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Hydrologic Studies on California Brush Lands

By

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This report prepared for presentation at the joint hearings of the Senate Interim Committee on the Economic Redevelopment of Cut-Over Timber Areas and Brush Lands and Senate Interim Committee on Forest Practices May 22, 1958, Sonora, California.

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The Department of Irrigation of the University of California, Agricultural Experiment Station at Davis, has been engaged in a research program in watershed management and hydrology for the past 25 years. In the course of this investigation many experiments both in the field and in the laboratory have been conducted to determine the effects of various practices applied to brush lands and as they influence the hydrology of the watershed. The earliest work was done on small plots which were subjected to the same type of treatment that was then being applied to brush lands. This essentially consisted of control burning of brushy vegetation with follow-up reburning to eliminate sprouts.

As the knowledge and experience in the management of brush areas were acquired, the techniques were modified to reflect these changes. The development of the control burn program in California's brush lands has led to a very extensive research program in range improvement within the University. A very broad project staff is currently engaged in these studies. Agronomists, foresters, range managers, zoologists, botanists and weed control people, economists, together with the hydrologists, are working on these problems.

The present scope of the hydrologic investigations is indicated on the attached Table 1 which describes the location and some of the important features of the small watershed studies which are currently being conducted by the Department of Irrigation. There are seven hydrologic stations in operation at the present time of sizes from less than 1 acre to more than 4,000 acres, which represent complete hydrologic units. The small watersheds are usually set up

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in pairs of nearly identical units which are equipped with precipitation, stream flow, and erosion measuring devices. Soil moisture records and climatic data are collected continuously throughout the runoff season. Of these seven stations, six have now been treated to some form of vegetation management. This treatment has varied over the several areas and throughout the duration of these studies.

The typical procedure followed in the course of these studies has included a period of calibration on the paired watersheds for 5 to 10 years. At the end of this calibration period a treatment is applied to one or more of the units. These treatments include removal of the brushy vegetation followed by reseeding, and a series of post-treatment management practices to promote the development of the desired forage cover and to eliminate the brushy species. About three seasons of operation after treatment are considered necessary to insure the completion of the conversion. All of the areas under study are normally grazed and in fact are even subjected to abnormal grazing in some instances. The new forage is utilized to its fullest extent consistent with good grazing management as far as it can be controlled. However, wild life such as deer and other animals have frequently been observed in large numbers on these managed watersheds which tends to add to the grazing load in an unmeasured amount.

The grasses which are reseeded on these study watersheds are selected on the basis of agronomic tests made in the general region of the study.

Results

The responses of these small watersheds are summarized here with respect to the hydrologic elements which are measured. This information has been published in a number of journals and reprints. Some of these are attached.

On all of the study areas a striking growth of grasses resulted from the reseeding after removal of the brushy species. An initial increase of erosion was measured from the watersheds during the critical period before the grasses were established. Upon the development of the grassy vegetation erosion rapidly diminishes to rates equal to or less than those from the adjacent brush areas. Increases in water yield have been measured on all of the study areas.

In the preceding discussion three principal responses of importance were noted as a result of the vegetative conversions on typical brush lands throughout northern California. Increased forage production, greater total water yields, and control of erosion are discussed in detail in the following sections. Measurements of livestock carrying capacities and hydrologic factors are being made on a typical study area, Watershed I, at the University of California's Hopland Field Station. This information is appended to this discussion.

Forage Production. One of the primary goals in the management of California brush lands is the improvement of forage to increase the carrying capacity of the range for greater meat production. Data from Hopland Watershed I show what can be done to improve carrying capacities in Table II. Here the production of feed has been increased by a factor of 10 within 1½ years of the treatment on the area. Grazing schedules have been programmed to promote the development of the desired grasses and legumes. Utilization of the feed is excellent and the procedures reflect a good grazing management plan for such an area.

Water Yield. The second of the major responses indicated for vegetation conversion is that of increased water yield. This factor may have less importance to the land owner than forage production. However, the importance of water in the economy of California is known to all, and the potential benefits in improved water supplies through vegetation management are significant.

The increased total seasonal runoff which has been reported for the experimental watersheds has ranged from less than 1 inch during some years to as much as 10 inches during other years. The values have averaged overall at approximately 2 inches depth of runoff per season--In some cases a very appreciable percentage of the total runoff.

Knowledge of the basic principles involved in the precipitation disposal cycle is necessary to interpret hydrologic changes which occur in vegetative conversions. When precipitation falls on the watershed, it is disposed into the following categories: interception, infiltration, surface runoff, deep percolation, soil moisture or evaporation. Little can be done on mountain watersheds to change the storage capacity of the soil. It therefore follows that any changes which occur on a mountain watershed must be associated with the management of the surface condition of the watershed. By this is meant the vegetation or the immediate soil surface and associated litter cover.

The vegetation on a watershed is involved in two of these processes. The vegetation intercepts portions of the precipitation and thereby creates a loss of moisture. Secondly, the vegetation utilizes the moisture which is stored within the soil profile. There are marked differences in the magnitudes of the interception loss and soil moisture use by cover types. In the process of converting watershed cover from brushy species to grasses, two major changes occur. Detailed laboratory and field investigations have been conducted to determine these factors.

Interception losses in brush have been estimated by research workers to range between 10 and 25 percent of the precipitation. During seasons of heavier rainfall the percentage loss is less and during seasons of lower total amounts of precipitation and especially when storms are small and occur early and late in the season, these losses will become higher. The percentages will vary according to vegetative type as well as with geographical location and season of the year.

Studies by the University have recently shown that the interception losses associated with grassy and herbaceous species are extremely low. A report released on interception studies in grasses discusses in detail a laboratory technique which was developed to evaluate the magnitude of such losses. One of the principal findings is that when grassy species are subjected to rainfall, that is when the blades of grass are wet, there is a reduction of transpiration or soil moisture use which is essentially equal to the amount of water stored by these grass plants. The magnitude of the interception storage capacity of grasses has been determined at about .05 inch. Thus whenever grasses are wetted and during the period while this storage is being depleted by evaporation, a reduction in transpiration takes place to compensate for the intercepted moisture. When a portion of the grassy vegetation is not live and growing, a small loss may take place. The magnitude of the loss is some percentage of the interception storage capacity of the plant and will be a function of the management of the vegetation, the climate and perhaps the species of grass involved.

Detailed soil moisture studies in the same general areas as the small watersheds have been carried on for many years previously. These studies have shown that the native and introduced species of grass have not utilized the full amount of soil moisture stored within the profile. Two factors are involved, shallow rooting by typical grasses and shorter transpiring seasons, since the grasses go dormant earlier in the summer. The consequence is that the grassy vegetation does not utilize as much of the available moisture stored in the soil as did the indigenous brushy vegetation.

The interception losses and the reduced consumptive use by grasses tend to result in an increase in the total water yield from watershed areas so converted. The inevitable result of reducing interception losses is an increase in water yield since the soils cannot store more water. Most of California's watersheds receive sufficient precipitation to satisfy the soil moisture deficit annually. Therefore, any residual soil moisture which is carried forward to the next season will reduce the amount of priming necessary and give an additional increment of runoff. This additional runoff is not entirely in the form of surface flow. Part is released from the watershed as subsurface drainage. Upon the establishment of a dense grass cover a retardation of overland flow is indicated. This permits a greater opportunity for infiltration and consequent reduction of flood hazard.

Whenever precipitation rates are high and when soils on the watershed are primed, high percentages of runoff can be expected. Such conditions have prevailed in California during two seasons recently, 1955 and 1958. During both of these years the watersheds under study have shown high yields with equally high runoff rates from both brush and grass. No acceleration of flow rates has been noted from the grassy areas. A longer time base on the hydrograph has been noted for grassy watersheds which indicates a prolongation of runoff and a greater contribution from subsurface outflow on the watershed. Total seasonal runoff, erosion for Hopland Watershed I are attached.

Erosion. Another important consideration in the management of watersheds for any purpose is that of controlling erosion. Erosion rates on brush-covered watersheds have been measured and compared with those of the converted watersheds. These rates are temporarily accelerated following the removal of the brushy species and during the interval when the grasses are becoming established. This may take as much as one runoff season. As the grass develops erosion is reduced to the original rate and ultimately drops to values much lower than those from brush lands.

The fire used to remove brushy vegetation is not the responsible factor for these hydrologic changes. The same responses can be obtained by using any technique to remove the woody material. Accelerated erosion is a function of the amount of herbaceous cover on the surface of the soil to protect it from the action of raindrops and to retard overland flow. Brush cover is not a good erosion control vegetation. High erosion rates occur from brush under high intensity precipitation.

Hopland Watershed I

This watershed has an area of approximately 40 acres above the gaging station and lies within a larger 60-acre pasture. Elevation ranges between 900 and 1100 feet; annual rainfall has varied from less than 20 to more than 55 inches during the past five years. Northerly exposures are composed of Josephine soils covered with dense stands of black oak and madrone cover. The more exposed south slopes are of Los Gatos soils and support chamise brush and mixtures of chamise and grass.

The program of vegetation management followed a pretreatment calibration of 4 years beginning in 1952 and continuing through the summer of 1956. During this time precipitation, runoff and erosion were measured.

During the late spring of 1956 the conversion of Watershed I was started. The initial process was the slashing of all of the oak and madrone trees which were dropped by chain saw and allowed to dry on the ground. This procedure was necessary to insure an intense fire and a rapid conversion since the objective of the study was to make this change from one vegetative type to another in the shortest possible time. The watershed was ignited in a control burn on September 5, 1956. The center of the drainage was fired with electric igniters and the perimeter of the area was ignited in approximately 5 minutes by a control burn crew. This is known as the simultaneous ignition technique or more recently by the name "watershed ignition". A very intense burn was accomplished, the area being completely under control in 17 minutes.

The entire burned area was airplane seeded on September 18, 1956. The seed mix was composed of the following species and amounts per acre: Harding grass 4, Smilo 2, Palestine orchard grass 1/2, Tillerook sub-clover 1/2, Mount Barker sub-clover 1/2. Legumes were inoculated with Nitragin the day before seeding. Although the seeding plane flew on 20 foot intervals, bucket samples of the seeding pattern showed a great variation in seeding rate on lines perpendicular to the flight path. Los Gatos soils on the steep south slopes were overseeded by hand with soft chess at a rate of 2 lbs. per acre. The follow-up treatment for control of sprouts involved hand spraying of madrone sprouts with a chemical application of 2,4-D low volatile ester.

The pasture including the watershed was not grazed during the first growing season after seeding but livestock were introduced during July of 1957. By this date a majority of planted grasses and legumes had matured and set seed. Station records showed July and August to be the period of greatest browse used by sheep. Therefore, late grazing not only insured shattering and trampling of a full seed crop but also maximized browsing. Since the watershed was a part of a larger grazing unit it was difficult to calibrate in terms of grazing capacity. With the exception of grassy areas in the meadow below the watershed and a small area at the top of the watershed there was no available feed for livestock prior to conversion. The grazing data are shown in Table II.

Table II

Hopland Watershed I
Animal Carrying Capacities

Condition	Sheep Days/Acre	Sheep Months/Acre
Before treatment	25	1
1956-7 Grazing season (July 17-Sept. 19, 1957)	135	4.5
1957-8 Grazing season (Oct. 28, 1957-April 23, 1958)	266	8.8
Estimated remaining feed 1958-	50	

5 sheep months = 1 cow month

A series of 5 photographs illustrate the sequence of events in converting the vegetation on this area. Also attached is a view of the Mariposa County

Piney Watershed which was burned and reseeded in the late summer and fall of 1957.

Graphs of the seasonal runoff for several of the other small watershed studies are included.

Table I. Small Watershed Studies Location and Description of Areas

Station	County	Major Stream Watershed	Watershed Area	Vegetative Type	Elevation	Soil Series	Ave. Soil Depth	Season Started	Date of Treatment	Type of Treatment **
			Acres		Ft.		Ft.			
Ono [1]	Shasta	N. Fork of								
A*		Cottonwood Crk.	0.91	Chamise	1500	Aiken	2-3	1939-40	Fall 1949	Burned
B*			0.47	Chamise	"	Aiken	2-3		----	
C*			0.62	Chamise	"	Aiken	2-3		----	
D*			0.66	Chamise	"	Aiken	2-3		Fall 1949	Burned
Diamond Range										
A	Tehama	Cottonwood Crk.	5.32	(Oak, Pine,	1000	Corning	3-4	42-3	Fall 1953	----
B*		(Sacramento R.)	2.74	(Chaparral	1000					Slashed & Burned
Ahawahnee										
A*	Madera	Fresno R.	3.08	(Mixed	3000	Holland	3-4	47-8	Fall 1953	Slashed & Burned
B			3.80	(Chaparral	3000					----
Badger										
A*	Tulare	Cottonwood Crk.	12.2	(Mixed (	2900	Holland	3-4	49-50	54-56 (completed Fall '56)	Bulldozed & burned
B		(Kings R.	15.4	(Chaparral	2700					----
Placer [2]										
A	Placer	Doty Crk.	60	Oak, grass	800	Aiken	2-4	56-7		----
B		(Feather R.	50		800	(Variation)				----
C			20		800					----
Hopland										
Ia*	Mendocino	Russian R.	43	(Mixed	1000		1-6	52-3	Fall '56	Slashed & Burned
IIa		" "	213	(Chaparral	650	Laughlin			Spring '59	----
Mariposa										
A	Mariposa	Piney Creek	4000	(Mixed	1800	Aiken	1-4	52-3	Fall '57	Burned
B*		(Merced R.)	2000	(Chaparral	1200	(Variation)				----

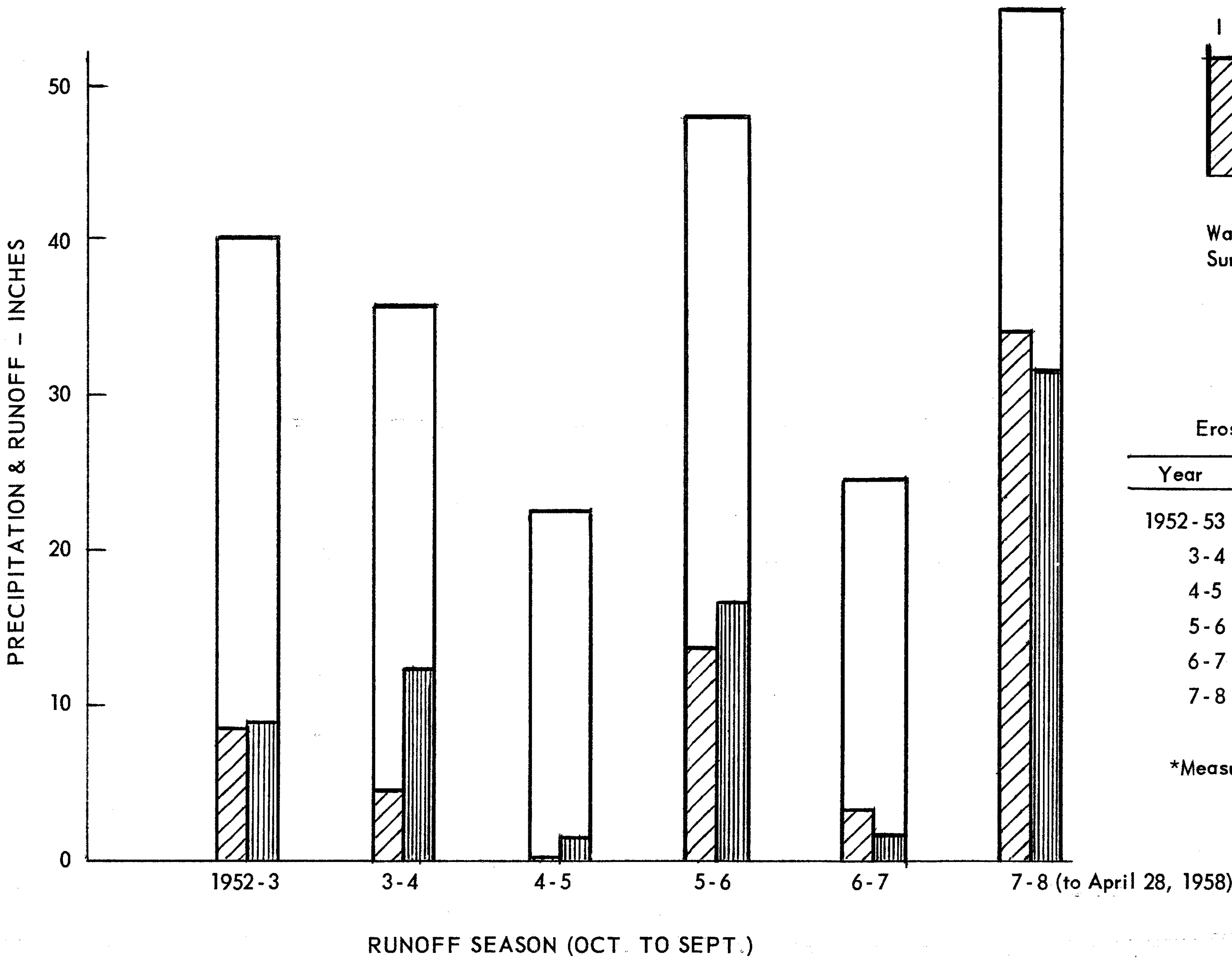
* Denotes the treated watershed of the pair. All watersheds calibrated 3 to 10 years.

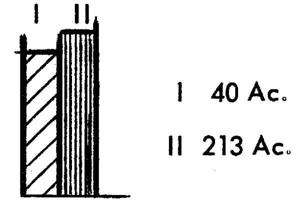
** All areas reseeded. Untreated areas held as controls, subject to later treatment.

1 Controls were burned 1957 (B & C).

2 Chemical and mechanical treatment after calibration.

SEASONAL PRECIPITATION AND RUNOFF
HOPLAND WATERSHEDS I & II





Watershed I treated
Summer–Fall 1956

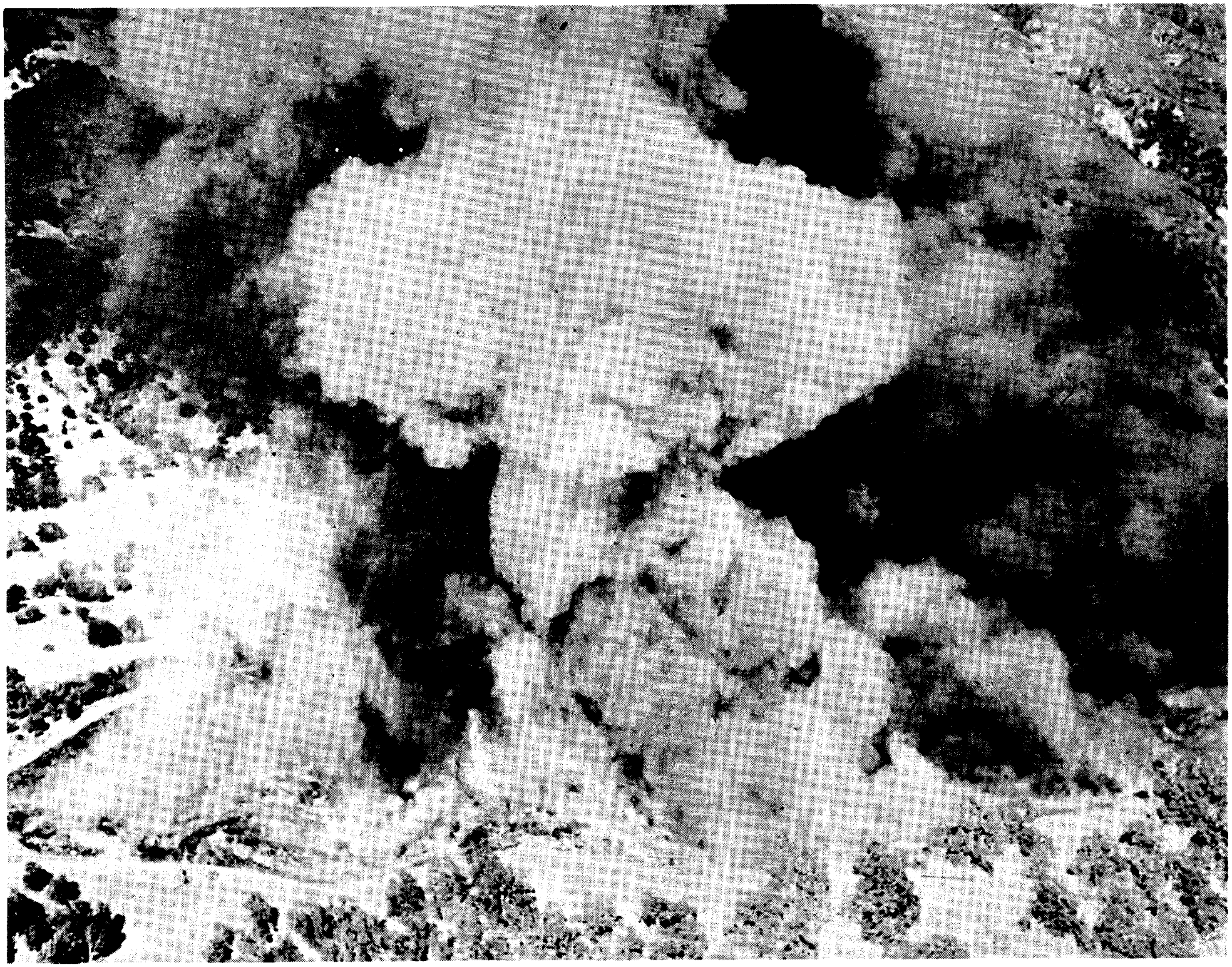
Erosion – Tons per Acre

Year	I	II
1952-53	–	0.52
3-4	–	0.67
4-5	–	0.0002
5-6	0.06*	0.477
6-7	2.94	0.082
7-8	0.34	1.4

*Measuring Basin Installed 1955

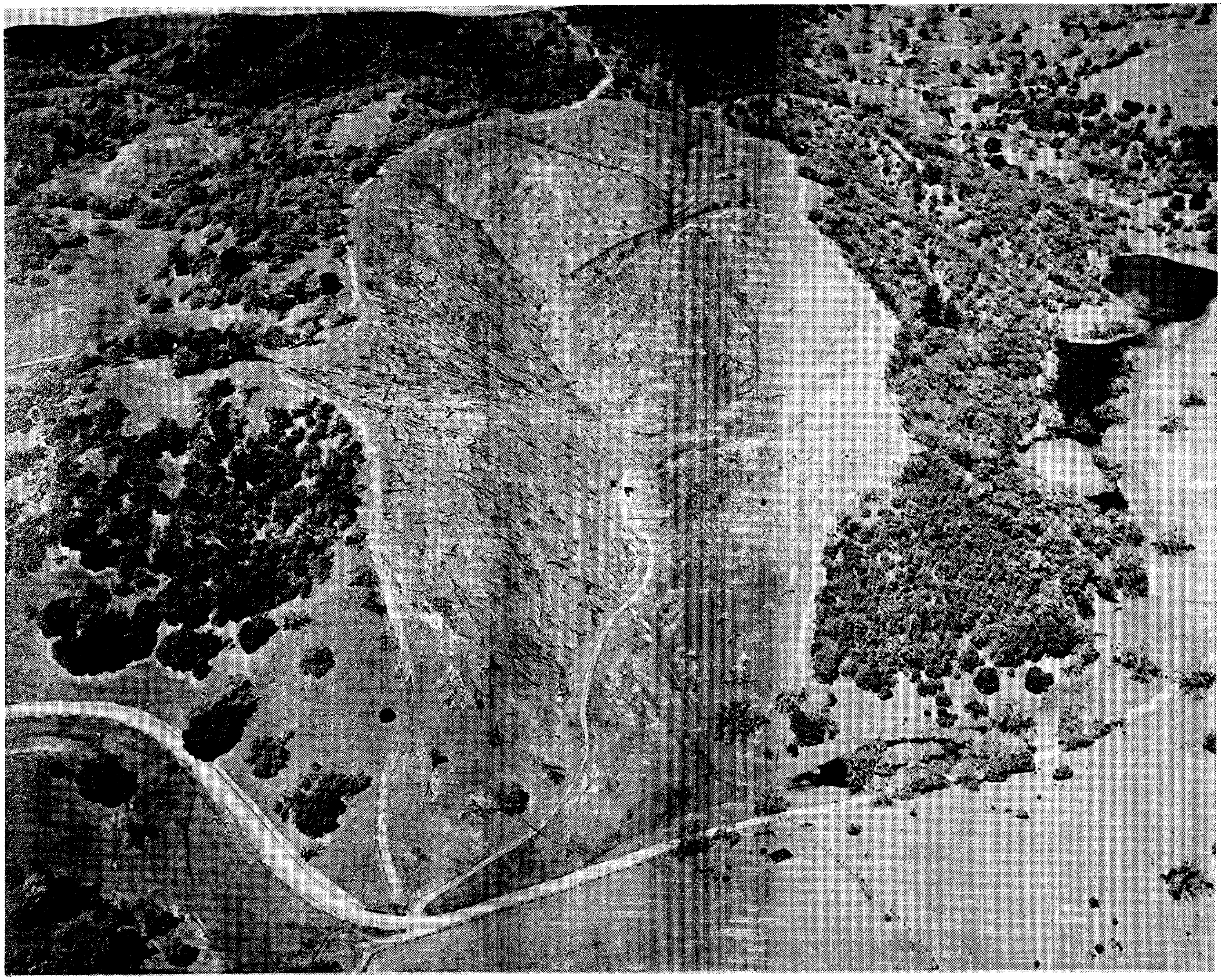
Hopland Watershed I - Prior to treatment

Hopland Watershed I - Trees slashed in pre-burning preparation; firebreaks completed

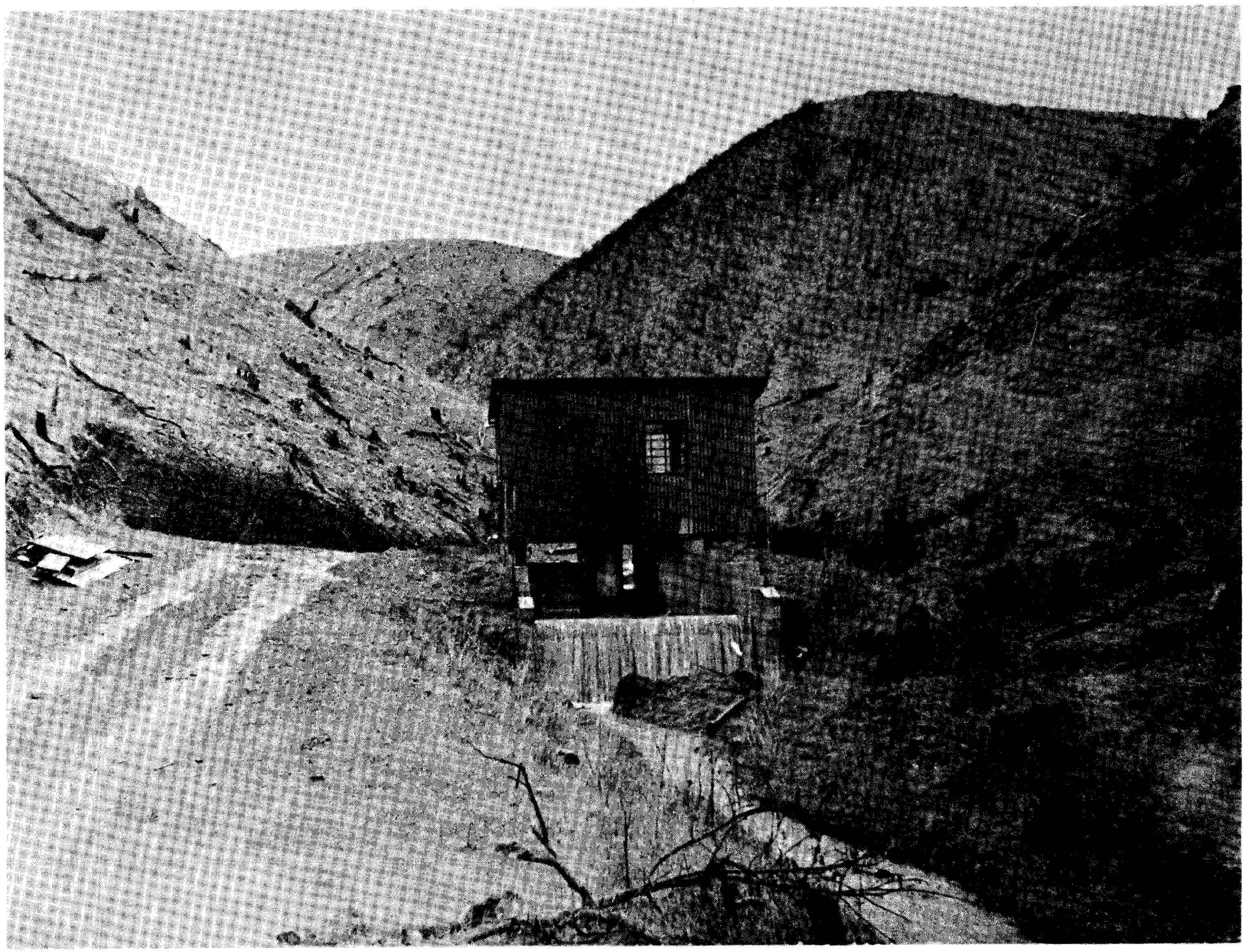


Hopland Watershed I - Controlled Burn, September 5, 1956

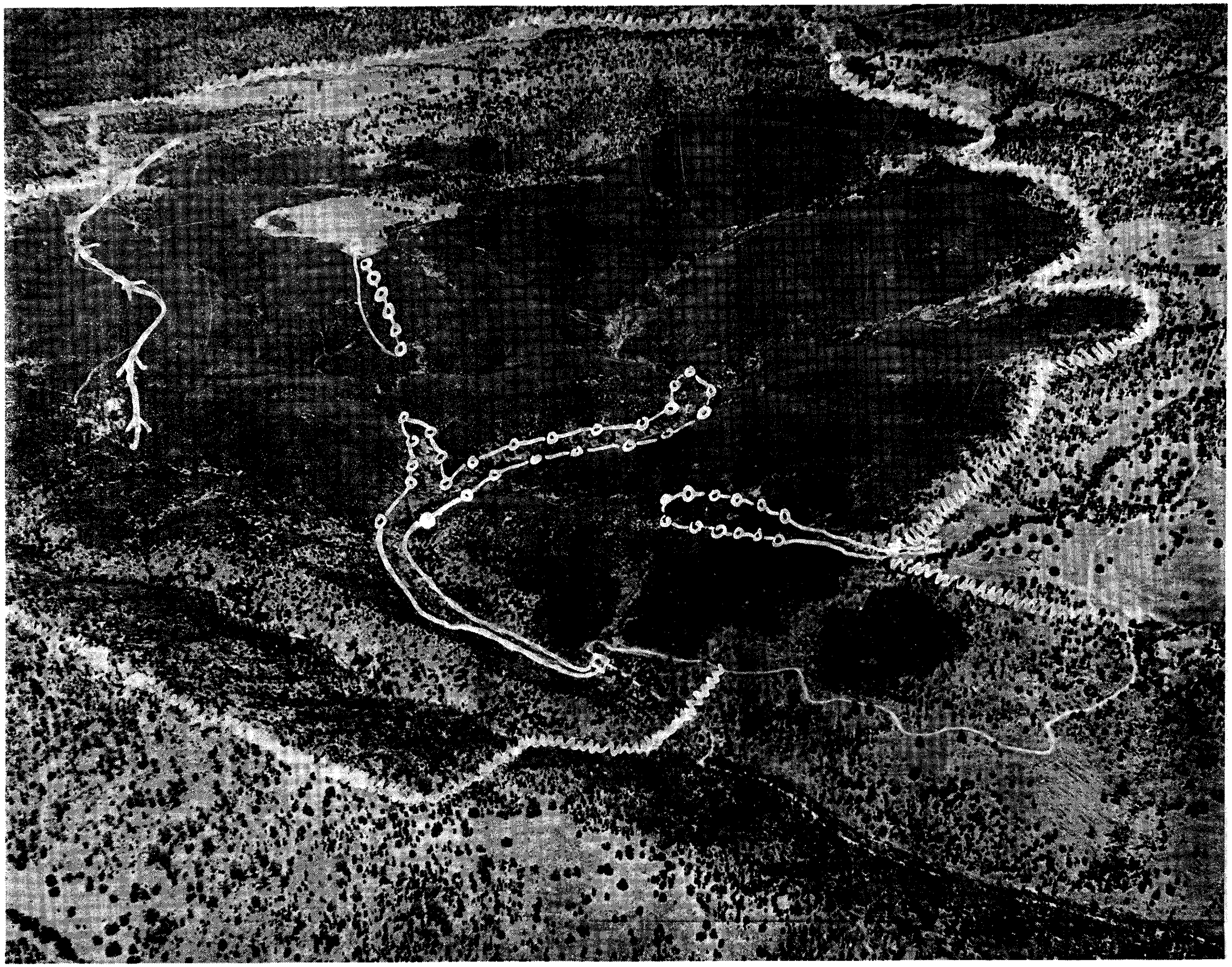
Hopland Watershed I - Denuded area after fire



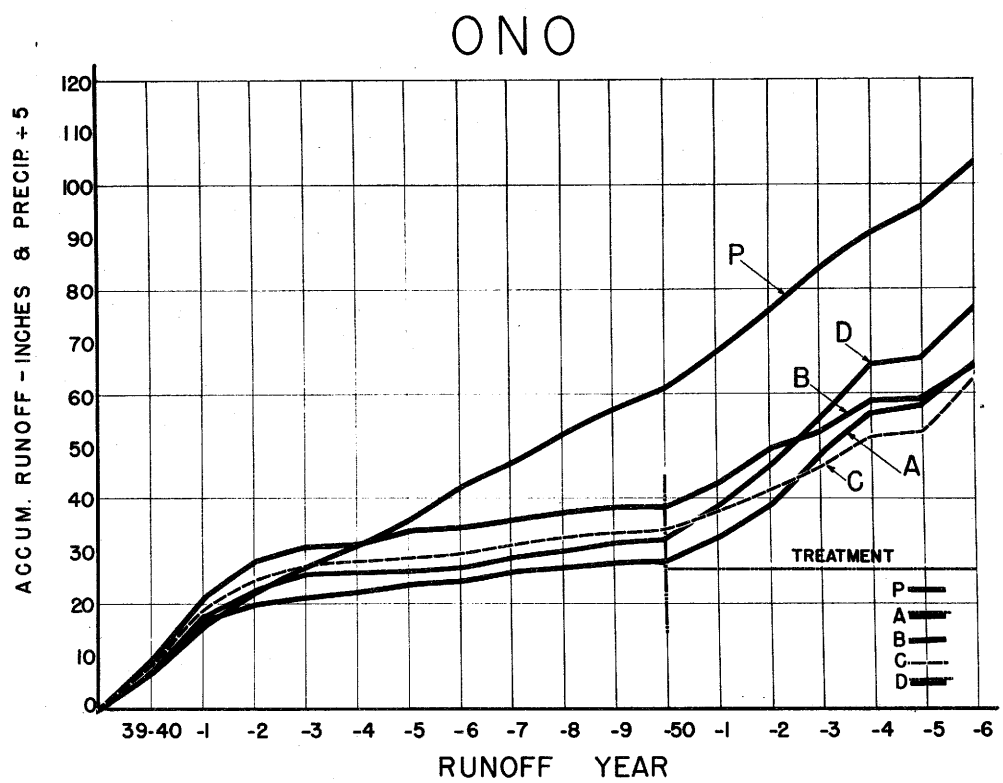
Hopland Watershed I - Grass cover at the end of first season after treatment

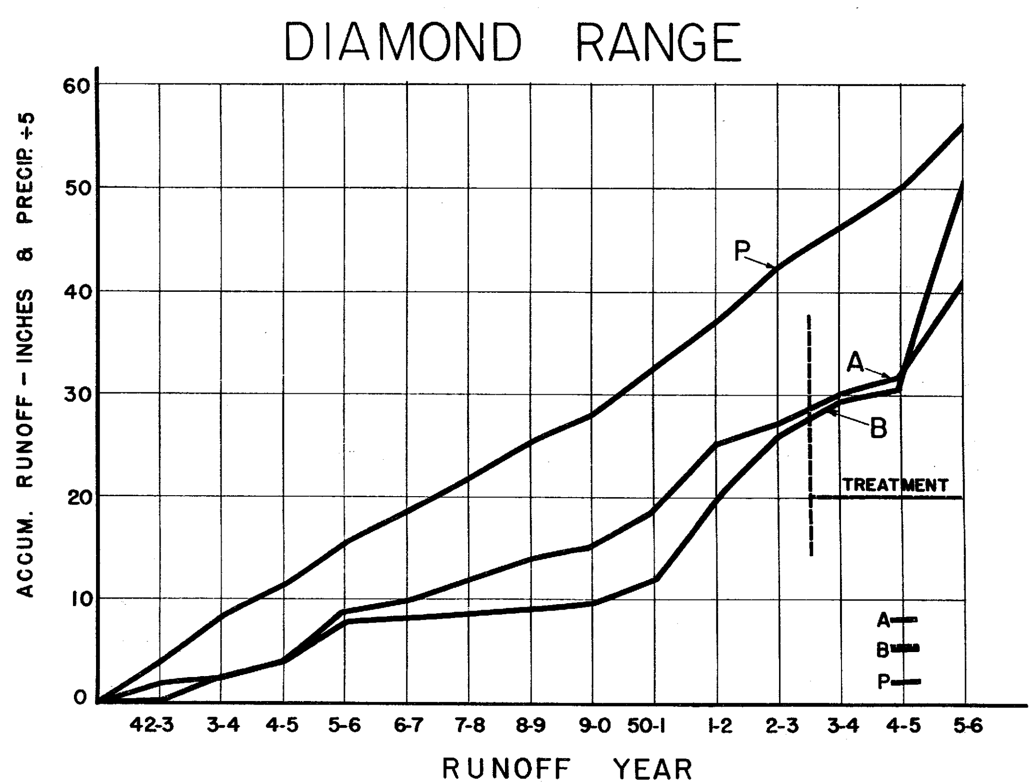


Hopland Watershed I - Stream gaging station and erosion sedimentation basin



Mariposa-Piney Creek Watershed - Area 4000 acres. Ignition system and burn area outlined


ONO
ACCUM. RUNOFF - INCHES & PRECIP. ÷ 5
120
110
100
90
80
70
60
50
40
30
20
10
0
P
D
B
A
C
TREATMENT
P
A
B
C
D
39-40 -1 -2 -3 -4 -5 -6 -7 -8 -9 -50 -1 -2 -3 -4 -5 -6
RUNOFF YEAR


DIAMOND RANGE
ACCUM. RUNOFF - INCHES & PRECIP. ÷ 5
60
50
40
30
20
10
0
P
A
B
TREATMENT
A
B
P
42-3 3-4 4-5 5-6 6-7 7-8 8-9 9-0 50-1 1-2 2-3 3-4 4-5 5-6
RUNOFF YEAR