Plant Community Development within the F- and H-Area Tree-Kill Zone

by

E A Nelson

Westinghouse Savannah River Company

Savannah River Site

Aiken, South Carolina 29808

H. M. Westbury, Jr.

MASTER

DOE Contract No. DE-AC09-89SR18035

This paper was prepared in connection with work done under the above contract number with the U. S. Department of Energy. By acceptance of this paper, the publisher and/or recipient acknowledges the U. S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper, along with the right to reproduce and to authorize others to reproduce all or part of the copyrighted paper.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

D. B. Moore-Shedrow, Manager
Authorized Derivative Classifier

**Plant Community Development Within the F- and H-Area
Tree-Kill Zones (U)**

Hugh M. Westbury, Jr., Environmental Sciences Section
Eric A. Nelson, Environmental Sciences Section

Approved by: DB Moore-Shedrow
D. B. Moore-Shedrow, Section Manager
Environmental Sciences Section

Publication date: October 1994

Westinghouse Savannah River Company
Savannah River Technology Center
Aiken, South Carolina 29808

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P. O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401.

Available to the public from the National Technical Information Service, U. S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Plant Community Development Within the F- and H-Area Tree-Kill Zones (U)

by

Hugh M. Westbury, Jr. and Eric A. Nelson

INTRODUCTION

The F- and H-Area Seepage Basins received liquid waste from the F and H chemical separation facilities from 1955 through 1988. Tree mortality in seepline fed wetlands down-slope from the basins was observed in the late 1970's, and investigations were conducted to determine the cause and source of the impacts (Loehle and Gladden, 1988; Mackey, 1988; Haselow et al., 1990; LeBlanc and Loehle, 1990; Greenwood et al., 1990). Analysis of the soil and water in the tree-kill zones demonstrated a strong chemical linkage with the F- and H-Area seepage basins (Killian et al., 1987a, 1987b). Although no single cause of the mortality was determined, it was believed to be the result of interactions of alterations in the hydrology and erosional deposition, along with lowering of pH and increased conductivity, sodium, aluminum, and nitrogen compounds (Looney et al, 1988). A mild drought during the growing season may also have increased the concentration of the chemical contaminants in the soils matrix.

In 1988, the F- and H-Area Seepage Basins were closed and covered with a clay cap to reduce the rate of dispersion of the contaminants in the soil beneath the basins. Subsequent studies of the chemical composition of the tree-kill zone groundwater (Dixon and Rogers, 1993) and toxicological characteristics of the seepline soil (Nelson and Westbury, 1994) have shown a reduced contaminant flux. In 1993, an initial vegetation study was undertaken to determine the level of recovery by the plant communities in the tree-kill zones (Nelson and Irwin, 1994). This study repeats the

initial vegetation investigation in order to further analyze and characterize the recovery of plant communities in the zones after an additional year of growth.

METHODS

The two study sites that were examined in 1993 were the most severely impacted wetlands in F- and H-Areas. Prior to the occurrence of tree mortality, the study sites were swamp tupelo (*Nyssa sylvatica* var. *biflora*) wetlands located between naturally occurring seep lines and Fourmile branch (Figure 1). All of the mature trees at these sites were killed, completely eliminating the overstory.

A series of vegetation characterization plots were established in 1993 at uniform intervals along transects (Nelson and Irwin, 1994). The F-Area site was sampled along four transects that crossed the zone laterally (Figure 2), while the H-Area site was sampled along a single transect that bisected the zone length-wise (Figure 3). The transects were located in order to best characterize the variation present in the areas based on visual assessment and chemical data. Each plot along the transects was marked in 1993 with a surveyors flag and re-sampled in this study. Beginning and ending points of each transect are marked with PVC pipe and identified with metal tags.

Forty circular milacre plots (43.56 sq. ft./plot, 4.05 sq. m/plot) were examined at the F-Area site and 56 plots were examined at the H-Area site. These are the same plots as those established and measured in 1993. Within each plot, all individual were identified to the lowest possible taxonomic level, usually species, and named following the USDA-SCS National List of Scientific Plant Names. For each plot the height of tree

and shrub seedlings, the number of vine stems, and the percent cover of herbaceous plants was recorded.

F-AREA TREE-KILL SITE

The F-Area site exhibited minimal plant community development. The substrate consists of unconsolidated, saturated sediments mixed with woody debris from the initial tree mortality, such as logs and stumps. Most of the vegetation was found to be growing on or near this woody structure where the roots were elevated above the saturated sediments. Thirty plant species were identified in 1994, and were similar in composition to the 26 species found in 1993 (Table 1).

Two live, mature (>10 cm DBH) swamp tupelo trees were observed in the study plots in both 1993 and 1994. All other tree species individuals were considered seedlings because of their size. The same seven tree species were found in 1994 as in 1993. The most prevalent tree species was red maple (*Acer rubrum*), of which 265 individuals were observed with an average height of only 8 cm (Table 2). This is an increase in numbers from the 1993 survey where only 53 individuals with an average height of 17 cm were observed. The decrease in average height between the studies is indicative of the addition of a large number of new seedlings. With the exception of American holly (*Ilex opaca*), the number of individuals of all tree species increased between the two studies. The total number of tree seedlings increased nearly three-fold from 129 in 1993 to 377 in 1994. This appears to be due to new germinant individuals. General vigor of these individuals was poor and their survival through the first growing season would be questionable.

In 1994, the most common shrub species was wax myrtle (*Myrica cerifera*), of which 41 individuals were observed as compared to only 6 in 1993. The number of Virginia willow (*Itea virginica*) decreased from 22 individuals in 1993 to 9 in 1994. The total number of shrub seedlings increased more than three-fold between the studies, from 22 in 1993 to 71 in 1994. Most of this increase was also probably due to new individuals which germinated this year. The species composition of shrubs was the same in both years.

Greenbriers (*Smilax* spp.) were the most common vine species encountered. In 1994, 44 greenbrier stems were identified compared to 19 in 1993 (Table 3). Yellow jessamine (*Gelsemium sempervirens*) also increased between the studies, from 4 to 23 individuals. These two species accounted for the general increase in vine stems from 27 in 1993 to 72 in 1994. Species composition was similar between years.

The herbaceous plant community in the F-Area tree-kill area did not exhibit the improvement found in the woody plants. Total herbaceous cover in 1994 was similar to 1993 at only about 8% cover (Table 4). The grass species, such as broomsedge (*Andropogon virginicus*) and giant cane (*Erianthus gigantea*) accounted for nearly all of the sparse herbaceous cover.

Between 1993 and 1994, the number of woody plants increased three-fold. This increase was especially pronounced in plots on Transect 4. This transect accounted for over half of the woody plants found in the area, as was the case in 1993. Red maple seedlings accounted for the largest increase in numbers of individuals. If the survival rate of these seedlings is good and they are able to send roots into the saturated sediments, then the substrate could become more consolidated and amenable to colonization by wetland plants. In general, this site continues essentially

to be devoid of plant development, with only 8% herbaceous cover and very small tree and shrub seedlings confined to dryer locations. There is no evidence of the development of a herbaceous wetland plant community, which would indicate a reduction of the toxicity of the sediments in the tree-kill zone. Virtually all plants growing within the F-Area tree-kill zone are rooted out of the saturated sediments.

H-AREA TREE-KILL SITE

The H-Area tree-kill site substrate was found to be much more densely vegetated with more consolidated sediments of a higher organic content than the F-Area site. Extensive development of a herbaceous wetland plant community indicates that the toxicity of the sediments has been reduced considerably. The general character of the plants in the area did not show signs of stress and the high percent coverage indicates minimal impairment of plant establishment and growth.

The transect along which the sample plots was located starts at the north end of the zone and proceeds south for approximately 100 m (20 plots), then turns to the west (Figure 3). The first part of the transect is classified (Cowardin et al., 1979) as a scrub-shrub, broad-leaved deciduous wetland, the remainder of the zone is open-canopy, persistent emergent wetland dominated by cattails (*Typha* spp.) and cutgrass (*Leersia oryzoides*).

In 1994, 50 plant species were identified in the study plots (Table 1) as compared to 40 in 1993. Species composition was similar in both studies, with most of the increase due to the difference in the sample dates with respect to season. Canopy development was minimal and herbaceous plant species were dominant. Only two living swamp tupelo trees (> 10cm DBH) were encountered in the plots.

The total number of tree seedlings in the study plots increased from 17 in 1993, to 32 in 1994 (Table 2). The largest contributor was red maple, which increased from 8 stems in 1993 with an average height of 22 cm, to 22 stems in 1994 with an average height of 10 cm. The decrease in average height was due to the addition of small, newly germinated, seedlings. One new tree species, sweetbay (*Magnolia virginiana*), was added in 1994.

Shrub seedling stem numbers were similar between the two studies (Table 2). The number of blackberry (*Rubus* spp.) stems counted increased from 14 in 1993, to 45 in 1994. This was offset by a reduction of stem numbers of red bay (*Persea borbonia*), from 80 in 1993, to 40 in 1994. The shrub species composition was the same in both years. Both tree and shrub seedlings were confined to the first part of the transect.

Vine stem numbers increased from 81 in 1993, to 130 in 1994 (Table 3). The largest increase in stem numbers was due to honeysuckle (*Lonicera japonica*), which increased from 8 in 1993 to 50 in 1994. Two additional vine species, muscadine grape (*Vitis rotundifolia*) and Virginia creeper (*Parthenocissus quinquefolia*), were included in 1994.

The total herbaceous cover decreased from 93% in 1993 to 77% in 1994 (Table 4). The largest decrease was with the two most frequent and dominant species; cattail decreased from 54% in 1993 to 40% in 1994, while cutgrass decreased from 30% in 1993 to 18% in 1994. The decrease in percent cover of these two species was probably due to the 1994 sample being taken earlier in the growing season (June) than in 1993 (September). Eight additional plant species were measured in 1994. Most of these additions can also be attributed to the earlier sample date because the

plants were in flower and could be identified to species, or, as with bishop-weed (*Ptilimnium capillaceum*), the plant flowers and senesces early in the season. The increase in herbaceous plant species numbers is probably not significant.

Figure 4. presents the distribution of the dominant herbaceous plant species along the transect. The herbaceous cover of the first 20 plots is dominated by rushes (*Eleocharis tortilis*, *Juncus effusus*, *Juncus coreaseus*). Total percent herbaceous cover in this area is lower than the remainder of the transect due to the presence of a sub-canopy of shrubs and saplings. Plots 21-35 are in an area of intermediate herbaceous cover and reduced sub-canopy. The dominant species in this area are southern cattail (*Typha domengensis*) and cutgrass. The sub-canopy is absent in plots 36-56, and the total herbaceous cover is very high. The dominant species are broad-leaf cattail (*Typha latifolia*) and cutgrass. Reductions in percent cover, such as in plot 43, were the results of fallen snags within the plot boundary.

The H-Area tree-kill site has developed an extensive post-disturbance plant community that is dominated by herbaceous wetland plants. After the swamp tupelo canopy was removed by the initial impact, wetland herbaceous species would be expected to colonize the saturated sediments as soon as the toxicity of the sediments became sub-lethal. With the passage of time shrub and then tree species would be expected to become dominant, eventually returning to the pre-disturbance composition. The northern portion of the zone (plots 1-20) has developed a sub-canopy of shrubs and saplings indicating a more advanced successional stage than the remainder of the zone. The main tree species present is red maple, which is an early successional invader. The intermediate section (plots 21-35) is dominated by southern cattail as opposed to broad-leaf cattail in the more open western section (plots 36-56). This abrupt shift in species composition may be due to variations in

hydrology, light availability, or pH. Southern cattail prefers more alkaline conditions than broad-leaf cattail (Radford et al., 1968)

SUMMARY

General conditions at both tree-kill zones have remained unchanged between the 1993 and 1994 studies. Differences due to sampling date were seen. Future characterization should be on a standardized date to reduce this variability. The F-Area site continues to exhibit toxicity in the saturated sediments, and is largely devoid of vegetation with only 8% herbaceous cover. The typically three-fold increase in tree, shrub, and vine seedlings is a positive sign, although general vigor and health of the new individuals is poor. If the survival rate of these seedlings is good and they are able to send roots into the saturated sediments, then the substrate could become more consolidated and amenable to colonization by wetland plants.

The H-Area site exhibits far greater plant community development and successional recovery than the F-Area site. The presence of a shrub sub-canopy in the northern and middle portions of the zone, and the generally high percent cover (77-93%) of herbaceous wetland plants, indicate lowered toxicity of the substrate to germination and establishment of vegetation.

REFERENCES

Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. Classification of Wetland and Deepwater Habitats of the United States. FWS/OBS-79/31. United States, Fish and Wildlife Service, Biological Services Program.

Dixon, K.L. and V.R. Rogers. 1993. Results of the second quarter tritium surveys of the F- and H-Area seepines: September 1992. WSRC-TR-93-129, Westinghouse Savannah River Co., Aiken, SC 29808.

Greenwood, K.P., M.E. Hane, A.L. Lander, C. Loehle, and C.J. Richardson. 1990. Assessment of tree toxicity near the F- and H-Area seepage basins of the Savannah River Site (U). WSRC-TR-90-253, Westinghouse Savannah River Co., Aiken, SC 29808.

Haselow, J.S., M. Harris, B.B. Looney, N.V. Halverson, and J.B. Gladden. 1990. Analysis of soil and water at the Four Mile Creek seepine near F & H Area of SRS (U). WSRC-RP-90-0591, Westinghouse Savannah River Co., SRL, Aiken, SC 29808.

Killian, T.H., N.L. Kolb, P. Corbo, and I.W. Marine. 1987a. Environmental Information Document: F-Area seepage basins. DSPT-85-704, E.I. duPont de Nemours & Co., SRL, Aiken, SC 29808.

Killian, T.H., N.L. Kolb, P. Corbo, and I.W. Marine. 1987b. Environmental Information Document: H-Area seepage basins. DSPT-85-706, E.I. duPont de Nemours & Co., SRL, Aiken, SC 29808.

LeBlanc, D.C. and C. Loehle. 1990. The effect of contaminated groundwater on tree growth: a tree-ring analysis (U). WSRC-RP-90-552, Westinghouse Savannah River Co., SRL, Aiken, SC 29808.

Loehle, C. and J. Gladden. 1988 Preliminary assessment of tree mortality near F- and H-Area seepage basins. DPST-88-260, E.I. duPont de Nemours & Co., SRL, Aiken, SC 29808.

Looney, B.B., J.E. Cantrell and J.R. Cook. 1988 Sampling and analysis of surface water in the vicinity of the F- and H-Area seepage basins. DSPT-88-229, E.I. duPont de Nemours & Co., SRL, Aiken, SC 29808.

Mackey, H.E. Jr. 1988. Initial evaluation of photographic data of F- and H-Area seepage basin outcrops. DSPT-88-314, E.I. duPont de Nemours & Co., SRL, Aiken, SC 29808.

Nelson, E.A., and J.E. Irwin. 1994. Current vegetation characteristics within tree-kill zones of the F- and H-Areas (U). WSRC-TR-94-0203, Westinghouse Savannah River Co., SRTC, Aiken, SC 29808.

Nelson, E.A., and H.M. Westbury Jr. 1994. Lettuce seed germination and root elongation toxicity evaluation of the F-Area seepage soils (U). WSRC-TR-94- Westinghouse Savannah River Co., SRTC, Aiken, SC 29808.

Radford, A.E., H.E. Ahles, and C.R. Bell. 1968. Manual of the Vascular Flora of the Carolinas. Univ. of North Carolina Press, Chapel Hill, NC.

USDA-SCS. 1982. National List of Scientific Plant Names: Volume 1, List of Plant Names. United States Department of Agriculture- Soil Conservation Service.

Table 1. F- and H-Area plant species listing by strata, June 1994 sampling.

F-AREA

TREE STRATUM

Nyssa sylvatica var. *biflora*

swamp tupelo

SEEDLING STRATUM

Tree Seedlings

Acer rubrum

red maple

Ilex opaca

American holly

Liquidambar styraciflua

sweetgum

Liriodendron tulipifera

tulip tree

Magnolia virginiana

sweet bay

Nyssa sylvatica var. *biflora*

swamp tupelo

Pinus taeda

loblolly pine

Shrub Seedlings

Ilex glabra

ink-berry

Itea virginica

Virginia-willow

Myrica cerifera

wax myrtle

Rubus sp.

blackberry

VINE STRATUM

Gelsemium sempervirens

yellow Jessamine

Lonicera japonica

honeysuckle

Parthenocissus quinquefolia

Virginia creeper

Smilax glauca

cat-brier

Smilax laurifolia

laurel-leaf greenbrier

Smilax sp.

greenbrier

Vitis rotundifolia

muscadine grape

Toxicodendron radicans

poison ivy

GROUNDCOVER STRATUM

Forbs

Ambrosia artemisiifolia

ragweed

Boehmeria cylindrica

false nettle

Eupatorium capillifolium

dog-fennel

Murdannia keisak

marsh dew-flower

Peltandra virginica

arrow arum

Viola sp.

violet

Grasses

Andropogon virginicus

broomsedge

Arundinaria gigantea

giant cane

Dichanthelium dichotomum

cypress witchgrass

Poaceae

unknown grass

Ferns

Woodwardia areolata

netted chain fern

H-AREA

TREE STRATUM

Nyssa sylvatica var. *biflora*

swamp tupelo

SEEDLING STRATUM

Tree Seedlings

Acer rubrum

red maple

Ilex opaca

American holly

Magnolia virginiana

sweet bay

Nyssa sylvatica var. *biflora*

swamp tupelo

Persea borbonia

red bay

Pinus taeda

loblolly pine

Shrub seedlings

Baccharis halimifolia

sea-myrtle

Callicarpa americana

French mulberry

Cephalanthus occidentalis

button bush

Ligustrum sp.

privet

Myrica cerifera

wax myrtle

Persea borbonia

red bay

Rubus sp.

blackberry

VINE STRATUM

Berchemia scandens

rattan vine

Lonicera japonica

honeysuckle

Mikania scandens

climbing hempweed

Parthenocissus quinquefolia

Virginia creeper

Smilax laurifolia

laurel-leaf greenbrier

Smilax sp.

greenbrier

Smilax walteri

greenbrier

Vitis rotundifolia

muscadine grape

GROUND COVER STRATUM

Forbs

Bidens sp.

beggar-ticks

Boehmeria cylindrica

false nettle

Eupatorium capillifolium

dog fennel

Hydrocotyle verticillata

water pennywort

Ludwigia leptocarpa

river seed-box

Lycopus virginicus

water hoar-hound

Murdannia keisak

marsh dewflower

Peltandra virginica

arrow arum

Pluchea camphorata

marsh-fleabane

Polygonum punctatum

dotted smartweed

Ptilimnion capillaceum

bishop-weed

Sambucus canadensis
Tillandsia usneoides
Triadenum walteri
Typha domingensis
Typha latifolia
Viola sp.

elderberry
spannish moss
marsh St. John's wort
southern cattail
broad-leaf cattail
violet

Grasses

Carex lupulina
Cyperus sp.
Dichanthelium dichotomum
Eleocharis tortilis
Erianthus giganteus
Juncus coriaceus
Juncus effusus
Leersia oryzoides

sedge
flatsedge
cypress witch-grass
spike rush
giant plume grass
leathery rush
soft rush
cut grass

Ferns

Asplenium platyneuron
Isoetes engelmannii
Woodwardia areolata

ebony spleenwort
quill-wort
netted chain fern

Table 2. Comparison of 1993 and 1994 tree and shrub seedling components.

<u>F-AREA</u>	<u>1993</u>		<u>1994</u>	
	Total Count	Ave. Ht. (cm)	Total Count	Ave. Ht. (cm)
Tree Seedlings				
<i>Acer rubrum</i>	53	17	265	8
<i>Pinus taeda</i>	32	9	52	8
<i>Liquidambar styraciflua</i>	14	24	22	16
<i>Nyssa sylvatica</i> var. <i>biflora</i>	19	60	24	83
<i>Magnolia virginiana</i>	6	48	7	53
<i>Liriodendron tulipifera</i>	3	7	6	7
<i>Ilex opaca</i>	2	46	1	130
TOTAL	129		377	
Shrub seedlings				
<i>Rubus</i> sp.	6	48	41	8
<i>Itea virginica</i>	9	19	22	18
<i>Myrica cerifera</i>	6	68	7	44
<i>Ilex glabra</i>	1	110	1	110
TOTAL	22		71	
<u>H-AREA</u>	<u>1993</u>		<u>1994</u>	
	Total Count	Ave. Ht. (cm)	Total Count	Ave. Ht. (cm)
Tree Seedlings				
<i>Acer rubrum</i>	8	22	22	10
<i>Magnolia virginiana</i>	0		6	104
<i>Ilex opaca</i>	1	312	2	166
<i>Pinus taeda</i>	4	9	2	10
<i>Nyssa sylvatica</i> var. <i>biflora</i>	4	28	0	
TOTAL	17		32	
Shrub seedlings				
<i>Rubus</i> sp.	14	66	45	11
<i>Persea borbonia</i>	80	143	40	98
<i>Myrica cerifera</i>	18	187	28	147
<i>Baccharis halimifolia</i>	10	85	11	13
<i>Callicarpa americana</i>	3	117	3	58
<i>Ligustrum</i> sp.	1	90	2	75
<i>Cephalanthus occidentalis</i>	1	30	1	80
TOTAL	127		130	

Table 3. Comparison of 1993 and 1994 vine count of F- and H-Areas.

F-AREA

	Total Count	
	1993	1994
<i>Smilax spp.</i>	19	44
<i>Gelsemium sempervirens</i>	4	23
<i>Vitus rotundifolia</i>	2	3
<i>Lonicera japonica</i>	0	1
<i>Parthenocissus quinquefolia</i>	2	1
TOTAL	27	72

H-AREA

	Total Count	
	1993	1994
<i>Lonicera japonica</i>	8	50
<i>Mikania scandens</i>	35	46
<i>Smilax spp.</i>	36	26
<i>Berchemia scandens</i>	2	5
<i>Vitus roundifolia</i>	0	2
<i>Parthenocissus quinquefolia</i>	0	1
TOTAL	81	130

Table 4. Comparison of 1993 and 1994 herbaceous cover and presence.

<u>F-Area</u>	<u>1993</u>		<u>1994</u>	
	Percent Cover	Presence (Max=40)	Percent Cover	Presence (Max=40)
<i>Andropogon virginicus</i>	4	27	4	30
<i>Poaceae</i>	3	20	3	19
<i>Arundinaria gigantea</i>	1	3	1	2
<i>Dichanthelium dichotomum</i>	0	0	0	1
<i>Eupatorium capillifolium</i>	0	2	0	3
<i>Viola</i> sp.	0	0	0	3
<i>Ambrosia artemisiifolia</i>	0	0	0	1
<i>Murdannia keisak</i>	0	0	0	1
<i>Boehmeria cylindrica</i>	0	1	0	1
<i>Peltandra virginica</i>	0	1	0	1
<i>Woodwardia areolata</i>	0	1	0	1
TOTAL	8		8	

<u>H-Area</u>	<u>1993</u>		<u>1994</u>	
	Percent Cover	Presence (Max=56)	Percent Cover	Presence (Max=56)
<i>Typha</i> spp.	54	48	40	49
<i>Leersia oryzoides</i>	30	55	18	51
<i>Murdannia keisak</i>	4	14	4	15
<i>Juncus coriaceus</i>	0	0	4	19
<i>Eleocharis tortilis</i>	2	26	3	12
<i>Ptilimnion capillaceum</i>	0	0	2	32
<i>Hydrocotyle verticillata</i>	0	45	2	37
<i>Erianthus giganteus</i>	1	7	2	13
<i>Juncus effusus</i>	1	10	1	11
<i>Triadenum walteri</i>	0	14	1	10
<i>Boehmeria cylindrica</i>	0	9	1	7
<i>Carex lupulina</i>	0	1	1	2
<i>Dichanthelium dichotomum</i>	0	0	0	3
<i>Peltandra virginica</i>	0	4	0	5
<i>Polygonum punctatum</i>	0	3	0	1
<i>Pluchea camphorata</i>	0	13	0	9
<i>Eupatorium capillifolium</i>	0	0	0	1
<i>Lycopus virginicus</i>	0	4	0	1
<i>Bidens</i> sp.	0	2	0	5
<i>Sambucus canadensis</i>	0	0	0	1
<i>Woodwardia areolata</i>	0	2	0	1
<i>Asplenium platyneuron</i>	0	0	0	1
<i>Cyperus</i> sp.	0	20	0	1
<i>Isoetes engelmannii</i>	0	0	0	1
<i>Ludwigia leptocarpa</i>	0	7	0	2
<i>Tillandsia usneoides</i>	0	2	0	2
<i>Viola</i> sp.	0	0	0	2
TOTAL	93		77

Figure 1. Map of study area showing sampling locations in localized tree-kill zones (X's). The dash line through F-Area is a steam pipeline. Letters and numbers within boxes are road designations. Cross-hatched areas are seepage basins. Seepage basins are approximately 15-20 m in elevation above Four Mile Creek.

Figure 2. F-Area tree-kill vegetation sampling transects.

Figure 3. H-Area tree-kill vegetation sampling transect.

Figure 4. Distribution of Selected Herbaceous Species (H-Area)