1980 MONITORING OF COOLING TOWER OPERATIONAL EFFECTS ON VEGETATION IN THE VICINITY OF THE THREE MILE ISLAND NUCLEAR STATION

PREPARED FOR

METROPOLITAN EDISON COMPANY

8104010421

1980 MONITORING OF COOLING TOWER OPERATIONAL EFFECTS ON VEGETATION IN THE VICINITY OF THE THREE MILE ISLAND NUCLEAR STATION

PREPARED FOR

METROPOLITAN EDISON COMPANY

BY

ENVIRONMENTAL SERVICES DIVISION
NUS CORPORATION

CLIENT NO. 3521

JANUARY 1981

APPROVED BY:

G. P. FRIDAY, Ph.D.
MANAGER, TERRESTRIAL
ECOSYSTEMS DEPARTMENT

B. C. MARCY, JR.
MANAGER, PITTSBURGH OFFICE
ENVIRONMENTAL SERVICES DIVISION

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

NUS Corporation was contracted by Metropolitan Edison Company to monitor the vegetation in the vicinity of Three Mile Island Nuclear Station (TMINS) as part of the environmental technical specifications for TMI-2 issued by the Nuclear Regulatory Commission. This monitoring program, which was initiated in 1977 and scheduled for completion in 1982, was designed to detect and assess the significance of damage (or lack thereof) to vegetative communities resulting from the deposition of cooling tower drift. The following report presents the results of the monitoring program, and summarizes the principal findings and conclusions concerning vegetative stress in the vicinity of TMINS during 1980.

METHODS

Vegetation in the vicinity of TMINS was photographed from an altitude of 3000 feet above ground level on 25 July 1980 with color infrared and color negative film. Flight logs of each photomission are given in Tables 1 and 2. Flight lines were flown in a north-south direction and are shown in Figure 1. With the exception of film type, lens filter, and temporal aspects, photographic equipment and technique for each annual photomission were identical.

Following development of the film, clear acetate was positioned over 9x9 inch color prints. Each print was subsequently examined with a hand lens and stereoscope, and areas of apparent vegetative stress were delineated with ink. Ground truthing of these potential stress areas was performed from predetermined aquatic (island) and terrestrial (mainland) sampling transects (Figure 2) on 17 and 18 September by G. P. Friday and T.R. Rojahn of NUS Corporation, and T. R. Teitt and L. F. Toke of General Public Utilities. It should be noted that the point observations shown in Figure 2 represent sampling points taken in 1977; only the terrestrial and aquatic transects, however, were traversed in the 1980 sampling program. Representative samples of stressed vegetation were collected, pressed, and causal agents identified. Other field procedures included: (1) the examination of potential salt-stress indicator species for visible injury symptoms, (2) description and identification of existing environmental factors which could influence or cause stress symptoms, and (3) identification of species affected by stress symptoms. These data and other pertinent information were recorded on cassette tape, transcribed, and submitted separately from this report as required by the contract. Taxonomic identification of causal stress agents was confirmed by the Department of Botany and Plant Pathology, Michigan State University (Perry 1980).

RESULTS AND DISCUSSION

Structural and Operational Features of TMINS Cooling Towers

The Three Mile Island Nuclear Station (TMINS) contains four 370 foot high hyperbolic natural draft cooling towers - two for TMI-1 and two for TMI-2. The purpose of these structures is to dissipate condenser heat. In addition, two 3-cell wet mechanical draft towers (one for each unit) are used to cool the combined service water effluent and blowdown from the natural draft cooling towers. One potential problematic result of natural draft cooling tower operation is the deposition of drift constituents (salt particles) on the surrounding biota. In order to control the pH and biological slimes (algae), sulfuric acid and chlorine are added to the circulating cooling water. Thus, blowdown from the towers contain salts of sulfur and chlorine, and miscellaneous (Na, K, P) salts that occur naturally in the river make-up water (USAEC 1972).

Both cooling towers for TMI-1 were not in operation during 1980; for TMI-2, only one natural draft tower was in operation (at approximately 50% capacity). These reduced operations represent a markedly significant decrease in vapor emissions during 1980 as compared to normal operational mode (personal communication, T. R. Teitt and G. P. Friday, 4 December 1980).

Effects of Cooling Tower Operation on Vegetation

The operation of wet cooling towers has the potential to cause adverse impacts to the terrestrial environment through the effects of fogging, icing, and salt drift. Salt drift can be especially problematic at certain levels by adding an increased chemical load to the vegetation (via foliar uptake) in the vicinity of the cooling towers and by increasing leaching of soil cations (bases) by excess anions (Rochow 1978). Because a large number of variables affect the severity of this impact, cooling tower effect must be evaluated individually for each power plant. Variables include weather, climate, salt drift, station design, time of year, distribution of the vegetation, soil conditions, land use practices, and others.

Distribution of Vegetation in the Vicinity of TMINS

For this program, major types of forest cover in the vicinity of TMINS were initially mapped, and relative abundances of the principal species were estimated in 1977 (NUS 1978) from predetermined sampling transects (Figure 2). Because the structure and productivity of woody plant communities varies relatively little during a five year period, it is reasonable to assume that these 1977 data (Tables 3-18) reflect existing flora.

The distribution of vegetation in the vicinity of the TMINS is shown in Figure 3. Major categories of vegetation/land use include urban, cropland, pasture and abandoned cropland, shrubland, forest land, wetland, and water.

Riparian shrubland was dominated by white ash; other abundant associates included honey locust, dogwood, American elm, black oak, silver maple, sycamore, and river birch (Table 3). Common vascular flora were poison ivy and fringed loosestrife.

Forest land at the southern end of Three Mile Island was dominated by black locust in both the canopy and understory strata (Table 4). Silver maple, red oak, and black locust were the most abundant canopy species observed on the western shore (Table 5). Midslope forest stands characteristically contained black oak, white oak, chestnut oak, ironwood, flowering dogwood, yellow poplar, black locust, various hickories and oaks, white ash and red maple (Tables 7 and 8). Black locust, tree-of-heaven, and black cherry were typical successional species of seral forests (Table 9).

A total of 42 species of plants was compiled from a representative old field (Table 10). Species presence is commonly more variable from year to year in old fields due to climatic conditions, composition and structure of adjacent habitats, and history of land utilization.

Agricultural lands included active cropland, pasture, and abandoned cropland. Major crops include corn, tobacco, wheat, and alfalfa. Small vegetable gardens and orchards exist in some areas. Grazed and mowed pastures containing grasses and shrubs occurred throughout the area. Abandoned fields also were common. Wetland habitat at the southern extremity of Three Mile Island was classified as intermittent riverine with a rock bottom (Cowardin et al. 1979). Because of the extremely gradual elevational gradient, a slight increase in the water level of the Susquehanna River will inundate this area. It is therefore transitional and characterized by a mosaic of hydrophytic vegetation interspersed among large boulders.

Causes and Symptoms of Salt Stress

Although the effects of salt are due to its ions, Levitt (1980) recognizes two types of stress: (1) salt stress - occurs where the salt concentration is high enough to lower the water potential appreciably (0.5-1.0 bar), and (2) ion stress - occurs where the salt (acid or base) concentration is not high enough to lower the water potential appreciably. Only the former category will be addressed in this report.

Vegetative stress from salt can result by direct deposition of salts on the foliage or indirectly from excess accumulation of salts in the soil (Shipley et al. 1980). Drift impact to area soils is not expected to be detrimental because of adequate rainfall, good soil permeability, and designed low drift rate (Met. Ed. Co. et al. 1975). Stress due to direct deposition is highly influenced by available moisture. For example, dew is more detrimental (via stomata absorption) than is a heavy rain (i.e. cleansing effect). Mechanisms by which salt stress in plants may occur include: (1) increased osmotic potential which will reduce the availability of water to plants, (2) alteration of mineral nutritional balance in plant tissue, and/or (3) toxic effects due to specific ion concentrations in the plants (Bernstein 1975, Hanes 1970, and Allison 1964).

Symptoms of salt stress may also vary considerably due to length of exposure, concentration, environmental conditions, plant genetics, and many other factors. Typical symptoms include: (1) general reduction in growth, (2) marginal necrosis (browning) of leaves, (3) premature senescence (followed by premature leaf drop), (4) twig die back, (5) chlorosis (yellowing) of leaves, and (6) plant mortality.

Vegetative Stress Observed in the Vicinity of TMINS

Color infrared photography revealed several areas of vegetative stress that were present in the fall of 1980 (Figure 4). These areas appeared as scattered patches of brownish-colored crowns on the photographs, and occurred relatively uniformly in forested areas on each side of the river. Hill Island and the southern portion of Three Mile Island contained the most extensive areas of stress as measured by infrared imagery.

Locust Leaf Miner

Examination of stressed areas revealed that the affected species was black locust, and the causal agent was the locust leaf miner (Xenochalepus dorsalis). Black locust, a legume, grows rapidly in disturbed (e.g. logged, mined, etc.) areas and may dominate other hardwoods in early seral stages of forest development. In the vicinity of TMINS, black locust was a principal canopy dominant, and in some areas nearly pure (greater than 90%) stands existed.

The adult leaf miner is a beetle approximately 6 mm long that hibernates in the winter. In the spring, the adults emerge and begin feeding on the developing foliage. In addition to locust, adults will attack dogwood, elm, oak, beech, cherry, wisteria, and even hawthorn (Johnson and Lyon 1976). After hatching from eggs deposited on the underside of leaves, the emerging larvae eat into the inner layer of leaf tissue, forming a mine. The larvae, which will consume only black locust, may eventually affect the entire leaflet.

When stands of black locust are attacked they appear "burned" or brownish as though dead, but late summer defoliation is not very harmful (Hepting 1971). Outbreaks of locust leaf miner occur practically every year, and tens of thousands of acres in the United States are often defoliated (Baker 1972).

A comparison of the distribution of locust leaf miner from 1977-1980 (NUS 1978, 1978a, 1980) indicated that this insect has been the prevalent agent of vegetative stress in the vicinity of TMINS. On the eastern and western shores of the Susquehanna River, the intensity and distribution of infestation has varied slightly each year. However, the southern portion of Three Mile Island has consistently been affected each year both in terms of areal extent and pattern. Despite this reoccurrence, significant crown mortality has not occurred.

Fall Webworm

The second most frequently observed causal agent of vegetative stress in the vicinity of TMINS was the fall webworm (Hyphantria cunea). This lepidopteran occurs throughout most of the United States and Canada and consists of a blackheaded and a redheaded race. Females of both races deposit their eggs as single large masses in spring. The emerging larvae then pass through as many as 11 stages of development. They spin silk webs over the foliage and skeletonize the leaves as they feed. It is at these larval stages that defoliation of host trees or shrubs occurs. Adults are small white moths (Borror and White 1970). Damage is of minor importance in forestry, but infestation in ornamental plantings sometimes affect esthetic values enough to warrant control (Baker 1972). Woven nets of the fall webworm were common in the study area, and black cherry was particularly infested in several areas.

Other Vegetative Stresses

Other causes of vegetative stress include innumerable pathogens associated with bacteria, viruses, fungi, and insects. Insects that cause non-pathogenic injury alone are countless. Perhaps one of the most frequently observed causes of miscellaneous stress observed in the study area was anthracnose. Anthracnose is a general term used to describe leaf spots caused by a Gloeosporium or Colletotrichum (Gnomonia or Glomerella) fungus (Westcott 1971). These fungi are most active during wet springs and often cause leaf spotting and premature defoliation. Under normal circumstances, anthracnose is only a minor problem because spring weather conditions necessary for infection to occur are seldom consistent from year to year (Personal communication, letter dated 11 November 1980 from S. Perry to G. P. Friday). Plant species that were affected by anthracnose included hickory, black walnut, box elder (Cylindrosporium negundinis), ash (Gloeosporium aridium), and tree-of-heaven (Gloesporium ailanthi).

One large yellow poplar was observed affected with powdery mildew (Oidium sp.), a very common summertime disease in moist shaded areas having restricted air movement. Numerous occurrences of stress to elm were also located. Leaves were typically characterized by large necrotic leaf spots caused by a fungus (Phyllostica sp.).

Other miscellaneous causes of vegetative stress or mortality were insects, structural damage from ice, lightening, or wind throw. One isolated instance of nicrotic flecking on a tree-of-heaven suggested stress due to air pollution or toxic chemical uptake, but widespread symptoms such as these were not observed in the area. Mortality of mature trees along the river was due to bank erosion. In several places, over half of the roots were exposed. Ice damage was most evident on Shelly Island, an area west of the cooling towers. Because this area is outside the principal drift area and due to reduced emissions during 1980, this structural damage is not related to cooling tower operation.

Conclusions

None of the causes of vegetative stress identified in the vicinity of the TMINS were attributable to the operation of the cooling towers. Compared to earlier studies, no new forms of stress were identified. The principal causal agents of vegetative stress were arthropods, particularly the locust leaf miner and fall webworm. Miscellaneous causes of stress were anthracnose, mildew, and other insects. These stress agents are not considered unique or out of the ordinary, and will probably be present in the future.

Chlorosis or necrosis of leaves due to salt accumulation was not observed, nor was there any evidence of abnormal salt loading upon local vegetation. The degree of stress to black locust is perhaps reflected by its abundance in the area. It is important to note that only one cooling tower was operable during 1980, and this was at only 50% capacity. Given this markedly significant decrease in vapor emissions, and following the examination of infrared photography and plant analyses, it is concluded that the forms of stress observed were attributable to natural causes, and are unrelated to cooling tower operation.

SUMMARY

Vegetative stress in the vicinity of the Three Mile Island Nuclear Station has been monitored since 1977 using color infrared imagery. Remote sensing of the TMINS in 1980 was performed 25 July, followed by ground reconnaissance and systematic sampling of vegetation. Operation of the cooling towers during 1980 was restricted to one tower which operated at approximately 50% capacity.

The major causes of vegetative stress were the locust leaf miner and fall webworm. Other stress agents included other insects, anthracnose, mildew, ice, windthrow, and erosion. Symptoms associated with salt stress such as chlorosis or necrosis were not observed, nor were any conditions of salt damage detected. Based on the examination of infrared photography and analyses of stressed vegetation, it was concluded that resulting conditions were attributable to natural causes, and were unrelated to cooling tower operation.

LITERATURE CITED

Allison, L. E. 1964. Salinity in relation to irrigation. Advances in Agronomy 16:139-180.

Baker, W. L. 1972. Eastern forest insects. USDA Forest Service Misc. Pub.. No. 1175. 642 pp.

Bernstein, L. 1975. Effects of salinity and sodicity on plant growth. Annual Review Photopathology 13:295-312.

Borror, D. J. and R. E. White. 1970. A field guide to the insects of America north of Mexico. Houghton Mifflin Co., Boston. 404 pp.

Cowardin, L. M., V. Carter, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. Fish and Wildlife Service, USDI. Washington, D.C. 103 pp.

Hanes, R. E., L. W. Zelazyn, and R. E. Blaser. 1970. Effects of deicing salts on water quality and biota. Natl. Coop. Highway Res. Prog. Rep. 91, Highway Research Board, NAS, Washington, D.C. 70 pp.

Hepting, G. H. 1971. Diseases of forest and shade trees of the United States. USDA Forest Service Handbook No. 386, Washington, D.C. 685 pp.

Johnson, W. T. and H. H. Lyon. 1976. Insects that feed on trees and shrubs. Comstock Publishing Associates, Ithaca. 464 pp.

Levitt, J. 1980. Responses of plants to environmental stress. Vol. II, Academic Press. 606 pp.

Metropolitan Edison Company, Jersey Central Power and Light Company, and Pennsylvania Electric Company. 1975. Supplement II Environmental Report Operating License Stage - Unit 2 Three Mile Island Nuclear Station.

NUS Corporation. 1978. 1977 Monitoring of cooling tower operational effects on vegetation in the vicinity of the Three Mile Island Nuclear Station. Annual Report. 22 pp.

NUS Corporation. 1978a. 1978 Monitoring of cooling tower operational effects on vegetation in the vicinity of the Three Mile Island Nuclear Station. Annual Report. 36 pp.

NUS Corporation. 1980. 1979 Monitoring of cooling tower operational effects on vegetation in the vicinity of the Three Mile Island Nuclear Station. Annual Report. 28 pp.

Perry, S. 1980. Letter to G. P. Friday dated September 11.

Rochow, J. J. 1978. Compositional, structural, and chemical changes to forest vegetation from fresh water cooling tower drift. In: Proceedings of Cooling Tower Environment - 1978, pp. 11-18.

Shipley, B. L., S. B. Pahwa, M. D. Thompson, and R. B. Lantz. 1980. Remote sensing for detection and monitoring of salt stress on vegetation: evaluation and guidelines. USNRC, Wahington, D.C. 92 pp.

United States Atomic Energy Commission. 1972. Final environmental statement related to operation of Three Mile Island Nuclear Station Units 1 and 2. Docket Nos. 50-289 and 50-320.

Westcott, Cynthia. 1971. Plant disease handbook. Van Nostrand Reinhold Company, New York. 843 pp.

TABLE 1

PHOTOMISSION FLIGHT LOG
(Aerocolor Negative Film)

Camera	Zeiss Jena MRB 15/2323 (#247136)
Magazine	#246436
Lens	#7370200
Camera Focal Length	151.76
Filter	KLR
Film	Kodak Type 2445 Aerocolor Neg.
Altitude	3000 ft.
Scale	1" - 500' (1:6000)
Shutter Speed	1/300+
f-Stop	5.6
Date	25 July 1980
Time	11:22 AM to 12:01 PM, EDT

Flight Line	Direction	Exposure No.	Time	
			Start	Finish
1	S	98-105	11:22	11:23
2	N	106-113	11:26	11:28
3	S	114-121	11:32	11:33
4	N	122-129	11:38	11:40
5	S	130-138	11:43	11:45
6	N	139-146	11:49	11:50
7	N	147-155	11:50	12:01

TABLE 2

PHOTOMISSION FLIGHT LOG
(Aerocolor IR Film)

Camera	Zeiss Jena MRB 15/2323 (#247136)
Magazine	#246436
Lens	#247136
Camera Focal Length	151.75
Filter	MB
Film	Kodak Type 2443 Aerocolor IR
Altitude	3000 ft.
Scale	1" - 500' (1:6000)
Shutter Speed	1/300+
f-Stop	5.6
Date	25 July 1980
Time	1:00 PM to 1:31 PM, EDT

Flight Line	Direction	Exposure No.	Time Start	Time Finish
1	S	84-97	1:00	1:02
2	N	69-83	1:04	1:06
3	S	55-68	1:09	1:11
4	N	41-54	1:14	1:15
5	S	28-40	1:19	1:21
6	N	15-27	1:24	1:26
7	S	01-14	1:29	1:31

TABLE 3

RELATIVE ABUNDANCE OF PLANT SPECIES OBSERVED IN
RIPARIAN SHRUB LAND
OCTOBER 1977
(FIGURE 2, POINT OBSERVATION P10)

Scientific Name	Colloquial Name	Relative Abundance[(a)]
	Shrub Stratum	
Fraxinus americana	White ash	5
Gleditsia triacanthos	Honey locust	3
Cornus stolonifera	Red osier dogwood	3
Ulmus americana	American elm	3
Quercus velutina	Black oak	3
Acer saccharinum	Silver maple	3
Platanus occidentalis	Sycamore	3
Betula nigra	River-birch	3
Salix sp.	Willow	2
Quercus alba	White oak	2
Carya ovata	Shellbark hickory	2
Fraxinus pennsylvanica	Green ash	2
	Ground Stratum	
Lysimachia ciliata	Fringed loosestrife	5
Rhus radicans	Poison ivy	5
Verbesina alternifolia	Wingstem	4
Hordeum sp.	Barley	3
Polygonum hydropiperoides	Mild water-pepper	3
Helianthus spp.	Sunflower	3
Panicum sp.	Panic-grass	3
Aster lateriflorus	Calico aster	3
Hibiscus sp.	Rose-mallow	3
Ambrosia trifida	Giant ragweed	2
Hypericum sp.	St. John's-wort	2
Vitis sp.	Wild grape	2
Smilax sp.	Smilax	2

(a) Key: 1 - Very infrequent; 2 - infrequent; 3 - common; 4 - frequent; 5 - very frequent

TABLE 4

RELATIVE ABUNDANCE OF PLANT SPECIES OBSERVED IN
A STREAM BORDER
SEPTEMBER 1977
(FIGURE 2, POINT OBSERVATION P2)

Scientific Name	Colloquial Name	Relative Abundance[(a)]
	Canopy/Subcanopy Stratum	
Robinia pseudoacacia	Black locust	5
Betula nigra	River birch	3
Sassafras albidum	Sassafras	3
Tilia americana	Basswood	3
Ulmus americana	American elm	3
Platanus occidentalis	Sycamore	3
Acer negundo	Box elder	2
Acer saccharinum	Silver maple	2
Liriodendron tulipifera	Yellow poplar	2
Prunus spp.	Wild cherry	2
	Shrub Stratum	
Robinia pseudoacacia	Black locust	4
Rhus radicans	Poison ivy	3
Betula nigra	River birch	3
Carya cordiformis	Bitternut hickory	2
Fraxinus americana	White ash	2
Tilia americana	Basswood	2
Acer negundo	Box elder	2
Prunus sp.	Wild cherry	2
Quercus velutina	Black oak	2
Fraxinus pennsylvanica	Green ash	2
Vitis sp.	Wild grape	2
Sassafras albidum	Sassafras	2
Viburnum sp.	Viburnum	2
	Ground Stratum	
Lonicera japonica	Japanese honeysuckle	5
Glecoma hederacea	Ground-ivy	4
Eupatorium rugosum	White snakeroot	3
Solidago altissima	Tall goldenrod	3
Teucrium sp.	Wood sage	3
Boehmeria cylindrica	False nettle	3
Urtica dioica	Stinging nettle	3
Polygonum scandens	False buckwheat	3

TABLE 4 (Continued)

Scientific Name	Colloquial Name	Relative Abundance[a]
	Ground Stratum	
Verbesina alternifolia	Wingstem	3
Oxalis sp.	Wood-sorrel	3
Betula nigra	River birch	2
Robinia pseudoacacia	Black locust	2
Rubus allegheniensis	Blackberry	2
Geum spp.	Avens	2
Verbena hastata	Blue vervain	2
Sassafras albidum	Sassafras	2
Ulmus americana	American elm	2
Hackelia virginiana	Beggar's lice	2
Phytolacca americana	Pokeweed	2
Fraxinus pennsylvanica	Green ash	2
Fraxinus americana	White ash	2
Viola spp.	Violet	2

[a] Key: 1 - Very infrequent; 2 - infrequent; 3 - common; 4 - frequent; 5 - very frequent

TABLE 5

RELATIVE ABUNDANCE OF PLANT SPECIES OBSERVED IN
A STREAM TERRACE FOREST
SEPTEMBER 1977
(FIGURE 2, POINT OBSERVATION P9)

Scientific Name	Colloquial Name	Relative Abundance[(a)]
	Canopy/Subcanopy Stratum	
Acer saccharinum	Silver maple	4
Quercus rubra	Northern red oak	3
Robinia pseudoacacia	Black locust	3
Fraxinus pennsylvanica	Green ash	2
Celtis occidentalis	Hackbery	2
	Shrub Stratum	
Acer rubrum	Red maple	2
Rhus radicans	Poison ivy	2
	Ground Stratum	
Glecoma hederacea	Ground-ivy	5
Solidago canadensis	Canada goldenrod	4
Aster sp.	Aster	4
Impatiens pallida	Touch-me-not	3
Rumex sp.	Dock	2
Eupatorium perfoliatum	Boneset	2
Verbesina alternifolia	Wingstem	2
Laportea canadensis	Wood-nettle	2
Oxalis sp.	Woodsorrel	2
Boehmeria cylindrica	False nettle	2
Pilea pumila	Clearweed	2
Asclepias sp.	Milkweed	2
Viola sp.	Violet	2
Rudbeckia sp.	Coneflower	2
Dactylis glomerata	Orchard grass	2
Tridens flava	Tall redtop	2

(a) Key: 1 - Very infrequent; 2 - infrequent; 3 - common; 4 - frequent; 5 - very frequent

TABLE 6

RELATIVE ABUNDANCE OF PLANT SPECIES OBSERVED IN A MIDSLOPE DISTURBED FOREST SEPTEMBER 1977 (FIGURE 2, POINT OBSERVATION P4)

Scientific Name	Colloquial Name	Relative Abundance[a]
	Canopy/Subcanopy Stratum	
Quercus velutina	Black oak	4
Quercus alba	White oak	3
Quercus prinus	Chestnut oak	3
Ostrya virginiana	Ironwood	3
Cornus florida	Flowering dogwood	3
Carya tomentosa	Mockernut hickory	3
Fraxinus americana	White ash	2
Carya glabra	Pignut hickory	2
Acer rubrum	Red maple	2
Prunus serotina	Black cherry	2
Quercus rubra	Northern red oak	2
Diospyros virginiana	Persimmon	2
	Shrub Stratum	
Viburnum sp.	Viburnum	4
Quercus velutina	Black oak	3
Cornus florida	Flowering dogwood	3
Fraxinus americana	White ash	3
Prunus serotina	Black cherry	3
Lindera benzoin	Spicebush	3
Quercus alba	White oak	2
Carya glabra	Pignut hickory	2
Quercus prinus	Chestnut oak	2
Acer rubrum	Red maple	2
Carya tomentosa	Mockernut hickory	2
Vaccinium vacillans	Lowbush blueberry	2
Amelanchier sp.	Serviceberry	2
Juniperus virginiana	Red cedar	2
Ulmus americana	American elm	2
Celtis americana	Hackberry	2
Nyssa sylvatica	Black gum	2

TABLE 6 (Continued)

Scientific Name	Colloquial Name	Relative Abundance[a]
	Ground Stratum	
Lonicera japonica	Japanese honeysuckle	3
Viola sp.	Violet	3
Eupatorium rugosum	White snakeroot	3
Prunus serotina	Black cherry	3
Fraxinus americana	White ash	3
Cornus florida	Flowering dogwood	3
Ostrya virginiana	Ironwood	2
Geum canadensis	Avens	2
Pilea pumila	Clearweed	2
Hedeoma sp.	Pennyroyal	2
Circaea canadensis var. quadrisulcata	Enchanters nightshade	2
Parthenocissus quinquefolia	Virginia creeper	2
Hackelia virginiana	Beggar's-lice	2

[a] Key: 1 - Very infrequent; 2 - infrequent; 3 - common; 4 - frequent; 5 - very frequent

TABLE 7

RELATIVE ABUNDANCE OF PLANT SPECIES OBSERVED IN
UPPER SLOPE FOREST
SEPTEMBER 1977
(FIGURE 2, POINT OBSERVATION P6)

Scientific Name	Colloquial Name	Relative Abundance[a]
	Canopy/Subcanopy Stratum	
Carya glabra	Pignut hickory	4
Quercus alba	White oak	3
Celtis occidentalis	Hackberry	3
Robinia pseudoacacia	Black locust	3
Fraxinus americana	White ash	3
Acer rubrum	Red maple	3
Cornus florida	Flowering dogwood	3
Carya tomentosa	Mockernut hickory	3
Liriodendron tulipifera	Yellow-poplar	3
Nyssa sylvatica	Black gum	2
Ailanthus altissima	Tree-of-heaven	2
Sassafras albidum	Sassafras	2
Populus grandidentata	Large-tooth aspen	2
Ulmus rubra	Red elm	2
Prunus serotina	Black cherry	2
Ulmus americana	American elm	2
	Shrub Stratum	
Lindera benzoin	Spice bush	4
Cornus florida	Flowering dogwood	4
Carya tomentosa	Mockernut hickory	3
Liriodendron tulipifera	Yellow-poplar	3
Celtis occidentalis	Hackberry	2
Nyssa sylvatica	Black gum	2
Fraxinus americana	White ash	2
Ailanthus altissima	Tree-of-heaven	2
Sassafras albidum	Sassafras	2
Ulmus rubra	Red elm	2
Ulmus americana	American elm	2
	Ground Stratum	
Lonicera japonica	Japanese honeysuckle	5
Parthenocissus quinquefolia	Virginia creeper	3
Fraxinus americana	White ash	3
Circaea quadrisulcata	Enchanter's nightshade	3

TABLE 7

Scientific Name	Colloquial Name	Relative Abundance[a]
	Ground Stratum	
Eupatorium rugosum	White snakeroot	3
Carya glabra	Pignut hickory	2
Rhus radicans	Poison ivy	2
Vitis sp.	Wild grape	2
Hackelia virginiana	Beggar's lice	2
Solidago rugosa	Rough-stemmed goldenrod	2
Impatiens biflora	Spotted touch-me-not	2

[a] Key: 1 - Very infrequent; 2 - infrequent; 3 - common; 4 - frequent; 5 - very frequent

TABLE 8

RELATIVE ABUNDANCE OF PLANT SPECIES OBSERVED IN A MIXED HARDWOODS COVE FOREST SEPTEMBER 1977 (FIGURE 2, POINT OBSERVATION P7)

Scientific Name	Colloquial Name	Relative Abundance[(a)]
	Canopy/Subcanopy Stratum	
Tsuga canadensis	Hemlock	4
Quercus prinus	Chestnut oak	4
Quercus rubra	Northern red oak	4
Cornus florida	Flowering dogwood	3
Quercus velutina	Black oak	3
Acer rubrum	Red maple	2
Sassafras albidum	Sassafras	2
Ostrya virginiana	Ironwood	2
Carpinus caroliniana	Blue beech	2
Quercus alba	White oak	2
	Shrub Stratum	
Cornus florida	Flowering dogwood	4
Lindera benzoin	Spicebush	3
Tsuga canadensis	Hemlock	3
Quercus prinus	Chestnut oak	3
Viburnum acerifolium	Maple-leaved viburnum	3
Quercus alba	White oak	2
Hamamelis virginiana	Witch hazel	2
Nyssa sylvatica	Black gum	2
Liriodendron tulipfera	Yellow-poplar	2
Ostrya virginiana	Ironwood	2
Prunus avium	Sweet cherry	2
Amelanchier sp.	Serviceberry	2
Quercus rubra	Northern red oak	2
Prunus serotina	Black cherry	2
Acer rubrum	Red maple	2
Quercus velutina	Black oak	2
	Ground Stratum	
Acer rubrum	Red maple	3
Quercus prinus	Chestnut oak	2
Quercus velutina	Black oak	2
Fraxinus americana	White ash	2
Cornus florida	Flowering dogwood	2

TABLE 8 (Continued)

Scientific Name	Colloquial Name	Relative Abundance[a]
	Ground Statum	
Prunus serotina	Black cherry	2
Castanea dentata	American chestnut	2
Carya tomentosa	Mockernut hickory	2
Rhus radicans	Poison ivy	2
Polystichum acrostichoides	Christmas fern	2
Eupatorium rugosum	White snakeroot	2
Parthenocissus quinquefolia	Virginia creeper	2
Rubus occidentalis	Black raspberry	2

[a] Key: 1 - Very infrequent; 2 - infrequent; 3 - common; 4 - frequent; 5 - very frequent

TABLE 9

RELATIVE ABUNDANCE OF PLANT SPECIES OBSERVED IN A DISTURBED SERAL FOREST SEPTEMBER 1977 (FIGURE 2, POINT OBSERVATION P3)

Scientific Name	Colloquial Name	Relative Abundance[(a)]
	Canopy/Subcanopy Stratum	
Robinia pseudoacacia	Black locust	5
Ailanthus altissima	Tree-of-heaven	3
Prunus sp.	Wild cherry	3
Rhus typhina	Staghorn sumac	2
Juglans nigra	Black walnut	2
Acer negundo	Boxelder	2
	Shrub Stratum	
Robinia pseudoacacia	Black locust	2
Prunus sp.	Wild cherry	2
Cornus florida	Flowering dogwood	2
Lindera benzoin	Spice bush	2
Ligustrum vulgare	Privet	2
Vitis sp.	Wild grape	2
	Ground Statum	
Pilea pumila	Clearweed	5
Unknown	Sterlie grass	4
Polygonum punctatum	Smartweed	4
Glecoma hederacea	Ground-ivy	4
Viola sp.	Violet	3
Polygonum hydropiperoides	Mild water-paper	3
Polygonum scandens	False buckwheat	3
Boehmeria cylindrica	False nettle	3
Panicum sp.	Panic-grass	3
Commelina communis	Apiatic dayflower	3
Solidago rugosa	Rough-stemmed goldenrod	3
Phytolacca americana	Pokeweed	2
Carex sp.	Sedge	2
Acalypha virginica	Three-seeded mercury	2
Rhus radicans	Poison ivy	2
Verbena hastata	Blue vervain	2
Geum canadensis	Avens	2

(a)Key: 1 - Very infrequent; 2 - infrequent; 3 - common; 4 - frequent; 5 - very frequent

TABLE 10

RELATIVE ABUNDANCE OF PLANT SPECIES OBSERVED IN OLD FIELDS
SEPTEMBER 1977
(FIGURE 2, POINT OBSERVATION P1)

Scientific Name	Colloquial Name	Relative Abundance[a]
	Ground Stratum	
Setaria geniculata	Foxtail	5
Melilotus spp.	Sweet-clover	5
Solidago altissima	Tall goldenrod	5
Agrostis stolonifera	Red-top	4
Chrysanthemum leucanthemum	Ox-eye daisy	3
Cirsium arvense	Canada thistle	3
Desmodium sp.	Tick-trefoils	3
Ambrosia artemisiifolia	Common hogweed	3
Daucus carota	Queen Anne's-lace	3
Aster pilosus	Pilose aster	3
Solidago graminifolia	Grass-leaved goldenrod	2
Solidago rugosa	Rough-stemmed goldenrod	2
Erigeron annuus	Daisy fleabane	2
Lonicera japonica	Japanese honeysuckle	2
Rubus allegheniensis	Blackberry	2
Carex sp.	Sedge	2
Triodia flava	Tall redtop	2
Solidago juncea	Early goldenrod	2
Phytolacca americana	Pokeweed	2
Betula nigra	River-birch	2
Achillea millefolium	Common yarrow	2
Oenothera biennis	Evening primrose	2
Fragaria virginiana	Wild strawberry	2
Verbesina alternifolia	Wingstem	2
Hypericum spp.	St. John's wort	2
Rhus radicans	Poison ivy	2
Platanus occidentalis	Sycamore	2
Oxalis sp.	Woodsorrel	2
Geum sp.	Avens	2
Solanum carolinense	Horsenettle	2
Eupatorium perforliatum	Boneset	2
Polygonum punctatum	Smartweed	2
Polygonum pennsylvanicum	Pennsylvania smartweed	2
Polygonum sagittatum	Arrow-leaved tearthumb	2
Rumex sp.	Dock	2
Apocynum sp.	Indian hemp	2
Phalaria arundinacea	Reed canary grass	2

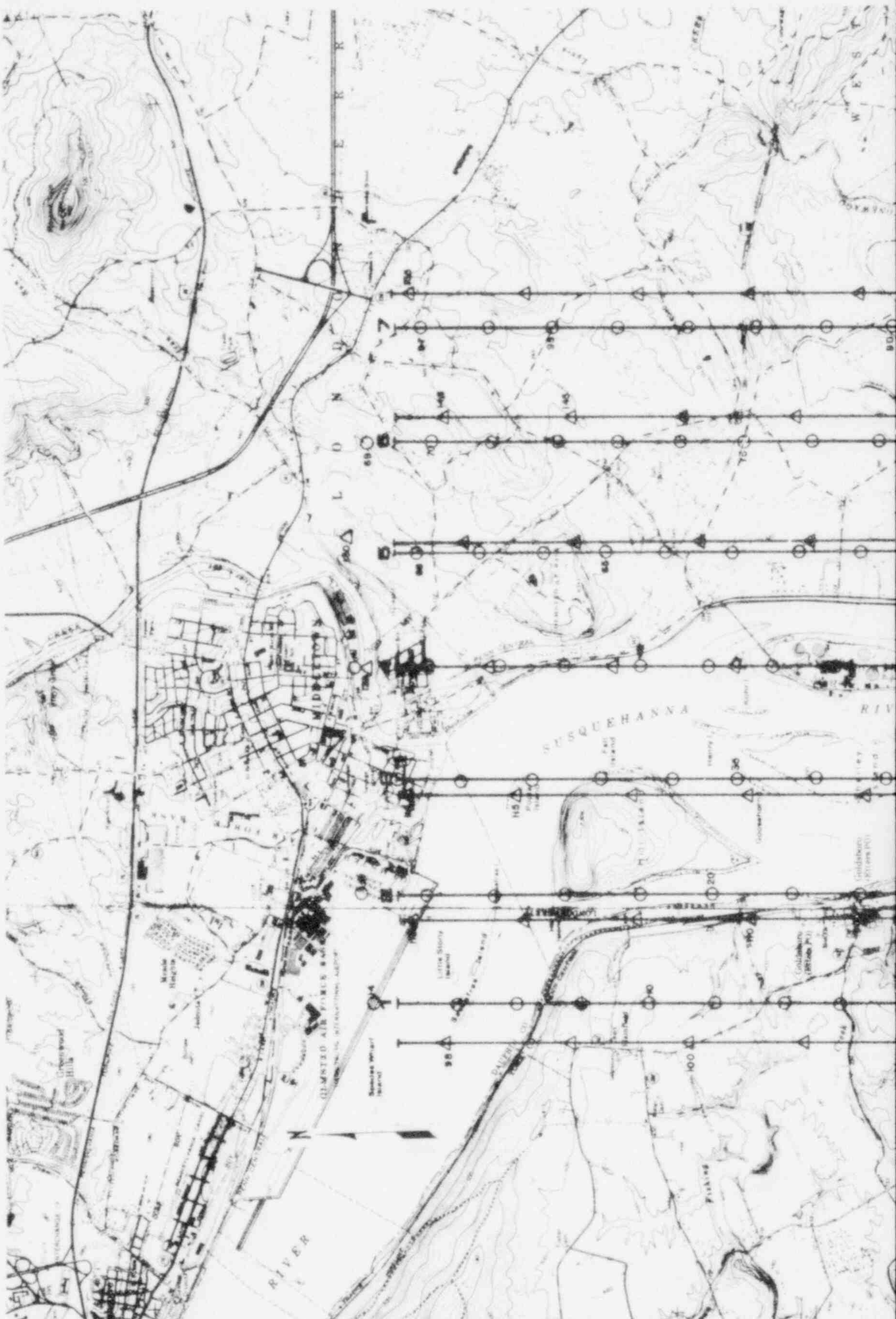
TABLE 10 (Continued)

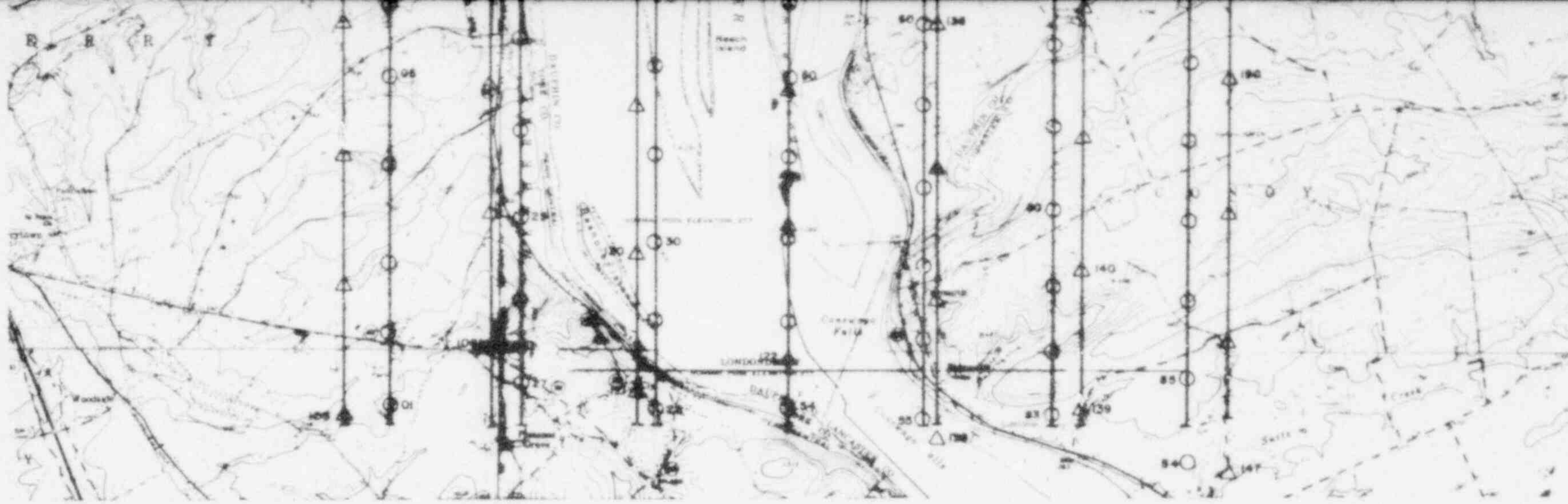
Scientific Name	Colloquial Name	Relative Abundance[a]
	Ground Stratum	
Verbascum thapsus	Common mullein	2
Impatiens biflora	Spotted touch-me-not	2
Euphorbia maculata	Wartweed	2
Setaria viridis	Foxtail grass	2
Taraxacum officinale	Dandelion	2

[a] Key: 1 - Very infrequent; 2 - infrequent; 3 - common; 4 - frequent; 5 - very frequent

LIST OF FIGURES

Figure


SUSQUEHANNA
RIV
RIVER



LEGEND

PHOTOGRAPH FRAME
NUMBER AND CENTER
POINT LOCATIONS

○ 1–97 INFRARED PHOTOS

△ 98–155 TRUE COLOR PHOTOS

2000 0 2000 4000 6000 FEET

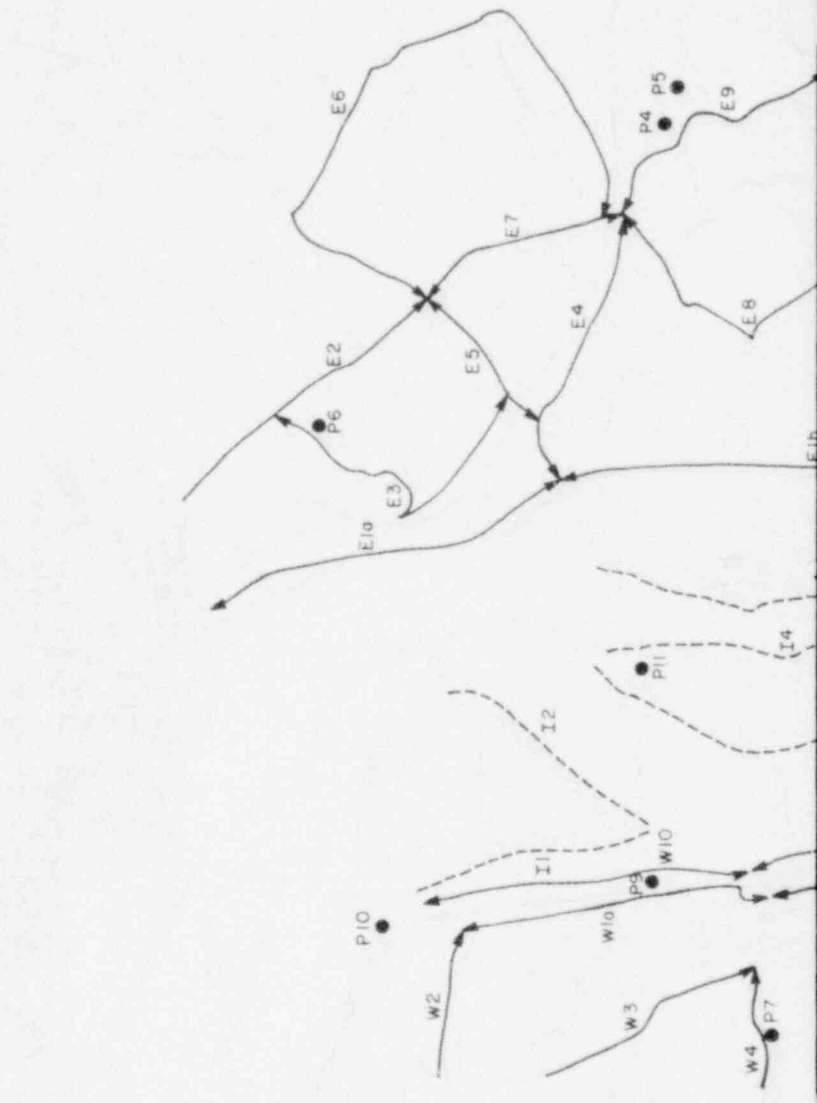
NUS CORPORATION

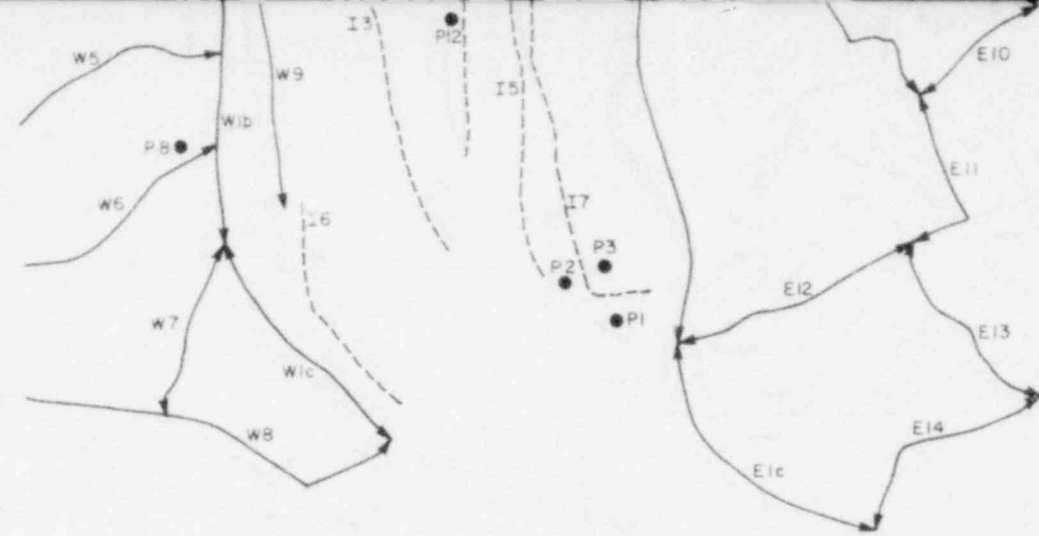
FIGURE 1

INDEX TO PHOTOGRAPHY
THREE MILE ISLAND AND VICINITY
JULY 25, 1980

POOR ORIGINAL

POOR ORIGINAL



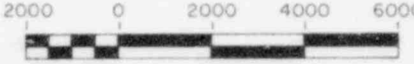


LEGEND

MAINLAND TRANSECTS (1980)
W1 - W8
E1 - E14

ISLAND TRANSECTS (1980)
I1 - I6 Aquatic
I7 Terrestrial

POINT OBSERVATIONS (1977)
P1 - P12



NUS CORPORATION

FIGURE 2

LOCATION OF SAMPLING TRANSECTS AND GROUND OBSERVATIONS THREE MILE ISLAND AND VICINITY

POOR ORIGINAL

LEGEND

- URBAN AND BUILT-UP LAND
- CROPLAND
- PASTURE AND ABANDONED CROPLAND
- SHRUB LAND
- FOREST LAND
- WETLAND
- WATER

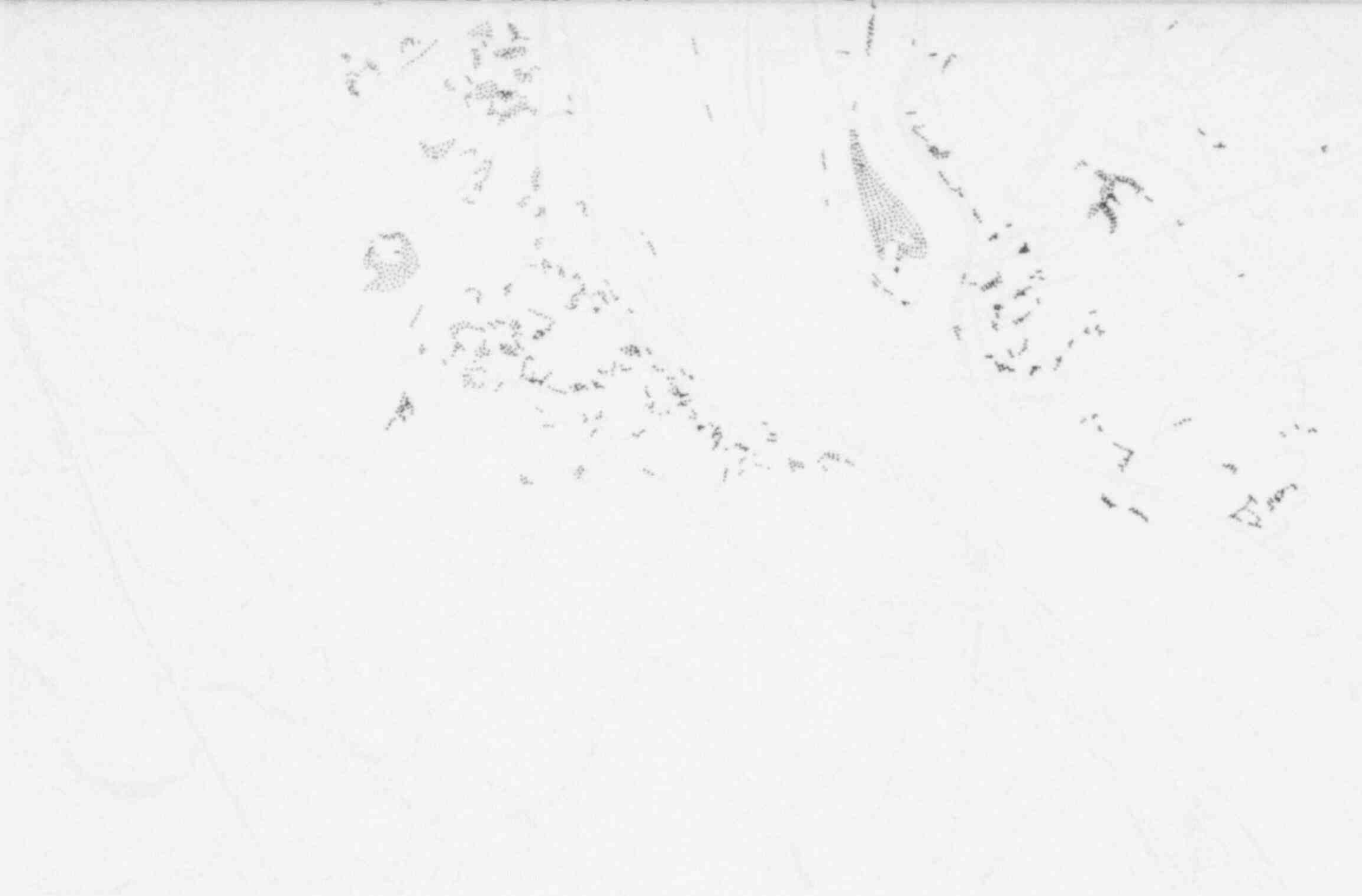
2000 0 2000 4000 6000 FEET

NUS CORPORATION

ECOLOGICAL SCIENCES DIVISION

FIGURE 3
VEGETATION MAP OF
THREE MILE ISLAND
AND VICINITY, 1980.

POOR ORIGINAL



LEGEND

LOCUST LEAF MINER

2000 0 2000 4000 6000 FEET

NUS CORPORATION

FIGURE 4

DISTRIBUTION OF LOCUST LEAF MINER
THREE MILE ISLAND AND VICINITY
1980