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Forests and Floods

by

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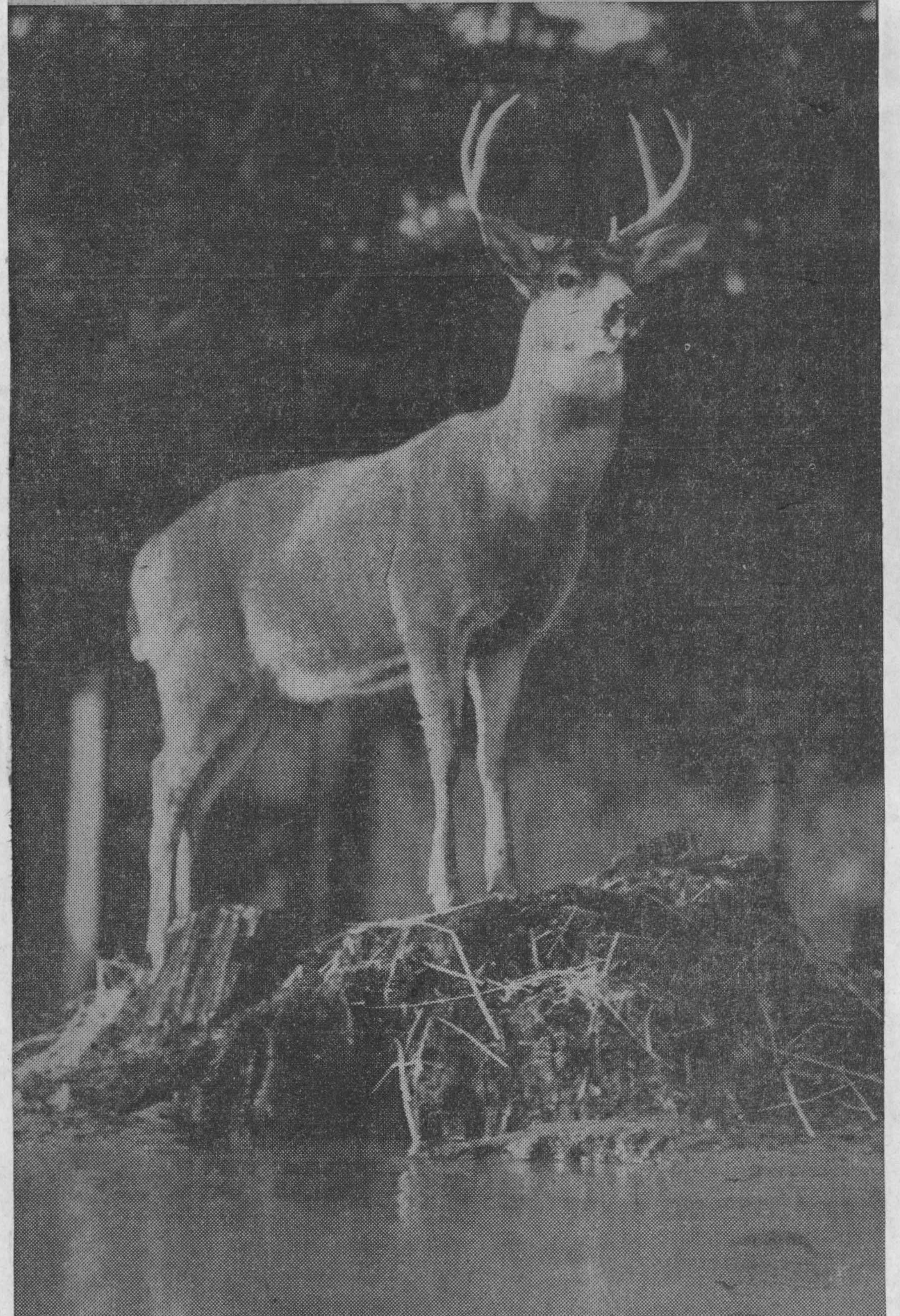
River Stay 'Way From My Doe!



A buck deer that kept vigil on this stump near Tualatin must have pondered the fate of his mate as waters swished about him. Marooned by the flood for the past three days, the animal has been provided with food, but cannot be lured from his precarious perch. Disdaining the dampness of the world about him, he is shown as he looked yesterday to Frank Sterrett, staff photographer of The Oregonian.

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Although soil conservation and soil erosion are associated studies this paper does not take them up in detail. It does, however, show the effect of erosion on the height of floods but in the main deals only with forests and floods.

The Author.

FOREST AND FLOODS

INTRODUCTION

No phase of forestry has aroused such a wide public interest as the influences of forests upon floods. It was one of the main issues in formulating the United States Forest Policy, and for over a century the modern nations of the world notably France has proceeded on the basis that denudation of mountain slopes cause serious damage by torrents of flood waters on the lower lands, and that the only effective means of control were reforestation of these slopes combined with artificial barriers in the beds of the torrents.

HISTORY

Disasterous floods, the worst of which were in 1917, have occured in China. Chapman (1) states that this flood can be laid to the denudation of approximately 60,000 square miles of mountainous area which is the source of most of the prominent rivers of that country.

Floods in the Mississippi River Basin, which has been conspicious among the great river basins of the world for its large percentage of nonforest land, (originally 60 percent and now 80 percent nonforest land) date back as far as history reaches. (2) De la Vega, who in describing the difficulties encounted by De Sota's men when, following their leader's

RAINY WEATHER. Residents of the Lents district in Southeast Portland either remained indoor or donned hip boots yesterday, as waters overflowed the banks of near-by Johnson creek and inundated many blocks.

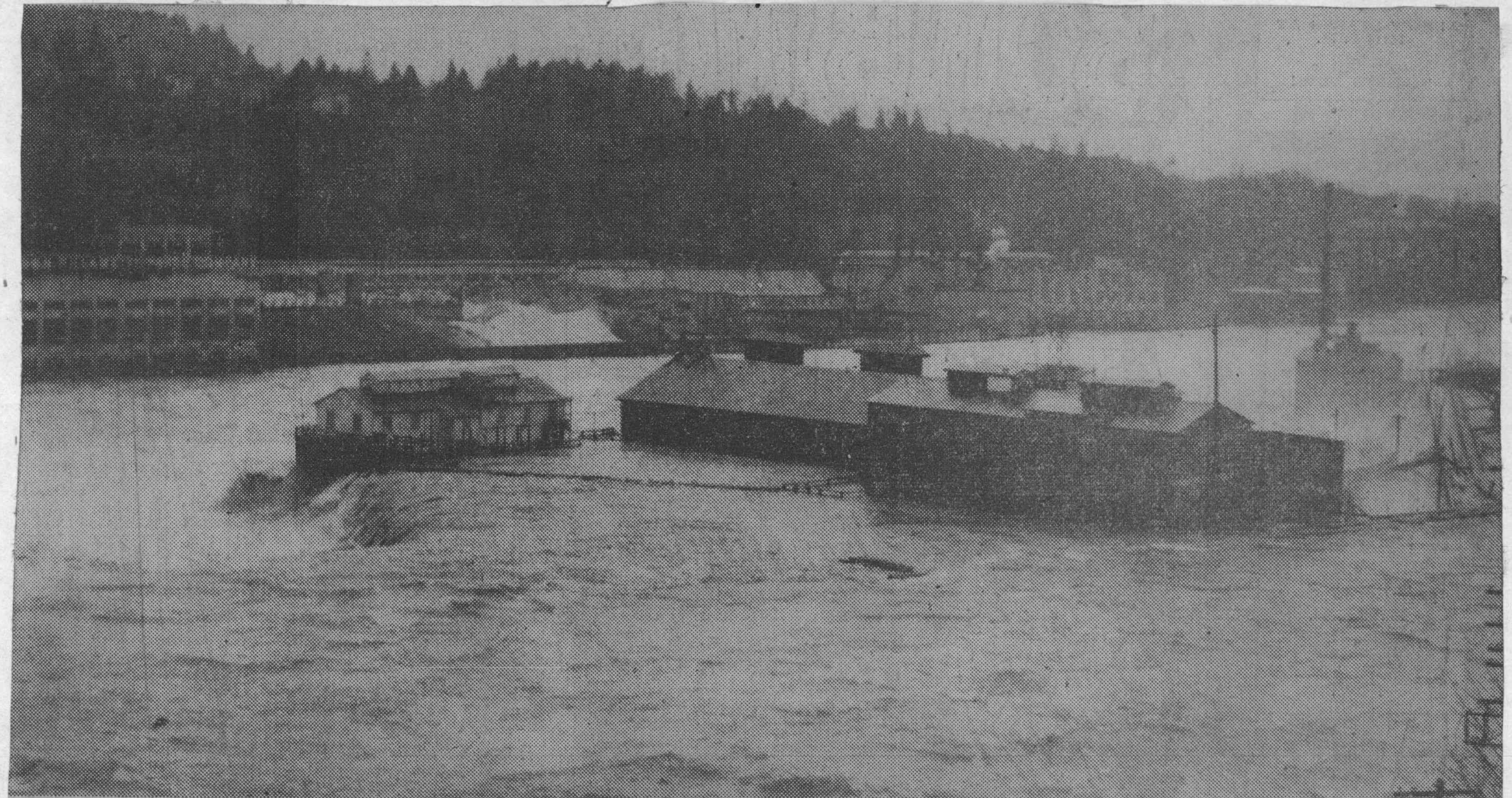
death, they determined to build boats and descend the Mississippi River says:

"Then God, our Lord, hindered the work with a mighty flood of the great river, which at this time began to come down with an enormous increase of water which in the beginning overflowed the wide level ground between the river and the cliffs; then little by little it rose to the top of the cliffs. Soon it began to flow over the fields in an immense flood, and as the land was level, without any hills, there was nothing to stop the inundation. The flood was forty days in reaching its greatest height, which was the twentieth of April, and it was a beautiful thing to look upon the sea where there had been fields, for on each side of the river the water extends over twenty leagues of land, and all of this area was navigated by canoes, and nothing was seen but the tops of the tallest trees."

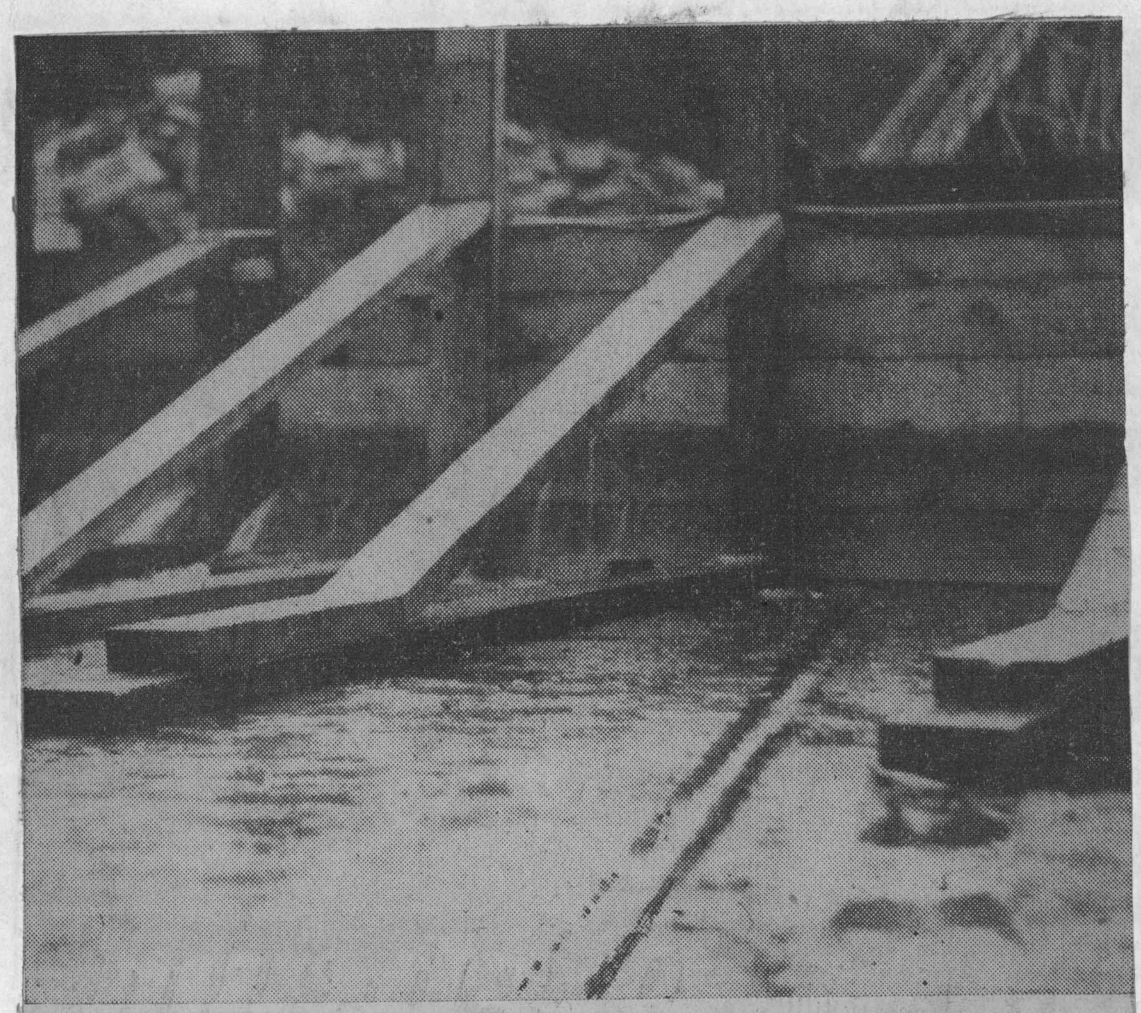
As population increased towns and villages sprang up in the low lands where there was always an attraction for agricultural development because of the fertility of the soil. As a consequence, floods even of moderate severity, which in early days passed almost unnoticed, carry in their wake today destruction of property and loss of life.

By construction of a dense net work of roads, with the attendant provision for the rapid disposal of adjacent drainage water, and the laying bare of a large part of many watersheds, as well as the destruction of forest and vegetative cover, together with the bringing into cultivation and pastures steep slopes, have all added enormously to the rapid run-off and the creation of high water stages. (3)

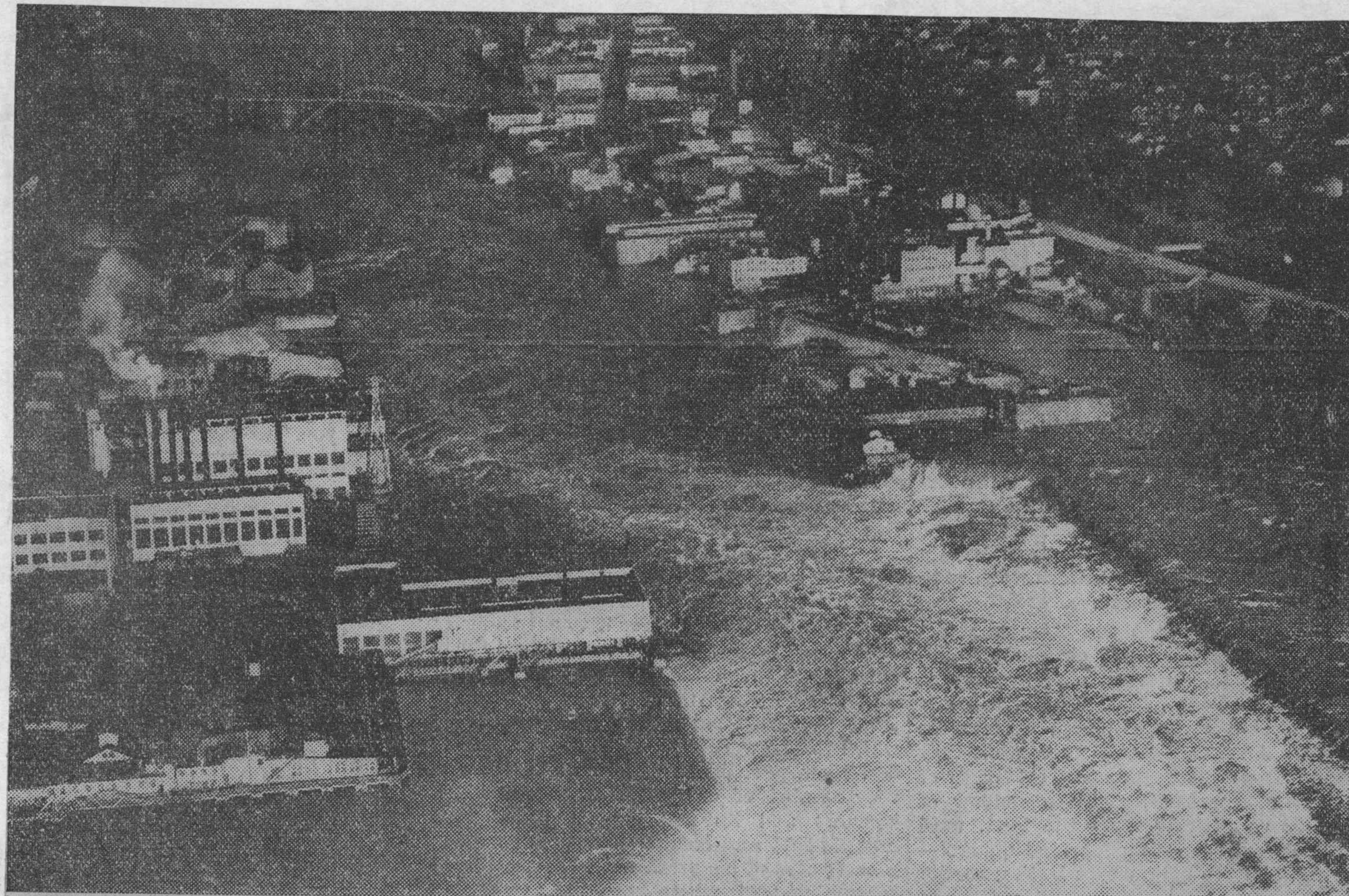
Floods in the Pacific Northwest are also increasing. In December 1937 the Willamette River threatened Oregon City mills along the water front were flooded, and a bulk head had to be erected at the head of Main street to keep the swirling water out of the business section. The Lents district of Southeast



BOUND FOR THE PACIFIC. Buildings of the Oregon City plant of the Hawley Pulp and Paper company looked as if they were afloat in the Willamette river yesterday when a photographer of The Oregonian snapped this picture. At the left of the picture only a slight ripple remains to show where the water usually takes a decided drop. The stream, filled with debris from other flooded areas, roared past the buildings and on through Portland at an accelerated pace.



RIVER, STAY 'WAY FROM MY DO'. That's what Oregon City business men were saying yesterday for this four-foot "dam" of wood and canvas was all that kept the Willamette river from flooding the city's principal street. Note the water seeping through the boards.



PICTURE OF A RIVER AND a CITY. And it's mostly river in this aerial view of Oregon City and the churning waters of the Willamette. Taken last night, this picture shows how the heavy rains throughout western Oregon have transformed the usually placid Willamette into a roaring torrent, threatening destruction to homes and cities in its path. Story on page 3.

11.

Portland, Oregon was flooded by Johnson Creek so that business was paralyzed, and many home owners were marooned. At Gaston, Oregon the flood waters dug a 60 foot hole through the $75,000 dike across Wapato lake causing a serious flood in the town of Tualatin, flooding homes and causing business to come to a standstill.

At the present time there is a Willamette Valley project pending which amounts to $56,000,000 for construction of seven dams at strategic points along the Willamette River to serve for the storage of flood waters and to eliminate the present average flood loss of a million dollars. (4) Engineers are planning the construction of 32 miles of levee embankment for the Columbia River in the vicinity of Clatskanie, Oregon for flood control. (5)

A reclamation project on Sauvies Island will be the last large project of its type feasible in the vicinity of Portland, Oregon. The project calls for the diking of approximately 14,000 acres. Work on this project will be started soon at a cost estimated to be in excess of $1,000,000. The maintainance costs to be provided by the farmers. (6)

CAN DAMS, LEVEES AND ENGINEERING WORKS CONTROL FLOODS?

"Construction of levees and engineering works will probably be found to be a minor factor in permanent flood control." Professor P. A. Herbert (7) states that we are going to have "more and better" floods if engineers are permitted to dominate flood control policies. Billions of dollars have been spent in this country for flood control and flood relief but still our floods are becoming more frequent and more destruc-

WHERE DIKE LET GO. Wapato lake, at Gaston, last night was inundated as of old, after flood waters dug a 60-foot hole through the $75,000 dike, intended to keep the lake bed dry. Shown in the foreground is the swollen moat outside the dike and the break in the wall. The flooded area in the background was an onion field a few days ago. Flood stories on pages 1 and 4.

WATER, WATER EVERYWHERE. Most of the town of Tualatin was under water, much of it as deep as pictured above. The residences were flooded, their porches lying under a foot or more of water, which laps at the window sills. Note the state highway marker on the left, nearly submerged in the torrent. Damage mounted high in Tualatin and surrounding country.

OREGON HIGHWAY NO. 217. The Tualatin river, swollen by heavy rains, plagued residents of Tualatin yesterday, flooding the state highway, which is the town's principal traffic artery, and pouring into homes. Here a boat serves as a conveyance, its operators wisely attired in hip boots. Other towns in the valley offered similar scenes as this.

tive. No one can control and prevent floods after the water has reached the larger streams. Huge levees have been built on the advice of engineers to hold the water in the channel, then the militia has been sent out to rout the farmers who resist efforts to dynamite and tear them down again so that the city property down stream can be saved. It is only natural that farmers receiving the protection of a levee will oppose efforts to flood their farms and homes by dynamiting the levee that protects them.

Even in the Tennessee River valley where dams and levees are being constructed, the Tennessee Valley Authority (8) states that it is not feasible to control floods by levees alone though they may be controlled by a combination of levees, channel improvements, reservoirs storage, forestation, erosion control, and changes in agricultural practices which lead to reduced flood run-offs.

The general custom of dredging, of straighting channels, and clearing brush from the margins of the small water courses which drain 25 to 50 miles has only resulted in the sum total effect of hurrying flood waters into the main stream, and of aggravating flood conditions. Bank covering, erosion, and gullying have been accelerated and silt deposits in navigable streams increased.

Zon (3) states that we have been overlooking an ancient adage that "natura magna est in minimis" (the power of nature lies in the small things). If we could control the water in the small creeks throughout the hills, we would not have to worry so much about the construction of levees and other engineering works by which man has tried to counteract the brutal force of rushing waters with the force of concrete barriers, only to find too often that they are feeble compared to the forces of nature.

It should be emphasized however, that forests cannot prevent floods in the face of heavy, long-continual rains or the rapid melting of masses of snow. For the control of immense volumes of water suddenly flung upon the earth under such circumstances in their rush to the sea, we must rely upon some form of levees, reservoirs or diversion channels, but only with the proper forestation, will these engineering works be stable, efficient and reduced to a minimum.

FORESTS AS CONSERVERS OF PRECIPITATION

Interception by Tree Crowns:

The amount of water intercepted by the crowns of trees vary considerably with the character of the trees, their age, crown density, the amount and severity of precipitation, velocity and direction of the wind, etc. As the result a great many investigations (9) it may be assumed that coniferous forests intercept more precipitation than broad leaf forests. Under average conditions a spruce forest will intercept about 30% of the percipitation, a broad leaf forest about 13%. The following table illustrates this fact.

Table I. RAINFALL WHICH REACHED THE GROWN IN WELL-STOCKED WOODS, IN PERCENT OF TOTAL

	Beech Woods	Spruce Woods	Scotch Pine Woods	Larch Woods
Prussian Stations	76	78	73	--
Bavanian Stations	78	77	66	--
Swiss Stations	90	77	--	80

Doctor Bruhler (9) in his investigations in Switzerland in dense beech stands of different ages has brought out the fact that the amount of percipitation intercepted is the smallest in a young stand and greatest in a middle-aged one. The following table shows the results of from two to three years observations in stands of beech of various ages:

Table II. PERCIPITATION INTERCEPTED

	AGE OF STAND			
	20 years	50 years	60 years	90 years
	percent	percent	percent	percent
Proportion reached the ground	98	73	77	83
Proportion retained by tree crowns	2	27	23	17

The amount of water retained by the tree crowns is not much greater than that retained by a meadow of dense grass or cultivated plants at the time of their full development. Ney (9) estimates, on the basis of the average number and weight of beech leaves shed, that the aggregate foliage of a middle-aged beech forest on one acre would occupy 8.4 acres, and on the basis of the average yield of straw and hay, that the aggregate area occupied by the foliage of cereals would be 7.4 acres ; of clover 5.6 acres; and meadow grass 4.8 acres. Though cultivated plants present less surface per acre than do beech leaves, the latter offer more of mechanical hinderances to the run-off of the water. It is very likely, therefore, that during the summer months cultivated fields retain as much water as does a beech forest, but for the entire year the tree crowns intercept more water than do field crops which are under cultivation for only a few months. (The foliage of deciduous forests, even though they remain intact for approximately six months still prevent a portion of the perception from reaching the ground directly.)

The interceptive influence of forest is much greater in light than in heavy rains: It is evident, therefore, that all the figures which show the interceptive influence of tree crowns have a value only for the place and time that the measurements were taken, and for this reason cannot be of general application. In regions where precipitation is in the form of heavy or prolonged rains the ground under the forest, no matter whether the latter is deciduous or coniferous, will receive as much or nearly as much water as the bare ground, while in regions where rains are neither heavy nor of long duration a larger portion of the precipitation will remain in the tree crowns and never reach the soil.

Studies by Ney (9) after deducting from the amount of precipitation retained by tree crown the amount of water which runs down the trunks and branches, computed the loss precipitation for the whole year, through interception by the crowns, to average for beech forest, 15 percent; for pine, 20 percent, and for spruce, 33 1/3 percent. Mathiue, at Nancy, France, (9) on a basis of 11 years observations, found that a forest of blue beech intercepts by its foliage and returns into the atmosphere on the average of 4.48 percent of the percipitation. Thus the forest more than any other form of vegetative cover intercepts more atmospheric precipitation and prevents or prolongs its reaching the ground.

It is by this process that the amount of water which would otherwise be available for stream flow is held back to help prevent streams from reaching the flood stage.

Surface Run-Off Obstructed:

The forest floor, penetrated by a network of roots and covered by branches and stumps, offers many obstructions to surface run-off and so permits the water to sink into the ground. Percolation is made easier by the presence of deep channels in the soil, left by the decay of large roots.

The understory of brush and reproduction found in the forest also tend to make the under lying soil and sub-soil more receptive to percolation. (7) The quantity of litter and obstructions to run-off are also increases.

In addition to the water actually absorbed by the leaf litter and so held there, is a restraining influence which is too often overlooked (10). Thus while a heavy litter cover might actually absorb and so hold against capillarity an inch or more of water the litter by means of its arrangement and its porosity holds more water, under certain exceptional conditions probably several times as much. Even hardwood leaves curl and cup and water so held and restrained from flowing away.

An unbroken forest soil cover of half decomposed leaf mulch and humus aids greatly in retarding surface run-off and forcing it into the ground. The importance in this respect is brought out by the following facts: "The leaf mulch on an acre of virgin beech forest weighs, when air-dried, about 8,818 pounds, in a pine forest 15,873 pounds, and in a spruce forest 12,346 pounds. If the specific gravity of the air-dry leaf litter be only 0.5, then the dry substance of the leaf mulch if evenly distributed over an acre would cover it in a beech forest to a depth of only 0.08 inch, in a pine forest to 0.14 inch and in a spruce forest to 0.11 inch. In nature, however this amount of leaf litter covers the ground in beech and pine forests to a depth of 3.1 inches, and in a spruce forest to a depth of 3.9 inches, which gives an idea of the space within the leaf litter and the volume of water it may accomodate".(9)

Huffel (2), (10) and (9) from investigations found that a forest with leaf litter, after a rainfall of from 2.4 to 2.8 inches, did not give off, even on the steepest slopes, a drop of water in the form of surface run-off. If water does not run off from such stands it comes from the precipitation which falls on an area deprived of its forest cover. W. D. Lowdermilk (11) of the California Forest Experiment Station in attempting to find a definite function of forest litter carried out an investigation by placing typical forest soils in tanks 10 feet long, 2 feet wide and 5 inches deep. Eight tanks were used in the experiment, two for each of three soil types studied, with one pair in duplicate. The litter on each alternate tank was burned. The study then compared differences in run-off, seepage and erosion for bare and forest litter covered soils.

These studies show that the forest litter has little effect on surface run-off through its own absorbtion of water, its principal function being to maintain the soil profile at its maximum capacity for percolation. Briefly the removal of the forest litter may increase the immediate surface run-off three to 30 times depending on the intensity of the percipa-tation. The litter prevents the beating drops of rain from so rearranging the soil particles that they clog up the pores in the soil and cement the channel openings.

Measurement of surface run-off made in 1860 by Jeandel, Canlegril, and Bellot (9) in the Vosges Mountains, Switzerland, show that the surface run-off from wooded slopes is only about half as much as that from deforested slopes, while, from the former, the under ground seepage is greater. Huffel (9) also states that under ordinary conditions of rainfall there is practically no surface run-off from wooded water sheds having an abundant leaf litter.

Surface Run-Off Converted To Seepage:

In mountainous areas, the greatest sources of loss of precipitation is through surface run-off, and the most important influence which a forest cover has is in reducing this.

Ney (9) estimates the amount of water which the forest cover saves to the soil by reducing the surface run-off and changing it to underground seepage to be as follows: "For forests at low altitudes where the rains are not heavy and the soil is less subject to freezing, 20 percent; for forest of moderate altitudes, 35 percent; and for mountain forests 50 percent of the percipitation."

Forest litter because of its complex nature increases seepage. The soil organisms which are most numerous in forest soils make the soil more porous. Roots of trees and other forest vegetation die leaving channels which increase percolation of water in the soil. This water may be stored under ground or it may seep through under ground channels and come out in rivers, streams and springs days or even months later when it will not have any effect on floods as they are created by the actual immediate surface run-off. (12)

Absorption of Water:

The absorption power of the forest litter cannot be employed too strongly in its part of the forest in preventing floods. Investigations by the Forest Service and other agencies (10) have shown that forest litter can absorb water equal to many times its own weight.

A number of investigations have determined the water-holding capacity of litter from typical forests in various parts of the county.

In the Northeast the water-holding capacity of the litter ranges from 300 to 900 percent of the dry weight of the litter, its highest values being obtained in the spruce and the northern hardwoods forest. Freshly fallen pine litter in the Lake states absorbs water to 156 percent of its dry weight. In the Central states region the absorptive capacity of scanty hardwood litter averages about 360 percent. In the Southern hardwood forests it ranges up to 400 percent and in the southern pines from 150 to 350 percent.

The absorptive capacity of forest litter varies, in terms of rain fall equivalent from 0.10 to 0.93 inch. The poorest values were from the litter of a hardwood forest where cutting had been quite heavy and where the stand was open. The best results were obtained in relatively dense forests of spruce, birch, cedar, and poplar, and where the forest formed a complete canopy.

Investigations in Ohio by the Central States Forest Experiment Station indicate that comparatively young planations have a considerable influence upon flood flow and erosin. It was found that forest plantations ranging in age from 12 to 20 years had developed a uniform litter cover which was rapidly increasing in depth and in value. The absorptive capacity of the forest floor was determined to range between 100 and 250 percent of the dry weight of the material. (13)

Burger's studies (14) and (9) show a remarkable contrast in the time required for a given volume of water to pass from the surface in the forest as compared with a similar soil in the open. He found that the forest soil beneath the normal litter had numerous burrows formed by animal life and various openings due to decayed roots, which the soil in the open did not have. His investigations show that the time required for a given volume of water to sink into forest soil over a unit area was often less than one-fifth the time required to sink into a similar soil in the open, and the more compact and finer the texture of the soil, the greater the difference in time required. Similar investigations conducted by Toumey and Craib at Keene New Hampshire have brought out the same results (14).

Vermeule (15) from studies made in New York has reported the amount of water, expressed in inches of rainfall, that reaches the streams through springs and by underground seepage from forested, cultivated and denuded watersheds during the dry season where rainfall equals the evaporation and its effect on stream-flow is eliminated.

YIELD OF SPRINGS ON FORESTED, CULTIVATED, AND BARREN WATERSHEDS DURING DROUTH

Table III.

Month	Forested Watershed Passaic	Cultivated Watershed Raritan	Barren Watershed
	In. of Rain	In. of Rain	In. of Rain
First month	1.16	1.43	0.94
Second month	.54	.64	.38
Third month	.40	.45	.26
Fourth month	.33	.35	.20
Fifth month	.32	.30	.14
Sixth month	.31	.27	.12
Seventh month	.30	.25	.10
Eight month	.29	.23	.08
Ninth month	.28	.22	.07
Total	3.93	4.14	2.29

These figures, which are the result of computation based upon actual gaugings, show that while the cultivated and forested water sheds yield almost the same amount, the cultivated watersheds give off water faster during the first months, and therefore, sooner becomes exhausted. The barren watershed, whose underground storage capacity is small, has little flow for springs, which almost dry out toward the end of the drought.

Europe abounds in authentic records of the disappearance of springs as the result of deforestation, and in the United States there are numerous other examples.

McGee (16) states that during a period of 22 years, 9,507 wells dug in Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Ohio, Tennessee, and Wisconsin, showed a lowering of the ground-water at a minimum mean rate of 1.315 feet in the 80 years since settlement began. This lowering of the ground-water, according to McGee, is due to the increased surface run-off and decreased seepage following the progressive removal of the forests.

The Forest As A Soil Holder:

"A well kept forest is the best of natural soil holders." (17) It has a dense ground cover of trees, shrubs, and lesser plants that impedes the flow of water. Tree roots spread far and wide to a depth of two feet or more, usually much deeper than the roots of grass or farm crops; and the roots of the lesser forest plants help to bind the top soil together. On top of the ground is a mat of leaves, twigs and branches, varying from a few inches to more than a foot in depth; and beneath this mat is the spongy humus derived from the decay of generations of litter. It is by these means, even in heavy rains and regardless of absorption, the forest soil is little disturbed and streams that derive their water from such a forest are likely to remain clear.

Transpiration By Forest Vegetation:

A large part of the water absorbed by vegetation is taken from the soil, enters the transpiration current and is returned to the air through the leaves. This may be termed physiological evaporation as it is essential for the life process of the tree. The loss of moisture from the ground through transpiration is very large in well wooded areas and nothing on barren soil (14). Although extensive experiments have been undertaken in many localities in effort to determine the amount of transpiration water lost from different kinds of vegetation and from different species of trees, the problem is so complex we have as yet but little dependable information.

Hohnell (9) and (14) has proposed the following table as a result of experiments carried on for a long period of years and with utmost care. The figures are only for the vegetative season and give the comparative water consumption of different species as well as the amount of water transpired by different forest trees per pound of dry leaf substance:

Table IV. TRANSPIRATION TABLE

	1878	1879	1880
Birch	697.87	845.13	918.00
Ash	566.89	983.05	1,018.50
Combeam	562.51	759.01	871.70
Beech	472.46	859.50	913.80
Maple (Spitzahorn)	462.87	517.22	611.80
Maple (Bergahorn)	435.77	618.30	703.80
Elm	407.31	755.00	822.80
Oak	283.45	622.21	691.50
Oak (Zerreiche)n	253.33	614.22	492.20
Spruce	58.47	206.36	140.20
Scotch pine	58.02	103.72	121.05
Fir	44.02	77.54	93.80
Austrian pine	32.07	99.92	70.05

The quanties of water transpired in 1880 in percent of the percipitation of that year were found to be: elm 43 percent, beech 25 percent, and birch 40 percent. In 1878 and 1879 the percents were lower due to the fact there was more rainfall and therefore more water penetrated the soil.

Wollny (9) in observations carried on for six years, determined the amount of water transpried by different species of trees in pots containing identical amounts and kinds of soil, by measuring the amounts of water which percolated through the pots. He found that spruce transpries, on any average, during the year 37.9 percent of the annual percipitation and birch 27.8 percent; but that during the vegetative period the amount transpired by the two species is almost the same, spruce 33 percent and birch 32.1 percent.

Sherman (2) states that a rapidly growing forest may during the year consume and transmit into the air a volume of water equivalent in depth to 12 inches over its entire area. On rocky slopes, upon which through generations the forest has spread its carpet of humus to hold in its store the moisture and help secrete water in crevices where it may be reached by the searching tree roots and used in plant growth, the forest obviously uses moisture which otherwise would have been contributed to immediate run-off causing torrents of water to rush down the streams and overflow the valleys below.

<u>The Retardation of Snow Melt</u>:

Numerous studies of the forest cover retarding the melting of snow have been made in various parts of the world which show that the forests retard the melting of the snow sufficiently to form an important factor in preventing floods in the early spring and prolonging stream flow far into the dry summer months. In 1916 and 1917 the U.S.F.S. made a series of careful studies in three different localities of the cascade Ranges of Oregon and Washington (18). The average water equivalent of the snow retained on the forested areas of all stations was 7.5 inches greater than on the open areas and the snow lasted an average of 17 days longer. Although at some of the stations the snow was retained for 42 days longer under forest cover than at the same elevations in the open. These studies also showed that the density of the forest is of primary importance in retarding the melting of snow.

The effect was greatest at the Wind River stations on the west slope of the mountains in Southern Washington. The following table shows the results of the studies:

The water equivalent of the mean depths of snow retained by the forested stations when the corresponding open stations became bare and for three weeks thereafter, expressed in inches and in percent of the maximum snow cover:

Table V. SNOW RETARDATION

Study	Water Equiv. Inches	Weeks after open stations became barren: 0		I		II		III	
		in.	%	in.	%	in.	%	in.	%
Tumalo 1916	47,0	8.7	18	6.0	12	2.1	4	-	-
Tumalo 1917	44.0	5.2	12	.1	-	-	-	-	-
Wind River 1916*	25.8	13.5	56	9.5	37	8.0	31	5.3	21
Wind River 1917	7.6	3.0	40	.6	8	-	-	-	-
Yakima 1917	24.6	6.9	28	3.2	12	1.6	7	.3	1
Mean	29.8	7.5	30	3.9	14	2.3	9	1.1	4

*Average of flat and mountainous slopes.

Studies by Jaenicke and Foerster (13) show that in Idaho the snow cover in the forest disappeared from 3 to 10 days later than in the open; at least 10 days later in Nevada; several weeks later in Arizona, the snow occurring however, merely as drifts in the timber and from 1 to 5 weeks later in Washington. Dr. J. E. Church, Jr., in his experiments in the Sierras of California, found essentially the same results.(19)

Zon (9) states that the rapidity with which snow melts in the forest varies with the species and with the density, age and location of the stand. The snow disappears first of all from clearings in the forest, simultaneously with its disappearance from young forest plantations in which the tips have not begun to touch each other; then from the thin oak forests on southerly slopes and old, open pine forests; then from the dense stands of birch on northerly slopes, later from the pine; and last of all from the spruce.

To illustrate this the following data taken by the Imperial Agronomic Institute in 1908 lists the dates when the ground in the field and forest became entirely free of snow.

In fields, clearings, and open places	April 22
In young, open stands	April 24
In old, stands on south slopes	April 26
In birch stands	April 29
In pine stands	May 6
In spruce stands	May 15

This also compares deciduous stands with coniferous forests in their ability to retard snow melting and for this reason they are more efficient in reducing the height of spring floods.

The snow cover prevelant in the forest during the winter prevents the ground from freezing. Rain falling on ground already frozen, or water from melting snow on frozen gound will run off very rapidly causing high water and floods. Observations at the Arnot Experiment Station in Schuyler County, New York show that the ground in the forests did not freeze during the severe winter of 1935-36, while that in open fields at a depth of 12 inches remained frozen through March 25. The snow in a beech maple forest was 12 inches deep on March 25, 1936, while there was no snow at all left in the open. This was after the destructive flood period of March 17 to 24. (13)

DEFORESTATION, RUN-OFF

The effects of deforestation are summed up and clearly pointed out by E. M. Rowalt, who states the following: (20)

"Land denuded of its vegetation is like a tin roof. It delivers water to a creek as a tin roof delivers water to a down spout. Streams fed from denuded watersheds overflow their banks more frequently. After a storm they rage. Soil slips and slides and torrents transport soil and rock. Streams fill with debris and cut new channels. Valley properties decline in value. Populations endangered. Life is lost".

Reed W. Bailey and C. L. Forsling (21) in studies of floods and accelerated erosion in northern Utah have found that a delicate balance exists between the vegetation, soil and run-off. Where this balance was broken by excessive grazing, fires, timber destruction, etc. run-off from cloudbursts was rapid. The excessive amount of water in stream channels cut deep gorges, eroded banks and carried great quanties of enormous boulder and debris to the valleys below. The variation from previous years when forest were untouched until the present when violent floods and a distinctly accelerated rate of run-off and erosion are occurring is directly traceable to the depletion of the plant cover.

Studies of comparable forested and deforested areas show that in regions of alternately heavy precipitation and prolonged dry spells the forest has a decided influence in equalizing the flow (18). On deforested areas, however, the annual flow is remarkably ununiform. Proper forest cover will hold back the water and cause it to seep into the ground where it gradually trickles down to reappear at lower levels through seepage and springs. (22)

The following examples are good illustrations of the effect of forest cover on water conservation: (18)

In the Sierras of California, the north fork of the Yuba River is forest covered and the south fork has been denuded. The first has a watershed of 139 square miles, and the second a watershed of 120 square miles. The first, well covered with timber and brush gives a minimum run-off of 113 cubic feet per second. The second should have a minimum run-off of about 100 cubic feet per second, but it is reported to have practically no run-off for four months of the year.

Queen's Creek in Arizona, having a drainage area of 143 miles, where the annual rain fall is only 15 inches, which has an unforested watershed is subject to violent floods. The maximum discharge in 1896 was 9,000 cubic feet per second, where as the mean discharge was only 15 cubic feet per second, and during a large part of the year the streams were dry.

Compared with this is Cedar Creek in Washington, flowing over well timbered watersheds, having a drainage area equal to that of Queen's Creek, and a percipitation of from 93 to 150 inches. This stream in 1907 had a maximum flood discharge of 3,600 cubic feet per second, and a mean discharge of over 1,000 feet. According to Pinchot (18): "This radical difference in the behavior of the two streams can be explained only by the difference in the soil cover of the two basins."

One of the most famous of these experiments was carried on for many years at Emmenthal, in Switzerland, where the run-off from two small valleys, one completely forested, the other only partially forested, was measured and compared. It was found that the stream from the completely forested valley was more uniform in its flow and carried less debris than the other streams. After very heavy rainfall of brief duration the forested stream carried only from one-half to a third as much water as the partially forested stream. In the summer the forested stream kept up a higher and more regular flow.

C. L. Forsling (23), who made exhaustive studies of the influence of herbaceous plant cover on surface run-off and soil erosion in relation to grazing on the Wasatch Plateau in Utah found that the heavier stands of vegetation on a mountainous slope reduce and delay surface run-off in various ways, causing more of the water to be absorbed by the soil and that which runs off to be discharged fairly regularly over a considerable period. In thin stands the influence of the vegetation is decreased and a system of gullies soon form which hasten the run-off. The gullies soon gather the water from the denuded hill sides and cause it to reach the stream in a much larger head. It is the size and speed with which this head reaches the main stream that causes streams to reach the flood stage.

That such effects come in part from destroying the absorptive capacity of the forest floor is shown by experiments made by the Forest Service in the mountains of southern

California (17). Within three years after the brush cover on a canyon drainage was destroyed by fire the soil had lost 45 percent of its water-absorbing power. This loss was due partly to the burning of the litter and humus and partly to the rapid erosion of the topsoil.

Bennett (13) in reporting on an unpublished finding of S. W. Phillips and I. T. Goddard at the Red Plains erosion experiment station near Guthrie, Oklahoma, in the spring of 1930, states that on two plots in post-oak timber, one on which the forest litter was burned, and the other, immediately alongside, on which the natural ground cover of leaves and twigs, was left undisturbed the run-off was measured during a period of almost continuous rainfall in May. Run-off from the unburned plot was clear and amounted to 250 gallons per acre, but that from the burned plot, having the same soil and slope, was muddy and attained a volume of 27,600 gallons per acre. The excess of run-off from the burned area over that from the unburned area plus the 16.7 tons per acre absorbed by the leaf-litter itself was approximately 90 tons per acre. The absorbed water went to replace the underground soil water supply while that held by the litter was largely evaporated. From the burned plot an average of 0.15 ton of soil per acre per year was eroded, and from the unburned plot 0.01 ton.

Hoyt and Troxell (13) have compared the run-off of Fish Creek with that of Santa Anita Creek, neighboring watersheds, for the 7 year period from October 1917 to September 1924 when both were covered with forest and chaparral, and then for the 6 year period following a fire in the fall of 1924 which denuded the Fish Creek watershed. In the first year following the fire they found a 231 percent increase in 1,700 percent in the maximum daily discharge resulting from the first four storms occurring after the fire. The flood peak, which was ordinarly 2.5 times the maximum daily discharge prior to the fire, increased to 16.2 times on April 4, 1935.

THE RELATION OF EROSION TO FLOOD RUN-OFF

"Erosion has a direct bearing on the height of flood water in the river, since sediment carried by the rivers and the coarser detritus brought down by mountain streams often increases stream volume to such an extent that the height of water is raised far beyond the point it would have reached if it came free of detritus and sediment." (2) and (10)

The presence of sand and gravel not only increases the volume of the flood and raises its height but in addition such abrasive material furnishes teeth to the freshet and enables it to tear up the earth, wear away embankments, and carry off accumulations of soil and other material otherwise safe from the ordinary flood waters. The first few cubic yards of sand that enable the stream to wear away the protective covering of sod from an exposed embankment may expose a thousand cubic yards of similar material.

This eroded material which is deposited in the channels of streams, increases the frequency of floods. A slight rainfall will cause a flood, while if the channel were deep it would have no perceptible effect upon the height of water in the stream. The filling of mountainous streams with waste not only increases the frequency of floods but causes the

EVERY GULLY became a stream in southern Oregon this week as heavy rains set new records. Torrents like the one above, which washed out a county road and broke through an irrigation ditch east of Grants Pass, hampered traffic and communications. Storms showed signs of abating yesterday. In California, storms were even more fierce. (See below.)

streams to assume the character of torrents. A channel filled entirely or partially with foreign material cannot hold large quanties of water, while the denuded slopes deliver the storm water almost as fast as it falls. (9)

The terrific power of mountain freshets has been pointed out by the famous French engineer Demontsey, (9), (2),(24) and (10) who found that one such torrent brought down, after one storm, in 85,000 cubic yards of water 221,000 cubic yards of detritus or more than two and one-half times its own water volume.

The disastrous flood in Los Angeles County, California January, 1934 which caused thousands of dollars worth of damage and the loss of 34 lives directed public attention on the source of floods, and demonstrated the value of forest cover. A special study made by the California Forest Experiment Station found that the destructive flood, which was more mud than water, originated on a watershed of 4,000 acres that had burned over a few weeks earlier. Neighboring watersheds with forest cover and the same amount of rainfall yielded clear water which caused no unusual erosion and did no damage. The maximum flood discharge from the burned over area reached 1,100 second-feet per square mile carrying some 67,000 cubic yards of eroded debris. The run-off on the unburned watershed a few miles distant was only 50 second-feet per square mile and carried only 56 cubic yards of eroded material.

Meginnis (25) in describing the studies of the Southern Forest Experiment Station of the United States Forest Service states that identical conditions existed in the disastrous flood of the Yazoo River in northern Mississippi in 1931-32.

Bates (26) as a result of the Wagon Wheel Gap experiment states that the measurable detritus carried by the stream in question after the forested headwaters had been denuded increased 25 percent. Most of this increase was secured during the flood stage.

Bennett and Silcox (27) report that the laying bare of watersheds above the headwaters of mountain streams cause gullies to form which soon become thousands of new tributaries. They concentrate run-off which otherwise would be conserved and discharge it directly and with maximum velocity into the nearest streams causing a torrent to start which demands that the rivers carry more water than they are created to carry.

THE RELATION OF EROSION TO FLOOD CONTROL STRUCTURES

The erosion of denuded lands not only increases flood heights and thereby increases flood damage, but also decreases the value, through silting of man's engineering works designed to control floods. It is one of the major problems of the Tennessee Valley Authority in the development of the Tennessee River by the construction of dams and levees (8).

In some places, this silting is proceeding at such a rate as to threaten to destroy proposed down stream engineering structures within a few decades. Silting may fill in the stream channel that levees must be raised higher to take care of floods of the same magnitude.

The Soil Conservation Service after examining 34 reservoirs in the southern Piedmont in 1934 found that 13 major reservoirs with dams averaging 29.8 feet in height were completely filled by eroded material within an average of 29.4 years. In the West, significant instances of complete filling of reservoirs include the Austin Dam at Austin, Texas, which was nearly filled in 5 years and completely filled in 15, and the Harding Reservoir near Santa Ana, California, which filled almost entirely during a single month of heavy rains following a burn in the basin during 1927.

The following table shows the rate of silting of reservoirs: (13)

Table VI. RATE OF RESERVOIR SILTING

Reservoir	Period Covered	Years	An. Loss of Storage Capacity	Yrs. Required to Reduce to Av. An. Draft
Spartanburg, S.C., City reservoir	1926-34	8.00	2.14	36
High Point, N.C., City reservoir	1927-34	7.00	.84	97
Rogers, Tex., City reservoir	1922-34	12.00	1.90	13
Elephant Butte Reservoir, N.Mex.	1915-25	10.70	.89	77
Zun Reservoir, Black Rock, N.Mex.	1907-32	25.00	3.62	18
Roosevelt Dam Reservoir, Ariz.	1910-25	15.00	.41	124
Elk City, Okla.	1925-35	10.00	4.80	-
Old Lake, Austin, Tex.	1800-1900	6.75	6.80	-
Waco, Tex.	1930-35	5.00	2.48	35

Talbot (28) after an intensive investigation of 30 reservoirs in the southwest used for livestock watering, reports an average silt deposit of one foot annually making the average life for reservoirs less than fifteen years.

Herbert (7) reports that much of the soil carried in the flood waters when they pour into the large rivers is

CORVALLIS, OREGON, WEDNESDAY, JANUARY 19, 1938.

Willamette Floods Wreak Havoc With Mud Banks of River

Eighty seven floods in 47 years!

This is the story of the Willamette river. During the past 47 years the water has risen above flood stage 87 times, or almost twice each year.

These floods and excessive high water has wrought havoc with, not only close lying farm lands, but also with the river bed. The destruction of the land is in some cases excessive.

The pictures are of the Irish Bend country, showing where erosion has made worst inroads. The water has cut through to an old creek bed, through which it is now flowing. The river channel at this point may be entirely changed, for a distance of some five miles and affecting more than 20 farms. The pictures were taken one year apart in 1936 and in 1937.

The Benton district improvement company No. 3 is now under organization. As soon as the district is completely organized applications will be made to the United States engineers for funds to protect the banks and to prevent further damage.

BEFORE—Picture taken in 1936 showing new channel being made as soft mud banks of Willamette river in the Irish Bend country are erased by swirling flood waters.

AFTER—Picture taken in 1937, showing new channel formed by Willamette river isolating fertile area from mainland, and forming an island.

deposited on the bottom of the river so that as the bed of the river is built up the levees will have to be raised.

An outstanding example of sedimentation is evident on many of the minor tributaries of the Yazoo River in Northern Mississippi.(25) Here erosion of the uplands have caused such heavy deposition of sand and gravel in stream channels that the streams no longer flow in their old beds but now flow in new channels cut in former agricultural land. Many of these new channels are several feet above the original stream. (13) Numerous other authentic cases of this kind could be cited.

SUMMARY

That forests have a definite essential part of play in the flood control program is not to be questioned. A well kept forest is the best water and soil holder that is able to prevent floods at the source.

The canopy of the forest with its leaves, twigs, and branches intercept the rainfall and breaks the force with which it would ordinarily hit the ground. The surface of the forest floor frequently has an understory of minor vegetation which aid in the process and help to prevent the rapid run-off which causes floods in the valleys below. The deep litter and humus of the forest absorb large quantities of water which seep under ground to springs and streams or is given off by the trees in the process of

transpiration. Over winter the forest soil remains more absorptive because it freezes less freely and deeply, thereby causing the melting snow to turn to underground seepage instead of rapid run-off.

Forests prolong the melting of snow for several weeks after it has disappeared in the open, diminishing the volume and prolonging the time of the flood run-off.

Erosion is prevented by a good forest cover. The numerous roots which hold the soil, subsoil, and rocks firmly in place prevent eroded material from increasing the height of flood waters and silt from damaging engineering works down stream.

It should be pointed out, however, that control of floods by forests should not entirely take the place of engineering works, but they should both work together to treat rivers as a unit from the source to the mouth.

In order to reduce floods and damage to flood structures the following recommendations are offered;

1. Publicly owned protection forests should be established at the headwaters of all major rivers which are causing floods. Watersheds which are now denuded should be reforested and intensively managed.

2. Lands which are sub-marginal for agriculture should be planted to forests.

3. Fire protection should be established;maintained to the fullest possible extent.

4. A scientific system of land planning should be established for all agricultural lands so that the ground will

have a vegetative cover throughout the entire year.

5. Grazing should be regulated in order to prevent erosion and at the same time build up the range for the best interests of the livestock industry.

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