EXPERIMENTAL WATERSHEDS IN THE ROCKY MOUNTAINS, ALBERTA, CANADA[1,2]

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Beginning in 1960, interest in watershed management in the Saskatchewan River headwaters has grown. A comprehensive, long-term research program with the objective of evaluating and improving land management for water yield has been set up. Part of this program involves the selection and instrumentation of experimental watersheds.

A selection process has been devised to minimize the risks of selecting watersheds for instrumentation.

Two watersheds have been established. The first, Marmot Creek Basin, was almost completely instrumented during 1962 to 1964. It is planned to carry out forest manipulation studies in subalpine spruce-fir (*Picea-Abies*) forest, with the objective of improving water yield. The second watershed, Streeter Basin, will be used for study of the hydrologic effects of converting aspen forest to grassland. Streeter Basin received most of its instrumentation in 1964. A third basin in which to study the hydrology of lodgepole pine forests is in process of selection.

All basins have an intensive instrumentation network for (*a*) meteorology (*b*) surface water, and (*c*) groundwater. Further watersheds will probably be required in the future, but these are unlikely to be so heavily instrumented.

The experimental watershed component of the research program is closely integrated with other types of studies. After the watersheds are calibrated, the treatment experiments carried out in them will be based upon intensive studies into hydrologic processes, which are currently underway or to be instituted in the future.

NTRODUCTION

Beginning in 1960, a program of watershed research began to take shape in the Saskatchewan River headwaters which are located in the Rocky Mountains in the extreme west of the Province of Alberta, Canada. This program of research into watershed management has the major objective of evaluating and improving upstream land management for water production.

Part of this program of research deals with the establishment of experimental watersheds in which, after an adequate calibration period, manipulative treatments will be carried out to establish the effect of land management upon water yield. Such experiments, it is hoped, will in time help provide a reliable scientific base for integrated land management within the headwaters area.

This paper deals with the experimental watersheds established or contemplated as part of this research program.

THE WATERSHED RESEARCH PROGRAM AND THE ROLE OF EXPERMENTAL WATERSHEDS

The Saskatchewan River supplies water to a large portion of the more densely settled parts of the Provinces of Alberta, Saskatchewan and Manitoba. In these provinces, development, agriculture and population are primarily concentrated in the south, which is heavily dependent for water needs upon the Saskatchewan River

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(2)Paper presented at the International Association of Scientific Hydrology Symposium on Representative and Experimental Basins to be held in Budapest, Hungary on September 29 to October 5, 1965.

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system. Most of the water flowing in this river system originates in the headwaters area located in south and central western Alberta.

For some time, concern has been growing that water supply eventually might become limiting to growth and development within the river basin. As a result, authorization was given for an ambitious, long-term program of watershed management research, to be carried out within the Saskatchewan River headwaters, with the objective of developing and testing methods of land management to improve or sustain water yield, regime and quality in the headwaters area. This program is therefore primarily oriented to long-term experimental objectives dealing with water yield in its various aspects. It has been described in some detail by Jeffrey (1964) and only its experimental watershed component will be treated in this paper.

The program is an inter-agency endeavour in which a large number of agencies of the Canada and Alberta Governments co-operate. The organizational aspects of the program are discussed by Redmond (1964), and will not be considered here.

The Saskatchewan River headwaters extend between latitudes 49° 00′ N. and 53° 02′ N., and between longitudes 113° 40′ W. and 114° 05′ W. in their narrow southern portion, and longitudes 114° 30′ W. and 117° 10′ W. in their broadest northern extremity. They are 290 miles in length and vary between 25 and 120 miles in width. Their total area, accepting the 4,000 feet M.S.L. contour of elevation as their lower boundary, is about 15,400 square miles.

The headwaters, occupying the eastern face of the southern Canadian Rocky Mountains, are mountainous, rugged and steeply sloping. They have been heavily glaciated, and deep surficial deposits are common. Major valleys are commonly broad and U-shaped in profile. The geology of the area is primarily Mesozoic in the foothills, Devonian-Carboniferous in the Front Ranges and Proterozoic and Cambrian in the Main Ranges. The geology of the main ranges is not completely known. Elevation varies from 4,000 feet M.S.L. to the highest peak of 12,000 feet M.S.L.

Vegetation consists of forests of lodgepole pine (*Pinus contorta var. latifolia*)(4), engelmann spruce (*Picea engelmannii*) and alpine fir (*Abies lasiocarpa*), with scrubby aspen (*Populus tremuloides*) forests and willow (*Salix* spp.) shrub present in the drier southern foothills. In the southern foothills there are fairly extensive grasslands in which *Festuca scabrella*, *F. idahoensis* and *Danthonia parryii* are major components, while in the northern foothills there are areas of bog forest (muskeg) in which black spruce (*Picea mariana*) is the primary species.

Soils of the area, save for the relatively small areas of peats and organic soils of the bog forests, are primarily podzolic under forests, with pronouncedly leached upper horizons. Under grasslands, soils are chernozemic with organically enriched upper horizons.

The Saskatchewan River headwaters have been described in more detail by Jeffrey (1961), while climatic data have been summarized by McKay, Curry and Mann (1963). Climatic information is relatively sparse. Measured mean annual precipitation varies from 10 inches in low foothills and intermountain valleys to 45 inches at high elevations. In the higher elevation areas, where water yield is highest, precipitation occurs primarily as winter snowfall. Winters are long and cold. At lower elevations, occasional warm chinook (föhn) winds are experienced.

In order to fulfill the objectives of the program, three major types of complementary studies have been undertaken, or are envisaged. The first of these consist of surveys and inventories, and the compilation and analysis of existing information, dealing with the headwaters area as a whole. Such studies provide information of value, not only for research planning, but for the eventual application of research results. Gauged watersheds are the second type of study. This involves the establishment and maintenance of small instrumented basins in which to carry out manipulative experimental

(4)Botanical nomenclature follows Moss (1959).

treatments, seeking to elucidate the relationships between land management and the amount, timing and quality of water yield.

The last type of study in many ways is regarded as the most important. These are studies of processes which may be influential in water yield management. Different terrestrial phases of the hydrologic cycle are studied to obtain a greater understanding of the processes actually at work in the transformation of precipitation to runoff. It is the aim of the program to use such studies of processes, carried out on small experimental plots, to provide a basis for the rational, scientific planning of the manipulative treatments to be undertaken in experimental watersheds.

In this way, the experimental watersheds, and the results they will yield, are regarded as "integrators" of the results of a series of plot studies, more limited, more detailed and more searching in their objectives. The treatments carried out in gauged basins will provide overall, integrated effects of watershed treatment by vegetative manipulation. These effects will be more readily interpretable in relation to the results of preceding, companion studies of hydrologic processes. Without such companion studies, watershed treatment will supply only a rather crude index of the effect of manipulation. Such results would be only limited utility.

Thus the treatment experiments, to be carried out in experimental watersheds, will integrate the results of other more restricted and more controlled studies carried out in advance of watershed treatment. This philosophy dominates the planning of the experimental watershed component of the research program. It is presented here to define the terms of reference of the experimental watersheds established or contemplated in the Alberta Rocky Mountains.

It is apparent that purposive watershed manipulation will only be undertaken when a sufficient reservoir of research findings has been established for each watershed. In the meantime, watershed calibration is progressing, while the hydrometric and meteorological data being collected are supplying interesting and valuable information upon local climate and small basin hydrology in the headwaters area.

At time of writing, two experimental watersheds have been established and a third is in process of selection, prior to instrumentation. Marmot Creek Basin is designed to study the hydrology of spruce-fir forests. Its instrumentation was begun in 1962 and is now almost complete. Streeter Basin was selected to study the hydrology of montane aspen forests and grasslands. It is partially instrumented, having received most of its instrumentation in 1964. An experimental watershed, in which to study the hydrology of lodgepole pine forests, will be chosen in 1965 and will begin to be instrumented in 1966.

Within these watersheds, two major tasks are undertaken, once selection is made. These are (*a*) watershed inventory and (*b*) watershed instrumentation. Each of these tasks may take several years to complete.

In watershed inventory, the aim is to establish, as completely as is possible, the characteristics of the basin. This process involves the following endeavours:

(*a*) large scale aerial photography,
(*b*) detailed topographic mapping,
(*c*) area-elevation, slope-area and stream profile computations,
(*d*) ecological vegetation mapping,
(*e*) detailed forest cover type mapping,
(*f*) geological mapping,
(*g*) soil survey and mapping,
(*h*) detailed forest inventory,
(*i*) establishment of suspended sediment levels,
(*j*) establishment of chemical water quality,
(*k*) forest insect and disease survey.

Watershed instrumentation aims to measure, adequately for the objectives of the project, (*a*) climate, principally precipitation, but also including other meteorological parameters (*b*) surface water flows, and (*c*) groundwater flows.

The selection of experimental watersheds

Shortly after the program began, it became obvious that it was desirable to develop some means of making an objective and rational choice of watersheds in which to carry out research. A special selection process was developed. It was used in the choice of Streeter Basin as a gauged watershed and is currently underway to select a basin for studies of lodgepole pine forests. This selection process has proved very useful. It has been described in detail by Jeffrey (1964) and only a summary will be made here.

A number of steps, carried out in approximate sequence, are followed. These are:

(*a*) Air photo examination,
(*b*) Preliminary examination by air and on the ground,
(*c*) Geologic and groundwater evaluation,
(*d*) Assessment of suitability for streamgauging,
(*e*) Land inventory and timber cruise,
(*f*) Assessment of road access,
(*g*) Assessment of suitability for meteorological instrumentation,
(*h*) Preliminary appraisal of basin hydrology.

The first step picks out, on maps and air photos, a number of basins which appear to be promising. These are called "candidate basins". Once these have been chosen an observer flies over them to obtain a better impression of such factors as topography, cover, channel definition and stream characteristics.

The ground phase then begins. Appropriate specialists examine these areas to assess their geologic suitability, particularly from the groundwater standpoint. Basins which appear to have a possibility of "leakage", that is, of receiving a sub-surface water contribution from outside the basin or of losing water underground to areas outside the basin, other than by sub-surface flow along the main drainage channel itself, are immediately rejected. This is a key step in the appraisal.

Basins which survive this assessment are appraised for the existence of suitable streamgauging and meteorological instrumentation sites and for the suitability of their cover for manipulative treatments. Insect and forest disease factors are assessed. The feasibility, magnitude and cost of providing adequate road access are also evaluated. It is desirable to establish whether the ecology and soils of the candidate basins are representative of the region. As a result of these appraisals, the number of candidate basins is progressively reduced.

In these few remaining basins a preliminary appraisal of basin hydrology is carried out. Existing records are scrutinized, local persons are questioned regarding flow characteristics, and channels are examined to obtain an impression of stream behaviour. Under Alberta conditions only meagre and fragmentary information can generally be obtained in this final step of the selection process.

The data collected as the result of this sequence are brought together and one basin is chosen for instrumentation. It is believed that this approach minimizes the risks inherent in selection of gauged watersheds.

Marmot Creek basin

Marmot Creek basin is the experimental watershed established for study of subalpine spruce-fir forest hydrology. The basin was selected for study in August, 1962. Instrumentation began in that year and, with the exception of groundwater instrumentation, was largely completed in 1963 and 1964.

Study Objectives

The forest type dominant on Marmot Creek Basin, subalpine spruce-fir forest, is presently being commercially exploited in the headwaters area. This raises two valid research questions. Firstly, any cutting which is going on is having an effect upon water flows. Secondly, the fact that the type is commercially exploitable enhances the possibility of being able to carry out manipulative treatments for desired objectives in water production.

The study objectives reflect these factors. These objectives are: (1) to establish the hydrology, particularly relating to precipitation, runoff and groundwater, and their interrelationships, within the basin, (2) to establish the effect of commercial timber harvest, and subsequent regrowth, in subalpine spruce-fir forest, upon water yield and regime and upon groundwater factors, and (3) eventually, and dependent upon the results of preliminary research, to develop methods and establish the effects of purposive manipulation of high elevation, non-commercial spruce-fir forests upon water yield and regime.

Some words of explanation are necessary here. While timberline is at 7,500 feet M.S.L. approximately, by administrative edict no cutting is carried out at elevations greater than 6,500 feet M.S.L. This provides a zone, 1,000 feet in depth, which effectively is reserved for possible future manipulative treatment. In addition, the area and extent within the headwaters of commercial, lower elevation spruce-fir forest is being progressively reduced by logging and it is debatable whether special management for water production can afford to wait for the results of gauged watershed experiments. Accordingly, watershed management for water yield improvement within the commercial zone is being approached for the moment exclusively by means of plot studies. Purposive manipulative treatments within the basin are regarded in long-term planning as being concentrated in the high elevation, non-commercial forest zone. This is regarded as realistic assignment of research effort.

The study objectives, within the framework of explanation above, define the terms of reference of the Marmot Creek project.

Location and Topography

The basin is located in the Kananaskis River Valley about fifty miles west of Calgary, Alberta, at latitude 55° 57′ N. and longitude 115° 10′ W. Total area of the basin is 3.63 square miles approximately. The basin ranges in elevation between 5,000 feet M.S.L. and 9,000 feet M.S.L. Figure 1 gives the area-elevation curve of the basin.

There are three sub-basins (fig. 2) having areas of 0.8, 1.1 and 1.0 square miles respectively. Topography is moderately to steeply sloping throughout. Slopes vary from about 24 percent in the lowest reaches of the basin to over 50 percent above treeline. The average slope for the basin as a whole is 39 percent.

Stream channels are boulder paved. They are not incised to bedrock except infrequently. Channel gradients are steep. Topographic boundaries between sub-basins, while well-defined in the upper reaches of the basin, tend to be rather indefinite in some parts of the lower portions.

Geology, Soils and Vegetation

The basin consists of four poorly developed glacial cirques with intervening ridges. Over half of the basin is covered by superficial deposis including till, outwash and talus. Bedrock outcrops are uncommon in the lower reaches but are predominant in the upper portions.

The bedrock geology shows five formational units, ranging in age from late Paleozoic to early Cretaceous. Bedrock geology is shown by figure 3.

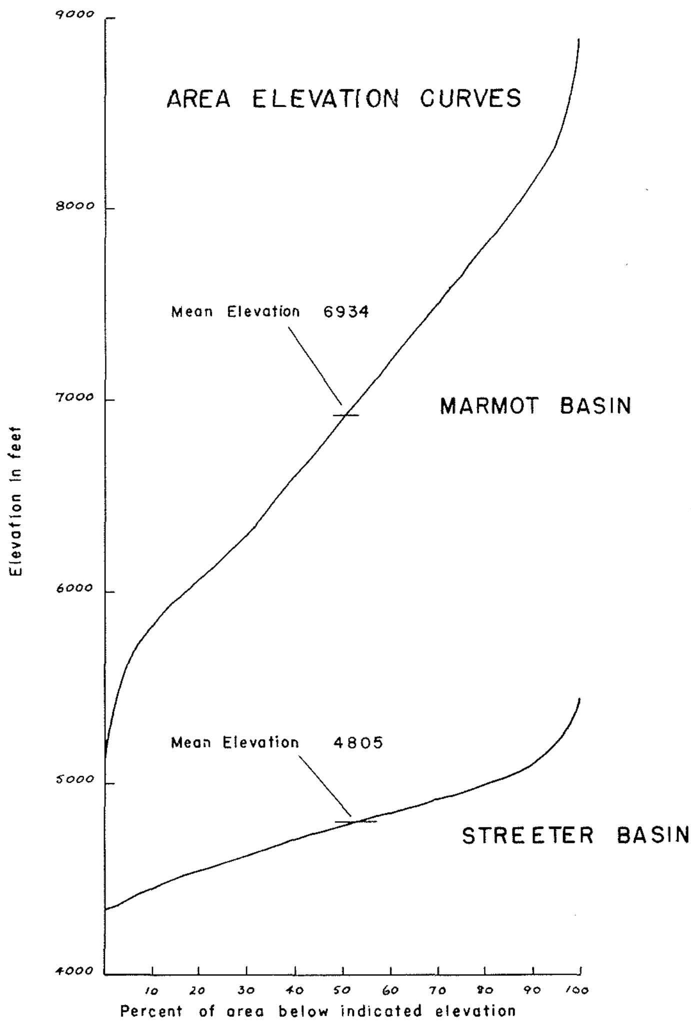

Figure 1 - Area-elevation curves for Marmot Creek and Streeter Basins.

The *Rocky Mountain Formation* is composed of hard compact dolomite, dolomitic sandstone, and quartzite. This crosses the lower portion of the basin. The *SprayRiver Formation* consists predominantly of thin bedded siltstones and forms a band approximately one mile wide through the eastern portion of the basin. The *Fernie Formation* does not outcrop in the basin itself, but forms a band estimated to be about 1/3 of a mile in width across the basin. This rock unit consists predominantly of dark grey to black shale. The *Kootenay Formation* is the thickest (3,400 feet) and the predominant rock unit. It is formed of sandstone and shale, with a number of coal seams towards the base. A few scattered outcrops are present along the banks of streams, but the formation is predominantly exposed on the higher slopes above treeline. The *Blairmore Formation,* of which the basal member is the *Cadomin Conglomerate,* is exposed almost continously in the headwaters area of the basin. Other strata of the Blairmore Formation, exposed in the headwalls, consist predominantly of sandstones and conglomerates.

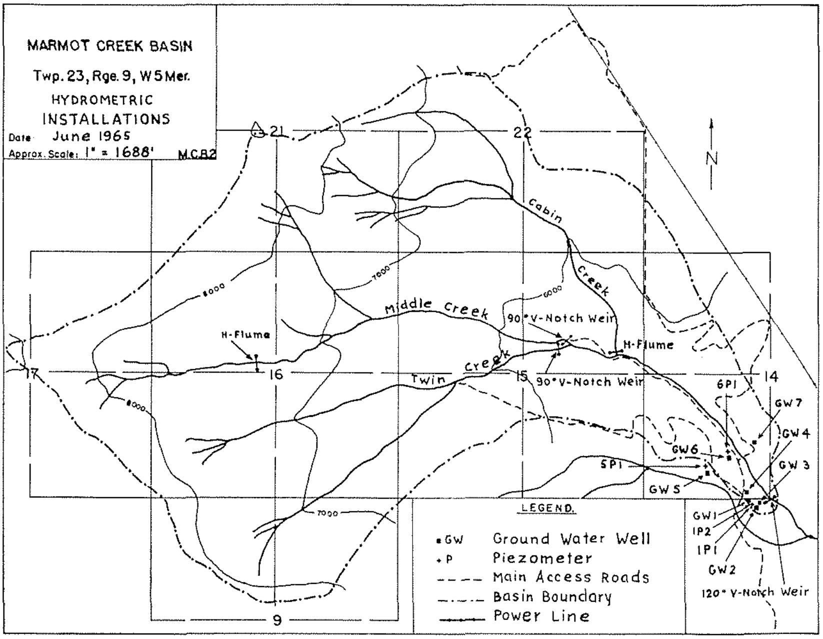

Figure 2 - Map of Marmot Creek Basin showing the three sub-basins and the surface water and groundwater instrumentation installed up to June, 1965.

Pleistocene and recent deposits of varying thickness overlie bedrock. These deposits are predominantly till with abundant boulders, through local areas with outwash sand and gravel are also found. These deposits appear fairly thick, 20 to 40 feet in depth.

A major objective in study is to establish the general characteristics of groundwater geology. The materials forming bedrock, consisting of sandstones, siltstones, shales, conglomerates, coal seams, dolomite, quartzite and limestone, are generally well-indurated, well-cemented and relatively impermeable. For this reason, they are thought probably to contribute little groundwater to flow. The rocks appear well jointed and are in some cases fractured. As such, they probably possess some fracture permeability. Whether or not this fracture permeability persists at depth is not known, but it was believed doubtful that any significant groundwater is contributed.

The deep surficial deposits appear very coarse and contain a high fraction of boulders. These deposits are fairly permeable and probably have a moderate infiltration capacity. Precipitation no doubt percolates down through them to bedrock. The pressure gradients of the water-table are thought to be steep, in outline probably roughly conforming to the topography. Direction of groundwater discharge is considered to be towards the drainage channel of Marmot Creek (Green and Jones, 1961).

Generalized mapping of soils within the basin has been carried out. Soil mapping in greater detail is now underway. Present knowledge of soils is summarized in figure 4 (Lindsay and Peters, 1964).

Five distinct soil types are found: (1) Bisequa Grey-Wooded, (2) Podzol, (3) Regosol, (4) Alpine Black, and (5) Organic.

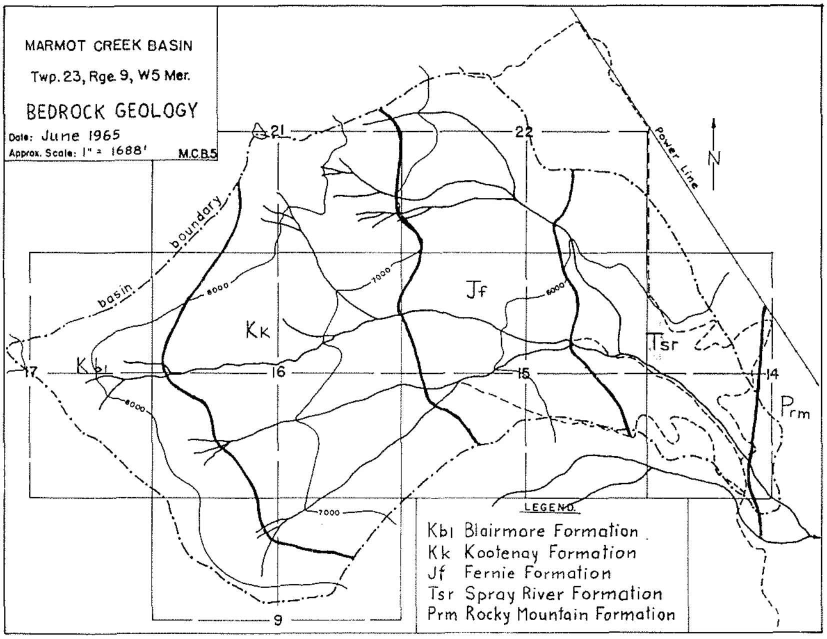

Figure 3 - Bedrock geology of Marmot Creek Basin.

The sequence of soil development appears to be controlled by elevation and by nature of the underlying strata (carbonated versus non-carbonated). Bisqua Grey-Wooded soils occur at lower elevations, while in mid-slope positions Podzols are most prominent. Regosols and alpine soils occur at higher elevations, at or above timberline.

The basin is forested up to treeline at 7,500 feet M.S.L. Dominant three species are *Picea engelmannii* and *Abies lasiocarpa* with *Pinus contorta* var. *latifolia* a frequent and abundant concomitant. In the lower reaches, where fire removed the mature spruce-fir forest in 1936, a dense young stand of lodgepole pine has grown up. Over the remainder of the basin the forest is mature spruce-fir forest, up to 90 feet in height. Near timberline the forest becomes more open and has a high admixture of *Larix lyallii* and *Pinus albicaulis*.

Instrumentation Installed

Instrumentation is designed to furnish information upon (*a*) surface flows (*b*) groundwater and (*c*) meteorology.

Surface flow instrumentation

Hydrometric installations are shown by figure 2. A total of five surface flow controls have been emplaced.

In October 1962, a control was built on the main Marmot Creek channel. This is a 120°, V-notch sharp-crested weir with a maximum capacity of 150 cfs. This control was emplaced where a bedrock sill allows total streamflow to be measured.

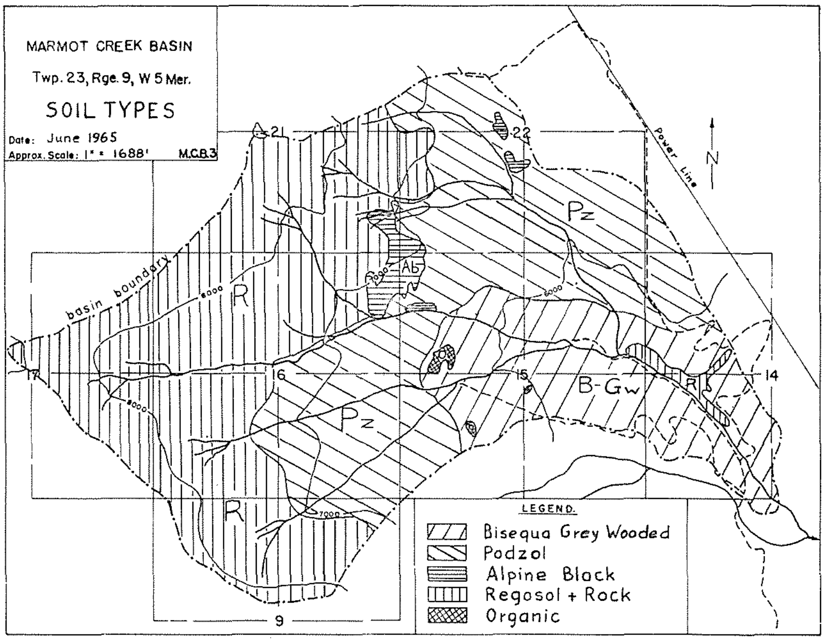

Figure 4 - Soils map of Marmot Creek Basin

A 2.5 foot head H-type flume, capacity 19 cfs approximately, was built on Cabin Creek (fig. 2), the most northerly sub-basin. The H-flume was preferred to a V-notch control because of depth of surficial deposits present and the difficulty of moving construction equipment to the site. The H-flume has good accuracy at low flows and will pass sediment and debris at higher flows.

On the other two sub-basins, identical 90°, V-notch, sharp-crested weirs were installed. Their individual capacity is 30 cfs approximately. Adequate pool design ensures no side or bed interference at peak flows and provides room for debris storage. The pools are log-cribbed, and bentonite mud is used to minimize seepage. The theoretical rating of all controls is checked by current meter readings. These controls were built in August, 1963.

In 1964, a wooden prefabricated H-type flume was flown by helicopter into the upper reaches of Middle Creek where it was put in place at timberline to measure flows coming from the alpine zone.

The four controls in the lower reaches are operated throughout the year, being heated by electricity in winter. Davis (1964) has described the streamgauge controls on Marmot Creek Basin in detail.

While the main control, measuring the total flow of the basin, is built upon bedrock, other controls are built upon till. There is believed to be a subsurface flow component at these sites. For this reason, considerable emphasis has been placed upon groundwater instrumentation at these gauge sites.

Groundwater instrumentation

Groundwater instrumentation is shown by figure 2. These wells and piezometers were installed during fall, 1964. This network is not yet complete and is being expanded in 1965.

Seven groundwater wells and four piezometers have been installed to date.

Groundwater levels in wells are continuously recorded by Leupold-Stevens recorders. Piezometers are read once weekly by tape.

Meteorological instrumentation

Meteorological instrument network is shown by figure 5. The total meteorological instrumentation in the basin is given by Table 1.

TABLE 1

Marmot Creek - Summary of meteorological instrumentation

Standard M. S. C. rain gauges	—	27
Stereo-capped rain gauges	—	18
Small orifice rain gauges (1/4 catch)	—	3
Tipping bucket rain gauges	—	4
Sacramento precipitation storage gauges	—	8
Leupold-Stevens Q12M precipitation storage gauge	—	1
Thermographs	—	9
Hygrothermographs	—	3
Max. & min. thermometer (sets)	—	3
Net radiometer	—	1
Class "A" evaporation pan	—	1
Anemometer	—	1

There is a total of 27 meteorological instrument sites in the basin. The instrumentation located at each site varies considerably. Some sites only have rain gauges, while at the main station at 5,600 feet there is a full range of instruments, measuring temperature, radiation, precipitation and evaporation. In addition to conventional meteorological sites, there are 17 snow courses.

In the measurement of precipitation on a year-round basis there is a network of eight Sacramento storage gauges and one Leupold-Stevens precipitation recorder. During summer, standard and small orifice rain gauges are used in addition, to provide a better indication of summer precipitation variation, according to such factors as aspect, slope, exposure and elevation. Rain gauges in the upper basin are read once weekly. In the lower basin rainfall readings are taken daily.

Precipitation intensity during summer is recorded at two sites in the lower basin and at two sites in the upper reaches.

Five stations measure air temperature during winter in the lower basin. Another four are added in the upper basin during summer. Humidity is measured during summer at three high elevation stations.

Using a U.S.W.B. standard Class A evaporation pan, evaporation is measured at one site during summer. Solar radiation measurements are made at one lower site on a year-round basis. Wind measurements are made at one site.

Mann (1964) has discussed meteorological instrumentation in Marmot Creek Basin.

Results

Only a few results of interest are given. Results show summer precipitation to be comparatively meager. During summer 1963, rainfall during June to September inclusive ranged from 14.3 inches to 21.3 inches. Summer rainfall appears to be greater at higher elevations (Mann, 1964). Total annual precipitation measured on September 30, 1964, to correspond to the water year beginning October 1, 1963, in the Sacramento storage gauges ranged from 35.4 inches to 50.0 inches, with precipitation for the months of July to September, 1964 inclusive varying between 4.1 inches and 7.4 inches. This illustrates the variability in precipitation from year to year within the basin.

Overwinter snow accumulations have been measured at the 17 snow courses during winters 1963-64 and 1964-65. At the lower snow courses, snow melt takes place early. Maximum snow accumulation at snow course N° 3 (fig.5) was 6.3 inches water equivalent in mid-April, 1964 and 5.0 inches water equivalent in mid-April, 1965. By contrast, maximum snow accumulation at snow course 17 (fig.5) was 30.3 inches water equivalent in mid-May, 1964 and 12.9 inches water equivalent in mid-May, 1965.

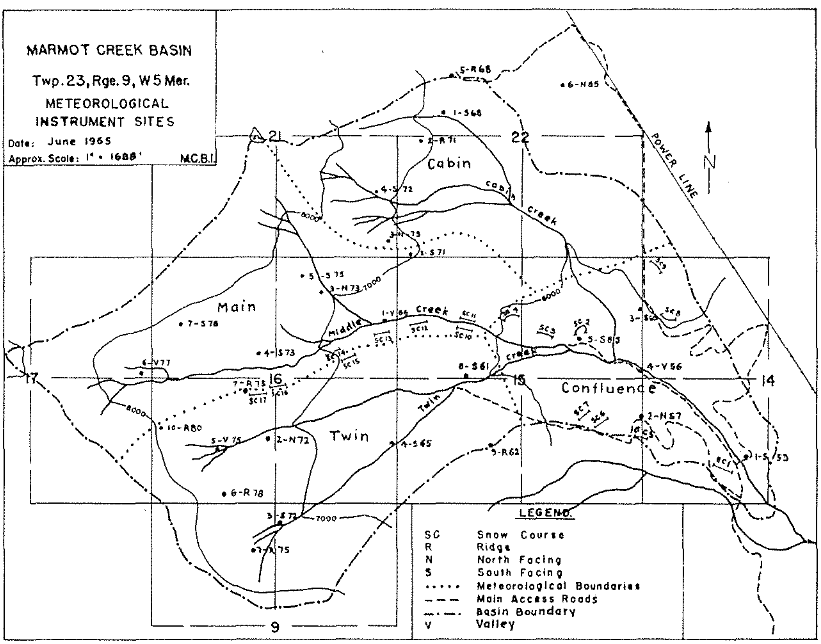

Figure 5 - Meteorological instrumentation in Marmot Creek Basin

The extreme minimum temperature recorded in the lower basin is -27.5 °F. in January 1963, the extreme maximum 84.4 °F. in August, 1963. Summer temperatures are somewhat lower at higher elevations. During August, 1964 the mean monthly maximum temperature at 5,800 feet M.S.L. was 62.0 °F., at 7,100 feet M.S.L. 57.6 °F. Corresponding mean monthly minima were 37.7 °F. and 38.4 °F., and monthly means 49.8 °F. and 48.0 °F.

Mean daily discharges and monthly flows at the lower controls are given by Table 2 for the period October, 1962 to September, 1964. Peak runoff occurs during June. The hydrographs for 1963 and 1964, with their corresponding summer hyetographs are

TABLE 2

Marmot Creek mean daily discharge (cfs) and monthly flows (Ac.ft.)

Month	Marmot Creek				Middle Creek				Twin Creek				Cabin Creek			
	1962/63		1963/64		1962/63		1963/64		1962/63		1963/64		1962/63		1963/64	
	Mean Daily Discharge	Monthly Flow (Ac.ft.)	Mean Daily Discharge	Monthly Flow (Ac.ft.)	Mean Daily Discharge	Monthly Flow (Ac.ft.)	Mean Daily Discharge	Monthly Flow (Ac.ft.)	Mean Daily Discharge	Monthly Flow (Ac.ft.)	Mean Daily Discharge	Monthly Flow (Ac.ft.)	Mean Daily Discharge	Monthly Flow (Ac.ft.)	Mean Daily Discharge	Monthly Flow (Ac.ft.)
October	2.21	136.0	1.65	101.0			0.55	33.6			0.58	36.0			0.32	19.9
November	1.15	68.5	1.14	68.0			0.33	19.5			0.38	22.5			0.23	13.8
December	0.90	55.1	0.82	50.3			0.19	11.8			0.27	16.8			0.17	10.6
January	0.64	39.4	0.64	39.6			0.15	9.1			0.21	12.8			0.14	8.3
February	0.59	32.6	0.54	30.9			0.12	6.9			0.20	11.3			0.11	6.1
March	0.50	30.7	0.49	30.0			0.90	5.5			0.17	10.3			0.08	4.9
April	0.94	55.7	0.88	52.2			0.16	9.5			0.25	14.6			0.16	9.4
May	6.02	370.0	5.85	360.0	2.59	159.0	1.95	120.0	1.49	91.8	0.98	60.3	1.10	67.6	1.19	73.2
June	20.84	1240.0	33.70	2000.0	6.61	394.0	12.30	729.0	7.68	457.0	12.00	714.0	3.38	201.0	6.85	408.0
July	16.54	1020.0	11.20	692.0	5.31	326.0	4.53	279.0	4.91	302.0	4.15	255.0	3.23	198.0	1.63	100.0
August	4.81	296.0	2.53	155.0	1.84	113.0	0.82	50.3	1.52	93.2	0.89	54.6	1.03	63.5	0.46	28.4
September	2.54	151.0	3.11	185.0	1.37	81.8	1.26	74.7	0.93	55.4	1.09	64.6	0.43	25.3	0.39	23.1
Total Annual Flow	—	*3495*	—	*3764*	—	*1074*	—	*1349*	—	*999*	—	*1273*	—	*555*	—	*706*

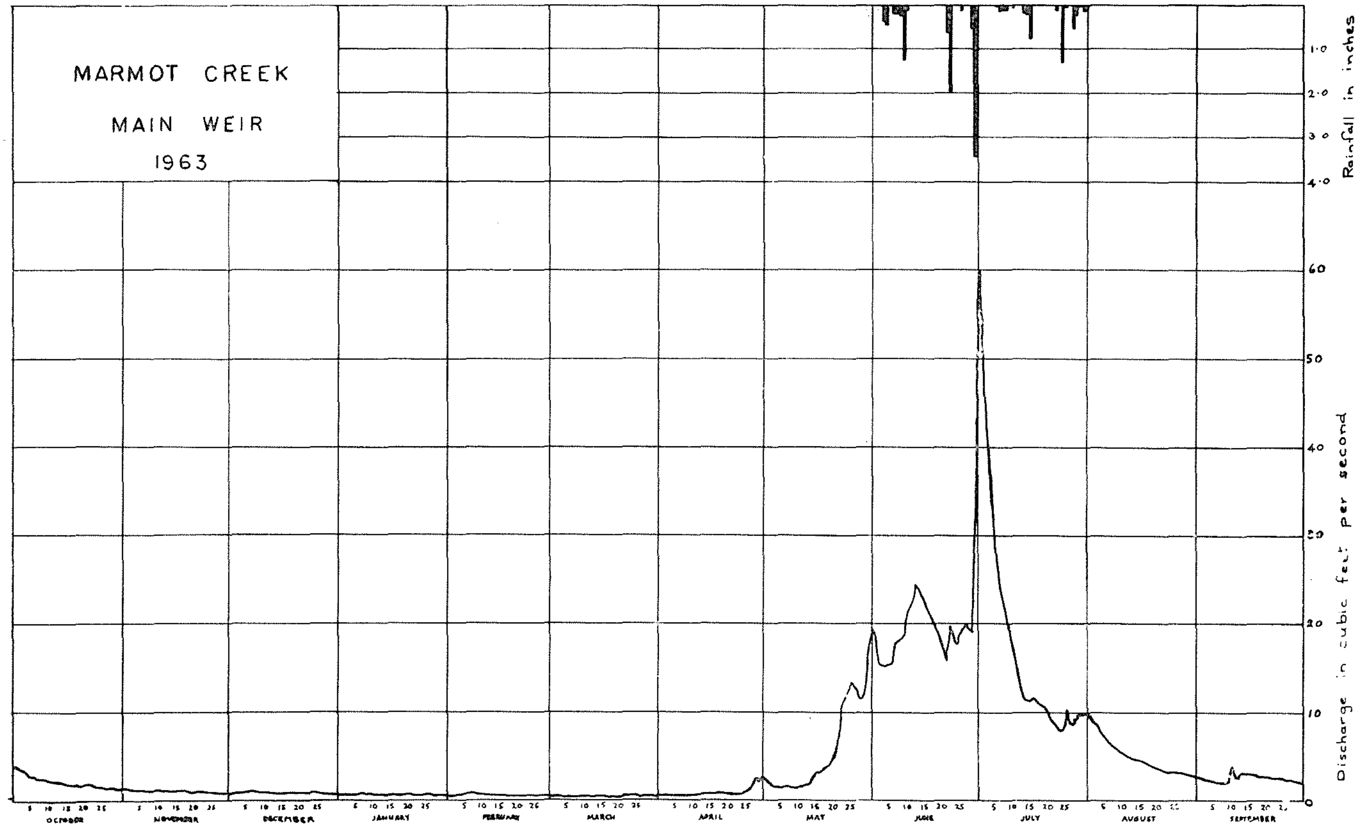

Figure 6 - Hydrograph and summer hyetograph at the main Marmot Creek streamgauge control during 1963.

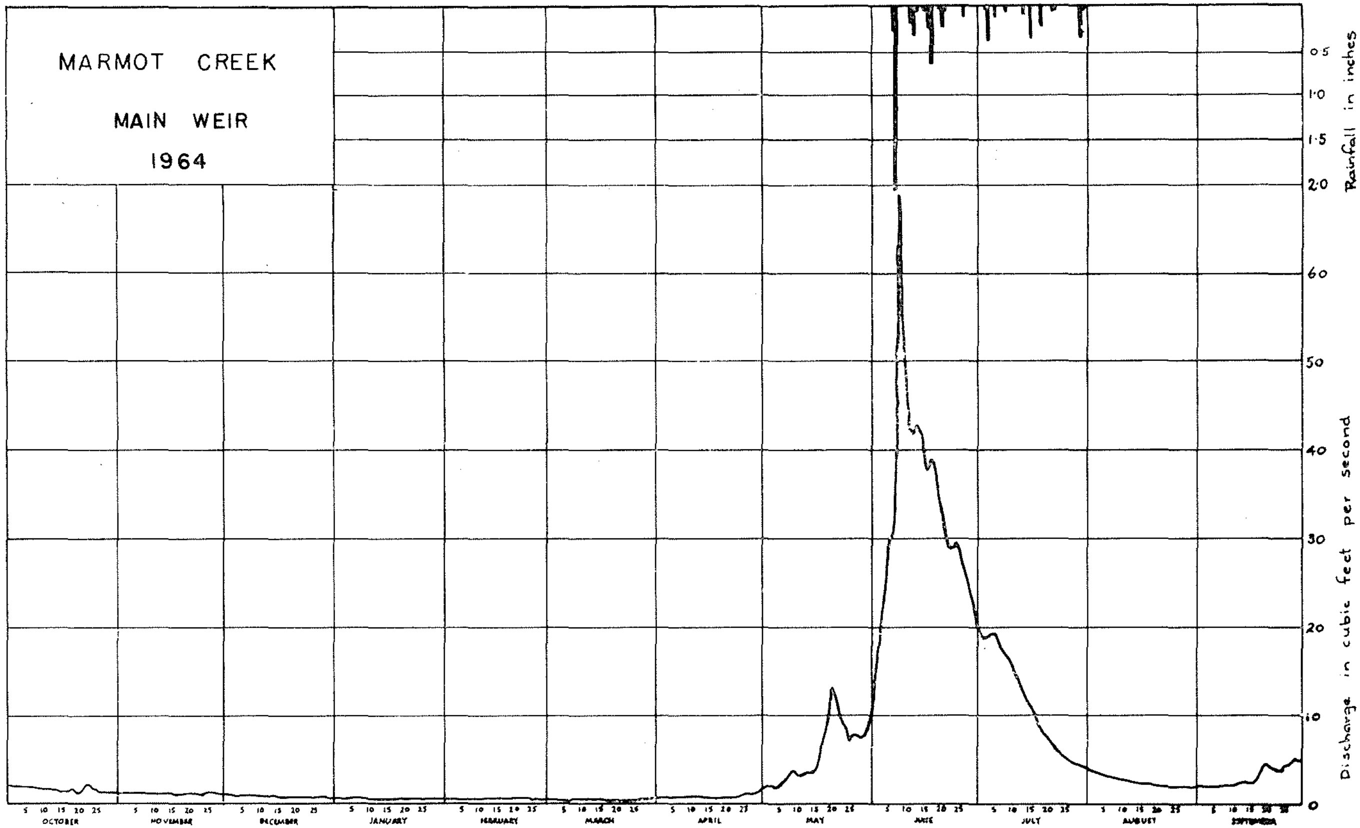

Figure 7 - Hydrograph and summer hyetograph at the main Marmot Creek stream-gauge control during 1964.

provided by figures 6 and 7. While most of the spring and early summer runoff is attributable to snowmelt, the effect of large storms is well demonstrated. Discharge in 1963 was 18.02 area-inches, in 1964 19.45 area-inches.

Suspended sediment and water quality data are obtained by periodic sampling and analysis. Sediment yields are very low. The highest suspended sediment concentration recorded was 0.087 grams per litre. Water quality data have been discussed by Thomas (1964). Total hardness in 1964 varied from 215 ppm in late April to 104 ppm in mid-June. Measurements of pH showed variation of 7.6 to 8.3.

STREETER BASIN

Streeter Basin is the gauged watershed established for study of montane aspen forests and associated grasslands of the southern foothills. The basin was selected in November, 1963 and received much of its basic instrumentation during 1964. Installation of instruments is continuing in 1965.

In this project, the approach differs somewhat in emphasis from Marmot Creek. While the Marmot Creek project will attempt to increase water yield through forest manipulation, Streeter Basin will supply guidelines to prevent hydrologic deterioration of watersheds undergoing cover changes as a result of management for increased forage production.

The woody vegetation in the drier eastern portions of the southern mountains and foothills is already being removed to supply more grazing capacity. Because of economic pressures, it is assumed that livestock producers will wish to remove more forest and shrub vegetation (primarily aspen and willow) and convert such areas to grassland. This trend if it occurs will present problems of range and watershed management.

Study Objectives

Study objectives reflect the concern of the research group over a potential problem of hydrologic change and sediment production resulting from an anticipated increase in forest clearance for range management purposes. These objectives are:

(1) to assess the suitability of existing methods of forest removal and conversion to grassland, from the standpoints of range management (including big game) and watershed protection, and to develop satisfactory methods, if necessary, (2) within the experimental basin to gather information on hydrology, particularly relating to precipitation, runoff and ground water, and to their interrelationships, (3) to establish, by means of plot studies, the effect of forest removal and conversion to grassland, upon sedimentation, water quality, water yield and water regime, and upon rangeland productivity, and (4) finally, within the basin, upon culmination of adequate and satisfactory plot studies, to carry out experiments to assess the integrated effect of forest removal and conversion to grassland upon water quality, yield and regime.

These objectives define the terms of reference of the Streeter Basin project.

Location and Topography

The basin is located in the Porcupine Hills of southerwestern Alberta at latitude 50° 7′ N. and longitude 114° 3′ W., approximately. The lowest portion of the basin is at elevation 4,350 feet M. S. L., the highest point at 5,450 feet M. S. L.

There are three sub-basins, as shown in figure 8. The total experimental area is 2.31 square miles. The individual sub-basin areas have not yet been calculated, pending topographic mapping, but the actual area to be involved in cover manipulation, if two of the three sub-basins are eventually treated, will be about one square mile.

Topography is moderately sloping. Stream channels are not deeply incised and in the lower portions of the basin, below the sub-basin stream gauges, are of low gradient and rather poor definition. Topographic boundaries between sub-basins are well defined.

Geology, Soils and Vegetation

The whole basin area is underlain by light brown, fine to coarse grained, flaggy to massive, cross-bedded, argillaceous sandstone, probably cemented by calcareous cement. This Porcupine Hills sandstone is probably subject to some joint permeability, at least in the weathered zone of the bedrock. This assessment is supported by the frequent occurrence of springs throughout the basin.

A shallow covering of silty to sandy till overlies bedrock. Depth of this till varies from 0 to 2 feet on ridge tops to 5 to 10 feet on lower slopes and along the upper stream channels. In the lower portion of the basin this till thickens to reach depths of 10 to 20 feet and becomes more organic in composition.

Granitic erratics found throughout the basin indicate that the area was completely overridden by the Laurentide ice, while limestone erratics from the mountains to the west show that the Cordilleran ice also covered the basin, at least in part.

No detailed soils information from the basin is available. Observation indicates chernozemic soils under grass cover, with some leaching of the organic upper horizon occurring under forest. Soils studies are now underway.

Vegetative cover is divisible into forests and grasslands. The forests are usually dominated by aspen (*Populus tremuloides*). Such forests have an understory in which *Calamagrostis canadensis* is the dominant component, with *Rosa acicularis*, *Symphoricarpos albus*, *Lathyrus ochroleucus*, *Vicia americana*, *Fragaria glauca* and *Epilobium augustifolium* as associates. In the overstory, the aspen forest has a closed canopy, less than 50 feet in height. The forest has no commercial value for wood products.

Lesser areas, rather insignificant in extent, are dominated by *Populus trichocarpa*. *Calamagrostis canadensis* and *Elymus innovatus* are the most prominent components of the lesser vegetation. Somewhat larger areas are occupied by a vegetation dominated by *Salix* spp. and *Betula occidentalis*. The lesser vegetation contains most of the species listed above. *Calamagrostis canadensis* is dominant.

Grasslands are divisible into three sub-types. The first of these is dominated by *Festuca idahoensis* and *Danthonia parryii* with *Carex* spp., *Festuca scabrella*, *Galium boreale* and *Lupinus argenteus* important associates.

A second sub-type is confined to valley bottoms and is strongly dominated by *Phleum pratense*. The third sub-type is restricted to slopes and has a prominent herb component. Species noted as important are *Carex* spp., *Monarda fistulosa*, *Rosa acicularis*, *Galium boreale*, *Stipa columbiana*, *Vicia americana*, *Fragaria glauca*, *Achillea mille-folium*, *Aster laevis*, and *Agropyron subsecundum*.

A generalized map of the vegetation of the basin is given in figure 9.

Instrumentation Installed

With the exception of groundwater instrumentation, it is intended to install a less intensive network of instruments in Streeter Basin than in Marmot Creek basin. This is a reflection of more limited project objectives.

Instrumentation was begun in 1964 and is continuing. Steam-gauges have been constructed on the three sub-basins. These controls are H-flumes having capacities of 30, 19 and 19 cfs, based upon a design discharge of 60 CSM. These flumes have been installed upon bedrock or clay, in spite of deep fills in the lower valley bottoms. They will be supplemented by groundwater wells to measure any subsurface flows at the gauge sites. Groundwater instrumentation, because of greater ease of access, is much simpler to install in Streeter Basin than in Marmot Creek. In addition to the H-flumes at the sub-basin mouths, gauges have been installed on three major springs near these sub-basin gauges. These spring gauges are small V-notch controls which are read manually at weekly intervals. Stage at the H-flume locations is recorded on

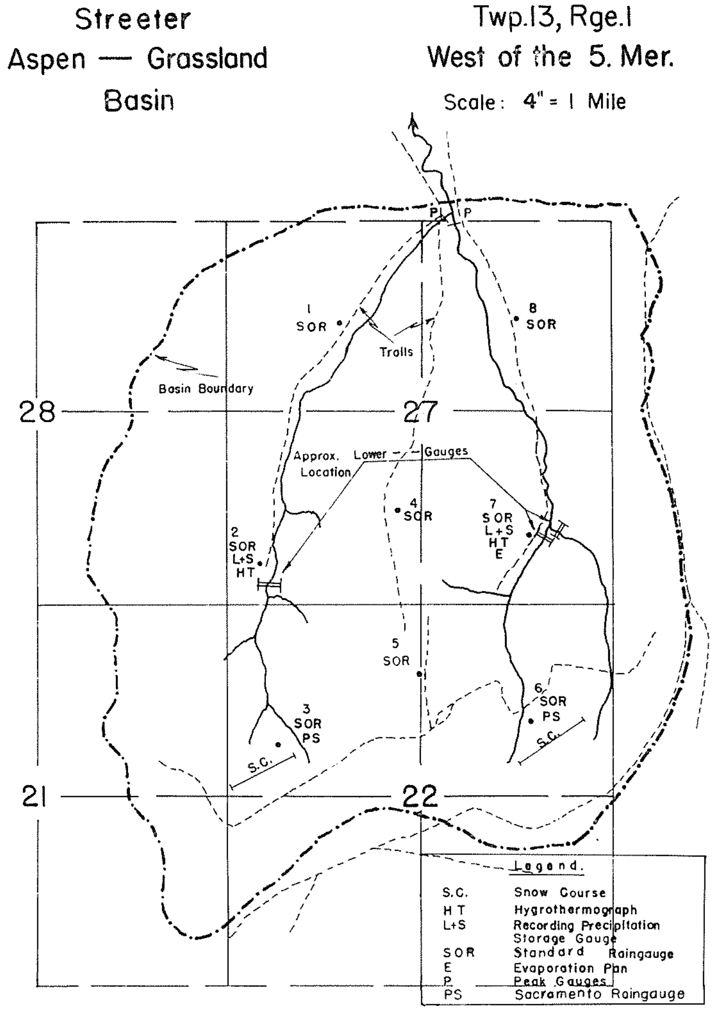

Figure 8 - Map of Streeter Basin, showing stream channels and meteorological and hydrometric instrumentation.

Leupold-Stevens negator spring-driven A-35 recorders which need attention once monthly, but which in practice are checked at intervals of no more than one week. H-flume controls have sloping floors to facilitate sediment clearance through the controls.

Flows at Streeter Basin are ephemeral. Springs flow throughout the year but their flow is absorbed into the valley fills. This makes intensive groundwater instrumentation of the basin essential.

Eight meteorological stations have been set up. Location of these stations is shown by figure 8. Rainfall is the major meteorological variable being measured. Small

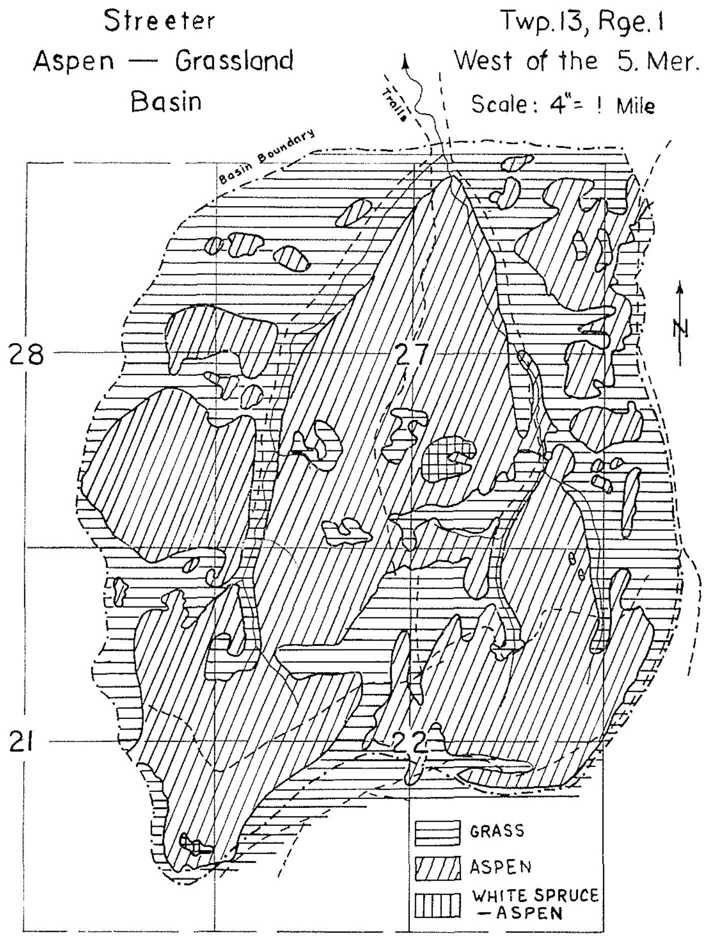

Figure 9 - Generalized map of the vegetation of Streeter Basin.

orifice rain gauges allow readings to be taken once weekly. Leupold-Stevens recording precipitation gauges give a constant record of rainfall experienced at stations 2 and 7 (fig.8). Temperature and humidity are also recorded, as is evaporation at Station 7, where a class A evaporation pan is installed. Two snow courses have been laid out in the upper basin.

Results

Few results are available from Streeter Basin. Tentative estimates indicate water yield to be in the neighborhood of one or two area-inches per year. Observations during winter 1964-65 show no measurable snow accumulation in the basin. Mean monthly temperatures between July, 1964 and May, 1965 show an extreme mean monthly minimum of -2.7 °F in December, 1964 and an extreme mean monthly maximum of 72.3 °F in July, 1964. Precipitation has been significant only in two months since records began in July, 1964. In September, 1964 rainfall varying from 2.61 inches to 2.96 inches was measured by the small orifice rain gauges, while in April, 1965, 1.40 inches of precipitation was recorded in the Leupold-Stevens precipitation recorder. Otherwise, monthly precipitation at all stations has been less than one-half inch.

LODGEPOLE PINE EXPERIMENTAL WATERSHED

Originally it was proposed that two experimental watersheds be set up to investigate the effects of manipulative treatments in lodgepole pine forests upon water yield. These watersheds were to carry a cover of (*a*) merchantable lodgepole pine forest, and (*b*) overdense, sapling lodgepole pine forest, respectively. As a result of fiscal and manpower considerations, only the first of these has currently been authorized, research into overdense, sapling lodgepole pine forests being for the moment held in abeyance.

Research into the hydrology of lodgepole pine forest is accorded high importance (Jeffrey, 1964), in part due to the large area of the headwaters supporting a cover of lodgepole pine, in part to the possibility of intensified commercial exploitation of this forest type. During 1964, eight candidate basins were chosen for appraisal by the accepted selection process. A choice of one of these basins will be made in 1965, and instrumentation begun.

The objectives of the lodgepole pine experimental watershed have been defined as: (1) to establish the hydrology, particularly relating to precipitation, runoff and groundwater, within the basin (2) to establish the effect of commercial timber harvest, and subsequent regrowth, in merchantable lodgepole pine forest, upon water yield, regime and quality, and (3) to establish the effect of purposive manipulation in merchantable lodgepole pine forest upon water yield, regime and quality.

To attain these objectives will require a combination of (*a*) gauged basin instrumentation and calibration, (*b*) reconnaissance and plot studies, and (*c*) based upon the results of plot studies, watershed treatment experiments in the calibrated basin.

The lodgepole pine experimental watershed will have approximately the same intensity of instrumentation as Marmot Creek Basin. As a project, it is accorded a similar level of priority; in fact, it is believed that in time the lodgepole pine experimental watershed will come to be regarded as the most important basin of the three major projects.

CONCLUSION

The three watersheds described are the major projects involving experimental watersheds in the Alberta Rocky Mountains. They are instrumented at a relatively high level of intensity and represent considerable investment in both money and manpower. It is not anticipated that further watersheds instrumented at this level of intensity will be set up.

It is regarded as likely, however, that other small watersheds may be required as the program develops, and research needs become apparent in greater detail. These other watersheds, if needed, will have more limited objectives, largely of a manipulative trial nature, and will be instrumented at a much lower level of intensity (Jeffrey, 1965).

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