GROUNDWATER INVENTORY

CARBON COUNTY MONTANA

STATE OF MONTANA

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MONTANA WATER RESOURCES BOARD
Helena, Montana 1969

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COMPILED AS OF JANUARY 1969
MONTANA WATER RESOURCES BOARD

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May, 1969

Honorable Forrest H. Anderson
Governor of Montana
Capitol Building
Helena, Montana

Dear Governor Anderson:

Submitted herewith is a report on the Groundwater Inventory of Carbon County, Montana, compiled by the Groundwater Division of the Montana Water Resources Board.

The report is part of the comprehensive and continuing inventory of the groundwater resources of Montana being compiled by the Montana Water Resources Board, and was prepared at this time in response to a request by the Carbon Soil and Water Conservation District, through its chairman, Mr. J. D. Dykstra.

The inventory report includes discussions of the general geology, aquifers, groundwater uses, water quality, the availability of groundwater, and effective recharge in Carbon County. Specific problems related to groundwater, enumerated by members of the Carbon Soil and Water Conservation District, are also discussed.

Information contained herein is relevant to the use of resources in Montana and to the economy of Carbon County.

Respectfully submitted,
E. V. DARLINTON, Director
Montana Water Resources Board

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TO THE READER:

There are several minor unintentional typographical errors in this publication. They do not present a problem in comprehending the material, and hopefully will not detract from the Reader's interest in the content of the report.

GROUNDWATER INVENTORY

CARBON COUNTY, MONTANA

INTRODUCTION

A groundwater inventory of Carbon County is part of the comprehensive inventory of Montana's water resources being compiled by the Montana Water Resources Board. In conjunction with a general inventory of the groundwater resources of the county, additional research and investigation were carried out in response to a request by the Carbon Soil and Water Conservation District, through its chairman, Mr. J. D. Dykstra. The Carbon Soil and Water Conservation District outlined specific areas and problems in the county which could benefit from increased knowledge of groundwater conditions. In compiling the inventory, data and information were gathered from the records of the Groundwater Code Administrator, the Department of Health, the Oil and Gas Conservation Commission, and various publications. Three field geologists made a reconnaissance investigation of selected areas within the county during the summer of 1968, and collected additional data.

This inventory depicts conditions of groundwater availability in Carbon County at present, and points out areas where data is lacking or inadequate. The accompanying inventory (geologic) map is a composite of published maps modified locally as a result of field-examination. The map is a reconnaissance tool, and can be used as a base from which to plan additional investigation; much detailed field work is necessary before the surface geology of Carbon County can be considered as reliably mapped everywhere.

FIELD PROGRAM

A summer field program was incorporated as part of the inventory. Mr. Gary Knudson, a student at Montana College of Mineral Science and Technology, made a field inventory of selected wells, collected groundwater samples for analysis, made aquifer tests, selected potential observation wells and mapped the extent of the alluvium and terraces. Mr. Bradley Bruce, another student, assisted Mr. Knudson in the field. Mr. Robert Marsh, a Certified Professional Geologist, was retained as a Consultant to advise the student field geologists and coordinate activities. Formation boundaries and well locations were mapped in the field on aerial photographs, and later transferred to a base map that was constructed by the Water Resources Survey Division of the Montana Water Resources Board. An attempt was made to determine the thickness of alluvium and depth to water table by use of a portable seismograph (hammer-type). Aquifer tests were made at several sites by personnel provided by the Groundwater Division of the Montana Bureau of Mines and Geology, in order to determine characteristics of aquifers in which these wells were drilled. Water samples were collected and analyzed in the Montana Bureau of Mines and Geology laboratory. Potential observation wells were located, based on ease of year-round accessibility, geographic location, well-construction, and type of aquifer. More than 200 personal contacts were made by the field geologists in order to obtain first-hand information on wells and groundwater use.

ACKNOWLEDGMENTS

The work done by Messrs. Marsh, Knudson, and Bruce was extremely helpful in augmenting existing information and in providing new data used to compile this report. These gentlemen in turn received assistance from numerous individuals and agencies including Dr. Sid Groff, Messrs. Maxwell Botz and Marvin Miller, all of the Montana Bureau of Mines and Geology in Butte; Mr. Fred McCotter of the American Stratigraphic Company in Billings; Messers. Merle Brunsvold and John Parker of the U. S. Soil Conservation Service in Joliet; Mr. George Darrow, Consulting Geologist of Billings and former Representative from Yellowstone County; and Mr. Dick Feltis, Geologist with the U. S. Geological Survey in Billings, Mr. Cliff Balster, Petroleum Geologist with the Montana Bureau of Mines and Geology at Billings, was especially helpful to the student field geologists.

Mr. J. D. Dykstra and members of the Carbon Soil and Water Conservation District were very helpful, and the friendly cooperation of all Carbon County inhabitants involved was greatly appreciated. Appreciation is also extended to the Mueller Engineering Company of Billings for releasing company information pertinent to the inventory.

A great amount of information was found in reports and "logs" filed with the Oil and Gas Conservation Commission and appreciation is extended to Mr. Norman Beaudry, Executive Secretary, and Commission personnel in Helena and Billings for making this information available.

Dr. G. B. Maxey, Consulting Hydrologist to the Montana Water Resources Board, critiqued the report and offered relevant suggestions.

Appreciation is extended to Messrs. R. G. McMurtrey and D. L. Coffin, Hydrologists with the U. S. Geological Survey, Water Resources Division in Helena, for their suggestions and assistance.

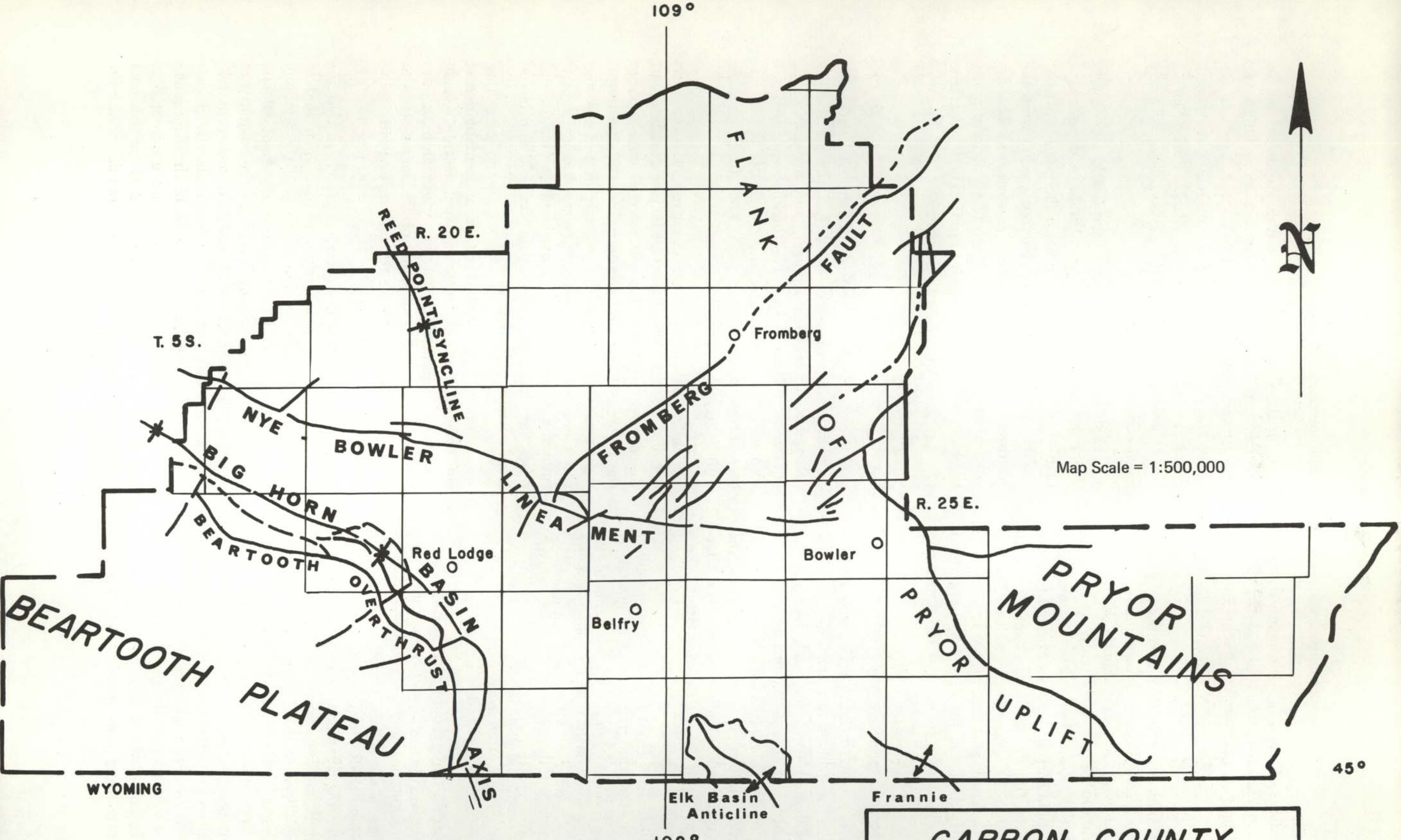
GEOLOGY

The availability of groundwater in Carbon County is closely related to geologic events and changing conditions of environment associated with the development of the present physiography. The Clarks Fork River and Rock Creek are important in the development of the water regimen in the county, but even more significant were events that took place during a mountain-building epoch which began in mid-Tertiary time, some 30- to 40-million years past. During this period of geologic history, a structural pattern developed in response to new stresses placed upon a system of ancient faults and fractures. Large rectangular fault-blocks were uplifted thousands of feet. The Beartooth Plateau was uplifted at this time, as was the Pryor Mountain area. The intervening valley region was downfaulted with respect to the mountainous regions. The low region now is the topographic expression of the north end of the Big Horn Basin and the south end of the Reed Point Syncline. The separation of these features in Carbon County is effected by the Nye-Bowler lineament, represented at the surface by a system of faults extending completely across Carbon County in an approximate east-west direction. Figure 1 illustrates the regional structural features of the county.

On the west flank of the Pryor Mountain uplift, the exposed outcrop pattern reflects an anticlinal fold trending northwest. Successively younger sedimentary strata are exposed in a westward direction, dipping into the Bighorn Basin and the Reed Point Syncline. The axis of the Bighorn Basin (lowest structural area) is very close to the Beartooth overthrust fault zone. The dipping strata which outline the flank of the Pryor uplift are cut by several series of longitudinal (across the strike, approximating the direction of dip) faults in an area extending from the Wyoming state line northward as far as the town of Fromberg. The most significant of these cross-faults define the Fromberg fault zone, about 20 miles long in Carbon County, and interpreted as passing under the Clarks Fork River floodplain in Township 5 South, Range 23 East. A two-mile lateral displacement along this zone is apparent. Faults are breaks in the rock-section and can either be barriers to the movement of fluid in the subsurface, or conduits which thieve water from underground formations and recharge other formations, or discharge water at the surface. In the development of water resources, faulting in or near the recharge area can significantly affect the availability of groundwater at a particular locality. Faulting increases the risk of prospecting for groundwater in the early stages of exploration; as more information becomes available, an understanding of the character of the faults becomes an aid in the development of the groundwater resources of a particular area.

Bedrock geology has a pronounced effect on the development of surface drainage and the distribution of groundwater. In the area of alternating dipping beds of sandstones and shales along the steep flank of the Pryor uplift, the less resistant shales host streams which flow down the strike of the valleys, while the sandstone hogbacks are cut by streams flowing down the dipslopes and joining the trunk drainages in the shale valleys. Large quantities of water probably are absorbed by sandstone as streams cross the outcrops. According to reports, numerous streams and creeks disappear while running down the flank of the Pryor uplift; some reappear in the form of springs.

Drainage on the Beartooth Plateau has developed in "hard rock" and reflects topographic relief more than changes in lithology (rock-type). The numerous lakes in the Beartooth Mountains are accumulations of water in surface depressions, and many of them originated as a result of uplift whereby stream gradients were abruptly altered. Water flowing out of the Beartooth Mountains supplies much of the perennial stream flow



(Generalized from "Tectonic Map of portions of Southern Montana and Northern Wyoming," by John R. Fanshawe and Andrew G. Alpha, in Billings Geological Society Fifth Annual Field Conference Guidebook, 1954)

CARBON COUNTY

REGIONAL STRUCTURAL

FEATURES

Figure 1

in the lower valleys. The surface drainage divisions are generalized in Figure 2, which also shows the locations of stream gaging stations, precipitation stations, and surface storage sites investigated by the Montana Water Resources Board.

The Clarks Fork River follows a winding course from the Wyoming state line northward through Carbon County and joins the Yellowstone River near the town of Laurel in Yellowstone County. It has been postulated that the Clarks Fork River at one time flowed into Montana east of the present point of entry and was a part of the Pryor Creek drainage. At an ancient time the lower Clarks Fork hypothetically was tributary to Rock Creek and had its headwaters near the town of Belfry. Uplift of the Pryors brought about a change in the drainage pattern, and the upper segment of the Clarks Fork River was "captured" by the tributary to Rock Creek. Pryor Gap, now "high and dry" at an elevation of about 5,000 feet, has been described as being a gorge of the ancient river system which included the ancestral Clarks Fork. During recent geologic time Rock Creek became a tributary to the Clarks Fork River.

East-flowing tributaries to the Clarks Fork River which originate in the Beartooths have deposited a blanket of terrace gravels between the mountain front and the river, composed of material eroded from the Beartooth Plateau and carried downstream. The development of the Rock Creek terraces was in response to changes brought about by uplift. This is also true of other gravel benches in the county.

AQUIFERS

An aquifer is a water-bearing rock stratum. This general definition has evolved to mean a geologic rock unit or unconsolidated earth material, beneath the surface of the earth, capable of producing or yielding water as from a well. Other terms have been proposed, such as aquiclude, aquitard, and aquifuge, to describe a relative degree of water-yielding ability. The character of a rock unit can change drastically in a short distance, and what may be an excellent aquifer at one location will be hard and tight nearby. An aquifer can be the same as a stratigraphic unit or formation, or only part of a formation, or an accumulation of unnamed (excepting generically) unconsolidated earth material. Names are given particular sequences of rock, primarily based on lithology, in order to identify and correlate the stratigraphic section from one locality to another. (The stratigraphic section of Carbon County is generalized in Table 1, on page 11.)

Water occurring underground that is suitable for domestic, municipal, livestock, and agricultural uses originates as precipitation and percolates downward through openings in the soil and rock into the zone of saturation, where the water occupies spaces in the rock—the greater the aggregate volume of space in the rock (porosity), the more water in storage. Porosities and permeabilities of some bedrock aquifers are recorded in Table 2. Groundwater is "stored" in both unconsolidated and consolidated aquifers. In the unconsolidated aquifers, (such as alluvium and terrace gravels) the source material, mode of transportation and deposition of the material, and thickness of the deposit are all very important in the development of storage space. In consolidated (bedrock) aquifers the development of porosity and permeability, and the geologic structure are very significant. The processes of uplift and erosion very strongly influence the development of bedrock aquifers, and unconsolidated aquifers to a lesser extent. The thicknesses of bedrock formations in Carbon County vary greatly due to the tectonism which has taken place, and abrupt changes in lithology also occur.

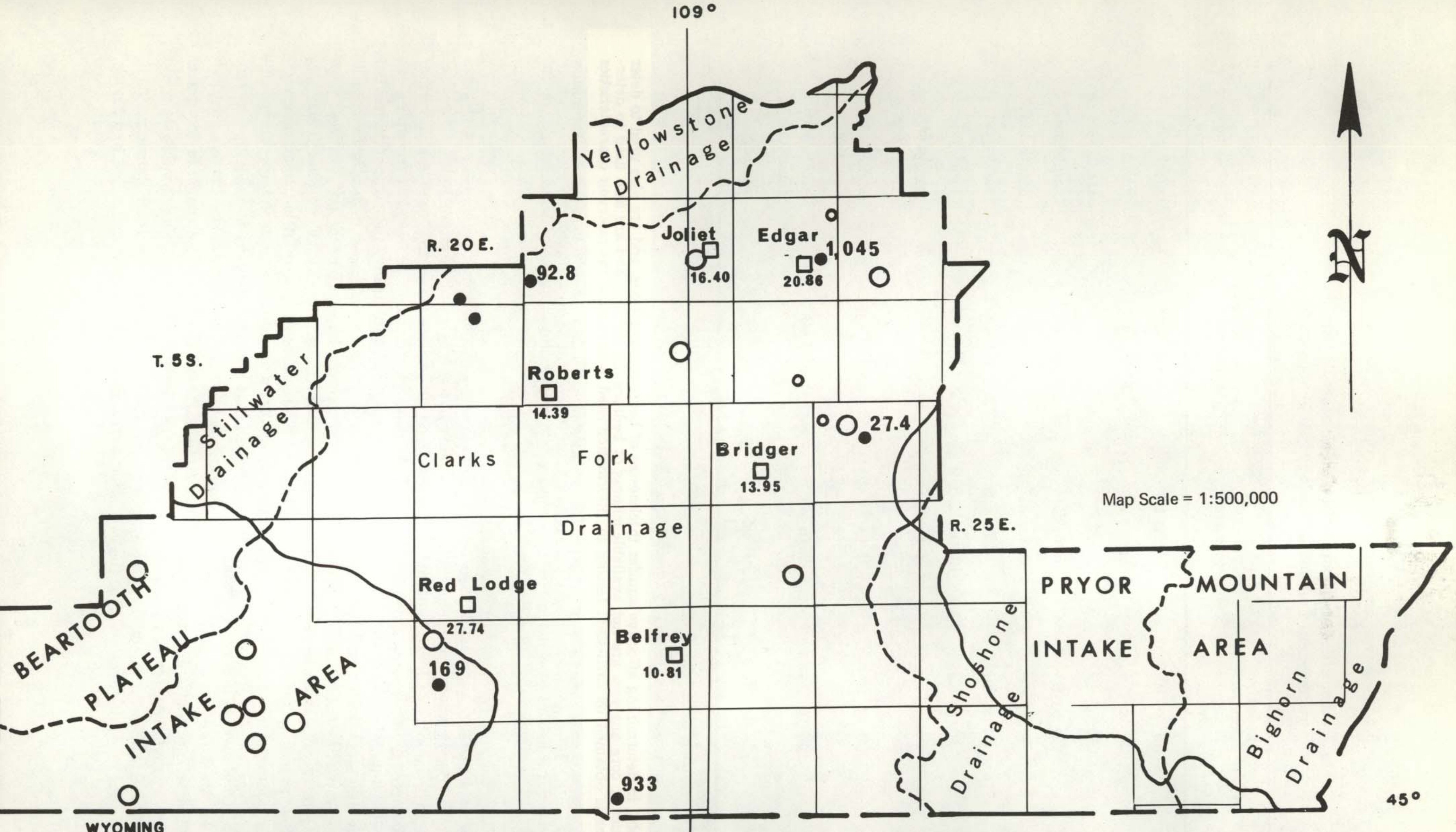
Individual aquifers are discussed in reverse order of deposition, the shallowest or youngest first and the deepest or oldest last. Water-well data is from the records of the Groundwater Code Administrator, deep-well data is from the records of the Oil and Gas Conservation Commission, water-quality data is from the records of the Department of Health, and other data has been collected in the field and culled from various publications.

Alluvium (Quaternary) is a recent accumulation of silt, sand, and gravel, unconsolidated or only weakly cemented, deposited by moving water and includes fluvial deposits of floodplains of the major streams, local deposits of smaller streams, fan deposits, colluvium, and lake deposits.

Alluvium differs from terrace gravels in that the median grain size of alluvium is finer than that of terrace gravels. The average thickness of the alluvium is about 30 feet, with a maximum of about 80 feet and a minimum of about 5 feet. In the majority of wells, thicknesses between 20 and 40 feet are reported. Alluvium in the Clarks Fork valley is slightly thicker than along Rock Creek or elsewhere in the county. The thickness of saturated aquifer varies from 3 to 30 feet, with an average of 12 feet. The reported static water levels vary from 5 to 43 feet below ground level,

Table 1.—Carbon County stratigraphic section

Years duration (est.) (after Harbaugh, 1968)		Era			Stratigraphic Unit (Aquifer)	Thickness (feet)	Hydrologic Characteristics
1,000,000 to present time	63 Million	Cenozoic	Quaternary		Alluvium and Colluvium	5 to 80	Yields of 10 to 300 gpm reported, larger yields possible locally
					Terrace gravels	7 to 115	Yields of 10 to 50 gpm reported; 1,000 gpm also reported locally.
62,000,000			Tertiary		Wasatch formation	unreported	Springs reported, but potential for wells unknown.
					Fort Union formation	600 to 8,500	Widely utilized aquifer; yields of 1 to 50 gpm.
72,000,000	167 Million	Mesozoic	Cretaceous		Hell Creek formation	100 to 600	Yields of 1 to 15 gpm reported.
				Montana Group	Lennep sandstone	125 to 300	Unknown potential.
					Bearpaw shale	250 to 1,000	Not normally an aquifer.
					Judith River sandstone	600	Yields of 1 to 40 gpm reported.
					Claggett formation	550 to 675	Sandstones within the formation, specifically the Parkman, can be waterbearing.
					Eagle formation	200 to 250 (600 max. reported)	Yields of 12 to 330 gpm reported.
					Telegraph Creek formation	180 to 300	Yields of 1 to 18 gpm reported; potential for larger yields exists.
				Colorado Group	Basal Cody shale	400 to 1,500	Unknown potential.
					Frontier formation	500 to 825	Includes one or more sandstone aquifers; water usually is mineralized.
					Mowry-Thermopolis formations	350 to 1,000	Unknown potential.
				Cloverly	Dakota formation	200 to 600	Artesian aquifer, flowing yields from Greybull sandstone.
					Kootenai formation		Mosser sandstone may be water-bearing.
					Lakota formation		Flowing yields from Pryor conglomerate.
46,000,000			Jurassic		Morrison formation	0 to 400	Soft sandstone may be water-bearing.
				Ellis Group	Sundance formation	100 to 200	Unknown potential.
					Rierdon formation	40 to 250	Not normally an aquifer.
					Gypsum Spring (Piper) formation	50 to 530	Not normally an aquifer.
49,000,000			Triassic		Chugwater formation	100 to 650 (including Dinwoody)	Large flowing yields reported; may be hydraulically connected to Madison.
50,000,000	370 Million	Paleozoic	Permian	Embar	Dinwoody formation		Unknown potential.
					Phosphoria (Park City) formation	10 to 100	Unknown potential.
30,000,000			Pennsylvanian	Minnelusa	Tensleep formation	100 to 200+	Large flowing yields reported; may be hydraulically connected to Madison.
					Amsden formation Darwin	100 to 300	Unknown potential; Darwin sandstone at base.
35,000,000			Mississippian		Madison limestone	1,000+	Large flowing yields reported; large quantities of underground water stored in limestone.
60,000,000			Devonian		undifferentiated	200 to 500	Unknown potential.
20,000,000			Silurian		absent		
75,000,000			Ordovician		undifferentiated	200 to 400	Unknown potential.
100,000,000			Cambrian		undifferentiated	1,000+	Unknown potential.
4,400,000,000			Pre-Cambrian		"hard rock"		Exposed in Beartooth Plateau recharge area.



□ Precipitation station, values are 1968 annual inches of precipitation (from 1968 Annual Summary, U.S. Dept. of Commerce, ESSA)

● Stream gaging station, values are 1967 annual average flows in cfs (from Water Resources Data for Montana, Part 1, Surface Water Records – 1967, U.S. Geological Survey in cooperation with the State of Montana and other agencies)

⊙ Partial – record station

○ Surface storage sites previously investigated by the Montana Water Resources Board.

CARBON COUNTY

SURFACE DRAINAGE DIVISIONS

Figure 2

Table 2.—Porosities and permeabilities of bedrock formations (reported in Petroleum Geology publications)

Formation	Effective Aquifer Thickness (feet)	Porosity (percent)	Permeability (millidarcies)	Lithology
Eagle	50 to 100	15 to 20	50 to 150	sandstone
Frontier*	20 to 250	13 to 20	50 to 200	sandstone
Muddy	10 to 20	21	8	sandstone
Dakota	30 to 60	6 to 20	0 to 150	sandstone
Greybull	15	8 to 15	14	sandstone
Mosser	30 to 50	24	200 to 4,400	sandstone
Fuson "stray"	10 to 20	10 to 12.5	250	sandstone
Lakota (Pryor)	100	8 to 15	27	sandstone conglomerate
Embar-Tensleep	50 to 100	0 to 10	118	sandstone, limestone
Tensleep	50 to 200	9 to 33	0 to 1,000	sandstone, limestone
Madison	50 to 200	12		limestone

* 1 to 5 individual aquifers, each 20 to 50 feet thick.

Permeabilities are greatly increased locally due to fracturing of the bedrock.

Electric Logs are useful in determining effective aquifer thicknesses of bedrock formations, and are also used to determine relative porosities if core analyses are not available. Information used to determine the reservoir characteristics of bedrock formations is obtained by drill-stem testing intervals of rock while the well is being constructed.

As a comparison, the porosity of unconsolidated aquifers is generally estimated to be about 40 percent. The ability of an unconsolidated aquifer to transmit water is not measured in millidarcies of permeability, but is given as a field coefficient of permeability (in gallons of water per day per square foot at the prevailing water temperature), or coefficient of transmissivity (in gallons per day per foot).

and pumping yields of 10 to 300 gpm (gallons per minute) and an average specific capacity of about 10 gpm per foot of drawdown per well are reported. Most of the wells completed in alluvium (about 65 percent of the reported total) furnish water for domestic use. Domestic and stock wells combined constitute 90 percent of the alluvium wells of record. Exceptional wells (from records) are the one which claims 1,000 gpm for irrigation, and another which claims 2,000 gpm for domestic use.

Terrace Gravels (Quaternary/Tertiary) represent the remnants of older stream deposits and indicate the various stages of drainage development that occurred. As many as five gravel terraces are reported locally, as distant as 30 miles from the mountain front. As interpreted by previous geologic investigations, the distribution of these different levels indicates changes in drainage patterns resulting from uplift. The lowest terrace in each series is the youngest, a further indication of development in response to uplift—as uplift progressed periodically, the main streams cut deeper in response to increases in headwater gradients. The terraces have relatively flat surfaces, sloping in a downstream direction. Even though the surfaces of the benches show very little topographic variation, the buried bedrock underlying the gravel undoubtedly has abrupt variations in relief due to erosion prior to gravel deposition. The gravels are both glaciofluvial and fluvial in origin; much of the gravel west of the Clarks Fork of the Yellowstone River could have accumulated during periods of mountain glaciation in the Beartooths. In the vicinity of Red Lodge,

Table 3.—Specific capacities of bedrock water wells

Formation	Specific Capacity
Fort Union	Usually less than 1 gpm for each foot of drawdown; maximum reported 5½ gpm per foot of drawdown.
Hell Creek	Considerably less than 1 gpm for each foot of drawdown (1 gpm with 50 feet of drawdown); maximum reported 0.6 gpm per foot of drawdown.
Judith River	Usually less than 1 gpm per foot of drawdown; maximum reported 5 gpm per foot of drawdown.
Eagle	Usually in the range of 3 to 5 gpm per foot of drawdown.
Telegraph Creek	Usually less than 1 gpm per foot of drawdown.
Frontier	Considerably less than 1 gpm per foot of drawdown.
Chugwater-Tensleep-Madison	From about 1 gpm per foot of drawdown to 25 gpm per foot of drawdown.

an exposure near the mountain front reveals about 200 feet of gravel and till resting on gently tilted Tertiary sedimentary rocks. The lower 60 feet of this deposit is coarse gravel derived from crystalline rock. Near the mountain front, boulders in the gravel attain diameter-sizes up to 5 feet; the size decreases away from the mountains, but boulders are nearly 1 foot in diameter 25 miles from the mountain front. The gravels form wedge-shaped deposits, thickest at the mountain front.

Along Rock Creek the reported thickness of terrace gravels is 7 to 115 feet with 15 to 50 feet being common. Along East Rosebud they are 4 to 70 feet and commonly 15 to 25 feet thick. The gravel is mostly coarse-grained, with some finer sand and silt. Terrace gravels are water-bearing and are recharged directly by precipitation and the flow of mountain streams. The gravel-covered benches are used for agriculture and are also recharged by irrigation water. The gravels have good porosity and permeability and can be depleted rapidly. They can also act as areas of recharge for underlying aquifers. Numerous wells have been drilled into terrace gravels and report small yields. Two wells in Section 34, Township 6 South, Range 20 East are reported to yield 3,000 gpm and 2,000 gpm, the latter for irrigation. A well in Section 35, Township 6 South, Range 20 East is reported to yield 1,000 gpm for irrigation; total depth is 63 feet.

Wasatch Formation (Tertiary) consists of light-colored massive sandstone, similar to intervals within the underlying Fort Union. In Carbon County it is present as an isolated remnant at the front of the Beartooth Mountains, near the town of Luther, and even though springs are known to discharge from the Wasatch, its limited extent makes it unfavorable as a dependable source of groundwater.

Fort Union (Tertiary) is a sequence of sandstone, shales, clays, and coal beds attaining an aggregate thickness of from about 600 to more than 8,500 feet. The shales and clays are impervious and do not yield water readily, but the sandstones are regional sources of groundwater. Coal beds can also be aquifers, due to intense fracturing of the beds, and openings which develop at contacts of the coal with other rock-types. The coal occurs in individual seams, as many as nine, each having a thickness of 3 to 12 feet. The top of the coal series usually is found some 6,500 feet above the base of the Fort Union (in the Bear Creek mining district) and has an overall thickness of approximately 825 feet. The maximum coal development is reported in the vicinity of Red Lodge where mining operations were underway as early as 1882. The extent of the coal is limited by erosion, "pinching out," and facies change (change in rock-type due to depositional environment). Some old mine workings are known to be filled with water, and wells drilled into abandoned mine shafts and tunnels might encounter large supplies of water. Individual sandstone units within the Fort Union are not normally continuous over extensive areas but the formation is present for many miles and does provide water for numerous low-yield (less than 50 gpm) wells. Specific capacities for water wells in the Fort Union and some other bedrock aquifers are given in Table 3.

Hell Creek Formation (Cretaceous) is the youngest sequence of Cretaceous rocks exposed in Carbon County. Yellow, green, and darker colored sandstones and shales of this sequence are exposed as part of the faulted outcrop-belt along the flank of the Pryor uplift and dip westward beneath the Fort Union formation. Sandstones within the Hell Creek are water-bearing, and small yields (1 to 15 gpm) are possible through properly constructed wells. The sequence is known to include soft shales, and wells in or through the Hell Creek should be constructed so as to prevent "caving shales" from causing premature abandonment or costly rework.

Lennep Sandstone (Cretaceous) consists of hard, cemented, lenticular brown sandstones and sandy clay and shale. It has tentatively been correlated with the *Fox Hills* sandstone of eastern Montana due to its stratigraphic position. The Lennep usually develops an escarpment standing above underlying soft shale. The thickness of the Lennep has been estimated to be from 125 to 300+ feet. The Lennep could locally be an aquifer, but only if porosity and permeability permit water movement in the subsurface, or if fracturing and faulting in or near the outcrop have induced permeability. The *Colgate* sandstone is mentioned in some reports, and is the upper part of the Lennep, or Fox Hills.

Bearpaw Shale (Cretaceous) is an interval of soft grey-black shale not normally considered an aquifer. Thickness in the subsurface is known to be about 1,000 feet, and about 250 to 500 feet in the eroded outcrop.

Judith River Sandstone (Cretaceous) consists of alternating beds of sandstone and shale, with an overall thickness reported as about 600 feet. Sandstones commonly are water-bearing excepting where they are above the zone of saturation, and well yields of 1 to 40 gpm are reported. The Judith River is one of the more resistant formations exposed on the flank of the Pryor uplift, but in a relatively short distance dips under the Bearpaw shale and is at uneconomic drilling depths (for most uses) in much of Carbon County.

Claggett Formation (Cretaceous) is a light grey, very soft shale with light grey or white sandstone stringers. The amount of sandstone increases in a westward direction near the town of Fromberg. The upper part of the formation is very sandy and has been correlated with the *Parkman* sandstone of Wyoming. The Claggett thickness varies from 550 to 675 feet where measured, and the Parkman equivalent can be more than 300 feet thick. Sandstones within the Claggett, especially the Parkman, can be water-bearing. (The Parkman has also been correlated with the Judith River sandstone in northern Montana.)

Eagle Formation (Cretaceous) consists of three units, an upper buff-colored massive sandstone, a medial zone of soft shale and soft sandstone, and a basal massive grey-white sandstone (*Virgelle* sandstone). The overall thickness of the Eagle is about 200 to 250 feet (as much as 600 feet in one report) and the Virgelle thickness is about 60 to 140 feet. Coal stringers are found in the Eagle, and occurrences of natural gas have been reported. The Eagle formation locally exhibits porosity and permeability indicative of reservoir rock and is water-bearing. Well yields of 12 to 330 gpm are reported. Depth to aquifer deters extensive development of the Virgelle in Carbon County.

Telegraph Creek Formation (Cretaceous) is a shale and sandstone unit below the Virgelle, and includes a basal sandstone member, named by Wyoming Geologists the *Elk Basin* sandstone. The Elk Basin commonly is about 50 feet thick but has been reported as much as 160 feet thick locally, and is a reservoir for hydrocarbons or water. The total thickness of the Telegraph Creek Formation has been reported as 180 to 300 feet.

Sandstones within this formation are utilized as sources of shallow groundwater in Carbon County. Small well yields (1 to 18 gpm) are reported. The Elk Basin sandstone is similar to the Eagle and should be capable of yielding from 50 to 200 gpm, depending on aquifer thickness.

The accompanying inventory map (Plate 1) shows the Telegraph Creek formation exposed as an outcrop band from the town of Bridger north to the Yellowstone River, but not exposed south of Bridger. This is also how it is shown on geology maps prepared by the U. S. Geological Survey. This could be related to severe faulting and associated with the Nye-Bowler lineament, but more likely indicates that the Telegraph Creek is distinct enough to be recognized in the outcrop north but not south of Bridger. The formation is reported present in the subsurface south of Bridger, as interpreted from electric logs, near the exposures of Eagle and Cody beds, and this suggests that the Telegraph Creek is so much like the formations above and below that its identity is lost in the outcrop south of Bridger. (The Claggett, Eagle, and Telegraph Creek formations comprise the upper Cody.)

Basal Part Cody Shale (Cretaceous) is a sequence of dark shales and not normally considered an aquifer. The basal Cody is equivalent to the combined Niobrara - Carlile - Greenhorn - Belle Fourche interval. The thickness is very irregular, ranging from a reported 400 to 1,500 feet, commonly in the range of 1,100 to 1,500 feet, and thinner over anticlinal structures and in areas of normal faulting.

Frontier Formation (Cretaceous) is a sequence of interbedded sandstones and shales, reportedly 500 to 825 feet thick. There are from 1 to 5 sandstones within the sequence, separated by shale similar in character to the Cody shale. Each sandstone is from 20 to 50 feet thick, and sometimes contains hydrocarbons and/or water. Two important sandstones are the *Torchlight* sandstone, at the top (called the "first sand") and the *Peay* sandstone (called the "second sand") lower in the formation. (The *South Byron* sandstone may be present above the Torchlight in the subsurface, near the State line.)

The Torchlight sandstone is the dominant member of the Frontier and is a cliff former in the outcrop. Porosity in this member has been measured by core analyses to be about 13 percent. The Peay sandstone is similar but can be thicker and have a slightly better porosity development, reportedly about 20 percent.

Sandstones in the Frontier are utilized as sources of groundwater where the depth to aquifer is not excessive. Water quality is variable. Several oil exploration wells reported flowing water from the Frontier; some of these, such as the well in Section 17, Township 3 South, Range 23 East which flowed from Frontier sandstones at depths of 940 to 960 and 1,380 to 1,420 feet, reportedly were completed as water wells and used for irrigation.

Mowry-Thermopolis (Cretaceous) is an interval of grey sandstones and black shales in the upper part and grey shales below. Sandstones, including the *Muddy*, may locally be water-bearing but the overall interval would not be considered as containing reliable aquifers. The thickness of this sequence is reported in drillers' logs to vary from less than 350 to 1,000 feet.

Cloverly (Cretaceous) is a series of sandstones and vari-colored shales (denoted as "Kootenai" on previously published maps) which is divided into three distinct members from top to bottom: the *Dakota*, the *Kootenai*, and the *Lakota*. The Dakota includes one or more reservoir sandstones which sometimes contain oil and gas, and commonly are water-bearing. Within the Dakota, the *Greybull* sandstone has about 15 feet of porosity in a 50-foot section of fine to medium grained white and grey sandstone. The Kootenai (also known as the Fuson) is vari-colored shale but does locally include a prominent sandstone, the *Mosser* or Second Cat Creek sandstone, with a reported local porosity of 24 percent and a permeability range of 200 to 4,400 millidarcies. The Mosser is water-bearing (1,700 ppm total dissolved solids reported) and locally contains oil and gas. The Lakota, commonly called the *Pryor* conglomerate in Carbon County, is water-bearing and at strategic locations contains commercial quantities of hydrocarbons. The Pryor averages 100 feet of fine to medium grained sandstone, with coarse chert-pebble conglomerate at the base. The Greybull and Pryor reportedly have 8 to 15 percent porosity and very low matrix permeability. Fracturing enhances permeability locally and increases the potential yield. A water flow of 6 gpm from the Pryor at a depth of 1,360 feet was reported in an oil exploration well in Section 2, Township 4 South, Range 23 East.

The overall thickness of the Cloverly is reported to be from less than 200 to almost 600 feet. The units within the Cloverly are important oil and gas horizons both in Montana and Wyoming, and because of this the nomenclature has developed independently in each state. Differences in terminology are evident, and reported thicknesses may vary significantly depending on the origin of the report (see Table 4). Differences in terminology are carried through the Cloverly and into Jurassic units to the top of the Gypsum Spring formation.

Morrison Formation (Jurassic) is light-colored clay and shale and yellow sandstone, with tints of green, red, and purple. Pre-Cloverly erosion has removed much or all of the Morrison locally. The Morrison thickness, where reported, varies from 100 to 400 feet. The Morrison is not considered a reliable aquifer (one that can be depended upon to yield some water everywhere) although soft sandstones locally may be water-bearing.

Sundance Formation (Jurassic) is 100 to 200 feet of brown sandy clay and sandstone, equivalent to the Swift formation of northern Montana. The type Sundance section of Wyoming includes the Rierdon formation described separately in this report.

Rierdon Formation (Jurassic) consists of 40 to 250 feet of dense grey and olive-drab limey clay and limestone, and is not normally an aquifer.

Gypsum Spring Formation (Jurassic) is 50 to 530 feet of gypsiferous limestone, red siltstone and shale with interbeds of pink-white gypsum, and not normal-

Table 4.—Terminology of the Cloverly Series

CLOVERLY SERIES				
		MONTANA TERMINOLOGY	WYOMING TERMINOLOGY	
CLOVERLY	"DAKOTA"	Dakota Siltstone	Dakota Siltstone	CLOVERLY
CLOVERLY	"DAKOTA"	Dakota Sandstone (First Cat Creek Sandstone)	Dakota Sandstone (Greybull Sandstone)	CLOVERLY
CLOVERLY	"DAKOTA"	Greybull Sandstone	Fuson Formation	CLOVERLY
CLOVERLY		Kootenai Formation Mosser Sandstone (Second Cat Creek Sandstone)	Lakota Sandstone	CLOVERLY
CLOVERLY			Morrison Formation	
CLOVERLY		Lakota Sandstone (Third Cat Creek Sandstone) (Pryor Conglomerate)	Morrison Sandstone	
		Morrison Formation		
		Swift Sandstone	Sundance Formation	
		Rierdon Formation		
		Gypsum Spring Formation (Piper Formation)	Gypsum Spring Formation	

(From Billings Geological Society Guidebook, 5th Annual Field Conference, 1954, "Pryor Mountains—Northern Big-horn Basin, Montana")

ly an aquifer. It is equivalent to the Piper formation of central Montana.

Chugwater-Dinwoody Interval (Triassic) is 100 to 650 feet of red sandstone, siltstone, clay, and gypsum, conspicuous in the outcrop by its bright red color. In the subsurface the Chugwater's red color is more subdued and the color is red-brown and brown as well as red. The Dinwoody in the subsurface is 10 to 50 feet of greenish-grey shale with thin laminae of calcareous sandstone or shaly dolomite, at the base of the Chugwater. The Chugwater is equivalent to the Spearfish formation of the Williston Basin (eastern Montana), and the Dinwoody correlates with the upper part of the Embar formation of Wyoming.

Chugwater sandstones normally are very fine or fine grained and well-cemented and would not be considered good aquifers. However, secondary permeability due to fracturing and faulting has locally resulted in high-capacity springs and conditions favorable for potential wells on the flank of the Pryor uplift. A well reportedly flowed 1,500 gpm from the Chugwater, and spring flow has been measured in excess of 3,000 gpm. It has been reported that the combined flow of springs originating in the Chugwater and other formations provides the perennial flow of Bluewater Creek. Large springs and wells are near fault traces, and there probably is hydraulic continuity between the Chugwater and other water-bearing formations.

Phosphoria Formation (Permian) is 10 to 100 feet of phosphatic shales and thin limestones (thicknesses greater than 100 feet, as much as 190 feet in one instance, have also been reported). The limestones locally are porous and could be water-bearing. The Phosphoria is equivalent to part of the Embar formation, and the interval is also referred to as the Park City formation. Porosities of zero to 10 percent and low permeabilities are reported.

Tensleep Formation (Pennsylvanian) consists of buff to cream-colored and tan to white, fine to medium sandstone. Sandstone intervals in this formation have uniform grain-size distribution which reduces effective permeability. However, the reservoir character of the formation has been enhanced by fracturing, by solution of cementing material between the grains and of soluble matrix rock, and by pre-Phosphoria erosion. The Tensleep is one of the better aquifers and high-capacity flowing wells (1,000 to 3,000 gpm) are not uncommon. Hydrocarbons associated with the sandstone reservoirs may locally affect water-quality. Tensleep thickness is variable, reportedly from less than 100 to more than 200 feet. Although Tensleep sandstones are considered good aquifers with reported porosities of 9 to 33 percent and as much as 1,000+ millidarcies permeability, oil exploration wells have locally encountered sections which are impervious and would not be considered reliable aquifers.

Amsden Formation (Pennsylvanian) is a sequence of interbedded red, green, and purple shales, grey limestone stringers, and thin beds of light-colored sandstones. Sometimes a thicker sandstone (*Darwin* member) is present at the base, and even though this basal sandstone is almost always a reservoir rock, the restricted type of development infers only local aquifer capability. The overall thickness of the Amsden is reported to vary from less than 100 to 300 feet. The Amsden normally is not considered an aquifer but may be hydraulically connected to other water-bearing rocks through fractures. (The Tensleep-Amsden interval is stratigraphically equivalent to the Minnelusa formation of the Powder River Basin.)

Madison Limestone (Mississippian) is about 1,000 feet of grey and dark blue massive limestone having cavernous porosity in the upper part. Matrix porosity (primary) by core analyses is reported as 12 percent (see Table 1). Cavernous (secondary) porosity may be 50 percent or greater locally. Where secondary porosity has not been infilled with Amsden-type clastics or cemented breccia, the buried karst topography provides conduits for essentially unrestricted movement of groundwater. Large springs originate from the Madison, and oil exploration wells in Carbon County have encountered large water flows (as much as 12,000 gpm reported in a U. S. Geological Survey publication) from the limestone. There are, however, localities where the limestone is dense and impervious and not an aquifer.

Devonian Interval is 200 to 500 feet of argillaceous limestone, not considered an aquifer in Carbon County.

Ordovician Interval is 200 to 400 feet of light-colored dolomite, thin-bedded at the top and massive below, sometimes having a thin interval of sandstone at the base. Primary porosity/permeability is poor, but dolomite can be an aquifer in certain instances.

Cambrian Interval is about 1,000 feet of sandstone, shale, and limestone. Aquifers may exist but drilling depths have deterred exploration of this interval.

Pre-Cambrian rocks are exposed in the Beartooth Mountains, and underlie the sedimentary section in the subsurface. These are metamorphic and igneous rocks ("hard rocks") and not normally considered aquifers, but in the outcrop are capable of conducting precipitation and runoff into the subsurface through conduits formed by fractures, or at contacts between different rock-types.

GROUNDWATER AREAS

Carbon County is herein divided into three general groundwater areas, based on physiography and geology. These are (1) the Beartooth Plateau, (2) the Pryor Uplift, and (3) the Basin Area.

Beartooth Plateau. The Beartooth Plateau is a mountainous area in southwestern Carbon County extending south into Wyoming and west in Montana. Mountain peaks rise more than 12,000 feet above sea level; the highest mountain in Montana (Granite Peak, elevation 12,799 feet) is on the Plateau. A significant amount of precipitation falls on the Plateau and supplies water for numerous lakes, and runoff to recharge streams and aquifers. The hydrologic significance of the Plateau lies in its being a recharge area and an area of surface-water storage in lakes, and snow and ice accumulations. Groundwater is available through wells locally, but the utilization of groundwater undoubtedly is very small compared to the availability of surface water. Records of wells drilled in mountain reaches of Rock Creek and other streams report yields of from 3 to 50 gpm with 13 to 24 feet of drawdown.

Pryor Uplift. The Pryor Uplift includes the mountainous region and the flanking area. The Pryor Mountains is a significant intake area, and a considerable amount of runoff finds its way into the subsurface. The large-capacity water wells in bedrock thus far have been found on the flank of the Uplift. Accounting for this are the outcrop pattern and proximity to the recharge area, enhanced permeability due to intense faulting and fracturing and weathering, and the relative shallow depths to aquifers. Alluvium on the

Figure 3.—Origin of Bluewater Springs. (Left to right, Gary Knudson, Bob Marsh, Bradley Bruce.)

flank is widespread but thin, and probably does not store much water. The alluvium-colluvium here appears to have been deposited by numerous mountain streams which are close-spaced and have not cut deeply into the underlying bedrock. The result is a thin blanket of coalescing gravels, spread over dipping bedrock formations on the flank of the Uplift. Several small springs are reported in this unconsolidated material; these are probably seeps where runoff percolates into the gravel at higher elevation and discharges in topographic depressions in which groundwater conduits have been breached by erosion. Small-yield wells might also be possible.

This area hosts large-yield springs and wells, especially in the vicinity of the Bluewater Springs in Township 6 South, Range 24 East. Springs reportedly sustain Bluewater Creek which has an average annual flow of 27.4 cfs (cubic feet per second). A flow

Figure 4.—Water of Bluewater Springs diverted for Montana Fish and Game Department fish hatchery.

of 1 cfs is equal to 448.8 gpm. The maximum reported individual spring-discharge is 3,720 gpm. Spring water is used for irrigation, livestock, and fish-rearing. Large-yield artesian wells are also known to have been developed. One such well of record (Town and Marks) in Township 6 South, Range 24 East was originally drilled as an oil exploration well and encountered an artesian flow of 330 miners inches at a depth of 786 feet (1 miners inch equals 11.25 gpm). Of this amount, 150 miners inches have been claimed for irrigation; an additional 250 miners inches of spring water have been claimed by the same ap-

Figure 5.—Close-up of oxygenation sprinkler, Bluewater Springs Fish Hatchery.

propriation. Unused water is allowed to flow into Bluewater Creek. The Montana Fish and Game Commission has appropriated 2,534 gpm of water from the Bluewater Springs for fish-rearing and has established a fish hatchery in the area.

Northward along the flank of the Uplift, artesian flows have been encountered by oil exploration wells from Cretaceous sandstones, but none have been nearly as large as those known or suspected to be from Paleozoic rocks.

Basin Area. The Basin Area herein includes all of Carbon County between the Beartooth Plateau and the flank of the Pryor Uplift, from the Beartooth Mountain front on the southwest, to the eastern edge of the Clarks Fork valley on the northeast and the formation limit of the Fort Union on the southeast. The significant features of this area are the alluvium-filled valleys of major drainages and the gravel-capped terraces. Wells have been completed in the upper part of the Fort Union, but depth to aquifer has deterred development of deeper bedrock aquifers.

Most of the water wells completed in alluvium are located in teh Clarks Fork valley. The width of the Clarks Fork floodplain varies from 2 to 6 miles. Clusters of alluvium water-wells are also found near the juncture of Red Lodge Creek with Rock Creek, where the width of the fused floodplain has increased from less than 1 mile to more than 2 miles. The average depth of the floodplain alluvium is about 30 feet, and much of the material is sand and gravel. Reported well-yields are mostly in the range of 5 to 50 gpm, with several reported at 200 to 300 gpm and others commonly between 50 and 200. In some instances alluvial water is bypassed intentionally due to sand-flowage or unsuitable water-quality. Water-quality deterioration can occur due to the solution of minerals in nearby bedrock, particularly shale, and due to the percolation of irrigation water through chemically treated soil to the shallow water-table.

Terrace gravels are widely distributed along Rock Creek, between the eastern front of the Beartooth Mountains and the Clarks Fork River, and along the north front of the mountains. From available information, only the gravels along Rock Creek are utilized as sources of groundwater. The gravels are water-saturated at least part of the time, as indicated by the dozens of groundwater appropriations filed on springs issuing from these gravels. Wells in the gravels also yield water. Two drawbacks to utilizing this source of groundwater are the inherent condition of relatively rapid depletion due to elevation above Rock Creek and good aquifer permeability. A clean gravel bed of sufficient thickness and extent overlying a bedrock depression could support large yields; several wells report yields in excess of 1,000 gpm but most wells have small yields. The Rock Creek gravel benches are extensively irrigated and some deterioration of water-quality could be expected. A few springs are reported in other localities, but data on these areas of terrace gravels is very sparse or nonexistent.

Shallow sandstones of the Fort Union are utilized as sources of groundwater. Well-yields are small but apparently adequate in quality and quantity for stock-use. Deeper bedrock aquifers are not extensively utilized, mainly due to depth to aquifer, although oil exploration wells have indicated that water is available at depth. Depth to aquifer would be considerably less in areas of domal uplift compared to synclinal parts of the basin. Groundwater from the Madison limestones is presently being used for the secondary recovery of oil in the Elk Basin oil field straddling the State line in Range 23 East.

GROUNDWATER AVAILABILITY AND USE

Availability of groundwater implies that the resource is economically obtainable and can be produced in quantity and quality adequate for a specific need. Shallow groundwater is available in much of the county and groundwater of suitable quality and quantity is obtained from unconsolidated sands and gravels at or near the surface, and from underlying bedrock aquifers. Most of the wells in the county were drilled to provide water for domestic and livestock uses, but most of the utilized groundwater discharge is used for irrigation. Most of the wells have been drilled into unconsolidated aquifers, but most of the groundwater discharge is from bedrock. It is estimated that about 5,000 acre-feet of water are withdrawn through wells each year from unconsolidated aquifers, and about 12,000 acre-feet from bedrock (Table 5). Springs in the county are estimated to discharge an additional 20,000 to 25,000 acre-feet annually, and most of this is from bedrock. From Table 6, the estimated amount of water stored in the unconsolidated aquifers and available through wells is 37 times greater than the total annual withdrawal from these aquifers. Annual recharge to the alluvium and terrace gravels (not counting irrigation excess) is estimated to be about 44,000 acre-feet (Table 7). Recharge to alluvium and terrace gravels is greater than dis-

Table 5.—Amounts of groundwater from wells used annually*

	Clarks Fork-Rock Creek Alluvium	Rock Creek Terraces	Red Lodge Creek Alluvium	Rosebud Creek Alluvium	Willow Creek Alluvium	Bedrock
No. wells reporting	155	83	25	9	11	24
Annual withdrawal reported, in acre-feet	1,500	1,700	20	6	6	11,500**
Additional estimated withdrawal, in acre-feet	1,200	300	10	4	1	200
Total withdrawal (estimated), in acre-feet	2,700	2,000	30	10	7	11,700

Total annual withdrawal of groundwater through wells in Carbon County (estimated), in acre feet:

Alluvium 4,745 + Bedrock 11,700 = 16,445 Total

* From groundwater appropriations filed with the Montana Water Resources Board. There are approximately 800 water wells in the county, of which approximately 600 take water from unconsolidated aquifers. (There are approximately 400 utilized springs in the county.)

** 5,840 acre-feet are attributed to one well, flowing from the Tensleep, of which 45 percent is used for irrigation and the remainder flows into Bluewater Creek. Another 5,475 acre-feet are attributed to two wells flowing from the Chugwater.

Table 6.—Groundwater available in unconsolidated aquifers
(All values approximate)

Aquifer	Extent of alluvium, in acres	Average saturated thickness, in feet	Vol. of sat. aquifer, in acre-feet	Yield factor, in percent**	Water in storage available through wells, in acre-feet***
Clarks Fork alluvium	65,000	16	1,040,000	10	104,000
Rock Creek alluvium	8,500	16	136,000	10	13,600
Rock Creek terrace gravels	35,000	15*	525,000	10	52,500
Rosebud Creek (East) alluvium#	4,500	10	45,000	10	4,500
Red Lodge Creek alluvium##	9,000	10	90,000	10	9,000
Willow Creek alluvium	3,000	5	15,000	10	1,500
TOTALS	125,000	12	1,851,000	10	185,100

* thickness of terrace gravel is very irregular, ranging from 7 to 115 feet.

** personal communication with R. G. McMurtrey, U. S. Geological Survey, Helena.

*** 1 acre-foot is equivalent to 325,850 gallons of water.

includes Butcher Creek.

includes tributaries to Red Lodge Creek.

Table 7.—Effective recharge*

Recharge to alluvium aquifers is estimated from the change in storage which occurs annually (net recharge between the times of lowest and highest water levels in the alluvium, as measured in wells). Water levels have not been measured periodically in Carbon County, necessitating estimates of water level fluctuations based on records from other areas of Montana.

Recharge to the terrace gravels is estimated from precipitation on the terraces.

Aquifer	Extent of alluvium, acres	Fluctuation in water level, feet	Recharge factor, percent	Effective recharge, acre-feet
Clarks Fork alluvium	65,000	5	10	32,500
Rock Creek alluvium	8,500	5	10	4,250
Rosebud Creek alluvium	4,500	3	10	1,350
Red Lodge Creek alluvium	9,000	3	10	2,700
Willow Creek alluvium	3,000	2	10	600
Rock Creek terrace gravels				3,000
TOTALS				44,400

* personal communication with R. G. McMurtrey, U. S. Geological Survey, Helena.

charge through wells and springs because alluvial aquifers also provide the base flows of streams during times of low water and lose water to the atmosphere by evapo-transpiration; terrace gravels lose water due to gravity drainage.

Annual recharge to the Madison and hydraulically connected formations is estimated to be from about 29,000 to 37,000 acre-feet, based on quantities of water reportedly discharging from flowing wells and springs suspected to originate within the Chugwater-Tensleep-Madison interval (assuming that equilibrium between discharge and recharge has been established). The annual recharge to shallower bedrock aquifers is esti-

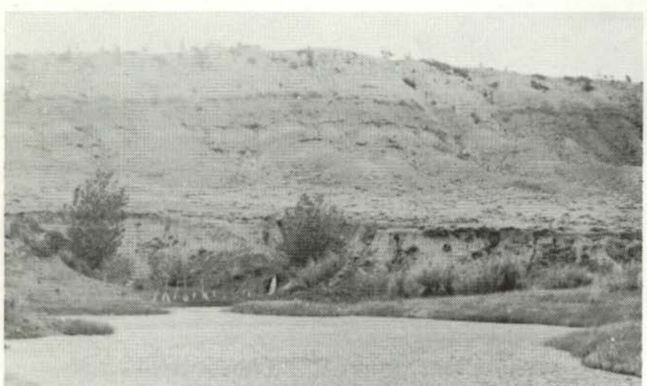


Figure 6.—Stevens "Spring." Note source of water in center background and diving board in foreground.

Figure 7.—Source of Stevens "Spring."

mated to be about 2,000 acre-feet per year. Estimates of recharge quantities are based on empirical data and subject to revision as new data becomes available. The gross amount of groundwater stored in all bedrock aquifers in the county is probably in the range of 100 to 150 million acre-feet, and perhaps 10 percent of this would be available through wells. Obviously, much of this storage is in the limestone and sandy limestone of the Madison and Tensleep, at uneconomical drilling depths for most uses, excepting on the flank of the Pryor Mountains. Sometimes oil exploration wells are drilled into aquifers which yield large amounts of groundwater, and if these wells are unproductive of oil they can be utilized as water wells. A land owner can "take-over" such a well by making the necessary arrangements with the original operator and the Montana Oil and Gas Conservation Commission, before the well is plugged and abandoned.

The ability of a properly constructed well at a specific location to sustain a given yield is dependent upon local aquifer characteristics. Aquifer tests are performed in order to determine these characteristics. The coefficient of transmissivity ("T") is an indication of the ability of an aquifer to transmit water, and can be used to calculate the quantity of water moving through the aquifer (providing the slope of the water table or pressure surface is also known). Unconsolidated aquifers almost always have greater "T" values than bedrock indicating that groundwater normally moves through sands and gravels more rapidly than through sandstones. Transmissivity in cavernous limestone sometimes is greater than in alluvium.

Several aquifer tests were made in Carbon County by personnel of the Montana Bureau of Mines and Geology. Results of the tests are enumerated below:

Aquifer	Value of "T" (gpd/ft.)
Eagle	1,300
Hell Creek	180
Fort Union	240
Terrace gravel	2,300
Clarks Fork alluvium	1,400

The value of "T" is the number of gallons of water per day flowing through a vertical strip of the aquifer 1 foot wide and the full saturated height, with a hydraulic gradient of 100 percent. The tests thus far performed are not adequate in number or distribution for aquifer-evaluation.

Groundwater may be available in sufficient quantity but may contain natural elements and minerals which make it unsuitable for a particular purpose. The U.S. Public Health Service has adopted standards of water quality (1946) that provide a means of determining water suitability. Standards were first established in 1914 to control the quality of water supplied by common carriers to passengers for drinking or for use in culinary processes. As reported in publications of the U. S. Geological Survey, these standards indicate that good-quality drinking water for humans contains no more than 500 ppm (parts per million) total dissolved solids. If no better water is available, not more than 1,000 ppm total dissolved solids is the upper limit for good drinking water. Upper restrictive limits for specific constituents in the water are given as:

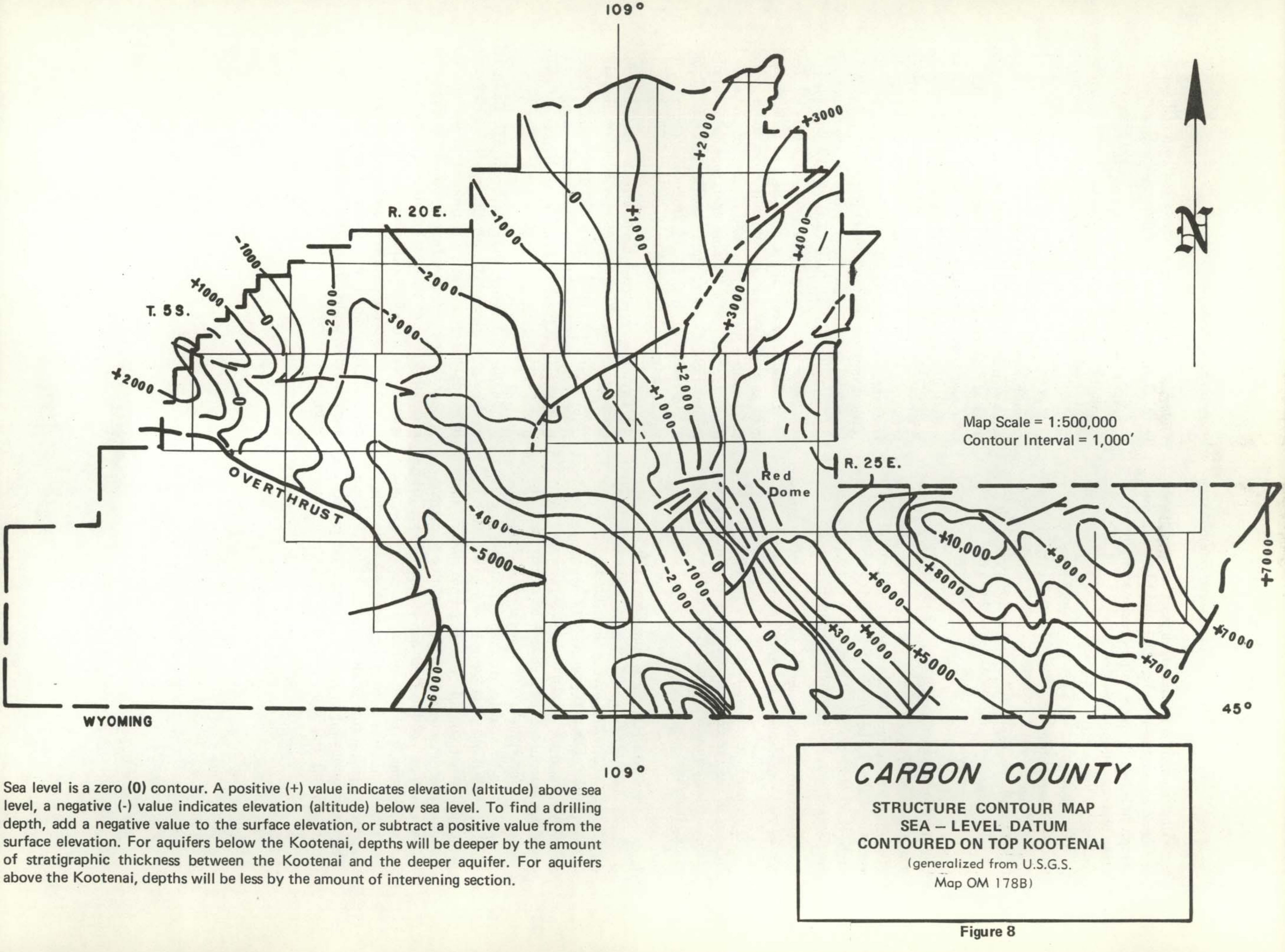
copper	3.0 ppm
iron and manganese (together)	0.3 ppm
magnesium	125 ppm
zinc	15 ppm
chloride	250 ppm
sulfate	250 ppm
phenol	0.005 ppm

An excess concentration, above the limits indicated, of any of the following is a valid basis for not using the supply as drinking water:

lead	0.1 ppm
arsenic	0.05 ppm
selenium	0.05 ppm
hexavalent chromium	0.05 ppm
fluoride	1.5 ppm (1.7 ppm, depending on the average maximum daily air temperature)

Water having more than 10 ppm of nitrate expressed in terms of nitrogen may be hazardous to the health of infants. When concentrations are expressed as NO_3, the tentative upper limit is about 44 ppm.

Radioactive elements are not common in groundwater supplies, and work in this field has not progressed far enough to set limits. However, the National Bureau of Standards has stated the maximum permissible concentration of radium in drinking water to be 40 micromicrocuries. One curie is defined as 3.7×10^{10} radioactive disintegrations per second, which is very large unit for the minute amounts of natural radioactivity in water, and data are often expressed in micromicrocuries (curies x 10^{-12}).



Sea level is a zero (0) contour. A positive (+) value indicates elevation (altitude) above sea level, a negative (-) value indicates elevation (altitude) below sea level. To find a drilling depth, add a negative value to the surface elevation, or subtract a positive value from the surface elevation. For aquifers below the Kootenai, depths will be deeper by the amount of stratigraphic thickness between the Kootenai and the deeper aquifer. For aquifers above the Kootenai, depths will be less by the amount of intervening section.

CARBON COUNTY

STRUCTURE CONTOUR MAP
SEA – LEVEL DATUM
CONTOURED ON TOP KOOTENAI
(generalized from U.S.G.S. Map OM 178B)

Figure 8

Most animals reportedly can become accustomed to highly mineralized water. The upper limits of total dissolved solids in water to be consumed by livestock have been given as:

horses	6,435 ppm
beef cattle	10,000 ppm
dairy cattle	7,150 ppm
adult sheep	12,900 ppm
pigs	4,290 ppm
poultry	2,860 ppm

The above limits were quoted by officers of the Department of Agriculture of Western Australia (1950). Some studies indicate an upper limit of 5,000 ppm in water to be used by livestock, while others state concentrations as high as 15,000 ppm to be safe for limited periods but not for continuous use.

Selenium is known to be very toxic to animals, above concentrations of 0.4 or 0.5 ppm.

The hardness of water is another quality which influences the use of the water for a specific purpose. Expressed as equivalent amounts of calcium carbonate, water that has:

less than 60 ppm is considered soft,
60 to 120 ppm is moderately hard,
120 to 200 ppm is hard and,
more than 200 ppm is very hard.

The amount of total dissolved solids and the amounts of individual constituents need be considered if water is to be used for irrigation. Water having an amount of total dissolved solids in excess of 1,500 ppm generally is not suitable for irrigation. Water that contains a large amount of sodium, relative to calcium and magnesium combined, is not satisfactory for irrigation. Drainage of the irrigated area is very important, because the disposal of excess soluble sodium and other constituents is always a problem. For the long term successful operation of irrigation projects, practically all the salts added in irrigation water should be removed from the irrigated land and appear in the drainage water (favorable "salt balance").

Most of the groundwater appropriations by wells and developed springs in alluvium and terrace gravels claim as beneficial uses "domestic" and "stock"; fewer wells take water from shallow bedrock aquifers such as Fort Union sandstone, the Eagle, the Judith River, or the Frontier. Municipal supplies are obtained from surface streams and underground aquifers. Some supplies are obtained through infiltration wells drilled near major water courses. The quality of the surface waters is reported to be more suitable (in terms of total dissolved solids) than groundwater where both are used. The Montana Department of Health reports, however, that water-quality of some municipal wells (drilled into alluvium aquifers) is good (see Table 8). Municipal supplies are taken from alluvium and terrace gravels, and shallow bedrock aquifers such as the Eagle and Telegraph Creek. The City of Red Lodge has filed two appropriations, one claiming 760 gpm and 400,000 gallons annually from three gravel aquifers in a well 74 feet deep (70 feet of gravel and boulders); the second claims 900 gpm as a supplemental right to water rights on Rock Creek. Table 9 is a record of analyses of groundwater from individual domestic and stock wells in the county.

Groundwater from deep artesian aquifers has been appropriated for irrigation and fish-rearing. Because very few deep wells are presently utilized, there is no reason to believe that overdevelopment of the Chugwater-Tensleep-Madison aquifers could occur in the near future.

In the Elk Basin and Northwest Elk Basin oil fields, water produced with the oil is injected into oil-producing formations to produce more oil. At present this water comes from the Madison formation, and is injected at the rate of about one-half million gallons per day (0.78 cubic feet per second). Water is injected into the "Embar-Tensleep-Madison" reservoir at Elk Basin field, and into both the Tensleep and Frontier reservoirs at the Northwest Elk Basin field.

Table 8.—Chemical analysis of municipal water supplies*

(All figures in milligrams per liter)

City or Town	Source (Aquifer)	Date	Total Solids	Hard- ness	Ca	Mg	CO_3	HCO_3	Cl	SO_4	NA +K	Fe	F	NO_3	Pb	Cu	AS_2O_3
BEAR CREEK	Bear Creek	5/58	151	108	30	8	0	131	6.3	21	15	0.26	0.3	0.27	--	--	--
BRIDGER	(alluvium)Well # 1	5/58	659	500	98	62	0	448	12	219	54	0	0.3	0.11	--	--	--
	(alluvium)Well # 2	5/58	636	513	104	62	0	448	12	220	46	0.05	0.3	8.5	--	--	--
	(alluvium)Well # 3	5/58	602	491	98	60	0	442	14	209	53	0	0.3	0.11	--	--	--
	Well # 4 (1963)																
FROMBERG	(horizontal)Infiltration Well	5/58	761	515	124	50	0	265	10	393	6	0.14	0.6	0.25	--	--	--
	New Well	6/59	1835	1356	313	140	0	342	6	1098	38	0.1	1.1	1.7	0	0	0
JOLIET	(Eagle Fm)Well # 1	3/54	465	260	57	29	0	332	8	134	92	0.16	0	0	0	0	0
	(Eagle Fm)Well # 2																
RED LODGE	W. Fork Rock Cr.	2/54	60	35	8	4	0	39	2	3	0	0	0	0	0.01	0	0
	(gravels)Well	10/62	78	72	22	4	0	92	0	6	5	0.2	0	1.0	--	--	--

* Provided by Montana State Department of Health, Division of Environmental Sanitation (data as of January, 1964).

Table 9.—Chemical analysis of groundwater supplies*

(All figures in milligrams per liter)

Well Name and Location	Aquifer	Date	Total Solids	Hardness (as $CaCO_3$)	Ca	Mg	CO_3	HCO_3	Cl	SO_4	Na+K
Vukovitch Sec. 13-4S.-21E.		9/18/68	1,225	269	28	115	0	328	58	521	175
F. Ropp Sec. 19-4S.-21E.	Ft. Union	9/18	486	248	72	27	2	298	5	55	26
L. Saarela Sec. 32-4S.-21E.		8/29	981	339	64	43	0	646	0	101	125
R. Krook Sec. 34-4S.-21E.	Ft. Union	8/29	659	342	68	43	0	417	0	94	37
T. Grill Sec. 11-4S.-22E.	Eagle	8/29	893	308	77	58	0	375	5	297	81
F. McClintock Sec. 1-4S.-23E.	Alluvium	9/18	563	313	78	32	0	381	2	45	24
Alec Krug Sec. 14-4S.-23E.	Frontier	9/10	2,480	218	43	27	0	561	0	1,219	630
N. Long Sec. 24-5S.-20E.	Terrace gravel	9/18	478	170	55	35	4	198	1	164	20
Ed Daty Sec. 27-5S.-20E.	Alluvium	9/18	1,051	170	50	11	0	421	0	325	244
R. Young Sec. 25-5S.-21E.	Ft. Union	9/16	690	12	2	2	0	405	24	65	192

W. White Sec. 6-5S.-22E.	Judith River	8/28	2,408	217	46	25	0	605	0	1,122	610
F. Horst Sec. 10-5S.-23E.	Alluvium	9/11	1,287	194	276	0	0	237	3	692	79
R. Felton Sec. 29-6S.-20E.	Ft. Union	9/18	989	370	60	53	0	583	0	182	110
L. Zumbrun Sec. 34-6S.-20E.	Terrace gravel	8/26	97	47	13	4	0	58	1	16	4
Emil Kober Sec. 7-6S.-21E.	Ft. Union	9/11	375	166	41	15	0	271	1	11	34
L. Hunter Sec. 8-6S.-21E.	Terrace gravel	8/27	482	272	59	30	4	325	3	39	21
G. Langstaff Sec. 14-6S.-22E.	Judith River	8/28	1,478	308	45	47	7	444	0	628	305
A. Dietz Sec. 3-6S.-23E.	Frontier	9/11	782	138	133	32	0	168	2	409	38
Parker Sec. 28-6S.-23E.	Alluvium	9/11	663	287	82	28	0	350	2	147	54
Town & Marks Sec. 4-6S.-24E.	Tensleep	9/16	1,010	171	248	12	0	204	1	536	3
C. Parker Sec. 11-7S.-23E.	Alluvium	9/10	1,509	280	179	89	0	341	5	759	136
Stevens Sec. 20-7S.-24E.	Tensleep	9/16	1,239	155	218	82	0	189	3	740	6

* Analyses by the Montana Bureau of Mines and Geology.

REPORTED GROUNDWATER PROBLEMS

The problems encountered in Carbon County, as reported, are: (1) local shortages of irrigation water, (2) local shortages of municipal and rural water, (3) local high water tables, and (4) poor water-quality. Another problem concerns the hot water well at Montaqua.

Shortages of irrigation water. Alluvial and terrace gravel aquifers are capable of supporting some high-capacity (1,000 gpm) wells, but most of the reported well-yields are much smaller. Properly constructed wells should yield from 250 to 1,000 gpm from alluvium aquifers. The regional thinness of the alluvium is a deterrent to supporting large sustained yields from numerous wells, because aquifer-thickness is dependent upon the thickness of the alluvium, and the amount of potential drawdown depends upon overall aquifer thickness. If aquifer thickness and drawdown are small, very large transmissivities would be required. An estimate based on empirical data is not recommended as a basis for the large investment that probably would be required to develop groundwater for irrigation. More aquifer-test data is required.

The irrigated lands along Rock Creek between Red Lodge and Boyd are located on terraces above the valley. Alluvium is present as a very narrow and thin deposit and therefore does not store much water. The higher terrace gravels are much more extensive and are water-bearing (note the number of reported springs on the inventory map (Plate 1), many of which discharge only part of the time). A few large-yield wells have been reported in terrace gravels; most are low-yield wells. Aquifer-test data is required for an evaluation of irrigation-potential.

If the amount of additional water needed for irrigation is relatively small, aquifer-testing would be practical. A large amount of water would probably require the construction of surface storage facilities. The development of an irrigation project from either groundwater or surface water or both must recognize existing water rights.

Present practices utilize surface water extensively and groundwater locally for irrigation. Shortages of irrigation water occur during late summer. Groundwater that is used for irrigation apparently is available all year in sufficient quantity for the relatively small areas being thus serviced.

The Montana Water Resources Board has made preliminary investigations of numerous potential storage sites in Carbon County in order to help alleviate late-season water shortages (see Figure 2). Almost all the potential sites are on the Beartooth Plateau, or in the Basin Area. The flank of the Pryors has a greater potential for groundwater development than for the construction of surface storage facilities. If surface storage facilities were constructed on the flank of the Pryors, stored water most likely would come from groundwater discharging at the surface.

The Bowler Flat is on the flank of the Pryor Uplift, where uplift and erosion have removed the rock-section above the Ellis group (Jurassic). Part of the Flat is mantled with a thin veneer of alluvium. A well drilled in Townships 7 and 8 South, Range 24 East would start in the Ellis formation and reach the Tensleep at depths of 400 to 800 feet below the surface, and the Madison 300 to 600 feet deeper. These are not unrealistic drilling depths for artesian aquifers capable of supporting large flows (500 to 3,000 gpm). The Madison limestone would be the best source of large-yield wells, and other formations hydraulically connected to the Madison would also support large-yield wells. Updip from the Ellis outcrop (towards the Pryor Mountains) bands of Chugwater "redbeds" and outcropping Tensleep sandstone are encountered. A well located in the "redbeds" would need to be drilled less deeply to reach the Madison than one located in the Ellis, and one in the Tensleep would have to drill only through that formation and into the Madison. A well located in the Madison or in the Pennsylvanian close to the Madison contact could miss the zone of saturation entirely, or would not have the benefit of strong artesian pressure. In the downdip direction, a well located in the Cloverly (Kootenai) would need to be drilled 1,500 to 2,000 feet to reach the Madison. Depth to the Madison aquifer increases rapidly in a downdip direction. A well started in the Kootenai and drilled 2,000 feet deep might encounter large artesian yields in the Chugwater, the Tensleep, and the Madison. A well located in the Ellis might do the same without penetrating nearly as much overburden, but would have less artesian pressure. Figure 8 is a regional structure contour map from which relative drilling depths can be inferred.

The geology of the Bowler Flats is complicated by numerous faults, and the surface bedrock is partially concealed by a thin veneer of alluvium. These factors must be considered if a development program is contemplated. Even though faulting has not had a

Figure 9.—Outlet for Town and Marks artesian well, flowing 3,700 gpm from the Tensleep. (Bob Marsh, Gary Knudson, left to right.) In the background are fields irrigated with water from this well.

detrimental effect on large yields in the Bluewater Springs area, faulting in the vicinity of Bowler Flat and Red Dome is more intense and has not been completely deciphered. In 1923 an oil exploration well in Section 20, Township 7 South, Range 24 East, in an intensely faulted area, encountered several water-flows drilling to a total depth of 1,846 feet. Water flows were reported at 270 to 273, 632 to 634, 634 to 638, 656 to 661, 695 to 696, 700 to 705, 707 to 709, and 856 to 887 feet. It is estimated that water flowed from this well at the rate of 15,000 to 20,000

Figure 10.—Diversion pipe, Town and Marks well.

barrels per day (about 550 gpm), most of it from above 1,000 feet, out of the Madison and Tensleep, and perhaps the Chugwater. Several oil exploration wells drilled about 4 miles to the northeast reported no water in a tight Tensleep section (the Madison was not reached). It is concluded that fracturing associated with faulting locally can provide permeability necessary for large-yield wells and springs, and can provide hydraulic continuity between formations. The amount of available information is not sufficient to consider this a general statement applicable to all faulted areas.

According to information compiled by the U.S. Geological Survey, fracturing of the rock section is very significant in the Bluewater Springs area and

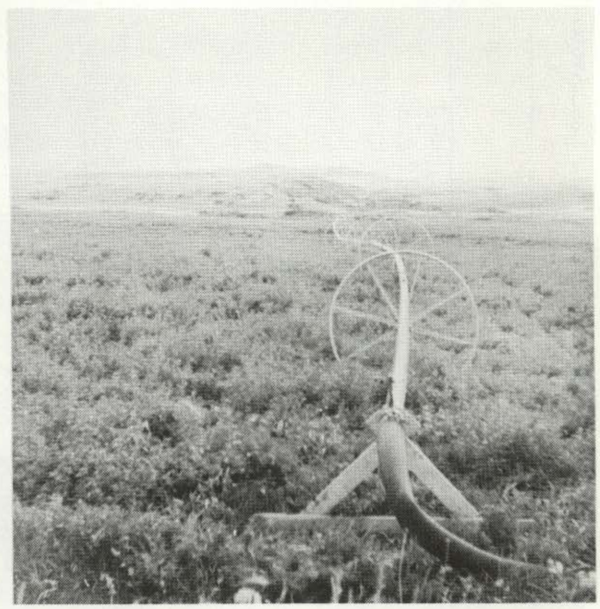


Figure 11.—Town and Marks sprinkler used to irrigate fields with Tensleep groundwater.

accounts for large-yield springs and wells. The U.S. Geological Survey also reports that water in the Chugwater formation contains 600 to 700 ppm total dissolved solids; that in the Tensleep contains 1,160 ppm, and that in the Madison probably contains 1,000 to 1,500 ppm. Wells and springs discharging groundwater from the Chugwater-Tensleep-Madison interval are enumerated in Table 10.

South of the Bowler Flat, an oil test well in Section 32, Township 8 South, Range 25 East drill-stem tested the Madison interval 2,937 to 3,029 feet, and recovered 3,015 feet of water in the pipe in one hour. Water probably would have flowed to the surface if the formation test had been of slightly longer duration.

Table 10.—Reported wells and springs utilizing groundwater from the Chugwater-Tensleep-Madison interval

Name	Location	Year	T.D. (ft.)	Use	Yield	SWL (ft.)	PWL (ft.)	Remarks
Town & Marks	NW SE SE 4 6S.-24E.	1950	789	Domestic, Irrigation	F 3,712 gpm* F 3,720 gpm**			Oil test drilled in 1950. Tensleep reported at 635 feet. Artesian flow to surface from 786 feet.
Bureau of Land Management	NE SW 15 9S.-26E.	1954	616	Stock, Wildlife	6 gpm	300	500	Tensleep reported at 590 feet.
Bureau of Land Management	NE NE 28 7S.-25E.	1962	283	Stock	10 gpm	221	230	Tensleep reported at 200 feet.
Bureau of Land Management	SW SW 4 8S.-25E.	1960	169	Stock	21 gpm	40	45	Embar reported at 44 feet.
Bureau of Land Management	NE NE 27 9S.-26E.	1962	1,430	Stock				Oil test turned over to BLM for water well. Tensleep reported at 1,325 feet.
Conoco	SE SE SE 33 9S.-25E.	1940		Industrial	20,580 gallons per month		3,574	Tensleep reported at 3,523 feet.
Conoco	SW SW 34 9S.-25E.	1941	3,556	Industrial	32,760 gallons per month		3,436	Tensleep reported at 3,466 feet.
Unknown	SE NW 19 8S.-25E.	1948	2,080					Oil test, left as water well by request of land owner. Tensleep reported at 1,560′, Madison at 2,010 feet.
Stevens, Wm. M.	SW SW 22 7S.-24E.	1916		Stock	15 gpm			Spring near fault trace.
Stevens, Wm. M.	N½ N½ 18 7S.-24E.	1900		Stock	30 gpm			Spring near fault zone.
Clarence Parker	SE SW 24 7S.-24E.	1958	87	Stock	60 gpm			Questionable source of water.

Jack Parker	NE SE 23 7S.-24E.	1914	110	Stock	60 gpm	Questionable source of water.
Atlantic Oil Co. (may be source of Stevens "Spring")	Red Dome 20-7S.-24E.	1929	1,846		F 450± gpm	Overflow reportedly has been used several miles distant for irrigation.
Wm. M. Stevens	SE SE NW 20 7S.-24E.	1916		Stock	F 100 gpm	Data lacking; may be source of Stevens "Spring."
Jake Hahn	NW SE 10 7S.-23E.	1957	3,200	Domestic	F 1,167 gpm	Oil test; Chugwater reported at 3,155 feet.
Jake Hahn	NW NE 15 7S.-23E.	1961	2,000	Stock, Irrigation	F 2,153 gpm	Oil test; TD reported in Morrison from sample examination; water flow probably from lower formation, through fractures.
Town & Marks	3, 9 6S.-24E.	1895		Domestic, Irrigation	2,812 gpm* 43+ gpm**	Springs.
Montana Fish & Game Comm.	SW NE 9 6S.-24E.	1947		Fish-rearing	2,534 gpm* 2,506 gpm**	Bluewater Springs (one at 2,080, one at 426 gpm).
Mary E. Weaver	23, 24 8S.-25E.	1965		Stock, Irrigation	3,375 gpm	Spring; used May 1 thru October 30.
G. T. Lester	15 6S.-24E.	1897		Domestic, Stock, Irrigation	3,960± gpm* 5,099 gpm**	Three springs; locations reported by U.S.G.S. differ from appropriation locations.
Thiel	16, 22, 27 6S.-24E.			Domestic, Stock	Under 10 gpm**	Springs; no record of appropriation.

* claimed by appropriation.

** reported yield, U.S.G.S. W.S.P. 1779-J (1964).

There obviously is a great amount of groundwater available in the Madison and hydraulically connected formations in the vicinity of Bowler Flats, at reasonable drilling depths, and under strong artesian pressure. It is assumed that water-quality is adequate for irrigation, inasmuch as one nearby artesian well is presently utilized as a source of irrigation water. There is a risk in attempting to develop this source, due to the vagaries of limestone lithology. Fracturing associated with faulting apparently is very significant in the development of large-yield wells.

Shortages of municipal and rural water. Towns located along major drainages can find sufficient water in the alluvium, or can augment supplies with infiltration wells or galleries. Sometimes wells in bedrock aquifers are developed in preference to alluvial wells, because bedrock aquifers are much less susceptible to pollution and contamination. Farmsteads can obtain water through wells in the alluvium, in terrace gravels, and in shallow bedrock. In the Basin area, several Fort Union water wells may be required to provide adequate supplies for one farmstead. In fortuitous circumstances, abandoned mines filled with water may be found by the drill. In grazing areas, small storage facilities can be constructed to retain surface runoff, and wells can be drilled.

Three towns in the county—Belfry, Edgar, and Silesia—reportedly do not have central water systems. Belfry is on the Clarks Fork floodplain in Township 8 South, Range 22 East and most likely could utilize alluvial water. Wells drilled in nearby shallow bedrock would find small amounts of water in the Fort Union. To utilize bedrock aquifers with better hydrologic characteristics, wells would need be drilled 3,000 to 4,000 feet into the Eagle-Telegraph Creek interval. Shallower wells could be drilled on the flank of the Pryor uplift and water could be transported 10 or more miles to the valley, across the river and into town.

The town of Edgar, in Township 4 South, Range 23 East is on the Clarks Fork floodplain where the floodplain has the widest extent in the county. Shallow groundwater is available in the alluvium. Development in the Eagle-Telegraph Creek interval about five miles to the west might be preferred, and this would require a system to transport water to the townsite.

Silesia is on the floodplain 5 miles north of Edgar in Township 3 South, Range 23 East and has a hydrologic setting similar to Edgar. Silesia and Edgar might feasibly construct one system to supply both towns, particularly if a bedrock source were preferred.

High water tables. High-water tables many times are caused by irrigation. Water-management and engineering can help alleviate the problem. Once irrigation is established, a system of drains is required to transmit surplus water out of irrigated areas which have been developed on impervious or only slightly pervious soil.

Water-quality. Water-quality is attributed to the source of the groundwater, the rate of percolation, soluble minerals in the host material, and man's use of the land. Precipitation absorbs dust and gases in the atmosphere which are mostly filtered out of groundwater as it percolates downward; deterioration can be expected if the water moves slowly across or through shale, and if agricultural chemicals are leached from the soil by groundwater over a period of years.

The Clarks Fork River, where it flows across the flank of the Pryor uplift, has developed its alluvial floodplain over bedrock of the Colorado Group and the Montana Group. The bedrock underlying the thin alluvium is dark-colored shale and narrow outcrop bands of Judith River and Eagle sandstones. The great expanse of shale undoubtedly contributes minerals in solution to the water resources which cause a deterioration of water-quality.

Montaqua. The hot water well at Montaqua is not operating, reportedly due to the effects of the

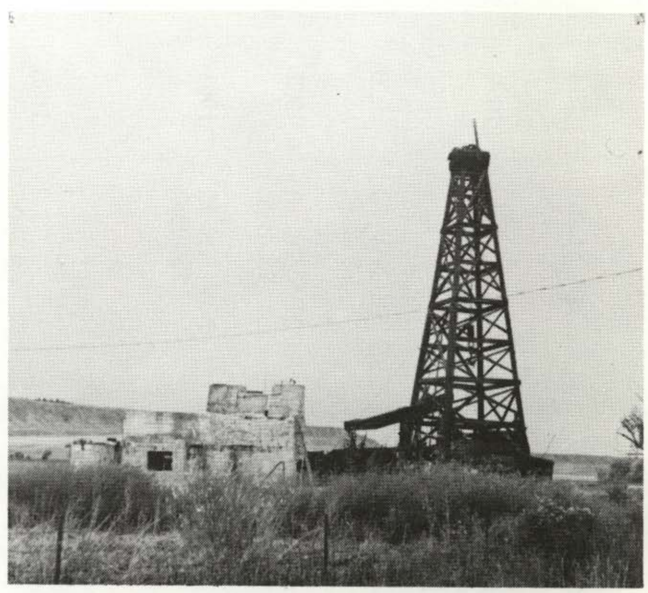


Figure 12.—Montaqua hot water well and recreation facilities. The well practically ceased flowing during the earthquake of 1959.

West Yellowstone earthquake of 1959. This same earthquake rejuvenated a water well near Lewistown, Montana, which had stopped flowing about 12 years earlier during another earthquake.

The most logical source of hot water in the Montaqua area is the Madison limestone, at depths in excess of 4,000 feet. Exploitation of this source would be risky due to the vagaries of buried limestone lithology and of subsurface structure.

SUMMARY

The amount of groundwater being used annually in Carbon County is relatively small compared to the total amount estimated in storage. Bedrock aquifers contain considerably more water in storage than unconsolidated aquifers, due to the greater extent and effective aquifer thickness of the bedrock. The Chugwater-Tensleep-Madison interval discharges considerably more water than all other aquifers combined, due to the greater storage capability of the limestone of the former, hydraulic connections through open fractures, and artesian pressure. The quality of groundwater is variable but all of the aquifers reportedly contain water suitable for livestock, and water in the shallow (200 feet maximum depth) aquifers—excepting the Frontier formation—appear suitable for domestic use everywhere in the county with local exceptions. Very few shallow wells report water unsuitable for human consumption. However, this is at times a matter of preference, and water that is suitable for one individual may not be tolerated by another.

Alluvial aquifers, particularly in the Clarks Fork valley, are capable of locally supporting large yields (500 gpm and greater); however, a greater potential for sustained large yields is from the Chugwater-Tensleep-Madison interval. Water from the latter is being used locally for irrigation.

There are general factors to be considered in the development of any groundwater resource. In Carbon County the most significant are:

1. Geologic structure and erosion which determine depth to aquifer, or even presence of a particular aquifer.

2. Well-construction, specifically where a thick section of soft shale and/or sandstone is penetrated, and where strong artesian pressure is encountered.

3. Protection of water-supplies from contarmination or pollution, especially domestic water. In heavily irrigated areas, shallow domestic well-water should be analyzed periodically. Groundwater is mobile and constantly subject to quality changes due to composition of the host material and utilization of the surface. Even under natural conditions, groundwater is subject to slow changes in quality as the water percolates through soil and rock.

4. Fluctuations in water tables; there are presently no observation wells in Carbon County which are part of the State-wide program. A recommendation will be made to establish and monitor several observation wells, as part of the cooperative program managed by the U.S. Geological Survey. Potential observation wells are lised in Table 11.

5. Development of large-yield artesian wells; caution should be observed in order to prevent undue waste and economic loss from flooding which might be caused by greatly increasing discharges into surface drainages.

6. Aquifer-test data is lacking for Carbon County, and any contemplated program to develop groundwater for sustained large yields should include provisions for adequate aquifer evaluation.

7. Groundwater recharge data needed to estimate recharge quantities is not available. Large withdrawals of groundwater would be taken out of storage and therefore subject to depletion similar to a mineral deposit. The amount of water now stored in bedrock aquifers is very large due to the wide extent of aquifers and the present limited use of the water.

8. Existing water rights must be recognized whenever additional development is contemplated.

Table 11.—Potential observation wells

Location	Owner	Aquifer	Depth (ft.)	Use	Remarks
T. 6S., R. 23E. Sec. 14: SW NE SW	Cliff Larson	Frontier	110	Stock	Unfit for humans.
T. 6S., R. 22E. Sec. 14: SW NE NE	George & Andy Langstaff	Judith River	86	Domestic	Drinking water.
T. 6S., R. 21E. Sec. 7: SE NE SE	Emil Kober	Fort Union	135	Domestic	Soft water.
T. 6S., R. 20E. Sec. 34: SW NE SW	Lloyd Zumbrun	Terrace gravels	28	Domestic	Soft water; artesian.
T. 6S., R. 20E. Sec. 24: NW SW SE	Robert Felton	Fort Union	40	Domestic	Hard water; plenty of water.
T. 5S., R. 23E. Sec. 27: SW NW NW	Farias Bros.	Alluvium	47	Dom./Stock	Good water.
T. 5S., R. 22E. Sec. 6: NW NW SE	William White	Hell Creek	135	Domestic	Alkali water at 50 feet; good water at bottom of well.
T. 5S., R. 21E. Sec. 25: SW SE SE	Ralph Young	Fort Union	90	Dom./Stock	Good water; very soft.
T. 5S., R. 21E. Sec. 24	E. C. Russell	Fort Union	150	Domestic	Good water; very soft; same pipe since 1918.
T. 4S., R. 23E. Sec. 28: NE NE NE	John Foos	Frontier	92	Dom./Stock	Good water.
T. 4S., R. 23E. Sec. 14: NW SW SW	Alec Krug	Frontier	95	Dom./Stock	Good, some sodium.
T. 4S., R. 23E. Sec. 25: SW SE SE	Russ David	Eagle	180	Dom./Stock	Good water.
T. 4S., R. 21E. Sec. 34: NE SW NE	Ronald Krook	Fort Union	55	Domestic	Fairly soft water.

MONTANA WATER RESOURCES BOARD
GROUNDWATER INVENTORY
CARBON COUNTY
COMPILED FROM DATA AVAILABLE AS OF JANUARY 1, 1969
Compiled from reports of U.S. Geological Survey, the Montana Bureau of Mines & Geology, and others.
Geologist: A. J. Mancini
Asst'd by: R. J. Guse
Drafted by: L. J. Petersen
Scale
2mi.
8mi.
FIELD GEOLOGY
Field Geologist: Gary Knudson
Asst'd by: Bradley Bruce
Consultant: Robert Marsh, C.P.G.
PLATE 1
EXPLANATION
Qal Alluvium--normally contains good aquifers; includes colluvium of unreported potential at higher elevations.
QTt Terrace Gravels--can be good aquifer locally; development hindered by rapid depletion, numerous springs.
Tw Wasatch--unknown potential.
Tfu Fort Union--widely utilized as an aquifer; small yields from shallow sandstones.
Khc Hell Creek--small well-yields possible.
Kl Lennep--unreported potential.
Kb Bearpaw--not normally an aquifer.
Kjr Judith River--potential for small well-yields.
Kcl Claggett--small yields from Parkman sandstone member.
Ke Eagle--small yields possible.
Ktc Telegraph Creek--small yields possible from Elk Basin sandstone member.
Kc Cody--not normally an aquifer.
Kf Frontier--small yields mineralized water possible locally.
Kmo Mowry
Kt Thermopolis
Not normally aquifers, but small yields possible from erratic sandstone stringers.
Kk Cloverly--small to moderate yields possible from Greybull, Pryor Conglomerate, Mosser and stray sandstones.
Ju Jurassic
Morrison--not normally an aquifer, but soft sandstone locally may be water-bearing.
Ellis
Sundance--may locally contain aquifers.
Rierdon--not normally an aquifer.
Gypsum Spring--may contain local aquifers.
Tru Chugwater-Dinwoody--large yields reported, but may be hydraulically connected with other aquifers.
P Permian-Pennsylvanian
Phosphoria--may contain local aquifers, normally too thin to be reliable.
Tensleep--large yields possible, artesian aquifer.
Amsden--may contain local aquifers or be hydraulically connected to other aquifers.
M Madison--large yields possible; artesian aquifer.
pM Pre-Madison--unknown potential.
Reported Spring
Fault trace
R. 16 E
R. 17 E
R. 18 E
R. 19 E
R. 20 E
R. 21 E
R. 22 E
R. 23 E
R. 24 E
R. 25 E
R. 26 E
R. 27 E
R. 28 E
R. 29 E
T. 2 S
T. 3 S
T. 4 S
T. 5 S
T. 6 S
T. 7 S
T. 8 S
T. 9 S
COUNTY
MONTANA
WYOMING
BOUNDARY
PRE-CAMBRIAN ROCK
Yellowstone River
Clarks Fork River
Big Horn River
Cooney Reservoir
RED LODGE
BEAR CREEK
BELFRY
BRIDGER
FROMBERG
EDGAR
JOLIET
SILESIA
BOYD
ROBERTS
ROSCOE
LUTHER

GLOSSARY

Aquifer test—a means of evaluating an aquifer locally, under controlled conditions, by observing well-yields, drawdowns, and elapsed time intervals.

Artesian—refers to a well or water; such water is under sufficient pressure so that it rises above the top of the zone of saturation for that aquifer; the water may flow to the surface at which time it is a flowing artesian well.

Dip—is the term used by a geologist to describe the acute angle a layer of bedrock makes with the horizontal. "Vertical" is used to describe a rock-layer making a 90-degree angle with the horizontal.

Dipslope—used to describe the local topography, where the slope of the land surface approximately parallels the dip of the bedrock on which the topography has developed.

Drawdown—is the lowering of the water level or pressure head in a well due to discharge from it or from another well.

Drill-stem test—a method of evaluating reservoir characteristics of deep rock formations, and bringing fluids to the surface, during or after the drilling of a deep well.

Fluvial—refers to rivers or streams; a fluvial gravel is an accumulation of gravel deposited by running water of a river (stream, creek, etc.). These deposits are unconsolidated or only weakly cemented.

Glaciofluvial—refers to gravel or sand and silt deposited by streams flowing from melting glaciers.

Groundwater—(or ground water) is water within the zone of saturation; the Montana Groundwater Code defines groundwater as "any fresh water under the surface of the land including the water under the bed of any stream, lake, reservoir, or other body of surface water."

Hogback—a ridge resulting from erosion; a steeply dipping or vertical layer of hard bedrock which originally was deposited horizontally.

Millidarcy—the degree of permeability of an aquifer, indicating the ability of a fluid to move through pore spaces in the rock.

Permeability—refers to that character of rock, unconsolidated or bedrock, which permits water to move through connected spaces within the rock.

Static water level—the level at which water in a well is supported by hydrostatic pressure; it is measured from the surface when the well is not discharging.

Strike—describes the bearing or direction of an outcropping geologic formation; it is perpendicular to the direction of dip, and normally measured from the north compass direction.

Tectonism—refers to the structural behavior of the earth's crust; infers instability of the earth's crust.

Transmissivity—or transmissibility (coefficient of) is the rate of flow of groundwater, in gallons per day, through a one-foot width of aquifer section having a height equal to saturated aquifer thickness and under a unit hydraulic gradient of one foot per foot. "T" values, with the dimensions of gallons per day per foot, are determined from aquifer tests and are used to evaluate aquifer-potential.

Zone of Saturation—refers to rocks or that part of a rock formation, unconsolidated or bedrock, in which all openings are saturated with water. In deep aquifers, openings locally may be partially filled with hydrocarbons or inert gases.

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(Note: Reports of the U.S.D.A. Soil Conservation Service, and of Mueller Engineering of Billings, Montana, were also used as references.)