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ATTACHMENT 5

**DETERMINATION OF THE EFFECTIVENESS OF HERBICIDE
BUFFER ZONES IN PROTECTING WATER QUALITY ON NEW
YORK STATE POWERLINE
RIGHTS-OF-WAY**

(One copy sent to the APA)

**Determination of the
Effectiveness of Herbicide
Buffer Zones in Protecting
Water Quality on New York State
Powerline Rights-of-Way**

**RESEARCH
REPORT
EP 89-44**

**PREPARED BY:
ENVIRONMENTAL CONSULTANTS, INC.**

**FINAL REPORT
AUGUST, 1991**



ESEERCO

EMPIRE STATE ELECTRIC ENERGY RESEARCH CORPORATION

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FINAL REPORT
ESEERCO PROJECT EP 89-44

**DETERMINATION OF THE EFFECTIVENESS
OF HERBICIDE BUFFER ZONES
IN PROTECTING WATER QUALITY
ON NEW YORK STATE POWERLINE RIGHTS-OF-WAY**

August, 1991

Prepared by:

**Environmental Consultants, Inc.
207 Lakeside Drive
Southampton, PA 18966**

Principal Investigator:

Logan A. Norris, Ph.D.

Prepared for:

**Empire State Electric Energy Research Corporation
1155 Avenue of the Americas
New York, New York 10036**

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Prepared by:

Environmental Consultants, Inc.
Southampton, Pennsylvania

Abstract

A study was conducted to test buffer zone effectiveness in protecting stream water quality and to evaluate herbicide toxicity to provide a technical basis for establishing water quality protection goals or standards. The study was conducted between August, 1989, and September, 1990, and consisted of three major parts: (a) effect of buffer zone width and vegetation density on herbicide deposition outside the treated area, (b) field test of effectiveness of specific buffer strategies in protecting water quality during operational use of herbicides, and (c) determination of water quality criteria that will protect aquatic organisms and human health.

The first study determined the extent of spray deposition in buffer zones to determine the buffer zone width needed to achieve water protection goals. The study compared the deposition at distances from 0 to 100 feet from the downwind edge of areas treated by either stem-foliar or basal methods. The results show distinct differences in deposition pattern with the method of application, the density of the vegetation, and the distance from the edge of the treatment zone. Where medium to low density vegetation is in the treated area adjacent to the buffer zone, no buffer zone or buffers of only 10 feet were sufficient to meet water quality criteria depending on the herbicide. Larger buffer zones for some herbicides were indicated where high density vegetation was being treated; however, in all cases where there was vegetation in the buffer zone, stream water quality criteria would be achieved if buffers of 25 feet or more are used.

The second study was a field test of buffer zone effectiveness in protecting water quality under operational conditions using high-volume stem-foliar and low-volume basal applications. Picloram, triclopyr, 2,4-D, or imazapyr were applied operationally to rights-of-way (R/W) at eight sites. Buffers of 10 to 100 feet were employed. Water samples were collected automatically for two to three months after application until late November, and then for two to three months after spring thaw. Chemical analysis of selected samples showed most did not contain detectable herbicide. Nearly all samples that were positive had concentrations of herbicide of 0.001 to 0.002 mg/liter, very close to the limit of quantitative detection. The highest concentration detected in any sample was 0.006 mg/liter. In no case did the concentration of the herbicide found approach levels, or persist for periods that would be harmful to aquatic organisms or downstream human water users.

The third study evaluated published literature and other sources of information on the toxicity of herbicides used in this study and a few others that are used on R/W in some instances. The study identified concentrations of specific herbicides not harmful to populations of commonly abundant aquatic organisms, or individuals within rare populations of aquatic organisms that might be resident in surface water near R/W, and to humans that might consume water originating on the R/W. Specific concentrations of individual herbicide, which include margins of safety, were identified as criteria that could be used by R/W managers or regulatory agencies in establishing water quality standards.

In aggregate, this study provides a solid basis for evaluation of the effectiveness of various buffer zones in achieving specific water quality protection goals. Application of these water quality protection criteria to the results from this project show the buffer zones tested in this study protected surface water quality with a significant margin of safety. While wider buffer zones could be used, the results of this study indicate no substantive gain in safety would be achieved.

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PART I

EXECUTIVE SUMMARY

**DETERMINATION OF THE EFFECTIVENESS
OF HERBICIDE BUFFER ZONES
IN PROTECTING WATER QUALITY
ON NEW YORK STATE POWERLINE RIGHTS-OF-WAY**

Results of a Study

EXECUTIVE SUMMARY

Managers and regulatory officials need better information on the potential impact of herbicide use on quality of surface water on or near electric and gas utility rights-of-way (R/W). This study is a test of buffer zone effectiveness in protecting stream water quality, and an evaluation of herbicide toxicity to provide a technical basis for establishing water quality protection goals or standards. The study was conducted between August, 1989, and September, 1990.

The study has three major parts: (a) effect of buffer zone width and vegetation density on herbicide deposition outside the treated area, (b) field test of effectiveness of specific buffer strategies in protecting water quality during operational use of herbicides, and (c) determination of water quality criteria that will protect aquatic organisms and human health.

The first study determined the extent of spray deposition in buffer zones to determine the buffer zone width needed to achieve water protection goals. The study compared the deposition at distances from 0 to 100 feet from the downwind edge of areas treated by either stem-foliar or basal methods. It also evaluated the effect of vegetation density adjacent to and in the buffer zone on spray deposition. The results show distinct differences in deposition pattern with the method of application, the density of the vegetation, and the distance from the edge of the treatment zone. Where medium to low density vegetation is in the treated area adjacent to the buffer zone, no buffer zone or buffers of only 10 feet were sufficient to meet water quality criteria depending on the herbicide. Larger buffer zones for some herbicides were indicated where high density vegetation was being treated; however, in all cases where there was vegetation in the buffer zone, stream water quality criteria would be achieved if buffers of 25 feet or more are used.

The second study was a field test of buffer zone effectiveness in protecting water quality under operational conditions using high-volume stem-foliage and low-volume basal applications. Picloram, triclopyr, 2,4-D, or imazapyr were applied operationally to R/W at eight sites. Buffers of 10 to 100 feet were employed. Water samples were collected automatically for two to three months after application until late November, and then for two to three months after spring thaw. The water samples were chemically analyzed for herbicide residues.

Chemical analysis of selected samples showed most did not contain detectable herbicide (less than 0.001 milligrams per liter or parts per million). There was almost no entry of herbicide to water due to direct application or drift on the day of application. In several instances, the first significant rain storms after application caused small quantities of herbicide to appear in stream samples for a period ranging from one to eight days. The highest concentration detected in any sample was 0.006 mg/liter. Nearly all samples that were positive had concentrations of herbicide of 0.001 to 0.002 mg/liter, very close to the limit of quantitative detection. Once these storms were past no herbicide was found in samples collected over the next several months, except in one instance.

In no case did the concentration of the herbicide found approach levels, or persist for periods that would be harmful to aquatic organisms or downstream human water users. This study demonstrates that current buffer zone strategies employed by the utilities protect stream water quality with a large margin of safety.

The third study evaluated published literature and other sources of information on the toxicity of herbicides used in this study and a few others that are used on R/W in some instances. The study identified concentrations of specific herbicides not harmful to populations of commonly abundant aquatic organisms, or individuals within rare populations of aquatic organisms that might be resident in surface water near R/W, and to humans that might consume water originating on a R/W. The following specific concentrations of individual herbicide, which include margins of safety, were identified as criteria that could be used by R/W managers or regulatory agencies in establishing water quality standards:

<u>Herbicide</u>	<u>Water Quality Criteria</u>
<u>2,4-D:</u>	
Amines (including in Tordon 101)007 mg/liter
Esters0005 mg/liter
<u>Picloram:</u>	
Tordon 10102 mg/liter
Tordon K007 mg/liter
Access007 mg/liter
<u>Triclopyr:</u>	
Garlon 3A05 mg/liter
Garlon 4003 mg/liter
<u>Imazapyr:</u>	
Arsenal, Chopper	5.0 mg/liter
<u>Fosamine:</u>	
Krenite	1.0 mg/liter
<u>Glyphosate:</u>	
Accord	2.0 mg/liter

The basis for more stringent standards to protect individual organisms in rare or endangered populations is also presented.

In aggregate, this study provides a solid basis for evaluation of the effectiveness of various buffer zones in achieving specific water quality protection goals. Application of these water quality protection criteria to the results from this project show the buffer zones tested in this study protected surface water quality with a significant margin of safety. While wider buffer zones could be used, the results of this study indicate no substantive gain in safety would be achieved.

PART II

STUDY OBJECTIVES

**DETERMINATION OF THE EFFECTIVENESS
OF HERBICIDE BUFFER ZONES
IN PROTECTING WATER QUALITY
ON NEW YORK STATE POWERLINE RIGHTS-OF-WAY**

Results of a Study

STUDY OBJECTIVES

Tall-growing vegetation can significantly impact the safe and cost-effective distribution of electric power. A variety of strategies for the control of this vegetation are possible, and many have been tested. The fundamental criteria for these strategies are that they are effective, efficient, and environmentally safe.

Several studies have shown the efficacy and efficiency with which herbicides can be used for the control of tall-growing vegetation on power line rights-of-way (R/W). However, as with any method for controlling vegetation, managers and regulatory agencies must give careful consideration to potential adverse environmental effects. Of particular interest is the potential impact of herbicides on water quality in streams which flow through or near R/W.

Research done in forest environments has determined the primary processes by which herbicides enter surface waters. Direct application and drift are the most important, followed by mobilization of herbicide residues from the soil surface during periods of heavy precipitation. The literature does not in most cases report data indicating entry of herbicides to woodland streams from leaching through the soil profile, or in overland flow (except perhaps in areas that have been heavily compacted) (Norris, 1981, Norris et al., 1983).

There are a number of strategies that are used to prevent or minimize the entry of R/W herbicides into surface water. These include (a) careful attention to the methods of application and the conditions under which applications are made, (b) effective training and supervision of field crews involved in application, and (c) the use of buffer zones between areas of application and surface water. Buffer zones are a common strategy, but critical tests of their effectiveness in protecting stream water quality in connection with the use of herbicides on powerline R/W in New York are lacking.

This study was designed to achieve two general objectives:

1. Determine buffer zone effectiveness in protecting stream water quality, and
2. Evaluate the toxic effects of herbicide residues in stream water on aquatic organisms and humans, and recommend quantitative water quality protection goals.

Objective one was met with the completion of two studies.

- a. The first study determines the effects of two methods of application (stem-foliage and basal) and four buffer zone vegetation densities (high, medium, low and none) on the amount of spray deposition that occurs at various distances from the edge of the treatment area. This study identifies the width of buffer needed to reduce spray deposition outside the treated area to achieve specific levels of stream water quality protection.

This study was conducted in the field near Binghamton, New York, in August, 1989, with the assistance of New York State Electric and Gas Corp. personnel. Chemical analyses were done at Oregon State University.

- b. The second study monitored water quality for up to nine months after operational herbicide application at eight field sites. This was a direct test of the effectiveness of existing buffer zone strategies, including evaluation of herbicide entry by drift or direct application, overland flow during periods of heavy rains, and long-term leaching of herbicide residues through the soil profile to stream channels .

This study was established in the field during the late summer and fall of 1989 by Environmental Consultants, Inc. (ECI), with the assistance of New York State Electric and Gas Corp. and Niagara Mohawk Power Corp. personnel and their herbicide contractors. Water samples were collected by ECI personnel from immediately preceding time of application until freeze-up in late November, 1989, and again from mid-March to early June, 1990. The samples were managed in Corvallis, Oregon, by TAXON, and were subsequently analyzed for herbicide residues at Oregon State University.

Objective two was met by evaluation of published and unpublished toxicity data to identify concentrations of specific herbicides that do not harm aquatic organisms or mammals. With the application of appropriate margins of safety, these values were used to establish quantitative water quality protection goals. Literature and data were collected and evaluated by Logan Norris, the principal study investigator.

This report is in six parts. Parts 1 and 2 are the Executive Summary and Study Objectives. Parts 3, 4, and 5 report the three studies used to meet the objectives outlined above. These three subreports are prepared so they can stand alone, or can be used as subparts of this overall report. Part 6 is a general discussion with conclusions for the entire study.

LITERATURE CITED

Norris, L.A. 1981. The movement, persistence and fate of the phenoxy herbicides and TCDD in the forest. *Residue Reviews* 80:66-135

Norris, L.A., H.W. Lorz and S.V. Gregory. 1983. Influence of forest management on anadromous fish habitat in western North American: Forest Chemicals. USDA Forest Service General Technical Report PNW-149. Pacific Northwest Forest and Range Experiment Station, Portland, OR.

PART III

**INFLUENCE OF BUFFER ZONE WIDTH,
VEGETATION DENSITY, AND
METHOD OF APPLICATION
ON SPRAY DRIFT DEPOSIT
ON POWERLINE RIGHTS-OF-WAY
IN NEW YORK**

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**INFLUENCE OF BUFFER ZONE WIDTH,
VEGETATION DENSITY, AND METHOD OF APPLICATION
ON SPRAY DRIFT DEPOSIT
ON POWERLINE RIGHTS-OF-WAY IN NEW YORK**

A. PART III SUMMARY

A study of buffer zone effectiveness in minimizing off-site spray deposition was conducted in August, 1989, near Binghamton, NY, on rights-of-way managed by New York State Electric and Gas Corp. (NYSEG). Stem-foliage and basal spray applications were made to areas dominated by low, medium, and high density vegetation. The spray material contained only a dye, and no herbicide, but was otherwise like that normally applied for these purposes. A contract spray applicator with an experienced crew made the application. Each treatment was replicated three times.

Spray entering the adjacent buffer zone was captured using string collection arrays at 0, 10, 25, 50, 75, and 100 feet from the edge of the sprayed area. The string was analyzed for the dye, and the results expressed in herbicide equivalents.

String arrays were effective for monitoring spray deposits, at a low cost compared to the cost for herbicide analysis. Some dye was detected in all buffer zones, but the amounts were generally low 10 feet to 25 feet or more from the edge of the sprayed area.

The highest levels of dye in the buffer zones were from stem-foliage applications in high density vegetation, but the level of deposition decreased rapidly with increasing distance from the treated zone. For both methods of application in medium and low density vegetation areas, buffer zones of 10 feet were sufficient to protect stream water quality, while 25 feet might be required where high density vegetation exists. When air movement is away from the buffer, smaller zones can probably be used, although this variable was not included in the test.

When there was no vegetation in the buffer zone adjacent to an area of high density vegetation, higher levels of dye deposition occurred in the buffer, and there was little reduction in levels with distance beyond 25 feet. Clearly the density of the vegetation is important in reducing off-site deposition with increasing distance. The basal applications in medium and low density vegetation produced higher levels of herbicide equivalents (dye data adjusted for differences in herbicide concentration in typical spray mixtures) in the buffer zone than the stem-foliage applications.

In general, the results of this test show that trained, supervised crews can apply herbicide to vegetation on the R/W with no biologically significant damage to non-target organisms resulting from drift or direction deposition beyond vegetated buffer zones. Vegetated buffer zones of 10 or 25 feet depending on the situation are sufficient to provide adequate margins of safety for the most commonly used herbicides. Methods of application other than stem-foliage may be needed to assure safety near non-vegetated buffer zones. While wider buffer zones could be used in areas of high biological or social sensitivity, the results of this study indicate no substantive gain in safety would be achieved.

B. INTRODUCTION

Tall-growing vegetation can significantly impact the safe and cost-effective distribution of electric power. A variety of strategies for the control of this vegetation are possible, and many have been tested. The fundamental criteria for these strategies are that they are effective, efficient, and environmentally safe.

Several studies have shown the efficacy and efficiency with which herbicides can be used for the control of tall-growing vegetation on power line rights-of-way (R/W). However, as with any method for controlling vegetation, managers and regulatory agencies must give careful consideration to potential adverse environmental effects. Of particular interest is the potential impact of herbicides on water quality in streams that flow through or near R/W.

Research conducted in forest environments has determined the primary processes by which herbicides enter surface waters. Direct application and drift during and shortly after the application are the most important, followed by mobilization of herbicide residues from the soil surface during periods of heavy precipitation. The literature does not report data indicating entry of herbicides to woodland streams from leaching through the soil profile, or in overland flow (except perhaps in areas which have been heavily compacted) (Norris, 1981, Norris et al., 1983).

There are a number of strategies that are used to prevent or minimize the entry of R/W herbicides into surface water. These include (a) careful attention to the methods of application and the conditions under which applications are made, (b) effective training and supervision of field crews involved in application, and (c) the use of buffer zones between areas of application and surface water. Although utilities employ a combination of all three strategies critical tests are lacking of the effectiveness of buffer zones in protecting stream water quality in connection with the use of herbicides on powerline R/W in New York.

The buffer zones currently employed by New York State Electric and Gas Corporation and Niagara Mohawk Power Corporation are as follows:

New York State Electric and Gas Corporation

Method of Application

Buffer Zone Distance

Basal Spray and Stump Treatment

30 feet from all water bodies and 100 feet from regulated wetlands unless NYSDEC permit allows for applications closer to regulated wetland.

Foliar Spray

50 feet from all water bodies and 100 feet from regulated wetlands unless DEC permit allows for applications closer to regulated wetlands.

Niagara Mohawk Power Corporation

Basal Spray and Stump Treatment	30 feet from streams, ponds, lakes, standing water and 100' from regulated wetlands unless NYSDEC permit allows for application closer to regulated wetlands.
Foliar Spray	50 feet from streams, ponds, lakes, standing water and 100' from regulated wetlands unless NYSDEC permit allows for application closer to regulated wetlands.
Helicopter Spray	250 feet from streams, ponds, lakes, standing water and regulated wetlands.

1. Purpose of the Research

The research reported here evaluates the effect of three variables (distance from treated area, vegetation density, and method of application) on spray deposition in the buffer zone. The purpose is to provide a critical test of the effectiveness of buffer zone and application strategies in minimizing spray deposition outside the treated area. This is important in protecting stream water quality, and in evaluating potential impacts to non-target organisms off the R/W.

2. Specific Research Objective

The specific objective of this research was to evaluate the effects of the following:

- Method of spray application (i.e. high-volume stem-foliage and low-volume basal).
- Vegetation density in and adjacent to the buffer zone (high, medium, and low vegetation density in the buffer zone and in the adjacent R/W, and no vegetation in the buffer zone adjacent to a R/W area of high vegetation density).
- Buffer zone width (0, 10, 25, 50, 75, and 100 feet) on buffer zone effectiveness in reducing the potential for deposition of spray materials in streams beyond the treated area.

The study scope was limited to evaluating two methods of application: high-volume stem foliage and low-volume basal. These account for the vast majority of herbicide application on New York rights-of-way, and they also represent the greatest breadth of application conditions in which buffer zones may be important.

3. Overview of Strategy of Study

This study was conducted in the field near Binghamton, New York, in August, 1989, on four New York State Electric and Gas Corp. powerline R/W sites with various vegetation densities. Herbicide deposition outside the treatment site was measured indirectly by using an easily measured dye to represent the herbicide. The dye was applied in spray solutions, which were the same as those normally used except they contained no herbicide. The spray material containing the dye was captured on strings, which were arrayed parallel to, but at various distances from the edge of the buffer zone.

The strings were analyzed by Eugene Johnson in the Oregon State University Department of Agricultural Chemistry laboratory for deposition of dye, and the amount of herbicide that would have been deposited was calculated. The results were expressed as a function of the three variables in the study.

The string system allowed repeated applications to be made at one site to get good replication, and to test various application techniques without the use of repeated applications of herbicide at the site. This approach allowed a large number of samples to be analyzed, thereby improving the accuracy of the test. In addition the test provided data which are applicable to any herbicide, because direct deposition is a function of the distribution of droplets, and has nothing to do with the active herbicide ingredient. Thus, by determining how droplet distribution is influenced by methods of application, buffer zone width, and buffer zone vegetation characteristics, a model of buffer zones to accomplish specific protection standards can be developed.

C. METHODS

1. Field Methods

a. Study Area and Specific Study Sites

The study area included four specific study sites near the NYSEG 345 kV Oakdale substation in the Town of Union, Broome County, near Binghamton, NY. Figure 1 shows the location of the four study sites.

The specific study sites contained four different densities of vegetation. Specifically:

H - High density vegetation in the treated portion of the R/W and in the adjacent buffer zone. Densities estimated at over 3,000 stems per acre were considered high.

M - Medium density vegetation in the treated portion of the R/W and in the adjacent buffer zone. Densities estimated at 1,500 to 3,000 stems per acre were considered medium.

L - Low density vegetation in the treated portion of the R/W and in the adjacent buffer zone. Densities estimated at less than 1,500 stems per acre were considered low.

N - High density vegetation in the treated portion of the R/W but no vegetation in the adjacent buffer zone. The buffer zone in this case had been totally cleared of vegetation, and served as a parking and turn-around area for heavy equipment.

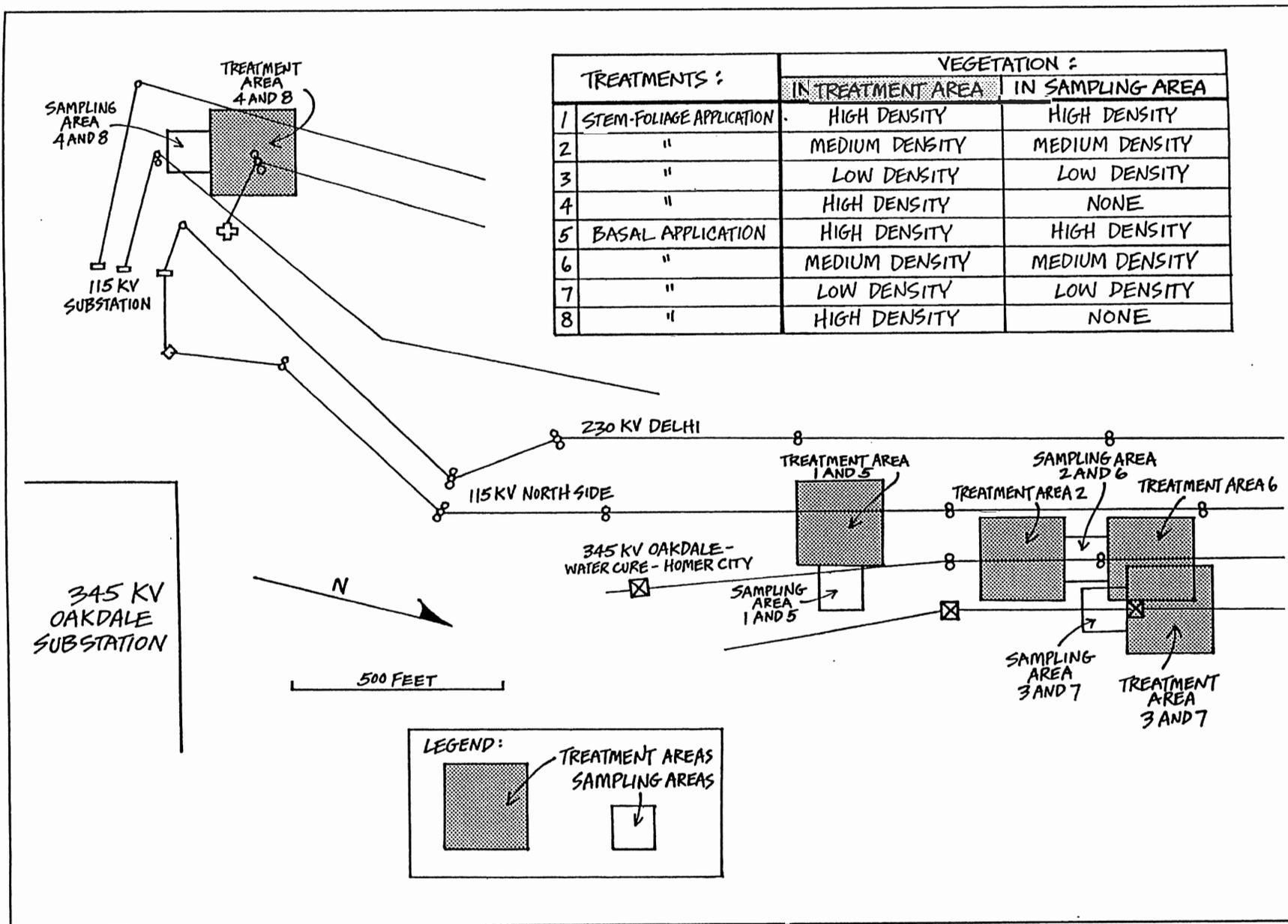


Figure 1. Overall view of treatment and sampling areas.

Specific study sites H, M, and L are located between structures A1 and A3 on the 345 kV Oakdale-Water Cure-Homer City NYSEG powerline. Specific study site N is located just outside the 115 kV substation. Figures 2, 3A, 3B, 4, and 5 show the distribution and density of the vegetation and the location of string arrays at each site.

b. Spray Collection Device

Whitney and Roth (1985) reported a system for collecting spray materials on string, which can then be evaluated for spray deposit based on the use of fluorescent dyes. This was the method used in this study.

A six-string array was established at each of the following distances from the edge of the R/W buffer zone: 0, 10, 25, 50, 75, and 100 feet (Figures 6 and 7-left). The vegetation was removed in a narrow path to accommodate each string array (Figure 7-right). The strings were oriented parallel to the edge of the buffer zone and were placed at ground level and at 1-foot intervals to 5 feet above the ground. Each string array covered approximately 100 feet, providing approximately 605 feet of string for analysis at each distance. The string was Coats and Clark's white, six-strand cotton floss, without brightener.

Table 1 shows the total length (in feet) and the one-sided longitudinal surface area (in square feet) for each array during each application of spray material. The shorter length of string in the low density vegetation test indicates the physical constraints of the site (Figure 4).

c. Spray Application Methods

The area treated with spray material was a square about 200 feet on each side. The treated area extended about 200 feet perpendicular from the edge of the buffer zone, and extended 50 feet on either side of the ends of the string arrays (Figure 8). The purpose of this orientation was to ensure spray material was being applied in areas that could contribute spray drift to the string arrays, even though the direction of air flow might vary during the test.

The spray application was made by an experienced herbicide application crew under contract to New York State Electric and Gas. They used procedures normally used on sites of this type; that is, they traversed the area to be treated parallel to the edge of the buffer zone, applying herbicide to the edge of the buffer zone (Figure 9). They directed spray away from the buffer as much as possible, as is their normal practice.

Two types of application were made by the crew. Specifically:

- Selective stem-foliage, high-volume application, and
- Selective basal, low-volume application.

Selective stem-foliage application is a common R/W treatment in New York. The application is directed at wetting the stems and foliage of target vegetation to the point of runoff. In this study, the high-volume stem-foliage treatment was made using a gasoline-powered hydraulic pump and tank mounted on an all-terrain tracked vehicle (Figure 10-top). The spray solution was water mixed with 0.87 or 0.79 mg rhodamine B dye/ml. The solution was applied through hand-held FMC 785 spray guns equipped with No. 8 nozzle disks. The nozzles were adjusted to produce a coarse spray of large droplets with the system operated at a pressure of 50 pounds per square inch. The applicators rode on the spray rig while making the foliar applications.

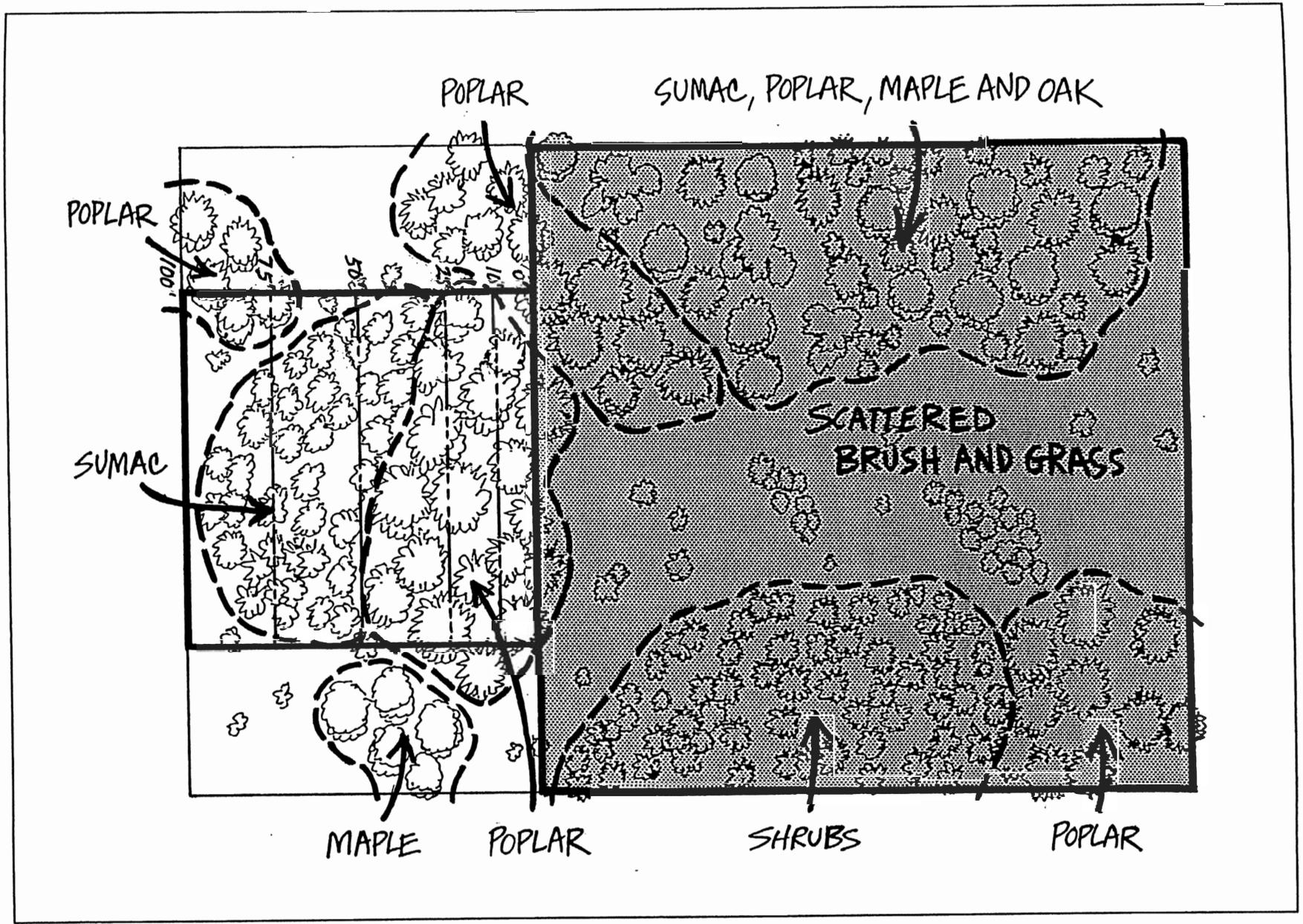


Figure 2. High density vegetation buffer and treatment area used in connection with treatments one and five.

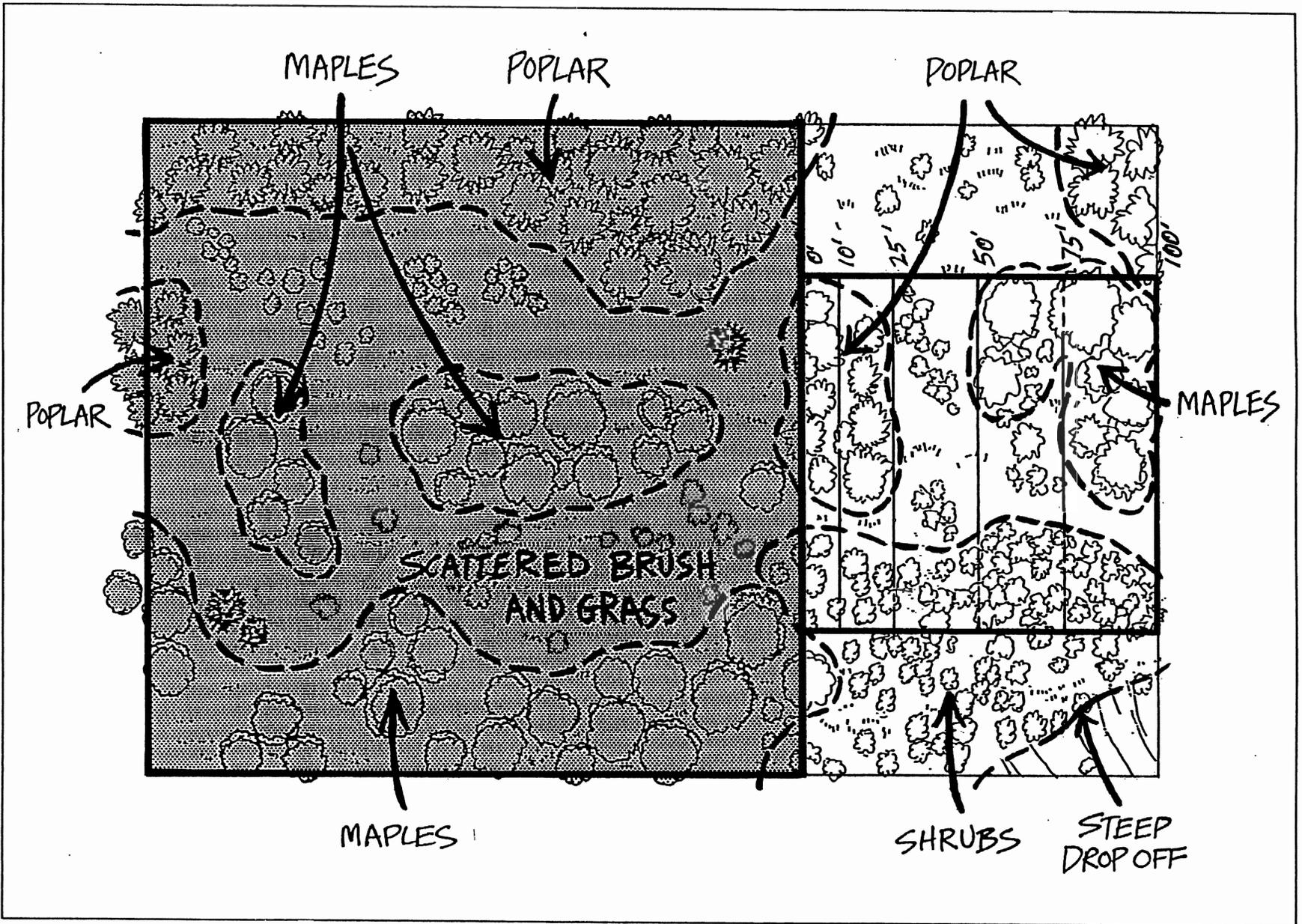


Figure 3A. Medium density vegetation buffer and treatment area used in connection with treatment two.

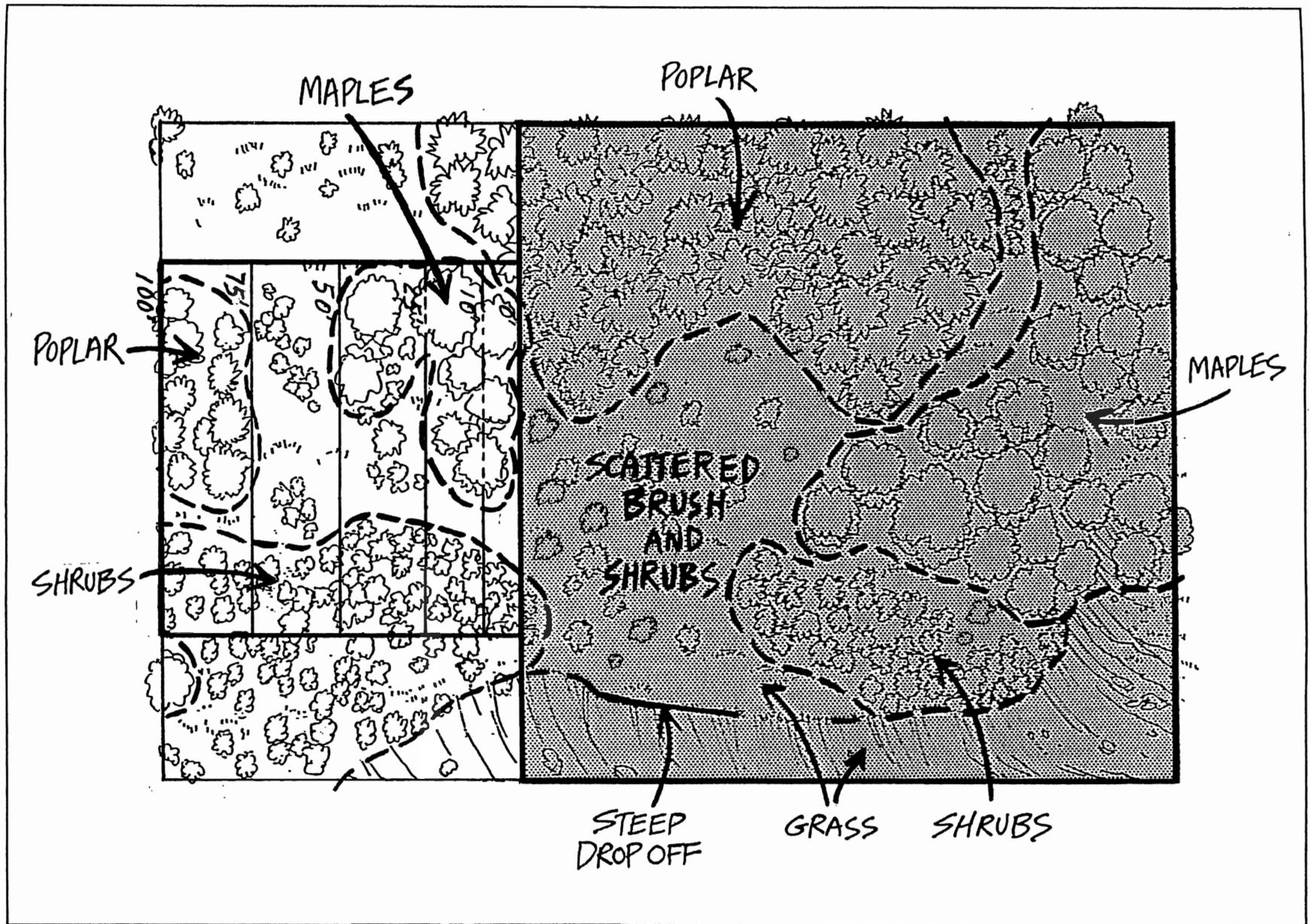


Figure 3B. Medium density vegetation buffer and treatment area used in connection with treatment six.

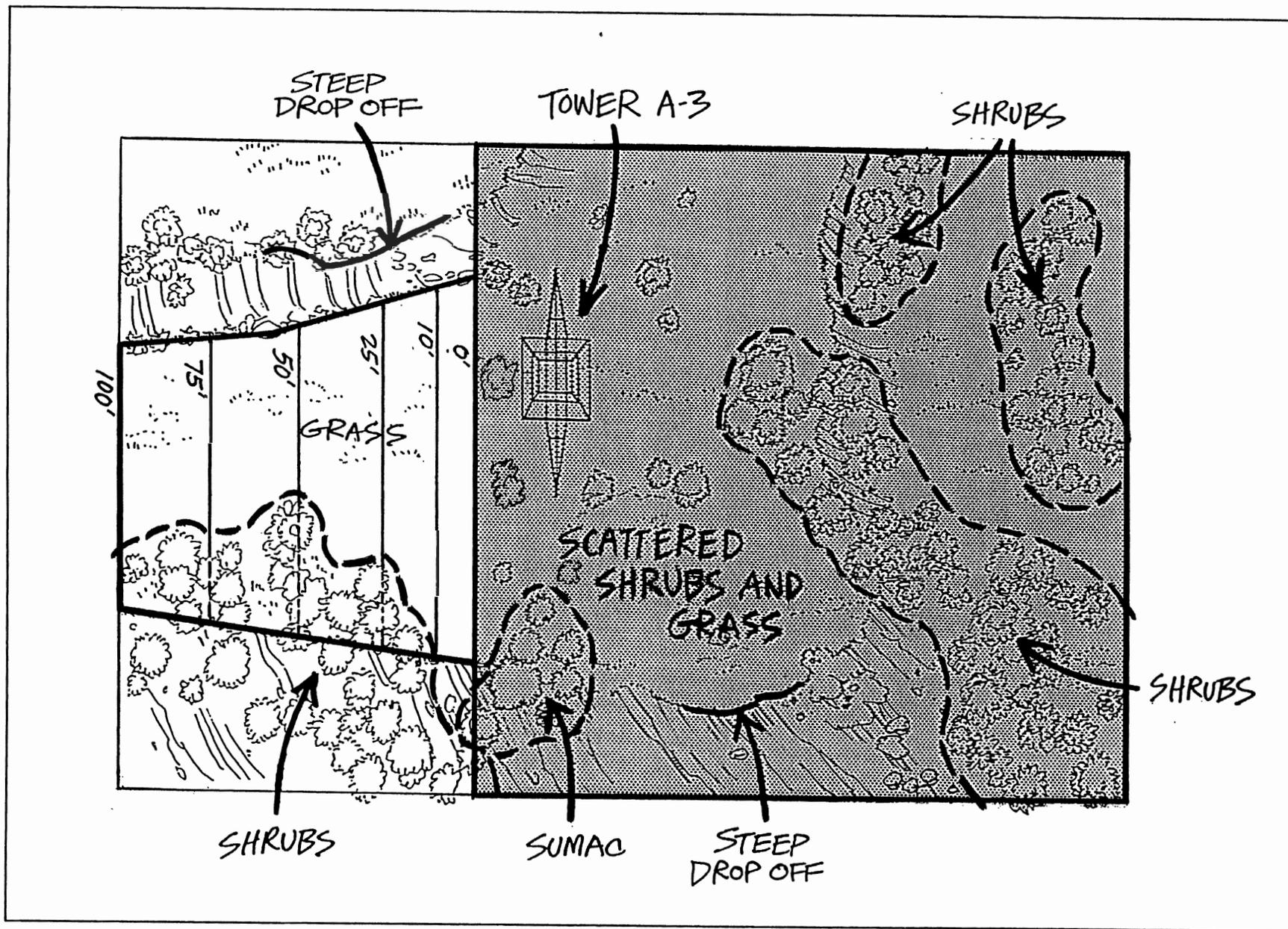


Figure 4. Low density vegetation buffer and treatment area used in connection with treatments three and seven.

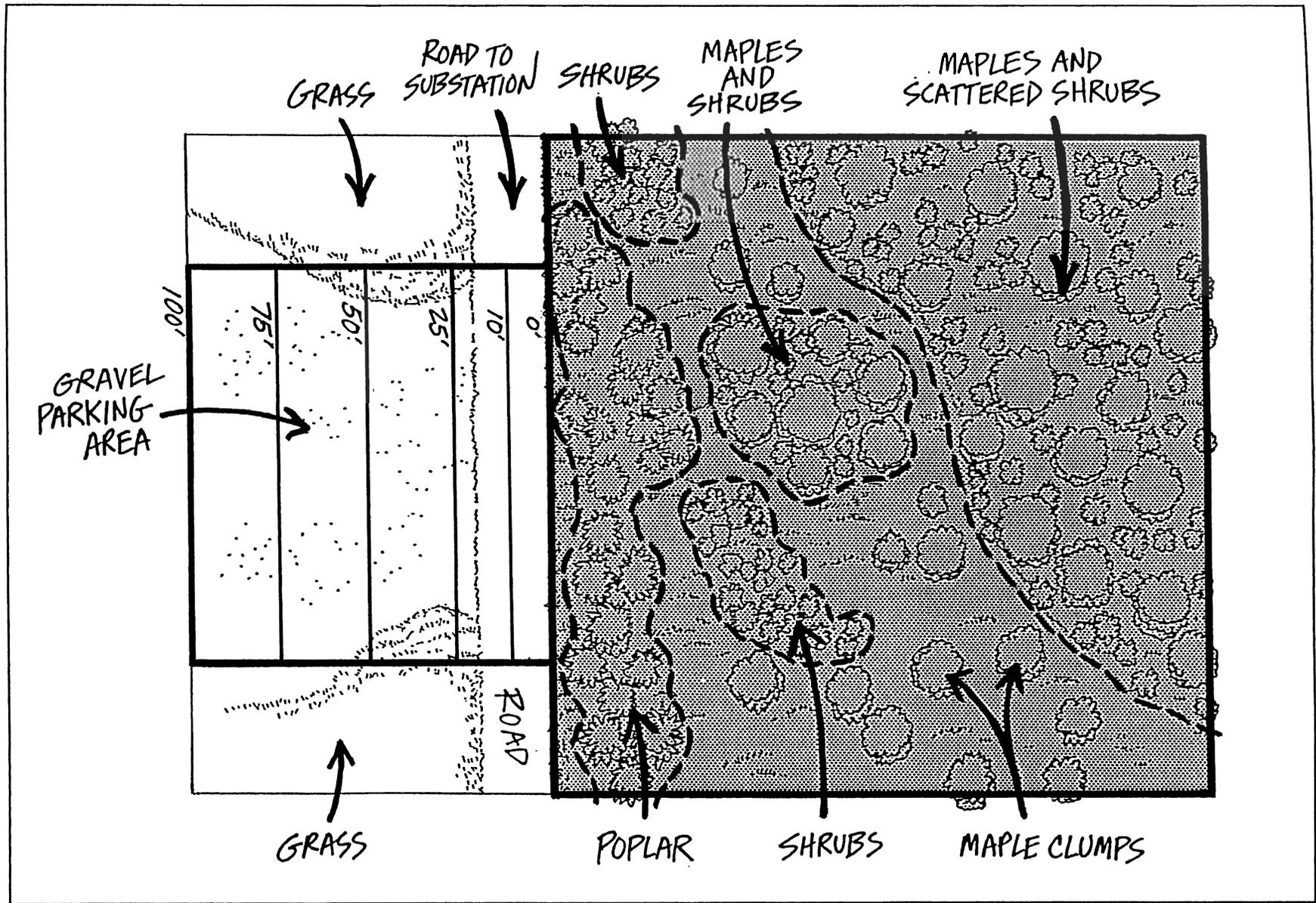


Figure 5. No vegetation buffer zone and high density vegetation treatment area used in connection with treatments four and eight.

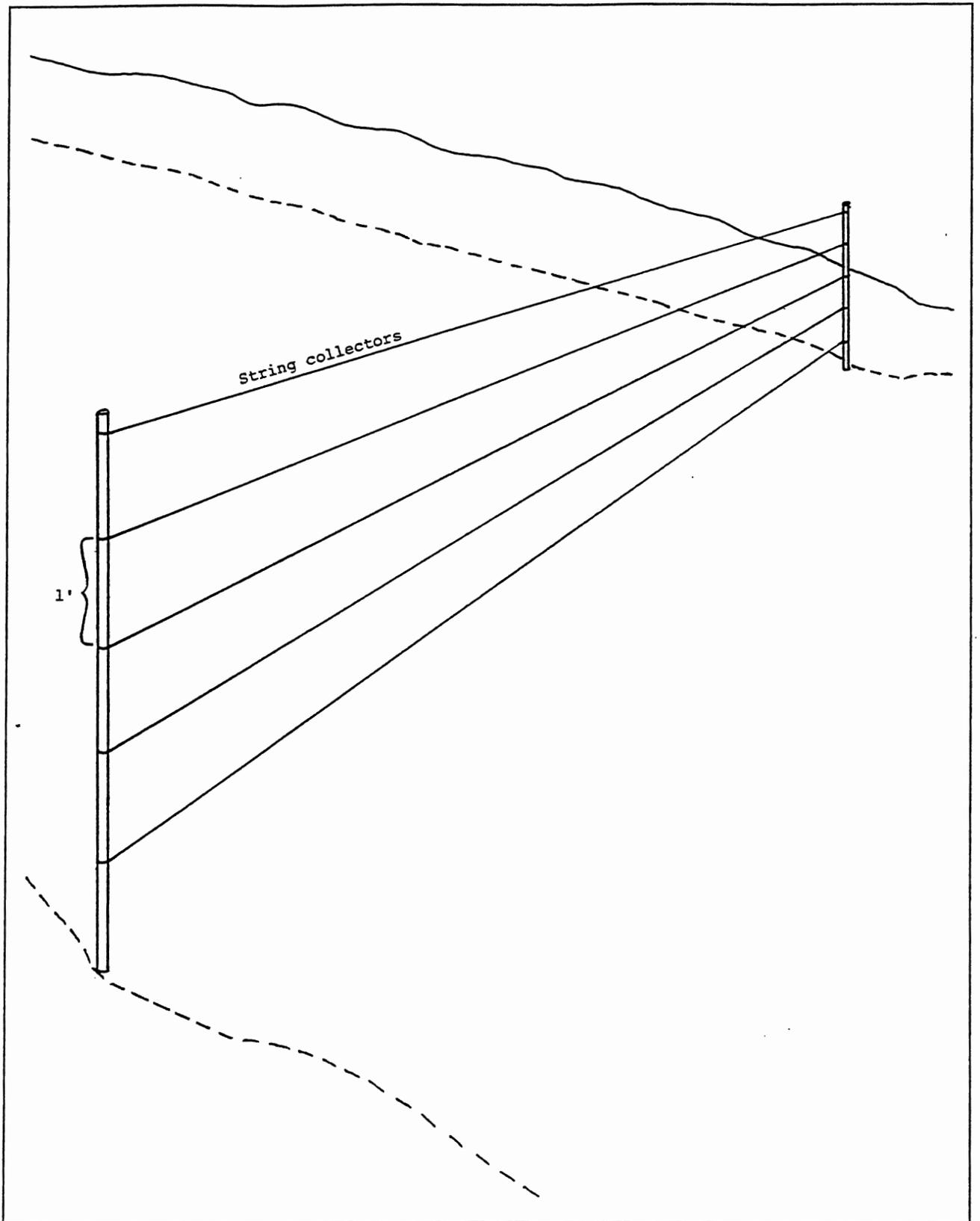


Figure 6. Schematic of a single string array.

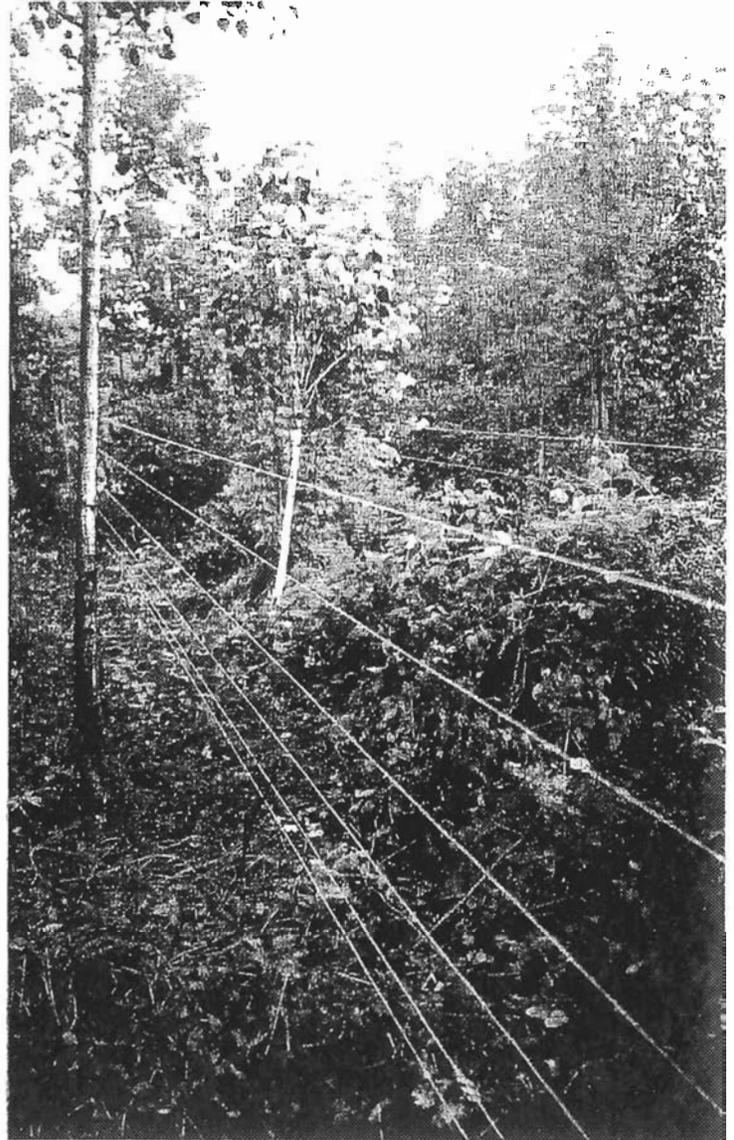
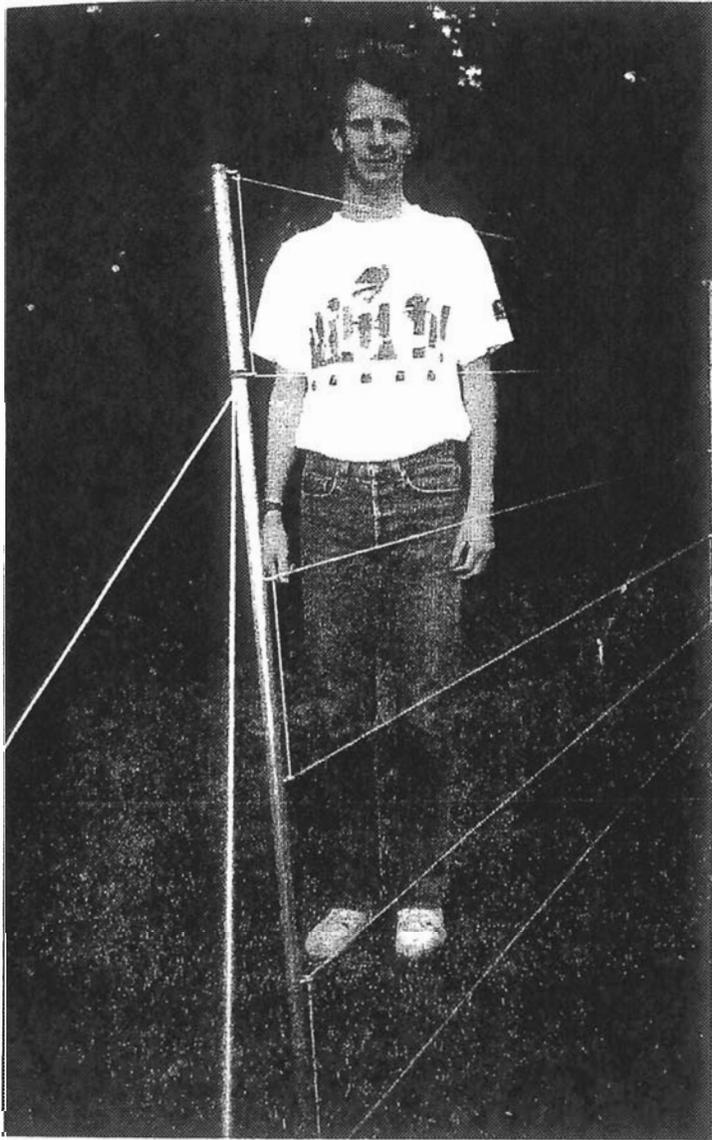


Figure 7. (Left) Closeup of one string array, with the array developer. (Right) The zero- and ten-foot string arrays in the heavy vegetation zones. The vegetation to the left of the zero-foot array was treated.

Table 1

**Length and Surface Area of String in Each Array
by Vegetation Density in the Buffer Zone**

FEET ¹	STRING LENGTH (Feet)	STRING SURFACE AREA (Square Feet)	FEET ¹	STRING LENGTH (Feet)	STRING SURFACE AREA (Square Feet)
----- High Density -----			----- Medium Density -----		
0	593.00	1.7494	0	599.00	1.7671
10	593.00	1.7494	10	605.00	1.7848
25	605.00	1.7848	25	596.00	1.7582
50	602.00	1.7759	50	605.00	1.7848
75	599.00	1.7671	75	602.00	1.7759
100	614.00	1.8113	100	605.00	1.7848
----- Low Density -----			----- No Vegetation -----		
0	533.00	1.5724	0	695.00	1.7848
10	515.00	1.5193	10	605.00	1.7848
25	461.00	1.3600	25	605.00	1.7848
50	437.00	1.2892	50	605.00	1.7848
75	371.00	1.0945	75	605.00	1.7848
100	329.00	0.9706	100	605.00	1.7848

¹Feet refers to the distance into the buffer zone from the edge closest to the treated portion of the right-of-way.

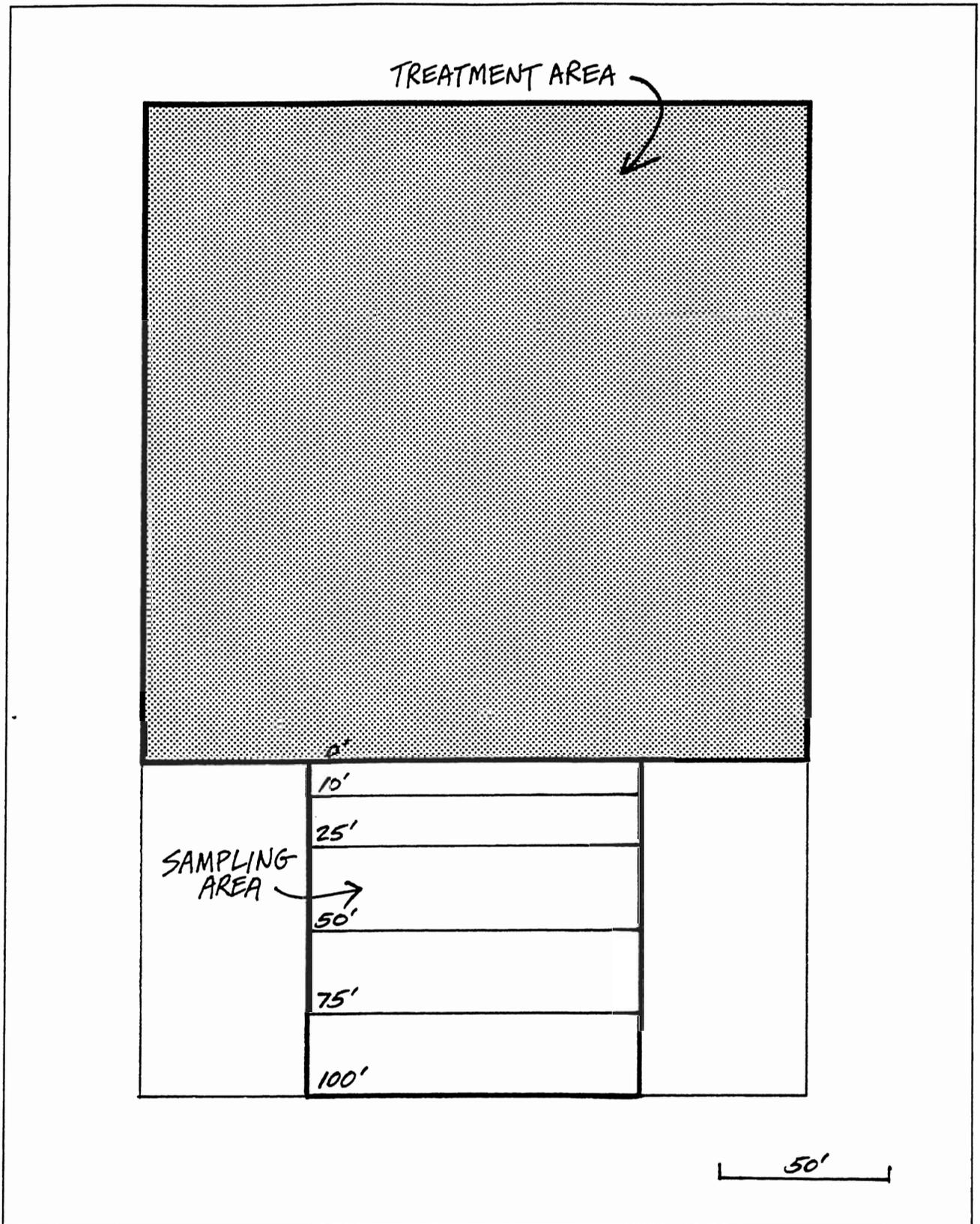


Figure 8. Schematic of idealized treatment area and buffer zone. Actual dimensions varied from site to site to mesh with site-specific vegetation and topographic characteristics.

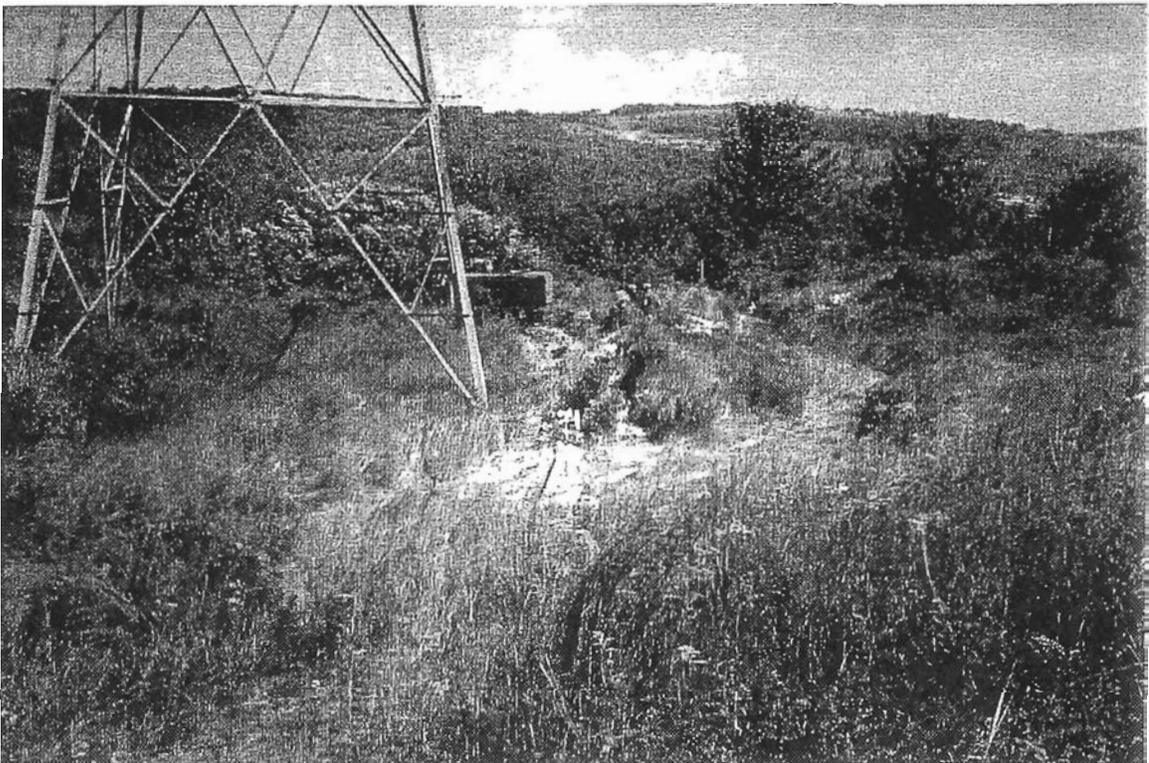


Figure 9. (Top) A portion of the heavy vegetation treatment area, with the zero- and ten-foot string arrays in the left background. The crushed vegetation in the foreground shows the path taken by the tracked application vehicle.

(Bottom) Stem-foliar application being made to scattered vegetation in the low density vegetation treatment zone. The zero-foot string array is just to the left of the worker with the light-colored cap.

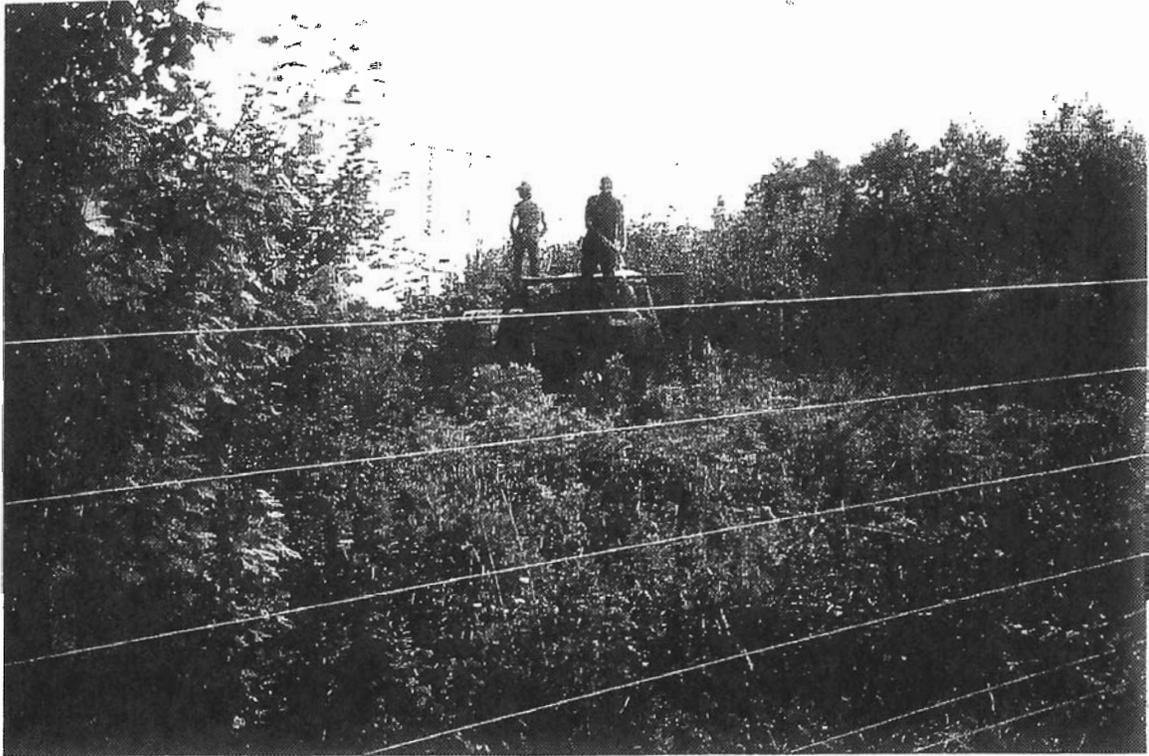


Figure 10. (Top) Stem-foliar application being made to low vegetation in the medium density vegetation treatment area. The zero-foot string array is in the foreground.

(Bottom) Basal application being made in the low density vegetation treatment zone.

The low-volume basal application requires the herbicide to be applied evenly to all exposed bark on the lower 18 inches of each stem. The study application was made using a hand-operated backpack sprayer equipped with a Spraying System Model 23L-7676 gun and Spraying System 5500 Y2 Cone Jet Nozzle (Figure 10-bottom). Pressure was the minimum necessary to provide a coarse spray of large droplets and was controlled by each individual applicator. The spray solution was of Clear Cut oil with 1.23 mg rhodamine WT dye/ml.

d. Conduct of the Test

Figure 8 shows a schematic of one test site. This set-up was used at all four sites, each of which had different densities of vegetation in the buffer zone. At each site, this installation was used for three applications of each of the two methods of application, or six applications at one site, with the string being carefully changed between each application. Thus for any one site, a total of 36 string arrays would be collected and analyzed (2 application types x 6 distances x 3 replications). After each application was completed, the string at each distance was removed and placed in a labeled Zip Lock bag and stored in the dark until analyzed. Wind speed and direction were monitored during each application (Figure 11-top).

Figures 11-bottom and 12 show various aspects of the application and the deposition of spray material on target vegetation.

2. **Laboratory Methods**

Samples were analyzed by Eugene Johnson, Department of Agricultural Chemistry, Oregon State University. Samples of the string were weighed and placed in a pint Mason jar. Methanol (200 to 400 ml depending on the size of the sample) was added to the jar, and the jar sealed with an aluminum foil-lined lid. The jar was shaken vigorously periodically over at least 4 hours, and two aliquots of the methanol extract were removed, with one being stored for future reference if needed.

The other aliquot was placed directly in a cuvette, or diluted as appropriate and placed in a cuvette, and the florescence measured on a Turner Model III fluorometer (Color Spec. #546 primary filter, and Color Spec. #590 secondary filter). A Color Spec. 10 percent neutral density filter in combination with different slit widths was used to facilitate the measurement of a wide range of dye concentrations. The concentration of dye was determined by comparison to a standard curve of known rhodamine B or WT concentration run at the same time.

Recovery studies were performed on 20-gram samples of string that were fortified with known amounts of dye in methanol. After the samples were fortified, the string was allowed to air-dry for 30 minutes to permit evaporation of the methanol. Then the fortified samples were extracted with 200 ml methanol and the dye measured as previously described. The following recovery values were obtained:

MICROGRAMS OF DYE ADDED	PERCENT RECOVERY BY REPLICATION			
	Rhodamine WT		Rhodamine B	
	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>
0.25	lost	71	88	85
0.50	83	94	98	96
1.00	95	95	100	102
2.00	96	101	100	102

These results indicate reliable recoveries at least to 0.25 micrograms of dye per sample. actual testing the analyst found consistent results to 0.15 micrograms, based on analysis of gram samples of string that provided fluorescence readings that were more than 1 fluorescence unit above background readings. Consequently, the analyst recommended that the minimum detectable level be established at 0.15 micrograms of dye per sample.

D. RESULTS

1. Summary of Variables

The following is a summary of variables for each test application:

<u>TEST APPLICATION NUMBER</u>	<u>VEGETATION DENSITY</u>		<u>METHOD OF APPLICATION</u>
	<u>In R/W</u>	<u>Buffer</u>	
1	High	High	Stem-foliage
2	Medium	Medium	Stem-foliage
3	Low	Low	Stem-foliage
4	High	None	Stem-foliage
5	High	High	Basal
6	Medium	Medium	Basal
7	Low	Low	Basal
8	High	None	Basal

2. Wind and Temperature

The wind speed, wind direction, and air temperature data collected during these tests are summarized in Table 2. In each case wind orientation of zero degrees means the wind is blowing exactly perpendicular to the string arrays from the treated portion of the R/W towards the string arrays. Wind direction of 25 degrees or 335 degrees would mean the wind was 25 degrees from the perpendicular to the edge of the string arrays. With the exception of portions of tests 6 and 7, the wind was calm during most parts of the test. The variation in wind direction, but lack of measurable wind, indicated in Table 2 for many of the applications shows that there were infrequent, slight puffs of wind that would move through the area. These often changed the orientation of the wind vane, but were either not blowing when the readings were taken, or were less than the 1 MPH required to activate the anemometer. In all cases however, the general average direction of the wind during each test was such that spray material would be expected to move from the treated portion of the R/W into the string array.

The cross wind values are a measure of wind speed and directional variability between readings. For example, the relatively high cross wind values during test 6, replication A illustrate the variable nature of wind during these tests. Frequent instrument readings were made in an effort to record as much of the variability as possible during this period when the wind was blowing the hardest.

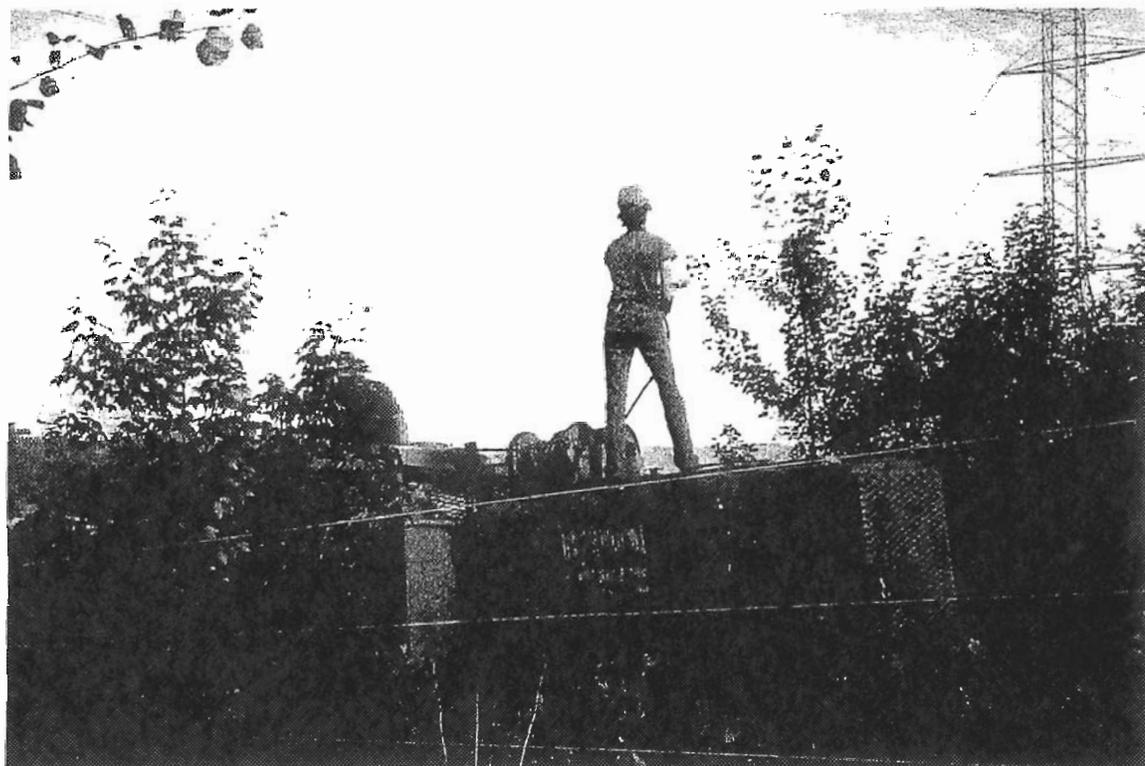


Figure 11. (Top) Weather station in the middle of the medium density vegetation buffer zone. (Bottom) Stem-foliar application being made to some tall vegetation near the zero-foot string array in the medium density vegetation zone.



Figure 12. (Top) Deposition of dye showing the distribution of spray material from a stem-foliar application to a clump of young maples. (Bottom) Deposition of dye showing the distribution of spray material from a basal application to a young poplar stem.

Table 2
Wind and Temperature During Spray Application

TEST	REP.	TIME	WIND			TEMP. (Degrees F)	
			Direction (Degrees)	Speed (MPH)	Cross Wind (MPH)		
1	A	1250	0	0	0	67	
		1255	0	0	0	66	
		1305	29	2	-1.1	66	
		1320	32	0	0	66	
	B	0620	0	0	0	66	
		0637	0	0	0	65	
		0650	0	0	0	65	
	C	0732	359	0	0	72	
		0745	315	0	0	70	
		0805	315	0	0	69	
	2	A	1600	0	0	0	91
			1604	303	0	0	91
1609			269	0	0	85	
1615			269	0	0	83	
1628			266	0	0	83	
1632			266	0	0	83	
B			1724	266	1	+0.9	83
		1734	355	0	0	82	
		1737	355	0	0	80	
		1744	355	0	0	79	
C		1836	355	0	0	74	
		1852	355	0	0	72	
3		A	1252	347	5	-1.2	80
			1305	0	5	0	80
		B	1324	344	2	-0.8	79
	1334		18	2	+0.6	79	
	1340		1	3	0	80	
	C	1347	15	5	+1.3	79	
	4	A	1848	339	0	0	71
			1907	341	0	0	68
		B	1917	331	0	0	67
1928			345	0	0	65	
C		1939	345	0	0	65	
		1955	345	0	0	65	

(Continued)

Table 2 (Continued)
Wind and Temperature During Spray Application

TEST	REP.	TIME	WIND			TEMP. (Degrees F)
			Direction (Degrees)	Speed (MPH)	Cross Wind (MPH)	
5	A	0906	315	0	0	77
		0920	55	0	0	82
	B	1010	28	4	0	80
		C	1100	10	2	+1.3
	1120		340	1	+0.9	79
6	A	1533	331	5	+2.5	80
		1535	45	8	+7.7	82
		1546	28	7	+6.9	85
		1549	37	11	+10.9	83
		1602	34	9	+8.9	82
	B	1608	352	4	+3.1	79
		1619	21	5	+4.9	78
	C	1635	13	2	+1.9	80
		1642	38	6	+5.9	81
	7	A	1410	15	7	+1.8
B			1435	359	3	0
		1448	337	8	-3.2	78
C		1457	354	4	-0.4	78
		1506	1	4	0	80
8	A	1740	314	2	-1.9	78
		1752	329	2	-1.8	76
	B	1810	355	1	-0.9	74
	C	1826	276	1	-0.9	74

3. Calculated Concentration of Herbicide

The amount of herbicide deposited on the string arrays was calculated based on the concentration of dye in the spray solution and the amount of herbicide that would normally be present in spray solutions applied by stem-foliage or basal methods. These relationships are developed below.

4. Concentration of Dye in the Spray Solutions

Solution 1 - 0.87 mg dye/ml of spray solution. This solution was used in the low, medium, and high vegetation density buffer zones in connection with the stem-foliage applications (treatments 1 A; 2 A,B,C; and 3 A,B,C).

Solution 2 - 0.79 mg dye/ml of spray solution. This solution was used in the high vegetation density buffer zone and the no vegetation buffer zone in connection with the stem-foliage applications (treatments 1 B, C and 4 A, B, C).

Solution 3 - 1.23 mg dye/ml of spray solution. This solution was used in all treatment areas involving basal applications (treatments 5 A, B, C; 6 A, B, C; 7 A, B, C; and 8 A, B, C).

Normal high-volume stem-foliage treatment solutions contain 0.03 pounds of herbicide per gallon of spray material. Basal treatment solutions contain 1.00 pound of herbicide per gallon of spray solution. Thus, the dye in the treatment solutions used in this test have the following correspondence to the amount of herbicide that would normally be in spray mixtures of these types.

Solution 1 - 1 milligram of dye is equivalent to 4.132 milligrams of herbicide.

Solution 2 - 1 milligram of dye is equivalent to 4.551 milligrams of herbicide.

Solution 3 - 1 milligram of dye is equivalent to 97.431 milligrams of herbicide.

5. Test Results

The results of each application method are described separately for each of the four sites.

Tables 3A, B, C, and D show the data as reported by the laboratory, expressed in micrograms of dye per string array, for each application. This is the fundamental data from this study. Note that values of 0.0 micrograms of dye per string array indicate a nondetectable level. The true values could be as low as 0.0 or as high as 0.15 micrograms of dye on each string array. All nondetectable values were considered as 0.0 micrograms for purposes of calculation.

Figure 13 and Tables 4A, B, C, and D show the dye data from Table 3 converted to micrograms of herbicide per square foot at each string array for each application. This is based on the herbicide-dye relationships described above. It adjusts for differences in the amount of herbicide among application methods. These are averaged by vegetation density in Table 5.

Table 6 shows the calculated instantaneous concentration of herbicide that would result in a body of water 6-inches deep if the stream had been located at each string array. The assumptions in this calculation are that the dye (herbicide) captured at the string array enters the stream and instantly mixes throughout the 6-inch water column.

Table 3A
Micrograms of Dye on Each String Array
for High Density Vegetation in the Buffer Zone

FEET ¹	REPLICATION					
	A	B	C	A	B	C
	----- Stem-Foliage, Treatment 1 -----			----- Basal, Treatment 5 -----		
0	60.00	1050.00	1010.00	2.59	0.79	1.58
10	0.98	5.40	55.00	1.58	1.17	0.63
25	0.74	4.10	2.30	0.39	0.83	0.49
50	0.55	1.98	2.28	0.00	0.39	0.54
75	0.00	0.81	1.27	0.25	1.16	0.00
100	0.25	0.70	2.57	0.00	0.18	0.00

Table 3B
Micrograms of Dye on Each String Array
for Medium Density Vegetation in the Buffer Zone

FEET ¹	REPLICATION					
	A	B	C	A	B	C
	----- Stem-Foliage, Treatment 2 -----			----- Basal, Treatment 6 -----		
0	84.00	54.00	103.00	2.09	27.80	8.84
10	0.46	0.00	1.20	0.00	0.35	0.17
25	0.16	0.00	0.55	0.24	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.16	0.21	0.00
100	1.10	0.00	0.00	1.39	0.82	0.55

¹Feet refers to the distance into the buffer zone from the edge closest to the treated portion of the right-of-way.

Table 3C

**Micrograms of Dye on Each String Array
for Low Density Vegetation in the Buffer Zone**

FEET ¹	REPLICATION					
	A	B	C	A	B	C
	--- Stem-Foliage, Treatment 3 ---			---- Basal, Treatment 7 ----		
0	2.87	1.67	3.32	0.26	0.19	0.20
10	1.56	1.59	2.79	0.42	0.15	0.00
25	1.36	1.17	2.70	0.47	0.44	0.34
50	0.91	0.91	2.10	0.34	0.42	0.41
75	2.20	1.70	2.80	0.16	0.00	0.58
100	1.40	1.20	1.80	0.29	0.29	0.00

Table 3D

**Micrograms of Dye on Each String Array
for No Vegetation in the Buffer Zone**

FEET ¹	REPLICATION					
	A	B	C	A	B	C
	---- Stem-Foliage, Treatment 4 ----			---- Basal, Treatment 8 ----		
0	635.00	212.00	201.00	0.54	0.39	0.53
10	109.00	23.00	23.00	0.18	0.00	0.00
25	21.80	8.70	9.20	0.00	0.20	0.00
50	14.00	8.80	9.60	0.54	0.15	0.00
75	19.10	9.80	26.70	0.37	0.00	0.00
100	18.60	30.90	35.50	0.00	0.00	0.00

¹Feet refers to the distance into the buffer zone from the edge closest to the treated portion of the right-of-way.

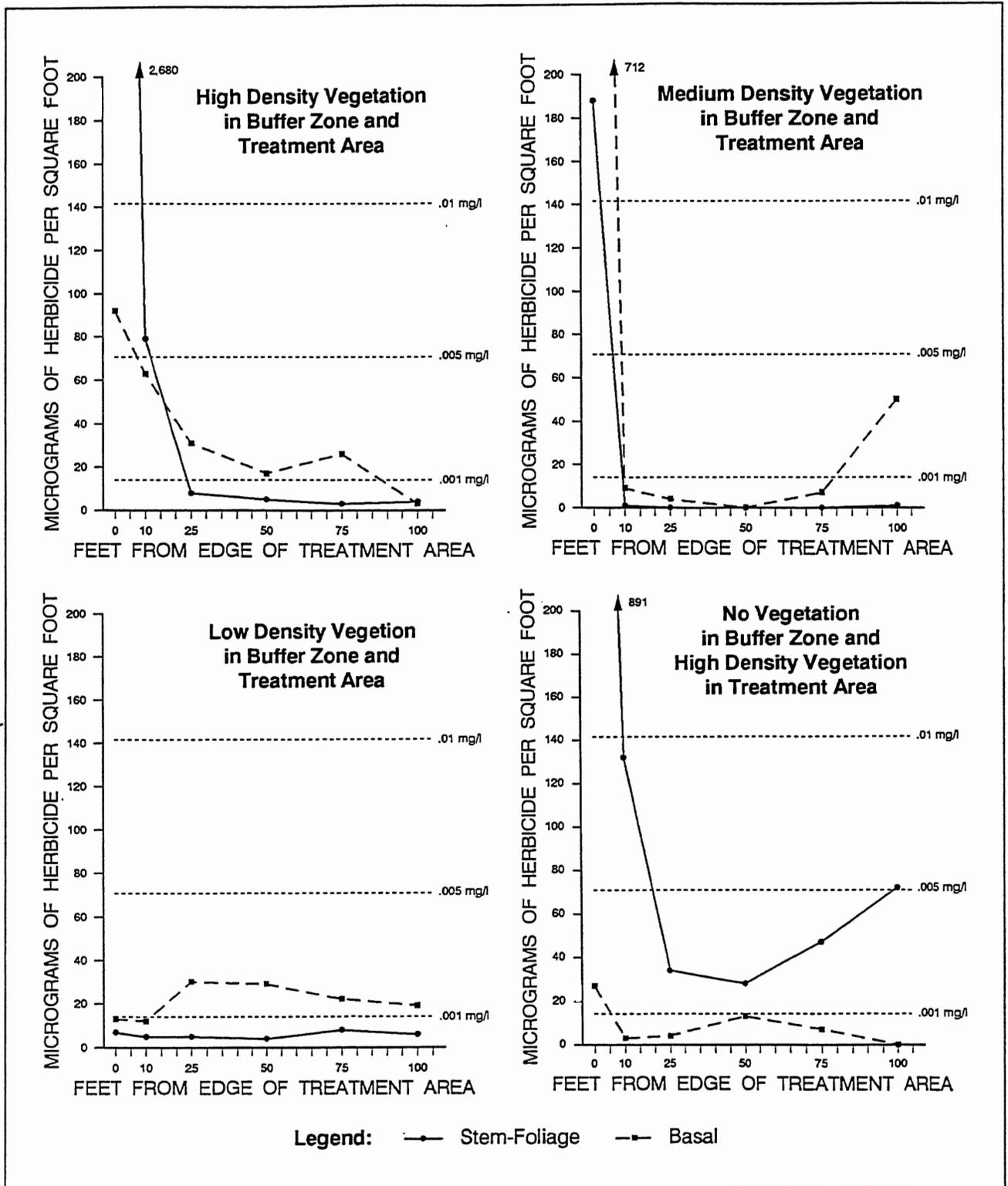


Figure 13. Calculated deposition of herbicide in buffer zone by vegetation density in the buffer zone. Example concentrations (.001, .005, and .01 mg/l) in a 6-inch stream are shown for comparison. The .005 mg/l concentration is the lowest concentration standard recommended for protection of human health and populations of commonly abundant aquatic organisms.

Table 4A

**Micrograms of Herbicide per Square Foot at Each String Array
for High Density Vegetation in the Buffer Zone**

FEET ¹	REPLICATION					
	A	B	C	A	B	C
	---- Stem-Foliage, Treatment 1 ----			----- Basal, Treatment 5 -----		
0	141.72	2731.62	2627.55	144.25	44.00	88.00
10	2.32	14.05	143.08	88.00	65.16	35.09
25	1.71	10.46	5.86	21.29	45.31	26.75
50	1.28	5.07	5.84	0.00	21.40	29.63
75	0.00	2.09	3.27	13.78	63.96	0.00
100	0.57	1.76	6.46	0.00	9.68	0.00

Table 4B

**Micrograms of Herbicide per Square Foot at Each String Array
for Medium Density Vegetation in the Buffer Zone**

FEET ¹	REPLICATION					
	A	B	C	A	B	C
	---- Stem-Foliage, Treatment 2 ----			----- Basal, Treatment 6 -----		
0	196.42	126.27	240.85	115.24	1532.83	487.42
10	1.06	0.00	2.78	0.00	19.11	9.28
25	0.38	0.00	1.29	13.30	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	8.78	11.52	0.00
100	2.55	0.00	0.00	75.88	44.76	30.02

¹Feet refers to the distance into the buffer zone from the edge closest to the treated portion of the right-of-way.

Table 4C

**Micrograms of Herbicide per Square Foot at Each String Array
for Low Density Vegetation in the Buffer Zone**

FEET ¹	REPLICATION					
	A	B	C	A	B	C
	---- Stem-Foliage, Treatment 3 ----			----- Basal, Treatment 7 -----		
0	7.54	4.39	8.72	16.11	11.77	12.39
10	4.24	4.32	7.59	26.94	9.62	0.00
25	4.13	3.56	8.20	33.67	31.52	24.36
50	2.92	2.92	6.73	25.70	31.74	30.99
75	8.31	6.42	10.57	14.24	0.00	51.63
100	5.96	5.11	7.66	29.11	29.11	0.00

Table 4D

**Micrograms of Herbicide per Square Foot at Each String Array
for No Vegetation in the Buffer Zone**

FEET ¹	REPLICATION					
	A	B	C	A	B	C
	---- Stem-Foliage, Treatment 4 ----			----- Basal, Treatment 8 -----		
0	1619.21	540.59	512.54	29.48	21.29	28.93
10	277.94	58.65	58.65	9.83	0.00	0.00
25	55.59	22.18	23.46	0.00	10.92	0.00
50	35.70	22.44	24.48	29.48	8.19	0.00
75	48.70	24.99	68.08	20.20	0.00	0.00
100	47.43	78.79	90.52	0.00	0.00	0.00

¹Feet refers to the distance into the buffer zone from the edge closest to the treated portion of the right-of-way.

Table 5
Average Calculated Herbicide Deposition in Micrograms
per Square Foot at Each String Array

FEET ¹	VEGETATION DENSITY IN BUFFER ZONE			
	High	Medium	Low	None
----- Stem-Foliage Treatments -----				
0	2679.58	187.85	6.88	890.78
10	78.57	1.28	5.38	131.75
25	8.16	0.56	5.30	33.74
50	5.46	0.00	4.19	27.54
75	2.68	0.00	8.43	47.26
100	4.11	0.85	6.24	72.25
----- Basal Treatments -----				
0	92.08	711.83	13.43	26.57
10	62.75	9.46	12.18	3.28
25	31.12	4.43	29.85	3.64
50	17.01	0.00	29.48	12.56
75	25.92	6.77	21.96	6.73
100	3.23	50.22	19.41	0.00

¹Feet refers to the distance into the buffer zone from the edge closest to the treated portion of the right-of-way.

Table 6
Calculated Instantaneous Concentration of Herbicide in a Stream
6 Inches Deep in Parts per Million at Each String Array

FEET ¹	VEGETATION DENSITY IN BUFFER ZONE			
	High	Medium	Low	None
----- Stem-Foliage Treatments -----				
0	0.1892	0.0133	0.0005	0.0629
10	0.0055	0.0001	0.0004	0.0093
25	0.0006	0.0000	0.0004	0.0024
50	0.0004	0.0000	0.0003	0.0019
75	0.0002	0.0000	0.0006	0.0033
100	0.0003	0.0001	0.0004	0.0051
----- Basal Treatments -----				
0	0.0065	0.0503	0.0009	0.0019
10	0.0024	0.0007	0.0009	0.0002
25	0.0022	0.0003	0.0021	0.0002
50	0.0012	0.0000	0.0021	0.0009
75	0.0018	0.0005	0.0016	0.0005
100	0.0002	0.0035	0.0014	0.0000

¹Feet refers to the distance into the buffer zone from the edge closest to the treated portion of the right-of-way.

The results are quite different among treatment variables. For instance:

- a. The stem-foliage applications generally produced more herbicide deposition on the buffer zone edge when high density vegetation was treated. The basal applications produced more deposition on the buffer zone edge when medium and low density vegetation was treated.
- b. The deposition decreased rapidly with distance from the edge of the buffer zone. This was particularly true in the buffer zones with high density vegetation where deposition rates at the edge of the zone are highest. Where levels of deposition at the edge of the buffer zone are low, there is little change in deposition with distance, suggesting slight movement of aerosols, or possibly some minor contamination of the strings as they were handled after the application had been made.
- c. The basal applications generally produced more herbicide deposition in vegetated buffer zones. The stem-foliage applications produced more in areas where there was no vegetation in the buffer zone. Interestingly, the effect of distance in reducing deposition was less pronounced with the basal applications. Except for the vegetation-free buffer zone, higher deposition levels occurred further from the edge of the buffer zone with the basal treatment than with the stem-foliage application, although in all cases the deposition rate was exceedingly low.
- d. The density of vegetation in the buffer zone appears to play an important role in reducing deposition with increasing distance from the edge of the buffer zone. This is most clearly illustrated in treatments 1 and 4 where heavy vegetation density occurred in both treatment areas, but was high only in buffer zone 1, with no vegetation in buffer zone 4. Even in the low density vegetation zone, there was less effect of distance on deposition than there was in the medium density zone. Clearly, the vegetation plays an important role in capturing spray droplets, and minimizing deposition at greater distances from the treatment area.
- e. The variation in deposition between replications was low, with the exception of replication A in treatment 1, which shows levels of deposition substantially less than replications B and C (which are quite similar). Replication A was made when the strings were wet from a light mist, which continued to fall intermittently during the application in replication A. Strings from the array at the edge of the buffer zone in replication A showed dye that was uniformly distributed throughout the string. This was in contrast to all other string collections made when there was no rain. Strings collected closest to the buffer zone in dry weather showed distinct spray droplets. The conclusion is that significant portions of the dye were lost from the wet strings in replication A of treatment 1. Only replication A of treatment 1 was run on that day because of the weather. All other test-days were dry. For these reasons, the average values in Tables 5 and 6 for treatment 1, include only values from replications B and C.

6. Statistical Analysis

The dye deposition data (converted to micrograms of herbicide per square foot) were subjected to statistical analysis. The experimental design was a randomized split plot with vegetation density and application methods as the whole plots and distance from the edge of the treatment zones as the split plot. The data were transformed with logarithms to satisfy the

assumptions of the analysis of variance. Analysis of variance showed differences in deposition due to vegetation density, application method and distance from the treated zone as all statistically significant ($P < 0.01$).

There was a significant interaction ($P < 0.001$) between vegetation density and method of application which means the change in pattern of deposition that occurred with distance from the treatment zone was not the same for the two methods of application. There was also a significant ($P < 0.001$) interaction between vegetation density and distance, meaning the pattern of deposition that occurred with distance from the edge of the treatment zone was not the same in all densities of vegetation. Most important, there was a significant ($P < 0.021$) three-way interaction between vegetation density, application method, and distance.

Analysis of least squares means was used to determine least significant difference with replanned comparisons among selected treatment means (Tables 7A, B, and C).

Some examples will help illustrate the results of these comparisons.

- a. There was no significant difference in the mean deposition level at 0 feet between the high density or the no vegetation density buffer zone for the stem-foliage application or for the basal application (Table 7A).
- b. Within the stem-foliage application group, deposition at 100 feet was higher in the no vegetation zone, and there was no difference among deposition levels at 100 feet in any of the other vegetation density groups (Table 7A).
- c. Within the low density vegetation group, there was no difference in deposition at any distance in either method of application, likely reflecting the very low values found in this test (Table 7B).
- d. In all stem-foliage applications except in the low density vegetation zone, the highest levels of deposition were at 0 feet, with no differences among other distances in the no vegetation or the medium density vegetation zones (Table 7B).
- e. In the high density vegetation buffer, there was no significant difference among deposition values at 25 feet and beyond (Table 7B).
- f. In contrasts between the stem-foliage and the basal application methods, there were significant differences at all distances except 50 feet in the no vegetation buffer zone, but no differences in the low density zone except at 25 and 50 feet, or at distances at 10 feet and beyond in the high density zone (Table 7C).

These contrasts help to evaluate the reality of the apparent differences in deposition that occurred among treatments. Many of the apparent differences may not be real, based on the results of this statistical analysis. The most important (largest) differences are real, and are the emphasis of the discussion.

Table 7A

**Results of Comparisons of Deposition (log. micrograms
per square foot) Among Selected Treatment Means, Based on
Least Significant Differences With Pre-Planned Comparisons Test**

Effect of Vegetation Density

DISTANCE (Feet)	STEM-FOLIAGE		BASAL	
	Vegetation Density in Buffer Zone	Mean Deposition Contrast ¹	Vegetation Density in Buffer Zone	Mean Deposition Contrast ¹
0	High	a	Medium	a
	None	a,b	High	b
	Medium	b	None	b,c
	Low	c	Low	c
10	None	a	High	a
	High	a	Low	b
	Low	b	Medium	b
	Medium	b	None	b
25	None	a	High	a
	High	a,b	Low	a
	Low	b,c	Medium	b
	Medium	c	None	b
50	None	a	Low	a
	High	a,b	High	a
	Low	b	None	a
	Medium	c	Medium	b
75	None	a	High	a
	Low	a,b	Low	a
	High	b,c	Medium	a
	Medium	c	None	a
100	None	a	Medium	a
	Low	b	Low	b
	High	b	High	b,c
	Medium	b	None	c

¹Values within a given group that have a lower case letter in common are not significantly different ($P > 0.05$). An example of a group is basal, 0 feet distance; a separate group is basal, 10 feet distance. The order of vegetation density in a given group is determined by average deposition level. As an example, in the basal application, 0 feet group, the highest average deposition level was in the medium vegetation density, followed by the high and none vegetation density groups. The lowest average deposition was in the low vegetation density group.

Table 7B

**Results of Comparisons of Deposition (log. micrograms
per square foot) Among Selected Treatment Means, Based on
Least Significant Differences With Pre-Planned Comparisons Test
Effect of Distance From the Edge of the Treatment Zone**

VEGETATION DENSITY IN BUFFER ZONE	STEM-FOLIAGE		BASAL	
	Distance (Feet)	Mean Deposition Contrast ¹	Distance (Feet)	Mean Deposition Contrast ¹
High	0	a	0	a
	10	b	10	a
	25	b,c	25	a,b
	50	c	75	b,c
	100	c	50	b,c
	75	c	100	c
Medium	0	a	0	a
	10	b	100	b
	25	b	10	c
	100	b	75	c
	50	b	25	c,d
	75	b	50	d
Low	75	a	25	a
	0	a	50	a
	100	a	0	a
	10	a	100	a
	25	a	75	a
	50	a	10	a
None	0	a	0	a
	10	b	50	a,b
	100	b	75	b,c
	75	b	25	b,c
	25	b	10	b,c
	50	b	100	c

¹Values within a given group that have a lower case letter in common are not significantly different ($P > 0.05$). An example of a group is basal, high vegetation density; a separate group is basal, medium vegetation density. The order of distance in a given group is determined by average deposition level. As an example, in the basal application, high vegetation density, the highest average deposition level was in the 0 feet distance, followed by 25, 10, 75, and 50 feet distances. The lowest average deposition was in the 100 feet distance.

Table 7C

Results of Comparisons of Deposition (log. micrograms per square foot) Among Selected Treatment Means, Based on Least Significant Differences with Pre-Planned Comparisons Test
Effect of Method of Application

DISTANCE (Feet)	VEGETATION DENSITY IN BUFFER ZONE ¹			
	High	Medium	Low	None
0	* (<0.001)	NS (0.27)	NS (0.43)	* (<0.001)
10	NS (0.78)	NS (0.17)	NS (0.93)	* (<0.001)
25	NS (0.17)	NS (0.53)	* (0.044)	* (<0.001)
50	NS (0.72)	NS (1.0)	* (0.025)	NS (0.07)
75	NS (0.26)	* (0.048)	NS (0.99)	* (<0.001)
100	NS (0.42)	* (<0.001)	NS (0.71)	* (<0.001)

¹* = Significant ($P \leq 0.05$). NS = Not Significant ($P > 0.05$). Value in parentheses is the P value, which shows the level of significance/insignificance for each comparison.

E. DISCUSSION AND CONCLUSIONS

Many of the following conclusions on buffer widths are based on use of 2,4-D ester, the most toxic of the herbicide formulations evaluated in this report (see Part V of this report). As noted in these conclusions, narrower buffers will achieve comparable protection when herbicides of lower toxicity are used. None of the electric utilities in New York are using 2,4-D ester.

- a. The string array and dye procedure is effective for monitoring spray drift in the field. The considerably less expensive analysis of dye permits more tests to be conducted, or a less costly study to be conducted than would be possible if chemical analysis of the herbicide were required.
- b. Based on the risk analysis in Part V of this report and the use of 2,4-D ester (most toxic of the herbicides evaluated in the risk assessment), buffer strips of 25 feet would have achieved the recommended water quality protection goals for every herbicide formulation evaluated - based on direct application and drift of spray material to surface water. Buffer strips narrower than this could be used with herbicides of lower toxicity, as shown in Part V.
- c. In those instances where vegetation density in the treated area adjacent to the buffer zone is medium to low, buffer zones of 10 feet are sufficient to prevent off-site contamination that might be injurious to aquatic organisms or downstream human water users when using stem-foliage spray techniques. Even when using the basal spray (which, except in the high vegetation density areas, produced more deposit of active ingredient in the buffer than the stem-foliage treatments), buffers of 10 feet will prevent damage.
- d. Where vegetation density in the treatment area and the buffer zone is high, buffer zones of 25 feet are required for stem-foliage treatments, but 10 feet is adequate for basal applications.
- e. Where vegetation density is high in the treatment area and there is no vegetation in the buffer zone, buffer zones of 100 feet or more may be required for stem-foliage sprays. Basal applications with buffer zones of 10 feet may be preferred in instances such as this.
- f. Evaluation of calculated stream contamination levels follows a similar pattern. The results indicate that, on the average, buffer zones of only 10 feet are sufficient to prevent stream contamination at levels greater than 0.01 ppm, regardless of the method of application. In most cases, this size buffer zone will prevent contamination greater than 0.005 ppm, the critical concentration for 2,4-D ester in water. The critical concentration is higher for the other herbicides covered in the risk analysis in Part V.
- g. The assumption that basal spraying will result in less off-site deposit may not be warranted in all cases. The nature of the oil-based spray carrier is such that aerosol formation may be greater, resulting in more drift of a type which is not as effectively screened by vegetation as the water-based spray. Care to minimize aerosol formation should always be taken in areas where off-site deposition is a critical issue.

The previous conclusions are derived directly from the results of this test, which includes making applications in some instances when the wind was moving air from the treated area into the buffer. Additional reductions in deposition in the buffer can likely be achieved by spraying when the air movement is away from the buffer, although this variable was not part of this test.

Tables 8A and 8B provide a summary of the buffer widths required to achieve the water quality standard values recommended for protection of populations of common aquatic organisms, and for protection of human health. These are based on the calculated values for the concentration of herbicides in water presented in Table 6. See Part V of this report for the basis of the standards, and Part VI for the standards for specific herbicides.

These results indicate that for several commonly used herbicides in stem-foliar or in basal applications, there is no need for buffers to prevent direct application or drift of herbicide to the stream. This is based on the deposition of dye measured in this test and the toxicity of specific herbicide formulations as analyzed in Part V of this report. This is the case for Garlon 3A, Arsenal, Chopper, Krenite, and Accord herbicides. Buffers of 10 to 25 feet are effective in preventing direct application and drift in achieving water quality goals suggested in Part VI in all other instances.

Based on the analysis above, it is possible to prescribe specific buffer widths for specific sites, methods of application and herbicide formulations. They provide a chemical and site-specific approach to protection of water quality.

F. GENERAL CONCLUSIONS

Trained field crews that are effectively supervised can achieve safe herbicide applications that do not result in biologically significant direct application or drift of herbicide into vegetated areas more than 25 feet from the edge of the treated area. This provides protection for humans using water from, and for aquatic organisms that are in, the areas designed to be protected by the use of buffers of the dimensions found effective in this test when using 2,4-D ester. When herbicides of lower toxicity than 2,4-D ester are used, narrower buffers could be used and still achieve protection.

Where there is no vegetation in the buffer zone adjacent to areas to be treated, treatments other than high-volume, stem-foliage application may be needed to assure safety.

G. LITERATURE CITED

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Table 8A

**Buffer Width to Achieve Water Quality Goals¹
With Stem-Foliar Application**

HERBICIDE	VEGETATION DENSITY IN BUFFER ZONE			
	High	Medium	Low	None
	----- (feet) -----			
2,4-D				
Amines	10	0	0	0
Esters	25	10	0	25
Tordon 101	10	0	0	0
Picloram				
Tordon 101 ²	10	0	0	0
Tordon K	10	0	0	0
Access	10	0	0	0
Triclopyr				
Garlon 3A	0	0	0	0
Garlon 4	10	0	0	10
Imazapyr				
Arsenal	0	0	0	0
Chopper	0	0	0	0
Fosamine				
Krenite	0	0	0	0
Glyphosate				
Accord	0	0	0	0

¹Standards are in Part VI of this report.

²The buffer width is based on the 2,4-D standard. If it were based only on the content of Picloram, no buffer would be required to meet the standard at any vegetation density.

Table 8B
Buffer Width to Achieve Water Quality Goals¹
With Basal Application

HERBICIDE	VEGETATION DENSITY IN BUFFER ZONE			
	High	Medium	Low	None
	----- (feet) -----			
2,4-D				
Amines	0	0	0	0
Esters	10	0	0	0
Tordon 101	0	0	0	0
Picloram				
Tordon 101	0	0	0	0
Tordon K	0	0	0	0
Access	0	0	0	0
Triclopyr				
Garlon 3A	0	0	0	0
Garlon 4	0	10	0	0
Imazapyr				
Arsenal	0	0	0	0
Chopper	0	0	0	0
Fosamine				
Krenite	0	0	0	0
Glyphosate				
Accord	0	0	0	0

¹Standards are in Part VI of this report.

PART IV

**EFFECTS ON STREAM WATER QUALITY
FROM OPERATIONAL
VEGETATION MANAGEMENT
WITH HERBICIDES
ON POWERLINE RIGHTS-OF-WAY
IN NEW YORK**

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**EFFECTS ON STREAM WATER QUALITY
FROM OPERATIONAL VEGETATION MANAGEMENT
WITH HERBICIDES ON POWERLINE RIGHTS-OF-WAY
IN NEW YORK**

Results Of An Operational Monitoring Study

A. PART IV SUMMARY

Herbicide applications on eight powerline right-of-way (R/W) sites were monitored to determine the effectiveness of buffer zones in protecting stream water quality. Picloram and triclopyr were applied to three sites (two also received 2,4-D) and imazapyr was applied to five sites. Normal operational applications were made by experienced crews. This test was not designed to evaluate differences among herbicides in their entry to water - only buffer zone and application strategies.

Water samples were taken once each 6 hours by automatic sampling equipment after the application in September, 1989. Sampling continued until November when freezing weather stopped the samplers and was resumed in March, 1990, and continued until April, May, or June. Selected individual and composite water samples were analyzed by gas chromatography for herbicide with a minimum detection limit of 0.001 mg/liter (1 part per billion) or less.

Most samples of water analyzed contained no detectable herbicide. A few samples collected shortly after application or during the first significant rainstorms after application contained low levels of herbicide. Herbicide was not detected the next spring during runoff, except in one sample.

Triclopyr was found (0.001 and 0.002 mg/liter) in five samples and picloram was found (0.001 mg/liter) in one sample collected during the first significant rainstorm(s) after application at one site. A few samples from the two sites treated with picloram, triclopyr, and 2,4-D contained trace amounts (less than 0.001 mg/liter, primarily triclopyr, no 2,4-D) of herbicide. These samples were collected during the first significant rainstorms after application. No other residues were found at these three sites during sampling which extended to late May.

Similar results were found for imazapyr. No imazapyr was found at two sites. At two other imazapyr sites, two and five samples collected in the first month after application contained imazapyr. After the first month, seven and eight samples, respectively, were found with imazapyr (maximum 0.003 and 0.006 mg/liter). These samples were collected over several days of heavy precipitation (4.2 inches in 8 days and 2.32 inches in 7 days). At the other site, one composite sample from the first week after treatment contained imazapyr (0.001 mg/liter). Two individual samples about 3 weeks after treatment showed residue (0.002 mg/liter) during a period of little rain. Except in one sample, no further residues were found at any site treated with imazapyr during the spring runoff period.

In no case were the specific herbicide residue levels found in this study sufficient to cause acute or chronic toxic responses in aquatic or terrestrial organisms, including humans. Since safety was achieved in each case, these results provide no basis for selecting one herbicide over another, furthermore, the study design was not intended to evaluate differences among herbicide products.

The results from this study show the buffer zone strategies used during these applications were sufficient to protect water quality from the herbicides used due to direct application or drift during the application, or by runoff or leaching after the application. The results also

show that accurately identifying and using the boundaries of wet areas in the application of the buffer zone strategy is necessary if these results are to be uniformly achieved.

B. INTRODUCTION

Tall-growing vegetation can significantly impact the safe and cost-effective distribution of electric power. A variety of strategies for the control of this vegetation are possible, and many have been tested. The fundamental criteria for selecting a particular strategy is that it must be effective, efficient, and environmentally safe.

Several studies have shown the efficacy and efficiency with which herbicides can be used for the control of tall-growing vegetation on powerline rights-of-way (R/W). However, as with any method for controlling vegetation, managers and regulatory agencies must give careful consideration to potential adverse environmental effects. Of particular interest is the potential impact of herbicides on water quality in streams that flow through or near R/W.

Research done in forest environments has determined the primary processes by which herbicides enter surface waters. In terms of concentration, direct application and drift are the most important, followed by mobilization of herbicide residues from the soil surface during periods of heavy precipitation. The preponderance of literature does not report data indicating entry of herbicides to woodland streams from leaching through the soil profile, or in overland flow (except perhaps in areas which have been heavily compacted) (Norris, 1981, Norris et al., 1983).

There are a number of strategies that are used to prevent or minimize the entry of R/W herbicides into surface water. These include (a) careful attention to the methods of application and the conditions under which applications are made, (b) effective training and supervision of field crews involved in application, and (c) the use of buffer zones between areas of application and surface water. Buffer zones are a common strategy, but critical tests are lacking of their effectiveness in protecting stream water quality in connection with the use of herbicides on powerline R/W in New York.

The buffer zones currently employed by New York State Electric and Gas Corporation and Niagara Mohawk Power Corporation are as follows:

New York State Electric and Gas Corporation

Method of Application

Buffer Zone Distance

Basal Spray and Stump Treatment

30 feet from all water bodies and 100 feet from regulated wetlands unless NYSDEC permit allows for applications closer to regulated wetland.

Foliar Spray

50 feet from all water bodies and 100 feet from regulated wetlands unless DEC permit allows for applications closer to regulated wetlands.

Niagara Mohawk Power Corporation

Basal Spray and Stump Treatment	30 feet from streams, ponds, lakes, standing water and 100' from regulated wetlands unless NYSDEC permit allows for application closer to regulated wetlands.
Foliar Spray	50 feet from streams, ponds, lakes, standing water and 100' from regulated wetlands unless NYSDEC permit allows for application closer to regulated wetlands.
Helicopter Spray	250 feet from streams, ponds, lakes, standing water and regulated wetlands.

1. Purpose of the Research

The purpose of the research conducted in this study is to test buffer zone effectiveness in protecting stream water quality in connection with the operational application of herbicides on typical R/W in New York. The goal is to determine if current buffer zone strategies are effective in achieving water quality protection goals.

2. Specific Research Objectives

- Determine the effect of buffer zone and application strategies on entry of herbicide by direct application and drift to surface water intended to be protected by the buffer.
- Determine the effect of buffer zones on entry of herbicide by movement from application areas to surface water intended to be protected by the buffer during the fall and early winter and in the spring following application.

3. Scope of the Research

The scope of the study includes the following:

- Four herbicides used in controlling vegetation on R/W were included in this study, specifically: 2,4-D, picloram, triclopyr, and imazapyr, as registered for use on R/W by the United States Environmental Protection Agency. Detailed information about the chemistry, environmental behavior, and toxicology of these herbicides are in Jagan et al., 1987, and USDA Forest Service, 1984, 1987, and 1988.
- Sites with streams crossing the R/W, and around which normal practice is to provide a buffer for stream water quality protection.
- An 8-month period following application from early fall until late spring. This includes the early winter wet period and the period of spring thaw and enhanced runoff.

- High-volume stem foliage and low-volume stem basal methods of application.

These characteristics account for the vast majority of herbicide applications on New York State Electric and Gas Corp. and Niagara Mohawk Power Corp. R/W, and cover the breadth of application conditions in which buffer zones may be important. They also include the most widely used or potentially most widely used herbicides, and those about which more information is needed on movement to streams via leaching or overland flow.

Other herbicides which are commonly used on R/W are glyphosate (Accord) and fosamine (Krenite). Neither of these have significant mobility and they tend to absorb to soil organic matter, where they are quickly decomposed. In addition they are difficult to analyze. Thus from a combined consideration of the potential for their entry to water and the cost of their analysis, it was not effective to include them in this study.

4. Overview of Strategy of Study

Herbicide can conceivably move from a treated area by the following mechanisms:

- Direct application or drift during and immediately after application (usually the day of application).
- Mobilization of herbicide residues from the surface of the litter, vegetation, or soil after application, and movement of the water by surface flow to streams (which may occur during the first few rainstorms. After that, herbicide residues on the surface are dissipated or have moved into the surface layers of soil or organic matter and are no longer available for movement by this process.)
- Leaching of herbicide residues through the soil profile with subsurface drainage carrying residues to the stream. (If it occurs, it will most likely be evident several weeks to months after application, and residues will appear in streams in the absence of rain.)
- Overland flow of herbicides with surface runoff water or on erosion particles (which may occur in areas of significant soil compaction and steep topography).

It is believed that current buffer zone and application strategies are successful in protecting stream water quality, but a rigorous validation in New York is lacking. This study tests the effectiveness of buffer zones in connection with the operational application of herbicides on New York powerline R/W.

Water samples were collected from surface water locations to be protected by buffer zones and analyzed by sensitive and specific chemical methods to quantify the herbicide that might be in the water. By sampling frequently and on a regular basis, a large number of samples were collected. Through compositing and the selection of individual samples as determined by precipitation, patterns of herbicide entry to streams and the effectiveness of buffer zones can be determined. This is the approach used in this study. This study is not designed to evaluate differences among herbicides in their entry to water - only the effectiveness of different buffer zone and application strategies.

Automatic water sampling equipment was used to permit collection of daily samples. Not all samples collected were analyzed. A predetermined strategy was used to select samples for analysis that would most logically be expected to contain residues if herbicide entry to streams was occurring. Samples were collected immediately downstream from the application zone to monitor entry of herbicide from the application on the R/W. Separate sets of samples were

collected upstream from the same location to serve as controls. All field samples and quality control samples were analyzed by John Deagen (for 2,4-D, picloram or triclopyr) or Marvin Montgomery (for imazapyr), Department of Agricultural Chemistry, Oregon State University. These strategies are explained in detail in the methods.

C. METHODS

The methods section is divided into sections that focus on field and laboratory operations.

1. Field Methods

a. Site Selection

The purpose of this study was to determine the effectiveness of various buffer zones in achieving water quality protection goals. Sandy or loamy soils are most likely to allow herbicide leaching into the stream. The occurrence of these soil types was the principal factor in site selection. The selected sites have vegetation and topography typical of the study area. The study sites also contain a stream that crosses the R/W area and has vegetation in the buffer zone and on both sides of the buffer zone.

The focus of this study was on both entry during application due to direct application or drift to open water and the movement of herbicide after treatment from the R/W to the stream. The study strategy included an upstream location not exposed to water originating from the treated portion of the R/W, and a downstream site where stream water does include water originating from the R/W.

In general, R/W on relatively gentle to steep terrain and crossing streams at 45 to 90 degrees were considered to best meet these goals. Under these conditions, the R/W would be at right angles to the contour where the buffer zone was to be used. Sites where the R/W was parallel to contours on a steep side slope were avoided because surface water would drain for a long distance down slope before entering the stream. Selected sites all had the water originating on the R/W entering the stream channel within a few feet of the downstream edge of the R/W.

The purpose of protecting stream water quality is to ensure protection of aquatic life and the health of humans who might be downstream water users. Therefore, stream size also had an important role in the site selection process. Sites with very large streams were avoided because the volume of water is so large there is virtually no chance normal patterns of herbicide use will alter water quality to the level it will endanger aquatic life. The dilution potential is too great for high levels of herbicide to occur. Very small streams were also avoided. Streams that are too small contain relatively insignificant amounts of aquatic life, and the role of any one such stream in supply water for human consumption is small.

Thus, for purposes of this study, selected sites were to have streams that were neither too large nor too small. The general guidelines used for selection were that the stream was to be 1 to 8 feet in width and 1 to 8 inches in depth. Figure 1 shows the approximate location of the eight sites selected. Two sites are on R/W maintained by New York State Electric and Gas Corp. The remaining sites are located on R/W maintained by Niagara Mohawk Power Corp. Detailed site descriptions, with illustrations, accompany the study results in Section D (Results and Discussion).

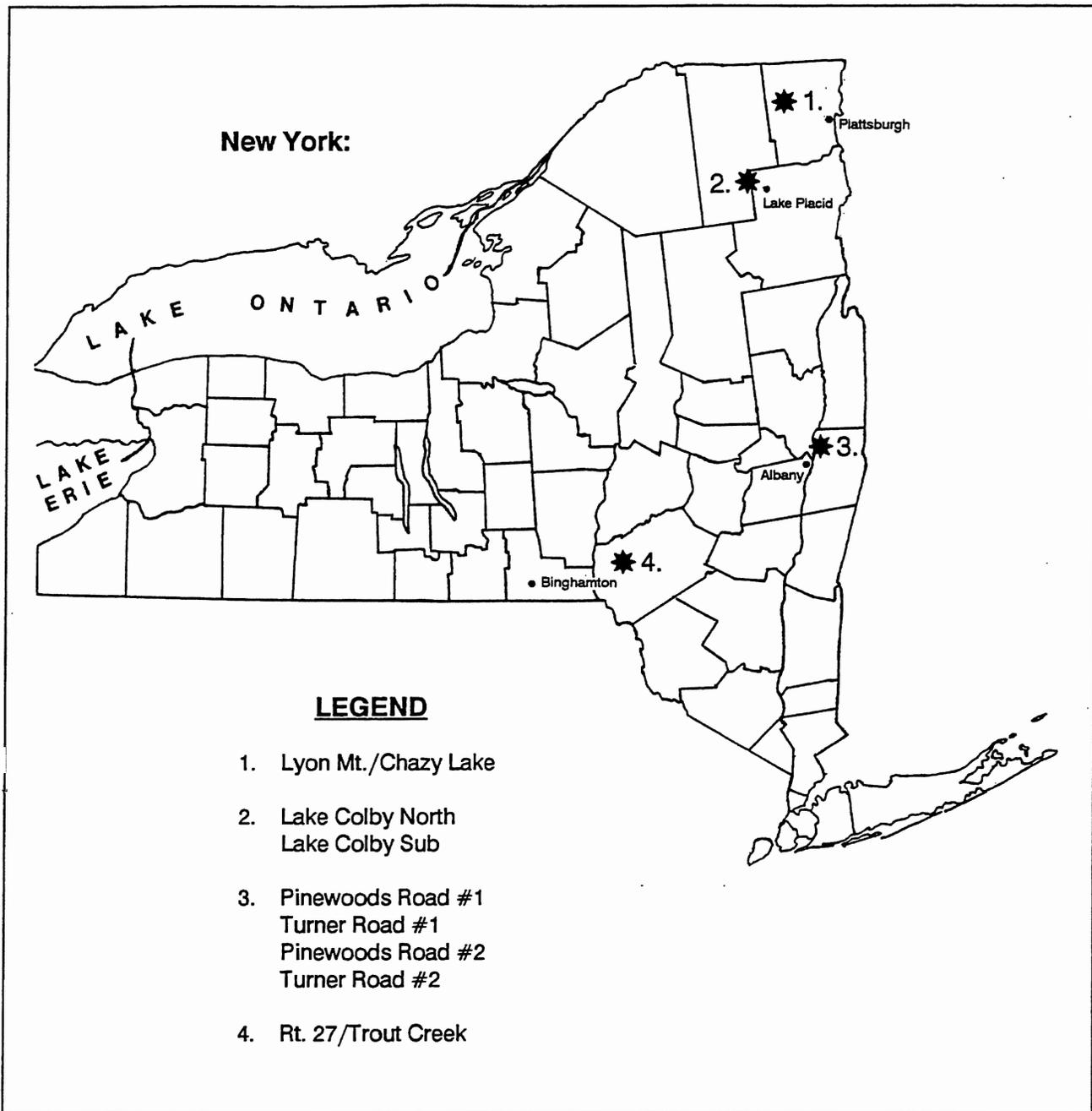


Figure 1. Map showing the eight study sites where water monitoring was conducted.

b. Herbicide Application

Each of the eight study sites were treated with either a high-volume stem-foliage treatment or a low-volume basal application. Each treatment was done as a normal operational application. Table 1 presents details of the application on each site.

The high-volume stem-foliage application (Figure 2-top) was applied using a gasoline-powered hydraulic pump and tank mounted on an all-terrain tracked vehicle. The solution was applied through hand-held spray guns equipped with No. 8 nozzle disks. The lowest pressure that would provide adequate coverage with a spray of coarse droplets was used.

The basal treatment (Figure 2-bottom) performed for this study was a low-volume basal application made with a hand-operated backpack sprayer. The minimum pressure necessary to deliver a coarse spray of large droplets was used.

The herbicide applications were limited to commonly used herbicide formulations with the greatest potential for mobilization on the R/W. Active ingredients included 2,4-D, picloram, triclopyr, and imazapyr.

Trained herbicide application crews working under contract with New York State Electric and Gas Corp. and Niagara Mohawk Power Corp. performed the treatments. These crews operated under the direct supervision of the contractor's crew foreman. As is typical of operational applications, the power companies did not provide additional on-site supervision during treatment of the study sites.

c. Weather Records

Rainfall had an important role in the sampling strategy. Rainfall records (as shown in Table 2) were obtained from local climatological data provided by the National Climatic Data Center. Records from the weather station nearest each site were used.

d. Sampling Procedures and Equipment

The basic sampling strategy was to collect water samples from both the upstream and downstream sites, before, during, and after treatment. Four samples (one each 6 hours) were taken during each 24-hour period and deposited in a single bottle, giving a 24-hour average sample. The sampler then advanced to the next bottle for the next 24-hour period. This cycle continued until the streams began to freeze in the winter. Sampling began again after spring thaw and continued for one or more 24-day cycles.

ISCO Model 2700 battery-operated water samplers (Figure 3) were used to collect the upstream and downstream samples. Each sampler contained a sufficient number of bottles for a 24-day cycle. The sampling units were programmed to collect 4 samples (maximum of 85 milliliters) per bottle at 6-hour intervals. The beginning of each 24-hour sampling period was set to coincide with the 24-hour precipitation recording period of the closest weather station.

Two units were installed at each study site. One unit was placed upstream where it was not believed to be exposed to surface water from the treated R/W. The downstream sampler was located to assure the water collected did include water that originated from the R/W, usually less than 20 feet from the downstream edge of the R/W.

Table 1

Site by Site Summary of Application

SITE	APPLICATION (mix rate)	COMPOSITION OF HERBICIDE MIXTURE	ACTIVE INGREDIENT (lbs./acre)	BUFFER ZONE	DATE OF APPLI- CATION
Lyon Mt./ Chazy Lake	Basal (4 gals./ acre)	0.5 gal. Access and 0.5 gal. Garlon 4 in 3 gals. #2 fuel oil	Picloram (0.5 lbs.), Triclopyr (3.0 lbs.)	30'	9/12/89
Lake Colby North	Stem-foliage (167 gals./ acre)	2 qts. Arsenal in 99.5 gals. water	Imazapyr (1.7 lbs.)	10'	9/6/89
Lake Colby Sub	Stem-foliage (106 gals./ acre)	2 qts. Arsenal in 99.5 gals. water	Imazapyr (1.1 lbs.)	35'	9/6/89
Pinewoods Rd. #1	Stem-foliage (200 gals./ acre)	2 qts. Tordon 101 and 1.5 qts. Garlon 4 in 99.25 gals. water	2,4-D (2.0 lbs.), Picloram (0.5 lbs.), Triclopyr (3.0 lbs.)	100'	9/18/89
Pinewoods Rd. #2	Stem-foliage (220 gals./ acre)	2 qts. Tordon 101 and 1.5 qts. Garlon 4 in 99.25 gals. water	2,4-D (2.2 lbs.), Picloram (0.55 lbs.), Triclopyr (3.3 lbs.)	100'	9/18/89
Turner Rd. #1	Basal (3 gals./ acre)	10 ozs. Chopper in 1 gal. #2 fuel oil	Imazapyr (0.47 lbs.)	10'	9/17/89
Turner Rd. #2	Basal (1.3 gals./ acre)	10 ozs. Chopper in 1 gal. #2 fuel oil	Imazapyr (0.20 lbs.)	100'	9/17/89
Rt. 27/ Trout Creek	Basal (1.6 gals./ acre)	10 ozs. Chopper in 1 gal. #2 fuel oil	Imazapyr (0.25 lbs.)	15'	9/25/89

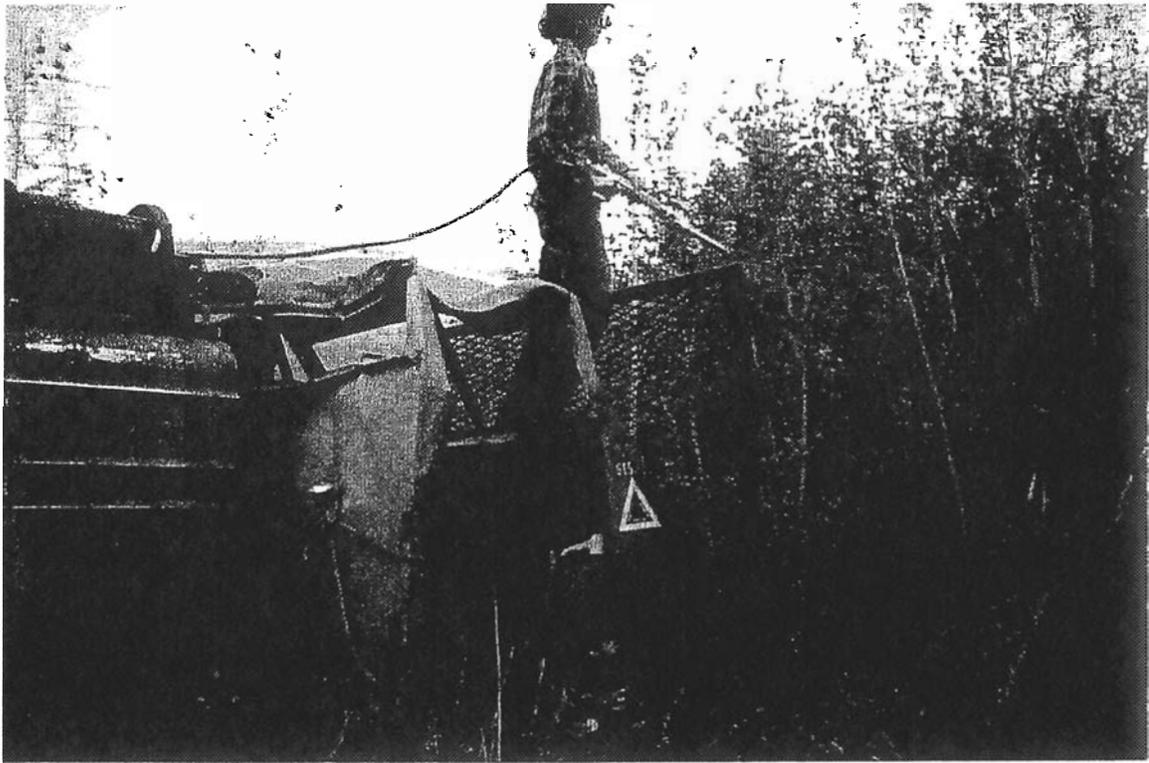


Figure 2. The study scope included two application methods commonly used on R/W in New York. High-volume stem-foliage applications (top) were used on four of the sites. A low-volume basal application (bottom) was used on the remaining four sites.



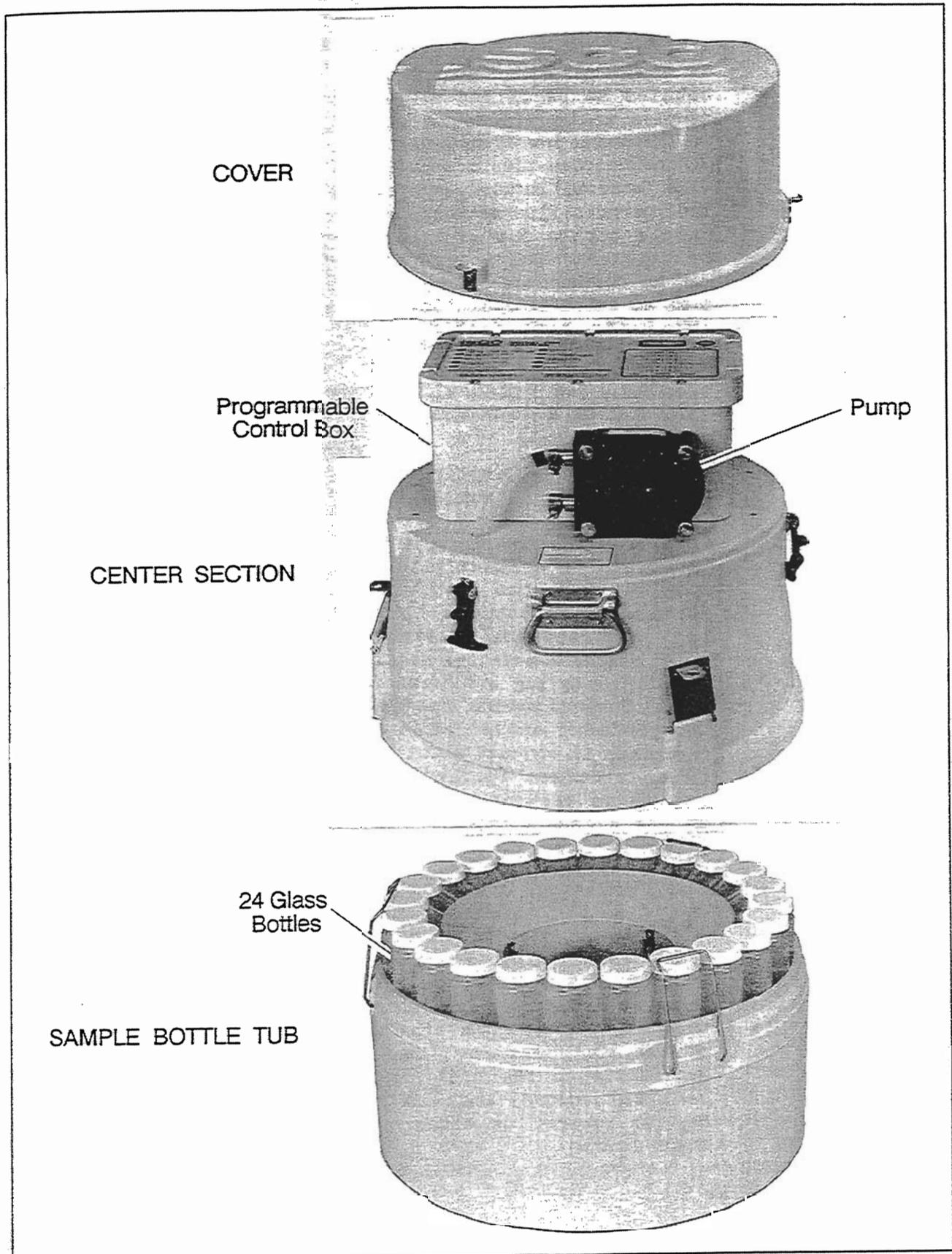


Figure 3. Exploded view of the equipment used to collect water samples.

Table 2
Monthly Precipitation (as rain in inches)

MONTH	WEATHER STATION/(STUDY SITES)			
	Dannemora (Lyon Mt./ Chazy Lake)	Lake Placid 2S (L.Colby North) (L.Colby Sub)	Albany (Pinewoods Rd.1 & 2) (Turner Rd.1 & 2)	Deposit (Rt. 27/ Trout Creek)
<u>1989</u>				
September	6.24	6.99	2.81	2.92
October	3.06	3.87	5.53	4.16
November	2.22	4.19	1.90	4.54
December	0.42	1.00	0.75	0.88
<u>1990</u>				
January	3.73	3.02	3.84	3.95
February	3.34	3.83	3.94	2.77
March	2.07	1.91	3.66	2.34
April	3.29	3.73	3.87	2.86
May	4.62	5.35	6.12	4.86
June	2.75	4.63	2.66	2.51

Each sampling unit was located as close to the stream as possible with a maximum distance of 10 feet. The unit was secured to a tree or stake to prevent it from being dislodged during periods of increased stream flow. The strainer on the end of the uptake hose was located where it would remain below water at all times, and where it would least likely be buried by streambed movement.

The sampling units were serviced on a maximum 24-day interval. A complete log was maintained for each bottle within each unit. Numbers from 1 to 24 were etched on the bottles. All bottles were labelled with the position number when they were removed from the sampler (which corresponds to the day the sample was taken). They were then transferred to a shipping container. Bottle numbers were carefully verified whenever removed from the unit and placed in the shipping container, and when the sampler was replenished.

Specially designed shipping crates were constructed to assure safe transport of all samples. Each container was loaded with the filled bottles and promptly shipped to TAXON in Corvallis, Oregon. The containers were returned with clean bottles to be used when the units were next serviced.

2. Laboratory Methods

a. Sample Receipt and Storage

Samples were received and stored in Corvallis, Oregon, by Richard Miller, TAXON. As individual boxes of samples were received, TAXON transferred the contents of each sample bottle into a clean canning jar, which was labeled with a unique number (permanent sample number). To insure sample stability until the samples could be analyzed, 5.0 ml 35% sulfuric acid was added.

b. Sample Identification

Various combinations of individual samples and composited samples were submitted to the analytical laboratory for analysis. Individual samples submitted for analysis carried the permanent sample number assigned on receipt by TAXON. Composite samples prepared by TAXON and quality assurance samples were assigned a previously unused permanent sample number.

c. Downstream Sample Selection for Analysis

Samples from each downstream sampling location were generally selected for analysis according to the following scheme:

- Day 0 to day 24.
 - One prespray sample, if possible, to serve as a pretreatment control.
One sample collected the day of application (to detect direct application or drift).
 - One 6-day composite sample for each 6-day period.
If herbicide was detected in the composite sample, the individual components of the composite sample were analyzed to determine the pattern of herbicide entry.
 - During the first three significant rainfall events (more than 0.1 inches per day) after application, daily samples were analyzed during the storm and for three days after the end of the rain storm.
- Day 25 to time when sampler operation became unreliable due to freezing of water in the sampler tube.
 - One 6-day composite sample for every other 6-day period.
 - If herbicide was detected in the composite sample, the alternate composite sample was analyzed and the individual components of composite samples containing herbicide were also analyzed to determine the pattern of herbicide entry to the water.
- Day 0 at beginning of the thaw period until about two 24-day sampling periods were completed for each site.
 - One 6-day composite sample for every other 6-day period.

If herbicide was detected in the composite sample, the alternate composite sample was analyzed and the individual components of composite samples containing herbicide were also analyzed to determine the pattern of herbicide entry to the water.

d. Upstream Sample Selection for Analysis

Samples from each upstream sampling location were generally selected for analysis according to the following scheme:

- Day 0 to end of study
 - One sample to serve as a control, especially if a prespray sample was not available from the downstream site.
 - Analyze only samples that correspond in time to samples from the downstream station that contain detectable herbicide residue.

Samples selected for analysis were delivered by TAXON to the analytical laboratory where they were placed in cold storage until analyzed. The analytical laboratory knew the source of the samples by study site, and the chemicals they were to analyze for, but they did not know the order in which samples were collected or if they were individual or composite samples. Additionally, quality assurance samples, which were in the same types of containers and with the same type of identification numbers as samples from the field sites, were mingled with field site samples. Quality assurance procedures are explained in the section on quality assurance.

e. Methods of Analysis

Chemical analyses were conducted by professional chemists in the Department of Agricultural Chemistry, Oregon State University, Corvallis, Oregon. Selected individual and composite water samples were analyzed by gas chromatography for herbicide with a minimum detection limit of 0.001 mg/liter (1 part per billion) or less.

f. Imazapyr

A 200 ml water sample was adjusted to pH 2.0 with either 1.0 molar hydrochloric acid or saturated sodium carbonate solution as needed. The sample was then extracted with three successive 100 ml portions of nanograde dichloromethane. The combined DCM extracts were concentrated to dryness in a 300 round bottom boiling flask. After adding 20 ml of methanol to dissolve imazapyr residues, the sample was transferred to a 100 ml round bottom boiling flask. The sample was again evaporated to dryness on the rotary evaporator to ensure complete removal of DCM residues.

The residues were then dissolved in 4 ml of warm methanol and transferred to a 10 ml glass-stoppered graduated tube. A 2 to 3 ml rinse was used to obtain complete transfer of residue to the 10 ml tube. The extract was concentrated to 1 ml using a stream of nitrogen and was ready for derivatization and analysis.

Just prior to analysis, 0.14 ml of TMAH reagent (0.2 M trimethylanilium hydroxide in methanol) was added and the solution and mixed thoroughly. This reagent provides on-column methylation during gas chromatographic analysis. GLC analyses were performed on a Varion 2100 gas chromatograph equipped with a thermionic detector. The column was 3 feet long and was packed with 10% OU-101 on 80/100 Mes Gaschrom Q. At an operating temperature of 195 deg. C., the retention time of imazapyr was about 4 minutes. The quantitative sensitivity of the method is about 1.0 ppb.

g. 2,4-D, Picloram, Triclopyr

A 200 ml aliquot of water sample was acidified with 12 N hydrochloric acid to give a pH of 1-2. The sample was then extracted with three 100 ml aliquots of nanograde dichloromethane in a 500 ml separatory funnel. The combined DCM extracts were concentrated to about 25 ml by boiling the sample on a steam bath. The sample was then transferred to a 50 ml screw-cap volumetric flask and was taken to dryness on a rotary evaporator.

In preparing the samples for gas chromatographic analysis, it was necessary to convert the pesticide residues to their methyl esters. This was done by adding 5 ml of BF₃ methanol reagent (12% boron trifluoride in methanol), tightening the cap, and heating the sample on a steam bath for 90 minutes. After cooling, 2 ml of benzene and about 45 ml of water was added. After vigorous shaking, the samples were allowed to stand overnight to allow complete separation of benzene from the alcohol-water mixture.

The benzene extract was analyzed for the herbicides using electron capture gas chromatography. The analyses were performed on a Varian model 3700 GC, using a SPB-1 capillary column at 165 degrees. The retention times of 2,4-D, triclopyr and picloram were 3.5, 4.5 and 9.3 minutes respectively. With an injection of 2 microliters, the sensitivity of the method was at least 0.3 ppb for all compounds.

h. Quality Assurance

Quality assurance is a vital component of studies involving the analysis of field samples for herbicide residues. Norris (1986) recommended quality assurance after conducting a study that found poor precision and accuracy in water analysis for herbicide residues by several contract laboratories.

Internal quality assurance is accomplished when the analyst includes samples of known fortification levels to be run with unknown samples. Independent, external quality assurance is obtained by including fortified samples (unknowns to the analyst) with the regular samples. Both procedures were used in this study.

For the external, independent quality assurance program, water from a local (Oregon) source that was free of herbicide residues was used to prepare quality assurance samples. Quality assurance water samples were fortified to a known level with one or more of the herbicides included in the study and submitted for analysis as if they were regular field site samples. Quality assurance samples were mingled with field samples and were indistinguishable from them.

Samples were fortified at random to contain 0.000, 0.005, 0.01, 0.02, 0.05 or 0.10 mg/liter of herbicide, with 14 being analyzed for 2,4-D, picloram, and triclopyr, and 21 being analyzed for imazapyr. Approximately 8.6 percent of the samples analyzed for 2,4-D, picloram and triclopyr were quality assurance samples. Approximately 11 percent of the samples analyzed for imazapyr were quality assurance samples. (These percentages include the quality assurance samples from the sample stability study described below). The results of analysis of the independent, external quality assurance samples are in Table 3.

Table 3
Results of the Analysis of Quality Assurance Samples

PERM. SAMPLE NUMBER	ANALYZED ¹ W/SAMPLE NUMBERS	LEVEL FOUND/(LEVEL FORTIFIED)			
		2,4-D	Picloram	Triclopyr	Imazapyr
----- (mg/liter) -----					
4	141-149, 155-158	0.005 (0.005)	0.005 (0.005)	0.005 (0.005)	
7	19, 22, 24, 27-28	0.110 (0.100)	0.107 (0.100)	0.114 (0.100)	
8	288, 633-639	0.006 (0.005)	0.006 (0.005)	0.006 (0.005)	
12	184, 191-195 200-202				ND (0.000)
43	185-190, 410-411, 1094-1095				0.078 (0.100)
47	85-89, 245, 257-258, 552-553				0.040 (0.050)
48	963-964, 971-972,	0.010 (0.010)	0.011 (0.010)	0.012 (0.010)	
288	288, 633-639	0.021 (0.020)	0.022 (0.020)	0.019 (0.020)	
304	184, 408, 412-415, 953-958				0.075 (0.100)
306	184, 408, 412-415, 953-958				ND (0.000)
307	246-256,				0.056 (0.050)

(Continued)

Table 3 (Continued)
Results of the Analysis of Quality Assurance Samples

PERM. SAMPLE NUMBER	ANALYZED ¹ W/SAMPLE NUMBERS	LEVEL FOUND/(LEVEL FORTIFIED)			
		2,4-D	Picloram	Triclopyr	Imazapyr
----- (mg/liter) -----					
308	963-964, 971-972, 976-977	0.012 (0.010)	0.012 (0.010)	0.011 (0.010)	
679	160-166, 386-389, 679-682				0.007 (0.010)
680	160-166, 386-389, 679-682				ND (0.000)
681	160-166, 386-389, 679-682				ND (0.005)
682	160-166, 386-389, 679-682				0.002 (0.005)
979	141-149, 155-158	0.021 (0.020)	0.022 (0.020)	0.023 (0.020)	
980	55-62, 72, 368-371, 377-385, 948-950				0.011 (0.010)
981	288, 633-639	0.050 (0.050)	0.051 (0.050)	0.055 (0.050)	
982	55-62, 72, 368-371, 377-385, 948-950				0.005 (0.005)

(Continued)

Table 3 (Continued)
Results of the Analysis of Quality Assurance Samples

PERM. SAMPLE NUMBER	ANALYZED ¹ W/SAMPLE NUMBERS	LEVEL FOUND/(LEVEL FORTIFIED)			
		2,4-D	Picloram	Triclopyr	Imazapyr
----- (mg/liter) -----					
983	55-62, 72, 368-371 377-385, 948-950				0.020 (0.020)
984	700, 702 936	ND (0.000)	ND (0.000)	ND (0.000)	
989	986-988				0.012 (0.010)
1097	363-367, 605-610, 1096				0.012 (0.010)
1098	363-367, 605-610, 1096				ND (0.000)
1099	363-367, 605-610, 1096				0.019 (0.020)
1336	1326-1327, 1330-1331	ND (0.000)	ND (0.000)	ND (0.000)	
1337	1328-1329, 1332-1335, 1463-1464, 1466-1467				0.005 (0.005)
1465	998, 1612, 1615	0.005 (0.005)	0.005 (0.005)	0.006 (0.005)	
1622	1610-1621				0.004 (0.005)

(Continued)

Table 3 (Continued)

Results of the Analysis of Quality Assurance Samples

PERM. SAMPLE NUMBER	ANALYZED ¹ W/SAMPLE NUMBERS	LEVEL FOUND/(LEVEL FORTIFIED)			
		2,4-D	Picloram	Triclopyr	Imazapyr
		----- (mg/liter) -----			
1623	1620-1621	0.005 (0.005)	0.006 (0.005)	0.007 (0.005)	
1625	98-108, 2, 13, 14, 17, 118, 119, 122, 123, 126, 313, 690	0.020 (0.020)	0.028 (0.020)	0.022 (0.020)	
1626	98-108, 2, 13, 14, 17, 118, 119, 122, 123, 126, 313, 690	0.010 (0.010)	0.011 (0.010)	0.011 (0.010)	
1627	1078-1088				0.006 (0.010)
1628	1078-1088				0.014 (0.020)

¹The quality assurance samples were mixed with field samples when they were sent to the analytical laboratory. Numbers in this column indicate the field samples that were analyzed at the same time as a particular quality assurance sample.

A special quality assurance study was conducted to determine the stability of the herbicide in samples during the collection, handling, shipping, and storage. For this purpose six samples of clean water were fortified with herbicide: Three contained 0.100 mg/liter each of 2,4-D, picloram, and triclopyr, and three contained 0.100 mg/liter of imazapyr. 5.0 ml of 35% sulfuric acid as a preservative was added to two in each set and no acid was added to the third. These samples were in tightly capped sample jars used in the automatic samplers. TAXON prepared the samples and sent them to ECI, who placed them in the field for a 21-day sampling period, and then returned them to TAXON using the same sample handling and shipping procedures as used with all samples from this study. These samples were assigned permanent sample numbers by TAXON and sent to the analytical laboratory along with regular samples from the field study sites. The results of analysis of these samples are in Table 4.

The results of the quality assurance tests are excellent. None of the herbicide-free samples were reported as containing herbicide residues. Equally, none of the samples that did contain herbicide were reported as non-detectable (although one sample fortified at 0.005 mg/liter of imazapyr was reported as a trace - slightly less than 0.001 mg/liter). These results indicate a high level of probability that the results of analysis of field samples show neither false negatives nor false positives. The agreement between residue levels found and levels of fortification are excellent, far surpassing quality of analysis found in many contract laboratories (Norris, 1986).

Results from the sample stability study are also good. Analysis of the data indicate no significant difference in results between samples fortified and sent directly to the laboratory and those that had been in the field and shipped the same as other field study site samples.

These results indicate a good degree of reliability in accuracy of sample analysis.

D. RESULTS AND DISCUSSION

The results of this study are presented in this section on a site-by-site basis, with sites treated with picloram, triclopyr, and 2,4-D presented first followed by sites treated with imazapyr. The data tables are arranged to show every sample collected with the upstream control and downstream treated sites side by side. This makes it easy to see when samples were collected, the daily rainfall pattern, and which samples were selected for analysis as individual samples and which were submitted as composite samples.

Table 4
Results of the Analysis of Dissipation Study Samples

PERM. SAMPLE NUMBER ¹	LEVEL FOUND/(LEVEL FORTIFIED)			
	2,4-D	Picloram	Triclopyr	Imazapyr
	----- (mg/liter) -----			
998*	0.111 (0.100)	0.128 (0.100)	0.129 (0.100)	
1002*				0.095 (0.100)
1612	0.100 (0.100)	0.116 (0.100)	0.135 (0.100)	
1613*				0.070 (0.100)
1614				0.073 (0.100)
1615*	0.104 (0.100)	0.109 (0.100)	0.126 (0.100)	

¹An asterisk (*) indicates samples that included acid stabilization. Those without an asterisk did not include acid stabilization.

LYON MOUNTAIN - CHAZY LAKE

LYON MOUNTAIN - CHAZY LAKE SITE DESCRIPTION

Date of Construction: 1958 (final widening)
R/W Width: 100'
Treatment History: Last treatment in 1984
Study Treatment: Low-volume basal application of 0.5 gal. Access with 0.5 gal. Garlon 4 in 3 gals of #2 fuel oil
Active Ingredient: Picloram and Triclopyr, 0.5 lbs., 3.0 lbs. per acre respectively
General Description:

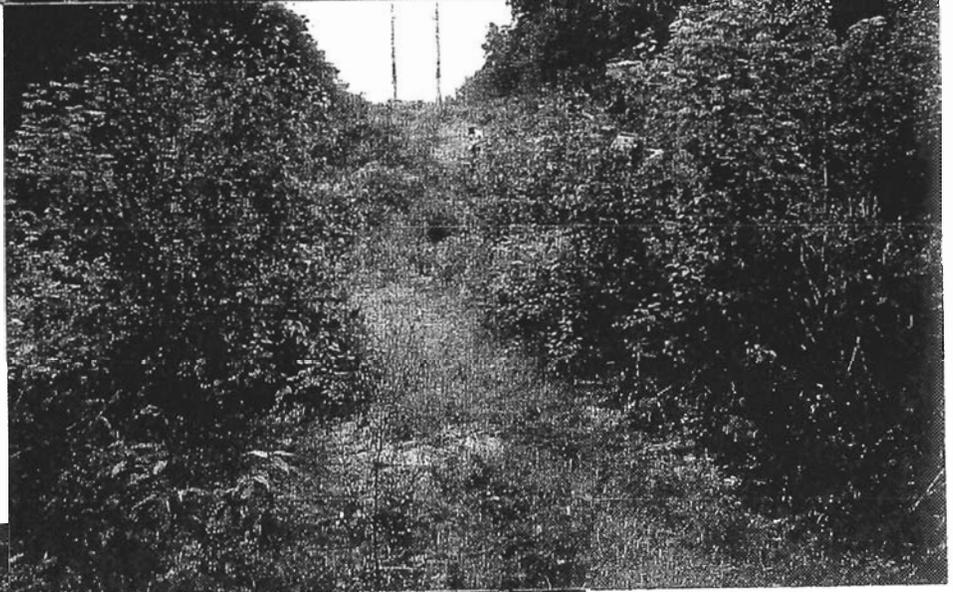
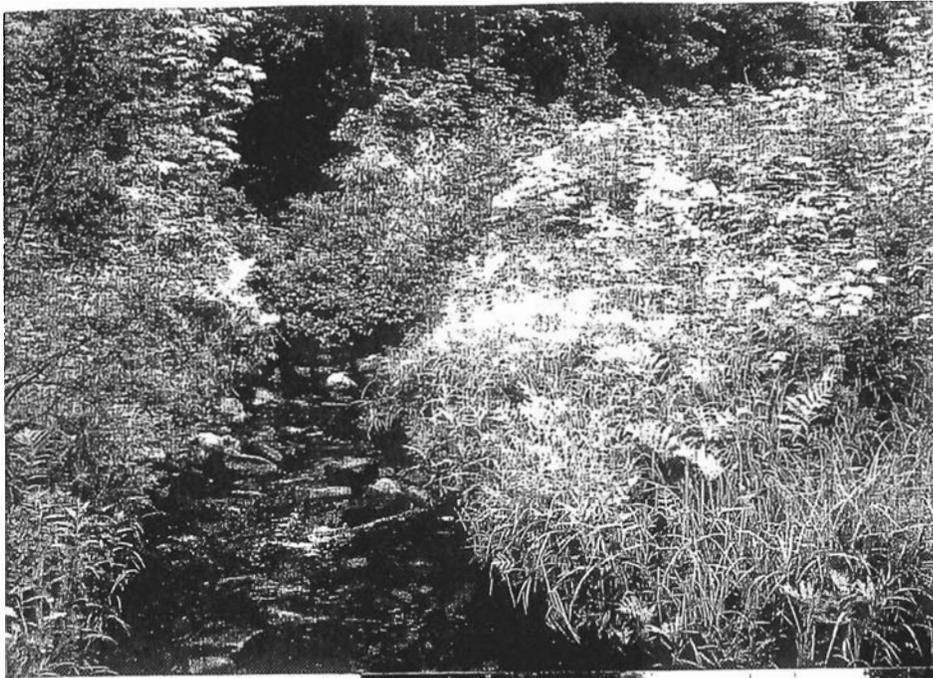
The Lyon Mountain Chazy Lake site is located on a 115 kV R/W west of Plattsburg, NY. The R/W runs in a north-south direction. A basal application was performed on September 12, 1989, with a 30 foot buffer zone of high density vegetation left untreated on both sides of the stream (Table 1).

The R/W is crossed by a well-defined stream channel (Photo A) at about a 90 degree angle. The streambed is composed of fine to coarse gravel with many rounded pebbles up to 8 inches in diameter. The water flows evenly as it crosses the R/W.

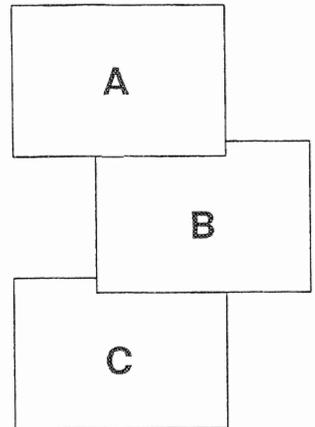
Heavy rains that occurred in early October, 1989, changed the streambed significantly. At the location of the downstream sampler, a significant gravel bar developed on the stream bed opposite the sampler. Sampling was not affected by this change.

On the north side of the stream (Photo B - foreground), the slope rises quickly and uniformly away from the stream. It rises 6 to 8 feet in elevation during the first 100 feet. On the south side of the stream there is a low depression that accumulates water during heavy rains (Photo C) and carries water as a secondary channel during periods of high water. This depressed area extends 30 feet from the stream, abutting the treated area. Although this area was dry at the time of application, it was wet throughout most of the study period.

The stream channel is paralleled on either side by a dense growth of grass, except where it is crossed by the access road. The vegetation at the road crossing is comprised of mainly sedges. Vegetation away from the R/W is composed of typical upland species and is undifferentiated from the R/W. A few very small woody plants were present on the access road.



Lyon Mt./
Chazy Lake



LYON MOUNTAIN - CHAZY LAKE STUDY RESULTS

Sampling was successful at this site, with downstream samples missing only from April 20 through May 5 due to a mechanical malfunction. The results of sample collection and of analysis of selected samples from the upstream and downstream sampling sites are in Table 5. The first three significant rainfall events were identified as occurring during the periods of September 14-19, September 20-23, and October 3-6.

At the downstream sampling location, no herbicide was detected the day of application. A single sample collected eight days after application (on a day when 2.20 inches of rain fell) contained 0.001 mg/liter picloram. Triclopyr was found in five samples, with the last detectable residue found also on the eighth day after application. The highest residue level found was 0.002 mg/liter in two separate samples.

All the residues found in samples from this site were collected during the first two rainstorms after application. Most of these were during the first storm when 2.36 inches fell over 4 days. The second storm (which began 3 days after the first storm) dropped 2.2 inches of rain in 1 day (8 days after the application). No samples collected more than eight days after application contained detectable herbicide.

Results from this site indicate the 30-foot buffer and the basal application strategies used at this site prevented both direct application and drift of herbicide to the stream. Herbicide that was detected in the stream the first few days after application likely resulted from mobilization of surface deposits during heavy rains, probably from the area immediately adjacent to the buffer which was dry at the time of application, but wet throughout the study period. Low concentrations however, also indicate the adequacy of the buffer. Lack of residues during later periods indicate leaching was not a significant mechanism of picloram and triclopyr entry to the stream. The buffer zone strategy used at this site protected water quality.

Table 5

Concentration of Herbicide in Stream Water From Lyon Mt./Chazy Lake Study Site
in Connection With Application of Picloram and Triclopyr on September 12, 1989

DATE	RAIN (Inches)	----- SITE A, UPSTREAM -----				----- SITE B, DOWNSTREAM -----			
		SAMPLE NO.1		HERBICIDE ²		SAMPLE NO.1		HERBICIDE ²	
		Perm.	Lab.	Picloram	Triclopyr	Perm.	Lab.	Picloram	Triclopyr
				----- (mg/liter) -----				----- (mg/liter) -----	
1989									
SEPT									
12		108	108	ND	ND	78	78	ND	ND
13		107	107	ND	ND	84	84	ND	0.001
14	0.50	106	106	ND	ND	80	80	ND	0.001
15	1.50	105	105	ND	ND	77	77	ND	0.002
16		104	104	ND	ND	83	83	ND	ND
17	0.36	103	103	ND	ND	79	79	ND	0.001
18		102	102	ND	ND	76	76	ND	ND
19		101	101	ND	ND	75	75	ND	ND
20	2.20	100	100	ND	ND	82	82	0.001	0.002
21		99	99	ND	ND	74	74	ND	ND
22		98	98	ND	ND	81	81	ND	ND
23	0.17	97				73	73	ND	ND
24		215				236			
25		216				237			
26	0.07	217				238	965*	ND	ND
27		218				239			
28		219				240			
29		203				224			
30		204				225	966*	ND	ND
OCT									
1		205				226			
2		206				227			
3	0.84	207				228	228	ND	ND
4		208				229	229	ND	ND

(Continued)

Table 5 (Continued)

Concentration of Herbicide in Stream Water From Lyon Mt./Chazy Lake Study Site
in Connection With Application of Picloram and Triclopyr on September 12, 1989

DATE	RAIN (Inches)	----- SITE A, UPSTREAM -----				----- SITE B, DOWNSTREAM -----			
		SAMPLE NO.1		HERBICIDE ²		SAMPLE NO.1		HERBICIDE ²	
		Perm.	Lab.	Picloram	Triclopyr	Perm.	Lab.	Picloram	Triclopyr
OCT				----- (mg/liter) -----				----- (mg/liter) -----	
5		209				230	230	ND	T
6	0.38	210				231	231	ND	ND
7		211				232	} 967*		
8	0.06	212				233			
9		213				234			
10		214				235			
11	0.05	220				241			
12		221				242			
13	0.06	222				243			
14		223				244			
15		432				456			
16	0.29	433				457			
17	0.14	434				458			
18	0.33	435				459			
19		436				460	} 968*		
20	0.66	437				461			
21		438				462			
22	0.25	439				463			
23		440				464			
24		441				465			
25		442				466			
26		443				467			
27		444				468			
28		445				469			
29		446				470			

(Continued)

IV-29

Table 5 (Continued)

Concentration of Herbicide in Stream Water From Lyon Mt./Chazy Lake Study Site
in Connection With Application of Picloram and Triclopyr on September 12, 1989

DATE	RAIN (Inches)	----- SITE A, UPSTREAM -----				----- SITE B, DOWNSTREAM -----			
		SAMPLE NO.1		HERBICIDE ²		SAMPLE NO.1		HERBICIDE ²	
		Perm.	Lab.	Picloram	Triclopyr	Perm.	Lab.	Picloram	Triclopyr
				----- (mg/liter) -----				----- (mg/liter) -----	
OCT									
30		447				471			
31		448				472			
NOV									
1	0.03	449				473	} 969*	ND	ND
2		450				474			
3		451				475			
4		452				476			
5		453				477			
6	0.16	454				478			
7		455				479			
8	0.24	795				807			
9	0.45	796				808			
10		797				809			
11	0.01	798				810	} 970*	ND	ND
12	0.13	799				811			
13		800				812			
14		801				813			
15	0.10	802				814			
16	1.00	803				815			
17		804				816			
18	0.02	805				817			
19	0.04	806				818			

Precipitation (as rain) for November 20, 1989, through April 19, 1990, was 13.59 inches.

(Continued)

IV-30

Table 5 (Continued)

Concentration of Herbicide in Stream Water From Lyon Mt./Chazy Lake Study Site
in Connection With Application of Picloram and Triclopyr on September 12, 1989

DATE	RAIN (Inches)	----- SITE A, UPSTREAM -----				----- SITE B, DOWNSTREAM -----			
		SAMPLE NO.1		HERBICIDE ²		SAMPLE NO.1		HERBICIDE ²	
		Perm.	Lab.	Picloram	Triclopyr	Perm.	Lab.	Picloram	Triclopyr
1990				----- (mg/liter) -----				----- (mg/liter) -----	
APR									
20			1338			empty			
21	0.08		1339			empty			
22			1340			empty			
23			1341			empty			
24			1342			empty			
25	0.04		1343			empty			
26	0.08		1344			empty			
27			1345			empty			
28			1346			empty			
29			1347			empty			
30			1348			empty			
MAY									
1			1349			empty			
2			1350			empty			
3			1351			empty			
4			1352			empty			
5	0.71		1353			1362			
6	0.08		1354			1363			
7			1355			1364			
8	0.05		1356			1365			
9	0.13		1357			1366			
10	0.04		1358			1367			
11	0.46		1359			1368			

Empty samples due to
mechanical malfunction
(needed recalibration).

(Continued)

Table.5 (Continued)

Concentration of Herbicide in Stream Water From Lyon Mt./Chazy Lake Study Site
in Connection With Application of Picloram and Triclopyr on September 12, 1989

DATE	RAIN (Inches)	----- SITE A, UPSTREAM -----				----- SITE B, DOWNSTREAM -----			
		SAMPLE NO. ¹		HERBICIDE ²		SAMPLE NO. ¹		HERBICIDE ²	
		Perm.	Lab.	Picloram	Triclopyr	Perm.	Lab.	Picloram	Triclopyr
				----- (mg/liter) -----				----- (mg/liter) -----	
MAY									
12	0.01	1360				1369			
13	0.46	1361				1370			
14	0.18	1469				1493	} 1620*	ND	ND
15		1470				1494			
16		1471				1495			
17	0.80	1472				1496			
18	0.46	1473				1497			
19	0.04	1474				1498			
20	0.03	1475				1499			
21	0.87	1476				1500			
22	0.01	1477				1501			
23		1478				1502			
24		1479				1503			
25	0.13	1480				1504			
26		1481				1505	} 1621*	ND	ND
27		1482				1506			
28		1483				1507			
29	0.06	1484				1508			
30	0.10	1485				1509			
31		1486				1510			
JUNE									
1		1487				1511			
2		1488				1512			
3	0.44	1489				1513			

(Continued)

Table 5 (Continued)

Concentration of Herbicide in Stream Water From Lyon Mt./Chazy Lake Study Site
in Connection With Application of Picloram and Triclopyr on September 12, 1989

DATE	RAIN (Inches)	----- SITE A, UPSTREAM -----				----- SITE B, DOWNSTREAM -----			
		SAMPLE NO. ¹		HERBICIDE ²		SAMPLE NO. ¹		HERBICIDE ²	
		Perm.	Lab.	Picloram	Triclopyr	Perm.	Lab.	Picloram	Triclopyr
JUNE				----- (mg/liter) -----				----- (mg/liter) -----	
4	0.09	1490				1514			
5		1491				1515			
6	0.08	1492				1516			

¹All field samples were assigned a permanent (perm.) sample number. Samples sent to the laboratory for analysis were given a laboratory (lab.) sample number. Any field sample that does not also have a laboratory number was not analyzed. An asterisk (*) indicates a composite sample.

²ND means not detectable (less than 0.001 mg/liter). T means trace (less than 0.001 mg/liter, but more than 0.0003 mg/liter; detectable qualitatively, but not quantitatively).

PINEWOODS ROAD #1

**PINEWOODS ROAD #1
SITE DESCRIPTION**

Date of Construction: About 1940
R/W Width: 100'
Treatment History: No treatment in at least 8 years
Study Treatment: High-volume stem-foliage application of 2 qts. Tordon 101 and 1.5 qts Garlon 4 in 99.25 gals. water
Active Ingredient: 2,4-D, Picloram, and Triclopyr, 2.0 lbs., 0.5 lbs., 3.0 lbs. per acre respectively
General Description:

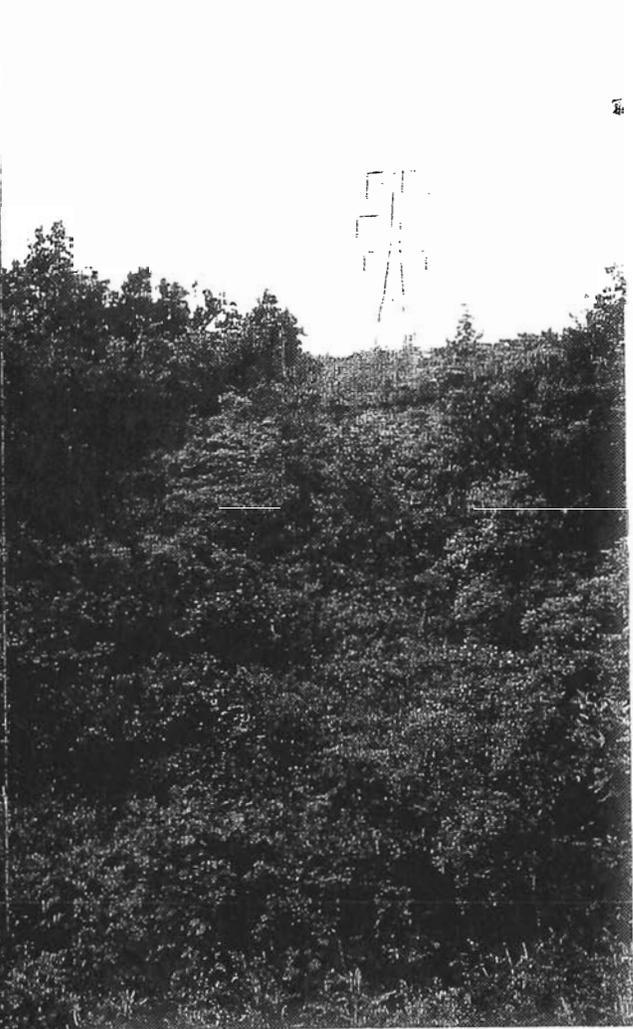
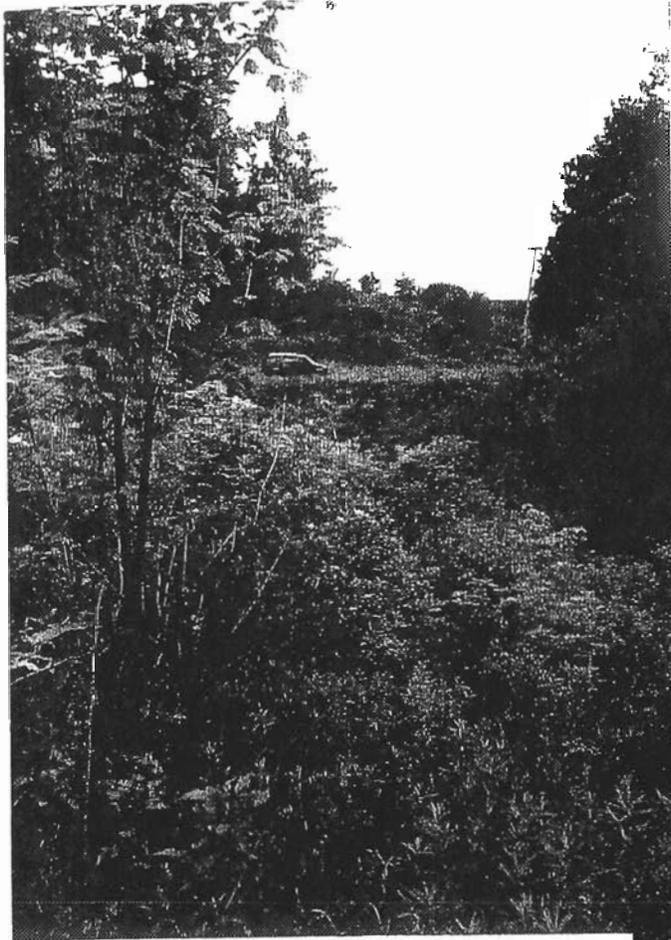
The R/W runs in a northeasterly direction at the Pinewoods Road #1 site, which is located northeast of Troy, NY. The site was treated on September 18, 1989 using a high-volume foliar application of Tordon 101 and Garlon 4 (Table 1). Because of the site's location next to the road (Photo A), only the R/W on one side of the stream was treated. A high vegetation density buffer zone of 100 feet was left on the side toward the treated area (Photo B).

The stream crosses the R/W at about a 60 degree angle, flowing away from the road to the northwest. From the road, the R/W drops sharply (40 to 50 percent slope) toward the stream with very little side slope (Photo A). On the side away from the road (Photo B), the slope rises at about a 30 to 40 percent slope.

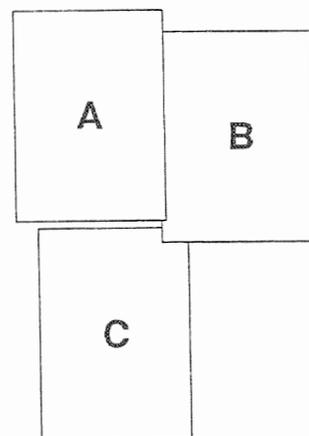
The stream channel is well defined across the R/W. It is approximately 18 inches wide and 2 to 4 inches deep (Photo C). The channel is located in a broad flood plain extending 10 to 25 feet on either side of the stream. This entire area floods during heavy rains.

Vegetation on the R/W is very dense. It is primarily composed of clumps of various shrub species, including blackberry and willow. These are interspersed with a dense growth of tall-growing herbaceous species comprised of golden rod, asters, greenbrier, and Japanese honeysuckle.

The upstream sampler was located below a 30 inch metal pipe that carries the stream under Pinewoods Road. When the sampler was set up, the suction tube was placed in a pool that had formed where water discharged from the pipe. At the time of installation this pool was 3 feet wide, 8 feet long and 2 feet deep. During the spring run-off, the streambed in this area eroded severely. The pool is gone completely and the streambed eroded to a depth approximately 4 feet below the previous level. This erosion extended over 40 feet downstream from the pipe. The streambed, which had been muddy, is now rock and densely packed gravel.



Pinewoods Road #1



PINEWOODS ROAD #1 STUDY RESULTS

Sampling downstream at this site was quite successful, with freezing weather causing the loss of samples only during a 3-day period in November, and a mechanical malfunction causing loss during an 11-day period in late March - early April. The results of analysis of samples from the upstream and downstream sampling sites are in Table 6. The first three significant rainfall events were identified as occurring during the periods of September 19-22, September 23-26, and October 2-6.

No 2,4-D was detected in any sample, and only a trace (less than 0.001 mg/liter) of picloram was found in two samples collected about 30 days after application.

Triclopyr was found at trace levels (less than 0.001 mg/liter) in six samples and at 0.001 mg/liter in one sample during the study period. The one sample that was quantifiable and four of the trace samples occurred during the first 8 days after application when about 1.08 inches of rain fell during storm one.

No samples collected more than 35 days after application contained detectable herbicide residues.

None of the samples at the upstream location contained detectable residues, indicating residues detected at the downstream location originated on the R/W and probably from the stem-foliage application under study.

Results from this study indicate the 100-foot buffer zone and the stem-foliage application strategies used prevented direct application and drift of herbicide to the stream. Note the buffer zone is in effect reduced to 75 to 90 feet during periods of heavy stream discharge due to the flood plain character of this site. The few samples that contained detectable residues of herbicide were associated with periods of heavy rain the first 30 days after application, indicating mobilization of surface residues. There was no indication of leaching or long-term entry of herbicide to the stream. The lack of 2,4-D and the low level of picloram and triclopyr residues indicate the adequacy of the buffer zone at this location. The buffer zone strategy used at this site protected water quality.

Table 6 (Continued)

Concentration of Herbicide in Stream Water From Pinewoods Road #1 Study Site
in Connection With Application of 2,4-D, Picloram, and Triclopyr on September 18, 1989

DATE	RAIN (Inches)	----- SITE G, UPSTREAM -----					----- SITE H, DOWNSTREAM -----				
		SAMPLE NO. ¹		HERBICIDE ²			SAMPLE NO. ¹		HERBICIDE ²		
		Perm.	Lab.	2,4-D	Picloram	Triclopyr	Perm.	Lab.	2,4-D	Picloram	Triclopyr
SEPT											
26	0.27						314	314	ND	ND	T
27							315				
28							316				
29							317				
30							318		ND	ND	ND
OCT											
1							319				
2	0.53						320	320	ND	ND	ND
3							321	321	ND	ND	ND
4							322	322	ND	ND	ND
5							323	323	ND	ND	ND
6	0.07						324	324	ND	ND	ND
7							325				
8	0.02						326				
9							327		ND	ND	ND
10	0.02						328				
11	0.13						329	329	ND	ND	ND
12							330	330	ND	ND	ND
13							331	331	ND	ND	ND
14	0.49						332	332	ND	ND	ND
15	0.27						333	333	ND	ND	ND
16							334	334	ND	ND	ND
17	0.95			ND	ND	ND	335	335	ND	T	T
18	0.02						336	336	ND	ND	T
19	0.30						337	337	ND	ND	ND

(Continued)

IV-41

Table 6 (Continued)

Concentration of Herbicide in Stream Water From Pinewood
in Connection With Application of 2,4-D, Picloram, and Triclopyr

DATE	RAIN (Inches)	----- SITE G, UPSTREAM -----					----- SITE			
		SAMPLE NO.1		HERBICIDE 2			SAMPLE NO.1		Perm.	Lab.
		Perm.	Lab.	2,4-D	Picloram	Triclopyr	Perm.	Lab.		
		----- (mg/liter) -----								
OCT										
20	2.15	568				580	580			
21	0.02	569				581				
22		570				582				
23		571				583				
24		572				584	961*	ND		ND
25		573				585				
26		574				586				
27		empty				587				
28		empty				588				
29		empty				589				
30		empty				590				
31	0.56	empty	Empty samples due to unknown cause.			591				
NOV										
1	0.14	575				661				
2		empty				662				
3	0.15	576				663				
4		577				664	962*	ND	ND	ND
5		empty				665				
6	0.08	empty				666				
7	0.04	empty				667				
8	0.03	578				668				
9	0.45	579				669				
10		924				891				
11		925				892				

Study Site
ND 1989

PERM
LAB

IV-42

(Continued)

Table 6 (Continued)

Concentration of Herbicide in Stream Water From Pinewoods Road #1 Study Site
in Connection With Application of 2,4-D, Picloram, and Triclopyr on September 18, 1989

DATE	RAIN (Inches)	----- SITE G, UPSTREAM -----					----- SITE H, DOWNSTREAM -----				
		SAMPLE NO. ¹		HERBICIDE ²			SAMPLE NO. ¹		HERBICIDE ²		
		Perm.	Lab.	2,4-D	Picloram	Triclopyr	Perm.	Lab.	2,4-D	Picloram	Triclopyr
				----- (mg/liter) -----					----- (mg/liter) -----		
NOV											
12		926				893					
13		927				894					
14		928				895	} 963*	ND	ND	ND	
15	0.04	929				896					
16	0.42	930				897					
17		931				898					
18		932				899					
19		933				900					
20	0.35	934				901					
21		935				902					
22		819				empty					
23	0.07	empty	Empty samples due			empty	Empty samples due				
24		empty	to freezing weather.			empty	to freezing weather.				
25		820				825					
26	0.06	821				826	} 964*	ND	ND	ND	
27	0.03	822				827					
28		823				828					
29		824				829					

Precipitation (as rain) for November 30, 1989, through March 21, 1990, was 12.05 inches.

(Continued)

IV-43

Table 6 (Continued)

Concentration of Herbicide in Stream Water From Pinewoods Road #1 Study Site
in Connection With Application of 2,4-D, Picloram, and Triclopyr on September 18, 1989

DATE	RAIN (Inches)	----- SITE G, UPSTREAM -----					----- SITE H, DOWNSTREAM -----				
		SAMPLE NO. ¹		HERBICIDE ²			SAMPLE NO. ¹		HERBICIDE ²		
		Perm.	Lab.	2,4-D	Picloram	Triclopyr	Perm.	Lab.	2,4-D	Picloram	Triclopyr
				----- (mg/liter) -----					----- (mg/liter) -----		
1990											
MAR											
22		1006					1008				
23		1007					1009				
24		empty					1010	} 1090*	ND	ND	ND
25		empty				1011					
26	0.01	empty				1012					
27		empty				empty					
28		empty				empty					
29		empty				empty					
30	0.17	empty	Empty samples due to change			empty					
31	0.20	empty	of stream flow and water			empty					
			level. Sample collection			empty					
			tube was buried.			empty					
APR								Empty samples due to			
1	0.01	empty				empty		mechanical malfunction.			
2	0.08	empty				empty					
3	1.57	empty				empty					
4	0.62	empty				empty					
5		empty				empty					
6		empty				empty					
7		1100				1124					
8		1101				1125					
9		1102				1126	} 1326*	ND	ND	ND	
10	0.49	1103				1127					
11	0.21	1104				1128					
12		1105				1129					
13		1106				1130					

(Continued)

IV-44

Table 6 (Continued)

Concentration of Herbicide in Stream Water From Pinewoods Road #1 Study Site
in Connection With Application of 2,4-D, Picloram, and Triclopyr on September 18, 1989

DATE	RAIN (Inches)	----- SITE G, UPSTREAM -----					----- SITE H, DOWNSTREAM -----					
		SAMPLE NO. ¹		HERBICIDE ²			SAMPLE NO. ¹		HERBICIDE ²			
		Perm.	Lab.	2,4-D	Picloram	Triclopyr	Perm.	Lab.	2,4-D	Picloram	Triclopyr	
APR				----- (mg/liter) -----								
14		1107				1131						
15	0.22	1108				1132						
16		1109				1133						
17	0.04	1110				1134						
18		1111				1135						
19		1112				1136						
20	0.13	1113				1137						
21	0.38	1114				1138	} 1327*	ND	ND	ND		
22		1115				1139						
23		1116				1140						
24		1117				1141						
25	0.08	1118				1142						
26	0.04	1119				1143						
27		1120				1144						
28		1121				1145						
29		1122				1146						
30		1123				1147						

IV-45

¹All field samples were assigned a permanent (perm.) sample number. Samples sent to the laboratory for analysis were given a laboratory (lab.) sample number. Any field sample that does not also have a laboratory number was not analyzed. An asterisk (*) indicates a composite sample.

²ND means not detectable (less than 0.001 mg/liter). T means trace (less than 0.001 mg/liter, but more than 0.0003 mg/liter; detectable qualitatively, but not quantitatively).

PINEWOODS ROAD #2

**PINEWOODS ROAD #2
SITE DESCRIPTION**

Date of Construction: About 1940
R/W Width: 100'
Treatment History: No treatment for at least 8 years
Study Treatment: High-volume stem-foliage application with 2 qts. Tordon 101 and 1.5 qts. Garlon 4 in 99.25 gals. water.
Active Ingredient: 2,4-D, Picloram, and Triclopyr, 2.2 lbs., 0.55 lbs., 3.3 lbs. per acre respectively

General Description:

The Pinewoods Road #2 site is located approximately 1,000 feet north of the Pinewoods Road #1 site. It was also treated with a high-volume stem-foliage application on September 17, 1989 (Table 1). A 100-foot buffer zone with high density vegetation was left untreated between the stream and the treatment areas.

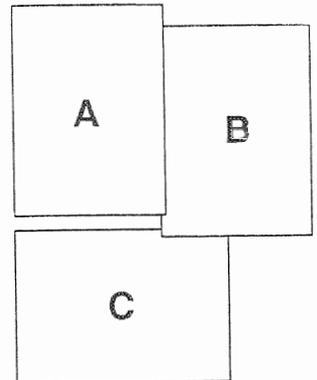
The stream that crosses the site is located in a broad flood plain and meanders across the R/W at about a 45 degree angle to the southwest. The stream channel is well defined across the entire R/W. The streambed is very unstable, covered with a deep layer of silt.

On the south side, the R/W slopes to the stream at about a 20 percent slope. There is also a 20 to 30 percent side slope, draining towards the downstream portion of the stream. The north side of the stream is very flat for approximately 200 feet before rising at a 10 to 20 percent slope. This area has several small streams feeding the main channel.

Approximately 100 feet north of the stream channel is what was initially identified as a second stream. It was later determined that this is actually an upstream portion of the same stream with the stream crossing the R/W twice (below). As a result, both sampling units were effectively located downstream of the application.



Pinewoods
Road #2



PINEWOODS ROAD #2 STUDY RESULTS

Sampling at this site was quite successful, with a mechanical malfunction causing the loss of downstream samples only during an 10-day period in late March - early April. The results of analysis of samples from the upstream and downstream sampling sites are in Table 7. The first three significant rainfall events were identified as occurring during the periods of September 19-22, September 23-26, and October 2-6.

No 2,4-D was detected in any sample, and only a trace (less than 0.001 mg/liter) of picloram was found in two samples collected 4 and 5 days after application during storm one and two.

Triclopyr was found at trace levels (less than 0.001 mg/liter) in six samples, including in one sample the day of application, in four samples over the next 8 days (during storm one and two), and in a single sample collected about 32 days after application during a period when 4.18 inches of rain fell in 7 days.

No samples collected more than 33 days after application contained detectable herbicide residues.

Several of the samples collected at the upstream location contained detectable residues. Careful investigation of the site showed the upstream sampler was incorrectly placed. It was not upstream of all parts of the treated R/W and obviously received runoff from the treated area. What was intended as an upstream control was actually an independent verification of results from the downstream site. In many cases trace quantities of herbicide (levels that could be qualitatively identified but not quantified) were found in samples collected the same days at both sites.

Results from this study indicate the buffer zone used prevented nearly all direct application and drift of herbicide to the stream. The few samples that contained detectable residues of herbicide were associated with periods of heavy rain the first 33 days after application, indicating mobilization of surface residues. There was no indication of leaching or long-term entry of herbicide to the stream. The low level of residues indicate the adequacy of the buffer zone at this location. The buffer zone strategy used at this site protected water quality.

. Table 7

**Concentration of Herbicide in Stream Water From Pinewoods Road #2 Study Site
in Connection With Application of 2,4-D, Picloram, and Triclopyr on September 18, 1989**

DATE	RAIN (Inches)	----- SITE K, UPSTREAM -----					----- SITE L, DOWNSTREAM -----				
		SAMPLE NO.1		HERBICIDE ²			SAMPLE NO.1		HERBICIDE ²		
		Perm.	Lab.	2,4-D	Picloram	Triclopyr	Perm.	Lab.	2,4-D	Picloram	Triclopyr
				----- (mg/liter) -----					----- (mg/liter) -----		
1989											
SEPT											
13		113	} 976*	ND	ND	ND	136				
14	0.44	114					137				
15	0.08	115					138				
16	0.43	116	} 977*	ND	ND	ND	139				
17	0.15	117					140				
18		118		118	ND	T	0.001	141	141	ND	ND
19	0.36	119	119	ND	T	T	142	142	ND	ND	T
20	0.72	120					143	143	ND	ND	ND
21		121					144	144	ND	ND	ND
22		122	122	ND	T	T	145	145	ND	T	ND
23	0.21	123	123	ND	T	T	146	146	ND	T	T
24		124					147	147	ND	ND	T
25		125					148	148	ND	ND	ND
26	0.27	126	126	ND	T	T	149	149	ND	ND	T
27		127					150				
28		128					151				
29		129					152	} 936*			
30		130					153		ND	ND	ND
OCT							154				
1		131					155	155	ND	ND	ND
2	0.53	132					156	156	ND	ND	ND
3		133					157	157	ND	ND	ND
4		134					158	158	ND	ND	ND
5		135									

(Continued)

Table 7 (Continued)

Concentration of Herbicide in Stream Water From Pinewoods Road #2 Study Site
in Connection With Application of 2,4-D, Picloram, and Triclopyr on September 18, 1989

DATE	RAIN (Inches)	----- SITE K, UPSTREAM -----					----- SITE L, DOWNSTREAM -----				
		SAMPLE NO. ¹		HERBICIDE ²			SAMPLE NO. ¹		HERBICIDE ²		
		Perm.	Lab.	2,4-D	Picloram	Triclopyr	Perm.	Lab.	2,4-D	Picloram	Triclopyr
OCT				----- (mg/liter) -----					----- (mg/liter) -----		
6	0.07	616				628					
7		617				629					
8	0.02	618				630	} 937*	ND	ND	ND	
9		619				631					
10	0.02	620				632					
11	0.13	621				633		633	ND	ND	ND
12		622				634	634	ND	ND	ND	
13		623				635	635	ND	ND	ND	
14	0.49	624				636	636	ND	ND	ND	
15	0.27	625				637	637	ND	ND	ND	
16		626				638	638	ND	ND	ND	
17	0.95	627				639	639	ND	ND	ND	
18	0.02	688				700	700	ND	ND	ND	
19	0.30	689				701	701	ND	ND	ND	
20	2.15	690	690	ND	T	T	702	702	ND	ND	T
21	0.02	691				703					
22		692				704					
23		693				705	} 938*				
24		694				706		ND	ND	ND	
25		695				707					
26		696				708					
27		697				709					
28		698				710					
29		699				711					

(Continued)

Table 7 (Continued)

Concentration of Herbicide in Stream Water From Pinewoods Road #2 Study Site
in Connection With Application of 2,4-D, Picloram, and Triclopyr on September 18, 1989

DATE	RAIN (Inches)	----- SITE K, UPSTREAM -----					----- SITE L, DOWNSTREAM -----				
		SAMPLE NO. ¹		HERBICIDE ²			SAMPLE NO. ¹		HERBICIDE ²		
		Perm.	Lab.	2,4-D	Picloram	Triclopyr	Perm.	Lab.	2,4-D	Picloram	Triclopyr
APR				----- (mg/liter) -----					----- (mg/liter) -----		
13		1202				1226					
14		1203				1227					
15	0.22	1204				1228					
16		1205				1229					
17	0.04	1206				1230					
18		1207				1231					
19		1208				1232					
20	0.13	1209				1233					
21	0.38	1210				1234					
22		1211				1235	} 1331*	ND	ND	ND	
23		1212				1236					
24		1213				1237					
25	0.08	1214				1238					
26	0.04	1215				1239					
27		1216				1240					
28		1217				1241					
29		1218				1242					
30		1219				1243					

IV-55

¹All field samples were assigned a permanent (perm.) sample number. Samples sent to the laboratory for analysis were given a laboratory (lab.) sample number. Any field sample that does not also have a laboratory number was not analyzed. An asterisk (*) indicates a composite sample.

²ND means not detectable (less than 0.001 mg/liter). T means trace (less than 0.001 mg/liter, but more than 0.0003 mg/liter; detectable qualitatively, but not quantitatively).

LAKE COLBY NORTH

LAKE COLBY NORTH SITE DESCRIPTION

Date of Construction: 1968
R/W Width: 150'
Treatment History: Last treatment in 1978
Study Treatment: High-volume stem-foliage application of 2 qts. Arsenal in 99.5 gals. water
Active Ingredient: Imazapyr, 1.7 lbs per acre
General Description:

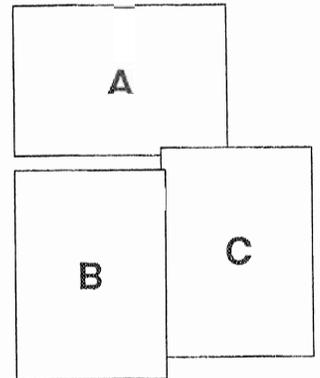
The Lake Colby North site is located just north of Saranac Lake, NY, along Route 86. The R/W lies in a generally east-west orientation. The site was treated with imazapyr on September 6, 1989 (Table 1). The 150-foot R/W has a medium density cover of spruce, fir, maple, cherry, birch, and assorted other hardwoods (Photo A). A 10-foot buffer zone with low to medium density vegetation was left on both sides of the stream.

The stream crosses the R/W at approximately a 90 degree angle. The stream channel is fairly well defined (Photo B) at both R/W edges and several locations across the R/W. It loses definition and is largely unexposed throughout the center portion of the R/W. This is because about two-thirds of the stream is bordered to the east by a very low depression (Photo C). The stream is visible only intermittently, and spreads to create a marsh for up to 20 feet east of the stream. This marsh area extends well beyond the buffer zone into the treatment area. Elevation along the R/W increases rapidly beyond this 20-foot zone.

The western side of the stream rises away from the stream at about a 5 to 10 percent slope. The vegetation on this side quickly changes to typical terrestrial species within 10 to 20 feet. The vegetation is comprised of dense clumps of grasses and sedge interspersed with frequent clumps of Eastern larch and balsam fir. In the areas of higher elevation, quaking aspen and white birch are common.



Lake Colby
North



LAKE COLBY NORTH STUDY RESULTS

Sampling at this site was complicated by loss of downstream samples for a 15-day period, which began on the 7th day after application due to nonfunctioning of the sampler. Unfortunately this was during the first three significant rain periods when 5.78 inches of rain fell during an 11-day period. A further gap in the record exists for about two weeks beginning about 3 weeks after application, again due to an unknown cause. Individual samples were collected and analyzed during a storm of 2.4 inches in 7 days, which occurred about 5 weeks after application. A few additional samples were not collected due to intermittent freezing weather, which began to interrupt sample collection in November. There was no loss of samples due to freezing during the spring. The results of analysis of samples from the upstream and downstream sampling sites are in Table 8. The first three significant rainfall events were identified as occurring during the periods of September 14-16, September 17-19, and September 20-25.

No imazapyr was detected in any sample from this site. While there are significant uncertainties due to loss of samples from at least two significant periods, equally there is no indication of imazapyr entry to the stream during the application, during heavy rains about 5 weeks after application, or at any period after this time for the duration of the sampling at this site. For the period when samples are available, results indicate the 10-foot buffer zone and stem-foliage application strategy used at this site was successful, but there are gaps in the record.

Table 8

Concentration of Herbicide in Stream Water From Lake Colby North Study Site
in Connection With Application of Imazapyr on September 6, 1989

DATE	RAIN (Inches)	----- SITE C, UPSTREAM -----			----- SITE D, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
				----- (mg/liter) -----			----- (mg/liter) -----
1989							
SEPT							
6		281			303	303	ND
7		282			304		
8		283			305		
9		284			empty		
10		285			306	939*	ND
11		286			307		
12		287			308		
13		288			empty		
14	0.70	289			empty		
15	1.65	empty		Empty samples due	empty		
16		empty		to unknown cause.	empty		
17	0.28	290			empty		
18	0.01	291			empty		
19		292			empty		Empty samples due
20	2.43	293			empty		to unknown cause.
21	0.03	294			empty		
22		295			empty		
23	0.66	296			empty		
24	0.02	297			empty		
25		298			empty		
26		299			empty		
27		300			empty		
28		301			309	309	ND
29		302			310		

(Continued)

Table 8 (Continued)

Concentration of Herbicide in Stream Water From Lake Colby North Study Site
in Connection With Application of Imazapyr on September 6, 1989

DATE	RAIN (Inches)	----- SITE C, UPSTREAM -----			----- SITE D, DOWNSTREAM -----		
		SAMPLE NO.1		HERBICIDE ²	SAMPLE NO.1		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
September 30 to October 14, 1989, no samples (due to unknown cause).							
Precipitation (as rain) for September 30, through October 14, 1989, was 1.15 inches.							
				----- (mg/liter) -----			----- (mg/liter) -----
OCT							
15		lost			498	498	ND
16	0.36	lost	Lost samples were		499	499	ND
17	0.48	empty	empty on receipt		500	500	ND
18		lost	at the laboratory.		501	501	ND
19		lost			502	502	ND
20	0.71	480			503	503	ND
21	0.70	481			504	504	ND
22	0.15	482			505	505	ND
23		483			empty	Unknown cause.	
24		484			506	940*	ND
25		485			507		
26		486			508		
27		487			509		
28		488			510		
29		489			511		
30		490			512		
31		491			513		
NOV							
1	0.46	492			514		
2		493			515		

(Continued)

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Table 8 (Continued)

Concentration of Herbicide in Stream Water From Lake Colby North Study Site
in Connection With Application of Imazapyr on September 6, 1989

DATE	RAIN (Inches)	----- SITE C, UPSTREAM -----			----- SITE D, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
				----- (mg/liter) -----			----- (mg/liter) -----
NOV							
3	0.20	494			516		
4		495			empty		Unknown cause.
5		496			517		
6	0.21	497			518		
7		empty	Unknown cause.		519	941*	ND
8	0.25	903			858		
9	0.48	904			859		
10	0.02	905			860		
11	0.07	906			861		
12	0.09	907			862		
13		908			863		
14		909			864		
15		910			865		
16	1.02	911			empty		
17	0.09	912			866		
18	0.02	empty			empty		
19	0.01	empty			empty	942*	ND
20	0.52	empty			867		
21	0.54	empty			868		
22	0.07	empty	Empty samples due		empty		Empty samples due
23		empty	to freezing weather.		empty		to freezing weather.
24		empty			empty		
25	0.05	empty			empty		
26	0.09	empty			869		
27		empty			empty		

(Continued)

IV-64

Table 8 (Continued)

Concentration of Herbicide in Stream Water From Lake Colby North Study Site
in Connection With Application of Imazapyr on September 6, 1989

DATE	RAIN (Inches)	----- SITE C, UPSTREAM -----			----- SITE D, DOWNSTREAM -----		
		SAMPLE NO.1		HERBICIDE ²	SAMPLE NO.1		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
NOV							
28		empty			870	870	ND
29		empty			empty		
30		empty	Empty samples due to freezing weather.		empty	Empty samples due to freezing weather.	
DEC							
1	0.03	empty			empty		

----- (mg/liter) -----

----- (mg/liter) -----

Precipitation (as rain) for December 2, 1989, through April 19, 1990, was 12.86 inches.

1990

APR

20		1371		1395	} 1463*	ND
21	0.39	1372		1396		
22		1373		1397		
23		1374		1398		
24		1375		1399		
25	0.12	1376		1400		
26	0.09	1377		1401		
27		1378		1402		
28		1379		1403		
29		1380		1404		
30		1381		1405		
<u>MAY</u>						
1		1382		1406		

(Continued)

IV-65

Table 8 (Continued)

Concentration of Herbicide in Stream Water From Lake Colby North Study Site
in Connection With Application of Imazapyr on September 6, 1989

DATE	RAIN (Inches)	----- SITE C, UPSTREAM -----			----- SITE D, DOWNSTREAM -----		
		SAMPLE NO.1		HERBICIDE ²	SAMPLE NO.1		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
MAY				----- (mg/liter) -----			----- (mg/liter) -----
2		1383			1407		
3		1384			1408		
4		1385			1409		
5	0.40	1386			1410		
6	0.02	1387			1411		
7	0.55	1388			1412		
8	0.19	1389			1413		
9		1390			1414		
10	0.09	1391			1415		
11	0.58	1392			1416		
12	0.02	1393			1417		
13	0.85	1394			1418		
14	0.08	1517			1541		
15		1518			1542		
16		1519			1543		
17	0.42	1520			1544		
18	0.38	1521			1545		
19	0.16	1522			1546		
20	0.13	1523			1547		
21	0.93	1524			1548		
22	0.02	1525			1549		
23		1526			1550		
24		1527			1551		
25	0.15	1528			1552		

(Continued)

1464*

1618*

ND

ND

Table 8 (Continued)

Concentration of Herbicide in Stream Water From Lake Colby North Study Site
in Connection With Application of Imazapyr on September 6, 1989

DATE	RAIN (Inches)	----- SITE C, UPSTREAM -----			----- SITE D, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
		----- (mg/liter) -----			----- (mg/liter) -----		
MAY							
26		1529			1553	} 1619*	ND
27		1530			1554		
28		1531			1555		
29	0.20	1532			1556		
30	0.18	1533			1557		
31		1534			1558		
JUNE							
1		1535			1559		
2	0.03	1536			1560		
3	0.60	1537			1561		
4	0.28	1538			1562		
5		1539			1563		
6	0.03	1540			1564		

IV-67

¹All field samples were assigned a permanent (perm.) sample number. Samples sent to the laboratory for analysis were given a laboratory (lab.) sample number. Any field sample that does not also have a laboratory number was not analyzed. An asterisk (*) indicates a composite sample.

²ND means not detectable (less than 0.001 mg/liter). T means trace (less than 0.001 mg/liter, but more than 0.0003 mg/liter; detectable qualitatively, but not quantitatively).

LAKE COLBY SUB

LAKE COLBY SUB SITE DESCRIPTION

Date of Construction: 1968
R/W Width: 150'
Treatment History: Last treatment in 1978
Study Treatment: High-volume stem-foliage application of 2 qts Arsenal in 99.5 gallons of water
Active Ingredient: Imazapyr, 1.1 lbs. per acre
General Description:

The Lake Colby Sub site was treated using a high-volume stem-foliage application on September 6, 1989 (Table 1). A 50-foot buffer zone was left along the eastern side of the stream. A 35-foot buffer zone was left on the western side of the stream. The application equipment was taken inside the buffer zone on the western side of the stream and was at one point within 15 feet of the downstream sampler. The buffer zones had medium to high density vegetation cover.

The Lake Colby Sub site is a very level, wet site. An access road is located in the center of the R/W (Photo A). Water passes through a culvert in the road, which is the only location where the channel is defined.

The upstream side of the access road forms a pond surrounded on both sides by a typical northern bog (Photo B). Vegetation in the bog is comprised of sphagnum moss and various woody plants including willows, spruce, balsam fir, and Eastern larch. The R/W edge has been widened as a result of trees killed by the formation of the pond.

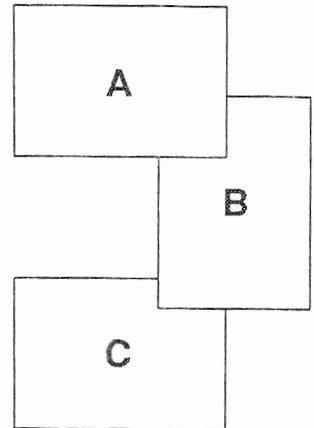
The downstream side of the road is a boggy area that has no clearly defined main channel. Large clumps of sphagnum moss and various shrubs are scattered throughout the area. The adjacent R/W gradually changes from common riparian vegetation to medium density terrestrial species (Photo C). Fir and larch dominate the treatment area.

The slope on the eastern side (Photo B) of the sampling area is very gradual with a 1 to 3 percent grade, extending almost 800 feet from the sampling area. On the west side, the slope is gradual for 75 to 100 feet from the stream.

This area is marshy and periods of high precipitation result in standing surface water extending well into the treated area. This water drains into the stream between the access road and the downstream sampler. Thus the intended 35- and 50-foot buffers are accurate relative to the defined stream margin, but there was no effective buffer for the intervening marshy area.



Lake Colby Sub



LAKE COLBY SUB STUDY RESULTS

Sampling was successful on this site, with downstream samples missing for only a 15-day period about 3 weeks after application due to nonfunctioning sampler and a 13-day period in late November due to freezing weather. The results of analysis of samples from the upstream and downstream sampling sites are in Table 9. The first three significant rainfall events were identified as occurring during the periods of September 14-16, September 17-19, and 20-25.

Imazapyr residues were found in 13 samples, more than at any other site. Additionally the highest residue found in the entire study (0.006 mg/liter) was found in one sample from this site.

Imazapyr at 0.002 mg/liter was detected in the sample collected during the day of application indicating either drift or direct application of herbicide to the water, since there were no additional residues found for 5 days. Other samples had sporadic residues of 0.001 to 0.002 mg/liter, with the first and third storm (2.35 inches in 2 days, and 3.12 inches in 4 days respectively) each generating a single sample with a detectable residue. Unfortunately, no samples were collected during the fourth storm, which deposited 1.15 inches in 11 days. This period immediately precedes a period when detectable residues were found in eight of the next ten samples. It is difficult to estimate residues that may have been in the stream during this period. Given the rainfall pattern (less rain during this period than in either the preceding or following period) it seems reasonable that the residue level may have been similar to that in the October 15th to 26th sampling period.

The next storm (the fifth storm, 2.32 inches in 7 days) produced eight positive samples out of ten samples collected, including the highest residue level recorded at any site for any herbicide in this study. Once this storm was over, herbicide movement from this site to the stream ended. No other samples collected more than 50 days after application contained a detectable residue of herbicide.

At the upstream site, two samples were found with detectable residues (both 0.001 mg/liter), one on the day of application, which could be the result of drift from the application or contamination from some upstream point, and one sample on the 6th day after application. All other samples were negative indicating the residues found at the downstream station likely originated in the treated area of the R/W.

Although the majority of downstream samplers showed non-detectable amounts of residue, results from this site indicate the buffer zone strategy resulted in a greater degree of stream contamination than at other sites, possibly reflecting the second highest rate of imazapyr application but more likely the boggy character of the site and the lack of a buffer between treated areas and the edge of the "wet" area. None of the levels found are toxic to aquatic organisms against which it has been tested. Lack of residues in samples collected more than 50 days after application indicate leaching is not an important mechanism of herbicide entry to water at this site.

Table 9

Concentration of Herbicide in Stream Water From Lake Colby Sub Study Site
in Connection With Application of Imazapyr on September 6, 1989

DATE	RAIN (Inches)	----- SITE E, UPSTREAM -----			----- SITE F, DOWNSTREAM -----		
		SAMPLE NO.1		HERBICIDE ²	SAMPLE NO.1		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
1989				----- (mg/liter) -----			----- (mg/liter) -----
SEPT							
6		96	96	0.001	90	90	0.002
7		92	92	ND	88	88	ND
8		91			86	86	ND
9		93	93	ND	89	89	ND
10		94			87	943*	0.001
11		95	95	0.001	85	87	ND
12		263			245	85	0.001
13		264			246	245	ND
14	0.70	265			247	246	ND
15	1.65	266	266	ND	248	247	ND
16		267			249	248	0.001
17	0.28	268			250	249	ND
18	0.01	269			251	250	ND
19		270			252	251	ND
20	2.43	271			253	252	ND
21	0.03	272	272	ND	254	253	ND
22		273	273	ND	255	254	ND
23	0.66	274			256	255	ND
24	0.02	275			256	256	0.002
25		276			257	257	ND
26		277			258	258	ND
27		278			259	944*	ND
28		279			260		
29		280			261		
					262		

(Continued)

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Table 9 (Continued)

Concentration of Herbicide in Stream Water From Lake Colby Sub Study Site
in Connection With Application of Imazapyr on September 6, 1989

DATE	RAIN (Inches)	----- SITE E, UPSTREAM -----			----- SITE F, DOWNSTREAM -----		
		SAMPLE NO.1		HERBICIDE ²	SAMPLE NO.1		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr

September 30 to October 14, 1989, no samples (due to unknown cause).

Precipitation (as rain) for September 30, through October 14, 1989, was 1.15 inches.

OCT		----- (mg/liter) -----			----- (mg/liter) -----		
15		520	520	ND	544	544	0.002
16	0.36	521			545	545	0.001
17	0.48	522	522	ND	546	546	0.001
18	0.32	523			547	547	0.001
19		524	524	ND	548	548	0.006
20	0.31	525			549	549	0.003
21	0.70	526	526	ND	550	550	ND
22	0.15	527			551	551	0.001
23		528	528	ND	552	552	ND
24		529			553	553	0.001
25		530			554	945*	ND
26		531			555		
27		532			556		
28		533			557		
29		534			558		
30		535			559		
31		536			560		
NOV							
1		537			561		

(Continued)

IV-75

Table 9 (Continued)

Concentration of Herbicide in Stream Water From Lake Colby Sub Study Site
in Connection With Application of Imazapyr on September 6, 1989

DATE	RAIN (Inches)	----- SITE E, UPSTREAM -----			----- SITE F, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
NOV				----- (mg/liter) -----			----- (mg/liter) -----
27		887			empty		
28		888			empty		
29		889			empty	Empty samples due	
30		890			empty	to freezing weather.	
DEC							
1		empty			empty		

Precipitation (as rain) for December 2, 1989, through April 19, 1990, was 12.86 inches.

1990

APR

23		1419		1441	} 1466*	ND
24		1420		1142		
25	0.12	1421		1443		
26	0.09	1422		1444		
27		1423		1445		
28		1424		1446		
29		1425		1447		
30		1426		1448		
MAY						
1		1427		1449		
2		1428		1450		
3		1429		1451		
4		1430		1452		

(Continued)

Table 9 (Continued)

Concentration of Herbicide in Stream Water From Lake Colby Sub Study Site
in Connection With Application of Imazapyr on September 6, 1989

DATE	RAIN (Inches)	----- SITE E, UPSTREAM -----			----- SITE F, DOWNSTREAM -----		
		SAMPLE NO.1		HERBICIDE2	SAMPLE NO.1		HERBICIDE2
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
				----- (mg/liter) -----			----- (mg/liter) -----
MAY							
5	0.40	1431			1453	1467*	ND
6	0.02	1432			1454		
7	0.55	1433			1455		
8	0.19	1434			1456		
9		1435			1457		
10	0.09	1436			1458		
11	0.58	1437			1459		
12	0.02	1438			1460		
13	0.85	1439			1461		
14	0.08	1440			1462		
15		1566			1590	1616*	ND
16		1567			1591		
17	0.42	1568			1592		
18	0.38	1569			1593		
19	0.16	1570			1594		
20	0.13	1571			1595		
21	0.93	1572			1596		
22	0.02	1573			1597		
23		1574			1598		
24		1575			1599		
25	0.15	1576			1600		
26		1577			1601		
27		1578			1602		

(Continued)

Table 9 (Continued)

Concentration of Herbicide in Stream Water From Lake Colby Sub Study Site
in Connection With Application of Imazapyr on September 6, 1989

DATE	RAIN (Inches)	----- SITE E, UPSTREAM -----			----- SITE F, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
				----- (mg/liter) -----			----- (mg/liter) -----
MAY							
28		1579			1603		
29	0.20	1580			1604		
30	0.18	1581			1605		
31		1582			empty		ND
JUNE							
1		1583			1606		
2	0.03	1584			1607		
3	0.60	1585			1608		
4	0.28	1586			1609		
5		1587			1610		
6	0.03	1588			1611		

¹All field samples were assigned a permanent (perm.) sample number. Samples sent to the laboratory for analysis were given a laboratory (lab.) sample number. Any field sample that does not also have a laboratory number was not analyzed. An asterisk (*) indicates a composite sample.

²ND means not detectable (less than 0.001 mg/liter). T means trace (less than 0.001 mg/liter, but more than 0.0003 mg/liter; detectable qualitatively, but not quantitatively).

TURNER ROAD #1

TURNER ROAD #1 SITE DESCRIPTION

Date of Construction: About 1940
R/W Width: 100'
Treatment History: No treatment in at least 8 years
Study Treatment: Low-volume basal application of 10 ozs. of Chopper in 1 gal. #2 fuel oil.
Active Ingredient: Imazapyr, 0.47 lbs. per acre
General Description:

The Turner Road #1 site is located northeast of Troy, NY. The R/W at this location runs southwesterly with a stream crossing it at about a 75 degree angle. The low to medium density site was treated on both sides of the stream with a low-volume basal application on September 17, 1989 (Table 1). The buffer zone between the stream and the adjacent treatment area was approximately 10 feet.

The stream passes through a large concrete pipe under the access road (Photo A). It is unexposed across most of the R/W. The stream is exposed and well defined at both R/W edges.

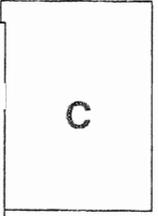
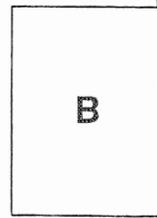
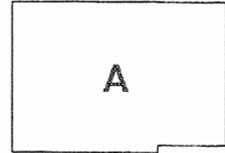
The middle portion of the R/W, including the access road, is relatively level throughout the length of the site. On the north side the R/W slopes gradually down to the upstream end of the concrete pipe. There is a very abrupt drop-off (50 to 60 percent slope) from the access road to the downstream end of the pipe. A small pool approximately 18 to 24 inches deep has formed at the bottom of this steep slope, just below the pipe (Photo C).

In the summer and fall of 1989, when the site was selected and treated, the area on both sides of the stream was dry. After the snow melted, the side slope was very wet. Water was flowing from many locations and pooling in wheel tracks on the access road. The saturated portion of the side slope extended approximately 150 feet from the stream well into the treated portion of the R/W. Water flowing over the surface, from this area, enters the stream on the upstream side of the downstream water sampler.

Both the upstream and downstream sides of the R/W are covered with relatively dense vegetation. This vegetation is primarily composed of small trees and shrubs, with a ground cover of grass and herbs (Photo B). The center of the R/W is the access road, bordered by dense herbaceous cover.



Turner
Road #1



TURNER ROAD #1 STUDY RESULTS

Sampling was highly successful at this site with only two downstream samples lost due to freezing weather in late November. The results of analysis of samples from the upstream and downstream sampling sites are in Table 10. The first three significant rainfall events were identified as occurring during the periods of September 17-22, September 23-26, and October 2-5.

Imazapyr was found in ten samples, all but two collected nearly 1 month after application during a period of heavy rainfall (the fifth storm, 4.2 inches over 8 days). The maximum residue level found was 0.003 mg/liter. No imazapyr was detected in samples collected more than 5 weeks after application.

None of the samples at the upstream location contained detectable levels of imazapyr, indicating residues detected at the downstream location originated on the R/W and probably from the application under study.

The lack of detectable imazapyr the day of application indicates the 10-foot buffer zone and the basal application strategy at this site was successful in preventing direct application or drift of imazapyr to the stream. Mobilization of surface residues during the first major storms after application resulted in measurable but low residues of imazapyr at this site. This pattern of residue entry to the stream probably results from the flow of water from treated portions of the R/W during early rains. There was however no evidence of leaching or long-term entry to the stream probably because surface residues enter the upper parts of the soil profile where they are immobilized (absorbed) or degraded. The buffer zone strategy used at this site protected water quality.

Table 10
Concentration of Herbicide in Stream Water From Turner Road #1 Study Site
in Connection With Application of Imazapyr on September 17, 1989

DATE	RAIN (Inches)	----- SITE I, UPSTREAM -----			----- SITE J, DOWNSTREAM -----		
		SAMPLE NO.1		HERBICIDE ²	SAMPLE NO.1		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
				----- (mg/liter) -----			----- (mg/liter) -----
1989							
SEPT							
8	48				66		
9	43				65		
10	0.02	47			67		
11		46	} 973*	ND	64		
12		42			68		
13		41			70		
14	0.44	39	} 974*	ND	69		
15	0.08	45			63		
16	0.43	40			71		
17	0.15	44			61	61	ND
18		38			62	62	ND
19	0.36	37			72	72	ND
20	0.72	50		ND	59	59	0.001
21		52			56	56	ND
22		53			57	57	ND
23	0.21	54			55	55	ND
24		49			58	58	ND
25		51			60	60	ND
26	0.27	338			362	362	ND
27		339			363	363	ND
28		340			364	364	ND
29		341			365	365	ND
30		342			366	366	0.001
OCT							
1		343			367	367	ND

(Continued)

Table 10 (Continued)

Concentration of Herbicide in Stream Water From Turner Road #1 Study Site
in Connection With Application of Imazapyr on September 17, 1989

DATE	RAIN (Inches)	----- SITE I, UPSTREAM -----			----- SITE J, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
				----- (mg/liter) -----			----- (mg/liter) -----
OCT							
2	0.53	344			368	368	ND
3		345			369	369	ND
4		346			370	370	ND
5		347			371	371	ND
6	0.07	348			372		
7		349			373		
8	0.02	350			374	949*	ND
9		351			375		
10	0.02	352			376		
11	0.13	353			377	377	ND
12		354			378	378	ND
13		355			379	379	ND
14	0.49	356			380	380	ND
15	0.27	357	357	ND	381	381	0.001
16		358	358	ND	385	385	ND
17	0.95	359	359	ND	384	384	0.001
18	0.02	360	360	ND	383	383	0.002
19	0.30	361	361	ND	382	382	ND
20	2.15	592	592	ND	604	604	0.003
21	0.02	593	593	ND	605	605	0.002
22		594	594	ND	606	606	0.001
23		595	595	ND	607	607	0.001
24		596	596	ND	608	608	0.001
25		597	597	ND	609	609	ND
26		598	598	ND	610	610	ND

(Continued)

IV-87

Table 10 (Continued)

Concentration of Herbicide in Stream Water From Turner Road #1 Study Site
in Connection With Application of Imazapyr on September 17, 1989

DATE	RAIN (Inches)	----- SITE I, UPSTREAM -----			----- SITE J, DOWNSTREAM -----		
		SAMPLE NO.1		HERBICIDE ²	SAMPLE NO.1		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
OCT				----- (mg/liter) -----			----- (mg/liter) -----
27		599			611		
28		600			612		
29		601			613		
30		602			614		
31	0.56	603			615		
NOV							
1	0.14	670			679		
2		671			680		
3	0.15	672			681		
4		673			682		
5		674			683		
6	0.08	675			684		
7	0.04	676			685		
8	0.03	677			686		
9	0.45	678			687		
10		729			749		
11		730			750		
12		731			751		
13		732			752		
14		733			753		
15	0.04	734			754		
16	0.42	735			755		
17		736			756		
18		737			757		
19		738			758		
20	0.35	739			759		

(Continued)

88-VI

611-615 } 1096* ND

753-759 } 951* ND

Table 10 (Continued)

Concentration of Herbicide in Stream Water From Turner Road #1 Study Site
in Connection With Application of Imazapyr on September 17, 1989

DATE	RAIN (Inches)	----- SITE I, UPSTREAM -----			----- SITE J, DOWNSTREAM -----		
		SAMPLE NO.1		HERBICIDE ²	SAMPLE NO.1		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
NOV				----- (mg/liter) -----			----- (mg/liter) -----
21		740			760		
22		741			778		
23	0.07	742			empty		Empty samples due to freezing weather.
24		743			empty		
25		744			779		
26	0.06	745			780		
27	0.03	746			781	} 952*	ND
28		747			782		
29		748			783		
30	0.04	empty	Freezing weather.		784		

Precipitation (as rain) for November 30, 1989, through March 21, 1990, was 12.05 inches.

1990

MAR

22		1013			1018	} 1091*	ND
23		1014			1019		
24		1015			1020		
25		1016			1021		
26	0.01	1017			1022		
27		empty			1023		
28		empty			1024		
29		empty	Empty samples due to		1025		
30	0.17	empty	mechanical malfunction.		1026		
31	0.20	empty			1027		

(Continued)

Table 10 (Continued)

Concentration of Herbicide in Stream Water From Turner Road #1 Study Site
in Connection With Application of Imazapyr on September 17, 1989

DATE	RAIN (Inches)	----- SITE I, UPSTREAM -----			----- SITE J, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
APR				----- (mg/liter) -----			----- (mg/liter) -----
26	0.04	1167			1191		
27		1168			1192		
28		1169			1193		
29		1170			1194		
30		1171			1195		

¹All field samples were assigned a permanent (perm.) sample number. Samples sent to the laboratory for analysis were given a laboratory (lab.) sample number. Any field sample that does not also have a laboratory number was not analyzed. An asterisk (*) indicates a composite sample.

²ND means not detectable (less than 0.001 mg/liter). T means trace (less than 0.001 mg/liter, but more than 0.0003 mg/liter; detectable qualitatively, but not quantitatively).

TURNER ROAD #2

TURNER ROAD #2 SITE DESCRIPTION

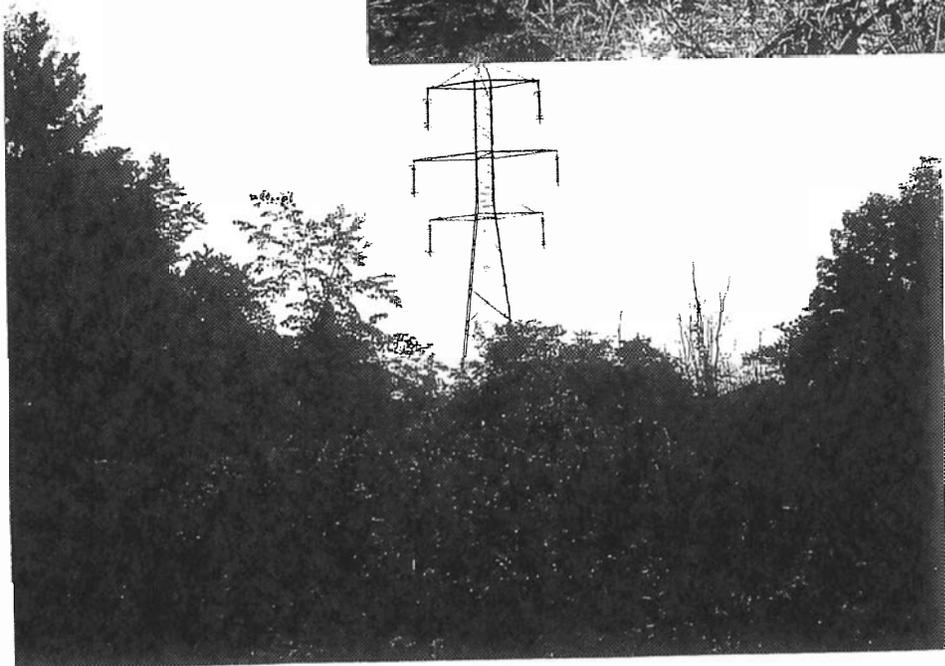
Date of Construction: About 1940
R/W Width: 100'
Treatment History: No treatment in at least 8 years
Study Treatment: Low-volume basal application of 10 ozs. of Chopper in 1 gal. #2 fuel oil.
Active Ingredient: Imazapyr, 0.2 lbs. per acre
General Description:

The Turner Road #2 site is located approximately 1,500 feet south of the Turner Road #1 site. This site was treated with a low-volume basal application on September 17, 1989 (Table 1). A 100-foot buffer zone was left on both sides of the stream. The heavy density vegetation in the buffer zones was hand-cut about 1 month after herbicide application.

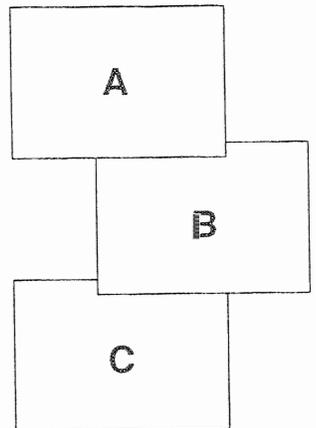
The stream is located in a deep gully and flows directly across the R/W (Photo A). On the north side of the stream the R/W rises about 20 feet from the stream at a 20 to 30 percent slope. On the south side, the R/W climbs about 25 feet at a 50 to 60 percent slope away from the stream (Photo B).

The stream channel is well defined across the R/W. The main channel is 18 to 24 inches wide, paralleled on either side by clumps of grass and wetland vegetation. The entire stream channel area is 5 to 7 feet wide and apparently floods during heavy rains. Soil on either side of the stream is silty, and large amounts of silt can be observed moving along the streambed even at periods of low flow.

The stream channel is bordered by mixed grasses. Dense vegetation, consisting primarily of blackberry mixed with clumps of red maple and various shrubs, covers the north and south slopes which parallel the stream (Photo C).



Turner
Road #2



TURNER ROAD #2 STUDY RESULTS

Sampling at this site was complicated by loss of downstream samples for a 21-day period due to siltation in the channel, which buried the sampler intake hose in silt. Unfortunately this loss began just before application and continued during the first three major storm periods when 3.19 inches of rain fell. A further gap in the record exists for about 7 days due to an unknown cause. During this 7-day period 3.71 inches of rain fell.

Another 11 day period of no samples occurred in November, but it was during a period of little rain. Other gaps in the record occurred in late November (freezing weather) and in the spring (dead battery). The results of analysis of samples from the upstream and downstream sampling sites are in Table 11. The first three significant rainfall events were identified as occurring during the periods of September 17-20, September 23-26, and October 2-5.

No imazapyr was detected in any sample from this site, but the sampling record is significantly incomplete during the first 2 months after application. Beginning in mid-November, the record of sample collection is good, and no imazapyr was detected in samples from this site, indicating the 100-foot buffer zone and the basal application strategy prevented leaching or long-term entry of imazapyr to the stream, but the lack of early record prevents conclusions about direct application or drift to the stream, or mobilization by the first rains.

86-11

Table 11
Concentration of Herbicide in Stream Water From Turner Road #2 Study Site
in Connection With Application of Imazapyr on September 17, 1989

DATE	RAIN (Inches)	----- SITE M, UPSTREAM -----			----- SITE N, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
				----- (mg/liter) -----			----- (mg/liter) -----
1989							
SEPT							
13		111			109		
14	0.44	112			110	975*	ND
15	0.08	empty			empty		
16	0.43	empty			empty		
17	0.15	empty			empty		
18		empty			empty		
19	0.36	empty			empty		
20	0.72	empty			empty		
21		empty			empty		
22		empty			empty		
23	0.21	empty			empty		
24		empty	Empty samples due to		empty	Empty samples due to	
25		empty	siltation of channel,		empty	siltation of channel,	
26	0.27	empty	which buried sample		empty	which buried sample	
27		empty	collection tube.		empty	collection tube.	
28		empty			empty		
29		empty			empty		
30		empty			empty		
OCT							
1		empty			empty		
2	0.53	empty			empty		
3		empty			empty		
4		empty			empty		
5		empty			empty		

(Continued)

Table 11 (Continued)

Concentration of Herbicide in Stream Water From Turner Road #2 Study Site
in Connection With Application of Imazapyr on September 17, 1989

DATE	RAIN (Inches)	----- SITE M, UPSTREAM -----			----- SITE N, DOWNSTREAM -----		
		SAMPLE NO.1		HERBICIDE ²	SAMPLE NO.1		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
OCT				----- (mg/liter) -----			----- (mg/liter) -----
6	0.07	640			652		
7		641			653		
8	0.02	642			654	985*	ND
9		643			655		
10	0.02	644			656		
11	0.13	645			657		
12		646			658	658	ND
13		647			659	659	ND
14	0.49	648			660	660	ND
15	0.27	649			empty		
16		650			empty		
17	0.95	651			empty		
18	0.02	712			empty		
19	0.30	713			empty	Empty samples due to unknown cause.	
20	2.15	714			empty		
21	0.02	715			empty		
22		716			723		
23		717			empty		
24		718			empty		
25		719			724		
26		720			725		
27		721			726	986*	ND
28		722			727		
29		empty		Unknown cause.	728		

(Continued)

IV-99

Table 11 (Continued)

Concentration of Herbicide in Stream Water From Turner Road #2 Study Site
in Connection With Application of Imazapyr on September 17, 1989

DATE	RAIN (Inches)	----- SITE M, UPSTREAM -----			----- SITE N, DOWNSTREAM -----		
		SAMPLE NO.1		HERBICIDE ²	SAMPLE NO.1		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
OCT							
30							
31	0.56						
NOV							
1	0.14						
2							
3	0.15						
4							
5							
6	0.08						
7	0.04						
8	0.03						
9	0.45						
10		761			empty		
11		762			785		
12		763			786	987*	ND
13		764			787		
14		765			empty		
15	0.04	766			788		
16	0.42	767			789		
17		768			790		
18		769			791	988*	ND
19		770			792		
20	0.35	771			793		
21		772			794		

(Continued)

IV-100

Table 11 (Continued)

Concentration of Herbicide in Stream Water From Turner Road #2 Study Site
in Connection With Application of Imazapyr on September 17, 1989

DATE	RAIN (Inches)	----- SITE M, UPSTREAM -----			----- SITE N, DOWNSTREAM -----		
		SAMPLE NO.1		HERBICIDE ²	SAMPLE NO.1		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
				----- (mg/liter) -----			----- (mg/liter) -----
NOV							
22		empty			empty		
23	0.07	empty	Empty samples due		empty		
24		empty	to freezing weather.		empty		
25		773			empty		
26	0.06	774			empty	Empty samples due	
27	0.03	775			empty	to freezing weather.	
28		776			empty		
29		777			empty		
30	0.04	empty			empty		

Precipitation (as rain) for December 1, 1989, through March 21, 1990, was 12.01 inches.

1990

MAR

22		1040			1052		
23		1041			1053		
24		empty	Unknown cause.		1054	} 1093*	ND
25		1042			1055		
26	0.01	1043			1056		
27		empty	Unknown cause.		empty		
28		1044			empty		
29		1045			empty	Empty samples due	
30	0.17	1046			empty	to dead battery.	
31		1047			empty		

(Continued)

IV-101

Table 11 (Continued)

Concentration of Herbicide in Stream Water From Turner Road #2 Study Site
in Connection With Application of Imazapyr on September 17, 1989

DATE	RAIN (Inches)	----- SITE M, UPSTREAM -----			----- SITE N, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
				----- (mg/liter) -----			----- (mg/liter) -----
APR							
1	0.01	1948			empty		
2	0.08	1049			empty		
3	1.57	1050			empty		Empty samples due
4	0.62	1051			empty		to dead battery.
5		empty	Empty samples due		empty		
6		empty	to unknown cause.		empty		
7		1244			1268		
8		1245			1269		
9		1246			1270		
10	0.49	1247			1271	1332*	ND
11	0.21	1248			1272		
12		1249			1273		
13		1250			1274		
14		1251			1275		
15	0.22	1252			1276		
16		1253			1277		
17	0.04	1254			1278		
18		1255			1279		
19		1256			1280		
20	0.13	1257			1281		
21	0.38	1258			1282	1333*	ND
22		1259			1283		
23		1260			1284		
24		1261			1285		

(Continued)

Table 11 (Continued)

Concentration of Herbicide in Stream Water From Turner Road #2 Study Site
in Connection With Application of Imazapyr on September 17, 1989

DATE	RAIN (Inches)	----- SITE M, UPSTREAM -----			----- SITE N, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
				----- (mg/liter) -----			----- (mg/liter) -----
APR							
25	0.08	1262			1286		
26	0.04	1263			1287		
27		1264			1288		
28		1265			1289		
29		1266			1290		
30		1267			1291		

¹All field samples were assigned a permanent (perm.) sample number. Samples sent to the laboratory for analysis were given a laboratory (lab.) sample number. Any field sample that does not also have a laboratory number was not analyzed. An asterisk (*) indicates a composite sample.

²ND means not detectable (less than 0.001 mg/liter). T means trace (less than 0.001 mg/liter, but more than 0.0003 mg/liter; detectable qualitatively, but not quantitatively).

RT. 27/TROUT CREEK

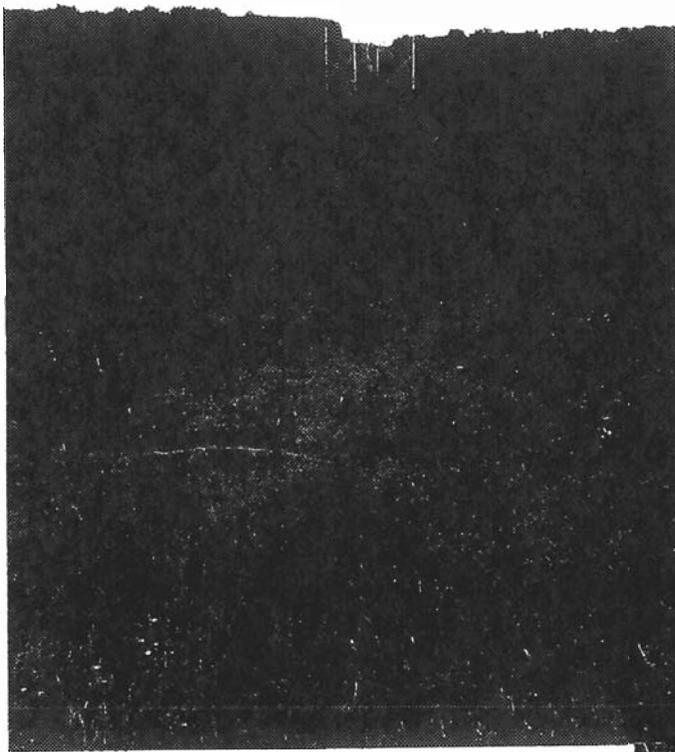
RT. 27/TROUT CREEK SITE DESCRIPTION

Date of Construction: 1967
R/W Width: 180'
Treatment History: Last treatment in 1982
Study Treatment: Low-volume basal application of 10 ozs. of Chopper in 1 gal. #2 fuel oil.
Active Ingredient: Imazapyr, 0.25 lbs. per acre
General Description:

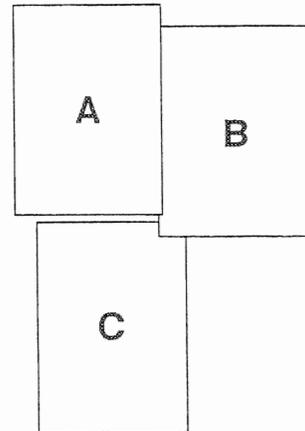
The Rt. 27/Trout Creek Site (Photo A) is located on the Oakdale - Fraser 345kV line along County Route 27 northeast of Trout Creek, NY. The R/W runs east-west with a stream running across the R/W at nearly a 90 degree angle. An access road crosses the stream along the southern edge of the R/W. A basal application was performed on September 25, 1989, leaving a 15-foot buffer zone of medium density vegetation on each side of the stream (Table 1).

The stream has a well-defined central channel, paralleled on either side by clumps of grasses and herbaceous plants (Photo B). Water runs around and behind these clumps most of the year. The streambank on the east side rises 18 to 24 inches and continues up the slope from that point. The vegetation on the slope is typical of moist woodland plant species that quickly turn to typical terrestrial species within 50 to 75 feet of the stream channel. On the west side the stream bank rises 18 to 24 inches from the edge of the streambed. The slope is very gradual from the edge of the bank, rising only 1 or 2 feet in the first 80 to 100 feet. Vegetation in this relatively flat area is composed of typical wetland species such as cattails, sphagnum moss, false hellebore, and many sedges and rushes.

In the summer and fall of 1989, when the site was selected and treated, this flat area was moist but water was not pooling or flowing on the surface. After the snow melted, water was pooled on the surface to a depth of 1 to 2 inches, and slow surface flow was apparent in many places in the buffer and treated area. Most of this flat area is located between the access road and the north (upstream) side of the R/W. Water flowing from this area enters the stream above the downstream sampling unit. Water was also noted standing and flowing 50 to 60 feet into the stream from wheel tracks on the access road (Photo C).



Rt. 27/
Trout Creek



RT. 27/TROUT CREEK STUDY RESULTS

This site was treated with imazapyr on September 25, 1989. Sampling was successful in the early part of the fall and winter, but freezing weather caused sampling to end in late November. Two samples were collected in mid-February, but no others due to freezing weather until a two-week period in mid-March. This was followed by a 12-day gap at the end of March - early April due to an unknown cause. The results of analysis of samples from the upstream and downstream sampling sites are in Table 12. The first three significant rainfall events were identified as occurring during the periods of October 2-6, October 11-14, and October 18-21.

A total of four samples contained detectable residues of imazapyr. Occurrence of positive samples was scattered, not bearing any strong relationship to weather patterns. No residues were detected between 24 days after application and winter freeze-up.

A single composite sample collected during the spring contained a residue of 0.003 mg/liter. All the individual samples from which the composite sample was prepared were then analyzed. None showed a detectable residue, indicating the composite analysis was likely in error. However, a single sample collected the day after the last sample to be used to prepare the composite did contain imazapyr at the limit of detection. The uncertainties of analysis at this level combined with the lack of residues in preceding samples, or similar samples from other sites, suggests an artifact. No other samples with herbicide residues were found.

None of the samples collected at the upstream site contained positive residues of imazapyr, indicating the residues found at the downstream sites likely originated on the treated portion of the R/W.

The 15-foot buffer zone and the basal application strategy used at this site prevented direct application and drift of imazapyr to the stream. Low level and sporadic residues indicate the strategy was also successful in protecting water quality from runoff and leaching.

Table 12 (Continued)

Concentration of Herbicide in Stream Water From Rt. 27/Trout Creek Study Site
in Connection With Application of Imazapyr on September 25, 1989

DATE	RAIN (Inches)	----- SITE O, UPSTREAM -----			----- SITE P, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
OCT				----- (mg/liter) -----			----- (mg/liter) -----
13		179			202	202	ND
14		386	386	ND	408	408	0.002
15	0.02	387	387	ND	409	409	ND
16		lost	Bottle broken.		410	410	ND
17	0.03	388	388	ND	411	955*	ND
18	0.53	389	389	ND	412	412	0.002
19	0.32	390			413	413	ND
20	1.07	391			414	414	ND
21	1.21	392			415	515	ND
22	0.09	393			416	956*	ND
23		394			417		
24		395			418		
25		396			419		
26		397			420		
27		398			421		
28		399			422		
29		400			423		
30		401			424		
31		402			425		
NOV							
1	0.30	403			426		
2		404			427		

(Continued)

IV-111

Table 12 (Continued)
Concentration of Herbicide in Stream Water From Rt. 2
in Connection With Application of Imazapyr on S

DATE	RAIN (Inches)	----- SITE O, UPSTREAM -----			SA
		SAMPLE NO. ¹		HERBICIDE ²	
		Perm.	Lab.	Imazapyr	Perm
				----- (mg/liter) -----	
NOV					
3		405			428-
4	0.20	empty		Unknown cause.	429
5		406			430
6	0.08	407			431
7	0.01	830			843
8	0.09	lost		Bottle broken.	844
9	0.16	831			lost
10	0.49	832			845
11	0.10	833			846
12	0.02	834			847
13		835			848
14		836			849
15	0.01	837			850
16	0.07	838			851
17	2.33	839			852
18		empty			853
19	0.06	empty			854
20	0.15	empty			855
21	0.25	empty			856
22	0.06	empty		Empty samples due	857
23	0.07	empty		to freezing weather.	empty
24		empty			empty
25		empty			empty
26	0.01	empty			empty
27	0.05	840			empty

successful in the
 and in late
 freezing
 the end
 in the
 fall

958* ND

(Continued)

IV-112

Table 12 (Continued)

Concentration of Herbicide in Stream Water From Rt. 27/Trout Creek Study Site
in Connection With Application of Imazapyr on September 25, 1989

DATE	RAIN (Inches)	----- SITE O, UPSTREAM -----			----- SITE P, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
NOV				----- (mg/liter) -----			----- (mg/liter) -----
28	0.13	841			empty		
29		842			empty	Empty samples due	
30		empty	Freezing weather.		empty	to freezing weather.	
Precipitation (as rain) for December 1, 1989, through February 18, 1990, was 7.07 inches.							
1990							
FEB							
19		992			990	} 1094*	ND
20	0.01	empty			991		
21		993			empty		
22		994			empty		
23	0.22	995			empty		
24	0.14	empty			empty		
25	0.09	empty			empty		
26	0.01	empty			empty		
27		empty	Empty samples due		empty	Empty samples due	
28	0.06	empty	to freezing weather.		empty	to freezing weather.	
MAR							
1		empty			empty		
2		996			empty		
3		997			empty		
4		empty			empty		
5	0.01	empty			empty		
6	0.05	No samples collected; too cold.			No samples collected; too cold.		
7		No samples collected; too cold.			No samples collected; too cold.		

(Continued)

IV-113

Table 12

Concentration of Herbicide in Stream Water From Rt. 27/Ti
in Connection With Application of Imazapyr on Sept

successful in the
and in late
freezing
the end
in the
fall
and

DATE	RAIN (Inches)	----- SITE O, UPSTREAM -----			SAMPLE Perm.	SAMPLE Perm.	SAMPLE Perm.
		SAMPLE NO. ¹ Perm.	Lab.	HERBICIDE ² Imazapyr			
		----- (mg/liter) -----					
1989							
SEPT							
22		159			181		
23	0.31	160	160	ND	182		
			978*	ND			
24	0.37	161			183		
25		162	162	ND	184	184	ND
26	0.02	163			185	185	ND
27	0.03	164	164	ND	186	186	ND
28		165			187	187	ND
29		166	166	ND	188	188	ND
						953*	0.001
30		167			189	189	ND
OCT							
1		168			190	190	ND
2	0.01	169			191	191	ND
3	0.23	170			192	192	ND
4		171			193	193	ND
5		172			194	194	ND
6	0.18	173			195	195	ND
7	0.02	174			196		
8		175			197		
9	0.01	176			198	954*	ND
10		177			199		
11	0.14	178			200	200	ND
12		180			201	201	ND

(Continued)

IV-110

Table 12 (Continued)

Concentration of Herbicide in Stream Water From Rt. 27/Trout Creek Study Site
in Connection With Application of Imazapyr on September 25, 1989

DATE	RAIN (Inches)	----- SITE O, UPSTREAM -----			----- SITE P, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
MAR				----- (mg/liter) -----			----- (mg/liter) -----
8		No samples collected; too cold.			No samples collected; too cold.		
9		No samples collected; too cold.			No samples collected; too cold.		
10	0.01	No samples collected; too cold.			No samples collected; too cold.		
11	0.02	No samples collected; too cold.			No samples collected; too cold.		
12	0.13	No samples collected; too cold.			No samples collected; too cold.		
13		No samples collected; too cold.			No samples collected; too cold.		
14		No samples collected; too cold.			No samples collected; too cold.		
15		1057			1078	1078	ND
16		1058			1079	1079	ND
17	0.06	1059			1080	1080	ND
18	0.58	lost	Bottle broken.		1081	1081	ND
19		1060			1082	1082	ND
20	0.82	1061			1083	1083	ND
21	0.46	1062			1084	1084	0.001
22		1063			1085	1085	ND
23		1064			1086	1086	ND
24		empty	Unknown cause.		1087	1087	ND
25		1065			1088		
26		1066			1089		
27		empty	Unknown cause.		empty		
28		1067			empty		
29		1068			empty		
30	0.17	1069			empty		Empty samples due
31	0.03	1070			empty		to unknown cause.

(Continued)

IV-114

Table 12 (Continued)

Concentration of Herbicide in Stream Water From Rt. 27/Trout Creek Study Site
in Connection With Application of Imazapyr on September 25, 1989

DATE	RAIN (Inches)	----- SITE O, UPSTREAM -----			----- SITE P, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
				----- (mg/liter) -----			----- (mg/liter) -----
APR							
1		1071			empty		
2	0.02	1072			empty		
3	0.53	1073			empty		
4	0.42	1074			empty		Empty samples due to unknown cause.
5	0.08	1075			empty		
6		1076			empty		
7		1077			empty		
8		1292			1304		
9		1293			1305		
10		1294			1306	1334*	ND
11	1.06	1295			1307		
12		1296			1308		
13		1297			1309		
14		1298			1310		
15	0.08	1299			1311		
16		1300			1312		
17		1301			1313		
18	0.16	1302			1314		
19		1303			1315		
20		empty			1316	1335*	ND
21	0.32	empty			1317		
22		empty	Empty samples due to mechanical malfunction.		1318		
23		empty			1319		
24	0.19	empty			1320		
25		empty			1321		

(Continued)

Table 12 (Continued)

Concentration of Herbicide in Stream Water From Rt. 27/Trout Creek Study Site
in Connection With Application of Imazapyr on September 25, 1989

DATE	RAIN (Inches)	----- SITE O, UPSTREAM -----			----- SITE P, DOWNSTREAM -----		
		SAMPLE NO. ¹		HERBICIDE ²	SAMPLE NO. ¹		HERBICIDE ²
		Perm.	Lab.	Imazapyr	Perm.	Lab.	Imazapyr
				----- (mg/liter) -----			----- (mg/liter) -----
APR							
26				empty			1322
27				empty	Empty samples due to		1323
28				empty	mechanical malfunction.		1324
29				empty			1325

¹All field samples were assigned a permanent (perm.) sample number. Samples sent to the laboratory for analysis were given a laboratory (lab.) sample number. Any field sample that does not also have a laboratory number was not analyzed. An asterisk (*) indicates a composite sample.

²ND means not detectable (less than 0.001 mg/liter). T means trace (less than 0.001 mg/liter, but more than 0.0003 mg/liter; detectable qualitatively, but not quantitatively).

E. SUMMARY OF FINDINGS AND OVERALL CONCLUSIONS

In all but two cases, no herbicide was detected in a sample collected the day of application. In these instances the concentrations were low (0.002 mg/liter and a trace, meaning less than 0.001 mg/liter), indicating the methods and strategies of application and the buffer zones used prevented important amounts of herbicide from entering the streams due to direct application or drift of herbicide to the streams.

Most samples of water from this study did not contain detectable herbicide. Nearly all samples that did were collected during the first few rain storms after application, indicating mobilization of residues of herbicide on the surface by rainfall and subsequent runoff. In the few samples where herbicide was found, the levels were much less than would harm aquatic life or downstream water users based on the risk analysis in Part V of this report.

Once the early storms passed, there was no further mobilization of herbicide residues, probably because the rain had moved the herbicide into the surface layers of the litter or soil where it binds with organic matter and is subject to microbial decomposition. There was no long-term runoff of herbicide from these sites as indicated by the lack of residues in the streams during the spring runoff period.

In this field test, picloram in Tordon 101 and triclopyr in Garlon 4 were only applied as a stem foliage application with 100 foot buffer strips (Pinewoods Road 1 and 2). However picloram in Access and triclopyr in Garlon 4 were applied in a basal application with a 30-foot buffer strip on one site (Lyon Mountain - Chazy Lake). The question is, will the 30-foot buffer which protected water quality during basal applications at Lyon Mountain - Chazy Lake protect water quality in connection with a stem-foliage application?

- a. The results of the buffer strip width test (Part III of this report) indicate buffer strips of 25 feet would protect water quality from direct entry of herbicide during application.
- b. Since the same amount of active ingredient was applied per acre at all three sites during the water quality test (Part IV), it is a reasonable assumption that the same pattern of herbicide entry to streams observed with the 30-foot buffer at Lyon Mountain - Chazy Lake would hold for mobilization, overland flow and leaching of these same herbicides at the Pinewoods Road sites. Thus the conclusion is the 30-foot buffer would protect water quality for stem-foliage applications of Tordon 101 and Garlon 4 as well as it did for the basal application.

The buffer zones (10-150 feet) and application strategies (stem-foliar and basal) used at the study sites protected water quality in connection with the operational application of herbicide in these tests. The test design did not evaluate differences in behavior among herbicides, thus the results should not be used in selecting chemical products - only in evaluating buffer zone and application strategies.

The following comments are provided to assure proper perspective is maintained in interpreting the specific results of this study as outlined above.

- a. The specific herbicide values reported are a 24-hour average concentration based analysis of single samples composed of four equal aliquotes of water pumped at 6-hour intervals. For composite samples, the concentration reported is the average for the period represented by the composite. Whenever a detectable quantity of herbicide was found in a composite sample, the individual samples used to make the composite were then analyzed individually. Thus in any case where herbicide was detected, a 24-hour average value is reported.

It is unlikely that the absolute highest concentration which occurred in the water would be captured by this strategy; however, it is a reasonable approximation of the 24-hour average concentration for either dry or wet (rainy) periods.

- b. The consequence of not capturing the absolute maxima is minimal because the risk analysis is not based on exposure to instantaneous maxima but on continuous exposure to concentrations for various period of time ranging from 48 to 96 hours for aquatic species and much longer periods for mammals. The risk analysis is the basis for development of the recommended water quality standards, and thus 24-hour average concentrations can logically be used as a basis for determining compliance with the standard, which is intended to protect aquatic species and humans.
- c. At some sampling sites automatic sampling equipment malfunctioned and an incomplete record is available. However, there is at least one reasonably complete record for each herbicide and method of application included in the test. In most instances there are several. While there is some variation in findings among sites and chemicals, without exception the record which is available shows compliance with the suggested water quality standards (Part VI of this report). Without question an unbroken sample collection record is preferred, but the uniform result of compliance found in this study should provide confidence in the conclusions of the study.

The purpose of this test included determination of the efficacy of the buffer zones used by the Niagara Mohawk Power Corp. and New York State Electric & Gas Corp. in the Adirondak Park and elsewhere. While the Public Service Commissioner's order in Case 27605 does not establish the objective to be attained by use of these buffers, we assume it is intended to protect aquatic organisms and human health. This is the purpose of the recommended water quality standards in Part VI of this report which are as follows:

<u>Herbicide</u>	<u>Concentration of Herbicide</u>
<u>2,4-D:</u>	
Amines (including in Tordon 101)	0.07 mg/liter
Esters	0.005 mg/liter
<u>Picloram:</u>	
Tordon 101	0.2 mg/liter
Tordon K.	0.07 mg/liter
Access	0.07 mg/liter
<u>Triclopyr:</u>	
Garlon 3A	0.5 mg/liter
Garlon 4	0.03 mg/liter
<u>Imazapyr:</u>	
Arsenal, Chopper	5.0 mg/liter
<u>Fosamine:</u>	
Krenite	1.0 mg/liter
<u>Glyphosate:</u>	
Accord	2.0 mg/liter

As summarized in the PSC's order, the buffers used by Niagara Mohawk Power Corp. and New York State Electric and Gas are such that:

- a. Herbicide is not used within 100 feet of a potable water supply or regulated wetland or protected waters.
- b. A minimum approach distance of 50 feet is used for stem-foliar application methods and 30 feet for basal and cut-and-stump methods of application around other wetlands, perennial and intermittent streams.

The results of this test (summarized in Table 13) show each of the buffer strategies tested successfully protected water quality to the standards recommended (for the herbicides applied) for protection of aquatic organisms and human health developed in Part VI of this report and shown above.

Relative to the buffers mandated in the PSC's order:

- a. The 100-foot buffer was well tested and achieve the presumed goal of protecting aquatic organisms and human health.
- b. The 30-foot buffer (or less) was well tested in connection with basal applications and it achieved the presumed goal of protecting aquatic organisms and human health. There is no reason to believe the cut-and-stump method of application would produce different results and it is suggested the 30-foot buffer is adequate for this purpose as well.
- c. The 50-foot buffer for stem foliar application was used in one application. In this instance the actual buffer was 35 to 50 feet to live water, the application vehicle was within 15 feet of live water at one point, and the marshy area adjacent to the stream extended into the treatment zone and was thus not buffered. The area immediately adjacent to the stream was apparently dry during the application, but during periods of heavy rain (which occurred shortly after application) contained surface water which flowed into the stream, upstream from the sampler.

In this instance successful water sampling was achieved during the first three rain storms and the fifth storm, but the sampler malfunctioned during the fourth storm. Extensive sampling was successful later in the study period. Thus the record is partially incomplete for this particular site, and it is the site where the highest concentration of herbicide was found. The concentration of imazapyr found at this site was 833 times less than the recommended standard for protection of aquatic organisms and human health.

Since this site was not effectively buffered, it is necessary to rely on indirect evidence as well as sampling data in evaluating the adequacy of the 50-foot buffer for stem-foliar applications. There are two lines of evidence pertinent to this evaluation. The buffer strip width test (Part III of this report) indicated buffer widths of 25 feet would protect water quality from direct entry and drift of the most toxic of the herbicides evaluated in the risk assessment (2,4-D ester) for both the foliar and basal applications. Since approximately the same rate of herbicide application (pounds per acre) is used in basal and stem-foliar applications, data from the low-volume basal applications with buffer strips of less than 50 feet can be used to judge mobilization, overland flow and leaching of herbicides from stem-foliar applications into surface water.

Table 13
Highest Herbicide Level Detected in Any Sample for Each Study Site

STUDY SITE ¹	BUFFER WIDTH	METHOD OF APPLICATION (Herbicide Formulation)	SINGLE HIGHEST CONCENTRATION OF HERBICIDE ²	SAMPLING SUCCESS DURING FIRST THREE RAINSTORMS ³
	- (feet) -		----- (mg/liter) -----	
1	30	Basal (Access/ Garlon 4)	0.001 picloram 0.002 triclopyr	Complete, first three storms
2	100	Stem-foliar (Tordon 101/ Garlon 4)	ND 2,4-D Trace picloram 0.001 triclopyr	Complete, first three storms
3	100	Stem-foliar (Tordon 101/ Garlon 4)	ND 2,4-d Trace picloram Trace triclopyr	Complete, first three storms
4	10	Stem-foliar (Arsenal)	ND imazapyr	Poor, first three storms
5	35-50 ⁴	Stem-foliar (Arsenal)	0.006 imazapyr	Complete, first three storms
6	10	Basal (Chopper)	0.003 imazapyr	Complete, first three storms
7	100	Basal (Chopper)	ND imazapyr	Poor, first three storms
8	15	Basal (Chopper)	0.002 imazapyr	Complete, first three storms

¹Name of site and basic location of data are as follows:

- | | |
|--------------------------------|----------------------------------|
| 1 - Lyon Mt./Chazy L., Table 5 | 5 - Lake Colby Sub, Table 9 |
| 2 - Pinewoods Rd. #1, Table 6 | 6 - Turner Rd. #1, Table 10 |
| 3 - Pinewoods Rd. #2, Table 7 | 7 - Turner Rd. #2, Table 11 |
| 4 - Lake Colby North, Table 8 | 8 - Rt. 27/Trout Creek, Table 12 |

²See the following summary of recommended water quality standards to evaluate the single highest reported values in Table 13. ND means not detectable (less than 0.001 mg/liter). Trace means detectable qualitatively, but not quantitatively (less than 0.001 mg/liter, but more than 0.0003 mg/liter).

³The study emphasized collection of samples during the first three rainstorms and on a periodic (specified) basis otherwise.

⁴However, application equipment was within 15 feet of live water, and marshy area extended into treated area.

The results of these tests indicate the 50-foot buffer used in stem-foliar applications will achieve water quality protection goals. We suggest however, that it is important for the herbicide application supervisor to recognize areas where surface water might collect during periods of heavy precipitation and mobilize residues which may flow to the stream as apparently occurred at the Lake Colby Sub 50-foot buffer test site.

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PART V

**WATER QUALITY GOALS FOR
PROTECTION OF AQUATIC ORGANISMS
AND HUMAN HEALTH IN CONNECTION
WITH THE USE OF HERBICIDES
ON POWERLINE RIGHTS-OF-WAY
IN NEW YORK**

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**WATER QUALITY GOALS FOR PROTECTION OF
AQUATIC ORGANISMS AND HUMAN HEALTH
IN CONNECTION WITH THE USE OF HERBICIDES
ON POWERLINE RIGHTS-OF-WAY IN NEW YORK**

Report of an Analysis

A. PART V SUMMARY

Protection of water quality is an important goal influencing the conduct and the regulation of vegetation management programs on electric and gas utility rights-of-way (R/W). However, standards of desired water quality specifically related to utility practices (i.e. herbicide use) are lacking, and managers of R/W maintenance programs and those charged with regulatory responsibilities have no guidelines for determining if protection goals are being met.

In this study, data on the toxicity of various forms of 2,4-D, picloram, triclopyr, and imazapyr herbicides were examined to identify the most sensitive (lowest concentrations) indicators of toxicity to freshwater aquatic organisms and mammals (as surrogates for humans). In some cases (2,4-D and picloram) the U. S. Environmental Protection Agency has established acceptable concentrations of specific herbicides in water, and these were used. For triclopyr the EPA tolerance in an experimental use permit was used. In other cases (imazapyr, fosamine and glyphosate), margins of safety of more than 100 were applied to established no-observable-effect-levels as a means of establishing comparable values for protecting human health. For commonly abundant aquatic organisms, 0.05 times the lowest reported 50 percent lethality level was used to protect populations of these organisms. For individuals in rare or endangered populations of aquatic species, 0.01 times the lowest reported 50 percent lethality level was used to establish a 10-fold safety factor below the no-observable-effect-level.

Concentrations, which will protect water quality by protecting human health and aquatic organisms, were determined for specific herbicide formulations. From these, standards are recommended for evaluating effectiveness of measures taken to protect water quality.

These recommended standards are as follows:

<u>Herbicide</u>	<u>Recommended Standard</u>
<u>2,4-D:</u>	
Amines (including in Tordon 101)	0.07 mg/liter
Esters	0.005 mg/liter
<u>Picloram:</u>	
Tordon 101	0.2 mg/liter
Access	0.07 mg/liter
Tordon K.	0.07 mg/liter
<u>Triclopyr:</u>	
Garlon 3A	0.5 mg/liter
Garlon 4	0.03 mg/liter
<u>Imazapyr:</u>	
Arsenal, Chopper	5.0 mg/liter
<u>Fosamine:</u>	
Krenite	1.0 mg/liter
<u>Glyphosate:</u>	
Accord	2.0 mg/liter

B. INTRODUCTION

Tall-growing vegetation can significantly impact the safe and cost-effective distribution of electric power. A variety of strategies for the control of this vegetation are possible, and many have been tested. The fundamental criteria for these strategies are that they are effective, efficient, and environmentally safe.

Several studies have shown the efficacy and efficiency with which herbicides can be used for the control of tall-growing vegetation on powerline R/W. However, as with any method for controlling vegetation, managers and regulatory agencies must give careful consideration to potential adverse environmental effects. Of particular interest is the potential impact of herbicides on water quality in streams that flow through or near R/W.

There are a number of strategies that are used to prevent or minimize the entry of herbicides used on R/W into surface water. These include (a) careful attention to the methods of application and the conditions under which applications are made, (b) effective training and supervision of field crews involved in application, and (c) the use of buffer zones between areas of application and surface water.

Although utilities employ a combination of all three strategies including buffer zones, critical tests are lacking of the effectiveness of buffer zones in protecting stream water quality in connection with the use of herbicides on powerline R/W in New York. Additionally, standards of water quality protection that should be achieved have not been clearly articulated in most instances. The lack of standards makes it difficult for R/W managers and those with regulatory responsibility to evaluate the effectiveness of water quality protection procedures.

1. Purpose of the Research

The purpose of this research effort is to evaluate the toxic effects of herbicide residues to aquatic organisms and humans, and to use this as a basis for recommending standards for water quality protection. These standards could then be used to evaluate the effectiveness of surface water quality protection procedures used in operational vegetation control programs.

2. Specific Research Objectives

- Identify concentrations of specific herbicides and herbicide formulations that cause no observable toxic effect on freshwater aquatic organisms.
- Identify concentrations of herbicide that either cause no observable effect on mammals or that have been established by the U.S. Environmental Protection Agency (EPA) as acceptable levels of contamination for human drinking water.
- Recommend concentrations of herbicide in surface water which will provide for protection of aquatic organisms and human health.

3. Scope of the Research

The scope is limited to three specific areas:

- Freshwater aquatic organisms likely to be present in surface water on or near R/W in New York.
- Acute and chronic human health hazards due to ingestion of herbicide-contaminated water.

- 2,4-D, picloram, triclopyr, imazapyr, fosamine, and glyphosate herbicides as they are formulated for use in New York on powerline R/W.

4. General Overview of the Study

Buffer zones are used to ensure protection of water quality. Often the objectives of water quality protection are poorly articulated, and consequently, managers and regulators alike lack specific criteria to permit a determination of the level of water protection that is needed.

For purposes of this study, the impact on aquatic organisms and human health are of primary concern. Impact on aquatic organisms can be determined by laboratory testing using standard toxicological testing procedures or in complex field tests. These approaches are reviewed in Norris et al. (1983).

The field test approach usually works very poorly because of the restrictions against adding known amounts of herbicide to streams. In addition, it is extraordinarily difficult to collect and analyze sufficient numbers of aquatic organisms to evaluate the potential effects of the herbicide as contrasted with the effects of other factors (both natural and human related) in the environment.

The laboratory test procedure is a good one both for aquatic and mammalian species, and it has been regularly applied to herbicides that are used for vegetation control on R/W as part of the EPA's pesticide registration process. Sufficient research is available in this area to allow for determinations based on literature review and risk analysis for both aquatic organisms and humans. To ensure relevance to aquatic organisms on R/W in New York, however, the toxicity data used in the risk analysis needs to be for herbicides as they are formulated for use in the field, and not just for purified forms of the chemicals.

There are two basic strategies for achieving protection of aquatic life - one focuses on the welfare of any individual in the population and the other focuses on the welfare of the population.

Protection of populations. When dealing with relatively common and abundant organisms in a setting where only small areas are affected and population recovery is likely, standards which protect at the population level are appropriate. This is the situation for aquatic organisms in most instances. In this case, intermittent (not continuous) concentrations of herbicide in water which do not exceed the no-observed-effect level (NOEL) will not adversely affect populations of aquatic organisms. Where population protection is the goal, water quality standards which are equal to or less than the NOEL are identified in this report.

Protection of individuals. In those unusual instances where rare or endangered species are resident in or near a treated area, a protection strategy which focuses on the individual is important because of the increased importance of each individual to the welfare of the species. In this case, a protection standard is needed which provides an additional margin of safety to allow for the uncertainties of extrapolation from toxicity tests using similar types of organisms, and for the effect of other environmental stressors. In this report a 10-fold safety factor or more is used in developing recommended water quality protection criteria for rare or endangered aquatic species, or those instances where other factors require a level of protection which focuses on the welfare of each individual in the population of aquatic organisms.

A different approach is appropriate for human toxicity determinations. Humans are not likely to be directly exposed to herbicides in water on or near treated R/W, but possibly through ingestion of water at some downstream point. The active ingredient of the herbicide will act

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stituents of the formulation as it moves with the water; thus, for
ons, data for the active ingredient is sufficient. In many instances
ceptable concentrations of herbicide in human drinking water.
ed. When such standards are not available, the NOEL from
1, a 100 fold safety factor added and the concentration of
does not exceed this exposure level. This, or a lower level is used
ection of water quality relative to human health.

ar values of toxicity (such as the no-observable-effect-level of exposure for aquatic
isms or the maximum acceptable daily ingestion level for humans) have been
etermined, it is possible to establish water quality criteria that will ensure protection of
aquatic species and humans. This is done in this report by adopting the value which is most
conservative, i.e., the lower of the 2 concentrations identified as protecting (a) aquatics or (b)
humans. These can in turn be related to the use of buffer zones and the management of
vegetation control programs on R/W. This is the approach used in this study.

C. METHODS

Published literature likely to contain results of toxicity testing for aquatic and mammalian
organisms was identified and searched to establish no-observable-effect-levels (NOEL).
Unpublished research results were solicited from primary chemical manufacturers and were
searched for NOEL or the basis for estimating NOEL.

For aquatic organisms, in many cases clear definitions of NOEL was not possible. In these
cases, fractional values of the median lethal tolerance level (TL_m50) was used to establish
margins of safety as reviewed in Norris et al. (1983).

D. RESULTS

The results section is organized on a herbicide-by-herbicide basis. For each herbicide a brief
overview is given followed by a review of the toxicity of the herbicide to aquatic and
mammalian species.

1. 2,4-D

2,4-D is the common name for the phenoxy herbicide 2,4-dichlorophenoxy acetic acid. It is an
organic acid whose biological properties resemble those of the natural plant growth regulator,
indoleacetic acid. Other phenoxy herbicides are MCPA, 2,4-DB, and dichlorprop (2,4-DP).

2,4-D was available as an herbicide to the public shortly after World War II and is the first of
the modern organic chemical herbicides. For more than 25 years it was the herbicide of
choice in agriculture, forestry, and R/W management, surpassing the other materials by at
least one order of magnitude in forestry and R/W management, and several orders of
magnitude in agriculture.

It has been reviewed extensively by Norris (1981), USDA Forest Service (1984, 1987, 1988),
Newton and Dost (1981), Little (1987), Norris et al. (1983), Loos (1975), and Ghassemi et al.
(1981).

a. Toxicity

A comprehensive review and analysis of toxicity data on 2,4-D was published by USDA Forest
Service (1984) and Bonneville Power Administration (BPA) (1982). In general they
concluded that most formulations of 2,4-D were mildly toxic to mammals, and that most ester
formulations were toxic to highly toxic to aquatic species. The inorganic and organic (amine)

salt and the acid forms of 2,4-D, in contrast, are quite low in toxicity to aquatic organisms. Some formulations are eye irritants, which can cause injury, although this is considered an occupational risk associated with an accident involving massive exposure, rather than one associated with environmental exposure. Inhalation toxicity is minimal. There is no conclusive data indicating carcinogenicity or teratogenicity, although testing continues on these points. 2,4-D can be fetotoxic. In addition to the extensive review by USDA Forest Service (1984), which concentrated on published literature since the mid-1960's, other reviews were published by Mullison (1981), Pimentel (1971), Minnesota Dept. Health (1978), Lommen (1981), Ghassemi et al. (1981), and the International Agency for Research on Cancer (1977).

b. Mammalian Toxicity

2,4-D is classified as moderately toxic in mammals, with an LD₅₀¹ of 375 mg/kg (EPA, 1984a, 1986a). The symptoms observed in test animals exposed to acute and chronic dosages have also been observed in the few instances in which human exposures (usually attempted suicides) have been documented and reported.

In data summarized by EPA (1984a, 1986a), 2,4-D had a systemic effects NOEL of 125 mg/kg in the dog during a 2-year feeding study. In a chronic rat exposure study, the NOEL was established as 1 mg/kg/day, with the lowest effect level set at 5 mg/kg/day. Fetotoxic and maternal toxic NOEL of 5 mg/kg/day were established in a reproductive test (EPA, 1986b). No teratogenic effects were observed (EPA, 1985c, as cited in USDA Forest Service, 1987). Mutagenic studies with 2,4-D are varied in their results, with many showing no effect, and a few suggesting weakly positive to positive effects. EPA has requested additional data, and for purposes of most risk assessments it is considered to be mutagenic, although Newton and Dost (1981) argue it is without significance as an environmental mutagenic hazard.

A number of studies have assessed the carcinogenicity of 2,4-D. There is no conclusive evidence thus far to indicate it is carcinogenic; however, there is also general agreement that none of the studies are adequate in their entirety. A preliminary review of the most recent study by EPA (1985, 1986a) indicates positive evidence of cancer in rats. However, a preliminary report from Hazelton Laboratories (1986) shows no evidence of oncogenic effects after 106 weeks in mice exposed at levels ranging from 1 to 45 mg/kg/day after 106 weeks of continuous exposure. Epidemiological studies generally show no effect, but some suggest an association.

The EPA applied a 100-fold safety factor to the NOEL systemic effect value to establish a provisional acceptable daily intake (ADI) of 0.01 mg/kg/day. The acceptable daily intake value is defined as the maximum dose of a substance that is anticipated to be without lifetime risk when taken daily for a lifetime (USDA Forest Service, 1987).

The ADI can be used to calculate the concentration of 2,4-D that could be in water consumed by humans as follows:

ADI = 0.01 milligrams of 2,4-D that can be consumed each day (for life) per kilogram of human body weight with no adverse effect.

Human body weight = 121 pounds or 55 kilograms.

Human consumption of water, daily = 2 liters.

Assumption is all 2,4-D consumed is in water.

¹LD₅₀ is the dose causing death in 50% of a test population of animals exposed at this level.

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in water that will not exceed human ADI is $(0.01 \text{ mg 2,4-D/kg body weight})/2 \text{ liters/day} = 0.275 \text{ mg 2,4-D/liter}$.

and an "acceptable" drinking water contamination level for 2,4-D is approximately 25 percent of the concentration in water

Toxicity

USDA Forest Service (1984) provides an extensive and detailed review of toxicity testing with various forms of 2,4-D with aquatic species. The data is voluminous. The following material reports the lowest (most toxic) LC₅₀² values and NOEL values for types of 2,4-D formulations used on R/W. For details, refer to USDA Forest Service (1984).

Toxicity to fish -

Dimethyl amine salt formulation: 96-hour LC₅₀, > 100 mg/liter.

Butoxyethanol ester formulation: 96-hour LC₅₀, 1.2 mg/liter.

PGBE ester formulation: 96-hour LC₅₀, 0.6 mg/liter.

Tordon 101 (4:1 mixture of triisopropylamine salts of 2,4-D and picloram) formulation: 96-hour LC₅₀, 20 mg/liter combined concentration of 16 mg 2,4-D and 4 mg picloram per liter.

Tordon 101 is a mixture of two herbicides, and thus the toxicity reported here is a reflection of the presence of both, as well as of the constituents of formulation. The standard for aquatics for 2,4-D alone in water (developed in the previous section) is lower than the standard based on 2,4D in this 4:1 mixture with picloram. Thus the 2,4D-alone standard can be applied in both cases with an assurance of achieving the water protection goals. The standard for picloram in Tordon 101 is specific to picloram when applied in that form, as reflected in the tables.

Toxicity to crustaceans -

Dimethyl amine salt formulation: 48-hour EC₅₀, 4.0 mg/liter.

Butoxyethanol ester formulation: 48-hour TL₅₀, 1.8 mg/liter.

PGBE ester formulation: 96-hour LC₅₀, 0.1 mg/liter.

Based on these results the lowest toxicity value for aquatic species and crustaceans is 0.1 mg/liter for PGBE ester formulations, 1.2 mg/liter for butoxyethanol ester formulations, and 4.0 mg/liter for dimethyl amine salt formulations, and 16 mg/liter for 2,4-D in Tordon 101.

None of these are NOEL values. Norris et al. (1983) used 0.1 (96-hour LC₅₀) as the NOEL for survival of aquatic species after relatively brief exposure to pesticides in forest streams. Other values have been suggested, ranging from 0.1 (48-hour LC₅₀) to 0.05 (toxic units) as a safe level for nonaccumulative chemicals, to 0.01 (toxic units) for those which persist and

²LC₅₀ is the concentration in the water causing 50% death in organisms exposed at that concentration (usually exposure is for a specified period of time such as 24-, 48-, or 72-hours).

accumulate in aquatic organisms (Norris et al. 1983). A toxic unit is the EC₅₀, LC₅₀ or TL₅₀ value.³

2,4-D is not an accumulation chemical in aquatic species, therefore 0.05 (toxic units) is used as the standard for protection of populations of aquatic species. This provides values of 0.005 mg/liter for formulations of PGBE ester, 0.06 mg/liter for butoxyethanol ester and 0.2 mg/liter for 2,4-D amine salts (0.8 mg/liter for 2,4-D in Tordon 101) for protection of population of commonly abundant aquatic organisms.

At least a ten-fold safety factor is provided at 0.01 (toxic units). This is the standard used in this report in those cases where protection of individuals in rare populations is the goal. This provides values of 0.001 mg/liter for formulations of PGBE ester, 0.012 mg/liter for butoxyethanol ester and 0.04 mg/liter for 2,4-D dimethylamine salt formulations (0.16 mg/liter for 2,4-D in Tordon 101) for protection of freshwater aquatic organisms.

2. Picloram

Picloram is the common name for 4-amino-3,5,7-trichloropicolinic acid. Picloram is marketed in a number of formulations, some of which contain only picloram, while others contain a mixture of 2,4-D or triclopyr and picloram. Tordon 101 is the formulation most commonly used on R/W in New York and is a 1:4 picloram: 2,4-D mixture of the isopropyl amine salts of these herbicides. Picloram is also occasionally applied as Tordon K (the potassium salt of picloram) and Access (isooctyl ester of picloram) which is a 1:2 picloram: triclopyr mixture of the isooctyle esters of these herbicides.

Picloram has been reviewed by BPA (1982) as part of their environmental impact statement for R/W management in the U.S. Pacific Northwest, and extensively by USDA Forest Service (1984, 1987, 1988), Ghassemi et al. (1981), Mayes and Oliver (1985) Norris et al. (1983), National Research Council of Canada (1974), and Foy (1976).

a. Toxicity

Picloram has been the subject of numerous toxicity trials. The results of these tests are reviewed in detail in USDA Forest Service (1984). The material that follows includes only the most important findings, with the emphasis on identifying those values that are of pertinence for the risk assessment.

b. Toxicity to Mammals

Picloram is slightly toxic based on its LD₅₀ of 8200 mg/kg in rats (EPA, 1984b, d). The chronic NOEL is 7 mg/kg/day based on a 6-month feeding study with the dog (exposed to dietary levels of picloram of 0, 7, 35, and 175 mg/kg/day). The lowest reproductive NOEL is 50 mg/kg/day in the rat, with the next higher exposure level of 150 mg/kg/day causing slightly increased liver weights. Minor skeletal abnormalities were observed in fetus from rats exposed at 750 mg/kg/day, but no deformed offspring were observed. A teratology study with mice identified 15 mg/kg/day as the lowest NOEL (EPA, 1984b, d, and USDA Forest Service, 1984).

Picloram is non-mutagenic in microbial bioassay. In the rat it was mutagenic in one in-vivo cytogenetic assay, which has not been validated for use as a standard bioassay (USDA Forest Service, 1984, and EPA, 1984b, d). EPA has requested additional mutagenic testing data (USDA Forest Service, 1987).

³EC is effective concentration, LC is lethal concentration, and TL is tolerance level.

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(743 mg/kg/day) was negative for males, but liver tumors were observed in female rats. Because of the indication of tumors in female rats, picloram is the basis of this risk assessment. Crump (1983) estimated cancer risk at 7 mg/kg/day.

At this temperature, the most critical level of "short-term" mammalian NOEL is 7 mg/kg/day based on systemic effects.

NOEL can be used to calculate the concentration of picloram that could be in water consumed by humans as follows:

NOEL = 7 mg/kg/day.

$0.01 \times \text{NOEL}$ (for a 100-fold safety factor) = 0.07 milligrams of picloram that can be consumed day per kilogram of human body weight with no adverse effects.

Human body weight = 121 pounds or 55 kilograms.

Human consumption of water, daily - 2 liters.

Assumption is all picloram consumed is in water.

Concentration of picloram in water that will not exceed estimated 0.01 NOEL is $(0.07 \text{ mg picloram/kg body weight/day} \times 55 \text{ kg body weight}) / 2 \text{ liters/day} = 1.925 \text{ mg picloram/liter}$.

However, the EPA has established an "acceptable" drinking water contamination level for picloram of 0.500 mg/liter. This value is approximately 25 percent of the concentration in water calculated from 0.01 NOEL.

c. Aquatic Toxicity

USDA Forest Service (1984) provides an extensive and detailed review of toxicity testing with various forms of picloram with aquatic species. The following material reports the lowest (most toxic) LC₅₀ values and NOEL values for types of picloram formulations used on R/W. For details, refer to USDA Forest Service (1984).

Toxicity to fish -

Tordon 101 (4:1 mixture of triisopropylamine salts of 2,4-D and picloram) formulation: 96-hour LC₅₀, 20 mg/liter combined concentration of 16 mg 2,4-D and 4 mg picloram per liter.

Tordon 101 is a mixture of two herbicides, and thus the toxicity reported here is a reflection of the presence of both, as well as of the constituents of formulation. The standard for aquatics for 2,4-D alone in water (developed in the previous section) is lower than the standard based on 2,4-D in this 4:1 mixture with picloram. Thus the 2,4-D-alone standard can be applied in both cases with an assurance of achieving the water protection goals. The standard for picloram in Tordon 101 is specific to picloram when applied in that form, as reflected in the tables.

Access (isooctyl ester of picloram) and 1:2 triclopyr formulation: 96-hour LC₅₀, 4.0 mg/liter.

Tordon K (potassium salt of picloram) formulation: 96-hour LC₅₀, 1.5 mg/liter - although this value is uniquely low in a population of LC₅₀ values for the potassium salt which are all higher than 10 mg/liter.

Toxicity to crustaceans -

Salts of Picloram: 48-hour LC₅₀, 48 mg/liter.

Isooctyl/ester of Picloram: 96-hour EC₅₀, 1.4 mg/liter.

Based on these results the lowest toxicity value for aquatic species is 20 mg/liter (combined 2,4-D and picloram) for formulations of Tordon 101, 1.4 mg/liter for Access and 1.5 mg/liter for Tordon K.

None of these are NOEL values. Norris et al. (1983) used 0.1 (96-hour LC₅₀) as the NOEL for survival of aquatic species after relatively brief exposure to pesticides in forest streams. Other values have been suggested, ranging from 0.1 (48-hour LC₅₀) to 0.05 (toxic units) as a safe level for non accumulative chemicals to 0.01 (toxic units) for those which persist and accumulate in aquatic organisms (Norris et al., (1983). A toxic unit is the EC, LC or TL₅₀ value.

Picloram is a non-accumulative chemical in aquatic species, therefore 0.05 (toxic units) is used as the standard for protection of populations of aquatic species. This provides values of 0.2 mg/liter picloram in Tordon 101, 0.07 mg/liter picloram in Access and 0.075 mg/liter picloram in Tordon K for protection of populations of commonly abundant aquatic organisms.

At least a ten-fold safety factor is provided at 0.01(toxic units). This is the standard used in this report in those cases where protection of individuals in rare population is the goal. This provides a value of 0.04 mg/liter for Tordon 101, 0.014 mg/liter for Access and 0.015 for Tordon K for protection of freshwater aquatic organisms.

3. Triclopyr

Triclopyr is the common name for [(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid. It is a selective herbicide marketed in three major formulations: Access and two formulations of Garlon. Garlon 3A is an amine salt. Garlon 4 is a low-volatile ester (butoxy ethyl). Published information on triclopyr is relatively limited. Much of what is available was generated as part of the EPA registration process. Major reviews are in Ghassemi et al. (1981), BPA (1982), Little (1987), and USDA Forest Service (1984, 1987, 1988). The toxicology of triclopyr is reviewed in detail in USDA Forest Service (1984). Only the most critical values for the risk assessment are included in the review that follows.

a. Toxicity to Mammals

With an acute LD₅₀ of 630 mg/kg, triclopyr is classed as slightly toxic (EPA, 1984c). The systemic NOEL was originally identified as 30 mg/kg/day in the rat based on a 2-year feeding study, but this study was considered deficient, and a 228-day feeding study with the dog identified a level of 5 mg/kg/day. A 6-month feeding study also with the dog has refined this level to 2.5 mg/kg/day [USDA Forest Service, 1984, EPA, 1984c, and 40 CFR part 180 5(84):184-185 May 1, 1985].

It is worth noting that the effects observed in the dog reflect its tendency to excrete compounds of this type more slowly than other animals. For instance, the renal excretion half-time for triclopyr in the dog when exposed to higher amounts of triclopyr is 96 hours, compared to 1.5 hours in the rat and 3.1 hours in the monkey. The higher level of toxicity noted in the dog is probably related to its increased tendency to retain this compound. A

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- 2,4-D. Using this data in connection with human exposure risk assessment.

effects have been noted during a 3-generation reproductive study. The value is 25 mg/kg/day in the rabbit. Fetotoxic effects

in microbial bioassays and in a dominant lethal study in mice, and in the same type of test in the rat (USDA Forest Service, 1984). The NOEL of triclopyr carcinogenicity based on both rat and mouse 2-year feeding studies and a 28-day feeding study in the dog (USDA Forest Service, 1984).

Based on this analysis of literature, the most sensitive NOEL of exposure are for systemic effects at 2.5 mg/kg/day.

This value can be used to calculate the concentration of triclopyr that could be in water consumed by humans as follows:

NOEL = 2.5 mg/kg/day.

0.01 x NOEL (for a 100-fold safety factor) = 0.025 milligrams of triclopyr that can be consumed per day per kilogram of human body weight with no adverse effects.

Human body weight = 121 pounds or 55 kilograms.

Human consumption of water, daily = 2 liters.

Assumption is all triclopyr consumed is in water.

Concentration of triclopyr in water that will not exceed estimated 0.01 NOEL is (0.025 mg triclopyr/kg body weight/day x 55 kg body weight)/2 liters/day = 0.69 mg triclopyr/liter.

The EPA has not established an "acceptable" drinking water contamination level for triclopyr in water. However, EPA did establish an allowable residue level of 0.5 mg/liter in potable water as part of an experimental use permit (Federal Register, 1988).

b. Aquatic Toxicity

There is wide variation in the toxicity of triclopyr to fish, depending on the formulation. In general, the amine salt (Garlon 3A) is much less toxic than the ester (Garlon 4). Garlon 3A has an LC₅₀ value for rainbow trout and bluegill that is greater than 100 ppm. Mayes et al. (1984) indicated LC₅₀ values also greater than 100 ppm in flow-through tests. Tests with Garlon 4 show a much higher level of inherent toxicity. DOW (as reported in USDA Forest Service, 1984) reported LC₅₀ values for Garlon 4 of 0.74 ppm for rainbow trout and 0.87 ppm for bluegill. Obviously the ester form is much more toxic than the amine (a situation that holds for 2,4-D as well). USDA Forest Service (1984) notes that usually in both natural soil and water systems, however, the ester is rapidly hydrolyzed to the acid, which is then neutralized to a salt significantly reducing the toxic hazard to aquatic species.

The toxicity tests with Garlon do not include determination of the form of the triclopyr after the Garlon 4 has been added to water. But it is apparent that toxicity is still high, despite any rapid conversion of the ester to the acid or salt form. It is possible (though not investigated) that the constituents of formulation, or the butoxyethanol, is released during hydrolysis of the butoxyethylester, which is the primary toxic agent. A high degree of toxicity to fish has been

noted with other "butoxy" ester compounds, and it appears butoxy type alcohols are also fairly toxic to fish.

USDA Forest Service (1984) provides an extensive review of toxicity data for triclopyr in aquatic species. In general there are major differences in toxicity between the two commercial formulations of triclopyr. Garlon 3A is the triethylamine salt and is generally much less toxic to aquatic organisms than the butoxyethyl ester formulation, which is Garlon 4. The following material reports the lowest (most toxic) LC₅₀ values and NOEL values for Garlon 3A and Garlon 4. For details refer to USDA Forest Service (1984).

Toxicity to fish -

Garlon 4 formulation: 96-hour LC₅₀, 0.74 mg/liter.

Garlon 3A formulation: 96-hour LC₅₀, > 100 mg/liter.

Toxicity to crustaceans -

Garlon 4 formulation: 48-hour LC₅₀, 2.2 mg/liter.

Garlon 3A formulation: 96-hour LC₅₀, 895 mg/liter.

Based on these results, the lowest toxicity values for aquatic species are 0.74 mg/liter for Garlon 4 and 100 mg/liter for Garlon 3A.

None of these are NOEL values. Norris et al. (1983) used 0.1 (96-hour LC₅₀) as the NOEL for survival of aquatic species after relatively brief exposure to pesticides in forest streams. Other values have been suggested, ranging from 0.1 (48-hour LC₅₀) to 0.05 (toxic units) as a safe level for non accumulative chemicals to 0.01 (toxic units) for those which persist and accumulate in aquatic organisms (Norris et al., 1983). A toxic unit is the EC, LC or TL₅₀ value.

Triclopyr is not an accumulative chemical in aquatic species, therefore 0.05 (toxic units) is used as the standard for protection of populations of aquatic species. This provides values of 0.037 mg/liter for triclopyr in Garlon 4 and 5.0 mg/liter for triclopyr in Garlon 3A for protection of populations of commonly abundant aquatic organisms.

At least a ten-fold safety factor is provided at 0.01 (toxic units). This is the standard used for triclopyr in this report in those cases where protection of individuals in rare populations is the goal. This provides yielding values of 0.007 mg/liter for Garlon 4 and 1.0 mg/liter for Garlon 3A for protection of freshwater aquatic organisms.

4. Imazapyr

Imazapyr is the common name for 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imadazol-2yl]-3-pyridinecarboxylic acid. When it is made as the isopropylamine salt, it is the active ingredient in Arsenal and Chopper herbicides. It is a broad spectrum, post-emergence herbicide with excellent phytotoxic and residual activity on a wide range of plants. Additional information is in Weeks, et al (1988) and USDA (1989).

a. Toxicity to Mammalian Species

Based on an acute oral LD₅₀ of greater than 5,000 mg/kg in rats, imazapyr is classed as very slightly toxic to humans. There is no evidence from laboratory studies that imazapyr is mutagenic or terratogenic, with studies of oncogenicity still in progress (Weeks et al., 1988).

The highest doses tested (500 mg/kg/day) in acute and chronic feeding studies with laboratory animals show no observable effects (Weeks et al., 1988).

Based on these results, the critical NOEL level for imazapyr is 500 mg/kg/day.

This value can be used to calculate the concentration of imazapyr that could be in water consumed by humans as follows:

NOEL = 500 mg/kg/day.

$0.01 \times \text{NOEL}$ (for a 100-fold safety factor) = 5.0 milligrams of imazapyr that can be consumed per day per kilogram of human body weight with no adverse effects.

Human body weight = 121 pounds or 55 kilograms.

Human consumption of water, daily = 2 liters.

Assumption is all imazapyr consumed is in water.

Concentration of imazapyr in water which will not exceed estimated 0.01 NOEL is $(5.0 \text{ mg imazapyr/kg body weight/day} \times 55 \text{ kg body weight}) / 2 \text{ liters/day} = 137 \text{ mg imazapyr/liter}$.

The EPA has not established an "acceptable" drinking water contamination level for imazapyr in water. However, the acceptable levels set for 2,4-D and picloram are 25 percent of the 0.01 NOEL-derived value. If this same relationship holds for imazapyr, an "acceptable" drinking water contamination level would be 34 mg/liter.

b. Aquatic Toxicity

There is relatively little data on imazapyr toxicity to most aquatic species. The 96-hour LC₅₀ values for Arsenal herbicide are 110 mg/liter for rainbow trout and 180 mg/liter for bluegill. The 48-hour LC₅₀ for the water flea (as a representative of aquatic invertebrates) is 350 mg/liter. The results of tests of Arsenal herbicide conducted by Analytical Biochemistry Laboratories for the manufacturer in 1984 also report 48-hour LC₅₀ values for Daphnia of 350 mg/liter, with a no-effect level after 48 hours of 180 mg/liter based on lack of mortality and abnormal effects (Iverson, 1990). The nonformulated herbicide is reported to be less toxic to aquatics. Weeks et al. (1988) speculate the surfactant used in formulation is responsible for the greater toxicity of the formulated herbicide.

Only the value of 180 mg/liter for Daphnia is a NOEL. Norris et al. (1983) used 0.1 (96-hour LC₅₀) as the NOEL for survival of aquatic species after relatively brief exposure to pesticides in forest streams. Other values have been suggested, ranging from 0.1 (48-hour LC₅₀) to 0.05 (toxic units) as a safe level for nonaccumulative chemicals to 0.01 (toxic units) for those which persist and accumulate in aquatic organisms (Norris et al., 1983). A toxic unit is the EC, LC or TL₅₀ value.

Imazapyr is a non-accumulative chemical in aquatic species, therefore 0.05 (toxic units) is used as the standard for protection of populations of aquatic species. This provides a volume of 5.5 mg/liter imazapyr in Arsenal and Chopper herbicides for protection of commonly abundant aquatic organisms.

At least a ten-fold safety factor is provided at 0.01 (toxic units). This is the standard used for imazapyr in this report in those cases where protection of individuals in rare populations is the goal. This provides values of 1.1 mg/liter as the value for imazapyr for protection of rare, individual freshwater aquatic organisms.

5. Fosamine

Fosamine is the common name for the chemical ammonium ethyl carbamoylphosphonate which is used as a selective herbicide for conifer release in forestry, right-of-way maintenance, noxious weed control, wildlife habitat improvement and range management. It is also known by the trade name Krenite. Fosamine is a new herbicide, consequently the volume of literature is relatively small compared to several other materials. USDA Forest Service (1984) reviewed its patterns of use, behavior in the environment and toxicology. Additional useful reviews are in BPA (1982), Ghassemi et al. (1982), and Newton and Dost (1982).

a. Mammalian Toxicity

Based on the acute LD 50 of 24,400 mg/kg in the rat (formulated product) (USDA, Forest Service, 1984), fosamine is classified as very slightly toxic. In a 6-month study with the dog (exposed to 1,000 ppm in the diet), the systematic NOEL was established at 25 mg/kg/day, while the systematic NOEL in a 90-day rat feeding study was 250 mg/kg/day. The NOEL is 500 mg/kg/day for teratologic effects in the rat, with no fetal toxic, teratogenic or reproductive toxic effects noted (Schneider and Kaplan, 1983, as cited in USDA, Forest Service, 1984). Fosamine is generally considered non-mutagenic. There is no evidence of carcinogenic effects with fosamine based on results from a 6-month feeding study with the dog, or a 90-day feeding study with the rat (Schneider and Kaplan, 1983, as cited in USDA Forest Service, 1984). A 2-year feeding study has been conducted but the reports which are available do not indicate exposure levels, preventing a definitive assessment of carcinogenicity in this study.

Based on these results, the critical NOEL level for fosamine is 25 mg/kg/day.

This value can be used to calculate the concentration of fosamine which could be in water consumed by humans as follows:

NOEL = 25 mg/kg/day.

0.01 X NOEL (for a 100 fold safety factor) = 0.25 milligrams of fosamine which can be consumed each day per kilogram of human body weight with no adverse effect.

Human body weight = 121 pounds or 55 kilograms.

Human consumption of water, daily - 2 liters.

Assumption is all fosamine consumed is in water.

Concentration of fosamine in water which will not exceed estimated 0.01NOEL is $(0.25 \text{ mg fosamine/kg body weight/day} \times 55 \text{ kg body weight}) / 2 \text{ liters/day} = 6.875 \text{ mg fosamine/liter}$.

The EPA has not established an "acceptable" drinking water contamination level for fosamine. However, the acceptable levels set for 2,4-D and picloram are 25 percent of the 0.01NOEL-derived value. If the same relationship holds true for fosamine, an "acceptable" drinking water contamination level would be 1.72 mg/liter.

b. Aquatic Toxicity

There is little published data on toxicity to aquatic species. Norris et al. (1983) reviewed the data. USDI (1979) reported the LC₅₀ values for bluegill to be 670 ppm, and value for rainbow trout to be more than 1000 ppm. The most extensive set of data is from McLeay and Gordon (1980) working with coho salmon and rainbow trout at several life stages. They reported the egg sack fry were the most sensitive, with LC₅₀ values of 618 mg/liter for coho and 367 mg/liter for rainbow trout. In comparing their data with that obtained with other herbicides, fosamine was 2 to 4 orders of magnitude less toxic. Lorz et al. (1979) found a NOEL for coho salmon (yearling) of 200 ppm. The 48-hour LC₅₀ for *Daphnia* is 1524 ppm according to research cited in Ghassemi et al. (1982).

Based on these results the lowest NOEL toxicity value for aquatic species is 200 mg/liter for formulations of Krenite. Except for the Lorz et al. (1979) data, none of these values are non-observable-effect levels. Norris et al. (1983) used 0.1 (96-hour LC₅₀) as the no-effect-level for survival of aquatic species after relatively brief exposure to pesticides in forest streams. Other values have been suggested, ranging from 0.1 (48-hour LC₅₀) to 0.05 (toxic units) as a safe level for non-accumulative chemicals in aquatic organisms (Norris et al. (1983) A toxic unit is the EC, LC or TL₅₀ value.

Since fosamine is non-accumulative, populations of commonly abundant aquatic organisms would not be harmed at concentrations less than 18 mg/liter (0.05 LC₅₀ of 367 mg/liter).

At least a ten-fold safety factor is provided at 0.01 (toxic units) for individuals in a rare population. This gives a value of 3.7 mg/liter for formulations of Krenite for protection of rare, individual freshwater aquatic organisms.

6. Glyphosate

Glyphosate is the common name for N-(phosphonylmethyl)glycine, a chemical with significant herbicidal properties. It is marketed in several formulations. The most common formulations are based in the isopropyl amine salt of glyphosate.

Extensive reviews of literature for glyphosate were published by USDA Forest Service (1984, 1987, 1988), Ghassemi et al. (1982) and Norris et al. (1983).

a. Mammalian Toxicity

Glyphosate is slightly toxic based on its LD₅₀ of 4320 mg/kg in the rat. A NOEL of greater than 31 mg/kg/day was established by EPA (1984e) based on a 26-month feeding study in the rat. No carcinogenic effects were observed in the study. A 3-generation reproductive study of glyphosate in the rat established a NOEL of 10 mg/kg/day.

Glyphosate was non-mutagenic in microbial assays and mammalian cell assay systems, both in vitro and in vivo (EPA, 1984e). The 26-month rat feeding study found no evidence of carcinogenicity at doses up to 31 mg/kg/day (the highest dose tested) EPA, 1984e), but EPA has not accepted this test as definitive because the highest dose tested was not the maximum tolerated dose. While kidney tumors were found in male mice in another study, the EPA Science Advisory Panel reviewed all the data and concluded there is not sufficient evidence to conclude glyphosate is carcinogenic (USDA Forest Service, 1987). Glyphosate is considered as neither mutagenic or carcinogenic for purposes of this risk assessment.

Based on these results, the critical NOEL level for glyphosate is 10 mg/kg/day. EPA has established an ADI of 0.1 mg/kg/day for a daily lifetime exposure (EPA, 1984e).

The NOEL value can be used to calculate the concentration of glyphosate which could be in water consumed by humans as follows:

NOEL = 10 mg/kg/day.

0.01 X NOEL (for a 100 fold safety factor) = 0.1 milligrams of glyphosate which can be consumed each day per kilogram of human body weight with no adverse effect. This is equal to the EPA ADI of 0.1 mg/kg/day for a daily lifetime exposure.

Human body weight = 121 pounds or 55 kilograms.

Human consumption of water, daily - 2 liters.

Assumption is all glyphosate consumed is in water.

Concentration of glyphosate in water which will not exceed either the EPA ADI or 0.01NOEL is $(0.1 \text{ mg glyphosate/kg body weight/day} \times 55 \text{ kg body weight}) / 2 \text{ liters/day} = 2.75 \text{ mg glyphosate/liter}$.

b. Aquatic Toxicity

In aquatic species, the toxicity of glyphosate is substantially influenced by the formulation. The formulations which contain the surfactant are significantly more toxic to aquatics than those which do not. Daphnia exhibit an LC 50 of 192 ppm, but Folmar et al. (1979) reported 50% were immobilized at 3 ppm (Roundup formulation which contains surfactant) after 48 hours of exposure. In a simulated aerial application in a forested area, Hilderbrand et al. (1980) found no detectable effect on Daphnia in a forest pond after direct application of Roundup at rates up to 220 kg/ha, rates which far exceed those which are used on ROW.

Glyphosate alone is relatively low in toxicity to fish, with LC₅₀ values in excess of 10 ppm for several species (USDA Forest Service, 1984). Tests of the surfactant alone shows LC₅₀ values which are close to 1 ppm (Folmar et al., 1979). The most sensitive fish test reported had an LC₅₀ of 2.3 ppm for bluegill exposed to Roundup formulation (which contains the surfactant).

Aquatic testing with the Accord formulation has been reported by Martin Lemmon of Monsanto Company (in a personal communication dated May 25, 1990, to Logan Norris). LC₅₀ values for trout, bluegill and carp were all higher than 1000 mg/liter. Daphnia had 48-hour EC₅₀ value of 930 mg/liter.

Based on this analysis, the lowest toxicity value for aquatic species is 930 mg/liter for the Accord formulation of glyphosate. This is not the no-observable-effect-level. Norris et al. (1983) used 0.1 (96-hour LC₅₀) as the no-effect-level for survival of aquatic species after relatively brief exposure to pesticides in forest streams. Other values have been suggested, ranging from 0.1 (48-hour LC₅₀) to 0.05 (toxic units) as a safe level for non-accumulative chemicals to 0.01 (toxic units) for those which persist and accumulate in aquatic organisms (Norris et al. (1983) A toxic unit is the EC, LC or TL₅₀ value.

Since glyphosate is non-accumulative, populations of commonly abundant aquatic organisms would not be harmed at concentrations of glyphosate in the Accord formulation of less than 46 mg/liter.

At least a ten-fold safety factor is provided at 0.01 (toxic units) for individuals in a rare population. This gives a value of 9 mg/liter for glyphosate in the Accord formulation for protection of rare, individual freshwater aquatic organisms.



7. Water Quality Criteria

Water quality criteria that protect human health and aquatic life can be established based on the review of toxicity data in the previous sections. Table 1 summarizes these values.

E. DISCUSSION

The values identified in Table 1 are adequate to protect human health and freshwater aquatic life. They will not harm populations of common aquatic species and include margins of safety of at least 10 for individuals in rare populations of aquatic species and more than 100 for humans. Water quality protection goals could be set based on these values.

F. CONCLUSIONS

The values reported in this study can be used to establish water quality goals that will not cause deleterious effects on populations of common aquatic organisms or human health. For the herbicides used in this project, the following values are suggested as goals. These are based on the values reported in Table 1. They have been rounded off for convenience and in the case of 2,4-D, to allow some combining of formulations under one standard.

<u>Herbicide</u>	<u>Water Quality Criteria</u>
<u>2,4-D:</u>	
Amines (including in Tordon 101)	0.07 mg/liter
Esters	0.005 mg/liter
<u>Picloram:</u>	
Tordon 101	0.2 mg/liter
Tordon K	0.07 mg/liter
Access	0.07 mg/liter
<u>Triclopyr:</u>	
Garlon 3A	0.5 mg/liter
Garlon 4	0.03 mg/liter
<u>Imazapyr:</u>	
Arsenal, Chopper	5.0 mg/liter
<u>Fosamine:</u>	
Krenite	1.0 mg/liter
<u>Glyphosate:</u>	
Accord	2.0 mg/liter

Alternative goals for unusual circumstances could be derived from the values for rare individual aquatic organisms in Table 1.

Table 1

**Summary of Concentrations of Herbicide in Surface Water
That Protect Human Health and Aquatic Organisms**

HERBICIDE	ACCEPTABLE CONCENTRATION OF HERBICIDE IN WATER ¹		
	Human Health	Populations of Aquatic Organisms	Rare Individual Aquatic Organisms
	----- (mg/liter) -----		
<u>2,4-D</u>			
PGBE ester	0.07	0.005	0.001
butoxyethanol ester	0.07	0.06	0.012
dimethyl amine	0.07	0.2	0.040
Tordon 101	0.07	0.8	0.16
<u>Picloram</u>			
Tordon 101	0.5	0.875	0.04
Access	0.5	0.07	0.014
Tordon K	0.5	0.075	0.015
<u>Triclopyr</u>			
Garlon 3A	0.5	5.0	1.0
Garlon 4	0.5	0.037	0.007
<u>Imazapyr</u>			
Arsenal, Chopper	34	5.5	1.10
<u>Fosamine</u>			
Krenite	1.72	18	3.7
<u>Glyphosate</u>			
Accord	2.75	46	9

¹These values are taken from the text.

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PART VI

DISCUSSION AND CONCLUSIONS



DISCUSSION AND CONCLUSIONS

A. DISCUSSION AND CONCLUSIONS

The purpose of this project is to evaluate various buffer zones as strategies for protecting stream water quality in connection with the use of herbicides to control unwanted vegetation on powerline rights-of-way (R/W). Stream water quality is protected if aquatic organisms and humans using surface water on or near herbicide-treated R/W are not adversely affected. The impact of herbicides on aquatic organisms and humans is determined by (a) the exposure of these organisms to the herbicides and (b) the toxicity of the herbicides to these organisms. Both of these elements are determined in this project.

1. Exposure

The exposure of organisms to a herbicide is determined by the concentration and persistence of herbicide that appears in the water. Herbicide may enter water by one or more of the following routes:

- Direct application to the surface of the water during application.
- Drift of spray material to the surface of the water during and shortly after application.
- Mobilization of herbicide from the surface of vegetation or soil and runoff to surface water during periods of heavy precipitation.
- Leaching of herbicide through the soil profile to enter surface water from subsurface drainage.

This project included two field studies to evaluate buffer zone effectiveness in minimizing exposure of organisms by minimizing entry of herbicides to surface water.

The first study evaluated the effectiveness of buffer zone width and vegetation density on herbicide deposition beyond the edge of treatment areas. This study showed vegetation density, method of herbicide application, and distance from the edge of the treated area were important factors in influencing the amount of herbicide deposition beyond the treated area.

In general, the greater the distance from the edge of the treated area, the less deposit that occurred; although in most instances there was little practical difference in level of deposit at 25 feet or more. This effect was most striking in areas where vegetation density was heavy and when stem-foliage application methods were used.

In general, the greater the density of the vegetation, the less deposition of dye that occurred beyond the edge of the treated zone. However, there was little practical difference among vegetation density classes except when there was no vegetation in buffer zones adjacent to areas of heavy vegetation. This latter seems like an unlikely occurrence, representing a "worst case" scenario unless vegetation in the buffer is cut before herbicide application is made. A rational strategy to minimize herbicide deposition in the buffer and streams it is intended to protect is to not cut vegetation in the buffer until applications of herbicide on the R/W are complete.

Considering streams that are 6 inches deep and a water quality protection criteria of 0.07 mg/liter is adopted for the 2,4-D and 0.5 mg/liter for the picloram, which are in Tordon 101, and 0.5 mg/liter for the triclopyr, which is in Garlon 3A, buffer zones of 10 feet are sufficient in every case tested.

If a water quality protection criteria of 0.03 mg/liter is adopted for the triclopyr which is in Garlon 4, vegetated buffer zones of 10 feet are sufficient in all cases.

If a water quality criteria of 0.005 mg/liter is adopted for the 2,4-D, which is in low-volatile ester formulations of this herbicide, buffer widths of 25 feet may be required.

If a water quality criteria of 5.0 mg/liter is adopted for the imazapyr in Arsenal and Chopper herbicides, 1.0 mg/liter for fosamine in Krenite herbicide and 2.0 mg/liter for glyphosate in Accord herbicide no buffer zones are required.

In the second study, the effectiveness of operational buffer zone strategies and application procedures for 2,4-D, picloram, triclopyr, and imazapyr in protecting water quality were evaluated at eight sites in New York. Sampling was conducted successfully at least through the first three rainstorms at six of the eight sites, including (a) all three sites treated with 2,4-D, picloram or triclopyr, and (b) three of the five sites treated with imazapyr. Sampling equipment failure prevented collection of samples during critical rainy periods shortly after herbicide application at two sites of the five sites treated with imazapyr. Sampling continued at all sites throughout the fall until freezing weather stopped sampler operation in November. Sampling was resumed for one month or more at all sites in the spring. Thus while the sampling record is not complete at all stations, extensive numbers of samples were collected at all stations during the first fall and spring after application.

The results showed buffer zone and application strategies were successful in nearly totally preventing entry of herbicide to streams due to direct application or drift. In no case did the concentration of herbicide in water due to direct application or drift exceed the water quality protection criteria suggested in Part V of this project (see additional comments below).

No 2,4-D was found in any sample, and only traces of picloram (less than 0.001 mg/liter) were found in four samples and 0.001 mg/liter of picloram in one sample. This indicates buffer zone and application strategies were wholly effective in protecting water quality for applications involving these herbicides (see additional comments below).

Triclopyr was found in several samples (0.002 mg/liter or less) collected during the first few rainstorms after application at one site. At this site a buffer zone of 30-feet was used. At the other two sites where buffer zones of 100 feet were used, barely measurable or trace amounts of triclopyr were found in only a few scattered samples. In no instance was the suggested triclopyr water quality criteria (see additional comments below) exceeded, indicating the buffer zone and application procedures were successful in protecting water quality.

Imazapyr was applied to five of the eight study sites. At two sites, no imazapyr was found. These sites had buffer zones of 10 and 100 feet. At three other sites where buffer zones ranged from 10 to 35 feet, imazapyr was found in several samples collected during the first several rain storms after application. At two sites where buffers of 10 and 15 feet were used, residues were less common than at a site where a 35-foot buffer zone was used. This indicates the site-specific nature of buffer zone requirements. In no instance did the concentration of imazapyr exceed the suggested water quality protection criteria recommended below,

although there was major sampling failure during critical periods at two of these sites. Note that the values reported in this report are 24-hour mean concentrations for single samples and it is likely instantaneous maximum concentrations were higher than reported. However, the risk assessments which lead to the recommended water quality standards are derived from exposures which are longer than 24 hours, hence are conservative in evaluating risk from the exposures suggested by this part of the study.

With only a single exception, no herbicide was detected in any sample more than 45 days after application, including samples from the spring thaw and runoff period.

These results indicate that herbicide that appeared in some water samples resulted from mobilization of residues from surfaces of vegetation and soil and from surface water runoff, which flows to stream channels during periods of heavy precipitation. Equally, the lack of residues in samples more than 45 days after application indicates leaching of herbicide through the soil profile is not a mechanism of herbicide entry into streams at these sites.

The PSC order which resulted in this study specified the buffer zones to be used by NMPC and NYSEG. These buffers are such that

- a. herbicide is not used within 100 feet of a potable water supply or regulated wetland or protected waters.
- b. a minimum approach distance of 50 feet is used for stem-foliar application methods and 30 feet for basal and cut-and-stump methods of application around other wetlands, perennial and intermittent streams.

The adequacy of these buffers in protecting aquatic organisms and human health were evaluated in Part IV of this report. In summary it was found by direct testing that the 100-foot and the 30-foot buffers did achieve water quality protection goals. One test of the 50-foot buffer was conducted. It included four confounding factors: (a) the buffer to the live stream was 35 feet on one side and 50 feet on the other, (b) the buffer area and the adjacent treatment area contained surface water flowed to the monitored stream, (c) the application vehicle entered (but did not spray) the buffer, coming within 15 feet of the stream at one point, and (d) the fourth period of rain after application was not sampled due to sampler malfunction, although the first three storms and the fifth storm were sampled successfully.

Despite these limitations, the results showed the 50-foot buffer strategy used at this site protected water quality for the herbicide applied at this site (with a safety factor of 833). This conclusion is based on indirect evidence from the buffer-width study (Part III of this report) and field tests of basal applications (from part IV of this report) combined with the data from the field test of the 50-foot buffer at the Lake Colby Sub test site.

We note however that if 2,4-D ester (the most toxic herbicide evaluated in Part V) had been applied and the same pattern of residue occurred, the recommended water quality standard would have been exceeded by 0.001 mg/liter in one sample. We feel this result emphasizes the importance of the herbicide application supervisor being able to recognize areas which, while dry during application, may (during periods of heavy precipitation) collect surface water which may flow to other bodies of surface water.

Had the 50-foot buffer been measured from the edge of the wet area at the Lake Colby Sub test site, we are confident the water quality standards for all herbicides evaluated in Part V of this report would have been met.

2. Toxicity

The toxicity of a herbicide to aquatic organisms or humans is determined by the nature of the chemical and its interaction with the organism. These are determined with standard toxicity testing procedures with common laboratory animals, which serve as surrogates. The procedures used for these determinations are accepted and widely used by toxicologists in evaluating the safety of food additives, pharmaceuticals, pesticides, and other chemicals. The common procedure is to determine the level of exposure that does not cause a discernible effect on the test animal (or population of animals), and then apply an additional safety factor in establishing a level of exposure that would not be expected to harm the organisms for which the test animals are surrogates.

For aquatic species, a commonly used protection criteria is $0.05 \times LC_{50}$ (or some other measure of toxic response) for herbicides which do not accumulate in aquatic organisms. None of the herbicides evaluated in this test do. For the herbicides involved in this project, these values range from 0.005 mg/liter for low-volatile esters of 2,4-D to 46 mg/liter for glyphosate (in Accord).

The U. S. Environmental Protection Agency has established human drinking water quality criteria that permit 0.07 mg/liter of 2,4-D and 0.5 mg/liter of picloram and via a tolerance, 0.5 mg/liter for triclopyr. By applying the same concepts to the lowest known no-observable-effect-level for triclopyr and imazapyr, corresponding levels in drinking water would be 34 mg/liter for imazapyr, 1.0 mg/liter for fosamine and 2.0 mg/liter for glyphosate.

By adopting the lowest concentrations from evaluation of both aquatics and humans, water quality protection criteria are recommended that will achieve protection of both aquatic species and human health and that are relatively simple to administer. These are recommended as follows:

<u>Herbicide</u>	<u>Water Quality Criteria</u>
<u>2,4-D:</u>	
Amines (including in Tordon 101)	0.07 mg/liter
Esters	0.005 mg/liter
<u>Picloram:</u>	
Tordon 101	0.2 mg/liter
Access	0.07 mg/liter
Tordon K.	0.07 mg/liter
<u>Triclopyr:</u>	
Garlon 3A	0.5 mg/liter
Garlon 4	0.03 mg/liter
<u>Imazapyr:</u>	
Arsenal, Chopper	5.0 mg/liter
<u>Fosamine:</u>	
Krenite	1.0 mg/liter
<u>Glyphosate:</u>	
Accord	2.0 mg/liter

Application of these water quality protection criteria to the results from this project show the buffer zones as used in this study, protect surface water quality. While wider buffer zones could be used, the results of this study indicate no gain in safety would be achieved.

