Common Name	Scientific Name	No. of Years Species Has Been Affected
Passionflower	Passiflora incarnata	2
Poison Ivy	Rhus radicans	3
Sawbrier	Smilax sp.	2
Sensitivebrier	Schrankia microphylla	1
Supplejack	Berchemia scandens	2
Trumpetvine	Campsis radicans	1
Virginia Creeper	Parthenocissus quinquefolia	1
	Grasses	
Fescue	Festuca obtusa	1
	Herbs	
Alfalfa	Medicago sativa	2
Amaranth, Spiny	Amaranthus spinosus	1
Aster, Many-Flowered	Aster sp.	2
Aster, White Heath	Aster pilosus	1
Azalea	Rhododendron sp.	1
Bean, Bunch	Phaseolus vulgaris var. humilis	1
Bean, Half-Runner	Phaseolus vulgaris	1
Bean, Pole	Phaseolus vulgaris	2
Beardtongue	Penstemon sp.	1
Beet	Beta sp.	1
Beggar Lice	Desmodium sp.	5
Begonia	Begonia sp.	1
Bicolor	Lespedeza bicolor	1
Bittercress	Cardamine hirsuta	1
Black-Eyed Susan	Rudbeckia serotina	2
Black Snakeroot	Sanicula canadensis	2
Boneset	Eupatorium perfoliatum	1
Cabbage	Brassica oleracea var. capitata	2
Cantaloupe	Cucumis melo var. cantalupensis	1
Carrot, Wild	Daucus carota	5
Chickweed	Stellaria media	1
Cinquefoil, Common	Potentilla canadensis	6
Cinquefoil, Oldfield	Potentilla simplex	1
Clover, Bush	Lespedeza sp.	4
Clover, Low-Hop	Trifolium procumbens	3
Clover, Red	Trifolium pratense	2
Clover, White	Trifolium repens	3
Cocklebur	Xanthium pennsylvanicum	3
Corn	Zea mays	4
Corn Salad	Valerianella radiata	2
Cotton	Gossypium herbarum	1
Cranesbill, Carolina	Geranium carolinianum	3
Crownbeard	Verbesina sp.	2
Cucumber	Cucumis sativus	1

Common Name	Scientific Name	No. of Years Species Has Been Affected
Cudweed	Gnaphalium sp.	1
Daisy, Ox-Eye	Chrysanthemum leucanthemum	1
Dandelion, Dwarf	Krigia virginica	1
Dandelion, Giant	Taraxacum sp.	1
Dock, Curly	Rumex crispus	4
Dog Fennel	Eupatorium capillifolium	1
Eveningprimrose, Common	Oenothera biennis	7
Eveningprimrose, Cutleaf	Oenothera laciniata	3
Fleabane, Daisy	Erigeron annuus	3
Forsythia	Forsythia sp.	1
Garlic, Wild	Allium vineale	1
Geranium, Wild	Geranium maculatum	2
Gladiolus	Gladiolus sp.	4
Goldenrod	Solidago sp.	5
Groundcherry	Physalis sp.	1
Hollyhock	Althaea rosea	2
Horsenettle, Carolina	Solanum carolinense	1
Horseweed	Erigeron canadensis	3
Iris	Iris sp.	1
Jimsonweed	Datura stramonium	2
Lambsquarters	Chenopodium album	3
Leafcup	Polymnia uvedalia	1
Lespedeza	Lespedeza sp.	2
Lettuce, Domestic	Lactuca sativa	2
Marigold	Tagetes sp.	1
Mexicantea	Chenopodium ambrosioides	1
Millet	Panicum miliaceum	1
Mullein, Common	Verbascum thapsus	1
Okra	Hibiscus esculentus	2
Pansy	Viola tricolor	1
Pea, English	Pisum sativum	3
Pea, Partridge	Cassia fasciculata	1
Pepper, Hot	Capsicum frutescens	1
Pepperweed	Lepidium sp.	1
Phlox, Pink	Phlox sp.	1
Pigweed, Smooth	Amaranthus hybridus	1
Plantain, Broadleaf	Plantago major	2
Plantain, Buckhorn	Plantago lanceolata	4
Plantain, Paleseed	Plantago virginica	1
Pokeweed	Phytolacca americana	4
Poorjoe	Diodia teres	1
Potato, Irish	Solanum tuberosum	3
Prickly Lettuce (sp.)	Lactuca sp.	5
Prickly Lettuce	Lactuca scariola	1
Radish	Raphanus sativus	1
Ragweed, Giant	Ambrosia trifida	11
Ragweed, Lesser	Ambrosia artemisiifolia	6
Ragwort, Small's	Senecio smallii	5
Sedum	Sedum sp.	1

Common Name	Scientific Name	No. of Years Species Has Been Affected
Sericea	Lespedeza cuneata	4
Smartweed, Pennsylvania	Polygonum pensylvanicum	2
Solomon's Seal	Polygonatum biflorum	2
Soybean	Glycine max	2
Spurge	Euphorbia sp.	1
Squash	Cucurbita sp.	2
St. Andrew's Cross	Ascyrum hypericoides	1
St. Johnswort	Hypericum punctatum	3
Strawberry	Fragaria sp.	2
Sultana	Impatiens sultani	1
Sunflower, Tickseed	Bidens aristosa	1
Sunflower, Wild	Helianthus sp.	6
Tall Coreopsis	Coreopsis major	4
Thistle, Sow	Sonchus oleraceus	2
Tomato	Lycopersicon esculentum	3
Touch-Me-Not	Impatiens pallida	1
Trillium	Trillium sp.	1
Turnip	Brassica napus	1
Venus' Lookingglass	Specularia perfoliata	4
Vetch	Vicia sp.	3
Violet	Viola sp.	3
Watermelon	Citrullus vulgaris	1
Woodsorrel, Common Yellow	Oxalis stricta	6
Yarrow, Common	Achillea millefolium	2
	Ferns	
Fern, Bracken	Pteridium aquilinum	1

APPENDIX H

PLANT SPECIES OCCURRING IN THE VICINITY OF WIDOWS CREEK STEAM PLANT

THAT HAVE SHOWN AN APPARENT RESISTANCE TO AIR POLLUTION EFFECTS

Common Name	Scientific Name
Trees	
Cedar, Eastern red	*Juniperus virginiana*
Cottonwood	*Populus deltoides*
Honeylocust	*Gliditsia triacanthos*
Pecan	*Carya illinoensis*
Poplar, Lombardy	*Populus nigra*
Serviceberry	*Amelanchier arborea*
Tree of Heaven	*Ailanthus altissima*
Shrubs	
Althea	*Hibiscus syriacus*
Buckeye, Red	*Aesculus pavia*
Coral-Berry	*Symphoricarpos orbiculatus*
Crepe Myrtle	*Lagerstromia indica*
Fig	*Ficus carica*
Flowering Quince	*Chaenomeles japonica*
Mexican Bamboo	*Polygyrum* sp.
Osmanthus	*Osmanthus* sp.
Vines	
English Ivy	*Hedera helix*
Wisteria	*Wisteria floribunda*
Herbs	
Ginger, Wild	*Asarum canadensis*
Ironweed	*Vernonia altissima*
Milkweed	*Asclepias* sp.
Pea, Sweet	*Lathyrus* sp.
Ruellia	*Ruellia* sp.
Spring Beauty	*Claytonia virginica*

APPENDIX I

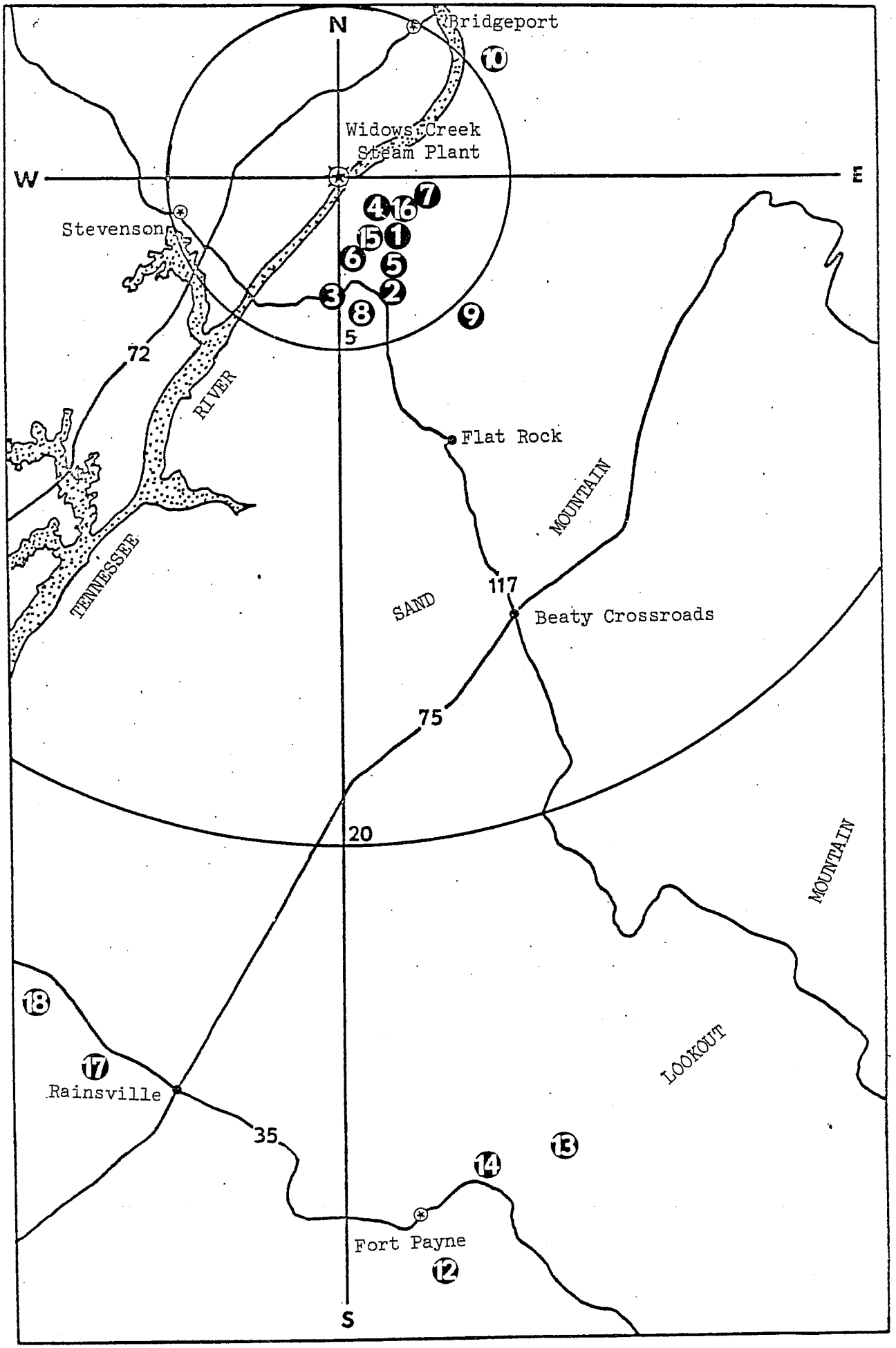
RECORD OF HIGH SO_2 CONCENTRATIONS MONITORED DURING DAYLIGHT (0600-1800) HOURS AT AUTOMETERS IN THE VICINITY OF WIDOWS CREEK STEAM PLANT - 1953-1972 GROWING SEASONS[a]

Autometer	Service Dates	Location Relative to Steam Plant		SO_2 Concentration (ppm)	Year												
		Distance (mi)	Azimuth		1953	1954	1955	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
1-1[b]	6/18/53-5/31/55	1.2	45°	Peak ≥1.00	0	0	0	-	-	-	-	-	-	-	-	-	-
				1-h avg ≥0.50	0	0	0	-	-	-	-	-	-	-	-	-	-
				3-h avg ≥0.50	0	0	0	-	-	-	-	-	-	-	-	-	-
1-2	3/31/64-6/9/72	3.5	33°	Peak ≥1.00	-	-	-	0	0	0	0	0	0	0	0	0	-
				1-h avg ≥0.50	-	-	-	0	0	0	0	1	0	0	1	0	-
				3-h avg ≥0.50	-	-	-	0	0	0	0	0	0	0	0	0	-
2	3/31/64-7/1/71	9.0	45°	Peak ≥1.00	-	-	-	0	0	0	0	0	0	0	0	-	-
				1-h avg ≥0.50	-	-	-	0	0	0	0	0	0	1	0	-	-
				3-h avg ≥0.50	-	-	-	0	0	0	0	0	0	0	0	-	-
3	3/6/68-Present	2.5	125°	Peak ≥1.00	-	-	-	-	-	-	-	1	4	21	24	11	28
				1-h avg ≥0.50	-	-	-	-	-	-	-	5	2	13	20	11	17
				3-h avg ≥0.50	-	-	-	-	-	-	-	0	0	3	6	1	3
4-5[c]	6/23/69-6/8/62	5.6	135°	Peak ≥1.00	-	-	-	-	-	-	-	-	0	0	0	0	-
				1-h avg ≥0.50	-	-	-	-	-	-	-	-	0	5	4	1	-
				3-h avg ≥0.50	-	-	-	-	-	-	-	-	0	0	0	0	-
6	6/10/70-Present	2.2	145°	Peak ≥1.00	-	-	-	-	-	-	-	-	-	26	22	10	30
				1-h avg ≥0.50	-	-	-	-	-	-	-	-	-	14	15	10	18
				3-h avg ≥0.50	-	-	-	-	-	-	-	-	-	3	5	1	4
7-9[d]	6/11/70-Present	2.4	105°	Peak ≥1.00	-	-	-	-	-	-	-	-	-	13	35	14	23
				1-h avg ≥0.50	-	-	-	-	-	-	-	-	-	11	25	13	19
				3-h avg ≥0.50	-	-	-	-	-	-	-	-	-	2	5	4	4
8	7/1/71-Present	7.0	54°	Peak ≥1.00	-	-	-	-	-	-	-	-	-	-	0	12	8
				1-h avg ≥0.50	-	-	-	-	-	-	-	-	-	-	0	7	3
				3-h avg ≥0.50	-	-	-	-	-	-	-	-	-	-	0	2	0
10	6/9/72-Present	2.0	91°	Peak ≥1.00	-	-	-	-	-	-	-	-	-	-	-	1	18
				1-h avg ≥0.50	-	-	-	-	-	-	-	-	-	-	-	3	9
				3-h avg ≥0.50	-	-	-	-	-	-	-	-	-	-	-	1	1
11	6/8/72-Present	2.1	153°	Peak ≥1.00	-	-	-	-	-	-	-	-	-	-	-	3	14
				1-h avg ≥0.50	-	-	-	-	-	-	-	-	-	-	-	3	7
				3-h avg ≥0.50	-	-	-	-	-	-	-	-	-	-	-	1	1

a. April 1-September 30.
b. Autometer 1 was installed in a new location in 1964. Maximum peak and 1-h and 3-h average SO_2 concentrations at locations 1 and 2 were 0.50, 0.20, and 0.13 ppm and 0.90, 0.55, and 0.41 ppm respectively.
c. Installed as autometer 4; redesignated autometer 5 on 4/16/70.
d. Installed as autometer 7; moved approximately 200 yards and redesignated autometer 9 on 4/12/72.

APPENDIX J

LOCATION OF LEAD PEROXIDE STATIONS IN THE VICINITY OF WIDOWS CREEK STEAM PLANT



APPENDIX K

AVERAGE SULFATION RATE AT LEAD PEROXIDE STATIONS IN THE VICINITY OF WIDOWS CREEK STEAM PLANT--1970-1973 GROWING SEASONS

Station No.[a]	Distance from Steam Plant (mi)	Sulfation Rate (mg SO_3/100 cm^2/day) 1970	1971	1972	1973	4-Yr Avg	2-Yr Avg
1	2.50	0.274	0.265	0.134	0.261	0.243	
2	3.75	0.138	0.191	0.080	0.136	0.136	
3	3.50	0.079	0.106	0.091	0.110	0.101	
4	1.70	0.185	0.360	0.189	0.294	0.270	
5	4.48	0.175	0.182	0.075	0.250	0.197	
6	2.58	0.114	0.155	0.040	0.107	0.105	
7	2.63	0.111	0.164	0.069	0.292	0.204	
8	4.11	0.083	0.088	0.065	0.127	0.103	
9	5.60	0.168	0.211	0.183	0.230	0.209	
10	5.68	0.234	0.286	0.147	0.182	0.202	
Average		0.156	0.201	0.107	0.194		
11	29.87	0.031	-	-	-	-	
12	32.17	0.031	0.066	0.053	0.043	0.047	
13	29.50	0.053	0.046	0.047	0.077	0.048	
14	31.00	-	0.069	0.063	0.065	-	
Average		0.038	0.060	0.054	0.062		
15	2.14	-	-	0.259	0.375	-	0.317
16	2.30	-	-	0.239	0.342	-	0.291
Average				0.249	0.359		
17	27.50	-	-	0.126	0.128	-	0.127
18	25.90	-	-	0.106	0.112	-	0.109
Average				0.116	0.120		

a. Stations 1-10 - on Sand Mountain within 6-mi radius of the steam plant; 11-14 - Hi-Top Mountain and Lookout Mountain control stations; 15-16 - Sand Mountain field study plots; 17-18 - Rainsville, Alabama, field study plots.

1971 - 1 filtered-air greenhouse
6 small field plots (4 test and 2 control)
Comparisons were made between plants grown in greenhouses in filtered or unfiltered air and between plants grown at control and test field plot locations. All plants were grown in containers. Potatoes were planted in April and harvested in July and followed by soybeans that were planted in July and harvested in November.

1972 - 3 filtered-air greenhouses at a single location
4 large field plots (2 test and 2 control)
Same comparisons as in 1971. Only soybeans were planted in the greenhouse. Potatoes and soybeans were planted at field plots. All plants were grown in soil row culture.

1973 - 3 filtered-air greenhouses
4 large field plots (2 test and 2 control)
11 small field plots (6 test and 5 control)
Same comparisons as in 1971. Only soybeans were planted. Plants in greenhouses and large field plots grown in soil rows. Plants in small field plots grown in containers.

The most significant results from these studies have come from the greenhouse plots where plants grown in unfiltered air have consistently yielded less than plants grown in filtered air. Yield reductions were 19% for potatoes in 1971 and 32% and 16% for soybeans in 1971 and 1972 respectively. Although data are still being processed for 1973, preliminary results indicate that soybean yields will be about 33% lower for plants grown in unfiltered air.

The differences in yield noted to date in greenhouse experiments have not been accompanied by obvious differences in growth rate of plants grown in filtered and unfiltered air. Most of the yield reduction of these plants appeared to have been associated with a reduced average size of storage organs (potato tubers and soybean seed). Foliar necrosis attributed to exposure of plants to SO_2 was light (less than 5% leaf area affected) on potatoes grown in the greenhouse in 1971 and totally absent on soybeans in both 1971 and 1972; however, necrosis and chlorosis were detected on soybeans growing in unfiltered air on two occasions during the 1973 growing season. The most consistent difference between treatments

has been the earlier senescence of plants growing in unfiltered air. Premature leaf senescence is one well-known effect produced by repeated exposure of plants to air pollutants such as SO_2 and may be contributing to the yield reductions noted in these studies.

The results from the greenhouse studies have indicated that atmospheric emissions from the Widows Creek Steam Plant may be adversely affecting yield of agricultural crops growing in surrounding areas. These studies have thus far provided valuable information on the relationship between SO_2 exposure, visible appearance of foliage, and yield. The greenhouse experiments represent the most effective means of studying the relationship between these variables because differences in site factors other than pollution level are greatly reduced between treatments. No definite conclusions should be drawn from these studies, however, until yield of field-grown plants has been more thoroughly investigated.

To date, similar yield differences between field plots in test and control locations have not been demonstrated. One possible reason for this has been large differences in site factors such as rainfall and soil fertility, which have contributed to a high within-treatment variability in yields. Differences in soil productivity between sites are being reduced by cultural practices, and accumulation of data from several years should permit valid statistical comparisons to be made between control and test treatments.

Surveys Conducted During 1973 Growing Season

Five regularly scheduled surveys were made in the vicinity of Widows Creek Steam Plant during the 1973 growing season. Survey dates were May 22-25, June 6-7, June 26-28, July 18-20, and August 27-29. Limited surveys were also made on May 4, June 22, and July 30 to document effects to vegetation immediately after high SO_2 concentrations were recorded by autometers on Sand Mountain.

A. Methods

During routine surveys, vegetation was inspected within a maximum radial distance from the plant that ranged from approximately 8 mi in the valley, where air pollution effects have been infrequent in the past, to 12 mi on Sand Mountain, where effects have historically been most extensive.

Because of the large area involved (in excess of 300 mi^2), the use of automobiles to conduct surveys along roadsides around the plant was mandatory. The technique involved traversing available roadways in a pattern to provide coverage of the surrounding countryside in concentric circles at approximately 1-mi-radius intervals. The speed of coverage ranged from 5 to 30 mi/h depending on availability and proximity of sensitive roadside vegetation. Short field excursions were made at 1/2- to 1-mi intervals to provide more detailed examinations of vegetation.

Use of the roadside survey method requires that heavy reliance be placed on the inspection of vegetation known to be sensitive to SO_2. Indicator species are inspected first to determine whether further inspection of more resistant species may be warranted. Commonly available indicator species useful for detecting SO_2 effects in the vicinity of Widows Creek Steam Plant are blackberry, yellow poplar, Virginia pine, loblolly pine, lesser ragweed, giant ragweed, and eveningprimrose.

When air pollution effects were detected, more extensive roadside coverage was begun to delineate the affected areas. An extensive survey of vegetation at from 1 to 10 data points distributed throughout the affected area was made to describe the diversity and severity of the effects. At each point, a list was made of both affected and unaffected species, and visual estimates of the degree of foliar necrosis, chlorosis, and anthocyanosis and other symptoms or conditions possibly related to air pollution exposure were made for each species (Appendix C describes the system used in making these observations). Vegetation in the vicinity of the six Thomas autometers, located on Sand Mountain southeast of the plant (see figure 1), was also examined closely during each survey to obtain data relating the degree of foliar effects with levels of SO_2 registered at each autometer.

The areal extent of air pollution effects on vegetation was delineated on the basis of the distribution of foliar necrosis of sensitive species along roadways in the area. Where access to an area was not available, the intensity and distribution of foliar necrosis and topographical features of adjacent areas were considered in determining whether vegetation in the inaccessible area might also have experienced exposure to concentrations of air pollutants high enough to produce foliar necrosis.

Following each survey, a report was prepared describing the number of plant species affected and the location and size of areas where recent effects were detected. Data sheets summarizing information gathered at each observation point were filed with the original copy of each report.

B. Results

During the 1973 growing season, interveinal necrosis of broad-leaved species and tip necrosis of conifers attributed to SO_2 exposure[1] were detected on 71 plant species distributed over a total land area of approximately 47,660 acres in the vicinity of Widows Creek Steam Plant. Foliar effects were found on vegetation during each of the five regularly scheduled surveys and in three additional limited surveys. The areas affected during each survey are delineated in figure 4, while the size of the areas and the distribution of the effects relative to the steam plant are shown in table 2. The predominant species affected during each survey are noted in table 3.

During the first survey, May 23-25, 20 plant species exhibited air pollution effects over a total area of 12,000 acres. Most of this area was delineated on the basis of effects to blackberry and immature leaves of yellow poplar. Most of the effects were in the southeast at distances ranging from 2 to 11 mi from the steam plant. Information on foliar necrosis on 20 plant species, including 5 trees, 12 herbs, 1 shrub, and 2 vines, was collected at 13 data points distributed throughout four affected areas found during this survey.

Air pollution effects during the second survey, June 6-7, were limited to a single area of 500 acres located in the valley and extending from 0.8 to 1.6 mi north of the plant. Loblolly pine was the most extensively affected species. Information on the effects to 6 plant species, including 3 trees, 1 shrub, and 2 herbs, was collected at three data points within the affected area.

The most extensive effects noted during the past season were found during the third survey, June 26-28. A total of 41 species, including 13 trees, 20 herbs, 6 shrubs, and 2 vines, exhibited air pollution effects over a land area of approximately 30,185 acres. Effects were noted in both the valley and on Sand Mountain extending from 2 to 11.5 mi from the steam

1. Although vegetation is exposed to a variety of air pollutants present in atmospheric emissions from steam plants, SO_2 is the predominant pollutant involved, and effects noted on vegetation have consistently been typical of those caused by SO_2.

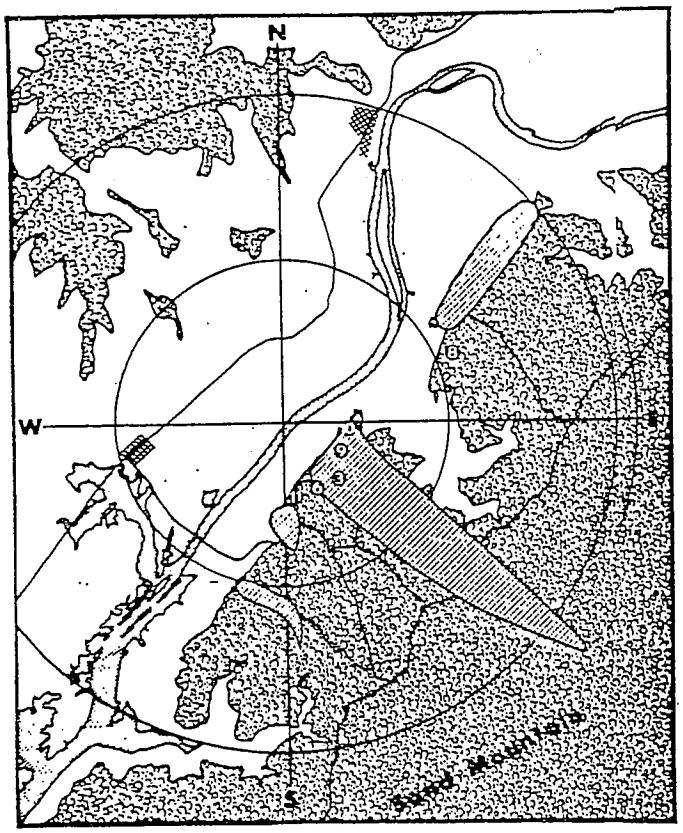
Table 2

DISTRIBUTION OF AREAS IN THE VICINITY OF WIDOWS CREEK STEAM PLANT WHERE AIR POLLUTION EFFECTS WERE DETECTED ON VEGETATION DURING FIVE SURVEYS - 1973 GROWING SEASON

Distribution of Effects	Survey Dates: May 23-25 Acreage	%	June 6-7 Acreage	%	June 26-28 Acreage	%	July 18-20 Acreage	%	Aug. 27-29 Acreage	%	Season Total: By Surveys[a] Acreage	%	By Land Area[b] Acreage	%
(by sectors)														
N			395	79							395	1	397	
NE	2,600	22			8,570	29			4,585	22	15,755	20	10,190	21
E	640	5			1,475	5	3,215	23	1,010	5	6,335	8	4,615	10
SE	7,560	63			5,225	17	4,190	29	13,280	65	30,260	39	15,805	33
S	1,200	10			14,915	49	6,835	48	215	1	23,165	30	15,090	31
SW									1,495	7	1,495	2	1,460	
W														
NW			105	21							105	<1	105	<
Total Acreage	12,000	100	500	100	30,185	100	14,240	100	20,585	100	77,510	100	47,660	100
(by 2-mi radius intervals)														
0-2	200	2	500	100	605	2	100	1	320	2	1,725	2	1,120	
2-4	3,200	27			5,970	20	2,580	18	3,520	17	15,270	20	5,845	12
4-6	2,900	24			8,590	28	5,580	39	3,730	18	20,800	27	11,160	23
6-8	3,100	26			10,550	35	4,130	29	8,000	39	25,780	33	17,500	37
8-10	2,300	19			3,570	12	1,850	13	5,010	24	12,730	16	11,785	25
10-12	300	2			900	3			5	<1	1,205	2	250	
Total Acreage	12,000	100	500	100	30,185	100	14,240	100	20,585	100	77,510	100	47,660	100

a. Sum of all acreages affected during five surveys.

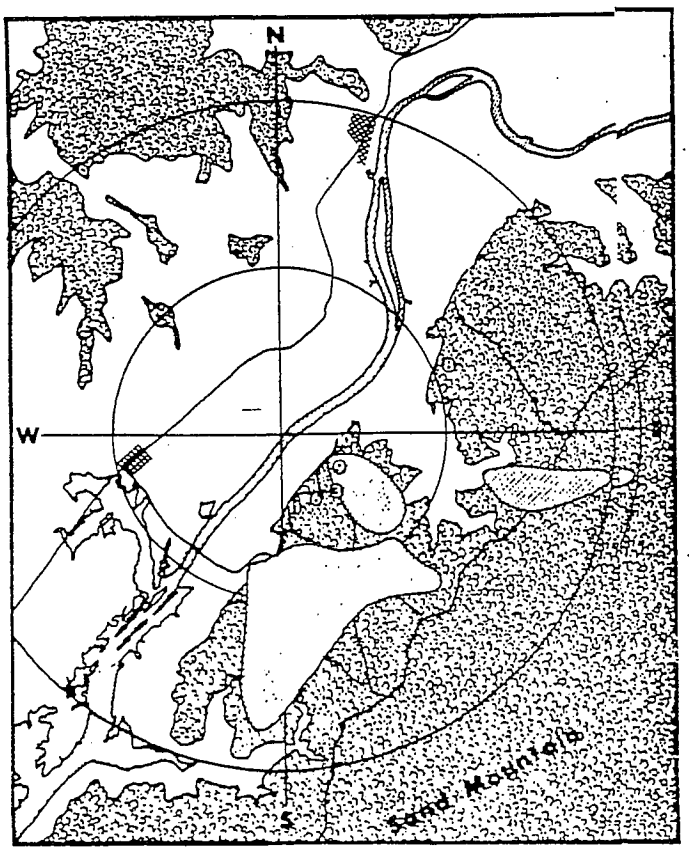
b. Total land area affected. Repetitive effects in the same area not considered.



Survey 1 - May 23-25
12,000 Acres Affected

Legend:

No. Times Areas Affected	
1	
2	
3	
4	
5	
Autometer No.	
Areas with Elevation ≥ 1,500 ft	



Survey 4 - July 18-20
14,240 Acres Affected

Figure 4. Areas in the Vicinity of Widows Creek Steam Plant Where Foliar Necrosis Attributed to Air Pollution was Detected - 1973 Growing Season

Table 3

PREDOMINANT PLANT SPECIES ON WHICH FOLIAR NECROSIS OF THE TYPE CAUSED BY SO_2 WAS DETECTED DURING FIVE SURVEYS IN THE VICINITY OF WIDOWS CREEK STEAM PLANT - 1973 GROWING SEASON

	Survey Dates					
	May 23-25	June 6-7	June 26-28	July 18-20	August 27-29	Season Total
Total Number of Species Affected	20	6	41	26	45	72
Most Extensively Affected Species[a]	Blackberry Eveningprimrose, common Alfalfa Gladiolus	Pine, Loblolly Blackberry Queen Anne's Lace	Pine, Virginia Blackberry Ragweed, Lesser Desmodium Pine, Loblolly	Pine, Loblolly Ragweed, Lesser Pine, Virginia Sumac, Smooth Blackberry	Ragweed, Lesser Blackberry Pine, Loblolly Ragweed, Giant Soybean	Blackberry Pine, Virginia Pine, Loblolly Ragweed, Lesser Ragweed, Giant Desmodium Sumac, Smooth Pine, Shortleaf Soybean Eveningprimrose, Common

a. Rank of species is based on three criteria: the number of data points at which a species was affected; the percentage of data points at which a species was affected when found; and the maximum degree of foliar necrosis observed.

plant. Most of the effects were noted on Sand Mountain in the south and northeast sectors. Virginia and loblolly pine were the most extensively affected species observed during this survey with individual young Virginia pine trees exhibiting from 50 to 100% needle necrosis at distances in excess of 11 mi from the plant. Information on the severity of effects was collected at 24 data points distributed throughout the three areas where effects were detected during this survey.

On July 18-20, the fourth survey of the Widows Creek area was conducted. Foliar necrosis of the type caused by SO_2 was found on 26 species of plants in four separate areas totalling approximately 14,240 acres. All of the affected area was located on Sand Mountain at distances ranging from 2 to 10 mi from the plant and most of this area was in the south and southeast sectors. Loblolly and Virginia pines and lesser ragweed were the most extensively affected species found during this survey. Information on the degree of effects to 10 species of trees, 12 species of herbs, 2 species of shrubs, and 2 species of vines was collected at 12 data points distributed throughout three principal affected areas.

The final regularly scheduled survey at Widows Creek for the 1973 growing season was conducted on August 27-29. Foliar air pollution effects were found on 45 plant species distributed over 20,590 acres during this survey. Over 90% of the affected area was located on Sand Mountain at distances ranging from 2 to 10.3 mi from the plant, and most of the effects were in the southeast sector where over 3,000 acres showed evidence of having been affected twice since the previous survey. Lesser ragweed, blackberry, and loblolly pine were the predominant species affected; however, six vegetable species in two gardens, approximately 60 acres of hay, and 70 acres of soybeans also exhibited foliar necrosis attributed to SO_2 exposure. These effects resulted in complaints from three Sand Mountain residents. Information on the degree of foliar effects on 12 species of trees, 24 species of herbs, 5 species of shrubs, and 4 species of vines was collected at a total of 19 data points distributed throughout the affected areas.

The total area affected during the growing season (table 2) was determined by both adding the acreages found during individual surveys and measuring the total land area affected without regard to recurrent effects in the same area. Because of repeated effects in many areas, the season

total by surveys, 77,510 acres, exceeded the land area total, 47,600 acres, by about 55%. The areas that were affected repeatedly throughout the growing season are delineated and coded in figure 4 and are listed by size and frequency of effects in table 4. Approximately 23,000 acres were affected more than once (2 to 5 times) during the 1973 growing season. On a land area basis, the maximum impact of air pollution effects to vegetation occurred southeast of the steam plant and at distances between 6 to 8 mi from the plant, while the areas most frequently affected (4 to 5 times) occurred predominantly in the southeast sector at distances between 2 and 7 mi from the steam plant.

To evaluate the total impact of foliar air pollution effects on an area-wide basis, affected areas within successive 5-mi-radius increments from the steam plant are described in table 5 as percentages of the total land area present within each respective increment. From this table it can be seen that approximately 25% of the total land area within a 10-mi radius of the steam plant exhibited air pollution effects during the 1973 growing season and that, on a percentage-area basis, effects were relatively evenly distributed out to distance of 10 mi from the plant. Although vegetation on 12% of the area within a 15-mi radius of the plant showed visible evidence of having been affected by air pollution, effects were quite limited beyond 10 mi, and the maximum distance from the steam plant at which effects were observed was 11.5 mi.

Of the 72 plant species on which foliar necrosis was detected during the current season, there were 23 species of trees, 26 species of herbaceous weeds, 12 species of garden and field crops, 7 species of shrubs, and 4 species of vines. The list of predominant species affected during each survey shown in table 3 indicates which species were the most useful indicators of air pollution effects during each survey and reflects the maturity-related changes in sensitivity of vegetation throughout the growing season. In general, blackberry and yellow poplar were the most sensitive species early in the season, while the pines reached maximum susceptibility during midsummer when new needles were actively elongating. Lesser ragweed was the most useful indicator plant during the last part of the growing season.

Table 4

THE RELATIONSHIP BETWEEN FREQUENCY OF DETECTION OF AIR POLLUTION EFFECTS AND SIZE AND DISTRIBUTION OF AFFECTED AREAS IN THE VICINITY OF WIDOWS CREEK STEAM PLANT - 1973 GROWING SEASON

			Relationship of Effects to Steam Plant					
			Predominant Direction			Predominant Distance		
No. Times Area Affected	Acreage	%[a]	Sector	Acreage	%[b]	Radius Interval	Acreage	%[b]
1	24,715	52	S	8,580	30	6-8	11,155	39
2	15,360	32	S	5,810	46	6-8	4,860	38
3	5,225	11	NE	1,620	39	4-6	1,335	32
4	1,305	3	SE	1,240	93	2-4	760	57
5	1,055	2	SE	765	100	2-4	745	87
Total Land Area Affected	47,660	100	SE	15,805	33	6-8	17,500	37

a. Percentage of total land area affected

b. Percentage of total acreage affected in each respective frequency class

Table 5

AFFECTED ACREAGE AS A PERCENTAGE OF TOTAL ACREAGE
WITHIN A 15-MILE RADIUS OF WIDOWS CREEK STEAM PLANT
1973 GROWING SEASON

Radius Interval (Mi)	Affected Acreage	Affected Area as Percentage of Total Land Area
0-5	12,200	26
5-10	34,220	24
0-10	46,420	25
10-15	1,240	<1
0-15	47,660	12

All plant species on which air pollution effects were detected during the 1973 season are listed in table 6. The list is divided into two categories based on the potential economic importance of each species in the Widows Creek area. Species within each category are ranked on the basis of the frequency and severity of effects observed on each. This ranking was based on information collected at 71 data points established during the current growing season. Included in this list are 34 species of potential economic importance in the area of which there are 21 trees, 6 garden crops, 6 field crops, and 1 shrub. Virginia, loblolly, and shortleaf pines were the predominant economically important species affected, while blackberry, lesser ragweed, and giant ragweed were the predominant economically unimportant species affected during the past year.

Information on the number of data points at which each species was affected, the frequency of occurrence of foliar necrosis when a species was observed at data points, and the maximum degree of necrosis for each of the 72 species on which air pollution effects were observed during the past growing season is provided in Appendix D. For the whole season, blackberry (37 data points), Virginia pine (31 data points), loblolly pine (25 data points), lesser ragweed (24 data points), and giant ragweed (16 data points) were the most extensively affected species in the Widows Creek area.

Based on the orientation of affected areas relative to the plant and the approximate time of occurrence of the effects noted in each, there were 12 to 14 separate occasions during the past growing season when vegetation was exposed to SO_2 concentrations high enough to visibly affect foliage. During seven of these occasions Thomas autometers, located within the affected areas, recorded the ground level SO_2 concentrations that produced the effects. To document the number of species affected and the degree of foliar necrosis associated with each known high SO2 concentration occurring during the past growing season, data points were established adjacent to the Thomas autometers within each affected area. The occurrence dates, SO_2 concentrations, time intervals, and number of species affected at each autometer are listed in table 7. Of the 22 documented occurrences there were 14 times when vegetation was affected by SO_2 concentrations that did not exceed the current secondary ambient air quality standard--0.50 ppm, 3-h avg. On three occasions, SO2 concentrations producing necrosis were

Table 6

PLANT SPECIES ON WHICH FOLIAR NECROSIS OF THE TYPE CAUSED BY SO_2 WAS DETECTED DURING FIVE SURVEYS IN THE VICINITY OF WIDOWS CREEK STEAM PLANT 1973 GROWING SEASON

Rank[a]	Species of Potential Economic Importance	Species of No Potential Economic Importance
1	Pine, Virginia	Blackberry
2	Pine, Loblolly	Ragweed, Lesser
3	Pine, Shortleaf	Ragweed, Giant
4	Clover, Red	Desmodium
5	Soybean	Sumac, Smooth
6	Poplar, Yellow	Smartweed, Pennsylvania
7	Pine, White	Eveningprimrose, Common
8	Pine, Slash	Sunflower, Wild
9	Alfalfa	Sassafras
10	Gladiolus	St. Johnswort
11	Sweetgum	Morningglory
12	Pea, Garden	Wild Carrot
13	Dogwood	Aster
14	Oak, Blackjack	Farkleberry
15	Sericea	Fleabane, Daisy
16	Hickory	Horseweed
17	Pear	Greenbrier
18	Cucumber	Grapes
19	Cherry, Black	Bidens cier
20	Sycamore	Coreopsis
21	Ash, White	Sumac, Winged
22	Bean, Garden	Cinquefoil, Common
23	Oak, Post	Venus' Lookingglass
24	Pine, Longleaf	Lettuce, Wild
25	Azalea	Jimsonweed
26	Okra	Yellow Woodsorrel
27	Corn	Blueberry
28	Locust, Black	Cocklebur
29	Apple	Crownbeard
30	Tomato	Sourwood
31	Lespedeza	Pokeweed
32	Oak, White	Touch-Me-Not
33	Oak, Northern	Elderberry
34	Oak, Black	Kudzu
35		Eveningprimrose, Gutleaf
36		Cinquefoil, Oldfield
37		Cranesbill, Carolina
38		Plantain, Buckhorn

a. Rank based on (1) number of data points at which a species exhibited foliar necrosis; (2) frequency of occurrence of foliar necrosis when species observed; and (3) maximum degree of foliar necrosis detected.

less than one-half this standard. The minimum peak, 1-h avg, and 3-h avg SO_2 concentrations associated with foliar necrosis during the 1973 season were 0.80 ppm, 0.30 ppm, and 0.20 ppm respectively.

Sulfur Dioxide Registrations During the 1973 Growing Season

To describe the potential for air pollution effects to vegetation during the 1973 growing season, a summary of the SO_2 concentrations recorded by each of the six Thomas autometers on Sand Mountain is shown in table 8. All of these autometers are situated within areas that were affected on one or more occasions during the 1973 season. For each autometer, the number of daylight (6 a.m. to 6 p.m.) occurrences during which peak SO2 concentrations equalled or exceeded 1.0 ppm and 1-h and 3-h avg concentrations equalled or exceeded 0.50 ppm is listed.[1] Maximum SO_2 concentrations recorded by each autometer and minimum concentrations associated with the appearance of foliar necrosis of vegetation at each autometer site are also listed in this table. During the 1973 growing season, high SO_2 concentrations were recorded with the greatest frequency at autometers 3, 6, and 9, all of which were situated within areas affected four or five times during the 1973 season (see figure 3). The highest SO_2 concentration was recorded at autometer 3 where peak, 1-h avg, and 3-h avg concentrations were 4.60 ppm, 2.10 ppm, and 1.03 ppm respectively. The national secondary ambient air quality standard (3-h avg 0.50 ppm) was exceeded 13 times during daylight hours and at five of the six autometers. These 13 exceptions occurred on four separate days (June 23 and 24, July 28, and August 20) during the 1973 season, and foliar necrosis of vegetation was detected after each occurrence.

In addition to the relatively high SO_2 concentrations that intermittently cause foliar necrosis of vegetation on Sand Mountain, plants were more frequently exposed to subacute levels of SO_2. To describe the frequency of exposure of vegetation on Sand Mountain to both acute and subacute levels, records from each of the six Thomas autometers were consulted to calculate the frequency and average duration of SO_2 exposure at each. These data are presented in table 9 and indicate the relatively high frequency of SO_2 visitations at ground level on Sand Mountain during the 1973 growing

1. Although foliar necrosis has been recorded at Widows Creek at 1-h and 3-h avg SO_2 concentrations as low as 0.30 and 0.20 ppm, respectively, higher levels were chosen to describe the air quality in the area because effects have been much more consistently found at these levels (see Appendix F).

Table 7

CONCENTRATIONS OF SO_2 ASSOCIATED WITH FOLIAR NECROSIS OF FORTY-FIVE PLANT SPECIES GROWING NEAR SIX AUTOMETERS IN THE VICINITY OF WIDOWS CREEK STEAM PLANT

1973 GROWING SEASON

Date of Occurrence	Date of Observation	Registering Autometer	Maximum SO_2 Concentration (ppm) Registered Prior to Detection of Foliar Necrosis[a] Peak	1-h	3-h	Time Interval	No. Species Affected
4/28	5/4	3	1.40	0.70	0.43	0700-1000	3
4/28	5/4	9	1.50	0.30	0.23	0600-0900	6
[b] 4/28	5/4	10	0.90	0.20	0.07	0700-1000	1
[b] 4/29	5/4	10	0.80	0.30	0.20	0900-1200	
[b] 5/4	5/24	6	0.90	0.60	0.43	0700-1000	4
[b] 5/11	5/24	6	1.10	0.40	0.17	1300-1600	
5/9	5/24	3	1.10	0.60	0.23	0900-1100	4
5/9	5/24	9	1.20	0.70	0.40	0700-1000	1
----------Survey I - 5/23 to 5/25----------							
----------Survey II - 6/6 to 6/7----------							
6/11	6/22	3	1.30	0.70	0.43	0900-1200	8
6/11	6/22	6	2.20	1.10	0.60	0800-1100	11
6/16	6/28	8	1.30	0.80	0.43	1000-1300	4
6/23	6/28	11	2.80	0.70	0.37	0800-1100	4
[b] 6/23	6/28	6	2.50	1.30	0.87	0600-0900	9
[b] 6/24	6/28	6	3.40	1.30	0.77	0600-0900	
6/24	6/28	9	1.10	0.60	0.37	0700-1000	3
----------Survey III - 6/26 to 6/28----------							
7/28	7/18	3	1.70	0.40	0.30	1000-1300	5
7/28	7/18	9	1.50	0.80	0.60	1100-1400	6
----------Survey IV - 7/18 to 6/28----------							
7/28	7/30	3	3.10	1.80	0.87	0800-1100	17
7/28	7/30	6	1.40	0.70	0.37	0700-1000	7
7/28	7/30	9	3.70	1.00	0.47	0800-1100	10
8/20	8/27	3	4.60	2.10	1.03	0800-1100	16
8/20	8/27	6	3.20	1.80	0.76	0600-0900	3
8/20	8/27	9	2.90	0.90	0.63	0800-1100	5
[b] 8/9	8/27	10	4.70	0.60	0.20	1300-1600	2
[b] 8/20	8/27	10	3.10	1.70	0.83	0600-0900	
8/20	8/27	11	3.70	1.60	0.60	0600-0900	1
----------Survey V - 8/27 to 8/29----------							

a. Only occurrences between 0600 and 1800 hours were considered. Dates and times given describe the occurrence of the designated maximum 3-h average.

b. For each of these occurrences, two dates are given since maximum peak SO_2 concentrations occurred on separate days from maximum 1-h average and 3-h average concentrations. In all cases effects to vegetation were assumed to have occurred on the date of the maximum 3-h average.

Table 8

SUMMARY OF HIGH SO_2 CONCENTRATIONS REGISTERED BY SIX THOMAS AUTOMETERS IN THE VICINITY OF WIDOWS CREEK STEAM PLANT - 1973 GROWING SEASON

	Autometer Number					
	3	6	8	9	10	11
Location Relative to Steam Plant						
Distance (mi)	2.5	2.2	7.0	2.2	2.0	2.1
Azimuth (degrees)	125	145	54	117	91	153
SO_2 Concentration (No. of Occurrences)[a]						
Peak ≥1.00 ppm	28	30	8	23	18	14
1-h avg ≥0.50 ppm	17	18	3	19	9	7
3-h avg ≥0.50 ppm	3	4	0	4	1	1
Hours Lost Record	87	220	58	96	17	144
% Time Lost Record	4	10	3	4	1	7
Maximum Concentrations Registered[b]						
SO_2 Concentrations (ppm)						
Peak	4.60	3.20	1.30	3.70	4.70	3.70
1-h avg	2.10	1.80	0.80	1.00	1.70	1.60
3-h avg	1.03	0.76	0.43	0.63	0.83	0.50
Minimum Concentrations at Which Necrosis Observed[b]						
SO_2 Concentrations (ppm)						
Peak	1.10	1.10	1.30	1.50	0.80	2.80
1-h avg	0.60	0.60	0.80	0.30	0.30	0.70
3-h avg	0.20	0.43	0.43	0.23	0.20	0.37

a. Number of 1-h (or 3-h) intervals between 6 a.m. and 6 p.m. when these concentrations were equalled or exceeded.

b. Between 6 a.m. and 6 p.m.

Table 9

FREQUENCY AND DURATION OF SO_2 REGISTRATIONS BY SIX THOMAS AUTOMETERS IN THE VICINITY OF WIDOWS CREEK STEAM PLANT - 1973 GROWING SEASON[a]

Number of SO_2 Registrations[b]	Autometer Number					
	3	6	8	9	10	11
Days	57	94	76	69	83	60
% days	31	51	41	38	45	33
Hours	220	221	194	261	278	219
% hours	10	11	9	12	13	11
Number of exposure intervals[c]	82	95	95	106	127	94
Avg duration of exposure[c] (hours)	2.7	2.3	2.0	2.5	2.2	2.3
Maximum duration of exposure[d] (hours)	11	10	6	10	8	9

a. Growing season, April 1-September 30.
b. Only registrations occurring between 6 a.m. and 6 p.m. were considered.
c. Exposure intervals ranged from 1 h to 12 h in length.
d. Out of a possible 12 daylight hours.

season. On the average, a measurable level of SO_2 occurred on approximately 40% of the days and during 11% of the daylight hours at these six autometers. The maximum duration of SO_2 exposure during daylight hours ranged from 6 h at autometer 8 to 11 h at autometer 3, while the average duration of each exposure was considerably less, ranging from 2.0 h at autometer 8 to 2.7 h at autometer 3. Although foliar necrosis of vegetation typically occurs immediately after exposure of plants to high SO_2 concentrations, it is possible that plants on Sand Mountain may be sensitized to these high exposure levels by more frequent exposure to relatively lower levels of SO_2. Foliar necrosis of the plants following SO_2 exposure has been related to the rate at which plants can detoxify the incoming pollutant by converting it to SO_4. Necrosis is thought to ensue when the detoxification capability is exceeded. Repeated exposure to low levels of SO_2 may saturate the detoxification system and lower the threshold concentration for the production of necrosis by subsequent higher SO_2 concentrations.

Complaints Investigated During the 1973 Growing Season

Five complaints of alleged SO_2 injury to vegetation were registered by residents of Sand Mountain during the 1973 growing season. Three of these involved vegetable crops grown in private gardens and two involved field crops.

On July 26, the gardens of both Andrew Hicks and John W. Harden were visited to determine the cause of foliar abnormalities observed on vegetable crops. The foliar necrosis of pole beans, sweet peas, and cucumbers observed in Mr. Hicks' one-half-acre garden, approximately 5.5 mi northeast of the plant, did not resemble SO_2 effects, and sensitive indicator species in the area showed no evidence of recent foliar necrosis. The root systems of several plants showed evidence of damage by soil-borne organisms, however, and Mr. Hicks was advised that SO_2 probably did not cause the observed symptoms.

Mr. Harden's one-half-acre garden, located approximately 5 mi south of the plant, was visited next. Although there was some light foliar necrosis of indicator species in the area, the severe marginal and interveinal necrosis and chlorosis observed primarily on pole beans, October beans, and peanuts did not closely resemble symptoms typically produced by SO_2 exposure. Foliage on pumpkin and grape vines, two species that are normally sensitive

to SO_2, was unaffected. Mr. Harden was advised that, although SO_2 could not be eliminated entirely as a causal agent, the symptoms observed in his garden were probably caused by either nutritional deficiency in the soil or drift of defoliants possibly used during harvest of nearby potato fields. Soil samples from Mr. Harden's garden were collected for analysis and results will be reported to him when they are obtained.

On July 31, an investigation was made of a 1-acre vegetable garden owned by John Sims and a 60-acre hay field belonging to John Little. Both Mr. Sims' garden and Mr. Little's hayfield were located on Sand Mountain approximately 2.5 mi southeast of the plant in an area that was exposed to very high SO_2 concentrations on July 28. On that date, peak, 1-h avg, and 3-h avg SO_2 concentrations recorded at nearby autometer 3 were 3.10 ppm, 1.80 ppm, and 0.87 ppm respectively. Foliar necrosis attributable to SO_2 was found on peas, beans, okra, corn, and tomatoes in Mr. Sims' garden, sericea and Korean lespedeza in Mr. Little's hayfield, and on numerous other herbs and shrubs in the area. Mr. Sims was told that since most of the affected species were immature they should show considerable recovery from the episode. Yields in his garden were not expected to be large, however, because of weediness and poor cultural practices. Mr. Little's hayfield, which exhibited approximately 30% foliar necrosis, may well have sustained some yield loss since it had not attained full height for harvest. His main concern was about any adverse effects on his cattle if they ate the hay, and he was assured that the hay would still be edible.

The fifth complaint was registered by J. V. Buckner following the appearance of foliar necrosis and chlorosis of seven soybean fields totalling 53 acres. The effects had first been noticed by Mr. Buckner on August 22 and were probably produced by a high-level exposure occurring on August 20 when five autometers between his fields and the steam plant registered SO_2 concentrations in excess of the secondary ambient air quality standard (0.50 ppm - 3-h avg).

Mr. Buckner's fields were located approximately 7 mi south-southeast of the steam plant and were within an area in which widespread air pollution effects had been detected during a survey on August 27-29. The fields were visited on September 3, and foliar symptoms, including both necrosis and chlorosis that were typical of those caused by SO_2, were estimated at from 6 to 10 data points within each field. Samples of foliage and soil were also taken from each field to document the degree of effects and the level of soil fertility and soil acidity.

Estimates of foliar necrosis and chlorosis averaged 1% and 35%, respectively, for these seven fields. At the time the fields were affected, they had just begun flowering and were badly in need of rainfall. The fields were examined 1 month later after they had received adequate rainfall and appeared to be growing well; however, it was not possible to determine whether yields had been reduced by the SO_2 exposure without conducting an extensive field investigation.

Emission Limitation During the 1973 Growing Season

In the emission limitation program in use at Widows Creek, reliance is placed on both predicted and measured meteorological conditions in the area as a basis for initiation of operational controls to limit SO_2 emissions. When analysis of weather charts indicates that adverse atmospheric conditions will be present in the Widows Creek area, the Air Quality Branch requests that low-sulfur coal (approximately 0.9% sulfur) be fired in units 1-6 on the following day. In addition, when meteorological parameters measured during airplane flights in the area on any given day indicate that a prolonged period of high groundline concentrations will ensue, load reductions are requested for that day. The system relies on a computer-analyzed dispersion model into which meteorological parameters and the current operating loads are inserted to determine the amount of load reduction required to avoid exceeding the national secondary ambient air quality standard at groundline on Sand Mountain.

Operational controls were initiated on a total of 17 days at Widows Creek during the 1973 growing season. Of this total, there were 13 days when controls were implemented by burning low-sulfur coal in from 3 to 6 of the smaller units and 4 days when load reductions ranging from 14 to 440 MW were implemented. This represented an increase from the 10 days of operational controls during the 1972 growing season when a load reduction was implemented on only 1 day. The dates, methods of control, and maximum SO_2 concentrations recorded by the autometer network on Sand Mountain for both 1972 and 1973 are shown in Appendix E.

During the 1973 growing season, peak SO_2 concentrations $\geq$1.00 ppm occurred on 4 of the 17 days during which operational controls were in effect; 1-h avg and 3-h avg SO_2 concentrations $\geq$0.50 ppm occurred on 5 days and 2 days, respectively, during the same interval. The highest SO_2 concentrations recorded while the plant was under operational controls occurred on June 23 and June 24 when low-sulfur coal was being burned in units 1-5; 3-h avg SO_2 concentrations of 0.87 ppm and 0.77 ppm were registered at autometer 6 on these two days, which were the only two days when the national secondary air quality standard was exceeded with operational controls in effect. Heavy morning fog on both days prevented airplane flights from being made in time to identify the meteorological conditions that contributed to the period of high SO_2 concentrations that ensued.

There were only two occasions during the 1973 growing season when vegetation appeared to have been affected by SO_2 while operational controls were in effect. Effects detected on vegetation at autometers 3 and 9 during the survey on May 24 are thought to have occurred on May 9, a day when a 177-MW load reduction was implemented. Foliar effects were also detected within an area of approximately 1,500 acres around autometers 6 and 9 following occurrence of the high SO_2 concentrations recorded there on June 23 and 24. Low-sulfur coal was burned in units 1-5 on both of these days.

It is difficult to evaluate the effectiveness of the operational control program during the 1973 season since the concentrations of SO_2 that might have occurred in the absence of controls are not known; however, there were seven days when controls were in effect when 1-h avg concentrations registered were very close to the approximate threshold for foliar necrosis of sensitive vegetation (1-h avg $\geq$0.30 ppm). SO_2 effects might have occurred on vegetation in the area on some of these days if operational controls had not been in effect.

Discussion

During the 1973 growing season air pollution effects in the vicinity of Widows Creek Steam Plant were extensive in both terms of land area affected (47,660 acres) and diversity of species (72) exhibiting foliar necrosis. Although 34 species of potential economic importance in the area were affected by air pollution, there were only seven species (Virginia pine, loblolly pine, yellow poplar, shortleaf pine, soybeans, sericea, and Korean lespedeza) that were affected over extensive acreages. Yellow poplar was affected over most of the 12,000 acres found during the first survey, while extensive needle tip necrosis of all three pine species was noted during the third, fourth, and fifth surveys. Foliar necrosis was found on approximately 85 acres of soybeans and 60 acres of sericea and Korean lespedeza hay during the last survey.

Necrosis of the pines was confined mainly to immature needles, but was more severe and more uniformly distributed throughout the area than that found on any other species. Pines in several areas on Sand Mountain may have experienced a growth loss during the past year as a result of the needle tip necrosis noted during surveys 3, 4, and 5. In studies near a smelter at Trail, British Columbia, in 1929 and 1930[1], growth reduction of lodgepole pine, ponderosa pine, and douglas fir was detected in association with needle necrosis, which extended as far as 15 mi from the smelter. Growth reduction was also detectable to a lesser degree in the absence of foliar necrosis out to a maximum distance of 39 mi from the smelter. At Widows Creek necrosis was most pronounced in the area extending from 5.0 to 11.5 mi northeast of the plant and in the area 2 to 5 mi southeast of the plant, which was affected repeatedly throughout the growing season (see figure 4).

One significant finding during the past year was the detection of both necrosis and chlorosis on soybeans in several fields. Because of its high cash return, this crop is becoming increasingly important, and soybean acreages in the area were noticeably larger in 1973 than in previous years. Both chlorosis and necrosis of soybeans were detected during the third survey; however, the most extensive effects on

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1. "The Effects of Sulfur Dioxide on Diameter Increment of Conifers" by F. E. Lathe and A. W. McCollum. In: The Effect of Sulfur Dioxide on Vegetation, 447 pp. National Research Council of Canada, Ottawa, Canada, 1939.

this crop were found during the last survey of the season when approximately 85 acres (predominantly Bragg variety) exhibited foliar necrosis and chlorosis, and an additional 130 acres exhibited chlorosis only. It was not possible to determine the effect that these symptoms may have had on yields of these fields without conducting an extensive field study. Plants were already under stress from three weeks of drought at the time they were examined and would not have been expected to obtain maximum yields anyway. They did show considerable vegetative growth three weeks later after experiencing a needed rain; however, chlorotic leaves were still evident at that time and comprised about 30% of the foliage area of these plants. Soybeans can be expected to be an increasingly important crop in the Widows Creek area in the future and, because of high sensitivity to SO_2, may experience even more extensive air pollution effects.

Another significant finding during the past year was the repeated occurrence of levels of SO_2 high enough to affect vegetation around autometers. The 22 data points established at autometers during the 1973 season were helpful in establishing an approximate threshold level for SO_2 effects in the area. A list of 84 species affected at these 22 points and at 9 additional points established during the previous three years is presented in Appendix F. A summary of these data is included in table 10, which shows the number of affected trees, shrubs, herbs, and vines for which necrosis-producing SO_2 concentrations have been documented during the past four years. From this table it can be seen that necrosis has not occurred below peak concentrations of 0.50 ppm, 1-h avg concentrations of 0.25 ppm, and 3-h avg concentrations of 0.10 ppm. For most species, necrosis has not occurred below peak, 1-h avg, and 3-h avg SO_2 concentrations of 1.00 ppm, 0.50 ppm, and 0.20 ppm respectively.

Since surveys have been conducted at Widows Creek, air pollution effects have been detected on a total of 196 plant species in the area. A list of the common names, scientific names, and the number of years during which effects have been noted on each species is included in Appendix G. The list includes 51 species of trees, 20 species of shrubs, 15 species of vines, and 110 herbaceous species. In addition, 23 species have been found in areas in which other species have been affected but have never been affected themselves. Common and scientific names for

Table 10

CONCENTRATIONS OF SO_2 ASSOCIATED WITH FOLIAR NECROSIS OF EIGHTY-FOUR PLANT SPECIES FOUND IN THE VICINITY OF WIDOWS CREEK STEAM PLANT - 1970-1973 GROWING SEASONS

Concentrations of SO_2 (ppm) at or below Which Necrosis Was Detected	Number of Plant Species Affected				
	Trees	Shrubs	Herbs	Vines	Total
Peak					
0.50	0	0	0	0	0
1.00	0	0	2	2	4
1.50	6	1	25	2	34
2.00	9	2	34	4	49
3.00	17	7	39	5	68
4.00	22	7	45	5	79
5.00	23	9	47	5	84
1-h Avg					
0.25	0	0	0	0	0
0.50	4	1	5	0	10
0.75	7	1	19	2	29
1.00	8	3	23	4	38
1.50	17	6	38	4	65
2.00	22	7	44	4	77
2.50	22	7	46	4	79
3.00	22	8	47	4	81
3.50	23	9	47	5	84
3-h Avg					
0.10	0	0	0	0	0
0.20	0	0	2	0	2
0.30	5	1	7	0	13
0.40	7	1	11	0	19
0.50	7	1	21	4	33
0.75	17	6	31	4	58
1.00	17	7	38	4	66
1.25	22	7	46	4	79
1.75	22	7	46	4	79
2.25	22	8	47	4	81
2.75	22	8	47	4	81
3.25	23	9	47	5	84