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June, 1965

AN INVESTIGATION OF THE EFFECT OF DIRECT HUMAN IMPACT AND
OF ADVANCED PLANT SUCCESSION ON SEQUOIA GIGANTEA IN SEQUOIA
AND KINGS CANYON NATIONAL PARKS, CALIFORNIA

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TABLE OF CONTENTS

Resumé	1.
Giant Forest Chronology	5.
Methods of Study	
Growth Rate Changes	7.
Soil Bulk Density-Root Penetration Studies	8.
Soil Moisture Conditions Beneath Pavement, Compacted Soils and in Unmodified Areas	10.
Results	
a.) Measurement of the Effects of Root Pruning, Pavement and Ground Compaction on a Selected Group of Specimen Trees	12.
Root Pruning	12.
Pavement, Roadfill and Buildings Over Sequoia Root Systems	13.
Sequoias in Campgrounds and Other Areas of Heavy Human Use	18.
b.) Soil Moisture Relationships Beneath Pavement, Compacted Soil and in Unmodified Areas	20.
c.) Growth Rate Measurements of Mature Sequoias in Selected Areas Approaching Successional Climax	28.
d.) Establishment of Soil Bulk Density-Root Penetration Study Plots	31.
e.) The Fire-Sequoia Regeneration Studies	
Resumé	33.
Vegetational Analysis of the North Study Area	33.
Plans for Vegetational Studies, Summer, 1965	35.
The Small Mammals Study	36.
Discussion and Plans for Mammal Studies, 1965	37.
Miscellaneous	
Sequoia Snag-top Study	40.
Radiocarbon Dating of Giant Sequoia Wood	44.
Sequoia Root Study	45.
References Cited	46.
Appendixes	47.

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LIST OF FIGURES

- Fig. 1. Comparison of Growth Rates of Giant Sequoias in Areas
of Heavy, Moderate and No Human Use Shown in Percentages
of Growth Rate Increase or Decrease During the Last 50
Years vs. the Previous 50 - - - - - 3.
- Fig. 2. Average Bulk Densities of Trampled and Untrampled
Soils in Giant Forest - - - - - 21.
- Fig. 3. Soil Moisture Percentage by Weight - - - - - 22.
- Fig. 4. Soil Moisture Percentage by Volume - - - - - 22.
- Fig. 5. Location of Soil Moisture Electrodes and Soil Temperature
Thermistors Beneath Pavement in Giant Forest Village,
Sequoia National Park, California - - - - - 24.
- Fig. 6. Location of Soil Moisture Electrodes and Soil Temperature
Thermistors Beneath Pavement at the Visitor Center,
Sequoia National Park, California - - - - - 25.
- Fig. 7. Schematic Diagram of Soil Moisture Electrodes and Soil
Temperature Thermistors Set Beneath the Pavement - - - - - 26.
- Fig. 8. Sequoia Root Regrowth in Soil Bulk Density Plots,
Giant Forest, Sequoia National Park, California - - - - - 31.

Resume

The studies of human impact upon giant sequoia trees and their environments in Sequoia and Kings Canyon National Parks indicate that mass human impact is of little or no negative consequence to mature sequoias and that only two types of human activities have caused a significant reduction in sequoia growth rate. These were root pruning for road construction and the response to advanced plant succession, a result of fire prevention. In fact, however, there is a general increase in the growth rates of some sequoias which is apparently due to building, road construction where pavement covers the roots and to wide-spread soil compaction in camp and picnic areas.

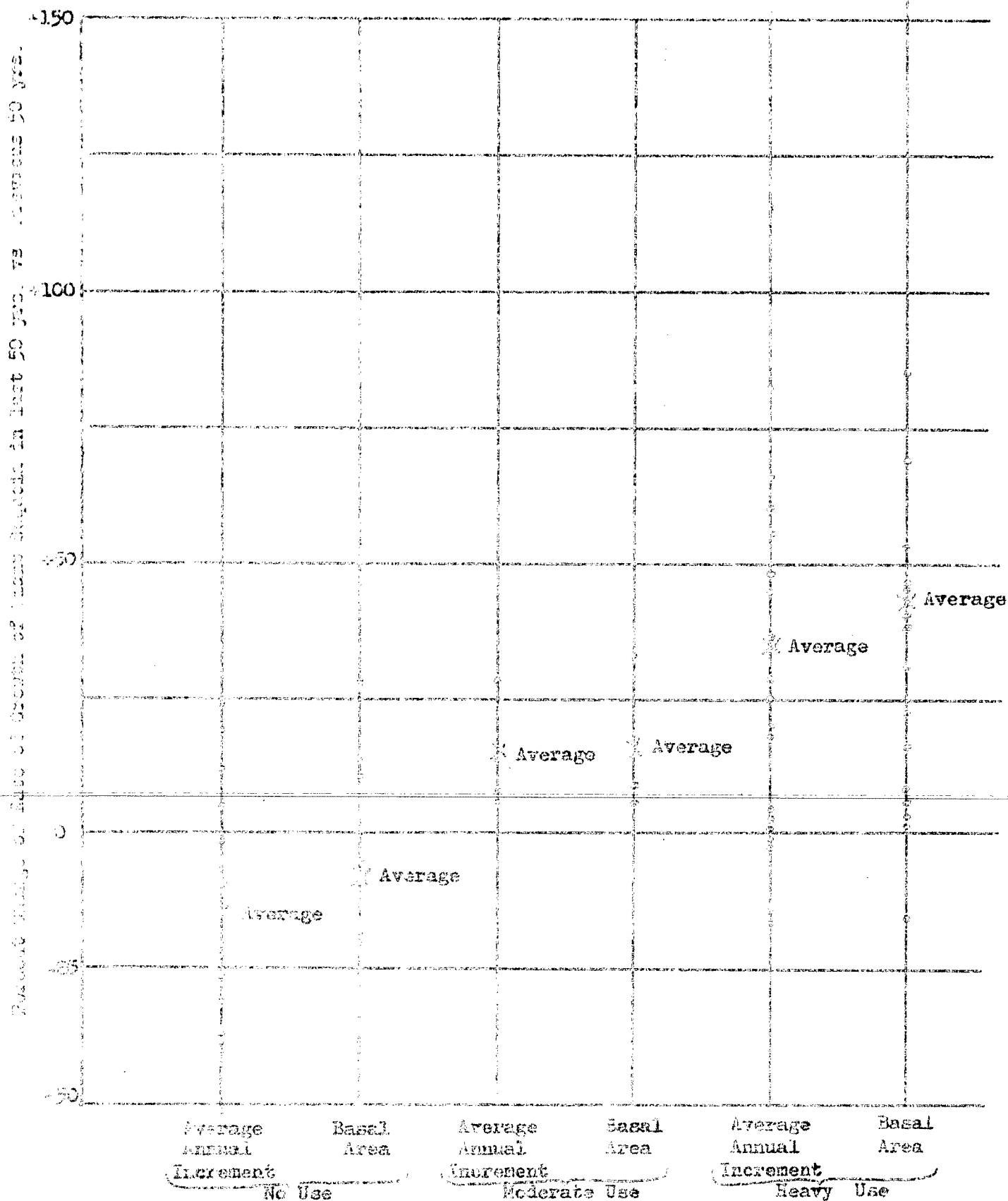
For those sequoias whose growth rates have been reduced, the reduction cannot necessarily be construed as being detrimental to the health of the trees inasmuch as pathogens have not been found to be associated with them. Nor has human activity been established as the cause of the toppling of any sequoia tree in either park. Many sequoias growing under near climax conditions in areas remote from human use are growing increasingly slower at the same time other sequoias in areas of human use are growing more rapidly than before. Even severely burned trees, such as the Black Chamber (Fig. 31, Appendix E) in the Giant Forest, show much greater annual increment than some relatively unburned sequoias in nearly undisturbed areas of poor site quality. Contrary to previous beliefs ^{1/}, these growth studies show that sequoia trees in campgrounds and other high use areas tend to increase in growth rate more or less proportionately to the amount of cleared and/or artificially covered root zone area.

^{1/} Heinicke, E.P. Memorandum on the Effects of Tourist Traffic on Plant Life, Particularly Big Trees, Sequoia National Park, California. Berkeley, California: Typed report to National Park Service, June 9, 1926, 19 pp.

Whereas detrimental effects to sequoia trees because of mass human use have been shown to be of little negative consequence, changes to the environment which affect other vegetation and sequoia reproduction are of much greater significance. Soil compaction because of trampling and auto traffic is such that root growth of many plants is retarded or completely restricted in the surface few inches of soil and that the germination of seeds and the early growth of plants is impaired. Soil moisture relationships are altered by soil compaction and by the presence of pavement and buildings over the surface of the soil. Where the soil moisture regime is altered for the worse, it may be a significant factor in reduced seed germination. On the other hand, it is often altered for the better and the affected sequoias respond with increased rates of growth. In general, soil moisture reduction is restricted to the surface inch or two which represents but a small fraction of the rooting zone of single large sequoias and cannot be construed as a meaningful loss. Beneath pavements, extensive buildings and compacted soil, soil moisture values in the rooting zone remain high throughout the growing season and are reflected clearly in the increased growth rates of those sequoias with roots growing under those conditions (Fig. 1, next page).

Sequoias growing in the apparent increased competition of advanced plant succession where human disturbances are minimal or absent, show reductions in their rates of growth. At a theoretically perfect climax stage of plant succession, the utilization of available energy would be at a maximum but would be distributed to a much larger number of plants than at earlier stages. In these conditions, sequoia growth is necessarily slowed. This effect is evident in the greater percentage of the larger sequoias. Young sequoias under near climax conditions of severe root competition and

Fig. 1. Comparison of Growth Rates of Giant Sequoias in Areas of Heavy, Moderate and No Human Use Shown in Percentages of Growth Rate Increase or Decrease During the Last 50 years vs. the Previous 50 Years.



Shading usually succumb after a period of slowed growth.

Sequoias whose roots have been severely pruned to accomodate road construction show by far the greatest amount of growth reduction. Even here, however, specimens with pruned roots show some recovery of growth rate a number of years after pruning.

The fire-sequoia regeneration studies are well underway and the indications at this time are that the results will provide much information about the natural history of sequoia plant communities which will be valuable in both management and interpretation.

Giant Forest Chronology

Many of the dates given in this chronology are approximate. Accurate records were not kept during the early years of the park as to where people camped, picnicked, etc. For instance, a report states that the Giant Forest Camp in 1920 was 140 acres in size. It is not known whether this included the Firwood Campground, the Hazelwood Picnic Area and other nearby land. The general feeling is that the camping areas were diffuse and simply grew in size with the demand. It is known that the Hazelwood area has been used extensively since before it became a part of the national park. Records have not been found of its status since that time. Certainly, it has received heavy usage for many years.

In the growth comparisons made in this report, known dates as stated in this chronology are used for some of the before-after human use studies. Since growth responses take place over a period of years, the exact dates for these comparisons are not critically important.

1903 - First road into Giant Forest completed August 15 from Colony Mill.

Road to Moro Rock constructed.

General Sherman Tree first fenced.

1909 - A small building was constructed in the area which is now the front end of the Giant Forest Lodge dining hall.

1917 - The Wolverton-Lodgepole Road was constructed.

1920 - The road from the Parker Group to Crescent Meadow was cut through and was roughly graded.

1921 - Giant Forest Lodge dining room was constructed.

The first permanent overnight cabins were built at Giant Forest Lodge. These are the ones now covered with sequoia wood shakes.

The Crescent Meadow Road was finished.

1924 - The Giant Forest Museum (Visitor Center) was constructed. The parking lot was probably constructed at the same time although there is no mention of it in reports.

A restroom was constructed in the Firwood Campground. However, there is no notation of the original construction date of the camp.

1926 - Firwood Campground was improved to a capacity of 40 campsites.

The Giant Forest Village Site was started.

The Generals Highway, including the roadway to the General Sherman Tree and to Lodgepole Camp, was begun.

1927 - A new grade from Soldier Camp to Crescent Meadow was completed.

The roadway to Log Meadow was closed, restricting traffic no farther than to Crescent Meadow.

Giant Forest Lodge dining hall was enlarged.

1928 - In Camp Kaweah, the office, warehouse and central toilet and bath house were started. Canvas-top cabins in upper Camp Kaweah were being built or moved there from other locations.

A gasoline station whose location is not now known was built somewhere in the Giant Forest Village.

1929 - Giant Forest Market construction was completed.

The Village road was widened and parking space was constructed.

1930 - The building which is now the Giant Forest Coffee Shop was built by Lindley Eddy as a photographic shop.

1934 - The Generals Highway was opened to the public.

1935 - Building was begun in what is now called Lower Camp Kaweah with the construction of the central toilet and bath house. This was followed by rustic cabins and canvas-top cabins, a few each year over a period of years.

Methods of Study - Growth Rate Changes

Those aspects of the study involving growth reactions by sequoia trees to various environmental conditions were assessed by means of studying annual growth ring variations. Approximately 75 cores were taken from sequoia trees by means of a standard 15 3/4-inch Swedish increment borer. The cores were preserved according to a method devised by Heath ^{2/} in which each core was glued in pre-grooved pieces of wood in order to prevent both shrinkage and warping.

Each core was studied under a dissecting binocular scope fitted with an ocular micrometer and the growth was recorded to the nearest one-tenth millimeter year by year or in ten-year increments where the growth rate was slow. Three growth rate comparisons were made:

- 1.) The average annual radial increment and the basal area growth for the last 50 years were compared with the averages of the 50 years immediately previous.
- 2.) The average annual radial increment and the average basal area growth for the last 50 years were compared with the averages of all previous years represented on each core.
- 3.) Where manipulations, such as road building or building construction, affected sequoia trees, the growth averages for the years since the manipulation were compared with an equal number of years prior to the manipulation date.

These growth comparisons are expressed as a percentage of increase or decrease in the average rates of growth and are shown graphically for 51 selected trees in Appendix I.

The best indication of the degree of photosynthetic success (total tree vigor and health) would be to calculate the annual volume of wood added by a specific tree in a unit of time, such as a year. Such calculations are virtually impossible. While basal area calculations are less valuable than

^{2/} Heath, J.P. "Increment Core Technique and Preventing Core Shrinkage." *Journal of Forestry*, 56(12): 909-10, December, 1958.

volume calculations, they are much more indicative of tree growth responses to environmental changes than annual radial increment and they can be rather simply made by recording the diameter inside the bark at the height of the increment boring and then calculating the basal area of the circular cross section of the tree. ^{2/} Using the yearly increment measurements from the core, the radius, and, therefore the basal area, can be regressed to the date of the earliest ring taken in the core. The resulting growth curve tends to be a straight-line function. On the assumption that the basal area growth after a tree reaches maturity is more or less continuously the same (a straight-line function), then the continued regression of the curve based only upon a short core can be used to calculate more accurately the approximate age of the tree.

Methods of Study - Soil Bulk Density-Root Penetration Studies

Two programs were undertaken to determine:

- 1.) The degree and depth of soil compaction in heavily used areas of the parks.
- 2.) The bulk density value beyond which sequoia root growth is impaired or completely limited.

Bulk density is the ratio of volume of soil over the oven-dry weight of the sample. The more compact the soil, the higher the bulk density value.

Soil samples were removed carefully by spoon and placed in soil sample cans. The volume of soil removed in each sample was measured by placing thin plastic film in the resulting hole and filling the lined hole with water from a graduated half-liter cylinder. The amount of water in millimeters to fill the hole exactly to the top is the volume of the soil sample. The soil samples were weighed wet, then oven-dried for 8 hours at 225° F and then reweighed.

^{2/} Spurr, S.H. Forest Inventory. New York: The Ronald Press Company, 1952, 476 pp.

Soil compaction studies were made by removing soil samples beginning with the surface two inches and then at each two-inch depth to an overall depth of 16 inches. Identical measurements were made for comparison purposes in both heavily used soils and in areas nearby where human use was minimal. Soil moisture content in percentage by weight and by volume were also calculated by gravimetric methods from these same data.

In order to determine bulk density limitations to root penetration, six plots 3 feet long by 6 inches wide by 18 inches deep were excavated along radial lines at a distance of about 35 feet from the trunk of a large sequoia between the east boundary of the old Firwood Campground and the Generals Highway. The excavation took place on September 1, 1963. With a quarter-inch mesh screen box, all rocks and roots from these pits were screened out of the soil which was collected carefully on a tarpaulin. All roots protruding into the excavations were cut off flush with the excavation walls so that all six pits were totally devoid of roots.

The screened soil materials were returned to the excavation pits with varying degrees of compacting force applied to four of the six plots. The two remaining plots were retained as uncompacted controls. In Plot No. 2, ~~after each three shovel fulls of soil, each square inch was tamped once~~ with a wooden tamping device with a four square inch compacting surface. The compacting force consisted only of the weight of the compacting device falling from a height of three feet. In Plot No. 3, the soil was tamped twice on each square inch with a slight degree of tamping force after each three shovels of soil. The soil in Plot No. 4 received 5 tamps with the same tamping force as in Plot No. 3 and the soil in Plot No. 5 was tamped 5 times with as much tamping force as could be exerted. Each plot was marked with numbered stakes and was covered with the leaf litter which

had been removed before excavation.

The plots were not disturbed in any way until October 10, 1964, a period of more than 13 months. On this date, bulk density samples were taken from each plot, the plots were reexcavated to the same dimensions and all new root growth was screened from the soil and clipped from the sides of the excavations with the intent of determining the amount of root growth under varying soil bulk densities. The roots were air-dried for one month and then weighed.

Methods of Study - Soil Moisture Conditions Beneath Pavement, Compacted Soils and in Unmodified Areas.

In unpaved areas, gravimetric measurements were most commonly employed to determine soil moisture contents. One hundred and thirty-three samples were taken and weighed in the field immediately to obtain the wet weight. They were then oven-dried and reweighed. The ratio of water lost over the oven-dry weight of the soil gives the moisture content of the soil in percent by weight. The percentage of soil moisture by weight multiplied by the bulk density of the soil gives the moisture content by volume.

Another method was employed to determine the soil moisture depletion rates during the entire growing season in specific areas. Gypsum soil moisture blocks with embedded electrodes were buried at depths of one, two and three feet beneath the soil surface around one selected study tree in well drained soil. Others were installed under other conditions including drainageways where soil moisture appeared to remain high throughout the entire growing season. Two soil moisture-soil temperature stations were established beneath the large expanses of pavement in the Giant Forest Village and in the Visitor Center parking area. Electrodes for moisture and thermistors for temperature were set at one and two-foot depths at

at each of the four stations (Figs. 5, 6 and 7). Controls were set at the same depths in unpaved soil nearby. Measurements were taken at one-week intervals with a Delmhorst Ohmmeter for moisture content and with an Ideal Precision Meter Co. mmeter, model 460-P for temperature.

RESULTS

a.) Measurement of the Effects of Root Pruning, Pavement and Ground Compaction on a Selected Group of Specimen Trees.

Root Pruning

Of the manipulative procedures affecting sequoia trees, severe root pruning has been responsible for the greatest reduction of growth rate in the 75 sequoias sampled for this study. A selected group of four sequoias on the up-slope side of the Generals Highway in the Giant Forest show an average growth reduction of 31.2 percent since the date the highway was completed with a range of reduction from 4.8 percent to 65.0 percent (Fig. 1, Appendix I, and Fig. 5, Appendix II). The variability of reduced growth rates is the result of several factors such as variable soil moisture, the size of the tree affected by root pruning, and the distance from the tree of the severance of the roots. Where the cut was close to the base of the tree, as much as 30 to 35 percent of the root system was eliminated.

It is surprising and significant that no one of these trees has fallen to its death because of the severity of its injuries. After the growth rates of these trees fell to their lowest levels, each has shown some degree of growth rate recovery. One small sequoia (2.3 feet d.b.h.) near Trinity Corner in Giant Forest has not only recovered its pre-pruning rate of growth but is now growing approximately three times faster.

The recorded reduction in the rate of growth is not necessarily an indication of reduced health of the tree but rather one of at least temporary reduced vigor. None of these trees has been injured as severely as many sequoias which have been burned repeatedly in the same area of the trunk over the centuries until huge gaping fire scars now show a root/crown severance of as much as 20 percent to 80 percent. As these naturally

injured trees show recovery after fires, so also do these trees with pruned root systems show a recovery. Root pruning, then, represents a limited and somewhat temporary disturbance to the affected trees because the roots grow and proliferate in whatever soil remains after road construction and is clearly reflected in the growth patterns of the affected trees as an increased rate of wood growth.

Pavement, Roadfill and Buildings Over Sequoia Root Systems.

Each sequoia with road fill, pavement or buildings covering a large portion of its root system which was cored for study has responded only by a rather striking increase in growth rate (Figs. 2 through 10, Appendix I, and Figs. 4 and 6, Appendix II). Basal area increases for the four trees with pavement over the root systems average 110.1 percent since the date of highway completion with a range of increase from 57.9 percent to 252.2 percent. The latter tree (Fig. 5, Appendix I), a sequoia measuring 12.209 d.b.h. inside the bark, is located just north of the Sherman Tree parking area turn-off along the Generals Highway. It is situated in a low drainage way where normal water drainage is impaired by a six- or seven-foot road fill so that the soil about the base of the tree is saturated with water during the early part of the growing season and remains wetter than adjacent better drained soils much or all of the growing season. The sequoia is a tree of the continuous seasonal flush type and commences growth in the spring and continues to grow as long as there is available soil moisture or until cold temperatures inhibit growth in the autumn, which ever occurs first. In years of low precipitation, soil moisture deficiencies often limit the growth of this type of tree. ^{4/} The sequoia was determined to be a tree of this type during the summers of 1963 and 1964 when daily radial increment

^{4/}Kramer, P.J., and E.T. Kozlowski. Physiology of Trees. New York: McGraw-Hill Book Co., 1960, p. 501.

was measured on three sequoia trees by means of a modified Bormann and Kozlowski dendrometer.^{5/} Thus, the sequoia in question may continue its growth well beyond the date of nearby sequoias less amply supplied with soil moisture. The growing season may well be extended from late August or early September until late October or even November when cold temperatures limit growth regardless of available soil moisture. In the summer of 1964, the Pinewood study tree had slowed to a virtual stop by the last week in August when soil moisture contents were near the permanent wilting point.

Of particular interest is the Sentinel Tree (Fig. 3, Appendix I) in the Giant Forest Village. Perhaps no other sequoia in its native range has as great a percentage of its root system covered with pavement. Using a composite of three cores from this tree for the basal area calculations, it was determined that since the advent of the pavement in the late 1920's, the basal area growth of the Sentinel Tree has increased by 58.7 percent. Its growth rate remains high indicating no direct or indirect impairment to the overall health of the tree because of the pavement. Somewhat contrary to this pattern of growth are those of sequoias in the Mariposa Grove which actually have less of their roots covered by pavement than the

Sentinel Tree. The Mariposa Grove records showed first a rather striking increase in growth rate which was followed by a decline in growth rate to an all-time low.^{6/} For these trees, however, the reduction in growth rate was very likely due to excess water entering the watershed by means of the Grove water system which raised the water table in the main drainageway to

^{5/} Bormann, F.H., and W.T. Kozlowski. "Measurements of Tree Ring Growth with Dial-Gage Dendrometers and Vernier Tree Ring Bands." Ecology 43(2): 289-294, Spring, 1962.

^{6/} Hartesveldt, R.J. The Effects of Human Impact Upon Sequoia gigantea and its Environment in the Mariposa Grove, Yosemite National Park, California. Ann Arbor, Michigan: The University of Michigan, unpublished thesis, 1963, pp. 74-75.

an unprecedented high. Other sequoias with no pavement over their roots but growing in the same drainageway displayed similar growth responses. In the Giant Forest Village area and at the Visitor Center, soil moisture measurements beneath the broad expanses of pavement (see also Sect. b) showed very little depletion during the growing season compared to adjacent soils without pavement. Once again, the increased growth of the Sentinel Tree apparently results largely because of the extended growing season due to the maintenance of relatively high soil moisture for a longer period of time.

Another possible difference in growth reactions of sequoias in the Mariposa Grove and the Giant Forest could be the greater sand-silt content of soils in the Giant Forest and the higher clay content in soils in the drainageways of the Mariposa Grove. The sand permits better drainage and root aeration which, in turn, minimizes damage to roots by lack of aeration and further minimizes the activities of root pathogens which have high water and low oxygen requirements. Concern over the eventual reduced growth rates of affected sequoias in the Mariposa Grove led to an attempt to secure the services of two pathologists to ascertain the reasons for the reduced growth rates under these conditions. Although each had expressed an interest in the determinations, neither was available during this period of study. Inasmuch as the growth rates of sequoia trees in Sequoia National Park have failed to slow because of the presence of pavement on root systems, it is assumed that pathogenic activity or other adverse conditions are minimal or absent and that there is no immediate concern for the presence of pavement over root systems.

The emplacement of impervious pavement over the rooting zone of sequoias creates four conditions which are apparently favorable to the

to the increased growth rates of sequoia trees:

1. Most important, wherever pavement exists, other plants which could otherwise be competing for the same soil moisture and nutrients are eliminated. This leaves the remaining sequoia trees with a greater amount of available soil moisture for late summer and autumn growth.

2. The impervious nature of the pavement reduces evaporative soil moisture losses to a minimum, again conserving moisture for sequoia growth.

3. The black-top pavement absorbs solar energy more efficiently than the local soils and thus heats the soil and its moisture significantly to a depth of more than two feet. This depth includes the greater percentage of a sequoia's rooting zone. Warmer water is less viscous than cold water and moves more freely into root conductive tissue than does cold water.^{2/} The soil temperature at one foot depth beneath the pavement averaged 25° warmer during two summers than at one foot depth in partially shaded and relatively undisturbed forest area nearby. At two feet depth, the soils beneath the pavement averaged nearly 9° warmer than those of the same depth without pavement.

4. Warm soils and warm soil solutions warm the root tissues. Warmer plant tissues metabolize at a faster rate, therefore increasing active transport of nutrients and more rapid uptake of water.

It is also likely that higher soil temperatures alter the microflora of the soil, reducing certain pathogenic forms and increasing others.

It has also been suggested that the condensation of soil vapors, which may be at saturation at higher temperatures, may take place when warmed pavements are cooled at night or on cool cloudy days. Such an occurrence

^{2/} Kramer, P.J., and T.T. Kozlowski. Physiology of Trees. New York: McGraw-Hill Book Co., 1960, p. 326.

might possibly explain the occasional increases in the soil moisture content beneath the pavement in the prolonged absence of precipitation.

The cores of five sequoias with buildings over portions of their root systems also show striking growth rate increases since the dates of building construction. Two of the three sequoias with root systems covered by the Giant Forest Lodge dining hall show basal area increases of 115.6 percent and 160.5 percent since the date of construction (Figs. 6 and 7, Appendix I and Fig. 6, Appendix II) when compared with the preceeding 50 years. The third tree, whose diameter was not taken because of an immense fire scar, showed an annual increment increase of 40.5 percent and for this reason, basal area computations were not made. The increased rate of growth is ostensibly the same as for those trees with pavement over the root systems. The soil temperature regime is probably cooled somewhat by the presence of buildings.

Two sequoias (Figs. 9, 10, Appendix I) cored in Camp Kaweah and others among the cabins of the Giant Forest Lodge show similar patterns of increased growth since the cabins were built. The one sequoia in Camp Kaweah which showed the striking increase of 121.7 percent since the building of the camp is located near the most heavily used part of the camp.

The change is most probably due to a combination of buildings, pavement and soil compaction.

The foliage of all the aforementioned trees appears full and healthy. From these studies, it is concluded that no harm has resulted to the overall health and vigor of sequoias because of either pavement or buildings over their root systems. Certainly, the trees in these heavily used areas should be reexamined periodically to make sure that this trend continues.

Sequoias in Campgrounds and Other Areas of Heavy Human Use.

Seven cores (Figs. 11 through 16, Appendix I) represent the growth responses of sequoias to heavy campground, picnic area and other human uses. The five trees in the campgrounds and picnic areas all show growth rate increases during the last 50 years of growth compared to the previous 50. Each tree is surrounded by a compaction sole with a bulk density of the upper several inches of soil which reduces, in places, root penetration, the infiltration of water and the percentage of soil moisture by weight. The constant attrition of trampling feet "erodes" away much of the potentially competing herbaceous plant life and the seedlings of both shrubs and trees. The dry, compact surface layer of soil further creates conditions which are adverse to the germination of seeds and the early growth of young plants. Excessively trampled areas were veritable deserts. The result to the sequoia trees is very much like the result of pavement over the root systems of the trees. With reduced plant competition, the sequoias grew later in the season and so produced wider growth rings than before the alteration of the soil and the reduction of plant numbers. Other than occasional vandalism in the camp- and picnic grounds, it is doubtful whether heavy human use of these areas is detrimental to the larger sequoias with fully grown root systems.

The two largest sequoias, the General Sherman Tree (Fig. 15, Appendix I) and the General Grant Tree (Fig. 16, Appendix I) fail to show comparable growth increases to those trees cored in the camp- and picnic grounds. In fact, the General Sherman Tree has decreased somewhat in growth rate during the past 50 years while the General Grant Tree has increased only slightly. Because of the size and importance of these two trees, each has been afforded more protection than those in the camping areas. As early as

1903, the General Sherman Tree was surrounded by a fence enclosure and the General Grant Tree was given similar protection at an early date. Pathways and railings have helped channel foot traffic near these trees so that foot erosion and soil compaction has remained minimal and no wide-spread compaction sole exists over the root system of either tree at this time. Because of the soil moisture natural to these areas, herbaceous vegetation is more plentiful than in the campgrounds. Further, young sequoias have been planted in the rooting area of each of these trees so that competition for soil moisture has not been as severely reduced as elsewhere.

Perhaps of great significance is the fact that these two trees are growing in sites of high quality with ample soil moisture available for plant growth until late in the season. It is significant that, of approximately 250 sequoias cored by the author during the past nine years, only one sequoia has been found to be growing as rapidly as these two trees and it is a tree less than half the diameter of these two. Indeed, the General Grant Tree is one of the world's fastest growing trees, based on calculations of basal area increase. From these same data, it is apparent that neither tree is as old as previously estimated and that their great size is a result of near optimum growing conditions.

b.) Soil Moisture Relationships Beneath Pavement, Compacted Soil and in Unmodified Areas.

A portion of the soil moisture studies was made concurrently with the bulk density tests in those soils not covered with pavement. Thirty-nine samples were taken in unmodified soils and 94 in severely trampled soils. Human trampling and auto traffic have compacted soils significantly to a depth of 8 inches but with the greatest amount of compaction occurring in the upper 2 inches (Fig. 2). A bulk density in light sandy soils of 1.6 to 1.8 is regarded as limiting to root growth and as completely restricting in densities greater than 1.8. In clayey soils, the limiting and restricting densities are somewhat less. However, of the samples taken in Sequoia and Kings Canyon National Parks, all of the soils were sands, loamy sands and sandy loams.^{3/} Of the untrampled soils sampled, none was as high as 1.6 bulk density. Of the compacted soils, 26 samples had bulk densities greater than 1.6 and 4 were in excess of 1.8. The latter 4 samples all were taken from the upper 6 inches of soil. The average densities for the two-inch depth groups are shown as Fig. 2. It will be noted that the densest layer, 4 to 6 inches, fails to reach a bulk density of 1.6.

Based upon a heavy compaction depth of 6 inches, only 25 to 30 percent of the rooting zone of mature sequoias would be within this zone of root restriction. Assuming that root restrictions really do occur in this layer, growth reductions would be expected. However, the increased moisture content of the compacted soils seems to more than compensate for it as determined by the measurement of radial stem growth.

Soil moisture was calculated by both weight and volume and is repre-

^{3/} Hartesveldt, R.J., Sequoia-Human Impact Soil Analyses. Memorandum to the Regional Director, Western Region, U.S. National Park Service, San Francisco, California, February 10, 1964, p. 3.

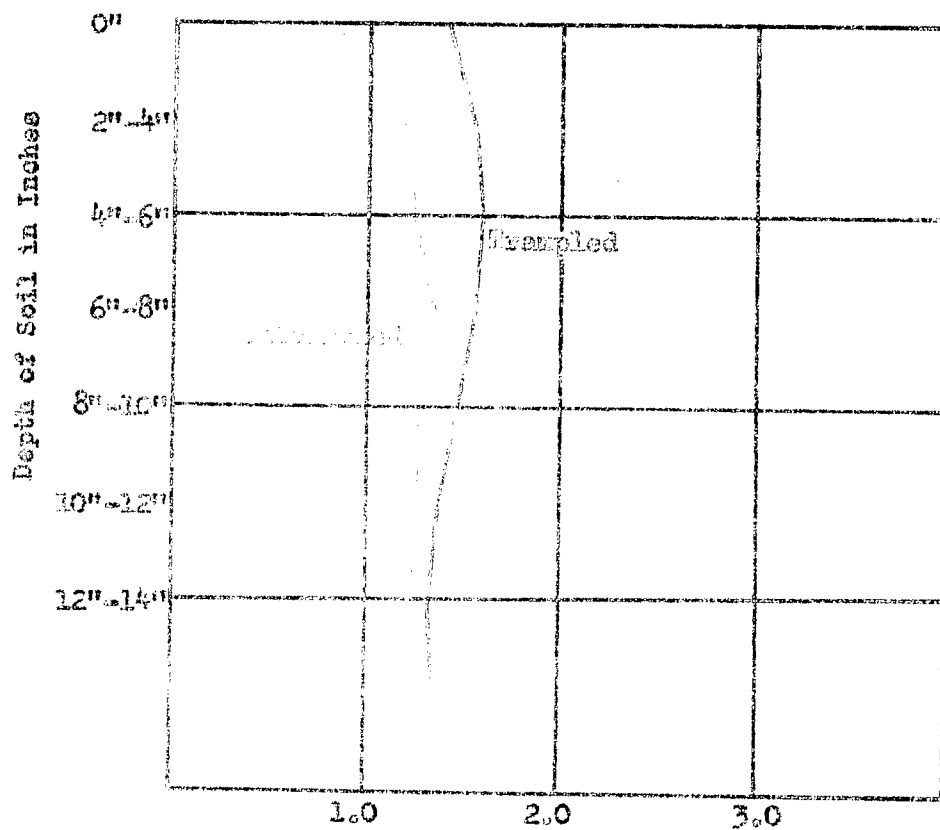


Fig. 2. Average Bulk Densities of Trampled and Untrampled Soils in Giant Forest, Sequoia National Park.

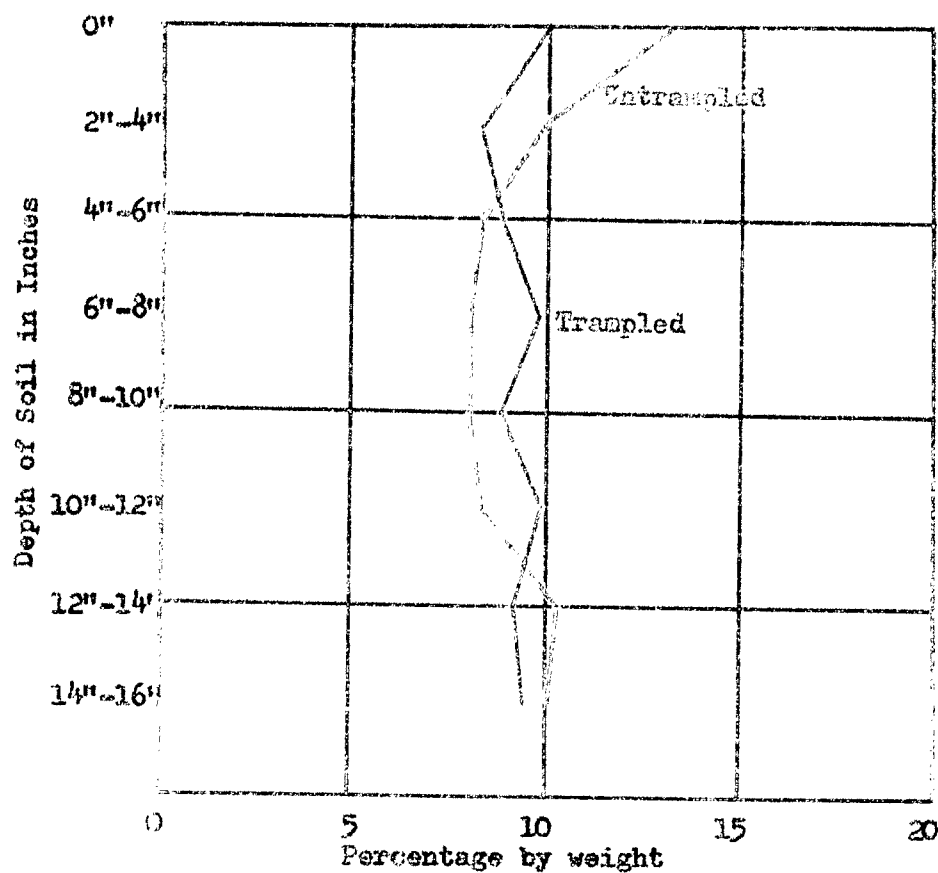


Fig. 3. Soil Moisture Percentage by Weight

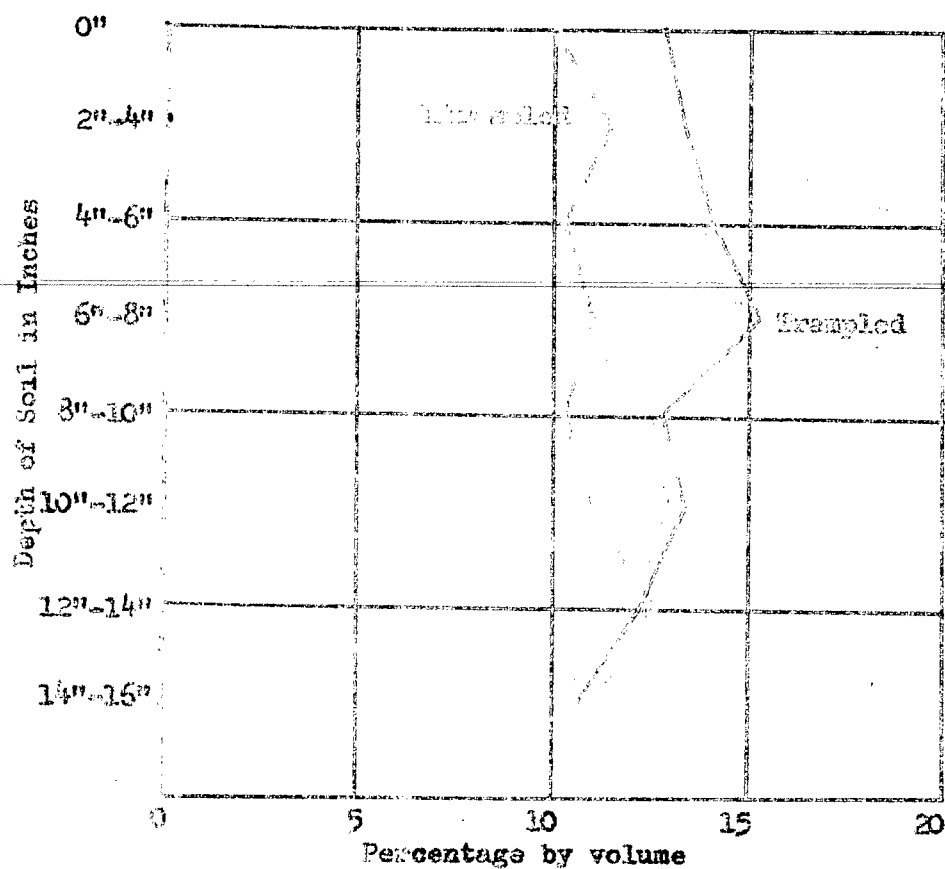


Fig. 4. Soil Moisture Percentage by Volume

sented graphically in Figs. 3 and 4. The difference between the two moisture patterns is due to the soil compaction which affects greatly the percentage of moisture by volume in the surface two inches of soil. Although percentage by volume is generally regarded as the better index of soil moisture, the percentage by weight comparison is perhaps a bit more indicative of the true surface moisture losses here. It shows a lesser weight of moisture because of trampling which leads to increased surface evaporation. The excessive surface drying may prove to be an important reason for poor germination of seeds and part of the reason for the reduced number of small plants. Direct attrition of small plants by trampling feet is probably the major cause of these local desert-like areas.

The improved soil moisture regime at depths below 6 inches is apparently due in large measure to the reduction of these small plants which, if present, would be removing soil moisture. Soil evaporation effects do not go very deeply into the soil despite the increased capillarity of compacted soils. Capillary water movement in partially dried soils is negligible and contributes little to evaporative losses of water at the surface. Consequently, soils remain moist for a longer period of time and thus, ~~again, the growing season for the remaining sequoias is extended.~~

Wherever pavement covers a significant portion of sequoia rooting systems, competing plants are eliminated and surface evaporation in any noticeable amount is prevented. Soil moisture depletion, then, is due almost entirely to root absorption by sequoias and a few other trees with roots beneath the pavement. Records derived from the four beneath-pavement moisture-temperature stations (Figs. 5, 6, and 7) indicate that soil moisture there is readily available for root absorption until a much later date than in adjacent unpaved areas. Thus, sequoias growing in these situ-

Giant
Forest
Village

Sentinel
Tree

Electrode Stations
Beneath Pavement
at 1 foot and
2 feet.

Fig. 5. Location of Soil Moisture Electrodes and Soil Temperature Thermistors beneath Pavement in Giant Forest Village, Sequoia National Park, California.

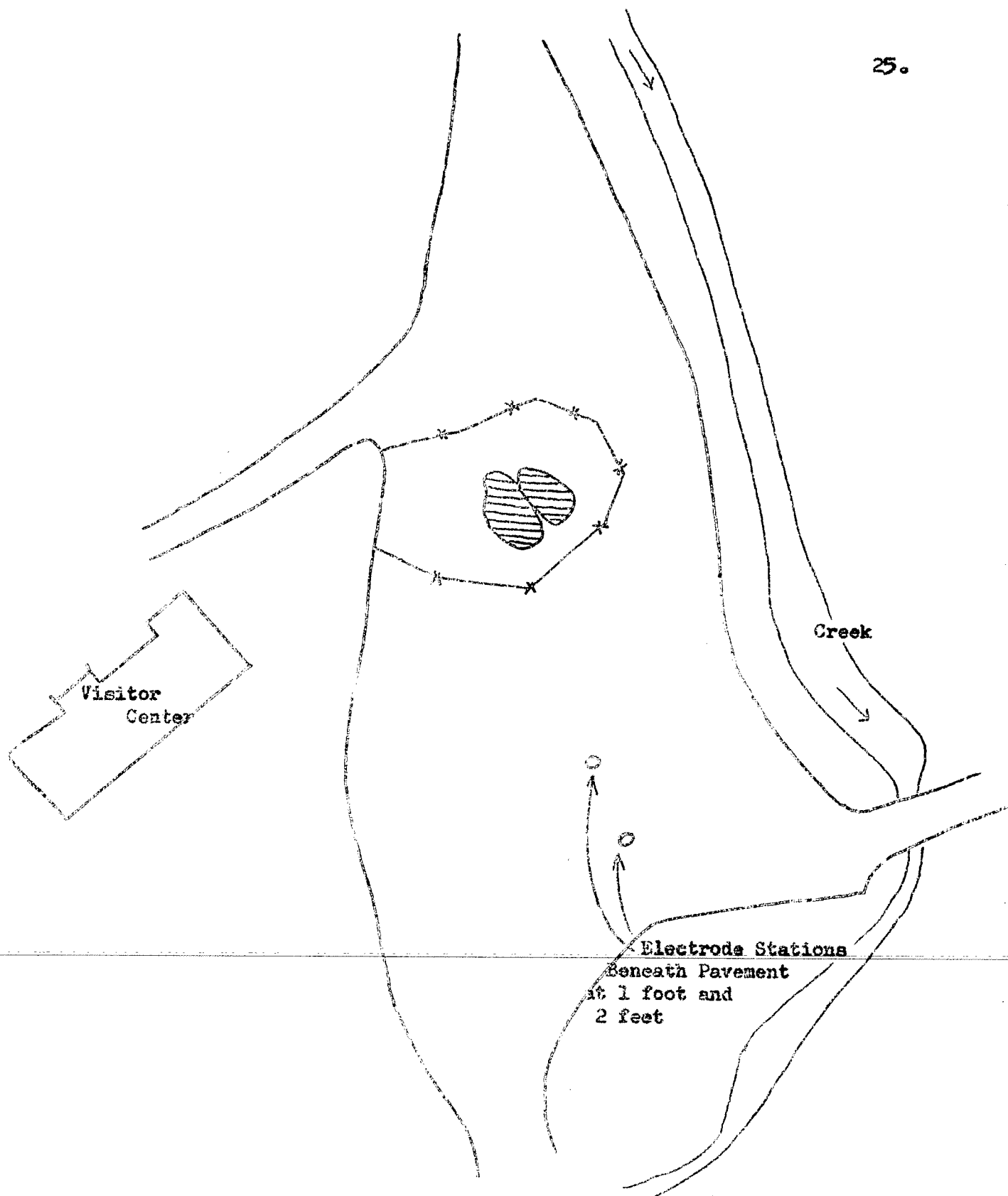


Fig. 6. Location of Soil Moisture Electrodes and Soil Temperature Thermistors beneath Pavement in the Parking Area at the Visitor Center, Sequoia National Park, California.

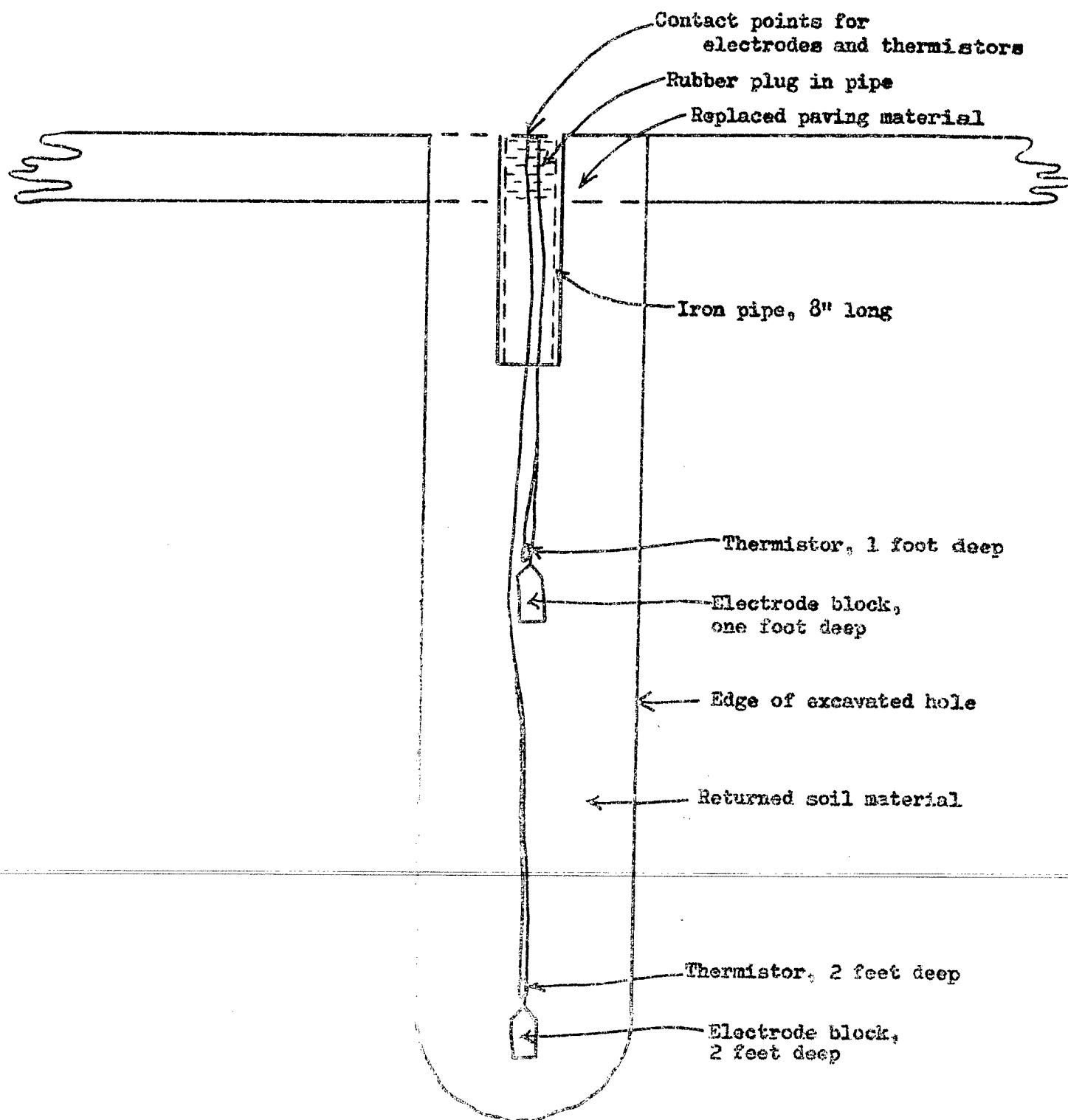


Fig. 7. Schematic diagram of soil moisture electrodes and soil temperature thermistors set beneath pavement.

ations respond by continuing growth well after the time when others have ceased growth because the soil moisture content was at the wilting point. Daily dendrometer records of two sequoias, one in a well drained site and the other in a drainageway, showed clearly the relationship of growth to availability of soil moisture. In 1964, the well drained soil was near the wilting point by the first of September and tree growth had slowed to a virtual stop while soil moisture in the drainageway remained fairly high and the sequoia there continued daily growth.

Much of these growth data collected during 1963 and 1964 will be presented at a later date as supplemental report.

c.) Growth Rate Measurements of Mature Sequoias in Selected Areas Approaching Successional Climax.

Twenty cores were taken from sequoias in areas of little or no human impact (Figs. 17 through 31, Appendix I, and Fig. 1, Appendix II) where plant succession was approaching the climax as evidenced by the presence of large numbers of white fir trees. Sixteen of these trees show growth rates which have declined during the last 50 years compared to the previous 50, and 17 of them have declining growth rates over the previous years of record on the cores. The average decline for all 20 trees for the past 50 years over the previous 50 is 8.7 percent and the average decline for the last 50 over the previous years of the cores is 15.2 percent. In one tree (Core No. S-56), the reduction in average yearly growth exceeded 50 percent. In comparing reductions in growth with increases, it should be born in mind that reduction percentages cannot be as large as increase percentages since there is a finite limit of 100 percent which is represented by a stoppage of growth and death.

The general reduction of sequoia growth rate in the advanced successional stages is due apparently to increased competition with other plants, namely the white fir. Two effects are responsible for the decreased rate of growth. The more important of the two is increased competition for soil moisture and nutrients as the overall density of plants or at least of rooting density is increased. The preponderance of white fir trees is largely responsible for this. Secondly, and of increasing importance with time, is the shading of the lower parts of sequoia crowns by the taller firs and other trees and a reduction in the production of photoaynthate. Whereas the sequoia is intolerant of shade^{2/}, its chief competitor, white

^{2/} Beetham, N.M. The Ecological Tolerance Range of the Seedling Stage of Sequoia gigantea. Ann Arbor, Michigan: University Microfilms, Inc., 1963, p. 73.

fir, is highly tolerant of shade.^{10/}

A reason for some sequoias reducing their growth rates while others increase under apparently similar conditions of plant succession cannot be assessed from the data gathered for this study. There are too many independent growth variables involved for such a calculation. However, it is interesting to note that of those trees which increased in growth rate despite advancing succession, the average annual increment of those trees during the period 1864 to 1914 was less than one-half that of the trees whose rate decreased since 1914. This either implies an improvement in site quality concurrent with advancing plant succession, or that trees whose growth rates had been reduced to an extremely low level because of fire were still recovering earlier growth rates in the absence of fire.

That rates of growth of these trees will continue to become slower and slower as the climax stage develops is problematical. It is doubtful whether sequoias often endured climactic competition as severe as now exists in fire-protected groves so that there is no precedent for comparison. Probably the sequoia growth rates will be further reduced if disturbances are prevented for another hundred years or more. It seems likely that minimum annual growth rates for mature sequoias will not fall much below 0.50 mm since few of them approach this average now. Even those sequoias whose rates of annual growth for the last 50 years are nearing the 0.50 mm rate display healthy crowns and there is no evidence recorded thus far that would indicate that a large sequoia has ever succumbed because of the competition of advanced plant succession. Reduced growth rates, then, cannot at this time be termed unhealthy or dangerous to the future of sequoia

^{10/} Baker, F.S., "A Revised Tolerance Table," *Journal of Forestry*, 47: 179-181, March, 1949.

trees in such a situation. In view of the newness of the climax situation in the sequoia range, it will be of interest to measure sequoia growth rates again in another 100 years where no disturbances occur.

Whereas large sequoias seem in no danger from advancing plant succession, young sequoias have succumbed to this competition for light and soil moisture. This occurrence is less prevalent in groves of Sequoia and Kings Canyon National Parks than in the Mariposa Grove.^{11/} More apparent in these two parks is the scarcity of young sequoias in certain groves or parts of groves.^{12/}

^{11/} Hartesveldt, R.J., The Effects of Human Impact upon Sequoia Gigantea and Its Environment in the Mariposa Grove, Yosemite National Park, California. Ann Arbor, Michigan: The University of Michigan, unpublished thesis, 1963. p. 145.

^{12/} Alley, T.J., Final Report on the Type Mapping and Regeneration Studies in the Giant Sequoia Groves of Kings Canyon and Sequoia National Parks. Typed (spirit reproduction) contract report for the Western Region, U.S. National Park Service, Nov., 1963. p. 11.

d.) Establishment of Soil Bulk Density-Root Penetration Study Plots.

This experiment failed to achieve one of its intended goals, that of determining bulk densities beyond which sequoia roots fail to penetrate. Despite the failure, the data are of some value and are here presented.

The failure was one of not attaining sufficiently high bulk densities of the soil to prohibit or even to restrict root growth in measurable amounts in the plots of highest bulk density. It is significant, however, that artificial compaction of soil in a short period of time did not produce bulk densities as high as man's 10 to 20 pounds per square inch of soil by trampling over a long period of years.

<u>Plot Number</u>	<u>Average Bulk Density</u>	<u>Weight of Roots, 13 months growth</u>
1 (control)	1.193	12.2 grams
2	1.243	13.5 grams
3	1.309	41.9 grams
4	1.485	7.7 grams
5	1.723	13.4 grams
6 (control)	1.101	48.1 grams

Fig. 8. Sequoia Root Regrowth in Soil Bulk Density Plots, Giant Forest, Sequoia National Park, California, 1963 - 1964.

It will be noted in Fig. 8 that there was little relationship between the bulk density and the weight of the roots which grew into the plots in the intervening 13-month period. Each plot was penetrated throughout by roots indicating that damage to smaller roots is rather quickly repaired. Moisture absorption by trees is accomplished largely by the extension of root tips into soil of higher soil moisture content.^{13/} Where soil compaction results in reduced root penetration, it is probably due more to reduced availability of soil moisture and oxygen than to a physical re-

^{13/} Kramer and Kozlowski, op. cit., p. 50.

striction of growth. If these soils were much heavier in clay content than they are, restrictions would very likely be more evident in the compacted areas than they are.

In consideration of the fact that the commonest soils in sequoia groves are light and sandy, it is apparent that the amount of root growth inhibition is not now significant and, unless soil compaction becomes increasingly severe in the future, there should be little concern regarding it where large sequoias are involved. Seedling sequoias in the old Firwood Campground in the Giant Forest seem to be stunted. All or most of the root system of the smaller of these trees could be within the compaction layer. The number of sequoia seedlings in compacted soils, however, is insignificant.

e.) The Fire-Sequoia Regeneration Studies.

Work Accomplished in Summer, 1964.

Resumé.

In order to study the effects of various forest management techniques which might encourage giant sequoia regeneration, three study areas have been established in the Redwood Mountain Grove of Kings Canyon National Park. These areas were assigned the following names for reference purposes: North Study Area, Trail Study Area and South Study Area.

The North Study Area has been analysed as to its present natural vegetation and small mammal populations and one-half of it has been modified by felling dead snags and burning all logs and white fir thickets in the burn area. This area, because of the preponderance of young white fir, is apparently in an advanced stage of plant succession. There are only 27 large sequoias on this area, each one more than 5 feet d.b.h., and no small sequoias.

Each of these study areas is on the floor of Redwood Canyon. The establishment of one more small study area near the ridge of Redwood Mountain is desirable.

Vegetational Analysis of the North Study Area.

Prior to the manipulation of the center two acres of the North Study Area, two types of plots were established in order to study the vegetational changes which will take place: 1.) eighteen permanent regularized plots measuring 5 meters wide by 20 meters long were established and marked on each corner with numbered metal stakes. All trees taller than one meter were recorded and those measuring more than 6 inches d.b.h. were measured and the diameters were recorded. Nine of the 18 plots were within the area to be manipulated and 9 were outside as controls for comparison after manipu-

lation. 2.) The second type of study plots were primarily to sample the vegetation smaller than one meter tall. A total of 53 regularized plots measuring 1 meter by 2 meters were established, 28 of which were in the area to be manipulated and 25 were in the adjacent control area. Further, the plots within the two-acre area to be manipulated are also being considered as a part of the controls since they represent natural vegetation prior to manipulation.

The analysis of the data gathered from these plots shows that of the tree species, white fir (Abies concolor) is the most abundant and widespread. It was found in 50 of the 71 plots with a total of 344 individuals. By contrast, the giant sequoia was found in only 3 of the 71 plots with only 3 individuals recorded. Young white firs less than 1 meter tall numbered 144 while young giant sequoias were totally absent from the plots. In fact, none was observed within the entire North Study Area.

The ground cover plants and young trees were studied with respect to their occurrence in various depths of leaf litter and duff. It seems that the white fir can tolerate both low light intensities and relatively thick litter and duff and would, therefore, be able to perpetuate itself as a climax species where fire and other disturbances have not cleared the forest floor or opened the crown canopy.

Seed dispersal studies were begun to assess the distances seed would be spread from mature sequoia trees and to determine the extent of sequoia seed consumption by small mammals and birds.

A general cover map was made of the entire North Study Area with all giant sequoias, lupine and fir thickets delimited. Black and white and color photographic records were made of each of the large sample plots. On the map, the selection of the giant sequoia, lupine and fir was based

upon: 1.) the giant sequoia being the main object of the studies, the proximity of the manipulated areas to mature sequoias is vital; 2.) the white fir is the tree species in greatest abundance and frequency and it is an indicator of climax community conditions; and 3.) the lupine is the species of greatest density and it apparently influences the abundance of pocket gophers which may, in turn, affect the development of young sequoias.

Plans for Vegetational Studies, Summer, 1965.

The central 2 acres of the North Study Area were manipulated during the fall of 1964 by the felling of dead snags, the cutting and burning of all dead logs and the removal of dense patches of white fir. The mechanical disturbance of the leaf litter and duff exposed mineral soil which constitutes a good potential seed bed for giant sequoias. The 1 by 2 meter plots are to be recharted this summer to determine which plant species are returning or becoming more widely distributed and which are invading as a result of the manipulation. Their frequency, density and distribution will be determined. Particular attention will be given to any sequoia regeneration.

The natural vegetation of the Trail and South Study Areas will be charted and analyzed in much the same manner as explained for the North Study Area.

It is recommended that a fourth study area high on the ridge of Redwood Mountain near the old CCC camp be added to the study program so that a well drained site may be tested for the same general purposes and by the same general methods. We would hope that this area could be about 2 acres in size and represent a relatively open situation without dense canopies of shrubs and young trees. The goal would be as natural a ground fire as possible without prior manipulation of any sort.

If the latter project is approved for addition to the study, there is

a possibility that federal work study funds may be made available to San Jose State College for a special undergraduate student to make an intensive comparative analysis of different vegetation sampling techniques.

One cost that was not previously included in requests by the contractors is the manipulation costs to the park. The project we are undertaking relies ²almost wholly upon the manipulation of parts of the study areas. To make this aspect of the work more realistic for the park administration, we are recommending that a minimum of \$2,500. be made available to the superintendent of Sequoia and Kings Canyon National Parks for this purpose. The money should be forth-coming in the summer of 1965 if the entire project is to continue on schedule.

In conjunction with the management studies, we anticipate certain other natural history studies which will add to the growing sequoia life history story. The most important of our anticipated projects is to develop a method of age-dating living sequoias by means of increment borings. Based upon the regression of basal area growth curves, a more accurate estimate of a tree's age can be made than by simply applying the average annual increment to the radius of a tree. To perfect this method, we are collecting data on entire cross sections of sequoias to ascertain the variance in slope of these growth curves of sequoias found in differing site qualities. This project is already progressing, thanks to Ray Murphy, Jim Dempsey and Jack Hickey and others on the Sequoia National Park Staff. We are also obtaining the cooperation of the U.S. Forest Service in making available cutover sequoia groves for additional comparisons. The technique, when perfected, will be of great value to foresters, ecologists and naturalists for interpretive purposes.

The Small Mammals Study

Studies carried out by Dr. Howard Shellhammer during August, 1964.

provided the following information about the North Study Area:

- 1.) The genera Peromyscus, Sorex, Microtus, and Thomomys were present in a 14:2:1:3 ratio.
- 2.) There was no significant difference with respect to trap success of the size of traps used.
- 3.) Sunflower seeds were readily acceptable as bait.
- 4.) There was a high rate of recapture, especially of Peromyscus.
- 5.) Low nighttime temperatures had a deleterious effect on trapped animals. A method is being devised at this time for better insulation of the traps.
- 6.) The parameters used by Brant^{13/} are applicable to this study. The average distance moved between captures for Peromyscus is much less than that found for races in the Coast Ranges.
- 7.) The pattern of traps can be increased from a 10-meter to a 15-meter grid without affecting the validity of the study.

Discussion and Plans for Mammal Studies, 1965.

The populations of shrews and pocket gophers present the greatest sampling problem in the small mammals study. The primary mortality among shrews was due to loss of body heat while trapped. It may be necessary to supplement all traps with foodstuffs acceptable to shrews along with the usual sunflower seed bait. Outside of numerous checks during each night of trapping, a process which may or may not outweigh the value of saving all shrews caught, the most logical approach is to concentrate on reducing the heat loss of the trapped animals. This problem is also a serious one in saving all immature deer mice, the primary species of this study. Dr.

^{13/} Brant, D. H. "Measures of the Movements and Population Densities of small Rodents." Univ. Calif. Pub. Zoo., 62(2): 105-184, 1962.

Shellhammer is now experimenting with various insulating materials to find the most efficient method of providing protection against the cold for trapped mammals.

Censusing a population of pocket gophers without killing the animals or grossly disturbing their habitat is a particularly difficult problem. Techniques to accomplish such a census will be tested during the summer of 1965.

The parameters suggested by Brant^{14/} can be used with success to monitor the movements of small mammals into and out of the burned areas. The 15-meter grid will cover the burned area and the non-burned area on three sides of the burn.

The Trail Study Area will be trapped during the summer of 1965 to determine the density and the composition of rodents in the area prior to manipulation.

Seedling preference tests will be run using a variety of seed types: sequoia, white fir, red fir, incense cedar, sugar pine, ponderosa pine and sunflower. Seedlings may be grown in flats for this test.

Small mammal exclosures like those described in Wagg^{15/} are being built. These will be emplaced as originally proposed. Most exclosures will not protect against damage by ground squirrels, but the use of several different types, both semi- and fully inclosed exclosures, will provide a good idea of the damage caused by various rodents, birds and larger mammals.

The only areas with gopher diggings were those covered with lupines. It will be interesting to see what effect of the destruction of the turf by

^{14/} Brant, D.H. Op cit.

^{15/} Wagg, J.W.B. "Design of Small Mammal Enclosures for Forest Seedling Studies." Ecology 45(1): 199-200, 1964.

fire and the opening up of the canopy will have on the distribution of lupine and gophers.

A small number of mammals will be removed from the general area in order to study the stomach contents.

Bird census and ethological studies as outlined in the original proposal will be carried out during the summer.

MISCELLANEOUSSequoia Snag-top Study

A common phenomenon of sequoia trees is the familiar snag-top which is the dead top of the main stem and, often, a few lateral branches near the top. Speculation has brought about various explanations such as hot dry winds from the Central Valley causing excessive transpiration at the very tops of the trees, lightning, and fire scars which have severed the roots from the crown, thus severing the sapwood connections and starving the upper part of the crown.

Although lightning undoubtedly plays a part in this phenomenon, it became evident during the reconnaissance studies in 1962 that all snag-top sequoias had fire scars and those trees without fire scars penetrating through the bark always had full crowns. The following sampling of 100 snag-top sequoias was made by David J. Hartesveldt in the summer of 1963 and tends to bear this out.

<u>Tree Number</u>	<u>Total Circumference</u>	<u>Total Burn</u>	<u>Percentage of Total</u>
1.	70.0'	25.0'	35.8
2.	50.5'	23.0'	41.8
3.	64.0'	26.0'	40.6
4.	106.0'	43.0'	40.6
5.	67.0'	29.0'	43.4
6.	80.0'	13.0'	16.6
7.	85.0'	27.0'	31.8
8.	77.0'	24.0'	31.1
9.	77.0'	43.0'	56.0
10.	66.0'	22.0'	33.4
11.	85.0'	38.0'	44.8
12.	79.0'	46.0'	58.4
13.	78.5'	29.0'	37.0
14.	81.0'	52.0'	64.2
15.	85.0'	48.0'	56.4
16.	96.0'	75.0'	78.0
17.	49.5'	13.0'	26.6
18.	84.5'	50.0'	59.3
19.	107.0'	71.0'	66.3
20.	51.0'	1.0'	1.9
21.	80.0'	32.0'	40.0
22.	80.0'	48.0'	60.0

<u>Tree Number</u>	<u>Total Circumference</u>	<u>Total Burn</u>	<u>Percentage of Total</u>
23.	86.0'	64.0'	74.3
24.	84.0'	45.0'	53.6
25.	79.5'	53.0'	66.6
26.	85.0'	77.0'	90.3
27.	42.5'	21.5'	50.6
28.	51.0'	33.0'	65.0
29.	74.0'	52.0'	70.3
30.	61.0'	6.0'	9.8
31.	88.5'	35.0'	39.6
32.	86.0'	34.0'	39.5
33.	94.0'	41.0'	43.6
34.	82.0'	48.0'	58.5
35.	80.0'	14.0'	17.5
36.	63.0'	40.0'	63.5
37.	72.0'	43.0'	59.8
38.	55.0'	2.0'	3.6
39.	87.0'	69.0'	79.4
40.	60.0'	14.0'	23.3
41.	85.0'	46.0'	54.2
42.	77.0'	39.0'	50.7
43.	67.0'	27.0'	40.4
44.	63.0'	15.0'	23.9
45.	72.0'	50.0'	69.4
46.	69.0'	54.0'	78.1
47.	59.0'	25.0'	42.4
48.	68.0'	5.0'	13.6
49.	95.0'	54.0'	57.0
50.	100.0'	90.0'	90.0
51.	74.0'	27.0'	36.4
52.	46.0'	15.0'	32.7
53.	79.0'	11.0'	14.0
54.	68.0'	41.0'	60.2
55.	86.0'	56.0'	65.2

<u>Tree Number</u>	<u>Total Circumference</u>	<u>Total Burn</u>	<u>Percentage of Total</u>
56.	73.0'	32.0'	43.8
57.	57.0'	34.0'	59.8
58.	87.0'	64.0'	73.5
59.	78.0'	45.0'	57.7
60.	73.0'	16.0'	21.9
61.	63.0'	32.0'	50.9
62.	90.0'	45.0'	50.0
63.	67.0'	35.0'	52.3
64.	90.0'	67.0'	74.3
65.	51.0'	39.0'	76.5
66.	48.0'	23.0'	48.0
67.	59.0'	35.0'	59.4
68.	54.0'	17.0'	31.5
69.	59.0'	38.0'	64.5
70.	60.0'	46.0'	76.7
71.	74.0'	57.0'	77.0
72.	67.0'	41.0'	61.2
73.	41.0'	25.0'	61.0
74.	59.0'	30.0'	50.9
75.	53.0'	14.0'	26.5
76.	80.0'	54.0'	67.5
77.	73.0'	44.0'	60.3
78.	54.0'	13.0'	24.0
79.	63.0'	53.0'	84.0
80.	87.0'	33.0'	38.0
81.	54.0'	23.0'	42.5
82.	57.0'	45.0'	79.0
83.	74.0'	20.0'	27.2
84.	86.0'	45.0'	52.5
85.	83.0'	48.0'	57.8
86.	75.0'	38.0'	50.6
87.	60.0'	51.0'	85.0
88.	43.0'	16.0'	37.2
89.	59.0'	53.0'	89.6

<u>Tree Number</u>	<u>Total Circumference</u>	<u>Total Burn</u>	<u>Percentage of Total</u>
90.	55.0'	30.0'	54.6
91.	64.0'	19.0'	29.7
92.	54.0'	37.0'	68.5
93.	52.0'	42.0'	80.8
94.	51.0'	35.0'	68.7
95.	78.5'	42.0'	53.6
96.	67.0'	47.0'	70.2
97.	62.0'	37.0'	59.6
98.	85.0'	79.0'	92.8
99.	62.0'	23.0'	37.1
100.	73.0'	45.0'	61.7

Average percentage of circumferential damage 51.9 %

Size Distribution of Burned Trees

<u>Distribution by Percentage Burned</u>	<u>Percent of All Trees</u>	<u>Average Size by Circumference</u>
0 - 10 %	3 %	56 feet
10 - 20 %	4 %	77 feet
20 - 30 %	8 %	61 feet
30 - 40 %	13 %	71 feet
40 - 50 %	12 %	71 feet
50 - 60 %	24 %	74 feet
60 - 70 %	17 %	70 feet
70 - 80 %	12 %	75 feet
80 - 90 %	4 %	59 feet
90 - 100 %	3 %	90 feet

MISCELLANEOUSRadiocarbon Dating of Giant Sequoia Wood

During the reconnaissance studies of giant sequoia in 1962, remnants of sequoia wood were noticed which appeared to be much older than others. With the knowledge that sequoia wood rots very slowly, it occurred that some of these remnants might have laid there many centuries. If so, it would be interesting to know the length of time.

In 1963, I wrote to Dr. W.F. Libby of the Institute of Geophysics and Planetary Physics of the University of California at Los Angeles and inquired as to their possible interest in assisting on this question. He replied favorably, stating that they would accept three samples for radiocarbon dating without cost. The normal cost is \$300. per sample. Below is the record sent by Dr. G.J. Fergusson. It indicates a wide range of age. In consideration of the smallness of the sample, it is possible that much older remnants may exist. Each sample was taken from the outermost portion of the log or stump to most nearly approximate the time elapsed since the death of the tree.

UCLA-655. Sample No. 1. From a heavily burned sequoia stump along the trail between Hazelwood Picnic Area and Circle Meadow, in Giant Forest.

Age: 770 ± 80 years

UCLA-656. Sample No. 2. From a heavily burned sequoia stump on the edge of Circle Meadow, Giant Forest.

Age: $2,100 \pm 100$ years

UCLA-657. Sample No. 3. From a burned sequoia stump in Buena Vista Grove, Kings Canyon National Park.

Age: Modern, i.e., less than 200 years

MISCELLANEOUSSequoia Root Study

In order to better understand the nature of the giant sequoia and its natural history, radial trenches were dug by David J. Hartesveldt in the four cardinal directions from a nearly unburned sequoia of about 12 feet diameter. The tree is located between the Generals Highway and the Old Firwood Campground in well drained sandy loam. The trenches were extended outward and downward until sequoia roots seemed to disappear.

Small feeder roots extended downward approximately 4 feet to a distance of about 10 feet from the trunk of the tree. Proceeding outward from the trunk, the feeder roots became limited more and more to the upper layers of the soil. Although the lower limits of rooting varied from place to place, the surface area of rooting formed very nearly a circle with a radius of 125 feet. An area of land with this radius covers 49,087 square feet, or 1.13 acres.

To obtain the volume of soil occupied by roots, the volumes of four cylinders were calculated:

$$(125')^2 \times 3.1416 \times 1.0' \text{ deep} = 49,087 \text{ cu. ft.}$$

$$(110')^2 \times 3.1416 \times 0.5' \text{ deep} = 19,007 \text{ cu. ft.}$$

$$(70')^2 \times 3.1416 \times 1.5' \text{ deep} = 22,149 \text{ cu. ft.}$$

$$(20')^2 \times 3.1416 \times 1.0' \text{ deep} = 1,257 \text{ cu. ft.}$$

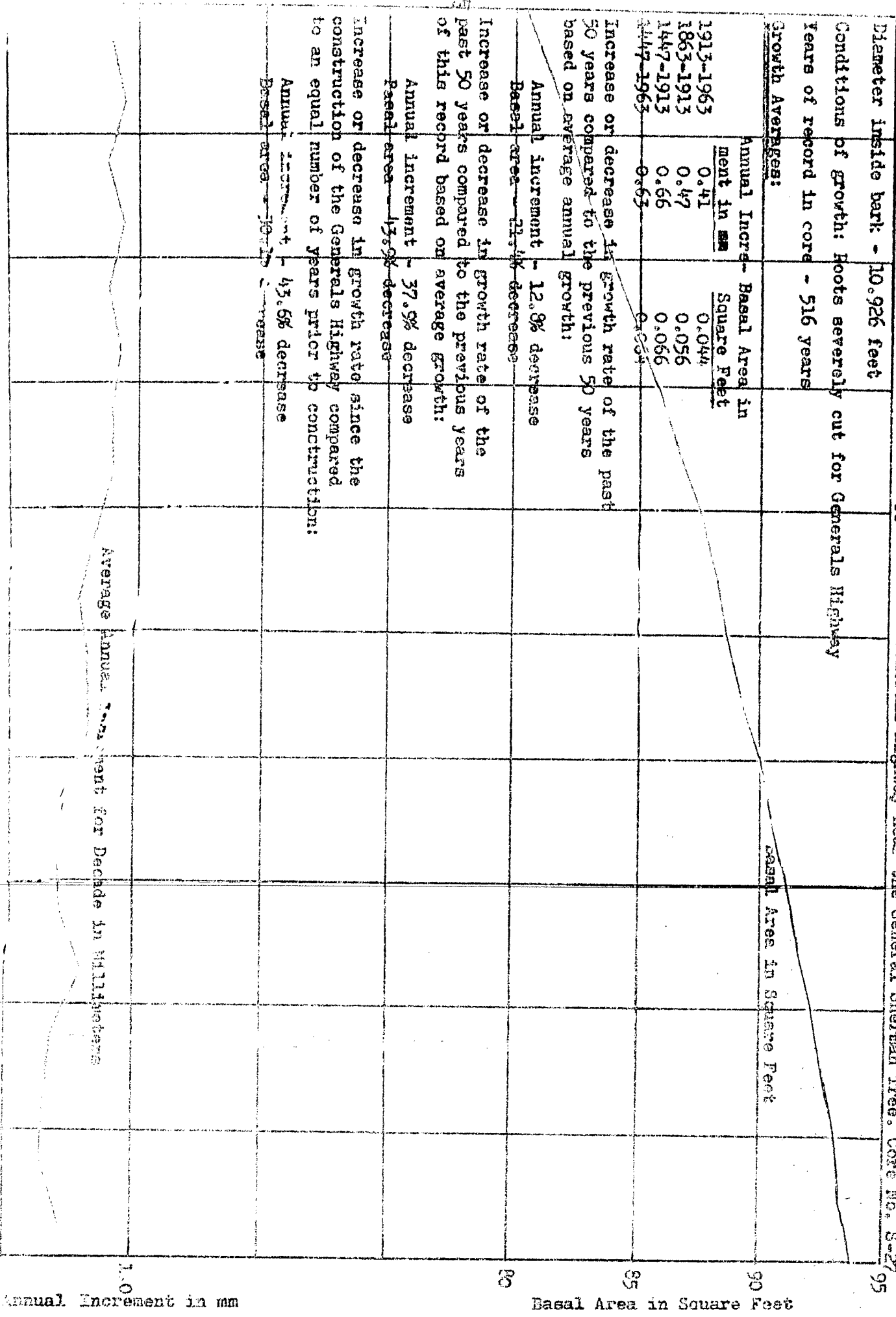
Total rooting volume of soil = 91,500 cubic feet

The field capacity of soil is that amount of water left in a soil after all gravitational water drains from it. It is the maximum amount of water that can be retained against the forces of adhesion and cohesion. Field capacity minus the wilting point moisture content equals the amount of water available for plant growth. On the assumption that field capacity of this soil might be around 25 percent and wilting point about 5 percent, the 91,500 cubic feet of soil occupied by the roots of this tree would contain, at field capacity, approximately 18,300 cubic feet of available water for plant growth, or nearly 137,000 gallons of water. From the studies reported earlier in this report, it would indicate that in years when soils are at field capacity, tree growth would be greatest. However, it is known from soil moisture testing in the Giant Forest that in years of light precipitation, field capacity soil moisture contents may extend only a short distance into the ground. In the lower parts of the rooting volume of soil, the moisture may be held at much higher tensions such that it becomes unavailable for plant growth early in the growing season.

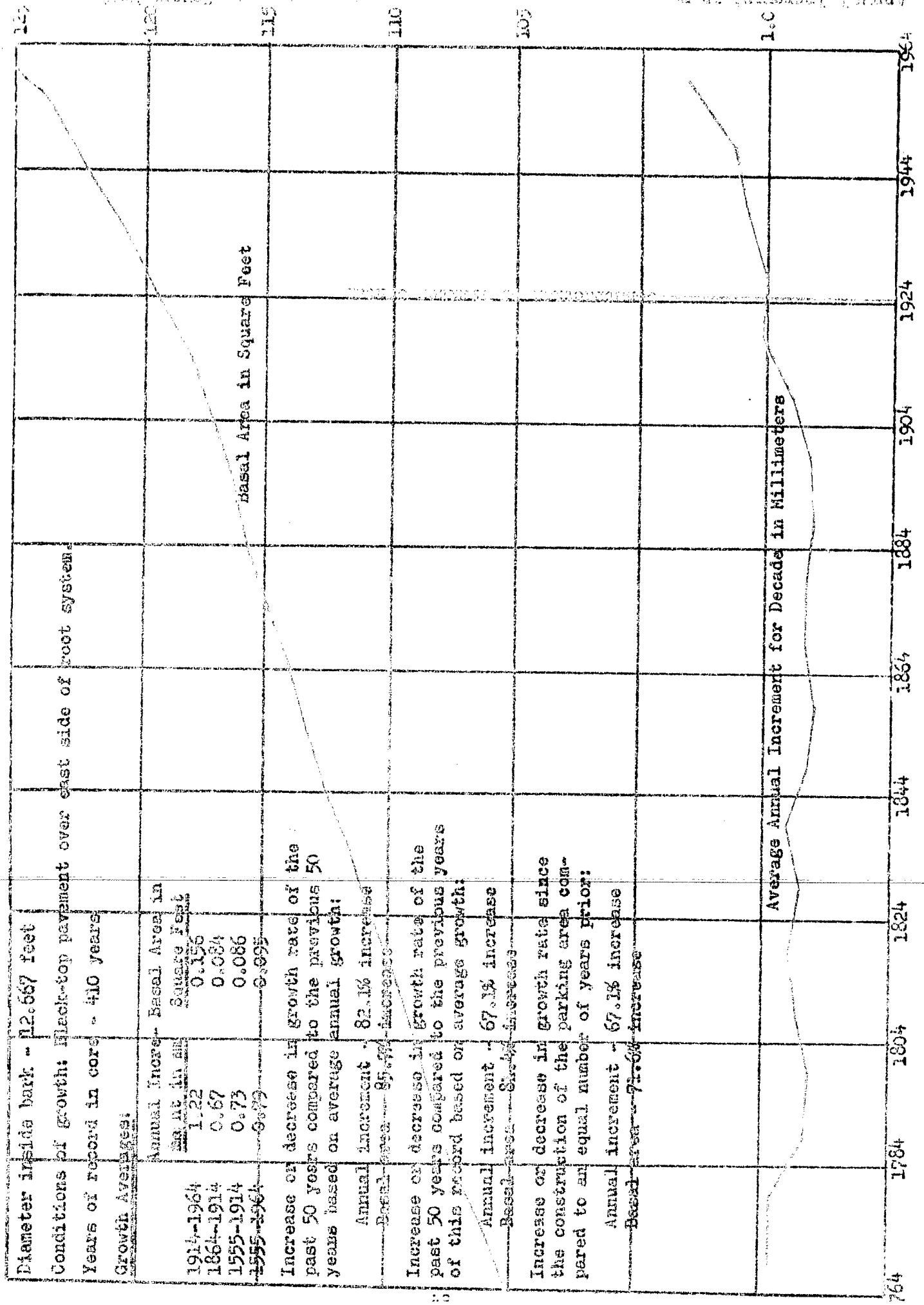
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APPENDIX I - FIG. 1. Giant Forest, sequoia on upper side of Generals Highway near the General Sherman Tree. Core No. S-27



APPENDIX 1 - Fig. 2. Growth Forest, sequoia in front of Visitor Center next to parking area. Core No. 3-47



5

Growth Averages:

	Annual Increment	Basel Area in Square Feet
1909-1959	<u>1.47</u>	<u>0.192</u>
1859-1909	1.00	0.126
1819-1909	1.00	0.126
1809-1959	1.16	0.149

Increase or decrease in growth rate of the past 50 years compared to the previous 50 years based on average annual growth:

Basil Area in Square Feet

Annual increment -	47.0% Increase
Basal area -	52.4% Increase

Increase or decrease in growth rate of the past 50 years compared to the previous years of this record based on average growth:

Annual Increment -	47.0% increase
--------------------	----------------

~~Based upon 52.4% increase~~

increase or decrease in growth rate since the construction of the highway and parking areas compared to an equal number of years prior to that construction:

~~Approved for Release 5274 INC 6850~~

Basal area = 58.7% increase

Average Annual Increment for Decade In 1911-1920

Basal Area in Square Feet

Annual Increment in mm

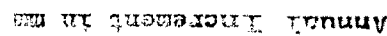
APPENDIX I - Fig. 4. Giant Forest, along Generals Highway near the General Sherman Tree Parking Area. Core No. S-23

Diameter inside bark - 6.167 feet		on one side by 10 to 12 feet of rocks and other road fill.							
Conditions of growth: Roots covered									
Years of record in core - 300 years									
Growth Averages:									
Annual Increment in mm		Basal Area in square feet		Basal Area Growth in Square Feet					
1913-1963		1.07		0.064					
1863-1913		.82		0.048					
1663-1913		.98		0.050					
1663-1963		1.00		0.053					
Increase or decrease in growth rate of the past 50 years compared to the previous 50 years based on average annual growth:									
Annual Increment - 30.2% increase									
Basal Area - 33.2% increase									
Increase or decrease in growth rate of the past 50 years compared to the previous years of this record based on average growth:									
Annual Increment - 20.8% increase									
Basal Area - 32.0% increase									
Increase or decrease in growth rate since the construction of the Generals Highway compared to the same length of time before its construction:									
Annual Increment - 66.7% increase									
Basal Area - 172.7% increase									
Average Annual Increment for Decade in Millimeters									

1954 1974 1804 1824 1844 1884 1904 1924 1944 1964

APPENDIX I - Fig. 5. Giant Forest, sequoia on east side of Generals Hwy., just north of turn to Sherman parking area, Core S-1.

Diameter inside bark - 12.209 feet	Conditions of growth: Pavement and about 7 feet of road fill over the west side of the tree's root system.	Years of record in core - 21.5 years	Growth Averages:
1913-1963	Annual Increment - Basal Area in mm Square Feet	1.81	0.224
1863-1913		1.13	0.154
1750-1913		1.23	0.138
1750-1963		1.37	0.158
Increase or decrease in growth rate of the past 50 years compared to the previous 50 years based on average annual growth:			
Annual increment - 60.2% increase			
Basal area - 47.4% increase			
Increase or decrease in growth rate of the past 50 years compared to the previous years of this record based on average growth:			
Annual increment - 47.1 % increase			
Basal area - 41.0% increase			
Increase or decrease in growth rate since the completion of the Generala Hwy compared to an equal number of years before:			
Annual increment - 236.8% increase			
Basal area - 202.4% increase			
Average Annual Increment for Decade in Millimeters			



APPENDIX I - Fig. 6. Giant Forest, sequoia at entrance to Giant Forest Lodge dining hall. Core No. S-37

Diameter inside bark - not taken; immense fire scar.		Conditions of growth: Roots on west side of tree covered by dining hall		Years of record in core - 181 years		Growth Averages:	
Annual Increment							
1915-1965		1.08					
1865-1915		0.83					
1784-1915		0.79					
1784-1965		0.87					
Increase or decrease in growth rate of the past 50 years compared to the previous 50 years based on average annual increment:							
Annual increment - 30.1% increase							
Increase or decrease in growth rate of the past 50 years compared to the previous years of this record based on average growth:							
Annual increment - 35.7% increase							
Increase or decrease in growth rate since the construction of the dining hall compared to an equal period of time before construction:							
Annual increment - 40.5% increase							

Average Annual Increment for Decade in Millimeter

Annual Increment in mm

1785

1805

1825

1845

1865

1885

1905

1925

1945

1965

PENDING - Page 9. Census Bureau, East Branch, and vicinity northwest of camp office among the buildings. Core No. S-9

State for 1940s 20.00 East

1. 1. The first
 2. 2. The second
 3. 3. The third
 4. 4. The fourth
 5. 5. The fifth
 6. 6. The sixth
 7. 7. The seventh
 8. 8. The eighth
 9. 9. The ninth
 10. 10. The tenth
 11. 11. The eleventh
 12. 12. The twelfth
 13. 13. The thirteenth
 14. 14. The fourteenth
 15. 15. The fifteenth
 16. 16. The sixteenth
 17. 17. The seventeenth
 18. 18. The eighteenth
 19. 19. The nineteenth
 20. 20. The twentieth
 21. 21. The twenty-first
 22. 22. The twenty-second
 23. 23. The twenty-third
 24. 24. The twenty-fourth
 25. 25. The twenty-fifth
 26. 26. The twenty-sixth
 27. 27. The twenty-seventh
 28. 28. The twenty-eighth
 29. 29. The twenty-ninth
 30. 30. The thirtieth
 31. 31. The thirty-first
 32. 32. The thirty-second
 33. 33. The thirty-third
 34. 34. The thirty-fourth
 35. 35. The thirty-fifth
 36. 36. The thirty-sixth
 37. 37. The thirty-seventh
 38. 38. The thirty-eighth
 39. 39. The thirty-ninth
 40. 40. The fortieth
 41. 41. The forty-first
 42. 42. The forty-second
 43. 43. The forty-third
 44. 44. The forty-fourth
 45. 45. The forty-fifth
 46. 46. The forty-sixth
 47. 47. The forty-seventh
 48. 48. The forty-eighth
 49. 49. The forty-ninth
 50. 50. The fiftieth
 51. 51. The fifty-first
 52. 52. The fifty-second
 53. 53. The fifty-third
 54. 54. The fifty-fourth
 55. 55. The fifty-fifth
 56. 56. The fifty-sixth
 57. 57. The fifty-seventh
 58. 58. The fifty-eighth
 59. 59. The fifty-ninth
 60. 60. The sixtieth
 61. 61. The sixty-first
 62. 62. The sixty-second
 63. 63. The sixty-third
 64. 64. The sixty-fourth
 65. 65. The sixty-fifth
 66. 66. The sixty-sixth
 67. 67. The sixty-seventh
 68. 68. The sixty-eighth
 69. 69. The sixty-ninth
 70. 70. The seventieth
 71. 71. The seventy-first
 72. 72. The seventy-second
 73. 73. The seventy-third
 74. 74. The seventy-fourth
 75. 75. The seventy-fifth
 76. 76. The seventy-sixth
 77. 77. The seventy-seventh
 78. 78. The seventy-eighth
 79. 79. The seventy-ninth
 80. 80. The eightieth
 81. 81. The eighty-first
 82. 82. The eighty-second
 83. 83. The eighty-third
 84. 84. The eighty-fourth
 85. 85. The eighty-fifth
 86. 86. The eighty-sixth
 87. 87. The eighty-seventh
 88. 88. The eighty-eighth
 89. 89. The eighty-ninth
 90. 90. The ninetieth
 91. 91. The ninety-first
 92. 92. The ninety-second
 93. 93. The ninety-third
 94. 94. The ninety-fourth
 95. 95. The ninety-fifth
 96. 96. The ninety-sixth
 97. 97. The ninety-seventh
 98. 98. The ninety-eighth
 99. 99. The ninety-ninth
 100. 100. The hundredth

2002-2003

1. The first step in the process is to identify the problem or issue that needs to be addressed. This involves gathering information and understanding the context of the problem.

[illegible][illegible]

83

1990

Increase in income in private rate of the past 10 years compared to the previous 50 years based on average annual growth:

DATE	DESCRIPTION	AMOUNT	BALANCE
1900	Jan 1		
	Feb 1		
	Mar 1		
	Apr 1		
	May 1		
	Jun 1		
	Jul 1		
	Aug 1		
	Sep 1		
	Oct 1		
	Nov 1		
	Dec 1		
1901	Jan 1		
	Feb 1		
	Mar 1		
	Apr 1		
	May 1		
	Jun 1		
	Jul 1		
	Aug 1		
	Sep 1		
	Oct 1		
	Nov 1		
	Dec 1		
1902	Jan 1		
	Feb 1		
	Mar 1		
	Apr 1		
	May 1		
	Jun 1		
	Jul 1		
	Aug 1		
	Sep 1		
	Oct 1		
	Nov 1		
	Dec 1		
1903	Jan 1		
	Feb 1		
	Mar 1		
	Apr 1		
	May 1		
	Jun 1		
	Jul 1		
	Aug 1		
	Sep 1		
	Oct 1		
	Nov 1		
	Dec 1		
1904	Jan 1		
	Feb 1		
	Mar 1		
	Apr 1		
	May 1		
	Jun 1		
	Jul 1		
	Aug 1		
	Sep 1		
	Oct 1		
	Nov 1		
	Dec 1		
1905	Jan 1		
	Feb 1		
	Mar 1		
	Apr 1		
	May 1		
	Jun 1		
	Jul 1		
	Aug 1		
	Sep 1		
	Oct 1		
	Nov 1		
	Dec 1		
1906	Jan 1		
	Feb 1		
	Mar 1		
	Apr 1		
	May 1		
	Jun 1		
	Jul 1		
	Aug 1		
	Sep 1		
	Oct 1		
	Nov 1		
	Dec 1		
1907	Jan 1		
	Feb 1		
	Mar 1		
	Apr 1		
	May 1		
	Jun 1		
	Jul 1		
	Aug 1		
	Sep 1		
	Oct 1		
	Nov 1		
	Dec 1		
1908	Jan 1		
	Feb 1		
	Mar 1		
	Apr 1		
	May 1		
	Jun 1		
	Jul 1		
	Aug 1		
	Sep 1		
	Oct 1		
	Nov 1		
	Dec 1		
1909	Jan 1		
	Feb 1		
	Mar 1		
	Apr 1		
	May 1		
	Jun 1		
	Jul 1		
	Aug 1		
	Sep 1		
	Oct 1		
	Nov 1		
	Dec 1		
1910	Jan 1		
	Feb 1		
	Mar 1		
	Apr 1		
	May 1		
	Jun 1		
	Jul 1		
	Aug 1		
	Sep 1		

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increase of decrease in growth rate of the past 30 years compared to the previous years of this report based on average growth:

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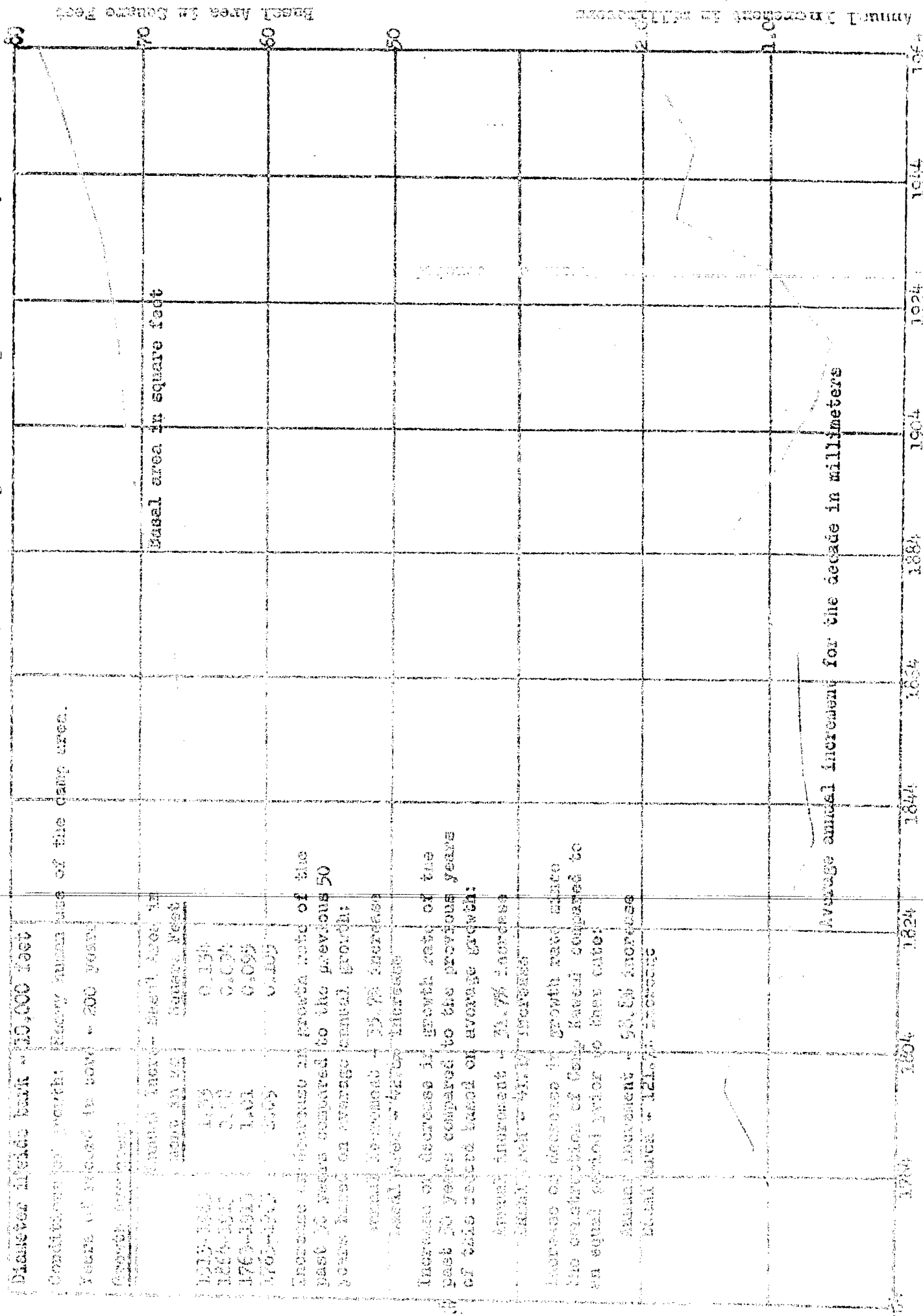
...the ...

There was a decrease in growth rate after the construction of Camp Kaserai compared to an equal period prior to their entry.

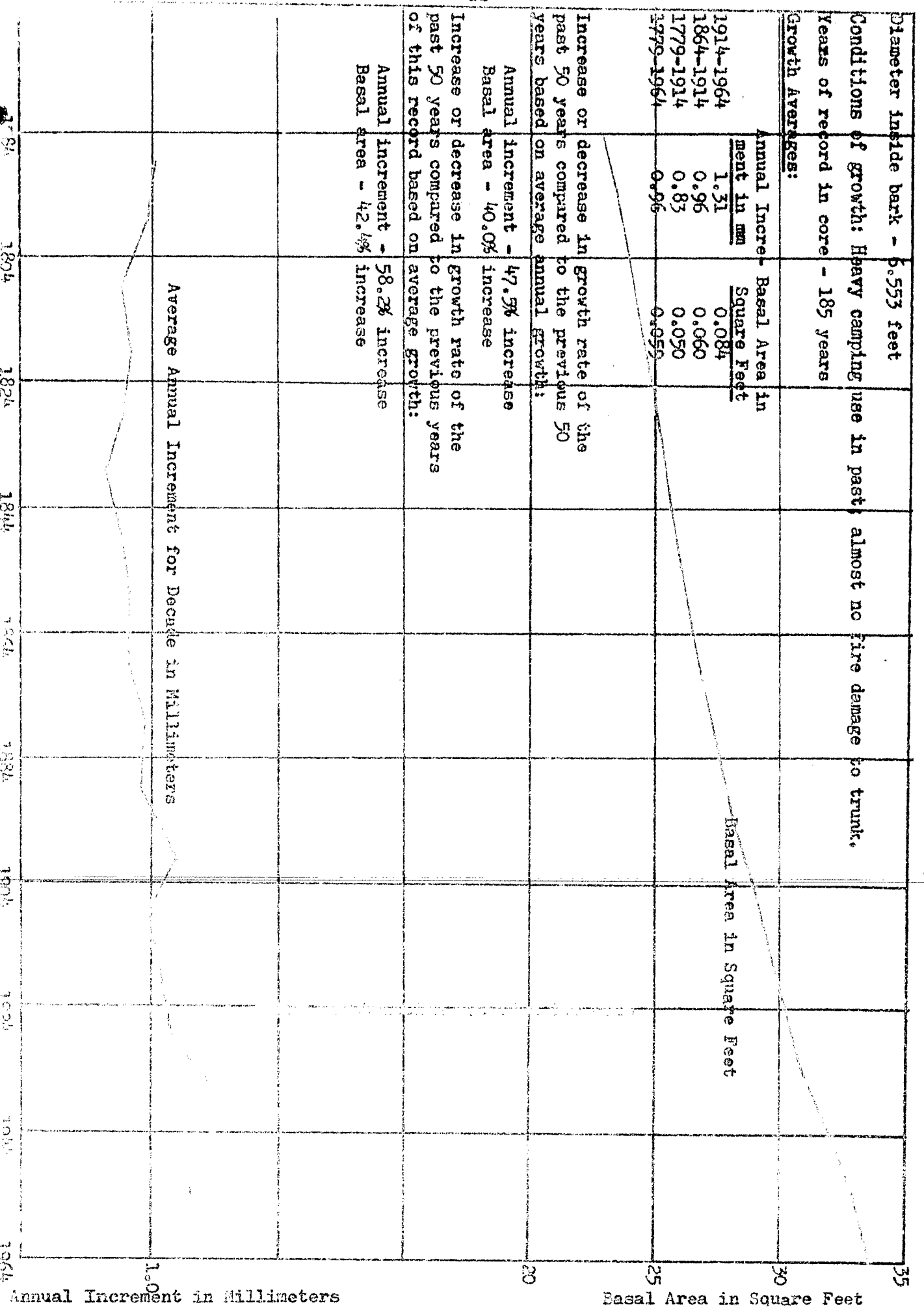
Minimum Investment - \$0.50 Knowledge
 Minimum Return - 12% - 15% per year

100

Average annual increment for the decade in millimeters



APPENDIX I - Fig. 11. Giant Forest, sequoia in Old Firwood Campground. Core No. S-13



[illegible][illegible]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

姓名	性别	年龄	籍贯	职业	文化程度	健康状况	婚姻状况	子女情况	其他
王德胜	男	45	山东	工人	高中	良好	已婚	2子1女	
李秀英	女	38	河北	教师	大学	良好	已婚	1子1女	
张国强	男	52	河南	农民	初中	一般	已婚	3子2女	
赵红梅	女	41	江苏	医生	大专	良好	已婚	1子1女	
刘伟明	男	35	浙江	工程师	本科	良好	已婚	1子1女	
陈丽娟	女	48	安徽	护士	中专	良好	已婚	2子1女	
孙志强	男	55	湖北	干部	高中	一般	已婚	2子1女	
周小芳	女	32	湖南	会计	大专	良好	已婚	1子1女	
吴大伟	男	43	江西	工人	初中	一般	已婚	2子1女	
郑晓燕	女	39	四川	教师	大学	良好	已婚	1子1女	
冯国强	男	50	广东	农民	小学	一般	已婚	3子2女	
马小红	女	46	广西	医生	大专	良好	已婚	1子1女	
朱大明	男	37	福建	工程师	本科	良好	已婚	1子1女	
林丽娟	女	49	贵州	护士	中专	良好	已婚	2子1女	
胡志强	男	53	云南	干部	高中	一般	已婚	2子1女	
周小芳	女	33	陕西	会计	大专	良好	已婚	1子1女	
吴大伟	男	44	山西	工人	初中	一般	已婚	2子1女	
郑晓燕	女	40	重庆	教师	大学	良好	已婚	1子1女	
冯国强	男	51	四川	农民	小学	一般	已婚	3子2女	
马小红	女	47	湖南	医生	大专	良好	已婚	1子1女	
朱大明	男	38	湖北	工程师	本科	良好	已婚	1子1女	
林丽娟	女	50	江西	护士	中专	良好	已婚	2子1女	
胡志强	男	54	安徽	干部	高中	一般	已婚	2子1女	
周小芳	女	34	浙江	会计	大专	良好	已婚	1子1女	
吴大伟	男	45	江苏	工人	初中	一般	已婚	2子1女	
郑晓燕	女	41	河南	教师	大学	良好	已婚	1子1女	
冯国强	男	52	河北	农民	小学	一般	已婚	3子2女	
马小红	女	48	山东	医生	大专	良好	已婚	1子1女	
朱大明	男	39	广东	工程师	本科	良好	已婚	1子1女	
林丽娟	女	51	广西	护士	中专	良好	已婚	2子1女	
胡志强	男	55	福建	干部	高中	一般	已婚	2子1女	
周小芳	女	35	贵州	会计	大专	良好	已婚	1子1女	
吴大伟	男	46	云南	工人	初中	一般	已婚	2子1女	
郑晓燕	女	42	陕西	教师	大学	良好	已婚	1子1女	
冯国强	男	53	四川	农民	小学	一般	已婚	3子2女	
马小红	女	49	湖南	医生	大专	良好	已婚	1子1女	
朱大明	男	40	湖北	工程师	本科	良好	已婚	1子1女	
林丽娟	女	52	江西	护士	中专	良好	已婚	2子1女	
胡志强	男	56	安徽	干部	高中	一般	已婚	2子1女	
周小芳	女	36	浙江	会计	大专	良好	已婚	1子1女	
吴大伟	男	47	江苏	工人	初中	一般	已婚	2子1女	
郑晓燕	女	43	河南	教师	大学	良好	已婚	1子1女	
冯国强	男	54	河北	农民	小学	一般	已婚	3子2女	
马小红	女	50	山东	医生	大专	良好	已婚	1子1女	
朱大明	男	41	广东	工程师	本科	良好	已婚	1子1女	
林丽娟	女	53	广西	护士	中专	良好	已婚	2子1女	
胡志强	男	57	福建	干部	高中	一般	已婚	2子1女	
周小芳	女	37	贵州	会计	大专	良好	已婚	1子1女	
吴大伟	男	48	云南	工人	初中	一般	已婚	2子1女	
郑晓燕	女	44	陕西	教师	大学	良好			

the 1990s, the number of people in the world who are illiterate has increased from 1.2 billion to 1.5 billion. The number of illiterate people in the world is projected to increase to 1.7 billion by the year 2015. The number of illiterate people in the world is projected to increase to 1.7 billion by the year 2015. The number of illiterate people in the world is projected to increase to 1.7 billion by the year 2015.

100

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(continued)

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ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED

2

REPORT NO. 10. Grant Number, United Nations Order, Project No. 10. Title, Agency Use, Core No. 10.

[illegible]

conditions of contract available to many men use of area.

THE SILVER AGE

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Table 1. *Continued*

Variable	Mean	SD	Median	Mode	Range
Age	30.2	10.1	27.0	27.0	18.0-50.0
Gender					
Male	10.0	0.0	10.0	10.0	10.0-10.0
Female	10.0	0.0	10.0	10.0	10.0-10.0
Marital status					
Married	10.0	0.0	10.0	10.0	10.0-10.0
Single	10.0	0.0	10.0	10.0	10.0-10.0
Divorced	10.0	0.0	10.0	10.0	10.0-10.0
Widowed	10.0	0.0	10.0	10.0	10.0-10.0
Education					
High school	10.0	0.0	10.0	10.0	10.0-10.0
College	10.0	0.0	10.0	10.0	10.0-10.0
Postgraduate	10.0	0.0	10.0	10.0	10.0-10.0
Income					
Low	10.0	0.0	10.0	10.0	10.0-10.0
Medium	10.0	0.0	10.0	10.0	10.0-10.0
High	10.0	0.0	10.0	10.0	10.0-10.0

[illegible][illegible][illegible][illegible]

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Expenditure Actual Expenditure for 1900-01 in millions of rupees

100

20.

— 11 —

25

200

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27

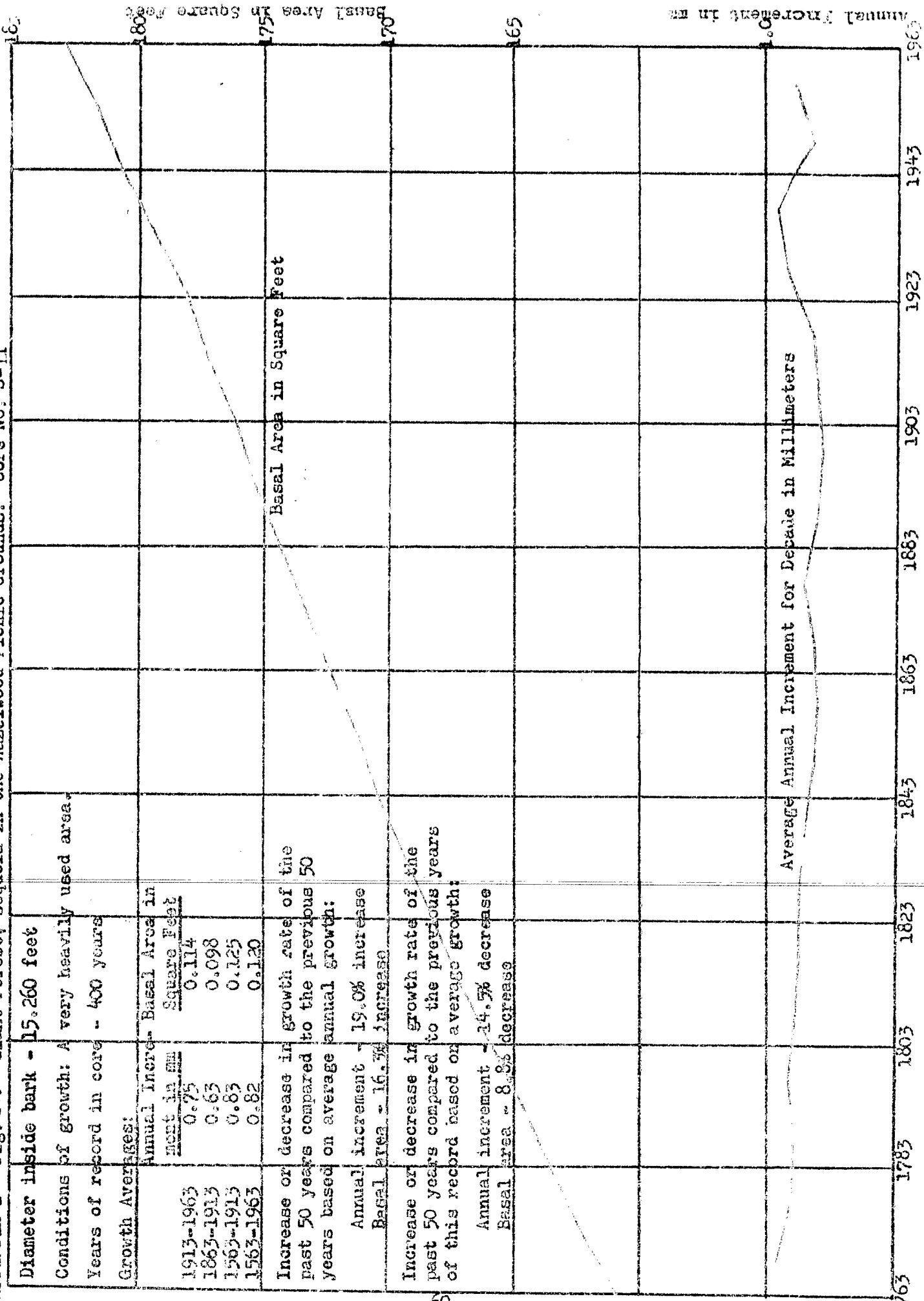
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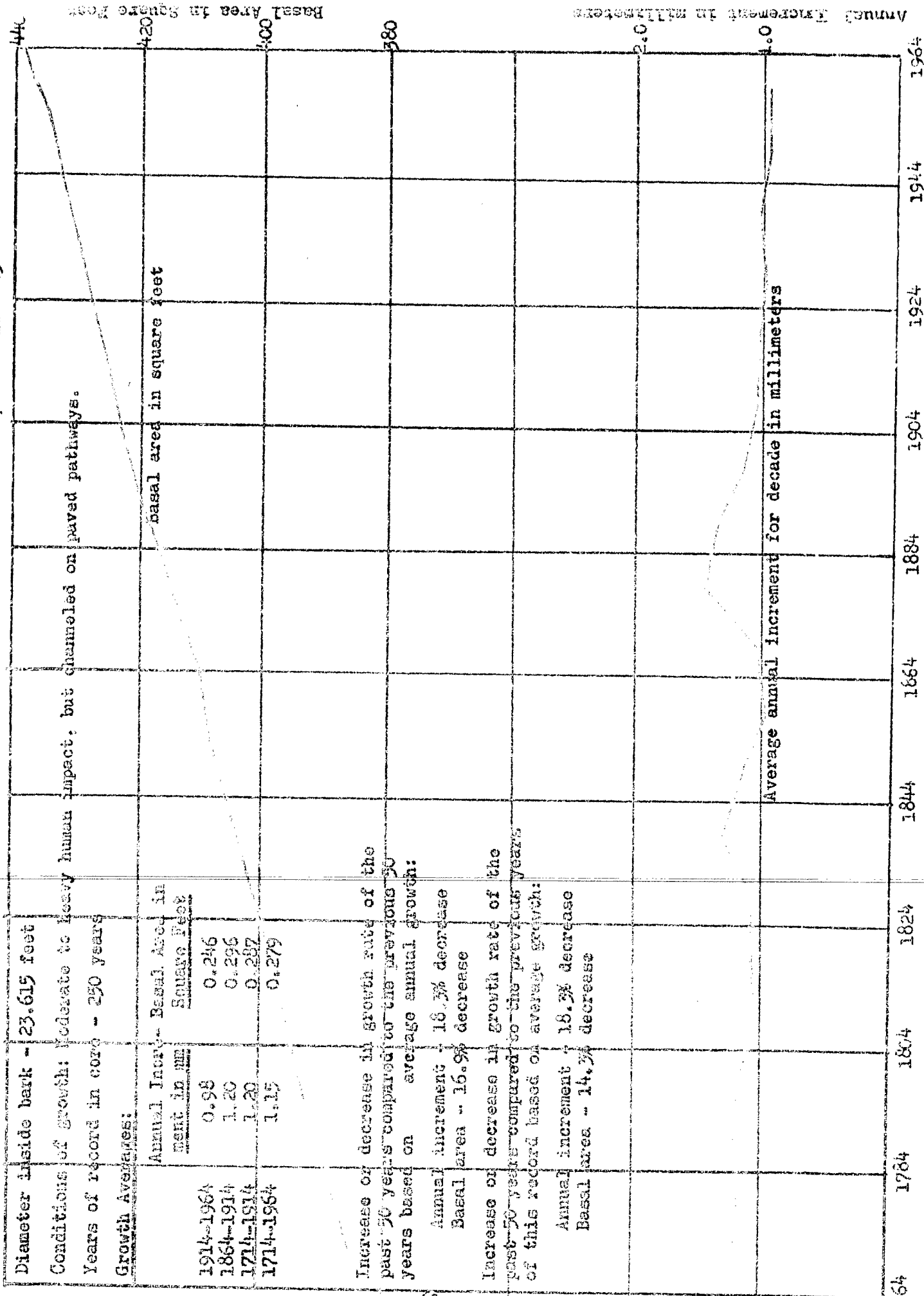
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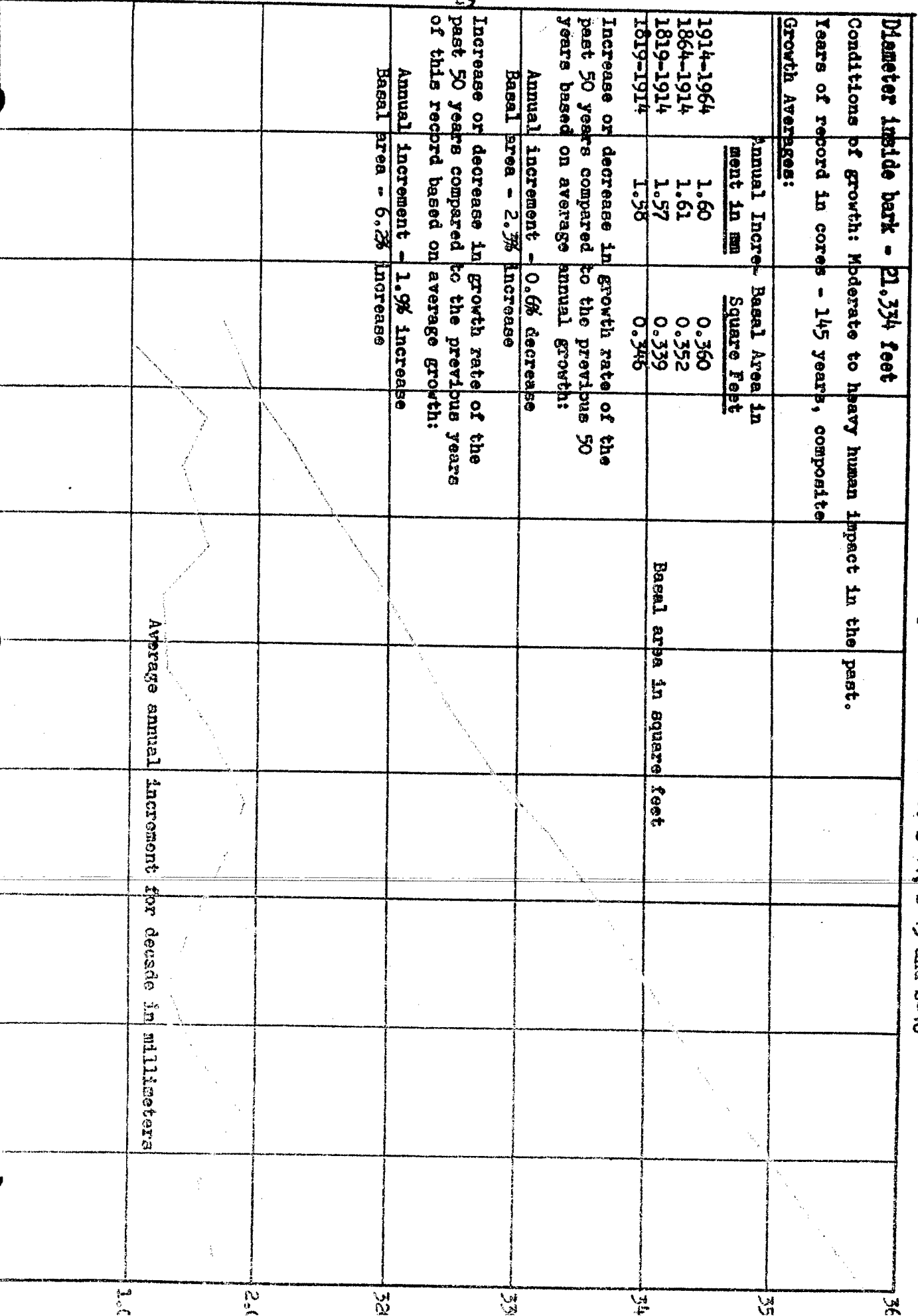
APPENDIX I - Fig. 14. Giant Forest, Sequoia in the Hazelwood Picnic Grounds. Core No. S-11



APPENDIX I - Fig. 15. Giant Forest, General Sherman Tree. Composite of Cores No. S-41, S-42 and S-43



APPENDIX I - FIG. 16. Grant Grove, General Grant Tree. Composite of Cores No. S-44, S-45 and S-46



APPENDIX I - FIG. 17. Giant Forest. Sequoia along the Congress Trail near the Sequoyah Trees. Core No. S-32.

Diameter inside bark - 7.230 feet

Conditions of growth: Advancing plant succession; very little human use.

Years of record in core - 496 years

Growth Averages:

Annual Increment in mm Basal Area in square feet

1914-1964
1864-1914
1470-1914

0.55
0.61
0.65

0.082
0.086
0.087

Basal area in square feet

1470-1964

0.63

0.087

Increase or decrease in growth rate of the past 50 years compared to the previous 50 years based on average annual growth:

Annual increment - 0.8% decrease

Basal area - 4.7% decrease

Increase or decrease in growth rate of the past 50 years compared to the previous years of this record based on average growth:

Annual increment - 15.4% decrease

Basal area - 5.7% decrease

Average annual increment for decade in millimeters

1804

1824

1844

1864

1884

1904

1924

1944

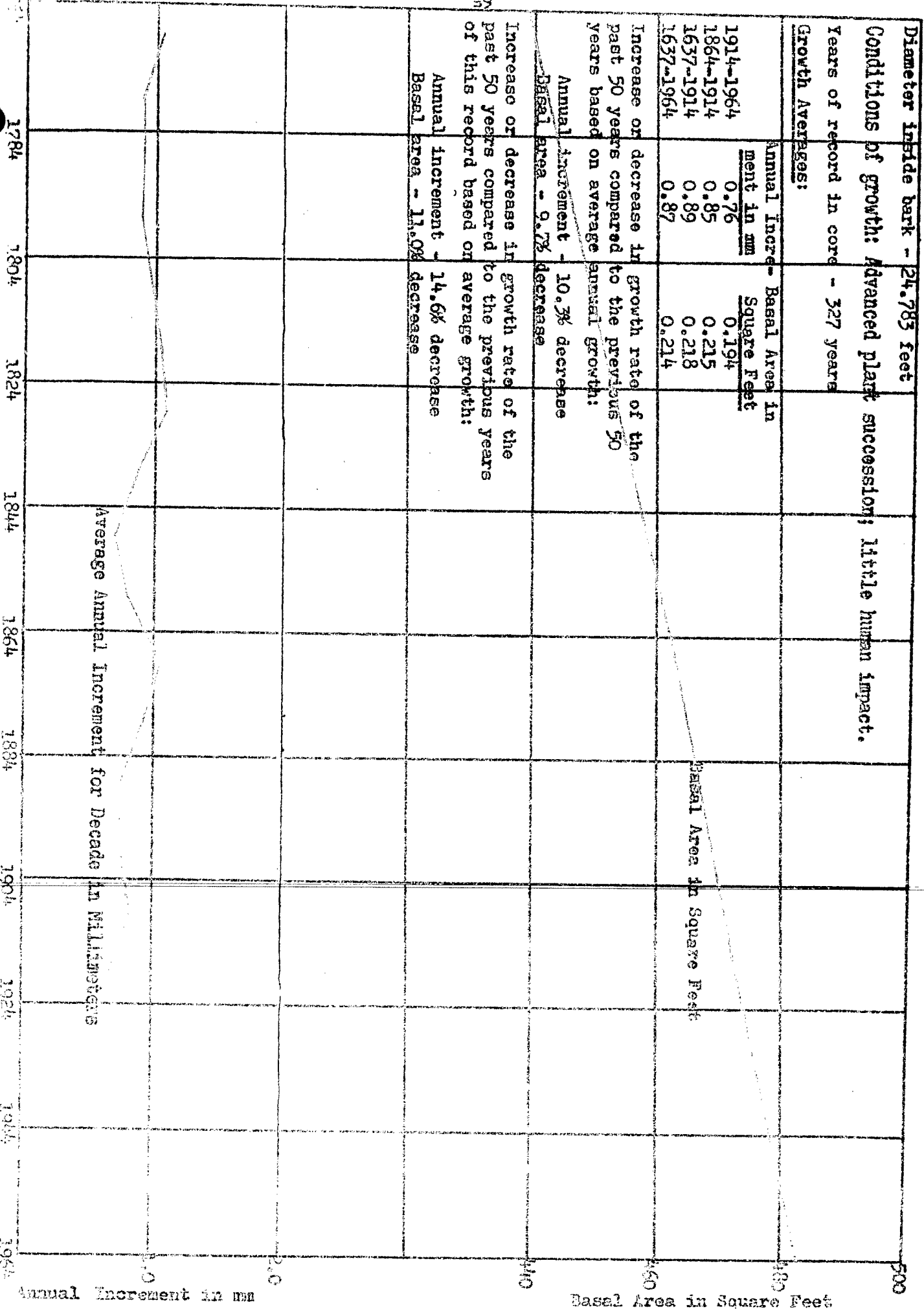
1964

Annual Increment in mm

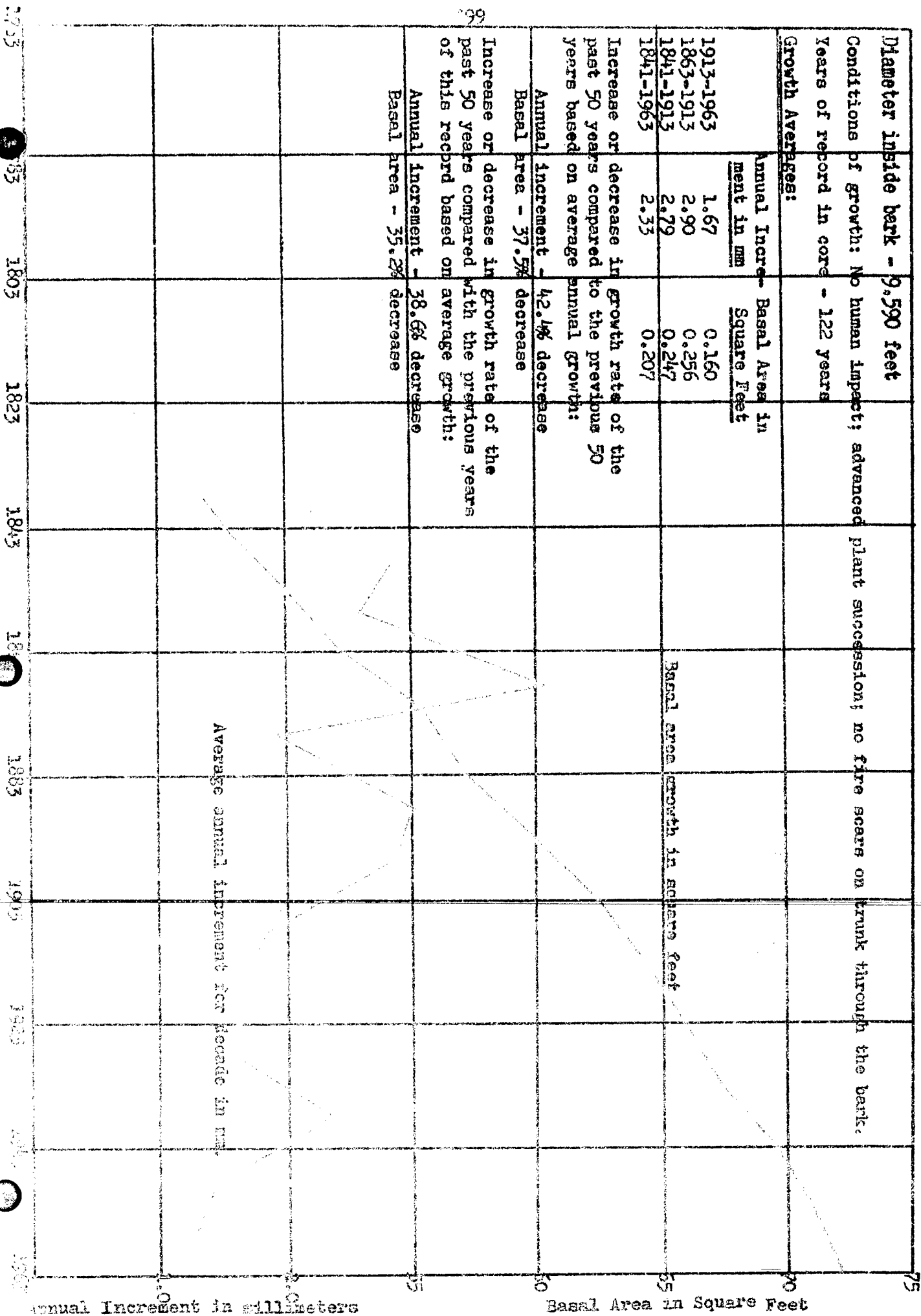
Basal Area in Square Feet

Diameter inside bark - 17.015 feet																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	</
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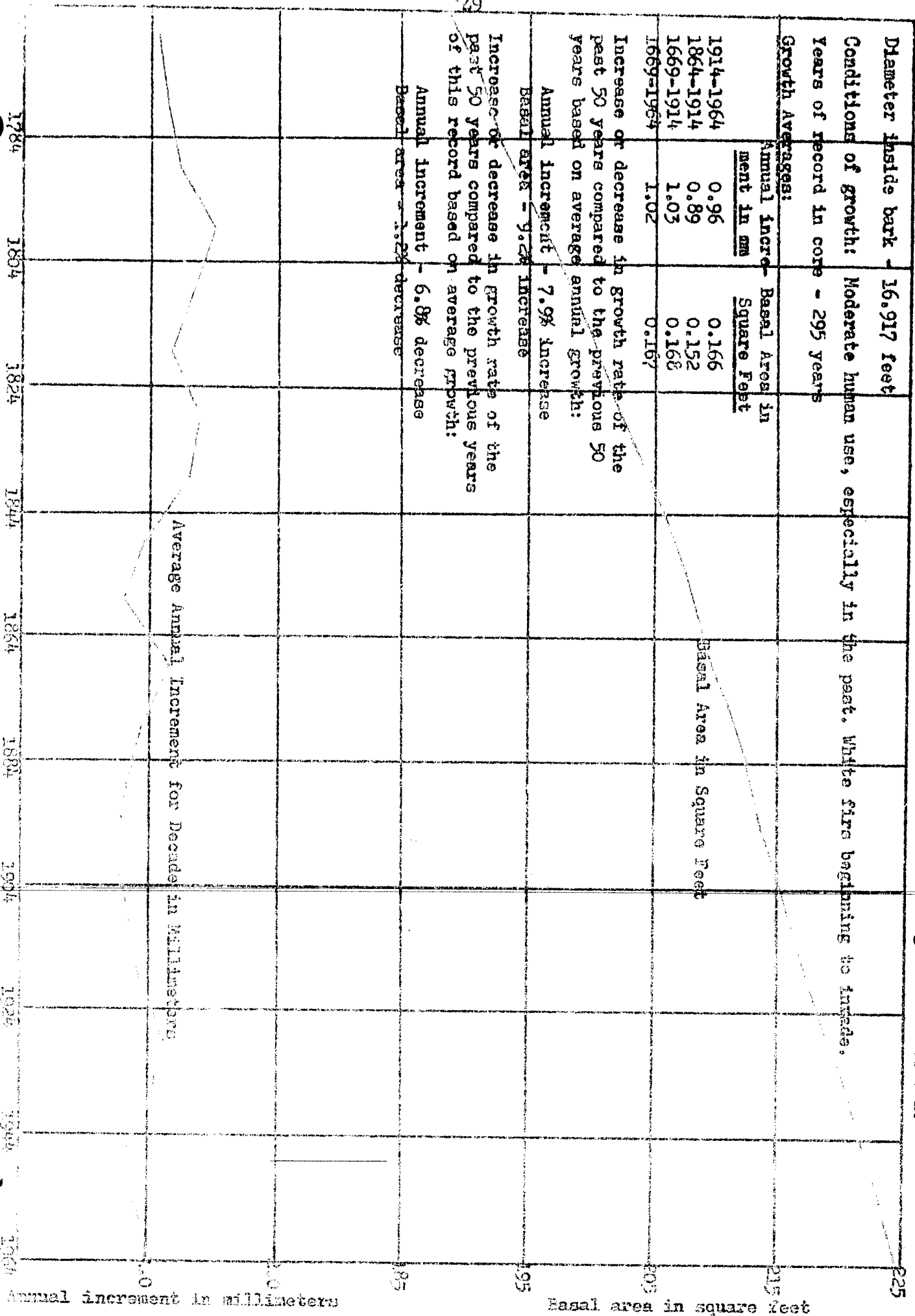
APPENDIX I - Fig. 19. Giant Forest, The Washington Tree. Core No. S-31.



APPENDIX I - Fig. 20. Giant Forest, sequoia in low drainage way near the Trail of the Sequoias. Core No. S-4.

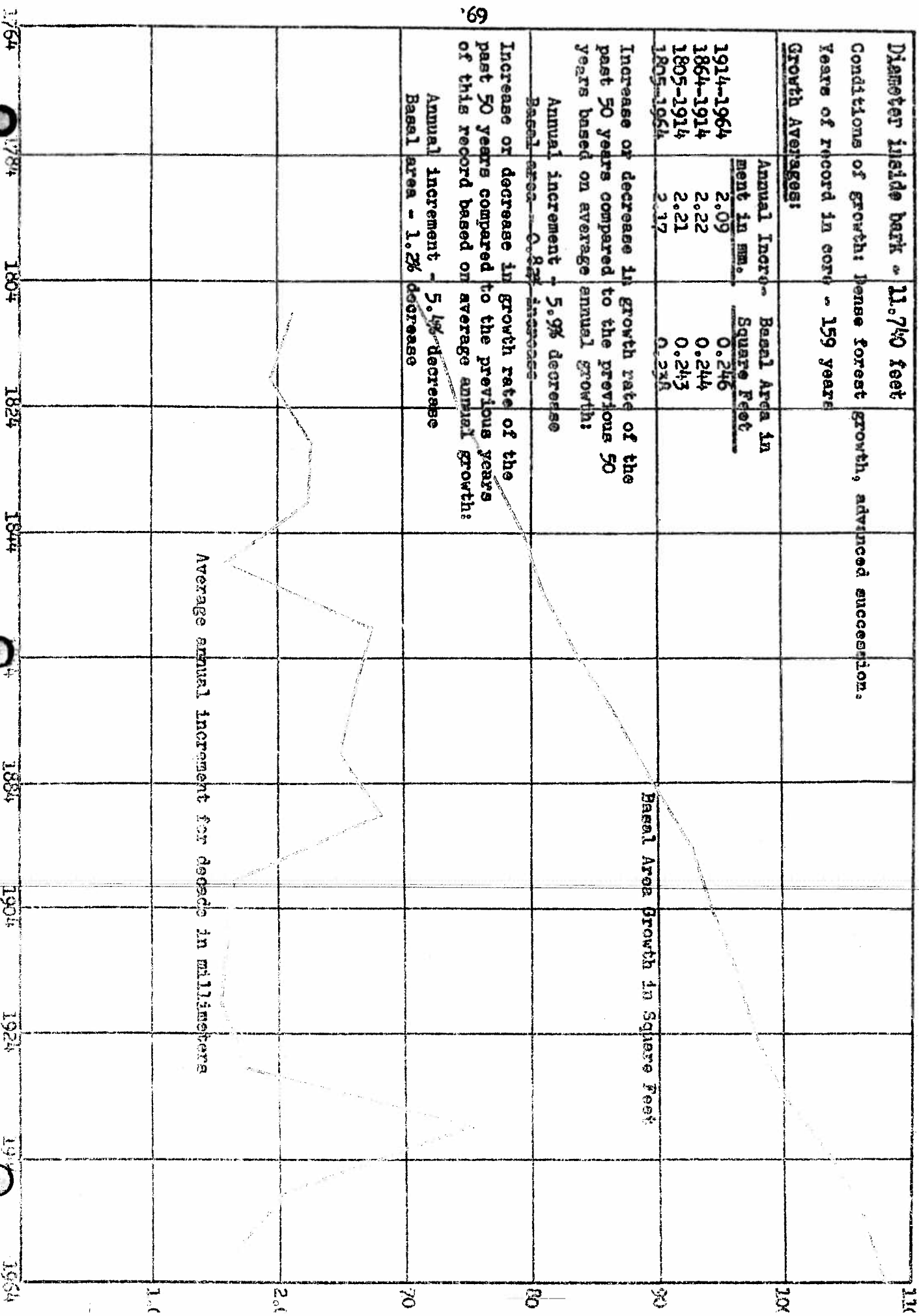


APPENDIX I - Fig. 21. Giant Forest, sequoia across Generals Highway from Giant Forest Lodge. Core No. S-2.



Annual Increment in mm

APPENDIX I - Fig. 23. Giant Forest, Lowest sequoia in the grove. Fl. approx. 5,200 feet. Core No. S-24

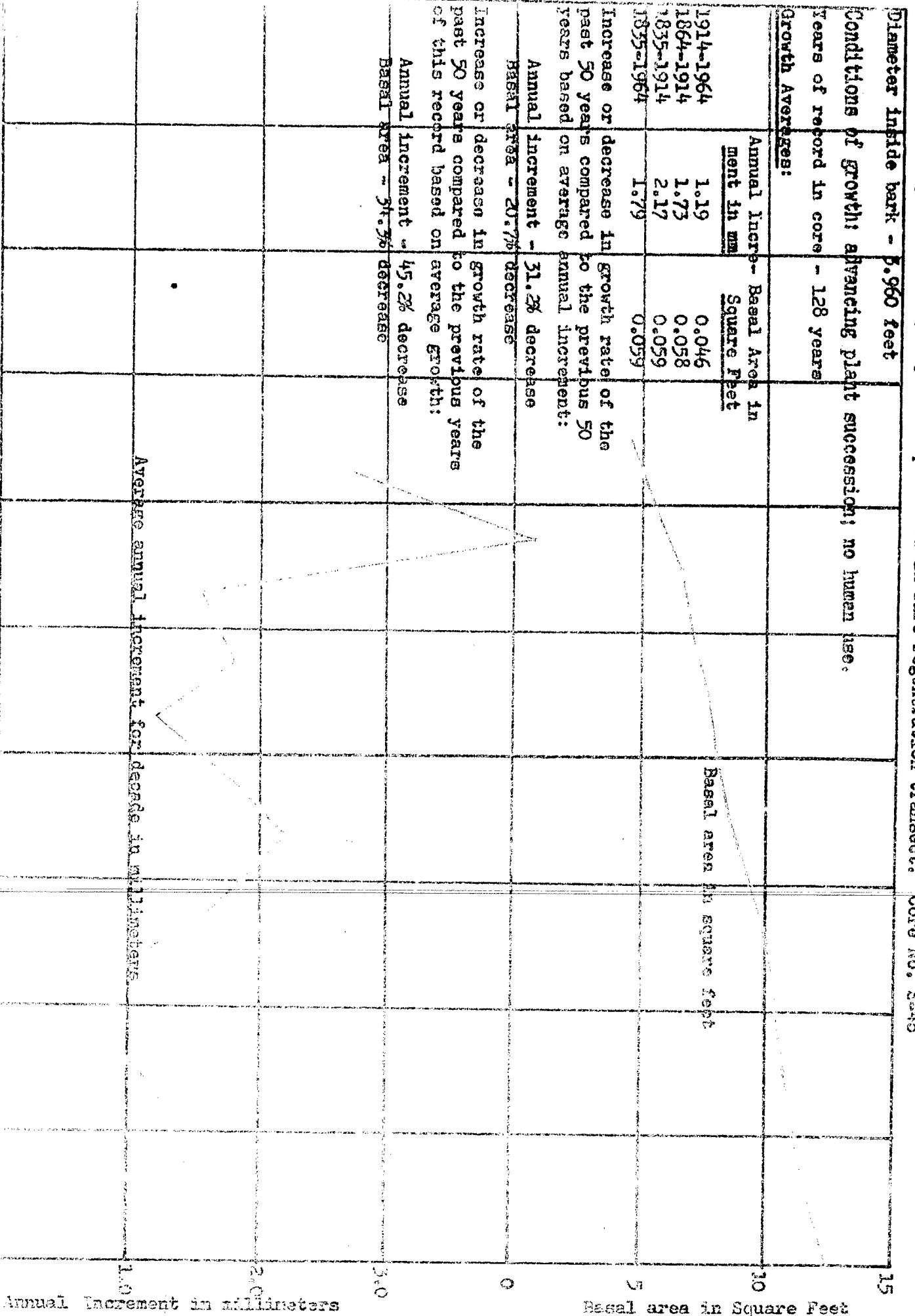


Core No. S-22.

Annual Increment in mm

APPENDIX I - FIG. 25. Muir Grove, sequoia on perimeter in fire regeneration transect.

Core No. S-48



APPENDIX I - Fig. 26. Atwell Grove, sequoia growing at highest known elevation, el. 8,800 feet. Core No. S-26

72

Diameter inside bark - 12.750 feet	Conditions of growth: Advancing plant succession; no human impact.	Years of record in core - 254 years	Growth averages:	Annual increment in mm	Basal area in square feet	Basal Area in square feet	Annual increment for decade in millimeters
1913-1963	0.63	0.084					
1863-1913	0.81	0.104					
1709-1913	0.88	0.129					
1709-1963	0.82	0.104					
Increase on decrease in growth rate of the past 50 years compared to the previous 50 years based on average annual growth:							
Annual increment -	22.2% decrease						
Basal area - 19.2% decrease							
Increase on decrease in growth rate of the past 50 years compared to the previous years of this record based on average growth:							
Annual increment -	29.2% decrease						
Basal area - 34.8% decrease							

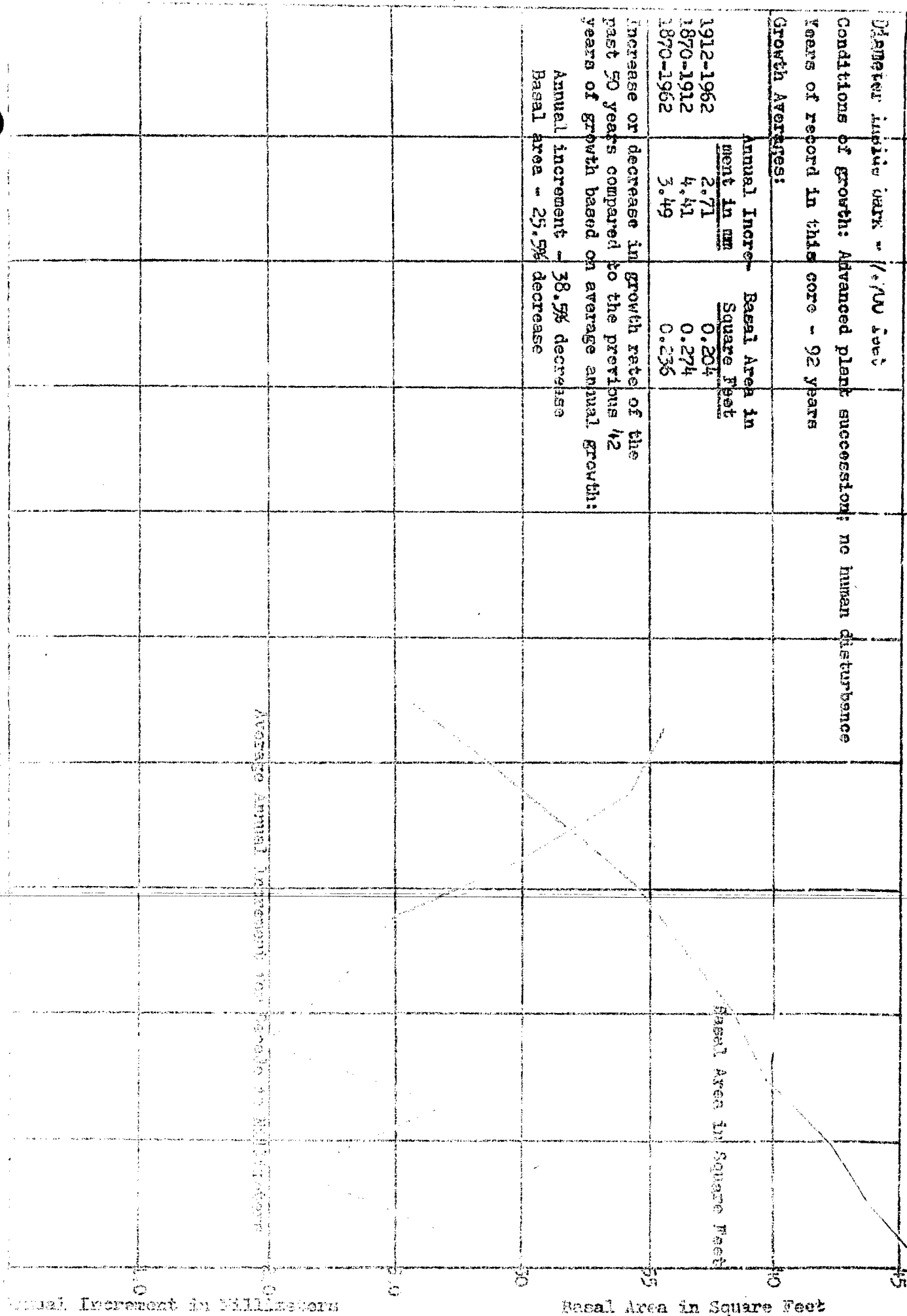
1804 1824 1844 1884 1904 1924 1944 1964

50

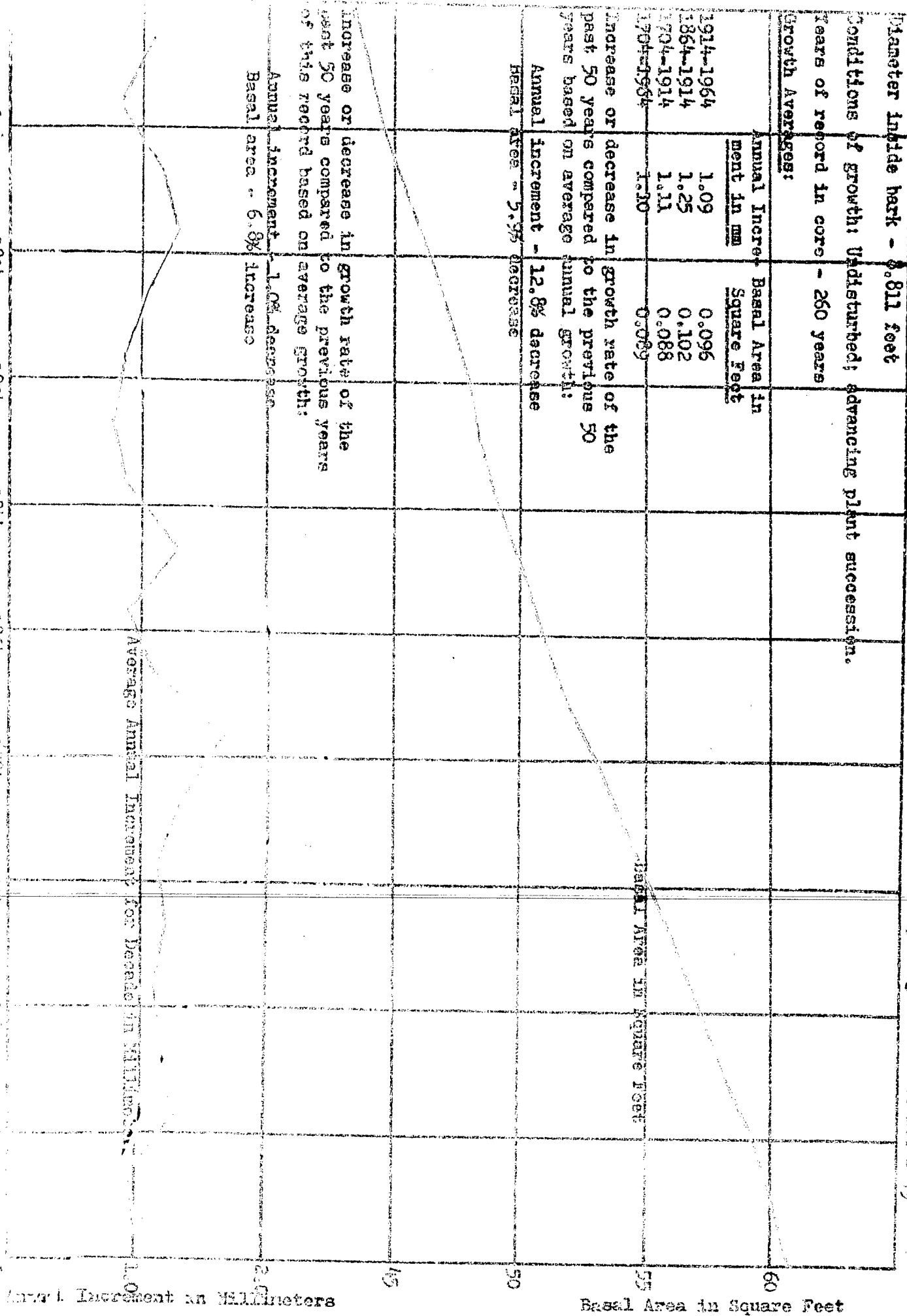
ANNUAL INCREMENT IN IN

Basal Area in Square Feet

INDEX I - Fig. 28. Lost Grove, sequoia near high elevation boundary of grove. Core No. S-58



APPENDIX I - Fig. 29. Muir Grove, sequoia in fire regeneration transect near east boundary of Grove. Core No. S-49



APPENDIX I - Fig. 30. Suisun Grove, Sequoia National Park. Very dense white fir forest. Core No. 8-56

Diameter inside bark = 11.494 feet
 Conditions of growth: Undisturbed; plant succession well advanced.
 Years of record in the core: 256 years

Growth Averages:

Annual Increment - Basal Area in
 mm. square feet

1914-1964 0.55
 1864-1914 1.13
 1708-1914 1.28
 1708-1964 1.19

Basal area growth in square feet

Increase or decrease in growth rate of the
 past 50 years compared to the previous 50
 years based on average annual growth:

Annual increment - 51.4% decrease
 Basal area - 37.8% decrease

Increase or decrease in growth rate of the
 past 50 years compared to the previous years
 of this record based on average annual growth:

Annual increment - 57.3% decrease
 Basal area - 54.5% decrease

Average Annual Increment for decade in millimeters

Annual Increment in millimeters

Basal Area in square feet

1824 1834 1844 1854 1864 1874 1884 1894 1904 1914 1924 1934 1944 1954 1964

1. The first step is to identify the problem. In this case, the problem is that the company is not meeting its sales targets. The second step is to analyze the data. The third step is to develop a plan. The fourth step is to implement the plan. The fifth step is to evaluate the results.

APPENDIX II.

The growth rate percentages of increase or decrease in this appendix are based upon three sets of comparisons: 1.) A comparison of the last 50 years with the previous 50; 2.) A comparison of the last 50 years with the average growth rate of all previous years on the increment cores; and 3.) A comparison of the growth rates since the dates of construction compared to the rates during an equal number of years prior to construction. The comparisons of the last 50 years with the rates of all previous years is not valid for statistical comparisons because the number of years represented on the cores is highly variable. They are, however, of great individual value and are here included.

Blank spaces in the tabulations represent insufficient years of record for comparison, lack of data for comparisons, lack of need for before/after construction comparisons or for lack of meaningful diameters on trees with excessive fire scars.

APPENDIX II. Fig. 1. Changes in Sequoia Growth Rates in Percentage.
Trees in Areas of Little or No Human Use.

Core No.	Diameter in feet	Last 50 years comp. to previous 50 years		Last 50 years comp. to all previous years on core	
		Annual Increment	Basal Area	Annual Increment	Basal Area
S-22	7.2	+24.5	+26.3	-20.4	- 7.7
S-31	24.8	-10.3	- 9.7	-14.6	-11.0
S-10	13.7	-21.2	-12.7	-19.6	- 5.8
S-33	17.0	- 9.4	+ 4.4	-31.0	-24.7
S-25	9.2	+19.9	+27.9	+ 0.4	+16.4
S-35	9.7	-10.6	- 5.6	-33.3	-23.4
S-4	9.6	-42.4	-37.5	-38.6	-35.2
S-30	17.4	+12.7	+14.6	+10.7	+18.3
S-29	5.9	-32.4	-18.9	-35.2	-45.5
S-39	13.4	-38.5	-36.1	-21.0	-13.2
S-26	12.7	-22.2	-19.2	-29.2	-34.8
S-24	11.7	- 5.9	- 0.8	- 5.4	- 1.2
S-48	3.9	-31.2	-20.7	-45.2	-34.3
S-49	3.8	-12.8	- 5.9	- 1.0	+ 6.8
S-51	9.5	+ 5.1	+11.0	-16.5	- 4.8
S-32	14.5	- 9.8	- 4.7	-15.4	- 5.7
S-14	12.3	- 1.9	0.0	-21.7	-22.0
S-56	11.5	-51.4	-37.8	-57.2	-54.5
S-59	15.9	-26.5	-22.4	-11.3	- 5.3
S-58	7.7	-38.5	-23.5	-	-
Averages		-15.0	- 8.7	-21.4	-15.2

APPENDIX II, Fig. 2. Changes in Sequoia Growth Rates in Percentage.
Trees in Areas of Various Types of Heavy Human Use.

Core No.	Diameter in feet	Last 50 yrs comp. to previous 50		Last 50 yrs comp. to all previous yrs. on core		Comparison before/after construction	
		Annual Increment	Basal Area	Annual Increment	Basal Area	Annual Increment	Basal Area
S-6	5.1	- 2.5	+ 8.7	---	---	- 15.6	+ 7.5
S-7	18.0	+ 2.4	+ 3.2	+ 14.9	+ 10.6	+ 9.3	+ 13.0
S-8	7.2	+ 34.5	+ 44.9	+ 19.6	+ 43.4	+ 10.2	+ 15.5
S-9	10.0	+ 35.7	+ 42.6	+ 46.1	+ 41.0	+ 98.8	+121.7
S-13	6.5	+ 47.1	+ 40.3	+ 58.6	+ 42.3	---	---
S-5	8.0	+ 25.3	+ 24.1	+ 1.3	+ 12.3	+ 28.4	+ 33.3
S-20	13.8	+150.9	+177.8	+129.3	+148.0	+138.9	+160.5
S-11	15.8	+ 19.0	+ 16.3	- 14.5	- 8.8	---	---
S-12	14.3	+ 55.1	+ 52.6	- 7.1	0.0	---	---
S-36	9.9	+116.0	+113.2	+ 88.7	+ 30.8	+106.0	+115.6
S-34	6.5	+ 4.1	+ 24.5	+ 14.0	+ 31.3	---	---
S-37	-	+ 30.1	---	+ 36.7	---	+ 40.5	---
S-28	8.0	+ 2.1	+ 6.6	+ 3.8	+ 6.6	---	---
S-38	16.2	+ 65.2	+ 68.1	+100.0	+ 71.9	---	---
S-44-6	21.3	- 0.6	+ 2.3	+ 1.9	+ 6.2	---	---
S-47	12.7	+ 82.1	+ 85.7	+ 67.1	+ 81.4	+ 67.1	+ 71.6
S-23	8.1	+ 28.6	+ 37.5	+ 32.0	+ 32.0	+ 51.0	+ 63.6
S-18	-	---	---	---	---	+ 66.0	+ 67.2
S-53	12.2	+ 60.2	+ 45.4	+ 47.1	+ 41.8	+236.8	+252.2
S-41-3	23.6	- 18.3	- 16.9	- 18.3	- 14.3	---	---
S-61	6.2	---	---	---	---	+ 27.0	+ 51.5
S-62	3.0	+ 18.2	+ 30.8	+ 42.3	+400.0	+ 2.7	+ 30.9
S-63	-	+ 45.7	---	---	---	---	---
S-64	-	- 15.9	---	---	---	---	---
Averages		+ 34.3	+ 42.5	+ 34.9	+ 36.8	+ 61.9	+ 71.7

** Not averaged in with other basal area figures. Because of the small size of this tree, the excessively high basal area figure probably represents more a normal expected increase of an immature tree than the effect of human use.

APPENDIX II

Fig. 3. Changes in Sequoia Growth Rates in Percentage. Trees in Areas of Light to Moderate Human Use.

Core No.	Diameter in feet	Last 50 yrs. comp. to previous 50		Last 50 yrs. comp. to all previous yrs. on core	
		Annual Increment	Basal Area	Annual Increment	Basal Area
S-2	16.9	+ 7.9	+ 9.2	+ 6.8	+1.2
S-3	11.6	+14.8	+17.0	+75.4	+57.1
S-50	20.7	+ 7.7	+ 5.8	+ 5.4	+ 7.8
S-57	12.0	+27.9	+33.3	+20.0	+35.2
Averages		+14.5	+16.6	+20.7	+20.8

Fig. 4. Changes in Sequoia Growth Rates in Percentage. Trees in Areas Where Roots are Covered by Pavement.

Core No.	Diameter in feet	Last 50 yrs comp. to previous 50		Last 50 yrs.comp. to all previous yrs. on core		Compar. before/after construction	
		Annual Increment	Basal Area	Annual Increment	Basal area	Annual Increment	Basal Area
S-53	12.2	+60.2	+45.5	+47.1	+41.8	+236.8	+252.2
S-28	8.0	+ 1.1	+ 6.6	+ 3.8	+ 6.6	--	--
S-47	12.7	+82.1	+85.7	+67.1	+81.4	+ 67.1	+ 71.6
S-23	8.1	+30.2	+33.3	+ 9.2	+28.0	+ 66.7	+ 57.9
S-18	13.0	+47.0	+52.4	+47.0	+52.4	+ 52.7	+ 58.7
Averages		+44.0	+46.8	+34.9	+42.0	+105.8	+110.1

APPENDIX II

Fig. 5. Changes in Sequoia Growth Rates in Percentage. Trees With Roots Cut For Roadway.

Core No.	Diameter in feet	Last 50 yrs comp. to previous 50		Last 50 yrs comp. to all previous yrs. on core		Compar. before/after Construction	
		Annual Increment	Basal Area	Annual Increment	Basal Area	Annual Increment	Basal Area
S-40	-	-	-	-	-	-11.3	-
S-43	-	-	-	-	-	-65.0	-
S-27	12.0	-12.8	-21.4	-37.9	-43.9	-43.6	-30.1
S-17	-	-	-	-	-	-4.8	-
Averages		-	-	-	-	-31.2	-

Fig. 6. Changes in Sequoia Growth Rates in Percentage. Trees With Giant Forest Lodge Dining Hall Built Over Root Systems.

Core No.	Diameter in feet	Last 50 yrs comp. to previous 50		Last 50 yrs comp. to all previous yrs. on core		Compar. before/after construction	
		Annual Increment	Basal Area	Annual Increment	Basal Area	Annual Increment	Basal Area
S-20	13.8	+150.9	+177.8	+129.3	+148.0	+138.9	+160.5
S-36	9.9	+116.0	+113.2	+88.7	+80.8	+106.0	+115.6
S-37	-	+30.1	-	+36.7	-	+40.5	-
Averages		+99.0	+145.0	+84.7	+114.4	+95.1	+138.0