are to use. Most 2,4,5-T labels warn people to avoid swallowing or to avoid contact with clothing, eyes, and skin. Most aerial spray workers wear protective clothing such as coveralls, caps, and gloves which are removed between exposures.

Table 12--Forest area treated annually with 2,4,5-T by aerial application - all ownerships

Region	Total acres of commercial forest land	Acres treated[a]	Lb ae per acre	Lb used	Commercial forest land treated
	million	thousand		thousand	percent
North	177.9	1.5	2	3	<0.001
South	192.5	614.0	3	1,842	0.319
Rocky Mt.	61.6	<1	2	<1	<0.001
Pacific	67.6	261.0	2.5	652	0.386
TOTAL	499.6	876.5		2,497	0.175

[a] Based on 1976 and 1977 data.

Possible Alternatives

Refer to tables 14-19, chapter 1. The exposure considerations presented here are very similar for chemical alternatives for 2,4,5-T. For nonchemical alternatives, potential intoxication and accident rates are described later in Part 5 of this chapter.

Ground Application with Tractor Mistblower - Broadcast Treatment

Formulation and Containers

2,4,5-T is available for pine release as low-volatile, emulsifiable isooctyl and butoxyethyl esters in several formulations (table 13). These products are available in 1 gallon or 5 gallon cans and 30 or 55 gallon steel drums.

Recent FIFRA ammendments (PL 95-396) permit the use of any application method not specifically prohibited on the label. Current mistblower application labels (Vertac) require that operators wear full protective clothing, goggles, and respirators.

Methods of Application

The most common method of application is by a mistblower mounted on a medium-sized crawler tractor or with a mistblower mounted on a trailer pulled by a crawler tractor or wheel skidder. The mist blower has a 2-foot long outlet tube containing three nozzles. The direction of spray, duration, and droplet size can be controlled. Droplet size ranges from 90 to 250 μm with an average of 150 μm. Nozzles may be directed at any angle from straight up to straight down. The maximum vertical reach is 30 to 40 feet. The mistblower is mounted on the back of the tractor or trailer facing away from the operator.

The tractor or skidder moves away from the treated area into the untreated area. The tractor moves at about 2 miles per hour depending

Table 13--Formulations of 2,4,5-T for pine release

Manufacturer	Chemical product name	ae lb/gal	EPA Reg. No.
Vertac	Brush Rhap LV4T	4	39511-24-AA
"	" " LV6T	6	39511-22-AA
"	" " LV OXY 4T	4	39511-26-AA
"	" " LV OXY 6T	6	39511-27-AA

on the amount of obstacles, soil condition, or steepness of slope. Tractors are limited to slopes of 30 percent or less. Tractor-mounted spray tanks hold about 100 gallons. The trailer-mounted tanks hold about 160 gallons.

Application on National Forests is limited to windspeeds under the canopy of less than 6 mph, relative humidity greater than 50 percent, temperatures less than 70 degrees, vegetation free of snow or ice. Precipitation is not occurring or about to occur and air turbulence is not sufficient to affect normal spray patterns. As a practical matter, applicators generally follow the same rules on all other lands.

Rate and Timing of Application and Number of Applicators

Application by tractor-mounted mist blowers is used primarily in the South. Formulations used vary by type of treatment. From 1.5 to 2 lb ae per acre is used for release, and 2 to 4 lb ae per acre is used for site preparation, rehabilitation, and understory treatments. 2,4,5-T esters are diluted and applied with oil, oil-water, or water carriers at a total mix rate of 5 to 10 gallons per acre. Only one application is made per year with intervals between treatments of 3 to 5 years. Only two or three applications are made during a rotation period of 30 to 80 years. In the South, the application interval for uneven-age management of southern pines is about 15 years. The size of treatment areas varies considerably from about 10 to 300 acres. The average treatment size is about 40 acres.

Time Required for Treatment and Exposure During Application

Crew size varies from a tractor operator working by himself to situations where he has as many as two additional helpers. The helpers are responsible for operating the tank trucks and mixing the chemical. They also load the spray tanks. Mixing and loading takes 10 minutes per refill; 3 to 4 refills are necessary each day.

About 5-8 acres are treated per hour. From 2 to 8 hours each day is usually suitable for spraying with the actual daily treatment period averaging about 4 hours. Applications are made under calm conditions (winds less than 5 mph) and usually during mid-April to mid-July. About 12 percent of the total forest acres treated annually with 2,4,5-T is done by ground application with tractor mistblower - broadcast treatments (table 14).

Additional Exposure Possibilities

No re-entry is necessary immediately following this type of application. Exposure to people using the forest areas for dispersed recreation or hunting could occur, but odors from the oil residues and the wilting and browning of foliage forewarn visitors to the area that treatment has taken place.

Planting normally follows site preparation by 3-6 months or more. The average planting crew is about 10 people. Each planter will plant 1 to 2 acres per day. The maximum amount of treated area that would normally be planted during a season or year is about 200 acres.

Protective Equipment

Goggles, respirator, gloves, and full protective clothing are required by the product label for these uses. Pesticide users must read the label of the particular herbicide they are to use. Most 2,4,5-T labels warn people to avoid swallowing or to avoid contact with clothing, eyes, and skin.

Possible Alternatives

Refer to tables 14-19, chapter 1. The exposure considerations are very similar in rate of application, but alternative chemicals are not applied by mist blower.

Table 14--Forest area treated annually with 2,4,5-T by tractor mistblowers - all ownerships

Region	Total acres of commercial forest land	Acres treated[a]	lb ae per acre	Total lbs used	Commercial forest land treated
	million	thousand		thousand	percent
North	177.9	2	2	4	0.001
South	192.5	132	3	396	0.069
Rocky Mts.	61.6	0	-	0	0
Pacific Coast	67.6	6	2	12	0.009
TOTAL	499.6	140		412	0.029

a/ Based on 1976 and 1977 data.

Ground Application with Backpack Mistblowers - Broadcast Treatment

Formulation and Containers

Several low-volatile ester 2,4,5-T formulations, such as butoxyethanol, 2-ethylhexyl, isooctyl, and propylene glycol butyl ether are used with backpack mistblowers. Products for this use are available in 1- and 5-gallon cans and 30- and 55-gallon steel drums.

Methods of Applicaion

Backpack mistblowers are used to broadcast treat competing vegetation beneath pole-size timber for understory control. This use is almost entirely limited to more or less level terrain in the South. The equipment tank capacity is usually 3 gallons. Applicators normally use string to keep track of progress and work abreast of one another about 20 feet apart. Droplet size varies from 90 to 250 μm with an average of about 150 μm. This is usually a "fill-in" job and so is not a continuous operation during a season. Backpack mistblowers are not used where large contiguous areas make the use of tractor-mounted equipment more practical. They are used where only scattered spots require treatment.

Rate and Timing of Application and Number of Applications

Backpack mistblowers are used to apply 2,4,5-T on a broadcast basis to foliage in young conifer stands at a rate of about 2 pounds ae per acre. The season of use is early foliar (May to July). Applications are usually required only once during a rotation of 30 to 60 years. However, in some cases, this method is used to increase crop tree growth where understory vegetation competition for moisture or nutrients in the soil has become severe.

Each applicator usually treats 3 to 5 acres per day. The herbicide is diluted in 5 to 15 gallons of water which is applied to 1 acre. During late-season treatments, one-half gallon of diesel oil is sometimes added to the mixture to increase penetration and effectiveness.

Application is restricted to periods when wind speeds are less than 5 mph; thus, actual spraying is done only about 4 hours per day, with 2 hours nozzle time.

Time Required for Treatment and Exposure During Application

Most areas treated by this method are small and are treated within 1 day or less. Crew size is small, mostly 2 to 3 applicators although 5 or 6 occasionally work together. Less than 5 minutes are required to refill a mistblower. About five refills are made per applicator per day. About 2 percent of the total forest acres or less, is treated annually with 2,4,5-T by backpack mistblowers - broadcast treatment (table 15).

Protective Equipment and Additional Exposure Possibilities

Pesticide users must read the label of the particular herbicide they use. Most 2,4,5-T labels warn people to avoid swallowing and contact with clothing, eyes, and skin. No reentry is necessary immediately after this type of application. No followup planting is involved.

Possible Alternatives

Refer to tables 14-19, chapter 1. The exposure considerations are very similar when chemicals are applied similarly.

Ground Application with Backpack Sprayers and Tree Injectors - Individual Stem Treatment

Formulation and Containers

Ester formulations of 2,4,5-T are used for individual stem treatments by

Table 15--Forest area treated annually with 2,4,5-T by backpack mistblower - all ownerships

Region	Total acres of commercial forest land	Acres treated[a]	lb ae per acre	Total lb used	Commercial forest land treated
	million	thousand		thousand	percent
North	177.9	2	2	4	0.001
South	192.5	16	3	48	0.008
Rocky Mts.	61.1	0	2	0	0
Pacific Coast	67.6	6	2	12	0.009
TOTAL	499.6	24		64	0.005

[a] Based on 1976 and 1977 data.

backpack sprayers. Amines are preferred for injection. Recent FIFRA amendments permit the use of any application method not specifically prohibited on the label, and numerous combinations of 2,4,5-T with 2,4-D, dicamba, and picloram are used. Products for this use are available in 1- and 5-gallon cans, 30- and 55-gallon steel drums.

Method of Application

Backpack and garden sprayers are occasionally used for basal sprout control and basal treatment of individual stems. Spray is applied directly on the stump or lower 6 inches of individual stems. Crew speed is highly variable depending on the density of the vegetation to be treated. Spray droplet size is normally large. A straight stream is used in most basal stem applications. This method is used primarily for spot treatment in forests.

Tree injection involves several methods of direct application, such as frill, or hack and squirt in which the chemical is applied to the stem by a cutting tool with an automatic injection apparatus (hypo-hatchet or tree injector) or into cuts in the bark with a squirt can or squirt bottle, Cuts are made at intervals of 1 to 4 inches apart around the stem located near the root collar or up to about 4.5 feet above the ground. The 2,4,5-T used for injection is usually the amine salt applied in a nondiluted form. It is permissible, however, to use an ester-in-oil solution up to 32 pounds acid equivalent per 100 gallons (aehg).

Rate and Timing of Application and Number of Applications

Backpack garden sprayer application is made by spot treatment to individual stems or stumps at a rate of about 2 lb per acre. Applications are usually made once during a rotation, but may be repeated as a cultural improvement method to control understory vegetation in pole-sized or mature stands where competition for moisture or nutrients becomes severe. Only spot spraying is required due to spacing of stems or stumps to be treated.

Applications can be done at any time, but are usually made during the summer foliage season (mid-May through July) and the dormant season (late November through March). Tree injection applications can take place year-round, but most of it is done during the fall dormant season when using 2,4,5-T in oil, or in spring and summer when using the amine concentrate. One milliliter is injected or squirted into each frill or cut when using the concentrate; the frill is filled when using the oil mixture.

Time Required for Treatment and Exposure During Application

Individual stem and stump treatment projects do not require the degree of advanced planning necessary for tractor and helicopter projects. Most acres treated by this method are small and are treated within 1 day or less. Crew size is small, usually 6 or less. Refills require less than 5 minutes. About six refills are made per applicator per day, depending on equipment used.

Each applicator treats about 3 to 5 acres per day depending on amount to be treated and density of vegetation. Although the applicator works about 8 hours per day, usually less than 4 hours is involved in actual treatment. This method involves considerable no-spray time spent walking between spots to be treated. These treatments are applied directly to the stems or stumps. With the direct coarse spray the applicator usually does not come in contact with spray. A spray cloud or mist situation such as occurs with insecticides for mosquito control is not created. About 11 percent of the total forest acres treated annually with 2,4,5-T is done by ground application with backpack sprayer and tree injection - individual stem treatment (table 16).

Protective Equipment and Additional Exposure Possibilities

Pesticide users must read the label of the particular herbicide they use. Most 2,4,5-T labels warn people to avoid swallowing or to avoid contact with clothing, eyes, and skin. Coveralls and gloves are often

Table 16--Forest area treated annually with 2,4,5-T by backpack sprayer and injector - all ownerships

Section	Total acres of commercial forest land	Acres treated	lb ae per acre	Total lb used	Commercial forest land treated
	million	thousand		thousand	percent
North	177.9	92	2	184	0.052
South	192.5	28	3	84	0.015
Rocky Mts.	61.6	0	0	0	0
Pacific	67.6	5	2	10	0.007
Total	499.6	125		278	0.025

worn. Leaking hoses and valves on backpack equipment are the major sources of exposure. Rubber gloves can reduce exposure, and periodic maintenance can reduce leakage. No re-entry provision is necessary immediately after this type of application, nor would re-entry result in significant exposure. No followup planting is involved.

Possible Alternative

Refer to tables 14-19, Chapter 1. The exposure considerations are very similar when application methods are identical. When using injection and backpack sprayers, only phenoxy herbicides, perhaps in combination with picloram, are likely substitutes. See calculation summary no. 1.

CALCULATION SUMMARY NO. 1: USE INFORMATION FOR EXPOSURE, AERIAL APPLICATION - FOREST

1. Commodity: Forest

2. Equipment: Aircraft (Helicopter), nozzles (no whirl plate, aligned with slipstream)
D6 900 μm VMD
D6-46 46 μm VMD

		Situation	
3.	Target: Brush, for site preparation & conifer release	Typical (>50%):	Extreme (10-20%):
4.	Rate:	1.5-2 lb/A	3 lb/A
	Dilution:	20 lb/100 gal 8 to 10 gal/A	40 lb/100 gal
5.	Exposure Times:		
	Day:		
	Application Time:	6 hrs/day	6 drs/day
	Nozzle Time:	1 hr/day	3 hr/day
	Drift Time and/or fraction direct exposure occurs:	15 sec/day	1 min/day
	Week:	2 days/week	4 days/week
	Year: 5.8 hrs/day & 5.7 days/year is the average work. Upper 15% is 5.4 hrs/day & 14 days/year	6 days/year	14 days/year
6.	Treatment Area: Total acres or units:	1 site up to 180 acres/day usually 1 to 3 hrs.	
	Days or units of work per year:	6 to 14 such units/yr. Assume 100 A sites and 90% of crews service 6 sites per year and 10% of crews service 14 sites/year.	
7.	Population Exposed: Supervisor, timekeeper, observer		
	Number of exposed workers:	Industry will use 2 ground personnel. U.S.F.S. will use 4 ground personnel. They are not in the treated area, but may be 50-100 feet from the boundary or on some other topographic feature. Cannot be exposed unless a wind swirl catches the drift. This may occur once per site for 15-45 seconds.	
8.	Dress: Work clothes - long pants, long sleeve shirts, hard hat, boots.		
9.	Workers and Exposure Time: Round the single 15 sec exposure up to 1 min.		
	1 min/day x 6 days/year = 6 min/year	2,476 workers @ 6 min/year	
	1/day x 14 days/year = 14 min/year	120 workers @ 14 min/year	

Aerial Application

Formulation and Containers

Registered products for range and pasture brush and weed control include numerous low-volatile esters formulations of 2,4,5-T and amine formulations of 2,4,5-T/picloram (Tordon 225) and 2,4,5-T/dicamba in ratios of 1+1 and 2+2, respectively. All products are available in 1, 5, 30, and 55-gallon cans or drums.

Method and Rate of Application

About 90 percent of all rangeland brush control is done by broadcast spraying using fixed-wing aircraft. A variety of agricultural equipment is used, ranging in capacity from 160 to 450 gallons and delivering 1-4 gallons per acre with VMD of 250-500 μm and an average VMD of 300 μm.

Aerial application to mesquite and sand-shinnery oak entails three rates of application, depending on specific site requirements. Approximately 137,000 acres are treated at the rate of one pound of 2,4,5-T ester in 1-4 gallons of water, oil or water-oil emulsion per acre, most is 4 gallons per acre as a 1:4 oil-water emulsion containing 25 pounds acid equivalent per 100 gallons (aehg) 2,4,5-T (table 17). A minor acreage is treated with one pound in two gallons (50 aehg mixtures) of emulsion. Volumes of one gallon per acre do not disperse well with concentrations of 100 aehg <u>and</u> are not used.

Another 500,000 acres are treated with 1/2 pound 2,4,5-T per acre, mostly in 2 to 4 gallons of water-oil emulsion at a 25 aehg concentration. A portion of this acreage is treated at one gallon per acre of 50 aehg mixture. About 400,000 acres of mesquite are treated with a mixture of picloram and 2,4,5-T containing 1/4 lb 2,4,5-T per acre as the amine salt. This is usually applied in one, two, or four

Table 17--Aerial applications of 2,4,5-T is mesquite and oak savannah

	Rate/A	Vol/A	Conc.	Acres/yr
	lb ae	gal	aehg[a]	
Mesquite/shinnery oak	1 lb	2-4	25-50	137,000
	1/2	1-2	25-50	500,000
	1/4	1-2	12.5-25	400,000
Oak savannah	2	2-6	33.3-100	541,000

[a] Acid equivalent per 100 gallon

gallons per acre as a water spray of 12.5 to 25 aehg 2,4,5-T plus an equal amount of picloram. Dicamba is used in place of picloram on some of this acreage (table 17).

Oak savannah receives a higher rate of application than mesquite. Aerial application also accounts for 90 percent of the oak range treatments, with dosage ranging up to 3 pounds per acre in 6 gallons water-oil emulsion (50 aehg) and the average being 2 pounds per acre in 4-6 gallons. A total of 541,000 acres is treated in this way, all by fixed-wing aircraft (table 17).

Time Required for Treatment and Exposure During Application

Aerial treatment of rangelands uses larger aircraft and lower volumes per acre than most other applications of 2,4,5-T. This results in a large number of acres treated per batch and per aircraft loading and resultant relatively low exposure of the mixer-loader.

Fixed wing aerial applications cover 100-300 acres per hour and 30 to 450 acres per load. A typical day is 3 hours of operation in the early morning and 3 hours in the late afternoon and evening. The season for treatment usually lasts 1-4 weeks, depending on moisture conditions. Applicators will not usually be applying 2,4,5-T during the remainder of the year, because no crops or utility rights-of-way are treated with fixed-wing equipment during complementary seasons (table 17).

A typical aerial application crew consists of a pilot and mechanic-mixer-loader, who may be involved in several operations during one season, and two flag persons, who are employees of the local ranch. The pilot and mechanic normally wear coveralls and gloves while handling herbicides. The flaggers normally wear broad-brim hats and long-sleeved shirts, traditional ranch attire.

Normal spraying operations for a one-airplane crew includes a pilot, two to prepare and load the herbicides in the aircraft, and two flaggers to accurately mark swath passes. No flaggers are used if foam markers are used. Spraying is done with a slight cross wind with the flaggers walking against the wind before each pass of the airplane. The flaggers move to the next swath when the aircraft is approaching about 300 feet away. The flaggers do not receive appreciable spray since they are not beneath the aircraft during spraying. The pilot "shuts off" the spray 50 feet before the end of the pass and delays spraying until 50 feet is covered on the next pass. The mixing crew measures the required amount of carrier (diesel oil and water) and 2,4,5-T. The carrier and herbicide is vigorously mixed until the desired emulsion is attained. The tank mix is then pumped into the spray hopper through an opening in the bottom of the hopper. Cut-off valves minimize spillage when the loading hose is disconnected. The pilot remains in the aircraft during the loading operation. The crew is exposed intermittently to 2,4,5-T for about 4 hours, usually early morning, during a normal spraying day.

There is little opportunity for exposure after treatment. Normal range management practice allows 3 to 6 months delay between treatment and range stocking while the grass cover develops.

Ground Application

Ground equipment accounts for 10 percent of range improvement work and nearly all of the pasture maintenance with 2,4,5-T. The principal method is backpack or garden sprayers used either for spot sprays in mesquite or pasturelands, or as basal sprays in oak savannahs. High-mounted boom sprayers are also used in low-mesquite stands (table 18).

Backpack Sprayers

Backpack sprayers used for basal and spot sprays entail mixtures of 8-16 aehg in oil for bark treatment and 6-8 aehg in water-oil emulsions for basal-stem treatments. Pasture spot sprays utilize 4-6 aehg in water.

Table 18--Estimated total area treated by the various ground methods

Type	Rate/acre	2,4,5-T concentration	acres
	lb ae	aehg[a]	
Mesquite	1/2 lb	8	75,000
Oak savannah	2	16	60,000
Pasture	1/2	4-6	1,000,000

[a] Acid equivalent per 100 gallon

The typical crew for hand sprayers is 1-4 persons. The area covered ranges from 1/4 to 1 acre per man-hour and crews normally wear long-sleeved shirts or coveralls. Treatments are seldom above waist level, and hats, though usually worn, are not necessary to protect from spray deposits.

Most exposure is the result of leaky hoses and valves. Careful maintenance can prevent exposure perhaps more than protective clothing.

Tractors

A small area of mesquite is treated with high-mounted boom rigs on special tractors. This equipment is used on about 75,000 acres a year of low brush in dense stands. Typical tractor sprays entail the use of 0.67 lb 2,4,5-T in 10-20 gallons oil-in-water emulsion per acre. This equipment normally carries a 200-400 gallon tank that must be refilled approximately every 20 acres with the 3.3 to 6.7 aehg mixture.

A typical crew consists of a tractor operator and an assistant who mixes and loads. The tractor driver is exposed briefly but occasionally moderately, if wind carries spray to him when making turns. The loader is exposed while mixing and loading. His exposure is greater than that of the tractor driver. Both persons typically wear coveralls and broad-brim hats. A crew normally treats 50-100 acres per day. See calculation summaries 2-5.

Alternative Herbicides for Ground Application

Tordon 225^R can be substituted for 2,4,5-T or silvex for mesquite control using low and high boom sprayers. Silvex can be substituted for 2,4,5-T for oak control using a low and high boom sprayer or backpack sprayer. Undiluted 2,4-D can be substituted for 2,4,5-T or silvex for oak control, cut surface application only. There is no effective chemical substitute for 2,4,5-T for mesquite control using backpack sprayer.

CALCULATION SUMMARY NO. 2: USE INFORMATION FOR EXPOSURE, AERIAL - RANGE AND PASTURE

1. Commodity: Range & Pature

2. Equipment: Fixed wing aircraft. Nozzles: 15° into the airstream, no whirl plates
D6 (10 ea) @ 1 gpa
D8 (12 ea) @ 2 gpa (50% are these), VMD 300-400 μm
D12 (22 ea) @ 4 gpa

	Situation	
	Typical (>50%):	Extreme (10-20%):
3. Target: Mesquite, oak and other woody plants		
4. Rate:	0.5 lb/A	1-2 lb/A
Dilution: 2% treated at 2 lb/A 6% treated at 1 lb/A	25 lb/100 gal 50% use Nalcotrol	50 lb/100 gal
5. Exposure Times:		
Day:		
Application Time:	2 hr	
Nozzle Time:	1 hr	
Drift Time and/or fraction direct exposure occurs:	6 min	20 min
Week:	3-6 days/week	
Year: Over a 10 week period (70 days) planes will operate a max. of 20 days, treating typical field of 500 A (1/2 mi x 1.56 mi or 8,250 feet or 206 passes) each day. There are 2 flaggers (1 on each boundary, not 100 feet from the boundary as in rice) exposed. 18 min/run, exposed once per 3 runs, unless nalcotrol used, then once per 10 runs.	30 days/yr	9 days/yr
6. Treatment Area: Total acres or units:	9-30 500 A fields/yr; various ownerships	
Days or units of work per year: There are about 75 planes (150 flaggers); 25 operate 30 days @ 500 acres per day treating 13,000 acres each or a total of 375,000 acres, 25 operate 20 days treating 10,000 acres or 250,000 acres, & 25/9 days for 4,500 ea or 112,000 acres, for a total of 737,000 acres in Texas.	9-30 days	
7. Population Exposed: Flagmen		
Number of work sites:	30	9
Number of exposed workers:	50	50
Total number of flagmen:	150	

8. Dress: Work clothes - blue jeans, long sleeve shirt, levi jacket, kepi, wide brim hat, leather boots.

9. Workers and Exposure Time:

500 A = 206 passes x 18 sec drift x 1/3 passes = 20 min/site x 30 sites = 10 hr/year

x 1/10 passes = 6 min/site x 30 sites = 3 hrs/year

x 9 sites = 54-3 hr/yr

25 flagmen @ 10 hr/yr

25 flagmen @ 1 hr/yr

100 flagmen @ 1-6 hrs ($\bar{x}$ = 3 hrs)/yr

CALCULATION SUMMARY NO. 3: USE INFORMATION FOR EXPOSURE, TRACTOR LOWBOOM - RANGE AND PASTURE

1. Commodity: Range & Pasture

2. Equipment: Tractor Mounted low boom
   30 psi, #8002 or 8003 fan pt. nozzle, VMD ca. 200-300 μm

	Situation	
3. Target: Oak & mesquite sprouts on range	Typical (>50%):	Extreme (10-20%):
4. Rate:	2 lb/A	
Dilution:	10 lb/100 gal	
5. Exposure Times:		
Day:		
Application Time:	3-4 hrs	
Nozzle Time:	45 min-60 min	
Drift Time and/or fraction direct exposure occurs:	1 day/week	3 days/week
Week:	1 day/year	3 days/year
Year:	3 hr/year	7 hr/year
Rancher does own application on 40-100 A. If more needs treatment he will use commercial applicator. Will treat about 5 A in about 5 min with 15 min return & reloading, or 15 A/hr & 15 min nozzle time/hr. With 3-4 hrs/day application time, the units will be completed in 1-3 days. 200-500 units covering about 20,000 A are treated annually, Texas		
6. Treatment Area: Total acres or units:	200-500 units; 20,000 A	
Days or units of work per year:	1-3 days work/yr; 1 unit/man/yr	
7. Population Exposed: Sprayman		
Number of work sites:	1	500
Number of exposed workers:	200	

8. Dress: Work clothes - blue jeans, long sleeve shirt, levi jacket, wide brim hat, kepi, leather boots

9. Workers and Exposure Time:

15 min/hr x 3 hr/year = min/yr; 500 workers @ 45 min/year or
15 min/hr x 7 hr/year = 105 min/yr; 200 workers @ 1 hr 45 min/yr or
90% of acreage is 40 A & 10% is 100 A

CALCULATION SUMMARY NO. 4: USE INFORMATION FOR EXPOSURE, TRACTOR HIGHBOOM - RANGE AND PASTURE

1. Commodity: Range & Pasture

2. Equipment: Tractor mounted, high boom

	Situation	
3. Target: Mesquite & oak	Typical (>50%):	Extreme (10-20%):
4. Rate:	2 lb/A	
Dilution:	10 lb/100 gal	
5. Exposure Times:		
Day:		
Application Time:	4 hr/day	
Nozzle Time:	2 hr/day	
Drift Time and/or fraction direct exposure occurs:	assume 2 hr/day	
Week:	6 days/week	
Year: These are larger commercial rigs and spray for 15 min each load instead of 5 min. About 15 min nozzle time & 15 min loading time. There are about 15 such rigs in Texas (5 operators @ 1 rig & 5 @ 2 rigs). They will treat about 5000 A over a 6 to 8 week period, Texas	6-8 weeks/year	
6. Treatment Area: Total acres or units:	75 A/day, 5000 A/yr, various ownerships	
Days or units of work per year:	6 days x 8 weeks = 48 days	
7. Population Exposed: Sprayman		
Number of exposed workers:	15	

8. Dress: Work clothes - blue jeans, long sleeve shirt, levi jacket, wide brim hat, kepi, leather boots, gloves

9. Workers and Exposure Time:

2 hrs x 6 days x 8 weeks = 96 hr/yr

15 workers @ 96 hr/year

CALCULATION SUMMARY NO. 5: USE INFORMATION FOR EXPOSURE, BACKPACK SPRAYER - RANGE AND PASTURE

1. Commodity: Range & Pature

2. Equipment: Backpack, hand pressure, 30 psi, T-jet 8004, VMD 300 μm

	Situation	
	Typical (>50%):	Extreme (10-20%):
3. Target: Mesquite or oak stems in rangeland or pasture		
4. Rate:		
Dilution: Mesquite	8 lb/100 gal	
Oak	16 lb/100 gal	
5. Exposure Times:		
Day:		
Application Time:	6 hr/day	6 hr/day
Nozzle Time:	0.6 hr/day	1.2 hr/day
Drift Time and/or fraction direct exposure occurs:		
Week:	2 days/week	4 days/week
Year: 60 sec travel time stem to stem; results in typical ratio of 6 sec/60 sec nozzle time (10 percent).	10 days/year	20 days/year
6. Treatment Area: Total acres or units:	30	50
Days or units of work per year: Sprayman will be ranch employee; cover 3-5 A per day, working about 2 days/week over a 5 week period. About 8-10,000 A are treated this way per year in Texas. One sprayman will treat a maximum of 50 A/yr; if more needed, another applicator is contracted.	1	1
7. Population Exposed: Sprayman		
Number of work sites:	1	1
Total number of exposed workers:	334 or	200

8. Dress: Work clothes - blue jeans, long sleeve shirt, levi jacket, wide brim hat, kepi, leather boots.

9. Workers and Exposure Time:

0.6 hr/day x 6 hr/day x 10 days/year = 6 hr/year

334 workers @ 6 hr/yr

or 200 workers @ 12 hr/yr

or 200 @ 6 hrs & 20 @ 12 hrs

Aerial Application

Formulations and Containers

Numerous formulations of 2,4,5-T, alone and in premix combinations, are available for aerial application on rights-of-way. Low-volatile emulsifiable esters include propylene glycol butyl ether, butoxyethanol, 2-ethylhexyl and isooctyl esters. The formulations used most commonly contain 4 lb ae per gallon. Tordon 101 (0.54 lb ae picloram and 2 lb ae 2,4-D as triisopropanolamine salts) is frequently tank mixed with 2,4,5-T. The most popular containers are 30 and 50-gallon steel drums.

Method of Application

Aerial application on rights-of-way is totally accomplished with helicopters. The ships are generally equipped with a Microfoil Boom with a nozzle orifice of 0.060 inches inside diameter. The Microfoil Boom is shaped similar to an airfoil. It can be trimmed in flight to release the herbicide solution into the still trailing air of the boom. This equipment produces very uniform droplets, approximately 0.094 inches VMD, which fall like gentle rain. Elimination of fines and swirling vortices enables the pilot to place the herbicide very accurately on the right-of-way. Another version of the Microfoil Boom has nozzle orifices 0.028 inches inside diameter which produce droplets in the diameter range of 1700-2000 μm. The Microfoil Boom is used on approximately 90 percent of the aerially treated right-of-way acreage. The remaining 10 percent is generally treated with one of the inverting systems such as the bifluid or Spray-disk.

Helicopter tank capacity varies from 50 to 250 gallons. Boom lengths range from 10 to 30 feet and spray swaths range from 20 to 60 feet. Speed of application ranges from 25 to 30 mph.

Rate and Timing of Application

Aerial applications are broadcast foliar treatments made between May and September depending on geographic area. Weather restrictions are particularly important in rights-of-way treatments. Conditions suitable for application tend to occur for very short periods during the day, and may not occur at all on some days. Consequently, treatments tend to be made between 5 and 9 a.m. and 5 and 9 p.m. Operationally, crew productivity ranges from 6-15 acres per hours in good weather. A typical work day is 4 hours application time with one hour nozzle time.

An important treatment in the northeastern U.S. is a tank mix of 2 gallons 2,4,5-T (8 lb ae 2,4,5-T) plus 2.5 gallons Tordon 101 or Amdon 101 applied in a total volume of 25 gallons per acre (32 lb aehg 2,4,5-T) with water as the carrier. In southeastern U.S. a major treatment is 1.5 gallons 2,4,5-T (6 lb ae 2,4,5-T) plus 2 gallons Tordon 101 or Amdon 101 applied in 15 gallons per acre with water carrier (40 aehg 2,4,5-T). A standard cycle, i.e., number of years before the same acre is retreated, in the Northeast is 5 years. A standard cycle in the southeastern U.S. would be 3 years.

Time Required for Treatment and Number of Applicators

There are an estimated 50-75 crews involved with aerial application of herbicides on rights-of-way. A crew typically consists of three people - the pilot, a mechanic-service person, and the mix truck driver, who also serves as loader. The mix truck driver is the most likely to be exposed but exposure time is brief, limited to mixing and loading periods. No flaggers are involved. Personnel exposure is considered to be minimal. The herbicides are pumped from the drums, through the mix truck, to the helicopter in a closed system.

Acres Treated

Based on data used for the economic analysis of 2,4,5-T applied aerially (a weighted average of 7.4 lb ae 2,4,5-T per acre), approximately 1,526,294 lb of 2,4,5-T are applied with this treatment. Aerial application accounts for about 30 percent of the rights-of-way acres treated with 2,4,5-T each year (table 19).

Protective Equipment and Additional Routes of Exposure

Crews applying 2,4,5-T aerially will dress according to the weather. This will usually include boots, pants, and shirts--long-sleeved shirts in cool weather and short-sleeved when warm. Hardhats and safety glasses may be worn and may be required for the loader and mechanic. There are no standard management practices which would require re-entry into a treated area.

Additional practices include close inspection of equipment as required for FAA and state licenses, and use of spray thickeners or other drift control measures when specified. Buffer zones are maintained around water, homes, and sensitive crops. All applications are made in close cooperation with public and private agencies. Clean clothes daily is a recommended practice.

Selective Basal and Cut Stump Application

Formulations and Containers

Various formulations of 2,4,5-T, alone and in premix combinations are available for selective basal and cut stump treatments. Low-volatile esters include propylene glycol butyl ether, butoxyethanol, 2-ethylhexyl, and isooctyl esters. The formulations commonly contain 2 lb ae 2,4,5-T plus 2 lb ae 2,4-D, 4 lb ae 2,4,5-T plus 1 lb ae picloram (Tordon 155), or 4 lb ae 2,4,5-T. The most popular containers are 30 and 55-gallon steel drums.

Table 19--Right-of-way acres treated annually with 2,4,5-T by aerial application

	Acres treated annually	% of total ROW acreage
Railroad	27,386	1.1
Pipeline	19,391	0.9
Electric	159,479	3.2
U.S. Total	206,256	2.2

Methods of Application

Both treatments are applied totally from the ground and have been combined in this discussion since the treatments are essentially the same. The nature of what is treated changes in that the stem is cut off before the stump is sprayed. Both treatments are an individual stem/stump type of treatment.

The great majority of acres treated (approximately 90%) are treated with handgun equipment connected to a central source, a tank truck (200-400 gallon capacity) with pumping unit and reels of hose. The remaining 10 percent is treated with 5 gallon knapsack sprayers or 3 gallon back-pack mist-blowers with a special wand attachment for basal stem/stump treatment.

The sprayer speed is determined by the walking speed of the individual. With walking time from spot to spot, the handgun or sprayer is actually spraying only 50-60 percent of the time. The application must wet the entire lower 21 to 14 inches of the stem or thoroughly soak the stump. All exposed roots are also treated in both treatments.

Rate and Timing of Application

Applications made with either hose and handgun or knapsack sprayer use the same herbicide concentrations. The major treatments in decreasing order of use are (1) 1 gallon Tordon 155 per 100 gallons oil (4 lb aehg 2,4,5-T), (2) 4 gallons of a 2,4-D - 2,4,5-T mixture per 100 gallons oil [8 lb acid equivalent per 100 gallons (aehg) 2,4,5-T], and (3) 3-4 gallons 2,4,5-T per 100 gallons oil (12-16 lb aehg 2,4,5-T). Basal treatments usually require 40-125 gallons of herbicide mixture per acre when applied with these equipment. Stump treatment requires 35-55 gallons of herbicide mixture per acre. The maximum use rate is 10 lb/A 2,4,5-T.

Motorized back pack mistblowers do not hold as much volume so the herbicide concentration is increased but fewer gallons are applied per acre. The important treatments for this method of application are (1) 3.5 gallons Tordon 155 per 100 gallons oil (14 lb aehg 2,4,5-T) and (2) 15.5 gallons of a 2,4-D - 2,4,5-T mixture per 100 gallons oil (31 lb aehg 2,4,5-T). 2,4,5-T is not used alone. Basal treatments are usually applied at rates of 15-25 gallons of herbicide mixture per acre while stump treatments are applied at 15-20 gallons of mixture per acre.

The herbicide application and the air carrier generation are two separate operations with a backpack mistblower. This gives the equipment a unique potential. The operator increases engine rpm's to blow leaves, sawdust, and other trash away from the root collar or stump. Then, after reducing engine rpm's, the herbicide valve is opened for actual treatment. The lack of extraneous litter around the root collar permits satisfactory control with less herbicide per acre.

Knapsack sprayers and motorized backpack mistblowers play minor, but unique, roles in rights-of-way management. They are most commonly used for spot treatments, small areas, or areas inaccessible to other equipment.

Basal or stump-spraying treatments are generally applied on a four year cycle. Crew productivity ranges from 1/2 - 2/3 acres per hour. These treatments can generally be applied during the normal working day (within weather limitations) and can be applied year round, theoretically. Obviously snow and ice can create operational problems.

Time Required for Treatment and Number of Applicators

A typical crew consists of a truck driver, two spraying personnel, and a foreman. All personnel could be involved with herbicide application during the day's activities. Assuming one hour per day is spent in travel and one hour in loading and refilling, there would be approximately three hours of actual nozzle time in the remaining six hours. However, since the application is only being made to the lower portion of stems or to stumps, this exposure would be minimal. Boots and pants will generally prevent skin exposure other than that resulting from leaky equipment and mixing.

The number of applicators is unknown. Given the estimated acres treated annually (244,931), 0.5 acre/hour/crew productivity, 5 hours/day application time, 5 days/week, 8 months/year treating season and 4 men per crew, there are approximately 1,808 full-time applicator equivalents required to apply basal treatments. Similarly, 76 full-time applicator equivalents are required to spray all acres with the cut stump treatment (table 20; table 5 - Chapter 3).

Acres Treated

Based on data used for the economic analysis of 2,4,5-T applied by these treatments, 1,071,737 lb of 2,4,5-T are applied in a selective basal treatment and 25,396 lb of 2,4,5-T are applied as a cut stump treatment (table 20; table 5 - Chapter 3).

Protective Equipment and Additional Routes of Exposure

No special equipment is required beyond label requirements. Additional practices include spray thickeners or other drift-control measures when specified, clean clothes recommended daily, buffer zones around water and homes, and treatments are not applied to wet stems. There are no standard-management practices which would require re-entry into a treated area.

Conventional Foliar Broadcast (Vehicular Mounted Sprayer)

Formulations and Containers

Various formulations of 2,4,5-T, alone and in premix combinations are available. Low-volatile emulsifiable esters include propylene glycol butyl ether, isooctyl, 2-ethylhexyl, and butoxyethanol esters. The formulations commonly contain 2 lb ae 2,4,5-T plus 2 lb ae 2,4-D or 4 lb ae 2,4,5-T. The most popular containers are 30 and 55-gallon drums.

Table 20—Rights-of-way acres treated annually with 2,4,5-T by selective basal or cut stump applications

	Acres treated annually	% of total ROW acres
	selective basal	
Railroad	43	0
Highway	733	0.003
Electric	234,254	4.7
U.S. Total	235,030	1.8
	cut stump	
Highway	3,373	0.04
Electric	6,528	0.13
U.S. Total	9,901	0.07

Methods of Application

The methods discussed here involve only ground equipment. Vehicular mounted sprayers are common for treating highway and railroad rights-of-way. However, uniquely different and highly specialized equipment are used for railroads. Highway equipment is usually a sprayer unit mounted on a truck or trailer. Railroad equipment is either a spray train or a Hyrail unit. In all cases the equipment (with boom or nozzle configuration attached) moves at a constant speed.

Highway equipment uses spray booms with conventional flat fan or flooding tips. Some equipment with off-center nozzles which permits herbicide application to the side of the vehicle is sometimes used while driving on the shoulder. Highway equipment could have a mobile boom that extends out over the right-of-way for added swath width. Herbicide applications will control undesired herbaceous and woody species.

Railroad useage of 2,4,5-T is largely directed to woody plant control. Woody-plant control as the primary treatment objective tends to occur under the communication wires. Consequently, treatments from Hyrail units involve a mobile boom with some nozzle configuration such as off-center tips, Directa-Spray or oscillating straight stream nozzles. Brush control from a spray train is done with turrents or handguns mounted on the spray car.

Tank capacities for highway equipment and Hyrail units generally range from 1,000-2,500 gallons. Spray trains have access to 10,000 gallon tank cars. Spray swaths may range from 5-50 feet as required. Equipment speeds range from 3-10 mph. Spray thickeners or other drift reducing measures are very important and commonly used.

Rate and Timing of Application

Conventional foliar-broadcast applications cover a variety of weed-control situations. The rates of 2,4,5-T per acre are adjusted to the particular weed problem. The most versatile concentration is one gallon of a 2,4,5-T - 2,4-D mixture per 100 gallons water (2 lb aehg 2,4,5-T). Highway treatments apply 40 gallons of this mixture per acre (0.8 lb ae 2,4,5-T/acre). High volume railroad applications, i.e., spray trains, apply this mixture at an average of 300 gallon per acre (6 lb ae 2,4,5-T/acre). Low volume railroad applications, i.e., Hyrail units, commonly use 2.5 gallons of the 2,4,5-T - 2,4-D combination per 25 gallons of water applied at the rate of 25 gallons per acre (5 lb ae 2,4,5-T/acre).

Applications generally follow a four-year cycle. Since these treatments are applied to foliage, the spray season is essentially the 5-month period from May through September. Weed control around bridge structures, on the roadbed ballast area, and in the yards is of higher priority to the railroads; however, so brush-control treatments tend to occur later in the growing season (July through September). Wind and weather limitations are the major restrictions for these treatments. Crew productivity ranges from 1-10 acres per hour for highway applications and 10-30 acres per hour for railroad treatments.

Time Required for Treatment and Number of Applicators

Highway and Hyrail crews typically consist of one driver for the equipment and one operator for the spray boom or nozzles. Both would be involved with loading. A railroad representative accompanies all applicator units when on the tracks as a safety precaution. This person's job is to maintain contact with the central dispatcher for track clearance and has no involvement with the herbicide application. Highway representatives tend to monitor contractors for job performance but have no involvement with the application. Spray train applicator crews typically consist of four people. The supervisor monitors speed and pressure and looks for sensitive areas and crops; the other three people act as applicators. Two are responsible for the wider side of the right-of-way, the pole side (side with communication lines), and one is responsible for the narrow side of the right-of-way, the off-pole side.

All crews are estimated to spend one hour per day in travel time and one hour loading and refilling for an application day of approximately 6 hours and 2 to 3 hours nozzle time. Sprayer operation on railroads is only 4-5 hours per day. Railroad applicators have the unique problems associated with interfacing their operation with continuous rail usage. Consequently, considerable time, 1-3 hours per day, is spent waiting for track time or track clearance.

Assuming crew productivity of 1 acre/hour/day, 6 hours/day, 5 days/week, 5 months/season, 2 members/crew, and 58,447 highway acres treated, 178 full time equivalents of personnel would be involved in treating highway right-of-way with a conventional broadcast application. Assuming crew productivity of 3 acres/hour/day, 4 hours/day, 5 days/week, 3 months/season, 3 members/crew and 99,996 railroad acres treated annually, 114 full time equivalents of personnel would be needed to treat the railroad right-of-way.

Acres Treated

Based on data used for the economic analysis of 2,4,5-T applied by this method, 620,748 lbs 2,4,5-T are applied as a conventional foliar broadcast application (table 21).

Protective Equipment and Additional Routes of Exposure

No special equipment is required beyond label requirements. Additional practices include wind speed limitations, buffer zones around water, and homes and clean clothes recommended daily. Spray thickeners or other drift-control measure are used when specified. Almost all railroad brush-control treatments include the thickener Nalco-trol. There are no standard management practices which would require re-entry into a treated area.

Table 21--Rights-of-way acres treated annually with 2,4,5-T by conventional broadcast foliar applications

	Acres treated annually	% of total ROW acres
Railroad	99,996	4.1
Highway	58,447	0.3
U.S. Total	158,443	0.7

Broadcast and Selective Foliar Ground Applications

Formulation and Container

Numerous formulations of 2,4,5-T, alone and in premix combinations, are available for foliar applications. Low-volatile emulsifiable esters include propylene glycol butyl ether, isooctyl, 2-ethylhexyl, and butoxyethanol esters. Amine salt formulations are also used such as the dimethylamine salt of 2,4,5-T in Banvel 710 (2 lb ae 2,4,5-T plus 1 lb ae dicamba). Formulations of 2,4,5-T commonly contain 2 lb ae 2,4-D plus 2 lb ae 2,4,5-T. Tordon 101 (0.54 lb ae picloram and 2 lb ae 2,4-D as triisopropanolamine salts) is frequently tank mixed with 2,4,5-T. The most commonly used containers are 30 and 55-gallon drums.

Method of Application

Broadcast foliar application, as used here, is the treatment of all woody plant species. In a selective foliar application only specific clumps of brush are treated. Lower pressure is used for selective foliar than for broadcast applications. Since fewer stems may be treated and lower pressure is used, the total volume per acre is less for selective foliar than for a broadcast treatment. Broadcast foliar application with handguns is used only on electric rights-of-way. Pipeline, highway, and electric rights-of-way are treated to some degree with selective foliar application because they are applied with a handgun not directly attached to a vehicle. The handgun is typically operated by personnel walking on the ground.

Nearly all of the acres are treated with hose and handguns connected to a central source, a tank truck with 200-400 gallon capacity. A very small amount, approximately 2 percent, is treated with 3 gallon backpack mistblowers. The sprayer, in effect, moves at the walking speed of the individual as the applicator sprays the plant foliage. With the constant walking and treating, the handgun is on only 50-60 percent of the time. Droplets are usually 200-400 μm in diameter in the normal pattern of the adjustable handgun.

Rate and Timing of Application

Four important treatments applied with hydraulic sprayers and handguns are (1) 1 gallon 2,4-D - 2,4,5-T combination per 100 gallons water (2 lb aehg 2,4,5-T), (2) 1 gallon 2,4,5-T alone per 100 gallons water (4 lb aehg 2,4,5-T), (3) 0.5 gallon 2,4,5-T + 0.5 gallon Tordon 101 or Amdon 101 per 100 gallons water (2 lb aehg 2,4,5-T), and (4) 1 gallon Banvel 710 per 100 gallon water (2 lb aehg 2,4,5-T). The foliage is sprayed to wet. Broadcast foliar treatment may require 250-300 gallons total volume per acre. Selective foliar treatment may require 150-250 gallons per acre.

The motorized backpack mistblower is used essentially for spot treatments. Herbicide concentration used in the backpack mistblower is 5 gallons 2,4,5-T plus 5 gallons Tordon 101 or Amdon 101 per 100 gallons water (20 lb aehg 2,4,5-T). This mixture is applied at the rate of 20-25 gallons per acre.

Foliage applications generally follow a 4-year cycle. Treatments are usually applied May through September. Crew productivity ranges from 1/3 - 2 acres/hour. Treatments can be applied throughout the day subject to wind and weather limitations.

Time Required for Treatment and Number of Applicators

A typical crew consists of a truck driver, 2 spray personnel, and a foreman. All personnel are likely to be involved in the herbicide application during the day's activities. Approximately one hour per day is spent in travel and one hour per day in loading and refilling.

Assuming crew productivity of 1/3 acre/hour, 6 hours of application/day, 5 days/week, 5 months/spray season, 4 people/crew, and 43,927 acres treated, 800 full time equivalents of applicators would be needed for broadcast foliar ground application. For a similar set of assumptions, excepting crews productivity at 1.5 acre per hour and 29,400 acres treated, 356 full time equivalents would be needed for selective foliar ground application.

Acres Treated

Based on data used for economic analysis of 2,4,5-T applied by this method, 342,631 lb ae 2,4,5-T are applied as a broadcast foliar ground application on electric rights-of-way, and 152,880 lb ae 2,4,5-T are applied as a selective foliar ground application on rights-of-way (table 22).

Protective Equipment and Additional Routes of Exposure

No special equipment is required beyond those required by the herbicide label. Additional practices include buffer zones around homes and water, clean clothes recommended daily, and spray thickeners or other drift-control measures used when specified. Spray is directed parallel to right-of-way edge rather than perpendicular to avoid right-of-way damage. There are no standard-management practices which require re-entry into a treated area.

See calculation summaries 6-12.

Table 22--Rights-of-way acres treated with 2,4,5-T by broadcast or selective foliar application

	Acres treated annually	% of total ROW acres
	----------broadcast foliar----------	
Electric	43,927	0.9
U.S. Total	43,927	0.9
	----------selective foliar----------	
Pipeline	2,635	0.12
Highway	5,614	0.03
Electric	21,151	0.43
U.S. Total	29,400	0.10

CALCULATION SUMMARY NO. 6: USE INFORMATION FOR EXPOSURE, AERIAL - RIGHTS-OF-WAY

1. Commodity: ROW - aerial

2. Equipment: Helicopter with microfoil boom, 060 (3/32") nozzle

	Situation	
	Typical (>50%):	Extreme (10-20%):
3. Target: Mixed brush		
4. Rate:	8 lb/A	
Dilution:	32 lb/100 gal	
5. Exposure Times:		
Day:		
Application Time: 5-9 am; 5-9 pm	6 hr	
Nozzle Time:	6 min/hr, 36 min/day	
Drift Time and/or fraction direct exposure occurs:	None	
Week:	5 days/week	
Year: (May-September) No flagger or ground observer used. Loader & mechanic too far from application site to receive drift.	22 weeks/year	
6. Treatment Area: Total acres or units:	206,256 A	
7. Population Exposed: Loader, mechanic, pilot		
Number of exposed workers:	156	

8. Dress: Work clothes - long trousers, long sleeve shirt, some hats, work boots, about 1 month in summer will wear T-shirt

9. Workers and Exposure Time:

   156 workers @ 66 hrs/year nozzle time; no exposure time during application but loader-mixer may be exposed during mixing/loading functions.

CALCULATION SUMMARY NO. 7: USE INFORMATION FOR EXPOSURE, SELECTIVE BASAL - RIGHTS-OF-WAY

1. Commodity: ROW - selective basal

2. Equipment: Powered hydraulic handgun nozzle - 5500 adjustable cone tip

	Situation	
	Typical (>50%):	Extreme (10-20%):
3. Target: Mixed brush	Handgun or knapsack mistblower	
4. Rate:	6.4 lb/A	6.2 lb/A
Dilution:	8 lb/100 gal	31 lb/100 gal
5. Exposure Times:		
Day:		
Application Time:	6 hr/day	
Nozzle Time:	3 hr/day	
Drift Time and/or fraction direct exposure occurs:	0.3 hr/day 10%	
Week:	5 days/week	
Year:	34 weeks/year	
6. Treatment Area: Total acres or units:	235,030	
7. Population Exposed: Foreman, driver, 2 spraymen		
Number of work sites:	3 A/day, 15 A/week, 520 A/season	
Number of exposed workers:	Max 1808	

8. Dress: Work clothes

9. Workers and Exposure Time:
1808 workers @ 87 hr/year

CALCULATION SUMMARY NO. 8: USE INFORMATION FOR EXPOSURE, CUT STUMP - RIGHTS-OF-WAY

1. Commodity: ROW - Stump spray after cutting

2. Equipment: Powered hydraulic handgun

	Situation	
3. Target: Cut stumps - mixed species	Typical (>50%):	Extreme (10-20%):
	Handgun	Mistblower
4. Rate:	3.2 lb/A	4.6 lb/A
Dilution:	8 lb/100 gal	31 lb/100 gal
	40 gal/A	15 gla/A
5. Exposure Times:		
Day:		
Application Time:	6 hr/day	
Nozzle Time:	3 hr/day	
Drift Time and/or fraction direct exposure occurs:	No drift, but contamination may be 5% or 15 min/day	
Week:	5 day/week	
Year:	34.7 weeks/year	
6. Treatment Area: Total acres or units:	9,901 A	
7. Population Exposed:		
Number of exposed workers:	76	

76 workers @ 15 min x 5 day x 34.7 weeks =
43 hours/year

8. Dress: Work clothes

9. Workers and Exposure Time:
76 workers @ 43 hrs/year

CALCULATION SUMMARY NO. 9: USE INFORMATION FOR EXPOSURE, SELECTIVE FOLIAR - RIGHTS-OF-WAY

1. Commodity: ROW - Selective foliar

2. Equipment: Bean 785 spraymaster (handgun)

3. Target: Mixed brush

Situation

			Typical (>50%):	Extreme (10-20%): Mistblower
4.	Rate:		6 lb/A	5 lb/A
	Dilution:		2 lb/100 gal 300 gal/A	20 lb/100 gal 25 gal/A
5.	Exposure Times:			
	Day:			
		Application Time:	6 hr/day	
		Nozzle Time:	3 hr/day	
		Drift Time and/or fraction direct exposure occurs:	1.5 hr/day	
	Week:		5 day/week	
	Year:		22 week/year	
6.	Treatment Area:	Total acres or units:	29,400 A/season/330 = 39 crews	
		Days or units of work per year:	1/2 A/hr/crew; 3 A/day/crew 15 ac/week; 330 ac/season/crew	
7.	Population Exposed:	Sprayers in 4 person/crew		
		Number of exposed workers:	356 workers	

8. Dress: Work clothes

9. Workers and Exposure Time:
Equivalent of 356 workers @ 165 hrs/season

CALCULATION SUMMARY NO. 10: USE INFORMATION FOR EXPOSURE, BROADCAST FOLIAR ROADSIDE - RIGHTS-OF-WAY

1. Commodity: ROW - foliar, roadsides

2. Equipment: Truck mounted with boom
Nozzle - off center nozzles 150-OC nozzle 1500-1600 nozzle or 1-3 sets

	Situation Typical (>50%):	Extreme (10-20%):
3. Target: Roadside, mixed brush		
4. Rate:	0.8 lb/A	
Dilution:	2 lb/100 gal 40 gal/A	
5. Exposure Times:		
Day:		
Application Time:	6 hr/day	
Nozzle Time:	5 hr/day	
Drift Time and/or fraction direct exposure occurs: (1 min/20 min)	15 min/day	
Week:	5 days/week	
Year:	22 weeks/year	
The 5 day/week, 22 week per year is a maximum assumption. Assumes a crew moving across the country with the season and using 2,4,5-T every day.		
6. Treatment Area: Total acres or units:	58,447 A	
7. Population Exposed: Driver and sprayman		
Number of exposed workers:	178 workers @ 5 days/week 22 weeks/yr or may be 1780 workers @ 5 days/week for 2 weeks/year.	

Driver in cab, removed for spray. Sprayman sets up high, less exposed that farm tractor driver with low boom and 8003 nozzles, plus roadside usually uses drift control agent.

8. Dress: Work clothes

9. Workers and Exposure Time:

178 workers @ 27.5 hr/year

or 1780 workers @ 2.75 hr/yr

CALCULATION SUMMARY NO. 11: USE INFORMATION FOR EXPOSURE, BROADCAST FOLIAR (RAILROAD) - RIGHTS-OF-WAY

1. Commodity: ROW - Foliar, broadcast, ground railroad

2. Equipment: Hi-Rail (HR) (highway or railroad), OC nozzles, directed spray, oscillating nozzle clusters, etc., straight stream spray train (ST) - John Bean spray gun 785 spraymaster, 1 1/4" & 2" mystery nozzle

	Situation Typical (>50%):	Extreme (10-20%):
3. Target:		
4. Rate:	ST 6 lb/A HR 2 lb/A	
Dilution:	ST 2 lb/100 gal HR 8 lb/100 gal	
5. Exposure Times:		
Day:		
Application Time: HR-tracktime	4 hr/day	
Nozzle Time:	3 hr/day	
Drift Time and/or fraction direct exposure occurs:	6 min/day	
Week:	5 day/week	
Year:	13 weeks/year	
Hi-Rail uses Nalcotrol, coarse		
6. Treatment Area: Total acres or units:	10 A/hr/crew	
Days or units of work per year:	40 A/day; 200 A/week, 2600 A/season/crew; 99,996 A treated/year ÷ 2600 = 38 crews	
7. Population Exposed:	3 people (2 HR, 4 ST)	
Number of exposed workers:	114 workers, equivalent	

8. Dress: Work clothes - long pants, long sleeve shirt, for a month boots, may have T-shirt for 1 month, jackets for 1 month

9. Workers and Exposure Time:

6 min x 5 days x 13 weeks = $\frac{390\ \text{min}}{60}$ = 6.5 hr

equivalent of 114 workers @ 6.5 hr/year

CALCULATION SUMMARY NO. 12: USE INFORMATION FOR EXPOSURE, BROADCAST FOLIAR (ELECTRIC) - RIGHTS-OF-WAY

1. Commodity: ROW - Foliar broadcast, ground, electric right-of-way

2. Equipment: Bean 785 spraymaster (handgun)

	Situation	
3. Target: Mixed brush	Typical (>50%):	Extreme (10-20%):
		Mistblower
4. Rate:	6 lb/A	5 lb/A
Dilution:	2 lb/100 gal 300 gal/A	20 lb/100 gal 25 gal/A
5. Exposure Times:		
Day:		
Application Time:	6 hr/day	
Nozzle Time:	3 hr/day	
Drift Time and/or fraction direct exposure occurs:	1.5 hr/day	
Week:	5 day/week	
Year:	22 week/year	
6. Treatment Area: Total acres or units:	43,927 A	
Days or units of work per year:	0.5 A/hr/crews, 2 A/day 10 A/week, 220 A/season per crew 43,927 A/season/220 = 200 crews	
7. Population Exposed: Driver, foreman, 2 sprayers		
Number of exposed workers:	800	

8. Dress: Work clothes

9. Workers and Exposure Time:
1.5 hr x 5 x 22 = 165 hrs/season
equivalent of 800 workers @ 165 hrs/season

RICE

Formulation and Container

1. Formulation--Amine salts of a water soluble liquid are used in rice. Principal amines used are diethanol, triethanol, dimethyl, triethyl, and isopropyl amines.

2. Package size and description--2,4,5-T amine is packaged in 5, 30 and 55-gallon metal drums.

Methods of Application

Aerial

About 97 percent of the 2,4,5-T is applied to rice by aircraft. Fixed-wing planes apply 99 percent of it; a few helicopters are used in some years. Boom-nozzle sprayers mounted on fixed-wing planes are used to apply 2,4,5-T. Tank capacities range from 100 to 250 gallons. Boom length is 70 percent of the length of the wingspan for the plane. Swath coverage ranges from 30 to 50 ft. depending on the size of the plane. Speed of spraying is 85-105 mph. Spray droplets size range from 100 to 300 µm in diameter (90% of the droplets are in this range; 10% of them are above or below this range). Drift-control agents are used with 2,4,5-T spray mixtures.

Ground

Only about 3 percent of the 2,4,5-T is applied by ground; this is used mainly for levee spraying. A light-weight, 4-wheel drive machine equipped with tank, pump, boom, and nozzles straddles the levee and sprays a 5 to 6-foot swath. The spray is released just above the rice canopy in a volume of 15 to 20 gpa. Spray pressure is 20 to 40 psi.

Rate and Timing of Application (Fixed-Wing Aircraft)

1. Rate--1 lb/A ai.
2. Dilution--1 qt. of 4 lb/gal ai per 3 gal; this is applied to 1 acre.
3. Pressure--20 psi, maximum.
4. Carrier--water.
5. Volume--3 gpa.
6. Spray ht.--5-10 ft. above crop.
7. No. applications--one application per season in 90%+ of the fields.
8. Acres treated per hr.--80 acres can be sprayed with one aircraft.
9. Hours suitable for spray each day--5 hr. per day (5:30-7:30 a.m.; 6:00-9:00 p.m.).
10. Season during which spraying takes place--last week of May through first week of August.

Time Required for Treatment and Number of Applicators (2,4,5-T Use Area)

1. All aerial applications are by commercial applicators.
2. No. of pilots--307.
3. No. of farmers--6,555.
4. Size of average site treated and time required to treat site--46 acres; 35 minutes.
5. Pilot and loaders--one pilot and one loader (pilot helps load plane).
6. No. of flaggers--1 or 2 (about 50% of the time there is one flagman and 50% of the time there are two flaggers).
7. Length of exposure--pilot, 35 minutes; flaggers, 25 minutes; loadman, 5 minutes.
8. Time required for loading--5 minutes.

Acres Treated (Air)

1. Total acres treated.

   Arkansas--------------172,000
   Mississippi----------- 99,000
   Louisiana------------- 17,000
   Missouri-------------- 4,000
   Total---------------292,000

2. Percentage of total acres in 2,4,5-T use area (1,075,000 acres)--27%.
3. Percentage of total rice acreage in U.S.--12%.
4. Total pounds active ingredient used--air, 292,000 lb; ground, 8,000 lb.

Exposure During Application

Aerial Application

The normal procedure of applying 2,4,5-T aerially to ricefields is to use a pilot for the aircraft, two flagmen, one on each end of the field, to guide the pilot, and one workman at the landing strip who drives the spray tank truck and helps load the aircraft (USDA-SEA-AR 1978). 2,4,5-T is hauled to the airstrip by the farmer or herbicide supplier in 5, 30, or 55-gallon drums. The herbicide is mixed with water in open 55-gallon drums and pumped into the aircraft through a closed hose system on the spray tank truck. The aircraft then flies across the ricefield covering a strip that ranges from 30 to 50 feet and using the flagmen as guides. The flagmen move upwind after they have lined up the pilot and before the aircraft comes directly over them; hence, the flagmen are not directly sprayed with 2,4,5-T. Since they are moving upwind, exposure to the spray is kept to a minimum. Because the aircraft travels across the ricefield at a low altitude (5-10 above the crop) flagmen must move before they would be sprayed directly (Smith et al. 1977).

Ground Application

About 8,000 acres of rice levees are sprayed each year with 2,4,5-T. Levees are sprayed with a 4-wheel-drive, light-weight machine operated by one man. The operator also mixes and loads the herbicide mixture. If the average rice farmer sprays 46 acres of rice land, a total of 3 acres of rice would be treated (table 13, chapter 4). This would be about 4 miles of levees [(43,560 x 3) ÷ 6) ÷ 5,280]. About 4 hours would be required to spray all the levees on 46 acres (spraying, mixing, and ferrying time). However, the actual spraying time would be about 1.3 hours. Each farmer treats only the levees on his farm. Presently, custom applications are not used to spray levees.

If a farmer had 500 acres of rice, the operator of the spraying machine would be exposed to the spray for a total of 14 hours (actual spraying time).

Additional Routes of Exposure

Under normal conditions workmen seldom re-enter rice fields soon after spraying with 2,4,5-T at midseason (the time when most of the 2,4,5-T is applied for weed control). The field is re-flooded or water is added to increase the flood depth soon after 2,4,5-T spraying. However, the ricefield is equipped with floodgates in each levee so that the water enters from the canal on the high end and subsequently fills the paddies successively with the slope of the field. There is little need for the irrigation man to enter the ricefield because the floodgates regulate the water in each field. The fields are entered after the rice matures and when the floodgates must be removed to drain the field; this is 40 to 45 days after applying 2,4,5-T.

When ricefields are sprayed during the early season (3 to 6 weeks after crop emergence) workmen may enter the field soon after treatment to adjust floodgates, to fill drain furrows, and to check growth and development of the rice crop. However, most fields are treated with 2,4,5-T at midseason when re-entry of the field is infrequent. Re-entry of ricefields after spraying with 2,4,5-T is not regulated.

When rice fields are sprayed by ground applicators the operator is exposed to the spray during mixing and spraying in the field. However, the boom is located to the rear of the operator which reduces exposure to the spray.

Time required for these practices with number of individuals and exposure time for each--the water-man (irrigation man) would be the only person exposed (1 individual per farm). Exposure time would be less than 1 hour per day during the 7 days after application.

Protective Equipment

Normal work clothes. Flagmen move before the airplane sprays them directly. They usually flag upwind so that the spray does not drift on them; however, there is little wind movement at time of spraying (less than 5 mph).

Size of Rice Farms in 2,4,5-T Use Area and Number of Workers Exposed

No. rice farms in Arkansas in 1977 (Arkansas Cooperative Extension Service (1978e)	6,441
No. rice farmers in Arkansas in 1977 (Arkansas Cooperative Extension Service 1978g)	5,100
Rice acreage in Arkansas in 1977 (table 1, Chapter 4)	347,000
Avg. no. rice acres/farm (calculation)	130

Avg. no. rice acres/ farmer (calculation)............................164

The data from Arkansas can be extrapolated to Mississippi, northern Louisiana, and Missouri because their production systems are similar to Arkansas: Extrapolations would indicate the following averages:

No. rice farms in 2,4,5-T use area, 1975-77	8,269
No. rice farmers in 2,4,5-T use area, 1975-77	6,555
Rice acreage in 2,4,5-T use area, 1975-77 (tables 1 and 4, Chapter 4)	1,075,000
Avg. no. rice acres/farm, 1975-77 (from above calculation)	130
Avg. no. rice acres/farmer, 1975-77 (from above calculation)	164

In order to maintain a satisfactory cropping (crop rotation) system, the farmer needs 3 to 4 times his rice acreage in the total farm. On the alternate acres he may produce soybeans, grain sorghum, small grains, cotton, lespedeza, or fish (catfish or minnows). He also may have some land devoted to surface water storage for irrigation use. Therefore, a good assumption would be that the average rice farmer manages a total of 3.5 times the acres he has in rice. If this assumption is used, we can calculate the number of acres that each farmer manages--164 X 3.5 = 574 (the avg. size of a rice farm). Usually a rice farm will contain more acres than cotton or soybean farms because of the cropping system required for growing rice.

In 1975-77, 300,000 acres of rice were treated with 2,4,5-T. This is 28 percent of the total acres in the 2,4,5-T use area (300,000 ÷ 1,075,000 X 100). Although some farmers treat all of their rice acreage with 2,4,5-T, others do not apply any 2,4,5-T. A good assumption is that, on the average, the rice farmer would treat 28 percent of his rice acreage with 2,4,5-T or 46 acres (164 acres/farmer X 28%) with 2,4,5-T.

Therefore, only 8 percent of the acreage on each farm is treated with 2,4,5-T each year [(46 ÷ 475) X 100].

Aerial Application

An aerial applicator can spray 46 acres of rice in 35 minutes (this includes time for loading, ferrying, and spraying the field) (Eichler 1978b). A loadman will help the pilot fill the plane; this requires about 5 minutes. About one-half of the fields are sprayed using 2 flagmen and half using one flagman--this averages to be 1.5 flagmen/field. The actual spraying time is about 25 minutes. Therefore, for a 46-acre field the exposure time would be:

Workmen	Exposure time (min.)
Pilot (1 X 35)	35
Flagmen (1.5 X 25)	38
Loadman (1 X 5)	5
Total man-minutes to spray a 46-acre rice field	78

If we extropolate the above data to the total 2,4,5-T use area, we get the following data for the 6,555 rice farmers each with an average of 46 acres of rice sprayed with 2,4,5-T:

Workmen	Man-hours
Pilot (0.58 hr. X 6555)	3,802
Flagmen (0.63 hr. X 6555)	4,130
Loadmen (0.08 hr. X 6555)	524
Total man-hours involved in 2,4,5-T spraying in 2,4,5-T use area	8,456

Most spray jobs are done during the early morning (5-8 a.m.) or late afternoon (6-9 p.m.) when the wind is below 5 mph.

The number of pilots registered to apply phenoxy herbicides in Arkansas and Mississippi in 1976 (Jan.-Sept.) was 242 and 82, respectively. The number of aircraft inspected to apply phenoxy herbicides in Arkansas and Mississippi in 1976 (Jan.-Sept.) was 211 and 118, respectively. The number of operators registered to apply phenoxy herbicides in Arkansas in 1978 (Jan.-Sept.) was 198; this value is not known for Mississippi. An operator may or may not be a pilot. About 90 percent of the pilots and aircraft in Arkansas and Mississippi spray phenoxy herbicide on rice. However, they may not all be applying 2,4,5-T. We estimate that most of them apply some 2,4,5-T on rice. Most of the phenoxy herbicides applied to rice in Missouri is by operators located in Arkansas. The above data were obtained from Pay (1978b, data for AR) and McCarty (1978, data for MS). Data are not available from Louisiana but some of the spray jobs are done by operators, pilots, and aircraft located in Arkansas and Mississippi. It is safe to assume that in Louisiana the number of pilots and aircraft would be proportional to the acreage sprayed in Arkansas and Mississippi. If this is the case, then the following data are indicated for number of pilots exposed to 2,4,5-T:

State	No. Pilots
Arkansas	218
Mississippi	74
Louisiana	15
Total	307

For each pilot exposed to 2,4,5-T there is one loadman exposed.

Therefore, 7,169 (worst case) people are exposed to 2,4,5-T each year; these include pilots, loadmen, and flagmen.

These data indicate that pilots are exposed to 2,4,5-T for longer periods than other workmen. On the average, a pilot is exposed to 2,4,5-T for 12.4 hr/yr., compared with 1.7 hr/yr for a loadman, and 0.65-2.25 hr/yr for a flagman. Although these are average exposure cases, the exposure time per year of each class of workman would be relatively low, even if the exposure time were multiplied by a factor of 10- to give 124, 17, and 6.3-22.5 hours exposure time per year for pilots, loadmen, and flaggers. The high exposure person (pilots) in this group is protected most of the time by the airplane; he is in the cockpit ahead of and above the spray (tables 23 and 24).

Although one flagger has a nozzle time exposure of 25 minutes, he receives contact with spray drift for only 1 pass out of 10. The spray dispensed by the airplane settles while the plane completes a 0.25 mile turn to start another pass. About 18 seconds are required to complete the turn. Flaggers wear ordinary field clothes--long pants, long-sleeved shirts, caps or hats, and leather boots. They do not use special protective gear.

Ground Application

About 8,000 acres of rice levees are sprayed with 2,4,5-T annually. This is the acreage of levees in 50,000 acres of rice. Each farmer treats the levees on his farm; custom applicators are not used. A total of 1,087 operators would be required to spray the levees on all 50,000 acres of rice. If a farmer had 500 acres of rice, the spray operator would be exposed for 14 hours actual spray time annually. A total of 100 operators would be required if all 50,000 acres were in 500 acre ownerships.

See calculation summaries 13 and 14.

Table 25 summarizes the number of applicators and their annual exposure time for various methods of application in each commodity group.

Table 23--Number of workers exposed annually to 2,4,5-T in rice production

State	Workmen		
	Pilot	Loader	Flaggers[a]
	No. of people exposed/yr.		
Arkansas	218	218	5,213
Mississippi	74	74	866
Louisiana	15	15	387
Missouri	---	---	---
Total	307	307	6,555

[a] 1.5 flaggers per farm for spraying 46 acres of rice with 2,4,5-T. A total of 6,555 farmer operations in the 2,4,5-T use area.

Table 24--Man-hours of exposure to 2,4,5-T for classes of workmen in the total 2,4,5-T use area

Workmen	No. persons exposed/yr.	Man-hours of nozzle time/yr	Man-hours of nozzle time per man/yr.
Pilot	307	3,802	12.4
Loadmen	307	524	1.7
Flagman[a]	6,555	4,130	.63
Flagmen[b]	1,835	4,130	2.25

[a] Low exposure case--assumes each rice farmer treats 28% of the average acreage with 2,4,5-T.

[b] High exposure case--assumes 28% of the rice farmers treat all (164 acres) of the average acreage of rice.

CALCULATION SUMMARY NO. 13: USE INFORMATION FOR EXPOSURE, AERIAL RICE

1. Commodity: Rice

2. Equipment: Fixed wing aircraft, 40 foot swath VMD 250 m (range 100-300 m)

Situation

	Typical (~50%):	Extreme (10-20%):
3. Target: Weed in rice crop		
4. Rate:	1.0 lb/A	
Dilution:	33 lb/100 gal	
5. Exposure Times:		
Day:		
Application Time:	25 min	272 min
Drift Time and/or fraction direct exposure occurs:	1 min/day	10.9 min/day
Week: 1 day or 1 field/worker	1 min/week	10.9 min/week
Year: 1 day or 1 field/worker	1 min/year	10.9 min/year
6. Treatment Area: Total acres or units:	46 A	500 A
Days or units of work per year:	1	1
7. Population Exposed: Flagman	1	2
Number of work sites:	1	1
Number of exposed workers:	6,555	(total @ 1.5/field)
8. Dress: Work clothes - blue jeans or khakis, long sleeve shirt, cap or wide brim hat, work boots		
9. Workers and Exposure Time:	Assume 90/10 distribution 5,900 @ 1 min	60 @ 11 min

*Drift time: Drift only occurs at end or start of a pass and only then in dead calm, this will be about 1/10 of passes, when it occurs, it will have disappeared in 18 seconds or time it takes for a turn. There are 33 passes per 46 A field x 18 sec = 594 sec x 1/10 equals 60 sec or 1 minute

Equivalent of 6,555 workers @ 1 min/year
or 603 workers @ 10.9 min/year

CALCULATION SUMMARY NO. 14: USE INFORMATION FOR EXPOSURE, BOOM SPRAYER - RICE

1. Commodity: Rice

2. Equipment: 4-wheel drive, low boom sprayer

Situation

	Typical (>50%):	Extreme (10-20%):
3. Target: Weeds on levee; field boundaries and interior dikes		
4. Rate:	1.0 lb/A	
Dilution:	5 to 7 lb/100 gal 15 to 20 gal/A	
5. Exposure Times:		
Day:		
Application Time:	1.3 hrs/day	7 hrs/day
Nozzle Time:	1.3 hrs/day	7 hrs/day
Drift Time and/or fraction direct exposure occurs: *Assume fraction of drift time/nozzle time is the same as in Staiff et al. (1975) which provides the base level exposure used by EPA.	1.3 hrs/day*	7 hrs/day
Week:	1 day/week	2 day/week
Year:	1.3 hr/year	14 hrs/year
6. Treatment Area: Total acres or units:	46 A	500 A
Days or units of work per year:	1	1
7. Population Exposed: Sprayman		
Number of work sites:	1/worker	1/worker
Number of exposed workers: Note: The units of work can be done by 2667 or 245 workers, but not by both. Perhaps 10% or 25 units would be 500 A operations; 25 workers would be exposed at 14 hrs rather than 1.3 hrs.	2667 or	245
8. Dress: Work clothes - blue jeans or khakis, long sleeve shirt, cap or wide brim hat, work boots.		
9. Workers and Exposure Time:	Assume 90/10 distribution 2,400 @ 1.3 hrs	25 @ 14 hrs

Equivalent of 2,667 workers @ 1.3 hrs/year
or 245 workers @ 14 hrs/year

Table 25--Application methods, distribution of effort, persons and hours per year potentially exposed

Commodity	Method	Percent of acreage	Number of persons	Exposure time hr/yr
Timber	Backpack mistblower	2		
	tree injection	11		
	Tractor mounted mist blower	12		
	Helicopter - D6 - nozzle	37	1,238	0.1
			60	0.23
	D6-46 nozzle	38	1,238	0.1
		100	60	0.23
Range & pasture	Backpack handpress	1	300	6
			20	12
	Tractor mounted low boom	2	450	0.75
			20	1.75
	Tractor mounted high boom	9	15	96
	Fixed wing aircraft	88	25	1
		100	100	3
			25	10
Rights-of-way	Hydraulic power gun			
	Selective foliar	4	356	165
	Broadcast foliar	6	600	165
	Selective basal	35	1,808	87
	Stump	1	76	43
	Vehicle mounted - Highway	9	178	28
	Vehicle mounted - Hi-Rail	15	114	6.5
	Helicopter - microfoil	30	156	0
		100		
Rice	4-wheel drive mounted low boom	3	2,400	1.3
			25	14
	Fixed wing aircraft	97	5,900	0.67
		100	60	0.18

ESTIMATION OF EXPOSURE BY THE FACTORIAL METHOD

The factorial method uses the exposure scenarios as presented in PD-1 (EPA 1978) as the base to which corrections are applied. The assumptions both explicit and implied are adjusted according to the actual exposure which results from specific patterns of use (see earlier section, "Exposure of applicators according to use pattern" in Part 5 of this chapter). The adjustment is applied as a decimal correction factor which can be used to correct either the calculated exposure level (as done in this section) or directly to the calculated margin of safety. In this report, adjusted margins of safety were calculated by dividing the no-adverse-effect levels specified in PD-1 by the exposure levels corrected by the factorial method.

The factorial approach to modifying estimates of exposure is used in this section to (1) determine the effects of a few reasonable changes in assumption on the magnitudes of the safety margin, and (2) calculate safety margins for exposure situations as we believe they exist in practice.

THE FIRST PRESUMPTION OF RISK - ONCOGENIC EFFECTS

The oncogenic effects presumption of risk was not based on exposure in PD-1 (EPA 1978). The toxicological properties of 2,4,5-T and TCDD were the sole criteria used, therefore this report makes no further evaluation of the first presumption risk.

THE SECOND PRESUMPTION OF RISK - DERMAL EXPOSURE/BACKPACK SPRAYER

The effect of assumptions on the safety margins is illustrated by comparing the scenario for backpack sprayers using the assumptions in PD-1 (EPA 1978) and by an alternate set of assumptions. The following assumptions were stated or implied in the scenario describing the dermal exposure of a spray applicator using a (hand pressure) backpack sprayer on a right-of-way, pasture, or rangeland in PD-1:

1. Applicator is female, pregnant, in the first trimester, and weighs 60 kg.
2. Finished spray: 1.6 lb ae/32 pints or 40 lb ae/100 gallons.
3. Applicator is exposed at a rate of 10.5 ml/hr, the maximum single value available (or 0.177 pints/day).
4. Applicator wears no protection; only short-sleeved shirt, open-necked, no gloves, no hat.
5. Application wand was directed upward or horizontal a portion of the time.
6. Application exposure is 8 hrs per day.
7. The applicator is exposed daily from the 15th through the 60th days of pregnancy.
8. Ten percent of the dermal dose of 2,4,5-T and TCDD is absorbed.
9. The rate of dermal absorption is the same as from oral exposure.

A close examination of these assumptions is necessary to determine if they have a rational and orderly relationship to actual conditions. The following considerations should be given to these assumptions (numbered to correspond to numbers above):

1. The stated assumption by the EPA is that the spray applicator be a female of child-bearing age, but the "hidden" assumption is that she is pregnant. The assumption that a pregnant woman is a backpack sprayer is obviously fundamental to risk assessment involving teratogenic or fetotoxic effects. The frequency of this assumption being satisfied currently or in the future needs consideration. No cases of female spray operators involved in the application of 2,4,5-T were identified by Norris and Klingman (1979). Since the data on which the no-adverse-effect-level are based involved daily exposure from the 6 to 15 days of pregnancy in rats, this is translated in terms of human fetal development as being during the 15th to 60th day in the first trimester, which as a further restriction consitutes another hidden assumption.

It is not clear how to translate the improbable event of a human in the first trimester of pregnancy involved in spraying 2,4,5-T on the appropriate days into the quantitative terms of a probability coefficient necessary to compute the hazard. We shall, therefore, continue to use this assumption in this and subsequent scenarios, but only because to exclude it aborts the scenario. This risk needs to be identified in a more quantitative fashion.

2. The "typical" concentration of 40 lb/100 gallons in a finished spray is not typical. The EPA figure seems to have been chosen as being typical on the basis of being near the midpoint of concentrations found on all the registered labels [shown in the Exposure Analysis by the EPA 2,4,5-T Working Group (Reference No. 164 in EPA 1978) as being from 2.5 lb to 100 lb/100 gallons] rather than identifying the frequency with which various concentrations are used in practice. Some very high spray concentrations are registered presumably to allow the flexibility to deal with an intractable, but rare, pest problem. The most common, and therefore typical, concentration for use with backpack sprayers is 8 lb/100 gal. or 1/5 that used in the PD-1 calaculation. Application of this "correction factor" (0.2) decreases exposure thereby increasing the margin of safety from 3:1 to 15:1 and from 43:1 to 215:1, for 2,4,5-T and TCDD respectively.

3. The assumed rate of exposure of 10.5 ml/hour is taken from the single highest value obtained from a set of 10 measurements (Wolfe, et al. 1974, Reference No. 166 in EPA 1978). Ordinary scientific practice is to use the mean value of a set of replicates rather than a single high or low extreme value, because the extreme low value has the same probability of being a correct forecast as an extreme high value, but both a lower probability of occurring than the mean. This was done in spite of the fact that the authors of the source document observe in their paper that exposure rates were measured for a brief period and clearly stated that "maximum exposure levels would probably rarely be maintained throughout a

full working day considering the variation in values obtained." The PD-1 did not identify the choice of exposure rate as a single extreme value, but presented the value in a way which leads the reader to believe the mean value was chosen: "Exposure ranged from 0.1 to 6.3 mg/hour, with a mean of 3.6 mg/hour (6 ml/hour)" (EPA 1978). The Working Group paper (Reference No. 164 in EPA 1978) made it clear that 6.3 mg/hour is used, but the PD-1 makes it appear that 3.6 mg/hour is used. The authors of the source document have stated that they object to the use of the extreme value rather than the mean as being a meaningful interpretation of their data. The potential exposure rate is therefore corrected by a factor of 0.6.

4. Applicators do not normally work while dressed as described in PD-1, and did not do so in the experiment cited in the PD-1 (Wolfe et al. 1974) nor in another paper cited later (Wolfe et al. 1959, Ref. No. 145 in EPA 1978). The technique used in both of these studies was to fasten cellulose pads to various parts of the body over the clothing or protection actually worn. The amount of chemical deposited on any segment of the epidermis is then calculated from the amount on the patches and a <u>theoretical</u> exposure pattern developed to show the contribution of each part of the body. In the studies cited, no spraymen were actually dressed in short-sleeve shirts, etc.; this was a theoretical model. Examination of the detailed data supporting the data cited for dermal exposure (Ref. No. 166 in EPA 1978) reveals the following distribution; hands - 62.3 percent; forearms - 25.4 percent; V of chest - 2.2 percent; back of neck - 1.3 percent, face 8.8 percent.

   Thus, simply wearing a long-sleeved shirt and gloves reduces the exposure by 87.7 prcent or increases safety by a factor of 8 bringing the margin of safety to 344 and 1720, respectively for 2,4,5-T and TCDD. If a wide-brim hat and button-up shirt is worn the exposure is further reduced to at least 91.2 prcent. If, as shown in Wolfe et al. (1959), a Type I cape is worn with hat and gloves, exposure will be reduced by more than 98.6 percent, probably by 99.3 percent. We may dress the applicators (in our subsequent scenarios) in the Type I cape, etc., and reduce the exposure level by 99 percent, increasing the margin of safety by 100 or use only a long-sleeve shirt, buttoned up, with hat and gloves and increase the margin of safety by 10. If other scenarios with other modes of dress are desired, appropriate changes in the correction factors will permit calculation of the correct margin of safety.

5. The experiments in the source document were for mosquito control instead of brush control; this means that conditions were more conducive to exposure of personnel than they should have been due to smaller droplet size, angle of the wand, and in one case, indoor spraying. It is our judgment that these factors should reduce exposure by at least a factor of 2, but since we lack specific data we will not enter this correction at this time.

6. The assumption that an applicator who works an 8-hour day is exposed for 8 hours per day is not correct. Their exposure is limited by a number of factors including weather conditions, preparation time, travel time, etc. The approximate time spent in treatment per day is: pastures and range - 6 hours; forests - 4 hours; right-of-way - 6 hours. Since the largest proportion of the 2,4,5-T applied by backpack sprayers is on powerline rights-of-way, the principal scenario will utilize that illustration.

7. The no-adverse-effect-level is expressed as a daily dose and based on daily doses from the 6th to the 15th day of a 21-day pregnancy according to the source document. In terms of human fetal development this translates to a daily exposure for 45 consecutive days between the 15th and 60th days of pregnancy. It can be argued that the terata (birth defects) are formed on a single day within

that time span, but if so the exposure causing the terata would be a result of accumulation of chemical from several preceeding days doses. Several assumptions are possible. The simplest is that exposure occurs on each 45 days. A more complex assumption is that a narrow window exists and that daily exposure for 7 days prior to the window would provide a dose reflecting the experimental exposure. The seven days is chosen based on data from Newton (1978) showing excretion from dermal doses to be slower than oral doses. Either assumption requires a change in the exposure factors. If we assume that persons doing this type of spraying engage in it for 2 work days per week or 28.6 percent of the possible time and round that up to 1/3 of the time, we decrease exposure by a factor of 3 in both cases. However, we must not forget that in one case we are limiting access in that exposure must occur over a precise 6.5 week period of the pregnancy and in the other it must occur during a single week of the pregnancy. We will not put in a reduction factor to reflect the probability that a narrow window of 1 day or 1 week would occur during spraying season, but assume that it does happen. The reduction factor of 0.33 being used here applies to both kinds of assumptions and reflects 2 days per week over the 5 weeks that back-pack sprayers work on the range.

8. The assumption that 10 percent of the dermal dose of 2,4,5-T and TCDD is absorbed is weak in that the derivation of this figure is not explained. It appears the work of Serat, Feldman, and Maibach (1973) (which showed a 5.8% absorption for 2,4-D and a 15% absorption for DDT) was used on the basis that 2,4-D could be compared to 2,4,5-T and DDT could be compared to TCDD (the citation used in PD-1 was not explicit). While it is risky to use analogs since each chemical has its own set of specific properties, we appreciate the problem confronting the Working Group and the need to identify some useful absorption values. 2,4-D is a reasonable analog for 2,4,5-T. Lavy (1978b) reported data which related urine excretion of 2,4,5-T with dermal exposure. He concluded about 4

percent of the 2,4,5-T which came in contact with the skin was actually absorbed (and excreted). The analog comparison between TCDD and DDT is not as good. DDT is poorly water soluble and highly lipid soluble, while TCDD is poorly water soluble and poorly lipid soluble. This characteristic will significantly reduce the dermal penetration of TCDD in comparison with DDT. What is inexplicable is why the values for 2,4-D and DDT were apparently averaged in PD-1. We will accordingly slightly reduce the absorption figure of 15 percent to 10 percent for TCDD, keeping it as it is in the PD-1, but believing that it should be much lower. There is strong justification for not using a 2,4,5-T absorption rate of 10 percent. We shall use 5 percent to keep the calculations simple. This will reduce the exposure for 2,4,5-T by 1/2 (a correction factor of 0.5). The exposure for TCDD is unchanged.

9. The experiments which provide the basis for the no-adverse-effect-level used oral doses whereas the exposure in this scenario is by the dermal route. Concentration from oral doses of 2,4,5-T reach a maximum within 24 hours. But those from dermal doses do not do so for 48 hours (Newton 1978). This will result in a decrease in the effective concentration by a factor of 2, or require a correction factor of 0.5.

Thus we are able to construct a new scenario using a modified set of assumptions as follows:

Modified Assumption	Correction factor
1. Applicator is female, pregnant, in the first trimester and weighs 60 kg.	--
2. Finished spray: 8 lb ae/100 gal.	0.2
3. Potential exposure rate is 6.0 ml/hour	0.6
4. Applicator wears long-sleeve, button-up shirt and wide brim hat, kepi	0.7
5. Applicator is still assumed to be spraying for mosquitoes.	--

6.	Applicator has 36 min nozzle time per day	0.075
7.	Applicator works at nozzle 2 days per week	0.33
8.	Absorption rate of 2,4,5-T is 5% and for TCDD is 10%	0.5 --
9.	Dermal absorption rate is 1/2 oral rate	0.5

Cumulative exposure correction factors: $\frac{2,4,5\text{-T}}{0.00052}$; $\frac{\text{TCDD}}{0.001}$

Based on the assumptions in Appendix 3 the EPA calculated that an unacceptable risk of the woman applicator bearing a child with a birth defect exists. We calculated the margin of safety used by EPA (from PD-1), the margin of safety derived from the modified assumptions, above, and the margins of safety from two additional modifications in dress (table 26).

This exercise shows (1) that the selection of assumptions has a profound effect on calculated dose levels (or margins of safety), and (2) that when assumptions are used which more reasonably reflect conditions encountered in actual practice, a large margin of safety exists. In the following paragraphs the factorial approach is used with assumptions which are derived from the earlier section on "Exposure of applicators according to use patterns" in Part 5 of this chapter. The scenarios used in the PD-1 (EPA 1978) are used as the basis for this new evaluation of exposure.

THE THIRD PRESUMPTION OF RISK - DERMAL EXPOSURE/TRACTOR MOUNTED BOOM

The following assumptions were stated or implied in PD-1 in the scenario describing the dermal exposure of a spray applicator driving a tractor mounted with a low boom sprayer on rangeland or right-of-way.

1. The applicator is female, pregnant, in the first trimester, and weighs 60 kg.
2. Finished spray: 1.6 lb ae/32 pints or 40 lb/100 gallons.

Table 26--Backpack sprayer dermal exposure and margin of safety

	2,4,5,T		TCDD	
	Exposure mg/kg/day	Margin of safety	Exposure g/kg/day	Margin of safety
No-adverse-effect-level, PD-1[a]	20		0.03	
Calculated dose level, PD-1[a]	6.8	3	7×10^{-4}	43
Modified assumptions exposure level	0.0035	5,656	7×10^{-6}	41,208
Add gloves[b] (CF[a] = 7.4×10^{-5})	0.0005	39,611	1×10^{-7}	285,714
Add gloves and Type I cape (CF = 7.4×10^{-6})	0.0005	396,110	1×10^{-8}	2.85×10^{6}

[a] EPA (1978)

[b] CF = cumulative exposure correction factor

3. Applicator is exposed at a rate of 0.048 pints/day (this is the extreme rate or 8.5 times the mean rate).
4. Applicator wears no protection: short-sleeved shirt, open neck, no gloves, no hat.
5. Applicator is spraying a herbicide.
6. Applicator exposure is 8 hours per day.
7. Applicator is exposed daily from the 15th to the 60th day of pregnancy.
8. Ten percent of the dermal dose of 2,4,5-T and TCDD is absorbed.
9. The rate of dermal absorption is the same as for oral exposure.

Many of the same arguments apply to the assumptions which were presented in the discussion of the second presumption of risk. For the third scenario, only the assumptions which are different from the second are discussed here.

2. The concentration of finished spray used in tractor-mounted spray booms are lower than those in back-pack sprayers: Rights-of-way 2 lb/100 gal. on 58,447 A; range, 10 lb/100 gal. on 75,000 A; rice 5 lb/100 gal. on 8,000 A. In our scenario we will use a finished spray of 10 lb/100 gal. because this rate is used on the largest acreage and therefore is the most typical. If 2 or 5 lb/100 gal are desired it is a simple matter to calculate an adjustment of the safety factor as shown before. The 10 lb/100 gal. concentration requires a correction factor of 0.25.

3. The exposure for the tractor-mounted spray boom is computed from the paper by Staiff et al. (1975) (Ref. No. 147 in EPA 1978) and again the single highest experimental value from 20 exposures is used. The exposures found by Staiff et al. range from 0.01 to 3.4 mg/hr with a mean of 0.4 mg/hr. The EPA value is 8.5 times larger than the mean, and the exposure becomes 0.0056 pts/day in the terms used by EPA rather than 0.048 pts. The correction factor for the exposure level is 0.118.

4. Scantily garbed operators as assumed in the EPA scenario is not the usual practice. This will be corrected in the modified scenario. Inspection of Staiff, et al.'s original data reveal some information not emphasized in their publication. The principal dermal contamination is to the hands. This is acquired <u>during loading operations</u>; 3.36 mg were on the hands after loading, and less than 0.006 mg were on the hands after spraying (99.82% after loading, and 0.18% on hands after spraying). Thus a correction factor of 0.0018 would be appropriate if gloves were worn only during loading! The use of typical work clothes (long-sleeve shirt, long trousers, wide-brim hat, leather boots, and kepi) require a correction factor of 0.7 . If gloves are worn the correction factor becomes 0.01 (Wolfe et al. 1974) or 0.002 (Staiff et al. 1975).

6. This scenario is for a tractor driver spraying mesquite sprouts with a low boom on the range. He is a ranch employee who will typically treat 40-50 acres once a year. A few persons may treat up to 100 acres per year. This will take about 3 hrs to treat 45 acres and his exposure will be about 15 minutes per hour or 45 minutes per day or per year. This results in a correction factor of 0.75 hrs/8 hrs or 0.094.

7. On the typical job the sprayman will work 1 day per year. Since the daily dose level is predicted on receiving such a dose for 45 consecutive days (15th to 60th day of pregnancy) the correction factor is 1 day/45 days or 0.02. The extreme case requires a correction factor of 2.25/45 or 0.05.

We can set forth the modified assumptions as follows:

Modified assumptions	Correction factor
1. The applicator is female, pregnant, in the first trimester, and weighs 60 kg.	--
2. Finished spray: 10 lb/100 gal	0.25

3.	Applicator is potentially exposed to 4 mg/hr or 0.0056 pts of spray per day	0.118
4.	Applicator wears leather boots, long trousers, long-sleeve shirt, kepi, wide brim hat	0.7
5.	Applicator is spraying a herbicide	—
6.	Applicator is exposed 6 hrs/day	0.094
7.	Fraction of trimester exposed	0.02
8	Five percent of the 2,4,5-T is dermally absorbed	0.5
	Ten percent of the TCDD is dermally absorbed	—
9.	The rate of dermal absorption is 1/2 that for oral	0.5

Cumulative correction factor:	2,4,5-T	TCDD
	$9.7x10^{-6}$	$1.9x10^{-5}$

Under the conditions stated in this scenario, and only when these assumptions are met, the dose levels shown below result. The margin of safety calculated from PD-1 (EPA 1978) did not constitute an ample margin of safety for a pregnant woman according to EPA. The exposure levels shown for what we believe to be conditions which actually exist show margins of safety which are much larger. In addition to results of the detailed scenario (above), the results of incorporating some other assumptions are also shown (table 27).

THE FOURTH PRESUMPTION OF RISK - DERMAL EXPOSURE/AERIAL APPLICATION

The following assumptions were stated or implied in the scenario describing the dermal exposure of a person standing directly under the airplane or helicopter during application on an unspecified commodity.

1. The exposed person is female, pregnant, in the first trimester, and weighs 60 kg.
2. Finished spray: 4 lb/10 gal or 40 lb/100 gal.
3. The rate of application is 4.0 lbs/acre.
4. The person is exposed to 31 mg/day of 2,4,5-T.
5. The person wears no protection and few clothes; has bare head, neck, shoulders, forearms, hands, and even bare thighs.

Table 27--Tractor mounted boom sprayer dermal exposure and margin of safety

	2,4,5-T		TCDD	
	Exposure mg/kg/day or season	Margin of safety	Exposure μg/kg/day or season	Margin of safety
No-adverse-effect-level, PD-1[a]	20		0.03	
Calculated dose level, PD-1[a]	1.8	11	$1.8x10^{-4}$	167
Modified assumptions for season	$1.7x10^{-5}$	$1.1x10^{6}$	$3.4x10^{-9}$	$8.8x10^{6}$
Use 2.25 workdays		$4.4x10^{5}$		$3.5x10^{6}$
Add gloves		$7.7x10^{6}$		$5.0x10^{7}$

a/ EPA (1978)

6. The airplane spray system is set for insect control and produced droplets with an MMD of 109 μm from a solvent mixed from Shell solvent No. 2 and medium grade diesel.
7. The person is standing directly beneath the airplane during the application.
8. The person does this for 8 hours.
9. The person is so exposed daily for 45 days during the first trimester.
10. Ten percent of the dermal dose of 2,4,5-T and TCDD is absorbed.
11. The rate of dermal absorption is the same as for oral absorption.

The modifications to the PD-1 assumptions differ from those in previous scenarios in the following respects:

2. The concentration of finished sprays range from 20 - 50 lb/100 gal. In forestry 20-40 lb/100 gal are used on about 410,000 A; on range and pasture 25-50 lb/100 gal on 725,00 A; on rights-of-way 32 lb/100 gal on about 200,000 A; and on rice 33 lb/100 gal are used on about 290,000 A. The largest acreage is on range and the concentration of 30 lb/100 gal will be chosen as most typical for this scenario. This requires a correction factor of 0.75.

3. The rate of use is 1/4 to 2 lb/A for range, 1.5 to 3 lb/A for forests, 1 lb/A for rice and 8 lb/ac for rights-of-way. The figure of 2 lb/A will be used in this scenario since it will be constructed using range as "typical", even though it is in the extreme, or high 20 percent for range. Forestry uses average less than 2.5 lb/A and rice uses are never more than 1 lb/A. The ROW rate of 8 lb/A is not considered because the placement of the potentially exposed persons precludes interception of drift. The correction factor for the rate of 2 lb/A is 0.5. However, this correction and the one for concentration should not be used simultaneously. A given rate of application should produce the same amount of chemical per unit volume of air and area of interception surface regardless of concentration as more drops will

be produced with less concentrated sprays. We will omit the correction factor for concentration (0.75) and use the factor for rate (0.5).

4. The exposure level of 31 mg per person cited in PD-1 is within the expected limits for a person working directly beneath an aircraft for 8 hours. The rate of 0.46 lb/A would deposit 4.26 mg/ft^2 per pass if 90 percent were deposited on target as shown in the source document (Caplan et al. 1956). The PD-1 describes the exposed area as head, neck, shoulders, forearms, hand, and thighs. The mode of dress is not clear, but appears to be a pair of shorts and sneakers. The exposed dermal area is at least 15 ft^2 and the theoretical exposure level would be 64 mg/person. The PD-1 describes the exposure condition as being directly beneath the aircraft for 8 hours. The source document derived the exposure level figure from a 2 hour exposure, apparently from a single pass and remaining in position for the next 2 hours. There is no condition under which a person would be directly under a spray plane. Any such episode would be in the accident category rather than the occupational exposure category. The EPA did not make it clear how and why the person was directly under the spray plane. The research cited in the EPA analysis (Caplan et al. 1956) was undertaken to determine the feasibility of aerial application of malathion over towns for mosquito control. No such uses are contemplated for 2,4,5-T. No persons are directed to work under a spray plane, or any other sprayer, and in fact are directed not to be in the application zone. The persons who may be positioned near a treatment zone are flaggers, observers, timekeepers, supervisors, etc. The person with the highest exposure potential for exposure is the flagman, when one is used. Flagmen are usually positioned just beyond the treatment boundary and move upwind as the aircraft starts its run from the opposite end of the field in order to be in position for the next run. This scenario uses the flagger as the closest approximation to the PD-1 scenario.

5. If the flagman is clothed in a long-sleeved shirt, trousers, and hat instead of having all primary epidermal areas bare, the exposure will be reduced by 90 percent to give a correction factor of 0.1.

7. Moving the flagger off to the side just a little will, according to Caplan, further reduce exposure 90 percent, resulting in a further correction factor of 0.1. Akesson (1978) identified the potential deposit on a person standing anywhere from 0 to 165 feet from the treatment boundary to be less than 0.1 percent of the deposit under the plane when the spray is applied as herbicides are with D6-46-back nozzles and no whirlplate. D6-46-back or D6 angled have a drift potential of 2 percent. These data result in correction factors of 0.001 or 0.02, respectively.

8. Aerial application does not result in 8 hours nozzle time during an 8-hour working day. Flagmen in range application are exposed 1 to 10 hours/year and the typical exposure time is 3 hours/year; in forestry it is 0.1 to 0.2 hours/year; in rice it is 0.02 to 0.2 hours/year; and in ROW there is no exposure because flaggers are not used. Since these seasonal exposures could occur within the 45 day period essential for teratogenesis, they will be treated as 1 days exposure in the set of 45. The correction factor for typical range flagmen is 0.008; forestry, 0.0002; and rice, 0.0005.

We can set forth the modified assumptions as follows:

Modified assumptions	Correction factor
1. The exposed person is female, pregnant, in the second trimester, and weighs 60 kg.	--
2. Finished spray: 30 lb/100 gal. (0.75)	--
3. Rate of application is 2 lb/acre	0.5
4. The person wears work clothes; long-sleeve shirt, buttoned up; long trousers, boots, wide brim hat, kepi.	0.1

5.	The airplane spray system uses D-6 angled nozzles with no whirlplates	(deferred)
6.	The person is a flagman to the side of the treatment (using the Caplan reduction factor)	0.1
7.	The person is exposed 3 hrs/year	0.008
8.	The dermal absorption of 2,4,5-T is 5% and for TCDD it is 10%	0.5 —
9.	The rate of dermal absorption is 1/2 that of oral exposure.	0.5

	2,4,5-T	TCDD
Cumulative correction factor:	1×10^{-5}	2×10^{-5}

The results of these two sets of assumptions are shown below. The assumptions used in the PD-1 resulted in no risk from TCDD, but the EPA concluded that there was an unreasonable risk (using the assumptions in PD-1) of a pregnant woman bearing a child with a birth defect. The assumptions in the modified scenario show exposure is much lower thus the calculated margin of safety is larger (table 28). In addition to these two sets of assumptions some simple alternatives are also shown. The Akesson drift figures are shown because the Caplan data are based on 109 µm drops, but 450-900 µm are used in herbicide applications.

THE FIFTH PRESUMPTION OF RISK - INHALATION/AERIAL APPLICATION

The following assumptions were stated or implied in the scenario describing the inhalation exposure of a person directly under a spray plane as in the previous presumption.

The set of assumptions used in the PD-1 appear to be as follows:

1. The exposed person is female, pregnant, in the first trimester, and weighs 60 kg.
2. The finished spray is 4 lb/10 gal or 40 lb/100 gal.
3. The rate of application is 4 lb/acre.
4. The person inhales 1.36 mg/day.

Table 28--Aerial application dermal exposure and margin of safety

	2,4,5-T		TCDD	
	Exposure mg/kg/day or season	Margin of safety	Exposure µg/kg/day or season	Margin of safety
No-adverse-effect-level[a]	20		0.03	
Calculated dose level PD-1[a]	0.051	392	$5x10^{-6}$	$6x10^{3}$
Modified assumptions for season	$5.1x10^{-7}$	$392x10^{5}$	$1x10^{-10}$	$3x10^{8}$
Use D6 angle (0.1 becomes 0.02)		$196x10^{7}$		$6x10^{10}$
Use D6 back (0.1 becomes 0.001)		$392x10^{8}$		$3x10^{11}$

[a] EPA (1978)

5. The lung absorption rate is 100%.
6. The plane is spraying a 109 μm VMD spray.
7. The solvent is Shell solvent No. 2 and medium diesel oil.
8. That the inhalation from a 2,4,5-T spray (450 to 900 μm VMD) would be 1/6 that from a malathion spray (109 μm VMD) and that a correction factor of 0.17 could be used.
9. The person inspires at a rate of 63.5 cubic feet per hour or 1 cu. ft/min.
10. The person is standing directly beneath the plane for 1 pass and remains there for two hours.
11. The person does this 4 times over an 8 hour period.
12. The person is so exposed daily for 45 days during the first trimester.

The assumptions which we feel need to be modified are as follows:

2. The finished spray should be 30 lb/100 gal. and has a correction factor of 0.75.

3. The rate of application is 2 lb/A and has a correction factor of 0.5. This factor cannot be used concurrently with that in assumption No. 2.

4&8. The person inhales 0.1 μg of 2,4,5-T per day. This is based on work by Akesson (1978) in which he computed that a person such as a flagger standing between 0 and 165 feet of a swath, and <u>downwind</u> from the swath (which is never done as the pilot cannot fly safely downwind from the last swath), would inhale 0.005 μg of pesticide per minute (a concentration 0.01 μg per ft^3) per 1.0 lb per acre of applied material when using a D-6 back nozzle, pointed with the airstream, no whirlplates, and using Nalcotrol. This is corrected to the rate of application and no use of a thickener such as Nalcotrol to 0.1 $\mu g/ft^3$ (still using a D6-back nozzle). For a D6-angled nozzle as is used in range brush control, the inhalation exposure would be corrected to 1.6 $\mu g/ft^3$. The PD-1 uses a concentration of 2.75 $\mu g/ft^3$. The corrections are 0.036 and 0.58, respectively.

6. The aircraft are using D6-back or D6-angled nozzles.

9. The inspiration rate of 1.8 m^3/hr (1 ft^3/min) is for more strenuous activity than is utilized in flagging. The appropriate rate is 0.5 ft^3/min. The correction factor is 0.5.

10. The seasonal exposure is as before: range, 3 hrs; forest, 0.1 hr; rice, 0.02 hr; and ROW, none. The correction factors are range, 0.008; forestry, 0.0002; and rice, 0.00005.

We can set forth the modified assumptions as follows:

Modified Assumptions	Correction factor
1. The exposed person is female, pregnant, in the second trimester and weighs 60 kg.	--
2. The finished spray is 30 lb/100 gal.	--
3. The rate of application is 2 lb/acre	0.50
4. The person inhales 1.6 μg/ft^3	0.58
5. The lung absorption rate is 100% for 2,4,5-T and TCDD	--
6. The plane is using a D-6 nozzle with no whirlplate aligned with the airstream (see assumption no. 4)	--
7. The person is a flagman standing 40 feet upwind of the last swath (see assumption no. 4)	--
8. The person receives 3 hrs exposure per season	0.008
9. The inspiration rate is 0.5 ft^3/min	0.5

	2,4,5-T	TCDD
Cumulative correction factor:	1.2x10^{-3}	1.2x10^{-3}

Based on these assumptions (and only under these conditions) the margins of safety we calculated from PD-1 and the modified scenarios are in table 29. The EPA concluded that the 2,4,5-T exposure level did not provide an ample margin of safety, thus it constitutes an unreasonable risk for a pregnant woman. The margin of safety calculated from the exposures we developed from the modified assumptions is much larger.

Citizens interested in applying margins of safety to their own circumstances may not be familar with the use of safety margins and be uncertain as to their usual magnitude. The example of caffein may clarify this. It has a minimum detectable effect level (MDEL) for teratogenic effects of 75 mg/kg/day (Shepard 1976). A single ounce cup of coffee per day provides a dose level of 2 mg/kg/day of caffein for a 60 kg person, or a safety margin with respect to the MDEL of 37. However, since no-averse-effect-levels are usually one-half to one-tenth of minimum detectable effect levels, the safety margin corresponding to those used in the PD-1 would be lower, probably between 4 and 18.

THE SIXTH PRESUMPTION OF RISK - ORAL, DERMAL AND INHALATION EXPOSURE

The sixth scenario is an analysis of the combined oral, dermal, and inhalation routes of exposure in three situations. According to PD-1 four presumptions of risk occur (out of a possible six - 3 of 3 for 2,4,5-T and 1 of 3 for TCDD). This cumulate exposure analysis merely repeats and cumulates the errors of the previous analyses.

One conceptual error exists in the analysis of oral exposure. The amount of 2,4,5-T entering the human diet from beef and dairy animals which had been on a 300 ppm 2,4,5-T diet for two weeks prior to taking samples was calculated. It was recognized in PD-1 that this was a very unrealistic assumption, but made the point that even under that extreme situation a presumption of risk did not arise. However, if such unrealistic values are then added to other sources of exposure which are in themselves near the acceptable safety margin, the unrealistic values function as the extra weight needed and the safety margin limits will be exceeded.

Table 29—Aerial application inhalation exposure and margin of safety

	2,4,5-T		TCDD	
	Exposure mg/kg/day or season	Margin of safety	Exposure µg/kg/day or season	Margin of safety
No-adverse-effect-level, PD-1[a]	20		0.03	
Calculated dose level (daily), PD-1[a]	$2.3x10^{-2}$	$8.7x10^{2}$	$2x10^{-6}$	$15x10^{3}$
Modified assumptions (seasonal)	$2.8x10^{-5}$	$7.2x10^{5}$	$2.4x10^{-9}$	$12.5x10^{6}$

[a] EPA (1978)

ESTIMATION OF EXPOSURE BY THE ABSOLUTE METHOD

The absolute method of estimating exposure uses a combination of assumptions and direct measurements. The assumptions are geared to particular applicator exposure situations as described in the section on "Exposure of Applicators According to Use Pattern" in Part 5 of Chapter 5.

These assumptions and direct measurements have been applied to exposure situations as they exist in the field. Clothing described are the kinds actually used. Estimates of skin area exposed are believed to be accurate for the types of clothing described.

The direct measurements involve data from two experiments: (1) a 2,4,5-T dermal absorption experiment involving four human volunteers in a laboratory experiment (Newton 1978) and (2) a field experiment in which 2,4,5-T deposition (and absorption) was measured during operational application by helicopter (5 individuals), tractor sprayer (5 individuals), and backpack sprayer (12 individuals) (Lavy 1978a&b).

In the first part of this section the various assumptions are used with the data from the laboratory experiment to calculate maximum absorption (exposure) levels for particular exposure situations. The absorption (exposure) levels from the field experiment are used to calculate exposure as it occurs during actual use. In the second part of this section, exposure levels from both sources are presented in narrative form for each method of 2,4,5-T application in each of the four commodity groups.

EXPOSURE CALCULATED FROM A LABORATORY EXPERIMENT

Assumption Sets

The likelihood of an applicator or observer in spray operations being exposed to a given level of 2,4,5-T depends on the physical circumstances during exposure. A series of sets of assumptions have been developed which describe the nature and extent of the exposure of applicators involved with particular types of application. Each set of assumptions closely approximates the actual conditions in which the chemical is used, based on experience of Assessment Team members and users in Oregon, Texas, Arkansas, California, Indiana, and Pennsylvania (Norris et al. 1979). Table 30 identifies the type of application (or situation) associated with each assumption set, and some of its conditions.

There are five sets of assumptions for ground spray workers and five for aerial spray workers. The various situations are those typical for backpack sprayer operators, tractor sprayer operators, tree injection personnel, aircraft mixer-loaders, and flaggers. Conditions for pilots were not described because they are protected more than the other workers. Each set embodies different assumptions relating to the concentration of spray mixture, protective clothing, skin exposed, and skin absorption. In addition there are 2 sets of assumptions from PD-1. In general, the assumptions in sets 1 through 10 are different from those used in PD-1 (EPA 1978). An explanation for the choices used follows.

Concentration of Spray Material

Concentrations of 2,4,5-T greater than 16 lb acid equivalent per hundred gallons (aehg) are seldom used in ground equipment. The higher cost for higher concentrations which do not substantially increase effectiveness precludes widespread use. None of the widely used products recommends higher than 6 aehg in water for general use; 2 to 4 aehg is more widely used. The rates of 8 to 16 aehg used here are in the upper range for oil sprays, but they are used with sufficient frequency to warrant calculations as upper limits of ordinary exposure. Higher concentrations are limited to mist blowers and aircraft.

Table 30--Typical job descriptions of workers exposed under assumption sets listed in Tables 31 and 32

Assumption set	Job description
1	Tractor mounted boom sprayer on rice levees or range and pasture lands
2	Backpack or handgun operator in right-of-way or rangeland basal spray operation, with gloves and long-sleeve shirt
3	Backpack, handgun or mistblower operator in forest or power line basal spray operation, short-sleeve shirt, no gloves
4	Same as 3, with long-sleeve shirt and gloves
5	Hypo-hatchet tree injector operator, 2,4,5-T amine, long-sleeved shirt, gloves
PD-1 a	Backpack spray operator without protection as described in PD-1
6	Helicopter mechanic-mixer, light (common) dose, gloves and long-sleeved shirt
7	Helicopter mechanic-mixer maximum concentration, wearing gloves and long-sleeved shirt
8	Flag person, 1 lb/A 2,4,5-T in 3 gpa, wearing broad-brim hat, long-sleeved shirt
	Exposure is derived as follows: flagger fails to move out of spray swath once for each 10 passes of the spray plane, or 4 times per hour. This gives an exposure of 1.042 mg 2,4,5-T.
9	Flag person, 2 lb/A 2,4,5-T in 5 gpa, wearing broad-brim hat, long-sleeved shirt.
	Exposure is as the same basis as in assumption 8, but adjusted by a factor of 2 for the higher rate of application. This gives an exposure of 2.084 mg 2,4,5-T.
10	Flag person, 2 lb/A 2,4,5-T in 5 gpa without protective clothing
	Exposure is as the same basis as in assumption 8, but adjusted by a factor of 2 for the higher rate of application and a factor of 8 for the greater degree of absorbtion due to less clothing.
PD-1 b	Flag person described in PD-1, with both dermal and inhalation exposure

Protective Clothing

Protective clothing of some kind is normally worn by all pesticide applicators. Long-sleeved shirts alone reduce exposure substantially below that of a tee shirt. Use of gloves and a long-sleeved shirt reduces skin exposure to 12.3 percent of that received when the applicator wears a short-sleeved shirt and no gloves (Wolfe et al. 1974). Addition of a wide-brim hat to long-sleeved shirt and gloves reduces exposure to 8.8 percent. Assumption sets 2, 4, and 5 for ground application and 6 and 7 for aerial application provide for long-sleeved shirts and gloves as protective clothing. This reduces exposure to 12.3 percent of the two square feet of skin surface estimated to be exposed to spray mixtures when a short-sleeved shirt and no gloves are used (assumption sets 1, 3 and PD-1a). Assumption sets 8 and 9 for flaggers involved with aerial applications include broad-brim hard hats, long-sleeved shirts, and gloves.

Dermal Absorption

In a previous section (The Factorial Method) the inappropriate use of the 10 percent 2,4,5-T absorption figure in PD-1 was discussed and a factorial correction factor developed. Unfortunately there are very limited data on which human exposure (via dermal absorption) to 2,4,5-T can be estimated. In this section we use data from a preliminary experiment involving humans as a basis for calculating 2,4,5-T absorption from dermal exposure (Newton 1978). In this experiment, four human volunteers were exposed to one of four spray solutions containing 2,4,5-T at concentrations of 2, 4, 16, or 32 aehg. The exposure involved placing a 144 square inch denim cloth soked with 40 ml of the appropriate spray mixture on the sking of one upper thigh. The cloth was covered and bound tightly in place with plastic wrap to insure good contact with the skin and to prevent drying. The skin was wet to saturation throughout the 2-hour exposure period. The assumption is this type of exposure results in maximum dermal uptake because the skin is as wet as it can be without the spray running off and the soaked cloth provides a reservoir of chemical to replace any that is removed by dermal absorption. At the end of the 2 hour exposure period, the cloth was removed and the treated area washed with alcohol and wiped dry. Urine was then collected for 5-24 hour periods. 2,4,5-T excretion beyond 5 days was estimated by extension of the excretion curves to zero (to 15 days for the 16 and 32 aehg material and to 8 days for the 2 and 4 aehg material) and integration. The assumption is that all the 2,4,5-T absorbed was excreted in this time period. A reasonable correlation was observed between the concentration of 2,4,5-T in spray mixtures kept moist on skin and the amount of 2,4,5-T appearing in the urine during five days post-treatment period, although it was not strictly proportional (table 31).

Net absorption of 2,4,5-T per hour per square foot of skin exposed was estimated from data in table 31.

Concentration of spray material aehg	2,4,5-T absorbed (dermal) (mg/sq ft/hr)
2	0.220
4	0.419
16	0.570
32	1.125

It is emphasized these are maximum possible values because the skin was saturated throughout the exposure period. In actual practice these levels will not normally be attained. The assumptions outlined above and the dermal absorption data in table 31 (Newton 1978) were used to calculate maximum applicator exposure for each of the 5 assumption sets involving ground application (table 32) and the 5 sets involving aerial application (table 33). These calculations indicate lightly clad backpack sprayer, handgun sprayer, and backpack mistblower operators will receive the greatest exposure. Addition of a hat, gloves, and long-sleeved shirt will markedly reduce exposure.

Table 31--Absorption and excretion of 2,4,5-T by humans after dermal exposure [a]

Concentration of spray mixture[b]	2,4,5-T recovered in urine					Estimated 2,4,5-T excretion in urine beyond the 5th day	Estimated 2,4,5-T absorbed[c]
	Day						
	1	2	3	4	5		
lb/100 gal	mg					mg	mg
2	0.073	0.142	0.107	0.025	0.034	0.062	0.441
4	0.218	0.250	0.134	0.079	0.037	0.125	0.843
16	0.116	0.222	0.124	0.107	0.095	0.500	1.164
32	0.276	0.358	0.250	0.210	0.196	1.000	2.380

[a] Exposure involved 144 square inch denim patches soaked with 40 ml of 2,4,5-T spray solution of the appropriate concentration and applied to the upper thigh. The patches were covered with plastic wrap to prevent drying and were bound snugly to insure good contact with the skin. The skin was wet with the spray mixture throughout the exposure period. Patches were removed after 2 hours, the skin washed with alcohol and dried, and urine collected for 5-24 hour periods. 2,4,5-T excretion in urine beyond the 5th day was estimated by extention of the excretion curves (to 15 days for the two highest concentrations and to 8 days for the two lowest concentration) and integration. (Newton 1978).

[b] Acid equivalent per 100 gallon (aehg).

[c] Estimated 2,4,5-T absorbed is the sum of 2,4,5-T excreted in five days and estimated excretion beyond 5 days.

Table 32—Sets of assumptions for exposure of applicators using 2,4,5-T with ground equipment. Maximum levels of exposure are listed for each assumption set because they assume constant wetness of exposed skin. Dosage based on 60 kg worker except for the applicator monitored data (80 and 110 kg).

Variable	Assumption set 1	 2	 3	 4	 5	 PD-1a
Spray concentration, aehg	4	8	16	16	400	40
Fully clothed[a]	No	Yes	No	Yes	Yes	No
Square feet of skin exposed	2	1/4	2	1/4	1/4	2+
Dermal absorption of 2,4,5-T mg/hr	0.838[b]	0.11[b]	1.14[b]	0.142[b]	0.15[c]	51[d]
2,4,5-T dosage, mg/kg/hr	0.014	0.0018	0.019	0.0024	0.0025	0.85
TCDD dosage[e] µg/kg/hr	8.4×10^{-7}	1.1×10^{-7}	1.14×10^{-6}	1.4×10^{-7}	1.5×10^{-7}	2.1×10^{-5}
Applicator monitoring mg/kg/day 2,4,5-T			0.026 (for 8 aehg)		0.0025 (for 6 aehg)	

[a] Long-sleeved shirt and gloves reduces exposure 91 percent compared to short-sleeve shirt and no gloves (Wolfe et al. 1974).

[b] Newton (1978).

[c] Norris (1974) Based on absorption salts of organic arsenicals by injector operators using 6 lb/gal concentrate, maximum concentration of 1 ppm in urine with daily 6-hour exposure. The organic arsenicals as salts are better models for 2,4,5-T amine than is the 2,4,5-T ester used by Newton (1978).

[d] Value from PD-1 (EPA 1978).

[e] Based on 3×10^{-8} ppm TCDD in 2,4,5-T (Alford 1978) and an absorption rate for TCDD which is twice as great as for 2,4,5-T. Thus µg TCDD absorbed = mg 2,4,5-T absorbed x (6×10^{-5}).

Table 33—Sets of assumptions for exposure of applicators using 2,4,5-T with aerial equipment. Maximum levels of exposure are listed for each assumption set because they assume constant wetness of all exposed skin. Dosage based on 60 kg workers.

Variable	Assumption set					
	6	7	8	9	10	PD-1b
Spray concentration aehg	10	40	10	40	40	40
Fully clothed[a]	Yes	Yes	Yes	Yes	No	No
Square feet of skin exposed	1/4	1/4	1/4	1/4	2	2+
Inhaled 2,4,5-T, mg/hr	0	0	2.5×10^{-5}[b]	1×10^{-4}[b]	1×10^{-4}[b]	0.17[c]
Skin deposit of 2,4,5-T, mg[d]	-	-	1.042	2.084	16.86	-
Dermal absorption of 2,4,5-T mg/hr	0.125	0.371	0.052	0.104	0.834	0.75
Total exposure to 2,4,5-T, mg/hr	0.125	0.371	0.052	0.1041	0.8341	0.92
2,4,5-T dosage mg/kg/hr	0.002	0.006	8×10^{-4}	0.002	0.014	0.0103
TCDD dosage µg/kg/hr[e]	1.2×10^{-7}	3.7×10^{-6}	5.2×10^{-8}	1×10^{-7}	8.3×10^{-7}	6.7×10^{-6}[c]

[a] Long-sleeved shirt and gloves for assumption sets 6 & 7 reduces skin exposure 91 percent compared to short-sleeved shirt and no gloves. A broad brim hat is added for assumption sets 8 and 9 (Wolfe et al. 1974).

[b] Assumes inhalation rate of 0.1 µg/min per acre pound applied in adjacent swath when air movement carries fine droplets into flagmen's position (based on 20 min/day exposure between 0 and 165 feet downwind from spray swath, Akesson 1978).

[c] Value from PD-1 (EPA 1978)

[d] Value from table 30.

[e] Based on 3×10^{-8} ppm TCDD in 2,4,5-T (Alford 1978) and an absorption rate for TCDD which is twice as great as for 2,4,5-T. Thus µg TCDD absorbed = mg 2,4,5-T absorbed x (6×10^{-5}).

EXPOSURE MEASURED DURING OPERATIONAL APPLICATION

Lavy (1978b) monitored the deposition of 2,4,5-T on 22 applicators engaged in the operational application of herbicide by helicopter (5 applicators), tractor-mounted boom sprayer (1 applicator), tractor-mounted mistblower (4 applicators), and backpack sprayer (12 applicators). Workers were actively involved with the application for 1.93 hours (helicopter), 1.08 hours (tractor boom sprayer), 4.08 hours (tractor mistblower), or 3.0 hours (backpack sprayer). Patches (6 - 100 cm^2 patches for each worker) were attached to the clothing on the chest, back, both biceps, and both thighs. At the end of the spray period the patches were removed and analyzed for 2,4,5-T. The assumption is that the spray deposited on the six patches was representative of the spray deposited on exposed areas of skin.

Lavy (1978a) reported urine samples were collected from these same workers but a complete report of the data is not yet available (January 15, 1979). Lavy (1978b) indicates, however, that it appears approximately 4 percent of the 2,4,5-T estimated to be on the skin was recovered in urine. Lavy's (1978b) data, recalculated to show mg/kg/hour 2,4,5-T deposited on the skin and the amount of herbicide and TCDD absorbed (exposure), are in table 34.

The levels of exposure from an actual operational application (table 34) are substantially lower than those calculated from the laboratory experiment (tables 32 and 33). When calculated to be on a directly comparable basis in terms of concentration of spray and skin area exposed, the following values were obtained from the two experiments:

Table 34--Deposition and dermal absorption (exposure) of 2,4,5-T by humans during operational application.

Application method	Worker number	Skin exposed	Deposition of 2,4,5-T[a]	Absorption of 2,4,5-T[b]	Absorption of TCDD[c]
		m^2	------------mg/kg/hr------------		µg/kg/hr
Helicopter[d]	1	0.294	0.0046	0.0002	1.2×10^{-8}
"	2	0.294	0.0072	0.0003	1.8×10^{-8}
"	3	0.173	0.0019	0.0001	6.0×10^{-9}
"	4	0.294	0.0070	0.0003	1.8×10^{-8}
"	5	0.294	0.0095	0.0004	2.4×10^{-8}
			Average	0.0003	1.6×10^{-8}
Tractor, boom[d]	6	0.294	0.042	0.0017	1.0×10^{-7}
Tractor, mistblower[d]	7	0.294	0.050	0.0020	1.2×10^{-7}
" "	8	0.173	0.035	0.0014	8.4×10^{-8}
" "	9	0.294	0.012	0.0005	3.0×10^{-8}
" "	10	0.173	0.026	0.0011	6.6×10^{-8}
			Average	0.0012	7.5×10^{-8}
Backpack[e]	11	0.294	0.054	0.0021	1.3×10^{-7}
"	12	0.294	0.373	0.0149	8.9×10^{-7}
"	13	0.294	0.281	0.0112	6.7×10^{-7}
"	14	0.294	0.299	0.0120	7.2×10^{-7}
"	15	0.294	0.615	0.0246	1.4×10^{-6}
"	16	0.294	0.676	0.0271	1.6×10^{-6}
"	17	0.294	0.123	0.0049	2.9×10^{-7}
"	18	0.294	0.027	0.0011	6.6×10^{-8}
"	19	0.294	0.107	0.0043	2.6×10^{-7}
"	20	0.294	0.202	0.0081	4.9×10^{-7}
"	21	0.294	0.197	0.0079	4.7×10^{-7}
"	22	0.294	0.749	0.0300	1.8×10^{-6}
			Average	0.0123	7.4×10^{-7}

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[a] Data from table 5 (Lavy 1978b) adjusted to per hour basis.

[b] 4 percent of deposit

[c] mg/kg/hr 2,4,5-T absorbed x (6×10^{-5}), see footnote e, table 32 in chapter 5 of this report.

[d] Concentration of 2,4,5-T in spray solution: 40 aehg

[e] Concentration of 2,4,5-T in spray solution: 20 aehg

Method of application	Concentration of spray	Exposure to 2,4,5-T[a/] Laboratory Experiment[b/]	Field Experiment[c/]
	------aehg------	---------mg/kg/hr---------	
Helicopter	40	0.076	0.0003
Tractor mistblower	40	0.076	0.0012
Backpack sprayer	20	0.038	0.0123

[a/] 0.294 m^2 exposed skin (3.28 ft^2)

[b/] From tables 32 and 33

[c/] From table 34

This illustrates the maximum nature of the exposure calculated using the data from the laboratory experiment where skin was soaked throughout the exposure period. In practice this level of exposure does not occur except in rare instances where abnormally high, accidental exposure occurs. There are two cases of this type of exposure noted in tables 32 and 33.

The two spray workers who received substantial exposure to 2,4,5-T were (1) one worker sprayed Texas mesquite with 8 aehg 2,4,5-T in diesel fuel 3 out of 5 days for 8 hours each day. Clothing was coveralls without gloves. (2) One worker in Oregon sprayed blackberry bushes with 6 aehg 2,4,5-T in water. The sprayer hose broke and soaked the trousers and leather boots. The trousers and boots were worn for 4 hours before washing up (Newton 1978).

The Texas worker did not use gloves and his hands came in contact with the solution and the concentrate. The 80 kg Texas applicator equilibrated at the level of 2.12 mg total absorption per 6 hour day, for a dosage of 0.026 mg/kg/day. This is half the predicted dosage encountered with one-hour exposure under assumption set 3, table 32, which most closely resembles his situation in the field but is based on 16 aehg spray mixture. This emphasizes the "maximum nature" of the estimates in tables 32 and 33 which were derived from data in table 31.

The Oregon applicator data in table 32 indicated an uptake of between 3 and 4 mg 2,4,5-T from an exposure surface of 2 sq ft over a 4-hour period (0.037-0.50 mg/sq ft/hr). Assuming partial drying and soaked skin for 2 hours, this exposure is estimated to be the equivalent of 2 square feet for 2 hours (0.075 mg/sq ft/hr). This is slightly higher than the rates shown for either the 4 or 16 aehg data in table 32. In addition to the spill, however, the Oregon applicator reported a 3-hour exposure the same day in which a leaky valve kept his spray-wand hand wet constantly. Under the circumstances, this observation was clearly an extreme example under assumption set 3, table 32, corrected to 6 aehg. Both the above observations suggest that the data in tables 32 and 33 give maximum estimates of exposure under the described conditions.

It is unfortunate there is not a more adequate data base currently available on dermal absorption of 2,4,5-T by applicators. Lavy (1978a) indicates data on 2,4,5-T and its relation to deposition on applicators will be available for inspection by March 1, 1979. There is another study of applicator exposure to 2,4,5-T that is being planned by the Cook College Agricultural Experiment Statment, Rutgers University, New Jersey. The study will be completely by June 1, 1980 (Norris et al. 1979).

EXPOSURE LEVELS IN THE FIELD

Personnel applying 2,4,5-T in the field are usually operating under conditions reasonably close to one of the assumption sets - job descriptions in table 30. The exposures for each type of application listed below were estimated for the first hour of operation from tables 32, 33, and 34.

The following discussion of exposure opportunities in the various commodity uses has been presented to show the level of exposure and area treated for each worker hour. These may be expanded according to the number of hours per day actual operator time. Generally 2 values are given; one is the normal operational level as predicted by the data in table 34 and the other is the maximum exposure expected under unusual circumstances based on data in tables 32 and 33. In all cases the data have been adjusted to a common base of 0.294 m^2 of skin exposed to spray unless otherwise stated.

The data are summarized in table 35 for each exposure situation. Generally four different exposure values are shown: (1) the operational exposure based on Lavy (1978b) with an exposed skin area of 0.294 m^2 (short-sleeved shirt), (2) reduced operational exposure based on Lavy (1978b) but with long-sleeved shirt and gloves added which reduces exposure 91 percent (Wolfe et al. 1974), (3) maximum exposure based on Newton (1978) with an exposed skin area of 0.294 m^2 (short-sleeve shirt), and (4) reduced maximum exposure based on Newton (1978) but with long-sleeved shirt and gloves added which reduces exposure 91 percent (Wolfe et al. 1974).

Exposures to TCDD are not included in this section but can be calculated as in tables 32, 33, and 34, assuming that TCDD is 3 x 10^{-8} ppm in 2,4,5-T (Alford 1978), and that it is absorbed twice as efficiently as 2,4,5-T. Thus the μg TCDD absorbed is equal to the mg 2,4,5-T absorbed x (6×10^{-5}).

Forest

The following descriptions and calculations of net exposure are for the specific types of 2,4,5-T application described in an earlier section "Exposure of applicators according to use patterns - forests" in this chapter.

Aerial Application

Based on Lavy's (1978b) data (table 34) aerial applicators may be exposed to 0.0003 mg/kg/hr 2,4,5-T under operational conditions. The mechanic-mixer is the person in an aerial spray operation likely to receive the largest exposure. This worker may receive maximum exposure up to 0.076 mg/kg/hr for each 60 acres treated (assumption set 7, table 33).[1] Adding gloves and a long-sleeved shirt, the exposure would be reduced to 0.007 mg/kg/hr even for a worst case of exposure based on data of Wolfe et al. (1974) (table 35).

Ground Application with Tractor Mistblowers - Broadcast Treatment

Lavy (1978b) (table 34) reports tractor mistblower operators may be exposed to 0.0012 mg/kg/hr 2,4,5-T under operational conditions. A comparable assumption set for the worst case of exposure was not developed, but is likely to be similar to that for the backpack sprayer (table 35).

Ground Application with Backpack Mistblowers - Broadcast Treatment; and Backpack Sprayers and Tree Injectors - Individual Stem Treatment

No operational exposure data are available for workers using backpack mistblowers. The similarity to backpack sprayers suggests the use of those data. Lavy (1978b) (table 34) reports exposure for this group is 0.0123 mg/kg/hr 2,4,5-T under operational conditions. Worst case exposure is illustrated from assumption set 3, table 32. Performance rate of one acre per hour per applicator would lead to an exposure of 0.030 mg/kg/hr. If long-sleeved shirts and gloves are used (assumption set 4) exposure is reduced to 0.003 mg/kg/hr in covering one acre. Workers using injectors are described in assumption set 5, table 32. Based on one-half acre treated per hour, a worker receives a maximum dose of 0.032 mg/kg/hr (table 35).

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[1] Sample calculation: 0.006 mg/kg/hg (assumption set 7, table 33) x 12.67 (to adjust exposed area from 0.25 square feet to 0.294 m^2) = 0.76 mg/kg/hr. The exposed area correction factor is 1.58 to adjust from 2 square feet to 0.294 m^2. Adding long-sleeved shirt and gloves reduces exposure 91 percent or 0.076 mg/kg/hr x 0.09 = 0.007 mg/kg/hr.

Table 35—Summary of hourly exposure to 2,4,5-T estimated by absolute method

Exposure situation	Area treated per hour	Time exposed per day	Operational exposure[a]	Reduced operational exposure[b]	Maximum exposure[c]	Reduced maximum exposure[d]
	acres	hours	mg/kg/hr			
Timber						
Aerial	60	4	0.0003	0.00003	0.076	0.007
Backpack	1	4	0.0123	0.0011	0.030	0.003
Injection	0.5	4	—	—	0.032	0.003
Tractor mist blower	6.5	4	0.0012	0.0001	0.030	0.003
Backpack mist blower	1	4	0.0123	0.0011	0.030	0.003
Range and pasture						
Aerial						
mechanic	100-300	4	0.0004	0.00004	0.095	0.009
flagger (2)	100-300	4	—	—	0.034[a]	0.003[c]
Backpack	1	6	0.0049	0.0004	0.016	0.001
Tractor Boom spray	20	4	0.0028	0.0003	0.007	0.0006
Rights of way						
Aerial-mixer	20	6	0.0003	0.00003	0.076	0.007
Backpack and handgun	0.25-1.25	6	0.0123	0.0011	0.030	0.003
Truck-mount	1-10	6	0.00003	0.000003	0.011	0.001
Backpack mistblower	0.25-1.25	6	0.0123	0.0011	0.037	0.003
Rice						
Aerial						
mixer-loader	80	1	0.0002	0.00002	0.063	0.006
flag person (2)	80	1	—	—	0.034[a]	0.003[b]
Tractor boom sprayer	5	1.3	0.0026	0.0002	0.007	0.006

a/ Calculated from Lavy (1978b) with 0.294 m^2 exposed skin area (short-sleeved shirt).

b/ Calculated from Newton (1978) adjusted to 0.294 m^2 exposed skin area.

c/ Calculated from Lavy (1978b). Long-sleeved shirt and gloves reduces exposure 91 percent (Wolfe et al. 1974).

d/ Calculated from Newton (1978). Long-sleeved shirt and gloves reduces exposure 91 percent (Wolfe et al. 1974).

Range and Pasture

The following descriptions and calculations of net exposure are for the specific types of 2,4,5-T applications described in an earlier section "Exposure of applicators according to use pattern - range brush and pasture weed control" in this chapter.

Aerial Application

Principal exposure is likely to involve the mechanic-loader. Lavy's (1978b) data (table 34) indicate exposure of 0.0003 mg/kg/hr 2,4,5-T for 40 aehg material; adjusted proportionally, this is equal to 0.0002 mg/kg/hr or 0.0004 mg/kg/hr for 25 and 50 aehg material respectively. The maximum exposure is derived from assumption set 7, table 33. The mechanic-mixer would be exposed at the rate of 0.095 mg/kg/hr (for 50 aehg) while accomplishing 100-300 acres of treatment. Adding a long-sleeved shirt and gloves reduces exposure to 0.009 mg/kg/hr. Flaggers involved with 2 lb/A applications (the maximum rate) would be exposed according to assumptions set 9, tables 30 and 33. Their exposures would be very brief and very minor. Flaggers would be exposed to 0.002 mg/kg/hr from inhalation and dermal sources for 100-300 acres maximum. Exposure would be less for flaggers working into the wind according to normal procedure. This exposure would occur once a year or less often (table 35). To estimate maximum exposure, Lavy (1978b) measured deposition on a human standing directly under a helicopter spray path. This would approximate the rare case when a flagger would fail to move and was directly sprayed. Data are available for only one individual. These shows deposition of 0.86 mg/kg 2,4,5-T on 0.294 m^2 exposed skin. Assuming 4 percent absorption, this equals an exposure of 0.034 mg/kg each time sprayed when dressed in a short-sleeved shirt. Adding a long-sleeved shirt and gloves reduces exposure to 0.003 mg/kg.

Ground Application - Backpack Sprayer

Lavy's (1978b) data (table 34) for backpack sprayers indicate an exposure of 0.0123 mg/kg/hr for 20 aehg material; adjusted proportionally to 8 aehg, this exposure is 0.0049 mg/kg/hr 2,4,5-T. Evaluation of maximum exposure uses assumption sets 2 and 3, table 32. For crews with short-sleeved shirts and no gloves, an 8 aehg treatment (assumption set 3, X 0.5 to correct for concentration) will produce a maximum exposure of 0.016 mg/kg/hr. If a long-sleeved shirt and gloves are worn (assumption set 2, x0.5 to correct for concentration) the exposure would be 0.001 mg/kg/hr to cover 1/4 to 1 acre (table 35). Basal spray treatments would produce twice this level, and pasture treatments half to three-fourths this level of dosage as adjusted for concentration used.

Ground Application - High Mounted Booms on Tractors

Lavy's (1978b) data (table 34) show an operational exposure (based on a single observation) of 0.017 mg/kg/hr 2,4,5-T for 40 aehg material. Adjusted proportionally for concentration, this is 0.0028 mg/kg/hr for 6.7 aehg material. Maximum exposure is derived from assumption set 1, table 32, for the tractor driver. The exposure would be adjusted according to the concentration used by a factor of 6.7/4. Thus, for a driver using 6.7 aehg spray at the rate of 20 acres per hour, exposure would be 0.037 mg/kg/hr. This assumes the driver is constantly wet with spray. Because the driver sits ahead of the boom, we multiply by 0.2 to allow for intermittent exposure. This gives an exposure of 0.007 mg/kg/hr. Adding a long-sleeved shirt and gloves reduces exposure to 0.0006 mg/kg/hr (table 35).

Rights-of-Way

The following descriptions and calculations of net exposure are for the specific types of 2,4,5-T applications described in an earlier section. "Exposure of applicators according to use pattern - Rights-of-way" in this chapter.

Aerial-Broadcast Foliar

Lavy's (1978b) data (table 34) indicate an operational exposure of 0.0003 mg/kg/hr 2,4,5-T. Maximum exposure is derived from assumption set 7, table 33. It shows the mixer-loader will be exposed to 0.076 mg/kg/hr for 20 acres of application. If a long-sleeved shirt and gloves are worn, maximum exposure decreases to 0.007 mg/kg/hr (table 35).

Ground Application - Selective Basal and Cut Stump Application

Lavy's (1978b) data (table 34) show operational exposure for backpack sprayers of 0.0123 mg/kg/hr 2,4,5-T. Worst case exposure is derived from assumption set 3, table 32. It indicates an exposure of 0.030 mg/kg/hr. If long-sleeved shirt and gloves are used, exposure is decreased to 0.0034 mg/kg/hr (table 35).

Ground Application - Broadcast Foliar (Spray Boom or Nozzles Mounted on Vehicle) and Selective Foliar (Hydraulic Sprayers with Hoses and Handguns)

Lavy's (1978b) data (table 34) for backpack sprayers are a reasonable approximation for these types of application if adjusted for concentration. Spray solutions of 4 aehg should result in exposure of 0.00003 mg/kg/hr 2,4,5-T. Maximum exposure is estimated according to assumption set 2, table 33. When adjusted to reflect the 4 aehg solution (correction factor 0.5), the net exposure is 0.011 mg/kg/hr. Addition of a long-sleeved shirt and gloves reduces maximum exposure to 0.001 mg/kg/hr (table 35).

Motorized backpack mistblower operators using 20 aehg mixtures would be exposed to 0.0123 mg/kg/hr 2,4,5-T based on Lavy's (1978b) data (table 34). In a worst case exposure, assumption set 3, table 32, (with a 25 percent upward ajustment for concentration) indicates an exposure of 0.0375 mg/kg/hr. If the operator wore a long-sleeved shirt and gloves, the exposure would decrease to 0.003 mg/kg/hour (table 35). Occasionally mistblowers are used with 80 aehg mixtures. Although this is beyond the data of Newton (1978) the trend of the data suggests the relation:

$$\text{mg absorbed} = 0.2 + 0.029\ (\text{concentration, aehg}).$$

Following this relation, an 80 aehg mixture applied by mistblower as in assumption set 3, table 32, would result in a maximum applicator exposure of 0.132 mg/kg/hr, reduced to 0.012 mg/kg/hr if a long-sleeved shirt and gloves are worn.

Rice

The following descriptions and calculations of net exposure are for the specific types of 2,4,5-T applications described in an earlier section "Exposure of applicators according to use pattern - rice" in this chapter.

Aerial Application

Lavy's (1978b) data (table 34) indicate an exposure of 0.0002 mg/kg/hr 2,4,5-T adjusted for the 33 aehg mixture used on rice. The worst case example is derived from assumption set 7, table 33 and indicates an exposure of 0.063 mg/kg/hr. Addition of a long-sleeved shirt and gloves reduces maximum exposure to 0.006 mg/kg/hr (table 35).

Flaggers would be exposed according to assumption set 8, table 33. Their exposure would be brief and minor, and limited to their own farms. Flaggers would be exposed, as in range treatment, to minor inhalation and occasional "tails" from adjacent swaths. Net exposure would be 0.0008 mg/kg/hr for 80 acres (table 35).

Ground Application

Lavy's (1978b) data (table 34) indicate the tractor boom sprayer operator would be exposed to 0.017 mg/kg/hr for 40 aehg material, or 0.0026 mg/kg/hr for 6 aehg material used on rice. The worst case exposure is derived from assumption set 1, table 32. It indicates an exposure of 0.033 mg/kg/hr while covering 5 acres. This operator is exposed intermittently and the exposure should be adjusted by a factor of 0.2 to give 0.007 mg/kg/hr. Adding a long-sleeved shirt and gloves reduces exposure to 0.0006 mg/kg/hr (table 35).

RISKS OF ALTERNATIVE METHODS, SOME CONSIDERATIONS

The chemical alternatives to 2,4,5-T expose operators to potential intoxication in similar ways. An assessment of relative risk must take these into account. Chemical alternatives to 2,4,5-T will generally produce similar absorption patterns. The biochemical and toxicological properties of these materials are generally less well known, hence relative risks cannot be estimated as accurately as for 2,4,5-T.

Nonchemical alternatives also expose operators to chemical intoxication as well as physical accidents which are discussed later in this chapter. Exposure to chemical intoxicants occurs in both fires and in use of power saws. Recent data from Dow Chemical Company (DOW 1978a,b) suggest that both are significant sources of numerous dioxins, including TCDD. Fire produces numerous carcinogens as products of pyrolysis, as well as carbon monoxide and various organic volatiles of substantial acute and chronic toxicity. Chain saws produce hearing loss as well as potential chronic intoxication from hydrocarbons and lead. Peripheral nerve damage has recently been reported in Oregon and Washington loggers using chain saws in cold, wet weather.

Chain saws produce particularly noxious exhaust during brush clearing. Ordinary exhaust contains carbon monoxide and lead. Lead causes symptoms nearly identical to those described for 2,4,5-T chronic intoxication (EPA 1978). In addition, the two-cycle motors emit large amounts of unburned hydrocarbons and adjuvants in partially combusted oil smoke. Chain saw combustion products are particularly noxious during brush-clearing operations. Woody plant clearing is normally done in some protection from wind, leading to a tendency for exhaust fumes to build up near the operator. There is also a high percentage of idling and no-load time for the saws. This leads to inefficient oxidation of fuel and oil and excessive emissions. Intoxication from carbon monoxide and smoke inhalation is so common that most cases are not recorded. One member of the 2,4,5-T Assessment Team (Newton) with substantial experience operating a brush saw reported being mildly poisoned on several occasions (Norris et al. 1979).

On balance, control of woody vegetation with any of the acceptable practices entails some exposure to chemicals of known carcinogenic and teratogenic potential. The data for all the alternatives are far less precise than for 2,4,5-T, and no estimates of absolute exposure are possible except for other phenoxy herbicides. Smoke from fires and chain saws at this time would appear to offer the greatest potential for acute and chronic intoxication of any of the alternatives, including 2,4,5-T. The degree of intoxication, and its long term implications must remain speculative until these sources have undergone comparable examination.

PART 6: CONSEQUENCES OF EXPOSURE OF ANIMALS

This section reviews some acute and subacute toxicity data for 2,4,5-T in animals important to agriculture and some species of wildlife.

LIVESTOCK

Research data indicated that cattle were not affected when dosed (oral) 10 times at 100, 50 and 50 mg/kg with the propylene glycol butyl ether esters (Palmer and Radeleff 1969), the 2-ethylhexyl ester, and the triethylamine salt of 2,4,5-T, respectively (Palmer 1972). However, after 4 to 7 days, treatments of all three formulations at 250 mg/kg were lethal. At 100 mg/kg the 2-ethylhexyl ester and the triethylamine salt either had no effect or caused some weight loss.

Sheep tolerated 10 daily oral dose of 50, 25, and 25 mg/kg of the propylene glycol butyl ether esters (Palmer and Radeleff 1969), the 2-ethylhexyl ester and the triethylamine salt of 2,4,5-T, respectively (Palmer 1972). Higher dosages of each herbicide caused effects that ranged from minimal to lethal. The investigators (Palmer and Radeleff 1969, Palmer 1972) concluded from their studies that application rates of 2,4,5-T up to 5 kg/ha would not be hazardous for cattle, sheep or chickens.

Palmer and Radeleff (1969), and Palmer (1972) interpreted their data as follows: To relate the toxic dosages found for cattle, sheep, and chickens to the application rates recommended for each herbicide, the probable amounts that could be consumed daily from recently sprayed fields or pastures were calculated. In these calculations, neither the influence of environmental factors nor the decomposition rates of the herbicides were considered.

An arbitrary, although realistic, yield of 45 g of air-dry forage per 0.3 m of area was selected, which is the equivalent to approximately 4,480 kg/ha. This quantity would represent a high-quality, improved pasture (with adjustment for local conditions). A sparse cover of vegetation would allow more of the herbicide to reach the ground and be unavailable to animals, whereas a more lush cover would tend to hold more of the material available. In the latter case, however, less of the forage of the area would be consumed in any one day.

Further assumptions were: (1) that an animal would consume, as forage, three percent of its body weight each day, and (2) that all the chemical formulation applied would adhere to the vegetation. Although the latter is never actually the case, this assumption gives the maximum possible exposure.

An application of 454 g of chemical to 1 ha of land provides 11.6 mg for each square foot. We may simplify the whole calculation to a single statement that 1.12 kg/ha of herbicide provides a 7 mg/kg dosage to the animal under the conditions of their experiments.

In actual field experiments horses, cattle, sheep, pigs, and chickens were grazed on pastures immediately after spraying with 2,4-D and 2,4,5-T at two to four times the normal rate.

Grigsby and Farwell (1950) concluded that the use of these materials for pasture weed control was a reasonably safe procedure. The only detrimental effect was damage to legume forage plants. Goldstein and Long (1958) actually observed livestock (cattle, sheep, swine) grazing pastures sprayed with four times the recommended concentration of 2,4-D and 2,4,5-T. No harmful effects were noted.

POULTRY

Rowe and Hymas, (1954) indicated that the average LD_{50} for Hampshire Red chicks for the acid, isopropyl ester, and mixed butyl ester of 2,4-D was 541, 1,420 and 2,000 mg/kg, respectively. The LD_{50} for 2,4,5-T acid and the mixed butyl esters of silvex was 310 and 1,190 mg/kg. Chicks were considered more tolerant of 2,4-D than dogs and other animals.

Andersson et al. (1962) estimated contamination of animals drinking water from recommended treatments of 2,4-D, 2,4,5-T, dalapon, and amitrole could possible reach an upper concentration of 10 ppm. Data by Bovey et al. (1974) support this conclusion for 2,4,5-T and picloram. Andersson et al. (1962) found no harmful effect of 100 ppm of the herbicides in drinking water or in feed up to 510 ppm fed for 8 weeks to chicks, and concluded the contamination of water sources by these herbicides, under normal use, does not consititute a hazard to livestock.

The triethylamine salt of 2,4,5-T appeared more toxic to chickens than the propylene glycol butyl ether ester or 2-ethylhexyl ester (Palmer 1972). However, chickens were not affected when exposed to 100 mg/kg/day for 10 days of the ester formulations of 2,4,5-T or when 25 mg/kg of the triethylamine salt was used. Chickens also tolerated 50 mg/kg/day for 10 days without apparent effect when exposed to the propylene glycol butyl ether esters of silvex. At high dosages (500 mg/kg) most formulations of 2,4,5-T or silvex caused death of some birds.

Silvex amd 2,4,5-T were no more toxic than 2,4-D or MCPA. Palmer and Radeleff (1969) and Palmer (1972) concluded none of the phenoxy herbicides studied constituted a hazard to chickens when applied at recommended agricultural rates.

Erne and Björklund (1970) studied the nature of the renal change induced by 2,4-D or 2,4,5-T in poultry. Groups of day-old broiler chicks were fed 2,4-D or 2,4,5-T at 1,000 ppm in drinking water for up to 7 months. In another experiment, 2,4-D and 2,4,5-T were fed to 8-week-old broiler chickens. Some birds died at these high levels of herbicide and reduced mobility and decreased food and water intake were observed. In dead and killed animals, kidney enlargement was the predominant finding. It was appreciable after 14 days of exposure to 2,4-D or 2,4,5-T, increasing with exposure time. Histologically the kidney enlargement proved to be due to hypertrophy of the proximal tubular epithelium. Electron microscopy showed increased numbers of mitochondria in the tubular cells, with variations in mitochondria size, shape, and structure (Björklund and Erne 1971). The number of micro-bodies in the cytoplasm was increased and intranuclear bodies were observed. This information provides a better understanding of the mode-of-action of agricultural chemicals in animals, but such excessive doses will not be encountered in nature.

Whitehead and Pettigrew, (1972) found in subacute toxicity studies that chicks were able to tolerate large dietary doses of 2,4-D and 2,4,5-T for short periods. The only adverse affects were reductions in food consumption and growth rate. Chicks were able to tolerate 5,000 mg/kg of either 2,4-D or 2,4,5-T for up to 1 week, and resumed a normal growth rate when returned to uncontaminated food. The birds rejected contaminated (herbicide-treated) food when given a choice and grew at a normal rate.

Roberts and Rogers (1957) placed male turkeys, averaging about 6.8 kg each, in pens of alfalfa and bluegrass immediately after and three days after spraying the vegetation with a low-volatile ester of 2,4,5-T at 1.6 lb/A. The turkeys consumed most of the treated vegetation after three or four days and no harmful effect resulted when compared to birds in the control pen. In another experiment, birds received a ration containing the equivalent of 80 mg/kg of 2,4,5-T acid per day for 11 days. Weight of gain and feed consumption of the turkeys was not affected.

Foster (1974) recently reviewed over 230 scientific articles on the physiological and biological effects of pesticide residues in poultry. Foster found that lethal doses for most pesticides, including the phenoxy herbicides, are quite high and are not likely to be found except as a result of an accident. Residues of pesticides in eggs and meat rarely occurred under good management practices.

WILDLIFE

George (1963) summarized the various toxicities of commonly used pesticides in comparison to DDT. With DDT equal to 1, toxicity for 2,4,5-T and derivatives compared to DDT were 0.4, 0.2, 0.1, 0.2, and 0.1 for rats, bobwhite, pheasants, mallards, and bluegills, respectively. Data used to determine relative toxicities were based on amounts necessary to kill 50 percent of the test animals (LD_{50}) of acute toxicity for rats; chronic toxicity (10 to 100 days) for birds; and 96-hour tests for fish. Research currently in progress by the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station and the USDI Fish and Wildlife Service indicates blacktail deer show no feeding preference either for sprayed or unsprayed forest vegetation in browse for food. This research will be completed in June 1979.

Somers et al. (1974) found no adverse effects of aqueous solutions of 2,4-D:picloram and 2,4-D:2,4,5-T mixtures when applied to fertile pheasant eggs preceding incubation at 10 times the normal field rate. No treatments caused any adverse effects on hatching success, incidence of malformed embryos, or subsequent chick mortality.

Recent work in Finland consisted of spraying pheasants with emulsions of 2,4,5-T or placing pheasants in enclosures sprayed with 2,4,5-T (Helminen and Raites 1969). No visible health effects were observed. No case of herbicide poisoning among wildlife species has been diagnosed in Finland. Herbicides may influence local game densities, however, by changing the density and composition of the vegetation.

AQUATICS

Pimentel (1971) prepared an extensive report of the effect of various agricultural chemicals on nontarget plants and animals. After review of available research, he concluded that various 2,4-D, 2,4,5-T and silvex formulations varied greatly in their toxicity to fish with the ester formulations being most toxic. Results vary between the same and different species of fish and also between investigators due to different conditions of the experiments. Fish tolerated high levels of the acid and salt formulations of 2,4-D, 2,4,5-T and silvex for long periods of time, but are more sensitive to the ester formulations, particularly the butyl ester of 2,4-D (<1 ppm). Earlier, it was indicated that the concentrations of 2,4-D or 2,4,5-T seldom exceeded 0.01 ppm in streams adjacent to forest spray operations in Oregon. The no-effect level for most fish is well above the 0.01 ppm concentration found in some water sources, even soon after application.

The concentration which is lethal to 50 percent of the test species (LC_{50}) or median tolerance limit (TLm) varies with formulation and species of fish. For example, after 48 hours exposure, the LC_{50} for bluegill for the dimethylamine salt, isooctyl ester, propylene glycol butyl ether ester, butoxyethanol ester of 2,4,5-T was 144, 31, 17, and 1.4 ppm, respectively (Hughes and Davis 1963).

As indicated by Hughes and Davis (1963), ester formulations are more toxic to fish than the acid or salts, probably due to more effective penetration. The same ester formulations from different sources (manufacturers) also vary in toxicity. Granular formulations of esters of 2,4-D, 2,4,5-T, and silvex were less toxic than liquid formulations (Hughes and Davis 1962). No-effect levels for 2,4,5-T have been established for some fish (table 36).

More recently, Kenaga (1974) reviewed the literature on the toxicity of 2,4,5-T to fish, shrimp, oysters, aquatic invertebrates, and marine and freshwater algae. Except for certain esters, 2,4,5-T is relatively low in toxicity to these organisms. Esters of 2,4,5-T, except in highly acidic waters, are usually hydrolyzed within a few days. Fish also hydrolyze the esters of 2,4,5-T. For these reasons, the more toxic esters of 2,4,5-T should not pose prolonged hazards to aquatic animals and algae under normal use conditions. Documented cases of fish mortality from operational uses of 2,4,5-T consistent with current registrations are not known.

Table 36—No effect levels of 2,4,5-T to fish

Formulation	Species	Exposure	Concentration	Source
Acid	Juvenile white mullet	48 hours	50 ppm	Butler, 1963
Isooctyl ester (liquid)	Bluegill	12 days	1 ppm	Hiltibran 1967
Isooctyl ester (granular)	Bluegill	12 days	10 ppm	Hiltibran 1967
Sodium salt	Bluegill	12 days	50 ppm	Hiltibran 1967

INSECTS

Moffet et al. (1972) found that various formulations (amine salts and esters) of 2,4-D, 2,4,5-T, silvex, and picloram were nontoxic to caged honey bees when the herbicide was applied in water carrier. Diesel oil alone showed considerable toxicity the first day after spraying. Diesel oil-water and diesel oil-water-DMSO combination carriers were less toxic than straight diesel oil, but more toxic than water alone. The authors concluded the phenoxy herbicides have relatively low toxicity to honeybees. Oil carriers are more toxic.

Morton et al. (1972) and Morton and Moffett (1972) fed herbicides to newly emerged worker honeybees in 60 percent sucrose syrup at concentrations of 0, 10, 100, and 1,000 ppm. At 1,000 ppm, ester and salt formulations of 2,4-D, 2,4,5-T, silvex, and 2,4-DB severely reduced or eliminated brood production. There was less effect at 100 ppm. At 10 ppm the phenoxy herbicides caused no adverse effect on brood development. The adverse effects of the phenoxy herbicides were temporary since once the herbicide was removed, normal brood development was resumed.

In other studies, Morton et al. (1974) placed apiaries where the bees' only source of water contained either paraquat or 2,4,5-T (triethylamine salt) at 1,000 ppm. When colonies were exposed to 2,4,5-T, large numbers of bees drowned because of the lower surface tension of the water. Production of the brood was reduced below that of check colonies during the period the treated water was used and for 3 months thereafter; however, in the subsequent 9 months, production returned to normal. Concentrations of 2,4,5-T in bees using water containing 2,4,5-T were as high as 149 ppm, but dropped to about 5 ppm as soon as bees used untreated water. Honey contained 2,4,5-T as high as 50 ppm, but dropped to 5 ppm within 1 week after bees began using untreated water. Trace amounts of 2,4,5-T could be detected in bees and honey after more than a year from time of exposure. The occurrence of 2,4,5-T phenoxy herbicide at this high dosage (1,000 ppm) after normal use is very unlikely.

Way (1969) indicated the hazard to bees and possibly other nectar feeding insects from applications of phenoxy herbicides was also a hazard to plants in flower (apparently from toxicity of the nectar or loss of nectar from herbicide treatment). Otherwise, there appears to be little hazard to insects from direct toxicity of the compound at normal agricultural rates of application.

PART 7: ECOLOGICAL EFFECTS

The principal thrust of most concerns about the use of 2,4,5-T has centered on direct toxic effects on animals. The previous sections in this chapter have reviewed some data in this perspective. Recognizing, however, that 2,4,5-T is most highly active biologically on plants, it is more likely that this chemical will have its greatest effect through modification of plant communities of all types. This section gives only a brief overview of this subject. Some additional discussions are also in Chapters 1, 2, 3, and 4.

SOIL ENVIRONMENT (MICROBES)

As early as 1947 (Newman 1947), it was recognized from research by several investigators that the disappearance of 2,4-D and 2,4,5-T from soil was due largely to microbial action. Certain groups of soil microorganisms, as determined by carbon dioxide evolution, nitrification plate counts, and growth of fungi were injured more readily than others. However, the workers concluded the quantity of phenoxy herbicides reaching the soil from weed control would probably not have a serious effect on most soil microorganisms.

Initial 2,4,5-T residues commonly found in soil from normal application practices are far below levels causing inhibition of soil microbes. Studies showing massive rates of 2,4-D and 2,4,5-T stimulate growth of certain microbes and suggest the herbicides are used as a carbon source.

There are some microorganisms that are susceptible to phenoxy herbicides (2,4-D and 2,4,5-T) at concentrations of about 50 ppm (100 lb/A in top 6" of soil) (Bollen 1961). However, most microorganisms are resistant to high concentrations. Shennan and Fletcher (1965) subjected 38 species of soil bacteria, fungi, and actinomycetes to 2,4-D and 2,4,5-T at concentrations up to 10,000 ppm; twenty-four organisms required 10,000 ppm 2,4,5-T for growth restriction to occur. Stojanovic et al. (1972) added a mixture of 2,4-D and 2,4,5-T to soil at a concentration of 5,000 ppm. The bacteria and actinomycetes were inhibited but the total number of fungi increased during a 56-day incubation period.

Fletcher (1956) investigated the effect of the sodium salts of 2,4-D, MCPA, 2,4,5-T, 2,4-DB, and MCPB on the growth of Rhizobium trifolii. Since growth was not affected at concentrations of 25 ppm by any phenoxy studied, it was assumed that concentrations used in agriculture of 1 lb/A (2 to 2.5 ppm) in soil would have no adverse effect on growth of Rhizobium trifolii, a nodule-forming organism of clover.

Large doses (25-250 ppm) of 2,4-D, 2,4,5-T, and silvex were required to cause inhibition of growth and inhibition of oxygen evolution by 50 percent (EC_{50}) in four species of unicellular algae (Walsh 1972). Silvex was more inhibitory to growth than 2,4-D or 2,4,5-T. The acid formulation of 2,4-D was more inhibitory than the butoxyethanol ester of 2,4-D.

Poorman (1973) indicated 50 and 100 ppm of 2,4-D and 2,4,5-T, respectively, was required to inhibit growth of Euglena gracilis cultures. Cells were morphologically altered by the herbicides, but recovered rapidly and completely when transferred to an herbicide-free medium. 2,4-D stimulated growth of the soil amoeba Acanthamoeba castellanii at 0.1 to 1 ppm, but stimulation was less pronounced at 10 to 100 ppm (Prescott and Olson 1974). The investigators indicated Acanthamoeba may be able to degrade 2,4-D and use it as an energy source.

Under field conditions, some workers have found that phenoxy herbicides have little or no effect on microbial populations (McCurdy and Molberg 1974, Chulakov and Zharasov 1973), while others have shown both depression and stimulation of numbers and growth of some soil organisms (Audus 1964).

Microbial studies by Stark et al. (1975) have shown that the application of 2,4-D and 2,4,5-T at massive rates (5,000-40,000 ppm) did not sterilize the soil, but stimulated the growth of certain microflora. These bacteria, actinomycetes, and fungi proliferated to such an extent that they are probably using the herbicide and TCDD as carbon source which contributes to their degradation.

Spraying big sagebrush with 2,4-D reduced the rate of soil moisture withdrawal (Tubler 1968). About 75 percent of the difference in total moisture depletion occured within the 3 to 5 foot soil depth. The opposite effect occurred in the 1-2 foot depth indicating an increase in grass herbage production. Total evapotranspiration losses from the 0 to 5 foot soil profile were reduced about 14 percent over the 4-month growing period the second year after spraying. Similar data would be obtained with 2,4,5-T on sagebrush and many other brush species.

Herbicide-induced changes in the composition and density of higher plant communities will alter moisture, nutrient, and carbon levels, cycles and relationships in the soil. These effects will cause changes in the density and composition of microfoil populations.

AQUATIC ENVIRONMENT

Young et al. (1975) studied the effect of massive doses of 2,4-D and 2,4,5-T sprayed from 1962 through 1970 on an aquatic environment (Test Area C-52A) at Eglin Air Force Base, Florida. The aquatic area was immediately adjacent to the sprayed area and was drained by five streams. A total of 22 species of fish was collected from 1969 to 1974. The results indicated no significant change had occurred in the ichthyofauna of either the test or the control streams during this period.

As part of a National Academy of Sciences program to assess the effects of defoliants on the plant and animal life of Vietnam, mollusks, which are extemely diverse and sensitive to environmental change, were surveyed in the Rung Sat Special Zone where defoliation by agents Orange (n-butyl ester of 2,4-D + 2,4,5-T, 1:1) and White (2,4-D + picloram, 4:1) had turned mangrove forest into barren mud flats (Davis 1973). More than 40 species of living mollusks were found between this area and the control Vung Tau, and 50 percent of the species were found in both areas. Fields of grass, new mangrove growth, and old trees provided habitat for large numbers of snails. No abnormalities were found in the snails. No molluscan species could be considered endangered. Shellfish, which depend on the nutrients from the mangrove areas, were being produced at a normal rate. Full recovery of the mangroves will occur within 10 years based on evidence of reseeding.

HIGHER PLANT COMMUNITIES

Controlling undesirable plants and causing ecological shifts in plant communities to favor desirable species are the main reasons for using the phenoxy herbicides. Broadleaved plants, in general, are much more susceptible to 2,4,5-T than grasses and conifers. The herbicide is used to suppress sensitive species growing among resistant species. A large volume of data concerning the response of common weeds of crops and pastureland are available from most State Agricultural Experiment Stations, USDA, or private industry relative to 2,4,5-T use. It is beyond the scope of this report to attempt to list the numerous uses and recommended practices; however, a few examples will be cited relative to their effect on various plant species.

Marker (1974) reported that 2,4,5-T caused a weak reduction in the number of species, but a great decrease in the frequency and vitality of the herbs. Tomkins and Grant (1974) found dicots were more susceptible than nonocots to 2,4-D, picloram, picloram + 2,4-D, and 2,4-D + 2,4,5-T. However, grasses growing in disturbed areas (immature) were more susceptible to the auxin type herbicides than mature communities. Hammerton (1966) showed that susceptibility of a weed species to a particular herbicide is not a constant property of that species. Variations in susceptibility may be due to environmental factors or to intrinsic or plant factors (ecotypes, stage of growth, etc.) or both. Norris (1967) reviewed the physiologic bases for selective herbicide action.

Young et al. (1975) assessed vegetation changes after repeated and massive applications of the n-butyl esters of 2,4-D + 2,4,5-T at Eglin Air Force Base. Treated areas continue to revegetate but the invading species are different than those on the control area.

Research has shown pasture and rangeland improvement with herbicides by controlling brush (Barrons 1969, Scifres and Haas 1974) and establishment of shrub communities on rights-of-way (Pierce 1958, Bramble and Byrnes 1972). The use of herbicides, such as 2,4,5-T and silvex has been proposed by Decker (1959) to maintain trails and control poison ivy in a nature sanctuary in New York. Herbicides may be the only effective means of controlling some weed populations since other methods, such as grazing or plowing, may not be satisfactory (Batranoff and Burrows 1973).

WILDLIFE HABITAT

Martin (1965), however, found areas of post oak and blackjack oak forest sprayed with 2,4,5-T provided significantly more suitable habitat for pairs of the eastern bluebird, eastern meadowlark, mockingbird, mourning dove, and bobwhite. The eastern woody pewee, blue gray gnatcatcher, and brown-headed cowbird had higher populations in the treated area than in the control area. The investigator concluded that there was no marked adverse effect upon any nesting species of birds and 2,4,5-T actually improved the habitat for a few species.

Kenaga (1975) recently reviewed the literature on the effect of 2,4,5-T on bird populations under recommended field practices. He concluded that birds in treated areas should not be affected acutely or chronically in the egg, chick, or adult stages of life since dietary levels of 2,4,5-T causing no effect in laboratory tests are high enough so that they normally exceed the residues expected in food of birds in the treated areas.

Newton and Norris (1968) studied blacktail deer on the Oregon Coast Range after treatment with 2,4,5-T and atrazine, and concluded the deer do not leave the treated area, do not accumulate 2,4,5-T or atrazine, that detectable levels of herbicide in deer was rare, and that the ruminant was able to degrade the herbicides almost completely soon after ingestion.

Data from Germany indicated herbicides (including phenoxys) had no harmful effects on deer, wild pigs, hare, rabbit, pheasant, and wood pigeon (Madel 1970). A decline in the population of partridge has been ascertained due to removal of weed seed, protective hedges, and pheasant competition. Giban (1972) concluded phenoxy herbicides and other herbicides used in forestry posed no appreciable risk to game animals since only a small fraction of the land was treated and at extended intervals.

2,4,5-T has been used to maintain or improve wildlife habitat in the north central United States. Bramble and Byrnes (1972) report the use of 2,4,5-T (and other herbicides) have enhanced wildife habitat on power line rights-of-way.

CHAPTER 6

ACCIDENTS DUE TO APPLICATION OF HERBICIDES AND THE USE OF MECHANICAL HAND LABOR AND BURNING FOR BRUSH CONTROL ON RANGELANDS, IN FORESTS, AND ON RIGHTS OF WAY.

SUMMARY

During approximately 1.4 million man-hours (includes air and ground workers) of aerial application of herbicides to brush in Texas, one accident occurred in which a flagger lost sight in one eye. The injury was diagnosed as being caused by diesel oil in the eye. During 75,000 hours of chemical application by ground equipment, no accidents occurred. The accident rate for air and ground application of herbicides to rangeland in Texas was 0.07 and 0 per 100,000 man hours respectively. During nearly 2 million man-hours of mechanical operation, it was estimated 201 accidents occurred or 6.7 accidents per 100,000 man-hours.

Two studies were conducted on control of brush by chain saws or manual clearing of brush in Oregon. Where chain saws were used, one accident per every 130 man-hours was reported or 769 accidents per 100,000 man-hours. In the other study, one accident per every 245.6 man-hours or 407 accidents per 100,000 man-hours was reported.

Thirty-five states separate Workmen's Compensation rates into two categories-- (1) tree trimming and brush cutting and (2) chemical spray. The average Workmen's Compensation rates are 8.14 for tree trimming and brush cutting and 2.65 for chemical spray.

The briefs of accidents involving aerial application operations for 1976 from the National Transportation Safety Board were used to estimate accident rate for aerial application of herbicides on rangelands, rights of way, forests, and rice. The estimated annual numbers of accidents for spraying rangeland, rights of way, forests, and rice are 2.42, 1.73, 1.59, and 0.63, respectively. The estimated numbers of annual fatalities for these same groups are 0.24, 0.16, 0.16, and 0.06, respectively.

A comparison of accidents per 100,000 man-hours shows that the accident rate for aerial and ground application of herbicides on rangeland in Texas is the lowest followed by mechanical control, all aerial application operation accidents, and clearing of brush in forests with a chain saw.

INTRODUCTION

The purpose of this section is to compare the accidents that happened during the application of 2,4,5-T by air or ground equipment compared to those accidents occurring as a result of mechanical-brush control, clearing brush by hand labor, or burning. Data in the report consist of the following:

1. A report of accidents from controlling range weeds and brush in Texas.
2. Two reports from Oregon on control of brush on cutover land.
3. Workmen's Compensation rates for tree trimming and brush cutting versus chemical spray.
4. The 1976 report of the National Transportation Safety Board briefs of accidents involving aerial-application operations.

RANGE WEEDS AND BRUSH

The information from Texas (table 1) for herbicide application by air on range weeds and brush represents nearly 1.4 million man-hours over the period operators have been in business, which was an average of 14.4 years. This includes all man-hours, air and ground.

There was one eye injury due to aerial application of 2,4,5-T. This happened to a flagger who continued to look up as the plane passed overhead and did not move out of the line of flight. The injury was diagnosed as eye injury from the diesel oil component of the spray mixture and not from the 2,4,5-T (Hardcastle 1974). This person lost sight in one eye. There were 0.07 accidents per 100,000 man-hours for aerial application of herbicides to weeds and brush in Texas. No accidents were reported for 75,000 man-hours of ground application of herbicides to range and brush in Texas (Hoffman 1978e, Hardcastle 1978).

Over a 32-year period, a contractor operating mechanical equipment for nearly 1 million man-hours (table 1) reported one accident resulting in

Table 1--Estimated man hours and accidents from controlling range weeds and brush in Texas

Method of control	Man-hours	Death	Disability	Other	Time lost
Chemical					
Air [a] (78)[b]	1,393,776	None	None	eye loss	Did not re-employ
Ground (6)[b]	75,300	None	None	None	None
Mechanical[c]					
(1) [b]	998,400	None	None	1 (Bruise)	20 hrs.
(200)[b]	1,996,800	None	None	200	4,000 hrs.
Burning 10 years at Texas A&M University - No injury					
Hand labor - Not enough done to get data					

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[a] Texas Aerial Applicators Association.

[b] Number of applicators or contractors.

[c] Contractors belonging to Texas Conservation Contractors Association.

20 hours lost from the job. There are 200 other contractors belonging to the Texas Conservation Contractors Association. It was estimated that these contractors operated a total of nearly 2 million man-hours with 200 accidents for a total loss of 4,000 hours of worktime. The accident rate was estimated as 6.7 per 100,000 man hours for mechanical control of brush.

There were no injuries as a result of burning up to 2,500 acres annually by the Texas A&M University personnel over a 10-year period. There is not enough hand labor done on controlling brush on rangelands to obtain data.

BRUSH ON CUTOVER LAND

In 1977, the Josephine County Forestry Department in Oregon conducted studies on the use of a chain saw to control brush on cutover land that was not replanted and was overgrown with brush. Brush was defined as shrubs and shrub-size hardwoods. These studies were conducted in three areas consisting of 10.26 acres, 15.49 acres, and 4.61 acres in size. Data were reported on injuries requiring first-aid, medical attention, or deemed serious enough to warrant the filling out of an accident report by a foreman. Injuries were measured in terms of man-days. The control period was from November 1976 to March 1977 and consisted of precommercial thinning in the forest (Bernstein 1977). The brush-control study was conducted in late April and early May in 1977.

The accident rate during the brush-control study period was one injury for every 13 man-days, based on a 10-hour day. There were 769 accidents per 100,000 man-hours which was about twice the accident rate for the precommercial thinning work.

In another study, the State of Oregon, Forestry Department, documented some statistics for accident rates associated with manual clearing of brush. In 1977, hand clearing was performed on 168 acres of brush. The work required 2,455 man-hours for an average of 14.6 hours per acre.

Ten accidents were reported including three bee stings, two poked eyes, one laceration from a saw, one laceration with a machete, one infection from a thorn, one short stub in knee, and a tooth injury. This is one accident per 30.7 man-days or 407 accidents per 100,000 man-hours (Greaves 1978).

WORKMEN'S COMPENSATION RATES

Workmen's Compensation rates were compiled by the Asplundh Tree Expert Company on (1) tree trimming and brush cutting, and (2) chemical spray for all States from which the data were available (Asplundh Tree Expert Company 1978). These rates were effective August 1, 1978. The data in table 2 represent the percent of total labor cost spent on Workmen's Compensation. There were no data available from four states, Nevada, North Dakota, South Dakota, and Wyoming. Nine states, Arizona, Colorado, Georgia, Idaho, Kansas, Missouri, Montana, New Mexico, and Utah did not separate tree trimming and brush cutting from chemical spray rates. Of those states that did separate the two categories, 32 had average Workmen's Compensation rates for chemical spray much lower than for tree trimming or brush cutting. However, three of the states had the rates equal for both categories. The average Workmen's Compensation rates for the 35 states that separated the two categories are 8.14 for tree trimming and brush cutting and 2.65 for chemical spray (Asplundh Tree Expert Company 1978). These data definitely show that the accident rate to persons performing chemical spraying is less than for tree trimming or brush cutting.

AERIAL APPLICATION

The National Transportation Safety Board annually publishes briefs of accidents involving aerial application operations. There were 17.3 accidents per 100,000 hours flown to apply insecticides, herbicides, etc., in 1976 (US General Aviation 1976). The fatal accident rate was 1.56 per 100,000 hours flown (table 3). The total number of accidents and fatalities involved with treating of rangeland, rights of way, forests, and rice by aircraft were computed on the basis of these rates

Table 2--Workmen's Compensation rates a/ effective 8-1-78

State	Tree trimming brush cutting	Chemical spray
Alabama	4.00	1.14
Arizona	23.35	
Arkansas	6.84	1.46
California	16.74	5.05
Colorado	7.39	
Connecticut	6.41	1.70
Delaware	7.61	2.35
Florida	9.32	3.81
Georgia	5.78	
Idaho	8.00	
Illinois	5.26	1.48
Indiana	3.18	.94
Iowa	5.08	2.32
Kansas	5.41	
Kentucky	10.10	3.34
Louisiana	10.08	1.77
Maine	13.31	2.72
Maryland	6.59	1.70
Massachusetts	5.36	1.77
Michigan	8.19	3.45
Minnesota	26.75	3.91
Mississippi	6.29	1.18
Missouri	4.85	
Montana	6.52	
Nebraska	4.33	.90
Nevada		
New Hampshire	12.67	3.14
New Jersey	5.34	2.60
New Mexico	5.68	
New York	12.36	2.50
North Carolina	3.66	.76
North Dakota		
Ohio	7.50	7.50
Oklahoma	7.68	2.82
Oregon	14.75	5.21
Pennsylvania	7.20	2.30
Rhode Island	8.97	2.15
South Carolina	5.63	1.12
South Dakota		
Tennessee	4.73	1.17
Texas	8.48	3.63

continued

Table 2--Workmen's Compensation rates a/ effective 8-1-78 (continued)

State	Tree trimming brush cutting	Chemical spray
Utah	7.50	
Vermont	5.48	1.48
Virginia	6.06	1.12
Washington	6.50	6.50
West Virginia	6.36	6.36
Wisconsin	5.63	1.48
Wyoming		
Average[b/]	8.14	2.65

a/ Percent of total labor costs spent on Workmen's Compenstion. (Asplundh Tree Expert Company, 1978)

b/ Average of figures from States that separated tree trimming and brush cutting rates from chemical spray rates.

Table 3--Aerial application operation accidents reported by U.S. General Aviation 1976

Aerial application hours flown	Total accidents	Total accident rate a/	Fatal accidents	Fatal accident rate	Fatalities
2,498,600	433	17.3	39	1.56	43

a/ Accident rates per 100,000 hours flown during aerial application of insecticides, herbicides, etc.

for the estimated acres treated annually for each commodity group (table 4). An estimated 3,412,950 acres are treated each year for these four commodity groups. A total of 47,635 hours in the air is required to treat these acres.

These estimates give some idea of the number of accidents and fatalities resulting from the use of aircraft in treating these commodity groups. However, the accident rate in treating rangelands and forests may actually be lower than that for general agricultural spraying and therefore lower than indicated (table 3) because fewer obstructions such as powerlines, and buildings are present. The data from spraying rangeland in Texas bear this out (table 1). The estimated annual number of accidents for spraying rangeland, rights of way, forests, and rice are 2.42, 1.73, 1.59, and 0.63, respectively (table 4). The estimated annual numbers of fatalities for the same commodity groups are 0.24, 0.16, 0.16, and 0.06, respectively (table 4). It must be recognized also that flight personnel are not the only ones at risk. Ground crews and other support personnel are subject to accidents although presumably at a lesser rate.

Table 4--The estimated acres treated annually by aircraft with 2,4,5-T for each commodity group and the total annual accidents and fatalities for each estimated on the basis of data available from the National Transportation Safety Board 1976

Commodity group	Acres treated	Average acres treated per hour	Total number of hours required	Total accidents	Fatalities
Rangeland	2,321,000[a]	166	13,990	2.42	0.24
Rights of Way	249,950[b]	25	9,998	1.73	0.16
Forests	550,000[c]	60	9,166	1.59	0.16
Rice	292,000[d]	80	3,650	.63	0.06
Total	3,412,950		47,635	8.25	0.82

[a] Acreage treated annually with 2,4,5-T by air in Texas, New Mexico, Oklahoma, Arkansas, and Missouri. Estimated by Garlyn O. Hoffman 2,4,5-T Assessment Team.

[b] Acreage treated annually with 2,4,5-T by air in the United States. Estimated by Harvey A. Holt, 2,4,5-T Assessment Team.

[c] Acreage treated with 2,4,5-T in forests in the United States in 1976 estimated by Robert W. Pearl, 2,4,5-T Assessment Team.

[d] Acreage treated annually with 2,4,5-T by aircraft from 2,4,5-T assessment report, Chapter 4.

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APPENDIX I

FORESTRY-RELATED IMPACTS OF 2,4,5-T IN OREGON

by

Walter H. Knapp, Robert D. Greaves,
and Jerome J. Chetock

January 30, 1979

This Report was done as a cooperative effort between the U.S. Forest Service, Region 6, and the Oregon State Department of Froestry.

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ABSTRACT

This report is designed to estimate current and potential use levels of 2,4,5-T for silvicultural operations; determine alternatives to 2,4,5-T; evaluate impacts on future timber supply if 2,4,5-T is unavailable; compare the economic efficiency of using versus not using 2,4,5-T for forest management; indicate the potential changes in silviculture budgets; and estimate employment impacts if 2,4,5-T is unavailable.

The general approach to assessing alternative management practices and their cost and yield impacts was based primarily on a survey of experienced silviculturists within each of four vegetative subregions in Oregon. These subregions included northwestern Oregon (salmonberry-alder type); southwestern Oregon (tanoak-madrone and tanoak-chinquapin types); Cascade Range (vine maple-ceanothus type); and eastern Oregon (ceanothus and manzanita types).

During 1976 and 1977, 2,4,5-T was used on about 88,000 acres each year for forestry purposes in Oregon, roughly one-third of the potential level.

If 2,4,5-T is unavailable for forestry use in Oregon, a wide range of substitute practices would be used in the four major areas of the State. These practices generally result in increased silvicultural costs ranging from -3 percent to +67 percent of present levels. They are less efficient economically than the use of 2,4,5-T on potential use areas.

The economic impact of managing Oregon's forests without 2,4,5-T would be felt now and in the future in terms of both increased management costs and decreased revenues (i.e. yields). The state-wide impact in perpetuity of these consequences can be measured as the difference in the present net worth of the land when managed with and without 2,4,5-T. Management of Oregon's forests with 2,4,5-T could provide from $383 million (at current application rates) to $1.10 billion (at potential rates) greater present net worth than management without 2,4,5-T.

Furthermore, use of these alternatives could potentially result in an 11 percent reduction in timber yield--a current annual loss of 936 million board feet. The employment impacts of this reduction are estimated to be about 20,000 jobs, including both primary and secondary employment.

These impacts would be most heavily felt in western Oregon. In this area, not only are vegetative types more dependent upon the use of herbicides, but timber supplies are also critically short (Beuter et al. 1976). If 2,4,5-T is not available, projections in this study indicate that current harvest levels in this area and the State as a whole cannot be maintained.

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FORESTRY-RELATED IMPACTS OF 2,4,5-T IN OREGON

by

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INTRODUCTION

This report assesses the effects of management with and without the herbicide 2,4,5-T on timber production, economic efficiency, employment, and related aspects for the State of Oregon. The assessment focuses on the four major geographic areas in Oregon: northwestern, southwestern, Cascade Range, and eastern. A more detailed case study for southwestern Oregon compares the economic efficiency among alternatives within this area (Appendix A).

Recent timber supply projections for western Oregon forecast a 22 percent decline in timber harvest by the year 2000 unless the

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[1] Respectively, Silviculturist, USDA Forest Service, Region 6, Portland, Oregon; Forest Resource Analyst, and Silviculturist, Oregon State Dept. of Forestry, Salem, Oregon

intensity of forest management is increased (Beuter et al. 1976). Herbicides have been an integral part of intensive forest management. In particular, the herbicide 2,4,5-T has been regarded as an effective tool for vegetation management within many forest types in Oregon.

The toxicity of 2,4,5-T and the hazards associated with its use have been studied with increasing intensity. In reviewing the chemical for reregistration, the United States Environmental Protection Agency (EPA) found that products containing this chemical exceeded the risk criteria relating to toxic effects specified in federal regulations. Thus, the EPA initiated a review process, a Rebuttable Presumption Against Registration (RPAR), to determine the relative risks and benefits derived from using this chemical.

This assessment in Oregon was undertaken to provide detailed information regarding the benefits of using 2,4,5-T in a key forestry state. This effort was conducted by representatives from the United States Forest Service, the Oregon State Department of Forestry, forest industry, and the Oregon State University School of Forestry.

The assessment was designed to:

* Estimate current and potential use levels of 2,4,5-T for silvicultural operations in Oregon.

* Determine alternatives to 2,4,5-T.

* Evaluate impacts on future timber supply projections if 2,4,5-T is not available for use.

* Compare the economic efficiency of forest management with and without 2,4,5-T.

- * Indicate the potential changes in silviculture budgets.
- * Estimate employment impacts if 2,4,5-T is not available for use.

PROCEDURE

The assessment of alternatives to the use of 2,4,5-T, including their cost and yield impacts, was based primarily on a survey of experienced silviculturists within each of four vegetative subregions in Oregon. The basic study procedure is shown in figure 1; additional details for the key steps follow.

GEOGRAPHIC AREAS

The herbicide 2,4,5-T has been used throughout the State in a wide variety of plant communities. To simplify the analysis, Oregon was divided into four general areas (figure 2) where alternatives to 2,4,5-T vary significantly because of major vegetative differences.[1/] The areas are northwestern (salmonberry-alder type); southwestern (tanoak-madrone and tanoak-chinquapin types); Cascade Range (vine maple-ceanothus type); and eastern (ceanothus and manzanita types). Divisions for analysis were based on political boundaries that approximated these vegetative zones in order to correlate with other data sources.

[1/] Approach based on similar technique developed by the U.S. Forest Service for their 1978 Herbicide Environmental Statement. (USDA FS 1978)

SURVEY

Within each geographic area a survey of selected silviculturists was taken, representing a cross-section of owner classes and experiences. The following information was derived through the initial survey and followup:

- Potential use of 2,4,5-T for silvicultural purposes.

- Alternative vegetation control methods.

- Yield impacts of alternatives.

SELECTION OF ALTERNATIVES

To evaluate the economic and silvicultural impacts of not having 2,4,5-T for management, a representative set of management practices with 2,4,5-T was defined for comparison within each region. Typical practices for site preparation and rehabilitation were based on "Suggested Site Preparation Methods" in Stewart (1978).

To simplify analysis, only one set of representative management practices was selected for all owner classes. Many industrial forest owners will manage their lands more intensively and many small woodland owners less intensively than the selected typical management level.

2,4,5-T MODEL DEVELOPMENT
FLOW DIAGRAM

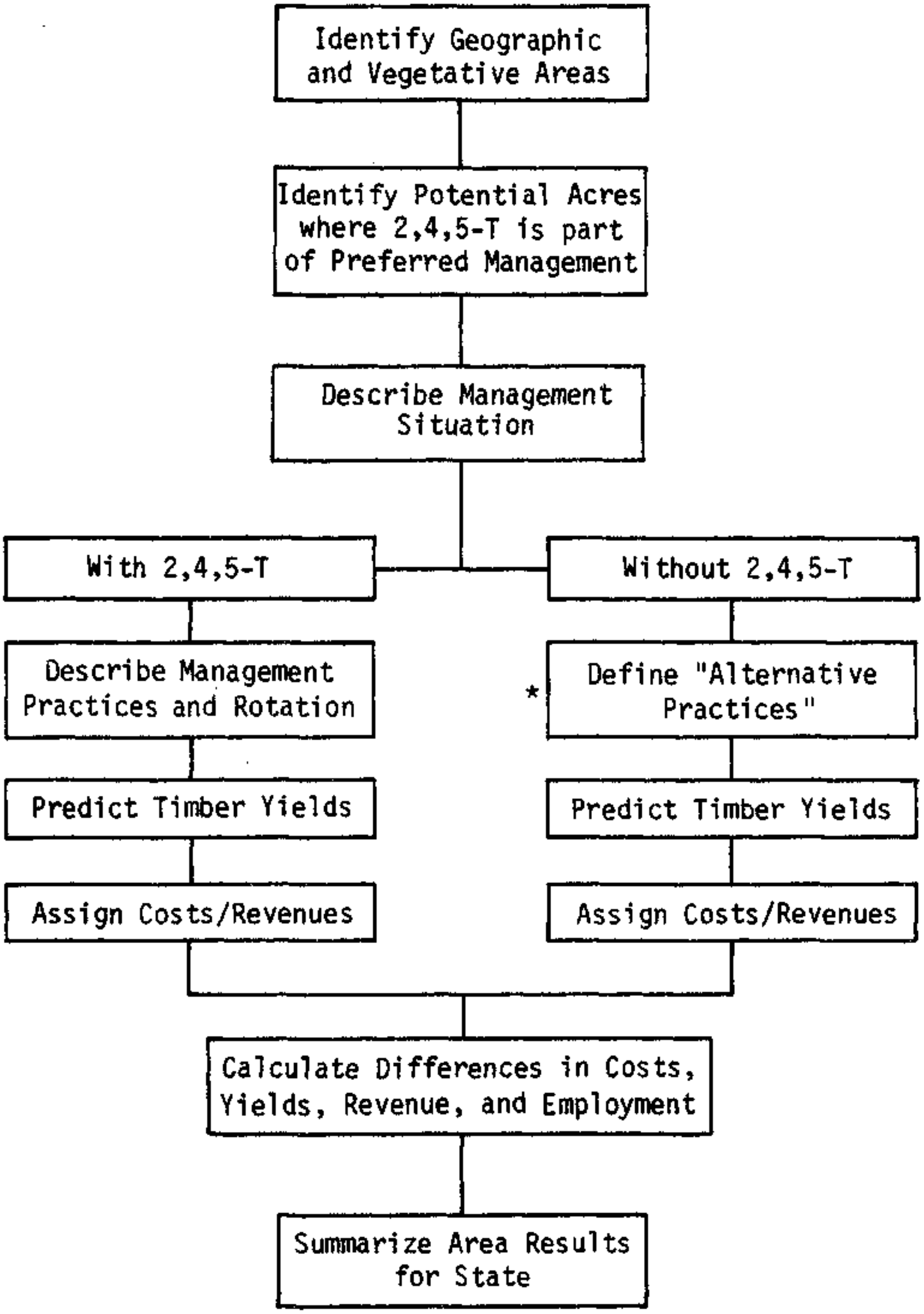

Figure 1--Flow diagram for assessing forestry-related impacts of 2,4,5-T in Oregon.

*Information derived from survey of silviculturists.

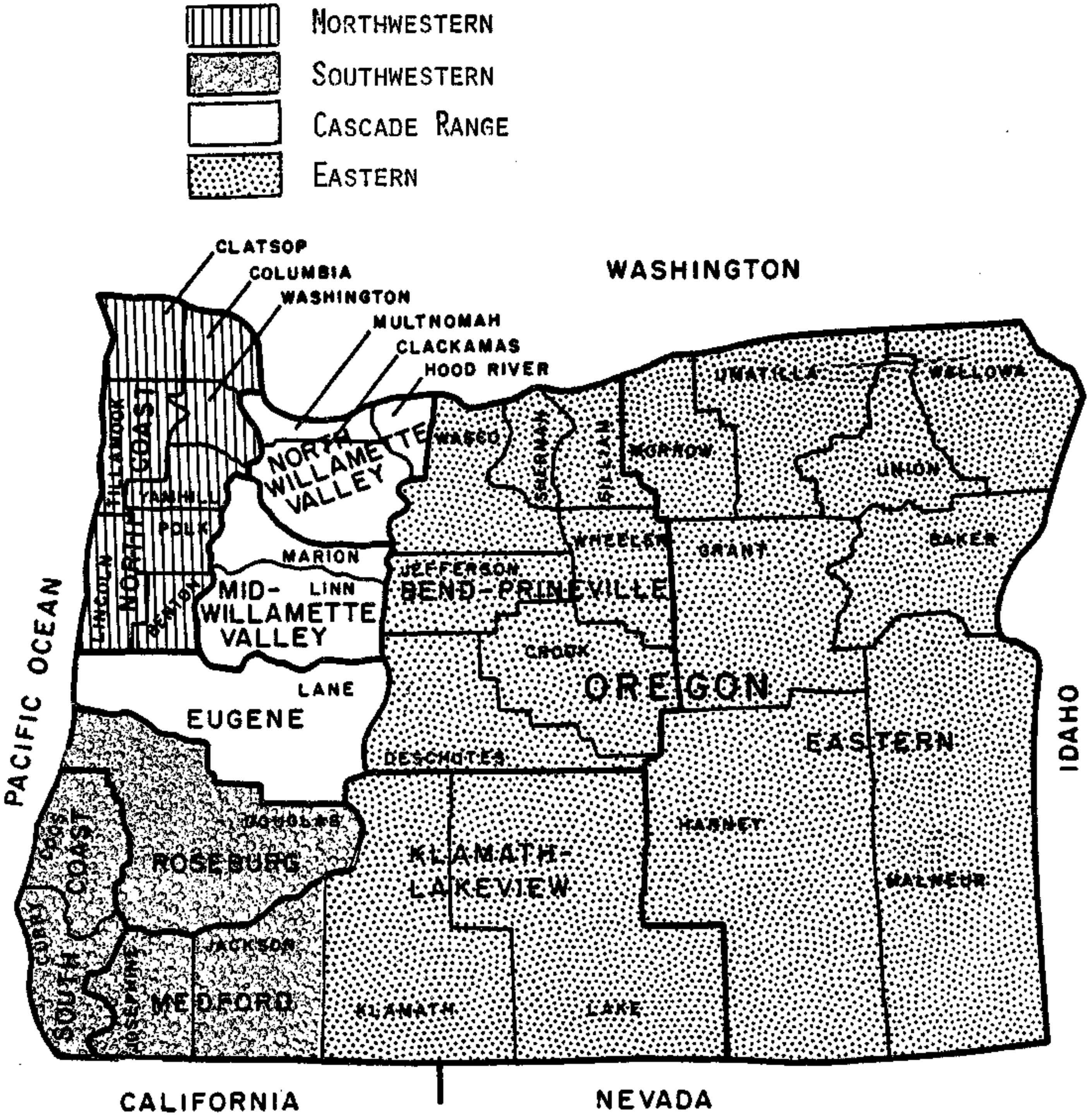

FIGURE 2. MAP OF OREGON SHOWING FOUR MAJOR GEOGRAPHIC AREAS.

The most prevalent alternatives to 2,4,5-T for silvicultural purposes were derived from survey results. Alternatives were not restricted by cost or yield assumptions, but tend to reflect the next choice management practices and the area to which these practices apply. Alternative chemicals were considered if registered and applicable for use.

Effect of Owner Class on Selection of Alternatives

Management intensity and selection of alternative treatments will vary among and within owner classes. Evaluating these differences within the model was beyond the scope of this project. Thus, differences in cost (silvicultural budget), yield, and subsequent projections for timber supply and employment represent an average approximation of the overall impact of losing 2,4,5-T as a silvicultural tool.

Actual impacts among and within owner classes may be higher or lower depending on owner objectives, individual management or funding constraints, productive quality of forest land, and management intensity. For example, forest industry lands in western Oregon are predominantly medium site or high site class (41 and 47 percent of total in owner class, respectively)(Beuter et al. 1976). Brush problems on these lands will generally be more severe than on low site class lands. When coupled with the fact that industry manages its lands on shorter rotations than other owner classes, selection of alternatives to 2,4,5-T that are less effective for brush control will cause a relatively larger decrease in yield on industry land. In most cases, industry managers will choose the most economically efficient alternative available. Some industry owners may choose not to manage their lands when economically viable alternatives are not available.

Small nonindustrial private forest owners manage their lands for a variety of objectives--not all economically motivated. Those who do manage for commercial timber would tend to have funding constraints that limit the application of more costly alternatives to 2,4,5-T. Losing 2,4,5-T in this owner class may result in changes in ownership or objectives (e.g., conversion to nonforest or noncommodity uses).

State and federal public agencies may have labor-intensive alternatives available on some lands where alternatives such as slashing or hand-clearing of brush are effective. The major limitations to increased use of manual brush control are the high treatment costs, lack of manpower, predominance of resprouting species, and safety considerations.

In all cases, choice of an effective alternative to 2,4,5-T depends on: ground cover, physical factors such as topography and soil type, site preparation or release requirements, available manpower and equipment, external constraints such as regulations and objectives, environmental impacts, and cost (Stewart 1978). Each owner or land manager has a unique combination of these variables for each site that needs treatment. The impact of losing 2,4,5-T as a silvicultural tool will depend on these variables and ultimately on the alternative(s) selected.

If 2,4,5-T were unavailable for forestry use in Oregon, that portion of site preparation, rehabilitation, and release currently requiring 2,4,5-T would have to be accomplished by different means. The most likely silvicultural substitutes for 2,4,5-T are identified in Tables 3, 6, 8, and 10. Although no presently registered herbicide can fully substitute for 2,4,5-T as a broad spectrum silvicultural tool, other chemicals would be utilized on some sites in the absence of 2,4,5-T.

Substitute herbicides for site preparation, rehabilitation, and release in Oregon include 2,4-D, Silvex, Amitrole, glyphosate (Roundup), and Fosamine ammonium (Krenite). In addition, 2,4-DP (Dichlorprop), Tordon 101 (Picloram and 2,4-D), Dicamba, and Dinoseb are partial substitutes for site preparation and rehabilitation. The degree of actual replacement for 2,4,5-T varies with the specific herbicide and vegetative species (Stewart 1978, USDA ARS, Undated, and Newton, unpublished). 1/ No single presently registered herbicide can fully substitute for 2,4,5-T as a broad spectrum silvicultural tool.

PREDICTION OF TIMBER YIELDS

With 2,4,5-T

Potential timber production with 2,4,5-T was predicted in western Oregon from DFIT (Douglas-fir Interim Tables) computer simulations (Bruce et al. 1977) using the average site productivity summarized from U.S. Forest Service survey data.2/ These simulations reflect the anticipated development of an average future stand of timber managed as described in the alternatives for each region. Timber yields for an average site in eastern Oregon had been developed in an earlier analysis (Sassaman et al. 1977). Stand age for each silvicultural operation was based on standard practices within each region without regard to ownership variations. The assumed rotation ages were: northwestern, 65 years; southwestern, 85 years; Cascade Range, 75 years; and eastern, 120 years. Rotation ages were based on averages for industry and federal lands, given an assumed level of management.

1/Newton, M. 1978. Chart on susceptibility of forest species to herbicides. Unpublished data on file at Oregon State Univ. Forest Research Laboratory, Corvallis, Oregon.

2/Data on file, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Without 2,4,5-T

Potential yield decreases without 2,4,5-T were estimated by survey respondents. DFIT computer simulations for western Oregon were modified to be consistent with these estimates. Eastern Oregon yield predictions were also reduced consistent with the estimates from the survey of silviculturists. These yield impacts were calculated using weighted averages. A sample derivation of overall yield effects is displayed in Appendix B.

ECONOMICS

Costs

The cost for each management practice was derived from recent reports (OSDF 1977, USDA FS 1978; Bernstein and Brown 1977). Costs reflect statewide averages for all owner classes.

Revenues

Revenues for commercial thinnings and final harvests for western Oregon start at the U.S. Forest Service's 1980 Resources Planning Act Timber Assessment stumpage value of $124 per cunit[1/]. Eastern Oregon revenues were reduced by 33 percent to reflect recent stumpage value differences. Thinning revenues were reduced to 75 percent of the final harvest stumpage value.

Economic Efficiency

The economic efficiency of management with and without 2,4,5-T was evaluated using MULTIPLOY (Row 1976), a computer-assisted economic analysis. Present net worth and benefit-cost ratios were calculated from cost and yield data for the alternatives. Treatment costs were

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[1/] A cunit equals 100 cubic feet or approximately 500 board feet for the assessment area.

assumed to be constant in real terms, and timber values were increased at 2.5 percent annually in real terms, based on trend analysis. Because real prices are used in the analysis, the most relevant interest rate for interpreting the results is a real rate which is below the current market rate. In this report an alternative investment rate of 6 5/8 percent was used as presently recommended by the Water Resources Council (WRC) for long-term investments on federal lands. Rates of 4, 8, and 10 percent are also analyzed for comparison.

Employment

Changes in yield will affect both direct and indirect forest industry employment.[1/] Multipliers of 7.51 jobs per million board feet of timber processed for direct employment and 15.02 jobs per million board feet for indirect (secondary) employment were based on recent averages for the State of Oregon.[2/] Employment increases resulting from alternatives to 2,4,5-T that require more intensive labor were not considered. For a discussion of these effects, refer to the Final Environmental Statement for Vegetation Management With Herbicides for Region 6 of the U.S. Forest Service (USDA FS 1978).

CURRENT AND POTENTIAL USE OF 2,4,5-T

Intensive forest management is an integrated series of practices designed to establish, maintain, and utilize stands of commercial tree species in an efficient and economical manner. Site preparation, conifer release, and rehabilitation of underproductive lands are

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[1/] Direct employment includes those jobs that are specifically a part of timber harvesting and processing. Indirect employment includes those additional jobs resulting from direct employment, from shops, restaurants, and the like. Synonyms: Primary employment and secondary employment.

[2/] Western Environmental Trade Association, Oregon TREE project, phase 1 data, October 1976, on file.

practices within this series which are commonly accomplished, at least in part, with 2,4,5-T. For a variety of reasons, not all commercial forest lands are presently managed according to their potential for timber production. Nevertheless, the potential use of 2,4,5-T was defined as that level of usage which would accompany intensive management on commercial forest land where 2,4,5-T would normally be a part of the preferred management. For example, survey respondents estimated that 2,4,5-T is part of preferred management on 75 percent of the commercial forest lands in northwestern Oregon. The potential use of 2,4,5-T for all silvicultural purposes is shown in table 1. In 1976 and 1977, 2,4,5-T was used on approximately 88,000 acres per year, roughly one-third of the potential level. Details are included in Appendix C.

DESCRIPTION OF ALTERNATIVES

Vegetation management is frequently accomplished with silvicultural tools other than 2,4,5-T, or by combining another method with 2,4,5-T. Mechanical methods, fire, other herbicides, and hand slashing of vegetation are viable alternatives to 2,4,5-T in some specific situations. Although alternatives are available and are used where appropriate, 2,4,5-T currently remains the preferred treatment on a significant part of the commercial forest in Oregon.

Table 2 shows the potential use of 2,4,5-T for rehabilitation of forest lands presently nonstocked or understocked with conifers. Unless these areas are treated, they are not likely to produce satisfactory stands of commercial species within a reasonable time span.

NORTHWESTERN OREGON

The typical management for northwestern Oregon involves the use of 2,4,5-T on 75 percent of the commercial forest land. Thirty percent of site preparation in this area is done with 2,4,5-T in combination with a slash disposal fire. Rehabilitation of underproductive forest lands uses 2,4,5-T in combination with fire and hand slashing on 50

Table 1--Potential use of 2,4,5-T for silvicultural practices in Oregon

Silvicultural Practice	Geographic Area				
	Northwestern	Southwestern	Cascades	Eastern	State Total
	--Thousands of acres (percent of CFL [1] in geographic area)--				
Rehabilitation and Release With 2,4,5-T [2]	255(9%)	129(2%)	199(4%)	incidental	583(2%)
Site Preparation and Release With 2,4,5-T [2]	569(20%)	894(15%)	319(7%)	incidental	1,782(8%)
Release Only With 2,4,5-T	1,329(46%)	3,574(58%)	1,808(39%)	1,944(19%)	8,655(36%)
Subtotal: All 2,4,5-T	2,153(75%)	4,597(75%)	2,326(50%)	1,944(19%)	11,020(46%)
No 2,4,5-T	718(25%)	1,532(25%)	2,325(50%)	8,287(81%)	12,862(54%)
TOTAL	2,871(100%)	6,129(100%)	4,651(100%)	10,231(100%)	23,882(100%)

[1] CFL = commercial forest land.

[2] Areas that require 2,4,5-T for site preparation or rehabilitation also require 2,4,5-T for release.

Table 2--Potential use of 2,4,5-T for rehabilitation in western Oregon[1]

Treatment Description	Geographic Area		
	Northwestern	Southwestern	Cascades
	---Thousands of acres (percent of CFL in geographic area)---		
Rehabilitation with 2,4,5-T	255 (50%)	129 (45%)	199 (30%)
Rehabilitation without 2,4,5-T	255 (50%)	157 (55%)	463 (70%)
Total Rehabilitation	510 (100%)	286 (100%)	662 (100%)

[1] The use of 2,4,5-T for rehabilitation in eastern Oregon is minor and is not included.

percent of this underproductive area. Two release operations are generally applied to forest plantations in northwestern Oregon, with 2,4,5-T being the preferred treatment on 75 percent of the area.

If 2,4,5-T were unavailable for forestry use in northwestern Oregon, the practices of site preparation, rehabilitation, and release would have to be accomplished by different means. The range of alternative treatments available include mechanical, other chemical, fire, hand slashing, no management, and combinations of these methods. The silvicultural alternatives to 2,4,5-T identified by survey respondents in northwestern Oregon are listed in table 3. The resulting alternative management is contrasted to the typical management in table 4. Note that the silvicultural cost--the sum of anticipated stand investments--is slightly lower without 2,4,5-T in northwestern Oregon. This decrease in costs occurs because (1) 15 percent of the time no release is done because no cost effective alternatives are available, and (2) alternatives to 2,4,5-T, though less effective, are only slightly more expensive.

Although these substitute practices decrease costs, they also directly impact timber yield. The analysis indicates that in northwestern Oregon, 39 cubic feet per acre per year would be lost if 2,4,5-T were unavailable--a reduction of 19 percent on areas that would normally use 2,4,5-T (table 11).

SOUTHWESTERN OREGON

Typical management for southwestern Oregon involves the use of 2,4,5-T on 75 percent of the commercial forest land. Twenty percent of site preparation in this area uses 2,4,5-T in conjunction with a slash disposal fire. Forty-five percent of the rehabilitation of nonmerchantable multistoried hardwood stands on steep slopes, prevalent in this area, involves combining 2,4,5-T with hand slashing and fire. Seventy-five percent of the forest plantations in southwestern Oregon are expected to require two release operations, both typically done with 2,4,5-T.

Table 3--Silvicultural substitutes for 2,4,5-T in northwestern Oregon

Silvicultural Substitutes for 2,4,5-T	Percent Replacement for 2,4,5-T	Percent 1/ Yield
Site Preparation		
Fire	30% 3/	90%
Other Chemical	15%	100%
Other Chemical and Fire	35%	100%
Clean Log Only 2/	20%	70%
Rehabilitation		
Other Chemical	35%	85%
Hand Slash, Other Chem., and Fire	50%	100%
No Rehabilitation	15%	10%
Release		
Other Chemical	85%	90%
No Release	15%	55%

1/Percentage of full yield obtainable with 2,4,5-T under typical management regime.

2/"Clean log only" refers to more intensive harvest operations that would leave more ground exposed. It may include yarding of unmerchantable material or some other form of slash removal.

3/The use of fire as a substitute may be limited by state and federal smoke management regulations.

Table 4. Management with and without 2,4,5-T in northwestern Oregon

	Stand Age		Revenue or Cost (-) [2]		Volume	
	With [1]	W/O [1]	With	W/O	With	W/O
	yrs.	yrs.	$/acre	$/acre	cunits/acre	
Site Prep	0	0	-60	-45 [3]		
Planting Operations	0	0	-130	-130		
Rehabilitation	0	0	-200	-200 [3]		
Release	2	2	-30	-28 [3]		
Release	4	4	-30	-28 [3]		
Precommercial Thin	12	12	-95 [4]	-95		
Commercial Thin	30	--	1,144	None	12.3	None
Commercial Thin	35	35	884	1,209	9.5	13.0
Commercial Thin	45	45	1,144	1,311	12.3	14.1
Harvest	65	65	11,668	9,399	94.1	75.8
Slash Disposal	65	65	-110	-110		

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[1] "With" refers to "with 2,4,5-T," i.e., the typical management practices. "W/O" refers to "without 2,4,5-T," i.e., the alternative management practices.

[2] Revenues and costs are for a single rotation, current dollars.

[3] Weighted average cost of substitute treatments for 2,4,5-T identified in Table 3; see Appendix B for method.

[4] Because of initial stocking levels and anticipated early stand development, precommercial thinning is estimated to be needed on only 25 percent of the land area. This proportional treatment was used in the economic analysis.

The unavailability of 2,4,5-T for forestry uses would require alternative practices for those situations described above. These alternative practices are listed in table 5. The resulting alternative management is contrasted to typical management in table 6.

In southwestern Oregon, a reduction of 31 cubic feet per acre per year (a loss of 23 percent) is expected if 2,4,5-T is not available (table 11).

A more detailed case study for southwestern Oregon is found in Appendix A.

OREGON CASCADES

Typical management in the Oregon Cascades involves the use of 2,4,5-T on 50 percent of the commercial forest land. Fifty percent of the release operations, 30 percent of the rehabilitation projects, and 15 percent of the site preparation activities occurring on forest lands in this area typically use 2,4,5-T.

Alternatives to these silvicultural uses of 2,4,5-T in the Oregon Cascades are listed in table 7. The management resulting from the use of these substitutes is contrasted with typical management in table 8.

If 2,4,5-T is not available for forestry use a loss of 24 cubic feet per acre per year is predicted--a reduction of 16 percent (table 11).

EASTERN OREGON

The use of 2,4,5-T for site preparation and rehabilitation of underproductive forest lands is incidental and is not included in this analysis. Release is the only silvicultural practice significantly dependent on 2,4,5-T. Approximately 19 percent of the forest land base could potentially benefit from a release spray containing

Table 5--Silvicultural substitutes for 2,4,5-T in southwestern Oregon

Silvicultural Substitutes for 2,4,5-T	Percent Replacement for 2,4,5-T	Percent [1] Yield
Site Preparation		
Clean Log Only [2]	60%	60%
Hand Slash, Other Chem., and Fire [3]	25%	100%
Fire	15%	95%
Rehabilitation		
Hand Slash, Other Chem., and Fire [3]	60%	100%
No Rehabilitation	25%	20%
Other Chemical	15%	85%
Release		
Other Chemical	50%	95%
No Release	35%	60%
Hand Slashing	15%	85%

[1] Percentage of full yield obtainable with 2,4,5-T under typical management regime.

[2] "Clean log only" refers to more intensive harvest operations that would leave more ground exposed. It may include yarding of unmerchantable material or some other form of slash removal.

[3] The use of fire as a substitute may be limited by state and federal smoke management regulations.

Table 6--Management with and without 2,4,5-T in southwestern Oregon

Practice	Stand Age		Revenue or Cost (-) [2]		Volume	
	With [1]	W/O [1]	With	W/O	With	W/O
	yrs.	yrs.	$/acre	$/acre	cunits/acre	
Site Prep	0	0	- 60	- 78 [3]		
Planting Operations	0	0	-130	-130		
Rehabilitation	0	0	-200	-211 [3]		
Release	4	4	-30	-150 [3]		
Release	6	6	-30	-150 [3]		
Release	--	9	--	-376 [3] [4]		
Precommercial Thin	15	15	-95 [5]	- 95		
Commercial Thin	40		1,247	none	13.4	none
Commercial Thin	50	45	1,153	1,116	12.4	12.0
Commercial Thin	65	60	1,088	1,163	11.7	12.5
Harvest	85	85	9,511	7,775	76.7	62.7
Slash Disposal	85	85	-110	-110		

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[1] "With" refers to "with 2,4,5-T," i.e., the typical management practices. "W/O" refers to "without 2,4,5-T," i.e., the alternative management practices.

[2] Revenues and costs are for a single rotation, current dollars.

[3] Weighted average cost of substitute treatments for 2,4,5-T identified in Table 5; see Appendix C for method.

[4] All release operations in this alternative in southwestern Oregon include manual release on 15 percent of the area. Costs are mid-range values from RPAR timber assessments.

[5] Because of initial stocking levels and anticipated early stand development, precommercial thinning is estimated to be needed on only 40 percent of the land area. This proportional treatment was used in the economic analysis.

Table 7--Silvicultural substitutes for 2,4,5-T in the Oregon Cascades

Silvicultural Substitutes for 2,4,5-T	Percent Replacement for 2,4,5-T	Percent [1] Yield
Site Preparation		
Clean Log Only [2]	90%	80%
Other Chemical	10%	100%
Rehabilitation		
Other Chemical	35%	100%
No Rehabilitation	25%	50%
Hand Slash, Other Chem., and Fire	20%	115%
Mechanical	20%	110%
Release		
Other Chemical	50%	100%
No Release	50%	75%

[1] Percentage of full yield obtainable with 2,4,5-T under typical management regime.

[2] "Clean log only" refers to more intensive harvest operations that would leave more ground exposed. It may include yarding of unmerchantable material or some other form of slash removal.

Table 8--Management with and without 2,4,5-T in the Oregon Cascades

Practice	Stand Age With [1]	 W/O [1]	Revenue or Cost (-) [2] With	 W/O	Volume With	 W/O
	yrs.	yrs.	$/acre	$/acre	cunits/acre	
Site Prep	0	0	-60	-9 [3]		
Planting Operations	0	0	-130	-130		
Rehabilitation	0	0	-200	-180 [3]		
Release	5	5	-30	-45 [3]		
Precommercial Thin	13	13	-95 [4]	-95		
Commercial Thin	35	--	1,125	none	12.1	none
Commercial Thin	45	40	1,200	1,200	12.9	12.9
Commercial Thin	60	50	1,247	1,088	13.4	11.7
Harvest	75	75	9,412	8,940	75.9	72.1
Slash Disposal	75	75	-110	-110		

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[1] "With" refers to "with 2,4,5-T," i.e., the typical management practices. "W/O" refers to "without 2,4,5-T," i.e., the alternative management practices.

[2] Revenues and costs are for a single rotation, current dollars.

[3] Weighted average cost of substitute treatments for 2,4,5-T identified in Table 7; see Appendix B for method.

[4] Because of initial stocking levels and anticipated early stand development, precommercial thinning is estimated to be needed on only 90 percent of the land area. This proportional treatment was used in the economic analysis.

2,4,5-T. The alternatives to using 2,4,5-T for release are listed in table 9. Management resulting from the use of substitutes is contrasted with typical management in table 10.

If 2,4,5-T is not available for use in eastern Oregon, a reduction of 12 cubic feet per acre per year (a loss of 23 percent) is expected on areas needing 2,4,5-T for release. This represents a large proportionate impact on yield, but because of the lower productivity of typical eastern Oregon sites and the comparatively small area which would use 2,4,5-T, the total yield reduction is less than in other areas.

ECONOMIC EFFICIENCY

In all areas of the State where 2,4,5-T is part of the preferred treatment, management with 2,4,5-T is economically more efficient than management without 2,4,5-T (tables 12 and 13). The greatest difference in management efficiency is found in southwestern Oregon. Here management with 2,4,5-T results in a return of $3.80 per acre for every dollar invested, compared with a return of $1.68 without 2,4,5-T (table 12, WRC rates).

On a Statewide basis, management with 2,4,5-T results in $288 per acre greater present net worth than management without 2,4,5-T. Since 2,4,5-T has the potential for use on 11 million acres (table 1), or 253,000 acres annually, management with 2,4,5-T could provide as much as $1.1 billion greater present net worth from these lands than management without 2,4,5-T. In other terms, the benefit-cost ratio with 2,4,5-T indicates a return of $4.13 for every dollar invested in management, dropping to $2.43 in the absence of 2,4,5-T.

In eastern Oregon, lower timber production makes management less profitable than in other areas. The analysis shows that management with 2,4,5-T is efficient at approximately the 6 percent discount level or less. It must be understood, however, that only timber values are included in this assessment. Inclusion of other commodities could result in substantial changes.

SILVICULTURE COSTS

Proportional changes in silvicultural costs and yields with and without 2,4,5-T are shown in Figure 3. These values compare the average undiscounted management costs of alternatives on potential use areas. They could be viewed as likely changes in silvicultural budgets if 2,4,5-T is not available.

If 2,4,5-T becomes unavailable, costs are expected to decrease slightly in northwestern Oregon, but yields will also be reduced. Anticipated budget costs of alternatives increase in all other areas, reaching a maximum in southwestern Oregon. The likely management alternatives in this area would require a 67 percent increase in silviculture budgets, but even with these added expenditures, yields would be reduced by 23 percent. Similar comparisons can be made for each geographic area.

STATE IMPACTS

TIMBER SUPPLY IMPACTS

Reductions in timber yield without 2,4,5-T have been expressed only in terms of loss on areas that would potentially use 2,4,5-T for one or more silvicultural operations. However, these areas represent only a portion of the total commercial forest land area (table 1). To assess the net change in wood volume production with and without 2,4,5-T, the entire commercial forest land area must be evaluated. To simplify this analysis, changes in wood production on areas using 2,4,5-T are expressed as a proportion of change in production on all commercial forest lands in each region (table 14).[1] This analysis assumes

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[1] Procedural details are shown in Appendix B.

Table 9--Silvicultural substitutes for 2,4,5-T in eastern Oregon

Silvicultural Substitutes for 2,4,5-T	Percent Replacement for 2,4,5-T	Percent [1/] Yield
Release		
No Release	39%	66%
Mechanical	33%	80%
Other Chemical	28%	90%

[1/] Percentage of full yield obtainable with 2,4,5-T under typical management regime.

Table 10--Management with and without 2,4,5-T in eastern Oregon

Practice	Stand Age		Revenue or Cost (-) 2/		Volume	
	With 1/	W/O 1/	With	W/O	With	W/O
	yrs.	yrs.	$/acre	$/acre	cunits/acre	
Planting Operations	0	0	-130	-130		
Release	6	6	-60	-144 3/		
Precommercial Thin	13	20	-85 4/	-85		
Commercial Thin	40	--	249	none	4.0	none
Commercial Thin	60	60	461	548	7.4	8.8
Commercial Thin	80	80	498	386	8.0	6.2
Harvest	120	120	3,340	2,575	40.2	31.0
Slash Disposal	120	120	-110	-110		

1/"With" refers to "with 2,4,5-T," i.e., the typical management practices. "W/O" refers to "without 2,4,5-T," i.e., the alternative management practices.

2/Revenues and costs are for a single rotation, current dollars.

3/Weighted average cost of substitute treatments for 2,4,5-T identified in Table 9; see Appendix B for method.

4/Because of initial stocking levels and anticipated early stand development, precommercial thinning is estimated to be needed on only 35 percent of the land area. This proportional treatment was used in the economic analysis.

Table 11--Potential productivity with and without 2,4,5-T for areas which would use 2,4,5-T for vegetation management

Geographic Area	Potential Productivity Mean Annual Increement with 2,4,5-T cu. ft./ acre/year)	without 2,4,5-T cu. ft./ acre/year)	Difference 1/ cu.ft./ acre/year	percent
Northwestern	197	158	-39	-19%
Southwestern	134	103	-31	-23%
Cascade Range	152	128	-24	-16%
Eastern	50	38	-12	-23%

---

[1] Compared with potential productivity with 2,4,5-T. Percentages are adjusted to compensate for rounding differences in DFIT simulations.

Table 12--Benefit-cost ratios for management with and without 2,4,5-T in Oregon

Geographic Area	Management Alternative	Benefit-cost Ratio at Discount Rate of:			
		4%	6-5/8%	8%	10%
Northwestern	With 2,4,5-T	24.98	6.73	3.58	1.54
	Without 2,4,5-T	20.37	5.21	2.66	1.06
Southwestern	With 2,4,5-T	19.27	3.80	1.79	.67
	Without 2,4,5-T	9.12	1.68	.76	.26
Cascades	With 2,4,5-T	19.32	4.55	2.29	.92
	Without 2,4,5-T	16.82	3.74	1.81	.68
Eastern	With 2,4,5-T	5.24	.74	.33	.13
	Without 2,4,5-T	2.98	.36	.14	.04
State	With 2,4,5-T		4.13		
	Without 2,4,5-T		2.43		

TABLE 13--Present net worth per acre for management with and without 2,4,5-T in Oregon

Geographic Area	Management Alternative	Present Net Worth at Discount Rate of: 4%	6-5/8%	8%	10%
Northwestern	With 2,4,5-T	6,413	1,349	591	121
	Without 2,4,5-T	5,023	962	368	13
	Difference	1,390	387	223	108
Southwestern	With 2,4,5-T	4,201	578	158	-65
	Without 2,4,5-T	2,955	218	-74	-212
	Difference	1,246	360	232	147
Cascades	With 2,4,5-T	4,801	805	280	-16
	Without 2,4,5-T	4,014	598	168	-64
	Difference	787	207	112	48
Eastern	With 2,4,5-T	841	-48	-119	-151
	Without 2,4,5-T	515	-152	-195	-207
	Difference	326	104	76	56
State	With 2,4,5-T		666		
	Without 2,4,5-T		378		
	Difference		288		
State (Total)[1]	Potential Level (253,000 acres treated annually)		$1.10 billion		
	Current Level (88,000 acres treated annually)		$383 million		

---

[1] The equation for a perpetual series of annual payments was used to estimate present net worth loss without 2,4,5-T.

$V_o = \frac{a}{i}$ Where V_o = present net worth;
a = periodic payment (i.e. net revenue or cost; or difference in per acre value); and
i = annual interest rate (i.e. 6 5/8 percent).

$$\text{e.g.} \quad V_o = \frac{(\$288/\text{acre})(253{,}000 \text{ acres})}{0.06625}$$

that the 2,4,5-T acres are of average productivity. In fact, 2,4,5-T acres tend to be more productive, thereby supporting more competing vegetation that must be controlled. Thus, the weighted average yield impact in each region tends to be a conservative estimate.

These yield impacts were applied to long-term projections of timber supply in order to estimate total volume reduction within each region.[1] This expansion of results is based on the assumption that per-acre changes in productivity from this 2,4,5-T assessment are directly proportional to changes in productivity for the area as a whole. The results are shown in figures 4-8. The intensity of management now being practiced in Oregon is approximated by the "A-1" level (Beuter et al. 1976). Management at this level would result in a timber supply decline in western Oregon by the year 2000. The curves reflecting a higher level of management, labeled "FPFO", are based on maintaining future harvest levels at or above the current harvest levels (OSDF 1977). [2]

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[1] The general form of the projection is given by the equation:

$$\begin{array}{l}\text{supply at year } n\\ \text{without 2,4,5-T}\end{array} = (1-a) + ay \quad S_n$$

Where: a = proportion of area using 2,4,5-T
y = proportion of full yield attainable without 2,4,5-T
S_n = projected supply at year n

[2] Both projection studies cited used linear programing techniques which may give substantially different results from per-acre projections. However, in a comparison of both techniques on the Siskiyou National Forest in southwestern Oregon, the per-acre projection method gave approximately the same result as linear programing using Timber-RAM (Navon 1971). These results are on file with USDA Forest Service, Pacific Northwest Region, Portland, Oregon.

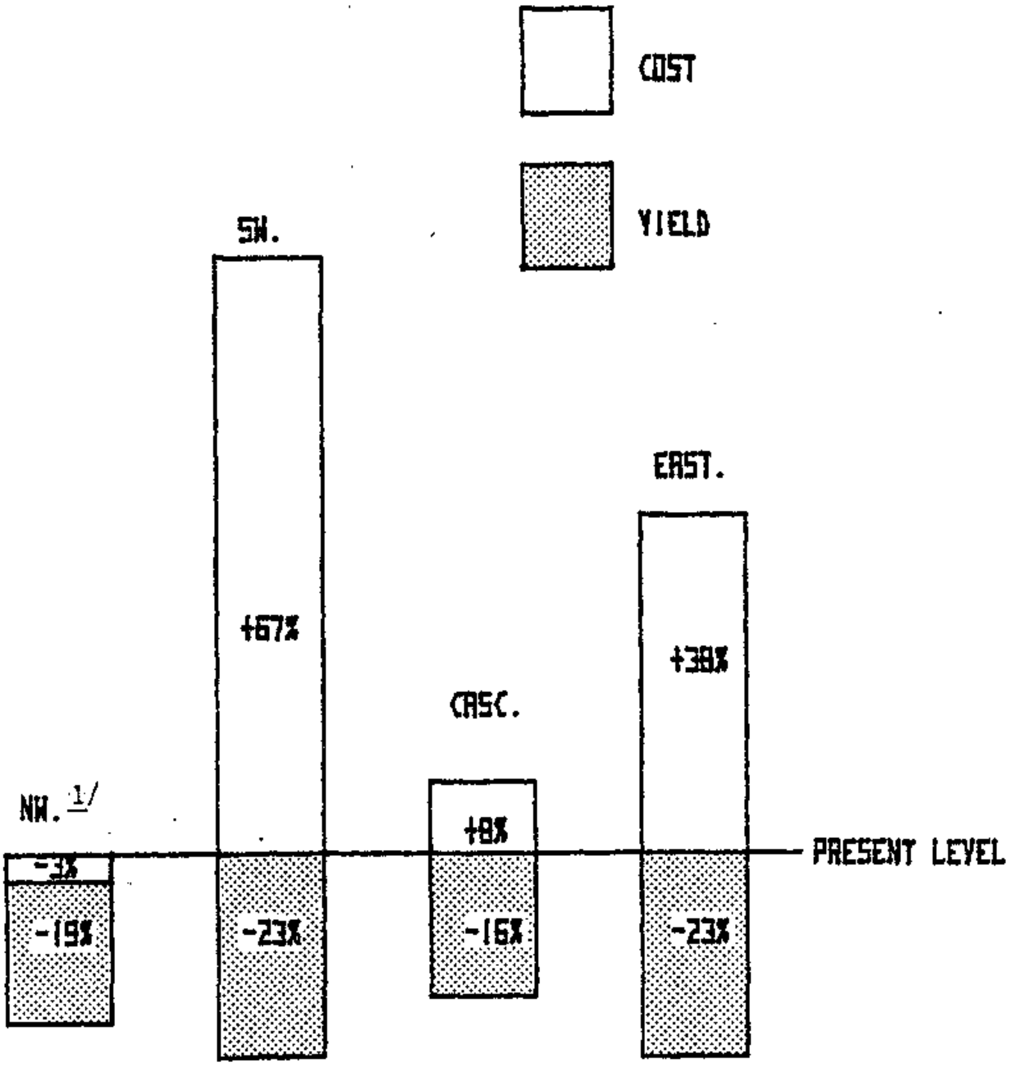

FIGURE 3. CHANGES IN SILVICULTURE COSTS AND TIMBER YIELDS ON POTENTIAL USE AREAS IF 2,4,5-T IS UNAVAILABLE.

[1] This decrease in silvicultural costs in northwestern Oregon occurs because alternatives to 2,4,5-T, though less effective, are only slightly more expensive in this region, and 15 percent of the time no release is done (and no expense incurred). The combined impact is a slight reduction in silvicultural cost.

Table 14--Summary of yield effects for management without 2,4,5-T

Region	Yield on 2,4,5-T Areas	Overall Yield [1]
Northwestern	81%	86%
Southwestern	77%	83%
Cascades	84%	93%
Eastern	77%	96%
State	--	89%

[1] Percentage of full yield obtainable with 2,4,5-T. Includes the yield from 2,4,5-T areas plus the areas not requiring 2,4,5-T. See equation, footnote 2, p. 30.

In northwestern Oregon, for example, yield without 2,4,5-T is 86 percent of the potential yield with 2,4,5-T. Total harvest would decline about 14 percent from the projected 300 million cubic feet per year[1] through the year 2000--a loss of 42 million cubic feet (206 million board feet) annually. Thereafter, as the full yield potential with 2,4,5-T rose, potential impacts would increase, culminating in losses of over 45 million cubic feet (220 million board feet) per year by the year 2070 if 2,4,5-T were unavailable and no new substitutes were introduced.

EMPLOYMENT IMPACTS

One of the most critical social and economic changes resulting from a reduction of timber supplies is loss of employment. About 20,000 jobs will potentially by lost if 2,4,5-T is unavailable (table 15, figure 9), based on timber supply projections for the first three decades. The economic impact of this job loss is additional to the loss of stumpage revenue.

SUMMARY

If 2,4,5-T is unavailable for forestry use in Oregon, a range of substitute practices would be used in the four major areas of the State. In some situations, no suitable substitutes are available. These practices generally result in increased silvicultural costs ranging from -3 percent to +67 percent of present levels. They are less efficient economically than the use of 2,4,5-T on potential use areas. Furthermore, use of these alternatives could potentially result in a loss of more than $1.1 billion in present net worth and an 11 percent reduction in timber yield--a current annual loss of 936 million board feet. The employment impacts of this reduction are estimated to be about 20,000 jobs, including both primary and secondary employment.

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[1] Beuter et al. 1976, A-1 level.

These impacts would be most heavily felt in western Oregon. In this area, not only are vegetative types more dependent upon the use of herbicides, but timber supplies are also critically short (Beuter et al. 1976). If 2,4,5-T is not available, projections in this study indicate that current harvest levels in this area and the State as a whole cannot be maintained.

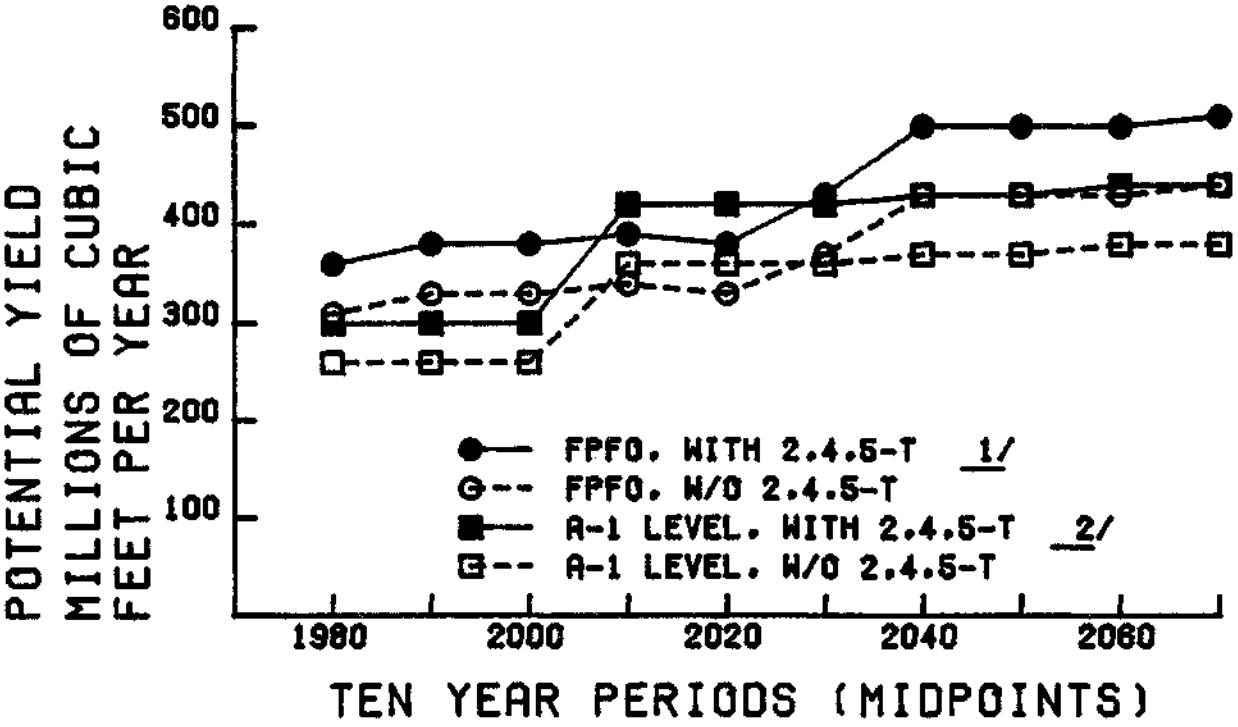

FIGURE 4. HARVEST PROJECTIONS FOR TWO MANAGEMENT INTENSITIES IN NORTHWEST OREGON, SHOWING ANTICIPATED LEVELS WITH AND WITHOUT 2,4,5-T.

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[1] FPFO: Forestry Program for Oregon (OSDF 1977). The anticipated level of management needed to maintain future harvest levels at or above current levels. Projected yield without 2,4,5-T would fall 14 percent short of FPFO potential.

[2] A-1 level (Beuter et al. 1976). The harvest levels anticipated if current policies and resultant management intensities are projected into the future. Projected yield without 2,4,5-T would fall 14 percent short of A-1 level.

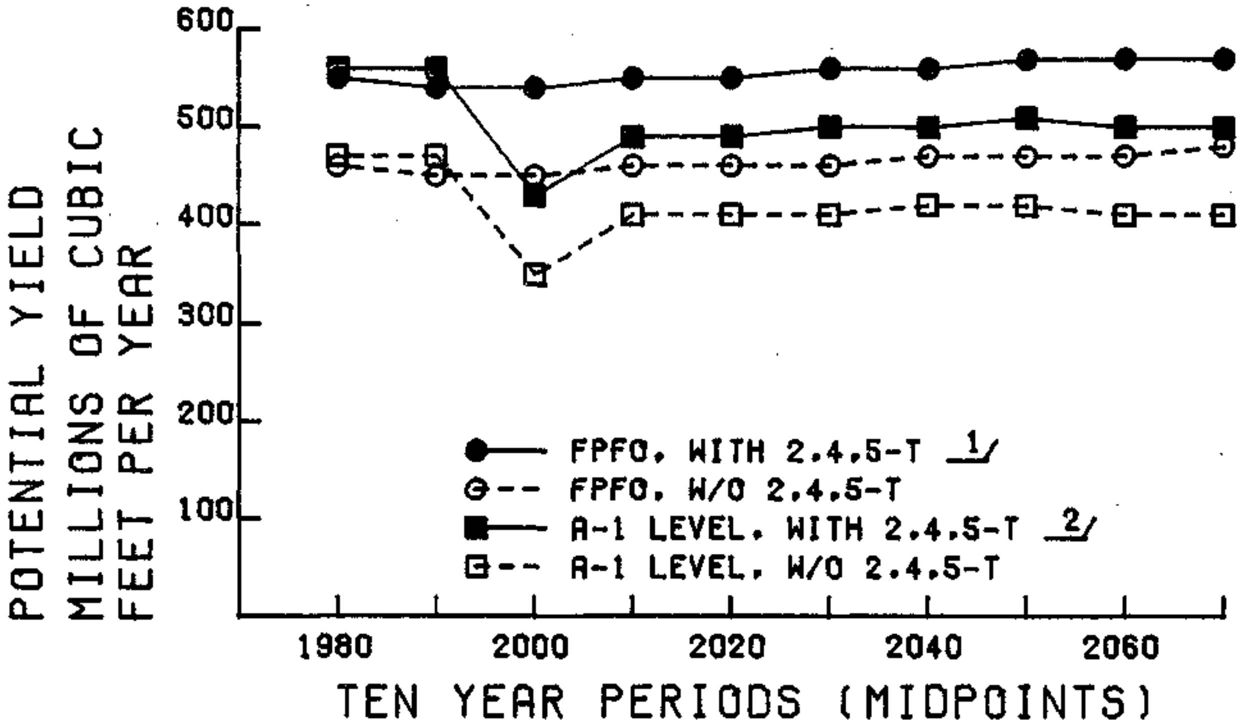

FIGURE 5. HARVEST PROJECTIONS FOR TWO MANAGEMENT INTENSITIES IN SOUTHWEST OREGON, SHOWING ANTICIPATED LEVELS WITH AND WITHOUT 2,4,5-T

[1] FPFO: Forestry Program for Oregon (OSDF 1977). The anticipated level of management needed to maintain future harvest levels at or above current levels. Projected yield without 2,4,5-T would fall 17 percent short of FPFO potential.

[2] A-1 level (Beuter et al. 1976). The harvest levels anticipated if current policies and resultant management intensities are projected into the future. Projected yield without 2,4,5-T would fall 17 percent short of A-1 level.

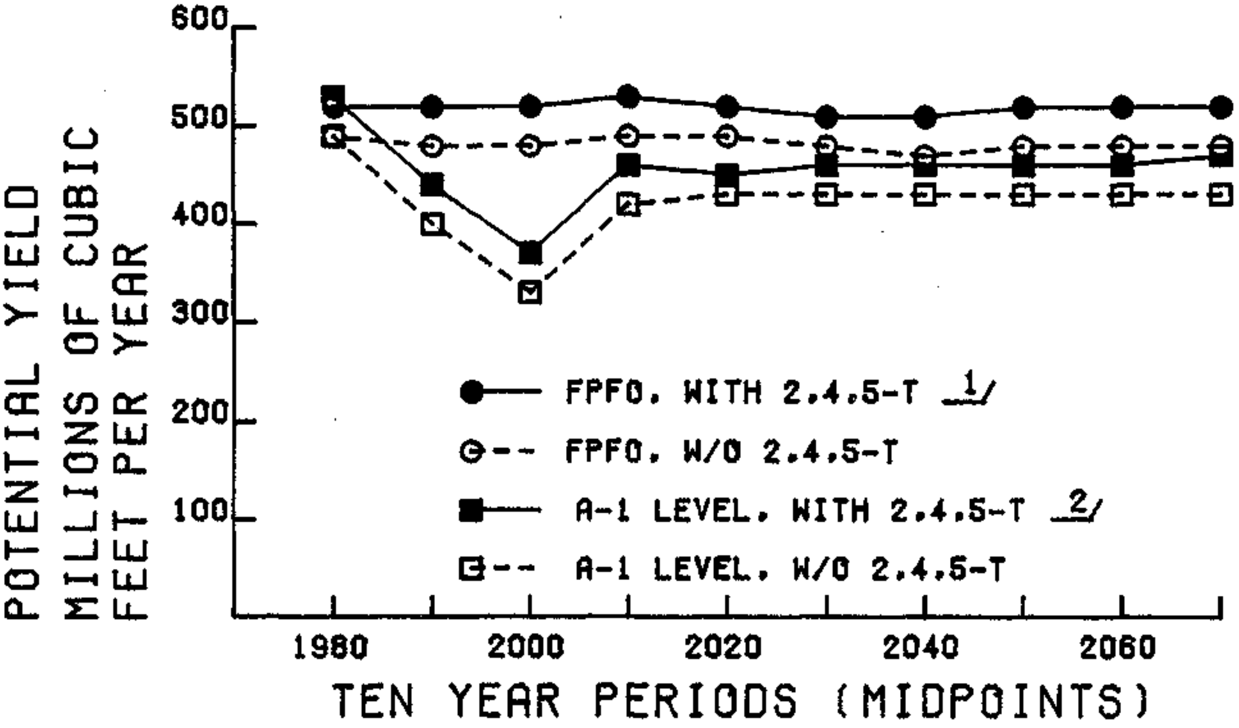

FIGURE 6 . HARVEST PROJECTIONS FOR TWO MANAGEMENT INTENSITIES IN CASCADES OF OREGON, SHOWING ANTICIPATED LEVELS WITH AND WITHOUT 2,4,5-T

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[1] FPFO: Forestry Program for Oregon (OSDF 1977). The anticipated level of management needed to maintain future harvest levels at or above current levels. Projected yield without 2,4,5-T would fall 7 percent short of FPFO potential.

[2] A-1 level (Beuter et al. 1976). The harvest levels anticipated if current policies and resultant management intensities are projected into the future. Projected yield without 2,4,5-T would fall 7 percent short of A-1 level.

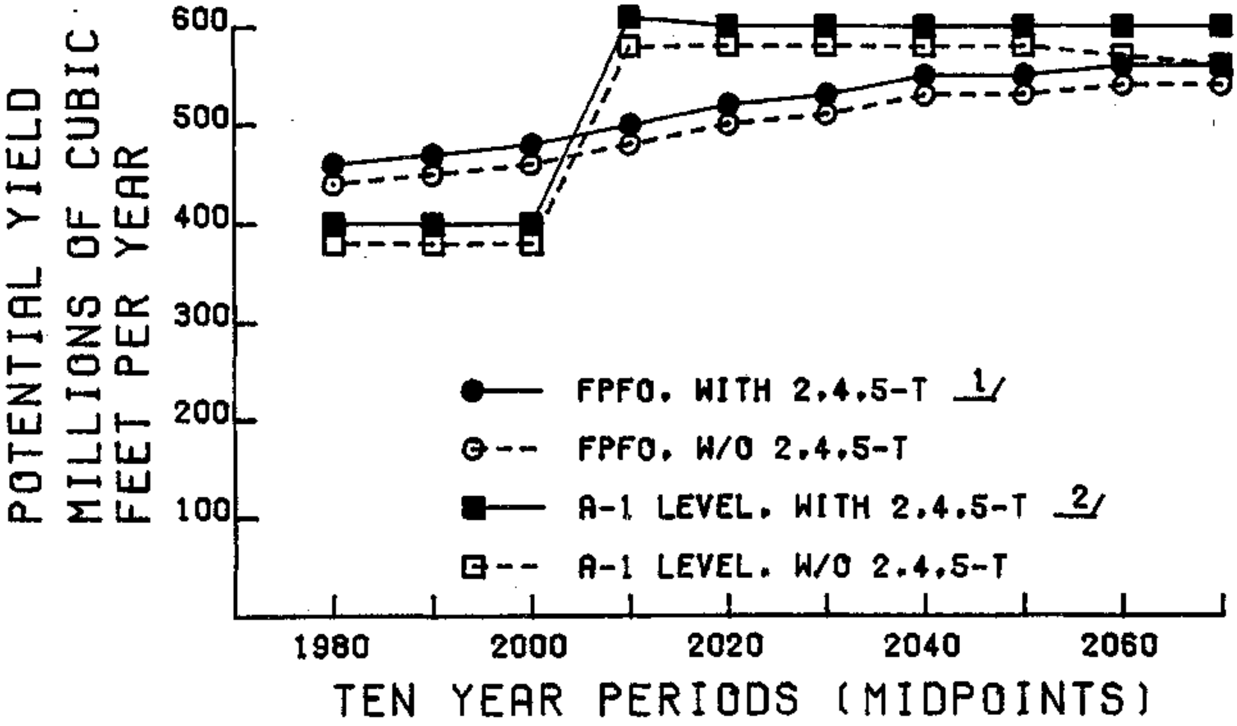

FIGURE 7 . HARVEST PROJECTIONS FOR TWO MANAGEMENT INTENSITIES IN EASTERN OREGON, SHOWING ANTICIPATED LEVELS WITH AND WITHOUT 2,4,5-T

[1] FPFO: Forestry Program for Oregon (OSDF 1977). The anticipated level of management needed to maintain future harvest levels at or above current levels. Projected yield without 2,4,5-T would fall 4 percent short of FPFO potential.

[2] A-1 level (Beuter et al. 1976). The harvest levels anticipated if current policies and resultant management intensities are projected into the future. Projected yield without 2,4,5-T would fall 4 percent short of A-1 level.

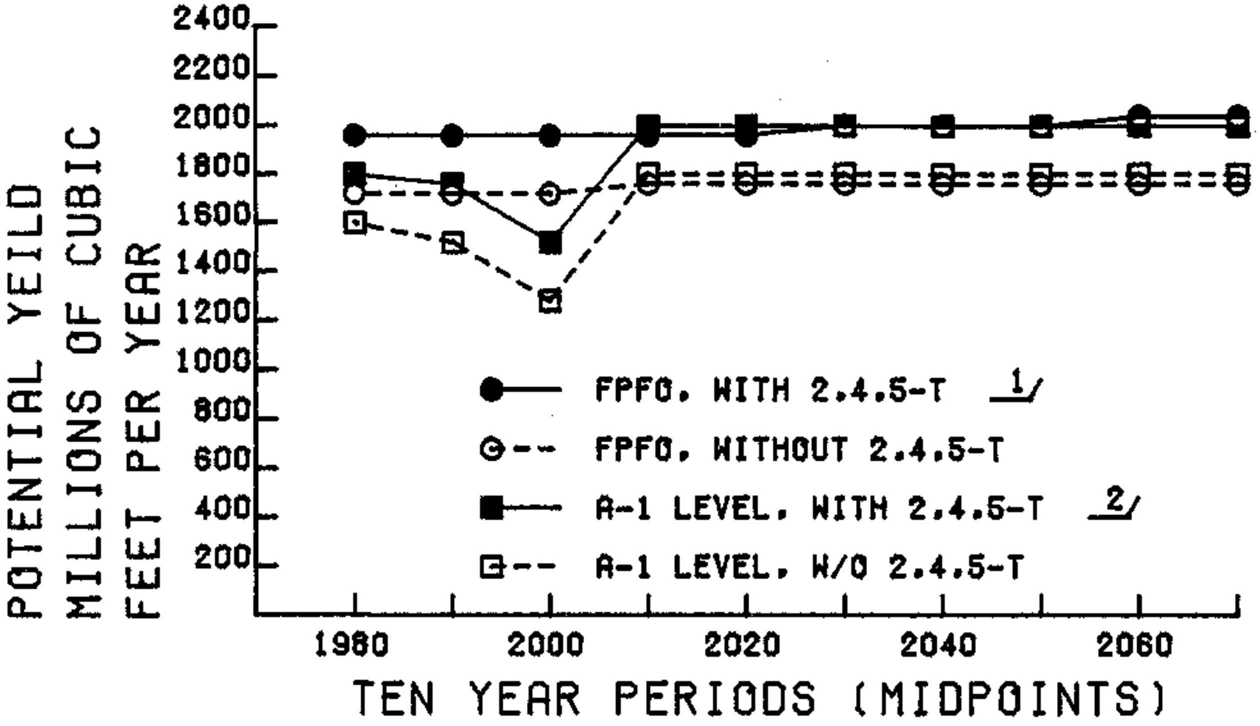

FIGURE 8. HARVEST PROJECTIONS FOR TWO MANAGEMENT INTENSITIES IN STATE OF OREGON, SHOWING ANTICIPATED LEVELS WITH AND WITHOUT 2.4.5-T

[1] FPFO: Forest Program for Oregon (OSDF 1977). The anticipated level of management needed to maintain future harvest levels at or above current levels. Projected yield without 2,4,5-T would fall 11 percent short of FPFO potential.

[2] A-1 level (Beuter et al. 1976). The harvest levels anticipated if current policies and resultant management intensities are projected into the future. Projected yield without 2,4,5-T would fall 11 percent short of A-1 level.

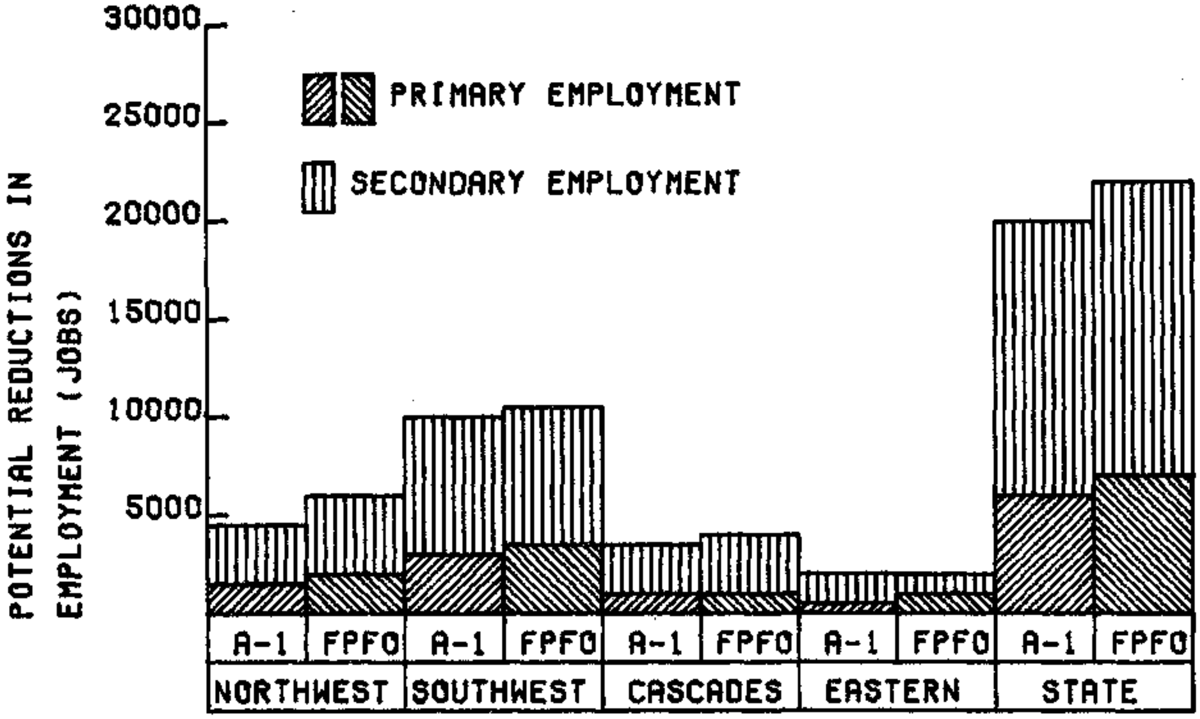

FIGURE 9. POTENTIAL REDUCTIONS IN TIMBER-RELATED EMPLOYMENT, 1980-2000, FROM LOSS OF 2,4,5-T

Table 15--Potential losses in yield and employment if 2,4,5-T is unavailable in Oregon 1/

	Geographic Area				
	Northwestern	Southwestern	Cascades	Eastern	State Total
	---Yield impacts, MMCF (percent)---				
Current Annual Yield	300	563	530	400	1,793
Reduction Without 2,4,5-T	-42(-14%)	-96(-17%)	-37(-7%)	-16(-4%)	-191(-11%)
Yield Without 2,4,5-T, MMCF	258	467	493	384	1,602
	---Yield impacts, MMBF---				
Current Annual Yield	1,470	2,759	2,597	1,960	8,786
Reduction Without 2,4,5-T	-206	-470	-181	-78	-936
Yield Without 2,4,5-T	1,264	2,289	2,416	1,882	7,850
	---Employment impacts, average job loss 1980-2000---				
Direct Employment Loss	1,546	3,235	1,145	589	6,515
Indirect Employment Loss	3,091	6,469	2,289	1,178	13,027
Total Employment Loss	4,637	9,704	3,434	1,767	19,542

1/Based on A-1 levels, representing current intensity of management. FPFO levels are approximately 13 percent greater.

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APPENDIX A

SOUTHWESTERN OREGON CASE ANALYSIS

In southwestern Oregon substitute vegetation management practices could be used on part of the commercial forest if 2,4,5-T were unavailable. These substitutes were discussed and analyzed within the body of the report using a composite approach (e.g., see tables 5 and 6).

The following discussion goes still further. It independently examines the effects of each of the major substitute methods by displaying likely yields and economic efficiencies. In essence, the discussion presents an expanded case analysis for a major timber producing area within Oregon.

RELEASE

The total area which would use 2,4,5-T was described in table 1. In southwestern Oregon, 58 percent of the commercial forest land would use 2,4,5-T just for release. Site preparation on these areas would result from logging and slash disposal from the previous rotation. Thus, the early stand development costs prior to release are the same for 2,4,5-T and its alternatives. It is only at the time of release treatment that differences between alternatives become apparent. From this point on, the cost and yield differences from the use of 2,4,5-T or its substitutes can be evaluated.

These effects are displayed in table A-1. It should be noted that if 2,4,5-T is unavailable, the next most efficient method may not be an alternative on a particular site. For example, although other chemical substitutes are economically more efficient than hand slashing or no release treatment, these chemicals will not effectively control many of the vegetative types in southwestern Oregon. This is why other chemical substitutes would be selected only about half the time (table 5).

Table A-1--The expected efficiency of alternative release methods on areas which would potentially use 2,4,5-T in southwestern Oregon 1/

			Economic Efficiency 3/		
			Present Net Worth		
Release Method	Percent Use 2/	Percent Timber Yield		Diff. From 2,4,5-T 4/	Benefit-Cost Ratio
2,4,5-T	--	100%	$612	--	4.23
Other Chemical	50%	95%	$518	-$94	3.51
No Release	35%	60%	$196	-$416	2.34
Hand Slashing	15%	85%	-$273	-$885	.70

1/Assumes site preparation was accomplished from logging and slash disposal in the previous rotation.
2/Percent of time the method would be used if 2,4,5-T were unavailable. From survey of silviculturists.
3/At Water Resources Council rate, 6-5/8 percent discount.
4/The expected difference in present net worth of the substitute method is used to replace 2,4,5-T.

Table A-2--The expected efficiency of alternative methods for site preparation, rehabilitation, and release in southwestern Oregon[1]

	Method of Release											
	2,4,5-T			Other Chemical			None			Hand Slash		
Method of Site Preparation	Yield % [2]	PNW $	B/C	Yield %	PNW $	B/C	Yield %	PNW $	B/C	Yield %	PNW $	B/C
2,4,5-T	100%	$534	3.14									
Clean Logging				54%	$114	1.59	33%	$10	1.07	52%	-$624	.31
Hand Slash-Other Chemical-Fire				90%	$130	1.26	55%	-$145	.68			
Fire				86%	$442	3.30	52%	$137	1.94			
Method of Rehabilitation												
2,4,5-T	100%	$364	2.01									
Other Chemical				76%	$81	1.18	47%	-$150	.62			
No Rehabilitation							11%	-$80	.45			
Hand Slash-Other Chemical-Fire				90%	$130	1.26	55%	-$145	.68	86%	-$564	.53

[1] Does not include areas which would use 2,4,5-T only for release.

[2] Yield is in comparison with use of 2,4,5-T.
PNW = Present Net Worth
B/C = Benefit-Cost Ratio

OTHER TREATMENTS

The herbicide 2,4,5-T is used for rehabilitation and release on 2 percent and for site preparation and release on 15 percent of the commercial forest land in southwestern Oregon. The most likely management substitutes for 2,4,5-T for site preparation, rehabilitation, and release combinations are shown in table A-2. These substitutes are contrasted with management with 2,4,5-T to show yield effects and economic efficiencies as in the previous case where release alone was examined. The analysis isolates the specific management practices rather than building a composite analysis such as that used in the main report.

APPENDIX B

SAMPLE DERIVATION OF YIELD IMPACTS

The following calculations show how the impact of cancelling forestry uses of 2,4,5-T was calculated for each silvicultural operation and how the weighted average impact for each region was derived. The Northwest Coast Range is used as an example.

STEP 1.

Selection of alternatives to 2,4,5-T. Based on the survey, the following alternative management practices were identified by one or more silviculturists for each operation. Those with an asterisk were, by consensus, the most prevalent. The proportion of use within the region for the most prevalent alternatives as derived from the survey is shown in the right-hand column. "Chemical" refers to the use of alternative chemicals that are currently registered for use.

Site Preparation Alternatives	Proportion of Use
*Chemical	0.15
*Fire	0.30
*Chemical and Fire	0.35
*No Management (clean log only)	0.20
Mechanical	--
Hand	--

Rehabilitation Alternatives	Proportion of Use
*Chemical	0.35
*Slash, Chemical, and Fire	0.50
*No Management	0.15
Chemical and Fire	--
Mechanical	--

Release Alternatives	Proportion of Use
*Chemical	0.85
*No Management	0.15
Hand	--

STEP 2.

Calculation of weighted average yield impact by silvicultural operation. Survey respondents estimated the yield impact (i.e., difference in yield attributable to using an alternative practice instead of a practice including 2,4,5-T). The average response of each alternative is shown below. The weighted average impact for each silvicultural operation overall was derived by multiplying the proportion of use by the yield impact for each alternative and summing the products.

Site Preparation

Alternative	Average Estimated Yield Impact*	Proportion of Use	Product (Yield x Use)
Fire	0.90	0.30	0.27
Chemical	1.00	0.15	0.15
Chemical and Fire	1.00	0.35	0.35
No Management (clean log)	0.70	0.20	0.14
Weighted Average			0.91

Rehabilitation

Alternative	Average Estimated Yield Impact*	Proportion of Use	Product (Yield x Use)
Chemical	0.85	0.35	0.30
Slash, Chemical, and Fire	1.00	0.50	0.50
No Management	0.10	0.15	0.015
Weighted Average			0.81

Release

Alternative	Average Estimated Yield Impact*	Proportion of Use	Product (Yield x Use)
Chemical	0.90	0.85	0.77
No Management	0.55	0.15	0.08
Weighted Average			0.85

*Estimated yield impacts are expressed as a proportion of yield obtainable with 2,4,5-T.

STEP 3.

Calculation of yield impact by not using 2,4,5-T in each region. A weighted average yield impact in each region was derived by multiplying the proportion of each silvicultural operation by its corresponding yield impact and adding the products. Survey results indicated that the number of acres needing 2,4,5-T for release equalled the total acres using 2,4,5-T for one or more silvicultural operations. It is assumed that 2,4,5-T is used for release on all the 2,4,5-T acres. In addition, it is also used for site preparation and rehabilitation on a portion of these areas. Thus, three combinations of silvicultural operations with 2,4,5-T had to be proportioned to derive a weighted yield impact; namely, site preparation and release, rehabilitation and release, and release alone. The example below shows how the operations were proportioned and the weighted average yield impact calculated.

	(Thousands of Acres)
a. Commercial forest land in N.W. Oregon[1]	2,871.40
b. Total use of 2,4,5-T in region = 75 percent of a.[2]	2,153.55
c. Total acres of rehabilitation[3]	510.77
d. Rehabilitation with 2,4,5-T = 50 percent of c.[2]	255.39
e. Remaining acres needing 2,4,5-T = 2,153.55 - 255.39 =	1,898.16
f. Site preparation with 2,4,5-T = 30 percent of e.[2]	569.45
g. Release only with 2,4,5-T is e. - f. =	1,328.71

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[1] Data from Pacific Northwest Forest and Range Experiment Station.

[2] Consensus estimate from survey.

[3] Data from adding "nonstocked regeneration" and "conversion" acres from beginning inventory in Beuter et al., 1976.

Summary of Proportions of 2,4,5-T Operations in northwest Oregon

Operations	Thousands of Acres	Percent
Rehabilitation and Release	255.39	12
Site Preparation and Release	569.45	26
Release Only	1,328.71	62
TOTAL	2,153.55	100

h. Weighted yield impacts using proportions and yield impacts by operation (from Step 2):

	Yield Effects		Prop. of Area		Product
Rehabilitation and Release	0.81 x 0.85	x	0.12	=	0.08
Site Preparation and Release	0.91 x 0.85	x	0.26	=	0.20
Release Only	0.85	x	0.62	=	0.53
Weighted Average =					0.81

Thus, without 2,4,5-T there is a projected 19 percent growth or yield reduction in the northwest Oregon region compared to similar management intensity using 2,4,5-T on total 2,4,5-T acres.

To find the overall yield impact on all commercial forest land in the region, those acres not needing 2,4,5-T for any silvicultural operation must be taken into account:

Acres using 2,4,5-T	0.75 x 0.81 (from Step h.)	= 0.61
Acres not using 2,4,5-T	0.25 x 1.00 (full yield)	= 0.25
Weighted average overall yield impact		= 0.86

APPENDIX C

AMOUNT OF 2,4,5-T USED IN SILVICULTURAL OPERATIONS

CURRENT USE OF 2,4,5-T

The 1976-1977 use of 2,4,5-T for forestry operations in Oregon was determined by surveying commercial and private aerial applicators. [1] Nineteen companies located in the Pacific Northwest were contacted. Of these, six companies had applied 2,4,5-T in Oregon for forestry purposes in either 1976 or 1977. State and federal land management agencies and most major private owners contracted with one or more of these six applicators to spray 2,4,5-T on their forest lands. These companies sprayed about 81,000 acres in calendar year 1976 and 95,000 acres in calendar year 1977, an average of 88,000 acres per year. Based on current trends, use appears to be increasing in Oregon.

Applicators and agency representatives estimated that figures supplied by these respondents accounted for over 85 percent of the aerial applications for forestry in Oregon during those years. A 100 percent survey was beyond the scope and limitations of this study. Details of the survey are on file.

CURRENT VERSUS POTENTIAL USE

Oregon has about 24 million acres of commercial forest land. Less than half of that acreage, about 11 million acres, has the type of ground cover that might require the application of 2,4,5-T to control undesirable plant species during commercial forest management. Silvicultural operations that require 2,4,5-T occur only during the early ages of a new stand of trees (i.e., 0 to 10 years); older stands in the state do not require the use of 2,4,5-T for effective forest management. Generally, 2,4,5-T is applied from one to three times on

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[1] Over 98 percent of all 2,4,5-T for forestry in Oregon was applied aerially as estimated by the survey of silviculturists.

applicable acres during each rotation. Thus, only a small portion of the 11 million acres that might require 2,4,5-T would need treatment in any given year, as depicted in figure C-1, because the large majority of the forest would be older and established.

If all commercial forest lands in Oregon were managed at the intensity assumed in this report, an average of about 253,000 acres per year would require treatment with 2,4,5-T. This is the highest annual application rate which could be expected in the future. Not every commercial forest acre is presently managed this intensively, so the application rate in Oregon averages 88,000 acres per year.

For a variety of reasons that encompass landowner objectives as well as economic, political, and social constraints, the reasonable potential use level in Oregon is not likely to reach the maximum potential use. For example, some of the current constraints include the following:

* Small nonindustrial private lands generally are not managed as intensively as forest lands in other ownerships (because of other management objectives or constraints) and therefore use less 2,4,5-T than the assumed management at the potential level.

* Bureau of Land Management policy precludes the use of 2,4,5-T on forest lands in Oregon.

* National Forest lands include a large area of old growth timber that will not require 2,4,5-T until it is harvested and regenerated.

* Temporary management constraints have been imposed on the aerial application of 2,4,5-T on all forest lands through the Oregon

Forest Practices Act. These restrictions include a 200-foot buffer strip on each side of specified streams and roads and a 500-foot buffer around residences. [1]

This residence buffer has been extended to 1 mile on National Forest lands. Other restrictions have occurred, such as the 1977 court injunction against use of 2,4,5-T on the Siuslaw National Forest. This ban was extended to all National Forest lands in Washington and Oregon, but was lifted following completion of a revised environmental statement.

* Current management intensity for some owners and areas of the State is less than the maximum potential level of management. This is attributable to many reasons, including lack of awareness or knowledge, cash-flow problems, tax disincentives, owner objectives, funding constraints, environmental, political, or legal pressures from interest groups, and slow conversion from old growth to regulated forests.

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[1] The Oregon State Department of Forestry, in a recent unpublished study on its lands, estimated that 4 percent of the acreage in spray units could not be treated by aerial application of herbicides when buffer strips around streams were one swath width (50-75 feet); with 200-foot wide buffer strips, 18 percent of the acreage is left untreated.

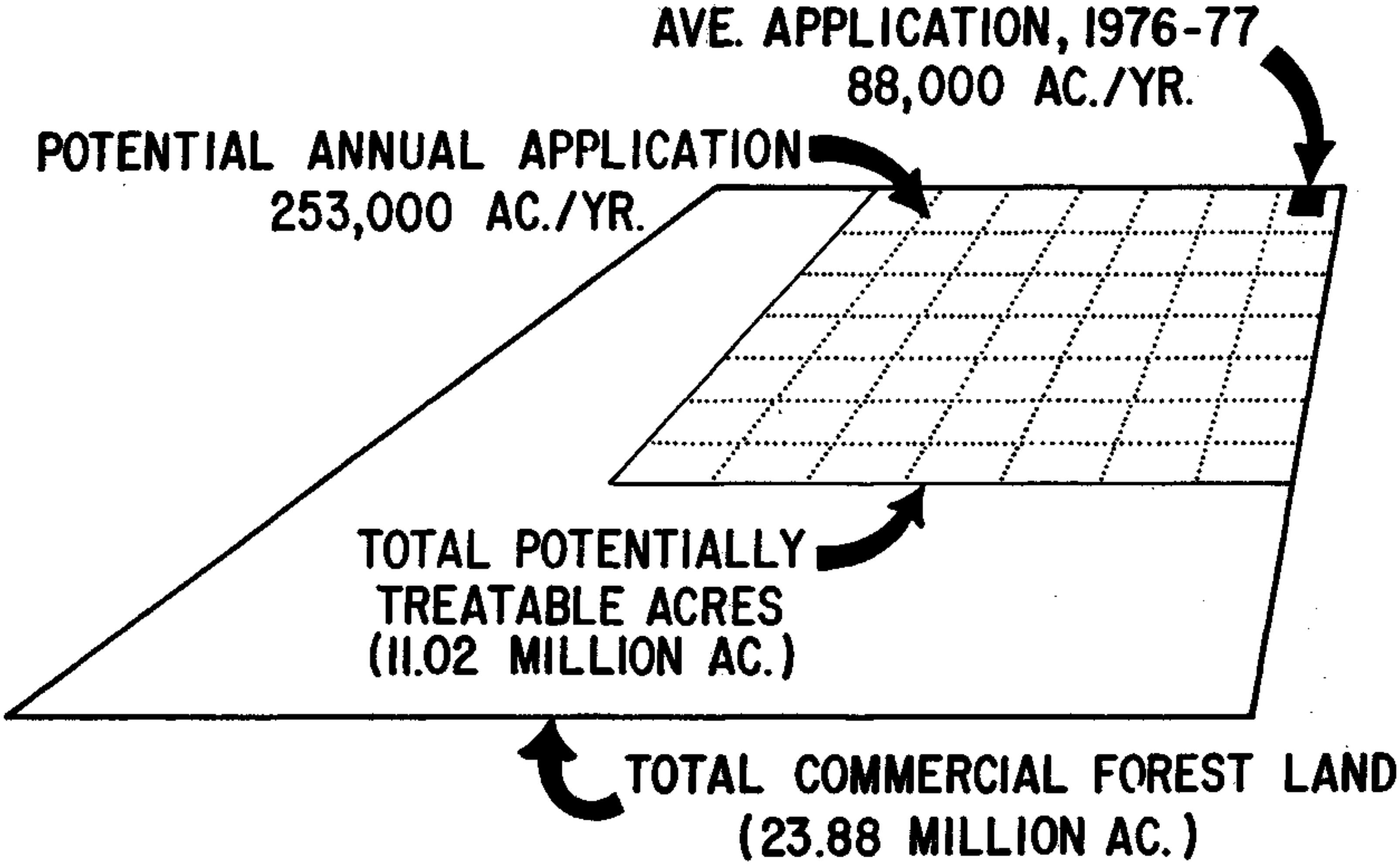

FIGURE C-1 HERBICIDE APPLICATION ON COMMERCIAL FOREST LAND IN OREGON.

APPENDIX 2

SUMMARY OF UNSOLICITED PUBLIC COMMENTS RECENTLY RECEIVED BY USDA ON THE USE OF 2,4,5-T

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The issue of public concern over the use of the herbicide 2,4,5-T is not simply stated. It is complicated and confused by many sub-issues. In the years since Rachel Carson wrote Silent Spring the public has become sensitized to the use of all pesticides. Although the initial focus of her book was on "broad spectrum insecticides," public attention has recently shifted more toward the vegetation-management chemicals—herbicides. Among these: 2,4,5-T now occupies center stage. This shift in attention appears to have resulted from:

1. Success in the regulation and restriction of the use of certain insecticides such as DDT, chlordane, heptachlor, aldrin, and dieldrin.

2. Use of a 2,4-D and 2,4,5-T formulation (Agent Orange) by the U.S. Armed Forces for military purposes in Vietnam and the general lack of support among young people for our involvement in that conflict.

3. Increasing uses of herbicides nationwide due to increasing food and fiber demands both domestic and abroad.

4. Adverse effects (from the growers' and users' points-of-view) of herbicides to destroy marijuana.

5. Presence of the toxic impurity 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) in 2,4,5-T.

6. Several recent chemical manufacturing plant accidents, industrial spills, and water-contamination incidents that are continuing to receive widespread media coverage.

These and similar considerations have changed public and scientific response to the use of herbicides from one of general indifference to one of considerable involvement in the decision-making process involving their use and regulation. Two major recent events have resulted in a considerable acceleration of public involvement; on April 11 the issuance of an RPAR on 2,4,5-T by EPA; and on April 27 the decision by the Assistant Secretary of Agriculture to personally review all proposals to use 2,4,5-T and related TCDD containing compounds on National Forest System lands. As a result, the U.S. Department of Agriculture (USDA) received, during March 1 to December 1, 1978, almost 1,000 unsolicited letters, mailgrams, and telegrams from persons concerned about the entire gamut of 2,4,5-T issues, including: registration, use, exposure, cost, alternatives, and policy on its use. A few of these were copies of information sent to EPA as a result of their issuance of the RPAR, but most were directed specifically to USDA.

The following paragraphs summarize the issues which received most attention in the correspondence.

HUMAN HEALTH

The area of human health hazard received a great amount of comment and is one of the most emotional issues relating to 2,4,5-T. Many citizens do not accept EPA registration as an adequate guarantee of safety. Instances of anecdotal information on adverse human health effects were presented in all forms of correspondence ranging from affidavits to appeals. Medical opinions supporting adverse effects due to 2,4,5-T exposure were presented in a few instances. Overwhelmingly, however, actual 2,4,5-T users reported no observed adverse human health effects. In fact, 134 users indicated a combined total of 2,650 person-years of experience with, and direct exposure to 2,4,5-T with no adverse effects. They strongly suggest that their ± 30 year record is the best evidence

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4. Adverse effects (from the growers' and users' points-of-view) of herbicides to destroy marijuana.

5. Presence of the toxic impurity 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) in 2,4,5-T.

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COST/BENEFIT ANALYSIS OF 2,4,5-T

Major concerns were expressed in the correspondence about the cost of 2,4,5-T relative to the costs of alternatives, and the benefits of using manual labor to assist local economies by reducing unemployment. Most of these responses dealt with the use of the herbicide for forest vegetation management. Throughout the correspondence against the use of 2,4,5-T there was concern that the frequently quoted costs of its use were inordinately low as compared to costs of alternatives. Actual use figures presented in the correspondence were computed for the various vegetation management alternatives as follows:

Cost Comparison

Vegetation management alternative	Average cost/acre of treatment	Range of costs	Number of respondents
Aerial release with 2,4,5-T	$ 20.53	$ 10-35	41
Manual release (without herbicide)	249.13	94-500	24
Mechanical release	147.95	60-375	11
Manual release (with herbicide using ground equipment)	80.13	68-123	4
Aerial site preparation with 2,4,5-T	20.00	10-35	3
Manual site preparation with herbicide	150.00	100-200	2

These actual costs indicate that 2,4,5-T is very cost effective and that alternatives, although used, are 7 to 12 times more expensive.

A related topic of discussion in the correspondence is the viewpoint that the use of manual labor could reduce local unemployment. This socio-economic counterbalance might thereby influence any decision where cost differential was being considered. In actual practice, however, the correspondence indicates that an available work force of manual laborers to do this kind of work simply does not exist in most areas.

ALTERNATIVES

There are a number of possible alternatives to the use of herbicides. However, their acceptability, as indicated in the correspondence, was highly dependent on the particular special interests of individual correspondents.

Manual control of vegetation was the most frequently proposed alternative to the use of herbicides. This method supposedly devoid of toxicological effects is seen as a highly desirable technique by many citizens. The major drawbacks of manual control expressed by those involved in vegetation management are those of cost, ineffectiveness necessitating repetitive treatments, lack of labor, human health hazard, and creation of excessive fire hazard through fuel concentration.

Mechanical control was suggested as a solution in some correspondence. Recognized by those involved in vegetation management as a viable alternative, mechanical control is dependent on gentle topography with well-drained soils and lack of large rocks or stumps. Soil compaction, erosion and nutrient leaching were discussed as frequently accompanying mechanical control operations.

Fire was also a frequently discussed alternative to herbicides. Although burning was preferred by some, it was recognized by those with actual use experience as having more dramatic ecological effects than herbicides.

The correspondence which involves over 3,100 pages of views, opinions, and factual data represents a broad cross-section of interests nationwide.

A content analysis of the correspondence indicates a ratio of 2.3:1 in favor of 2,4,5-T use in vegetation-management programs. This can be summarized as follows:

2,4,5-T USERS

	Number	Percent
Commercial (pest-control operators, industry representatives, consulting foresters, forest-products personnel, etc.)	186	20.2
Noncommercial (universities, weed-control districts, Government agencies, etc.)	5	.5
Private citizens (farmers, ranchers, homeowners, etc.)	86	9.3

NONUSERS

	Number	Percent		Number	Percent
Family of user	4	0.4	Governmental agency		
Forest resident	15	1.6	Federal	1	0.1
Woods worker	20	2.2	State	10	1.1
Recreationist	2	.2	Local	7	.7
Citizen	262	28.5	Organization/Assoc.	143	15.5
Elected Official	40	4.3	Industry Rep.	112	12.2
Academician	26	2.8	Other	1	0.1

Among 2,4,5-T users, commercial concerns represented primarily by professional or consulting foresters, accounted for the greatest number of responses (20.2%). Among non-2,4,5-T users, individual citizen response was the greatest, accounting for more than 28 percent of the total number of responses.

Correspondence from 277 persons expressed opposition to the use of 2,4,5-T in general, use of 2,4,5-T in Forest Service Regions 1 (Idaho), 5 (California), and 6 (Oregon and Washington) as outlined in their respective environmental statements, and use of chemical pesticides in general.

Opposition to the use of herbicides in the form of "Motions to Stay Decisions and Appeals" was received from 36 groups representing 1,221 persons as indicated by signed petitions, affidavits, and related appeal documentation.

Correspondence was received from 643 persons representing citizens, users, industry representatives, etc. supportive of the registration and use of 2,4,5-T. Herbicide-use support letters received from organizations and associations (e.g., National Cattleman's Association, American Farm Bureau, Society for Range Management, Western Environmental Trade Association, Society of American Foresters, Alaska Loggers Association, etc.) indicated a combined membership of more than 327,522 members in favor of continued use of 2,4,5-T.

In summary, it is apparent that in the future, the general public will expect persons involved in vegetation-management activities to fully examine all alternatives to the use of herbicides. The environmental consequences of both chemical and nonchemical alternatives may not be ecologically superior to the careful, safe use of currently registered herbicides documented by the many letters by actual users with long records of experience and exposure who strongly support the continued use of 2,4,5-T.

APPENDIX III

EXCERPTS FROM POSITION DOCUMENT - 1 (PD-1)

US EPA, 2,4,5-T WORKING GROUP

III. B. (3) Exposure Analysis

(a) Oral Exposure pages 102-104

For purposes of this analysis, the Working Group considered currently registered uses where the possibility of oral exposure to 2,4,5-T and/or TCDD existed. Treatment of range and pasture land could result in oral exposure through ingestion of meat and milk from animals grazing on the treated area. Since actual data on residues of 2,4,5-T in animals grazing on treated rangeland is unavailable, for purposes of the 2,4,5-T oral exposure analysis, the Working Group used residue information obtained in a feeding study (37) in which cattle were fed considerably higher amounts of 2,4,5-T than they would normally be exposed to in grazing on treated land. The following calculations are based on the average quantities of food eaten per day (1.5 kg), as reported by Lehman (144, 165).

To find the average daily intake of a single food item, multiply the average daily food intake by the percent of that item in the total diet: for milk, 1.5 kg X 19.6% = 0.294 kg; and for meat (beef), 1.5 kg X 4.6% = 0.069 kg.

The quantity of 2,4,5-T in the average daily diet equals the average daily intake of each food item multiplied by the level of 2,4,5-T in the food item: for milk, 0.294 kg X 0.103 ppm = 0.03 mg; and for meat (beef), 0.069 kg X 0.2 ppm = 0.014 mg.

The theoretical exposure of an average woman equals the amount of 2,4,5-T in the daily diet divided by the weight of the average woman: for milk, 0.03 mg / 60 kg = 0.0005 mg/kg; and for meat (beef), 0.014 mg / 60 kg = 0.0002 mg/kg; total exposure from milk and beef products could be 0.0007 mg/kg per day.

Existing data on TCDD residues in animals grazing on treated rangeland are too meager to use for an analysis of TCDD exposure to humans through ingestion of meat or milk from animals so exposed.

The Working Group considers that the difference between the no-adverse-effect level of 2,4,5-T for teratogenic effects (20 mg/kg) and the calculated oral exposure level for 2,4,5-T (0.0007 mg/kg per day) does constitute an

Table 25. 2,4,5-T Oral Exposure Analysis

	Whole Milk	Meat (Beef)
No-adverse-effect level for teratogenicity in mice	20 mg/kg	20 mg/kg
Average level of 2,4,5-T identified	0.103 ppm[a]	0.2 ppm[a]
% of food item in total human diet	19.6%	4.6%
Average amount of food eaten per day	1.5 kg	1.5 kg
Exposure to 2,4,5-T per day	0.0005 mg/kg	0.0002 mg/kg

[a] Animals were fed at 300 ppm 2,4,5-T in the diet for 2 to 3 weeks. This is a worst case assumption for cows grazing on freshly-treated pasture without a withdrawal period; all milk and meat was obtained from such cows. Meat (beef) includes muscle, fat, and liver tissues which constitute the major portion of edible meat.

ample margin of safety. Since this risk criterion for other chronic adverse effects has not been met or exceeded, a rebuttable presumption does not arise.

III. B. (3) Exposure Analysis
(b) Dermal
(i) Back Pack pages 105 - 108

For purposes of this analysis, the Working Group assumes the applicator to be a 60-kg woman of child-bearing age, and the site of application either a right-of-way or spot treatment of pasture or rangeland. The equipment is a back-pack sprayer (166). The following calculations of exposure are based on dilution for spraying of three pints of formulated product per 32 pints of water. Typical 2,4,5-T formulations, based on inspection of a large number of registered labels (164), range from 4 to 6 pounds active ingredient (acid equivalent) per gallon. The product used in this exposure analysis has an assumed concentration of 4 pounds 2,4,5-T per gallon. Label recommendations vary from a recommended dilution of 0.094 to 4 pounds acid equivalent per 32 pints of water. A dilution rate of 1.6 pounds per 32 pints has been selected as representative of a typically-used spray mixture.

Wolfe et al. (166) studied dermal exposure to fenthion during hand back-pack spraying for mosquitoes for ten situations. Exposure ranged from 0.1 to 6.3 mg/hr, with a mean value of 3.6 mg/hr (6 ml/hr). Method of application was a hand pressure sprayer, using a 0.06% spray. Workers wore short-sleeved, open-necked shirts with no gloves or hat. Based on Wolfe's data, CED (164) calculated a dermal exposure of approximately 0.177 pints per day. CED (164) also determined that approximately 10% of the 2,4,5-T and TCDD coming in contact with the skin of the applicators would be absorbed even after washing, based on absorption studies with other pesticides (145, 146, 163).

Table 26. Back-pack Sprayer Dermal Exposure Data

	2,4,5-T	TCDD
Use Dilution rate	3 pints (1.6 pounds 2,4,5-T) per 32 pints water	3 pints (0.00000016 pounds TCDD) per 32 pints water
Amount of diluted material gotten on skin daily	0.18 pint	0.18 pint
% Diluted material absorbed	10%	10%
Exposure level	409 mg	0.0409 ug
Dose level	6.8 mg/kg	0.0007 ug/kg
No-Adverse-Effect level for teratogenic effects	20 mg/kg	0.03 ug/kg

The following calculations (see Table 27 for mathematics) will give the daily dermal exposure for both 2,4,5-T and TCDD: 1) convert the dilution rate to grams; 2) multiply this figure by 1,000 (for 2,4,5-T) to convert to milligrams and by 1,000,000 (for TCDD) to convert to micrograms; 3) multiply this figure by the daily dermal dose of diluted material; 4) multiply this figure by the percent absorbed; and 5) divide this figure by the weight of the applicator for the daily exposure to 2,4,5-T or TCDD per 8-hour working day.

Table 27

2,4,5-T	TCDD
1) 1.6 pounds/32 pt X 454 g/-pound = 22.70 g/pt;	1) 0.00000016 pounds/-32 pt X 454 g/pound = 0.00000227 g/pt;
2) 22.70 g/pt X 1,000 mg/g = 22,700 mg/pt;	2) 0.00000227 g/pt X 1,000,000 ug/g = 2.27 ug/pt;
3) 22,700 mg/pt X 0.18 pt = 4,086 mg;	3) 2.27 ug/pt X 0.18 pt = 0.41 ug;
4) 4,086 mg X 10% = 408.6 mg	4) 0.41 ug X 10% = 0.041 ug;
5) 408.6 mg / 60 kg = 6.8 mg/kg per day	5) 0.041 ug / 60 kg = 0.0007 ug/kg per day

The Working Group considers that the difference between the no-adverse-effect level of 2,4,5-T for teratogenic effects (20 mg/kg) and this calculated dermal exposure level for 2,4,5-T (6.8 mg/kg), as well as the difference between the no-adverse-effect level of TCDD for teratogenic effects (0.03 ug/kg) and this calculated exposure level for TCDD (0.0007 ug/kg), do not constitute an ample margin of safety. The Working Group therefore recommends issuance of a rebuttable presumption against pesticide products containing 2,4,5-T and/or TCDD pursuant to 40 CFR Section 162.11(a)(3)(ii)(B).

III. B. (3) Exposure Analysis
(b) Dermal
(ii) Tractor Mounted pages 108 - 110

For the purpose of this analysis, the Working Group assumes the applicator to be a 60-kg female of child-bearing age clearing brush on either rangeland or rights-of-way. The same product cited above (2,4,5-T at 4 pounds/gal) is being used, and the dilution rate is 1.6 pounds of formulation to 32 pints of water (equal to 4 pounds of 2,4,5-T per 10 gallons of water). Based on exposure studies using similar equipment but a different herbicide (147), the Working Group determined that, during an eight-hour working day, the applicator would get 0.048 pints of diluted material on her skin. The Working Group determined that 10% of the pesticide on the skin would be absorbed (145, 146, 163).

Table 28. Dermal Exposure Data (Tractor Mounted Equipment)

	2,4,5-T	TCDD
Use Dilution rate	3 pints (1.6 pounds 2,4,5-T) per 32 pints water	3 pints (0.00000016 pounds TCDD) per 32 pints water
Amount of diluted material gotten on skin daily	0.048 pint	0.048 pint
% Diluted material absorbed	10%	10%
Exposure level	109 mg	0.0109 ug
Dose level	1.8 mg/kg	0.00018 ug/kg
No-Adverse-Effect level for teratogenic effects	20 mg/kg	0.03 ug/kg

The following calculations (see Table 29 for mathematics) will give the daily dermal exposure for both 2,4,5-T and TCDD: 1) convert the dilution rate to grams; 2) multiply this figure by 1,000 (for 2,4,5-T) to convert to milligrams and by 1,000,000 (for TCDD) to convert to micrograms; 3) multiply this figure by the daily dermal dose of diluted material; 4) multiply this figure by the percent absorbed; and 5) divide this figure by the weight of the applicator for the daily exposure to 2,4,5-T or TCDD per 8-hour working day.

Table 29

2,4,5-T	TCDD
1) 1.6 pounds/32 pt X 454 g/pound = 22.70 g/pt;	1) 0.00000016 pounds/32 pt X 454 g/pound = 0.00000227 g/pt;
2) 22.70 g/pt X 1,000 mg/g = 22,700 mg/pt;	2) 0.00000227 g/pt X 1,000,000 ug/g = 2.27 ug/pt;
3) 22,700 mg/pt X 0.048 pt = 1,089.6 mg;	3) 2.27 ug/pt X 0.048 pt = 0.109 ug;
4) 1,089.6 mg X 10% = 108.96 mg;	4) 0.109 ug X 10% = 0.011 ug;
5) 108.96 mg / 60 kg = 1.8 mg/kg per day	5) 0.011 ug / 60 kg = 0.00018 ug/kg per day

The Working Group considers that the difference between the no-adverse-effect level of 2,4,5-T for teratogenic effects (20 mg/kg) and this calculated dermal exposure level for 2,4,5-T (1.8 mg/kg), as well as the difference between the no-adverse-effect level of TCDD for teratogenic effects (0.03 ug/kg) and this calculated exposure level for TCDD (0.00018 ug/kg), do not constitute an ample margin of safety. The Working Group therefore recommends issuance of a rebuttable presumption against pesticide products containing 2,4,5-T and/or TCDD pursuant to 40 CFR Section 162.11(a)(3)(ii)(B).

III. B. (3) Exposure Analysis
(b) Dermal
(iii) Aerial Application pages 110 - 113

Caplan et al. (167), working with aerially applied malathion in oil sprays applied at 0.46 pounds per 0.76 gallons water/acre, determined a dermal exposure to persons directly beneath the spray plane for bare skin (head, neck, shoulders, forearms, hands, and thighs) of 3.556 mg/day. With these data, an equivalent dermal exposure for 2,4,5-T and TCDD, aerially applied at 4 pounds acid equivalent 2,4,5-T per 10 gallons water/acre, can be determined.

Table 30. Dermal Exposure Data (Aerial Application)

Dermal exposure to aerially applied malathion	3.556 mg/0.46 pounds malathion per acre	
	2,4,5-T	TCDD
Use Dilution rate	4 pounds 2,4,5-T per 10 gallons of water/acre	0.0000004 pounds TCDD per 10 gallons of water per acre
% Diluted material absorbed	10%	10%
Exposure level	3.1 mg	0.0003 ug
Dose level	0.051 mg/kg	5×10^{-6} ug/kg
No-Adverse-Effect level for teratogenic effects	20 mg/kg	0.03 ug/kg

The following calculations (see Table 31 for mathematics) will give the daily dermal exposure for both 2,4,5-T and TCDD: 1) divide the dermal exposure to malathion by the malathion application rate and multiply by the application rate of 2,4,5-T and TCDD to obtain the dermal exposure; for TCDD, multiply this figure by 1,000 to convert to micrograms; 2) multiply this figure by the percent absorbed; and 3) divide this figure by the weight of the applicator for the daily exposure to 2,4,5-T or TCDD per 8-hour working day.

Table 31

2,4,5-T	TCDD
1) 3.556 mg/0.46 pounds X 4 pounds = 31 mg;	1) 3.556 mg/0.46 pounds X 0.0000004 pounds = 0.000003 mg X 1,000 = 0.003 ug;
2) 31 mg X 10% = 3.1 mg;	2) 0.003 ug X 10% = 0.0003 ug;
3) 3.1 mg/ 60 kg = 0.051 mg/kg per day	3) 0.0003 ug / 60 kg = 5 X 10^{-6} ug/kg per day

The Working Group considers that the difference between the no-adverse-effect level of TCDD for teratogenic effects (0.03 ug/kg) and this calculated dermal exposure level for TCDD (5 X 10^{-6} ug/kg) does constitute an ample margin of safety. The Working Group also considers, however, that the difference between the no-adverse-effect level of 2,4,5-T for teratogenic effects (20 mg/kg) and this calculated dermal exposure level for 2,4,5-T (0.051 mg/kg) does not constitute an ample margin of safety. The Working Group therefore recommends issuance of a rebuttable presumption against pesticide products containing 2,4,5-T pursuant to 40 CFR Section 162.11(a)(3)(ii)(B).

III. B. (3) Exposure Analysis
(c) Inhalation pages 113 - 116

There are no studies available on inhalation exposure of 2,4,5-T. There are, however, several studies on inhalation exposure to malathion (167, 168) which CED used as a model for this 2,4,5-T exposure analysis (164). Caplan et al. (167) determined an air concentration, for unprotected persons directly beneath the spray plane during application and for two hours afterward, of 0.067 mg malathion/m^3 from aerial application of 0.46 pounds AI/gallon per acre. The collection period spanned the course of the actual application time plus two hours thereafter. The authors considered the sampling technique to be equivalent to average inspiration through the nostrils. This inhalation exposure (amount available for inhalation) was 12% of the applied malathion. Caplan et al. further reported that the average median diameter (= volume median diameter, or vmd[16]) was 109 microns. Based on work by Akesson and Yates (168), CED (164) estimated that the size of the malathion droplets which could be inhaled was under 60 microns. Since 2,4,5-T is typically applied as a medium or coarse spray, while malathion is applied as a fine spray, the percent of 2,4,5-T droplets small enough to be inhaled (under 60 microns) would be less than the percent of malathion droplets small enough to be inhaled. According to

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16/ The vmd is that droplet size which divides the total volume of drops in half, i.e., 50% of the volume is in drops above the vmd size and 50% below it.

Akesson and Yates (168), 2% of 2,4,5-T spray droplets would be available for inhalation (or 1/6 the amount of malathion droplets available for inhalation), on a "worst case" basis.

Table 32. Inhalation Exposure Data (Aerial Application)

Air concentration of aerially applied malathion	$0.067\ mg/m^3$ with application rate of 0.46 pounds malathion per gallon per acre	
	<u>2,4,5-T</u>	<u>TCDD</u>
Use Dilution rate	4 pounds 2,4,5-T per 10 gallons of water/acre	0.0000004 pounds TCDD per 10 gallons of water per acre
Lung Absorption Rate	100%	100%
Breathing Rate	$1.8\ m^3/hr$	$1.8\ m^3/hr$
Exposure level	0.34 mg per 2 hr	0.000032 ug per 2 hr
Dose level	0.023 mg/kg per 8 hr	2×10^{-6} ug/kg per 8 hr
No-Adverse-Effect level for teratogenic effects	20 mg/kg	0.03 ug/kg

The following calculations (see Table 33 for mathematics) will give the daily inhalation exposure for both 2,4,5-T and TCDD: 1) multiply the air concentration of malathion by the amount of 2,4,5-T and TCDD applied, then multiply this figure by 1/6 for the inhalation exposure to 2,4,5-T and TCDD; for TCDD, multiply this figure by 1,000 to convert to micrograms; 2) multiply this figure by the breathing rate; 3) multiply this figure by eight [8] to get the 8-hour exposure total; and 4) divide this figure by the weight of the applicator for the inhalation exposure to 2,4,5-T or TCDD per 8-hours exposure.

Table 33.

2,4,5-T	TCDD
1) 0.067 mg/cu m per 0.46 pounds X 4 pounds = 0.58 mg/cu m X 1/6 = 0.097 mg/cu m;	1) 0.067 mg/cu m per 0.46 pounds X 0.0000004 pounds = 0.000000058 mg/cu m X 1/6 = 0.000000009 mg/cu m X 1,000 = 0.000009 ug/cu m;
2) 0.097 mg/cu m X 1.8 cu m/-hr = 0.17 mg/hr;	2) 0.000009 ug/cu m X 1.8 cu m/hr = 0.000016 ug/hr;
3) 0.17 mg/hr X 8 = 1.36 mg;	3) 0.000016 ug/hr X 8 = 0.000128 ug;
4) 1.36 mg / 60 kg = 0.026 mg/kg exposure per day	4) 0.000128 / 60 kg = 2 X 10^{-6} ug/kg per day

The Working Group considers that the difference between the no-adverse-effect level of TCDD for teratogenic effects (0.03 ug/kg) and this calculated dermal exposure level for TCDD (2 X 10^{-6} ug/kg) does constitute an ample margin of safety. The Working Group also considers,

however, that the difference between the no-adverse-effect level of 2,4,5-T for teratogenic effects (20 mg/kg) and this calculated dermal exposure level for 2,4,5-T (0.026 mg/kg[17])

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[17] Johnson (63) [see Section I.G.(3)], in a review article, calculated a daily inhalation exposure to phenoxy herbicides of 0.025 ug/kg for a 70-kg adult. The calculations were based on actual air monitoring data of air samples collected in two wheat-growing areas in the state of Washington during spring and summer and analyzed for phenoxy herbicides. The author did not specify how soon after application the samples were taken.

does not constitute an ample margin of safety. The Working Group therefore recommends issuance of a rebuttable presumption against pesticide products containing 2,4,5-T pursuant to 40 CFR Section 162.11(a)(3)(ii)(B).

III. B. (3) Exposure Analysis
(d) Cumulative pages 116 - 117

The Working Group has also considered the possibility of a single individual being exposed through two or more of the above routes. The results (derived from Tables 27, 29, and 31) are shown in Table 34. The Working Group also notes that possible cumulative exposure to several dioxin-containing pesticides could increase the total body burden and increase total risk from dioxin exposure.

The Working Group considers that the differences between the no-adverse-effect level of TCDD for teratogenic effects (0.03 ug/kg) and the calculated cumulative exposure levels for TCDD in Situations 2 and 3 (see Table 34) do constitute an ample margin of safety. The Working Group also considers, however, that the differences between the no-adverse-effect levels of 2,4,5-T and TCDD for teratogenic effects (20 mg/kg and 0.03 ug/kg, respectively) and the calculated cumulative exposure levels for 2,4,5-T in Situations 1, 2, and 3 and TCDD in Situation 1 (see Table 34) do not constitute an ample margin of safety. The Working Group ~~therefore~~ recommends issuance of a rebuttable presumption against pesticide products containing 2,4,5-T pursuant to 40 CFR Section 162.11(a)(3)(ii)(B).

Table 34. Cumulative Exposure to 2,4,5-T and TCDD

Situation #1: 2,4,5-T	**Situation #1: TCDD**
Oral- 0.0007 mg/kg	Oral- -----
Dermal- 6.8 mg/kg	Dermal- 0.0007 ug/kg
Inhal.- 0.2 mg/kg[a]	Inhal.- negligible[a]
Cum. = 7.0 mg/kg	Cum. = 0.0007 ug/kg
Situation #2: 2,4,5-T	**Situation #2: TCDD**
Oral- 0.0007 mg/kg	Oral- -----
Dermal- 1.8 mg/kg	Dermal- 0.00018 ug/kg
Inhal.- 0.05[a]	Inhal.- negligible[a]
Cum. = 1.85 mg/kg	Cum. = 0.00018 ug/kg
Situation #3: 2,4,5-T	**Situation #3: TCDD**
Oral- 0.0007 mg/kg	Oral- -----
Dermal- 0.051 mg/kg	Dermal- 5 X 10^{-6} ug/kg
Inhal.- 0.026 mg/kg	Inhal.- 2 X 10^{-6} ug/kg
Cum. = 0.0777 mg/kg	Cum. = 7 X 10^{-6} ug/kg

[a] Calculations were made on a worst-case basis as 3% of dermal exposure based on Wolfe (179) who states, "over 97% of the pesticide to which the body is subjected during most exposure situations, and especially to applicators of liquid sprays, is deposited on the skin." TCDD inhalation exposure values were negligible: Situation #1, 21 X 10^{-6} ug/kg; Situation #2, 54 X 10^{-7} ug/kg.