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CASCADING FIRE-TROL 931 FIRE RETARDANT INTO A JACK PINE STAND

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ABSTRACT

Observations on the effectiveness of Fire-Trol 931 forest fire retardant dropped from an Otter air tanker ahead of a fire in a mature jack pine stand are presented and the effect a single tree and a whole stand have on retardant distribution are discussed.

RESUME

Ce rapport traite de l'efficacité du produit ignifugeant Fire-Trol 931 largué d'un avion de type Otter en avant d'un feu dans un peuplement de pin gris. Il examine également les effets d'un peuplement forestier et d'un arbre isolé sur la distribution au sol du produit ignifugeant.

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Introduction

Retardant effectiveness trials were initiated in a semi-laboratory type establishment at the Petawawa Forest Experiment Station (PFES) with the premise that limited air tanker trials on fires in the forest would relate these test findings to the real world situation. The White River Study Area (White River, Ont.) was established in 1972 to provide the researchers from the Great Lakes Forest Research Centre (GLFRC) with a location to conduct prescribed fire tests in green standing jack pine (Pinus banksiana Lamb.) and provisions were made to permit researchers from the Forest Fire Research Institute (FFRI) to study the application of forest fire retardant (FT-931)[1] by air tanker to a 30 m strip at one end of each test block.

Twenty-four 40 by 100 m test blocks were isolated in mature jack pine timber by establishing 10 m wide fire guards around each plot. The drop target was identified by groups of three helium-filled weather balloons atop mast poles at tree top level on either side of the designated portion of each plot. The markers served as flight path centerline identifiers for the air tanker pilot. The Ontario Ministry of Natural Resources provided an Otter air tanker on an "on request" basis.

During the course of three fire seasons only one fire burned with adequate continuity to meet our test requirements, consequently the field testing portion of the study was terminated in 1975.

The Test Site

The jack pine cover on this gently rolling sandy site had a mean stand density of 1590 trees per hectare. The understory varied from nil to clusters of black spruce (Picea mariana (Mill.) B.S.P.) and balsam fir (Abies balsamea (L.) Mill.), approximately 1000 stems per hectare ranging from 1 to 14 m in height, with occasional clusters

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[1] Fire-Trol 931 (FT-931) is a liquid forest fire retardant concentrate sold by Chemonics Industries (Canada) Ltd. The product is 93% diammonium phosphate (Poly N 10-34-0, liquid fertilizer), 4% attapulgite clay (color carrier), 2% iron oxide (coloring agent) and 1% corrosion inhibitor. Mixing ratio was four parts water to one part concentrate.

of alders (Alnus rugosa (Du Roi) Spreng.) in the lower lying depressions. Random sampling throughout the area indicated that the average specifications for jack pine were:

Tree diameter	-	14.7 cm
Tree height	-	17.7 m
Height to live crown	-	11.6 m
Crown depth	-	6.1 m
Crown width	-	2.3 m
Tree age	-	75 years

(Walker and Stocks, 1975).

Test Methods and Results

Each 30 m wide strip designated for retardant application across the end of each block was subdivided into a 3.05 by 4.6 m grid and catch cups were placed at the node points. The cup catch weight was converted to applied depth in cm to determine retardant concentration and to identify drop pattern configurations. One free-standing pine tree in each block was selected as a "master tree" to determine the effect its crown had on the retardant distribution beneath it relative to the aircraft flight path (Fig. 1). Four lines of four catch cups per line (cup to tree and cup to cup spacing, 30.5 cm) radiated from the master tree at right angles to each other. Distribution below these "trees" for Plots #4, 7 and 8 are shown in Figure 2. The perimeter of each air tanker retardant drop, as drawn in Figure 1, was based on an ocular estimation of the periphery of the continuous trace coverage. The drop contour patterns in Figures 3 to 8 inclusive were determined from drop catch data, consequently only that portion of the load that landed on the grid within a specific plot was mapped. Although it is not known exactly which portion of the drop pattern each segment represents, reasonable comparisons of these contour patterns can be made with that of the drop made in an open field (Fig. 9) to evaluate canopy effect on pattern modification and crown interception.

The fuel and fire weather data (Table 1) and the fire data for the untreated portion of Plot #7 (Table 2) were collected and compiled by the GLFRC researchers for their burning index study.

Placement of the drop relative to a target depends largely on the pilot's ability to compensate for wind drift and his knowledge of the trajectory path of his payload. In these tests the red and white (75 cm diam.) balloons were located on either side of the 40 m long target in full view of the on-coming air tanker. The sketches in Figure 1 together with the patterns in Figures 3 to 8 indicate in comparison with the drop pattern in Figure 9, that there was a tendency to over-shoot the target but laterally the loads were well placed considering that flight corrections had to be made to compensate for a 15 to 20 km/h crosswind.

TABLE 1. Fire Weather and fuel moisture information for June 5, 1974

Wind velocity	19.2 km/h
Temperature	26° C
Relative humidity	48%
Fine Fuel Moisture Code	89
Drought Code	102
Initial Spread Index	10
Adjusted Duff Moisture Code	34
Fire Weather Index	18
Moisture Content	
- litter	21.8%
- dead twigs, 0 - .32 cm	14.4%
- dead twigs, .32 - .64 cm	14.3%
- dead twigs, .64 - 1.27 cm	22.5%
- moss, 0 - 2.5 cm	80 - 186%

TABLE 2. Fire Data for Plot #7 in untreated fuels

Aerial fuels consumed	NIL
Surface fuels consumed,>1.8 cm diam.	NIL
Surface fuels consumed,<1.8 cm diam.	0.097 kg/m²
Depth of burn (duff)	2.6 cm
Duff consumed	0.971 kg/m²
Vegetation consumed	0.065 kg/m²
Total fuel consumed	1.133 kg/m²
Rate of fire spread	0.0116 m/s
Heat yield	4444 cal/g
Fire intensity	58.3 kcal(s·m)

The "master tree" was chosen solely on the basis of its position relative to other trees and not its position within the plot. The tree's crown in each case was totally independent of other branches, consequently these trees were usually in the 20 cm diameter breast height (dbh) range with crown diameters of approximately 2.5 m. The tree in plot #4 was located in the less than 0.005 cm retardant depth portion of the drop pattern. Here application distribution confirmed that the increase in gradient was towards the centre of the pattern but the distribution fore and aft of the tree indicated no shadow effect due to the tree's bole. In plot #7 the "tree" was entirely within the 0.07 cm drop zone but the retardant distribution beneath its crown varied randomly from 26 to 73% below the amount recorded at the nearest sampling node (0.077 cm). The distribution beneath the "tree" in plot #8 confirmed that other than that small

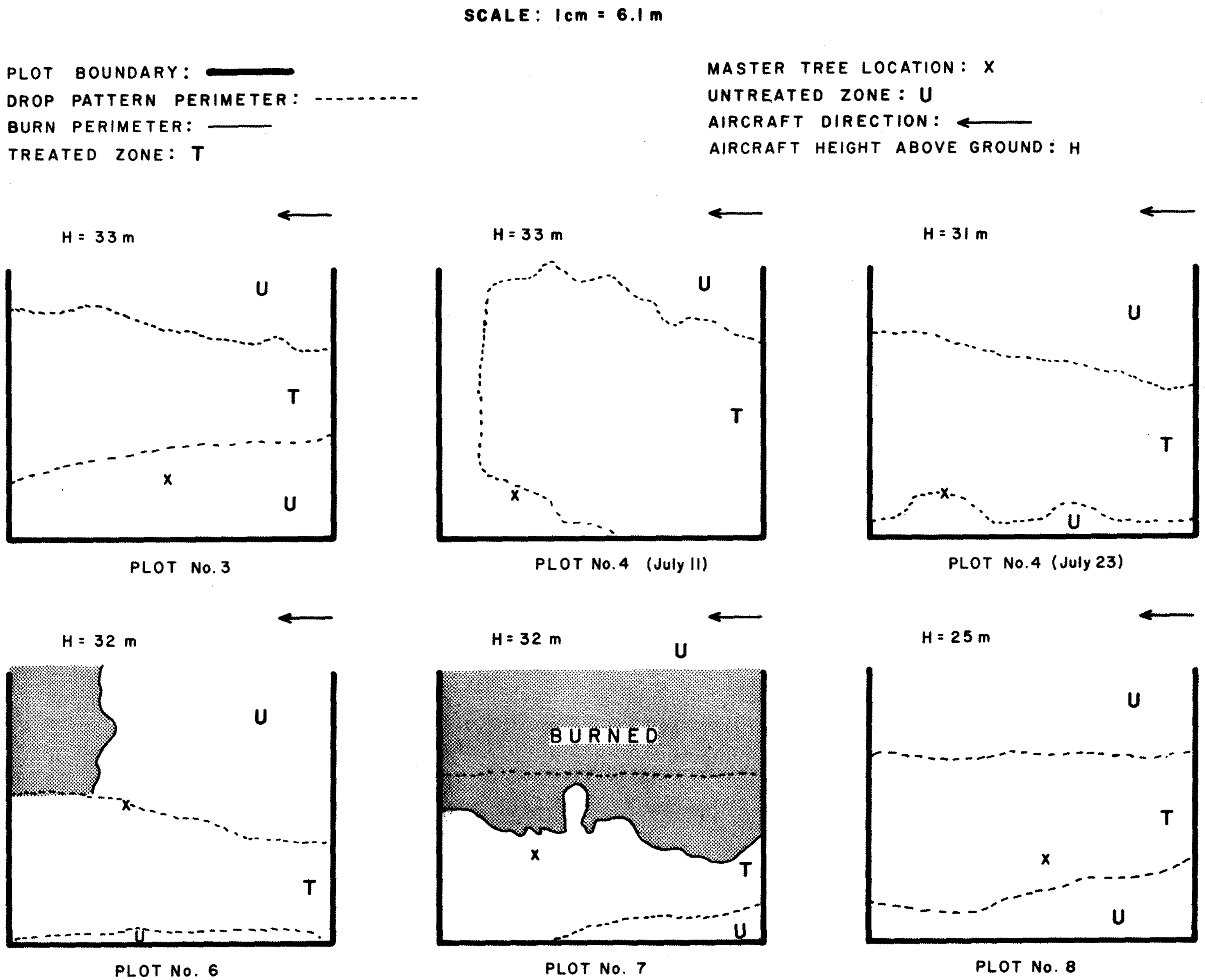

Figure 1. Sketches of portions of plots showing load placement and areas burned.

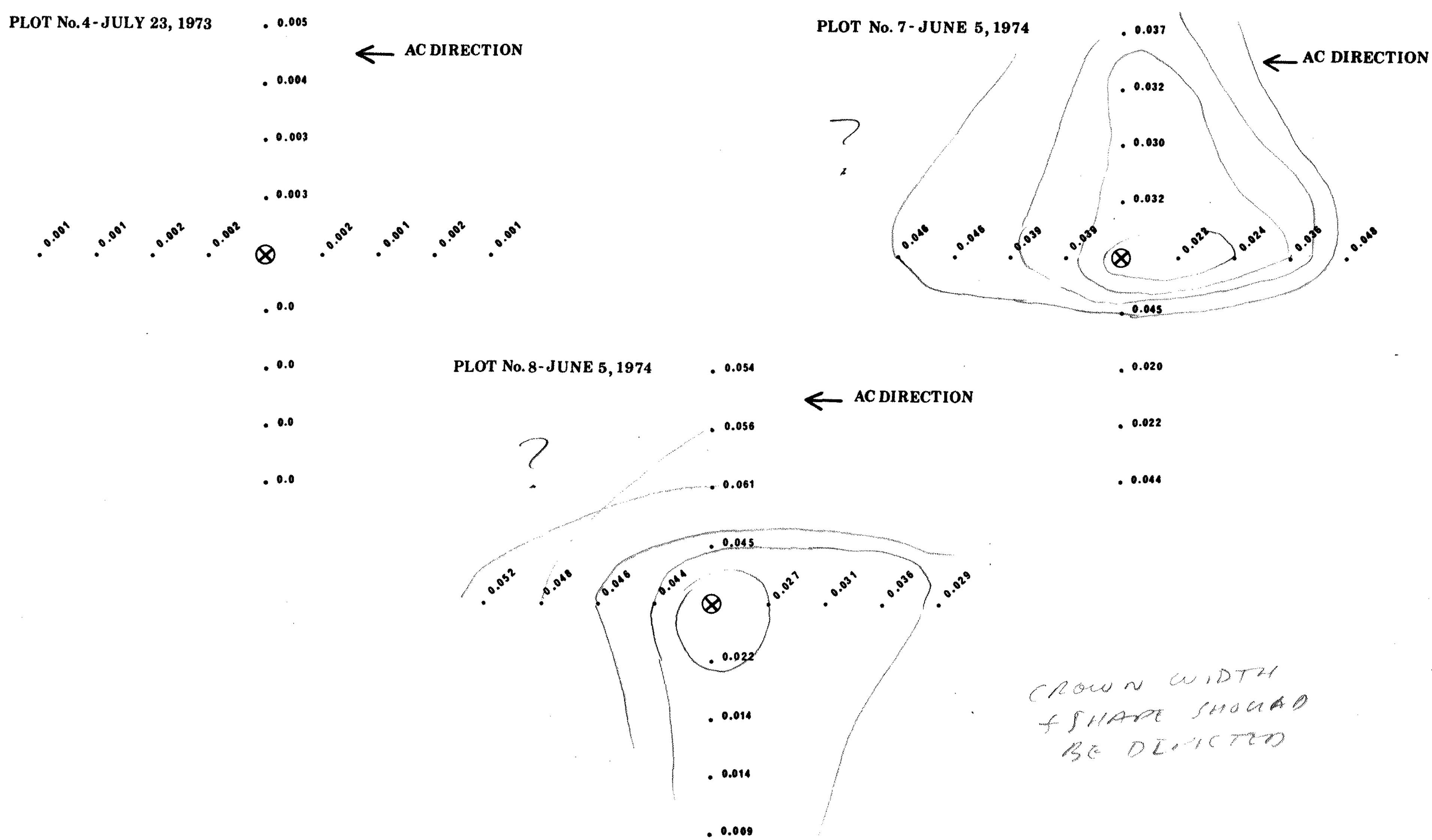

Figure 2. Retardant depth in cm beneath "Master Trees" (⊗) at sampling points where tree to cup and cup to cup distances were 30.5 cm.

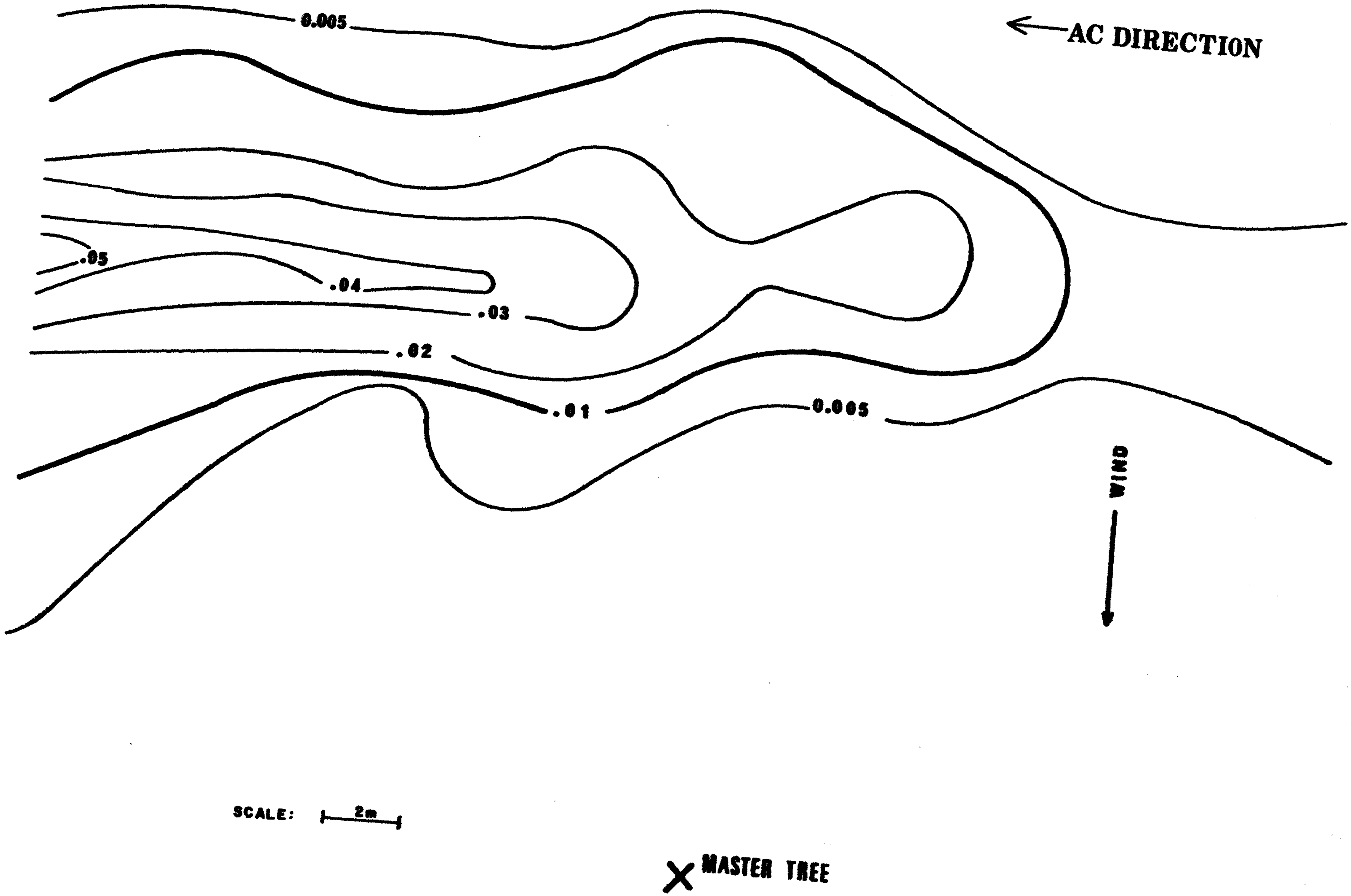

Figure 3. Drop pattern contours in cm on Plot No. 3.

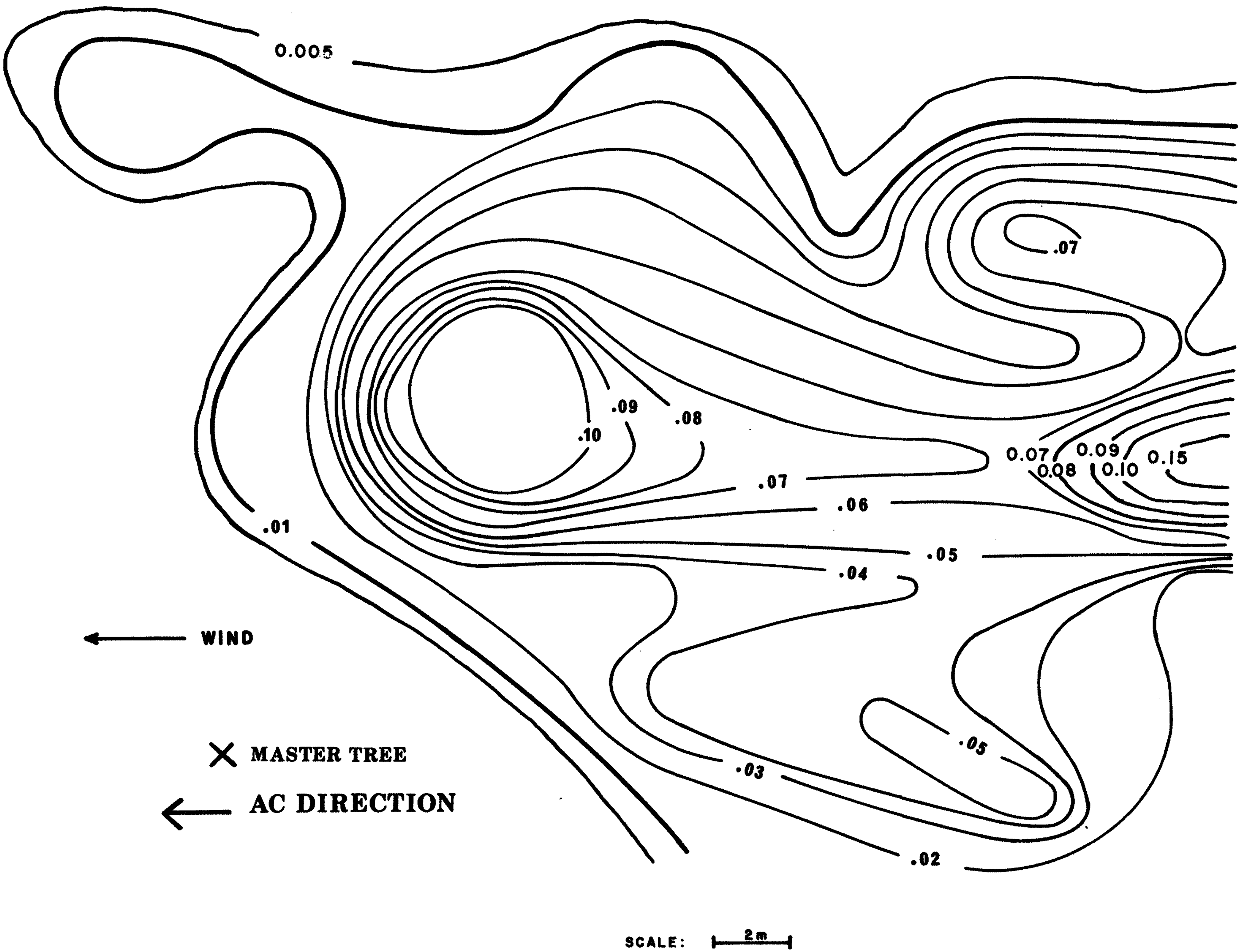

Figure 4. Drop pattern contours in cm on Plot No. 4 (July 11/73 Drop).

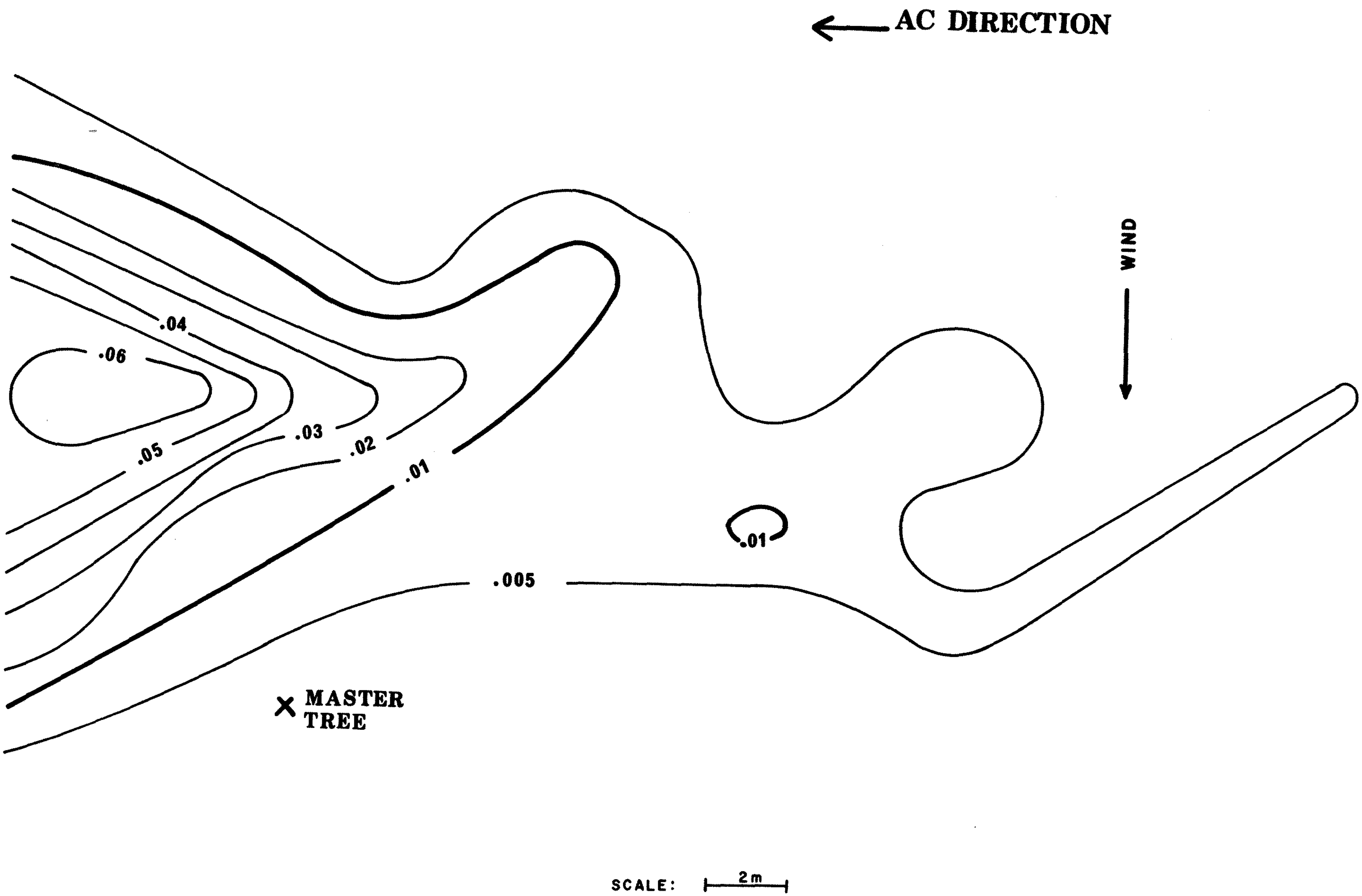

Figure 5. Drop pattern contours in cm on Plot No. 4 (July 23/73 Drop).

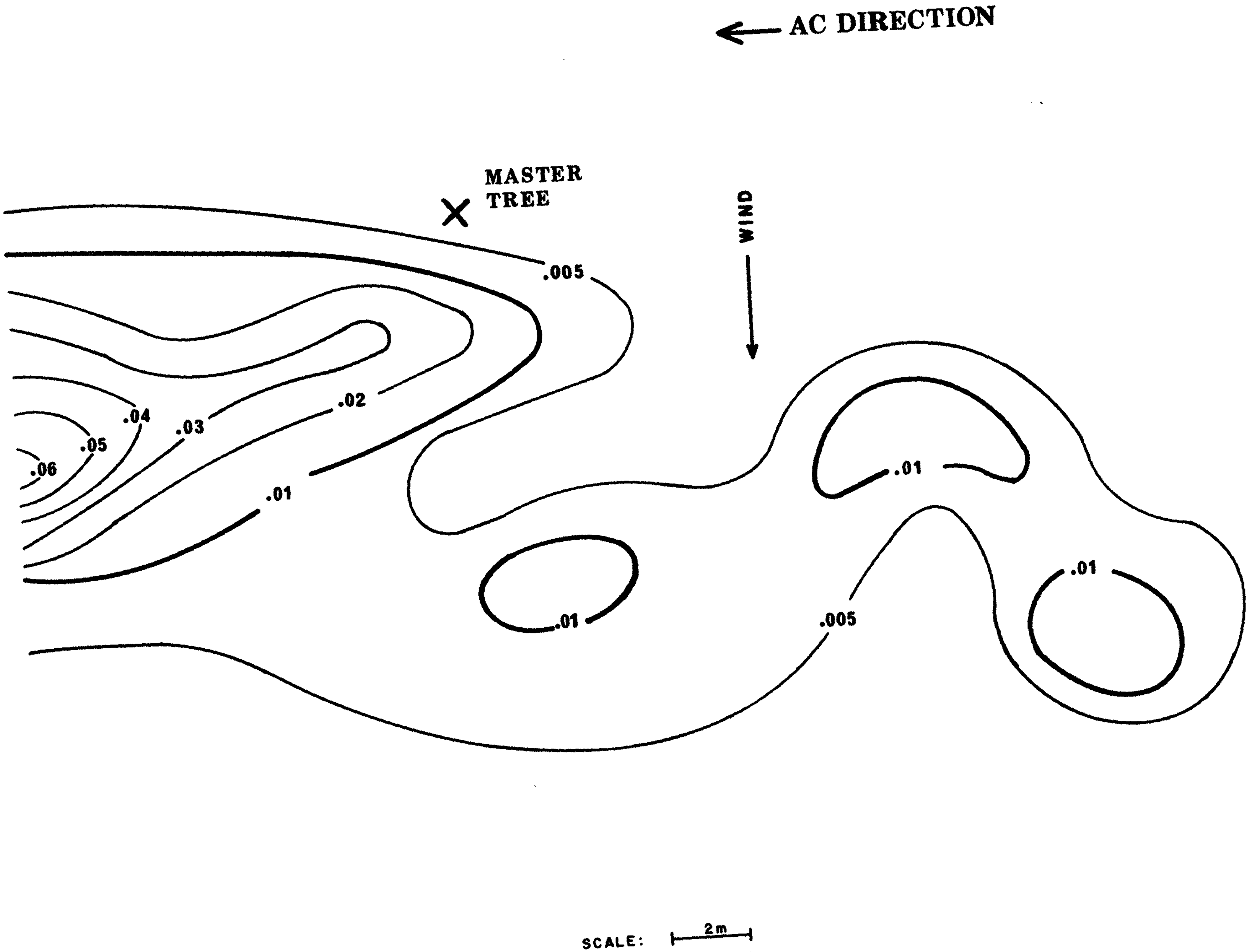

Figure 6. Drop pattern contours in cm on Plot No. 6.

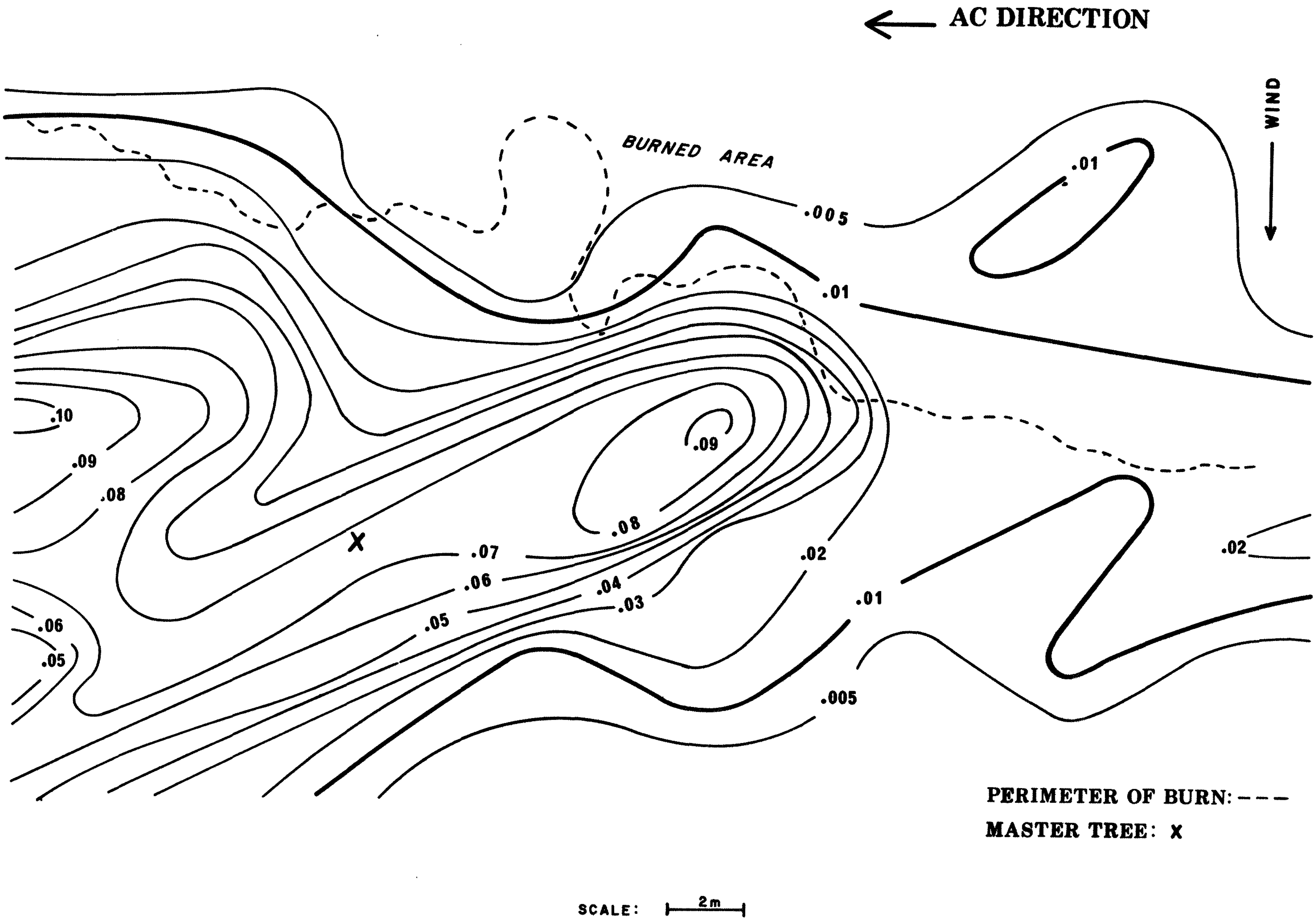

Figure 7. Drop pattern contours in cm on Plot No. 7.

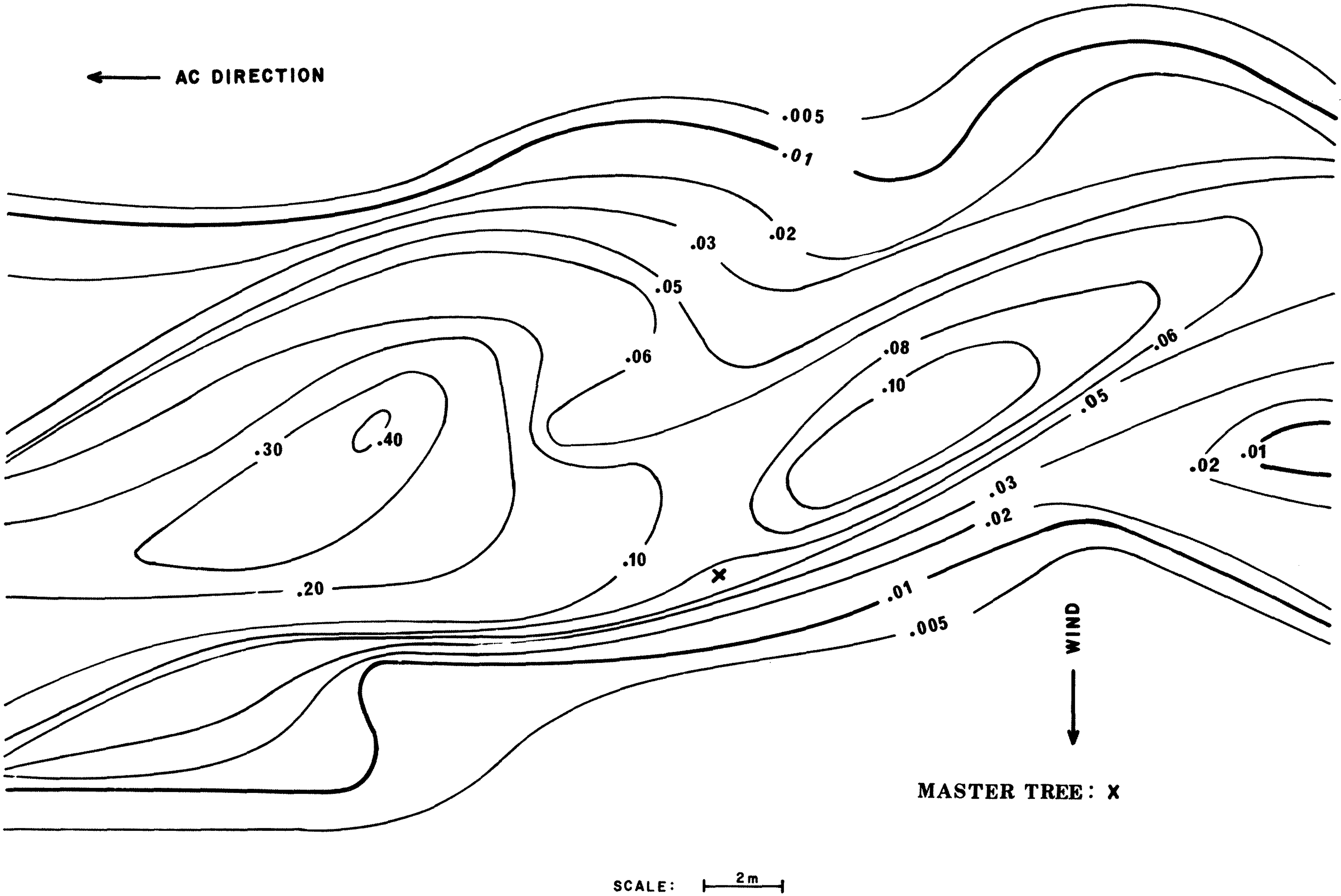

Figure 8. Drop pattern contours in cm on Plot No. 8.

Errata
0.035 should read 0.025
0.071 " " 0.051
0.142 " " 0.102

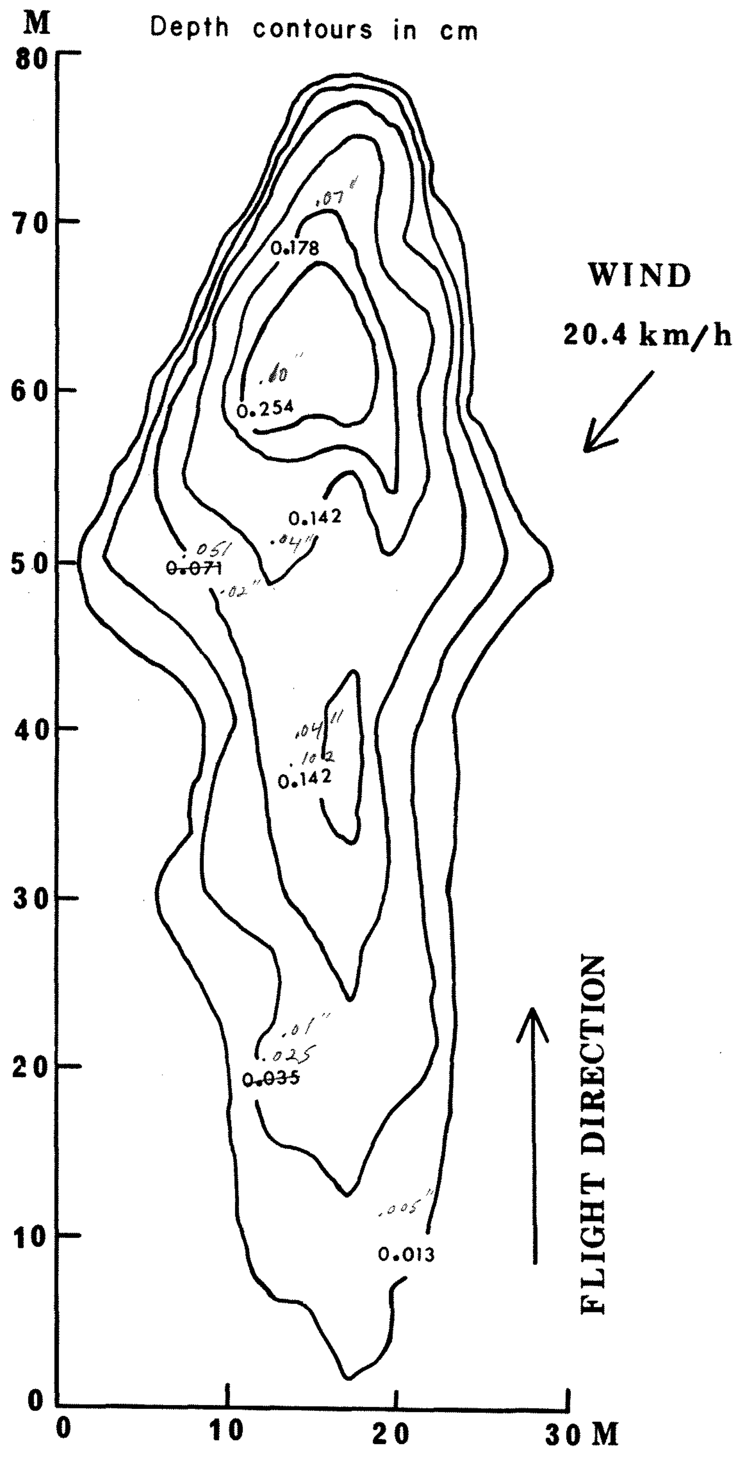

Figure 9. Drop pattern for Otter air tanker.

Pretreatment of jack pine slash ahead of a fire required a minimum of 0.09 cm of FT-931 to stop fire from penetrating bed 1/2 metre, average fire intensity was 67.8 k cal/(m·s).

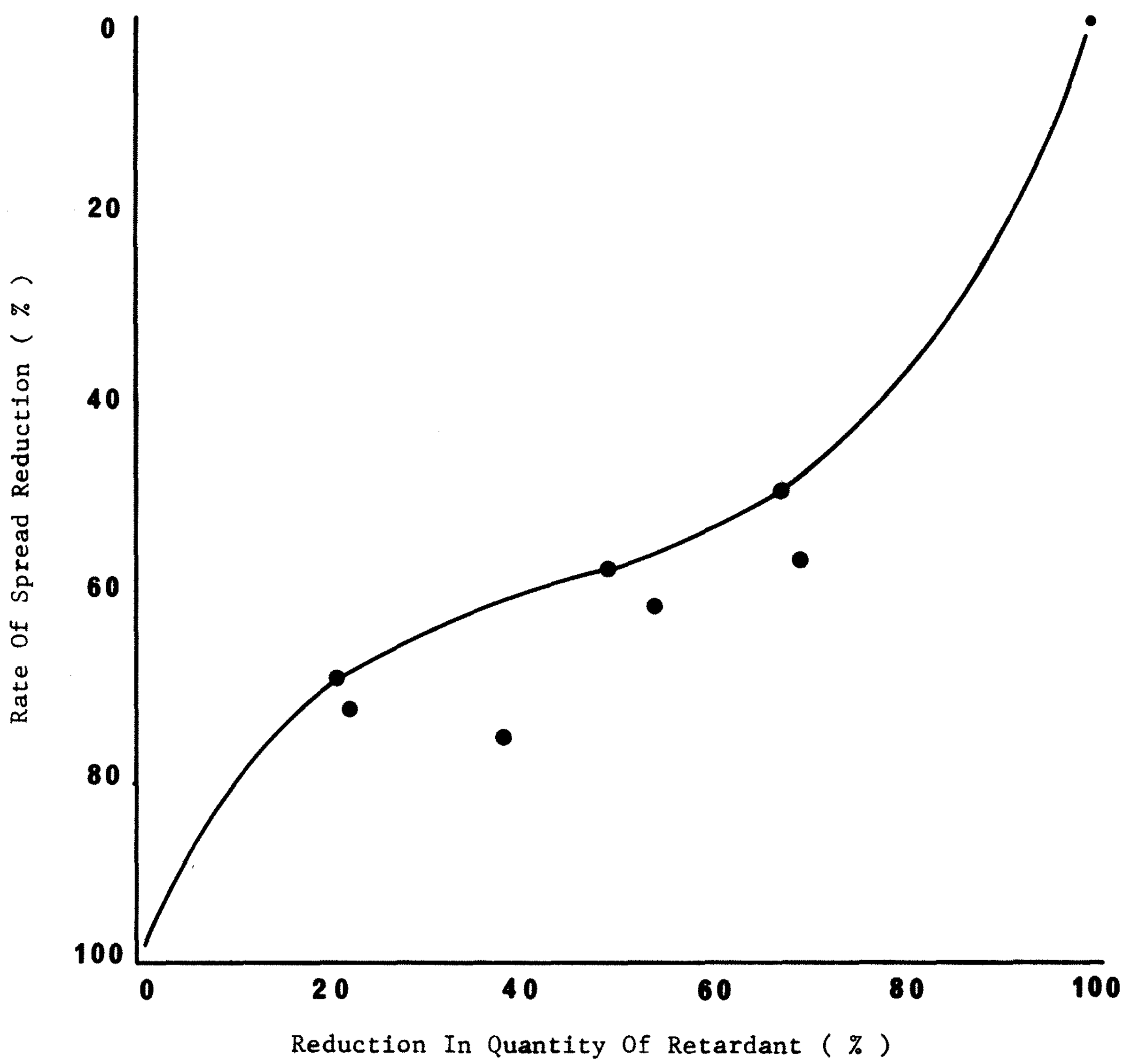

Figure 10. The effect of insufficient application on fire rate of spread expressed in percent ROS reduction as a function of percent reduction of the required amount of retardant.

quantity of retardant that was intercepted by the crown, the limbs and bole did not alter the distribution in any set pattern in terms of distance from the tree stem. This tree was located in the 0.05 to 0.06 cm concentration range and the catch beneath it ranged from 0.009 to 0.061 cm (from 18 to 100 per cent of the amount recorded at the nearest sampling point) in a very irregular fashion. This indicated that when the retardant was dropped from a low altitude, the adjacent trees had as much influence on drop distribution beneath the "master tree" as did its own crown.

The slow moving surface fire on Plot #7 consumed only fine twigs, surface litter and a minute portion of the moss. The 19.3 km/h wind outside the stand was basically blowing down the length of the plot but within the stand its velocity was 3.4 km/h and it was turbulent and multi-directional due to the influence of the cleared fire guards. The wind was responsible for some sporadic changes in rate of spread but, on the whole, the fire was not wind-driven as it progressed down the plot. The fire's rate of spread through the untreated stand varied with fuel pattern changes and its penetration into the treated zone was influenced by the extent of cover provided by plants and understory growth: where surface vegetation was lacking, the moss required only a thin film of retardant to stop the fire's spread, but, where overhead shielding was provided by young growth (black spruce primarily), the fire penetrated into the higher retardant concentration zone. Variations in available fuel caused the fire to burn more vigorously along some parts of the fire front than on others. Although the mean fire intensity (I) was 58.3 kcal/(s·m) at any given time and place along the fire front, the intensity varied from 30 to 70 kcal/(s·m) (ocular estimate). From the tests conducted at PFES under no-wind conditions using FT-931 on jack pine slash fires, the required application for this intensity range was 0.031 to 0.059 cm. These laboratory type tests were in fuel beds having depths from 11 to 14 cm and fuel moisture content (MC) in the 10 to 13 per cent range, but, within the pine stand the dead twig MC varied from 14 to 22% and the fuel structure was a mat of litter with varying amounts of suspended fuel above it. Retardant penetration through the man-made test bed (a mat of randomly oriented pine branches with all needles intact) and coatability in this fuel structure was not as efficient as in the field site, consequently, the required application appears to be approximately half the amount needed to control test bed fires of the same intensity. This then indicates that equivalent or better results can be expected in the field than at our test laboratory from a given application of FT-931. Since the MC of the underlying fuel, the moss, ranged from 80 to 186% in the first 2.5 cm and more than 200% deeper down, the moist base enhanced the retardation capabilities of FT-931.

TABLE 3. Calculated Fire Intensity Changes Relative to Amount of Retardant Applied

I (kcal/(m·s))	Required FT-931 (cm)	Applied FT-931 (cm)	FT-931 Reduction (%)	ROS Reduction (%)	New I (kcal/(m·s))
30	0.031	0.005	84	33	20
20	0.024	0.010	58	55	9
9	0.016	0.020	Fire will not reach 0.02 cm contour		
58	0.051	0.005	90	24	44
44	0.041	0.010	76	42	26
26	0.028	0.020	29	65	9
9	0.016	0.030	Fire will not reach 0.03 cm contour		
10	0.059	0.005	92	20	56
56	0.049	0.010	80	38	35
35	0.034	0.020	41	60	14
14	0.020	0.030	Fire will not reach 0.03 cm contour		

The litter on Plot #7 was primarily pine needles and branchwood and, therefore, there was some semblance of similarity between this site and the slash beds at PFES. Assuming that this limited similarity is adequate to justify the application of PFES test findings to the field situation, performance of FT-931 in the field can be appraised in terms of retardation afforded for each concentration noted in Figure 7. The minimum application of FT-931 that stopped the spread of fire in the test beds is given by the equation $Y = 0.1 + 0.0007 X$ (where Y is the amount required in cm and X is the fire intensity in kcal/(m·s)) for the 25 to 95 kcal/(m·s) intensity range.[2] The curve in Figure 10 represents the minimum reduction in fire rate of spread (ROS) for a given reduction in quantity of retardant used in treating the fuel. Considering that this relationship holds equally well for fire intensities as low as 30 kcal/(m · s), the effectiveness of FT-931 in stopping the fire on Plot #7 should read as indicated in Table 3. The reduction in fire intensity, as the fire penetrated the treated area, should have been somewhat greater than calculated, since step increases in amount applied were considered and not the continuous depth increase that actually existed. Table 3 values indicate that when the fire was burning at its lowest estimated intensity (30 kcal/(m·s) extinguishment should have occurred before the fire reached the 0.02 cm application, and when at its highest estimated intensity, it should have gone out before reaching the 0.03 cm level of application.

Judging by the periphery of the fire relative to the contour lines (Fig. 7), the retardant performed as expected with two exceptions: where surface litter and overlying fuels were sparse and moss growth was profuse, the required application was 0.005 cm or less; where there was a continuum of spruce understory, the fire persisted till it reached the 0.045 cm (approximately) retardant application level.

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[2] From Study FF-001 files, Forest Fire Research Institute.

Conclusion

The protective line built by the deposition of one Otter air tanker load of FT-931 (990 litres) can stop the spread of a light surface fire in a mature jack pine stand provided extensive spotting ahead of the fire front does not occur. If the embers that drop out from the convection column fall within the range of the treated strip, even low applications of retardant will effectively control spotting. Aircraft backwash during low level retardant dropping created sufficient turbulence within the crown to overcome the shielding effect that the tree boles and crowns might have otherwise provided consequently load penetration, dispersion and concentration distribution were not notably altered by the pine stand.

The retardant performance information derived from the semi-laboratory tests at PFES correlated reasonably well with Plot #7 test results.

References

Macpherson, J.I., 1967. Ground distribution contour measurements for five fire-bombers currently used in Canada. NRC, NAE, Ottawa, Ont., Rep. LR-493. 66 p.

Walker, J.D. and B.J. Stocks, 1975. The fuel complex of mature and immature jack pine stands in Ontario. Can. For. Serv., Sault Ste. Marie, Ont., Inf. Rep. O-X-229. 19 p.