

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

UMI[®]

A

**Ecological and floristic analyses of vascular plants
along a gradient on disturbed serpentinite on
opposing slopes on Staten Island, NY**

by

Maureen E. Levine

**A dissertation submitted to the Graduate Faculty in Biology in partial
fulfillment of the requirements for the degree of Doctor of Philosophy,
The City University of New York.**

2002

UMI Number: 3037415

Copyright 2002 by
Levine, Maureen E.

All rights reserved.

UMI[®]

UMI Microform 3037415

Copyright 2002 by ProQuest Information and Learning Company.

All rights reserved. This microform edition is protected against
unauthorized copying under Title 17, United States Code.

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

© 2002

Maureen E. Levine

All Rights Reserved

This manuscript has been read and accepted for the Graduate Faculty in Biology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

1-10-02
Date

Andrew M. Greller
Chair of Examining Committee
Dr. Andrew M. Greller, Queens College

1/14/02
Date

Richard L. Chappell
Executive Officer
Dr. Richard L. Chappell

David C. Locke
Dr. David C. Locke, Queens College

Leslie F. Marcus
Dr. Leslie F. Marcus, Queens College

Steven E. Clemants
Dr. Steven E. Clemants, ~~Brooklyn College~~ Brooklyn Botanic Garden

Gregory P. Cheplick
Dr. Gregory P. Cheplick, The College of Staten Island

Alfred E. Schuyler
Dr. Alfred E. Schuyler, The Academy of Natural Sciences

Supervising Committee

The City University of New York

Abstract

ECOLOGICAL AND FLORISTIC ANALYSES OF VASCULAR PLANTS
ALONG A GRADIENT ON DISTURBED SERPENTINITE ON OPPOSING SLOPES
ON STATEN ISLAND, NY

Maureen E. Levine

Adviser: Dr. Andrew M. Greller

Bloodroot Valley, in central Staten Island, in southeastern New York State has unusual vegetation. It is a highly disturbed area in which serpentinite rubble has been deposited on till-covered serpentinite bedrock. Bloodroot Valley is reputed to contain the only wild population of *Sanguinaria canadensis* found on Staten Island. The hypothesis of the study is that variation in observed plant associations will correlate with variations in soil properties. This study compares two distinct vegetative patterns on opposing slopes, existing within meters of each other and associates each with different soil properties. Human disturbance in one area of Bloodroot Valley has fostered a unique soil condition that reflects a blend of features of serpentinite soils and river floodplains. Vegetation in Bloodroot Valley contains neither "serpentinite flora" nor flora typical of the adjacent mixed oak forest, but rather, a floodplain type plant association with *Hydrophyllum virginianum* as dominant.

ACKNOWLEDGEMENTS

I am deeply grateful to my mentor and thesis advisor, Dr. Andrew M. Greller. He encouraged me to pursue graduate studies and shared with me, his botanical expertise, comprehensive writing skills, charming wit, love for field work and excitement over new discoveries. He generously guided me through my doctoral studies.

I would like to thank my advisory committee. In addition to offering many invaluable insights, special thanks go to Dr. David C. Locke for advice in the soil and water analyses work, to Dr. Leslie F. Marcus for guidance through the labyrinth of statistical analyses, to Dr. Steven E. Clemants for reviewing the plant collection specimens and plant nomenclature, and to Dr. Gregory P. Cheplick for arranging my pre-defense seminar. Dr. Alfred E. Schuyler, my outside examiner, also offered invaluable advice and traveled from Philadelphia to be at my defense.

I would like to thank the Queens College School for Earth and Environmental Sciences, previously the Geology Department. Dr. Patrick W. G. Brock, an extremely supportive friend, gave unstintingly of his time and expertise to advise me on the geology of the area. Dr. Julie A. Mankiewicz offered encouragement and advice on soil testing and hydrology.

I thank Richard P. Buegler, president of Protectors of Pine Oak Woods, for introducing me to the area and for fielding numerous botanical and historical questions. Additional historical information was provided by Mr. Ed Johnson and Ms. Dottie Doletto, of the Staten Island Institute of Arts and Sciences and Mr. Richard Lynch of the Sweetbay Magnolia Bio-Reserve Conservancy. Mr. Jim Roberts and Ms. Ann Collini of

Seaview Hospital, provided access to Bloodroot Valley via the hospital grounds and Ms. Collini provided historical information.

I am grateful to Mr. Michael Goudket and Dr. Andrew M. Greller for taking and sharing photographs of the area.

Director W. Shaw Reid and researcher Mr. Mark F. Joyce of Cornell Nutrient Analysis Lab were very helpful in providing background information about soil testing and chemical results.

I thank Mr. Bruce Kershner and the United States Geological Society for permission to modify and print their maps of Staten Island.

Dr. George R. Robinson provided me with the database that he used to analyze the changes in Staten Island flora over a 150-year period.

The staff at Soldier's Delight Natural Environmental Area allowed me the use of their library and facilities, and Mrs. Jean Worthley sent me a copy of her husband's paper, "A nature walk for Soldier's Delight, Baltimore County, Maryland".

Mr. Steven D. Glenn of the Brooklyn Botanic Garden provided information about *Acer rubrum* abundance in the NY Metropolitan area.

Thanks to the professors and staff at Queens College and City University Graduate Center for their friendship, encouragement, assistance and advice.

Many thanks to my family and my friend Arlene Litwack, who encouraged me to take a chance and go to the finish line and to Siril Wijesundara who helped me in innumerable ways.

I give my love and gratitude to my unsurpassable Partner and Helper, the P and the H in my Ph.D., my husband and best friend, Hy.

SOILS - FIELD AND LAB	14
SOILS - STATISTICS - Correlations	17
- Cluster Analysis	17
WATER - FIELD AND LAB	17
RESULTS	18
TREES	18
SHRUB AND SAPLING LAYER	20
SPRING HERB LAYER	20
FALL HERB LAYER	22
SOIL ANALYSIS - General	22
- Correlation Analysis	24
- Cluster Analysis	24
ADDITIONAL SOIL ANALYSIS	24
WATER ANALYSIS	25
STATISTICS - PLANTS - Distance and Similarity	26
- Ordination	27
- Cluster Analysis	27
DISCUSSION - NEUTRAL AND ACIDIC SOIL COMMUNITIES	28
- TREES	31
- SHRUB AND SAPLING LAYER	33
- HERBACEOUS LAYER	34

- SOIL PROPERTIES DATA	37
- HYDROLOGY	42
CONCLUSION	43
ADDENDUM	45
TABLES	46
FIGURES	78
APPENDIX 1. US Standard Sieve Sizes and USDA Classification of Soil Separates	101
APPENDIX 2. Conversion Factors	102
APPENDIX 3. Vascular Plants of Bloodroot Valley, Staten Island	103
APPENDIX 4. Matrices of Distance/Similarity Measures	106
BIBLIOGRAPHY	118

LIST OF TABLES

1a. Trees of the west slope, by location on slope: upper, middle, and lower slope.	46
1b. Trees of the east slope, by location on slope: lower, middle and upper slope.	47
2. Shrub and sapling layer (>1m and <6m), by transects on west and east slopes.	48
3a. Spring herb layer (≤ 1 m), by transects, on west slope.	49
3b. Spring herb layer (≤ 1 m), by transects, on east slope.	51
4a. Fall herb layer (≤ 1 m), by transects, on west slope.	54
4b. Fall herb layer (≤ 1 m), by transects, on east slope.	56
5. Summary of Appendix 4 distance/similarity measures across the ravine.	58
6a. Trees of west and east slopes.	60
6b. Trees of neutral and acidic communities.	61
7. Shrub and sapling layer (>1m and <6m) of neutral and acidic communities.	62
8. Spring herb layer (≤ 1 m) of neutral and acidic communities.	63
9. Fall herb layer (≤ 1 m) of neutral and acidic communities.	65
10. Results of Principal Components Analysis for vegetation.	67
11. Summary of Cluster Analysis.	68
12. Analysis of soil texture.	69
13. Soil properties for west slope, creekbed and east slope.	70
14. Summary of soil properties for west and east slope.	73
15. Water samples tested for presence of calcium and magnesium.	74
16. Additional soil samples - total nutrient and available nutrient amounts for: calcium, magnesium, manganese, iron and aluminum.	75
17. Summary of correlation analysis of soil properties data.	76
18. Spring distribution of ferns.	77

LIST OF FIGURES

1. Map of Staten Island.	78
2. Contour map of study area and surroundings.	79
3. Profile of the geology of the ravine based on surficial evidence and information provided by Dr. Patrick W. G. Brock.	80
4. Diagram of study area and surroundings.	81
5. Map indicating additional water and soil sampling sites.	82
6. Size structure – Trees - West Slope.	83
7. Size structure – Trees – East Slope.	84
8. Size Structure – All Trees – West and East Slopes.	85
9. Size Structure – Native Trees – West and East Slopes.	86
10. Principal Component Analysis – All Trees.	87
11. Principal Component Analysis – Native Trees.	88
12. Principal Component Analysis – Shrub and Sapling layer.	89
13. Principal Component Analysis – Herb layer.	90
14. Cluster Analysis – Soil properties data.	91
15. Cluster Analysis – All Trees.	92
16. Cluster Analysis – Native Trees.	93
17. Cluster Analysis – Shrub and Sapling layer.	94
18. Cluster Analysis – Herb layer.	95
19. Photograph – Bloodroot Valley – both slopes.	96
20. Photograph – Bloodroot Valley – west slope.	97
21. Photograph – Bloodroot Valley – east slope.	98

LIST OF FIGURES cont'd

22. Photograph - Bloodroot Valley – both slopes.	99
23. Photograph – Seaview Hospital grounds – Children's Hospital.	100

INTRODUCTION

A vital tool for ecological management is an inventory of our natural resources, including the location and description of any unique and rare microhabitats. To this end, it is important to document the remaining biodiversity of Staten Island (SI) in New York City, and to encourage preservation of its many unique habitats.

Staten Island is a mosaic of fragile microhabitats. In its 16,576 hectares, one can find tidal marshes, fresh water marshes, swamps, ponds, lakes, at least three different types of forest-communities, open fields, serpentine barrens, sandy oak barrens and coastal beaches (Buegler and Parisio 1982). This study will focus on the vegetation and soil properties along a west to east gradient from a highly disturbed area to a relatively undisturbed area, in and on the opposing slopes of a ravine on a serpentinite substrate.

The Bloodroot Valley (BRV) site was chosen because it has unusual herbaceous vegetation in a highly disturbed area that includes serpentinite outcrops and serpentinite rubble. It also includes the only wild population of *Sanguinaria canadensis* (bloodroot) found on Staten Island (Lofaso 1993)[see Addendum]. Previous studies have not tested for a relationship between differences in soil pH and plant diversity on Staten Island (Robinson and others 1994). The hypothesis of this study is that variation in observed plant associations are correlated with variations in soil properties. Comparisons were made between two distinct vegetative patterns, existing within meters of one another. These patterns will be associated with their soil properties. The field study of shrub and herbaceous layers was done in the late spring of 1996, and then the area was resurveyed in the fall of 1998. All the tree data were provided through the kindness of Dr. Andrew

M. Greller. They were recorded in the spring of 1996 for the west slope and in the summer of 1999 for the east slope.

Approximately one-third of Staten Island is underlain with serpentinite bedrock. Serpentinites are ultramafic rocks composed mainly of serpentine. Serpentine is a secondary mineral, a magnesian silicate, formed from minerals such as olivine and orthopyroxene. It can occur in igneous rocks containing these minerals but most typically it is formed by the alteration of olivine-bearing rocks. This alteration is referred to as metamorphism. Serpentine is usually various shades of green to brown in color and has a greasy lustre and texture (Hamilton and others 1974). It is always high in magnesium, and can include iron and it is always low in calcium, potassium, sodium and aluminum. It is common for calcium to be completely absent. Heavy metals such as chromium, nickel and cobalt are often present (Whittaker 1975). It has been common practice to use the words serpentine (mineral) and serpentinite (rock) interchangeably even though the mineral has a very restricted composition while the rock can be more variable (pers. comm. Patrick W.G. Brock 2001). The word "serpentine" is also used as an adjective to describe the soils that weather from these serpentinite rocks and as an adjective to describe the flora that is associated with these soils (Reed 1986). We will use "serpentinite" when referring to the rocks and "serpentine" when referring to the soils or flora.

Interest in the flora of serpentine soils dates back to 1583 when Caesalpino described a plant restricted to the ultramafic region of the Upper Tiber Valley in Tuscany (Brooks 1987). From as early as the mid-nineteenth century, it was noted that serpentine vegetation exhibited a paucity of species, xeromorphism, and a tendency toward

dwarfism (Brooks 1987). The serpentinite areas most studied are referred to as "barrens" and the soils are generally considered infertile. The soils are mostly shallow and stony, resulting in poor root penetration and a relative openness of plant cover (Dann 1988). Serpentine floras of northern North America and northwestern Europe are extremely impoverished due to the Pleistocene ice advances that removed all vegetation in their path about 22,000 years ago (Sirkin 1999). This is a relatively short time compared to a place such as Cuba, which has a very high number of serpentine endemic plant species (902) growing on serpentine soils that are about 30 million years old (Brooks 1987). On the Pacific coast of North America, serpentinite formations are narrow, essentially double, bands of ridges running from Santa Barbara in the southeast to Alaska and the Yukon in the northwest. The eastern portion of North America has a mirror image of ridges ranging from Alabama in the southwest to Quebec and Newfoundland in the northeast. Serpentinite sites on the western coast of North America have been studied much more than sites on the eastern coast (Brooks 1987). There are as many as 282 rare plants endemic to California's serpentinite areas (Leppig 1997), whereas very few serpentine endemic taxa have been reported on the east coast of the United States, viz., *Cerastium arvense* L. forma *villosissimum* (Muhl.) Britt. & Hollick, *Aster depauperatus* Fernald and *Adiantum pedatum* L. var. *aleuticum* Rupr. (Brooks 1987). Vegetation on the serpentinite barrens of North Carolina to Pennsylvania is most notable for plants that are at the extremes of, or disjunct from, their normal climatic ranges. Their survival on serpentinite has been attributed to lack of competition from local flora (Brooks 1987), but there are other factors that are probably affecting the serpentine vegetation composition.

In the New York Metropolitan area, there are very few outcrops of serpentinite outside of Staten Island, and even there a lot of the serpentinite has been covered by subsequent glacial deposits. Serpentinite barrens are visible on both sides of the Staten Island Expressway where bedrock was exposed when new roads were cut during the mid 1960s for the construction of the Verrazano-Narrows Bridge, the Staten Island Expressway and the start of a proposed expressway through the Greenbelt.

C.F. Reed did extensive field research on the serpentine flora of eastern North America, including several trips through the serpentinite areas of Staten Island, in the late 1960s. For Staten Island, he listed 21 Families with 44 species, 39 of which he collected and deposited in the Reed Herbarium, Baltimore, Maryland. The other 5 species were collected in the late nineteenth and early twentieth century and are on deposit in several herbaria. Of these 44 species, *Cerastium arvense f. villosissimum* is the only listed plant that is endemic to serpentine soils. The native floras of these serpentinite areas have been completely extirpated. In 1986 Reed noted that except for a few mosses and lichens, perhaps none of the plants currently growing in these areas were among the original flora (Reed 1986).

There are some recent studies of serpentine vegetation in eastern North America (Hart 1980. Barton and Wallenstein 1997). There are, however, no studies known to us of vegetation on serpentine soils in highly disturbed urban areas, although there are studies of areas that were previously mined.

Staten Island has lost over 40% of its native plant species since Hollick and Britton first started a flora inventory of the island, in the 1870s. The major declines occurred after 1930 and coincided with the construction of three bridges connecting Staten Island

to New Jersey in the 1930s and the opening of the Verrazano-Narrows Bridge to Brooklyn in 1964 (Robinson and others 1994). These bridges and the construction of the Staten Island Expressway were instrumental in the disturbance and fragmentation of major environmental habitats, through direct construction and also through the increase in urbanization that occurred with the easier access to the island.

STUDY AREA

GEOLOGY AND GEOGRAPHY

The study area is located in Bloodroot Valley, in the Willowbrook section of Richmond County, New York, lat 40°35'28" N, long 74°07'41" W (USGS 1981). The site (Reed 1986; Figure 1) is located near the center of the 500 million year-old, northeast extent of the serpentinite belt that makes up about one-third of Staten Island (Roberts 1996). Below this lies the 1.1 billion year old Grenville basement rocks (Isachsen and others 2000). Glacial till and outwash cover much of the serpentinite bedrock as a result of the area being very close to the southeastern extremity of the last glacial ice advance, the Wisconsinan, which retreated from this area about twenty two thousand years ago (Sirkin 1999). The valley, previously known as Blackhorse Ravine (Lofaso 1993), is situated in the Staten Island Greenbelt, which is administered by the Department of Parks and Recreation, City of New York. References to the name Bloodroot Valley date back to Hollick's 1870s notes on the flora of Staten Island. The area was called Bloodroot Valley because of the profusion of bloodroot flowers that blanketed the valley in the early spring (pers. comm. Ed Johnson 2001). William T. Davis, in providing "Ye Olde Names and Nicknames" to Charles W. Leng's 1896 Map of Staten Island, referred to the area as both Blackhorse Ravine and Bloodroot Valley. Bloodroot Valley is immediately east of

and below the Seaview Children's Hospital building and west of Manor Road (Figure 2). The steep-sided valley runs north to south and is an incised headwater tributary of Richmond Creek (per. comm. Patrick W.G. Brock 1996 and USGS map 1981). The tributary has been referred to as Manor Creek in the Landmarks Preservation 1985 report on the area. It is referred to as Deadman's Creek by William T. Davis in the Map of Staten Island by Charles W. Leng (1896). Figure 3 is a profile of the ravine's physical structure based on surficial evidence and personal communication with Patrick W.G. Brock (1996, 2001). The west slope has a perched water table related to the fact that it rests on top of the serpentinite ridge. This side probably has no more than 6 meters (20 feet) of till and frequently less. Outcrops of serpentinite along with glacial detritus can be seen along the west slope and where the hill was leveled for the construction of the Children's Hospital (pers. comm. Patrick W.G. Brock 1996). The east slope of the ravine was covered with much deeper till deposits (probably up to 30 plus meters) and was well-drained (pers. comm. Patrick Brock 1996, 2001). The elevation in the study area is 61m (200') at the creek bed and slopes up on either side to 79m (260'). The west slope has an extremely steep grade (150%) and a slope of 56.3° while the east slope has a very steep grade ($\sim 45.5\%$) and a slope of 24.5° . "Slope gradient is the inclination of the surface of the soil from the horizontal." (Soil Survey Manual 1993) and is measured as the slope rise/horizontal distance x 100.

CLIMATE

The climate in Staten Island is comparable to that of northern New Jersey. Using the United States Department of Agriculture Forest Service's (USDA FS) modification of the Köppen-Trewartha Regional Climate Classification System, Staten Island is in the

Eastern broadleaf forest (oceanic) province of the hot continental division of the humid temperate domain (USDA FS 2001). It has warm tropical winds in the summer and cold polar winds in the winter. The coldest month, January, has an average temperature of -1.0°C (30.2°F). The warmest month, July, has an average temperature of 23.3°C (74.0°F). The growing season, which is measured as an average of the number of consecutive days with an average temperature of 6.1°C (43°F), is 245 days and there are about 200 frost-free days. The average annual precipitation is 117cm (46"; Collins and Anderson 1994).

HISTORY

Directly west of the study area lies the main grounds of the Seaview Hospital complex, an area designated in 1985 as an historic district (Landmarks Preservation Committee of the City of New York 1985). In 1905, the City of New York, in their search for the ideal place for a hospital complex - peaceful, scenic, isolated and elevated - purchased a 10.1ha (25 acre) tract, which had been the hilltop estate of Charles Schmidt. The goal was to build the most advanced and hygienic center for the care and treatment of tuberculosis patients. Construction began in 1908. The highest point on the site was 94.5m (310'). Most of the original portion of the hospital complex, including the grounds which would later become the site of the Children's Hospital, were set on a slightly lower plateau (ca.91.4m, 300') which had been created for it (Landmarks Preservation Commission 1985). In 1915, an additional 200 adjacent acres were purchased. The original buildings were joined in a loop by a road system. As additional buildings were added, new sections of road were also added to the loop. The Children's Hospital, a concrete and limestone structure located to the east of the original buildings, was completed in 1938. The base of the building is at the bottom of a steep slope, the front

entrance is joined by a circular drive to the loop road, at an elevation of ca. 91.4m (300'). This entrance is equivalent to the second floor. The building's first floor, rear parking area, and the bottom of the east service road are at least a full story lower, at an elevation of ca. 79m (260', Landmarks Preservation Commission 1985). Soil and broken-up serpentinite bedrock were removed, in order to level the land and cut the new entry roads to the loop. This, along with subsequent blocks of concrete about 1 m² in size and other construction debris, appear to have been dumped directly onto the slope of Bloodroot Valley, to the east of the building site. Use of the Children's Hospital was discontinued in 1961 and the building has not been maintained since that time. At present, it is in a dilapidated condition with crumbling and collapsing exterior walls.

PREVIOUS STUDIES

In addition to Reed's previously mentioned study, Charles Arthur Hollick and Nathaniel Lord Britton (1879) published a flora for all of Staten Island. They updated this list through 1930 but it was unpublished until Buegler and Parisio incorporated it into their 1982 publication, "A Comparative Flora of Staten Island". This work included a botanical survey of Staten Island from 1977 to 1981, sponsored by the Staten Island Institute of Arts and Sciences, along with a comparison to the two previous Hollick and Britton surveys of 1879 and 1930. Bloodroot Valley was included in all of these studies; and it was noted in the 1981 study that the valley still contained many of the plant species from the two previous plant surveys taken fifty and 100 years earlier (Buegler and Parisio 1982). Robinson and others expanded on the database from this comparative survey for their study of the ecological species losses and invasions in Staten Island (1994).

MATERIALS AND METHODS

PLANTS - FIELD

Samples of shrub and herbaceous layers were taken within an area 100m long by 22m wide on the disturbed west side of the creek and a parallel 100m by 22m area on the relatively undisturbed east side of the creek. The width was determined by the location of a fence on the west slope between the disturbed area and the deserted Seaview Children's Hospital building and parking lot. The west slope had 18.3m (60') of relief and comprised three sections from north to south: the first 20 meters was in the south part of a deep concavity (hollow), the second 30 meters was a convexity (nose) and the last 50 meters was a shallow concavity (Figure 4). The study area was subdivided in six sections - upper, middle and lower west slope (WU, WM, WL) and upper, middle and lower east slope (EU, EM, EL). Wherever possible plant data tables were visually laid out to conform with the gradient from the upper west slope on the left to the upper east slope on the right, with the upper direction of the tables representing north.

Trees, in the entire study area with trunk diameter at breast height of 5cm or greater, were listed by species for each of the six sections. Breast height is 1.4m (4.5') above ground level (Barbour and others 1987). The diameter at breast height was then converted to basal area (BA). Basal area, an indication of dominance, is the cross-sectional area of the tree at breast height (Barbour and others 1987). The formula is: $BA = \pi(\text{dbh})^2 / 4$. In addition, trees in the adjacent areas on either side of the study area, on the west slope, were recorded. The tree data on the east slope covered an area of approximately 100m by 22m, while on the west slope it covered an area of about 200m

by 22m. West slope tree data were recorded in the spring of 1996 and east slope data were recorded in the summer of 1999. Since the tree data on the west slope covered 4400m² and the east slope only covered 2200m², the abundance data were converted into per unit (dkm²) area data. These units were used for all analyses of tree data.

The data for the six sections of the shrub and sapling layer and the herbaceous layer were collected along three 100m line transects on both sides of the ravine and parallel to the creek bed. These transects were located at distances of 3m, 9m and 18.6m from the creek bed. They represented the lower, middle and upper slope of the western side. The slope on the eastern side was not as steep as the western side, which meant that the "upper" area (18.6m from creek) of the east slope was not at the top of the slope but actually between the middle and upper sections of the slope (Figure 4.). These transects were laid out to best follow the course of the creek. The spring and the fall surveys may not be exact duplicates, as the course could have had shifts between the two surveys. Shrub and sapling layer (> 1m and <6m tall) vegetation was recorded, along these transects, based on their canopy cover, using the line intercept method (compare Greller and others 1978). Data excluded clearings and were recorded as relative canopy cover.

The herb layer (≤ 1 m), first recorded in the spring of 1996, was measured along the same six line transects used for the shrub and sapling layer. A one square meter quadrat was used at intervals of 5 meters, for a total of 18 quadrats per transect, except the fall 1998 west lower slope which only had 17 quadrats. Ground cover was recorded as a percentage of the following categories; plant cover, bare soil, rubble, leaf litter and twigs, and "other". "Other" comprised tree trunks, roots, moss, lichens, boulders and rubbish.

Data were analyzed using actual plant cover only. The site was re-sampled in the fall of 1998. Thus spring and fall aspects were recorded for the herbaceous vegetation.

Appendix 3 is a list of the vascular plants in the study area. Voucher specimens that are on deposit at the Brooklyn Botanic Garden are indicated with an asterisk in the BBG column. A few specimens were taken of plants in the study area that were not in the transects. These have been indicated by an asterisk in the NIT (not in transects) column.

Unless otherwise noted, nomenclature follows Gleason and Cronquist (1991).

All references to individual species distributions on Staten Island are from Buegler and Parisio (1982).

PLANTS – STATISTICS

Angular transformation. Shrub and sapling layer data and herb layer data were compared, using both raw data and by applying angular transformation to the raw data. In a binomial distribution, the variance is a function of the mean. Arcsine angular transformation prevents this dependence. This process stretches both tails of a distribution of percentages or proportions and compresses the middle and approximates a normal distribution. (Sokal and Rohlf 1995).

Distance and Similarity. In order to determine if there were more than one community, and to establish any transitional zones between communities, data for all three areas on each slope were analyzed for similarity or distance (dissimilarity). This included the six sections for trees: upper, middle and lower; west and east, and the six transects for shrub and sapling layer and herb layer. This was done using a SAS program developed by D. Siril A. Wijesundara (1998), for use with SAS-PC Version 6.12 (SAS 1989,1993). For

actual formulae and discussions of their merits see Pielou (1984), Magurran (1988) and Wijesundara (1998). The program computes ten different distance or similarity indices. These formulae were applied to the six sections or transects using the following data sets:

1. Trees - actual abundance per square decameter
 - a. All trees
 - b. Native trees only
2. Shrub and Sapling layer - relative percentage canopy cover
3. Herb layer - percentage plant cover
 - a. Spring 1996
 - b. Fall 1998

In addition, species similarity for each stratum was compared, using the Sorensen (C_s) and Jaccard (C_J) Indices of Similarity (Magurran 1988). Ruzicka Percent Remoteness distance measure was selected to use for the ordination and clustering analyses. It has the distinct advantage of having a universal reference range (0 to 1) which means that the results from various strata, environments, communities, etc. can be easily related to each other. It is also a metric measure. "The merit of metric dissimilarity measures is that they often permit the quadrats to be represented as a swarm of points in a many-dimensional space." (Pielou 1984).

Ordination. Ordination is the process of ordering sets of data points along one or more axes in order to make the relationships among points (transects) visible on inspection (Pielou 1984). Ordination was done using Principal Components Analysis (PCA) that uses the actual data and takes "the axes of the original coordinate frame in which the data points are (conceptually) plotted" and rigidly rotates it (the frame) around its origin until

the distance between the points is most visible (Pielou 1984). This origin is usually the mean of the data (pers. comm. Leslie F. Marcus 2001). Eigenvalues, which represent the proportions of variance along the principal axes, were computed. The first principal component accounts for the greatest amount of variability (highest eigenvalue) and the second principal component accounts for the second greatest amount of variability, and so forth. (Sokal & Rohlf 1995). The higher the cumulative eigenvalues of the first two principle components (at least 50%) are, the more information one can derive from looking at a scattergram, which plots the coordinates of Principal Components 1 and 2 .

Cluster Analysis. Three types of clustering procedures were used to analyze the data:

1. Minimum variance (SAS refers to this as Ward's, Between Cluster Sum of Squares), in which the "two clusters united at each step are those, whose fusion brings about the smallest possible increase in the within-cluster dispersion" (Pielou 1984).
2. Complete linkage or farthest neighbor (SAS refers to this as Complete, Maximum Distance Between Clusters), in which "the distance between two clusters is taken to be the longest distance between a pair of points with one member of the pair in each cluster" (Pielou 1984).
3. Average linkage (unweighted) is the average of all interpoint distances between two clusters weighted according to the size of each point (Pielou 1984).

Complete linkage tends to yield clusters that are fairly equal in size, which is usually preferred for vegetation mapping and descriptive classifications (Pielou 1984).

Cluster analysis dendrograms (Figures 14 –18) were done using Complete linkage.

Ordination and clustering procedures were done using SAS 6.12 (SAS 1989, 1993).

Community Analysis. The results from distance and similarity measures and clustering were used to determine the presence of two different communities. These communities were then compared for species diversity, a combination of richness (the number of species in a given area) and evenness (the distribution of individuals among the species). It is species richness weighted by species evenness (Barbour and others 1987). Diversity, dominance and evenness were measured using Simpson's indices (Brower and others 1990). In addition, species density (number of species/area) was compared for each stratum. This is the most commonly used measure of species richness and especially favored by botanists (Magurran 1988).

SOILS - FIELD AND LAB

In total, eighteen sites were sampled for soil in the fall of 1998. The samples were taken at 0, 50 and 100 meters on the same five of six line transects used for the vegetation survey, running from north to south on the west slope at 3m (lower) and 9m (middle). The upper slope on the western side was too steep and eroded to remove any soil. Three samples were also taken from the east slope at 3m (lower), 9m (middle) and 18.6m (upper) and another 3 samples were taken along the creek bed. At each sample site two 227g soil samples were extracted, one at 0-5cm depth and another at 10-15cm depth. All samples were air-dried and weighed using a triple beam balance. They were then sorted by particle size using a series of sieves (mesh-bottomed canisters) that are arranged so the soil passes through progressively smaller hole openings in the sieves (Appendix 1 is a list of the US Standard Sieve Sizes and the USDA Classification of Soil Separates). The finest silt and clay particles end up in the last closed-bottom canister. The aggregates of soil that remain in each canister is measured for volume and weighed. Each sample was

separated into two parts. Those particles larger than 2mm diameter (gravel), which are not considered part of the soil, were removed before the soil testing was performed. Those particles equal to or less than 2mm diameter were recorded by grain size to determine the percentage of sand and the percentage of silt and clay. Based on the ratios of the particle sizes a soil texture was determined, using the USDA soil separates system (Soil Survey Division Staff 1993). The particles equal to or less than 2mm were recombined, labeled and sent to Cornell Nutrient Analysis Lab (CNAL). They were analyzed for moisture content, organic matter, pH, exchange acidity and presence of available nutrients: phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), and nitrate (NO_3). Available nutrients are any “elements or compounds in the soil solution that can be absorbed readily into plant roots, and that function as nutrients to growing plants. The available amount is usually much less than the total amount of that plant nutrient in the soil” (Allaby 1992). Available aluminum (Al) and chromium (Cr), as well as total chromium were also measured. The analyses were done using CNAL routine laboratory analytical methods, as described in their assay report: "Available" nutrients and elements were extracted by Morgan's solution (10% sodium acetate in 3% acetic acid buffered to pH 4.8 using 1:5 soil:solution ratio[by volume]). The percent moisture content is obtained by drying the soil at 55°C overnight. Then an accurately weighed sample is put into a crucible and placed in a 110°C oven for 2 to 4 hours. It is then re-weighed. The difference between these two weights is the moisture loss and is recorded as the percent moisture content. Organic matter is determined by loss on ignition. The same crucible and 2 gram sample from above is then placed in a furnace at 550°C for two hours. It is cooled and weighed

and the difference between the beginning and ending weights is reported as loss on ignition. This value can be converted to organic matter by multiplying it by 0.7 and then subtracting 0.23. This equation is only valid up to 6% moisture. Soil pH was determined on a 1:1 [by volume] soil: water or by soil: 0.01M CaCl₂ suspension (CNAL 1999). Tables 13 and 14 include pH averages. These averages were computed by converting the CNAL provided pH results to hydrogen ion concentrations, which were then averaged and converted back to pH values. Soil colloids, mostly humus and clay, have a negatively charged surface that attracts cations. Cation exchange capacity (CEC) is a measure of the soil's ability to hold cations that supply nutrients for plants. Clay and organic soils have the highest cation holding capacities. Hydrogen ions are adsorbed most strongly, followed by aluminum. These are the acidic cations. Adsorption hierarchy continues with calcium, magnesium, potassium, ammonium and sodium. These are the base ions. Of these, calcium, magnesium, potassium and ammonium are macronutrients needed for plant survival (Plaster 1985). Exchange acidity is a measure of the acidic cations available for extraction by a solution of barium chloride /triethanolamine, buffered at pH 8.0, followed by titration of the excess base. The units, cmol (+)/kg, stand for centimoles of positive ion charge per kilogram of soil, and are equivalent to meq/100g (CNAL 1999). Exchange acidity is usually highest when pH is low. For the purpose of discussion all soil nutrient and mineral values have been converted to parts-per-million (ppm) and a conversion table is located in Appendix 2. Potassium, magnesium, calcium, manganese, iron, aluminum and zinc were determined by atomic absorption. Phosphorus and nitrate were determined colorimetrically by stannous chloride reduction and automated hydrazine reduction, respectively. Available

chromium was extracted in the same manner as the other available minerals. Total chromium was extracted with a strong nitric acid leach. The second extraction is equivalent to the total chromium content in the soil (pers. comm. Mark Joyce of CNAL 1999). Because of budget limitations, only the subsurface soil samples were tested for total chromium. The values of the surface soil and sub-surface soil samples at each location were so similar that they were averaged, for all categories except total chromium. The mean numbers were rounded to the nearest tenth's place and recorded in Table 13.

SOILS - STATISTICS

Correlations. The soil properties data were compared for possible linear correlations using Pearson's estimated Coefficient of Correlation (r). Of many estimates, this is the one most frequently used to measure samples of populations for a covariance between X and Y , where the covariance is a measure of how X and Y vary together (Milton 1999). Each variable is standardized to have a coefficient of correlation range between -1 (perfect negative correlation) to $+1$ (perfect positive correlation). A zero value means there is no correlation. Correlation values (r) in general are interpreted as weak (>0 to ± 0.5), moderate (± 0.5 to 0.9) or strong (± 0.9 to 1 , Milton 1999). Although P -values are reported, they should be used cautiously as it is problematical as to whether the data fit the assumptions for a P -test, i.e. randomness, independence and normality.

Cluster Analysis was applied to the Table 14 soil properties data.

WATER - FIELD AND LAB

Six rainwater and one creek water samples were taken during the period November 9, 10 and 11, 2000. They were collected in Bloodroot Valley and its vicinity, in conjunction

with collecting additional soil samples. Figure 5 is a map indicating the locations of the sampling sites. Rainwater was collected in clean water buckets (20cm diameter and 15cm deep) that had been rinsed with distilled water. The samples were stored in 57g, wide-mouth, glass specimen jars that had been rinsed with a 2% solution of nitric acid. The creek water was collected directly into a cleaned specimen jar at a location just south of the study area. The water was tested on November 13, 2000 under the guidance of Dr. David C. Locke in his laboratory at Queens College. Using a Perkin-Elmer 3030-B Atomic Absorption Spectrophotometer, the samples were tested to determine the levels of calcium and magnesium ions present.

RESULTS

TREES

Table 1a is a list of the trees on the west slope. It contains data on abundance (number of trees in the area), density (abundance per unit area, 44dkm^2), relative species density (total number of individuals of a species expressed as a percentage of the total number of individuals of all species), basal area (in m^2), and relative basal area (basal area for a species/total basal area for the section).

Table 1b is a list of trees on the east slope, including abundance, density (abundance/unit area, 22dkm^2), relative species density, basal area, and relative basal area. Table 6 is a summary of the same information for the west and east slopes. In Table 6, *Quercus rubra* was the only tree found in all six sections and it is the dominant tree on both slopes. It represents 27.3% of the total basal area on the west slope and 57.6% of the total basal area on the east slope. The four exotic tree species present, *Acer platanoides*, *Ailanthus altissima*, *Morus alba* and *Prunus avium* are predominantly on the west slope.

They comprise 54.2% of tree abundance on the west slope but only 27.1% of the basal area. On the east slope there was only one exotic tree, an *Ailanthus altissima* that only accounted for 1% of tree abundance and only 0.3% of the basal area. Because of the disparity between abundance and basal area of the exotic species, it was decided to do a size class analysis of the trees, comparing the density of trees along a continuum of dbh measures. This analysis was used to compare total and native trees on each slope and then to compare native trees on both slopes and total; trees on both slopes (Figures 6, 7, 8 and 9). On the west slope (Figure 6), there has been a decline in new growth of native trees (between 24cm and 5cm dbh) although 20.9% of the shrub layer is comprised of native saplings. There has been a sharp increase in growth of exotic trees (between 29cm and 5m dbh) as well as 30.7% of the shrub layer being comprised of exotic saplings. No data were recorded for those trees with a dbh of less than 5cm. On the east slope (Figure 7), there is only one exotic tree which is in the 15-19cm range. The smallest native trees have greatly declined but no new exotics have occurred and 49.7% of the shrub layer is comprised of native saplings. Figure 8 shows that the west slope has many more new young trees but as seen in Figures 6 and 9, these trees are not natives. Figure 9 shows a greater density of native trees, of almost all sizes and ages, to occur on the east slope. Both slopes show a decline new growth. Tables 1a and 1b show *Acer saccharum* on both slopes but only in the lower and middle areas. *Fraxinus americana* was located on both slopes but only in the lower area. *Betula lenta*, *Liquidambar styraciflua*, and *Quercus velutina* are on both slopes but only in the middle and upper areas. *Juglans nigra* and *Ulmus americana* were in all sections of the west slope, and the lower section of the east slope. Trees found only on the west slope were: *Liriodendron tulipifera* , *Nyssa*

sylvatica, *Prunus avium* and *Prunus serotina* Trees found only on the east slope were: *Carpinus caroliniana*, *Fagus grandifolia*, *Quercus alba* and *Quercus coccinea*. The entire study area only contained two *Acer rubrum* trees, one on the east middle slope and another on the east upper slope.

SHRUB AND SAPLING LAYER

Table 2 is a list of the species in the shrub and sapling layer, by transects. *Lindera benzoin*, which represented about a third of the plant cover on each slope, and *Acer saccharum* saplings, were the only species that were in all six transects. As was the case with the tree distribution, *Acer saccharum* was mainly in the lower and middle transects of each slope. The exotics, *Ailanthus altissima* and *Lonicera japonica*, were only in the transects on the west slope, where they represented 31.2% of the plants in this stratum. *Ligustrum obtusifolium*, another exotic, was predominantly on the west slope (12.1%) with a small representation on the east slope (0.5%). Saplings of *Acer rubrum*, *Fagus grandifolia*, *Liquidambar styraciflua*, and *Quercus rubra* were only in the transects on the east slope. Shrubs of *Kalmia latifolia*, *Rhododendron periclymenoides*, *Vaccinium corymbosum*, *Vaccinium pallidum*, *Viburnum acerifolium* and *Viburnum dentatum* were only in the transects on the east slope, and vines of *Amphicarpaea bracteata*, *Lonicera japonica*, *Rubus occidentalis* and *Toxicodendron radicans* were only in transects on the west slope.

SPRING HERB LAYER

Table 3a is a list of the spring herb layer on the west slope and Table 3b is a list for the east slope. Only 4 species out of a total of 54 were in all 6 transects. They were *Hydrophyllum virginianum*, *Lonicera japonica*, *Polygonatum pubescens* and *Urtica*

dioica. The upper west slope had 4 dominant species composing 78.0% of the plant cover: *Hydrophyllum virginianum*, which dominated four of the six transects, *Lonicera japonica* and *Stellaria media*, which are exotics and *Rubus occidentalis*, which grows in disturbed areas (Gleason and Cronquist 1991). The middle, west slope was dominated by *Hydrophyllum virginianum*, *Lonicera japonica*, and *Stellaria media* for a total of 64.1% cover and an additional 10.0% was contributed by the fern, *Cystopteris protrusa*.

Hydrophyllum virginianum, *Urtica dioica*, a *Viola* species and *Rubus occidentalis* dominated the lower west slope. These four plants composed 75.8% of the plant cover. Three ferns, *Athyrium thelypteroides*, *Cystopteris protrusa* and *Polystichum acrostichoides* composed an additional 10.2% of the plant cover. The lower east slope was dominated by *Hydrophyllum virginianum*, *Urtica dioica*, *Acer* seedlings and *Polygonatum pubescens*, which composed 65.2% of the plant cover. The fern, *Athyrium thelypteroides* accounted for an additional 9.8% cover. *Athyrium thelypteroides*, *Urtica dioica*, *Viburnum acerifolium* and *Aster divaricatus* dominated the middle east slope. These four plants composed 49.2% of the plant cover, of which 24.2% was *Athyrium thelypteroides*. *Adiantum pedatum* and *Cystopteris protrusa* added another 5.7% to the fern cover. *Maianthemum canadense*, *Viburnum acerifolium*, *Urtica dioica* and a *Viola* species dominated the upper east slope. These four plants comprised 50.3% of the plant cover. The ferns, *Osmunda claytoniana*, *Athyrium thelypteroides* and *Cystopteris protrusa* contributed additional plant cover (19.4%). Tables 1a, 1b, 2, 3a and 3b contain the data that were used in the statistical analyses. Table 18 shows the distribution of the ferns on both slopes, by quadrats.

FALL HERB LAYER

Table 4a is a list of the fall herb layer on the west slope, by transects. These transects for the fall survey were similar to the spring survey transects. As would be expected, the fall leaf litter was significantly greater than the spring accumulation. The west slope had 15-19% leaf litter in the spring and 18-25% in the fall. The east slope (Table 4b) had 38-45% in the spring and 51-76% in the fall. The major difference in the two surveys was not in the plants present but in their amount of cover. Spring herbs were wilting and losing biomass while herbs such as *Aster divaricatus* and *Eupatorium rugosum* had gained biomass. *Cystopteris protrusa* had disappeared but *Polystichum acrostichoides*, a semi-evergreen fern, had increased in dominance. *Lindera benzoin* seedlings were spreading and providing more ground cover than in the spring.

SOIL ANALYSIS

General. Table 12 is an analysis of soil texture. It reflects the grain-size composition of five of the six transects and the creek bed. Dr. Patrick Brock was kind enough to do an analysis of one of the soil samples to get an indication of some of the minerals in the soil. The results were that the coarse sand sized grains were a composite of quartz and rust colored grains with black flecks that appeared to be weathered iron from serpentinite. The finer silt size grains were an aggregate of equal parts quartz, silt and rusty soil fragments (pers. comm. Patrick W.G. Brock 2001).

Table 13 contains the soil properties data for the creek and the west and east slopes, listed by soil sample location and using the mean of the two samples collected at each site, at 0-5cm and 10-15cm depths. The 50-meter level on the middle of the east slope was near a fence that acted as a net, accumulating dead leaves, twigs, etc. up to a depth of

about a half-meter. The total weight of this 0-5cm deep sample was about 57% lighter than other samples from the middle slope. It showed an extremely high amount of organic matter lost on ignition (54.2%). This was the mean of 78.87% at 0-5cm depth and 29.47% at 10-15cm depth. The top sample has to be considered part of the organic O-horizon, which is located above the actual soil substrate. It was therefore removed from the data used for statistical analyses. The 10-15cm level still reflected the highest concentration of organic matter of all the samples tested. Values for pH range from neutral (7.04) to extremely acid (4.04), in this relatively small, 4,400m² area (Table 13). The high pH values were located on the west slope, in the creek bed and to a lesser extent in the northern lower and middle section of the east slope. Low pH values were found on the east slope. Table 14 is a summary of the soil properties data from Table 13 for the west and east slopes. The data for the top sample of middle of the east slope at the 50m site were removed. The table shows the mean of the values of the three sample locations along each transect. The creek data have been omitted because soil from a creek bed, being washed with water for the greater part of the year, would be expected to have a different chemical composition than the soil where the vegetation data were collected. The data show some clear patterns of changes along the gradient. The mean pH ranges from neutral (6.66) at the middle of the west slope to very strongly acid on the upper section of the east slope (4.41). Moisture content and organic matter are fairly high from the middle of the west slope to the middle of the east slope but then drop considerably in the upper east slope. There is a decline along the gradient from west to east in the available ppm of the following minerals: potassium, calcium, magnesium, and total chromium. There is an increase in the available ppm across the same gradient for iron

and aluminum. Manganese and zinc first increase and then decrease in available ppm.

There is no apparent pattern for available nitrate, phosphorus, or copper.

Correlation Analysis. Table 17 is a summary of correlation analysis of the soil properties data from Table 13 for those variables that had a linear relationship. Except for chromium (n=18) all the variables had n=35. This included the creek bed and the two slopes. There is a strong positive correlation ($r=+0.87$) between percentage of organic matter and percentage of moisture content in the soil samples. Available calcium and magnesium have moderate positive correlation with moisture. Available iron and aluminum are strongly positively correlated with each other ($r=+0.86$) and strongly negatively correlated with pH: iron ($r=-0.90$) and aluminum ($r=-0.91$). Available calcium is strongly positively correlated with available magnesium ($r=+0.89$) and moderately positively correlated with pH ($r=+0.68$). Chromium is moderately positively correlated with calcium ($r=+0.72$) and magnesium ($r=+0.71$).

Cluster Analysis. Results (Table 11) of soil properties data for Complete Linkage (Figure 14) and Average Unweighted Linkage clustering separated the two areas as west middle and lower and east lower and middle as one group of the terminal cluster (final two groups) and the east upper as the second group. Minimum Variance separated the area into west middle and west lower as one group and east lower, middle and upper as a second group

ADDITIONAL SOIL ANALYSIS

The results of testing additional soil samples are in Table 16. The samples were collected from around the Bloodroot Valley area and at Clove Lakes, an area about 2½ miles northeast of Bloodroot Valley. In addition, a comparative sample from a serpentine

area in Maryland was included. These soils were tested for both total nutrients in the soil and for nutrients available to the plants. The results are listed for calcium, magnesium, manganese, iron and aluminum, in order of pH from low to high, along with a list of average concentrations in the soil for these elements (Bowen 1966). The highest calcium concentration was by Building #21 in the Seaview complex. Rainwater/throughfall analysis (Table 15) shows the highest calcium concentration at this same location. Bloodroot Valley's east slope and North Seaview (Table 16) are the only two locations that do not have above average magnesium levels. High manganese and iron levels, along with high magnesium are at Clove Lakes, the west slope of Bloodroot Valley and Soldiers Delight, MD. The available iron for these same locations is extremely low (much less than 0.01%). Although most sites had from two to two hundred times more magnesium than calcium, the percent of available calcium at all but No. Seaview's location ranged from a low of 19.4% to a high of 74%, with an average of 35%, while available magnesium was much less, only from 0.4 to 4.6%, with an average of 2%. Available iron ranged from much less than 0.01 to 0.42% with an average of 0.1%. Available manganese ranged between 1.7 and 7.9% of the total amount and had an average of 4.2% available. Available aluminum ranged from 0.04 to 1.77% with an average of 0.4%. Iron and aluminum decreased in availability as pH increased. Iron availability is the lowest where manganese totals are the highest. Calcium was highest at Building # 21 and Children's Hospital on the Seaview grounds.

WATER ANALYSIS

Results of the water analysis are in Table 15. The highest concentrations of both calcium and magnesium are in the sample collected near Building # 21 on the Seaview

Hospital grounds. The lowest concentrations of both elements were in the open area at North Seaview. The creek water was the only place that had more magnesium than calcium.

STATISTICS - PLANTS

Distance and Similarity. Table 5 contains the results of the distance and similarity analyses of all three vegetation strata. The results are listed in the format of a gradient from west to east, starting with the upper west slope down to the lower west slope and across the creek from the lower east slope up to the upper east slope. The matrices from which this table was constructed are in Appendix 4. All the matrices are symmetric, square matrices. Values below the diagonal are the same as those above the diagonal. For clarity, only the values above the diagonal are shown. The values in bold print in Table 5 denote the adjacent transects that have the largest distance or the least similarity between them. Data used for the analyses were: density of trees, relative canopy cover of shrubs and saplings and the plant cover of the herbs. Results of the analyses showed the majority of measures in each stratum with the greatest distance between two transects to be:

Data	Least Similar Transects	% of measures concurring
All Trees	west lower – east lower	70%
Native Trees	east lower – east middle	80%
Shrubs and saplings	east lower – east middle	90%
Herbs	east lower – east middle	50%

Results of the two species similarity measures indicate the greatest dissimilarity to be between the following two transects:

All Trees	east lower – east middle
Shrubs and saplings	west lower – east lower
Herbs	east middle – east upper

Ruzicka's Percent Remoteness measure was used for ordination and clustering classification. Ruzicka results agreed with the majority of measures in every category.

Ordination. Table 10 is a list of the results of the Principal Component Analysis for each stratum. PCA values were calculated first using the raw data and then using the angular transformation of the data. The results are eigenvalue proportions that represent the percent of variability accounted for by the first two principal components, using Ruzicka's Percent Remoteness distance measure. Values for Principal Component 1 represent the variability accounted for on the x-axis of the PCA scattergrams (Figures 10-13). Values for Principal Component 2 represent the variability accounted for on the y-axis of the PCA scattergrams (Figures 10-13). Values using raw data are desirable because they account for more of the total variability on the first two axes. Raw data were therefore used for analyses.

Cluster Analysis. Table 11 shows a summary of the Cluster Analysis results. The summary reflects the final two clusters (terminal groups) for each of the three clustering methods. This indicates the major separation between the two areas. Clustering results for all trees divide the two groups by west and east slopes. However, when the exotic trees are removed from the data, the native trees separated into the same two groups as the shrub and sapling layer and the herb layer, namely, west upper, middle, lower and east lower as one group and east middle and upper as a second group. Soil properties

data separated slightly differently: west middle, lower, east lower and middle as one group and east upper alone as the second group.

DISCUSSION

NEUTRAL (SOIL) AND ACIDIC (SOIL) COMMUNITIES

The study area is divided into two distinct communities that are influenced by the underlying soil pH, the moisture and drainage regimes, and the effects of disturbance on the west slope.

Cluster analysis of the soil properties data divide the communities into two groups: west middle & lower, east lower & middle as one group and east upper as a separate group. Table 14 shows a pH gradient from neutral in the west middle & lower slopes to strongly acid in what could be considered the transitional zone of east lower and middle slopes to an extremely acid pH on the east upper slope. The three most abundant soil nutrients, calcium, magnesium and potassium follow this same gradient with very large amounts on the west slope that gradually diminishing to very small amounts on the upper east slope. Iron and aluminum increase in availability across the gradient and are highest in the lowest pH areas.

Clustering analysis of all trees divides the two groups into west and east slopes. Tree density on each of these slopes is similar (west = $.0473/\text{m}^2$ and east = $.0441/\text{m}^2$). This separation is caused by two exotic trees, *Ailanthus altissima* and *Acer platanoides*, which are dominating the entire west slope, with a relative density of slightly over 50%. Since these exotic trees were predominantly young trees invading the disturbed west slope, a separate analysis was made using only the native trees. This clustering separated the trees into the same groups as the shrub and sapling layer and the herb layer, namely, west

upper, middle & lower with east lower as Group 1 and east middle and upper as Group 2. Size Structure analysis of native trees (Figure 9) indicates that there is about twice as much density of trees on the east slope. The additional density is from the exotic trees. With the exception of a large amount of 15-20cm trees on the east slope, the distribution of sizes on both slopes appears to be similar. Table 6a groups the trees by west and east slopes and Table 6b groups them by neutral and acidic communities. Either grouping, by east slope or by acidic community, represents an oak-beech forest whereas the west slope or neutral community group represents trees of a disturbed ravine in a mixed hardwood forest. Although recognizing that the study site has transitional zones, the area was divided into two distinct communities. The west slope and lower area of the east slope shall be referred to as the "Neutral (soil) Community" and the middle and upper areas of the east slope shall be referred to as the "Acidic (soil) Community". The plant distributions in both communities are closely correlated with the soil properties (Tables 13 and 14) obtained from the soil samples and from an analysis of the hydrology of the area.

The neutral community occurs in sandy, nutrient rich, moist soils with slightly acid to neutral pH (6.1 -7.1), except in two areas of the lower east slope which have higher acidity (4.8 and 5.4). The plant associations found in this community are comparable to floodplain communities, such as Burnt Mills and Mertensia Woods, of the Raritan River in northern New Jersey (Wistendahl 1958). The river flows through the New Jersey Highlands and Piedmont Plateau before crossing the Coastal Plain and emptying into Raritan Bay, which is located immediately southeast of Staten Island. Since the prevailing winds at this latitude are westerly, at least some of the vegetative propagules in

Staten Island are very likely to have originated in the Raritan floodplain. Other floodplains farther west have similar vegetative associations, such as Glade Creek/New River Gorge, West Virginia and the Mississippi River Gorge in Seward, Minnesota (Mueller 1999, Paddock 1998). The forest community in the neutral community is also comparable to the Sugar Maple-Mixed Hardwood type of northern New Jersey, which usually occurs in moist valleys and ravines and flourishes on fertile limestone valleys (Collins and Anderson 1994). Northern Hardwood forest types are also found in the New Jersey Highlands, where they characterize the mesic low areas and ravines (Ohmann and Buell 1968). These stands are dominated by *Acer saccharum*, *Betula lenta* and *Fagus grandifolia*, among others, and so they are similar in floristic composition to the Bloodroot Valley neutral, disturbed forest.

The second community, on the east slope, is best developed on the upper slope, but occurs also in the middle slope. It will be referred to as the "acidic community". Here, the soils are slightly less sandy, less nutrient rich, and drier, with strongly acid to extremely acid pH (5.0 to 4.0), except for the middle slope at 0m, which has a moderately acid pH (5.8). This community is comparable to the ecosystem of the native mixed oak forests on the Staten Island Greenbelt. Composition is also similar to forests described along the terminal moraine of the Wisconsinan ice sheet. For example, Mixed Oak Forest of north New Jersey (Collins and Anderson 1994) and the Oak, Beech, Mixed Dicot Forest on Mill Neck, Long Island (Greller and others 1990), reflect similar vegetation to the Bloodroot Valley forest in the acidic, undisturbed community. The Sugar Maple-Mixed Hardwood Forest has more diversity and equability than the Mixed Oak Forest, although they have many trees in common (Collins and Anderson 1994).

Simpson's Index of Diversity indicates that Bloodroot Valley has greater tree diversity in the neutral community (84.4% in total and 83.7% excluding exotics) than in the acidic community (73.6%). The neutral community also has a more even distribution at the tree level (neutral=.945, acidic=.913). Both Sugar Maple-Mixed Hardwood and Mixed Oak forests support the spice bush shrub, *Lindera benzoin*. It is very abundant on moist lands of the Piedmont as well as throughout the entire New York Metropolitan area (Clemants 1999) and is an important shrub in both the communities at Bloodroot Valley.

TREES

Table 6b is a summary of the trees in both communities. The neutral community represents a mixed hardwood forest that has clearly been invaded by exotic trees such as, *Ailanthus altissima*, *Acer platanoides*, *Morus alba* and *Prunus avium*. These exotic species, which represent 47.6.7% relative abundance (RA) and 22.7% of relative basal area (RBA), are disturbance indicators. Apparently, the allochthonous gravel and all the disturbance relating to the hospital construction has allowed the exotic young trees and saplings to come into this area. *Ailanthus altissima*, an exotic and the most abundant exotic species (29.3% RA, 13.1% RBA), was most prevalent on the upper slope (Table 1a). *Acer platanoides*, another exotic species, was the second most abundant tree (RA 15.7%, RBA 5.1%) in the neutral community. The larger trees were growing on the bedrock and the smaller, younger trees were colonizing the gravelly section. Figures 6, 7, 8 and 9 compare the size structure of native and exotic trees on the two slopes. It is apparent that some of the larger trees are old enough to predate the disturbance, and they were probably not affected by it. The next four most important trees were *Quercus rubra* (14.8% RA, 26.1% RBA), *Acer saccharum* (8.7% RA, 9.4% BA), *Juglans nigra* (7.9%

RA, 15.1% RBA) and *Ulmus americana* (7.9% RA, 6.5% RBA). *Juglans nigra* and *Ulmus americana* are water tolerant species and were located only in the neutral community. Bloodroot Valley is one of only two places on Staten Island where *Acer saccharum* grows (Kershner 1998). It was present on both sides of the study area but only on the lower, more moist, floodplain-like sections. *Acer saccharum* composed only 8.7% of tree abundance in the neutral community and 2.8% in the acidic community (Table 6b). However, in the shrub and sapling layer it composed 20.7% of the neutral community and 24.9% of the acidic community (Table 7). The oak trees in the neutral community comprised 16.1% RA and 32.2% RBA. They had their highest concentrations on the middle slope. Trees in the acidic community were representative of the local Mixed Oak Forests. Combined oaks had a RA of 65% and RBA of 90%. The oaks increased in importance as one went up the slope. The middle slope had 58% RA, 87% RBA area and the upper slope had 73% RA and 95% RBA. *Acer saccharum*, on the contrary, was not present on the upper slope, and had a small (5% RA, 3% RBA) representation on the middle slope. It was well represented on the lower slope (38% RA, 15% RBA). There were no exotics in this area.

Acer rubrum is the second-most widespread woody plant in the 25 counties of the NY Metropolitan Flora project (pers. comm. Steven Glenn Brooklyn Botanical Garden 2001). It is a dominant tree in the SI wet woodlands (Buegler and Parisio 1982), but it was only represented by two trees in the entire study area, one on the middle east slope and one on the upper east slope reason. The shrub and sapling layer (Table 2) had 21.7% cover for *Acer rubrum* saplings in the middle of the east slope but it appears that the saplings do not have a high survival rate. *Acer rubrum* is susceptible to both manganese deficiency

and manganese toxicity. Manganese is an important nutrient for chlorophyll synthesis. Excess calcium and high pH (above 6.5) can cause manganese deficiency (Dirr 1990, Craul 1992). Excess manganese, can cause toxicity to plants by reducing the availability of iron and thereby causing chlorosis (Brooks 1987, Craul 1992). Ericaceae and some water-tolerant plants are better able to tolerate manganese toxicity (Graham 1988). Ferns may accumulate manganese (Lounamaa 1956 cited in Bowen 1966). Manganese is considered toxic at pH levels below 5.5, but if the pH is very low the available manganese is mobilized and leached, and becomes unavailable to plants.

SHRUB AND SAPLING LAYER

The neutral community contained a mixture of native and exotic saplings and shrubs (Table 7). Exotics *Ailanthus altissima*, *Ligustrum obtusifolium* and *Lonicera japonica*, represented 23% of the species and 35% of the plant cover. The dominants, *Acer saccharum* and *Lindera benzoin*, combined represented 61.5% of the plant cover in the neutral community and 36.4% of the plant cover in the acidic community. *Ligustrum obtusifolium* composed 9.9% of the neutral community but this figure reflects efforts to eradicate this exotic species by a local naturalist, prior to the inception of the present study. Additional species included *Rubus occidentalis*, *Toxicodendron radicans* and *Robinia pseudoacacia*, which are frequently associated with disturbed areas and *Amphicarpaea bracteata*, an abundantly distributed vine.

The acidic community supported 6 unique species, five of which require acid soils (Wyman 1971): *Kalmia latifolia*, *Quercus rubra*, *Rhododendron periclymenoides*, *Vaccinium pallidum* and *Vaccinium corymbosum*. Four others, *Acer rubrum*, *Fagus grandifolia*, *Lindera benzoin*, *Viburnum acerifolium* all prefer acidic soils. Only *Acer*

saccharum and *Liquidambar styraciflua* prefer neutral soils (Wyman 1971, Dirr 1990).

There were no exotics. The shrubs in the acidic community are similar to those of the mesic upland Mixed Oak Forests of northern New Jersey (Collins and Anderson 1994).

HERBACEOUS LAYER

Sorensen's Coefficient of Community indices for presence and abundance (Magurran 1988) show a large difference between the two herbaceous communities. They had 47.9% similarity of species but when this was weighted to account for abundance, the similarity between the communities dropped to 19.6%. The acidic community had higher diversity (.927) than the neutral community (.783). Its species density was 0.944spp/m² compared to the neutral community's species density, 0.514 spp/m². The acidic community also had a more even distribution (.955) than the neutral community (.805). The most dominant plant in the acidic community, *Athyrium thelypteroides*, only represented 15.5% of the plant cover. *Athyrium thelypteroides* represented the highest amount of plant cover in the acidic community but its frequency was only 17%. *Maianthemum canadense* had almost as much plant cover (11.5%) but 31% frequency. *Hydrophyllum virginianum*, the most dominant plant of the neutral community, represented 43.9% of the plant cover. Calculation of the amount of species per square meter indicated that the acidic community had 43% more species per square meter than the neutral community, even though it had only 44.8% plant cover as compared to the neutral community's 66.6% plant cover. As would be expected in a temperate climate, the plant cover for both communities dropped about 20% in the fall survey.

The herb layer in the neutral community is not only very different from its neighboring acidic community but it is completely different from serpentine barrens

herbaceous plants listed for nine eastern United States locations, from Georgia to Pennsylvania (Brooks 1987). It is therefore to be considered a unique community. *Hydrophyllum virginianum*, the dominant herb in this community (Table 8) and *Sanguinaria canadensis*, a small presence in the community, appear to co-occur throughout the Piedmont Plateau lowlands, many times in association with *Juglans nigra* and *Acer saccharum*. Some examples are Burnt Mills and Mertensia Woods, NJ (Wistendahl 1958), Mississippi River Gorge, MN (Paddock 1998) and Glade Creek, WV (Mueller 1999). *Juglans nigra*, an important tree in this community, is considered an allelopathic plant. It secretes a chemical called juglone that has been found to inhibit growth of plants. *Hydrophyllum virginianum* and *Sanguinaria canadensis* are plants that are not affected by the juglone toxicity (Robinson 1998). Although *Hydrophyllum virginianum* is considered an aggressive native (Great Lakes National Program 1998) and its presence is well documented in New York State (NYFA 1990) and New Jersey (Hough 1983), it is not common on SI. *Sanguinaria canadensis* is also common in New York State and New Jersey but is rare in Staten Island, as mentioned earlier. In New Jersey, *Sanguinaria canadensis* is associated with the Sugar Maple- Mixed Hardwood forest of Collins and Anderson (1994). *Urtica dioica* is a weedy, aggressive nitrophile (Uva et al. 1997) that actually delays colonization by less competitive woodland plants (Gilbert and Anderson 1998). It is rare on Staten Island. *Hydrophyllum virginianum*, *Sanguinaria canadensis* and *Urtica dioica* all require rich, moist well-drained soils. *Hydrophyllum virginianum* and *Sanguinaria canadensis* prefer a neutral to slightly acid pH (Wherry 1948). *Lonicera japonica*, the second most important plant in the neutral community, is an extremely invasive exotic that is common throughout Staten Island

(Buegler and Parisio 1982) and the NY Metropolitan area (Clemants 1999). The exotic, *Stellaria media* is commonly distributed throughout SI (Buegler and Parisio 1982) and northeast North America (Peterson and McKenny 1968). *Polygonatum pubescens*, also considered an aggressive native, was equally distributed in both communities. It had 4.6% cover in the neutral community and 5.2% cover in the acidic community. It prefers moderately acidic, wooded slopes (Wherry 1948) and it adapts to moist woods (Gleason and Cronquist 1991) and dry woods (Seymour 1993). The herbaceous layer of the acidic community is similar to that of the Mixed Oak Forest of Collins and Anderson (1994) and the Oak, Beech, Mixed Dicot bottomlands of Greller (1990). *Maianthemum canadense*, which is listed in the original Collins' work (Robichaud and Buell 1973) as present in the Mixed Oak forest, was the most important species in the acidic community. Twenty of the 37 species in the neutral community were unique to it. Seventeen of the 34 species in the acidic community were unique to it.

Ferns were an important component in both communities. Table 8 is a distribution of the spring ferns in the entire study area. *Cystopteris protrusa* [see Addendum] is predominantly located on the lower and middle west slopes, in the neutral area. It prefers rich, moist, shaded rock crevices and tree stumps (Cobb 1984), with a pH range between 6.0 and 8.0 (LaMotte 1978), and is rarely found on Staten Island. *Polystichum acrostichoides* is only located on the lower and middle west slope. It prefers rocky, sandy rich soils of ravines and streams (Small 1975). It does not demand, but prefers rich, limy soil (Cobb 1984) with a pH range of 6.0-8.0 (LaMotte 1978). It is not commonly found on Staten Island. *Athyrium thelypteroides*, predominantly on the east slope, prefers rich, moist well-drained woods and shaded banks (Cobb 1984). It prefers a

lower pH (5.0-6.0) than *Cystopteris protrusa* and *Polystichum acrostichoides*. Although it is a fairly common fern of the northeast (Cobb 1984), it is rare on Staten Island.

Adiantum pedatum is most abundant in rich, shaded, limestone areas, often in ravines (Cobb 1984). A subspecies, *Adiantum pedatum* subsp. *calderi* Cody, is also found at scattered serpentine slopes in northeast America, but usually with fewer and smaller pinnae (Gleason and Cronquist 1991). It is rare on Staten Island. *Osmunda claytoniana* is a rugged and persistent fern of stony, dry places (Cobb 1984) but it does best in highly acid, constantly damp, shaded areas (Foster 1984). Although this fern is common on Staten Island, it was only located in one quadrat in the entire study area, in the upper slope of the acidic community.

Non-native species account for 8% of the total species of vascular plants in Staten Island in the lowlands and 17% in the uplands (Robinson and others 1994). In this Bloodroot Valley study, the acidic community had about 3% exotics, which is below the lowland average. The neutral community had about 20% exotics, which is higher than the upper range of the average, again reflecting the increase in invasive plants in disturbed areas.

SOIL PROPERTIES DATA

Table 12 is a summary of the results of soil sieving. As would be expected, the amount of gravel in the soil samples collected on the disturbed, gravelly west slope (41%) was twice as much as on the undisturbed east slope (21%). The soils in the disturbed area and in the creek bed contained more sand (averages of 93% and 95%, respectively) than soils in the undisturbed area (89% average). Table 17 shows a strong positive correlation between percentage of organic matter and percentage of moisture

content in the soil samples ($r=+0.87$). Organic matter in an otherwise sandy soil would be responsible for holding most of the moisture and many of the nutrients. The moisture content in the creek bed was low because the samples were taken when the creek was dry and because the organic matter in the creek bed was low. Organic soils are defined as those that contain 20% or more organic matter (Plaster 1985). Although most of the soil samples tested at Bloodroot Valley were not organic soils, their organic content was quite high, averaging about 15% in both communities, without including the exceptionally high organic content of the top sample at the 50 meter location on the middle, east slope. Organic matter holds six times its weight in water and therefore accounts for the strong positive correlation. Nitrogen, phosphorus and potassium (N, P, and K) are highly variable components of a soil assay and they will only be discussed in general terms. It should be noted that it is normal for sandy soils to be low in nitrogen, as it is easily leached. Available nitrogen is also cyclical and soil assays should not be relied on solely as a definitive measurement of nitrogen present. Excessively acid soils slow down the nitrification process and render nitrogen unavailable. A good nitrate range for plant nutrition is 30-235ppm. The nitrogen levels that were reported in Tables 13 and 14 are not to be interpreted as the total nitrogen available to plants. Most nitrogen in soils is derived from nitrogen fixation by soil microbes and from precipitation. Between 97% and 99% of soil nitrogen is tied-up in organic matter and at any given time only a small percent of this is mineralized to forms used by plants (Plaster 1985). Plants can take up nitrogen in the form of ammonium ions or nitrates. The N values that are reported in Tables 13 and 14 only reflect nitrate N. CNAL tests for nitrate N instead of ammonia because the nitrate N is the primary mode of N uptake by plants. Ammonia only exists

for a short time in the warm agricultural soils of the NYS area (pers. corres. W.Shaw Reid CNAL 2001). It can be assumed, from the abundant presence of *Urtica dioica*, a known nitrophile, that nitrogen levels are more than sufficient for plant needs.

Phosphorus levels (2-8ppm) were below those considered good nutrient levels for plants (3-18ppm). Potassium levels (71-225 ppm) were very high, even where they dropped considerably on the upper east slope. A good potassium range for plant nutrition is 25-110ppm. Acid soils (pH 4.2) free iron, aluminum and other heavy metal ions so that they become soluble and enter the soil solution. As the pH decreases, the availability of these minerals to plants increases. This was reflected in the highly negative correlation between pH and aluminum ($r=-0.91$) and pH and iron ($r=-0.90$). That was not the case with manganese ($r=+0.42$). The low correlation value for manganese is actually a blending of two separate trends. Available manganese increases from pH 4.0 to 5.2 but then decreases from pH 5.2 to pH 7.1 (the maximum pH in this study). This was also the case with available magnesium ($r=0.57$); as pH increased from 4 to 6.5 magnesium increased but from pH 6.5 to 7.1 magnesium decreased. The available manganese in the upper acidic east slope was very low, as was available zinc. This is probably caused by the fact that these nutrients were leached. Calcium, magnesium and potassium were also greatly reduced in this area, but still above plant nutrition requirements. Good nutrient levels for calcium are 300-1600ppm, and for magnesium, 20-150ppm. The good nutrient levels were reported in Craul (1992) using data from the University of Massachusetts. Available copper appeared unaffected by the pH range in this study.

The calcium to magnesium ratios are much higher than one would expect for serpentine or strongly acidic soils, both of which are represented at Bloodroot Valley.

Calcium is the third most used nutrient of plants. Adequate calcium helps plants to avoid stress effects due to the presence of heavy metals or salinity (Rendig and Taylor 1989). Calcium comes from the weathering of very common minerals and rocks, and shortages are rarely found. The exceptions are serpentine soils, acidic soils, or leached sandy soils (Plaster 1985). The study area has sandy soils on both slopes, serpentine soil on the west slope and acidic soil on the east slope, all of which would contribute to low calcium levels. Calcium is usually more available to plants than magnesium because magnesium is subject to more leaching than calcium (Brooks 1987). There was a strong positive correlation between available calcium and magnesium ($r=+0.89$). There were more calcium and magnesium in the surface samples than in the subsoil, at most sampling sites. Since both minerals are easily leached, this would suggest that a constantly renewable source is supplying these minerals to the site. The magnesium is probably leached from the serpentinite gravel. The calcium is probably coming from another source, possibly the concrete and limestone from the crumbling hospital. Sandy soil, such as that of the disturbed area, has little or no buffering capacity to resist the action of lime in changing its reaction. It therefore needs just a small amount of lime to raise the pH. The calcium levels, on the upper undisturbed slope, were much lower, but were still above levels required by plants. Further investigation was conducted to determine if the amount of calcium dropped abruptly as a function of the distance from the calcium source or for some other reason. The additional testing showed an appreciable levels of calcium and magnesium in the rainwater/throughfall near Building #21 in Seaview and in the creek water collected at BRV (Table 15). These results were compared with results of an

11 year-study in an undisturbed forest in the Hubbard Brook Ecosystem Study in New Hampshire. This eastern broadleaf forest has many of the same trees as Bloodroot Valley, namely, *Fagus grandifolia*, *Acer saccharum*, *Fraxinus americana*, *Acer rubrum*, *Quercus rubra* and *Ulmus americana* (Likens and Bormann 1995). The additional soil testing (Table 16) showed a significantly large amount of calcium in the area by Building #21 and also a large amount by the top of the road to Children's Hospital, on the west slope of Bloodroot Valley and at Mt. Moses. This increases the possibility that the high calcium levels are coming from crumbling concrete and limestone buildings and construction rubble. Mount Moses or Moses Mountain, named after city planner, Robert Moses, is a 61 m (200') high pile of rocks and debris removed from the construction site of the Staten Island Expressway vicinity and placed in the southern Seaview swamp area (Mittelbach and Crewdson 1997). The Ca:Mg ratios at the study site ranged from 0.5 (a single location below 1) to a high of 3.4 and averaged 1.6. Calcium ratios are unusually high for serpentinite soils. On non-serpentine soils, ratios for Ca:Mg in humid, temperate conditions, such as Staten Island, range from a low of 1.3 to a high of 10.7, spanning both alkaline and acid soils (Buckman and Brady 1969, Balter and Loeb 1983, Collins and others 1984, Bridges 1987, Sposito 1989, Craul 1992). An average of six worldwide serpentinite locations had ratios ranging from a low of 0.06 to a high of 0.71 (Brooks 1987). Parisio (1982) reported a ratio on Staten Island serpentinite of 0.33 and on nearby New Jersey non-serpentine Somerset red shale of 2.88.

The mean total chromium values found at the study site ranged from 28.5ppm to 3955ppm. In many serpentinite soils the range is from 1,000 to 25,000ppm. On both slopes and in the creek bed, total acid-soluble chromium was rated high for non-

serpentine soils and low for serpentine soils. "Typical" agricultural soils, used as Master soils by Cornell's Nutrient Analysis Lab, have chromium ranges of ~11ppm to 21ppm (pers. comm. with Mark Joyce, CNAL 1999). Available chromium was insignificant in our samples and therefore doesn't influence plant uptake. Brooks (1987) cited work by Proctor (1969,1971) that showed that the chromic ion toxicity is reduced by the presence of calcium ions.

HYDROLOGY

The road leading from the main loop road of the hospital grounds down to the parking lot and lower level of the Children's Hospital measures about 5.7m wide and 160.9m long, with a 10-12 cm high curb on both sides, and a strongly sloping grade (7.5%). Most normal rainfall would be completely channeled down to the bottom of the road, which then runs directly off the west slope into Bloodroot Valley, at the northern section of the study area (Figure 4). Average monthly rainfall for this area is about 4" (10.2cm) or 0.102m /mo. Water running off the road can be contributing as much as 93,500L/mo (24,700gal/mo) in addition to the actual rainfall on the slope. For the north section, this was calculated as 50.0m long * 22.0m wide * .102m rain/mo. * 1000L /m³ = 11.2 x 10⁴ L/mo. for the entire area or 102L/m²/mo (26.9gal/m²/mo). This represents an additional 83% rainwater supply. A very conservative calculation was computed for water run-off from the parking lot area. An assumption is made that there is a sheet-like run-off on the two sides that slope downwards from the west to the east and south of the lot and it only using the rainfall from the southeast section of the lot. Another assumption is that only half of this water spreads out to the entire 100 meters of the study area. The result suggests that the area could receive at the least 20% additional rainwater.

CONCLUSION

The data clearly show that there are two distinct vegetative communities that correlate with two distinct sets of soil properties. The vegetation in the first “neutral” community, on the west slope and lower east slope, has been greatly influenced by anthropogenic disturbances to the area. The mixing of glacial till and serpentinite gravel, the excessive rainfall, that is running-off from upland paved surfaces, and the additional calcium from deteriorating upland buildings, along with the naturally perched water table, have all contributed to a nutrient rich, circumneutral, very moist soil. The vegetation is similar to floodplains of a mixed hardwood forest, which has become overrun by invasive exotic species and aggressive native species. The second, undisturbed “acidic” community is similar to the native mixed oak forests of the Wisconsin terminal moraine area, with acidic, well-drained, less nutrient rich soil. The vegetation is predominantly plants that thrive on acidic soil. We therefore accept the hypothesis that variation in herbaceous vegetation can be an indicator of variation in soil composition. Human disturbance in Bloodroot Valley has fostered a unique soil condition. What is unique about the BRV site is that upland till and serpentinite rubble were deposited on top of till-covered serpentine bedrock. Although the soil composition of the serpentine community has much in common with other serpentine soils, namely high levels of chromium and magnesium, there are factors that make it different, including a high calcium-magnesium ratio. This unusual soil composition, a mixture of weathering serpentinite gravel and glacial deposits, has created an ecosystem that contains neither typical “serpentine flora” nor flora typical of the adjacent mixed-oak forest. Trees, which were already established in the area, provided shade and organic matter, two factors not typical of serpentinite

sites. In leveling the area west of the study site, the serpentine bedrock was broken up. This allowed greater porosity and root penetration than would be found in typical serpentinite sites. It also allowed for protection of weathered soil that normally would be blown away on a typical serpentinite site. Gravelly serpentinite holds water and also protects the slope from some of the erosive forces of the additional water runoff that the area receives. Shade, organic matter, good porosity and additional water influx and a perched water table all contribute to very moist conditions that are supporting vegetation more common to a river floodplain than an ephemeral creek in a mixed-oak forest. These findings correspond with similar findings by Del Moral (1982) in his study of herb patterns on serpentine and sandstone substrates. He concluded "that it is moisture, not adverse mineral effects, that restricts species on serpentine. It follows that floodplain species should grow on the gentle serpentine slopes if sufficient water were provided, taking care not to leach the soil."

ADDENDUM

Additional information about the history of *Sanguinaria canadensis* and the *Cystopteris* sp growing in Bloodroot Valley was provided by Richard Lynch, botanist and founder of Sweetbay Magnolia Bio-Reserve Conservancy on Staten Island, during a lecture I gave at The College of Staten Island on July 12,2001.

He stated that the *Sanguinaria canadensis* population, which Hollick and Britton reported as abundant in the Bloodroot Valley area in their 1870s survey, had dwindled to six wild plants by the early 1970s. Mr. Lynch took seeds from these six plants and propagated them at the High Rock native plant center. He reintroduced these seedlings to Bloodroot Valley in 1986 and 1987. Mr. Lynch also stated that he did extensive research on the fern reported by Hollick and Britton as *Cystopteris fragilis* var. *dentata*. He said that the original records and the subsequent reports of *C. fragilis* (common brittle fern) in "A Comparative Flora of Staten Island 1879-1981" are actually the lowland fragile fern, *Cystopteris protrusa* (Weath.) Blasd. This is an endangered species in New York State.

I have reported the fragile fern at Bloodroot Valley as *Cystopteris protrusa*, based on Mr. Lynch's information.

Table 1a. Trees of the west slope, by location on slope: west to east. Area=200m x 22m=4400m ² =44dkm ²															
A=abundance, number of individuals in a given area. D=density(dkm ²), abundance per unit area(44dkm ²). RD=relative species density, total number of individuals of a species expressed as a percentage of the total number of individuals of all species. BA=basal area in m ² . RBA=relative basal area, basal area of a species as a percentage of BA of all species.															
	West Slope														
	Upper					Middle					Lower				
	A	D	RD	BA	RBA	A	D	RD	BA	RBA	A	D	RD	BA	RBA
<i>Acer platanoides</i> *	16	0.36	18.8	0.25	6.3	11	0.25	16.8	0.29	7.9	13	0.29	22.0	0.12	3.8
<i>Acer saccharum</i>						5	0.11	7.4	0.15	4.1	5	0.11	8.3	0.73	23.3
<i>Ailanthus altissima</i> *	30	0.68	35.3	0.96	24.2	16	0.36	24.2	0.39	10.6	20	0.45	34.1	0.33	10.5
<i>Betula lenta</i>	7	0.16	8.2	0.25	6.3	1	0.02	1.3	0.04	1.1					
<i>Fraxinus americana</i>											1	0.02	1.5	0.06	1.9
<i>Juglans nigra</i>	4	0.09	4.7	0.37	9.3	4	0.09	6.0	0.31	8.4	9	0.20	15.2	1.13	36.0
<i>Liquidambar styraciflua</i>	4	0.09	4.7	0.18	4.5	3	0.07	4.7	0.04	1.1					
<i>Liriodendron tulipifera</i>	2	0.04	2.4	0.22	5.5						1	0.02	1.5	0.01	0.3
<i>Morus alba</i> *	3	0.07	3.5	0.33	8.3						4	0.09	6.8	0.17	5.4
<i>Nyssa sylvatica</i>	1	0.02	1.2	0.03	0.8										
<i>Prunus avium</i> *											1	0.02	1.5	0.09	2.9
<i>Prunus serotina</i>	2	0.05	2.4	0.08	2.0	1	0.02	1.3	0.01	0.3					
<i>Quercus rubra</i>	7	0.16	8.2	0.64	16.1	17	0.39	26.2	1.85	50.4	3	0.07	5.3	0.45	14.3
<i>Quercus velutina</i>	1	0.02	1.2	0.29	7.3	2	0.04	2.7	0.24	6.5					
<i>Ulmus americana</i>	8	0.18	9.4	0.37	9.3	6	0.14	9.4	0.35	9.5	2	0.05	3.8	0.05	1.6
Totals	85	1.92	100	3.97	99.9	66	1.49	100	3.67	99.9	59	1.32	100	3.14	100
* exotic species															

Table 1b. Trees of the east slope, by location on slope: west to east. Area=100m x 22m=2200m²=22dkm²

A=abundance, number of individuals in a given area. D=density(dkm²), abundance per unit area(22dkm²).

RD=relative species density, total number of individuals of a species expressed as a percentage of the total number of individuals of all species.

BA=basal area in m². RBA=relative basal area, basal area of a species as a percentage of BA of all species.

	East Slope														
	Lower					Middle					Upper				
	A	D	RD	BA	RBA	A	D	RD	BA	RBA	A	D	RD	BA	RBA
<i>Acer rubrum</i>						1	0.05	2.6	0.03	0.7	1	0.04	3.0	0.01	0.4
<i>Acer saccharum</i>	10	0.45	38.5	0.35	15.3	2	0.09	5.3	0.12	2.8					
<i>Ailanthus altissima</i> *	1	0.04	3.8	0.03	1.3										
<i>Betula lenta</i>						9	0.41	23.7	0.34	7.9	5	0.23	15.2	0.08	3.1
<i>Carpinus caroliniana</i>						1	0.05	2.6	0.01	0.2					
<i>Fagus grandifolia</i>	1	0.04	3.8	0.27	11.8	1	0.05	2.6	0.02	0.5					
<i>Fraxinus americana</i>	3	0.14	11.5	0.65	28.5										
<i>Juglans nigra</i>	1	0.05	3.8	0.16	7.0										
<i>Liquidambar styraciflua</i>						2	0.09	5.3	0.04	0.9	3	0.14	9.1	0.04	1.5
<i>Quercus alba</i>	1	0.04	3.8	0.27	11.8						4	0.18	12.1	0.19	7.3
<i>Quercus coccinea</i>											3	0.14	9.1	0.32	12.4
<i>Quercus rubra</i>	7	0.32	26.9	0.47	20.6	20	0.91	52.6	3.42	79.9	13	0.59	39.4	1.38	53.3
<i>Quercus velutina</i>						2	0.09	5.3	0.30	7.0	4	0.18	12.1	0.57	22.0
<i>Ulmus americana</i>	2	0.09	7.7	0.08	3.5										
Totals	26	1.17	99.8	2.28	99.8	38	1.74	100	4.28	99.9	33	1.50	100	2.59	100
* exotic species															

Table 2. Shrub and sapling layer, >1m and <6m, by transects on west and east slopes.									
	West Slope					East Slope			
	% Relative Canopy Cover					% Relative Canopy Cover			
	Total	Upper	Middle	Lower		Lower	Middle	Upper	Total
<i>Acer rubrum</i>							21.7		7.2
<i>Acer saccharum</i>	20.9	6.1	21.4	35.1		20.3	43.2	6.5	23.3
<i>Ailanthus altissima</i> *	30.3	53.2	17.5	20.1					
<i>Amphicarpaea bracteata</i> **	0.3			0.8					
<i>Fagus grandifolia</i>						1.1	28.5	25.0	18.2
<i>Kalmia latifolia</i>								1.7	0.6
<i>Ligustrum obtusifolium</i> *	12.1	8.2	20.8	7.3		1.6			0.5
<i>Lindera benzoin</i>	32.5	24.0	40.3	33.2		74.6	2.8	21.5	33.0
<i>Liquidambar styraciflua</i>						0.6		1.7	0.8
<i>Lonicera japonica</i> *	0.9			2.7					
<i>Quercus rubra</i>								0.7	0.2
<i>Rhododendron periclymenoides</i>								7.5	2.5
<i>Robinia pseudoacacia</i> ***	0.4	1.2							
<i>Rubus occidentalis</i>	0.3			0.8					
<i>Toxicodendron radicans</i>	2.4	7.3							
<i>Vaccinium corymbosum</i>							1.9	1.7	1.2
<i>Vaccinium pallidum</i>								5.3	1.8
<i>Viburnum acerifolium</i>						1.0	1.9	28.4	10.4
<i>Viburnum dentatum</i>						0.8			0.3
Totals	100.1	100.0	100.0	100.0		100.0	100.0	100.0	100.0
*=exotic species									
**=twining on shrubs									
***= native to N. America but not NYS									

Table 3a. Spring herb layer($\leq 1\text{m}$), by transects, on west slope. Area = 3 transects * 18 quadrats @ $1\text{m}^2 = 54\text{m}^2$
f = frequency, the percentage of quadrats within a transect, in which a given species is present.
Rf = the frequency of a species as a percentage of the total frequencies of all the species present.
C = cover in cm^2 . RC = relative cover, the percentage of cover of a species as compared to the cover of all species

	West Slope											
	Upper				Middle				Lower			
	f	Rf	C	RC	f	Rf	C	RC	f	Rf	C	RC
<i>Acer</i> sp.									5.5	1.7	5	0.4
<i>Allium vineale</i> *					5.5	1.5	10	0.8	5.5	1.8	5	0.4
<i>Aster divaricatus</i>					11.1	3.0	11	0.8	5.5	1.7	10	0.8
<i>Athyrium thelypteroides</i>									5.5	1.8	40	3.1
<i>Berberis thunbergii</i> *	5.5	1.6	5	0.4								
<i>Carex</i> sp.					5.5	1.5	10	0.8				
<i>Caulophyllum thalictroides</i>					5.5	1.5	5	0.4	5.5	1.7	1	0.1
<i>Celastrus orbiculatus</i> *									5.5	1.8	2	0.2
<i>Cystopteris protrusa</i>					22.2	6.1	130	10.0	27.8	8.8	46	3.6
<i>Deutzia scabra</i> *	5.5	1.6	10	0.7	16.7	4.6	70	5.4				
<i>Erythronium americanum</i>	5.5	1.6	40	2.9	11.1	3.0	2	0.2	16.7	5.3	16	1.2
<i>Eupatorium rugosum</i>	5.5	1.6	30	2.1	5.5	1.5	5	0.4				
<i>Galium</i> sp.	33.3	9.8	71	5.1	22.2	6.1	75	5.8				
<i>Hydrophyllum virginianum</i>	77.7	23.0	572	40.9	88.9	24.3	695	53.4	88.9	28.1	625	48.7
<i>Ligustrum obtusifolium</i> *	11.1	3.3	40	2.9	5.5	1.5	5	0.4	5.5	1.7	10	0.8
<i>Lindera benzoin</i>	11.1	3.3	25	1.8					5.5	1.8	25	1.9
<i>Lonicera japonica</i> *	66.7	19.7	244	17.4	44.4	12.1	85	6.5	11.1	3.5	30	2.3
<i>Menispermum canadense</i>	5.5	1.6	5	0.4								
<i>Osmorhiza longistylis</i>					5.5	1.5	5	0.4				
<i>Paronychia canadensis</i>	5.5	1.6	1	0.1								

Table 3a Cont'd					West Slope									
					Upper					Middle				
					f	Rf	C	RC		f	Rf	C	RC	
<i>Polygonatum pubescens</i>					11.1	3.3	30	2.1		33.3	9.1	47	3.6	
<i>Polystichum acrostichoides</i>										11.1	3.0	2	0.2	
<i>Robinia pseudoacacia*</i>					5.5	1.6	1	0.1						
<i>Rubus occidentalis</i>					33.3	9.8	165	11.8		5.5	1.5	10	0.8	
<i>Sanguinaria canadensis</i>										5.5	1.5	10	0.8	
<i>Smilacina racemosa</i>										11.1	3.0	35	2.7	
<i>Solidago caesia</i>					5.5	1.6	5	0.4						
<i>Stellaria media*</i>					33.3	9.8	110	7.9		33.3	9.1	55	4.2	
<i>Toxicodendron radicans</i>					5.5	1.6	5	0.4						
<i>Urtica dioica</i>					11.1	3.3	40	2.9		16.7	4.6	35	2.7	
<i>Viola pensylvanica</i>														
Plant Totals					338.2	100.0	1399	100.0		366.1	100.0	1302	100.3	
GROUND COVER (GC)														
Plant cover														
Soil														
Rubble														
Leaf litter & twigs														
Other														
Total Ground Cover														
* exotic species														

Table 3b. Spring herb layer($\leq 1\text{m}$), by transects, on east slope. Area = 3 transects * 18 quadrats @ $1\text{m}^2 = 54\text{m}^2$													
f = frequency, the percentage of quadrats within a transect, in which a given species is present.													
Rf = the frequency of a species as a percentage of the total frequencies of all the species present.													
C = cover in cm^2 . RC = relative cover, the percentage of cover of a species as compared to the cover of all species													
		Lower				East Slope Middle				Upper			
		f	Rf	C	RC	f	Rf	C	RC	f	Rf	C	RC
<i>Acer</i> sp.		50.0	15.0	93	11.4	16.7	4.8	41	5.2	16.7	5.9	3	0.4
<i>Adiantum pedatum</i>						5.5	1.5	30	3.8				
<i>Amphicarpaea bracteata</i>						11.1	3.2	32	4.1				
<i>Arisaema triphyllum</i>						11.1	3.2	3	0.4				
<i>Aster divaricatus</i>		16.7	5.0	9	1.1	16.7	4.8	60	7.6	27.8	9.8	24	2.9
<i>Athyrium thelypteroides</i>		22.2	6.7	80	9.8	22.2	6.4	190	24.2	11.1	3.9	60	7.3
<i>Berberis thunbergii</i> *										5.5	1.9	20	2.4
<i>Carex pensylvanica</i>										5.5	2.0	40	4.8
<i>Caulophyllum thalictroides</i>		11.1	3.3	35	4.3	5.5	1.6	5	0.6				
<i>Celastrus orbiculatus</i> *		5.5	1.7	1	0.1								
<i>Cinna arundinaceae</i>		5.5	1.7	2	0.2	5.5	1.5	2	0.3				
<i>Cryptotaenia canadensis</i>										5.5	1.9	5	0.6
<i>Cystopteris protrusa</i>						5.5	1.6	15	1.9	5.5	2	30	3.6
<i>Hydrophyllum virginianum</i>		27.8	8.3	215	26.4	16.7	4.8	22	2.8	5.5	1.9	5	0.6
<i>Impatiens capensis</i>		5.5	1.7	1	0.1	27.8	8.0	45	5.7				
<i>Lindera benzoin</i>		22.2	6.7	38	4.7	11.1	3.2	3	0.4				
<i>Lonicera japonica</i> *		11.1	3.3	6	0.7	16.7	4.8	52	6.6	5.5	2	40	4.8
<i>Lysmachia quadrifolia</i>										5.5	1.9	1	0.1
<i>Maianthemum canadense</i>						11.1	3.2	11	1.4	50.0	17.7	175	21.2
<i>Osmunda claytoniana</i>										5.5	2	70	8.5

Table 3b Cont'd													
	Lower				East Slope Middle				Upper				
	f	Rf	C	RC	f	Rf	C	RC	f	Rf	C	RC	
<i>Parthenocissus quinquefolia</i>					16.7	4.8	3	0.4	22.2	7.9	24	2.9	
<i>Parthenocissus tricuspidata</i> *					5.5	1.5	1	0.1					
<i>Polygonatum pubescens</i>	50.0	15	92	11.3	27.8	8	56	7.1	16.7	5.9	27	3.3	
<i>Prenanthes trifoliolata</i>					5.5	1.6	10	1.3					
<i>Quercus</i> sp.	11.1	3.3	2	0.2									
<i>Rhododendron pericylmenoides</i>									11.1	3.9	15	1.8	
<i>Robinia pseudoacacia</i> *					5.5	1.5	2	0.3					
<i>Rosa multiflora</i> *	16.7	5.0	70	8.6									
<i>Sanicula marilandica</i>	16.7	5.0	22	2.7									
<i>Smilacina racemosa</i>	11.1	3.3	7	0.9	11.1	3.2	15	1.9					
<i>Smilax herbacea</i>	5.5	1.7	2	0.2									
<i>Solidago caesia</i>					5.5	1.6	5	0.6					
<i>Toxicodendron radicans</i>					5.5	1.5	5	0.6					
"Unknown" grass									5.5	1.9	5	0.6	
<i>Urtica dioica</i>	27.8	8.3	131	16.1	33.3	9.5	75	9.5	11.1	3.9	70	8.5	
<i>Vaccinium pallidum</i>									11.1	3.9	40	4.8	
<i>Viburnum acerifolium</i>					27.8	8	62	7.9	27.8	9.8	100	12.1	
<i>Viburnum dentatum</i>									5.5	2	1	0.1	
<i>Viola pensylvanica</i>	16.7	5.0	8	1.0									
<i>Viola</i> sp.					22.2	6.4	41	5.2	22.2	7.9	70	8.5	
Plant Totals	333.2	100.0	814	99.8	349.6	100.2	786	99.9	282.8	100.0	825	99.8	

Table 3b. Cont'd													
GROUND COVER (GC)		Lower				Middle				Upper			
Plant cover				814				786				825	
Soil				50				257				77	
Rubble				0				0				0	
Leaf litter & twigs				801				691				784	
Other				135				70				117	
Total Ground Cover				1800				1804				1803	
* exotic species													

Table 4a. Fall herb layer($\leq 1\text{m}$), by transects, on west slope.

Area = 3 transects (2*18 quadrats + 1@ 17 quadrats=53) 53 quadrats @ $1\text{m}^2 = 53\text{m}^2$.

f = frequency, the percentage of quadrats within a transect, in which a given species is present.

Rf = relative frequency, the frequency of a species as a percentage of the total frequencies of all species present.

C = cover in cm^2 . RC = relative cover, the percentage of cover of a species as compared to the cover of all species.

	West Slope											
	Upper				Middle				Lower			
	f	Rf	C	RC	f	Rf	C	RC	f	Rf	C	RC
<i>Acer saccharum</i>	5.5	2.3	20	2.1					5.9	2.2	1	0.1
<i>Ailanthus altissima</i> *					11.1	4.2	6	0.7	5.9	2.2	20	2.1
<i>Amphicarpaea bracteata</i>									5.9	2.2	50	5.3
<i>Artemisia vulgaris</i> *	5.5	2.2	1	0.1								
<i>Aster divaricatus</i>	11.1	4.5	2	0.2	11.1	4.2	15	1.6	23.5	8.9	56	5.9
<i>Carex sp.</i>					5.5	2.0	15	1.6				
<i>Celastrus orbiculatus</i> *									11.8	4.5	15	1.6
<i>Commelina communis</i> *	5.5	2.3	1	0.1								
<i>Eupatorium rugosum</i>	11.1	4.5	100	10.2	5.5	2.1	10	1.1				
<i>Hydrophyllum virginianum</i>	66.7	27.3	355	37.0	83.3	31.3	305	33.3	76.5	28.9	395	41.7
<i>Ligustrum obtusifolium</i> *					5.5	2.0	50	5.5	5.9	2.2	10	1.1
<i>Lindera benzoin</i>	11.1	4.5	20	2.1	5.5	2.1	100	10.9	23.5	8.9	45	4.7
<i>Lonicera japonica</i> *	55.6	22.8	225	23.5	27.8	10.5	37	4.0	11.8	4.5	35	3.7
<i>Osmorhiza longistylis</i>	5.5	2.2	5	0.5	22.2	8.3	55	6.0				
<i>Polygonatum pubescens</i>									5.9	2.2	5	0.5
<i>Polystichum acrostichoides</i>	27.8	11.4	120	12.5	11.1	4.2	45	4.9	17.6	6.6	50	5.3
<i>Rosa multiflora</i> *	5.5	2.3	20	2.1	5.5	2.0	5	0.5	5.9	2.2	5	0.5
<i>Rubus occidentalis</i>	11.1	4.5	20	2.1	5.5	2.1	10	1.1				
<i>Smilax rotundifolia</i>	5.5	2.2	20	2.1								

Table 4a. Cont'd														
			Upper				West Slope Middle				Lower			
			f	Rf	C	RC	f	Rf	C	RC	f	Rf	C	RC
<i>Solidago caesia</i>			5.5	2.3	20	2.1	11.1	4.2	21	2.3				
<i>Toxicodendron radicans</i>			11.1	4.5	30	3.1								
<i>Urtica dioica</i>							55.6	20.9	242	26.4	58.8	22.2	256	27.0
<i>Viola spp.</i>											5.9	2.2	5	0.5
Plant Totals			244.1	99.8	959	99.8	266.3	100.1	916	99.9	264.8	99.9	948	100.1
Soil					155				130				225	
Rubble					150				130				0	
Leaf litter & twigs					435				460				310	
Other					105				170				220	
Total Ground Cover					1804				1806				1703	

Table 4b. Fall herb layer(≤ 1 m), by transects, on east slope. Area = 3 transects*18 quadrats @ $1\text{m}^2 = 54\text{m}^2$													
f = frequency, the percentage of quadrats within a transect, in which a given species is present.													
Rf = relative frequency, the frequency of a species as a percentage of the total frequencies of all species present.													
C = cover in cm^2 . RC = relative cover, the percentage of cover of a species as compared to the cover of all species.													
	Lower				East Slope Middle				Upper				
	f	Rf	C	RC	f	Rf	C	RC	f	Rf	C	RC	
<i>Acer saccharum</i>	16.7	8.9	16	3.6	27.8	15.7	92	30.9	11.1	4.4	2	0.5	
<i>Allium vineale</i> *	5.5	2.9	1	0.2									
<i>Amphicarpaea bracteata</i>					11.1	6.3	11	3.7					
<i>Aster divaricatus</i>					5.5	3.1	5	1.7	33.3	13.3	24	5.8	
<i>Athyrium thelypteroides</i>	5.5	2.9	30	6.7	5.5	3.1	1	0.3	11.1	4.4	15	3.6	
<i>Berberis thunbergii</i> *	5.5	2.9	5	1.1									
<i>Carex abscondita</i>									16.7	6.7	130	31.5	
<i>Chimaphila maculata</i>									5.5	2.2	1	0.2	
<i>Collinsonia canadensis</i>									5.5	2.2	5	1.2	
<i>Cryptotaenia canadensis</i>					11.1	6.2	30	10.1					
<i>Heuchera americana</i>					5.5	3.1	5	1.7	5.5	2.2	2	0.5	
<i>Impatiens capensis</i>					5.5	3.1	15	5.0					
<i>Lindera benzoin</i>	66.7	35.4	231	51.6	11.1	6.3	10	3.3	22.2	8.9	36	8.7	
<i>Liquidambar styraciflua</i>					5.5	3.1	5	1.7					
<i>Lonicera japonica</i> *	5.5	2.9	1	0.2									
<i>Maianthemum canadense</i>	5.5	2.9	1	0.2	16.7	9.4	16	5.4	50.0	20.0	13	3.1	
<i>Parthenocissus quinquefolia</i>	5.5	2.9	1	0.2					5.5	2.2	1	0.2	
<i>Parthenocissus tricuspidata</i> *					5.5	3.1	1	0.3	5.5	2.2	1	0.2	
<i>Poa</i> sp.									5.5	2.2	5	1.2	

Table 4b. Cont'd														
			East Slope											
			Lower				Middle				Upper			
			f	Rf	C	RC	f	Rf	C	RC	f	Rf	C	RC
<i>Polygonatum pubescens</i>			22.2	11.8	16	3.6	5.5	3.1	5	1.7	5.5	2.2	1	0.2
<i>Prunus serotina</i>							16.7	9.4	21	7.0	5.5	2.2	1	0.2
<i>Rosa multiflora*</i>			5.5	2.9	10	2.2					5.5	2.2	10	2.4
<i>Smilax rotundifolia</i>			5.5	2.9	5	1.1								
<i>Smilax herbacea</i>			5.5	2.9	5	1.1					11.1	4.4	6	1.5
<i>Tilia americana</i>							5.5	3.1	1	0.3				
<i>Toxicodendron radicans</i>							5.5	3.1	10	3.4				
<i>Urtica dioica</i>			27.8	14.8	125	27.9								
<i>Vaccinium pallidum</i>											16.7	6.7	25	6.1
<i>Viburnum acerifolium</i>							16.7	9.4	35	11.7	16.7	6.7	105	25.4
<i>Viola spp.</i>			5.5	2.9	1	0.2	16.7	9.4	35	11.7	11.1	4.4	30	7.3
Plant Totals			188.4	99.9	448	99.9	177.4	100.0	298	99.9	249.5	99.7	413	99.8
Soil					145								265	
Rubble														
Leaf litter & twigs					914				1364				1064	
Other					145				140				76	
Total Ground Cover					1802				1802				1818	

Table 5. Summary of Appendix 4 distance/similarity measures across the ravine, along a gradient from upper west slope to upper east slope.

	WU/WM	WM/WL	WL/EL	EL/EM	EM/EU
All Trees - density (abundance per unit ground-surface area)					
Bray Curtis Dissimilarity	0.26	0.51	0.71	0.65	0.70
Canberra Distance	0.32	0.53	0.55	0.51	0.22
City Block/Manhattan	0.04	0.07	0.08	0.09	0.05
Ruzicka Percent Remoteness	0.41	0.67	0.83	0.79	0.52
Similarity Ratio Distance	0.21	0.67	0.78	0.62	0.23
Chord Distance	0.47	0.92	1.10	0.87	0.42
Euclidean Distance	0.31	0.56	0.56	0.73	0.42
Geodesic Distance	0.47	0.95	1.17	0.91	0.42
Morisita (1959) Similarity	-0.11	0.03	0.04	-0.07	-0.20
Morisita-Horn (1966) Similarity	0.89	0.58	0.38	0.57	0.86
Native Trees Only- density					
Bray Curtis Dissimilarity	0.38	0.53	0.63	0.71	0.34
Canberra Distance	0.35	0.50	0.39	0.68	0.28
City Block/Manhattan	0.04	0.05	0.07	0.13	0.07
Ruzicka Percent Remoteness	0.56	0.69	0.77	0.83	0.50
Similarity Ratio Distance	0.46	0.67	0.71	0.68	0.24
Chord Distance	0.72	0.91	0.87	0.93	0.40
Euclidean Distance	0.30	0.36	0.47	0.84	0.45
Geodesic Distance	0.74	0.94	0.90	0.97	0.40
Morisita (1959) Similarity	0.03	0.04	-0.10	-0.06	-0.28
Morisita-Horn (1966) Similarity	0.72	0.59	0.62	0.55	0.89
Shrub and Sapling Layer- percent canopy cover					
Bray Curtis Dissimilarity	0.44	0.21	0.45	0.75	0.62
Canberra Distance	0.20	0.20	0.49	0.40	0.45
City Block/Manhattan	4.65	2.17	4.73	7.87	6.54
Ruzicka Percent Remoteness	0.61	0.34	0.62	0.86	0.77
Similarity Ratio Distance	0.47	0.14	0.43	0.86	0.73
Chord Distance	0.79	0.39	0.66	1.22	1.06
Euclidean Distance	44.58	20.87	48.80	83.12	54.52
Geodesic Distance	0.80	0.40	0.67	1.31	1.12
Morisita (1959) Similarity	0.70	0.95	0.74	0.25	0.44
Morisita-Horn (1966) Similarity	0.69	0.92	0.73	0.24	0.43
WU - west slope upper	EL - east slope lower				
WM - west slope middle	EM - east slope middle				
WL - west slope lower	EU - east slope upper				

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

Table 5. Summary of Appendix 4 distance/similarity measures across the ravine, along a gradient from upper west slope to upper east slope.						cont'd
	WU/WM	WM/WL	WL/EL	EL/EM	EM/EU	
Herb Layer - plant cover						
Bray Curtis Dissimilarity	0.35	0.36	0.53	0.61	0.55	
Canberra Distance	0.39	0.33	0.37	0.45	0.51	
City Block/Manhattan	17.43	17.02	20.61	18.19	16.46	
Ruzicka Percent Remoteness	0.52	0.52	0.69	0.76	0.71	
Similarity Ratio Distance	0.18	0.13	0.55	0.66	0.66	
Chord Distance	0.44	0.37	0.60	0.98	0.99	
Euclidean Distance	306.6	263.9	453.8	280.1	252.9	
Geodesic Distance	0.44	0.37	0.61	1.03	1.03	
Morisita (1959) Similarity	0.90	0.93	0.78	0.51	0.52	
Morisita-Horn (1966) Similarity	0.89	0.93	0.78	0.51	0.51	
Species similarity measures						
Trees(all)						
Sorensen Index of Similarity C_S	81.8	60.0	66.7	37.5	66.7	
Jaccard Index of Similarity C_J	69.2	42.9	50.0	23.1	50.0	
Shrub and Sapling Layer						
Sorensen Index of Similarity C_S	80	73	43	62	63	
Jaccard Index of Similarity C_J	67	58	28	45	46	
Herb Layer						
Sorensen Index of Similarity C_S	57.9	71.8	59.5	55.8	52.1	
Jaccard Index of Similarity C_J	40.7	56.0	42.3	38.7	35.3	
WU - west slope upper	EL - east slope lower					
WM - west slope middle	EM - east slope middle					
WL - west slope lower	EU - east slope upper					

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold

Table 6a. Trees of west and east slopes. Rank of first 5 species is given in brackets. * = exotics

A = abundance, D=density, RD=relative density(dkm²), BA=basal area(m²), RBA=relative basal area.

Species on both slopes	West Slope Area=44dkm ²						East Slope Area=22dkm ²							
	A	D	RD		BA	RBA		A	D	RD		BA	RBA	
<i>Acer saccharum</i>		10	0.23	4.8	[4]	0.88	8.2	[3]	12	0.54	12.4	[4]	0.47	5.1
<i>Ailanthus altissima</i> *	[1]	66	1.50	31.4	[3]	1.68	15.6		1	0.04	1.0		0.03	0.3
<i>Betula lenta</i>		8	0.18	3.8		0.29	2.7	[2]	14	0.64	14.4		0.42	4.6
<i>Fraxinus americana</i>		1	0.02	0.5		0.06	0.6		3	0.14	3.1	[3]	0.65	7.1
<i>Juglans nigra</i>	[4]	17	0.39	8.1	[2]	1.81	16.8		1	0.05	1.0		0.16	1.7
<i>Liquidambar styraciflua</i>		7	0.16	3.3		0.22	2.0	[5/6]	5	0.23	5.2		0.08	0.9
<i>Quercus rubra</i>	[3]	27	0.61	12.9	[1]	2.94	27.3	[1]	40	1.82	41.2	[1]	5.27	57.6
<i>Quercus velutina</i>		3	0.07	1.4		0.53	4.9	[4]	6	0.27	6.2	[2]	0.87	9.5
<i>Ulmus americana</i>	[5]	16	0.36	7.6	[5]	0.77	7.1		2	0.09	2.1		0.08	0.9
Species only on west slope														
<i>Acer platanoides</i> *	[2]	40	0.91	19.0		0.66	6.1							
<i>Liriodendron tulipifera</i>		3	0.07	1.4		0.23	2.1							
<i>Morus alba</i> *		7	0.16	3.3		0.50	4.6							
<i>Nyssa sylvatica</i>		1	0.02	0.5		0.03	0.3							
<i>Prunus avium</i> *		1	0.02	0.5		0.09	0.8							
<i>Prunus serotina</i>		3	0.07	1.4		0.09	0.8							
Species only on east slope														
<i>Acer rubrum</i>									2	0.09	2.1		0.04	0.4
<i>Carpinus caroliniana</i>									1	0.05	1.0		0.01	0.1
<i>Fagus grandifolia</i>									2	0.09	2.1		0.29	3.2
<i>Quercus alba</i>								[5/6]	5	0.22	5.2	[5]	0.46	5.0
<i>Quercus coccinea</i>									3	0.14	3.1		0.32	3.5
Total		210	4.77	99.9		10.8	99.9		97	4.41	100.1		9.15	99.9

Table 6b. Trees of neutral and acidic communities. A=abundance, RA= rel.abund., BA=basal area in m², RBA=rel.BA

	Neutral Community				Acidic Community			
	A	RA	BA	RBA	A	RA	BA	RBA
Species in both communities								
<i>Acer saccharum</i>	[4] 20	8.7	[4] 1.23	9.4	2	2.8	0.12	1.7
<i>Betula lenta</i>	8	3.5	0.29	2.2	[2] 14	19.7	[3] 0.42	6.1
<i>Fagus grandifolia</i>	1	1.7	0.27	2.1	1	1.4	0.02	0.3
<i>Liquidambar styraciflua</i>	7	3.1	0.22	1.7	[4] 5	7	0.08	1.2
<i>Quercus alba</i>	1	0.4	0.27	2.0	4	5.6	[5] 0.19	2.8
<i>Quercus rubra</i>	[3] 34	14.8	[1] 3.41	26.1	[1] 33	46.5	[1] 4.80	69.9
<i>Quercus velutina</i>	3	0.9	0.53	4.1	[3] 6	8.5	[2] 0.87	12.7
Species only in neutral community								
<i>Acer platanoides*</i>	[2] 40	15.7	0.66	5.1				
<i>Ailanthus altissima*</i>	[1] 67	29.3	[3] 1.71	13.1				
<i>Fraxinus americana</i>	4	0.4	0.71	5.4				
<i>Juglans nigra</i>	[5/6] 18	7.9	[2] 1.97	15.1				
<i>Liriodendron tulipifera</i>	3	1.3	0.23	1.8				
<i>Morus alba*</i>	7	2.2	0.50	3.8				
<i>Nyssa sylvatica</i>	1	0.4	0.03	0.2				
<i>Prunus avium*</i>	1	0.4	0.09	0.7				
<i>Prunus serotina</i>	3	1.3	0.09	0.7				
<i>Ulmus americana</i>	[5/6] 18	7.9	[5] 0.85	6.5				
Species only in acidic community								
<i>Acer rubrum</i>					2	2.8	0.04	0.6
<i>Carpinus caroliniana</i>					1	1.4	0.01	0.1
<i>Quercus coccinea</i>					[5] 3	4.2	[4] 0.32	4.6
Total	236	99.9	13.06	• 100	71	99.9	6.87	100.0

* = exotics

Table 7 . Shrub and sapling layer, >1m and <6m, of neutral and acidic communities. Rank of first 5 species is given in brackets.

	Neutral Community				Acidic Community			
	% Relative Canopy Cover				% Relative Canopy Cover			
	Total Saplings	Shrubs	Vines		Total Saplings	Shrubs	Vines	
Species in both communities								
<i>Acer saccharum</i>	[3] 20.7	20.7			[2] 24.9	24.9		
<i>Fagus grandifolia</i>	0.3	0.3			[1] 26.8	26.8		
<i>Liquidambar styraciflua</i>	0.1	0.1			0.8	0.8		
<i>Lindera benzoin</i>	[1] 43.0		43.0		[4] 12.2		12.2	
<i>Viburnum acerifolium</i>	0.3		0.3		[3] 15.2		15.2	
Species only in neutral community								
<i>Ailanthus altissima</i> *	[2] 22.7	22.7						
<i>Robinia pseudoacacia</i> ***	0.3	0.3						
<i>Ligustrum obtusifolium</i> *	[4] 9.5		9.5					
<i>Viburnum dentatum</i>	0.2		0.2					
<i>Amphicarpaea bracteata</i> **	0.2			0.2				
<i>Lonicera japonica</i> *	0.7			0.7				
<i>Rubus occidentalis</i>	0.2			0.2				
<i>Toxicodendron radicans</i>	[5] 1.8			1.8				
Species only in acidic community								
<i>Acer rubrum</i>					[5] 10.9	10.9		
<i>Quercus rubra</i>					0.3	0.3		
<i>Kalmia latifolia</i>					0.8		0.8	
<i>Rhododendron periclymenoides</i>					3.7		3.7	
<i>Vaccinium corymbosum</i>					1.8		1.8	
<i>Vaccinium pallidum</i>					2.6		2.6	
Total	100.0	44.1	53.0	2.9	100.0	63.7	36.3	-

*=exotic species ** twining on shrubs ***=native to N.America but not NYS.

Table 8. Spring herb ($\leq 1\text{m}$) layer of neutral and acidic communities. *=exotics
Rank of first 5 spp. given in brackets. C=plant cover in cm^2 . RC=rel.cover.

f=frequency	Neutral Community			Acidic Community		
	Sample Area=7200 cm^2			Sample Area = 3600 cm^2		
	C	RC	f	C	RC	f
Species in both communities						
<i>Acer</i> sp.	98	2.0	14	44	2.7	17
<i>Aster divaricatus</i>	30	0.6	8	84	5.2	22
<i>Athyrium thelypteroides</i>	120	2.5	7	[1] 250	15.5	17
<i>Berberis thunbergii</i> *	5	0.1	1	20	1.2	3
<i>Caulophyllum thalictroides</i>	41	0.9	6	5	0.3	3
<i>Cinna arundinaceae</i>	2	<.1	1	2	0.1	3
<i>Cystopteris protrusa</i>	176	3.7	13	45	2.8	6
<i>Hydrophyllum virginianum</i>	[1] 2107	43.9	71	27	1.7	11
<i>Impatiens capensis</i>	1	<.1	1	45	2.8	14
<i>Lindera benzoin</i>	88	1.8	10	3	0.2	6
<i>Lonicera japonica</i> *	[3] 365	7.6	33	92	5.7	11
<i>Polygonatum pubescens</i>	[5] 220	4.6	28	83	5.2	22
<i>Rosa multiflora</i> *	70	1.5	4	2	0.1	3
<i>Smilacina racemosa</i>	42	0.9	6	15	0.9	6
<i>Solidago caesia</i>	5	0.1	1	5	0.3	3
<i>Toxicodendron radicans</i>	5	0.1	1	5	0.3	3
<i>Urtica dioica</i>	[2] 401	8.4	26	[4] 145	9.0	22
Species only in neutral community						
<i>Allium vineale</i> *	15	0.3	3			
<i>Carex</i> sp.	10	0.2	1			
<i>Celastrus orbiculatus</i> *	3	0.1	3			
<i>Deutzia scabra</i> *	80	1.7	6			
<i>Erythronium americanum</i>	58	1.2	8			
<i>Eupatorium rugosum</i>	35	0.7	3			
<i>Galium</i> sp.	146	3.0	14			
<i>Ligustrum obtusifolium</i> *	55	1.1	6			
<i>Menispermum canadense</i>	5	0.1	1			
<i>Osmorhiza longistylis</i>	5	0.1	1			
<i>Paronychia canadensis</i>	1	<.1	1			
<i>Polystichum acrostichoides</i>	47	1.0	8			
<i>Quercus</i> sp.	2	<.1	3			
<i>Robinia pseudoacacia</i> *	1	<.1	1			
<i>Rubus occidentalis</i>	[4] 250	5.2	11			
<i>Sanguinaria canadensis</i>	30	0.6	3			
<i>Sanicula marilandica</i>	22	0.4	4			
<i>Smilax herbacea</i>	2	<.1	1			
<i>Stellaria media</i> *	170	3.5	18			
<i>Viola pensylvanica</i>	85	1.8	10			

Table 8. Spring herb (≤ 1 m) layer of neutral and acidic communities. cont'd

	Neutral Community			Acidic Community		
	C	RC	f	C	RC	f
Species only in acidic community						
<i>Adiantum pedatum</i>				30	1.9	3
<i>Amphicarpaea bracteata</i>				32	1.9	6
<i>Arisaema triphyllum</i>				3	0.2	6
<i>Carex pensylvanica</i>				40	2.5	3
<i>Cryptotaenia canadensis</i>				5	0.3	3
<i>Lysimachia quadrifolia</i>				1	0.1	3
<i>Maianthemum canadense</i>				[2] 186	11.5	31
<i>Osmunda claytoniana</i>				70	4.3	3
<i>Parthenocissus quinquefolia</i>				27	1.7	19
<i>Parthenocissus tricuspidata</i> *				1	0.1	3
<i>Prenanthes trifoliolata</i>				10	0.6	3
<i>Rhododendron periclymenoides</i>				15	0.9	6
"Unknown" grass				5	0.3	3
<i>Vaccinium pallidum</i>				40	2.5	6
<i>Viburnum acerifolium</i>				[3] 162	10.1	28
<i>Viburnum dentatum</i>				1	0.1	3
<i>Viola</i> sp.				[5] 111	6.9	22
Totals	4798	99.7		1611	99.9	

Table 9. Fall herb layer ($\leq 1\text{m}$) of neutral and acidic communities. * = exotics
 Rank of first 5 species is given in brackets. C = plant cover in cm^2 .
 RC = relative cover f = frequency

	Neutral Community				Acidic Community		
	Sample Area = 7100cm ²				Sample Area = 3600cm ²		
	C	RC	f		C	RC	f
Species in both communities							
<i>Acer saccharum</i>	37	1.1	7	[3]	94	13.2	19
<i>Amphicarpaea bracteata</i>	50	1.5	1		11	1.5	6
<i>Aster divaricatus</i>	73	2.1	11		29	4.1	19
<i>Athyrium thelypteroides</i>	30	0.9	1		16	2.3	8
<i>Lindera benzoin</i>	[3] 396	11.6	27	[5]	46	6.5	17
<i>Maianthemum canadense</i>	1	<.1	1		29	4.1	33
<i>Parthenocissus quinquefolia</i>	1	<.1	1		1	0.1	3
<i>Polygonatum pubescens</i>	21	0.6	7		6	0.8	6
<i>Rosa multiflora</i> *	40	1.2	6		10	1.4	3
<i>Smilax herbacea</i>	5	0.1	1		6	0.8	6
<i>Toxicodendron radicans</i>	30	0.9	3		10	1.4	3
<i>Viola</i> sp.	6	0.2	3	[4]	65	9.1	14
Species only in neutral community							
<i>Ailanthus altissima</i> *	26	0.8	4				
<i>Allium vineale</i> *	1	<.1	1				
<i>Artemisia vulgaris</i> *	1	<.1	1				
<i>Berberis thunbergii</i> *	5	0.1	1				
<i>Carex</i> sp.	15	0.4	1				
<i>Celastrus orbiculatus</i> *	15	0.4	3				
<i>Commelina communis</i> *	1	<.1	1				
<i>Eupatorium rugosum</i>	110	3.2	4				
<i>Hydrophyllum virginianum</i>	[1] 1205	35.2	63				
<i>Ligustrum obtusifolium</i> *	60	1.8	3				
<i>Lonicera japonica</i> *	[4] 298	8.7	25				
<i>Osmorhiza longistylis</i>	60	1.8	7				
<i>Polystichum acrostichoides</i>	[5] 215	6.3	14				
<i>Rubus occidentalis</i>	30	0.9	4				
<i>Smilax rotundifolia</i>	25	0.7	3				
<i>Solidago caesia</i>	41	1.2	4				
<i>Urtica dioica</i>	[2] 623	18.2	36				

Table 9. Fall herb layer ($\leq 1\text{m}$) of neutral and acidic communities. cont'd

	Neutral Community			Acidic Community		
	Area = 7100cm ²			Area = 3600cm ²		
	C	RC	f	C	RC	f
Species only in acidic community						
<i>Carex abscondita</i>				[2] 130	18.3	8.3
<i>Chimaphila maculata</i>				1	0.1	2.8
<i>Collinsonia canadensis</i>				5	0.7	2.8
<i>Cryptotaenia canadensis</i>				30	4.2	5.6
<i>Heuchera americana</i>				7	1.0	5.6
<i>Impatiens capensis</i>				15	2.1	2.8
<i>Liquidambar styraciflua</i>				5	0.7	2.8
<i>Parthenocissus tricuspidata</i> *				2	0.3	5.6
<i>Poa</i> sp.				5	0.7	2.8
<i>Prunus serotina</i>				22	3.1	11.1
<i>Tilia americana</i>				1	0.1	2.8
<i>Vaccinium pallidum</i>				25	3.5	8.3
<i>Viburnum acerifolium</i>				[1] 140	19.7	16.7
Totals	3421	99.9		711	99.8	

* exotic species

Table 10. Results of Principal Components Analysis-percent variability (eigenvalue proportions) accounted for by first two principal components, using Ruzicka's Percent Remoteness distance measure. Values for Prin1 represent the variability accounted for on the x-axis of the PCA scattergrams (Figures 10-13). Values for Prin 2 represent the variability accounted for on the y-axis of the PCA scattergrams (Figures 10-13). Values using raw data are desirable because they account for more of the total variability on the first two axes.

Stratum	Using raw data			Using angular transformed data		
	Eigenvalue proportion cumulative			Eigenvalue proportion cumulative		
	PRIN 1	PRIN2	BOTH	PRIN 1	PRIN 2	BOTH
Trees- All	0.53	0.23	0.76	0.39	0.22	0.61
Trees- Native only	0.40	0.23	0.63	0.31	0.22	0.53
Shrub & sapling	0.47	0.21	0.68	0.34	0.21	0.55
Herb	0.50	0.21	0.71	0.36	0.21	0.57

Table 11. Summary of Cluster Analysis. Dendrogram grouping results.

Using Ruzicka's Percent Remoteness distance measure.

	Final Clusters - Groups 1 and 2					
	WU	WM	WL	EL	EM	EU
Herb layer						
Complete Linkage	1	1	1	1	2	2
Average Linkage	1	1	1	1	2	2
Minimum Variance	1	1	1	2	2	2
Shrub and sapling layer						
Complete Linkage	1	1	1	1	2	2
Average Linkage	1	1	1	1	2	2
Minimum Variance	1	1	1	1	2	2
Trees - All						
Complete Linkage	1	1	1	2	2	2
Average Linkage	1	1	1	2	2	2
Minimum Variance	1	1	1	2	2	2
Trees - Native Only						
Complete Linkage	1	1	1	1	2	2
Average Linkage	1	1	1	1	2	2
Minimum Variance	1	1	1	1	2	2
Soil Properties Data						
Complete Linkage	NA	1	1	1	1	2
Average Linkage	NA	1	1	1	1	2
Minimum Variance	NA	1	1	2	2	2

Table 12. Analysis of soil texture.

Location	Total Sample	Gravel Weight (g)	Net Sample Weight (g)	Sand 2.0mm-0.05mm Weight (g)	Silt/Clay <0.05mm Weight (g)	Texture USDA
		% of Sample	% of Soil	% of Soil	% of Soil	
West Slope						
Serpentine gravel & bedrock						
Middle slope	192.2	74.9	39	117.3	108.3	coarse sand
Lower Slope	191.5	82.4	43	109.1	101.5	coarse sand
Average %			41		93	
Creek bed	281.9	118.4	42	163.5	155.7	coarse sand
East Slope						
Till						
Lower slope	164.1	33.8	21	130.3	118.6	loamy coarse sand
Middle slope	132.3	27.7	21	104.6	93.6	loamy coarse sand
Upper slope	196.3	38.9	20	157.4	138.4	loamy coarse sand
Average %			21		89	

Table 13. Soil properties for west slope, creekbed and east slope.

Soil properties	Line	West Slope		Creek	East Slope		
		Middle	Lower		Lower	Middle	Upper
Moisture content %	0m	5.0	2.7	1.3	4.5	5.1	2.0
	50m	5.2	3.6	4.2	4.4	8.6	2.5
	100m	4.7	6.8	2.5	3.5	4.5	2.6
	Mean	5.0	4.4	2.7	4.1	6.1	2.4
LOI (organic matter)	0m	17.5	7.7	2.3	13.9	16.4	6.2
	50m	17.7	11.2	6.1	17.9	54.2	8.5
	100m	13.0	24.2	6.0	8.2	17.7	10.0
	Mean	16.1	14.4	4.8	13.3	29.4	8.2
Organic matter	0m	12.0	5.1	1.4	9.5	11.3	4.1
	50m	12.2	7.6	4.0	12.3	*	5.7
	100m	8.9	~16.7	4.0	5.6	12.2	6.8
	Mean	11.0	~9.8	3.3	9.1	**11.8	5.5
pH in water	0m	7.04	6.76	6.95	6.08	5.78	4.57
	50m	6.55	6.83	6.53	4.75	4.04	4.27
	100m	6.54	6.34	6.69	5.46	4.98	4.46
	Mean	6.66	6.59	6.69	5.13	4.63	4.41
Exchange acidity cmol/Kg	0m	0	0	0	10.0	27.6	17.4
	50m	0	0	0	35.0	87.8	22.8
	100m	0	0	0	20.5	29.9	25.2
	Mean	0	0	0	21.8	48.4	21.8
NO ₃ mg/Kg***	0m	14.4	6.5	0	4.6	0	0
	50m	26.4	7.2	0	0	0	0
	100m	0	10.2	0	0	0	0
	Mean	13.6	8	0	1.5	0	0

* too high to calculate

** average of two values

*** see text page 38 for explanation of these values.

Table 13. Soil properties west slope, creekbed and east slope.					cont'd		
Soil properties	Line	West Slope		Creek	East Slope		
		Middle	Lower		Lower	Middle	Upper
<u>Nutrients available mg/Kg</u>							
Phosphorus	0m	5.7	2.5	1.9	1.6	1.4	1.7
	50m	15.8	2.7	0.4	3.3	27.2	8.9
	100m	3.1	3.6	1.4	0	2.8	3.5
	Mean	8.2	2.9	1.2	1.6	10.5	4.7
Potassium	0m	174.0	159.5	35.0	160.5	130.0	77.5
	50m	322.5	219.0	88.0	149.0	401.0	68.0
	100m	179.5	166.5	63.0	54.5	113.5	67.0
	Mean	225.3	181.7	62.0	121.3	214.8	70.8
Calcium	0m	3314.0	1461.0	668.5	1679.0	2047.0	164.5
	50m	2674.5	2189.0	1920.0	677.0	1248.0	122.0
	100m	1779.0	3004.5	1433.0	364.5	1204.5	124.0
	Mean	2589.2	2218.2	1340.5	906.8	1499.8	136.8
Magnesium	0m	1673.9	837.2	195.0	1258.6	1171.6	133.2
	50m	1793.6	1070.8	702.8	456.6	1040.6	54.8
	100m	1593.2	2213.3	476.6	694.2	364.7	109.4
	Mean	1686.9	1373.8	458.1	803.1	859.0	99.1
Ca:Mg Ratio	0m	2.0	1.7	3.4	1.3	1.7	1.2
	50m	1.5	2.0	2.7	1.5	1.2	2.2
	100m	1.1	1.4	3.0	0.5	3.3	1.1
Iron	0m	1.7	4.1	12.9	5.5	19.3	61.8
	50m	3.3	2.1	16.1	119.0	59.9	95.2
	100m	3.2	3.6	14.9	41.3	73.3	113.9
	Mean	2.7	3.3	14.6	55.3	50.8	90.3
Aluminum	0m	7.7	17.9	15.3	16.7	47.0	184.6
	50m	8.3	11.2	34.3	175.8	68.4	172.7
	100m	9.2	16.7	17.8	81.8	123.1	160.7
	Mean	8.4	15.3	22.5	91.4	79.5	172.7

Table 13. Soil properties west slope, creekbed and east slope. cont'd

Soil properties	Line	West Slope		Creek	East Slope		
		Middle	Lower		Lower	Middle	Upper
Nutrients available mg/Kg							
Manganese	0m	26.6	49.9	23.1	32.6	38.6	6.1
	50m	27.4	32.5	33.2	40.7	54.8	5.2
	100m	32.0	45.2	39.2	43.7	33.6	6.5
	Mean	28.7	42.5	31.8	39.0	42.3	5.9
Zinc	0m	6.5	20.8	23.1	13.8	31.1	5.4
	50m	6.0	8.8	10.8	29.0	59.3	5.2
	100m	6.2	70.2	34.7	20.8	98.5	8.7
	Mean	6.2	33.3	22.9	21.2	63.0	6.4
Copper	0m	3.7	2.5	2.0	2.1	3.4	3.3
	50m	3.1	2.7	2.5	6.3	1.6	4.2
	100m	2.5	3.6	3.1	4.0	4.3	3.8
	Mean	3.1	2.9	2.5	4.1	3.1	3.8
Chromium - available	0m	0	0	0	0	0	0
	50m	0	0	0	0.7	0	0.5
	100m	0	0	0	0.5	0	0.5
	Mean	0	0	0	0.4	0	0.3
Chromium - total	0m	131.4	102.9	93.2	214.8	176.1	37.0
	50m	252.4	158.6	395.4	95.0	28.5	68.5
	100m	350.3	308.5	150.8	141.2	81.1	111.7
	Mean	244.7	190.0	213.1	150.3	95.2	72.4

USDA Soil Survey Manual pH Classes

6.6 - 7.3	neutral
6.1 - 6.5	slightly acid
5.6 - 6.0	medium acid
5.1 - 5.5	strongly acid
4.5 - 5.0	very strongly acid
below 4.5	extremely acid

Table 14. Summary of soil properties for west slope and east slope.

Soil properties	West Slope		East Slope		
	Middle	Lower	Lower	Middle	Upper
Moisture content %	5.0	4.4	4.1	5.0	2.4
LOI (organic matter) %	16.1	14.4	13.3	21.2	8.2
Organic matter content %	11.0	~9.8	9.1	14.6	5.5
pH in water	6.66	6.59	5.13	4.63	4.41
Exchange acidity cmol/Kg	0	0	21.8	39.9	21.8
Nutrients Available mg/Kg					
NO ₃ (Nitrate)*	13.6	8.0	1.5	0	0
Phosphorus	8.2	2.9	1.6	3.8	4.7
Potassium	225.3	181.7	121.3	140.2	70.8
Calcium	2589.2	2218.2	906.8	1303.8	136.8
Magnesium	1686.9	1373.8	803.1	686.7	99.1
Calcium:Magnesium ratio	1.5	1.6	1.1	1.9	1.4
Iron	2.7	3.3	55.3	60.3	90.3
Aluminum	8.4	15.3	91.4	89.8	172.7
Manganese	28.7	42.5	39.0	34.5	5.9
Zinc	6.2	33.3	21.2	51.7	6.4
Copper	3.1	2.9	4.1	3.4	3.8
Chromium - total	244.7	190	150.3	95.2	72.4
Chromium - available	0	0	0.4	0	0.3

USDA Soil Survey Manual pH Classes

6.6 - 7.3	neutral
6.1 - 6.5	slightly acid
5.6 - 6.0	medium acid
5.1 - 5.5	strongly acid
4.5 - 5.0	very strongly acid
below 4.5	extremely acid

* see text page 38 for explanation of these values.

Table 15. Water samples tested for presence of calcium and magnesium.

Site #'s are from Figure 5. Map of Bloodroot Valley and Seaview area.

Site #	Site Description	Rainwater Throughfall Samples(ppm)		
		Ca	Mg	Ca:Mg
1	top road of Children's Hospital	0.99	0.25	4.0
2	bottom of loop in front of Bldg# 21	4.55	3.33	1.4
3	southeast bottom of Mt.Moses	1.04	0.66	1.6
4	BRV 100' west of Manor Rd.	3.06	0.62	4.9
5	BRV west slope ~upper study area	1.51	1.33	1.1
7	No.Seaview open area near Graves St,	0.97	0.21	4.6
		Creek water sample (ppm)		
		Ca	Mg	Ca:Mg
	~5 creek just south of study area	3.58	7.9	0.5
Comparative data from Hubbard Brook Ecosystem Study, NH		Ca	Mg	Ca:Mg
1963-1974 study of undisturbed forest watershed-throughfall ppm		1.59	0.45	3.5
- rainfall ppm		0.16	0.04	4.0
- streamwater		1.65	0.38	4.3

Table 16. Additional soil samples -nutrient results for calcium, magnesium, manganese, iron and aluminum.
Site #'s 1 to 7 are indicated on Figure 5. Map of Bloodroot Valley and vicinity.

Site #	pH	Calcium			Magnesium			Manganese			Iron			Aluminum		
		Total	Avail.	% Avail	Total	Avail.	% Avail	Total	Avail.	% Avail	Total	Avail.	% Avail	Total	Avail.	% Avail
6a	4.38	507	160	31.6	1420	65	4.6	155	10	6.3	21,403	90.2	0.42	9,738	172	1.77
6	4.53	1821	359	19.7	31,684	778	2.5	366	29	7.9	30,591	92.6	0.30	38,057	121	0.32
3	4.77	3073	1141	37.1	140,052	597	0.4	733	21	2.9	36,971	9.3	0.03	565	6	1.04
7	4.96	1811	37	2.0	3319	19	0.6	297	6	2.1	19,513	16.1	0.08	39,027	197	0.50
20	5.65	2413	469	19.4	15,183	458	3.0	4643	230	4.9	75,815	8.4	<<0.01	41,125	61	0.15
1	6.62	3935	1699	43.2	6054	262	4.3	468	14	3.1	22,602	3.0	0.01	41,672	22	0.05
5	6.94	2698	1498	55.5	83,448	1456	1.7	1243	59	4.8	44,772	1.4	<<0.01	9,694	5	0.05
30	7.16	505	373	73.9	105,628	950	0.9	1464	25	1.7	69,846	0.3	<<0.01	2,729	1	0.04
2	7.95	17535	5204	29.7	6809	124	1.2	397	18	4.5	26,302	5.3	0.02	28,634	22	0.08

Site Description

Average total concentrations in soil - ppm (Bowen 1966)

- 1 top road of Children's Hospital
- 2 bottom of loop in front of Bldg.# 21
- 3 southeast bottom of Mt. Moses
- 5 BRV west upper slope
- 6 BRV east slope - above study area
- 6a BRV east middle slope
- 7 No.Seaview open area near Graves St.
- 20 Clove Lakes, Staten Island
- 30 Soldiers Delight, Maryland

Calcium	13,700
Magnesium	5,000
Manganese	850
Iron	38,000
Aluminum	71,000

Bold numbers denote above average concentrations.

Table 17. Summary of correlations of soil properties data for variables that have linear relationships. Pearson coefficient of correlation r values.

chromium sample size=18
all others sample size=35

X variable	Y variable	r value	P value
moisture	organic matter	+ 0.87	0.0001
moisture	calcium	+ 0.76	0.0001
moisture	magnesium	+0.78	0.0001
pH	iron	-0.90	0.0001
pH	aluminum	- 0.91	0.0001
pH	calcium	+ 0.68	0.0001
calcium	magnesium	+ 0.89	0.0001
aluminum	iron	+ 0.86	0.0001
chromium	calcium	+0.72	0.0007
chromium	magnesium	+0.71	0.0009

r value interpretation of correlation

>0 to +/- 0.5 = weak

+/- 0.5 to 0.9 = moderate

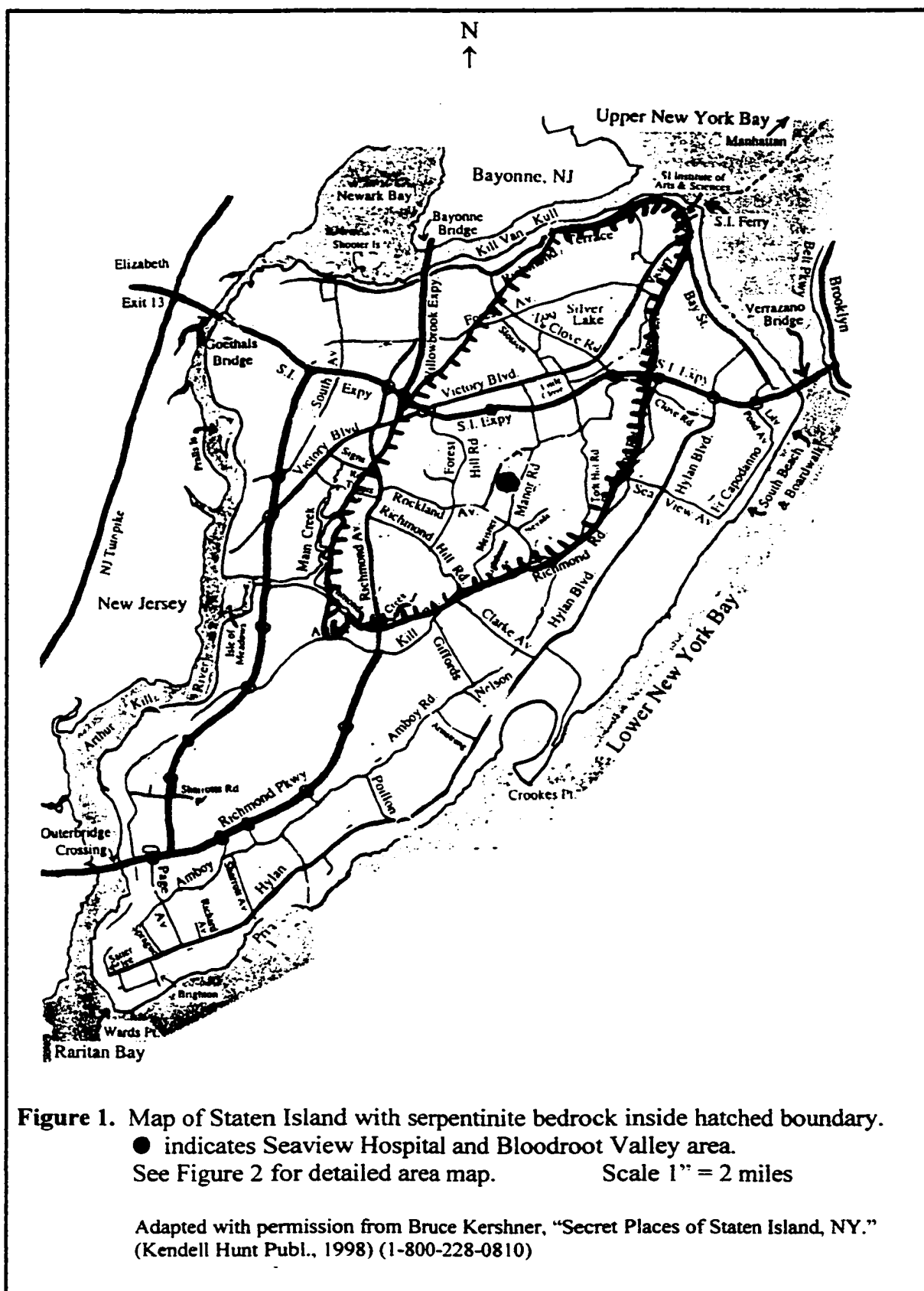
+/- 0.9 to 1.0 = strong

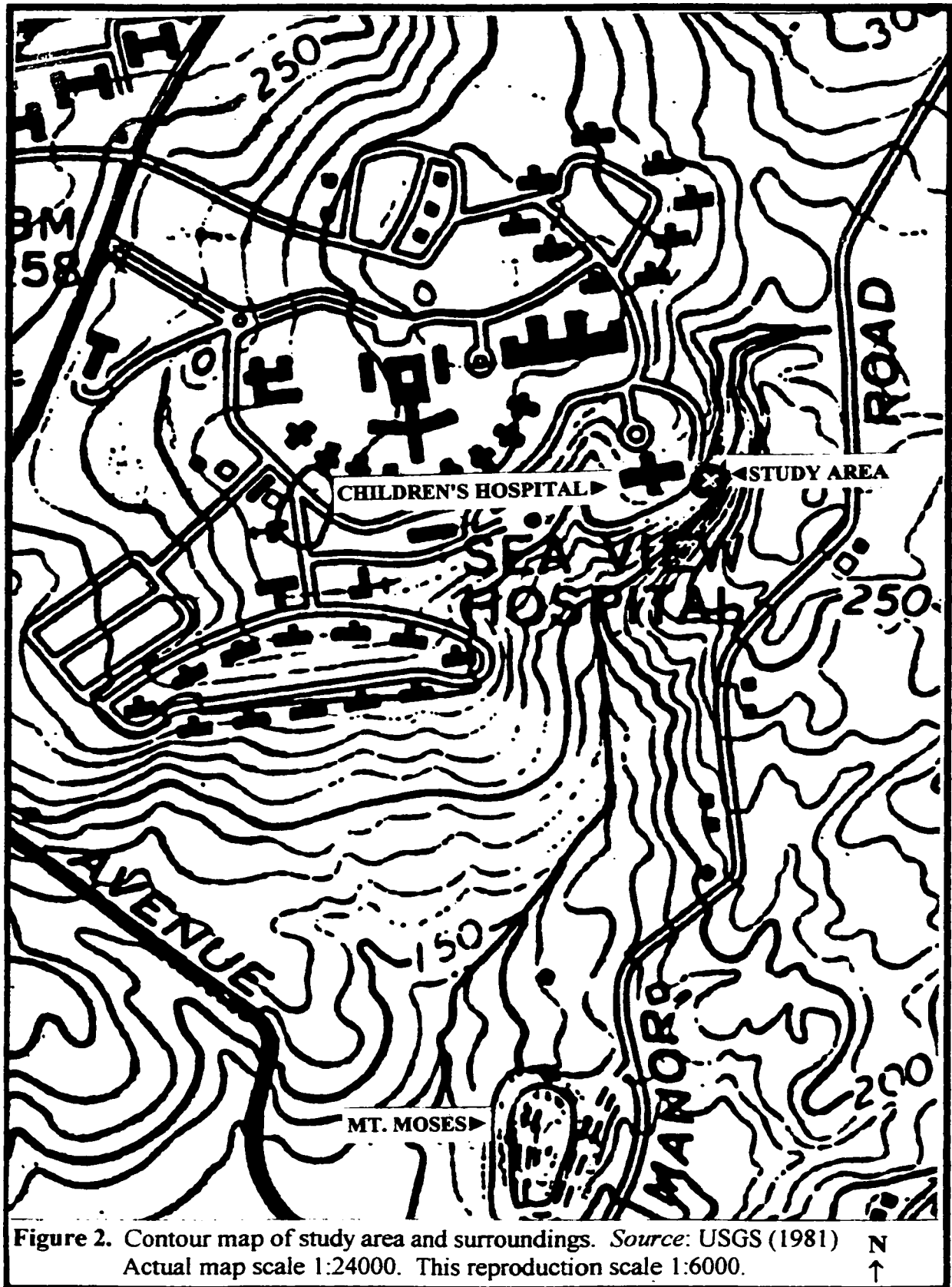
Table 18. Spring distribution of ferns.

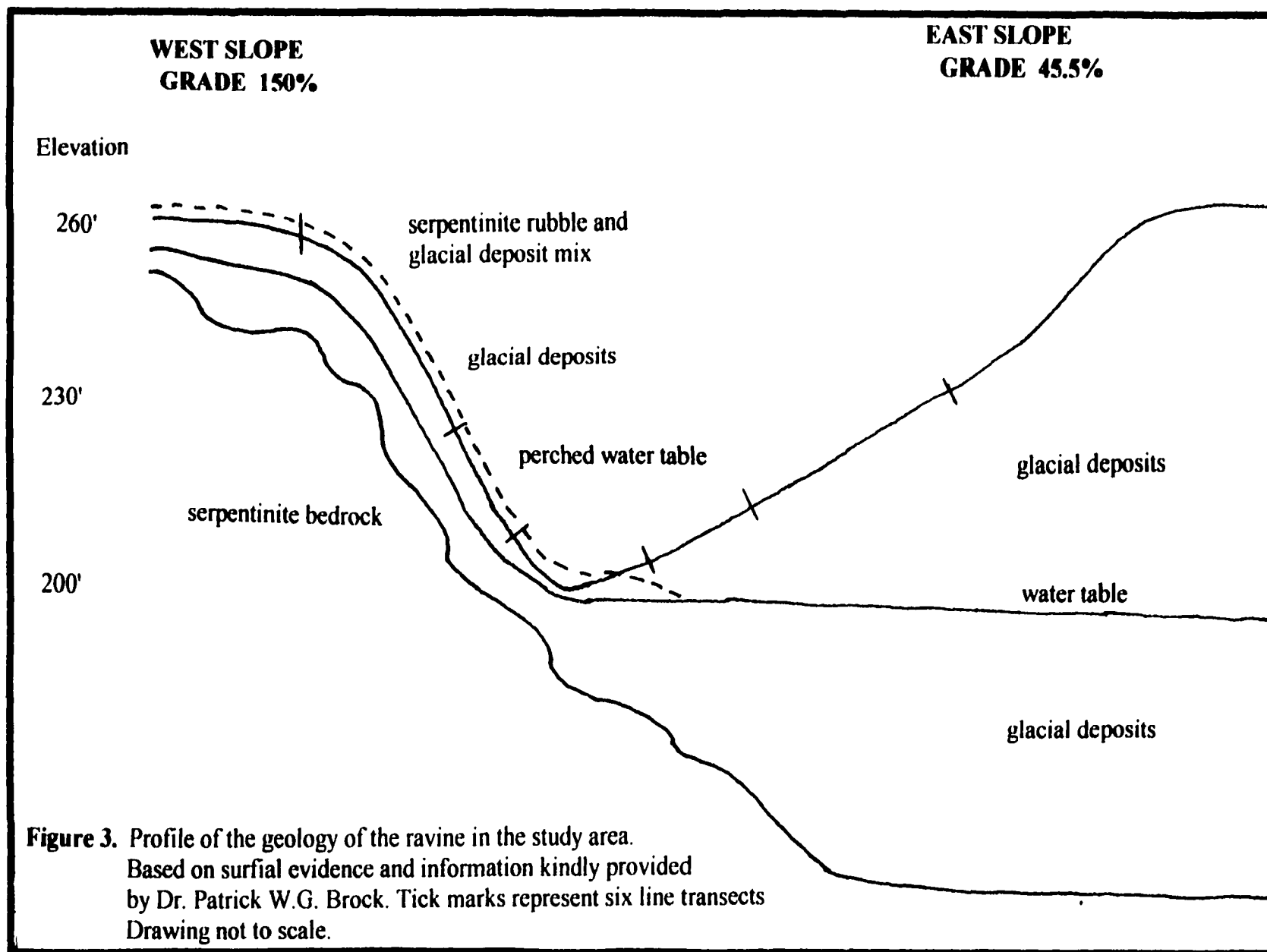
Quadrat #		18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
S O U T H	WEST																		
	Upper																		N
	West slope Middle			C	C									C		C		P	P
	Lower			C	C		C		C	C				A	P	P	P	P	R
	Creek																		T
	Lower								A		A		A						A
	East slope Middle			A								M		C	A	A	A		H
	Upper			O									A					A	C
EAST																			

Legend

- A *Athyrium thelypteroides* - silvery spleenwort
C *Cystopteris protrusa* - lowland brittle fern
M *Adiantum pedatum* - maidenhair fern
O *Osmunda claytoniana* - interrupted fern
P *Polystichum acrostichoides* - Christmas fern







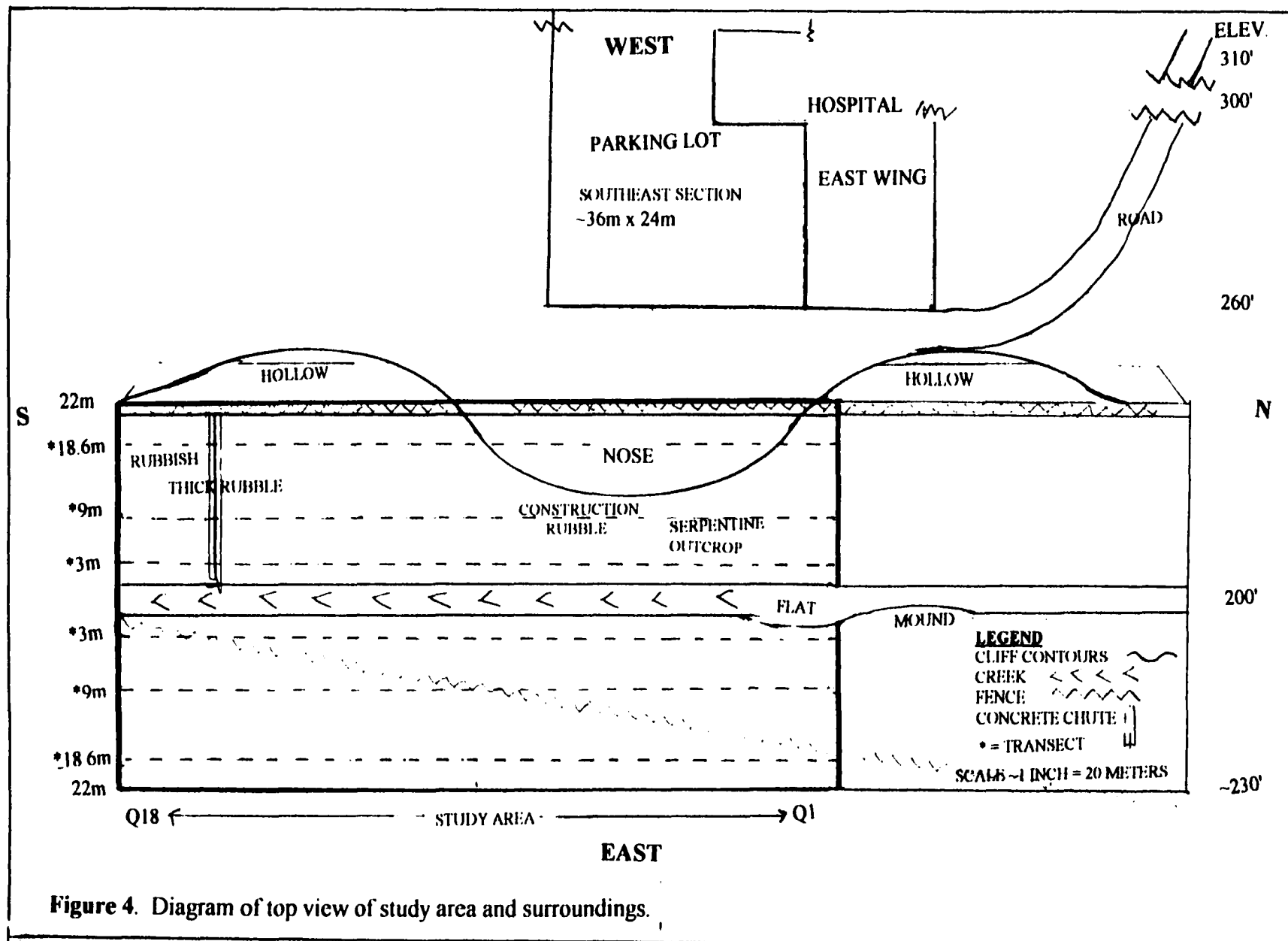


Figure 4. Diagram of top view of study area and surroundings.

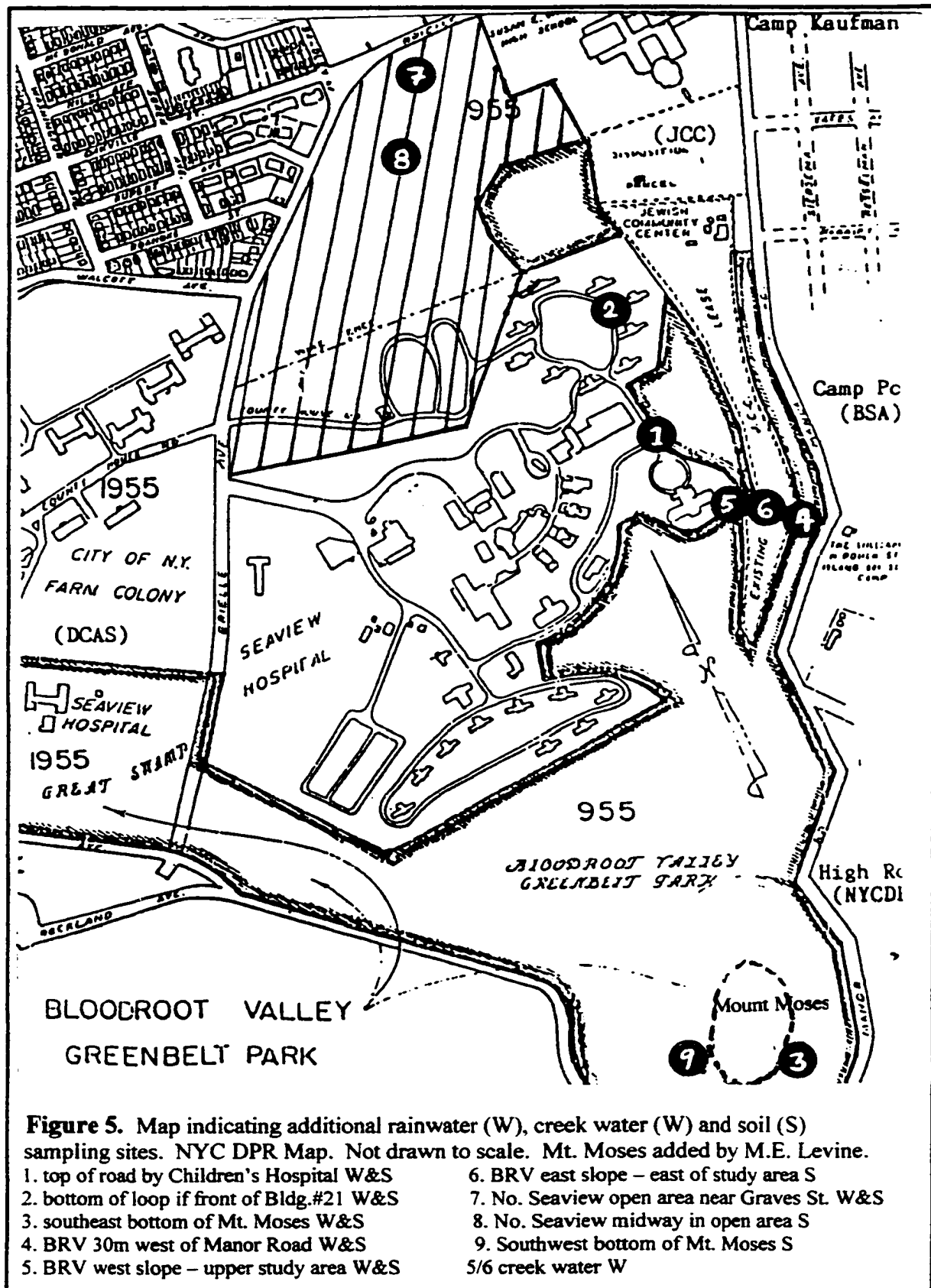


Figure 6. Size Structure - Trees - West Slope

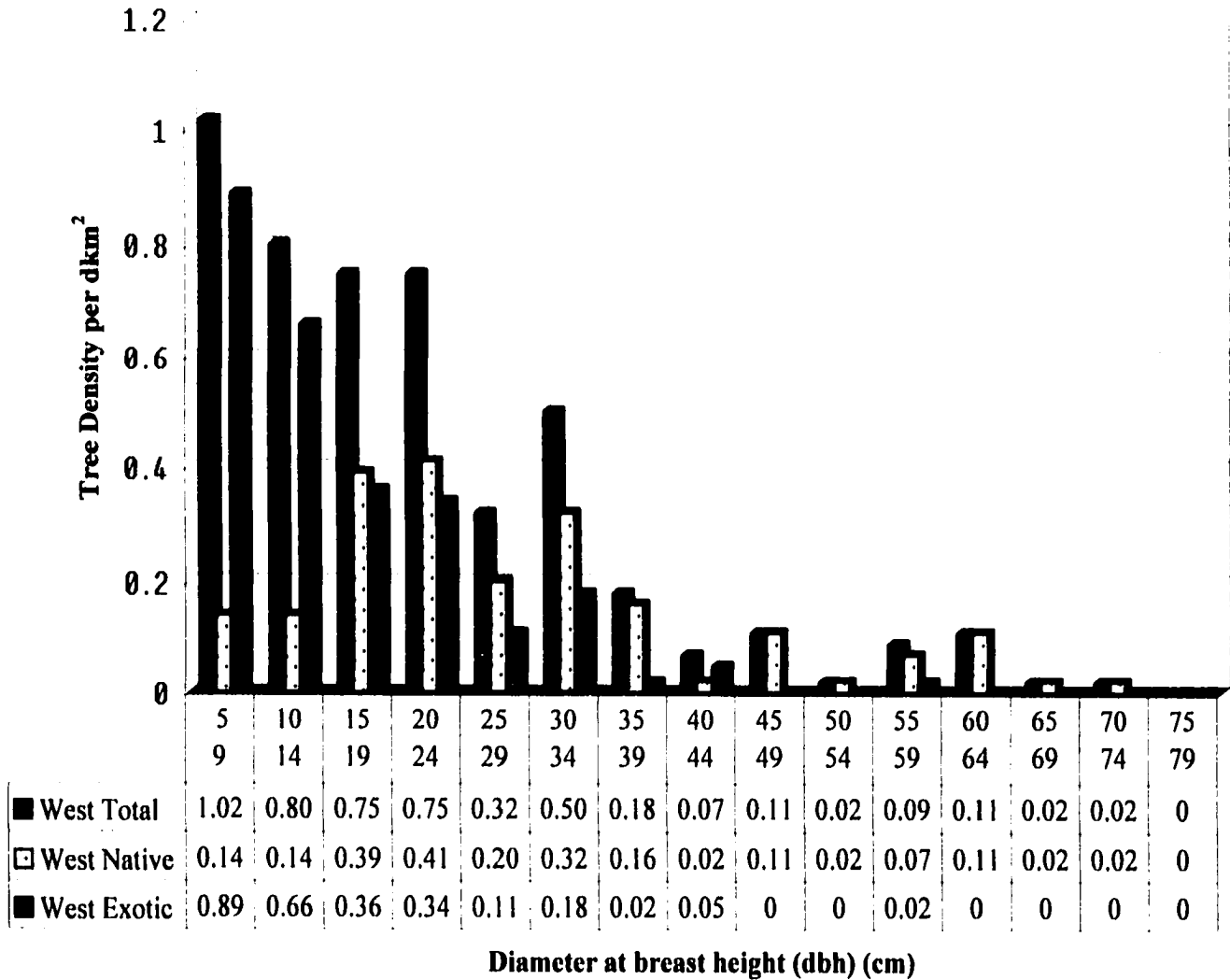


Figure 7. Size Structure - Trees - East Slope

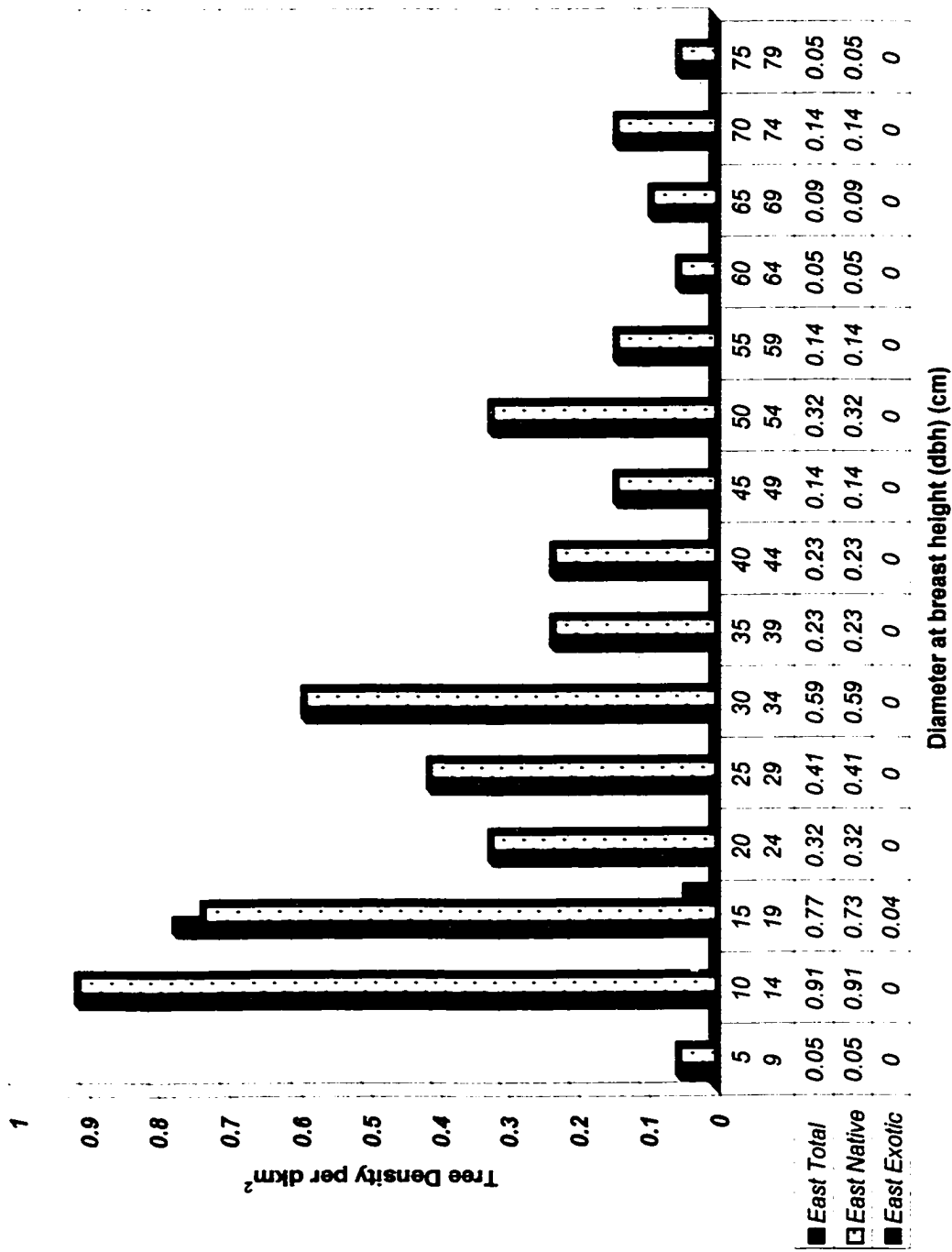


Figure 8. Size Structure - Total Trees -West and East Slopes

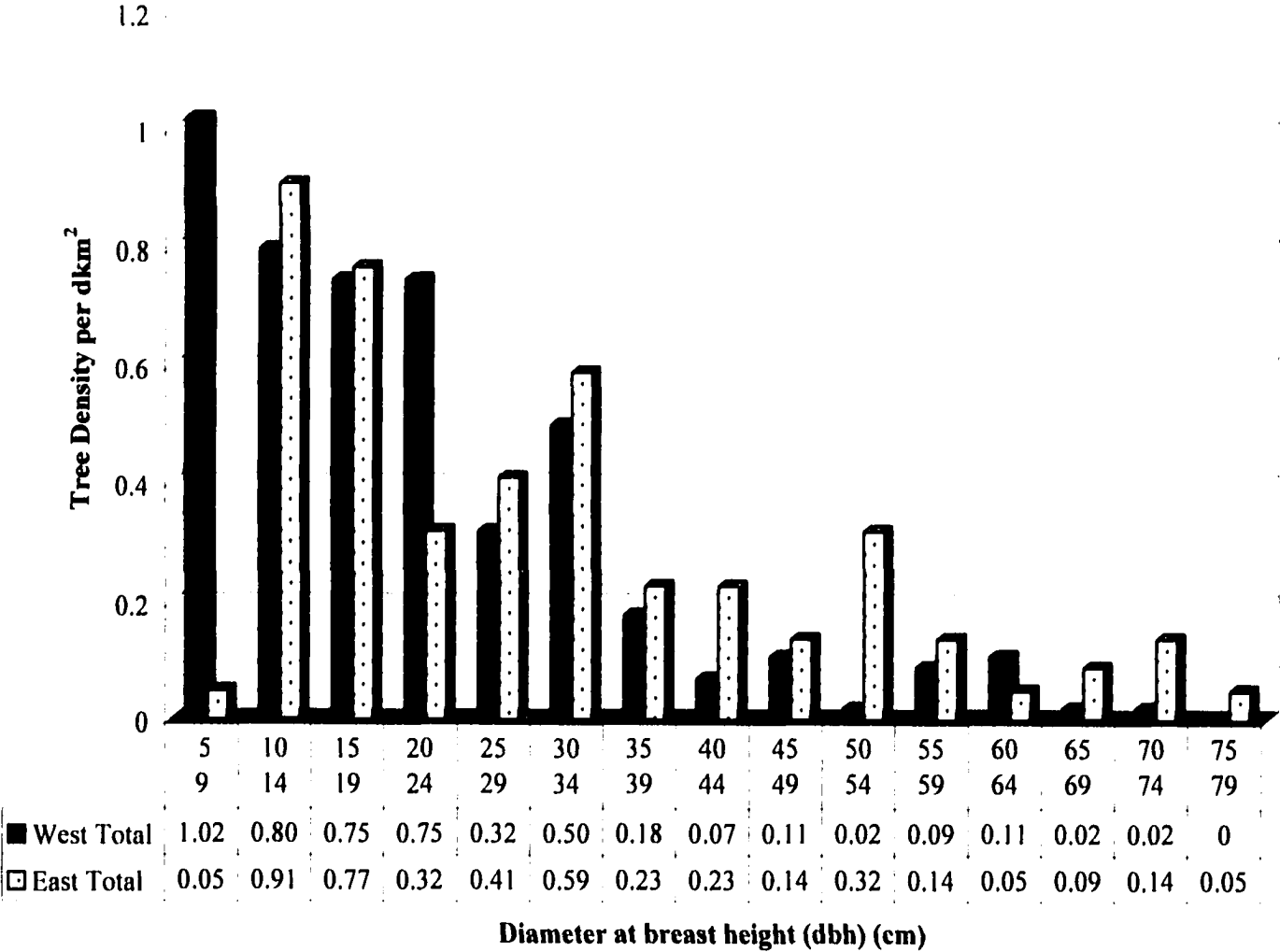


Figure 9. Size Structure - Native Trees - West and East Slopes

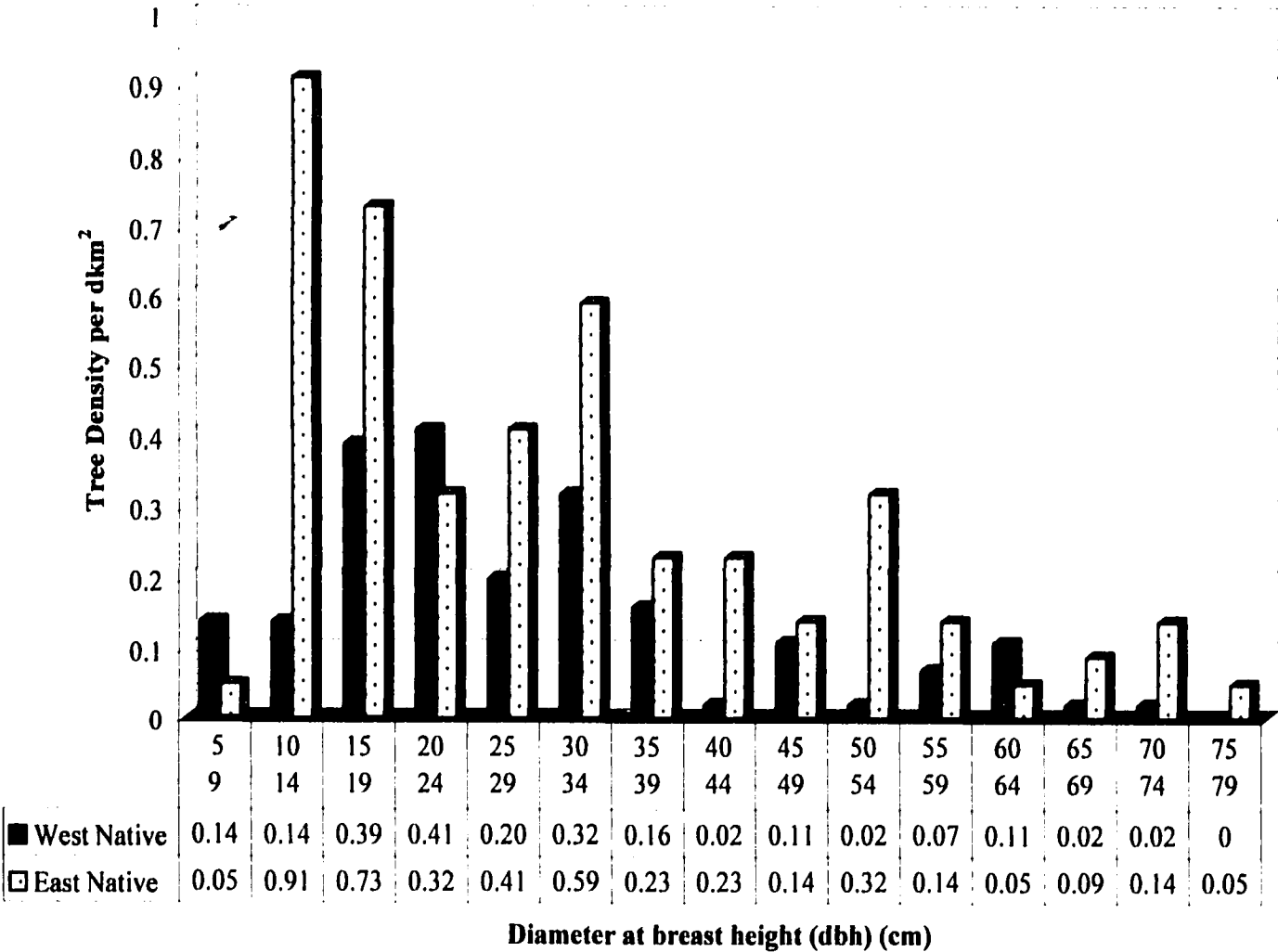


Figure 10. Principal Component Analysis – All Trees

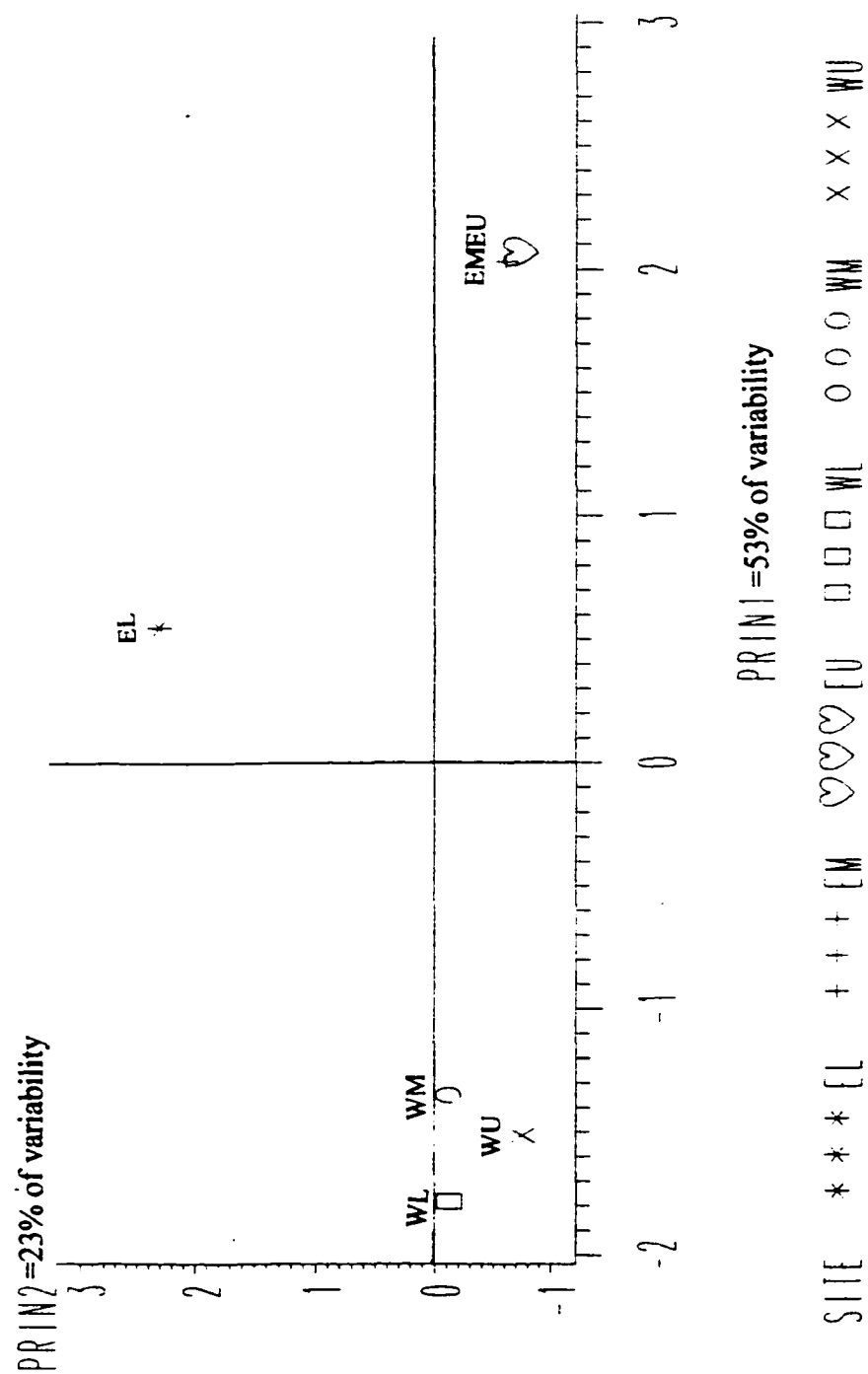


Figure 11. Principal Component Analysis – Native Trees

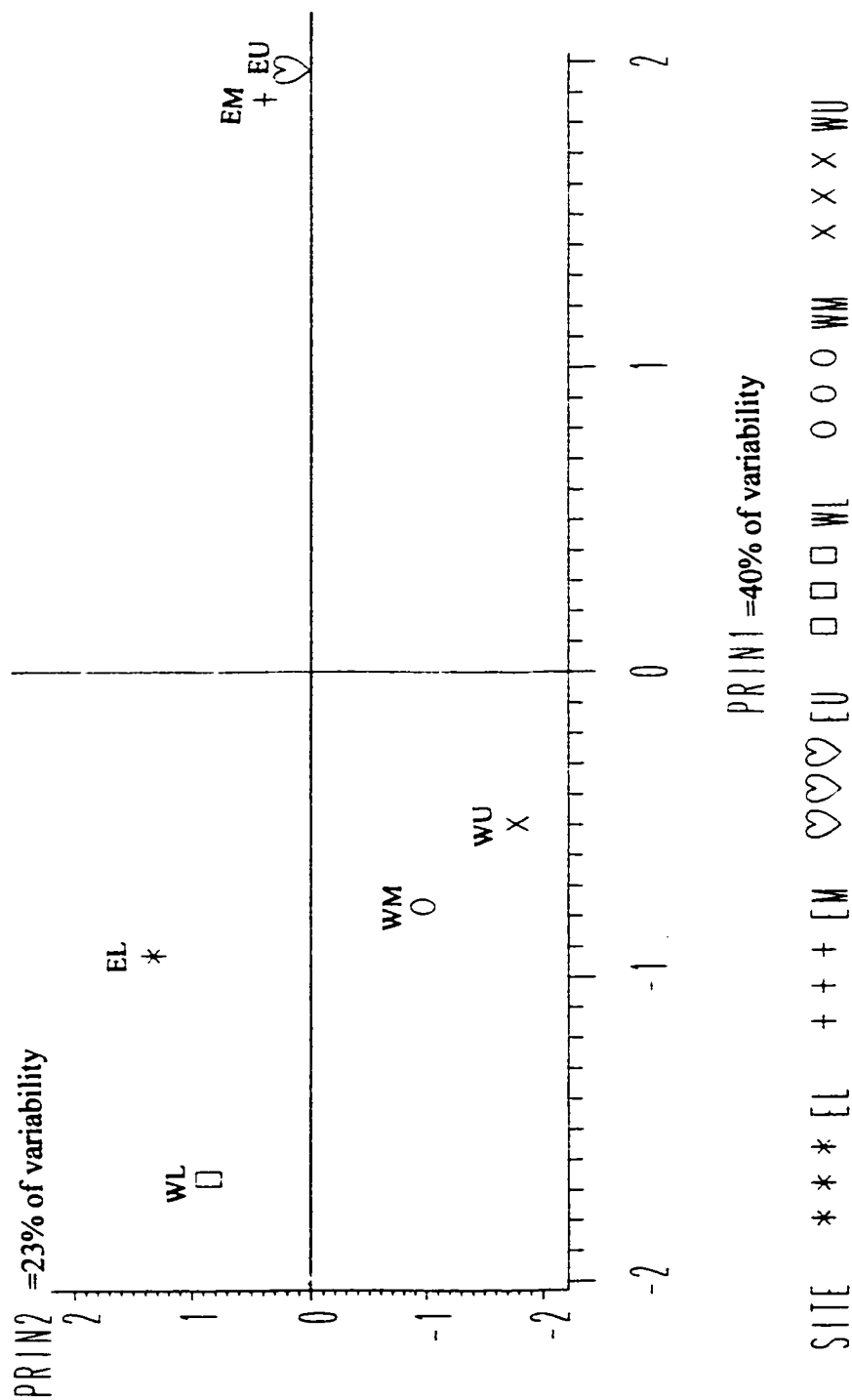


Figure 12. Principal Component Analysis – Shrub and Sapling Layer

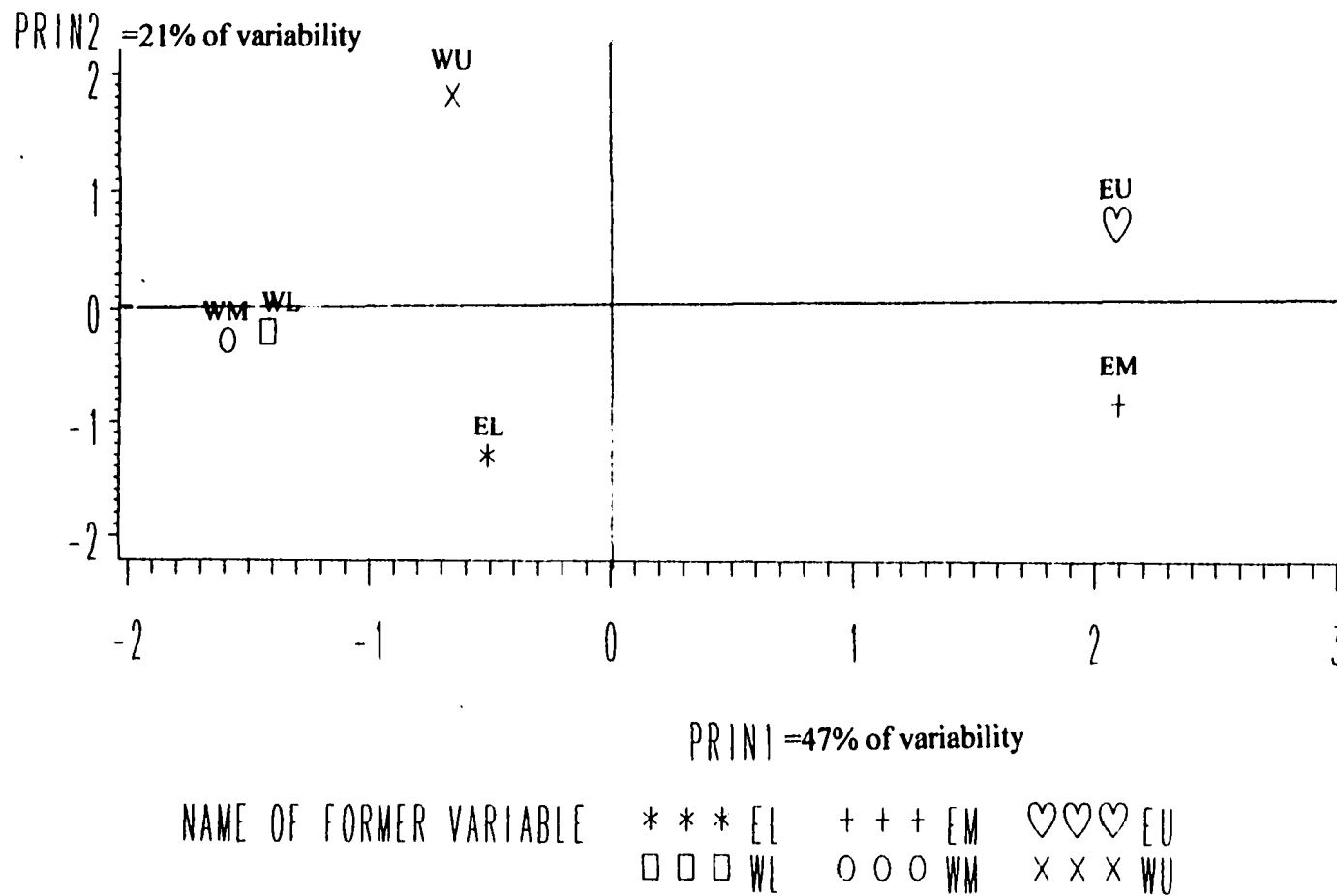


Figure 13. Principal Component Analysis – Herb Layer

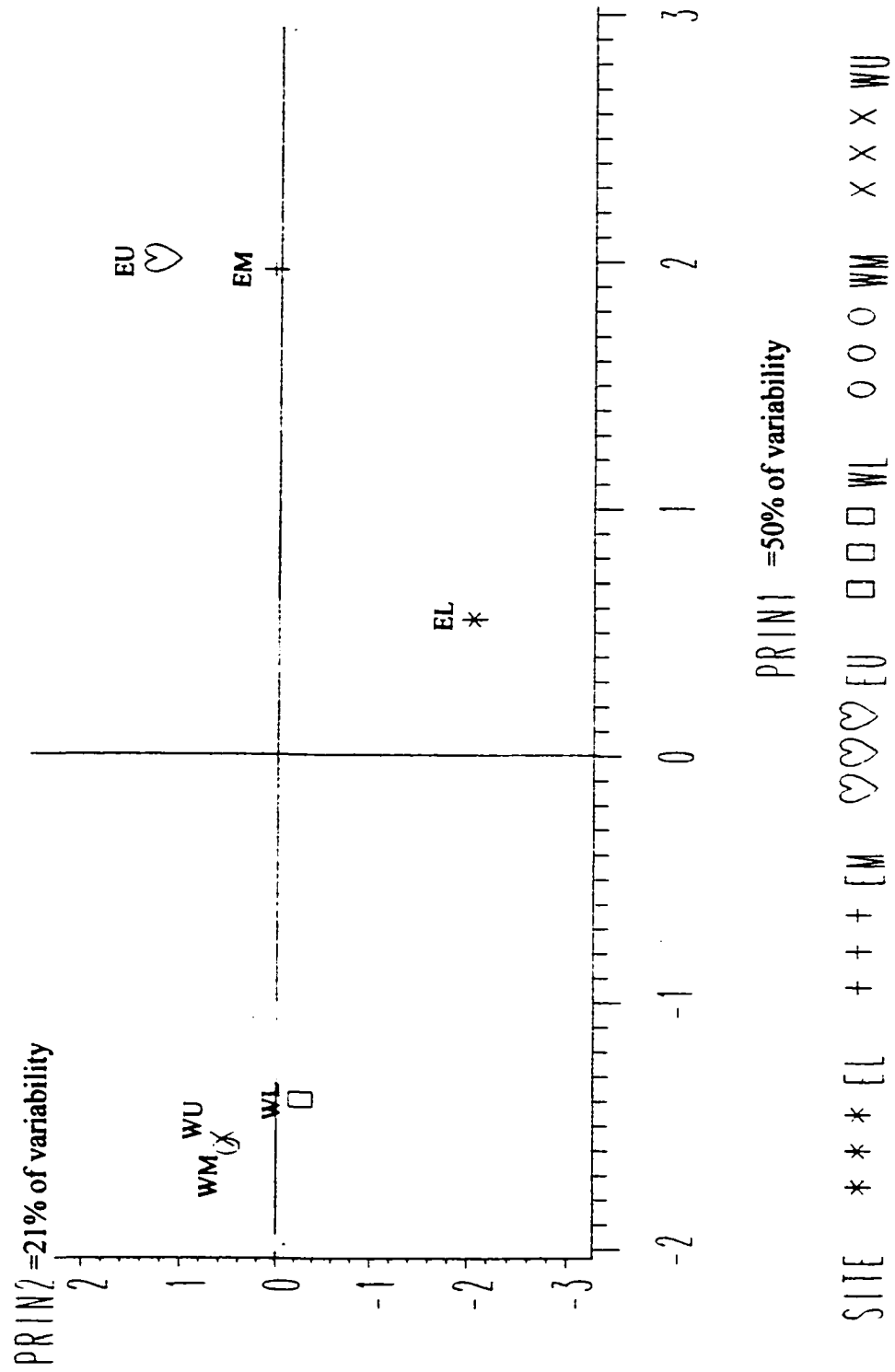


Figure 14. Cluster Analysis – Soil properties data

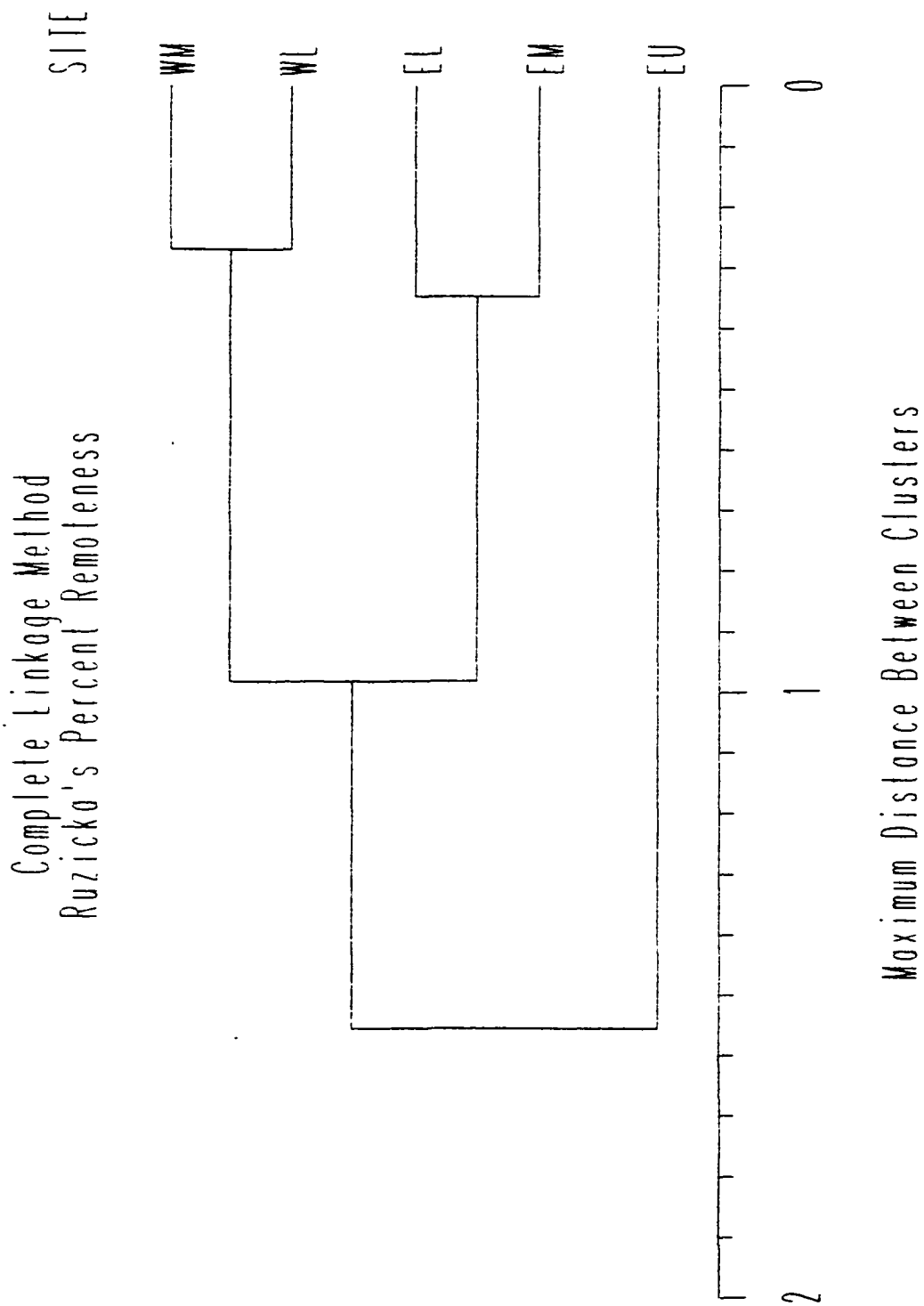


Figure 15. Cluster analysis – All Trees

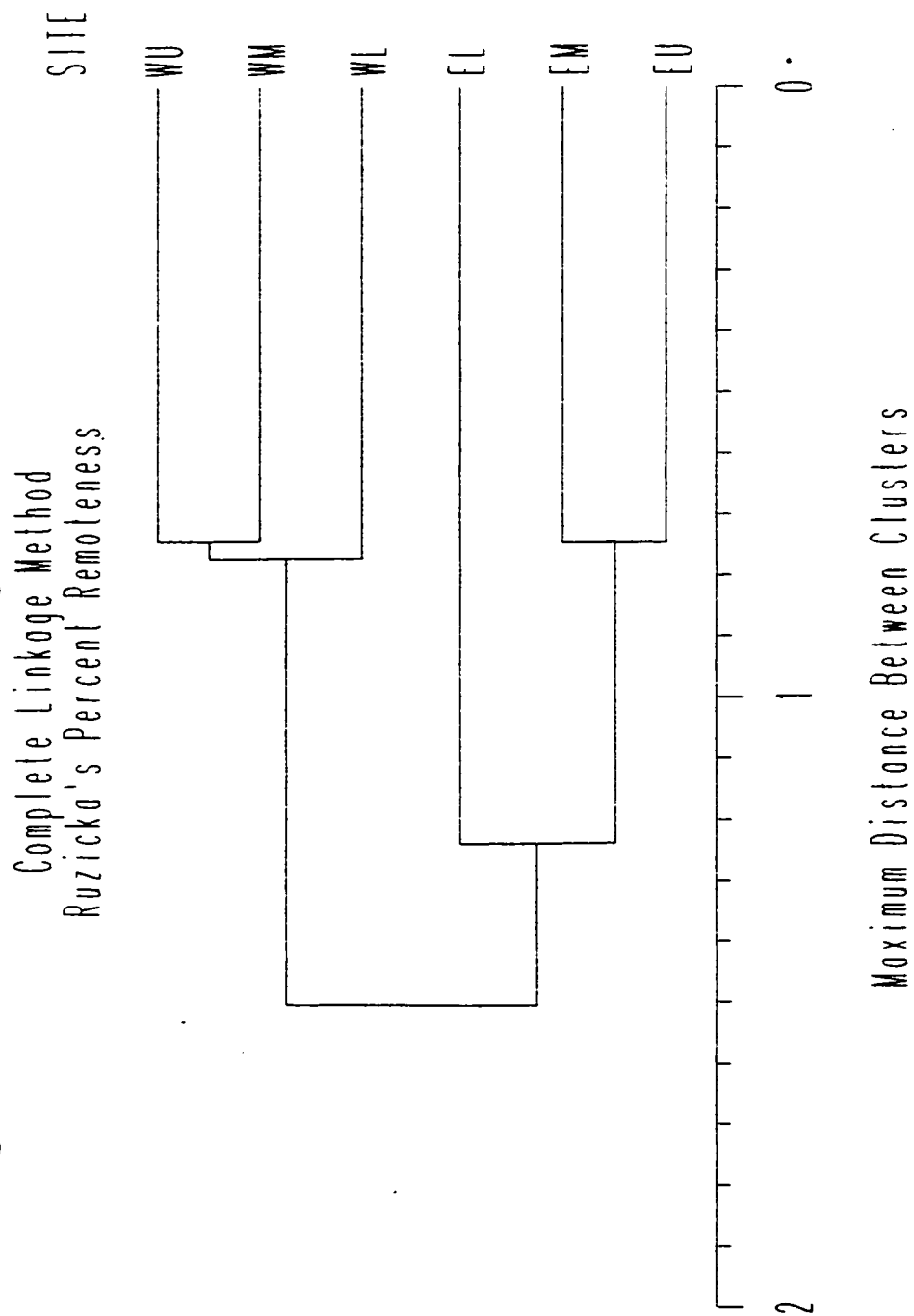


Figure 16. Cluster analysis – All Trees

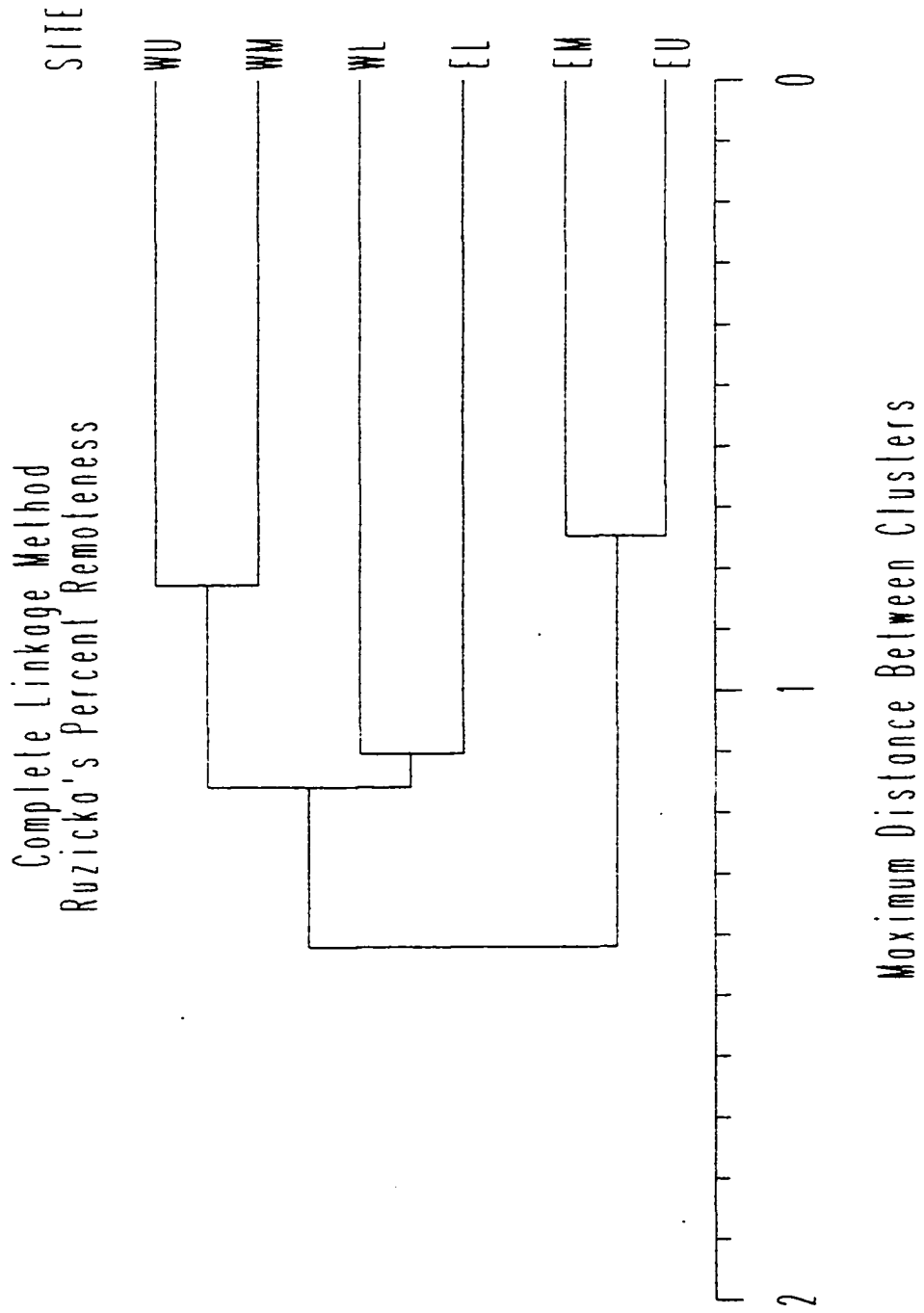


Figure 17. Cluster Analysis – Shrub and Sapling Layer

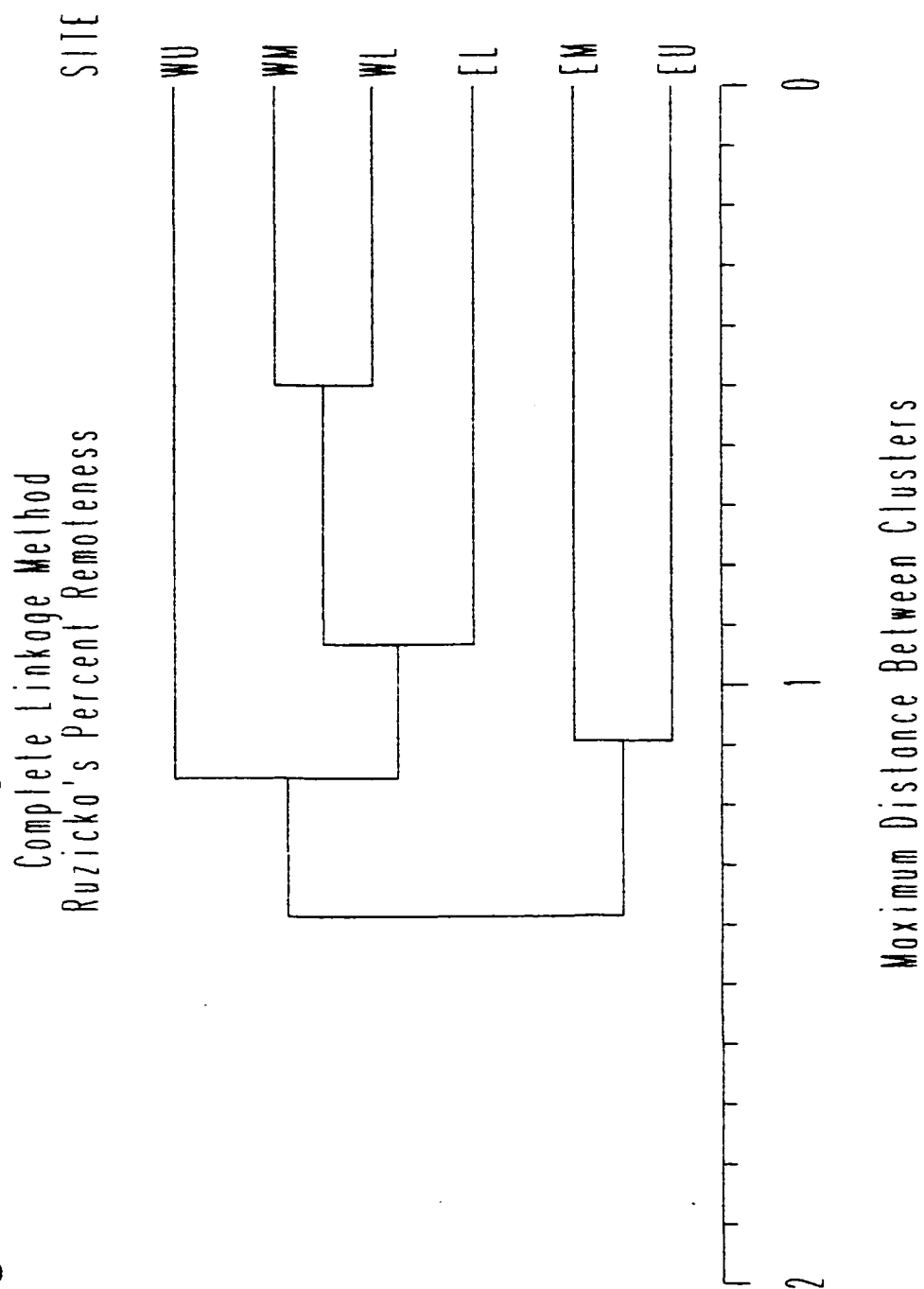


Figure 18. Cluster Analysis – Herb layer

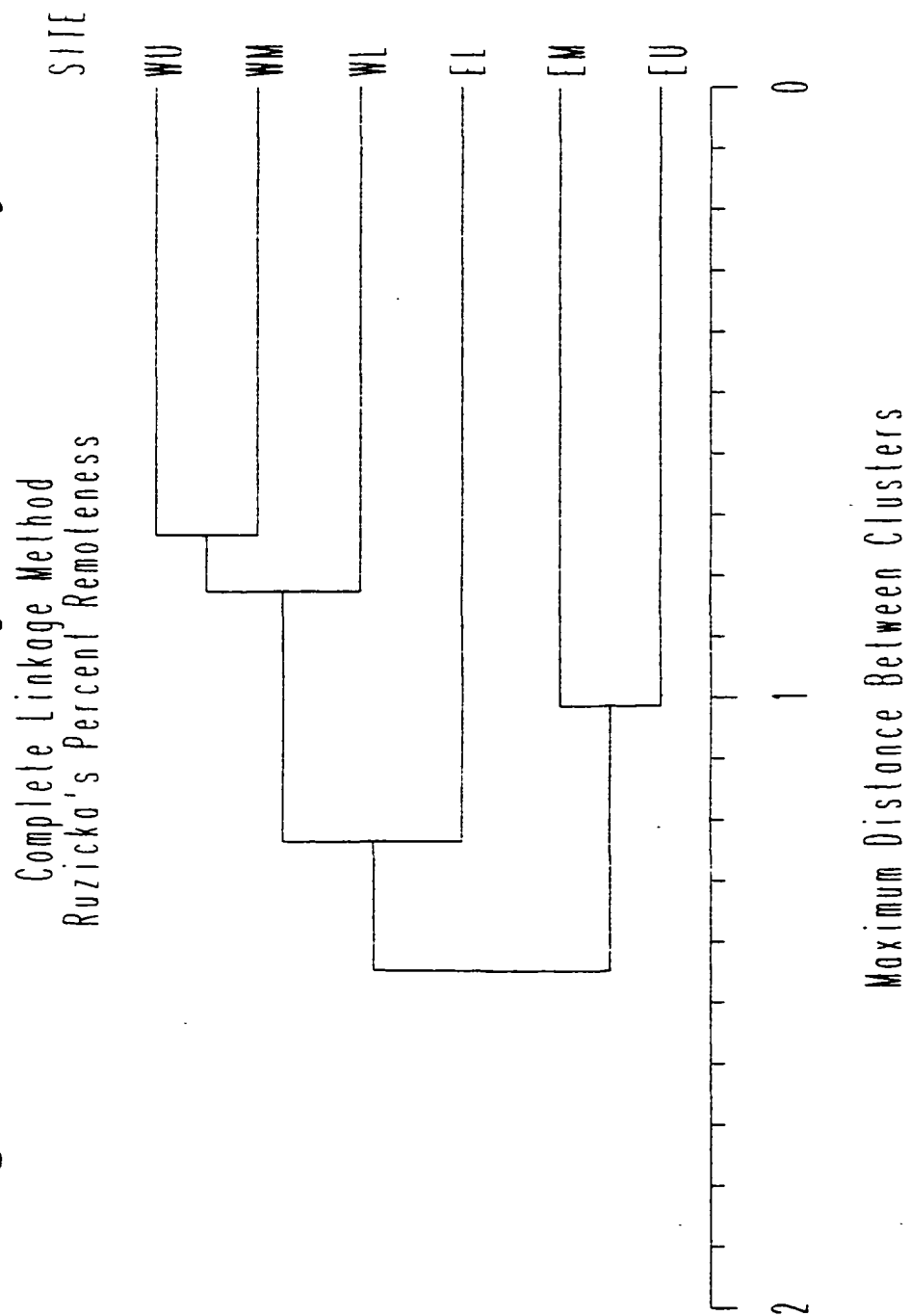




Figure 19. Bloodroot Valley looking north. Manor Creek bed visible in lower center. Arrow points to location of Children's Hospital.
Date: July 27, 1996
Photo credit: Michael Goudket



Figure 20. Serpentinite outcrop on west embankment of study area in Bloodroot Valley, includes large *Acer saccharum*, herbs of *Viola* and *Polygonatum* spp., *Polystichum acrostichoides* fern, and the liverwort, *Conocephalum conicum*.

Date: July 27, 1996

Photo credit: Michael Goudket

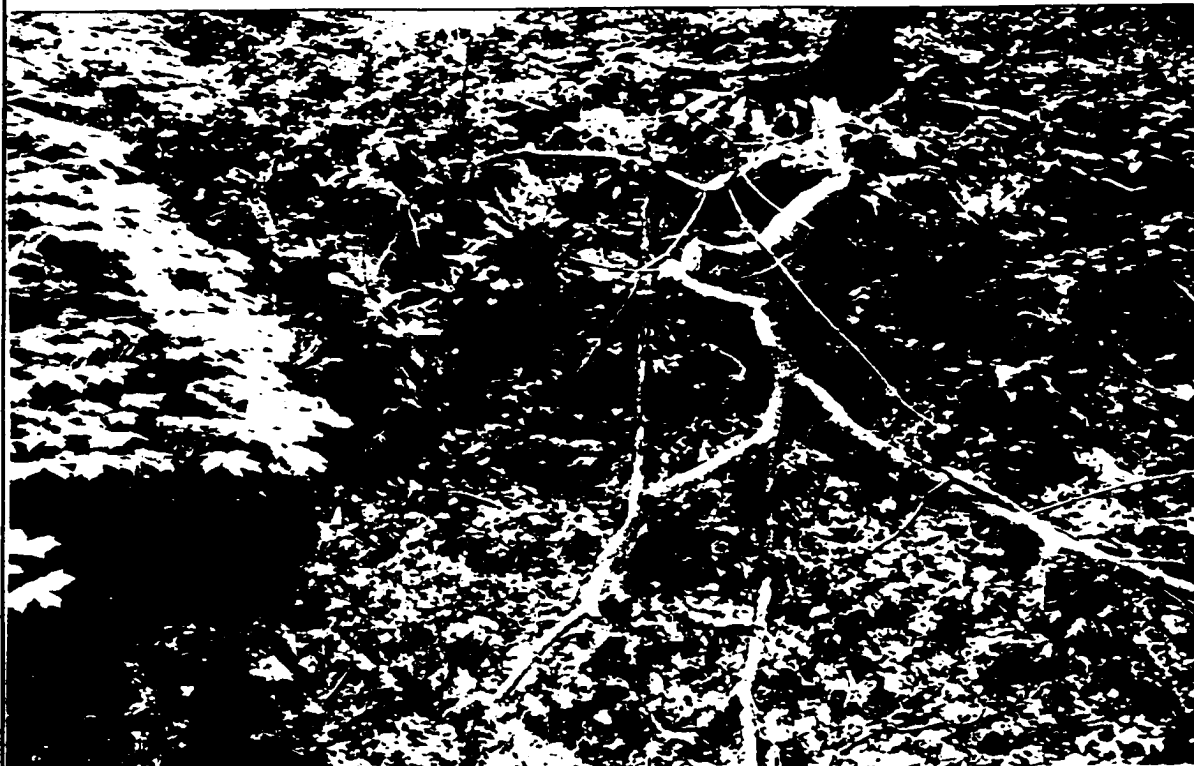


Figure 21. East embankment of Bloodroot Valley, just north of study area, where till thickness is more than 3 m.

Date: July 27, 1996

Photo credit: Michael Goudket



Figure 22. View from upper east slope in foreground to west slope.
Arrow points to Children's Hospital in upper right corner of view.
Date: August 21, 1998
Photo credit: Maureen E. Levine



Figure 23. View of north facing entrance to Children's Hospital on the Seaview Hospital grounds. Arrow pointing to the study area in Bloodroot Valley which is located to the left (east) and below the picture. Photo Credit: Carl Forster, Landmarks Preservation Commission , City of New York.

APPENDIX 1

SI US Standard Sieve Sizes and USDA Classification of Soil Separates

Sieve #	Opening Size		Name of Separate	Diameter range
			mm. in.	
10	2.000	0.0787	gravel (not part of soil)	75.00-2.00mm
18	1.000	0.0394	very coarse sand	2.00-1.00mm
35	0.500	0.0197	coarse sand	1.00-0.50mm
60	0.250	0.0098	medium sand	0.50-0.25mm
80	0.180	0.0070	fine sand	0.25-0.10mm
230	0.063	0.0025	very fine sand/silt	0.10-0.05mm
<230	<0.063	<0.0025	silt	0.05-0.002mm
		clay		<0.002mm

Sieve sizes: Forestry Supplies Inc. Catalog # 51 (2000-2001)

Soil Separates: Soil Survey Manual (1993)

APPENDIX 2
Conversion Factors

Author	Author's Units	Conversion to ppm
Balter and Loeb 1983	ppm	
Gilbert 1998	ppm	
Bridges 1987	mg/kg	=ppm
Sposito 1989	mg/kg	=ppm
CNAL 1999	µg/g	=ppm
Collins 1984	g x 10 ⁻⁶ /g soil	= µg/g =ppm
Brooks 1987	µmol/g x atomic mass	=µg/g =ppm
Buckman and Brady 1969	lb/acre-furrow slice	x 0.5 =ppm
Craul 1992	kg/ha	x 0.892=lb/acre x 0.5 =ppm
Parisio 1982	meq/100g	x (atomic mass x 1mg/valence)/0.1kg =mg/kg=ppm
CNAL 1999	cmol(+)/kg	=meq/100g=(atomic mass x 1mg/valence)/0.1kg=mg/kg=ppm

Milliequivalent weight expresses the chemical activity or combining power of a substance, relative to the activity of one milligram of Hydrogen. It is the atomic weight/valence. The following is a list of common chemical elements and their conversion from 1 mEq/100g soil to ppm (Merck 1992).

ppm		ppm	
Al+++	90	K+	390
Ca++	200	Mg++	120
Cd++	560	Mn++	275
Co++	295	Na+	230
Cr+++	170	Ni++	295
Cu++	640	P+++	60
Fe++	280	Pb++	1040
H+	10	Zn++	325

APPENDIX 3

Vascular Plants of Bloodroot Vailey, Staten Island

Scientific Name	Author	Family	BBG	NIT
<i>Acer platanoides</i> **	L.	Aceraceae		
<i>Acer rubrum</i>	L.	Aceraceae		
<i>Acer saccharum</i>	Marshall	Aceraceae		
<i>Acer sp.</i>		Aceraceae		
<i>Adiantum pedatum</i>	L.	Polypodiaceae	*	
<i>Agrostideae</i> tribe		Poaceae	*	*
<i>Agrostis hyemalis</i> var. <i>scabra</i>	(Willd.)Blomq.	Poaceae	*	*
<i>Ailanthus altissima</i> **	(Miller)Swingle	Simaroubaceae		
<i>Allium vineale</i> **	L.	Liliaceae	*	
<i>Amphicarpaea bracteata</i>	(L.)Fern.	Fabaceae	*	
<i>Aralia nudicaulis</i>	L.	Araliaceae	*	*
<i>Aralia racemosa</i>	L.	Araliaceae	*	*
<i>Arisaema triphyllum</i>	(L.)Schott.	Araceae	*	
<i>Artemisia vulgaris</i> **	L.	Asteraceae		
<i>Aster divaricatus</i>	L.	Asteraceae	*	
<i>Athyrium filix-femina</i>	(L.)Roth	Polypodiaceae	*	*
<i>Athyrium thelypteroides</i>	(Michx.)Desv.	Polypodiaceae	*	
<i>Berberis thunbergii</i> **	DC.	Berberidaceae	*	
<i>Betula lenta</i>	L.	Betulaceae	*	
<i>Carex abscondita</i>	MacKenzie	Cyperaceae	*	
<i>Carex pensylvanica</i>	Lam.	Cyperaceae	*	
<i>Carex rosea</i>	Schk.	Cyperaceae	*	*
<i>Carex sp.</i>		Cyperaceae	*	
<i>Carpinus caroliniana</i>	Walter.	Betulaceae		
<i>Caulophyllum thalictroides</i>	(L.)Michx.	Berberidaceae	*	
<i>Celastrus orbiculatus</i> **	Thunb.	Celasteraceae		
<i>Chimaphila maculata</i>	(L.)Pursh.	Pyrolaceae		
<i>Cinna arundinacea</i>	L.	Poaceae	*	
<i>Collinsonia canadensis</i>	L.	Lamiaceae	*	
<i>Commelina communis</i> **	L.	Commelinaceae		
<i>Cryptotaenia canadensis</i>	(L.)DC	Apiaceae	*	
<i>Cuscuta gronovii</i>	Willd.	Cuscutaceae	*	*
<i>Cystopteris protrusa</i>	(Weath.)Blasd.	Polypodiaceae	*	
<i>Deutzia scabra</i> **	Thunb.	Hydrangeaceae	*	
<i>Erythronium americanum</i>	Ker Gawler	Liliaceae		

APPENDIX 3

Vascular Plants of Bloodroot Valley, Staten Island		cont'd p.2		
Scientific Name	Author	Family	BBG	NIT
<i>Eupatorium rugosum</i>	Houttuyn.	Asteraceae	*	
<i>Fagus grandifolia</i>	Ehrh.	Fagaceae		
<i>Forsythia</i> sp. **		Oleaceae	*	*
<i>Forsythia viridissima</i> **	Lind.	Oleaceae	*	*
<i>Fraxinus americana</i>	L.	Oleaceae		
<i>Galium</i> sp.		Rubiaceae	*	
<i>Geranium maculatum</i>	L.	Geraniaceae	*	*
<i>Heuchera americana</i>	L.	Saxifragaceae	*	
<i>Hydrophyllum virginianum</i>	L.	Hydrophyllaceae	*	
<i>Impatiens capensis</i>	Meerb.	Balsaminaceae	*	
<i>Juglans nigra</i>	L.	Juglandaceae		
<i>Kalmia latifolia</i>	L.	Ericaceae		
<i>Ligustrum obtusifolium</i> **	Sieb.&Zucc.	Oleaceae	*	
<i>Lindera benzoin</i>	(L.)Blume	Lauraceae	*	
<i>Liquidambar styraciflua</i>	L.	Hamamelidaceae		
<i>Liriodendron tulipifera</i>	L.	Magnoliaceae		
<i>Lonicera japonica</i> **	Thunb.	Caprifoliaceae	*	
<i>Lysimachia quadrifolia</i>	Sims.	Primulaceae	*	
<i>Maianthemum canadense</i>	Desf.	Liliaceae	*	
<i>Menispermum canadense</i>	L.	Menispermaceae	*	
<i>Mitchella repens</i>	L.	Rubiaceae	*	
<i>Morus alba</i> **	L.	Moraceae		
<i>Nyssa sylvatica</i>	Marshall	Cornaceae		
<i>Osmorhiza longistylis</i>	(Torr.)DC	Apiaceae	*	
<i>Osmunda claytoniana</i>	L.	Osmundaceae	*	
<i>Panicum boscii</i>	Poir.	Poaceae	*	*
<i>Panicum</i> sp.		Poaceae	*	
<i>Paronychia canadensis</i>	(L.)A. Wood	Caryophyllaceae	*	*
<i>Parthenocissus quinquefolia</i>	(L.)Planchon	Vitaceae	*	
<i>Parthenocissus tricuspidata</i> **	(Siebold&Zucc.)Planchon	Vitaceae	*	
<i>Polygonatum pubescens</i>	(Willd.)Pursh.	Liliaceae	*	
<i>Polygonum cespitosum</i> **	Blume.	Polygonaceae	*	*
<i>Polygonum virginianum</i>	L.	Polygonaceae	*	*
<i>Polystichum acrostichoides</i>	(Michx.)Schott	Polypodiaceae	*	
<i>Prenanthes trifoliolata</i>	(Cass.)Fern.	Asteraceae	*	
<i>Prunus avium</i> **	L.	Rosaceae		

APPENDIX 3

Vascular Plants of Bloodroot Valley, Staten Island cont'd p.3

Scientific Name	Author	Family	BBG	NIT
<i>Prunus serotina</i>	Ehrh.	Rosaceae	*	
<i>Pyrus malus</i> **	L.	Rosaceae	*	*
<i>Quercus rubra</i>	L.	Fagaceae		
<i>Quercus sp.</i>		Fagaceae		
<i>Rhododendron pericylmenoides</i>	(Michx.)Shinn.	Ericaceae	*	
<i>Robinia pseudoacacia</i> ***	L.	Fabaceae	*	
<i>Rosa multiflora</i> **	Thunb.	Rosaceae	*	
<i>Rubus occidentalis</i>	L.	Rosaceae	*	
<i>Sanguinaria canadensis</i>	L.	Papaveraceae	*	
<i>Sanicula marilandica</i>	L.	Apiaceae	*	
<i>Sassafras albidum</i>	(Nutt.)Nees.	Lauraceae		
<i>Silene stellata</i>	(L.)Aiton f.	Caryophyllaceae	*	*
<i>Smilacina racemosa</i>	(L.)Desf.	Liliaceae	*	
<i>Smilax herbacea</i>	L.	Smilacaceae	*	
<i>Smilax rotundifolia</i>	L.	Smilacaceae	*	*
<i>Solidago caesia</i>	L.	Asteraceae	*	
<i>Stellaria media</i> **	(L.)Villars.	Caryophyllaceae	*	
<i>Thelypteris hexagonoptera</i>	(Michx.)Weatherby	Polypodiaceae	*	*
<i>Tilia americana</i>	L.	Tiliaceae	*	
<i>Toxicodendron radicans</i>	(L.)Kuntze	Anacardiaceae		
<i>Ulmus americana</i>	L.	Ulmaceae	*	
<i>Urtica dioica</i> var. <i>dioica</i>	L.	Urticaceae	*	
<i>Vaccinium corymbosum</i>	L.	Ericaceae	*	
<i>Vaccinium pallidum</i>	Ait.	Ericaceae	*	
<i>Viburnum acerfolium</i>	L.	Caprifoliaceae	*	
<i>Viburnum dentatum</i> var. <i>dentatum</i>	L.	Caprifoliaceae	*	
<i>Viola pubescens</i>	Aiton.	Violaceae	*	
<i>Viola sp.</i>		Violaceae		
<i>Vitis riparia</i>	Michx.	Vitaceae	*	*

Note: Nomenclature follows Gleason and Cronquist (1991).

** = exotic species

***=native to N.Amer but not NY

BBG - vouchered specimen(s) on file at the Brooklyn Botanic Garden

NIT - species not in transects but in nearby area

APPENDIX 4. Matrices of Distance/Similarity Measures.

Trees- Native and Exotic- density comparison								Trees- Native Only- density comparison							
Bray Curtis Dissimilarity Matrix								Bray Curtis Dissimilarity Matrix							
West Slope				East Slope				West Slope				East Slope			
Upper	Middle	Lower	Lower	Middle	Upper			Upper	Middle	Lower	Lower	Middle	Upper		
West Slope Upper	0	0.26	0.46	0.77	0.80	0.80		West Slope Upper	0	0.38	0.64	0.69	0.65	0.63	
Middle		0	0.51	0.58	0.58	0.65		Middle		0	0.53	0.44	0.52	0.56	
Lower			0	0.71	0.85	0.94		Lower			0	0.63	0.85	0.93	
East Slope Lower				0	0.65	0.7		East Slope Lower				0	0.71	0.73	
Middle					0	0.35		Middle					0	0.34	
Upper						0		Upper						0	
Canberra Distance								Canberra Distance							
West Slope				East Slope				West Slope				East Slope			
Upper	Middle	Lower	Lower	Middle	Upper			Upper	Middle	Lower	Lower	Middle	Upper		
West Slope Upper	0	0.32	0.54	0.72	0.63	0.64		West Slope Upper	0	0.35	0.58	0.73	0.59	0.65	
Middle		0	0.53	0.51	0.39	0.51		Middle		0	0.50	0.55	0.39	0.60	
Lower			0	0.55	0.66	0.77		Lower			0	0.39	0.60	0.79	
East Slope Lower				0	0.51	0.5		East Slope Lower				0	0.68	0.66	
Middle					0	0.22		Middle					0	0.28	
Upper						0		Upper						0	

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

APPENDIX 4. Matrices of Distance/Similarity Measures cont'd p.2

Trees- Native and Exotic- density comparison

City Block/Manhattan Distance							
West Slope				East Slope			
	Upper	Middle	Lower	Lower	Middle	Upper	
West Slope Upper	0	0.04	0.61	0.11	0.12	0.10	
Middle		0	0.07	0.09	0.09	0.08	
Lower			0	0.08	0.10	0.11	
East Slope Lower				0	0.09	0.09	
Middle					0	0.05	
Upper						0	

Ruzicka Percent Remoteness Index							
West Slope				East Slope			
	Upper	Middle	Lower	Lower	Middle	Upper	
West Slope Upper	0	0.41	0.63	0.87	0.89	0.89	
Middle		0	0.67	0.73	0.73	0.79	
Lower			0	0.83	0.92	0.97	
East Slope Lower				0	0.79	0.82	
Middle					0	0.52	
Upper						0	

Trees- Native Only- density comparison

City Block/Manhattan Distance							
West Slope				East Slope			
	Upper	Middle	Lower	Lower	Middle	Upper	
West Slope Upper	0	0.04	0.05	0.09	0.11	0.10	
Middle		0	0.05	0.06	0.09	0.09	
Lower			0	0.07	0.12	0.12	
East Slope Lower				0	0.13	0.12	
Middle					0	0.07	
Upper						0	

Ruzicka Percent Remoteness Index							
West Slope				East Slope			
	Upper	Middle	Lower	Lower	Middle	Upper	
West Slope Upper	0	0.56	0.78	0.82	0.79	0.77	
Middle		0	0.69	0.61	0.68	0.72	
Lower			0	0.77	0.92	0.96	
East Slope Lower				0	0.83	0.84	
Middle					0	0.50	
Upper						0	

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

APPENDIX 4. Matrices of Distance/Similarity Measures cont'd p3

Trees- Native and Exotic- density comparison

		Similarity Ratio Distance					
		West Slope			East Slope		
		Upper	Middle	Lower	Lower	Middle	Upper
West Slope	Upper	0	0.21	0.51	0.88	0.85	0.84
	Middle		0	0.67	0.69	0.60	0.63
	Lower			0	0.78	0.92	0.93
East Slope	Lower				0	0.62	0.67
	Middle					0	0.23
	Upper						0

		Chord Distance					
		West Slope			East Slope		
		Upper	Middle	Lower	Lower	Middle	Upper
West Slope	Upper	0	0.47	0.76	1.26	1.19	1.20
	Middle		0	0.92	1.02	0.90	0.96
	Lower			0	1.10	1.26	1.30
East Slope	Lower				0	0.88	1.00
	Middle					0	0.42
	Upper						0

Trees- Native Only- density comparison

		Similarity Ratio Distance					
		West Slope			East Slope		
		Upper	Middle	Lower	Lower	Middle	Upper
West Slope	Upper	0	0.46	0.69	0.81	0.76	0.68
	Middle		0	0.67	0.45	0.54	0.45
	Lower			0	0.71	0.93	0.92
East Slope	Lower				0	0.68	0.70
	Middle					0	0.24
	Upper						0

		Chord Distance					
		West Slope			East Slope		
		Upper	Middle	Lower	Lower	Middle	Upper
West Slope	Upper	0	0.72	1.01	1.11	0.81	0.85
	Middle		0	0.91	0.73	0.55	0.64
	Lower			0	0.87	1.19	1.24
East Slope	Lower				0	0.93	1.03
	Middle					0	0.4
	Upper						0

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

APPENDIX 4. Matrices of Distance/Similarity Measures cont'd p.4

Trees- Native and Exotic-density comparison

Euclidean Distance							
West Slope				East Slope			
	Upper	Middle	Lower	Lower	Middle	Upper	
West Slope Upper	0	0.31	0.41	0.73	0.94	0.67	
Middle		0	0.56	0.65	0.75	0.47	
Lower			0	0.56	0.93	0.72	
East Slope Lower				0	0.73	0.63	
Middle					0	0.42	
Upper						0	

Geodesic Distance							
West Slope				East Slope			
	Upper	Middle	Lower	Lower	Middle	Upper	
West Slope Upper	0	0.47	0.78	1.36	1.28	1.29	
Middle		0	0.95	1.07	0.93	1.00	
Lower			0	1.17	1.37	1.41	
East Slope Lower				0	0.91	1.05	
Middle					0	0.42	
Upper						0	

Trees- Native Only- density comparison

Euclidean Distance							
West Slope				East Slope			
	Upper	Middle	Lower	Lower	Middle	Upper	
West Slope Upper	0	0.30	0.29	0.55	0.83	0.56	
Middle		0	0.36	0.39	0.68	0.45	
Lower			0	0.47	0.97	0.70	
East Slope Lower				0	0.84	0.67	
Middle					0	0.45	
Upper						0	

Geodesic Distance							
West Slope				East Slope			
	Upper	Middle	Lower	Lower	Middle	Upper	
West Slope Upper	0	0.74	1.06	1.18	0.83	0.88	
Middle		0	0.94	0.74	0.56	0.66	
Lower			0	0.90	1.27	1.33	
East Slope Lower				0	0.97	1.08	
Middle					0	0.40	
Upper						0	

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

APPENDIX 4. Matrices of Distance/Similarity Measures cont'd p.5

Trees- Native and Exotic- density comparison								Trees- Native Only- density comparison							
Morisita (1959) Similarity Index								Morisita (1959) Similarity Index							
West Slope				East Slope				West Slope				East Slope			
Upper	Middle	Lower	Lower	Middle	Upper			Upper	Middle	Lower	Lower	Middle	Upper		
West Slope Upper	0	-0.11	0.03	-0.01	-0.06	-0.03		West Slope Upper	0	0.03	0.03	-0.36	0.08	0.07	
	Middle		0	0.03	-0.03	-0.15	-0.07		Middle		0	0.04	0.27	0.09	0.07
	Lower			0	0.04	0.02	0.01		Lower			0	-0.10	0.18	0.37
East Slope Lower					0	-0.07	-0.04	East Slope Lower					0	-0.06	-0.04
	Middle					0	-0.20		Middle					0	-0.28
	Upper						0		Upper						0
Morisita-Horn (1966) Similarity Index								Morisita-Horn (1966) Similarity Index							
West Slope				East Slope				West Slope				East Slope			
Upper	Middle	Lower	Lower	Middle	Upper			Upper	Middle	Lower	Lower	Middle	Upper		
West Slope Upper	0	0.89	0.71	0.21	0.24	0.27		West Slope Upper	0	0.72	0.47	0.37	0.62	0.63	
	Middle		0	0.58	0.48	0.52	0.53		Middle		0	0.59	0.74	0.83	0.79
	Lower			0	0.38	0.17	0.15		Lower			0	0.62	0.29	0.24
East Slope Lower					0	0.57	0.50	East Slope Lower					0	0.55	0.47
	Middle					0	0.86		Middle					0	0.89
	Upper						0		Upper						0

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

APPENDIX 4. Matrices of Distance/Similarity Measures cont'd p.6

Shrub and Sapling Layer -percent canopy cover comparison

Bray Curtis Dissimilarity Matrix								Canberra Distance							
West Slope				East Slope				West Slope				East Slope			
	Upper	Middle	Lower	Lower	Middle	Upper		Upper	Middle	Lower	Lower	Middle	Upper		
West Slope	Upper	0	0.44	0.43	0.68	0.91	0.72	West Slope	Upper	0	0.20	0.34	0.46	0.50	0.64
	Middle		0	0.21	0.38	0.76	0.72		Middle		0	0.20	0.33	0.38	0.57
	Lower			0	0.45	0.62	0.72		Lower			0	0.49	0.52	0.73
East Slope	Lower				0	0.75	0.69	East Slope	Lower				0	0.40	0.55
	Middle					0	0.62		Middle					0	0.45
	Upper						0		Upper						0
City Block/Manhattan Distance								Ruzicka Percent Remoteness Index							
West Slope				East Slope				West Slope				East Slope			
	Upper	Middle	Lower	Lower	Middle	Upper		Upper	Middle	Lower	Lower	Middle	Upper		
West Slope	Upper	0	4.65	4.47	7.19	9.59	7.62	West Slope	Upper	0	0.61	0.60	0.81	0.95	0.84
	Middle		0	2.17	3.98	7.98	7.58		Middle		0	0.34	0.55	0.86	0.84
	Lower			0	4.73	6.54	7.58		Lower			0	0.62	0.77	0.84
East Slope	Lower				0	7.87	7.29	East Slope	Lower				0	0.86	0.82
	Middle					0	6.54		Middle					0	0.77
	Upper						0		Upper						0

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

APPENDIX 4. Matrices of Distance/Similarity Measures cont'd p.7

Shrub and Sapling Layer -percent canopy cover comparison

Similarity Ratio Distance								Chord Distance							
West Slope				East Slope				West Slope				East Slope			
Upper	Middle	Lower	Lower	Middle	Upper			Upper	Middle	Lower	Lower	Middle	Upper		
West Slope Upper	0	0.47	0.49	0.75	0.95	0.89		West Slope Upper	0	0.79	0.80	1.08	1.34	1.26	
Middle		0	0.14	0.35	0.79	0.74		Middle		0	0.39	0.56	1.14	1.08	
Lower			0	0.43	0.63	0.76		Lower			0	0.66	0.96	1.10	
East Slope Lower				0	0.86	0.71		East Slope Lower				0	1.22	0.99	
Middle					0	0.73		Middle					0	1.06	
Upper						0		Upper						0	
Euclidean Distance								Geodesic Distance							
West Slope				East Slope				West Slope				East Slope			
Upper	Middle	Lower	Lower	Middle	Upper			Upper	Middle	Lower	Lower	Middle	Upper		
West Slope Upper	0	44.58	45.67	75.46	77.90	66.96		West Slope Upper	0	0.80	0.83	1.14	1.47	1.36	
Middle		0	20.87	43.08	62.54	53.29		Middle		0	0.40	0.56	1.22	1.14	
Lower			0	48.80	52.40	54.28		Lower			0	0.67	1.00	1.16	
East Slope Lower				0	83.12	66.54		East Slope Lower				0	1.31	1.03	
Middle					0	54.52		Middle					0	1.12	
Upper						0		Upper						0	

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

APPENDIX 4. Matrices of Distance/Similarity Measures cont'd p.8

Shrub and Sapling Layer -percent canopy cover comparison

Morisita (1959) Similarity Index							Morisita-Horn (1966) Similarity Index								
West Slope				East Slope			West Slope				East Slope				
	Upper	Middle	Lower	Lower	Middle	Upper		Upper	Middle	Lower	Lower	Middle	Upper		
West Slope	Upper	0	0.70	0.69	0.41	0.10	0.20	West Slope	Upper	0	0.69	0.67	0.40	0.10	0.20
	Middle		0	0.95	0.80	0.36	0.43		Middle		0	0.92	0.79	0.35	0.41
	Lower			0	0.74	0.55	0.40			Lower			0	0.73	0.54
East Slope	Lower				0	0.25	0.45	East Slope	Lower					0	0.24
	Middle					0	0.44		Middle					0	0.43
	Upper						0			Upper					

Spring Herb Layer - plant cover comparison

Bray Curtis Dissimilarity							Canberra Distance									
West Slope			East Slope				West Slope			East Slope						
	Upper	Middle	Lower	Lower	Middle	Upper		Upper	Middle	Lower	Lower	Middle	Upper			
West Slope	Upper	0	0.35	0.40	0.71	0.86	0.89	West Slope	Upper	0	0.39	0.43	0.53	0.59	0.59	
	Middle		0	0.36	0.69	0.81	0.86		West Slope	Middle		0	0.33	0.52	0.60	0.59
	Lower			0	0.53	0.76	0.80			West Slope	Lower			0	0.37	0.55
East Slope	Lower				0	0.61	0.78	East Slope			Lower				0	0.45
	Middle					0	0.55		East Slope		Middle					0
	Upper						0			East Slope	Upper					

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

APPENDIX 4. Matrices of Distance/Similarity Measures cont'd p.9

Spring Herb Layer - plant cover comparison

City Block/Manhattan Distance								Ruzicka Percent Remoteness Index							
West Slope				East Slope				West Slope				East Slope			
	Upper	Middle	Lower	Lower	Middle	Upper		Upper	Middle	Lower	Lower	Middle	Upper		
West Slope	Upper	0	17.43	19.93	29.28	34.65	36.85	West Slope	Upper	0	0.52	0.57	0.83	0.92	0.94
	Middle		0	17.02	27.19	31.19	33.91		Middle		0	0.52	0.82	0.89	0.93
	Lower			0	20.61	28.98	31.07		Lower			0	0.69	0.86	0.89
East Slope	Lower				0	18.19	23.69	East Slope	Lower				0	0.76	0.88
	Middle					0	16.46		Middle					0	0.71
	Upper						0		Upper						
Similarity Ratio Distance								Chord Distance							
West Slope				East Slope				West Slope				East Slope			
	Upper	Middle	Lower	Lower	Middle	Upper		Upper	Middle	Lower	Lower	Middle	Upper		
West Slope	Upper	0	0.18	0.22	0.67	0.94	0.97	West Slope	Upper	0	0.44	0.50	0.83	1.28	1.35
	Middle		0	0.13	0.65	0.95	0.97		Middle		0	0.37	0.76	1.30	1.36
	Lower			0	0.55	0.91	0.95		Lower			0	0.60	1.23	1.32
East Slope	Lower				0	0.66	0.87	East Slope	Lower				0	0.98	1.24
	Middle					0	0.66		Middle					0	0.99
	Upper						0		Upper						0

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

APPENDIX 4. Matrices of Distance/Similarity Measures cont'd p. 10

Spring Herb Layer - plant cover comparison

Euclidean Distance								Geodesic Distance								
West Slope				East Slope				West Slope				East Slope				
	Upper	Middle	Lower	Lower	Middle	Upper		Upper	Middle	Lower	Lower	Middle	Upper			
West Slope	Upper	0	306.6	334.7	516.6	664.8	687.8	West Slope	Upper	0	0.44	0.51	0.86	1.39	1.48	
	Middle		0	263.9	550.0	730.3	750.8		Middle		0	0.37	0.78	1.42	1.49	
	Lower			0	453.8	656.3	686.6			Lower			0	0.61	1.32	1.44
East Slope	Lower				0	280.1	354.8	East Slope			Lower				0	1.03
	Middle					0	252.9		Middle						0	1.03
	Upper						0			Upper						0

Morisita (1959) Similarity Index								Morisita-Horn (1966) Similarity Index								
West Slope				East Slope				West Slope				East Slope				
	Upper	Middle	Lower	Lower	Middle	Upper		Upper	Middle	Lower	Lower	Middle	Upper			
West Slope	Upper	0	0.90	0.87	0.64	0.17	0.09	West Slope	Upper	0	0.89	0.87	0.64	0.17	0.09	
	Middle		0	0.93	0.66	0.13	0.07		Middle		0	0.93	0.66	0.13	0.07	
	Lower			0	0.78	0.22	0.12			Lower			0	0.78	0.22	0.12
East Slope	Lower				0	0.51	0.23	East Slope			Lower				0	0.51
	Middle					0	0.52		Middle						0	0.51
	Upper						0			Upper						0

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

APPENDIX 4. Matrices of Distance/Similarity Measures cont'd p. 11

Trees- species comparison - Percent Similarity

Sorensen Index of Similarity C_S							Jaccard Index of Similarity C_J								
West Slope				East Slope			West Slope				East Slope				
	Upper	Middle	Lower	Lower	Middle	Upper		Upper	Middle	Lower	Lower	Middle	Upper		
West Slope	Upper	0	81.8	63.6	40.0	40.0	42.1	West Slope	Upper	0	69.2	46.7	25.0	25.0	26.7
	Middle		0	60.0	55.6	55.6	47.1		Middle		0	42.9	38.5	38.5	19.0
	Lower			0	66.7	22.2	11.8			Lower			0	50.0	12.5
East Slope	Lower				0	37.5	26.7	East Slope	Lower					0	23.1
	Middle					0	66.7		Middle					0	50.0
	Upper						0			Upper					

Shrub and Sapling Layer -species comparisons- Percent Similarity

Sorensen Index of Similarity C_S							Jaccard Index of Similarity C_J									
West Slope				East Slope			West Slope				East Slope					
	Upper	Middle	Lower	Lower	Middle	Upper		Upper	Middle	Lower	Lower	Middle	Upper			
West Slope	Upper	0	80	62	47	34	25	West Slope	Upper	0	67	45	30	20	15	
	Middle		0	73	73	40	29		East Slope	Middle		0	58	38	25	17
	Lower			0	43	31	24			East Slope	Lower			0	28	19
East Slope	Lower				0	62	59	East Slope			Lower				0	45
	Middle					0	63		East Slope		Middle					0
	Upper						0			East Slope	Upper					

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

APPENDIX 4. Matrices of Distance/Similarity Measures cont'd p. 12

Spring Herb Layer - Percent Similarity

Sorensen Index of Similarity C _S							Jaccard Index of Similarity C _J									
West Slope				East Slope			West Slope				East Slope					
	Upper	Middle	Lower	Lower	Middle	Upper		Upper	Middle	Lower	Lower	Middle	Upper			
West Slope	Upper	0	57.9	48.6	27.8	37.2	25.6	West Slope	Upper	0	40.7	32.1	16.1	22.9	14.7	
	Middle		0	71.8	36.8	35.6	29.3		Middle		0	56.0	22.6	21.6	17.1	
	Lower			0	59.5	45.5	40.0			Lower			0	42.3	29.4	25
East Slope	Lower				0	55.8	35.9	East Slope			Lower				0	38.7
	Middle					0	52.1		Middle						0	35.3
	Upper						0			Upper						0

Note: Adjacent transects along the west to east gradient with the greatest distance/least similarity in bold.

Bibliography

- ALLABY, M. ed. 1992. The Concise Oxford Dictionary of Botany. Oxford Univ Pr. New York. 442p.
- BALTER, H. AND R.E. LOEB. 1983. Arboreal relationships on limestone and gneiss in northern New Jersey and southeastern New York. Bull. Torrey Bot. Club Vol.110 No.3:370-379.
- BARBOUR, M.G., J.H. BURK AND W.D. PITTS. 1987. Terrestrial Plant Ecology. 2nd ed. Benjamin/Cummings, Menlo Park. 634 p.
- BARTON, A.M. AND M.D. WALLENSTEIN. 1997. Effects of invasion of *Pinus virginiana* on soil properties in serpentine barrens in southeastern Pennsylvania. J.Torrey Bot. Soc. Vol.124 No.4: 297-305.
- BERKOW, R. Editor-in-Chief. 1992. The Merck Manual. Sixteenth Edition. Merck Research Laboratories, Rahway, NJ. 2844p.
- BOWEN, H.J.M . 1966. Trace Elements in Biochemistry. Academic Press, London and New York. 241p.
- BRIDGES, E M. 1987. Surveying Derelict Land. Claredon Pr, Oxford. 137 p.
- BROOKS, R.R. 1987. Serpentine and its Vegetation. A Multidisciplinary Approach. Ecology, Phytogeography & Physiology Series. Vol 1. T. R. Dudley, General Editor. Dioscorides Press, Portland. 454 p.
- BROWER, J.E., J.H. ZAR and C.N. VON ENDE. 1990. Field and Laboratory Methods for General Ecology. 3rd Ed. Wm. C. Brown Pblrs. Dubuque, IA. 237p.
- BUCKMAN, H.O. AND N.C. BRADY. 1969. The Nature and Properties of Soils. 7th ed. Macmillan, New York. 653 p.
- BUEGLER, R. AND S. PARISIO. 1982. A Comparative Flora of Staten Island. The Staten Island Institute of Arts and Sciences, Staten Island. 127 p.
- CLEMANTS, S. editor. 1999. New York Metropolitan Flora Woody Plant Workbook. Brooklyn Botanic Garden, Brooklyn. 350p.
- CNAL Cornell Nutrient Analysis Laboratories. 1999. Chemical analysis of soils report and explanation of analysis procedures.
- COBB, B. 1984. A Field Guide to Ferns and their related families. Houghton Mifflin, New York. 281 p.

COLLINS, B.R. AND K.H. ANDERSON. 1994. *Plant Communities of New Jersey. A Study of Landscape Diversity*. Rutgers University Pr, New Brunswick. 287 p.

COLLINS, B.S., L.S.FERRARA AND H.L. MORRO. 1984. Coincidence of spring herb distribution and flowering with tree bases in a New Jersey Piedmont forest. *Bull Torrey Bot Club* 111:301-306.

CRAUL, P.J. 1992. *Urban Soil in Landscape Design*. J Wiley, New York. 396 p.

DANN, K.T. 1988. *Traces on the Appalachians. A natural history of serpentine in eastern North America*. Rutgers Univ Pr, New Brunswick. 159p

DAVIS, W.T. see LENG, C.W.

DEL MORAL, R. 1982. Control of vegetation on contrasting substrates: Herb patterns on serpentine and sandstone. *American Journal of Botany* 69(2): 227-238

DIRR, M.A. 1990. *Manual of Woody Landscape Plants: Their Identification, Ornamental Characteristics, Culture, Propagation and Uses*. 4th ed. Stipes Publishing, Champaign, IL. 1007 p.

FORESTRY SUPPLIES INC. 2000-2001. *Catalog # 51*. Jackson, MS.

FOSTER, F.G. 1984. *Ferns to Know and Grow*. Timber Pr, Portland. 229 p.

GILBERT, O.L. AND P. ANDERSON. 1998. *Habitat Creation and Repair*. Oxford University Press, New York. 288p.

GLEASON, H.A. AND A. CRONQUIST. 1991. *Manual of Vascular Plants of Northeastern United States and Adjacent Canada*. 2nd Edition. The New York Botanical Garden, Bronx, NY. 910 p

GRAHAM, R.D., R.J. HANNAM, N.C. UREN, Eds. 1988. *Developments in Plant and Soil Sciences. Manganese in Soils and Plants*. Kluwer Acad. Pblrs, The Netherlands. 344p.

GREAT LAKES NATIONAL PROGRAM, WILD ONES __ NATURAL LANDSCAPERS, LTD. AND P. PRANCKEVICIUS. (1998). *Wild Ones Handbook: Aggressive Species* [WWW]. <http://www.epa.gov/glnpo/greenacres/wildones/wo29.htm> (January 3,2000)

GRELLER, A.M., R.E. CALHOUN and J.M. MANSKY. 1978. Grace Forest, a mixed mesophytic stand on Long Island, New York. *Bot.Gaz.* 139(4): 482-489

- GRELLER, A.M., D.C. LOCKE, V. KILANOWSKI AND E. LOTOWYCZ. 1990. Changes in vegetation composition and acidity between 1922 and 1985 at a site on the North Shore of Long Island, New York. *Bull. Torrey Bot. Club* 117: 450-458
- HAMILTON, W.R., A.R. WOOLLEY, A.C. BISHOP. 1974. *The Henry Holt Guide to Minerals, Rocks, and Fossils*. Originally published in Great Britain in 1974 by The Hamlyn Pblg. Group Ltd. First American Edition. 1989. Henry Holt and Company, Inc., NY. 320p.
- HART, R. 1980. Coexistence of weeds and restricted native plants of serpentine barrens in southeastern Pennsylvania. *Ecology* 61(3): 688-701
- HOLLICK, C.A. and N.L. BRITTON. 1930. Unpublished survey of the flora of Richmond County, New York. Located at the Staten Island Institute of Arts and Sciences, Staten Island, NY.
- HOUGH, M.Y. 1983. *New Jersey Wild Plants*. Harmony Pr, New Jersey. 414 p.
- ISACHSEN, Y.W. 1980. *Continental Collisions and Ancient Volcanoes. The Geology of Southeastern New York*. New York State Geological Survey. Educational Leaflet 24. 15p.
- KERSHNER, B. 1998. *Secret Places of Staten Island*. Kendall/Hunt Publishing, Dubuque, IO. 148 p.
- LAMOTTE CHEMICAL PRODUCTS CO. RESEARCH DEPARTMENT. 1978. *The LaMotte Soil Handbook*. LaMotte Chemical Products Co, Chesterton, MD. 59 p.
- LANDMARK PRESERVATION COMMISSION OF THE CITY OF NEW YORK. 1985. *New York City Farm Colony-Seaview Hospital Historic District Designation Report*. (Designation List 177 LP-1408)
- LENG, C.W. 1896. *Map of Staten Island with Ye Olde Names and Nicknames* by Wm. T. Davis. Staten Island Institute of Arts and Sciences, Staten Island (1968).
- LEPPIG, G. (1997) *North Coast Chapter-CNPS: Rarity and endemism in the California flora*.
<http://www.northcoast.com/~cnps/artf97a.htm>. Accessed April 9,2000.
- LIKENS, G.E. and F.H. BORMANN. 1995. *Biogeochemistry of a Forested Ecosystem*. 2nd Ed. Springer-Verlag. New York. 159p.
- LOFASO, D. editor. 1993. *20 Years of Green (A Protectors of Pine Oak Woods Commemorative Journal)*. Tanner-Durso Publishing, New York. 83 p.

- LOUNAMAA, J. 1956. Suomal. Eläin- ja kasvit. Seur. Van. Julk 29, no. 4.
- MAGURRAN, A.E. 1988. Ecological Diversity and Its Measurement. Princeton Univ Pr. Princeton, NJ. 179 p.
- MILTON, J.S. 1999. Statistical Methods in the Biological and Health Services. 3rd Edition. WCB/McGraw-Hill, New York. 588p
- MITTELBAACH, M. AND M. CREWDSON. 1997. Wild New York. Nevaumont Pblg., New York. 196p.
- MUELLER, R.F. (1999). Forests of the Central Appalachians Project- link- Glade Creek/New River Gorge [WWW]. <http://www.spies.com/~gus/forests/glades.htm>. (January 3 and March 1, 2000)
- NYFA NEW YORK FLORA ASSOCIATION OF THE NEW YORK STATE MUSEUM INSTITUTE. Edition 1, 1990. Atlas of New York State Flora. Albany. 496 p.
- OHMANN, L.F. AND M.F. BUELL. 1968. Forest vegetation of the New Jersey Highlands. Bull. Torrey Bot. Club Vol. 95, No. 3: 287-298
- PADDOCK, S. (1998). NPCR Report 1097: The Ecology and Geology of the Mississippi River Gorge. [FRENET]. <http://freenet.msp.mn.us/org/npcr/reports/npcr1097.htm> (January 3, 2000)
- PARISIO, S. 1982. Uptake by plants of calcium, magnesium and nickel on a serpentine soil in Staten Island, New York. Proceedings - Staten Island Institute of Arts and Sciences. Vol. 31 Nos. 2, 3: 70-76
- PETERSON, R.T. AND M. MCKENNY. 1968. A Field Guide to Wildflowers of Northeastern and Northcentral North America. Houghton Mifflin, Boston. 420 p.
- PIELOU, E.C. 1984. The Interpretation of Ecological Data. John Wiley & Sons, New York. 263p.
- PLASTER, E.J. 1985. Soil Science and Management. Delmar Publishers, Albany. 454 p.
- PROCTOR, J. 1969. Studies in Serpentine Plant Evolution. D. Phil. Thesis, Oxford Univ.
- PROCTOR, J. 1971. The plant ecology of serpentine. III. The influence of a high calcium/magnesium ratio and high nickel and chromium levels in some British and Swedish serpentine soils. J. Ecol., 59: 827-842

- REED, C.F. 1986. Floras of Serpentine Formations in Eastern North America, with descriptions of geomorphology and minerology of the formations. Reed Herbarium, Baltimore. 858 p.
- RENDIG, V.V. AND H.M. TAYLOR. 1989. Principles of Soil-Plant Interrelationships. McGraw-Hill, New York. 275 p.
- ROBERTS, D.C. 1996. A Field Guide to Geology. Eastern North America. Houghton Mifflin, New York. 402 p.
- ROBICHAUD, B. AND M.F. BUELL. 1973. Vegetation of New Jersey. A study of Landscape Diversity. Rutgers Univ Pr, New Brunswick. 340 p.
- ROBINSON, F. (1998). Plant Friends of the Black Walnut. [WWW]. <http://www.efn.org/~bsharoy/bwtol.html> (March 1,2000)
- ROBINSON, G.R., M.E. YURLINA AND S.N. HANDEL. 1994. A century of change in Staten Island flora: Ecological correlates of species losses and invasions. Bull. Torrey Bot.Club 121(2): 119-129
- SAS INSTITUTE INC. SAS PC Version 6.12 (1989,1993)
- SEYMOUR, F.C. 1993. The Flora of New England. 2nd ed. Privately Printed. 611 p.
- SIRKIN, L. 1999. The Hudson-Champlain lobe of the Laurentide ice sheet and the moraines of western Long Island. In: Long Island Geologists Conference "Geology of Long Island and Metropolitan New York". 1999 Apr 24. State University of New York at Stony Brook.
- SMALL, J.K. 1975. Ferns of the Vicinity of New York. Dover, New York. 285 p.
- SOKAL, R.R. AND F.J. ROHLF. 1995. Biometry. 3rd Edition. W.H.Freeman and Co., New York. 887p.
- SSDS SOIL SURVEY DIVISION STAFF. 1993. Soil Survey Manual. USDA Handbook No.18. Issued October, 1962 and revised October, 1993. United States Department of Agriculture, Washington, DC. 437 p.
- SPOSITO, G. 1989. The Chemistry of Soils. Oxford Univ Pr., New York. 277 p.
- USDA Forestry Service. Ecosystem Divisions. http://www.fs.fed.us/colorimagemap/ecoreg1_divisions.html (July 25, 2001)

- U.S. GEOLOGICAL SURVEY. 1981. Arthur Kill Quadrangle, NY-NJ. U.S. Geol. Survey, Washington, DC.
- UVA, R.H., J.C. NEAL AND J.M. DI TOMASO. 1997. Weeds of the Northeast. Cornell Univ Pr, Ithaca. 397 p.
- WHERRY, E.T. 1948. Wild Flower Guide. Northeastern and Midland United States. Doubleday, Garden City. 202 p.
- WHITTAKER, R.H. 1975. Communities and Ecosystems. 2nd ed. Macmillan, New York. 385p.
- WIJESUNDARA, D.S.A. 1998. Phytosociological Studies of Floyd Bennett Field, Brooklyn, New York. Ph.D.thesis, unpublished.
- WISTENDAHL, W.A. 1958. The flood plain of the Raritan River. Ecological Monographs 28(2): 129-153
- WYMAN, D. 1971. Gardening Encyclopedia. Macmillan, New York. 1222 p.