Order Number 8809981

Anchoring of thin colluvium on hillslopes in Cincinnati by roots of sugar maple and white ash

Riestenberg, Mary Margaret, Ph.D.

University of Cincinnati, 1987

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark __√__.

1. Glossy photographs or pages __√__
2. Colored illustrations, paper or print __√__
3. Photographs with dark background __√__
4. Illustrations are poor copy __√__
5. Pages with black marks, not original copy __√__
6. Print shows through as there is text on both sides of page ______
7. Indistinct, broken or small print on several pages __√__
8. Print exceeds margin requirements ______
9. Tightly bound copy with print lost in spine ______
10. Computer printout pages with indistinct print ______
11. Page(s) __________ lacking when material received, and not available from school or author.
12. Page(s) ____*____ seem to be missing in numbering only as text follows.
13. Two pages numbered ______. Text follows.
14. Curling and wrinkled pages __√__
15. Dissertation contains pages with print at a slant, filmed as received __√__
16. Other ______

*341, 353, 354

UMI

ANCHORING OF THIN COLLUVIUM ON HILLSLOPES IN CINCINNATI BY ROOTS OF SUGAR MAPLE AND WHITE ASH

A dissertation submitted to the

Division of Graduate Studies and Research
of the University of Cincinnati

in partial fulfillment of the
requirements of the degree of

DOCTOR OF PHILOSOPHY

in the Department of Geology
of the College of Arts and Sciences

1987

by

Mary M. Riestenberg

B.S., College of Mt. St. Joseph, 1968

M.S., University of Cincinnati, 1981

UNIVERSITY OF CINCINNATI

October 8 *19* 87

I hereby recommend that the thesis prepared under my supervision by Mary M. Riestenberg

entitled Anchoring of Thin Colluvium on Hillslopes in Cincinnati by Roots of Sugar Maple and White Ash

be accepted as fulfilling this part of the requirements for the degree of Doctor of Philosophy

Approved by:

David B. Nash

Susan A. Brunford

[signature]

ABSTRACT

Roots of white ash have a better configuration than roots of sugar maple for anchoring shallow colluvium against landsliding on hillslopes along the Ohio River and its tributaries in southwestern Ohio. The landslides are in a shallow layer of colluvium, about one meter thick, overlying shale and limestone bedrock. The sliding hillsides range in slope angle from 16 to 36 degrees and the roots which penetrate shear surfaces are anchored in the weathered bedrock and help to hold landmasses in place. The hillsides are covered by a mesophytic forest, locally known as a ravine community, dominated by white ash, sugar maple and sweet buckeye. Sugar maple is the most common species on the landslides; its roots do not penetrate the soil as deeply as the roots of the white ash.

Incorporation of measurements of pull-out resistance and root morphology of both sugar maple and white ash into stability analyses indicates that for slopes just above critical thickness, here defined as the thickness yielding a factor of safety of one for slopes of 30°, and representative soil strength parameters both sugar maple and white ash increase stability. The roots of a small white ash will increase the factor o. safety in colluvium up to 1m thick, but roots of a sugar maple of comparable size do not penetrate to this depth.

Slope stability modeling suggests that small white ash trees may be widely spaced and still stabilie a hillslope. For example, stability is critical if white ash are spaced up to 7m apart on a 30° slope underlain by 0.43m of colluvium.

Acknowledgments

I am grateful to the many people who have assisted me with this research. First, I would like to thank my advisory committee, Drs. David B. Nash, Susan A. Dunford, and Arvid M. Johnson, for their continued support and encouragement. Drs. Andrew Bodocsi and Michael Baseheart of the University of Cincinnati, Dr. Tien Wu of the Ohio State University, and Dr. Donald Gray of the University of Michigan gave valuable advice concerning soil mechanics and strength of materials. Tom Smith, horticulturist at the Spring Grove Cemetery, Steve Sandfort, Cincinnati urban forester, and George Cummings of the Soil Conservation Service helped with selection of species and sites for the study. The combined expertise of the above persons in the fields of geology, biology, and engineering greatly enhanced the scope and value of this interdisciplinary project.

My colleagues in the Geology department, friends outside the department, and devoted relatives helped me in all aspects of the project. Daniel Joyce, electronics technician in the department, designed the field equipment and spent many hours in the field assisting me with its operation. Allan Taylor, Patrick Fox, Jim Beaujon, Bill Haneberg, and Kevin O'Bryan helped with the hand excavations of the maples and ash. Many persons helped with measuring the resistance of roots to pull-out: Kitty Riley; Ron, David, Beth and Ted Riestenberg; Dottie Kennedy; Joan Brogan; Mary Garner; Amy Lamborg and Connie Bertka. Others who helped with various aspects of the field study were Virginia Pfaff, George Losonsky, Robert Fleming, Onder Gokce, Scott Brockman, Ken Riestenberg and Ed Riley. The computer programs used to reduce the field data were written by David Nash and Ken Cruikshank of the Geology department, and Roger Stuebing of the Institute for Policy Research of the University of Cincinnati. Many figures in the dissertation have been expertly drafted by Lyla Messick of the Department of Geology.

I am grateful to the Sisters of Charity and to the administrators of Spring Grove Cemetery for use of their property for the research.

The research was generously funded by the Hillside Trust, Sigma Xi, and the Department of Geology of the University of Cincinnati.

I am most grateful to my family for unwavering support during my years in graduate school. I dedicate this mountain of work to you.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Figure Page

TABLE IN TEXT

Foreword

Cincinnati is a city of hills, a product of the Ohio River and its tributaries. Dissection of uplands created both steep and gentle hillsides composed of residual soils, and in place with quaternary glacial deposits underlain by Ordovician shale and limestone. In their mature state, these southwestern Ohio hillsides are covered by mixed forests of broad-leafed, deciduous trees.

Landsliding is common on the hillsides of Cincinnati, and trees can help to stabilize hillsides throughout the area, but a number of unanswered questions give rise to this study. First, do tree roots help to stabilize hillsides by reinforcing soil or by acting as anchors? Second, what effect does root configuration have on slope stability? Third, can the resistance contributed by a single tree be quantified? Three sets of studies were conducted in order to answer these questions. Roots intersecting landslide shear surfaces were observed and described, root systems of two tree species were excavated and described, and the pull-out resistance of some roots was measured.

This dissertation contains some answers to the questions posed above. Chapter One reviews the forest ecology of some Cincinnati hillsides and outlines criteria for the selection of tree species used in this study. Chapter Two describes in detail the morphology and distribution of some tree roots in the field. Chapter Three describes deformation of tree roots associated with landslide shear surfaces and Chapter Four reports the pull-out resistance of roots. Finally, a mechanical model based on these observations is proposed in Chapter Five.

CHAPTER ONE

A Study of Species of Trees Dominating the Ravine Area of Unstable Hillslopes in Cincinnati and Their Involvement in Slope Failures

Introduction

Examination of several landslides in forested hillslopes in Cincinnati suggests that trees of different species have dissimilar abilities to increase soil strength and stabilize hillslopes. In hillslopes, part of which have failed within the past ten to twenty years, some species of trees tend to occur on failed soil mats, whereas others tend to occur on anchored soil masses adjacent to the failure. A study of species associated with in-place and failed masses on a forested ridge at the confluence of the Ohio River and Rapid Run Creek in western Cincinnati illustrates differences in involvement of species of trees with landslides (Figure 1).

The ridge, underlain by colluvial soil, trends east-west and has steep sides which average 35 degrees in slope. Its hillsides have failed on many occasions in the past as evidenced by their undulating, hummocky appearance. The south-facing hillside supports forest communities of two ages, an old forest on the swell or in-place areas, and a young forest on the swale or failed areas. The old forest is dominated by white and chinquapin oaks. White ash, sugar maple, buckeye, and hickory occur in descending order of frequency. The young forest is composed, in descending order of dominance, of sugar maple, buckeye, and ash, with an understorey of sugar maple, ash, elm, black cherry, and buckeye.

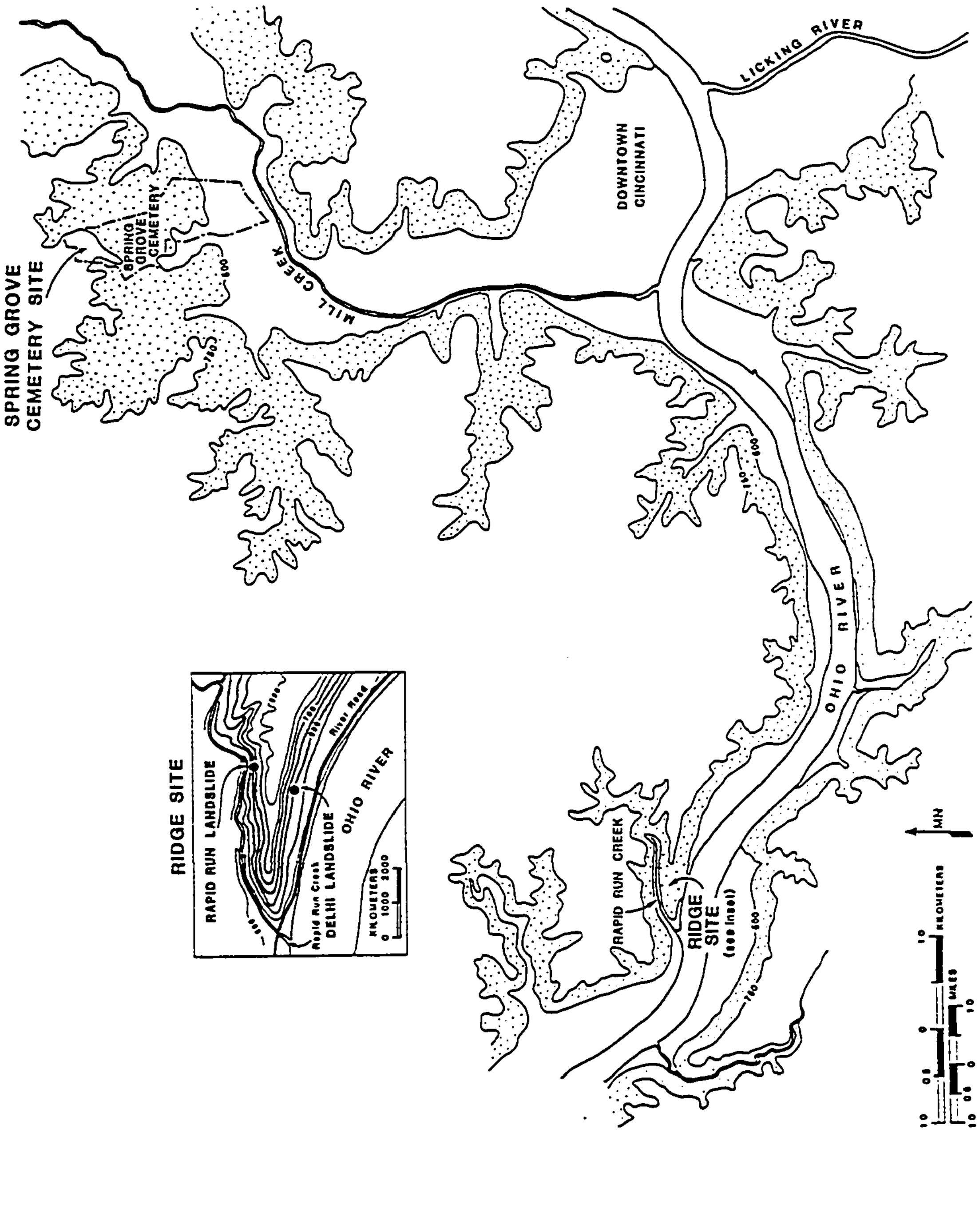
Figure 1

Location of the two study sites and river bluffs.

The bluffs along the Ohio River and its tributaries are forested and contain numerous shallow, planar landslides. The failures occur at the interface of the colluvium and the flat-lying bedrock. Tree roots penetrate the failure surfaces and are involved in the shallow landslides.

The ridge near the Ohio River is the site of both the Delhi landslide and the Rapid Run landslide. The wooded hillsides of the ridge are divided into two ecological areas, the upslope bluff area, and the ravine area. The ravine area, which slopes more gently than the bluff area, is especially prone to landsliding and is the area analyzed in this study. The ravine area on either face of the ridge contains numerous landslide scars, as well as progressing landslides. The forest community of the ravine area is co-dominated by sugar maple, white ash, and buckeye; the composition of the community is insensitive to slope aspect.

The Spring Grove site is on a gently sloping, upland part of Cincinnati. The site is underlain by the same type of soil as is the ridge described above, and its forest is dominated by sugar maple and white ash.


SPRING GROVE CEMETERY SITE
SPRING GROVE CEMETERY
MILL CREEK
DOWNTOWN CINCINNATI
LICKING RIVER
OHIO RIVER
RAPID RUN CREEK
RIDGE SITE (see inset)
RIDGE SITE
RAPID RUN LANDSLIDE
DELHI LANDSLIDE
Rapid Run Creek
River Road
OHIO RIVER
KILOMETERS
0 1000 2000
MN

The north-facing slope of the ridge supports sugar maple, ash, and buckeye as co-dominants on its in-place areas, but studies of bank failures along Rapid Run Creek suggest that these species did not co-dominate failed soil blocks before landsliding. The failed blocks are dominated by sugar maple, and other species occurr as minor constituents of the community. The in-place scarp areas are bordered by hickory, box elder, and sugar maple trees, and less commonly by elm, ironwood, and buckeye trees (Table 1).

A detailed study of the species associated with the Rapid Run landslide (Figure 2) reinforces the notion that species may be associated with failed and anchored soil masses. The landslide, 45m long, 22m wide, and 0.5m thick failed in March, 1980. The failed area, which had been selectively cut eight years before the landslide developed, supported a young stand comprised of 85% sugar maple, 6% white ash, 6% ironwood, and 3% buckeye. The failed area was surrounded by forests of approximately 50% sugar maple, 25% buckeye, and 15% white ash, with basswood, ironwood, elm, hackberry, walnut, hickory, and pawpaw as minor members of the forest community. In 1987, the scar is vegetated by sugar maple and cottonwood seedlings.

These observations pose the question of whether there is a correlation between tree species and slope failure.

Also, the density of trees on the failed area was 109 per hectare, as compared with 176 to 259 per hectare on the stable part of the hillslope (Riestenberg and Sovonick-Dunford, 1983).

This study raises questions about how closely spaced trees must be to hold the soil in place.

TABLE ONE

Observations of Tree Species Involved in Landsliding

Numbers following tree name are diameters in centimeters

A. Ridge site: steep, south-facing slope bordering the Ohio River in western Cincinnati, soil derived from bedrock

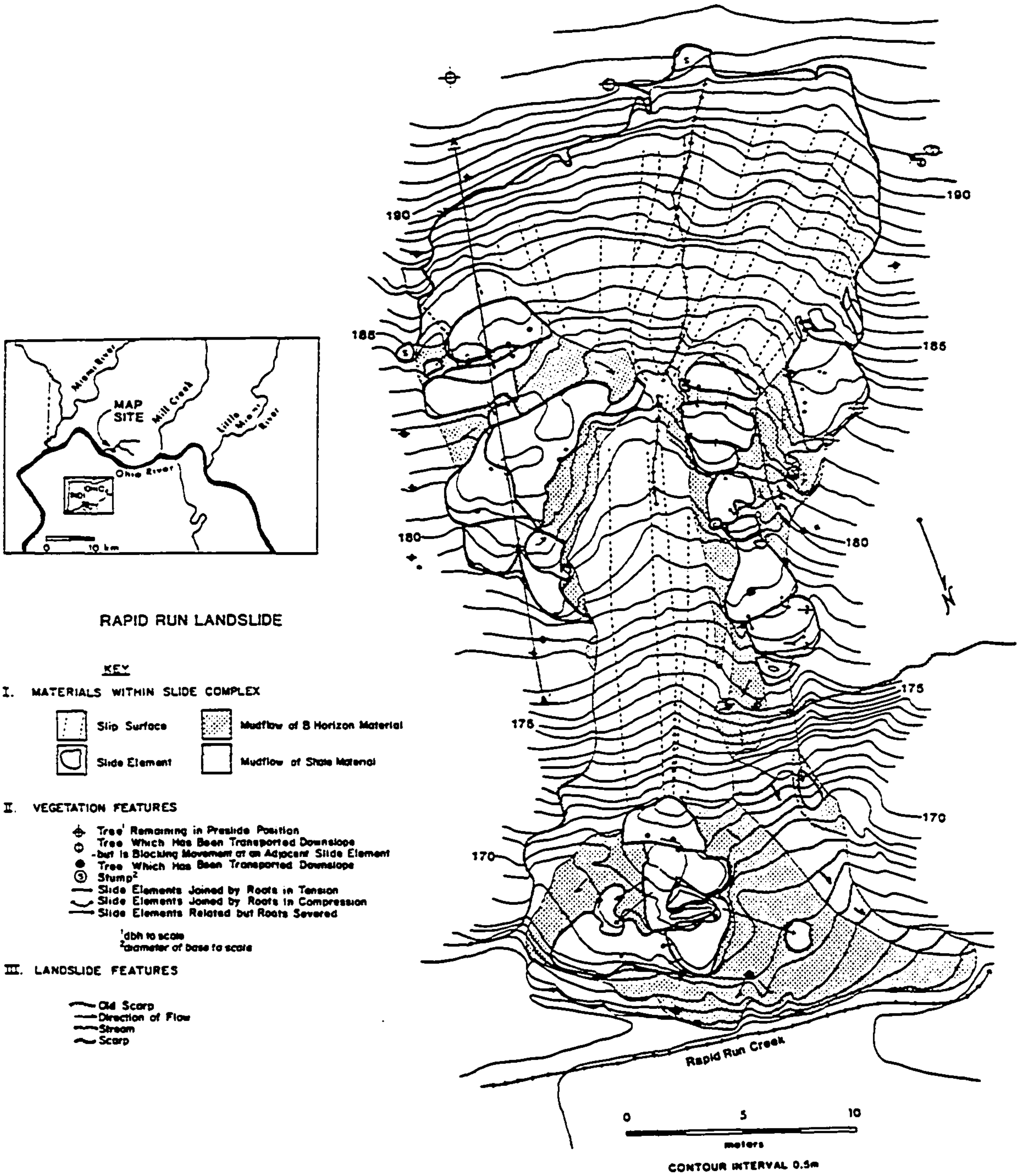
1. swell areas, old forest
   dominated by large oaks (white and chinquapin), with white ash, sugar maple, buckeye, and hickory
2. swale areas, young forest
   a. 8cm dbh (diameter at breast height) or less
      in descending dominance: ash, elm, black cherry, buckeye
      saplings: oak, sugar maple, redbud
   b. 8cm dbh or more
      in descending dominance: sugar maple, buckeye, ash

B. Ridge site: steep, north-facing slope bordering Rapid Run creek in western Cincinnati, soil derived from bedrock

1. bank failures
   a. on $3.24m^2$ block: 1 sugar maple, 15cm diameter
   b. on $0.81m^2$ block: chinquapin oak (7.6cm diam) and elm (10cm diam)
   c. $18m^2$ bank failure
      1) failed trees (5cm diam or greater)
         box elder 11.4, 19, 7.6, 5
         sugar maple 24, 5, 7.6, 7.6, 5, 12.7, 7.6, 7.6, 8.9, 12.7
         elm 5
         buckeye 5
      2) saplings on failed block
         4 sugar maples, 1 ash
      3) in-place trees at head scarp
         hickory 77, 77, 77.5, 37, 37
         ironwood 32
         sycamore 58
      4) on in-place mat ($5.4m^2$ in area)
         box elder 5,2,5,4,3
         sugar maple 2,3,2
         elm 7, 2
   d. $22.5m^2$ bank failure
      1) failed mat, $7.2m^2$
         Sugar maple 38.5, 8.9
      2) failed mat, $0.81m^2$
         buckeye 7.6
      3) $9m^2$ failed mat
         sugar maple 21.6, 7.6, 5
         elm 15.2
2. Rapid Run landslide, toe area, tree diameters range from 10 to 20cm
   2 ash
   6 sugar maple
   4 basswood
   3 buckeye

Figure 2

The Rapid Run landslide. The soil mat which failed supported a forest community which was dominated by a nearly pure stand of sugar maple trees. The surrounding stable soil supports a mixed stand dominated by sugar maple, white ash, and buckeye trees. (Mapped by M. Riestenberg, S. Brockman, and T. Lion, 1980)



190
185
180
175
170
MAP SITE
Mill Creek
Miami River
Little Miami River
Ohio River
0 10 km
RAPID RUN LANDSLIDE
KEY
I. MATERIALS WITHIN SLIDE COMPLEX
Slip Surface
Slide Element
Mudflow of B Horizon Material
Mudflow of Shale Material
II. VEGETATION FEATURES
Tree[1] Remaining in Preslide Position
Tree Which Has Been Transported Downslope -but is Blocking Movement of an Adjacent Slide Element
Tree Which Has Been Transported Downslope
Stump[2]
Slide Elements Joined by Roots in Tension
Slide Elements Joined by Roots in Compression
Slide Elements Related but Roots Severed
[1]dbh to scale
[2]diameter of base to scale
III. LANDSLIDE FEATURES
Old Scarp
Direction of Flow
Stream
Scarp
N
Rapid Run Creek
0 5 10
meters
CONTOUR INTERVAL 0.5m

If there is a correlation between tree species and tree spacing with slope stability and instability, do different types of root configurations of different species significantly affect the ability of trees to stabilize a slope?

These are the kinds of questions which will be addressed in this research. Sugar maple and white ash were selected for this study because the trees are native to the forests within southwestern Ohio, so the results of the study should be broadly applicable. The trees are canopy trees on local, oversteepened hillslopes involved in shallow landsliding, so the species could be used in horticultural programs to stabilize local hillsides. Also, sugar maple and white ash have strongly contrasting, nearly end-member, root habits.

Forest Ecology of Landslide Areas in Southwestern Ohio

Southwestern Ohio is within an transitional ecological area. It is bounded by glacial plains to the north and west, the Knobs area to the south, and the Appalachian Plateau to the east (Braun, 1916). Because glaciation has been so recent, the region has not yet become ecologically stabilized. The glacial disturbance and the proximity to the physiographic borders complicates the forest patterns. The area is characterized by diversified vegetational stands, due to overlapping and migration of species (Braun, 1950).

The forest ecological area around Cincinnati, called the Western Mesophytic Forest, supports a patchy distribution of tracts of mature broadleaf, deciduous forests partly as a result of diverse topography. The local landscapes grade from flat uplands to steep slopes or bluffs with gently sloping bases along major streams.

The patchy pattern of mature forests in Cincinnati reflects the varying ecological pressures within the area. Because the vegetational patterns are controlled by the topographic and edaphic pressures, generalizations may be made about mature forests growing within well-defined physiographic regions of the city. Because no two species have the same physiological requirements, different combinations of slope, aspect, and hydrologic regimes will result in ecologically compatible mixtures of species, which are referred to as communities.

This study will focus on the plant communities which naturally inhabit the oversteepened bluffs bordering the Ohio River, such as the ridge between Rapid Run Creek and the Ohio River (Figure 1). Most of the shallow landsliding in Cincinnati occurs in the bluff area (Fleming *et al.*, 1981). Figure 1 shows landslide areas along bluffs in the western part of Cincinnati. In this area, and the related bluff area in eastern Cincinnati, some landslides occur in colluvium of the steep, upper parts of the bluff but many occur on the moderately steep middle to lower parts of the bluff. Deeper landslides lie dormant in most places along the base of the bluff.

The bluffs rise 100 to 140 meters above the Ohio River, with a gently sloping base and steep midsection. They are underlain by the Kope and Fairview Formations, nearly flat-lying, Ordovician, biogenic limestone interbedded with calcareous shale. The gently sloping base of the bluff is underlain by the Kope Formation, and supports a mesophytic forest community. The upper part of the bluff is steeply sloping, underlain by the Fairview Formation, and supports xerophytic communities.

The Fairview Formation consists of shale interbedded with limestone in a 3:1 ratio, with the shale units ranging in thickness from a centimeter to one-half meter. The Kope Formation, underlying the Fairview, has a 4:1 thickness ratio of shale to limestone, with the shale units ranging up to two meters in thickness (Ford, 1967). The shale is composed of illite, chlorite, vermiculite, calcite and quartz (Bassarab and Huff, 1969).

The colluvium derived from the Kope and Fairview formations is a flaggy, silty, clay loam, and is named the Eden soil by the USDA Soil Conservation Service (Lerch *et al.* 1980)(Appendix A). The soil is poorly suited for most uses due to its low permeability and low water capacity, but has moderate potential as a woodland substrate.

On the south-facing, upland parts of the bluff, white oak (*Quercus alba* L.) dominates the forest community along with the sub-dominant honey locust (*Robinia pseudo-acacia*), hackberry (*Celtis laevigata* Willd.), and blue ash (*Fraxinus quadrangulata*), with sugar maple (*Acer saccharum* Marsh.) as an important member of the understorey. On the north-facing bluffs the sweet buckeye (*Aesculus octandra* Marsh.), basswood (*Tilia* sp.), wild black cherry (*Prunus serotina* Ehrh.), walnut (*Juglans* sp.) and red oak (*Quercus borealis* f. var. *maxima* (Marsh.) Ashe) are co-dominants with sugar maple a secondary species.

The lower part of the bluff, termed "ravine" by E. L. Braun (1935), is dominanted by sugar maple, white ash (*Fraxinus americana* L.), white elm (*Ulmus americana* L.), and sweet buckeye. This community type persists despite continual undercutting and slumping of banks. Unlike most forest communities, it is insensitive to slope aspect.

The study conducted within the ravine area formed by Rapid Run Creek showed that sugar maple, buckeye, and white ash dominate the area both in numbers and in biomass per community (Riestenberg and Sovonick-Dunford, 1983). White elm occurs as a member of the understorey. Sugar maple dominates in patchy areas thinned by selective logging because it tolerates shade and dominates the understorey. Once areas are opened by logging, the sugar maple is released and begins to grow rapidly into canopy-sized trees.

The observations of failed areas within the ravine area of the ridge as described above show that, of the three species dominating the ravine portion of the bluffs, the sugar maple is most commonly associated with the failed soil masses. For this reason, sugar maple was selected for detailed study.

Dominance of sugar maple on failed blocks may partly be due to its dominance within the local forests. Sugar maple is common in the understorey of forests of the Ohio River bluffs, and quickly occupies scars of landslides as observed in the Rapid Run landslide. However, its root system may contribute less to the strength of the soil than the root systems of the species of trees which remain anchored to the stable parts of the hillslopes. Sugar maple tends to be shallow-rooted, so it will not anchor soil to the bedrock as well as some other trees, and thus it might contribute to high landslide potential.

Of the two remaining species, white ash was chosen as the species to contrast with sugar maple, because it commonly is associated with the stable parts of the hillside, even occurring within the same microenvironment as the maple. A closer look at the roots of the sugar maple and white ash, where they were exposed by stream erosion shows that the roots of the two trees are morphologicaly distinct. Roots of the sugar maple are highly branched and the roots of the white ash are massive and poorly branched (Figure 3). The two species may grow in a range of environments, from uplands to ravines, and tolerate shade, a characteristic of canopy trees. The two species have wind-disseminated seeds, and so they can invade areas distant from the seed-bearing tree, and are easy to plant and raise locally.

Figure 3

Roots of sugar maple and white ash trees. The sugar maple, which is growing upslope from the white ash has numerous, spindly roots in contrast with the few, massive roots of the ash tree. Field observations reveal that the maple is more commonly associated with failed soil than the ash, which may be observed to remain at landslide scarps on the in-place soil.

CHAPTER TWO

The Distribution of the Roots of Sugar Maple and White Ash

Introduction

Many methods have been devised to study shapes of roots, including use of radioactive tracers, dyes, auger samples and the encasement of growing plants in glass containers (Bohm, 1979). The most reliable method for describing plant roots is to study an entire root system exposed by hand-excavation. This method dates back to the early 1700's and was the only means used to study roots until the second decade of this century. The introduction of plant fertilizers in the late 1800's brought with it a demand for for detailed studies of the roots of crop plants. Weaver (1926), a pioneer in root studies, devised the first sampling methods for analysis of the roots of crop plants. He was the first investigator to utilize excavation faces for analysis of root distribution with subsequent washing of the roots for analysis of root morphology.

The method one selects for describing tree roots depends on the time available, and the degree of accuracy needed. The best method for describing the morphology of tree roots especially as associated with soil texture is by complete excavation, which still remains the only method of choice in dry, sandy or extremely rocky soil. More than one specimen must be excavated at a site to assure that the distributional trends described by the full exposure of the roots are representative of a species, but complete excavations of trees at a study site are time- and labor-consuming and highly destructive. Sampling methods may be used to assure that the distributions are representative for the species (Bohm, 1979).

The lack of information about tree roots is partly due to difficulties encountered in exposing the roots, but it is also due to the numerous parameters affecting the character of roots. The root distribution and morphology within a species are controlled by a combination of genetic and environmental parameters. Inherited traits generally are affected by a bewildering combination of environmental pressures, such as soil texture, physical obstructions to elongation, intra- and interspecific competition, aeration, nutrition, light availability, temperature, frost action, moisture availability, and slope.

Most studies of root distribution and morphology have been limited to crop plants. Few detailed descriptions of tree roots exist in the current literature, although descriptions of the morphology of root segments exist in texts (Kramer and Kolowski, 1979). The distribution of the roots of sugar maple and white ash have been described in general by the study of exposures at trench faces (Biswell, 1935; Scully, 1942; and Kochendorfer,1973), but there have been no detailed studies of the distribution and morphology of the roots of the two species.

Selection of Study Sites

Two study sites with similar environmental conditions were selected, so that the morphological and distributional characteristics of the roots of the two species with respect to that environment might be described. The sites are underlain by the Eden Series soil, which is derived from bedrock (Lerch et al., 1980).

The Delhi site (Figure 1) is on the south side of the steep, wooded ridge between Rapid Run Creek and the Ohio River. The Delhi site was selected because it has been extensively studied by others, and supports the ravine-plant community.

The Spring Grove site (Figure 1) is a gently sloping woodlot adjacent to the Spring Grove cemetery in Cincinnati. The woodlot, a mature forest stand dominated by sugar maple and white ash, is accessible to truck-mounted excavating devices needed for root sampling.

Soil profiles were measured at both sites. They were so nearly the same that the profiles were combined (Figure 4). Both soils belong to the Eden series (Appendix A). The soil at both sites is shallow (0.5m to 2.0m in thickness) and fine-textured. It grades from a clay loam to clay with depth, and is mottled from water-logging due to poor drainage. The clayey horizon is characterized by well-defined structure, with striations between the peds, indicating shrink-swell movement with changes in water content. Limestone float is common within this horizon. Roots are mainly restricted to the zone above the bedrock (Lerch *et al.*, 1980).

Field Methods

It was decided to use a combination of excavation and sampling methods for the description of roots to make optimal use of both sites. Three trees were hand-excavated, one at the Delhi site, and two at the Spring Grove site. The results were compared with those of eleven trees at Spring Grove whose roots were analyzed by sampling a conical soil wall exposed about the root ball to assure that the excavated roots were representative for the species.

Figure 4

Soil profile for the Spring Grove and Delhi sites. The characteristics of the soil at both sites are described in the profile. The soil, called an Eden series soil, grades from a silty clay loam to a clay with depth. The brown to yellow-brown soil is mottled suggesting that it is sometimes water-logged. The strong structure indicates that it is a mature soil.

This soil, called colluvium when associated with steep hillslopes, is involved in the shallow landsliding on the bluffs along the Ohio River and its tributaries in the Cincinnati area.

SOIL PROFILE FOR DELHI AND SPRING GROVE SITES

Horizon	Depth (cm)	Color Mottles	Color Moist	Texture	Structure	Consistence Moist	Consistence Wet	Boundary	Clay films
A1	0 - 6		7.5 YR 3/2 dark brown	silty, clay loam	moderate, fine, granular	friable	slightly sticky, plastic	abrupt	
B1t	6-19	10 YR 5/4 dark yellowish brown few, fine, faint	10 YR 5/3 brown	silty clay	moderate, medium, sub-angular, blocky	firm	sticky, plastic	clear	
B22t	19 - 47	7.5 YR 3/2 dark brown, common, medium, distinct	10 YR 5/4 yellowish brown	silty clay	medium, strong, sub-angular, blocky	firm	sticky, plastic	clear	
B24t	47 - 70	10 YR 6/4 light, yellowish brown few, fine, faint	10 YR 4/4 dark, yellowish brown	clay	medium, strong, sub-angular, blocky	firm	sticky, plastic	clear	yes
B3	70 - 80	2.5 YR 3/6 dark red, many, fine, distinct	7.5 YR 6/4 light brown	clay	strong, moderate, sub-angular, blocky	firm	very sticky, very plastic	clear	yes

Morphology and Distribution of the Roots of Sugar Maple

Sugar Maple at the Delhi Site

The Delhi site is the south-facing upper-ravine area of a ridge, dominated by white ash, sugar maple, and white oak.

An understorey-sized sugar maple chosen for excavation was growing two to three meters from canopy trees within an area in which the soil had been thinned to 0.5m by landsliding. The tree, designated maple #1, had a height of 6m, diameter at breast height (dbh) of 6cm, and a crown width of four meters.

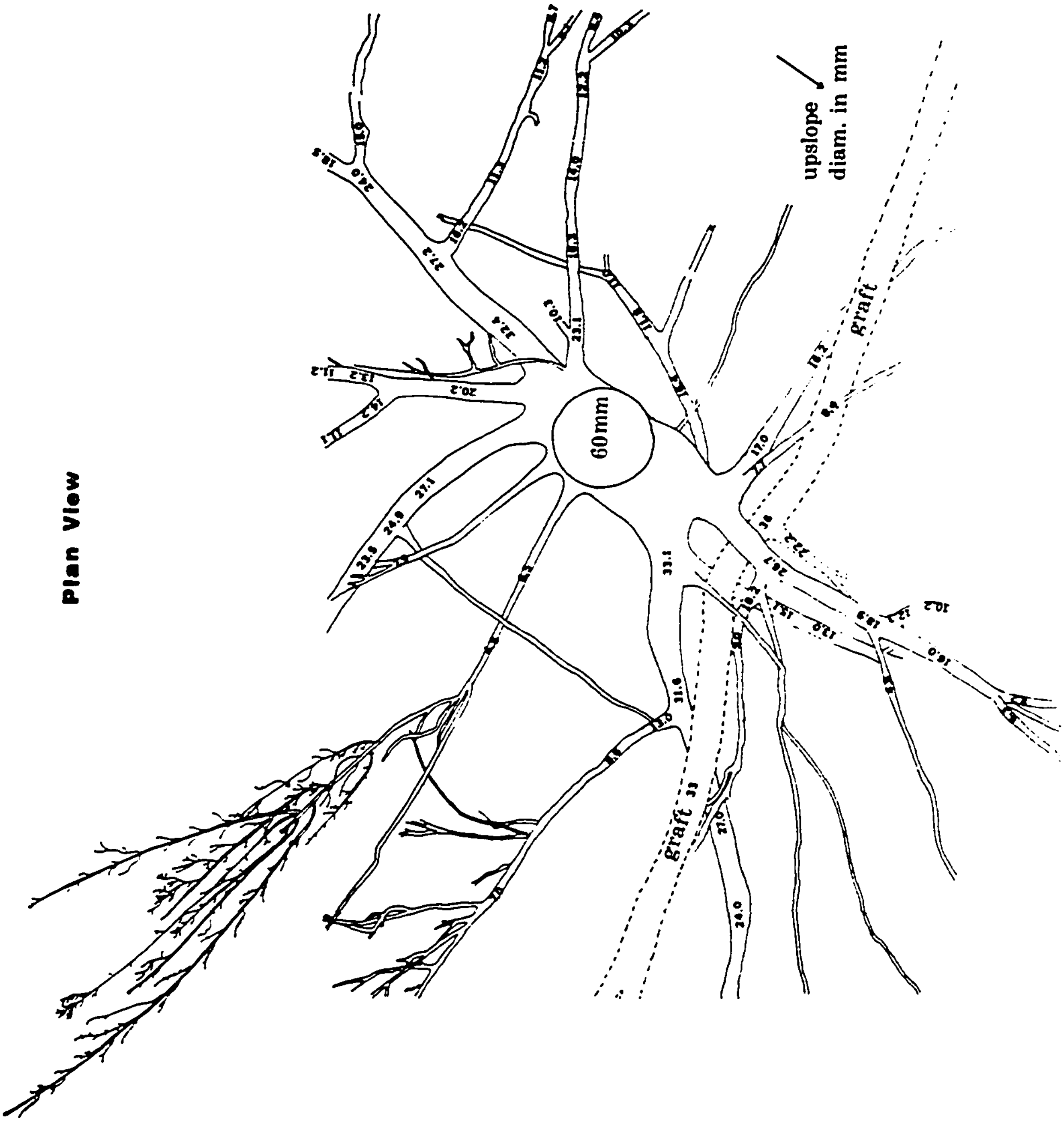
The roots of the maple were excavated with a trowel and hand rake. The diameter, azimuth and plunge of the main roots and branch roots were measured. Segments of each root were measured between branches at 10cm from branching points.

Figure 5 shows the excavated root system. All of the roots larger than 1mm in diameter are woody, that is, the roots have been widened by divisions of cells which formed woody tissue. The woody tissue has cell walls impregnated with lignin, a phenolic compound which strengthens the cell walls, reduces the permeability of the cell wall to water, and prevents the cell from reproducing or enlarging.

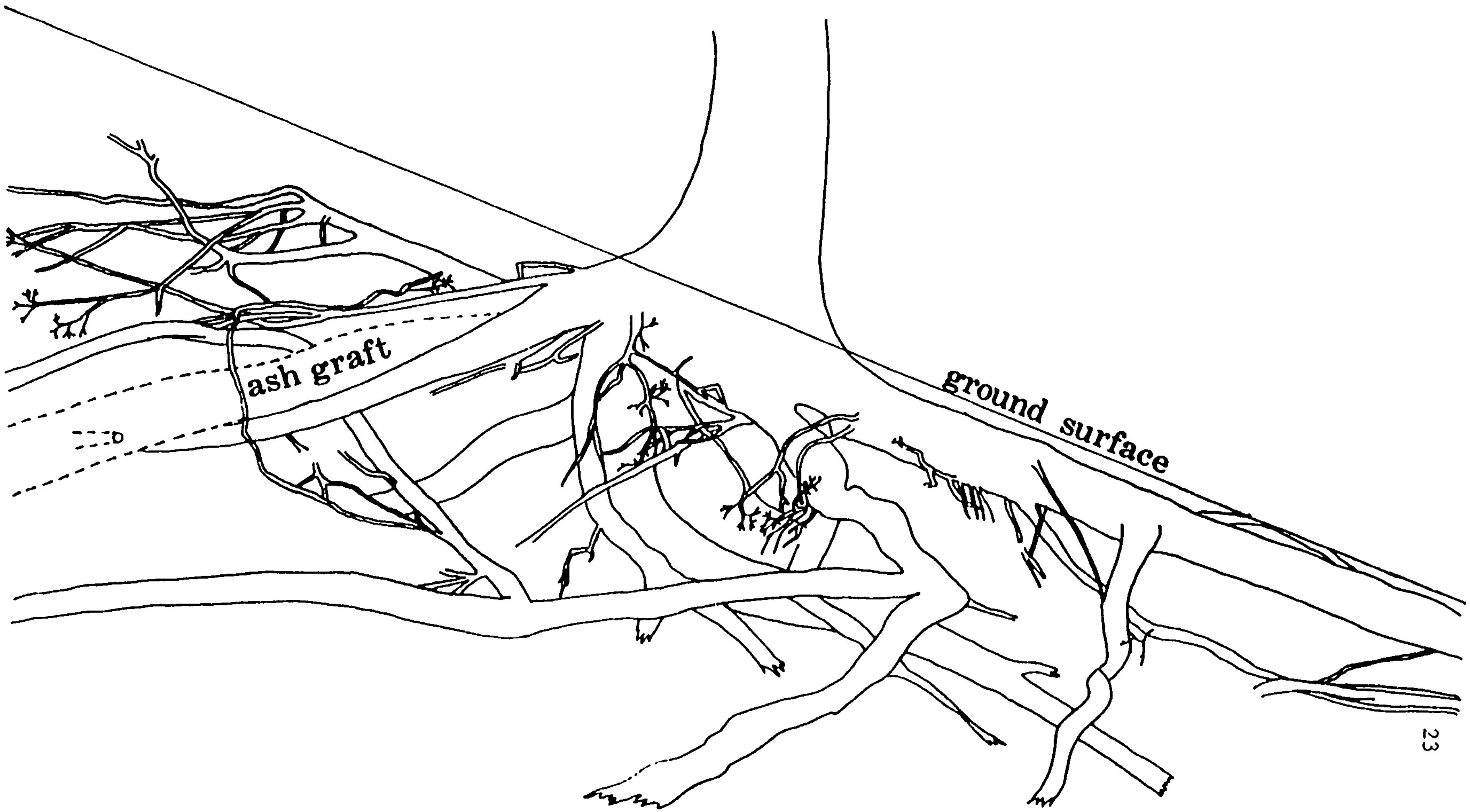
The first root to emerge from a seed of a tree is called the radicle. It is highly sensitive to gravity, and grows in a vertical orientation within the soil. On maturing, the radicle becomes woody and is called the taproot, which may retain its sensitivity to gravity (Zimmerman and Brown, 1980). The lateral roots all initiate from the tap root in the early life of the maple, and radiate evenly about the tree. This radial symmetry may readily be distorted by slope, proximity to other trees, and soil disturbance (McMinn, 1963).

Figure 5

The excavated roots of sugar maple #1 from the Delhi site. The roots, shown in plan and cross-sectional views, are numerous, highly branched, and are concentrated within the uppermost soil horizons. The roots taper markedly with distance from the trunk, a characteristic associated with frequency of branching.


Plan View
60mm
upslope
diam. in mm
graft
graft

Oblique View



In the excavated maple, the taproot is vertically oriented for 0.2m, then branches, narrows, and reorients subparallel with the roots growing close to and in nearly the same orientation as the ground surface (Figure 5). The large lateral roots which radiate from the base of the tree abruptly taper to about 0.5cm, then stretch out as cylinders which intermittently branch. The lateral roots taper highly as they branch, and then extend with nearly uniform diameter to about crown width. The roots terminate in fans of tiny rootlets. These terminal rootlets are nonwoody, and fragile.

The lateral roots initiate from swelled areas on the tap root, near its basal end (closest to its origin). The swelled areas project laterally about 4 to 5 or more centimeters from the tap, then terminate where the branching occurs (Figure 5). Individual lateral roots themselves taper gradually and branch at random; the branches grow about 45 degrees from the root and are one third to one half the diameter of the root. The roots taper, at first markedly, then more gently, until they reach about crown width (in this case, about 2m from the trunk), terminating in highly branched fans of tiny rootlets. A network of sinker roots, about one or less centimeter in diameter originate either directly from large lateral roots or from branches off the laterals.

The high taper in the lateral roots appears to be a result of many side branches, as recognized by McMinn (1963) and Wilson (1964).

The extent of the roots from the base of the tree may vary from crown width in a forested environment such as the Delhi site (Bookman 1982) to two to three times the crown width in open-grown trees, but the absorbing roots tend to remain within crown width (Zimmerman and Brown, 1980). The restriction of root growth to within crown width in a forested environment has been attributed to competition, which is especially intense in shallow rooted species (Ashton, 1975).

Roots were given a hierarchical order with the smallest, unbranched root designated as order one. The second-order roots are those from which the first-order roots branch, and so on, with the highest-order roots being the major lateral and tap roots. The ordering is similar to that used to describe river tributaries (Bloom, 1978). Woody roots are divided into size classes for the sake of simplification, with class 1=1-2mm, class 2=2.1-5mm, class 3=5.1-10mm, class 4=10.1-17mm, class 5=17.1-25mm, and class 6=>25mm (Riestenberg and Sovonick-Dunford, 1983).

The diameter of the first-order roots in the excavated maple averages 0.1mm and of second-order roots averages 0.12mm. These roots which make up the bulk of the root tips in sugar maple, are nonwoody, delicate and flexible. Examination of several finely branched root fans shows the following pattern:

Order	Length	Diameter	# Roots/Next Order	Surface Area per Root
1	0.4mm	0.1mm	6	0.0031mm^2
2	2.0mm	0.12mm	3	0.0226mm^2
3	20.0mm	0.2mm	3	0.6283mm^2
4	50.0mm	0.75mm	5	22.0890mm^2
5	200.0mm	1.2mm		

The bifurcation ratio, or the average number of branches per higher order branch, is 3.69. The average surface area per each 1.2-2mm root with its branches is 335mm^2.

The predictable bifurcation ratio in the excavated sugar maple breaks down with the fifth order, which is designated as a class-one woody root (1-2mm in diameter). In the sugar maple at the Delhi site, there is approximately one class one root per 4cm length of class-four root. The breakdown in predictable bifurcation ratio begins with the fifth order because numerous class-one (order five) and smaller roots commonly project directly from roots of a order five to eight orders higher, and a bifurcation ratio can no longer be fitted to the series.

The sugar maple was grafted to a root from a white ash growing nearby. The graft involves a combination of vascular and cambium tissue of roots from the two trees.

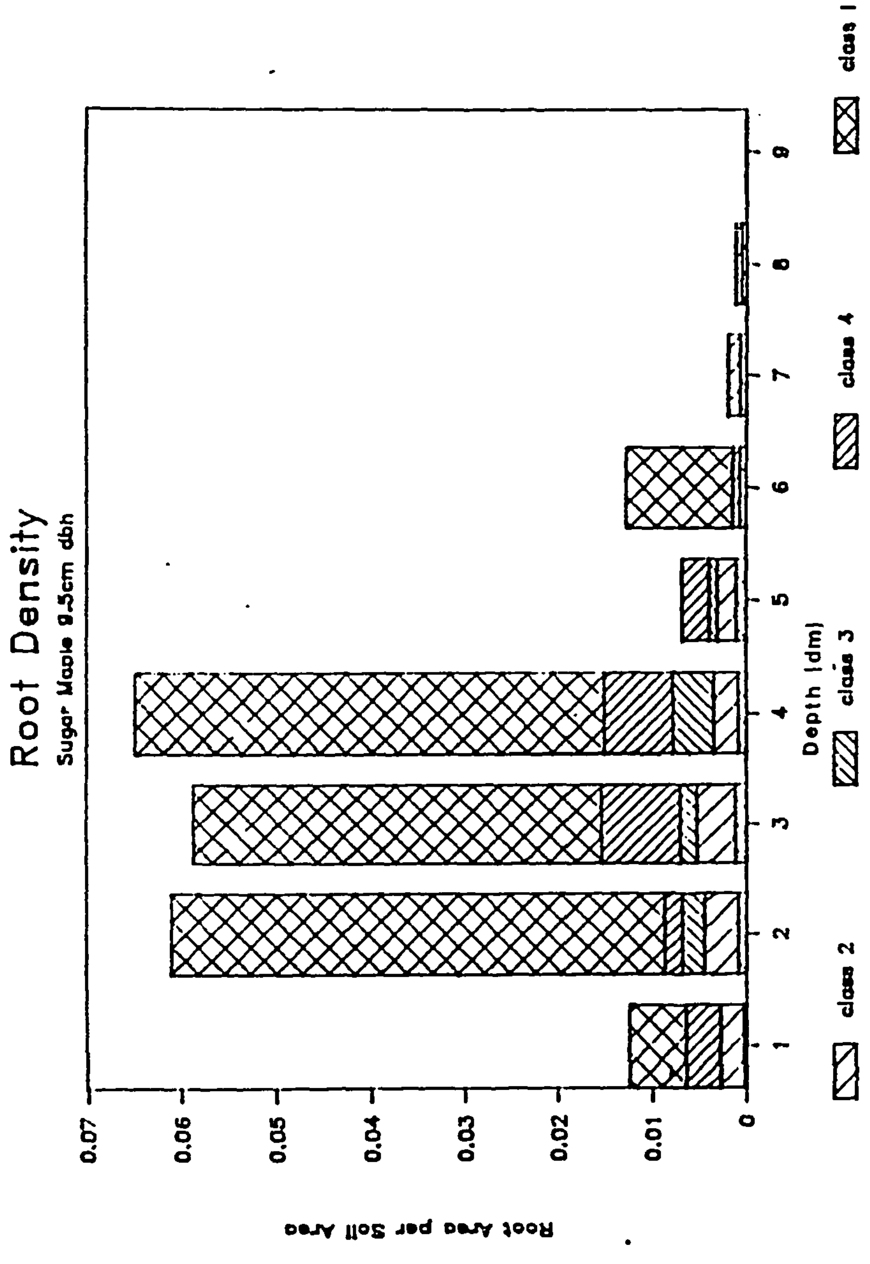
Grafting is a common occurrence in soils ranging from dry to boggy moisture regimes (Kozlowski, 1979). Grafting may be enhanced by tight spacing of trees and may add resistance to windthrow, nourishment to understorey trees, and help maintain a stand which grows in thin soil, bogs or swamps. That intraspecific grafting may be common was demonstrated by a study of a stand of white pine consisting of 84 trees, in which 41 were grafted to 54 receptor trees (Bormann and Graham, 1959). Interspecific grafting develops to a much lesser degree (Kozlowski, 1979).

Figure 6 demonstrates the high concentration of the roots of the excavated maple near the soil surface, and the abrupt decline in concentration with depth.

Roots are generally within the top 4dm of soil (Scully, 1942). Kockenderfer (1973) reported that 77-89% of root endings are in the upper 0.6m of soil in a hardwood forest in West Virginia, and Stout (1956) found that sugar maple penetrates the soil to a depth of 58.4cm in the Harvard Black Rock Forest in Orange County, New York. The depth to which roots penetrate is highly sensitive to soil texture. Roots penetrate to the greatest depth in well-aerated, moist soil (Biswell, 1935).

Figure 6

The density of roots as a function of soil depth. The cross-sectional area of roots per area of soil exposed at a trench face decreased markedly with depth.


Root Density
Sugar Maple 9.5cm dbh
Root Area per Soil Area
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Depth [dm]
1
2
3
4
5
6
7
8
9
class 2
class 3
class 4
class 1

The shallow distribution of the roots of maple #1 may be inherent to the species, or may result from inhibition of growth due to the density of the soil, but may also be due to slope, or to obstructions from limestone float near the interface between soil and bedrock. The soil at the Delhi site becomes dense and clayey immediately below the A-horizon. The excavation of another maple, in deeper soil with no obstruction from the bedrock, may confine the pressures on root distribution to fewer than those listed above, and help isolate the factors which control root depth.

Sugar Maples at Spring Grove Site

Spring Grove Cemetery, Cincinnati, owns a 400-acre woodlot which borders the cemetery to the northwest (Figure 1). An understorey-sized maple tree, designated sugar maple #2, growing in a heavily wooded area of the Spring Grove woodlot dominated by sugar maple and white ash, was selected for excavation. At the excavation site, the land slopes at 8 degrees, and the soil averages 1.5m thickness.

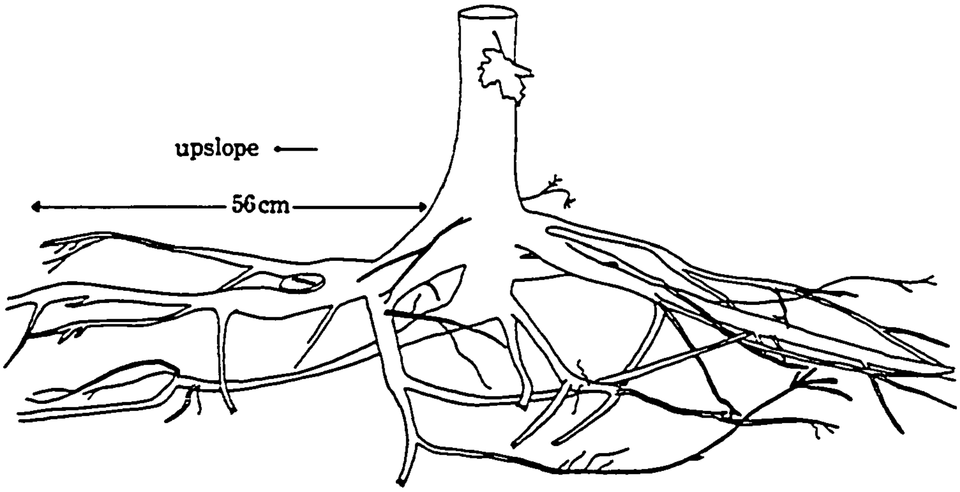
Sugar maple #2 has a shallow rooting habit similar to that of sugar maple #1 excavated at the Delhi site. The soil in each site is an Eden series residual soil, and both trees grow within a mature hardwood forest. The known differences between the sites are the ground slope and aspect, and the depth to bedrock.

The general form of the root system of the sugar maple at Spring Grove is similar to that of the Delhi site (Figure 7). The tap abruptly reorients from vertical to parallel the ground surface. Swelled projections from the tap root branch near the trunk into lateral roots which radiate about the center of the tree. The laterals branch at high angles to the source root. The abundant branching

Figure 7

Excavated roots of sugar maple #2 at the Spring Grove site. The general distribution and morphology of the roots are similar to that of the maple excavated at the Delhi site. The tree grows on gently sloping terraine underlain by deep soil here; at the Delhi site the tree grew on a steep hillslope underlain by a thin mantle of soil.

Plan View



Oblique View

coupled with high taper gives the roots a spindly appearance. Upon tapering to about 0.5cm in diameter, the roots project as more gradually tapering tubes for up to 2m. These narrow tubes terminate in fans at about crown width (3-4m from the center of the tree).

Root asymmetry has been correlated with surface gradient (Parizek and Woodruff, 1957), but for both sugar maple #1 and sugar maple #2, the radial distribution of roots is insensitive to slope, at least within 50cm of the trunk (Figures 5 and 7).

Comparison of the cross-sectional views of the two excavated trees, (Figures 5 and 7) indicates that the rooting habits are similar. The tap roots of both trees abruptly reorient parallel to the ground surface at a shallow depth; the reorientation probably develops independently of the barrier presented by underlying bedrock, because the bedrock lies over a meter below the tap in the Spring Grove site.

The shallow rooting habit of the sugar maple may be inherent to the species, or may be due to local conditions such as poor aeration due to a high water table, or to the root's inability to thrive in dense clay.

A study performed by Biswell (1935) on the rooting habit of the sugar maple in two soils, a clay and an alluvial soil which was poorly aerated and mottled demonstrated that the sugar maple is highly sensitive to texture and aeration, but the study was unable to separate the two effects.

The mottling of the peds in the soil profile of the Eden soil suggests that the soil in both sites is frequently water-logged, but the mottling is developed well-below the curvature of the tap root.

It is interesting to note that the sugar maple's rooting habit is contrastingly different from that of the box elder (*Acer negrundo* L.), so it seems that rooting behavior of a tree may be determined at the specific level, rather than at the generic level. The box elder, a floodplain species, was noted to have a dominant tap root which will extend to a depth of 3 meters in the same soil in which sugar maple roots extend to only 1 meter. The box elder and the sugar maple share the same genus, but have distinctly different aerial and subaerial morphologies.

Roots of several sugar maples were sampled by a modified trench method to determine whether the distributions described for the two excavated maples are representative of small maples growing on Eden soil in Cincinnati. Conical excavations cut by a vermeer spade were chosen for the sampling of root distribution.

The vermeer spade is a truck-mounted, 4-bladed spade, which can remove a small tree, complete with the soil surrounding its central root system. It is used by nurseries for removal and transplanting of saplings (Figure 8). The advantage of the vermeer spade over other excavating devices is that it severs only those roots which grow at a specified distance from the tree, and the spade's blades are sharp, so the roots are cut with little or no tearing.

The spade cuts a conical soil face about a tree, exposing the three-dimensional root distribution. The cone is conical, 1.1m in diameter at the ground surface, and pinches out at approximately 0.85m below the ground surface. The technique offers a compromise between complete excavation of a root system on one hand, and a two dimensional trench face on the other.

Figure 8

The Vermeer spade was used to expose the roots of some of the trees. The spade removes a cleanly-cut cone of roots from the soil allowing subsequent study of root characteristics. It also exposes truncated roots on the conical trench face for measurement of resistance to pull-out.

Saplings ranging from 8 to 15cm dbh were selected because they were accessibile from a dirt road running through the Spring Grove woodlot. The north side of each tree was marked with a nail. The trees were then excavated during the spring, and the cut root systems were freed from clinging soil and transported to a frame from which they were hung for easy measurement of root sizes and orientations. A soil profile was measured at a representative excavation. The excavations were kept saturated by daily watering for later studies of root pull-out resistance.

The excised root systems were analyzed as follows: each lateral root was measured individually by noting its branching pattern, presence and nature of grafts, and the azimuth, plunge, and diameter of the lateral and its branches as they projected through a hemisphere 30cm from the center of the base of the tree (See SM#4 in appendix B).

The Vermeer-excavated sugar maple shows essentially the same habit near the base of the tree as do the roots of the hand-excavated sugar maples; the numbers and cross-sectional area of roots are highest near the ground surface, and diminish in number with depth. The roots display the same spindly form as the excavated trees, with the laterals tapering highly as they branched, and the tap reorienting from vertical to horizontal near the base of the tree. The roots are grafted intraspecifically; one tree has two or more grafts within its own root system.

Morphology and Distribution of the Roots of White Ash

A white ash, 8.8cm in diameter, was selected for hand-excavation at the Spring Grove site. It grew five meters from the sugar maple that was excavated from the woodlot.

All roots of the excavated white ash larger than 4th order are woody. The highest order root of this ash's root system is 12th order.

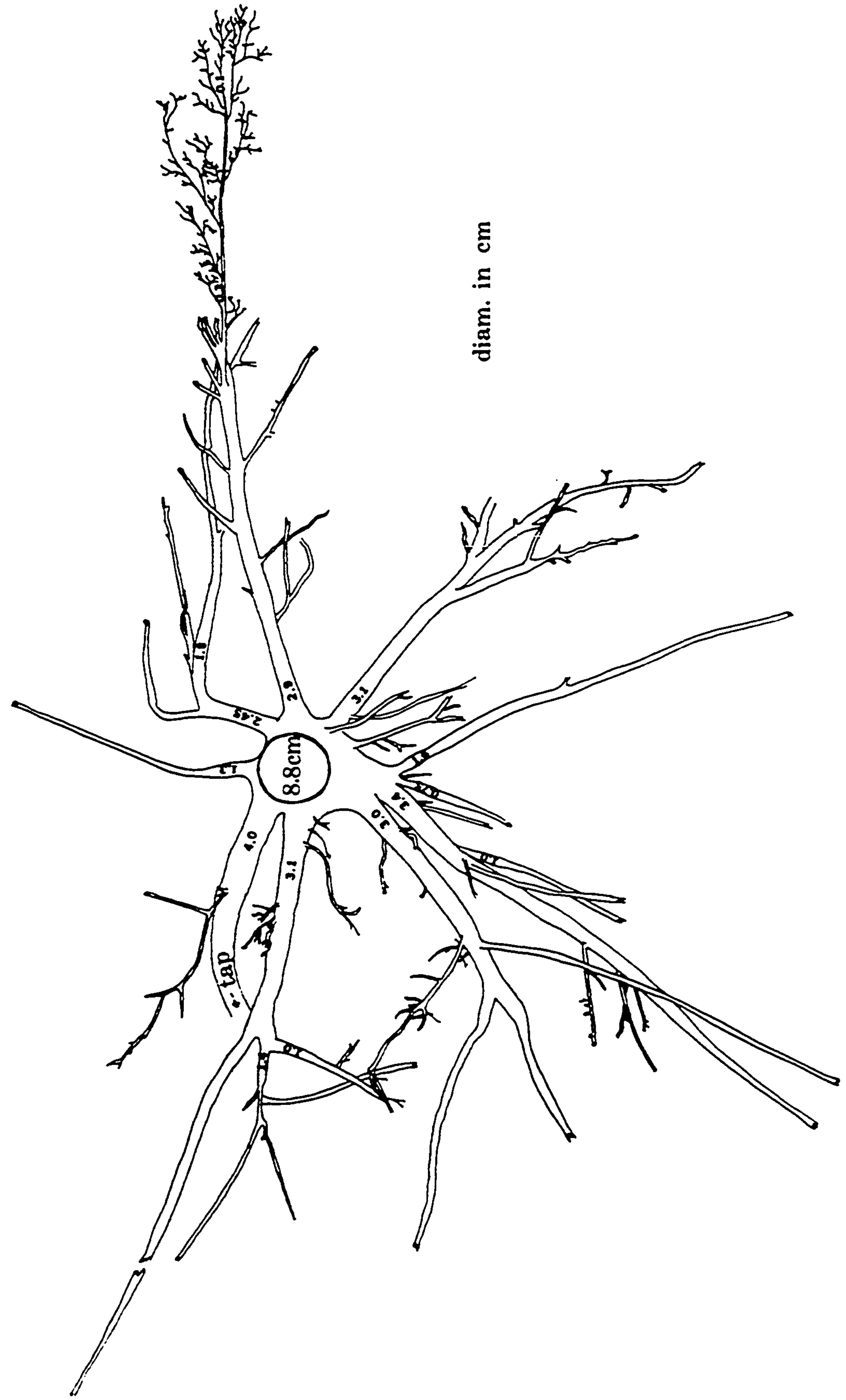
The lateral roots radiate from the tap root, and disperse about the trunk. The roots either initiate directly from the tap, or from a swollen site which formed from the fusion of initiating laterals. As the laterals radiate from the tree, they generally project in the same direction as that in which they started (Figure 9).

The roots are circular in cross-section, and taper continuously, never abruptly, so the roots appear to be almost cylindrical in shape, in contrast to the highly tapering and branched roots of the maple. In ash the taper averages .03 increments of diameter per incremental length of root (cm/cm) in orders 11-12, then averages about 0.01 in orders 8-10. A comparison of the two species shows that the sugar maple tapers 0.025 in orders 11-12, then falls off to 0.01 in order 10, 0.005 in order 9, and 0.003 in order 8. The maple tapers abruptly in orders 10 to 8, and the ash maintains the same diameter through orders 10 to 8. This difference in taper gives the two species their characteristic shapes --- the sugar maple appears to be spindly, and the ash appears to be massive.

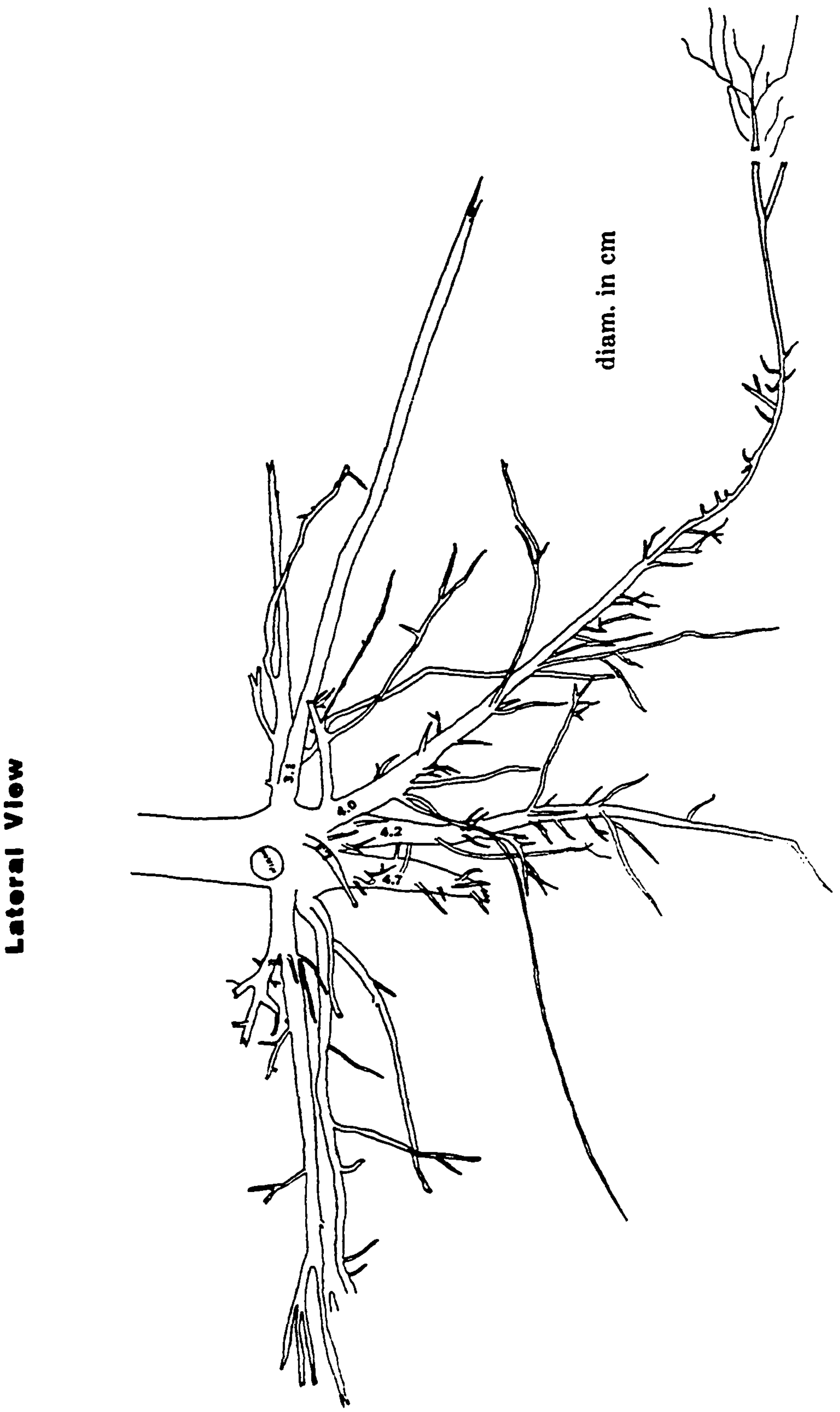
The lateral roots in ash either terminate as a fan of tiny rootlets, or abruptly (Figure 9). The termini of the blunt lateral roots are sealed with a waxy covering and reflect root mortality or cessation of growth. (Blunt termination is observed infrequently in

Figure 9

Excavated white ash at the Spring Grove site. The roots of the ash tree have two contrasting orientations: one set of roots is oriented nearly parallel with the ground surface, and another set is oriented at high angles to the ground surface. The tree is similar in girth to the excavated sugar maple, which grew adjacent to it within the woodlot, but the roots of the ash extend deeper into the soil than those of the sugar maple.



Plan View


Lateral View
diam. in cm
3.1
4.0
4.2
4.7

sugar maple). When the annual elongation of a lateral root ceases the root tips turn brown as the tip becomes impregnated with lignin and metacutin, a wax (Kramer and Kozlowski, 1979).

The roots of the white ash have the same bifurcation ratio as maple for orders one through four. The bifurcation ratio for the ash also breaks down with orders greater than four.

The white ash is less branched than the sugar maple. The sugar maple has approximately one class-one root branch per 4cm length of class 4 root, and the ash has one class-one root per 5cm length of class-four root. The branching is at low angles to the parent root.

Unlike the shallow-rooted sugar maple, the lateral roots of the ash may plunge steeply. One lateral of the ash projects at an angle 55 degrees from horizontal, and continues to a depth of 1m below the ground surface. It has 34 branches along its 1.8m length beyond the point at which it reorients horizontally. It has a higher rate of taper than the horizontal laterals. It tapers 0.05 along 60 cm of root length, then 0.01 for the next 70 cm, then 0.005 to the root's disappearance within the soil.

The tap root of the white ash bifurcates into two branches which taper highly as they project nearly vertically into the soil. The taps are intermittantly branched; the branches are at a high angle to the tap and are generally less than 1cm in diameter.

The tap root has the form of a frustum, rather than the cylindrical shape of the laterals. Its branches also taper strongly as they project nearly vertically into the soil. The tap tapers 0.074 for 30cm of its length, then 0.005 for 150cm, then it has a taper of zero until it disappears into the soil. A branch 0.85cm in diameter emerges from the tap at 70 degrees from the adaxial direction of the root and tapers 0.03 along a 0.3m length, then 0.001 to the root's tip, 0.9m from its origin.

The tap root of the white ash extended to a depth of one meter below the ground surface and then reoriented horizontally. The reorientation at depth may be due to the following factors: a mechanical obstruction to growth, poor aeration due to the density of the soil or to standing water, or the resistance offered by compacted soil. It would be difficult to isolate the most important factor, however. The soil profile shows mottling at depth, indicating poor aeration due to standing water. Often, the open trench made in excavating the tree filled with standing water.

An obstruction, such as a fragipan, bedrock, or isolated cobbles will induce reorientation of a tap root. Upon reaching the obstruction, the tap will reorient, and follow the contour of that obstruction (McMinn, 1963; Heath, 1968). Numerous large limestone flags lay within the soil at and below 1m beneath the ground surface which may have also contributed to the reorientation at depth. It has also been established that increased confining pressure will reduce root growth.

A study of roots growing in soils with increasing bulk densities showed that root tips exert a pressure of 1-3 atmospheres on soil as they grow, and that the pressure required to grow within dense soils may exceed the root's strength. As the bulk density approaches this critical level, the size of the individual cells will decrease (Barley, 1962). The wet density of the colluvium in Cincinnati (Eden series) increases with depth. The density of the top soil is 1.74g cm^{-2}, and increases from 1.89g cm^{-2} at 0.3m depth to 2.11g cm^{-2} at 1.52m below the ground surface (Fleming, in prep.).

The Vermeer-excavated roots of five white ash trees at the Spring Grove site are similar in form to those of the fully-excavated ash roots. Roots exposed by both hand-excavation and vermeer spade are distributed in two distinct directions within the soil. There is a set of laterals oriented nearly horizontally, and a massive, branched tap root projecting vertically. The laterals show poor branching, and massive dimensions with little taper. All ash trees display a dominant, vertically-oriented tap root (e.g. Ash#8 in Appendix B).

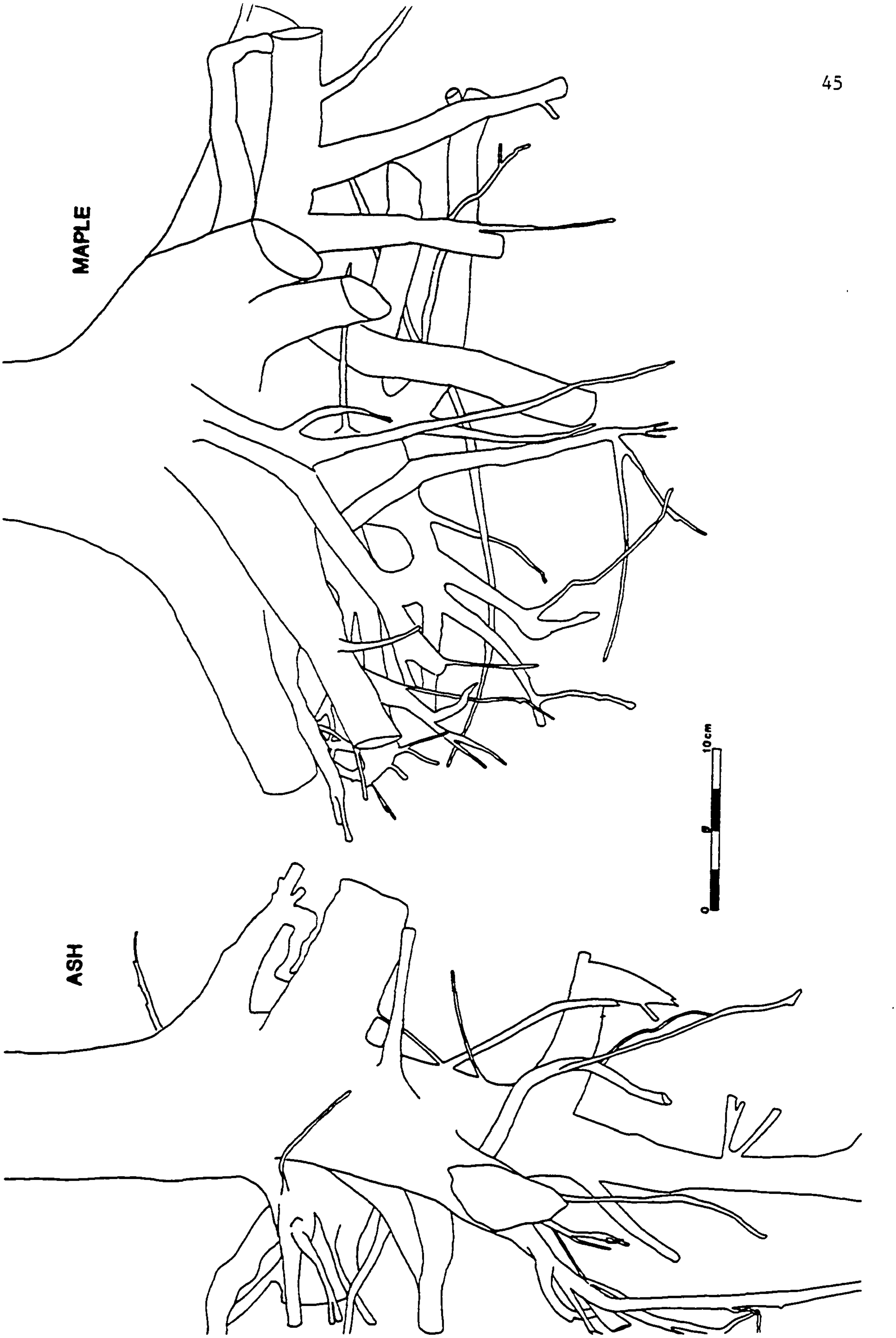
Summary of the Study of the Roots of Sugar Maple and White Ash

The observations of the roots of sugar maple and white ash demonstrate that rooting habits differ greatly between the two species and that, in general, the root configurations for both species are predictable. Figure 10 displays the roots of sugar maple and white ash which were excavated by a Vermeer spade. The trunks of the trees have the same diameter trunk, but the roots quite different in form. The root balls shown in Figure 10 represent two of 15 trees which were removed from the Spring Grove site. All of the excised root balls were examined for similarity and differences in trends in root distribution and morphology as compared with the hand-excavated trees, and five of the excised root balls were measured and described in detail.

Stereonets showing contours of root area as a function of orientation and distance (30cm) from the base of the fully excavated maple trees and the ash tree demonstrate the most obvious and predictable difference between the root distributions of the two

Figure 10

Sugar maple and white ash roots removed from the soil by the vermeer spade. The orientations and characteristics of the roots near the trunk are similar to those described with the hand-excavated roots. The ash in contrast to the highly branched maple has a massive root system which is dominated by a tap root. (Illustration by Ted Riestenberg)


MAPLE
ASH
0
10cm

species (Figure 11). The sugar maple roots are concentrated at low angles from the base of the tree, and the white ash roots are concentrated into two orientations, a group oriented nearly horizontally, and a dominant, vertically oriented tap.

Root area and depth are compared for the two species are compared in Figure 12. The cross-sectional area of roots penetrating planes parallel to the ground surface for all three excavated trees is highest near the ground surface, and decreases rapidly with depth. The root areas of the sugar maples approach zero at a depth of 0.6m, but the tap root of the ash projects to a depth of 1.10m. This plot was drawn using the orientations and dimensions of the roots of the fully excavated trees, which were entered into a S.A.S. computer program written by Roger Steubing, named DEPTH (Appendix C), which extropolates the area of roots per plane below the ground surface.

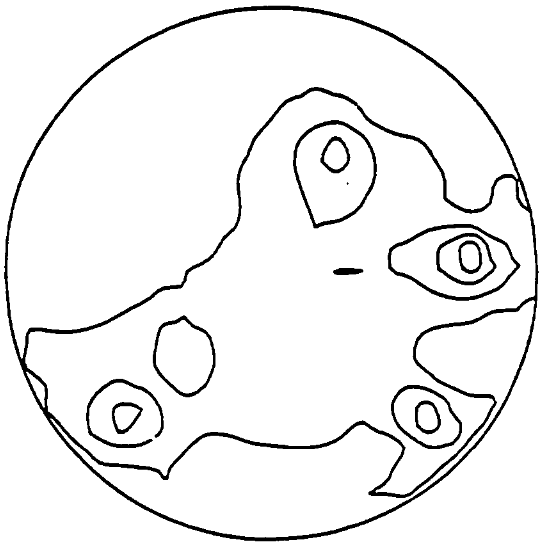
Rose diagrams of orientations of the lateral roots of the fully excavated trees and those sampled by the vermeer excavations show similarities between the two species (Figure 13). The measurements are made at a distance of 30cm from the base of the tree trunk. The laterals tend to be spaced nonpreferentially about the trunk, despite differences in slope. This probably is made most apparent by comparing the orientations of the Delhi maple with those of the Spring Grove woodlot. The Delhi site sloped at 30 degrees, and the Spring Grove slope ranged from zero to 10 degrees.

The biomass of roots is qualitatively correlated with above-ground biomass for those trees excavated in this study. Sugar maple #4 (SM#4 in Appendix B) is larger in girth than, for instance, sugar maple #1 excavated at the Delhi site. Sugar maple #4, 12.6cm dbh, has 33

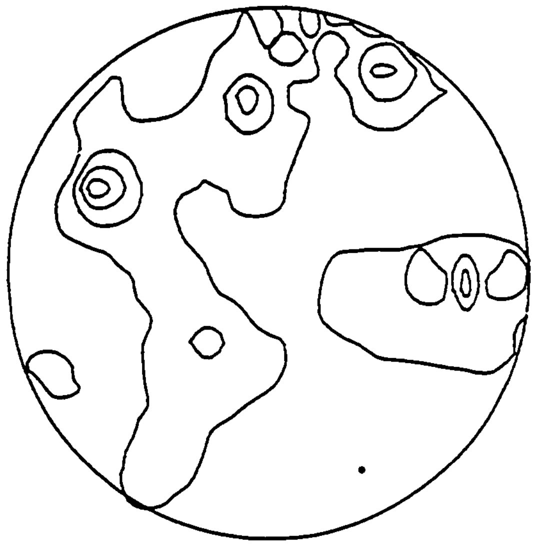
Figure 11

Stereonets of cross-sectional area of roots cutting the surface of a hemisphere at a radius of 30cm from base of trunk. The two species show contrasting root distribution. The sugar maple roots are most concentrated at low angles from horizontal and the white ash roots are concentrated at low and high angles from horizontal. The sugar maple is shallow rooted, the white ash is deeply rooted due to its dominant, vertically oriented tap root. (Program written by K. Cruikshank)

Sugar Maple 1



Sugar Maple 2



Ash

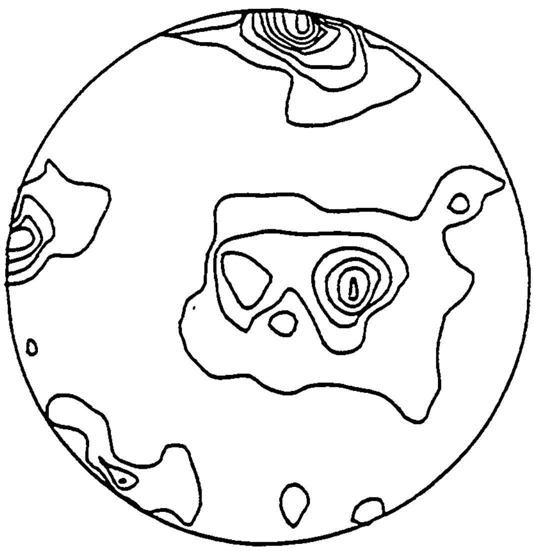
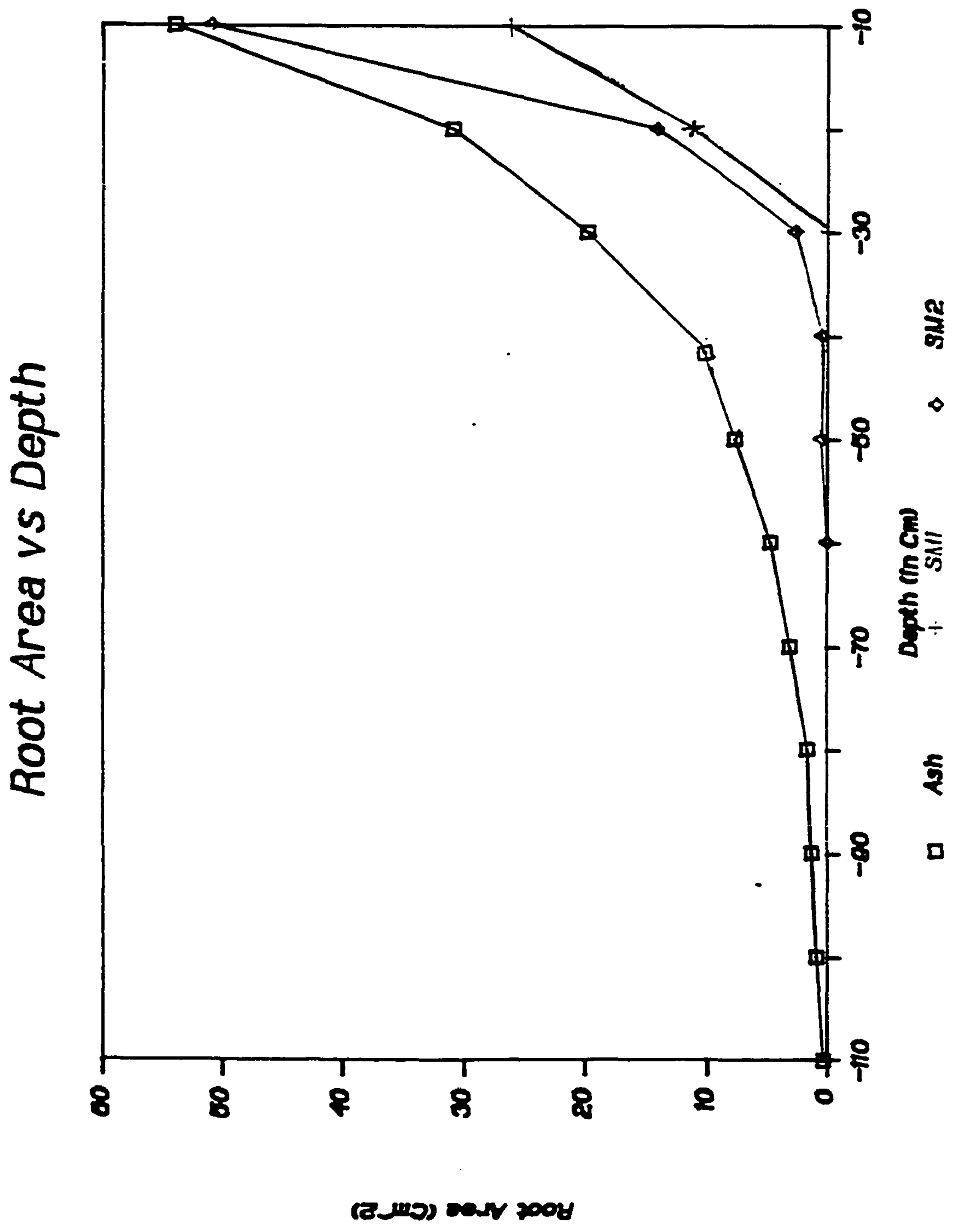


Figure 12

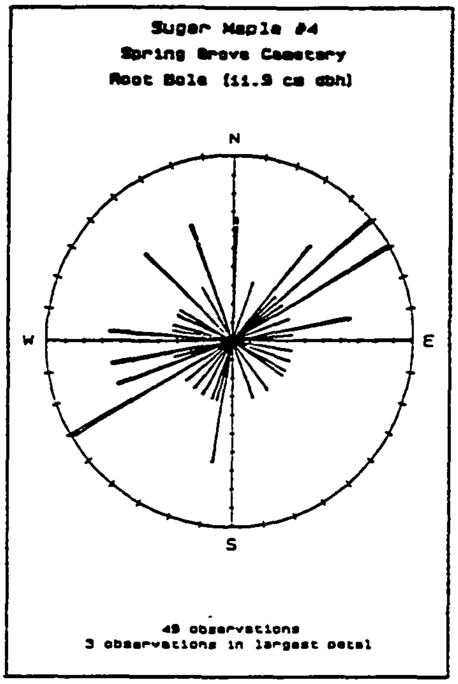
The cross-sectional area of roots of the hand-excavated trees as a function of depth. The roots of both species are concentrated in number and size in shallow soil, and decrease in numbers and cross-sectional area with depth. The maple roots extend to 0.6m and the white ash to 1.1m below the ground surface. (DEPTH program written by R. Stuebing)

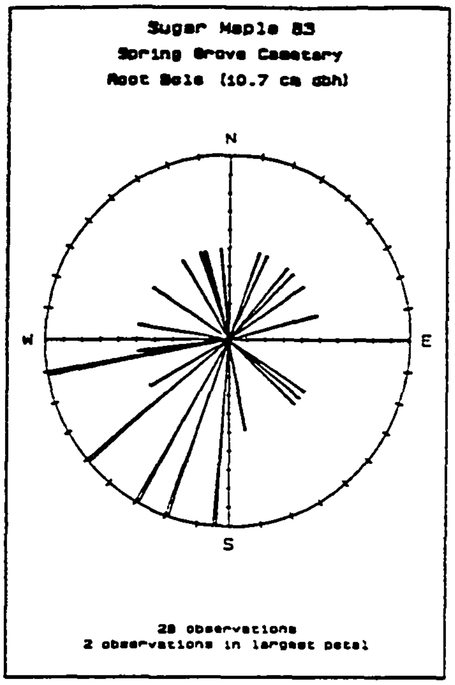


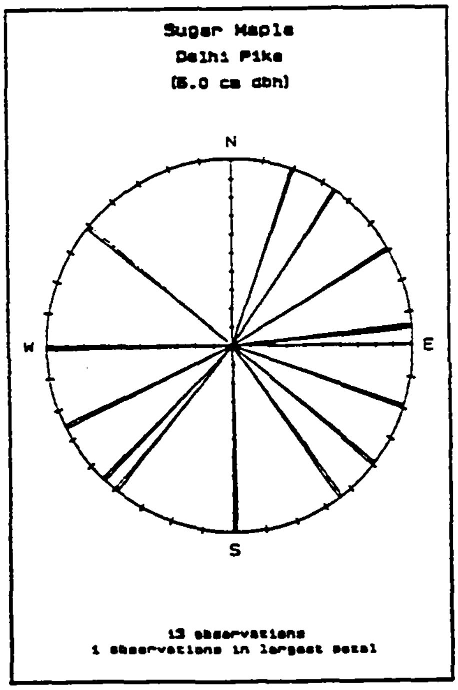
Root Area vs Depth
Root Area (Cm^2)
0
10
20
30
40
50
60
-10
-30
-50
-70
-90
-110
Depth (In Cm)
Ash
SAI1
SAI2

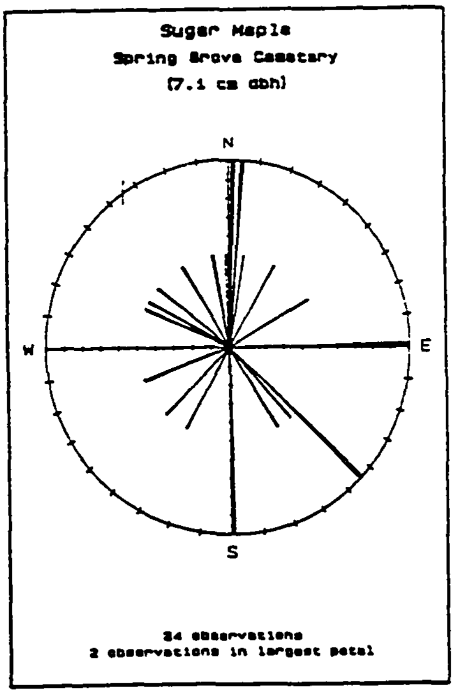
Figure 13

Rose diagram of occurrence and azimuth of lateral roots. The two species display an insensitivity to slope for root growth within 30cm from the base of the tree trunk. (Computer program written by K. Cruikshank and J. Beaujon)

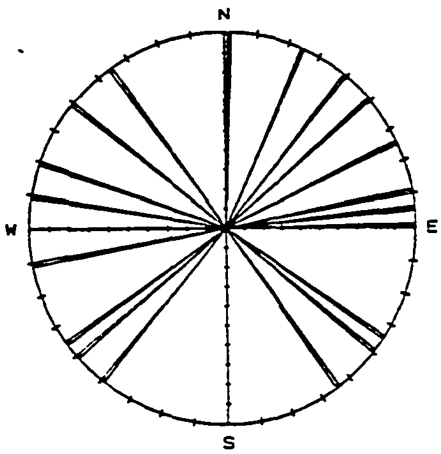

Sugar Maple #4
Spring Grove Cemetery
Root Bole (11.9 cm dbh)
N
W
E
S
49 observations
3 observations in largest petal


Sugar Maple #3
Spring Grove Cemetery
Root Bole (10.7 cm dbh)
N
W
E
S
28 observations
2 observations in largest petal


Sugar Maple
Delhi Pike
(8.0 cm dbh)
N
W
E
S
13 observations
1 observations in largest petal

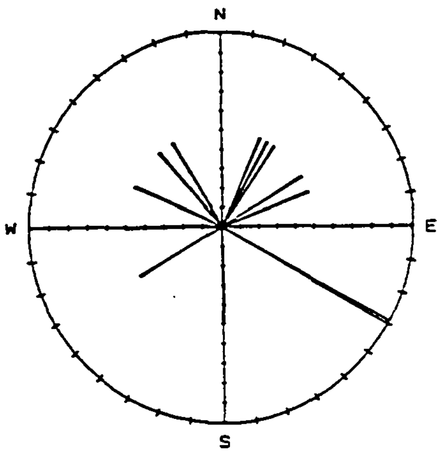

Sugar Maple
Spring Grove Cemetery
(7.1 cm dbh)
N
W
E
S
24 observations
2 observations in largest petal

Ash #8
Spring Grove Cemetery
Root Bole (8.3 cm dbh)



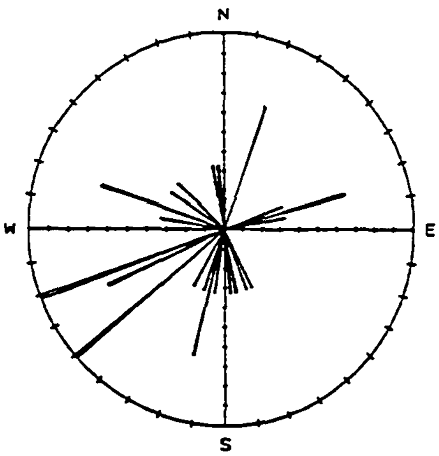
19 observations
1 observations in largest petal

Ash #8
Spring Grove Cemetery
Bole Check (ID = 8.0)



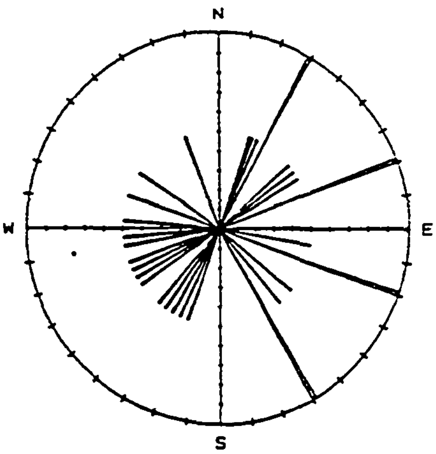
13 observations
2 observations in largest petal

Ash 1983
Spring Grove Cemetery
Root Bole (14 cm dbh)



30 observations
3 observations in largest petal

Ash
Spring Grove Cemetery
Root Bole (13 cm dbh)



33 observations
2 observations in largest petal

primary lateral roots, i.e., those projecting from the trunk, which average 2cm in diameter at a distance of 30cm from the trunk. In contrast, sugar maple #1, 6cm dbh, has 13 primary lateral roots which average 1.8cm in diameter 30cm from the trunk. But it is difficult to project below-ground biomass and depth of rooting from the size of the plant above-ground. Kramer and Kozlowski (1979) point out that rooting depth shows no correlation with the above-ground size of the plant. Competition, age, and edaphic and climatic factors may alter root configurations, size, and extent. The predictions and correlations made in this study will be limited to maple and ash trees of small girth (6-16cm dbh) which grow on Eden series soil in Cincinnati.

CHAPTER THREE

Observations of Roots Associated with Failure Surfaces

Introduction

It is well documented in the literature that roots increase soil strength, but the mode of interaction of roots with soil during failure has not been described. In this chapter observations of roots projecting through shear surfaces will be analyzed to determine how roots interact with the soil in shear.

Tree roots increase the tensile strength of soil three to five times (Kaul, 1965; Endo and Tsuruta, 1969). The shear strength of the soil increases with rising biomass of roots per unit volume of soil (Endo and Tsuruta, 1969; O'Loughlin, 1972; Ziemer, 1981). This increase in soil shear strength is attributed to a rise in the cohesive component of soil shear strength (Endo and Tsuruta, 1969; Waldron, 1977, Gray 1974, 1978; Wu, 1985). The increased cohesion of rooted soil ranges from one to twenty kilopascals (O'Loughlin and Pearce, 1984). The increase is a function of the surface area of roots per plane within the soil (Wu, 1976, 1985; Waldron, 1977; Wu *et al.*, 1979, 1983; Waldron and Dakessian, 1982). Measurements of shear strength demonstrate that both peak and residual strengths of the soil are augmented by the presence of roots (Manbeian, 1973), and that rooted soil can be deformed to a greater extent in shear than fallow soil before failure (Kaul, 1965). Waldron and others (1983) demonstrated that the increase in shear strength peaks at 18mm displacement in soils with alfalfa and pine roots.

Thus, it has been established that tree roots increase the shear strength of soil, but it is unclear how they do so. The complexity of the interaction between roots and soil is such that simplifying assumptions must be made in order to describe and quantify the process of shear in rooted soil.

Rapid Run Site

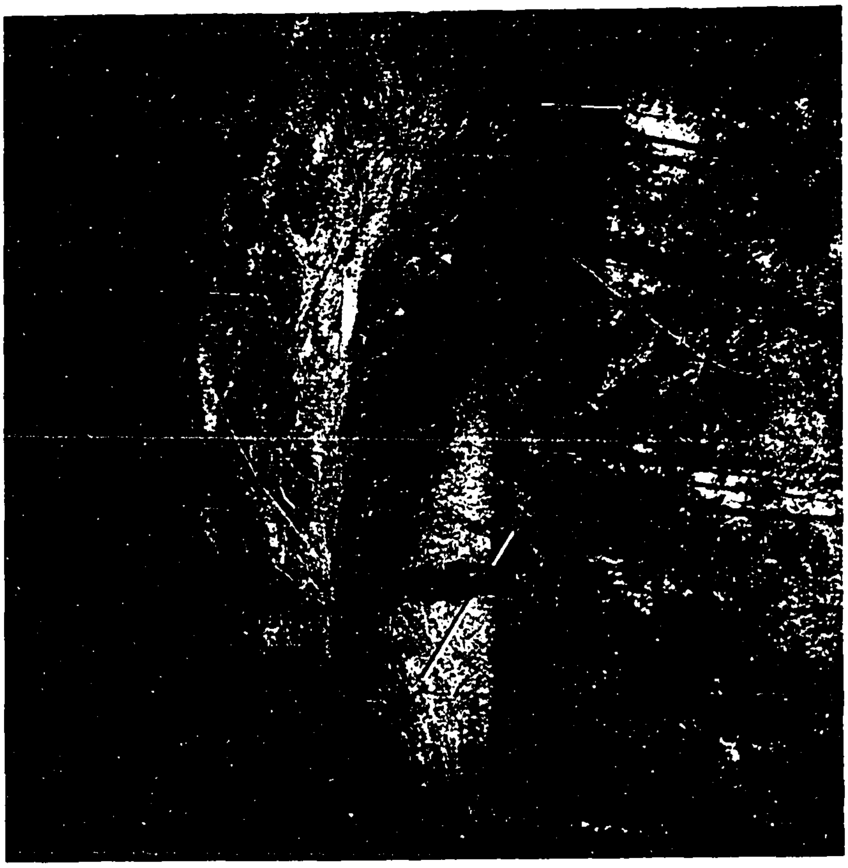
An analysis of the Rapid Run landslide demonstrates the complexity of the failure of rooted soil.

The Rapid Run landslide failed as a series of blocks, or slide elements, each supporting a segment of the maple-dominated forest on the north-facing slope of the ridge between Rapid Run Creek and Ohio River (figure 2). The slide elements were bounded by scarps draped with roots. The roots which projected from the scarps were oriented upslope, indicating the direction of displacement of the soil and the original position of the slide element. Many of the roots were broken, but about 40% of those which grew in the topsoil were pulled out of the soil intact (Figure 14).

The slide elements slid either to the toe of the landslide or part way to the toe where they were stopped by ash, basswood, or buckeye trees which remained in place during the landslide. A sugar maple tree growing on a slide element which moved to the landslide toe was partly excavated to determine the extent and nature of damage to the roots. Numerous roots were reoriented but were apparently undamaged by the sliding process. Many roots, however, were broken, and splitting of the bark of the roots in circumferential bands suggests that the roots failed in tension.

Figure 14

Roots project from scarps produced by the failure of a wooded hillslope. Some roots are broken, others remain intact, with their long axes oriented in the direction of displacement. (Photograph by T. Lion)



Numerous roots (5 to 120 per square meter of scar surface) projected through the surface of the landslide scar. The roots were overlain by a thin clay layer which covered the entire surface of the slide scar. The roots were broken in tension and aligned downslope on the scar in the orientation of the slickenlines etched on the surface of the scar.

A stability analysis was performed in which the factors promoting failure of the hillslope were compared with those resisting failure. In performing a stability analysis of a hillslope, a factor of safety, the ratio of forces which resist failure to forces which drive failure, is calculated. A factor of safety greater than one indicates that the slope is stable; as the factor of safety approaches unity, failure is imminent. A factor of safety less than one indicates that the hillslope is unstable. In the case of the Rapid Run landslide, a modification of the model derived by Wu (1976) and Waldron (1977) was selected as most appropriate. Assumptions of the model are that flexible roots are deformed as the soil shears and they deform the soil within a shear zone, and tangential forces which resist deformation develop along the root as a function of the angle of distortion. The deformation of the roots increases the cohesive strength of the deformed soil at the shear zone. At some critical displacement, the roots of all sizes break simultaneously in tension, with their full tensile strength mobilized.

Using 12 degrees for the residual angle of internal friction, assuming no cohesive strength, and assuming that the water table was at the ground surface at failure, a factor of safety of unity was calculated for individual failed blocks, and a factor of safety approaching unity was calculated for the entire landslide mass. The analysis suggests that 85% of the forces resisting failure were contributed by the roots and 15% by the soil strength itself.

These results imply that the strength contributed by roots is much higher than the soil strength. It is improbable, however, that the roots failed simultaneouly, so the contribution of root breakage to the factor of safety is probably less than that calculated. But if the roots did not fail at once, how can the calculated factor of safety of unity be explained? A considerable number of roots pulled out intact, and the strength contributed by these roots was ignored in the stability analysis.

Further field observations suggest that the roots on the shear plane may vary in length and diameter, and that the flexibility of roots may vary within and among species. A thick zone of deformed soil at the discontinuity which defines a landslide has not been observed, but rather, shear has been observed to develop at one or more paper-thin planes within the soil.

The variation in root length suggests that the roots probably did not all fail at once. Although roots often fail in tension, a substantial fraction of roots which were involved in the landsliding process pulled out of the soil intact or nearly intact, at considerably less than their full tensile strength.

The discrepancies between the assumptions of the model used to explain root involvement with the Rapid Run landslide and field observations suggest that the manner in which roots fail in the shear zone be examined in detail.

The Delhi Landslide

The Delhi landslide illustrates the progressive involvement of roots in failing soil, shear zones of an active, planar landslide. Failure zones of the Delhi landslide were exposed in two places, one in cross-section, the other plan exposure. The Delhi landslide is one of a series of shallow failures which have developed on the south-facing slope of the wooded, oversteepened ridge described above.

The failures are progressive, with movements occurring throughout the year, but most dramatically during the spring, when rainfall reaches a peak, and the trees have not leafed-out. The rate of movement ranges from fractions of centimeters to 2 to 3cm per year (Fleming and others, in prep.).

According to Fleming and others (in prep.), the failure zone is generally a single slip surface which develops at the soil-bedrock interface from 0.5 to 1.5 meters below the soil surface (Figure 15). Near the toe, in the foot of the landslide, it is a series of slip surfaces.

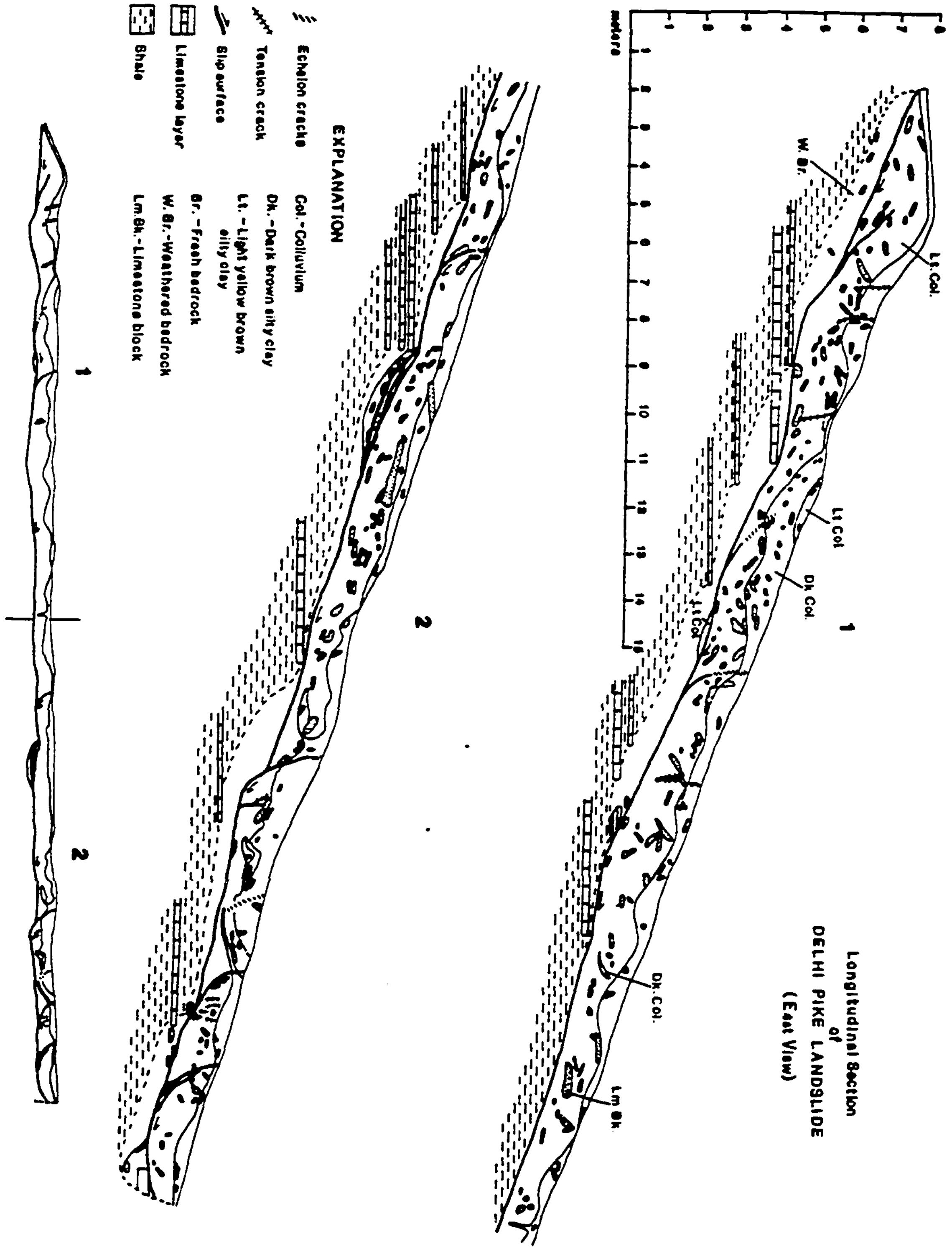
Two excavations were made in the foot of the landslide. Using a backhoe for removal of the overlying, intact soil, followed by hand-excavation by means of trowels and brushes, a $2.53m^2$ area of the shear surface was exposed and mapped in one trench. The dominant shear surface was paper-thin and etched with slickenlines. The surface divided into a series of anastomosing shear surfaces defining localized shear zones.

Seventy roots, averaging 0.15cm in diameter, projected through the exposed shear surface of about $2.5m^2$. The roots passed through fissures in other planes which anastomosed with the exposed surface. The roots, penetrating joints within the weathered bedrock below, projected though

Figure 15

Cross-section through a shallow, planar landslide on the south-facing slope of the ridge in Delhi. The failure surface is paper-thin and occurs at the interface between the colluvium and the bedrock. At irregularities in the contact, such as at projections of limestone slabs, the surface splits into numerous anastomosing, paper-thin surfaces. These anastomosing surfaces are most common at the landslide toe, where roots were examined for this study.

The cross-section of the landslide was described and mapped by Onder Gokce and Robert Fleming, and drafted by Lyla Messick.


Longitudinal Section
of
DELHI PIKE LANDSLIDE
(East View)
Lt.Col.
W.Br.
Lt.Col.
Dk.Col.
Lt.Col.
Dk.Col.
Lm.Bk.
meters
1
2
1
2
EXPLANATION
Echelon cracks
Tension crack
Slip surface
Limestone layer
Shale
Col.-Colluvium
Dk.-Dark brown silty clay
Lt.-Light yellow brown silty clay
Br.-Fresh bedrock
W.Br.-Weathered bedrock
Lm.Bk.-Limestone block

the shear surfaces, stretched along the surfaces in the direction of landslide movement, and then projected upward in random directions toward the soil surface. A photograph (Figure 16) of a shear surface shows that numerous roots project through the shear surface, with many of the roots clustered in groups, suggesting preferential growth along bedrock fissures.

Individual roots associated with the surface (Figure 16b) are reoriented abruptly in the vicinity of the shear surface. The roots are reoriented at angles aproaching 90°, with the distortion in the direction of shear.

A second trench was dug within the same active landslide to observe the landslide in cross-section to order to see the effect that a stack of shear surfaces within a shear zone would have on the reorientation of roots. A "V"-shaped trench, 2m in depth, 4m long, and 2-4m wide was made to expose the active shear zone. The zone, 1m below the ground surface, was penetrated by tree roots.

A single root deformed along five anastomosing planes best illustrates the deformation of roots and their involvement with failure surfaces. A 28cm length of the root, measuring 0.7cm in diameter at its widest end is deformed so that it lies parallel with and along all of the shear surfaces. Figure 17 shows the direction of movement along the shear surface, and the orientation of the root along the surface as reflected in the root's alignment within the soil. The root was deformed along the paper-thin surfaces which defined the zone.

The root was within a thin film of remolded soil, which either surrounded the root or formed adjacent to the root. The root appeared to

Figure 16

The shear surface of a shallow, planar landslide.

Figure 16a: The surface, measuring $2.53m^2$ in area, is exposed at 1m below the ground surface. Seventy roots project through the shear surface.

Figure 16b: Roots associated with the shear surface are reoriented abruptly at the surface in the direction of landslide movement.

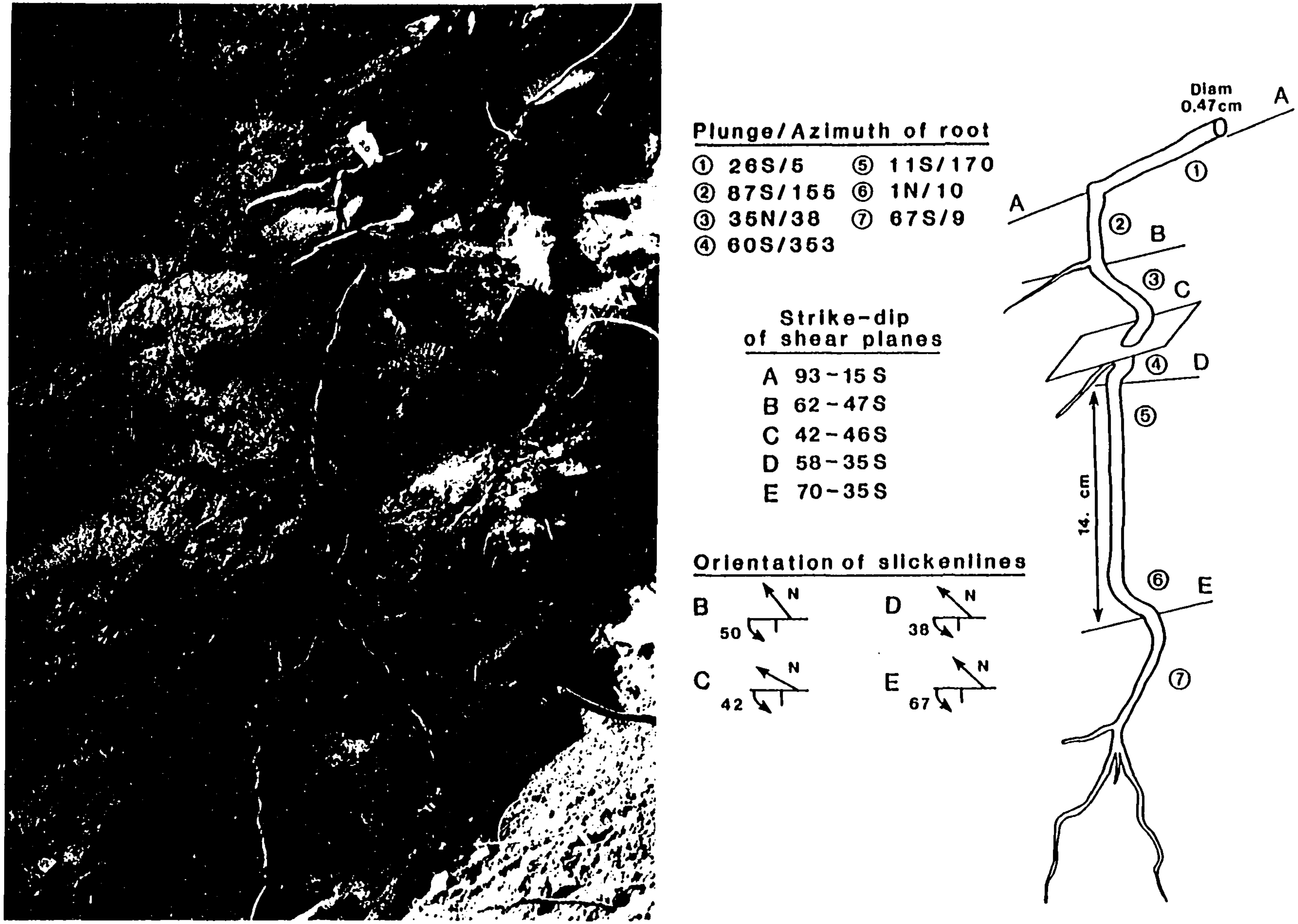
The exposure of the shear surface involved two steps:Approximately 0.9m of the soil overburden was removed by a backhoe, and then the soil lying immediately above the shear surface was removed by hand-excavation. The excavators were Onder Gokce, Robert Fleming, Arvid Johnson and the author.

Figure 17

A root deformed along five shear surfaces in a zone of anastomosing surfaces near the landslide toe.

Figure 17a, The 28cm-long, deformed root passes through a tortuous path within the failed soil. The root is encapsulated within a film of remolded soil. The soil outside the film exhibits little evidence of deformation.

Figure 17b, the deformation of the root is related to the positions of the shear surfaces, and direction of displacement. The root is realigned on each shear surface in the direction of shear as indicated by slickenlines on the shear surface.


Diam 0.47cm
A
Plunge/Azimuth of root
① 26S/5
② 87S/155
③ 35N/38
④ 60S/353
⑤ 11S/170
⑥ 1N/10
⑦ 67S/9
Strike-dip of shear planes
A 93-15 S
B 62-47S
C 42-46S
D 58-35S
E 70-35S
Orientation of slickenlines
B 50 N
C 42 N
D 38 N
E 67 N
14. cm
A B C D E
① ② ③ ④ ⑤ ⑥ ⑦

have slipped through the soil within the film of remolded soil, and to have had little effect on the structure of the surrounding soil.

Figure 18 illustrates two shorter root segments, each reoriented along and nearly parallel with a shear surface, and aligned in the direction of shear as determined by the orientation of slickenlines on the the surface. The association of the roots with the shear planes and their involvement with soil shear is demonstrated by Figure 19, a stereonet of the orientations of root above, and below the shear plane, and the orientations of the slickenlines.

The roots below the surface are randomly oriented. They become reoriented at the surface, and where the roots intersect the shear surface they are approximately colinear with the slickenlines. This suggests that they maintained their original orientation below the surface, and were deformed at the surface.

There is overwhelming evidence that roots are stretched along shear planes during soil failures, and thus do not fail in shear at the plane, but rather are pulled from the soil, and may fail in tension, with the main axis of the root oriented in the direction of soil shear.

A root grows in length from its tips alone, not at any other point along its length. So, to accomodate the stretching and realignment at the shear surfaces roots must be pulled out of the soil during shearing. They cannot lengthen there by growth.

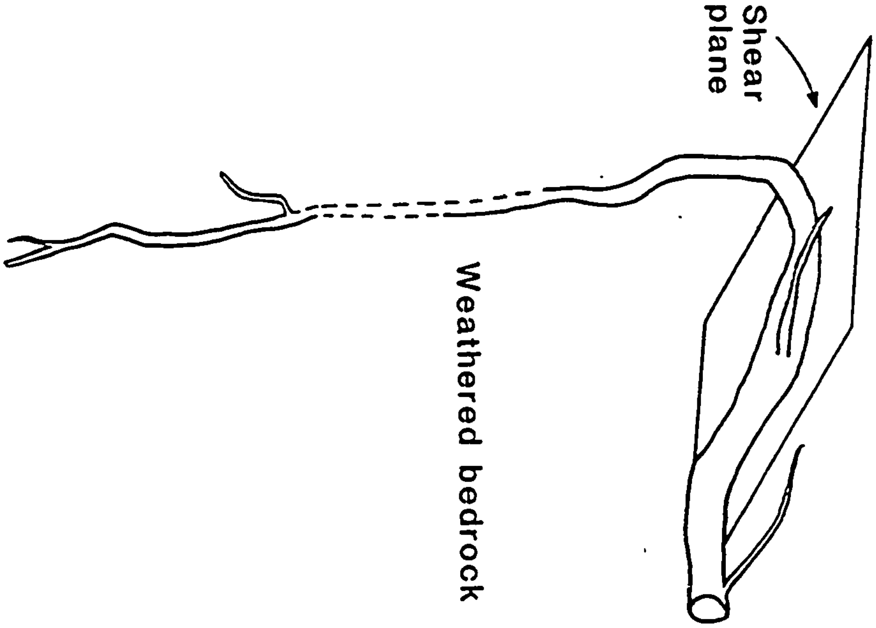
The root is thus acting as a soil anchor, that is, it reaches across a discontinuity, and transmits tensile forces from the failing soil above to the stable substratum below.

Figure 18

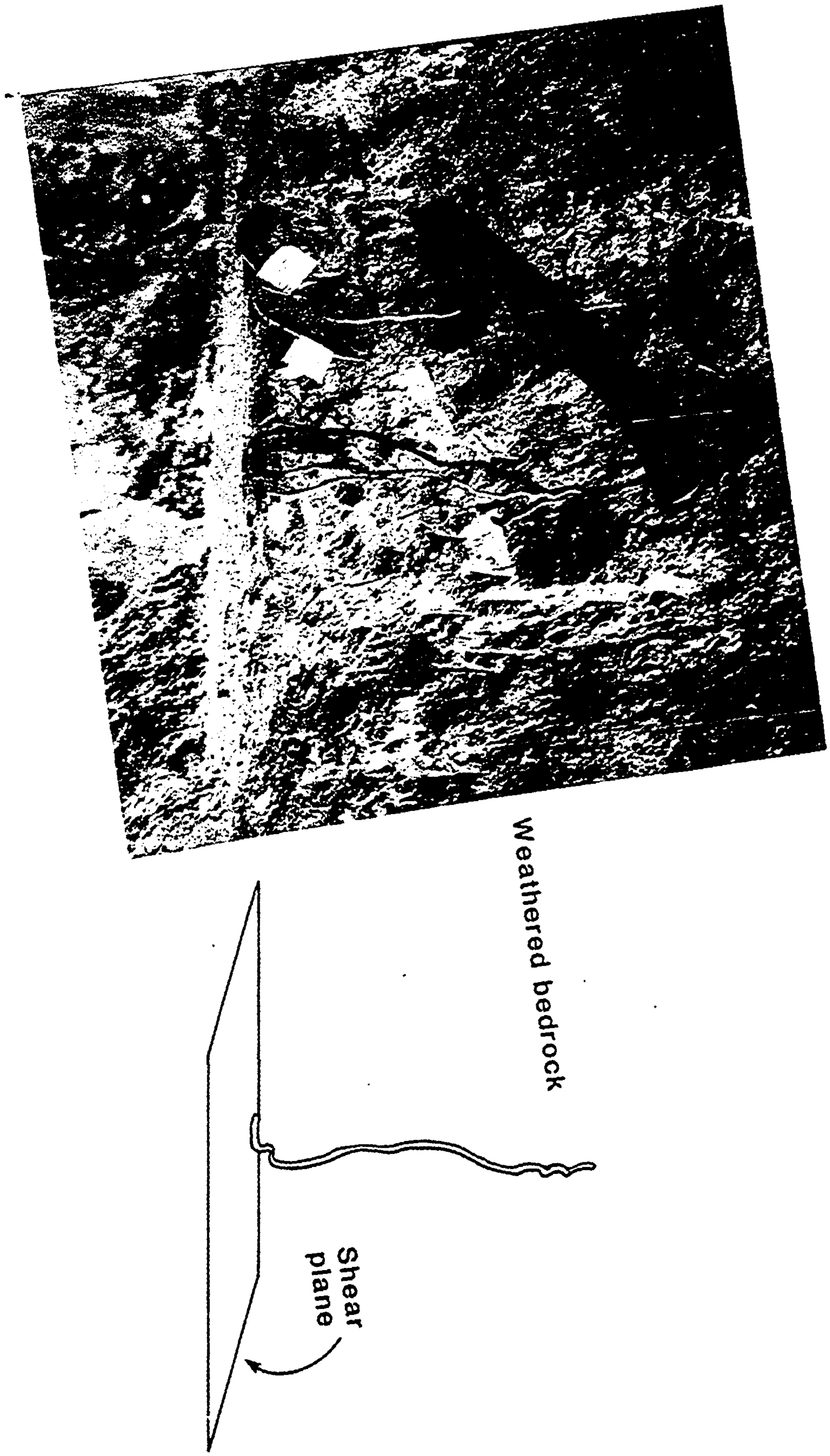
Two deformed roots exposed at the excavated shear plane. The roots are pulled out of their preslide position and realigned at the shear surface during landsliding.

Figure 18a: The root is realigned in the direction of shear at the shear surface. The root is deformed more than 90^{o} from its orientation below the surface.

Figure 18b: The root is realigned from its orientation below the shear surface in the direction of shear at the failure surface. It is abruptly deformed again above the surface at an angle approaching 90^{o} from its orientation at the surface.



Shear plane
Weathered bedrock


Weathered bedrock
Shear plane

CHAPTER FOUR

In-situ Resistance of Roots to Pull-out, a Measurement of the Effectiveness of Tree Roots as Soil Anchors

Introduction

A soil anchor is a "sub-structural member which transmits a tensile force from the main structure to the surrounding ground" (Hanna, 1982). The strength of the ground which is penetrated by the anchor resists the tensile force and holds the structure in place.

A tree is anchored to the soil in which it grows by the anchoring potential of its roots, that is, the potential of the roots to resist tensile forces. This anchoring potential is a result of two properties of the roots, first, the tensile strength of the wood itself, and second, the adhesion of the root to the soil. An anchor may fail in pull-out, or in tensile rupture.

Few studies have been made of the anchoring potential of roots. Fraser (1962) studied windthrow and the associated forces required to pull down spruce and fir trees down, and determined that the force necessary to pull out a tree increases with loading rate. The resistance to pull-out increases with root size and with the maturity of the root system. There is a high correlation between pull-out resistance of tree roots and areal extent of the roots. The force required to uproot a plant is reduced if roots are diseased (Ortman *et al.*, 1968) or if the roots have begun to decay (Kitamura and Namba, 1968).

During shear tests of soil pedestals supporting alder saplings, numerous roots failed as anchors in pull-out (Endo and Tsuruta, 1969), rather than by shear along the shear plane.

Measurement of the Resistance of Tree Roots to Pull-out

The resistance of the roots of sugar maple and white ash to pull-out was measured at the excavations dug by the vermeer spade for the study of root distribution at the Spring Grove site.

The shallow landslides in Cincinnati are highly seasonal, with most occurring during the late winter and early spring, the seasons during which the water content of the soil is high. The trees are not in leaf during these seasons, so there is no water loss due to transpiration. In order to try to reproduce soil conditions similar to those during winter and spring, the water content in the soil at the test sites in Spring Grove was maintained as high as possible by daily watering.

Samples were removed from the horizons of the soil through which roots penetrate to determine water content. The samples were taken during late April, 1984, after a heavy rainfall, and during early March, 1984. The percent moisture by weight was determined at various depths.

Throughout the late spring and summer, the soil was kept wet by continual watering. The daily watering of the soil reduced the effects of changing moisture levels on the strength of the soil. The soil moisture throughout the testing period is compared with that measured during the spring in Figure 19A. The average soil moisture was 21.8%, both during the early spring and during the field season.

Trees with girths ranging fom eight to 16cm were tagged and excavated by a vermeer spade at the Spring Grove site. The soil outside the conical excavations (115cm in diameter at the ground surface, pinching out to 45cm in diameter 85cm below the ground surface) was mapped, and the roots exposed at the surface labeled with a tag listing its species, tree number, and individual root number. Measurements of

Figure 19

Stereonet of orientations of roots at and below a shear surface, and of orientations of slickenlines on the surface. The roots below the shear surface ("L") plunge randomly; roots at the surface ("U") are colinear with the slickenlines ("S") on the shear surface. (Program written by K. Cruikshank)

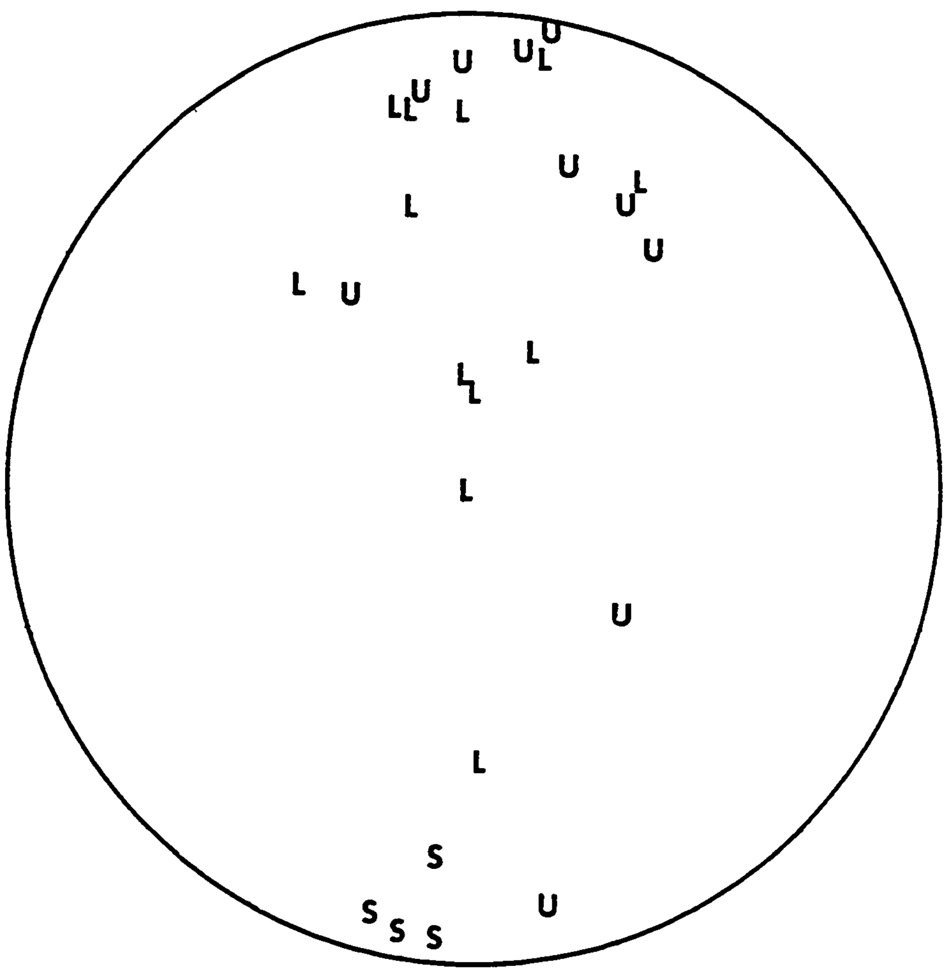
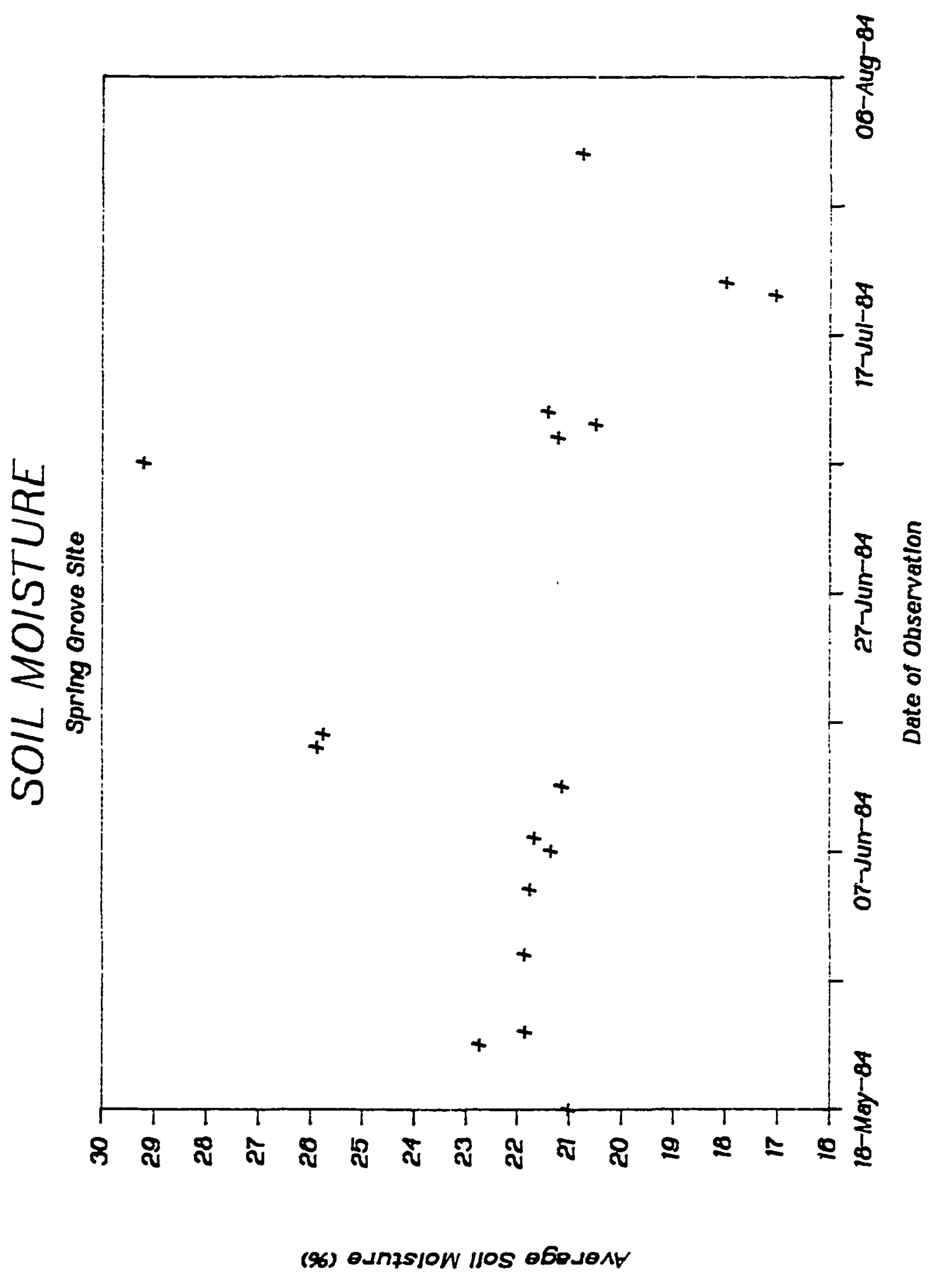


Figure 19A

Moisture content of soil measured in March after a week of rain averaged 21.8%. The average soil moisture measured during the testing of pull-out resistance of roots during late spring and summer also averaged 21.8%. The soil was kept moist throughout the summer field season by frequent watering of the study site.

The soil moisture content is determined as the percent water content by weight per weight of the wet soil; the soil moisture levels are compared with those calculated by comparing the water content by weight with the dry weight of soil in the appendix.


SOIL MOISTURE
Spring Grove Site
Average Soil Moisture (%)
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
18-May-84
07-Jun-84
27-Jun-84
17-Jul-84
06-Aug-84
Date of Observation

the diameters of the roots projecting from the excavation face, their depth, and orientations were noted. The tips of the roots were skinned of bark to prepare them for gripping with cable pullers as part of the pull-out test described below.

A boat winch of 5.3kN capacity was modified by Daniel Joyce (electronics technician, Dept. of Geology) to pull out the roots (Figure 20). The hand-operated winch was anchored, and its load cable attached to the root by an electrician's cable puller. Either a single cable or a pulley with a mechanical advantage of four was chosen, depending on the size of the root to be pulled. The cable was threaded through a pulley supported by a beam to eliminate friction and to accomodate alignments of the cable (Figure 21).

The winch was modified by adding two plates, which were separated by calibrated springs. A linear potentiometer was attached to the hinged plate. Dial cord was wrapped around the potentiometer shaft, and attached to the fixed plate. As the load on the cable was increased, the calibrated springs compressed between the boards, and the potentiometer rotated, recording the force as a function of spring compression. The number and size of springs could be altered as needed. As the load developed in the cable, bolts were tightened between the plates, to reduce the effect of rapid pressure release. To insure safety, workers[1] (see acknowledgements) wore goggles and gloves, and stood behind barriers. The cable was snared in several places.

To measure displacement, a linear potentiometer was attached to the pulley beam. Dial cord was attached to the root, and wound around a potentiometer. The free end of the cord was weighted. As the root

Figure 20

The modified winch used to pull roots from the vermeer excavations. As the load on the cable was increased, the calibrated springs between the two boards attached to the winch were compressed. The compression was sensed by a potentiometer and recorded on a chart recorder powered by a portable generator. Calibrations of the winch preceded each field session.

MODIFIED WINCH

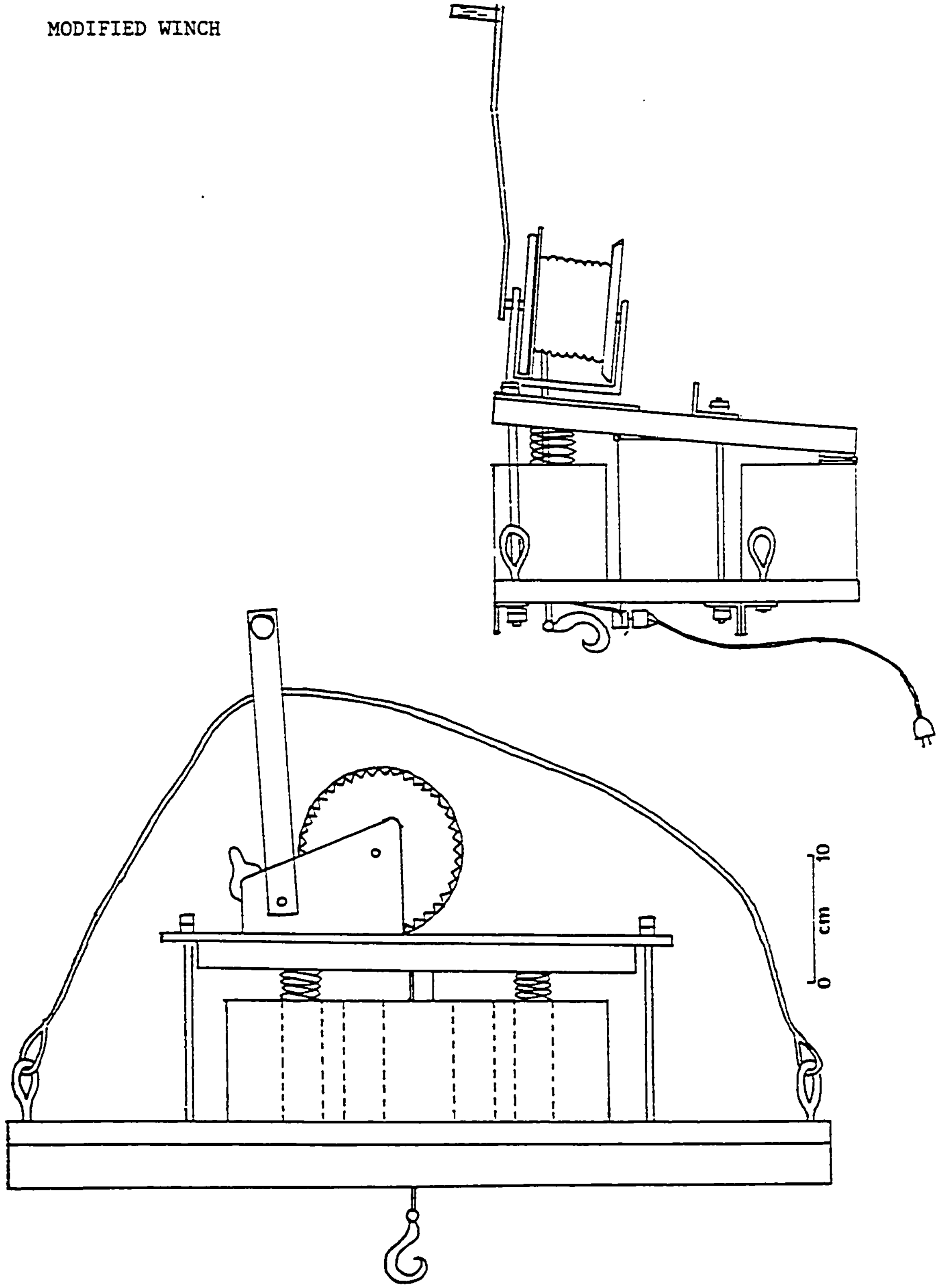
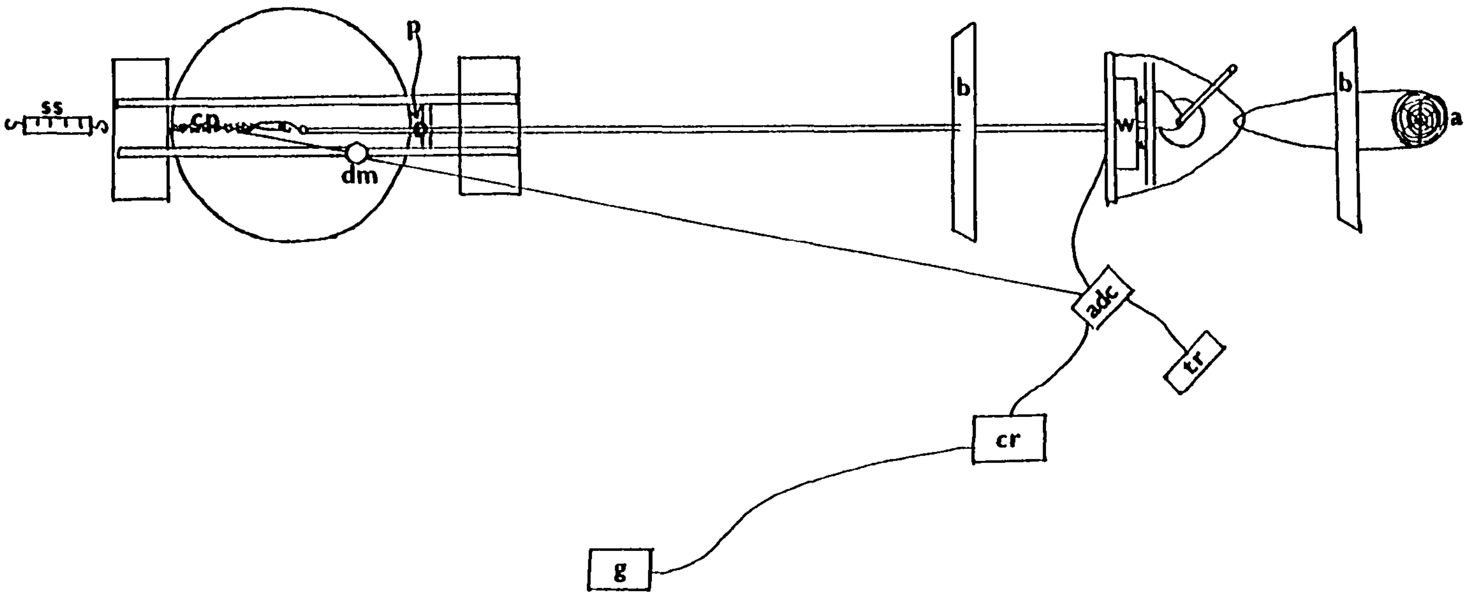


Figure 21

The field set-up for the testing of resistance to pull-out. Both load and displacement were measured for each root and recorded on a chart recorder powered by a portable generator. The field equipment was designed and built by D. Joyce.

FIELD EQUIPMENT

ss	spring scale	adc	analog to digital converter
cp	cable puller	tr	tape recorder
dm	displacement monitor	cr	chart recorder
p	pulley	g	generator
b	barrier	a	anchor
w	modified winch		



displaced, the cord loosened and the weight turned the potentiometer, recording the displacement.

The potentiometers delivered signals related to load and displacement to a dual channel chart recorder. Readings of the chart recorder were calibrated before each run. The load was calibrated by pulling a reference spring scale. The displacement was calibrated by pulling the cord measured distances.

For every root pulled, several parameters were measured including:

1. Diameter of root at soil face, and diameters of all truncated ends.
2. Length of root from cut end at excavation face to largest truncated terminis.
3. Order of root pulled, with the first order roots being smallest (i.e., having no smaller roots branching off them), and second order roots being those from which first order roots branch, and so on.
4. Depth of root in the soil at face of excavation, and it its azimuth and plunge.
5. Species of root. Sugar maple and ash sometimes protruded from the same soil face but were easy to distinguish from each other; the ash has a distinctive thick, pale gray-brown bark, and is ring porous, whereas the sugar maple has a deep brown bark, underlain by red phloem layer, and is diffuse porous.

Analysis of Data

A plot relating load, displacement and time was constructed for each root removed from the soil. These plots were drawn from data recorded by the portable chart recorder. The charts for each root were coded by measuring the magnitude of the displacement and force at each inflection on the chart recording. The coded data were entered into a computer program written by David Nash, which calibrated the data and then plotted force and displacement as a function of time, and then force as a function of displacement. The coded data for the tests, the plots, and the computer program which generated the plots are in Appendix C. These data are complex and difficult to interpret. Two end-member data sets, SM4.08 and SM6.02 illustrate the measurable characteristics of the pull-out test, as well as the complexity of the recordings for the pull-out test.

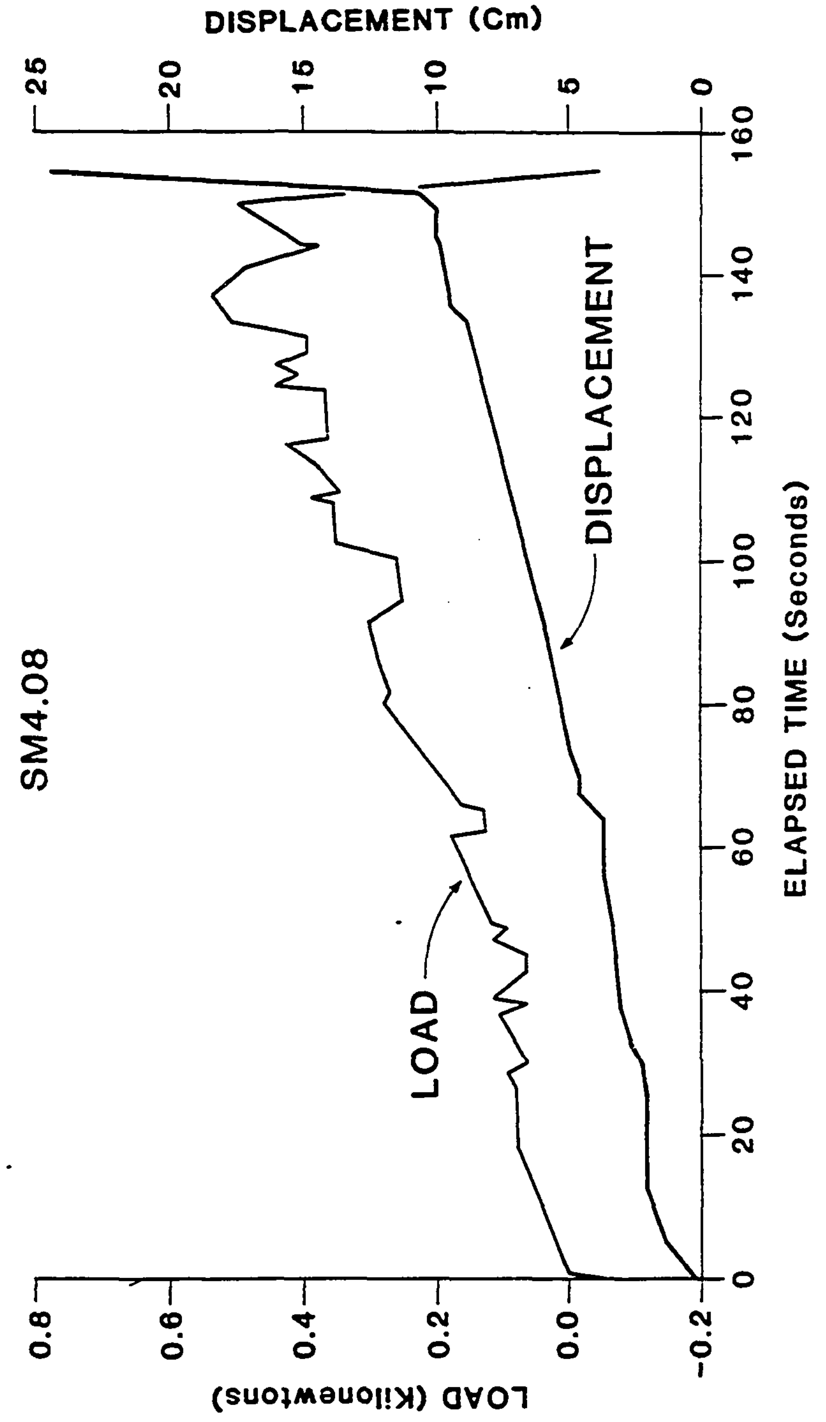
Constant velocity test, SM4.08---The load on the root was increased by slowly turning the winch by hand. The load-displacement-time plot for sugar maple #4.08 (Figure 22) illustrates the pull-out of a 0.7cm diameter root from soil 0.18m below the ground surface. The extracted root segment was 32.5cm in length, with its largest broken end measuring 0.62cm in diameter. The relatively straight root segment contained five class one branch that roots which were truncated within 10cm from the main root. The duration of the test was 150s, total root displacement 9.85cm, tensile breaking force 0.47kN, breaking stress $3 \times 10^3 kN/m^2$, velocity $6.56 \times 10^{-2} cm/s$, and strain 4×10^{-4}. The deformation rate (change in length per length per time) was $2.02 \times 10^{-3}/s$.

On the plot of load and displacement versus time the load curve is spiked, but on the average its slope remains positive until failure. The maximum load is applied near the end of the test, the load decreases, then increases to the tensile breaking force, after which it falls to zero.

The displacement curve of SM4.08 is of nearly uniform slope, with intermittant rises in magnitude. Occasionally the rise in magnitude of displacement is associated with a drop in load.

Figure 22

Sugar maple #4.08 (SM4.08). The load and displacement recorded in the pull-out test are plotted against elapsed time. This is an example of a constant velocity test.


SM4.08
DISPLACEMENT (Cm)
0
5
10
15
20
25
LOAD (Kilonewtons)
-0.2
0.0
0.2
0.4
0.6
0.8
ELAPSED TIME (Seconds)
0
20
40
60
80
100
120
140
160
LOAD
DISPLACEMENT

The root displaced 32.5cm during the test; 1.3×10^{-2}cm of displacement may be explained by the elastic deformation of the root.

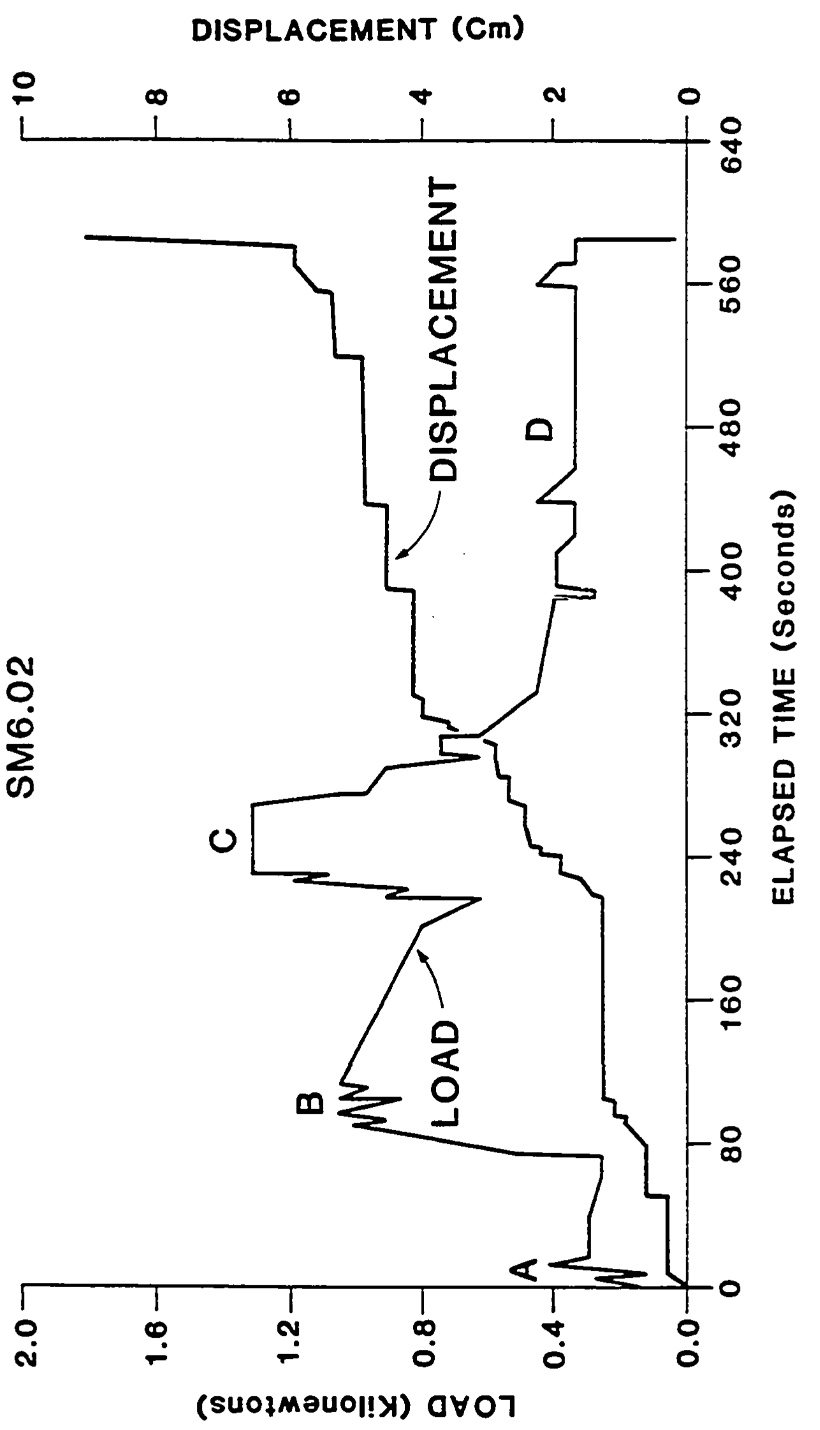
Creep test,SM6.02---The plot of load and displacement versus time for SM 6.02 is more complex than the plot for SM4.08 (Figure 23). The root was 1.56cm in diameter, and required a larger force to fail than SM4.08. The time elapsed was 590s, during which loading had to be interrupted to change the amplitude of the chart recorder. These interruptions inadvertently tested for creep under constant load.

The root displaced six centimeters with an average pull-out velocity of 1.02×10^{-2}cm/s until it failed at 590s. The initial segment of the test was a constant velocity test (see "a" on plot), during which the root displaced 0.31cm at a velocity of 4.43×10^{-2}cm/s, with a deformation rate of 6.4×10^{-4}/s, at a stress of 5×10^2kN/m^2. The strain measured 5.6×10^{-4} with a 3.8×10^{-2}cm change in length due to elastic deformation. At a load of 0.3kN, there is no creep for 30s, followed by an abrupt change in deformation with a gradual decrease in load. The segment of the plot designated "b" shows another constant velocity test, but the velocity here is 2×10^{-2}cm/s, about half as fast as the beginning of the test. The increment of displacement here is 0.6cm, with an increase in load of 0.77kN, with a rate of deformation of 2.9×10^{-4}/s.

The segments of the plot marked "c" and "d" show relatively constant loads associated with displacement, or creep. In the "d" range, the elapsed time is 240s, displacement increment is 1.7cm, with an average load of 0.38kN. The velocity is 7.08×10^{-3}cm/s, an order of magnitude less than the constant velocity test. The stress is 6.3×10^2kN/m^2, and

Figure 23

Sugar maple #6.02 (SM6.02). Creep test of pull-out resistance. The root displaces under constant load, as seen in segments "c", and "d" of the plot.


SM6.02
DISPLACEMENT (Cm)
LOAD (Kilonewtons)
ELAPSED TIME (Seconds)
DISPLACEMENT
LOAD
A
B
C
D
0.0
0.4
0.8
1.2
1.6
2.0
0
2
4
6
8
10
0
80
160
240
320
400
480
560
640

rate of deformation 10^{-4}/s. The strain is 7×10^{-4}, with the change in length due to elastic deformation equal to 4.8×10^{-2}cm.

The root segment which pulled out was 69cm in length, measured from the pulled end to the largest truncated terminus, and 1.0cm in diameter. The relatively straight segment had one major side branch, 20 class one branches and two class-two branches. One 0.55cm-diameter short branch projected from the root near its largest truncated end. All branches were truncated, but several were branched with numerous nonwoody, broken, tiny laterals.

Displacement as a function of root sinuosity---Only about 4% of the measured displacement can be explained in terms of the root's elasticity, so an analysis was performed to determine whether the straightening of the root's curvature during loading could explain the measured displacement. Ten roots were selected randomly, and the straight-line distance, and the distance along the root's length between the pulled- and truncated ends, were measured and compared. The difference in length between the straight and sinuous paths could account for only 13% of the measured displacement.

Therefore, roots with large displacements and small differences in length between the straight line distance and the distance along the root's length between their two termini, must have moved along most of their length during testing. The distance between the truncation at the termini and the point at which the soil-root bond failed allowing displacement cannot be determined by the field data.

Laboratory testing of root tensile strength

The computer program (written by David B. Nash, Dept. of Geology) which plotted the relationships between load, displacement and time listed all forces and displacements for each root tested. To compare the measured forces with the tensile breaking force for maple and ash roots, the tensile strength of the roots of the two species was measured in a laboratory. A MTS testing machine (courtesy of the College of Engineering), with a capacity of 22kN was used to measure the tensile strength of sugar maple and white ash roots.

Fresh, green roots were collected, cut into lengths appropriate for the testing machine (20 to 30 cm), and kept moist. The bark was shaved from the ends of the root to reduce slippage of the roots during testing. Electrician's cable pullers were used to hold the root. The bias weave of the cable puller allowed for tight holding with little damage to the root. The root was placed between two rods, one stationary, and the other which displaced at a rate determined by the operator. As the spacing between the rods increased, load on the root increased. The stroke (displacement) was increased and the load monitored until the root broke in tension.

Results of the strength tests for both species are as follows. The average strength of a sugar maple root is 2.85×10^4 kPa ($r^2 = 0.92$). The average breaking strength of a white ash root is 2.22×10^4kPa ($r^2 = 0.83$). The error associated with the test is such that the strengths of the two species may be considered to be essentially the same, however the best-fit curve for each species is used in further analyses of the pull-out test.

Although the breaking strength of the two species are similar, the mode of failure for each species is related to the morphology of its wood. The white ash has ring-porous wood, with obvious bands of large and small xylem vessels and the sugar maple has diffuse porous wood, which appears homogeneous. The white ash would display a stepped failure surface due to longitudinal failure within the large vessels, and failure transverse to the long axis of the root. The failure surface in sugar maple appeared ragged to smooth, with no preferred planes of failure. In tests performed on root segments with intact bark, failure always occurred at the interface of bark with wood for both species.

Analysis of the field data

The results of the laboratory testing of root strength in association with the field measurements of root pull-out resistance illustrate the following:

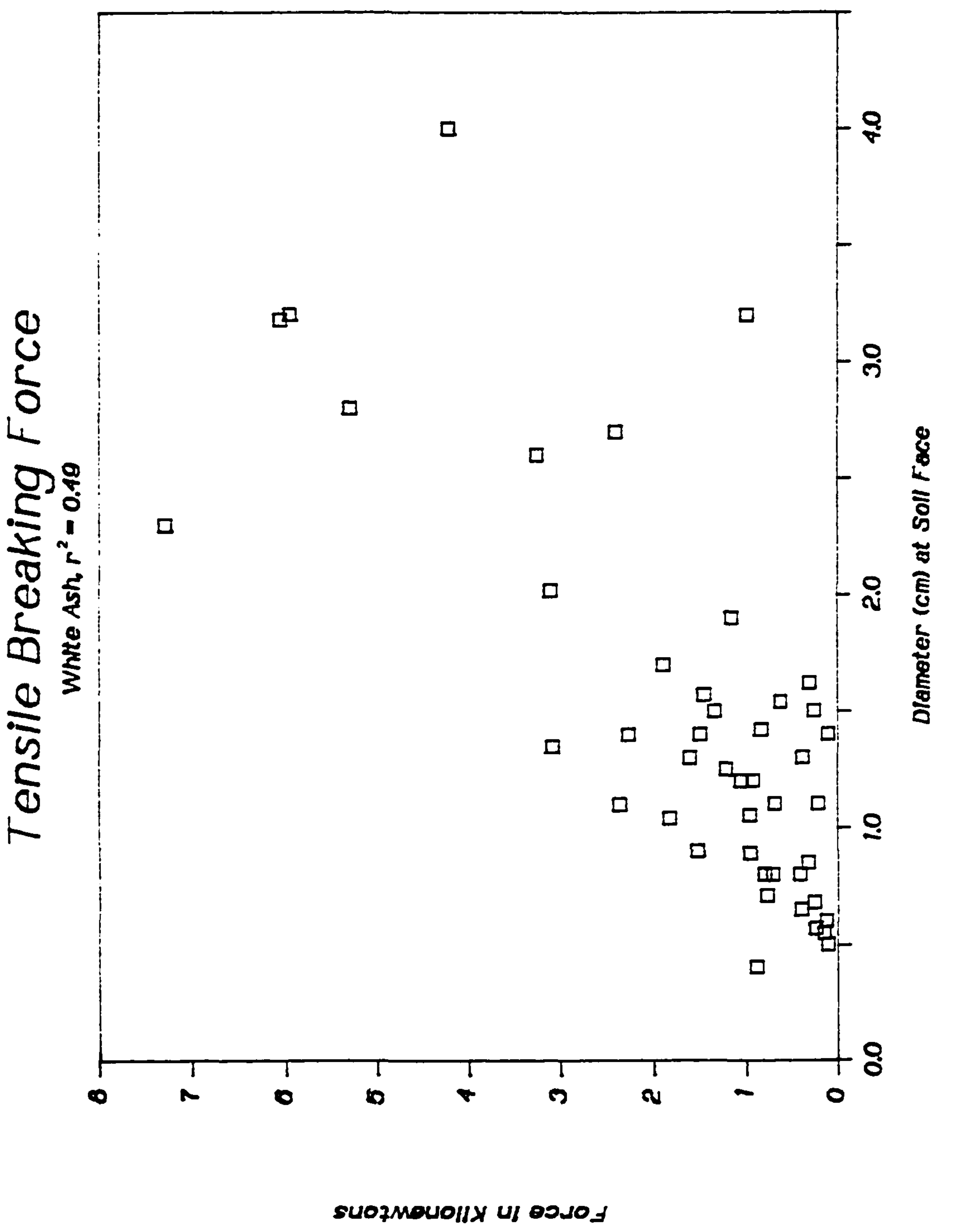
1. The tensile breaking force of a root being pulled from soil increases with root diameter for sugar maple and white ash (Figure 24). The breaking force is the final major force acting on the root which causes failure.

The accompanying correlation coefficients show that the field data have a fair amount of scatter, especially for white ash. A step-wise multiple regression of the parameters measured in testing the pull-out resistance of a root selected diameter as the factor which best predicts the breaking force (Appendix D).

2. There is a better correlation between the maximum tensile force applied to the root and root diameter than between the final tensile breaking force and root diameter. The tensile breaking force was

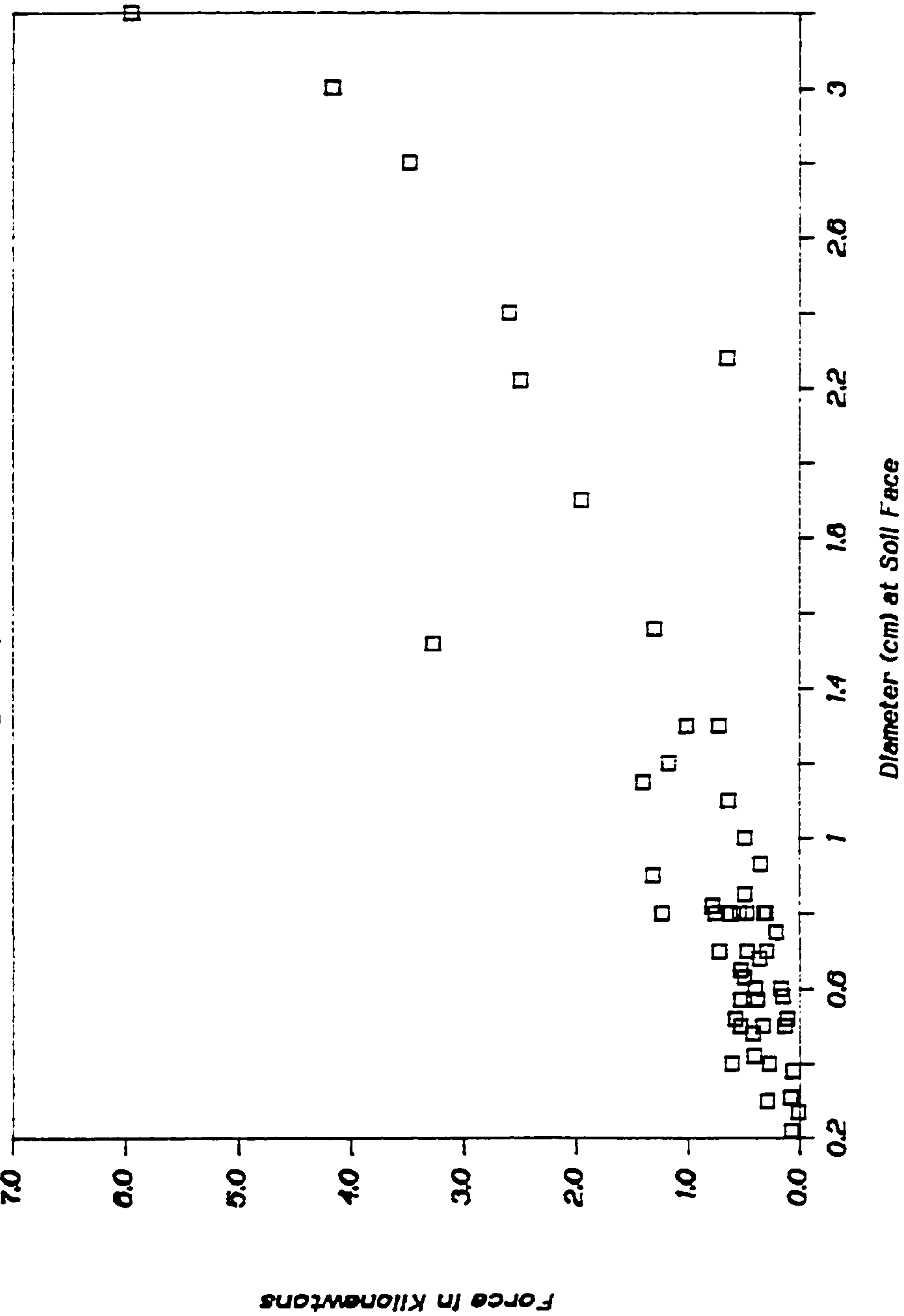
Figure 24

The tensile breaking force of a root in pull-out. The factor which best predicts the resistance of a root to pull-out is its diameter. A secondary factor affecting pull-out resistance is the length of the root.


Tensile Breaking Force
White Ash, r² = 0.49
Force in Kilonewtons
Diameter (cm) at Soil Face
0
1
2
3
4
5
6
7
8
0.0
1.0
2.0
3.0
4.0

Tensile Breaking Force

Sugar Maple, $r^2 = 0.78$



commonly less than the maximum tensile force acting on the root in pull-out (Figure 25).

There are three basic patterns of force-displacement observed in the pull-out test. In the first pattern there is an initial rise in force with little or no displacement, and a gradual reduction in force with continuing displacement. A second pattern is an abrupt rise in force with little displacement, followed by a plateau in force which falls off abruptly. The third pattern is a rise in force with displacement, followed by a fall in force, then another rise in force with displacement, then failure. In the third pattern, the maximum force applied to the root is associated with the initial peak, and is greater than the tensile breaking force associated with the second peak.

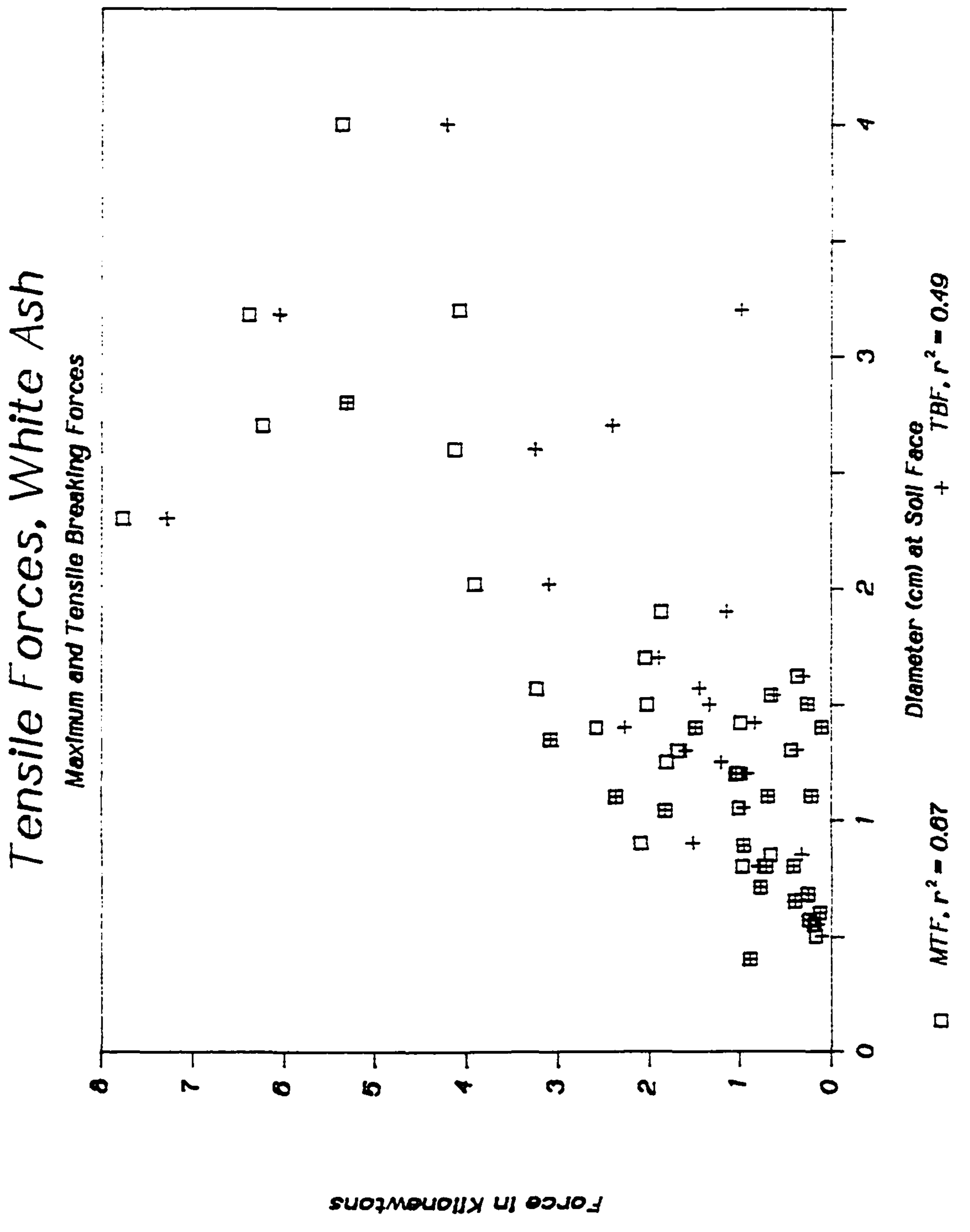
3. The force predicted by the best fit line for breaking strength as measured in the laboratory to break a root of the diameter exposed at the soil face is greater than the measured tensile breaking force (Figure 26).

This difference between observed and predicted breaking forces may be explained by the observation that roots pull out of the soil under an axial force, and break at a segment of smaller diameter than that exposed at the trench face.

The model used in the analysis of the Rapid Run landslide (Riestenberg and Sovonick-Dunford, 1983) assumed that the breaking force of a root can be predicted from its diameter at the shear surface. The pull-out test shows that root failure occurs at a distance from the applied force as demonstrated by the different lengths of broken roots of similar diameters.

Figure 25

Tensile breaking force (TBF) compared with the maximum tensile force (MTF).The final force which breaks a root (tensile breaking force) may be less than the loads applied earlier in the pull-out test. The forces placed on the root may peak several times during the course of the test before a root fails. The relationships of force versus displacement for the roots tested are varied and complex.


Tensile Forces, White Ash
Maximum and Tensile Breaking Forces
Force in Kilonewtons
Diameter (cm) at Soil Face
0
1
2
3
4
5
6
7
8
MTF, r² = 0.87
TBF, r² = 0.49

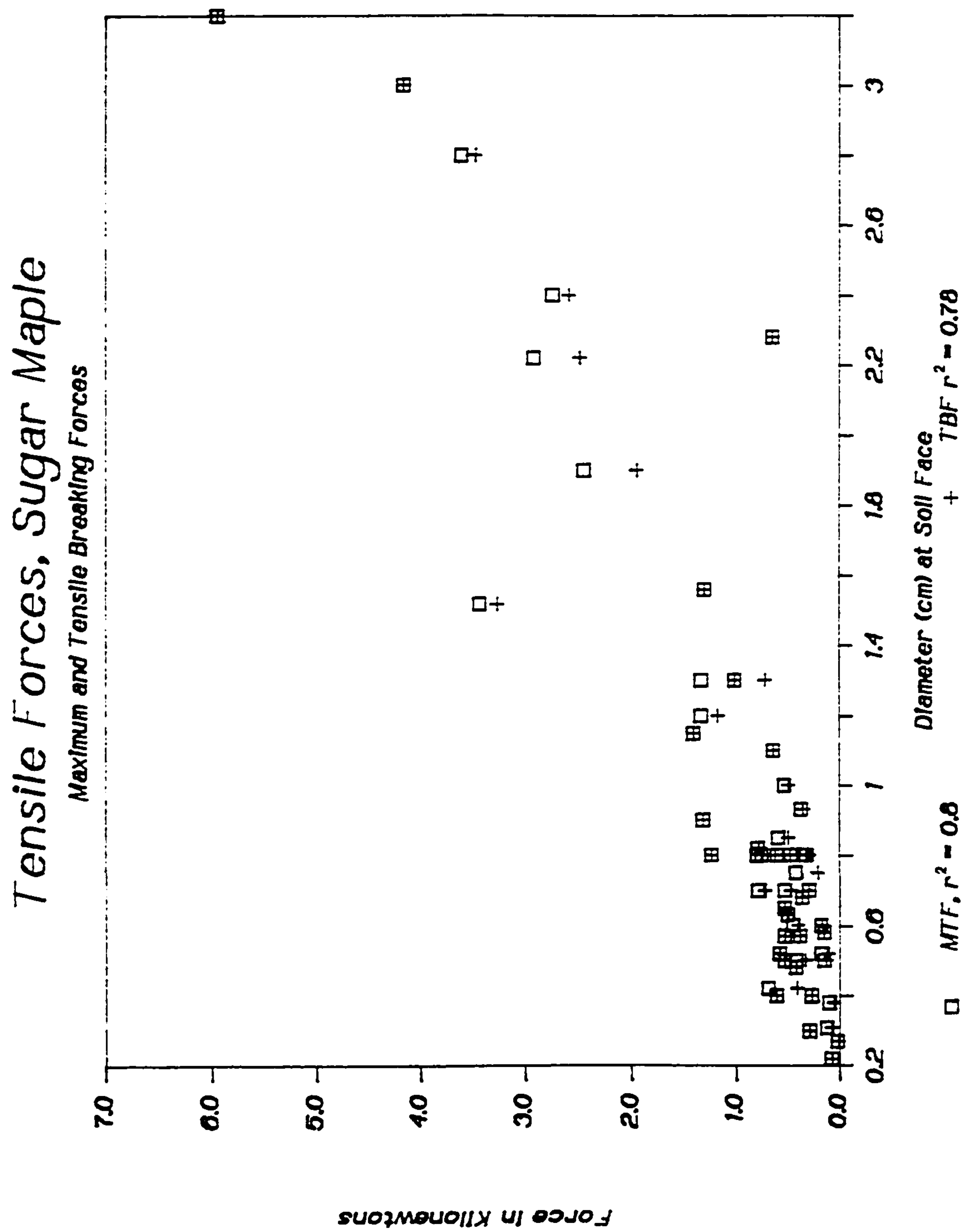
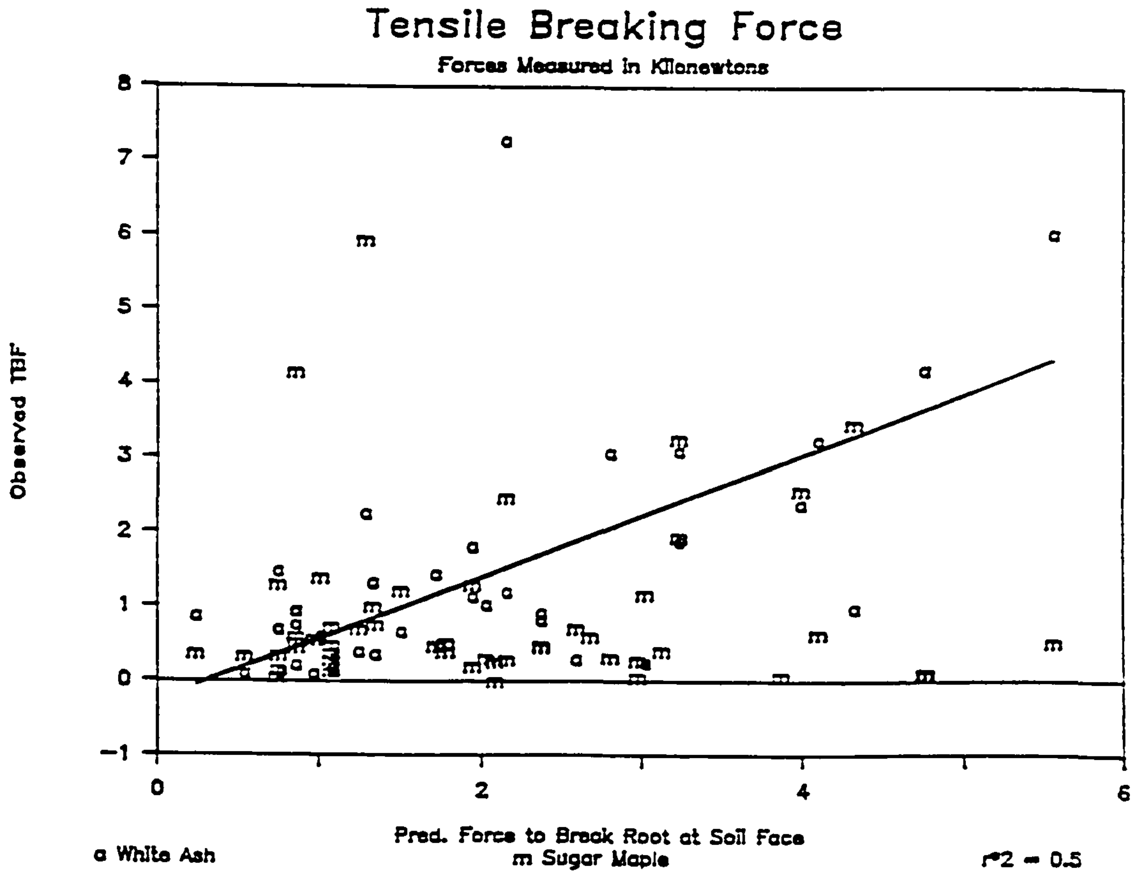

Tensile Forces, Sugar Maple
Maximum and Tensile Breaking Forces
Force in Kilonewtons
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.2
0.6
1
1.4
1.8
2.2
2.6
3
Diameter (cm) at Soil Face
MTF, r^2 = 0.8
TBF r^2 = 0.78

Figure 26

Predicted tensile breaking force versus pull-out resistance. The force predicted to break a root of the diameter exposed at the soil face is greater than the measured resistance to pull-out. The surface area of the truncated ends is less than that of the exposed root. Since the strength is linearly correlated with diameter for the sizes of roots tested, the stressed root segment would naturally reach breaking stress at its smaller branches first.


Tensile Breaking Force
Forces Measured in Kilonewtons
Observed TBF
Pred. Force to Break Root at Soil Face
a White Ash
m Sugar Maple
r*2 = 0.5

Thus, the root fails as an anchor; it displaces under tension and then breaks within the soil at a distance from the axially applied force.

4. The force required to break all truncated termini at once is greater than either the measured tensile breaking force or the measured maximum tensile force (Figure 27). This difference suggests that the branches break sequentially as the root displaces within the soil. The sequence of failure of the branches within the soil cannot be determined from the field data; the patterns of force versus displacement for the roots tested in pull-out display a bewildering variation in form. The fact that all the branches do not break at once suggests that the breaking forces are not mobilized at all root termini at the same time. This may be due to many factors, such as anisotropy of the soil, tortuosity of the root's form, and rate of loading in testing.

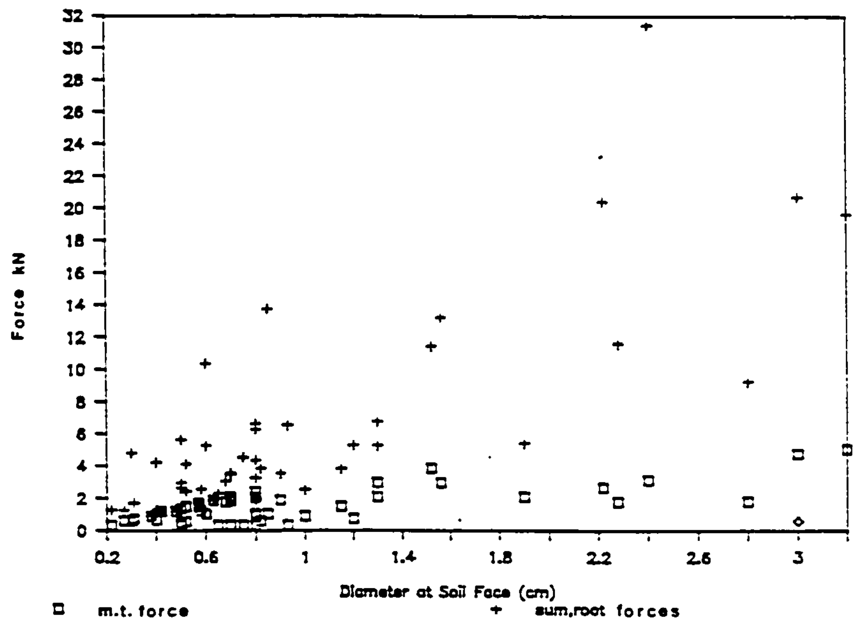
5. The force predicted to break all root termini within the soil at once is greater than that predicted to break a root of the diameter exposed at the excavation face, and that force in turn is greater than the measured tensile breaking force applied to the root (Figure 28). This heirarchy in breaking forces develops because the sum of the cross-sectional areas of the termini of broken branches is greater than the cross-sectional area of the root trunk exposed at the soil face, and the breaking strength of the roots within the species is essentially the same for the range of root diameters tested.

6. There is no preferred plane in the soil within which roots tend to break despite differences in soil texture and gradients in soil moisture. Figure 29 illustrates depths in the soil within which roots failed. The step-wise multiple regression shows a negligible effect of

Figure 27

Predicted force to break all root termini versus tensile breaking force and maximum tensile force. The force required to break all truncated termini of a root at once is greater than either the tensile breaking force or the measured maximum tensile force applied to a root. This suggests that the root branches break sequentially as the root displaces within the soil.

Sugar Maple



White Ash

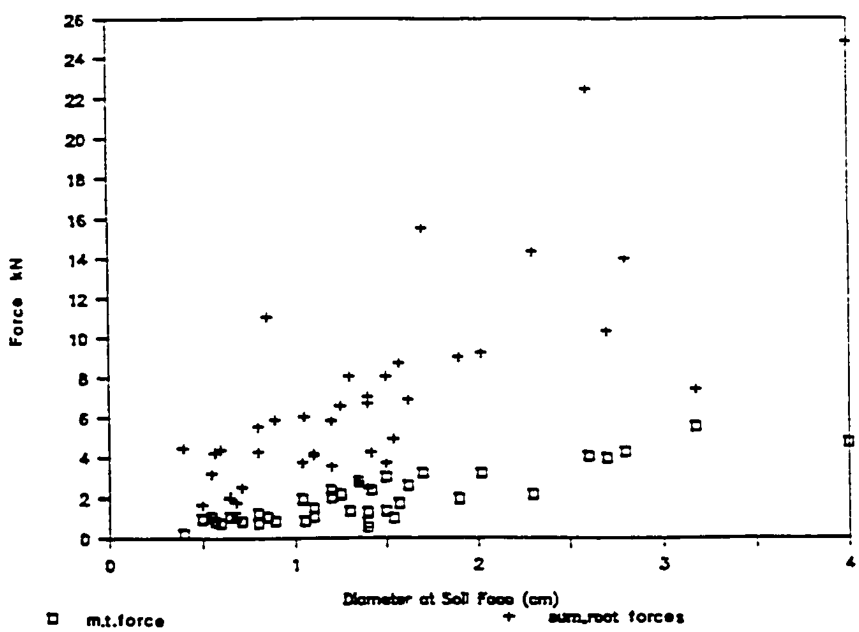
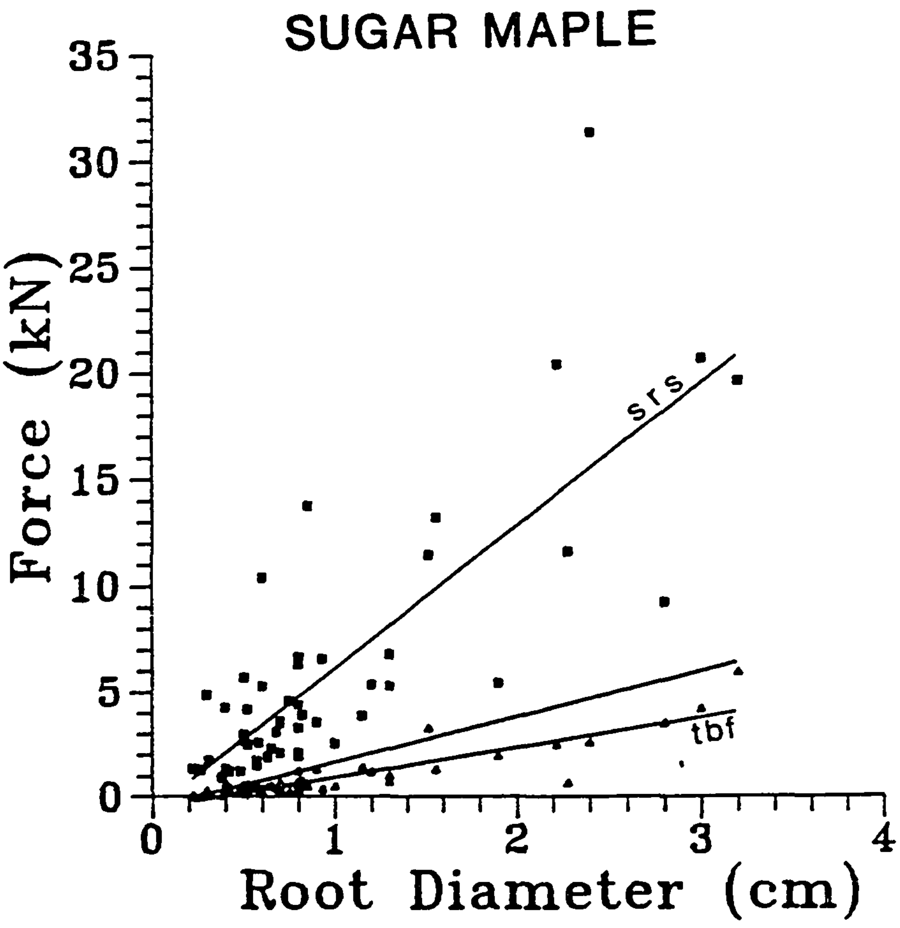


Figure 28

Predicted tensile breaking force versus predicted force to break all termini at once and measured tensile breaking force. The force predicted to break all termini within the soil at once is greater than the force predicted to break a root of the diameter exposed at the soil face, which in turn is greater than the measured tensile breaking force applied to the root. These observations invalidate the assumptions used in the model for the Rapid Run landslide, i.e., that all roots break at once, and that the tensile breaking force is determined by the size of the root which projects through the shear plane in the soil.


SUGAR MAPLE
Force (kN)
35
30
25
20
15
10
5
0
srs
tbf
0
1
2
3
4
Root Diameter (cm)

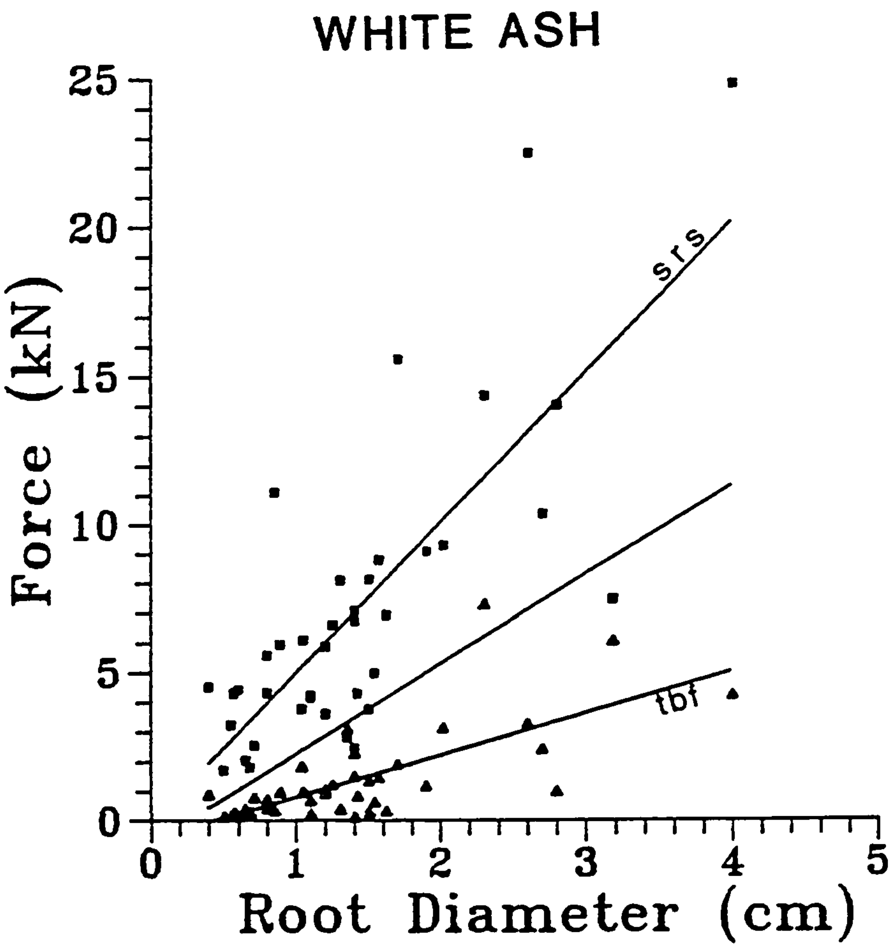
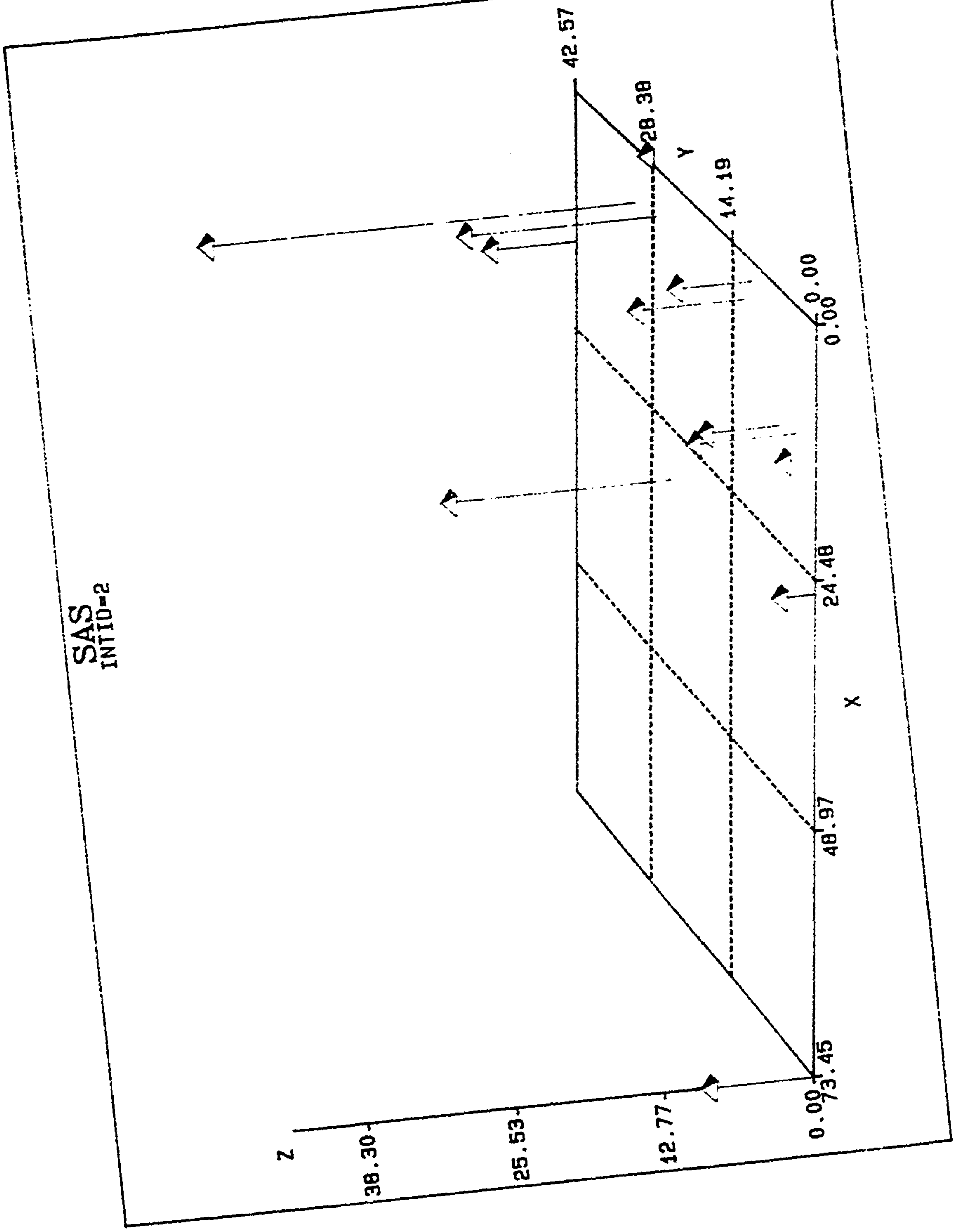
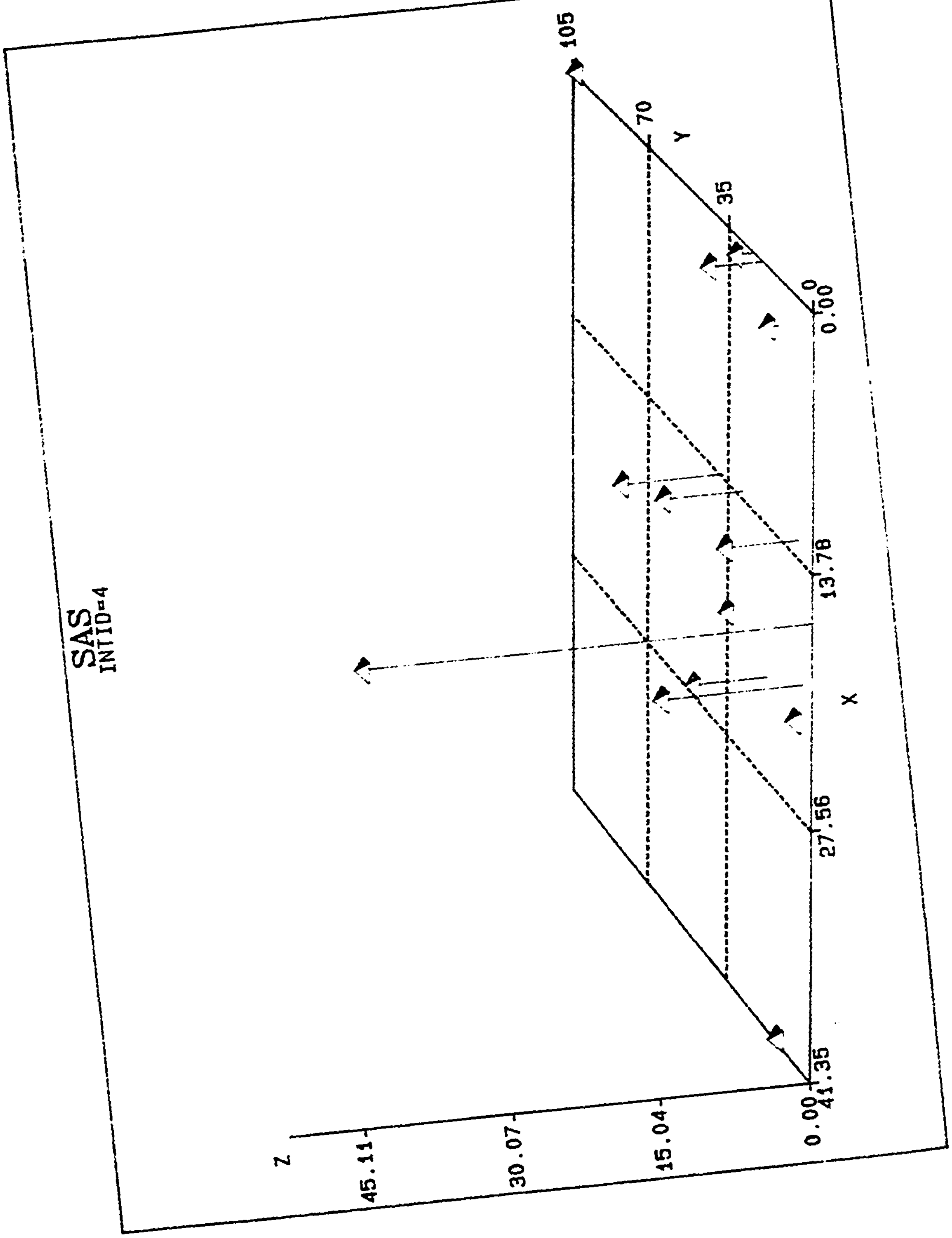
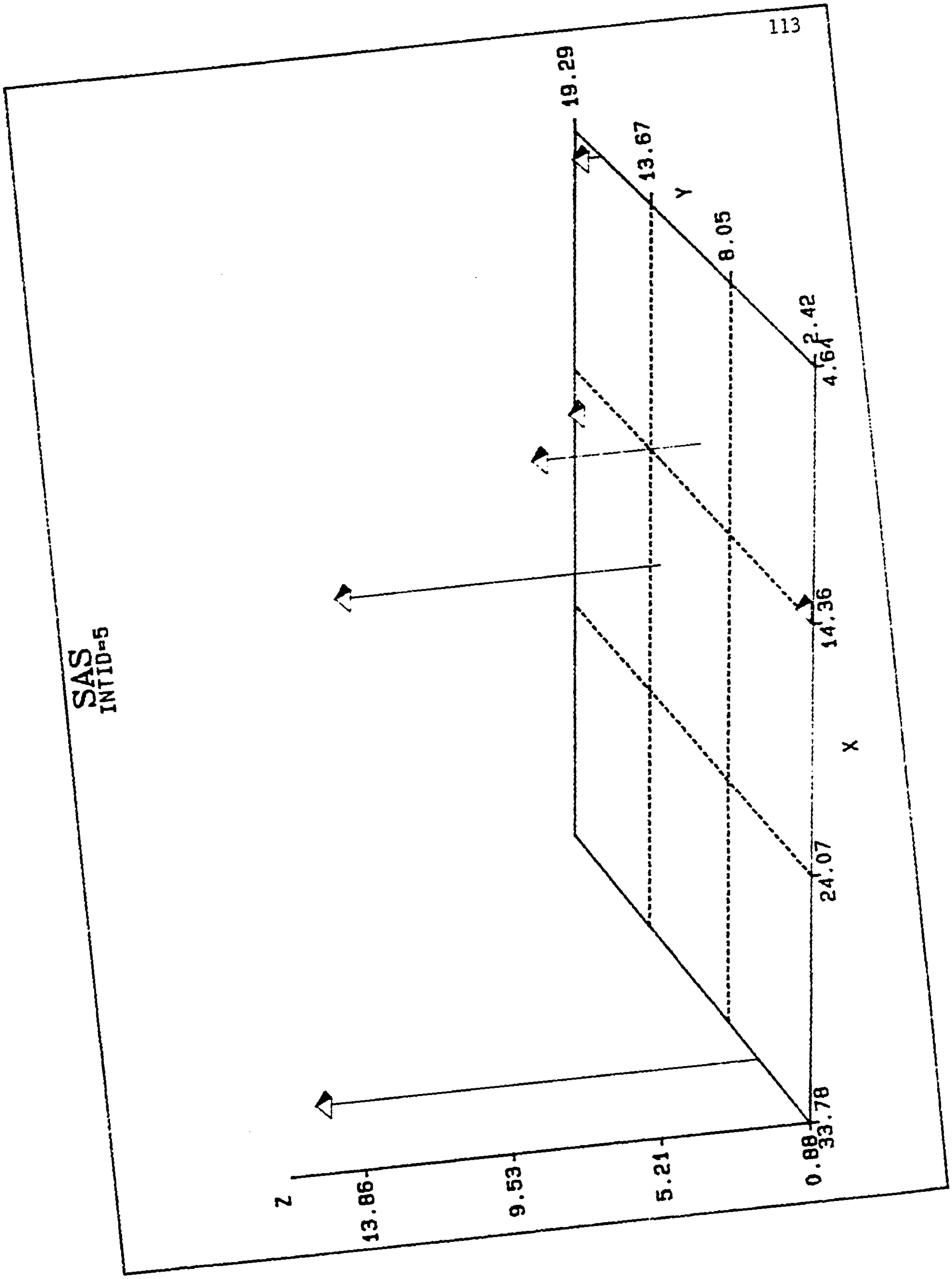

WHITE ASH
Force (kN)
Root Diameter (cm)
srs
tbf
0
5
10
15
20
25
0
1
2
3
4
5

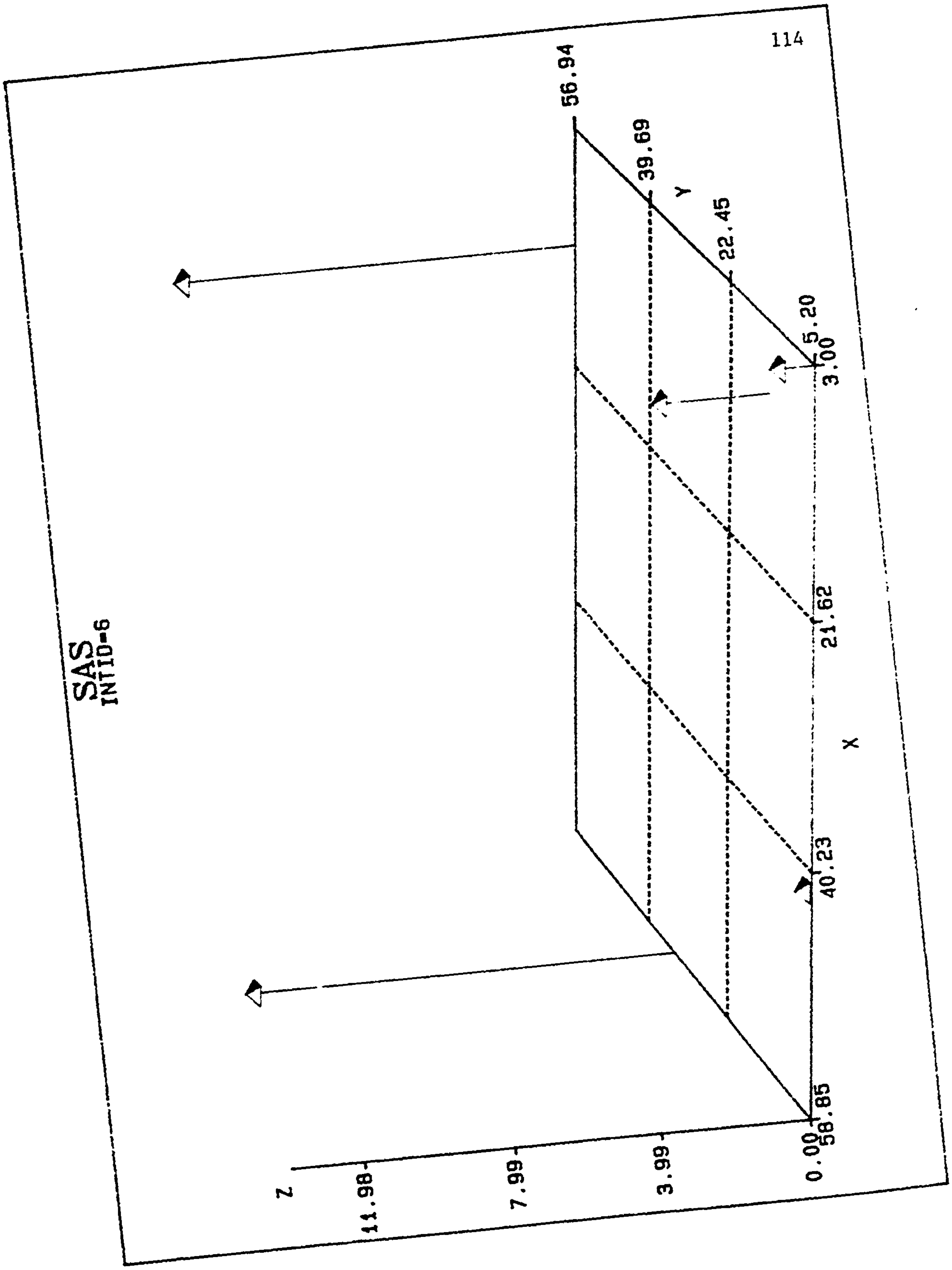
Figure 29

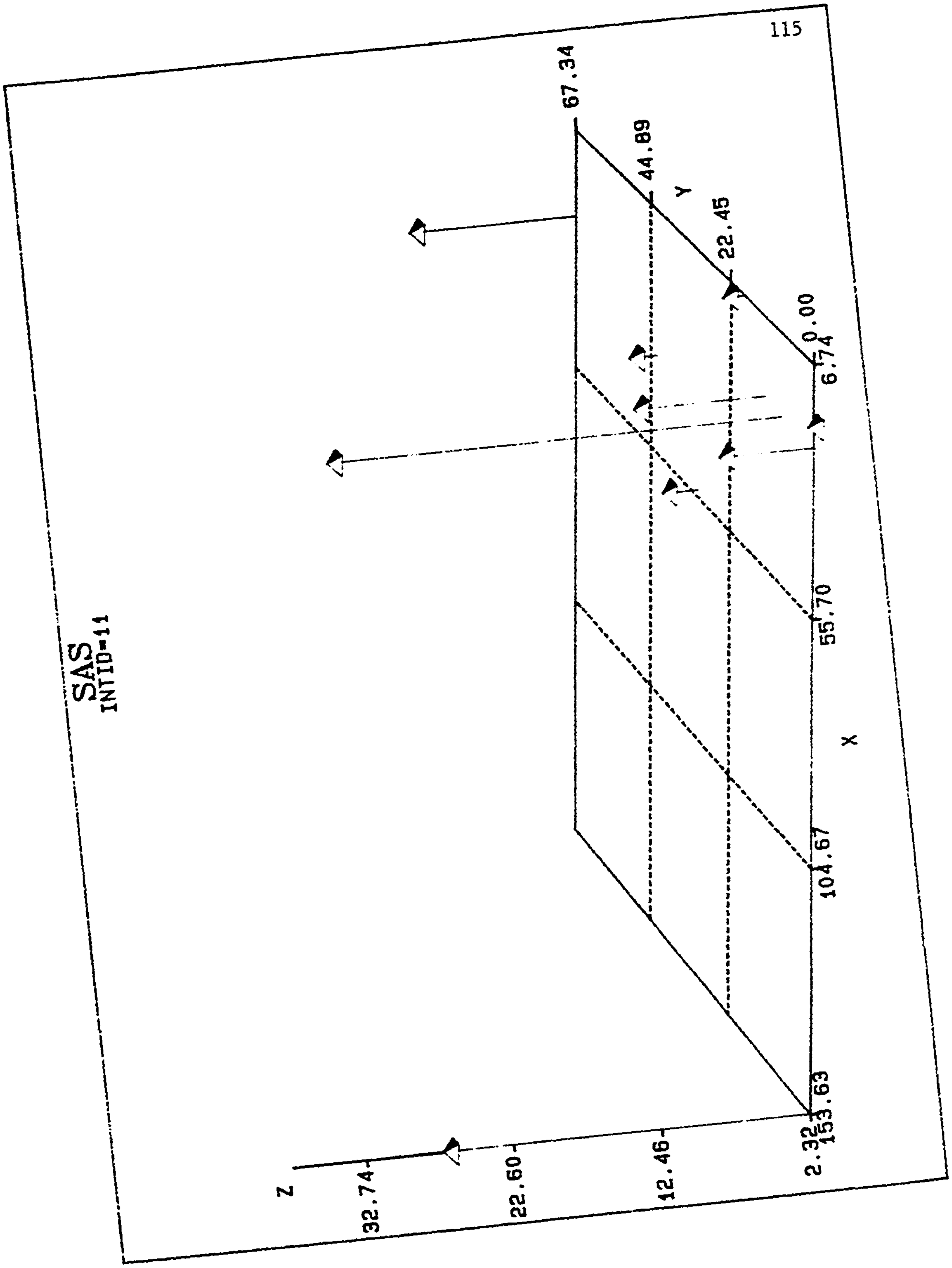
Soil horizon within which roots tend to break. There is no preferred zone within which roots break. The "x" and "z" axes are the horizontal and vertical components of the actual length of the inclined root "y" which was extracted from the soil. The soil is anisotropic, but analyses of the depths at which roots failed within the soil indicate that this has no effect on pull-out resistance. (Program written by R. Stuebing)

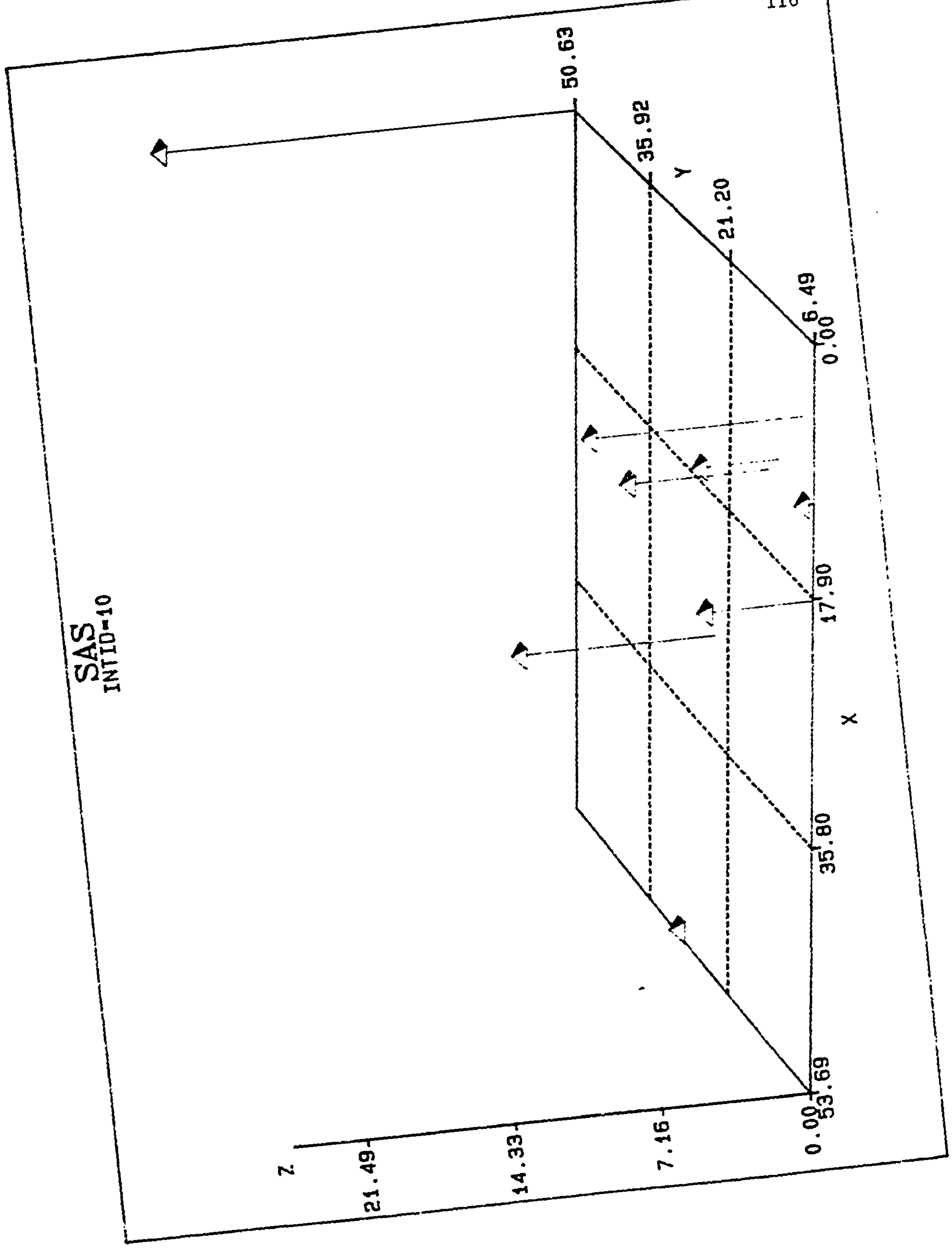

SAS
INTID=2
Z
38.30
25.53
12.77
0.00
73.45
48.97
24.48
0.00
X
0.00
14.19
28.38
Y
42.57

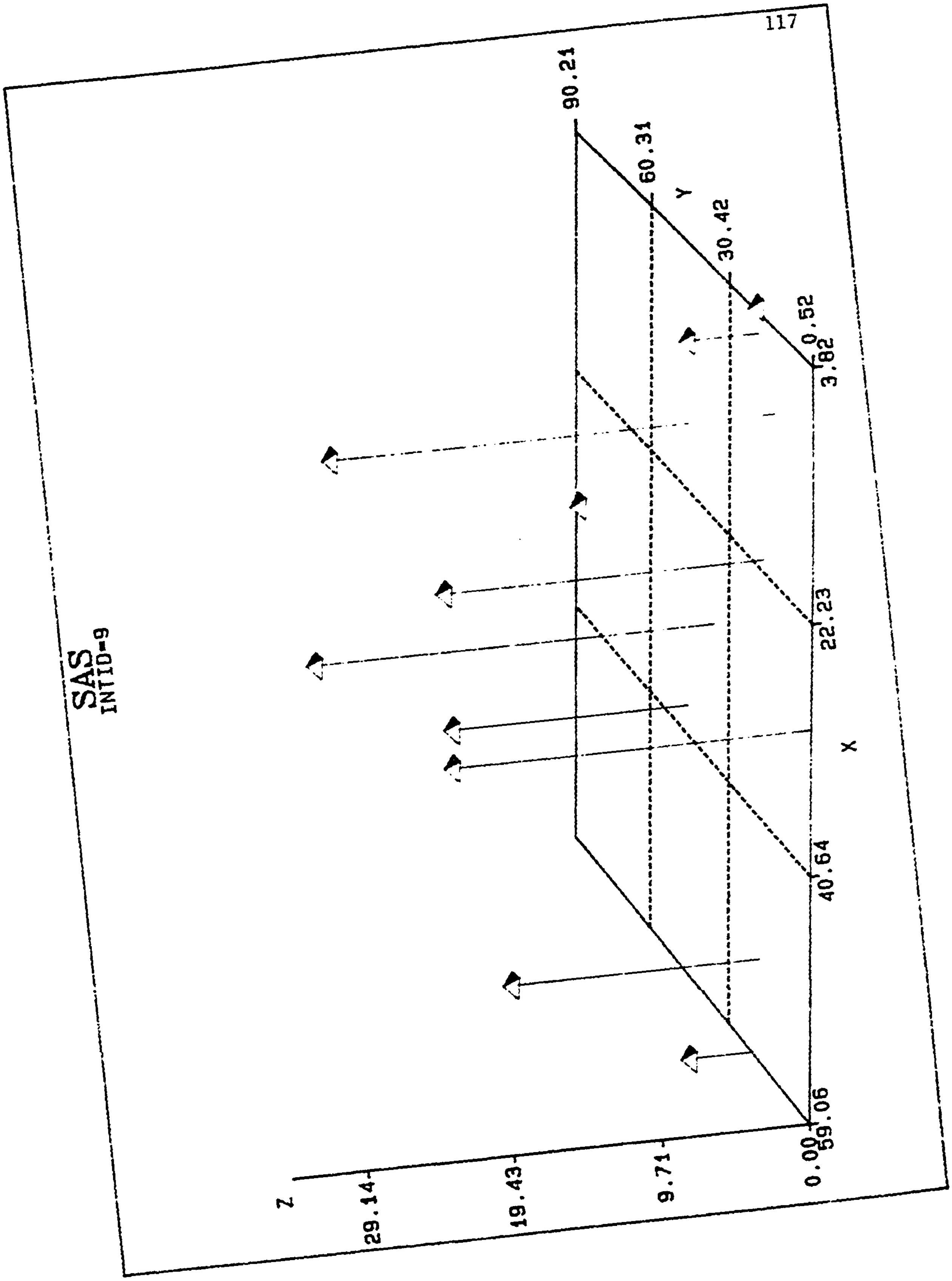

SAS
INTID=4
Z
45.11
30.07
15.04
0.00
41.35
27.56
13.78
0.00
X
0
35
70
105
Y

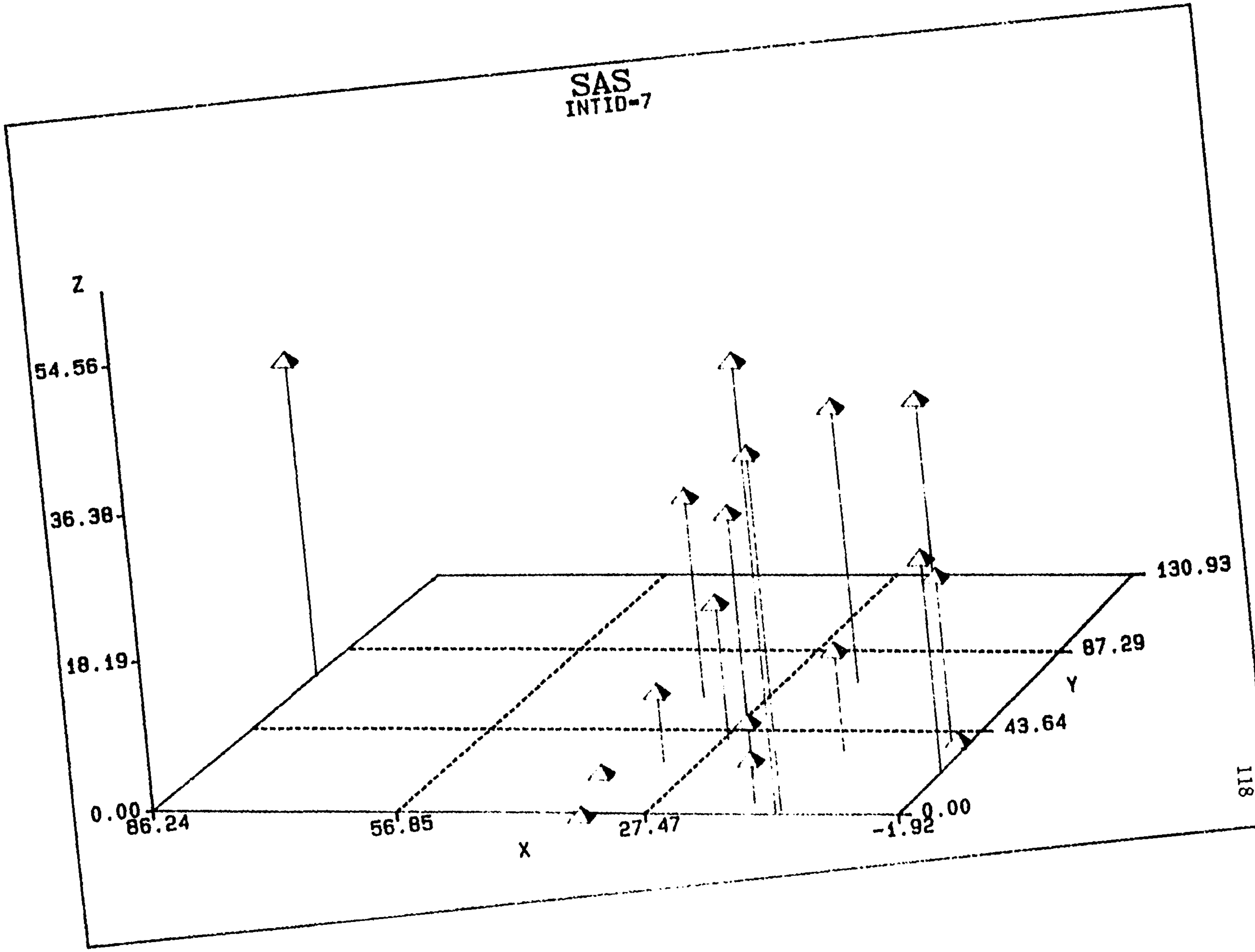

SAS
INTID=5
Z
13.86
9.53
5.21
0.88
X
33.78
24.07
14.36
4.64
Y
2.42
8.05
13.67
19.29


SAS
INTID-6
Z
11.98
7.99
3.99
0.00
58.85
40.23
21.62
3.00
X
5.20
22.45
39.69
56.94
Y


SAS
INTID=11
Z
32.74
22.60
12.46
2.32
153.63
104.67
55.70
6.74
X
0.00
22.45
44.89
Y
67.34


SAS
INTID=10
Z
21.49
14.33
7.16
0.00
53.69
35.80
17.90
0.00
X
6.49
21.20
35.92
50.63
Y


SAS
INTID=9
Z
29.14
19.43
9.71
0.00
59.06
40.64
22.23
3.82
X
0.52
30.42
60.31
90.21
Y


SAS
INTID=7
Z
54.56
36.38
18.19
0.00
86.24
56.85
27.47
-1.92
X
0.00
43.64
87.29
130.93
Y

soil moisture and texture on the tensile forces measured in the *in-situ* pull-out test (Appendix D).

7. The step-wise multiple regression run to determine which parameters best explain the observed tensile breaking force selected root diameter as the best predictor of pull-out resistance. A second, less sensitive predictor of resistance is the length of the root being stressed. For the two species considered as a unit, there is a correlation coefficient of 0.736 between tensile breaking force and the diameter of the root exposed at the soil face, and a correlation of 0.623 between the force and the length of the root (Appendix D).

Discussion

The validity of the *in-situ* pull-out resistance test as a measurement of the anchoring potential of roots may be tested by comparing the factors determining pull-out resistance of an engineered ground anchor with those determining the resistance of a root anchor. The pull-out resistance of an artificial ground anchor is a function of the anchor's cross-sectional area, its bonding with the ground, and its length (Hanna, 1982). Similarly, resistance of a tree root to pull-out is highly correlated to its diameter.

The results of the *in-situ* test of tree root pull-out resistance complete the information necessary for development of the model for tree root stabilization of hillslopes in Cincinnati.

CHAPTER FIVE

The Roles of Sugar Maple and White Ash in Anchoring Soil on a Hillslope

Introduction

The morphology, distribution, and material properties of the maple and ash roots have been described, and their pull-out resistance measured. With these data and the engineering properties of the colluvium, the anchoring effect of the roots of the two species on the local soils may be evaluated.

The thickness of the colluvium underlying Cincinnati's river bluffs tends to be highly variable, depending on the steepness of the hillslope and its landslide history. The silty-clay soil overlies bedrock and has two layered zones, a dark-brown soil layer consisting of the A1 and B1t horizons, and a yellow-brown soil layer consisting of the B22t, B24t, and B3 soil horizons (Figure 30). The mineral components of the soil are 60 to 90% illite and mixed-layer illite/smectite, with kaolinite, with traces of montmorillonite and chlorite (Fleming et al.,in prep.). About 10% of the volume of the soil layers is occupied by slabs of limestone.

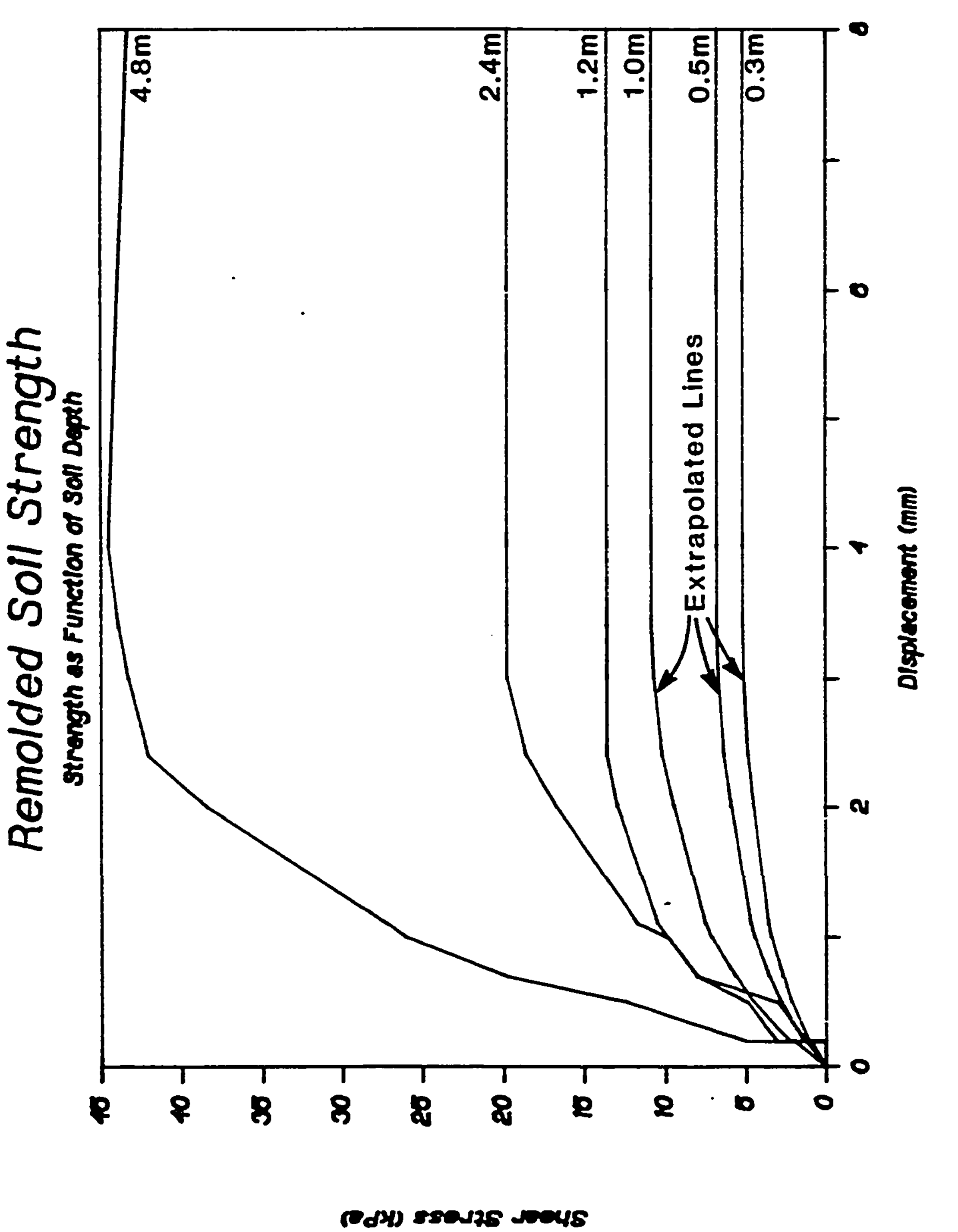
The water content of the soil after two days of heavy spring rain are shown in the table below:

NATURAL WATER CONTENT OF THIN COLLUVIUM
(Fleming *et al.*, in prep)

Depth (m)	Water Content (% of dry weight)
0	52
0.3	34
0.6	27
0.9	21
1.2	24
1.5	19

Figure 30

Shear strength of remolded soil. The lines showing strength at 4.8m, 2.4m, and 1.2m record the results of drained shear tests of the strength of the colluvium, and the other lines extrapolate the strength with normal stresses of relevance to this study. Tests run by Robert Fleming of the U.S.G.S.


Remolded Soil Strength
Strength as Function of Soil Depth
4.8m
2.4m
1.2m
1.0m
0.5m
0.3m
Extrapolated Lines
Shear Stress (kPa)
0
5
10
15
20
25
30
35
40
45
Displacement (mm)
0
2
4
6
8

The Atterberg limits of the soil at 1.2m depth with a water content of 28 (weight of water/weight of dry soil) liquid limit of 50 and plastic limit of 25 (Fleming *et al.*, in prep.). The remolded strength of the soil measured by the direct shear method is shown in Figure 30. The plot shows the measured shear strength of a remolded sample of soil removed from the yellow-brown layer of the colluvium near the shear surface. The drained shear test was run on a soil sample with a shear area of $81cm^2$. With applied normal stresses of 24.01, 47.51 and 96.14kPa, the residual strengths of the soil were determined to be 14.4, 19.6, and 43.2kPa, respectively. A friction angle of 22.4 degrees and cohesion of 2.7kPa were calculated from the measured stresses. The extrapolated lines in Figure 30 predict shear strength at normal stresses lower than those tested.

The relationships of load and displacement to time established from the *in-situ* field test were used to generate plots of force as a function of displacement for each root tested. There is high variablity among the plots of force versus displacement for the tested roots, but the force-displacement plots can be divided into three general types.

Type I is characterized by an initial rise in force with little or no displacement, and a peak skewed to the left, followed by a gradual reduction in force with increasing displacement (Figure 31).

Type II is characterized by an abrupt rise in force with little displacement, followed by a broad, nearly flat peak which falls off abruptly (Figure 31).

In Type III, the force rises somewhat steeply with displacement, falls off, then rises again (Figure 31).

The three basic force-displacement types are associated with

Figure 31

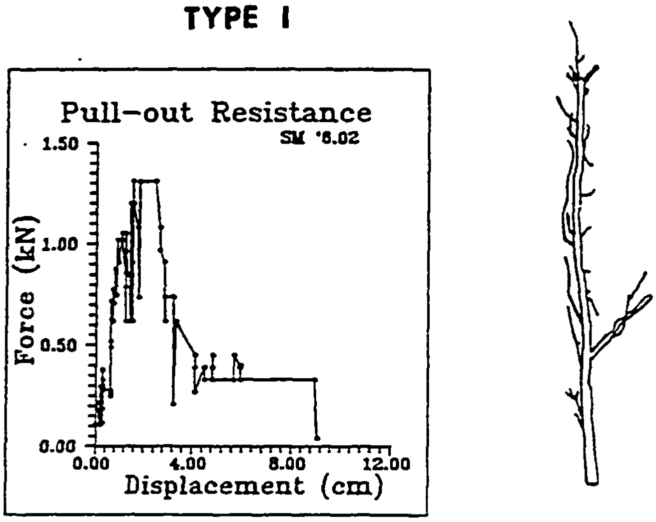
Force-displacement relationships fall into three general types.

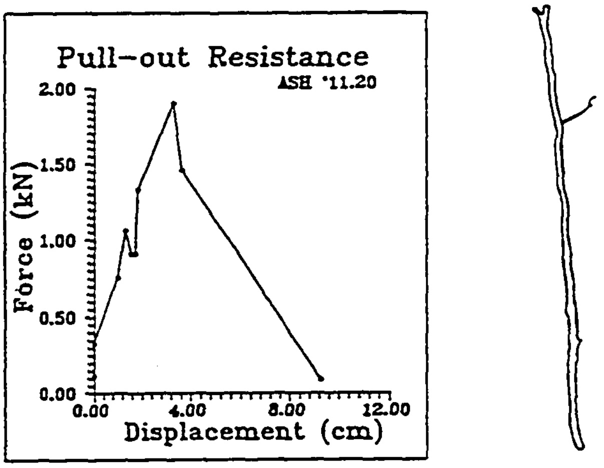
The type I relationship develops a peak in force at a small displacement, followed by a gradual reduction in force with displacement. The roots associated with the type I plots are generally long, and poorly branched.

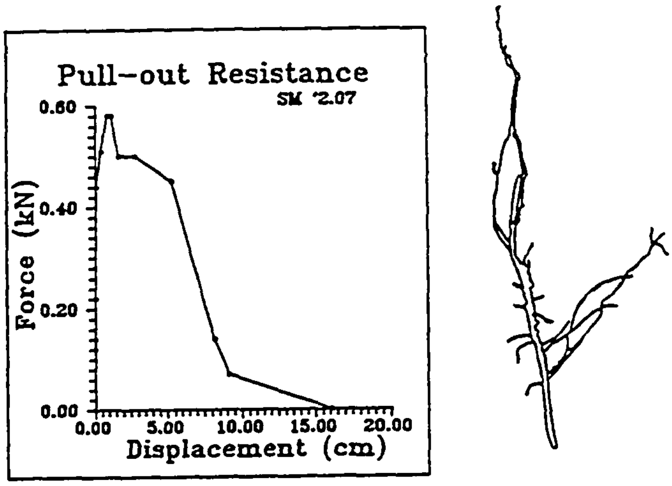
The type II relationship has an abrupt rise in force with displacement, followed by a plateau in force with displacement, then abrupt failure. The roots associated with type II are short and highly branched.

In the type III relationship, the force rises rapidly with displacement, is reduced, then rises again with further displacement, and then fails. The type III roots fork into two major branches.

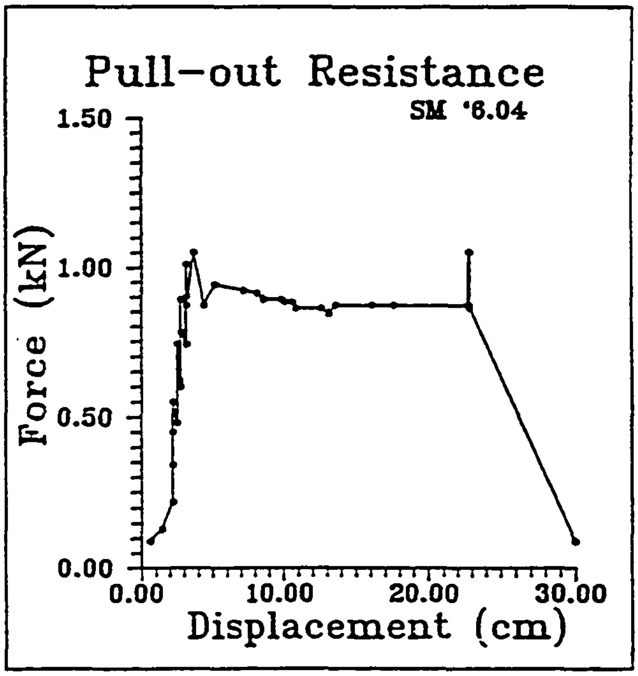
TYPE I

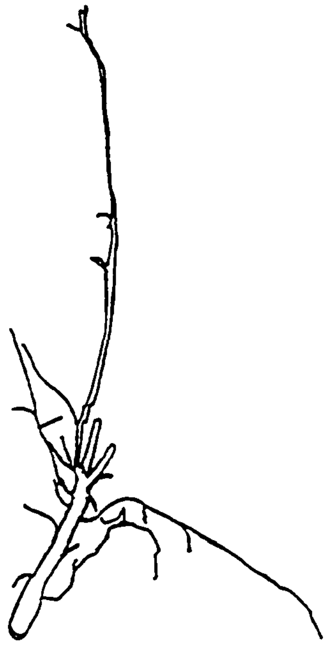

Pull-out Resistance
SM '6.02
Force (kN)
1.50
1.00
0.50
0.00
0.00
4.00
8.00
12.00
Displacement (cm)

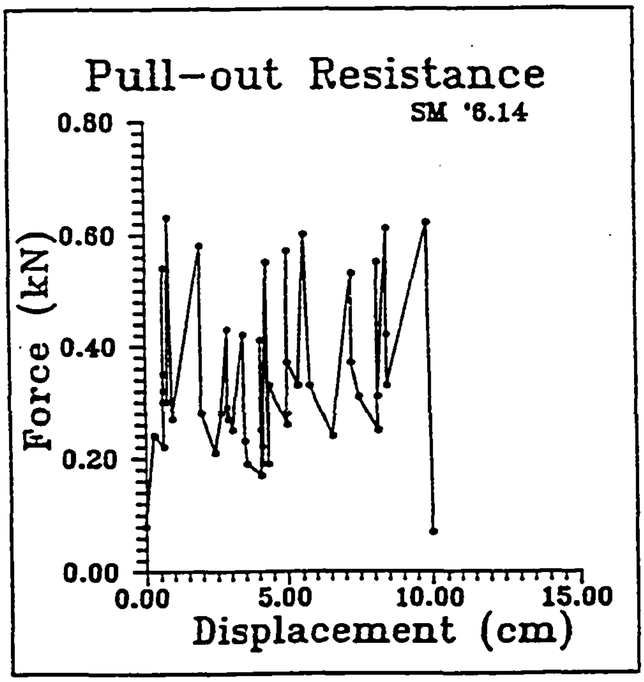

Pull-out Resistance
ASH '11.20
Force (kN)
2.00
1.50
1.00
0.50
0.00
0.00
4.00
8.00
12.00
Displacement (cm)


Pull-out Resistance
SM '2.07
Force (kN)
0.60
0.40
0.20
0.00
0.00
5.00
10.00
15.00
20.00
Displacement (cm)

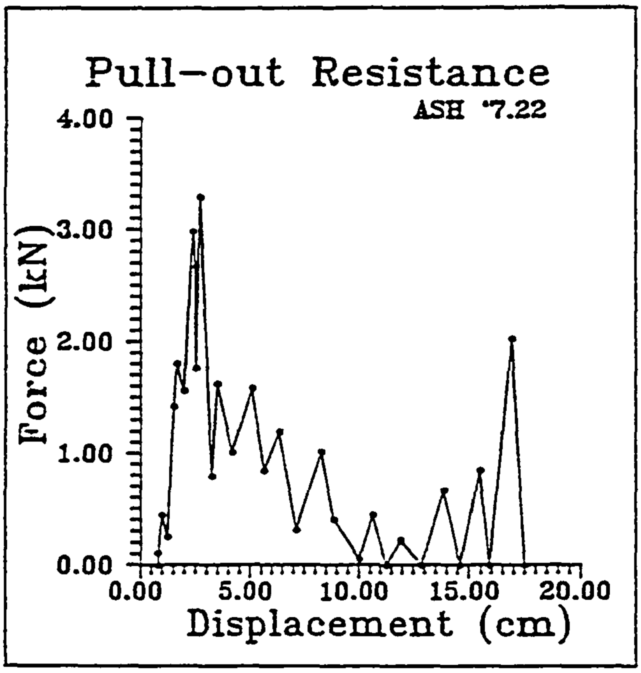
TYPE II

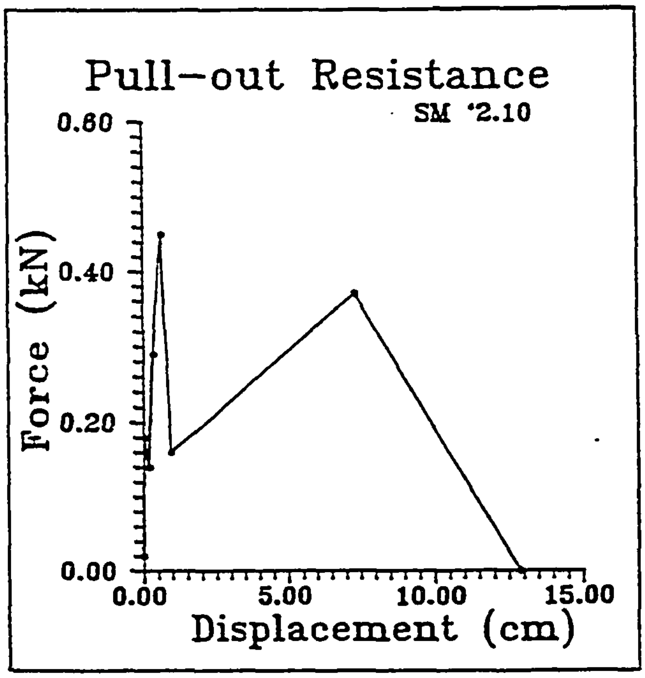

Pull-out Resistance
SM '6.04
1.50
1.00
0.50
0.00
Force (kN)
0.00
10.00
20.00
30.00
Displacement (cm)

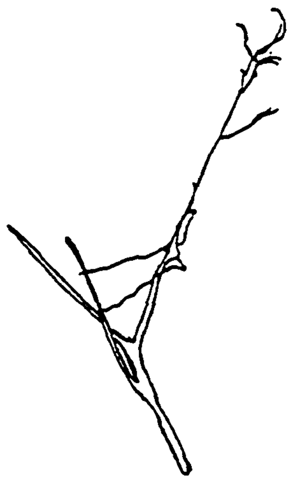



Pull-out Resistance
SM '6.14
0.80
0.60
0.40
0.20
0.00
Force (kN)
0.00
5.00
10.00
15.00
Displacement (cm)

TYPE III


Pull-out Resistance
ASH *7.22
Force (kN)
4.00
3.00
2.00
1.00
0.00
0.00
5.00
10.00
15.00
20.00
Displacement (cm)


Pull-out Resistance
SM *2.10
Force (kN)
0.60
0.40
0.20
0.00
0.00
5.00
10.00
15.00
Displacement (cm)



different root morphologies. Type I roots are generally long (0.8 to 1.5m), straight segments with few to moderate numbers of branches. They have one or two large, truncated termini aligned in the same direction in which the root was pulled. Type II roots are short (0.1m to 0.7m), highly branched segments, with large numbers of truncated termini having similar small diameters. Type III roots are forked into two major branches, mostly at a 45 degree angle or more between the two branches. A sketch of each root is shown with its corresponding plot of force versus displacement in Figure 31.

Association of the Pull-out Resistance of Roots with the Resistance of Remolded Soil to Shear

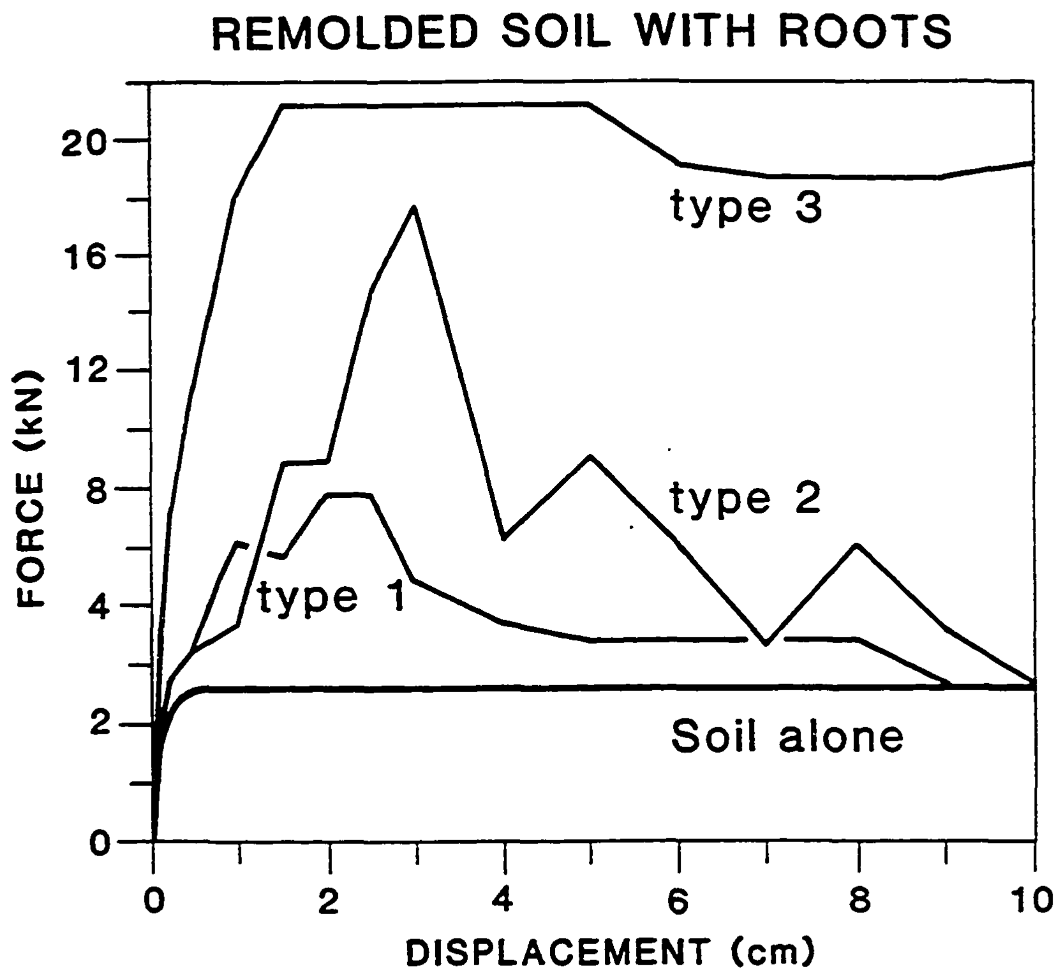
A plot of force versus displacement for a block of remolded colluvium with a surface area of $1m^2$, with a normal force of 10kN acting on it equivalent to an overburden of 0.5m of soil, shows that the force resisting shear rises abruptly with displacement, and reaches a plateau of 5kN at 0.5cm of displacement (Figure 30).

To determine the effect roots have on the soil with the same overburden, the force required to displace a root as recorded on the "type" plots of force versus displacement is summed with the soil's resistance to displacement. The type roots which are summed with the soil's resistance to displacement are: type I, SM6.02, 1.56cm in diameter; type II, ASH11.13, 2.6cm in diameter; and type III, ASH7.22, 1.57cm in diameter.

Figure 32 shows that even one root representative of each root type with the same diameter may have a marked effect on the force required to displace the soil-root assemblage in shear. The peak force resisting

Figure 32

Strength of remolded soil with roots. Roots representing the three type roots are included in a plot of force versus displacement for remolded soil. The base line on the plot is the strength of the soil alone, and the three lines above represent rooted soil strength. The peak strength of the rooted soil is reached at 2-3cm of displacement, in contrast to the peak strength of soil without roots which is reached at 3-4mm of displacement.


REMOLDED SOIL WITH ROOTS
FORCE (kN)
0
2
4
8
12
16
20
type 3
type 2
type 1
Soil alone
0
2
4
6
8
10
DISPLACEMENT (cm)

shear for the soil itself is reached at a displacement of 0.5cm, but peak force may not be reached until 3cm of displacement, when the force to displace the soil is summed with the force to displace a root of type II.

None of the root-soil combinations reaches peak force at a displacement as small as that at which the soil alone reaches its peak force. Not only is the displacement at which the peak force is developed larger for the root-soil assemblage, but the magnitude of the peak force is also increased 2 to 5 times with the addition of a single root anchor to the soil.

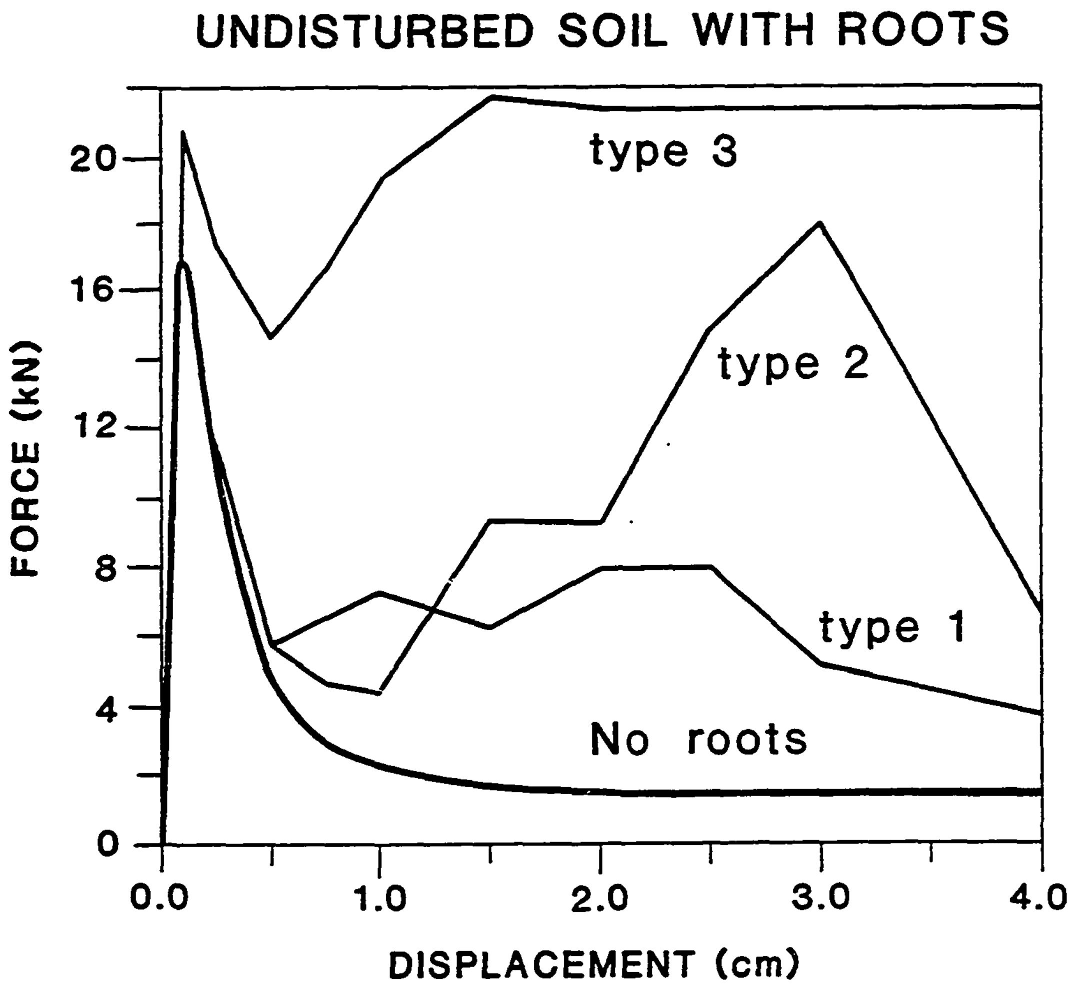
The roots used to construct the plots are representative of each root type and have a relationship of force versus displacement characteristic of that group. The magnitude of force and displacement associated with peak force may vary greatly within each root type, as a function of root diameter.

Association of the Pull-out Resistance of Roots with the Resistance of Undisturbed Soil to Shear

The strength of the colluvium was determined using a sample of remolded colluvium, but undisturbed colluvium would be expected to be stronger. The relationship between force and displacement of a typical undisturbed soil is characterized by an initial, abrupt rise in force with little displacement, followed by an abrupt decrease in force at a displacement of 2 to 5mm; the force falls to about one half or less that of the peak force, and remains constant for all further displacement (Skempton, 1964). Figure 33 illustrates a profile for shear force on an undisturbed clay. The profile is modeled after a direct-shear test described by Skempton for an undisturbed clay collected from Walton

Figure 33

Shear strength of undisturbed soil with roots. Undisturbed soil similar in composition to the colluvium has a peak strength 4-5 times its residual strength. Roots enhance the peak strength of the soil at 2-3mm displacement. After a peak is reached, the strength falls off then increases with further displacement, in a pattern determined by the type root associated with the soil.


UNDISTURBED SOIL WITH ROOTS
type 3
type 2
type 1
No roots
FORCE (kN)
0
4
8
12
16
20
0.0
1.0
2.0
3.0
4.0
DISPLACEMENT (cm)

Wood. The materials tested are similar to those in the colluvium and so are used as an example of a drained shear strength test on an undisturbed sample.

The forces required to pull the same 3 roots as those described are added to the shear force for the Walton Wood soil (Figure 33). The results of the summation differ from those with the remolded soil, especially at low displacements. An initial peak force is reached at 2mm, for the soil alone and for soil with roots. The peak is followed by a trough of low shearing resistance. Then, as displacement continues, the root anchors begin to add additional forces and the overall curve rises and appears essentialy the same as that derived for remolded soil. Undisturbed soil requires a greater initial force to cause failure in shear than does remolded soil, but after undergoing little displacement it behaves in the same manner as the remolded soil.

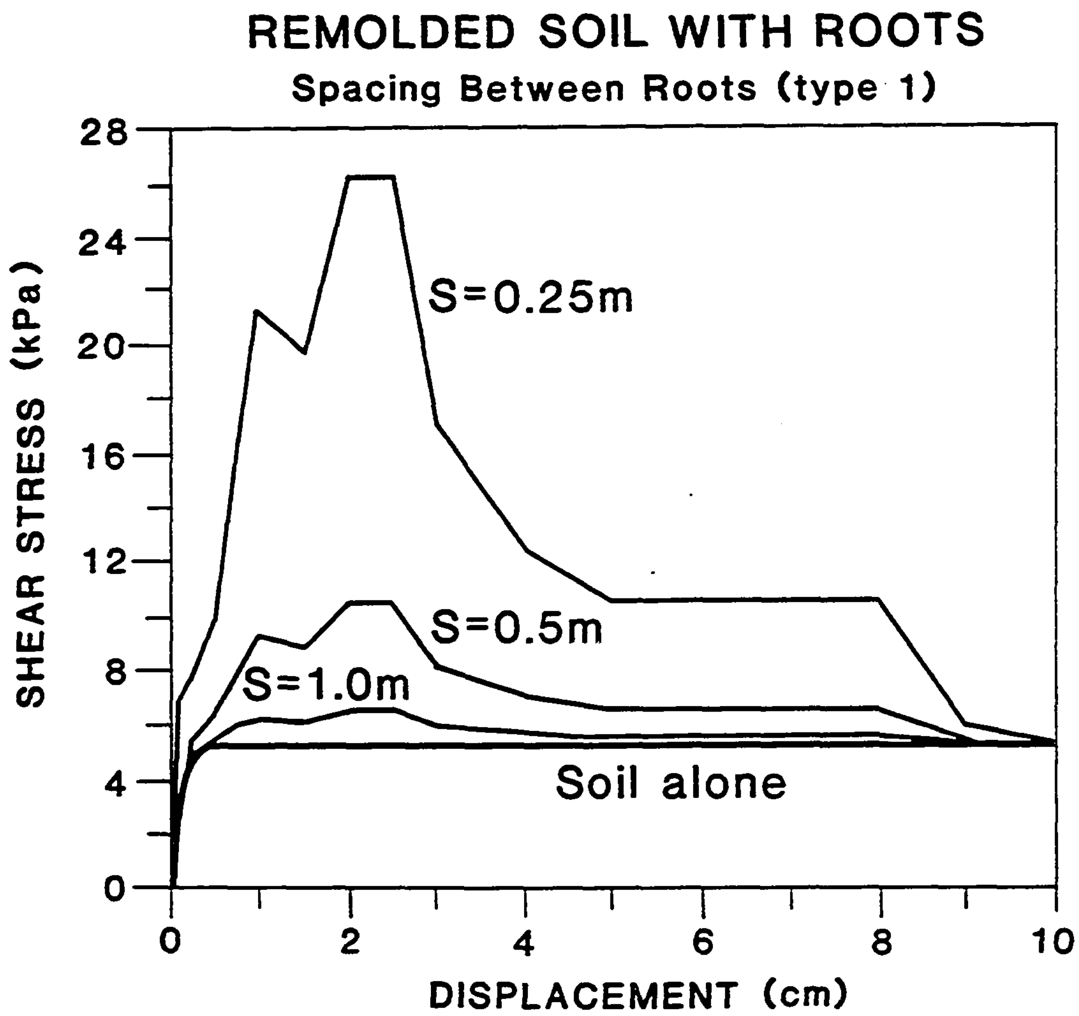
The Effect of the Areal Spacing of Roots on Soil Strength

The above figures demonstrate that the soil's resistance to shear increases when a root anchor is incorporated within the soil. The distribution of roots within the soil is dependent on many factors, particularly proximity to the tree and depth below the soil surface. An analysis of the addition of groups of roots representing differing densities of the three root types to the remolded colluvium shows that the resistance to soil shear is greatly enhanced by densely packed roots.

Figure 34 illustrates the resistance to shear contributed by the remolded soil itself, and the increase in shear strength (resistance to shear) with increasing density of type I roots. All three root densities

Figure 34

Shear strength of remolded soil with increasing root densities. The strength of the soil/root complex is increased by decreasing the spacing between roots. At one meter spacing between type I roots, the strength is 6kPa; at 0.5m spacing, 10kPa; and at 0.25m spacing, 20kPa.


REMOLDED SOIL WITH ROOTS
Spacing Between Roots (type 1)
SHEAR STRESS (kPa)
0
4
8
12
16
20
24
28
DISPLACEMENT (cm)
0
2
4
6
8
10
S=0.25m
S=0.5m
S=1.0m
Soil alone

considered increase the peak strength of the soil/root complex, with the peak resistance to shear at 2cm of displacement. A density of one type I root per square meter of soil shear surface increases the shear strength 1kPa more than that of the residual soil strength; 1 root/0.5m^2 (4 roots/m^2) increases the peak strength 5kPa more than the residual soil strength, and a density of 1 root/0.25m^2 (16 roots/m^2) increases the peak strength 14kPa above that of the soil alone. At a displacement of 9cm, the enhancement of strength by the type I root anchors approaches zero for any density of roots.

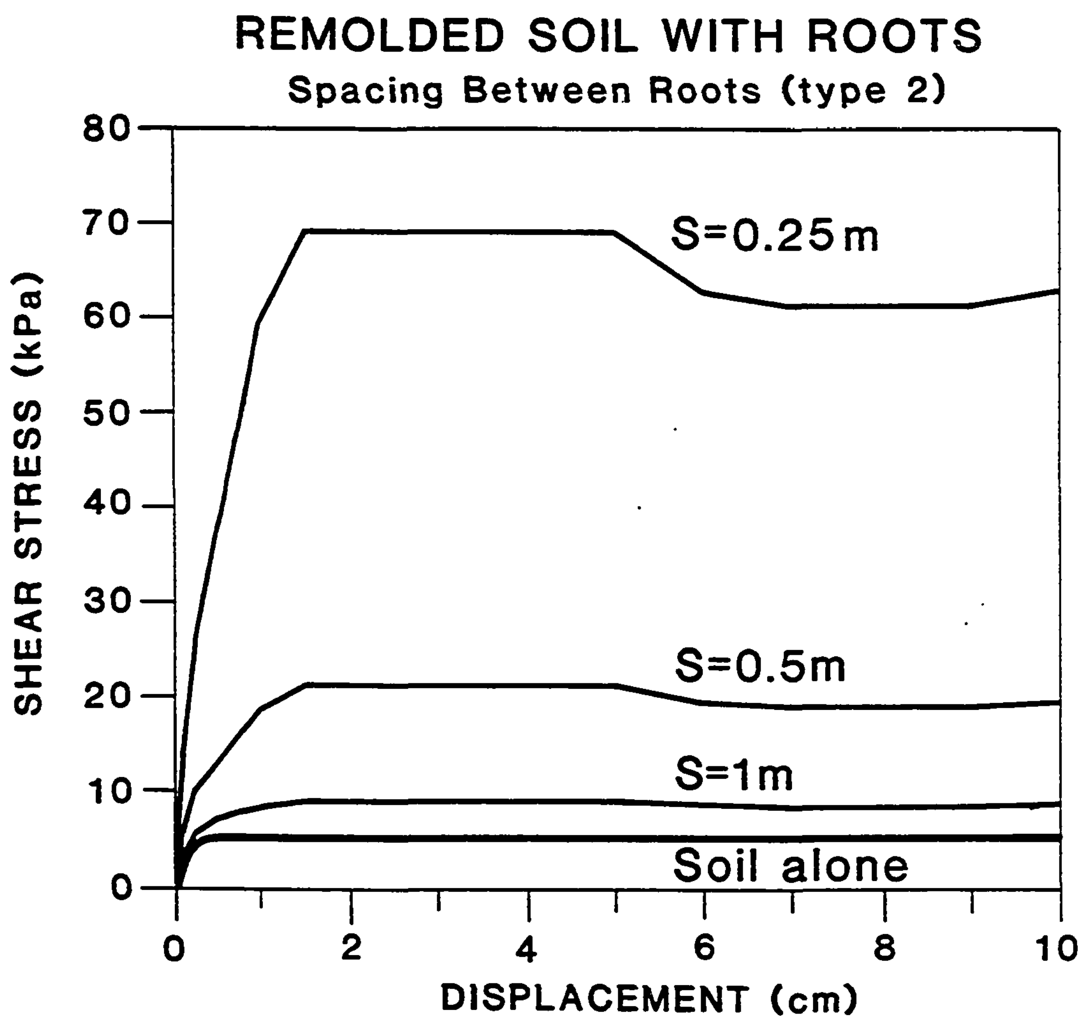
The shear strength of remolded soil with type II roots is increased for the 10cm of displacement as illustrated in Figure 35. The peak resistance of the soil/root complex is reached at 2cm of displacement, and remains constant for the next 3cm of displacement. Spacing of the roots has a marked effect on the soil's resistance to shear. At a spacing of one root per square meter, the peak shear strength increases 2-fold over that of the remolded soil alone; at 0.5m spacing (4 roots/sq. meter) the peak shear strength increases 4-fold, and at 0.25m spacing (16 roots/sq. meter) the peak shear strength increases 14-fold over that of the remolded soil alone.

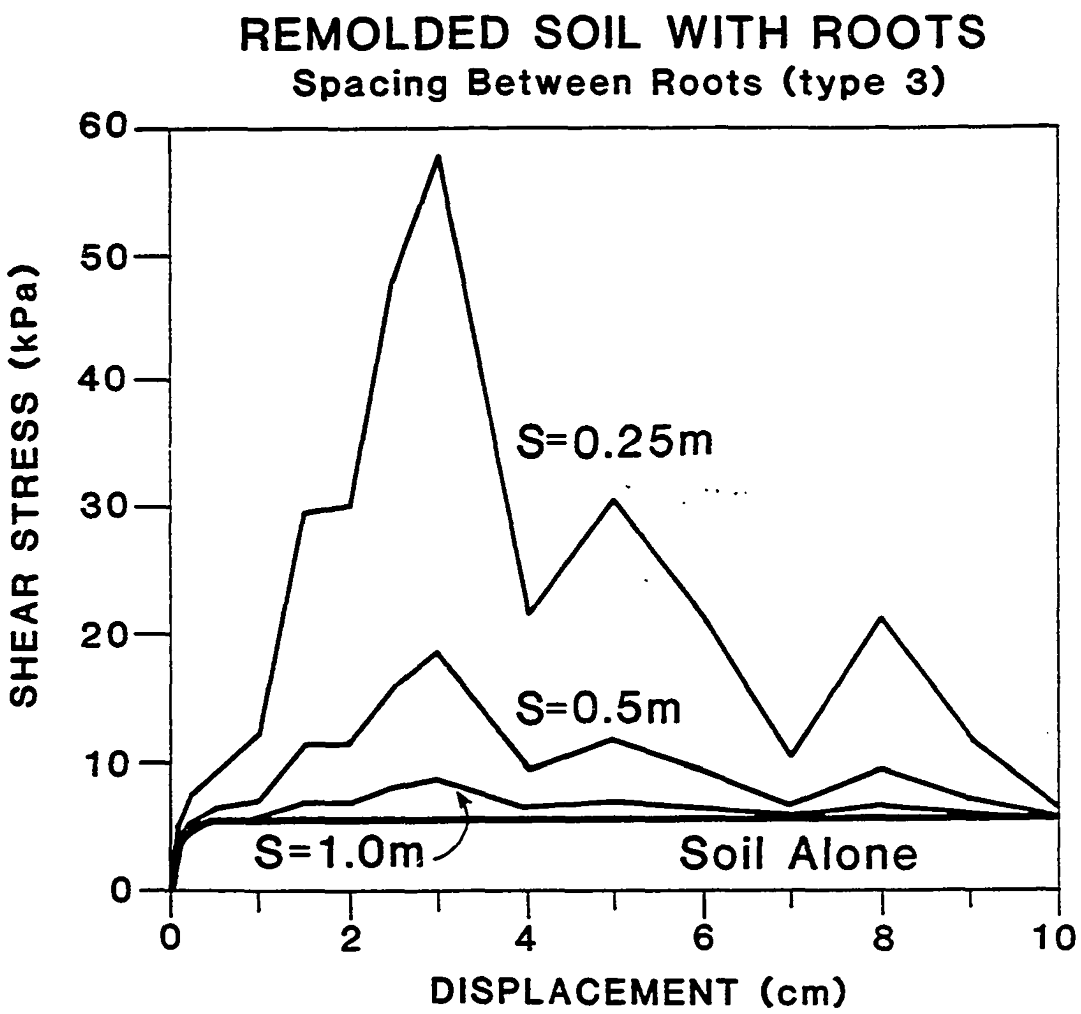
The type III roots also enhance the shear strength of the soil as their spacing decreases, but the form of the relationship between stress and displacement differs from that of the first two root types (Figure 35). The rise to peak shear strength is gradual, with the peak strength being reached at 3cm of displacement. The stress associated with displacement beyond three centimeters intermittently falls and rises but trends toward decreasing stress. The peak strength increases 1.5-fold

Figure 35

The enhancement of soil's resistance to shear with spacing of type II and III roots. The type II roots maintain a high resistance to shear over a displacement of 4cm, after reaching peak resistance at 2 cm of displacement. The type III soil/root complex reaches peak resistance at 3cm displacement, which falls off with further displacement.

Both types of root/soil complexes are highly sensitive to root density, with the resistance to shear increasing six- to seven-fold as the root density is increased from one root per meter to 16 roots per meter.


REMOLDED SOIL WITH ROOTS
Spacing Between Roots (type 2)
SHEAR STRESS (kPa)
80
70
60
50
40
30
20
10
0
S=0.25m
S=0.5m
S=1m
Soil alone
0
2
4
6
8
10
DISPLACEMENT (cm)


REMOLDED SOIL WITH ROOTS
Spacing Between Roots (type 3)
SHEAR STRESS (kPa)
0
10
20
30
40
50
60
S=0.25m
S=0.5m
S=1.0m
Soil Alone
0
2
4
6
8
10
DISPLACEMENT (cm)

with a spacing of 1 root/m^2, 3-fold with 4 roots/m^2 and 12-fold with a spacing of 16 roots/m^2.

The magnitude of the increase in strength with decreased root spacing and the shapes of the stress-displacement curve for each root type illustrated in the above figures are calculated from a root which typifies each root type. There is considerable variation within each group, but the sequences of stress as a function of displacement within a root type are similar in form and the roots within a type are similar in morphology.

Stability Analysis of a Hillslope Underlain by Soil Anchored by Sugar Maple and White Ash Roots

The stability of the soil on a hillslope is determined by comparing the forces acting on the soil mass which resist failure with the forces acting on the soil mass which enhance failure. The factor of safety against sliding is defined as the ratio of the forces which resist failure to the forces which drive failure.

Consider an anchored soil block lying on an inclined surface, such as the bedrock-soil interface. The factors which resist failure of the block are the strength of the soil, $\underline{S}_s$, and the strength of the anchors; factors which drive failure are the unit weight of the soil mass, γ, and slope angle, α. Soil strength is defined by the Terzaghi-Coulomb equation as

1. $S_s = c + \sigma \tan\phi$

where

c = effective cohesion

σ = effective normal stress, where $\sigma = \gamma_t - \gamma_w$

and γ_t = unit weight of the saturated soil

and γ_w = unit weight of water

ϕ = soil internal friction angle

For a block of soil with a volume, v, resting on an inclined plane (hillslope), the force resisting basal shearing is:

2. $AS_s = v(\gamma_t - \gamma_w)\cos(\beta)\tan(\phi) + c(A)$

where

v = volume of soil block

A = area of base of block

β = slope angle

If an anchor projects through the block into the underlying material at an angle, α, from vertical, the block resists shear by:

3. $AS_a = F\{\cos(\alpha)\}\tan(\phi) + F\{\sin(\alpha)\}$

where F = tensile force on anchor

AS_a = resistance of anchored block to shear

The forces which resist failure, F_r, equal AS_a plus AS_s, the block's resistance to shear.

The forces driving failure of the anchored block are:

4. $F_d = v(\gamma_t)\sin(\beta)$

Thus, the factor of safety against sliding, FS, is equal to:

5. $FS = F_r/F_d = \{[(1\gamma_w/\gamma_t)\cos(\beta)+(F/\gamma_t V)\cos(\alpha)]\tan(\phi)$
$+(F/\gamma_t V)\sin(\alpha)+(A/V)C/\gamma_t\}/\sin(\beta)$

It has been demonstrated that roots act as ground anchors. As the anchored soil displaces, tensile forces, F, are mobilized in the roots which anchor the mass to a stable substrate below the colluvium. The tensile forces which develop in the roots are a function of the root type and size, and the magnitude of displacement of the anchored soil block. For example, a type I root will develop peak resistance to failure at about 2cm of displacement at which point the root will contribute its greatest force resisting failure.

A computer program (DEPTH, written by Roger Stuebing) incorporating measurements of the azimuth and plunge, and starting and ending diameter of each unbranched segment of root was developed to determine the numbers and diameters of roots which penetrate planes horizontal to the ground surface beneath a tree (Appendix B).

The force-displacement relationships of nineteen roots, each belonging to one of the three root types, are used in developing stability analyses of wooded hillslopes. The roots chosen are of differing sizes and were growing at various orientations within the soil before pull-out.

The computer program lists the sizes and orientations of the roots projecting through soil planes at depths selected for the stability analyses. A root is selected from the nineteen type-roots to represent each root segment enumerated by the program for the stability analysis of soil of a thickness corresponding to the chosen depth or soil plane. The root is selected on the basis of its size, orientation, and type. For instance, a small root projecting through a shallow plane is selected from the set of type II roots, because those roots are highly branched as shallow roots observed in the excavations. A steeply plunging root is selected from either type I or III depending on the depth of the plane. A root which projects through a deep plane is poorly branched as roots of group I, and a root projecting through a more shallow plane is branched as a type III root.

Figure 36 illustrates the results of a stability analysis for a block of soil inclined at 30°. The block width and length are each 1m, its thickness is 0.43m, and the water table is at the soil surface. The soil properties used in the analysis are the residual values measured for remolded colluvium (Fleming et al., in prep.). Constants used in the analysis are: 2.7kPa cohesion, 22.4 degrees internal friction, 20kN/m^3 soil unit weight, and 9.8kN/m^3 water unit weight.

Initially, the root anchors are assumed to be aligned perpendicular to the shear surface, so a, the root angle, is zero. The numbers and sizes of roots which penetrate the shear plane at 0.43m depth are calculated for the trees which were hand-excavated at the Spring Grove site (Figure 36 and Appendix B).

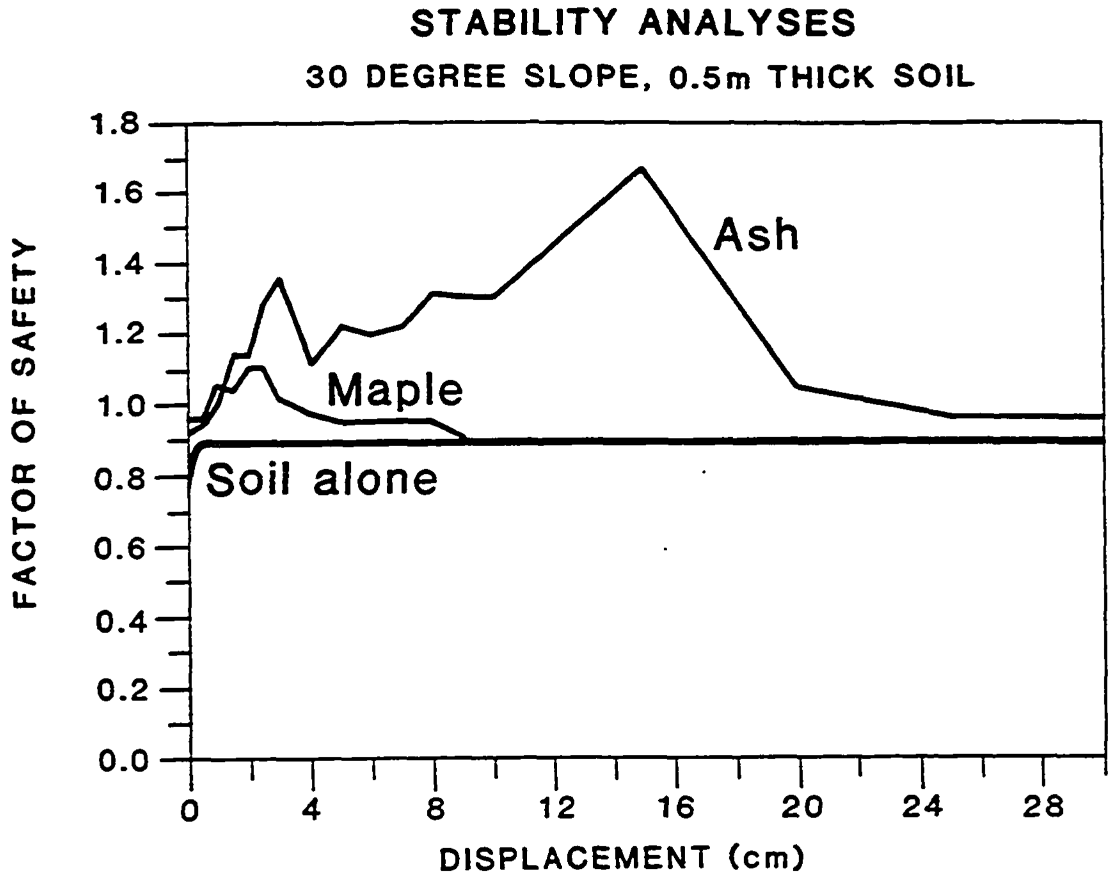
The depth of 0.43m chosen for the analysis approaches the critical thickness of the block which is 0.42m, that is, the thickness at which the factor of safety equals unity. Figure 36 indicates that for both the soil anchored by the maple and the ash, the factor of safety of the failed block is increased to a value greater than one at 2cm of displacement, the increase being much greater for the soil anchored by ash than for soil anchored by maple. This difference in anchoring is due to the difference in root mass at depth between the two species.

Critical Spacing of Ash Trees on a Hillslope

The density of roots within soil affects the soil's resistance to shear, and, since roots are most concentrated near the base of the tree from which they originate, it follows that close spacing of trees will

Figure 36

Stability analyses of a soil block inclined at 30° with and without roots. The numbers, sizes, and types of roots which project through a shear plane with an area of $1m^2$ at a depth of 0.43m are assumed to be the same as those of the hand-excavated sugar maple and white ash trees. The soil penetrated by ash roots develops a peak factor of safety of 1.65; the soil penetrated by maple roots develops a peak factor of safety of 1.1. (Program written by K. Cruikshank)

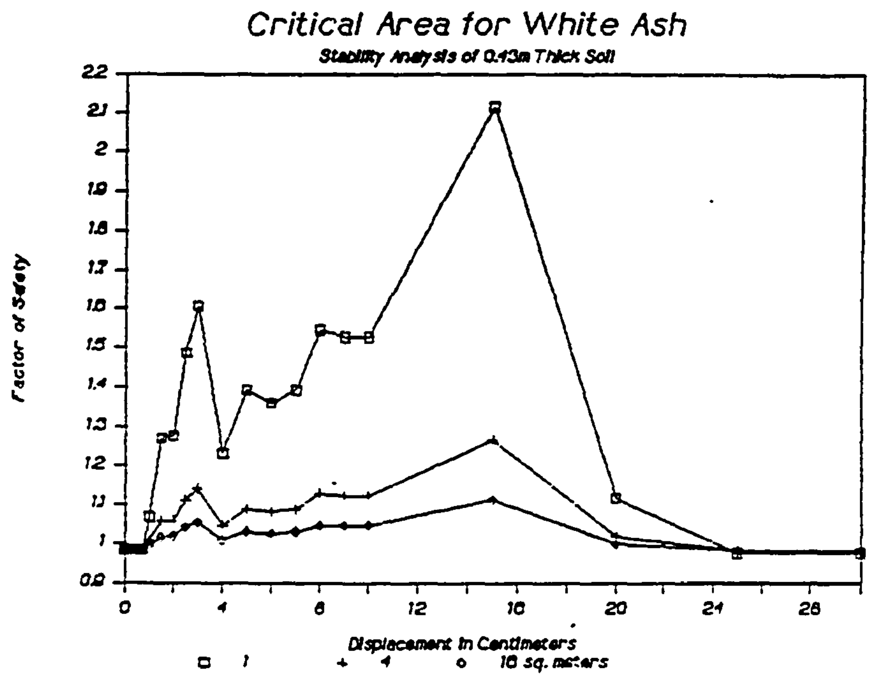

STABILITY ANALYSES
30 DEGREE SLOPE, 0.5m THICK SOIL
FACTOR OF SAFETY
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Ash
Maple
Soil alone
0
4
8
12
16
20
24
28
DISPLACEMENT (cm)

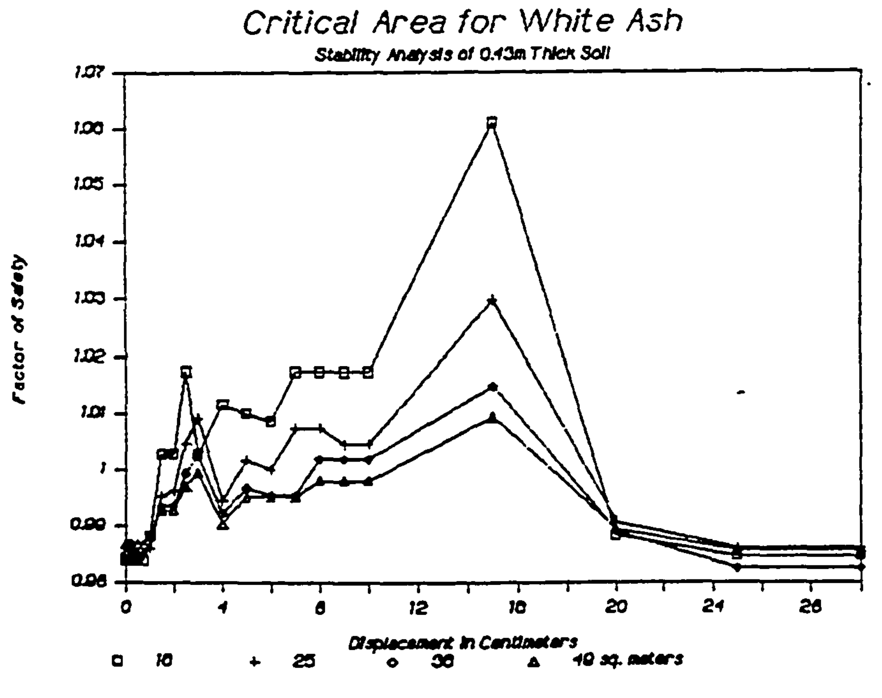
strengthen soil. A stability analysis of an inclined soil block supporting an ash tree shows that the factor of safety decreases with increasing spacing of trees (Figure 37). The analysis uses the dimensions of the excavated ash from Spring Grove, and a soil block 0.43m thick, with increasing shear surface area. The initial area of the block's shear surface is $1m^2$, which may be translated into 1m spacing between trees, if the tree is centrally placed on the soil block. At 1m spacing, the peak factor of safety is 1.45. With increased block surface area, the factor of safety decreases, until it approaches unity at seven meters spacing between ash trees, or 0.14 trees per meter. This is the critical spacing for ash trees of the same girth as the fully excavated tree, on soil with the physical properties of the colluvium. A slope angle of 30° was used in the analysis, and it was assumed that the ground water surface was at the soil surface at failure.

A spacing of seven meters between small ash trees translates into about 200 trees per hectare. This density compares with that of an actual mixed forest growing on a steep hillside; at the Rapid Run site there were 259 trees per hectare on the portion of hillslope east of the landslide, and 176 trees per hectare on the portion of hillslope west of the landslide. The forests were not monocultures of ash trees, of course, but the comparison shows that the critical density calculated for ash trees is close to that observed on the stable portions of hillsides which lie between failed areas.

Figure 37

The effect of spacing of ash trees on stability of a hillslope. Stability analyses of an ash/soil complex 0.43m in thickness indicates that the factor of safety is sensitive to tree spacing. The critical spacing for ash trees of the size excavated on colluvial soil sloping at 30° with a thickness of 0.43m is 1 tree/7m, or 0.02 trees/m^2.


Critical Area for White Ash
Stability Analysis of 0.43m Thick Soil
Factor of Safety
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0
4
8
12
16
20
24
28
Displacement in Centimeters
1
4
16 sq. meters


Critical Area for White Ash
Stability Analysis of 0.43m Thick Soil
Factor of Safety
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0
4
8
12
16
20
24
28
Displacement in Centimeters
16
25
36
49 sq. meters

Critical Thickness of Rooted Soil

Not only the spacing of trees within a soil mass affects soil stability; the numbers of roots and their anchoring effect declines with depth in soil to some critical depth at which they they can no longer pin the soil in place. For the following analyses, the slope angle is set at 30° and the water table is at the ground surface.

An analysis of the shear strength and factor of safety of rooted soil as a function of depth demonstrates the effect of rooting depth on slope stability. Figure 38 shows the effect of the root system of the excavated sugar maple #2 (Spring Grove) on soil at various thicknesses. The root configuration and density used in the analysis were derived from numbers, type, and orientations of roots per given depth as indicated by the computer program DEPTH for the excavated sugar maple.

The factor of safety for the soil alone is 0.96, and its residual shear strength is 5kPa with a normal stress equivalent to 0.3m thick colluvium overburden. The root density falls off rapidly with depth, so that the peak factor of safety of rooted soil at a 0.3m depth is 1.23, and at a 0.5m depth is 1.05. No roots project through a plane at 1m depth, so the factor of safety measured at that depth is due to the soil strength alone.

The analysis of the ash roots based on data from the excavated tree at Spring Grove is illustrated in Figure 39. The ash roots penetrate deeper into the soil than do sugar maple roots, and so they increase soil strength at depths as great as 1m. The initial rise in strength to its peak value is similar to that of the soil with sugar maple roots; it rises steeply, and peaks first at about 2 to 3cm of displacement, and diminishes with displacement. Another peak strength follows at 15cm

Figure 38

Critical thickness of soil with sugar maple roots. Factor of safety is plotted against displacement for sugar maple at 0.3m and 0.5m depths. It indicates that the maple has a profound effect on stability at 0.3m depth, but its effect rapidly falls off with increasing soil thickness. At 0.5m the root anchors increase the factor of safety from 0.96 at no displacement to 1.23 at 3cm displacement.

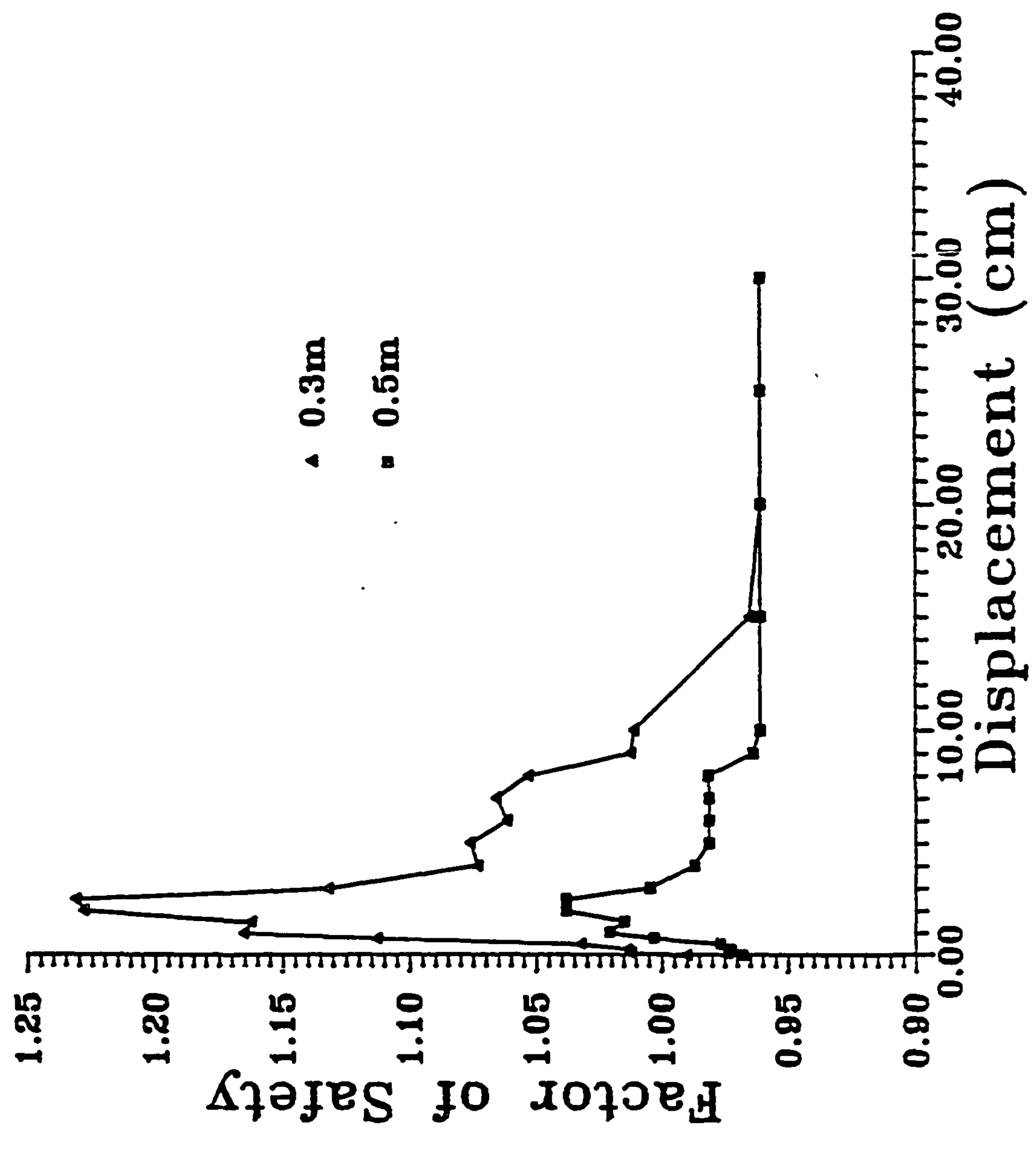
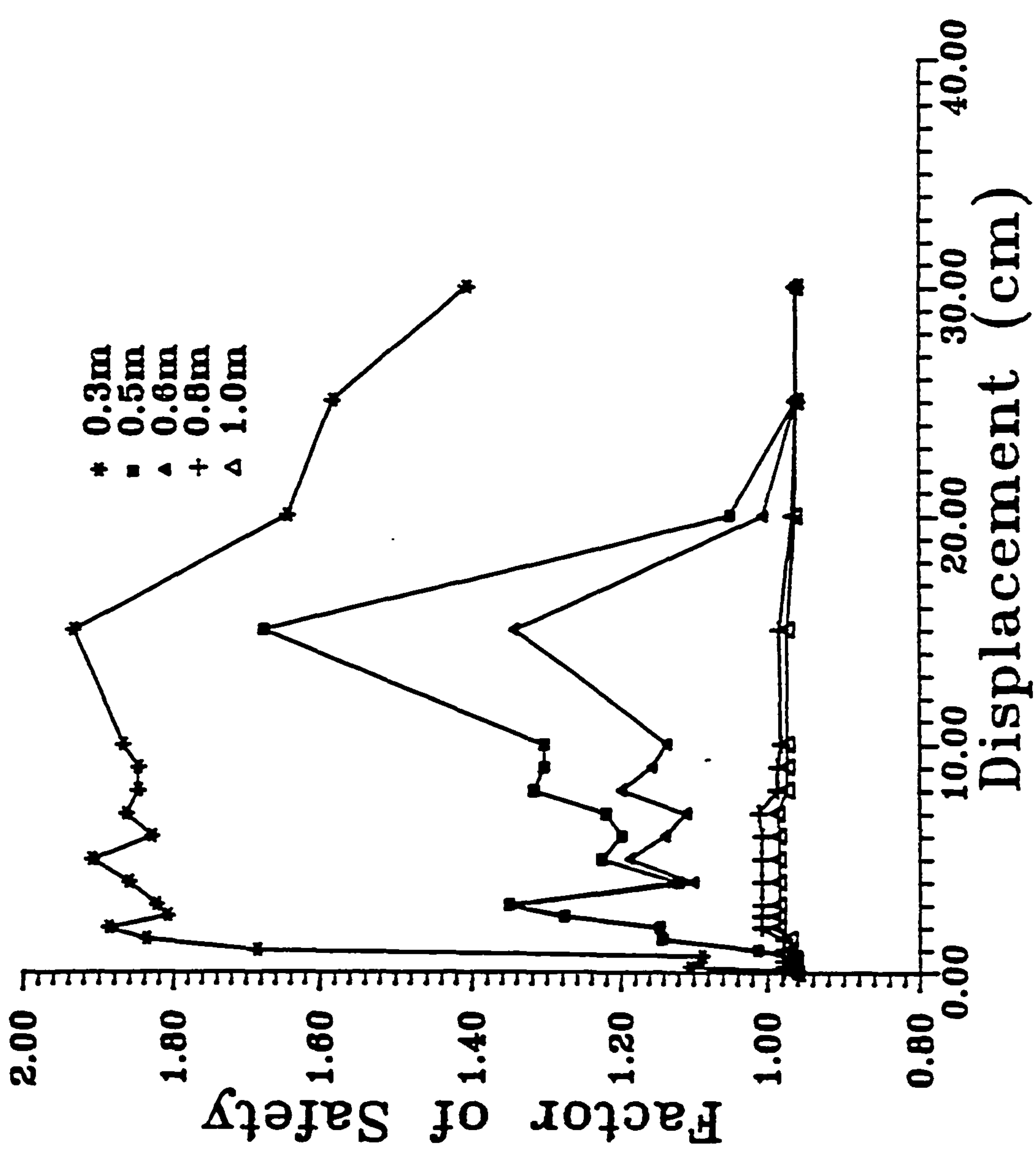

0.3m
0.5m
Factor of Safety
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.00
10.00
20.00
30.00
40.00
Displacement (cm)

Figure 39

Critical thickness of soil with white ash roots. The ash has the potential to increase the factor of safety from 0.96 at no displacement to 1.9 at 2-3cm displacment at a depth of 0.3m. Its stabilizing effect decreases with depth. This decrease in root anchoring with depth is due to reduction in numbers of roots with depth. The changes in the patterns of force versus displacement are due to the change in root type associated with depth.



Factor of Safety
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.00
10.00
20.00
30.00
40.00
Displacement (cm)
0.3m
0.5m
0.6m
0.8m
1.0m

displacement, greater in magnitude than the first peak. The patterns of stress versus displacment differ with depth. At 0.3m depth, the factor of safety reaches a broad peak, which persists for 13cm displacement, and then gradually declines. At 0.5m and 0.6m depths, the first peak develops at 3cm displacement, and is followed by a trough which reaches a minimum at 4cm displacement, and then is followed by another, higher peak at 15cm displacement. The curve illustrating the anchoring by roots at 0.3m depth has the general shape of a type II root's force-displacement curve. The similarity is due to the fact that the type II roots dominate at shallow depth. With increasing depth, the types I and III roots are entered into the stability analysis, and their characteristic forces sum into the relationships illustrated in the figure (data used for analysis in Appendix E). At one meter depth, a single tap root acts as an anchor, but it is not large enough to raise the factor of safety above the critical value of one.

Roots of trees as small as those which were excavated by hand should insignificantly affect the resistance to sliding of the Delhi landslide (Figure 15), which is 0.5 to 1.5m thick.

From this analysis of the anchoring effects of ash and maple roots, it is clear that the ash provides far better soil anchoring than the maple. The results are not surprising in light of observations of the species associated with failed portions of the local hillslopes. The sugar maple tends to have many more type II roots than does the ash. Type II roots are highly branched and resist soil shear with a continually high force as the soil is sheared. This is in contrast with the type I and type III roots which have varying resistances with displacement. Despite the fact that the type II roots of the sugar maple seem to be better anchors, their absence at depths at which landslide shear surfaces are likely to form reduces the significance of this characteristic.

The ash roots anchor better at greater depths than maple roots simply because they are present at greater depths.

Discussion

Tree roots stabilize colluvium on Cincinnati's hillslopes by acting as soil anchors which transfer shear stress at the failure surface to a stable underlying substratum. The roots project through the soil, across the shear surface, to the weathered, fissured bedrock below. Roots are realigned at the shear surface by the movement of the overlying, failing soil. This realignment pulls the root terminis out from its preslide growth position. The root resists failure by a combination of its bond with the soil, its size, and strength. The strength of soil can be greatly increased by the addition of root anchors. Even one root anchor can profoundly increase the resistance of a soil mass to shear; the addition of one root anchor to a soil block with a surface area of $1m^2$ with a thickness of 0.5m may increase its resistance to shear five-fold. A critical spacing between root anchors may be determined for soil of different thicknesses. Small white ash trees of the same girth as those studied may be spaced 7m from each other and anchor a hillside mantled with 0.43m of saturated clay soil sloping at 30°.

The best root configuration has one or more deep tap roots. The sugar maple has a biomass below the ground similar to the ash, but is shallow rooted, and so does not penetrate to a depth at which failure is likely to occur. The roots of the white ash might increase the factor of safety above unity for a block of soil 0.8m in thickness inclined at 30°; neither sugar maple which was hand-excavated in this study had roots which extend 0.8m into the soil.

The Rapid Run landslide averaged 0.5m in thickness. The monoculture of sugar maples which forested the site had girths similar to those of the two maples which were excavated by hand. Maples of this girth have the potential to anchor soil up to but not greater than 0.5m in thickness, depending upon their spacing on the hillslope. The density of trees on the landslide mass was about one half that of the trees in the stable forested area adjacent to the landslide. The spacing of the trees on the stable portion of the hillslope mass averaged 7m, the critical spacing for ash trees on soil 0.43m in thickness. The landslide was probably inevitable as the spacing of the maple trees on the landslide mass even exceeded the critical spacing calculated for the more deeply-rooted white ash. The roots of the sugar maple are highly branched and so bind shallow soil well. Maple roots probably reduce surficial erosion better than the sparsely-branched roots of white ash, but in an established forest, leaf litter and understorey trees may serve this purpose as well.

With knowledge of the distribution of roots for a species and the resistance to pull-out from the soil, one can calculate the resistance offered by a root system to failure as shown above. But trees also can stabilize the soil by reducing the moisture content of the soil by transpiration during the growing season. The timing of Cincinnati's landslides may reflect the stabilizing effect that transpiration has on hillslopes. They occur in the late winter, and spring i.e., before leaf-out. The effect of altered soil moisture was controlled in the field testing of the resistance of roots to pull-out by the continual watering of the field site in order to maintain spring saturated levels of ground water. The extent to which the roots are effective in stabilizing a hillslope depends upon the displacement of soil that can be tolerated for a given site. The roots' resistance to failure peaks at about three to four centimeters of soil displacement. This displacement may be allowable in some areas, such as on hillslopes underlain by thin soil on which engineering structures are anchored in bedrock, but not in other areas where damage to structures will occur at small displacements.

A tree species selected for stabilization of a hillslope must have strong roots which penetrate deeply into the soil; the species must have the potential to thrive in the local climate and soil, and to tolerate competition with local biota. A species with the above characteristics as well as high rate of transpiration would be ideal for stabilization of soil. Trees may be combined with engineering materials in some cases to produce an inexpensive, attractive means of hillslope protection (Gray and Leiser, 1982).

BIBLIOGRAPHY

Archer, R.R., and Wilson, B.F., 1970, Mechanics of the compression wood response: Plant Physiology, Vol. 46, p. 550-556.

Ashby, W.C., 1962, Root growth in American Basswood: Ecology, Vol. 43, No. 2, p. 336-339.

Barley, K.P., 1962, The effects of mechanical stress on the growth of roots: Journal of Experimental Botany, Vol. 13, No. 37, p.95-110.

Bartos, M.J., Jr., 1979, 101 uses for earth reinforcement: Civil Engineering, ASCE, Jan. '79, p. 51-57.

Bassarab, D.R., and Huff, W.D., 1969, Clay mineralogy of kope and fairview formations (Cincinnatian) in the Cincinnati area: Journal of Sedimentary Petrology, Vol. 39, No. 3, p. 1014-1022.

Bishop, D.M., and Stevens, M.E., 1964, Landslides on logged areas in southeast Alaska: US Forest Service Research Paper NOR-1, p. 1-18.

Biswell, H.H., 1935, Effects of environment upon the root habits of certain deciduous forest trees: Botanical Gazette, June '35, p. 676-708.

Bohm, W., 1979, Methods of studying root systems: Heidelberg, Springer-Verlag, 188 p.

Bohm, W., 1976, In situ estimation of root length at natural soil profiles: Journal agric. Sci., Vol. 87, p. 365-368.

Bookman, P.A., and Mack, R.N., 1982, Root interaction between *Bromus tectorum* and *Poa pratensis*: A three-dimensional analysis: Ecology, Vol. 63(3), p. 640-646.

Boone, F.R., and Veen, B.W., 1982, The influence of mechanical resistance and phosphate supply on morphology and function of maize roots: Neth. J. agric. Sci., Vol. 30, p. 179-192.

Bormann, F.H., and Graham, B.F., Jr., 1959, The occurrence of natural root grafting in Eastern White Pine, *Pinus strobus* L., and its ecological implications: Ecology, Vol. 40, No. 4, p.677-691.

Boyd, J.D., 1982, An anatomical explanation for visco-elastic and mechano-sorptive creep in wood, and effects of loading rate on strength: New Perspectives in Wood Anatomy, Peter Baas, ed., Martenes Nyhoff/Dr. W. Junk, 252 p. (Check spelling)

Braun, E.L., 1916, The physiographic ecology of the Cincinnati region: Ohio Biological Survey, Bulletin No. 7, Vol. 2, No. 3, p. 115-211.

Braun, E.L., 1935, The undifferentiated deciduous forest climax and the association-segregate: Ecology, Vol. 16, No. 3, p. 514-519.

Braun, E.L., 1936, Notes on root behavior of certain trees and shrubs of the Illinoian Till Plain of Southwestern Ohio: Ohio Journal of Science, Vol. 36, No. 3, p. 141-146.

Braun, E.L., 1936, Notes on root behavior of certain trees and shrubs of the Illinoian till plain of Southwestern Ohio: Ohio Journal of Science, Vol. 36, No. 3, p. 141-146.

Braun, E.L., 1950, Deciduous forests of Eastern North America: New York, The Free Press, 596 p.

Braun, E.L., 1956, The development of association and climax concepts: their use in interpretation of the deciduous forest: American Journal of Botany, Vol. 43, No. 10, p. 906-911.

Braun, E.L., 1935, Affinities of the flora of the Illinoian till plain of Southwestern Ohio: Rhodora, Vol. 37, No. 422, p. 349-361.

Braun, E.L., 1938, Deciduous forest climaxes: Ecology, Vol. 19, No. 4, p. 515-522.

Burroughs, E.R., Jr., and Thomas, B.R., 1977, Declining root strength in douglas-fir after felling as a factor in slopes stability: USDA Forest Service Research Paper INT-190, p. 1-27.

Canode, C.L., 1977, Sampling technique for estimation of root production of Kentucky bluegrass: Crop Science, Vol. 17, No. 1, p. 28-30.

Carson, M.A., and Kirkby, M.J., 1972, Hillslope form and process, Chapter 7 - Instability in soil masses: Cambridge University Press, p. 148-187.

Christian, J.T., and Whitman, R.V., 1969, A one-dimensional model for progressive failure: Proceedings of the 7th International Conference of Soil Mechanics and Foundation Engineers, p. 541-545.

Cochran, P.H., 1979, Response of thinned lodgepole pine after fertilization: USDA Forest Service, Research Note PNW-335, p. 1-6.

Cosgrove, D.J., 1985, Cell wall yield properties of growing tissue: Plant Physiology, Vol. 78, p. 347-356.

Coutts, M.P., 1982, Growth of sitka spruce seedlings with roots divided between soils of unequal matric potential: New Phytol., Vol. 92, p. 49-61.

Crow, T.R., 1977, Biomass and production regressions for trees and woody shrubs common to the enterprise forest: The Enterprise, Wisconsin, Radiation Forest Radioecological Studies, NTIS, TID-26113-P2, p.63-65.

DeGraff, J.V., 1979, Initiation of shallow mass movement by vegetative-type conversion: Geology, Vol. 7, p. 426-429.

Duncan, W.H., 1941, A study of root development in three soil types in the Duke Forest: Ecological Monographs, Vol. 11, No. 2, p. 143-164.

Durrell, R.H., 1977, A recycled landscape: Quarterly of the Cincinnati Museum of Natural History, Vol. 14, No. 2, p. 1-9.

Ellison, L. and Coaldrake, J.E., 1954, Soil mantle movement in relation to forest clearing in Southeastern Queensland: Ecology, Vol. 35, No. 3, p. 380-388.

Endo, T., 1969, Probable distribution of the amount of rainfall causing landslides: Translated from the Annual Report of the Hokkaido Branch, Tokyo Forest Experiment Station, p. 122-136.

Endo, T., and Tsuruta, T., 1969, A report in regard to the reinforcement action of the vegetational roots upon the tensile strength of the natural soil: Translated from 1968 Annual Report of the Hokkaido Branch Forest Experiment Station, p. 183-189.

Endo, T., and Tsuruta, T., 1969, On the effect of the tree's roots upon the shear strength of soil: Translated from the 1968 Annual Report of the Hokkaido Branch, Forest Experiment Station, Sapporo, Japan, by Joseph M. Arata and Robert R. Ziemer, p. 167-182.

Faulkner, M.E., and Malcolm, D.C., 1972, Soil physical factors affecting root morphology and stability of scots pine on upland heaths: Forestry, Vol. 45, No. 1, p. 23-36.

Fenneman, N.M., 1948, Geology of Cincinnati and vicinity: Columbus, Heer Printing Co., 207 p.

Flaccus, E., 1959, Revegetation of landslides in the white mountains of New Hampshire: Ecology, Vol. 40, No. 4, p. 692-703.

Fleming, R.W., 1975, Geologic perspectives -- the Cincinnati example: Proceedings of Sixth Ohio Valley Soil Seminar, p. 1-22.

Fleming, R.W., and Taylor, F.A., 1980, Estimating the costs of landslide damage in the United States: U.S. Department of the Interior, Geological Survey Circular 832, p. 1-21.

Fleming, R.W., Gokce, A.O., and Johnson, A.M., 1981, Landslides in Colluvium: GSA Cincinnati '81 Field Trip Guidebooks, Vol. 3.

Ford, J.P., 1967, Cincinnatian geology in Southwest Hamilton County, Ohio: The American Association of Petroleum Geologists Bulletin, Vol. 51, No. 6, p. 918-936.

Fraser, A.I., 1962, The soil and roots as factors in tree stability: Forestry, Vol. 35, p. 117-127.

Fujihara, S., Yamamoto, R., and Masuda, Y., 1978, Viscoelastic properties of plant cell walls-I. Mathematical formulation for stress relaxation with consideration for pre-extension rate: Biorheology, Vol. 15, p. 63-75.

Gardner, W.R., and Ehlig, C.F., 1962, Some observations on the movement of water to plant roots: Agronomy Journal, No. 54, p. 453-456.

Gholz, H.L., Grier, C.C., Campbell, A.G., and Brown, A.T., 1979, Equations and their use for estimating biomass and leaf area of plants in the Pacific Northwest: Forest Research Laboratory, Oregon State University, Corvallis, Research Paper 41, p. 1-37.

Gilman, E.F., et al., 1981, Vertical root distribution of American Basswood in sanitary landfill soil: Forest Sci., Vol. 27, No. 4, p. 725-729. Gokce, A.O., Lion, T., Johnson, A.M., and Fleming, R.W., 1981, Landslides in glacial lake clays at Huffman Court and McKelvey Road: GSA Cincinnati '81 Field Trip Guidebooks, Vol. 3.

Gokce, O.A., 1979, Mechanisms of landsliding in Cincinnati area, Ohio: Research Proposal to the Department of Geology, University of Cincinnati.

Gray, D.H., 1974, Reinforcement and stabilization of soil by vegetation: Journal of the Geotechnical Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 100, No. GT6., p. 695-699.

Gray, D.H., 1977, Creep movement and soil moisture stress in forested vs. cutover slopes: results of field studies: Final Report to the National Science Foundation, DRDA Project 012577, 141 p.

Gray, D.H., 1977, Potential erosion and mass wasting impacts of proposed Big Butte Road and logging operations in Henthorne Lakes area - Middle Fork Eel River: Report on Geotechnical Investigation, Department of Civil Engineering, University of Michigan.

Gray, D.H., 1978, The role of woody vegetation in reinforcing soils and stabilizing slopes: Paper presented at a Symposium on Soil Reinforcing and Stabilizing Techniques in Engineering Practice, Sydney, Australia, Oct '78.

Gray, D.H., 1978, The role of woody vegetation in reinforcing soils and stabilizing slopes: Paper presented at Symposium on Soil Reinforcing and Stabilizing Techniques in Engineering Practices, Sydney, Australia.

Gray, D.H., and Megahan, W.F., 1981, Forest vegatation removal and slope stability in the Idaho batholith: USDA Forest Service, Research Paper INT-271, p. 1-23.

Gray, D. H. and H. Ohashi, 1982, Mechanics of Fiber reinforcements in sand: Journal of the Geotechnical Division, ASCE, Vol. 108 (GT3), p. 335-353.

Gray, D. H. and A. T. Leiser, 1982, Biotechnical slope protection and erosion control: Van Nostrand Reinhold Company, New York, pp. 271.

Gray, D. H., A. M. ASCE and Talal Al-Refeai, 1986, Behavior of fabric-versus fiber-reinforced sand, Journal of Geotechnical Engineering, Vol. 112, No. 8, P. 804-820.

Hackett, B., 1972, Landscape development of steep slopes: Newcastle upon Tyne, England, Oriel Press, p. 17-130.

Hanna, T. H., 1982, Foundations in Tension, Ground Anchors, Trans Tech Publications and McGraw-Hill Book Company, Germany and United States, pp. 572.

Hart, S.S., 1978, Potentially swelling soil and rock in the front range urban corridor, Chapter 14: Geology in the Urban Environment, Burgess Publishing Co., p. 109-120.

Hartsog, W.S., and Martin, G.L., 1974, Failure conditions in infinite slopes and the resulting soil pressures: USDA Forest Service, Research Paper INT-149, p. 1-28.

Hathaway, R.L., and Penny, D., 1975, Root strength in some *Populus* and *Salix* clones: New Zealand Journal of Botany, Vol. 13, p. 333-344.

Heath, M.E., 1968, Fitting plants to fragipan soils in Southern Indiana: Proceedings of the Indiana Academy of Science, No. 78, p. 429-434.

Heilman, P., 1981, Root penetration of Douglas-fir seedlings into compacted soil: Forest Sci., Vol. 27, No. 4, p. 660-666. Hoexter, D.F., Holzhausen, G., and Soto, A.E., 1978, A method of evaluating the relative stability of ground for hillside development: Engineering Geology, Vol. 12, p. 319-336.

Jillson, W.R., 1962, The Maysville earth slides: Roberts Printing Co., Frankfort, KY, p. 1-18.

Johnson, A.M., and Rodine, J.R., 1984, Chapter 8 - Debris flow: Slope Instability, John Wiley & Sons, Ltd., p. 257-361.

Johnson, R.B., 1979, Factors that influence the stability of slopes: Federal Highway Administration Report No. FHWA-RD-79-54, p.101-123.

Karisumi, N., and Tsutsumi, T., 1958, Literature on the tree root system until 1955: Translated by Joseph M. Arata and Robert R. Ziemer from the Japanese Forestry Society Journal, Vol. 40, No. 5, p. 1-97.

Keefer, D.K., and Johnson, A.M., 1983, Earth flows: morphology, mobilization, and movement: Geological Survey Professional Paper 1264, p. 1-56.

Keith, C.T., 1974, Longitudinal compressive creep and failure development in white spruce compression wood: Wood Science, Vol. 7, No. 1, p. 1-12.

Kitamura, Y. and Namba, S., 1968, A field experiment on the uprooting resistance of tree roots: Translated by Joseph M. Arata and Robert R. Ziemer from Proceedings of the 79th Meeting of the Japanese Forestry Society, p. 360-361.

Kittredge, J., DATE, Estimation of the amount of foliage of trees and stands: Journal of Forestry, Vol.?, p. 905-912.

Kochenderfer, J.N., 1973, Root distribution under some forest types native to West Virginia: Ecology, Vol. 54, No. 2, p. 445-448.

Kohno, Y., et al, 1968, Roles of topography, soil and forest in the landslides of a weathered granite area: Translated from Reports of Cooperative Research for Disaster Prevention, No. 14, Science and Technology Agency, Tokyo, Japan.

Kramer, P.J., and Kozlowski, T.T., 1979, Physiology of woody plants: New York, Academic Press, 811 p.

Kramer, P.J., 1969, Plant and soil water relationships: a modern synthesis: New York, McGraw-Hill, Inc., 482 p.

Kucera, L.J. and Bariska, M., 1982, On the fracture morphology in wood, Part 1: Wood Science and Technology, Vol. 16, p. 241-259.

Lerch, et al., 1980, An inventory of Ohio soils, Hamilton County: Ohio Department of Natural Resources, Division of Lands and Soils, Progress Report No. 60, 67 p.

Lutz, H.J., 1940, Disturbance of forest soil resulting from the uprooting of trees: Yale University School of Forestry Bulletin, No. 45, p. 1-27.

Lyford, W.H., 1980, Development of the root system of northern red oak (*Quercus rubra* L.): Harvard Forest Paper No. 21, p. 1-30.

Lyford, W.H., and Wilson, B.F., 1964, Development of the root system of *Acer rubrum* L.: Harvard Forest Paper No. 10, p. 1-17.

Manbeian, T., 1973, The influence of soil moisture suction, cyclic wetting and drying and plant roots on the shear strength of a cohesive soil and stability of slopes: PhD Thesis, University of California, Berkeley.

McMahon, T.A., 1975, The mechanical design of trees: Scientific American, Vol. 233, No. 1, p. 93-102.

McMahon, T., 1973, Size and shape in biology: Science, Vol. 179, p. 1201-4.

McMinn, R.G., 1963, Characteristics of Douglas-Fir root systems: Canadian Journal of Botany, Vol. 41, p. 105-122.

McNutt, J.A., 1974, Effects of forest cover on slope stability: Research Paper to the Department of Forest Engineering at Oregon State University, p. 1-23.

Megahan, W.F., 1974, Deep-rooted plants for erosion control on granitic road fills in the Idaho Batholith: USDA Forest Service Research Paper INT-161, p. 1-18.

Miller, L., and Woods, F.W., 1965, Root-grafting in loblolly pine: Botanical Gazette, 126(4), p. 252-255.

Noble, H.L., 1973, Residual strength and landslides in clay and shale: Journal of the Soil Mechanics and Foundations Division, SM9, p. 705-719.

Noble, H.L., 1973, Residual strength and landslides in clay and shale: Journal of the Soil Mechanics and Foundations Division, SM9, p. 705-718.

O'Loughlin, C.L., 1974, A study of tree root strength deterioration following clearfelling: Canadian Journal of Forest Research, Vol. 4, p.107-113.

O'Loughlin, C.L., 1972, An investigation of the stability of the steepland forest soils in the Coast Mountains, Southwest British Columbia: PhD Thesis, University of British Columbia, p. 1-147.

O'Loughlin, C.L., and Pearce, A.J., 1984, Symposium on effects of forest land use on erosion and slope stability: Proceedings of Symposium, International Union of Forestry Research Organisations, New Zealand Forest Service and USDA Forest Service, p. 91-122.

O'Sullivan, M.F., and Ball, B.C., 1982, A comparison of five instruments for measuring soil strength in cultivated and uncultivated cereal seedbeds: Journal of Soil Science, Vol. 33, p. 597-608.

Ortman, E.E., et al., 1968, Vertical-pull technique for evaluating tolerance of corn root systems to northern and western corn rootworms: Journal of Economic Entomology, Vol. 61, p. 373-375.

Ostermayer, H., 1975, Construction, carrying behaviour and creep characteristics of ground anchors, Institution of Civil Engineers, London, p. 141-151. Palmer, A.C., and Rice, J.R., 1973, The growth of slip surfaces in the progressive failure of over-consolidated clay: Proc. Roy. Soc. Lond. A., Vol. 332, p. 527-548.

Parizek, E.J., and Woodruff, J.F., 1957, Mass wasting and the deformation of trees: American Journal of Science, Vol. 255, p. 63-70.

Parker, W.C., and Pallardy, S.G., 1982, Seasonal changes in tissue water relations of three woody species of the *Quercus-Carya* forest type: Ecology, Vol. 63(5), p. 1259-67.

Patric, J.H., Douglass, J.E., and Hewlett, J.D., 1965, Soil water absorption by Mountain and Piedmont Forests: Soil Science Society Proceedings, p. 303-308.

Peck, R.B., 1967, Stability of Natural Slopes: Journal of the Soil Mechanics and Foundations Division, Proceedings of the American Society of Civil Engineers, July, 1967, p. 403-417.

Preisig, C.L., Carlson, W.C., and Promnitz, L.C., 1979, Comparative root system morphologies of seeded-in-place, bareroot, and containerized Douglas-fir seedlings after outplanting: Canadian Journal of Forest Research, Vol. 9, No. 3, p. 399-405.

Reid, J.B., and Goss, M.J., 1981, Effect of living roots of different plant species on the aggregate stability of two arable soils: Journal of Soil Science, Vol. 32, p. 521-541.

Riestenberg, M.M., and Sovonick-Dunford, S., 1983, The role of woody vegetation in stabilizing slopes in the Cincinnati area, Ohio: Geological Society of America Bulletin, Vol. 94, p. 506-518.

Rothacher, J.S., et al., Estimating the quantity of tree foliage in oak stands in the Tennessee Valley: Journal of Forestry, Vol. , p. 169-173.

Russell, R.S., 1977, Plant root systems: London, McGraw-Hill Book Company (UK) Limited, 298 p.

Sandfort, S., 1979, Trees!: Publication of the Cincinnati Park Board, Cincinnati, OH.

Santantonio, D., Hermann, R.K., and Overton, W.S., 1977, Root biomass studies in forest ecosystems: Pedobiologia, Bd. 17, p. 1-31.

Schlaegel, B.E., 1975, Estimating aspen volume and weight for individual trees, diameter classes, or entire stands: USDA Forestry Service General Technical Report NC-20, p. 1-16.

Schmidt, A. E., 1956, Rock anchors hold TV tower on Mt. Wilson: Civil Engineering, Vol. p. 24, p. 56-58.

Schniewind, A.P., 1980, Mechanical behavior and properties of wood: Proceedings of the Clark C. Heritage Workshop, p. 57-94.

Schniewind, A.P., and Lyon, D.E., 1971, Tensile strength of redwood dimension lumber - I. Relation to grade and working stress: Forest Products Journal, Vol. 21, No. 7, p. 18-27.

Scotford, D.M., 1965, Petrology of the Cincinnatian Series Shales and Environmental Implications: Geological Society of America Bulletin, Vol. 76, p. 193-222.

Scully, N.J., 1942, Root distribution and environment in a maple-oak forest: Botanical Gazette, March '42, Vol. 103, p. 492-517.

Shewbridge, S., and Sitar, N., 1985, The influence of fiber properties on the deformation characteristics of fiber-soil composites: USDA Forest Service Report No. UCB/GT/85-02, 100 p.

Skempton, A.W., 1964, Long-term stability of clay slopes: Geotechnique, Vol. 14, p. 77-102.

Skempton, A. W., 1985, Residual strength of clays in landslides, folded strata and the laboratory: Geotechnique, Vol. 35, No. 1, P. 3-18.

Snell, J.A.K., 1979, Preliminary crown weight estimates for tanoak, black oak, and pacific madrone: USDA Forest Service, Research Note PNW-340, p.1-4.

Stafford, J.V., and Tanner, D.W., 1983, Effect of rate on soil shear strength and soil-metal friction: Soil & Tillage Research, Vol. 3, p. 245-260.

Stocker, F.R., and Fitch, S.D., 1982, Forest modeling and root growth simulation: Computer Graphics World, Vol. 5, No. 7, p. 33-38. Stoeckeler, J.H., and Kluender, W.A., 1938, The hydraulic method of excavating the root systems of plants: Ecology, Vol. 19, No. 3, p. 355-369.

Stout, B.B., 1956, Studies of the root systems of deciduous trees: Harvard Black Rock Forest Bulletin, No. 15, p. 3-45.

Swanson, F.J., and Dyrness, C.T., 1975, Impact of clear-cutting and road construction on soil erosion by landslides in the western Cascade Range, Oregon: Geology, July, 1975, p. 393-396.

Swanson, F.J., and James, M.E., 1975, Geology and Geomorphology of the H.J. Andrews Experimental Forest, Western Cascades, Oregon: USDA Forest Service Research Paper PNW-188, p. 1-14.

Turmanina, V.I., 1963, The magnitude of the reinforcing role of tree roots: Translated by Dorothy Hiestand from the Moscow University Herald, Scientific Journal, Series V, No. 4, p. 78-80.

Turmanina, V.I., 1965, The strength of tree roots: Translated by Leo Kanner Associates from the Bulletin of the Moscow Society of Naturalists, Biological Section, Vol. 70(5), p. 36-45.

Turnbull, W.J., and Hvorslev, M.J., 1967, Special problems in slope stability: Journal of the Soil Mechanics and Foundations Division, Proceedings of the American Society of Civil Engineers, July, 1967, p. 499-528.

Turner, L.M., 1936, A comparison of roots of Southern Shortleaf Pine in three soils: Ecology, Vol. 17, No. 4, p. 649-658.

Vidal, Henri, 1969, The principle of reinforced earth: Highway Research Record No. 282, Highway Research Board, National Research Council, Division of Engineering, p. 1-16.

Von Schlichten, O.C., 1935, Landslides in the vicinity of Cincinnati: The Compass of Sigma Gamma Epsilon, Vol 15, No. 3, p. 151-154.

Waldron, L.J., 1977, The shear resistance of root-permeated homogeneous and stratified soil: Soil Science Society of America Journal, Vol. 41, p. 843-849.

Waldron, L.J., Dakessian, S., and Nemson, J.A., 1983, Shear resistance enhancement of 1.22-meter diameter soil cross sections by pine and alfalfa roots: Soil Science Society of America Journal, Vol. 47, No. 1, p. 9-14.

Wardrop, A.B., and Addo-Ashong, F.W., 1963, The anatomy and fine structure of wood in relation to its mechanical failure: Proceedings of the First Tewksbury Symposium, University of Melbourne, p. 169-200.

Waring, R.H., Gholz, H.L., Grier, C.C., and Plummer, M.L., 1977, Evaluating stem conducting tissue as an estimator of leaf area in four woody angiosperms: Canadian Journal of Botany, Vol. 55, No. 11, p. 1474-1477.

Weiss, M.P., and Sweet, W.C., 1964, Kope formation (Upper Ordovician): Ohio and Kentucky: Science, Vol. 145, p. 1296-1302.

Whiteley, G.M., et al., 1982, The buckling of plant roots: Physiologia Plantarum, Vol. 54, p. 333-342.

Whitman, R.V., and Bailey, W.A., 1967, Use of computers for slope stability analysis: Journal of the Soil Mechanics and Foundations Division, ASCE, July '67, p. 475-498.

Wilson, B.F., and Archer, R.R., 1979, Tree design: some biological solutions to mechanical problems: BioScience, Vol. 29, No. 5, p. 293-298.

Wilson, B.F., 1964, Structure and growth of woody roots of *Acer rubrum* : Harvard Forest Paper No. 11, p. 1-14.

Wilson, B.F., 1976, The basis for a model of tree root system development: Research Paper from the Department of Forestry and Wildlife Management, University of Massachusetts, p. 1-31.

Wu, T.H., 1984, Soil movements on permafrost slopes near Fairbanks, Alaska: Canadian Geotechnical Journal, Vol. 21, No. 4, p. 699-709.

Wu, T.H., and McKinnell, W.P., III, and Swanston, D.N., 1979, Strength of tree roots and landslides on Prince of Wales Island, Alaska: Canadian Geotechnical Journal, Vol. 16, No. 1, p. 19-33.

Wu, T. H., 1987, Soil reinforcement by roots: Progress report to National Science Foundation and U. S. Forest Service, Department of Civil Engineering, Ohio State University, pp. 50.

Yawney, H.W., and Trimble, G.R., Jr., 1968, Oak soil-site relationships in the Ridge and Valley Region of West Virginia and Maryland: US Forest Service, Research Paper NE-96, p.1-19.

Ziemer, R.R., 1981, Management of steepland erosion: Keynote Address, Theme 4, Part 2, International Symposium on Erosion and Sediment Transport in Pacific Rim Steeplands, Christchurch, New Zealand, p. 1-15.

Ziemer, R.R., 1981, The role of vegetation in the stability of forested slopes: Proceedings of the International Union of Forest Research Organizations, IUFRO World Congress, Divison 1, p. 297-308.

Ziemer, R.R., 1981, Watershed rehabilitation: A process view: Symposium on Watershed Rehabilitation in Redwood National Park and Other Pacific Costal Areas, p. 1-10.

Ziemer, R.R., 1981, Roots and the stability of forested slopes: International Symposium on Erosion and Sediment Transport in Pacific Rim Steep Lands, Christchurch, New Zealand, p. 1-19.

Ziemer, R.R., and Swanston, D.N., 1977, Root strength changes after logging in southeast Alaska: USDA Forest Service, Research Note PNW-306, p. 1-10.

Ziemer, R.R., and Swanston, D.N., 1977, Root strength changes after logging in Southeast Alaska: USDA Forest Service Research Note PNW-306, p. 1-9.

Ziemer, R.R., 1980, Some effects of silvicultural options on the stability of slopes: National Council of the Paper Industry for Air and Stream Improvement Special Report, p. 1-17.

Zimmermann, M.H., and Brown, C.L., 1980, Trees - structure and function: New York, Springer-Verlag, Inc., 336 p.

APPENDIX A

Description of Eden Soil

Excerpt from the Soil Survey of Hamilton County, Ohio, United States Department of Agriculture Soil Conservation Service in cooperation with Ohio Department of Natural Resources Division of Lands and Soil, and Ohio Agricultural Research and Development Center. Issued August 1982.

"Eden Silty Clay Loam is a well drained soil that occupies gently sloping to steep hillsides and strongly sloping, narrow crests of ridges on uplands. It formed in residuum weathered from the underlying, interbedded shale and limestone bedrock."

"In a representative Eden soil the surface layer is very dark grayish brown, friable silty clay loam 5 inches thick. The subsoil is 23 inches thick. The upper part of the subsoil is yellowish brown, friable silty clay loam; the middle part is yellowish brown and light olive brown, firm silty clay; and the lower part is olive brown, firm flaggy clay. The substratum to a depth of 60 inches is olive brown, interbedded, flaggy clay shale and limestone bedrock. The depth to the bedrock ranges from 20 to 40 inches. Some small areas of this soil have a flaggy silty clay loam surface texture while other areas have a silt loam surface texture."

"Eden silty clay loam has slow permeability in the subsoil above the bedrock, a low available water capacity and a moderately deep root zone. Most areas are moderately eroded and have a higher rate of runoff than slightly eroded or uneroded areas. This soil is highly susceptible to slippage when saturated or disturbed. Shallowness to bedrock, slow permeability and slope are also severe use limitations of Eden silty clay loam. Gently sloping and strongly sloping areas of this soil have medium potential for building sites, farm cropland, pasture and woodland and some recreational uses. Moderately steep and steep areas of Eden silty clay loam have low potential for building sites and cropland and medium potential for pasture and woodland. All areas of Eden silty clay loam have mostly low potential for sanitary facilities because of shallowness to bedrock, slow permeability and clayey textures. Most areas of this soil are used for pasture and woodland, but some strongly sloping areas are utilized for building sites and cropland. Some moderately steep and steep areas are used for such recreational purposes as hiking paths and trails and nature study sites in county and city parks and for which these areas are potentially suitable. The bedrock underlying Eden silty clay loam makes excavating difficult, however, it is rippable using heavy equipment and rarely requires blasting."

APPENDIX B

Data from Vermeer Excavations

VERMEER EXCAVATED ROOTS

Sugar maple #4
trunk diameter --- inside, 11.9cm; outside, 12.6cm

Root diameters are measured 30cm from the base of the trunk. Each primary lateral root is assigned a number, and the large roots which branch from the lateral and project through a hemisphere 30cm away from the trunk are given the mother lateral's number plus a letter. The azimuth and plunge are measured out, in a direction away from the trunk. The numbers of roots greater than and less than 5mm are those which grow from the lateral, but do not project through the hemisphere. The grafts per lateral are numbered. The vertical distance is the distance from the base of the trunk at which the laterals originate.

root	diam.(mm)	azimuth/plunge	#roots>5mm	#roots<5mm	grafts	vert.dist.(cm)
1	18.8	60/15n	0	0	0	0
2	16	60/15n	1	10	0	0
3	17.8	40/86n	2	7	0	0
4	18	45/27n	3	9	0	0
5	11.8	125/19s	0	4	0	0
6	26.1	110/27s	3	0	0	0
6a	13	160/52s	3	2	0	0
6b	7.4	200/27s	1	6	0	0
7	19.2	70/12s	1	4	0	0
8	19.5	80/25e	2	14	0	4
9	12.1	80/33e	1	7	0	0
10	12	195/38s	0	3	0	6
11	6	220/28	0	5	1	0
12	6.5	100/18s	0	6	0	6
13	9	120/30s	1	7	0	0
14	12.1	120/35s	0	4	0	26
15	15	210/25s	1	3	0	20
16	73	200/26s	7	11	0	0
16a	16.2	260/12w	0	4	0	0
16b	15	220/52s	1	3	0	0
16c	11	145/66s	1	12	0	0
16d	19	240/52s	1	3	0	0
17	19	315/14w	0	5	0	18
18	14	190/47s	0	4	0	21
19	12	240/14s	2	5	0	0
20	13.4	250/4s	1	6	0	7
21	17	50/86n	0	4	0	16
22	17	275/10n	1	3	0	0
23	16.2	275/5w	0	3	0	0
24	graft from another tree					
25	33	275/27n	4	9	0	0
25a	27	250/65s	8	20	2	0
25b	16.2	60/20s	1	3	0	0
25c	19.3	0/25n	0	1	0	0
26	22	330/0	0	3	1	14
27	46.5	260/52w	2	7	0	8
27a	24.8	230/38s	3	2	1	0

27b	29	285/62n	4	1	2	0
27c	18.9	280/20w	1	3	1	0
28	28	300/5s	3	15	0	0
28a	14	340/35n	0	2	0	0
29	40	20/21n	3	12	1	0
29a	12	85/27w	0	8	0	0
30	26	0/0	3	5	1	15
30a	9.5	40/55n	0	6	0	0
31	17.5	100/20n	1	9	0	18
32	12	50/6n	1	3	0	0
32a	10	50/17n	0	1	0	0
33	27	40/28n	5	10	0	0
33a	10.9	340/5n	0	10	0	0
34	10.5	55/18n	1	15	0	19
33	27	40/28n	5	10	0	0

White Ash #8
trunk diameter --- inside, 8.3cm; outside, 9.8cm

root#	diam(mm)	azimuth	plunge	dir	#>5mm	#<5mm	grafts	vert dist cm
1	23	40	23	s	1	0	0	1
2	14	290	23	n	0	0	0	0
3	25.5	25	13	s	0	0	0	0
4	16.6	325	0		0	1	0	0
5	7.1	20	20	n	0	2	0	0
6	17.8	85	30	n	5	11	0	10
7	18.1	80	65	n	3	3	0	10
7a	11.0	90	38	e	0	4	0	7
8	5.3	140	10	s	0	2	0	1
9	29.5	220	10	s	1	4	0	1
9a	19.5	125	30	s	1	4	0	0
10	16.1	235	0		1	5	1	6
11	21	230	22	n	1	5	0	8
11a	10	130	65	n	0	6	0	0
12	24	280	0		0	1	0	0
13	13.6	260	10	w	0	2	0	0
14	54.9	65	82	e	4	12	0	0
14a	10	0	60	n	2	5	0	0
14b	12.3	145	37	s	0	5	0	0
14c	10	50	8	s	1	5	0	0
14d	6.5	55	5	s	0	8	0	0
15	15.1	310	15	n	0	1	0	1

APPENDIX C

DEPTH, written by Roger Stuebing

```
// JOB ,MARY,
// REGION=1024K,TIME=(,15)
/*JOBPARM L=6
// EXEC SAS,REL=855
//SYSIN DD *
DATA ROOT1 ; INFILE RAW ;
INPUT  ID1 1-3  DIAM1 4-6 PLUNGE 7-8  LENGTH 9-11 AZIMUTH 12-14
  DIAM2 15-17 ID2 18-20;
PI=3.14159;  RAD1 = DIAM1/2;  RAD2=DIAM2/2;
PROC SORT; BY ID1;
DATA BUILD; FILE PRINT;
ARRAY LEVEL1  L1N1- L1N40;
ARRAY LEVEL2  L2N1- L2N40;
ARRAY LEVEL3  L3N1- L3N40;
ARRAY LEVEL4  L4N1- L4N40;
ARRAY LEVEL5  L5N1- L5N40;
ARRAY LEVELS(N) LEVEL1- LEVEL5;
ARRAY PLANE (P)  PL1 - PL6 ;
DO K = 1  TO  TOTAL;
   SET ROOT1  POINT=K   NOBS=TOTAL;
   IF ID1 GT 20  THEN GO TO A;
     _I_=ID1; N=1;   LEVELS = 0;
     _I_=ID2; N=2; I=2;
     ANGLE = 2*PI*PLUNGE/360 ;
     DEPTH = LENGTH *  SIN ( ANGLE) ;
     LEVELS = DEPTH;
     LINK  PLANE ;
PUT (ID1 ANGLE DEPTH LEVELS PLANE) (10.2);
 END;
   END;
PUT (L1N1-L1N50)(@5 50*2.)//(L2N1-L2N50)(@5 50*2.)
DO  I= 3  TO  5 ;
 DO K = 1 TO TOTAL ;
   SET  ROOT1 POINT=K  NOBS=TOTAL;
   IF  ID1 LE  20  THEN GO TO A;
   LIST;
   N=I-1;  _I_ =ID1;
   IF LEVELS = .  THEN GO TO A;
   ANGLE = 2*PI*PLUNGE/ 360 ;   DPTH1= LEVELS;
   DEPTH = LENGTH *  SIN ( ANGLE);
   N=I;  _I_= ID2;  LEVELS = DPTH1 + DEPTH;
   LINK PLANE;
 A:END;
END;
PLANE :
  P=0;
  DO  D =  200, 150, 100, 50;
  N=I - 1;   _I_ = ID1;  DPTH1 = LEVELS;
  DPTH2 = DPTH1 + DEPTH;  P=P+1;
  IF  D  LE  DPTH2 AND  D GE DPTH1 THEN DO;
  RAD  = RAD1 +  (RAD2 - RAD1) *  (D - DPTH1)/ (DPTH2 - DPTH1);
  AREA = PI * RAD * RAD;
  PLANE = PLANE +  AREA;
  END;
```

```
END;
PUT (ID1 ANGLE DEPTH LEVELS PLANE)(10.2);
A:END;
PUT (LIN1-LIN40)(@ 40*3.)//(L2N1-L2N40)(@ 40*3.)
PROC PRINT ;
/*
//RAW  DD *
  1 5045 50 10 48 21
 21 4020 94 90 35 22
 22 2545 50 20 10 23
 21 3845 72 10 35 24
 24 2060 40180 15 26
 26 1050 50200  5 27
 26 1060 50 10  5 28
  2 8089180270 10 29
  3 6060100 90  5 30
  4 7530200180  5 31
 24 1845144 20  2 25
/*
```

Root Area vs Depth for CODEASH

INPUT DATA SET

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2
1	1	3.1	5	2	280	3.1	21
2	21	0.5	45	19	310	0.4	22
3	21	3.1	5	21	280	2.3	23
4	23	1.2	5	14	310	0.8	24
5	24	0.8	20	15	310	0.4	25
6	24	0.4	5	12	250	0.3	26
7	23	2.3	5	7	280	1.9	27
8	27	1.9	5	19	280	1.2	28
9	28	0.3	10	5	95	0.3	29
10	28	1.2	10	8	285	0.8	30
11	30	0.4	5	2	25	0.4	31
12	30	0.8	5	4	280	0.7	32
13	2	3.3	10	14	220	2.5	33
14	43	0.4	40	9	270	0.4	34
15	44	2.3	10	5	220	2.5	35
16	35	0.8	20	13	180	0.3	36
17	35	2.5	10	9	220	2.1	37
18	37	0.6	20	20	280	0.4	38
19	37	0.3	20	9	180	0.1	39
20	37	2.1	10	12	220	2.1	40
21	43	0.3	15	12	230	0.1	41
22	44	0.3	70	13	290	0.1	42
23	33	0.8	10	2	310	0.4	43
24	33	2.5	10	8	220	2.3	44
25	3	2.5	20	12	170	2.9	45
26	45	1.0	4	26	260	0.5	46
27	45	2.9	4	7	240	2.0	47
28	47	0.9	44	30	240	0.1	48
29	47	2.0	4	26	260	1.5	49
30	49	1.5	4	32	240	0.5	50
31	4	1.3	4	29	160	0.7	51
32	6	3.1	15	30	70	2.9	54
33	54	2.9	15	41	70	1.7	55
34	54	1.9	25	1	90	1.9	56
35	56	1.2	49	19	0	0.6	57
36	56	1.5	7	8	70	1.4	58
37	58	0.8	70	15	320	0.3	59
38	58	1.4	15	28	75	0.4	60
39	58	0.3	25	4	90	0.3	61
40	7	3.0	3	26	25	2.4	62
41	62	0.8	43	11	105	0.6	63
42	63	0.3	3	4	80	0.3	64
43	63	0.6	43	12	105	0.5	65
44	62	2.4	3	2	25	2.4	66
45	66	1.1	25	36	335	0.8	67
46	66	2.4	3	5	25	2.0	68
47	68	2.0	0	25	30	0.8	69
48	68	1.1	3	40	80	0.6	70
49	79	3.4	0	4	10	3.2	71
50	71	3.2	0	12	10	2.3	72

Root Area vs Depth for CODEASH

INPUT DATA SET (ctd.)

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2
51	72	2.3	0	18	10	1.9	73
52	73	0.3	30	12	60	0.1	74
53	73	1.9	0	3	10	1.7	75
54	75	0.3	30	23	40	0.1	76
55	75	1.7	0	25	10	1.5	77
56	71	1.1	25	9	350	0.5	78
57	80	3.8	0	2	10	3.4	79
58	8	3.8	0	1	10	3.8	80
59	80	1.6	30	30	305	1.3	81
60	81	0.5	65	11	280	0.4	82
61	81	1.3	30	24	305	0.9	83
62	79	0.8	25	18	350	0.4	84
63	9	0.9	50	17	305	0.4	85
64	27	1.9	50	9	250	0.8	86
65	72	0.4	3	5	55	0.3	87
66	5	4.0	55	16	90	4.0	88
67	88	4.0	55	3	90	3.9	89
68	89	3.9	55	18	90	2.6	90
69	90	2.6	55	57	90	1.2	91
70	91	1.2	55	17	90	1.0	92
71	92	1.0	0	15	80	0.6	93
72	92	1.0	45	17	40	0.7	94
73	90	0.5	10	46	100	0.1	95
74	89	0.9	80	32	120	0.3	96
75	88	1.2	52	170	180	0.1	97
76	91	0.4	15	5	10	0.1	98
77	5	2.0	45	19	30	0.8	99
78	11	4.2	86	33	125	2.4	100
79	100	0.3	15	10	350	0.1	101
80	100	0.5	9	28	70	0.1	102
81	100	0.3	43	9	145	0.1	103
82	100	0.4	22	12	220	0.1	104
83	106	0.6	15	11	270	0.1	105
84	100	2.4	86	12	125	1.6	106
85	106	1.6	86	3	125	1.6	107
86	107	0.9	0	24	215	0.3	108
87	107	1.6	86	25	130	0.8	109
88	10	5.4	80	8	300	4.9	110
89	110	4.9	80	19	300	2.2	111
90	110	2.9	0	3	155	2.2	112
91	111	1.8	20	40	40	0.8	113
92	111	2.8	45	40	285	0.8	114

Root Area vs Depth for CODEASH

ORIGINAL OBSERVATIONS WITH DEPTH ADDED FOR EACH NODE

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2	DPTH1	ANGLE	DPTH2
1	1	3.1	5	2	280	3.1	21	0.00000	0.08727	0.1743
2	21	0.5	45	19	310	0.4	22	0.17431	0.78540	13.6093
3	21	3.1	5	21	280	2.3	23	0.17431	0.08727	2.0046
4	23	1.2	5	14	310	0.8	24	2.00458	0.08727	3.2248
5	24	0.8	20	15	310	0.4	25	3.22476	0.34907	8.3551
6	24	0.4	5	12	250	0.3	26	3.22476	0.08727	4.2706
7	23	2.3	5	7	280	1.9	27	2.00458	0.08727	2.6147
8	27	1.9	5	19	280	1.2	28	2.61467	0.08727	4.2706
9	28	0.3	10	5	95	0.3	29	4.27063	0.17453	5.1389
10	28	1.2	10	8	285	0.8	30	4.27063	0.17453	5.6598
11	30	0.4	5	2	25	0.4	31	5.65981	0.08727	5.8341
12	30	0.8	5	4	280	0.7	32	5.65981	0.08727	6.0084
13	2	3.3	10	14	220	2.5	33	0.00000	0.17453	2.4311
14	43	0.4	40	9	270	0.4	34	.	0.69813	.
15	44	2.3	10	5	220	2.5	35	.	0.17453	.
16	35	0.8	20	13	180	0.3	36	.	0.34907	.
17	35	2.5	10	9	220	2.1	37	.	0.17453	.
18	37	0.6	20	20	280	0.4	38	.	0.34907	.
19	37	0.3	20	9	180	0.1	39	.	0.34907	.
20	37	2.1	10	12	220	2.1	40	.	0.17453	.
21	43	0.3	15	12	230	0.1	41	.	0.26180	.
22	44	0.3	70	13	290	0.1	42	.	1.22173	.
23	33	0.8	10	2	310	0.4	43	2.43107	0.17453	2.7784
24	33	2.5	10	8	220	2.3	44	2.43107	0.17453	3.8203
25	3	2.5	20	12	170	2.9	45	0.00000	0.34907	4.1042
26	45	1.0	4	26	260	0.5	46	4.10424	0.06981	5.9179
27	45	2.9	4	7	240	2.0	47	4.10424	0.06981	4.5925
28	47	0.9	44	30	240	0.1	48	4.59253	0.76794	25.4323
29	47	2.0	4	26	260	1.5	49	4.59253	0.06981	6.4062
30	49	1.5	4	32	240	0.5	50	6.40620	0.06981	8.6384
31	4	1.3	4	29	160	0.7	51	0.00000	0.06981	2.0229
32	6	3.1	15	30	70	2.9	54	0.00000	0.26180	7.7646
33	54	2.9	15	41	70	1.7	55	7.76456	0.26180	18.3761
34	54	1.9	25	1	90	1.9	56	7.76456	0.43633	8.1872
35	56	1.2	49	19	0	0.6	57	8.18718	0.85521	22.5267
36	56	1.5	7	8	70	1.4	58	8.18718	0.12217	9.1621
37	58	0.8	70	15	320	0.3	59	9.16214	1.22173	23.2575
38	58	1.4	15	28	75	0.4	60	9.16214	0.26180	16.4091
39	58	0.3	25	4	90	0.3	61	9.16214	0.43633	10.8526
40	7	3.0	3	26	25	2.4	62	0.00000	0.05236	1.3607
41	62	0.8	43	11	105	0.6	63	1.36073	0.75049	8.8627
42	63	0.3	3	4	80	0.3	64	8.86271	0.05236	9.0721
43	63	0.6	43	12	105	0.5	65	8.86271	0.75049	17.0467
44	62	2.4	3	2	25	2.4	66	1.36073	0.05236	1.4654
45	66	1.1	25	36	335	0.8	67	1.46541	0.43633	16.6797
46	66	2.4	3	5	25	2.0	68	1.46541	0.05236	1.7271
47	68	2.0	0	25	30	0.8	69	1.72709	0.00000	1.7271
48	68	1.1	3	40	80	0.6	70	1.72709	0.05236	3.8205
49	79	3.4	0	4	10	3.2	71	.	0.00000	.
50	71	3.2	0	12	10	2.3	72	.	0.00000	.

Root Area vs Depth for CODEASH

ORIGINAL OBSERVATIONS WITH DEPTH ADDED FOR EACH NODE (ctd.)

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2	DPTH1	ANGLE	DPTH2
51	72	2.3	0	18	10	1.9	73	.	0.00000	.
52	73	0.3	30	12	60	0.1	74	.	0.52360	.
53	73	1.9	0	3	10	1.7	75	.	0.00000	.
54	75	0.3	30	23	40	0.1	76	.	0.52360	.
55	75	1.7	0	25	10	1.5	77	.	0.00000	.
56	71	1.1	25	9	350	0.5	78	.	0.43633	.
57	80	3.8	0	2	10	3.4	79	.	0.00000	.
58	8	3.8	0	1	10	3.8	80	0.0000	0.00000	0.000
59	80	1.6	30	30	305	1.3	81	0.0000	0.52360	15.000
60	81	0.5	65	11	280	0.4	82	15.0000	1.13446	24.969
61	81	1.3	30	24	305	0.9	83	15.0000	0.52360	27.000
62	79	0.8	25	18	350	0.4	84	.	0.43633	.
63	9	0.9	50	17	305	0.4	85	0.0000	0.87266	13.023
64	27	1.9	50	9	250	0.8	86	2.6147	0.87266	9.509
65	72	0.4	3	5	55	0.3	87	.	0.05236	.
66	5	4.0	55	16	90	4.0	88	0.0000	0.95993	13.106
67	88	4.0	55	3	90	3.9	89	13.1064	0.95993	15.564
68	89	3.9	55	18	90	2.6	90	15.5639	0.95993	30.309
69	90	2.6	55	57	90	1.2	91	30.3086	0.95993	77.000
70	91	1.2	55	17	90	1.0	92	77.0002	0.95993	90.926
71	92	1.0	0	15	80	0.6	93	90.9258	0.00000	90.926
72	92	1.0	45	17	40	0.7	94	90.9258	0.78540	102.947
73	90	0.5	10	46	100	0.1	95	30.3086	0.17453	38.296
74	89	0.9	80	32	120	0.3	96	15.5639	1.39626	47.078
75	88	1.2	52	170	180	0.1	97	13.1064	0.90757	147.068
76	91	0.4	15	5	10	0.1	98	77.0002	0.26180	78.294
77	5	2.0	45	19	30	0.8	99	0.0000	0.78540	13.435
78	11	4.2	86	33	125	2.4	100	0.0000	1.50098	32.920
79	100	0.3	15	10	350	0.1	101	32.9196	0.26180	35.508
80	100	0.5	9	28	70	0.1	102	32.9196	0.15708	37.300
81	100	0.3	43	9	145	0.1	103	32.9196	0.75049	39.058
82	100	0.4	22	12	220	0.1	104	32.9196	0.38397	37.415
83	106	0.6	15	11	270	0.1	105	.	0.26180	.
84	100	2.4	86	12	125	1.6	106	32.9196	1.50098	44.890
85	106	1.6	86	3	125	1.6	107	44.8904	1.50098	47.883
86	107	0.9	0	24	215	0.3	108	47.8831	0.00000	47.883
87	107	1.6	86	25	130	0.8	109	47.8831	1.50098	72.822
88	10	5.4	80	8	300	4.9	110	0.0000	1.39626	7.878
89	110	4.9	80	19	300	2.2	111	7.8785	1.39626	26.590
90	110	2.9	0	3	155	2.2	112	7.8785	0.00000	7.878
91	111	1.8	20	40	40	0.8	113	26.5898	0.34907	40.271
92	111	2.8	45	40	285	0.8	114	26.5898	0.78540	54.874

Root Area vs Depth for CODEASH

ALL SEGMENTS CONTRIBUTING TO PLANE AT 10 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	21	0.5	45	310	0.4	22	0.17431	13.6093	0.1447
2	47	0.9	44	240	0.1	48	4.59253	25.4323	0.4731
3	54	2.9	15	70	1.7	55	7.76456	18.3761	5.6919
4	56	1.2	49	0	0.6	57	8.18718	22.5267	1.0237
5	58	0.8	70	320	0.3	59	9.16214	23.2575	0.4770
6	58	1.4	15	75	0.4	60	9.16214	16.4091	1.3759
7	58	0.3	25	90	0.3	61	9.16214	10.8526	0.0707
8	63	0.6	43	105	0.5	65	8.86271	17.0467	0.2707
9	66	1.1	25	335	0.8	67	1.46541	16.6797	0.6992
10	80	1.6	30	305	1.3	81	0.00000	15.0000	1.5551
11	9	0.9	50	305	0.4	85	0.00000	13.0227	0.2442
12	5	4.0	55	90	4.0	88	0.00000	13.1064	12.5664
13	5	2.0	45	30	0.8	99	0.00000	13.4350	1.1774
14	11	4.2	86	125	2.4	100	0.00000	32.9196	11.0201
15	110	4.9	80	300	2.2	111	7.87846	26.5898	17.1503

ALL SEGMENTS CONTRIBUTING TO PLANE AT 20 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	47	0.9	44	240	0.1	48	4.5925	25.432	0.17164
2	56	1.2	49	0	0.6	57	8.1872	22.527	0.43220
3	58	0.8	70	320	0.3	59	9.1621	23.258	0.17052
4	81	0.5	65	280	0.4	82	15.0000	24.969	0.16090
5	81	1.3	30	305	0.9	83	15.0000	27.000	1.03934
6	89	3.9	55	90	2.6	90	15.5639	30.309	9.94920
7	89	0.9	80	120	0.3	96	15.5639	47.078	0.55657
8	88	1.2	52	180	0.1	97	13.1064	147.068	1.07318
9	11	4.2	86	125	2.4	100	0.0000	32.920	8.18574
10	110	4.9	80	300	2.2	111	7.8785	26.590	9.10381

ALL SEGMENTS CONTRIBUTING TO PLANE AT 30 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
15.5639		30.309	9.94920						
2	89	0.9	80	120	0.3	96	15.5639	47.078	0.55657
3	88	1.2	52	180	0.1	97	13.1064	147.068	1.07318
4	11	4.2	86	125	2.4	100	0.0000	32.920	8.18574
5	111	1.8	20	40	0.8	113	26.5898	40.271	.
6	111	2.8	45	285	0.8	114	26.5898	54.874	.

Root Area vs Depth for CODEASH

ALL SEGMENTS CONTRIBUTING TO PLANE AT 40 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	90	2.6	55	90	1.2	91	30.3086	77.000	1.13097
2	89	0.9	80	120	0.3	96	15.5639	47.078	0.07069
3	88	1.2	52	180	0.1	97	13.1064	147.068	0.00785
4	100	2.4	86	125	1.6	106	32.9196	44.890	2.01062
5	111	1.8	20	40	0.8	113	26.5898	40.271	0.50265
6	111	2.8	45	285	0.8	114	26.5898	54.874	0.50265

ALL SEGMENTS CONTRIBUTING TO PLANE AT 50 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	90	2.6	55	90	1.2	91	30.3086	77.000	3.54716
2	88	1.2	52	180	0.1	97	13.1064	147.068	0.82166
3	107	1.6	86	130	0.8	109	47.8831	72.822	1.88262
4	111	2.8	45	285	0.8	114	26.5898	54.874	1.47712

ALL SEGMENTS CONTRIBUTING TO PLANE AT 60 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	90	2.6	55	90	1.2	91	30.3086	77.000	2.65228
2	88	1.2	52	180	0.1	97	13.1064	147.068	0.73782
3	107	1.6	86	130	0.8	109	47.8831	72.822	1.27796

ALL SEGMENTS CONTRIBUTING TO PLANE AT 70 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	90	2.6	55	90	1.2	91	30.3086	77.000	1.75741
2	88	1.2	52	180	0.1	97	13.1064	147.068	0.65398
3	107	1.6	86	130	0.8	109	47.8831	72.822	0.67330

ALL SEGMENTS CONTRIBUTING TO PLANE AT 80 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	91	1.2	55	90	1.0	92	77.0002	90.926	1.05653
2	88	1.2	52	180	0.1	97	13.1064	147.068	0.57015

Root Area vs Depth for CODEASH

ALL SEGMENTS CONTRIBUTING TO PLANE AT 90 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	91	1.2	55	90	1.0	92	77.0002	90.926	0.808373
2	88	1.2	52	180	0.1	97	13.1064	147.068	0.486306

ALL SEGMENTS CONTRIBUTING TO PLANE AT 100 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	92	1.0	45	40	0.7	94	90.9258	102.947	0.483031
2	88	1.2	52	180	0.1	97	13.1064	147.068	0.402468

ALL SEGMENTS CONTRIBUTING TO PLANE AT 110 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	88	1.2	52	180	0.1	97	13.1064	147.068	0.318629

Root Area vs Depth for CODESM1

INPUT DATA SET

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2
1	1	1.5	43	18	145	0.8	21
2	67	3.0	25	7	130	2.7	22
3	3	2.4	55	16	180	2.1	23
4	22	2.7	25	14	130	2.4	24
5	23	1.5	28	10	140	0.9	25
6	23	1.8	55	7	180	1.4	26
7	22	1.1	10	36	30	0.4	27
8	21	0.3	43	9	145	0.2	28
9	21	0.8	43	8	145	0.6	29
10	4	3.9	35	18	225	3.0	30
11	30	3.0	35	13	225	2.4	31
12	31	2.4	35	4	225	1.8	32
13	31	1.4	30	18	270	0.9	33
14	30	1.6	10	26	295	1.1	34
15	34	1.1	10	5	290	0.9	35
16	34	0.7	10	5	298	0.6	36
17	7	1.0	51	12	225	0.9	38
18	6	2.3	10	35	270	1.2	39
19	39	0.9	4	6	295	0.8	40
20	39	1.2	18	8	310	1.1	41
21	8	1.6	15	13	245	1.5	42
22	42	1.2	15	10	245	1.1	43
23	43	0.6	24	25	195	0.5	44
24	43	0.3	31	5	310	0.1	45
25	42	1.0	3	15	290	0.8	46
26	9	0.8	4	32	320	0.3	47
27	9	2.4	6	43	310	0.9	48
28	11	3.3	42	9	35	2.7	49
29	49	2.7	42	16	35	1.9	50
30	50	1.9	42	10	35	1.6	51
31	50	1.2	11	9	0	1.0	52
32	50	0.7	12	33	70	0.5	53
33	49	1.8	5	3	80	1.8	54
34	54	1.2	10	30	100	0.8	55
35	54	0.6	10	6	75	0.6	56
36	13	5.1	22	5	85	3.3	57
37	57	2.3	12	31	20	1.5	58
38	57	3.3	22	18	85	3.2	59
39	59	3.2	22	34	85	2.1	60
40	59	1.3	24	34	145	0.7	61
41	57	0.5	20	23	35	0.4	62
42	62	0.3	20	36	82	0.1	63
43	62	0.3	20	35	70	0.1	64
44	14	0.6	18	22	110	0.4	65
45	65	0.3	18	34	110	0.2	66
46	2	3.0	25	8	130	3.0	67
47	67	1.2	21	15	215	0.6	68
48	7	0.5	19	7	350	0.4	69
49	61	0.2	18	19	180	0.1	69
50	61	0.5	24	13	145	0.3	70

Root Area vs Depth for CODESM1

INPUT DATA SET (ctd.)

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2
51	61	0.3	24	17	110	0.1	71
52	65	0.2	18	15	180	0.1	72
53	5	3.4	27	20	220	2.0	73
54	10	2.2	7	16	20	1.3	74
55	12	1.5	4	30	60	1.1	75

ORIGINAL OBSERVATIONS WITH DEPTH ADDED FOR EACH NODE

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2	DPTH1	ANGLE	DPTH2
1	1	1.5	43	18	145	0.8	21	0.0000	0.750491	12.2760
2	67	3.0	25	7	130	2.7	22	.	0.436332	.
3	3	2.4	55	16	180	2.1	23	0.0000	0.959930	13.1064
4	22	2.7	25	14	130	2.4	24	.	0.436332	.
5	23	1.5	28	10	140	0.9	25	13.1064	0.488692	17.8011
6	23	1.8	55	7	180	1.4	26	13.1064	0.959930	18.8405
7	22	1.1	10	36	30	0.4	27	.	0.174533	.
8	21	0.3	43	9	145	0.2	28	12.2760	0.750491	18.4139
9	21	0.8	43	8	145	0.6	29	12.2760	0.750491	17.7319
10	4	3.9	35	18	225	3.0	30	0.0000	0.610865	10.3244
11	30	3.0	35	13	225	2.4	31	10.3244	0.610865	17.7809
12	31	2.4	35	4	225	1.8	32	17.7809	0.610865	20.0752
13	31	1.4	30	18	270	0.9	33	17.7809	0.523598	26.7808
14	30	1.6	10	26	295	1.1	34	10.3244	0.174533	14.8392
15	34	1.1	10	5	290	0.9	35	14.8392	0.174533	15.7075
16	34	0.7	10	5	298	0.6	36	14.8392	0.174533	15.7075
17	7	1.0	51	12	225	0.9	38	0.0000	0.890117	9.3257
18	6	2.3	10	35	270	1.2	39	0.0000	0.174533	6.0777
19	39	0.9	4	6	295	0.8	40	6.0777	0.069813	6.4962
20	39	1.2	18	8	310	1.1	41	6.0777	0.314159	8.5498
21	8	1.6	15	13	245	1.5	42	0.0000	0.261799	3.3646
22	42	1.2	15	10	245	1.1	43	3.3646	0.261799	5.9528
23	43	0.6	24	25	195	0.5	44	5.9528	0.418879	16.1212
24	43	0.3	31	5	310	0.1	45	5.9528	0.541052	8.5280
25	42	1.0	3	15	290	0.8	46	3.3646	0.052360	4.1497
26	9	0.8	4	32	320	0.3	47	0.0000	0.069813	2.2322
27	9	2.4	6	43	310	0.9	48	0.0000	0.104720	4.4947
28	11	3.3	42	9	35	2.7	49	0.0000	0.733038	6.0222
29	49	2.7	42	16	35	1.9	50	6.0222	0.733038	16.7283
30	50	1.9	42	10	35	1.6	51	16.7283	0.733038	23.4196
31	50	1.2	11	9	0	1.0	52	16.7283	0.191986	18.4455
32	50	0.7	12	33	70	0.5	53	16.7283	0.209439	23.5893
33	49	1.8	5	3	80	1.8	54	6.0222	0.087266	6.2836
34	54	1.2	10	30	100	0.8	55	6.2836	0.174533	11.4931
35	54	0.6	10	6	75	0.6	56	6.2836	0.174533	7.3255
36	13	5.1	22	5	85	3.3	57	0.0000	0.383972	1.8730
37	57	2.3	12	31	20	1.5	58	1.8730	0.209439	8.3183
38	57	3.3	22	18	85	3.2	59	1.8730	0.383972	8.6159

Root Area vs Depth for CODESM1

ORIGINAL OBSERVATIONS WITH DEPTH ADDED FOR EACH NODE (ctd.)

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2	DPTH1	ANGLE	DPTH2
39	59	3.2	22	34	85	2.1	60	8.6159	0.383972	21.3526
40	59	1.3	24	34	145	0.7	61	8.6159	0.418879	22.4450
41	57	0.5	20	23	35	0.4	62	1.8730	0.349066	9.7395
42	62	0.3	20	36	82	0.1	63	9.7395	0.349066	22.0522
43	62	0.3	20	35	70	0.1	64	9.7395	0.349066	21.7102
44	14	0.6	18	22	110	0.4	65	0.0000	0.314159	6.7984
45	65	0.3	18	34	110	0.2	66	6.7984	0.314159	17.3049
46	2	3.0	25	8	130	3.0	67	0.0000	0.436332	3.3809
47	67	1.2	21	15	215	0.6	68	3.3809	0.366519	8.7565
48	7	0.5	19	7	350	0.4	69	0.0000	0.331612	2.2790
49	61	0.2	18	19	180	0.1	69	22.4450	0.314159	28.3163
50	61	0.5	24	13	145	0.3	70	22.4450	0.418879	27.7326
51	61	0.3	24	17	110	0.1	71	22.4450	0.418879	29.3595
52	65	0.2	18	15	180	0.1	72	6.7984	0.314159	11.4336
53	5	3.4	27	20	220	2.0	73	0.0000	0.471238	9.0798
54	10	2.2	7	16	20	1.3	74	0.0000	0.122173	1.9499
55	12	1.5	4	30	60	1.1	75	0	0.0698131	2.09269

ALL SEGMENTS CONTRIBUTING TO PLANE AT 10 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	1	1.5	43	145	0.8	21	0.00000	12.2760	0.73709
2	3	2.4	55	180	2.1	23	0.00000	13.1064	3.71491
3	4	3.9	35	225	3.0	30	0.00000	10.3244	7.22181
4	43	0.6	24	195	0.5	44	5.95283	16.1212	0.24836
5	49	2.7	42	35	1.9	50	6.02217	16.7283	4.65168
6	54	1.2	10	100	0.8	55	6.28364	11.4931	0.68274
7	59	3.2	22	85	2.1	60	8.61594	21.3526	7.54490
8	59	1.3	24	145	0.7	61	8.61594	22.4450	1.23300
9	62	0.3	20	82	0.1	63	9.73949	22.0522	0.06936
10	62	0.3	20	70	0.1	64	9.73949	21.7102	0.06932
11	65	0.3	18	110	0.2	66	6.79837	17.3049	0.05872
12	65	0.2	18	180	0.1	72	6.79837	11.4336	0.01514

ALL SEGMENTS CONTRIBUTING TO PLANE AT 20 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	31	2.4	35	225	1.8	32	17.7809	20.0752	2.60953
2	31	1.4	30	270	0.9	33	17.7809	26.7808	1.31667
3	50	1.9	42	35	1.6	51	16.7283	23.4196	2.43206
4	50	0.7	12	70	0.5	53	16.7283	23.5893	0.29496
5	59	3.2	22	85	2.1	60	8.6159	21.3526	3.94985
6	59	1.3	24	145	0.7	61	8.6159	22.4450	0.55148
7	62	0.3	20	82	0.1	63	9.7395	22.0522	0.01833
8	62	0.3	20	70	0.1	64	9.7395	21.7102	0.01683

Root Area vs Depth for CODESM2

INPUT DATA SET

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2
1	1	6.5	30	15	300	4.7	21
2	21	4.7	30	14	305	1.8	22
3	22	1.2	0	17	5	0.1	23
4	21	0.6	0	59	20	0.1	24
5	26	1.3	5	9	295	1.0	25
6	21	2.9	68	4	225	2.4	26
7	26	2.4	68	7	225	1.5	27
8	22	1.8	25	22	305	1.2	28
9	28	0.3	20	31	70	0.1	29
10	28	0.6	20	21	305	0.3	30
11	30	0.3	10	29	295	0.1	31
12	30	0.3	10	38	305	0.1	32
13	21	1.0	90	3	135	0.9	33
14	2	2.4	20	21	250	2.1	34
15	34	2.1	20	6	250	1.5	35
16	35	0.3	20	32	270	0.1	36
17	35	1.5	20	37	255	1.2	37
18	3	5.3	26	12	360	4.4	38
19	40	0.9	30	23	255	0.6	39
20	38	2.1	5	37	255	0.9	40
21	40	0.3	30	17	270	0.1	41
22	38	4.4	26	9	359	4.1	42
23	45	2.1	22	6	150	2.1	43
24	43	0.6	20	74	230	0.3	44
25	42	2.2	22	16	140	0.6	45
26	45	0.4	30	29	10	0.1	46
27	42	1.8	7	37	357	0.6	47
28	47	1.7	60	6	30	0.7	48
29	47	1.0	26	20	20	0.7	49
30	47	1.0	7	12	5	0.3	50
31	38	2.3	50	19	60	1.2	51
32	51	0.2	10	46	60	0.1	52
33	51	1.2	5	32	140	0.3	53
34	34	0.4	30	14	160	0.3	54
35	43	2.1	35	21	150	1.2	55
36	4	2.5	22	16	90	2.0	56
37	56	2.0	22	26	90	1.6	57
38	57	1.6	22	9	90	1.3	58
39	58	1.3	22	70	90	0.3	59
40	56	0.5	35	41	90	0.1	60
41	57	0.7	25	26	230	0.3	61
42	58	0.3	15	18	130	0.1	62
43	5	4.4	3	6	10	4.1	63
44	63	4.1	3	8	30	3.2	64
45	64	3.2	3	61	10	0.9	65
46	65	0.9	25	30	10	0.8	66
47	63	0.8	10	34	30	0.6	67
48	67	0.4	10	11	30	0.3	68
49	67	0.6	3	31	10	0.5	69

Root Area vs Depth for CODESM2

INPUT DATA SET (ctd.)

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2
50	64	1.9	3	122	310	0.9	70
51	65	0.5	10	40	90	0.1	71
52	6	1.3	10	23	30	1.1	72
53	72	1.1	10	19	30	0.5	73
54	72	0.7	0	76	60	0.1	74
55	7	2.5	10	69	0	1.2	75
56	8	2.8	65	7	5	3.8	76
57	76	0.9	42	24	30	0.8	77
58	84	0.6	15	98	310	0.5	78
59	76	1.5	65	51	330	0.7	79
60	85	0.6	72	47	10	0.1	80
61	85	0.6	15	19	340	0.5	81
62	81	0.3	0	19	350	0.1	82
63	81	0.3	10	18	30	0.1	83
64	76	1.6	50	20	340	0.9	84
65	84	0.9	50	17	340	0.8	85
66	9	3.6	30	47	210	1.8	86
67	86	0.3	25	21	330	0.1	87
68	86	1.8	25	24	330	1.2	88
69	101	2.6	60	10	350	1.6	89
70	11	3.0	60	14	90	2.8	90
71	90	1.0	8	9	180	0.7	91
72	90	2.8	20	8	90	2.0	92
73	92	1.8	32	12	180	1.2	93
74	92	0.4	10	21	90	0.2	94

ORIGINAL OBSERVATIONS WITH DEPTH ADDED FOR EACH NODE

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2	DPTH1	ANGLE	DPTH2
1	1	6.5	30	15	300	4.7	21	0.0000	0.52360	7.5000
2	21	4.7	30	14	305	1.8	22	7.5000	0.52360	14.5000
3	22	1.2	0	17	5	0.1	23	14.5000	0.00000	14.5000
4	21	0.6	0	59	20	0.1	24	7.5000	0.00000	7.5000
5	26	1.3	5	9	295	1.0	25	11.2087	0.08727	11.9931
6	21	2.9	68	4	225	2.4	26	7.5000	1.18682	11.2087
7	26	2.4	68	7	225	1.5	27	11.2087	1.18682	17.6990
8	22	1.8	25	22	305	1.2	28	14.5000	0.43633	23.7976
9	28	0.3	20	31	70	0.1	29	23.7976	0.34907	34.4002
10	28	0.6	20	21	305	0.3	30	23.7976	0.34907	30.9800
11	30	0.3	10	29	295	0.1	31	30.9800	0.17453	36.0158
12	30	0.3	10	38	305	0.1	32	30.9800	0.17453	37.5786
13	21	1.0	90	3	135	0.9	33	7.5000	1.57079	10.5000
14	2	2.4	20	21	250	2.1	34	0.0000	0.34907	7.1824
15	34	2.1	20	6	250	1.5	35	7.1824	0.34907	9.2345
16	35	0.3	20	32	270	0.1	36	9.2345	0.34907	20.1792
17	35	1.5	20	37	255	1.2	37	9.2345	0.34907	21.8893
18	3	5.3	26	12	360	4.4	38	0.0000	0.45379	5.2604

Root Area vs Depth for CODESM2

ORIGINAL OBSERVATIONS WITH DEPTH ADDED FOR EACH NODE (ctd.)

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2	DPTH1	ANGLE	DPTH2
19	40	0.9	30	23	255	0.6	39	.	0.52360	.
20	38	2.1	5	37	255	0.9	40	5.2604	0.08727	8.4852
21	40	0.3	30	17	270	0.1	41	8.4852	0.52360	16.9852
22	38	4.4	26	9	359	4.1	42	5.2604	0.45379	9.2058
23	45	2.1	22	6	150	2.1	43	.	0.38397	.
24	43	0.6	20	74	230	0.3	44	.	0.34907	.
25	42	2.2	22	16	140	0.6	45	9.2058	0.38397	15.1995
26	45	0.4	30	29	10	0.1	46	15.1995	0.52360	29.6995
27	42	1.8	7	37	357	0.6	47	9.2058	0.12217	13.7149
28	47	1.7	60	6	30	0.7	48	13.7149	1.04720	18.9111
29	47	1.0	26	20	20	0.7	49	13.7149	0.45379	22.4824
30	47	1.0	7	12	5	0.3	50	13.7149	0.12217	15.1774
31	38	2.3	50	19	60	1.2	51	5.2604	0.87266	19.8153
32	51	0.2	10	46	60	0.1	52	19.8153	0.17453	27.8031
33	51	1.2	5	32	140	0.3	53	19.8153	0.08727	22.6043
34	34	0.4	30	14	160	0.3	54	7.1824	0.52360	14.1824
35	43	2.1	35	21	150	1.2	55	.	0.61086	.
36	4	2.5	22	16	90	2.0	56	0.0000	0.38397	5.9937
37	56	2.0	22	26	90	1.6	57	5.9937	0.38397	15.7335
38	57	1.6	22	9	90	1.3	58	15.7335	0.38397	19.1049
39	58	1.3	22	70	90	0.3	59	19.1049	0.38397	45.3274
40	56	0.5	35	41	90	0.1	60	5.9937	0.61086	29.5103
41	57	0.7	25	26	230	0.3	61	15.7335	0.43633	26.7215
42	58	0.3	15	18	130	0.1	62	19.1049	0.26180	23.7637
43	5	4.4	3	6	10	4.1	63	0.0000	0.05236	0.3140
44	63	4.1	3	8	30	3.2	64	0.3140	0.05236	0.7327
45	64	3.2	3	61	10	0.9	65	0.7327	0.05236	3.9252
46	65	0.9	25	30	10	0.8	66	3.9252	0.43633	16.6037
47	63	0.8	10	34	30	0.6	67	0.3140	0.17453	6.2180
48	67	0.4	10	11	30	0.3	68	6.2180	0.17453	8.1282
49	67	0.6	3	31	10	0.5	69	6.2180	0.05236	7.8405
50	64	1.9	3	122	310	0.9	70	0.7327	0.05236	7.1177
51	65	0.5	10	40	90	0.1	71	3.9252	0.17453	10.8711
52	6	1.3	10	23	30	1.1	72	0.0000	0.17453	3.9939
53	72	1.1	10	19	30	0.5	73	3.9939	0.17453	7.2932
54	72	0.7	0	76	60	0.1	74	3.9939	0.00000	3.9939
55	7	2.5	10	69	0	1.2	75	0.0000	0.17453	11.9817
56	8	2.8	65	7	5	3.8	76	0.0000	1.13446	6.3442
57	76	0.9	42	24	30	0.8	77	6.3442	0.73304	22.4033
58	84	0.6	15	98	310	0.5	78	.	0.26180	.
59	76	1.5	65	51	330	0.7	79	6.3442	1.13446	52.5658
60	85	0.6	72	47	10	0.1	80	.	1.25664	.
61	85	0.6	15	19	340	0.5	81	.	0.26180	.
62	81	0.3	0	19	350	0.1	82	.	0.00000	.
63	81	0.3	10	18	30	0.1	83	.	0.17453	.
64	76	1.6	50	20	340	0.9	84	6.3442	0.87266	21.6650
65	84	0.9	50	17	340	0.8	85	21.6650	0.87266	34.6878
66	9	3.6	30	47	210	1.8	86	0.0000	0.52360	23.5000
67	86	0.3	25	21	330	0.1	87	23.5000	0.43633	32.3750

Root Area vs Depth for CODESM2

ORIGINAL OBSERVATIONS WITH DEPTH ADDED FOR EACH NODE (ctd.)

OBS	ID1	DIAM1	PLUNGE	LENGTH	AZIMUTH	DIAM2	ID2	DPTH1	ANGLE	DPTH2
68	86	1.8	25	24	330	1.2	88	23.5000	0.43633	33.6428
69	101	2.6	60	10	350	1.6	89	.	1.04720	.
70	11	3.0	60	14	90	2.8	90	0.0000	1.04720	12.1243
71	90	1.0	8	9	180	0.7	91	12.1243	0.13963	13.3769
72	90	2.8	20	8	90	2.0	92	12.1243	0.34907	14.8605
73	92	1.8	32	12	180	1.2	93	14.8605	0.55850	21.2195
74	92	0.4	10	21	90	0.2	94	14.8605	0.17453	18.5071

ALL SEGMENTS CONTRIBUTING TO PLANE AT 10 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	21	4.7	30	305	1.8	22	7.49999	14.5000	12.0620
2	21	2.9	68	225	2.4	26	7.49999	11.2087	5.2022
3	21	1.0	90	135	0.9	33	7.49999	10.5000	0.6610
4	35	0.3	20	270	0.1	36	9.23454	20.1792	0.0663
5	35	1.5	20	255	1.2	37	9.23454	21.8893	1.7287
6	40	0.3	30	270	0.1	41	8.48521	16.9852	0.0595
7	42	2.2	22	140	0.6	45	9.20579	15.1995	3.3351
8	42	1.8	7	357	0.6	47	9.20579	13.7149	2.1463
9	38	2.3	50	60	1.2	51	5.26045	19.8153	3.1701
10	34	0.4	30	160	0.3	54	7.18242	14.1824	0.1035
11	56	2.0	22	90	1.6	57	5.99370	15.7335	2.6764
12	56	0.5	35	90	0.1	60	5.99370	29.5103	0.1642
13	65	0.9	25	10	0.8	66	3.92519	16.6037	0.5722
14	65	0.5	10	90	0.1	71	3.92519	10.8711	0.0315
15	7	2.5	10	0	1.2	75	0.00000	11.9817	1.7558
16	76	0.9	42	30	0.8	77	6.34415	22.4033	0.6058
17	76	1.5	65	330	0.7	79	6.34415	52.5658	1.6578
18	76	1.6	50	340	0.9	84	6.34415	21.6650	1.6826
19	9	3.6	30	210	1.8	86	0.00000	23.5000	6.9302
20	11	3.0	60	90	2.8	90	0.00000	12.1243	6.3171

ALL SEGMENTS CONTRIBUTING TO PLANE AT 20 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	22	1.8	25	305	1.2	28	14.5000	23.7976	1.70840
2	35	0.3	20	270	0.1	36	9.2345	20.1792	0.00888
3	35	1.5	20	255	1.2	37	9.2345	21.8893	1.22595
4	45	0.4	30	10	0.1	46	15.1995	29.6995	0.08666
5	47	1.0	26	20	0.7	49	13.7149	22.4824	0.49826
6	51	0.2	10	60	0.1	52	19.8153	27.8031	0.03087
7	51	1.2	5	140	0.3	53	19.8153	22.6043	1.06075
8	58	1.3	22	90	0.3	59	19.1049	45.3274	1.28443

Root Area vs Depth for CODESM2

ALL SEGMENTS CONTRIBUTING TO PLANE AT 20 cm (ctd.)

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
9	56	0.5	35	90	0.1	60	5.9937	29.5103	0.08408
10	57	0.7	25	230	0.3	61	15.7335	26.7215	0.26286
11	58	0.3	15	130	0.1	62	19.1049	23.7637	0.05861
12	76	0.9	42	30	0.8	77	6.3442	22.4033	0.52264
13	76	1.5	65	330	0.7	79	6.3442	52.5658	1.35875
14	76	1.6	50	340	0.9	84	6.3442	21.6650	0.78554
15	9	3.6	30	210	1.8	86	0.0000	23.5000	3.68167
16	92	1.8	32	180	1.2	93	14.8605	21.2195	1.40209

ALL SEGMENTS CONTRIBUTING TO PLANE AT 30 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	28	0.3	20	70	0.1	29	23.7976	34.4002	.
2	28	0.6	20	305	0.3	30	23.7976	30.9800	.
3	58	1.3	22	90	0.3	59	19.1049	45.3274	1.28443
4	76	1.5	65	330	0.7	79	6.3442	52.5658	1.35875
5	84	0.9	50	340	0.8	85	21.6650	34.6878	.
6	86	0.3	25	330	0.1	87	23.5000	32.3750	.
7	86	1.8	25	330	1.2	88	23.5000	33.6428	.

ALL SEGMENTS CONTRIBUTING TO PLANE AT 40 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	58	1.3	22	90	0.3	59	19.1049	45.3274	0.070686
2	76	1.5	65	330	0.7	79	6.3442	52.5658	0.384845

ALL SEGMENTS CONTRIBUTING TO PLANE AT 50 cm

OBS	ID1	DIAM1	PLUNGE	AZIMUTH	DIAM2	ID2	DPTH1	DPTH2	AREA
1	76	1.5	65	330	0.7	79	6.34415	52.5658	0.461578

APPENDIX D

NUREGRSS, written by David Nash

```
// JOB ,'NUREGRSS',
//  TIME=(2,0),REGION=2048K,MSGLEVEL=(2,0)
/*ROUTE PRINT RMT41
/*JOBPARM L=99
//CLG EXEC VTFTVCLG,L=77
//FORT.SYSIN DD *
      CHARACTER*68 TITLE
      LOGICAL*1 PULLEY(300)
      DIMENSION B(300),DINTRP(300),DISP(300),FORCE(300),NCAL(300),
     -          R(300),SLOPE(300),TAXIS(4),TDISP(300),TFORCE(300),
     -          X(300),Y(300)
   10 READ(1,20,END=70)ICAL,ITYPE,NPNTS
   20 FORMAT(I2,3X,I1,I2)
      READ(1,30)(Y(I),X(I),I=1,NPNTS)
   30 FORMAT(16F5.0)
      IF(ITYPE.EQ.1) THEN
        DO 40 I=1,NPNTS
   40   Y(I)=4.448E-3*Y(I)
      END IF
      CALL REGRES(NPNTS,B(ICAL),SLOPE(ICAL),R(ICAL),X,Y)
      IF(ITYPE.EQ.1)THEN
        WRITE(2,50)ICAL,B(ICAL),SLOPE(ICAL),R(ICAL)
   50   FORMAT(1X,I3,'.',9X,'FORCE = ',F7.2,' + ',F7.2,' * READING',
     -         10X,'R=',F6.4)
      ELSE
        WRITE(2,60)ICAL,B(ICAL),SLOPE(ICAL),R(ICAL)
   60   FORMAT(1X,I3,'.  ','DISPLACEMENT = ',F7.2,' + ',F7.2,' * READ',   ,
     -         'ING',10X,'R=',F6.4)
      END IF
      GO TO 10
   70 WRITE(2,80)
   80 FORMAT(10(/))
   90 READ(5,100,END=240)NCHAR,TITLE
  100 FORMAT(I2,A68)
C      CALL BGPLT1
C      CALL NEWPEN(1)
C      CALL PLT1(0.0,0.0,-3)
C      CALL PLT1(1.0,1.0,-3)
C      CALL PLT1(0.0,6.0,2)
C      CALL PLT1(9.0,6.0,2)
C      CALL PLT1(9.0,0.0,2)
C      CALL PLT1(0.0,0.0,2)
C      CALL SYMBL1((9.0-0.1*FLOAT(NCHAR))/2.0,5.8,0.1,TITLE,0.0,NCHAR)
C      CALL PLT1(0.5,0.5,-3)
      READ(5,110)IDTREE,IDROOT,ITYPE,NFORCE
  110 FORMAT(I2,1X,I2,I1,I3)
      READ(5,120)(NCAL(I),PULLEY(I),TFORCE(I),FORCE(I),I=1,NFORCE)
  120 FORMAT(5(I2,L1,F8.2,F4.1))
      TFORCE(1)=15.0*TFORCE(1)
      TAXIS(1)=TFORCE(1)
      TAXIS(2)=TAXIS(1)
      DO 130 I=1,NFORCE
        TFORCE(I)=15.0*TFORCE(I)
        TAXIS(1)=AMIN1(TAXIS(1),TFORCE(I))
```

```
        TAXIS(2)=AMAX1(TAXIS(2),TFORCE(I))
        IF(PULLEY(I))THEN
          FORCE(I)=4.0*(SLOPE(NCAL(I))*FORCE(I)+B(NCAL(I)))
        ELSE
          FORCE(I)=(SLOPE(NCAL(I))*FORCE(I)+B(NCAL(I)))
        END IF
  130 CONTINUE
      CALL SCALE(FORCE,5.0,NFORCE,1)
      ORGFRC=FORCE(NFORCE+1)
      DELFRC=FORCE(NFORCE+2)
      READ(5,110)IDTREE,IDROOT,ITYPE,NDISP
      READ(5,120)(NCAL(I),PULLEY(I),TDISP(I),DISP(I),I=1,NDISP)
      DO 140 I=1,NDISP
        TDISP(I)=15.0*TDISP(I)
        TAXIS(1)=AMIN1(TAXIS(1),TDISP(I))
        TAXIS(2)=AMAX1(TAXIS(2),TDISP(I))
        IF(PULLEY(I))THEN
          DISP(I)=4.0*(SLOPE(NCAL(I))*DISP(I)+B(NCAL(I)))
        ELSE
          DISP(I)=SLOPE(NCAL(I))*DISP(I)+B(NCAL(I))
        END IF
  140 CONTINUE
      CALL SCALE(DISP,5.0,NDISP,1)
      ORGDSP=DISP(NDISP+1)
      DELDSP=DISP(NDISP+2)
      CALL SCALE(TAXIS,8.0,2,1)
      ORGTIM=TAXIS(3)
      DELTIM=TAXIS(4)
C      CALL AXS1(0.0,0.0,'ELAPSED TIME (SECONDS)',-22,8.0,0.0,ORGTIM,
C     -          DELTIM)
C      CALL AXS1(0.0,0.0,'FORCE (KILONEWTONS)',19,5.0,90.0,ORGFRC,DELFRC)
C      CALL PLT1((TFORCE(1)-ORGTIM)/DELTIM,(FORCE(1)-ORGFRC)/DELFRC,3)
C      DO 160 I=2,NFORCE
C  160 CALL PLT1((TFORCE(I)-ORGTIM)/DELTIM,(FORCE(I)-ORGFRC)/DELFRC,2)
C      CALL NEWPEN(3)
C      CALL AXS1(8.0,0.0,'DISPLACEMENT (CM)',-17,5.0,90.0,ORGDSP,DELDSP)
C      CALL PLT1((TDISP(1)-ORGTIM)/DELTIM,(DISP(1)-ORGDSP)/DELDSP,3)
C      DO 170 I=1,NDISP
C  170 CALL PLT1((TDISP(I)-ORGTIM)/DELTIM,(DISP(I)-ORGDSP)/DELDSP,2)
      DO 180 I=1,NFORCE
  180 DINTRP(I)=EXORIN(TDISP,DISP,NDISP,TFORCE(I))
C      CALL NEWPEN(1)
C      CALL PLT1(0.0,0.0,-999)
      CALL BEGPLT
      CALL PLOT(1.5,2.0,-3)
      CALL PLOT(0.0,6.0,2)
      CALL PLOT(6.0,6.0,2)
      CALL PLOT(6.0,0.0,2)
      CALL PLOT(0.0,0.0,2)
      CALL SYMBOL((6.0-0.1*FLOAT(NCHAR))/2.0,5.8,0.1,TITLE,0.0,NCHAR)
      CALL PLOT(0.5,0.5,-3)
      CALL AXIS(0.0,0.0,'FORCE (KILONEWTONS)',19,5.0,90.0,ORGFRC,DELFRC)
      CALL AXIS(0.0,0.0,'DISPLACEMENT (CM)',-17,5.0,0.0,ORGDSP,DELDSP)
      CALL SCALE(DINTRP,5.0,NFORCE,1)
```

```
      ORGINT=DINTRP(NFORCE+1)
      DELINT=DINTRP(NFORCE+2)
      DO 190 I=1,NFORCE
  190 CALL SYMBOL((DINTRP(I)-ORGINT)/DELINT,(FORCE(I)-ORGFRC)/DELFRC,
     -            0.1,3,0.0,-1)
      CALL PLT1(0.0,0.0,-999)
      WRITE(2,200)TITLE,IDTREE,IDROOT
  200 FORMAT(////A68//'TREE:',I3,5X,'ROOT:',I3///T14,'TIME',
     -       T28,'DISPLACEMENT'/T12,'(SECONDS)',T31,'(CM)'/)
      WRITE(2,210)(TDISP(I),DISP(I),I=1,NDISP)
  210 FORMAT(T11,F7.1,T28,F7.2)
      WRITE(2,220)
  220 FORMAT(///T14,'TIME',T28,'FORCE',T39,'DISPLACEMENT'/T12,
     -       '(SECONDS)',T24,'(KILONEWTONS)',T43,'(CM)'/)
      WRITE(2,230)(TFORCE(I),FORCE(I),DINTRP(I),I=1,NFORCE)
  230 FORMAT(T11,F7.1,T26,F7.2,T40,F7.2)
      GO TO 90
  240 CALL ENDPLT
      STOP
      END
C
C PERFORMS LINEAR REGRESSION
C
      SUBROUTINE REGRES(NPNTS,B,SLOPE,R,X,Y)
      DIMENSION X(1),Y(1)
      PNTS=FLOAT(NPNTS)
      SUMX=0.0
      SUMX2=0.0
      SUMXY=0.0
      SUMY=0.0
      SUMY2=0.0
      DO 10 I=1,NPNTS
        SUMX=SUMX+X(I)
        SUMX2=SUMX2+X(I)**2
        SUMXY=SUMXY+X(I)*Y(I)
        SUMY=SUMY+Y(I)
        SUMY2=SUMY2+Y(I)**2
   10 CONTINUE
      B=(SUMY*SUMX2-SUMX*SUMXY)/(PNTS*SUMX2-SUMX**2)
      SLOPE=(PNTS*SUMXY-SUMX*SUMY)/(PNTS*SUMX2-SUMX**2)
      R=(PNTS*SUMXY-SUMX*SUMY)/SQRT((PNTS*SUMY2-SUMY**2)*(PNTS*SUMX2-
     -  SUMX**2))
      RETURN
      END
C
C LINEAR INTERPOLATION OR EXTRAPOLATION OF A DEPENDENT VARIABLE GIVEN
C AN ARRAY OF INDEPENDENT AND DEPENDENT VARIABLES
C
      FUNCTION EXORIN(XARRAY,YARRAY,N,X)
      DIMENSION XARRAY(300),YARRAY(300)
      IF(X.LE.XARRAY(1))THEN
        N1=1
        N2=2
      ELSE
```

```
        IF(X.GT.XARRAY(N))THEN
          N1=N-1
          N2=N
        ELSE
          DO 10 I=2,N-1
   10     IF(X.LT.XARRAY(I))GO TO 20
   20     N1=I-1
          N2=I
        END IF
      END IF
      IF(XARRAY(N1).EQ.XARRAY(N2))THEN
        EXORIN=(YARRAY(N1)+YARRAY(N2))/2.0
      ELSE
        EXORIN=YARRAY(N2)-(XARRAY(N2)-X)*(YARRAY(N2)-YARRAY(N1))/
     -       (XARRAY(N2)-XARRAY(N1))
      END IF
      RETURN
      END
/*
//GO.PLOTPARM DD *
 &PLOT SCALE=1.0 &END
/*
//GO.FT01F001 DD *
1. 214
 0. 4. 10. 6. 15. 8. 25. 17. 30. 21. 50. 25. 65. 41. 80. 40.
115. 67. 117. 66. 123. 66. 150. 76. 155. 80. 200. 95.
2. 2 3
 0. 2. 20. 66. 30. 99.
3. 1 9
 0. 1. 20. 10. 35. 30. 50. 43. 100. 53. 70. 45. 50. 31. 135. 89.
150. 91.
4. 1 4
 0. 1. 140. 13. 205. 17. 240. 20.
5. 2 3
 0. 2. 20. 66. 30. 99.
6. 1 5
 0. 1. 50. 7. 100. 36. 155. 69. 200. 80.
7. 1 3
 0. 1. 193. 7. 225. 10.
8. 2 2
 0. 4. 30. 100.
9. 1 5
 0. 2. 200. 98. 145. 63. 90. 29. 152. 67.
10. 1 4
152. 8. 203. 11. 245. 12. 178. 8.
11. 2 3
 0. 1. 15. 50. 30. 97.
12. 1 9
 0. 2. 25. 23. 55. 49. 80. 58. 100. 75. 130. 75. 130. 87. 170. 98.
115. 70.
13. 1 6
 0. 2. 160. 12. 205. 15. 225. 17. 250. 18. 185. 11.
14. 2 4
 0. 1. 10. 32. 20. 65. 30. 99.
```

15. 1 4
0. 15. 55. 37. 100. 77. 125. 97.
16. 1 3
125. 57. 175. 78. 225. 92.
17. 1 4
125. 32. 175. 40. 225. 46. 245. 50.
18. 2 3
0. 7. 15. 48. 30. 92.
19. 110
0. 20. 35. 31. 55. 44. 80. 56. 105. 63. 140. 74. 175. 85. 175. 85.
190. 93. 185. 85.
20. 1 4
200. 46. 195. 42. 200. 52. 215. 53.
21. 1 4
0. 7. 200. 16. 200. 17. 200. 18.
22. 2 3
0. 4. 30. 99. 15. 53.
23. 1 3
0. 3. 75. 48. 110. 88.
24. 1 4
110. 44. 158. 58. 210. 75. 250. 87.
25. 1 2
0. 1. 250. 31.
26. 2 3
0. 5. 15. 48. 30. 90.
27. 1 4
0. 27. 190. 99. 150. 87. 100. 65.
28. 1 5
0. 16. 190. 53. 150. 45. 250. 45. 250. 65.
29. 1 5
0. 7. 190. 23. 150. 20. 250. 28. 100. 15.
30. 2 2
0. 0. 30. 100.
31. 1 6
0. 1. 55. 33. 105. 61. 155. 90. 185. 93. 205. 99.
32. 2 3
0. 3. 15. 48. 30. 100.
33. 1 4
0. 26. 150. 92. 100. 70. 50. 50.
34. 1 4
150. 53. 200. 60. 225. 66. 100. 40.
35. 1 4
0. 11. 150. 28. 200. 31. 225. 33.
36. 2 3
0. 7. 15. 43. 30. 85.
37. 1 6
0. 20. 150. 31. 225. 49. 275. 57. 165. 33. 125. 24.
38. 2 3
0. 14. 15. 49. 30. 93.
39. 1 3
0. 22. 220. 97. 120. 43.
40. 1 4
0. 5. 300. 47. 280. 39. 222. 27.
41. 2 3

```
  0. 15. 15. 55. 30. 96.
42. 1 4
  0. 21. 70. 63. 110. 81. 115. 102.
43. 1 5
 115. 28. 150. 46. 190. 60. 215. 69. 250. 79.
44. 2 3
  0. 9. 15. 46. 30. 86.
45. 1 5
  0. 20. 70. 37. 140. 75. 180. 93. 100. 51.
46. 1 6
  0. 2. 180. 24. 190. 32. 175. 30. 225. 46. 255. 54.
47. 2 3
  0. 12. 15. 52. 30. 89.
48. 1 4
  0. 20. 80. 35. 140. 81. 155. 90.
49. 1 4
  0. 2. 160. 22. 205. 36. 250. 49.
50. 2 3
  0. 11. 15. 50. 30. 93.
51. 1 5
  0. 20. 35. 39. 70. 57. 120. 84. 145. 97.
52. 1 6
  0. 5. 120. 37. 145. 43. 175. 51. 200. 59. 235. 65.
53. 1 3
  0. 2. 235. 19. 250. 23.
54. 2 3
  0. 12. 15. 40. 30. 83.
55. 1 3
  0. 26. 200. 207. 200. 206.
56. 1 2
  0. 26. 200. 44.
57. 1 4
  0. 14. 80. 64. 125. 110. 140. 122.
/*
//GO.FT02F001 DD DSN-PGELGEO.TABLES,DISP-SHR
//GO.SYSIN DD *
42ASH #7.01 1.1CM 0.1M 270/20E 24.1%S 31.2%R
 7  11 40
 3F    0.0020.0 3F    0.5021.0 3F    1.5022.0 3F    2.3022.0 3F    2.4024.0
 3F    2.5022.5 3F    2.6024.0 3F    2.7022.5 3F    2.7525.0 3F    2.8524.0
 3F    2.9017.0 3F    3.0013.0 3F    3.1024.0 3F    3.7024.5 3F    3.8011.0
 3F    4.0031.0 3F    4.2030.0 3F    4.3026.0 3F    4.4032.0 3F    4.6029.0
 3F    4.9069.0 3F    5.0054.0 3F    5.4054.0 3F    5.5076.0 3F    5.6069.0
 3F    5.7069.0 3F    6.0099.9 3F    6.1090.0 3F    6.3090.0 3F    6.4099.9
 3F    6.5099.9 3F    6.6097.0 3F    6.9098.0 3F    7.1097.0 3F    7.3096.0
 3F    7.4093.0 3F    7.5017.0 3F    7.9017.0 3F    8.0020.0 3F    8.10 5.0
 7  12 16
 5F    0.00 5.0 5F    3.75 5.0 5F    4.30 5.5 5F    4.60 6.0 5F    5.20 7.0
 5F    5.30 8.0 5F    5.80 8.0 5F    5.90 8.5 5F    6.00 8.5 5F    6.10 9.0
 5F    6.4010.0 5F    7.2010.0 5F    7.2512.0 5F    7.9012.0 5F    8.0016.0
 5F    8.1040.0
```

```
41ASH #7.04 1.540M 0.2M AZ/PL 21.3%S 59.4%R
 7  41 41
 3F    0.00 8.0 3F    0.2010.0 3F    0.2511.0 3F    0.3014.0 3F    0.50 8.0
 3F    0.7015.0 3F    0.7521.0 3F    0.8020.0 3F    0.8510.0 3F    1.0010.0
 3F    1.4065.0 3F    1.5063.0 3F    1.6041.0 3F    1.7585.0 3F    1.8573.0
 3F    2.0070.0 3F    2.2089.0 3F    2.3091.0 3F    2.4083.0 3F    2.6099.9
 3F    2.8083.0 3F    2.9098.0 3F    3.0088.0 3F    3.1086.0 3F    3.2099.9
 3F    3.3093.0 3F    3.4083.0 3F    3.5085.0 3F    3.6083.0 3F    3.8053.0
 3F    3.8599.9 3F    4.1084.0 3F    4.3085.0 3F    4.3599.9 3F    4.4091.0
 3F    4.7055.0 3F    4.8055.0 3F    4.8567.0 3F    5.0042.0 3F    5.1025.0
 3F    5.2020.0
 7  42 20
 5F    0.00 4.0 5F    0.90 4.5 5F    1.3010.0 5F    1.5010.0 5F    1.6511.0
 5F    2.0011.0 5F    2.6015.5 5F    2.7016.0 5F    3.1017.0 5F    3.2018.0
 5F    3.5018.5 5F    3.8018.5 5F    3.9019.5 5F    4.3020.0 5F    4.3526.0
 5F    4.4027.0 5F    4.7027.0 5F    4.7133.0 5F    5.0054.0 5F    5.2070.0
38SM #4.09 1.00M 0.42M 100/70E 19%S 15%R
 4  91 75
12F    0.00 2.012F    0.01 9.012F    0.20 9.012F    0.3010.012F    0.4010.0
12F    0.6011.012F    0.8011.012F    0.8513.012F    0.9515.512F    1.3015.5
12F    1.3514.012F    1.4014.012F    1.4515.512F    1.8019.012F    1.9019.0
12F    1.9515.012F    2.0019.012F    2.2017.012F    2.4017.012F    2.4518.0
12F    2.8519.012F    2.9018.012F    3.0018.012F    3.0117.012F    3.0516.5
12F    3.1016.512F    3.1115.012F    3.5015.012F    3.7519.012F    4.0020.0
12F    4.5022.012F    4.8029.512F    4.9530.012F    5.0533.012F    5.1529.0
12F    5.3029.012F    5.4534.012F    5.6029.012F    5.8034.012F    5.9532.5
12F    6.0030.012F    6.1531.512F    6.4030.012F    6.4534.012F    7.0037.0
12F    7.4537.512F    8.0050.012F    8.2054.512F    8.4058.512F    8.6557.5
12F    8.8054.012F    9.2047.512F    9.3057.012F    9.5053.012F    9.6561.0
12F    9.8556.012F   10.0055.512F   10.1065.012F   10.2562.512F   10.3059.0
12F   10.7559.012F   10.8077.012F   10.9060.012F   11.0062.012F   11.2062.0
12F   11.2179.012F   11.3579.012F   11.5060.012F   11.9060.012F   12.0074.0
12F   12.3074.012F   12.4062.012F   12.6044.012F   13.2522.012F   13.26 2.0
 4  92 32
14F    0.00 1.014F    0.30 2.014F    0.70 2.514F    1.50 3.014F    1.65 3.0
14F    1.80 4.014F    2.55 4.514F    3.55 4.714F    4.55 5.014F    5.55 5.7
14F    5.70 5.714F    5.80 6.014F    6.50 6.014F    6.90 6.514F    7.00 7.0
14F    7.50 7.014F    8.30 8.014F    8.65 8.014F    8.85 8.714F    9.75 8.7
14F    9.85 9.114F   10.85 9.514F   10.9010.014F   11.3010.014F   11.4011.0
14F   12.3011.014F   12.4011.514F   12.5011.814F   12.6514.514F   12.9016.5
14F   13.2022.014F   13.2652.0
37SM #4.08 0.70M 0.18M 65/15N 24%S 52%R
 4  81 45
12F    0.00 2.012F    0.05 8.012F    1.2018.012F    1.7518.512F    1.9020.0
12F    2.0016.012F    2.2519.012F    2.4521.512F    2.5516.012F    2.6022.5
12F    2.8516.012F    3.0016.012F    3.1522.512F    3.2520.012F    3.3023.0
12F    4.1031.012F    4.1524.012F    4.3524.512F    4.4029.012F    5.3544.0
12F    5.4543.012F    5.7545.012F    6.1047.012F    6.3040.512F    6.7041.5
12F    6.8553.512F    7.2054.012F    7.2558.012F    7.3052.512F    7.5557.0
12F    7.7563.012F    7.8055.012F    8.2555.512F    8.3065.012F    8.4061.0
12F    8.5065.012F    8.6059.012F    8.7559.012F    8.9073.512F    9.1577.5
12F    9.4071.012F    9.6057.012F    9.6160.012F   10.0072.512F   10.30 2.0
 4  82 21
14F    0.00 1.014F    0.35 4.714F    0.85 7.014F    1.70 7.014F    2.00 7.5
```

```
14F   2.15 8.514F   2.5010.014F   3.2511.014F   3.7512.014F   4.2512.0
14F   4.5015.014F   4.6515.014F   4.8516.014F   5.9519.014F   8.9029.0
14F   9.0531.014F   9.6532.514F   9.7032.814F   9.9532.814F   10.1035.0
14F   10.3080.0
35SM #4.01 0.90M 0.9M 90/5S 222S 300R
 4  11 46
12F   0.0512.012F   0.1017.012F   0.2517.012F   0.3019.512F   0.3521.5
12F   0.4514.012F   0.5021.012F   0.6038.012F   0.9563.012F   1.1099.9
12F   1.6599.912F   2.1099.913F   2.8011.013F   3.3015.013F   3.4015.0
13F   3.4112.013F   5.1012.013F   5.1111.013F   5.8511.013F   5.90 8.2
13F   7.00 9.013F   8.45 9.313F   8.46 6.213F   8.70 7.513F   9.50 8.0
13F   11.20 9.013F  11.3012.013F  12.0016.513F  12.5016.513F  12.5518.0
13F   12.7018.513F  13.9016.013F  14.5020.013F  14.8518.013F  15.2020.5
13F   15.8018.513F  15.9020.513F  16.1020.013F  17.1020.013F  17.2519.5
13F   17.5519.513F  17.8521.013F  18.3020.513F  18.4022.013F  18.7023.0
13F   18.71 2.0
 4  12 29
14F   0.00 2.014F   0.01 3.014F   0.10 4.014F   0.60 4.014F   0.70 7.0
14F   1.60 8.014F   3.30 8.014F   3.45 9.514F   5.1010.014F   5.8511.5
14F   7.0012.014F   11.9012.014F  12.1013.014F  13.8013.014F  14.2013.3
14F   14.5013.314F  14.7514.014F  15.0514.014F  15.5015.014F  15.7015.0
14F   15.8516.014F  16.1016.014F  16.3020.014F  16.9021.014F  18.3021.0
14F   18.6022.014F  18.6129.014F  18.6529.014F  18.7144.0
37SM #4.03 1.150M 0.21M 80/5N 244S 522R
 4  31 47
13F   0.00 3.013F   0.25 3.013F   0.70 8.013F   0.90 7.513F   1.3012.0
13F   1.70 9.513F   3.00 9.513F   3.01 8.013F   3.50 8.013F   3.5111.5
13F   3.8012.013F   4.2015.013F   4.5016.813F   5.0016.513F   5.4021.5
13F   5.8020.013F   6.2021.513F   6.3020.213F   6.4020.213F   6.6021.0
13F   6.8018.013F   7.2016.013F   7.4516.013F   7.5018.013F   8.1518.0
13F   8.5016.013F   8.8015.513F   9.2519.513F   9.2718.013F   9.7018.0
13F   10.2021.513F  10.4019.513F  10.4521.513F  10.7022.513F  11.2018.3
13F   11.4019.013F  11.8018.013F  12.2016.513F  12.2118.013F  12.8018.0
13F   12.8117.013F  13.3017.013F  13.4018.013F  13.4116.513F  13.9016.5
13F   14.3521.513F  14.39 2.0
 4  32  2
14F   0.00 0.014F   14.39 0.0
37SM #4.07 1.20M 0.09M 70/15N 222S 300R
 4  71 24
13F   0.00 2.013F   0.8017.513F   0.8515.013F   1.3515.013F   1.5018.0
13F   2.0018.013F   2.3021.013F   2.8021.813F   2.9017.513F   3.1017.0
13F   3.2017.013F   3.4019.013F   3.8517.513F   4.1517.513F   4.3019.0
13F   4.5019.113F   4.5114.013F   4.8012.013F   5.20 7.013F   5.40 8.0
13F   5.80 8.013F   5.81 5.013F   6.20 5.013F   6.25 2.0
 4  72 10
14F   0.00 0.014F   2.40 8.514F   2.8511.014F   3.4015.014F   4.3517.0
14F   4.6023.014F   4.8024.014F   5.8051.514F   6.2052.014F   6.2580.0
35SM #4.10 2.80M 0.1M 290/0 222S 300R
 4 101 56
12T   0.00 2.012T   0.4033.012T   0.5526.512T   0.8026.512T   1.1061.5
12T   1.3045.512T   1.4047.012T   1.7548.012T   1.8561.512T   2.1099.9
12T   2.5099.912T   2.6567.512T   3.4070.012T   4.4571.012T   4.7067.5
12T   5.1568.512T   5.5068.512T   5.5199.912T   6.6099.913T   7.4012.5
13T   9.5012.513T   9.6014.513T   9.9514.013T   10.0015.013T  10.4014.0
```

```
13T 10.7014.013T 11.5012.013T 11.8512.513T 12.1514.013T 12.2012.0
13T 12.6012.013T 12.6114.013T 12.9614.513T 13.1012.513T 14.1512.5
13T 14.7011.513T 15.7511.013T 16.2011.513T 16.3010.513T 17.1010.5
13T 17.2012.513T 17.7510.513T 17.9512.513T 18.05 8.013T 18.2012.0
13T 18.9012.013T 18.95 6.013T 19.40 6.012T 19.7033.512T 20.7032.0
12T 21.0039.512T 21.4039.512T 22.1028.012T 22.3019.512T 22.6014.5
12T 22.65 2.0
 4 102 22
14F 0.00 0.014F 10.90 0.014F 10.91 1.014F 11.90 1.014F 12.10 2.0
14F 12.65 2.114F 13.70 4.514F 13.80 4.714F 14.7011.514F 15.4012.0
14F 16.2511.514F 17.0016.014F 17.8519.014F 18.2023.514F 18.5523.8
14F 18.8524.514F 18.9036.014F 19.2041.014F 19.4542.014F 21.0042.0
14F 22.3083.014F 22.6599.0
37SM #6.14 0.850M 0.17M 310/0 21%S 58%R
 6 141 50
 9F 0.00 2.7 9F 0.2520.5 9F 0.6018.5 9F 0.7033.0 9F 0.7154.0
 9F 0.9029.0 9F 1.1027.0 9F 1.3027.0 9F 1.3164.0 9F 1.6027.0
 9F 1.6124.0 9F 2.2058.5 9F 2.2525.0 9F 3.0517.0 9F 3.1025.0
 9F 3.1542.0 9F 3.2524.0 9F 3.3026.0 9F 4.3622.0 9F 4.5041.0
 9F 4.6019.0 9F 4.7515.0 9F 5.3012.5 9F 5.3539.0 9F 5.4022.0
 9F 5.8018.0 9F 5.8115.0 9F 6.1055.0 9F 6.2015.0 9F 6.3030.0
 9F 6.7523.0 9F 7.0025.0 9F 7.0557.0 9F 7.1035.0 9F 7.4030.0
 9F 7.5560.0 9F 7.7030.0 9F 8.3020.0 9F 8.8253.0 9F 8.8035.0
 9F 9.0028.0 9F 10.0022.0 9F 10.1055.0 9F 10.2028.0 9F 10.3028.0
 9F 10.4061.0 9F 10.5040.0 9F 11.2030.0 9F 11.3063.0 9F 11.31 2.0
 6 142 24
11F 0.0010.011F 0.1011.011F 0.3011.011F 0.3112.011F 1.2012.0
11F 1.4013.011F 2.1213.011F 2.1516.011F 2.5017.011F 3.0017.0
11F 3.1519.211F 4.3019.211F 4.5021.011F 5.2022.011F 5.3023.0
11F 5.7023.011F 6.3024.011F 6.4026.011F 7.1026.011F 9.5036.0
11F 10.3036.011F 10.3537.011F 11.2037.011F 11.3142.0
41SM #6.15 0.630M 0.37M 360/10N 21.4%S 44%R
 6 151 24
 9F 0.00 2.0 9F 0.2013.0 9F 0.25 2.0 9F 1.05 2.0 9F 1.1532.0
 9F 1.2520.5 9F 1.5517.5 9F 1.6043.5 9F 1.7020.0 9F 2.0020.0
 9F 2.0124.0 9F 2.3022.0 9F 2.3152.0 9F 2.5025.0 9F 2.6523.0
 9F 2.6655.0 9F 2.7036.0 9F 2.8528.0 9F 2.9029.0 9F 2.9554.0
 9F 3.0037.0 9F 3.3030.0 9F 3.3155.8 9F 3.40 2.0
 6 152 13
11F 0.00 8.011F 0.40 8.011F 0.5011.011F 0.9511.011F 1.1013.0
11F 1.6513.011F 1.7014.011F 2.3014.011F 2.3515.511F 2.7015.5
11F 2.7116.011F 3.3016.011F 3.4045.0
38SM #6.17 2.40M 0.19M 355/12N 21%S 58%R
 6 171 45
 9T 0.00 2.0 9T 0.1022.0 9T 0.1514.0 9T 0.9013.0 9T 1.1552.0
 9T 1.3027.0 9T 1.7027.0 9T 1.8548.0 9T 2.0040.0 9T 2.5037.0
 9T 2.8037.0 9T 2.9040.0 9T 3.0565.0 9T 3.2040.0 9T 3.7040.0
 9T 3.7559.0 9T 3.9050.0 9T 4.3047.0 9T 4.4080.0 9T 4.5057.0
 9T 4.8056.0 9T 4.8581.0 9T 5.0056.0 9T 5.3055.5 9T 5.6088.0
 9T 5.7055.0 9T 6.0056.0 9T 6.1072.0 9T 6.2066.0 9T 6.2568.5
 9T 6.3057.0 9T 6.8057.0 9T 6.9084.0 9T 7.0557.0 9T 7.5057.0
 9T 7.6572.0 9T 7.8053.5 9T 8.0554.0 9T 8.1062.0 9T 8.3056.0
 9T 8.4553.0 9T 8.8054.0 9T 9.0060.0 9T 9.2053.0 9T 9.21 2.0
 6 172 27
```

```
11F   0.00 1.011F   0.15 2.011F   1.00 2.011F   1.30 3.511F   1.75 3.7
11F   1.95 5.711F   3.10 5.711F   3.25 7.511F   3.60 7.611F   3.75 9.0
11F   4.30 9.011F   4.4011.011F   4.7011.011F   4.9014.011F   5.4014.0
11F   5.7017.711F   6.0017.711F   6.3022.011F   6.9022.011F   7.1026.5
11F   7.5026.511F   7.8531.011F   8.1531.011F   8.5037.011F   9.0037.0
11F   9.2043.011F   9.2175.0
38SM #6.20 3.00M 0.07M 278/11W 22%S 30%R
 6 201103
 9T   0.00 2.0 9T   0.1021.5 9T   0.2013.0 9T   0.3538.0 9T   0.4521.0
 9T   0.5521.0 9T   0.6536.0 9T   0.7041.0 9T   0.8526.5 9T   0.9546.5
 9T   1.1033.0 9T   1.8531.0 9T   1.9059.0 9T   2.1043.0 9T   2.2040.0
 9T   2.4075.0 9T   2.5537.0 9T   3.4538.0 9T   3.4637.0 9T   3.9037.0
 9T   4.0560.0 9T   4.1558.0 9T   4.4582.0 9T   4.5088.0 9T   4.8067.0
 9T   4.9083.0 9T   5.0562.0 9T   5.3063.0 9T   5.4598.0 9T   5.5078.0
 9T   6.0075.0 9T   6.1582.0 9T   6.2065.0 9T   6.6565.0 9T   6.7099.0
 9T   6.9081.0 9T   7.6583.0 9T   7.7079.0 9T   7.7599.0 9T   7.8582.0
 9T   8.0079.0 9T   8.2572.0 9T   8.3099.9 9T   8.5082.0 9T   9.2083.0
 9T   9.4099.9 9T   9.4596.0 9T   10.1596.0 9T  10.5094.010T  11.2512.0
10T   12.2011.010T  12.2113.010T  12.5012.010T  13.4012.010T  13.5010.0
10T   13.7512.010T  13.8510.010T  14.4910.010T  14.50 9.010T  15.40 9.0
10T   15.4111.010T  16.9010.010T  24.6010.010T  24.61 8.010T  29.60 8.0
10T   29.70 5.010T  31.40 5.010T  31.41 7.010T  33.49 7.0 9T  33.6054.0
 9T   34.6554.0 9T  34.7052.0 9T  40.0052.0 9T  40.1051.0 9T  40.5051.0
 9T   40.5150.0 9T  40.8047.0 9T  41.1554.0 9T  41.2045.0 9T  41.7046.0
 9T   41.7553.0 9T  41.9043.0 9T  42.6546.0 9T  42.7040.0 9T  43.1542.0
 9T   45.7043.0 9T  45.8040.0 9T  46.4041.0 9T  49.8041.0 9T  50.0042.0
 9T   60.3042.5 9T  60.4041.5 9T  84.4041.5 9T  84.5042.0 9T  85.8042.0
 9T   85.9034.0 9T  86.4036.0 9T  86.8048.0 9T  86.9031.0 9T  87.5033.0
 9T   87.7551.0 9T  87.9953.0 9T  88.00 2.0
 6 202 46
11F   0.00 1.011F   3.00 1.011F   3.20 9.011F   3.30 3.011F   3.40 6.0
11F   4.15 6.011F   5.10 8.011F   5.30 8.011F   5.65 9.011F   6.10 9.0
11F   6.2010.011F   6.8010.011F   6.9011.011F   7.5011.011F   7.9013.0
11F   8.6016.011F   8.9516.011F   9.0016.511F   9.4016.511F   9.8017.0
11F   10.6018.011F  12.3018.011F  12.6519.011F  13.3519.011F  14.7524.0
11F   15.4524.011F  16.0026.011F  17.0026.011F  17.6026.111F  18.5026.1
11F   18.7576.011F  20.4076.011F  20.6089.011F  20.9089.011F  21.0089.0
11F   21.5089.011F  21.9089.011F  22.4089.011F  22.6089.011F  23.2589.0
11F   24.0092.011F  24.5093.011F  37.9093.011F  48.0097.011F  50.0099.9
11F   88.0099.9
42ASH #7.24 0.55CM 0.38M 110/74N 21.4%S 63%R
 7 241 25
33F   0.0031.033F   0.1038.033F   0.3544.033F   0.4538.033F   0.6038.0
33F   0.6144.033F   0.8038.033F   1.0038.033F   1.1046.033F   1.2040.0
33F   1.4039.033F   1.7539.033F   2.0049.033F   2.1040.033F   3.5039.0
33F   3.7038.033F   6.3039.033F   6.4047.033F   6.5037.033F   6.6036.0
33F   6.7538.033F   7.1032.033F   7.3032.033F   7.3534.033F   7.5531.0
 7 242  3
36F   0.00 7.036F   7.02 7.036F   7.5522.0
40ASH #7.28 0.68CM 0.13M 120/18N 30%S 45%R
 7 281 10
33F   0.0025.033F   0.1028.033F   0.2020.233F   0.3040.033F   0.7037.0
33F   0.8054.033F   0.9046.533F   1.0046.033F   1.2057.033F   1.4025.0
 7 282  3
```

```
36F    0.00 7.036F    1.20 7.036F    1.4032.0
32ASH #7.29 0.650M 0.15M 30%S 45%R
 7 291 11
33F    0.0026.033F    0.4035.033F    0.4533.033F    0.6033.033F    0.7552.0
33F    0.8044.033F    0.9543.533F    1.2072.533F    1.2565.033F    1.4564.0
33F    1.5227.0
 7 292  4
36F    0.00 6.036F    1.42 6.036F    1.5028.036F    1.5240.0
40ASH #7.26 3.180M 0.12M 100/32W 30%S 45%R
 7 261 66
33T    0.0018.033T    0.2519.033T    2.3020.033T    2.3129.033T    3.7029.0
33T    4.0033.033T    4.2032.033T    4.3034.033T    4.4530.033T    4.6032.5
33T    4.9035.033T    5.0036.033T    5.3033.033T    5.8033.033T    6.4052.0
33T    6.5041.033T    7.0041.033T    7.1054.033T    7.2051.033T    7.4057.0
33T    7.5055.033T    8.2093.034T    9.0047.034T    9.3056.034T    9.5054.0
34T    9.8565.034T   10.0062.534T   10.2069.034T   10.3063.034T   10.9063.0
34T   11.3074.034T   11.6070.034T   12.1080.034T   12.6073.034T   12.8067.0
34T   13.2082.034T   13.5073.034T   17.0071.034T   17.2585.034T   17.3080.0
34T   17.7079.534T   18.0086.034T   18.2086.034T   18.3078.034T   18.7079.0
34T   18.7583.034T   19.1083.034T   19.1178.034T   19.5078.034T   20.2094.0
34T   20.4589.035T   20.5043.035T   22.5041.035T   23.3040.035T   23.5045.0
35T   23.7045.035T   23.8043.035T   28.0042.035T   34.7042.035T   38.1044.0
35T  131.0145.035T  141.3045.535T  150.2045.535T  150.3046.035T  175.8046.0
35T  175.8136.0
 7 262 23
36F    0.0021.036F    0.3021.236F    0.3525.036F    0.6026.036F    3.7526.0
36F    4.2030.036F    4.7530.036F    5.3033.036F    5.9033.036F    6.1035.0
36F    6.3036.036F   11.8040.036F   12.5043.036F   36.4043.036F   37.8544.0
36F   63.8044.036F   63.8545.036F  125.2345.036F  139.9946.036F  152.7046.0
36F  152.8047.036F  175.8047.036F  175.8172.0
36ASH #7.27 2.020M 0.1M 90/0 33%S 43%R
 7 271 24
33T    0.0037.033T    0.3038.033T    0.3537.033T    0.4039.033T    0.6540.0
33T    0.8044.033T    0.8839.533T    1.1051.033T    1.2547.033T    1.4058.0
33T    1.6053.033T    2.0094.033T    2.7053.034T    2.8562.034T    3.0060.0
34T    3.1058.034T    3.3054.034T    3.7557.034T    4.0068.034T    4.1061.0
34T    4.3561.034T    4.5066.034T    4.7070.034T    4.7156.0
 7 272  3
36F    0.00 7.536F    4.70 7.536F    4.7160.0
40SM #5.01 0.580M 0.15M 310/5N 20.5%S 43%R
 5  11  4
 1F    0.00 2.0 1F    0.4023.0 1F    0.4939.0 1F    0.50 2.0
 5  12  5
 2F    0.00 4.8 2F    0.12 6.0 2F    0.45 7.0 2F    0.4910.0 2F    0.5040.0
41SM #5.02 0.220M 0.165M 350/2N 20.5%S 43%R
 5  21 18
 1F    0.00 1.5 1F    0.10 3.0 1F    0.45 4.0 1F    0.50 7.0 1F    0.60 6.0
 1F    0.65 8.5 1F    1.5012.0 1F    1.51 7.5 1F    1.60 4.0 1F    1.6511.0
 1F    1.7014.0 1F    1.7512.0 1F    1.9012.0 1F    2.0014.0 1F    2.1512.0
 1F    2.2011.0 1F    2.5011.0 1F    2.51 2.0
 5  22  7
 2F    0.00 4.0 2F    0.65 8.0 2F    1.25 9.0 2F    1.60 9.0 2F    1.7810.0
 2F    2.5010.0 2F    2.5111.0
39SM #5.03 0.310M 0.28M 310/22N 22%S 42%R
```

```
5  31 22
1F    0.00 2.5 1F    0.30 9.5 1F    0.3514.5 1F    0.4014.5 1F    0.5016.0
1F    1.1516.5 1F    1.2518.0 1F    1.3016.0 1F    1.5517.0 1F    1.7517.0
1F    1.8015.5 1F    2.0016.0 1F    2.3111.0 1F    2.4015.0 1F    2.5016.0
1F    2.7017.0 1F    2.8016.0 1F    3.2017.0 1F    4.20 9.5 1F    4.3816.5
1F    4.5015.0 1F    4.51 1.0
5  32 12
2F    0.00 2.0 2F    0.30 2.0 2F    1.70 7.0 2F    1.75 8.0 2F    2.30 9.0
2F    2.40 9.5 2F    3.4512.2 2F    3.7012.5 2F    4.0014.0 2F    4.1014.5
2F    4.5020.0 2F    4.5132.0
39SM #5.05 0.68CM 0.32M 135/25S 22%S 42%R
5  51 27
1F    0.00 1.0 1F    0.10 9.0 1F    0.25 8.5 1F    0.3514.5 1F    0.40 9.0
1F    0.90 9.0 1F    1.00 8.0 1F    1.62 8.0 1F    1.8518.0 1F    2.0021.0
1F    2.2820.0 1F    2.3516.0 1F    2.6823.0 1F    2.7021.0 1F    2.7521.0
1F    2.8023.0 1F    3.0020.0 1F    3.3023.0 1F    3.3522.0 1F    3.6035.0
1F    3.7037.0 1F    3.8017.0 1F    4.2022.0 1F    4.7042.5 1F    5.0046.0
1F    5.3048.5 1F    5.31 1.0
5  52 14
2F    0.00 0.0 2F    0.40 0.0 2F    0.45 1.0 2F    1.80 1.0 2F    2.05 2.0
2F    2.50 2.0 2F    2.80 2.3 2F    2.95 7.0 2F    3.35 8.0 2F    3.8012.0
2F    4.5019.0 2F    4.8019.2 2F    5.3021.0 2F    5.3140.0
40SM #5.06 0.38CM 0.44M 175/5N 21.3%S 30%R
5  61 15
1F    0.00 1.5 1F    0.4012.0 1F    0.5014.0 1F    0.6213.0 1F    0.6514.0
1F    1.0514.5 1F    1.1014.0 1F    1.4513.8 1F    1.5012.0 1F    1.6012.0
1F    1.6511.0 1F    2.3010.2 1F    2.4013.5 1F    2.5015.0 1F    2.55 1.5
5  62 10
2F    0.00 0.0 2F    0.50 0.0 2F    0.75 2.0 2F    1.50 6.0 2F    1.54 7.0
2F    1.95 7.0 2F    2.05 7.2 2F    2.31 7.2 2F    2.51 8.0 2F    2.5530.0
41SM #5.07 0.27CM 0.51M 140/20N 20.3%S 32%R
5  71 10
1F    0.00 1.5 1F    0.15 3.0 1F    0.30 4.0 1F    0.70 5.9 1F    0.78 5.9
1F    0.80 4.0 1F    0.85 4.0 1F    0.95 5.0 1F    1.40 5.0 1F    1.41 1.0
5  72  9
2F    0.00 0.0 2F    0.50 0.0 2F    0.51 0.5 2F    0.62 1.5 2F    0.70 3.0
2F    0.90 4.0 2F    1.10 5.0 2F    1.40 6.0 2F    1.4120.0
40SM #10.16 0.80CM 0.3M 350/20N 22.4%S 99%R
10 161  5
45F   0.0019.045F   0.0521.545F   0.6045.045F   0.6549.045F   0.8517.0
10 162  6
47F   0.0012.047F   0.3013.047F   0.3214.047F   0.6016.047F   0.8016.5
47F   0.8541.0
39SM #10.15 0.52CM 0.25M 20/15N 21%S 60%R
10 151  9
45F   0.0021.045F   0.1022.045F   0.1821.045F   0.4526.545F   0.5526.5
45F   0.7531.045F   0.8532.045F   0.8736.045F   0.9018.0
10 152  6
47F   0.0012.047F   0.6012.047F   0.6213.047F   0.7013.747F   0.8914.2
47F   0.9027.0
49%SH #10.21 SHEARED 0.50M 0.4M 350/13N 20.3%S 99%R
10 211 11
45F   0.0019.045F   0.0521.045F   0.1220.045F   0.4020.045F   0.5022.0
45F   0.6022.045F   0.7525.045F   0.7726.045F   0.9529.545F   1.2529.8
```

45F 1.3017.5
10 212 7
47F 0.0011.047F 0.5011.047F 0.5514.047F 0.6014.047F 0.7217.0
47F 1.2520.547F 1.3070.0
42ASH #10.19 1.050M 0.017M 90/23E 22%S 50%R
10 191 14
45F 0.0020.045F 0.2030.045F 0.2530.045F 0.4055.045F 0.5044.0
45F 0.7044.045F 0.7593.045F 0.8595.045F 1.3089.045F 1.3589.0
46F 2.3044.046F 2.3543.046F 2.70 5.046F 2.73 2.0
10 192 7
47F 0.0012.047F 2.2012.047F 2.5017.547F 2.6018.047F 2.6119.5
47F 2.6820.047F 2.7343.0
33ASH #10.17 3.20M 0.4M 22.4%S 99%R
10 171 65
45T 0.0018.045T 0.2021.045T 0.8021.045T 0.9019.545T 1.2024.0
45T 1.2523.045T 1.5027.045T 1.6033.045T 1.7022.045T 1.8222.0
45T 2.0023.045T 2.2023.045T 2.5047.045T 2.6032.045T 2.7032.0
45T 2.8030.045T 2.9030.045T 3.0046.045T 3.3053.045T 3.4052.0
45T 3.4532.045T 4.0032.045T 4.0150.045T 4.1050.045T 4.2069.0
45T 4.4067.045T 4.5069.045T 4.8092.045T 5.0088.045T 5.0179.0
45T 5.1079.045T 5.2086.045T 5.9092.046T 7.4030.046T 7.7030.0
46T 7.8036.046T 8.0044.046T 8.0145.046T 8.5034.046T 9.3524.0
46T 9.5024.046T 9.5128.046T 10.0039.045T 11.7064.045T 12.0051.0
45T 12.5054.045T 13.0049.045T 13.1054.045T 13.7046.045T 14.0042.0
45T 14.3042.045T 14.4044.045T 14.6036.045T 14.8034.045T 15.0037.0
45T 15.3035.045T 15.6038.045T 15.8028.045T 16.0029.045T 16.2020.0
45T 16.7020.045T 16.7528.045T 17.0023.045T 17.2025.045T 17.5020.0
10 172 29
47F 0.0011.547F 1.6012.047F 2.3012.047F 2.5013.047F 3.0013.0
47F 3.7014.047F 4.2014.047F 5.5017.047F 6.5018.047F 7.5018.0
47F 8.6020.047F 8.8021.047F 9.0021.047F 9.0121.547F 9.3522.0
47F 9.8022.047F 10.3024.047F 10.4024.047F 10.5030.047F 10.9033.0
47F 11.1033.047F 11.5033.047F 14.6059.047F 14.7059.047F 15.9075.0
47F 16.1080.047F 16.7080.047F 17.1090.047F 17.3099.9
40ASH #10.11 1.90M 0.12M 340/15N 22%S 50%R
10 111 20
45T 0.0018.045T 0.1020.045T 0.1120.145T 1.3522.045T 1.6022.0
45T 2.4542.045T 2.5022.045T 2.5125.545T 2.6025.045T 2.6523.0
45T 2.9024.045T 3.0024.045T 3.0138.045T 3.4049.045T 3.5046.0
45T 3.9560.045T 4.1051.045T 4.3051.045T 4.4056.045T 4.5020.0
10 112 14
47F 0.0011.047F 0.1011.047F 0.2512.547F 0.7013.047F 1.2013.0
47F 1.5014.047F 1.7514.047F 2.6016.047F 3.2016.047F 3.3016.0
47F 3.5016.547F 4.4022.047F 4.4536.547F 4.5040.0
39ASH #10.13 1.620M 0.09M 30/3S 22%S 50%R
10 131 9
45T 0.0017.045T 0.1019.045T 0.3019.545T 0.5019.045T 0.5120.0
45T 0.7022.045T 1.0022.045T 1.3023.045T 1.3116.0
10 132 2
47F 0.00 0.047F 1.31 0.0
42ASH #11.13 2.60M 0.05M 170/10S 25.2%S 84%R
11 131 34
37F 0.0023.043T 0.9059.043T 1.7559.043T 2.0070.043T 2.0164.0
43T 3.8064.043T 3.9069.043T 4.0573.043T 4.2071.543T 4.2866.0

43T	4.4066.043T	4.5072.043T	4.6068.043T	4.8068.043T	4.8572.0
43T	4.8664.043T	6.7064.043T	6.[illegible].043T	6.8566.043T	7.1066.0
43T	7.1173.043T	7.3577.043T	7.5066.043T	7.9076.043T	8.0070.0
43T	8.3070.043T	8.7069.043T	8.8057.043T	9.7557.043T	9.8060.0
43T	10.0560.043T	10.1059.043T	10.4559.043T	10.6056.0	
11 132 23					
38F	0.0015.038F	1.8515.038F	2.1018.038F	4.0518.038F	4.4020.0
38F	4.6020.038F	4.8021.038F	5.0521.538F	6.9021.038F	7.0022.0
38F	7.7023.038F	7.8024.538F	8.1025.038F	8.2025.038F	8.4027.0
38F	8.5027.038F	8.5528.038F	8.8028.538F	8.8538.038F	9.8038.0
38F	10.1047.038F	10.3047.038F	10.6085.0		
44ASH #11.05 2.80M 0.18M 170/11N 27.6%S 68.2%R					
11 51 65					
37F	0.0039.537F	1.0051.037F	1.1569.037F	1.5093.037F	1.7099.9
37F	2.5099.943T	2.8032.043T	3.1048.043T	3.4546.043T	3.5039.0
43T	4.0036.043T	4.2049.043T	4.6071.543T	4.8073.043T	5.0069.0
43T	5.1063.043T	5.3060.043T	5.4081.043T	5.7597.043T	6.1089.0
43T	6.3078.043T	6.4092.543T	6.5073.543T	6.6099.943T	7.8599.9
43T	8.2588.043T	9.0085.043T	9.0199.943T	10.3099.943T	11.1096.0
37F	14.0080.037F	14.0199.037F	15.2099.037F	15.2099.037F	15.3095.0
37F	15.4058.037F	15.8558.037F	15.8657.037F	17.3057.037F	17.3195.0
37F	19.2078.037F	19.5084.037F	20.0083.037F	20.3072.037F	20.6070.0
37F	21.0071.037F	21.3050.037F	21.4554.037F	21.8554.037F	22.0051.0
37F	22.5060.037F	22.7091.037F	22.9056.037F	23.1057.037F	23.3049.0
37F	24.2049.037F	24.2053.037F	24.4054.037F	24.5046.037F	25.2545.0
37F	25.3554.037F	25.5045.037F	25.7050.037F	25.8042.037F	26.2040.0
11 52 24					
38F	0.0013.538F	0.5013.538F	1.2517.038F	2.2019.538F	3.0020.0
38F	3.4022.038F	4.3022.038F	5.2024.038F	5.5024.038F	5.5124.5
38F	6.5027.038F	6.8029.038F	15.6029.038F	18.0054.038F	19.0062.0
38F	19.2062.038F	19.2163.038F	19.5063.038F	20.4071.038F	20.6072.0
38F	21.0077.038F	24.1077.038F	24.1599.938F	26.2099.9	
40SM #10.16 0.80M 0.3M 350/20N 22.4%S 99%R					
10 161 5					
45F	0.0019.045F	0.0521.545F	0.6045.045F	0.6549.045F	0.8517.0
10 162 6					
47F	0.0012.047F	0.3013.047F	0.3214.047F	0.6016.047F	0.8016.5
47F	0.8541.0				
39SM #10.15 0.520M 0.25M 20/15N 21%S 60%R					
10 151 9					
45F	0.0021.045F	0.1022.045F	0.1821.045F	0.4526.545F	0.5526.5
45F	0.7531.045F	0.8532.045F	0.8736.045F	0.9018.0	
10 152 6					
47F	0.0012.047F	0.6012.047F	0.6213.047F	0.7013.747F	0.8914.2
47F	0.9027.0				
49ASH #10.21 SHEARED 0.50M 0.4M 350/13N 20.3%S 99%R					
10 211 11					
45F	0.0019.045F	0.0521.045F	0.1220.045F	0.4020.045F	0.5022.0
45F	0.6022.045F	0.7525.045F	0.7726.045F	0.9529.545F	1.2529.8
45F	1.3017.5				
10 212 7					
47F	0.0011.047F	0.5011.047F	0.5514.047F	0.6014.047F	0.7217.0
47F	1.2520.547F	1.3070.0			
42ASH #10.19 1.050M 0.017M 90/23E 22%S 50%R					

```
10 191 14
45F   0.0020.045F   0.2030.045F   0.2530.045F   0.4065.045F   0.5044.0
45F   0.7044.045F   0.7593.045F   0.8595.045F   1.3089.045F   1.3589.0
46F   2.3044.046F   2.3543.046F   2.70 5.046F   2.73 2.0
10 192  7
47F   0.0012.047F   2.2012.047F   2.5017.547F   2.6018.047F   2.6119.5
47F   2.6820.047F   2.7343.0
33ASH #10.17 3.20M 0.4M 22.4%S 99%R
10 171 65
45T   0.0018.045T   0.2021.045T   0.8021.045T   0.9019.545T   1.2024.0
45T   1.2523.045T   1.5027.045T   1.6033.045T   1.7022.045T   1.8222.0
45T   2.0023.045T   2.2023.045T   2.5047.045T   2.6032.045T   2.7032.0
45T   2.8030.045T   2.9030.045T   3.0046.045T   3.3053.045T   3.4052.0
45T   3.4532.045T   4.0032.045T   4.0150.045T   4.1050.045T   4.2069.0
45T   4.4067.045T   4.5069.045T   4.8092.045T   5.0088.045T   5.0179.0
45T   5.1079.045T   5.2086.045T   5.9092.046T   7.4030.046T   7.7030.0
46T   7.8036.046T   8.0044.046T   8.0145.046T   8.5034.046T   9.3524.0
46T   9.5024.046T   9.5128.046T  10.0039.045T  11.7064.045T  12.0051.0
45T  12.5054.045T  13.0049.045T  13.1054.045T  13.7046.045T  14.0042.0
45T  14.3042.045T  14.4044.045T  14.6036.045T  14.8034.045T  15.0037.0
45T  15.3035.045T  15.6038.045T  15.8028.045T  16.0029.045T  16.2020.0
45T  16.7020.045T  16.7528.045T  17.0023.045T  17.2025.045T  17.5020.0
10 172 29
47F   0.0011.547F   1.6012.047F   2.3012.047F   2.5013.047F   3.0013.0
47F   3.7014.047F   4.2014.047F   5.5017.047F   6.5018.047F   7.5018.0
47F   8.6020.047F   8.8021.047F   9.0021.047F   9.0121.547F   9.3522.0
47F   9.8022.047F  10.3024.047F  10.4024.047F  10.5030.047F  10.9033.0
47F  11.1033.047F  11.5033.047F  14.6059.047F  14.7059.047F  15.9075.0
47F  16.1080.047F  16.7080.047F  17.1090.047F  17.3099.9
40ASH #10.11 1.90M 0.12M 340/15N 22%S 50%R
10 111 20
45T   0.0018.045T   0.1020.045T   0.1120.145T   1.3522.045T   1.6022.0
45T   2.4542.045T   2.5022.045T   2.5125.545T   2.6025.045T   2.6523.0
45T   2.9024.045T   3.0024.045T   3.0138.045T   3.4049.045T   3.5046.0
45T   3.9560.045T   4.1051.045T   4.3051.045T   4.4056.045T   4.5020.0
10 112 14
47F   0.0011.047F   0.1011.047F   0.2512.547F   0.7013.047F   1.2013.0
47F   1.5014.047F   1.7514.047F   2.6016.047F   3.2016.047F   3.3016.0
47F   3.5016.547F   4.4022.047F   4.4536.547F   4.5040.0
39ASH #10.13 1.620M 0.09M 30/3S 22%S 50%R
10 131  9
45T   0.0017.045T   0.1019.045T   0.3019.545T   0.5019.045T   0.5120.0
45T   0.7022.045T   1.0022.045T   1.3023.045T   1.3116.0
10 132  2
47F   0.00 0.047F   1.31 0.0
42ASH #11.13 2.60M 0.05M 170/10S 25.2%S 84%R
11 131 34
37F   0.0023.043T   0.9059.043T   1.7559.043T   2.0070.043T   2.0164.0
43T   3.8064.043T   3.9069.043T   4.0573.043T   4.2071.543T   4.2866.0
43T   4.4066.043T   4.5072.043T   4.6068.043T   4.8068.043T   4.8572.0
43T   4.8664.043T   6.7064.043T   6.7282.043T   6.8566.043T   7.1066.0
43T   7.1173.043T   7.3577.043T   7.5066.043T   7.9076.043T   8.0070.0
43T   8.3070.043T   8.7069.043T   8.8057.043T   9.7557.043T   9.8060.0
43T  10.0560.043T  10.1059.043T  10.4559.043T  10.6056.0
```

```
11 132 23
38F   0.0015.038F   1.8515.038F   2.1018.038F   4.0518.038F   4.4020.0
38F   4.6020.038F   4.8021.038F   5.0521.538F   6.9021.038F   7.0022.0
38F   7.7023.038F   7.8024.538F   8.1025.038F   8.2025.038F   8.4027.0
38F   8.5027.038F   8.5528.038F   8.8028.538F   8.8538.038F   9.8038.0
38F   10.1047.038F  10.3047.038F  10.6085.0
44ASH #11.05 2.8CM 0.18M 170/11N 27.6%S 68.2%R
11  51 65
37F   0.0039.537F   1.0051.037F   1.1569.037F   1.5093.037F   1.7099.9
37F   2.5099.943T   2.8032.043T   3.1048.043T   3.4546.043T   3.5039.0
43T   4.0036.043T   4.2049.043T   4.6071.543T   4.8073.043T   5.0069.0
43T   5.1063.043T   5.3060.043T   5.4081.043T   5.7597.043T   6.1089.0
43T   6.3078.043T   6.4092.543T   6.5073.543T   6.6099.943T   7.8599.9
43T   8.2588.043T   9.0085.043T   9.0199.943T   10.3099.943T  11.1096.0
37F   14.0080.037F  14.0199.037F  15.2099.037F  15.2099.037F  15.3095.0
37F   15.4058.037F  15.8558.037F  15.8657.037F  17.3057.037F  17.3195.0
37F   19.2078.037F  19.5084.037F  20.0083.037F  20.3072.037F  20.6070.0
37F   21.0071.037F  21.3050.037F  21.4554.037F  21.8554.037F  22.0051.0
37F   22.5060.037F  22.7091.037F  22.9056.037F  23.1057.037F  23.3049.0
37F   24.2049.037F  24.2053.037F  24.4054.037F  24.5046.037F  25.2545.0
37F   25.3554.037F  25.5045.037F  25.7050.037F  25.8042.037F  26.2040.0
11  52 24
38F   0.0013.538F   0.5013.538F   1.2517.038F   2.2019.538F   3.0020.0
38F   3.4022.038F   4.3022.038F   5.2024.038F   5.5024.038F   5.5124.5
38F   6.5027.038F   6.8029.038F   15.6029.038F  18.0054.038F  19.0062.0
38F   19.2062.038F  19.2163.038F  19.5063.038F  20.4071.038F  20.6072.0
38F   21.0077.038F  24.1077.038F  24.1599.938F  26.2099.9
44ASH #10.03 0.85CM 0.1M 190/10S 22.9%S 45.3%R
10  31 42
48F   0.0015.048F   0.6015.548F   1.3016.048F   1.3117.048F   1.3517.0
48F   1.6118.548F   1.8022.048F   1.8217.548F   1.8322.048F   2.0030.0
48F   2.0524.048F   2.0641.548F   2.1030.048F   2.2053.048F   2.3053.0
48F   2.3867.048F   2.5050.048F   2.5181.048F   2.5562.048F   2.7085.0
48F   2.8072.048F   2.8589.048F   2.9580.048F   3.0091.048F   3.1082.0
48F   3.2082.048F   3.3092.048F   3.4571.048F   3.5081.048F   3.6054.0
48F   3.6564.048F   3.7054.048F   3.8058.048F   3.9060.548F   4.0022.0
48F   4.2019.048F   4.2517.048F   4.2716.048F   4.3016.548F   4.4016.0
48F   5.2016.048F   5.3015.0
10  32 32
50F   0.0011.550F   1.5011.550F   1.8013.050F   1.9013.050F   2.2014.0
50F   2.4014.050F   2.4114.550F   2.5014.850F   2.5115.550F   2.6015.6
50F   2.6516.050F   2.7016.050F   2.8017.050F   2.9517.050F   2.9918.0
50F   3.0118.050F   3.1521.050F   3.3021.050F   3.3822.050F   3.5022.0
50F   3.5125.050F   3.6025.050F   3.6127.050F   3.7027.050F   3.7529.0
50F   3.7829.050F   4.0060.050F   4.2093.050F   4.3093.050F   4.3593.5
50F   5.0093.550F   5.3099.9
42ASH #10.04 1.7CM 0.04M 230/0 22.9%S 45.3%R
10  41 35
48F   0.0014.548F   0.1015.048F   0.5019.548F   0.7015.548F   1.0034.5
48F   1.2058.048F   1.2121.548F   1.4079.048F   1.4144.048F   2.0099.9
48F   2.0186.049F   3.8051.049F   3.8131.049F   4.1055.549F   4.1141.5
49F   4.5061.049F   4.5150.049F   4.7071.049F   4.7158.049F   6.1080.0
49F   6.1167.049F   6.7081.049F   6.7165.049F   7.1087.049F   7.1171.0
49F   8.1089.049F   8.1176.049F   8.7089.549F   8.7175.549F   9.0079.5
```

```
48F   10.0058.048F   10.3088.548F   10.6081.049F   11.1014.549F   11.8014.5
10  42 17
50F    0.0011.550F    1.2011.550F    2.1013.050F    3.2013.550F    4.1014.0
50F    4.4015.050F    5.0017.050F    5.9019.050F    7.2021.050F    9.1024.5
50F    9.2032.050F   10.2032.050F   10.8041.050F   10.9090.050F   11.1090.0
50F   11.7990.050F   11.8099.9
57SM #10.07 0.80M 0.15M 180/2N 17.4%S 55.7%R BROKE AT CLAMP
10  71 14
48F    0.0015.048F    0.1017.048F    1.0017.048F    1.5018.048F    1.6018.5
48F    2.0023.548F    2.2562.548F    2.6078.048F    2.6151.048F    3.0581.0
48F    3.0659.048F    3.3584.048F    3.3667.048F    3.5015.0
10  72  6
50F    0.0011.050F    1.5011.050F    2.0015.050F    2.6018.550F    3.3519.0
50F    3.5086.0
42ASH #10.01 40M 0.07M 220/0 22.9%S 45.3%R
10  11 30
48T    0.0013.548T    0.7513.548T    1.0017.548T    1.5020.048T    1.9038.5
48T    2.0040.048T    2.5048.048T    3.0047.048T    3.4058.048T    3.5549.5
48T    3.9069.548T    4.2060.548T    4.6086.049T    5.6020.049T    6.0018.0
49T    6.3032.549T    6.5023.049T    6.9029.549T    7.2019.049T    7.6034.0
49T    7.8022.549T    8.0035.549T    8.10 2.549T    9.00 2.549T    9.2027.0
49T    9.5053.049T    9.7047.049T    9.9058.049T   10.0064.049T   10.1013.5
10  12 14
50F    0.0011.050F    1.5011.050F    2.6014.050F    3.6017.050F    5.5024.0
50F    6.6027.050F    7.6031.050F    8.1035.050F    8.1141.050F    8.4041.0
50F    8.9056.050F    9.5056.050F   10.0967.050F   10.1091.0
44ASH #10.06 1.10M 0.18M 255/45S 17.4%S 55.7%R
10  61 12
48F    0.0014.548F    0.4033.048F    0.6036.048F    0.8023.048F    1.1034.0
48F    1.6022.048F    1.9018.548F    2.2018.048F    5.0018.048F    9.5018.0
48F   10.0015.048F   10.3014.5
10  62  9
50F    0.0011.050F    0.5011.050F    0.6016.050F    1.0023.050F    1.6056.0
50F    2.5061.050F    2.9084.050F    3.1099.950F   10.3099.9
61ASH #11.15 FULL TENSILE STR. 1.250M .001M 200/10S 25.2%S 84%R
11 151 39
37F    0.0039.037F    0.1039.037F    0.1845.037F    0.4042.037F    0.5038.0
37F    0.5143.037F    0.6043.537F    0.7043.537F    0.8046.037F    1.0148.0
37F    1.2055.037F    1.3041.037F    1.5050.037F    1.6048.037F    2.1062.5
37F    2.4080.037F    2.5068.037F    2.6078.037F    2.7080.037F    2.9078.0
37F    2.9578.037F    2.9877.037F    3.1077.037F    3.1178.037F    3.3071.0
37F    3.3572.537F    3.5053.037F    3.7071.037F    3.8570.037F    4.0073.0
37F    4.5055.037F    4.5556.037F    4.9547.037F    5.0053.037F    5.1550.0
37F    5.2142.537F    5.3052.537F    5.3151.037F    5.4041.0
11 152 15
38F    0.0013.038F    1.3013.038F    1.5014.538F    1.6515.038F    1.8016.0
38F    2.0016.038F    2.5017.038F    2.8517.038F    3.0018.038F    3.1518.0
38F    3.6818.038F    3.7026.038F    3.9026.038F    5.1038.038F    5.3038.5
40ASH #11.17 2.70M 0.34M 190/30S 30%S 67%R
11 171155
37F    0.0033.037F    0.4032.037F    0.4541.037F    0.6042.037F    0.8042.0
37F    0.8539.037F    1.1042.537F    1.2543.037F    1.4042.037F    1.9063.0
37F    2.0074.037F    2.2090.037F    2.2570.037F    2.3599.937F    2.7599.9
43T    3.0026.043T    3.1040.043T    3.2540.043T    3.5078.043T    3.6072.0
```

```
43T   3.8095.043T   3.9084.043T   4.0099.943T   5.0099.921T   5.40 7.0
21T   5.70 7.021T   5.7114.021T   5.75 9.021T   5.76 9.021T   6.10 9.0
21T   6.2017.021T   6.3018.021T   6.3513.021T   6.5013.021T   6.5111.0
21T   6.8011.021T   6.82 4.021T   7.50 3.021T   7.8018.021T   8.0021.5
21T   8.1017.021T   8.3017.021T   8.3125.021T   8.3522.021T   8.5022.0
21T   8.5125.021T   8.6022.021T   8.7020.021T   8.8020.021T   8.9017.0
21T   9.2017.021T   9.2514.021T   9.5014.021T   9.6017.021T   9.9016.0
21T   10.1022.021T  10.1515.021T  10.3515.021T  10.3825.021T  10.4023.0
21T   11.0017.021T  11.1025.021T  11.2020.021T  19.0013.021T  19.0124.0
21T   19.2024.021T  19.2119.021T  19.4019.021T  19.4125.521T  19.6025.5
21T   19.6123.021T  21.4521.521T  21.5015.021T  21.7015.021T  21.8023.0
21T   21.9020.021T  22.0020.021T  22.1023.021T  22.1519.021T  30.8519.0
21T   30.8623.021T  30.9025.021T  31.1524.021T  31.1820.021T  32.6020.0
21T   33.4021.021T  33.8020.021T  34.3016.521T  35.0016.521T  35.2019.0
21T   35.2118.021T  35.9021.521T  36.0022.021T  36.1018.021T  36.3018.0
21T   36.3521.521T  36.5018.021T  40.0018.021T  40.1016.021T  40.4516.0
21T   40.5017.021T  40.7017.021T  40.8016.021T  41.0023.521T  41.0520.0
21T   41.3019.521T  41.3518.021T  41.8018.021T  41.8523.021T  42.1023.0
21T   42.1118.021T  42.2018.021T  42.2524.021T  42.3523.021T  42.3616.0
21T   46.6016.021T  46.6823.021T  46.8019.021T  46.9019.021T  46.9522.0
21T   47.1522.021T  47.2017.021T  47.3017.021T  47.3521.021T  47.4523.5
21T   47.4818.021T  48.0018.021T  50.3018.021T  50.3521.521T  50.5020.0
21T   50.6014.021T  51.8013.021T  54.3012.021T  54.3114.021T  55.1014.0
21T   55.2512.037F  55.2928.037F  55.7536.037F  56.0536.037F  56.2032.0
37F   56.8081.037F  56.9071.037F  57.0077.537F  57.1040.037F  57.3049.0
37F   57.4041.037F  58.2043.037F  58.5064.037F  58.6053.037F  58.7060.0
37F   58.9046.037F  59.0051.537F  59.2046.037F  59.4056.037F  59.5040.0
11 172 32
38F   0.0014.038F   1.7514.038F   2.8016.038F   3.7516.038F   3.9017.0
38F   4.5017.038F   4.9518.038F   5.6018.038F   5.7018.538F   6.4018.5
38F   6.5019.038F   7.8019.038F   8.0020.038F   9.0020.038F   9.0121.5
38F   10.5022.038F  11.5023.038F  19.4023.038F  19.7524.038F  31.5524.0
38F   31.5624.538F  34.1024.538F  34.2525.038F  34.4025.038F  34.6027.0
38F   35.4027.038F  36.0029.038F  37.3033.038F  55.6033.038F  57.0037.0
38F   59.4037.038F  59.5060.0
35SM #4.14 0.50M 0.14M 90/15S 22XS&R
 4 141  8
23F   0.00 4.023F   0.80 5.023F   1.20 7.023F   1.6023.023F   1.9044.5
23F   2.1070.023F   2.3599.923F   2.60 5.0
 4 142  6
26F   0.00 1.526F   0.60 1.526F   0.90 7.526F   1.6015.026F   2.0017.0
26F   2.6043.0
36SM #4.19 1.30M 0.16M 40/15S 20.6XS&R
 4 191 19
23T   0.00 4.023T   0.15 4.023T   0.3065.023T   0.70 5.523T   1.3011.0
23T   1.9013.023T   2.9016.023T   4.0025.023T   5.3025.523T   6.2528.0
23T   7.3032.023T   8.3040.023T   8.7056.523T   9.3057.523T   9.6037.0
23T   10.3033.023T  11.3033.023T  11.5043.523T  11.60 6.0
 4 192 14
26F   0.00 1.026F   1.20 1.026F   1.50 2.026F   2.50 3.026F   3.50 5.0
26F   4.5010.026F   5.8020.026F   6.8530.026F   7.5538.026F   7.9039.5
26F   9.9039.526F   10.2045.026F  11.5045.026F  11.5199.0
34SM #4.20 0.80M 0.11M 60/0 22.7XS&R
 4 201 11
```

```
23F    0.00 1.023F    0.10 5.023F    1.8039.023F    1.9061.523F    2.2094.5
24F    2.5048.024F    3.1093.024F    3.4081.024F    3.5098.525F    4.2035.0
25F    4.21 1.0
 4 202  7
26F    0.00 2.026F    0.10 2.026F    1.00 7.526F    1.9012.026F    3.5016.5
26F    4.0017.526F    4.2099.9
33SM #4.15 0.60M 0.16M 120/0 21%S&R
 4 151 11
23F    0.00 4.023F    0.20 4.023F    0.3013.023F    0.9013.023F    1.3030.0
23F    1.6030.023F    1.8018.023F    2.5029.523F    2.3516.523F    3.10 8.0
23F    3.50 4.0
 4 152  7
26F    0.00 0.026F    0.50 1.026F    1.05 3.026F    1.5010.026F    2.0037.0
26F    2.4037.026F    3.5040.0
37SM #4.12 1.080M 0.27M 60/35N 20.6%S&R
 4 121 18
23F    0.00 6.523F    0.3016.023F    0.8024.023F    1.3027.523F    1.5527.5
23F    2.0048.523F    2.4048.023F    2.8543.523F    3.0059.023F    3.2064.0
23F    3.4071.523F    3.6074.023F    4.0076.523F    4.4075.523F    4.5069.0
23F    5.0029.023F    5.5034.023F    6.10 6.0
 4 122 10
26F    0.00 4.526F    3.30 4.526F    3.35 6.526F    3.8010.026F    4.5020.0
26F    4.9030.026F    5.5040.526F    5.6052.026F    5.9052.026F    6.0099.9
35SM #4.16 0.50M 0.4M 10/35N 20.4%S&R
 4 161 13
23F    0.00 5.023F    0.30 5.023F    0.40 7.023F    1.30 7.023F    1.5011.5
23F    3.2011.523F    3.3020.523F    3.6018.023F    3.9020.523F    4.2026.0
23F    4.5021.023F    4.8011.023F    5.80 3.5
 4 162  8
26F    0.00 0.026F    2.00 4.026F    3.75 4.026F    4.20 7.526F    4.5021.0
26F    4.7031.026F    4.8034.026F    4.9099.9
66SM #4.17 0.40M 0.36M 25/28N 20.4%S&R MOVED LATERALLY AS PULLED OUT
 4 171 13
23F    0.00 5.023F    0.40 5.023F    0.7010.023F    0.8015.023F    1.1020.0
23F    1.9028.523F    2.2528.523F    2.4021.523F    3.8021.523F    4.4545.0
23F    4.7041.023F    5.0047.523F    5.30 6.5
 4 172  6
26F    0.00 3.026F    2.60 3.026F    2.7010.026F    3.9010.026F    4.7515.0
26F    5.0019.5
35SM #2.11 0.570M 0.2M 125/24N 20%S&R
 2 111  5
19F    0.0021.019F    0.4530.019F    0.7540.019F    1.1558.019F    1.3021.0
 2 112  5
22F    0.00 7.022F    0.5011.022F    1.0519.522F    1.2919.522F    1.3037.0
35SM #2.01 1.90M 0.14M 170/10S 21%S&R
 2  11 28
19T    0.0021.019T    0.4026.019T    0.6019.019T    0.8530.019T    1.7042.0
19T    2.9060.019T    3.8068.019T    4.2058.019T    4.7069.019T    5.2062.0
19T    6.6072.519T    6.9063.019T    7.1029.019T    7.2035.019T    7.3033.0
19T    7.9031.019T    8.0030.519T    8.0122.019T    8.1026.019T    8.3026.5
19T    8.4022.019T    8.4527.019T    8.7028.019T    8.8027.019T    8.8123.0
19T    8.9024.019T    8.9522.019T    9.0021.0
 2  12 12
22F    0.00 7.222F    2.10 7.222F    4.0014.022F    5.3520.022F    6.6030.0
```

```
22F    7.1036.022F    7.1542.522F    7.9042.522F    8.1052.522F    8.4052.5
22F    8.8069.022F    9.0090.0
34SM #2.18 0.80M 0.21M 100/7N 20%S&R
 2 181  9
19F    0.0021.019F    0.7021.019F    1.0026.019F    1.5029.019F    2.0037.0
19F    2.5050.019F    2.6531.019F    2.8037.019F    2.9020.0
 2 182  8
22F    0.00 6.022F    0.2018.022F    0.8025.022F    1.4026.022F    2.3030.0
22F    2.6032.022F    2.6140.022F    2.9053.0
36SM #2.16 0.80M 0.08M 100/7N 23.2%S&R
 2 161  9
19F    0.0021.029F    0.6021.019F    0.9029.019F    1.4050.019F    1.9087.0
19F    2.4084.019F    2.8089.019F    3.0079.019F    3.2020.0
 2 162  9
22F    0.00 5.022F    0.10 5.022F    0.4013.022F    1.0016.222F    1.8018.5
22F    2.2021.022F    2.6024.022F    3.0039.522F    3.1099.9
34SM #2.15 0.70M 0.27M 70/36N 21%S&R
 2 151  9
19F    0.0020.019F    0.3020.019F    0.6028.019F    1.4044.519F    2.2067.0
19F    3.0084.019F    3.8084.019F    3.9088.019F    4.4082.5
 2 152  8
22F    0.00 6.522F    0.60 6.522F    1.6011.522F    2.7525.022F    3.6035.0
22F    4.3043.522F    4.4043.522F    4.4199.9
36SM #2.12 0.420M 0.21M 115/35N 20%S&R
 2 121  8
19F    0.0021.019F    0.5023.019F    0.8025.022F    0.9530.019F    1.3040.0
19F    1.4050.019F    1.8560.519F    2.0021.0
 2 122  7
22F    0.00 7.022F    0.2020.022F    1.0028.022F    1.5035.022F    1.8543.5
22F    1.9567.022F    2.2099.9
63ASH #11.06 0.80M 0.1M 180/40N 25.2%S 84%R FULL TENSILE STRENGTH
11  61 10
37F    0.00 3.037F    0.3033.037F    0.9035.037F    2.0036.037F    2.6045.0
37F    3.0099.943F    3.3037.543F    3.6562.043F    3.8062.043F    3.81 4.0
11  62  8
38F    0.00 8.538F    1.20 9.038F    1.80 9.038F    1.9011.038F    2.4012.5
38F    3.6015.038F    3.8015.038F    3.8162.0
62ASH #11.12 0.90M 0.14M 200/20S 26%S 75%R FULL TENSILE STRENGTH
11 121 14
37F    0.0025.037F    0.6028.037F    1.1531.537F    1.5034.537F    1.7046.0
37F    2.0076.037F    2.2594.543F    2.5038.037F    2.7060.037F    2.9072.5
37F    3.20 8.037F    4.00 8.037F    4.2045.537F    4.40 3.0
11 122  9
38F    0.00 8.038F    1.10 8.038F    1.70 9.038F    1.9010.038F    2.4012.0
38F    2.6015.038F    2.6526.038F    3.2026.038F    4.4094.0
62ASH #11.11 1.10M 0.1M 180/7N 25.2%S 84%R FULL TENSILE STRENGTH
11 111  9
37F    0.0035.037F    0.2032.037F    0.3035.037F    0.8039.037F    1.1045.0
37F    1.3560.037F    1.4099.937F    2.0099.937F    2.55 3.0
11 112  6
38F    0.00 8.038F    0.70 8.038F    1.30 9.038F    2.0010.538F    2.5013.0
38F    2.5540.5
```
63ASH #11.06 0.80M 0.1M 180/40N 25.2%S 84%R FULL TENSILE STRENGTH
11 61 10

```
37F   0.00 3.037F   0.3033.037F   0.9035.037F   2.0036.037F   2.6045.0
37F   3.0099.943F   3.3037.543F   3.6562.043F   3.8062.043F   3.81 4.0
11  62  8
38F   0.00 8.538F   1.20 9.038F   1.80 9.038F   1.9011.038F   2.4012.5
38F   3.6015.038F   3.8015.038F   3.8162.0
62ASH #11.12 0.90CM 0.14M 200/20S 26%S 75%R FULL TENSILE STRENGTH
11 121 14
37F   0.0025.037F   0.6028.037F   1.1531.537F   1.5034.537F   1.7046.0
37F   2.0076.037F   2.2594.543F   2.5038.037F   2.7060.037F   2.9072.5
37F   3.20 8.037F   4.00 8.037F   4.2045.537F   4.40 3.0
11 122  9
38F   0.00 8.038F   1.10 8.038F   1.70 9.038F   1.9010.038F   2.4012.0
38F   2.6015.038F   2.6526.038F   3.2026.038F   4.4094.0
62ASH #11.11 1.10CM 0.1M 180/7N 25.2%S 84%R FULL TENSILE STRENGTH
11 111  9
37F   0.0035.037F   0.2032.037F   0.3035.037F   0.8039.037F   1.1045.0
37F   1.3560.037F   1.4099.937F   2.0099.937F   2.55 3.0
11 112  6
38F   0.00 8.038F   0.70 8.038F   1.30 9.038F   2.0010.538F   2.5013.0
38F   2.5540.5
41SM #9.05 0.75CM 0.22M 0/38N 17.4%S 51.2%R
 9  51 22
51F   0.00 2.051F   0.1030.051F   0.4034.051F   0.5045.051F   0.6060.0
51F   0.8074.051F   1.0061.551F   1.6076.051F   1.8074.551F   2.0060.0
51F   2.2057.551F   2.3067.051F   2.4058.051F   2.6054.551F   3.0041.5
51F   3.1051.551F   3.2041.551F   3.6025.051F   3.9022.551F   4.0019.0
51F   4.2018.051F   4.6017.0
 9  52 12
54F   0.00 5.054F   1.60 5.054F   2.0010.554F   2.2010.554F   2.5516.5
54F   3.1016.554F   3.2529.054F   3.4539.054F   3.5039.054F   3.7042.5
54F   4.1042.554F   4.2099.9
40SM #9.07 0.70M 0.3M 50/30N 17.8%S 51.9%R
 9  71 15
51F   0.0025.051F   0.1028.051F   1.3028.051F   1.8558.551F   1.9547.0
51F   2.1060.551F   2.3040.051F   2.6025.551F   2.9025.051F   3.0027.5
51F   3.1024.051F   3.2028.051F   3.4026.051F   4.5026.051F   4.5525.0
 9  72 10
54F   0.00 5.054F   2.10 5.054F   2.3010.054F   2.5022.054F   2.7023.5
54F   3.0026.054F   3.1026.054F   3.2533.054F   4.5033.054F   4.5569.0
63SM #9.09 0.80M 0.31M 320/17N 17.7%S 51.9%R LATERAL DISPLACEMENT
 9  91 13
51F   0.0021.051F   0.3035.051F   0.6046.051F   1.0057.051F   1.5067.5
51F   1.8054.051F   1.9054.051F   2.0573.051F   2.3077.051F   2.4079.0
51F   2.8030.051F   3.0528.051F   3.3021.5
 9  92 11
54F   0.00 6.554F   0.10 6.554F   0.3012.054F   0.8016.054F   1.0016.0
54F   1.1017.054F   1.2068.054F   1.8069.054F   2.5073.054F   2.6099.9
54F   3.3099.9
43SM #9.06 0.930M 0.22M 40/37N 17.4%S 51.2%R
 9  61 14
51F   0.0016.051F   0.2031.051F   0.6041.051F   1.1053.551F   1.4060.0
51F   1.5068.551F   1.7053.051F   1.9067.051F   2.1035.051F   2.4031.0
51F   2.6026.051F   2.9021.551F   3.7021.551F   3.8019.0
 9  62 11
```

```
54F    0.00 5.054F    0.30 6.054F    0.70 8.054F    1.1511.054F    1.5017.0
54F    2.1025.054F    2.4537.054F    2.6042.054F    2.7057.054F    2.8083.0
54F    3.8099.9
63SM #9.03 0.48DM 0.2M 75/13W 17.4%S 51.2%R FULL TENSILE STRENGTH
 9  31 10
51F    0.0018.051F    0.1018.051F    0.2020.051F    0.8023.051F    1.2030.0
51F    1.6040.051F    2.0055.051F    2.5070.051F    2.8077.051F    3.0015.0
 9  32 10
54F    0.00 5.054F    0.10 5.054F    0.30 8.054F    0.50 9.054F    1.0018.5
54F    1.3021.054F    2.1026.054F    2.6534.054F    2.9037.554F    3.0064.0
57SM #9.11 0.30M 0.35M 80/0 16%S 45%R FULL TENSILE STRENGTH
 9 111 10
51F    0.0018.551F    0.5030.051F    0.8040.051F    1.3048.051F    1.7052.0
51F    1.9054.051F    2.3055.051F    2.5053.051F    2.8048.051F    3.0015.5
 9 112  7
54F    0.00 5.054F    0.80 5.054F    1.7010.054F    2.6015.054F    2.8517.0
54F    2.8552.054F    3.0099.9
41SM #9.04 2.22DM 0.18M 20/4N 17.4%S 51.2%R
 9  41 27
51T    0.0016.051T    0.4016.051T    0.9026.051T    1.0017.551T    1.3528.5
51T    1.6030.051T    2.0040.051T    2.3055.551T    2.9074.551T    3.3070.0
51T    3.5082.051T    3.9573.051T    4.2086.052T    4.8035.052T    5.0038.0
52T    5.3046.052T    5.7042.052T    6.1048.552T    6.5044.052T    6.7015.0
51T    7.1047.051T    7.6043.551T    8.0033.051T    8.2031.051T    8.6031.0
51T    9.0019.051T   10.0019.0
 9  42 14
54F    0.00 5.054F    0.90 5.054F    1.5010.054F    2.3015.054F    3.3020.0
54F    4.4026.054F    4.9026.054F    6.0032.054F    6.8036.054F    6.8045.0
54F    7.5054.054F    8.5083.054F    8.8095.554F   10.0099.9
 0     39SM #9.02 1.52DM 0.1M 70/0 18.4%S 53.6%R
 9  21 25
51T    0.0017.051T    0.1017.051T    0.2020.051T    0.4022.051T    0.6027.0
51T    0.9034.051T    1.3038.051T    1.6050.051T    1.7045.051T    2.2064.0
51T    2.5064.051T    2.9077.051T    3.1068.051T    3.6088.051T    3.8087.0
51T    4.1099.952T    5.0041.052T    5.2048.052T    5.5047.052T    5.7045.0
52T    5.8056.052T    6.1056.052T    6.4051.052T    6.7059.552T    6.90 2.0
 9  22 10
54F    0.00 4.554F    0.55 4.554F    2.4010.054F    4.1015.054F    4.6016.0
54F    5.1016.054F    5.8019.054F    6.6021.554F    6.7043.054F    7.2050.0
39SM #9.10 2.28DM 0.13M 350/15N 18%S 52%R
 9 101 16
51T    0.0012.051T    0.3013.051T    1.7013.551T    2.2014.051T    3.0014.0
51T    3.3029.051T    3.6037.051T    3.8039.851T    4.0039.551T    4.2534.0
51T    4.5032.051T    4.7026.551T    5.0020.051T    5.3019.051T    5.5016.0
51T    6.3016.0
 9 102  8
54F    0.0018.054F    3.4018.054F    3.8025.554F    4.2035.054F    4.6044.5
54F    5.0059.054F    5.3068.054F    5.5089.5
37SM #9.19 1.10M 0.16M 260/5W 18%S 52%R
 9 191  8
51F    0.0017.051F    0.2017.051F    0.5043.051F    0.6053.551F    1.4097.0
52F    2.1037.052F    2.3060.052F    2.31 1.0
 9 192  8
54F    0.00 5.054F    0.30 5.054F    0.45 6.554F    0.75 8.054F    1.00 8.0
```

54F 1.3016.054F 2.3016.054F 2.3199.9
42SM #9.22 0.65CM 0.3M 255/59S 17.8%S 51.9%R
9 221 16
51F 0.0024.051F 0.3037.051F 0.8047.051F 1.1555.051F 1.6056.0
51F 2.2058.051F 2.4077.051F 2.6085.051F 2.8083.551F 3.0057.0
51F 3.1562.551F 3.4056.051F 3.8041.051F 4.2050.551F 4.5049.0
51F 4.6022.0
9 222 13
54F 0.00 5.054F 0.50 5.054F 0.60 8.554F 1.2013.054F 1.9016.5
54F 2.4016.554F 2.9023.054F 3.2037.554F 3.7037.554F 4.0040.0
54F 4.3041.054F 4.6045.054F 4.7077.0
43ASH #7.15 0.57CM 0.1M 340/12N 26.4%S 100%R?
7 151 8
33F 0.0015.033F 0.2515.033F 0.4039.533F 0.6052.033F 1.0029.5
33F 1.0529.533F 1.1044.033F 1.3015.0
7 152 7
36F 0.00 7.036F 0.50 8.036F 0.8015.036F 1.1015.036F 1.2022.5
36F 1.5029.536F 1.9030.0
41ASH #7.14 0.80CM 0.2M 355/20S 26.9%S 83%R
7 141 7
33F 0.0015.033F 0.3515.033F 0.4084.033F 0.6054.533F 0.7079.0
33F 0.9523.033F 1.0515.0
7 142 4
36F 0.00 8.036F 0.90 8.036F 1.0510.036F 1.5015.0
59ASH #7.17 0.80CM 0.42M 105/77S 27.3%S 30%R SLIP NOT RECORDED
7 171 10
33F 0.0015.533F 0.2079.033F 0.5090.033F 0.6099.934F 0.8049.5
34F 1.8046.034F 7.4043.034F 7.6055.034F 8.0039.034F 8.5015.5
7 172 2
36F 0.00 8.036F 8.50 8.0
44ASH #7.19 0.89CM 0.12M 190/30N 26.4%S 100%R?
7 191 8
33F 0.0015.533F 0.4544.033F 0.5529.533F 0.9593.034F 1.2057.0
34F 1.4569.534F 1.7015.534F 2.3015.5
7 192 6
36F 0.00 7.036F 0.70 7.036F 1.30 9.036F 1.5021.536F 1.9021.7
36F 2.3034.0
42ASH #7.21 0.71CM 0.05M 100/0 26.4%S 100%R?
7 211 8
33F 0.0015.533F 0.5058.033F 0.9597.533F 1.8051.533F 1.9098.5
34F 2.0052.034F 2.1068.034F 2.3015.5
7 212 4
36F 0.0014.036F 0.5015.036F 2.3015.036F 2.3145.0
41ASH 7.23 0.60CM 0.1M 145/14W 26.4%S 100%R?
7 231 7
33F 0.0015.533F 0.1515.533F 0.2031.533F 0.5031.533F 0.7521.0
33F 0.8015.533F 1.2515.5
7 232 6
36F 0.00 7.536F 0.30 7.536F 0.6015.036F 1.0025.036F 1.1527.5
36F 1.2556.5
43ASH #7.22 1.57CM 0.1M 140/20N 26.4%S 100%R?
7 221 39
33T 0.0015.233T 0.1526.533T 0.3017.033T 1.0031.033T 1.4025.0
33T 1.8023.033T 1.9015.533T 5.8015.533T 5.9029.533T 6.1537.5

```
33T   6.4033.033T   6.7061.533T   6.8571.033T   7.2065.033T   7.6099.9
34T   8.0051.034T   8.8040.534T   9.0058.034T   9.3029.534T   9.5039.0
34T  10.0032.034T  10.7038.534T  11.1030.034T  11.6034.034T  12.0024.0
34T  12.6032.034T  12.9025.034T  13.5021.034T  13.8025.534T  14.1015.5
34T  14.4023.034T  14.8015.534T  15.2028.034T  15.5015.534T  15.8030.0
34T  15.9515.534T  16.3043.534T  16.5015.534T  18.5015.5
 7 222 17
36F   0.00 8.036F   4.20 8.036F   4.25 8.036F   5.95 8.036F   7.7512.5
36F   8.9012.536F   9.2014.036F  11.5022.036F  13.5032.036F  14.5037.5
36F  15.5044.036F  16.5051.536F  17.0056.036F  17.5064.536F  18.0073.5
36F  18.4073.536F  18.5098.0
41ASH #7.20 2.30M 0.17M 180/10N 26.9%S 83%R
 7 201 22
33T   0.0015.533T   0.7515.533T   1.0043.033T   1.6073.033T   2.1596.0
34T   2.7053.034T   3.1570.034T   4.0081.034T   4.4068.534T   4.9090.0
34T   5.2082.034T   5.7099.035T   6.3045.535T   6.8053.035T   7.1545.0
35T   7.7049.035T   8.4043.035T   9.0050.035T   9.9042.535T  10.0030.0
35T  10.5025.035T  11.2015.5
 7 202  7
36F   0.00 6.036F   0.5011.036F   1.0019.036F   2.0027.536F   3.9039.0
36F   6.0039.036F  11.2049.0
43ASH #7.08 1.40M 0.22M 275/26N 21.3%S 59.4%R
 7  81 16
27T   0.00 1.027T   0.3526.527T   0.7543.027T   1.0057.527T   1.3072.0
27T   1.8558.527T   2.0039.027T   2.2087.527T   2.4074.027T   2.8070.0
27T   2.9087.027T   3.2073.027T   3.4071.027T   3.6078.027T   3.90 8.0
27T   4.60 1.0
 7  82  5
30F   0.00 2.530F   3.60 2.530F   3.70 9.030F   4.00 9.030F   4.8019.5
41ASH #7.07 0.60M 0.42M 295/50N 20.7S 37.5R
 7  71  8
27T   0.00 1.027T   0.10 2.527T   0.20 1.027T   0.50 1.027T   0.60 6.5
27T   0.80 8.027T   1.0010.527T   1.01 1.0
 7  72  4
30F   0.00 2.730F   0.40 6.030F   0.90 9.030F   1.5038.0
43ASH #7.09 0.40M 0.05M 260/20W 24.1%S 31.2%R
 7  91  7
27T   0.00 0.527T   0.30 0.527T   0.5012.027T   0.9029.527T   1.1032.0
27T   1.3026.027T   1.50 0.5
 7  92  5
30F   0.00 2.530F   0.30 2.530F   1.00 6.030F   1.3017.030F   1.6032.0
39ASH #7.10 1.40M 0.16M 260/27W 22%S 45%R
 7 101 12
27T   0.00 1.027T   0.4027.027T   0.5546.527T   0.8051.027T   0.9048.0
27T   1.0831.527T   1.2034.027T   1.3020.027T   1.4020.527T   1.5017.0
27T   1.6010.027T   1.65 1.0
 7 102  7
30F   0.00 4.530F   0.75 4.530F   1.10 7.030F   1.3010.030F   1.3512.0
30F   1.4513.530F   1.6525.0
57ASH #7.11 1.420M 0.1M 30/0 24.1%S 31.2%R WINCH PLUS SCOUT
 7 111 20
27T   0.00 1.027T   0.15 7.527T   0.2018.027T   0.4025.027T   0.9036.0
27T   1.0026.027T   1.3025.027T   1.6021.527T   3.5021.527T   3.9020.0
27T   4.9020.027T   5.0027.527T   5.1019.027T   5.6019.027T   5.9045.0
```

```
27T   5.9513.027T   6.6013.027T   6.6510.027T   7.5011.027T   7.51 1.0
 7 112  5
30F   0.00 3.030F   5.75 3.030F   5.80 5.730F   7.50 5.730F   7.5130.0
36SM #2.10 0.50M 0.36M 115/3S 22.2%S&R
 2 101 10
19F   0.0020.019F   0.3023.019F   0.7023.519F   0.9036.519F   1.1033.0
19F   1.3045.519F   1.7059.019F   1.9035.019F   2.5552.519F   2.7019.0
 2 102  5
22F   0.00 7.022F   0.80 7.022F   1.70 9.022F   2.4012.522F   2.6036.0
49SM #2.08 0.80M 0.18M 90/0 20%S&R LATERAL MOVEMENT
 2  81 16
19F   0.0021.519F   0.4021.519F   0.5032.019F   1.0037.519F   1.3539.0
19F   1.8048.019F   2.0047.019F   2.6048.519F   3.2054.019F   3.8562.0
19F   4.7070.519F   5.4070.519F   5.8081.519F   6.0084.519F   6.4082.5
19F   6.9052.5
 2  82 15
22F   0.00 5.022F   1.00 5.022F   1.30 8.022F   1.6013.522F   2.1022.0
22F   2.6031.022F   3.2039.022F   3.9048.522F   4.2053.022F   4.8057.0
22F   5.4070.022F   6.2077.022F   6.4077.022F   6.5087.022F   7.0090.0
35SM #2.07 0.520M 0.3M 140/27S 21%S&R
 2  71 16
19F   0.0020.019F   0.2020.019F   0.6031.519F   1.1033.019F   1.4039.5
19F   1.9058.019F   2.3064.019F   2.7070.019F   2.9570.019F   3.1563.0
19F   3.5063.019F   3.6558.519F   3.8533.019F   4.0027.019F   5.0020.0
19F   6.0020.0
 2  72 11
22F   0.00 3.222F   1.00 3.222F   2.00 3.522F   3.00 7.022F   3.5012.0
22F   3.8028.022F   4.5042.022F   5.0054.022F   5.4060.022F   5.9068.0
22F   6.0099.9
36SM #2.02 0.570M 0.16M 210/25S 20%S&R
 2  21 11
19F   0.0022.519F   0.1025.019F   0.4030.019F   0.9035.019F   1.3542.0
19F   1.8057.519F   2.1065.019F   2.3067.019F   2.5058.519F   2.6068.0
19F   2.6515.0
 2  22  4
22F   0.00 4.022F   0.30 4.022F   2.6012.022F   2.6599.9
37SM #2.05 0.40M 0.37M 180/31S 22.2%S&R
 2  51 15
19F   0.0021.019F   0.7021.019F   0.8024.519F   1.5030.019F   2.1532.0
19F   2.5050.019F   3.3557.519F   3.6551.019F   4.0060.019F   4.1066.0
19F   4.5070.019F   4.7072.519F   4.9071.519F   5.1031.019F   6.2025.0
 2  52 12
22F   0.00 5.022F   0.50 5.022F   0.95 7.522F   2.50 8.522F   3.5010.0
22F   4.5015.022F   4.9017.522F   5.0031.022F   5.4031.022F   5.8070.0
22F   6.1096.522F   6.2099.9
38SM #2.17 0.820M 0.38M 180/50S 22.2%S&R
 2 121 12
19F   0.0020.019F   0.3026.019F   0.8027.019F   1.5038.019F   2.0056.0
19F   3.0087.019F   3.8087.019F   4.1081.019F   4.4089.019F   4.5082.0
19F   4.8041.019F   5.0038.5
 2 122 10
22F   0.00 4.022F   0.50 5.022F   1.00 6.022F   1.50 6.022F   2.20 8.0
22F   2.7010.022F   4.0015.022F   4.5019.522F   4.7035.022F   5.8599.9
41ASH #11.23 1.50M 0.17M 50/4N 22.4%S 4.4%R
```

```
11 231 14
39F    0.0020.039F    0.3025.039F    0.6025.039F    0.7026.039F    1.0026.0
39F    1.8536.039F    2.5059.039F    2.5256.039F    3.2095.040F    3.3024.0
40F    4.0566.040F    4.2152.040F    4.3057.040F    4.31 5.0
11 232 11
41F    0.0013.041F    0.6513.241F    2.2515.041F    2.6015.041F    3.2016.0
41F    3.3017.041F    3.8018.041F    4.0020.041F    4.0221.541F    4.2022.0
41F    4.3050.0
42ASH #11.22 1.30M 0.14M 100/20N 21.8%S 45%R
11 221 18
39F    0.0021.039F    0.7025.039F    1.1025.039F    1.7040.039F    1.8845.0
39F    2.0045.039F    2.2051.039F    2.3047.039F    2.4547.039F    2.4625.0
39F    2.5530.039F    2.8030.039F    3.1027.539F    3.3227.039F    3.4524.5
39F    3.6025.039F    3.8528.539F    3.8615.0
11 222 13
41F    0.0013.041F    0.3013.541F    0.5014.041F    0.7517.041F    1.0018.0
41F    2.0018.541F    2.1024.041F    2.2830.041F    2.4532.541F    3.5048.0
41F    3.5548.041F    3.7051.041F    3.8655.0
76ASH #11.21 1.50M 0.08M 130/23N 21.4%S 47.8%R BROKE OBLIQUE TO GROUND
11 211  5
39F    0.0024.039F    0.1025.039F    0.3034.039F    0.7299.939F    0.7320.0
11 212  6
41F    0.0013.041F    0.2515.041F    0.5020.041F    0.6523.041F    0.7223.0
41F    0.7340.0
44ASH #11.24 1.350M 0.3M 140/15S 21.5%S 33.3%R
11 241 42
39F    0.0023.539F    0.3028.039F    0.5528.039F    1.6093.040F    1.7521.0
40F    2.3048.040F    2.7064.040F    3.0571.040F    3.7082.040F    3.9082.0
40F    4.0065.040F    4.2075.040F    4.6075.040F    4.7079.040F    7.4076.0
40F    7.5580.040F    8.6579.040F    8.9083.040F   10.5082.040F   10.8092.0
40F   12.4090.040F   18.0089.040F   18.2092.040F   23.9091.040F   24.0592.0
40F   28.7092.040F   30.9592.040F   31.1093.040F   32.8593.040F   33.0094.0
40F   37.3092.540F   37.5093.040F   41.0093.040F   41.2095.040F   42.3094.0
40F   42.4097.040F   43.1096.540F   43.3097.040F   45.0096.540F   45.2097.0
40F   48.7096.540F   48.8028.0
11 242 13
41F    0.0012.041F    1.0012.041F    1.2013.041F    1.9013.241F    2.1214.0
41F    2.9015.041F   23.8015.041F   28.5216.041F   42.2016.041F   42.2817.0
41F   48.6017.041F   48.6280.041F   48.8099.9
41ASH #11.18 1.20M 0.14M 100/7N 21.9%S 45%R
11 181 12
39F    0.0018.039F    0.5025.039F    0.9530.039F    1.7099.940F    1.8020.0
40F    2.1519.540F    2.3532.040F    2.4536.040F    2.4627.040F    2.6027.0
40F    2.6537.040F    2.70 5.0
11 182  9
41F    0.0011.041F    1.3511.041F    1.4511.541F    1.7512.041F    2.1812.0
41F    2.3513.041F    2.5513.041F    2.6019.041F    2.7020.0
43ASH #11.19 1.30M 0.03M 130/4N 21.4%S 47.8%R
11 191 18
39F    0.0018.539F    0.2022.539F    1.0026.539F    1.6031.039F    1.9050.0
39F    2.4090.040F    2.8825.040F    3.0039.040F    3.4056.040F    3.4148.5
40F    3.5948.040F    3.6857.040F    3.7551.040F    3.8056.040F    3.9032.0
40F    4.0027.040F    4.3550.040F    4.40 5.0
11 192 13
```

41F 0.0010.041F 0.4011.041F 0.7011.041F 0.8512.041F 1.1012.0
41F 1.8012.541F 2.1014.041F 2.7014.041F 3.0015.041F 3.7215.0
41F 3.7319.041F 4.2025.041F 4.4026.0
44ASH #11.25 1.20M 0.02M 120/53S 21.4%S 47.8%R
11 251 19
39F 0.0015.039F 0.1016.039F 0.2820.039F 0.4021.039F 0.7520.5
39F 1.1124.539F 1.9080.039F 2.3098.039F 2.5039.039F 2.8040.0
39F 2.9065.039F 3.0897.039F 3.3099.939F 3.4097.040F 3.5025.0
40F 3.6825.040F 3.7538.040F 4.5866.040F 4.70 5.0
11 252 13
41F 0.0010.041F 0.2010.041F 0.3512.041F 0.5513.041F 0.9013.0
41F 0.9815.041F 1.2015.041F 1.9024.041F 2.2525.041F 2.2826.0
41F 2.5029.041F 3.0729.041F 3.0830.0
44ASH #11.20 1.040CM 0.06M 130/4N 21.4%S 47.8%R
11 201 10
39F 0.0022.539F 0.3040.039F 0.5575.039F 0.8099.940F 0.9830.0
40F 1.1030.040F 1.1843.040F 1.8360.540F 1.9747.040F 2.05 5.0
11 202 6
41F 0.0010.041F 0.3010.041F 0.5012.541F 1.2015.041F 2.0020.0
41F 2.0535.0
40SM #6.02 1.560CM 0.11M 30/10S 24%S 36.3%R
6 21 82
6F 0.00 4.0 6F 0.1515.0 6F 0.30 4.0 6F 0.3523.0 6F 0.45 5.0
6F 0.6012.0 6F 0.7032.0 6F 0.8023.0 6F 0.8532.0 6F 1.0026.0
6F 1.1023.0 6F 2.5023.0 6F 3.0022.0 6F 3.1021.0 6F 3.6021.0
6F 3.6120.0 6F 3.8520.0 6F 4.0019.0 6F 4.9019.0 6F 4.9118.0
6F 5.0057.5 6F 5.0546.0 6F 5.2046.0 6F 5.2543.0 6F 5.3066.0
6F 5.4556.0 6F 5.5072.5 6F 5.6065.0 6F 5.7583.0 6F 5.8569.0
6F 6.0097.0 6F 6.0588.0 6F 6.3086.0 6F 6.5099.9 6F 6.6597.0
6F 7.0080.0 6F 7.0599.9 6F 7.4591.0 6F 7.6099.9 7F 13.50 7.5
7F 14.50 6.0 7F 14.51 9.0 7F 14.60 8.0 7F 14.70 8.0 7F 14.75 6.0
7F 14.8011.0 7F 14.81 8.0 7F 15.00 8.5 7F 15.05 6.0 7F 15.1012.0
7F 15.1511.0 7F 15.3010.0 7F 15.35 7.0 7F 15.3612.0 7F 17.9512.0
7F 18.3010.0 7F 18.35 9.0 7F 19.30 8.5 7F 19.60 7.0 7F 19.70 6.0
7F 19.75 7.0 7F 20.50 7.0 7F 20.51 2.5 7F 20.60 6.0 7F 22.10 4.5
7F 25.70 4.0 7F 25.71 3.0 7F 25.90 3.0 7F 26.10 4.0 7F 27.30 4.0
7F 28.00 3.5 7F 29.20 3.5 7F 29.25 4.5 7F 29.85 4.0 7F 30.50 3.5
7F 37.25 3.5 7F 37.30 4.5 7F 38.00 4.0 7F 38.05 4.1 7F 38.10 3.5
7F 39.00 3.5 7F 39.01 1.0
6 22 42
8F 0.00 4.0 8F 0.50 5.0 8F 3.35 5.0 8F 3.40 6.0 8F 5.25 6.0
8F 6.10 7.0 8F 6.35 7.0 8F 6.40 7.5 8F 6.90 7.5 8F 7.00 8.0
8F 14.50 8.0 8F 14.65 8.5 8F 15.15 9.0 8F 15.4010.0 8F 16.0010.0
8F 16.1011.0 8F 16.3511.0 8F 16.4011.5 8F 17.0511.7 8F 17.9011.7
8F 18.1012.5 8F 18.9012.5 8F 18.9513.0 8F 19.6013.2 8F 20.1513.2
8F 20.8015.5 8F 21.0015.5 8F 21.2016.7 8F 21.5516.7 8F 22.0017.2
8F 25.9017.2 8F 26.0018.5 8F 29.0018.5 8F 29.1019.5 8F 34.6019.7
8F 34.6121.0 8F 36.8021.2 8F 37.0021.2 8F 37.1022.0 8F 38.0023.0
8F 38.7023.0 8F 39.0133.0
41SM #6.04 1.120CM 0.14M 160/10S 24%S 36.3%R
6 41 40
6F 0.00 2.0 6F 0.10 6.0 6F 0.2015.0 6F 0.3539.0 6F 0.4527.0
6F 0.6027.0 6F 0.6549.0 6F 0.7541.5 6F 0.8041.5 6F 0.9068.0
6F 0.9556.0 6F 1.1054.0 6F 1.1584.0 6F 1.2072.0 6F 1.5068.0

```
6F    1.5596.0 6F    1.6585.0 6F    1.7082.0 6F    2.0081.0 6F    2.1099.9
6F    2.2582.0 6F    2.4089.0 6F    2.8087.0 6F    3.0086.0 6F    3.1084.0
6F    3.3584.0 6F    3.4083.0 6F    3.5083.0 6F    3.5580.0 6F    3.9080.0
6F    4.0078.0 6F    4.1081.0 6F    4.6082.0 6F    4.9081.0 6F    6.5081.0
6F    6.6099.9 6F    6.8099.9 6F    7.0080.0 6F    7.2582.0 6F    7.30 2.0
6  42 16
8F    0.00 6.0 8F    0.2011.0 8F    0.6511.0 8F    0.7012.0 8F    0.9012.0
8F    0.9512.5 8F    1.3013.0 8F    1.3513.5 8F    1.5014.0 8F    2.0014.0
8F    5.5070.0 8F    5.7075.0 8F    6.2076.0 8F    6.7077.0 8F    7.2977.0
8F    7.3099.9
37SM #6.12 3.20M 0.1M 165/0 24XS 36.3XR
6 121 85
6T    0.00 2.0 6T    0.05 3.0 6T    0.10 3.0 6T    0.4027.0 6T    0.45 8.0
6T    0.60 8.0 6T    0.6566.0 6T    0.7045.0 6T    1.0045.0 6T    1.0542.0
6T    1.1043.0 6T    1.3543.0 6T    1.4044.0 6T    1.6544.0 6T    2.2041.0
6T    2.2542.0 6T    2.3041.0 6T    2.6541.0 6T    2.7055.0 6T    2.8587.0
6T    3.0070.0 6T    3.3568.5 6T    3.6099.9 6T    3.7085.0 6T    4.4575.5
6T    4.7075.5 6T    5.0079.5 6T    5.1076.0 6T    5.1579.0 6T    5.2079.5
6T    5.3086.5 6T    5.4094.0 6T    5.4579.0 6T    5.6095.0 6T    5.6580.5
6T    5.9081.0 6T    6.7581.0 6T    6.8599.9 6T    7.0084.0 6T    7.2084.0
6T    7.3083.0 6T    7.5083.0 6T    7.6087.0 6T    8.2087.0 6T    8.3585.0
6T    8.5085.0 6T    8.5199.9 7T   14.55 9.5 7T   16.70 9.5 7T   16.80 6.0
7T   17.75 6.5 7T   17.90 9.5 7T   23.40 9.0 7T   24.00 7.0 7T   24.20 7.0
7T   24.25 7.5 7T   27.60 7.5 7T   27.65 9.0 7T   28.30 9.0 7T   28.8013.0
7T   28.9013.0 7T   29.0012.0 7T   29.1013.5 7T   29.2513.0 7T   29.5014.0
7T   30.0513.5 7T   30.5013.0 7T   31.5013.0 7T   31.5511.0 7T   34.5010.0
7T   35.6010.0 7T   35.70 7.0 7T   38.70 7.0 7T   38.80 2.0 6T   40.9035.0
6T   41.1037.0 6T   41.5037.0 6T   41.6035.0 6T   41.7580.0 6T   42.0049.0
6T   42.5046.0 6T   42.7045.0 6T   43.0045.0 6T   43.2057.5 6T   43.25 2.0
6 122 32
8F    0.00 4.0 8F    0.10 6.0 8F    0.3012.0 8F    0.4012.0 8F    0.6014.5
8F    1.3015.0 8F    2.7015.0 8F    3.0016.0 8F    3.4016.0 8F    3.4016.0
8F    3.5017.0 8F    3.6019.0 8F    5.4020.0 8F    7.4521.0 8F    8.8021.0
8F    9.5022.0 8F   19.0022.0 8F   20.1022.5 8F   22.9023.0 8F   25.9023.5
8F   27.2023.5 8F   27.6024.0 8F   29.0024.0 8F   31.9025.0 8F   35.2025.5
8F   37.4026.0 8F   37.6026.5 8F   38.5027.0 8F   38.6527.0 8F   38.7029.5
8F   43.2029.5 8F   43.2547.0
/*
//SIGNAL EXEC WNOTIFY
```

1. DISPLACEMENT = -7.34 + 2.02 * READING R=0.9921
2. DISPLACEMENT = -0.57 + 0.31 * READING R=1.0000
3. FORCE = -0.01 + 0.01 * READING R=0.9805
4. FORCE = -0.07 + 0.06 * READING R=0.9982
5. DISPLACEMENT = -0.57 + 0.31 * READING R=1.0000
6. FORCE = 0.07 + 0.01 * READING R=0.9817
7. FORCE = -0.07 + 0.12 * READING R=0.9797
8. DISPLACEMENT = -1.25 + 0.31 * READING R=1.0000
9. FORCE = 0.06 + 0.01 * READING R=0.9830
10. FORCE = 0.09 + 0.08 * READING R=0.9292
11. DISPLACEMENT = -0.41 + 0.31 * READING R=0.9999
12. FORCE = -0.06 + 0.01 * READING R=0.9754
13. FORCE = -0.07 + 0.07 * READING R=0.9780
14. DISPLACEMENT = -0.05 + 0.31 * READING R=0.9998
15. FORCE = -0.05 + 0.01 * READING R=0.9840
16. FORCE = -0.17 + 0.01 * READING R=0.9934
17. FORCE = -0.42 + 0.03 * READING R=0.9973
18. DISPLACEMENT = -2.29 + 0.35 * READING R=0.9998
19. FORCE = -0.26 + 0.01 * READING R=0.9932
20. FORCE = 0.63 + 0.01 * READING R=0.7605
21. FORCE = -0.59 + 0.09 * READING R=0.9869
22. DISPLACEMENT = -1.42 + 0.32 * READING R=0.9998
23. FORCE = 0.01 + 0.01 * READING R=0.9851
24. FORCE = -0.14 + 0.01 * READING R=0.9998
25. FORCE = -0.04 + 0.04 * READING R=1.0000
26. DISPLACEMENT = -1.82 + 0.35 * READING R=1.0000
27. FORCE = -0.31 + 0.01 * READING R=0.9989
28. FORCE = -0.27 + 0.02 * READING R=0.8983
29. FORCE = -0.36 + 0.05 * READING R=0.9994
30. DISPLACEMENT = 0.00 + 0.30 * READING R=1.0000
31. FORCE = -0.04 + 0.01 * READING R=0.9890
32. DISPLACEMENT = -0.54 + 0.31 * READING R=0.9991
33. FORCE = -0.27 + 0.01 * READING R=0.9994
34. FORCE = -0.45 + 0.02 * READING R=0.9920
35. FORCE = -0.50 + 0.04 * READING R=0.9939
36. DISPLACEMENT = -2.27 + 0.38 * READING R=0.9990
37. FORCE = -0.26 + 0.03 * READING R=0.9217
38. DISPLACEMENT = -4.66 + 0.38 * READING R=0.9978
39. FORCE = -0.15 + 0.01 * READING R=0.9550
40. FORCE = -0.07 + 0.03 * READING R=0.9737
41. DISPLACEMENT = -5.49 + 0.37 * READING R=1.0000
42. FORCE = -0.12 + 0.01 * READING R=0.9769
43. FORCE = 0.16 + 0.01 * READING R=0.9939
44. DISPLACEMENT = -3.30 + 0.39 * READING R=0.9997
45. FORCE = -0.13 + 0.01 * READING R=0.9825
46. FORCE = 0.11 + 0.02 * READING R=0.9473
47. DISPLACEMENT = -4.86 + 0.39 * READING R=0.9997
48. FORCE = -0.08 + 0.01 * READING R=0.9545
49. FORCE = 0.05 + 0.02 * READING R=0.9723
50. DISPLACEMENT = -3.77 + 0.37 * READING R=0.9996
51. FORCE = -0.17 + 0.01 * READING R=1.0000
52. FORCE = -0.09 + 0.02 * READING R=0.9989
53. FORCE = -0.09 + 0.06 * READING R=0.9920
54. DISPLACEMENT = -3.74 + 0.42 * READING R=0.9926
55. FORCE = -0.13 + 0.00 * READING R=1.0000
56. FORCE = -1.28 + 0.05 * READING R=1.0000
57. FORCE = -0.05 + 0.01 * READING R=0.9931

ASH #7.01 1.1CM 0.1M 270/20E 24.1%S 31.2%R

TREE: 7 ROOT: 1

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.97
56.3	0.97
64.5	1.13
69.0	1.28
78.0	1.59
79.5	1.90
87.0	1.90
88.5	2.06
90.0	2.06
91.5	2.21
96.0	2.52
108.0	2.52
108.8	3.14
118.5	3.14
120.0	4.38
121.5	11.81

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.13	0.97
7.5	0.14	0.97
22.5	0.15	0.97
34.5	0.15	0.97
36.0	0.16	0.97
37.5	0.15	0.97
39.0	0.16	0.97
40.5	0.15	0.97
41.3	0.17	0.97
42.8	0.16	0.97
43.5	0.11	0.97
45.0	0.08	0.97
46.5	0.16	0.97
55.5	0.16	0.97
57.0	0.07	0.99
60.0	0.21	1.04
63.0	0.20	1.10
64.5	0.17	1.13
66.0	0.22	1.18
69.0	0.20	1.28
73.5	0.48	1.44

75.0	0.38	1.49
81.0	0.38	1.90
82.5	0.53	1.90
84.0	0.48	1.90
85.5	0.48	1.90
90.0	0.71	2.06
91.5	0.63	2.21
94.5	0.63	2.42
96.0	0.71	2.52
97.5	0.71	2.52
99.0	0.69	2.52
103.5	0.69	2.52
106.5	0.69	2.52
109.5	0.68	3.14
111.0	0.66	3.14
112.5	0.11	3.14
118.5	0.11	3.14
120.0	0.13	4.38
121.5	0.02	11.81

ASH #7.04 1.54CM 0.2M AZ/PL 21.3%S 59.4%R

TREE: 7 ROOT: 4

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.66
13.5	0.82
19.5	2.52
22.5	2.52
24.7	2.83
30.0	2.83
39.0	4.23
40.5	4.38
46.5	4.69
48.0	5.00
52.5	5.16
57.0	5.16
58.5	5.47
64.5	5.62
65.3	7.48
66.0	7.79
70.5	7.79
70.6	9.65
75.0	16.15
78.0	21.11

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.04	0.66
3.0	0.06	0.70
3.8	0.07	0.71
4.5	0.09	0.72
7.5	0.04	0.75
10.5	0.10	0.79
11.3	0.14	0.79
12.0	0.13	0.80
12.8	0.06	0.81
15.0	0.06	1.25
21.0	0.45	2.52
22.5	0.37	2.52
24.0	0.28	2.73
26.3	0.60	2.83
27.8	0.51	2.83
30.0	0.49	2.83
33.0	0.63	3.30
34.5	0.64	3.53
36.0	0.58	3.76
39.0	0.71	4.23
42.0	0.58	4.46
43.5	0.69	4.54
45.0	0.62	4.61
46.5	0.61	4.69
48.0	0.71	5.00
49.5	0.66	5.05
51.0	0.58	5.10
52.5	0.60	5.16
54.0	0.58	5.16
57.0	0.58	5.16
57.8	0.71	5.31
61.5	0.59	5.54
64.5	0.60	5.62
65.3	0.71	7.48
66.0	0.64	7.79
70.5	0.38	7.79
72.0	0.38	11.66
72.8	0.47	12.79
75.0	0.29	16.15
76.5	0.17	18.63
78.0	0.13	21.11

SM #4.09 1.0CM 0.42M 100/70E 19%S 15%R

TREE: 4 ROOT: 9

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.25
4.5	0.56
10.5	0.71

22.5	0.86
24.7	0.86
27.0	1.17
38.3	1.32
53.3	1.38
68.3	1.47
83.3	1.69
85.5	1.69
87.0	1.78
97.5	1.78
103.5	1.93
105.0	2.09
112.5	2.09
124.5	2.39
129.7	2.39
132.7	2.60
146.2	2.60
147.7	2.73
162.7	2.85
163.5	3.00
169.5	3.00
171.0	3.31
184.5	3.31
186.0	3.46
187.5	3.55
189.7	4.38
193.5	4.99
198.0	6.67
198.9	15.84

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.05	0.25
0.1	0.01	0.26
3.0	0.01	0.45
4.5	0.01	0.56
6.0	0.01	0.59
9.0	0.02	0.67
12.0	0.02	0.73
12.8	0.04	0.74
14.2	0.06	0.76
19.5	0.06	0.82
20.3	0.05	0.83
21.0	0.05	0.84
21.7	0.06	0.85
27.0	0.08	1.17
28.5	0.08	1.19
29.2	0.05	1.20
30.0	0.08	1.21
33.0	0.07	1.25
36.0	0.07	1.29
36.7	0.08	1.30
42.8	0.08	1.34
43.5	0.08	1.34
45.0	0.08	1.35
45.1	0.07	1.35
45.8	0.06	1.35
46.5	0.06	1.35
46.6	0.05	1.36
52.5	0.05	1.38
56.3	0.08	1.40
60.0	0.09	1.42
67.5	0.11	1.47
72.0	0.17	1.53
74.2	0.17	1.56
75.8	0.19	1.58
77.2	0.16	1.60
79.5	0.16	1.63
81.7	0.20	1.67
84.0	0.16	1.69
87.0	0.20	1.78
89.2	0.19	1.78
90.0	0.17	1.78
92.2	0.18	1.78
96.0	0.17	1.78
96.7	0.20	1.78
105.0	0.22	2.09
111.7	0.23	2.09
120.0	0.32	2.28
123.0	0.36	2.35
126.0	0.39	2.39
129.7	0.38	2.39
132.0	0.35	2.55
138.0	0.30	2.60
139.5	0.38	2.60
142.5	0.35	2.60
144.7	0.41	2.60
147.7	0.37	2.73
150.0	0.37	2.75
151.5	0.44	2.76
153.7	0.42	2.78
154.5	0.39	2.78
161.2	0.39	2.84
162.0	0.53	2.84
163.5	0.40	3.00
165.0	0.42	3.00
168.0	0.42	3.00
168.1	0.55	3.00
170.2	0.55	3.15
172.5	0.40	3.31
178.5	0.40	3.31
180.0	0.51	3.31
184.5	0.51	3.31
186.0	0.42	3.46
189.0	0.28	4.10
198.7	0.11	14.31

198.9	-0.05	15.84

SM #4.08 0.7CM 0.18M 65/15N 24%S 52%R

TREE: 4 ROOT: 8

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.25
5.3	1.38
12.8	2.09
25.5	2.09
30.0	2.24
32.2	2.54
37.5	3.00
48.8	3.31
56.3	3.61
63.8	3.61
67.5	4.53
69.7	4.53
72.8	4.84
89.2	5.75
133.5	8.81
135.7	9.42
144.7	9.88
145.5	9.97
149.2	9.97
151.5	10.64
154.5	24.40

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.05	0.25
0.8	0.00	0.41
18.0	0.08	2.09
26.3	0.08	2.11
28.5	0.09	2.19
30.0	0.06	2.24
33.8	0.08	2.67
36.7	0.10	2.94
38.3	0.06	3.02
39.0	0.11	3.04
42.8	0.06	3.14
45.0	0.06	3.21
47.2	0.11	3.27
48.8	0.09	3.31
49.5	0.11	3.34
61.5	0.18	3.61
62.2	0.12	3.61
65.3	0.13	3.98
66.0	0.16	4.16
80.3	0.28	5.25
81.7	0.27	5.34
86.3	0.28	5.59
91.5	0.30	5.91
94.5	0.25	6.12
100.5	0.26	6.53
102.8	0.35	6.69
108.0	0.35	7.05
108.8	0.38	7.10
109.5	0.34	7.15
113.2	0.38	7.41
116.2	0.42	7.62
117.0	0.36	7.67
123.7	0.37	8.14
124.5	0.44	8.19
126.0	0.41	8.29
127.5	0.44	8.40
129.0	0.39	8.50
131.2	0.39	8.65
133.5	0.50	8.81
137.2	0.54	9.50
141.0	0.49	9.69
144.0	0.38	9.84
144.1	0.40	9.85
150.0	0.50	10.20
154.5	-0.05	24.40

5SM #4.01 0.9CM 0.9M 90/5S 22%S 30%R

TREE: 4 ROOT: 1

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.56
0.1	0.86
1.5	1.17
9.0	1.17
10.5	2.09
24.0	2.39
49.5	2.39
51.7	2.85
76.5	3.00
87.8	3.46
105.0	3.61
178.5	3.61
181.5	3.92
207.0	3.92
213.0	4.01
217.5	4.01

221.2	4.22
225.7	4.22
232.5	4.53
235.5	4.53
237.7	4.84
241.5	4.84
244.5	6.06
253.5	6.36
274.5	6.36
279.0	6.67
279.1	8.81
279.7	8.81
280.6	13.40

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
11.3	0.03	2.10
1.5	0.07	1.17
3.8	0.07	1.17
4.5	0.09	1.17
5.3	0.10	1.17
6.7	0.05	1.17
7.5	0.10	1.17
9.0	0.23	1.17
14.2	0.42	2.17
16.5	0.71	2.22
24.7	0.71	2.39
31.5	0.71	2.39
42.0	0.66	2.39
49.5	0.93	2.39
51.0	0.93	2.70
51.1	0.73	2.73
76.5	0.73	3.00
76.6	0.66	3.01
87.8	0.66	3.46
88.5	0.47	3.47
105.0	0.53	3.61
126.7	0.55	3.61
126.9	0.34	3.61
130.5	0.43	3.61
142.5	0.46	3.61
168.0	0.53	3.61
169.5	0.73	3.61
180.0	1.03	3.77
187.5	1.03	3.92
188.2	1.13	3.92
190.5	1.16	3.92
208.5	0.99	3.94
217.5	1.26	4.01
222.7	1.13	4.22
228.0	1.29	4.33

237.0	1.16	4.73
238.5	1.29	4.84
241.5	1.26	4.84
256.5	1.26	6.36
258.7	1.23	6.36
263.2	1.23	6.36
267.7	1.33	6.36
274.5	1.29	6.36
276.0	1.39	6.47
280.5	1.46	12.63
280.6	0.06	13.40

SM #4.03 1.15CM 0.21M 80/5N 24%S 52%R

TREE: 4 ROOT: 3

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.05
215.8	-0.05

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.13	-0.05
3.8	0.13	-0.05
10.5	0.46	-0.05
13.5	0.43	-0.05
19.5	0.73	-0.05
25.5	0.56	-0.05
45.0	0.56	-0.05
45.1	0.46	-0.05
52.5	0.46	-0.05
52.6	0.69	-0.05
57.0	0.73	-0.05
63.0	0.93	-0.05
67.5	1.05	-0.05
75.0	1.03	-0.05
81.0	1.36	-0.05
87.0	1.26	-0.05
93.0	1.36	-0.05
94.5	1.27	-0.05
96.0	1.27	-0.05
99.0	1.33	-0.05
102.0	1.13	-0.05
108.0	0.99	-0.05
111.7	0.99	-0.05

112.5	1.13	-0.05
122.2	1.13	-0.05
127.5	0.99	-0.05
132.0	0.96	-0.05
138.7	1.23	-0.05
139.1	1.13	-0.05
145.5	1.13	-0.05
153.0	1.36	-0.05
156.0	1.23	-0.05
156.7	1.36	-0.05
160.5	1.43	-0.05
168.0	1.15	-0.05
171.0	1.19	-0.05
177.0	1.13	-0.05
183.0	1.03	-0.05
183.1	1.13	-0.05
192.0	1.13	-0.05
192.1	1.06	-0.05
199.5	1.06	-0.05
201.0	1.13	-0.05
201.1	1.03	-0.05
208.5	1.03	-0.05
215.2	1.36	-0.05
215.8	0.06	-0.05

SM #4.07 1.2CM 0.09M 70/15N 22%S 30%R

TREE: 4 ROOT: 7

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.05
36.0	2.54
42.8	3.31
51.0	4.53
65.3	5.14
69.0	6.98
72.0	7.28
87.0	15.69
93.0	15.84
93.8	24.40

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.06	-0.05
12.0	1.09	0.81
12.8	0.93	0.87
20.3	0.93	1.41
22.5	1.13	1.57
30.0	1.13	2.11
34.5	1.33	2.44
42.0	1.38	3.22
43.5	1.09	3.42
46.5	1.06	3.86
48.0	1.06	4.09
51.0	1.19	4.53
57.8	1.09	4.82
62.2	1.09	5.01
64.5	1.19	5.11
67.5	1.20	6.24
67.6	0.86	6.32
72.0	0.73	7.28
78.0	0.39	10.64
81.0	0.46	12.33
87.0	0.46	15.69
87.1	0.26	15.69
93.0	0.26	15.84
93.8	0.06	24.40

SM #4.10 2.8CM 0.1M 290/0 22%S 30%R

TREE: 4 ROOT: 10

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.05
163.5	-0.05
163.6	0.25
178.5	0.25
181.5	0.56
189.7	0.59
205.5	1.32
207.0	1.38
220.5	3.46
231.0	3.61
243.7	3.46
255.0	4.84
267.7	5.75
273.0	7.13
278.2	7.22
282.7	7.43
283.5	10.95
288.0	12.48
291.7	12.78
315.0	12.78

334.5	25.32
339.7	30.21

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.19	-0.05
6.0	0.77	-0.05
8.3	0.57	-0.05
12.0	0.57	-0.05
16.5	1.65	-0.05
19.5	1.15	-0.05
21.0	1.20	-0.05
26.3	1.23	-0.05
27.8	1.65	-0.05
31.5	2.83	-0.05
37.5	2.83	-0.05
39.7	1.83	-0.05
51.0	1.91	-0.05
66.7	1.94	-0.05
70.5	1.83	-0.05
77.2	1.86	-0.05
82.5	1.86	-0.05
82.6	2.83	-0.05
99.0	2.83	-0.05
111.0	3.04	-0.05
142.5	3.04	-0.05
144.0	3.57	-0.05
149.2	3.44	-0.05
150.0	3.71	-0.05
156.0	3.44	-0.05
160.5	3.44	-0.05
172.5	2.91	0.25
177.7	3.04	0.25
182.2	3.44	0.56
183.0	2.91	0.56
189.0	2.91	0.58
189.1	3.44	0.59
194.4	3.57	0.80
196.5	3.04	0.90
212.2	3.04	2.19
220.5	2.77	3.46
236.2	2.64	3.55
243.0	2.77	3.47
244.5	2.51	3.55
256.5	2.51	4.94
258.0	3.04	5.05
266.2	2.51	5.65
269.2	3.04	6.15
270.7	1.84	6.54
273.0	2.91	7.13
283.5	2.91	10.95
284.2	1.30	11.20
291.0	1.30	12.72
295.5	0.78	12.78
310.5	0.74	12.78
315.0	0.97	12.78
321.0	0.97	16.64
331.5	0.61	23.39
334.5	0.35	25.32
339.0	0.20	29.51
339.7	-0.19	30.21

SM #6.14 0.85CM 0.17M 310/0 21%S 58%R

TREE: 6 ROOT: 14

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	2.71
1.5	3.02
4.5	3.02
4.6	3.34
18.0	3.34
21.0	3.65
31.8	3.65
32.2	4.58
37.5	4.90
45.0	4.90
47.2	5.58
64.5	5.58
67.5	6.15
78.0	6.46
79.5	6.77
85.5	6.77
94.5	7.08
96.0	7.71
106.5	7.71
142.5	10.83
154.5	10.83
155.2	11.15
168.0	11.15
169.6	12.71

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.08	2.71
3.8	0.24	3.02

9.0	0.22	3.34
10.5	0.35	3.34
10.6	0.54	3.34
13.5	0.32	3.34
16.5	0.30	3.34
19.5	0.30	3.49
19.6	0.63	3.51
24.0	0.30	3.65
24.1	0.27	3.65
33.0	0.58	4.63
33.8	0.28	4.67
45.8	0.21	5.13
46.5	0.28	5.36
47.2	0.43	5.58
48.8	0.27	5.58
49.5	0.29	5.58
65.4	0.25	5.75
67.5	0.42	6.15
69.0	0.23	6.19
71.3	0.19	6.26
79.5	0.17	6.77
80.3	0.41	6.77
81.0	0.25	6.77
87.0	0.22	6.82
87.1	0.19	6.83
91.5	0.55	6.98
93.0	0.19	7.03
94.5	0.33	7.08
101.3	0.26	7.71
105.0	0.28	7.71
105.8	0.57	7.71
106.5	0.37	7.71
111.0	0.33	8.10
113.2	0.60	8.30
115.5	0.33	8.49
124.5	0.24	9.27
132.3	0.53	9.95
132.0	0.37	9.92
135.0	0.31	10.18
150.0	0.25	10.83
151.5	0.55	10.83
153.0	0.31	10.83
154.5	0.31	10.83
156.0	0.61	11.15
157.5	0.42	11.15
168.0	0.33	11.15
169.5	0.62	12.57
169.6	0.07	12.71

SM #6.15 0.63CM 0.37M 360/10N 21.4%S 44%R

TREE: 6 ROOT: 15

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	2.09
6.0	2.09
7.5	3.02
14.2	3.02
16.5	3.65
24.7	3.65
25.5	3.96
34.5	3.96
35.3	4.43
40.5	4.43
40.6	4.58
49.5	4.58
51.0	13.65

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.07	2.09
3.0	0.17	2.09
3.8	0.07	2.09
15.8	0.07	3.44
17.2	0.34	3.65
18.8	0.24	3.65
23.3	0.21	3.65
24.0	0.45	3.65
25.5	0.24	3.96
30.0	0.24	3.96
30.1	0.27	3.96
34.5	0.25	3.96
34.6	0.52	4.05
37.5	0.28	4.43
39.7	0.26	4.43
39.9	0.55	4.43
40.5	0.38	4.43
42.8	0.31	4.58
43.5	0.32	4.58
44.2	0.54	4.58
45.0	0.39	4.58
49.5	0.33	4.58
49.6	0.56	5.49
51.0	0.07	13.65

SM #6.17 2.4CM 0.19M 355/12N 21%S 58%R

TREE: 6 ROOT: 17

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.10
2.2	0.21
15.0	0.21
19.5	0.68
26.3	0.74
29.2	1.37
46.5	1.37
48.8	1.93
54.0	1.96
56.3	2.40
64.5	2.40
66.0	3.02
70.5	3.02
73.5	3.96
81.0	3.96
85.5	5.12
90.0	5.12
94.5	6.46
103.5	6.46
106.5	7.87
112.5	7.87
117.7	9.27
122.2	9.27
127.5	11.15
135.0	11.15
138.0	13.02
138.1	23.02

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.29	-0.10
1.5	1.01	0.11
2.2	0.73	0.21
13.5	0.69	0.21
17.2	2.10	0.44
19.5	1.19	0.68
25.5	1.19	0.73
27.8	1.95	1.05
30.0	1.66	1.37
37.5	1.56	1.37
42.0	1.56	1.37
43.5	1.66	1.37
45.8	2.56	1.37
48.0	1.66	1.74
55.5	1.66	2.25
56.3	2.35	2.40
58.5	2.02	2.40
64.5	1.92	2.40
66.0	3.11	3.02
67.5	2.28	3.02
72.0	2.24	3.49
72.8	3.14	3.73
75.0	2.24	3.96
79.5	2.22	3.96
84.0	3.39	4.73
85.5	2.20	5.12
90.0	2.24	5.12
91.5	2.82	5.56
93.0	2.60	6.01
93.8	2.69	6.24
94.5	2.28	6.46
102.0	2.28	6.46
103.5	3.25	6.46
105.8	2.28	7.51
112.5	2.28	7.87
114.7	2.82	8.47
117.0	2.15	9.07
120.7	2.17	9.27
121.5	2.46	9.27
124.5	2.24	10.08
126.7	2.13	10.88
132.0	2.17	11.15
135.0	2.38	11.15
138.0	2.13	13.02
138.1	0.29	23.02

SM #6.20 3.0CM 0.07M 278/11W 22%S 30%R

TREE: 6 ROOT: 20

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.10
45.0	-0.10
48.0	2.40
49.5	0.52
51.0	1.46
62.2	1.46
76.5	2.09
79.5	2.09
84.7	2.40
91.5	2.40
93.0	2.71

102.0	2.71
103.5	3.02
112.5	3.02
118.5	3.65
129.0	4.58
134.2	4.58
135.0	4.74
141.0	4.74
147.0	4.90
159.0	5.21
184.5	5.21
189.7	5.52
200.2	5.52
221.2	7.08
231.7	7.08
240.0	7.71
255.0	7.71
264.0	7.74
277.5	7.74
281.2	23.33
306.0	23.33
309.0	27.39
313.5	27.39
315.0	27.39
322.5	27.39
328.5	27.39
336.0	27.39
339.0	27.39
348.7	27.39
360.0	28.33
367.5	28.64
568.5	28.64
720.0	29.89
750.0	30.80
1320.0	30.80

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.29	-0.10
1.5	1.00	-0.10
3.0	0.69	-0.10
5.3	1.59	-0.10
6.7	0.98	-0.10
8.3	0.98	-0.10
9.7	1.52	-0.10
10.5	1.70	-0.10
12.8	1.18	-0.10
14.2	1.90	-0.10
16.5	1.41	-0.10
27.8	1.34	-0.10
28.5	2.35	-0.10
31.5	1.77	-0.10
33.0	1.66	-0.10
36.0	2.92	-0.10
38.3	1.56	-0.10
51.7	1.59	1.46
51.9	1.56	1.46
58.5	1.56	1.46
60.8	2.38	1.46
62.2	2.31	1.46
66.7	3.18	1.66
67.5	3.39	1.69
72.0	2.64	1.89
73.5	3.21	1.95
75.8	2.46	2.05
79.5	2.49	2.09
81.7	3.75	2.22
82.5	3.03	2.26
90.0	2.92	2.40
92.2	3.18	2.55
93.0	2.56	2.71
99.7	2.56	2.71
100.5	3.79	2.71
103.5	3.14	3.02
114.7	3.21	3.26
115.5	3.07	3.34
116.2	3.79	3.41
117.7	3.18	3.57
120.0	3.07	3.78
123.7	2.82	4.12
124.5	3.82	4.18
127.5	3.18	4.45
138.0	3.21	4.74
141.0	3.82	4.74
141.7	3.68	4.76
152.2	3.68	5.03
157.5	3.61	5.17
168.7	4.17	5.21
183.0	3.86	5.21
183.1	4.49	5.21
187.5	4.17	5.39
201.0	4.17	5.58
202.5	3.54	5.69
206.2	4.17	5.97
207.7	3.54	6.08
217.3	3.54	6.79
217.5	3.22	6.81
231.0	3.22	7.08
231.1	3.86	7.08
253.5	3.54	7.71
369.0	3.54	28.64
369.1	2.90	28.64
444.0	2.90	28.64
445.5	1.95	28.64
471.0	1.95	28.64

471.1	2.59	28.64
502.3	2.59	28.64
504.0	2.17	28.64
519.7	2.17	28.64
520.5	2.10	28.64
600.0	2.10	28.90
601.5	2.06	28.92
607.5	2.06	28.97
607.6	2.02	28.97
612.0	1.92	29.00
617.2	2.17	29.05
618.0	1.84	29.05
625.5	1.88	29.11
626.2	2.13	29.12
628.5	1.77	29.14
639.7	1.88	29.23
640.5	1.66	29.24
647.2	1.74	29.29
685.5	1.77	29.61
687.0	1.66	29.62
696.0	1.70	29.70
747.0	1.70	30.71
750.0	1.74	30.80
904.5	1.75	30.80
906.0	1.72	30.80
1266.0	1.72	30.80
1267.5	1.74	30.80
1287.0	1.74	30.80
1288.5	1.45	30.80
1296.0	1.52	30.80
1302.0	1.95	30.80
1303.5	1.34	30.80
1312.5	1.41	30.80
1316.2	2.06	30.80
1319.8	2.13	30.80
1320.0	0.29	30.80

ASH #7.24 0.55CM 0.38M 110/74N 21.4%S 63%R

TREE: 7 ROOT: 24

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.41
105.3	0.41
113.2	6.17

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.04	0.41
1.5	0.11	0.41
5.3	0.18	0.41
6.7	0.11	0.41
9.0	0.11	0.41
9.1	0.18	0.41
12.0	0.11	0.41
15.0	0.11	0.41
16.5	0.20	0.41
18.0	0.13	0.41
21.0	0.12	0.41
26.3	0.12	0.41
30.0	0.23	0.41
31.5	0.13	0.41
52.5	0.12	0.41
55.5	0.11	0.41
94.5	0.12	0.41
96.0	0.21	0.41
97.5	0.10	0.41
99.0	0.09	0.41
101.3	0.11	0.41
106.5	0.05	1.28
109.5	0.05	3.46
110.3	0.07	4.00
113.2	0.04	6.17

ASH #7.28 0.68CM 0.13M 120/18N 30%S 45%R

TREE: 7 ROOT: 28

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.41
18.0	0.41
21.0	10.01

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.02	0.41
1.5	0.01	0.41
3.0	-0.07	0.41
4.5	0.13	0.41
10.5	0.10	0.41

12.0	0.28	0.41
13.5	0.20	0.41
15.0	0.20	0.41
18.0	0.31	0.41
21.0	-0.02	10.01

ASH #7.29 0.65CM 0.15M 30%S 45%R

TREE: 7 ROOT: 29

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.03
21.3	0.03
22.5	8.47
22.8	13.08

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.01	0.03
6.0	0.08	0.03
6.7	0.06	0.03
9.0	0.06	0.03
11.3	0.26	0.03
12.0	0.18	0.03
14.2	0.17	0.03
18.0	0.47	0.03
18.8	0.39	0.03
21.7	0.38	3.20
22.8	0.00	13.08

ASH #7.26 3.18CM 0.12M 100/32W 30%S 45%R

TREE: 7 ROOT: 26

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	5.79
4.5	5.86
5.3	7.32
9.0	7.71
56.3	7.71
63.0	9.24
71.3	9.24
79.5	10.39
88.5	10.39
91.5	11.16
94.5	11.55
177.0	13.08
187.5	14.23
546.0	14.23
567.7	14.62
957.0	14.62
957.7	15.00
1878.4	15.00
2099.8	15.38
2290.5	15.38
2292.0	15.77
2637.0	15.77
2637.1	25.36

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.36	5.79
3.8	-0.32	5.85
34.5	-0.28	7.71
34.6	0.09	7.71
55.5	0.09	7.71
60.0	0.25	8.56
63.0	0.21	9.24
64.5	0.30	9.24
66.7	0.13	9.24
69.0	0.23	9.24
73.5	0.34	9.56
75.0	0.38	9.77
79.5	0.25	10.39
87.0	0.25	10.39
96.0	1.03	11.57
97.5	0.58	11.60
105.0	0.58	11.74
106.5	1.11	11.77
108.0	0.99	11.80
111.0	1.23	11.85
112.5	1.15	11.88
123.0	2.70	12.08
135.0	2.32	12.30
139.5	3.11	12.38
142.5	2.94	12.44
147.7	3.90	12.54
150.0	3.68	12.58
153.0	4.25	12.63
154.5	3.72	12.66

163.5	3.72	12.83
169.5	4.69	12.94
174.0	4.34	13.02
181.5	5.21	13.57
189.0	4.60	14.23
192.0	4.07	14.23
198.0	5.39	14.23
202.5	4.60	14.23
255.0	4.42	14.23
258.7	5.65	14.23
259.5	5.21	14.23
265.5	5.17	14.23
270.0	5.74	14.23
273.0	5.74	14.23
274.5	5.04	14.23
280.5	5.13	14.23
281.2	5.48	14.23
286.5	5.48	14.23
286.6	5.04	14.23
292.5	5.04	14.23
303.0	6.44	14.23
306.7	6.00	14.23
307.5	5.62	14.23
337.5	5.26	14.23
349.5	5.09	14.23
352.5	5.97	14.23
355.5	5.97	14.23
357.0	5.62	14.23
420.0	5.44	14.23
520.5	5.44	14.23
571.5	5.80	14.62
1965.1	5.97	15.15
2119.5	6.06	15.38
2253.0	6.06	15.38
2254.5	6.15	15.38
2637.0	6.15	15.77
2637.1	4.38	25.36

ASH #7.27 2.02CM 0.1M 90/0 33%S 43%R

TREE: 7 ROOT: 27

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.61
70.5	0.61
70.6	20.76

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.42	0.61
4.5	0.46	0.61
5.3	0.42	0.61
6.0	0.50	0.61
9.7	0.54	0.61
12.0	0.70	0.61
13.2	0.52	0.61
16.5	0.99	0.61
18.8	0.82	0.61
21.0	1.27	0.61
24.0	1.07	0.61
30.0	2.74	0.61
40.5	1.07	0.61
42.8	3.64	0.61
45.0	3.46	0.61
46.5	3.29	0.61
49.5	2.94	0.61
56.3	3.20	0.61
60.0	4.16	0.61
61.5	3.55	0.61
65.3	3.55	0.61
67.5	3.99	0.61
70.5	4.34	0.61
70.6	3.11	20.76

SM #5.01 0.58CM 0.15M 310/5N 20.5%S 43%R

TREE: 5 ROOT: 1

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.91
1.8	1.28
6.7	1.59
7.3	2.52
7.5	11.81

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-3.29	0.91
6.0	39.18	1.55
7.3	71.54	2.52

7.5	-3.29	11.81

SM #5.02 0.22CM 0.165M 350/2N 20.5%S 43%R

TREE: 5 ROOT: 2

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.66
9.7	1.90
18.8	2.21
24.0	2.21
26.7	2.52
37.5	2.52
37.6	2.83

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-4.30	0.66
1.5	-1.27	0.86
6.7	0.75	1.52
7.5	6.82	1.62
9.0	4.80	1.81
9.7	9.85	1.90
22.5	16.93	2.21
22.6	7.83	2.21
24.0	0.75	2.21
24.7	14.91	2.30
25.5	20.98	2.39
26.3	16.93	2.47
28.5	16.93	2.52
30.0	20.98	2.52
32.2	16.93	2.52
33.0	14.91	2.52
37.5	14.91	2.52
37.6	-3.29	2.83

SM #5.03 0.31CM 0.28M 310/22N 22%S 42%R

TREE: 5 ROOT: 3

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.05
4.5	0.05
25.5	1.59
26.3	1.90
34.5	2.21
36.0	2.37
51.7	3.20
55.5	3.30
60.0	3.76
61.5	3.92
67.5	5.62
67.6	9.34

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-2.28	0.05
4.5	11.88	0.05
5.3	21.99	0.10
6.0	21.99	0.16
7.5	25.02	0.27
17.2	26.03	0.99
18.8	29.07	1.10
19.5	25.02	1.15
23.3	27.04	1.43
26.3	27.04	1.90
27.0	24.01	1.93
30.0	25.02	2.04
34.6	14.91	2.23
36.0	23.00	2.37
37.5	25.02	2.45
40.5	27.04	2.61
42.0	25.02	2.69
48.0	27.04	3.01
63.0	11.88	4.34
65.7	26.03	5.11
67.5	23.00	5.62
67.6	-5.31	9.34

SM #5.05 0.68CM 0.32M 135/25S 22%S 42%R

TREE: 5 ROOT: 5

TIME (SECONDS)	DISPLACEMENT (CM)

0.0	-0.57
6.0	-0.57
6.7	-0.26
27.0	-0.26
30.8	0.05
37.5	0.05
42.0	0.14
44.2	1.59
50.3	1.90
57.0	3.14
67.5	5.31
72.0	5.37
79.5	5.93
79.6	11.81

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-5.31	-0.57
1.5	10.87	-0.57
3.8	9.85	-0.57
5.3	21.99	-0.57
6.0	10.87	-0.57
13.5	10.87	-0.26
15.0	8.84	-0.26
24.3	8.84	-0.26
27.8	29.07	-0.20
30.0	35.13	-0.02
34.2	33.11	0.05
35.3	25.02	0.05
40.2	39.18	0.10
40.5	35.13	0.11
41.3	35.13	0.12
42.0	39.18	0.14
45.0	33.11	1.63
49.5	39.18	1.86
50.3	37.16	1.90
54.0	63.45	2.59
55.5	67.49	2.87
57.0	27.04	3.14
63.0	37.16	4.38
70.5	78.62	5.35
75.0	85.69	5.60
79.5	90.75	5.93
79.6	-5.31	11.81

SM #5.06 0.38CM 0.44M 175/5N 21.3%S 30%R

TREE: 5 ROOT: 6

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.57
7.5	-0.57
11.3	0.05
22.5	1.28
23.1	1.59
29.2	1.59
30.8	1.66
34.6	1.66
37.6	1.90
38.3	8.72

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-4.30	-0.57
6.0	16.93	-0.57
7.5	20.98	-0.57
9.3	18.96	-0.28
9.7	20.98	-0.20
15.8	21.99	0.54
16.5	20.98	0.62
21.7	20.57	1.20
22.5	16.93	1.28
24.0	16.93	1.59
24.7	14.91	1.59
34.5	13.29	1.66
36.0	19.97	1.77
37.5	23.00	1.89
38.3	-4.30	8.72

SM #5.07 0.27CM 0.51M 140/20N 20.3%S 32%R

TREE: 5 ROOT: 7

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.57
7.5	-0.57
7.6	-0.42
9.3	-0.11
10.5	0.35
13.5	0.66

16.5	0.97
21.0	1.28
21.1	5.62

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-4.30	-0.57
2.2	-1.27	-0.57
4.5	0.75	-0.57
10.5	4.60	0.35
11.7	4.60	0.48
12.0	0.75	0.51
12.8	0.75	0.59
14.2	2.78	0.74
21.0	2.78	1.28
21.1	-5.31	5.62

SM #10.16 0.8CM 0.3M 350/20N 22.4%S 99%R

TREE: 10 ROOT: 16

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.19
4.5	0.20
4.8	0.59
9.0	1.37
12.0	1.57
12.8	11.11

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.06	-0.19
0.8	0.09	-0.12
9.0	0.33	1.37
9.7	0.37	1.42
12.8	0.04	11.11

SM #10.15 0.52CM 0.25M 20/15N 21%S 60%R

TREE: 10 ROOT: 15

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.19
9.0	-0.19
9.3	0.20
10.5	0.47
13.3	0.67
13.5	5.65

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.08	-0.19
1.5	0.09	-0.19
2.7	0.08	-0.19
6.7	0.14	-0.19
8.3	0.14	-0.19
11.3	0.19	0.53
12.8	0.20	0.63
13.0	0.24	0.65
13.5	0.05	5.65

ASH #10.21 SHEARED 0.5CM 0.4M 350/13N 20.3%S 99%R

TREE: 10 ROOT: 21

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.58
7.5	-0.58
8.3	0.59
9.0	0.59
10.8	1.76
18.8	3.12
19.5	22.40

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.06	-0.58
0.8	0.08	-0.58

1.8	0.07	-0.58
6.0	0.07	-0.58
7.5	0.09	-0.58
9.0	0.09	0.59
11.3	0.13	1.84
11.5	0.14	1.89
14.2	0.17	2.35
18.8	0.17	3.12
19.5	0.05	22.40

ASH #10.19 1.05CM 0.017M 90/23E 22%S 50%R

TREE: 10 ROOT: 19

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.19
33.0	-0.19
37.5	1.95
39.0	2.15
39.1	2.73
40.2	2.93
40.9	11.88

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.07	-0.19
3.0	0.18	-0.19
3.8	0.18	-0.19
6.0	0.43	-0.19
7.5	0.32	-0.19
10.5	0.32	-0.19
11.3	0.82	-0.19
12.8	0.85	-0.19
19.5	0.78	-0.19
20.3	0.78	-0.19
34.5	1.02	0.53
35.3	1.00	0.88
40.5	0.22	6.51
40.9	0.15	11.88

ASH #10.17 3.2CM 0.4M 22.4%S 99%R

TREE: 10 ROOT: 17

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.38
24.0	-0.19
34.5	-0.19
37.5	0.20
45.0	0.20
55.5	0.59
63.0	0.59
82.5	1.76
97.5	2.15
112.5	2.15
129.0	2.93
132.0	3.32
135.0	3.32
135.1	3.51
140.2	3.71
147.0	3.71
154.5	4.49
156.0	4.49
157.5	6.82
163.5	7.99
166.5	7.99
172.5	7.99
219.0	18.12
220.5	18.12
238.5	24.35
241.5	26.29
250.5	26.29
256.5	30.19
259.5	34.04

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.21	-0.38
3.0	0.34	-0.36
12.0	0.34	-0.28
13.5	0.27	-0.27
18.0	0.46	-0.24
18.8	0.42	-0.23
22.5	0.58	-0.20
24.0	0.83	-0.19
25.5	0.38	-0.19
27.3	0.38	-0.19
30.0	0.42	-0.19
33.0	0.42	-0.19
37.5	1.41	0.20

39.0	0.79	0.20
40.5	0.79	0.20
42.0	0.71	0.20
43.5	0.71	0.20
45.0	1.37	0.20
49.5	1.65	0.37
51.0	1.61	0.42
51.7	0.79	0.45
60.0	0.79	0.59
60.1	1.53	0.59
61.5	1.53	0.59
63.0	2.31	0.59
66.0	2.23	0.77
67.5	2.31	0.86
72.0	3.26	1.13
75.0	3.09	1.31
75.1	2.72	1.32
76.5	2.72	1.40
78.0	3.01	1.49
88.5	3.26	1.92
111.0	2.93	2.15
115.5	2.93	2.29
117.0	3.43	2.36
120.0	4.09	2.50
120.1	4.17	2.51
127.5	3.26	2.86
140.2	2.43	3.71
142.5	2.43	3.71
142.6	2.76	3.71
150.0	3.67	4.02
175.5	2.11	8.64
180.0	1.57	9.62
187.5	1.69	11.26
195.0	1.49	12.89
196.5	1.69	13.22
205.5	1.37	15.18
210.0	1.20	16.16
214.5	1.20	17.14
216.0	1.28	17.46
219.0	0.95	18.12
222.0	0.87	18.63
225.0	0.99	19.67
229.5	0.91	21.23
234.0	1.04	22.79
237.0	0.62	23.83
240.0	0.67	25.32
243.0	0.30	26.29
250.5	0.30	26.29
251.2	0.62	26.78
255.0	0.42	29.21
258.0	0.50	32.11
262.5	0.30	37.90

ASH #10.11 1.9CM 0.12M 340/15N 22%S 50%R

TREE: 10 ROOT: 11

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.58
1.5	-0.58
3.8	0.01
10.5	0.20
18.0	0.20
22.5	0.59
26.3	0.59
39.0	1.37
48.0	1.37
49.5	1.37
52.5	1.57
66.0	3.71
66.7	9.35
67.5	10.72

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.21	-0.58
1.5	0.30	-0.58
1.6	0.30	-0.54
20.3	0.38	0.40
24.0	0.38	0.59
36.7	1.20	1.23
37.5	0.38	1.28
37.6	0.52	1.29
39.0	0.50	1.37
39.7	0.42	1.37
43.5	0.46	1.37
45.0	0.46	1.37
45.1	1.04	1.37
51.0	1.49	1.47
52.5	1.37	1.57
59.2	1.94	2.64
61.5	1.57	2.99
64.5	1.57	3.47
66.0	1.78	3.71
67.5	0.30	10.72

ASH #10.13 1.62CM 0.09M 30/3S 22%S 50%R

TREE: 10 ROOT: 13

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-4.86
19.6	-4.86

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.17	-4.86
1.5	0.25	-4.86
4.5	0.27	-4.86
7.5	0.25	-4.86
7.6	0.30	-4.86
10.5	0.38	-4.86
15.0	0.38	-4.86
19.5	0.42	-4.86
19.6	0.13	-4.86

ASH #11.13 2.6CM 0.05M 170/10S 25.2%S 84%R

TREE: 11 ROOT: 13

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	1.01
27.8	1.01
31.5	2.14
60.8	2.14
66.0	2.90
69.0	2.90
72.0	3.28
75.8	3.47
103.5	3.28
105.0	3.66
115.5	4.03
117.0	4.60
121.5	4.79
123.0	4.79
126.0	5.55
127.5	5.55
128.2	5.93
132.0	6.11
132.7	9.71
147.0	9.71
151.5	13.11
154.5	13.11
159.0	27.48

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.36	1.01
13.5	3.40	1.01
26.3	3.40	1.01
30.0	3.91	1.69
30.1	3.63	1.74
57.0	3.63	2.14
58.5	3.87	2.14
60.8	4.05	2.14
63.0	3.98	2.47
64.2	3.72	2.64
66.0	3.72	2.90
67.5	4.01	2.90
69.0	3.82	2.90
72.0	3.82	3.28
72.8	4.01	3.32
72.9	3.63	3.32
100.5	3.63	3.30
100.8	4.48	3.30
102.8	3.72	3.28
106.5	3.72	3.71
106.6	4.05	3.72
110.3	4.24	3.85
112.5	3.72	3.93
118.5	4.19	4.66
120.0	3.91	4.73
124.5	3.91	5.17
130.5	3.87	6.04
132.0	3.30	6.11
146.2	3.30	9.71
147.0	3.44	9.71
150.7	3.44	12.54
151.5	3.40	13.11
156.7	3.40	20.29
159.0	3.25	27.48

ASH #11.05 2.8CM 0.18M 170/11N 27.6%S 68.2%R

TREE: 11 ROOT: 5

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.44
7.5	0.44
18.8	1.77
33.0	2.71
45.0	2.90
51.0	3.66
64.5	3.66
78.0	4.41
82.5	4.41
82.6	4.60
97.5	5.55
102.0	6.30
234.0	6.30
270.0	15.76
285.0	18.78
288.0	18.78
288.1	19.16
292.5	19.16
306.0	22.18
309.0	22.56
315.0	24.45
361.5	24.45
362.2	33.11
393.0	33.11

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.80	0.44
15.0	1.11	1.32
17.2	1.59	1.59
22.5	2.23	2.01
25.5	2.41	2.21
37.5	2.41	2.78
42.0	2.13	2.85
46.5	2.88	3.09
51.7	2.79	3.66
52.5	2.46	3.66
60.0	2.32	3.66
63.0	2.93	3.66
69.0	3.98	3.91
72.0	4.05	4.08
75.0	3.87	4.24
76.5	3.58	4.33
79.5	3.44	4.41
81.0	4.43	4.41
86.3	5.18	4.83
91.5	4.81	5.17
94.5	4.29	5.36
96.0	4.97	5.45
97.5	4.08	5.55
99.0	5.32	5.80
117.7	5.32	6.30
123.7	4.76	6.30
135.0	4.62	6.30
135.1	5.32	6.30
154.5	5.32	6.30
166.5	5.13	6.30
210.0	1.88	6.30
210.1	2.39	6.30
228.0	2.39	6.30
228.0	2.39	6.30
229.5	2.28	6.30
231.0	1.29	6.30
237.7	1.29	7.29
237.9	1.27	7.33
259.5	1.27	13.00
259.6	2.28	13.04
288.0	1.83	18.78
292.5	1.99	19.16
300.0	1.96	20.84
304.5	1.67	21.85
309.0	1.61	22.56
315.0	1.64	24.45
319.5	1.08	24.45
321.7	1.19	24.45
327.7	1.19	24.45
330.0	1.11	24.45
337.5	1.35	24.45
340.5	2.18	24.45
343.5	1.24	24.45
346.5	1.27	24.45
349.5	1.05	24.45
363.0	1.05	33.11
363.0	1.16	33.11
366.0	1.19	33.11
367.5	0.97	33.11
378.7	0.95	33.11
380.2	1.19	33.11
382.5	0.95	33.11
385.5	1.08	33.11
387.0	0.87	33.11
393.0	0.81	33.11

SM #10.16 0.8CM 0.3M 350/20N 22.4%S 99%R

TREE: 10 ROOT: 16

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.19
4.5	0.20
4.8	0.59
9.0	1.37
12.0	1.57
12.8	11.11

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.06	-0.19
0.8	0.09	-0.12
9.0	0.33	1.37
9.7	0.37	1.42
12.8	0.04	11.11

SM #10.15 0.52CM 0.25M 20/15N 21%S 60%R

TREE: 10 ROOT: 15

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.19
9.0	-0.19
9.3	0.20
10.5	0.47
13.3	0.67
13.5	5.65

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.08	-0.19
1.5	0.09	-0.19
2.7	0.08	-0.19
6.7	0.14	-0.19
8.3	0.14	-0.19
11.3	0.19	0.53
12.8	0.20	0.63
13.0	0.24	0.65
13.5	0.05	5.65

ASH #10.21 SHEARED 0.5CM 0.4M 350/13N 20.3%S 99%R

TREE: 10 ROOT: 21

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.58
7.5	-0.58
8.3	0.59
9.0	0.59
10.8	1.76
18.8	3.12
19.5	22.40

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.06	-0.58
0.8	0.08	-0.58
1.8	0.07	-0.58
6.0	0.07	-0.58
7.5	0.09	-0.58
9.0	0.09	0.59
11.3	0.13	1.84
11.5	0.14	1.89
14.2	0.17	2.35
18.8	0.17	3.12
19.5	0.05	22.40

ASH #10.19 1.05CM 0.017M 90/23E 22%S 50%R

TREE: 10 ROOT: 19

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.19
33.0	-0.19
37.5	1.95
39.0	2.15
39.1	2.73
40.2	2.93
40.9	11.88

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.07	-0.19
3.0	0.18	-0.19
3.8	0.18	-0.19
6.0	0.43	-0.19
7.5	0.32	-0.19
10.5	0.32	-0.19
11.3	0.82	-0.19
12.8	0.85	-0.19
19.5	0.78	-0.19
20.3	0.78	-0.19
34.5	1.02	0.53
35.3	1.00	0.88
40.5	0.22	6.51
40.9	0.15	11.88

ASH #10.17 3.2CM 0.4M 22.4%S 99%R

TREE: 10 ROOT: 17

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.38
24.0	-0.19
34.5	-0.19
37.5	0.20
45.0	0.20
55.5	0.59
63.0	0.59
82.5	1.76
97.5	2.15
112.5	2.15
129.0	2.93
132.0	3.32
135.0	3.32
135.1	3.51
140.2	3.71
147.0	3.71
154.5	4.49
156.0	4.49
157.5	6.82
163.5	7.99
166.5	7.99
172.5	7.99
219.0	18.12
220.5	18.12
238.5	24.35
241.5	26.29
250.5	26.29
256.5	30.19
259.5	34.04

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.21	-0.38
3.0	0.34	-0.36
12.0	0.34	-0.28
13.5	0.27	-0.27
18.0	0.46	-0.24
18.8	0.42	-0.23
22.5	0.58	-0.20
24.0	0.83	-0.19
25.5	0.38	-0.19
27.3	0.38	-0.19
30.0	0.42	-0.19
33.0	0.42	-0.19
37.5	1.41	0.20
39.0	0.79	0.20
40.5	0.79	0.20
42.0	0.71	0.20
43.5	0.71	0.20
45.0	1.37	0.20
49.5	1.65	0.37
51.0	1.61	0.42
51.7	0.79	0.45
60.0	0.79	0.59
60.1	1.53	0.59
61.5	1.53	0.59
63.0	2.31	0.59
66.0	2.23	0.77
67.5	2.31	0.86
72.0	3.26	1.13
75.0	3.09	1.31
75.1	2.72	1.32
76.5	2.72	1.40
78.0	3.01	1.49
88.5	3.26	1.92
111.0	2.93	2.15
115.5	2.93	2.29
117.0	3.43	2.36
120.0	4.09	2.50
120.1	4.17	2.51
127.5	3.26	2.86
140.2	2.43	3.71
142.5	2.43	3.71

142.6	2.76	3.71
150.0	3.67	4.02
175.5	2.11	8.64
180.0	1.57	9.62
187.5	1.69	11.26
195.0	1.49	12.89
196.5	1.69	13.22
205.5	1.37	15.18
210.0	1.20	16.16
214.5	1.20	17.14
216.0	1.28	17.46
219.0	0.95	18.12
222.0	0.87	18.63
225.0	0.99	19.67
229.5	0.91	21.23
234.0	1.04	22.79
237.0	0.62	23.83
240.0	0.67	25.32
243.0	0.30	26.29
250.5	0.30	26.29
251.2	0.62	26.78
255.0	0.42	29.21
258.0	0.50	32.11
262.5	0.30	37.90

ASH #10.11 1.9CM 0.12M 340/15N 22%S 50%R

TREE: 10 ROOT: 11

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.58
1.5	-0.58
3.8	0.01
10.5	0.20
18.0	0.20
22.5	0.59
26.3	0.59
39.0	1.37
48.0	1.37
49.5	1.37
52.5	1.57
66.0	3.71
66.7	9.35
67.5	10.72

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.21	-0.58
1.5	0.30	-0.58
1.6	0.30	-0.54
20.3	0.38	0.40
24.0	0.38	0.59
36.7	1.20	1.23
37.5	0.38	1.28
37.6	0.52	1.29
39.0	0.50	1.37
39.7	0.42	1.37
43.5	0.46	1.37
45.0	0.46	1.37
45.1	1.04	1.37
51.0	1.49	1.47
52.5	1.37	1.57
59.2	1.94	2.64
61.5	1.57	2.99
64.5	1.57	3.47
66.0	1.78	3.71
67.5	0.30	10.72

ASH #10.13 1.62CM 0.09M 30/3S 22%S 50%R

TREE: 10 ROOT: 13

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-4.86
19.6	-4.86

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.17	-4.86
1.5	0.25	-4.86
4.5	0.27	-4.86
7.5	0.25	-4.86
7.6	0.30	-4.86
10.5	0.38	-4.86
15.0	0.38	-4.86
19.5	0.42	-4.86
19.6	0.13	-4.86

ASH #11.13 2.6CM 0.05M 170/10S 25.2%S 84%R

TREE: 11 ROOT: 13

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	1.01
27.8	1.01
31.5	2.14
60.8	2.14
66.0	2.90
69.0	2.90
72.0	3.28
75.8	3.47
103.5	3.28
105.0	3.66
115.5	4.03
117.0	4.60
121.5	4.79
123.0	4.79
126.0	5.55
127.5	5.55
128.2	5.93
132.0	6.11
132.7	9.71
147.0	9.71
151.5	13.11
154.5	13.11
159.0	27.48

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.36	1.01
13.5	3.40	1.01
26.3	3.40	1.01
30.0	3.91	1.69
30.1	3.63	1.74
57.0	3.63	2.14
58.5	3.87	2.14
60.8	4.05	2.14
63.0	3.98	2.47
64.2	3.72	2.64
66.0	3.72	2.90
67.5	4.01	2.90
69.0	3.82	2.90
72.0	3.82	3.28
72.8	4.01	3.32
72.9	3.63	3.32
100.5	3.63	3.30
100.8	4.48	3.30
102.8	3.72	3.28
106.5	3.72	3.71
106.6	4.05	3.72
110.3	4.24	3.85
112.5	3.72	3.93
118.5	4.19	4.66
120.0	3.91	4.73
124.5	3.91	5.17
130.5	3.87	6.04
132.0	3.30	6.11
146.2	3.30	9.71
147.0	3.44	9.71
150.7	3.44	12.54
151.5	3.40	13.11
156.7	3.40	20.29
159.0	3.25	27.48

ASH #11.05 2.8CM 0.18M 170/11N 27.6%S 68.2%R

TREE: 11 ROOT: 5

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.44
7.5	0.44
18.8	1.77
33.0	2.71
45.0	2.90
51.0	3.66
64.5	3.66
78.0	4.41
82.5	4.41
82.6	4.60
97.5	5.55
102.0	6.30
234.0	6.30
270.0	15.76
285.0	18.78
288.0	18.78
288.1	19.16
292.5	19.16
306.0	22.18
309.0	22.56
315.0	24.45
361.5	24.45
362.2	33.11
393.0	33.11

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.80	0.44
15.0	1.11	1.32
17.2	1.59	1.59
22.5	2.23	2.01
25.5	2.41	2.21
37.5	2.41	2.78
42.0	2.13	2.85
46.5	2.88	3.09
51.7	2.79	3.66
52.5	2.46	3.66
60.0	2.32	3.66
63.0	2.93	3.66
69.0	3.98	3.91
72.0	4.05	4.08
75.0	3.87	4.24
76.5	3.58	4.33
79.5	3.44	4.41
81.0	4.43	4.41
86.3	5.18	4.83
91.5	4.81	5.17
94.5	4.29	5.36
96.0	4.97	5.45
97.5	4.08	5.55
99.0	5.32	5.80
117.7	5.32	6.30
123.7	4.76	6.30
135.0	4.62	6.30
135.1	5.32	6.30
154.5	5.32	6.30
166.5	5.13	6.30
210.0	1.88	6.30
210.1	2.39	6.30
228.0	2.39	6.30
228.0	2.39	6.30
229.5	2.28	6.30
231.0	1.29	6.30
237.7	1.29	7.29
237.9	1.27	7.33
259.5	1.27	13.00
259.6	2.28	13.04
288.0	1.83	18.78
292.5	1.99	19.16
300.0	1.96	20.84
304.5	1.67	21.85
309.0	1.61	22.56
315.0	1.64	24.45
319.5	1.08	24.45
321.7	1.19	24.45
327.7	1.19	24.45
330.0	1.11	24.45
337.5	1.35	24.45
340.5	2.18	24.45
343.5	1.24	24.45
346.5	1.27	24.45
349.5	1.05	24.45
363.0	1.05	33.11
363.0	1.16	33.11
366.0	1.19	33.11
367.5	0.97	33.11
378.7	0.95	33.11
380.2	1.19	33.11
382.5	0.95	33.11
385.5	1.08	33.11
387.0	0.87	33.11
393.0	0.81	33.11

ASH #10.03 0.85CM 0.1M 190/10S 22.9%S 45.3%R

TREE: 10 ROOT: 3

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.44
22.5	0.44
27.0	0.99
28.5	0.99
33.0	1.35
36.0	1.35
36.1	1.54
37.5	1.64
37.6	1.90
39.0	1.94
39.7	2.08
40.5	2.08
42.0	2.45
44.2	2.45
44.8	2.81
45.1	2.81
47.2	3.91
49.5	3.91
50.7	4.28
52.5	4.28
52.6	5.37
54.0	5.37
54.1	6.10
55.5	6.10
56.3	6.84

56.7	6.84
60.0	18.17
63.0	30.23
64.5	30.23
65.3	30.41
75.0	30.41
79.5	32.75

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.05	0.44
9.0	0.06	0.44
19.5	0.06	0.44
19.6	0.07	0.44
20.3	0.07	0.44
24.1	0.09	0.64
27.0	0.12	0.99
27.3	0.08	0.99
27.4	0.12	0.99
30.0	0.19	1.11
30.8	0.13	1.17
30.9	0.29	1.18
31.5	0.19	1.23
33.0	0.39	1.35
34.5	0.39	1.35
35.7	0.51	1.35
37.5	0.36	1.64
37.6	0.63	1.90
38.3	0.47	1.92
40.5	0.67	2.08
42.0	0.55	2.45
42.8	0.70	2.45
44.2	0.62	2.45
45.0	0.72	2.81
46.5	0.64	3.52
48.0	0.64	3.91
49.5	0.73	3.91
51.7	0.54	4.28
52.5	0.63	4.28
54.0	0.40	5.37
54.7	0.48	6.10
55.5	0.40	6.10
57.0	0.43	7.87
58.5	0.45	13.02
60.0	0.12	18.17
63.0	0.09	30.23
63.8	0.07	30.23
64.1	0.06	30.23
64.5	0.07	30.23
66.0	0.06	30.41
78.0	0.06	31.97
79.5	0.05	32.75

ASH #10.04 1.7CM 0.04M 230/0 22.9%S 45.3%R

TREE: 10 ROOT: 4

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.44
18.0	0.44
31.5	0.99
48.0	1.17
61.5	1.35
66.0	1.72
75.0	2.45
88.5	3.18
108.0	3.91
136.5	5.19
138.0	7.93
153.0	7.93
162.0	11.22
163.5	29.14
166.5	29.14
176.8	29.14
177.0	32.75

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.05	0.44
1.5	0.05	0.44
7.5	0.09	0.44
10.5	0.06	0.44
15.0	0.22	0.44
18.0	0.43	0.44
18.1	0.11	0.44
21.0	0.61	0.56
21.1	0.31	0.57
30.0	0.80	0.93
30.1	0.67	0.93
57.0	1.24	1.29
57.1	0.77	1.29
61.5	1.35	1.35
61.6	1.02	1.36
67.5	1.47	1.84
67.6	1.22	1.85
70.5	1.71	2.08

70.6	1.40	2.10
91.5	1.92	3.29
91.6	1.61	3.30
100.5	1.94	3.63
100.6	1.57	3.64
106.5	2.08	3.85
106.6	1.71	3.86
121.5	2.13	4.52
121.6	1.82	4.52
130.5	2.14	4.92
130.6	1.81	4.93
135.0	1.91	5.12
150.0	0.43	7.93
154.5	0.70	8.48
159.0	0.63	10.13
166.5	0.39	29.14
177.0	0.39	32.75

SM #10.07 0.8CM 0.15M 180/2N 17.4%S 55.7%R BROKE AT CLAMP

TREE: 10 ROOT: 7

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.26
22.5	0.26
30.0	1.72
39.0	3.00
50.3	3.18
52.5	27.67

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.05	0.26
1.5	0.07	0.26
15.0	0.07	0.26
22.5	0.08	0.26
24.0	0.09	0.55
30.0	0.13	1.72
33.8	0.47	2.25
39.0	0.60	3.00
39.1	0.37	3.00
45.8	0.63	3.11
45.9	0.44	3.11
50.3	0.66	3.18
50.4	0.51	4.81
52.5	0.05	27.67

ASH #10.01 4CM 0.07M 220/0 22.9%S 45.3%R

TREE: 10 ROOT: 1

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.26
22.5	0.26
39.0	1.35
54.0	2.45
82.5	5.01
99.0	6.10
114.0	7.57
121.5	9.03
121.6	11.22
126.0	11.22
133.5	16.71
142.5	16.71
151.3	20.73
151.5	29.50

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.17	0.26
11.3	0.17	0.26
15.0	0.31	0.26
22.5	0.39	0.26
28.5	1.04	0.65
30.0	1.09	0.75
37.5	1.37	1.25
45.0	1.34	1.79
51.0	1.72	2.23
53.3	1.42	2.39
58.5	2.12	2.85
63.0	1.81	3.26
69.0	2.70	3.80
84.0	2.06	5.11
90.0	1.87	5.51
94.5	3.23	5.81
97.5	2.34	6.00
103.5	2.95	6.54
108.0	1.96	6.98
114.0	3.37	7.57

117.0	2.29	8.15
120.0	3.51	8.74
121.5	0.42	9.03
135.0	0.42	16.71
138.0	2.71	16.71
142.5	5.15	16.71
145.5	4.58	18.07
148.5	5.61	19.43
150.0	6.18	20.11
151.5	1.45	29.50

ASH #10.06 1.1CM 0.18M 255/45S 17.4%S 55.7%R

TREE: 10 ROOT: 6

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.26
7.5	0.26
9.0	2.08
15.0	4.64
24.0	16.71
37.5	18.53
43.5	26.94
46.5	32.75
154.5	32.75

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.05	0.26
6.0	0.21	0.26
9.0	0.24	2.08
12.0	0.12	3.36
16.5	0.22	6.65
24.0	0.12	16.71
28.5	0.09	17.32
33.0	0.08	17.92
75.0	0.08	32.75
142.5	0.08	32.75
150.0	0.05	32.75
154.5	0.05	32.75

ASH #11.15 FULL TENSILE STR. 1.25CM .001M 200/10S 25.2%S 84%R

TREE: 11 ROOT: 15

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.25
19.5	0.25
22.5	0.82
24.7	1.01
27.0	1.39
30.0	1.39
37.5	1.77
42.8	1.77
45.0	2.14
47.2	2.14
55.2	2.14
55.5	5.17
58.5	5.17
76.5	9.71
79.5	9.90

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.79	0.25
1.5	0.79	0.25
2.7	0.95	0.25
6.0	0.87	0.25
7.5	0.76	0.25
7.6	0.89	0.25
9.0	0.91	0.25
10.5	0.91	0.25
12.0	0.97	0.25
15.2	1.03	0.25
18.0	1.21	0.25
19.5	0.84	0.25
22.5	1.08	0.82
24.0	1.03	0.95
31.5	1.41	1.46
36.0	1.88	1.69
37.5	1.56	1.77
39.0	1.83	1.77
40.5	1.88	1.77
43.5	1.83	1.89
44.2	1.83	2.02
44.7	1.80	2.09
46.5	1.80	2.14
46.6	1.83	2.14

49.5	1.64	2.14
50.3	1.68	2.14
52.5	1.16	2.14
55.5	1.64	5.17
57.8	1.61	5.17
60.0	1.69	5.55
67.5	1.21	7.44
68.3	1.24	7.63
74.2	1.00	9.14
75.0	1.16	9.33
77.2	1.08	9.75
78.1	0.88	9.81
79.5	1.15	9.90
79.6	1.11	9.90
81.0	0.84	9.99

ASH #11.17 2.7CM 0.34M 190/30S 30%S 67%R

TREE: 11 ROOT: 17

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.63
26.3	0.63
42.0	1.39
56.3	1.39
58.5	1.77
67.5	1.77
74.2	2.14
84.0	2.14
85.5	2.33
96.0	2.33
97.5	2.52
117.0	2.52
120.0	2.90
135.0	2.90
135.1	3.47
157.5	3.66
172.5	4.03
291.0	4.03
296.2	4.41
473.2	4.41
473.4	4.60
511.5	4.60
513.7	4.79
516.0	4.79
519.0	5.55
531.0	5.55
540.0	6.30
559.5	7.82
834.0	7.82
855.0	9.33
891.0	9.33
892.5	18.02

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.63	0.63
6.0	0.60	0.63
6.7	0.84	0.63
9.0	0.87	0.63
12.0	0.87	0.63
12.8	0.79	0.63
16.5	0.88	0.63
18.8	0.89	0.63
21.0	0.87	0.63
28.5	1.43	0.74
30.0	1.72	0.81
33.0	2.15	0.96
33.8	1.61	0.99
35.3	2.41	1.06
41.3	2.41	1.35
45.0	1.85	1.39
46.5	2.50	1.39
48.8	2.50	1.39
52.5	4.29	1.39
54.0	4.01	1.39
57.0	5.09	1.51
58.5	4.57	1.77
60.0	5.32	1.77
75.0	5.32	2.14
81.0	0.07	2.14
85.5	0.07	2.33
85.6	2.50	2.33
86.3	0.76	2.33
86.4	0.76	2.33
91.5	0.76	2.33
93.0	3.54	2.33
94.5	3.88	2.33
95.3	2.15	2.33
97.5	2.15	2.52
97.6	1.46	2.52
102.0	1.46	2.52
102.3	-0.97	2.52
112.5	-1.32	2.52
117.0	3.88	2.52
120.0	5.09	2.90
121.5	3.54	2.90
124.5	3.54	2.90
124.6	6.31	2.90

125.2	5.27	2.90	600.0	3.88	7.82
127.5	5.27	2.90	601.5	3.19	7.82
127.6	6.31	2.90	606.7	3.19	7.82
129.0	5.27	2.90	607.5	3.54	7.82
130.5	4.58	2.90	610.5	3.54	7.82
132.0	4.58	2.90	612.0	3.19	7.82
133.5	3.54	2.90	615.0	5.79	7.82
138.0	3.54	3.49	615.7	4.58	7.82
138.7	2.50	3.50	619.5	4.40	7.82
142.5	2.50	3.53	620.2	3.88	7.82
144.0	3.54	3.54	627.0	3.88	7.82
148.5	3.19	3.58	627.7	5.61	7.82
151.5	5.27	3.61	631.5	5.61	7.82
152.2	2.84	3.61	631.6	3.88	7.82
155.2	2.84	3.64	633.0	3.88	7.82
155.7	6.31	3.64	633.7	5.96	7.82
156.0	5.61	3.64	635.2	5.61	7.82
165.0	3.54	3.85	635.4	3.19	7.82
166.5	6.31	3.88	699.0	3.19	7.82
168.0	4.58	3.92	700.2	5.61	7.82
285.0	2.15	4.03	702.0	4.23	7.82
285.1	5.96	4.03	703.5	4.23	7.82
288.0	5.96	4.03	704.2	5.27	7.82
288.1	4.23	4.03	707.2	5.27	7.82
291.0	4.23	4.03	708.0	3.54	7.82
291.1	6.48	4.05	709.5	3.54	7.82
294.0	6.48	4.25	710.2	4.92	7.82
294.1	5.61	4.26	711.7	5.79	7.82
321.7	5.09	4.41	712.2	3.88	7.82
322.5	2.84	4.41	720.0	3.88	7.82
325.5	2.84	4.41	754.5	3.88	7.82
327.0	5.61	4.41	755.2	5.09	7.82
328.5	4.58	4.41	757.5	4.58	7.82
330.0	4.58	4.41	759.0	2.50	7.82
331.5	5.61	4.41	777.0	2.15	7.82
332.2	4.23	4.41	814.5	1.80	7.82
462.7	4.23	4.41	814.6	2.50	7.82
462.9	5.61	4.41	826.5	2.50	7.82
463.5	6.31	4.41	828.7	1.80	7.82
467.2	5.96	4.41	829.3	0.49	7.82
467.7	4.58	4.41	836.2	0.71	7.98
489.0	4.58	4.60	840.7	0.71	8.30
501.0	4.92	4.60	843.0	0.60	8.46
507.0	4.58	4.60	852.0	1.91	9.11
514.5	3.36	4.79	853.5	1.64	9.22
525.0	3.36	5.55	855.0	1.81	9.33
528.0	4.23	5.55	856.5	0.81	9.33
528.1	3.88	5.55	859.5	1.05	9.33
538.5	5.09	6.18	861.0	0.84	9.33
540.0	5.27	6.30	873.0	0.89	9.33
541.5	3.88	6.42	877.5	1.45	9.33
544.5	3.88	6.65	879.0	1.16	9.33
545.2	5.09	6.71	880.5	1.35	9.33
547.5	3.88	6.89	883.5	0.97	9.33

885.0	1.12	9.33
888.0	0.97	9.33
891.0	1.24	9.33
892.5	0.81	18.02

SM #4.14 0.5CM 0.14M 90/15S 22%S&R

TREE: 4 ROOT: 14

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.29
9.0	-1.29
13.5	0.82
24.0	3.47
30.0	4.18
39.0	13.35

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.03	-1.29
12.0	0.03	0.12
18.0	0.05	1.96
24.0	0.14	3.47
28.5	0.26	4.00
31.5	0.41	5.71
35.3	0.58	9.53
39.0	0.03	13.35

SM #4.19 1.3CM 0.16M 40/15S 20.6%S&R

TREE: 4 ROOT: 19

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.47
18.0	-1.47
22.5	-1.12
37.5	-0.76
52.5	-0.06
67.5	1.71
87.0	5.24
102.8	8.76
113.2	11.59
118.5	12.12
148.5	12.12
153.0	14.06
172.5	14.06
172.6	33.12

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.12	-1.47
2.2	0.12	-1.47
4.5	1.53	-1.47
10.5	0.15	-1.47
19.5	0.28	-1.35
28.5	0.33	-0.98
43.5	0.39	-0.48
60.0	0.60	0.82
79.5	0.61	3.88
93.8	0.67	6.75
109.5	0.77	10.58
124.5	0.95	12.12
130.5	1.33	12.12
139.5	1.36	12.12
144.0	0.88	12.12
154.5	0.79	14.06
169.5	0.79	14.06
172.5	1.03	14.06
174.0	0.16	204.65

SM #4.20 0.8CM 0.11M 60/0 22.7%S&R

TREE: 4 ROOT: 20

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.12
1.5	-1.12
15.0	0.82
28.5	2.41
52.5	4.00
60.0	4.35
63.0	33.43

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.01	-1.12
1.5	0.03	-1.12
27.0	0.23	2.24
28.5	0.36	2.41
33.0	0.55	2.71
37.5	0.55	3.01
46.5	1.20	3.60
51.0	1.03	3.90
52.5	1.28	4.00
63.0	1.26	33.43
63.1	0.00	34.89

SM #4.15 0.6CM 0.16M 120/0 21%S&R

TREE: 4 ROOT: 15

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.82
7.5	-1.47
15.8	-0.76
22.5	1.71
30.0	11.24
36.0	11.24
52.5	12.29

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.03	-1.82
3.0	0.03	-1.68
4.5	0.08	-1.61
13.5	0.08	-0.96
19.5	0.18	0.61
24.0	0.18	3.61
27.0	0.11	7.42
37.5	0.18	11.33
35.3	0.10	11.24
46.5	0.05	11.91
52.5	0.03	12.29

SM #4.12 1.08CM 0.27M 60/35N 20.6%S&R

TREE: 4 ROOT: 12

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.23
49.5	-0.23
50.3	0.47
57.0	1.71
67.5	5.24
73.5	8.76
82.5	12.47
84.0	16.53
88.5	16.53
90.0	33.43

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.04	-0.23
4.5	0.10	-0.23
12.0	0.14	-0.23
19.5	0.17	-0.23
23.3	0.17	-0.23
30.0	0.29	-0.23
36.0	0.28	-0.23
42.8	0.26	-0.23
45.0	0.35	-0.23
48.0	0.38	-0.23
51.0	0.42	0.61
54.0	0.43	1.16
60.0	0.45	2.71
66.0	0.44	4.73
67.5	0.41	5.24
75.0	0.17	9.38
82.5	0.20	12.47
91.5	0.04	50.34

SM #4.16 0.5CM 0.4M 10/35N 20.4%S&R

TREE: 4 ROOT: 16

TIME (SECONDS)	DISPLACEMENT (CM)

0.0	-1.82
30.0	-0.41
56.3	-0.41
63.0	0.82
67.5	5.59
70.5	9.12
72.0	10.18
73.5	33.43

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.03	-1.82
4.5	0.03	-1.61
6.0	0.05	-1.54
19.5	0.05	-0.91
22.5	0.07	-0.76
48.0	0.07	-0.41
49.5	0.12	-0.41
54.0	0.11	-0.41
58.5	0.12	0.00
63.0	0.16	0.82
67.5	0.13	5.59
72.0	0.07	10.18
87.0	0.03	242.76

SM #4.17 0.4CM 0.36M 25/28N 20.4%S&R MOVED LATERALLY AS PULLED OUT

TREE: 4 ROOT: 17

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.76
39.0	-0.76
40.5	1.71
58.5	1.71
71.3	3.47
75.0	5.06

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.03	-0.76

6.0	0.03	-0.76
10.5	0.06	-0.76
12.0	0.09	-0.76
16.5	0.12	-0.76
28.5	0.17	-0.76
33.8	0.17	-0.76
36.0	0.13	-0.76
57.0	0.13	1.71
66.7	0.27	2.85
70.5	0.24	3.37
75.0	0.28	5.06
79.5	0.04	6.97

SM #2.11 0.57CM 0.2M 125/24N 20%S&R

TREE: 2 ROOT: 11

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.79
7.5	2.06
15.8	4.74
19.3	4.74
19.5	10.26

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.01	0.79
6.7	0.10	1.93
11.3	0.22	3.28
17.2	0.44	4.74
19.5	-0.01	10.26

SM #2.01 1.9CM 0.14M 170/10S 21%S&R

TREE: 2 ROOT: 1

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.86
31.5	0.86

60.0	3.00
80.3	4.90
99.0	8.05
106.5	9.95
107.2	12.00
118.5	12.00
121.5	15.16
126.0	15.16
132.0	20.37
135.0	27.00

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.03	0.86
6.0	0.21	0.86
9.0	-0.12	0.86
12.8	0.41	0.86
25.5	0.99	0.86
43.5	1.85	1.76
57.0	2.24	2.78
63.0	1.76	3.28
70.5	2.29	3.99
78.0	1.95	4.69
99.0	2.46	8.05
103.5	2.00	9.19
106.5	0.36	9.95
108.0	0.65	12.00
109.5	0.55	12.00
118.5	0.46	12.00
120.0	0.43	13.58
120.1	0.02	13.74
121.5	0.21	15.16
124.5	0.24	15.16
126.0	0.02	15.16
126.7	0.26	15.81
130.5	0.31	19.06
132.0	0.26	20.37
132.1	0.07	20.70
133.5	0.12	23.68
134.2	0.02	25.34
135.0	-0.03	27.00

SM #2.18 0.8CM 0.21M 100/7N 20%S&R

TREE: 2 ROOT: 18

TIME	DISPLACEMENT
(SECONDS)	(CM)
0.0	0.48
3.0	4.27
12.0	6.48
21.0	6.79
34.5	8.05
39.0	8.69
39.1	11.21
43.5	15.32

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.01	0.48
10.5	-0.01	6.11
15.0	0.05	6.58
22.5	0.09	6.93
30.0	0.19	7.63
37.5	0.34	8.48
39.7	0.11	11.78
42.0	0.19	13.90
43.5	-0.02	15.32

SM #2.16 0.8CM 0.08M 100/7N 23.2%S&R

TREE: 2 ROOT: 16

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.16
1.5	0.16
6.0	2.69
15.0	3.70
27.0	4.42
33.0	5.21
39.0	6.16
45.0	11.05
46.5	30.12

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.01	0.16
9.0	0.74	3.03

13.5	0.09	3.53
21.0	0.34	4.06
28.5	0.79	4.62
36.0	0.75	5.69
42.0	0.81	8.61
45.0	0.69	11.05
48.0	-0.02	49.19

SM #2.15 0.7CM 0.27M 70/36N 21%S&R

TREE: 2 ROOT: 15

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.64
9.0	0.64
24.0	2.21
41.3	6.48
54.0	9.63
64.5	12.32
66.0	12.32
66.1	30.12

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.02	0.64
4.5	-0.02	0.64
9.0	0.08	0.64
21.0	0.28	1.90
33.0	0.55	4.44
45.0	0.75	7.41
57.0	0.75	10.40
58.5	0.80	10.78
66.0	0.74	12.32

SM #2.12 0.42CM 0.21M 115/35N 20%S&R

TREE: 2 ROOT: 12

TIME (SECONDS)	DISPLACEMENT (CM)

0.0	0.79
3.0	4.90
15.0	7.42
22.5	9.63
27.8	12.32
29.2	19.74
33.0	30.12

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.01	0.79
7.5	0.02	5.85
12.0	0.04	6.79
14.2	8.05	7.27
19.5	0.22	8.75
21.0	0.34	9.19
27.8	0.47	12.32
30.0	-0.01	21.81

ASH #11.06 0.8CM 0.1M 180/40N 25.2%S 84%R FULL TENSILE STRENGTH

TREE: 11 ROOT: 6

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.45
18.0	-1.26
27.0	-1.26
28.5	-0.50
36.0	0.06
54.0	1.01
57.0	1.01
57.1	18.78

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.18	-1.45
4.5	0.63	-1.40
13.5	0.68	-1.31
30.0	0.71	-0.39
39.0	0.95	0.22
45.0	2.41	0.54

49.5	0.60	0.77
54.7	0.88	1.01
57.0	0.88	1.01
57.1	0.20	18.78

ASH #11.12 0.9CM 0.14M 200/20S 26%S 75%R FULL TENSILE STRENGTH

TREE: 11 ROOT: 12

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.64
16.5	-1.64
25.5	-1.26
28.5	-0.88
36.0	-0.12
39.0	1.01
39.7	5.17
48.0	5.17
66.0	30.88

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.41	-1.64
9.0	0.49	-1.64
17.2	0.59	-1.61
22.5	0.67	-1.38
25.5	0.97	-1.26
30.0	1.77	-0.73
33.8	2.27	-0.35
37.5	0.60	0.44
40.5	1.35	5.17
43.5	1.68	5.17
48.0	-0.04	5.17
60.0	-0.04	22.31
63.0	0.96	26.60
66.0	-0.18	30.88

ASH #11.11 1.1CM 0.1M 180/7N 25.2%S 84%R FULL TENSILE STRENGTH

TREE: 11 ROOT: 11

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.64
10.5	-1.64
19.5	-1.26
30.0	-0.69
37.5	0.25
38.3	10.65

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.68	-1.64
3.0	0.60	-1.64
4.5	0.68	-1.64
12.0	0.79	-1.57
16.5	0.95	-1.38
20.3	1.35	-1.22
21.0	2.41	-1.18
30.0	2.41	-0.69
38.3	-0.18	10.65

ASH #11.06 0.8CM 0.1M 180/40N 25.2%S 84%R FULL TENSILE STRENGTH

TREE: 11 ROOT: 6

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.45
18.0	-1.26
27.0	-1.26
28.5	-0.50
36.0	0.06
54.0	1.01
57.0	1.01
57.1	18.78

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.18	-1.45

4.5	0.63	-1.40
13.5	0.68	-1.31
30.0	0.71	-0.39
39.0	0.95	0.22
45.0	2.41	0.54
49.5	0.60	0.77
54.7	0.88	1.01
57.0	0.88	1.01
57.1	0.20	18.78

ASH #11.12 0.9CM 0.14M 200/20S 26%S 75%R FULL TENSILE STRENGTH

TREE: 11 ROOT: 12

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.64
16.5	-1.64
25.5	-1.26
28.5	-0.88
36.0	-0.12
39.0	1.01
39.7	5.17
48.0	5.17
66.0	30.88

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.41	-1.64
9.0	0.49	-1.64
17.2	0.59	-1.61
22.5	0.67	-1.38
25.5	0.97	-1.26
30.0	1.77	-0.73
33.8	2.27	-0.35
37.5	0.60	0.44
40.5	1.35	5.17
43.5	1.68	5.17
48.0	-0.04	5.17
60.0	-0.04	22.31
63.0	0.96	26.60
66.0	-0.18	30.88

ASH #11.11 1.1CM 0.1M 180/7N 25.2%S 84%R FULL TENSILE STRENGTH

TREE: 11 ROOT: 11

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.64
10.5	-1.64
19.5	-1.26
30.0	-0.69
37.5	0.25
38.3	10.65

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.68	-1.64
3.0	0.60	-1.64
4.5	0.68	-1.64
12.0	0.79	-1.57
16.5	0.95	-1.38
20.3	1.35	-1.22
21.0	2.41	-1.18
30.0	2.41	-0.69
38.3	-0.18	10.65

SM #9.05 0.75CM 0.22M 0/38N 17.4%S 51.2%R

TREE: 9 ROOT: 5

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.65
24.0	-1.65
30.0	0.64
33.0	0.64
38.3	3.13
46.5	3.13
48.8	8.34
51.7	12.50
52.5	12.50
55.5	13.96
61.5	13.96

63.0	37.86

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.15	-1.65
1.5	0.08	-1.65
6.0	0.12	-1.65
7.5	0.21	-1.65
9.0	0.33	-1.65
12.0	0.45	-1.65
15.0	0.35	-1.65
24.0	0.47	-1.65
27.0	0.46	-0.51
30.0	0.33	0.64
33.0	0.31	0.64
34.5	0.39	1.35
36.0	0.32	2.06
39.0	0.29	3.13
45.0	0.18	3.13
46.5	0.26	3.13
48.0	0.18	6.60
54.0	0.04	13.23
58.5	0.02	13.96
60.0	-0.01	13.96
63.0	-0.02	37.86
69.0	-0.03	133.45

SM #9.07 0.7CM 0.3M 50/30N 17.8%S 51.9%R

TREE: 9 ROOT: 7

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.65
31.5	-1.65
34.5	0.43
37.5	5.42
40.5	6.05
45.0	7.09
46.5	7.09
48.8	10.00
67.5	10.00
68.3	24.99

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.04	-1.65
1.5	0.07	-1.65
19.5	0.07	-1.65
27.8	0.32	-1.65
29.2	0.23	-1.65
31.5	0.34	-1.65
34.5	0.17	0.43
39.0	0.05	5.74
43.5	0.04	6.74
45.0	0.06	7.09
46.5	0.03	7.09
48.0	0.07	9.03
51.0	0.05	10.00
67.5	0.05	10.00
68.3	0.04	24.99

SM #9.09 0.8CM 0.31M 320/17N 17.7%S 51.9%R LATERAL DISPLACEMENT

TREE: 9 ROOT: 9

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.03
1.5	-1.03
4.5	1.26
12.0	2.93
15.0	2.93
16.5	3.34
18.0	24.58
27.0	24.99
37.5	26.66
39.0	37.86
49.5	37.86

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.01	-1.03
4.5	0.12	1.26
9.0	0.22	2.26
15.0	0.31	2.93
22.5	0.40	24.78
27.0	0.28	24.99

28.5	0.28	25.23
30.8	0.44	25.59
34.5	0.48	26.18
36.0	0.49	26.42
42.0	0.08	37.86
45.8	0.07	37.86
49.5	0.01	37.86

SM #9.06 0.93CM 0.22M 40/37N 17.4%S 51.2%R

TREE: 9 ROOT: 6

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.65
4.5	-1.24
10.5	-0.40
17.2	0.84
22.5	3.34
31.5	6.67
36.7	11.67
39.0	13.75
40.5	20.00
42.0	30.82
57.0	37.86

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.03	-1.65
3.0	0.09	-1.38
9.0	0.17	-0.61
16.5	0.28	0.71
21.0	0.33	2.63
22.5	0.41	3.34
25.5	0.28	4.45
28.5	0.39	5.56
31.5	0.12	6.67
36.0	0.09	10.96
39.0	0.05	13.75
43.5	0.01	31.52
55.5	0.01	37.15
57.0	-0.01	37.86

SM #9.03 0.48CM 0.2M 75/13W 17.4%S 51.2%R FULL TENSILE STRENGTH

TREE: 9 ROOT: 3

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.65
1.5	-1.65
4.5	-0.40
7.5	0.01
15.0	3.97
19.5	5.01
31.5	7.09
39.7	10.42
43.5	11.88
45.0	22.91

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.02	-1.65
1.5	-0.02	-1.65
3.0	0.00	-1.03
12.0	0.02	2.38
18.0	0.08	4.66
24.0	0.17	5.79
30.0	0.29	6.83
37.5	0.42	9.51
42.0	0.48	11.29
45.0	-0.04	22.91

SM #9.11 0.3CM 0.35M 80/0 16%S 45%R FULL TENSILE STRENGTH

TREE: 9 ROOT: 11

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.65
12.0	-1.65
25.5	0.43
39.0	2.51
42.8	3.34
42.8	17.91

45.0	37.86

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.01	-1.65
7.5	0.08	-1.65
12.0	0.17	-1.65
19.5	0.23	-0.50
25.5	0.27	0.43
28.5	0.28	0.89
34.5	0.29	1.82
37.5	0.28	2.28
42.0	0.23	3.18
45.0	-0.04	37.86

SM #9.04 2.22CM 0.18M 20/4N 17.4%S 51.2%R

TREE: 9 ROOT: 4

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.65
13.5	-1.65
22.5	0.43
34.5	2.51
49.5	4.59
66.0	7.09
73.5	7.09
90.0	9.59
102.0	11.25
102.0	15.00
112.5	18.75
127.5	30.82
132.0	36.03
150.0	37.86

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.14	-1.65
6.0	-0.14	-1.65
13.5	0.20	-1.65
15.0	-0.09	-1.31
20.3	0.28	-0.09
24.0	0.33	0.69
30.0	0.67	1.73
34.5	1.19	2.51
43.5	1.82	3.76
49.5	1.67	4.59
52.5	2.07	5.05
59.2	1.77	6.07
63.0	2.21	6.64
72.0	2.03	7.09
75.0	2.23	7.32
79.5	2.78	8.00
85.5	2.50	8.91
91.5	2.95	9.80
97.5	2.64	10.63
100.5	0.66	11.04
106.5	0.90	16.61
114.0	0.78	19.95
120.0	0.43	24.78
123.0	0.36	27.20
129.0	0.36	32.56
135.0	-0.04	36.33
150.0	-0.04	37.86

39SM #9.02 1.52CM 0.1M 70/0 18.4%S 53.6%R

TREE: 9 ROOT: 2

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.86
8.3	-1.86
36.0	0.43
61.5	2.51
69.0	2.93
76.5	2.93
87.0	4.18
99.0	5.22
100.5	14.17
108.0	17.08

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.10	-1.86
1.5	-0.10	-1.86
3.0	0.00	-1.86
6.0	0.06	-1.86

9.0	0.23	-1.80
13.5	0.47	-1.43
19.5	0.60	-0.93
24.0	1.00	-0.56
25.5	0.83	-0.44
33.0	1.47	0.18
37.5	1.47	0.55
43.5	1.91	1.04
46.5	1.60	1.29
54.0	2.28	1.90
57.0	2.24	2.14
61.5	2.67	2.51
75.0	2.44	2.93
78.0	2.91	3.10
82.5	2.84	3.64
85.5	2.71	4.00
87.0	3.46	4.18
91.5	3.46	4.57
96.0	3.12	4.96
100.5	3.70	14.17
103.5	-0.23	15.33

SM #9.10 2.28CM 0.13M 350/15N 18%S 52%R

TREE: 9 ROOT: 10

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	3.76
51.0	3.76
57.0	6.88
63.0	10.84
69.0	14.79
75.0	20.83
79.5	24.58
82.5	33.53

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.27	3.76
4.5	-0.24	3.76
25.5	-0.22	3.76
33.0	-0.20	3.76
45.0	-0.20	3.76
49.5	0.30	3.76
54.0	0.57	5.32
57.0	0.66	6.88
60.0	0.65	8.86
63.8	0.47	11.33
67.5	0.40	13.80
70.5	0.21	16.30
75.0	0.00	20.83
79.5	-0.04	24.58
82.5	-0.14	33.53
94.5	-0.14	69.33

SM #9.19 1.1CM 0.16M 260/5W 18%S 52%R

TREE: 9 ROOT: 19

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.65
4.5	-1.65
6.7	-1.03
11.3	-0.40
15.0	-0.40
19.5	2.93
34.5	2.93
34.6	37.86

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.03	-1.65
3.0	-0.03	-1.65
7.5	0.19	-0.93
9.0	0.28	-0.72
21.0	0.64	2.93
31.5	0.54	2.93
34.5	0.93	2.93
34.6	-0.07	37.86

SM #9.22 0.65CM 0.3M 255/59S 17.8%S 51.9%R

TREE: 9 ROOT: 22

TIME (SECONDS)	DISPLACEMENT (CM)

0.0	-1.65
7.5	-1.65
9.0	-0.20
18.0	1.68
28.5	3.13
36.0	3.13
43.5	5.84
48.0	11.88
55.5	11.88
60.0	12.92
64.5	13.33
69.0	15.00
70.5	28.32

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.03	-1.65
4.5	0.14	-1.65
12.0	0.23	0.43
17.2	0.29	1.52
24.0	0.30	2.51
33.0	0.32	3.13
36.0	0.48	3.13
39.0	0.54	4.22
42.0	0.53	5.30
45.0	0.31	7.85
47.2	0.36	10.87
51.0	0.30	11.88
57.0	0.17	12.22
63.0	0.25	13.20
67.5	0.24	14.44
69.0	0.02	15.00

ASH #7.15 0.57CM 0.1M 340/12N 26.4%S 100%R?

TREE: 7 ROOT: 15

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.41
7.5	0.80
12.0	3.48
16.5	3.48
18.0	6.36
22.5	9.05
28.5	9.24

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.12	0.41
3.8	-0.12	0.61
6.0	0.13	0.72
9.0	0.26	1.69
15.0	0.03	3.48
15.8	0.03	3.48
16.5	0.18	3.48
19.5	-0.12	7.26

ASH #7.14 0.8CM 0.2M 355/20S 26.9%S 83%R

TREE: 7 ROOT: 14

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.80
13.5	0.80
15.8	1.56
22.5	3.48

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.12	0.80
5.3	-0.12	0.80
6.0	0.58	0.80
9.0	0.28	0.80
10.5	0.53	0.80
14.2	-0.04	1.05
15.8	-0.12	1.56

ASH #7.17 0.8CM 0.42M 105/77S 27.3%S 30%R SLIP NOT RECORDED

TREE: 7 ROOT: 17

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.80
127.5	0.80

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.11	0.80
3.0	0.53	0.80
7.5	0.64	0.80
9.0	0.75	0.80
12.0	0.64	0.80
27.0	0.56	0.80
111.0	0.49	0.80
114.0	0.76	0.80
120.0	0.41	0.80
127.5	-0.11	0.80

ASH #7.19 0.89CM 0.12M 190/30N 26.4%S 100%R?

TREE: 7 ROOT: 19

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.41
10.5	0.41
19.5	1.18
22.5	5.98
28.5	6.06
34.5	10.78

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.11	0.41
6.7	0.18	0.41
8.3	0.03	0.41
14.2	0.67	0.73
18.0	0.80	1.05
21.7	1.07	4.78
25.5	-0.11	6.02
34.5	-0.11	10.78

ASH #7.21 0.71CM 0.05M 100/0 26.4%S 100%R?

TREE: 7 ROOT: 21

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	3.10
7.5	3.48
34.5	3.48
34.6	15.00

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.11	3.10
7.5	0.32	3.48
14.2	0.72	3.48
27.0	0.25	3.48
28.5	0.73	3.48
30.0	0.69	3.48
31.5	1.04	3.48
34.5	-0.11	3.48

ASH 7.23 0.6CM 0.1M 145/14W 26.4%S 100%R?

TREE: 7 ROOT: 23

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.61
4.5	0.61
9.0	3.48
15.0	7.32
17.2	8.28
18.8	19.41

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.11	0.61

2.2	-0.11	0.61
3.0	0.05	0.61
7.5	0.05	2.52
11.3	-0.06	4.92
12.0	-0.11	5.40
18.8	-0.11	19.41

ASH #7.22 1.57CM 0.1M 140/20N 26.4%S 100%R?

TREE: 7 ROOT: 22

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.80
63.0	0.80
63.8	0.80
89.2	0.80
116.2	2.52
133.5	2.52
138.0	3.10
172.5	6.17
202.5	10.01
217.5	12.12
232.5	14.62
247.5	17.50
255.0	19.22
262.5	22.49
270.0	25.94
276.0	25.94
277.5	35.34

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.47	0.80
2.2	-0.01	0.80
4.5	-0.40	0.80
15.0	0.17	0.80
21.0	-0.07	0.80
27.0	-0.15	0.80
28.5	-0.46	0.80
87.0	-0.46	0.80
88.5	0.11	0.80
92.2	0.44	0.99
96.0	0.25	1.23
100.5	1.42	1.52
102.8	1.80	1.66
108.0	1.56	2.00
114.0	2.98	2.38
120.0	2.67	2.52
132.0	1.76	2.52
135.0	3.29	2.72
139.5	0.79	3.23
142.5	1.62	3.50
150.0	1.01	4.17
160.5	1.58	5.10
166.5	0.84	5.64
174.0	1.19	6.36
180.0	0.31	7.13
189.0	1.01	8.28
193.5	0.40	8.86
202.5	0.05	10.01
207.0	0.44	10.64
211.5	-0.43	11.28
216.0	0.22	11.91
222.0	-0.43	12.87
228.0	0.66	13.87
232.5	-0.43	14.62
237.0	0.84	15.48
239.2	-0.43	15.91
244.5	2.02	16.92
247.5	-0.43	17.50
277.5	-0.43	35.34

ASH #7.20 2.3CM 0.17M 180/10N 26.9%S 83%R

TREE: 7 ROOT: 20

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.03
7.5	1.95
15.0	5.02
30.0	8.28
58.5	12.70
90.0	12.70
168.0	16.54

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.46	0.03
11.3	-0.46	3.48
15.0	0.66	5.02

24.0	1.88	6.98
32.2	2.82	8.63
40.5	2.85	9.91
47.2	4.34	10.95
60.0	5.30	12.70
66.0	4.21	12.70
73.5	6.09	12.70
78.0	5.39	12.70
85.5	6.88	12.70
94.5	6.06	12.92
102.0	7.39	13.29
107.2	5.97	13.55
115.5	6.68	13.95
126.0	5.62	14.47
135.0	6.86	14.91
148.5	5.53	15.58
150.0	3.31	15.65
157.5	2.42	16.02
168.0	0.74	16.54

ASH #7.08 1.4CM 0.22M 275/26N 21.3%S 59.4%R

TREE: 7 ROOT: 8

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.75
54.0	0.75
55.5	2.70
60.0	2.70
72.0	5.85

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-1.20	0.75
5.3	-0.02	0.75
11.3	0.74	0.75
15.0	1.40	0.75
19.5	2.07	0.75
27.8	1.45	0.75
30.0	0.55	0.75
33.0	2.79	0.75
36.0	2.16	0.75
42.0	1.98	0.75
43.5	2.76	0.75
48.0	2.12	0.75
51.0	2.03	0.75
54.0	2.35	0.75
58.5	-0.88	2.70
69.0	-1.20	5.06

ASH #7.07 0.6CM 0.42M 295/50N 20.7S 37.5R

TREE: 7 ROOT: 7

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.81
6.0	1.80
13.5	2.70
22.5	11.40

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-1.20	0.81
1.5	-1.13	1.06
3.0	-1.20	1.30
7.5	-1.20	1.98
9.0	-0.95	2.16
12.0	-0.88	2.52
15.0	-0.76	4.15
15.2	-1.20	4.30

ASH #7.09 0.4CM 0.05M 260/20W 24.1%S 31.2%R

TREE: 7 ROOT: 9

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.75
4.5	0.75
15.0	1.80
19.5	5.10
24.0	9.60

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-1.22	0.75
4.5	-1.22	0.75
7.5	-0.69	1.05
13.5	0.11	1.65
16.5	0.23	2.90
19.5	-0.05	5.10
22.5	-1.22	8.10

ASH #7.10 1.4CM 0.16M 260/27W 22%S 45%R

TREE: 7 ROOT: 10

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	1.35
11.3	1.35
16.5	2.10
19.5	3.00
20.3	3.60
21.7	4.05
24.7	7.50

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-1.20	1.35
6.0	0.00	1.35
8.3	0.90	1.35
12.0	1.10	1.46
13.5	0.97	1.67
16.2	0.21	2.06
18.0	0.32	2.55
19.5	-0.32	3.00
21.0	-0.30	3.82
22.5	-0.46	4.91
24.0	-0.79	6.64
24.7	-1.20	7.50

ASH #7.11 1.42CM 0.1M 30/0 24.1%S 31.2%R WINCH PLUS SCOUT

TREE: 7 ROOT: 11

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.90
86.3	0.90
87.0	1.71
112.5	1.71
112.6	9.00

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-1.20	0.90
2.2	-0.90	0.90
3.0	-0.42	0.90
6.0	-0.09	0.90
13.5	0.41	0.90
15.0	-0.05	0.90
19.5	-0.09	0.90
24.0	-0.26	0.90
52.5	-0.26	0.90
58.5	-0.32	0.90
73.5	-0.32	0.90
75.0	0.02	0.90
76.5	-0.37	0.90
84.0	-0.37	0.90
88.5	0.83	1.71
89.2	-0.65	1.71
99.0	-0.65	1.71
99.7	-0.79	1.71
112.5	-0.74	1.71
112.6	-1.20	9.00

SM #2.10 0.5CM 0.36M 115/3S 22.2%S&R

TREE: 2 ROOT: 10

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.79
12.0	0.79
25.5	1.43
36.0	2.53
39.0	9.95

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.02	0.79
4.5	0.02	0.79
10.5	0.02	0.79
13.5	0.18	0.86
16.5	0.14	1.00
19.5	0.29	1.14
25.5	0.45	1.43
28.5	0.16	1.74
38.3	0.37	8.09
40.5	-0.03	13.66

SM #2.08 0.8CM 0.18M 90/0 20%S&R LATERAL MOVEMENT

TREE: 2 ROOT: 8

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.16
15.0	0.16
19.5	1.11
24.0	2.85
31.5	5.53
39.0	8.37
48.0	10.90
58.5	13.90
63.0	15.32
72.0	16.58
81.0	20.68
93.0	22.89
96.0	22.89
97.5	26.05
105.0	27.00

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.00	0.16
6.0	0.00	0.16
7.5	0.13	0.16
15.0	0.19	0.16
20.3	0.21	1.40
27.0	0.32	3.92
30.0	0.31	4.99
39.0	0.32	8.37
48.0	0.39	10.90
57.8	0.49	13.68
70.5	0.59	16.37
81.0	0.59	20.68
87.0	0.72	21.79
90.0	0.76	22.34
96.0	0.74	22.89
103.5	0.37	26.81

SM #2.07 0.52CM 0.3M 140/27S 21%S&R

TREE: 2 ROOT: 7

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.41
15.0	-0.41
30.0	-0.31
45.0	0.79
52.5	2.37
57.0	7.42
67.5	11.84
75.0	15.63
81.0	17.53
88.5	20.05
90.0	30.12

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.02	-0.41
3.0	-0.02	-0.41
9.0	0.12	-0.41
16.5	0.14	-0.40
21.0	0.22	-0.37
28.5	0.44	-0.32
34.5	0.51	0.02
40.5	0.58	0.46
44.2	0.58	0.74
47.2	0.50	1.27
52.5	0.50	2.37
54.7	0.45	4.90
57.8	0.14	7.74
60.0	0.07	8.69

75.0	-0.02	15.63
90.0	-0.02	30.12

SM #2.02 0.57CM 0.16M 210/25S 20%S&R

TREE: 2 ROOT: 2

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.15
4.5	-0.15
39.0	2.37
39.7	30.12

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.01	-0.15
1.5	0.04	-0.15
6.0	0.10	-0.04
13.5	0.16	0.51
20.3	0.25	1.00
27.0	0.43	1.49
31.5	0.52	1.82
34.5	0.55	2.04
37.5	0.45	2.26
39.0	0.56	2.37
39.7	-0.08	30.12

SM #2.05 0.4CM 0.37M 180/31S 22.2%S&R

TREE: 2 ROOT: 5

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.16
7.5	0.16
14.2	0.95
37.5	1.27
52.5	1.74
67.5	3.32
73.5	4.11
75.0	8.37
81.0	8.37
87.0	20.68
91.5	29.05
93.0	30.12

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	-0.01	0.16
10.5	-0.01	0.51
12.0	0.04	0.69
22.5	0.10	1.06
32.2	0.13	1.20
37.5	0.34	1.27
50.3	0.43	1.67
54.7	0.36	1.98
60.0	0.46	2.53
61.5	0.54	2.69
67.5	0.58	3.32
70.5	0.61	3.71
73.5	0.60	4.11
76.5	0.11	8.37
93.0	0.04	30.12

SM #2.17 0.82CM 0.38M 180/50S 22.2%S&R

TREE: 2 ROOT: 12

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.15
7.5	0.16
15.0	0.48
22.5	0.48
33.0	1.11
40.5	1.74
60.0	3.32
67.5	4.74
70.5	9.63
87.8	30.12

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)

0.0	-0.02	-0.15
4.5	0.05	0.04
12.0	0.07	0.35
22.5	0.20	0.48
30.0	0.42	0.93
45.0	0.79	2.11
57.0	0.79	3.08
61.5	0.72	3.60
66.0	0.81	4.46
67.5	0.73	4.74
72.0	0.23	11.41
75.0	0.20	14.98

ASH #11.23 1.5CM 0.17M 50/4N 22.4%S 4.4%R

TREE: 11 ROOT: 23

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.68
9.7	-0.60
33.8	0.06
39.0	0.06
48.0	0.43
49.5	0.80
57.0	1.17
60.0	1.91
60.3	2.47
63.0	2.65
64.5	13.02

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.09	-0.68
4.5	0.15	-0.64
9.0	0.15	-0.61
10.5	0.17	-0.58
15.0	0.17	-0.46
27.8	0.29	-0.10
37.5	0.56	0.06
37.8	0.53	0.06
48.0	1.00	0.43
49.5	0.71	0.80
60.8	2.08	2.50
63.1	1.63	3.69
64.5	1.79	13.02

64.6	0.09	14.06

ASH #11.22 1.3CM 0.14M 100/20N 21.8%S 45%R

TREE: 11 ROOT: 22

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.68
4.5	-0.49
7.5	-0.31
11.3	0.80
15.0	1.17
30.0	1.36
31.5	3.40
34.2	5.62
36.7	6.54
52.5	12.28
53.3	12.28
55.5	13.40
57.9	14.88

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.11	-0.68
10.5	0.15	0.58
16.5	0.15	1.19
25.5	0.33	1.30
28.2	0.40	1.34
30.0	0.40	1.36
33.0	0.47	4.63
34.5	0.42	5.73
36.7	0.42	6.54
36.9	0.15	6.60
38.3	0.21	7.09
42.0	0.21	8.46
46.5	0.18	10.10
49.8	0.18	11.30
51.7	0.15	12.01
54.0	0.15	12.65
57.8	0.20	14.78
57.9	0.03	14.88

ASH #11.21 1.5CM 0.08M 130/23N 21.4%S 47.8%R BROKE OBLIQUE TO GROUND

TREE: 11 ROOT: 21

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-0.68
3.8	0.06
7.5	1.91
9.7	3.03
10.8	3.03
10.9	9.32

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.14	-0.68
1.5	0.15	-0.38
4.5	0.26	0.43
10.8	1.06	3.03
10.9	0.09	9.32

ASH #11.24 1.35CM 0.3M 140/15S 21.5%S 33.3%R

TREE: 11 ROOT: 24

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.05
15.0	-1.05
18.0	-0.68
28.5	-0.60
31.8	-0.31
43.5	0.06
357.0	0.06
427.8	0.43
633.0	0.43
634.2	0.80
729.0	0.80
729.3	24.14
732.0	31.51

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.14	-1.05
4.5	0.19	-1.05
8.3	0.19	-1.05
24.0	0.98	-0.64
26.3	0.61	-0.62
34.5	1.50	-0.22
40.5	2.02	-0.03
45.8	2.25	0.06
55.5	2.60	0.06
58.5	2.60	0.06
60.0	2.05	0.06
63.0	2.38	0.06
69.0	2.38	0.06
70.5	2.51	0.06
111.0	2.41	0.06
113.2	2.54	0.06
129.7	2.51	0.06
133.5	2.64	0.06
157.5	2.60	0.06
162.0	2.93	0.06
186.0	2.87	0.06
270.0	2.83	0.06
273.0	2.93	0.06
358.5	2.90	0.07
360.7	2.93	0.08
430.5	2.93	0.43
464.2	2.93	0.43
466.5	2.96	0.43
492.7	2.96	0.43
495.0	3.00	0.43
559.5	2.95	0.43
562.5	2.96	0.43
615.0	2.96	0.43
618.0	3.03	0.43
634.5	3.00	0.80
636.0	3.09	0.80
646.5	3.08	0.80
649.5	3.09	0.80
675.0	3.08	0.80
678.0	3.09	0.80
730.5	3.08	27.41
732.0	0.84	31.51

ASH #11.18 1.2CM 0.14M 100/7N 21.9%S 45%R

TREE: 11 ROOT: 18

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.42
20.3	-1.42
21.7	-1.23
26.3	-1.05
32.7	-1.05
35.3	-0.68
38.3	-0.68
39.0	1.54
40.5	1.91

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.07	-1.42
7.5	0.15	-1.42
14.2	0.21	-1.42
25.5	1.06	-1.08
27.0	0.58	-1.05
32.2	0.57	-1.05
35.3	0.97	-0.68
36.7	1.10	-0.68
36.9	0.81	-0.68
39.0	0.81	1.54
39.7	1.14	1.73
40.5	0.09	1.91

ASH #11.19 1.3CM 0.03M 130/4N 21.4%S 47.8%R

TREE: 11 ROOT: 19

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.79
6.0	-1.42
10.5	-1.42
12.8	-1.05
16.5	-1.05
27.0	-0.86
31.5	-0.31
40.5	-0.31
45.0	0.06
55.8	0.06
55.9	1.54
63.0	3.77
66.0	4.14

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.07	-1.79
3.0	0.12	-1.60
15.0	0.17	-1.05
24.0	0.23	-0.92
28.5	0.46	-0.68
36.0	0.94	-0.31
43.2	0.75	-0.09
45.0	1.20	0.06
51.0	1.76	0.06
51.1	1.51	0.06
53.8	1.50	0.06
55.2	1.79	0.06
56.3	1.59	1.64
57.0	1.76	1.87
58.5	0.97	2.35
60.0	0.81	2.82
65.3	1.56	4.04
66.0	0.09	4.14

ASH #11.25 1.2CM 0.02M 120/53S 21.4%S 47.8%R

TREE: 11 ROOT: 25

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.79
3.0	-1.79
5.3	-1.05
8.3	-0.68
13.5	-0.68
14.7	0.06
18.0	0.06
28.5	3.40
33.8	3.77
34.2	4.14
37.5	5.25
46.0	5.25
46.2	5.62

TIME FORCE DISPLACEMENT

(SECONDS)	(KILONEWTONS)	(CM)
0.0	0.03	-1.79
1.5	0.04	-1.79
4.2	0.09	-1.39
6.0	0.11	-0.96
11.3	0.10	-0.68
16.6	0.15	0.06
28.5	0.82	3.40
34.5	1.04	4.24
37.5	0.32	5.25
42.0	0.33	5.25
43.5	0.64	5.25
46.2	1.02	5.62
49.5	1.06	13.77
51.0	1.02	17.47
52.5	0.75	21.17
55.2	0.75	27.84
56.3	1.17	30.43
68.7	2.08	61.17
70.5	0.09	65.61

ASH #11.20 1.04CM 0.06M 130/4N 21.4%S 47.8%R

TREE: 11 ROOT: 20

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	-1.79
4.5	-1.79
7.5	-0.86
18.0	0.06
30.0	1.91
30.8	7.47

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.12	-1.79
4.5	0.33	-1.79
8.3	0.76	-0.80
12.0	1.06	-0.47
14.7	0.91	-0.23
16.5	0.91	-0.07
17.7	1.33	0.04
27.4	1.90	1.52
29.6	1.46	1.84
30.8	0.09	7.47

SM #6.02 1.56CM 0.11M 30/10S 24%S 36.3%R

TREE: 6 ROOT: 2

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.00
7.5	0.31
50.3	0.31
51.0	0.63
78.8	0.63
91.5	0.94
95.3	0.94
96.0	1.09
103.5	1.09
105.0	1.25
217.5	1.25
219.7	1.41
227.2	1.56
231.0	1.88
240.0	1.88
241.5	2.19
245.3	2.19
246.0	2.34
255.8	2.41
268.5	2.41
271.5	2.66
283.5	2.66
284.2	2.81
294.0	2.87
302.2	2.87
312.7	3.59
315.0	3.59
318.0	3.97
327.7	3.97
330.0	4.12
388.5	4.12
390.0	4.53
435.0	4.53
436.5	4.84
519.0	4.91
519.1	5.31
552.0	5.37
555.0	5.37
556.5	5.63
570.0	5.94
580.5	5.94

585.1	9.06

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.11	0.00
2.2	0.22	0.09
4.5	0.11	0.19
5.3	0.30	0.22
6.7	0.12	0.28
9.0	0.19	0.31
10.5	0.38	0.31
12.0	0.30	0.31
12.8	0.38	0.31
15.0	0.33	0.31
16.5	0.30	0.31
37.5	0.30	0.31
45.0	0.29	0.31
46.5	0.28	0.31
54.0	0.28	0.63
54.1	0.27	0.63
57.8	0.27	0.63
60.0	0.26	0.63
73.5	0.26	0.63
73.6	0.25	0.63
75.0	0.63	0.63
75.8	0.52	0.63
78.0	0.52	0.63
78.8	0.49	0.63
79.5	0.72	0.64
81.7	0.62	0.70
82.5	0.78	0.72
84.0	0.71	0.75
86.3	0.88	0.81
87.8	0.75	0.85
90.0	1.02	0.90
90.8	0.93	0.92
94.5	0.91	0.94
97.5	1.05	1.09
99.7	1.02	1.09
105.0	0.86	1.25
105.8	1.05	1.25
111.7	0.96	1.25
114.0	1.05	1.25
202.5	0.79	1.25
217.5	0.62	1.25
217.6	0.97	1.26
219.0	0.85	1.35
220.5	0.85	1.42
221.2	0.62	1.44
222.0	1.20	1.45
222.1	0.85	1.46
225.0	0.91	1.52
225.7	0.62	1.53
226.5	1.31	1.55
227.2	1.20	1.56
229.5	1.08	1.75
230.2	0.74	1.81
230.4	1.31	1.83
269.2	1.31	2.47
274.5	1.08	2.66
275.2	0.97	2.66
289.5	0.91	2.85
294.0	0.74	2.87
295.5	0.62	2.87
296.2	0.74	2.87
307.5	0.74	3.23
307.6	0.21	3.24
309.0	0.62	3.34
331.5	0.45	4.12
385.5	0.39	4.12
385.6	0.27	4.12
388.5	0.27	4.12
391.5	0.39	4.53
409.5	0.39	4.53
420.0	0.33	4.53
438.0	0.33	4.84
438.7	0.45	4.85
447.7	0.39	4.85
457.5	0.33	4.86
558.7	0.33	5.68
559.5	0.45	5.69
570.0	0.39	5.94
570.7	0.40	5.94
571.5	0.33	5.94
585.0	0.33	8.96
585.1	0.04	9.06

SM #6.04 1.12CM 0.14M 160/10S 24%S 36.3%R

TREE: 6 ROOT: 4

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.63
3.0	2.19
9.7	2.19
10.5	2.50
13.5	2.50
14.2	2.66
19.5	2.81

20.3	2.97
22.5	3.13
30.0	3.13
82.5	20.63
85.5	22.19
93.0	22.50
100.5	22.81
109.3	22.81
109.5	29.97

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.09	0.63
1.5	0.13	1.41
3.0	0.22	2.19
5.3	0.45	2.19
6.7	0.34	2.19
9.0	0.34	2.19
9.7	0.55	2.19
11.3	0.48	2.50
12.0	0.48	2.50
13.5	0.74	2.50
14.2	0.62	2.66
16.5	0.60	2.72
17.2	0.89	2.75
18.0	0.78	2.77
22.5	0.74	3.13
23.3	1.01	3.13
24.7	0.90	3.13
25.5	0.87	3.13
30.0	0.87	3.13
31.5	1.05	3.63
33.8	0.87	4.38
36.0	0.94	5.12
42.0	0.92	7.13
45.0	0.91	8.13
46.5	0.89	8.63
50.3	0.89	9.88
51.0	0.88	10.12
52.5	0.88	10.63
53.3	0.86	10.88
58.5	0.86	12.62
60.0	0.84	13.13
61.5	0.87	13.63
69.0	0.87	16.13
73.5	0.87	17.62
97.5	0.87	22.69
99.0	1.05	22.75
102.0	1.05	22.81
105.0	0.86	22.81
108.8	0.87	22.81
109.5	0.09	29.97

SM #6.12 3.2CM 0.1M 165/0 24%S 36.3%R

TREE: 6 ROOT: 12

TIME (SECONDS)	DISPLACEMENT (CM)
0.0	0.00
1.5	0.63
4.5	2.50
6.0	2.50
9.0	3.28
19.5	3.44
40.5	3.44
45.0	3.75
51.0	3.75
51.0	3.75
52.5	4.06
54.0	4.69
81.0	5.00
111.7	5.31
132.0	5.31
142.5	5.63
285.0	5.63
301.5	5.78
343.5	5.94
388.5	6.09
408.0	6.09
414.0	6.25
435.0	6.25
478.5	6.56
528.0	6.72
561.0	6.88
564.0	7.03
577.5	7.19
579.7	7.19
580.5	7.97
648.0	7.97
648.7	13.44

TIME (SECONDS)	FORCE (KILONEWTONS)	DISPLACEMENT (CM)
0.0	0.36	0.00
0.8	0.40	0.31
1.5	0.40	0.63

6.0	1.34	2.50
6.7	0.60	2.70
9.0	0.60	3.28
9.7	2.87	3.29
10.5	2.05	3.30
15.0	2.05	3.37
15.8	1.93	3.38
16.5	1.97	3.39
20.3	1.97	3.44
21.0	2.01	3.44
24.7	2.01	3.44
33.0	1.89	3.44
33.8	1.93	3.44
34.5	1.89	3.44
39.7	1.89	3.44
40.5	2.44	3.44
42.8	3.70	3.59
45.0	3.03	3.75
50.3	2.97	3.75
54.0	4.20	4.69
55.5	3.62	4.70
66.7	3.24	4.84
70.5	3.24	4.88
75.0	3.40	4.93
76.5	3.26	4.95
77.2	3.38	4.96
78.0	3.40	4.97
79.5	3.68	4.98
81.0	3.97	5.00
81.7	3.38	5.01
84.0	4.01	5.03
84.7	3.44	5.04
88.5	3.46	5.08
101.3	3.46	5.21
102.8	4.20	5.22
105.0	3.58	5.24
108.0	3.58	5.27
109.5	3.54	5.29
112.5	3.54	5.31
114.0	3.70	5.31
123.0	3.70	5.31
125.2	3.62	5.31
127.5	3.62	5.31
127.6	4.20	5.31
218.2	4.10	5.63
250.5	4.10	5.63
252.0	2.48	5.63
266.2	2.71	5.63
268.5	4.10	5.63
351.0	3.87	5.96
360.0	2.94	5.99
363.0	2.94	6.01
363.7	3.17	6.01
414.0	3.17	6.25
414.7	3.87	6.25
424.5	3.87	6.25
432.0	5.72	6.25
433.5	5.72	6.25
435.0	5.26	6.25
436.5	5.95	6.26
438.7	5.72	6.28
442.5	6.18	6.30
450.7	5.95	6.36
457.5	5.72	6.41
472.5	5.72	6.52
473.2	4.79	6.52
517.5	4.33	6.69
534.0	4.33	6.75
535.5	2.94	6.75
580.5	2.94	7.97
582.0	0.63	7.97
613.5	1.66	7.97
616.5	1.73	7.97
622.5	1.73	7.97
624.0	1.66	7.97
626.2	3.42	7.97
630.0	2.21	7.97
637.5	2.09	7.97
640.5	2.05	7.97
645.0	2.05	7.97
648.0	2.54	7.97
648.7	0.36	13.44

APPENDIX E

MMRRENUM, a multiple regression directed by Roger Stuebing

MMRRENUM, a S.A.S. program written by Roger Stuebing, performs a multiple regression analysis of the data gathered fron the *in-situ* pull-out test. Numerous parameters, listed below, are regressed with the tensile breaking force, in order to determine which can best predict the force. For both species, the diameter at the trench face, DV, is the best predictor of resistance to pull-out.

```
// JOB,MMRRENUM,
// EXEC SAS
//SYSIN DD *
DATA ROOTS ;  INFILE RAW;
INPUT  ID  1-5 2  SP $ 6-10  PLUNG 11-16 2  MOIST  17-22 2
DEPH  23-26 2  S $  27-29  DV 30-34 2  DB  35-39  2
LENGH 40-46 2  ORDER  47-51 2  MTF  52-56 2  TBF  57-61 2
ENDS 62-66 2  EXDV 67-72  2  TIME  73-78 2;
DATA TIME ; INFILE TDAT;
INPUT  ID  1-5 2  TTF  7-13 2 ;
PROC SORT DATA=ROOTS;  BY ID;
PROC SORT DATA=TIME ;  BY ID;
DATA COMBO; MERGE ROOTS TIME; BY ID;
PROC CORR; VAR PLUNG -- DEPH  DV -- TTF;
PROC PLOT ;
 PLOT  (MTF TBF TTF ENDS EXDV TIME) * (PLUNG -- DEPH DV -- ORDER);
PROC REG ALL ;
 MODEL  TBF = PLUNG -- DEPH DV -- ORDER;
/*
//RAW DD *
 5.02 SM   2.00 20.50 0.17SC 0.22 0.09  25.20 5.00 0.08 0.07  0.29 0.11  28.50
 5.07 SM  20.00 20.30 0.51 C 0.27 0.20  16.70 4.00 0.02 0.01  0.26 0.17  12.00
 9.11 SM   0.00 16.00 0.35SC 0.30 0.20  22.00 4.00 0.29 0.21  0.94 0.21  34.50
 5.03 SM  22.00 22.00 0.22SC 0.31 0.25  37.00 4.00 0.12 0.08  0.22 0.23  17.25
 5.06 SM   5.00 22.00 0.44 C 0.38 0.30  18.00      0.10 0.06  0.21 0.34  15.75
 4.17 SM  28.00 20.40 0.36SC 0.40 0.22  16.00 4.00 0.27 0.27  0.26 0.37  66.75
 2.05 SM  31.00 22.20 0.37SC 0.40 0.22  33.00 5.00 0.61 0.61  0.90 0.37  70.50
 2.12 SM  35.00 20.00 0.21SC 0.42 0.40  15.50      0.79 0.78  0.37 0.41  45.00
 9.03 SM  13.00 17.40 0.20SC 0.48 0.40  21.50      0.42 0.42  0.37 0.54  37.50
 4.14 SM  15.00 22.00 0.14SC 0.50 0.45  21.80 5.00 0.53 0.53  0.76 0.59  28.50
 4.16 SM  35.00 20.40 0.40 C 0.50 0.15  25.00 5.00 0.15 0.15  1.20 0.58  63.00
 2.10 SM   3.00 22.20 0.36SC 0.50 0.11  16.00 5.00 0.42 0.33  0.60 0.58  25.50
 2.07 SM  27.00 21.00 0.30SC 0.52 0.19  43.70 5.00 0.58 0.58  0.87 0.63  40.50
10.15 SM  15.00 21.00 0.25SC 0.52 0.50  20.00      0.18 0.11  0.81 0.63  11.25
 2.02 SM  31.00 22.20 0.37SC 0.57 0.57  13.00      0.53 0.53  0.76 0.76  34.50
 2.11 SM  24.00 20.00 0.20SC 0.57 0.50  16.00 4.00 0.38 0.38  0.58 0.76  17.25
 5.01 SM   5.00 20.50 0.15SC 0.58 0.42  14.00      0.15 0.15  0.70 0.79   6.00
 4.15 SM   0.00 21.00 0.16SC 0.60 0.30  44.00 5.00 0.18 0.17  1.28 0.84  19.50
 4.12 SM   0.00 21.00 0.16SC 0.60 0.25  24.30 6.00 0.45 0.45  2.44 0.84  60.00
 6.15 SM  10.00 21.40 0.37SC 0.63 0.63   6.10      0.50 0.50  0.93 0.93  34.50
 9.22 SM  59.00 17.80 0.30SC 0.65 0.11  34.00 5.00 0.53 0.53  0.50 0.98  39.00
 5.05 SM  25.00 22.00 0.32 C 0.68 0.60  25.00      0.36 0.36  1.13 1.08  75.00
 2.15 SM  36.00 21.00 0.27SC 0.70 0.70  16.00      0.79 0.72  1.15 1.15  58.50
 9.07 SM  30.00 17.80 0.30SC 0.70 0.11  54.00 6.00 0.30 0.30  0.79 1.15  27.75
 4.08 SM  15.00 24.00 0.18SC 0.70 0.62  32.50 5.00 0.53 0.47  1.26 1.15 137.25
 9.05 SM  38.00 17.40 0.22SC 0.75 0.11  38.00 5.00 0.42 0.34  1.01 1.32  24.00
 2.16 SM   7.00 20.00 0.21SC 0.80 0.35  74.00 5.00 0.80 0.80  1.19 1.49  42.00
 2.18 SM   7.00 20.00 0.21SC 0.80 0.32  26.00 4.00 0.32 0.32  0.46 1.49  37.50
 4.20 SM   0.00 22.70 0.11SC 0.80 0.70  42.00 5.00 1.24 1.24  2.16 1.50  52.50
 2.08 SM   0.00 20.00 0.18SC 0.80 0.81  30.00      0.75 0.75  2.39 1.49  90.00
10.16 SM  20.00 22.40 0.30 C 0.80 0.70  20.00      0.33 0.30  1.16 1.50   9.00
```

10.07	SM	2.00	17.40	0.15	SC	0.80	0.80			0.60	0.54	1.49	1.49	45.90
9.09	SM	17.00	17.70	0.31	SC	0.80	0.20	57.00	5.00	0.47	0.47	0.72	1.50	34.50
2.17	SM	50.00	22.20	0.38	SC	0.82	0.20	50.00	5.00	0.79	0.78	0.81	1.57	
6.14	SM	0.00	21.00	0.17	SC	0.85	0.30	43.20	6.00	0.59	0.45	3.16	1.69	19.50
4.01	SM	5.00	22.00	0.28	SC	0.90	0.64	24.70	4.00	1.32	1.32	1.32	1.90	
9.06	SM	37.00	17.40	0.22	SC	0.93	0.11	35.00	6.00	0.37	0.35	1.44	2.02	22.50
4.09	SM	70.00	19.00	0.42	SC	1.00	0.30	48.00	4.00	0.53	0.53	0.56	2.34	168.00
9.19	SM	5.00	18.00	0.16	SC	1.10				0.64	0.53			21.00
4.03	SM	5.00	24.00	0.21	SC	1.15	0.50	15.00	6.00	1.41	1.10	1.17	3.09	160.00
4.07	SM	15.00	22.00	0.09	SC	1.20	0.25	41.00	7.00	1.34	1.17	1.16	3.36	42.00
6.04	SM	10.00	24.00	0.14	SC	1.30	0.70	17.10	6.00	1.02	1.02	1.86	3.95	102.00
4.19	SM	15.00	20.60	0.16	SC	1.30	1.00	29.70		1.34	1.34	3.34	3.95	139.50
9.02	SM	0.00	18.40	0.10	SC	1.52	1.30	96.00	6.00	3.44	3.27	5.68	5.41	91.50
6.02	SM	10.00	24.00	0.11	SC	1.56	1.00	69.00	6.00	1.31	1.31	4.78	5.69	269.25
2.01	SM	10.00	21.00	0.14	SC	1.90	0.70	46.00	6.00	2.45	1.96	2.21	8.45	70.50
9.04	SM	4.00	17.40	0.18	SC	2.22	0.90	63.00	8.00	2.92	2.49	5.93	11.50	91.50
9.10	SM	15.00	18.00	0.13	SC	2.28	0.60	62.00	6.00	0.65	0.65	3.00	12.16	57.00
6.17	SM	12.00	21.00	0.19	SC	2.40	1.05		6.00	2.74	2.59	11.14	13.50	103.50
4.10	SM	0.00	22.00	0.10	SC	2.80	0.60	105.00	6.00	3.61	3.48	2.70	18.30	194.40
6.20	SM	11.00	22.00	0.07	SCL	3.00	1.60	59.30	6.00	4.17	4.17	10.10	21.00	168.75
7.09	ASH	20.00	24.10	0.05	SCL	0.40	0.11	75.00	4.00	0.89	0.89	0.55	0.31	16.50
10.21	ASH	13.00	20.30	0.40	C	0.50	0.45	17.00		0.17	0.11	0.47	0.46	14.25
7.24	ASH	74.00	21.40	0.38	SC	0.55	0.50	45.00	5.00	0.19	0.15	0.72	0.55	30.00
7.15	ASH	12.00	26.40	0.10	SC	0.57	0.40	42.50	5.00	0.24	0.24	1.04	0.58	9.00
7.23	ASH	14.00	26.40	0.10	SC	0.60	0.25	28.50	5.00	0.13	0.13	0.94	0.64	7.50
7.29	ASH		30.00	0.15	SC	0.65	0.50	16.00		0.40	0.40	0.58	0.74	18.00
7.28	ASH	18.00	30.00	0.13	SC	0.68	0.50	18.00		0.26	0.26	0.55	0.46	13.50
7.21	ASH	0.00	26.40	0.05	SCL	0.71	0.40	35.00	5.00	0.78	0.78	0.51	0.88	31.50
7.17	ASH	77.00	27.30	0.42	SC	0.80	0.30	56.00	4.00	0.72	0.72	0.96	1.10	114.50
7.14	ASH	20.00	26.90	0.20	SC	0.80	0.58	50.00	6.00	0.42	0.42	1.16	1.09	10.50
11.06	ASH	40.00	25.20	0.10	SC	0.80				2.27	2.27			45.00
10.01	ASH	10.00	22.90	0.10	SC	0.85	0.50	65.00	6.00	0.67	0.33	1.77	1.29	148.50
7.19	ASH	30.00	26.40	0.12	SC	0.89	0.40	41.80	5.00	0.96	0.96	1.24	1.35	21.75
11.12	ASH	20.00	26.00	0.14	SC	0.90				2.10	1.53			33.75
11.20	ASH	4.00	21.40	0.06	SCL	1.04	0.90	63.00	7.00	1.83	1.83	1.81	1.83	27.45
10.19	ASH	23.00	22.00	0.02	SCL	1.05	0.40	55.00	5.00	1.01	0.96	0.95	1.86	34.50
11.11	ASH	7.00	25.20	0.10	SC	1.10				2.37	2.37			21.00
7.01	ASH	20.00	24.10	0.10	SC	1.10	0.70	37.00	5.00	0.69	0.69	1.17	2.03	97.50
10.06	ASH	45.00	17.40	0.18	SC	1.10	0.50	14.50	6.00	0.22	0.21	1.00	2.03	6.00
11.18	ASH	7.00	21.90	0.14	SC	1.20	0.94	19.00	5.00	1.05	1.05	3.87	2.41	36.90
11.25	ASH	53.00	21.40	0.02	SCL	1.20	1.10	41.00	5.00	1.89	1.89	2.18	3.03	68.70
11.15	ASH	10.00	25.50	0.01	SCL	1.25	1.00	156.00	7.00	1.82	1.67	2.86	2.61	40.50
11.19	ASH	4.00	21.40	0.02	SCL	1.30				1.70	1.61			51.15
11.22	ASH	20.00	21.80	0.14	SC	1.30	0.63	24.30	7.00	0.44	0.38	1.83	2.82	33.00
7.10	ASH	27.00	22.00	0.16	SC	1.40	0.15	59.00	5.00	1.50	1.50	1.18	3.26	12.00
7.07	ASH	50.00	20.70	0.42	SC	1.40	0.25	34.20	4.00	0.11	0.11	0.33	3.26	12.00
7.08	ASH	26.00	21.30	0.22	SC	1.40	0.60	80.00	5.00	2.59	2.59	1.66	3.26	33.00
7.11	ASH	0.00	24.10	0.10	SC	1.42	1.10	44.00		1.00	1.00	2.26	3.30	13.50
11.23	ASH	4.00	22.40	0.17	SC	1.50	0.62	56.20	5.00	2.03	2.03	1.98	3.74	60.75
11.21	ASH	23.00	21.40	0.08	SCL	1.50	1.40	28.00		0.26	0.26	3.35	3.74	4.50
7.04	ASH		21.30	0.20	SC	1.54	0.47	47.00	5.00	0.66	0.63	1.08	3.90	48.00
7.22	ASH	20.00	26.40	0.10	SC	1.57	0.80	119.80	6.00	3.24	1.46	2.30	4.10	114.00
10.13	ASH	3.00	22.00	0.09	SCL	1.62	1.20	13.00	5.00	0.37	0.31	3.67	4.35	10.50
10.04	ASH	0.00	22.90	0.04	SCL	1.70	1.20	62.00	6.00	2.05	2.05	7.99	4.78	130.65
10.11	ASH	15.00	22.00	0.12	SC	1.90	0.90	38.00	7.00	1.88	1.16	3.41	5.97	59.25
7.27	ASH	0.00	33.00	0.10	SC	2.02	1.50	40.00		3.92	3.11	4.71	6.74	67.50
7.20	ASH	10.00	26.90	0.17	SC	2.30	1.00	135.00	6.00	7.77	7.29	3.97	8.72	102.00
11.13	ASH	10.00	25.20	0.05	SCL	2.60	1.90	20.00	8.00	4.13	3.26	10.90	11.13	110.25

```
11.05ASH  11.00 27.60 0.18SC 2.80 2.00  73.00 7.00 5.31 5.25 11.2512.90  99.00
10.17ASH  90.00 22.40 0.40C  3.20                  4.08 0.99              120.00
10.10ASH   0.00 22.90 0.07SC14.00 2.20  95.00 7.00 5.36 4.22
/*
//TDAT DD *
 5.02  33.00350
 5.07  14.25140
 9.11  42.00 80
 5.03  65.75310
 5.06  36.00175
 4.17  75.00 25
 2.05  70.50180
 2.12  66.00115
 9.03  37.50 75
 4.14  35.25 90
 4.16  63.00 10
 2.10  38.25115
 2.07  44.25140
10.15  13.05 20
 2.02  34.51 80
 2.11  17.25125
 5.01   6.00310
 4.15  37.50120
 4.12  60.00120
 6.15  49.50360
 9.22  39.00255
 5.05  75.00135
 2.15  66.00 70
 9.07  31.50 50
 4.08 150.00 65
 9.05  34.50  1
 2.16  42.00100
 2.18  37.50100
 4.20  52.50 60
 2.08  90.00 90
10.16   9.75350
10.07  50.40180
 9.09  36.00320
 2.17          180
 6.14 156.00310
 4.01           90
 9.06  28.50 40
 4.09 168.00100
 9.19  34.50260
 4.03 192.00 80
 4.07  67.50 70
 6.04 102.00160
 4.19 139.50 40
 9.02 100.50 70
 6.02 269.25 30
 2.01 135.00170
 9.04  97.50 20
 9.10  57.00350
 6.17 114.75355
 4.10 194.40290
 6.20 187.50278
 7.09  16.50260
10.21  18.75350
```

```
 7.24  96.00110
 7.15   9.00340
 7.23   7.50145
 7.29  18.75
 7.28  18.00120
 7.21  31.50100
 7.17 114.00105
 7.14  10.50355
11.06  45.03180
10.01 114.50
 7.19  21.75190
11.12  43.50200
11.20  27.45130
10.19  35.25 90
11.11  30.02180
 7.01 103.50270
10.06  16.50255
11.18  36.90100
11.25  68.70120
11.15  60.00200
11.19  55.20130
11.22  36.90100
 7.10  12.00260
 7.07  12.00295
 7.08  43.50275
 7.11  13.50 30
11.23  60.75 50
11.21   4.50130
 7.04  66.00
 7.22 174.00140
10.13  49.50 30
10.04 130.65230
10.11  66.00340
 7.27  70.65 90
 7.20 135.00180
11.13 154.00170
11.05 117.75170
10.17 234.00  1
10.10 100.00
/*
```

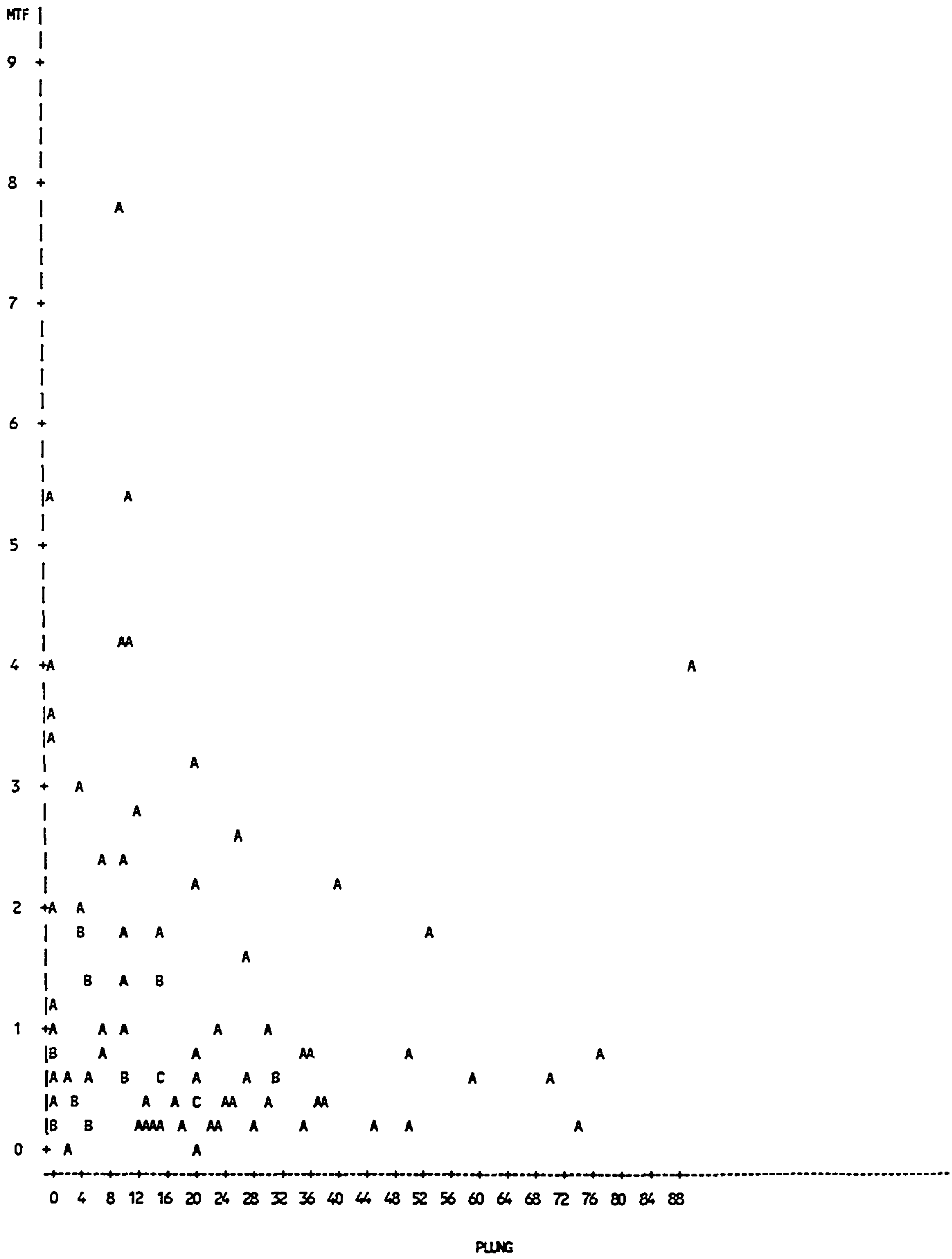
SAS 9:50 TUESDAY, AUGUST 25, 1987 1

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PLUNG	89	18.80898876	18.88654909	1674.00000000	0.00000000	90.00000000
MOIST	90	22.14111111	3.10794178	1992.70000000	16.00000000	33.00000000
DEPH	92	0.19010870	0.11985792	17.49000000	0.00000000	0.51000000
DV	91	1.11692308	0.72566244	101.64000000	0.22000000	4.00000000
DB	85	1.05047059	4.02503206	89.29000000	0.09000000	37.50000000
LENGH	83	41.83253012	28.55194286	3472.10000000	0.00000000	156.00000000
ORDER	65	5.44615385	0.98473933	354.00000000	4.00000000	8.00000000
MTF	90	1.25922222	1.40589787	113.33000000	0.02000000	7.77000000
TBF	90	1.11288889	1.24176500	100.16000000	0.01000000	7.29000000
ENDS	83	2.11120482	2.44036253	175.23000000	0.21000000	11.25000000
EXDV	83	3.05638554	4.01960639	253.68000000	0.11000000	21.00000000
TIME	87	56.37241379	50.17246868	4904.40000000	4.50000000	269.25000000
TTF	90	66.38020000	55.67717564	5974.21800000	0.01000000	269.25000000

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

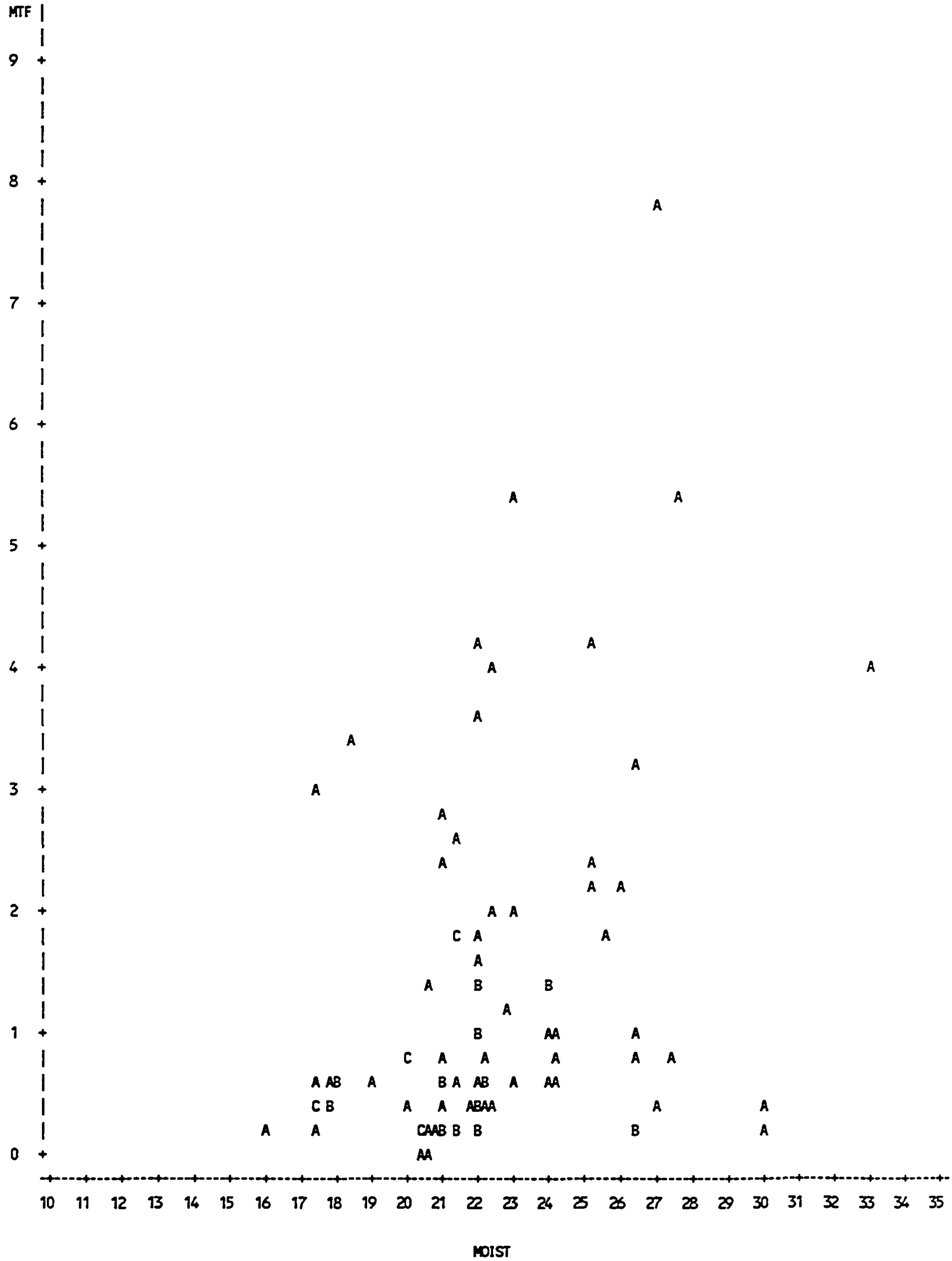
	PLUNG	MOIST	DEPH	DV	DB	LENGH	ORDER	MTF	TBF	ENDS	EXDV	TIME	TTF
PLUNG	1.00000	-0.08790	0.48672	-0.08976	-0.32919	-0.09801	-0.36530	-0.13837	-0.22361	-0.29907	-0.22550	0.01893	0.05532
	0.0000	0.4127	0.0001	0.4029	0.0024	0.3840	0.0028	0.1960	0.0352	0.0063	0.0417	0.8627	0.6108
	89	89	89	89	83	81	65	89	89	82	82	86	87
MOIST	-0.08790	1.00000	-0.30504	0.15993	0.30593	0.17523	0.11633	0.32367	0.30522	0.16355	0.07929	0.10414	0.10069
	0.4127	0.0000	0.0035	0.1321	0.0047	0.1154	0.3561	0.0019	0.0034	0.1396	0.4762	0.3371	0.3506
	89	90	90	90	84	82	65	90	90	83	83	87	88
DEPH	0.48672	-0.30504	1.00000	-0.35848	-0.23316	-0.32212	-0.51439	-0.33798	-0.37691	-0.39032	-0.34145	-0.10081	-0.08017
	0.0001	0.0035	0.0000	0.0005	0.0318	0.0030	0.0001	0.0011	0.0003	0.0003	0.0016	0.3529	0.4578
	89	90	92	91	85	83	65	90	90	83	83	87	88
DV	-0.08976	0.15993	-0.35848	1.00000	0.14649	0.49021	0.63027	0.81398	0.74040	0.80695	0.93458	0.51443	0.54618
	0.4029	0.1321	0.0005	0.0000	0.1809	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	89	90	91	91	85	83	65	90	90	83	83	87	88
DB	-0.32919	0.30593	-0.23316	0.14649	1.00000	-0.12997	0.58461	0.70645	0.68736	0.81457	0.63167	0.38528	0.39730
	0.0024	0.0047	0.0318	0.1809	0.0000	0.2416	0.0001	0.0001	0.0001	0.0001	0.0001	0.0004	0.0002
	83	84	85	85	85	83	65	84	84	83	83	81	82
LENGH	-0.09801	0.17523	-0.32212	0.49021	-0.12997	1.00000	0.33401	0.63791	0.62281	0.30904	0.41675	0.34026	0.36844
	0.3840	0.1154	0.0030	0.0001	0.2416	0.0000	0.0070	0.0001	0.0001	0.0050	0.0001	0.0022	0.0008
	81	82	83	83	83	83	64	82	82	81	81	79	80
ORDER	-0.36530	0.11633	-0.51439	0.63027	0.58461	0.33401	1.00000	0.53198	0.48320	0.58175	0.52345	0.26718	0.33094
	0.0028	0.3561	0.0001	0.0001	0.0001	0.0070	0.0000	0.0001	0.0001	0.0001	0.0001	0.0358	0.0081
	65	65	65	65	65	64	65	65	65	64	64	62	63
MTF	-0.13837	0.32367	-0.33798	0.81398	0.70645	0.63791	0.53198	1.00000	0.95805	0.69755	0.73589	0.46633	0.52280
	0.1960	0.0019	0.0011	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001
	89	90	90	90	84	82	65	90	90	83	83	87	88
TBF	-0.22361	0.30522	-0.37691	0.74040	0.68736	0.62281	0.48320	0.95805	1.00000	0.69899	0.73981	0.43511	0.43459
	0.0352	0.0034	0.0003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001
	89	90	90	90	84	82	65	90	90	83	83	87	88
ENDS	-0.29907	0.16355	-0.39032	0.80695	0.81457	0.30904	0.58175	0.69755	0.69899	1.00000	0.78410	0.46729	0.50371
	0.0063	0.1396	0.0003	0.0001	0.0001	0.0050	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001
	82	83	83	83	83	81	64	83	83	83	83	81	81
EXDV	-0.22550	0.07929	-0.34145	0.93458	0.63167	0.41675	0.52345	0.73589	0.73981	0.78410	1.00000	0.53707	0.55052
	0.0417	0.4762	0.0016	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001
	82	83	83	83	83	81	64	83	83	83	83	81	81
TIME	0.01893	0.10414	-0.10081	0.51443	0.38528	0.34026	0.26718	0.46633	0.43511	0.46729	0.53707	1.00000	0.90919
	0.8627	0.3371	0.3529	0.0001	0.0004	0.0022	0.0358	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001
	86	87	87	87	81	79	62	87	87	81	81	87	86
TTF	0.05532	0.10069	-0.08017	0.54618	0.39730	0.36844	0.33094	0.52280	0.43459	0.50371	0.55052	0.90919	1.00000
	0.6108	0.3506	0.4578	0.0001	0.0002	0.0008	0.0081	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000
	87	88	88	88	82	80	63	88	88	81	81	86	90

PLOT OF MTF*PLUNG LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 5 OBS HAD MISSING VALUES

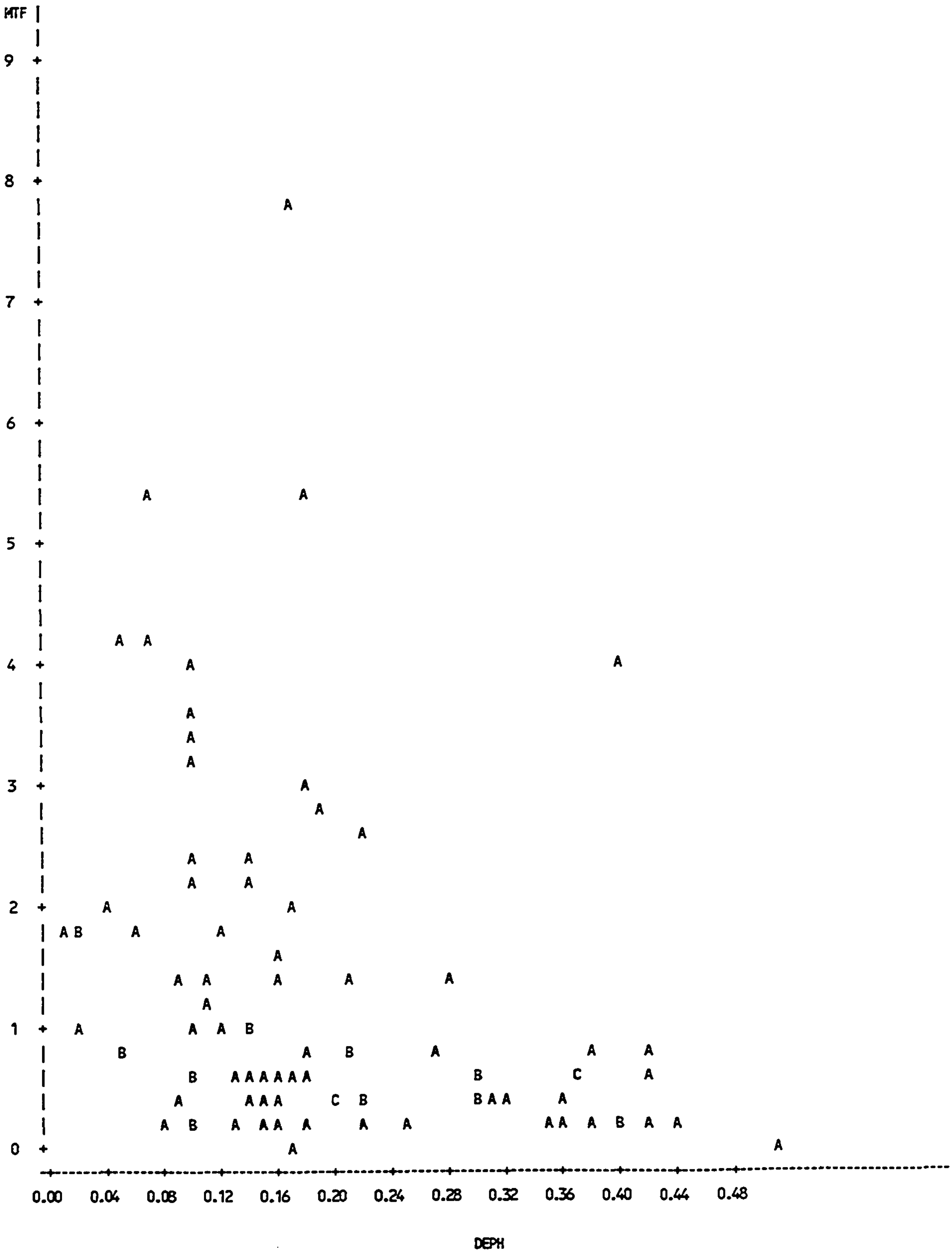
PLOT OF MTF*MOIST LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 4 OBS HAD MISSING VALUES

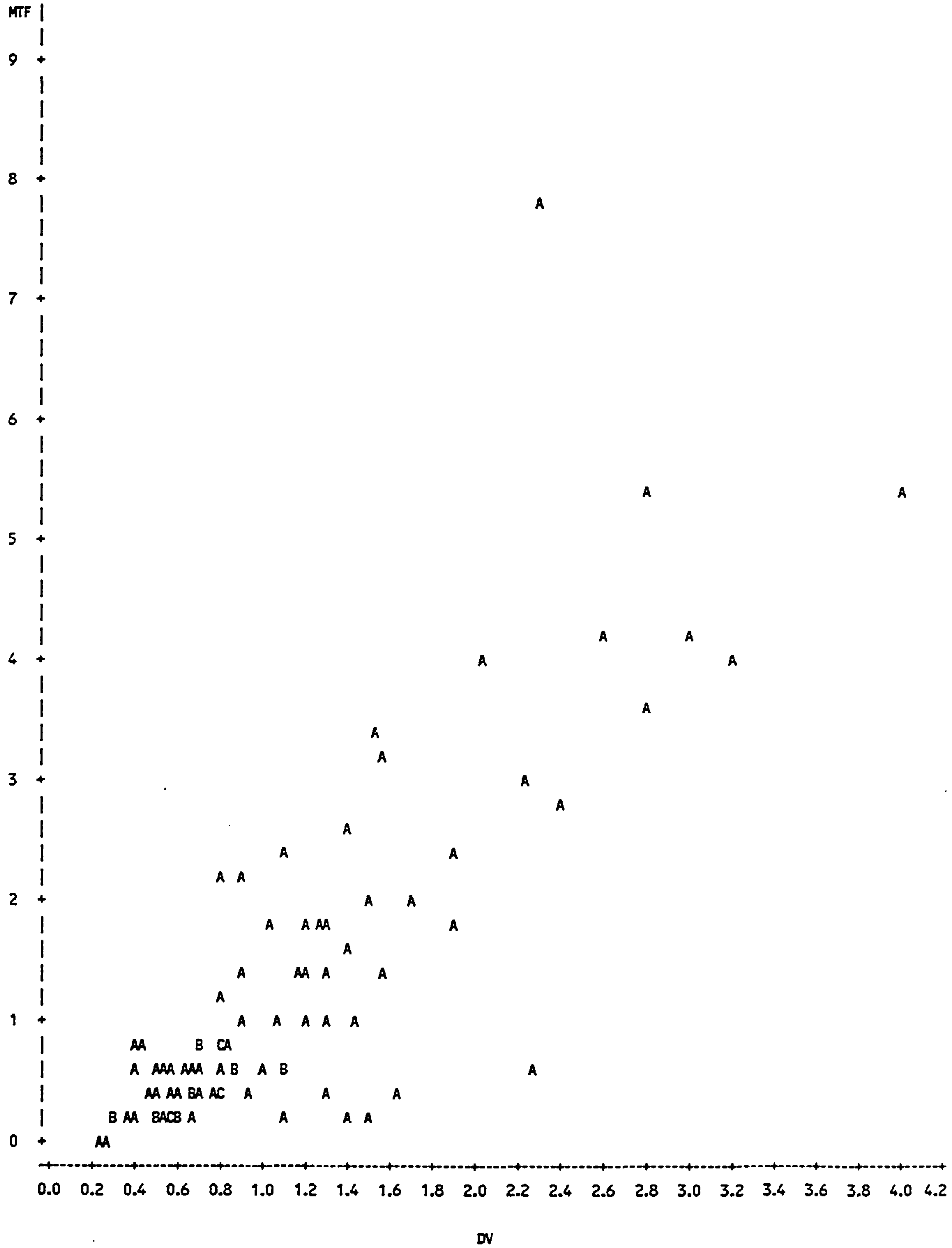
SAS 9:50 TUESDAY, AUGUST 25, 1987 5

PLOT OF MTF*DEPH LEGEND: A = 1 OBS, B = 2 OBS, ETC.



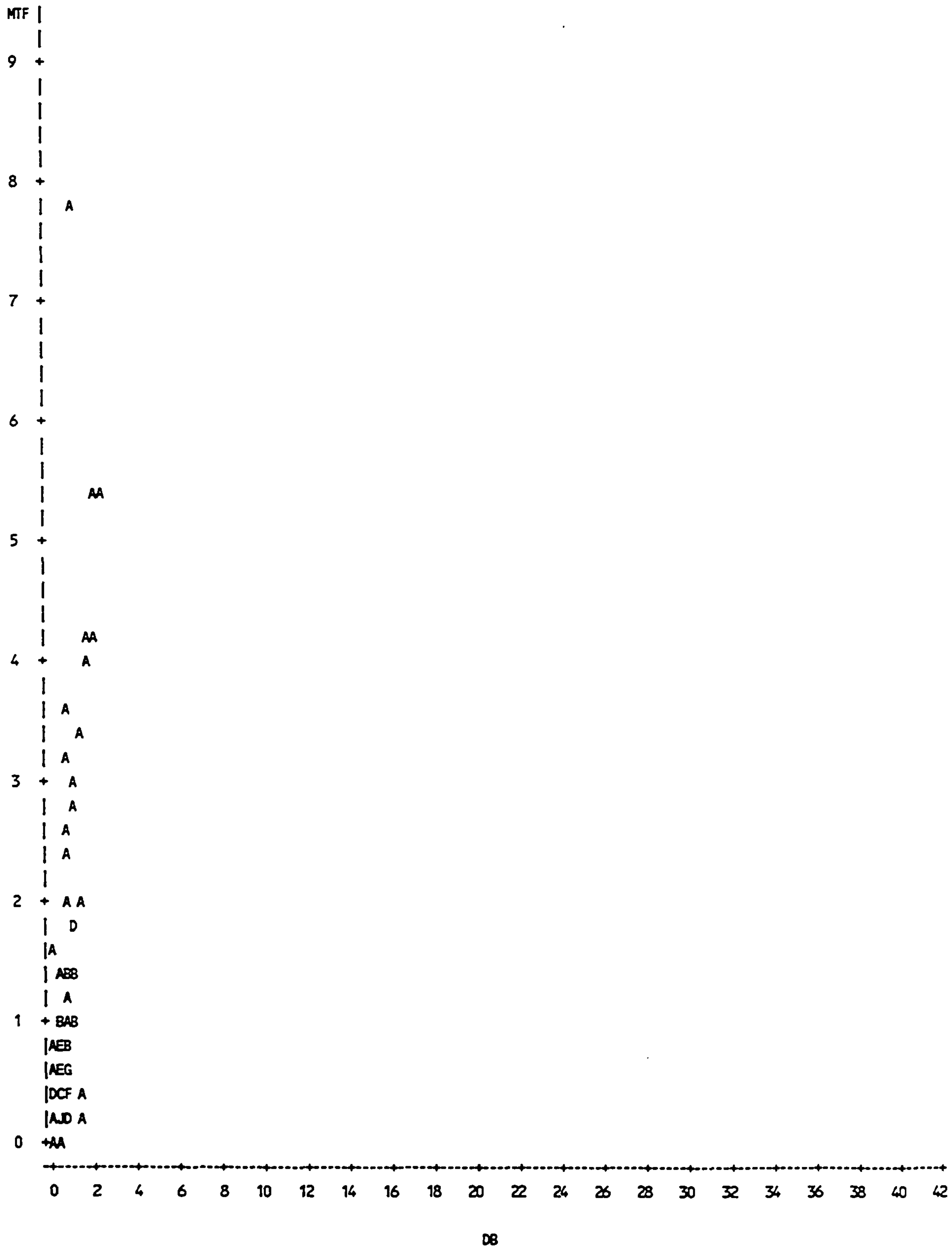
NOTE: 4 OBS HAD MISSING VALUES

PLOT OF MTF*DV LEGEND: A = 1 OBS, B = 2 OBS, ETC.



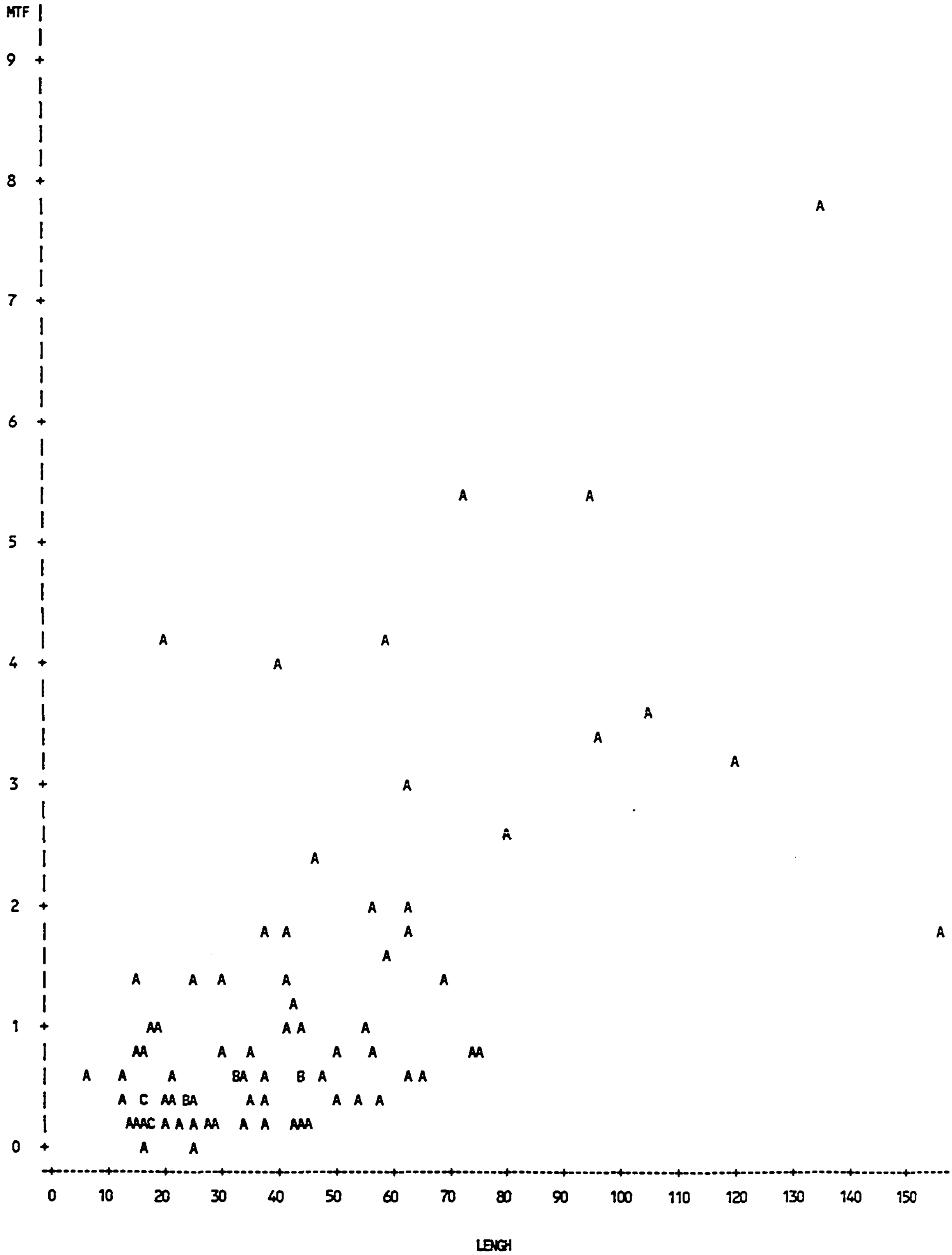
NOTE: 4 OBS HAD MISSING VALUES

PLOT OF MTF*DB LEGEND: A = 1 OBS, B = 2 OBS, ETC.



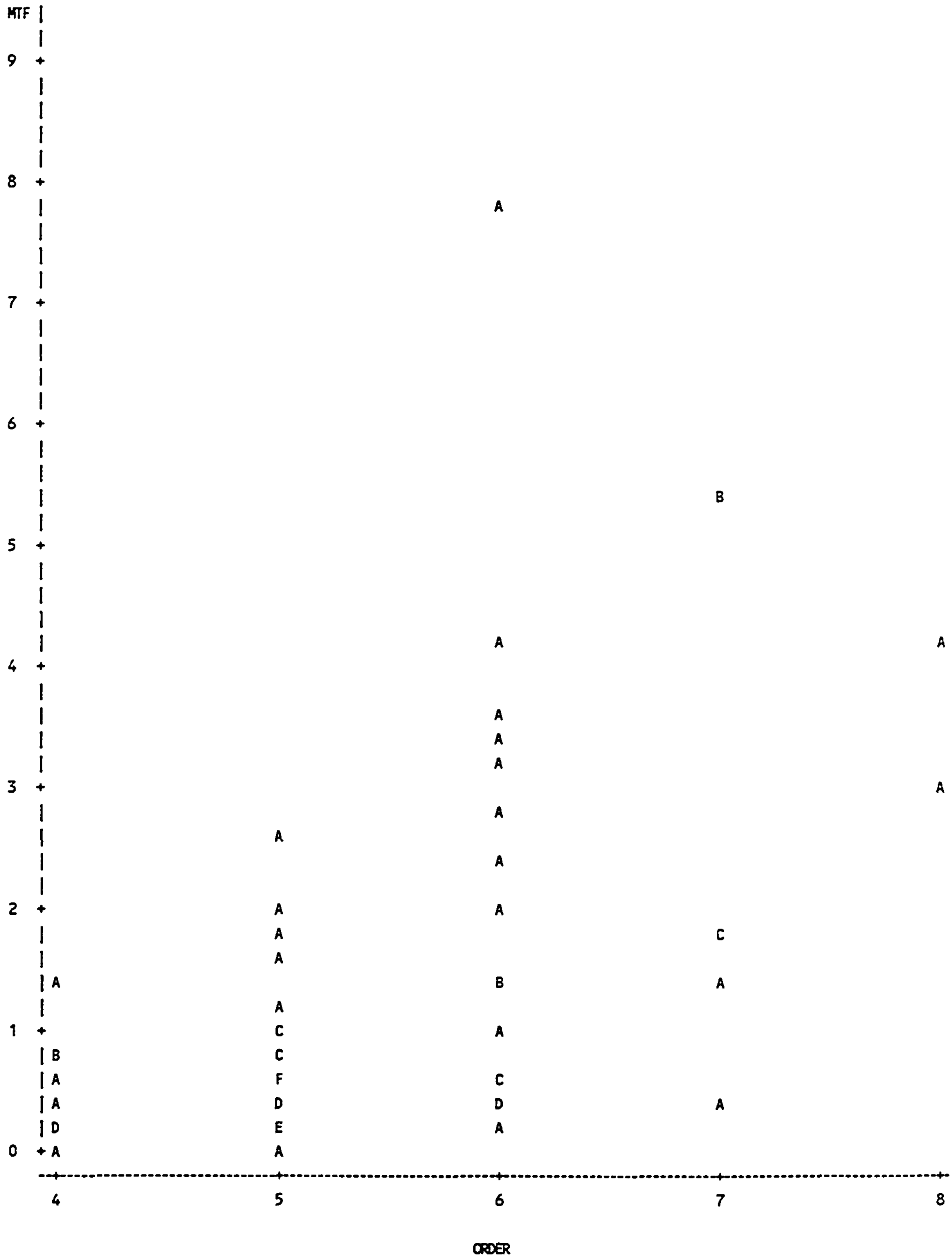
NOTE: 10 OBS HAD MISSING VALUES

PLOT OF MTF*LENGH LEGEND: A = 1 OBS, B = 2 OBS, ETC.



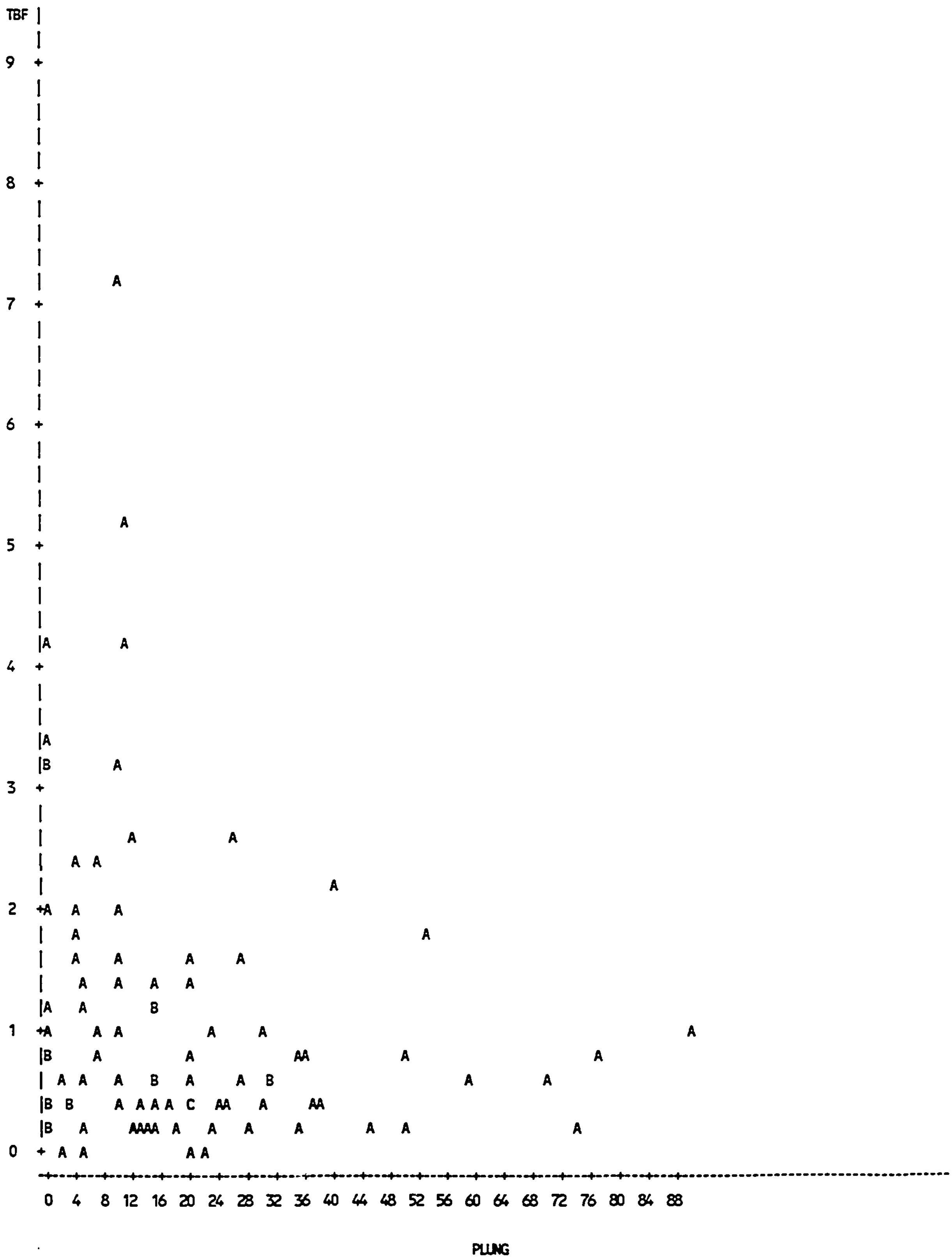
NOTE: 12 OBS HAD MISSING VALUES

PLOT OF MTF*ORDER LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 29 OBS HAD MISSING VALUES

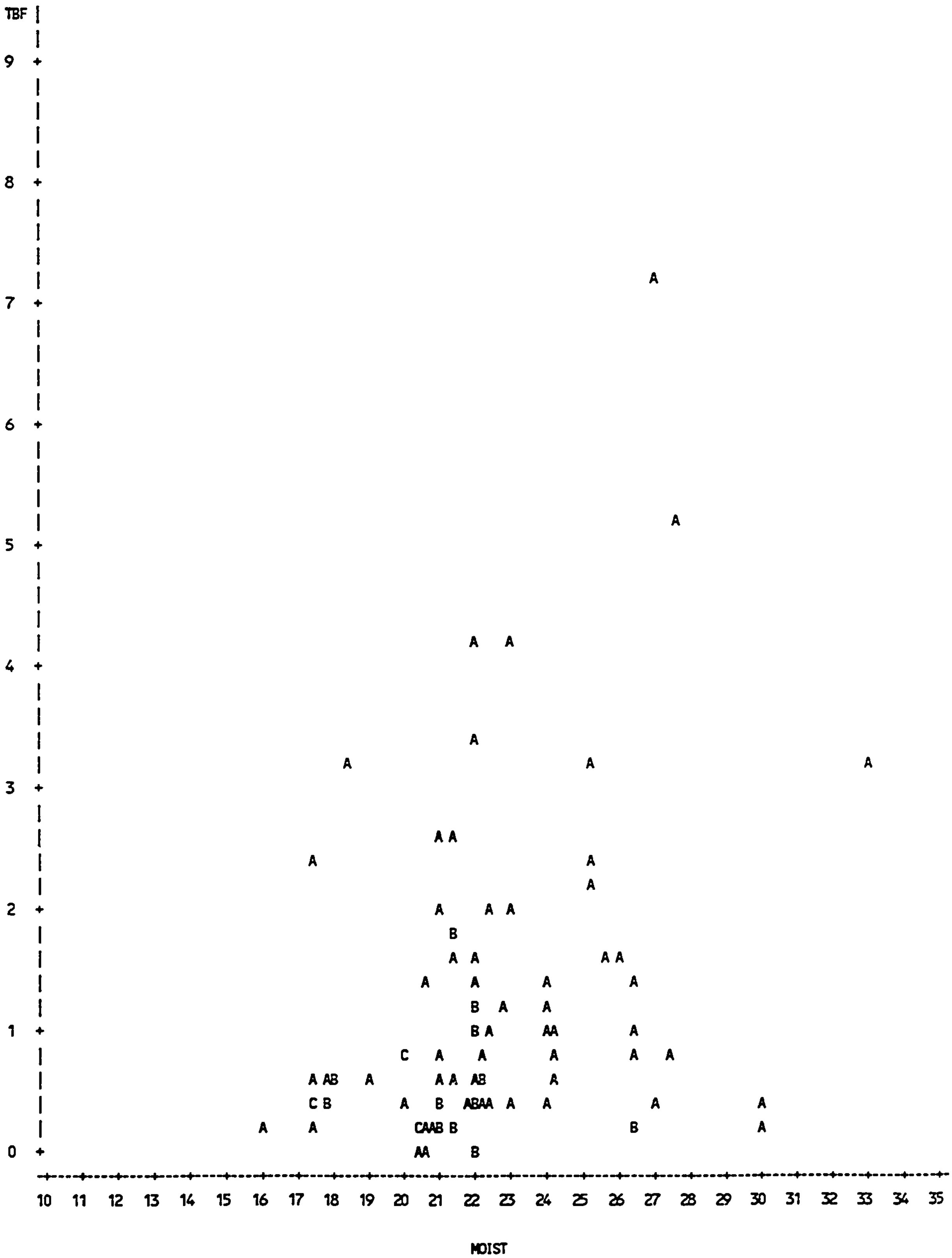
PLOT OF TBF*PLUNG LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 5 OBS HAD MISSING VALUES

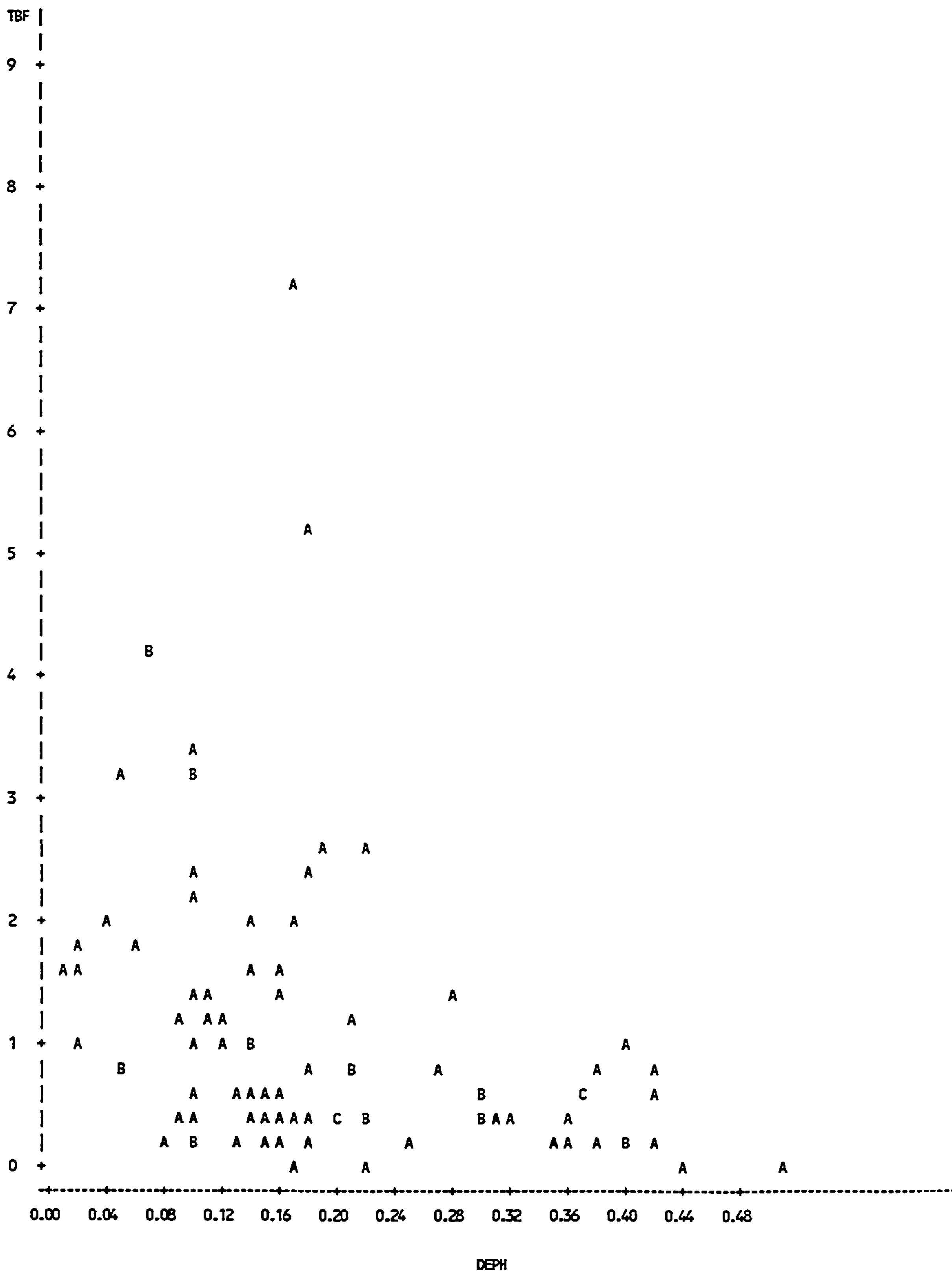
SAS 9:50 TUESDAY, AUGUST 25, 1987 11

PLOT OF TBF*MOIST LEGEND: A = 1 OBS, B = 2 OBS, ETC.



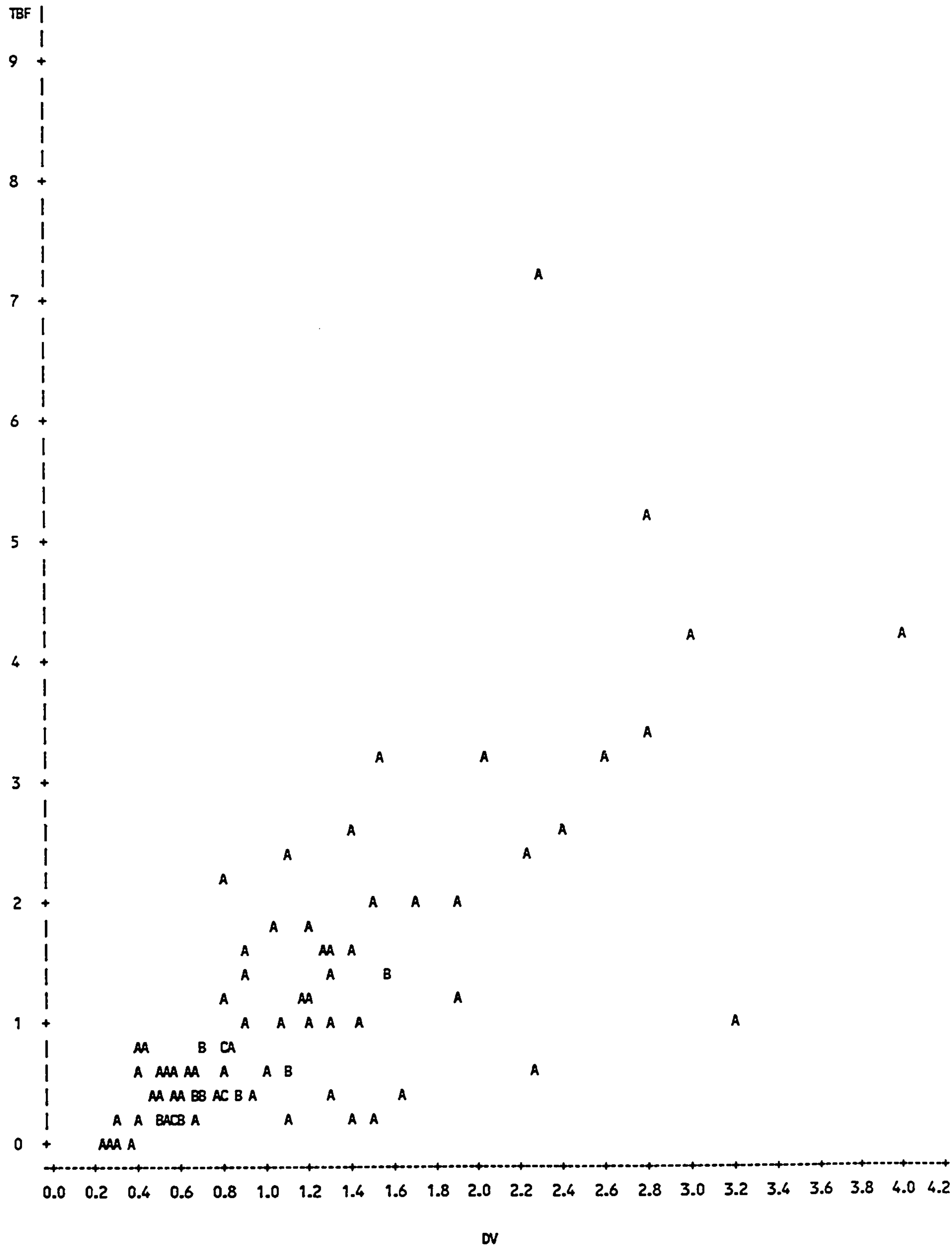
NOTE: 4 OBS HAD MISSING VALUES

PLOT OF TBF*DEPH LEGEND: A = 1 OBS, B = 2 OBS, ETC.



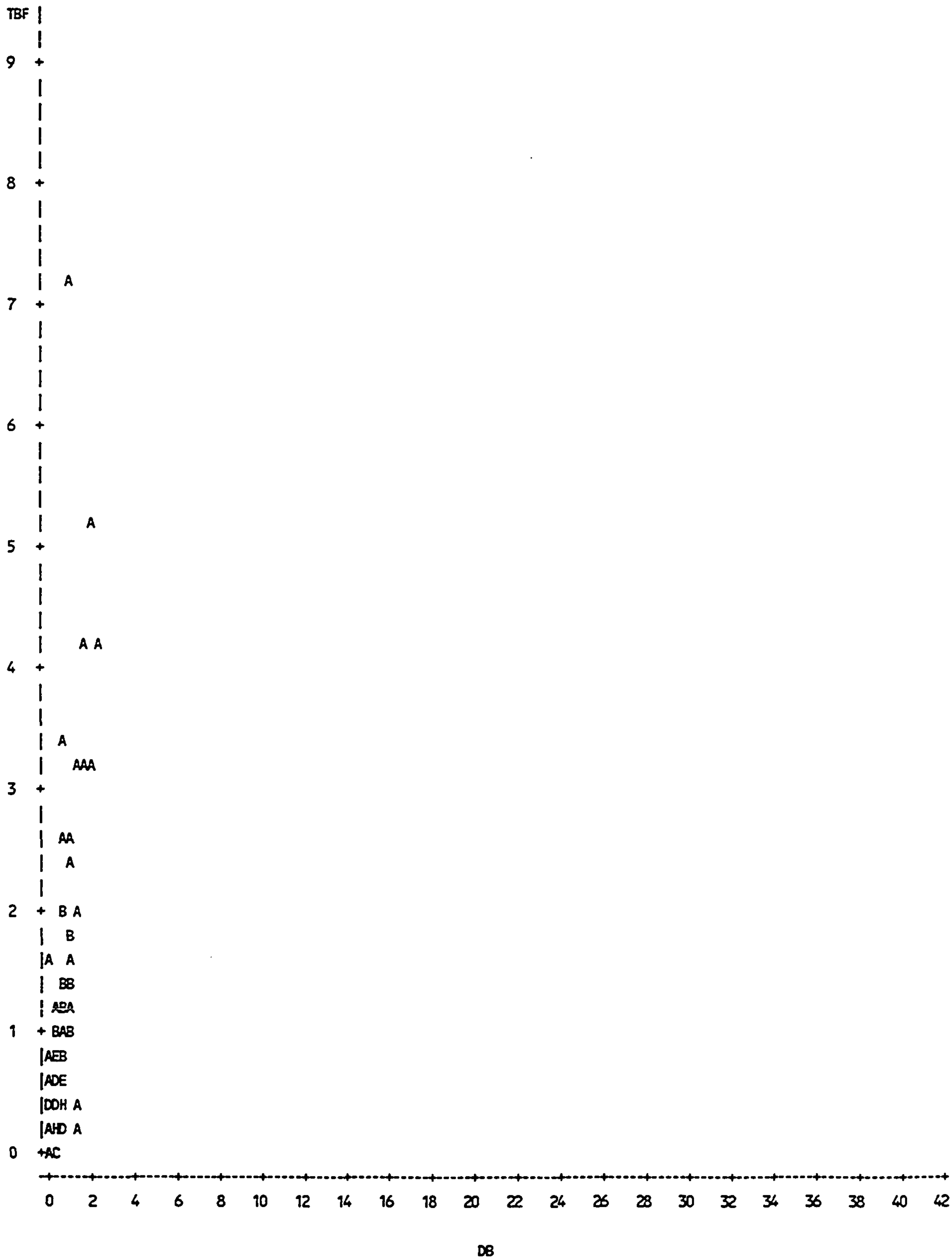
NOTE: 4 OBS HAD MISSING VALUES

PLOT OF TBF*DV LEGEND: A = 1 OBS, B = 2 OBS, ETC.



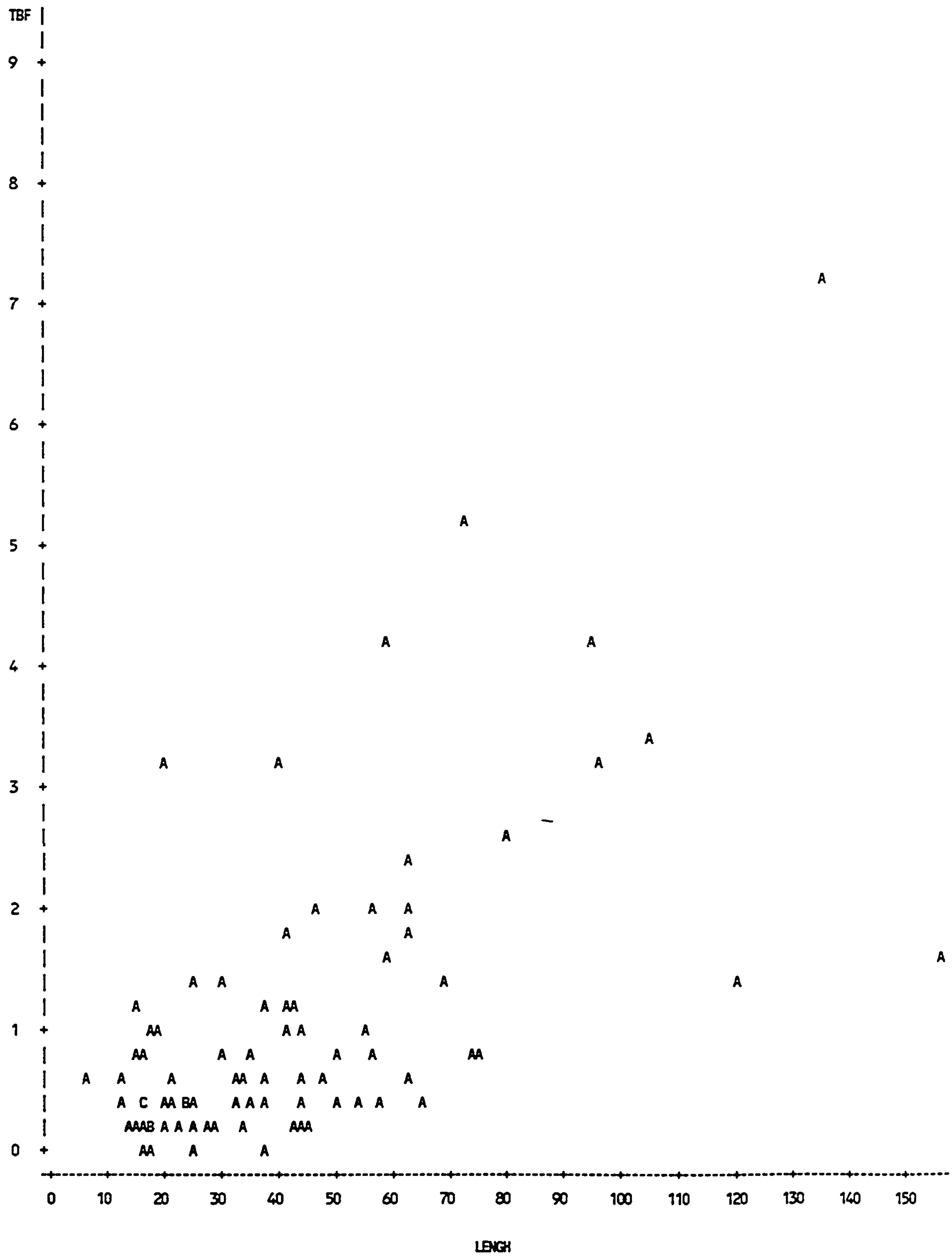
NOTE: 4 OBS HAD MISSING VALUES

PLOT OF TBF*DB LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 10 OBS HAD MISSING VALUES

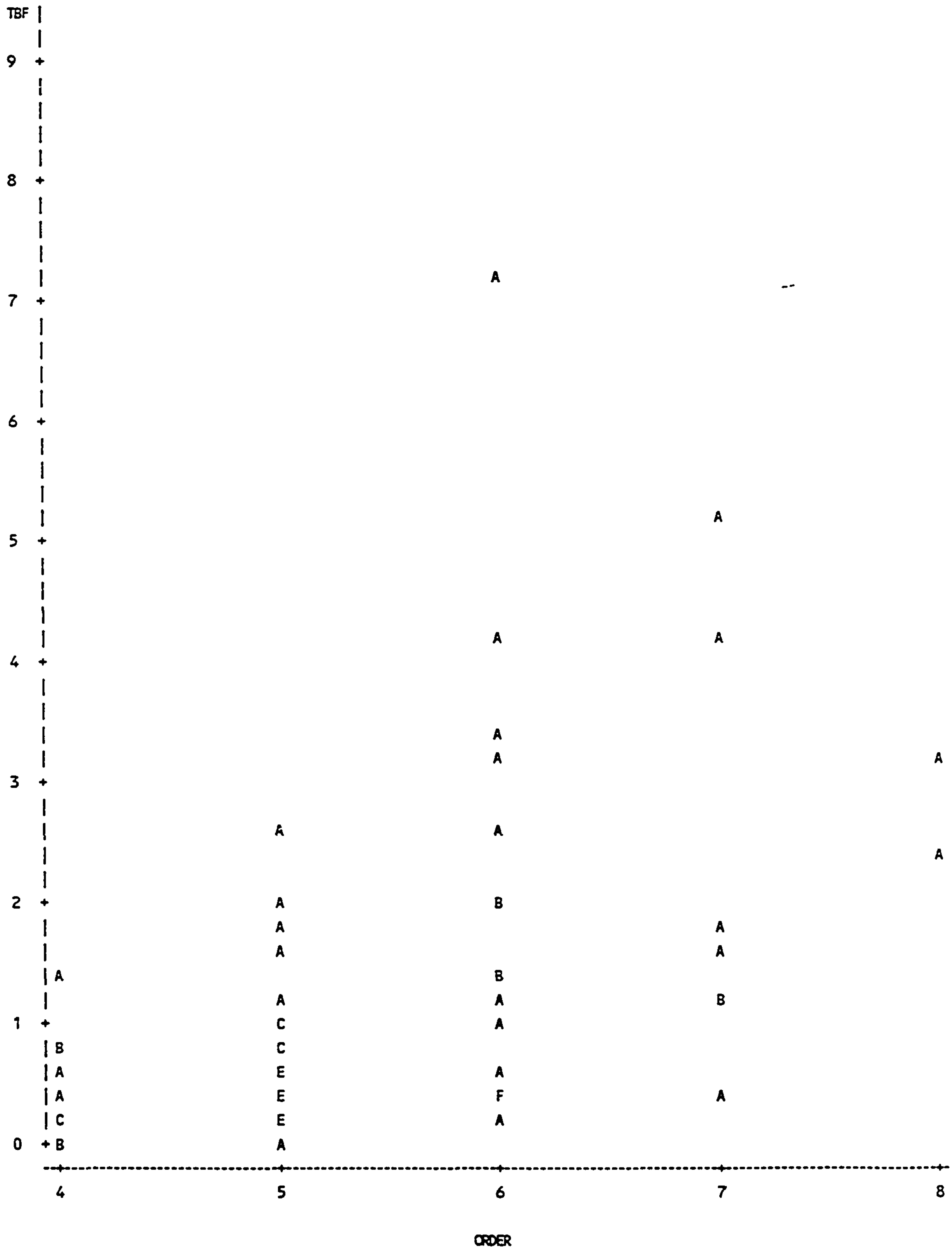
PLOT OF TBF*LENGH LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 12 OBS HAD MISSING VALUES

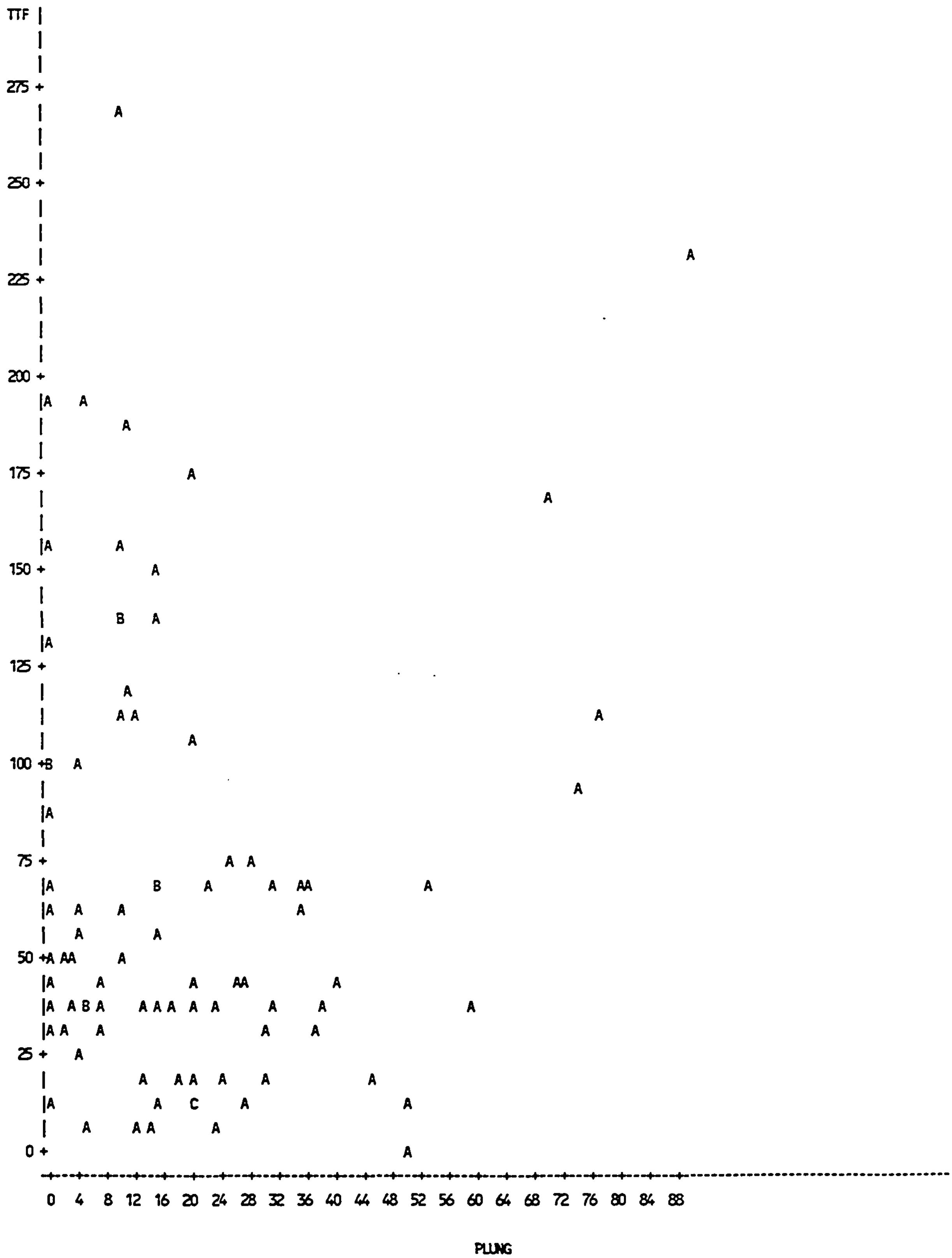
SAS 9:50 TUESDAY, AUGUST 25, 1987 16

PLOT OF TBF*ORDER LEGEND: A = 1 OBS, B = 2 OBS, ETC.



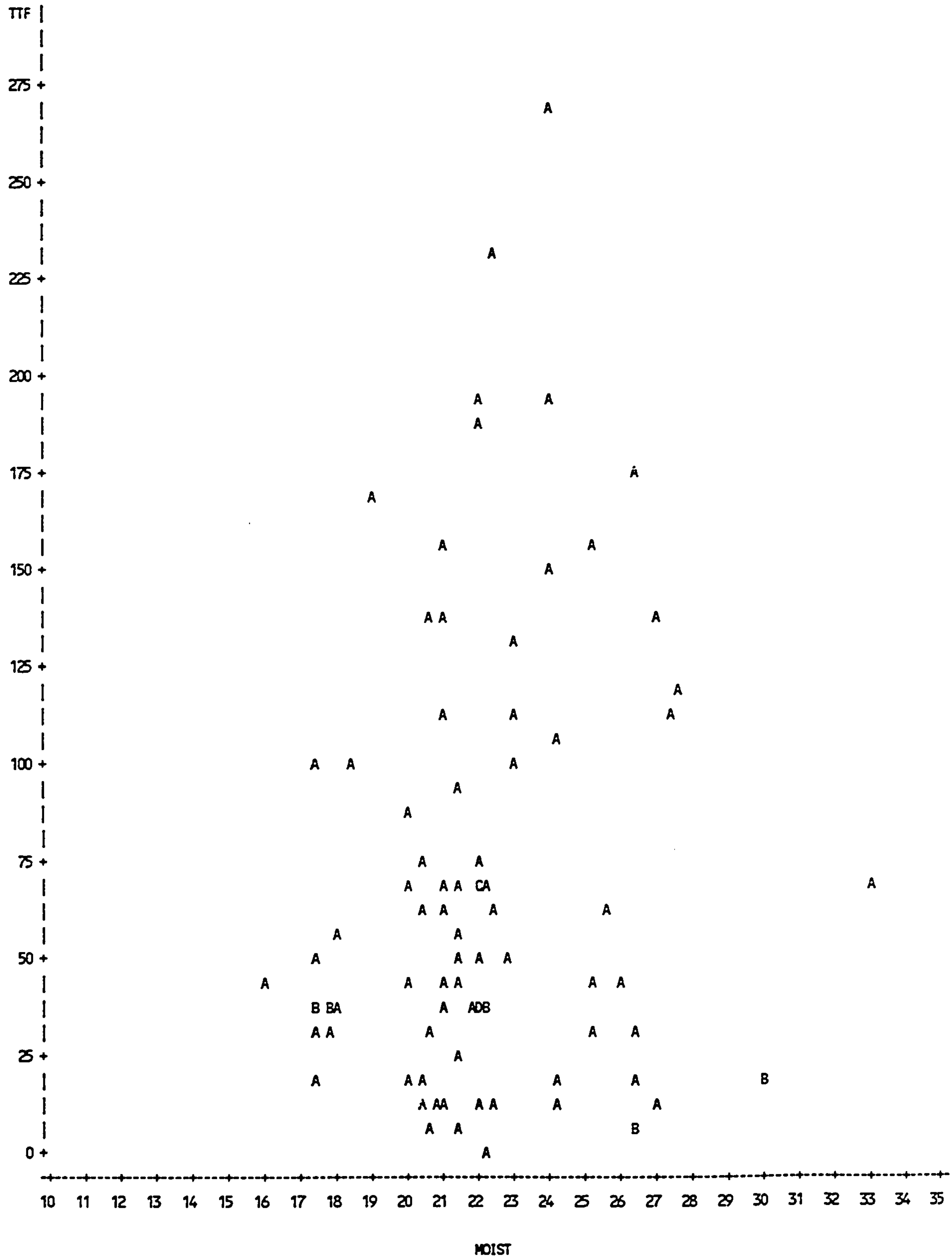
NOTE: 29 OBS HAD MISSING VALUES

PLOT OF TTF*PLUNG LEGEND: A = 1 OBS, B = 2 OBS, ETC.



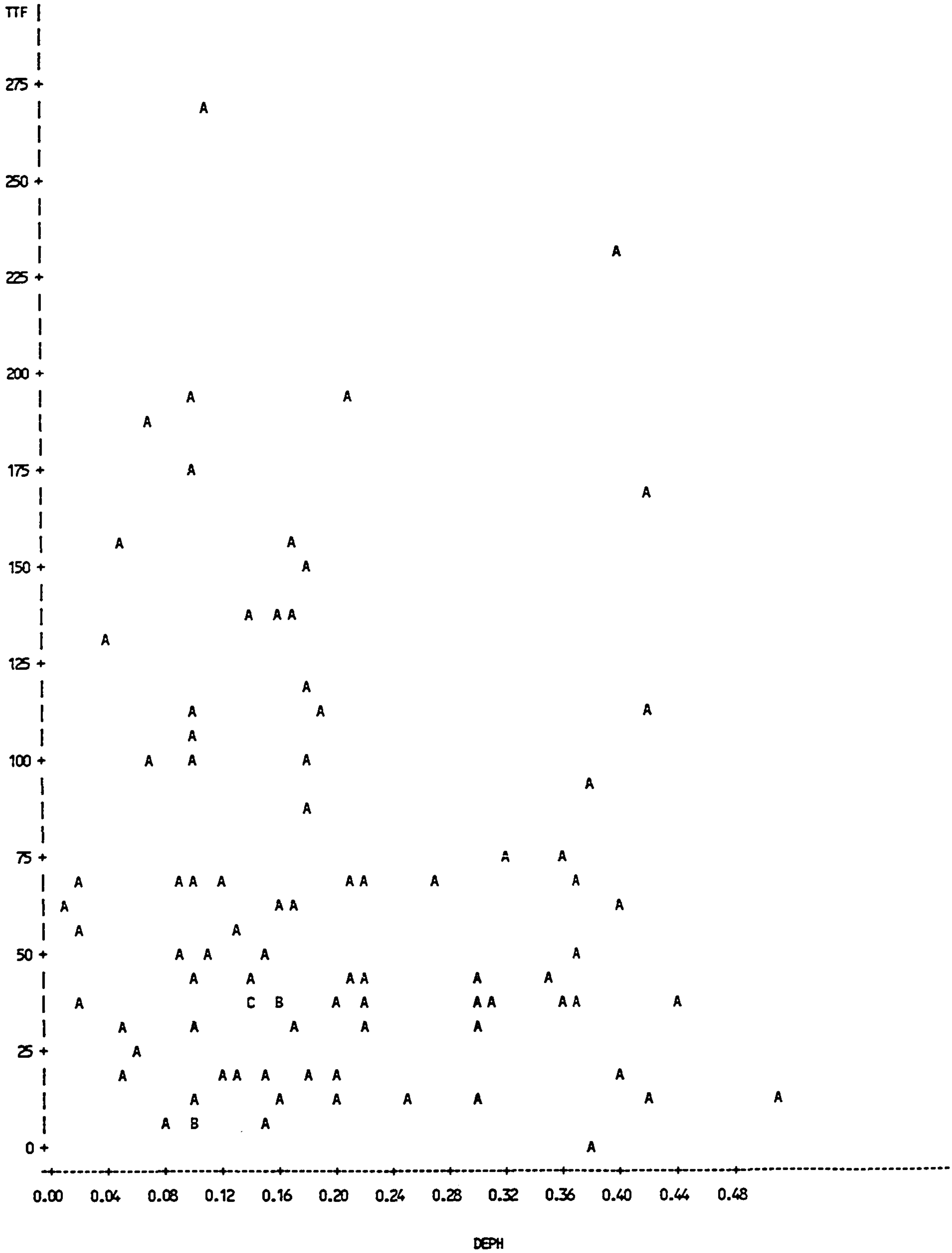
NOTE: 7 OBS HAD MISSING VALUES

PLOT OF TTF*MOIST LEGEND: A = 1 OBS, B = 2 OBS, ETC.



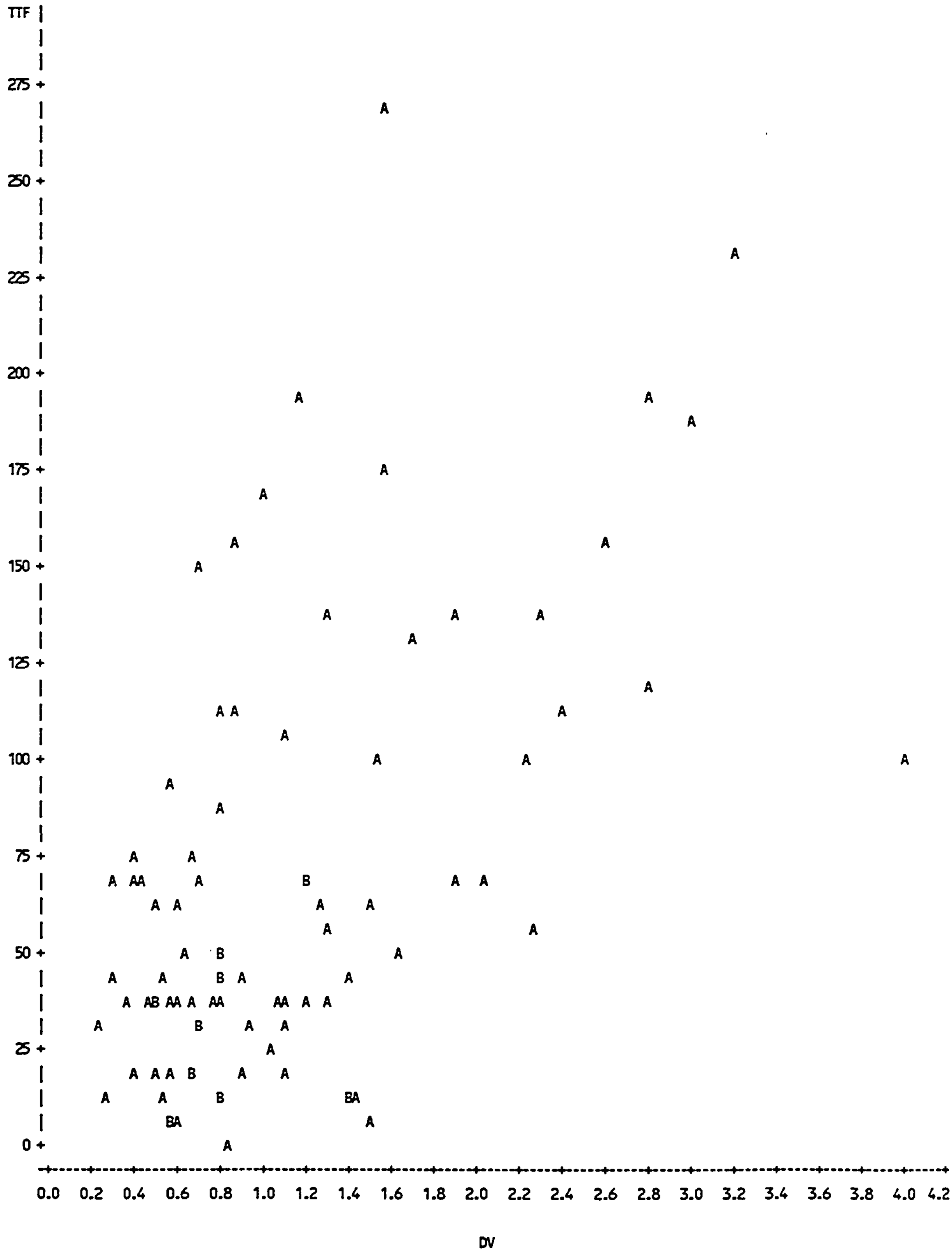
NOTE: 6 OBS HAD MISSING VALUES

PLOT OF TTF*DEPH LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 6 OBS HAD MISSING VALUES

PLOT OF TTF*DV LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 6 OBS HAD MISSING VALUES

PLOT OF TTF*DB LEGEND: A = 1 OBS, B = 2 OBS, ETC.

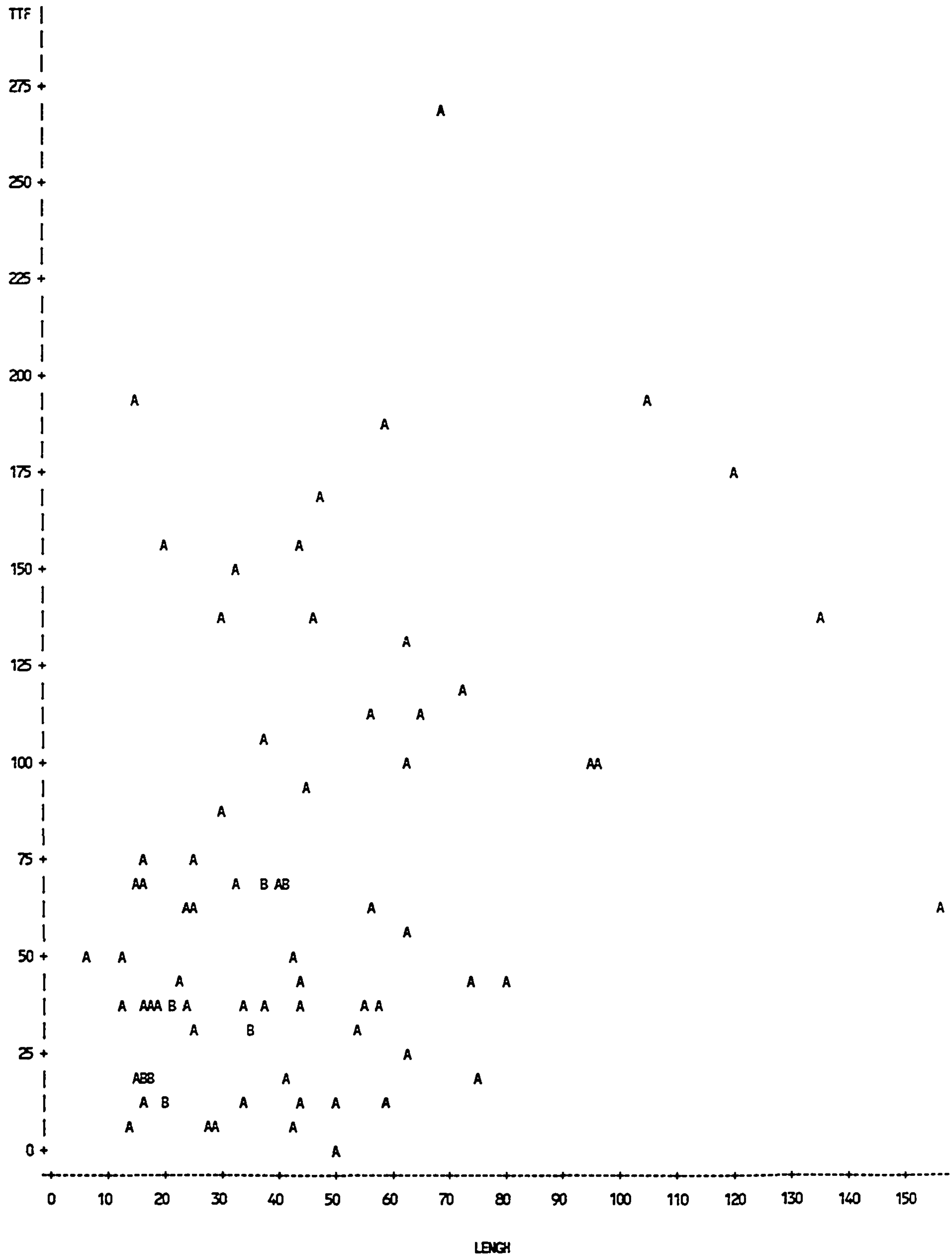
```
TTF |
    |
    |
275 +
    |  A
    |
    |
250 +
    |
    |
    |
225 +
    |
    |
    |
200 +
    | B
    |   A
    |
175 + A
    |A
    |
    |A   A
150 + A
    |
    | AB
    |   A
125 +
    |    A
    |AAA
    | A
100 +  AA A
    | A
    | A
    |
 75 +AA
    |DAB A
    |AAAA
    | A
 50 + C A
    |CA
    |CFBA
    |CA
 25 +  A
    |ABD
    |ABCA
    |C A
  0 +A
    -+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+-
     0    2    4    6    8   10   12   14   16   18   20   22   24   26   28   30   32   34   36   38   40   42

                                                  DB
```

NOTE: 12 OBS HAD MISSING VALUES

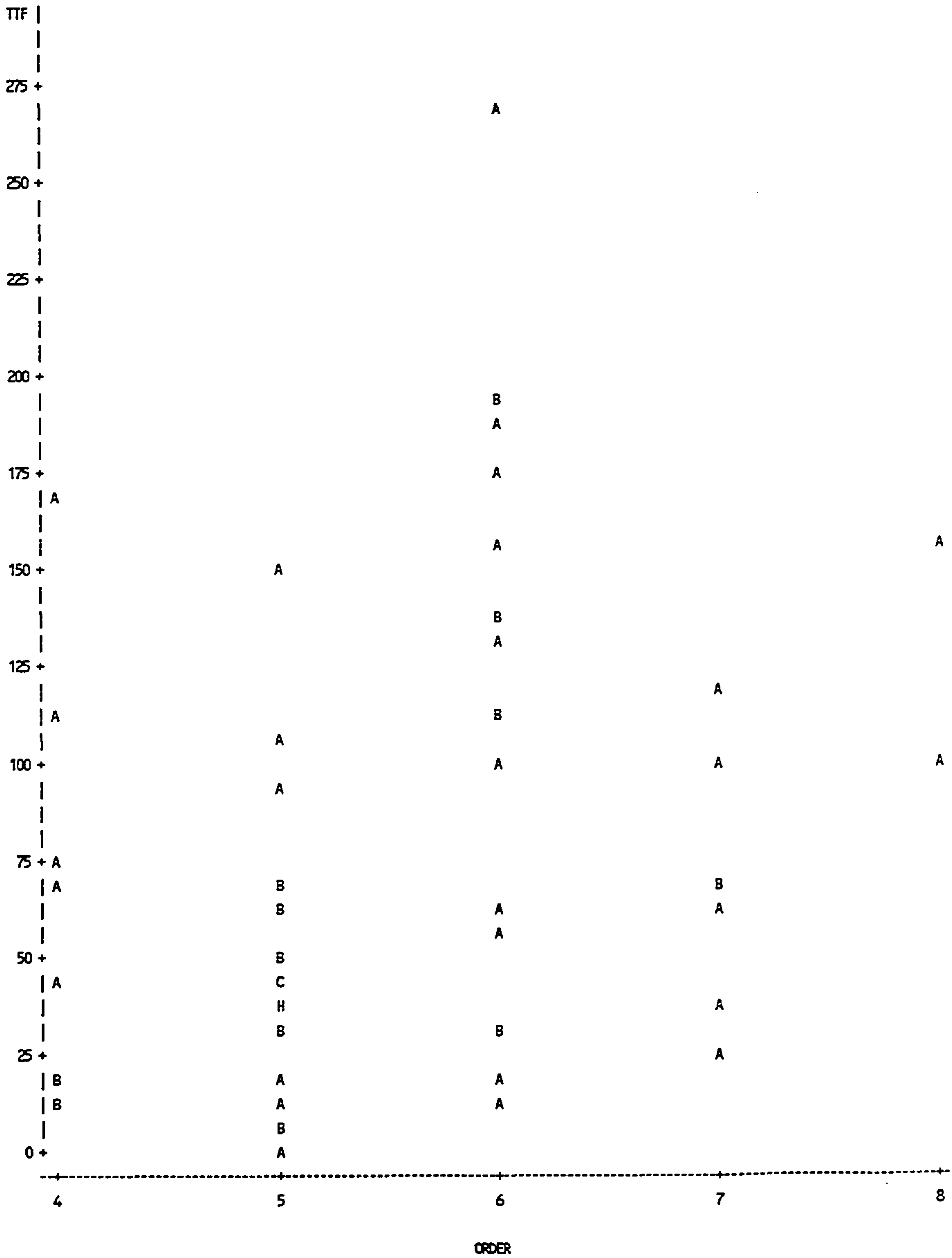
SAS 9:50 TUESDAY, AUGUST 25, 1987 22

PLOT OF TTF*LENGH LEGEND: A = 1 OBS, B = 2 OBS, ETC.



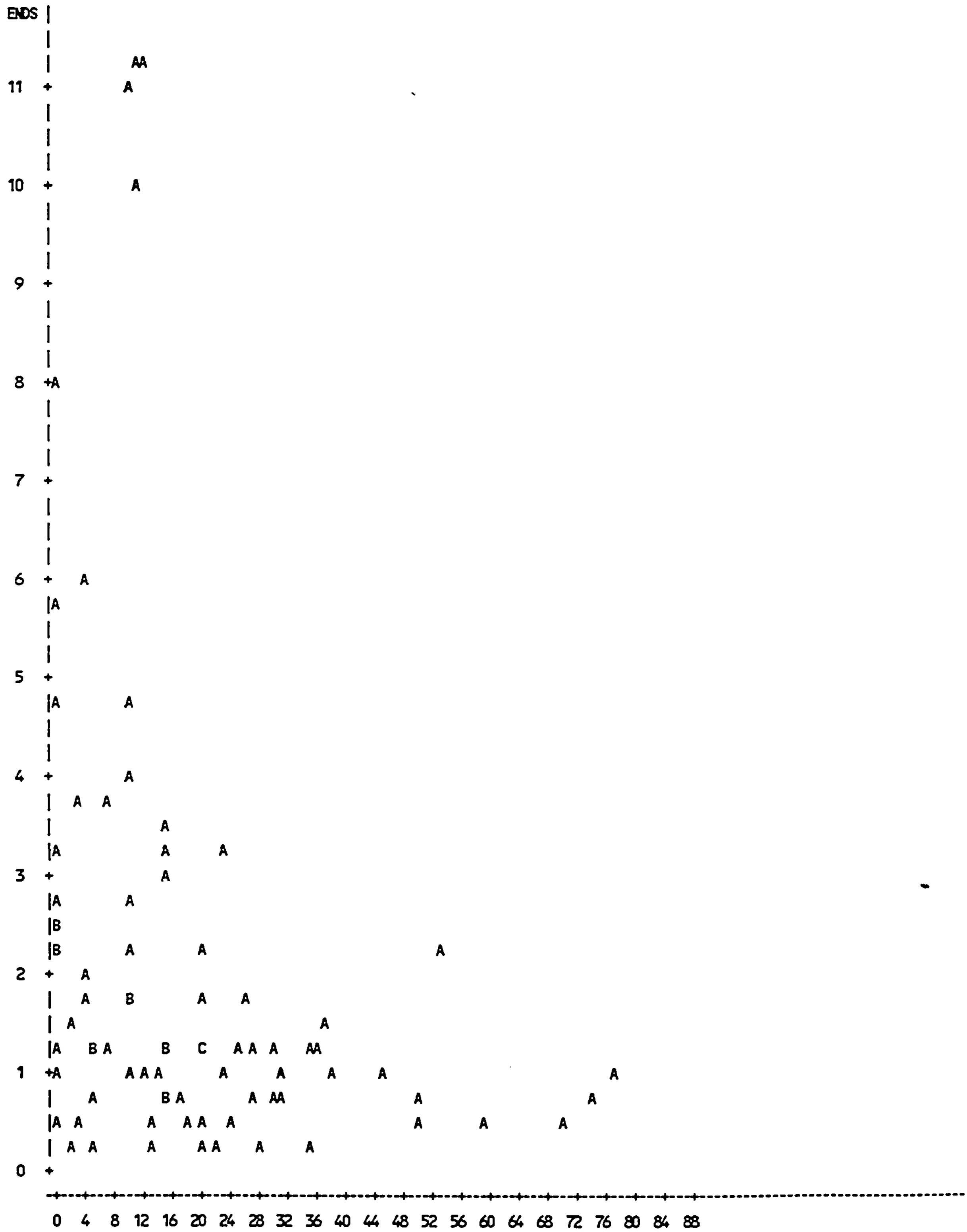
NOTE: 14 OBS HAD MISSING VALUES

PLOT OF TTF*ORDER LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 31 OBS HAD MISSING VALUES

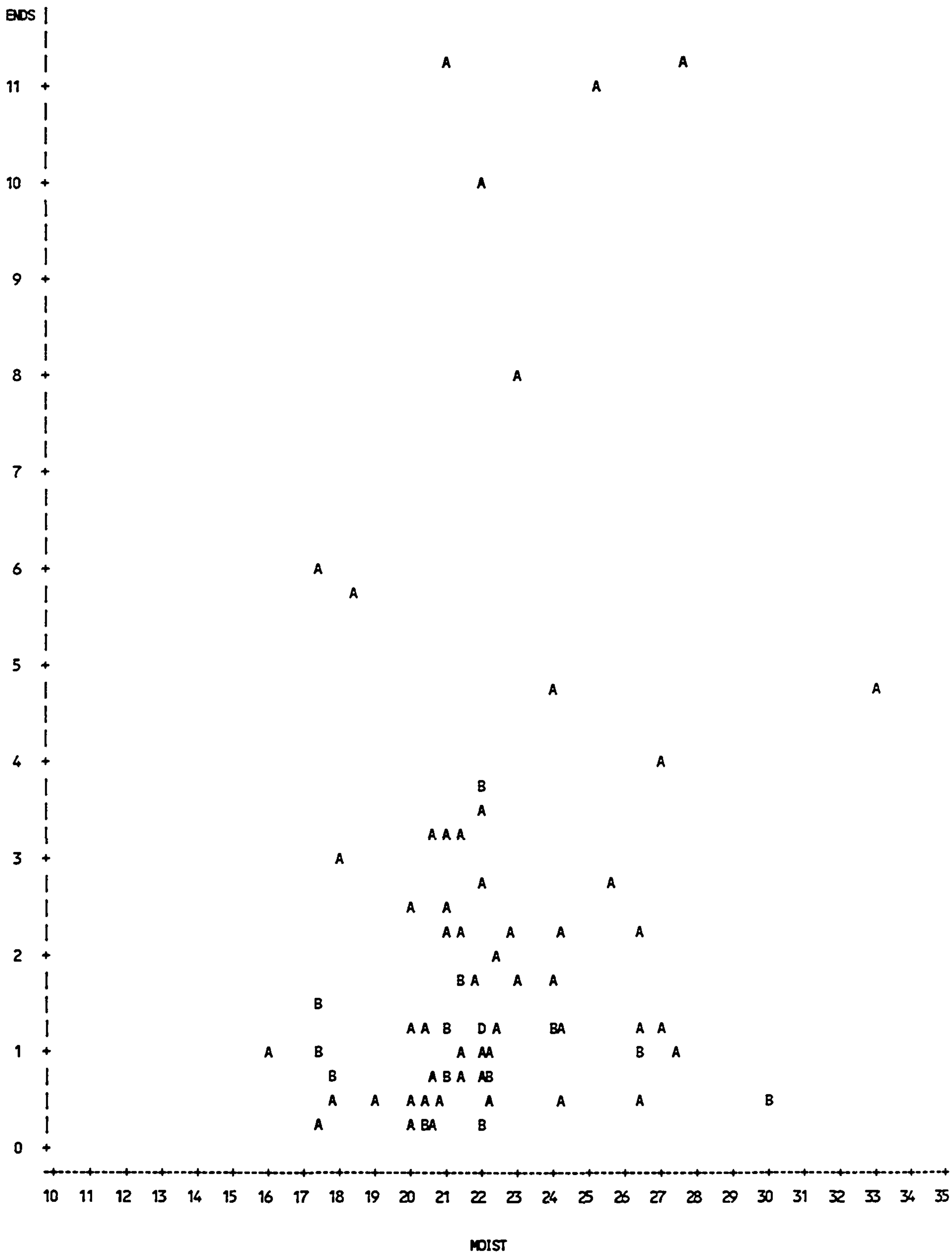
PLOT OF ENDS*PLUNG LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 12 OBS HAD MISSING VALUES

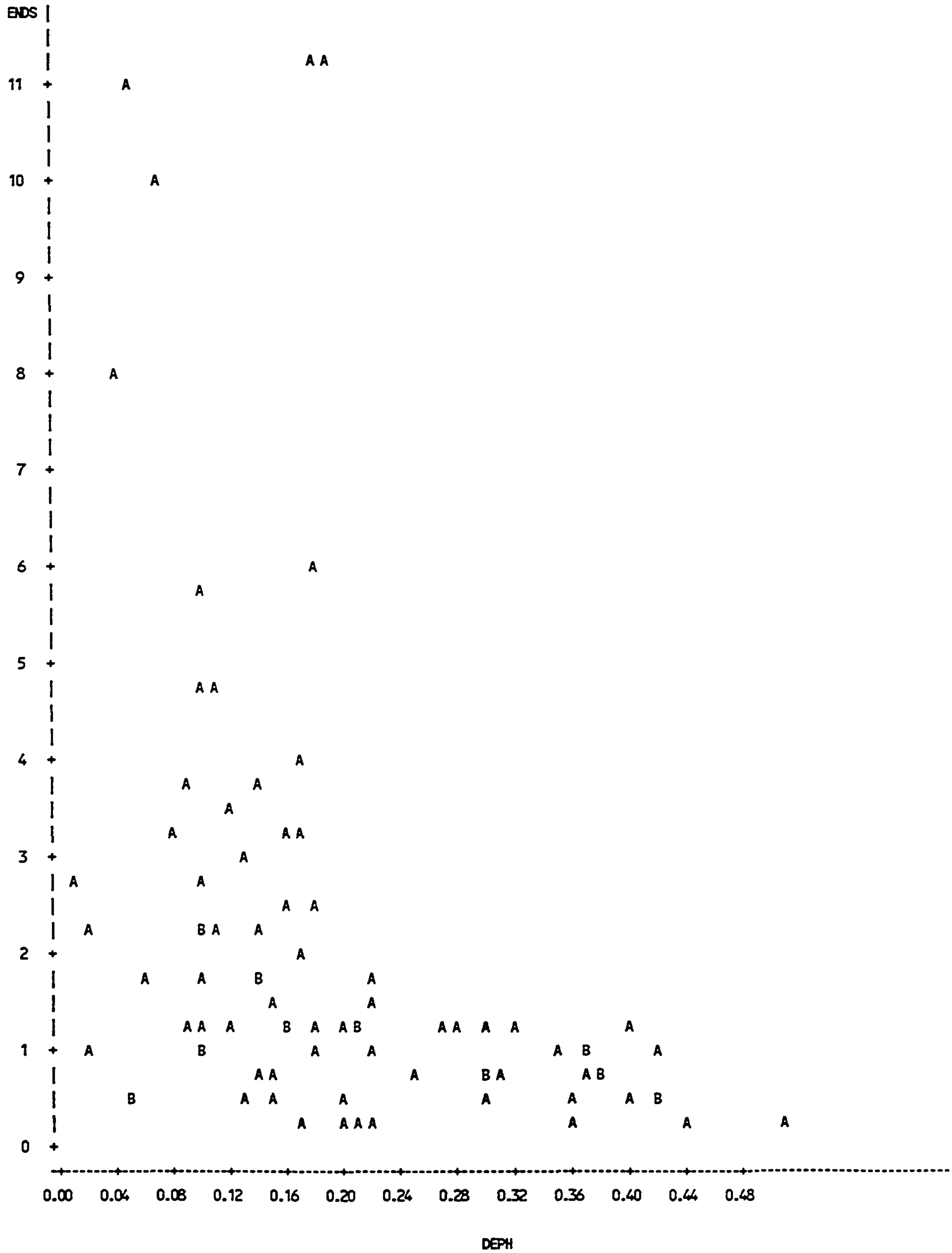
SAS 9:50 TUESDAY, AUGUST 25, 1987 25

PLOT OF ENDS*MOIST LEGEND: A = 1 OBS, B = 2 OBS, ETC.



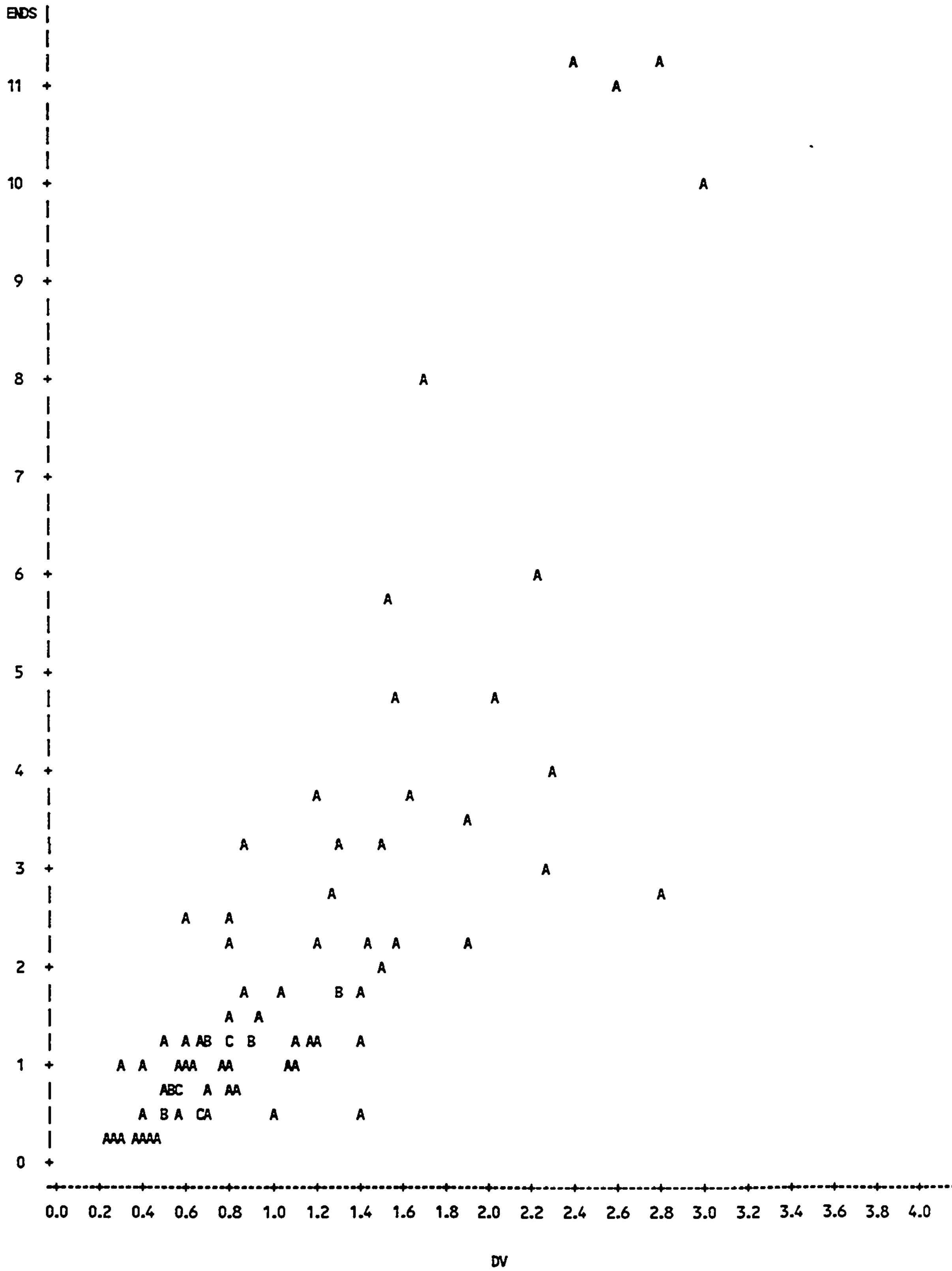
NOTE: 11 OBS HAD MISSING VALUES

PLOT OF ENDS*DEPH LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 11 OBS HAD MISSING VALUES

PLOT OF ENDS*DV LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 11 OBS HAD MISSING VALUES

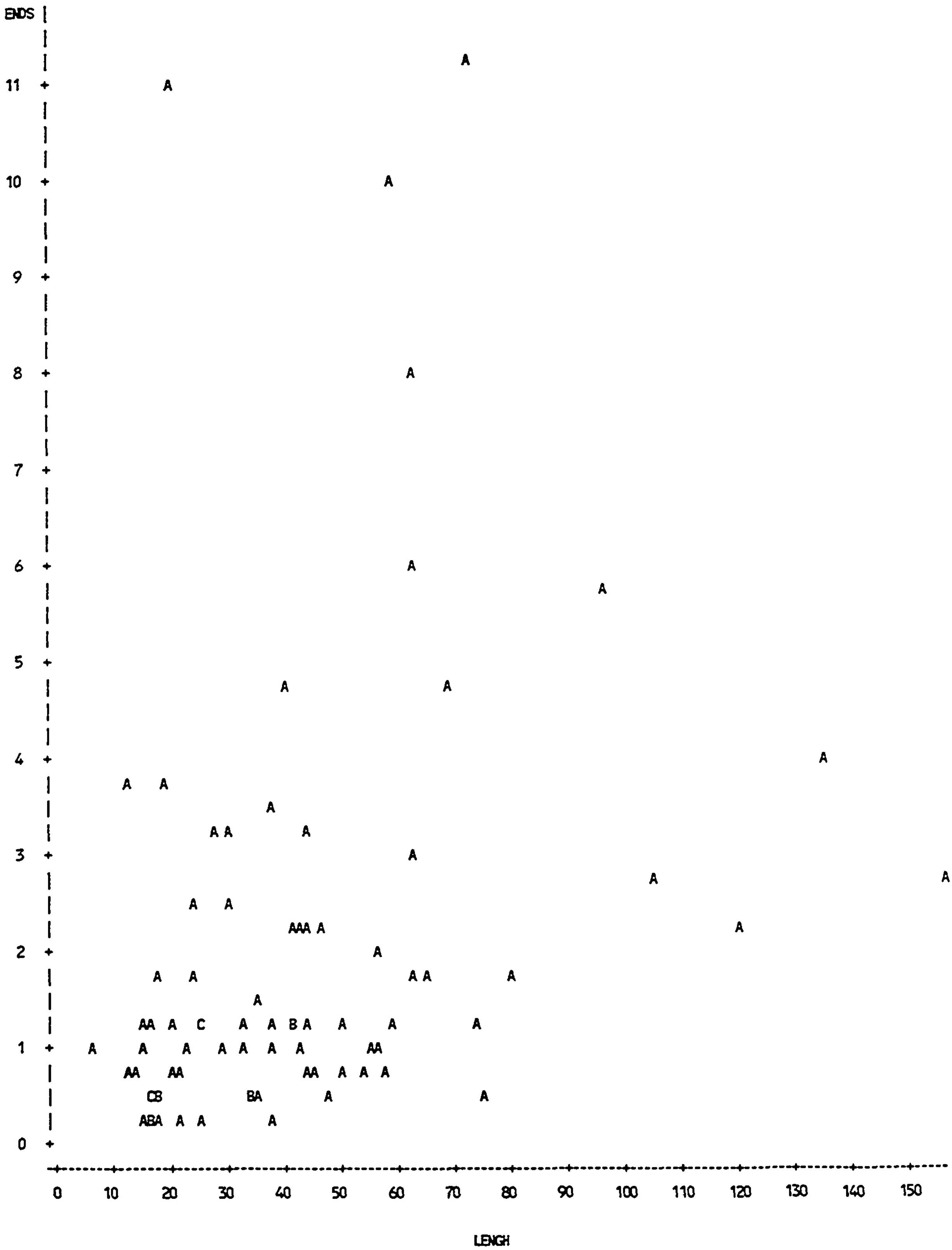
PLOT OF ENDS*DB LEGEND: A = 1 OBS, B = 2 OBS, ETC.

```
ENDS |
     |
     |   A  A
  11 +      A
     |
     |
     |
  10 +     A
     |
     |
     |
   9 +
     |
     |
     |
   8 +    A
     |
     |
     |
   7 +
     |
     |
     |
   6 +   A
     |    A
     |
     |
   5 +
     |   A A
     |
     |
   4 +   A
     |   AA
     |   A
     | A AA
   3 +  A
     |  AA
     | AA
     |  CB
   2 +  A
     |  DA
     |A A
     |BDH
   1 +AFB
     |AEC
     |CDC
     |AF
   0 +
     -+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+----
      0     2     4     6     8     10    12    14    16    18    20    22    24    26    28    30    32    34    36    38    40

                                                        DB
```

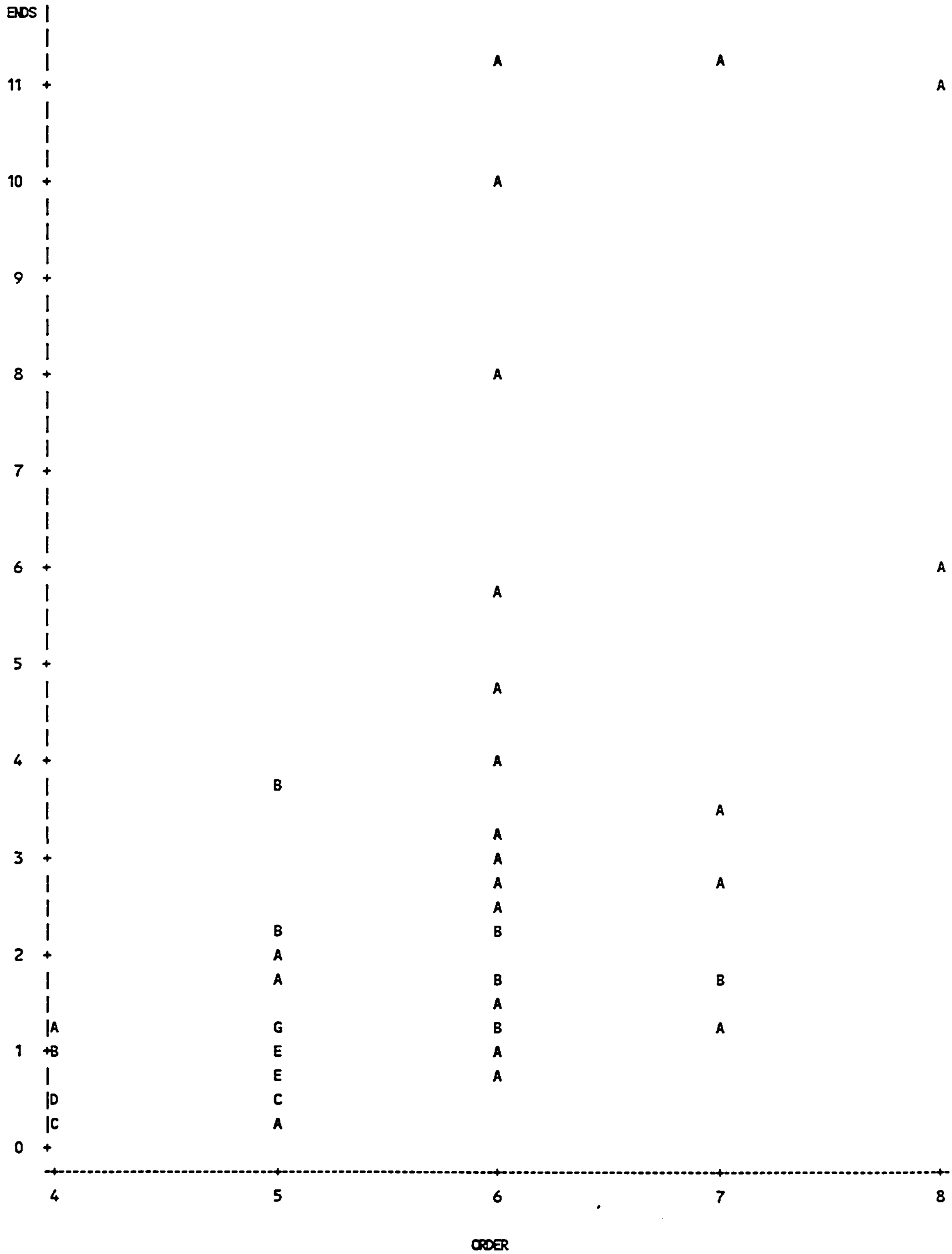
NOTE: 11 OBS HAD MISSING VALUES

PLOT OF ENDS*LENGH LEGEND: A = 1 OBS, B = 2 OBS, ETC.



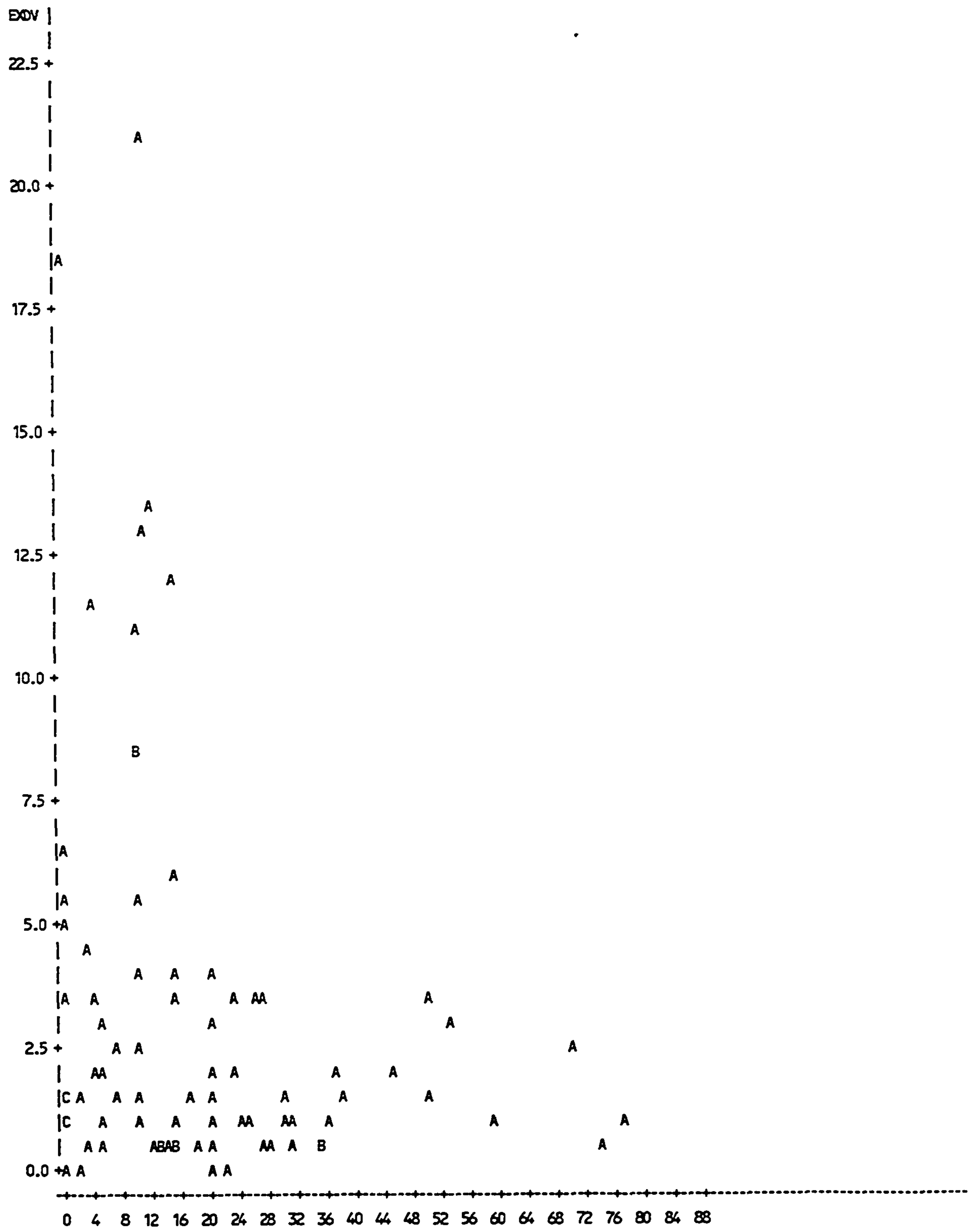
NOTE: 13 OBS HAD MISSING VALUES

PLOT OF ENDS*ORDER LEGEND: A = 1 OBS, B = 2 OBS, ETC.



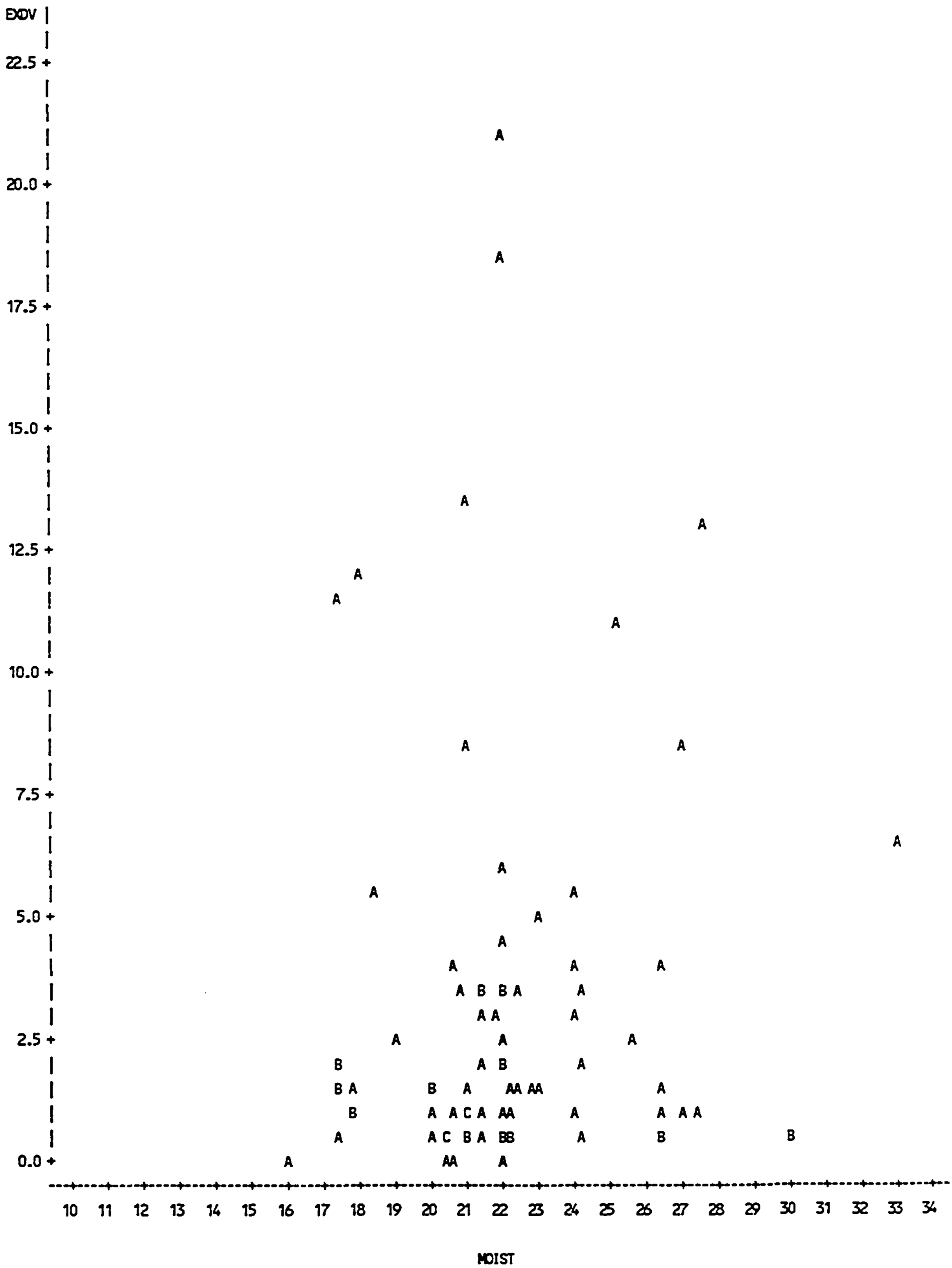
NOTE: 30 OBS HAD MISSING VALUES

PLOT OF EXOV*PLUNG LEGEND: A = 1 OBS, B = 2 OBS, ETC.



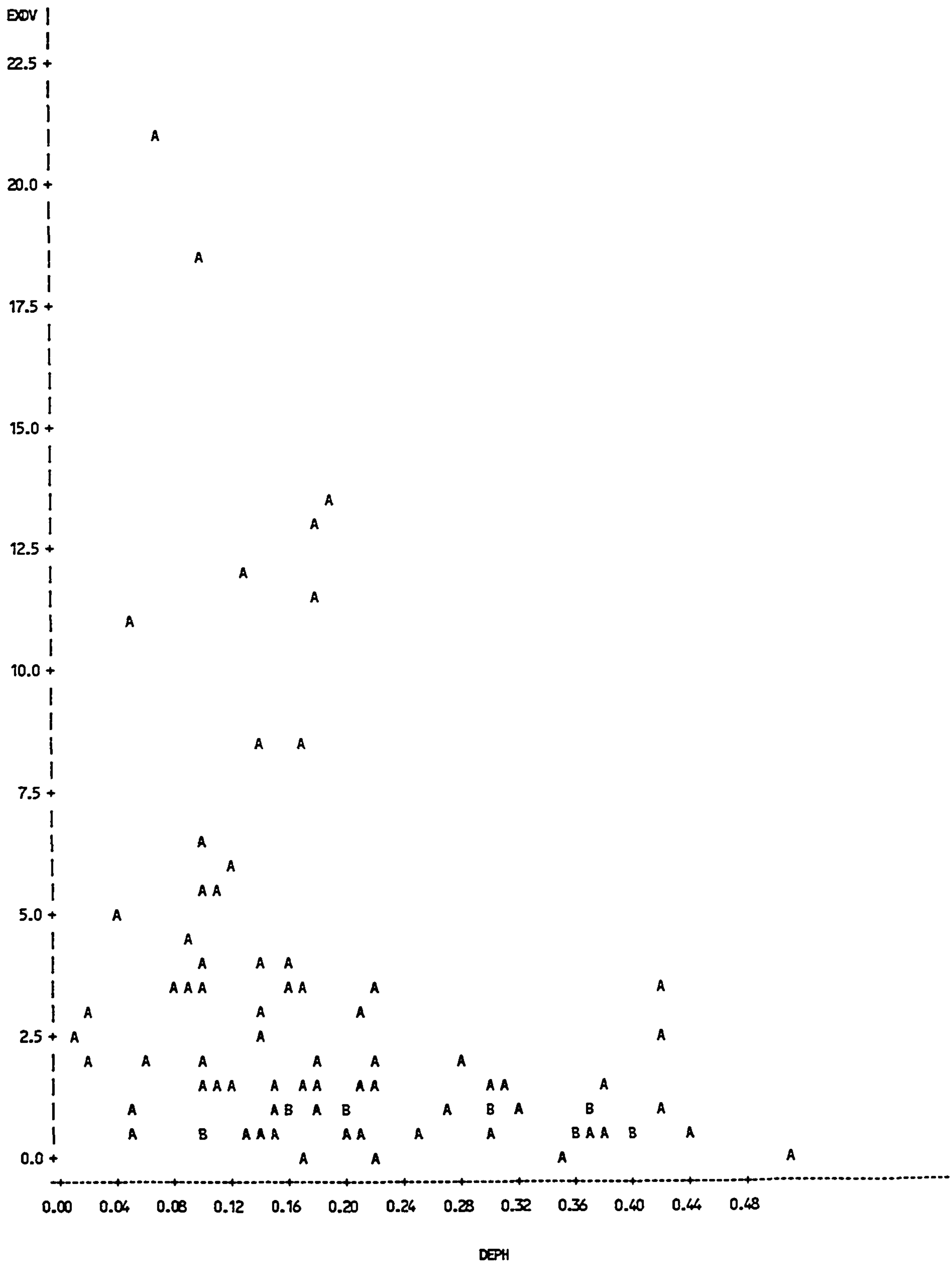
NOTE: 12 OBS HAD MISSING VALUES

PLOT OF EXDV*MOIST LEGEND: A = 1 OBS, B = 2 OBS, ETC.



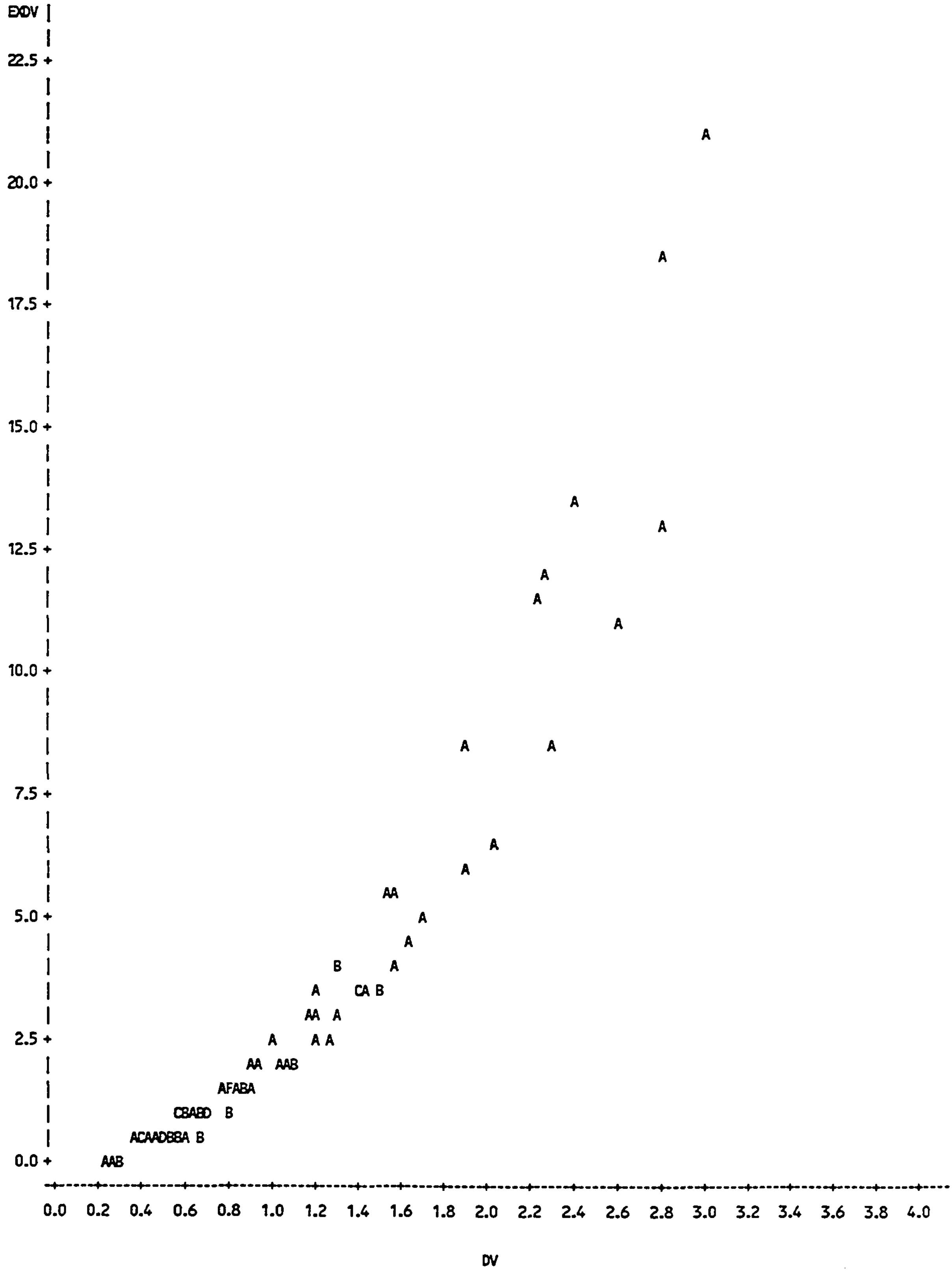
NOTE: 11 OBS HAD MISSING VALUES

PLOT OF EXDV*DEPH LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 11 OBS HAD MISSING VALUES

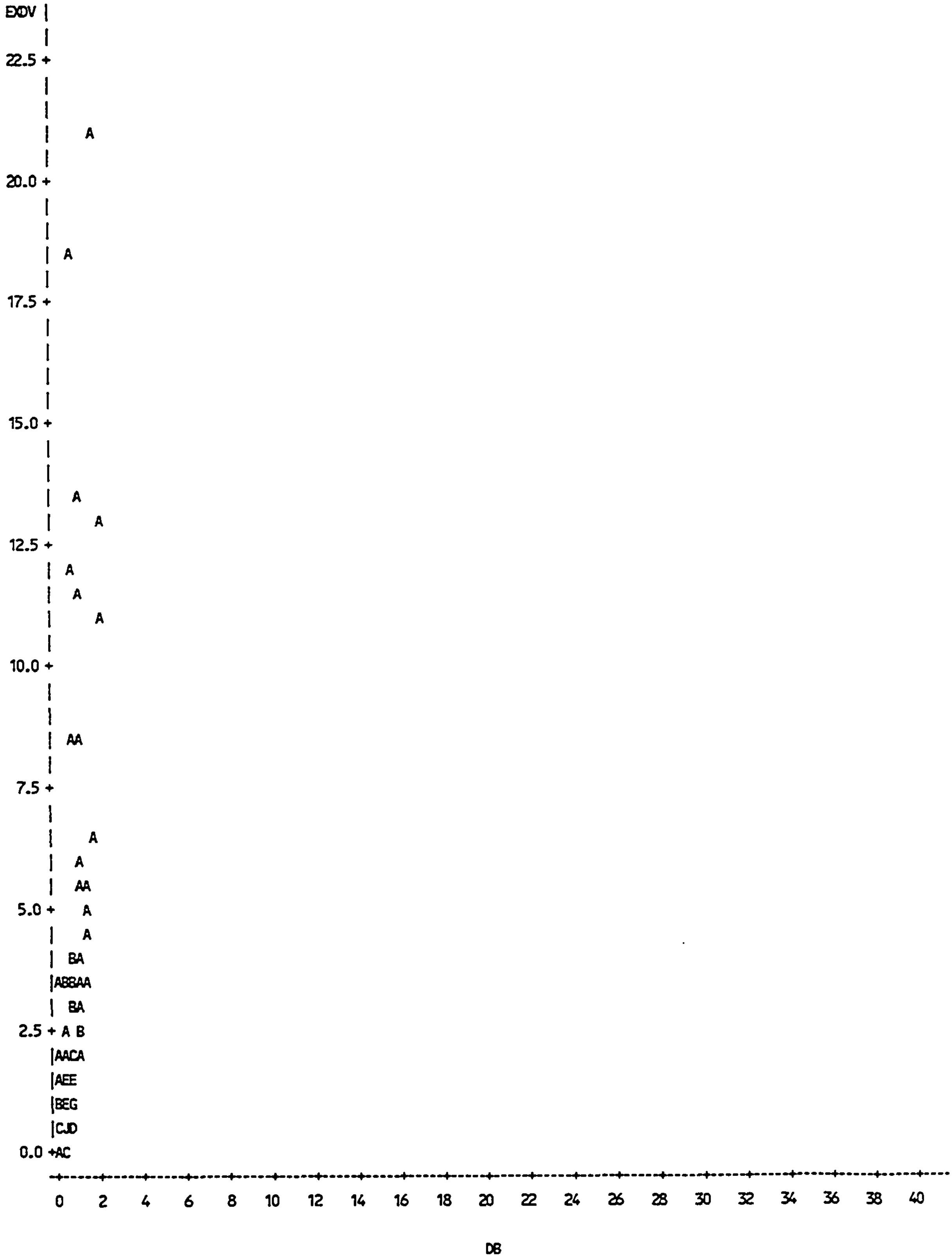
PLOT OF EXDV*DV LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 11 OBS HAD MISSING VALUES

SAS 9:50 TUESDAY, AUGUST 25, 1987 35

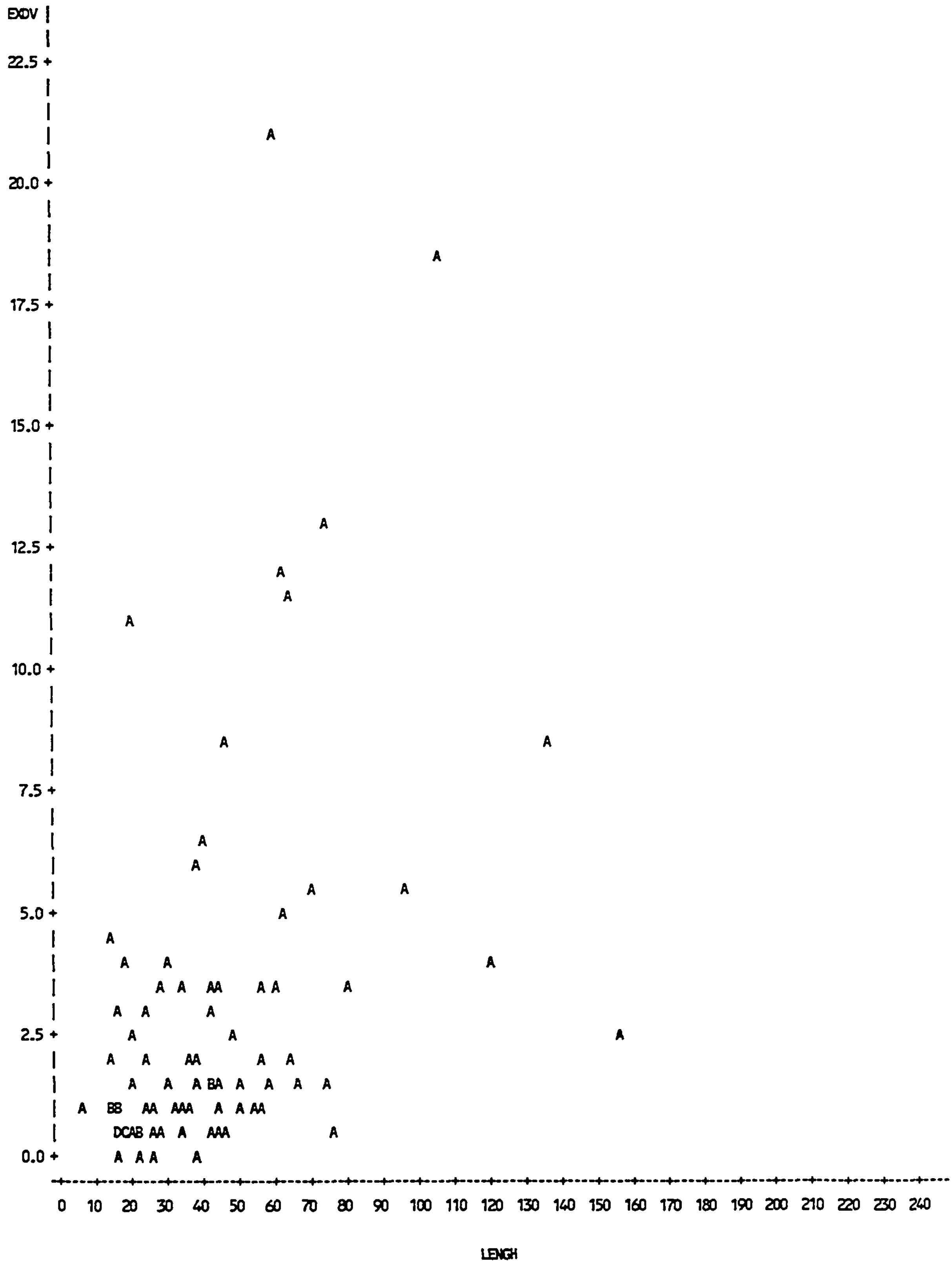
PLOT OF EXDV*DB LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 11 OBS HAD MISSING VALUES

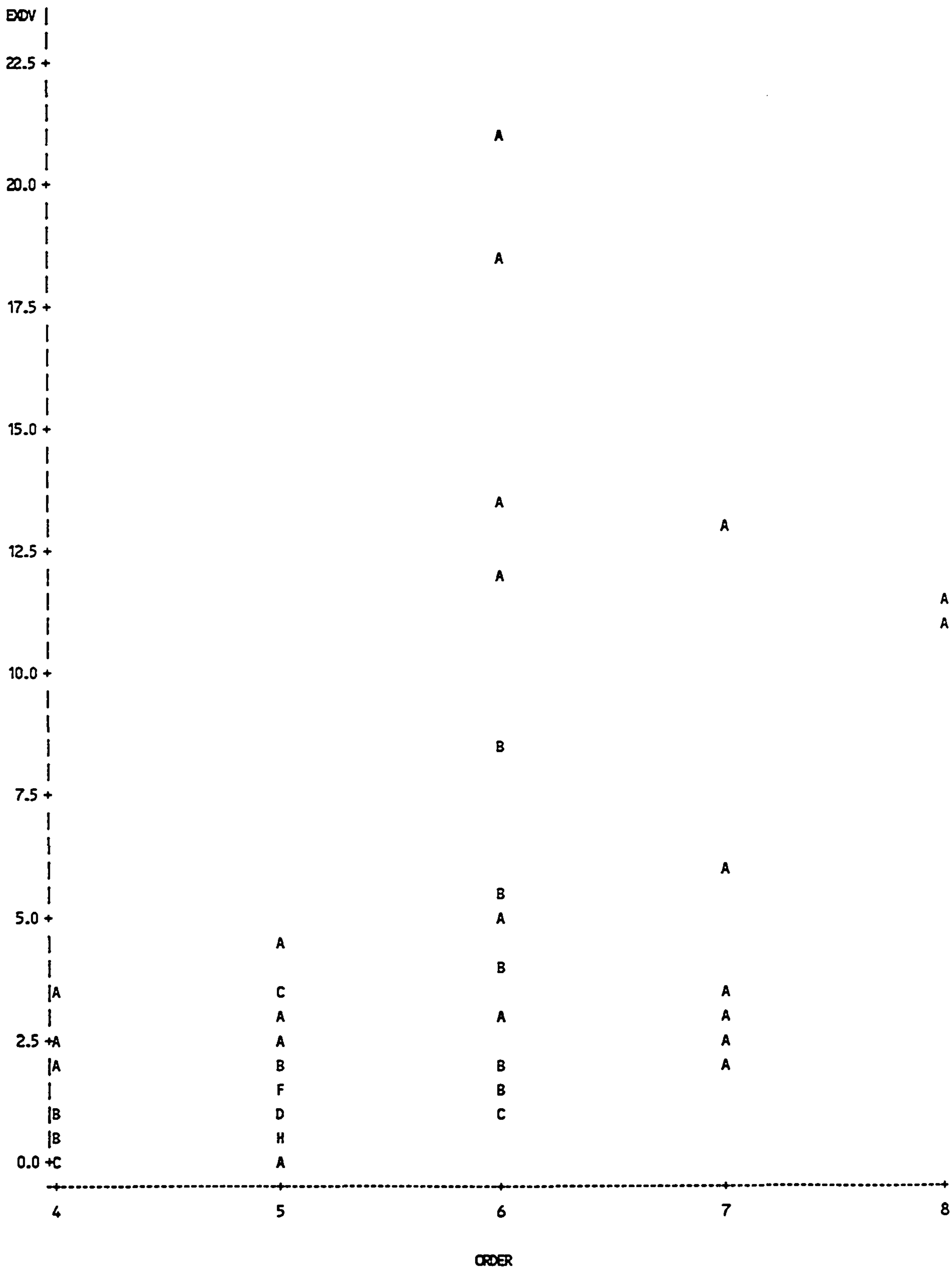
SAS 9:50 TUESDAY, AUGUST 25, 1987 36

PLOT OF EXDV*LENGH LEGEND: A = 1 OBS, B = 2 OBS, ETC.



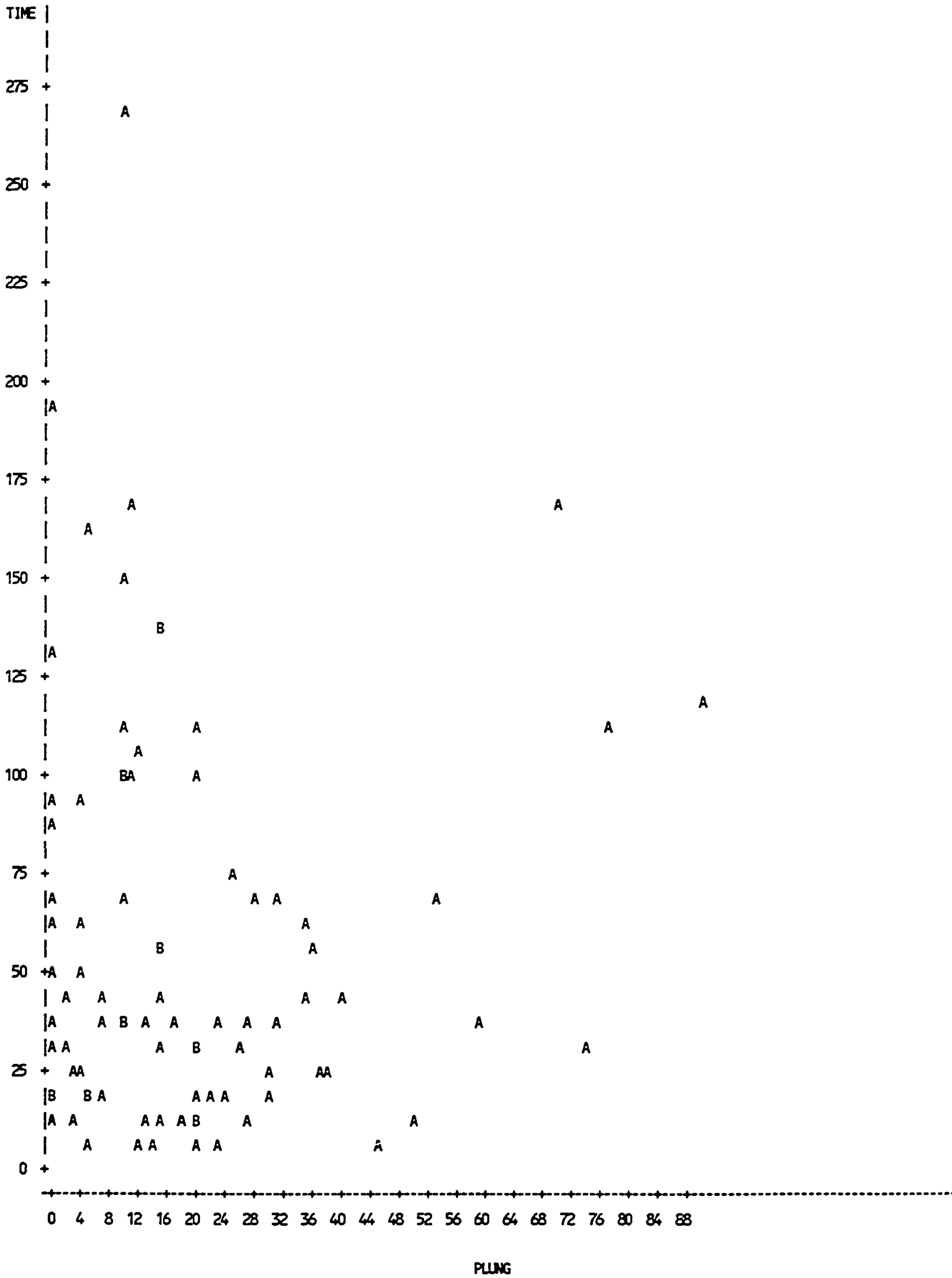
NOTE: 13 OBS HAD MISSING VALUES

PLOT OF EXDV*ORDER LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 30 OBS HAD MISSING VALUES

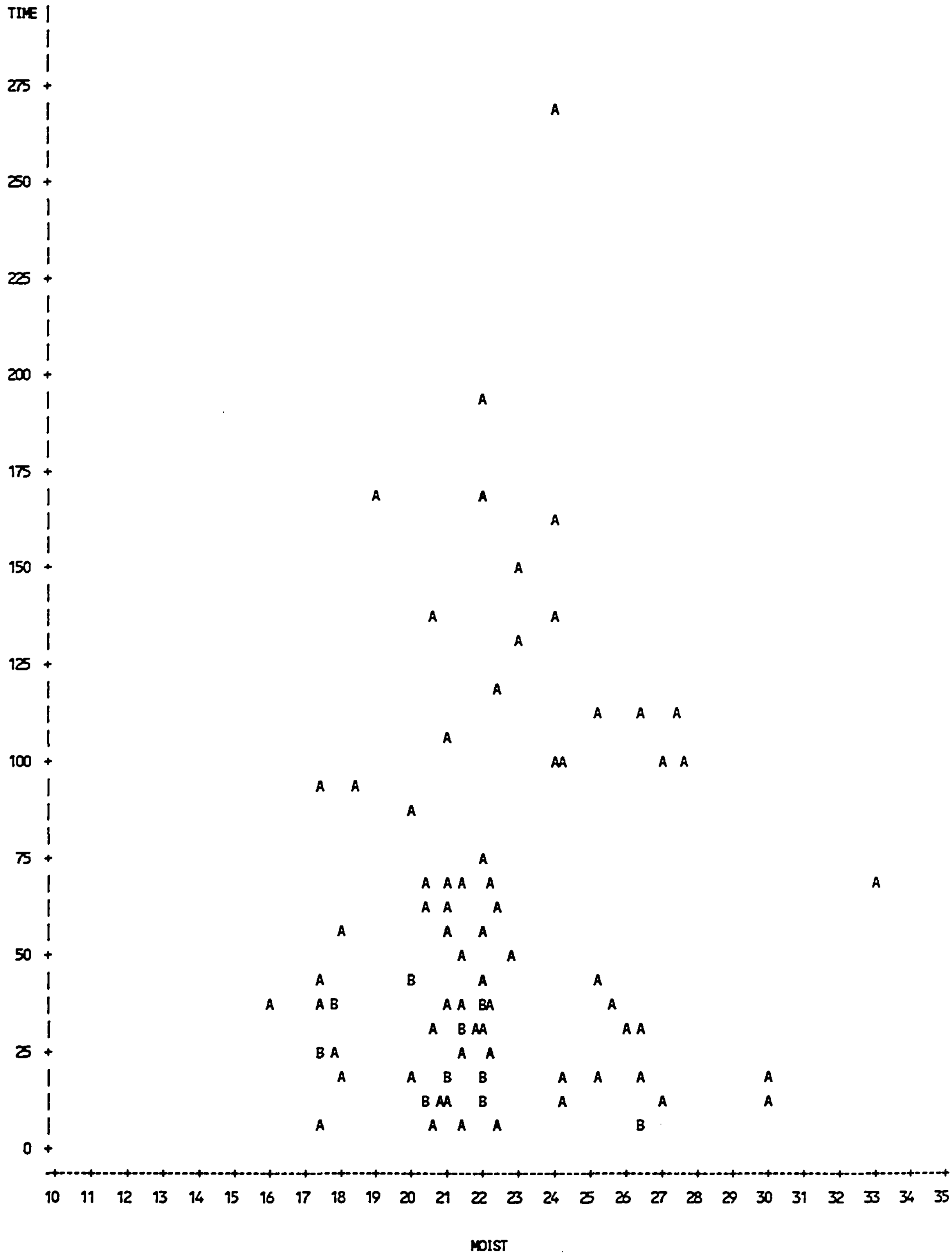
PLOT OF TIME*PLUNG LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 8 OBS HAD MISSING VALUES

SAS 9:50 TUESDAY, AUGUST 25, 1987 39

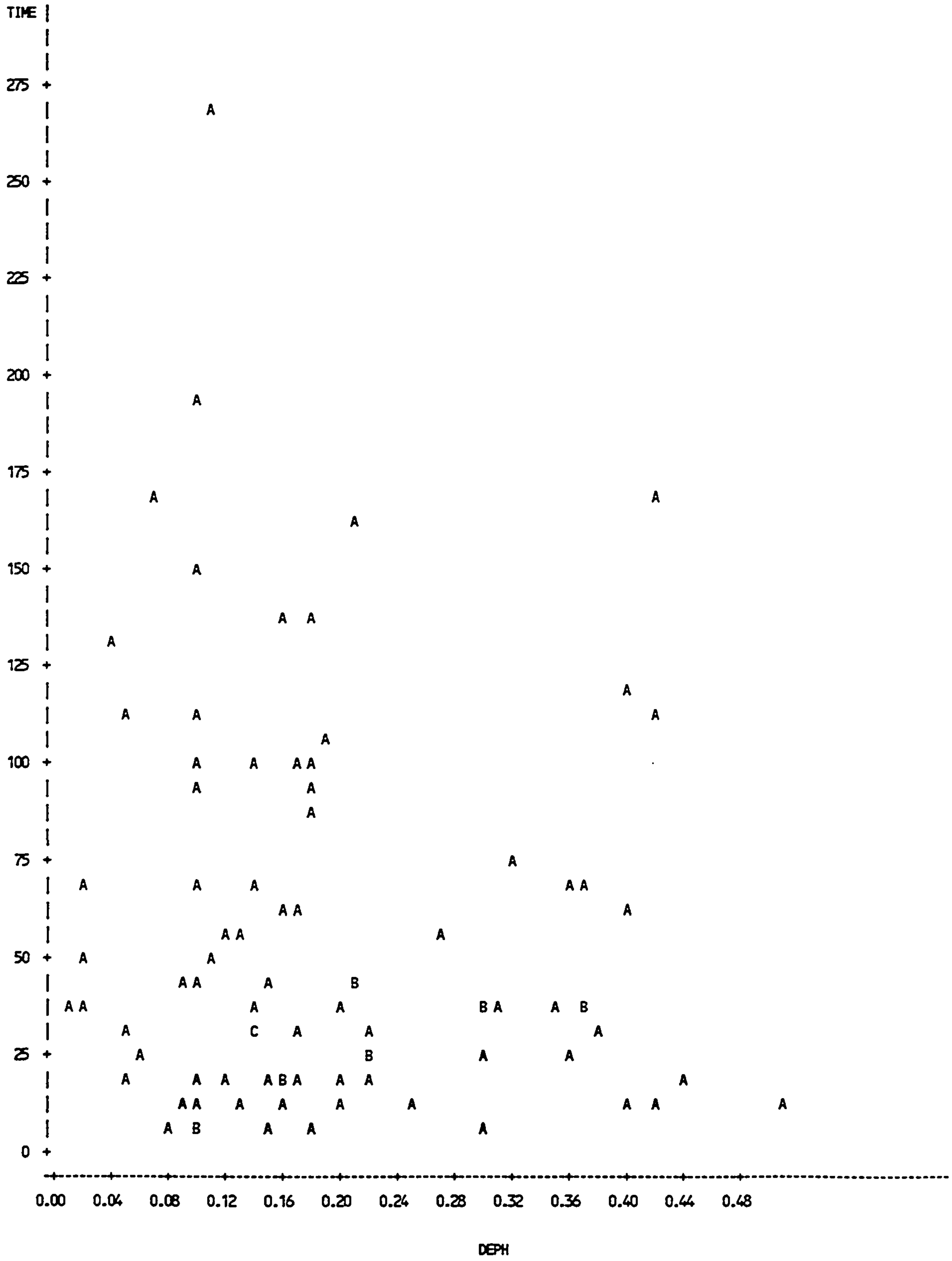
PLOT OF TIME*MOIST LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 7 OBS HAD MISSING VALUES

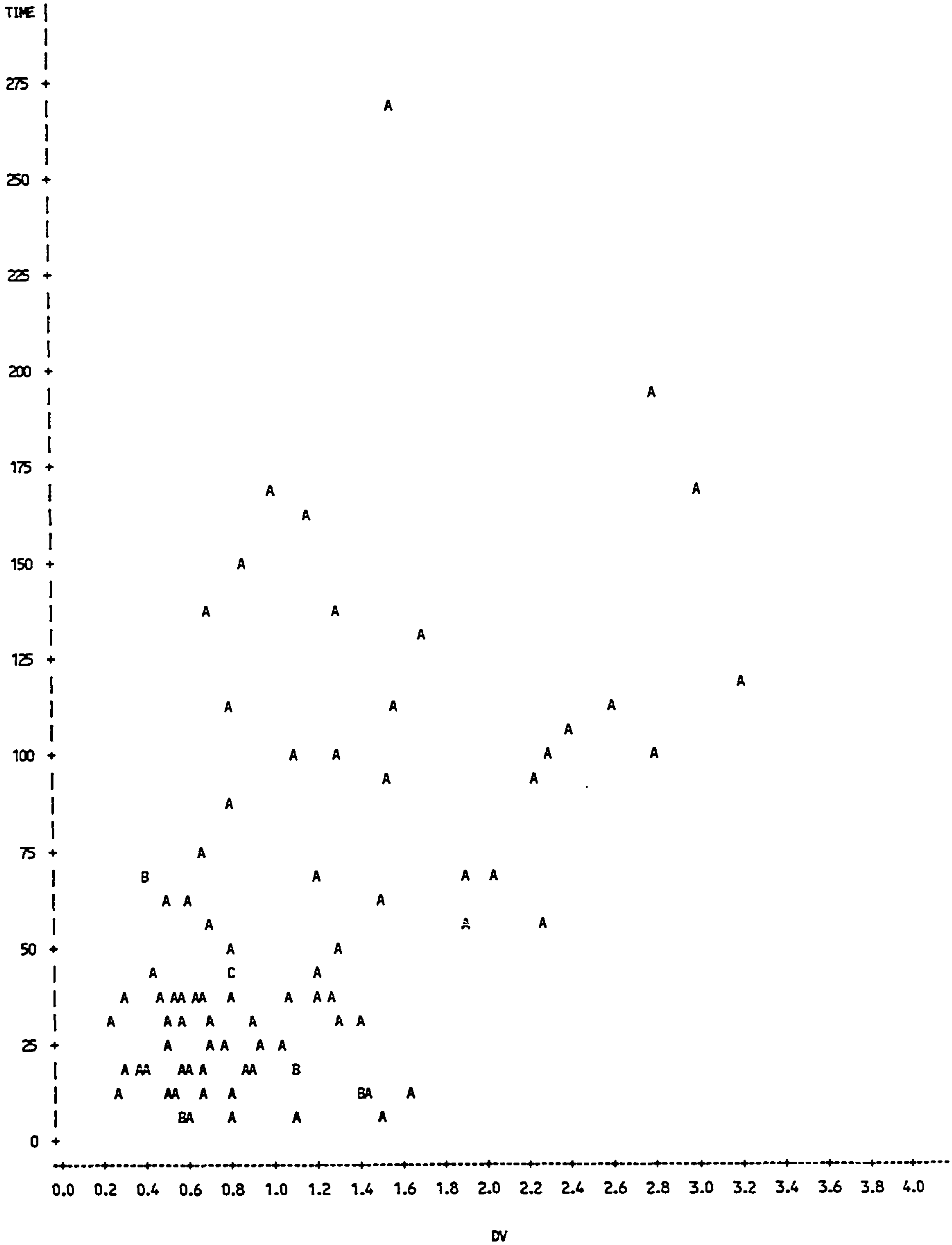
SAS 9:50 TUESDAY, AUGUST 25, 1987 40

PLOT OF TIME*DEPH LEGEND: A = 1 OBS, B = 2 OBS, ETC.



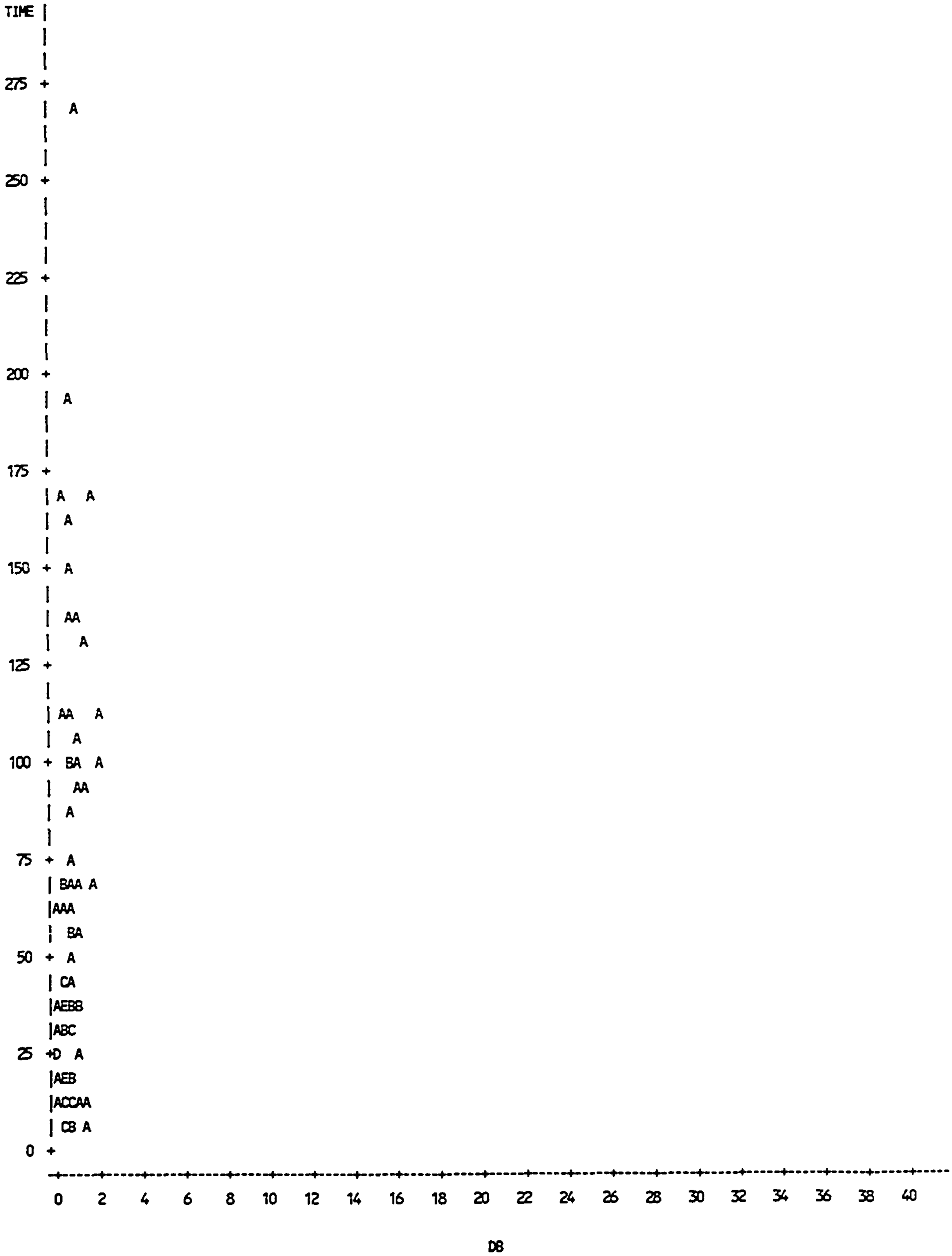
NOTE: 7 OBS HAD MISSING VALUES

PLOT OF TIME*DV LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 7 OBS HAD MISSING VALUES

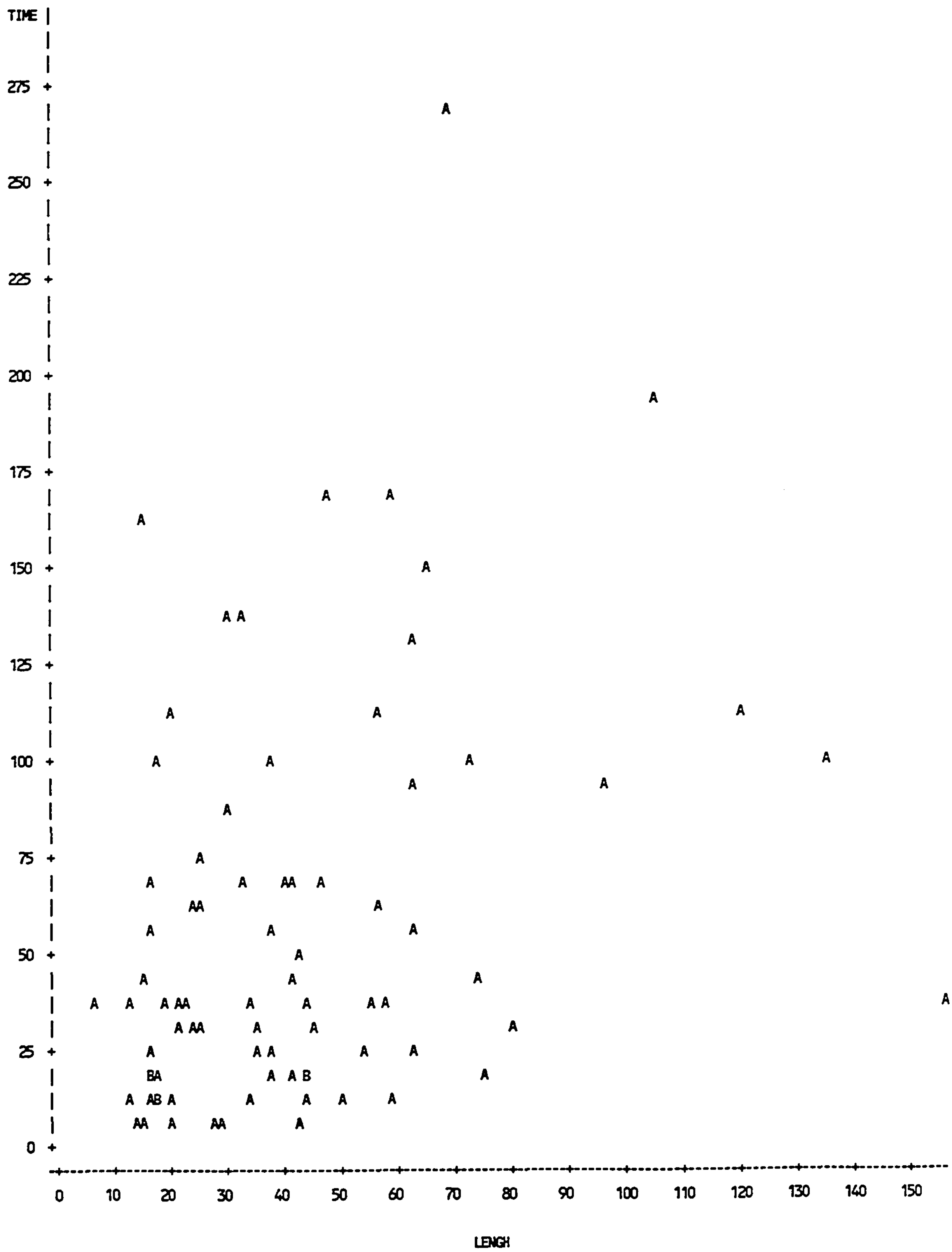
PLOT OF TIME*DB LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 13 OBS HAD MISSING VALUES

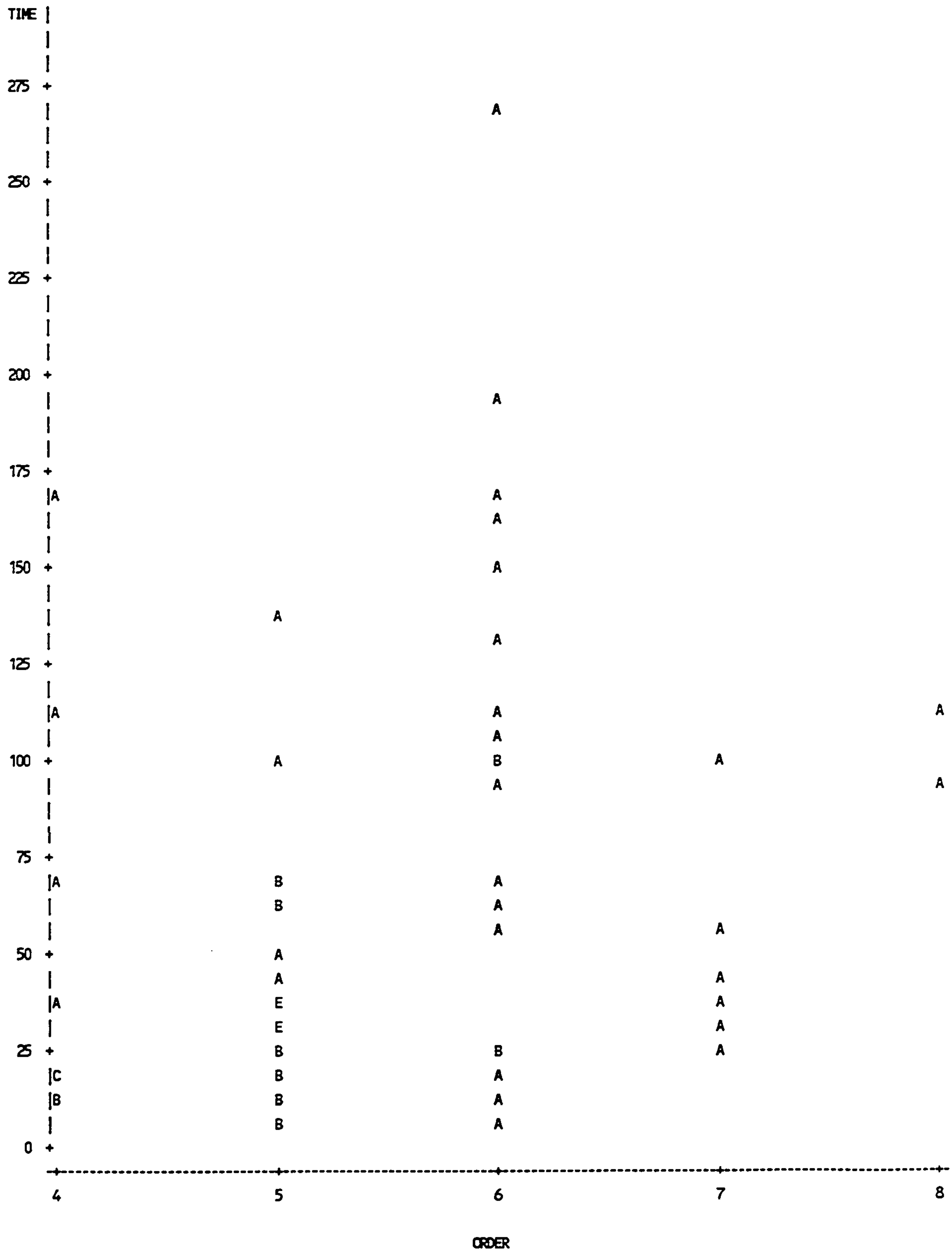
SAS 9:50 TUESDAY, AUGUST 25, 1987 43

PLOT OF TIME*LENGH LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 15 OBS HAD MISSING VALUES

PLOT OF TIME*ORDER LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 32 OBS HAD MISSING VALUES

DESCRIPTIVE STATISTICS

VARIABLE	SUM	MEAN	UNCORRECTED SS	VARIANCE	STD DEVIATION
TBF	76.570000	1.19640625	209.3103	1.8682774	1.36684943
PLUNG	1230.000000	19.21875000	46240.0000	358.7450397	18.94056598
MOIST	1406.800000	21.98125000	31416.9200	7.8364683	2.79936926
DEPH	12.050000	0.18828125	3.1625	0.0141859	0.11910453
DV	73.920000	1.15500000	121.2128	0.5688127	0.75419672
DB	37.460000	0.58531250	36.0014	0.2234221	0.47267549
LENGH	3080.300000	48.12968750	202013.4300	853.3262475	29.21174845
ORDER	348.000000	5.43750000	1954.0000	0.9801587	0.99002966
INTERCEP	64.000000	1.00000000	64.0000	0.0000000	0.00000000

SUMS OF SQUARES AND CROSSPRODUCTS

SSCP	TBF	PLUNG	MOIST	DEPH	DV
TBF	209.3103	1014.8	1757.056	10.7725	139.5581
PLUNG	1014.8	46240	26578.9	307.56	1187.18
MOIST	1757.056	26578.9	31416.92	257.682	1647.315
DEPH	10.7725	307.56	257.682	3.1625	11.5181
DV	139.5581	1187.18	1647.315	11.5181	121.2128
DB	74.4943	534.67	850.439	5.2404	61.5944
LENGH	5218.466	54833.9	69053.81	508.392	4201.87
ORDER	457.21	6259	7670.4	61.69	431.6
INTERCEP	76.57	1230	1406.8	12.05	73.92

SSCP	DB	LENGH	ORDER	INTERCEP
TBF	74.4943	5218.466	457.21	76.57
PLUNG	534.67	54833.9	6259	1230
MOIST	850.439	69053.81	7670.4	1406.8
DEPH	5.2404	508.392	61.69	12.05
DV	61.5944	4201.87	431.6	73.92
DB	36.0014	2104.462	220.84	37.46
LENGH	2104.462	202013.4	17357.7	3080.3
ORDER	220.84	17357.7	1954	348
INTERCEP	37.46	3080.3	348	64

MODEL CROSSPRODUCTS X'X X'Y Y'Y

X'X	INTERCEP	PLUNG	MOIST	DEPH	DV
INTERCEP	64	1230	1406.8	12.05	73.92
PLUNG	1230	46240	26578.9	307.56	1187.18
MOIST	1406.8	26578.9	31416.92	257.682	1647.315
DEPH	12.05	307.56	257.682	3.1625	11.5181
DV	73.92	1187.18	1647.315	11.5181	121.2128
DB	37.46	534.67	850.439	5.2404	61.5944
LENGH	3080.3	54833.9	69053.81	508.392	4201.87
ORDER	348	6259	7670.4	61.69	431.6
TBF	76.57	1014.8	1757.056	10.7725	139.5581

X'X	DB	LENGH	ORDER	TBF
INTERCEP	37.46	3080.3	348	76.57
PLUNG	534.67	54833.9	6259	1014.8
MOIST	850.439	69053.81	7670.4	1757.056
DEPH	5.2404	508.392	61.69	10.7725
DV	61.5944	4201.87	431.6	139.5581
DB	36.0014	2104.462	220.84	74.4943
LENGH	2104.462	202013.4	17357.7	5218.466
ORDER	220.84	17357.7	1954	457.21
TBF	74.4943	5218.466	457.21	209.3103

SEQUENTIAL PARAMETER ESTIMATES

INTERCEP	1.19641							
PLUNG	1.58483	-.020211						
MOIST	-1.40282	-.017504	0.133552					
DEPH	-.492868	-.010112	0.105952	-2.36532				
DV	-2.54962	-.007472	.0949864	1.05062	1.38866			
DB	-2.33515	-.006725	0.080716	1.32133	1.13687	0.554735		
LENGH	-2.22775	-.008202	.0493865	2.00017	0.784968	0.813006	.0153153	
ORDER	-1.75168	-.008595	.0467233	1.82362	0.82961	0.829169	.0154103	-.081348

X'X INVERSE, B, SSE

INVERSE	INTERCEP	PLUNG	MOIST	DEPH	DV
INTERCEP	2.51994	-0.000560245	-0.0625826	-1.14164	0.002083592
PLUNG	-0.000560245	.00006372036	-.0000210895	-0.00491259	-0.000117071
MOIST	-0.0625826	-.0000210895	0.002615275	0.01641972	0.003355231
DEPH	-1.14164	-0.00491259	0.01641972	2.214006	-0.0365255
DV	0.002083592	-0.000117071	0.003355231	-0.0365255	0.1097803
DB	0.1382396	0.0002703835	-0.00765018	0.1300155	-0.122168
LENGH	0.0003979021	-0.00000268	-.0000542847	0.001069958	-0.000575928
ORDER	-0.184906	0.0001526598	0.00103439	0.06857276	-0.0173387
TBF	-1.75168	-0.00859499	0.04672329	1.823615	0.8296097

X'X INVERSE, B, SSE

INVERSE	DB	LENGH	ORDER	TBF
INTERCEP	0.1382396	0.0003979021	-0.184906	-1.75168
PLUNG	0.0002703835	-0.00000268	0.0001526598	-0.00859499
MOIST	-0.00765018	-.0000542847	0.00103439	0.04672329
DEPH	0.1300155	0.001069958	0.06857276	1.823615
DV	-0.122168	-0.000575928	-0.0173387	0.8296097
DB	0.2632295	0.0004448792	-0.00627763	0.8291689
LENGH	0.0004448792	0.0000259893	-.0000369023	0.01541029
ORDER	-0.00627763	-.0000369023	0.03159549	-0.0813481
TBF	0.8291689	0.01541029	-0.0813481	29.64643

DEP VARIABLE: TBF

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	7	88.05504115	12.57929159	23.761	0.0001
ERROR	56	29.64643229	0.52940058		
C TOTAL	63	117.70147			

ROOT MSE	0.7275992	R-SQUARE	0.7481
DEP MEAN	1.196406	ADJ R-SQ	0.7166
C.V.	60.8154		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	TYPE I SS	TYPE II SS	STANDARDIZED ESTIMATE	SEMI-PARTIAL CORR TYPE I
INTERCEP	1	-1.75168187	1.15501404	-1.517	0.1350	91.60882656	1.21764407	0	.
PLUNG	1	-0.00859 4989	0.005808063	-1.480	0.1445	9.23181540	1.15934436	-0.11910161	0.07843415
MOIST	1	0.04672329	0.03720925	1.256	0.2144	8.64005851	0.83473651	0.09569140	0.07340655
DEPH	1	1.82361548	1.08263373	1.684	0.0977	3.20223362	1.50206195	0.15890621	0.02720640
DV	1	0.82960974	0.24107620	3.441	0.0011	56.52266513	6.26936323	0.45775997	0.48022054
DB	1	0.82916885	0.37330128	2.221	0.0304	1.20866599	2.61186906	0.28673809	0.01026891
LENGH	1	0.01541029	0.003709279	4.155	0.0001	9.04015756	9.13749158	0.32934241	0.07680581
ORDER	1	-0.08134810	0.12933162	-0.629	0.5319	0.20944492	0.20944492	-0.05892166	0.001779459

VARIABLE	DF	SEMI-PARTIAL CORR TYPE II	PARTIAL CORR TYPE I	PARTIAL CORR TYPE II	TOLERANCE
INTERCEP	1	.	.	.	.
PLUNG	1	0.009849871	0.23745451	0.03763399	0.69437697
MOIST	1	0.007091980	0.22566859	0.02738532	0.77450050
DEPH	1	0.01276162	0.09748443	0.04822262	0.50538719
DV	1	0.05326495	0.65595053	0.17455727	0.25419436
DB	1	0.02219062	0.03917233	0.08096735	0.26989741
LENGH	1	0.07763277	0.23367678	0.23559998	0.71573092
ORDER	1	0.001779459	0.007015199	0.007015199	0.51255209

COVARIANCE OF ESTIMATES

COVB	INTERCEP	PLUNG	MOIST	DEPH	DV	DB	LENGH	ORDER
INTERCEP	1.334057	-0.00029594	-0.0331312	-0.604386	0.001103055	0.07318412	0.0002106496	-0.0978893
PLUNG	-0.00029594	0.0000337336	-.0000111648	-0.00260073	-.0000619773	0.0001431412	-.0000014188	.00008081821
MOIST	-0.0331312	-.0000111648	0.001384528	0.008692608	0.001776261	-0.00405001	-.0000287384	0.0005476065
DEPH	-0.604386	-0.00260073	0.008692608	1.172096	-0.0193366	0.06883031	0.0005664363	0.03630246
DV	0.001103055	-.0000619773	0.001776261	-0.0193366	0.05811773	-0.0646757	-0.000304896	-0.00917913
DB	0.07318412	0.0001431412	-0.00405001	0.06883031	-0.0646757	0.1393538	0.0002355193	-0.00332338
LENGH	0.0002106496	-.0000014188	-.0000287384	0.0005664363	-0.000304896	0.0002355193	.00001375875	-.0000195361
ORDER	-0.0978893	.00008081821	0.0005476065	0.03630246	-0.00917913	-0.00332338	-.0000195361	0.01672667

CORRELATION OF ESTIMATES

CORRB	INTERCEP	PLUNG	MOIST	DEPH	DV	DB	LENGH	ORDER
INTERCEP	1.0000	-0.0442	-0.7709	-0.4833	0.0040	0.1697	0.0492	-0.6553
PLUNG	-0.0442	1.0000	-0.0517	-0.4136	-0.0443	0.0660	-0.0659	0.1076
MOIST	-0.7709	-0.0517	1.0000	0.2158	0.1980	-0.2916	-0.2082	0.1138
DEPH	-0.4833	-0.4136	0.2158	1.0000	-0.0741	0.1703	0.1411	0.2593
DV	0.0040	-0.0443	0.1980	-0.0741	1.0000	-0.7187	-0.3410	-0.2944
DB	0.1697	0.0660	-0.2916	0.1703	-0.7187	1.0000	0.1701	-0.0688
LENGH	0.0492	-0.0659	-0.2082	0.1411	-0.3410	0.1701	1.0000	-0.0407
ORDER	-0.6553	0.1076	0.1138	0.2593	-0.2944	-0.0688	-0.0407	1.0000

TEST OF FIRST AND SECOND MOMENT SPECIFICATION

DF: 35 CHISQ VALUE: 117999 PROB >CHISQ : 0.0001

CONSISTENT COVARIANCE OF ESTIMATES

ACOV	INTERCEP	PLUNG	MOIST	DEPH	DV	DB	LENGH	ORDER
INTERCEP	1.760538	0.002687652	-0.0493989	-1.15299	-0.00718928	0.09462286	-0.00584848	-0.0580712
PLUNG	0.002687652	.00002092156	-.0000899218	-0.00343332	-0.000411752	0.0004410923	-.0000110678	.00003942899
MOIST	-0.0493989	-.0000899218	0.001638591	0.03393438	0.002438203	-0.00434695	0.0001491161	0.0004741782
DEPH	-1.15299	-0.00343332	0.03393438	1.166914	0.08841584	-0.0720081	0.003845427	0.007043332
DV	-0.00718928	-0.000411752	0.002438203	0.08841584	0.08186384	-0.0683744	-0.000202973	-0.0172803
DB	0.09462286	0.0004410923	-0.00434695	-0.0720081	-0.0683744	0.1284368	-0.000143177	0.002939841
LENGH	-0.00584848	-.0000110678	0.0001491161	0.003845427	-0.000202973	-0.000143177	.00004367566	0.0001127066
ORDER	-0.0580712	.00003942899	0.0004741782	0.007043332	-0.0172803	0.002939841	0.0001127066	0.01047935

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2
1	.	.	.	.	.	.	.	.	.	.	
2	1.9600	1.7763	0.1752	1.4253	2.1273	0.2771	3.2755	0.1837	0.7062	0.2601	| | |
3	0.5300	.	.	.	.	.	.	.	.	.	
4	0.6100	0.3099	0.1971	-0.0849	0.7048	-1.2002	1.8200	0.3001	0.7004	0.4284	| | |
5	0.5800	0.4002	0.1419	0.1158	0.6845	-1.0849	1.8852	0.1798	0.7136	0.2520	| | |
6	0.7500	.	.	.	.	.	.	.	.	.	
7	0.3300	0.2621	0.2652	-0.2691	0.7933	-1.2892	1.8135	0.0679	0.6776	0.1002	| | |
8	0.3800	0.1499	0.2222	-0.2953	0.5950	-1.3742	1.6739	0.2301	0.6928	0.3322	| | |
9	0.7800	.	.	.	.	.	.	.	.	.	
10	0.7200	.	.	.	.	.	.	.	.	.	
11	0.8000	1.1931	0.1997	0.7931	1.5931	-0.3184	2.7046	-0.3931	0.6997	-0.5618	| *| |
12	0.7800	0.7587	0.2139	0.3302	1.1872	-0.7606	2.2779	0.0213	0.6954	0.0306	| | |
13	.	.	.	.	.	.	.	.	.	.	
14	1.3200	1.0764	0.2436	0.5883	1.5645	-0.4607	2.6135	0.2436	0.6856	0.3553	| | |
15	1.1000	0.8214	0.2279	0.3647	1.2780	-0.7060	2.3488	0.2786	0.6910	0.4033	| | |
16	1.1700	0.5766	0.2738	0.0282	1.1251	-0.9807	2.1340	0.5934	0.6741	0.8802	| |* |
17	0.4700	0.7579	0.1542	0.4490	1.0668	-0.7320	2.2478	-0.2879	0.7111	-0.4049	| | |
18	0.5300	0.7930	0.2966	0.1988	1.3872	-0.7810	2.3670	-0.2630	0.6644	-0.3958	| | |
19	3.4800	3.4090	0.3891	2.6294	4.1885	1.7561	5.0619	0.0710	0.6148	0.1155	| | |
20	0.4500	0.1127	0.2029	-0.2936	0.5191	-1.4004	1.6259	0.3373	0.6987	0.4827	| | |
21	0.5300	0.1197	0.1637	-0.2082	0.4477	-1.3742	1.6137	0.4103	0.7089	0.5787	| |* |
22	0.1700	0.5391	0.1705	0.1976	0.8806	-0.9579	2.0361	-0.3691	0.7074	-0.5218	| *| |
23	0.1500	0.1478	0.2001	-0.2530	0.5486	-1.3639	1.6595	.0022083	0.6995	.0031568	| | |
24	0.2700	0.0527	0.1923	-0.3325	0.4380	-1.4549	1.5603	0.2173	0.7017	0.3096	| | |
25	1.3400	.	.	.	.	.	.	.	.	.	
26	1.2400	0.9941	0.1805	0.6324	1.3558	-0.5076	2.4959	0.2459	0.7048	0.3488	| | |
27	0.1500	.	.	.	.	.	.	.	.	.	
28	0.0700	-0.2623	0.1958	-0.6546	0.1300	-1.7717	1.2471	0.3323	0.7008	0.4742	| | |
29	0.0800	0.1976	0.1768	-0.1565	0.5517	-1.3024	1.6975	-0.1176	0.7058	-0.1666	| | |
30	0.3600	.	.	.	.	.	.	.	.	.	
31	0.0600	.	.	.	.	.	.	.	.	.	
32	0.01	0.2767	0.3186	-0.3614	0.9149	-1.3144	1.8679	-0.2667	0.6542	-0.4078	| | |
33	1.3100	2.1829	0.1393	1.9039	2.4619	0.6989	3.6669	-0.8729	0.7141	-1.2223	| **| |
34	1.0200	0.9734	0.1914	0.5899	1.3568	-0.5338	2.4805	0.0466	0.7020	0.0664	| | |
35	0.4500	0.6711	0.1797	0.3110	1.0312	-0.8303	2.1724	-0.2211	0.7050	-0.3136	| | |
36	0.5000	.	.	.	.	.	.	.	.	.	
37	2.5900	.	.	.	.	.	.	.	.	.	
38	4.1700	3.5506	0.2868	2.9760	4.1251	1.9839	5.1173	0.6194	0.6687	0.9263	| |* |
39	0.6900	1.0412	0.1657	0.7093	1.3732	-0.4536	2.5361	-0.3512	0.7085	-0.4958	| | |
40	.	.	.	.	.	.	.	.	.	.	
41	0.1100	1.1220	0.2893	0.5426	1.7015	-0.4465	2.6906	-1.0120	0.6676	-1.5159	| ***| |
42	2.5900	1.9063	0.1679	1.5699	2.2426	0.4104	3.4021	0.6837	0.7080	0.9657	| |* |
43	0.8900	0.5471	0.2988	-0.0515	1.1456	-1.0286	2.1227	0.3429	0.6634	0.5169	| |* |
44	1.5000	1.1242	0.2419	0.6397	1.6088	-0.4118	2.6602	0.3758	0.6862	0.5476	| |* |
45	1.0000	.	.	.	.	.	.	.	.	.	
46	0.4200	1.1250	0.2378	0.6486	1.6014	-0.4084	2.6585	-0.7050	0.6876	-1.0253	| **| |
47	0.2400	0.6138	0.2119	0.1893	1.0382	-0.9043	2.1319	-0.3738	0.6961	-0.5370	| *| |
48	0.7200	1.0780	0.3844	0.3079	1.8481	-0.5705	2.7265	-0.3580	0.6178	-0.5795	| *| |

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2
49	0.9600	0.7502	0.2239	0.3018	1.1987	-0.7748	2.2752	0.2098	0.6923	0.3030	| | |
50	7.2900	4.0588	0.3366	3.3845	4.7332	2.4528	5.6648	3.2312	0.6450	5.0093	| |******|
51	0.7800	0.6263	0.2473	0.1310	1.1216	-0.9131	2.1657	0.1537	0.6843	0.2246	| | |
52	1.4600	2.8162	0.2694	2.2765	3.3559	1.2619	4.3704	-1.3562	0.6759	-2.0065	| ****| |
53	0.1300	0.2814	0.2423	-0.2040	0.7667	-1.2549	1.8176	-0.1514	0.6861	-0.2206	| | |
54	0.1500	0.4627	0.3253	-0.1889	1.1144	-1.1339	2.0593	-0.3127	0.6508	-0.4805	| | |
55	3.1100	.	.	.	.	.	.	.	.	.	
56	0.2600	.	.	.	.	.	.	.	.	.	
57	0.4000	.	.	.	.	.	.	.	.	.	
58	3.2700	2.6206	0.3584	1.9027	3.3385	0.9959	4.2454	0.6494	0.6332	1.0255	| |** |
59	0.4200	.	.	.	.	.	.	.	.	.	
60	2.4900	2.2632	0.3274	1.6074	2.9191	0.6649	3.8615	0.2268	0.6498	0.3490	| | |
61	0.3400	0.0282	0.2134	-0.3993	0.4556	-1.4908	1.5471	0.3118	0.6956	0.4483	| | |
62	0.3500	0.0585	0.2417	-0.4258	0.5428	-1.4774	1.5944	0.2915	0.6863	0.4248	| | |
63	0.3000	0.3852	0.2346	-0.0846	0.8551	-1.1462	1.9166	-0.0852	0.6888	-0.1237	| | |
64	0.4700	0.7957	0.2088	0.3774	1.2140	-0.7207	2.3121	-0.3257	0.6970	-0.4673	| | |
65	0.6500	2.0538	0.2827	1.4875	2.6202	0.4901	3.6176	-1.4038	0.6704	-2.0940	| ****| |
66	0.2100	0.0625	0.3222	-0.5829	0.7079	-1.5315	1.6565	0.1475	0.6524	0.2261	| | |
67	0.5300	.	.	.	.	.	.	.	.	.	
68	0.5300	-0.1324	0.2504	-0.6340	0.3693	-1.6738	1.4091	0.6624	0.6831	0.9696	| |* |
69	0.3300	1.0480	0.1652	0.7170	1.3791	-0.4466	2.5427	-0.7180	0.7086	-1.0133	| **| |
70	2.0500	2.2639	0.1809	1.9015	2.6263	0.7620	3.7658	-0.2139	0.7048	-0.3035	| | |
71	0.2100	0.0653	0.2793	-0.4941	0.6247	-1.4959	1.6265	0.1447	0.6719	0.2154	| | |
72	0.5400	.	.	.	.	.	.	.	.	.	
73	4.2200	5.4831	0.3842	4.7134	6.2528	3.8348	7.1314	-1.2631	0.6179	-2.0443	| ****| |
74	1.1600	1.7048	0.2020	1.3002	2.1094	0.1921	3.2175	-0.5448	0.6990	-0.7794	| *| |
75	0.3100	1.5471	0.2671	1.0120	2.0822	-.005542	3.0998	-1.2371	0.6768	-1.8279	| ***| |
76	0.1100	.	.	.	.	.	.	.	.	.	
77	0.3000	.	.	.	.	.	.	.	.	.	
78	0.9900	.	.	.	.	.	.	.	.	.	
79	0.9600	0.7586	0.2402	0.2774	1.2398	-0.7763	2.2935	0.2014	0.6868	0.2932	| | |
80	0.1100	.	.	.	.	.	.	.	.	.	
81	5.2500	4.3083	0.3627	3.5818	5.0349	2.6797	5.9370	0.9417	0.6308	1.4929	| |** |
82	2.2700	.	.	.	.	.	.	.	.	.	
83	2.3700	.	.	.	.	.	.	.	.	.	
84	1.5300	.	.	.	.	.	.	.	.	.	
85	3.2600	2.8208	0.3778	2.0641	3.5775	1.1785	4.4631	0.4392	0.6219	0.7063	| |* |
86	1.6700	3.0728	0.4358	2.1999	3.9457	1.3738	4.7718	-1.4028	0.5827	-2.4075	| ****| |
87	1.0500	1.1277	0.1999	0.7272	1.5282	-0.3839	2.6393	-0.0777	0.6996	-0.1111	| | |
88	1.6100	.	.	.	.	.	.	.	.	.	
89	1.8300	1.3337	0.2567	0.8195	1.8478	-0.2119	2.8793	0.4963	0.6808	0.7290	| |* |
90	0.2600	.	.	.	.	.	.	.	.	.	
91	0.3800	0.7562	0.2337	0.2880	1.2244	-0.7747	2.2871	-0.3762	0.6890	-0.5460	| *| |
92	2.0300	1.7884	0.1699	1.4481	2.1287	0.2916	3.2851	0.2416	0.7075	0.3415	| | |
93	1.8900	0.9618	0.3883	0.1839	1.7398	-0.6903	2.6140	0.9282	0.6153	1.5085	| |*** |
94	.	.	.	.	.	.	.	.	.	.	

OBS	COOK'S D
1	.
2	0.001
3	.
4	0.002
5	0.000
6	.
7	0.000
8	0.001
9	.
10	.
11	0.003
12	0.000
13	.
14	0.002
15	0.002
16	0.016
17	0.001
18	0.004
19	0.001
20	0.002
21	0.002
22	0.002
23	0.000
24	0.001
25	.
26	0.001
27	.
28	0.002
29	0.000
30	.
31	.
32	0.005
33	0.007
34	0.000
35	0.001
36	.
37	.
38	0.020
39	0.002
40	.
41	0.054
42	0.007
43	0.007
44	0.005
45	.
46	0.016
47	0.003
48	0.016

OBS	COOK'S D
49	0.001
50	0.854
51	0.001
52	0.080
53	0.001
54	0.007
55	.
56	.
57	.
58	0.042
59	.
60	0.004
61	0.002
62	0.003
63	0.000
64	0.002
65	0.097
66	0.002
67	.
68	0.016
69	0.007
70	0.001
71	0.001
72	.
73	0.202
74	0.006
75	0.065
76	.
77	.
78	.
79	0.001
80	.
81	0.092
82	.
83	.
84	.
85	0.023
86	0.405
87	0.000
88	.
89	0.009
90	.
91	0.004
92	0.001
93	0.113
94	.

SUM OF RESIDUALS	-8.87068E-14
SUM OF SQUARED RESIDUALS	29.64643
PREDICTED RESID SS (PRESS)	46.3138

APPENDIX F

SCATTER, written by Roger Stuebing

SCATTER,a S.A.S. program written by Roger Stuebing, determines the depth (soil horizon) at which the roots broke within the soil in the pull-out resistance test.

```
// JOB ,SCATTER,
// REGION=2048K,TIME=(,15)
/*JOBPARM L=6
/*ROUTE  PRINT RMT14
// EXEC SASP,REL=855
//SYSIN DD *
GOPTIONS  DEVICE =VTC1200 BORDER  HSIZE=9.5  VSIZE=7.0
ROTATE
 COLORS = (PEN1, PEN2, PEN3, PEN4, PEN5, PEN6, PEN7, PEN8);
DATA ROOTS ;  INFILE RAW;
INPUT  ID  1-5 2  SP $ 6-10  PLUNG 11-16 2  MOIST  17-22 2
DEPH  23-26 2  S $  27-29  DV 30-34 2  DB  35-39  2
LENGH 40-46 2  ORDER  47-51 2  MTF  52-56 2  TBF  57-61 2
ENDS 62-66 2  EXDV 67-72  2  TIME  73-78 2;
DATA TIME ; INFILE TDAT;
INPUT  ID  1-5 2  TTF  7-13 2  AZ 14-17;
PROC SORT DATA=ROOTS;  BY ID;
PROC SORT DATA=TIME ;  BY ID;
DATA COMBO; MERGE ROOTS TIME; BY ID;
RADIANS = 2*3.14159*AZ/360;  ANGLE =2*3.14159* PLUNG/360;
L=LENGH*COS(ANGLE); Z=LENGH * SIN(ANGLE);
X= L* COS(RADIANS) ;  Y=L*SIN (RADIANS); R=500;
R1=R-DEPH*0.36; L1=SQRT(R1*R1+DEPH*DEPH);
PHI=ATAN(DEPH/R1);
L2=LENGH; R2=LENGH*COS(PHI);
DEPH2=LENGH*SIN(PHI);
X=(R1+R2)*COS(RADIANS);
Y=(R1+R2)*SIN(RADIANS);
Z=(L1+LENGH)*SIN(PHI);
INTID = INT (ID);
PROC SORT ; BY INTID;
PROC G3D  DATA=COMBO ; BY INTID;
 SCATTER X * Y = Z ;
/*
//RAW DD *
 5.02 SM   2.00 20.50 0.17SC 0.22 0.09  25.20 5.00 0.08 0.07  0.29 0.11  28.50
 5.07 SM  20.00 20.30 0.51 C 0.27 0.20  16.70 4.00 0.02 0.01  0.26 0.17  12.00
 9.11 SM   0.00 16.00 0.35SC 0.30 0.20  22.00 4.00 0.29 0.21  0.94 0.21  34.50
 5.03 SM  22.00 22.00 0.22SC 0.31 0.25  37.00 4.00 0.12 0.08  0.22 0.23  17.25
 5.06 SM   5.00 22.00 0.44 C 0.38 0.30  18.00      0.10 0.06  0.21 0.34  15.75
 4.17 SM  28.00 20.40 0.36SC 0.40 0.22  16.00 4.00 0.27 0.27  0.26 0.37  66.75
 2.05 SM  31.00 22.20 0.37SC 0.40 0.22  33.00 5.00 0.61 0.61  0.90 0.37  70.50
 2.12 SM  35.00 20.00 0.21SC 0.42 0.40  15.50      0.79 0.78  0.37 0.41  45.00
 9.03 SM  13.00 17.40 0.20SC 0.48 0.40  21.50      0.42 0.42  0.37 0.54  37.50
 4.14 SM  15.00 22.00 0.14SC 0.50 0.45  21.80 5.00 0.53 0.53  0.76 0.59  28.50
 4.16 SM  35.00 20.40 0.40 C 0.50 0.15  25.00 5.00 0.15 0.15  1.20 0.58  63.00
 2.10 SM   3.00 22.20 0.36SC 0.50 0.11  16.00 5.00 0.42 0.33  0.60 0.58  25.50
 2.07 SM  27.00 21.00 0.30SC 0.52 0.19  43.70 5.00 0.58 0.58  0.87 0.63  40.50
10.15 SM  15.00 21.00 0.25SC 0.52 0.50  20.00      0.18 0.11  0.81 0.63  11.25
 2.02 SM  31.00 22.20 0.37SC 0.57 0.57  13.00      0.53 0.53  0.76 0.76  34.50
```

2.11	SM	24.00	20.00	0.20	SC	0.57	0.50	16.00	4.00	0.38	0.38	0.58	0.76	17.25
5.01	SM	5.00	20.50	0.15	SC	0.58	0.42	14.00		0.15	0.15	0.70	0.79	6.00
4.15	SM	0.00	21.00	0.16	SC	0.60	0.30	44.00	5.00	0.18	0.17	1.28	0.84	19.50
4.12	SM	0.00	21.00	0.16	SC	0.60	0.25	24.30	6.00	0.45	0.45	2.44	0.84	60.00
6.15	SM	10.00	21.40	0.37	SC	0.63	0.63	6.10		0.50	0.50	0.93	0.93	34.50
9.22	SM	59.00	17.80	0.30	SC	0.65	0.11	34.00	5.00	0.53	0.53	0.50	0.98	39.00
5.05	SM	25.00	22.00	0.32	C	0.68	0.60	25.00		0.36	0.36	1.13	1.08	75.00
2.15	SM	36.00	21.00	0.27	SC	0.70	0.70	16.00		0.79	0.72	1.15	1.15	58.50
9.07	SM	30.00	17.80	0.30	SC	0.70	0.11	54.00	6.00	0.30	0.30	0.79	1.15	27.75
4.08	SM	15.00	24.00	0.18	SC	0.70	0.62	32.50	5.00	0.53	0.47	1.26	1.15	137.25
9.05	SM	38.00	17.40	0.22	SC	0.75	0.11	38.00	5.00	0.42	0.34	1.01	1.32	24.00
2.16	SM	7.00	20.00	0.21	SC	0.80	0.35	74.00	5.00	0.80	0.80	1.19	1.49	42.00
2.18	SM	7.00	20.00	0.21	SC	0.80	0.32	26.00	4.00	0.32	0.32	0.46	1.49	37.50
4.20	SM	0.00	22.70	0.11	SC	0.80	0.70	42.00	5.00	1.24	1.24	2.16	1.50	52.50
2.08	SM	0.00	20.00	0.18	SC	0.80	0.81	30.00		0.75	0.75	2.39	1.49	90.00
10.16	SM	20.00	22.40	0.30	C	0.80	0.70	20.00		0.33	0.30	1.16	1.50	9.00
10.07	SM	2.00	17.40	0.15	SC	0.80	0.80			0.60	0.54	1.49	1.49	45.90
9.09	SM	17.00	17.70	0.31	SC	0.80	0.20	57.00	5.00	0.47	0.47	0.72	1.50	34.50
2.17	SM	50.00	22.20	0.38	SC	0.82	0.20	50.00	5.00	0.79	0.78	0.81	1.57	
6.14	SM	0.00	21.00	0.17	SC	0.85	0.30	43.20	6.00	0.59	0.45	3.16	1.69	19.50
4.01	SM	5.00	22.00	0.28	SC	0.90	0.64	24.70	4.00	1.32	1.32	1.32	1.90	
9.06	SM	37.00	17.40	0.22	SC	0.93	0.11	35.00	6.00	0.37	0.35	1.44	2.02	22.50
4.09	SM	70.00	19.00	0.42	SC	1.00	0.30	48.00	4.00	0.53	0.53	0.56	2.34	168.00
9.19	SM	5.00	18.00	0.16	SC	1.10				0.64	0.53			21.00
4.03	SM	5.00	24.00	0.21	SC	1.15	0.50	15.00	6.00	1.41	1.10	1.17	3.09	160.00
4.07	SM	15.00	22.00	0.09	SC	1.20	0.25	41.00	7.00	1.34	1.17	1.16	3.36	42.00
6.04	SM	10.00	24.00	0.14	SC	1.30	0.70	17.10	6.00	1.02	1.02	1.86	3.95	102.00
4.19	SM	15.00	20.60	0.16	SC	1.30	1.00	29.70		1.34	1.34	3.34	3.95	139.50
9.02	SM	0.00	18.40	0.10	SC	1.52	1.30	96.00	6.00	3.44	3.27	5.68	5.41	91.50
6.02	SM	10.00	24.00	0.11	SC	1.56	1.00	69.00	6.00	1.31	1.31	4.78	5.69	269.25
2.01	SM	10.00	21.00	0.14	SC	1.90	0.70	46.00	6.00	2.45	1.96	2.21	8.45	70.50
9.04	SM	4.00	17.40	0.18	SC	2.22	0.90	63.00	8.00	2.92	2.49	5.93	11.50	91.50
9.10	SM	15.00	18.00	0.13	SC	2.28	0.60	62.00	6.00	0.65	0.65	3.00	12.16	57.00
6.17	SM	12.00	21.00	0.19	SC	2.40	1.05		6.00	2.74	2.59	11.14	13.50	103.50
4.10	SM	0.00	22.00	0.10	SC	2.80	0.60	105.00	6.00	3.61	3.48	2.70	18.30	194.40
6.20	SM	11.00	22.00	0.07	SCL	3.00	1.60	59.30	6.00	4.17	4.17	10.10	21.00	168.75
7.09	ASH	20.00	24.10	0.05	SCL	0.40	0.11	75.00	4.00	0.89	0.89	0.55	0.31	16.50
10.21	ASH	13.00	20.30	0.40	C	0.50	0.45	17.00		0.17	0.11	0.47	0.46	14.25
7.24	ASH	74.00	21.40	0.38	SC	0.55	0.50	45.00	5.00	0.19	0.15	0.72	0.55	30.00
7.15	ASH	12.00	26.40	0.10	SC	0.57	0.40	42.50	5.00	0.24	0.24	1.04	0.58	9.00
7.23	ASH	14.00	26.40	0.10	SC	0.60	0.25	28.50	5.00	0.13	0.13	0.94	0.64	7.50
7.29	ASH		30.00	0.15	SC	0.65	0.50	16.00		0.40	0.40	0.58	0.74	18.00
7.28	ASH	18.00	30.00	0.13	SC	0.68	0.50	18.00		0.26	0.26	0.55	0.46	13.50
7.21	ASH	0.00	26.40	0.05	SCL	0.71	0.40	35.00	5.00	0.78	0.78	0.51	0.88	31.50
7.17	ASH	77.00	27.30	0.42	SC	0.80	0.30	56.00	4.00	0.72	0.72	0.96	1.10	114.50
7.14	ASH	20.00	26.90	0.20	SC	0.80	0.58	50.00	6.00	0.42	0.42	1.16	[illegible]	10.50
11.06	ASH	40.00	25.20	0.10	SC	0.80				2.27	2.27			45.00
10.01	ASH	10.00	22.90	0.10	SC	0.85	0.50	65.00	6.00	0.67	0.33	1.77	1.29	148.50
7.19	ASH	30.00	26.40	0.12	SC	0.89	0.40	41.80	5.00	0.96	0.96	1.24	1.35	21.75
11.12	ASH	20.00	26.00	0.14	SC	0.90				2.10	1.53			33.75
11.20	ASH	4.00	21.40	0.06	SCL	1.04	0.90	63.00	7.00	1.83	1.83	1.81	1.83	27.45
10.19	ASH	23.00	22.00	0.02	SCL	1.05	0.40	55.00	5.00	1.01	0.96	0.95	1.86	34.50
11.11	ASH	7.00	25.20	0.10	SC	1.10				2.37	2.37			21.00
7.01	ASH	20.00	24.10	0.10	SC	1.10	0.70	37.00	5.00	0.69	0.69	1.17	2.03	97.50

```
10.06ASH  45.00 17.40 0.18SC 1.10 0.50  14.50 6.00 0.22 0.21  1.00 2.03   6.00
11.18ASH   7.00 21.90 0.14SC 1.20 0.94  19.00 5.00 1.05 1.05  3.87 2.41  36.90
11.25ASH  53.00 21.40 0.02SCL1.20 1.10  41.00 5.00 1.89 1.89  2.18 3.03  68.70
11.15ASH  10.00 25.50 0.01SCL1.25 1.00 156.00 7.00 1.82 1.67  2.86 2.61  40.50
11.19ASH   4.00 21.40 0.02SCL1.30                  1.70 1.61              51.15
11.22ASH  20.00 21.80 0.14SC 1.30 0.63  24.30 7.00 0.44 0.38  1.83 2.82  33.00
 7.10ASH  27.00 22.00 0.16SC 1.40 0.15  59.00 5.00 1.50 1.50  1.18 3.26  12.00
 7.07ASH  50.00 20.70 0.42SC 1.40 0.25  34.20 4.00 0.11 0.11  0.38 3.26  12.00
 7.08ASH  26.00 21.30 0.22SC 1.40 0.60  80.00 5.00 2.59 2.59  1.66 3.26  33.00
 7.11ASH   0.00 24.10 0.10SC 1.42 1.10  44.00      1.00 1.00  2.26 3.30  13.50
11.23ASH   4.00 22.40 0.17SC 1.50 0.62  56.20 5.00 2.03 2.03  1.98 3.74  60.75
11.21ASH  23.00 21.40 0.08SCL1.50 1.40  28.00      0.26 0.26  3.35 3.74   4.50
 7.04ASH        21.30 0.20SC 1.54 0.47  47.00 5.00 0.66 0.63  1.08 3.90  48.00
 7.22ASH  20.00 26.40 0.10SC 1.57 0.80 119.80 6.00 3.24 1.46  2.30 4.10 114.00
10.13ASH   3.00 22.00 0.99SCL1.62 1.20  13.00 5.00 0.37 0.31  3.67 4.35  10.50
10.04ASH   0.00 22.90 0.04SCL1.70 1.20  62.00 6.00 2.05 2.05  7.99 4.78 130.65
10.11ASH  15.00 22.00 0.12SC 1.90 0.90  38.00 7.00 1.88 1.16  3.41 5.97  59.25
 7.27ASH   0.00 33.00 0.10SC 2.02 1.50  40.00      3.92 3.11  4.71 6.74  67.50
 7.20ASH  10.00 26.90 0.17SC 2.30 1.00 135.00 6.00 7.77 7.29  3.97 8.72 102.00
11.13ASH  10.00 25.20 0.05SCL2.60 1.90  20.00 8.00 4.13 3.26 10.9011.13 110.25
11.05ASH  11.00 27.60 0.18SC 2.80 2.00  73.00 7.00 5.31 5.25 11.2512.90  99.00
10.17ASH  90.00 22.40 0.40C  3.20                  4.08 0.99             120.00
10.10ASH   0.00 22.90 0.07SC14.00 2.20  95.00 7.00 5.36 4.22
/*
//TDAT DD *
 5.02  33.00350
 5.07  14.25140
 9.11  42.00 80
 5.03  65.75310
 5.06  36.00175
 4.17  75.00 25
 2.05  70.50180
 2.12  66.00115
 9.03  37.50 75
 4.14  35.25 90
 4.16  63.00 10
 2.10  38.25115
 2.07  44.25140
10.15  13.05 20
 2.02  34.51 80
 2.11  17.25125
 5.01   6.00310
 4.15  37.50120
 4.12  60.00120
 6.15  49.50360
 9.22  39.00255
 5.05  75.00135
 2.15  66.00 70
 9.07  31.50 50
 4.08 150.00 65
 9.05  34.50  1
 2.16  42.00100
 2.18  37.50100
 4.20  52.50 60
```

```
 2.08   90.00 90
10.16    9.75350
10.07   50.40180
 9.09   36.00320
 2.17         180
 6.14  156.00310
 4.01          90
 9.06   28.50 40
 4.09  168.00100
 9.19   34.50260
 4.03  192.00 80
 4.07   67.50 70
 6.04  102.00160
 4.19  139.50 40
 9.02  100.50 70
 6.02  269.25 30
 2.01  135.00170
 9.04   97.50 20
 9.10   57.00350
 6.17  114.75355
 4.10  194.40290
 6.20  187.50278
 7.09   16.50260
10.21   18.75350
 7.24   96.00110
 7.15    9.00340
 7.23    7.50145
 7.29   18.75
 7.28   18.00120
 7.21   31.50100
 7.17  114.00105
 7.14   10.50355
11.06   45.03180
10.01  114.50
 7.19   21.75190
11.12   43.50200
11.20   27.45130
10.19   35.25 90
11.11   30.02180
 7.01  103.50270
10.06   16.50255
11.18   36.90100
11.25   68.70120
11.15   60.00200
11.19   55.20130
11.22   36.90100
 7.10   12.00260
 7.07   12.00295
 7.08   43.50275
 7.11   13.50 30
11.23   60.75 50
11.21    4.50130
 7.04   66.00
 7.22  174.00140
```

```
10.13  49.50 30
10.04 130.65230
10.11  66.00340
 7.27  70.65 90
 7.20 135.00180
11.13 154.00170
11.05 117.75170
10.17 234.00  1
10.10 100.00
/*
```

APPENDIX G

ROOTS.BAS, written by Ken Cruikshank

```
'Program ROOTF.BAS      Version 1.00     20 July, 1987

' (c) 1987 Sister Meg Software
' "The Heavenly Software"

start.program:
CLS
WIDTH LPRINT 255
REDIM force.id$(10)

gamma.w = 9.8
gamma.t = 20
phi = 22
c = 2.7
to.rad = 3.14159/180
beta = 30
alpha = 0
v = 21
area =49

LPRINT CHR$(27);CHR$(77);chr$(15);

INPUT "Enter filename -> ",infile$
OPEN "I",1,infile$
INPUT #1, header$
length = LEN(header$)
i=0
temp=0
FOR j=1 TO length
  temp$ = MID$(header$,j,1)
  IF temp$ <> " " THEN
     force.id$(i) = force.id$(i) + temp$
  ELSE
     IF temp+1 <> j THEN
        i = i+1
     END IF
     temp = j
  END IF
NEXT
nforce = i
REDIM sum(nforce),force(nforce),scale(nforce)
PRINT
PRINT "The following roots are in the file:    ";
FOR i=1 TO nforce
  PRINT USING "#) \    \";i,force.id$(i)
  PRINT SPC(40);
NEXT
PRINT
INPUT "Sum roots (Y/N) -> ",buf$
FOR i=1 TO nforce
  scale(i) = 1
NEXT
```

```
IF buf$ = "Y" or buf$="y" THEN
  summation% = -1
  INPUT"Enter number next to root I.D.'s(space between numbers) -> ",buf$
  temp=0
  FOR i=1 TO nforce
     sum(i) = 0
  NEXT
  length = LEN(buf$)
  WHILE (temp+2 <= length)
     temp = INSTR(temp+1,buf$," ")
     temp2 = VAL(Mid$(buf$,temp-1,1))
     sum(temp2) = -1
  WEND
  temp2 = VAL(RIGHT$(buf$,1))
  sum(temp2) = -1
  INPUT "Do you want to multiply any of the summed forces (Y/N) -> ",buf2$
  IF buf2$ = "Y" or buf2$ = "y" THEN
     scale.flag% = -1
     PRINT
     PRINT "Enter scale factor...must be one or greater"
     PRINT
     FOR i=1 TO nforce
        IF sum(i) THEN
           PRINT "Root ";force.id$(i);
           INPUT " Scale factor -> ",scale(i)
        END IF
     NEXT
  ELSE
     scale.flag% = 0
  END IF
ELSE
  summation% = 0
END IF
LOCATE 9,1
LPRINT "Input file = ";infile$
LPRINT
IF summation% THEN
  LPRINT "The following roots are summed: ":LPRINT
  FOR i=1 TO nforce
     IF sum(i) THEN
        LPRINT SPC(5);force.id$(i)
     END IF
  NEXT
END IF
LPRINT
IF scale.flag% THEN
  LPRINT "The following forces are scaled:":LPRINT
  FOR i=1 TO nforce
     IF sum(i) THEN
        LPRINT SPC(5);"Force for ";force.id$(i);" scaled by a factor of"
                        ;scale(i)
     END IF
  NEXT
END IF
```

```
LPRINT
IF summation% THEN
  LPRINT USING "  \    \  ";force.id$(0);
ELSE
  LPRINT USING "  \    \  ";force.id$(0);
  FOR i=1 TO nforce
     LPRINT USING "          \   \     ";force.id$(i);
  NEXT
END IF
LPRINT
LPRINT SPC(17);
IF summation% THEN
  LPRINT "Fr";SPC(8);"Fd";SPC(10);
ELSE
  FOR i=1 TO nforce
     LPRINT "Fr";SPC(8);"Fd";SPC(10);
  NEXT
END IF
LPRINT
WHILE NOT(EOF(1))
  INPUT #1, disp
  LPRINT USING "##.#### ||  ";disp;
  FOR i=1 TO nforce
     INPUT #1, force(i)
     IF Summation% THEN
        IF sum(i) THEN
           fforce = fforce+force(i)*scale(i)
        END IF
        IF (i <> nforce) THEN GOTO next.force
     ELSE
        fforce = force(i)
     END IF
       cos.alpha = COS(alpha*to.rad)
     sin.alpha = SIN(alpha*to.rad)
     cos.beta = COS(beta*to.rad)
     sin.beta = SIN(beta*to.rad)
     tan.phi = TAN(phi*to.rad)
     Fr = (v*(gamma.t-gamma.w)*cos.beta+fforce*cos.alpha)*tan.phi_
          +fforce*sin.alpha+c*area
     Fd = v*gamma.t*sin.beta
     LPRINT USING "###.####  ###.#### --";Fr,Fd;
     fforce = 0
     next.force:
  NEXT
  LPRINT
WEND
LPRINT CHR$(12);
CLOSE
GOTO start.program
```

SUGAR MAPLE

displace. (cm)	Force kN ID #6.02	#6.14	#4.07	#4.12	#4.15	#4.16
0.00	0.11	0.08	0.06	0.38	0.03	0.03
0.10	0.22	0.12	0.06	0.40	0.03	0.03
0.25	0.20	0.20	0.06	0.40	0.08	0.03
0.50	0.28	0.22	0.06	0.40	0.08	0.05
0.75	0.71	0.30	1.09	0.42	0.08	0.05
1.00	1.00	0.27	0.93	0.42	0.08	0.06
1.50	0.90	0.40	1.00	0.43	0.08	0.11
2.00	1.31	0.28	1.13	0.45	0.12	0.11
2.50	1.31	0.21	1.35	0.45	0.16	0.15
3.00	0.74	0.25	1.35	0.17	0.18	0.14
4.00	0.45	0.17	1.06	0.17	0.18	0.14
5.00	0.33	0.57	1.09	0.17	0.18	0.12
6.00	0.33	0.33	1.00	0.17	0.17	0.13
7.00	0.33	0.40	0.80	0.17	0.15	0.13
8.00	0.33	0.27	0.60	0.17	0.13	0.10
9.00	0.04	0.50	0.50	0.17	0.11	0.08
10.00	0.00	0.62	0.39	0.17	0.15	0.07
15.00	0.00	0.07	0.46	0.20	0.18	0.00
20.00	0.00	0.00	0.46	0.07	0.00	0.00
25.00	0.00	0.00	0.06	0.30	0.00	0.00
30.00	0.00	0.00	0.00	0.04	0.00	0.00

WHITE ASH

displace. (cm)	Force kN ID #7.20	#7.22	#11.13	#11.15	#11.22
0.00	0.00	0.00	0.00	0.00	0.00
0.10	0.00	0.00	0.00	0.00	0.15
0.25	0.00	0.00	0.00	1.21	0.15
0.50	0.00	0.00	0.00	1.10	0.15
0.75	0.00	0.00	0.00	1.08	0.15
1.00	0.00	0.44	3.40	1.03	0.15
1.50	0.00	1.52	4.00	1.41	0.15
2.00	0.00	1.56	4.00	1.83	0.40
2.50	0.00	2.67	4.00	1.16	0.40
3.00	0.00	3.29	4.00	1.30	0.40
4.00	0.33	1.01	4.00	1.45	0.40
5.00	0.66	1.58	4.00	1.69	0.40
6.00	1.00	1.00	3.50	1.60	0.40
7.00	1.88	0.31	3.50	1.45	0.42
8.00	2.00	1.00	3.50	1.25	0.21
9.00	2.50	0.40	3.50	1.00	0.21
10.00	2.85	0.05	3.60	0.84	0.18
15.00	5.62	0.42	3.60	0.00	0.20
20.00	0.74	0.00	3.60	0.00	0.03
25.00	0.00	0.00	3.50	0.00	0.00
30.00	0.00	0.00	2.50	0.00	0.00

Input file = maple

The following roots are summed:

6.02
4.16

The following forces are scaled:

Force for 6.02 scaled by a factor of 1
Force for 4.16 scaled by a factor of 1

Slope angle (beta) = 30
Volume = .5
Area = 1

disp		Fr	Fd	
0.0000	¦¦	4.5410	5.0000	--
0.1000	¦¦	4.5855	5.0000	--
0.2500	¦¦	4.5774	5.0000	--
0.5000	¦¦	4.6178	5.0000	--
0.7500	¦¦	4.7915	5.0000	--
1.0000	¦¦	4.9127	5.0000	--
1.5000	¦¦	4.8925	5.0000	--
2.0000	¦¦	5.0582	5.0000	--
2.5000	¦¦	5.0744	5.0000	--
3.0000	¦¦	4.8400	5.0000	--
4.0000	¦¦	4.7228	5.0000	--
5.0000	¦¦	4.6703	5.0000	--
6.0000	¦¦	4.6703	5.0000	--
7.0000	¦¦	4.6703	5.0000	--
8.0000	¦¦	4.6582	5.0000	--
9.0000	¦¦	4.5330	5.0000	--
10.0000	¦¦	4.5128	5.0000	--
15.0000	¦¦	4.4845	5.0000	--
20.0000	¦¦	4.4845	5.0000	--
25.0000	¦¦	4.4845	5.0000	--
30.0000	¦¦	4.4845	5.0000	--

Input file = maple

The following roots are summed:

6.02
4.16

The following forces are scaled:

Force for 6.02 scaled by a factor of 1
Force for 4.16 scaled by a factor of 1

Slope angle (beta) = 30
Volume = 1.12
Area = 2.25

disp		Fr	Fd	
0.0000	¦¦	10.1288	11.2000	--
0.1000	¦¦	10.1732	11.2000	--
0.2500	¦¦	10.1651	11.2000	--
0.5000	¦¦	10.2055	11.2000	--
0.7500	¦¦	10.3793	11.2000	--
1.0000	¦¦	10.5005	11.2000	--
1.5000	¦¦	10.4803	11.2000	--
2.0000	¦¦	10.6459	11.2000	--
2.5000	¦¦	10.6621	11.2000	--
3.0000	¦¦	10.4278	11.2000	--
4.0000	¦¦	10.3106	11.2000	--
5.0000	¦¦	10.2581	11.2000	--
6.0000	¦¦	10.2581	11.2000	--
7.0000	¦¦	10.2581	11.2000	--
8.0000	¦¦	10.2460	11.2000	--
9.0000	¦¦	10.1207	11.2000	--
10.0000	¦¦	10.1005	11.2000	--
15.0000	¦¦	10.0722	11.2000	--
20.0000	¦¦	10.0722	11.2000	--
25.0000	¦¦	10.0722	11.2000	--
30.0000	¦¦	10.0722	11.2000	--

Input file = ASH

The following roots are summed:

07.20
11.13
11.15

The following forces are scaled:

Force for 07.20 scaled by a factor of 1
Force for 11.13 scaled by a factor of 4
Force for 11.15 scaled by a factor of 2

disp

	Fr	Fd
Slope angle (beta) =	30	
Volume =	.3	
Area =	1	

0.0000	¦¦	3.7707	3.0000	--
0.1000	¦¦	3.7707	3.0000	--
0.2500	¦¦	4.7484	3.0000	--
0.5000	¦¦	4.6595	3.0000	--
0.7500	¦¦	4.6434	3.0000	--
1.1000	¦¦	10.0977	3.0000	--
1.5000	¦¦	11.3745	3.0000	--
2.0000	¦¦	11.7138	3.0000	--
2.5000	¦¦	11.1724	3.0000	--
3.0000	¦¦	11.2855	3.0000	--
4.0000	¦¦	11.5401	3.0000	--
5.0000	¦¦	11.8674	3.0000	--
6.0000	¦¦	11.1240	3.0000	--
7.0000	¦¦	11.3583	3.0000	--
8.0000	¦¦	11.2452	3.0000	--
9.0000	¦¦	11.2452	3.0000	--
10.0000	¦¦	11.4189	3.0000	--
15.0000	¦¦	11.8593	3.0000	--
20.0000	¦¦	9.8876	3.0000	--
25.0000	¦¦	9.4270	3.0000	--
30.0000	¦¦	7.8109	3.0000	--

Input file = ash

The following roots are summed:

07.20
11.13
11.15

The following forces are scaled:

Force for 07.20 scaled by a factor of 1
Force for 11.13 scaled by a factor of 4
Force for 11.15 scaled by a factor of 2

disp
Slope angle (beta) = 30
Volume = .675
Area = 2.25

		Fr	Fd	
0.0000	¦¦	8.4840	6.7500	--
0.1000	¦¦	8.4840	6.7500	--
0.2500	¦¦	9.4618	6.7500	--
0.5000	¦¦	9.3729	6.7500	--
0.7500	¦¦	9.3567	6.7500	--
1.1000	¦¦	14.8111	6.7500	--
1.5000	¦¦	16.0878	6.7500	--
2.0000	¦¦	16.4272	6.7500	--
2.5000	¦¦	15.8858	6.7500	--
3.0000	¦¦	15.9989	6.7500	--
4.0000	¦¦	16.2535	6.7500	--
5.0000	¦¦	16.5807	6.7500	--
6.0000	¦¦	15.8373	6.7500	--
7.0000	¦¦	16.0716	6.7500	--
8.0000	¦¦	15.9585	6.7500	--
9.0000	¦¦	15.9585	6.7500	--
10.0000	¦¦	16.1322	6.7500	--
15.0000	¦¦	16.5726	6.7500	--
20.0000	¦¦	14.6010	6.7500	--
25.0000	¦¦	14.1404	6.7500	--
30.0000	¦¦	12.5243	6.7500	--

Input file = ash

The following roots are summed:

07.20
11.13
11.15

The following forces are scaled:

Force for 07.20 scaled by a factor of 1
Force for 11.13 scaled by a factor of 4
Force for 11.15 scaled by a factor of 2

Slope angle (beta) = 30
Volume = 1.2
Area = 4

disp		Fr	Fd	
0.0000	::	15.0827	12.0000	--
0.1000	::	15.0827	12.0000	--
0.2500	::	16.0605	12.0000	--
0.5000	::	15.9716	12.0000	--
0.7500	::	15.9554	12.0000	--
1.1000	::	21.4098	12.0000	--
1.5000	::	22.6865	12.0000	--
2.0000	::	23.0259	12.0000	--
2.5000	::	22.4845	12.0000	--
3.0000	::	22.5976	12.0000	--
4.0000	::	22.8522	12.0000	--
5.0000	::	23.1734	12.0000	--
6.0000	::	22.4360	12.0000	--
7.0000	::	22.6703	12.0000	--
8.0000	::	22.5572	12.0000	--
9.0000	::	22.5572	12.0000	--
10.0000	::	22.7309	12.0000	--
15.0000	::	23.1713	12.0000	--
20.0000	::	21.1997	12.0000	--
25.0000	::	20.7391	12.0000	--
30.0000	::	19.1230	12.0000	--

Input file = ash

The following roots are summed:

07.20
11.13
11.15

The following forces are scaled:

Force for 07.20 scaled by a factor of 1
Force for 11.13 scaled by a factor of 4
Force for 11.15 scaled by a factor of 2

disp
Slope angle (beta) = 30
Volume = 1.875
Area = 6.25

		Fr	Fd	
0.0000	¦¦	23.5668	18.7500	--
0.1000	¦¦	23.5668	18.7500	--
0.2500	¦¦	24.5445	18.7500	--
0.5000	¦¦	24.4556	18.7500	--
0.7500	¦¦	24.4395	18.7500	--
1.1000	¦¦	29.8938	18.7500	--
1.5000	¦¦	31.1705	18.7500	--
2.0000	¦¦	31.5099	18.7500	--
2.5000	¦¦	30.9685	18.7500	--
3.0000	¦¦	31.0817	18.7500	--
4.0000	¦¦	31.3362	18.7500	--
5.0000	¦¦	31.6635	18.7500	--
6.0000	¦¦	30.9200	18.7500	--
7.0000	¦¦	31.1544	18.7500	--
8.0000	¦¦	31.0413	18.7500	--
9.0000	¦¦	31.0413	18.7500	--
10.0000	¦¦	31.2150	18.7500	--
15.0000	¦¦	31.6554	18.7500	--
20.0000	¦¦	29.6837	18.7500	--
25.0000	¦¦	29.2231	18.7500	--
30.0000	¦¦	27.6070	18.7500	--

```
Input file = ash

The following roots are summed:

    07.20
    11.13
    11.15

The following forces are scaled:

    Force for 07.20 scaled by a factor of  1
    Force for 11.13 scaled by a factor of  4
    Force for 11.15 scaled by a factor of  2

Slope angle (beta) =  30
Volume             =  2.7
Area               =  9

 disp
                Fr        Fd
 0.0000 ||   33.9362   27.0000 --
 0.1000 ||   33.9362   27.0000 --
 0.2500 ||   34.9139   27.0000 --
 0.5000 ||   34.8250   27.0000 --
 0.7500 ||   34.8089   27.0000 --
 1.1000 ||   40.2632   27.0000 --
 1.5000 ||   41.5399   27.0000 --
 2.0000 ||   41.8793   27.0000 --
 2.5000 ||   41.3379   27.0000 --
 3.0000 ||   41.4510   27.0000 --
 4.0000 ||   41.7056   27.0000 --
 5.0000 ||   42.0328   27.0000 --
 6.0000 ||   41.2894   27.0000 --
 7.0000 ||   41.5238   27.0000 --
 8.0000 ||   41.4106   27.0000 --
 9.0000 ||   41.4106   27.0000 --
10.0000 ||   41.5844   27.0000 --
15.0000 ||   42.0248   27.0000 --
20.0000 ||   40.0531   27.0000 --
25.0000 ||   39.5925   27.0000 --
30.0000 ||   37.9764   27.0000 --
```

Input file = ash

The following roots are summed:

07.20
11.13
11.15

The following forces are scaled:

Force for 07.20 scaled by a factor of 1
Force for 11.13 scaled by a factor of 4
Force for 11.15 scaled by a factor of 2

Slope angle (beta) = 30
Volume = 3.675
Area = 12.25

disp		Fr	Fd	
0.0000	::	46.1909	36.7500	--
0.1000	::	46.1909	36.7500	--
0.2500	::	47.1686	36.7500	--
0.5000	::	47.0797	36.7500	--
0.7500	::	47.0636	36.7500	--
1.1000	::	52.5179	36.7500	--
1.5000	::	53.7946	36.7500	--
2.0000	::	54.1340	36.7500	--
2.5000	::	53.5925	36.7500	--
3.0000	::	53.7058	36.7500	--
4.0000	::	53.9603	36.7500	--
5.0000	::	54.2876	36.7500	--
6.0000	::	53.5442	36.7500	--
7.0000	::	53.7785	36.7500	--
8.0000	::	53.6654	36.7500	--
9.0000	::	53.6654	36.7500	--
10.0000	::	53.8391	36.7500	--
15.0000	::	54.2795	36.7500	--
20.0000	::	52.3078	36.7500	--
25.0000	::	51.8472	35.7500	--
30.0000	::	50.2311	36.7500	--

Input file = ash

The following roots are summed:

07.20
11.13
11.15

The following forces are scaled:

Force for 07.20 scaled by a factor of 1
Force for 11.13 scaled by a factor of 4
Force for 11.15 scaled by a factor of 2

Slope angle (beta) = 30
Volume = 4.8
Area = 16

disp		Fr	Fd	
0.0000	¦¦	60.3309	48.0000	--
0.1000	¦¦	60.3309	48.0000	--
0.2500	¦¦	61.3087	48.0000	--
0.5000	¦¦	61.2198	48.0000	--
0.7500	¦¦	61.2036	48.0000	--
1.1000	¦¦	66.6580	48.0000	--
1.5000	¦¦	67.9347	48.0000	--
2.0000	¦¦	68.2741	48.0000	--
2.5000	¦¦	67.7327	48.0000	--
3.0000	¦¦	67.8458	48.0000	--
4.0000	¦¦	68.1004	48.0000	--
5.0000	¦¦	68.4276	48.0000	--
6.0000	¦¦	67.6842	48.0000	--
7.0000	¦¦	67.9186	48.0000	--
8.0000	¦¦	67.8054	48.0000	--
9.0000	¦¦	67.8054	48.0000	--
10.0000	¦¦	67.9792	48.0000	--
15.0000	¦¦	68.4195	48.0000	--
20.0000	¦¦	66.4479	48.0000	--
25.0000	¦¦	65.9873	48.0000	--
30.0000	¦¦	64.3712	48.0000	--

Input file = ash

The following roots are summed:

07.20
11.13
11.15

The following forces are scaled:

Force for 07.20 scaled by a factor of 1
Force for 11.13 scaled by a factor of 4
Force for 11.15 scaled by a factor of 2

Slope angle (beta) = 30
Volume = 6.07
Area = 20.25

disp		Fr	Fd	
0.0000	¦¦	76.3385	60.7000	--
0.1000	¦¦	76.3385	60.7000	--
0.2500	¦¦	77.3163	60.7000	--
0.5000	¦¦	77.2274	60.7000	--
0.7500	¦¦	77.2112	60.7000	--
1.1000	¦¦	82.6656	60.7000	--
1.5000	¦¦	83.9423	60.7000	--
2.0000	¦¦	84.2817	60.7000	--
2.5000	¦¦	83.7403	60.7000	--
3.0000	¦¦	83.8534	60.7000	--
4.0000	¦¦	84.1079	60.7000	--
5.0000	¦¦	84.4352	60.7000	--
6.0000	¦¦	83.6918	60.7000	--
7.0000	¦¦	83.9261	60.7000	--
8.0000	¦¦	83.8130	60.7000	--
9.0000	¦¦	83.8130	60.7000	--
10.0000	¦¦	83.9867	60.7000	--
15.0000	¦¦	84.4271	60.7000	--
20.0000	¦¦	82.4555	60.7000	--
25.0000	¦¦	81.9949	60.7000	--
30.0000	¦¦	80.3788	60.7000	--

Input file = ash

The following roots are summed:

07.20
11.13
11.15

The following forces are scaled:

Force for 07.20 scaled by a factor of 1
Force for 11.13 scaled by a factor of 4
Force for 11.15 scaled by a factor of 2

Slope angle (beta) = 30
Volume = 7.5
Area = 25

disp		Fr	Fd	
0.0000	;;	94.2671	74.9999	--
0.1000	;;	94.2671	74.9999	--
0.2500	;;	95.2448	74.9999	--
0.5000	;;	95.1560	74.9999	--
0.7500	;;	95.1398	74.9999	--
1.1000	;;	100.5941	74.9999	--
1.5000	;;	101.8709	74.9999	--
2.0000	;;	102.2103	74.9999	--
2.5000	;;	101.6689	74.9999	--
3.0000	;;	101.7820	74.9999	--
4.0000	;;	102.0365	74.9999	--
5.0000	;;	102.3638	74.9999	--
6.0000	;;	101.6204	74.9999	--
7.0000	;;	101.8547	74.9999	--
8.0000	;;	101.7416	74.9999	--
9.0000	;;	101.7416	74.9999	--
10.0000	;;	101.9153	74.9999	--
15.0000	;;	102.3557	74.9999	--
20.0000	;;	100.3841	74.9999	--
25.0000	;;	99.9235	74.9999	--
30.0000	;;	98.3074	74.9999	--

Input file = ash

The following roots are summed:

07.20
11.13
11.15

The following forces are scaled:

Force for 07.20 scaled by a factor of 1
Force for 11.13 scaled by a factor of 4
Force for 11.15 scaled by a factor of 2

Slope angle (beta) = 30
Volume = 10.8
Area = 36

disp		Fr	Fd	
0.0000	;;	135.7446	107.9999	--
0.1000	;;	135.7446	107.9999	--
0.2500	;;	136.7224	107.9999	--
0.5000	;;	136.6335	107.9999	--
0.7500	;;	136.6173	107.9999	--
1.1000	;;	142.0717	107.9999	--
1.5000	;;	143.3484	107.9999	--
2.0000	;;	143.6878	107.9999	--
2.5000	;;	143.1464	107.9999	--
3.0000	;;	143.2595	107.9999	--
4.0000	;;	143.5141	107.9999	--
5.0000	;;	143.8413	107.9999	--
6.0000	;;	143.0979	107.9999	--
7.0000	;;	143.3322	107.9999	--
8.0000	;;	143.2191	107.9999	--
9.0000	;;	143.2191	107.9999	--
10.0000	;;	143.3928	107.9999	--
15.0000	;;	143.8332	107.9999	--
20.0000	;;	141.8616	107.9999	--
25.0000	;;	141.4010	107.9999	--
30.0000	;;	139.7849	107.9999	--

Input file = ash

The following roots are summed:

07.20
11.13
11.15

The following forces are scaled:

Force for 07.20 scaled by a factor of 1
Force for 11.13 scaled by a factor of 4
Force for 11.15 scaled by a factor of 2

Slope angle (beta) = 30
Volume = 14.7
Area = 49

disp		Fr	Fd	
0.0000	¦¦	184.7635	146.9999	--
0.1000	¦¦	184.7635	146.9999	--
0.2500	¦¦	185.7413	146.9999	--
0.5000	¦¦	185.6524	146.9999	--
0.7500	¦¦	185.6362	146.9999	--
1.1000	¦¦	191.0906	146.9999	--
1.5000	¦¦	192.3673	146.9999	--
2.0000	¦¦	192.7067	146.9999	--
2.5000	¦¦	192.1653	146.9999	--
3.0000	¦¦	192.2784	146.9999	--
4.0000	¦¦	192.5329	146.9999	--
5.0000	¦¦	192.8602	146.9999	--
6.0000	¦¦	192.1168	146.9999	--
7.0000	¦¦	192.3511	146.9999	--
8.0000	¦¦	192.2380	146.9999	--
9.0000	¦¦	192.2380	146.9999	--
10.0000	¦¦	192.4117	146.9999	--
15.0000	¦¦	192.8521	146.9999	--
20.0000	¦¦	190.8805	146.9999	--
25.0000	¦¦	190.4199	146.9999	--
30.0000	¦¦	188.8038	146.9999	--

APPENDIX H

Soil Moisture Measurements

DATE	depth (dm)	wet soil &dish	dry soil &dish	dish	%moisture	moisture content
3-30	1.00	126.30	114.00	68.10	21.20	26.80
(after	2.00	130.00	118.40	70.70	19.70	24.32
a	3.00	142.30	127.70	70.20	20.20	25.39
week	4.00	134.80	118.90	65.40	22.90	29.72
of	5.00	149.80	131.10	69.80	23.30	30.51
rain)	6.00	124.50	111.50	67.60	22.80	29.61
	7.00	152.60	133.50	65.10	21.80	27.92
	8.00	149.10	130.10	71.20	24.40	32.26
4-17	5.00	244.20	208.30	87.20	22.90	29.64
	5.00	289.90	231.60	91.10	29.30	41.49
	5.00	278.60	251.30	92.10	14.60	17.15
4-19	4.00	204.70	181.20	96.50	21.70	27.74
	5.00	279.20	234.30	93.00	24.10	31.78
	5.00	296.20	263.60	93.40	16.10	19.15
	7.00	242.20	213.30	107.40	21.40	27.29
	8.00	287.70	250.40	107.40	20.70	26.08
	9.00	301.40	274.10	106.70	14.00	16.31
5-18	1.00	176.50	158.40	88.40	20.50	25.86
	2.00	200.70	177.80	89.40	20.60	25.90
	3.00	187.80	165.80	86.20	22.00	27.64
	4.00	193.90	171.40	88.60	21.30	27.17
	5.00	221.10	194.60	90.30	20.30	25.41
	9.00	225.60	196.50	87.50	21.00	26.70
5-24	1.00	95.70	82.10	36.30	23.00	29.69
	2.00	113.00	96.50	34.30	21.00	26.53
	3.00	111.40	96.10	35.30	20.00	25.16
	4.00	111.40	94.70	33.40	21.40	27.24
	5.00	136.00	112.10	34.30	23.50	30.72
5-23	1.00	120.70	100.00	33.60	24.00	31.17
	2.00	131.60	110.40	34.50	22.00	27.93
	3.00	139.40	116.20	34.90	22.00	28.54
6-4	1.00	138.40	111.10	25.30	24.10	31.82
	2.00	147.40	121.40	25.30	21.30	27.06
	3.00	187.10	153.80	25.30	20.60	25.91
	4.00	528.40	460.70	202.10	20.70	26.18
5-30	1.00	235.80	202.70	85.10	22.00	28.15
	2.00	231.30	196.60	85.10	24.00	31.12
	3.00	303.00	260.50	117.60	23.00	29.74
	4.00	171.00	143.40	25.70	19.00	23.45
	5.00	215.00	175.50	27.40	21.00	26.67
6-7	1.00	83.50	69.30	23.60	23.70	31.07
	2.00	106.60	89.70	23.60	20.40	25.57
	3.00	101.50	85.10	23.60	21.00	26.67
	4.00	115.90	97.40	23.60	20.00	25.07
6-8	1.00	111.10	90.80	23.60	23.20	30.21
	2.00	83.40	71.40	23.60	20.00	25.10
	3.00	111.50	93.00	23.60	21.00	26.66
	4.00	115.20	94.80	23.60	22.20	28.65
6-12	1.00	92.30	76.70	23.60	22.70	29.38
	2.00	108.70	91.20	23.60	20.60	25.89
	3.00	100.80	84.90	23.60	20.60	25.94
	4.00	110.50	92.80	23.60	20.40	25.58
6-15	1.00	97.30	81.90	23.60	26.40	26.42
	2.00	102.70	85.90	23.60	26.90	26.97

	3.00	104.80	89.80	23.60	22.70	22.66
	4.00	103.70	86.50	23.60	27.30	27.34
6-16	1.00	120.20	96.00	23.60	33.40	33.43
	2.00	105.80	90.40	23.60	23.00	23.05
	3.00	124.10	104.10	23.60	25.00	24.84
	4.00	112.60	96.90	23.60	21.40	21.42
7-7	1.00	105.40	84.80	23.60	25.20	33.66
	2.00	123.00	101.10	23.60	27.60	28.26
	3.00	118.50	97.40	23.60	27.60	28.59
	4.00	144.50	114.20	23.60	36.10	33.44
7-9	1.00	108.50	90.30	23.60	21.40	27.29
	2.00	98.80	81.90	23.60	22.40	28.99
	3.00	116.20	96.30	23.60	21.50	27.37
	4.00	124.50	105.00	23.60	19.30	23.96
7-10	1.00	106.50	86.60	23.60	22.90	31.59
	2.00	107.80	89.60	23.60	17.40	27.58
	3.00	121.40	101.40	23.60	20.40	25.71
	4.00	126.90	105.20	23.60	21.00	26.59
7-11	1.00	101.80	84.50	23.50	22.00	28.36
	2.00	108.20	90.70	23.50	20.70	26.04
	3.00	132.50	108.10	23.50	22.40	28.84
	4.00	133.60	111.20	23.50	20.30	25.54
7-20	1.00	88.20	76.30	23.50	18.40	22.54
	2.00	98.80	85.70	23.50	17.40	21.06
	3.00	99.70	86.10	23.50	17.80	21.73
	4.00	116.50	100.30	23.50	14.30	21.09
7-21	1.00	90.10	77.20	23.50	19.40	24.02
	2.00	107.80	92.50	23.50	18.00	22.17
	3.00	119.10	102.70	23.50	17.00	20.71
	4.00	103.50	89.70	23.50	17.30	20.85
7-31	1.00	113.00	94.30	23.50	20.90	26.41
	2.00	114.20	96.70	23.50	19.30	23.91
	3.00	103.00	86.50	23.50	20.70	26.19