MULTIPLE USE MANAGEMENT ON MYRTLE CREEK

Charles E. Hardy

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MULTIPLE USE MANAGEMENT OF LYTLE CREEK

Submitted in Partial Fulfillment of
the Requirements for the Degree
of Master of Science

BY

CHARLES E. HARDY

May 12, 1949

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Submitted in Partial Fulfillment of
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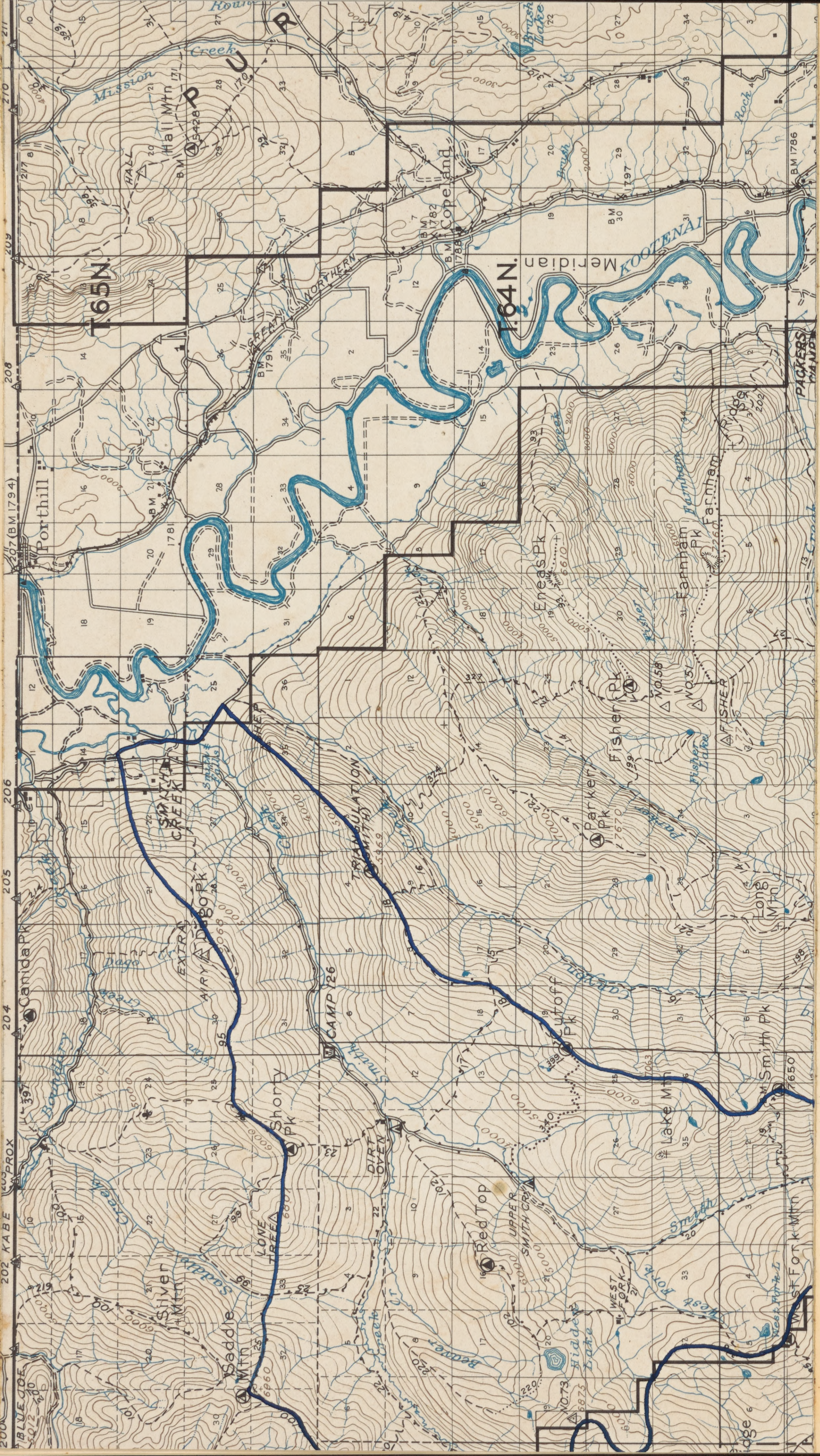
INTRODUCTION

Two natural resources that are becoming extremely critical in the United States are water and timber. It is becoming increasingly imperative that each of these be utilized wisely and to the fullest extent possible. Many communities obtain their domestic water from watersheds that also contain extensive stands of virgin timber--stands which produce no net growth and will not until they are put under regulation and managed scientifically. The reason so often given for using water but no other resource from some particular watershed is that the water supply will be reduced, and pollution and turbidity will render unfit for drinking that portion that does continue to flow. Should safeguarding this water supply necessarily relegate all other resources to the background? Or, can the drainage be so managed as to fulfill the primary objective of furnishing at least as much and as pure water as before, and, in addition, collect from two to three per cent income on the timber capital present? Should all other uses be excluded for the sake of pure water? Or, can fishing, hunting, recreation, and grazing also be allowed as sound secondary objectives of managing this watershed?

These are the problems confronting those concerned with the management of the Myrtle Creek watershed, near Bonners Ferry, Idaho.



Mission Creek
Hall Mtn
Brush Lake
Copeland
Meridian
KOOTENAI
GREAT NORTHERN
T.65N.
T.64N.
Porthill
PACKERS CAMP
Eneas Pk
Farnham Pk
Fisher Pk
Fisher Lake
Parker Pk
Long Mtn
SMITH CREEK
TRIANGULATION
Cutoff Pk
Smith Pk
Lake Mtn
CAMP 126
Shorty Pk
Red Top
Silver Mtn
Saddle Mtn
Hidden Lake

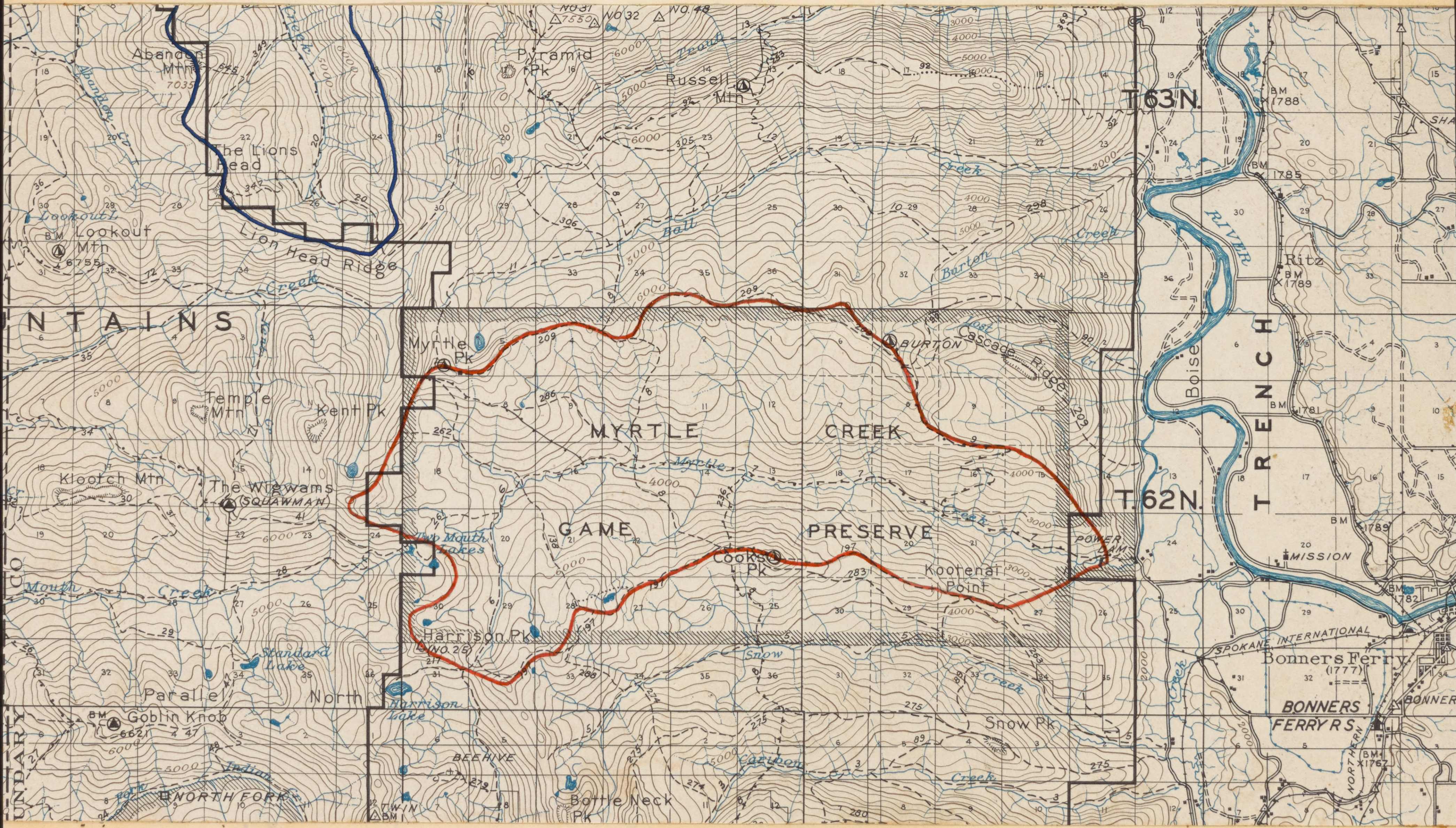


Fig. 1 — General Topographic Map

HISTORY AND BACKGROUND

Use of the Watershed

The Village of Bonners Ferry constructed a water line extending from the mouth of Myrtle Creek to the reservoir in town, a distence of between five and six miles, during the summer of 1928. Since November 24th of that year, Myrtle Creek has supplied the domestic water for the village. (Figure 1)

There were no legal restrictions on the use of the watershed until 1937 when the state legislature passed a law creating the Myrtle Creek Game Preserve.[1] The State Department of Public Health in cooperation with the Village Board of Trustees had been making requests for the closure from the time the water line was installed.

As it stands at present, the primary use of the watershed is water supply. Some recreationists travel through the drainage on the main trail to go fishing in Myrtle Lake (which flows north into Ball Creek). Forest improvement crews of from two to four men spend a week or two on trail and telephone lines every summer.

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[1]Game preserves are created for the better protection of birds and game and fur-bearing animals, for the establishment of breeding places therefore and for the preservation of the species thereof.

The Idaho legislature passed a law creating the Myrtle Creek Game Preserve in 1937. (1937 Session laws, Chapter 126.) The boundaries are as shown on the maps. This law prohibits any fishing, hunting, trapping, killing or chasing of game birds or animals. Also possession of any fish, birds, or animals, dead or alive, is unlawful. Predatory animals may be destroyed by the game warden or other authorized person. The preserve created is for a permanent game preserve. (18)

Water System for Bonners Ferry

The amount of water consumed by the village of about 2,000 population is conditioned by the size of the water line and not the volume of water available at the intake. The pipe will carry 2.5 cubic feet per second, which is hardly adequate for midsummer requirements of the village. The available water is more than sufficient, as at extreme low water the creek discharges 5 c.f.s.

The village has felt no need for a purification plant; however, the water is chlorinated as it enters the tanks in town. The treatment consists of the addition of liquid chlorine in sufficient quantity to leave a residual of .30 parts per million of free chlorine twenty minutes after application. The fact that little trouble in encountered over taste or odor speaks well for the high quality of the water. The water supply, since the installation of the chlorinator in 1941, has been approved by the State Health Department as meeting the Idaho and United States drinking water standards.

An Alternate Drainage

Instead of enlarging the size of the water line or putting in another pipe from Myrtle Creek to supply the increased demands for water, the village is considering installing a system from Snow Creek as an additional source. Snow Creek is the watershed next south from Myrtle Creek; its cover composition, topography, timber volumes, and stream flow are quite comparable to those of Myrtle Creek, except on a smaller scale. Its area is about half that of Myrtle Creek. (4)

Drinking Water Standards

Mr. H. C. Clare, Director of Public Health Engineering for the Idaho State Department of Public Health, states that adequate protection from contamination is now afforded by its adequate treating equipment--an automatic chlorinator--which is competently operated.(5)

In regard to physical characteristics, the United States Public Health Service and the Idaho Department of Public Health have set up standards as to the amount of turbidity allowed.(8,19) These standards are patterned after those of the federal government. Requirements for all filtered water supplies are that the turbidity shall not exceed 10 p.p.m. (silica scale) nor shall the color exceed 20 (platinum-cobalt scale). There should be no objectionable taste or odor. (8)

> Turbidity and color limits for unfiltered waters and the requirements of freedom from taste or odor for either filtered or unfiltered waters should be based on reasonable judgment and discretion, giving due consideration to all the local factors involved.
>
> . . . .
>
> Total solids should not exceed 500 p.p.m. for a water of good chemical quality. However, if such water is not available, a total solids content of 1,000 p.p.m. may be permitted. (8)

According to Idaho law, it is the responsibility of the furnisher of water to ". . . . protect the same and keep it free from all impurities and all other foreign substances which tend to injure the health of the ultimate consumers of such water . . . ."(17) The Department of Public Health officials are anxious to assist the village in planning protection operations and setting up an agreement between the village and the logging operators under which they might be carried out. (5)

Reasons for Desirability of a Planned Management of the Watershed

Logging the Private Timber.--The Pack River Lumber Company, whose sawmill with an annual capacity of about twenty million board feet is located twenty-four miles south of Bonners Ferry, owns considerable timberland in the two northernmost counties in Idaho; most of it is in a checkerboard pattern. The Pack River Company owns all or parts of eight sections in Myrtle Creek, or 17 per cent of the watershed's area, and 42 per cent of the volume.

There are no legal means whereby the company can be prevented from logging its own timber even though the watershed is set aside as a game preserve, as the law makes no reference to such activities.(18) However, since the Village of Bonners Ferry is the furnisher of the domestic water consumed by its inhabitants, it is required to protect that water supply. This could be done, either by means of a cooperative agreement with the loggers, or if this fails, after all precautions are adhered to by the logger, by installing additional water treatment equipment.

Another possibility of obtaining silvicultural and logging practices commensurate with a continued supply of satisfactory water is for the United States Forest Service and the Pack River Lumber Company to enter into a land exchange agreement. Investigations have been started in this direction, and three alternative solutions have been recognized. One is to make a tripartite agreement whereby the United States would buy the private land and timber from timber sales proceeds. Another solution is for the United States to exchange some of its timber for the residual timber on the company's land left as a result of a pre-cutting agreement concerning methods used by the company in cutting its own timber. Or, the United States could acquire the Pack River Lumber Company's lands after it had cut them in whatever manner it may have chosen.

Community's Desire for a Sustained Lumbering Industry in the County.--Most of the best timber in the county has in years past been logged off by large private operators, and only part of it was milled in the county. Thus the local people derived very little benefit from their once vast resource. Now, large private concerns from outside (outside at least in the eyes of some of the local people) are beginning to bid on national forest stumpage and the community is becoming fearful of having its small mill economy destroyed. They, therefore, would like the national forest lands logically tributary to Bonners Ferry formed into a Federal Unit under the Sustained Yield Law, except for the parts in the vicinity of Myrtle Creek that are checkerboarded with Pack River Lumber Company lands. This would leave such parts open to competitive bidding by all or subject to exchange and management as per pre-cutting agreement or other methods.(23,45,46,47,48,49)

DESCRIPTION OF THE WATERSHED

Acreage and Timber

The Myrtle Creek watershed lies almost entirely within Township 62 North, Ranges 1 & 2 West, Boise Meridian. The area involved is the same as that established for the Myrtle Creek Game Preserve, and covers 22,574 acres. Eighty-three per cent, or 18,691 acres, is national forest land; 17 per cent, or 3,883 acres, is private (Pack River Lumber Company, or under option by them from the Northern Pacific Railway Company). About half of the watershed is covered by merchantable stands, one-fourth poles and seedlings and saplings; and another fourth is composed almost entirely of subalpine type. Eighty-one per cent of the area and eighty-nine per cent of the volume are in Zones I and II.[1] See Figure 2 for ownership and operability patterns.

Table 1 shows the acreages per site class, degree of stocking, and volumes of each species present for all the timber types in the watershed. The legend in Figure 3 explains site class and degree of stocking.

Except for a body of ponderosa pine lying between two and four miles up the creek, on the south exposure, practically all the merchantable timber is in the upper half of the watershed. Downstream from this lie most of the immature

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[1]Under Forest Survey procedure timberlands were divided into three zones of operability. Zones I and II are considered to be operable now, while the topography and timber in Zone III make it appear quite unlikely that it will be economical to log for many years to come.

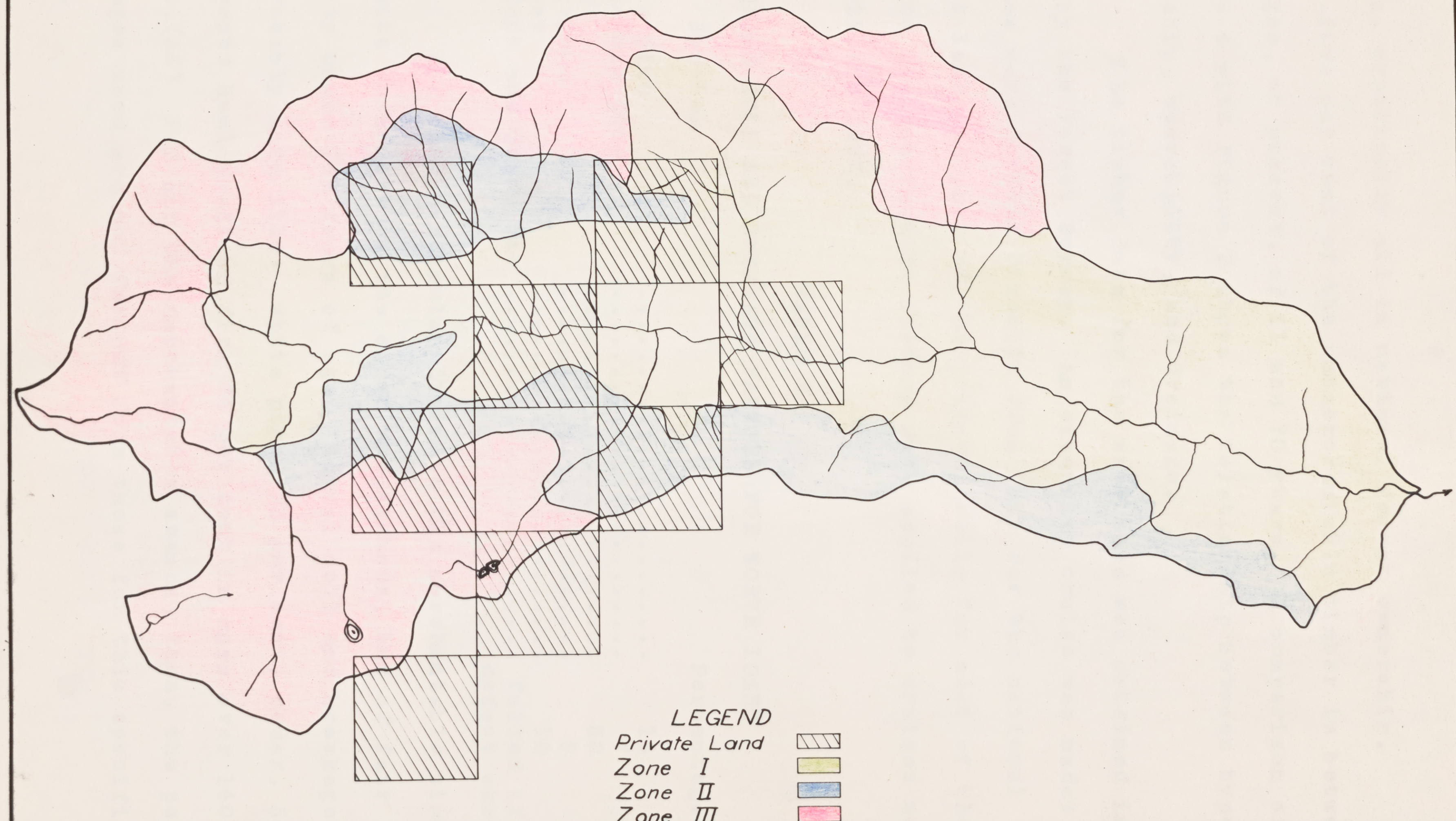


Fig. 2.—Ownership and zones of operability

stands, practically all in national forest ownership. Fifty-five per cent of the nonmerchantable timber is between the ages, at present, of 51 and 70 years. A comparison of Figure 4 with Figure 2 shows the relationship between types, ownership, operability, and drainage.

The timber data for the watershed was obtained in 1935 by the Forest Survey. An extensive cruise was made; volumes were derived directly from this for the national forest land and part of the private, while for most of the private land correction factors were applied to cruises made in 1921 and 1922.

TABLE 2

AVERAGE CULL AND BREAKAGE FACTORS FOR NORTH IDAHO

Species	Percentage
White pine	14
Ponderosa pine	7
Cedar	30
Lodgepole	5
Spruce	10
Hemlock and Grand Fir	Culled if defect showed

For this particular drainage the merchantable timber is quite defective in the older age classes, but of fair quality under 140 years of age. Actual cull and breakage is probably more like: white pine, 25 per cent; cedar, 50 per cent; hemlock-grand fir, 65 per cent in ages over 140 years.(36) For all the merchantable stands, then, the percentages used are not far off from those for this specific area.

FOREST SURVEY MAP LEGEND

Color 1/	Type No.	Type Name-Description	Stand class
		FOREST	
D 369	1	(Western white pine	) Saw timber
	1a	(	) Poles
	1b	(15% or more W. P. net cubic volume	) Seedling & sapling
D 372	2.8	(Pure ponderosa pine	) Saw timber
	2.8a	(	) Poles
	2.8b	(80% or more P. P. net cubic volume	) Seedling & sapling
D 372	2	(Mixed ponderosa pine	) Saw timber
	2a	(	) Poles
	2b	(25% to 79% P. P. net cubic volume	) Seedling & sapling
D 386	3	(Larch-Douglas fir	) Saw timber
	3a	(75% or more L-D.F. net cubic volume	) Poles
	3b	(10% or more larch	) Seedling
D 383	4	(Hemlock-grand fir	) Saw timber
	4a	(	) Poles
	4b	(50% or more H-G.F. net cubic volume	) Seedling & sapling
C 25	5	(Douglas-fir	) Saw timber
	5a	(	) Poles
	5b	(60% or more D.F. net cubic volume	) Seedling & sapling
D 376	6	(Engelmann spruce	) Saw timber
	6a	(	) Poles
	6b	(50% or more E. S. net cubic volume	) Seedling & sapling

Color 1/	Type No	Type Name-Description	Stand class
D 370	7	(Lodgepole pine	) Saw timber
	7a	(	) Poles
	7b	(50% or more L. P. net cubic volume	) Seedling & sapling
D 378	8	(Western redcedar	) Saw timber
	8a	(	) Poles & piling
	8b	(50% or more W. R. net cubic volume	) Seedling & sapling
D 378	9	(Redcedar-grand fir	) Saw timber
	9a	(	) Poles & piling
	9b	(50% or more W.R.-G.F. net cubic	) Poles
	9c	(volume	) Seedling & sapling
C 10	10	(Black cottonwood	) Saw timber
	10a	(50% or more B. C. net cubic volume	) Poles and Seedling & sapling

To the preceding type symbols may be prefixed the symbols x, 12x, or 12. The prefix x is used to indicate saw-timber stands from which logging has removed 10 percent or more of the volume. Similarly 12x and 12 indicate pole, and seedling and sapling stands respectively on areas that have been logged.

Whenever a given stand could be classified into more than one type according to the above definitions, preference was given to the white pine, ponderosa pine, and larch-Douglas fir types in the order named.

Stand Definitions

Saw-timber stands - Stands in which the plurality of the net cubic volume is in trees of saw-timber size - trees of all pines, redcedar and hardwoods 11.0" and larger d.b.h., and of all other species 13.0" and larger.

Poles and piling stands - Applies to cedar and cedar-grand fir types only. Stands averaging more than 8 merchantable cedar poles per acre.

Pole stands - Stands in which a plurality of the cubic volume is in trees 5.0" d.b.h. to saw-timber size.

Seedling and sapling stands - Stands in which a plurality of the net cubic volume is in trees less than 5.0" d.b.h. (less than 11.0" d.b.h. for cedar pole type).

1/ Saw-timber stands are colored solid. Pole stands are colored with diagonal lines. Seedling-sapling stands, with vertical lines.

Color	Type No.	Type Name	Description
	13	Nonrestocked cutover	Cut prior to 1925
2/	14	Nonrestocked cutover	Cut since 1925 (Less than 10% stocked at present. Shows type on area prior to cut or burn.)
	15	Nonrestocked burn	Burned prior to 1925
2/	16	Nonrestocked burn	Burned since 1925
D 381	11	Subalpine	Above upper limits of productivity.
D 335	22	Juniper	80% or more Rocky Mountain juniper.
D 309	23	Rocky noncommercial	Rocky, sterile areas. Shows type on area.
2/	(W)	Woodland	Areas of scattered trees singly or in groups generally bordering on nonforest areas.
		NONFOREST	
D352½	17	Barren	
D353½	18	Grass	
D324½	19	Brush	
C31	20	Cultivated	
C21	21	Stump pasture	

2/ Use type color

Stocking:
Saw-timber stands

	Ponderosa Pine & Lodgepole Pine types	Other types
	Thousand board feet per acre (Scribner log scale)	
P	3.0 to 6.9	4.0 to 9.9
M	7.0 to 12.9	10.0 to 19.9
W	13.0 and more	20.0 and more

Pole and seedling & sapling stands

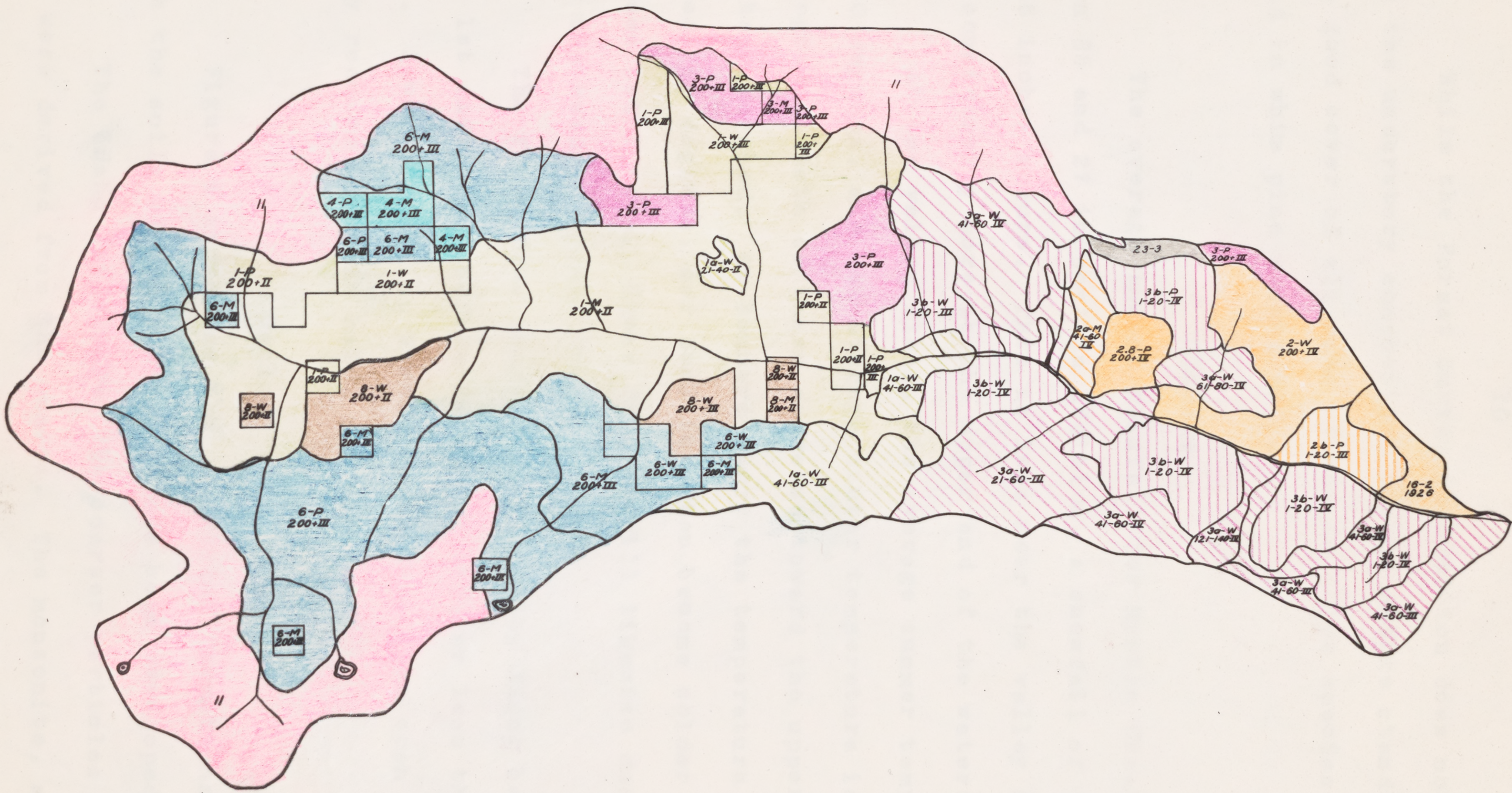
	All types
P	10 to 39 percent stocked (Stocked quadrat basis
M	40 to 69 percent stocked
W	70 percent and over

Site classes: I highest, III average, and V low.

Ages: Twenty-year classes: 1-20, 21-40, etc. to 160 years, then 161-200 and 200+

6-1942

Fig. 3—Forest Survey Map Legend



LEGEND
See Fig. 3

Fig. 4—Forest Survey Type Map

While the Forest Survey information does not indicate the understory composition of the mature stands, there is a good cover of all ages of the inferior species usually found in white pine association.

Climate

The average annual rainfall for Myrtle Creek is between 25 and 27 inches; in addition, a snowfall of from 48 to 56 inches occurs. This is less near the valley floor, and considerably more at the upper end of the watershed.

At the valley floor, the average summer temperature is 60 degrees, and the average winter temperature is 20 to 25 degrees. Both of these decrease toward the upper reaches of the watershed. At Bonners Ferry the temperature seldom exceeds 90 degrees, nor does it often become colder than 10 degrees below zero. These figures will likewise decrease near the head of Myrtle Creek.

The frost-free season in the valley floor begins after June 1st and closes before September 1st, or less than ninety days. Several miles up Myrtle Creek this time span is probably reduced about in half.

Geology

Figure 6 indicates the underlying formations from which the soils of the watershed have been developed.

The Idaho Batholith: The coarser particles of the soil were derived from the quartz. The monzonite, a granular igneous rock containing large quantities of feldspar,

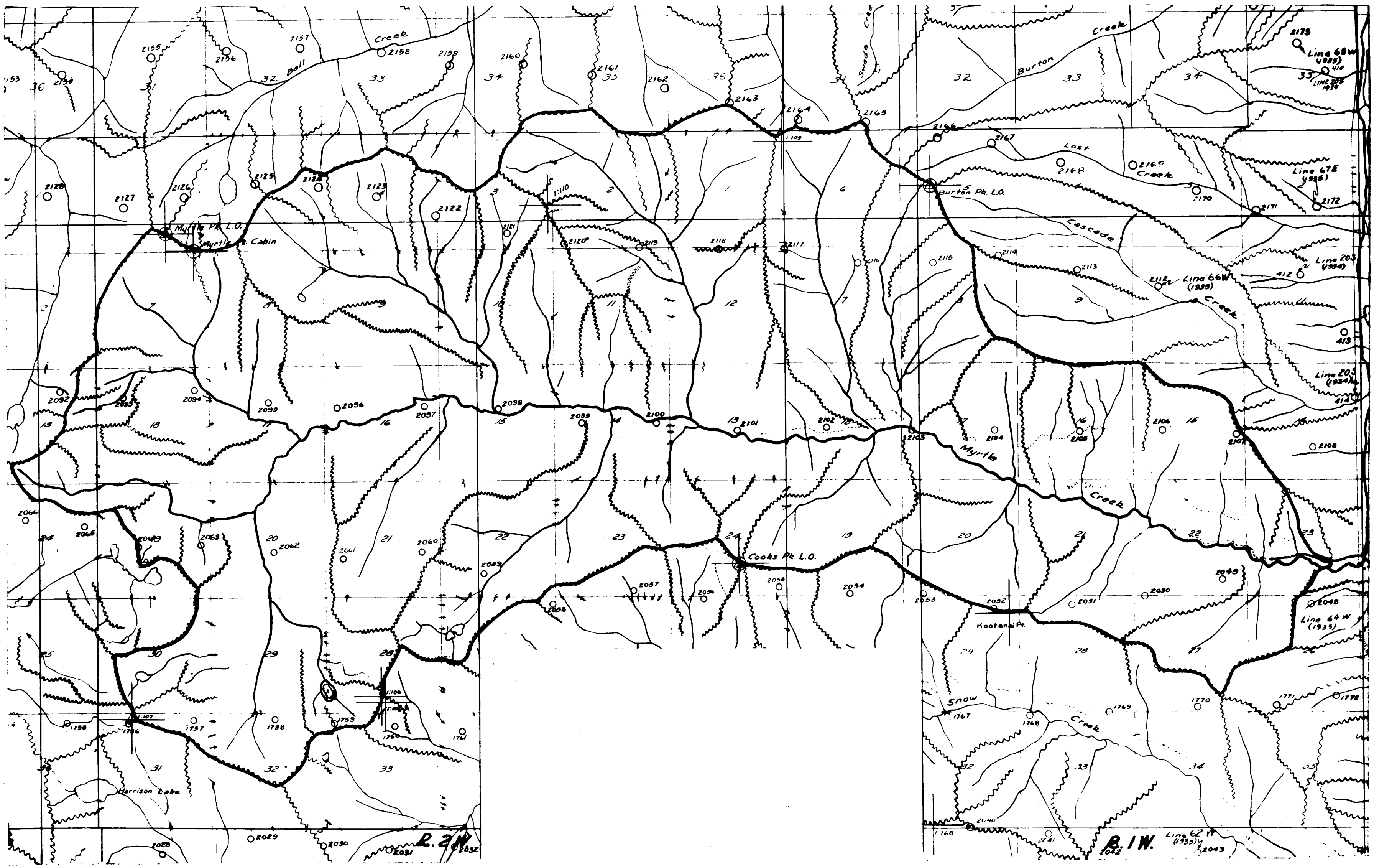


Fig. 5 — Drainage Map

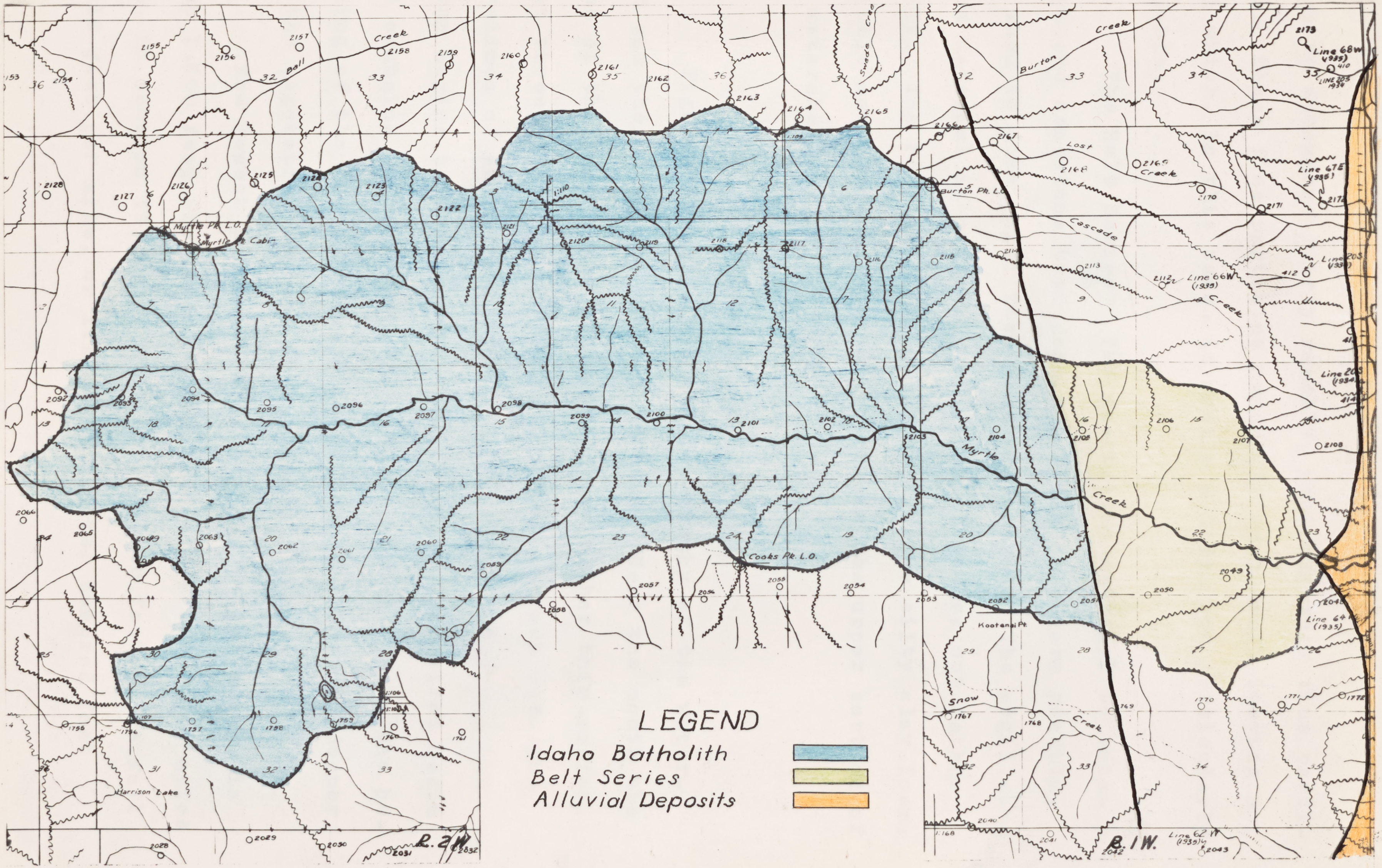


Fig. 6 — Geological Map

tends to decompose fairly readily, yielding very fine particles. These fine particles gradually wash away, leaving a soil which, in this case, is mostly a loam, not particularly erodable.

The Belt Series: The quartzitic material is metamorphosed sandstone that does not break down very readily, but when it does, will form sand and gravel. The argillaceous material is primarily clay, which washes out rather easily. The resulting soil is a silty to a silty clay loam, a little more erodable than the soil in the upper portion of the watershed.

Topography

Figures 1 and 5 show the topography of the watershed and the manner in which it drains. Near the mouth the sides of the canyon are quite steep and rather thin-soiled. About three miles up, the canyon begins to bench out--the shorelines of an ancient lake. About eight miles up, the canyon begins to broaden out into a rather good-sized basin that contains most of the merchantable timber. From the beginning of the old lake shore bench the soil becomes deeper and the vegetation becomes increasingly dense.

The lowest point of the drainage, at the mouth, is about 1,800 feet elevation; where the stream forks 9.4 miles west, in section 17, the elevation is 4,800 feet. The fall is 319 feet per mile, or six feet fall per hundred feet traverse. Myrtle Peak and Harrison Peak reach an elevation of 7,000 feet, although the average high rim around the upper portion of the watershed from Burton Peak to Cooks Peak is about 6,500 feet.

Figure 7 shows the profile of Myrtle Creek, from the old "Power Dam" (present intake station) at the lower end, along trail number 7 and along the branch just south of trail number 262 to the top of the watershed. Also shown are north and south transverse sections taken as indicated on the stream profile.

The Stream

There has never been any particular reason to take periodic stream flow measurements of Myrtle Creek, except for its extreme low water flow. As mentioned earlier, this is about 5 c.f.s., or twice the capacity of the present water line.

The stream bottom is down to the parent material through most of its course. The actual stream bed is very rocky, contains many long slabs of bedrock, a great number of weathered boulders, and deposits of sand in the pools and flatter stretches. As Figure 7 shows, it has an average gradient of 6 per cent through its main course.

The volume of stream flow is relatively unaffected by drouth. In dry years the minimum flow is still about 5 c.f.s.

Flood stage does cause a slight amount of silt in the

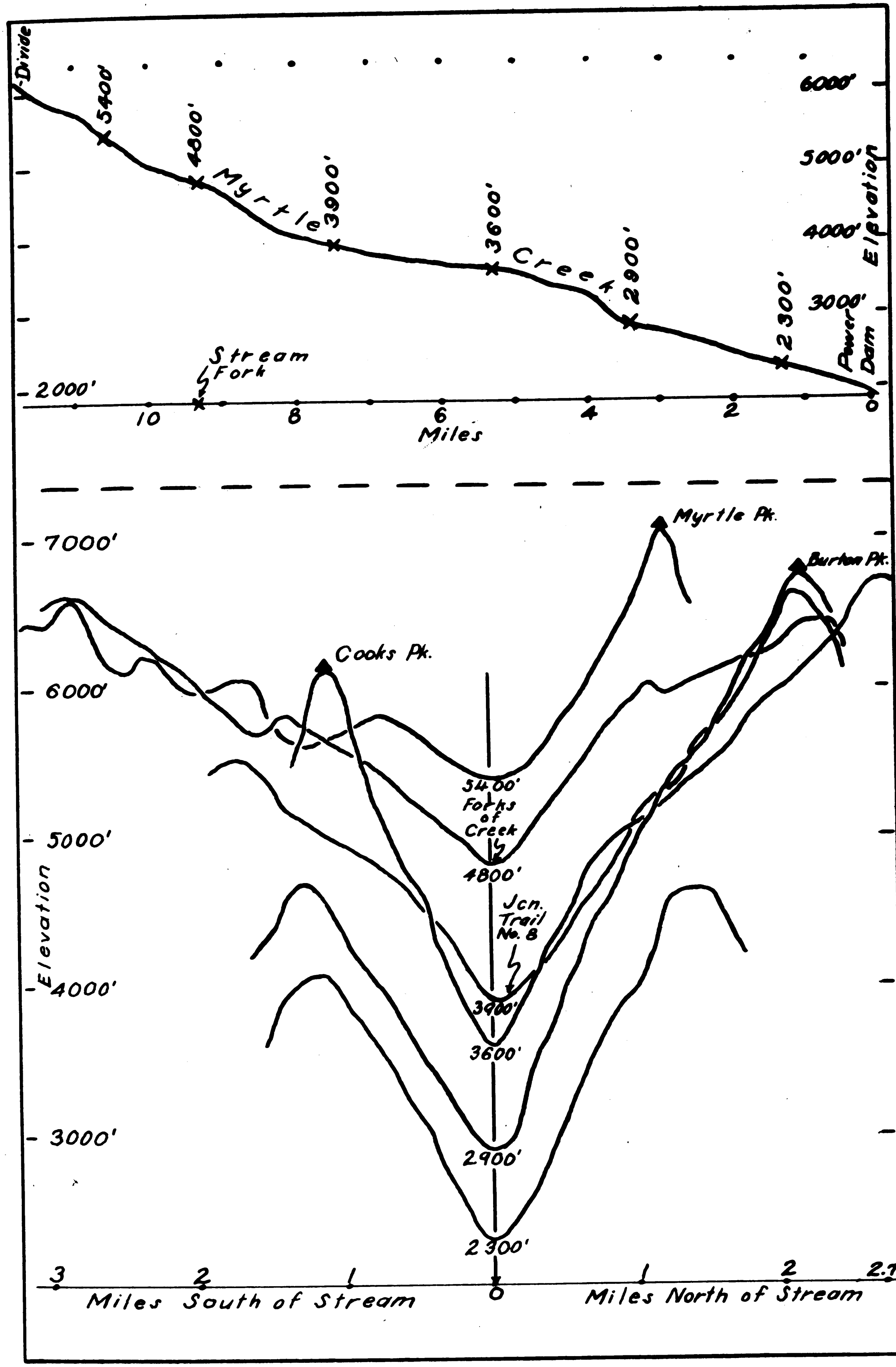


Fig 7—Profiles of Myrtle Creek

water for a short period of time. In May, 1948, the worst flood of this century flooded the entire Kootenai River Valley. Water rushing out of many streams nearby washed out the road along the west side of the valley and carried great quantities of debris with it. The flow from Myrtle Creek did not scour its banks, nor did it carry an undue amount of debris. Eddy currents caused by the large flow did undermine the center pier of the Myrtle Creek bridge on the 'west side' road, but had the construction principles been more sound, this would not have happened. The effect on the water supply was not determined, as the main water line was broken as a result of the river's breaking through its dikes.

Fire Occurrence

The fire problem in Myrtle Creek is not a particularly serious one. Figure 9 indicates the number and distribution of fires from 1931 through 1946. Several fires appear to be located outside the watershed area. The positions of such fires, however, are so located as to have the same potential danger to the watershed as those wholly within. This is especially so with the five fires in the vicinity of the intake station. No record was obtained as to the cause of the fires. It is very possible some of those last mentioned were man-caused, although lightning strikes do frequently come clear down to the stream bottom.

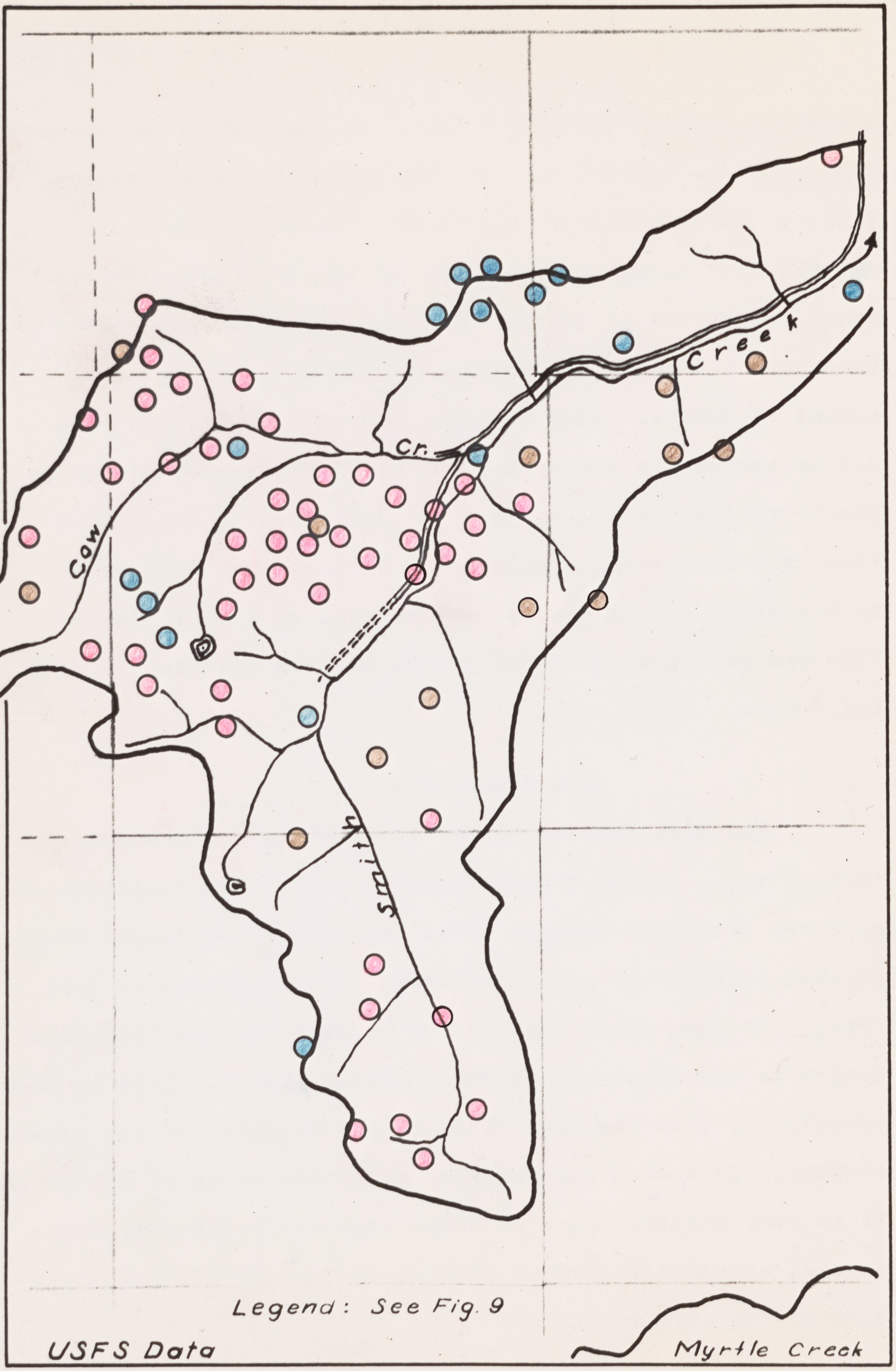


Fig. 8—Fire Occurrence in Smith Creek

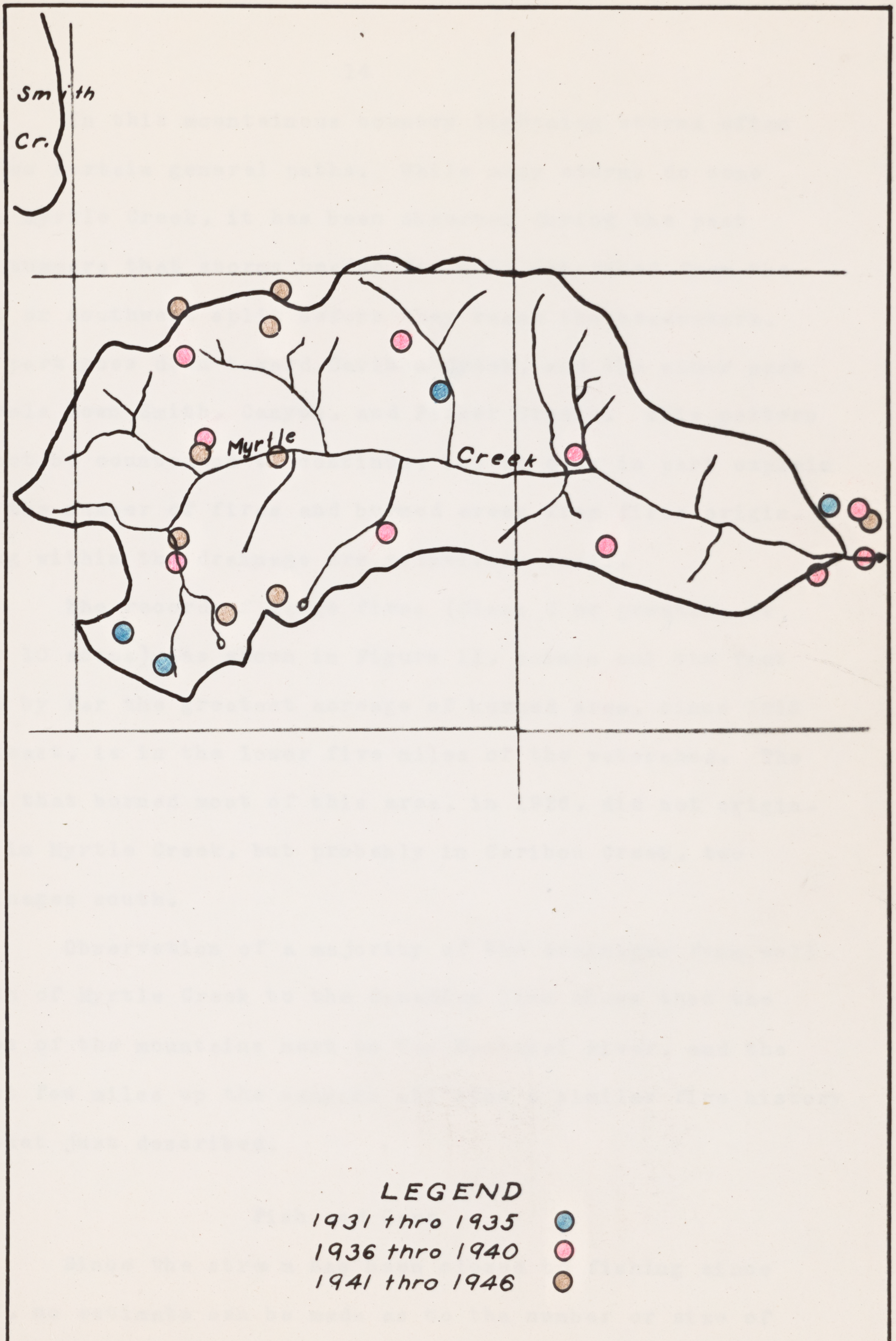


Fig. 9—Fire Occurrence in Myrtle Creek

In this mountainous country lightning storms often follow certain general paths. While many storms do come down Myrtle Creek, it has been observed during the past two summers that storms headed for this watershed from the west or southwest split before they reach the headwaters. One part goes down toward Caribou Creek, and the other part travels down Smith, Canyon, and Parker Creeks. This pattern cannot be counted on to continue, but it does in part explain why the number of fires and burned areas from fires originating within the drainage are relatively small.

The record of large fires (Class C or greater, or over 10 acres), as shown in Figure 11, points out the fact that by far the greatest acreage of burned area, since 1918 at least, is in the lower five miles of the watershed. The fire that burned most of this area, in 1926, did not originage in Myrtle Creek, but probably in Caribou Creek, two drainages south.

Observation of a majority of the drainages from well south of Myrtle Creek to the Canadian line shows that the faces of the mountains next to the Kootenai River, and the first few miles up the canyons all show a similar fire history to that just described.

Fish and Game

Since the stream has been closed to fishing since 1937, no estimate can be made as to the number or size of

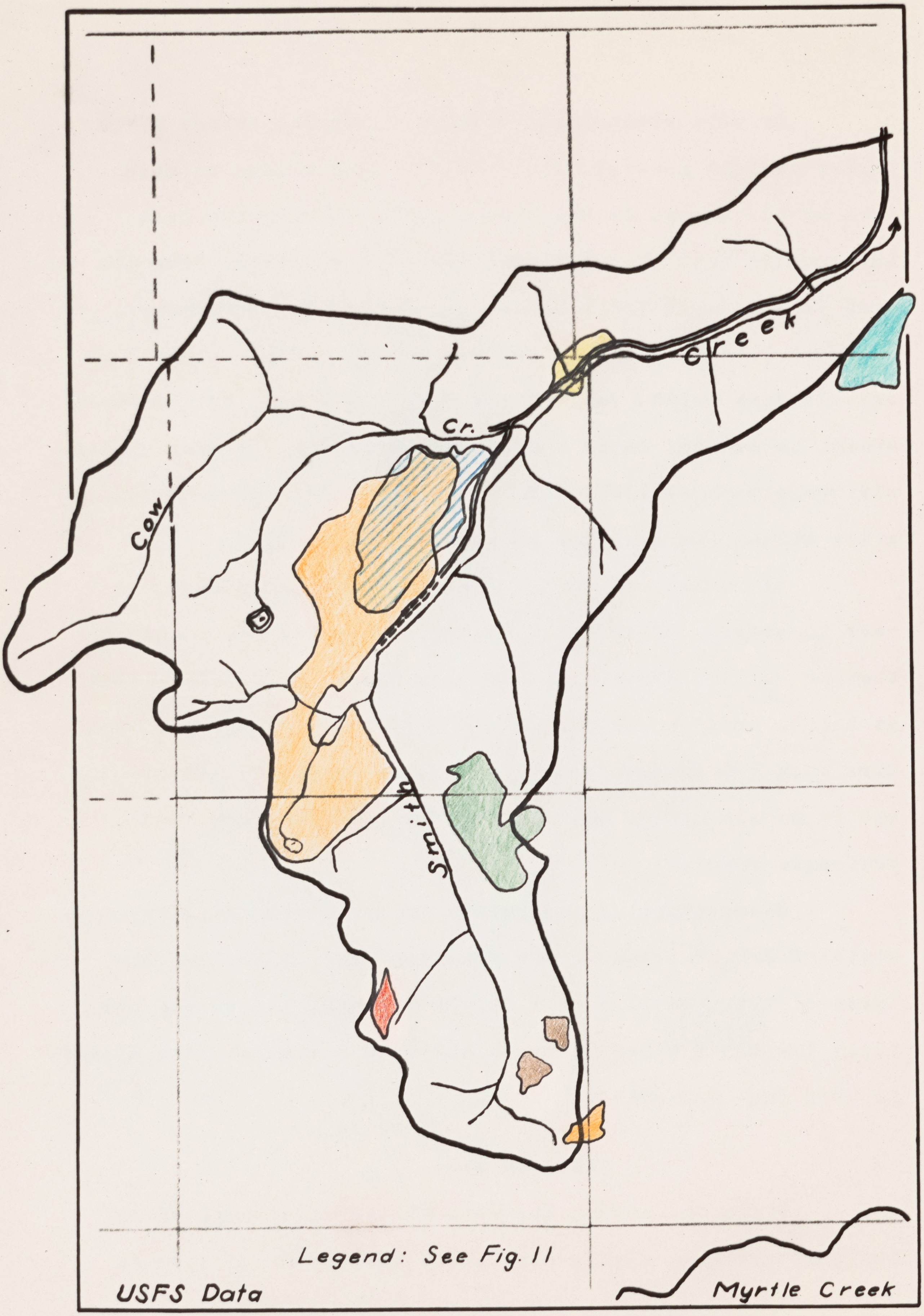


Fig. 10—Large Fires in Smith Creek

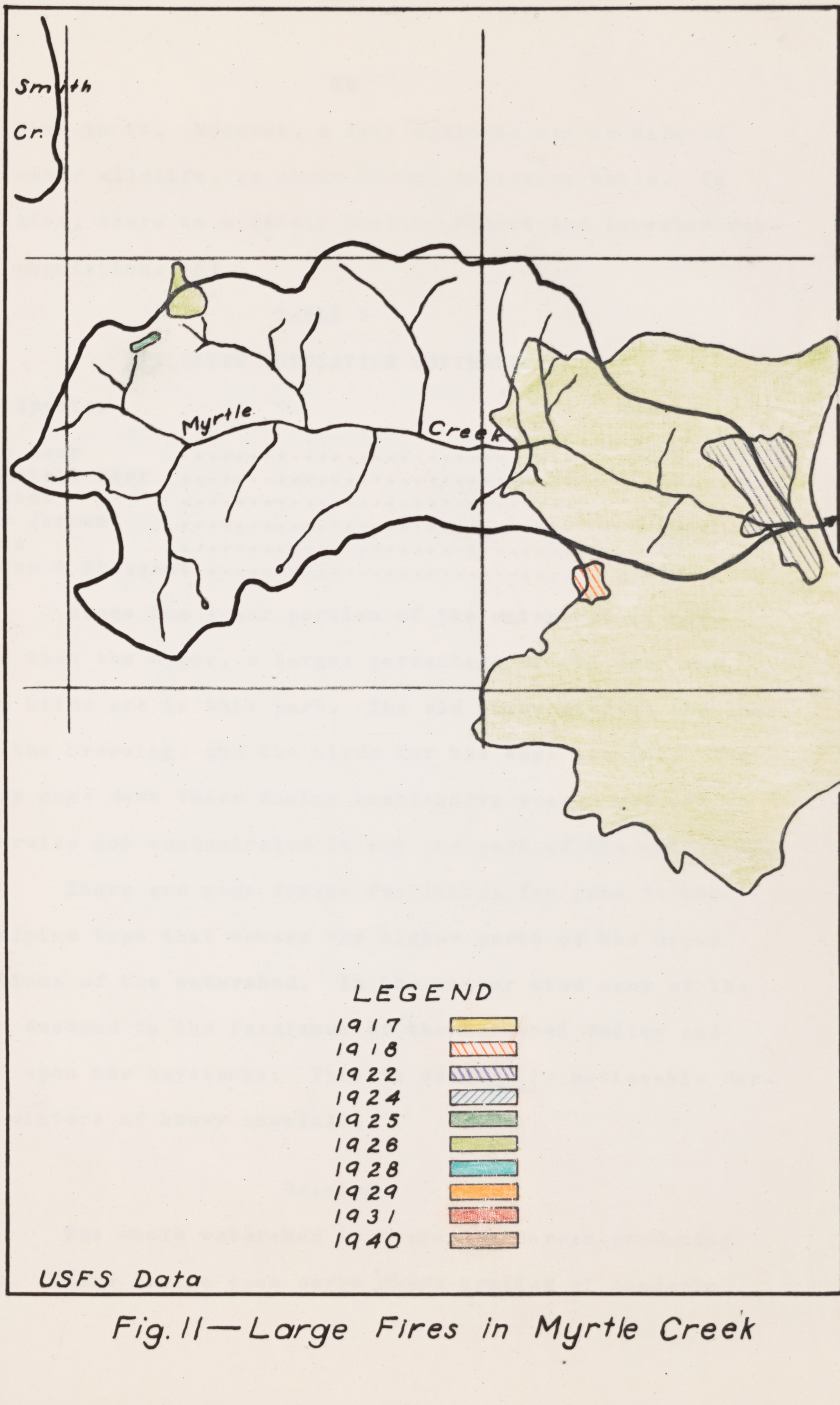


Fig. 11—Large Fires in Myrtle Creek

the fish in it. However, a fair estimate can be made of the other wildlife, as shown in the following table. In addition, there is a fairly healthy rodent and snowshoe rabbit population.(36)

TABLE 3

WILDLIFE POPULATION ESTIMATE

Species	Number
Mule Deer	200
Whitetail Deer	75
Coyotes	50
Bear (brown)	20
Goats	20
Grouse & Pheasant	500

Since the lower portion of the watershed is more open than the upper, a larger percentage of the deer and game birds are in this part. The old burns attract the deer for the browsing, and the birds for the edge present. The bears come down there during huckleberry season but are otherwise not concentrated in any one part of the watershed.

There are some forage facilities for game in the subalpine type that covers the higher parts of the upper portions of the watershed. In the winter time many of the deer descend to the farmlands of the Kootenai Valley and feed upon the haystacks. This is especially noticeable during winters of heavy snowfall.

Grazing

The whole watershed is typically forest-producing land. There are no open parks where grazing of domestic stock could be carried on. The areas that have burned come back to brush and reproduction before grass gains a foothold. This affords a certain amount of browse for the deer but little more.

Recreation

The only recreation afforded the people by Myrtle Creek at present is the opportunity to enjoy its beauty while hiking through. Outside of the forest protection and maintenance crews there is an estimated annual number of fifty visitors travelling through the watershed.(37) There are no developed camping or picnicking areas.

GENERAL INFORMATION

Experiments Conducted Relative to Forest Influences

There have been a number of controlled experiments conducted in the past forty years dealing with the interrelationship between forests and stream flow. The effects of such actions as denudation, logging, and burning on processes such as absorption, evaporation, transpiration, run-off, erosion, and stream flow have been studied. Each of the above will later be discussed separately as it applies to the Myrtle Creek watershed. However, since several of these studies involve more than one of the influences, the description and results of the experiments, and pertinent accompanying remarks will be grouped here for later reference.

The Wagon Wheel Gap Experiment

Forest and Stream-flow Experiment at Wagon Wheel Gap, Colorado is a very complete study of the effects of forest cover on stream flow and erosion, under the conditions of the central Rocky Mountains.(3) This was begun by the United States Forest Service on the Rio Grande National Forest, near Wagon Wheel Gap, Colorado, in 1909. The project was completed in 1926, and the final report written in 1928 by C. G. Bates of the United States Forest Service, and A. J. Henry of the United States Weather Bureau. Before the experiments were conducted, it had been assumed that forests reduce the magnitude of ordinary seasonal floods, tend to maintain stream flow in dry weather, and, perhaps most important of all, prevent erosion of the land which they occupy or adjoin, thereby reducing the amount of silt carried by the streams and lessening the damage done by flood waters to fertile fields.

The plan was to use two small contiguous and similar watersheds, keep close record of conditions of weather and stream flow on these areas for a number of years, then denude one of the areas and keep record on the effects upon the time and amount of stream flow, amount of erosion, and quantity of silt carried by the stream.

Observations were started satisfactorily in July, 1911. In July, 1919, denudation of watershed B was begun, and continued until the spring of 1920. The larger timber was taken out, and the loppings and most of the aspen were piled in windrows, running up and down the slopes and burned in 1921. A 25 foot wide strip of timber was left along the stream until the autumn of 1920.

The topography is as shown in Figure 12. Both areas contain about 200 acres; their slopes are 25 per cent.

The soil is an augite-quartz-latite, breaking down into a rather fine and compact clayey loam. However, the slope steepness causes just enough sheet erosion to take place to prevent a deep soil from developing; also much rock fragmentation is present. Leaching and erosion tend to rid the soil of finer sand and clay, leaving the coarser

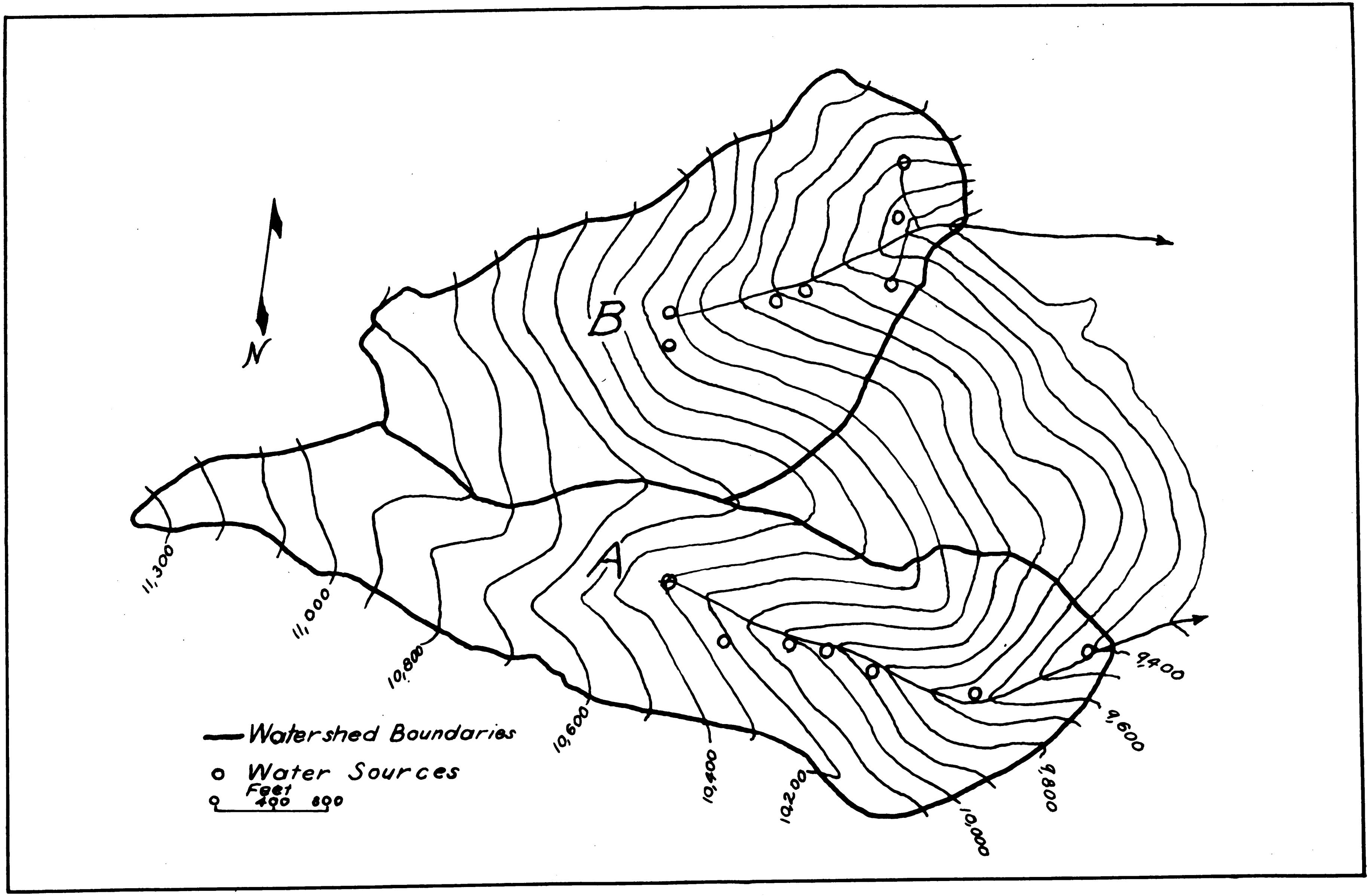


Fig. 12— Wagon Wheel Gap Watersheds A and B

sand. The result is a quite permeable and well-drained soil layer highly receptive to water. This fact should be kept in mind when considering the results of this experiment and their application under other conditions.

The permanent cover type is Douglas-fir, blending to spruce farther up. A fire in 1885 changed the composition temporarily to become as follows:

TABLE 4

COVER TYPES, WATERSHEDS A AND B

Cover Type	Area Percentage	
	A	B
Burned and not restocked	9	7
Barren or rock slide	3	3
Grass	9	6
Aspen and conifers	79	84
Total	100	100

Removing the cover on watershed B had no appreciable effect on the area, except for one small gully in one skid trail. Soil temperature in B was raised an average of 2.8°F over that of A. The average daily discharge, nearly the same before denudation, increased in B over A after denudation 9.4 per cent.

Since the timber stand was not heavy, denudation did not have as great an effect on snow melt as if a complete canopy of conifers had been present. The date of snow disappearance was four days earlier in relation to A after denudation. Removal of the aspens permitted several snowslides to occur in B.

Denudation was responsible for very little difference in soil moisture between A and B.

Table 5 shows the disposition of the annual precipitation.

TABLE 5

EFFECT OF FOREST ON DISPOSAL OF PRECIPITATION AFTER DENUDATION

Water-Shed	Precip-itation Total Inches	Stream Flow			Evaporation					
		July-Feb.	In Flood	Tot.	Losses from Ground and Snow Surface	Snow Interception	Transpiration by Cover	Winter Evaporation	Summer Evaporation	Total Losses by Evaporation
A	21.16	2.28	3.92	6.20	7.45	2.51	5.0	7.06	7.90	14.96
B	20.83	2.54	4.72	7.26	9.07	0.50	4.0	6.00	7.57	13.57

Before denudation the average annual discharge of both A and B was 29 per cent of the average precipitation of its own area. After denudation A was still 29 per cent, while B was 35 per cent, an increase of 6 per cent of B over A.

After denudation the discharge of B was decidedly higher than A for March and April, indicating the effect of earlier and more rapid melting as a reasult of denudation.

From this it might be expected that B stream would fall to a lower level than A during the decline of the flood, and this appears to be the case, but the deficiency in June is comparatively small.

> The outstanding facts of this general survey are that on these watersheds, despite, or perhaps as a result of great porosity of soil which guarantees deep penetration of precipitation and snow water, 70 per cent of the total precipitation goes back into the atmosphere without reaching the stream channels. An appreciable increase in streamflow is effected by removal of the trees, although this occurs mainly in the flood period where it is quite as likely to be damaging as beneficial.

Before denudation erosion and silt deposition of B was 82 per cent of A, while after denudation B was seven times that of A. The greater quantity of silt removed by B was not entirely due to higher floods each year, as the summer and winter quantities were also increased. "This undoubtedly denotes some loose material being brought to the stream channel, in addition to what might be considered normal scouring and deepening of the channel. . . . . this erosion from the slopes was practically invisible . . . ." This increase is not serious on this particular soil compared to other soils and conditions, as "there is no problem of freshets caused by surface run-off, the size and destructiveness of which is often greatly enhanced by the loads of silt which they carry."

Before denudation the flood run-off was the same on both watersheds. Three years after denudation B had reached a peak of 35 per cent excess over A; at the end of the experiment this was down to 22 per cent.

Conclusions.--The soil absorbs readily without appreciable run-off or erosion and therefore represents an excellent reservoir for the storage of precipitation that is released in greatest abundance when snow melts in the spring. High heads were produced only when the ground had become saturated with snow water.

The absolute height of a flood crest is an inverse measure of the value of the watershed for storage.

There was no evidence that the removal of forest cover appreciably affected the summer demand for moisture. Surface drying evidently proceeded in just about the same way with forest or herbaceous vegetation. Stream flow, then, is on the decline until the lessening of surface demands for moisture permits current precipitation to reach the deeper soil and add to the supply which is flowing slowly toward springs. Stream flow in the midsummer period, in the locality of this study, is dependent quite largely on the storage capacity of the watershed. In other localities it may be more, or less, dependent, as the current precipitation is less, or more, adequate to meet the current demands of evaporation. In other words, the low stage of stream flow reached in later summer is in some degree a further measure of the storage capacity of the watershed, and still more clearly a measure of the need for storage capacity. "The ratio of the high stage of a stream to its low stage, as reached within these general limits of time is, therefore, a direct measurement of the need for protection of the watershed as a storage reservoir." A high ratio means all possible should be done to lower the flood crests by retarding snow melt or increasing absorptive capacity of the soil.

"In the absence of direct measurements of stream flow, the extent to which erosion of a watershed has occurred may be used as a basis for estimating the liability of great extremes of run-off."

On the denuded area the original ratio of high to low stages was about 12 to 1, and denudation increased this only to 17 to 1. The high stages were made much higher and the low stages were also made slightly higher.

> . . . .In other words, though the snow water was made available earlier and in more concentrated volume, the watershed was still capable of absorbing it after denudation and of retaining for discharge throughout the year a greater volume than before, although the amount retained was not increased in proportion to the flood volumes. . . . Any flood excess of water that does not go into the storage reservoir, can have no effect on the low water flow from that reservoir.
>
> It is therefore proposed that the ratio of high to low stages indicates the liability of failure of the watershed to exercise its full storage function and hence the need for protective influences which will cause the function to be exercised to the fullest possible extent, with the probability that so far as spring storage is increased summer flow will be increased, and will not be appreciably decreased by the growing-season drain of the forest cover.
>
> From the evidence of this study it is estimated that in a locality where the normal ratio of high to low stages is more than 25 to 1 with moderate pro-

tective cover, the probabilities are strong that the low stages would be made still lower by removing that protection.

Many streams much larger than those involved in this study have ratios of from 50 to 1, and occasionally 150 to 1, "indicating infinite possibilities for variation in the climatic and soil factors affecting absorption and retention by watersheds and the need for inductive reasoning in the attempt to relate even quantitatively the results derived from one set of conditions to those which might be given by another set of conditions."

The Hoyt-Troxell Report

"Forests and Stream-flow" is a paper which was presented at the annual convention of the American Society of Civil Engineers, Yellowstone National Park, Wyoming, July 6, 1932.(15) The paper deals with a further consideration of the effects of the change in vegetative cover on the stream flow characteristics of the Wagon Wheel Gap experiment, and of the Fish and Santa Anita Creeks study in Southern California. The essential features of the latter study will first be summarized. Following that will be the conclusions drawn on both studies by the paper's authors, W. G. Hoyt and H. C. Troxell, engineers for the Conservation Branch, and Water Resources Branch, respectively, of the United States Geological Survey. Pertinent criticisms by several scientists and hydrological engineers will be considered under 'Discussion.'

In August, 1924, a forest fire completely denuded the Fish Creek and other watersheds, located a few miles east and north of Monrovia, California. The Santa Anita watershed nearby was not burned at all. The United States Geological Survey had been operating gauging stations in these watersheds for several years and had some reliable data, although since no fire studies had been planned,the information was not nearly so complete or appropriate as that for Wagon Wheel Gap.

Both Fish and Santa Anita Creek canyons are well defined topographically, and are quite similar as to elevations, slopes, gradients, and cover types. The side walls of both are steep and rugged. Fish Creek canyon, containing 6.5 square miles, is oblong and heads southeast, while Santa Anita Creek canyon, containing 10.5 square miles, is more fan-shaped, and heads southerly. Cover consists of sumac, mountain mahogany, white sage, grass, and yucca. Some oak grew in sheltered areas, and along the canyon bottoms were sycamores and alders.

The fire stripped Fish Creek of all plant life and tree litter, except for a few patches of sycamore and alder. After the first rains the following spring a different plant association comprising sage, wild flowers, and grasses developed, which tended to cover the soil left bare by the fire.

Rainfall and temperature records are those of nearby places, and give only general information as far as the two watersheds are concerned.

The maximum gain of actual run-off over normal in Fish Creek occurred during the second year after the fire, and amounted to 26 per cent. The average annual increase in run-off of Fish Creek over Santa Anita Creek was 28 per cent. The following table shows conclusively that the increase in run-off after the fire was not confined entirely to flood periods.

TABLE 6

DISTRIBUTION OF INCREASE, IN INCHES, IN RUN-OFF AFTER THE FIRE

Year ending Sept. 30	Total Increase	Increase during Flood Periods	Increase during Remainder of Year
1925	2.47	1.51	0.96
1926	3.12	1.61	1.51
1927	1.58	0.85	0.73
1928	0.68	0.08	0.60
1929	0.69	0.15	0.54
1930	0.74	0.23	0.51

The average ratio of discharge of Fish Creek to that of Santa Anita Creek was normally 1.55. During the first two years after the fire the maximum ratio was as high as 47.7. However, they soon dropped back to nearly normal.

The ratio of the run-off of Fish Creek to that of Santa Anita Creek for the first period was 0.45, and for the second period, 1.69. The maximum daily discharge during the first period (Fish Creek over Santa Anita Creek) was 0.32, while during the second period it was 1.67, an increase of some five times.

In Fish Creek, the first rains after the fire washed the ash and loose material from the side walls of the canyon into the stream to such an extent that three months after the fire the entire stream bed had been buried. This evened the gradient and decreased stream-bed friction enough to raise the normal velocity of 2 feet per second to an average post-fire velocity of 4.8 feet per second. Under normal conditions the erosion is negligible. Prior to the fire there was practically no movement of silt on Fish Creek except during the storm run-off, and by the third or fourth day after a storm the water was quite clear. In the first year after the fire the large deposits of silt caused considerable damage to orchards and other improvements. By 1930, the silt had been reduced to almost normal, and the appearance of the stream bed was much the same as before the fire.

Conclusions.--1. Total run-off. Forests did not conserve the water supply. Denudation caused an increase in annual yield of 15 per cent in Colorado and 29 per cent in Southern California.

2. Distribution of increase in run-off. The increase is not confined wholly to flood periods. Fifty-two per cent of the increase in Colorado occurred during

the non-flood period. This increase results from a) increased sub-surface flow and storage; or b) decreased transpiration; or c) both. The reasons for greater storage after denudation are a) less interception by trees, undergrowth, litter, and humus, and b) faster snow melting with corresponding decrease in evaporation. The gradual increase in plant growth and also transpiration may have caused the slowing down of the increase during the non-flood period after the second or third year.

3. Maximum daily discharge. In Colorado 46 per cent increase is due to increased sub-surface flow, as practically all the snow had melted several days prior to the date of maximum peak. The removal of vegetative covering clearly increases normal flood heights. In the second year after the Fish Creek fire the flood peak discharges were nearly the same as before the fire, indicating that the new growth, small as it was, exercised practically the same effect as the original cover in reducing flood crests. "Where rain passes directly into streams without entering the ground the flood peak for any small element of drainage area occurs so soon after the storm that removal of vegetative cover has little effect on the time element."

4. Summer run-off. This study disproves the belief that forests or vegetative covering will increase summer run-off and shorten the low-water period through the

exercise of storage functions. The average annual summer flow increased 12 per cent after denudation in Colorado, and 475 per cent in Southern California. Much of this latter great increase was probably a result of increase in sub-surface storage and decrease in transpiration and also the fact that summer flow in Fish Creek is normally very small.

5. Minimum daily discharge and date of occurrence. The average summer minimum flow in Colorado was increased about 12 per cent and the time of occurrence delayed about five days. In Fish Creek this was 400 per cent and a thirty day delay.

6. Winter minimum. There were no significant changes due to denudation in Colorado.

7. Erosion. In Colorado, there was practically no erosion after denudation, which should have been the case as there was little direct surface run-off either before or after denudation. In Southern California complete denudation increased erosion as a direct result of the increased surface run-off. Since data shows that new vegetation reduced the normal flood run-off to almost normal after two years, it can be argued that, if the Fish Creek watershed had been stripped of its vegetation by cutting instead of by fire, the presence of the roots and litter would have permitted the erosion to have been practically the same as with the original vegetative covering.

Deductions.--

If the facts as found are generally applicable to other similar areas which in their natural state support forest growth, then the hydraulic engineer and the water user mustweigh such protective influence as forest cover may have in lowering flood crests and in preventing or retarding erosion against the detriment resulting from decreased yield and reduced low-water flow during the critical growing period. If the small growth that springs up immediately after deforestation or denudation exercises practically the same effect as forests in reducing normal flood crests and in preventing erosion--without the detrimental effect which forest cover is shown to have on annual flow and flow during the summer low-water periods--then in basins where shortages in water supply are becoming critical or where abnormal expenditures have been made to augment water supplies, the maintenance of forests or reforestation for the 'conservation of water supply' may have an effect exactly opposite to that desired. . . . . Scientifically determined facts apparently do not warrant [forests] solely for the conservation of water supply. In regions where such supply is a controlling economic factor, careful study is needed to determine whether the value of increased water supply and better-sustained minimum flow which are shown to obtain without forests, does not outweigh the benefits of lowered normal flood flows and decreased erosion produced by forests, especially if these benefits can be obtained by shrubs or other small growth without the loss of water occasioned by forest growth.

Discussion.--C. G. Bates (Co-author of the Wagon Wheel Gap report) states in defense of his study:(2)

Criticism of this paper is not so much against the authors' conclusions, as they relate to the specific Western watersheds, but against their attempt to generalize from these water-sheds--which are extreme in character of soil and climate--as to the protective value of the forest under all conditions . . . .

. . . .

Much of this [Wagon Wheel Gap area] storage is undoubtedly beyond the reach of tree roots, so that the surface layer may become completely dried through root absorption, and still the deeper reservoir remains filled and supplies springs throughout long periods of dry weather. It is obvious that this effect on the low-

> water flow . . . . arises solely through increased surface absorption and the existence of a potential large reservoir in the deep soil and rock layers.
>
> . . . .
>
> It is for the conservation of the soil resource quite as much as the water resource or timber resource that the forester argues the need of 'protection forests'. In young, mountainous regions, Nature has decreed that one is indispensable to the other and that the building of soil in the first instance is dependent on the roots of trees and on lower forms of vegetation which grow on rock surfaces; then, on the chemical action of the organic matter which they deposit; and, finally, upon the protection from erosion which is furnished by the complete humus mantle.

A. L. Sondregger, Conservation Engineer, Los Angeles, California, mentions two schools of thought as to the better methods of salvaging part of the evapo-transpiration losses: (39)

> First--'Super-forestation' to the effect of producing a denser growth of native or other vegetation on the water-shed . . . . may be described as an effort to utilize the storage capacity of the water-shed to its maximum by increasing the absorption of precipitation and preventing flood waste by means of profuse vegetation. It presents, therefore, the logical solution for water-sheds overlying deep alluvial fills or glacial moraine, in regions enjoying abundant precipitation, where water supplies are required mainly for domestic purposes and depend upon underground supplies, springs, or unregulated stream-flow. Forestation of bare water-sheds would have a similar beneficial effect under such conditions.
>
> Second--'Light deforestation' to restrict the vegetation to a minimum compatible with the effective prevention of erosion, the intention being to diminish the evapo-transpiration requirements of the cover.
>
> . . . .
>
> The immediate effect . . . . is a greater surface run-off and lesser rainfall penetration, and the subsequent effect, a lesser evapo-transpiration loss. This result may be desirable in cases where the water demand exceeds the natural run-off and where storage of flood waste is practicable either in surface reservoirs or underground in the flood-plain.

J. C. Stevens, Conservation Hydrological Engineer, Stevens & Koon, Portland, Oregon, sums up the important conclusions quite simply: (40)

> The forest, like every other vegetable crop, consumes large quantities of water for its growth. Unlike small plants, however, it also dissipates large quantities of water by mechanical means. It prevents a substantial portion of rain and snow from reaching the soil, permitting rapid evaporation from branches and leaves. When the forest is removed, the water thus consumed by it appears as run-off. As new growths appear the run-off gradually diminishes again in proportion to this crop and mechanical consumption.

W. C. Lowdermilk states: (27)

> More recently the writer's studies (28) have shown that the capacity of a layer of forest litter to absorb water is of small importance in comparison with its function to maintain surface waters clear and the absorption capacity of underlying soil at its maximum. The mantle of soil in the final analysis is the absorbent of precipitation, not the forest.

R. E. Rule, Civil Engineer, Rule & Rule, Los Angeles, California, states: (35)

> Water that does not escape the root zone during the first quick gravitational drainage period following wetting has a negligible chance of ever passing out of reach of the plant roots. After gravitational movement has ceased, the ensuing capillary adjustment is so exceedingly slow and plant demands are so great that escape is practically impossible in any appreciable quantity. Where, as is the case in vast areas of mountain water-shed, the root zone comprises the total depth of the soil mantle, storage within the mantle for later release to streams is impossible except in negligible quantities.

H. S. Gilman, Civil Engineer; Member, California State Board of Forestry, San Dimas, California, states: (9)

> . . . . the measurement of water over a weir is not the final measurement of water yield. In practical diversion and application to use, the condition and usability

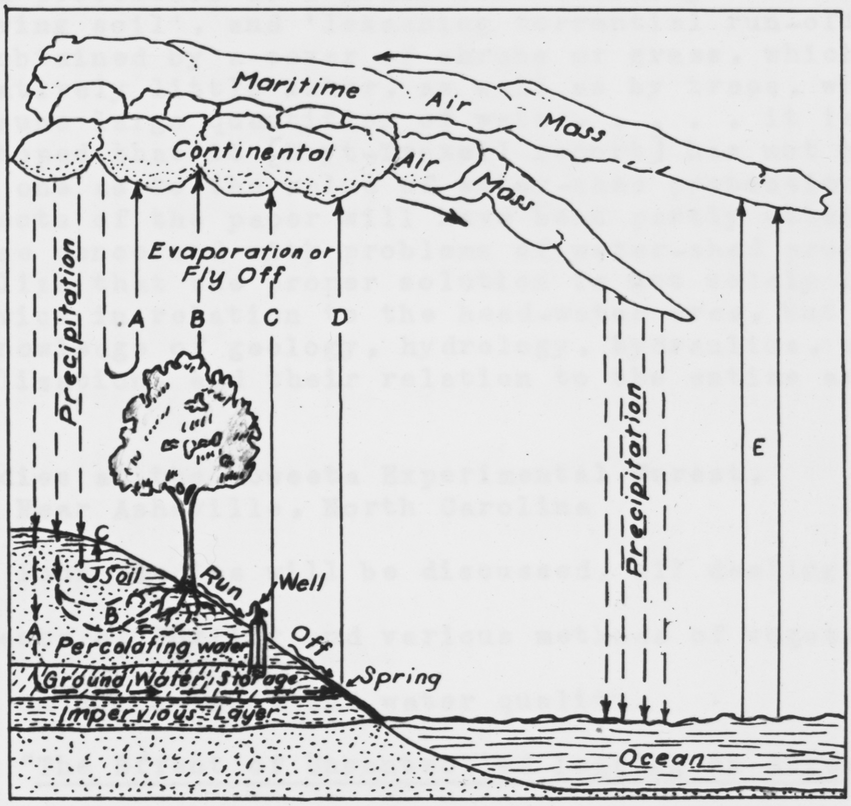
of the water, as well as the relation of mountain precipitation and run-off to basin recharge, are as important as the quantity. . . . . Suspended matter in water prevents percolation into the basins and is objectionable in both irrigation and domestic use.

C. H. Lee, Conservation Hydrological Engineer, San Francisco, California, states that proper conclusions cannot be reached by studying forest and stream flow data alone.(25) Refer to Figure 13--The Hydrologic Cycle. He summarizes the main hydrologic elements which influence stream flow:

Precipitation upon a water-shed finds disposal from the area either as water-shed losses, stream-flow, or sub-surface leakage. Water-shed losses consist of (a) evaporation from leaves and branches by interception (immediate); (b) evaporation from the soil (within 10 to 18 days after a storm); (c) evaporation from snow on the ground (within 2 to 6 months after a storm); (d) transpiration from vegetation (during growing season); and (e) evaporation from permanent water bodies, if any (continuous). Moisture that supplies transpiration from vegetation is derived from water temporarily absorbed by the soil, which remains within the root zone during the growing season and is in excess of the wilting coefficient of the soil.

Stream flow is derived from immediate surface run-off. . . . and from water permanently absorbed by the soil which penetrates below the zone of plant roots and joins ground-water at the water-table, reaching stream channels later as ground-water discharge . . . . Stream flow as measured at any point in the channel is a net quantity after deduction of channel losses, of which transpiration from riparian vegetation is usually the most important.

W. G. Hoyt, Principal Hydrological Engineer, Conservation Branch, United States Geological Survey, Washington, D. C., and H. C. Troxell, Assistant Hydrological Engineer, Water Resources Branch, United States Geological Survey, Los Angeles, California, in summing up their comments on the



Precipitation--Rain, Hail, Snow, Dew

Evaporation

- A. From air.
- B. Transpired and evaporated
- C. From land surface
- D. From lakes, streams, marshes, etc.
- E. From ocean.

Percolating Water

- A. Through soil to underground water storage--leaches soil.
- B. Enters roots of plants and trees.
- C. Returns directly to surface and is evaporated.

From Diagram, p. 90, Soil Conservation, Oct., 1937.

Fig. 13 --The Hydrologic Cycle

discussion of their report, state:(16)

> The writers would emphasize their belief that water-shed protection as a means of 'retarding erosion', 'conserving soil', and 'lessening torrential run-off', may be obtained by a cover of shrubs or grass, which may use relatively little water, as well as by trees, which may consume large quantities of water. . . . . it is sincerely hoped that it [Hoyt-Troxell report] has not misled any one as to the value of water-shed protection. The objects of the paper will have been partly attained if those concerned with problems of water-shed protection realize that the proper solution is not solely one of silvics in relation to the head-water area, but involves a knowledge of geology, hydrology, hydraulics, and water utilization, and their relation to the entire area.

Studies at the Coweeta Experimental Forest,
Near Asheville, North Carolina

Four studies will be discussed, all dealing with the effects of logging and various methods of vegetation removal on stream flow and water quality.

"The Effect of Uncontrolled Logging on Stream Turbidity".(26)--The purpose of this experiment was to measure how muddy the water became as a result of logging activity, and what effect run-off from the areas of disturbed soil had upon the stream hydrograph.

A timber sale was made in 1942 upon a 212 acre watershed, in which no regulations whatever, in way of protection of water, were made. The logging chance had a steep, generally rough topography, with the valuable trees in scattered stands. Horse teams ground-skidded the logs. Steep access roads and skid trails were constructed parallel and adjacent to natural stream channels, and comparatively little thought was given to their location and design.

Logging began in 1942, but not much was done until early 1945. Since then 2.3 miles of truck road have been bulldozed out. The volumes to be removed are about 200 M ft., b.m., of merchantable green timber, 80 M ft., b.m., of chestnut logs, and 1,300 cords of chestnut extract wood. Removal of this will result in a commercially clear-cut area. When the article was written, about 80 per cent of the volume had been logged off.

A comparison of the water samples taken daily on the logged area and on an adjacent control area similar in nature reveal what this type of logging has done to the resulting stream flow.

TABLE 7

STREAM TURBIDITIES

	Logged Area p.p.m.	Control Area p.p.m.
Average turbidity	94	4
Most frequent value	36	2
Maximum value	6000	120

The water from the logged area is always turbid and <u>never</u> meets the standard of 10 p.p.m. set for drinking water. The samples from the two watersheds indicated a marked difference in the composition of the material. The matter in the samples from the logging area was generally of a finely divided mineral character with low settling rates and no marked flocculating tendencies. In the samples from the control area

The material causing turbidity was, with one or two exceptions, almost entirely organic in composition. It exhibited a definite flocculating characteristic and the floc settled rapidly.

Discussion and Conclusion.--

> First, considerably more attention should be given to the location and grade of access roads. . . . . the road layout should be designed. An important factor involved here is the length of time of the operation. It is not only important to the timber operator, but also extremely important to the watershed manager since turbidities and soil losses are increased proportionately.

A road is very often in use several years longer than was first estimated, due mainly to exploitation of other forest products. Since it was not constructed to last, great damage results, as

> . . . . the greatest erosion, transportation of sediment, and resulting high turbidities occur while the actual logging is in progress on the watershed.
>
> Secondly, the matter of road drainage can hardly be overemphasized. . . . . Since the roads are generally unsurfaced, the ever-present wheel ruts nullify the use of crowning or sloping the road surface for drainage. The ruts concentrate water and are frequently sources of serious erosion. This means that water bars or turnouts are almost invariably necessary in order to overcome the erosive concentration of water.
>
> Track laying equipment and winches are valuable aids in any logging operation. . . . . The careful use of arches, sulkies, pans, cable systems and other equipment may do much to eliminate or reduce destructive erosion and sources of turbidities.
>
> Other items, such as location of skid trails to avoid both the concentration of skidding and the formation of gullies, also deserves thought and attention.
>
> Ultimately, the problems and their solutions are related to economic considerations. . . . . In almost all cases . . . . the economic problems resolve themselves into one of possible increased initial capital investment versus much higher maintenance costs. . . . . the properly operated job which abides by known and demonstrated principles of watershed management main-

tains the water resource of the watershed. This is of utmost importance in connection with municipal and industrial watershed management.

"A Study of the Effects of Slashing All Vegetation, with Natural Regrowth Cut Back" (52).--This watershed of 33 acres had never been cleared or logged. Elevations ranged from 2,422 feet to 3,381 feet, a difference of 959 feet. The dominant vegetation was oak-hickory. Rhododendron and mountain laurel formed a dense understory on 60 per cent of the area.

All vegetation was cut early in 1941, and kept cut back through 1947 except during three of the war years.

In the first year after cutting, run-off was increased 65 per cent, or 17 area inches. Stream flow was not increased because no change in infiltration was caused and outflow was still from groundwater. The largest increases occur during the late summer and fall. In the first year the increased run-off from August through October was 100 per cent. Even with regrowth of vegetation during the war, the increases persisted, although smaller in amount. No change in water quality took place, and the stream has been as clear since treatment as it was before.

"A Study of the Effects of Slashing All Vegetation, with Natural Regrowth Allowed" (51).--This watershed contained 40 acres, and ranged in elevation from 2,394 feet to 2.965 feet, a difference of 571 feet. Before treatment the stand was composed of vigorous second growth oak-hickory and cove hardwoods about 40 years old, with old-growth pitch pine-hardwoods on the upper slopes and ridges.

All woody vegetation was cut in the winter of 1939-1940. Nothing has been done since that time; regrowth has been vigorous; and sprouts are 20-30 feet in height at present.

The first year after cutting, water yield was increased 16.4 inches in the same manner as in the watershed previously described. After eight seasons of regrowth, water yield is still about 15-20 per cent higher than before cutting but shows a steady decrease with the growth of trees.

"A Study of the Effects of Cutting of a Strip Along the Water Course" (50).--This watershed covers 22 acres, and ranges in elevation from 2,282 feet to 2,955 feet, a difference of 673 feet. No clearing had ever been done, but a sawmill operated on the area in 1912, and the stand was heavily culled. Oak-hickory is the predominant timber type, with rhodendron composing a dense understory.

All woody vegetation less than 15 feet above the stream bed was cut, in the same way as in the two previously described areas, in July, 1941. The area cut was 12 per cent of the total watershed area--a strip 1,600 feet long and 60 to 250 feet wide.

Preliminary analysis of the results indicates that daily run-off during the first summer was increased from 4 to 20 per cent and averaged about 12 per cent for a ten-day period. This increase was due to the almost complete elimination of the normal summer diurnal fluctuation of stream flow caused by transpiration draft.

"The Effect of Timber Cutting in a Lodgepole Pine Forest on the Storage and Melting of Snow"(53)

This experiment was conducted in Colorado between 1938 and 1944. Twenty plots, of five acres each, containing mature lodgepole pine were studied in their natural condition for two years. Snow depth, water content, and rain-gauge records were taken from as many as twenty-five locations on each plot, during appropriate periods. These records were designed to show how much snow was stored in the uncut forest, how long the stored snow remained on the ground, and how storage and melting were affected by variations in the density of the forest canopy. In 1940, sixteen of the plots were cut. All trees over 9.5 inches d.b.h. were removed from four plots; four each were left with reserve merchantable stands of 2,000, 4,000, and 6,000 board feet per acre. Even the heavily cut plots contained an open stand of smaller trees to provide partial shade and to protect the soil.

A total of 17.15 inches of water passed through the forest-canopy on the heavily cut-over plots, as compared to only 13.33 inches in the uncut forest. This gives an excess of 3.82 inches, or about 29 per cent. Results in the intermediate plots yielded a linear relationship.

"Probably because of greater exposure to Sun and wind, the snow on the cut-over areas melted more rapidly than on the uncut plots." All the plots became bare at about the same time, however, due to the excess snow stored initially on the cut-over areas.

It has been shown that unmanaged mature lodgepole pine stands do not furnish optimum conditions for snow storage. These conditions can be improved by carefully managed timber cutting. The cutting should be done so as to open up the canopy just enough to minimize interception losses but still retain a forest dense enough to shade the ground and to protect the watershed against erosion.

Thinning second growth lodgepole pine stands will not only accelerate growth, but, if designed to provide a maximum number of shaded openings, should also increase the water-yield.

> These results obviously apply only to areas where water-yield is of prime importance, and where floods and erosion present no real problem. In areas of more delicate physiographic balance, where any pronounced disturbance of the watershed-cover may result in serious damage, only the most conservative timber cutting may be permitted. And for maximum protection against floods the forest should be kept as dense as possible, so as to promote maximum consumption and storage of flood-producing precipitation. In many western watersheds however, well-managed timber cutting should provide desirable conditions for snow-storage and water-yield, at the same time allowing an income from the sale of timber-products.

Other Communities Having Watersheds for Surface Water Supply

Seattle, Washington

The Cedar River watershed is the sole source of the domestic water supply for Seattle. It is thought to be able to supply a city twice Seattle's size, which is about a half million persons. The city's land was purchased in 1890, and water has been delivered since 1901. The watershed's capacity is 115 million gallons per day, with the demand varying from an average of 54 million gallons per day to a summer peak of 110 million gallons per day.

The watershed, above the intake, is 15 miles long and covers 91,500 acres. Elevations range from 520 feet to 5,500 feet. The eastern portion is mountainous, and the streams are swift. Figure 14 shows the main features of the drainage. Seattle owns 63,000 acres; 25,000 acres are within the Snoqualmie National Forest; 3,500 acres are in private ownership. The pattern is checkerboarded. Forty thousand acres are as yet uncut.

The soil is a loam, quite largely underlaid with gravel or other formations of porous texture which are easily penetrated by water. Due to this, no erosion control work need be done in order to insure high quality water.

Douglas-fir is the principal timber type in the lower portion of the watershed, then western hemlock; at 3,000 feet are hemlock, noble and silver fir. Higher yet are only the firs. All are mainly even-aged.

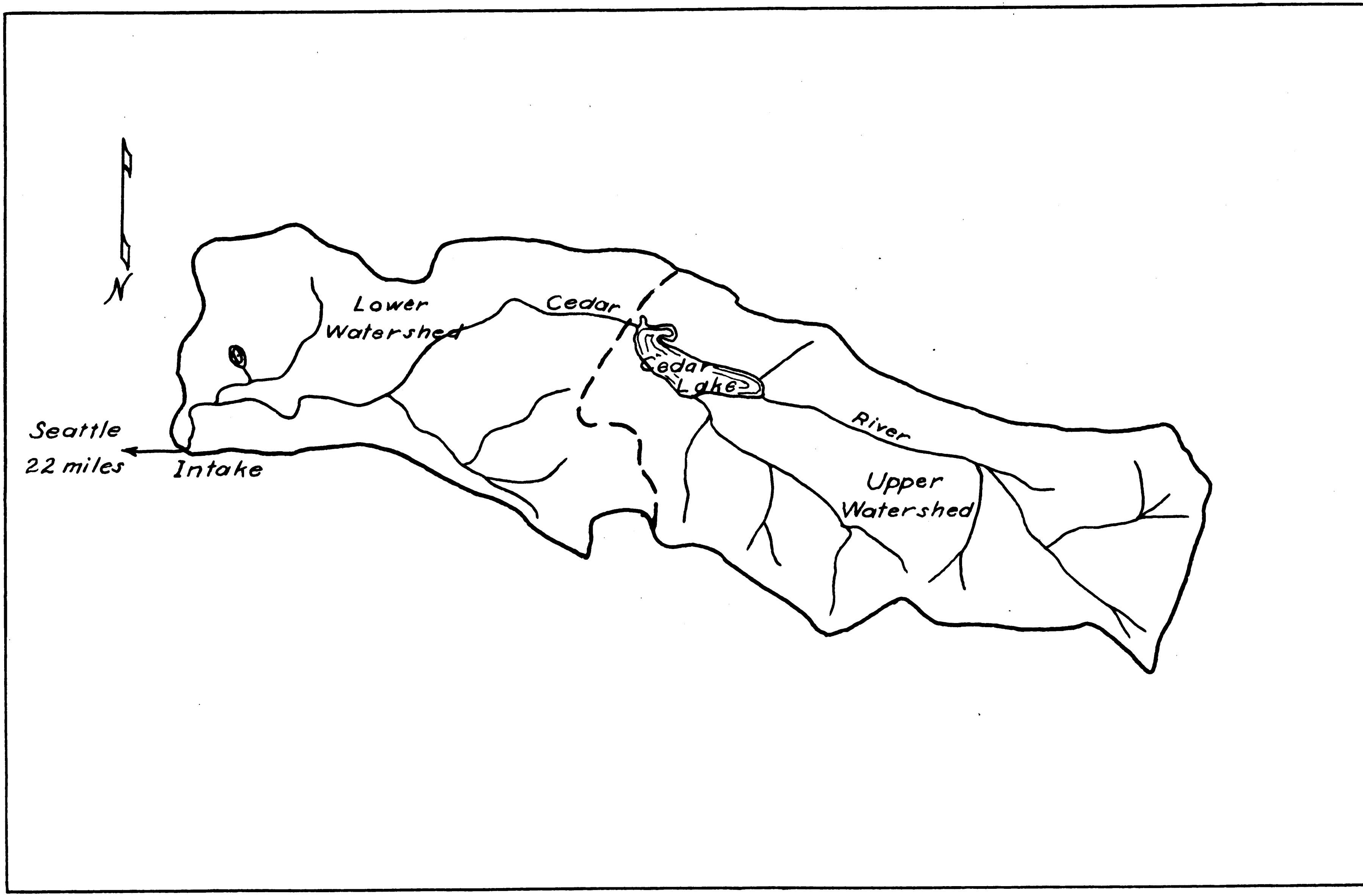


Fig. 14 — Cedar River Watershed

Logging methods follow conventional trends--high lead and ground yarding; truck-dozer-road systems. Cutting practice is primarily clear-cutting in strips or blocks, interspersed with blocks of standing timber. The Forest Service has done some tree selection, but the results have not been determined as yet. The policy is to cut the most accessible timber first. One contract in 1917 specified clear-cutting of at least forty million board feet per year. In 1925 a management plan was adopted; it recommended 1) acquisition of all except national forest lands above 3,000 feet, 2) limitation of cutting practice to get sustained-yield, 3) leaving seed trees for natural regeneration, 4) better planting program, 5) better fire protection, and 6) improvement in sanitation program. The latest logging agreement was made in 1943. It is a cooperative agreement, and all lands will be handled the same. The 35 million board feet allowed cut per year will be divided among several operators. The allowable cut is geared to sustained-yield, as second growth will be merchantable in forty years, then perhaps 40 million feet per year can be cut. Three guiding principles were established in setting up the cutting method: first consideration--protection for watershed purposes; second--protection of seeding and regrowth of the stand; third--utilization and economic handling of the timber.

Wherever possible, logging slash is being left unburned. When necessary to burn, the broadcast method is followed. There is no difference in slash disposal practices along the lake or main stream as compared to other areas.

The city operates its own nursery. Most reproduction is natural, and stocking is good. However, burned areas and adverse sites do need planting. It is hoped to have all areas needing artificial reproduction planted by 1954.

Fire protection is well-planned and considered quite adequate. Two lookouts are within the watershed, besides fire guards, et cetera.

In order to insure pure water the city employs four sanitary patrolmen to check continually on compliance with regulations and keep alert for cause of pollution. Crews are required to use portable latrines. Logging camps are located outside the drainage area, and the workmen travel to and from the job by crew trucks. All other access to the watershed areas is controlled by written permit. Hunting and fishing, or recreation in any form, is not permitted within the watershed areas.

There are about sixty miles of roads, city owned, use of which is paid for by set rates per thousand board feet or per cord. The maximum grade allowed on the main roads is 12 per cent, but it can be increased for short distances on branch roads if the topography necessitates it. (41, 42, 38)

In 1930 the city tried to oust the logging company from the upper watershed, with a heavy penalty for damage already done to the water utility. It contended that the city council in 1917 exceeded its authority. It alleged the forest growth on the city lands to be an integral part of the water system and necessary to conserve the purity, quantity, and quality of the water supply. The relation of forest cover to water supply was the important issue. The city attempted to demonstrate in court that the timber cover was not only beneficial but an indispensable part of the water utility. After every imaginable phase of forest influences had been argued back and forth and discussed by top-rate expert witnesses, the court decided in favor of the loggers as follows:

1. Forest is beneficial but is not a necessary or integral part of the water system in this case.
2. Evidence showed no contamination due to the logging operation.
3. The color, temperature, taste, rate of run-off is not materially affected by the influence of the forest cover; removal of forest cover under present or modified methods, and proper sanitation measures, is not detrimental to the water utility.
4. The city was prevented by equitable estoppel from voiding its contract with the defendant and re-

moving the operations from city lands.[1] (12)

A few years ago another dispute came up concerning logging the Cedar River watershed, only this time it was between two factions within the city. As a result of the controversy, the Cedar River Watershed Commission was established in 1943, to make a careful study of the watershed, with the primary object of deciding future policies with respect to logging. The commission reported in 1944, recommending a continuation of logging on the watershed on a controlled sustained-yield basis, as follows:

> (1) Due to the porosity of the soil in this watershed, there is virtually no surface runoff, and hence erosion is not accelerated by the removal of the forest cover.
> (2) Storage of snow is somewhat increased when the larger trees of the virgin forest are replaced by young growing stock.
> (3) The quality of the water is not adversely affected by the removal of the forest cover, as the lack of erosion prevents any increase of turbidity in the streams in the watershed after the timber has been cut.
> (4) Adequate control measures, already in practical operation, have conclusively demonstrated that pollution due to logging operations in the watershed can be prevented in a completely satisfactory manner.
> (5) All surface waters should be chlorinated or otherwise treated, regardless of the seeming absence of hazards. . . .
> (6) Revenue from logging is, and will be, substantial, and can in the future pay a large part of the administrative costs of the water department.
> (7) As almost all of the virgin timber remaining in the watershed is either privately owned or is in a national forest and is merchantable, prohibition of logging in the watershed area would compel the purchase of the pri-

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[1] The case was appealed to the State Supreme Court, but the decision was upheld. ("City of Seattle vs. Pacific States Lumber Co." Superior Court No. 8162, Kittitas County, Wash., State Supreme Court No. 23367.)

vately-owned timber. . . . . As no benefits in the form of additional or purer water supplies would accrue to the city, such large expenditures can not be regarded as justifiable.

(8) The timber in the watershed is economically important to the region, and . . . . will furnish employment, directly and indirectly, to several thousand persons for an indefinite period.

(9) Forest conditions in the watershed can be improved greatly by the practice of forestry.

(10) 'Ostrich-like' confidence in a 'closed' watershed, instead of controlled intelligent use, will create a false sense of security that will not facilitate the application of improvements in water treatment methods that existing hazards demand.

Logging of the timber on the watershed on a sustained annual yield basis, using advanced silvicultural methods, has been recommended by the commission as a safe rational conservation measure. (11)

Tacoma, Washington

The experience Tacoma has had with its water supply has been less fortunate than that of Seattle.

The principal source of Tacoma's domestic water supply since 1913 has been the Green River watershed. The 148,000 acre area lies twenty-eight miles east of Tacoma. The water system coming from there will furnish a maximum of 55 million gallons per day to the city of about 150,000 people.

The drainage is twenty-five miles long, ranging in elevation from 909 feet at the intake to over 5,000 feet at the top of the Cascade range. All but eight or nine thousand acres are rugged and mountainous. Annual precipitation varies from 74 to 111 inches. Run-off ratio to the high precipitation is 85 per cent and for the low is only 40 per cent. Except for about 5,000 acres along the river bank the entire watershed can well be devoted to forest purposes. There has been no artificial reforestation, and natural reproduction seems to obviate any necessity of it.

The sanitation problem has not given the city any appreciable trouble. There were nearly 2,000 residents in the drainage in 1913, but only about 300 now. The Northern Pacific Railway mainline follows the river through the entire watershed. The city employs a Watershed Inspector who checks sanitary conditions at each population point at least once a week and samples the water at various points of the river. An educational program has done much good by instructing the residents and miscellaneous crews in proper compliance with the state sanitary rules and regulations. The few fishermen and hunters going into the area create more of a menace to the water supply than do the residents.

The most serious problem the city is facing is that of the many small timber owners who carry on their logging operations without due regard to the effect that their operations may have on the quality of Tacoma's water supply. Where large areas have been denuded of the forest cover, surface soil erosion and consequent turbidity have been caused, which have on many occasions made the water supply unfit for use for days or weeks at a time.

The city maintains an auxiliary well supply system within the city with a capacity of 35 million gallons per day. They are used to augment the supply during peak demamd periods, when repairs are needed on the regular system, or when turbidity in Green River exceeds 10 p.p.m.

During 1933-34, the period of greatest run-off, there were sixty-four days with turbidities over 10 p.p.m., while during the period of lowest run-off in 1940-41, only fourteen days occurred with turbidities over 10 p.p.m. The average during the last twelve years is thirty-four days.

There is a great need for ". . . . a long range plan administered by a centralized authority looking toward a sustained-yield forest management operation." Since about two-thirds of the watershed is owned by the United States Forest Service, Northern Pacific Railway, Weyerhaeuser Timber Company, and the state of Washington, it is hoped the recently-passed sustained-yield law will provide the legal machinery for setting up such an organization. (24)

Syracuse, New York

The Skaneateles Watershed, of 38,400 acres, has supplied the domestic water for Syracuse since 1894. The seasonal flow is evened off by means of Skaneateles Lake. Near the lake the ground slopes gradually, and is used for agriculture. Farther away the land rises to rather steep slopes, fairly well wooded. The soil for the most part is clay, with a great deal of shale under the clay.

The major uses of the land are agriculture and grazing near the lake; protection forest on the hills; and recreation, summer homes, and bathing on the lake shore. Some hunting is present, mainly near the head of the lake. A little logging has also been conducted on city-owned land at this end of the lake. (33)

Under the Public Health Law of the state of New York very specific instructions have been set forth for the protection from contamination of the Public water supply of Syracuse. (32)

Glens Falls, New York

The main source of water is in the mountains, five miles west of town. About 6,000 acres are involved, 3,700 acres of which are city-owned. The water is drained into reservoirs at the sources, eliminating any difficulties with extreme high or low water flows. The water system was established in 1872 with one small drainage area and intake reservoir. There are now three drainage areas and storage reservoirs.

About 25 per cent of the land was originally in mountain farms. In 1910 reforestation of 2,100 acres was begun. Two and a half million red and yellow pine were planted. Some stands are now being thinned; the price of the products just about pays for the thinning. All work is done by the Water Department's own personnel in order to have more control of the work being done, and to lessen fire and pollution hazards. Portable chemical latrines are provided for the men.

Slash in inaccessible areas is windrowed and left to decay. Slash and grass in areas near roads and exposed fire lanes is bunched, loaded, and hauled to open areas where it is burned, usually during rainy weather.

Fires without a written permit are not allowed. There is also no hunting, grazing, picnicking or any form of recreation allowed. (6)

York, Pennsylvania

A private water company supplies the water for this city. In 1912, the company built an impounding dam upstream from the intake pumping station. Since then, they have acquired 1,008 acres of the surrounding drainage area and planted it with 1,250,000 white pine transplants, some of which are now 17 inches d.b.h. The company does not contemplate logging the white pine forest.

The rolling hills, some of which are rather steep, had been used as farm land or were covered with a growth of hardwoods.

No recreation other than fishing from the dam breast is permitted. (1)

Missoula, Montana

A private company supplies the domestic water for Missoula, from the Rattlesnake Creek watershed. This watershed begins north of town; the portion that supplies the water is about twenty miles long and is fan-shaped. A group of small lakes at the headwaters have been developed and gates installed to regulate flow during critical periods.

The ownership is checkerboarded between company land and national forest land. Fishing is allowed in some of the lakes and skiing is permissable, but otherwise no hunting, fishing, or other form of recreation is allowed throughout the major portion of the watershed. No logging operations have been conducted.

The company has a series of wells near Missoula to supply additional water during extreme low water, which is usually in the winter in this watershed.

Montana and Northern Idaho

> Numerous municipalities in Montana and Northern Idaho obtain their water supplies from drainages partly or wholly in the national forests. Except in one instance (one of the drainages serving Bozeman, Montana), no exclusions of resource utilization from national forest lands have been made, although of course, due consideration is given to protecting the water supplies. (54)

Table 8 is a list of the cities referred to above.

Smith Creek

Referring to Figure 1, Smith Creek is the watershed outlined in blue. A very brief description of it will be made in order to draw comparisons between the Myrtle Creek and Smith Creek watersheds later.

Smith Creek heads up two miles north and west of Myrtle Creek, runs northerly for several miles, then angles northeast until it empties into the Kootenai River. This

TABLE 8

MONTANA AND NORTHERN IDAHO CITIES OBTAINING WATER FROM DRAINAGES IN NATIONAL FORESTS

Forest	Names of Cities 2,500 - 50,000	Names of 3 Largest Below 2,500
Beaverhead	Dillon, Montana	Sheridan & Lima, Mont.
Bitterroot	Hamilton, Mont.	Darby, Stevensville, & Corvallis, Mont.
Cabinet	.....	Thompson Falls, Paradise, & Plains, Mont.
Clearwater	.....	Orofino, Weippe, & Pierce, Idaho
Coeur d'Alene	Spokane, Wash.; Coeur d'Alene, Kellogg & Wallace, Idaho	Mullan, Post Falls, & Harrison, Idaho
Colville	.....	Colville, Chewelah & Republic, Wash.
Custer	Red Lodge & Columbus, Mont.	Absarokee, Joliet, & Ekalaka, Mont.
Deerlodge	Butte, Anaconda, & Deer Lodge, Mont.	Philipsburg & Hall, Mont.
Flathead	Kalispell & Whitefish, Mont.	Polson, Columbia Falls, & Somers, Mont.
Gallatin	Bozeman & Livingston, Mont.	Big Timber, Townsend, & Gardiner, Mont.
Helena	Helena, Montana	Townsend, East Helena & Toston, Mont.
Kaniksu	Camp Farragut & Sandpoint, Ida.	Metaline Falls & Ione, Washington
Kootenai	.....	Libby, Eureak & Troy, Mont.
Lewis & Clark	Great Falls, Lewistown Cutbank, Shelby & Havre, Mont.	Browning, Choteau, Fort Benton, & Harlowton Mont.
Lolo	.....	Superior, Bonner, Alberton, Mont.
Nezperce	.....	Grangeville, Kamiah & Kooskia, Ida.
St. Joe	St. Maries, Ida.	Potlatch, Bovill & Clarkia, Ida.

point is about two miles south of the Canadian border and nineteen airline miles north and a bit west of the mouth of Myrtle Creek. It covers an area of 48,000 acres. The topography is similar to Myrtle Creek; the stream gradient is somewhat less, being 3.5 per cent average--flatter in the upper half and steeper in the lower half.

The timber types are quite similar to those in Myrtle Creek. The volumes per acre are fairly comparable, perhaps not quite so heavy. Figures 8 and 10 show the fire occurrence and large fire locations. Fire has devastated more area near the mouth of the stream than is indicated, but is not shown as there are no accurate records dating so far back.

About 1938 the Civilian Conservation Corps constructed a road from Smith Creek Ranger Station up the creek approximately thirteen miles. Near the mouth the road cut through several very sandy ridges; a short way up many flat slabs of bedrock were encountered. Trouble is had in spring with bank sloughing in the sandy stretches; the rest of the road shows no more than normal damage after all the snow has run off.

In 1939, a timber sale was opened up involving several hundred acres between the 'Dirt Oven' and 'Upper Smith Creek' campgrounds. During the next two years 16,000 M board feet of timber were removed. Since it was an overmature white pine type, most of the volume cut was white pine, with a little sound larch and other species also removed. Slash was disposed of by piling and burning. There were no specific plans set up for protection of the watershed against erosion or stream flow disturbances such as silting or pollution. No records or measurements were taken to show the effects of logging; however, no undue erosion of the roads or in the woods is noticeable, and the streambanks appear undisturbed.

Since the road has been in, there have been an estimated five hundred visitors annually. Before that time the number is not known, but probably in the neighborhood of 125. Fishing is the greatest attraction, followed by picnicking and camping. There are a number of hunters every fall during deer season. Cattle grazing on a limited scale in the watershed is permitted, most of it being in the Cow Creek fork of the drainage.

Opening of the watershed to public use has done no apparent damage. Man-caused fires are well below the average for the whole general area. In fact, since road development both the number of fires and severity rate have dropped off; however, this has no particular significance, as fire conditions have been less severe since 1938 than the preceding decade.

ATTAINING THE PRIMARY OBJECTIVES

In reference to managing a timbered area for the purpose of watershed improvement, Connaughton and **Wilm** state (7):

> . . . . virgin stands of timber can be materially improved for water-yield by employing proper practices in management. Such improvement may be accomplished by careful thinning of the forest-cover, to reduce the consumption of water by interception, evaporation, and transpiration, while leaving a forest dense enough to protect the soil from deterioration and erosion. Obviously this kind of management applies only to the large areas of forested watershed-land where water-yields are unusually important, and where floods and erosion present a relatively slight hazard--areas such as the water-yielding forests of the high Rocky Mountains, the Sierra Nevada, and other water-producing mountain areas."

The problem of multiple use of forest land can be said to be one of adjustment of relationships between two or more possible usefulnesses or resources. They may be either conflicting, supplementary, or complementary in character. (13) The more complementary the various uses can be to each other, the greater becomes the value of the watershed.

Effects of the **Removal** of Timber in Myrtle Creek

On Water Losses by Interception, Evaporation, and Transpiration

The amount of precipitation that is lost through these three processes is nearly impossible to determine accurately in the field. Kittredge has estimated, by measuring the difference between precipitation and run-off, the total annual water loss from vegetation in western regions to be between 15 and 20 inches for larch-white pine type, and 10 to 20 inches for ponderosa pine and spruce-fir types. (21)

Interception.--The study in thinning lodgepole pine gives an indication of how much additional snow will reach the ground if trees are not present to intercept it and expose it to rapid evaporation. Another study shows ponderosa pine snow interception to be about 25 per cent of the total snowfall. (43) Interception of summer precipitation apparently takes a large toll also. Heavy stands of virgin white pine-hemlock type in Idaho may have 21 per cent of the rainfall intercepted; (43) Douglas-fir in the Northwest may lose up to 43 per cent; while the average interception varies from 10 to 15 per cent of the total rainfall. (22)

Reduction of interception by removal of merchantable timber in Myrtle Creek will vary inversely with the amount of tree crown taken out, but to a somewhat lesser degree, as the next lower story of vegetation will catch part of this added precipitation.

Evaporation.--Moisture intercepted on the needles, by action of sunlight and wind, evaporates back into the atmosphere. Evaporation also takes place from the ground surface. If all vegetation is removed, evaporation becomes quite great. If some understory is left, the ground is kept cool and protected from much air movement, and evaporation is negligible from the source. Some evaporation takes place from the stream itself. The amount compared to the total is very small. Leaving a stand along the stream bank helps shade the stream and prevents some loss. Young growth along the stream in the lower part of the watershed will increase in size and thus increase the protection from evaporation.

Transpiration.--The amount of water transpired through a tree varies as to species and size of the tree, exposure of the slope, time of year, and relation of the size of that tree to its neighbors. A number of reaearchers have tried to determine the transpiration from several species, but have come out with divergent results. However, a general relationship between a few species studied indicates pine to transpire more than larch, and larch more than spruce. Measurement of water requirements, which have a high correlation with amounts of transpiration, shows pine to require more than spruce and fir. (34)

Nearly all the experiments cited indicate that, if the amount of vegetation is reduced, the amount of water that would have been transpired shows up in the stream as stream flow. This was especially so in the study where the streambank vegetation was removed. Thus, stream flow, particularly in the summer time, will increase as the amount of timber removed is increased. However, as pointed out earlier, there are many factors in addition to this one that determine the best method of increasing the value of the watershed for water supply and other uses.

E. N. Munns has aptly commented on the above factors by stating that one should remove trees of great transpiring power--the "old soaks" and "hard drinkers"; encourage "tipplers" and "drys". Remove wolf trees as they cause excessive interception losses. Provide openings for snow accumulation and delayed snow melt. Encourage stand improvement in the interest of water. Select species for reforestation with the same purpose in mind. (31)

On Infiltration and Water-Holding Capacity

Infiltration.--A well developed and undisturbed forest litter is the best possible instrument for maintaining an optimum infiltration rate of water into the soil. The vegetation itself aids in breaking up rain drops and dissipating their force. Litter acts more as a filter than a sponge. It filters out small soil particles as water runs through it before these particles can reach the soil surface and clog up the pores; the soil beneath the litter is the real absorbent, and should be kept as free to absorb as possible.

Any disturbance to the forest will do some damage to the litter. Removal of timber, even with the greatest care possible, and with as light a cut as is economically feasible to make, is bound to lay some soil bare and render many areas of litter less capable of performing its highly important job. The method of slash disposal used should be decided upon with its effect on litter disturbance in mind.

Water-holding Capacity.--Litter on the forest floor tends to keep frozen soil porous, loose, and permeable when bare soil becomes solid and impermeable. The removal of litter results in reduction of the degree of aggregation, as aggregation is promoted by additions of organic matter and colloidal material. (20) R. E. Horton explains water-holding capacity of soils very adequately:

> Every soil has a fairly definite capacity for holding water against gravity. This is called its field-moisture-capacity. As long as there is field-moisture-deficiency in the soil column between the surface and the water-table, any water entering the soil as infiltration is held in the soil. When there is no field-moisture-deficiency, then any additional water entering the soil goes directly to the water-table. (14)

The type and method of logging should be so selected that the least damage possible is done to the ability of the soil to absorb water at its maximum infiltration rate. The greater the amount of water to enter the soil the greater is the excess over plant needs that can percolate on down to be held in reserve for stream flow during times of greatest need.

On Run-off and Stream Flow

Run-off can be classed as a general term meaning the recoverable portion of precipitation water received on a drainage basin. It can be broken down to surface run-off--the part that passes over the surface--and seepage--the subsurface flow. Both will eventually reach the stream bed where they become the stream flow.

Run-off.--The perfect watershed would be the one in which all the water reaching the stream bed would be by seepage and none by surface run-off. The recommendations of this paper will attempt to indicate the methods of use of the watershed that will cause the least amount of run-off over the surface and the most by seepage. Erosion is directly related to the amount and velocity of run-off. Control of run-off will control erosion.

"The action of mountain forests in protecting the soil against erosion and in increasing underground seepage at the expense of surface run-off is the result of their ability to lessen the severity of rainfall, to retard the melting of snow, to offer mechanical obstacle to surface run-off, to hold the soil together, to keep it in a permeable state, to increase its volume by constantly adding new soil . . . ." and to absorb large quantities of water by means of the litter keeping soil porous. (55)

The rapidity at which snow melts in the spring determines largely the type of run-off and the damage it might do. In the Cascade range, Griffin found that snow in the forest remained after all had gone from open areas, according to Table 9. (10)

Also, Figure 15 shows the rate of snow melt in the spring in the Cascade range. (10)

The curves in this figure should be fairly applicable to Myrtle Creek, except that the maximum amounts should be

TABLE 9

RETENTION OF SNOW UNDER FOREST CANOPY

	Weeks After Open Stations Became Bare			
	0	1	2	3
Amount Retained under Canopy	30%	14%	9%	4%

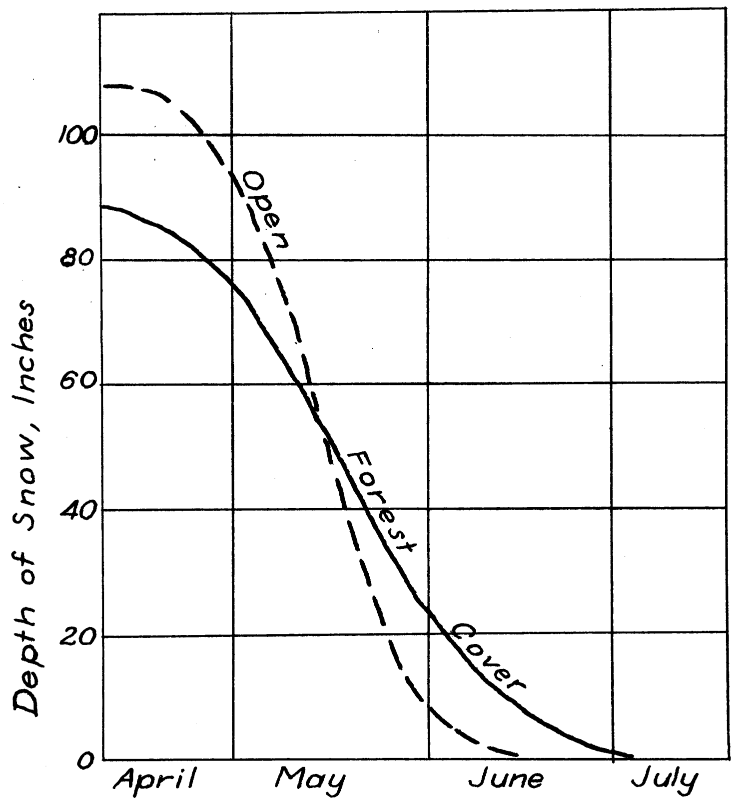

Fig. 15.--Relation of snow melt between forested and open areas.

between one-half and two-thirds those shown here. During the month of May, 85 inches ran off the open area, while 53 inches ran off the forested area. In April, 15 inches ran off the open area, while 11 inches ran off the forested area. The more that can be removed in the earlier part of the flood season the less will remain to cause damage when the usual peak occurs. However, during May, the difference between the two run-offs could mean the difference between a normal high flow and a serious flood condition. In Myrtle Creek it would be unwise to create too many large openings in the timber for fear of increasing the amount of snow available for rapid melting and run-off in the spring with resultant damage to the water supply.

Stream Flow.--As logging affects surface run-off and seepage, so it will affect stream flow, as it is the sum of those two elements.

E. N. Munns sums up several good practices to be followed on watersheds containing soils of moderate depth and having stream intakes to the water supply. He states that logging should be conservative, avoiding large openings, and not unduly disturbing the soil. Have adequate fire control. Thus one may expect relatively clear high-water flows during periods of excessive rainfall or snow melt, when the volume of available water exceeds the soil mantle's water-holding capacity. Also damaging flood flows during periods of intense rainfall may be reduced or eliminated. So as not to disturb channel conditions, logging close to the stream should be done carefully. (30)

On Erosion and Stream Turbidity

The type of logging practiced and the care and supervision given to any chosen method will determine to a great extent the amount of erosion and thus stream turbidity occurring in the watershed.

Tractor and horse skidding drag the logs downhill in a fanwise fashion to each landing. This creates a channel of increasing size the farther down the slope the water runs until it hits the landing alongside the road. Then, in a period of heavy rainfall or spring snow melt large volumes of water will cut over the road bank and travel down the road, transporting considerable amounts of soil. If numerous landings are used, this effect can be lessened. If this were carried too far, though, it would become uneconomical.

Cable logging, as can be practiced in Myrtle Creek, works pretty much in the opposite manner. It is not feasible to log very much above the road, but several hundred feet below can be handled with a double drum system, and a less amount with a single drum. Using single drum, a fan-shaped pattern is produced, but with the apex at the top, and each radius is a narrow channel that gradually pinches off; from the end of these small channels the water spreads out and filters into the ground. The double drum pattern is similar, but has few radii per setting, and these are of greater size and capacity. Each radius has many small more or less horizontal channels leading off from it where logs of individual trees are pulled, with the use of properly placed snatch blocks, into the radius.

If the distance a particle of water can travel without being stopped is kept short enough, it cannot gain much velocity and will have little chance to erode or transport soil. This can be shown by observing the following two mathematical ratios: the erosive power of water varies as the square of its velocity; the transporting power of water varies as the sixth power of its velocity. Thus, if strictures and means of diversion are placed at optimum positions, the water can never develop the power to erode and transport enough soil into the stream to damage the quality of the water.

The amount of road building necessary varies with the skidding method used. Single drum requires the most, and tractor skidding requires the least. The higher the class of road the less erosion will result from inadequate and poorly planned drainage. On the other hand, much more dirt is moved in constructing a high class road. Large amounts of overcast are almost sure to yield goodly quantities of soil that, if they don't get into the stream, will at least clog up the pores of the soil down the slope from the road and decrease its infiltration rate and capacity. Drainage, well planned in all respects, decreases the destructive power of the water that finds its way into the road.

A good erosion control plan for a timber sale area was worked out by Ranger Mendenhall on the Lolo National Forest. 1,850 M board feet were removed from 260 acres in 1945 and 1946. The soil is rather erodable, of decomposed granite base. Slopes are moderate to steep. Tractor and truck logging was done. Fifteen cents per M was collected for erosion control work. With a bulldozer check dams were put in the main skid trails--some to stop the water and some to divert it and fan it out; logging debris and brush were mixed with the dirt in these dams to help hold them together. In the minor skid trails some dozer work was done, but mainly slash was thrown into and across them with the idea of building up tiny check dams by the action of the water and soil movement. The roads were outsloped, and frequent transverse berms put in--not so big but what a truck could negotiate them in an emergency.

Subsequent inspections have shown that the results were very satisfactory. The trails, that had begun to erode, are stabilizing and plants are growing in on them. It appeared hardly worth the while to have thrown slash in the minor trails. It would have been better to have disposed of that slash and decreased the fire danger. (29)

The greatest erosion hazard area is in the ponderosa pine site which extends along the north side of the watershed for the first four miles or so. It is the steepest land (See Figure 7), the cover and litter is lightest, and the soil is shallower and slightly more erodable than farther west. Road planning will have to be done with great caution; an erosion control plan should be formulated so it could be applied as soon as the logging is done.

As stated before, the logging of Smith Creek caused no great amount of erosion. Since Smith and Myrtle Creeks are very similar, especially near the streams, care should prohibit most of the erosion in all but the more extreme circumstances.

On Other Stream Values

Solid Materials.--If adequate erosion control measures are taken throughout the watershed, there should be no appreciable amount of solid materials enter the stream. Preservation of the litter near the stream and protection of the streambanks themselves will do much to prohibit even the spring flood from carrying much solid material down to the intake. Bridges built at every stream crossing are a big factor in streambank maintenance.

Stream Clogging.--Careless felling near the streams clogs them up. This causes solid material and debris to get into the water, and, if done to any great extent, impedes the water flow; and the stream overflows its banks, removes much litter and organic material and transports it on down in the water. It is impossible to fall all trees correctly, but elimination of most of it will help maintain the high quality of the water.

Pollution.--It is not at all uncommon for a timber sale contract to stipulate that portable latrines be placed near all crews and used by them. The danger of pollution by the loggers is not great back from the streams; but, while operations are being carried on in the vicinity of the streams, sanitary provisions must be supplied, and regulations as to their use must be complied with.

On Reproducing the Species Desired

Naturally, it is very desirable to grow the species of timber that has high values and rapid growth rates. On watersheds whose highest use is production of timber this can fairly easily be done. However, in Myrtle Creek the highest use is production of domestic water; the best timber possible should be raised, but not beyond the point of compatibility with water production.

Most of the merchantable timber is in overmature stands. This means that timber over 140 years or so of age should be cut in order to allow for a larger net annual growth to take place. Most of the older trees are pretty decadent, and difficulty may arise in getting much of the volume of the inferior species removed, at least at a profit to the owners and the operators. It is thought that pulp sales can be made that will permit removal of much of the poorer timber either in conjunction with the sawlog removal or shortly afterwards.

From a permanent water supply standpoint, the removal of all the merchantable sized timber would be advantageous. From a quality standpoint, the least chances would be taken by leaving the watershed alone entirely. From a white pine silvicultural standpoint, the overmature stands (Class C) should be clear-cut in one or two cuts, broadcast burned in one or two burns, and replanted to white pine; the uneven aged, scattered, mature to overmature stands, with young growth beneath, (Class D) should have the merchantable timber removed in one or more cuttings but maintain a canopy at all times to suppress ribes, and lop and scatter or pile and burn the slash. The marking instructions (44) recommend removing not over 25 per cent of the merchantable volume in any one cutting along the creek bottom. It suggests favoring wester redcedar and Engelmann spruce. These species are quite low in their requirements and transpiration of water compared to white pine. In fact, tolerant species in general have more moderate water requirements than do the intolerant species.

Seeds germinate better on mineral soil than in the duff, although the larger seeded species--white pine, Douglas-fir, and grand fir--do germinate on duff under favorable conditions. Establishment of all species in the type is best under partial shade on the more severe sites, but best in the open on the more protected sites such as north slopes. White pine, Douglas-fir and grand fir develop best under some shade on exposed sites, and in the open on protected sites.

The ribes potential in Myrtle Creek is not known. In Smith Creek, there was no sign of infection on the white pine poles in the cut-over area, although the heavy canopy of decadent timber prevented either ribes or white pine reproduction from coming in. However, in the burn area of 1929--a hard single burn on a south to southeast exposure--a good stand of almost pure white pine has established itself, in which a few infected trees were found, but the percentage was very small.

Since the danger of blister rust will probably not be great, it may be best to ignore it inasmuch as management for water supply closely parallels management for ribes exclusion, anyway. Management for water does not tie in exactly parallel to management for white pine regeneration, however, as broadcast burning is almost a requisite on protected slopes for proper regeneration. It may be perfectly safe to clear-cut and burn strips where the site is not severe and where the duff probably would not burn clear out; if this is tried, the burning should be done when the duff is quite moist so that its filtering and soil pore protective actions are not materially damaged.

Reproducing ponderosa pine in its area is a hard job under any method of management. Silviculturally, this species should be logged under the selection system. If about 50 per cent of the merchantable volume were removed, the remaining stand would still be of an all-age character. Young growth is fair in spots, but needs planting to bring stocking up anywhere near to the site's capacity. From a water management standpoint the treatment of the timber would be the same as above. As mentioned before, erosion control work will be a very important phase of management here.

On Fire Danger and Hazard

A comparison appears to be the best way to illustrate this subject. Figures 8 and 9 show the fire occurrence in Smith Creek and Myrtle Creek. In tabular form, the information looks as follows:

TABLE 10

FIRE STATISTICS IN SMITH AND MYRTLE CREEKS

Period	Smith Creek		Myrtle Creek		
	Acreage[1]	No. Fires	Acreage	No. Fires	No. Fires, If Acreages Were the Same[2]
Prior to 1921	200	.....	.....	.....	.....
1921-1930	8950	.....	7780	.....	.....
1931-1935	50	15	.....	4	9
1936-1940	210	47	.....	10	22
1941-1946	.....	13	.....	9	20
Total	9410	75	7780	23	51

In 1947 and 1948 there were no fires in Myrtle Creek, while there were a few in Smith Creek. So, the occurrence rate is generally less than in Smith Creek.

Figures 10 and 11 reveal the extent and location of large fires since before 1917 in both drainages. The worst

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[1]Acreages in fires 10 acres and larger in size.

[2]Smith Creek is 2.2 times as large as Myrtle Creek.

ones in Smith Creek have been well up near the head of the drainage, while the bad ones in Myrtle Creek have occurred near its mouth. In Smith Creek, the occurrence frequency and the acreage burned are in about the same area. For Myrtle Creek, the greater frequency is near the head of the drainage and the greater acreage is near the mouth. This seems to indicate that the upper portions of the Myrtle Creek watershed are usually moist enough that fires do not reach conflagration proportions. It thus appears logical to assume that upper Myrtle Creek needs no greatly increased protection while it is being logged, but that the lower end should be well covered during fire season. This is actually the case at present.

The hazard of man causing an increased number of fires in Myrtle Creek is not great, if Smith Creek can be used as a comparison. Five fires between 1936 and 1940 could possibly be accounted for by the logging crew, but it is known lightning does strike in and near that logging chance; so probably not over two of the five could be attributed to man. The combination of the low frequency of man-caused fires to be expected in Myrtle Creek and the low acreage burned over in the last thirty years, except for the mouth of the creek, show that the hazard of man entering it and logging it is not nearly so great as are the benefits to be derived from so doing.

ATTAINING THE SECONDARY OBJECTIVES

Hunting and Fishing

In a land of fish and game it makes little difference if one drainage out of many is closed to the sportsmen. Even though Myrtle Creek is very close to town and will be one of the few watersheds nearby in which there will be a road, fishermen and hunters can go just a little farther and find their quarry. They have been doing this for eleven or twelve years now.

If people could be trusted to take every precaution to guard the stream against pollution, there would be no reason why Myrtle Creek could not be fished. But they will not, and thus a great risk is being taken if fishing is ever allowed in this stream.

Hunting is a little bit different. Deer season is late in the fall, just before or just after the ground is covered by snow. If a deer is killed and gutted, a good portion of the entrails will be devoured by birds and minor animals; the rest will decay very slowly, and by the time the spring flood comes, there will be little or no material left to pollute the stream. Very few deer winter in the part of the watershed that is heavily timbered or contains side streams that run during the fall or winter. So if hunters are kept, for instance, above the road that will be very near the location of the present trail, then surely very little chance will be taken in polluting the stream. The same situation occurs in reference to hunting grouse in the watershed.

Presence of game, particularly deer, in the watershed is liable to cause more trouble to the water supply than is the process of hunting them. Logging and logging roads create open spots in the forest. In these open spots browse material develops, thus creating more forage for the deer; then more deer might stay in the woods during the winter instead of feeding on the haystacks in the valley bottom. No hunting for a number of years or possibly an 'irruption' in the reproductive cycle of the species would cause large numbers of deer to yard up in the wintertime, probably near some stream. A severe winter would mean starvation for many. Thus lies a very great chance for pollution of the water supply. The hooves of deer are very sharp. If too many go to the same watering spots along the creek, trails will be worn through the duff and into the soil; also the integrity of the streambank will be destroyed in many places. The spring flood can tear out large portions of it once it gets started, and raise the turbidity above the allowable amount even though a perfect job had been done on the logging. Another factor that would cause streambank erosion is too heavy browsing on the vegetation there, gradually killing it so the roots would no longer have any holding power on the soil.

At present, regardless of the number or condition of the wildlife in Myrtle Creek, the law has no provision for handling extraordinary conditions such as overpopulation of the deer herd. Perhaps the law should be amended to allow at least controlled hunts when circumstances indicate the necessity.

Another alternative may become available after the village taps Snow Creek for an auxiliary water supply. The law permitting, Myrtle Creek could be fished and hunted while the water supply was obtained from Snow Creek, and vice versa.

Recreation

Recreationists fall in a similar category with hunters. There are many other places to go besides Myrtle Creek. The lack of fishing will discourage many people from desiring to enter the watershed. Many communities prohibit any form of recreation, hunting or fishing. Some, however, make provisions for public use.

It seems as though observation by the public of the progress of a carefully managed watershed for several uses would be one of the best educational instruments a conservation-minded organization could promote. Establishment of a small number of picnic grounds in spots that could not cause pollution would afford in part natural control of the users. The periodic presence of the courteous sanitary inspector would provide the rest of the control.

SUMMARY

The purpose of this thesis is to ascertain the feasibility of practicing multiple use management on the Myrtle Creek watershed, which supplies the domestic water supply for the Village of Bonners Ferry, Idaho.

The village's peak drain is, at a maximum, one-half of the extreme low water flow of the creek. A chlorination plant makes certain the purity of the already high quality water.

Nearly half the timber volume is privately owned; two miles of the main creek and over a mile of main feeder creeks go through the private timber. The village would like the watershed to be logged, if at all, scientifically, under one administrative unit.

Over 22,000 acres and 200,000 M board feet of timber--principally white pine types--are contained in the watershed. The soil ranges from a loam to a silty clay loam. The watershed is steep and narrow at the mouth and widens out into a basin containing most of the timber. Erosion is no problem. Fire occurrence and severity is light throughout the watershed; however, acreage burned is quite large in the lower portion. Game population is moderate. There is no grazing. Recreation is very limited since the watershed is closed to hunting and fishing.

The Wagon Wheel Gap experiment showed that removal of the forest cover actually increased the daily and annual discharges. Also the spring flood peak was earlier and

higher, but the summer flow was decreased only imperceptibly.

The Hoyt-Troxell report describes the Fish-Santa Anita Creeks comparative areas in light of Fish Creek having been burned off. They conclude that forests do not conserve the water supply; that the greater the deforestation the greater the supply. The report does not emphasize the great erosion problem encountered with too drastic a reduction of cover.

Studies at the Coweeta Experimental Forest show that a) uncontrolled logging causes so much turbidity due to erosion that the water is never potable. b) Cutting all vegetation without disturbing the soil results in marked increases in stream flow with no turbidity of the water. c) cutting all vegetation from a strip along the stream increased stream flow, due mainly to near elimination of the normal summer diurnal fluctuation of stream flow caused by transpiration draft.

A study of the effect of small open areas in a lodgepole pine stand in Colorado showed more snow to accumulate there than under a canopy. The snow melted faster in the open due to sun and wind; thus plots in both open and shade became bare at about the same time.

Various cities throughout the United States have widely divergent ideas as to how much protection should be given their domestic water supply watersheds. Seattle, Washington, has logged its watershed for over forty years without damage; no other uses are allowed. Tacoma, Washington. has permitted everything except pollution; it, therefore, has serious trouble with excessive turbidity every spring. Syracuse, New York, has a large lake reservoir, surrounded by farmland and steep woodland. The watershed is quite fully utilized, but with stringent sanitation rules. Glens Falls, New York, has planted a large part of its watershed to pine, which is being commercially thinned. No general public use is permitted. The water for York, Pennsylvania, is supplied by a private company; an impounding dam is used. A thousand acres have been planted to white pine, and it is not intended to be cut. No public use is allowed. A private company supplies the water for Missoula, Montana, also. Practically no public usage is allowed. No logging of the merchantable timber is contemplated at present.

Logging Myrtle Creek will decrease interception and transpiration. Evaporation, other than that caused by interception, will be increased, but not as much as the decrease in losses from interception and transpiration.

Logging will necessarily decrease infiltration and water-holding capacity a little bit, the amount dependent upon the method of skidding and of slash disposal.

Logging will increase surface run-off slightly; also it will cause seepage to increase due to decrease in interception and transpiration. Thus stream flow in all seasons will be increased slightly.

Logging will induce erosion. But, if done properly, water will not have a chance to go far before being diverted. Stream turbidity, even in spring flood, will be increased negligibly.

Logging need not increase hazards of pollution. If reasonable rules are laid down, compliance can be expected.

Reproducing white pine from an overmature white pine stand is not too compatible with furnishing a clear water supply. Some degree of success can be attained, but development of the other species is, in general, the best solution.

The inherent danger of fire is not great in the timbered portion of the watershed. Logging will not raise the hazard materially.

Fishing would create a definite danger to the water supply. Controlled hunts may be needed to prevent overpopulation of game animals, which would be dangerous to the water supply.

If facilities for picnicking, et cetera, are provided, recreation would not harm the water. If no facilities are provided, recreationists would be a hazard.

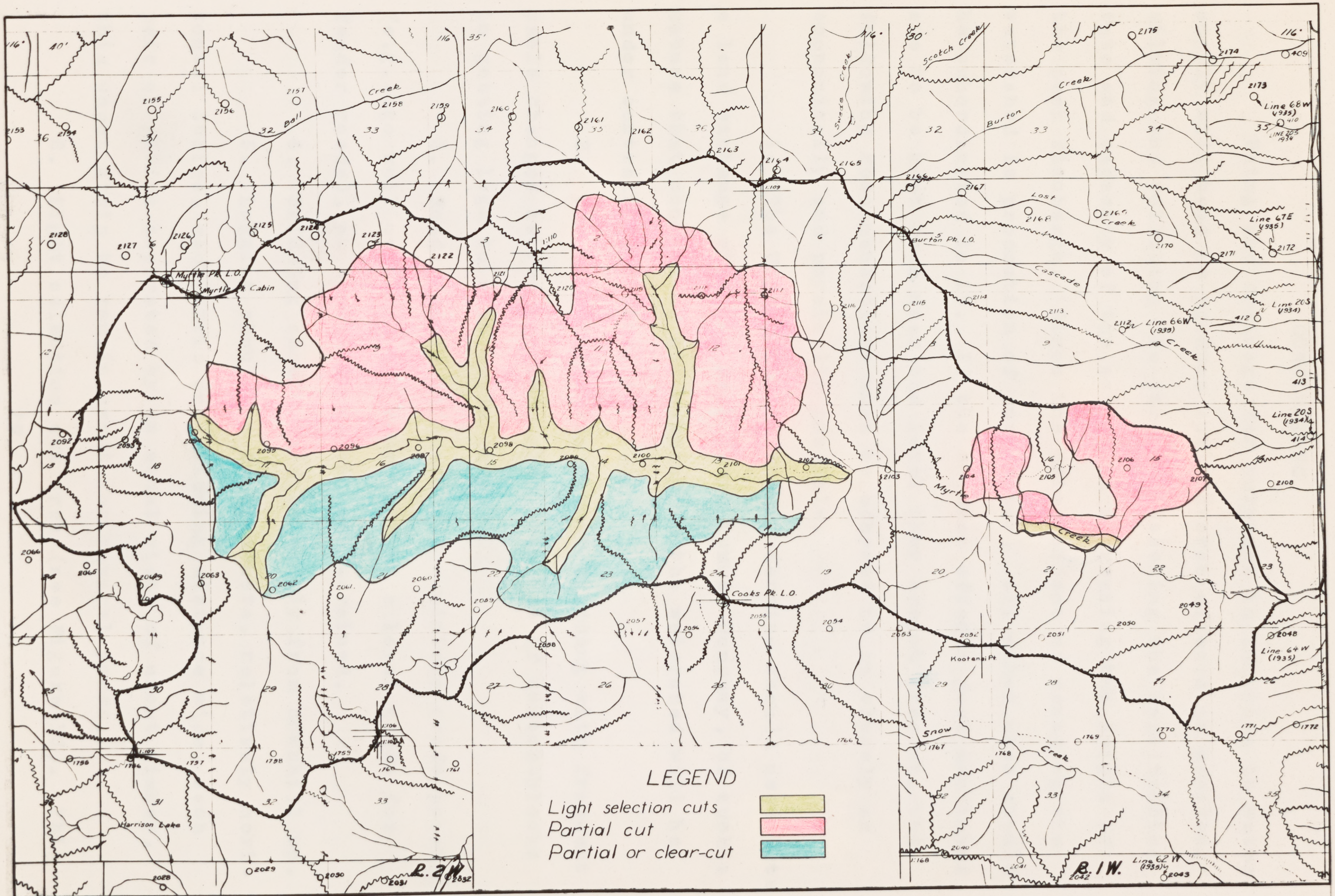

Fig. 16—Recommended cutting practices

CONCLUSIONS

Using the drainage for purposes in addition to water supply will tend to produce such adverse effects as erosion, silting and polluting the stream, lessening the infiltration rate and capacity of the soil, and increasing the height of the peak discharge. Since the prime object of managing the watershed is production of pure water, all other uses should be subordinated to it. If the adverse effects just mentioned are to be kept down near the level they are at present, the following recommendations must be adhered to as closely as economically and physically possible.

1. The United States Forest Service should negotiate a land exchange with the Pack River Lumber Company, of such a nature that control of all cutting in the watershed will be under centralized authority.

2. Use of double-drum jammer skidding with frequent cable changes is recommended, also free use of snatch-blocks in getting logs to main cable line.

3. Roads should be planned for minimum grade possible (e.g.--go well upstream and come back on a level grade for feeder roads), at a minimum width, well-drained.

4. Skidding should be done mostly from downhill up.

5. Logging should be in alternate, relatively horizontal strips, each strip one skidding distance wide, each pair of strips separated by an equal width of uncut timber, this uncut strip to remain uncut for several years.

6. Light selection cut area (see Figure 16). This

can be considered a buffer zone. Merchantable, then posts and poles, then pulp material should be removed. The interior species should be favored and a relatively young stand maintained. Pile and burn in small piles. All stream crossings should be bridged.

7. Partial cut area (see Figure 16). Merchantable and pulp material can best be removed during the same operation. Pile and burn, and lop and scatter. Some planting should be done; the species most suited can best be determined on the ground. The ponderosa pine area falls in this category; it should be replanted to ponderosa pine.

8. Partial or clear-cut area (see Figure 16). Treat similar to partial cut area, except that some protected aspects can be clear-cut and broadcast-burned.

9. Erosion control practices should be put into effect as soon as possible after logging. Roads should be prepared in the fall for the winter and spring, and checked during the spring run-off period to insure adequate drainage.

10. Portable latrines should be provided for logging crews. Logging camps should be prohibited. The Forest Service and village should coordinate inspection activities to obtain maximum cooperation with the watershed users.

11. Usual fire precautions should be taken, with additional coverage, probably from Cook's Peak, during the worst of the fire season.

12. No fishing should be allowed.

13. Legal provision should be made for controlled hunting.

14. It should be made possible for people to frequent the watershed. However, no recreational visitors should be allowed unless proper facilities are provided for them.

15. Some of the practices recommended may seem to show unwarranted cautiousness. In comparison to Seattle's watershed they are strict; but, compared to examples in the Southeast, recommendations for Myrtle Creek are lenient. It is more desirable to initiate conservative measures which may later be relaxed than to learn after a few seasons of logging that serious damage has been done, necessitating stringent regulation in order that the damage may possibly be corrected or at least minimized.

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