EFFECTS OF FOREST HARVESTING AND SITE PREPERATION ON WATER YIELD FROM THE CLAYTON LAKE WATERSHED

BY

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Master of Science in Forestry

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Peshawar, North West Frontier Province

1987

Submitted to the Faculty of the
Graduate College of the
Oklahoma State Universty
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1992

Thesis
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FROM THE CLAYTON LAKE WATERSHED

Thesis Approved:

Thesis Advisor

Dean of Graduate College

ACKNOWLEDGEMENTS

I would like to express my appreciation to Dr. Don Turton, my major advisor, for his support, constructive criticism and guidance throughout this project. This project is the result of a team effort, both in the field and office. I would also like to thank Dr. Edwin L. Miller and Dr. Steve Hallgren for their expert advice on certain aspects of my project and their review of this thesis. Thanks also go out to working members of Watershed Lab and graduate students of Forest Hydrology for sharing their computer expertise with me. I would also like to express my special thanks to Government of Pakistan and USAID who's financial support made my degree program possible.

Most importantly, I can not forget my father at this moment (may Allah bless him) who died back home and could not wait on my return. His moral support and words of encouragement have always inspired me towards achieving the goals of my life. Thanks also go out to my mother and sisters for their moral support and encouragement.

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CHAPTER I

INTRODUCTION

Among forest hydrologists, the impact of forest practices on water resources has always been a matter of concern. They have always been curious about silvicultural activities in terms of their potential effects on water yield, peak flow, water quality and sediment yield.

Within the past few decades water supply has become the growing and fundamental research issue. Man has always played an important role in affecting both soil and vegetation through different land use practices. Water quantity and water quality are two important factors which are affected through these practices. The magnitude of this affect on this basic natural resource is a subject of controversy and speculation among watershed researchers because of a lack of fundamental research data in this particular area.

Normally undisturbed forest areas regulate the flow of water towards the streams. Clear cutting as a silvicultural practice on these areas can cause a change in water yield. Because of high temperatures found in Oklahoma most of the precipitation is evaporated so water quantity which is of immeasurable economic and aesthetic value becomes a limiting factor. At the same time water demand has also increased due to unexpected rise in technology and high living standards. In the view of dry climatic conditions and rising water demand the management of water production is important. Vegetation manipulation in the form of forest harvesting is important from a water production point of view. Clearcut harvesting results in the reduction of evapotranspiration (ET) which in turn increases water yield. The objective of this paper is to determine and measure the actual increase in water yield as a result of forest harvesting so that future decisions about the management of water production can be assessed and evaluated based on the actual scientific observations

Sustained water yield is necessary to keep running the economic productivity of the region. it is important both for industrial and domestic life. One important way to get sustained water production is the manipulation of vegetation. Runoff can pose a flood threat every year and in the late summer low flow create problems of both water quantity and quality for municipalities, industry and water dependent recreation. Forest management has a potential for amelioration of these extremes in streamflow. Knowledge of characteristics like runoff and peakflows guides engineers or land managers in planning flood control measures or permit municipalities to select and manage watersheds and regulate consumption of water resources.

Whether or not clear cutting help increases water yield is the subject matter of this paper. The Two objectives of the study are:

1. To compare annual water yields between a clear-cut harvested and an undisturbed watershed
2. To compare seasonal water yields between a clear-cut harvested and an undisturbed watershed.

CHAPTER II

LITERATURE REVIEW

Water yield

People right from historic ages have recognized that healthy streams are dependent on good forest management. The Chinese emperor Yu in 1600 B.C, implented a forest management programme to control erosion and floods. The slogan of his programme was " to protect the river protect the forests" (Brown and Beschata 1985).

To prove the relationship between forest and water production scientific investigation started around the turn of this centuary. Rapheal Zon (1912) speculated that although severe metrological conditions can not be prevented by forests, without forests these are even more destructive. Because of high infiltration capacities runoff is very less in the forests as compared to other land uses. Zon (1912) also presented the scientific relationship of forests and water production before the public and congress (Hibbert, 1967).

The fact that forests do have some influence on streamflow was recognized in early 1930's. To investigate the scientific relationship between forests and streamflow research was begun in Southern California, Arizona and North

Carolina at their respective research experiment stations. At Coweeta Hydrological Labortory in North Carolina the impact of forest harvesting on streamflow was measured from three perspectives: 1.Influence of clear cutting without regrowth cutting 2.influence of clear cutting with annual regrowth cutting 3. clear cutting followed by conversion in to mountain farming. Hoover (1954) concluded from above research that peakflows are not much affected by clear cutting unless forest floors are also disturbed. Conversion into the farming, on the other hand increased peakflows and erosion after a period of years (Lull et al, 1972).

Changes in vegetative cover both in amount and type are the main factors behind water yield fluctuation. These changes result in low and high streamflows. Due to forest harvesting evapotranspiration is reduced and ground water storage is increased, which in turn increase the amount of available water for streamflow generation and water yield (Brooks et al, 1991).

There exists a direct relationship between forest cover and water yield (Auten, 1934; Dunford, 1962; Hursh, 1951; Lowdermilk, 1950). Generally the consumption of water through forest vegetation is high so any attempt to change the forest vegetation will result in a change of water yield. Evapotranspiration is reduced as a consequence of forest harvesting which means more soil moisture is available for ground water runoff to streams (Hewlett and Hibbert, 1961 and 1967; and Reinhart et al, 1963)

In a research study conducted to see what happens to water yield as a result of clear cutting in the Ouachita mountains, Oklahoma, Miller (1984) concluded that water yield results were inconclusive. Average water yields were 31.7 cm on uncut areas and 29.9 cm on clear cut areas the first year following harvest. On clear cut area contour ripping increased detention storage and infiltration and thus water yield from clearcut area was decreased. However, water yields increased the second year after forest harvest from clearcut areas. No significant difference was observed in water yield during 3rd and 4th years following harvest (Miller, 1984).

Changes in water yield depend upon many factors like soil depth, regrowth rate, climatic conditions and annual precipitation. Areas with high annual rainfall and deep soils generate high water yields as compared to the areas which are dry and have shallow soils. Faster rate of growth after clear cutting will also affect the water yield. Generally after clear cutting roots stop to grow in search of water and also interception capacities are decreased. All of these factors help increase the storage of ground water and thus water yield is increased (Brooks et al, 1991).

In a watershed study in the Ouchita mountains of Arkansas the effects of forest harvest (clear cutting and selection cutting) were measured on streamflow and peakflow (Miller, Beasley and Lawson, 1988). Watersheds were blocked according to aspect, location and geology in randomized complete block design to test the effects of treatments. Overall water yield did not increase due to forest harvesting in any of the post treatment years. This may have been due to the permeable soils and subsurface geology which allowed deep seepage. Only within one block treatment response was observed. The watersheds in block one, showed higher stormflows than the control after clear and selection harvest. The clearcut watershed in one block showed a 19-31 cm annual stormflow greater than the control and the selectioncut watershed showed a 7-15 cm annual stormflow greater than the control the first three years after harvest.

In another watershed study conducted in the South Central U.S, four representative locations with nine forested watersheds were put under intensive forest management practices like clear cutting and selection cutting. Impacts were observed on water quality, water yield , and site productivity. The four representative locations were, the Gulf coastal plain of Arkansas, Gulf coastal plain of Texas, the Ouachita mountains of Arkansas, and the Athens plateau of Arkansas. In the Gulf Coastal plain and the Athens plateau water yield and storm flow increased after clear cutting in first year. Selection cutting had no significant effect on water yield in any location (Beasley et al, Unpub).

Because of the clear cutting in the Athens Plateau effects on water yield continued beyond the first post treatment year (Beasley & Granillo, 1986). Sites which were given chemical treatment after clear felling did not differ significantly in water yields from controls. This may be due to the reason that chemical treatment did not kill all the residual hardwoods. Rainfall above the normal in the second year was of no significance among treatments in terms of water yield. On the other hand areas which were clearcut and mechanically prepared showed high water yield during third post treatment year despite the fact that rainfall in that year was about normal (Beasley et al, Unpub).

In New England stream flow changes were observed following forest clearing. The treatments included forest clearing and herbicides to control regrowth. Transpiration was eliminated and interception losses were reduced. As a result annual water yield increased an average of 31 cm over the untreated estimate for the first two years. A sizeable increase in annual water yield was observed in the growing season (June through September) and also during low flow periods in late summer and early fall. During the first water year after clearing the increase was 31.5 cm for four months that comprised the growing season and 2.54 cm for eight months that comprised dormant season (Hornbeck et al, 1970).

Researchers at Coweeta Hydrological Laboratory, Franklin, North Carolina conducted research into the effects of forest harvest on water yield. Earlier speculation that evapotranspiration from forests and consequent soil water deficits were the factors to minimize floods in down stream areas were verified by paired watershed experiments. A mature hardwood forest on a 108 acres watershed was clear felled and no forest material was removed. No overland flow occurred. A statistical analysis of all major storm hydrographs before and after clearing revealed that after felling, stormflow increased by 11 percent. The forest land consumed more water than the cleared land through evapotranspiration. This process can very well be explained by variable source area concept of runoff (Hewelett and Helvey 1970).

Watershed research on four small experimental watersheds in Japan was conducted for 22 years. According to this research removal of forest vegetation from the four watersheds increased annual runoff from 38 to 192 mm (8 to 24 percent), low flow runoff by 7 to 8 mm (74 to 84 percent) and direct runoff by 28 to 58 percent. Precipitation, antecedent soil moisture and topography are also important in determining the increase in water yield. It will vary under different level of soil moisture, precipitation and even under same set of silvicultural practices. The increase reaches the maximum just after the completion of logging and thereafter diminishes with recovery of vegetation so that runoff is restored to the normal just after the completion of regrowth. This research did not directly consider the reasons for runoff increase which perhaps were due to the reduction of transpiration and no interception, as well as due to the decline of infiltration on soil disturbed by logging (Nakano, 1967).

Patric and Reinhert (1971) conducted research on the effects of clear cutting on two mountain watersheds in the Fernow Experimental forest in West Virginia. According to this research partial forest cutting increased water yield, but complete deforestation is more important from an increase water yield point of view. Two watersheds were cut at their opposite halves one at the upper half and other at the lower half. These halves were left barren for three years, from 1965-1967. During this period the average water yield increase for both watersheds was 15.2 cm. After three years remaining halves were also deforested, the average water yield increase was 25.4 cm following complete deforestation.

Stream flow responses were measured under the effect of four forest practices in the Allegheny mountains of West Virginia. The four practices were; commercial clear cutting with skid roads not planned; selection cutting with planned skid roads and protection given to soil, forest stand, water resource and the skid roads; and intermediate extensive and intensive selection cuts. The forest floor was kept undisturbed except in skid roads. Water yield from the clear-cut watershed showed an increase of 12.7 cm during the first year following harvest. A proportionate increase of water yield was observed with the percent removal of timber. From four different watersheds per acre volume cuts were

8.5, 4.2, 3.7, and 1.7 thousand board feet respectively. Against these removals an increases of 7.62, 4.57, 3.55, and 0.76 cm, respectively, in water yield were observed. Low flows and high flows were also observed. Heavily cut watersheds showed an increase in low flows. High flows on clearcut watersheds during growing season were quite high. Snow melt flows were less than expected. Treatment effects declined with the passage of time (Reinhart and Eschner, 1962).

Clear cutting in the Pacific Northwest of Oregon showed the results which confirm the fact that forest harvest increases water yield. An increase of 45.72 cm was measured in high rainfall areas. In 1964, water yield was roughly proportional to the percent of the area clear cut. In the year following logging the water yield was higher than expected. This was due to the two storm events during this period which raised water yield. In second and third year after harvest water yield was representative to the logging conditions (Rothacher, 1970).

Accurate prediction of whether forest cutting or any other type of forest manipulation effects water yield is a research issue for hydrologists of this century. According to the Coweeta Hydrological Laboratory, North Carolina twenty years of research on controlled experiments showed that clearcutting hardwood forest on two small watersheds greatly increased water yield. This increase was 38.1 and 43.18 centimeters for two cut watersheds. The yearly increase levelled off at 27.94 centimeters after the third year where all regrowth was cut back annually. On the other hand where coppice forest grew back it declined progressively. An increase of about 5.08 cm was observed with cutting of shrubs in the under-story. Moreover north facing watersheds showed a greater increase in water yield than south facing watershed though both received the same amounts of rainfall. According to the researcher to avoid ill founded attempts to get more water yield from forests we need to know and understand the nature and mechanisms of water disposal processes on forest land (Meginnis, 1959).

Results of thirty nine watershed studies were analyzed to determine the effects of altering the forest cover on water yield. Taken collectively, this analysis revealed that water yield increases as a result of forest reduction. Reforestation again restores the water yield. Responses to treatment were highly variable and for the most part unpredictable. Increases of 34 mm to 450 mm were observed in the first year following cutting. For each percent reduction of forest cover maximum an increase of 4.5 mm per year was observed. Most treatments produced less than half this amount. It was also reported that increases were maximum soon after the treatment and declined during following years. Other factors like seasonal distribution of precipitation, climate, soils, topography also play a part in the response of water yield to forest harvest (Hibbert, 1967).

CHAPTER III

MATERIAL AND METHODS

The Study Area

General Description

Two forested watersheds which are part of the drainage basin of Clayton Lake were studied and data was collected. These watersheds are ephemeral and are located at longitude 95^0 20′ 00" and north latitude 34^0 41′ 45", at a distance of 13 km southeast of Clayton, Oklahoma (Figures 1 and 2). The areas of Watershed 1 and 3 were 7.86 hactare and 7.71 hectares respectively. Average slope in both watersheds was about 15 percent, however slopes as great as 40 percent were also measured in Watershed 1. Information regarding the other characteristics of the two watersheds are shown in Table 1.

Soils and Geology

The Carnasaw series is the principal soil type on the two watersheds under study (Bain and Waterson, 1979). Parent material of the soil on the study area is sandstone and weathered shale. The soil is moderately deep, well drained and has moderately steep slopes averaging from 12 to 20

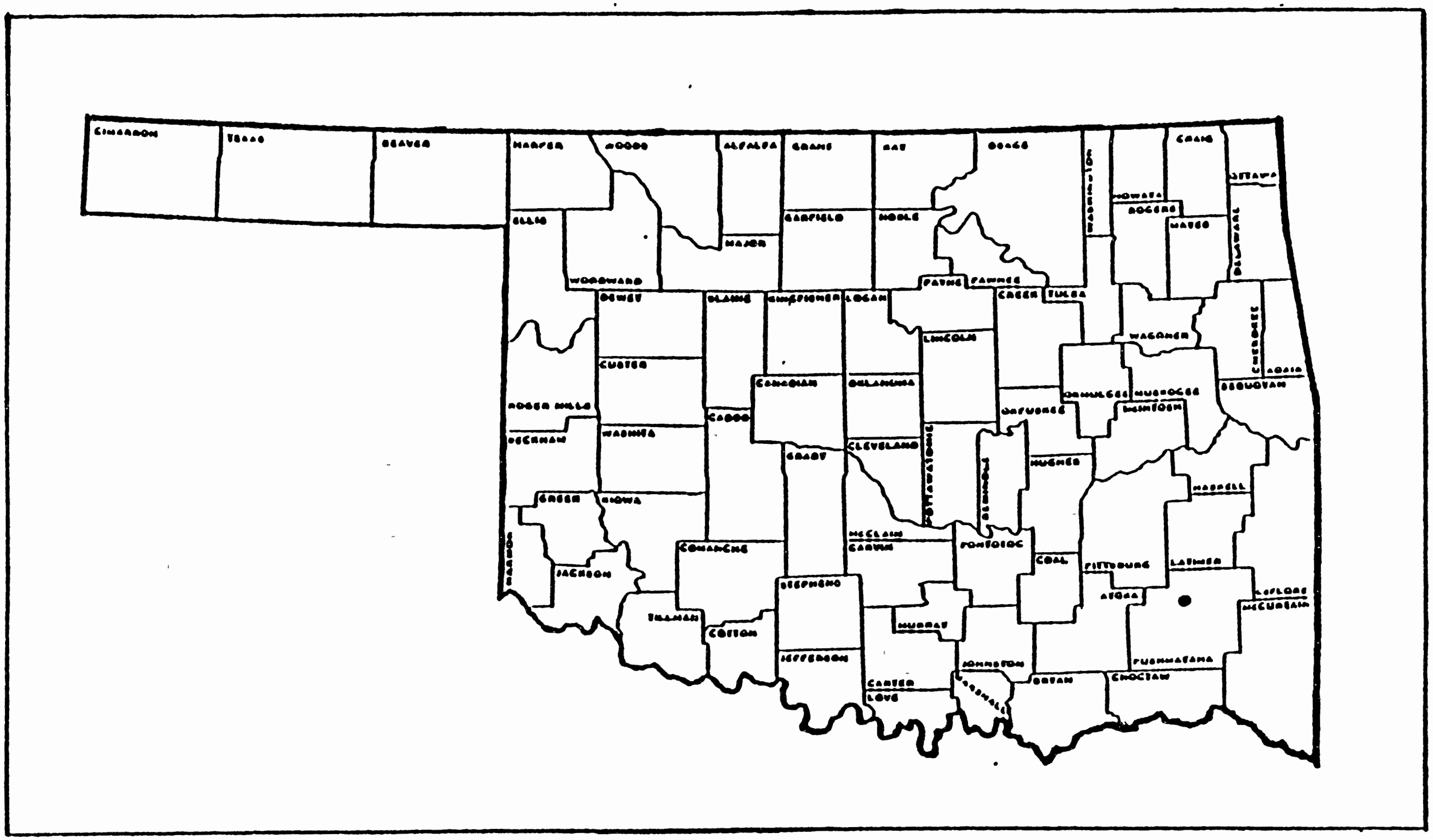

Figure 1. Location of Clayton Lake Watershed Research in Oklahoma

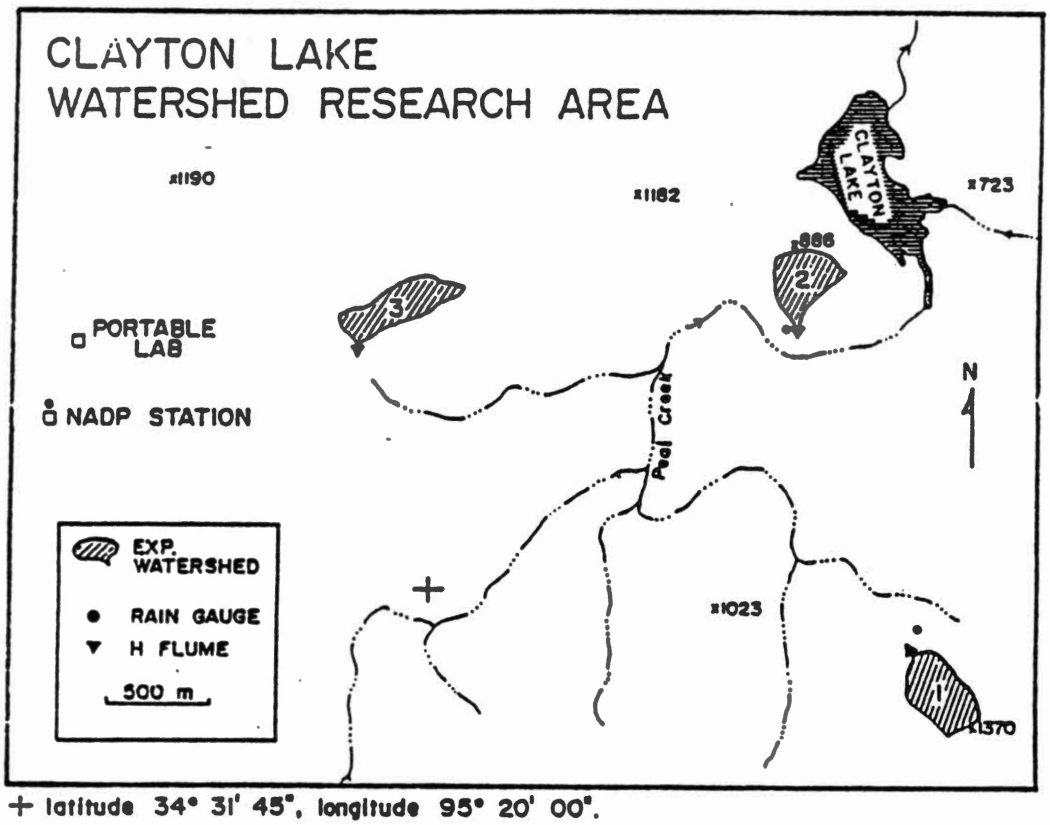

Figure 2. Clayton Lake Watershed Research Area

TABLE I

WATERSHED CHARACTERISTICS

Parameter	Units of Measure	WS I	WS III
Area	Hectares	7.86	7.71
Elevation	Meters		
Maximum		418	378
Minimum		335	286
Aspect		NNW	SW
Slope (Average[1])	Percent	16	14
Crown Cover[2]	Percent	90	80
Ground Cover Condition	Percent		
Litter		86	72
Rock		3	7
Tree		6	6
Erosion		1	1
Stream channel		4	13

[1]Change in elevation divided by watershed length.
[2]Crown cover was estimated from aerial photographs.
Data were collected by Vowell (1980) and a boundry survey completed in 1983

percent with extremes up to 40 percent. The Octavia series is also present with the Carnasaw-pirum-Clebit association on the study watersheds

Carnasaw soils are mixed, clayey, thermic typic Hapludults. Carnasaw soils are deep well drained and have slow permeability. Soil pH ranges from 4.5 to 5.5 and fertility of the soil is low. The A horizon of the soil is sandy loam, with an average depth of 8.9 cm.

The Clebit soils are shallow, well drained and have moderate to fast permeability. Soil pH ranges from 5.1 to 6.5 and natural fertility is low. The horizon whose average depth is 6.4 cm consists of stones and fine sandy loam. This type of soil is present on upland areas with slopes ranging from 8 to 45 percent. The Clebit soil series is a loamy skeletal, siliceous, and thermic Lithic Dystrochrept.

Pirum soils are deep, moderately permeable and well drained. Soil pH ranges from 4.5 to 5.5 and natural fertility is low. The Pirum soil series is a fine loamy, siliceous thermic Typic Hapludult. The fine sand loamy A horizon averages in depth from 0 to 25 cm. This type of soil is mostly present on upland areas with slopes ranging from 12 to 30 percent.

The Octavia soil series is a siliceous, loamy, thermic Typic Paleudult. These soils are deep and well drained with moderately low permeability. Soil pH ranges from 5.6 to 6.0 and natural fertility is low. This type of soil is found on foot slopes or colluvial benches with slopes ranging from 3 to 45 percent. The avearge depth of A horizon is 7.6 cm.

Vegetation

The two watersheds are predominantly covered with a mixed pine-hardwood forest type. Species include short leaf pine (Pinus echinata), Oak (Quercus sp), and Hickory (Carya sp). In some areas adjacent to the stream channels, especially in WS 1, Blackgum (Nyssa sylvatica) is also present.

Ground cover consists of shrubs of the Rosaceae and Ericaceae families. Low ground cover consists of Poison ivy (Rhus radicans), blueberry (Vaccinum sp) and bluestem grasses (Andropogan sp).

Climate

Climate at the study area is humid temperate. Winter and spring weather is mainly influenced by frontal systems moving in from the Pacific coast, while summer storms are convective in nature (Donn, 1975). The average precipitation for the two watersheds is 127 cm per year (Bain and Waterson, 1979). The major part of this precipitation is received in the winter and spring. Winter storms are of long duration and low intensity, whereas spring storms are typically of short duration and high intensity. Summer rainfall is widely scattered and results from convective storms.

Average daily temperature range from 6.5^0 C in the winter to 26.8^0 C in the summer. Extreme temperatures range from -16^0 C in the winter to 40^0 C in the summer.

Watershed Instrumentation

The two watersheds were equipped with 1.21 m H-flumes. To measure stream flow stage was measured on each watershed with a Belfort Stage Recorder. Stage was converted to discharge using rating curves developed for each watershed (Vowell, 1980). Flumes were installed on each watershed at a downstream control section. For continuous monitoring of precipitation a weighing bucket rainguage was located in each watershed. Based on rainfall data collected several parameters like storm duration, precipitation intensity and total precipitation were calculated.

Watershed Treatments

Forest harvest and site preparation treatment was applied to watershed I, while watershed III was kept as a control (no silvicultural treatment was applied). The timing of the activities in watershed 1 were as follows.

In September of 1983 pines were cut and along with some hardwoods. Chain saws were used to fell trees. Hand felled trees were delimbed and bucked to a 10 cm top diameter. Skidding of logs was done by rubber tire skidders. Drum chopping and knocking over of remaining hardwood was done in July of 1984. To get rid of forest waste material from the forest floor slash burning was carried out in August of 1984. The site preperation operations which also included contour ripping of watershed I was done in January of 1985. Rip furrows were on the contour and averaged about 45 cm deep. Planting of Loblolly pine was carried out and seedlings were planted by hand in rip furrows. About 1400 seedlings were planted per hectare. The last silvicultural activity of hand planting of loblolly pine was accomplished in March of 1985.

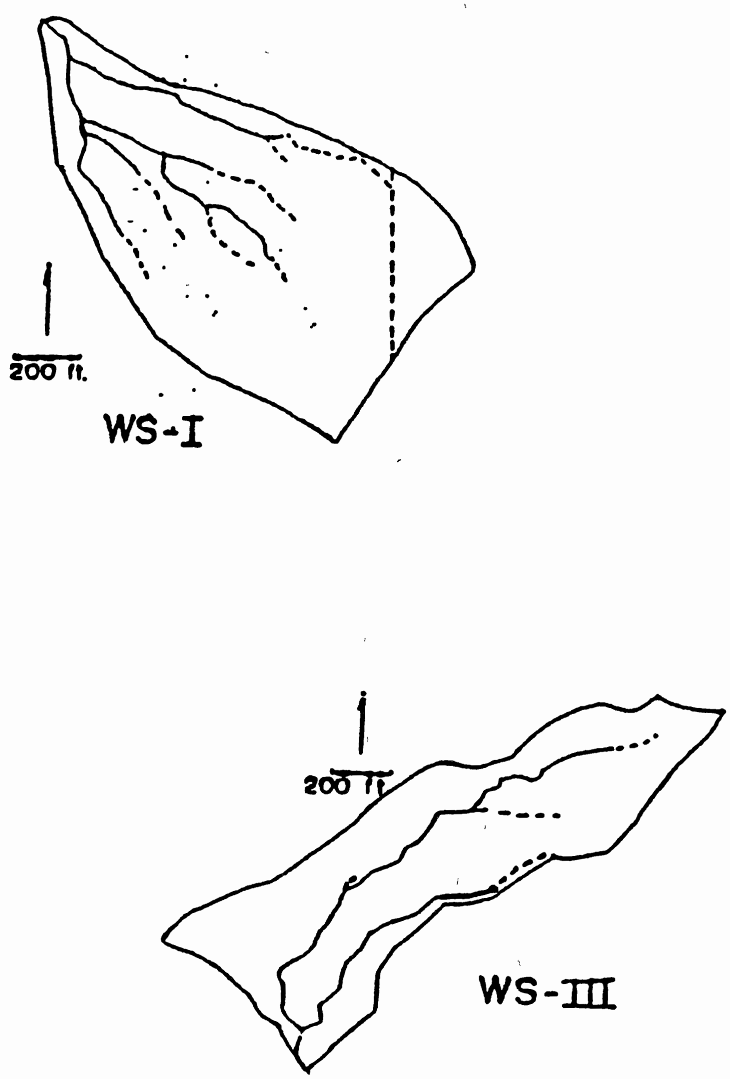

Figure 3. Drainage Pattern of Study Watersheds

CHAPTER IV

RESULTS AND DISCUSSION

Rainfall

Rainfall data from the Clayton watersheds for water years 1981-88 was compared with the average rainfall determined for the nearest rain guage located at Daisey, Oklahoma (NOAA, 1989). Water year 1985 was the wettest year during the study period. Precipitation received during this year was 43.3 cm above or 35 percent above the normal of 122.6 cm (Table II and III). Annual precipitation in water year 1986 was 155.7 cm the second highest of the study period. Water year 1982 was driest year of study period during which a precipitation of 25.4 cm or 21 percent less than normal occured. Annual precipitation for water years 1981, 1982, 1983, 1984 and 1988 were below normal. In water years 1985, 1986, and 1987 precipitation was greater than normal.

During eight water years 1981 to 1988 the fall season (October through December) showed precipitation above the normal except water years 1981 and 1982. The fall of 1985 was the wettest of the study period and precipitation received was 194 percent above the normal. The fall of 1982,

TABLE II

MONTHLY PRECIPITATION FOR THE NORMAL AND THE 1981 THROUGH 1988 WATER YEARS, CLAYTON WATERSHED STUDY OKLAHOMA

		Precipitation (cm)							
Month	*Normal	1981	1982	1983	1984	1985	1986	1987	1988
October	9.7	15.4	14.4	5.5	9.1	45.5	12.2	9.5	8.1
November	8.5	3.5	8.4	16.7	11.9	12.0	30 3	10 0	17.9
December	6.8	5.3	0.5	15.5	3.6	16.1	1.8	6.0	17.9
January	5.0	3.3	16.1	5.9	4.5	4.2	0.4	11 1	5.1
February	6.8	11.1	5.1	9.4	9.3	14.1	11.8	11.2	6 0
March	10.3	6.0	4.1	7.4	16.8	13.6	6.3	8.4	12.4
April	13.8	7.7	5.1	7.8	5.5	19.5	18.3	3.1	9.7
May	16.0	17.9	24.5	25.1	14.7	9.6	21.9	24.8	3.3
June	11 4	13.5	9.2	14.0	15.0	13.0	19 7	13.8	2.2
July	11.0	15.1	7.2	0.9	6.9	5.6	5 5	9 6	16 2
August	8.9	11.5	1.7	2.0	2.4	2.7	11 6	6.1	10.4
September	14.5	4.6	1.0	4.3	19.6	10.1	15 7	21.2	4.1
Total	122.7	114.9	97.4	114 7	119.3	165.9	155 7	134 8	113.3

*Normal based on period 1951-80
measured at Daisy 4 ENE, Oklahoma

TABLE III

SEASONAL PRECIPITATION FOR NORMAL AND THE 1981 THROUGH 1988 WATER YEARS, CLAYTON WATERSHED STUDY OKLAHOMA

		Precipitation (cm)							
Season	*Normal	1981	82	83	84	85	86	87	88
Fall	25 0	24.2	23 3	37.7	24.6	73.6	44.3	25.5	43 9
Winter	22.1	20.4	25.3	22.7	30.6	31.9	18.5	30.7	23.5
Spring	41 2	39.1	38.8	46 9	35.2	42.1	59.9	41.7	15.2
Summer	34 4	31.2	9.9	7.2	28.9	18.4	32.8	36.9	30.7
Total	122.7	114.9	97.3	114.5	119.3	166.0	155.5	134.8	113.3

*Normal based on period 1951-1988
measured at Daisey 4ENE, South Ok

the driest fall during the study, 1.7 cm precipitation less than normal occured.

Winter season (January through March) of all water years 1981 to 1988 received rainfall above the normal except 1981 and 1986. The highest rainfall of the study was recorded in the winter season of 1985 and it was 44 percent above the normal. Winter of water year 1981 received less rainfall than normal.

The spring of 1986 (April through June) had maximum rainfall and was 46 percent above the normal. Precipitation in water years 1981, 1982 and 1983 was less than normal and for other water years it was above the normal.

Summer of all water years (June through September) was dry, especially summer of 1982, 1983 and of 1985. Maximum precipitation was received in the summer of 1987 and it was 7 percent more than normal. Almost all water years in the summer season received precipitation less than normal except summer of water year 1987. The summer season of 1982, 1983 and 1985 was very dry, with high temperatures, windy conditions and low humidities. For water years 1981 to 1988 average monthly precipitation for both watersheds was highest for the month of May and lowest for the month of August and September (Tables XXII and XXIV Appendix).

Water Yield

The Clayton research watersheds both treated and control watersheds behaved almost in a similar fashion before the start of silvicultural activities. In water year 1981 through 1983 runoff observed in the control watershed was more than that of the treated watershed (Table II and IV) with the exception of a few months during which runoff was greater from the treated watershed (Figures 6, 7, 8).

During September of 1983 watershed I was clear felled. The felling operation included felling of pines but leaving residual hardwoods standing, and skidding. From the summer of 1983 to the summer of 1984 there was no appreciable increase observed in seasonal water yields as compared to the different seasons of the pre-treatment water years, despite the fact that forest harvesting was carried out during the above period. This no increase was because the forest floor was still covered with forest material.

In the summer of 1984 (July through August) site preparation consisting of drum chopping and slash burning was carried out. The forest floor was made clear and waste material was burned. Soon after clearing the forest floor a greater increase in water yield was observed in the following fall season (water year 1985). The measured depth of runoff was 58.6 cm. During the fall of 1985 we also received 73.6 cm of precipitation which is also responsible for this greater runoff (Table IV and V). Overall during water year 1985 precipitation of 166 cm in the treated watershed yielded a runoff of 93 cm, or about 54 percent of the precipitation became runoff (Table IV). On contrary the precipitation of 172 cm in the control watershed produced

TABLE IV

CLAYTON REASERCH WATERSHEDS
ANNUAL PRECIPITATION AND FLOW DATA 1981-88

Water Year	Watershed#I			Watershed#III		
	PPT (cm)	Flow (cm)	*** Runof response	PPt (cm)	Flow (cm)	Runoff response
1981	116	28	24	118	33	28
1982	97	28	29	108	30	28
*1983	115	20	17	118	31	26
**1984	119	30	25	129	20	16
1985	166	93	54	172	72	41
1986	156	55	35	164	57	35
1987	135	39	29	119	24	20
1988	113	39	34	118	39	33

*pines were cut in watershed III
** Site preparation and slash burning
***Percentage of the rainfall that became runoff

runoff of 72 cm, or about 41 percent of the precipitation became runoff. Runoff from treated watershed was 21 cm greater than the runoff from control watershed, despite the fact that treated watershed received 6 cm less rainfall. Fall season of 1985 showed a runoff response of 80 percent from the treated watershed as compared to the 60 percent runoff response from control watershed. The 20 percent increase in runoff response is due to silvicultural operations and the highest amount of rainfall in fall season of 1985. The winter runoff response (in water year 1985) from the treated and control watersheds was almost 60 percent. The spring runoff response (in water year 1985) from the treated and control watershed was 37 percent and 33 percent respectively. The seasonal runoff response gradually decreased from the fall of 1985 to the spring of 1985 in the treated watershed. This decrease was due to ripping and planting done in the winter season of 1985.

Such an increase in water yield in the first few years after harvesting and site preparation as reported by Hewlett and Hibbert (1961 and 1967) and Reinhart et al (1963) is the result of a reduction in evapotranspiration. The reduction in ET means more soil moisture reaches streams as ground water.

Results of this research confirm other research that attempted to find an exact relationship between forest harvesting and water yield. As a matter of fact water yield should increase after forest harvesting and site preperation in the first and second year after silvicultural operations and should decline during following years (Miller, 1984). In the Clayton research case the water yield increased after forest harvesting and site preperation (slash burning) and also the first year after forest harvest and site preparation. During the second year in 1986 water yield did not increase rather it went down from 93 cm to 55 cm. Water yield from the control watershed for water year 1986 was about same as the treated watershed. The equal amount of runoff in control watershed was due to 10 cm greater precipitation than the treated unit.

Hibbert (1967) and Nakano (1967) reported similar results that water yield increased immediately after treatment and declined following treatment. This decrease in runoff could be explained in the light of following facts. During the winter of 1985 in the month of January watershed I was ripped contourwise and in the March of 1985 planting of Loblolly pine was done by hand. Planting and ripping both appeared to have decreased this runoff though precipitation in the same water year was only 10 cm less than the previous water year. Miller (1984) reported that contour ripping treatment usually increases detention storage and surface roughness and thereby increases infiltration at the expense of surface runoff.

According to Hewlett and Hibbert (1967) subsurface channels which normally carry interflow to ephemeral streams are disturbed by ripping and thereby limit the expansion of

TABLE V

SEASONAL RUNOFF FROM THE TREATED WATERSHED (YEAR 1981-1988)
CLAYTON WATERSHED STUDY OKLAHOMA

	Runoff (cm)							
Season	1981	82	83	84	85	86	87	88
Fall	4	1.6	2.1	0.5	58.6	22.5	11.6	24.8
Winter	7.1	10.2	7.5	15.5	19.2	5.9	15.3	8.7
Spring	16.1	16.6	10.4	7.6	15.5	24.6	8	4.7
Summer	0.5	0.1	0	6.6	0	1.4	4.2	0.4

source area near ephemeral channels and prevent the normal stormflow response to harvest. Runoff in water year 1987 and 1988 was about same in treated watershed but it was certainly higher than control for same water years. This greater runoff in treated watershed was due the persistant after effects of silvicultural activities.

Fluctuations in water yield in all water years before and after the silvicultural treatment in the treated watershed are due to both silvicultural operations and variations in rainfall in the study period. Whereas differences in water yield in control watershed are only because of variations in precipitation in the study period (Figure 4 and 5).

Average monthly runoff in both watersheds was highest in the March and the may and was lowest in the August (Tables XXIII and XXV Appendix).

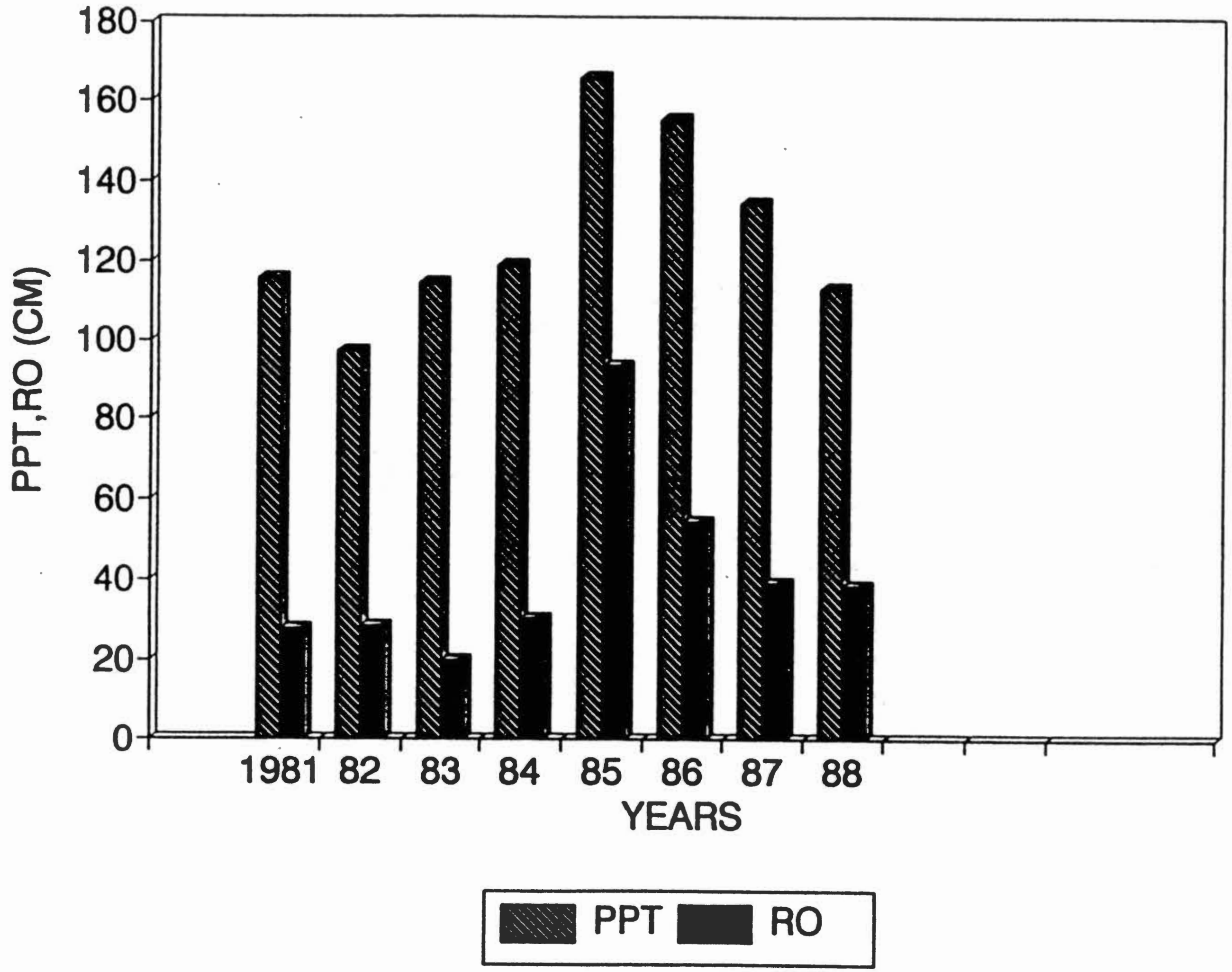

Figure 4. Yearly Precipitation and Runoff from Clayton Watershed 1 for Water Years 1981-1988.

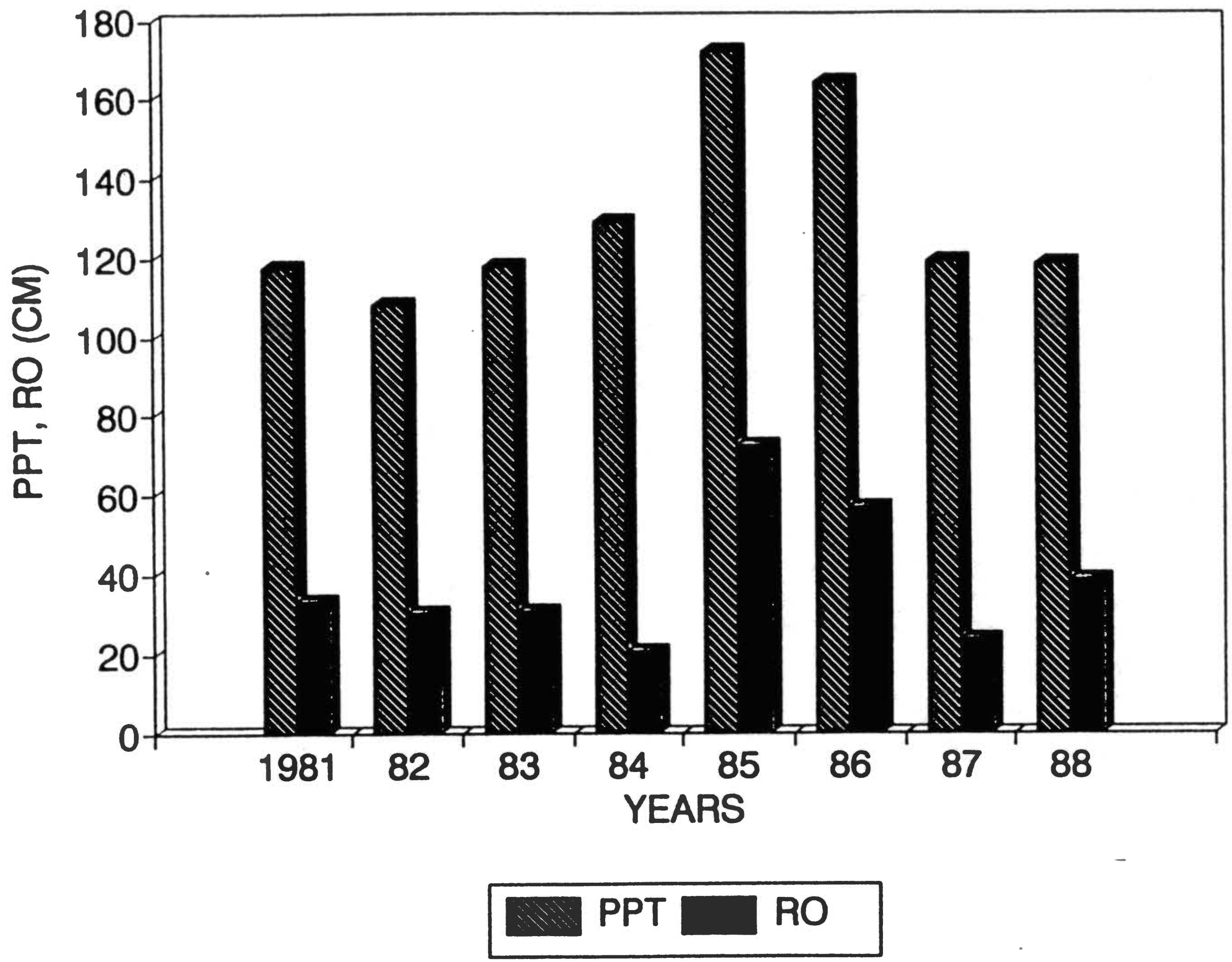

Figure 5. Yearly Precipitation and Runoff from Clayton Watershed 3 for Water Years 1981-1988.

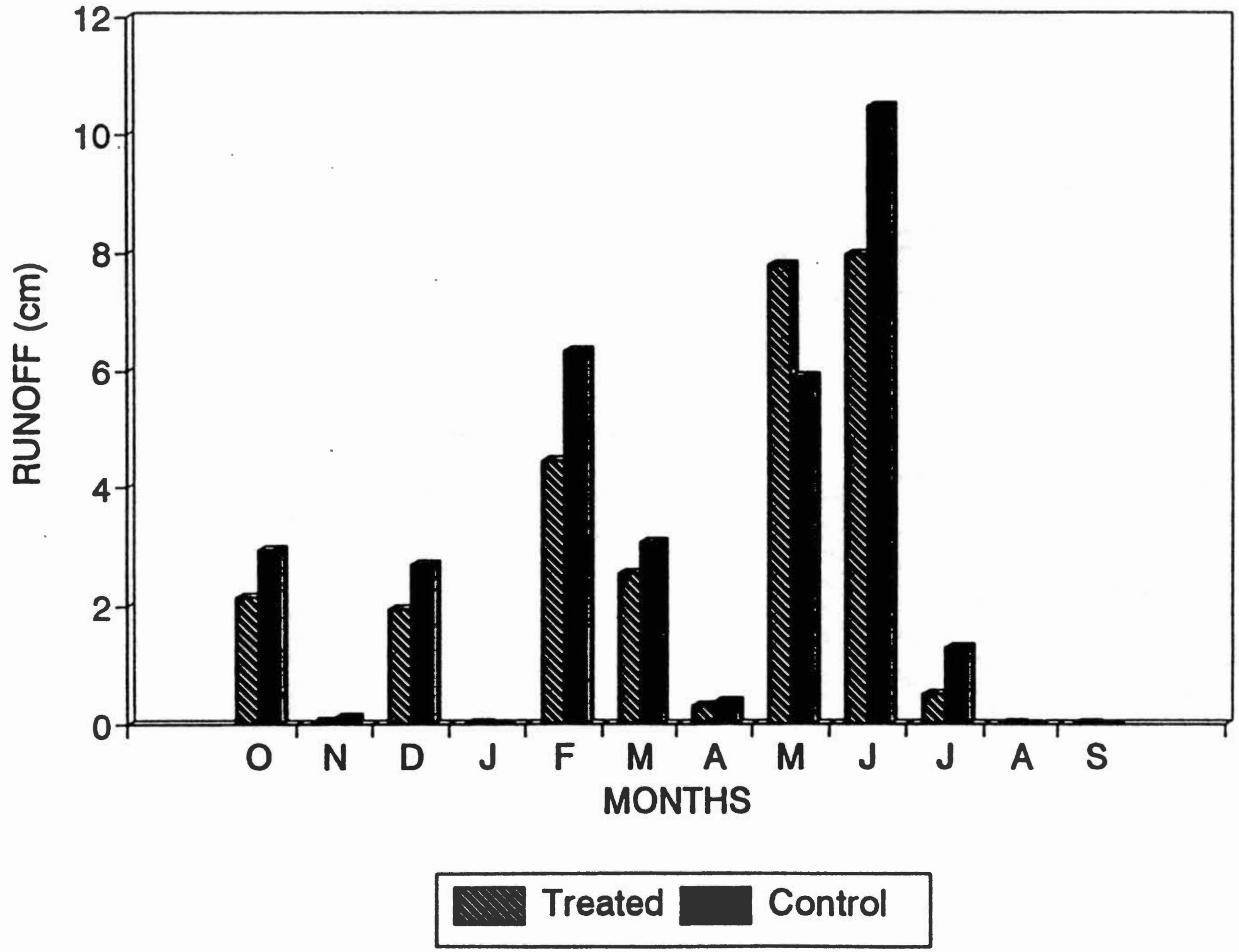

Figure 6. Runoff from Treated and Control Watersheds for Water Year 1981.

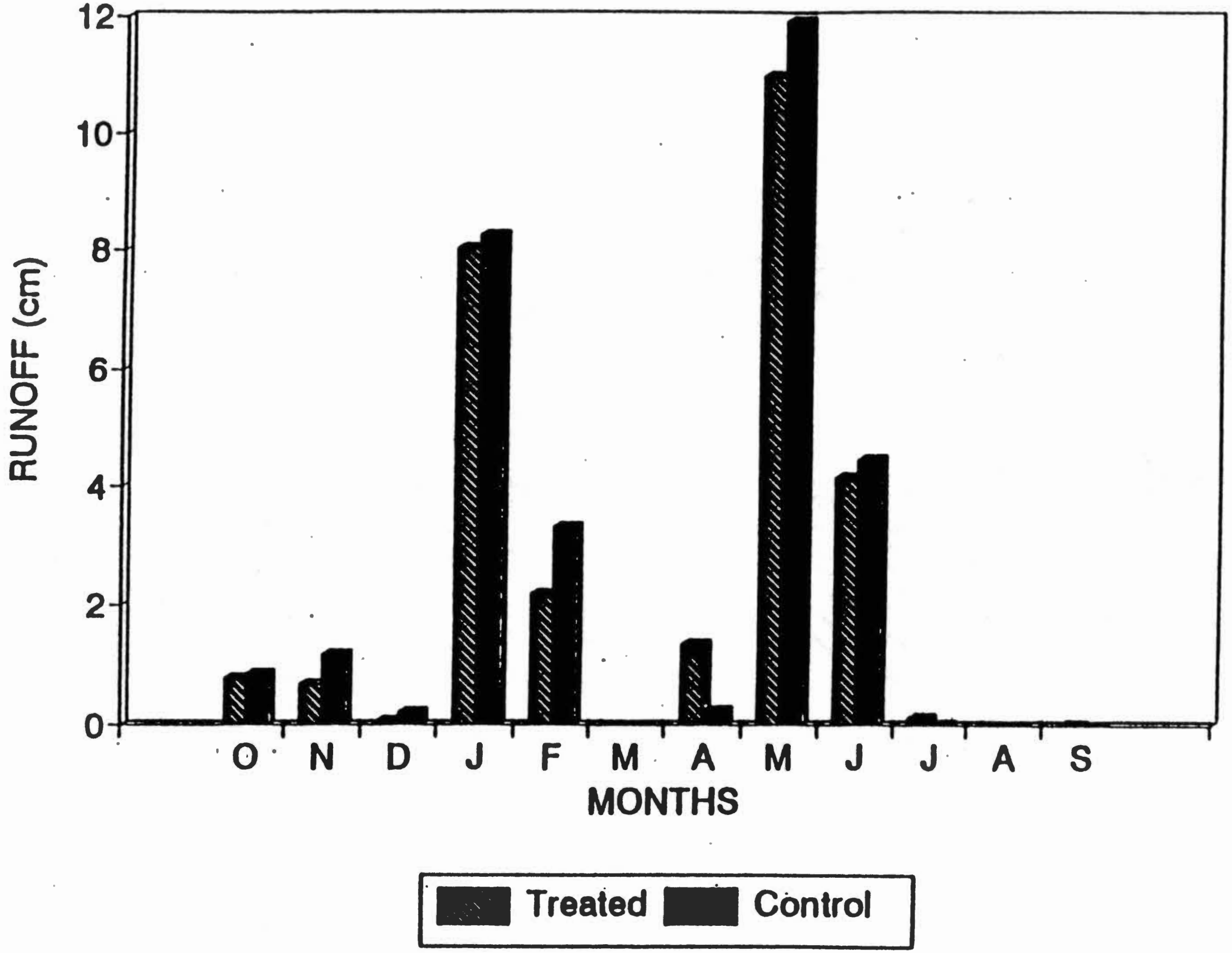

Figure 7. Runoff from Treated and Control Watersheds for Water Year 1982

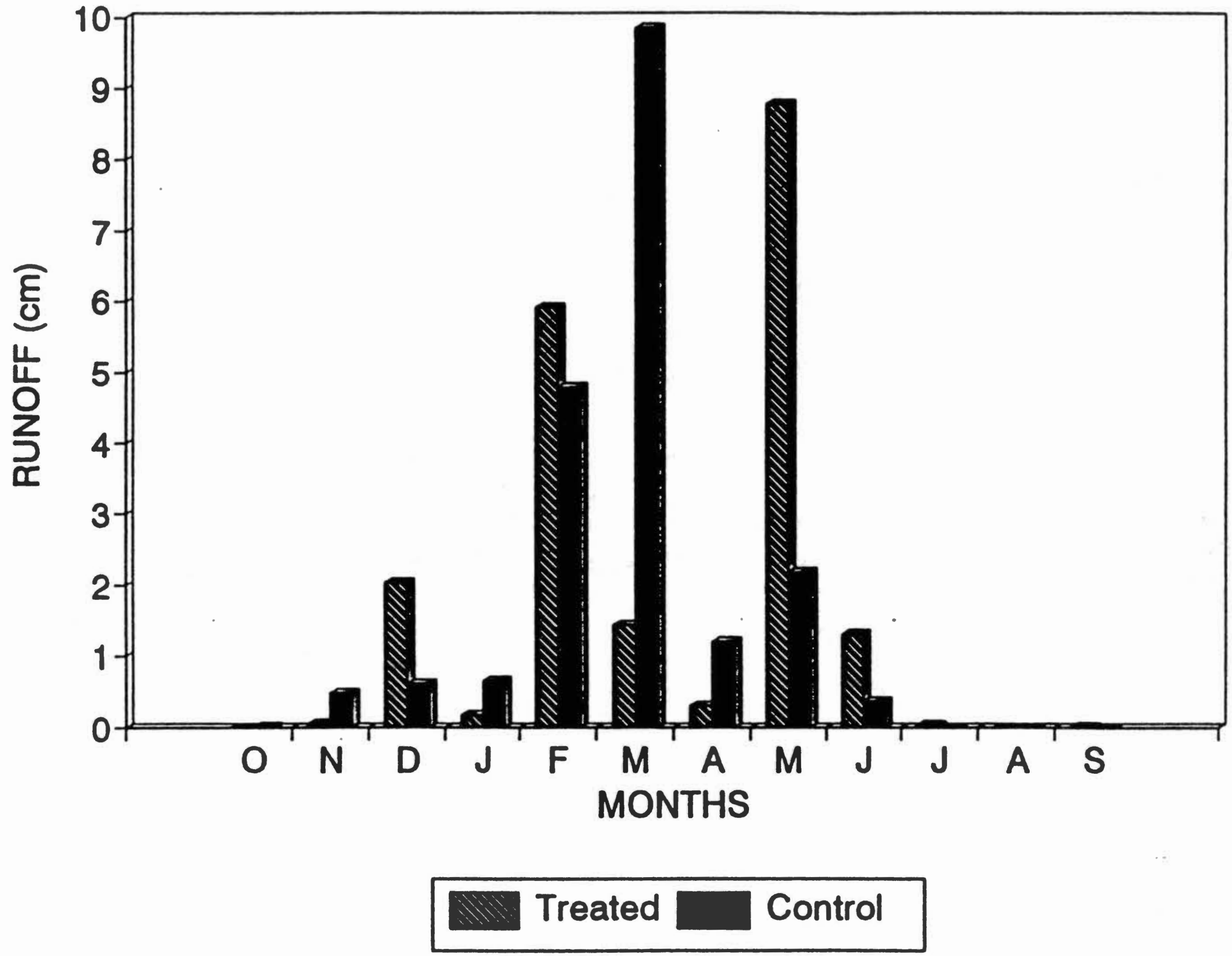

Figure 8. Rounoff from Treated and Control Watersheds for Water Year 1983.

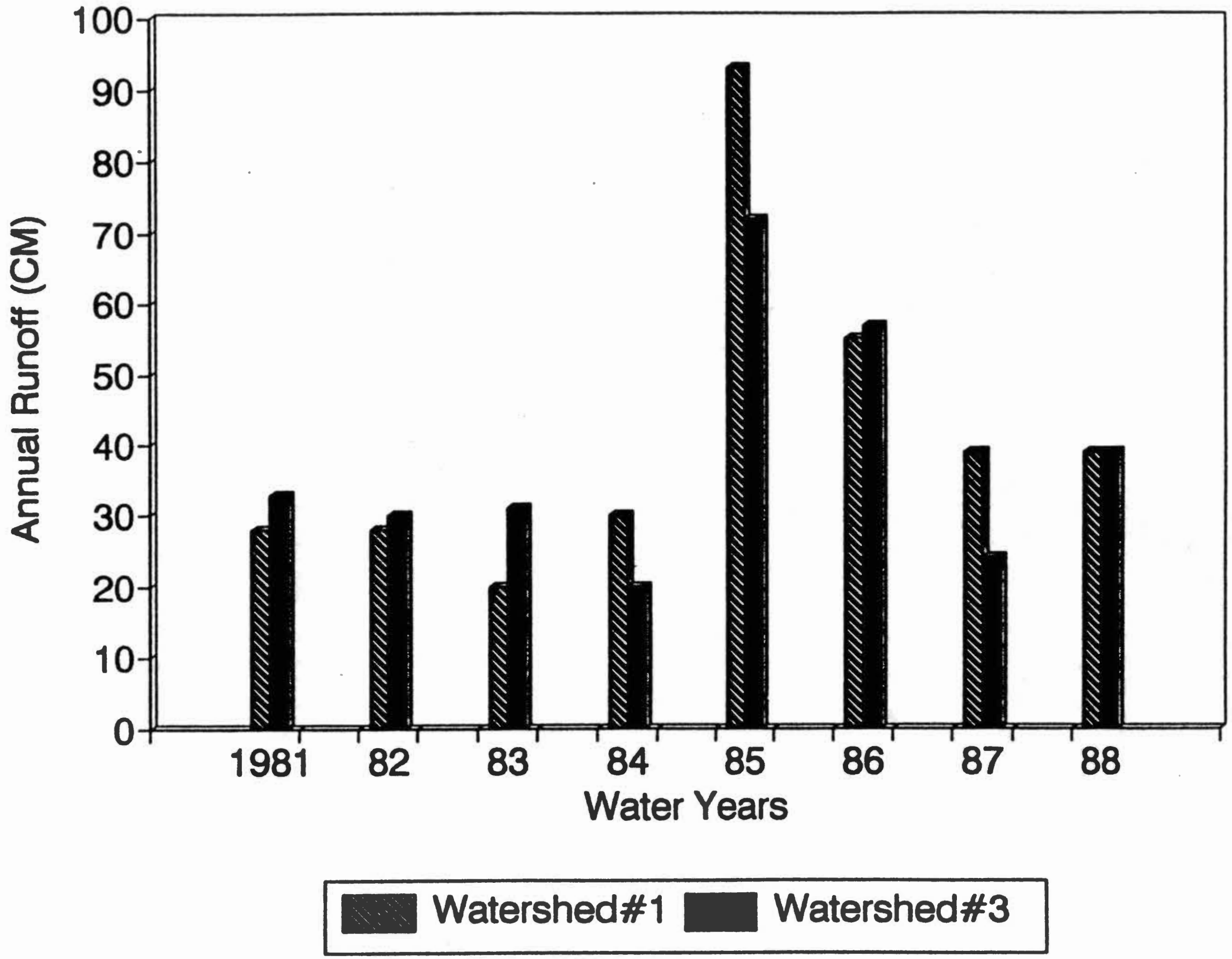

Figure 9. Annual Runoff from Watersheds 1 and 3 for Water Years 1981-1988.

CHAPTER V

SUMMARY AND CONCLUSIONS

The aim of this project was to measure the effects of forest harvest and site preparation on water yield (runoff) from two watersheds located southeast of Clayton, Oklahoma. This project examined the relationship of precipitation received in water years 1981 to 1988 with the normal based on 37 water year from 1951 to 1988. The annual and seasonal precipitation of water years 1981 to 1988 was analyzed and compared to the normal. Both annual and seasonal rainfall differed much from the normal. Comparison with the normal revealed that water year 1985 was the wettest and water year 1982 was the driest in the 8 year period.

Silvicultural activities which included forest harvesting and site preparation were analyzed and their effects on water yield were observed. This research proved that removal of forest vegetation did affect water yield. Based on observations it became clear both forest harvesting and site preparation considerably increased the water yield. The increase in water yield was greatest after the site preparation. Since in our case amount of rainfall received immediately after the completion of logging and site preparation was also highest recorded, henceforth the role of distribution of rainfall in the increase of this water yield can not be overlooked.

Increase in water yield reached a maximum just after the completion of logging and site preparation and diminished with the contour ripping, recovery of vegetation and also with the occurrence of less rainfall. The increase in water yield following the logging and site preparation may also have been due to high antecedent soil moisture, which was not measured in this experiment.

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APPENDIX

TABLE VI

PPTN & RUNOFF WATERSHED # 3 WATER YEAR 1981

Months	PPTN (cm)	FLOW (cm)
October	14.99	2.94
November	3.99	0.11
December	5.44	2.70
January	3.56	0.00
February	11.96	6.33
March	7.26	3.05
April	8.20	0.38
May	20.37	5.90
June	15.27	10.48
July	13.13	1.29
August	11.48	0.00
September	2.01	0.00
Total	117.65	33.16

TABLE VII

PPTN & RUNOFF WATERSHED # 3 WATER YEAR 1982

Months	PPTN (cm)	FLOW (cm)
October	23.65	0.85
November	6.01	1.19
December	0.41	0.21
January	15.60	8.26
February	5.44	3.33
March	4.27	0.00
April	6.02	0.23
May	26.65	11.92
June	8.00	4.44
July	9.40	0.01
August	1.63	0.00
September	0.74	0.00
Total	107.87	30.41

TABLE VIII

PPTN & RUNOFF WATERSHED # 3 WATER YEAR 1983

Months	PPTN (cm)	FLOW (cm)
October	7.29	0.01
November	15.19	0.48
December	20.27	0.60
January	6.20	0.65
february	9.50	4.78
March	8.28	9.85
April	7.98	1.20
May	22.05	2.19
June	11.38	0.36
July	1.35	0.00
August	4.75	0.00
September	4.17	0.00
Total	118.39	30.63

TABLE IX

PPTN & RUNOFF WATERSHED # 3 WATER YEAR 1984

Months	PPTN (cm)	FLOW (cm)
October	13.33	0.01
November	14.35	0.48
December	4.52	0.59
January	4.47	0.65
february	9.50	4.78
March	15.62	9.85
April	6.71	1.20
May	12.37	2.19
June	14.05	0.36
July	8.46	0.00
August	4.06	0.00
September	21.41	0.36
Total	129.31	20.46

TABLE X

PPTN & RUNOFF WATERSHED # 3 WATER YEAR 1985

Months	PPTN (cm)	FLOW (cm)
October	48.03	29.20
November	11.28	7.97
December	17.35	9.09
January	4.22	2.02
February	13.06	9.52
March	14.27	0.60
April	19.53	9.87
May	8.41	0.86
June	14.88	3.22
July	7.67	0.00
August	2.24	0.01
September	10.92	0.04
Total	171.86	72.41

TABLE XI

PPTN & RUNOFF WATERSHED # 3 WATER YEAR 1986

Months	PPTN (cm)	FLOW (cm)
October	14.27	0.12
November	29.64	13.92
December	1.96	1.94
January	0.53	0.00
February	12.09	7.54
March	7.00	1.41
April	21.97	11.39
May	26.21	11.83
June	21.77	8.47
July	3.33	0.00
August	11.30	0.01
September	14.20	0.08
Total	164.29	56.71

TABLE XII

PPTN & RUNOFF WATERSHED # 3 WATER YEAR 1987

Months	PPTN (cm)	FLOW (cm)
October	8.08	0.00
November	9.25	0.21
December	4.80	0.71
January	10.06	5.51
February	11.79	4.32
March	9.09	5.25
April	1.80	0.03
May	18.85	6.21
June	13.31	0.39
July	6.86	0.11
August	7.95	0.00
September	17.27	0.86
Total	119.10	23.61

TABLE XIII

PPTN & RUNOFF WATERSHED # 3 WATER YEAR 1988

Months	PPTN (cm)	FLOW (cm)
October	9.55	0.01
November	18.59	6.74
December	19.83	15.23
January	4.09	2.54
February	5.21	2.14
March	13.69	5.60
April	9.96	5.16
May	3.12	0.00
June	4.55	0.00
July	15.90	0.00
August	10.62	0.17
September	3.10	0.00
Total	118.26	37.50

TABLE XIV

PPTN & RUNOFF WATERSHED # 1 WATER YEAR 1981

Months	PPTN (cm)	FLOW (cm)
October	15.44	2.14
November	3.45	0.03
December	5.33	1.95
January	3.30	0.02
February	11.07	4.45
March	5.97	2.55
April	7.72	0.30
May	17.93	7.79
June	13.51	7.97
July	15.11	0.52
August	11.46	0.00
September	4.57	0.00
Total	114.88	27.74

TABLE XV

PPTN & RUNOFF WATERSHED # 1 WATER YEAR 1982

Months	PPTN (cm)	FLOW (cm)
October	14.40	0.77
November	8.43	0.67
December	0.48	0.07
January	16.05	8.04
February	5.08	2.20
March	4.14	0.00
April	5.13	1.35
May	24.51	10.96
June	9.22	4.16
July	7.24	0.10
August	1.70	0.00
September	0.97	0.00
Total	97.36	28.32

TABLE XVI

PPTN & RUNOFF WATERSHED # 1 WATER YEAR 1983

Months	PPTN (cm)	FLOW (cm)
October	5.51	0.00
November	16.71	0.05
December	15.49	2.04
January	5.92	0.17
February	9.45	5.91
March	7.42	1.44
April	7.80	0.30
May	25.15	8.79
June	14.02	1.31
July	0.94	0.02
August	2.01	0.00
September	4.32	0.00
Total	114.73	20.05

TABLE XVII

PPTN & RUNOFF WATERSHED # 1 WATER YEAR 1984

Months	PPTN (cm)	FLOW (cm)
October	9.14	0.00
November	11.89	0.30
December	3.63	0.19
January	4.52	0.56
February	9.32	3.82
March	16.76	11.12
April	5.54	2.32
May	14.66	4.05
June	14.96	1.25
July	6.86	0.01
August	2.44	0.00
September	19.58	6.62
Total	119.30	30.24

TABLE XVIII

PPTN & RUNOFF WATERSHED # 1 WATER YEAR 1985

Months	PPTN (cm)	FLOW (cm)
October	45.49	38.12
November	11.99	10.30
December	16.10	10.22
January	4.24	2.30
February	14.10	10.34
March	13.56	6.60
April	19.48	9.67
May	9.60	1.95
June	13.00	3.86
July	5.59	0.03
August	2.67	0.03
September	10.11	0.04
Total	165.94	93.45

TABLE XIX

PPTN & RUNOFF WATERSHED # 1 WATER YEAR 1986

Months	PPTN (cm)	FLOW (cm)
October	12.22	0.65
November	30.33	19.66
December	1.79	2.20
January	0.41	0.00
February	11.76	5.31
March	6.27	0.56
April	18.28	8.76
May	21.95	8.25
June	19.66	7.59
July	5.49	0.00
August	11.84	0.04
September	15.72	1.44
Total	155.70	54.46

TABLE XX

PPTN & RUNOFF WATERSHED # 1 WATER YEAR 1987

Months	PPTN (cm)	FLOW (cm)
October	9.47	2.60
November	10.00	4.86
December	6.00	4.11
January	11.13	6.59
February	11.15	4.13
March	8.38	4.58
April	3.12	0.21
May	24.76	6.87
June	13.82	0.94
July	9.55	2.12
August	6.15	0.00
September	21.23	2.11
Total	134.80	39.12

TABLE XXI

PPTN & RUNOFF WATERSHED # 1 WATER YEAR 1988

Months	PPTN (cm)	FLOW (cm)
October	8.05	1.66
November	17.86	10.67
December	17.93	12.42
January	5.13	2.72
February	6.02	2.29
March	12.44	3.69
April	9.68	4.72
May	3.30	0.01
June	2.21	0.00
July	16.15	0.25
August	10.36	0.12
September	4.11	0.00
Total	113.26	38.56

TABLE XXII

AVERAGE MONTHLY PRECIPITATION WS # 3
FOR YEARS 1981-1988

Year	October	November	December	January	February	March	April	May	June	July	August	September
1981	15.0	4.0	5.4	3.6	12.0	7.3	8.2	20.4	15.3	13.1	11.5	2.0
1982	23.6	6.1	0.4	15.6	5.4	4.3	6.0	26.6	8.0	9.9	1.6	0.7
1983	7.3	15.2	20.3	6.2	9.5	8.3	7.8	22.0	11.4	1.3	4.7	4.2
1984	13.3	14.4	4.5	4.5	10.0	15.6	6.7	12.4	14.0	8.5	4.1	21.4
1985	48.0	11.3	17.3	4.2	13.1	14.3	19.5	8.4	14.9	7.7	2.2	10.9
1986	14.3	29.6	2.0	0.5	12.1	7.0	22.0	26.2	21.8	3.3	11.3	14.2
1987	8.1	9.2	4.8	10.1	11.8	9.1	1.8	18.8	13.3	6.9	8.0	17.3
1988	9.6	18.6	19.9	4.1	5.2	13.7	10.0	3.1	4.6	15.9	10.6	3.1
Average	17.4	13.5	9.3	6.1	9.9	9.9	10.2	17.3	12.9	8.3	6.8	9.2

TABLE XXIII

AVERAGE MONTHLY RUNOFF WATERSHED # 3
FOR WATER YEARS 1981-1988

Year	October	Novembe	December	January	February	March	Apri	May	June	July	August	Septembe
1981	2.9	0.1	2.7	0.0	6.3	3.0	0.4	5.9	10.5	1.3	0.0	0.0
1982	0.8	1.2	0.2	8.3	3.3	0.0	0.2	11.9	4.4	0.0	0.0	0 0
1983	0.0	0.1	7.7	0.8	8.0	2.9	1.5	9.5	0 3	0.0	0.0	0.0
1984	0 0	0.5	0.6	0.7	4.8	9.8	1.2	2.2	0.4	0.0	0 0	0.4
1985	29.2	8.0	9.1	2.0	9.5	0.6	9.9	0.9	3.2	0.0	0.0	0 0
1986	0.1	13.9	1.9	0.0	7.5	1.4	11.4	11.8	8.5	0.0	0.0	0.1
1987	0.0	0.2	0.7	5.5	4.3	5.2	0.0	6.2	0 4	0.1	0 0	0 9
1988	0.1	6.7	15.1	3.5	2.1	5.6	5.2	0.0	0.0	0.0	0 2	0 0
Average	4.2	3.8	4.8	2.6	5.7	3.6	3.7	6.0	3.5	0.2	0 0	0 2

TABLE XXIV

AVERAGE MONTHLY PRECIPITATION FOR WS # 1
FOR YEARS 1981-1988

Year	October	Novembe	December	January	February	March	April	May	June	July	August	Septembe
1981	15.4	3.5	6.3	3.3	11.1	6.0	7.7	17.9	13.5	15.1	11.5	4.6
1982	14.4	8.4	0.5	16.1	5.1	4.1	5.1	24.5	9.2	7.2	1.7	1.0
1983	5.5	16.7	15.5	5.9	9.4	7.4	7.8	25.1	14 0	0.9	2 0	4 3
1984	9.1	11.8	3.6	4.5	9.3	16.8	5.5	14.7	15.0	6.9	2 4	19 6
1985	45.5	12.0	16.1	4.2	14.1	13.6	19.5	9.6	13.0	5.6	2.7	10.1
1986	12.2	30.3	1.8	0.4	11.8	6.3	18.3	21.9	19.7	5.5	11.8	15.7
1987	9.5	10.0	6.0	11.1	11.2	8.4	3.1	24.8	13.8	9.6	6.1	21.2
1988	8.1	17.9	17.9	5.1	6.0	12.4	9.7	3.3	2.2	16.2	10.4	4.1
Average	15.0	13.8	8.5	6.3	9.7	9.4	9.6	17.7	12.6	8.4	6.1	10.1

TABLE XXV

AVERAGE MONTHLY RUNOFF WS # 1
FOR YEARS 1981-1988

Year	*October*	*November*	*December*	*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*	*September*
1981	2.1	0.0	1.9	0.0	4.5	2.6	0.3	7.8	8.0	0.5	0.0	0.0
1982	0.8	0.7	0.1	8.0	2.2	0.0	1.4	11.0	4.2	0.1	0.0	0.0
1983	0.0	0.1	2.0	0.2	5.9	1.4	0.3	8.8	1.3	0.0	0.0	0.0
1984	0.0	0.3	0.2	0.6	3.8	11.1	2.3	4.1	1.2	0.0	0.0	6.6
1985	38.1	10.3	10.2	2.3	10.3	6.6	9.7	1.9	3.9	0.0	0.0	0.0
1986	0.6	19.7	2.2	0.0	5.3	0.6	8.8	8.2	7.6	0.0	0.0	1.4
1987	2.6	4.9	4.1	6.6	4.1	4.6	0.2	6.9	0.9	2.1	0.0	2.1
1988	1.7	10.7	12.4	2.7	2.3	3.7	4.7	0.0	0.0	0.3	0.1	0.0
Average	5.7	5.8	4.2	2.5	4.8	3.8	3.5	6.1	3.4	0.4	0.0	1.3

VITA

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