ENVIRONMENTAL INVENTORY
Portion of Piceance Basin
Colorado
for
Cameron Engineers, Inc.

December 15, 1971

ENVIRONMENTAL RESOURCES CENTER

Colorado State University
Fort Collins, Colorado

Special Report No. 4

AN ENVIRONMENTAL INVENTORY
OF
A PORTION OF PICEANCE BASIN
IN
RIO BLANCO COUNTY, COLORADO

Prepared by the

ENVIRONMENTAL RESOURCES CENTER
Colorado State University
Fort Collins, Colorado

for

CAMERON ENGINEERS, INC.
Denver, Colorado

December 1971

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CHAPTER I

INTRODUCTION

A. PURPOSE

In October, 1971, Cameron Engineers, Inc., Denver, Colorado, contracted with Colorado State University to make an inventory of environmental elements existing in a portion of Rio Blanco county. The inventory is presented in this report.

This inventory identifies, and quantifies so far as possible, those components of the ecosystem which might be affected by activities of man. It will form the data-base for future use in projecting environmental impacts.

Environmental elements are classified in six categories with a chapter for each: Geomorphology; Soils; Water Resources; Climate; Biota; and, Recreational, Cultural and Aesthetic Values.

Although analysis, interpretation and impact projection are not required by the agreement, a limited amount of discussion is unavoidable and will be found throughout the report.

B. STUDY AREA

The study area encloses 216 square miles within Rio Blanco county in Western Colorado. Figure I-1 shows the area outlined with a hatched line. Most of the area is within Piceance Creek Basin, with a small part on the west in the Douglas Creek watershed. Yellow Creek and Piceance Creek provide the principal surface drainage system.

Figure I-2 shows the location of these creeks within the White River Basin.

C. PERSONNEL and PROCEDURE

The study was conducted by a team of eight scientific experts organized through the Environmental Resources Center. The principal investigators and their respective section of the study are:

Dr. Stanley A. Schumm	Geomorphology
Dr. Robert D. Heil	Soils
Prof. Dale Romine	Soils and Man-made Features
Dr. Norman A. Evans	Water Resources
Dr. William E. Marlatt	Climate
Dr. C. Wayne Cook	Biota
Dr. Clinton H. Wasser	Biota
Dr. Arthur T. Wilcox	Recreational, Cultural and Aesthetic Values

Team coordination was provided by Norman A. Evans, Director of the Environmental Resources Center with assistance from Dale Romine.

The team spent two days in the field at the study site making observations and gathering data available from the files in local offices of federal and state agencies. Local citizens were interviewed, as well. File and published data were gathered from all known sources, inluding the Bureau of Land Management, Soil Conservation Service, Bureau of Reclamation, and the Colorado Department of Natural Resources and its several Divisions. Substantial information was obtained from the files of the CSU Department of Radiation Biology on material collected for a report on Piceance Basin.

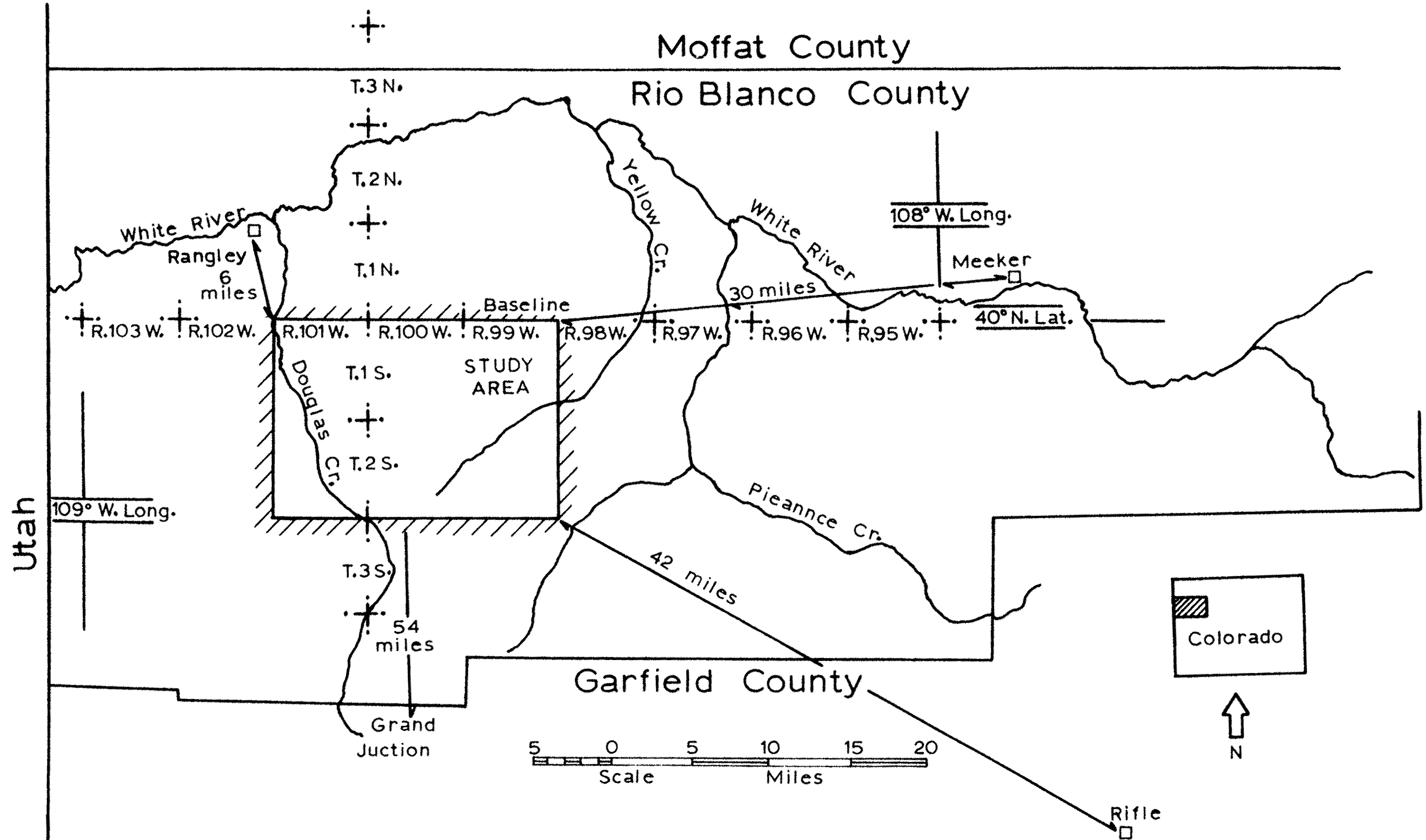

Figure I-1. Location map.

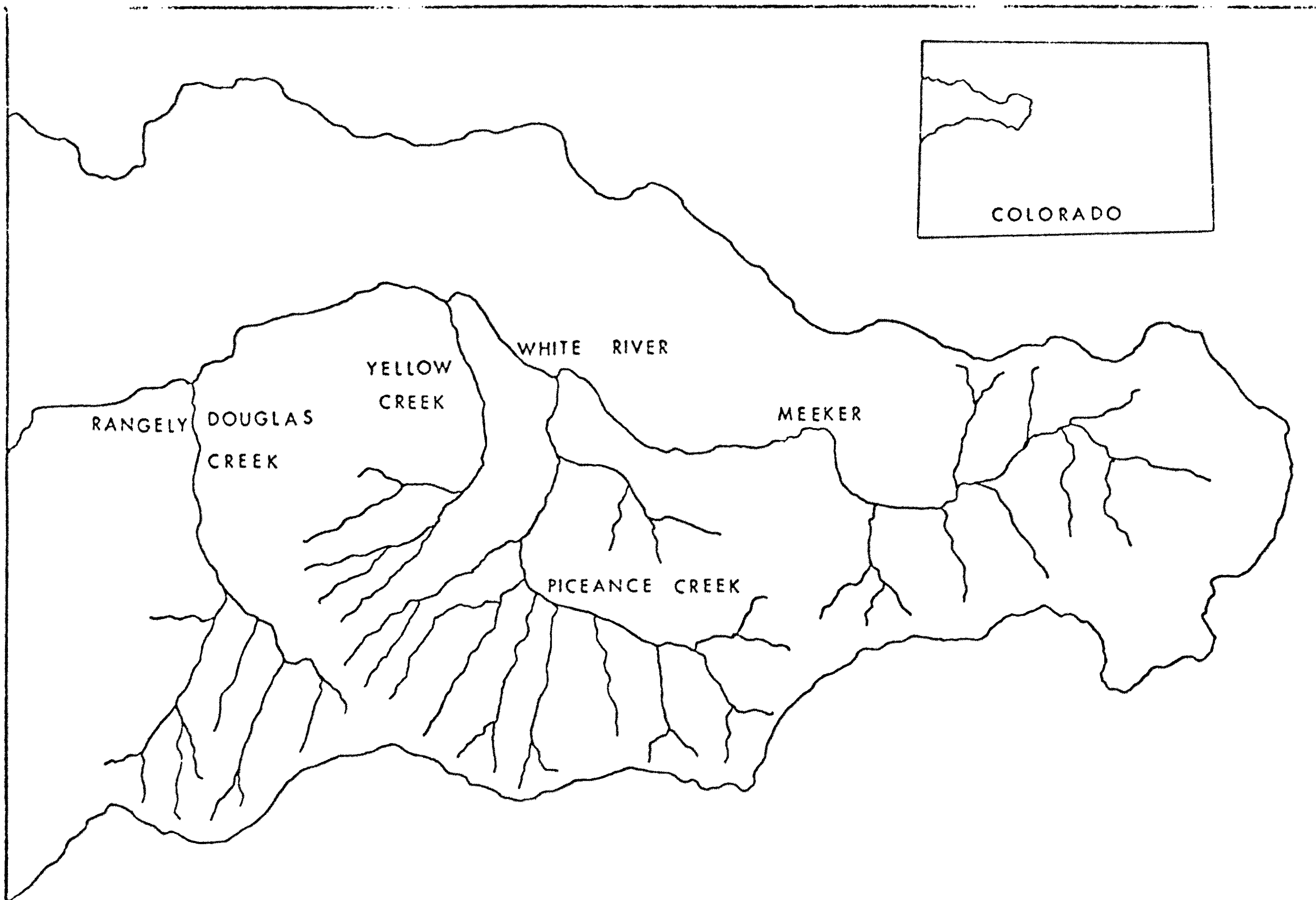

Figure 1-2. General Location Map, White River Basin

CHAPTER II

GEOMORPHOLOGY

A. INTRODUCTION

The Piceance Creek Basin is a structural basin and a topographic high forming the easternmost portion of the Tavaputs Plateau, which is part of the Uinta Basin Section of the Colorado Plateau Physiographic Province (1).

The geomorphology of the Uinta Basin has never been systematically studied, and only a very general description of the eastern part of the Tavaputs Plateau is available. Clark's (2) brief description of the area is quoted here as follows: "The interstream divides are broad, consisting of a series of discontinuous cuestas upheld by local sandstones and indurated limey and siliceous zones. Both stream and dry washes are deeply incised in canyons. The topography is large scale and coarse grained, with distances of half a mile to a mile between tributary drainages. The entire topography is subsequent and in late youth. The area is completely drained, relief is at a maximum, and the largest streams are beginning to develop small flood-plain scrolls along their lower courses. Even the longest streams are mere trickles at the bottom of canyons almost 1000 feet deep; flash floods accomplish most of the erosion." This general description can be partly applied to the Piceance Creek area, but it provides neither useful information on landscape details nor on the erosional and depositional processes operating within the area.

A reconnaissance investigation of that portion of the Piceance Creek area that is of concern to Cameron Engineers (TIS, R 101, 100, 99w; T 2S, R 101, 100, 99w) was made in the field. In addition, aerial photographs provided by the Meeker office of the Soil Conservation Service and topographic maps of the U. S. Geological Survey were used to supplement field observations.

B. GEOLOGY

The general geology of the study area is discussed in a report by Donnell (3). Hydrogeologic and surface water data and a structural map are contained in a hydrologic atlas prepared by Coffin et al. (4). A map showing major fold axes (5) was examined to determine the effect of structure on drainage lines. The channel patterns do not seem to be affected by the folds. However, it is apparent that the drainage patterns are controlled at least in part by the dip of the Evacuation Creek member of the Green River Formation, and the headwater tributaries of Ryan Gulch in T 3S; R 99W suggest a major control of their orientation and spacing by joints.

The only other obvious structural feature is a graben, which is clearly visible on the aerial photographs. It trends southeast from Stake Spring Draw in section 14, T 2S, R 99W to Ryan Gulch. This structure has only minor effect on drainage patterns.

Although the seismic waves generated by large earthquakes that occur elsewhere probably can be detected in the Piceance Creek area the seismic risk is minor (6). No obvious signs of landscape modification by earthquakes can be detected on the aerial photographs.

C. PHYSIOGRAPHY

The rectangular Cameron Area can be divided topographically into three parts as follows: 1) The western third, which is drained by Douglas Creek and which consists primarily of the westward flowing tributaries of Douglas Creek. 2) The headwaters of Spring Creek which occupy about half the area of T1S, R100W. Drainage in this area is to the north, and the west fork of Spring Creek lies between the major escarpments of Cathedral Bluffs and Big Ridge. 3) The eastern half is drained by the eastward and northeastward flowing tributaries of Yellow Creek and Piceance Creek.

These three topographic subdivisions are shown on the Fig. II.1 and on the Water Canyon, Philadelphia Creek, Sagebrush Hill, and Wolf Ridge U. S. Geological Survey topographic maps which cover essentially all of northern portion of the area, although a small part along the northern boundary is not included. The southern part of the area is shown on the White Coyote, Black Cabin Gulch and Yankee Gulch topographic maps.

D. GEOMORPHOLOGY AND GEOMORPHIC PROCESSES

Each of the previously noted physiographic subdivisions of the area will be described in this section.

1. Douglas Creek Area

That portion of the study area west of Cathedral Bluffs and Big Ridge is rugged and not easy of access. Dendritic drainage patterns are incised into deep valleys. V-shaped valleys with narrow flat alluvial floors are typical. The gradients of the tributaries to Douglas Creek are steep. For example, Philadelphia Creek rises at an altitude of 8000 feet and it enters Douglas Creek at an altitude of 5800. The 2200 feet of fall occurs over an airline distance of from 4.5 to 5.0 miles. These channels are steep, and they are efficient conveyors of water and sediment to Douglas Creek. This is especially true, because the alluvial floors of each valley are trenched by a gully or an arroyo. Douglas Creek itself has incised itself into the alluvium of its valley, and it is a typical arroyo similar to those of the Southwestern United States.

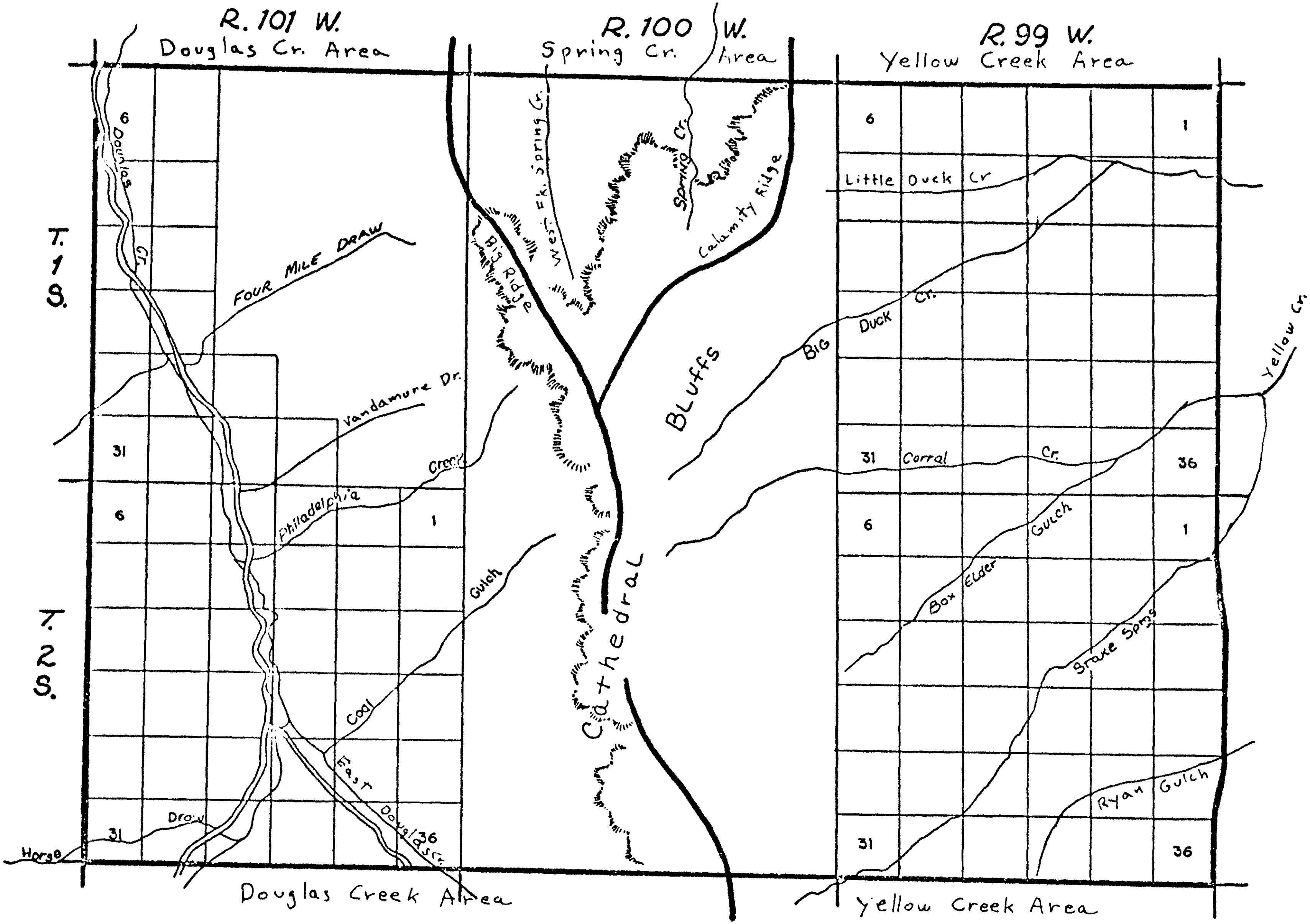

FIGURE II-1. GEOMORPHIC SUBDIVISIONS OF CAMERON AREA

The incision of Douglas Creek probably occurred during historic times, and it is this incision that is responsible for tributary rejuvenation. Near the junction of East and West Douglas Creeks a small log cabin is partly buried in the alluvium of East Douglas Creek. This cabin is probably less than 80 years old and its door fronts directly on a 20-foot drop into the deep gully of East Douglas Creek. There appears to be little doubt that the incision of Douglas Creek has occurred since the construction of this cabin. Although apparently having little bearing on the problems of oil shale extraction, this log cabin provides clear evidence that the valleys of the Piceance Creek area are fragile, and where they are untrenched they are susceptible to erosion. In the Douglas Creek area erosion of the valley floors is rapid, and large quantities of sediment are delivered to Douglas Creek and thus to the White River itself. This fact will be of little concern unless the valleys of the Douglas Creek tributaries are used for storage of mine waste and processed oil shale. Measures must be taken to retain such material in these valleys, for they are efficient conveyors of water and sediment, and unless the material is stabilized in the valleys it will reach the White River and eventually cause downstream sediment problems.

It should be noted that the numerous roads constructed to the west of Douglas Creek to service the oil wells of the Rangley oil field have apparently had little effect on erosion in that area. Thus, drilling and the construction of access roads in this area as well as in the other portions of the Cameron area will probably have a negligible influence on the land forms and on the erosional character of the area.

The raw or incised channels in the Douglas Creek area can be readily identified on aerial photographs. Only in a few cases such as Vandamore Draw and the Right Fork of East Fourmile Draw (Philadelphia Creek Quadrangle) has the trenching of the valley-fill alluvium not extended to the headwaters of the streams.

Hence, if overburden or processed shale disposal is anticipated in this area, as suggested in the report of the Special Committee of the Governors Oil Shale Advisory Committee (7), care must be taken that the material does not reach Douglas Creek.

In summary, the portion of the Cameron Area drained by Douglas Creek and its westward flowing tributaries is rugged, and in its present state it is probably a high sediment contributor to the White River. Flow is ephemeral in the tributaries, but in November 1971 there was flow in Douglas Creek. It is doubtful that a significant increase in erosion will occur unless large quantities of water are introduced into the tributary channels. If mine waste and processed shale are placed in these steep valleys, the sediment load of the stream will increase or this material is eroded.

Although there is no evidence of mass movement along the escarpment of Big Ridge and Cathedral Bluffs, an increase in the water content of the formations comprising these features might induce slumping and other types of large scale mass movement. There is some evidence of slumping along the Book Cliffs to the south and in the Roan Creek Valley. However, these events probably occurred during periods of higher precipitation during the Pleistocene Epoch.

2. Spring Creek Area

This small area is in T1S, R100W and shown on the Philadelphia Creek and Sagebrush Hills Quadrangles. Drainage is to the north, and Spring Creek flows directly to the White River. Spring Creek and its tributaries were and perhaps are aggressive and are eroding headward into the drainage area of Yellow Creek. The West Fork of Spring Creek occupies the area between Big Ridge and Cathedral Bluffs, and the separation of these two escarpments is due to the downdip shift of West Fork.

East Fork of Spring Creek has captured the headwaters drainage of Little Duck Creek and Buckhorn Draw. The Calamity Ridge divide between Spring Creek and Duck Creek drainage exhibits characteristics which suggest that the east flowing tributaries of East Fork at one time continued their courses to the east across Calamity Ridge, when their waters and sediment loads entered Yellow Creek. This geomorphic interpretation of the drainage patterns apparently has little significance for the development of the oil-shale resource.

The gradient of the Spring Creek tributaries, although rising at altitudes of about 8000 feet, are less steep than the Douglas Creek tributaries. For example, the West Fork drops 1700 feet in an airline distance of about 6 miles. The channels of both West and East Fork of Spring Creek are well defined and continuous, and they provide an efficient means of transport of water and sediment from this portion of the Cameron area.

In summary, this area is less rugged than the Douglas Creek Area. It is remote and not visible from the Douglas Creek road, and therefore would serve as an excellent place to dispose of waste materials. Again, it must be emphasized that these materials must be stabilized after emplacement or the material will move down the Spring Creek channel to the White River with serious consequences.

3. Yellow Creek Area

The eastern half of the Cameron Area is occupied by tributaries to the Yellow Creek, which flow to the White River, and by Ryan Gulch and its tributaries, which are tributary to Piceance Creek. Only a small part of T2S, R99W contains Ryan Gulch drainage.

The character of the topography in this part of the Cameron Area is significantly different from that in the Douglas Creek and Spring Creek Areas. The topography is more subdued, and the drainage appears to be controlled by the dip of the Green River formation. That is, the rivers flow down dip. The distance from Cathedral Bluffs, which forms the western drainage divide, to Piceance Creek and to the White River is considerably greater than the distance from this divide to Douglas Creek, and the slopes of the valleys and streams are gentler than the Douglas Creek and Spring Creek channels.

Although outside the area of specific interest, the condition of Piceance Creek may be of concern. The lower 3 or 4 miles of Piceance Creek is deeply entrenched. Farther upstream Piceance Creek is meandering on a well vegetated alluvial surface. If the downstream erosion is controlled by bedrock or by a drop structure then the upper portion of Piceance Creek will remain untrenched. However, if the incision continues up Piceance Creek the tributaries to Piceance Creek will probably be rejuvenated. Increased runoff from the Cameron Area could accelerate this process. Piceance Creek should be kept under observation, and headward growth of the arroyo, if it occurs, should be controlled.

The eastward flowing streams of the eastern half of the Cameron Area occupy valleys that are very different from those in the Douglas Creek and Spring Creek drainage basins. The valleys are less deep, and they contain an alluvial deposit that forms the flat valley floors. The relief is about 500 feet from divide to valley floor, and the gradient of valley floors is about 80 feet per mile (Wolf Ridge Quad.). Of major concern is the condition of the valley floors. Unlike the Douglas Creek and Spring Creek Areas the valleys do not everywhere contain a well-defined channel, and discontinuous gullies are common in these valleys. The fact that the channels are not continuous means that much of the sediment conveyed through these channels does not reach the White River or Piceance Creek, and that the sediment will be retained within or near the boundaries of the Cameron Area. For example, Ryans Gulch is trenched only near the junction of several of its major tributaries, but where Ryan Gulch leaves the Cameron Area no well-defined channel occupies the valley floor.

To the north discontinuous gullies occur in the tributaries of Yellow Creek, and much of the tributary drainage has well-defined entrenched channels. Hence, sediment from Corral Gulch and Stake Springs Draw will be delivered to Yellow Creek, which is formed by the union of these channels about 1½ miles east of the Cameron Area boundary (Wolf Ridge Quadrangle). Nevertheless, a short distance downstream of this junction a 3/4-mile-long reach of Yellow Creek does not contain a channel. Thus, the sediment from the large upstream drainage area of Yellow Creek is trapped a short distance below the junction of Stake Springs Draw and Corral Gulch.

The other major eastward flowing drainage is Duck Creek. Many of the channels of Big Duck Creek and Little Duck Creek are trenched, but both above and below the junction of these streams no channel exists. Therefore, sediment from the Duck Creek drainage will be retained in the valley of Duck Creek before it can leave the Cameron Area.

The channels and valleys of the eastern half of the Cameron Area at present do not appear to deliver appreciable quantities of sediment downstream, but the valley floors are inherently unstable, and any increase in discharge of sediment load will trigger an erosional response in the valleys. The discontinuous gullies can coalese to form continuous channels that will move large quantities of sediment downstream.

The development of discontinuous gullies, their coalescense to form arroyos, and the eventual healing of these channels by renewed deposition is a sequence of events that can be readily documented throughout the western United States (8). Therefore, the apparent stability of the alluvial valley-fill deposits in the area is deceiving. The current condition of sediment storage in the eastern half of the Cameron Area can change quickly to major export of sediment with serious downstream consequences if and when the drainage lines become continuous. Release of water into these channels can trigger a dramatic erosional response, which should be avoided.

The flat-floored valleys are separated by convex or flat-topped ridges. At present the erosion rates on these interfluve areas range from slight to critical with 3% of the areas in the Yellow Creek Unit (B.L.M.) subjected to slight erosion, 67% to moderate erosion and 30% to critical erosion (9). This qualitative evaluation is indicative of present erosion conditions in the area. For much of western United States this classification is normal. Therefore, in some parts of the area erosion is presently occurring at rapid rates.

The obvious effect of slope aspect is important in this regard with north-facing valley sides better vegetated, gentler, and less susceptible to erosion. South- and west-facing slopes and valley-sides are steeper, less well vegetated, and obviously more vulnerable to raindrop impact and surficial runoff. The north-facing slopes will be subjected to more cycles of freeze and thaw during the year and probably soil creep occurs on these slopes. The assymetry of some valleys apparently is the result of these very different erosion processes and rates of erosion on slopes of different aspect.

Storage of sedimentary materials in these relatively wide and gently sloping eastern valleys near Cathedral Bluffs will be less difficult than in the Douglas or Spring Creek Areas. Any attempt to stabilize erodible material in this area should take advantage of the better conditions on north-facing slopes. That is, the upper surface of the deposit could be graded to form a north-facing slope, which would aid in the establishment of vegetative cover.

E. SUMMARY

In summary, the Cameron Area can be subdivided topographically into three parts. Valley slopes and valley gradients are steep in the Douglas and Spring Creek Areas, and both water and sediment are exported from these areas in large quantities because of the trenched condition of the valley floors. Because these valleys are already severely eroded, waste waters could be introduced into them with less damage to the valley and streams than in the eastern part of the area.

However, natural stabilization of sedimentary materials will not occur, and some type of control is required.

In the eastern half of the area, which is underlain by oil shale, dramatic changes in the condition of the valleys can be expected if additional water is introduced into the channels (either large flood peaks or increased annual flow). Flow retarding or detention structures will need to be constructed if water is introduced into these channels. On the other hand, the stabilization of sedimentary materials in the headwaters of this area should be less difficult than in the Douglas and Spring Creek Areas.

Erosion on the valley sides and on the interfluves is similar to that occurring naturally elsewhere in the western United States, and the reconnaissance investigations both in Cameron Area and in adjacent areas to the west and south suggest that no significant acceleration of hillslope erosion should occur during operations in this area. Local problems of this type, which may develop can be controlled by use of standard conservation techniques.

<u>F. REFERENCES</u>

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CHAPTER III

SOILS AND EXISTING MAN-MADE FEATURES

A. INTRODUCTION

This chapter presents a general discussion of the soils which occur in the study area and gives a broad classification of their capabilities for agricultural, wildlife and recreation uses. Unavailability of detailed soils information and detailed soil maps within the study area made it necessary to discuss the soils in terms of their landscape association. A general soils map of the study area was prepared by delineating portions of land with broad similarities in soil pattern, relief, geology, erosion susceptibility and vegetative types. The soil association map is shown in Figure III-1. The six soil association areas delineated on the general soils map are described in the following pages. Primary sources of information used in the preparation of the soil map and soil association descriptions were a soil association map prepared by the Soil Conservation Service, aerial photographs, and from field notes and experiences of professional soil scientists of the Soil Conservation Service. (1) (4) (5) Erosion conditions and potential erosion hazards are briefly noted for each association.

The man-made features which currently exist in the study area are tabulated and their locations shown on maps of the area.

B. SOILS

1. Soil Associations

a. Soil association "A" (shallow, stony soils, moderately deep to deep wind laid soils and Rockland areas) -- This association lies in the extreme western part of the study area and occupies a north-south band from one and one-half to six miles in width straddling Douglas Creek. The landscape consists of high terraces, uplands and low mesas. The Rockland areas consist of sandstone or shale escarpment-like bluffs and cliffs.

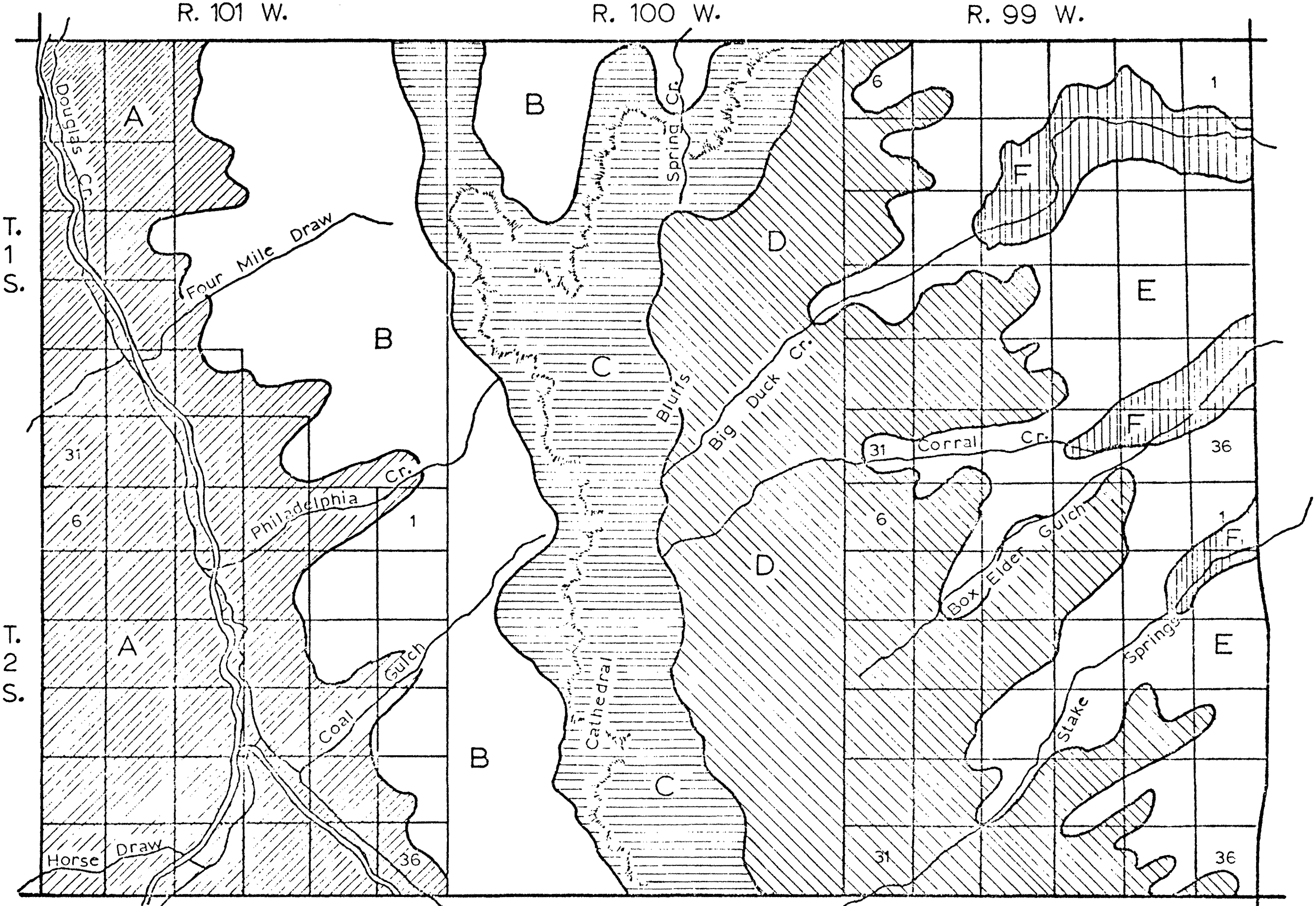


Figure III-1. General soils map of the study area. Scale: ½ inch = 1 mile.

The dominant soil component in this association is shallow over sandstone or shale materials which generally occur at less than 20 inches from the surface. The soils are light colored and have a gravelly to stony loam texture throughout.

A second soil component has developed in moderately deep to deep local wind deposited materials derived for the most part from sandstone and with shale influence. The soils usually have loamy surface soils and clay loam textured subsoils with slight to moderate lime accumulations. These soils occur mainly on top of the high terraces and low mesas. The Rockland areas are composed of geologic formations of sandstone or shale.

Included in this association are small areas of deep clayey soils from shale; areas of saline or alkaline soils; moderately deep stony loam colluvial soils and deep medium textured alluvial soils along drainage bottoms. Small areas of mixed coarse textured gravelly and cobbly outwash and rough gullied land also occur in this association. Most of the soils of this association have high susceptibility to water erosion because they are derived largely from soft silty shale materials. A combination of steeply sloping land and high intensity rainstorms during the summer greatly increased the severity of this problem. Most runoff waters carry a high silt content. Extreme care is needed to protect and maintain all vegetative cover on these soils. Re-establishment of vegetation is difficult in this area due to low rainfall and unstable soils. Erosion control measures are necessary around construction sites or new roads to prevent gullying from taking place.

Many salt affected areas occur on the alluvial soils in this association along Douglas Creek and its tributaries.

b. Soil association "B" (shallow and moderately deep, cobbly, stony and shaly soils) -- This association occurs mainly in the western one-third of the study area and lies east of and adjacent to soil association "A". The landscape is highly dissected by intermittent streams. It contains a repeating pattern of narrow, alluvial valleys bordered by steep canyons with rocky slopes below low cliffs or bluffs topped by sloping uplands and mesas.

The dominant soil component in this association is shallow over shale of the Wasatch formation. Shale occurs at 10 to 20 inches from the surface. These soils are light colored, low in organic matter and gravelly to stony loam textured. They are generally calcareous throughout. A second component of lesser extent is similar to the dominant component except the soils are deeper, contain less rock fragments and are more silty textured. They have formed in colluvial-alluvial materials. A third soil component of this association is moderately deep to deep and silty to loamy textured. These soils have developed in local wind deposited materials. They occupy the flatter mesas.

Included in this association are deep dark colored alluvial soils in valley bottoms and saline-alkali soils in low areas. Shaly badlands with cliff-like topography and gullied land also occur.

The soils of this association are highly erosive and have fragile stability. Water erosion on rocky, gravelly pinon-juniper slopes is principally along roads and hunting trails. Trails and roads along steep upper slopes have had a striking effect in concentrating runoff water. Deep gullying and destructive bank cutting is visible along all intermittent creeks and head cutting is common on side drains. Detrimental flood deposits are left on alluvial fans and bottomlands which formerly supported stands of grass. Any runoff carries a high silt content. Extreme care is needed to protect and maintain any vegetative cover on the soils of this association. Re-establishment of vegetation is difficult due to the low rainfall and unstable soils. On-site checking of most of these soils is necessary before starting any construction. Erosion control practices are necessary to prevent sheet and gully erosion.

c. Soil association "C" (shallow dark colored soils of mountain cliffs and ridges) -- This soil association extends as a narrow band less than 3 miles, seldom more than a mile or two wide, in a north-south direction across the center of the study area.

Conspicuous features of the landscape are light colored cliffs and escarpments known as Cathedral Bluffs which face westward toward the valley of Douglas Creek. The area along the west face of the bluff is rugged, with a maximum relief of about 3000 feet. The area east of the crest or the Cathedral Bluffs slopes gently northeastward. Above the cliffs are sharp rolling wind-swept ridge crests which form a divide between the Douglas Creek and Yellow Creek drainage basins, while below are very steep talus slopes.

Soils of this association are predominantly shallow. Underlying shales or fine grained sandstones are usually found at depths of 6 to 20 inches. Soil depth changes frequently within short distances. Shaly loams and channery sandy loams are the common surface soil textures on steep upper slopes. Deep soils containing high proportions of shale and stone occupy lower colluvial slopes.

The major component of this association consists of high cliffs, escarpments and bare exposures of shale, sandstone, marl and limestone bedrock. Plant roots enter most of the residual beds and most shales can be readily penetrated with digging tools.

Erosion within this association is mainly geologic in character. Accelerated erosion is principally by wind on ridge crests where overgrazing has denuded shallow loamy soils. Gullying is limited to narrow drainageways occupied by deep, friable soils.

d. Soil association "D" (moderately deep and deep, dark colored soils of the uplands) -- This association is located along the east slopes of the Cathedral Bluffs.

The landscape consists of steep lower mountain slopes of rugged relief dissected by narrow valleys and streams. Gently sloping areas occur on the lower footslopes, swales, fans and alluvial bottomlands. The soils have formed largely in Green River shale materials. The dominant soil component occurs mainly in the brush covered areas. These soils are moderately deep to deep. The surface soil is 8 to 15 inches thick and very dark brown in color. Organic matter content is high. Surface layers are loamy with loam and sandy loam textures being most common. This is underlain by a light to dark brown subsoil that is one to four feet thick and ranges from sandy clay loam to clay in texture. Many subsoils contain gravel, stone and rock fragments. Lime is usually leached to depths of 40 inches or more.

On steep colluvial slopes coarse fragments from higher lying rock ledges and outcrops are usually scattered over the surface soil.

The second major soil component of the association occurs mainly under forested areas. These soils are usually found in steep north facing canyons and on north facing slopes. Most of these soils will have a surface cover of forest litter. The surface soil is 2 to 6 inches thick and loam or fine sandy loam in texture. This is underlain by a leached fine sandy loam to light clay loam subsoil. The substratum is a shaly or sandstone material or bedrock occurring at depths of 10 to 40 inches.

A third soil component occurs in the open grass park areas. The soils are generally more than 20 inches deep over very stony or fractured bedrock materials. The surface is a loam or stony loam less than 12 inches thick. The loamy subsoil often contains some rock fragments.

Moderately deep and deep soils are intermingled in this association. Deep soils have formed in valley fill and may have dark colored buried soils within the upper four feet of the profile. Some dark surface soils are usually thick and extend to depths of 20 inches or more. Under the moderately deep soils, sandstone or shale occurs at depths between 20 and 40 inches.

Included in this association are small areas of very shallow soils over sandstone or shale, wet loamy soils in narrow swales and valley floors. Scattered small areas of rockland or rock outcrops also occur.

The greater depth of the soils and a relatively higher degree of profile development indicates that this soil association is the most stable in the study area. It is part of a high water producing area for tributaries to the White River.

Erosion is generally moderate. Because of the silty nature of the Green River parent materials the runoff waters from eroding soils may carry a high silt load. Care is needed to protect any vegetative cover on these soils.

e. Soil association "E" (shallow rocky and deep moderately dark colored soils of the uplands) -- This association lies in the extreme eastern part of the study area.

The landscape is highly dissected by creeks and their intermittent tributaries. There is a repeating pattern of narrow, gently sloping alluvial valleys along creeks flanked by canyons or very steep rocky slopes which rise to higher lying uplands. Narrow bands of rolling upland or mesas form divides between upper reaches of creek tributaries.

The dominant soil component of this association is shallow over weathered Green River shale which occurs at 10 to 20 inches from the surface. The surface soil is loam to silt loam 2 to 5 inches thick. The subsoil is silty clay loam to clay loam. Small shale fragments occur throughout the profile increasing with depth.

A second soil component is similar to the dominant one except that it is deeper to the Green River shale which occurs at 30 inches or more from the surface.

A third component has soils that are moderately deep to deep. The texture is a gravelly loam to gravelly sandy loam throughout. They contain an abundance of small shale fragments and varying amounts of cobble and/or stones. These soils are formed in recent colluvial materials and side slopes below Green River shale cliffs.

Included in this association are deep dark colored soils on north slopes and in alluvial valleys. Small areas of salt affected soils, rock outcrops and cliffs of fine grained, limy shales and sandstones are included.

The soils of this association are highly erosive due to the soft silty nature of the parent materials. Silt content of excessive runoff water is generally high. Water erosion on rocky, gravelly piñon-juniper slopes is principally along roads and hunting trails. On-site investigation should be made before any construction is undertaken. Erosion control measures are necessary around new construction sites on new roads to minimize water erosion hazard caused by disturbance of soils and destruction of protective vegetation.

f. Soil association "F" (moderately deep to deep, silty, narrow valley alluvial soils) -- This soil association occurs along Big Duck and Corral Creeks and tributaries of Yellow Creek in the study area.

The dominant component in this association is deep well-drained soils with loam or silt loam surface layers and clay loam or silty clay loam subsoils. The soils are generally alkaline.

A second component is very similar to the first but is affected somewhat by watertable conditions.

Included in this association are areas of highly saline or alkaline soils and small areas of gullied land.

2. <u>Land Capability Classes</u>

a. Definition -- Land capability classes which are broad land use suitability groupings are designated by Roman numerals I through VIII. Classes I through IV are considered suitable for cultivation with the numerals indicating progressively greater limitations and narrower choices for practical use. None of these classes are thought to occur in this study area. Classes V through VIII, which are found in the study area, are considered non-suitable for cultivation and again the increase in class number indicates progressively greater limitations of these lands with respect to use.

Class V - soils that are not likely to erode but have other limitations (i.e., wetness, alkalinity, etc.) impractical to remove, that limit their use largely to pasture, range, woodland, or wildlife.

Class VI - soils in these lands have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland, wildlife, or recreation.

Class VII - soils have very severe limitations that restrict their use largely to range, woodland, wildlife, or recreation.

Class VIII - soils and landforms have limitations that preclude their use for commercial plants and restrict their use to recreation, wildlife, or water supply, or to aesthetic purposes.

b. Probable occurrance of the land capability classes in each soil association --

Soil Association	Probable Land Capability Classes
A	V; VI (most dominant); VII; VIII (severly gullied areas)
B	VI; VII (most dominant); VIII
C	VII; VIII (most dominant)
D	VI (most dominant); VII; VIII
E	V; VI (most dominant); VII; VIII
F	V and VI (most dominant); VII

Percentage composition of Land-Capability Classes within soil association areas is not known.

The land classes found in this area indicate that a protective cover of vegetation is needed at all times to control water erosion. In some parts of the area except for a few annual plants, little or no vegetation grows and erosion is a severe hazard. Any disturbance of the surface on these areas will increase this hazard.

The land class groupings point out the need for developing very specific conservation plans on any area where soil disturbances are likely to occur. Detailed soil surveys with accompanying conservation plans are needed if adequate protection is to be achieved.

3. Availability of Soil Maps, Descriptions and Chemical and Physical Data on Soils of the Study Area

a. Soil maps -- The only soil map available for the study area is the general soil map shown in Figure III-1. This map is based on a general reconnaissance of the area and is a first approximation of the distribution of soils within the area.

b. Soil profile data -- Most of the soils information given for each soil association was based on field descriptions of soil profiles examined adjacent to or surrounding the study area. Some field descriptions were available for soil association "C" described within the study area. This reflects the lack of detailed soils information available within the study area. To our knowledge there is no laboratory data available for any soil samples taken from within the study area.

C. EXISTING MAN-MADE FEATURES

1. Transportation

The only hard surfaced highway passing through the study area is State Highway 139 which parallels Douglas Creek. The hard surfaced highway, improved roads and private roads are shown in Figure III-2. (7) No jeep trails are shown. Very probably some truck trails exist which are not shown. The closest scheduled airline service is provided at

Grand Junction, Colorado, and at Vernal, Utah. In addition, county airports at Rangely and Meeker have 4,500 foot runways and will accommodate light commercial aircraft.

2. Land Improvements

See Figure III-3 (See Refs. (2) (3) (6))

Type	Number in Study Area
Water wells	2
Developed springs	13
Windmills	1
Check dams	7
Reservoirs	2
Fences	40 miles

3. Public Utilities

See Figure III-4 (2) (3) (6)

Power lines - approximately 21 miles

Pipe lines - approximately 46 miles

4. Other Land Use Features

See Figure III-5 (2) (3) (6)

Type	Number in Study Area
Hunting Clubs	1
Landing strip	1
Cow camps	2

Type (Cont'd.)	Number in Study Area (Cont'd.)
Gravel pits	6
Gas wells	7
Pumping stations	1

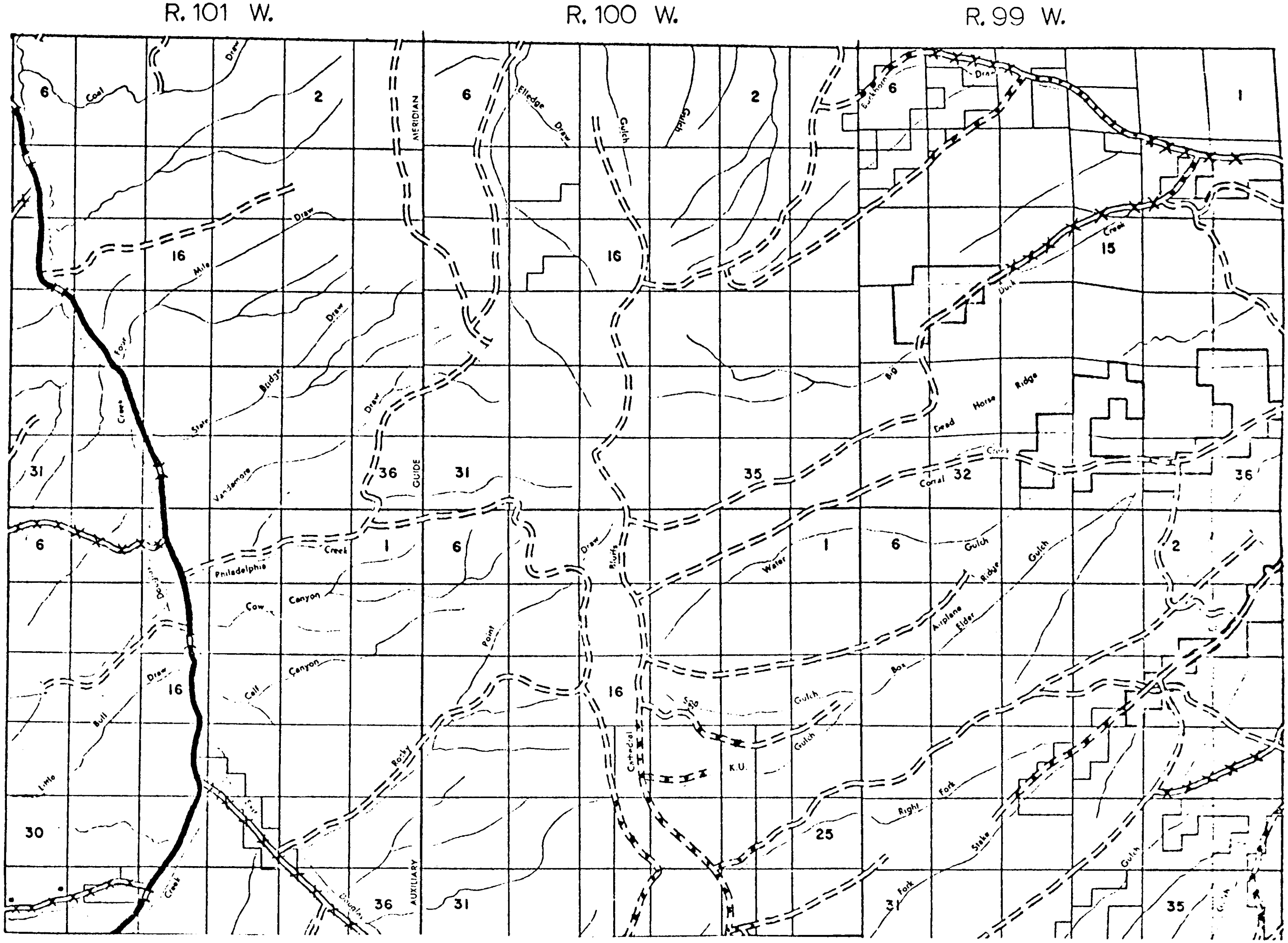


Figure III-2. Transportation.

Legend

- Paved roads
- Improved public roads
- Unimproved public roads
- Private roads

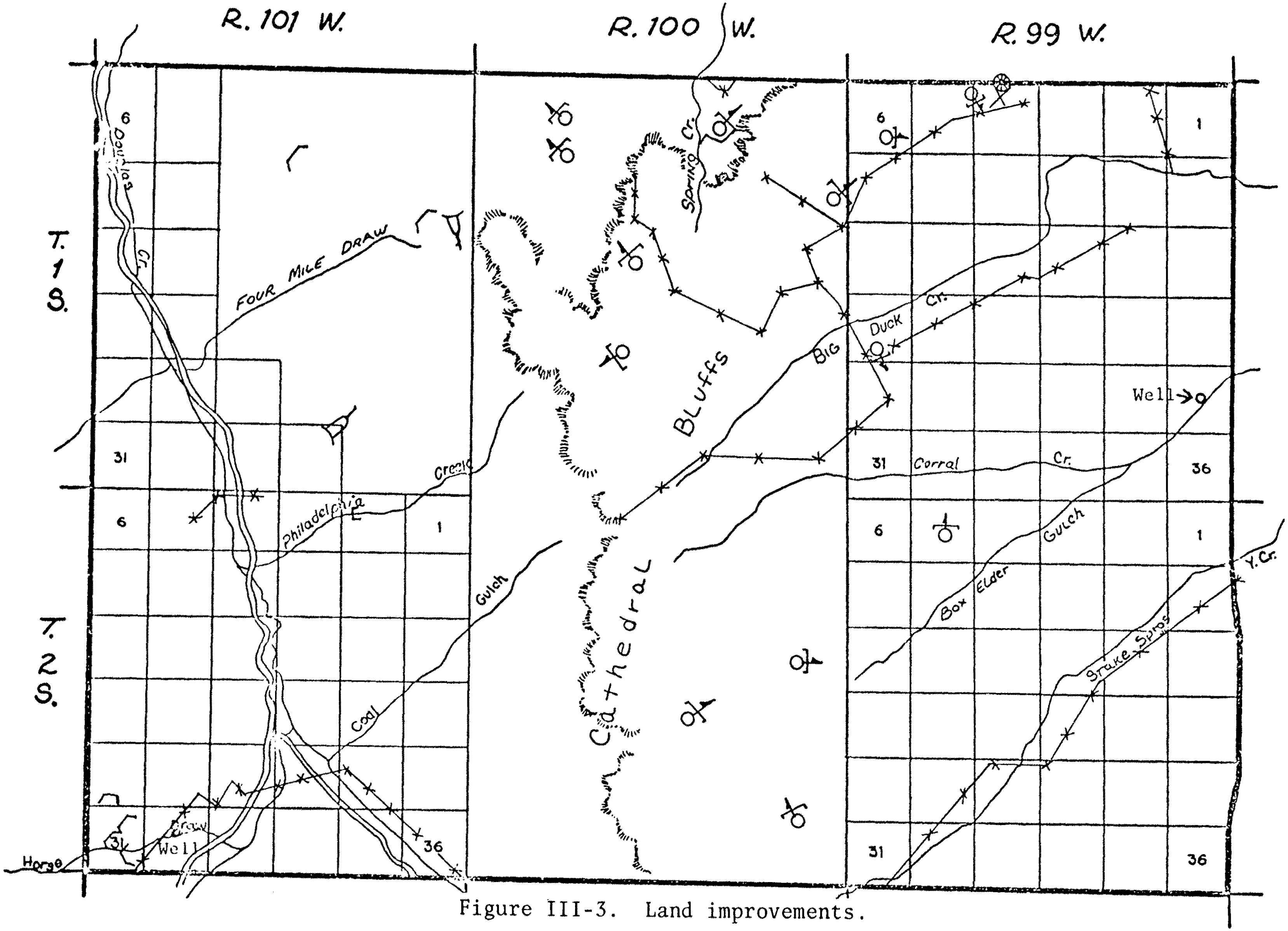


Figure III-3. Land improvements.

Legend

- Improved spring
- Reservoir
- Check dam
- Windmill
x-x - Fence
O - Water well

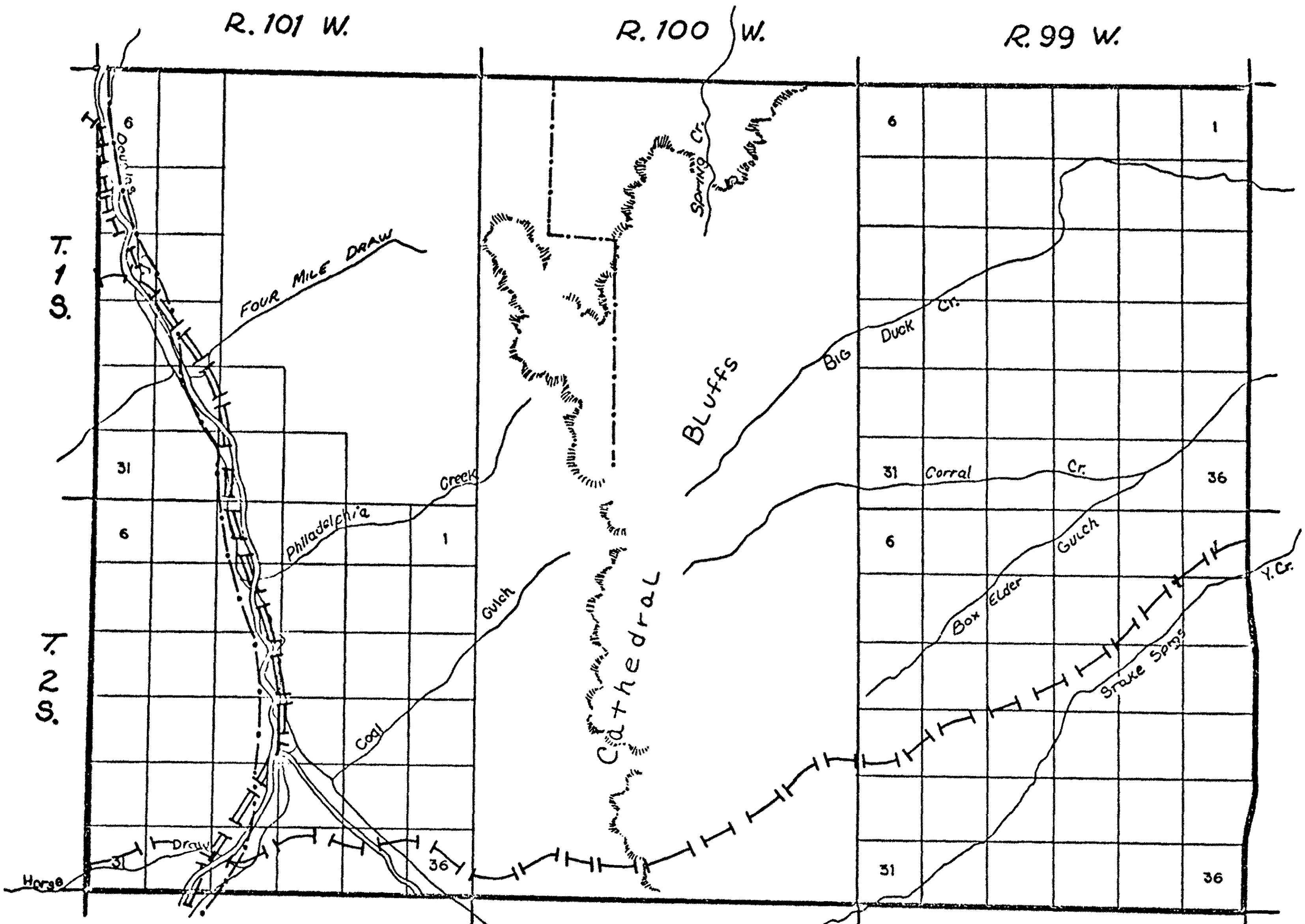


Figure III-4. Public utilities.

Legend

—·—·- Power lines

⊢⊣⊢⊣- Pipe lines

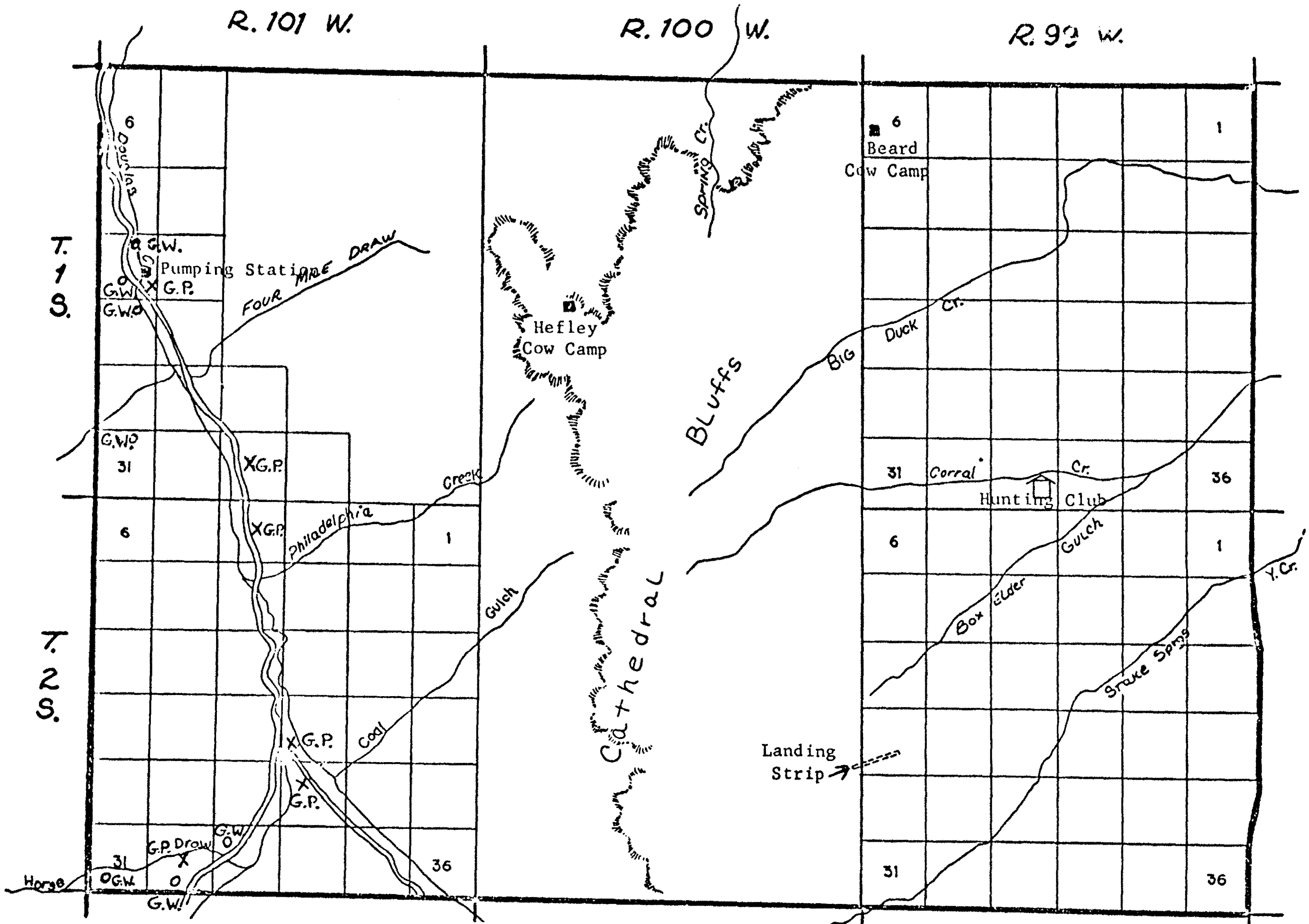


Figure III-5. Other land use features.

Legend G.P. - Gravel pit G.W. - Gas well Other types labeled on map

D. REFERENCES

1. Payne, E. M. and Romine, D. S., 1960, Land Resource Areas of Colorado, Colorado Agricultural Experiment Station, Colorado State University and Soil Conservation Service, U.S.D.A., General Series 727.

2. Bureau of Land Management, 1971, Resource Analysis of Douglas Creek Planning Unit, White River Resource Area, Unpublished Report.

3. Bureau of Land Management, 1971, Resource Analysis of Yellow Creek Planning Unit, White River Resource Area, Unpublished Report.

4. Soil Association Map of Rio Blanco County, Colorado, Soil Conservation Service, U.S.D.A., Unpublished Report.

5. Water and Related Land Resources, White River Basin in Colorado, 1966, Colorado Water Conservation Board and U.S.D.A.

6. United States Geological Survey, Topographic Maps, Scale 1 to 24,000. (Water Canyon, Philadelphia Creek, Sagebrush Hill, Texas Mountain, White Coyote Draw, and Black Cabin Gulch Quadrangles 1964, and Wolf Ridge and Yankee Gulch Quadrangles 1952)

7. Public Lands Outdoor Recreation Maps, Piceance Area, Colorado, United States Department of Interior, Bureau of Land Management and Colorado Department of Game, Fish and Parks.

CHAPTER IV

WATER RESOURCES

A. THE STUDY AREA

Townships 1 and 2 south and Ranges 99, 100, and 101 west of the 6th principal meridian enclose the study area. The eastern two-thirds of the area is within Piceance Basin while the balance is in the Douglas Creek watershed. Cathedral Bluffs, forming the western rim of Piceance Basin, separate the two areas.

The eastern drainage is through Yellow Creek to the White River, with minor runoff to Piceance Creek through Ryan Gulch. The drainage pattern is dense, vegetative cover on the watershed is sparse, and storm runoff is rapid. Watercourses are narrow with steep sides.

Douglas Creek drainage is less dense, although the watershed is severely eroded.

Figures I-1 and I-2 show the boundaries of the study area and the general location within the White River Basin.

B. SURFACE WATER

1. Stream Flow

Relatively little data are available on streamflows in tributaries of the White River and none for the study area itself. Consequently this section will include data from points close to the study area.

Stream channels are relatively straight throughout the study area. They appear to be quite stable. Sediment loads are high, evidently a result of erosion on the watershed. Annual sediment discharge from Piceance Creek is estimated as 1.598×10^6 cubic yards and from Yellow Creek, 2.395×10^6 cubic yards (2) (3).

Peak flows are reached during snowmelt (April - May) and low flows occur in September or October. Many streams are dry from December to April.

a. Piceance Creek -- The flow is relatively constant contrasted with that of all other streams in the basin. Ground water from bed-rock aquifers supplies some water to the stream (to be discussed in section C.). Water stored in the alluvium also tends to modulate the flow.

Table IV-1 summarizes stream flow records for three stations on Piceance Creek. The mean discharge at White River is 17.0 cfs; maximum of record is 550 cfs. Data are only of two or three year duration, however (4). The gaging stations are located on Figure IV-1.

b. Yellow Creek -- This is the primary drainage system for the east part of the study area. Extending into the higher elevations at Cathedral Bluffs, it produces very rapid runoff and high peak flows. Table IV-1 shows an average discharge into the White River of 1.37 cfs; but a peak of 1,060 cfs.

Precipitation at the higher elevations, above 8,000 ft., averages 26 inches annually, mostly snow. At elevations between 5,000 and 8,000 ft. the annual precipitation ranges from 12 to 20 inches.

c. Douglas Creek -- Less data on stream flow are available for Douglas Creek than for either of the others. A gaging station was operated in 1904-05 and again in 1915. No discharge records have been found of recent date. The nearest gaging station is on the White River 4 miles downstream from the mouth of Douglas Creek.

Reference (1) contains estimates of runoff from a 25-year storm on the watershed within the study area. Figure IV-1a shows these estimates by watershed sub-areas. Peak discharge is estimated at 20,530 cfs on watershed No. 6. Obviously, runoff is concentrated very rapidly in watersheds of this area.

Table IV-1. SUMMARY OF STREAMFLOW RECORDS

[Station numbers are those used in publication of surface-water records, except prefix 9 is omitted]

Station No.	Streamflow station	Period of record	Drainage area (sq mi)	Average discharge (cfs)	Extremes of discharge (cfs)	
					Maximum	Minimum daily
0928	West Fork Parachute Creek near Grand Valley	Oct. 1957 Sept. 1962	48.1	4.37	147	0
0930	Parachute Creek near Grand Valley	Oct. 1948 Sept. 1954 Oct. 1964 Sept. 1967	144	17.7	738	0
0935	Parachute Creek at Grand Valley	Apr. 1921 Sept. 1927 Oct. 1948 Sept. 1954	200	30.3	912	0
0940	Roan Creek at Simmons Ranch	June 1935 Sept. 1935 Apr. 1936 Oct. 1936 Mar. 1937 Sept. 1937	79	-----	142	0
0941	Carr Creek at Altenbern Ranch	June 1935 Nov. 1936 Mar. 1937 Sept. 1937	17	2.85	143	0
0942	Roan Creek above Clear Creek	Oct. 1962 Sept. 1967	151	14.8	800	1.0
0944	Clear Creek near DeBeque	July 1966 Sept. 1967	111	-----	1,540	0
0950	Roan Creek near DeBeque	Apr. 1921 Sept. 1926 Oct. 1962 Sept. 1967	321	40.0	1,220	3.2
3055	Piceance Creek at Rio Blanco	Oct. 1952 Sept. 1957	9	1.40	23	.1
3060	Piceance Creek near Rio Blanco	Oct. 1940 Sept. 1943	153	20.3	430	.1
3062	Piceance Creek below Ryan Gulch	Oct. 1964 Sept. 1967	485	12.5	400	.80
3062.22	Piceance Creek at White River[1]	Oct. 1964 Sept. 1966	629	17.0	550	.9
3062.55	Yellow Creek near White River[1]	Oct. 1964 Sept. 1966	258	1.37	1,060	0

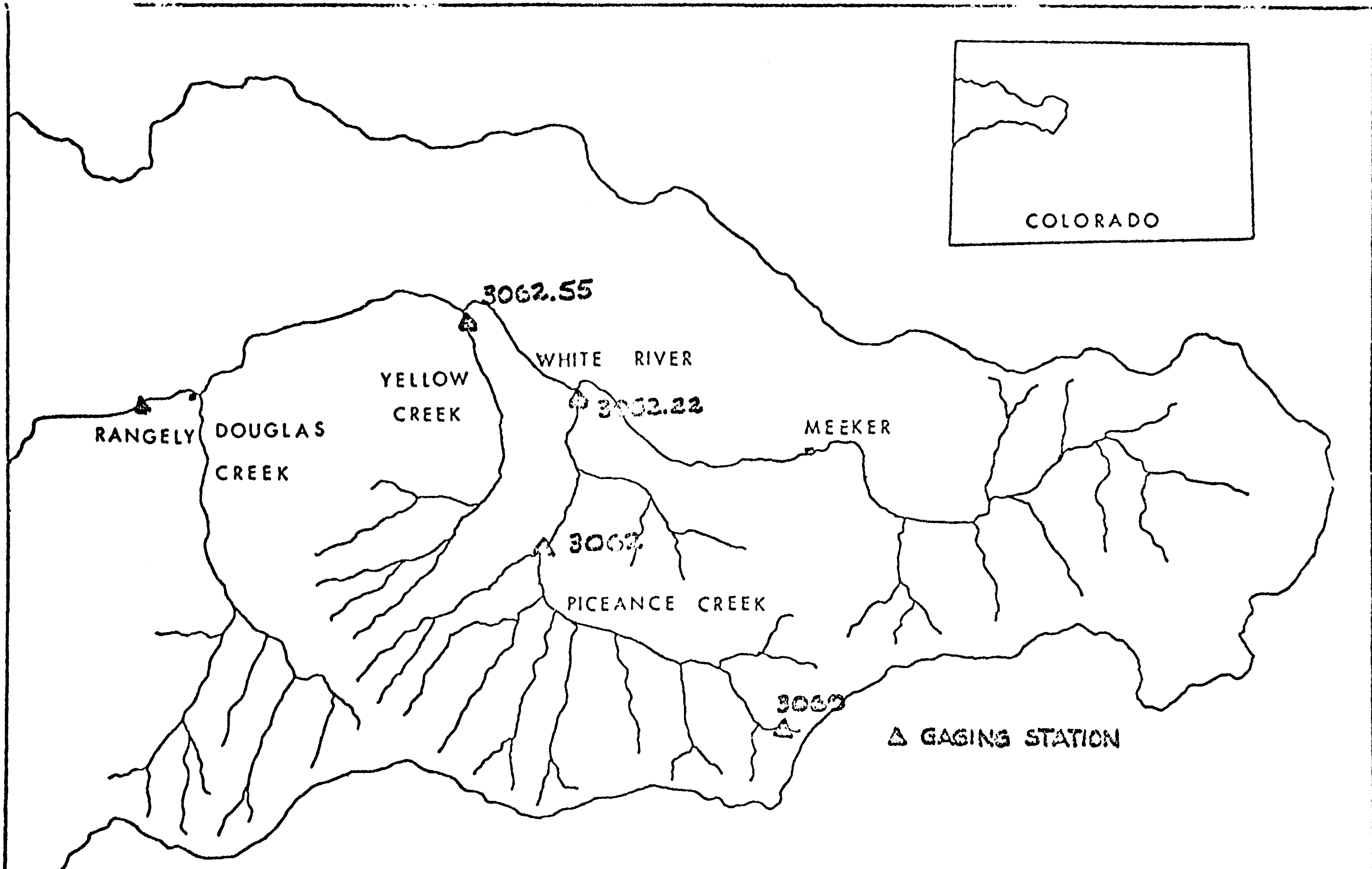


Figure IV-1. Stream Gaging Stations

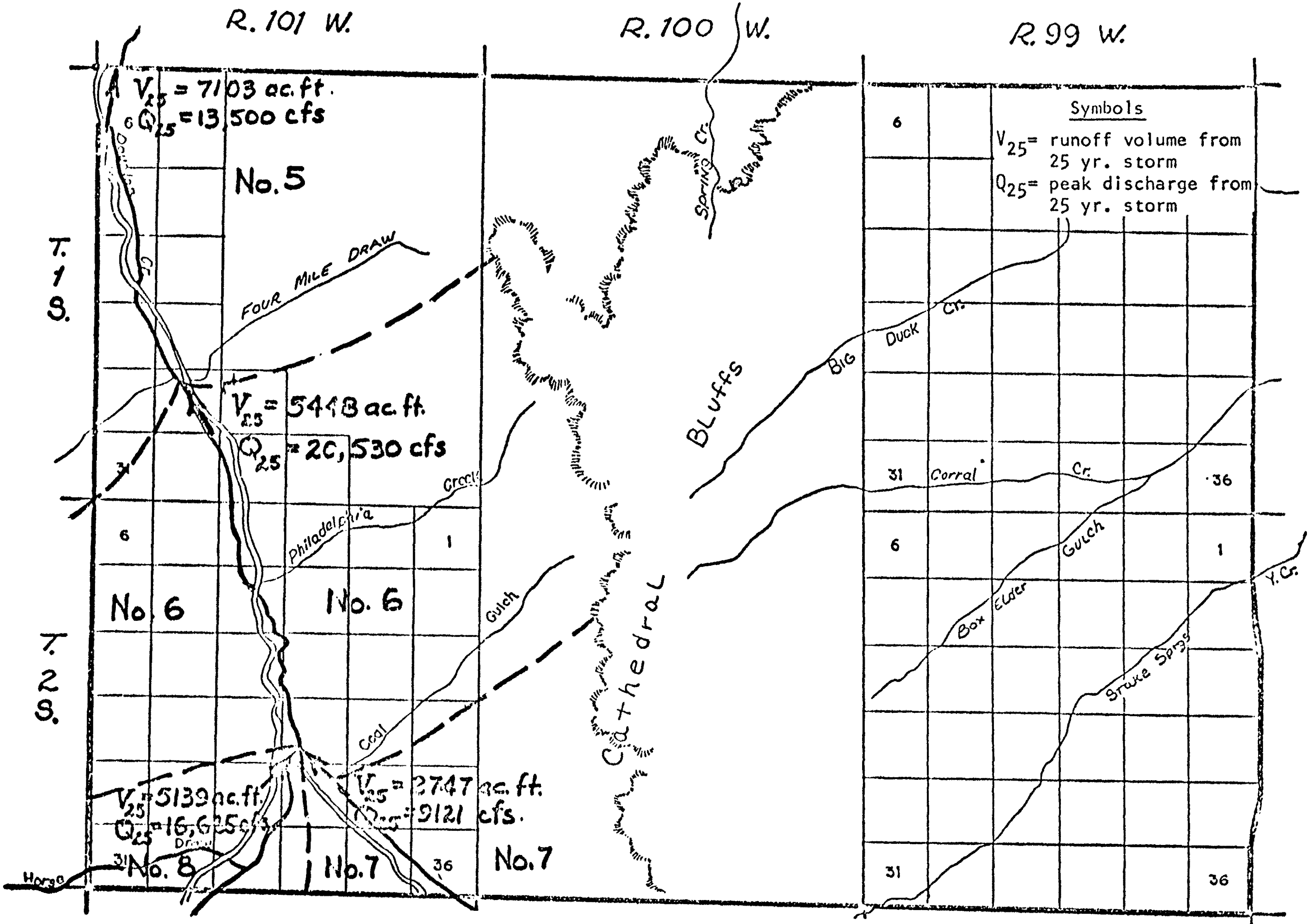


Figure IV-1a. Estimates of Douglas Creek Runoff from 25-year Storm. Ref. (1) .

2. Water Rights

A tabulation of water rights claimed on the streams in and around the study area was made from file records in the Colorado Division of Water Resources. Table IV-2 contains only those rights having earliest priority. None of the rights on Douglas Creek have early priority, but the earliest few are listed.

Priority within the Water Division determines the "value" of the right in terms of water. Early priorities will receive all the water authorized by the appropriation, whereas late priorities may take only that water left after earlier rights are filled. Except in flood periods, that may be none.

No diversions are indicated on any of the streams within the study area.

3. Quality of Water

a. Piceance Creek -- Surface water ranges from 500 mg/l dissolved solids near Rio Blanco to 3000 mg/l at the White River. A Department of Interior report (5) estimates a 100 ton/day of salts discharged to White River. An undetermined amount of this salt is due to irrigation of about 5000 acres along the creek.

b. Yellow Creek -- The observed range in dissolved solids is 1400 mg/l to 3000 mg/l (4). Reference (5) estimates a salt discharge to White River of 7 tons/day.

Reference (7) tabulates water quality data gathered in 1964-65 on both Piceance and Yellow Creeks. Table IV-3 contains that data. Sampling points are identified in a manner described in Reference (7). They begin upstream and are listed in order downstream. Figure IV-2 displays inorganic ion concentrations for both streams.

Table IV-2. PARTIAL LIST OF WATER RIGHTS

PICEANCE CREEK

Entity	cfs	Location	Date Adjud.	Date Approp.	Div. 6 Priority
P.L. Ditch	0.5	C2-97-35	1889	1883	6
Schulte Ditch	0.8	C3-95-15	1889	1884	9
Metz Ditch	1.00	C1-97-11	1889	1884	10
Metz 1st enlarg.	0.6	C1-97-11	1889	1884	11
Home Ditch	1.6	C3-95-15	1889	1884	13
Ryan Ditch	2.5	C1-97-32	1889	1884	14
Metz-Reigan Ditch	3.4	C1-97-11	1889	1885	22
Piceance Ditch	2.00	C2-97-36	1889	1886	37
Larson Ditch	25	C4-94-4	1889	1886	38
Morgan Ditch[2]	0.4	C4-94-4	1890	1886	43
Emily Ditch	2.00	C2-96-31	1889	1886	45
Case-Story Dist.	5.200	C1-97-33	1889	1886	47
BMH Ditch	5.4	C2-97-4	1889	1887	49
Burch Ditch	0.6	C1-97-2	1889	1887	50
Wallace Ditch	0.7	C3-95-18	1889	1887	53
MHM Ditch	7.00	C2-97-15	1889	1887	56
MHM Ditch	2.33	C2-97-15	1889	1887	56
Robert McKee Ditch	2.33	C2-97-22	1889	1887	56
Oldland Ditch	4.00	C3-96-12	1889	1887	57
Beard Watson Ditch	1.00	B1-94-35	1889	1887	58

Table IV-2. PARTIAL LIST OF WATER RIGHTS (Continued)

YELLOW CREEK

Entity	cfs	Location	Date Adjud.	Date Approp.	Div. 6 Priority
Wilson Ditch	1.00	C1-98-16	1889	1886	31
Latham Ditch	2.00	C1-98-30	1889	1887	56
Wilson 1st enlarg.	1.4	C1-98-16	1889	1887	62
Smith Ditch	0.36	C2-99-14	1926	1915	295
Smith Ditch	0.25	C2-99-14	1926	1915	295

DOUGLAS CREEK

Foundation Ditch	0.24	C4-102-35	1942	1905	445
J. P. White Ditch	0.80	C5-102-13	1942	1909	455
G. C. Bowman Ditch	0.70	C3-100-15	1942	1913	473
Banta Ditch	1.43	C4-102-10	1942	1916	482
Banta 1st enlarg.	3.35	C4-102-10	1942	1920	491
Foundation 1st enlarg.	0.56	C4-102-35	1942	1920	491
G. C. Bowman 1st enlarg	1.63	C3-100-15	1942	1920	491
J. P. White enlarg.	1.63	C5-102-13	1942	1920	491

Table IV-3. CHEMICAL ANALYSES OF SURFACE WATERS

(Concentrations of dissolved constituents, dissolved solids, and hardness given in parts per million)

Location: Locations are listed in downstream order. See text for well-numbering system. **Discharge (cfs):** Discharge measurements given in cubic feet per second; E, estimated.

Location	Discharge (cfs)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$	Noncarbonate hardness $CaCO_3$	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
										Piceance Creek														
C4-95- 1aa	. .	6- 8-65	. .	. .	. .	. .	126	33	. .	. .	328	0	. .	6	. .	. .	. .	. .	260	0	. .	. .	736	7.8
	0.55	10- 6-65	40	. .	. .	. .	75	52	. .	. .	418	0	. .	13	. .	. .	. .	. .	402	59	. .	. .	1,050	8.0
C3-95-36cc	.5E	7-17-64	. .	14	0.00	0.00	57	33	70	1.5	344	0	130	8.9	0.1	1.6	0.12	485	278	0	35	1.8	753	7.9
-26db	2.1	10- 6-65	47	. .	. .	. .	75	34	. .	. .	356	0	. .	9.5	. .	. .	. .	. .	324	32	. .	. .	812	8.0
- 9dc	2.0	10- 6-65	47	. .	. .	. .	58	39	. .	. .	324	0	. .	9.5	. .	. .	. .	. .	304	38	. .	. .	768	8.1
C3-96-11bd	9.1	10- 6-65	53	. .	. .	. .	66	47	. .	. .	484	0	. .	14	. .	. .	. .	. .	356	0	. .	. .	936	8.2
C2-97-36ba	11.9	10- 6-65	56	. .	. .	. .	59	57	. .	. .	476	0	. .	16	. .	. .	. .	. .	382	0	. .	. .	1,100	8.0
C2-96-32dd	2.5E	7-17-64	. .	15	.00	.00	40	46	149	1.9	554	0	144	23	1.3	.5	.31	693	290	0	53	3.8	1,090	8.1
C2-97-16dc	4E	7-17-64	. .	16	.00	.00	52	85	190	2.6	567	0	400	16	.5	1.0	.24	1,040	480	15	46	3.8	1,500	8.0
	. .	6- 8-65	59	. .	. .	. .	67	106	. .	. .	716	0	. .	23	. .	. .	. .	. .	602	15	. .	. .	1,500	8.2
	15.6	10- 6-65	58	. .	. .	. .	70	72	. .	. .	546	0	. .	16	. .	. .	. .	. .	472	24	. .	. .	1,350	8.0
C1-97-32ad	17	6- 8-65	65	. .	. .	. .	87	107	. .	. .	736	0	. .	18	. .	. .	. .	1,360	656	52	43	. .	1,670	8.1
B1-97-35ca	2.5E	7-17-64	. .	17	.00	.00	52	117	529	3.9	1,250	45	610	46	.4	1.3	.48	2,040	610	0	65	9.3	2,690	8.4
	. .	3-24-65	37	. .	. .	. .	64	73	. .	. .	808	0	. .	20	. .	. .	. .	A/1,150	460	0	. .	. .	1,680	8.1
	. .	4-12-65	38	. .	. .	. .	38	28	. .	. .	1,110	51	. .	39	. .	. .	. .	A/1,750	209	0	. .	. .	2,520	8.4
	. .	6- 8-65	67	. .	. .	. .	38	117	. .	. .	1,200	22	. .	46	. .	. .	. .	. .	574	0	. .	. .	2,890	8.4
	17.0	10- 6-65	60	. .	. .	. .	41	86	. .	. .	848	16	. .	30	. .	. .	. .	. .	456	0	. .	. .	2,010	8.3
B1-97- 2ab	2E	7-17-64	. .	11	. .	. .	12	95	1,240	6.4	2,540	182	479	208	2.5	2.3	.74	3,490	420	0	86	26	5,020	8.7
	32	3-24-65	36	. .	. .	. .	56	68	. .	. .	1,010	0	. .	45	. .	. .	. .	A/1,380	420	0	. .	. .	2,010	8.2
	14	4-12-65	40	. .	. .	. .	22	37	. .	. .	1,630	81	. .	94	. .	. .	. .	A/2,340	205	0	. .	. .	3,400	8.5
	18	6- 8-65	70	. .	. .	. .	24	107	. .	. .	1,430	59	. .	80	. .	. .	. .	2,370	500	0	. .	. .	3,370	8.4
	19.3	10- 6-65	64	. .	. .	. .	22	81	. .	. .	1,240	33	. .	79	. .	. .	. .	. .	386	0	. .	. .	2,680	8.5
										Black Sulphur Creek														
C2-97-20c	1E	7-17-64	. .	17	.00	.00	76	81	123	1.4	478	0	372	9.5	.3	.5	.15	916	525	133	34	2.3	1,330	7.8
										Hunter Creek														
C2-97-27ac	.5E	7-17-64	. .	19	.00	.00	92	106	157	2.2	566	0	532	9.5	.2	1.2	.16	1,200	665	201	34	2.6	1,630	8.0
										Yellow Creek														
B1-98-12bb	. .	5- 4-65	62	. .	. .	. .	60	175	. .	. .	842	20	. .	24	. .	. .	. .	A/2,020	870	155	. .	. .	2,600	8.3
B2-98-26bb	. .	5- 3-65	65	. .	. .	. .	56	165	. .	. .	832	30	. .	28	. .	. .	. .	A/1,970	820	89	. .	. .	2,540	8.4
- 9ab	5E	3-24-65	33	12	. .	. .	36	63	424		936	16	363	69	. .	3.1	. .	1,420	350	0	72	9.9	2,100	8.3
	. .	4- 8-65	50	. .	. .	. .	18	59	. .	. .	1,420	102	. .	112	. .	. .	. .	A/2,530	288	0	. .	. .	3,590	8.5
	. .	5- 4-65	65	. .	. .	. .	20	151	. .	. .	1,600	98	. .	128	. .	. .	. .	2,750	670	0	. .	. .	3,740	8.6
										Roan Creek														
C6-99-29ab	3E	10- 9-65	54	. .	. .	. .	. .	. .	. .	. .	. .	. .	146	. .	. .	. .	. .	. .	. .	. .	. .	. .	816	. .
C6-98-32bdd	2	10- 9-65	57	. .	. .	. .	. .	. .	. .	. .	. .	. .	263	. .	. .	. .	. .	. .	. .	. .	. .	. .	1,120	. .
C7-98-22ab	5	10- 9-65	51	. .	. .	. .	. .	. .	. .	. .	. .	. .	520	. .	. .	. .	. .	. .	. .	. .	. .	. .	1,630	. .
-25d	2E	10- 9-65	46	. .	. .	. .	. .	. .	. .	. .	. .	. .	809	. .	. .	. .	. .	. .	. .	. .	. .	. .	2,070	. .
C8-97-18aa	.5E	10- 9-65	62	. .	. .	. .	. .	. .	. .	. .	. .	. .	4,200	. .	. .	. .	. .	. .	. .	. .	. .	. .	7,160	. .

A/ Dissolved solids, residue on evaporation at 180°C.

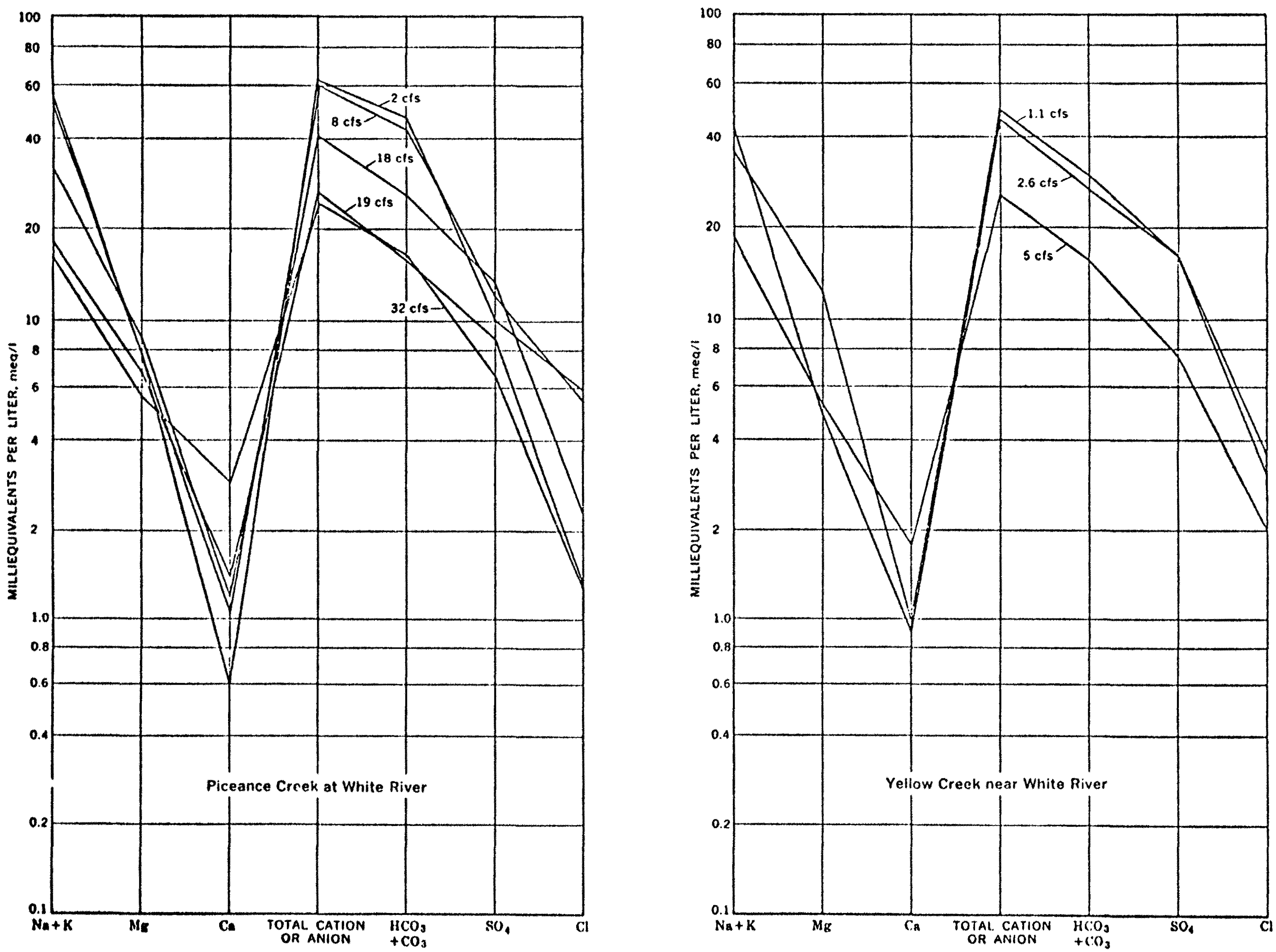


Figure IV-2. Graphs Showing Chemical Character of Selected Streams

c. Douglas Creek -- The only quality data found are contained in Reference (6), an extract of which has been attached in Appendix IV-1 p. 6. Occasional samples from the creek near Rangely indicate a T.D.S. range of 600 to 2000 p.p.m.

d. Colorado water quality standards -- Although the Colorado Water Pollution Control Commission has classified only the White River, but not its tributaries in the study area, the general provisions of the state water quality standards do apply. In particular, "Basic Standards" prohibit discharge of untreated waste into any waters of the state with certain exceptions. Noxious, odorous, unsightly, toxic or deleterious substances harmful to human, animal and plant life may not be introduced into waters of the state.

The White River between the mouth of Piceance Creek and Rangely is presently classified A, B_2, C, D_1. Appendix IV-2 is a statement of the Colorado water quality standards including limits established for certain quality parameters under each classified use.

4. Surface Storage

No major surface water storage facilities exist within the study area. Figure IV-3 shows springs, developed springs, reservoirs and check dams in the study area as reported in References (1,2,3). Three reservoirs and several check dams are noted in the Douglas Creek watershed. Their size and capacity are not documented. The reservoirs provide water for livestock.

C. GROUND WATER

1. Structural Geology

Major structural features include a major basin syncline centered at the north portion of Piceance Basin and a minor synclinal area near the center of the basin. A high, known as Piceance Creek dome, separates the two synclinal areas. Figure IV-4 shows these features. Formations dip sharply at the east and north boundary and less sharply in the south and west, illustrated in Figure IV-5. The Green River formation is exposed at the surface throughout the basin.

Subsurface stratigraphy is displayed in Figure IV-5 along a north-south line in R98W extending from T1N to T3S (see Figure IV-4) (8). The Evacuation Creek member is present at the surface throughout the northern portion of the basin, overlying the Parachute Creek member.

The Parachute Creek member consists of three zones: an upper zone, including the Mahogany zone containing a high concentration of kerogen; a middle zone called the "leached" zone, containing less kerogen; and a lower zone containing about 30% by weight of nahcolite and dawsonite minerals.

During times of tectonic stress the middle zone fractured extensively. The Mahogany zone was relatively unfractured due to toughness of the formation imparted by its kerogen content. Subsequently ground water percolated through the middle zone leaching out soluble minerals (nahcolite) leaving voids. The highly fractured and leached middle zone eventually collapsed into a "rubble" along its upper and lower boundaries. Figure IV-6 outlines the approximate area of leached zone.

Fractures penetrate from the middle zone into the lower zone and there has been some leaching from the upper part of the lower zone. This portion of the lower zone together with the middle zone constitute a large aquifer extending under most of the basin. (An estimated 2.5 million acre feet of water.)

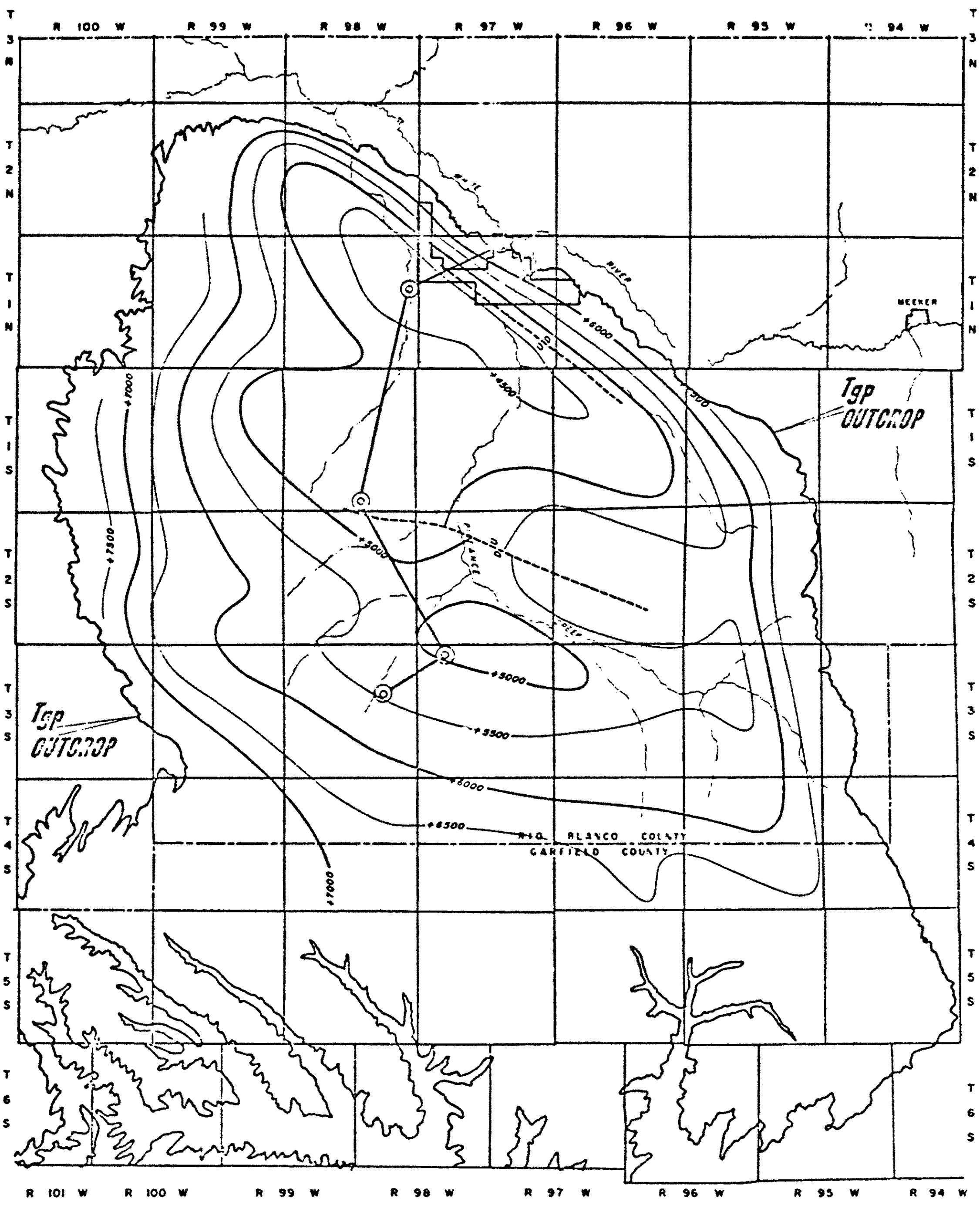


Figure IV-4. Surface Features of Piceance Basin

C.I.=500'

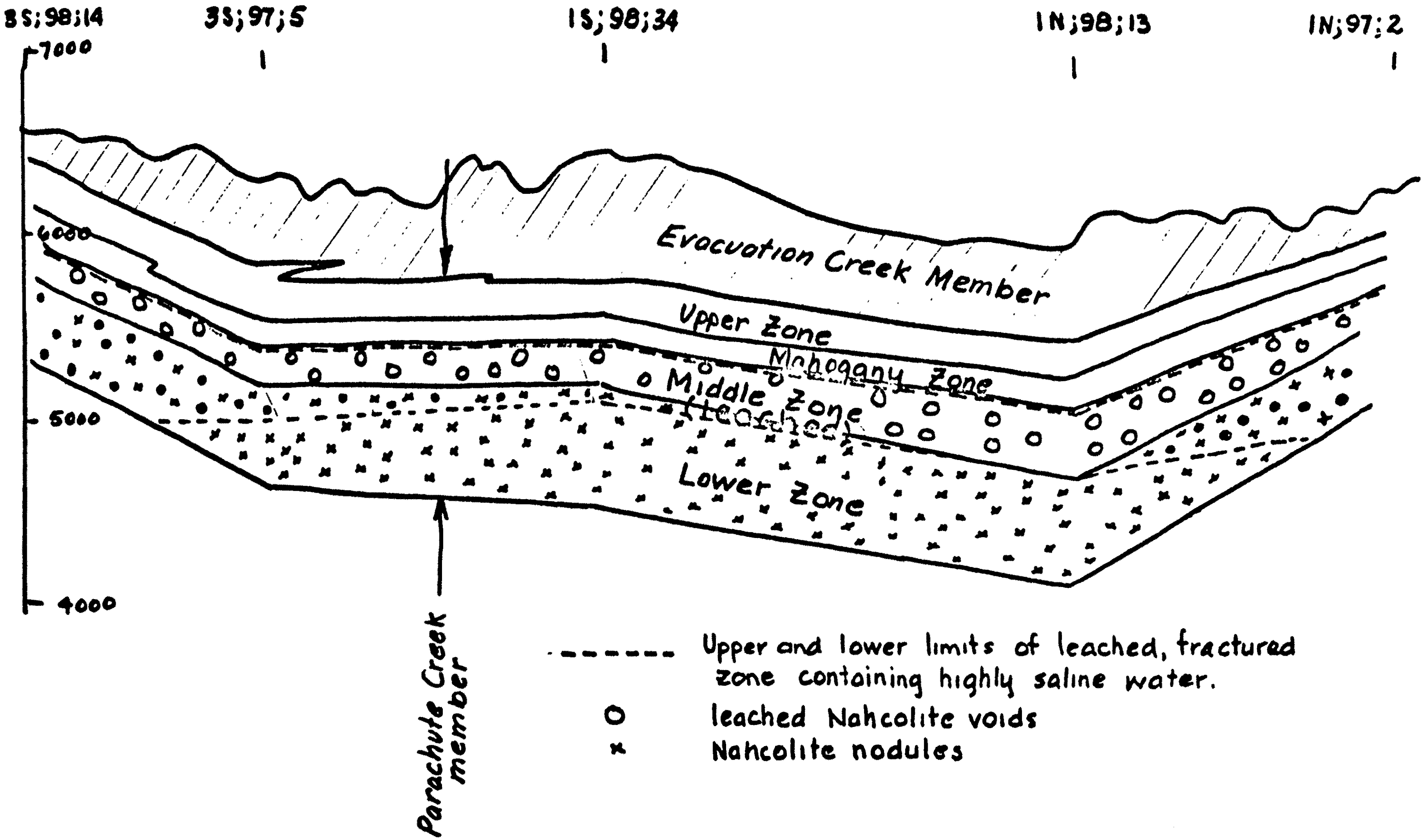


Figure IV-5. Schematic of Parachute Creek Member

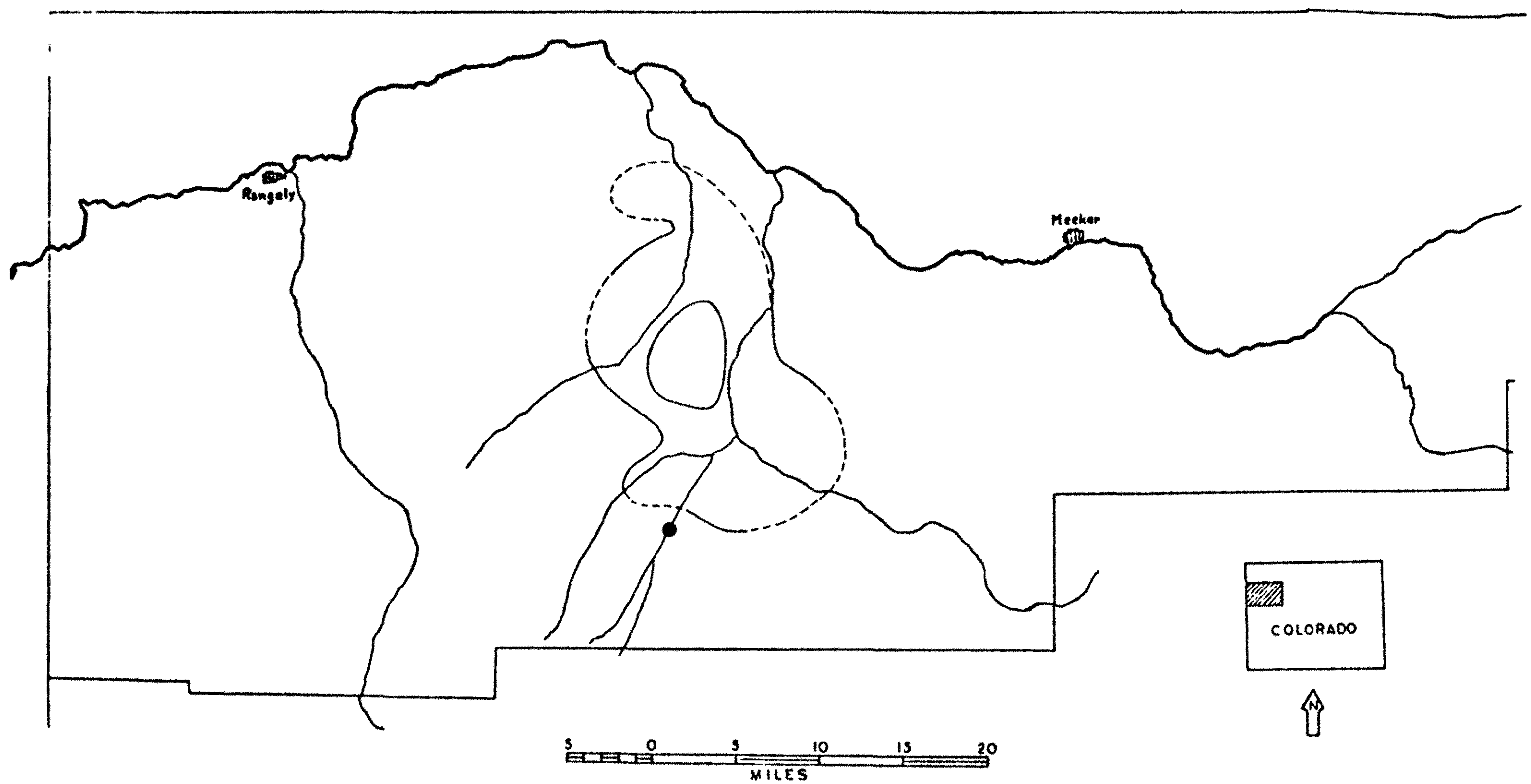


Figure IV-6. Approximate Area of Leached Zone

2. Alluvium Aquifers

Alluvial deposits along Piceance and Yellow Creeks and in some of the tributaries have formed aquifers, typical cross sections of which are illustrated in Figures IV-7 and IV-8. They are less than one mile wide and range up to 140 feet thick. Saturated thickness runs up to 100 feet (4). Both water table and artesian conditions are found. Lenses of gravel confined by low permeability clays produce flowing wells in some places.

Aquifer characteristics reported (4) include storage coefficient of 0.20 and transmissibility of 20,000 gpd/ft. Well yields are expected up to 2,000 gpm.

a. Quality of water -- Ground water in the alluvium is generally good, with less than 700 mg/l throughout the central basin. Principal ions are Ca^{++}, Mg^{++} and HCO_3^-. However, near the White River where Piceance Creek discharges, dissolved solids increase to 8300 mg/l and Na^+ becomes the dominant ion. A similar trend is found in the Yellow Creek alluvium. This is due to highly saline water from the leached zone of the Parachute Creek member coming into the alluvium from below.

Table IV-4 summarizes ground water quality from several aquifers, including the alluvium (7).

b. Recharge -- Alluvium aquifers are recharged primarily by surface infiltration and seepage from stream channels. No detailed analyses of recharge sites and amounts have been made. The surrounding Evacuation Creek member contains water which supplies numerous springs and may also contribute to recharge.

Figure IV-9 is a piezometric surface contour map indicating ground water flow toward both Piceance and Yellow Creeks.

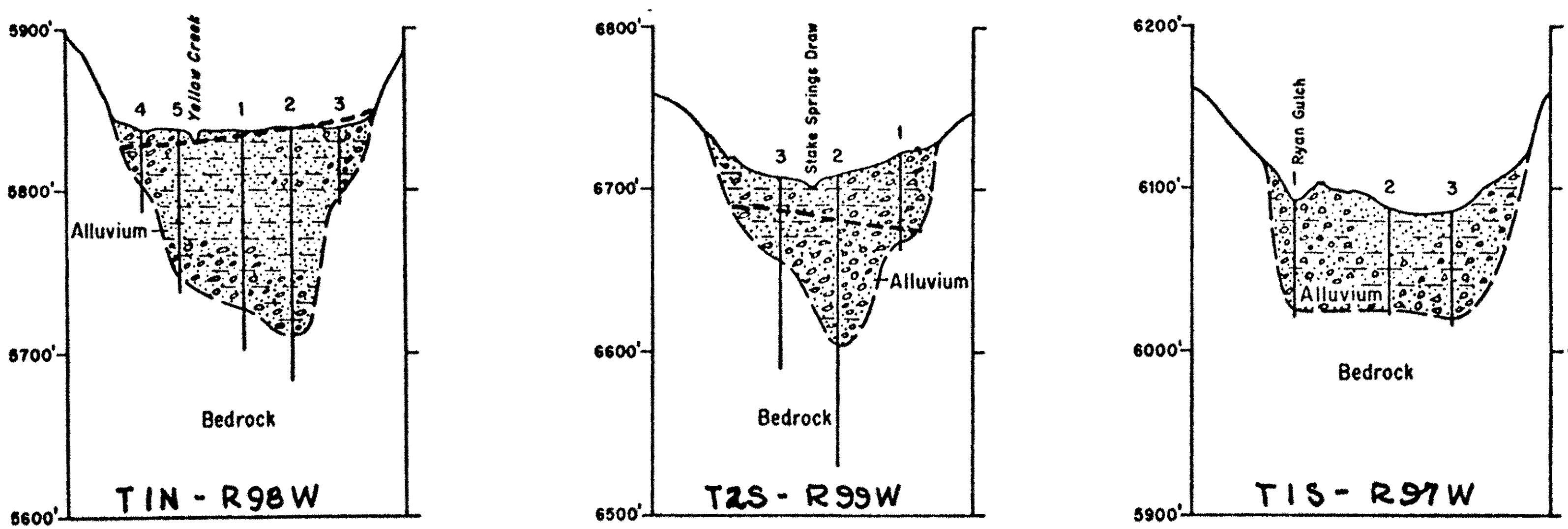


Figure IV-7. Alluvium Aquifers

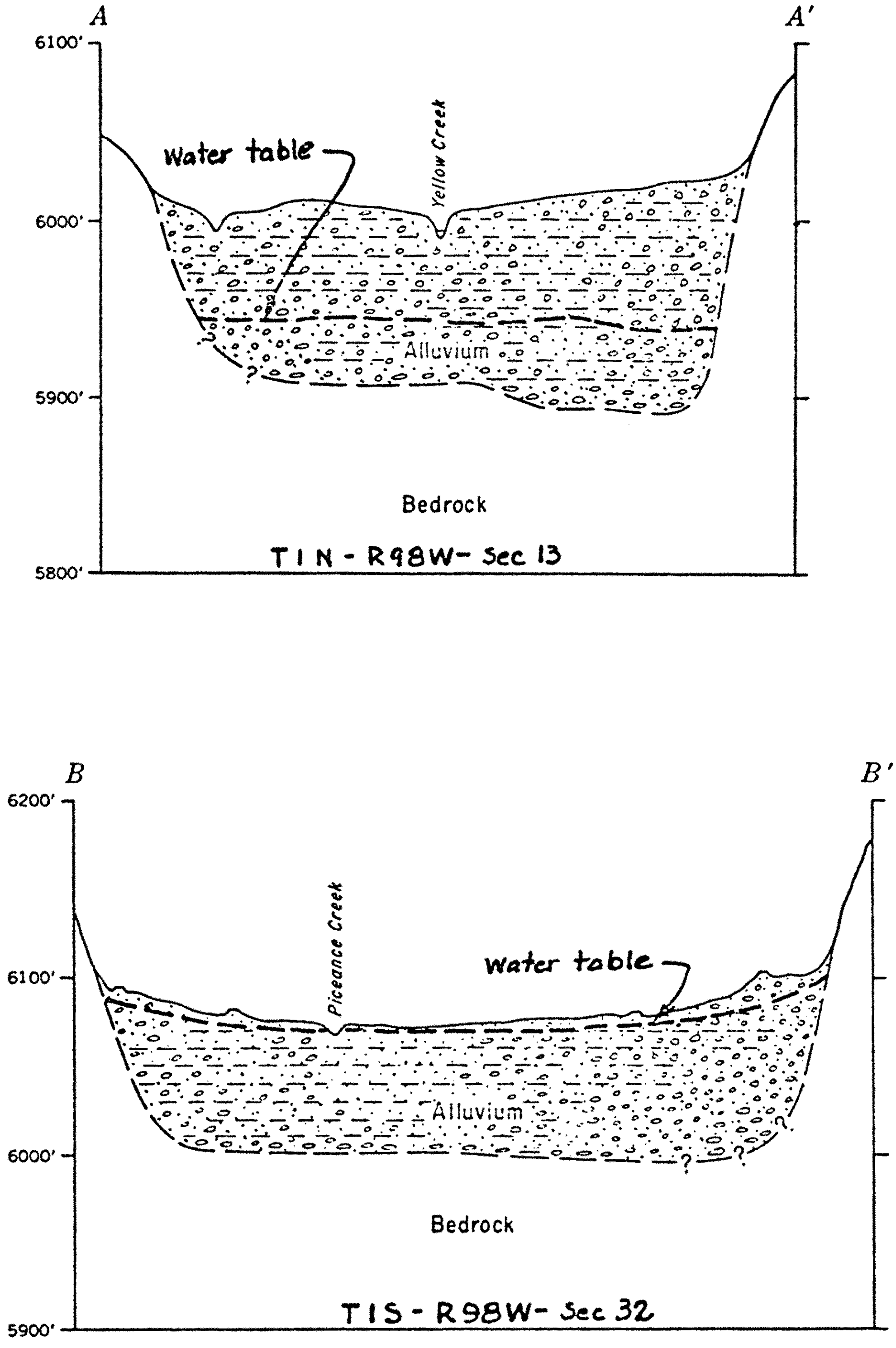


Figure IV-8. Alluvium Aquifers

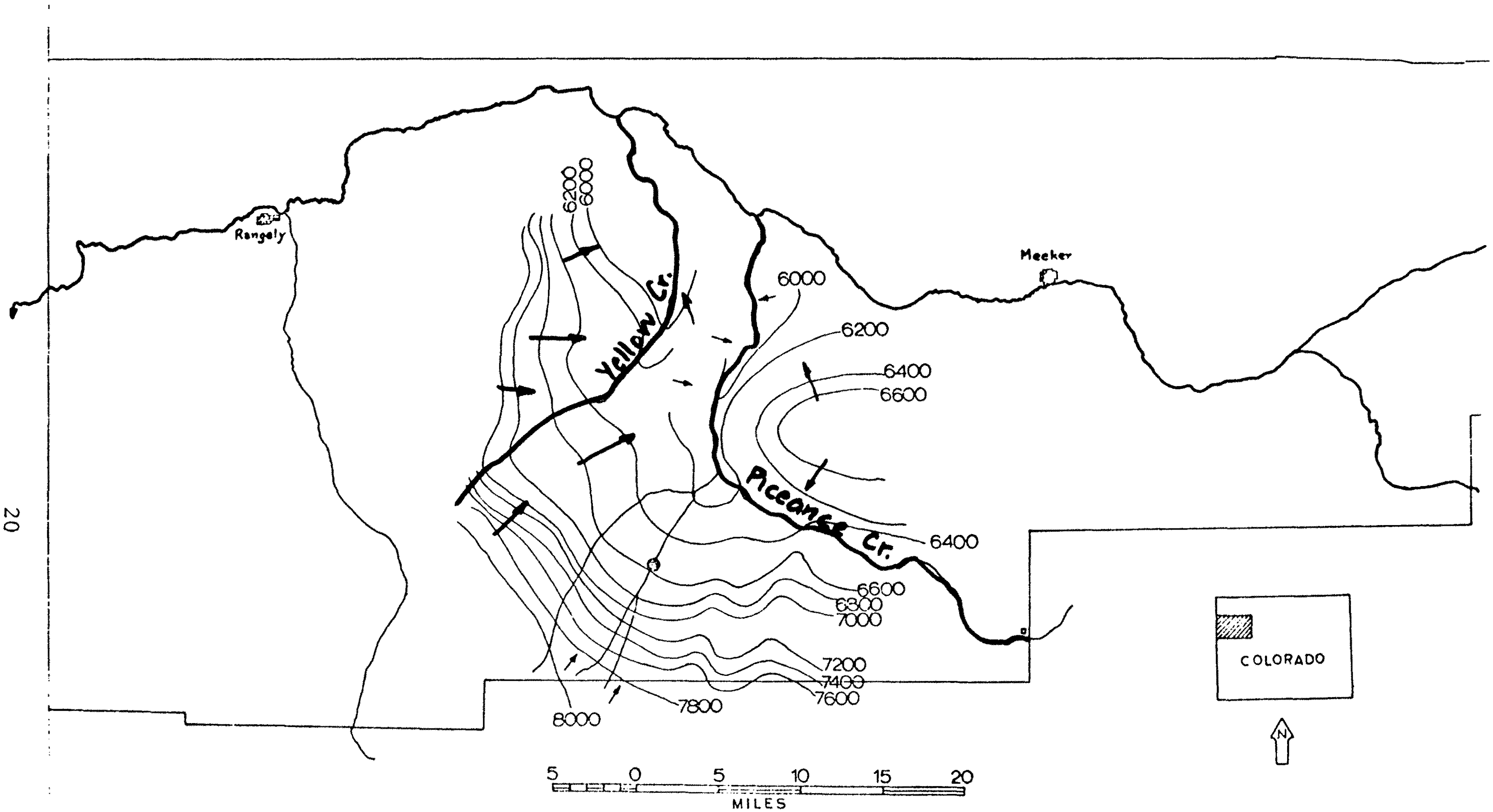


Figure IV-9. Potentiometric Contour Map

Table IV-4. CHEMICAL ANALYSES OF GROUND WATERS FROM SEVERAL AQUIFERS

(Concentrations of dissolved constituents, dissolved solids, and hardness given in parts per million)

Location: See text for well-numbering system.

Geologic source: Tga, Anvil Points Member of the Green River Formation; Tgg, Garden Gulch Member of the Green River Formation; Tgp, Parachute Creek Member of the Green River Formation; Tge, Evacuation Creek Member of the Green River Formation; Qal, alluvium; for the description of the physical character of the water-bearing formations see table 1.

Depth of well: Depth of well given in feet below land surface; R, reported.

Iron (Fe): In solution at time of sampling.

Location	Geologic source	Depth of well (feet)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$	Noncarbonate hardness $CaCO_3$	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
B1-97-11dc	Tgp	Spring	8-18-65	56	17	. .	42	98	516	0.8	1,030	19	640	47	2.5	0.1	0.40	1,890	508	0	69	9.9	2,6[illegible]	8.4
-22cd	Cal	Spring	8-18-65	60	14	. .	0.0	24	10,100	31	23,300	1,110	155	1,660	32	55	4.9	24,600	98	0	99	444	28,6[illegible]	8.5
-22da	Qal	Spring	10- 4-65	52	. .	. .	38	82	. .	. .	1,630	0	. .	68	. .	. .	. .	. .	430	0	. .	. .	2,970	8.2
-22dc	Cal	104	10-16-65	55	2.8	0.02	2.4	15	3,380	8.8	7,100	296	85	985	16	.5	1.1	8,290	66	0	99	181	12,0[illegible]	8.4
-35ca	Cal(?) Tge(?)	Spring	10- 4-65	55	. .	. .	80	57	. .	. .	588	0	. .	14	. .	. .	. .	. .	436	0	. .	. .	1,230	8.0
B1-98- 8cd	Cal,Tge	183	10- 5-65	54	. .	. .	70	92	. .	. .	1,110	0	. .	14	. .	. .	. .	. .	552	0	. .	. .	2,700	7.6
-13cb	Tge	2,600	6-16-65	50	15	. .	33	187	284	2.1	676	28	708	22	.4	5.8	.21	1,710	852	252	42	4.2	2,280	8.4
-18db	Cal,Tge	132	10- 5-65	54	. .	. .	127	132	. .	. .	816	0	. .	14	. .	. .	. .	. .	860	191	. .	. .	2,110	7.8
-24ac	Cal	80	10- 5-65	47	18	. .	116	156	292	1.9	748	12	854	28	.5	4.9	.27	1,850	930	297	41	4.2	2,410	8.3
B1-99- 2a	Cal,Tge	110	4- 8-65	46	18	. .	113	109	151	1.5	509	0	601	18	.6	14	.16	1,280	730	313	31	2.4	1,690	8.0
- 2a	Cal,Tge	110	10- 5-65	52	. .	. .	112	101	. .	. .	498	0	. .	18	. .	. .	. .	. .	694	286	. .	. .	1,650	8.0
- 4da	Tge,Tgp	171	4- 9-65	50	16	. .	101	92	125	1.0	443	0	492	18	1.0	11	.14	1,080	628	264	30	2.2	1,450	7.8
- 9cd	Cal,Tge(?)	. .	10- 5-65	52	. .	. .	56	46	. .	. .	446	0	. .	14	. .	. .	. .	. .	300	0	. .	. .	1,240	7.9
-20b	Tgp(?)	Spring	10- 5-65	52	. .	. .	144	95	. .	. .	570	0	. .	20	. .	. .	. .	. .	752	284	. .	. .	1,870	7.9
-26dd	Tge(?)	1,300R	10- 5-65	55	. .	. .	110	109	. .	. .	826	0	. .	12	. .	. .	. .	. .	725	48	. .	. .	2,040	7.6
B1-100-24b	Cal,Tgp	Spring	8-19-65	54	17	. .	73	90	119	.5	534	0	320	14	.7	25	1.1	923	552	114	32	2.2	1,360	8.1
B2-98-22cb	Tge,Tgp	Spring	9-23-64	53	15	.04	.0	99	3,910	8.8	1,260	4,150	65	746	6.9	14	2.1	9,630	408	0	95	84	12,800	8.5
-22ac2	Cal	45	6-22-65	50	17	. .	46	16.5	437	3.2	1,010	13	804	38	1.1	.1	.35	2,020	792	0	54	6.8	2,750	8.3
C1-96-10bd	Cal,Tge(?)	34	10- 9-64	49	17	.00	67	45	101	1.4	470	0	149	8.0	.3	9.3	.10	629	354	0	38	2.3	947	7.8
-10da	Tgp	3,000	8-17-65	80	12	. .	.0	7.1	246	.4	570	0	47	9.6	5.1	.2	.66	608	29	0	95	2.0	969	8.2
C1-97-11acd	Qal	68	10-25-65	52	18	. .	23	56	240	1.1	552	0	309	25	1.0	1.9	.11	946	290	0	64	6.1	1,380	8.2
-15db	Tge,Tgp	Spring	10- 8-65	50	. .	. .	32	56	. .	. .	1,090	49	. .	44	. .	. .	. .	. .	312	0	. .	. .	2,120	8.6
-28ab	Tgp	3,051	10-12-64	70	12	.04	.0	9.5	7,540	19	9,880	4,320	15	542	30	2.3	2.6	17,400	40	0	100	522	20,700	8.7
C1-99- 4bc	Cal	115	10- 7-65	51	1.1	. .	17	47	108	1.3	104	0	339	13	.0	.6	.04	578	234	149	50	3.1	909	7.5
- 4cc	Cal	115	10- 7-65	51	. .	. .	135	89	. .	. .	540	0	. .	16	. .	. .	. .	. .	702	259	. .	. .	1,570	7.7
- 6bc	Tge	Spring	10- 7-65	49	. .	. .	115	94	. .	. .	696	0	. .	18	. .	. .	. .	. .	674	103	. .	. .	1,540	9.0
-11aa	Cal	. .	10- 7-65	52	. .	. .	127	117	. .	. .	632	0	. .	17	. .	. .	. .	. .	796	278	. .	. .	1,670	7.7
C2-94-19c	Cal,Tga	58	8-27-65	50	31	. .	248	164	39	1.6	518	0	879	17	.5	1.0	.06	1,640	1,300	870	6	.5	1,960	7.5
-30c	Tga	205	8-27-65	48	14	. .	112	154	133	1.3	416	0	770	11	.7	.1	.08	1,400	910	569	24	1.9	1,830	7.6
C2-95-12d	Tga	203	8-27-65	49	40	. .	208	163	125	1.3	632	0	858	14	.3	4.1	.02	1,720	1,190	672	19	1.6	2,160	7.4
-23d	Tgp	75	8-27-65	48	27	. .	84	71	60	1.2	431	0	232	5.0	.7	4.4	.08	697	500	147	21	1.2	1,010	8.0
C2-96- 4cb	Tge	Spring	10- 8-65	47	. .	. .	59	29	. .	. .	376	0	. .	10	. .	. .	. .	. .	266	0	. .	. .	701	8.0
- 9cb	Tge	413	10- 9-65	. .	20	. .	46	19	55	1.3	324	0	34	10	.1	.8	.03	345	194	0	38	1.7	559	8.2
C2-97-27c	Cal(?), Tge(?)	Spring	8-17-65	47	. .	. .	114	109	. .	. .	556	0	. .	9.0	. .	. .	. .	. .	734	278	. .	. .	1,610	7.8
-30ad	Tge	Spring	10-13-64	45	15	.05	80	88	149	1.0	526	0	451	6.6	.1	.3	.12	1,050	562	131	37	2.7	1,450	7.9
C2-98- 9da	Tge	37	10- 8-65	48	16	. .	98	126	243	1.4	682	0	703	17	.3	3.4	.21	1,540	765	206	41	3.8	2,100	8.0
-10db	Cal,Tge(?)	Spring	10- 8-65	48	. .	. .	104	132	. .	. .	694	0	. .	20	. .	. .	. .	. .	804	235	. .	. .	2,160	7.8
-19ca	Cal(?), Tge(?)	Spring	8-17-65	47	. .	. .	98	110	. .	. .	540	0	. .	11	. .	. .	. .	. .	696	253	. .	. .	1,670	7.7
-28dd	Qal(?),Tge	Spring	8-20-65	47	16	.00	43	92	78	1.0	486	0	220	6.5	.4	6.3	.07	702	485	86	26	1.5	1,080	8.1
C2-99- 4cc	Tge(?), Tgp(?)	Spring	10- 7-65	47	17	. .	87	74	100	1.0	446	0	337	15	.2	3.6	.07	854	522	156	29	1.9	1,240	8.0
-12ac	Cal	Spring	10- 7-65	46	. .	. .	115	90	. .	. .	520	0	. .	14	. .	. .	. .	. .	658	231	. .	. .	1,530	7.7
-15dc	Cal	. .	10- 7-65	48	. .	.02	80	76	. .	. .	414	0	. .	14	. .	. .	. .	.	512	98	. .	. .	1,260	7.9

Table IV-4. CHEMICAL ANALYSES OF GROUND WATERS FROM SEVERAL AQUIFERS (Continued)

Location	Geologic source	Depth of well (feet)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$	Noncarbonate hardness $CaCO_3$	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
C3-95-18ab	Tge	Spring	10- 5-65	49	13	. .	51	54	119	2.4	508	0	154	12	1.3	0.9	0.23	658	346	0	43	2.8	1,030	8.1
-31cc	Qal,Tge(?)	. .	9- 1-65	53	. .	. .	67	37	. .	. .	366	16	. .	7.5	. .	. .	. .	. .	322	0	. .	. .	850	8.4
C3-96- 5aa	Tge	Spring	10- 8-65	47	11	. .	94	78	117	1.2	500	0	365	10	.3	5.6	.09	928	555	145	31	2.2	1,330	8.1
-11ba	Tgp	1,000R	5- 7-62	70	13	0.01	8.0	3.4	684	1.2	1,610	63	4.1	30	30	.4	.92	1,630	34	0	98	51	2,500	8.3
-11ba	Tgp	1,000R	4-13-65	70	11	. .	4.0	3.4	. .	. .	1,510	112	10	28	25	1.3	. .	1,640	24	0	98	62	2,470	8.4
-11bb	Tgp	1,300	9-29-65	76	. .	. .	15	4.4	. .	. .	1,480	24	. .	106	. .	. .	. .	. .	56	0	. .	. .	2,530	8.3
C3-97-14cb	Qal(?),Tge	Spring	8-18-65	47	. .	. .	101	79	. .	. .	542	0	. .	9.0	. .	. .	. .	. .	578	133	. .	. .	1,360	8.0
-27cd	Qal(?),Tge	Spring	8-18-65	46	. .	. .	104	74	. .	. .	498	0	. .	8.0	. .	. .	. .	. .	566	158	. .	. .	1,240	7.8
C3-98-22db	Qal(?),Tge	Spring	8-17-65	46	. .	. .	123	66	. .	. .	460	0	. .	6.0	. .	. .	. .	. .	578	201	. .	. .	1,300	7.7
C4-94-34b	Qal,Tga	Spring	8- -65	45	. .	. .	73	38	. .	. .	422	0	. .	3.0	. .	. .	. .	. .	340	0	. .	. .	687	7.8
C4-95- 1ba	Qal(?);Tge(?), Tgp(?)	74	8-30-65	48	12	. .	53	28	66	.3	255	0	161	14	.8	.3	.04	460	248	39	37	1.8	703	8.1
- 8bb	Tge(?),Tgp(?)	99	8-31-65	49	23	. .	88	49	90	.0	408	0	244	6.4	.8	3.9	.08	706	420	85	32	1.9	1,040	7.7
-19cc	Qal,Tge	128	10-11-65	45	11	.00	29	34	125	.5	384	0	141	5.2	.1	.6	.05	535	210	0	56	3.8	892	8.1
C4-97-12db	Qal,Tge,Tgp	80	8-30-65	48	15	. .	112	75	106	.4	464	0	393	5.8	.7	4.8	.08	940	588	208	28	1.9	1,310	7.9
-31bd	Tge	Spring	8-18-65	43	. .	. .	59	33	. .	. .	332	0	. .	3.0	. .	. .	. .	. .	282	10	. .	. .	600	7.9
-32ca	Tge	Spring	8-18-65	45	. .	. .	75	38	. .	. .	380	0	. .	4.0	. .	. .	. .	. .	344	32	. .	. .	730	7.8
-33cb2	Qal	Spring	8-18-65	57	. .	. .	103	55	. .	. .	510	0	. .	6.0	. .	. .	. .	. .	486	68	. .	. .	1,030	7.5
C4-98-14cc	Tge(?)	Spring	8-17-65	45	. .	. .	95	81	. .	. .	396	0	. .	6.0	. .	. .	. .	. .	570	245	. .	. .	1,210	8.0
-17cb	Tge(?)	Spring	8-28-65	46	. .	. .	73	41	. .	. .	350	26	. .	6.5	. .	. .	. .	. .	352	22	. .	. .	836	8.4
-36aa	Tge	Spring	9-18-65	44	. .	. .	76	47	. .	. .	388	0	. .	3.0	. .	. .	. .	. .	382	64	. .	. .	850	8.1
C4-99-10ac	Tgp	Spring	10-12-64	45	18	.02	69	29	35	.4	374	0	80	2.0	.0	1.8	.05	419	294	0	21	.9	668	7.7
-10ac	Tgp	Spring	8-16-65	46	. .	. .	74	29	. .	. .	354	0	60	2.0	. .	. .	. .	. .	304	14	. .	. .	639	8.1
C5-94-14ab	Tge	Spring	8- -65	49	. .	. .	57	21	. .	. .	308	0	. .	2.0	. .	. .	. .	. .	228	0	. .	. .	505	7.5
C5-95-30c	Qal(?)	Spring	8-16-65	48	16	. .	51	38	41	1.5	345	0	64	4.8	.6	3.4	.06	390	282	0	24	1.1	629	7.9
C5-96- 11d	Tge	Spring	8-27-65	46	. .	. .	51	33	. .	. .	310	0	. .	5.0	. .	. .	. .	. .	262	8	. .	. .	662	8.0
- 11d2	Qal	Spring	8-27-65	51	. .	. .	39	33	. .	. .	266	0	. .	6.0	. .	. .	. .	. .	232	14	. .	. .	596	8.2
-36aaa	Qal	50R	8-13-65	53	. .	. .	70	50	. .	. .	400	0	. .	8.0	. .	. .	. .	. .	378	50	. .	. .	862	7.9
C5-97- 1c	Tgp	. .	8- -65	55	. .	. .	47	33	. .	. .	344	0	. .	5.0	. .	. .	. .	. .	251	0	. .	. .	679	8.0
-23bb	Tge	Spring	8- -65	55	. .	. .	58	18	. .	. .	332	0	. .	3.0	. .	. .	. .	. .	218	0	. .	. .	521	7.6
C5-98- 2ac	Tgp	Spring	8-30-65	43	. .	. .	59	30	. .	. .	324	0	. .	4.0	. .	. .	. .	. .	270	4	. .	. .	650	7.5
C6-95-12ba	Tgp	Spring	8-26-65	46	. .	. .	87	31	. .	. .	416	0	. .	2.0	. .	. .	. .	. .	344	3	. .	. .	621	7.7
C6-96-29da	Qal	33	10-12-65	55	21	. .	124	73	92	16	700	0	267	10	1.2	10	.17	958	610	36	24	1.6	1,410	7.6
C6-98-16aa	Qal	68R	10-13-65	. .	16	. .	63	52	75	2.5	446	0	141	11	.9	5.4	.16	586	372	6	30	1.7	918	7.9
-34cd	Qal	70R	10-12-65	57	18	. .	100	79	117	3.1	616	0	252	12	1.2	32	.23	918	575	70	31	2.1	1,370	7.9
C7-96-11aa	Qal	50R	10-12-65	. .	19	. .	170	122	198	5.2	656	0	793	18	.9	.4	.20	1,650	925	387	32	2.8	2,180	7.9
C7-97- 5ba	Qal(?)	Spring	10-11-65	50	6.8	. .	44	69	67	3.4	484	0	129	6.0	.6	1.5	.11	565	392	0	27	1.5	1,000	8.0
C7-98- 4ba	Qal	61R	10- 9-65	52	15	. .	96	90	149	2.3	598	0	424	10	.7	6.6	.22	1,090	610	120	35	2.6	1,530	8.0
- 8ab	Tgp(?), Tgq(?)	Spring	10- 9-65	. .	. .	. .	48	94	. .	. .	689	0	. .	14	. .	. .	. .	. .	506	0	. .	. .	1,840	8.1
-14ca	Qal	68R	10- 9-65	54	15	.15	144	170	396	3.8	737	0	1,220	35	.8	.7	.57	2,350	1,060	456	45	5.3	3,010	8.0
C7-99-26cc	Qal(?), Tgp(?)	Spring	10-11-65	50	. .	. .	91	73	. .	. .	512	0	. .	10	. .	. .	. .	. .	528	108	. .	. .	1,410	7.7
-27bd	Qal(?), Tga(?)	Spring	10-11-65	47	16	. .	50	86	110	1.9	494	0	287	5.4	.3	.5	.10	800	478	73	33	2.2	1,220	8.1
C7-100-25db	Qal	Spring	10-11-65	48	. .	. .	86	57	. .	. .	496	0	. .	5.0	. .	. .	. .	. .	448	41	. .	. .	1,050	7.8
-35bb	Qal	Spring	10-11-65	51	. .	. .	72	57	. .	. .	424	0	. .	5.0	. .	. .	. .	. .	416	68	. .	. .	894	7.8
C8- 97- 7ab	Qal	75R	10- 9-65	54	16	. .	164	148	293	3.3	692	0	1,040	18	.8	5.5	.31	2,030	1,020	453	38	4.0	2,630	7.9

Saline water from the Parachute Creek member evidently flows upward into the alluvium in the north portion of the basin. This is indicated by both piezometric data and water quality data previously cited.

3. Evacuation Creek Member

Water is contained mainly in fractures. Test wells in the northwest basin yielded 100 gpm (4). Numerous springs flow from this member. Typical hydrographs of two such springs are displayed in Figure IV-10. Peak flow ranges from 1.0 to 3.0 cfs, occurring during snowmelt in early spring. Winter flows range between 0.3 to 0.7 cfs.

Figure IV-3 shows locations of springs and developed springs within the study area (3).

a. Quality of water -- Total dissolved solids in the ground water of this member ranges from 250 mg/l to 3000 mg/l. Figure IV-11 includes a display of the concentration range of several constituents. Table IV-5 summarizes data furnished by Shell Oil Company to the Colorado Water Pollution Control Commission from a well at T1S; R97W; Sec. 29 indicating T.D.S. greater than 4000 mg/l.

b. Recharge -- Major recharge occurs at the high elevation margins of the basin from snowmelt (4).

4. Parachute Creek Member

The physical nature of this aquifer is described previously and illustrated in Figure IV-5. The Mahogany zone is an impermeable material confining water in the middle zone and creating an artesian situation. Limited fracturing of the Mahogany permits water transfer from the middle zone into overlying formations.

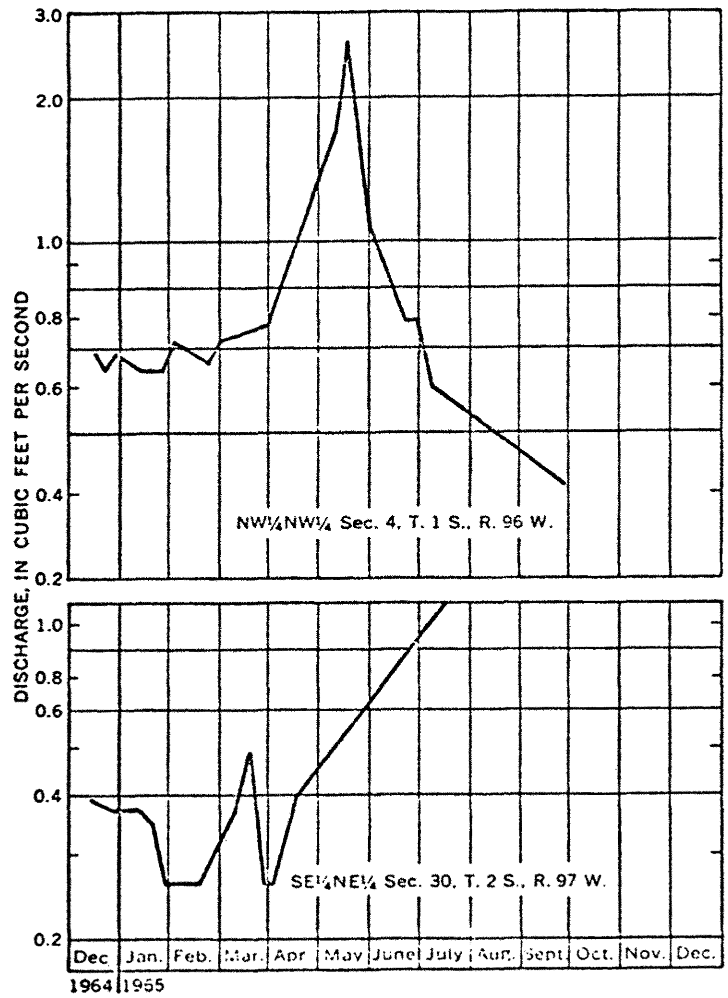
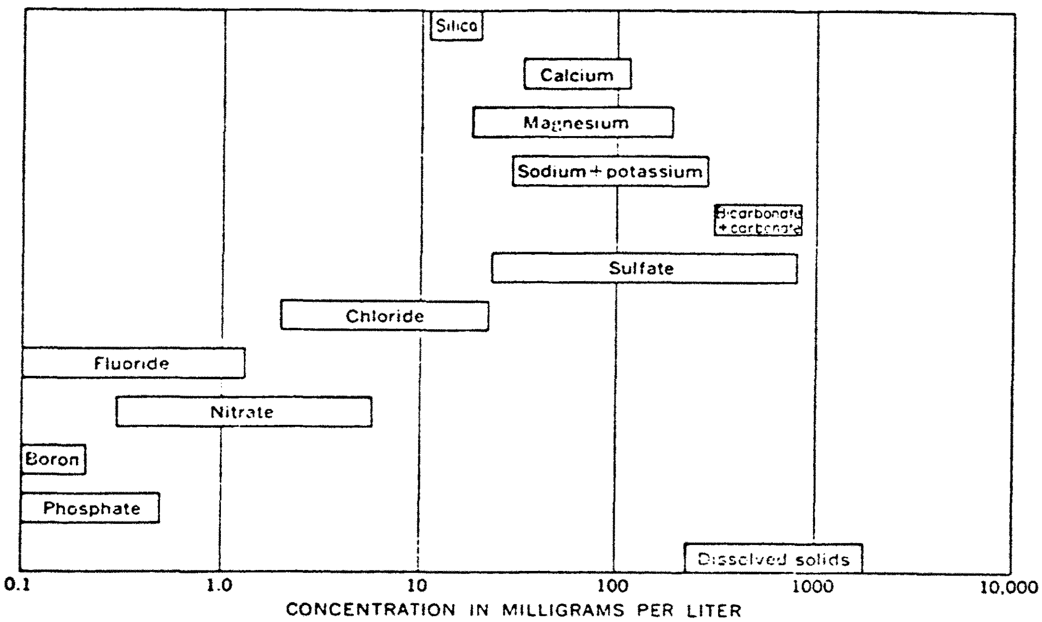


Figure IV-10. Hydrographs of Selected Springs



BAR GRAPH SHOWING RANGE OF WATER QUALITY IN THE EVACUATION CREEK MEMBER

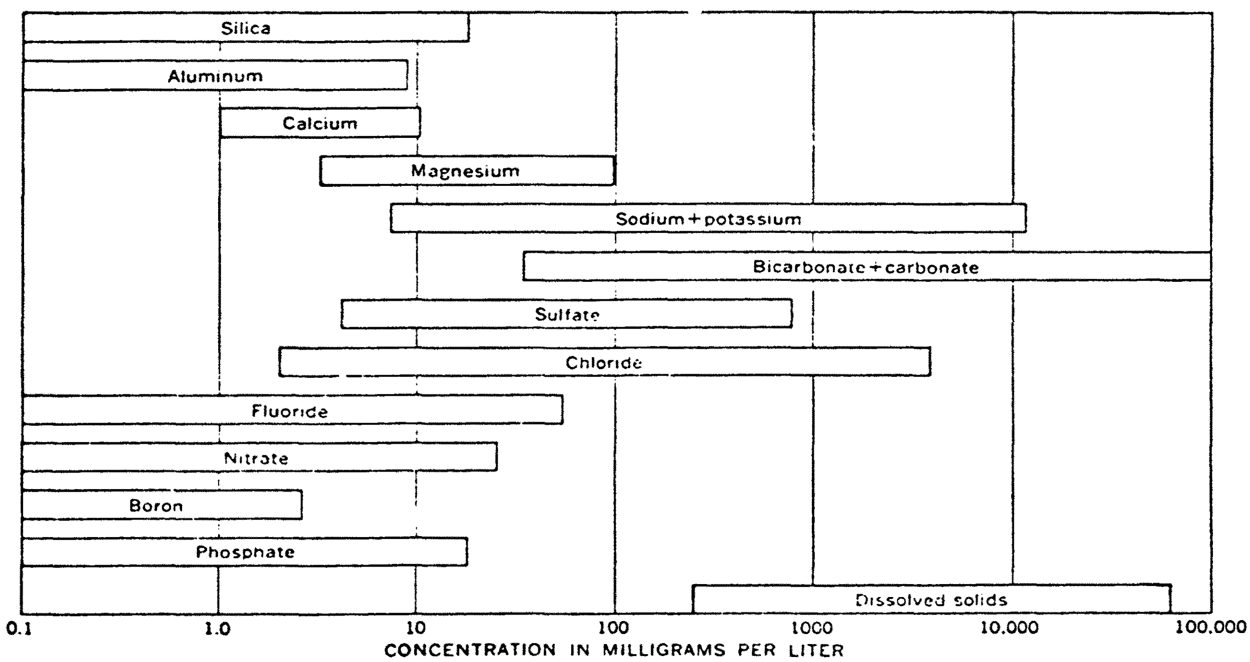


Figure IV-11. Ground Water Quality

Table IV-5. QUALITY OF GROUND WATER FROM ALLUVIUM

(mg/liter)

Date	Fe.	Ca	Mg.	Na	HCO_3	SO_4	Cl	T.D.S.	pH
Dec. 3, 1970	<1	140	250	1530	1510	2160	100	5700	7.9
Jan. 30, 1971	<1	142	281	830	1440	3360	87	6140	7.6
Feb. 13, 1971	1	148	315	730	1300	2450	100	5040	7.5
Mar. 19, 1971	<0.1	118	285	310	1500	2340	110	4670	7.5
Apr. 1, 1971	2.65	135	275	500	1588	2148	103	4414	7.9
May 15, 1971	5.0	68	237	4095	1768	2126	103	4628	7.7
June 1, 1971	5.0	67.2	237	1120	1854	1923	95.9	4679	7.6
July 1, 1971	4.11	68.8	208.8	2830	2292	2007	84.7	4637	7.7
July 15, 1971	5.55	67.2	223.4	2115	2166	2123	91.8	4642	7.7
Aug. 27, 1971	1.06	48.9	230	1090	1936	2136	141.2	4641	7.7
Sept. 1, 1971	17.6	54	210	2375	2072	2033	138.4	4739	7.8
Sept. 3 1971	33.6	48.9	226.2	914	1633	2036	84.7	4254	7.7
Sept. 15, 1971	13.7	56	230	2375	1806	1983	138.4	4417	7.6

The highly fractured and leached middle zone has an estimated storage coefficient of 10^{-4} under confined conditions but would increase to 10^{-1} unconfined (4).

The lower zone contains water but its transmissibility is very low; it cannot be considered to be a water-yielding aquifer.

a. Water quality -- Near the margins of the basin, water in this member is similar to that in the Evacuation Creek member (up to 2000 mg/l T.D.S.). Ions are mainly Ca^{++}, Mg^{++} and HCO_3^-. At half the radius of the basin, dissolved solids are approximately the same but ions are predominately Na^+ and HCO_3^-. At the center of the basin, water contains generally 25,000 mg/l T.D.S., mainly Na^+ and HCO_3^-. Chloride ion ranges from 500 to 2500 mg/l in this area.

Figure IV-11 includes a bar chart of water quality in this member. Water from the lower zone (see Figure IV-5) contains 63,000 mg/l dissolved salts.

b. Recharge -- Surface water at the margins of the basin percolate vertically through the Evacuation Creek member into the Parachute Creek member, recharging the middle (leached) zone. Piezometric data of Figure IV-9 support this conclusion (4).

5. <u>Summary of Aquifer Characteristics</u>

Table IV-6 from Reference (4) summarizes aquifer characteristics.

Table IV-6. SUMMARY OF GEOLOGIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS

System	Series	Geologic unit		Thickness (feet)	Physical character	Water quality	Hydrologic character
Quaternary	Holocene and Pleistocene(?)	Alluvium		0-140	Sand, gravel, and clay partly fill major valleys as much as 140 feet, generally less than half a mile wide. Beds of clay may be as thick as 70 feet, generally thickest near the center of valleys. Sand and gravel contain stringers of clay near mouths of small tributaries to major streams.	Near the headwaters of the major streams, dissolved-solids concentrations range from 250 to 700 mg/l. Dominant ions in the water are generally calcium, magnesium, and bicarbonate. In most of the area, dissolved solids range from 700 to as much as 25,000 mg/l. Above 3,000 mg/l the dominant ions are sodium and bicarbonate.	Water is under artesian pressure where sand and gravel are overlain by beds of clay. Reported yields as much as 1,500 gpm. Well yields will decrease with time because valleys are narrow and the valley walls act as relatively impermeable boundaries. Transmissivity ranges from 20,000 to 150,000 gpd per ft. The storage coefficient averages 0.20.
Tertiary	Eocene	Green River Formation	Evacuation Creek Member	0-1,250	Intertonguing and gradational beds of sandstone, siltstone, and marlstone, contains pyroclastic rocks and a few conglomerate lenses. Forms surface rock over most of the area. thins appreciably westward.	Water ranges from 250 to 1,800 mg/l dissolved solids.	Beds of sandstone are predominantly fine grained and have low permeability. Water moves primarily through fractures. The part of the member higher than valley floors is mostly drained. Reported to yield as much as 100 gpm where tested in the north-central part of the basin. Member has not been thoroughly tested, and larger yields may be possible.
			Parachute Creek Member	500-1,800	Kerogenaceous dolomitic marlstone (oil shale) and shale, contains thin pyroclastic beds, fractured to depths of at least 1,800 feet. Abundant saline minerals in deeper part of the basin. The member can be divided into three zones—high resistivity, low resistivity or leached, and Mahogany (oldest to youngest), which can be correlated throughout basin by use of geophysical logs.	Water ranges in dissolved-solids content from 250 to about 63,000 mg/l. Below 500 mg/l, calcium is the dominant cation, above 500 mg/l, sodium is generally dominant. Bicarbonate is generally the dominant anion regardless of concentration. Fluoride ranges from 0.0 to 54 mg/l.	High resistivity zone and Mahogany zone are relatively impermeable. The leached zone (middle unit) contains water in solution openings and is under sufficient artesian pressure to cause flowing wells. Transmissivity ranges from less than 3,000 gpd per ft in the margins of the basin to 20,000 gpd per ft in the center of the basin. Estimated yields as much as 1,000 gpm. Total water in storage in leached zone 2.5 million acre-feet, or more.
			Garden Gulch Member	0-900	Papery and flaky marlstone and shale, contains some beds of oil shale and, locally, thin beds of sandstone.	One water analysis indicates dissolved-solids concentration of 12,000 mg/l.	Relatively impermeable and probably contains few fractures. Prevents downward movement of water. In the Parachute and Roan Creeks drainages, springs are found along contact with overlying rocks. Not known to yield water to wells.
			Douglas Creek Member	0-800	Sandstone, shale, and limestone; contains oolites and ostracods.	The few analyses available indicate that dissolved-solids content ranges from 3,000 to 12,000 mg/l. Dominant ions are sodium and bicarbonate, or sodium and chloride.	Relatively low permeability and probably little fractured. Maximum yield is unknown, but probably less than 50 gpm.
			Anvil Points Member	0-1,870	Shale, sandstone, and marlstone grade within a short distance westward into the Douglas Creek, Garden Gulch, and lower part of the Parachute Creek Member. Beds of sandstone are fine grained.	The principal ions in the water are generally magnesium and sulfate. The dissolved-solids content ranges from about 1,200 to 1,800 mg/l.	Sandstone beds have low permeability. A few wells tapping sandstone beds yield less than 10 gpm. Springs issuing from fractures yield as much as 100 gpm.
		Wasatch Formation		300-5,000	Clay, shale, lenticular sandstone; locally, beds of conglomerate and limestone. Beds of clay and shale are the main constituents of the formation. Contains gypsum.	Gypsum contributes sulfate to both surface-water and ground-water supplies.	Beds of clay and shale are relatively impermeable. Beds of sandstone are poorly permeable. Not known to yield water to wells.

D. REFERENCES

1. Bureau of Land Management, 1971, Resource Analysis of Douglas Creek Planning Unit, White River Resource Area, Meeker, Colorado, (Unpublished).

2. Bureau of Land Management, 1970, Resource Analysis of Yellow Creek Planning Unit W-01-09, White River Planning Area, Meeker, Colorado, June-July, (Unpublished).

3. Bureau of Land Management, 1970, Resource Analysis of Piceance Creek Planning Unit, W-01-11, White River Planning Area, Meeker, Colorado, August-September, (Unpublished).

4. Coffin, D. L., F. A. Welder, and R. K. Glanzman, 1971, Geohydrology of the Piceance Creek Structural Basin between the White and Colorado Rivers, Northwestern Colorado, Hydrologic Investigations Atlas HA-370, U. S. Geological Survey.

5. U. S. Dept. of Interior, 1970, Federal Water Quality Admin., Southwest Region, Mineral Quality Problems in the Colorado River: Appendix A, Natural and Man-Made Conditions Affecting Mineral Quality, January, 170 pp.

6. Iorns, W. V. et. al., 1964, Water Resources of the Upper Colorado River Basin--Basic Data, Professional Paper 442, U. S. Geological Survey, Washington, D.C.

7. Coffin, D. L., F. A. Welder, R. K. Glanzman, and X. W. Dutton, 1968, Geohydrologic Data from Piceance Creek Basin between the White and Colorado Rivers, Colorado Water Conservation Board Circ. 12, 38 pp.

8. Weichman, B. E., 1971, Statement on the Compatibility of Simultaneous Oil Shale Development and Nuclear Stimulation of Adjacent Gas Reservoirs, to Governors Advisory Committee on Nuclear Experiments, October, (Unpublished).

CHAPTER V

THE BIOSPHERE: BIOTA AND ENVIROMENT

A. INTRODUCTION

This chapter concerns the indigenous and exotic flora and fauna, whether occurring naturally, as a result of domestication, seeding or transplanting, or feral escapees, and their abundance, importance, and ecological relationships with the environment. The area under consideration, in Townships 1 and 2 South, Ranges 99, 100, and 101 West in Rio Blanco County, Colorado, will hereafter be referred to either as "the area" or "the project area."

B. FLORA (DOMESTIC AND NATIVE)

1. Check-Lists and Plant Materials Guides

Preston and Hale (1) of the Soil Conservation Service have prepared a "List of Plants Existing in Rio Blanco County, Colorado." The list was prepared to substantiate the occurrence of the plants in the county when cases of allergies, poisoning, and other harmful effects are believed due to certain suspected plants. Seven categories of plants are used and the number of entries (mostly species) are as follows:

TABLE V-1. Summary of plant entries by categories, Rio Blanco County, Colorado.

	Category	Number of entries
I	Crop, Gardens, Weeds	145
II	Forbs (broadleaved herbs)	197
III	Native Grasses	95
IV	Introduced Grasses	18
V	Native grass-like plants	24
VI	Woody plants (trees, shrubs)	165
VII	Miscellaneous (cacti, parasites)	15

This list serves as a guide to species which potentially may be present and which may have some adverse effects or otherwise upon people. The list is reproduced in Appendix V-1.

A partial check-list of plant species which occur in the experimentally grazed pastures at the Little Hills Experiment Station close to the project area on the Dry Fork of Piceance Creek is believed to be more representative of the native rangeland vegetation found in the general vicinity of the area (2). This check-list includes four trees, 23 shrubs, 86 forbs, and 20 grass or sedge species, a total of 133 species. It is reproduced in the Appendix V-2.

A useful listing of recommended species and planting practices is contained in "Climatic Zone Planting Guide for Critical Areas,...Industrial Sites," prepared by the Soil Conservation Service (3). Climatic zones based on elevation, precipitation, and temperatures in Rio Blanco County are delimited on a map. Douglas Creek bottomlands and lower slopes are in Zone 2; the upper slopes, except for the crest of the Cathedral Bluffs, and intermediate slopes of Yellow Creek are in Zone VII. The upper slopes of Yellow Creek except the elevated crests of the Cathedral Bluffs are in Zone IV, while the crests are in Zone VIII. For further details about physical features affecting planting and specific grass, legume, and woody plants adapted to each zone with background information on planting equipment and practices, see the climatic zone planting guide and map reproduced in Appendix V-3.

Merkle, D., et al. (4) have tested introduced and native species and their adaptation, utility, and production for range improvement purposes in the Meeker and Rifle area. McGinnies et al. (5) have also tested species' adaptability state-wide including observations on several foothill loam sites rather similar to those prevailing on the project area. Hull et al. (6) have summarized recommendations for improving sagebrush ranges and include recommendations for three elevational zones in western Colorado. Their recommendations cover methods of controlling or removing sagebrush and species and methods for reseeding. Hervey (7) reported seeding and planting trials for improving game ranges using browse plants. He included tests at the Little Hills Experiment Station. Other work on restoring browse ranges using transplants has been reported by McKean and Bartmann (8) at Little Hills.

Research in Utah on foothill and lower mountain ranges similar to those found on the project area provide the bases for several range and habitat improvement or restoration recommendations and practices.

Cook et al. (9) provide useful guides for seeding roadsides and construction sites to stabilize and revegetate them esthetically. They specify certain topsoil quality guides including the maximum-minimum proportion of different soil fractions, and acceptable chemical properties, available moisture capacity, and organic matter content. They caution that "fertile top soil added to roadway cuts and fills can be as important to obtaining a stand of grass as it is to establishing lawns around new homes where subsoils are frequently used for fill material." Specific guidelines are offered regarding fertilizers, seeding methods, seeding equipment, rate and season of seeding, grass and legume species, use of natural or fabricated mulches, weed control, and maintenance. Such recommendations are believed applicable with adaptations based on local experience for stabilizing roadways and construction sites in the project area.

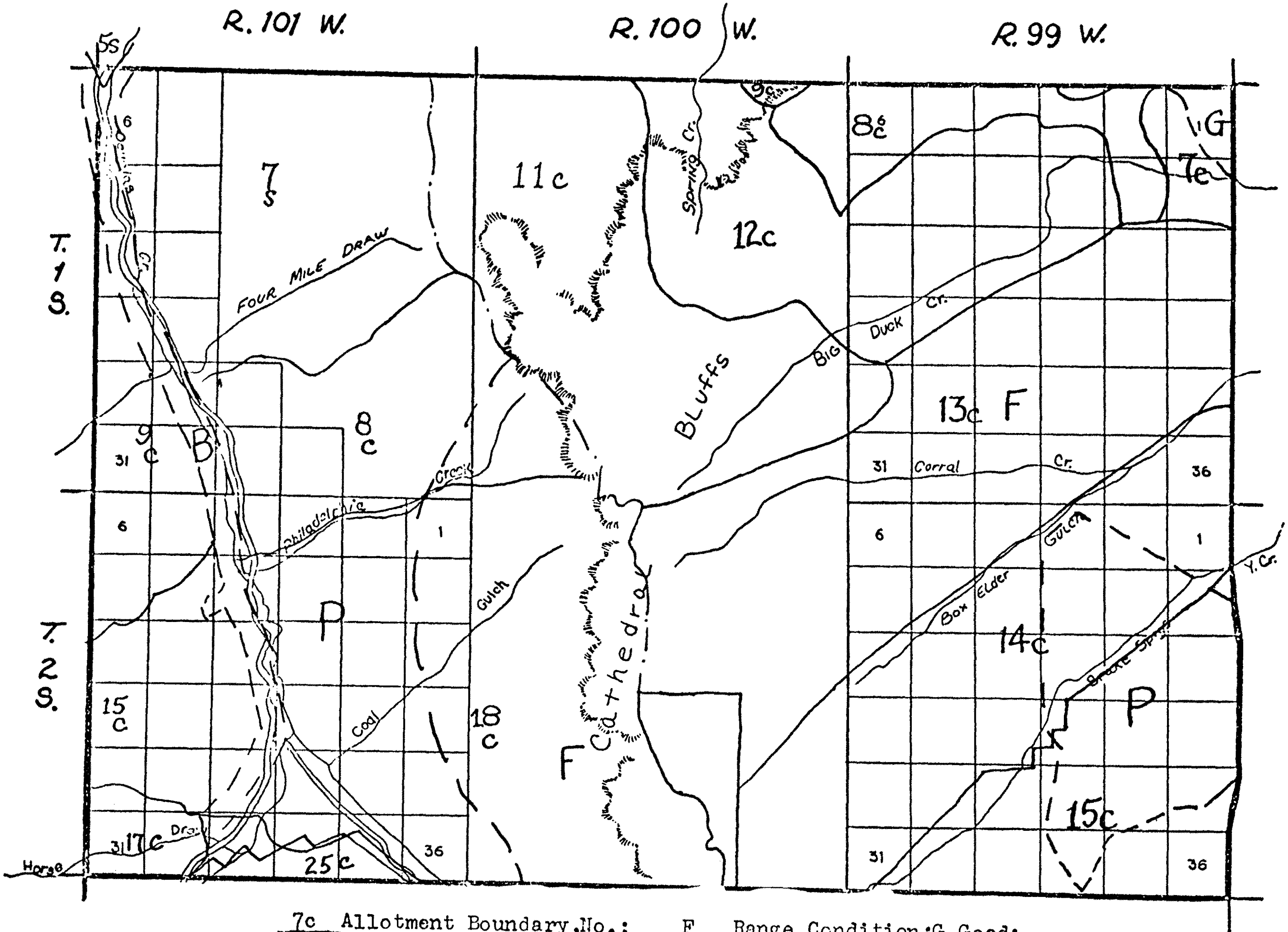
Plummer et al. (10) offer recommendations for restoring big game ranges based on over a decade of research. In Utah as in western Colorado, big-game winter ranges are most critical in maintaining thriving herds and usually they are in most need of restoration. In

Utah they have observed that the following types of winter ranges offer the best opportunities for improvement for game and livestock in order of decreasing importance: juniper-pinyon, mt. brush, cheatgrass and annuals, big sagebrush, greasewood, blackbrush, and shadscale. They further observe: "Burned areas within any of these types provide exceptionally favorable areas for treatment and should be seeded within the year of the fire." They provide ten cardinal principles generally applicable to the successful restoration of game ranges. Guides for seeding specific types of game ranges include recommendations concerning removal of competition, planting season, planting procedures, and adapted species and mixtures. Of special significance is the fact that guidelines are included for restoring pinyon-juniper, mountain brush, big sagebrush, aspen and conifer, greasewood, and shadscale types, which collectively comprise all of the vegetation types found on the project area.

2. Rangeland Vegetation

Virtually all of the land in the project area is rangeland and suitable for grazing by domestic and wild animals. Most of the area is in public ownership and administered by the Bureau of Land Management. This bureau divides its lands into planning units and the area under consideration is about equally divided into an eastern portion in the Yellow Creek Planning Unit and a western portion in the Douglas Creek Planning Unit. The Cathedral Bluffs divides these lands into their respective planning units. Refer to the Grazing Administration overlay, Fig. V-1, for the location of planning units and their boundaries.

Material for range vegetation types, condition and trend, grazing administration, and facilities or improvements on the range come from the comprehensive planning unit reports (11, 12) in the files of the Bureau of Land Management and is augmented by resource overlays.



7c Allotment Boundary, No.; Kind of Stock

F Range Condition: G-Good; F-Fair; P-Poor; B-Bad

Planning-Unit Boundary

Figure V-1. Grazing administration.

a. Vegetation types. -- Native vegetation in the project area consists principally of three extensive types or plant communities: sagebrush, northern or cold-desert scrublands of alluvial bottomlands and deep-soiled areas; pinyon pine-juniper woodlands of the shallower soiled hills and uplands; and a mixed mountain-shrub type on rocky slopes and ridges intermixed but mostly on elevated plateaus and slopes above the woodland type in the area. Lesser acreages of greasewood occur on saline bottomlands along streams with a high water-table, e.g., along lower Douglas Creek; and several aspen or cottonwood groves or stringer types occur where seeps, springs or live streams provide moist sites essential for their growth. Smaller areas of grassland and conifers occur in the Planning Units but are mostly outside the project area. The entire Yellow Creek Planning Unit shows the following vegetation pattern, similar but not identical to that portion within the project area. Refer to Fig. V-2 for a composite picture of vegetation types in the area. Note that all of the shrub types are consolidated.

Table V-2. Acreages of Vegetation Types in Yellow Creek Planning Unit (11)

Broad Vegetative Type	Acres	Common Species*
Mixed shrubs**	207,091	Big sagebrush, Black greasewood, serviceberry, Mt. Mahogany, Gambel oak
Pinyon-Juniper	206,507	Pinyon pine, Utah juniper, serviceberry, Mt. mahogany
Conifer	4,007	Douglas fir
Broadleaf trees	10,192	snowberry, chokecherry, aspen
Grass	2,178	Junegrass, western wheatgrass, needlegrasses
Barren	1,156	

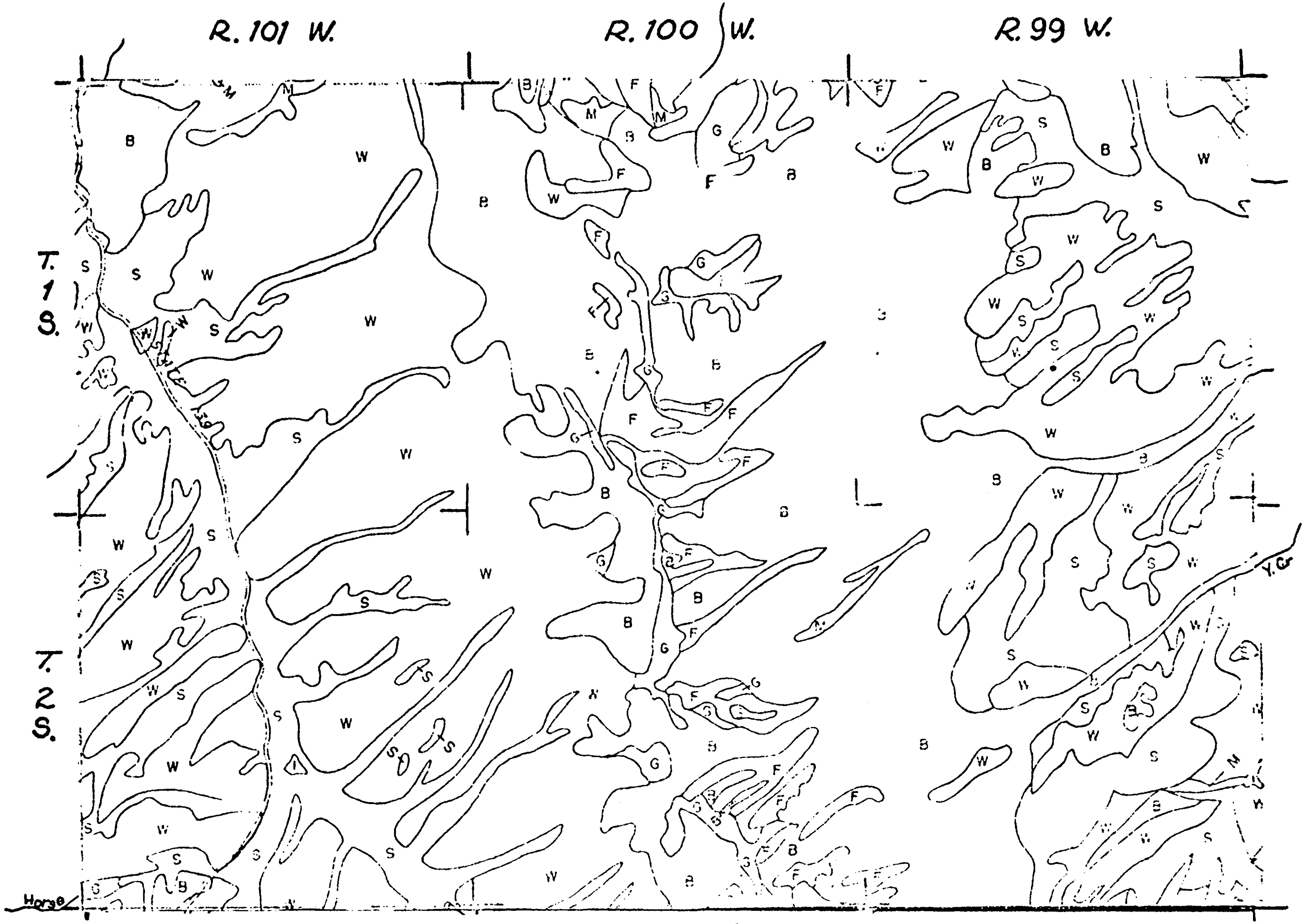
* Scientific names of plants are found in the appendix
** Sagebrush, mt. shrub, saltbush, greasewood types consolidated

A dot-grid estimate of the proportions (lacking precise acreage figures) of the various types is 62 percent pinyon-juniper, 37 percent mixed shrubs, 1 percent broadleaf trees (mostly aspen), and a trace (less than 1 percent) barren. A "Land Use and Cover Types" map dated 1954 by the Soil Conservation Service prepared for the Conservation Needs Inventory, on file in S.C.S. work-unit office, Meeker, Colorado, shows a small acreage of grassland (including half shrub mixtures), no Aspen but some "commercial timber species" (probably a mixture of Aspen - Conifers), and two small tracts of irrigated land. Prevailing cover types are woodland, brush, and sagebrush. (See Fig. V-2a.)

b. Individual species. -- Native grasses of major importance in the area are: western wheatgrass, thickspike wheatgrass, beardless and bearded bluebunch wheatgrasses, basin wild-rye, Indian ricegrass and Sandberg's bluegrass. Escaped exotic species of importance are cheat-grass brome and Kentucky bluegrass.

Introduced grasses that may be seeded for range improvement purposes in the area are: crested wheatgrass, desert wheatgrass, siberian wheatgrass, intermediate wheatgrass, pubescent wheatgrass, Amur wheatgrass, and smooth bromegrass. Several of the native grasses, notably western wheatgrass, beardless bluebunch wheatgrass, and Indian ricegrass are also seeded. Haylands are commonly seeded to Alfalfa and/or to timothy, smooth bromegrass, and redtop. Red and alsike clovers may be seeded as legumes with the grass hay or irrigated pasture mixtures.

Shrubs which provide forage and cover for domestic and big-game animals of the area are: big sagebrush, black sagebrush, antelope bitterbrush, mt. mahogany, rubber and lanceleaf rabbit brushes, shadscale, winterfat, serviceberry, chokecherry, and snowberry.



I-Irrigated Cropland
S-Sagebrush Land
B- Brush

Figure V-2a. Land use and cover types.
U.S.D.A. Soil Conservation Service
Albuquerque, N.M., 1954

F-Commercial Timber
G-Grassland
W-Woodland

Trees which provide cover and some forage are: Aspen, narrowleaf cottonwood, willows, pinyon pine, Utah and Rocky Mt. junipers, chokecherry, and Douglas fir. Utah juniper is used for fence post material. Pinyon pine is good quality fireplace wood.

A variety of forbs occur in the area. Some have forage value; some, esthetic value, while a few are poisonous to animals including man. Among the more showy forbs which are poisonous to certain animals are lupines, larkspurs, and death camas. Other esthetic species in the area include: Asters, penstemons (foxglove), skyrocket gilia, mariposa lily, paintbrushes, and Colorado columbine, state flower protected by law against picking. Refer to the Little Hills Experiment Station check list of plans (Appendix V-2) for a partial list of plants on the area.

c. Vegetation inventories.-- Range surveys were completed on the Douglas Creek planning unit in 1939 and for the Yellow Creek unit in 1941. The vegetation types and acreages are approximately the same today except for a few areas where range-improvement work has manipulated vegetation by cabling, spraying and/or seeding. Although the inventory information is inadequate today due to changes in "density," composition, and grazing capacity the range allotments have become established, grazing privileges adjudicated and there are no plans for another forage inventory.

3. <u>Rangeland Use and Grazing Administration</u>

a. Grazing allotments. -- Refer to the grazing adminstration overlays, Fig. V-1, for location of grazing allotments in the project area.

Of seventeen allotments in the whole of the Yellow Creek Planning Unit, three (Dry Duck Creek, Boxelder, and Reagle) are almost wholly in in the project area and four others (Barcus-Pinto, Indian Springs, Spring Creek, and the Square "S") have some portion of their allotment acreage in the project area. The project area in the Yellow Creek drainage is about one-fifth of the area of the entire Yellow Creek Resource Unit.

All allotments in the project area on the Yellow Creek side are grazed by cattle. For a summary of pertinent grazing information showing acreages grazed, qualifications, season of use, and animal unit months of grazing for the entire area of each allotment, whether wholly or partially in the project area, see Table V-3. It should be noted that only about one-fifth of these allotment acreages and animal unit months, roughly extrapolated, are in the project area. Season of use varies chiefly by elevation; areas at lower elevation are grazed during spring-fall and winter; those at higher elevations are grazed during the summer.

Table V-3. Summary of Yellow Creek Resource-Planning Unit Allotments in the Project Area (11).

Allotment	No.	No. Acres Fed.	State	Pvt.	Qualifications	Season Use	AUM's
Barcus-Pinto	7	33,670	1,069		2,054	Sp,Su,F	1,587
Boxelder	13	26,297	2,000	2,010	1,074	Su,F	2,193
Indian Spgs.	8	11,357		2,207	868	Sp.Su,FW	537
Spring Cr.	11	38,763		3,049	4,567	Sp,Su,F	2,365
Dry Duck Cr.	12	10,476	490	959	622	Sp,Su,F	1,252
Reagle	15	23,775	370	2,440	1,266	Sp,Su,FW	2,501
Square "S"	14	69,829	9,864	12,273	3,330	Sp,Su,FW	10,049

The Douglas Creek unit within the project area is grazed by both sheep and cattle. Refer to the Grazing Administration overlay (Fig. V-1) for the location of each allotment. One sheep allotment, "Hogan Draw," runs sheep in the northern portion of Township 1S, Range 101W, during winter which allotment is undivided from the Rocky Ford allotment.

All of the other allotments in the southern portion of that township and those in the one to the south graze in common except for Water Canyon and Texas Creek. Details are contained in the following table.

Table V-4. Summary of Grazing Data for Allotments of Douglas Creek Planning Unit in the project area (12).

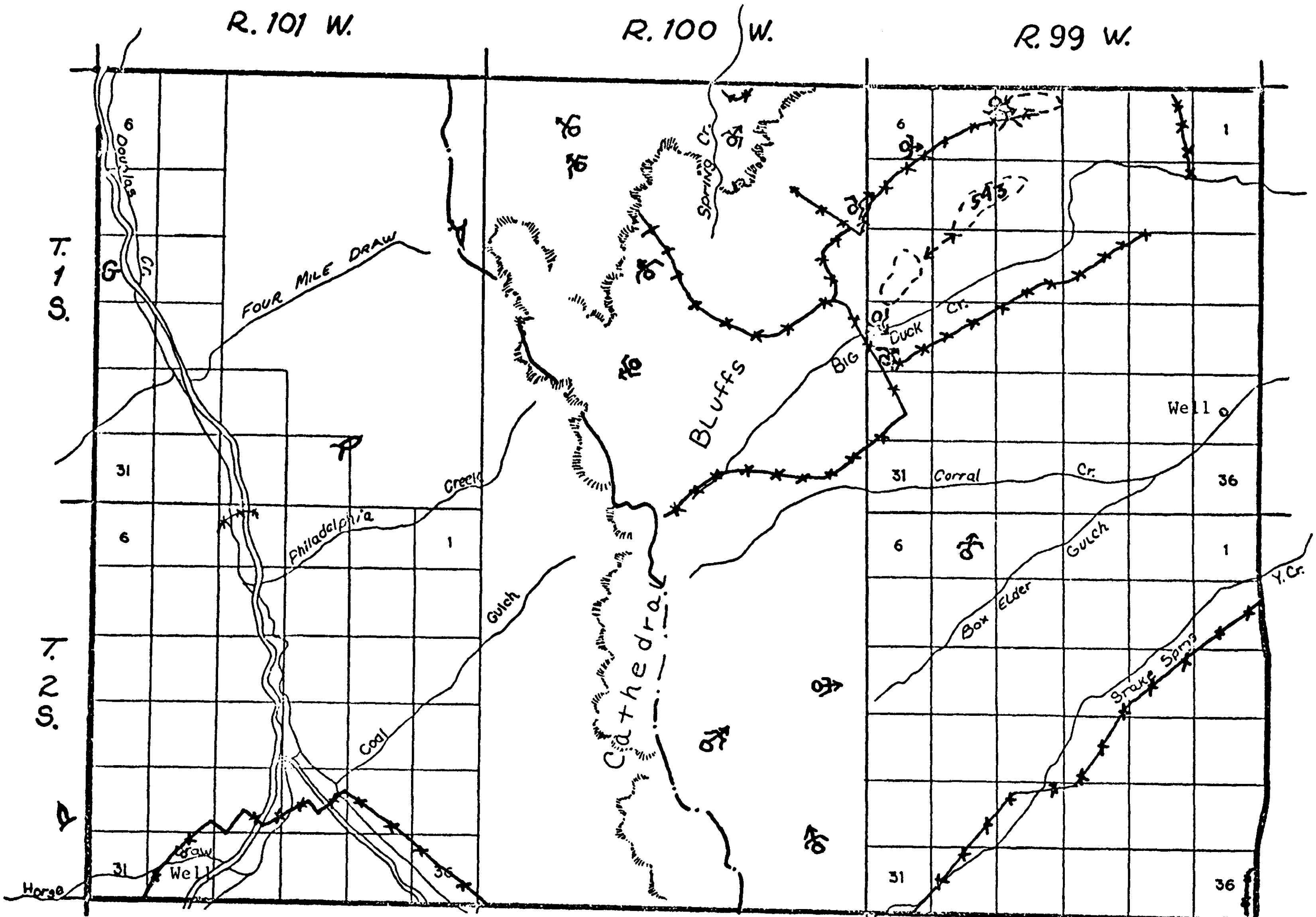
Allotment Name, No., Name of Operator	Qualifications in Allotment AUM's	Kind of Stock	Season of Use	Comments
7 Hogan Draw				
Halandras	2310	Sheep	W	Both allotments used at same time
(6-Rocky Ford)				
8 Philadelphia Dr. Brady		Cattle	W,Sp, Su,F	Common use in E.Douglas Cr.
15 Bull Draw		"		Allotment use area not yet established
25 E.Douglas Cr.		"		
Lowell Brady				
Douglas Brady	1492	"		
9 Water Canyon	3360	"	W,Sp	
17 Texas Cr.				
Kirby	3030	"	W,Sp	
C. F. Steele	52	"		
	3082			
18 Tommys Dr. - See #25 East Douglas Cr. (common use with it) Brady				

b. Grazing systems. -- Allotment management plans are developed for each unit. Ranges are generally fenced or combine fencing with natural barriers and some riding to hold stock on seasonal range units. Many of the ranges in Yellow Creek are subdivided into spring, summer, and fall units. Plans for the Reagle and Square "S" allotments suggest that a deferred-rotation grazing system is employed wherever feasible. The Reagle allotment grazes three seasonal spring, summer and fall pastures in rotation. After three years under the plan the fall unit is grazed in spring and the spring unit in the fall, thus giving the early grazed pastures a complete rest every few years until the end of the growing season to restore vigor and production. Some increase in plant cover by natural revegetation, either from reseeding or vegetative spread, may be expected from this practice. The Square "S" allotment uses a six-pasture deferred-rotation grazing system switching use of spring and fall units every fourth year.

No improved grazing management system is evident in discussions about the allotments in the Douglas Creek Planning Unit. The common grazing of areas by several permitees and lack of much fencing would seem to work against any deferred-rotation or other improved system.

c. Artificial range improvement. -- Three acreages of sagebrush or mixed brush are shown on the range improvement overlays (Fig. V-3) as having been sprayed for brush control in June, 1960, with excellent results. Two units total 550 acres and whether the third area is a part of the same project is uncertain at this date. The use of 2,4-D herbicide spray kills or suppresses most of the susceptible broadleaved plants which are growing vigorously and releases moisture and nutrients which usually permit the grasses and resistant species to respond with increases in height, production and cover. No such range improvement programs are shown on the Douglas Creek side in the project area.

d. Management facilities. -- The Range Improvement overlay (Fig. V-3) shows that there were 32 miles of fence, 14 developed springs, one developed reservoir, one windmill and one well on the Yellow Creek portion of the project area. On the Douglas Creek side there were 8 miles of fence, one reservoir, one well, and several check dams, the latter for erosion control purposes but might serve to augment stock water supplies occasionally.



Fence
G. Corral
Reservoir
Developed Spring

Figure V-3. Range improvements.

Well
Windmill
Treated Area: sprayed or chained

e. Livestock water. -- As noted under Management Facilities there is considerable water development on the Yellow Creek side. Most of these are spring developments which have limited capacity. More wells and rubber aprons are needed to accomplish fuller and more uniform use of the range but they are costly unless they can be coupled with pipelines to service more area or units. Water developments are much more limited on the Douglas Creek side and livestock and game animals appear to be dependent to a large extent upon intermittent streamflow augmented by a limited number of developed waters, only one reservoir and one well are shown in the project area.

f. Range condition and trend. -- Range condition was mapped several years ago for the two units using an earlier Deming two-step method (13). On that basis, B.L.M. estimates for the whole Yellow Creek unit show 10 percent of the public domain land in good, 69 percent in fair, 19 percent in poor and 2 percent in "bad" condition. The mapped areas in different condition classes on the project area (see Fig. V-1) show that most areas are in fair condition with lesser acreages in poor and good condition. The majority of the project area in the Douglas Creek unit is in poor condition with lesser acreage in fair and a small area along the road, creek and pipelines in "bad" condition. Trend in condition for the Douglas Creek ranges was judged to be mostly stationary.

4. Rare, Endangered, and Sensitive Species

Intensive collections of the flora have not been made in the project area to give a more definitive picture. Recently Mr. Bert Baker (pers. comm., Nov., 1971) of the Colorado Game, Fish and Parks Department made a collection of Ceanothus martinii in the project area, which species of deerbrush is known to occur sparingly in Utah but had never previously been known to occur in Colorado. Dr. Wm. Klein, curator of Colorado State University herbarium, responded to inquiry about rare and endangered species that there are many edaphic endemisms, rare species or ecotypes associated with peculiar soil types or geological formations, in western Colorado but that collections have not been made for much of that region.

Aside from the new record for the deerbrush, manzanita, which is highly prized for its decorative and novelty wood, occurs in isolated colonies in the area and spottedly elsewhere in extreme western Colorado. This esthetic shrub might be exposed to decimation by the development of new roads in the area and it should be protected from cutting by regulation on public lands. Similarly, the Colorado columbine should be protected from flower picking and Rocky Mt. juniper, Douglas fir and Aspen, valued for novelty wood, esthetics, and Christmas trees, respectively, should be protected from the cutting of live trees to preserve their contribution to the natural beauty of the area.

Potentially much greater danger and impact on the environment of the area will be the baring of soil surfaces and removal of topsoil in constructing roads and establishment of industrial and residential installations. Once a soil surface has been bared it may require a decade or a quarter of a century or longer for nature to restore some semblance of stability by natural plant succession, providing some topsoil remains intact. In the absence of any topsoil it may take a century or longer for nature to heal the scars if it ever can, hence the importance of regulations to preserve a natural cover wherever possible and to require restoration of all disturbed sites. Restoration measures which rely upon nature in that area usually result in a natural succession of Russian thistles and cheatgrass communities, which are unsightly and constitute fire hazards, before native perennial vegetation dominates the cover and stabilizes the site. Of special concern in this regard is the fact that there are no known economically feasible methods of restoring perennial vegetation on south-facing slopes, slopes greater than the normal angle of repose for the soil or geological material, nor for restoring cover on heavy clay or silt loam soils of a saline nature.

5. Sites

Almost all of the project area is non-cropland and such land in natural vegetative cover is classed as range or timberland. "Sites" or distinct types of land that have differing potentials for producing certain kinds and amounts of vegetation, e.g., range forage, timber, etc., are commonly used to describe rangelands and timberlands. The inherent productive capacity of such lands depends upon the interaction of all environmental factors, but more particularly upon soil and climate, impinging upon a site. The ultimate expression of that combination of interacting environmental forces peculiar to a particular site is the characteristic natural plant community potentially found on that site when in an undisturbed state.

Range-analysis surveys or studies map the location of distinct sites and evaluate range conditions as excellent, good, fair, poor, etc., according to how closely the kind and amount of vegetation approaches the potential or inherent productive capacity of each site.

Soil units 3 and 5 (mapped as soil associations "A", "B", and "E", and "D", respectively, in Fig. III-1) which constitute about 90 percent of the project area are grouped as "foothill sites." Within these soil mapping units are found the following major range sites: Salt Flats, Shallow Foothills, Clayey Foothills, Rocky Foothills, Rolling Loam, Deep Loam, Loamy Slopes, and Mt. Loam (14).

Only broad relationships concerning sites, prevailing vegetation types, range condition, stocking, and need for management are noted in the White River Basin Water and Related Land Resources report (14), as follows:

> "The general aspect of rangelands is brush with an understory of interspersed grasses. Big sagebrush is the distinguishing vegetation. Oakbrush is characteristic on some of the soils and elevation zones. Serviceberry, mt. mahogany, and snowberry are other brush types. Pinon pine and Utah juniper dominate the Shallow and Rocky Foothill sites. Salt flats contain greasewood but it is limited to conditions caused by high water table. Grass understory consists of western wheatgrass, Indian ricegrass, native bluegrass, and Junegrass. These grasses have decreased under heavy use and brush has increased."

> "Productivity varies by individual range sites. Generally 10 to 20 acres are required per animal unit month of grazing. Average range condition is fair. With application of good range management practices, the range condition could be raised to good condition and forage yields increased. Grazing management would include proper distribution of livestock aided by location of water developments, trails, fences, and salting grounds. Many of these ranges are low in grass forage and high in sagebrush so sagebrush control of adapted areas would improve range condition and forage yield."

> "Utah Juniper trees are prevalent in soil...units 3 and 5. Trees have invaded the grazing area and reduced forage production in certain areas. Removal of trees by chaining or other methods would improve forage production on areas of deeper soils. In other places the trees are a natural plant community and are described as a woodland type. These areas should be managed for production of wood products such as fence posts and firewood. Woodland areas also provide excellent protection for wintering livestock."

> "In soil...unit 8 (mapped as oil association "C" in Fig. III-1), the Cathedral Bluffs are the most predominant feature...Range sites include shallow loam and mountain loam. Grazing management is in conjunction with (soil) units 3, 5, and 7 (7 not in the project area)."

There is a small undetermined acreage of phreatophytes in the project area. Greasewood and cottonwoods are classed as phreatophytes in that they obtain their water supply from the zone of saturation.

Review of site analysis work indicates that the only detailed site analyses made in the area were prepared for the Colorado Game, Fish and Parks Department and cover their state lands and the surrounding allotment of the Square "S" Ranch. A copy of the site map together with site analyses data are on file in the Soil Conservation work-unit office in Meeker, Colorado.

No forage or herbage production figures were found for any of the sites on the project area. This information would be necessary to define the potential production for major sites in the project area in considering site or habitat restoration standards or goals. Some helpful guides to range sites, vegetation, expected annual herbage yields by site and condition classes, and initial stocking rates are contained in the Technical Supplement to "Water and Related Land Resources, The White River Basin" report (14a). Limited yield information is available for one pinyon-juniper site at the Little Hills Experiment Station. Colorado Division of Game, Fish and Parks has two fenced range study plots immediately adjacent to the project area, one on the Square "S" Ranch and one in Douglas Creek, which could be used for site production potential studies; but, unfortunately, no data have been recorded since the year of installation in the 1950's.

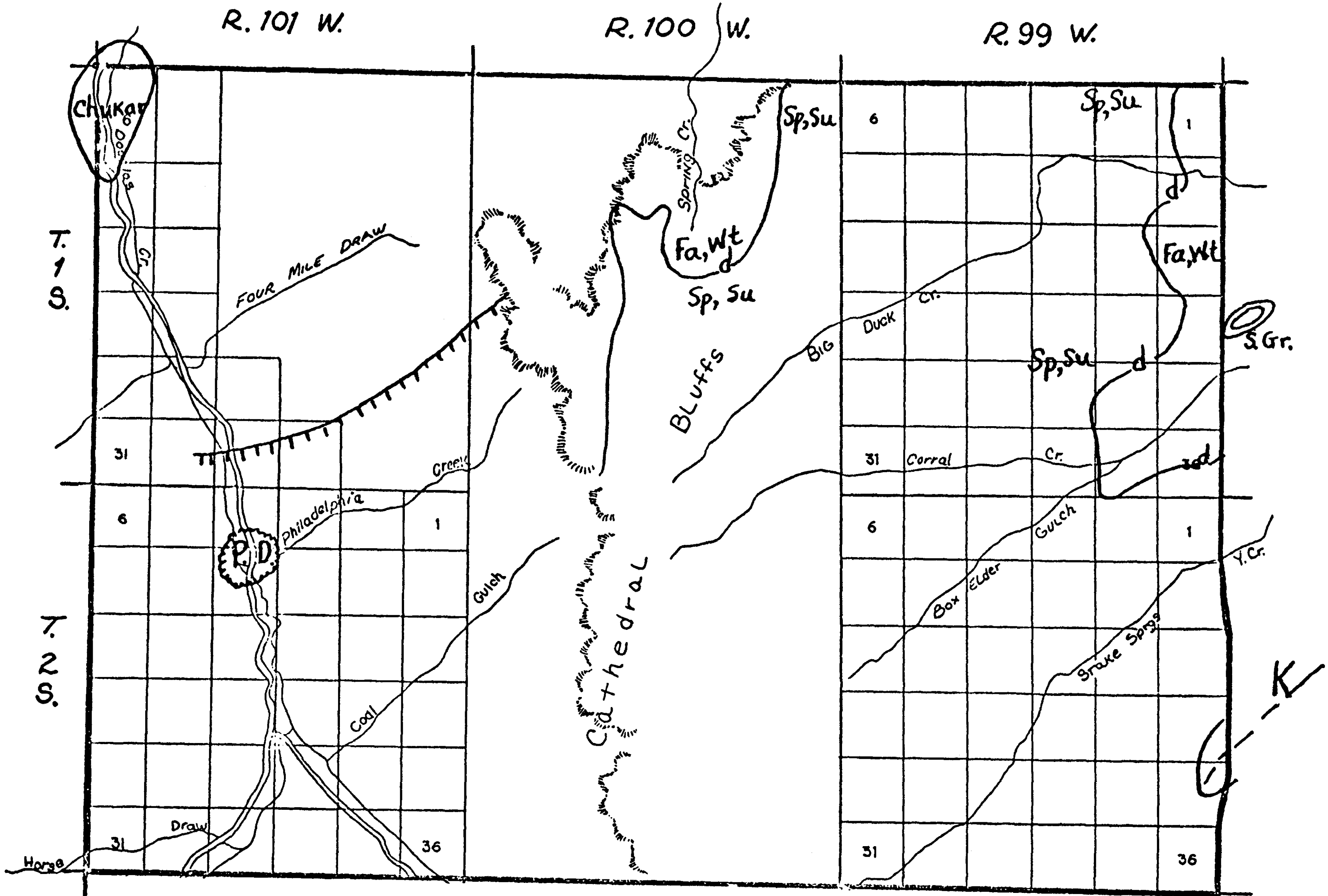
C. WILDLIFE

Most of the material in this section about animals and populations comes from Colorado Division of Game, Fish and Parks reports (15) for unit 22 or from small-game management unit 8 which is much more extensive in area covered. The Douglas Creek portion of the project area is in wildlife management unit number 21 for which there is no comprehensive report and little specific information. This unit (21) is generally characterized by department officers as similar to unit 22. Some material concerning wildlife distributions and impacts is taken from B.L.M. resource analysis reports concerning the Yellow Creek and Douglas Creek planning units (11, 12). The six townships in the project area being inventoried are but a small fraction of these two planning units. Except for the game distribution overlays (Fig. V-4), data do not come specifically just from the project area. Similarly, the Yellow Creek part of the area comprises but a small part of Wildlife Management unit, 22 known as the Piceance Creek unit.

1. Big-Game Animals

a. Mule deer. -- The most abundant game animal in the project area is the Rocky Mt. mule deer. The Piceance Creek - White River herd is believed to be one of the largest deer herds in North America. Carhart (16) estimated that the herd numbered 20,000 animals in 1943 and characterized it as "the most important flock of wild livestock in Colorado." Some estimates in more recent years have reached 100,000 (16a) but no precise figures exist. The herd summers on the higher elevations of the project area and on Roan and White River Plateaus and winters in the Piceance, Yellow Creek, Douglas Creek, and White River drainages.

The overlay (Fig. V-4) shows that most of the Yellow Creek area is transitional with some of it grazed in spring and summer while lower lying areas are fall-winter ranges. On the Douglas Creek side all of the project area is considered winter range; however, it is likely in either area that there is a monthly and yearly variation from this pattern with seasonal boundaries being higher or lower according to the prevailing weather conditions.



W d F, Wt / Su Sp, Su — Deer Ranges, Season

Mt. Lion Distribution (W / Su)

S.Gr. Sage Grouse Strutting Area

P.D. Prairie Dog Town

Chukar Chukar colony

K Key Game Range

Figure V-4. Wildlife ranges.

The wildlife management unit 22 report (15) shows that road-counts of deer along Piceance Creek in spring have varied from a low of 2,153 in 1966 to a high of 9,876 in 1947 and was at the intermediate level of 4,626 in 1970. W. T. McKean in a personal communication to Schiager (17), noted that aerial counts made during the winter of 1968 estimated 52 deer per square mile on Yellow Creek. Colorado Game, Fish and Parks Dept. estimated 5,720 persons hunted in 1968 and killed 5,512 animals in unit 22. Records (18; see Table V-5) show that 53,137 deer were killed in game management unit 22 and 35,783 deer were killed in game management unit 21 during the period 1959-1968, averaging 5,314 and 3,578 per year, respectively, based upon hunter-returned card records. The Douglas Creek game unit ranks fourth in the state in terms of deer harvested with Piceance first and Grand Mesa and Roan Creek second and third, respectively. Yellow Creek planning unit is a part of the Piceance Creek drainage and wildlife management unit 22.

The Yellow Creek and Douglas Creek watersheds provide favorable habitat conditions for mule deer. There is excellent interspersion, variety, and close proximity of suitable exposures, cover types, forage and browse, and water. The dominant shrubs are available most winters and are nutritious when present in mixtures. Trees may serve for cover and also for temporary sources of nutrition in emergencies even though inadequate in quality.

b. Predators. -- Mt. lions occur in limited numbers and naturally prey upon deer and occasionally upon livestock. Coyotes occur throughout the project area and although trapped or poisoned by a federal trapper stationed in Rangely, considerable losses of sheep occur and occasionally calves are reported lost. The Douglas Creek planning unit report notes

Table V-5. FIFTEEN GAME MANAGEMENT UNITS WITH THE HIGHEST TOTAL DEER HARVEST - TEN-YEAR PERIOD - 1959-68

Unit Number	Name	Harvest	Rank
22	Piceance	57,137	1
42	Grand Mesa	45,078	2
31	Roan Creek	39,061	3
21	Douglas Creek	35,783	4
62	East Uncompahgre	34,548	5
32	Parachute	32,677	6
11	Strawberry	28,913	7
44	Brush Creek	27,638	8
33	Rifle	27,087	9
23	Miller Creek	26,245	10
40	Glade Park	25,641	11
70	San Miguel	24,880	12
43	Roaring Fork	24,875	13
71	Dolores	21,907	14
78	San Juan	21,183	15

that it is estimated that over 1000 sheep are lost to such predation annually. Some bobcats are reported in the area. Black bear occur at higher elevations on summer range and may stray onto the area grazed by sheep as periodically some control of bear is necessary when they prey on sheep on summer ranges.

c. Other big-game animals. -- No exact data on populations of other large game and predator animals are available. The fact that 70 elk, 9 bear, and 9 mt. lions were reported killed during 1965-1969 in unit 22 suggests that such small populations probably have a minor impact except for local browsing and predation.

Some beaver are reported on Douglas Creek; most are above the project area but a few have been transplanted on the lower drainage where it may aid in reducing erosion.

A small herd of elk is believed present seasonally on the Douglas Creek side.

2. Small Game

Cottontail rabbits (5), white-tailed jackrabbits, snowshoe hare and pine squirrel occur rather abundantly in the Yellow Creek area. Game Dept. personnel estimate that there may be as many as 150-200 cottontails per square mile in the Piceance drainage. Small game management reports by the Colorado Division of Game, Fish and Parks estimate that in 1968 1,984 persons killed 24,813 rabbits in Small Game Management unit 8, which is three times the size of wildlife management unit 22 and suggests that such figures may be converted by one-third as estimates for Piceance Creek.

Sage grouse, transplanted chukar partridge, blue grouse, mourning doves and band-tailed pigeons occur in the area but are not abundant. Colorado Division of Game, Fish and Parks estimates that there are 300 ducks in residence in winter and 1000 in spring, summer and fall in Piceance drainage. One estimate (17) is 17 ducks per lineal mile of stream during summer in the drainage. Some 27 species of waterfowl and shore-birds are known to be present in the area. Effect of waterfowl is believed nominal on the local economy; only 64 hunters killed an estimated 571 ducks in 1969 according to one report (17).

3. Non-Game Animals

a. Mammals. -- Other mammals found in the area are: moles, shrews, bats, hares and rabbits, rodents, carnivores, and even-toed hoofed mammals (wild horses). One game and fish report (18) lists 26 species of furbearers and non-game mammals but it is believed that the list is incomplete.

The impact of small mammals upon native and seeded vegetation and on other dependent organisms is not known but could be considerable. Extensive prairie dog poisoning has reduced the population in places to low levels. One extensive prairie dog town is shown on Douglas Creek on the wildlife overlay. Rabbit populations periodically peak to high levels necessitating some control measures. Furriers in Denver paid a small price for pelts around 1960 when rabbits in the Meeker and adjacent areas were abundant. Craig Fur and Hide Co., Craig, Colorado, is said to still be purchasing rabbit carcasses (pers. comm. J. W. Hale, Nov., 1971). Wild horses occur in the project area. Their legal status and ecological impacts are uncertain. Likely, however, they contribute to some seasonal deficiencies in quantity of forage and range conditions.

b. Birds. -- Game unit 22 is known to have a good diversity of non-game bird species. Some 225 non-game species including 24 raptors are listed as occurring.

c. Fish. -- Sport fishing in the Yellow and Douglas Creeks is unimportant. The predominant fish are believed to be the mt. sucker and speckled dace. Reports (12, 15, 17) indicate that rainbow trout have been stocked by the Colorado Division of Game, Fish and Parks in several areas among which are Stake Springs on Yellow Creek, Ryan Ponds on Ryan Creek and in beaver ponds on Douglas Creek.

A list of animals known to occur in the Piceance Creek drainage is shown in Appendix V-4.

4. Rare, Endangered, and Sensitive Species

The golden and bald eagles winter in the area. The bald eagle is now classed as an endangered species. Prairie falcon is considered a rare species. The greater sandhill crane, an endangered species, is listed as a migrant in wildlife management unit 22, a part of which is in the project area.

Chukar (partridge) which was planted in the area may be sensitive but little is known of the fate of the colony listed on Douglas Creek.

There are still a few prairie dog towns in the area and the blackfooted ferret, a rare and endangered species, is dependent upon such habitats. Whether any ferrets occur in the area, however, is not known.

Dr. Richards of Western State College, Gunnison, Colorado (pers. comm., Nov., 1971), has reported that ringtail (cats) occur in limited numbers near Douglas Creek. This species is rather scarce in western Colorado and needs protection although nationally it is neither rare nor endangered.

A strutting ground is shown for sage grouse on the eastern edge of the project area. Since it is an essential and critical habitat for satisfactory reproduction such sites should be maintained undisturbed.

Schiager et al. (17) note: "It is possible, although not documented, that the native cutthroat trout of the Colorado - Green River Basin (Salmo clarki pleuriticus) may exist with (wildlife management) unit 22. ...This species is considered to be rare and endangered."

5. Habitats

As noted elsewhere in the sections concerning Mule Deer and Food Habits the project area is primarily deer winter range. The White River - Piceance Creek deer herd summers at higher elevations on the Roan and White River Plateaus including some of the higher elevations of the area around Cathedral Bluffs. A cardinal principle in big-game management is that the seasonal range that is in shortest supply is the range which restricts the population of a game species, in this case principally deer. The fact that the Colorado Game and Fish Commission purchased the Square "S" Ranch in the project area to protect the deer herd and key winter range (which was strongly advocated by Carhart (16) earlier) and to study forage requirements and livestock relationships testifies to the importance of the area as critical deer winter habitat. Moreover, as clarified in the Food Habits section which follows, the major forage plants comprising most of deer winter diets (stomach analyses) are dominants of the major range types in the project area. The interspersion of several shrub and tree communities on these lower foothill slopes, many of which remain relatively snow-free most winters due to favorable slope exposures, with adjacent live streams or developed waters combine to favor the area as key winter range for deer. As suggested by Carhart (16), from observations in the area, the prevalence of cattle rather than sheep allotments minimizes forage competition with deer and would appear to better meet multiple use objectives of public land administering agencies in the area. Some resource scientists (19) propose the elimination of all sheep from the project area. However, some 15 years of deer and livestock grazing studies at the Little Hills Experiment Station leads to the conclusion that both deer and sheep, and deer and cattle can graze the same experimental pastures without injury to animals or the range provided stocking of each is kept at a defined moderate level (2, 23).

Sage grouse occur in "light" population densities, 1 - 10 birds per square mile in the project area according to Rogers (20). His studies indicated that the low density of birds despite extensive acreages of sagebrush in Rio Blanco County may be due to the interspersion of pinyon-juniper type of rugged terrain which is inferior habitat compared to extensive level sagebrush plains with meadows, clover and water adjacent. The close assocation with the sage grouse population in Colorado with the big sagebrush type and the apparent dependence upon it seasonally for its diet and nesting cover suggests that sagebrush habitats are a critical requirement of this game bird. Certain exposed, snowfree sites within the type are traditionally used for strutting grounds essential in reproduction. Any plans for modifying these food, cover and reproduction sites need to take cognizance of, and make provision for, these sage grouse habitat requirements.

Chukar partridges were planted in or immediately adjacent to the project area in the 1950's; one colony is shown on the wildlife overlay (Fig. V-4) in the northwest corner of the area. An excellent guide to

Chukar habitat quality is given by Sandfort (21) in a revised rating sheet devised to help locate suitable transplant sites. Twelve essential characteristics are rated on a ten-point scale and each is weighted by the critical importance of the particular characteristic. The rating sheet was applied to the Little Hills Experiment Station to note that it was marginal Chukar range due to its high elevation and lack of sufficient roughness. Reference to the guide and to the marginal rating for Little Hills makes evident that only the lower Douglas Creek drainage adjacent to the Cathedral Bluffs or similar low-elevation, rough terrain would likely rate any higher than Little Hills and in any case would most likely still be marginal or secondary range.

Critical habitat needs of other game animals are not known in the area although it seems likely that the combination of rugged terrain and abundant deer and sheep populations in Douglas Creek favor mt. lions.

6. Food Habits

a. Deer. -- The following table summarizes earlier work on food habits of deer in the White River herd from 1938-1941, by Carhart et al. (22), based upon about ten stomach samples per month.

Species	Season			
	Winter*	Spring	Summer	Fall
	Percent	by	volume	
Myrtle boxleaf	--	0.64	2.57	5.89
Creeping hollygrape	0.05	4.64	--	3.28
Mt. mahoganies	5.50	0.44	2.07	12.85
Bitterbrush	1.38	--	--	3.48
Pinyon pine	21.41	7.20	--	6.29
Big sagebrush	37.16	26.49	--	14.86
Black chokecherry	--	0.34	19.53	1.42
Serviceberry	7.49	20.80	54.16	17.60
Rabbitbrushes	7.69	--	--	8.63
Junipers	14.02	2.52	--	2.47
Douglas fir	0.27	3.30	--	0.34
"Weeds," all species	1.54	9.16	5.63	2.63

Species	Season Winter*	Spring	Summer	Fall
	Percent	by	volume	
Shadscale	2.07	0.44	--	1.15
Scrub oak	0.90	3.43	12.57	5.72
Grasses, all species	0.52	12.22	0.38	0.30
Snowberries	--	8.38	1.91	0.64
Green jointfir	--	--	--	2.20
Roses	--	--	0.19	2.84
Aspen	--	--	0.84	7.41

*Winter:Dec.-Feb.; Spring:March-May; Summer:June-Aug.; Fall:Sept.-Nov.

These early studies show that both a higher proportion of the deer diet is browse and the preference is for certain browse species. For example, deer secured 93 percent of their winter food from 6 browse species, which comprised only 75 percent of the total forage available. Similarly, six forage categories or species provided 84 percent of the spring diet. During summer four species or categories provided 92 percent of the diet. In the fall six browse species again provided 68 percent of deer diets. Only in spring does grass comprise as much as one-eighth of the diet at which time broadleaved herbs approach a tenth of the diet.

McKean and Bartmann (2) have just concluded a long-time study of the forage preferences and the effects of deer, sheep, and cattle grazing singly and together at different intensities of stocking upon the vegetation and soil at the Little Hills Experiment Station. The prevailing cover types are similar to those grazed in winter by deer in the project area and also grazed by sheep and cattle most commonly in spring and fall, which seasonal pattern of use was studied in the investigations. Little overlap is shown between deer and cattle and some overlap between deer and sheep for the forages most preferred by each kind of animal. These investigators conclude that when each kind of animal is stocked at moderate rates as defined in the study cattle or sheep can be grazed during the spring-fall season and deer in winter on the same experimental pastures without injuring the range or the animals.

Unpublished file data (18) collected as a part of the Little Hills investigations show the volume percentage each species of plants comprise in the stomachs of all animals which died or were killed in each of the experimental pastures. These studies show that in all pastures grazed by deer alone or in combination with cattle or sheep four browse species (serviceberry, big sagebrush, snowberry, and pinyon pine) comprise 71 percent of the volume of the deer stomach contents. When the data area analyzed for pastures grazed only by deer these same four browse plants comprise 69 percent of the diet. It should be noted that these deer diets are for the winter grazing season. These four species on deer winter ranges are dominants of the major vegetative types and point up the reason that the prevailing cover types, i.e., sagebrush, pinyon-juniper, and mt. shrub communities, are so useful for deer winter ranges.

McKean (23) has published a separate leaflet summarizing experiences with stocking different kinds and number of animals on Little Hills experimental ranges and prescribes moderate stocking levels for deer, cattle and sheep.

b. Sage grouse. -- Food-habit studies (20) include analyses of 114 stomach samples collected in three counties, Jackson, Moffat and Gunnison, in a two-year period. Of 40 plants included in these samples big sagebrush, herbaceous sage, and clovers comprised most of the diets. Big sagebrush was generally the major constituent in the diet during the cooler months suggesting a greater dependence upon sagebrush for food during the periods when snow covered the herbaceous plants or when they were absent. Forbs and insects comprised a greater proportion of the diet in summer. Variations among samples from different locations suggest that meadows and seeded rangelands may affect sage grouse diets quantitatively and possibly qualitatively. Yearlong studies including winter as well as summer food habits are essential to ascertain critical needs of the species for food and cover.

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CHAPTER VI

CLIMATE

A. INTRODUCTION

As part of a reconnaissance and inventory of certain environmental elements existing in a six township area of Rio Blanco County, Colorado a short survey was made of the characteristics and controls of the climate and air quality over the region. This chapter discusses the major climatic features of the region with emphasis placed on those characteristics which must be included in planning for development of mining activities. An analysis of specific climatic elements with summaries of pertinent data will be forthcoming at a later date.

B. CLIMATIC CONTROLS

The climate of any region is the result of a complex of interactions of a number of factors usually referred to as the major climatic controls. The latitudinal position, distance from the ocean or other large moisture sources, elevation and topography are the primary large scale controls of the climate of the Western slope of Colorado.

The latitudinal position of the region determines its solar climate, i.e., the intensity and duration of solar radiation are identical for all areas along the same latitude. Due to clouds, water vapor, dust and turbidity, however, the solar heating will differ greatly at different points along the same meridian.

Due to marked differences in thermal properties of water and soil, regions whose climates are influenced by nearby oceans are very much different from those in interiors of large land masses. The "continentality" of a region, however, is not a simple function of the geometric distance from the ocean but includes features such as direction of prevailing winds, mountain barriers, etc.

Elevation above sea level and the orientation of mountain ranges are important climatic features of Western Colorado. The blocking action of the Sierra Nevada range of California and Oregon results in heavy precipitation along the western slopes of this range with marked aridity across Nevada, Utah and Western Colorado. Because the air crossing Rio Blanco County from the west is so low in water vapor content, precipitation amounts are generally insufficient for good forest stands below about 9000' msl. Likewise, the Continental Divide to the east is a very effective barrier of moisture flow from the Gulf of Mexico.

C. REGIONAL ASPECTS OF CLIMATE

The climate of Rio Blanco County, Colorado is classified as arid steppe. Comparative uniformity, especially in the valleys, is a distinct quality of the regional climate. Severe cold fronts are a rarity due to protection offered by the Continental Divide. Low pressure areas and storm tracks are usually deflected to the north or south by these mountains. High pressure areas tend to form over the western slopes of the Colorado Rockies in winter which results in moderate temperatures and abundant sunshine. The local climate is strongly influenced by microclimatic factors (slope, aspect, elevation, soil type and moisture, vegetation, air drainage).

Over the entire region, because of the normally low relative humidity, the warm summer days cause little discomfort, and, in mid-winter, when air temperatures are low, the strong solar radiation and dry air combine to make a generally pleasant environment for human activities.

D. ANALYSIS OF CLIMATIC RECORDS

Long term records are virtually non-existent for most climatic elements for the survey area. Precipitation maximum and minimum temperatures are currently being recorded at four stations within the general area. Data was collected at a fifth station for a ten year period in the early part of this century.

Table VI-1. Climate Stations in the Piceance Area, Rio Blanco County, Colorado

Station	Location	Elevation	Record Period
Little Hills	40° 00' N 108° 12' W	6200'	1946-
Lost Creek	40° 05' N 107° 25' W	8000'	1910-1920
Marvine	40° 00' N 107° 35' W	7200'	1936-
Meeker	40° 02' N 107° 54' W	6425'	1891-
Rangely	40° 05' N 108° 47' W	5216'	1894-

More complete weather records are available for Grand Junction (39° 07' N 108° 32' W) and Rifle (39° 32' N 107° 47' W). Unfortunately, the data from Rifle has not been summarized. Data from Grand Junction is included in this report when it is believed to be generally representative of the Piceance Area.

1. Temperature

Temperature statistics for Little Hills, Meeker and Rangely are given in Tables VI-2 and VI-3.

Surface temperatures within the survey area are strongly influenced by local topography. The temperatures measured at the three stations in Tables VI-2 and VI-3 are for a height approximately five feet above the

Table VI-2. Temperatures* at Little Hills, Meeker and Rangely, Colorado (^{o}F)

	Mean Maximum			Mean Minimum			Mean		
Month	L. Hills	Meeker	Rangely	L. Hills	Meeker	Rangely	L. Hills	Meeker	Rangely
J	38.3	38.1	33.2	5.0	9.5		21.7	23.8	18.4
F	41.8	40.3	39.2	7.8	11.0		24.6	25.7	23.7
M	47.4	46.8	50.3	16.6	19.7		32.0	33.3	35.2
A	59.1	58.6	63.6	24.5	28.0		41.9	43.3	47.4
M	68.8	68.9	74.9	32.3	35.5		50.5	52.2	57.6
J	79.5	80.6	86.5	37.9	41.9		58.7	61.3	67.0
J	86.3	86.4	93.0	44.4	47.6		65.3	67.0	73.6
A	83.4	83.1	89.3	43.7	45.7		63.4	64.4	70.4
S	77.8	77.7	82.9	34.2	36.7		56.0	57.3	62.2
O	65.0	65.2	69.3	23.7	27.8		44.4	46.6	49.6
N	48.8	48.6	49.8	13.7	17.1		31.2	32.9	33.6
D	41.2	39.4	37.0	7.7	10.6		24.4	25.0	22.6
A	61.5	61.1	64.1	24.3	27.6		42.8	44.4	46.8

* Computed for the period 1951-60.

Table VI-3. Temperature Statistics* for Little Hills, Meeker and Rangely, Colorado. Record High and Low (^{o}F)

	Highest			Lowest			# Days above 90^{o}/below 32^{o}		
Month	L. Hills	Meeker	Rangely	L. Hills	Meeker	Rangely	L. Hills+	Meeker	Rangely
J	60	59	53	-35	-28	-37		0/31	0/31
F	64	58	63	-32	-33	-36		0/28	0/28
M	70	70	74	-25	- 8	- 8		0/29	0/30
A	80	78	86	7	8	11		0/22	0/17
M	87	89	95	13	20	24		0/9	1/4
J	97	100	104	20	25	30		2/2	13/
J	98	97	102	30	33	40		8/	25/
A	98	94	101	28	29	32		4/	17/
S	95	94	98	12	20	25		0/8	5/3
O	91	83	86	- 1	9	8		0/23	0/23
N	68	69	72	-27	-17	- 5		0/28	0/29
D	69	59	57	-30	-20	-20		0/30	0/31
A	98	100	104	-35	-33	-37		14/210	61/196

* Computed for period 1951-60.
+ Data for Little Hills not available.

surface. Adjacent to the surface, the temperatures will often differ by as much as 20^{o}-30^{o} F between North facing and South facing slopes. Hillsides exposed to strong solar radiation and high evaporative demand versus those shaded much of the day by surrounding topographic features result in marked variations in the geography of plant species across the region.

2. Precipitation

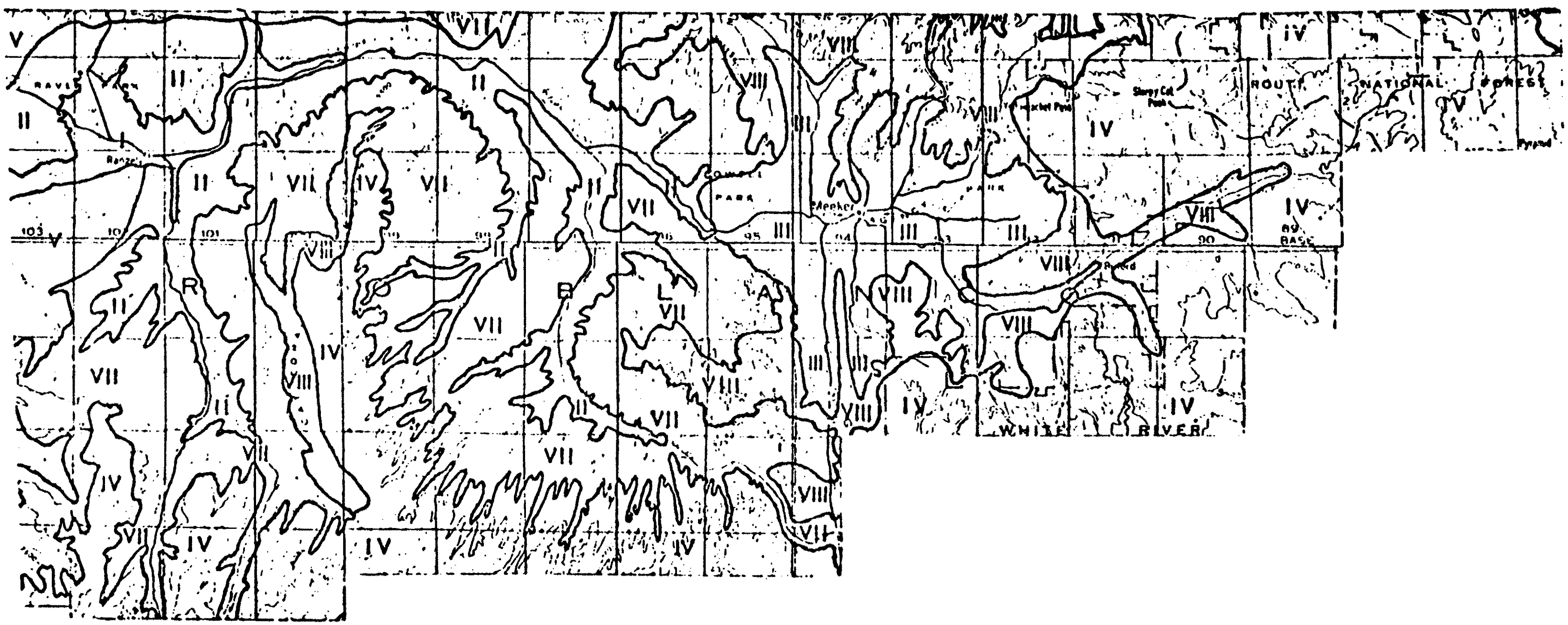
Precipitation totals over the environmental inventory area are strongly influenced by the local elevation and terrain. Because of this, detailed precipitation maps are usually quite unreliable. Rangely, elevation 5216, with an average annual precipitation of 8.87" receives only slightly over half that of Meeker, elevation 6347, Table VI-4. Each of the three recording stations receives precipitation on the average only 2-5 days per month with a raininess per rain day of about 0.3". If one extrapolates linearly, it might be expected that precipitation above 24" would be restricted to the highest ridges and elevations above 8000'.

Table VI-5 shows that Meeker receives an average of about 90 inches of snow per year with measurable snow occurring during eight months of the year. At an average ratio of 10 inches of snow per one inch water, it may be assumed that approximately one-half of the annual precipitation at Meeker occurs as snow. Although snow depths may reach two or three feet occasionally during mid-winter, the total number of days during which the ground is completely covered is small, particularly in areas exposed to solar radiation. At higher elevations, snowpack depths might be expected to exceed six feet each year.

Summer precipitation occurs almost entirely as local thunderstorms. These storms are often of high intensity with strong gusty winds, but are usually of short duration. Local flash flodding is not uncommon from these storms. Severe hail is rare.

Figure VI-1 shows a planting guide map of precipitation and temperature prepared by the Soil Conservation Service.

RIO BLANCO COUNTY



ZONE I DROUTHY, PPT. <12", WARM, ELEVATION APPROXIMATELY 5400'
ZONE V DROUTHY, PPT. <12", MODERATELY WARM, ELEVATION APPROXIMATELY 5400' to 6400'

ZONE II SEMI-DROUTHY, PPT. 12 to 15", MOD. WARM, ELEVATION APPROX. 5400 to 6400'
ZONE VII SEMI-DROUTHY, PPT. 12 to 15", MOD. COLD, ELEVATION APPROX. 6400 to 8000'

ZONE III MOD. MOIST, PPT. 15 to 20", MODERATELY COLD, ELEVATION APPROX. 6400 to 8000'
ZONE VIII MOD. MOIST, PPT. 15 to 20", COLD, ELEVATION APPROXIMATELY >8000'

ZONE IV MOIST, PPT. >20", COLD, ELEVATION APPROXIMATELY >8000'

SCALE - 1/8 inch = 1 mile

Figure VI-1 Precipitation Areas of the Piceance Creek Study Region

Table VI-4. Monthly and Annual Mean Precipitation at Little Hills, Meeker and Rangely, Colorado, 1951-60.

	Total Precipitation			Number of Days with Precipitation > 0.10"		
Month	Little Hills	Meeker	Rangely	Little Hills	Meeker	Rangely
J	0.80	1.42	0.73	3	5	3
F	0.99	1.21	0.84	4	4	3
M	1.18	1.58	0.81	4	6	2
A	1.12	1.53	0.62	3	5	2
M	1.07	1.83	0.76	4	5	3
J	0.76	1.08	0.52	2	2	2
J	0.95	1.70	0.42	3	4	2
A	1.91	2.15	1.37	4	5	3
S	0.81	1.27	0.76	4	4	2
O	1.05	1.34	0.81	3	5	3
N	0.95	1.19	0.53	4	4	2
D	0.90	1.38	0.69	3	4	2
A	12.49	17.68	8.87	41	53	29

Table VI-5. Total Monthly Snowfall at Meeker, Colorado 1951-60

Month	Average Snowfall (in.)
J	20.7
F	17.9
M	15.8
A	5.2
M	1.5
J	0
J	0
A	0
S	T
O	2.9
N	12.3
D	15.2
A	91.5"

3. Fog, Dew, and Relative Humidity

No data is available on occurrence or amounts of fog, dew, or relative humidity within the region. Steppe climates typically have low relative humidity. Spot fog occurrence in the White River Valley is probably somewhat more frequent than elsewhere in the region. At Grand Junction, the annual frequency of fog is 7 with 2 days each of fog in December, January and February and 1 day each in March and November.

4. Wind

Winds in mountains pose a particularly difficult analysis problem. Studies of local circulations such as mountain and valley winds, foehn winds, surface winds, and large scale interaction and the large scale flow itself require much more detail than is customarily available in these regions. There are no wind records of wind direction and velocities within the inventory area nor is wind information recorded at any station in the region. No long term records are available for Grand Junction and Rifle, Colorado. Local surface wind measurements have been made near Rulison, Rio Blanco and Grand Valley for short periods in conjunction with various research projects. Extrapolation of these data can only be done in a very generalized way.

Figure VI-2 shows the seasonal distribution of winds at the 700 millibar level over Grand Junction. It should be noted that these wind roses indicate the sectors <u>into</u> which the wind blows rather than the direction from which it blows. From this figure, it is seen that the prevailing winds at this level (approximately 8500') are from the Southwest and West-Southwest throughout the year. Winds from the North and Northeast occur on the average of only 10-15% of the time.

From vegetation and terrain observations and judicious application of a few laws of thermodynamics and fluid mechanics, some inferences can be made concerning the surface winds over the inventory area. In this geographical region, one may expect the following conditions will hold.

During the daytime hours wind is usually controlled by the geostropic flow at higher altitude. Below 50-100 meters, surface friction and shear will cause a reduction in velocity and a

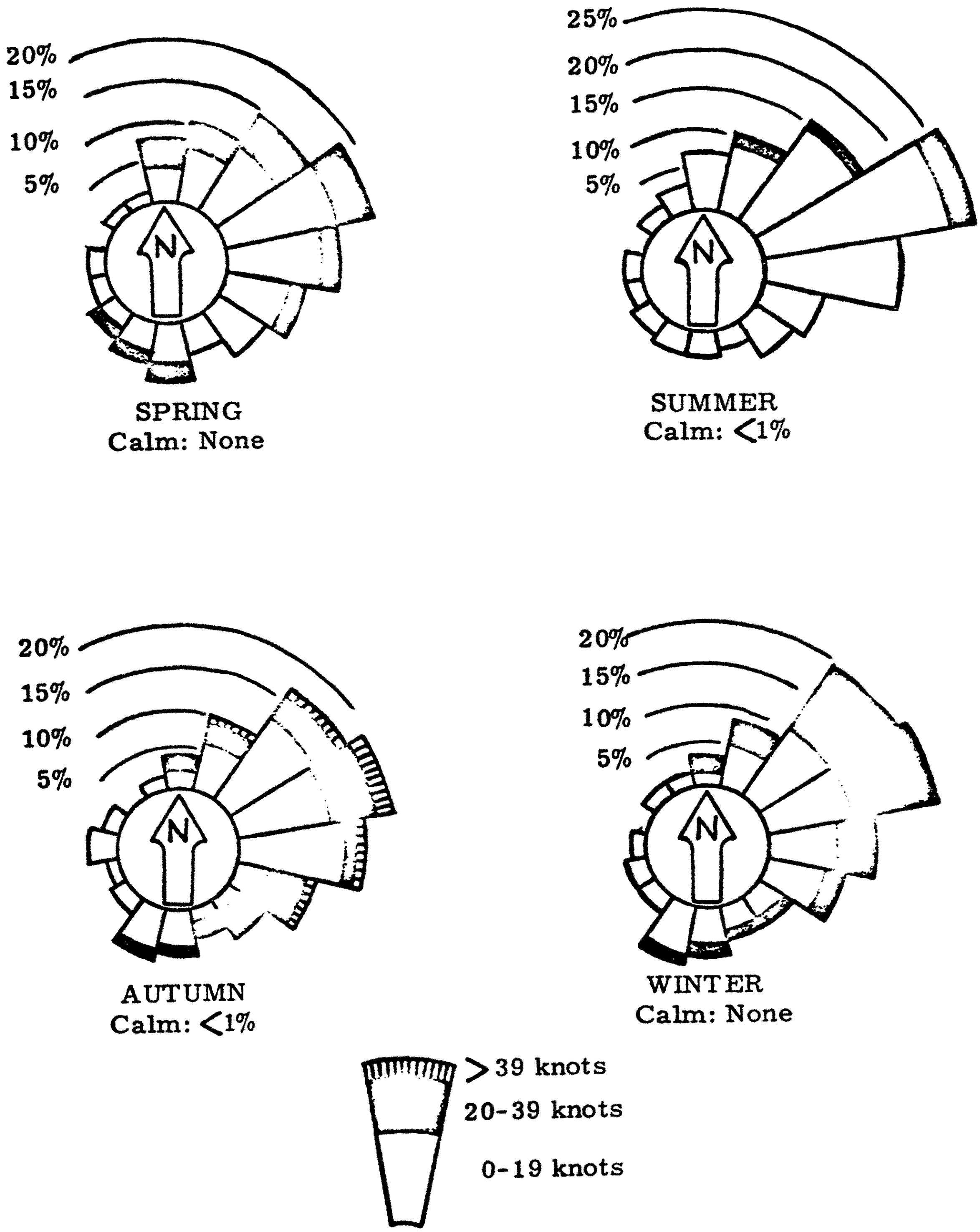


Figure VI-2. Seasonal Distribution of Winds at 700 Millibars, Grand Junction, Colorado (ESSA, 1969).

counter-clockwise shift in direction of 15-20°. The average daytime wind vector under fair weather conditions is a function of steepness of slope, character of slope surface, nearness of other peaks and aspect.

Strongest winds will normally occur in winter and in early spring and lightest winds during summer and fall. Vector changes in wind are very sensitive to net radiation changes. Because of this a more pronounced valley circulation will be found on south facing slopes than on north. On the north faces maximum valley winds will be found near the ridgetop and at the valley floor. Mountain (upslope) winds are strongest along steep slopes with aspects facing the direct solar radiation. Mean fair weather winds will rarely exceed 24 miles/hour. Wind speeds are usually sharply reduced by friction over disected plateaus.

5. <u>Air Quality</u>

From Table VI-2 it may be noted that January is the coldest month and July the warmest month. Night-time air temperatures are largely dependent upon physiography with air drainage (valley winds) the dominant elements. A night-time inversion, with light drainage winds, is typical throughout the Piceance Basin. Under these conditions the typical night-time surface flow pattern is down the creek drainages to the North and Northeast, then turning Westward down the White River valley. The vertical temperature structure is usually neutral to moderately unstable during afternoon with a temperature inversion forming shortly after sundown. The trapping layer under this inversion is probably less than 1500 feet thick. A short term temperature record on Cathedral Bluffs indicated that the inversion height is usually below

8500' msl. In Parachute Creek near Grand Valley, Colorado, the inversion height is between 7200' and 8500' msl. Inversion heights, it should be noted, are not a function of altitude above mean sea level but rather above the ground surface.

During mid-winter, the inversion normally breaks at least by early afternoon. Under certain synoptic conditions, however, temperature inversion conditions may persist for several days at a time. During the summer and fall months, the inversions will normally break by midmorning.

The tendency for air drainage and temperature inversion conditions indicates a potential air pollution problem. There are, at present, no major sources of pollution within the inventory area. If gaseous or particulate matter are to be released into the atmosphere as part of the oil shale processing, it would be necessary to assure that the stack height extend above the local area inversion level and that the plume be forced vertically to higher levels. The plume direction would then probably be in the general direction of the upper level wind, i.e., to the Northeast.

CHAPTER VII

RECREATIONAL, CULTURAL & AESTHETIC ELEMENTS

A. INTRODUCTION

This inventory is restricted to identifying, listing and describing those environmental elements in the study area which contribute to or detract from the area's value for recreation use. It does not interpret these elements as to their importance in determining either the quantity or the quality of recreation activity the area may support. It does not relate the resources of the area to the region of which it is a part nor does it inventory the outside influences of population size or location or competing resource attractions which may influence recreation use in the area.

An inventory of this nature poses important questions of choice of environmental elements to be considered. The scope of possible recreational uses, including cultural and aesthetic uses, of an area might range from highly developed urban-oriented activities to the careful preservation of unique and fragile natural history values. The natural resources of the area and its location in relation to potential users greatly restricts these potential uses. To more clearly define the limits of study the area was determined to fall into the Bureau of Outdoor Recreation Land Class III, Natural Environment (1). This decision is concurred in by the Bureau of Land Management which administers the area.

The dominant feature in this class of recreation land is natural scenery possessing varied and interesting land forms, flora and fauna in an attractive natural setting. Its dominant recreational use potential is for traditional outdoor recreation experiences where users are encouraged to enjoy the resources "as is" in a natural environment.

An important feature of the dominant natural environment in the study area is topography and vegetation which enhances the recreational value of "open space".

It is obvious that this land classification category is not static but that increased knowledge of scenic and cultural values might result in reclassification to reflect appropriate recreational uses.

B. ENVIRONMENTAL ELEMENTS

The environmental elements to be considered are those which affect this kind of recreational enjoyment. Thus the character of the natural landscape assumes major inventory importance. These elements may be grouped into three broad categories for convenience:

Scenery and landscape elements

Cultural elements including pre-history, history, natural history and modern land uses

Recreational facility elements which add to or detract from the area as a desirable setting for various recreational activities

A substantial array of data exists for inventory of some of the traditional natural resources of the area. However, there has been little study given to those environmental elements peculiar to a recreation inventory.

> No inventory work has been done due to lack of personnel, time and money. ----There is very little accurate information on which to base the present recreation use activities. There is even less information to base possible future recreation use. This lack of information should have a high priority for development. Observations by BLM, Game, Fish and Parks Department and by people living in the area are not enough to make any statements of useable accuracy. More work is needed in the future to provide accurate recreation information (2).

While much can be inferred by interpretation of standard resource information and discussions with knowledgeable people in the area, specific field studies will be necessary to provide satisfactory data for several categories of recreation inventory.

Standard inventory data for the lithosphere, biosphere, water resources and climate are necessary for an analysis of the recreation resources of the area. These comprise other sections of this report and will be referred to only incidentally as they may have special significance to this section.

While recorded recreation data generally is meager and cannot be accepted as representing a satisfactory inventory, excellent hunter information is available for Bureau of Land Management Units and Colorado Division of Game, Fish and Parks Game Management Units within whose boundaries this study area falls. However, firm isolated data for the study area is not available (8).

C. SCENERY AND LANDSCAPE ELEMENTS

The scenery of the area is considered to be good by the Bureau of Land Management (Fig. VII-1). The general region of Rio Blanco County is considered "excellent" in relation to the areas from which vacationing visitors come (4).

The scenery of the study area is dominated by the Cathedral Bluffs, extending NNW across the area in a high ridge rising to 8685 feet elevation near the center and dropping to near 5500 feet at the NW corner of the area along Douglas Creek and to about 6500 feet elevation along Duck Creek at the NE corner.

These bluffs act as a hipped roof, producing nearly parallel drainage channels at right angles to the line of the bluffs. Drainage to the west drops rapidly in a number of deep canyons which open into the narrow valley of Douglas Creek running NNW to the White River. Across Douglas Creek similar but less abrupt drainage channels rise to 7680 feet elevation between Texas Mountain and the Rabbit Hills beyond the study area.

To the east, the high lands near the bluffs consist of low parallel rolling ridges separating stream beds which form deep gullies with nearly vertical walls as they descend and finally open up to form narrow meadow strips with deeply eroded stream beds near the east boundary of the area. Drainage lines converge to form Yellow Creek and Ryan Gulch; the former flowing to the White River, the latter first entering Piceance Creek.

The landscape is essentially semi-desert with much exposed sedimentary rock and alluvial fills which weather to a relatively uniform buff color. Vegetation ranges from grasses and sagebrush to piñon-juniper forest.

No comprehensive inventory has been made of the scenic elements to be found in the area. The Bureau of Land Management has designated most of the area from Douglas Creek east to a diagonal line running from the NW corner of T1, R99W to the SE corner of T2, R99W as Category B scenery and the remainder as Category C scenery (Fig. VII-1). Travel influence zones, where scenic protection has major importance have been designated (Fig. VII-2). Two scenic overlooks are identified (Fig. VII-2).

One visit to the site by air and jeep (November 11, 1971) confirmed the existence of all landscape compositional types used for scenic inventories. Determining relative importance of these will require not

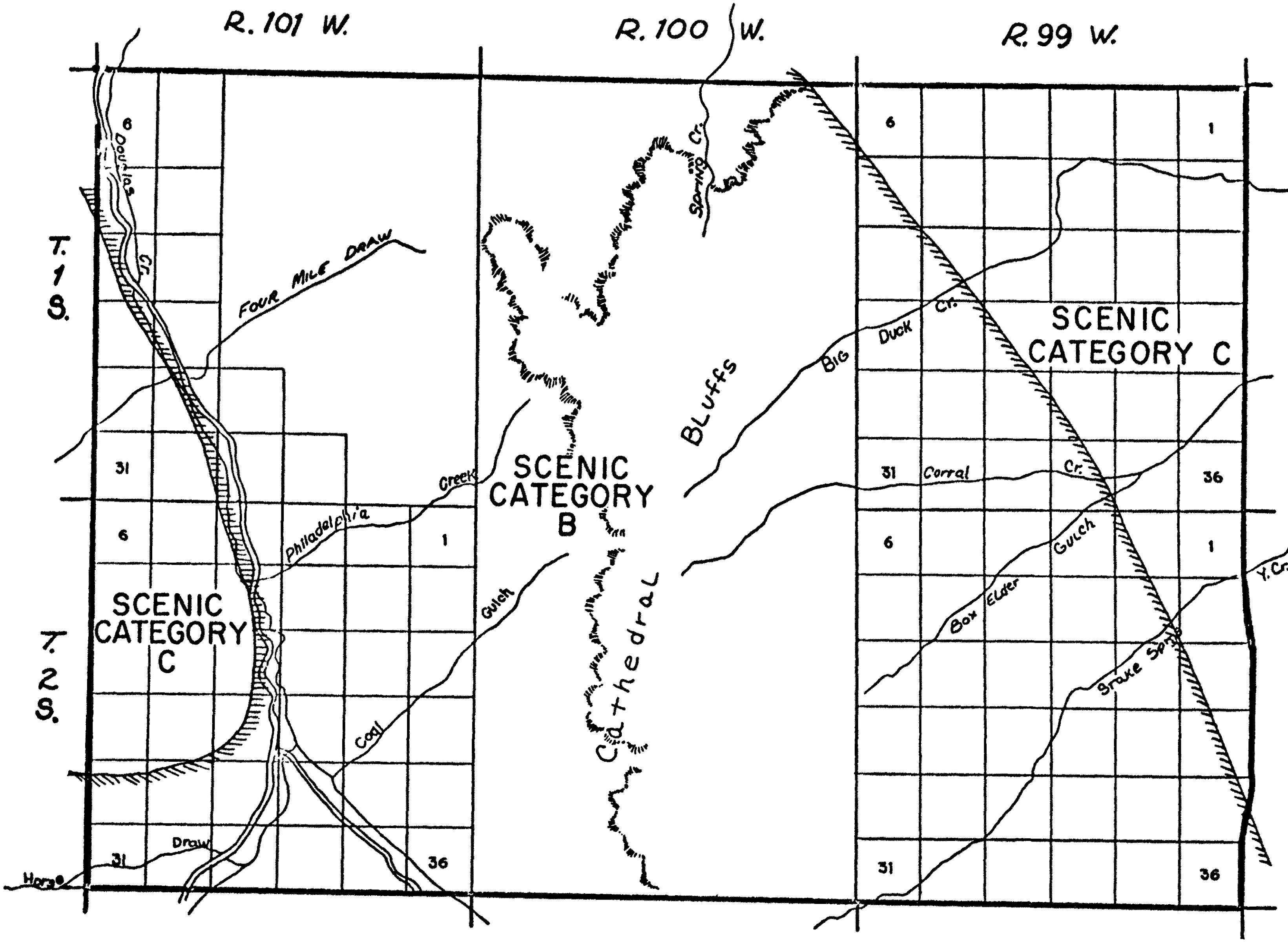


Figure VII - 1[2,3]
Scenic Category Boundary

only an on-site survey but also a regional analysis to isolate unique qualities which may qualify for regionally significant scenic recognition.

1. <u>Landscape Influence Factors</u>

Scenic inventories are based on identification of seven landscape compositional types. These are determined by six principal factors which affect the observer as he looks at a landscape (7). These are:

Distance

Observer position

Form (convex scenic elements)

Spatial definition (concave scenic elements)

Light

Sequence (progressive changes in scenery)

a. Distance -- The visual significance of a landscape feature is determined, in part, by its distance from the eye of the observer. Thus a landscape feature may assume great or little importance, depending on the distance from which it is viewed.

There are three basic distance zones for inventory purposes:

Foreground (0 to 1/2 mile)

Middleground (1/2 to 4 miles)

Background (4 to ∞ miles)

b. Observer position -- The position of the observer in relation to the view he sees influences his reaction to that view and the adaptability of that view to manipulation. There are three basic observer positions for inventory purposes:

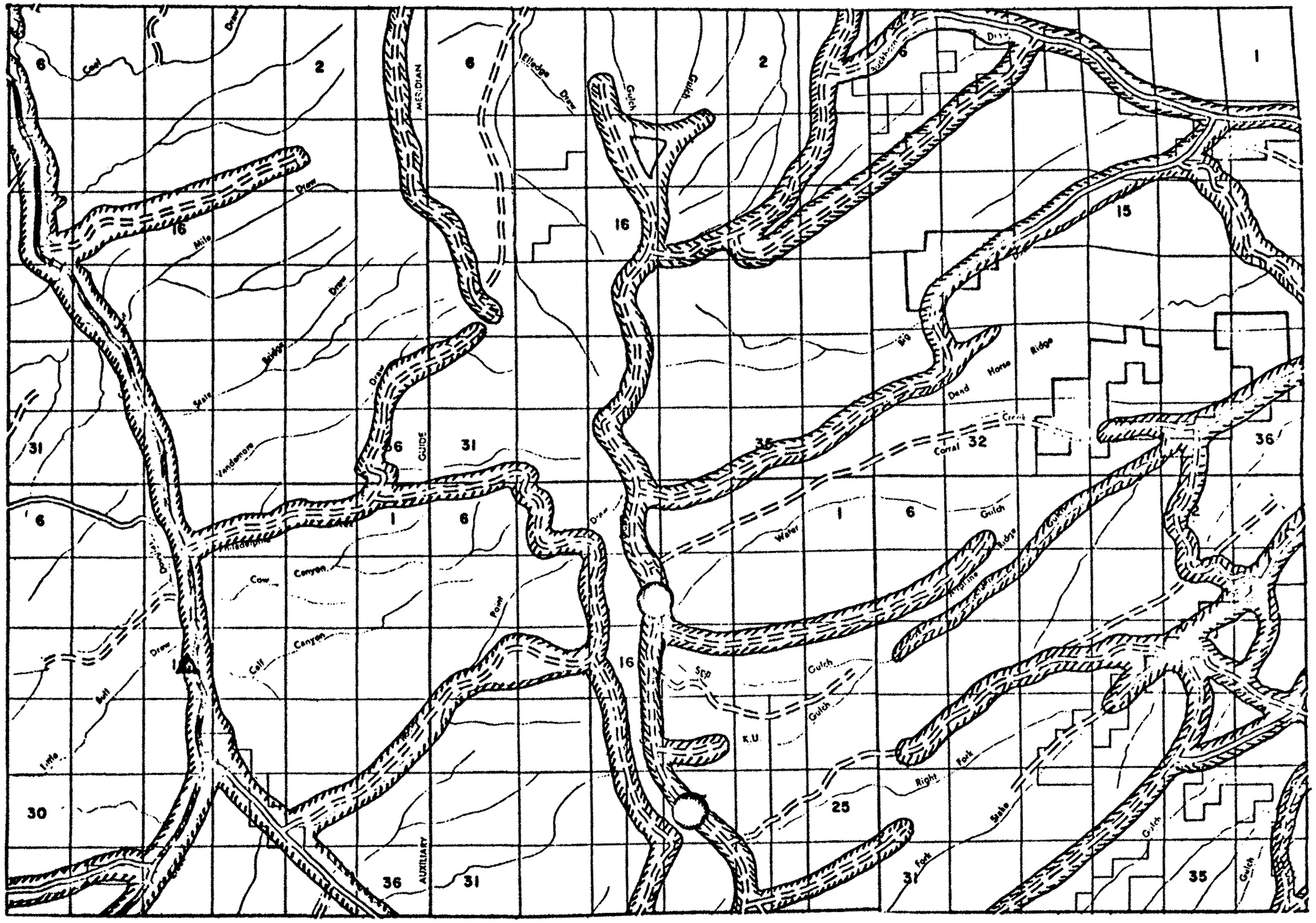


Figure VII - 2[2,3] Travel Influence Zone
Scenic Overlook
Pictograph

Inferior (Essentially below the foreground landscape)

Normal (Line of sight generally coincides with the dominant elements of the landscape)

Superior (Above the dominant elements of the landscape)

c. Form -- Form refers to the three-dimensional convex elements of the landscape. To have form as a factor in landscape definition there must be contrast to set it apart from the general view. Form is described with common landscape terms such as mountain, butte, ridge, range, escarpment and crag.

d. Spatial definition -- Spatial definition refers to the three dimensional concave elements of the landscape. Here there is space with boundaries ranging from narrow canyons to broad valleys. Descriptive terms include gorge, meadow, valley, canyon, ravine and glen.

e. Light -- The effects of light on the landscape change from day to day and during the course of the seasons. The influence of light on landscape value is seen in such situations as color changes on rock outcrops, the graying effect of distance and the impact of silhouettes against the sky.

Elements in describing the influence of light are:

Color hue and value.

Distance to the lighted object.

Direction of the light source.

f. Sequence -- Sequence is the progressive change in scenic elements as observed when one moves across a landscape. The amplitude of contrast in scenic elements enriches appreciation of the landscape and becomes important in scenic analysis of travel routes.

2. <u>Landscape Composition Types</u>

These factors of scenic analysis are represented in seven landscape composition types for inventory purposes. These are:

Panoramic

Feature

Enclosed

Focal

Canopied

Detail

Ephemeral

a. Panoramic landscape -- This landscape provides distant views, openness and little sense of boundary restriction. The sky and cloud formations become important quality considerations.

b. Feature landscape -- Here the eye is drawn towards a single landscape feature with other features being definitely subordinate. This feature may be characterized by distinctive size or shape which sets it apart from its surroundings.

c. Enclosed landscape -- This landscape may be compared to a framed picture with its enclosing boundaries. There are lines of visual attraction towards the central area of the view, and attention is held in by the boundaries of the view. A lake with its water's edge, or a canyon are examples.

d. Focal landscape -- A focal landscape is distinguished by series of parallel lines that appear to converge and guide the eye toward their apparent origin. Views up stream beds and canyons or along parallel ridges are examples.

e. Canopied landscape -- This is a small scale landscape composition such as might be found in walking through a grove of trees or along a narrow gully.

f. Detail landscape -- This is another small scale landscape characterized by minor details which typically assume importance because of their unusual form or contrast with the surrounding scenic features. Old trees, distinctive rock coloring or erosion forms and unusual plants are examples.

g. Ephemeral landscape -- Some landscape features are not permanent but when they occur, their affect on the observer is significant. Characteristically beautiful sunsets, striking colors on cliff faces, daily cloud formations over peaks and the tracks of wild animals are examples.

The following general remarks about landscape compositional types in the study area will serve to point out the importance of this inventory data in quantifying the scenic resource. Panoramic landscapes exist along the entire length of the Cathedral Bluffs. These are highlighted at selected points by scenic overlooks of exceptional quality (Fig. VII-1). In addition, a number of broad flats between stream beds on the west side of the area (i.e., Dead Horse Ridge) provide broad panoramas over sagebrush in the middle ground with juniper borders and vistas east and west toward mountainous backgrounds.

Feature landscapes occur along the Cathedral Bluffs, and at points along Douglas Creek and its several side drainages on both west and east slopes. These include rock formations along the walls of canyons and draws, and silhouettes in the Bluffs area.

Enclosed and focal landscapes are characteristic of the drainage beds on both west and east slopes. These provide a wide variety of landscape features and assume special importance because they are the location of roads and thus become focal areas in relating travel and accessibility to the enjoyment of scenery (Fig. VII-2).

Canopied landscapes are not common in this area. An example is found in a stand of old junipers at the confluence of Little and Big Duck Creeks. The narrow, vertical erosion banks of heavily silted stream beds are another example.

Detailed landscapes are found in unusual rock outcrops and the unusual appearance of such trees as the old junipers and the large sagebrush plants found in drainage channels on the western slope.

Ephemeral landscapes record the importance of atmospheric quality in coloring rock cliffs or providing scheduled spectacular cloud formations. Non-hunting enjoyment of wildlife, especially rare or interesting species such as the mountain lion illustrate this landscape type.

Travel influence zones or scenic corridors (Fig. VII-2) are visual areas along roads. They have special significance because of their accessibility to interested viewers. The scenery in these travel influence zones has not been inventoried. Two zones are briefly described here.

The road up Douglas Creek is a paved highway connecting the White River valley near Rangely with the Colorado River Valley at Loma, near Grand Junction. It is the only highway to traverse this area of varied scenic quality. Recently paved across Douglas Pass, it can be expected to assume increasing importance as a tourist scenic drive connecting

Colorado Route 50 (Pueblo, Gunnison, Montrose, Delta, Grand Junction) to Colorado Route 64 and US 40 going west towards Salt Lake City, Dinosaur National Monument and Flaming Gorge National Recreation Area. The road through the study area is essentially an enclosed, focal landscape with views to both sides cut off in the foreground and middle ground by bluffs and canyon walls.

The valley floor varies in width to approximately 1/2 mile and Douglas Creek forms a meandering, deeply cut channel with vertical walls in a thick alluvial valley floor. On the east side eight major canyons open up to provide middle distance views along narrow, high canyon walls. On a branch road up Douglas Creek are four similar canyons. In at least two places these canyon openings provide a background view to the Cathedral Bluffs. On the west side the hillsides are less abrupt and canyons provide views up six principal valleys.

The valley is essentially in a natural condition. Man made facilities include roads, pipelines, power and telephone lines and a few buildings for pipeline servicing. The status of a few trailer houses is not known. Negative scenic values are public utility wires and poles and inadequate maintenance of the roadsides. The scenery includes a number of significant features, combining enclosed, focal, detail and ephemeral landscape types with good sequential qualities.

Corral Creek illustrates the high sequential view characteristics of drainages on the western slope of the study area. Here the scenery varies from flat valley meadows and juniper covered gentle side slopes to narrow, rock bound valley passes and finally gullies with high, nearly vertical walls cut in recently deposited silt. This quality of sequential scenery is further emphasized when the observer cuts across to another drainage where broad sagebrush flats between draws provide open panoramic views in all directions.

D. CULTURAL ELEMENTS

Cultural elements are historical and natural history features which contribute to recreational enjoyment. Historical features are associated with archaeological, Indian, pioneer, mining, homesteading and modern land use sites. Natural history features are associated with paleontology, geology, botany, zoology, water and climate.

No planned surveys have been made of historical features in the area. General natural history inventories reveal the general distribution of these elements but do not reveal outstanding or unique features of value for recreational use. Known features are located on appropriate maps.

1. Archaeological and Indian Sites

Pictographs are found on rock walls along Douglas Creek (Fig. VII-2). No other sites are recorded. No Indian sites are recorded.

There are numerous recordings of petrographs and/or petroglyphs to be found on rock exposures throughout the region, especially near springs or streams. It may also be assumed that both archaeological and historical Indian sites may be found near water sources in the area. A major problem in surveying for these sites is the evidence of rapid erosion in all parts of the area. Deposition many feet thick appears to have occurred in the last few hundred years in several valleys and old historic and archaeological sites may be deeply buried in existing stream beds.

2. Pioneer Mining, Homestead and Modern Land Use Sites

Mining and drilling sites have been omitted from this section by direction. No pioneer or homestead sites are recorded in the area. There are two recorded cow camps (Fig. III-5) and field observation indicates that other resident or cattle structure sites are in the area, along valleys on the west slope.

Other man made features are:

Airstrip. Fig. III-5

Windmill. Fig. III-3

Wells or Springs. Fig. III-3

Fences. Fig. III-3

Hunting Club. Fig. III-5

Evidence of grazing and meadow management practices are found in much of the area.

Roads and trails (Fig. III-2) are supplemented by numerous unmarked trails and off-road vehicle traces.

3. Paleontology

While no fossil or petrified wood locations are recorded in the area there are records of both in the vicinity. It should be assumed that sites may exist. Local citizens and workers in the area refer vaguely to their locations (9).

Fossil insects have been reported in shale beds at lower elevations close to the study area.

4. Geology

The entire area is geologically interesting, especially in relation to the Mahogany ledge. Erosional and depositional features contribute to the recreation inventory, especially when combined with other landscape elements. Available geological data do not identify sites of special recreation value for collection or display-in-place.

5. Botany and Zoology

These resource elements are noted elsewhere. They contribute to the recreational resource of the area when they become available for recreational enjoyment. There is no inventory of botanical features of unusual natural history value. No known unique or outstanding ecological communities are in the area (2,3). One on-site examination revealed unusually large sagebrush plants (*Artemisia tridentata*) along Corral Creek and an impressive stand of old gnarled junipers (*Juniperus scopuloruim*) at the confluence of Big and Little Duck Creeks. A thorough inventory may be expected to reveal individuals or groves of important scientific or scenic value.

6. Wildlife

Wildlife resources are noted elsewhere. Wildlife is especially valuable in the total recreation use picture of this region. Big game hunting accounts for approximately 80% of the recreation activity in the vicinity. It is safe to say that 99% of all roads in the unit are traveled at least once during hunting season (2).

The study area is within a management unit which is very popular for hunting deer. Some of the heaviest hunting pressure in the state is in this unit. Elk, sage grouse, and cottontail rabbits are also hunted here (3). Wildlife is important as an element in sightseeing, especially in this type of natural environment. Good hunter use data is available for the game management units of which the study area is a part but no exclusive data for the area itself is available. In addition, non-game animal inventory data is available for the region (5).

7. Water and Climate

There are no open bodies of water for recreation use. Streams are cool to cold but are characterized by severe fluctuation and high salt and mineral content and fishing is limited.

Generally, the lower elevations are uncomfortably hot in summer with cool nights. Most recreation, including 4-wheel drive vehicle travel, artifact and rock hunting and hunting occurs in the spring and fall. The higher elevations are suitable for recreation in spring, summer and fall with picnicking, hunting and camping as typical activities.

Snow conditions are satisfactory for snowmobiling.

E. RECREATION FACILITY ELEMENTS

These are miscellaneous landscape or development features which add to or detract from the area as a desirable setting for recreational activities.

1. Accessibility

Accessibility to the area is good. Colorado Route 64 follows the White River a few miles to the north from Meeker to Rangely. Colorado Route 13 runs a few miles to the east from Meeker to Rifle. Closer, a good quality secondary road follows Piceance Creek, which picks up the drainage from the entire east side of the study area, from Route 64 on the White River diagonally to Rio Blanco on Route 13. To the south, US Highway 6 and 24 runs from Rifle to Grand Junction and provides a connection at Loma to the Douglas Creek road (Colorado 139) which runs from near Rangely through the west side of the study area and over

Douglas Pass. These roads provide ready access to the area, not only from nearby population centers but also from tourist routes along two major east-west highways and the principal north-south route in western Colorado.

Virtually all parts of the study area are readily available to wheeled vehicles over interconnecting gravel and dirt roads of varying quality (Fig. III-2). In addition there are numerous jeep trails interlacing the area (9).

There are no developed public recreation sites on the area. There is one private hunting club (Fig. III-5).

2. Population Influences

There is no permanent population in the study area. While this report does not call for a listing of outside influences affecting the area, it is apparent that recreational use is totally dependent on visitation from elsewhere, and that the environmental influence area for purposes of recreational use analysis must consider the fixed local population that provides day-to-day visitors to the area and the transient tourist population which in this case is part of the Rocky Mountain oriented national tourist market.

The composition of a changing population in the area will contribute to changes in recreation demand as evidenced by the potential demand of various occupation classes (6).

Occupation	Annual Activity Day in Recreation
Professional, Technical & Kindred Workers	36.7
Farm Workers	16.8
Clerical & Kindred Workers	32.8
Craftsmen, Foremen & Kindred Workers	30.0
Service Workers	26.0

3. General Recreation Activities

Bureau of Land Management Planning Unit statistics on recreation use are not definitive for the study area. However some indication of the relative amount of recreation activity in the area may be seen by comparing the estimated visitor days of use for listed activities in the Douglas Creek Unit (2).

Activity	Visitor Days
Driving for Pleasure	200
Sightseeing	100
Picnicking	1,000
Camping	200
Hunting	20,130
Fishing	200
Rock Hounding	50
Artifact Hunting	350

Even more interesting is the estimated proportions of local, instate and out-of-state use.

Activity	Percent of Total Use Local	 In-State Non Local	 Out-of-State
Driving for Pleasure	70	20	10
Sightseeing	70	20	10
Picnicking	90	8	2
Camping	50	40	10
Hunting	12	13	75
Fishing	90	10	--
Rock Hounding	90	10	--
Artifact Hunting	90	10	--

The following list is suggestive of the kinds of activities associated with this class of recreation area. These were considered in developing this inventory of environmental elements.

Sightseeing	Rock hounding	Vacation ranch use
Walking for pleasure	Camping	Organization camping
Driving for pleasure	Vacation cabin use	Resort use
Horseback riding	Archery	Winter sports
Hiking	Wilderness enjoyment	Hunting
Back country vehicle use	Picnicking	Fishing
Exploring	Nature study	Water sports

Fossil, Indian & historic site hunting

F. REFERENCES

1. U. S. Dept. of Interior, 1969, Land Classification, Manual Release 630 & 635, Bureau of Outdoor Recreation.

2. U. S. Dept. of Interior, Douglas Creek Planning Unit Report, Bureau of Land Management Office, Meeker, Colorado.

3. U. S. Dept. of Interior, Yellow Creek Planning Unit Report, Bureau of Land Management Office, Meeker, Colorado.

4. U. S. Dept. of Agriculture, 1971, An Appraisal of Outdoor Recreation Potentials in Rio Blanco County, Colorado, Soil Conservation Service.

5. Colorado State University, 1971, Biological-Ecological Considerations for Project Rio Blanco, Vol. 2.

6. U. S. Dept. of Interior, 1962, Outdoor Recreation for America, Outdoor Recreation Resources Review Commission.

7. U. S. Dept. of Agriculture Forest Service, 1968, Forest Landscape Description and Inventories, PSW49, Pacific Southwest Forest and Range Experiment Station.

8. Colorado Game, Fish and Parks Department, 1967, Colorado Outdoor Recreation Comprehensive Plan.

9. Personal visitation with local residents and government employees familiar with the area.

APPENDIX IV-1

Excerpts from the following documents are included in this appendix:

Table 223.--Green River basin between the Yampa and White Rivers including the White River basin--Continued

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Boron (B)	Dissolved solids (sum): Parts per million	Dissolved solids (sum): Tons per acre-foot	Dissolved solids (sum): Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH	Sodium adsorption ratio
3020B. Duchesne River at Ouray, Utah--Continued																					
1954																					
August 26	a 10	5.3	172 8.58	130 10.69	650 28.26	....	250 4.10	0.0	1,420 29.56	488 13.76	0.2 .00	....	2,990	4.07	81	965	760	59	4,080	7.9	9.1

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (residue at 180°C): Parts per million	Dissolved solids (residue at 180°C): Tons per acre-foot	Dissolved solids (residue at 180°C): Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH	Sodium adsorption ratio
WHITE RIVER BASIN																					
3030. White River at Buford, Colo.																					
1957																					
October 21	b 277	....	42 2.11	7.4 .61	2.6 .11	....	102 1.67	57 1.19	....	....	....	....	159	0.22	119	136	52	4	275	7.9	0.1
1958																					
May [illegible]	b 720	13	35 1.74	6.6 .54	2.0 .09		103 1.69	32 .67	0.2 .01	....	0.3 .00	....	148	.20	288	114	30	....	229	7.7	......
August 4	b 235	18	44 2.22	8.5 .70	4.9 .21		107 1.75	65 1.35	.8 .02	....	.1 .00	....	192	.26	122	146	58	....	304	7.8	......
3035. South Fork White River near Buford, Colo.																					
1957																					
October 21	b 166	....	...... 2.60		....		132 2.16	....	....	....	....	....	......	......	......	130	22	....	250	8.0	......
1958																					
May 9	b 425	13	37 1.84	8.3 .68	0.9 .04		139 2.28	13 .27	0.2 .01	....	0.1 .00	....	146	0.20	168	126	12	....	241	7.7	......
August 4	b 164	15	45 2.26	10 .82	4.3 .19		159 2.61	31 .64	[illegible]	....	[illegible] .00	....	178	.24	79	154	24	....	302	7.8	......

3045. White River near Meeker, Colo.

1957																					
October 21	b 568	... ...	56 2.80	13 1.04	2.4 .10	... ...	138 2.26	65 1.35	a12 .33	... ...	0.2 .00	... ...	i 217 ...	0.30 ...	333 ...	192 ...	79 ...	3 ...	390 ...	8.2 ...	0.1 ...
1958																					
May 8	b 1,860	12 ...	44 2.20	8.8 .72	19 .83		132 2.16	45 .94	23 .65	... ...	.3 .00	... ...	222 ...	.30 ...	1,110 ...	146 ...	38 ...	... ...	367 ...	8.1 ...	... ...
August 4	b 361	17 ...	63 3.12	13 1.10	13 .55		167 2.74	86 1.79	8.5 .24	... ...	.1 .00	... ...	282 ...	.38 ...	275 ...	211 ...	74 ...	... ...	446 ...	7.9 ...	... ...

3045A. Wh   er at bridge on State Highway 13, near Meeker, Colo.

1947																					
March 19	a 481	... ...	73 3.64	20 1.64	46 2.02		160 2.62	142 2.96	60 1.69	... ...	1.9 .03	... ...	i 422 ...	0.57 ...	548 ...	264 ...	133 ...	28 ...	679 ...	... ...	1 ...
September 19	a 384	17 ...	62 3.09	16 1.32	55 2.41		160 2.62	119 2.48	61 1.72	... ...	.0 .00	... ...	i 409 ...	.56 ...	424 ...	220 ...	90 ...	35 ...	644 ...	... ...	1.6 ...
1954																					
August 24	a 228	17 ...	88 4.39	20 1.64	69 3.00	... ...	192 3.15	173 3.60	85 2.40	... ...	.1 .00	... ...	i 547 ...	.74 ...	337 ...	301 ...	144 ...	33 ...	865 ...	8.2 ...	1.7 ...
August 25	a 225	17 ...	94 4.69	19 1.56	75 3.26	... ...	204 3.34	176 3.66	89 2.51	... ...	.1 .00	... ...	i 571 ...	.78 ...	347 ...	315 ...	148 ...	34 ...	904 ...	7.8 ...	1.9 ...
September 16	a 311	17 ...	83 4.14	14 1.15	64 2.77		184 3.02	148 3.08	69 1.95	... ...	.6 .01	... ...	i 487 ...	.66 ...	409 ...	265 ...	114 ...	34 ...	781 ...	7.6 ...	1.7 ...

3045B. White River 11 miles west of Meeker, Colo.

1954																					
September 16	a 311	17 ...	... 5.70		70 3.03		192 3.15	177 3.68	67 1.89	... ...	0.7 .01	... ...	... ...	... ...	... ...	285 ...	128 ...	35 ...	813 ...	7.9 ...	1.8 ...

3045C. White River above Piceance Creek, at White River, Colo.

1947																					
March 19	...	... ...	69 3.44	24 1.97	44 1.90		172 2.82	159 3.31	40 1.13	... ...	2.8 .05	... ...	i 424 ...	0.58 ...	... ...	270 ...	130 ...	26 ...	673 ...	... ...	1.2 ...
September 19	...	18 ...	77 3.84	18 1.48	44 1.91		172 2.82	133 2.77	58 1.64	... ...	.2 .00	... ...	i 433 ...	.59 ...	... ...	266 ...	125 ...	26 ...	685 ...	... ...	1.2 ...
1954																					
August 25	...	16 ...	91 4.54	25 2.06	90 3.91	... ...	221 3.62	216 4.50	84 2.37	... ...	.2 .00	... ...	i 631 ...	.86 ...	... ...	330 ...	149 ...	37 ...	957 ...	8.0 ...	2.2 ...
September 16	...	18 ...	... 5.84		65 2.85		190 3.11	177 3.68	67 1.89	... ...	.8 .01	... ...	... ...	... ...	... ...	292 ...	136 ...	33 ...	825 ...	7.5 ...	1.7 ...

See footnotes at end of table.

Green Division--Continued

Table 223.--Green River basin between the Yampa and White Rivers including the White River basin--Continued

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Boron (B)	Dissolved solids (sum): Parts per million	Dissolved solids (sum): Tons per acre-foot	Dissolved solids (sum): Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH	Sodium adsorption ratio
3060. Piceance Creek near Rio Blanco, Colo.																					
1957																					
October 21	b 2.4	......	39	41	46	......	294	0	120	......	......	....	......	......	......	268	27	27	760	8.2	1.2
		......	1.96	3.40	2.00	......	4.82	......	2.50	......	......	....	......	......	......	......	......	......	......	...	......
1958																					
May 9	b 18	7.4	63	16	18		212	0	78	3.5	0.7	....	c 277	0.38	13	220	46	......	472	7.6	......
		......	3.12	1.28	.80		3.47	......	1.62	.10	.01	....	......	......	......	......	......	......	......	...	......
3060A. Piceance Creek near White River, Colo.																					
1947																					
March 19	....	......	28	19	111		301	0	115	16	1.7	....	439	0.60	......	148	0	62	694	...	4.0
		......	1.40	1.56	4.84		4.93	......	2.39	.45	.03	....	......	......	......	......	......	......	......	...	......
September 19	....	21	60	78	313		788	0	421	45	4.3	....	1,330	1.81	......	470	0	59	1,870	...	6.3
		......	2.99	6.41	13.62		12.91	......	8.77	1.27	.07	....	......	......	......	......	......	......	......	...	......
1954																					
August 25	a 4	......	18	108	2,170	......	4,410	305	517	445	1.2	....	5,740	7.81	62	488	0	91	7,890	8.6	43
		......	.90	8.88	94.36	......	72.32	10.16	10.76	12.55	.02	....	......	......	......	......	......	......	......	...	......
September 16	a 8	3.7	21	92	1,190		2,320	143	577	193	1.9	....	3,360	4.57	73	430	0	86	4,740	8.5	25
		......	1.05	7.57	51.80		38.05	4.76	12.01	5.44	.03	....	......	......	......	......	......	......	......	...	......
1957																					
October 26	b 21	......	18	78	353	2.3	804	20	400	42	......	....	1,310	1.78	74	366	0	68	2,040	8.4	8.0
		......	.88	6.44	15.36	.06	13.18	.67	8.33	1.18	......	....	......	......	......	......	......	......	......	...	......
1958																					
May 9	b 19	8.8	67	22	34		272	0	98	3.5	.6	....	c 361	.49	19	256	33	23	592	8.0	.9
		......	3.34	1.78	1.49		4.46	......	2.04	.10	.01	....	......	......	......	......	......	......	......	...	......
August 9	b 26	16	27	81	411		934	17	418	46	1.3	....	c1,400	1.99	102	402	0	69	2,150	8.4	8.9
		......	1.36	6.68	17.86		15.31	.57	8.70	1.30	.02	....	......	......	......	......	......	......	......	...	......
3060B. White River below Piceance Creek, at White River, Colo.																					
1954																					
August 25	....	16	91	25	86	......	224	0	204	84	0.2	....	616	0.84	......	330	146	36	972	7.9	2.1
		......	4.54	2.06	3.74	......	3.67	......	4.25	2.37	.00	....	......	......	......	......	......	......	......	...	......
September 16	....	18	84	18	75		210	0	171	68	.7	....	538	.73	......	283	111	37	848	8.0	1.9
		......	4.19	1.48	3.26		3.44	......	3.56	1.92	.01	....	......	......	......	......	......	......	......	...	......

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (sum): Parts per million	Dissolved solids (sum): Tons per acre-foot	Dissolved solids (sum): Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH	Sodium adsorption ratio
3060C. Yellow Creek near White River, Colo.																					
1954																					
August 25	....	5.3	12 .60	114 9.37	967 42.05	....	1,950 31.98	79 2.63	659 13.72	154 4.34	1.1 .02	....	2,950	4.01	....	500	0	81	4,130	8.5	19
September 16	....	9.2	...... 10.60		898 39.08		1,700 27.88	123 4.10	664 13.82	137 3.86	1.7 .02	....	....	....	....	530	0	79	3,970	8.8	17
1957																					
October 26	b 1.8	....	...... 8.00		....	....	972 15.93	56 1.87	398 8.29	....	....	....	....	....	....	400	0	....	2,530	8.5	......
3060D. Wolf Creek near Massadona, Colo.																					
1958																					
May 7	b 0.1	7.1	423 21.10	116 9.50	259 11.24		246 4.03	0	1,790 37.27	19 .54	0.3 .00	....	c 2,960	4.03	0.8	1,530	1,330	27	3,060	8.1	2.9
3060E. White River 14 miles above Rangely, Colo.																					
1947																					
March 19	....	....	49 2.45	22 1.81	66 2.86		206 3.38	0	137 2.85	30 .85	2.4 .04	....	408	0.55	....	213	44	40	653	...	2.0
3061A. Spring Creek near Rangely, Colo																					
1954																					
September 16	....	18	...... 45.20		1,420 61.75		677 11.10	4,420 92.02	135 3.81	....	1.3 .02	....	....	....	....	2,260	1,700	58	7,680	7.9	13
3061B. White River 8.5 miles above Rangely, Colo.																					
1947																					
May 13	a 2,800	....	43 2.15	10 .82	16 .71		140 2.29	47 .98	14 .39	....	1.5 .02	....	200	0.27	1,510	148	34	....	345	...	......
September 19	a 450	17	73 3.64	23 1.89	61 2.64		212 3.47	146 3.04	58 1.64	....	1.3 .02	....	484	.66	588	276	103	32	769	...	1.6
1948																					
June 8	a 2,300	13	39 1.95	9.9 .81	19 .81		130 2.13	49 1.02	12 .34	....	4.9 .08	....	211	.29	1,310	138	32	....	335	...	......
September 30	a 370	19	76 3.79	28 2.30	83 3.62		233 3.82	200 4.16	61 1.72	....	.7 .01	....	582	.79	581	304	114	37	873	...	2.1

Green Division--Continued

Table 223.--Green River basin between the Yampa and White Rivers including the White River basin--Continued

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (sum): Parts per million	Dissolved solids (sum): Tons per acre-foot	Dissolved solids (sum): Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH	Sodium adsorption ratio
3061B. White River 8.5 miles above Rangely, Colo.--Continued																					
1949																					
April 8	a 630	....	....	....	....	....	222	254	50	....	....	....	....	....	....	....	....	....	985	....	....
		....	....	....	....	....	3.64	5.29	1.41	....	....	....	....	....	....	....	....	....	....	....	....
October 15	a 510	....	....	....	....	....	e 207	159	50	....	....	....	....	....	....	....	....	....	776	....	....
		....	....	....	....	....	3.39	3.31	1.41	....	....	....	....	....	....	....	....	....	....	....	....
1950																					
June 4	a 2,200	15	49	10	14		162	42	12	....	1.2	....	223	0.30	1,320	163	31	....	372	....	....
		....	2.45	.82	.62		2.66	.87	.34	....	.02	....	....	....	....	....	....	....	....	....	....
November 8	a 400	18	72	23	73		206	164	66	....	.6	....	518	.70	559	274	105	37	819	....	1.9
		....	3.59	1.89	3.18		3.38	3.41	1.86	....	.01	....	....	....	....	....	....	....	....	....	....
1954																					
August 25	a 200	15	81	26	90	....	214	199	83	....	.1	....	600	.82	324	307	132	39	953	7.9	2.2
		....	4.04	2.14	3.91	....	3.51	4.14	2.34	....	.00	....	....	....	....	....	....	....	....	....	....
September 16	a 380	17	83	20	88		219	182	78	....	.6	....	577	.78	592	290	110	40	918	7.7	2.2
		....	4.14	1.64	3.81		3.59	3.79	2.20	....	.01	....	....	....	....	....	....	....	....	....	....
3061C. Douglas Creek near Rangely, Colo.																					
1947																					
May 13	....	....	53	49	95		296	270	8	....	6.7	....	628	0.85	....	334	91	38	948	....	2.3
		....	2.64	4.03	4.14		4.85	5.62	.23	....	.11	....	....	....	....	....	....	....	....	....	....
September 19	....	27	104	59	144		374	456	24	....	1.0	....	999	1.36	....	502	196	38	1,370	....	2.8
		....	5.19	4.85	6.28		6.13	9.49	.68	....	.02	....	....	....	....	....	....	....	....	....	....
1948																					
June 8	....	19	62	59	108		e 31[illegible]	338	10	....	4.5	....	758	1.03	....	397	136	37	1,100	....	2.3
		....	3.09	4.85	4.68		[illegible]3	7.04	.28	....	.07	....	....	....	....	....	....	....	....	....	....
September 30	a 0.1	8.5	85	49	156		176	532	28	....	20	....	965	1.31	0.3	414	270	45	1,300	....	3.3
		....	4.24	4.03	6.80		2.88	11.08	.79	....	.32	....	....	....	....	....	....	....	....	....	....
1949																					
April 8	....	14	78	33	152		365	258	66	....	....	....	781	1.06	....	330	31	50	2,140	....	3.6
		....	3.89	2.71	6.61		5.98	5.37	1.86	....	....	....	....	....	....	....	....	....	....	....	....
October 15	....	....	....	....	....		e [illegible]93	....	....	....	....	....	....	....	....	....	....	....	2,240	....	....
		....	....	....	....		[illegible]	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1950																					
June 4	a 25	19	66	61	108		345	339	9	....	1.9	....	774	1.05	52	416	133	36	1,1[illegible]0	....	2.3
		....	3.29	5.02	4.68		5.65	7.06	.25	....	.03	....	....	....	....	....	....	....	....	....	....

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November 8	...	8.3 ...	100 4.99	153 12.58	[illegible] [illegible]		c 417 6.83	1,140 23.73	37 1.04	... ...	4.6 .07	... ...	1,970 ...	2.68 ...	... ...	878 ...	537 ...	45 ...	2,000 ...	... ...	4.[illegible] ...
1954																					
September 16	...	14 ...	... 12.92		224 9.74		245 4.02	853 17.76	26 .73	... ...	9.3 .15	... ...	... ...	... ...	... ...	646 ...	445 ...	43 ...	1,900 ...	7.9 ...	3.8 ...
1957																					
October 26	b 3.2	... ...	[illegible] 4.10	111 9.16	261 11.35	4.8 .12	398 6.52	600 12.49	34 .96	... ...	1.2 .02	... ...	1,2[illegible] ...	1.75 ...	11 ...	666 ...	340 ...	[illegible] ...	2,090 ...	8.2 ...	4.4 ...
1958																					
May 7	b 141	15 ...	82 4.08	55 4.56	103 4.75		e 386 6.33	323 6.72	9.0 .25	... ...	5.7 .09	... ...	c 776 ...	1.06 ...	295 ...	432 ...	115 ...	35 ...	1,140 ...	8.3 ...	2.3 ...

3061D. White River at Rangely, Colo.

1907																					
August 26	...	20 ...	66 3.29	24 1.97	35 1.52		e 205 3.36	146 3.04	11 .31	... ...	... ...	... ...	405 ...	0.55 ...	... ...	263 ...	95 ...	2[illegible] ...	... ...	... ...	0.9 ...
1947																					
March 19	a 1,300	... ...	59 2.94	23 1.89	78 3.40		218 3.57	173 3.60	36 1.02	... ...	2.3 .04	... ...	479 ...	.65 ...	1,680 ...	242 ...	63 ...	41 ...	748 ...	... ...	2.2 ...
May 13	a 2,800	... ...	40 2.00	12 .99	21 .90		144 2.36	56 1.17	12 .34	... ...	1.5 .02	... ...	213 ...	.29 ...	1,610 ...	150 ...	32 ...	23 ...	358 ...	... ...	.7 ...
September 19	a 450	17 ...	74 3.69	23 1.89	73 3.17		232 3.80	156 3.25	60 1.69	... ...	.9 .01	... ...	518 ...	.70 ...	629 ...	279 ...	89 ...	36 ...	797 ...	... ...	1.9 ...
1948																					
June 8	a 2,300	15 ...	40 2.00	11 .90	19 .82		134 2.20	53 1.10	12 .34	... ...	4.7 .08	... ...	221 ...	.30 ...	1,370 ...	145 ...	35 ...	... ...	343 ...	... ...	... ...
September 30	a 370	18 ...	75 3.74	29 2.38	78 3.39		224 3.67	196 4.08	62 1.75	... ...	.8 .01	... ...	569 ...	.77 ...	568 ...	306 ...	122 ...	36 ...	894 ...	... ...	1.9 ...
1949																					
April 8	a 630	... ...	... ...	... ...	... ...		198 3.24	... ...	54 1.52	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	954 ...	... ...	... ...
October 15	a 510	... ...	... ...	... ...	... ...		211 3.46	168 3.50	49 1.38	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	807 ...	... ...	... ...
1950																					
June 4	a 2,200	... ...	... 3.08		20 .85		154 2.52	50 1.04	13 .37	... ...	... ...	... ...	... ...	... ...	... ...	154 ...	28 ...	22 ...	375 ...	... ...	.7 ...
November 8	a 400	16 ...	70 3.49	25 2.06	79 3.43		214 3.51	170 3.54	68 1.92	... ...	.6 .01	... ...	534 ...	.73 ...	577 ...	278 ...	102 ...	38 ...	854 ...	... ...	2.1 ...
1954																					
August 25	a 200	15 ...	84 4.19	26 2.14	92 4.00	... ...	219 3.59	208 4.33	85 2.40	... ...	.2 .00	... ...	618 ...	.84 ...	334 ...	314 ...	134 ...	39 ...	975 ...	8.0 ...	2.3 ...
September 16	a 380	18 ...	82 4.09	20 1.64	86 3.75		235 3.85	179 3.73	67 1.89	... ...	.8 .01	... ...	569 ...	.77 ...	584 ...	290 ...	97 ...	40 ...	894 ...	7.8 ...	2.2 ...

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Federal Center, Denver, Colorado 80225

PRELIMINARY REPORT ON BUREAU OF MINES YELLOW CREEK CORE HOLE NO. 1, RIO BLANCO COUNTY, COLORADO

By

R. D. Carroll, D. L. Coffin, John R. Ege, and F. A. Welder

Abstract

Analysis of geologic, hydrologic, and geophysical data obtained in and around Yellow Creek core hole No. 1, Rio Blanco County, Colorado, indicate a 1,615-foot section of oil shale was penetrated by the hole. Geophysical log data indicate the presence of 25 gallons per ton shale for a thickness of 500 feet may be marginal. The richest section of oil shale is indicated to be centered around a depth of 2,260 feet. Within the oil shale the interval 1,182 to 1,737 feet is indicated to be relatively structurally incompetent and probably permeable. Extension of available regional hydrologic data indicate the oil shale section is probably water bearing and may yield as much as 1,000 gallons per minute. Hydrologic testing in the hole is recommended.

Introduction

At the request of the San Francisco office of the Atomic Energy Commission (SAN) the U.S. Geological Survey undertook to obtain pertinent data on the U.S. Bureau of Mines (USBM)- Atomic Energy Commission core hole No. 1, which penetrates oil shales of the Green River Formation in Rio Blanco County, Colorado. This project was accomplished in conjunction with personnel of the USBM and their cooperation is gratefully acknowledged. This report presents the results of a preliminary evaluation of available data with particular reference to the aforementioned drill hole. These data are the result of rapid analyses and should be considered subject to future refinement.

The density logs indicate two intervals wherein the yield averages in excess of 25 gallons per ton, in the Mahogany zone from 1,100 to 1,184 feet and near the bottom of the hole from 2,210 to 2,340 feet.

Average assays derived from the geophysical logs over several intervals centered on these sections are shown in table 3. If the method of obtaining oil assay relationships from the logs may be considered valid, the thickest and richest oil yield section is not in the vicinity of the Mahogany zone but at the base of the hole. The logs further indicate that the presence of a 500-foot section of oil shale assaying 25 gallons per ton is marginal. The actual laboratory oil assay is required to settle this question. The response of the geophysical logs, however, indicate a more detailed analysis between lithology, oil shale, and the response of the various logs is warranted pending core assay. This is true of all the logs as there are certain features which appear to be lithologically significant, particularly on the radiation logs.

Permeable zones

Permeable zones probably exist throughout the entire section of hole in both the Evacuation Creek and Parachute Creek Members. The drilling logs indicate permeability near 80 feet because of the presence of water in the returns. Without actual hydrologic testing in the hole, however, other permeable zones must be inferred from indirect evidence. This method of approach infers greater permeability with greater fracture frequency. On this basis the zone of poor core recovery (fig. 1) may be a likely permeable section.

Detailed analysis of the core indicates that this zone is included in Subunit C and Subunit D (figs. 1, 2, 3, and table 1). Subunit D (1,595 to 1,745 feet) should be the most porous and permeable interval in the hole. Subunit C (1,120 to 1,595 feet) is indicated to be the next most permeable and porous zone in the oil shale. Subunit A (770 to 1,020 feet) which spans the Evacuation Creek and oil shale contact has an index number close to Subunit C and hence should have a similar fracture porosity.

The interval between 1,745 and 2,545 (Subunit E) should be relatively impermeable. It is in unfractured, tight, and competent shale. In this core interval, however, the rock parts along shale-nahcolite boundaries, indicating potential zones of weakness.

The geophysical logs also indicate that the zone of poor core recovery is probably more fractured than is the rest of the oil shale section. This is most noticeable on the caliper logs. It is significant that this zone is also of relatively low resistivity and comparatively high radioactivity within the oil shale sequence. This, coupled with the high average neutron count rate in this zone, implies that processes other than increased fracturing have been operable in this section. A conclusion cannot be drawn on the preliminary data examined, however, the following processes which affect the various logs are presented for consideration:

Electric log decreased resistivity can be attributed to

(1) an increase in water content, other things being equal;

(2) an increase in water salinity, other things being equal;

(3) a decrease in the path length available for electrolytic conduction in the rock, or the converse, an increase in the number of path lengths (porosity) available for electrolytic conduction; or

(4) combinations of (1), (2), and (3).

Gamma-ray log increased count rate can be attributed to a relatively greater concentration of radioactive materials in these sections because of preferential environmental features, e.g., adsorption during deposition; or preferential removal of radioactive material from adjacent zones. The deposition of radioactive material by incoming ground waters is another possible mechanism.

The increased neutron log count rate indicates a decreased hydrogen content in these zones. In most lithologies this may be attributed to a decrease in water content, however, the relative abundance of hydrocarbons is another contributing factor to the hydrogen content in the oil shale. A general relationship between leaness of oil shale and neutron count rate was found by Bardsley and Algermissen (1963). Further analysis of all logs is considered desirable in this hole when more detailed data on the core is available.

The above considerations coupled with examination of the geophysical logs (fig. 1) of the zone of poor core recovery indicate that this zone merits a more detailed examination regionally. This is further substantiated by data pertaining to regional structure.

Water-bearing zones, flow rates, and regional distribution of water-bearing formations

Yellow Creek No. 1 Core Hole penetrated the three major aquifers in the northern part of the Piceance Creek Basin (here considered to be that part of the basin in Rio Blanco County). From top to bottom they are: alluvium and the Evacuation Creek and Parachute Creek Members of the Green River Formation. The distribution of these formations is shown in figure 5 (in pocket). These three aquifers yield water to many springs throughout the basin, and, although only a few wells have been drilled, preliminary data indicate that wells tapping the alluvium may yield as much as 1,000 gpm (gallons per minute), wells tapping the Evacuation Creek Member may yield as much as 100 gpm, and wells tapping the Parachute Creek Member may yield as much as 1,000 gpm. Permeable zones in the upper part of the alluvium may be above the water table, permeable zones in the Evacuation Creek Member topographically above the floor of the major stream valleys may be largely drained, and permeable zones in the Parachute Creek Member are probably saturated except near the edges of the basin.

In the Evacuation Creek and Parachute Creek Members in the northern part of the basin, regional movement of ground water is from the highlands near the edges of the basin toward the two major streams draining the basin, Piceance and Yellow Creeks. The ground-water reservoir in these two members is recharged solely from precipitation and probably eventually discharges into the alluvium along Piceance and Yellow Creeks, where the water leaves the basin either by streamflow or by evaporation and transpiration.

Parachute Creek Member.--The Parachute Creek Member is composed almost entirely of oil shale. Oil shale is relatively impermeable; however, the rock is fractured, and springs and seeps issuing from the fractures at the surface indicate water movement through the fractures, at least near the surface. Yields from the springs range from a few gallons per minute to about 500 gpm. Subsurface fracturing is indicated by zones of poor core recovery and recovered core that contains fractures. Water movement through the fractures is indicated by oxidization (bleaching) along the faces of the fractures and by deposition of carbonate minerals in and along the fractures. Further evidence for fracturing and water movement in the subsurface is indicated from abandoned oil-test wells that have been completed as water wells. Data are incomplete from these wells, but the casing records show that the wells were cased and cemented to slightly below the uppermost oil-shale beds and plugged above the lowermost oil-shale beds. Three of these wells (A, B, and C of fig. 5) were tested. A summary of the test results (table 4) shows the range of transmissibility of the Parachute Creek Member is small; however, additional tests may show a greater range. Until more data become available it may be assumed that the coefficient of transmissibility represents the transmissibility of the uncased and unplugged portion of the Parachute Creek Member. Because core recovery and well logs indicate that generally the entire thickness of the Parachute Creek Member is not fractured, the determined transmissibility probably represents only the fracture zones that contribute water to wells.

Table 4.--Summary of the results of aquifer tests in the Parachute Creek Member of the Green River Formation

Location	Water-bearing formation	Coefficient of transmissibility (gallons per day per foot)	Head at end of recovery period (in feet of water above land surface)	Duration of recovery period (days)	Average discharge (gallons per minute)	Duration of discharge (days)
A-Sec. 10, T.1S., R. 96W.	Parachute Creek Member, Green River Formation	2,000	22.8	1.0	57	135
B-Sec.10, T.3S., R.96 W..	do.	2,000	87.8	2.1	230	.92
C-Sec. 11, T.3S., R.96 W.	do.	1,000	1/ 2.5	.78	64	1.0

1/ Discharge point is 2.5 feet above land surface, well flows 20 gpm. Well was tested by pumping at 64 gpm and measuring recovery of water level after pumping stopped.

Present data are insufficient to define the contribution of water from various zones of the Parachute Creek Member.

Fractures in the Parachute Creek Member not only contribute water to wells and springs but also cause poor core recovery and lost circulation. Lost circulation, however, was not a serious problem during the drilling of Yellow Creek No. 1 Core Hole into the Parachute Creek Member. The small losses of drilling fluid were easily controlled by adding cedar shavings and cellophane strips to the drilling fluid. In other areas of the northern part of the Piceance Creek Basin, lost circulation in the Parachute Creek Member has been a serious problem and has caused at least two oil-test wells to be abandoned before the objective horizon was reached.

Throughout the area water from the Parachute Creek Member is of the sodium bicarbonate type. Measured conductivity ranges from 300 to 20,000 micromhos per centimeter at 25°C. The lower values are from springs near the edges of the basin and the higher values from springs or wells near the discharge points along Yellow or Piceance Creeks. Fluoride ranges from 0.1 ppm (parts per million) to 30 ppm. Chloride, boron, nitrate, and phosphate are present only in small amounts.

Evacuation Creek Member.--The Evacuation Creek Member is composed mainly of sandstone, barren marlstone, and siltstone. The sandstone is fine to medium grained, cemented with calcite, and is probably of relatively low permeability. The barren marlstone and siltstone are probably relatively impermeable except where fractured. Many of the exposed fractures of this member have been filled with clay-sized material or calcite.

The Evacuation Creek Member forms the surface rock over most of the basin. Downcutting by streams has formed a rough hilly topography, and the part of the member topographically higher than the level of the streams is mostly drained. Water wells are usually drilled in the valleys and usually must penetrate at least 100 feet of the member to yield sufficient water for domestic or stock supplies.

In Yellow Creek No. 1 core hole, the upper 90 feet of the Evacuation Creek Member was air drilled. During the drilling, from 50 to 100 gpm of water was blown to the surface with the cuttings. When drilling reached a depth of about 135 feet below land surface, drilling mud was used and formation water stopped coming into the hole. In drilling through the Evacuation Creek Member, drilling-mud losses were small and were controlled by the addition of cedar shavings and cellophane.

Water from the Evacuation Creek Member is of the magnesium, calcium, bicarbonate type; generally magnesium is equal to or greater than calcium. Amounts of sulfate are small and the amount of chloride is very low. Measured conductivity ranges from 1,000 to 2,500 micromhos per centimeter.

Alluvium.--The alluvium along Piceance and Yellow Creeks is generally poorly sorted sand, gravel, clay, and silt. Sorting generally becomes better and grain size larger near the base of the alluvium; in some places beds of clay compose the upper 50 to 80 feet. The thickness of the alluvium is as much as 130 feet, and the saturated thickness may be as much as 100 feet. Measured transmissibility ranges from 20,000 gpd per ft (gallons per day per foot) to 150,000 gpd per ft. Maximum well yields are estimated to be as much as 1,000 gpm.

The alluvium of the valleys tributary to Piceance and Yellow Creek generally is thinner, and saturated thickness is less than in the main valleys. The lithology is similar in the tributary and main valleys, but well yields would probably be less in the tributary valleys.

Along Piceance Creek and along the lower reaches of Yellow Creek, water in the alluvium moves toward and eventually discharges into the stream. Along the upper and middle reaches of Yellow Creek and along most of the tributaries, the water table is below the level of the streambed and flood flows percolate to the water table.

Drilling into the alluvium is almost always accompanied by lost-circulation problems. The permeability of the sand and gravel is relatively high, and even above the water table losses of drilling fluid are common. Heavy drilling mud and the addition of lost-circulation material are often sufficient to allow penetration of the alluvium, but all wells must be cased through the alluvium.

The 45 feet of alluvium penetrated by Yellow Creek No. 1 core hole was partly responsible for a four-day delay in drilling because circulation could not be maintained. Heavy drilling mud, cedar shavings, and cellophane strips did not stop fluid losses, and the problem was finally solved by air drilling.

Water in the alluvium generally is of the sodium bicarbonate type. Measured conductivity of water increases downstream and ranges from 700 micromhos per centimeter where Piceance Creek enters the basin to about 10,000 micromhos per centimeter near the mouth of Piceance Creek. Along Yellow Creek in the vicinity of Yellow Creek No. 1 core hole the conductivity is about 2,500 micromhos per centimeter.

Joint system

Aerial photographs taken of the ground around the drill site show lineations and drainage features which are interpreted as joints. Two strong joint trends and a minor trend were measured. The two strongest joint sets had average strikes of N. 32° E. and N. 48° W. The weaker trend averaged N. 6° E. Donnell (1961) describes a well-defined system of northwest and northeast-trending joints being present in the Green River strata. Welder (USGS, oral communication) described most of the oil shale joints at the surface as being of the high-angle type. The core indicates that the majority of the naturally occurring joints in the rock are high angle, i.e., greater than 60° dip. The near-horizontal bedding plane fractures in the core may be a combination of both naturally occuring joints and induced fractures caused by drilling stresses.

A statistical analysis of only the high-angle core fractures in the engineering subunits suggest the joint spacing in the rock (listed in table 5). These analyses are speculative and cannot be demonstrated, however, they may indicate relative joint intensities. The intersection of the two major high-angle northeast and northwest joint sets are assumed to produce rhombohedral-shaped blocks. Neither the minor N. 6° E. joints nor the effect of bedding plane fractures has been considered in table 5.

UNITED STATES
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PRELIMINARY REPORT ON THE GEOLOGY, GEOPHYSICS, AND HYDROLOGY OF USBM/AEC COLORADO CORE HOLE NO. 2, PICEANCE CREEK BASIN, RIO BLANCO COUNTY, COLORADO

By

John R. Ege, R. D. Carroll, and F. A. Welder

Abstract

Approximately 1,400 feet of continuous core was taken between 800-2,214 feet in depth from USBM/AEC Colorado core hole No. 2. The drill site is located in the Piceance Creek basin, Rio Blanco County, Colorado. From ground surface the drill hole penetrated 1,120 feet of the Evacuation Creek Member and 1,094 feet of oil shale in the Parachute Creek Member of the Green River Formation. Oil shale yielding more than 20 gallons per ton occurs between 1,260-2,214 feet in depth. A gas explosion near the bottom of the hole resulted in abandonment of the exploratory hole which was still in oil shale. The top of the nahcolite zone is at 1,693 feet. Below this depth the core contains common to abundant amounts of sodium bicarbonate salt intermixed with oil shale. The core is divided into seven structural zones that reflect changes in joint intensity, core loss and broken core due to natural causes. The zone of poor core recovery is in the interval between 1,300-1,450 feet.

Results of preliminary geophysical log analyses indicate that oil yields determined by Fischer assay compare favorably with yields determined by geophysical log analyses. There is strong evidence that analyses of complete core data from Colorado core holes No. 1 and No. 2 reveal a reliable relationship between geophysical log response and oil yield.

The quality of the logs is poor in the rich shale section and the possibility of repeating the logging program should be considered.

Observations during drilling, coring, and hydrologic testing of USBM/AEC Colorado core hole No. 2 reveal that the Parachute Creek Member of the Green River Formation is the principal aquifer and the

water in the Parachute Creek Member is under artesian pressure. The upper part of the aquifer has a higher hydrostatic head than, and is hydrologically separated from, the lower part of the aquifer. The transmissibility of the aquifer is about 3500 gpd per foot. The maximum water yield of the core hole during testing was about 500 gpm. Chemical analyses of water samples indicate that the content of dissolved solids is low, the principal ions being sodium and bicarbonate. Although the hole was originally cored to a depth of 2,214 feet, the present depth is about 2,100 feet.

This report presents a preliminary evaluation of core examination, geophysical log interpretation and hydrological tests from the USBM/AEC Colorado core hole No. 2. The cooperation of the U.S. Bureau of Mines is gratefully acknowledged. The reader is referred to Carroll and others (1967) for comparison of USBM/AEC Colorado core hole No. 1 with USBM/AEC Colorado core hole No. 2.

HYDROLOGY

By

F. A. Welder

Introduction

Drilling of the USBM/AEC Colorado core hole No. 2 began June 24, 1966, using compressed air at 90 psi. Air, cuttings, and fluid were discharged through a horizontal pipe 80 feet long and 6 inches in diameter. The hole was dry to 307 feet, where the cuttings became damp enough to plug the hole. Air pressure was then increased to 300 psi, and a mixture of soap and water was injected at about 3 gpm. This rate of water injection was maintained until total depth was reached except while water samples were being collected or discharge was being measured. The upper 411 feet of the hole is cased with 7-5/8-inch (O.D.) steel pipe.

The first noticeable discharge of ground water during drilling, about 1 gpm, was at 447 feet (table 4). Between 957 and 1,026 feet, the discharge increased from 30 to 153 gpm, as measured by a container and stop watch. During drilling below 1,161 feet, discharge was measured by a 9-inch Parshall flume 100 feet downhill from the end of the discharge pipe. Because of leakage, evaporation, and infiltration, discharge figures obtained with the flume may be 10 percent low.

Discharge rate, temperature, and specific conductance of water discharged with the cuttings were plotted against well depth (fig. 4).

Table 4.--Specific conductance, temperature and discharge rate of water during coring of USBM/AEC Colorado core hole No. 2
(Dash (-) shows that measurement was not made)

Date 1966	Well depth below Kelly bushing (ft)	Specific conductance micromhos per cm	Temp. (°F)	Discharge (gpm)	Other
6-25	447	1500	-	1	First water.
6-26	805	1000	57	25	150-minute recovery shows transmissibility less than 100 gpd per ft.
6-28	957	950	63	30	
6-29	1026	1000	63	153	
6-29	1032	1100	63	260	
6-30	1161	960	65	220	Installed 9-inch flume. Some water is lost by evaporation, leakage, and infiltration.
7-2	1211	975	64	250	
7-2	1290	875	65	315	
7-4	1385	990	68		
7-5	1423	990	67	420	
7-5	1456	950	69	435	Static water level about 290 ft below KB.
7-6	1517	990	68	460	
7-7	1570	1000	70	460	
7-8	1673	1000	69	490	
7-9	1758	1000	70	460	
7-10	1857	1000	70	450	
7-12	1990	1650	73	460	Water contains some gas.
7-13	1990	-	-	-	Static water level 315 ft below KB. 7 hours not pumping.
7-13	2089	1900	74	510	
7-14	2214	-	-	-	Total depth--unable to log below 2169 on 7-17-66.
7-17	2169-2214	-	-	-	Static water level 314 ft below KB after 10 hrs of no pumping. Started pumping test at 9:30 AM.
7-17	2169-2214	2200	76	450	After 7 hours of pumping recovery was started at 4:30 PM.

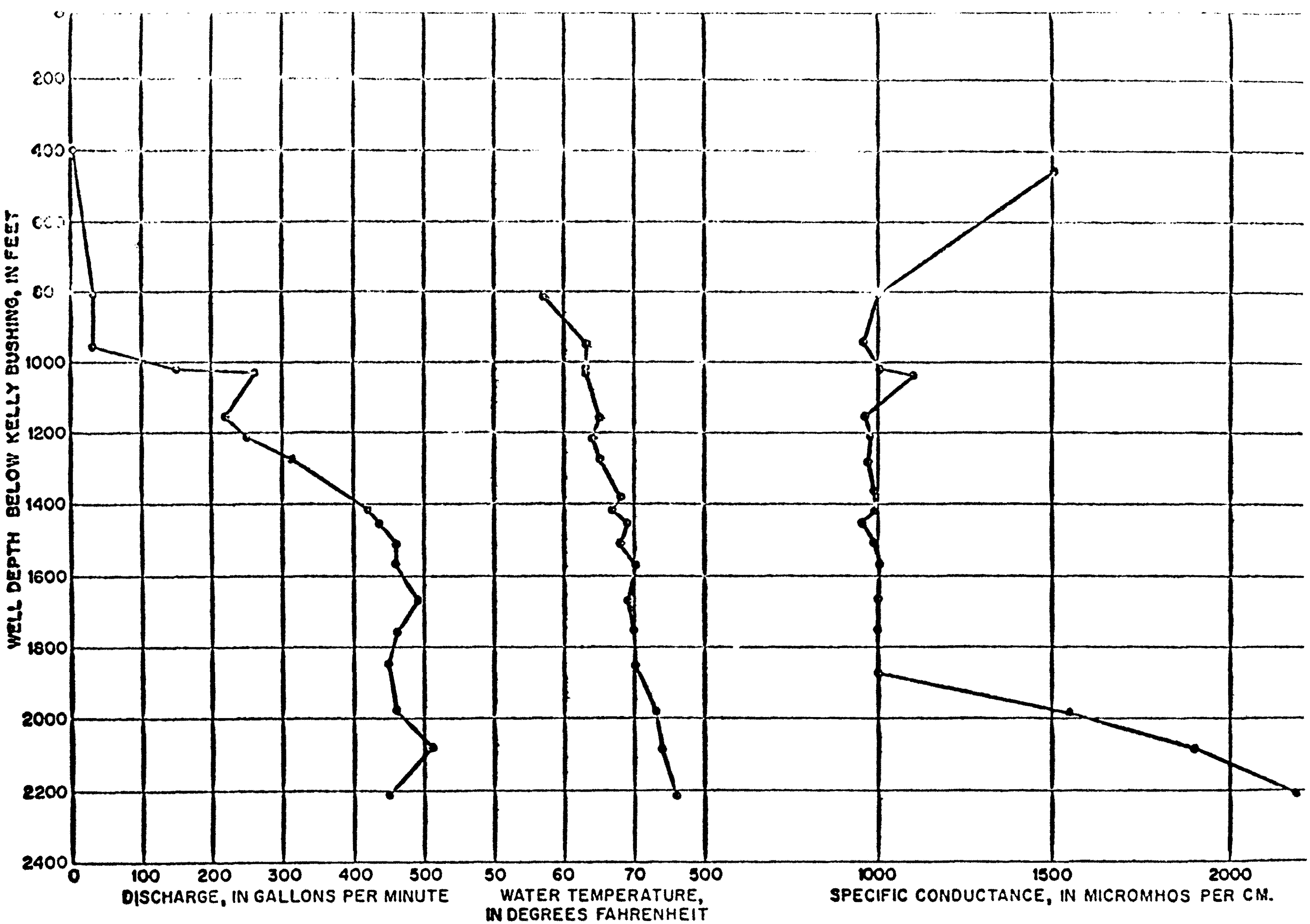


FIGURE 4.- Graph showing relation of water discharge, water temperature, and specific conductance to well depth, U.S.B.M./A.E.C. Colorado core hole

Between depths of 957 and 1,673 feet, the rate of increase of discharge was greatest. During drilling below 1,673 feet, the rate of discharge remained fairly constant--although water was entering the hole below 1,673 feet, as indicated by the rise in water temperature and specific conductance with depth.

The hole was cored to 2,214 feet, but the explosion near the bottom of the hole caused a cave-in. Coring was stopped after the explosion, but geophysical logging was subsequently completed, showing a depth of 2,169 feet. On August 21, 1966, the current-meter survey showed a depth of 2,100± feet.

The well was pumped by compressed air under 500 psi for 7 hours on July 17, 1966. After the compressors were turned off, water-level recovery was measured at regular intervals for 1,000 minutes. The water level was plotted against the log of time elapsed since pumping ceased (fig. 5) and the transmissibility was computed to be 2,400 gpd per foot.

Pumping tests using packers

From August 27 to August 30, 1966, pumping tests were made using two packers to seal off a 300-foot section of the hole. A Reda submergible pump was set 5 feet below the top packer and pumped from the interval between packers. Pumping tests were made under the following conditions: No. 1, packers set at depths of 900 and 1,200 feet; No. 2, packers set at depths of 1,198 and 1,498 feet; No. 3, upper

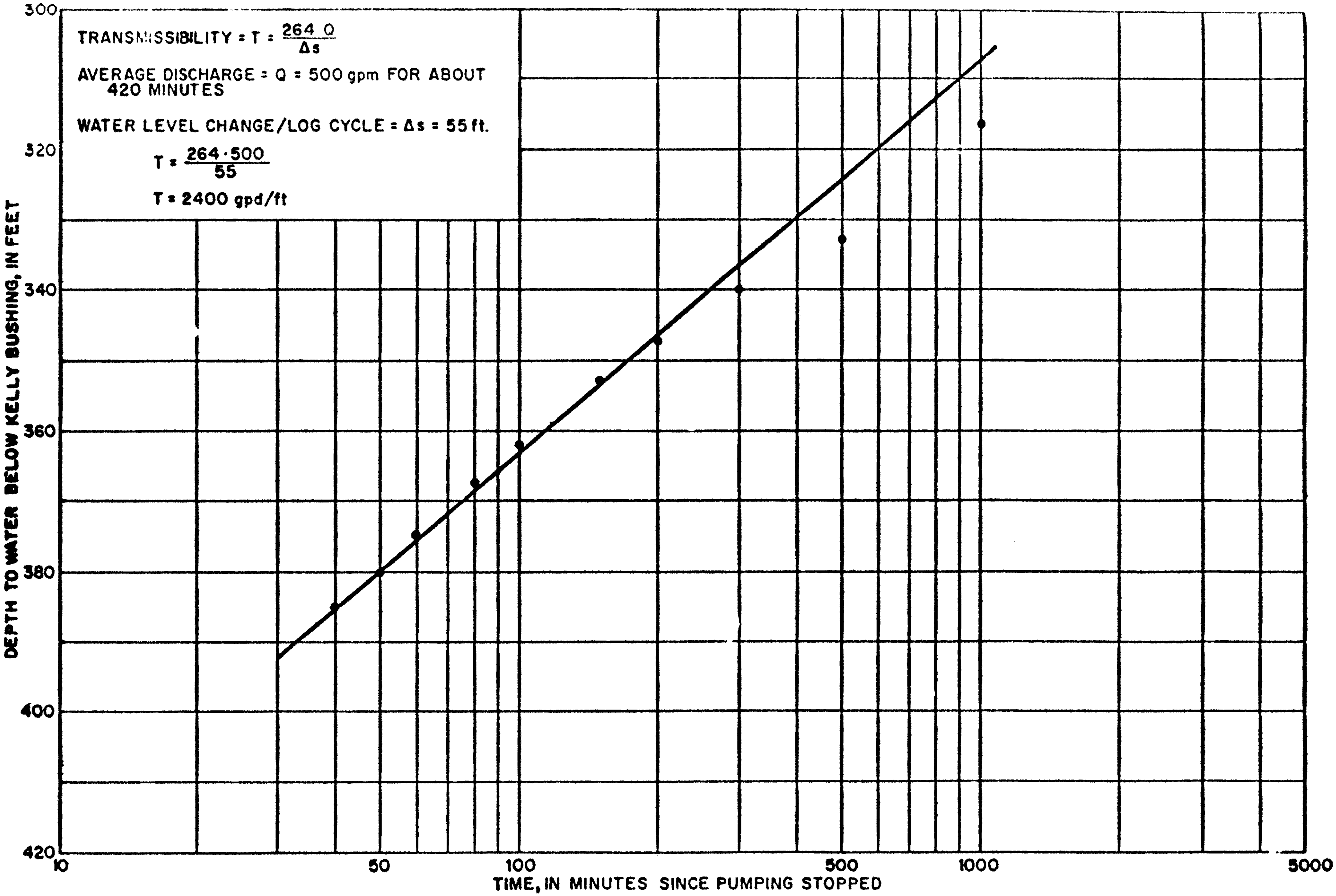


FIGURE 5.- Semilogarithmic graph of recovery data, after pumping open hole between casing and total depth (411'-2100'±) U.S.B.M./A.E.C. Colorado core hole No. 2, July 17, 1966.

packer set at 1,500, lower packer not used; No. 4, tested entire hole (below casing to total depth) without using packers. Water temperature, in degrees Fahrenheit, and specific conductance in micromhos per centimeter were taken periodically throughout each test.

Test No. 1.--Packers set at 900 and 1,200 feet. Water-level measurements were made in the zone between the bottom of the casing and the upper packer (411-900 feet), in the zone between the packers (900-1,200 feet), and in the zone between the bottom packer and total depth (1,200-2,100± feet), during both the pumping and recovery phases of the test (table 5). As soon as pumping started, water levels began to fall in the zone between the bottom of the casing and the upper packer and the zone between the packers (fig. 6), indicating that there is hydraulic connection between the zones. Between 150 and 200 minutes after pumping started, the water level in the zone between the casing and the upper packer rose 26 feet.

In the zone between the bottom packer and total depth, the water began to decline slowly 8 minutes after pumping started and after 30 minutes declined rapidly. The decline continued throughout the test, probably because the lower packer shut off recharge from a higher zone.

Table 5

Water-level measurements during test No. 1, USBM/AEC Colorado core hole No. 2

August 27, 1966

Time (min)	Zone between casing and upper packer (411- 900 ft)		Zone between packers (900-1200 ft)				Zone between bottom packer and total depth (1200 - 2100 ± ft)			
	Electric line depth to water below measuring point (ft)	Change in water level (drawdown) (ft)	Air gauge pressure on 900 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (drawdown) (ft)	Air gauge pressure on 1200 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (drawdown) (ft)
a	b	c	d	e	f	g	h	i	j	k
Pump on: August 27, 1966, 11:00 a.m., average discharge, 94 gpm from zone between packers										
0	249.2	0	255	0	311	0	356	0	378	0
2	294.3	45.1	242	13	341	30	356	0	378	0
4	304.5	55.3	240	15	346	35	356	0	378	0
6	309.6	60.4	238	17	340	39	356	0	378	0
8	312.1	62.9	236	19	355	44	356	0	378	0
10	313.5	64.3	235	20	357	46	355	1	380	2
12	314.1	64.9	235	20	357	46	355	1	380	2
15	314.6	65.4	235	20	357	48	355	1	380	2
20	317.0	67.8	234	21	359	51	355	1	380	2
25	318.2	69.0	233	22	362	51	355	1	380	2
30	318.9	69.7	233	22	362	53	355	1	380	2
40	320.3	71.1	232	23	364	53	354	2	382	5
50	321.4	72.2	232	23	364	53	353	3	385	7
60	322.3	73.1	232	23	364	53	353	3	385	7

Table 5
Water-level measurements during
test No. 1, USBM/AEC Colorado core hole No. 2 (continued)
August 27, 1966

Time (min)	Zone between casing and upper packer (411 - 900 ft)		Zone between packers (900-1200 ft)				Zone between bottom packer and total depth (1200 - 2100 ± ft)			
	Electric line depth to water below measuring point (ft)	Change in water level (drawdown) (ft)	Air gauge pressure on 900 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (drawdown) (ft)	Air gauge pressure on 1200 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (drawdown) (ft)
a	b	c	d	e	f	g	h	i	j	k
80	323.4	74.2	232	23	364	53	351	5	390	12
100	325.9	76.7	232	23	364	53	350	6	392	14
150	328.1	78.9	230	25	368	57	347	9	399	21
200	302.7	53.5	230	25	368	57	343	13	418	30
300	305	55.8	232	23	364	53	336	20	424	46
400	306.1	56.9	232	23	364	53	331	25	436	58
Pump off: August 27, 1966, 5:40 p.m.										
		(Residual drawdown)				(Residual drawdown)				(Residual drawdown)
0	306.1	56.9					334	22	430	51
2	292.0	42.8	232	23	364	53	333	23	432	53
4	289.8	40.6	232	23	364	53	333	23	432	53
6	288.4	39.2	232	23	364	53	333	23	432	53
8	287.6	38.4	232	23	364	53	333	23	432	53
10	286.8	37.6	232	23	364	53	333	23	432	53
12	286.2	37.0	232	23	364	53	333	23	432	53

Table 5
Water-level measurements during
test No. 1, USBM/AEC Colorado core hole No. 2 (continued)
August 27, 1966

Time (min)	Zone between casing and upper packet (41[illegible]-900 ft)		Zone between packers (900-1,200 ft)				Zone between bottom packer and total depth (1,200-2,100± ft)			
	Electric line depth to water below measuring point (ft)	Change in water level (Residual drawdown) (ft)	Air gauge pressure on 900 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (Residual drawdown) (ft)	Air gauge pressure on 1,200 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (Residual drawdown) (ft)
a	b	c	d	e	f	g	h	i	j	k
15	285.5	36.3	232	23	364	53	333	23	432	53
20	284.6	35.4	232	23	364	53	331	25	436	58
25	283.9	34.7	234	21	359	51	331	25	436	58
30	283.3	34.1	234	21	359	51	331	25	436	58
40	282.4	33.2	235	20	357	48	330	26	439	60
60	281.2	32	-	-	-	-	-	-	-	-
80	280.4	31.2	235	20	357	48	327	29	445	67
100	279.8	30.6	235	20	357	48	326	30	447	69
150	278.8	29.6	235	20	357	48	326	30	447	69
200	278.2	29.0	235	20	357	48	319	37	464	85
300	277.4	28.2	235	20	357	48	312	44	480	102

NOTE: To convert air gauge pressure to depth to water in feet:

Water level in feet below measuring point = length of airline in feet - (pressure in pounds per square inch X 2.31 feet of water per pound per square inch)

Drawdown in feet of water = pressure change in pounds per square inch X 2.31 feet of water per pound per square inch.

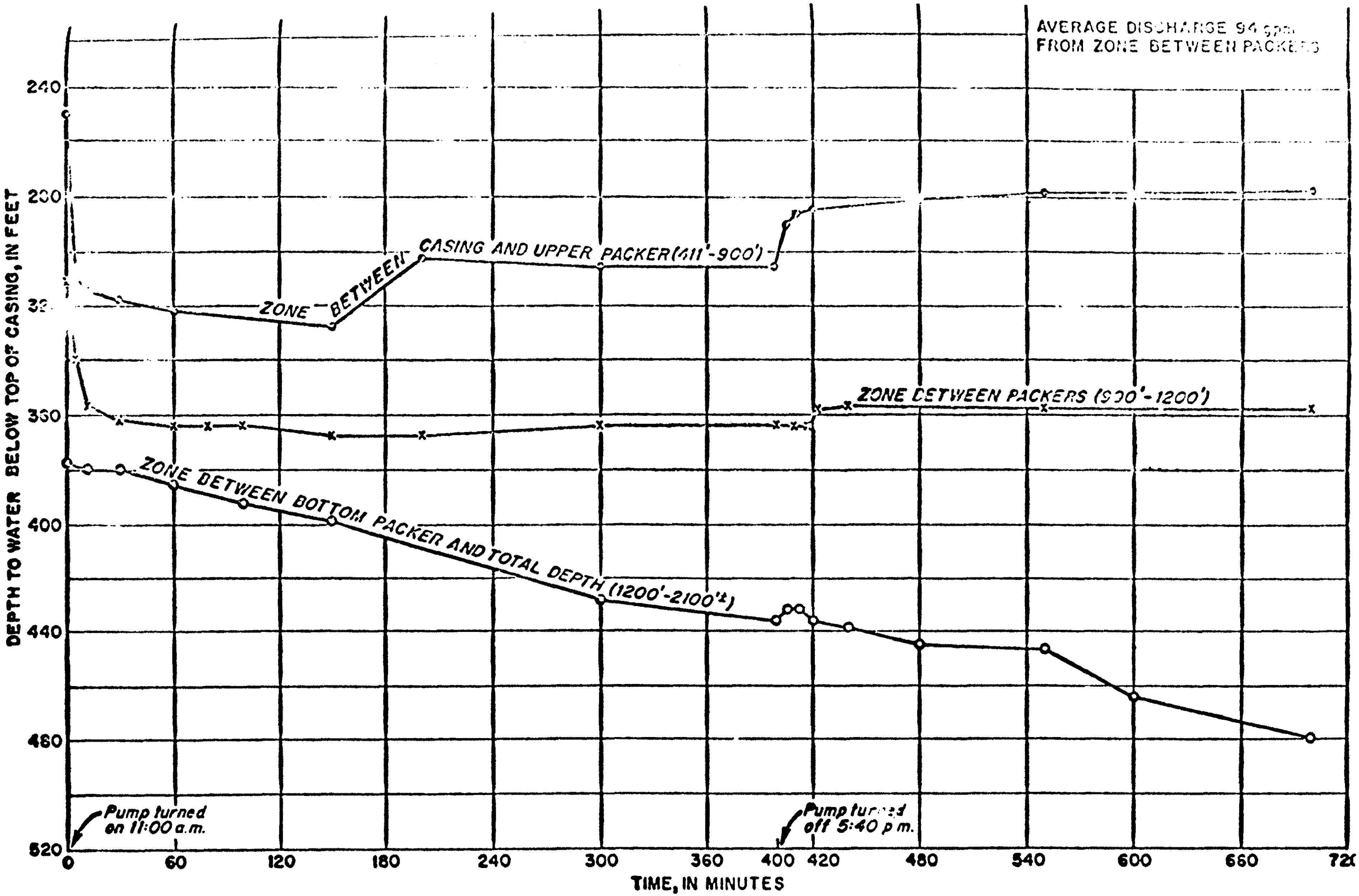


FIGURE 6.- Water-level measurements during test No. 1, U.S.B.M./A.E.C. Colorado core hole No. 2, August 27, 1966.

Well discharge, water temperature, and specific conductance are shown below:

Time in minutes since pumping started	Discharge (gpm)	Specific conductance (micromhos per cm)	Temperature (°F)
30	93.4	1,000	65
100	88.8	1,000	66
150	88.8	1,000	67
300	97.4	1,000	68
370	97.4	950	69.5
390	97.4	950	68
Average	94		

Test No. 2.--Packers set at 1,198 and 1,498 feet. Water-level measurements were made in the zone between the bottom of casing and the upper packer (411-1,198 feet), the zone between the packers (1,198-1,498 feet), and the zone between the bottom packer and total depth (1,498-2,100± feet), during both the pumping and recovery phases of the test (table 6).

During pumping, the water level in the zone between the bottom of the casing and the upper packer, recovered consistently (fig. 7). This was probably due to the fact that leakage from the upper zone to a lower zone was shut off by the packer. Water level in the zone between the packers declined during pumping and recovered after pumping started.

The water level in the zone between the bottom packer and total depth declined throughout the test except for a slight recovery immediately after pumping ceased. The decline probably was the result of recharge from a higher zone being shut off by the packers.

Table 6

Water-level measurements during
test No. 2, USBM/AEC Colorado core hole No. 2
August 28, 1966

Time (min)	Zone between casing and upper packer (411-1193 ft)		Zone between packers (1193-1498 ft)				Zone between bottom packer and total depth (1498 - 2100 ± ft)			
	Electric line depth to water below measuring point (ft)	Change in water level (recovery) (ft)	Air gauge pressure on 900 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (drawdown) (ft)	Air gauge pressure on 1500 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (drawdown) (ft)
a	b	c	d	e	f	g	h	i	j	k
Pump on: August 28, 1966, 3:00 p.m., average discharge 88.8 gpm from zone between packers										
0	274.5	0.0	398	0	278	0	464	0	426	0
2	261.3	13.2	390	8	297	18.5	462	2	431	4.5
4	256.0	18.5	385	13	308	30	461	3	433	7
6	255.1	19.4	381	17	318	39	461	3	433	7
8	254.5	20.0	379	19	323	43	460	4	435	9
10	254.0	20.5	378	20	325	46	460	4	435	9
12	253.5	21.0	377	21	328	47	460	4	435	9
15	252.9	21.6	378	20	325	46	459	5	438	12
20	252.1	22.4	378	20	325	46	459	5	438	12
25	251.5	23.0	377	21	328	47	458	6	440	14
30	251.0	23.5	376	22	330	51	457	7	443	16
40	250.0	24.5	374	24	334	55	456	8	446	18
50	249.4	25.1	373	25	336	58	454	10	449	23

Table 6

Water-level measurements during test No. 2, USBM/AEC Colorado core hole No. 2 (continued)

August 28, 1966

Time (min)	Zone between casing and upper packer (411-1198 ft)		Zone between packers (1198-1498 ft)				Zone between bottom packer and total depth (1498 - 2100 ± ft)			
	Electric line depth to water below measuring point (ft)	Change in water level (recovery) (ft)	Air gauge pressure on 900 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (drawdown) (ft)	Air gauge pressure on 1500 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (drawdown) (ft)
a	b	c	d	e	f	g	h	i	j	k
60	248.8	25.7	372	26	339	60	453	11	451	25
80	247.9	26.6	372	26	339	60	451	13	557	30
100	247.1	27.4	372	26	339	60	450	14	458	32
150	245.8	28.7	371	27	341	62	446	18	469	42
200	244.8	29.7	369	29	346	67	440	24	483	55
250	244.0	30.5	367	31	350	72	439	25	485	58
300	243.4	31.1	365	33	354	76	435	29	490	67
						(Residual drawdown)				(Residual drawdown)
Pump off: August 28, 1966, 8:00 p.m.										
2	243.4	31.1	368	30	348	69	440	24	483	55
4	243.4	31.1	368	30	348	69	439	25	485	58
6	243.4	31.1	369	29	346	67	439	25	485	58
8	-	-	370	28	343	65	438	26	486	53
12	243.4	31.1	372	26	339	60	440	24	483	56

Table 6

Water-level measurements during test No. 2, USBM/AEC Colorado core hole No. 2 (continued)

August 28, 1966

Time (min)	Zone between casing and upper packer ([illegible]-1198 ft)		Zone between packers (1198-1498 ft)				Zone between bottom packer and total depth (1498 - 2100 ± ft)			
	Electric line depth to water below measuring point (ft)	Change in water level (recovery) (ft)	Air gauge pressure on 500 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (drawdown) (ft)	Air gauge pressure on 1500 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (drawdown) (ft)
a	b	c	d	e	f	g	h	i	j	k
						(residual drawdown)				(residual drawdown)
15	243.4	31.1	372	26	339	60	440	24	483	56
20	-	-	373	25	336	58	439	25	485	53
25	-	-	372	26	339	60	439	25	485	58
30	-	-	371	27	341	62	437	27	489	62
40	243.1	31.4	371	27	341	62	433	31	493	72
50	-	-	371	27	341	62	432	32	500	74
60	-	-	375	23	332	53	429	35	508	81
80	243.0	31.0	375	23	332	53	426	38	514	88
100	-	-	372	26	339	60	424	40	518	93
150	242.2	32.3	371	27	341	62	419	45	528	102
200	241.9	32.6	370	28	343	65	414	50	539	113
300	241.1	33.4	370	28	343	65	405	59	562	136

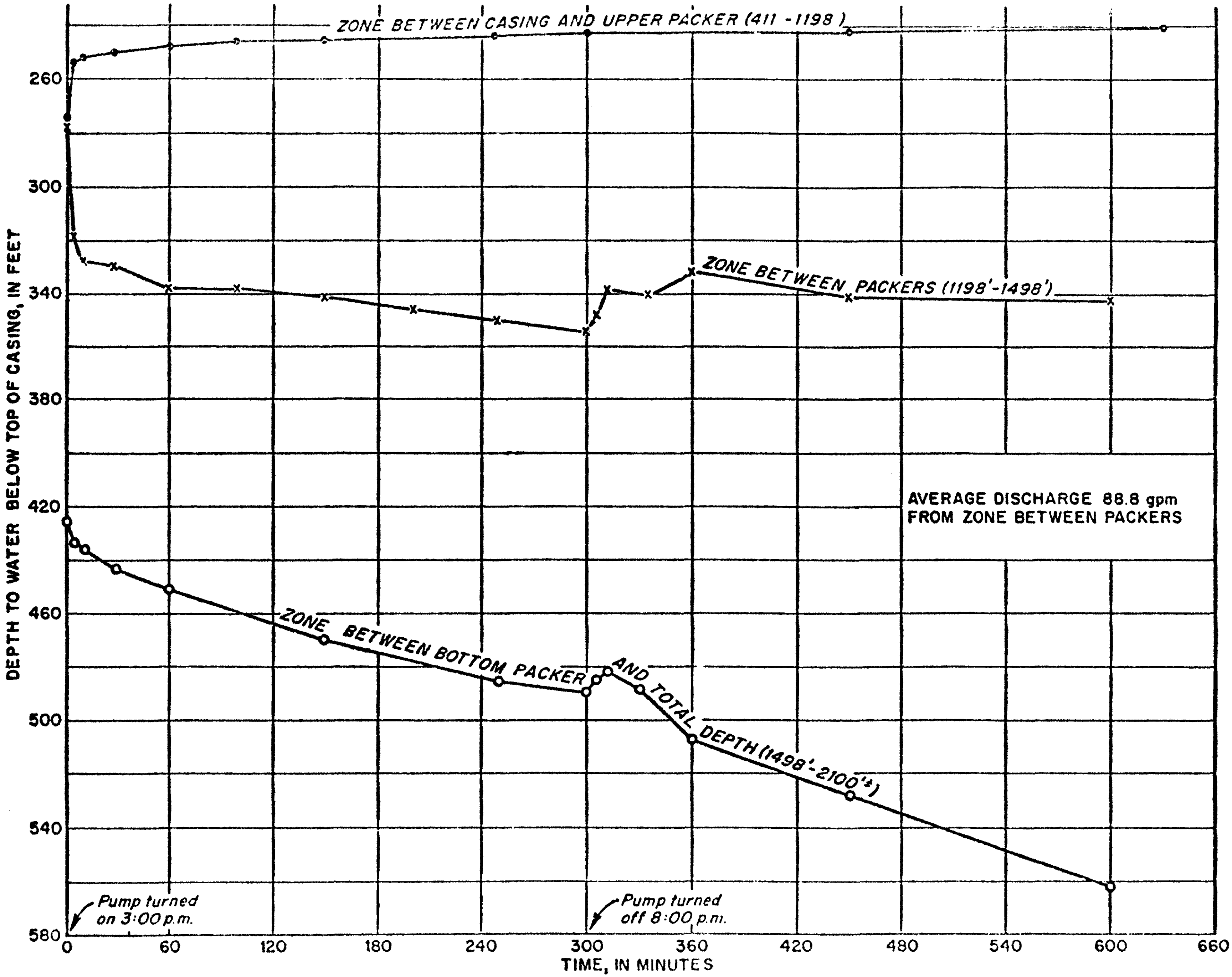


FIGURE 7.-Water-level measurements during test No. 2, U.S.B.M./A.E.C. Colorado core hole No. 2, August 28, 1966.

Well discharge, water temperature, and specific conductance are shown below:

Time in minutes since pumping started	Discharge (gpm)	Specific conductance (micromhos per cm)	Temperature (°F)
15	88.8	1,000	69
30	88.8	900	70
50	88.8	950	71.5
80	88.8	950	73
150	88.8	925	74
200	---	950	73.5
290	---	900	74
Average	88.8		

Test No. 3.--The upper packer set at 1,500 feet, and the lower packer not used. The core hole from 1,500 to total depth was pumped during the test (table 7). Water level in the zone above the upper packer rose gradually throughout the test, suggesting that the packer was holding and that hydrologic connection was negligible (fig. 8).

Well discharge, water temperature, and specific conductance are shown below.

Time in minutes since pumping began	Discharge (gpm)	Specific conductance (micromhos per cm)	Temperature (°F)
13	84.8	950	67
23	80.3	950	68
40	80.3	950	69.5
80	72.7	1,050	71
150	72.7	950	72
250	68.7	1,000	72
300	79	1,000	73
Average	74		

Table 7
Water-level measurements during
test No. 3, USBM/AEC Colorado core hole No. 2
August 29, 1966

Time (min)	Zone between casing and upper packer (411-1500 ft)		Zone between packer and total depth (1500 - 2100 ± ft)			
	Electric line depth to water below measuring point (ft)	Change in water level (recovery) (ft)	Air gauge pressure on 1500 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (drawdown) (ft)
a	b	c	d	e	f	g
Pump on: August 29, 1966, 1:00 p.m., average discharge 74 gpm from zone between the packer and total depth.						
0	260.1	0	391	0	597	0
2	259.8	0.3	387	4	606	9
4	259.6	.5	385	6	611	14
6	259.5	.6	384	7	613	16
8	259.3	.8	383	8	616	19
10	259.1	1.0	382	9	618	21
12	259.0	1.1	382	9	618	21
15	258.8	1.3	381	10	621	23
20	258.5	1.6	381	10	621	23
25	258.2	1.9	380	11	622	25
30	258.0	2.1	379	12	625	28
40	257.5	2.6	378	13	627	30
50	257.1	3.0	377	14	629	32
60	256.8	3.3	376	15	632	35

Table 7
Water-level measurements during
test No. 3, USBM/AEC Colorado core hole No. 2 (continued)
August 29, 1966

Time (min)	Zone between casing and upper packer (411-1500 ft)		Zone between packer and total depth (1500 - 2100 ± ft)			
	Electric line depth to water below measuring point (ft)	Change in water level (recovery) (ft)	Air gauge pressure on 1500 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (drawdown) (ft)
a	b	c	d	e	f	g
80	256.1	4.0	374.5	16.5	635	38
100	255.6	4.5	373.5	17.5	638	41
150	254.8	5.3	368	23	650	53
200	254.0	6.1	363.5	27.5	661	64
250	253.4	6.7	359.5	31.5	669	72
300	- -	- -	356	35	678	81
Pump off: August 29, 1966, 6:00 p.m.						(recovery)
0	253.4	6.7	356	35	678	81
2	252.9	7.2	359	32	671	74
4	- -	- -	361	30	666	69
6	252.8	7.3	363	28	662	65
10	- -	- -	367	24	652	55
12	- -	- -	369	22	648	51
15	- -	- -	372	19	640	43
20	- -	- -	374	17	636	39

Table 7
Water-level measurements during
test No. 3, USBM/AEC Colorado core hole No. 2 (continued)
August 29, 1966

Time (min)	Zone between casing and upper packer (411-1500 ft)		Zone between packer and total depth (1500 - 2100 ± ft)			
	Electric line depth to water below measuring point (ft)	Change in water level (recovery) (ft)	Air gauge pressure on 1500 ft airline (psi)	Pressure change (psi)	Air gauge pressure converted to depth to water below measuring point (ft)	Change in water level (recovery) (ft)
a	b	c	d	e	f	g
25	252.6	7.5	376	15	632	35
30	- -	- -	378	13	627	30
40	- -	- -	382	9	618	21
50	- -	- -	383	8	616	19
60	- -	- -	384	7	613	16
80	- -	- -	385	6	611	14
100	251.8	8.3	391	0	597	0
140	- -	- -	396	5	585	12
200	251.6	8.5	397	6	583	14
250	251.2	8.9	403	12	569	28
300	250.7	9.4	408.5	17.5	556	41

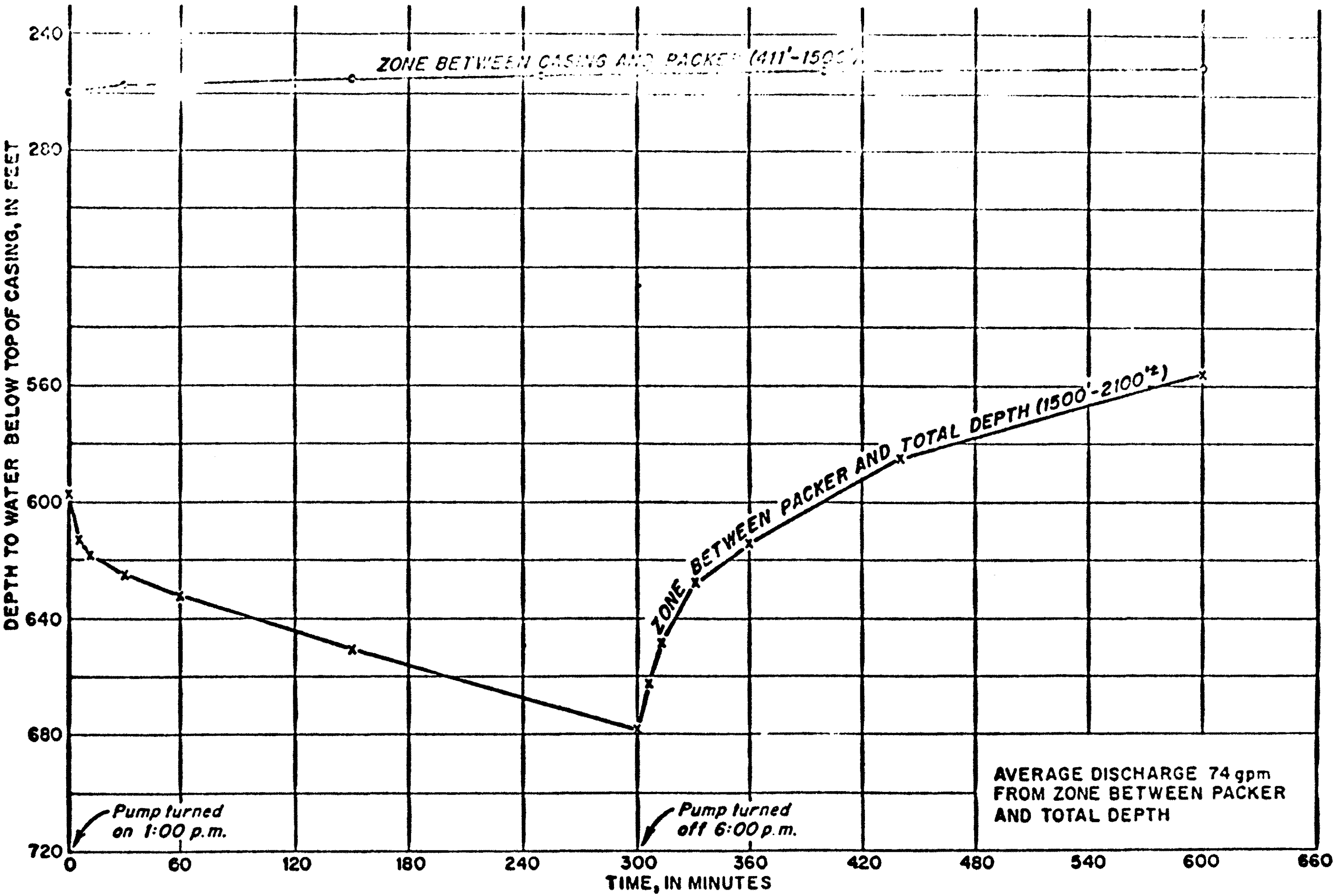


FIGURE 8.-Water-level measurements during test No. 3, U.S.B.M./A.E.C. Colorado core hole No. 2, August 29, 1966

Test No. 4.--No packers were used. The well was pumped at 93.4 gpm for 250 minutes. Drawdown was measured during pumping and recovery was measured for 120 minutes after pumping ceased (fig. 9). Transmissibility computed from the pumping phase was 3,400 gpd per foot (fig. 10) and that from the recovery phase was 3,600 gpd per foot (fig. 11). The computed transmissibilities are probably affected by different rates of flow between the upper losing zone and the lower gaining zone during both pumping and recovery.

Well discharge, water temperature, and specific conductance are shown below:

Time in minutes since pumping began	Discharge (gpm)	Specific conductance (micromhos per cm)	Temperature (°F)
40	93.4	900	67
100	93.4	900	68
150	93.4	750	69
240	93.4	800	68
250	93.4	950	69
Average	93.4		

Water was moving from rocks near the top of the uncased section down the hole and out into rocks near the bottom of the hole. The data indicating this are:

1. The head in the upper part of the hole is higher than in the lower part of the hole.

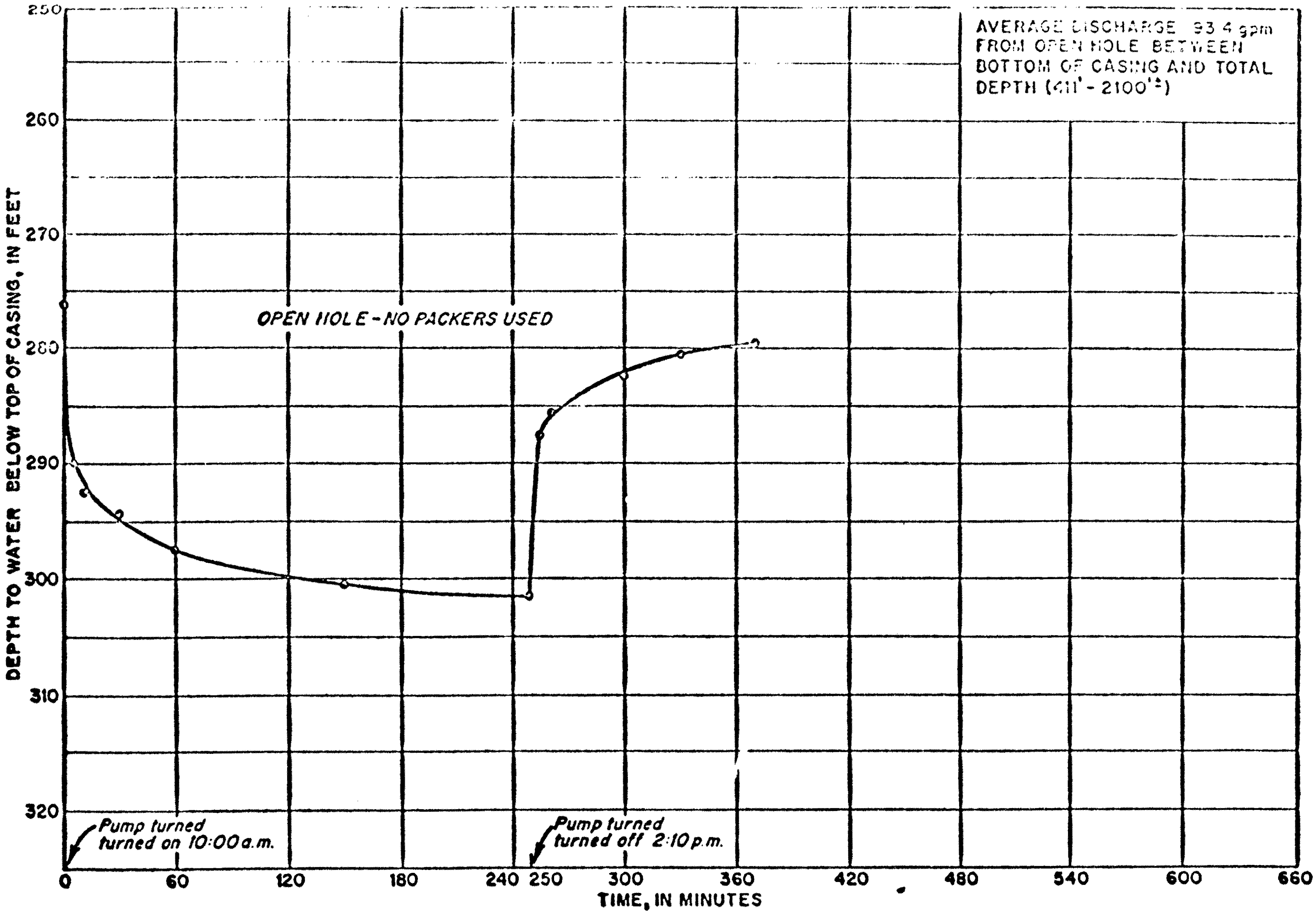


FIGURE 9.-Water-level measurements during test No. 4, U.S.B.M./A.E.C. Colorado core hole No. 2, August 30, 1966.

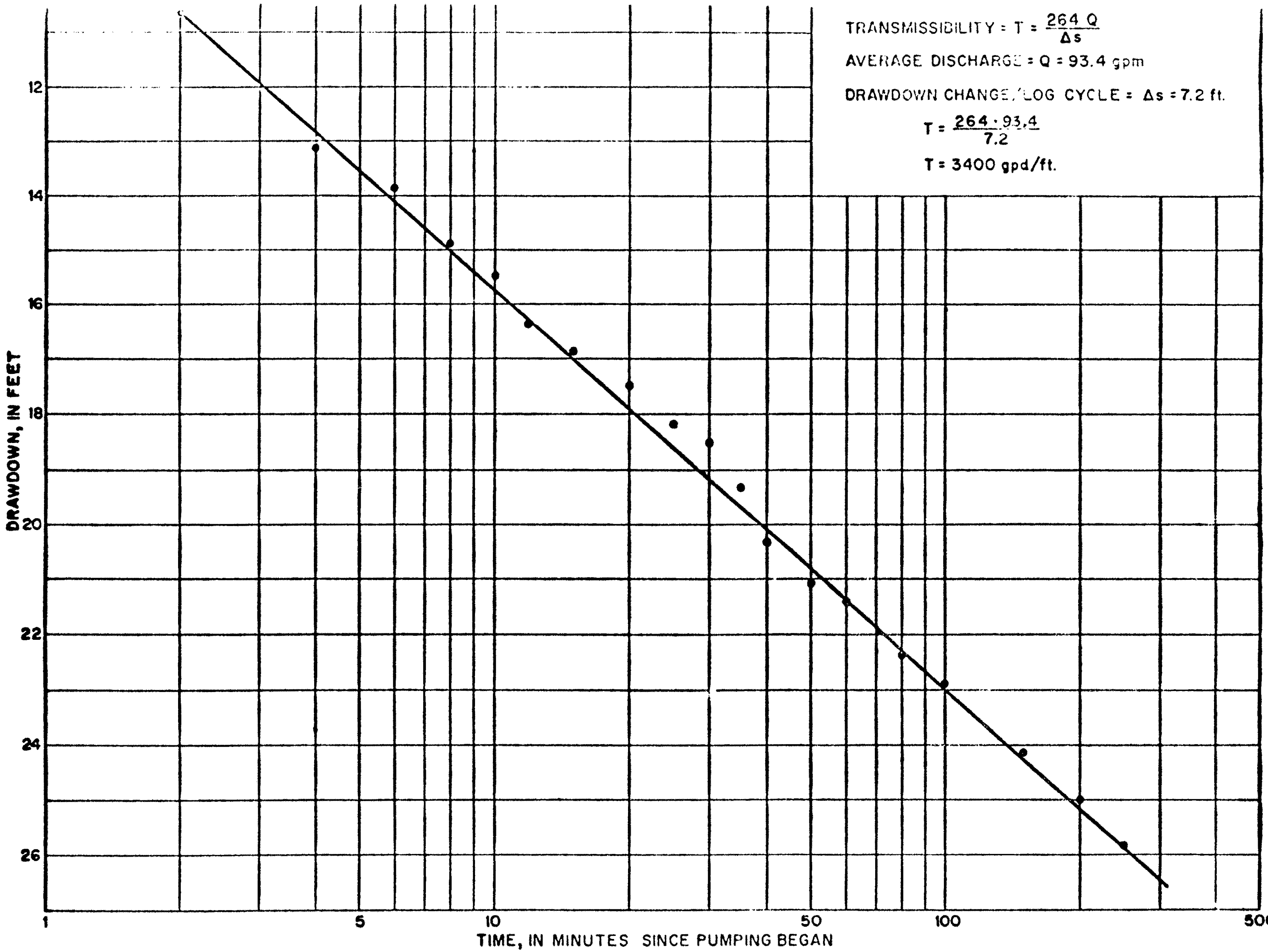


FIGURE 10. - Semilogarithmic graph of drawdown data, pumping open hole between casing and total depth (test No. 4, 411'-2100'±) U.S.B.M./A.E.C. Colorado core hole No. 2, August 30, 1966.

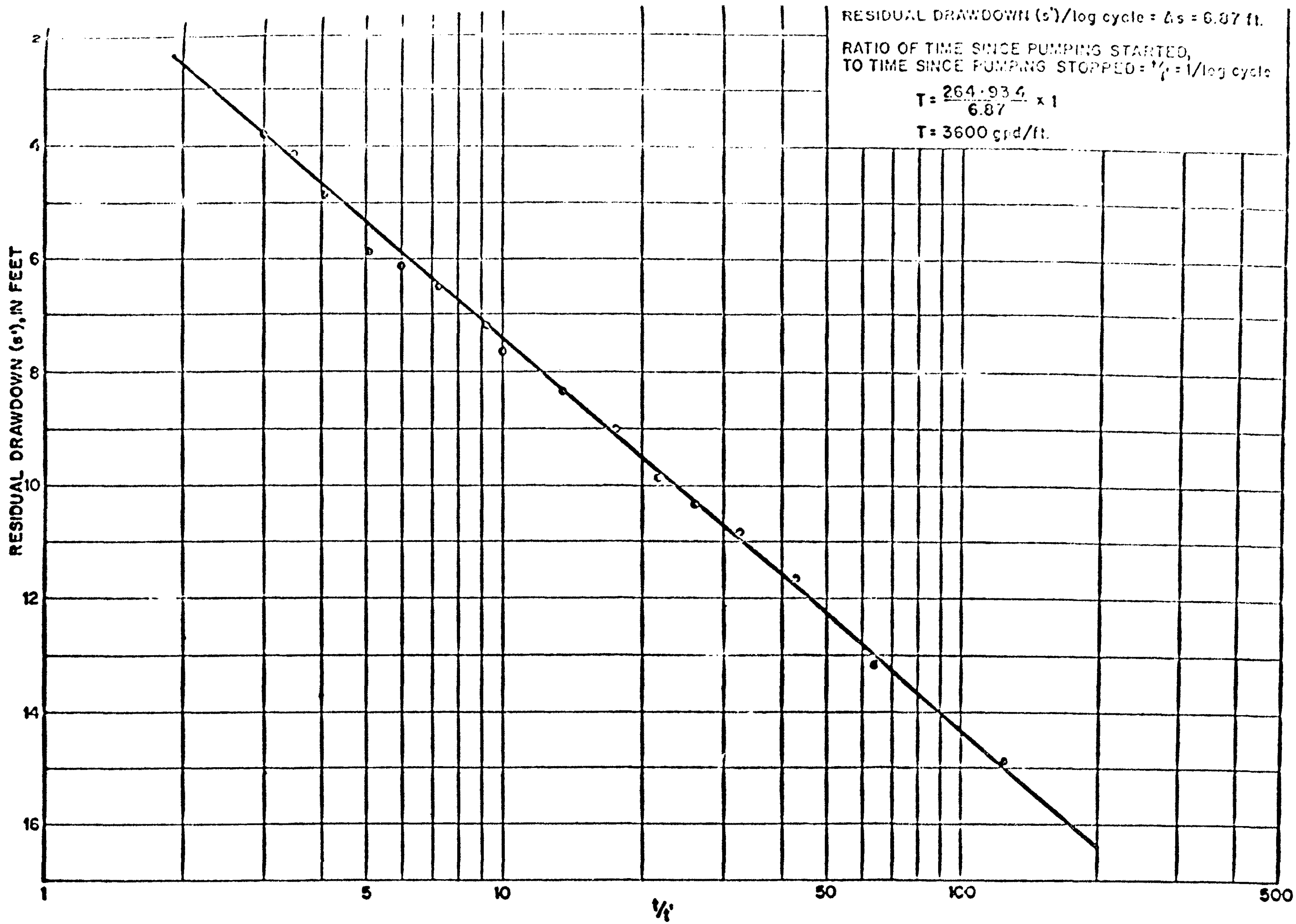


FIGURE 11. - Semilogarithmic graph of recovery data, after pumping open hole between casing and total depth (test No. 4, 411'-2100'±) U.S.B.M./A.E.C. Colorado core hole No. 2, August 30, 1966.

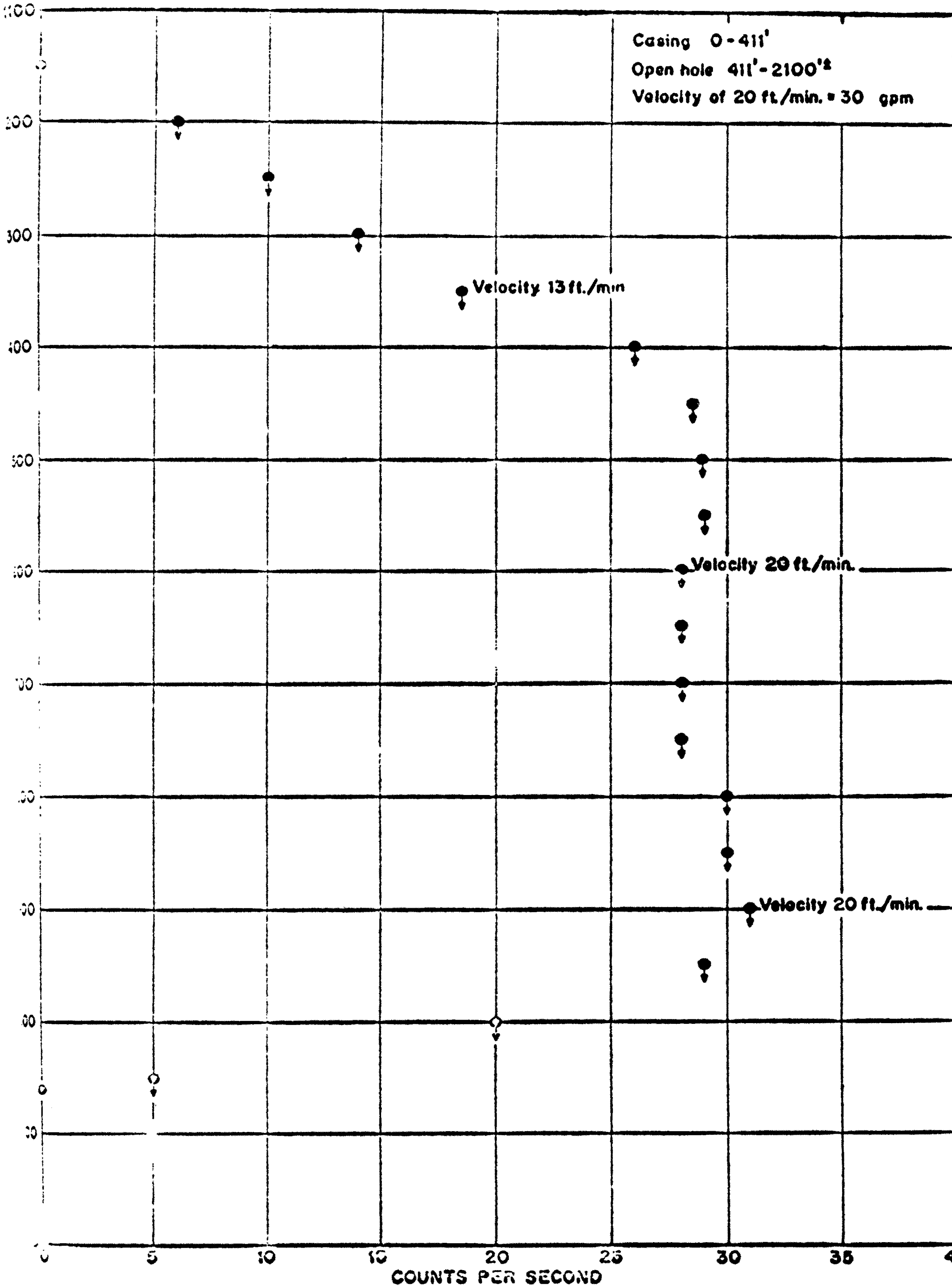
2. The specific conductance of the water from each test was about the same as that of the water from the upper part of the hole; whereas, during drilling the specific conductance of water from the bottom of the hole was much higher than that of the water from the top part of the hole. Water moved down the hole from the time that drilling was completed until the packer tests were made. The amount of water withdrawn during the test was too small to "retrieve" all the "top" water from the lower part of the hole.

Deep-well current-meter survey

On October 21, 1966, a current-meter survey was made on USBM/AEC Colorado core hole No. 2, using a Deerheardt-Owen spinner flowmeter. The well was not pumped during the survey. Results of the survey (fig. 12) indicate that on October 21, water was entering the hole between depths of about 1,200 to 1,400 feet, moving downward at velocities of as much as 20 feet per minute and leaving the hole between depths of about 1,900 to 2,070 feet. The quantity of water moving down the hole at that time was about 30 gpm.

Quality of water

The chemical analysis of water pumped from the zone between the packers (900-1,200 feet) during test No. 1, is shown in table 8, and the chemical analysis of water pumped from the zone between the packer



2.- Results of deep-well current meter survey in U.S.B.M./A.E.C Colorado core hole No. 2, October 21, 1966

Table 8 Chemical analysis of ground water pumped from zone between depths of 900 to 1200 feet.

Lab. No. 12217

U. S. DEPT. OF THE INTERIOR -- GEOLOGICAL SURVEY
Statement of Water Analysis

Source US [illegible]/AEC Colorado core hole No. 2
Location 33 miles WSW of Meeker, Colorado, Rio Blanco County
SW ¼ NW ¼ NE ¼ Sec 14 T 1S R 99W Field/Office No.

Date Coll. [illegible] 27, 19[illegible] Time	Well Type Core Use Test hole
Coll. By [illegible] A. Welder	Depth (ft.) 2100± Cased to 411
Field detns: Temp. (°F) 67 pH -	Diam. (in.) 7-5/8" Date drilled June 1966
Sp. Cond. (µmhos) 1000 Eh -	Water level (ft.) 311
Appearance	Discharge 94
Test No. 1. Zone between the packers (900-1200 ft)	W. B. F. Evacuation Creek & Parachute Creek Member Green River Formation
	Owner U. S. Bureau of Mines

Chemical components	ppm	epm
Silica (SiO_2)	13.0	
Aluminum (Al)		
Iron (Fe)		
Manganese (Mn)		
Calcium (Ca)	6.0	0.30
Magnesium (Mg)		0.58
Strontium (Sr)		
Sodium (Na)	235.0	10.22
Potassium (K)	0.5	0.01
Cations (epm)		11.11
Bicarbonate (HCO_3)	494	8.10
Carbonate (CO_3)		
Sulfate (SO_4)	113	2.35
Chloride (Cl)	4.8	0.14
Fluoride (F)	.3	0.17
Nitrate (NO_3)	0.2	
Phosphate (PO_4)	0.06	
Boron (B)	0.12	
Anions (epm)		10.76

Physical characteristics and computed values	
Dissolved Solids (ppm)	
Res. on evap. at 180°C	621
Calculated	626
Suspended solids (ppm)	
Hardness as $CaCO_3$ (ppm)	
Total	44
Non-carbonate	
Specific conductance (µmhos at 25°C)	970
pH	8.2
Color	

Radiochemical data	
Alpha activity (pc/l) as of	
Beta activity (pc/l) as of	
Radium (Ra) (pc/l)	
Uranium (U) (µg/l)	

Lab. No. ______ Analysts ______ Date Checked ______

GW-1

GPO 842836

and total depth (1,500-2,100± feet) during test No. 3, is shown in table 9. The analyses show that the water in the two zones is similar; in both samples the principal cation was sodium and the principal anion was bicarbonate. Samples from other zones were taken for analysis, but the results are not yet available.

Table 9 Chemical analysis of ground water pumped from zone between depths of 1500 to 2100 ± feet

Lab. No. 32238

U. S. DEPT. OF THE INTERIOR - GEOLOGICAL SURVEY
Statement of Water Analysis

Source USBM/AEC Colorado core hole No. 2
Location 33 miles WSW of Meeker, Colorado, Rio Blanco County
SW ¼ NE ¼ NE ¼ Sec 1 T 1S R 99 W Field/Office No.

Date Col. Aug. 29, 1966 Time	Well Type — Use Test hole
Col. By F. A. Welder	Depth (ft.) 2100 ± Cased to 411
Field data: Temp. (°F) 70 pH -	Diam. (in.) 7-5/8" Date drilled June 1966
Sp. Cond. (µmhos) 1020 Eh -	Water level (ft) 27
Appearance -	Discharge 74 GPM
Test No. 3 Zone between packer and total depth (1500-2100 ± feet).	W. B. F. Parachute Creek Member, Green River Formation
	Owner U. S. Bureau of Mines

Chemical components

	ppm	epm
Silica (SiO_2)	13	
Aluminum (Al)		
Iron (Fe)		
Manganese (Mn)		
Calcium (Ca)	6.4	.32
Magnesium (Mg)		.48
Strontium (Sr)		
Sodium (Na)	248.0	10.79
Potassium (K)	0.4	0.01
Cations (epm)		11.60
Bicarbonate (HCO_3)	564.0	9.24
Carbonate (CO_3)	277.0	
Sulfate (SO_4)	97.0	2.02
Chloride (Cl)	3.2	0.09
Fluoride (F)	6.8	0.36
Nitrate (NO_3)	0.3	0.001
Phosphate (PO_4)	0.01	
Boron (B)	0.11	
Anions (epm)		11.711

Physical characteristics and computed values

Dissolved Solids (ppm)	
Res. on evap. at 180°C	650
Calculated	650
Suspended solids (ppm)	-
Hardness as $CaCO_3$ (ppm)	
Total	40
Non-carbonate	
Specific conductance (µmhos at 25°C)	1040
pH	8.1
Color	

Radiochemical data

Alpha activity (pc/l) as of	
Beta activity (pc/l) as of	
Radium (Ra) (pc/l)	
Uranium (U) (µg/l)	

Lab. No. ____ Analysts ____ Date Checked ____

QW-1

GPO 848386

USGS-289-3

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Special Projects Branch

Federal Center, Denver, Colorado 80225

Oil Shale-6
December 1969

HYDRAULIC TESTING AND SAMPLING OF USBM-AEC COLORADO CORE HOLE 3, RIO BLANCO COUNTY, COLORADO

By

E. H. Cordes

ABSTRACT

On November 21, 1967, the U.S. Geological Survey, in cooperation with the U.S. Bureau of Mines and the U.S. Atomic Energy Commission, completed the hydraulic testing and sampling of USBM-AEC Colorado Core Hole 3 in Rio Blanco County, Colorado. This hole was drilled to explore the site for Project Bronco, a Plowshare experiment to study the feasibility of in situ retorting of oil shale after breaking the rock with a nuclear explosion.

The hydraulic tests indicate the existence of a highly permeable water-bearing zone in the upper and middle parts of the Parachute Creek Member of the Green River Formation of Eocene age. The zone yielded water in excess of 2,700 cubic meters per day (500 gallons per minute). During geologic time and even today, natural ground-water circulation is believed to have dissolved the syngenetic salt deposits from a part of the oil shale formations leaving a highly permeable zone of interconnected vugs and breccia channels. Older rocks underlying the Parachute Creek Member are comparatively impermeable to water flow and yielded less than 16 cubic meters per day (30 gallons per minuted) of highly saline (49,000 parts per million dissolved solids) fluid.

Potential flooding of a rubble chimney is an important consideration for project feasibility and safety. A first approximation of the magnitude of flooding was calculated from the test data.

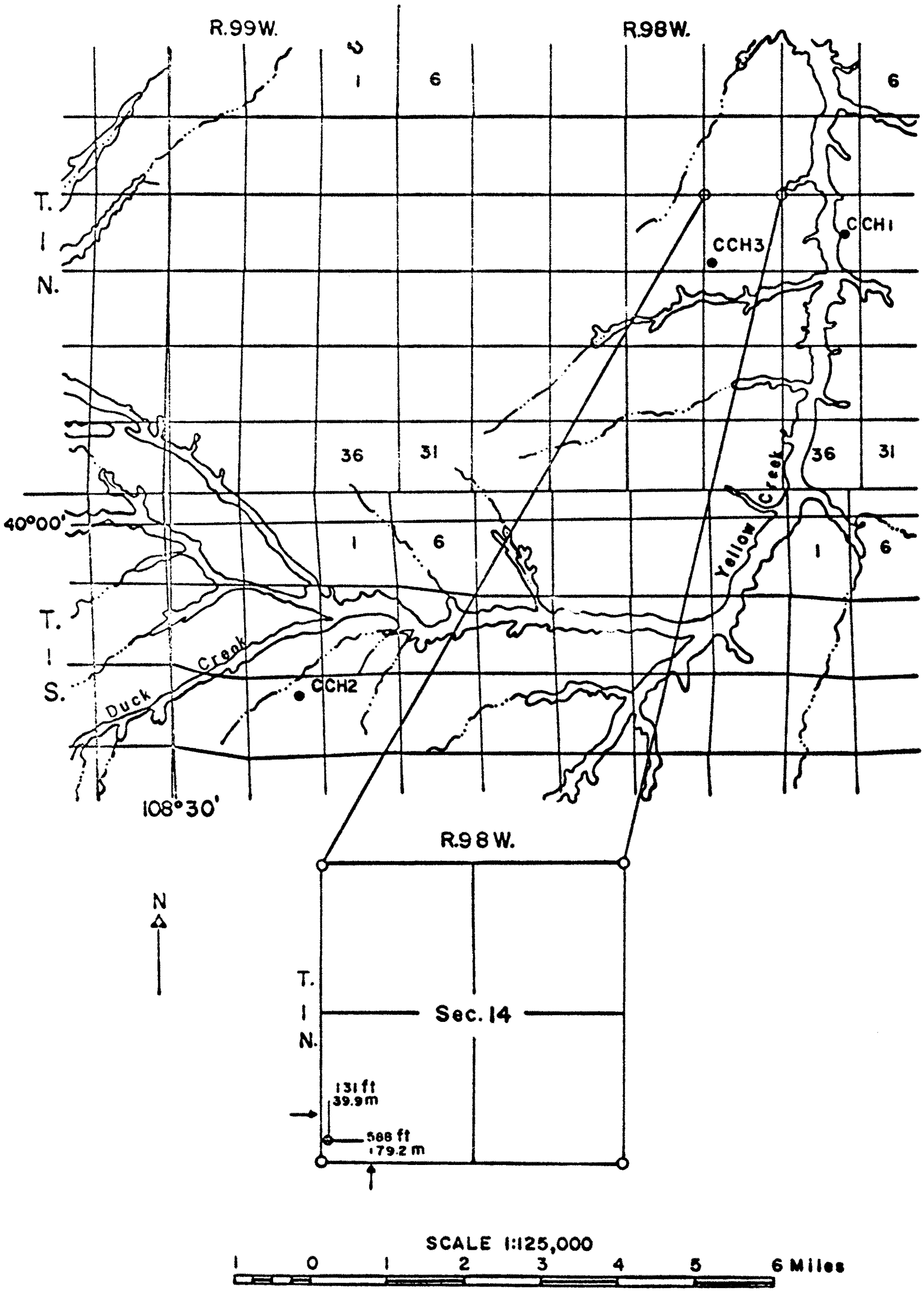


Figure 1.--Locations of USBM-AEC Colorado Core Holes (CCH) 3, 2, and 1.

A summary of the hydraulic test data is shown in table 1. Results of chemical analyses are presented in the next section.

CHEMICAL ANALYSES OF CCH-3 WATER SAMPLES

Water samples were collected from various depths during the drilling and testing of CCH-3. Table 2 describes the pertinent information relating these samples to the hydrologic system and to each other.

The results of the general chemical analyses, table 3, show a significant increase in dissolved-solids content with depth. The general trend is recognized even if the magnitude of change is somewhat affected by recirculation within the well bore during sampling.

Analyses of samples 68-637 and 68-638 are distinctly different and certainly originate from separate aquifers and lithologies. Water from the deepest zone, sample 68-638, showed a reversal in the anion concentration of carbonate and bicarbonate. Both of these constituents had been steadily increasing with depth (table 3). The chloride ion concentration of sample 68-638 increased five times in relation to the previous sample (68-637). A sharp change in ionic ratios suggests the presence of a geologic contact, somewhere between the two sampled intervals. The bottom-hole water may be fluid derived from the original evaporite environment.

The Denver Hydrogeochemical Laboratory, U.S. Geological Survey, analyzed samples 68-630 and 68-635 for tritium content and reported both samples below 400 tritium units. These analyses provide background data to be used in assessing the effects of Project Bronco.

Table 1.--Summary of hydraulic-test data for USBM-AEC Colorado Core Hole 3

	Test 1	Test 2	Test 3	Test 4
Interval tested, meters (feet) below lsd[1]	111.5-290.5 (360-953)	111.5 -456.3 (360-1,496)	111.5 -633.4 (360-2,078)	920-1,154.7 (3,018-3,786)
Static water level, meters (feet) below lsd[2]	112 (367)	118 (387)	124 (407)	200 (656)
Jetting depth, meters (feet) below lsd	283 (928)	444 (1,456)	427 (1,400)	975 (3,198)
Jetting pressure, bars (psi)	12.8 (186)	20.4 (295)	20.1 (292)	10.3 (150)
Jetting time, min.	236	515	1,353	732
Air volume,[3] m^3 per day (cfm)	49 x 10^3 (1,200)	49 x 10^3 (1,200)	100 x 10^3 (2,500)	49 x 10^3 (1,200)
Average well discharge,[4] m^3 per day (gpm)	600 (110)	2,000 (360)	3,000 (550)	60 (11)
Water level recovery period, min.	123	360	732	1,909
Transmissivity (T) m^2 per day (gpd per ft)	14 (1,100)	52 (4,200)	75 (6,000)	0.01 (1)
Estimated specific capacity m^3 per day per mdd[5] (gpm per ft dd)	[6]7.6 (0.42)	--	--	[7]0.1
$\frac{S}{S'}$[8]	0.56	--	--	1.3

[1] Land surface datum.
[2] Projected from recovery curves.
[3] Derated estimate.
[4] Recorded by weir, corrected for losses.
[5] Mdd, meter of drawdown; ft dd, foot of drawdown.
[6] After 4 hours.
[7] After 12 hours.
[8] S, storage coefficient during pumping; S', coefficient during recharge.

Table 2.--Water samples from USBM-AEC Colorado Core Hole 3

U.S.G.S. lab. no.	Sampled zone: meters below lsd	Sampled zone: feet below lsd	Type[1] of analysis	Date collected	Time	Jetting time (hours)	Jetting rate: m^3pd	Jetting rate: gpm	Specific[2] conductance (micromhos per cm at 25°C)	Temperature: °C	Temperature: °F
68-630	111.5 - 290.5	360 - 953	G, M, T	10-20-67	2400	3	600	110	e470	15.5	60
68-631	111.5 - 370.6	360 - 1,216	G, M	10-22-67	1345	0.75	e1,100	e200	e600	15.5	60
68-632	111.5 - 431.6	360 - 1,416	G, M	10-25-67	1125	1	1,600	300	700	15.5	60
68-633	111.5 - 456.3	360 - 1,496	G, M	10-26-67	1830	6	2,000	370	800	17.8	64
68-634	111.5 - 542.5	360 - 1,780	G, M	10-31-67	1400	1.5	2,500	460	9,000	18.3	65
68-635	111.5 - 633.4	360 - 2,078	G, M, T	11-3-67	0945	2.25	2,700	490	25,000	21.1	70
68-636	111.5 - 480	360 - 1,575	G, M	11-4-67	0715	23.5	3,000	550	14,000	22.2	72
68-637	688.5 - 960.7	2,259 - 3,152	G, M	11-16-67	1545	1	e60	e11	32,100	15.5	60
68-638	688.5 - 975.4	2,259 - 3,199	G, M	11-20-67	0400	11.5	60	11	e45,000	16.7	62

1/ G, general; M, minor elements; T, tritium. 2/ Field determination.
e Estimated value.

Table 3.--Chemical analyses of water from USBM-AEC Colorado Core Hole 3

(Results in milligrams per liter except as indicated)

Lab. no.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (Fl)	Nitrate (NO_3)	Boron (B)	Orthophosphate (PO_4)	Strontium (Sr)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$		Specific conductance (µmhos at 25°C)	pH	Percent sodium	Sodium absorption ratio
																		Calcium magnesium	Noncarbonate				
68-630	21	0.02	12	0.01	196	0.3	0.06	16	386	137	6.4	0.4	0.1	0.18	<0.01	3.7	602	75	0	1,040	8.5	85	9.9
68-631	21	.05	10	.02	225	.4	.07	14	515	130	6.4	1.2	.0	.25	<.01	3.7	717	112	0	1,070	8.5	81	9.3
68-632	16	.03	5.6	<.01	250	.2	.08	16	621	54	6.3	9.4	.1	.38	<.01	1.6	718	66	0	1,090	8.5	89	13.0
68-633	15	.03	5.2	<.01	280	.4	.08	16	655	40	5.9	11.0	.1	.62	<.01	1.4	704	55	0	1,120	8.5	92	16.0
68-634	17	.13	4.1	.01	3,880	9.2	.64	422	8,640	28	294	24	.0	2.1	2.2	.88	8,900	40	0	11,400	8.4	99	269.0
68-636	18	.07	4.1	<.01	7,200	28	.83	118	18,600	25	780	28	.0	3.4	4.7	.86	17,500	42	0	20,200	8.5	99	486.0
68-635	18	.21	3.4	<.01	10,700	48	1.5	884	26,800	24	1,180	34	.0	4.6	7.3	.60	26,500	32	0	27,500	8.3	100	823.0
68-637	21	10	8.8	.12	16,000	30	2.5	5,100	31,500	45	3,700	3.4	.0	3.4	7.0	.08	37,800	63	0	39,700	8.9	100	877.0
68-638	17	4.6	11	.17	18,400	71	3.3	3,210	14,100	205	18,800	2.8	.0	3.1	.16	4.4	48,700	267	0	50,300	8.8	99	490.0

CIRCULAR 11

GROUND-WATER SERIES

PUMPING TESTS IN COLORADO

By

Woodrow W. Wilson

United States Geological Survey

Prepared by

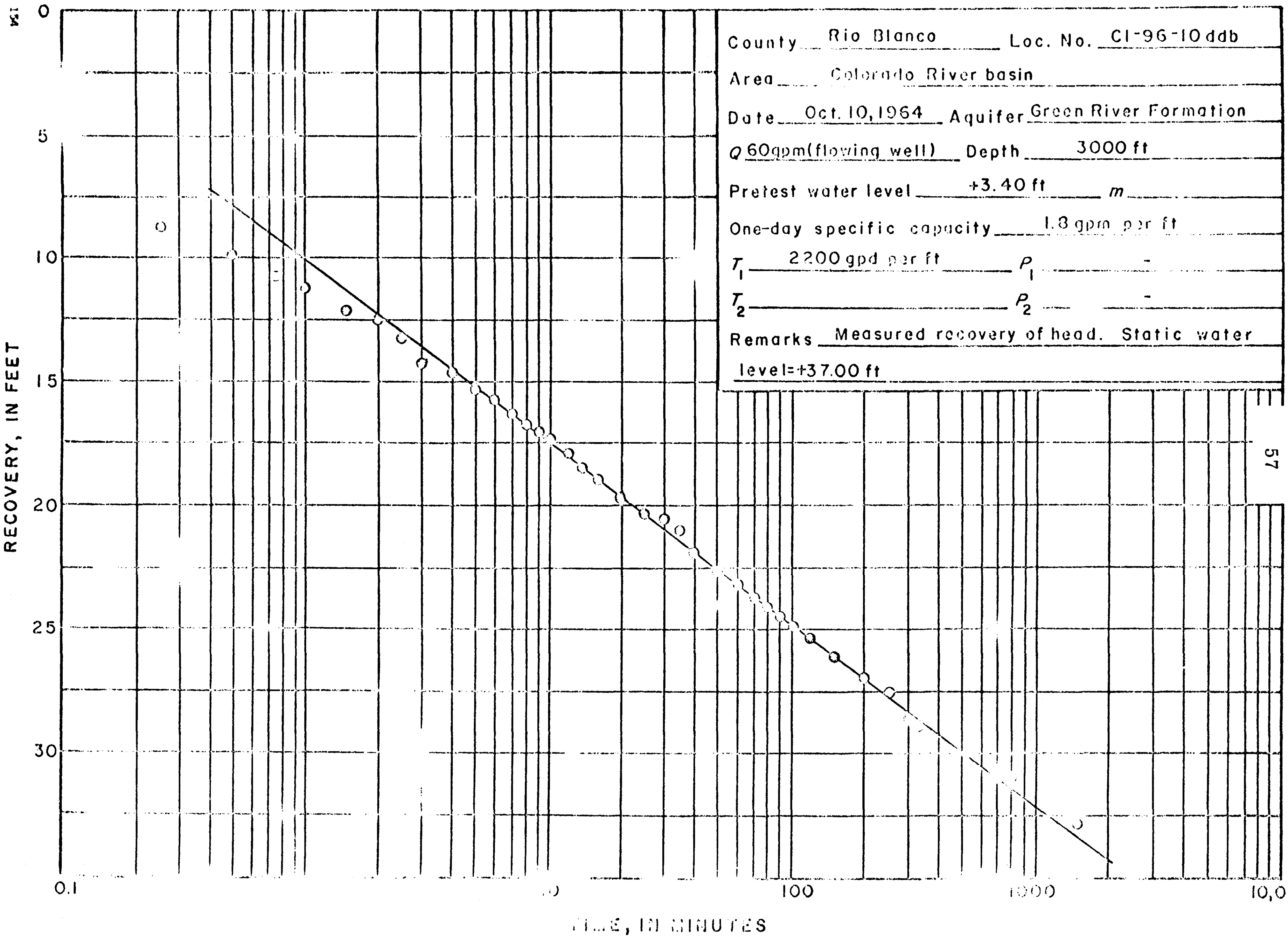
The United States Geological Survey

in cooperation with

The Colorado Water Conservation Board

Denver, Colorado

1965



County Rio Blanco
Loc. No. C1-96-10ddb
Area Colorado River basin
Date Oct. 10, 1964
Aquifer Green River Formation
Q 60gpm (flowing well)
Depth 3000 ft
Pretest water level +3.40 ft
m
One-day specific capacity 1.8 gpm per ft
T_1 2200 gpd per ft
P_1 -
T_2
P_2 -
Remarks Measured recovery of head. Static water level = +37.00 ft
RECOVERY, IN FEET
0
5
10
15
20
25
30
0.1
100
10,00

57

C22-45-15dda indicates a well in the northeast quarter of the southeast quarter of the southeast quarter of sec. 15, T. 22 S., R. 45 W. The capital letter C indicates the township is south of the base line and that the range is west of the principal meridian. The absence of a number following the lowercase letters shows that this was the first well inventoried in the quarter-quarter-quarter section.

Most well locations given in this report are in the area controlled by the sixth principal meridian, and the well-numbering system described above applies to these wells. There are two smaller areas in Colorado that are controlled by different meridians. One is the New Mexico principal meridian, and wells in this area have the letters NM before their location number. Another is the Ute principal meridian, and wells in this area have the letter U before their location number. The principal meridian and base-line systems in Colorado are shown on figure 2.

HYDRAULIC PROPERTIES OF AQUIFERS

The quantity of water that an aquifer will yield to wells depends upon the hydraulic properties of the aquifer. The principal hydraulic properties of an aquifer are its ability to transmit and to store water. The ability of an aquifer to transmit water is measured by its coefficient of transmissibility, and the capacity to store water is measured by its coefficient of storage.

In units commonly used by the Geological Survey, the coefficient of transmissibility (T) may be expressed as the rate of flow of water, in gallons per day, at the prevailing temperature through a vertical strip of the aquifer 1 mile wide extending the full height of the aquifer under a hydraulic gradient of 1 foot per mile. The field coefficient of permeability (P) is expressed as the rate of flow of water, in gallons per day, at the prevailing temperature through a strip of the aquifer 1 mile wide and 1 foot thick under a hydraulic gradient of 1 foot per mile. The average field coefficient of permeability is computed by dividing the coefficient of transmissibility by the aquifer thickness (m), in feet. The coefficient of storage (S) of an aquifer is defined as the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. Under water-table conditions, the coefficient of storage is nearly equal to the specific yield, which is defined as the ratio of (1) the volume of water a saturated material will yield by gravity to (2) its own volume. This ratio is stated as a decimal fraction.

Methods

The data presented in this report were analyzed by the Cooper-Jacob, Jacob-Lohman, or Thiem method. The equations used have been reduced to their simplest forms. For information concerning the development of the original equations and their reduction to the forms used here, the reader is referred to the following publications: Cooper and Jacob, 1946; Jacob and Lohman, 1952; Theis, 1935; Thiem, 1906; and Wenzel, 1942, p. 81.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Geohydrology of the Piceance Creek structural basin between the White and Colorado Rivers, northwestern Colorado

By

Donald L. Coffin, Frank A. Welder, and Richard K. Glanzman

Prepared in cooperation with the
COLORADO WATER CONSERVATION BOARD
Felix L. Sparks, Director

OPEN-FILE REPORT
Colorado District
Denver, Colorado
April 1969

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS--Continued

TABLES

Introduction

This atlas presents the results of an investigation of the water resources of part of the Piceance Creek structural basin in northwestern Colorado. The area of investigation is between the White and Colorado Rivers (see index map, fig. 1), an area of about 1,600 square miles in parts of Rio Blanco, Garfield, and Mesa Counties.

The U.S. Geological Survey's study of the water resources in the basin was begun in 1964 and completed in 1966. The study was made in cooperation with the Colorado Water Conservation Board. The basic hydrologic data collected during this study are published in a report by Coffin, Welder, Glanzman, and Dutton (1968). Additional basic data collected after publication of the Coffin, Welder, Glanzman, and Dutton report are in the files of the Geological Survey. The data include results of aquifer tests, logs of wells and test holes, hydrographs of streams, and chemical analyses of both ground water and surface water in the basin.

The objective of the investigation was to describe availability, occurrence, and chemical properties of the water resources of the basin. This description will be useful for developing water supplies and for coping with water problems associated with the development of the oil shale resources. The Piceance Creek basin contains some of the richest oil shale deposits in North America. These deposits represent a huge potential source of petroleum and efforts are currently being made to develop the resource. Some of the problems associated with the mining and retorting of oil shale are: removal of water from mines, supplying water for mining and retorting operations, supplying additional domestic water for an increase in population, effect of mining operations on present users of ground water and surface water, and water-quality problems created by mining operations.

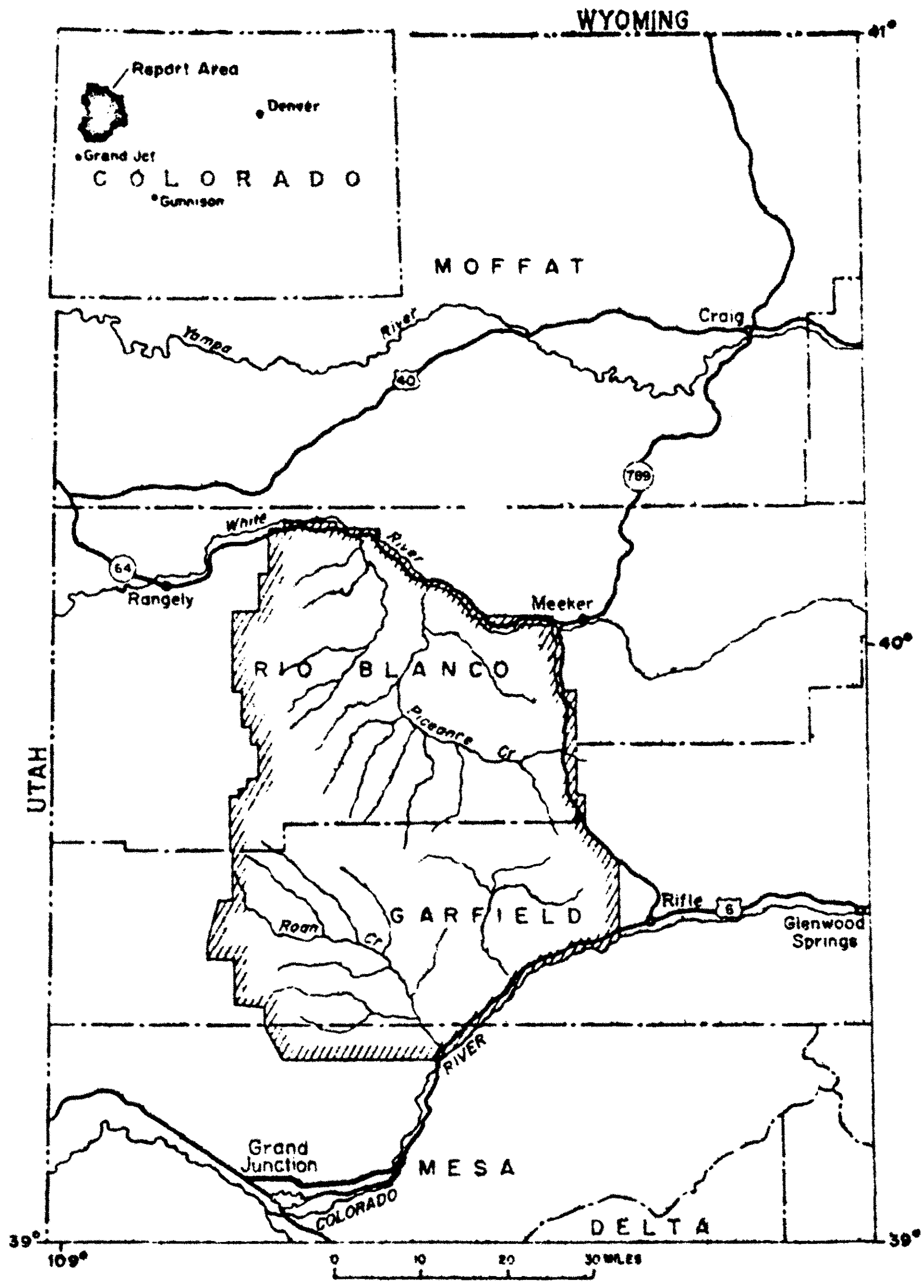


Figure 1. Index map showing report area.

The population of the basin is sparse, possibly less than 200. The major use of water is for irrigation and is supplied mostly by surface water. Hay meadows and feed crops are irrigated in the valleys of the four major streams (Piceance, Yellow, Roan, and Parachute Creeks). The surface water supply is adequate during the early part of the growing season and inadequate during the late summer months.

Ground-water resources of the basin are relatively undeveloped at the present because of sparse population and lack of arable land. The three irrigation wells in the basin are in the alluvium of Roan Creek. Four wells tapping the Green River Formation (originally drilled for oil) are occasionally used for irrigation along Piceance Creek. There are 65 small diameter wells, some of them flowing, and about 250 springs tapping the alluvium and the Green River Formation that supply water for domestic and stock use throughout the basin.

The Piceance Creek structural basin is a northwest-trending downwarp lying between the White River uplift on the east and the Douglas Creek arch on the west. The topography of the basin between the White and Colorado Rivers is illustrated by the block diagram (fig. 2). The edges of the basin are formed by cliffs of oil shale, which act as hydrologic boundaries separating the basin from adjacent areas. A major east-west topographic divide separates the structural basin into two drainage basins: the northern drainage basin contains Piceance and Yellow Creeks, which are tributary to the White River; the southern drainage basin contains Roan and Parachute Creeks, which are tributary to the Colorado River (fig. 2).

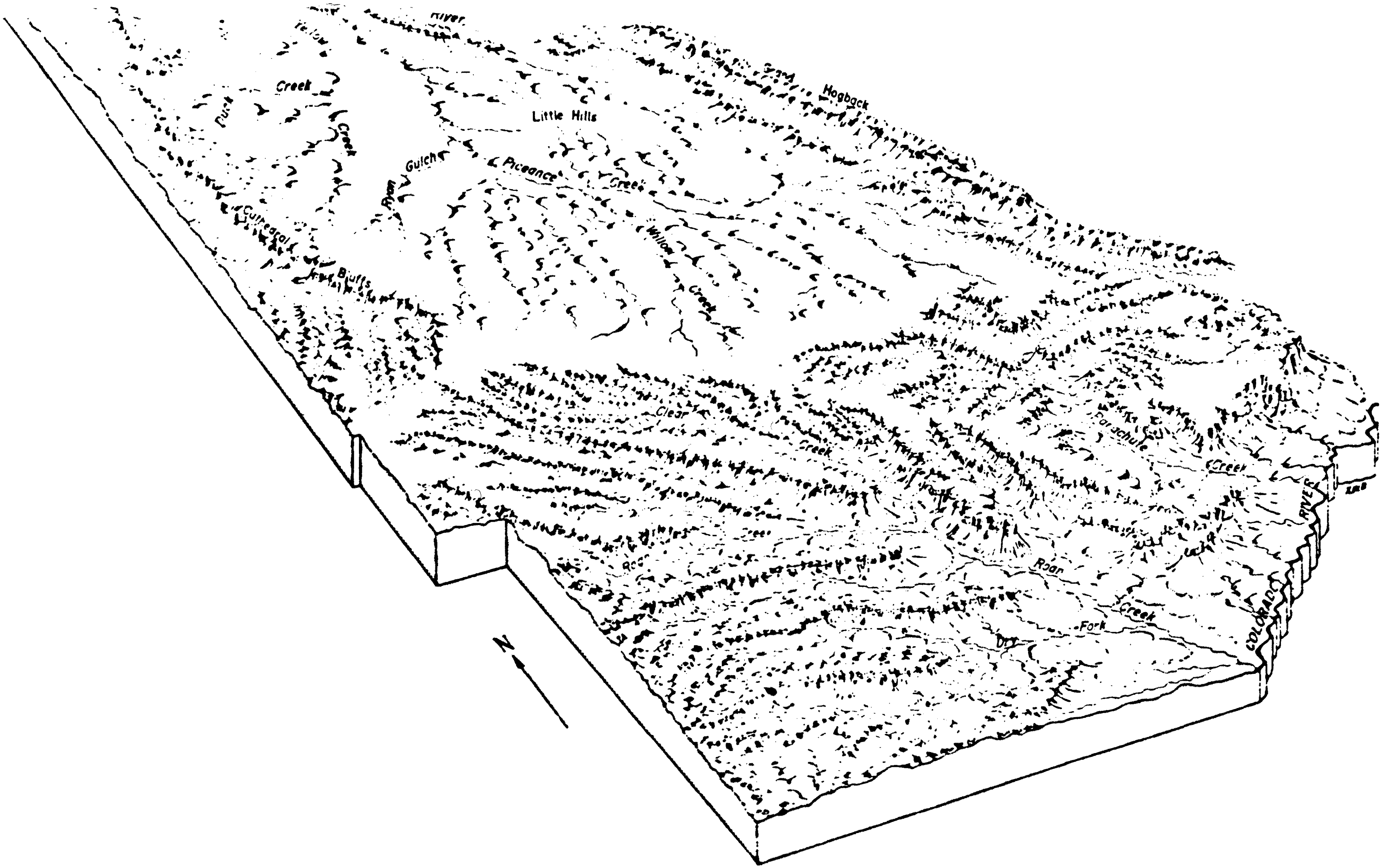


Figure 2. Block diagram of Piceance Creek basin.

Geology

A brief description of the geologic units in the Piceance Creek basin and their water-bearing characteristics is given in table 1.

Table 1. (omitted)

A geologic map and summary of the geology and oil resources of the basin is given in a report by Donnell (1961). The general shape of the basin and the relation of geologic units are shown on the structure contour map (fig. 3) and the diagrammatic section (fig. 4).

Surface rocks exposed in the basin are sedimentary and range in age from the Cretaceous to the Quaternary (Donnell, 1961). Discussion of the geologic units in this report will be limited to the Green River Formation and younger rocks because these sediments are of greatest economic interest and contain the principal aquifers in the basin.

The Green River Formation of Eocene age rests conformably on the Wasatch Formation and is the bedrock in the area (see diagrammatic section, fig. 4). The formation is divided into five members: Anvil Points, Douglas Creek, Garden Gulch, Parachute Creek, and Evacuation Creek.

The Anvil Points, Douglas Creek, and Garden Gulch Members are composed of marlstone, shale, and sandstone. These units are relatively impermeable. In general, they impede the movement of ground water between the Green River Formation and the underlying rocks.

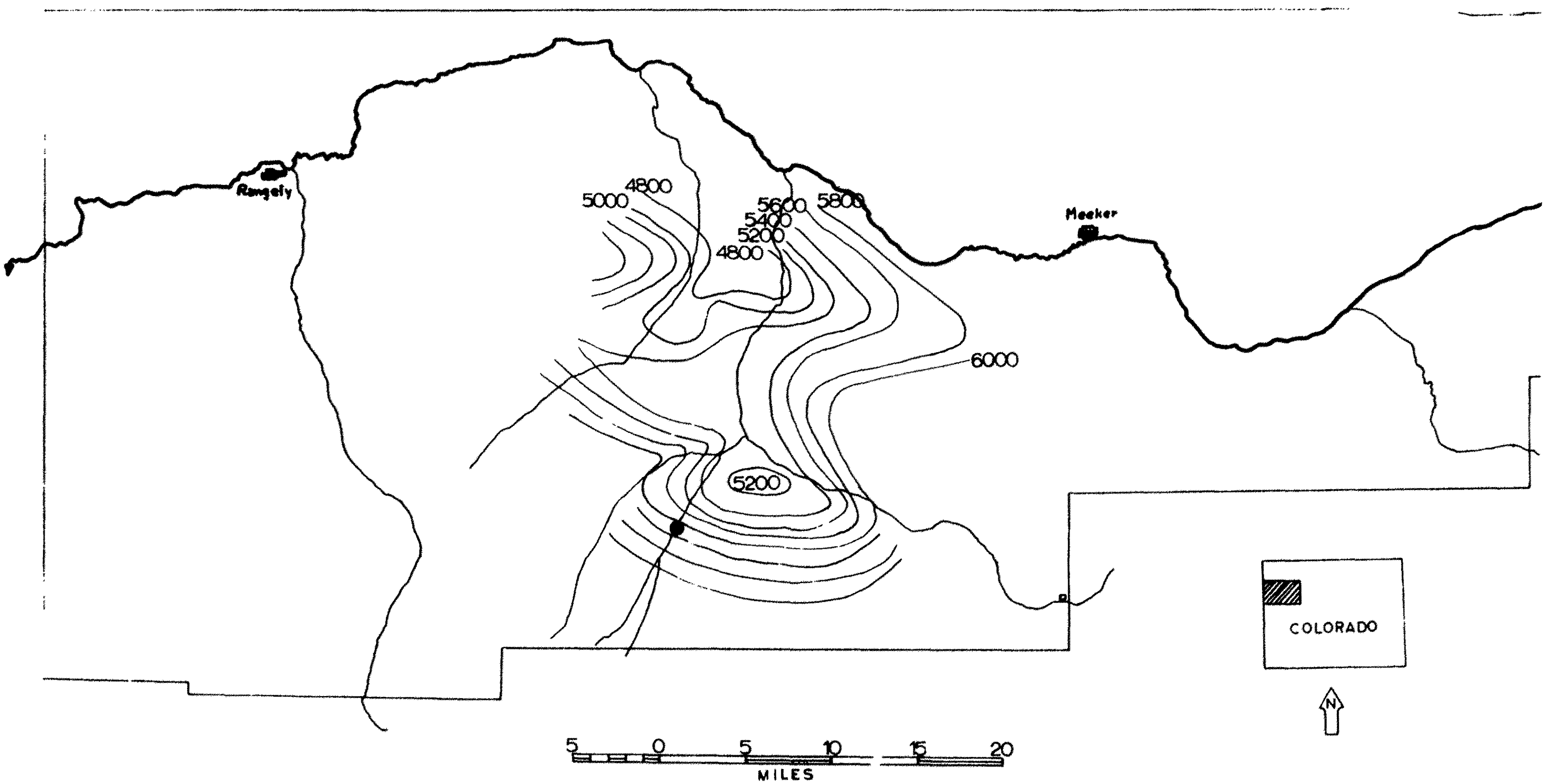


Figure 3. Structure contour map of the base of the Mahogany Zone of the Parachute Creek Member.

(Redrawn to show only the contours below the Piceance Creek-Fawn Creek drainage.)

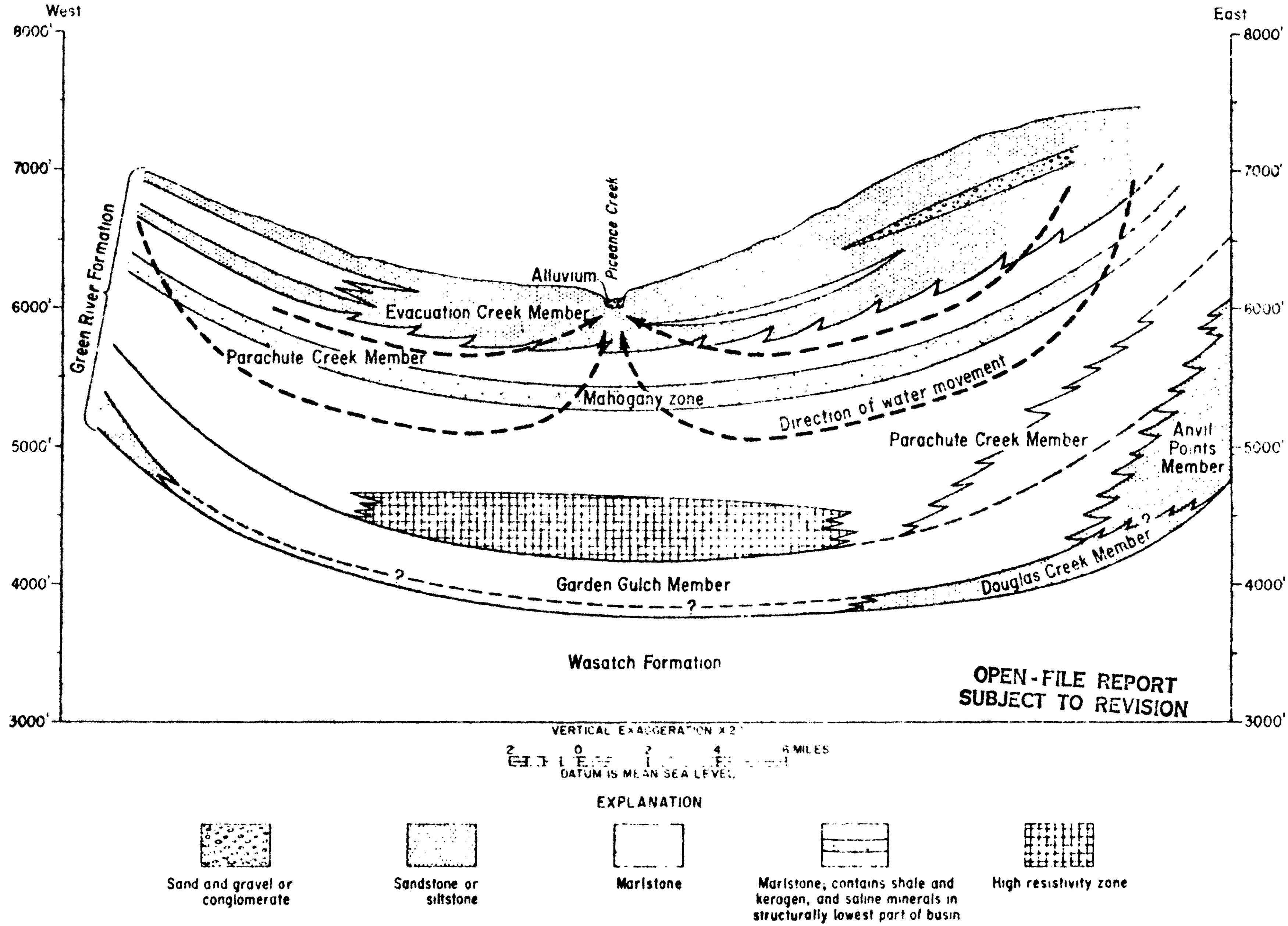


Figure 4. - Diagrammatic section across the Piceance Creek basin.

The Parachute Creek Member overlies the Garden Gulch Member and is composed principally of oil shale. This member contains the principal bedrock aquifer in the basin. The member can be divided into three zones (high resistivity, low resistivity or leached, and Mahogany) based on differences in both geologic and hydrologic character. These zones can be correlated throughout the central part of the basin based on their characteristic appearance on electric logs as shown on the stratigraphic section (fig. 5). The lowermost zone in the Parachute Creek Member is

---

Figure 5. (omitted)

---

called the high resistivity zone. This zone contains oil shale and beds of saline minerals, is relatively impermeable, and probably is little fractured. The high resistivity zone is confined to the center of the northern part of the Piceance Creek basin (see diagrammatic section, fig. 4) and ranges from less than 200 to more than 900 feet thick, as indicated on the thickness map of the zone (fig. 6). The absence of this zone elsewhere may be due to low concentration of kerogen or to removal of the saline minerals by solution. Apparently, some saline minerals were deposited throughout the basin in the Parachute Creek Member. Deposition in vugs and beds is undoubtedly most common near the center of the basin and less common on the edges of the basin.

The zone overlying the high resistivity zone is characterized by low resistivity on electric logs (see stratigraphic section, fig. 5).

In the center of the basin, where saline minerals make up a greater

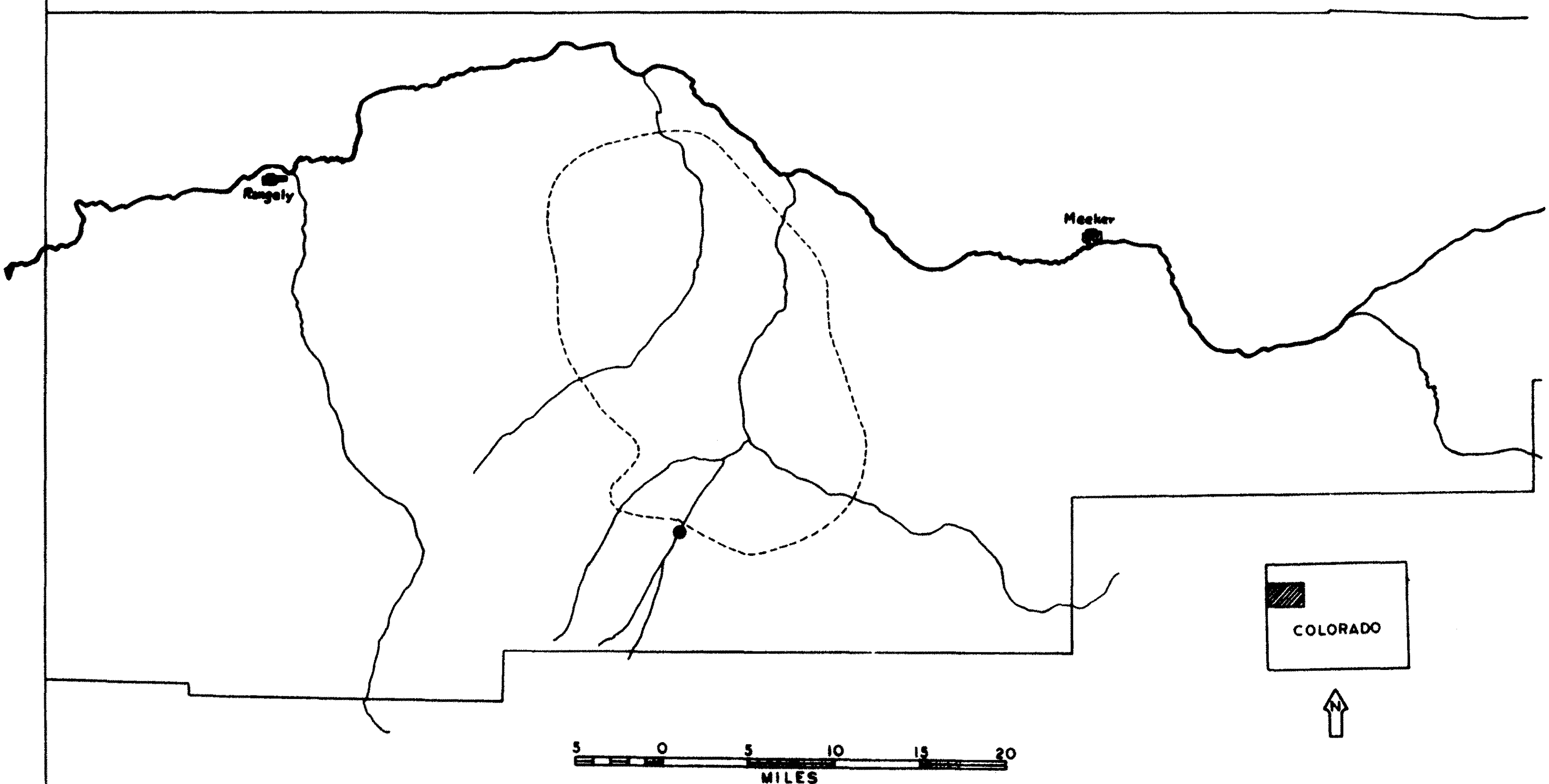


Figure 6. Thickness map of the high resistivity zone.

(Redrawn to show the approximate limit of the high resistivity zone.)

percentage of the member, the removal of minerals from the upper part has resulted in voids, fracturing, collapse, and irregular bedding. The low resistivity zone which corresponds to the leached zone is more porous and permeable than either the underlying or overlying zones. Because of its high porosity and permeability, the leached zone is the principal bedrock aquifer in the Piceance Creek basin. The low resistivity zone is best defined near the center of the northern part of the basin and ranges from less than 400 to 700 feet thick as shown on the thickness map of the zone (fig. 7).

The low resistivity zone thickens outward, but cannot be distinguished on electric logs outside of the 700-foot thickness line (see stratigraphic section, fig. 5). Core recovery from the leached zone is generally poor, but when core is recovered, it is highly fractured and contains vugs. Drillers often report lost circulation in this zone.

Overlying the leached zone is the Mahogany zone, or as it is called on the outcrop, the Mahogany ledge (see stratigraphic section, fig. 5). The zone contains a relatively thick section of oil shale. Saline minerals are sparse in this zone and apparently were never thickly deposited.

The Evacuation Creek Member, consisting of marlstone and fine-grained sandstone, overlies the Parachute Creek Member and forms the surface rock throughout most of the basin. That part of the member topographically higher than the level of the streams is mostly drained. The Evacuation Creek Member is more permeable than the Mahogany zone but is less permeable than the leached zone. The Evacuation Creek Member ranges from 0 to 1,250 feet thick.

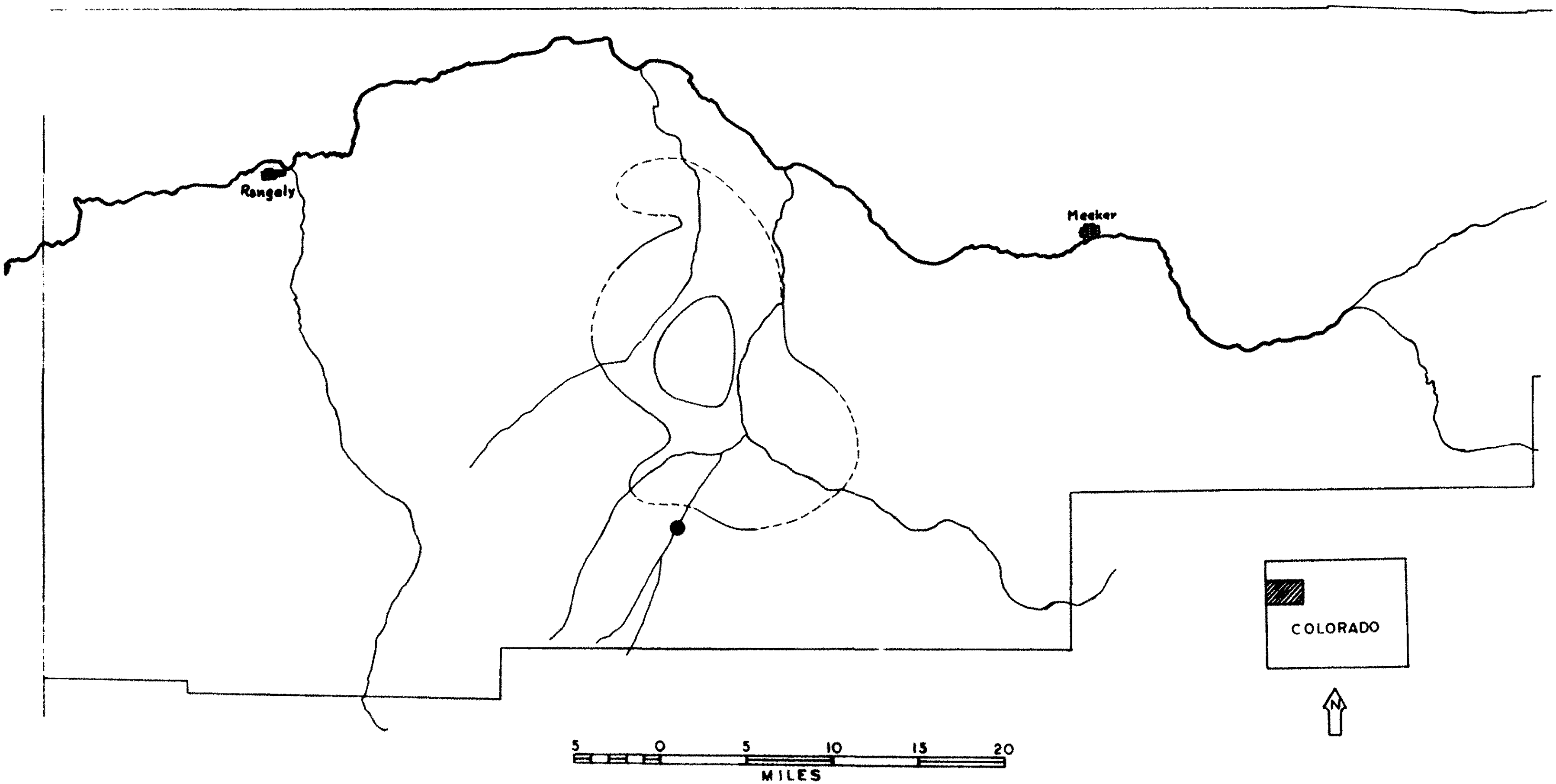


Figure 7. Thickness map of low resistivity or leached zone.

(Redrawn to show the area of minimum thickness, 400 ft., at the center and the outer definition of the zone at 700 ft thickness.)

Alluvium of Quaternary age contains sand, gravel, and clay and partly fills the stream valleys of Piceance, Yellow, Roan, and Parachute Creeks. The permeable alluvium is an aquifer in the Piceance Creek basin. The saturated thickness is as great as 100 feet. However, the areal extent of the alluvium is small and is usually confined to belts less than 1 mile wide. Because of this limited width, the alluvium is not capable of supplying large quantities of water to wells for more than a few months. The alluvium ranges from 0 to 140 feet thick.

Structure

The Green River Formation is cut by a very extensive joint or fracture system. The orientation of many of the streams and their tributaries appears to be controlled by these fractures. Streamflow along joints or fractures provide avenues for recharge to both the Evacuation and Parachute Creek Members. The joints are parallel to major structural features in the basin, but the primary trend is towards the northwest.

Precipitation

Distribution of precipitation in the Piceance Creek structural basin is markedly affected by altitude (Iorns and others, 1965, p. 184-185). Areas where the altitude is greater than 8,000 feet, such as along the major divide and Cathedral Bluffs as shown on the potentiometric contour map (fig. 8) receive as much as 26 inches of precipitation per year, mostly as snow in the winter months. Areas between altitudes of about 5,500 and 8,000 feet generally receive from 12 to 20 inches of precipitation annually. Streamflow generally is greatest during spring snowmelt. Some of the springs in the basin show a similar response to snowmelt as shown by the hydrographs of selected springs (fig. 9).

Samples of water having a dissolved-solids content ranging from 250 to 63,000 mg/l (milligrams per liter) have been collected in the basin. The best quality of water is found in streams and aquifers in the higher altitudes in the basin. The worst quality of water is found in the high resistivity zone of the Parachute Creek Member.

Ground water in the Green River Formation

The Green River Formation is the best potential source of ground water in the northern part of the Piceance Creek basin. The leached zones of the Parachute Creek Member and the Evacuation Creek Member are aquifers (fig. 5) and contain water under artesian pressure in most of the area. There are many flowing wells and the maximum depth to water is about 200 feet. The Garden Gulch Member and the high resistivity zone of the Parachute Creek Member have low permeability and confine water

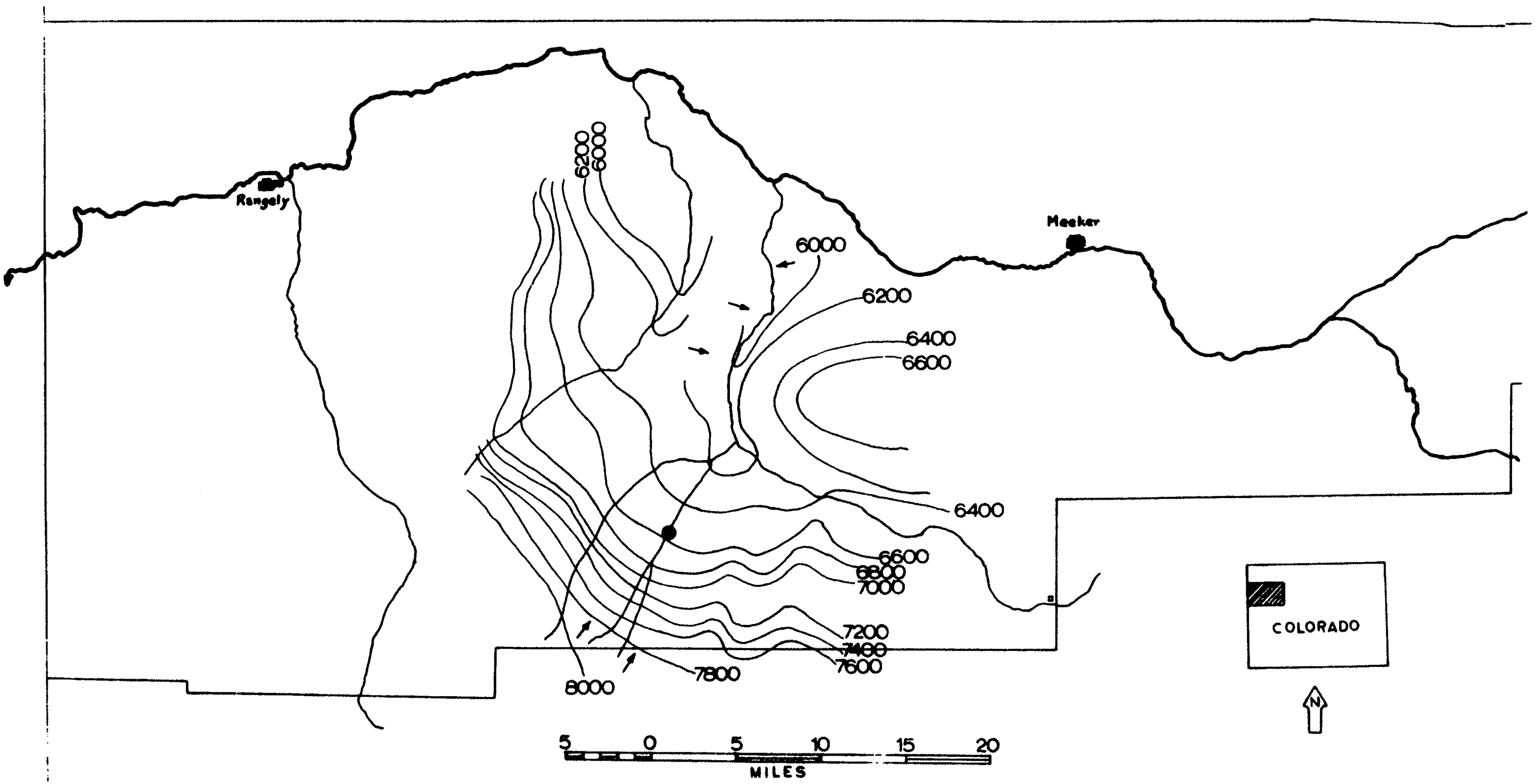


Figure 8. Potentiometric contour map.

(Redrawn to show the direction of ground water movement only.)

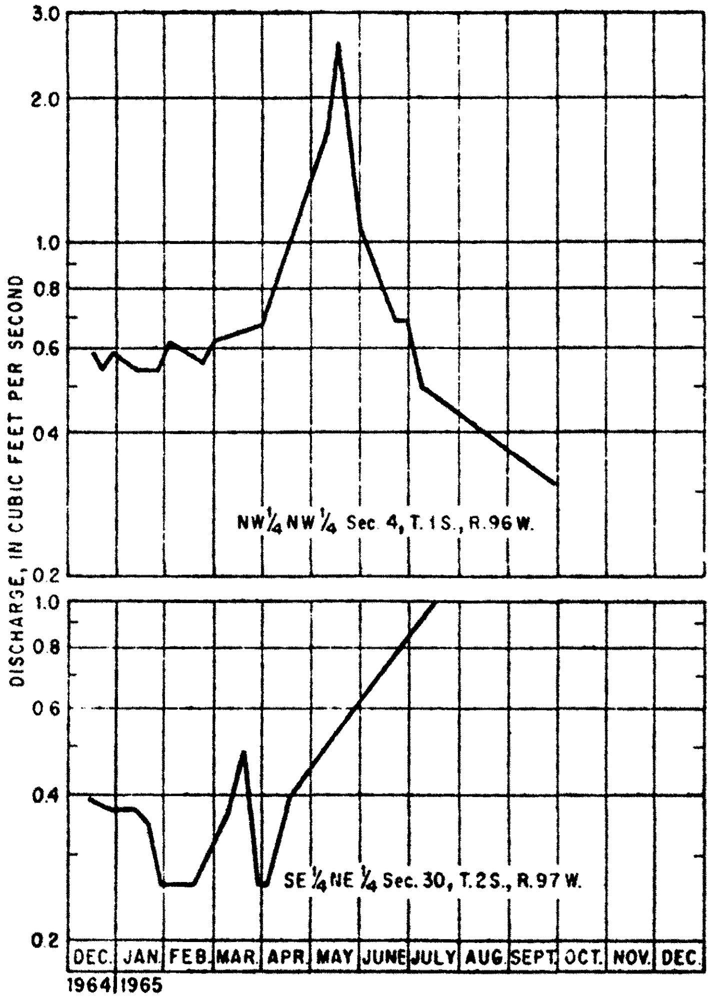


Figure 9. Hydrographs of selected springs.

in underlying aquifers. The Mahogany zone of the Parachute Creek Member also confines water except where it is cut by vertical fractures. These fractures permit water to move between aquifers (see diagrammatic section, fig. 4). The leached zone contains water in fractures and solution openings and is considered the principal bedrock aquifer in the northern part of the Piceance Creek basin because it has the greatest areal extent, permeability, and storage capacity. It contains 2.5 million acre-feet or more of water in storage (fig. 7). The transmissivity distribution in the leached zone was estimated from the thickness map of the zone (fig. 7) and from six aquifer tests (Coffin and others, 1968). The transmissivity of the zone ranges from less than 3,000 gpd per ft (gallons per day per foot) in the margins of the basin to 20,000 gpd per ft in the center of the basin. Tests indicate that the potential yield of a well tapping the leached zone may be as much as 1,000 gpm (gallons per minute). The artesian storage coefficient of the leached zone is estimated to be about 10^{-4}, but when not confined, the storage coefficient would be about 10^{-1}. Thus, pumping very large quantities of water would cause water levels to decline several hundred feet to the top of the leached zone in a short time, but after water levels reached the leached zone the decline would be much slower. The Evacuation Creek Member contains water mainly in fractures. Its permeability is much less than the leached zone. Test wells penetrating the Evacuation Creek Member in the north-central part of the basin yield 100 gpm or less.

The major ground-water divide in the basin is approximately the same as the topographic divide between the White River and the Colorado River. Ground-water movement in the Green River Formation (northern part of the Piceance Creek basin) is toward the two major drainages of the basin, Piceance and Yellow Creeks. Movement is normal to the contours shown on the potentiometric contour map (fig. 8). The Green River Formation is bounded on the west by Cathedral Bluffs. On the north, the divide is near the main stem of the White River (fig. 8). Recharge on the margins of the basin moves downward through the Evacuation Creek Member and Mahogany zone into the leached zone of the Parachute Creek Member. Data from a few wells indicate that the potentiometric head in the leached zone near the edges of the basin is lower than the head in the overlying zones. Other data indicate that near the center of the basin the head in the leached zone is higher than the head in the upper zone. These head relations indicate that the direction of flow is downward in the margins of the basins, laterally toward the center and northern edge of the basin, and upward in the lower reaches of Piceance and Yellow Creeks and in the White River valley (see diagrammatic section, fig. 4). In the center and northern edge of the basin water moves upward from the leached zone through the Mahogany zone into the Evacuation Creek Member where it discharges into Piceance Creek, Yellow Creek, the White River, or is evaporated. Smaller amounts of ground water are discharged to springs and flowing wells (fig. 8). The potentiometric contours indicate that about half of the northern part of the basin contributes ground water to Piceance Creek. South of the major divide, water is discharged by springs that issue from fractures near the top of the Mahogany zone. In the lower part of the stream valleys, the Mahogany forms part of a cliff as high as 2,000 feet above the stream. Spring discharge from the top of the zone in these areas can be seen as a dark band along the upper part of the cliff. However, most of this water evaporates before reaching a stream.

Pumping large quantities of ground water from the Green River Formation would change the points of discharge. Continuous pumping of large amounts of ground water for a number of years could dry up springs over a large part of the basin and stop much of the seepage to the creeks. Many of the water holes used by wildlife would disappear and the base flow of Piceance and Yellow Creeks would be appreciably diminished to the detriment of present appropriators.

The dissolved solids concentration of water in the Green River Formation ranges from 250 to 63,000 mg/l. Water near the edges of the basin contains less than 2,000 mg/l dissolved solids and the dominant ions are calcium, magnesium, and bicarbonate. About halfway between the edges of the basin and the center, dissolved solids are about the same as at the edges, but the dominant ions are sodium and bicarbonate. Near the center of the basin, the water has dissolved considerable amounts of saline minerals and the dissolved solids average 25,000 mg/l and the principal constituents are sodium and bicarbonate. Chloride concentration ranges between 500 and 2,500 mg/l. The graph (fig. 10) relating dissolved solids of water in the basin to specific conductance can be used to approximate dissolved solids concentrations from field conductivity measurements. Water in the Parachute Creek and Evacuation Creek Members are chemically similar in the higher parts of the basin (Coffin and others, 1968). However, in the lower parts of the basin, water in the Parachute Creek Member becomes highly mineralized from contact with the saline minerals. For example, water in an abandoned oil test well near Piceance Creek about 1.5 miles below Ryan Gulch contained 17,400 mg/l dissolved solids, principally sodium and bicarbonate. The water in the well contained 542 mg/l chloride and is unsuitable for most uses. Water in the Evacuation Creek Member is a mixed chemical type with no dominant cation or anion. The principal

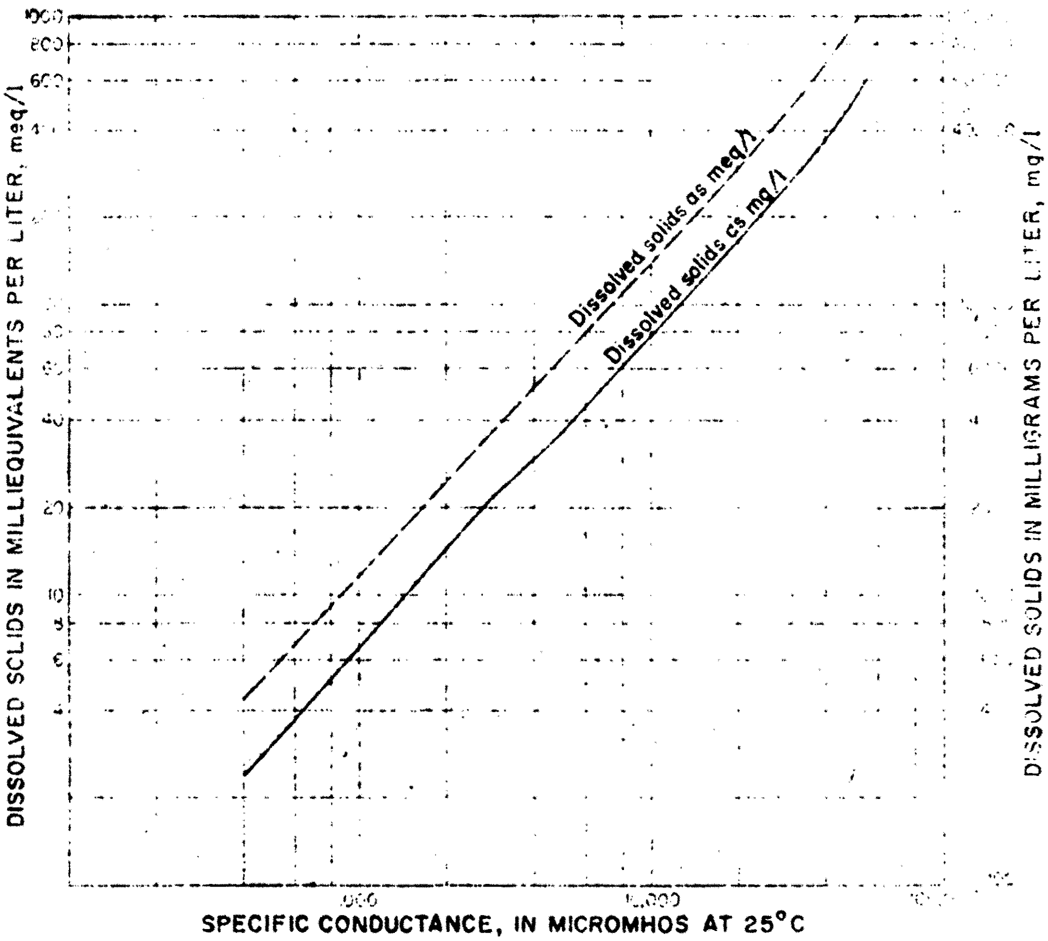


Figure 10. Graph relating specific conductance and dissolved solids.

constituents are sodium, magnesium, and sulfate. Analyses of water samples from the Evacuation Creek Member are summarized in a bargraph (fig. 11). The dissolved solids concentration ranges from 250 to 1,800 mg/l. Water in the Parachute Creek Member has sodium and bicarbonate as the principal ions, however, when the dissolved solids are less than 500 mg/l, the principal ions are calcium and bicarbonate. A summary of analyses of water samples from the Parachute Creek Member is given in a bargraph (fig. 12). The dissolved solids concentration ranges from 250 to 63,000 mg/l. The average dissolved solids concentration of 6 water samples obtained during a pumping test of the high resistivity zone was 63,000 mg/l.

Ground water in the alluvium

Alluvium is a source of ground water along Piceance, Yellow, Roan, and Parachute Creeks. The alluvial aquifer is capable of storing and transmitting more water per unit volume than any other aquifer in the basin. However, the areal extent of the deposits is small compared to that of the bedrock aquifers. The alluvium is confined to belts less than 1 mile wide along the creeks. Along the major drainages, the alluvium ranges from 0 to 140 feet thick and the saturated thickness may be as much as 100 feet in a few places (Coffin and others, 1968). Water in the alluvium occurs under both water-table and artesian conditions. The permeability of the clay is much less than that of the sand and gravel, and where it confines water in underlying sand and gravel under enough pressure, water flows at the land surface when tapped by a well. Typical occurrences of alluvium in the major stream drainages are shown by the sections below the potentiometric contour map (fig. 8, Sheet 3 of 3) (omitted)

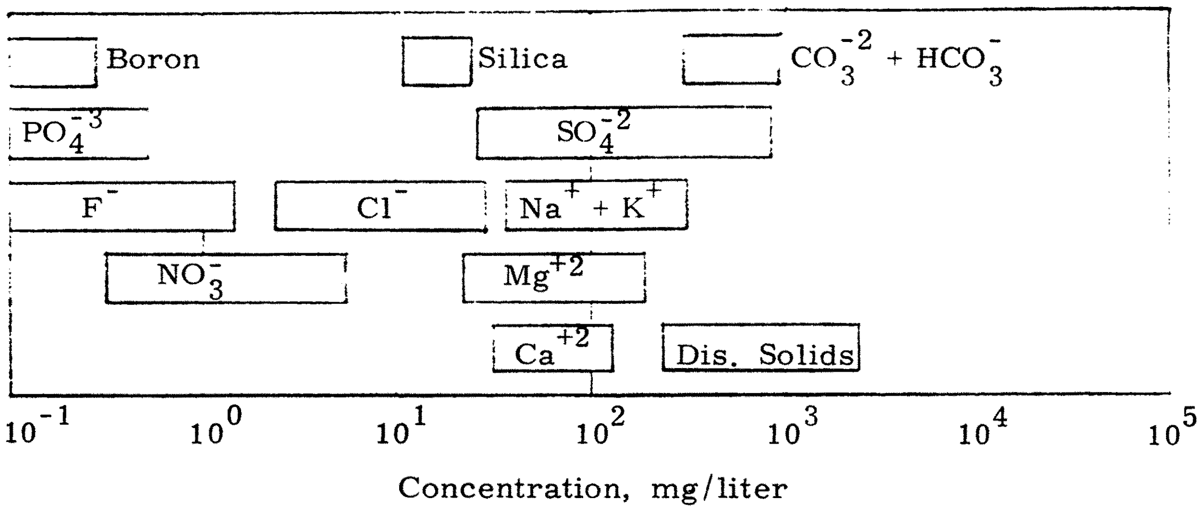


Figure 11. Range of water quality in the Evacuation Creek Member.

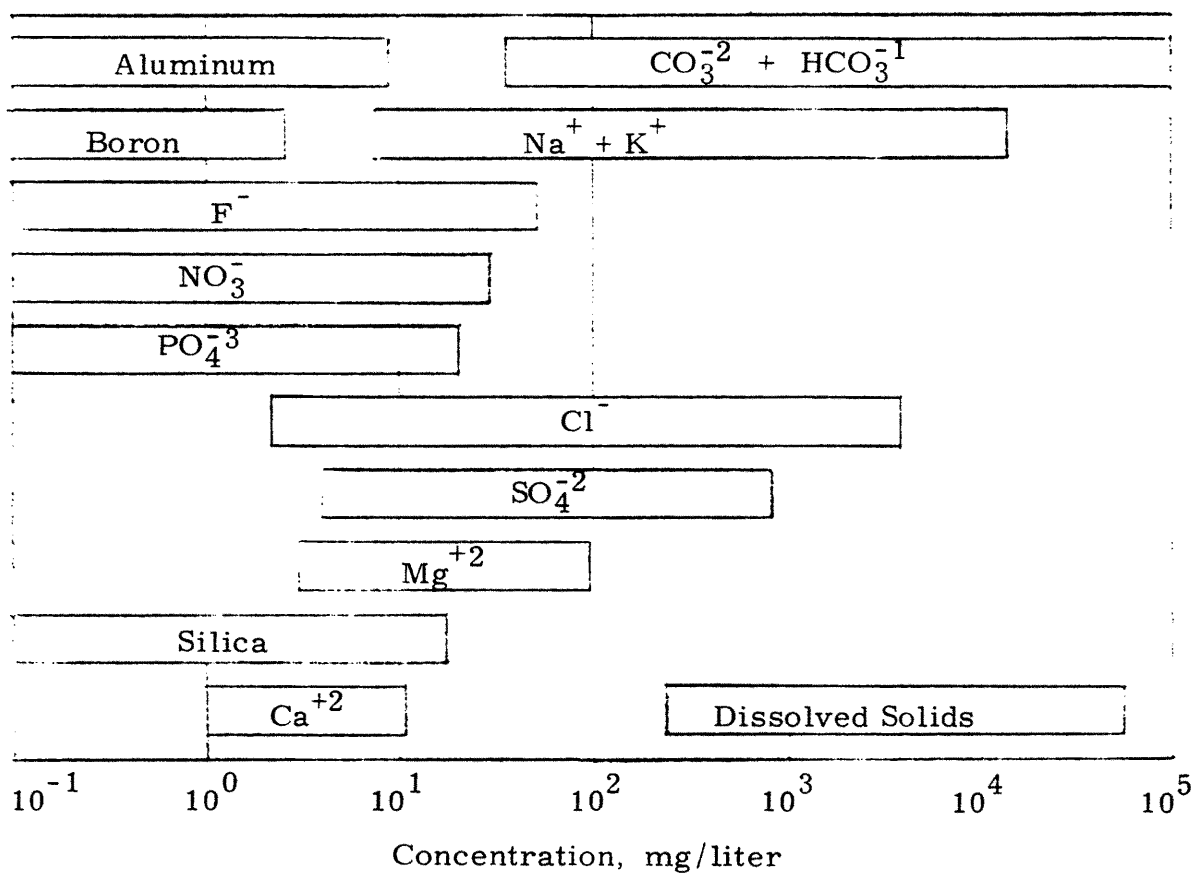


Figure 12. Range of water quality in the Parachute Creek Member

(The two figures above were redrawn in order to reduce the scale from the originals.)

An aquifer test in the alluvium of Piceance Creek showed that after pumping a few hours, the hydrologic boundaries of the alluvium will affect drawdowns and well yields (Coffin and others, 1968). The storage coefficient probably averages about 0.20. In places where the alluvium contains clay beds, the transmissivity may be as low as 20,000 gpd per ft. Thus, well yields vary widely from place to place according to variations in lithology of the alluvium at the well and proximity of the well to the hydrologic boundaries. Initial yields from properly located, developed, and constructed wells are estimated to be as much as 2,000 gpm. An irrigation well in Roan Creek was reported to yield 1,500 gpm.

The alluvial aquifer is recharged by precipitation, by applied surface water, by streams, and by infiltration from the Green River Formation. The aquifer discharges to streams, springs, wells, and to the atmosphere by evapotranspiration.

The dissolved solids concentration of water in the alluvium ranges from 250 to 25,000 mg/l. Water in alluvium in the upper reaches of the major drainages contains less than 700 mg/l dissolved solids. In general, the principal ions in the alluvial water are calcium, magnesium, and bicarbonate. Ions in the water in the alluvium of Piceance Creek are predominantly calcium, magnesium, sodium, and bicarbonate; the dissolved solids concentration increases downstream. The dissolved solids concentration is about 700 mg/l at Cow Creek and 2,500 mg/l at Dry Fork (fig. 8). Below Dry Fork the concentration increases to 8,300 mg/l and sodium becomes the dominant cation. These changes occur by solution and ion exchange and reflect the change in nature of the bedrock underlying the alluvium. Above Dry Fork the alluvium is underlain by the Evacuation Creek Member and below by the Parachute Creek Member. Abandoned flowing wells below Dry Fork tapping the Parachute Creek Member contribute locally to the increase in dissolved solids. Water in the alluvium in Yellow Creek appears to be within the range in composition and concentration of the water in the alluvium of Piceance Creek. Dominant ions in the water in the alluvium of Roan and Parachute Creeks are calcium, magnesium, sodium, bicarbonate, and sulfate. The dissolved solids concentration of the water is as much as 7,200 mg/l. The alluvium of Roan and Parachute Creeks contains some gypsum which was derived from the Wasatch Formation. Water in contact with the gypsum becomes increasingly concentrated with sulfate. The sulfate concentration of a water sample obtained near the mouth of Roan Creek was 4,200 mg/l.

Surface water

There are no long-term records of streamflow in the Piceance Creek structural basin between the Colorado and White Rivers. Gaging stations on seven streams have been operated at various times. The records at these stations are summarized in table 2 and the station locations are shown on the potentiometric contour map (fig. 8). Except for two unpublished records, these data are published in Water-Supply Papers of the U.S. Geological Survey and in the annual series, Surface Water Records for Colorado, Part 1.

[Station: Numbers are those used in publication of surface-water records, except prefix 9 is omitted.]

Station No.	Streamflow station	Period of record	Drainage area (sq mi)	Average discharge (cfs)	Extremes of discharge (cfs)	
					Maximum	Minimum daily
0928	West Fork Parachute Creek near Grand Valley	Oct. 1957-Sept. 1962	48.1	4.37	147	0
0930	Parachute Creek near Grand Valley	Oct. 1948-Sept. 1954 Oct. 1964-Sept. 1967	144	17.7	738	0
0935	Parachute Creek at Grand Valley	Apr. 1921-Sept. 1927 Oct. 1948-Sept. 1954	200	30.3	912	0
0940	Roan Creek at Simmons Ranch	June 1935-Sept. 1935 Apr. 1936-Oct. 1936 Mar. 1937-Sept. 1937	79	----	142	0
0941	Carr Creek at Altenbern Ranch	June 1935-Nov. 1936 Mar. 1937-Sept. 1937	17	2.85	143	0
0942	Roan Creek above Clear Creek	Oct. 1962-Sept. 1967	151	14.8	800	1.0
0944	Clear Creek near DeBeque	July 1966-Sept. 1967	111	----	1,540	0
0950	Roan Creek near DeBeque	Apr. 1921-Sept. 1926 Oct. 1962-Sept. 1967	321	40.0	1,220	3.2
3055	Piceance Creek at Rio Blanco	Oct. 1952-Sept. 1957	9	1.40	23	.1
3060	Piceance Creek near Rio Blanco	Oct. 1940-Sept. 1943	153	20.3	430	.1
3062	Piceance Creek below Ryan Gulch	Oct. 1964-Sept. 1967	485	12.5	400	.80
3062.22	Piceance Creek at White River[1/]	Oct. 1964-Sept. 1966	629	17.0	550	.9
3062.55	Yellow Creek near White River[1/]	Oct. 1964-Sept. 1966	258	1.37	1,060	0

1/Unpublished record.

Commonly, all streams in the basin reach a peak during the snowmelt runoff and decrease in flow beginning in June or July, and reach low flow in September or October. Low flow continues through the winter. Parachute Creek is often dry, or almost dry, from December until April. The flow of Piceance Creek is more uniform than that of Parachute or Roan Creeks because the flow is sustained by ground-water discharge from the Green River Formation. However, in 1965 and 1966 the flow of Piceance Creek below Ryan Gulch dropped below its average of 12.5 cfs (cubic feet per second) to as little as 0.8 cfs during April or May due to diversions for irrigation before the snowmelt runoff.

On October 6, 1965, discharge was measured at 13 sites and 8 samples for chemical analysis were collected from Piceance Creek from Rio Blanco to the White River gage. The results of this study are shown on the discharge-quality graph (fig. 13). Little water was being diverted for irrigation and there had been no precipitation for several weeks. The gain in flow downstream from Rio Blanco was caused by a thinning of the alluvium, forcing the ground water to the surface. The streamflow disappeared into the alluvium where it thickens at Cow Creek, but 2 miles downstream the alluvium was saturated and surface flow resumed. The potentiometric contour map (fig. 8) indicates that the reach between Thirteenmile Creek and Black Sulphur Creek is fed by ground water. The 14 cfs gain in this reach, as determined by the October 6, 1965 study, supports this conclusion.

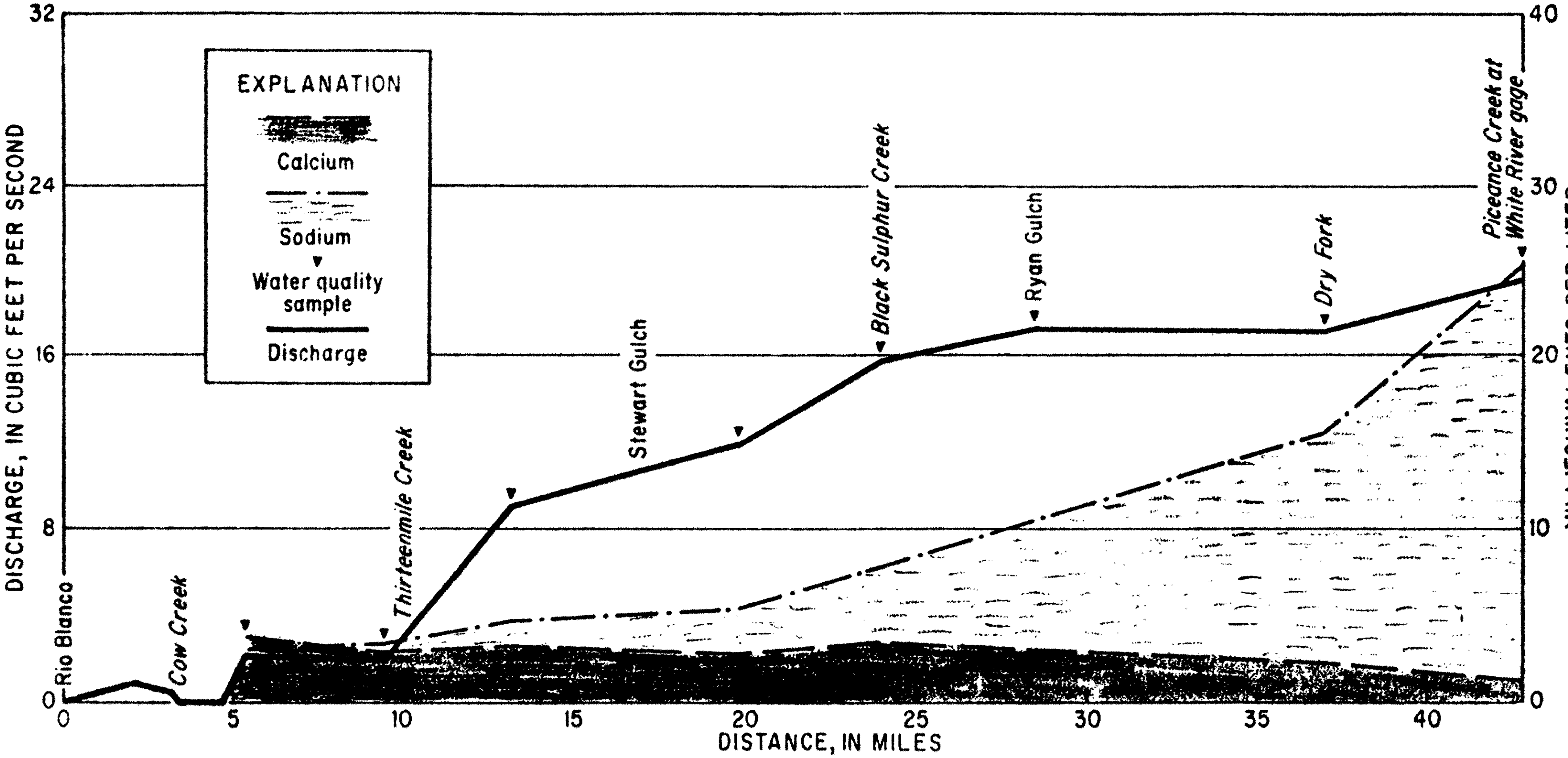


Figure 13. - Graph showing discharge at various places along Piceance Creek and changes in quality of water, October 6, 1965.

The effect of ground-water discharge from the Green River Formation on the chemical quality of water in Piceance Creek is illustrated on the discharge-quality graph (fig. 13). Above Thirteenmile Creek, the bedrock is the Evacuation Creek Member and ions in the water in Piceance Creek are predominantly calcium, magnesium, and bicarbonate; below Thirteenmile Creek, water contributed from the Parachute Creek Member caused a gradual increase in sodium, which became the dominant cation in the reach below Ryan Gulch. The dissolved solids concentration ranged from 600 mg/l at Cow Creek to 2,000 mg/l at the White River gage.

Samples of water for chemical analysis at various discharges were collected on Piceance, Yellow, Roan, and Parachute Creeks. The results of the analyses are shown on the graphs showing chemical character for the various streams (figs. 14 to 17). Water in the alluvium is generally the same chemical character as the water in the stream, but has a higher dissolved solids concentration. In general, the quality of the water is best at high discharges but the chemical character remains about the same. The observed range in dissolved solids concentration in the four streams was as follows: Piceance Creek, 440 to 5,700 mg/l; Yellow Creek, 1,400 to 3,000 mg/l; Roan Creek, 430 to 2,300 mg/l; and Parachute Creek, 360 to 1,280 mg/l.

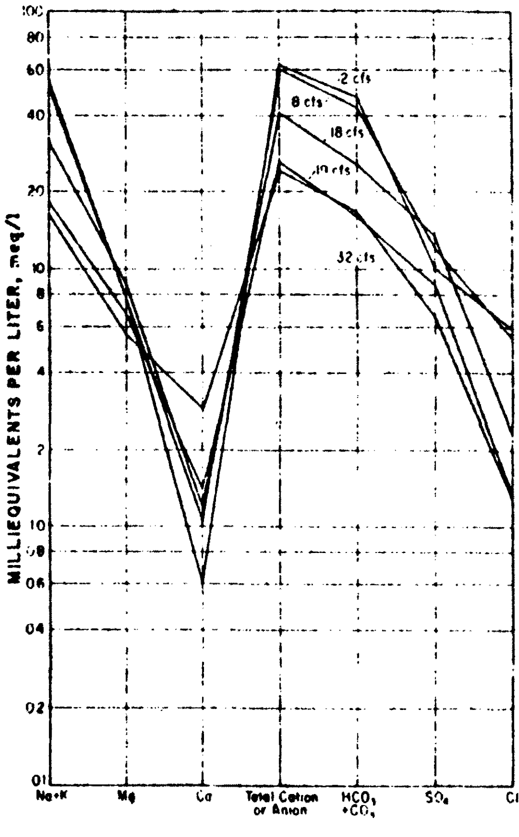


Figure 14. Chemical character of Piceance Creek at White River.

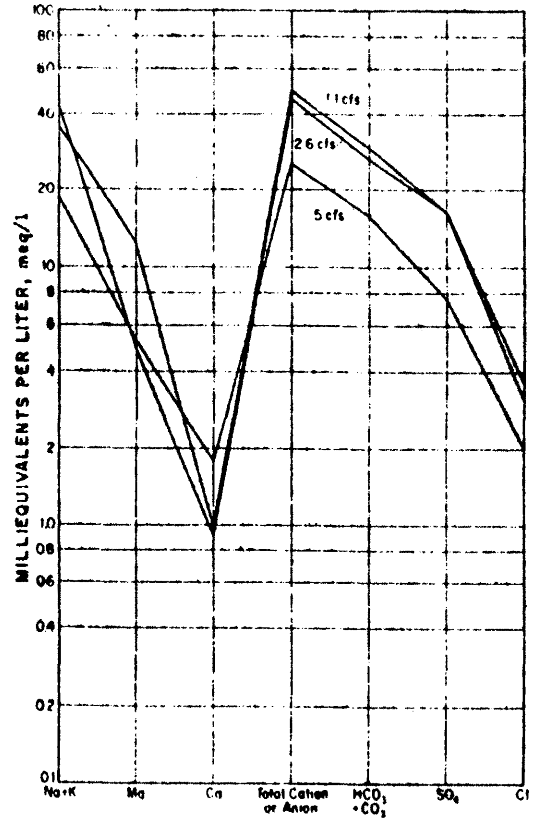


Figure 15. Chemical character of Yellow Creek near White River.

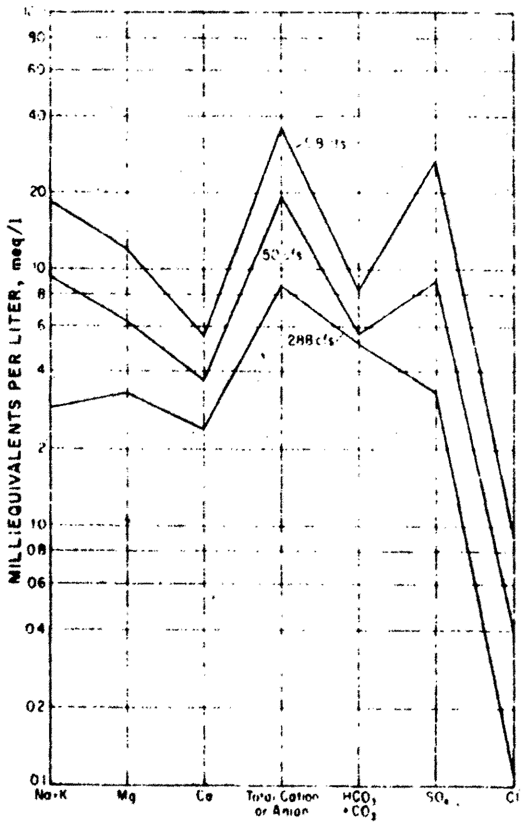


Figure 16. Chemical character of Roan Creek at De Beque.

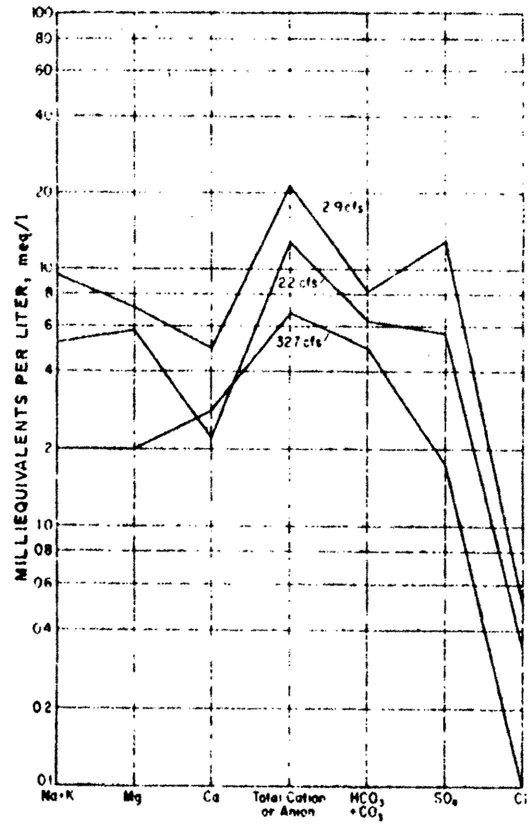


Figure 17. Chemical character of Parachute Creek at Grand Valley.

Conclusions

1. Surface-water supplies in the basin are small and are completely developed.

2. Additional ground-water supplies could be developed from the Green River Formation or from the alluvium. Wells in the Green River Formation might yield as much as 1,000 gpm. Wells in the alluvium might yield as much as 2,000 gpm.

3. Pumping large quantities of ground water from either the alluvium or from the leached zone of the Green River Formation would have adverse effects on present surface supplies.

4. The water stored in the leached zone represents a potential source of industrial supply that might last many years. The zone contains 2.5 million acre-feet of ground water in storage. Pumping large quantities of water from the Green River Formation would cause levels to decline several hundred feet in a short period of time (<1 yr).

5. Water pumped from the leached zone would contain dissolved solids ranging from less than 2,000 mg/l near the edges of the basin to more than 60,000 mg/l in the center of the northern half of the basin. The 60,000 mg/l water might have a chloride concentration of 1,000 mg/l or more. Water with a chloride concentration this high is unsuitable for most uses. Ions in the water near the edges of the basin are predominantly calcium, magnesium, and bicarbonate; the ions near the center of the basin are predominantly sodium and bicarbonate.

6. Oil shale mining operations may be hampered by ground water. Flooding by ground water would be most serious in mines which are excavated in or below the leached zone. For example, near the center of the basin, an open-pit mine with a radius of half a mile might require a pumping rate of as much as 60 cfs to keep the mine dewatered.

7. Disposal of mine effluent in surface streams would increase the salt load in the White and Colorado Rivers, which would pose a serious pollution problem.

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APPENDIX IV-2

Current water quality standards for Colorado and classification of the White River.

COLORADO DEPARTMENT OF HEALTH
Water Pollution Control Commission
4210 East 11th Avenue
Denver, Colorado 80220
Adopted: April 13, 1971
Effective: Sept. 1, 1971

WATER QUALITY STANDARDS FOR COLORADO

The Second Session of the Forty-Fifth General Assembly of the State of Colorado passed Water Pollution Control Legislation for the State of Colorado as set out in Chapter 66, Article 28, C.R.S. 1963 (1967 Perm. Cum. Supp.). In adopting this legislation, the following legislative declaration was made:

> "Whereas the pollution of the waters of this state constitutes a menace to public health and welfare, creates public nuisances, is harmful to wildlife, fish and other aquatic life, and impairs domestic, agricultural, industrial, recreational, and other beneficial uses of water; and whereas the problem of water pollution of this state is closely related to the problem of water pollution in adjoining states; and whereas it is the public policy of this state to conserve the waters of the state and to protect, maintain, and improve the quality thereof for public water supplies, for the propagation of wildlife, fish and other aquatic life, and for domestic, agricultural, industrial, recreational, and other beneficial uses, and to provide that no wastes be discharged into any waters of the state without first being given the degree of treatment necessary to protect the beneficial uses of such water, it is hereby declared that the prevention, abatement, and control of the pollution of the waters of this state are affected with a public interest and the provisions of this act are enacted in the exercise of the police powers of this state for the purpose of protecting the health, peace, and safety, and general welfare of the people of this state."

These standards are the foundation for the classification of the waters of the State of Colorado, as defined in the Water Pollution Control Act of 1966, as amended.

Standards are subject to revision as technical data, surveillance programs, and technological advances make such revisions desirable.

For purposes of enforcement of these standards, sampling will be done at a point where these standards can be evaluated.

For purposes of enforcement of water classification standards, sampling of the waters will be done at any point, except for areas immediately adjacent to outfalls and except as may be noted in the text of the standards. In such areas, cognizance will be given to the opportunity for admixture of waste effluents with receiving water.

Tests or analytical procedures to determine compliance with standards will, insofar as practicable and applicable, be made in accordance with the methods given in the latest edition of "Standard Methods For The Examination Of Water And Waste Water" published by the American Public Health Association, or in accordance with tests or analytical procedures that have been found to be equal or more applicable and satisfactory and accepted and approved by the Commission.

In areas where a body of water is classified for more than one use, the standards applicable to each use shall apply and in case of a conflict, the more restrictive standards shall prevail in each instance.

Where and when additional waters become available, hearings will be held on the possible classification or reclassification of such waters for further enhancement. The quality of water will be maintained as high as possible and in no case shall stream standards be violated.

It is expected that the present uses of the waters of Colorado will continue but if other uses develop, streams may be classified or reclassified after public hearings.

Waters of the state, the quality of which exceeds the limits set in these standards, will be maintained at existing quality unless and until it can be demonstrated to the State that a change in quality is justified to provide necessary economic or social development. In that case, the best practicable degree of waste treatment to protect the current classification of such waters will be required. The appropriate Federal authority will be provided with information, from time to time, required to discharge his responsibilities under the Federal Water Pollution Control Act, as amended.

I. BASIC STANDARDS APPLICABLE TO ALL WATERS OF THE STATE:

A. All wastes capable of treatment or control prior to discharge into any waters of the state, shall receive secondary treatment with disinfection or its industrial waste equivalent, as determined by the State Water Pollution Control Commission. Lesser degrees of treatment or control may be permitted only where it can be demonstrated that the standards applicable to the classified use of the water can be attained. Greater degrees of treatment or control will be required where it can be demonstrated that it is necessary to comply with the standards applicable to the classified use of the water.

B. Free from substances attributable to municipal, domestic, or industrial wastes, or other controllable sources that will either settle to form unsightly, putrescent, or odorous bottom deposits, or will interfere with the classified use of the water.

C. Free from unsightly floating debris, oil, grease, scum, and other floating material attributable to municipal, domestic, or industrial wastes, or other controllable sources.

D. Free from materials attributable to municipal, domestic or industrial wastes, or other controllable sources that will produce objectionable odor, color, taste, or turbidity in the water, or objectionable aquatic life which may result in eutrophication or other conditions that interfere with the classified use of the water.

E. Free from high temperatures, biocides, toxic, or other deleterious substances attributable to municipal, domestic, or industrial wastes, or other controllable sources in levels, concentrations, or combinations sufficient to be harmful to human or animal life.

F. Radioactive materials attributable to municipal, industrial or other controllable sources will be minimum concentrations that are physically and economically feasible to achieve. In no case shall such materials in the stream exceed the limits established in the current edition of the U. S. Public Health Service Drinking Water Standards or the limits approved by the Federal Radiation Council, or, in the absence of any limits specified by the U. S. Public Health Service or the Federal Radiation Council, 1/30 of the 168-hour-week values for other radioactive substances specified in the National Bureau of Standards Handbook 69.

II. ADDITIONAL WATER QUALITY STANDARDS FOR BODIES OF WATER THAT HAVE BEEN CLASSIFIED FOR ANY OF THE FOLLOWING USES:

CLASS A.

1. The following standards shall apply to water withdrawn for treatment as a potable supply:

   a. Bacteria: Wastes or substances from controllable sources shall not be discharged into these waters in amounts which will cause the number of organisms of the fecal coliform group, as determined by either multiple tube fermentation or membrane filter techniques, to exceed a log mean of 1000 per 100 milliliters or exceed 2000 per 100 milliliters in more than 10% of the samples collected in any 30 day period.

   b. Dissolved Oxygen: Dissolved oxygen shall not be less than 4 milligrams per liter.

   c. pH: The pH shall be maintained between 6.0 and 9.0.

   d. Taste and Odor: Free from materials attributable to municipal, domestic, or industrial wastes, or other controllable sources that will produce taste or odor in the water.

   e. Dissolved Solids: Total dissolved solids, annual volume weighted average, should be less than 500 milligrams per liter.

CLASS A. - continued

f. Selected Chemical Constituents: The following substances shall not be present in such amounts as to exceed the specified concentrations in a potable water supply according to the mandatory requirements of the latest edition of the U. S. Public Health Service Drinking Water Standards:

Substance	Concentration - mg/l
Arsenic	0.05
Barium	1.00
Cadmium	0.01
Chromium (Hexavalent)	0.05
Cyanide	0.20
Lead	0.05
Selenium	0.01
Silver	0.05

CLASS B.

1. The following standards shall apply to waters classified for fish and wildlife (Cold Water Fishery):

   a. Bacteria: Wastes or substances from controllable sources shall not be discharged into these waters in amounts which will cause the number of organisms of the fecal coliform group, as determined by either multiple tube fermentation or membrane filter techniques, to exceed a log mean of 1000 per 100 milliliters or exceed 2000 per 100 milliliters in more than 10% of the samples collected in any 30 day period.

   b. Dissolved Oxygen: In cold water fisheries, the dissolved oxygen content shall in no case go below 6 milligrams per liter.

   c. pH: pH shall be maintained between 6.5 and 8.5. No controllable pH change will be permitted which will interfere with fish and aquatic life.

   d. Turbidity: No turbidity shall exist in concentrations that will impair natural and developed fisheries.

   e. Temperature: In cold water fisheries the temperatures shall not exceed 70° F. No controllable temperature change will be permitted which will interfere with the spawning and other aspects of fish life. *Note: See additional temperature criteria on page 6.

   f. Toxic Material: Free from biocides, toxic, or other deleterious substances attributable to municipal, domestic, or industrial wastes, or other controllable sources in levels, concentrations, or combinations sufficient to be harmful to aquatic life.

CLASS B. - continued

g. Other Material: Free from materials attributable to municipal, domestic, or industrial wastes, or other controllable sources that will produce off-flavor in the flesh of fish.

2. The following standards shall apply to waters classified for fish and wildlife (Warm Water Fishery):

a. Bacteria: Wastes or substances from controllable sources shall not be discharged into these waters in amounts which will cause the number of organisms of the fecal coliform group, as determined by either multiple tube fermentation or membrane filter techniques, to exceed a log mean of 1000 per 100 milliliters or exceed 2000 per 100 milliliters in more than 10% of the samples collected in any 30 day period.

b. Dissolved Oxygen: In warm water fisheries, dissolved oxygen content shall in no case go below 5 milligrams per liter.

c. pH: pH shall be maintained between 6.5 and 8.5. No controllable pH change will be permitted which will interfere with fish and aquatic life.

d. Turbidity: No turbidity shall exist in concentrations that will impair natural and developed fisheries.

* e. Temperature: In warm water fisheries the temperatures shall not exceed 90° F. No controllable temperature change will be permitted which will interfere with spawning and other aspects of fish life. *Note: See additional temperature criteria on page 6.

f. Toxic Material: Free from biocides, toxic, or other deleterious substances attributable to municipal, domestic, or industrial wastes, or other controllable sources in levels, concentrations, or combinations sufficient to be harmful to aquatic life.

g. Other Material: Free from materials attributable to municipal, domestic, or industrial wastes, or other controllable sources that will produce off-flavor in the flesh of fish.

3. The following standards shall apply to recreational waters classified for body contact sports such as, but not limited to, swimming and water skiing:

CLASS B. - continued

a. Bacteria: Total coliform bacteria shall not exceed 1,000 per 100 milliliters as a monthly average (either MPN or MF count); nor exceed this number in more than 20% of the samples examined during any month; nor exceed 2,400 per 100 milliliters in a single sample. In addition, the fecal coliform count shall not exceed 100 per 100 milliliters, and the fecal streptococcus count shall not exceed 20 per 100 milliliters, both of these limits to be an average of five (5) consecutive samples within a month.

b. pH: pH shall be maintained between 6.5 and 8.5.

* Note: Limits on temperature change in fisheries have not been established due to lack of historical temperature data and lack of conclusive temperature change criteria for the aquatic biota of waters of the state. These factual data are being collected, however, to serve as a basis for setting limits. In the meantime, the following tentative criteria will be used as administrative policy:

In cold water fisheries an abrupt change in temperature must be avoided and the normal pattern of diurnal and seasonal fluctuations must be preserved. The maximum allowable temperature increase due to waste discharges in streams and in the epilimnion of lakes shall be 2°F. No warming waste discharge shall be permitted to the hypolimnion of lakes.

In warm water fisheries an abrupt change in temperature must be avoided and the normal pattern of diurnal and seasonal changes must be preserved. The maximum allowable temperature increase due to waste discharges in streams will be 5°F; in the epilimnion of lakes the maximum increase will be 3°F. No warming waste discharge shall be permitted in the hypolimnion of lakes.

In temperature measurement, allowance shall be made for a mixing zone. Provisions shall be made for adequate mixing and no thermal barrier to migration and free movement of aquatic biota shall be permitted in any waters of the state.

CLASS C.

1. The following standards shall apply to waters classified for industrial uses:

a. Dissolved Oxygen: Dissolved oxygen content shall not go below 3 milligrams per liter.

b. pH: pH shall be maintained between 5.0 and 9.0.

c. Turbidity: No turbidity shall exist in concentrations that will interfere with established levels of treatment.

d. Temperature: The temperature shall not exceed 90°F.

CLASS D.

1. The following standards shall apply to waters classified for irrigation:

   a. Total Dissolved Solids (Salt) Concentration: A time-weighted monthly mean at a monitoring station which exceeds the time-weighted monthly mean for a base period established by the Commission by more than two standard deviations shall be subject to review by the Commission.

   b. Sodium Adsorption Ratio: A time-weighted monthly mean at a monitoring station which exceeds the time-weighted monthly mean for a base period established by the Commission by more than two standard deviations shall be subject to review by the Commission.

   c. Toxic Material: Free from biocides, toxic, or other deleterious substances attributable to municipal, domestic, industrial wastes, or other controllable sources in concentrations or combinations which are harmful to crop life.

2. The following standards shall apply to waters classified for livestock watering:

   a. Soluble Salts: The soluble salts shall not exceed 3,000 milligrams per liter.

John R. Moran, Jr., Secretary
Colorado Water Pollution Control Commission

T. W. Ten Eyck, Chairman
Colorado Water Pollution Control Commission

WHITE RIVER SUB-BASIN STREAMS

CLASSIFICATION

AREA NO.	AREA	FROM	TO	QUALITY CLASS
1	Main Stem of White River	Source near Trappers Lake	Mouth of Piceance Creek	A, B_1, D_1
2	Main Stem of White River	Mouth of Piceance Creek	Intake for Town of Rangeley's public water supply	A, B_2, C, D_1
3	Main Stem of White River	Intake for Town of Rangeley's public water supply	Colorado-Utah State Line	B_2, C, D_1

APPENDIX IV-3

This appendix consists of extensive excerpts from "Biota and Chemistry of Piceance Creek", a thesis written by Bruce E. May, Colorado State University, Ft. Collins, Colorado, June, 1970.

The excerpts reproduced herein are primarily the portions of the thesis dealing with water quality. For complete details, e.g. data on aquatic biota, photographs, references cited, etc., the original thesis should be consulted.

The page numbers of the original thesis are shown in parentheses following the page numbers assigned for this appendix.

ABSTRACT

BIOTA AND CHEMISTRY OF PICEANCE CREEK

The impact of pollution on an aquatic ecosystem can best be measured by a comparison of the chemistry and biota before and after habitat alteration.

Monthly sampling of Piceance Creek, a small stream in northwestern Colorado, showed distinct seasonal trends in invertebrate populations. A marked spatial distribution within Piceance Creek was due to habitat preference. Invertebrates preferred the cool, clear water in upper Piceance Creek. Fish populations of Piceance Creek were limited to two species, however, these were not good indicators of pollution. Some data were collected from White River and Yellow Creek although no attempt was made to correlate the effects of Piceance and Yellow Creeks on White River.

Fluctuating discharge was a major influence upon the vertebrates and chemical composition of the water. Seasonal variation, biomass, and species composition of invertebrates of Piceance Creek appear to be characteristic of streams in this area.

Bruce E. May
Fishery and Wildlife Biology
Department
Colorado State University
Fort Collins, Colorado, 80521
June, 1970

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STUDY AREA

Piceance basin is located in the center of Colorado's oil shale deposits and covers 3,496.5 km^2. The basin has four major drainages: White River, Piceance Creek, Yellow Creek, and Douglas Creek (Figure 1). Geomorphologically, the Green River formation in Piceance basin is composed of light gray to light brown shale and marlstone with some sandstone and limestone (CWCB and USGS, 1966). Ground cover consists of browse plants, Juniper, Douglas fir, and grasses.

Piceance Creek arises from springs located along the basin at an altitude of 2,050 m and flows through the center of the basin to the White River. Piceance Creek is 80 km long with a discharge of 0.014 to 2.8 m^3/sec. During summer and fall months the upper fourth is usually dry. Extremes in width, depth, and discharge occur after heavy rainfalls and snow melt because of the geologic formation and sparce vegetation. Piceance Creek is a major source of water for agriculture in the area. Ponds located along the stream serve as irrigation storage and provide a limited fishery. The upper 4.8 km of permanent water is cold (0 to 11 C) and generally clear, while the remaining portion has higher temperatures and more turbidity.

Five permanent stations were established on Piceance Creek. Selection of these stations was based on substrate

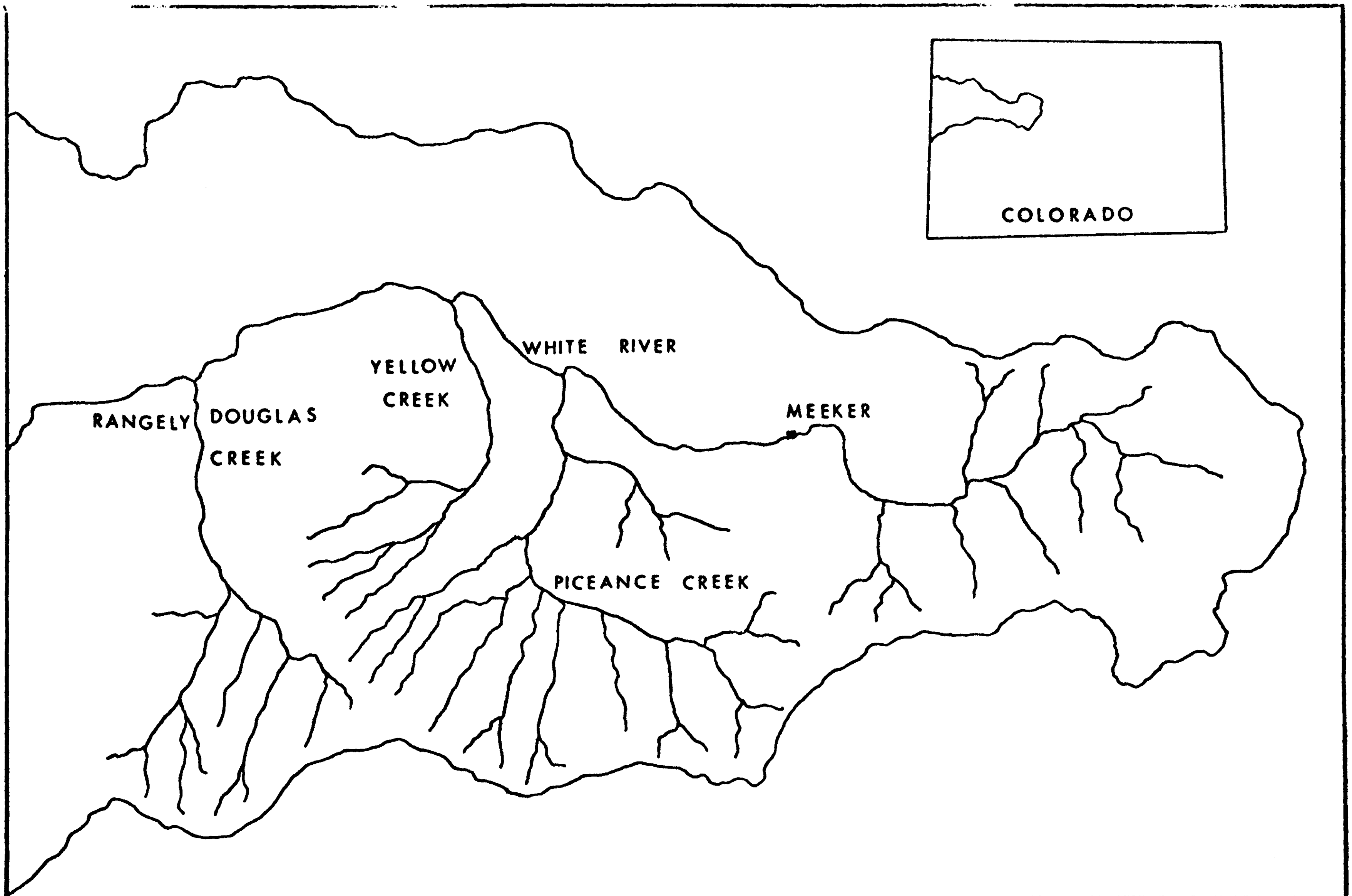

Figure 1. Map of oil shale location in Colorado

type and possible variations caused by springs and water sources.

Station I (Figure 2) was located 120 m from a spring origin of permanent water. Substrate consisted of gravel with occasional large rocks (15-18 cm). There was an ooze or mud type bottom in some parts of the sampling area. Water depth ranged from 8.7 to 26 cm with no deep pools. Discharge was nearly uniform throughout the year. Water at this station remained cool and generally clear throughout the sampling period. Samples were taken at Station I to evaluate the physical and chemical environment and the macrobenthic community.

Station II, 2.8 km below Station I, was similar in substrate composition to Station I. There were more large rocks (15-18 cm) and deeper pools. Depth ranged (in sampling area) from 8 cm (riffle area) to 60.8 cm (large pool). Discharge was increased slightly because of several springs entering into Piceance Creek. Water at Station II remained cool and generally clear. Only samples to evaluate the macrobenthic community were taken at this station.

Station III was located approximately midway between the upper limits of Piceance Creek and its confluence with White River. Three intermittent tributary streams enter above this station adding to discharge and sediment load. Only water samples were taken to evaluate the physical and chemical environment of this station.

Station IV, approximately 8 km below Station III, was considerably different in substrate composition than Stations I and II. One tributary and the three intermittent streams enter Piceance Creek above this station. Bottom composition was comprised mostly of fine gravel (shale) with a few large rocks (15-18 cm). Depth was from 23 to 60.8 cm in large, long pools. There was very little riffle area at this station. Water samples were taken to evaluate physical and chemical environment and bottom samples to evaluate the macrobenthic community at this station.

Station V, 1 km above confluence of Piceance Creek with the White River, was similar to Station IV. At this station the stream had just emerged from a narrow canyon characterized by many meanders and an increased gradient. Substrate consisted of fine gravel (shale) which was very unstable (Figure 3). Depth and width varied seasonally because of the unstable bottom. Samples were taken to evaluate the physical and chemical environment and macrobenthic community.

White River, largest river in the oil shale area, contributes substantial discharge to the Colorado River system. White River supports a coldwater fishery in the head waters and a warmwater fishery in the oil shale area. The river is a source of water for agriculture and fishery and non-fishery recreation. The White River study area, 25 km long, was located above and below the confluence with Piceance Creek.

Three stations were located on White River. Station VI was just above the confluence of Piceance Creek and White

River, Station VII, 10 km below, and Station VIII, 25 km below Station VI (Figure 4).

Yellow Creek, Rio Blanco County, Colorado, is a small stream, but discharge fluctuates greatly. Sediment and chemical components are carried into the White River during high flows. Low discharge limits Yellow Creek for agricultural and recreational uses.

One station was located on Yellow Creek near the bridge on Colorado Highway 64.

METHODS

Sampling Procedure

Physical factors, water samples for chemical analysis, and biological samples were collected monthly. Water samples were collected for physical and chemical determinations at the stations indicated in Figure 5. Sampling was hindered by ice conditions in winter and by high discharge in spring and summer. More intensive sampling was conducted during summer, 1969. Some physical and chemical parameters were monitored weekly and biological sampling was intensified.

Physical Parameters

Physical characteristics have a great influence on species and abundance of organisms capable of surviving in a given environment. Monitoring these parameters provides information about the particular aquatic environment.

Important physical parameters of a stream are water temperature, discharge, and conductivity. Temperature readings were taken with a centigrade pocket-type thermometer. Air and water temperatures were taken monthly. Discharge records were supplied by the United States Geological Survey. Specific conductance was determined with a Beckman Model RC-16B2 conductivity bridge and reported as u mho cm^{-1} at 25 C.

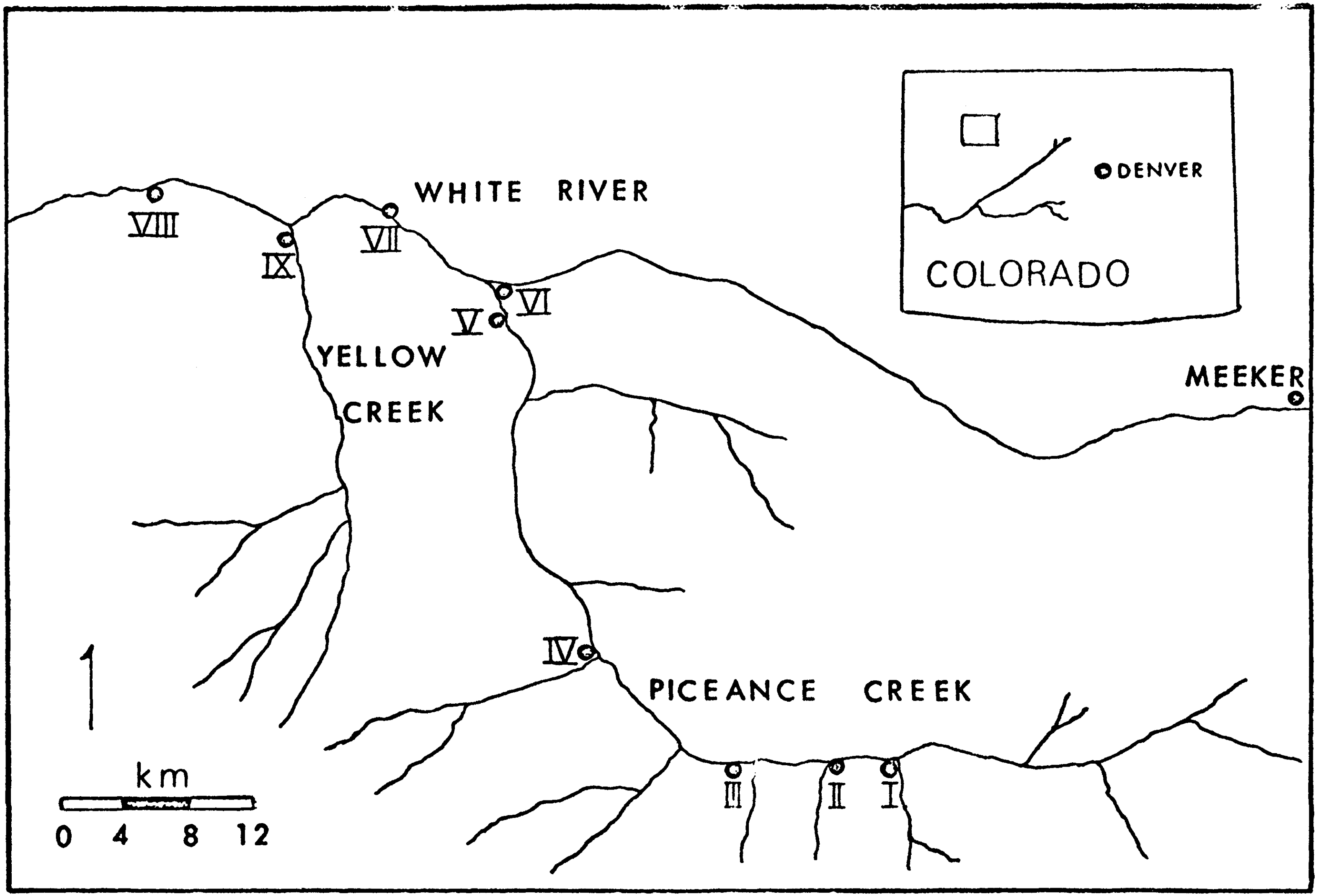

Figure 5. Map of Piceance Creek, White River, and Yellow Creek.

Chemical Parameters

All chemical analyses were carried out according to standard method APHA (1965) unless otherwise stated.

Dissolved oxygen was determined by the Alsterberg modification of the Winkler Method. Alkalinity was determined by the indicator method titrating with 0.02N H_2SO_4 to a pH 4.5 endpoint. Hydrogen ion concentration was determined with a Beckman Electromate glass electrode pH meter. Filtrable solids include all materials, liquid or solid, in solution or otherwise, which pass through a 0.45 u filter and are not volatilized during drying (APHA, 1965). Filtrable solids and total solids were determined by evaporation at 103-105 C with filtration (using No. 40 Whatman filter paper) when sediments were visable. Nonfiltrable solids were calculated as the difference between filtrable and total solids. Settleable matter was estimated by volume using an Imhoff cone.

Cations (calcium, magnesium, sodium, and potassium) and trace elements (cadmium, copper, chromium, iron, lead, manganese, molybedenum, nickel, silver, and zinc) were determined by a Perkin-Elmer 303 atomic absorption spectrophotometer. All samples were preserved by adding hydrochloric acid to 1% of sample volume (FWPCA, 1969).

Anions (chloride, nitrate, silica, and sulfate) were determined by standard quantitative techniques. Chlorides were determined by the mercuric nitrate method. Nitrate was determined by the phenoldisulfonic acid method (APHA, 1965;

Rainwater and Thatcher, 1968). Silica was determined by the colorimetric molybdosilicate method. Sulfate was determined by gravimetric method with ignition of residue; hydrochloric acid was added to prevent coprecipitation of other ions (APHA, 1965; Rainwater and Thatcher, 1968).

Biological Parameters

Bottom samples were collected from September, 1968 until December, 1969 with a regular sampling design from December, 1968 to December, 1969.

Stream bottom samples were collected with a standard square-foot bottom sampler (Surber, 1936) with 1 mm mesh. One sample was taken from Stations I, II, IV, and V, established on Piceance Creek, near the middle of each month. Fifty samples, consisting of 180 subsamples, were taken from Piceance Creek (December, 1968 to December, 1969). One sample (0.36 m^2) was taken from Stations I, II, IV, and V except during the months of October and November (1969) when a sample consisted of 0.19 m^2. Subsamples were combined to reduce sampling variability. All organisms were stored in 70% alcohol.

Most organisms were identified to genus with the use of Pennak (1953) and Usinger (1967). Identifications were confirmed by Dr. T. O. Thatcher, Entomology Department, Colorado State University.

Abundance of each kind of organism was determined to establish relative abundance trends, habitat preference, and linear distribution within Piceance Creek. Volumes and weights were taken to estimate biomass (standing crop).

Fish populations were sampled when conditions permitted with extensive sampling on Piceance Creek during summer (1969). Portable back-pack electrofishing gear was used to capture fish.

Macrobenthos and fish populations were sampled on White River and Yellow Creek when conditions permitted.

Macrobenthos was collected, in White River and Yellow Creek, with a screen (1 m long, 0.7 m high) constructed from wire screen attached to two poles (1 m long). Samples were taken from approximately 2 m above the screen by overturning the bottom substrate causing organisms to drift into the screen. Species compositions of the White River study area and Yellow Creek were monitored.

RESULTS

Physical Parameters

Water temperature readings on Piceance Creek are given in Figure 6. Differences between stations in a single month depended on the day and time of day at which readings were taken. Temperatures for White River and Yellow Creek were similar to Piceance Creek, ranging from 0 to 23 C. Yellow Creek reached a maximum of 31 C in August (1969) and had a low of 0 C during winter (1968-1969).

Discharge of Piceance Creek is shown in Figure 7. Mean discharge for White River (near study area) ranged from 6.2 m^3/sec (February, 1969) to 42.5 m^3/sec (May, 1969). Yellow Creek discharge rates have not been monitored since 1965.

Specific conductance was measured in the laboratory after adjusting the water to 25 C (Tables 9, 10, 11, 12, 21, 22, 23, 63, 64, 65, and 74). Variations in specific conductance were similar to those found in 1965 by the United States Geological Survey (Table 1). Specific conductance in Yellow Creek ranged from 3,000 to 4,000 μ mho cm^{-1} at 25 C. White River specific conductance was more nearly constant (500-800 μ mho cm^{-1} at 25 C) with values increasing with distance down stream.

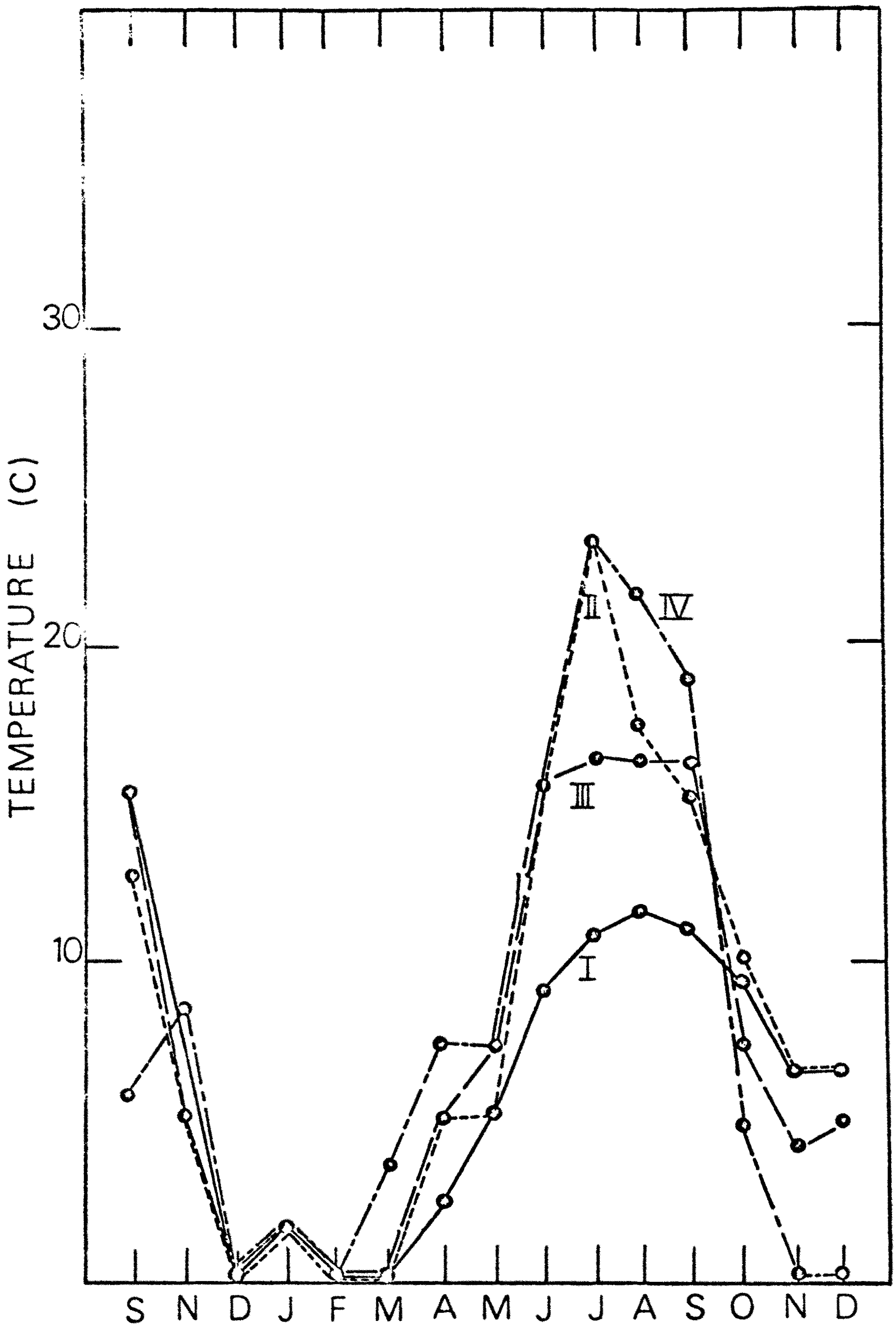

Figure 6. Monthly records of water temperature in Piceance Creek from September, 1968 to December, 1969.

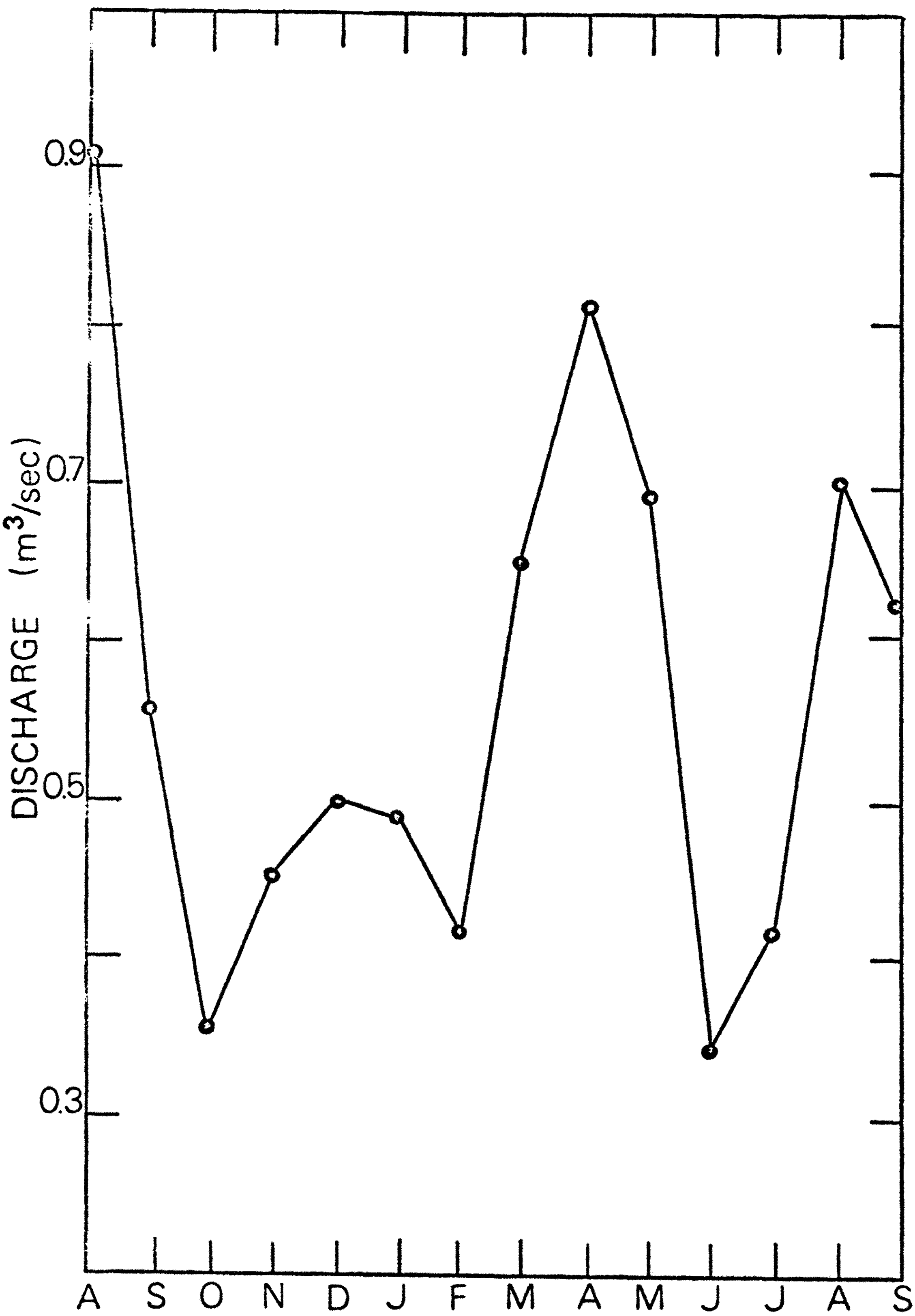

Figure 7. Discharge records for Piceance Creek from August, 1968 to September, 1969.

TABLE 1.--Specific conductance (μ mho cm^{-1} at 25 C) from various locations of Piceance Creek for three different years

Station	Sample Date		
	6 Oct. 1965[1]	2 Nov. 1968	4 Oct. 1969
1	986	--	925
2	1,350	1,160	1,265
3	2,010	--	1,400
4	2,680	2,250	2,000

[1]Analysis by USGS

Chemical Parameters

Field Determinations:

Dissolved oxygen values of Piceance Creek were inversely related to temperature (Figure 8). Dissolved oxygen in White River and Yellow Creek showed this same inverse relationship. Because of higher concentration of dissolved salts in Piceance Creek and Yellow Creek, dissolved oxygen concentration at saturation was lower than for White River at the same temperature.

Total alkalinity for Piceance Creek ranged from 300 to 1,600 mg/l. Stations I, III, and IV were more homogeneous with concentration increasing with distance down stream. Station V was more concentrated, reaching a high in July (1969) of 1,600 mg/l. Total alkalinity values for White River were lower and more homogeneous (Tables 66, 68, and 70). Yellow Creek data showed a high degree of variability.

Hydrogen ion concentration in Piceance Creek ranged from pH 7.9 at Station I, to pH 8.4 at Station V. All pH readings were similar with only slight variations. This same homogenity was found in White River and Yellow Creek. The pH of Yellow Creek was consistently higher (pH 8.5 to 8.8).

Filtrable solids from Piceance Creek showed some seasonal trends. There was an inverse relationship between discharge and filtrable solids (Figure 9). Total solids were not analyzed prior to March, 1969, and discharge data from October, 1969 to December, 1969 were unavailable;

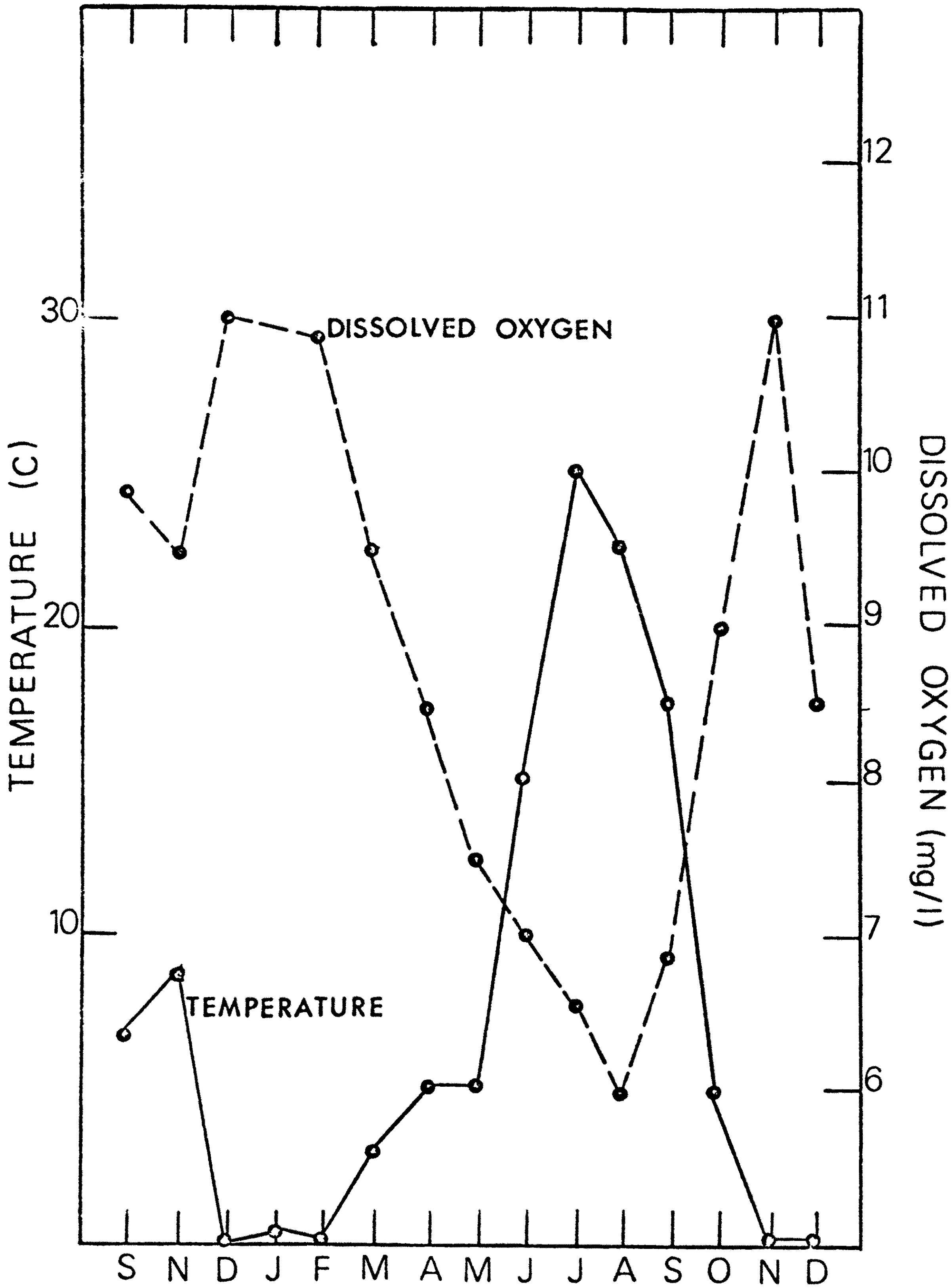

Figure 8. Monthly records of dissolved oxygen and water temperature in Piceance Creek from September, 1968 to December, 1969.

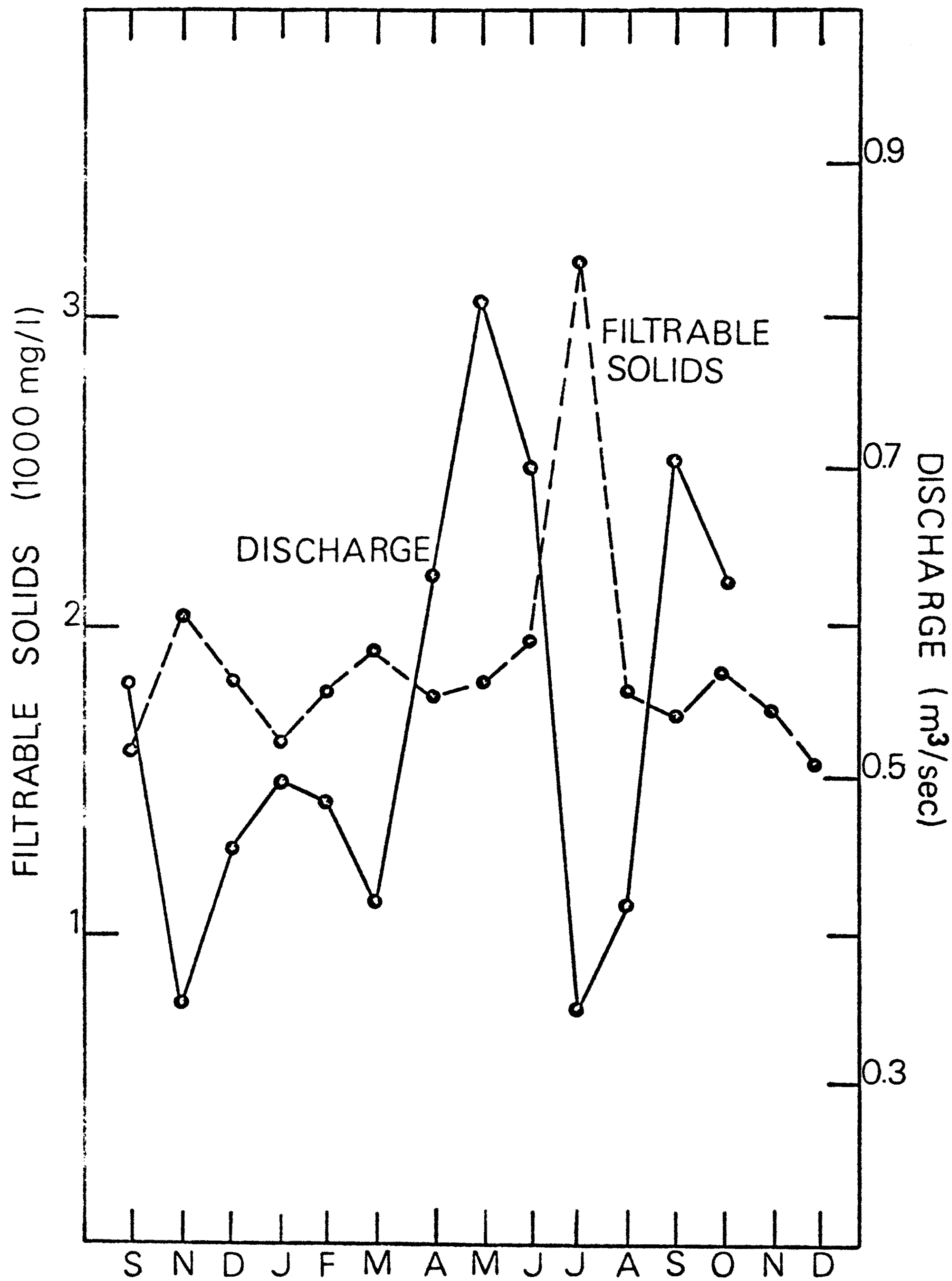

Figure 9. Filtrable solids and discharge records from Piceance Creek.

however, existing data indicated a direct relationship (Figure 10). Nonfiltrable solids data are listed in Tables 13, 15, 17, 19, 21, 22, 23, 66, 68, 70, and 75).

Major Cations:

Piceance Creek dissolved calcium values showed a high degree of variability (26 mg/l December, 1968 to 180 mg/l June, 1969). White River and Yellow Creek calcium data showed similar variability (Tables 67, 69, 71, and 76).

Dissolved magnesium values indicated a seasonal trend. Magensium concentration, when compared to discharge, indicated an indirect relationship (Figure 11). White River dissolved magnesium data were less variable, with concentrations ranging from 10 to 20 mg/l. Yellow Creek dissolved magnesium values were seven times those of White River (Table 76).

Sodium was the most concentrated cation in Piceance Creek, ranging from 150 to 2,950 mg/l. Station V had the highest concentration. A peak of 2,950 mg/l sodium was reached at Station V in August (1969), which coincided with a decrease in discharge. White River dissolved sodium values ranged from 20 to 100 mg/l; the majority of values found at the lower end of the range (Tables 67, 69, and 71). Yellow Creek had a low of 300 mg/l and a high of 3,710 mg/l (Table 76).

Potassium data for all three streams were highly variable (Tables 14, 16, 18, 20, 67, 69, 71, and 76).

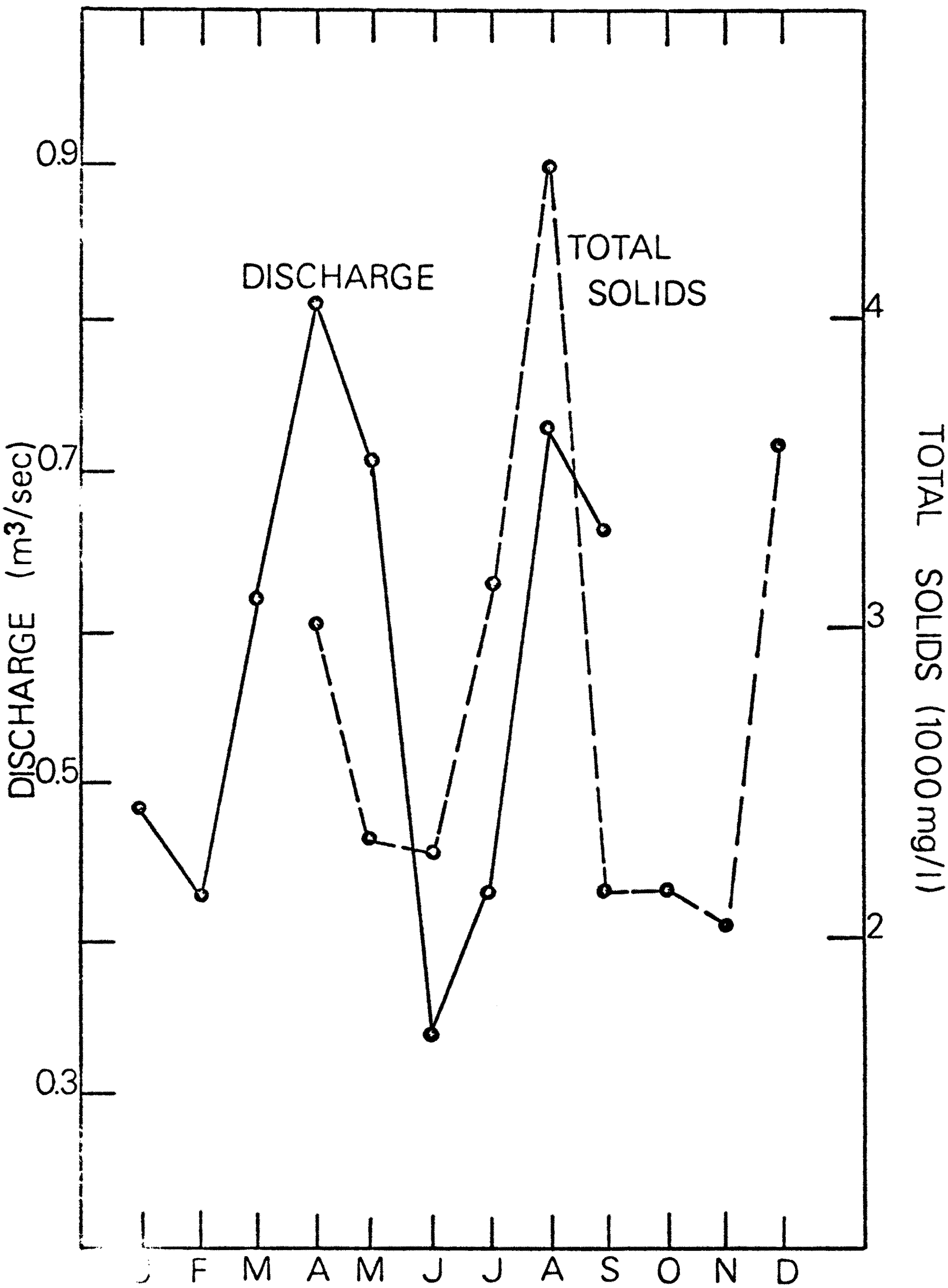

Figure 10. Total solids and discharge records from Piceance Creek (January, 1969 to December, 1969)

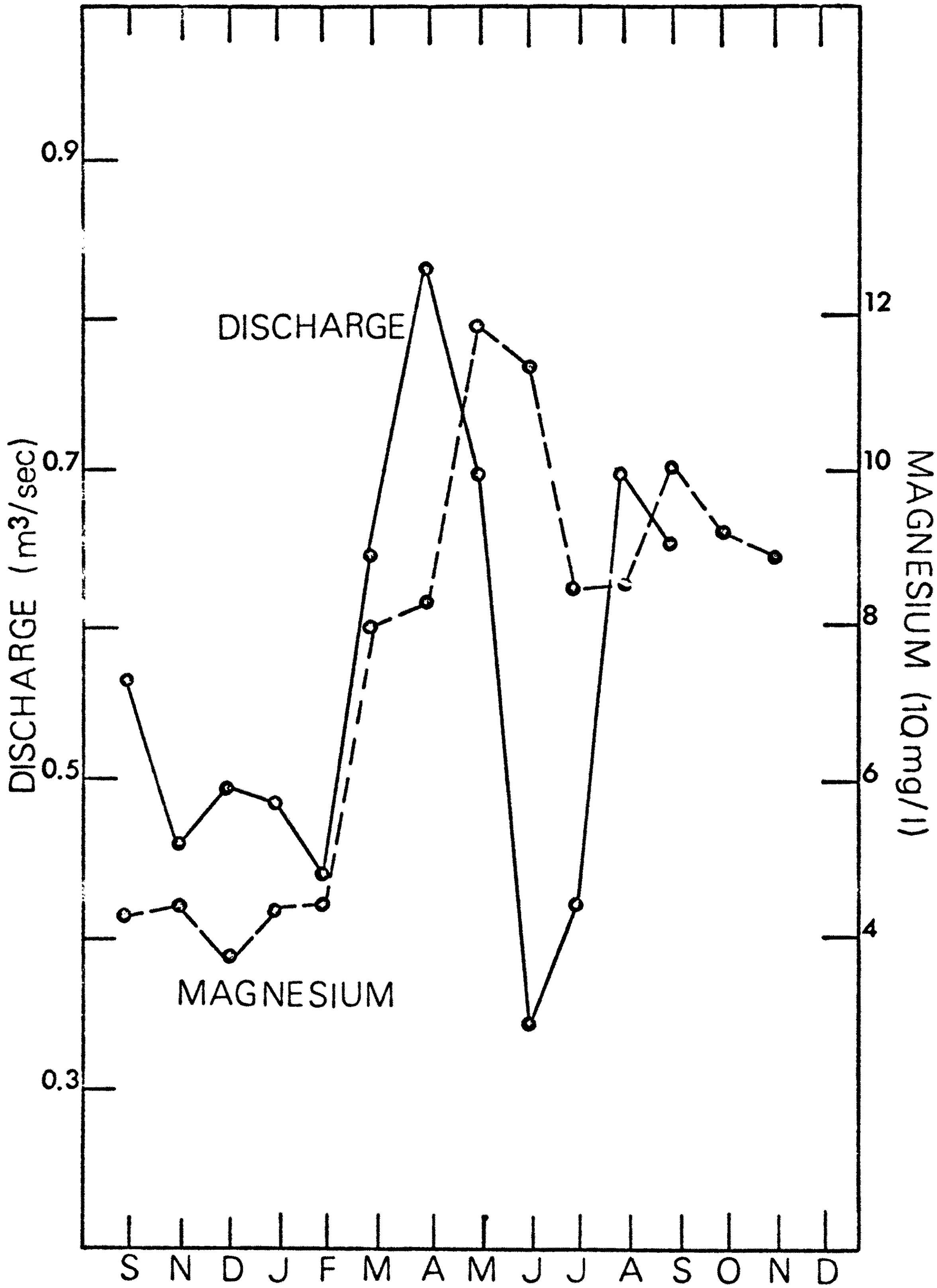

Figure 11. Magnesium concentration and discharge records in Piceance Creek (September, 1968 to December, 1969).

Anions:

Slight seasonal trends were observed in dissolved chloride concentrations. Chloride concentrations at Station V were an inversely related to discharge. Chloride ranged from 7 to 135 mg/l in Piceance Creek, 2 to 25 mg/l in White River, and 75 to 174 mg/l in Yellow Creek (Tables 14, 16, 18, 20, 67, 69, 71, and 76).

Dissolved nitrate presented some analytical problems. Piceance Creek and Yellow Creek were consistently high in chloride which had a masking effect on nitrate. Colorometric analysis required removal of chloride, which was only partially possible without causing further sensitivity problems due to the removal agent. Concentrations of chloride in Piceance Creek and Yellow Creek ranged from 0.4 to 4.3 mg/l. White River during the winter (1968-1969) had a high of 6.6 mg/l, but generally remained at 0.2 to 1.2 mg/l.

Dissolved silica in Piceance Creek showed no seasonal trend. There was a high degree of within month variation between stations on Piceance Creek. White River and Yellow Creek showed similar results.

Dissolved sulfate values for Piceance Creek indicated seasonal variation. Concentrations increased with distance down stream (Figure 12). White River data indicated no seasonal trend. Yellow Creek sulfate values were highest and ranged from 501 to 892 mg/l.

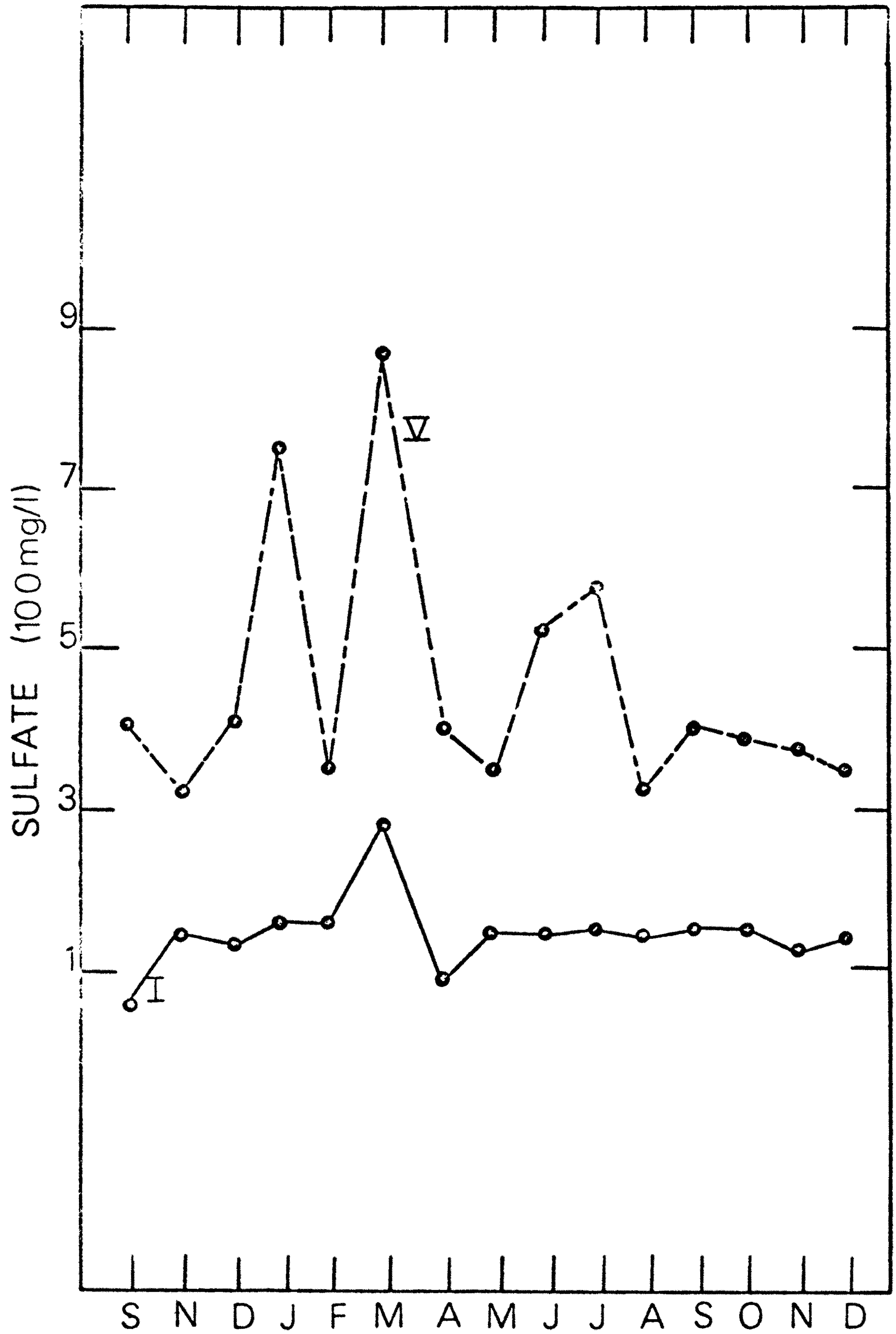

Figure 12. Sulfate concentration record in Piceance Creek (September, 1968 to December, 1969).

Trace Elements:

Trace elements (cadmium, copper, chromium, iron, lead, manganese, molybdenum, nickel, silver, and zinc) were less than 1 mg/l. There was no indication of seasonal trends in these elements.

Biological Parameters

Macrobenthos:

Abundance:

Bottom samples yielded 10,505 organisms. Peak total abundance of aquatic invertebrates in Piceance Creek occurred during June, 1969 (Figure 13). Mean monthly numbers ranged from 140 organisms per m^2 in April (1969) to 1,488 organisms per m^2 in June (1969).

Diptera and Ephemeroptera comprised the greatest number of organisms collected (Table 2). Dipterans were greatest in abundance and ranged from 47 to 58% of total organisms collected. Ephemeropterans, second in abundance, ranged from 17 to 27% of the total. Tricopterans, at Stations I, II, and V, ranged from 7 to 8% of the total at all stations except IV. Coleopterans ranged from 1 to 10% of the total. Plecopterans were least abundant of all aquatic insects collected. Noninsect aquatic invertebrates constituted the remaining organisms collected (Table 2). Oligochaetes contributed the largest number to this noninsect group and ranked third in total abundance. Table 2 also indicates the possibility of spatial distribution of organisms in Piceance Creek.

DISCUSSION

Standardization of techniques is important in any study designed to evaluate chemical conditions of a particular aquatic environment. Collection and handling of samples should be standardized to reduce error and variability. Analysis for cations and anions must be directed to the particular aquatic environment in question. Techniques are rarely the same for aquatic environments of different chemical compositions and chemical concentrations.

Physical - Chemical

Water temperatures and dissolved solids exerted a pronounced affect upon the dissolved oxygen concentration in Piceance Creek, White River, and Yellow Creek. This effect was consistent with the discussion by Reid, 1966.

The most pronounced physical parameter, and the parameter which seemed to have the greatest affect on other physical and chemical parameters, was stream discharge. Data from Piceance Creek showed that high discharge had a diluting influence upon filtrable solids and chemical parameters. Low discharge exhibited a concentrating effect on these same parameters.

White River physical and chemical content was also affected by discharge in a similar way.

Analytical problems caused by high dissolved salt concentrations may account for some of the variations. Interference and masking of certain elements by highly concentrated cations and anions caused the majority of detection problems associated with atomic absorption spectroscopy.

Calcium values from Piceance Creek ranged from 20 to 180 mg/l which exceeded the optimum range of the atomic absorption spectrophotometer. The optimum range is approximately 1 to 3 mg/l. Dilution of the samples into the optimum range did not fully solve analysis problems. Dissolved solids in the samples were more concentrated than in the standard causing variation and error. Calcium data from White River were more homogeneous between stations. Concentrations did exceed the optimum range of the absorption spectrophotometer.

Dissolved magnesium concentrations illustrated an inverse relationship between discharge and concentration very well. Seasonal trends were evident and generally due to discharge fluctuations.

Sodium and potassium data illustrated marked analytical problems. High sodium concentrations caused substantial ionization in the flame which suppressed the absorption of other elements. Potassium was affected to a greater extent by this masking.

Results from analysis of anions were generally less variable because of the analytical techniques involved in anion analysis.

Chloride concentrations in Piceance Creek showed slight seasonal trends, with Station IV having extremely high concentrations and exhibiting a high degree of seasonal variability. Seasonal variability of chloride at Station IV was related to the stream discharge. Chloride became highly concentrated during the low flows of June, July, and August (1969); with reduced concentrations occurring during months having high discharge (August and September, 1969).

White River and Yellow Creek also showed seasonal trends in chlorides related to stream discharge.

High chloride concentrations have an affect upon nitrate analysis. APHA (1965) states that small concentrations of chloride can cause losses of nitrate and that chloride content should be reduced to below 10 mg/l. Detection problems were created by the addition of silver sulfate which gave the residue a brown to red color. Nitrate concentrations in Piceance Creek were generally low and seasonal trends were hard to evaluate because of variations and errors in analysis.

White River was not affected by chloride interference as much as Piceance Creek, because chloride concentrations were much lower. Chloride content in White River showed seasonal trends. These trends appeared to be dependent upon stream discharge.

Silica values in Piceance Creek were high and variable with no apparent systematic seasonal variation. Silica is probably present largely as monomeric silicic acid.

TABLE 9.--Physical data collected at station I on Piceance Creek from September, 1968 to December, 1969

Month	Air Temperature (F)	Water Temperature (C)	Specific Conductance (μ mho cm^{-1})	Turbidity (JTU)
September (1968)	--	15	--	--
November	--	--	--	--
December	29	0	1,000	--
January (1969)	21	1	950	--
February	9	0	1,000	--
March	1	0	756	--
April	38	2	750	--
May	--	5	--	--
June	60	10	920	--
July	73	11	860	<25
August	67	12	960	<25
September	65	11	890	<25
October	54	8	925	<25
November	53	5	860	<25
December	49	5	830	<25

TABLE 10.--Physical data collected at station III on Piceance Creek from September, 1968 to December, 1969

Month	Air Temperature (F)	Water Temperature (C)	Specific Conductance (μ mho cm^{-1})	Turbidity (JTU)
September (1968)	52	12	1,000	--
November	47	6	1,100	--
December	36	1	1,300	--
January (1969)	39	1	1,250	--
February	20	0	1,300	--
March	26	0	1,400	--
April	42	5	1,150	--
May	--	5	--	--
June	62	15	1,440	--
July	84	19	1,440	<25
August	78	17	1,260	<25
September	75	14	1,140	<25
October	46	9	1,265	<25
November	58	5	1,240	<25
December	48	5	1,075	<25

TABLE 11.--Physical data collected at station IV on Piceance Creek from September, 1968 to December, 1969

Month	Air Temperature (F)	Water Temperature (C)	Specific Conductance (µ mho cm^{-1})	Turbidity (JTU)	Discharge (cfs)
September (1968)	--	15	2,200	--	20.2
November	32	5	2,250	--	16.7
December	36	1	1,000	--	17.8
January (1969)	35	1	1,450	--	17.2
February	22	0	1,454	--	15.6
March	30	0	1,506	--	22.6
April	48	5	1,450	--	28.8
May	--	6	--	--	24.3
June	70	15	1,760	--	12.4
July	84	15	1,750	<25	15.2
August	78	15	1,360	<25	25.3
September	76	14	1,270	<25	22.4
October	38	7	1,400	32	--
November	37	3	1,360	<25	--
December	46	4	1,190	28	--

TABLE 12.--Physical data collected at station V on Piceance Creek from September, 1968 to December, 1969

Month	Air Temperature (F)	Water Temperature (C)	Specific Conductance (μ mho cm^{-1})	Turbidity (JTU)
September (1968)	45	7	2,000	--
November	54	9	2,250	--
December	32	0	2,400	--
January (1969)	37	0	2,200	--
February	32	0	2,510	--
March	38	3	2,400	--
April	49	6	2,515	--
May	--	6	--	--
June	68	15	2,500	--
July	89	25	3,800	<25
August	84	22	1,875	63
September	76	17	1,850	38
October	34	6	2,000	36
November	28	0	1,750	28
December	38	0	1,525	110

List of Abbreviations and Their Meanings

DO - Dissolved Oxygen concentration (mg/l)

pH - Hydrogen ion concentration

phth - phenophthalein alkalinity (mg/l $CaCO_3$)

TA - Total Alkalinity (mg/l $CaCO_3$)

FS - Filtrable Solids (mg/l)

NFS - Nonfiltrable Solids (mg/l)

TR - Total Residue (mg/l)

SS - Settleable Solids (ml/l)

Ca - Calcium (mg/l)

Mg - Magnesium (mg/l)

Na - Sodium (mg/l)

K - Potassium (mg/l)

Cl - Chloride (mg/l)

SO_4 - Sulfate (mg/l)

SiO_2 - Silica (mg/l)

NO_3 - Nitrate (mg/l)

SC - Specific Conductance (μ mho cm^{-1})

T - Turbidity (JTU)

TABLE 13.--Chemical data from station I on Piceance Creek from September, 1968 to December, 1969

Month	DO	pH	phth	TA	FS	NFS	TR	SS
September (1968)	10.2	8.4	0.0	270.0	480.0	--	--	--
November	7.7	8.2	0.0	500.0	728.0	--	--	--
December	10.3	7.8	0.0	376.0	674.0	--	--	--
January (1969)	6.5	7.9	0.0	436.0	706.0	--	--	--
February	10.1	8.0	0.0	400.0	660.0	--	--	--
March	11.2	8.0	0.0	380.0	688.0	--	--	0.1
April	9.0	7.6	0.0	304.0	506.0	1,014.0	1,520.0	1.3
May	9.6	7.8	8.0	350.0	598.0	70.0	668.0	0.1
June	8.3	8.0	0.0	392.0	656.0	4.0	660.0	0.0
July	10.4	7.9	0.0	368.0	614.0	12.0	626.0	0.0
August	9.4	7.9	0.0	396.0	653.0	2.0	655.0	0.0
September	10.0	7.8	0.0	412.0	647.0	5.0	652.0	0.0
October	10.0	8.0	12.0	406.0	675.0	53.0	718.0	0.0
November	10.6	7.9	0.0	400.0	661.0	3.0	664.0	0.0
December	10.2	7.8	0.0	404.0	542.0	128.0	670.0	0.0

TABLE 14.--Chemical data from station I on Piceance Creek from September, 1968 to December, 1969

Month	Ca	Mg	Na	K	Cl	SO_4	SiO_2	NO_3
September (1968)	49.9	27.7	7.8	3.2	6.8	65.6	15.5	1.2
November	81.1	34.0	133.5	10.0	13.0	139.9	21.0	0.9
December	--	--	--	--	11.4	125.4	21.3	2.2
January (1969	75.0	31.9	107.7	3.7	12.0	150.1	15.5	0.9
February	79.3	32.2	107.1	4.2	11.0	148.7	15.0	2.1
March	79.3	33.0	111.6	4.0	11.0	283.0	16.0	0.5
April	77.0	32.0	97.9	2.4	8.0	91.1	18.0	3.0
May	90.0	50.0	131.3	4.3	8.5	146.5	16.0	3.8
June	99.0	47.6	110.0	2.8	10.5	141.0	16.5	3.2
July	94.0	44.8	105.7	2.4	10.8	147.3	16.5	1.7
August	110.0	48.7	129.2	3.1	11.5	134.4	18.0	0.8
September	82.0	48.1	107.9	0.6	10.8	153.4	15.5	0.7
October	85.6	60.6	235.0	6.0	11.0	154.9	25.0	2.5
November	64.6	53.9	197.0	5.1	11.0	128.6	20.0	0.5
December	61.6	46.4	202.0	5.8	10.5	139.2	19.5	2.9

TABLE 15.--Chemical data from station III on Piceance Creek from September, 1968 to December, 1969

Month	DO	pH	phth	TA	FS	NFS	TR	SS
September (1968)	8.1	8.2	0.0	396.0	650.0	--	--	--
November	7.7	8.2	0.0	500.0	728.0	--	--	--
December	10.3	7.8	0.0	376.0	674.0	--	--	--
January (1969)	7.0	8.2	0.0	480.0	454.0	--	--	--
February	10.4	8.2	0.0	500.0	948.0	--	--	--
March	10.7	8.0	0.0	492.0	1,014.0	--	--	0.8
April	8.3	7.8	0.0	424.0	760.0	865.0	1,625.0	1.3
May	8.2	7.8	12.0	496.0	902.0	178.0	1,080.0	0.2
June	8.1	7.9	0.0	552.0	1,064.0	4.0	1,108.0	0.1
July	8.4	8.0	4.0	532.0	1,122.0	13.0	1,135.0	0.1
August	8.0	8.1	0.0	496.0	900.0	200.0	1,100.0	0.3
September	9.0	7.9	0.0	468.0	837.0	101.0	938.0	0.1
October	9.0	8.0	12.0	582.0	954.0	135.0	1,089.0	0.1
November	10.8	8.0	0.0	508.0	945.0	49.0	994.0	0.1
December	10.0	7.9	0.0	496.0	842.0	116.0	958.0	0.2

TABLE 16.--Chemical data from station III on Piceance Creek from September, 1968 to December, 1969

Month	Ca	Mg	Na	K	Cl	SO_4	SiO_2	NO_3
September (1968)	73.5	32.3	10.5	4.0	11.1	118.8	17.9	2.7
November	102.0	44.7	308.0	3.6	16.3	676.9	22.0	2.2
December	--	--	--	--	11.4	125.4	21.3	2.2
January (1969)	82.7	38.4	129.1	4.0	13.0	269.7	16.5	2.4
February	99.4	40.4	138.8	4.7	13.0	305.0	16.5	2.9
March	95.8	41.1	176.0	5.4	14.0	401.0	16.5	1.7
April	91.0	56.0	155.6	3.6	13.0	177.5	19.5	2.1
May	89.0	67.0	195.5	3.5	14.5	305.0	19.0	1.4
June	101.0	91.4	199.2	4.8	17.0	337.2	20.0	0.2
July	108.0	84.7	242.3	4.6	14.0	319.9	20.0	0.6
August	100.0	74.4	171.3	3.8	11.0	226.1	19.5	0.6
September	99.0	69.4	155.1	0.7	12.5	229.6	16.5	0.8
October	74.3	78.4	293.0	7.1	14.3	269.1	26.0	0.9
November	72.6	74.7	253.0	7.0	14.0	254.6	17.0	0.5
December	70.8	76.9	276.0	6.0	13.3	248.2	25.5	2.6

TABLE 17.--Chemical data from station IV on Piceance Creek from September, 1968 to December, 1969

Month	DO	pH	phth	TA	FS	NFS	TR	SS
September (1968)	6.0	7.9	0.0	630.0	1,828.0	--	--	--
November	6.1	7.9	0.0	632.0	1,846.0	--	--	--
December	10.9	8.0	0.0	548.0	1,100.0	--	--	--
January (1969)	7.3	8.3	0.0	532.0	1,028.0	--	--	--
February	10.5	8.2	0.0	548.0	1,066.0	--	--	--
March	11.0	8.2	0.0	544.0	1,106.0	--	--	0.3
April	9.0	7.9	16.0	508.0	1,004.0	1,016.0	2,020.0	1.4
May	8.2	7.9	32.0	592.0	1,022.0	7,096.0	8,098.0	1.7
June	8.5	8.1	20.0	608.0	1,376.0	4.0	1,340.0	0.1
July	9.2	8.0	12.0	620.0	1,482.0	18.0	1,500.0	0.1
August	8.0	8.1	0.0	504.0	1,010.0	222.0	1,232.0	0.5
September	8.8	7.9	4.0	500.0	973.0	205.0	1,178.0	0.2
October	10.0	8.2	16.0	532.0	1,053.0	88.0	1,141.0	0.1
November	11.0	8.1	10.0	552.0	1,090.0	190.0	1,199.0	0.1
December	8.0	8.0	35.0	524.0	952.0	168.0	1,120.0	0.3

TABLE 18.--Chemical data from station IV on Piceance Creek from September, 1968 to December, 1969

Month	Ca	Mg	Na	K	Cl	SO_4	SiO_2	NO_3
September (1968)	100.7	44.6	308.5	3.7	16.5	656.3	22.0	4.3
November	76.0	42.3	528.0	7.6	53.5	320.1	29.0	1.8
December	--	--	--	--	11.4	125.4	21.3	2.2
January (1969)	75.0	31.9	107.7	3.7	12.0	150.1	15.5	0.9
February	95.1	41.6	202.0	4.9	14.5	358.0	16.5	3.3
March	88.2	41.9	268.5	5.1	15.0	441.0	16.5	1.5
April	93.0	80.0	199.7	4.3	15.8	294.3	20.0	1.8
May	100.0	87.0	190.8	5.7	16.8	358.0	19.0	2.6
June	113.0	119.9	233.7	4.9	19.0	471.3	20.0	0.3
July	95.0	109.0	242.3	4.5	19.8	460.6	19.5	0.4
August	86.0	83.8	165.0	3.4	11.8	314.7	20.0	0.6
September	96.0	85.2	164.2	0.8	9.5	302.3	19.5	1.2
October	100.4	101.4	287.0	7.3	13.3	344.0	30.0	0.6
November	76.7	91.2	274.0	7.8	15.0	341.8	17.0	0.6
December	73.2	83.2	281.0	7.6	14.5	320.4	24.0	2.6

TABLE 19.--Chemical data from station V on Piceance Creek from September, 1968 to December, 1969

Month	DO	pH	phth	TA	FS	NFS	TR	SS
September (1958)	9.7	8.2	0.0	834.0	1,654.0	--	--	--
November	9.1	8.2	0.0	1,036.0	1,930.0	--	--	--
December	10.9	8.1	0.0	976.0	1,794.0	--	--	--
January (1969)	6.8	8.3	16.0	888.0	1,610.0	--	--	--
February	10.6	8.3	0.0	888.0	1,682.0	--	--	--
March	9.5	8.4	44.0	942.0	1,786.0	1,806.0	3,592.0	--
April	8.8	8.1	48.0	836.0	1,562.0	1,358.0	2,920.0	1.4
May	7.6	8.3	6.0	800.0	1,640.0	708.0	2,348.0	0.7
June	7.4	8.4	44.0	916.0	1,911.0	379.0	2,290.0	0.6
July	6.8	8.5	90.0	1,620.0	3,159.0	16.0	3,175.0	0.0
August	6.2	8.2	28.0	716.0	1,560.0	2,780.0	4,340.0	17.0
September	7.2	8.1	20.0	768.0	1,530.0	1,438.0	2,168.0	0.7
October	9.6	8.3	36.0	856.0	1,621.0	471.0	2,150.0	0.5
November	11.4	8.3	44.0	810.0	1,480.0	491.0	1,971.0	0.6
December	8.0	8.0	48.0	738.0	1,266.0	1,240.0	3,506.0	3.0

TABLE 20.--Chemical data from station V on Piceance Creek from September, 1968 to December, 1969

Month	Ca	Mg	Na	K	Cl	SO_4	SiO_2	NO_3
September (1968)	53.5	61.3	411.5	6.1	40.7	409.0	21.0	2.2
November	76.0	42.3	528.0	7.6	53.5	320.1	29.0	1.8
December	--	--	--	--	53.2	413.0	23.5	4.0
January (1969)	69.3	40.2	--	5.6	48.5	772.0	16.0	--
February	78.4	41.7	--	6.2	55.0	338.0	16.5	--
March	54.8	41.6	494.0	6.8	63.0	885.0	16.3	--
April	71.0	90.0	385.1	5.1	44.5	392.0	19.5	1.6
May	67.0	101.0	394.1	0.9	39.5	348.0	19.5	1.4
June	180.0	117.,	512.0	6.0	49.8	538.2	20.0	0.7
July	82.0	105.1	1,544.0	7.6	136.0	584.3	15.5	0.5
August	74.0	80.1	295.7	5.6	37.0	327.6	19.5	1.1
September	89.0	88.4	325.3	1.4	38.5	395.9	19.5	0.7
October	115.6	101.5	400.0	8.1	13.3	344.0	30.0	0.6
November	67.3	93.9	365.0	8.4	39.0	352.2	17.0	0.7
December	25.5	29.0	87.4	4.4	36.0	322.9	24.0	2.2

TABLE 21.--Weekly sampling data from all stations June 10, 1969 to June 23, 1969

Date	Station	pH	SC	FS	NSF	TR	T
1969 June 10	1	8.0	889	714	6	720	<25
	2	7.9	1,550	1,041	93	1,134	<25
	3	8.2	1,900	1,352	6	1,358	<25
	4	8.4	3,800	2,946	262	3,208	<25
	5	8.0	410	216	2	218	<25
	6	8.0	439	--	--	--	<25
	7	8.2	450	--	--	--	<25
	8	8.6	3,850	2,565	545	3,110	<25
June 16	1	8.0	1,040	661	109	770	<25
	2	8.0	1,540	1,100	154	1,254	<25
	3	8.2	1,860	1,409	156	1,560	<25
	4	8.4	2,810	2,520	664	3,184	30
	5	8.0	465	329	261	590	<25
	6	8.1	525	367	240	616	30
	7	8.1	520	350	746	1,096	40
	8	8.8	3,750	2,949	335	3,284	<25
June 23	1	8.0	920	656	4	660	<25
	2	7.9	1,440	1,104	4	1,108	<25
	3	8.1	1,760	1,336	4	1,340	<25
	4	8.3	2,500	1,911	379	2,290	<25
	5	8.2	479	300	54	354	<25
	6	8.2	480	337	47	384	<25
	7	8.2	485	336	60	396	<25
	8	8.8	3,550	2,914	146	3,060	<25

TABLE 22.--Weekly sampling data from all stations July 10, 1969 to July 31, 1969

Date	Station	pH	SC	FS	NSF	TR	T
1969							
July 10	1	7.9	860	614	12	626	<25
	2	8.0	1,440	1,122	13	1,135	<25
	3	8.0	1,750	1,482	18	1,500	<25
	4	8.5	3,800	3,159	16	3,175	<25
	5	8.1	498	338	14	352	<25
	6	8.3	520	356	44	400	<25
	7	8.4	510	344	10	354	<25
	8	8.9	3,850	3,178	70	3,248	<25
July 17	1	7.9	880	648	8	656	<25
	2	7.9	1,490	1,048	44	1,122	<25
	3	8.1	1,790	1,398	6	1,404	<25
	4	8.5	3,600	2,948	144	3,092	<25
	5	8.2	580	418	8	426	<25
	6	8.3	61[illegible]	450	26	476	<25
	7	8.3	605	448	28	446	<25
	8	8.6	3,800	3,070	10	3,080	<25
July 23	1	8.0	940	645	19	664	<25
	2	8.0	1,430	880	208	1,088	<25
	3	8.1	1,775	1,260	536	1,796	31
	4	8.4	3,005	2,225	153	2,378	<25
	5	8.1	640	415	60	475	<25
	6	8.3	690	445	83	527	<25
	7	8.3	725	447	137	584	<25
	8	8.6	4,019	3,056	200	3,256	<25
July 31	1	8.0	938	662	2	664	<25
	2	8.0	1,290	894	47	941	<25
	3	8.0	1,460	1,082	434	1,516	<25
	4	8.3	2,450	1,816	329	2,145	<25
	5	8.2	590	414	67	481	<25
	6	8.2	700	491	218	709	<25
	7	8.3	730	539	605	1,144	50
	8	8.6	3,750	2,879	425	3,304	<25

TABLE 23.--Weekly sampling data from all stations August 7, 1969 to August 29, 1969

Date	Station	pH	SC	FS	NSF	TR	T
1969							
Aug. 7-8	1	7.9	940	628	6	634	<25
	2	8.0	1,310	986	66	1.052	<25
	3	8.0	1,450	1,024	686	1,710	28
	4	8.2	2,150	1,664	253	1,917	32
	5	8.2	580	471	17	488	<25
	6	8.3	665	369	123	492	<25
	7	8.3	665	462	88	550	<25
	8	8.6	3,450	2,890	144	3,034	<25
Aug. 19	1	7.9	920	--	--	--	<25
	2	8.0	1,215	--	--	--	118
	3	8.1	1,360	--	--	--	255
	4	8.1	1,810	--	--	--	2,000
	5	8.1	690	410	310	720	162
	6	8.0	700	465	2,019	2,484	800
	7	8.0	800	--	--	--	1,400
	8	8.9	3,015	--	--	--	<25
Aug. 29	1	7.8	880	646	35	681	<25
	2	8.1	1,080	849	261	1,110	52
	3	8.2	1,150	916	890	1,806	38
	4	8.4	1,825	1,522	1,082	2,604	53
	5	8.2	580	444	215	659	27
	6	8.3	640	457	823	1,280	70
	7	8.3	680	480	347	827	40
	8	8.8	3,550	3,054	246	3,300	25

TABLE 74.--Physical data collection at station IX on Yellow Creek from September, 1968 to December, 1969

Month	Air Temperature (F)	Water Temperature (C)	Specific Conductance (μ mho cm^{-1})	Turbidity (JTU)
September (1968)	73	19	3,400+	--
November	44	2	3,400+	--
December	14	0	3,400+	--
January (1969)	29	0	3,400+	--
February	32	0	3,400+	--
March	32	0	3,400+	--
April	42	--	3,400+	--
May	--	24	--	--
June	68	19	3,550	--
July	83	30	3,850	<25
August	87	31	3,000	<25
September	72	24	3,650	<25
October	44	11	3,500	<25
November	45	6	3,220	30
December	16	0	3,040	<25

List of Abbreviations and Their Meanings

DO	-	Dissolved Oxygen concentration (mg/l)
pH	-	Hydrogen ion concentration
phth	-	phenophthalein alkalinity (mg/l $CaCO_3$)
TA	-	Total Alkalinity (mg/l $CaCO_3$)
FS	-	Filtrable Solids (mg/l)
NFS	-	Nonfiltrable Solids (mg/l)
TR	-	Total Residue (mg/l)
SS	-	Settleable Solids (ml/l)
Ca	-	Calcium (mg/l)
Mg	-	Magnesium (mg/l)
Na	-	Sodium (mg/l)
K	-	Potassium (mg/l)
Cl	-	Chloride (mg/l)
SO_4	-	Sulfate (mg/l)
SiO_2	-	Silica (mg/l)
NO_3	-	Nitrate (mg/l)

TABLE 75.--Chemical data from station IX on Yellow Creek from September, 1968 to December, 1969

Month	DO	pH	phth	TA	FS	NFS	TR	SS
September (1968)	8.8	8.7	141.0	1,948.0	2,816.0	--	--	--
November	11.7	8.5	0.0	1,487.0	2,780.0	--	--	--
December	11.4	8.3	0.0	1,544.0	2,838.0	--	--	--
January (1969)	6.9	8.3	60.0	1,520.0	3,092.0	--	--	--
February	11.6	8.5	15.0	912.0	2,648.0	--	--	--
March	10.6	8.5	64.0	1,108.0	2,312.0	48.0	2,360.0	--
April	8.2	8.4	176.0	1,420.0	2,556.0	1,644.0	4,200.0	--
May	7.2	8.6	152.0	1,464.0	2,370.0	678.0	3,048.0	--
June	9.3	8.8	152.0	1,464.0	2,914.0	146.0	3,060.0	0.0
July	7.6	8.9	264.0	1,600.0	3,178.0	70.0	3,248.0	0.1
August	7.0	8.9	128.0	1,052.0	2,446.0	144.0	2,590.0	0.0
September	6.8	8.8	240.0	1,888.0	3,043.0	152.0	3,195.0	0.0
October	10.5	8.7	174.0	1,616.0	2,860.0	115.0	2,975.0	0.0
November	9.6	8.5	100.0	1,464.0	2,600.0	512.0	3,112.0	0.6
December	12.0	8.4	112.0	1,716.0	3,016.0	60.0	3,076.0	0.0

TABLE 76. Chemical data from station IX on Yellow Creek from September, 1968 to December, 1969

Month	Ca	Mg	Na	K	Cl	SO_4	SiO_2	NO_3
September (1968)	28.4	43.2	947.0	8.4	174.3	--	9.0	0.5
November	40.5	43.4	855.0	7.3	134.2	405.9	14.5	2.5
December	--	--	--	--	152.2	505.3	19.5	--
January (1969)	25.6	43.5	929.0	7.6	150.0	--	12.2	--
February	41.1	43.4	883.5	7.9	--	--	11.4	--
March	37.2	43.4	683.0	7.3	75.9	892.0	14.5	--
April	31.0	115.0	--	2.5	110.8	553.8	14.0	1.2
May	24.0	145.0	934.0	5.3	106.4	570.0	23.0	0.6
June	30.0	121.8	1,208.0	5.2	139.8	660.9	6.1	0.3
July	41.0	117.0	1,643.0	5.5	169.8	667.3	4.7	0.4
August	31.0	117.6	3,711.0	1.4	90.0	670.7	9.7	1.0
September	22.0	111.7	1,098.0	2.4	164.0	501.2	3.2	0.5
October	28.0	93.2	632.0	7.4	135.8	653.5	6.0	0.5
November	42.3	142.8	676.0	10.4	101.5	603.3	8.2	1.2
December	15.7	50.5	303.0	5.1	153.5	665.5	10.0	3.6

APPENDIX IV-4

Excerpts from "Resource Analysis of the Yellow Creek Planning Unit W-01-09" and "Resource Analysis of the Piceance Basin Planning Unit S-01-11," White River Planning Area, Craig District No. 1, U. S. Bureau of Land Management, Meeker, Colorado. These unpublished reports were provided through the courtesy of Mr. Stanley G. Colby, Area Manager. The Yellow Creek report is dated June-July, 1970 and the Piceance Basin report is dated August-September, 1970.

(Piceance Basin Planning Unit)

C. HYDROLOGY

This planning unit is located in the Green River sub-basin of the Colorado Hydrologic Region. Piceance Creek, a major tributary of the White River, traverses the planning unit from the southeast corner westward to a point midway on the western boundary and thence forms the boundary along the northwest quarter of the unit. The White River forms the north boundary of this planning unit.

The majority of the drainages in this planning unit are fairly stable. The only exceptions are those drainages in the northwest corner of the planning unit and down along the west boundary to the point where Piceance Creek forms the west boundary of the unit. Streambeds in the above described area drain land that is extremely steep, with a very fine grained soil which is easily eroded. The vegetative cover is relatively sparse due to the shallow soils and the impervious shale underlaying this soil. The balance of the unit supports a good ground cover on relatively deep soil with the exception of some isolated slopes with a south or east exposure.

Stream channels in the northwest portion of the unit are relatively straight with perpendicular banks exhibiting heavy sloughing. Heavy alluvial fans are apparent at the mouths of each side drainage where they enter the major drainges. Streams in the balance of the planning unit, with the one exception of Piceance Creek which meanders extensively, are also relatively straight channeled, but perpendicular, exposed banks are not noted in these streams until you get near their mouths. In their lower regions where runoff volumes are relatively high, these streams exhibit bank sloughing but not to a critical degree. Piceance Creek itself bissects hay meadows for nearly all of its length, and is relatively stable.

Available information pertaining to this planning unit on ground water is relatively scarce. There is data on 6 wells currently producing livestock water. These wells vary in depth from 130 feet to 400 feet. The Colorado State Game, Fish and Parks Division has drilled several wells in the bottom of the dry fork of Piceance Creek but the water content in many of these wells is so high in dissolved salts that pumping equipment does not last long. Water quality from wells on public lands is generally adequate for culinary and livestock use. Data concerning water quantities indicates it is sufficient for livestock use. As long as the use is limited to livestock, there is no question but what annual recharge would be adequate to maintain the present water table.

373,480 ac. 2ⁿ annual r

Form 1600–6
(August 1969)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

PHYSICAL PROFILE
HYDROLOGIC DATA

Unit	Date 3/31/70		
Piceance	By Papworth		
ITEM	UNIT	ESTIMATED ANNUAL AMOUNT	SOURCE REFERENCE
1. Water Yield †	ac. ft.	62,245 *	USGS Atlas HA-194
2. Water Use †	ac. ft.		
3. Sediment Production	cu. yds.	1,598,640	Factors Affecting Sed. Yield in Pac.SW
4. Other Pollutants ‡	ppm	700*	USGS Atlas HA-61
a. Calcium	ppm	100	USGS Atlas HA-189
b. Sodium	ppm	100	" "
c. Sulphate	ppm	100	" "
d. Chloride	ppm	100	" "
e. Magnesium	ppm	100	USGS Professional Paper 441

Remarks

Sed. Prod. based on:

17.7% of unit yielding 3 ac. ft./sec./yr.
39.8% of unit yielding 2 ac. ft./sec./yr.
23.2% of unit yielding 1 ac. ft./sec./yr.
19.3% of unit yielding .75 ac. ft./sec./yr.
Weighted ave.= 1.7 ac. ft./sec./yr.
583 secs. x 1.7 = 991.1 ac. ft./yr.
991.1 x 1613 = 1,598,640

*Balance of pollutants made up of misc. salts, primarily carbonates & bicarbonates per USGS Atlas HA-61

* note: figure does not agree with U.S.G.S. date. Appears high by a factor of 5.

† 1 cu. ft./sec (cfs) = 2 ac. ft./day = 730 ac. ft./year. 1 gal./min = .00223 cfs = 1.63 ac. ft./year.

Show total mean annual concentration of all salts on line 4. List mean annual concentration of major salts on lines 4a, b, c, etc.

* If additional space is required footnote under "Remarks"

C. Hydrology

This planning unit is located in the Green River sub-basin of the Colorado Hydrologic Region. Piceance Creek, a major tributary of the White River, forms the northeast boundary of the planning unit, with the White River forming the north boundary of the planning unit. Yellow Creek, another major tributary of the White River, dissects the eastern portion of the planning unit.

With the exception of the northwest portion of the unit, the headwaters of the major drainages are all fairly stable. They all contain headcuts, but the location of the cut varies from one-third of the stream length down from the headwaters to up to two-thirds of the stream length below the headwaters. Below the head cuts the channels are deep with perpendicular sides and nearly all of them exhibit heavy sloughing during peak flows. The stream channels of the major drainages have a meandering characteristic, but most of the tributary drainages are straight channeled. Channels in the northwest corner of the unit mentioned above are nearly all exhibiting bank cutting from the headwaters to the mouth. The channels are relatively straight and exhibit heavy cutting of the banks during peak flow periods.

Most of the streams in this planning unit carry heavy sediment loads at their mouths during periods of high flow. Refer to form 1600-6 attached for estimates of water yield, sediment production, water pollutants, etc.

Ground water, especially with regards to water quality, seems to be quite variable in this planning unit. Wells drilled in the major drainage bottoms in the unit vary in depth from less than 100 feet up to 350 feet. The water from these wells is palatable, but generally quite hard. Most of the producing wells on the ridges, used for watering livestock, are results of developing abandoned oil wells or test holes drilled in search of oil and gas. These range in depth from 300 feet down to 1100 feet. Water quality is good although the water is generally very hard. Some wells have a high sulphur content in the water but the water is palatable. The water content in some wells along Piceance Creek on the extreme east boundary of the planning unit is so high in dissolved salts that these wells have to be abandoned because conventional pumps cannot operate economically.

No documented information is available regarding water quantity in the area. Short term testing at very high volumes has been carried out on some of the oil and gas test holes, but is not of a duration to provide data that can be substantiated. Annual recharge is undoubtedly adequate as long as the wells are used only for stockwater. Recharge would also be adequate for large volume pumping in the major drainage bottoms and along Piceance Creek which is a perennial stream.

Form 1600–6
(August 1969)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

PHYSICAL PROFILE
HYDROLOGIC DATA

Unit	Date 3/30/70
Yellow Creek	By Papworth

ITEM	UNIT	ESTIMATED ANNUAL AMOUNT	SOURCE REFERENCE
1. Water Yield †	ac. ft.	72,000 *	U.S.G.S. Atlas HA-194
2. Water Use †	ac. ft.	2,280	District Records
3. Sediment Production	cu. yds.	2,395,300	Factors Affecting Sed. Yield in Pac. S.W.
4. Other Pollutants ‡	ppm	700	U.S.G.S. Atlas HA-61
a. Calcium	ppm	100	U.S.G.S. Atlas HA-189
b. Sodium	ppm	100	" "
c. Sulphate	ppm	100	" "
d. Chloride	ppm	100	" "
e. Magnesium	ppm	100	U.S.GS. Professional Paper 441

Remarks

Pollutants: 200 ppm misc. dissolved solids, primarily carbonates & bicarbonates per U.S.G.S. Atlas HA-61.

Water use based on an average consumption of 1 ac. foot per acre of hay raised. An additional amount is shown for stored water in livestock reservoirs.

* note: figure does not agree with other data. Appears high by a factor of about 5.

† 1 cu. ft./sec (cfs) = 2 ac. ft./day = 730 ac. ft./year. 1 gal./min = .00223 cfs = 1.63 ac. ft./year.

‡ Show total mean annual concentration of all salts on line 4. List mean annual concentration of major salts on lines 4a, b, c, etc.

* If additional space is required, footnote under "Remarks"

APPENDIX IV-5

Text of Reference (4) U.S.G.S. Hydrologic Investigations

Atlas HA-370

INTRODUCTION

This atlas presents the results of an investigation of the water resources of part of the Piceance Creek structural basin in northwestern Colorado. The area of investigation is between the White and Colorado Rivers (see index map), an area of about 1,600 square miles in parts of Rio Blanco, Garfield, and Mesa Counties.

The U.S. Geological Survey's study of the water resources in the basin was begun in 1964 and completed in 1966. The study was made in cooperation with the Colorado Water Conservation Board. The basic hydrologic data collected during this study are published in a report by Coffin, Welder, Glanzman, and Dutton (1968). Additional basic data collected after publication of the Coffin, Welder, Glanzman, and Dutton report are in the files of the Geological Survey. The data include results of aquifer tests, logs of wells and test holes, hydrographs of streams, and chemical analyses of both ground water and surface water in the basin.

The objective of the investigation was to describe availability, occurrence, and chemical properties of the water resources of the basin. This description will be useful for developing water supplies and for coping with water problems associated with the development of the oil shale resources. The Piceance Creek basin contains some of the richest oil shale deposits in North America. These deposits represent a huge potential source of petroleum and efforts are currently being made to develop the resource. Some of the problems associated with the mining and retorting of oil shale are: removal of water from mines, supplying water for mining and retorting operations, supplying additional domestic water for an increase in population, effect of mining operations on present users of ground water and surface water, and water-quality problems created by mining operations.

The population of the basin is sparse, possibly less than 200. The major use of water is for irrigation and is supplied mostly by surface water. Hay meadows and feed crops are irrigated in the valleys of the four major streams (Piceance, Yellow, Roan, and Parachute Creeks). The surface water supply is adequate during the early part of the growing season and inadequate during the late summer months.

Ground-water resources of the basin are relatively undeveloped at the present because of sparse population and lack of arable land. The three irrigation wells in the basin are in the alluvium of Roan Creek. Four wells tapping the Green River Formation (originally drilled for oil) are occasionally used for irrigation along Piceance Creek. There are 65 small diameter wells, some of them flowing, and about 250 springs tapping the alluvium and the Green River Formation that supply water for domestic and stock use throughout the basin.

The Piceance Creek structural basin is a northwest-trending downwarp lying between the White River uplift on the east and the Douglas Creek arch on the west. The topography of the basin between the White and Colorado Rivers is illustrated by the block diagram. The edges of the basin are formed by cliffs of oil shale, which act as hydrologic boundaries separating the basin from adjacent areas. A major east-west topographic divide separates the structural basin into two drainage basins: the northern drainage basin contains Piceance and Yellow Creeks, which are tributary to the White River; the southern drainage basin contains Roan and Parachute Creeks, which are tributary to the Colorado River.

GEOLOGY

A brief description of the geologic units in the Piceance Creek basin and their water-bearing characteristics is given in the table. A geologic map and summary of the geology and oil resources of the basin is given in a report by Donnell (1961). The general shape of the basin and the relation of geologic units are shown on the structure contour map and the diagrammatic section.

Surface rocks exposed in the basin are sedimentary and range in age from the Cretaceous to the Quaternary (Donnell, 1961). Discussion of the geologic units in this report will be limited to the Green River Formation and younger rocks because these sediments are of greatest economic interest and contain the principal aquifers in the basin.

The Green River Formation of Eocene age rests conformably on the Wasatch Formation and is the bedrock in the area (see diagrammatic section). The formation is divided into five members: Anvil Points, Douglas Creek, Garden Gulch, Parachute Creek, and Evacuation Creek.

The Anvil Points, Douglas Creek, and Garden Gulch Members are composed of marlstone, shale, and sandstone. These units are relatively impermeable. In general, they impede the movement of ground water between the Green River Formation and the underlying rocks.

The Parachute Creek Member overlies the Garden Gulch Member and is composed principally of oil shale. This member contains the principal bedrock aquifer in the basin. The member can be divided into three zones (high resistivity, low resistivity or leached, and Mahogany) based on differences in both geologic and hydrologic character. These zones can be correlated throughout the central part of the basin based on their characteristic appearance on electric logs as shown on the stratigraphic section. The lowermost zone in the Parachute Creek Member is called the high resistivity zone. This zone contains oil shale and beds of saline minerals, is relatively impermeable, and probably is little fractured. The high resistivity zone is confined to the center of the northern part of the Piceance Creek basin (see diagrammatic section) and ranges from less than 200 to more than 900 feet thick, as indicated on the thickness map of the zone. The absence of this zone elsewhere may be due to low concentration of kerogen or to removal of the saline minerals by solution. Apparently, some saline minerals were deposited throughout the basin in the Parachute Creek Member. Deposition in vugs and beds is undoubtedly most common near the center of the basin and less common on the edges of the basin. The zone overlying the high resistivity zone is characterized by low resistivity on electric logs (see stratigraphic section). In the center of the basin, where saline minerals make up a greater percentage of the member, the removal of minerals from the upper part has resulted in voids, fracturing, collapse, and irregular bedding. The low resistivity zone which corresponds to the leached zone is more porous and permeable than either the underlying or overlying zones. Because of its high porosity and permeability, the leached zone is the principal bedrock aquifer in the Piceance Creek basin. The low resistivity zone is best defined near the center of the northern part of the basin and ranges from less than 400 to 700 feet thick as shown on the thickness map of the zone. The low resistivity zone thickens outward, but cannot be distinguished on electric logs outside of the 700-foot thickness line (see stratigraphic section). Core recovery from the leached zone is generally poor, but when core is recovered, it is highly fractured and contains vugs. Drillers often report lost circulation in this zone.

Overlying the leached zone is the Mahogany zone, or as it is called on the outcrop, the Mahogany ledge (see stratigraphic section). The zone contains a relatively thick section of oil shale. Saline minerals are sparse in this zone and apparently were never thickly deposited.

The Evacuation Creek Member, consisting of marlstone and fine-grained sandstone, overlies the Parachute Creek Member and forms the surface rock throughout most of the basin. That part of the member topographically higher than the level of the streams is mostly drained. The Evacuation Creek Member is more permeable than the Mahogany zone but is less permeable than the leached zone. The Evacuation Creek Member ranges from 0 to 1,250 feet thick.

Alluvium of Quaternary age contains sand, gravel, and clay and partly fills the stream valleys of Piceance, Yellow, Roan, and Parachute Creeks. The permeable alluvium is an aquifer in the Piceance Creek basin. The saturated thickness is as great as 100 feet. However, the areal extent of the alluvium is small and is usually confined to belts less than 1 mile wide. Because of this limited width, the alluvium is not capable of supplying large quantities of water to wells for more than a few months. The alluvium ranges from 0 to 140 feet thick.

STRUCTURE

The Green River Formation is cut by a very extensive joint or fracture system. The orientation of many of the streams and their tributaries appears to be controlled by these fractures. Streamflow along joints or fractures provides avenues for recharge to both the Evacuation and Parachute Creek Members. The joints are parallel to major structural features in the basin, but the primary trend is towards the northwest.

PRECIPITATION

Distribution of precipitation in the Piceance Creek structural basin is markedly affected by altitude (Iorns and others, 1965, p. 184-185). Areas where the altitude is greater than 8,000 feet, such as along the major divide and Cathedral Bluffs, receive as much as 26 inches of precipitation per year, mostly as snow in the winter months. Areas between altitudes of about 5,500 and 8,000 feet generally receive from 12 to 20 inches of precipitation annually. Streamflow generally is greatest during spring snowmelt. Some of the springs in the basin show a similar response to snowmelt as shown by the hydrographs of selected springs.

Samples of water having a dissolved-solids content ranging from 250 to 63,000 mg/l (milligrams per liter) have been collected in the basin. The best quality of water is found in streams and aquifers in the higher altitudes in the basin. The worst quality of water is found in the high resistivity zone of the Parachute Creek Member.

GROUND WATER IN THE GREEN RIVER FORMATION

The Green River Formation is the best potential source of ground water in the northern part of the Piceance Creek basin. The leached zones of the Parachute Creek Member and the Evacuation Creek Member are aquifers and contain water under artesian pressure in most of the area. There are many flowing wells and the maximum depth to water is about 200 feet. The Garden Gulch Member and the high resistivity zone of the Parachute Creek Member have very low permeability and confine water in underlying aquifers. The Mahogany zone of the Parachute Creek Member also confines water except where it is cut by vertical fractures. These fractures permit water to move between aquifers (see diagrammatic section on Sheet 1). The leached zone contains water in fractures and solution openings and is considered the principal bedrock aquifer in the northern part of the Piceance Creek basin because it has the greatest areal extent, permeability, and storage capacity. It contains 2.5 million acre-feet or more of water in storage. The transmissivity distribution in the leached zone was estimated from the thickness map of the zone (Sheet 1) and from six aquifer tests (Coffin and others, 1968). The transmissivity of the zone ranges from less than 3,000 gpd per ft (gallons per day per foot) in the margins of the basin to 20,000 gpd per ft in the center of the basin. Tests indicate that the potential yield of a well tapping the leached zone may be as much as 1,000 gpm (gallons per minute). The artesian storage coefficient of the leached zone is estimated to be about 10^{-4}, but when not confined, the storage coefficient would be about 10^{-1}. Thus, pumping very large quantities of water would cause water levels to decline several hundred feet to the top of the leached zone in a short time (< 1 yr), but after water levels reached the leached zone the decline would be much slower. The Evacuation Creek Member contains water mainly in fractures. Its permeability is much less than the leached zone. Test wells penetrating the Evacuation Creek Member in the north-central part of the basin yield 100 gpm or less.

The major ground-water divide in the basin is approximately the same as the topographic divide between the White River and the Colorado River. Ground-water movement in the Green River Formation (northern part of the Piceance Creek basin) is toward the two major drainages of the basin, Piceance and Yellow Creeks. Movement is normal to the contours shown on the potentiometric contour map. The Green River Formation is bounded on the west by Cathedral Bluffs. On the north, the divide is near the main stem of the White River. Recharge on the margins of the basin moves downward through the Evacuation Creek Member and Mahogany zone into the leached zone of the Parachute Creek Member. Data from a few wells indicate that the potentiometric head in the leached zone near the edges of the basin is lower than the head in the overlying zones. Other data indicate that near the center of the basin the head in the leached zone is higher than the head in the upper zone. These head relations indicate that the direction of flow is downward in the margins of the basin, laterally toward the center and northern edge of the basin, and upward in the lower reaches of Piceance and Yellow Creeks and in the White River valley (see diagrammatic section on Sheet 1). In the center and northern edge of the basin water moves upward and discharges into Piceance Creek, Yellow Creek, the White River, or is evaporated. Smaller amounts of ground water are discharged to springs and flowing wells. The potentiometric contours indicate that about half of the northern part of the basin contributes ground water to Piceance Creek. South of the major divide, water is discharged by springs that issue from fractures near the top of the Mahogany zone. In the lower part of the stream valleys, the Mahogany forms part of a cliff as high as 2,000 feet above the stream. Spring discharge from the top of the zone in these areas can be seen as a dark band along the upper part of the cliff. However, most of this water evaporates before reaching a stream.

Pumping large quantities of ground water from the Green River Formation would change the points of discharge. Continuous pumping of large amounts of ground water for a number of years could dry up springs over a large part of the basin and stop much of the seepage to the creeks. Many of the water holes used by wildlife would disappear and the base flow of Piceance and Yellow Creeks would be appreciably diminished to the detriment of present appropriators.

The dissolved-solids concentration of water in the Green River Formation ranges from 250 to 63,000 mg/l. Water near the edges of the basin contains less than 2,000 mg/l dissolved solids and the dominant ions are calcium, magnesium, and bicarbonate. About halfway between the edges of the basin and the center, dissolved-solids are about the same as at the edges, but the dominant ions are sodium and bicarbonate. Near the center of the basin, the water has dissolved considerable amounts of saline minerals and the dissolved solids average 25,000 mg/l and the principal constituents are sodium and bicarbonate. Chloride concentration ranges between 500 and 2,500 mg/l. The graph relating dissolved solids of water in the basin to specific conductance can be used to approximate dissolved-solids concentrations from field conductivity measurements. Water in the Parachute Creek and Evacuation Creek Members are chemically similar in the higher parts of the basin (Coffin and others, 1968). However, in the lower parts of the basin, water in the Parachute Creek Member becomes highly mineralized from contact with the saline minerals. For example, water in an abandoned oil test well near Piceance Creek about 1.5 miles below Ryan Gulch contained 17,400 mg/l dissolved solids, principally sodium and bicarbonate. The water in the well contained 542 mg/l chloride and is unsuitable for most uses. Water in the Evacuation Creek Member is a mixed chemical type with no dominant cation or anion. The principal constituents are sodium, magnesium, and sulfate. Analyses of water samples from the Evacuation Creek Member are summarized in a bar graph at the left. The dissolved-solids concentration ranges from 250 to 1,800 mg/l. Water in the Parachute Creek Member has sodium and bicarbonate as the principal ions, however, when the dissolved-solids are less than 500 mg/l, the principal ions are calcium and bicarbonate. A summary of analyses of water samples from the Parachute Creek Member is given in a bar graph at the left. The dissolved solids concentration ranges from 250 to 63,000 mg/l. The average dissolved solids concentration of 6 water samples obtained during a pumping test of the high resistivity zone was 63,000 mg/l.

GROUND WATER IN THE ALLUVIUM

Alluvium is a source of ground water along Piceance, Yellow, Roan, and Parachute Creeks. The alluvial aquifer is capable of storing and transmitting more water per unit volume than any other aquifer in the basin. However, the areal extent of the deposits is small compared to that of the bedrock aquifers. The alluvium is confined to belts less than 1 mile wide along the creeks. Along the major drainages, the alluvium ranges from 0 to 140 feet thick and the saturated thickness may be as much as 100 feet in a few places (Coffin and others, 1968). Water in the alluvium occurs under both water-table and artesian conditions. The permeability of the clay is much less than that of the sand gravel, and where it confines water in underlying sand and gravel under enough pressure, water flows at the land surface when tapped by a well. Typical occurrences of alluvium in the major stream drainages are shown by the sections below the potentiometric contour map.

An aquifer test in the alluvium of Piceance Creek showed that after pumping a few hours, the hydrologic boundaries of the alluvium will affect drawdowns and well yields (Coffin and others, 1968). The storage coefficient probably averages about 0.20. In places where the alluvium contains clay beds, the transmissivity may be as low as 20,000 gpd per ft. Thus, well yields vary widely from place to place according to variations in lithology of the alluvium at the well and proximity of the well to the hydrologic boundaries. Initial yields from properly located, developed, and constructed wells are estimated to be as much as 2,000 gpm. An irrigation well in Roan Creek was reported to yield 1,500 gpm.

The alluvial aquifer is recharged by precipitation, by applied surface water, by streams, and by infiltration from the Green River Formation. The aquifer discharges to streams, springs, wells, and to the atmosphere by evapotranspiration.

The dissolved-solids concentration of water in the alluvium ranges from 250 to 25,000 mg/l. Water in alluvium in the upper reaches of the major drainages contains less than 700 mg/l dissolved-solids. In general, the principal ions in the alluvial water are calcium, magnesium, and bicarbonate. Ions in the water in the alluvium of Piceance Creek are predominantly calcium, magnesium, sodium, and bicarbonate; the dissolved-solids concentration increases downstream. The dissolved-solids concentration is about 700 mg/l at Cow Creek and 2,500 mg/l at Dry Fork. Below Dry Fork the concentration increases to 8,300 mg/l and sodium becomes the dominant cation. These changes occur by solution and ion exchange and reflect the change in nature of the bedrock underlying the alluvium. Above Dry Fork the alluvium is underlain by the Evacuation Creek Member and below by the Parachute Creek Member. Abandoned flowing wells below Dry Fork tapping the Parachute Creek Member contribute locally to the increase in dissolved solids. Water in the alluvium in Yellow Creek appears to be within the range in composition and concentration of the water in the alluvium of Piceance Creek. Dominant ions in the water in the alluvium of Roan and Parachute Creeks are calcium, magnesium, sodium, bicarbonate, and sulfate. The dissolved-solids concentration of the water is as much as 7,200 mg/l. The alluvium of Roan and Parachute Creeks contains some gypsum which was derived from the Wasatch Formation. Water in contact with the gypsum becomes increasingly concentrated with sulfate. The sulfate concentration of a water sample obtained near the mouth of Roan Creek was 4,200 mg/l.

SURFACE WATER

There are no long-term records of streamflow in the Piceance Creek structural basin between the Colorado and White Rivers. Gaging stations on seven streams have been operated at various times. The records at these stations are summarized in the table and the station locations are shown on the potentiometric contour map. Except for two unpublished records, these data are published in Water-Supply Papers of the U.S. Geological Survey and in the annual series, Surface Water Records for Colorado, Part 1.

Commonly, all streams in the basin reach a peak during the snowmelt runoff and decrease in flow beginning in June or July, and reach low flow in September or October. Low flow continues through the winter. Parachute Creek is often dry, or almost dry, from December until April. The flow of Piceance Creek is more uniform than that of Parachute or Roan Creeks because the flow is sustained by ground-water discharge from the Green River Formation. However, in 1965 and 1966 the flow of Piceance Creek below Ryan Gulch dropped below its average of 12.5 cfs (cubic feet per second) to as little as 0.8 cfs during April or May due to diversions for irrigation before the snowmelt runoff.

On October 6, 1965, discharge was measured at 13 sites and 8 samples for chemical analysis were collected from Piceance Creek from Rio Blanco to the White River gage. The results of this study are shown on the discharge-quality graph at the left. Little water was being diverted for irrigation and there had been no precipitation for several weeks. The gain in flow downstream from Rio Blanco was caused by a thinning of the alluvium, forcing the ground water to the surface. The streamflow disappeared into the alluvium where it thickens at Cow Creek, but 2 miles downstream the alluvium was saturated and surface flow resumed. The potentiometric contour map indicates that the reach between Thirteenmile Creek and Black Sulphur Creek is fed by ground water. The 14 cfs gain in this reach, as determined by the October 6, 1965 study, supports this conclusion.

The effect of ground-water discharge from the Green River Formation on the chemical quality of water in Piceance Creek is illustrated on the discharge-quality graph. Above Thirteenmile Creek, the bedrock is the Evacuation Creek Member and ions in the water in Piceance Creek are predominantly calcium, magnesium, and bicarbonate; below Thirteenmile Creek, water contributed from the Parachute Creek Member caused a gradual increase in sodium, which became the dominant cation in the reach below Ryan Gulch. The dissolved-solids concentration ranged from 600 mg/l at Cow Creek to 2,000 mg/l at the White River gage.

Samples of water for chemical analysis at various discharges were collected on Piceance, Yellow, Roan, and Parachute Creeks. The results of the analyses are shown on the graphs showing chemical character for the various streams. Water in the alluvium is generally the same chemical character as the water in the stream, but has a higher dissolved-solids concentration. In general, the quality of the water is best at high discharges but the chemical character remains about the same. The observed range in dissolved-solids concentration in the four streams was as follows: Piceance Creek, 440 to 5,700 mg/l; Yellow Creek, 1,400 to 3,000 mg/l; Roan Creek, 430 to 2,300 mg/l; and Parachute Creek, 360 to 1,280 mg/l.

CONCLUSIONS

1. Surface-water supplies in the basin are small and are completely developed.
2. Additional ground-water supplies could be developed from the Green River Formation or from the alluvium. Wells in the Green River Formation might yield as much as 1,000 gpm. Wells in the alluvium might yield as much as 2,000 gpm.
3. Pumping large quantities of ground water from either the alluvium or from the leached zone of the Green River Formation would have adverse effects on present surface supplies.
4. The water stored in the leached zone represents a potential source of industrial supply that might last many years. The zone contains 2.5 million acre-feet of ground water in storage. Pumping large quantities of water from the Green River Formation would cause levels to decline several hundred feet in a short period of time (< 1 yr).
5. Water pumped from the leached zone would contain dissolved solids ranging from less than 2,000 mg/l near the edges of the basin to more than 60,000 mg/l in the center of the northern half of the basin. The 60,000 mg/l water might have a chloride concentration of 1,000 mg/l or more. Water with a chloride concentration this high is unsuitable for most uses. Ions in the water near the edges of the basin are predominantly calcium, magnesium, and bicarbonate; the ions near the center of the basin are predominantly sodium and bicarbonate.
6. Oil shale mining operations may be hampered by ground water. Flooding by ground water would be most serious in mines which are excavated in or below the leached zone. For example, near the center of the basin, an open-pit mine with a radius of half a mile might require a pumping rate of as much as 60 cfs to keep the mine dewatered.
7. Disposal of mine effluent in surface streams would increase the salt load in the White and Colorado Rivers, which would pose a serious pollution problem.

SELECTED REFERENCES

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UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

APPENDIX V-1

LIST OF PLANTS
EXISTING IN
RIO BLANCO COUNTY, COLORADO

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UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

cooperating with
White River and Douglas Creek Soil Conservation Districts

LIST OF PLANTS EXISTING IN RIO BLANCO COUNTY, COLORADO

This Inventory was prepared for Rio Blanco County health officials, doctors, laboratory technicians, livestock and wildlife specialist, and all others concerned with man and animals reacting to plants and plant substances. This list can be used to substantiate the occurence of plants in the County in the cases of allergies, poisoning, injury, and other harmful effects caused by plants.

The list is set up with seven main categories in alphabetical order by technical names. The common names given are for the species, genera, or family of plants. As common names often vary in usage in different localities, they should not be considered technically correct, unless all concerned have full knowledge of the common names. The exception is that vegetable garden plants are most often known and referred to by the common names.

Taxonomically, plants are listed by families, genus and species, but when listed by categories the families, genus, and species appear in different categories. An example is the genus Lactuca, "wild lettuce", which has a respectable native forb species, pulchella, and a weed species, canadensis.

The preparation of this Inventory list involves time and study to make it practical. However, it is a first attempt for the County of Rio Blanco--so, the list may not be technically complete. The plants of Rio Blanco County are so numerous in kinds and amounts that books and books could be compiled on these plants--their good and their bad characteristics.

We attempted to recognize the plants that are especially ornamental, weedy, etc. This is difficult to do as values such as "ornamental", "weedy", etc. are many times variable as the particular person's conception of what he thinks is ornamental value, weedy, etc. All plants have some ornamental value and, of course, the old adage that any plant "out of place" is a weed, does have merit.

Quantitatively, the sunflower (Compositae) family of plants (i.e. sagebrush, rabbitbrush, dandelion, etc.) and the 'Grass family' of plants contribute most to Rio Blanco's pollen production. The lily (Lilacea), crowfoot (Ranunculaceae), spurge (Euphorbiaceae), parsley (Umbelliferae), and bean (Leguminosae) families probably contribute the most to the total poison problems. However, in rather rare cases, any plant can be suspected as the "troublemaker".

It must be understood that plants cannot be divided into just good or bad plants; most plants are harmless; many plants are bad under some conditions. A few plants are bad under nearly all conditions.

A green apple "bellyache" is bad, but on the other hand, an apple a day keeps the doctor away--providing you don't get in the "poison ivy".

I. CROPS, GARDENS, WEEDS

A. Grass:

Avena sativa	Grain oats
Hordeum vulgare (all strains)	Grain barley
Secale cereale	Rye
Sorghum sudanense (all var.)	Sudangrass
Sorghum vulgare (all var.)	Grain sorghum
Triticum spp.	All domestic wheat grains
Zea mays	All corn varieties

Forb:

Lotus spp.	Trefoil
Melilotus alba	White sweetclover
M. officinalis	Yellow sweetclover
Onobrychis viciafolia	Sanfoin
Trifilium spp.	Domestic clover

Garden: (vegetables, flowers, etc.)

Allium cepa (all varieties)	Garden onion
Allysum spp.	Allysum
Argemone hispida	
A. intermedia	Prickly poppy
Asparagus officinalis	Asparagus
Berberis spp.	Barberry (native)
Camelina microcarpa	False flax
Carthamnus tinctorius	Safflower (ornamental)
Carum carvi	Caraway
Chrysanthemum spp.	Chrysanthemum
Clematis columbiana	Garden clematis
C. jackmannis	Garden clematis
Cucurbita foetidissima	Gourd
Dadecatheon pulchellum	Shooting star (native)
Daucus spp.	Garden carrot
Delphinium spp.	Garden tall larkspur
Echinocactus spp.	Hedgehog cactus (native)
Eruca sativa	Garden rocket
Euphorbia albomarginata	Snow-on-the-mountain
E. pachysandra	Evergreen spurge
Eschscholzia californica	California poppy
Foeniculum vulgare	Fennel
Frageria spp.	Domestic strawberry
Gayophytum spp.	Baby breathe
Geranium spp.	Garden geranium
Gilia spp.	Gilia or trumpet flower (native)
Lathryus spp.	Wild sweet-pea
Lillium spp.	Lily
Linum lewisia	Wild flax (native)
Lobelia spp.	Lobelia

C. Garden: (continued)

Malva crispa	Hollyhock
Mamillaria missouriensis	Pinchshion cactus
Mimosa spp.	Mimosa
Nicotiana attenuata	Tobacco
Oxalis spp.	Wood sorrel
Pachystima myrsinites	Mountain lover
Paeonia brownii	Peony
Pastinaca sativa	Parsnip
Phlox spp.	Phlox (native)
Primula angustifolia	Fairy primrose
Prunus spp. (all strains)	Plum
Prunus spp. (all strains)	Cherry
Rheum rhaponticum	Rhubarb
Rhedodendron spp.	Rhododendron
Ribes, spp.	Gooseberry and currant (native)
Rorippa spp.	Cress
R. armorica	Horse radish
Rosa spp.	Garden rose
Rubus spp.	Blackberry and raspberry
Sedum spp.	Stonecrop
Spiraea spp.	Spiraea
Thermopsis spp.	Golden banner
Vaccinium spp.	Blueberry (native)
Verbena spp.	Vervain
Viola spp.	Violet (native)
Vitis spp.	Grape
Zinnia grandiflora	Zinnia

D. Weeds:

Amaranthus albus	Tumble pigweed
A. graecizanus	Prostrate pigweed
A. retroflexus	Redroot pigweed
Apocynum cannabinium	Dogbane
Arctium minus	Burdock
Aristida adscenionis	Six weeks three-awn
Asclepias spp.	Poison milkweed (native)
Asperugo procumbens	Catchweed
Avena fatua	Wild oats
Bidens spp.	Beggar ticks
Brassica spp.	Mustard
Bromus japonicus	Japanese brome
B. secalinus	Chess brome
B. tectorum	Cheatgress
Cannabis sativa	Harijuana or hemp
Cerastium vulgatum	Mouse-ear chickweed
Chenopodium album	Lambsquarters
C. berlandieri	Common pigweed
C. fremontii	Fremont pigweed
C. gigantospermum	Giant pigweed
C. lepthophyllum	Slimleaf pigweed
C. rubrum	Red pigweed

D. Weeds: (Continued)

Cirsium spp.	Thistle
Conium maculatum	European poison hemlock
Conringia orientalis	Hares-ear mustard
Convalvulus spp.	Bindweed
Cordaria draba	
Cryptantha spp.	Cryptantha (native)
Cuscuta spp.	Dodder
Datura spp.	Jimson weed
Daucus spp.	Wild carrot
Descurainia spp.	Tansy mustard
Eragrostis cilianensis	Stinkweed
Euphorbia esula	Leafy spurge (noxious)
Festuca octoflora	Six weeks fescue
Franseria spp.	Bur sage
Glycyrrhiza lepidota	Wild licorice
Gnaphalium spp.	Cudweed
Halogeton glomeratus	Halogeton
Hyoscyamus niger	Henbane
Hypericum perforatum	Klamath weed
Iva spp.	Povertyweed
Kochis americana	Kochia or fireweed
Lactuca spp.	Wild lettuce
Lappula spp.	Stickseed or beggar ticks
Linaria dalmatica	Toadflax (escaped flower)
L. vulgaris	
Lupine spp.	Lupine (native)
Madia glemerata	Tarweed
Malva neglecta	Common mallow
Matricaria spp.	Mayweed
Medicago lupulina	Black medic
Mirabilis spp.	Four-o-clock
Nuhlenbergia (annual spp)	Annual muhlys
Parthenocissus vitacea	Virginia creep
Paspalum racemosum	
Physalis spp.	Ground cherry
Plantage spp.	Plantain
Poa annua	Annual bluegrass
Portulaca oleracea	Purslane
Paoralea spp.	Scurf pea
Salsola kali	Russian thistle
Salvia reflexa	Mint sage
Setaria viridis	Wild millet
Solanum spp.	Nightshade
Sonchus spp.	Sow thistle
Stellaria spp.	Starwort and chickweed
Tanacetum spp.	Tansy (escaped garden plant)
Taraxacum spp.	Dandelion
Thalaspi spp.	Pennycress
Tragopogon spp.	Goatsbeard
Tribulus terrestris	Puncture vine

D. Weeds: (continued)

Vaccinium spp.	Blueberry (native)
Verbena spp.	Vervain
Veronica spp.	Speedwell
Xanthium spp.	Cocklebur

II. FORBS

Achillea lanulosa	Western yarrow
Aconicium bakeri	Monkshood
A. columbianum	Monkshood*
Actea arguta	Baneberry
Agastache spp.	Giant hyssop
Agoseris spp.	Mountain dandelion
Aletes spp.	Wild carrot
Allium spp.	Wild onion*
Alyssum alyssoides	Alyssum
Androsocae spp.	Rock jasmine*
Anemone cylindrica	Anemone*
A. globosa	Anemone*
A. parviflora	Anemone*
A. zephyra	Anemone
Angelica ampla	Angelica
Antennaria spp.	Pussytoes
Aquilega spp.	Columbine*
A. coerulea	Colorado columbine*
Arabis spp.	Rock cress
Arnica spp.	Arnica
Artemisia spp.	Herbaceous sage
Asclepias spp.	Milkweed
Aster spp.	Aster*
Astragalus spp.	Milkvetch (poison)
Atriplex (annual spp.)	Annual saltbush
Avenaria congesta	Sandwort
A. fendleri	Tuber starwort*
Bahia spp.	
Balsamorhiza saggittata	Balsamroot*
Berberis fendleri	Holly oregon grape
B. fremontii	
B. repens	
B. vulgarii	
Brickellia spp.	Bricklebush
Calachortus spp.	Marigosa lily*
Caltha leptosepala	Marsh marigold*
Calypso bulbosa	Calyspso (orchid)*
Campanula spp.	Harebell*
Cardimine spp.	Bittercress
Carum carvi	Indian potato
Castilleja spp.	Paintbrush*
Cerastium arvense	Field chickweed*
Chaenactis spp.	False yarrow
Chrypsopsis spp.	Golden aster
Cicharium intybus	Chicory
Cicuta oxidentalis	Water hemlock (poison)
Claytonia lanceolata	Spring beauty*

* Especially ornamental
** Weedy

Forbs (continued)

Clematis hirsutissima	Sugar bowl*
C. lingusticifolia	Creeping virgins bower
C. orientalis	
C. pseudoalpina	
Cleome lutea	
C. serrulata	Rocky mountain bee plant*
Clinopodium vulgare	Wild basil
Collinsia parviflora	Blue eyed may
Commandra umbellata	Bastard toadflax
Conioselinum scopulorum	Hemlock-parsley
Conyza spp.	
Cordylanthus ramosus	Birdbeak
Corallorhiza maculata	Coral root (orchid)*
C. trifida	Coral root*
Corydalis aurea	Corydalis*
Crepis spp.	Hawksbeard
Cryptantha spp.	Cryptantha
Cyneglossum officinalis	Houndstongue
Cypripedium fasciculatum	Ladys slipper*
Dodecatheon pulchellum	Shooting star
Delphinium spp.	Larkspur (poison)**
Descurainia spp.	Tansy mustard**
Dithyrea wistizeni	Spectacle pod**
Draba spp.	Whitlow-grass
Epilotium spp.	Fireweed*
Erigeron spp.	Fleabane or wild daisy
Eriogenum spp.	Buckwheat
Eritrichium elongatum	Alpine forget-me-not
Erysimum asperum	Wallflower*
Erythronium grandiflorum	Dog tooth lily*
Euphorbia spp.	Wild spurge**
Frageria spp.	Wild strawberry
Galium spp.	Bedstraw
Gentiana spp.	Gentian
Geranium spp.	Wild geranium*
Geum spp.	Avens
Gilia spp.	Scarlet gilia*
Grindelia spp.	Gumweed**
Gutierrezia spp.	Snakeweed
Habenaria spp.	Bog orchid*
Hackelia spp.	Oplz
Happlopappus spp.	Goldenweed
Hedysarum occidentale	Sweet vetch
H. uintahense	Purple joint-pod
Helenium hoopsii	Sneezeweed (poison)**
Helianthella spp.	Little sunflower*
Heracleum lanatum	Cow parsnip
Heuchera parvifolia	Alum root
Hydrophyllum capitatum	Water leaf*
Hymenepappus spp.	
Hymenoxys spp.	Actinea

Forbs (continued)

Iris missouiensis	Blue flags (Rocky mountain iris)*
Kalmia polifolia	Mountain laurel
Lactuca spp.	Wild lettuce
Lathryus spp.	Peavine
Leptodactylon spp.	Leptodactylon
Lepidium spp.	Pepperweed*
Lesquerella spp.	Bladderpod
Leucempyx spp.	Wild cosmos
Leursia pymaca	Bitter root
L. rediviva	Bitter root
L. triphylla	Bitter root
Liatria spp.	Blazing star
Ligusticum porteri	Lovage
Linum lewisia	Wild flax
Linnaea borealis	Twinflower
Lithophragma spp.	Woodland star
Lithospermum spp.	Gromwell
Lupinus spp.	Lupine*
Lycopus americanus	Water horehound
Lygodesmia spp.	Skeleton plant
Mentzella spp.	Evening star
Mertensia spp.	Bluebell*
Mimulus spp.	Monkey flower*
Moldarica parviflora	Dragon head
Monarda spp.	Bee balm
Meneses uniflora	Wood nymph
Morrubium vulgare	Hearhound
Mysotis alpestris	Forget-me-not
M. verna	Forget-me-not
Nepeta cataria	Catnip
Oentheracaesptosa	Evening primrose*
Orobanche spp.	Broomrope
Orthocarpus spp.	Owl clover*
Oxpolis fendleri	Cowbane
Oxypropis albiflora	White locoweed (poison)
O. lambert	Purple locoweed (poison)
O. mollissimus	Wooly locoweed (poison)
Ozmorhiza spp.	Sweet anise
Paranychia depressa	Nailwort
Parnassia spp.	Parnassia
Pedicularis greenlandica	Little elephanthead*
P. spp.	Lousewort
Pensetmon spp.	Beard tongue
Perideridia gairdneri	Yampa
Petasites sagittata	Butter bur
Phacelia spp.	Scorpion weed
Phlox spp.	Wild phlox*
Physaria floribunda	Twinpod
Polemonium spp.	Jacob's ladder*
Potentilla spp.	Herbaceous cinquefoil
Primula angustifolia	Fairy primrose
Prunella vulgaris	Self heal

Forbs (continued)

Pseudocymopterus montanus	Wild yellow parsley
Psilostrope bakeri	Paper flower
Pulsatilla ludoviciana	Pasque flower**
Ranunculus spp.	Buttercup*
Ratibida spp.	Prairie coneflower
Rudbeckia spp.	Coneflower
Rumex crispus	Dock**
R. pycanthus	Dock**
R. triangulivalvis	Dock**
R. venosus	Dock**
Saponaria offinialis	Bouncing bet
Saxifraga spp.	Saxifrage
Scropularia lanceolata	Figwort
Seedum spp.	Stonecrop*
Senecio spp.	Groundsel
Sibbaldia procumbens	False strawberry
Sidalcea neomexicana	Wild hollyhock*
Silene acaulus	Catchfly
Sisynbrium altissimum	Tumbling mustard*
Sium sauve	Water parsnip
Smilicina racemosa	False solomon seal*
S. stellata	False solomon seal*
Solidago spp.	Goldenrod
Sphaeralcea coccinea	Scarlet globemallow**
Stachys palustria	Betony
Stanleya pinnata	Princes plume (poison)**
Suckleya suckleyana	Poison suckleya
Swertia radiata	Monument plant**
Sysrinchium montanum	Blue-eyed grass*
Thalictrum spp.	Meadow rue*
Thermopsis divaricarpa	Golden banner*
T. montana	Golden banner
T. rhombifolia	Golden banner
Townsendia spp.	
Trifolium spp.	Native clover
Trollius laxus	Globeflower*
Urtica dioica	Nettle**
Valeriana spp.	Valerian
Veratrum californicum	False hellebore or skunk cabbage**
Verbascum thapsus	Mullein**
Veronica spp.	Speedwell
Vioia americana	Vetch
V. producta	Vetch
Viguierra multiflora	Showy goldeneye*
Viola spp.	Wild viola
Wyethia spp.	Mulesear
Zygadenus gramineus	Death camas

III. NATIVE GRASSES

Agropyron spp.	Wheatgrass
A. bakeri	Baker wheatgrass
A. dasytachyum	Thickspike wheatgrass
A. griffithsi	Griffiths wheatgrass
A. pseudovepens	False quackgrass
A. inerme	Beardless bluebunch wheatgrass
A. latiglume	Alpine wheatgrass
A. repens	Quackgrass
A. riparium	Streambank wheatgrass
A. scribneri	Scribner or spreading wheatgrass
A. smithi	Western wheat or Colorado bluestem
A. spicatum	Bluebunch wheatgrass
A. subsecundum	Bearded wheatgrass
A. trachycaulum	Slender wheatgrass
Agrostis spp.	Bentgrass
A. alba	Redtop
A. scabra	Ticklegrass
Alopecurus spp.	Native foxtail
Aristida longiseta	Red three-awn grass
Beckmannia syzigachne	American sloughgrass
Blepharoneuron tricholepsis	Pine dropseed
Bouteloua spp.	Grama grass
B. gracilis	blue grama
Bromus spp.	Bromegrass
B. anomalus	Nodding brome
B. carinatus	Mountain brome
B. ciliatus	Fringed brome
B. pumpellianus	Pumpelly brome
Calamagrostis spp.	Reedgrass
C. canadensis	Bluejoint reedgrass
C. montanensis	Plains reedgrass
C. purpurasoens	Purple pinegrass
Danthonia californica	California oatgrass
D. intermedia	Timber oatgrass
D. parryi	Parry oatgrass
Deschampsia caespitosa	Tufted hairgrass
Distichlis stricta	Saltgrass
Echinochloa crusgalli	Barnyardgrass
Elymus spp.	Wildrye
E. ambiguus	Colorado wildrye
E. idahoensis	Idaho fescue
E. ovina	Sheep fescue
E. ovina brachphylla	Alpine fescue
E. thurberi	Thurber fescue
E. Kingii	Giant fescue
E. salinus	Salina wildrye
E. triticoides	Creeping wildrye

Native Grasses (continued)

Festuca spp.	Fescue
F. arizonica	Arizona fescue
F. idahoensis	Idaho fescue
F. Kingii	Giant fescue
F. ovina	Sheep fescue
F. ovina brachphylla	Alpine fescue
F. thusberi	Thurber fescue
Glyceria pauciflora	Creeping manna grass
G. stricta	Foul manna grass
Hesperochloa kingi	Spike fescue
Hilaria jamesi	Galleta grass
Hordeum spp.	Barley
H. brachyantherum	Meadow barley
H. jubatum	Foxtail barley
Koelaria cristata	Junegrass
Melica bulbosa	Oniongrass
M. spectabilis	Showy oniongrass
Muhlenbergia spp.	Muhly
M. filiculmis	Slimstem muhly
M. montana	Mountain muhly
M. richardsonis	Mat muhly
Oryzopsis spp.	Ricegrass
O. hymenoides	Indian ricegrass
O. micrantha	Littleseed ricegrass
Phalaris arundacea	Reed canarygrass
Phleum spp.	Timothy
P. alpinum	Alpine timothy
Phragmites communis	Common reedgrass
Poa spp.	Bluegrass
P. ampla	Big bluegrass
P. bulbosa	Bulbous bluegrass
P. artica	Artic bluegrass
P. alpina	Alpine bluegrass
P. compressa	Canada bluegrass
P. fendleriana	Muttongrass
P. nevadensis	Nevada bluegrass
P. secunda	Sandberg bluegrass
Puccenellia airoides	Alkaligrass
Sitanion hystrix	Squirreltail
Sphenophlis obtusata	Wedgescale
Sporobolus spp.	Dropseed
S. airoides	Sand dropseed
S. crypandrus	Sand dropseed
Stipa spp.	Needlegrass
S. columbiana	Columbia needlegrass
S. comata	Needleandthreadgrass
S. lettermani	Letterman needlegrass
S. pinetorum	Pine needlegrass
S. viridula	Green needlegrass
S. robusta	Sleepygrass
Trisetum spicatum	Spike trisetum

IV. INTRODUCED GRASSES (Pasture and Hay)

Agropyron spp.	Wheatgrass
A. cristatum	Crested wheatgrass
A. elongatum	Tall wheatgrass
A. intermedia	Intermediate wheatgrass
A. sibiricum	Siberian wheatgrass
A. trichophorum	Pubescent wheatgrass
Agrostis palustris	Creeping bentgrass
A. tenuis	Colonial bentgrass
Alopecurus praetensis	Creeping meadow foxtail
Bromus inermus (all varieties)	Smooth brome
Dactylis glomerata (all varieties)	Orchardgrass
Elymus junceus	Russian wildrye
Festuca arundinaceae	Tall and Kentucky bluegrass
F. elatior	Meadow fescue
Lolium multiflorum	Italian ryegrass
L. perenne	Perennial ryegrass
Phelum pratense	Timothy
Poa pratensis	Kentucky bluegrass

V. NATIVE GRASS-LIKE PLANTS

Carex spp.		Sedge
C. angustior	(alpine)	
C. aquatilis	(wet meadow)	
C. douglasi		Douglas sedge
C. drummondia	(alpine)	
C. ebenea		Ebony sedge
C. elynoides	(alpine)	
C. festivella		Ovalhead sedge
C. filifolia	(wet meadow)	
C. geyeri		Elk sedge
C. nebraskensis	(wet meadow)	
C. nigricans		Ebony sedge
C. pysocarpa	(alpine)	
C. rostrata	(wet meadow)	
Juncus spp.		Rush
J. balticus		Baltic rush
J. nodosus		Jointed rush
J. saximontanus		Rocky Mountain rush
Kobresia bellardi (elyna)		Kobresia
Luzula spp.		Woodrush
Scirpus microcarpus		Panicled bulrush
S. occidentalis		Tule bulrush
S. paludosus		Alkali bulrush
S. validus		Sofstem bulrush

VI. WOODY PLANTS

Shrubs

Acer glabrum	Rocky Mountain maple
Alnus tenuifolia	Thinleaf alder
Amelanchier alnifolia	Serviceberry
Arctostaphyla patula	Manzanita
A. uvi-ursi	Kinnikinick
Artemisia spp.	Sagebrush
A. cana	Silver sage
A. dranunculoides	False tarragon
A. frigida	Fringed sage
A. gnaploides	Cudweed sagewort
A. scopulorum	Alpine sage
A. tridentata	Big sage
Atriplex canescens	Four-wing saltbush
A. confertifolia	Schadscale
A. gardneri	Gardners saltbush
Berberis spp.	Barberry
Caragana arborescens	Siberian pea tree
Ceanothus fendleri	Mountain ceanothus and buckbrush *
C. velutinus	Mountain ceanothus and buckbrush *
Cerco carpus montanus	Mountain mahogany
Cercis canadensis	Redbud
Chrysothamnus spp.	Rabbitbrush
Cornus stolonifera	Redosier dogwood
Corylus cornuta	Hazelnut *
Cowania mexicana	Cliffrose
Cratoegus rivuloris	River hawthorne
C. saligna	Willow hawthorne
Elaeagnus angustifolia	Russian-olive *
E. commutata	Silverberry *
Eriogonum spp.	Buckwheatbrush
Ephedra spp.	Jointfir or Mormon tea
Euonymus spp.	Euonymus *
Eurotia lanata	Winterfat
Fendlera rupicola	Fendlerbush
Forestiera neomexicana	Coyote bush
Fraxinus anomala	Singleleaf ash
Gragia brandegei	Spineless hop-sage
G. spinosa	Hop-sage
Holodiscus dumosus	Rock spirea *
Humulus americanus	Hops (vine)
Ilex spp.	Holly *
Juniperus spp.	Juniper (varieties) *
Lonicera spp.	Honeysuckle *
Lycium halimifolium	Desert thorn
Mahonia repens	Oregon grape

Woody Plants

Shrubs (continued

Pachystima myrsinites	Mountain lover or Boxleaf myrtle *
Parthenocissus inserta	Virginia creeper
Peraphyllum romosissimum	Squaw apple
Philadelphus microphyllus	Mock orange *
Poliamintha incana	Rosemary mint
Potentilla fruticosa	Woody cinquefoil
Prunus virginiana	Chokecherry
Prunus spp.	Plum and cherry varieties *
Purshia tridentata	Antelope bitterbrush
Quercus gambeli	Gambel oak
Rhamnus smithii	Buckthorn
Rhus trilobata	Skunkbush sumac *
Ribes spp.	Gooseberry and currant *
Robinia neomexicana	Locust *
Rosa spp.	Wild rose
Rubus spp.	Wild raspberry and thimbleberry *
Salix spp.	Willow
Sambucus spp.	Elderberry *
Sarcobatus vermiculatus	Greasewood
Shepherdia argentea	Silver buffaloberry *
S. canadensis	Russet buffaloberry *
Sorbus scopulina	Mountain ash
Spiraea spp.	Spirea *
Symphoricarpos spp.	Snowberry
Tamarix gallica	Salt cedar *
Tetrydemia spp.	Horsebrush
Toxicodendron radican	Poison ivy
Vaccinium spp.	Wholtleberry
Viburnum spp.	Cranberrybush *
Yucca glauca	Yucca

* Commonly used as ornamental shrubs. Other shrubs also used for ornamentals, but generally they are exotic to U.S. or introduced from other areas. Occurrence of these shrubs may have to be determined by on-site investigation.

Woody Plants

Trees

Abies spp.	Fir trees
A. lasiocorpa	Alpine fir
A. concolor	White fir
Acer spp.	Maple trees **
A. glabrum	Rocky Mountain maple *
A. macrophyllum	Bigleaf maple **
A. rubrum	Red maple **
A. saccharinum	Silver maple **
A. saccharophorum	Sugar maple **
A. spp.	Japanese, Norway, etc. **
Ailanthus altissima	Tree of Heaven
Alnus tenuifolia	Mountain alder *
Betula spp.	Birch trees
B. fontinalis	Water birch
B. pendula	European White birch **
B. pendula dalecarlica	Cut-leaf birch **
Catalpa speciosa	Catalpa **
Celtis occidentalis	Hackberry **
Cercis canadensis	Redbud **
Crataegus spp.	Hawthorn *
Elaeagnus angustifolia	Russian olive *
Fraxinus pennsylvanica lanceolata	Green ash **
Gleditsia triacanthos	Honeylocust **
Juniper spp.	Juniper trees
J. communis	Common juniper *
J. monosperma	One-seed juniper
J. pachyphloea	Alligator juniper (rare)
J. scopulorum	Rocky Mountain juniper
J. utahensis	Utah juniper
J. Virginiana	Eastern Redcedar **
J. spp.	Pyramid, Irish, Greek, Creeping, Pfitzer, etc. **
Malus spp.	Flowering crab and orchard apples **
Picea	Spruce trees
P. engelmanni	Engelman spruce
P. pungens	Colorado blue spruce
P. abies	Norway spruce **
Pinus spp.	Pine trees
P. aristata	Bristlecone pine (rare)
P. contorta latifolia	Lodgepole pine
P. edulis	Pinyon pine
P. flexilis	Timber pine (rare)
P. mugo	Mugho pine **
P. ponderosa	Ponderosa pine
P. sylvestris	Scotch pine **
P. thunbergi	Japanese black pine **

Woody Plants

Trees (continued)

Populus spp.	Aspen, poplar, cottonwood trees
P. acuminata	Lanceleaf cottonwood
P. alba	Silver or white poplar **
P. angustifolia	Narrowleaf cottonwood
P. alba bolleana	Bolleana poplar **
P. deltoides	Eastern cottonwood **
P. nigra italica	Lombardy poplar **
P. sargenti	Plains cottonwood **
P. tremuloides	Quaking aspen
P. wislizeni	Rio Grande cottonwood **
Prunus spp.	Cherry, peach, plum, almond apricot
P. pennsylvanica	Pin cherry (rare) *
P. virginiana	Western chokecherry *
P. spp.	Fruit and ornamental trees ** almond-apricot-cherry-peach-plum
Pseudotsuga taxifolia glauca	Douglas fir
Pyrus spp.	Pear tree (orchard) **
Quercus gambeli	Gambel oak *
Q. spp.	Ornamental trees **
Rhus spp.	Sumac *
R. typhina	Staghorn sumac **
Robinia spp.	Locust trees
R. neomexicana	New Mexico locust *
R. pseudoacacia	Black locust **
Salix spp.	Willow trees *
S. amygdaloides	Peachleaf willow
S. babylonica	Weeping willow *
S. lutea	Yellow willow **
S. alba vitellina	Golden willow **
S. matsudana tortuosa	Corkscrew willow **
Sorbus scopulina	Mountain ash *
Taxus spp.	Yew trees *
T. brevifolia	Pacific yew **
T. cuspidata	Japanese yew **
T. baccata	English yew **
T. canadensis	Canadian yew **
Thuja spp.	Arborvitae *
T. occidentalis	American arborvitae **
T. orientalis	Oriental arborvitae **
T. standishi	Japanese arborvitae **
T. spp.	Exotic arborvitae **
Tsuga spp.	Hemlock trees **

Woody Plants

Trees(Continued)

Ulmus spp.	Elm trees
U. americana	American elm **
U. parvifolia (all varieties)	Chinese elm **
U. pumila	Siberian elm **

* also classed as shrub, or varieties are shrubs

** ornamental--may be planted from native, introduced, or exotic (to U.S.) stocks.

VII. MISCELLANEOUS PLANTS (Natives)

Arceuthobium campylopedum	Dwarf mistletoe
A. douglasi (parasite on conifer trees)	Dwarf mistletoe
Callitriche spp.	Water star-wort (water species)
Ceratophyllum demersum	Coontail
Dryas octopetala	Dryad (inconsp. dry places in mtns)
Echinocactus spp.	Hedgehog cactus
Lemna minor	Common duckweed
Mamillaria missouriensis	Pincushion cactus
Mitella spp.	Miterwort (inconsp. wet places)
Monotropa latiscuama	Indian pipe (no clorophyll)
Nuphar polysepalum	Pond lily
Opuntia spp.	Prickly pear (cactus)
Phoradendron juniperinum	American mistletoe(parasite on junipers
Pteridium spp.	Bracken fern
Typha latifolia	Cattail

VIII. SPECIAL NOTE ON VEGETABLES, FRUITS, FLOWERS, HERBS, AND CROPS

Plants that are used for the above purposes have been domesticated through breeding or plant selections. There is not a complete up-to-date toxonomic list of all of these plants, except maybe by some research or experimental concerns. Even so, the listing would be by categories, such as, fruit, vegetables, etc., and it would take several listings to develop a complete single listing.

Domestic plants are constantly being worked with to find better or additional plants for certain uses. In the process, domestic plants have to be further recognized than just by genus and species, so they are further divided by variety, strain, cultivar, hybrid, etc.

The process became very complicated to list all of the subdivisions of these plants. So, domesticated plant materials (seed, etc.) are often sold on the market by some locally accepted common name.

A great majority of domestic plants can occur in Rio Blanco County. They may not be grown extensively, but they can be expected to be tried by "green thumbs". but, as a rule, plants that require long season of growth or adapted to tropical and subtropical zones are not likely to be found in Rio Blanco County. The exception would be small house plants.

APPENDIX V-2

Partial check list of vascular plants within grazing study pastures, Little Hills Game Experiment Station, Dry Fork, Piceance Creek, portions of Sections 3, 4, 5, 8, 9, 10, 11, 14, and 15, T1S, R96W, 6th P.M. White River Drainage, Rio Blanco County, Colorado, 1948-1968.

Trees

Scientific Name 1/	Common Name
Juniperus osteosperma (Torr.) Little	Utah juniper
Juniperus scopulorum Sarg.	Rocky Mountain juniper
Pinus edulis Engelm.	Pinon pine
Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir

Shrubs and Half-Shrubs

Amelanchier utahensis Kochne, Gattung	Utah serviceberry
Artemisia tridentata Nutt.	Big sagebrush
Artemisia dracunculoides Pursh*2/	Falsetarragon sagebrush, Wormwood
Artemisia frigida Willd.*	Fringed sagebrush
Berberis repens Lindl.	Creeping mahonia, Oregongrape
Cercocarpus montanus Raf.	True mountain mahogany
Chrysothamnus depressus Nutt.	Dwarf rabbitbrush
Chrysothamnus nauseosus (Pallas) Britt.	Rubber rabbitbrush
Chrysothamnus viscidiflorus (Hook.) Nutt.	Douglas rabbitbrush, Little rabbitbrush

1/ Sources of scientific names are Harrington (1954), Coulter and Nelson (1909), Range Plant Handbook (1937). Source of common names is American Joint Committee on Horticultural Nomenclature (1942).

2/ Asterisk denotes composites or mustards included in averaged utilization estimates (Table 11).

Shrubs and Half-Shrubs (continued)

Scientific Name	Common Name
Ephedra spp L.	Jointfir
Eurotia lanata (Pursh)	Common winterfat
Gutierrezia sarothrae (Pursh) Britt. & Rusby	Broom snakeweed
Leptodactylon pungens (Torr.) Rydb.	Gilia
Pachystima myrsinites (Pursh) Raf.	Mountain lover
Prunus virginiana L.	Common chokecherry
Purshia tridentata (Pursh) DC.	Antelope bitterbrush
Quercus gambelii Nutt.	Gambel oak
Rhus trilobata Nutt. ex T.& G.	Skunkbush
Ribes spp. L.	Currant
Rosa spp. L.	Rose
Sarcobatus vermiculatus (Hook.) Torr. in Emory's	Greasewood
Symphoricarpos tetonensis A. Nels.	Snowberry
Tetradymia canescens DC.	Gray horsebrush

Forbs

Achillea lanulosa Nutt.	Western yarrow
Agoseris glauca (Pursh) D. Dietr.*	Pale agoseris
Allium spp. L.	Onion
Amaranthus spp. L.	Amaranth
Androsace septentrionalis	Rockjasmine
Antennaria dimorpha (Nutt.) T. & G.*	Low pussytoes
Arabis spp. L.*	Rockcress
Artemisia wrighti A. Gray *	Wrights sagebrush

Forbs (continued)

Scientific Name	Common Name
Asclepias spp. L.	Milkweed
Aster adscendens Lindl. in DC.	Aster
Aster leucanthemifolius Greene *	Daisyleaf aster
Aster spp. L. *	Aster
Astragalus chamaeleuce Gray in Ives	Loco
Astragalus diversifolius A. Gray	Timber poisonvetch
Balsamorhiza sagittata (Pursh) Nutt. *	Arrowleaf balsamroot
Brickellia grandiflora (Hook.) Nutt. *	Tasselflower brickellia
Calochortus gunnisoni Watson	Gunnison mariposa
Capsella bursa-pastoris (L.) Medic.	Shepherdspurse
Castilleja chromosa A. Nels.	Paintedcup
Chaenactis douglasii (Hook.) H. & A.	Douglas chaenactis
Chenopodium album L.	Lambsquarters goosefoot
Chorispora tenella DC.	Purple mustard
Chrysopsis villosa (Pursh) Nutt. ex DC. *	Hairy gold aster
Cirsium spp. Hill *	Thistle
Clematis hirsutissima Pursh	Douglas clematis
Cleome serrulata Pursh	Bee spiderflower
Corydalis aurea Willd.	Golden corydalis
Crepis spp. L.	Hawksbeard
Cryptantha spp. L.	Cryptantha
Delphinium nelsoni Greene	Menzies larkspur
Descurainia pinnata (Walt.) Britt. *	Pinnate tansymustard
Erigeron pulcherrimus Heller *	Fleabane
Erigeron spp. L. *	Fleabane

Forbs (continued)

Scientific Name	Common Name
Eriogonum alatum Torr. in Sitgreaves	Wing eriogonum
Eriogonum tristichum Small	Eriogonum
Eriogonum umbellatum Torr.	Sulfur eriogonum
Erysimum asperum (Nutt.) DC.*	Plains erysimum, Wallflower
Euphorbia robusta (Engelm.) Small in Britt. & Brown	Robust euphorbia
Galium boreale L.	Northern bedstraw
Geranium caespitosum Torr. ex Gray, Pl. Fendl. 26.	Geranium
Gilia aggregata var. *formosissima* (Greene) Wherry	Skyrocket gilia
Haplopappus acaulis (Nutt.) Gray*	Stemless goldenweed
Hedeoma drummondi Benth.	Drummond falsepennyroyal
Hedysarum pabulare A. Nels.	Northern sweet vetch
Helianthus spp. L.	Sunflower
Heuchera parvifolia Nutt. ex. T. & G.	Mesa pepperweed
Hymenoxys acaulis (Purch) Parker	Stemless actinea
Kuhnia chlorelepsis Woot. & Standl.	False boneset
Lactuca pulchella (Purch) DC.	Chicory lettuce
Lappula redowskii (Hornem.) Greene	Stickseed
Lepidium montanum Nutt.; T. & G.*	Mesa pepperweed
Lesquerella spp. Watson*	Bladderpod
Leucelene ericoides (Torr.) Greene*	Heath aster
Linum lewisii Pursh	Lewis flax
Lithospermum ruderale Dougl. in Lehm.	Wayside gromwell
Lupinus greenei A. Nels.	Tailcup lupine
Medicago sativa L.	Alfalfa

Forbs (continued)

Scientific Name	Common Name
Melilotus officinalis (L.) Lam.	Yellow sweetclover
Mertensia spp. Roth.	Bluebells
Oenothera serrulata Nutt.	Eveningprimrose
Oenothera caespitosa var. *montana* (Nutt.) Durand	Tufted eveningprimrose
Opuntia spp. Mill.	Pricklypear
Oxytropis lambertii Pursh	Lamberts crazyweed
Penstemon caespitosa Nutt. ex. A. Gray	Mat penstemon
Penstemon fremontii T.& G. A. Gray	Fremont penstemon
Phacelia sericea (Graham) A. Gray	Silky phacelia
Phlox caespitosa Nutt.	Tufted phlox, Low phlox
Phlox longifolia Nutt.	Longleaf phlox
Physaria australis (Payson) Rollins	Common twinpod
Polanisia trachysperma T.& G.	Roughseed clammyweed
Salsola kali (L.) var. *tenuifolia* Tausch	Tumbling Russianthistle
Senecio multilobatus T.& G. ex. Gray *	Lobeleaf groundsel
Senecio sp. L. *	Groundsel
Senecio mutabilis Greene *	Groundsel
Sideranthus spp. Fraser *	Aplopappus, gumweed
Schoenocrambe linifolia (Nutt.) Greene *	Flaxleaf plainsmustard
Sisymbrium altissimum L. *	Tumblemustard
Sisymbrium officinalis (L.) Scop.	Tumblemustard
Solidago spp. L.	Goldenrod
Sphaeralcea coccinia (Pursh) Rydb.	Scarlet globemallow
Stephanomeria tenuifolia (Torr.) Hall *	Wirelettuce
Taraxacum officinale Wiggars *	Common dandelion

Forbs (continued)

Scientific Name	Common Name
Tragopogon porrifolius L. *	Vegetable-oyster salsify
Tragopogon pratensis L. *	Meadow salsify
Urtica dioica L.	Bigsting nettle

Grasses and Sedges

Agropyron albicans Scribn. & Smith	Montana wheatgrass
Agropyron inerme (Scribn. & Smith) Rydb.	Beardless bluebunch wheatgras
Agropyron smithii Rydb.	Bluestem wheatgrass, Western wheatgrass
Bouteloua gracilis (H.B.K.) Lag.	Blue grama
Bromus anamolus Rupr. ex. Fourn.	Nodding brome
Bromus inermis Leyss.	Smooth brome
Bromus tectorum L.	Cheatgrass brome
Carex nebraskensis Dewey	Nebraska sedge
Carex eleocharis L. H. Bailey	Needleleaf sedge
Elymus condensatus Presl.	Giant wildrye
Hilaria belangeri (Steud.) Nash	Curlymesquite
Hilaria jamesii (Torr.) Benth.	Galleta
Koeleria cristata (L.) Pers.	Prairie junegrass
Oryzopsis hymenoides (R.& S.) Ricker	Indian ricegrass
Oryzopsis micrantha (Trin. & Rupr.) Thurb.	Littleseed ricegrass
Poa canbyi (Scribn.) Piper	Canby bluegrass
Poa pratensis L.	Kentucky bluegrass
Poa secunda Presl.	Sandberg bluegrass
Sitanion hystrix (Nutt.) J. G. Smith	Bottlebrush squirreltail
Stipa comata Trin. & Rupr.	Needleandthread

CLIMATIC ZONE PLANTING GUIDE

for: CRITICAL AREAS ERODING AREAS

SPECIAL PROBLEMS BEAUTIFICATION

INDUSTRIAL SITES

In cooperation with White-Yampa Association of Soil Conservation Districts Rangely College and U.S. Soil Conservation Service

RIO BLANCO COUNTY

USDA SOIL CONSERVATION SERVICE
PLANTING GUIDE FOR
CRITICAL AREAS-ERODING AREAS-SPECIAL PROBLEMS-BEAUTIFICATION-INDUSTRIAL SITES-ETC.

INTRODUCTION:

I. Objective: This Guide (including climatic map) is to furnish planting information for sites that may not be planted by ordinary methods. This material is designed for plans which encompass a field, a highway, an industrial site, a county or multi-county situation that have unusual planting conditions.

II. Conditions: Plantings may be on best soils with minimum difficulty, but low precipitation, alkalinity, rock, etc., create problems.

1. Soil: Many variations of soil types are encountered in these planting sites. These may include undeveloped mineral soils (which can occur where there are deep cuts) or exposed shale, gypsum, clay, gravel, stony or cobbly soils. Each factor must be considered before planting plans are made.

2. Slope: When cut or fill slopes are steeper than 1:1 or contain more than 50% stones or rock by volume, or consist of shale, plants will not generally establish adequate cover for protection of the slope.

3. Moisture: Moisture availability for plant growth is affected by:

   a. Elevation, which influences annual precipitation.

   b. Increased evaporation of South slopes, which may cause droughty soils, where as, North slopes, valleys, ditches may cause a very moist situation.

   c. Runoff due to steepness of slope or texture of the soil. For example: Sandy, gravelly, or rough soils may be more permeable and thus make moisture available for plant growth more than the heavy clay or shale soils.

   d. Removal and deposition of snow by wind.

III. Establishment of Vegetation:

1. Equipment: Adequate equipment must be provided to efficiently perform the work. Grass seeding equipment with depth bands, double disc openers, and individual disc suspension are advisable. Use of drill to place the seed at a controlled depth ($\frac{1}{2}$ to 1 inch) in a packed furrow (no more than 10-spacing) is better than broadcasting. If a drill cannot be used (because of slope, rock, etc.), the seed can be broadcast and should be covered by use of a harrow, hydro mulcher, or other special equipment.

2. Seedbed Preparation and Seeding: A firm, relatively clean seedbed is advisable. All seeding operations should be done across slope. Seeding should be directly into the ground cover where present. If mixtures are used, the seed should be uniformly seeded.

3. Seeding time: Late fall is the best seeding time—late enough to prevent germination before winter weather. Spring seedings, if made at all, should be made before April 1st. On irrigated areas, plant anytime.

4. Fertilizer: Lack of soil fertility is a deterent to establishing successful seedings. Even under severely limiting rainfall regimes, 30 to 40 pounds of available nitrogen and 50 pounds available phosphorus should be considered the starting point for grasses. Plan a fertilization program the third growing season following establishment using soil or leaf test for accurate needs.

5. Avoid the use of companion crops for seedings: Elimination of competition is the key to successfully establishing a seeding. Don't plant annuals which use up moisture and fertilizer.

6. Mulching materials for critical area stablization: Almost all recommendations for mulching seedings of critical areas, such as right-of-ways, dams, borrow pits, etc., the following may be used as standards:

   a. Vegetative mulch applied mechanically: Fine-stemmed grasses are superior to grain straws, sorghum or corn stover. The best application rates on slopes of 3:1 or flatter is 4000 to 5000 lbs. of grass hay per acre. This rate applies only when the mulch is anchored with an anchoring disk. About 1/4 to 1/3 of the mulch will be incorporated into the soil depending whether one or two passes of the anchoring disk is used and on looseness of the prepared seedbed. A well prepared seedbed with 4 inches of depth requires only one pass with an anchoring disk with 9½" spacing between disks. Mulch cannot be adequately anchored on poorly prepared or rocky seedbeds. Few contractors will over-mulch an area because of the cost involved. Cost of hay to the contractor delivered at the site may be around $40/ton.

   b. Good grain straw with little grain left in it can be utilized for mulching. It is of lesser value than grass hay because of the hollow brittle stems. Mulch rates should be 5000 or 6000 lbs. per acre to get adequate soil protection.

   c. For areas with rocks, slopes in excess of 3:1 or other conditions where seedbed preparation with tractor equipment and achoring disk is not practical, the areas can be hand seeded, fertilized and the mulch applied with asphalt to anchor it to the soil. The recommended rates should be a minimum of 3000 lbs. per acre of grass hay or

6. c. grain straw. This lesser rate is necessary when the mulch is not incorporated into the soil, because amounts in excess of 3000 lbs. on the surface tend to smother seedlings.

d. Research work indicates that rapid-cure (RC) cutback asphalt works best for anchoring mulches. This formulation requires a mulch blower with a heater unit, pump and nozzles for applying a continuous stream of asphalt to the mulch as it is applied to the soil. Disadvantages of RC cutback asphalt is that it can be corrosive to equipment (pH-4.5-5.0) and can be difficult to pump if not heated sufficiently. Whether the formulation is cationic or anionic probably has little bearing on its use to tack the mulch. Recommended rates are 300 to 500 gallons per acre (3000 lbs. hay mulch) for concentrated RC cutback asphalt. The 500 gallons rate is best for anchoring grain straw.

e. Where the critical erosion force is water and wind velocities are not excessive, road grade asphalt can be used to anchor mulch. It does not give as good bonding with the soil as RC asphalt and the mulch will roll up when subject to high winds. Use 500 gallons per acre of 1:1 water to asphalt emulsion. Increasing the water to asphalt ration to 2:1 or more requires heating for smooth pumping and weakens the bonding strength. 500 gallons per acre appears to be the minimum needed to anchor 3000 lbs. of vegetative mulch.

Under most conditions, differences in cost between the asphalts will not be great.

f. Areas in which water flows are concentrated, such as median and ditch bottoms, require additional protection not afforded by hay or straw mulch alone.

Jute fibre mesh applied to the ditch sides and bottom after mulching with hay will afford good protection but is rather expensive. It has little value for erosion control or protection for seedlings when used alone.

g. Good success has been with an excelsior erosion control blanket. In construction, it is similar to cooler pads for evaporative type air conditioners. Generally, it comes in rolls of 3' X 150' and 4' X 180. It provides about .8 lbs./sq. ft. of excelsior mulch, or approximately 3,500 lbs. of mulch per acre. It provides good ditch side and bottom protection and does a good job of mulching slopes steeper than 3:1. Contract costs have been 50 to 70¢/sq. yd. installed. Excellent stands of grass have been established by using this material.

h. Baled excelsior can be used as a substitute for grass hay. It is an excellent mulch, but cannot be applied uniformly in the long fibre length needed for anchoring with present machinery. When techniques are developed to allow rapid, uniform application, this mulch could be

6. h. a superior material. The short fibre excelsior (6 inches or shorter) could be utilized when anchored with asphalt.

i. Hydroseeding using woodfibre mulches can be used in areas where summer rains are gently and humidity high. Certainly it would merit use when seed has been drilled into the soil prior to mulching. Under arid contitions and torrential summer rainstorms, seeds germinate poorly or not at all, when applied to the surface with the mulch. Soil losses have been extreme due to heavy run off which washed away the mulch.

j. Slow curing asphalt applied directly to the soil has applications under certain conditions. Undiluted slow cure cutback asphalt applied at the rate of 1/4 gallon per square yard will stablilize most soil effectively. The following items should be considered in using this asphalt:

1. The asphalt forms a thin impercious film over the soil surface. Soil must be moist enough to germinate seed when the seed is placed in the gound. Runoff will be increased and infiltration will be inhibited until the film is broken by frost or growing plants.

2. Seed must not come into contact with the asphalt. Rates up to 1200 gallons per acre applied after seeding will not inhibit germination, but in excess of 1200 gallons restrict emergence.

3. The treatment lasts longer on sandy soils than on finer textured soils due to plasticity of finer soils and subsequent cracking of the asphalt film.

4. Soil temperatures are increased by application of asphalt. This can be beneficial in extending the growing season in spring or fall. However, it can lead to lethal temperatures during the hot summer months if plants are not readily growing.

5. This mulch is best adapted for unstable sandy areas, but the cost of materials and application may exceed that for other mulch treatments.

k. A relative new method of seeding is with a chemical adhesive mulch which forms a plastic film that allows air and water to penetrate. The material may be sprayed over an area already seeded or mixed with seed, fertilizer, water and chemical and applied as a slurry - similar to hydroseeding, using woodfibre.

Use of this material has not been widespread in this area, so any use should be under the direction of the company selling the product. This material and method appears to have good possibilities.

Other Considerations For Mulching:

The wetness or dryness of the site will influence the choice of plant and seed materials. Also, the time of seeding may have to be other than in the growing season so that the soils can be tilled on the more moist sites.

Always consider plants which are drought tolerant and least selective to fit the site. Make sure that seeds or plants are available before recommending their use.

Increase fertilizer recommendations by 25 percent when using vegetative mulches. Recommend formulations with high analysis per bulk pound when working on soils with pH above 7.0. Use of large amounts of low analysis fertilizer that are chemically basic, adds to the total salts. Use Urea or special treated nitrogen when possible to get a slow release through the growing season. Recommend field check for fertilizing after the second growing season.

Consider competition, mowing needs and safety when recommending sweet-clover or other tall growing plants.

These are a few ideas which may help. An excellent publication for ideas is "Mulches for Wind and Water Control, "USDA, ARS 41-84, W. S. Chepil, et al. 23 pp. U. S. Gvt. Printing Office, Washington, D.C.

IV. Special Conditions applicable to Rio Blanco County:

1. Bare rooted trees and shrubs (nursery stock) should be planted early in spring, before natives leaf out. Potted stock may be planted spring or fall.

2. Evergreen species should be potted (not bare rooted) for best survival rates.

3. Watering trees and shrubs the first year is advised unless site receives run-on water.

4. The zones indicated will include microclimates due to changes in topography, exposure, topographic position, soils, etc. Judgement must be exercised in deciding on species to plant.

5. On seepy, alkaline sites, tall wheatgrass at 12# per acre is suggested.

6. A guide of this type, designed to cover such a broad scale will leave many problems unanswered. If there are special cases the problems can be worked out on the site. For more information, contact the Soil Conservation Service at Meeker, Colorado.

V. <u>Descriptions</u>: The map attached to this guide is divided into zones separated, primarily, on the basis of precipitation and temperature.

The species suitable for the growing conditions are indicated by an X in the column headed exposure. A large N after species name indicates native grass. Those not so designated are introduced grasses. This is done for grasses only. On the most difficult sites, twice the minimum rate of pure live seed should be planted. Sod formers will do a better job of erosion control on disturbed sites, but they also require more moisture than bunch-grasses.

Percentage of purity and germination are required by State law to be shown on a tag accompanying each lot of grass or legume seed. These percentages can be used to determine the Pure Live Seed in a batch. Purity x Germination x 100 = PLS. Mixtures of the Species can be used if there is a reason for them.

As an example:

(Western wheatgrass 1/2 of (7) = 3½ lbs.
(Indian ricegrass 1/2 of (8) = 4 lbs.

Total Mixture = 7½ lbs. per acre

The plants listed for the following zones are species that can be obtained from commercial concerns or easily gathered from material sources.

RIO BLANCO COUNTY

ZONE I (Drouthy - less than 12 inches) Warm

Elevation generally less than 5400'

Soils in this zone are light colored, low in organic matter and contain free salts. They are loamy, clayey or sandy in texture. Small areas of highly alkaline soils, rough gullied land, and swale soils are also present.

The following table is a list of plants adapted to conditions generally found in Zone I:

Species		Bunch Grass	Sod Former	Adapted Exposure			Seeding[1] Rate
				Moist	Ave.	Dry	
*Indian ricegrass Oryzopsis hymenoides	N	x		x	x	x	8
Alkali sacaton Sporobolus airoides	N		x	x	x		6
**Western wheatgrass Agropyron smithii	N		x	x	x		7
*Crested wheatgrass Agropyron cristatum		x		x	x	x	5
Bluebunch wheatgrass Agropyron spicatum	N	x		x	x		6
Siberian wheatgrass Agropyron sibiricum		x		x	x		5
*Russian wildrye Elymus junceus		x		x	x		7
Salina Wildrye Elymus salina	N		x	x	x	x	7
*Sand dropseed Sporobolus cryptandrus	N	x		x	x		1
Galleta Hilaria jamesi	N		x	x	x	x	5
*Yellow sweetclover Melilotus officinalis		(legume)		x			3

Species	Bunch Grass	Sod Former	Adapted Exposure Moist	Adapted Exposure Ave.	Adapted Exposure Dry	Seeding[1] Rate
Streambank wheatgrass N Agropyron riparium		x	x	-		6
Vetch Vicia americana	(legume)		x			60
Squawbush Rhus tilobata	(shrub)		x			
Winterfat Eurotia lanata	(shrub)		x	x		
Fourwing saltbush Atriplex canescens	(shrub)		x			
Rocky Mountain Juniper Juniperus scopulorum	(tree)		x			
Utah Juniper Juniperus utahensis	(tree)		x			
Pinyon pine Pinus edulis	(tree)		x			

1Seeding rate is expressed in pounds of pure live seed per acre.
*It is suggested these plants be given strong consideration when selecting mixtures.
**Western wheatgrass may be best for median strips, borrow ditches and other areas receiving extra moisture.

RIO BLANCO COUNTY

ZONE II (SemiDrouthy - 12-15 inches) Moderately Warm

Elevation approximately 5500' - 6200'

The major soils in this zone are deep. They also contain free salts in their profiles. The soils are variable in texture, being loamy, clayey, or sandy. They are generally low in organic matter. Small areas of deep, dark, loamy, fertile soils are present as well as small areas of rough gullied land, badlands, stone filled soils, rock-land, and wet soils.

Species		Bunch Grass	Sod Former	Adapted Exposure Moist	Ave.	Dry	Seeding Rate
Indian ricegrass Oryzopsis hemenoides	N	x		x	x	x	8
Bluebunch wheatgrass Agropyron spicatum	N	x		x	x	x	7
Streambank wheatgrass Agropyron riparium	N		x	x	x		7
*Western wheatgrass Agropyron smithii	N		x	x	x		7
Crested wheatgrass Agropyron desertorum		x		x	x	x	5
Siberian wheatgrass Agropyron sibiricum		x		x	x	x	5
*Crested wheatgrass (Fairway) Agropyron cristatum		x		x	x	x	5
Intermediate wheatgrass Agropyron intermedium			x	x			8
Pubescent wheatgrass Agropyron trichophorum			x	x	x		8
Russian wildrye Elymus junceus		x		x	x		7
Salina Wildrye Elymus salina	N		x	x	x	x	7
Yellow sweetclover Melilotus officinalis		(legume)		x	x	x	1 (C)

ZONE II - Rio Blanco Cont'd

Species	Bunch Grass	Sod Former	Adapted Exposure Moist	Ave.	Dry	Seeding Rate
**Sand dropseed Sporobolus cryptandrus N	x		x	x	x	1
Alkali sacaton Sporobolus airoides	x		x	x	x	1
Skunkbush Rhus trilobata	(shrub)		x			
Silver Buffaloberry Shepherdia argentea	(shrub)		x			
Pinyon pine Pinus edulis	(tree)		x	x		
Rocky Mountain Juniper Juniperus scopulorum	(tree)		x			
Utah Juniper Juniperus utahensis	(tree)			x	x	
Ponderosa pine Pinus ponderosa	(tree)		x			
Russian olive Elaeagnus augustifolia	(tree)		x	x		
Autumn Elaeagnus Elaeagnus umbellata	(shrub)		x	x		

*Consider for highway borrow ditch planting because of low to moderate height growth and limited palatability.
**On sandy soils.
(C)Mixture with grasses

RIO BLANCO COUNTY

ZONE III (Moderately moist - 15-20 inches) Moderately cold

Elevation approximately 6200' - 7200'

Nearly all soils in this zone are deep. About 70 percent of the zone consists of soils that have dark colored loam surface layers and loam or clay loam subsoils. Lime is generally at a depth of abuut 20-30 inches. Other important deep soils are those having thin loam or clay loam surface layers about 4 to 6 inches thick and clay loam or clay subsoils. These soils are formed from shale derived materials. Small areas of deep loamy soils having thin, dark, loam surface layers and loam or clay loam subsoils are also present.

Species	Bunch Grass	Sod Former	Adapted Exposure			Seeding Rate
			Moist	Ave.	Dry	
*Kentucky bluegrass Poa pratensis		x	x	x		3
Smooth brome (All adapted var.) Bromus inermis		x	x	x		8
Mountain Brome (All adapted var.) Bromus marginatus	x		x	x		8
Intermediate wheatgrass Agropyron intermedium		x	x	x	x	8
*Hard fescue Festuca ovina var. duriuscula	x		x	x	x	4
Pubescent wheatgrass Agropyron trichophorum		x	x	x	x	7
*Crested wheatgrass (All var.) Agropyron desertorum	x		x	x	x	5
*Western wheatgrass Agropyron smithii N		x	x	x	x	7
Orchard grass Dactylis glomerata	x		x			4
Bluebunch wheatgrass Agropyron spicatum N	x			x	x	7

ZONE III - Rio Blanco Cont'd

Species		Bunch Grass	Sod Former	Adapted Exposure Moist	Ave.	Dry	Seeding Rate
Beardless wheatgrass Agropyron inerme	N	x			x	x	7
Yellow sweetclover Melilotus officinalis		(legume)		x	x	x	1 (C)
Skunkbush Rhus trilobata		(shrub)		x	x	x	
Serviceberry Amelanchier alnifolia		(shrub)		x	x	x	
Pinyon pine Pinus edulis		(tree)			x	x	
Chokecherry Prunus		(shrub)		x	x		
Rocky Mountain Juniper Juniperus scopulorum		(tree)		x	x	x	
Native plum Prunus americana		(tree)		x	x		
***Ponderosa pine Pinus ponderosa		(tree)			x	x	
Douglas fir Pseudotsuga taxifolia		(tree)		x			
Russian olive Elaeagnus angustifolia		(tree)		x	x	x	
**Sand cherry		(shrub)		x	x	x	
**Bitterbrush Purshia tridentata		(shrub)		x	x	x	

*Consider for highway borrow ditch planting and other better moisture site, because of low to moderate height growth.
**On sandy soils.
***Limited to well-drained soils
(C)Mixture with grasses.

RIO BLANCO COUNTY

ZONE IV (Moist - 20 inches+) Cold

Elevation approximately 7200' - 8000'

The soils of this zone that are under evergreen trees have light colored loam or fine sandy loam surface and subsoil layers. They are generally about 20 to 36 inches deep over granitic, basaltic, shale or sandstone materials. Soils under grass are generally deep, very dark, fertile, loams with loam or clay loam subsoils. Some small areas of wet swale soils and very shallow, stony soils are included.

Species	Bunch Grass	Sod Former	Adapted Exposure Moist	Ave.	Dry	Seeding Rate
*Kentucky bluegrass Poa pratensis		x	x	x	x	3
Timothy Phleum pratense	x		x	x		4
Smooth brome (All adapted var.) Bromus inermis		x	x	x	x	8
Orchardgrass Dactylis glomerata	x		x	x	x	5
Intermediate wheatgrass Agropyron intermedium		x	x	x	x	8
Pubescent wheatgrass Agropyron trichophorum		x	x	x	x	7
*Crested wheatgrass (Fairway) Agropyron cristatum	x				x	5
Crested wheatgrass (All var.) Agropyron desertorum	x				x	5
Slender wheatgrass Agropyron trachycaulum N	x		x	x		5
Western wheatgrass Agropyron smithii N		x		x	x	7
Alsike clover Trifolium hybridum	(legume)		x	x		4

Species	Bunch Grass	Sod Former	Adapted Exposure Moist	Ave.	Dry	Seeding Rate
Yellow sweetclover Melilotus officinalis	(legume)		x	x	x	2 (C)
Boxleaf myrtle Pachystima myrsinites	(shrub)		x			
Redosier dogwood Cornus stolonifera	(shrub)		x			
Chokecherry Prunus	(shrub)		x	x		
Serviceberry Amelanchier alnifolia	(shrub)		x	x		
Rocky Mountain Juniper Juniperus scopulorum	(tree)				x	
Douglas fir Pseudotsuga taxifolia	(tree)		x	x		
Lodgepole pine Pinus contorta	(tree)			x		
Ponderosa pine Pinus ponderosa	(tree)			x	x	
Colorado blue spruce Picea pungens	(tree)		x			

*Consider for highway borrow ditch planting or better moisture sites because of low to moderate height growth.
(C)For mixture with grasses.

RIO BLANCO COUNTY

ZONE V (Drouthy - less than 12 inches) Moderately Warm

Elevation is approximatlly 5500'- 6200'

All soils in this group contain free salts. They are also low in organic matter. The textures are variable, being loamy, clayey, or sandy. Some areas of stone-filled soils are included. Small areas of rough gullied land, rockland and very shallow soils over sandstone or shale are scattered throughout the zone.

Species		Bunch Grass	Sod Former	Adapted Exposure Moist	Ave.	Dry	Seeding Rate
Indian ricegrass Oryzopsis hymenoides	N	x		x	x	x	8
*Western wheatgrass Agropyron smithii	N		x	x			8
Crested wheatgrass (Fairway) Agropyron cristatum		x		x	x	x	6
*Crested wheatgrass Agropyron desertorum		x		x	x	x	6
*Siberian wheatgrass Agropyron sibericum		x		x	x	x	6
Russian wildrye Elymus junceus		x		x	x		5
Salina wildrye Elymus salina	N		x	x	x		7
Yellow sweetclover Melilotus officinalis		(legume)		x	x		½ (C)
Pubescent wheatgrass Agropyron trichophorum			x	x			6
Bluebunch wheatgrass Agropyron spicatum	N	x		x	x		4
*Sand dropseed Sporobolus cryptandrus	N	x		x	x	x	1

Species		Bunch Grass	Sod Former	Adapted Exposure Moist	Ave.	Dry	Seeding Rate
Alkali sacaton Sporobolus airoides	N	x		x	x	x	1
*Streambank wheatgrass Agropyron riparium	N		x	x	x		6
Squawbush Rhus trilobata		(shrub)		x			
Silver buffaloberry Shepherdia argentea		(shrub)		x			
Winterfat Eurotia lanata		(shrub)		x	x	x	
Four-wing saltbush Atriplex canescens		(shrub)		x	x	x	
Rocky Mountain Juniper Juniperus scopulorum		(tree)		x			
Utah Juniper Juniperus utahensis		(tree)			x	x	
Pinyon pine Pinus edulis		(tree)		x	x	x	
Russian olive Elaeagnus angultifolia		(tree)		x			

*Consider for highway borrow ditch planting because of low to moderate height growth

(C)For mixture with grasses

RIO BLANCO COUNTY

ZONE VII (Semi-drouthy - 12-15 inches) Moderately Cold

Elevation is approximately 6200' - 7200'

Soils in this zone are mostly very shallow over sandstones and shales. Some large bodies of deep, dark, fertile soils with loam surface layers and loam or clay loam subsoils are present, however. Also present, are areas of badlands, deep clayey soils and deep salty soils.

Species		Bunch Grass	Sod Former	Adapted Exposure Moist	Ave.	Dry	Seeding Rate
Indian ricegrass Oryzopsis hymenoides	N	x		x	x	x	8
Bluebunch wheatgrass Agropyron spicatum	N	x		x	x	x	7
*Western wheatgrass Agropyron smithii	N		x	x	x	x	7
*Crested wheatgrass (All var.) Agropyron desertorum		x		x	x	x	5
*Siberian wheatgrass Agropyron sibericum		x		x	x	x	5
Intermediate wheatgrass Agropyron intermedium			x	x	x		8
Pubescent wheatgrass Agropyron trichophorum			x	x	x	x	8
*Streambank wheatgrass Agropyron riparium	N		x	x	x		8
Russian wildrye Elymus junceus		x		x	x	x	5
Salina wildrye Elymus salina	N		x	x	x	x	5
Yellow sweetclover Melilotus officinalis		(legume)		x	x	x	1 (C)
**Sand dropseed Sporobolus cryptandrus	N	x		x	x	x	1

ZONE VII - Rio Blanco Cont'd

Species	Bunch Grass	Sod Former	Adapted Exposure Moist	Ave.	Dry	Seeding Rate
Squawbush *Rhus trilobata*	(shrub)		x	x		
Pinyon pine *Pinus edulis*	(tree)			x	x	
Rocky Mountain Juniper *Juniperus scopulorum*	(tree)		x	x		
Utah Juniper *Juniperus utahensis*	(tree)			x	x	
Ponderosa pine *Pinus ponderosa*	(tree)		x	x		
Russian olive *Elaeagnus angustifolia*	(tree)		x	x	x	

*Consider for highway borrow ditch planting because of low to moderate height growth
**On sandy soils
(C)For misture with grasses

RIO BLANCO COUNTY

ZONE VIII (Moderately moist - 15-20 inches) - Cold

Elevation is approximately 7200' - 8000'

The dominant soils in this zone are mostly deep, well drained, very dark colored, and fertile. They have thick loam surface layers and loam or clay loam subsoils. The next most important kind of soils are those that have clay loam surface layers and clay loam or clay subsoils. These are deep soils forming in shale materials. There is an extensive area of shaley soils on Cathedral Bluffs. Many small areas of very shallow soils over stone or deeper stone-filled soils are present in this zone.

Species	Bunch Grass	Sod Former	Adapted Exposure			Seeding Rate
			Moist	Ave.	Dry	
Timothy Phleum pratense	x		x	x		4
*Kentucky bluegrass Poa pratensis		x	x	x		3
Smooth brome (All adapted var.) Bromus inermis		x	x	x		8
Big bluegrass Poa ampla N	x		x	x		2
Orchardgrass Dactylis glomerata	x		x			4
Intermediate wheatgrass Agropyron intermedium		x	x	x	x	8
*Hard fescue Festuca ovina var. duriuscula	x		x	x	x	4
Pubescent wheatgrass Agropyron trichophurum		x	x	x	x	7
*Sodar streambank wheatgrass Agropyron riparium		x	x	x	x	7
*Crested wheatgrass (All var.) Agropyron desertorum	x		x	x	x	5

Species		Bunch Grass	Sod Former	Adapted Exposure Moist	Ave.	Dry	Seeding Rate
*Western wheatgrass Agropyron smithii	N		x		x	x	7
Mountain Brome (All adapted var.) Bromus marginatus	N	x		x	x		8
Bluebunch wheatgrass Agropyron spicatum	N	x			x	x	7
Beardless bluebunch wheatgrass Agropyron inerme		x			x	x	7
Yellow sweetclover Melilotus officinalis		(legume)		x	x	x	1 (C)
Serviceberry Amelanchier alinfolia		(shrub)		x	x	x	
Chokecherry Prunus		(shrub)		x			
**Bitterbrush Purshia tridentata		(shrub)		x	x	x	
Rocky Mountain juniper Juniperus scopulorum		(tree)		x	x	x	
**Sandcherry Prunus besseyi		(shrub)		x	x	x	
Caragana		(shrub)		x	x		
Spruce (Engleman or Colo. Blue) Picea englemani or pungens							
Douglas fir Pseudotsuga taxifolia		(tree)		x			
Ponderosa Pine Pinus ponderosa		(tree)		x	x		
Pinyon pine Pinus edulis		(tree)			x	x	

*Consider for highway borrow ditch planting because of low to moderate height growth.
**On sandy soils
(C)For mixture with grasses

RIO BLANCO COUNTY

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ZONE I DROUTHY, PPT. <12", WARM, ELEVATION APPROXIMATELY 5400'
ZONE V DROUTHY, PPT. <12", MODERATELY WARM, ELEVATION APPROXIMATELY 5400' to 6400'

ZONE II SEMI-DROUTHY, PPT. 12 to 15", MOD. WARM, ELEVATION APPROX. 5400 to 6400'
ZONE VII SEMI-DROUTHY, PPT. 12 to 15", MOD. COLD, ELEVATION APPROX. 6400 to 8000'

ZONE III MOD. MOIST, PPT. 15 to 20", MODERATELY COLD, ELEVATION APPROX. 6400 to 8000'
ZONE VIII MOD. MOIST, PPT. 15 to 20", COLD, ELEVATION APPROXIMATELY >8000'

ZONE IV MOIST, PPT. >20", COLD, ELEVATION APPROXIMATELY >8000'

SCALE - 1/8 inch = 1 mile

OTHER MAMMALIAN SPECIES 1/ - WILDLIFE MANAGEMENT UNIT 22

Furbearers 2/

Beaver (Castor canadensis)
Muskrat (Ondatra zibethicus)
Ringtail (Bassariscus astutus)
Weasels (Mustela erminea; M. frenata)
Mink (Mustela vison)

Nongame mammals 2/

White-tailed jack rabbit (Lepus townsendii)
Black-tailed jack rabbit (Lepus californicus)
Yellow-bellied marmot (Marmota flaviventris)
White-tailed prairie dog (Cynomys leucurus)
Richardson's ground squirrel (Spermophilus richardsonii)
Thirteen-lined ground squirrel (Spermophilus tridecemlineatus)
Rock squirrel (Spermophilus variegatus)
Golden-mantled ground squirrel (Spermophilus lateralis)
White-tailed antelope squirrel (Ammospermophilus leucurus)
Least chipmunk (Eutamias minimus)
Colorado chipmunk (Eutamias quadrivittatus)
Uinta chipmunk (Eutamias umbrinus)
Coyote (Canis latrans)
Red fox (Vulpes fulva)
Kit (swift) fox (Vulpes velox)
Gray fox (Urocyon cinereoargenteus)
Raccoon (Procyon lotor)
American badger (Taxidea taxus)
Spotted skunk (Spilogale putorius)
Striped skunk (Mephitis mephitis)
Bobcat (wildcat) (Lynx rufus)

1/ These species, grouped separately as "Furbearers" and "Nongame mammals" and outside of "game" categories, follow Chapter 62, Colo. Rev. Statutes 1963 As Amended, in Colo. Game, Fish and Parks Div. Laws and Regulations Hdbk., 1970. (Art. 1, Item 3, Definitions, p. 327)

2/ Nomenclature according to Lechleitner, R. R. 1969. Wild mammals of Colorado. Pruett Publishing Co., Boulder, Colo. 254 pp.

OTHER AVIAN SPECIES [1] - WILDLIFE MANAGEMENT UNIT 22

Nongame birds [2]

Common loon (Gavia immer) Rare migrant.
Horned grebe (Podiceps auritus cornutus) Possible rare migrant.
Eared grebe (Podiceps caspicus californicus) Possible common migrant and occasional summer resident.
Western grebe (Aechmophorus occidentalis) Possible rare migrant.
Pied-billed grebe (Podilymbus podiceps podiceps) Uncommon migrant and rare summer resident.
Double-crested cormorant (Phalacrocorax auritus auritus) Possible rare migrant.
Great blue heron (Ardea herodias treganzai) Common summer resident 3/.
Snowy egret (Leucophoyx thula brewsteri) Possible uncommon summer resident.
Black-crowned night heron (Nycticorax nycticorax hoactli) Common summer resident.
Least bittern (Ixobrychus exilis exilis) Possible rare summer migrant.
American bittern (Botaurus lentiginosus) Rare summer migrant.
White-faced ibis (Plegadis chihi) Possible rare migrant.
Whistling swan (Olor columbianus) Uncommon migrant.
Sharp-tailed grouse (Pedioecetes phasianellus columbianus) Resident 3/, 4/.
Sandhill crane (Grus canadensis canadensis; G. c. tabida) Regular migrant.
Virginia rail (Rallus limicola limicola) Possible uncommon summer resident.
Sora (Porzana carolina) Possible uncommon summer resident.
Semipalmated plover (Charadrius semipalmatus) Possible rare migrant.
Killdeer (Charadrius vociferus vociferus) Common summer resident 3/and rare winter resident.
Mountain plover (Eupoda montana) Possible rare migrant.
Black-bellied plover (Squatarola squatarola) Possible uncommon migrant.

1/ These species, grouped separately as "Nongame birds" and "Raptores" and outside of "game" categories, follow Chapter 62, Colo. Rev. Statutes 1963 As Amended, in Colo. Game, Fish and Parks Div. Laws and Regulations Hdbk., 1970. (Art. 1, item 3, Definitions, p. 327).

2/ Nomenclature from Bailey, A. M., and N. J. Neidrach. 1967. Pictorial check-list of Colorado birds. Denver Mus. Nat. Hist. 168 pp. Information on occurrence, in employing term "possible", is adapted from foregoing reference and notes in Davis, W. A. 1969. Birds in western Colorado. Colo. Field Ornithologists. 61 pp. Where adjective "possible" is absent, actual sighting(s) have been reported verbally by anyone or more of Division personnel W. McKean, C. Reichert, G. Gore, S. Steinert, and R. Bartmann, or qualified by additional footnotes that follow.

3/ Sight records given in unpublished checklists of birds of the Little Hills Game Exp. Station by R. A. Ryder, I. R. Gabrielson, D. Charbonneau, C. White, and R. Lauridson, 1947 and 1948.

4/ Technically a game bird, but comparative rarity makes occurrence in Unit 22 questionable. Species is cited here to avoid its complete omission, since chances appear good enough for it to occur in the unit some time.

Nongame birds (continued)

Long-billed curlew (Numenius americanus americanus) Rare migrant.
Spotted sandpiper (Actitis macularia) Common summer resident.
Solitary sandpiper (Tringa solitaria cinnamomea) Common migrant and occasional summer resident 3/.
Willet (Catoptrophorus semipalmatus inornatus) Possible rare migrant.
Greater yellowlegs (Totanus melanoleucus) Possible common migrant.
Lesser yellowlegs (Totanus flavipes) Possible uncommon migrant.
Knot (Calidris canutus rufa) Possible rare migrant.
Pectoral sandpiper (Erolia melanotos) Possible rare migrant.
Baird's sandpiper (Erolia bairdii) Possible common migrant.
Least sandpiper (Erolia minutilla) Possible common migrant.
Long-billed dowitcher (Limnodromus scolopaceus) Possible uncommon migrant.
Stilt sandpiper (Micropalama himantopus) Possible rare migrant.
Semipalmated sandpiper (Ereunetes pusillus) Possible rare migrant.
Western sandpiper (Ereunetes mauri) Possible uncommon migrant.
Marbled godwit (Limosa fedoa) Possible rare spring migrant.
Sanderling (Crocethia alba) Possible rare migrant.
American avocet (Recurvirostra americana) Possible rare migrant.
Black-necked stilt (Himantopus mexicanus) Possible rare migrant.
Wilson's phalarope (Steganopus tricolor) Common migrant and uncommon summer resident.
Northern phalarope (Lobipes lobatus) Possible uncommon migrant.
Pomarine jaeger (Stercorarius pomarinus) Possible rare migrant.
Herring gull (Larus argentatus smithsonianus) Possible uncommon migrant.
California gull (Larus californicus) Possible rare migrant.
Ring-billed gull (Larus delawarensis) Possible uncommon migrant.
Franklin's gull (Larus pipixcan) Possible uncommon migrant.
Bonaparte's gull (Larus philadelphia) Possible rare migrant.
Sabine's gull (Xema sabini sabini) Possible rare migrant.
Forster's tern (Sterna forsteri) Possible rare migrant.
Common tern (Sterna hirundo hirundo) Rare migrant.
Least tern (Sterna albifrons athalassos) Possible rare migrant.
Black tern (Chlidonias niger surinamensis) Possible rare migrant.
Rock dove (Columba livia) Possible common resident.
White-winged dove (Zenaida asiatica mearnsi) Possible rare migrant.
Yellow-billed cuckoo (Coccyzus americanus americanus) Possible uncommon summer resident.
Poor-will (Phalaenoptilus nuttallii nuttallii) Common summer resident 5/.
Common nighthawk (Chordeiles minor hesperis; C. m. howelli) Common summer resident 3/.
White-throated swift (Aeronautes saxatalis sclateri) Common summer resident
Black-chinned hummingbird (Archilochus alexandri) Common summer resident.
Broad-tailed hummingbird (Selasphorus platycercus platycercus) Common summer resident 3/, 5/.
Rufous hummingbird (Selasphorus rufus) Possible common late summer migrant.
Calliope hummingbird (Stellula calliope) Possible rare migrant and summer resident.
Rivoli's hummingbird (Eugenes fulgens aureoviridis) Possible rare summer migrant.
Belted kingfisher (Megaceryle alcyon alcyon) Common resident.
Yellow-shafted flicker (Colaptes auratus luteus) Possible rare migrant.
Red-shafted flicker (Colaptes cafer collaris) Common resident 3/, 5/.

5/ Sight record given in unpublished checklist of birds of Naval Oil Shale Reserve, 1969-70, by L. M. Stephens.

Nongame birds (continued)

Lewis' woodpecker (Asyndesmus lewis) Possible common summer resident.
Yellow-bellied sapsucker (Sphyrapicus varius nuchalis) Common summer 3/, 5/ and occasional winter resident.
Williamson's sapsucker (Sphyrapicus thyroideus nataliae) Possible common summer resident.
Hairy woodpecker (Dendrocopos villosus monticola) Possible uncommon resident.
Downy woodpecker (Dendrocopos pubescens leucurus) Uncommon resident 5/.
Northern three-toed woodpecker (Picoides tridactylus dorsalis) Possible rare resident.
Eastern kingbird (Tyrannus tyrannus) Possible uncommon summer resident.
Western kindbird (Tyrannus verticalis) Common summer resident 3/.
Cassin's kingbird (Tyrannus vociferans vociferans) Possible uncommon summer resident.
Ash-throated flycatcher (Myiarchus cinerascens cinerascens) Common summer resident 3/.
Say's phoebe (Sayornis saya saya) Common summer 3/ and occasional winter resident.
Traill's flycatcher (Empidonax traillii) Possible uncommon summer resident.
Hammond's flycatcher (Empidonax hammondii) Possible migrant.
Dusky flycatcher (Empidonax oberholseri) Possible summer resident.
Gray flycatcher (Empidonax wrightii) Possible summer resident.
Western flycatcher (Empidonax difficilis hellmayri) Common summer resident 3/.
Western wood peewee (Contopus sordidulus veliei) Common summer resident 5/.
Olive-sided flycatcher (Nuttallornis borealis) Possible uncommon summer resident.
Horned lark (Eremophila alpestris leucolaema) Common resident 5/.
Violet-green swallow (Tachycineta thalassina lepida) Common summer resident 3/, 5/.
Tree swallow (Iridoprocne bicolor) Possible common migrant and uncommon summer resident.
Bank swallow (Riparia riparia riparia) Possible uncommon migrant and uncommon summer resident.
Rough-winged swallow (Stelgidopteryx ruficollis serripennis) Uncommon migrant and summer resident 3/.
Barn swallow (Hirundo rustica erythrogaster) Common migrant and summer resident 3/.
Cliff swallow (Petrochelidon pyrrhonota pyrrhonota) Common summer resident 3/, 5/.
Purple martin (Progne subis subis) Possible rare summer migrant.
Gray jay (Perisoreus canadensis capitalis) Possible uncommon resident.
Steller's jay (Cyanocitta stelleri macrolopha) Common resident 3/, 5/.
Scrub jay (Aphelocoma coerulescens woodhouseii) Common resident 3/, 6/.
Black-billed magpie (Pica pica hudsonia) Common resident 3/, 5/.
Common raven (Corvus corax sinuatus) Common resident 3/, 5/.
Common crow (Corvus brachyrhynchos brachyrhynchos) Uncommon resident.
Pinyon jay (Gymnorhinus cyanocephalus) Common summer resident 3/and possible uncommon winter resident.
Clark's nutcracker (Nucifraga columbiana) Common resident 3/, 5/
Black-capped chickadee (Parus atricapillus garrinus) Uncommon resident 5/.
Mountain chickadee (Parus gambeli gambeli) Common resident 3/, 5/.
Plain titmouse (Parus inornatus ridgwayi) Common resident 3/.
Common bushtit (Psaltriparus minimus plumbeus) Possible common resident.
White-brested nuthatch (Sitta carolinensis nelsoni) Uncommon resident 3/.

6/ Specimens collected and cited in checklists of the Little Hills Exp. Station.

Nongame birds (continued)

Red-breasted nuthatch (Sitta canadensis) Rare resident 3/, 5/, 6/.
Pygmy nuthatch (Sitta pygmaea melanotis) Possible uncommon resident.
Brown-creeper (Certhia familiaris montana) Possible uncommon resident and common migrant.
Dipper (Cinclus mexicanus unicolor) Common resident 5/.
House wren (Troglodytes aedon parkmanii) Common summer resident 3/, 5/.
Bewick's wren (Thryomanes bewickii eremophilus) Possible common summer resident and rare winter resident.
Long-billed marsh wren (Telmatodytes palustris plesius) Possible rare winter resident.
Canyon wren (Salpinctes mexicanus conspersus) Uncommon summer resident 3/.
Rock wren (Salpinctes obsoletus obsoletus) Common summer 3/ and possible rare winter resident.
Mockingbird (Mimus polyglottos leucopterus) Uncommon summer resident 3/.
Catbird (Dumetella carolinensis) Rare summer resident.
Sage thrasher (Oreoscoptes montanus) Common summer resident 3/, 6/.
Robin (Turdus migratorius propinquus) Common summer resident 3/, 5/.
Hermit thrush (Hylocichla guttata auduboni) Common summer resident 5/.
Swainson's thrush (Hylocichla ustulata almae) Possible common migrant.
Veery (Hylocichla fuscescens salicicola) Possible common migrant and uncommon summer resident.
Western bluebird (Sialia mexicana bairdi) Possible common migrant and uncommon summer resident 3/.
Mountain bluebird (Sialia currucoides) Common migrant and summer resident 3/, 5/ and occasional winter resident.
Townsend's solitaire (Myadestes townsendi townsendi) Uncommon resident 5/.
Blue-gray gnatcatcher (Polioptila caerulea amoenissima) Common summer resident 3/.
Golden-crowned kinglet (Regulus satrapa amoenus) Possible uncommon migrant and rare summer resident.
Ruby-crowned kinglet (Regulus calendula cineraceus) Possible common migrant.
Bohemian waxwing (Bombycilla garrulus pallidiceps) Possible irregular winter migrant.
Cedar waxwing (Bombycilla cedrorum) Possible uncommon and irregular resident.
Northern shrike (Lanius excubitor invictus) Possible common winter resident.
Loggerhead shrike (Lanius ludovicianus excubitorides) Uncommon summer 3/ and common winter resident.
Starling (Sturnus vulgaris vulgaris) Possible common resident.
Gray vireo (Vireo vicinior) Possible uncommon summer resident.
Solitary vireo (Vireo solitarius plumbeus) Possible common summer resident.
Red-eyed vireo (Vireo olivaceus) Rare summer resident 3/.
Warbling vireo (Vireo gilvus swainsonii) Possible common summer resident.
Tennessee warbler (Vermivora peregrina) Possible rare but regular migrant.
Orange-crowned warbler (Vermivora celata orestera) Possible uncommon migrant and summer resident.
Nashville warbler (Vermivora ruficapilla ridgwayi) Possible rare migrant.
Virginia's warbler (Vermivora virginiae) Possible common summer resident.
Yellow warbler (Dendroica petechia aestiva) Common summer resident 3/, 5/.
Myrtle warbler (Dendroica coronata coronata) Possible common migrant.

Nongame birds (continued)

Audubon's warbler (Dendroica auduboni memorabilis) Common summer resident 3/, 6/.
Black-throated gray warbler (Dendroica nigrescens) Common summer resident 3/.
Townsend's warbler (Dencroica townsendi) Possible uncommon fall migrant.
MacGillivray's warbler (Oporornis tolmiei monticola) Common migrant and uncommon summer resident 5/.
Yellowthroat (Geothlypis trichas occidentalis: G. t. campicola) Possible uncommon summer resident.
Yellow-breasted chat (Icteria virens auricollis) Possible common summer resident.
Wilson's warbler (Wilsonia pusilla pileolata) Possible common migrant.
American redstart (Setophaga ruticilla tricolora) Possible rare migrant.
House sparrow (Passer domesticus domesticus) Common resident 3/.
Bobolink (Dolichonyx oryzivorus) Possible rare summer migrant.
Western meadowlark (Sturnella neglecta neglecta) Common summer 3/ and uncommon winter resident.
Yellow-headed blackbird (Xanthocephalus xanthocephalus) Common summer resident
Red-winged blackbird (Agelaius phoeniceus fortis) Common resident 3/.
Bullock's oriole (Icterus bullockii bullockii) Common summer resident 3/.
Rusty blackbird (Euphagus carolinus carolinus) Possible rare winter migrant.
Brewer's blackbird (Euphagus cyanocephalus) Common resident 3/.
Brown-headed cowbird (Molothrus ater artemisiae) Common summer resident 3/.
Western tanager (Piranga ludoviciana) Possible common migrant and summer resident.
Scarlet tanager (Piranga olivacea) Possible rare summer migrant.
Black-headed grosbeak (Pheucticus melanocephalus melanocephalus) Common summer resident 5/.
Blue grosbeak (Guiraca caerulea interfusa) Possible uncommon summer resident.
Lazuli bunting (Passerina amoena) Uncommon summer resident 3/.
Evening grosbeak (Hesperiphona vespertina brooksi) Irregular resident.
Cassin's finch (Carpodacus cassinii) Possible common resident.
House finch (Carpodacus mexicanus frontalis) Common summer 3/, 5/ and possible uncommon winter resident.
Pine grosbeak (Pinicola enucleator montana) Possible uncommon resident.
Gray-crowned rosy finch (Leucosticte tephrocotis tephrocotis; L. t. littoralis) Possible common winter migrant.
Black rosy finch (Leucosticte atrata) Possible common winter migrant.
Brown-capped rosy finch (Leucosticte australis) Possible common winter migrant.
Common redpoll (Acanthis flammea flammea) Possible rare winter migrant.
Pine siskin (Spinus pinus pinus) Common resident 3/, 5/.
American goldfinch (Spinus tristis tristis; S. t. pallidus) Common summer 3/ and possible uncommon winter resident.
Lesser goldfinch (Spinus psaltria psaltria) Possible uncommon summer and rare winter resident.
Red crossbill (Loxia curvirostra) Possible rare resident.
White-winged crossbill (Loxia leucoptera leucoptera) Possible rare winter migrant.

Nongame birds (continued)

Green-tailed towhee (Chlorura chlorura) Common summer resident 3/, 5/, and possible rare winter resident.
Rufous-sided towhee (Pipilo erythrophthalmus montanus) Uncommon summer and rare winter resident.
Lark bunting (Calamospiza melanocorys) Uncommon summer resident.
Savannah sparrow (Passerculus sandwichensis nevadensis; P. s. anthinus) Possible uncommon migrant and summer resident.
Grasshopper sparrow (Ammodramus savannarum perpallidus) Uncommon summer resident 5/.
Vesper sparrow (Pooecetes gramineus confinis) Common migrant and summer resident 5/.
Lark sparrow (Chondestes grammacus strigatus) Possible common migrant and summer resident.
Black-throated sparrow (Amphispiza bilineata deserticola) Possible common summer resident.
Sage sparrow (Amphispiza belli nevadensis) Common summer resident 3/.
White-winged junco (Junco aikeni) Possible ra e winter migrant.
Slate-colored junco (Junco hyemalis hyemalis; J. h. cismontanus) Possible rare winter resident.
Oregon junco (Junco oreganus) Common winter resident.
Gray-headed junco (Junco caniceps caniceps) Common summer 5/ and winter resident.
Tree sparrow (Spizella arborea ochracea) Possible uncommon winter migrant.
Chipping sparrow (Spizella passerina boreophila) Common summer resident 3/.
Brewer's sparrow (Spizella breweri breweri) Common summer resident 3/, 6/.
Harris' sparrow (Zonotrichia querula) Possible rare winter resident.
White-crowned sparrow (Zonotrichia leucophrys) Common resident 3/, 5/.
Fox sparrow (Passerella iliaca schistacea) Rare summer resident 5/.
Lincoln's sparrow (Melospiza lincolnii alticola) Common migrant and summer resident 3/.
Song sparrow (Melospiza melodia) Common summer 3/ and possible uncommon winter resident.
Lapland longspur (Calcarius lapponicus alascensis) Possible rare winter migrant.
White-throated sparrow (Zonotrichia albicollis) Possible rare migrant.

Raptores 2/

Turkey vulture (Cathartes aura meridionalis) Common summer 3/, 5/ and rare winter resident.
Goshawk (Accipiter gentilis atricapillus) Rare resident.
Sharp-shinned hawk (Accipiter striatus velox) Possible rare summer and common winter resident.
Cooper's hawk (Accipiter cooperii) Uncommon summer 3/, 5/ and common winter resident.

Raptores (continued)

Red-tailed hawk (Buteo jamaicensis calurus) Common resident 3/, 5/.
Swainson's hawk (Buteo swainsoni) Uncommon summer 5/ and rare winter resident.
Rough-legged hawk (Buteo lagopus s. johannis) Rare summer 3/ and uncommon winter resident or migrant.
Ferruginous hawk (Buteo regalis) Rare summer and common winter resident.
Golden eagle (Aquila chrysaetos canadensis) Common resident 3/, 7/.
Bald eagle (Haliaeetus leucocephalus alascanus) Common winter resident 7/
Marsh hawk (Circus cyaneus hudsonius) Common summer 3/, 5/, and winter resident.
Osprey (Pandion haliaetus carolinensis) Possible rare migrant.
Prairie falcon (Falco mexicanus) Rare resident 3/.
Peregrine falcon (Falco peregrinus anatum) Possible rare migrant.
Pigeon hawk (Falco columbarius) Possible rare winter migrant.
Sparrow hawk (Falco sparverius sparverius) Common summer 3/, 5/ and uncommon winter resident.
Screech owl (Otus asio) Possible uncommon resident.
Flammulated owl (Otus flammeolus flammeolus) Possible rare summer resident.
Great horned owl (Bubo virginianus) Common resident 3/, 5/.
Pygmy owl (Glaucidium gnoma californicum) Possible rare resident.
Burrowing owl (Speotyto cunicularia hypugaea) Common summer 5/ and possible rare winter resident.
Long-eared owl (Asio otus wilsonianus) Uncommon resident 5/.
Short-eared owl (Asio flammeus flammeus) Possible uncommon winter migrant.
Saw-whet owl (Aegolius acadicus acadicus) Possible uncommon resident.

7/ Golden and bald eagle specifically excluded from statutes defining "Raptore" as cited in footnote 1/ but herein listed to avoid omission.

APPENDIX V-5

Scientific and common names of plant and animal species used in the text not otherwise referenced to a source list reproduced in the Appendix, i.e., to Appendix V-1, V-2, V-4.1/

Plants

Common Name	Scientific Name
Alfalfa	Medicago sativa
Aspen	Populus tremuloides
Asters	Aster spp.
Bitterbrush	Purshia tridentata
Bitterbrush, antelope	Purshia tridentata
Bluegrass, native	Poa spp.
Bluegrass, Kentucky	Poa pratensis
Bluegrass, Sandberg's	Poa secunda
Brome, Cheatgrass	Bromus tectorum
Bromegrass, smooth	Bromus inermis
Boxleaf, myrtle	Pachistima myrsinites
Cheatgrass	Bromus tectorum
Chokecherry,	Prunus virginiana
Chokecherry, black	Prunus virginiana
Columbine, Colorado	Aguilegia coerulea
Clovers	Trifolium spp.
Clover, alsike	Trifolium hybridum
Clover, red	Trifolium pratensis
Cottonwoods	Populus spp.
Cottonwood, narrowleaf	Populus angustifolia
Deathcamas	Zygadenus spp.
Deerbrush	Ceanothus spp.
Fir Douglas	Pseudotsuga menziesii
Foxglove	Penstemon spp.
Gilia, skyrocket	Gilia aggregata
Greasewood	Sarcobatus vermiculatus
Greasewood, black	Sarcobatus vermiculatus
Hollygrape, creeping	Berberis fremontii
Jointfir, green	Ephedra viridis
Junegrass	Koeleria cristata
Junipers	Juniperus spp.
Juniper, Rocky Mt.	Juniperus scopulorum
Juniper, Utah	Juniperus osteosperma
Larkspurs	Delphinium spp.
Lily, mariposa	Calochortus spp.
Lupines	Lupinus spp.
Mahogany, Mt.	Cercocarpus montanus
Manzanita	Arctostaphylos patula
Needlegrass	Stipa spp.
Oak, scrub	Quereus spp.
Oakbrush, gambel	Quercus gambelii

1/ Scientific names according to Harrington, H. D., 1954, Manual of the Plants of Colorado, Sage Books, Denver, 666 p., Common names as used in text from a variety of references.

Plants (continued)

Common Name	Scientific Name
Paintbrush	Castilleja spp.
Penstemons	Penstemon spp.
Pine, pinyon	Pinus edulis
Rabbitbrushes	Chrysothamnus spp.
Rabbitbrush, rubber	Chrysathamnus nauseosus
Rabbitbrush, lanceleaf	Chrysothamnus viscidiflorus
Redtop	Agrostis alba
Ricegrass, Indian	Oryzopsis hymenoides
Roses	Rosa spp.
Sagebrush	Artemisia spp.
Sagebrush, big	Artemisia tridentata
Sagebrush, black	Artemisia nova
Sage, herbaceous	Artemisia gnapholodes
Serviceberry	Amelanchier spp.
Shadscale	Atriplex confertifolia
Snowberry	Symphoricarpos spp.
Thistle, Russian	Salsola kali tenuifolia
Timothy	Phleum pratense
Wheatgrass, Amur	Agropyron amurense
Wheatgrass, beardless bluebunch	Agropyron inerme
Wheatgrass, bearded bluebunch	Agropyron spicatum
Wheatgrass, crested	Agropyron cristatum
Wheatgrass, desert	Agropyron desertorum
Wheatgrass, intermediate	Agropyron intermedium
Wheatgrass, pubescent	Agropyron trichophorum
Wheatgrass, Siberian	Agropyron sibiricum
Wheatgrass, thickspike	Agropyron dasystachyum
Wheatgrass, Western	Agropyron smithii
Wild-rye, basin	Elymus cinereus
Willows	Salix spp.
Winterfat	Eurotia lanata

Animals [1/]

Common Name	Scientific Name
Bobcat	Lynx rufus
Bear, black	Ursus americanus
Beaver	Castor canadensis
(Cat) Ringtail	Bassariscus astutus
Cattle	Bos taurus
Coyote	Canis latrans
Dace, speckled	Rhinichthys osculus
Deer, Rocky Mt. mule	Odocoileus hemionus
Dog, prairie	Cynomys spp.
Dove, mourning	Zenaidura macroura marginella
Elk	Cervus canadensis
Grouse, blue	Dendragapus obscurus obscurus
Grouse, sage	Centrocercus urophasianus urophasianus
Hare, snowshoe	Lepus americanus
Horse, wild	Equus caballus
Jackrabbit, white-tailed	Lepus townsendii
Lion, Mt.	Felis concolor
(Partridge) Chukar	Alectoris graeca
Pigeon, bandtailed	Columba fasciata fasciata
Rabbits, cottontail	Sylvilagus audubonii; S. nuttallii
Sheep	Ovis aries
Squirrel, pine	Tamiasciurus hudsonicus
Sucker, Mt.	Pantosteus platyrhynchus
Trout, rainbow	Salmo gairdneri

1/Scientific names of mammals according to Lechleitner, R. R., 1969, Wild mammals of Colorado, Pruett Publishing Co., Boulder, 254 p., Scientific names of birds according to Bailey, A. M., and R. J. Neidrach, 1967, Pictorial checklist of Colorado birds, Denver Mus. Nat. Hist., 168 pp.