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RED BUTTE CANYON RESEARCH NATURAL AREA: HISTORY, FLORA, GEOLOGY, CLIMATE, AND ECOLOGY

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ABSTRACT.—Red Butte Canyon is a protected, near pristine canyon entering Salt Lake Valley, Utah. It contains a well-developed riparian zone and a perennial stream; hillside vegetation ranges from grasslands on the lower limits to Douglas-fir and aspen stands at the upper elevations. In this paper we describe the history of human impact, natural history aspects of climate, geology, and ecology, and faunal and floral information for key species in the canyon. The role and importance of Research Natural Areas is discussed, particularly with respect to the need to protect Red Butte Canyon—one of the few remaining undisturbed riparian ecosystems in the Intermountain West.

Key words: grassland, Intermountain West, oak-maple, plant adaptation, Red Butte Canyon, Research Natural Area, riparian ecology.

Red Butte Canyon, one of many canyons in the Wasatch Range of Utah, opens westward into Salt Lake Valley, immediately east of the University of Utah (Fig. 1). Like most canyons along the Wasatch Front, it is a grassland at the lowest elevations, is forested at its upper end, and has a perennial stream. What makes this canyon unusual is its history. The canyon was the watershed for Fort Douglas, the U.S. Army post built in 1862 that overlooked Salt Lake City. As a protected watershed, these lands were, for the most part, kept free from grazing, farming, and other human-impact activities. When the U.S. Army declared these lands surplus in 1969, the U.S. Forest Service assumed responsibility for the canyon. Since that time, Red Butte Canyon has been kept in its protected state and designated a Research Natural Area (RNA).

The Research Natural Area designation denotes an area that has been set aside because it contains unusual or unique features of sub-

stantial value to society. These might include unique geological features, endangered plant and animal species, or areas of particular value for scientific research as baseline bench marks of ecosystems that have been largely destroyed by human impact. In the case of Red Butte Canyon, the RNA designation was given because this canyon is one of the few remaining (if not the last) undisturbed watersheds in the Great Basin. The U.S. Forest Service report proposing that Red Butte Canyon be declared a Research Natural Area described the canyon as "... a living museum and biological library of a size that exists nowhere else in the Great Basin ... an invaluable bench mark in ecological time." The Red Butte Canyon RNA is unique because it is a relatively undisturbed watershed adjacent to a major metropolitan area (Salt Lake Valley). To protect this valuable resource, access to the Red Butte Canyon RNA has been largely restricted to scientific investigators. One of the

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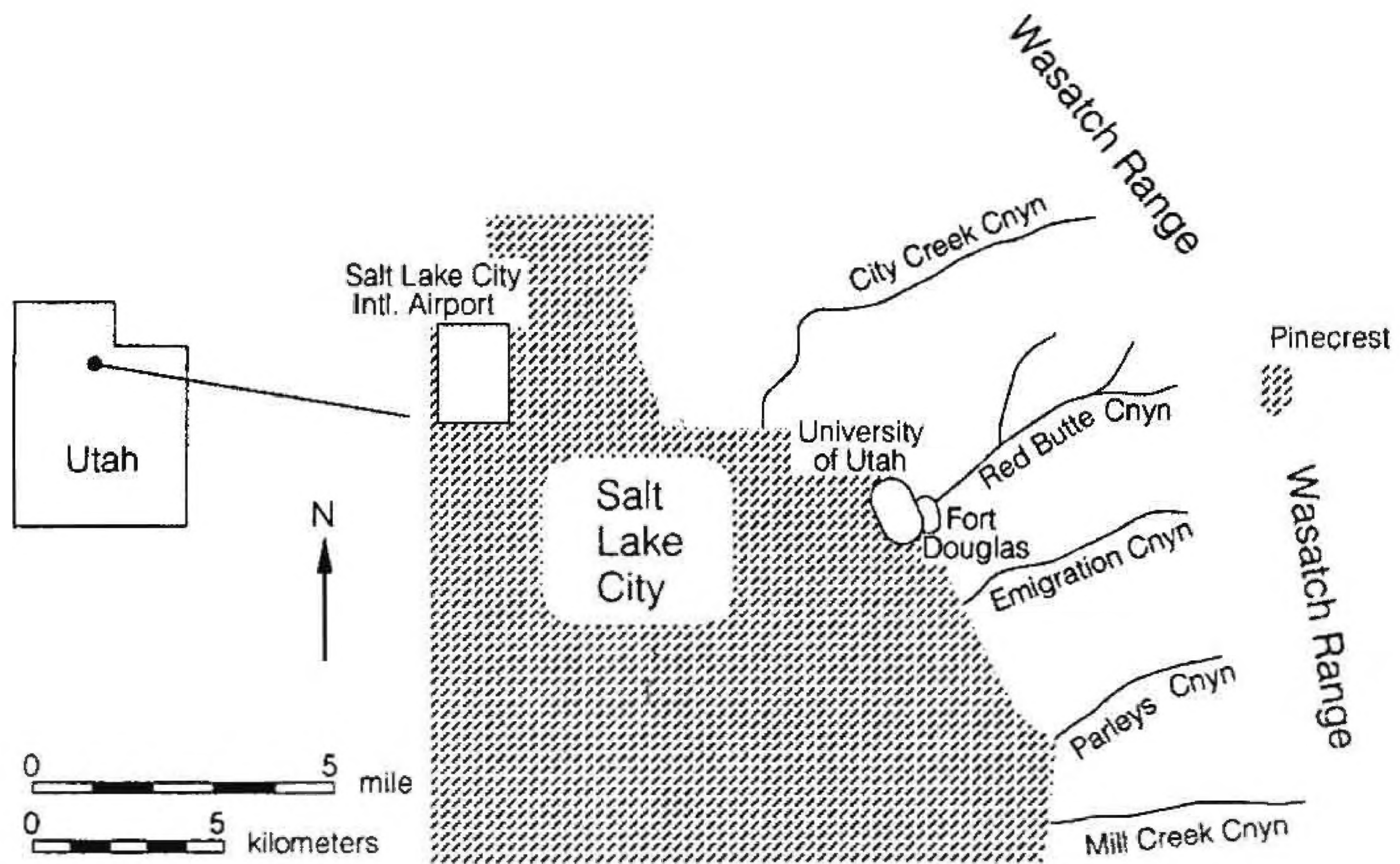


Fig. 1. Location of Red Butte Canyon and other sites referred to in text.

goals of the RNA Program is to protect and preserve a representative array of all significant natural ecosystems and their inherent processes as baseline areas. A second goal is to conduct research on ecological processes in these areas to learn more about the functioning of natural versus manipulated or disturbed ecosystems. Research activities in the Red Butte Canyon RNA are directed at both of these goals: understanding basic ecological processes (physiological adaptation, drought adaptation, nutrient cycling, etc.) and also the impact of humans on our canyons through both airborne (air pollution, acid rain, etc.) and land-related (grazing, human traffic, etc.) activities. The latter are conducted through comparison of Red Butte with other canyons along the Wasatch Range.

In size, Red Butte Canyon is relatively small compared with other drainages along the Wasatch Front. The drainage basin covers an area of approximately 20.8 km² (5140 acres) (Fig. 2). The drainage arises on the east from a minor divide between City Creek and Emigration canyons and drains to the west. The canyon has two main forks (Knowltons and Parleys) and many side canyons. Near the canyon base, a reservoir was constructed earlier this century to provide a more stable water supply to Fort Douglas. The diversity of slope and aspect combinations of the terrain contributes to a variety

of biotic communities along an elevation gradient from about 1530 m (5020 ft) on the west end to more than 2510 m (8235 ft) at the crest.

The purpose of this paper is to provide a brief description of the history, flora, geology, climate, and ecology of this unusual and valuable resource. There is increasing interest in Red Butte Canyon, in part by scientific investigators because of its utility as a protected, undisturbed watershed, and in part by curious citizens from the nearby Salt Lake Valley. Yet, there has not been an overall reference available for those interested in general features of the canyon or past ecological studies within the canyon. Most of the information on Red Butte Canyon is scattered. With the closure of Fort Douglas in 1991, many of the historical records will become more difficult to access. It is hoped that the synthesis presented in this paper will provide the necessary background for those interested in the history and ecology of the Red Butte Canyon RNA. Irving McNulty first summarizes the history of the canyon, followed by Ted Arnow's description of geology and soils. James Ehleringer contributed the hydrology, climate, and plant ecology sections. The section on vascular flora was prepared by Lois Arnow, and Norman Negus wrote the mammalian and avian fauna sections.

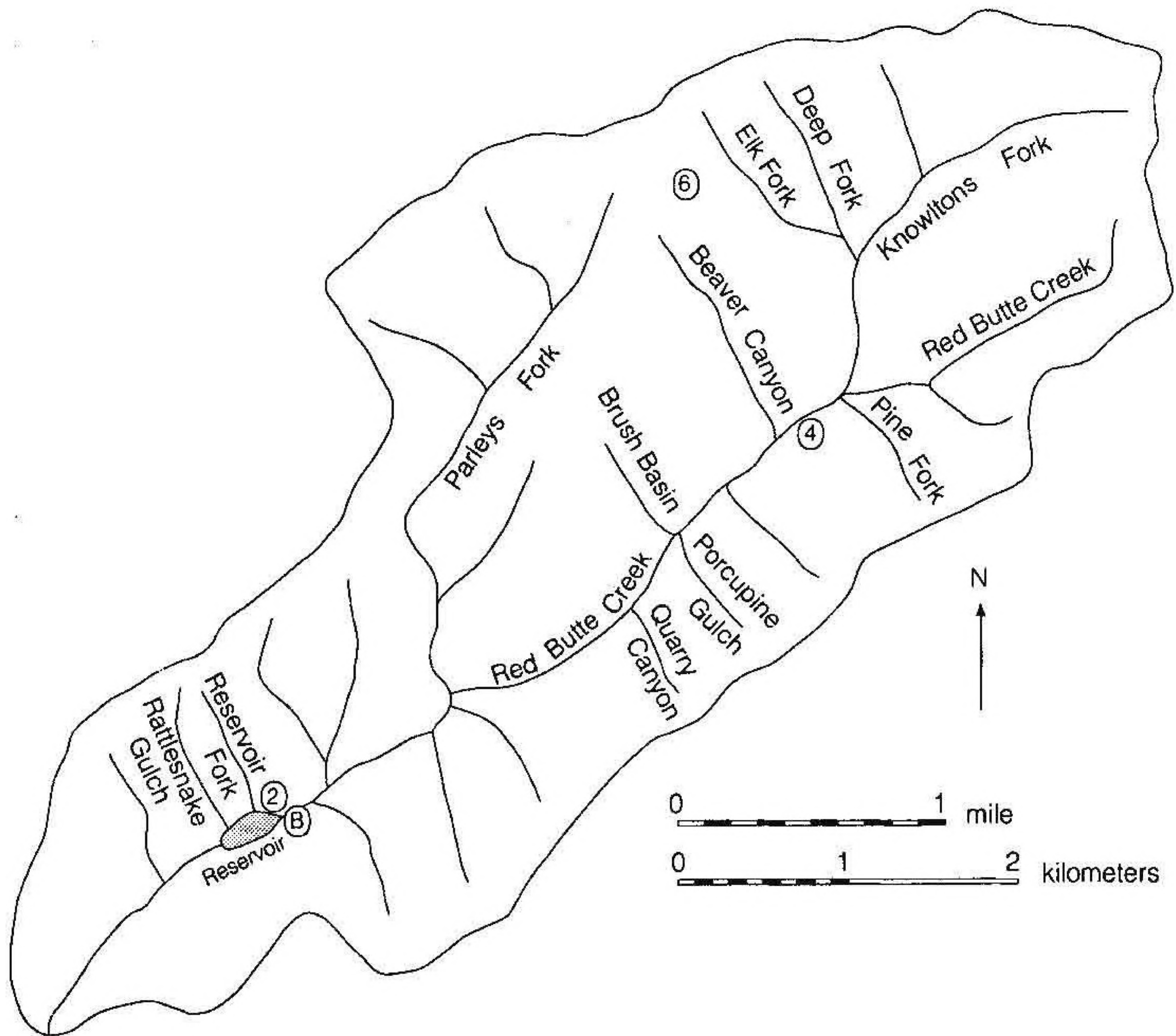


Fig. 2 Major drainages and weather and bench mark stations within the Red Butte Canyon Research Natural Area. B represents the location of the USGS Bench Mark station; circles numbers 2, 4, and 6 represent the locations of weather stations known as Red Butte #2, Red Butte #4, and Red Butte #6, respectively.

HISTORY

The history of Red Butte Canyon comes as bits and pieces from many sources, including Arrington and Alexander (1965), Hibbard (1980), and the Fort Douglas Army Engineers Office (1954), records of the Fort Douglas Museum, and discussions with C. G. Hibbard (Fort Douglas historian) and Harold Shore (Fort Douglas water master overseeing Red Butte Canyon). It is primarily a history of human impact on the utilization of natural resources provided by the canyon. Major resources were water from the stream and sandstone quarried for use in construction. Of minor importance were grazing and timber. In 1848, just one year after the arrival of the first pioneers in Salt Lake Valley, red sandstone was first quarried in the canyon

to be used in construction in the building of Salt Lake City. It was the closest source of construction-quality sandstone and was quarried for almost 100 years. This mining had considerable impact on the plant and animal life in the lower portion of the canyon. The major use of Red Butte Creek water was by the U.S. Army at Fort Douglas, which was established at the mouth of the canyon in 1862. This utilization of water outside the canyon had little effect on the canyon itself, as U.S. Army administrators worked over many years to protect the watershed and water quality. In fact, protection has grown steadily since Fort Douglas was first established, and particularly since the canyon was acquired by the U.S. Forest Service in 1969 and declared to be a Research Natural Area.

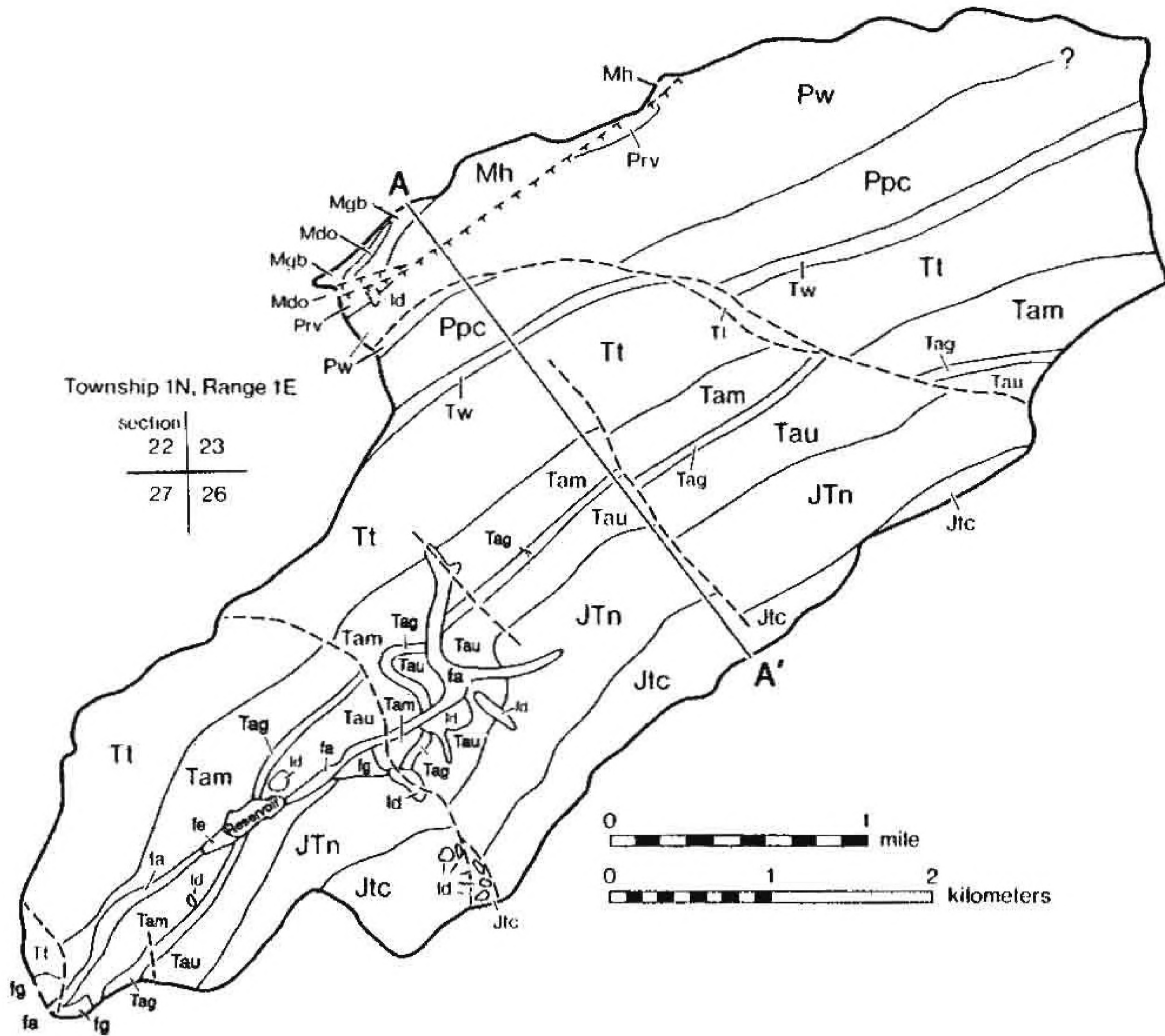


Fig. 3 Geologic map of Red Butte Canyon Research Natural Area. See Table 1 for a description of abbreviations. Solid lines represent contacts between formations, dashed lines represent normal faults, and T-dashed lines represent the Black Mountain thrust fault. The transect A-A' is shown in cross section in Figure 4. Adapted from Marsell and Threet (1960) and Van Horn and Crittenden (1987).

Red Butte sandstone (Nuggett Sandstone) was the first resource utilized from the canyon. Most sandstone was obtained from Quarry Canyon on the south side of the canyon, 4.4 km (2.9 mi) from the mouth of the canyon. Because of the proximity of Quarry Canyon to Salt Lake City, sandstone was quarried there from 1848 to the end of the century by private companies and intermittently by the Army until 1940. This required a road in the bottom of the canyon and housing for workers. In 1889, 66 men and 38 oxen and horses lived at the canyon bottom, contributing considerable downstream pollution to Red Butte Creek. In 1887 the U.S. Congress provided a railroad right-of-way to be built to the rock quarry to increase the amount of sandstone removed. Stream pollution caused by quarrying activity brought many complaints

from Fort Douglas and ultimately a court action in 1889, which required the Salt Lake Rock Company to control stream pollution and cease housing men and animals in the canyon.

Red Butte Creek was used for irrigation by a few pioneers east of Salt Lake City in the early 1850s. When Fort Douglas was established in 1862, Army personnel initially depended mostly on water from nearby springs. However, by 1875 Army personnel constructed two reservoirs east of Fort Douglas and diverted water from Red Butte Creek to fill them. In response to the recurrent stream pollution problems caused by quarrying activities, the Territory District Court, in 1890, declared that the waters of Red Butte Creek were the sole property of the U.S. Army and under the jurisdiction of Fort Douglas. Also in 1890, the U.S. Congress passed a law to

TABLE 1. Description of geological formations in Red Butte Canyon.

Cenozoic era, Quaternary system, Holocene series	
<i>fa Flood-plain alluvium.</i>	Sand, cobbly to silty, dark gray at top; grading downward to medium to light gray, sandy to cobbly gravel; locally bouldery.
<i>fe Engineered fill.</i>	Selected earth material that has been emplaced and compacted.
Cenozoic era, Quaternary and Tertiary systems, Holocene and Pleistocene series	
<i>fg Alluvial-fan deposits.</i>	Bouldery to clayey silt, dark gray to brown; rocks angular to subrounded.
<i>ld Landslide deposits.</i>	Composition similar to material upslope.
Mesozoic era, Jurassic system	
<i>Jtc Twin Creek Limestone.</i>	Brownish gray and pale gray to pale yellowish gray silty limestone, intercalated with greenish gray shale.
Mesozoic era, Jurassic? and Triassic? systems	
<i>JTn Nugget Sandstone.</i>	Pale pinkish buff, fine- to medium-grained, well-sorted sandstone that weathers orange-brown. Massive outcrops form the ridge called Red Butte.
Mesozoic era, Triassic system	
<i>Tau Ankareh Formation, upper member.</i>	Reddish brown, reddish purple, grayish red, or bright red shale, siltstone, and sandstone.
<i>Tag Ankareh Formation, Gartra Grit Member.</i>	White to pale purple, thick-bedded, crossbedded, pebbly quartzite. Forms a prominent white ledge for long distances.
<i>Tam Ankareh Formation, Mahogany Member.</i>	Reddish brown, reddish purple, grayish red, or bright red shale, siltstone, and sandstone.
<i>Tt Thaynes Formation.</i>	Medium to light gray, fossiliferous, locally nodular limestone, limy siltstone, and sandstone.
<i>Tw Woodside Shale.</i>	Grayish red, grayish purple, or bright red shale and siltstone.
Paleozoic era, Permian system	
<i>Ppc Park City Formation and related strata.</i>	Fossiliferous sandy limestone, calcareous sandstone, and a medial phosphatic shale tongue.
Paleozoic era, Pennsylvanian system	
<i>Pw Weber Quartzite.</i>	Pale tan to nearly white, fine- to medium-grained, crossbedded quartzite and medium gray to pale gray limestone.
<i>Prv Round Valley Limestone.</i>	Pale gray limestone with pale gray siltstone partings. Contains pale pinkish chert that forms irregular nodules.
Paleozoic era, Mississippian system	
<i>Mdo Doughnut Formation.</i>	Medium gray, thin-bedded limestone with pods of dark gray to black chert and abundant brachiopods and bryozoa.
<i>Mgb Great Blue Formation.</i>	Thick-bedded, locally cliff-forming, pale gray, fine-grained limestone.
<i>Mh Humbug Formation.</i>	Alternating, tan-weathering, limy sandstone and limestone or dolomite.
<i>Md Desert Limestone.</i>	Thick ledges of dolomite and limestone with moderately abundant lenses and pods of dark chert.
Paleozoic era	
<i>P Paleozoic rocks, undifferentiated.</i>	

protect the water supply of Fort Douglas. This law prevented any sale of land in the canyon or further watershed development. In 1906 the U.S. Army built a dam on Red Butte Creek to supply additional water for Fort Douglas. The present dam was constructed between 1928 and 1930, and the reservoir provided water for Fort Douglas until its closure in 1991.

There are no grazing records available for Red Butte Canyon prior to 1909, by which time the United States had acquired title to most of the land in the canyon. Cottam and Evans (1945) reported evidence of some gully erosion occurring in the canyon prior to 1909 and assumed it was due to overgrazing. Although we lack quantitative data, there are a few isolated incidents indicating the occurrence of grazing, including an 1854 report of a young man drowning in a flash flood in Red Butte Canyon while herding animals. Over forty head of oxen used to haul sandstone from the quarry in the late 1800s remained in the canyon during that time. In 1869 the War Department appointed a herder to control loose cattle grazing on Fort Douglas and in the canyon. In 1890 three squatters had settled into the canyon, and their forty head of cattle were grazing in the Parleys Fork area before being evicted. By 1909 the Army had built a gate at the mouth of the canyon to control access, thus further protecting the watershed. Although this did not prevent occasional animals from wandering into the canyon from adjacent canyons, it did reduce both their numbers and their length of stay. Consequently, most of the canyon has not been grazed by cattle or sheep through most of this century.

Portions of the upper reaches of the canyon were timbered. In 1848, when a road was built along the canyon bottom, it was reported that there was an abundance of timber suitable for fence poles. Later The Church of Jesus Christ of Latter-day Saints built a bowery on Temple Square in downtown Salt Lake City in the 1850s with wood obtained from Table Mound (between Knowltons Fork and Beaver Canyon). In 1863 the Army constructed 34 buildings at Fort Douglas from "timber hauled from the canyons," but there is no indication as to how much timber came from Red Butte Canyon. However, apparently not many timber-size trees were available in the lower canyon as indicated by a pioneer who built a log cabin in the canyon. He stated he had to travel five miles up the

canyon to obtain enough logs for the cabin in the early 1860s.

There are no available records of fires that may have occurred in the canyon. In 1988 a fire from Emigration Canyon spread into the upper headwaters of Red Butte Creek before it was contained. The land was subsequently reseeded with native species by the U.S. Forest Service.

Land ownership within the canyon changed several times during the late 1800s and early 1900s. Land occupied by Fort Douglas in 1862 was officially given to the U.S. Army in 1867 when President Johnson withdrew four square miles from public domain for the use of the Army. However, this included only a small portion of the mouth of Red Butte Canyon. The Salt Lake Rock Company, which quarried most of the sandstone in the canyon, owned part of the canyon, and the Union Pacific Railroad Co. acquired four sections in the lower portions of the canyon in the 1860s. Smaller portions of the canyon were claimed by private individuals under the Homestead Act of 1862. Such claims could be acquired easily under this act, which was very liberal and required only a small claim fee. Gradually, between 1884 and 1909, through a combination of acts of Congress, exchanges of property, and outright purchases, Fort Douglas obtained title to most of the canyon by 1896 and almost the entire canyon by 1909. Only three small parcels of a total of less than 90 hectares (~200 acres) are still privately owned today, and these are close to the margins of the canyon. In 1969 the U.S. Department of Defense relinquished ownership of Red Butte Canyon. The U.S. Forest Service is now responsible for these lands. The Forest Service recognized the natural state of the area had been preserved through many years of closure to the public and designated Red Butte Canyon a Research Natural Area in 1970. By definition such areas are tracts of land that have not been strongly impacted by human-related activities such as logging or grazing by domestic livestock. They are permanently protected from devastation by humans so they may serve as reference areas for research and education.

Red Butte Canyon has served as a research site for biologists for over fifty years and will continue to do so in the future. Public education about conservation and the need for the public to better understand the importance of Research Natural Areas are major concerns. Recently the Forest Service briefly opened the

canyon to the general public. In 1987 the canyon was opened to the public in late spring for several days; this weekend opening attracted over 5000 visitors and led to a trampling on vegetation along the main road in the canyon. This opening was repeated in 1988 and attracted 1100 people. Currently the State Arboretum at the University of Utah conducts natural history education classes (~10 individuals per group) in the lower portions of the canyon. Limited deer hunting has been permitted by the Forest Service each fall, but the impact of the hunts is unknown. A Red Butte Steering Committee, consisting of representatives from the Forest Service, the University of Utah, and other government agencies concerned with preservation of natural areas, is involved in making decisions pertinent to the jurisdiction and management of the Red Butte Canyon Research Natural Area.

The history of Red Butte Canyon, with the exception of the quarrying activity and some grazing in the past century, is largely a history of preservation. The U.S. Army at Fort Douglas was concerned with the protection of the watershed and gradually acquired sufficient control to protect it. The U.S. Forest Service declared the entire canyon a Research Natural Area and thus insured its protection for the future as a bench mark of riparian and shrub ecosystems in the Intermountain West.

GEOLOGY

The rocks underlying Red Butte Canyon range in age from recent Holocene deposits of our time to Mississippian rocks that are about 360 million years old. Holocene and Pleistocene deposits are unconsolidated, consisting mostly of landslides or alluvium deposited by existing streams. Their aerial distribution is shown in Figure 3, and a description of the deposits is given in Table 1.

The older rocks range in age from Mississippian to Jurassic, a span of about 220 million years. They are all consolidated now, but originally they were formed as deposits in oceans or inland seas or as sand dunes in an arid environment. No rocks representing the approximately 140 million years between the end of Jurassic time and the Holocene are present in Red Butte Canyon. Either they were never deposited or they have been eroded.

The consolidated rocks in most parts of the lower walls of the canyon consist chiefly of shale,

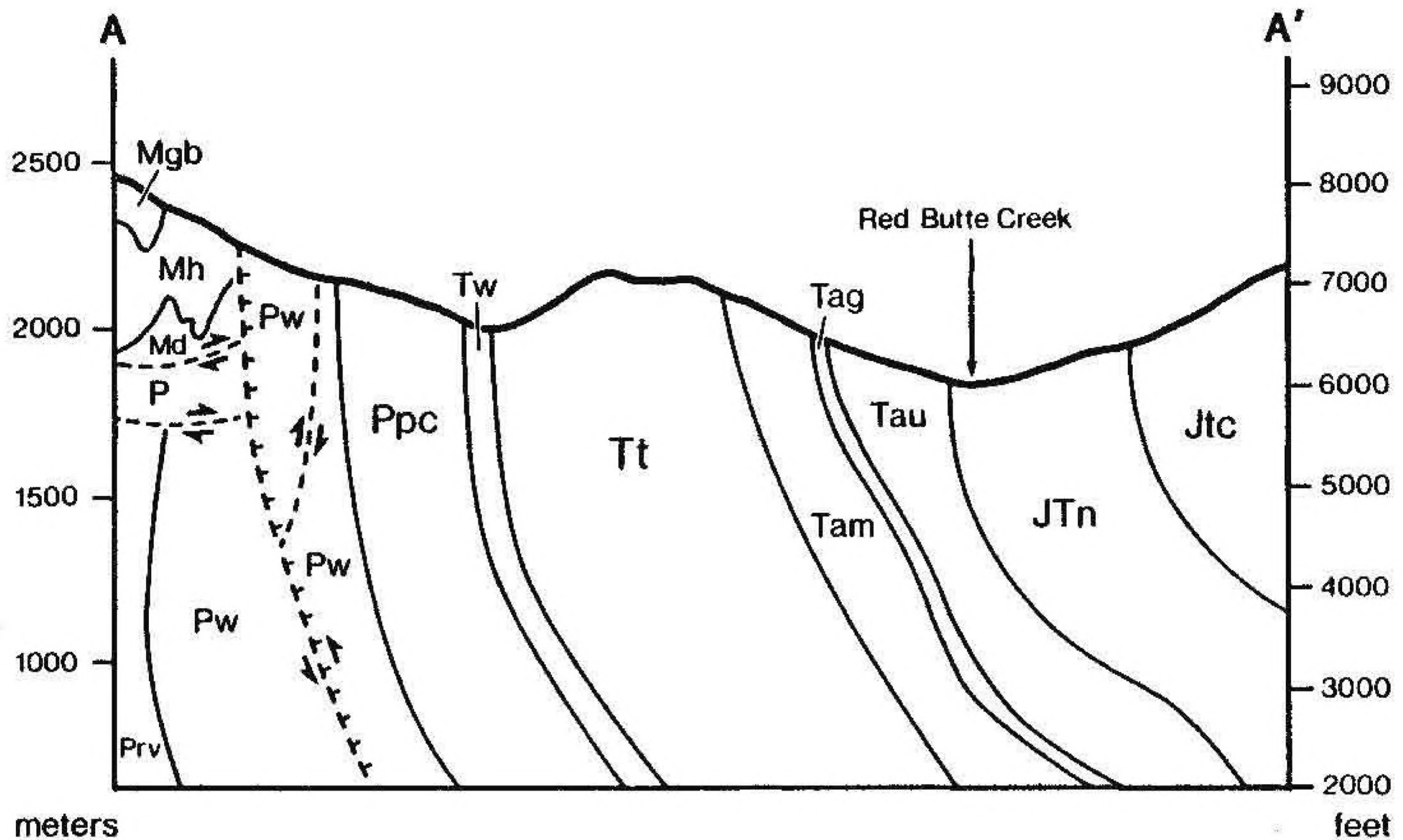


Fig. 4. Geologic cross section of Red Butte Canyon. Explanation as in Figure 3. Adapted from Van Horn and Crittenden (1987).

with some gritty quartzite and sandstone. The upper southeast-facing slopes consist mostly of limestone with some sandstone and limy shale. The upper northwest-facing slopes are made up mostly of sandstone with limestone and limy shale near the southeast divide. Figure 3 shows the distribution of the rocks in the canyon, and they are described in Table 1.

The older consolidated rocks in the canyon generally dip toward the southeast (Fig. 4), and they form the northern flank of a large syncline whose axis trends toward the northeast and whose southern flank is in Mill Creek Canyon, about 6.5 km to the south. The rocks are cut by numerous normal faults that are part of the Wasatch fault zone, a lengthy fault zone that bounds the west face of the Wasatch Range for almost its entire length. Movement along these normal faults has resulted in horizontal displacement of the rock formations, whereas movement along the Black Mountain thrust fault in the northwestern part of the canyon has raised older rocks to a position overlying younger rocks. The faults and their effects on the consolidated rocks are shown in Figures 3 and 4.

SOILS

Soils in Red Butte Canyon are derived from the weathering and erosion of the underlying

bedrock. The distribution of the soils in the canyon is shown in Figure 5. The relationship of the soils to the bedrock is apparent by comparing Figure 5 with Figure 3, a geologic map of the canyon. The soils map (Fig. 5) was adapted from Woodward et al. (1974). Soils in Red Butte Canyon have been characterized as dominantly strongly sloping to very steep and well drained. According to Bond (1979), most soils are neutral to slightly basic, vary in color from brick red to dark brown, with textures generally ranging from sandy to loamy clays. Depth of the soil is irregular, with depth to bedrock varying from nearly 2.4 m (94 in) at the canyon floor near the mouth to as little as 60 cm (24 in) or less on the slopes. Soil types include loams, silt loams, and dry loams. There is little profile development, but a pronounced litter layer and appreciable incorporated humus exist in places. Generally the soils are approximately 1 m (39 in) deep, especially those adjacent to streams. However, the steep, rocky upper slopes have shallow and cobbly soils. Table 2 includes a description of each of the soils shown in Figure 5. The descriptions were adapted from Woodward et al. (1974).

HYDROLOGY AND NUTRIENT FLOW

Red Butte Creek is a perennial third-order stream without upstream regulation or diversion

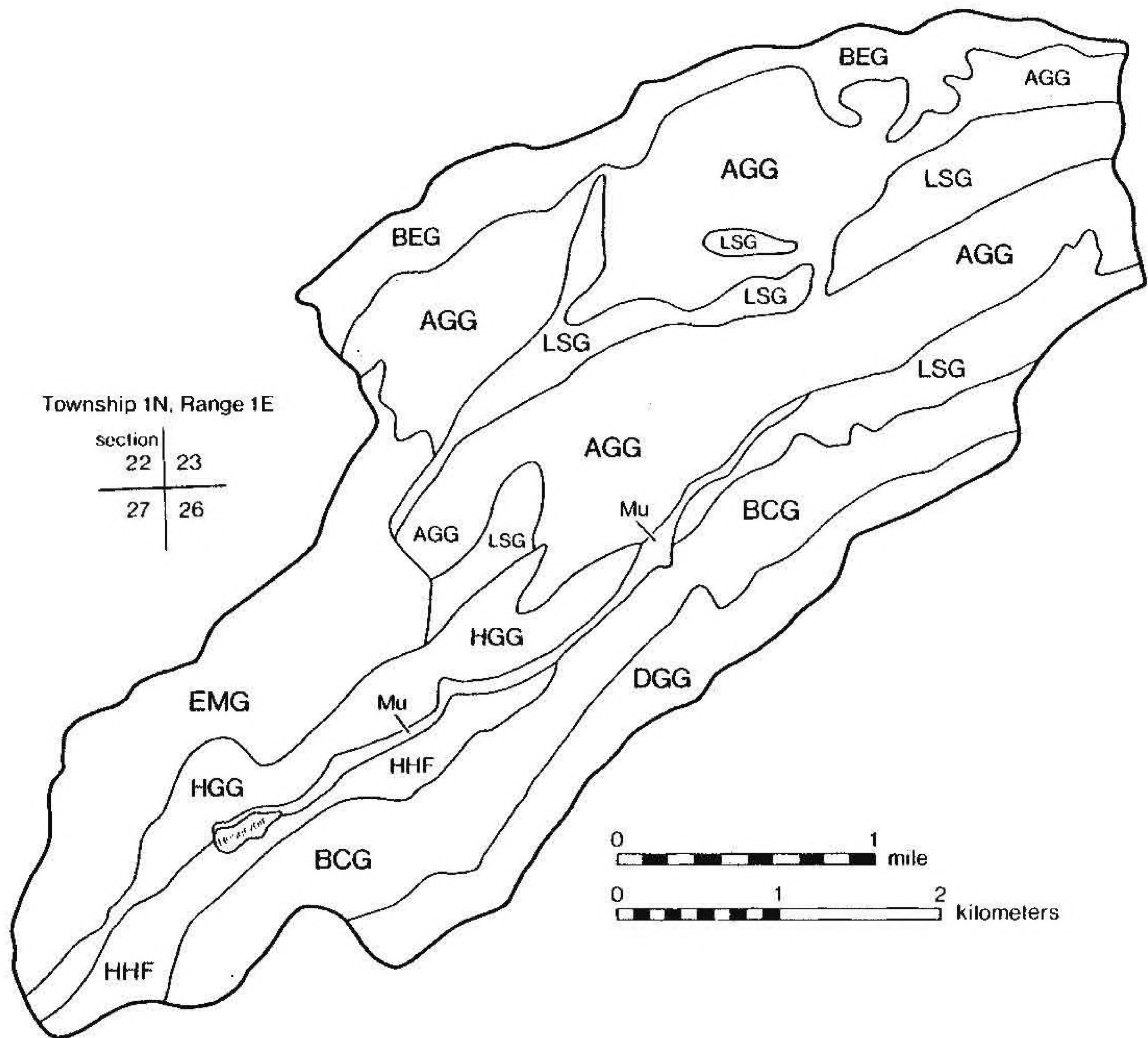


Fig. 5. Soils map of Red Butte Canyon. See Table 2 for a description of abbreviations. Adapted from Woodward et al. (1974).

until flow is collected in the reservoir located near the base of the canyon. The stream has created a narrow-based canyon with sides rising abruptly at an average slope of about 35 degrees to the north and about 40 degrees to the south. Immediately upstream of the reservoir is a U.S. Geological Survey Hydrologic Bench Mark Station. This gaging station has been maintained by the U.S. Geological Survey since October 1963. Prior to that, the Corps of Engineers, U.S. Army, recorded monthly discharge at this location beginning in January 1942.

The average monthly discharge (1964–88) is $0.133 \text{ m}^3/\text{sec}$ ($\sim 4.7 \text{ ft}^3/\text{sec}$) as it enters the reservoir at 1646 m (5400 ft) elevation (U.S. Geological Survey records). The stream flow exhibits a straightforward annual pattern, characteristic of this geographic region—high spring

flows driven by snowmelt followed by very much reduced flows derived from groundwater throughout the remainder of the year (Fig. 6). Spring melt flow, which is typically an order of magnitude greater than other periods of the year, peaks in May and persists for 6–8 weeks. The average monthly stream flow rate during May is $0.416 \text{ m}^3/\text{sec}$ ($14.7 \text{ ft}^3/\text{sec}$). By September, the lowest average monthly flow rate, stream discharge has decreased to $0.058 \text{ m}^3/\text{sec}$ ($2.0 \text{ ft}^3/\text{sec}$). Mean stream flow rates do not increase during the summer months, although nearly one-fourth of the annual precipitation falls during this period.

Average monthly stream flow values, however, hide much of the stream dynamics and resultant impact on riparian vegetation. On a daily basis, stream flows can vary tremendously

TABLE 2. Description of units on the soils map of Red Butte Canyon.

AGG Agassiz association, very steep. 40–70 percent slopes; moderately permeable, well drained. Agassiz—35 percent, very cobbly silt loam on ridges and convex areas of upper slopes. Picayune—55 percent, noncalcareous variant, gravelly loam in concave areas and in draws. Other soils—10 percent.

BCG Brad very rocky loamy sand, 40 to 80 percent slopes. Very permeable, extremely well drained. Very rocky, cobbly, loamy sand; dark reddish-brown; shallow.

BEG Bradshaw-Agassiz association, steep. 40–70 percent slopes; moderately permeable, well drained. Bradshaw—55 percent, very cobbly silt-loam in slightly concave areas. Agassiz—35 percent, very cobbly silt-loam in convex areas and ridgetops where soil is shallow. Other soils—10 percent.

DGG Deer Creek-Picayune association, steep. 30–60 percent slopes; moderately permeable, well drained. Deer Creek—55 percent; loam; very dark brown; deep on very steep, north- and northeast-facing mountain slopes. Picayune—35 percent; gravelly clay loam; very dark brown, deep, calcareous on west-facing slopes. Other soils—10 percent.

EMG Emigration very cobbly loam, 40 to 70 percent slopes. Moderately permeable, well drained. Cobbly loam; facing south; dark, grayish brown; shallow; patches of bedrock.

HGG Harkers-Wallsburg association, steep. Moderately permeable, well drained. Harkers—55 percent, loam, 6–40 percent slopes, very dark brown, deep in drainageways and concave areas of slope faces. Wallsburg—35 percent, very cobbly loam, 30–70 percent slopes, on ridges and convex areas of slopes where bedrock is near the surface, very dark grayish brown, shallow. Other soils—10 percent.

HHF Harkers soils, 6 to 40 percent slopes. Moderately permeable, well drained. Loam and cobbly loam, on sloping old alluvial fans and steep mountain slopes.

LSG Lucky Star gravelly loam, 40 to 60 percent slopes. Moderately permeable, well drained. Very dark grayish brown, deep on northerly slopes.

Mu Mixed alluvial land. Poorly drained, highly stratified mixed alluvium on undulating, gently sloping, and nearly level flood plains.

during snowmelt, depending on air temperatures and snowpack depth (primarily that of upper Red Butte Canyon and Knowltons Fork). The 1982–83 winter was one of unusually high precipitation along the Wasatch Front. Heavy snows in mid-May 1983 were followed by equally unusual warm temperatures at the end of the month. As a consequence, stream flow rates peaked at record values. On 28 May 1983, Red Butte Creek crested at a discharge rate exceeding 2.97 m³/sec (104.9 ft³/sec) (stream flow was above the maximum gage height), and

overland flow was substantial. This was by far the greatest discharge rate in recent times, having eclipsed the previous maximum single day rate of 1.70 m³/sec (60.0 ft³/sec) measured on 18 May 1975 (U.S. Geological Survey Records).

The unusually high stream discharge rate in May 1983 is of particular significance because of its impact on stream geomorphology and adjacent vegetation. The high flows quickly scoured the streambed, taking out beaver dams, eroding stream banks, knocking down riparian trees, and causing massive erosion. Gullies 5–10 m (16–33 ft) deep were cut into permanent streambeds in Knowltons Fork and throughout Red Butte Creek. Sediment flow associated with this record stream discharge was in excess of 269 metric tons (~593,000 lbs) per day in mid-May (compared to typical spring melt concentrations of 1 metric ton [~2200 lbs] per day) (U.S. Geological Survey Records); this resulted in a delta formation at the mouth of Red Butte Reservoir. Prior to the 1982–83 winter, no delta had existed. The delta was soon ~30 m (~100 ft) long. By 1990 the delta had fanned out more than 60 m into the reservoir. The heavy winter rains of 1982–83 saturated soils all along the Wasatch Front, and landslides were common. Red Butte Canyon was no exception. Slope sloughing, which killed the overlying perennial vegetation, was common throughout the canyon. No doubt this compounded the stream sediment load during the spring of 1983 and for several years thereafter. In 1990 signs of the 1982–83 slope sloughing were still clearly obvious in Knowltons Fork as well as in the upper and lower portions of the main canyon. Natural revegetation of both riparian and slope vegetation types has occurred since these floods. In particular, *Acer negundo* (boxelder) and *Salix exigua* (willow) have increased in frequency in the newly deposited alluvium along the stream-sides (Donovan and Ehleringer 1991). Recovery of the sloughed slopes, which were for the most part covered by *A. grandidentatum* (bigtooth maple) and *Quercus gambelii* (Gambel oak), has proceeded at a slower rate, with those slopes still dominated by herbaceous species.

As part of the bench mark analysis, the U.S. Geological Survey monitors several major aspects of stream quality in addition to stream discharge, including water temperature, suspended sediment, and chemical quality. Included with chemical quality are specific conductance, pH,

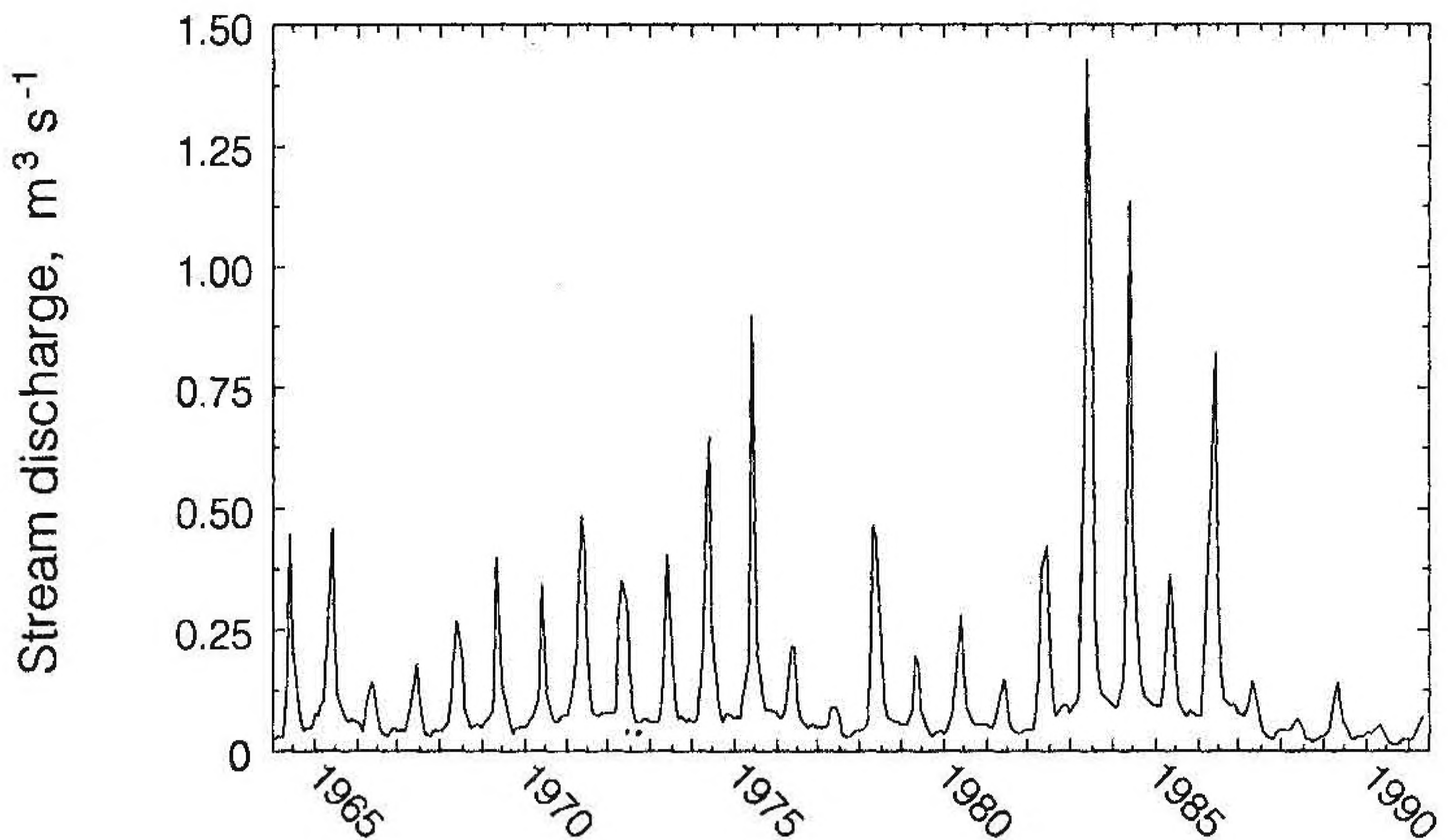


Fig. 6 Mean monthly discharge rates of Red Butte Creek just before it enters Red Butte Reservoir. Large and small tick marks indicate end-of-year and mid-year points, respectively. Data are from U.S. Geological Survey records.

dissolved oxygen concentration, coliform bacteria, and ionic and dissolved elemental concentrations (ammonium, arsenic, beryllium, cadmium, calcium, carbonate, chloride, chromium, cobalt, copper, fluoride, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, nitrate, nitrite, phosphate, potassium, selenium, silver, sodium, sulfate, strontium, vanadium, and zinc). The stream itself is strongly alkaline (pH 8.0–8.6), and travertine is deposited at several points along the stream channel (Bond 1979).

Summertime stream flow represents groundwater discharge, while the spring flows result primarily from snowmelt at higher elevations. Not all of the groundwater originating from upper-elevation sources enters the stream before it leaves the canyon. Tracing the possible sources of water into stream, and therefore that water which is available to plants, is possible by analyzing the isotopic composition of that water. The deuterium (^2H or D) to hydrogen (^1H) ratios of stream waters have been measured since June 1988 at the USGS Bench Mark station and at the mouth of Parleys Fork by the Stable Isotope Ratio Facility for Environmental Research at the University of Utah (Dawson and Ehleringer 1991). These naturally occurring stable isotopes of hydrogen provide long-term data that are useful in addressing both long-term regional climatic patterns and the specific

water sources used by plants for growth (see discussion below). Hydrogen isotope ratios (ratio of D/H of a sample to that of a standard) are measured relative to an ocean water standard; samples lighter than ocean water have less deuterium and are therefore negative in their values. Over the four-year measurement period (1988–91), hydrogen isotope ratios of stream waters have averaged near -122‰ , with the only seasonal changes being more negative values occurring during spring snowmelt. Typically the hydrogen isotope ratio of winter storm events (snow) is more negative than that of summer storms. The hydrogen isotope ratios of wells and springs near Pinecrest (immediately east of Red Butte Canyon) are -132‰ , slightly more negative than Red Butte Creek (Dawson and Ehleringer 1991), and suggest that a fraction of the groundwater originating from the upper portions of the canyon may persist as underflow and does not enter the creek before leaving the watershed. Hely et al. (1971) indicated that substantial fracturing occurs in the bedrock of Red Butte Canyon, which would have the effect of increasing groundwater loss from the canyon through these layers and not via stream discharge.

Bond (1977, 1979) investigated nutrient-concentration patterns of stream flow in Red Butte Creek. In particular, his studies focused

TABLE 3. Locations of weather stations of Red Butte Canyon. All stations were operated by the U.S. Army between 1942 and 1964, and only precipitation was recorded. The U.S. Geological Survey has maintained a storage gage at Red Butte #2 since 1964. The Biology Department at the University of Utah has maintained daily temperature, humidity, and wind speed records at Red Butte #2, Red Butte #4, and Red Butte #6 since 1982. Red Butte #1, while technically outside the canyon, forms an integrated part of the weather station complex.

Station	Location	Latitude	Longitude	Elevation	Period
Red Butte #1	Fort Douglas	40° 46'	110° 50'	1497 m	1942-1964
	Relocated to Biology Experimental Garden	40° 46'	110° 50'	1515 m	1991-present
Red Butte #2	Head of Red Butte Reservoir	40° 47'	111° 48'	1653 m	1942-1964 1982-present
Red Butte #3	Along Red Butte Creek at Brush Basin	40° 48'	111° 47'	1865 m	1942-1952
Red Butte #4	Along Red Butte Creek 100 m west of Beaver Canyon	40° 48'	111° 46'	1890 m	1942-1971 1982-present
Red Butte #5	Parleys Fork 100 m above inlet to Red Butte Creek	40° 47'	111° 48'	1753 m	1942-1956
Red Butte #6	Upper end Knowltons Fork;	40° 49'	111° 45'	2195 m	1946-1971
	relocated to top of Elk Fork	40° 49'	111° 46'	2195 m	1982-present

on relationships between nutrient transport out of the watershed and stream discharge rates. Solute concentration was not necessarily proportional to stream discharge. Instead, for many ions, such as magnesium, sulfate, and chloride, the relationship was logarithmic. The slopes of these relationships depend on whether stream flow is increasing (i.e., spring snowmelt) or decreasing. Over the course of the year, a loop or directional trajectory was formed by having two different slopes. For most of the major ions, the trajectory was clockwise; that is, ionic concentration was greater in winter when flow rates were low than during summer. Plant growth of the dominant riparian species commences near the end of the snowmelt period, and it is questionable whether riparian species are able to utilize the greater nutrient availability during the snowmelt period. After snowmelt, stream discharge is based primarily on groundwater input. Nitrate, ammonium, and phosphate concentrations in Red Butte Creek during groundwater discharge are low (Bond 1979). In contrast, overall concentrations of calcium, magnesium, sodium, chloride, and sulfate are much greater because of parent bedrock characteristics.

CLIMATE

Climate within Red Butte Canyon is characterized by hot, dry summers and long, cold winters. Most precipitation occurs in winter and spring, with the summer rains less predictable and dependent on the extent to which mon-

soonal systems penetrate into northern Utah. Mean annual precipitation ranges from about 500 mm (20 in) at the lower elevation to approximately 900 mm (35 in) at the higher elevations (Hely et al. 1971, Bond 1977; Table 3).

Precipitation stations have been monitored in Red Butte Canyon by several groups. The U.S. Army had six rain gages in operation between 1942 and 1964 (Table 3). Bond (1977) collected data at several of these stations between 1972 and 1974. In addition, the U.S. Geological Survey maintained storage gages at Red Butte #2, Red Butte #4, and Red Butte #6 between 1964 and 1974. Since that time, they have maintained a storage gage at Red Butte #2. Within the watershed, daily precipitation as rainfall is collected at each of the weather stations; snowfall is not adequately measured by the sensors in place. However, these data are currently collected at Hogle Zoo in Salt Lake City (same elevation as previous Red Butte #1, but 4 km south).

Variation in annual precipitation within Red Butte Canyon is strongly dependent on elevation (Fig. 7). The slope of this relationship is similar to that observed for other mountainous areas within the Great Basin (Houghton 1969), and precipitation at the Salt Lake City reporting station (Salt Lake City International Airport) falls on this relationship. Thus, while lacking continuous precipitation records for the canyon proper, precipitation records available for Salt Lake City can be used as a preliminary basis for estimating mean annual precipitation at different locations within the canyon.

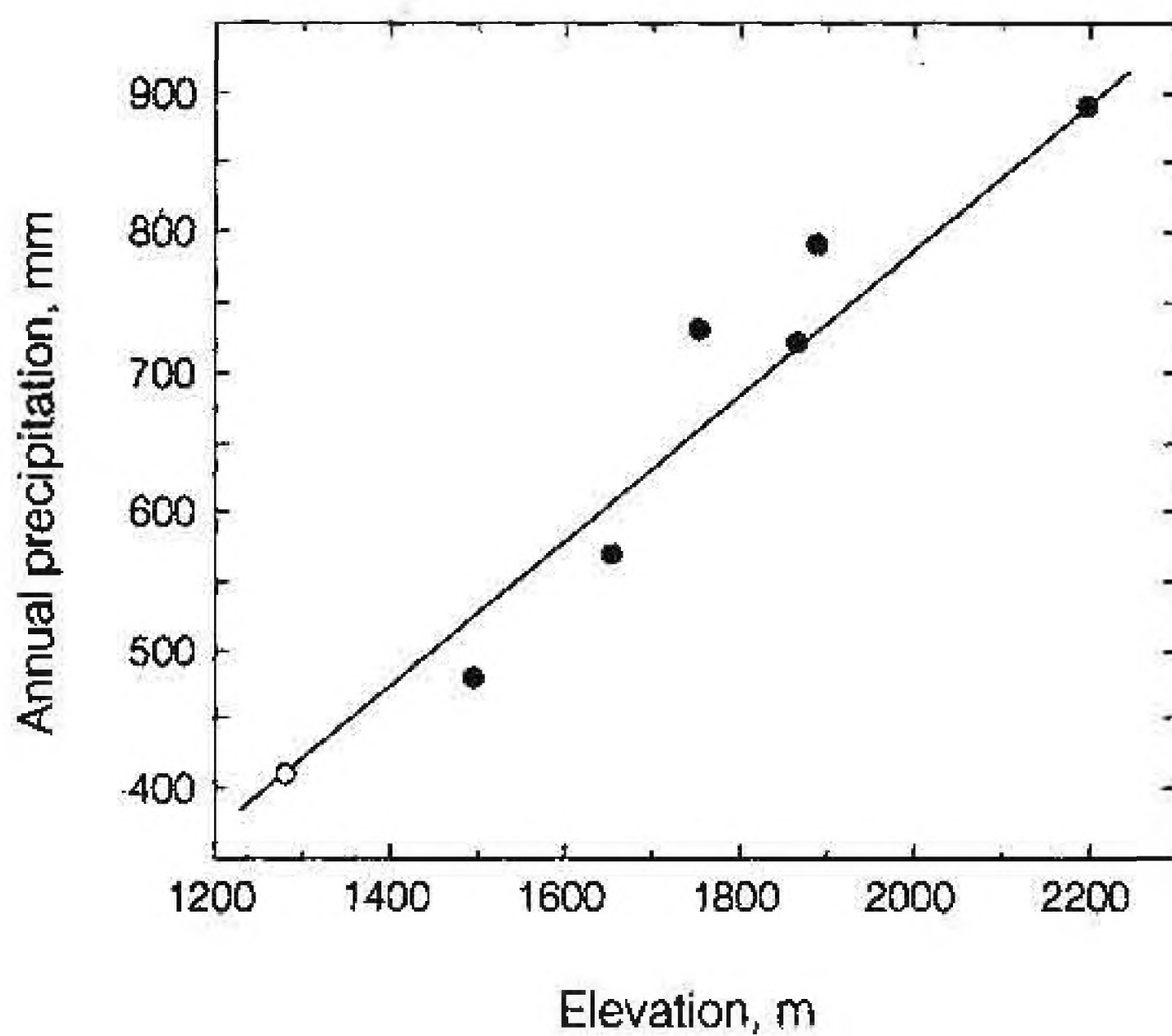


Fig. 7. Relationship between mean annual precipitation and elevation for Red Butte Canyon storage gages Red Butte #1-#6. Shown also is the mean annual precipitation for the primary station of Salt Lake City (Salt Lake City International Airport) as the open symbol.

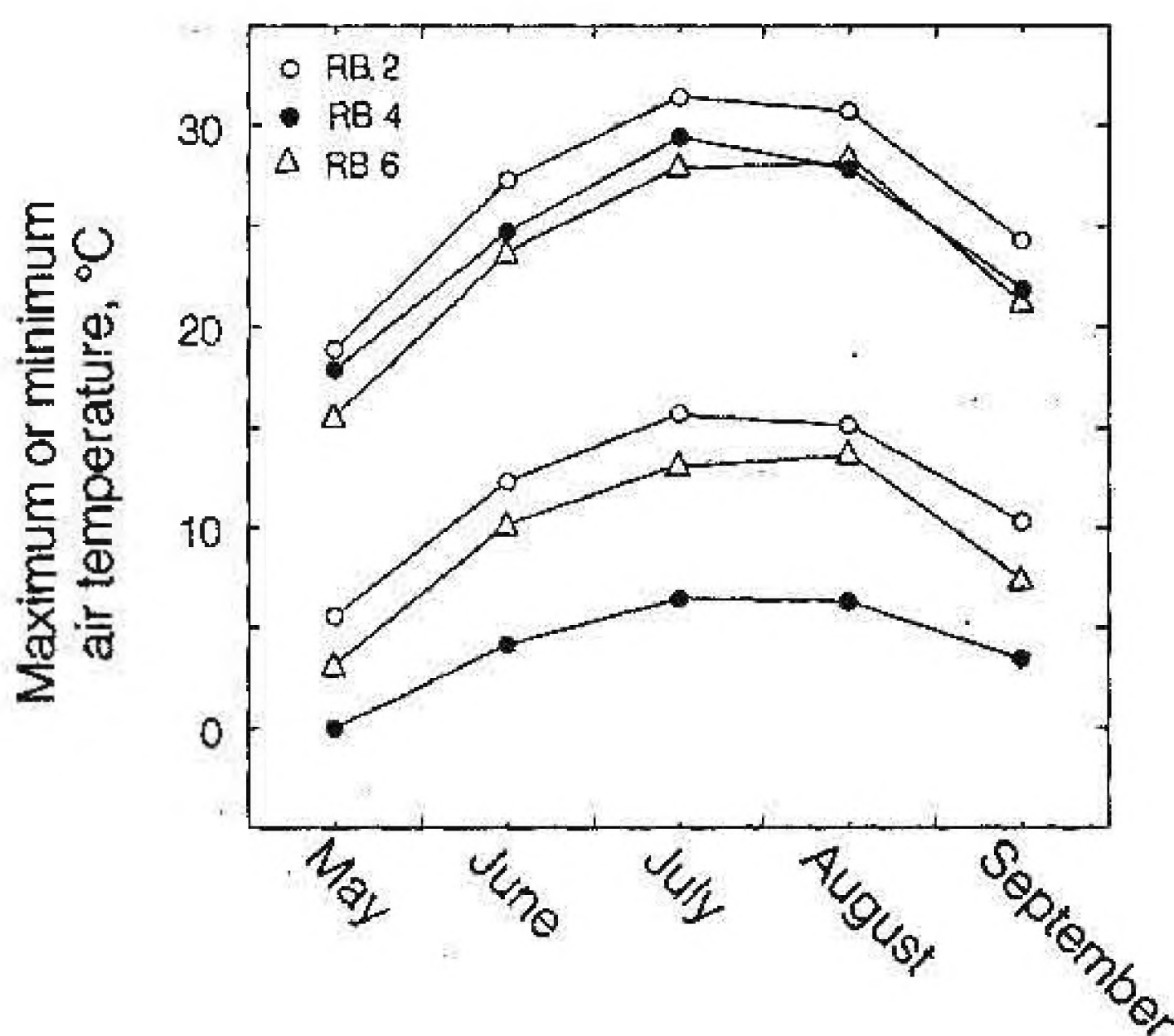


Fig. 9. Mean monthly maximum and minimum air temperature at Red Butte #2 (1653 m elevation), Red Butte #4 (1890 m elevation), and Red Butte #6 (2195 m elevation) during the growing season between 1982 and 1990.

Air temperatures have been collected from automated weather stations at Red Butte #2, Red Butte #4, and Red Butte #6 since 1982. Mean monthly air temperatures at Red Butte #2 were below freezing in December and January and above 20 C in June, July, and August (Fig. 8). In contrast, mean monthly temperatures at Red Butte #6 were below freezing only slightly longer, from November through February, and above 20 C in July and August. During the main growing period (May through September), daytime maximum temperatures ranged between

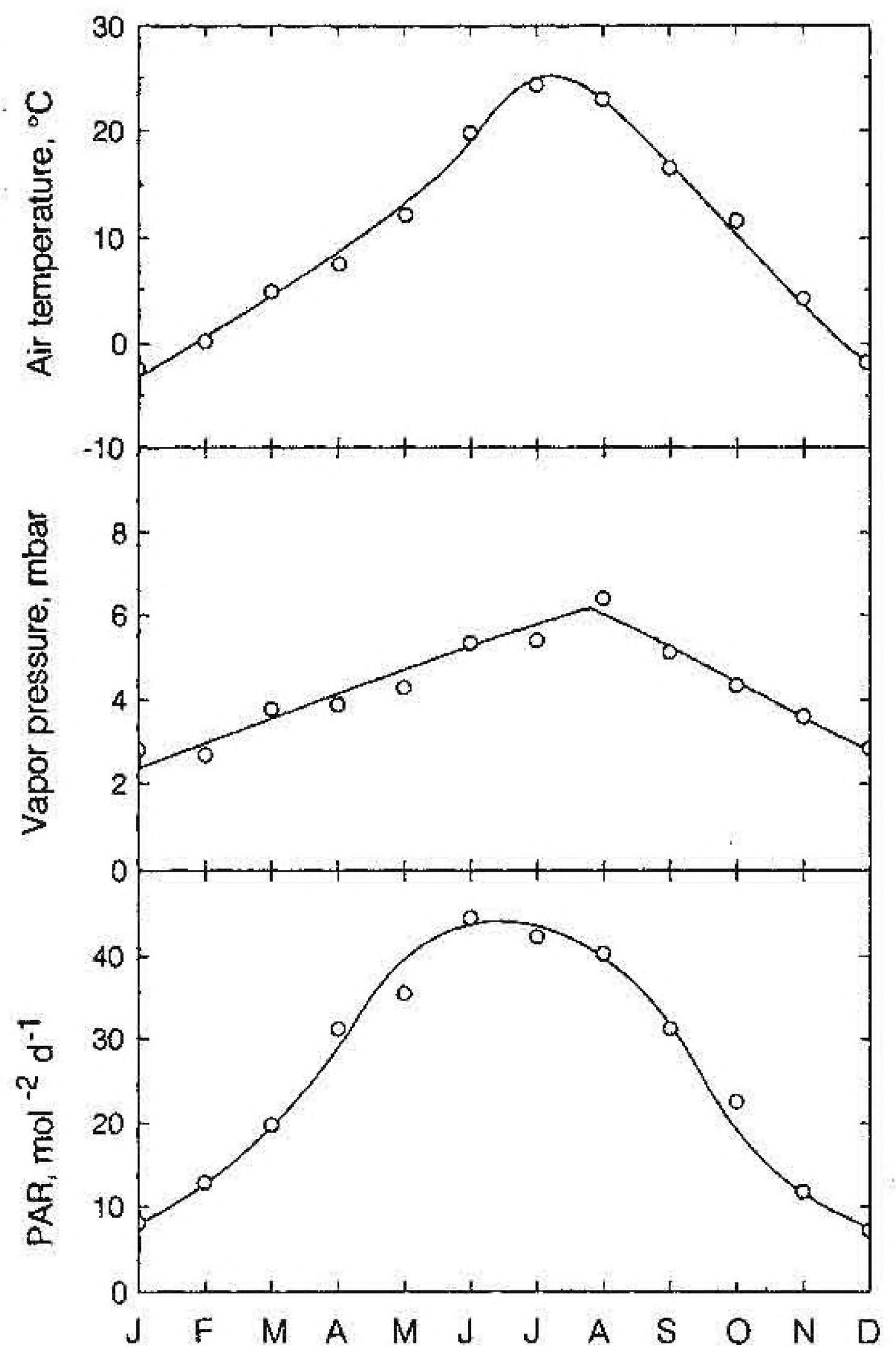


Fig. 8. Mean monthly air temperature, vapor pressure, and photosynthetically active solar radiation (400-700 nm) measured at Red Butte #2 between 1982 and 1990.

18.7 and 31.8 C (66-89 F) at Red Butte #2, while nighttime minimum temperatures ranged between 5.2 and 16.4 C (41-62 F) (Fig. 9). At the higher-elevation stations, daytime maximum air temperatures were lower. The difference in maximum temperatures was negatively related to elevation (maximum temperature [°C] = $34.3 - 0.00494 \cdot \text{elevation [m]}$, $r = .91$) at approximately half the dry adiabatic lapse rate. On the other hand, nighttime minimum temperatures were not related to elevation, because of cool-air drainage effects (Fig. 9). Red Butte #4 is located streamside within the canyon, whereas the other two stations are above the channel of cold air that develops at higher elevations and pours down the canyon at night. As seen in Figure 9, this cold-air drainage effect at Red Butte #4 (1890 m [6180 ft] elevation) depressed nighttime minimum air temperatures by 4-8 C (7-14 F) below that observed at Red Butte #6 (2230 m [7292 ft] elevation).

Photosynthetically active solar radiation (PAR, 400-700 nm), atmospheric vapor pressure,

and wind speed are also recorded at each of these stations. Between 1982 and 1990, mean daily total PAR values have exceeded $40 \text{ mol m}^{-2} \text{ d}^{-1}$ (Fig. 8), which is typical for mid-latitude sites having only moderate cloud cover and little summer precipitation. This number is quite useful not only in estimating the available photon flux for photosynthesis, but also in providing an estimate of the extent of solar heating of the surface, which ultimately affects air temperatures. Elevation has a limited impact on the PAR values within Red Butte Canyon, since the difference in elevation is relatively small. However, we suspect there may be relatively large differences in PAR between Red Butte Canyon and Salt Lake City because of increased air pollutants within the city that tend to reflect the sunlight before it strikes the earth's surface. Most notably we would see this as haze or smog within the valley that is lacking once in the canyon.

Average monthly atmospheric vapor pressure at site #2 showed little annual variation, ranging only about 3 mbar throughout the year (Fig. 8). Other sites exhibited a similar pattern. This parameter is largely affected by large air mass movements; and since subtropical air masses do not move into this region during the summer, the monthly changes in atmospheric vapor pressure change little during the course of the year. However, because of the large annual change in air temperature and the non-linear dependence of the evaporative gradient on temperature, relative humidity levels are substantially lower and evaporative gradients are substantially higher during the summer months.

VASCULAR FLORA

From the mouth of Red Butte Canyon at about 1530 m (5020 ft), its walls rise to their highest point—2510 m (8235 ft)—at the head of Knowltons Fork in the northeast corner of the canyon. Within this modest rise of 980 m (3215 ft) occur four distinct plant communities: riparian, grass-forb, oak-maple, and coniferous. Piñon-juniper and ponderosa pine communities, which often occur in this elevational range in Utah (Daubenmire 1943), are not present in Red Butte Canyon. Billings (1951, 1990), in discussions of vegetational zonation in the Great Basin, cites a greater incidence of winter cyclonic storms and slightly more moist sum-

mers as factors producing the variation in the vegetative zones of the eastern boundary of the Great Basin. Juniper is present in the central Wasatch Range, but only three Utah juniper (*Juniperus osteosperma*) are known to exist in Red Butte Canyon: a mature tree with a 0.5 m (1.6 ft) diameter trunk, located on the south slope of Parleys Fork and nearly obscured by the more mesophytic vegetation, and two shrublike plants 1–1.3 m (3–4 ft) tall growing on the southwest divide.

With few exceptions, notably the naturalized grasses *Agrostis stolonifera* (redtop bentgrass), *Bromus tectorum* (cheatgrass), and *Poa pratensis* (Kentucky bluegrass), only the most common indigenous plants that occur in the various plant communities are listed below, primarily because the presence of introduced plants is usually dependent on disturbance and tends to fluctuate accordingly. Some of the more frequently occurring introduced plants are listed in a separate section.

RIPARIAN COMMUNITY.—From the point at which Red Butte Creek emerges from the canyon and throughout the floor of the canyon the streamside vegetation (plants residing in soil kept moist to wet by the stream) consists chiefly of western water birch (*Betula occidentalis*) and mountain alder (*Alnus incana*), accompanied at intervals by usually dense stands of red osier dogwood (*Cornus sericea*) and willow (*Salix* spp.). Adjoining the stream along the floor of the canyon below and above the reservoir is an often densely wooded strip consisting chiefly of Gambel oak (*Quercus gambelii*), boxelder (*Acer negundo*), and bigtooth maple (*Acer grandidentatum*), many of these trees ranging from 9 to 18 m (30 to 60 ft) or more tall. Also included in this plant community are widely scattered individuals or small populations of cottonwoods (*Populus fremontii*, *P. angustifolia*, and *P. × acuminata*), chokecherry (*Prunus virginiana*), Woods rose (*Rosa woodsii*), bearberry honeysuckle (*Lonicera involucrata*), thimbleberry (*Rubus parviflorus*), serviceberry (*Amelanchier alnifolia*), western black currant (*Ribes hudsonianum*), and golden currant (*Ribes aureum*). Relatively few species of grass and forbs are found here, among them:

<i>Elymus glaucus</i>	blue wildrye
<i>Lomatium dissectum</i>	giant lomatium
<i>Mahonia repens</i> (<i>Berberis repens</i>)	Oregon grape
<i>Osmorhiza chilensis</i>	sweet cicely
<i>Poa compressa</i>	Canada bluegrass

<i>P. pratensis</i>	Kentucky bluegrass
<i>Smilacina stellata</i>	wild lily-of-the-valley
<i>S. racemosa</i>	false Solomon-seal
<i>Solidago canadensis</i>	goldenrod

Beaver, once native, were reintroduced into Red Butte Canyon in 1928 (Bates 1963) and were active along Red Butte Creek and some of its tributaries for 54 years thereafter. Numerous marshy areas between elevations of 1645 m (5400 ft) and 2133 m (7000 ft) were created by the impoundment of water due to their dam-building activities. To prevent the beaver populations from becoming undesirably large, the Utah Division of Wildlife Resources in 1971 undertook management of the populations. In December 1981 a recommendation was made, based on an analysis of the water supply to Fort Douglas from Red Butte Canyon, that all beaver be eliminated from the canyon because their feces could contaminate the water with the parasite *Giardia lamblia*. Accordingly, in 1982 the colonel in command of Fort Douglas applied for and received from the Utah Division of Wildlife Resources a permit to remove the beaver from the canyon. Subsequently, all beaver were "harvested."

Bates (1963) studied the impact of beaver on stream flow in Red Butte Canyon. The vegetative cover was affected for approximately 91 m (298 ft) on either side of the portion of the stream in which the beaver were active, and sediment deposited behind the beaver dams in the canyon varied from 0.6 to 2.4 m (2 to 8 ft) in depth. He also noted that the small alluvial plains formed by the sediment made it apparent that during periods of high runoff, and perhaps during normal flow, the dams allowed the retention of quantities of suspended materials. Schefter (1938), in a report on beaver as upstream engineers, ascertained that two beaver dams retained 4468 m³ (157,786 ft³) of silt. It is not known whether an actual count of the number of beaver dams in Red Butte Canyon was ever made; but the environmental change effected by their ultimate displacement during the 1983 flooding of what had to have been enormous quantities of sediment has been significant. The removal of all inactive beaver dams has inevitably led to the elimination of or significant reduction in the density of some 55 species of typically wetland plants from once marshy areas within Red Butte Canyon. For example, in 1990 it was noted that in an area which once supported a nearly pure stand of closely spaced cattails

(*Typha latifolia*) covering approximately 0.25 hectare (0.62 acre), only a few scattered clumps remained. According to Forest Service personnel, these losses would not have been as severe had the beaver dams been active during flooding. Species in the following genera are among those undoubtedly affected: *Eleocharis*, *Scirpus*, *Juncus*, *Agrostis*, *Catabrosa*, *Deschampsia*, *Glyceria*, *Poa*, *Polypogon*, *Equisetum*, *Angelica*, *Betula*, *Cicuta*, *Heracleum*, *Rudbeckia*, *Solidago*, *Barbarea*, *Cardamine*, *Nasturtium*, *Rorippa*, *Lonicera*, *Cornus*, *Trifolium*, *Mentha*, *Nepeta*, *Lemna*, *Epilobium*, *Habenaria*, *Polemonium*, *Polygonum*, *Rumex*, *Aconitum*, *Ranunculus*, *Geum*, *Ribes*, *Salix*, *Mimulus*, *Veronica*, and *Urtica*.

The U.S. Forest Service, Salt Lake Ranger District, requested the Utah Division of Wildlife Resources to reintroduce the beaver during the summer of 1991. At the time of this publication, beaver had not yet been reintroduced. It is hoped that with time the plant diversity typically associated with beaver dams will be reestablished.

GRASS-FORB COMMUNITY.—According to Stoddart (1941), the grasslands of northern Utah form the southernmost extension of the Palouse prairie. Of the two communities into which the Palouse prairie is divided, only that dominated by bluebunch wheatgrass (*Elymus spicatus*, originally known as *Agropyron spicatum*) occurs in Red Butte Canyon. Relatively large open areas inhabited by grasses and forbs, with an occasional big sagebrush (*Artemisia tridentata*), squawbush (*Rhus trilobata*), and bitterbrush (*Purshia tridentata*), are found chiefly below the 1829 m (6000 ft) contour (Kleiner and Harper 1966), although smaller grass-forb associations also occur in forest clearings at higher elevations. Some of the more commonly occurring species within the grass-forb community at lower elevations are:

<i>Achillea millefolium</i>	milfoil yarrow
<i>Allium acuminatum</i>	tapertip onion
<i>Ambrosia psilostachya</i>	western ragweed
<i>Arabis holboellii</i>	Holboell rockcress
<i>Aristida purpurea</i> (<i>A. longiseta</i>)	purple threeawn
<i>Artemisia ludoviciana</i>	Louisiana wormwood
<i>Astragalus utahensis</i>	Utah milkvetch
<i>Aster adscendens</i>	everywhere aster
<i>Balsamorhiza macrophylla</i>	cutleaf balsamroot
<i>Balsamorhiza sagittata</i>	arrowleaf balsamroot
<i>Bromus tectorum</i>	cheatgrass
<i>Cirsium undulatum</i>	gray thistle
<i>Collomia linearis</i>	narrowleaf collomia
<i>Comandra umbellata</i>	bastard toadflax

<i>Crepis acuminata</i>	mountain hawkbeard
<i>Cymopterus longipes</i>	long-stalk spring-parsley
<i>Elymus trachycaulus</i> (<i>Agropyron caninum</i>)	slender wheatgrass
<i>Epilobium brachycarpum</i> (<i>E. paniculatum</i>)	autumn willowherb
<i>Erigeron divergens</i>	spreading daisy
<i>Gutierrezia sarothrae</i>	broom snakeweed
<i>Hedysarum boreale</i>	northern sweetvetch
<i>Heliomeris multiflora</i> (<i>Viguiera multiflora</i>)	showy goldeneye
<i>Lomatium triternatum</i>	ternate lomatium
<i>Lupinus argenteus</i>	silvery lupine
<i>Microsteris gracilis</i>	little polecat
<i>Phacelia linearis</i>	threadleaf scorpionweed
<i>Phlox longifolia</i>	longleaf phlox
<i>Poa secunda</i> (<i>P. sandbergii</i>)	Sandberg bluegrass
<i>Stipa comata</i>	needle-and-thread
<i>Wyethia amplexicaulis</i>	mulesears

OAK-MAPLE COMMUNITY.—Gambel oak (*Quercus gambelii*) is the dominant type of vegetation throughout the altitudinal range of the canyon. It forms what appear to be randomly spaced clones throughout much of the area. In accordance with the moisture regimen, the clones may range from thickets 0.3 m (1 ft) or less in height in dry upland sites to stands of stately, well-spaced trees in lowland areas. Both walls of the canyon support often nearly impenetrable oak in association with bigtooth maple (*Acer grandidentatum*), the latter growing chiefly in drainageways. Few species thrive as understory with dense oak cover. The most common are *Galium aparine* (catchweed bedstraw) and *Mahonia repens* (Oregon grape). Others appearing seasonally under oak are *Erythronium grandiflorum* (dogtooth violet), *Claytonia lanceolata* (lanceleaf spring beauty), *Hydrophyllum capitatum* (ballhead waterleaf), and *H. occidentale* (western waterleaf). Among plants commonly fringing oak clones are:

<i>Agoseris glauca</i>	mountain dandelion
<i>Apocynum androsaemifolium</i>	spreading dogbane
<i>Arabis glabra</i>	tower mustard
<i>Bromus carinatus</i>	mountain brome
<i>Comandra umbellata</i>	bastard toadflax
<i>Delphinium nuttallianum</i>	Nelson larkspur
<i>Descurainia pinnata</i>	blue tansy mustard
<i>Eriogonum heracleoides</i>	whorled buckwheat
<i>E. racemosum</i>	redroot buckwheat
<i>Geranium viscosissimum</i>	sticky geranium
<i>Helianthella uniflora</i>	one-headed sunflower
<i>Heliomeris multiflora</i> (<i>Viguiera multiflora</i>)	hairy goldeneye
<i>Hydrophyllum</i> spp.	waterleaf
<i>Koeleria macrantha</i> (<i>K. cristata</i>)	Jumegrass
<i>Leucopoa kingii</i> (<i>Hesperochloa kingii</i>)	spike fescue
<i>Lomatium dissectum</i>	giant lomatium
<i>Machaeranthera canescens</i>	hoary aster

<i>Mertensia brevistyla</i>	Wasatch bluebell
<i>Microseris nutans</i>	nodding scorzonella
<i>Phacelia heterophylla</i>	varileaf scorpionweed
<i>Poa fendleriana</i>	muttongrass
<i>P. pratensis</i>	Kentucky bluegrass
<i>Senecio integerrimus</i>	Columbia groundsel

Mountain mahogany (*Cercocarpus ledifolius*) occurs as individuals and as scattered, mostly small populations, often in association with oak, sagebrush, or other mountain shrubs, generally on northwest-facing, sparsely vegetated slopes. It can be seen from the main road through the canyon as small trees against the sky along the exposed, rocky, south rim of the canyon, especially toward its western end. As low shrubs it occurs sporadically, chiefly on exposed dry sites above 1980 m (6500 ft).

Big sagebrush (*Artemisia tridentata*) occurs sporadically in drier sites throughout the canyon's altitudinal range. Low sagebrush (*Artemisia arbuscula*) occurs as relatively pure stands at about 2133 m (7000 ft) along the southeast rim of the canyon.

CONIFEROUS COMMUNITY.—Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and aspen (*Populus tremuloides*) dominate this community, either in pure or in mixed stands, growing chiefly on north- to northeast- and northwest-facing slopes; the aspen reach as low as 1706 m (5600 ft) and the firs occur mostly above 1828 m (6000 ft). Achlorophyllous *Corallorhiza* spp. (coralroot orchid) are among the few plants able to flourish in the shade of dense stands of mixed conifers. Many small trees, shrubs, forbs, and grasses thrive in less dense stands or in openings between stands of trees in this community. Among them are:

<i>Acer glabrum</i>	Rocky Mountain maple
<i>Amelanchier alnifolia</i>	Saskatoon serviceberry
<i>Aquilegia coerulea</i>	Colorado columbine
<i>Arnica</i> spp.	arnica
<i>Castilleja</i> spp.	Indian paint brush
<i>Ceanothus velutinus</i>	mountain lilac
<i>Elymus glaucus</i>	blue wildrye
<i>Erigeron speciosus</i>	showy fleabane
<i>Galium</i> spp.	bedstraw
<i>Hordeum brachyantherum</i>	meadow barley
<i>Lathyrus pauciflorus</i>	Utah sweetpea
<i>Physocarpus malvaceus</i>	mallow ninebark
<i>Poa nervosa</i>	Wheeler bluegrass
<i>Prunus virginiana</i>	chokecherry
<i>Ribes viscosissimum</i>	sticky currant
<i>Rubus parviflora</i>	thimbleberry
<i>Sambucus</i> spp.	elderberry
<i>Sorbus scopulina</i>	American mountain ash
<i>Symphoricarpos oreophilus</i>	mountain snowberry
<i>Thalictrum fendleri</i>	Fendler meadowrue

PLANTS ENDEMIC TO UTAH.—Only two species occurring in Red Butte Canyon are said to be endemic to Utah: *Angelica wheeleri* Wats. (Mathias and Constance 1944–45) (Wheeler angelica) and *Erigeron arenarioides* (D. C. Eat.) Gray (rock fleabane). *Angelica wheeleri* has, however, been collected close to both the Idaho and the Nevada boundaries with Utah (Albee et al. 1988). *Erigeron arenarioides* is known from Salt Lake, Utah, Tooele, Weber, and Box Elder counties (Albee et al. 1988, Cronquist 1947).

PLANTS INTRODUCED TO UTAH.—In Red Butte Canyon, plants introduced to Utah, either from other portions of the United States or from another country, are largely restricted to roadside and trailside sites and to open grassy or rocky slopes below 1829 m (6000 ft). Some of the more commonly occurring plants in this category are:

<i>Alyssum alyssoides</i>	alyssum
<i>Arabidopsis thaliana</i>	mouse-ear cress
<i>Bromus briziformis</i> (<i>B. brizaeformis</i>)	rattlesnake chess
<i>B. japonicus</i>	Japanese or meadow chess
<i>B. tectorum</i>	cheatgrass
<i>Capsella bursa-pastoris</i>	shepherd's purse
<i>Cynoglossum officinale</i>	hound's tongue
<i>Dactylis glomerata</i>	orchard grass
<i>Draba verna</i>	spring draba
<i>Erodium cicutarium</i>	storksbill or alfileria
<i>Grindelia squarrosa</i>	curlycup gumweed
<i>Holosteum umbellatum</i>	jagged chickweed
<i>Isatis tinctoria</i>	dyer's woad
<i>Lactuca serriola</i>	prickly lettuce
<i>Lepidium perfoliatum</i>	peppergrass
<i>Linaria dalmatica</i>	Dalmation toadflax
<i>Lithospermum arvense</i>	corn gromwell
<i>Malva neglecta</i>	cheeses
<i>Melilotus alba</i>	white sweetclover
<i>M. officinalis</i>	yellow sweetclover
<i>Poa bulbosa</i>	bulbous bluegrass
<i>Ranunculus testiculatus</i>	bur buttercup
<i>Sisymbrium altissimum</i>	Jim Hill mustard
<i>Taraxacum officinale</i>	common dandelion
<i>Thlaspi arvense</i>	pennycress
<i>Tragopogon dubius</i>	goatsbeard
<i>Veronica anagallis-aquatica</i>	water speedwell

The incidence of *Isatis tinctoria* and *Linaria dalmatica* increased greatly between 1970 and 1990.

FLORISTIC DIVERSITY.—The following species were reported from Red Butte Canyon by Cottam and Evans (1945) and by Bates (1963). Not only is the presence of these plants unverified by herbarium specimens (see Albee et al. 1988, which is based on specimens in the herbaria of Brigham Young University, Utah State University, and the University of Utah), but at

least six of them would not ordinarily occur within the elevational limits of the canyon:

<i>Agrostis semiverticillata</i>	water polypogon
<i>Amsinckia tessellata</i>	rough fiddleneck
<i>Angelica pinnata</i>	small-leaved angelica
* <i>Brickellia grandiflora</i>	tasseflower
<i>Castilleja angustifolia</i>	Indian paintbrush
<i>Cirsium flodmanii</i>	Flodman thistle
<i>Cryptantha flavoculata</i>	yellow-eye cryptanth
<i>Deschampsia caespitosa</i>	tufted hairgrass
* <i>Erigeron glabellus</i>	smooth fleabane
* <i>Eriogonum ovalifolium</i>	cushion buckwheat
<i>Gayophytum ramosissimum</i>	branchy groundsmoke
<i>Geranium bicknellii</i>	Bicknell cranesbill
<i>Glyceria grandis</i>	American mannagrass
<i>Juncus mertensianus</i>	Merten's rush
* <i>Lathyrus brachycalyx</i>	Rydberg sweetpea
<i>Mentzelia albicaulis</i>	whitestem blazing star
<i>Scirpus maritimus</i>	alkali bulrush
* <i>Stellaria longipes</i>	long-stalked starwort
<i>Valeriana edulis</i>	edible valerian

The following species were reported by Arnow (1971), but, for the reasons stated below, can no longer be considered part of the flora of the canyon:

<i>Arabis puberula</i> Nutt. (puberulent rockcress)	Collection identified by R. C. Rollins as an anomalous <i>A. lemmonii</i> Wats., the correction too late for the 1971 publication.
<i>Calypso bulbosa</i> (L.) Oakes (fairy slipper orchid)	1971 report based on a basal leaf, no subsequent evidence of its presence available.
<i>Carex muricata</i> L. (as <i>C. angustior</i> Mack)	A misidentification.

Species names now submerged with those of other species present in the canyon (also included in section on nomenclatural changes):

<i>Arabis divaricarpa</i> A. Nels = <i>A. holboellii</i> Hornem.	Holboell rockcress
<i>Bromus commutatus</i> Schrad. = <i>B. japonicus</i> Thunb.	Japanese or meadow chess
<i>Glyceria elata</i> (Nash) M. E. Jones = <i>G. striata</i> (Lam.) Hitchc.	fowl mannagrass
<i>Juncus tracyi</i> Rydb. = <i>J. ensifolius</i> Wikst.	swordleaf rush
<i>Taraxacum laevigatum</i> (Willd.) DC. = <i>T. officinale</i> Wiggers	common dandelion

Thus, the 511 species representing 73 families reported from Red Butte Canyon by Arnow (1971) can now be placed at 484 species (390 indigenous and 94 introduced) known to have

*With the assistance of Kaye Thorne and Leila Shultz, curators of the herbaria at Brigham Young and Utah State universities, respectively, a herbarium check was made to be certain that no Red Butte Canyon specimens exist for those species marked with an asterisk that, according to Albee et al. (1988), are not in Red Butte Canyon or its vicinity.

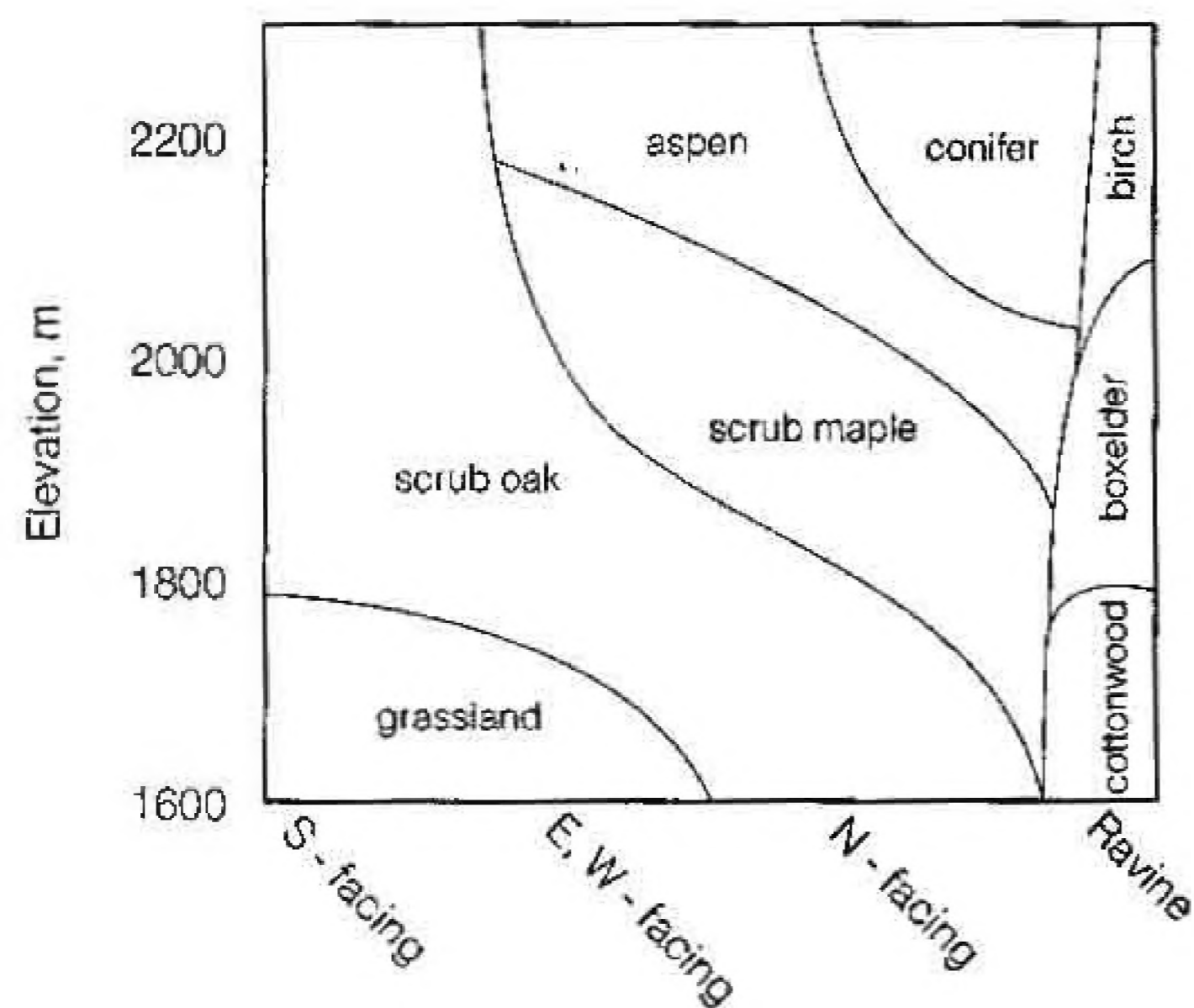


Fig. 10 Distribution, by elevation, of the major plant communities in Red Butte Canyon.

been present in the canyon at one time or another. Only two populations present in 1971 are definitely known to have been eliminated: *Lactuca biennis* (biennial wild lettuce), which was introduced into Utah from the north about 1967 but did not survive; and *Solidago occidentalis* (western goldenrod), a single streamside population at the mouth of the canyon taken out by the 1983–84 flooding.

According to Albee et al. (1988), the 390 indigenous species reported from Red Butte Canyon (Arnow 1971) also occur in at least one other canyon to the south. Arnow et al. (1980) and Albee et al. (1988) indicate that roughly 130 native plants not found in Red Butte Canyon have been collected between an elevation of 1828 and 2438 m (6000 and 8000 ft) in canyons having a greater altitudinal range in southern Salt Lake County. This figure indicates that the floristic diversity in Red Butte Canyon, while greater than that in heavily disturbed Emigration Canyon (Cottam and Evans 1945), is less than that in canyons farther south.

Nomenclatural changes since Arnow (1971) are listed in the Appendix.

PLANT ECOLOGY

VEGETATION DISTRIBUTION.—A number of studies have focused on describing the vegetation distribution within Red Butte Canyon (Kleiner and Harper 1966, Swanson, Kleiner, and Harper 1966, Kleiner 1967). There is a strong xeric to mesic elevation gradient, with lower portions of the canyon dominated by a spring-active grassland community and the

upper portions of the canyon typically consisting of summer-active scrub oak, aspen, and coniferous forest communities (Fig. 10). Composition within each of these communities is not constant, but instead species vary in their importance within a community type as orientation and elevation change. These elevation gradients represent a continuum of moisture availability, with high temperatures and low precipitation amounts at lower elevations making conditions more xeric, while slope orientations less southerly in exposure become progressively more mesic within an elevation band. Soil type (Fig. 5) and depth also play a major role in affecting plant distribution by providing variation in the water-holding capacity of the substrate. The distribution of the scrub-oak community to the highest elevations within the canyon is most likely related to soil conditions, since at high elevations scrub oak persists on south-, east-, and west-facing slopes that would normally be expected to be dominated by aspen if it were not for the very shallow, rocky soils that typify these elevations within Red Butte Canyon.

Red Butte Canyon has been largely protected from grazing since its acquisition by the U.S. Army almost a century ago. The consequence of this lack of grazing pressure at lower elevations is a recovery to near pristine levels, and this is clearly reflected in the early community analyses of Evans (1936) and Cottam and Evans (1945). Within the scrub oak and grassland communities of Red Butte Canyon and adjacent Emigration Canyon, a canyon annually exposed to sheep grazing, there are large differences in plant density (Fig. 11). Emigration Canyon was originally described by early pioneers as having a dense vegetation at lower elevations. However, grazing not only reduced that cover but also increased the fraction of the plant cover occupied by ruderal, weedy species (Cottam and Evans 1945). While plant density in Red Butte Canyon may be greater and weedy species composition lower as a result of reduced disturbance and grazing, the canyon is not free of these weedy components and historical effects (as noted in early sections). Dam construction during the 1920s and other U.S. Army activities within the lower portions of Red Butte Canyon have resulted in sufficient disturbance that many ruderal, weedy species, such as *Grindelia squarrosa* (curly gumweed), *Lactuca serriola* (prickly lettuce), and *Polygonum aviculare* (knotweed), are now common.

Samuelson (1950) conducted an analysis similar to that of Cottam and Evans (1945) on the algal components of the streams in Red Butte and Emigration canyons. He observed that as a result of livestock grazing and human settlement, sediment load and turbidity were much greater in Emigration than in Red Butte Creek. The consequence of this stream-quality difference was the dominance by algal genera in Emigration Creek that are turbidity tolerant, such as *Oscillatoria* and *Phormidium*. Conversely, in the clear waters of Red Butte Creek filamentous algae, primarily *Nostoc*, were most common. Overall algal densities were three times greater in Red Butte Creek, owing to the greater light penetration into that stream. At the same time, Whitney (1951) compared the distributions of aquatic insects in the two streams. He found that densities of aquatic insects were greater in Red Butte Creek. Of those insects persisting in Emigration Creek, there was a preponderance of species characterized by gills protected from silt, which would better allow them to tolerate the more turbid conditions in Emigration Creek.

PHENOLOGY.—Plant activity is governed by two parameters: temperature and soil moisture availability. Cold winter temperatures limit growth activity between November and March (Caldwell 1985, Comstock and Ehleringer 1992). While a limited number of species, such as the early spring ephemeral *Ranunculus testiculatus* (bur buttercup), may begin activity during warm periods in February, most annuals do not begin growth until the warm periods between snowstorms in early March. At lower elevations, a number of herbaceous perennials such as *Balsamorhiza macrophylla* (cutleaf balsamroot) may begin to leaf out during March, but most woody perennials do not leaf out until mid- to late April. The annuals and most herbaceous species at lower elevations have completed growth and reproduction by mid-June and then remain dormant until the following autumn or spring (Smedley et al. 1991). In contrast, woody species at lower elevations remain active from April through October, although the vast majority of the growth will occur during the spring (Donovan and Ehleringer 1991). At higher elevations, vegetative and reproductive growth are delayed until late May or June by cold temperatures. Plants at the higher elevations will remain active throughout the summer,

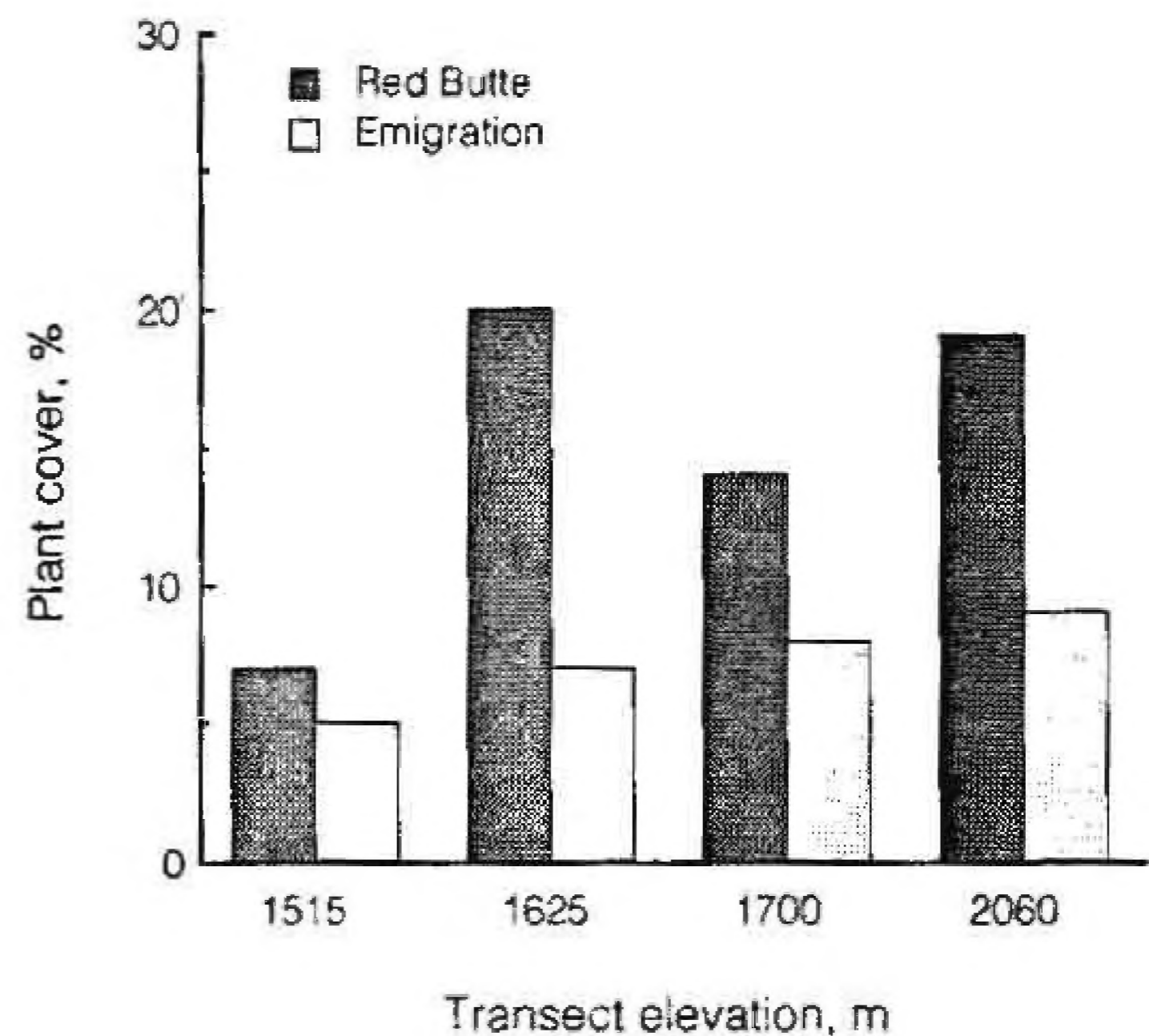


Fig. 11. A comparison of the plant cover in open grassland communities of different elevations in Red Butte and Emigration canyons. Adapted from Cottam and Evans (1945).

even though there may be little summer precipitation (Dina 1970, Dina and Klikoff 1973).

ADAPTATION.—In the nonforested portions of the Intermountain West, plant growth is largely restricted to spring and early summer periods by cold temperatures during winter and limited water availability during the summer (Caldwell 1985, Dobrowolski, Caldwell, and Richards 1990, Comstock and Ehleringer 1992). A number of recent reviews have addressed adaptation characteristics of plants growing in these environments (Caldwell 1985, DeLucia and Schlesinger 1990, Smith and Knapp 1990, Smith and Nowak 1990). For the most part, plants within Red Butte Canyon are exposed to a hot, dry environment, with little relief from developing water stress during the summer months. The only clear exception to this pattern is the series of plants within the riparian communities along the canyon bottom. To gain a better understanding of this occurrence, many of the recent ecological researchers within the Red Butte Canyon RNA have focused on mechanisms by which plant species have adapted to limited water availability.

Among the first ecophysiological studies was that by Dina (1970), who examined water stress levels of the dominant tree species in the lower portions of the canyon: *Acer grandidentatum* (bigtooth maple), *Acer negundo* (boxelder), *Artemisia tridentata* (big sagebrush), *Purshia tridentata* (bitterbrush), and *Quercus gambelii* (Gambel oak). Dina (1970) observed that

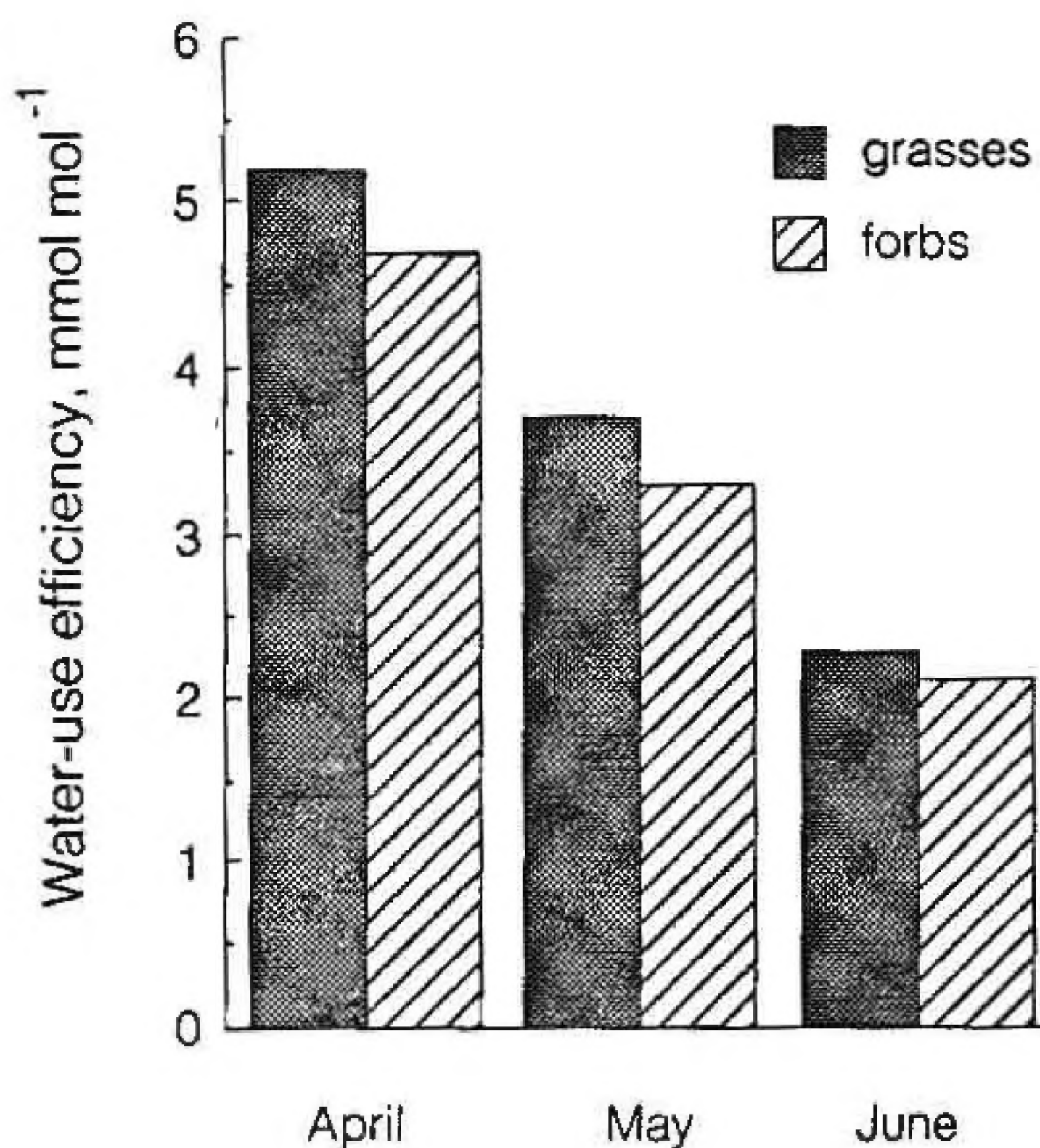


Fig. 12. The mean water-use efficiency values for grasses and forbs within the grassland community of Red Butte Canyon during main period of the growing season. Water-use efficiencies were calculated from carbon isotope discrimination values from Smedley et al. (1991) and the vapor pressure data in Figure 8.

midday leaf water potentials of -30 to -65 bars develop in perennials occupying slope sites during late summer, whereas water potentials of adjacent riparian tree species are maintained between -20 and -30 bars during the same periods. Water potentials in the range of -10 to -15 bars cause many crop species to wilt and close their stomata, reducing transpirational water loss. Tolerance of water stress levels as low as -40 to -60 bars is thought to occur in only the most drought-adapted aridland species. These late-summer water potential values on slope species are sufficiently low to close stomata and reduce photosynthesis to near zero values. In Dina's (1970) study photosynthetic rates of riparian species decreased by 50–80% from nonstress values, but riparian trees were able to maintain positive net photosynthetic rates throughout the summer. More recently, Dawson and Ehleringer (1992) and Donovan and Ehleringer (1991) conducted related studies and again observed that photosynthetic carbon gain of slope species is largely limited to spring and early summer, whereas riparian species are able to maintain photosynthetic rates throughout the year, albeit that photosynthetic rates are lower in summer than in spring.

Two common responses to limited water

availability are avoidance and tolerance. Avoidance of water stress is accomplished by completion of growth and reproductive activities before the onset of the summer drought, whereas tolerance is associated with the evolution of features that allow plants to persist through the drought period.

Several interesting studies have been conducted in Red Butte Canyon that shed light onto the nature of a plant's ability to tolerate water stress and persist through time. Treshow and Harper (1974) examined longevity of herbaceous perennials in grass, mountain brush, aspen, and conifer communities throughout the canyon. They observed that life expectancies of dominant herbaceous perennial species, such as *Astragalus utahensis* (Utah milkvetch), *Balsamorhiza macrophylla* (cutleaf balsamroot), *Hedysarum boreale* (northern sweetvetch), and *Wyethia amplexicaulis* (mulesears), are relatively short (3–20 years) when compared to the longer-lived (>65 years) grass species, such as *Agropyron spicatum* (bluebunch wheatgrass) and *Stipa comata* (needle-and-thread). The inability to persist through successive drought years may be one of the reasons that dicotyledonous species have shorter life expectancies than monocotyledonous species. Related to this, Smedley et al. (1991) examined the water-use efficiency of these and other herbaceous grassland species. Water-use efficiency, the ratio of photosynthesis to transpiration, serves as a measure of how much photosynthetic carbon gain occurs per unit water loss from the leaf. Dicot herbaceous perennials had consistently lower water-use efficiencies than their monocot counterparts (Fig. 12). The differences in intrinsic water-use efficiency within this life form may be a major contributing factor to the shorter life expectancy in dicot herbaceous species. Consistent with this pattern, Smedley et al. (1991) observed that water-use efficiency of annual species is significantly lower than that of perennial species in grasslands along the lower portions of the canyon. They also observed that perennials which persist longer into the summer drought period have higher water-use efficiencies than those species that became dormant in late spring. During 1988–90, precipitation was unusually low. The effects of the three-year drought are now seen in Gambel oak and bigtooth maple at their lower distribution limits, especially on shallow soils, where stem dieback has become prevalent.

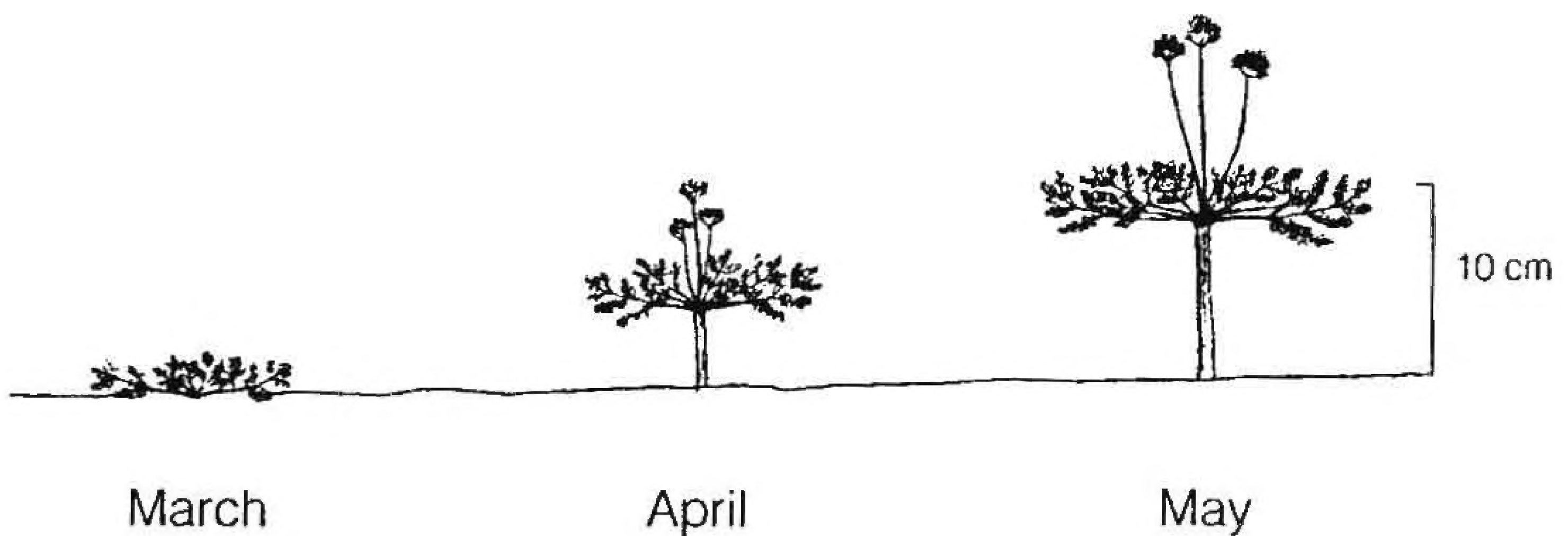


Fig. 13. Height of *Cymopterus longipes* above the ground surface at different months during the spring growing season. After Werk et al. (1986).

Ehleringer (1988) examined leaf-level adaptations of plants along the entire elevational transect within Red Butte Canyon. This study focused on determining patterns of leaf angle and leaf absorptance variation among species within communities exposed to different degrees of drought stress. Increased leaf angle and decreased leaf absorptance reduce the solar energy incident on leaves and are viewed as mechanisms for both reducing leaf energy loads (reducing leaf temperature) and increasing water-use efficiency. Along a transect from grassland through coniferous forest, very few plant species exhibit any significant changes in leaf absorptance. However, leaf angles among species become progressively steeper in drier habitats. This pattern is consistent with the notion that as plants are exposed to progressively drier environments, the general adaptive response of species within the community is to increase leaf angle, thereby reducing incident solar radiation levels.

In the grasslands on the lower portions of Red Butte Canyon is a most unusual plant species, *Cymopterus longipes* (long-stalk spring-parsley). Sometimes known as the "elevator plant," *C. longipes* is a prostrate herbaceous perennial with an elongating pseudoscape (a scape is a leafless flowering stalk arising from ground level; the pseudoscape is an elongation of the leaf-bearing stem in the region between the roots and existing leaves). Other *Cymopterus* species also have a pseudoscape, but in none of the other species is it as well developed as in *C. longipes*. In spring, solar heating of the ground surface increases soil and leaf temperatures and can result in moderately warm leaf temperatures (30–35 C). These tem-

peratures are substantially higher than the optimum photosynthetic temperature for the elevator plant and result in both a decreased photosynthetic rate and a decreased water-use efficiency (Werk et al. 1986). To increase both the rate of photosynthetic carbon gain and water-use efficiency, the pseudoscape elongates as spring temperatures progressively increase (Fig. 13). The result is that what was once a prostrate canopy is elevated above the warm soil surface and now exposed to cooler air temperatures above the ground surface. Werk et al. (1986) showed that the rate at which the pseudoscape elongates is dependent on the rate of soil-surface heating. Plants from protected or north-facing sites elongate less than those from exposed, southerly sites.

Donovan and Ehleringer (1991) examined relationships between water use and the likelihood of establishment by common shrub and tree species in the lower portions of Red Butte Canyon. They observed that photosynthesis is greater in seedlings than in adults throughout most of the growing season, but that water stress and water-use efficiency are lower in seedlings. Seedling mortality in several of the species is associated with higher water-use efficiencies, suggesting that mortality selection occurs with greater frequency in seedlings that are conservative in their water use before they have established sufficiently deep roots to survive the long summer drought period.

Few studies have addressed ecophysiological aspects of riparian ecosystems in the Intermountain West. This is somewhat surprising since riparian ecosystems are most often among the first to be damaged by human-related activities, from outdoor recreation to water

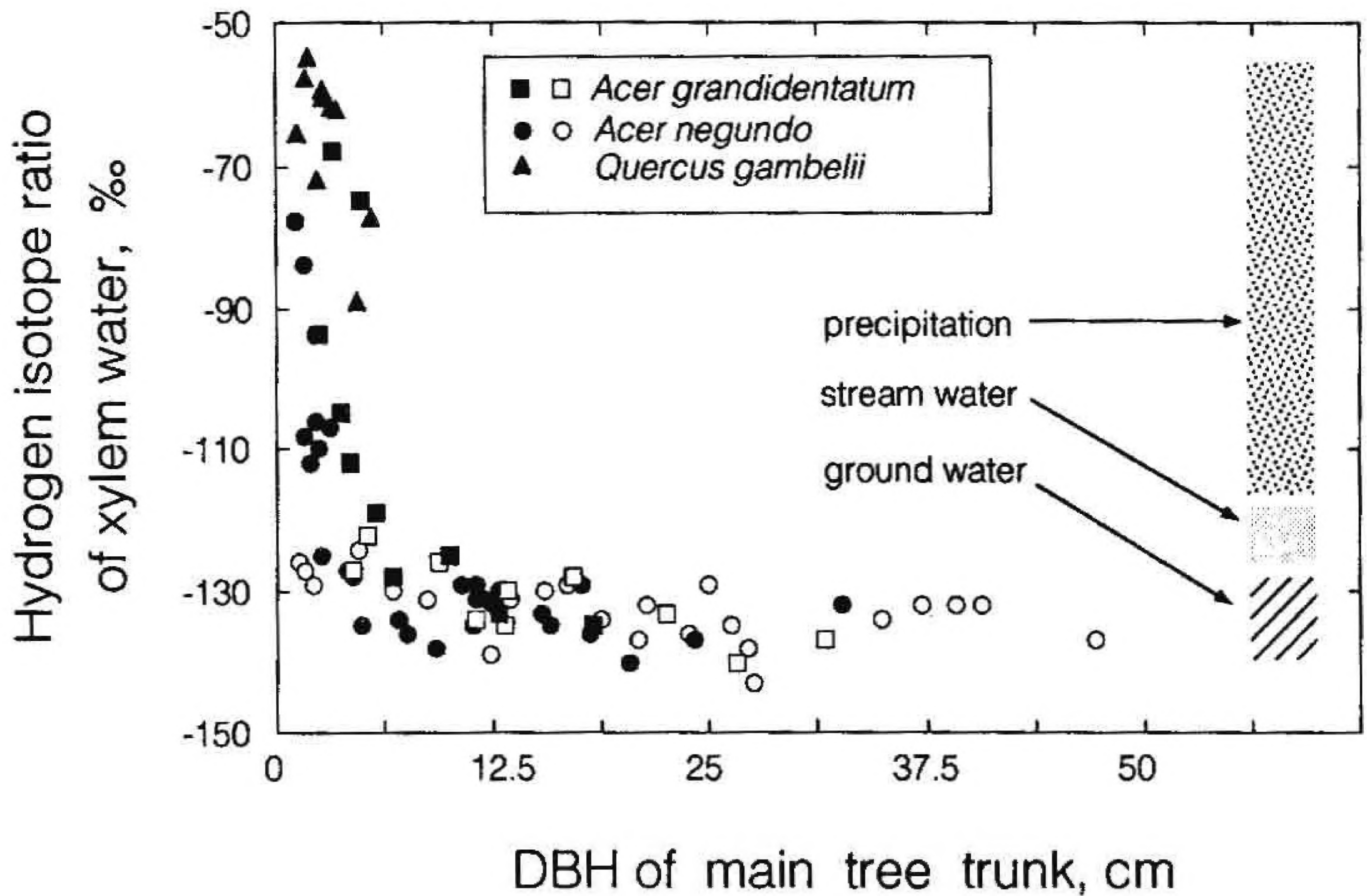


Fig. 14. Hydrogen isotope ratio of stem waters of three common streamside and adjacent nonstreamside tree species in Parleys Fork of Red Butte Canyon as a function of the diameter at breast height of the main trunk. Plotted as gray bars are also the hydrogen isotope ratios of the three possible water sources for these plants: local precipitation, stream water, and groundwater. Open symbols represent streamside plants and closed symbols represent nonstreamside plants. Adapted from Dawson and Ehleringer (1991).

impoundment to grazing. Red Butte Canyon, as one of the few remaining riparian systems in the Intermountain West not severely impacted by human activities, is ideal for studies of the adaptations of riparian plants and for comparative studies of species sensitivities to human-related activities.

In a recent study Dawson and Ehleringer (1992) examined water sources used by riparian plants species. In their study, plants were segregated according to microhabitat and size: streamside versus nonstreamside and juvenile versus adult (based on diameter at breast height). Their results were rather startling and suggest that a new perspective is necessary when evaluating riparian communities, their establishment potentials, and their sensitivity to disturbance. Dawson and Ehleringer (1991) used hydrogen isotope analyses of stem waters to determine the extent to which different categories of riparian trees utilize stream water, recent precipitation, or groundwater. Hydrogen isotopes are not fractionated by roots during water uptake; therefore, the hydrogen isotope ratios of stem water will reflect the water

sources currently used by that plant. Rain, groundwaters, and stream waters differ in their hydrogen isotope ratios, providing a signal difference that could be detected by stem-water analyses. Dawson and Ehleringer (1991) observed that among mature tree species none were directly using stream water (Fig. 14). All were using waters from a much greater depth, which had a hydrogen isotope ratio more negative than either stream water or precipitation. Young streamside trees utilized stream water, but only when small. Young trees at nonstreamside locations utilized precipitation, having access to neither stream water nor deeper groundwater. One possible reason that streamside trees may not depend on stream water is that this surface water source may occasionally dry up during extreme drought years and become unavailable to these trees; another is that stream channels occasionally change their course, and dependence on surface moisture would then result in increased drought stress and likely increased mortality rates. The long-term stream discharge rates suggest that stream

water may be less dependable than deeper groundwater sources (Fig. 6).

Many plants do not contain both male and female reproductive structures in their flowers, but are present as either male or female plants (dioecy). Freeman et al. (1976, 1980) noted that dioecy is a common feature of plants in the Intermountain West. Furthermore, they observed that the two sexes are usually not randomly distributed across the landscape. Rather there is a spatial segregation of the two sexes such that females tend to predominate in less stressful microsites (wetter, shadier, etc.), whereas males occur with greater frequencies on more stressful sites (drier, sunnier, saltier, etc.). In Red Butte Canyon, Freeman et al. (1976) investigated spatial distributions of *Acer negundo* (boxelder, a riparian tree) and *Thalictrum fendleri* (Fendler meadowrue, a perennial herb). In both species, there was a strong spatial segregation of the two sexes.

Dawson and Ehleringer (1992) have followed up on the initial observations of spatial segregation in *Acer negundo* (boxelder), seeking to determine whether intrinsic physiological differences among the sexes may contribute to plant mortality in different microsites. They observed that female trees have significantly lower water-use efficiencies than male trees on both streamside (where female predominate) and nonstreamside locations (where males predominate). Male trees exhibit a higher water-use efficiency in dry sites than in streamside locations, but female trees exhibit no such response across microhabitats. The lack of a change in water-use efficiency by female trees on dry, nonstreamside locations may contribute to an increased mortality rate, which then ultimately results in a male-biased sex ratio at these sites.

MAMMALIAN FAUNA

The mammalian fauna of Red Butte Canyon is remarkably diverse, due in part to the altitudinal gradient and numerous small patches of various plant communities indigenous to the area. A particularly rich small mammal fauna is associated with the patches of riparian habitat along Red Butte Creek and its tributaries. Prior to the run-off of 1983, riparian habitats were much more extensively developed than at present. Numerous marshy meadows existed in association with large, active beaver dams prior

to 1982. The loss of active beaver dams in the early 1980s has doubtless greatly reduced the populations of small mammals that are restricted to the mesic-marshy habitats of the canyon.

Nonetheless, based on the altitudinal gradient and vegetational diversity of Red Butte Canyon, a total of 51 species of mammals should hypothetically occur there. Below is a list of the 39 species of mammals known to occur in Red Butte Canyon.

INSECTIVORA—SORICIDAE	
<i>Sorex palustris</i>	water shrew
<i>Sorex vagrans</i>	wandering shrew
<i>Sorex cinereus</i>	masked shrew
CHIROPTERA—VESPERTILIONADAE	
<i>Eptesicus fuscus</i>	big brown bat
LACOMORPHA—LEPORIDAE	
<i>Lepus townsendi</i>	white-tailed jackrabbit
<i>Sylvilagus nuttallii</i>	Nuttall cottontail
RODENTIA—SCIURIDAE	
<i>Tamiasciurus hudsonicus</i>	red squirrel
<i>Marmota flaviventris</i>	yellow-bellied marmot
<i>Spermophilus armatus</i>	Uinta ground squirrel
<i>Spermophilus variegatus</i>	rock squirrel
<i>Eutamias minimus</i>	least chipmunk
<i>Glaucomys sabrinus</i>	northern flying squirrel
RODENTIA—GEOMYIDAE	
<i>Thomomys talpoides</i>	northern pocket gopher
<i>Thomomys bottae</i>	botta pocket gopher
RODENTIA—CASTORIDAE	
<i>Castor canadensis</i>	beaver
RODENTIA—MURIDAE	
<i>Reithrodontomys megalotis</i>	western harvest mouse
<i>Peromyscus maniculatus</i>	deer mouse
<i>Peromyscus boylii</i>	brush mouse
<i>Clethrionomys gapperi</i>	red-backed vole
<i>Ondatra zibethicus</i>	muskrat
<i>Phenacomys intermedius</i>	heather vole
<i>Microtus montanus</i>	montane vole
<i>Microtus longicaudus</i>	long-tailed vole
<i>Arvicola richardsoni</i>	water vole
RODENTIA—ZAPODIDAE	
<i>Zapus princeps</i>	western jumping mouse
RODENTIA—ERETHIZONTIDAE	
<i>Erethizon dorsatum</i>	porcupine
CARNIVORA—CANIDAE	
<i>Canis latrans</i>	coyote
CARNIVORA—PROCYONIDAE	
<i>Bassariscus astutus</i>	ring-tailed cat
<i>Procyon lotor</i>	raccoon
CARNIVORA—MUSTELIDAE	
<i>Mustela frenata</i>	long-tailed weasel
<i>Mustela erminea</i>	ermine
<i>Mustela vison</i>	mink
<i>Taxidea taxus</i>	badger
<i>Mephitis mephitis</i>	striped skunk
CARNIVORA—FELIDAE	
<i>Lynx rufus</i>	bobcat
<i>Felis concolor</i>	mountain lion
ARTIODACTYLA—CERVIDAE	
<i>Cervus canadensis</i>	elk
<i>Odocoileus hemionus</i>	mule deer
<i>Alces americanus</i>	moose

Some of the larger species have been observed only occasionally, such as the bobcat, mountain lion, and moose. But others such as the mule deer, elk, and coyote are observed with high frequency at some seasons. A rather rich rodent fauna inhabits the canyon, with many of the species preferentially occupying the moist riparian communities of grasses, forbs, and shrubs. Thus, the red-backed vole, heather vole, montane vole, long-tailed vole, water vole, and jumping mouse are virtually restricted to the small mesic meadows along Red Butte Creek and its tributaries. Similarly, the three species of shrews in the canyon are distributed almost exclusively in the riparian habitats.

In some larger meadows, such as along Parleys Fork and at Porcupine Gulch, the microtine rodents are distributed in a strongly zonal pattern. Long-tailed voles are found in the driest parts of the meadows, montane voles in the more mesic areas where grasses, sedges, and forbs comprise a diverse community, and water voles in the immediate streamside area, their burrows often entering the bank at the water's edge. Red-backed voles and heather voles are typically found around the bases of willows in the meadows, as well as around the edges of conifers at higher elevations.

A few species are found only at higher elevations in association with *Pseudotsuga menziesii* (Douglas-fir) and *Populus tremuloides* (aspen). These include the red squirrel, Uinta ground squirrel, yellow-bellied marmot, and least chipmunk. The oak-mountain mahogany zone seems to be the preferred habitat of the rock squirrel and perhaps the ring-tailed cat as well. Several dissertations dealing with the ecology and physiological adaptations of shrews, microtine rodents, and jumping mice have utilized study sites in Red Butte Canyon (Forslund 1972, Cranford 1977).

AVIAN FAUNA

In his study of the birds of Red Butte Canyon, Perry (1973) found that 106 species occurred in the area during his study. Of these, 32 species are permanent residents and 44 are summer residents. The remainder (30) are migrants or winter residents. The permanent resident birds include:

FALCONIFORMES—ACCIPITRIDAE	
<i>Accipiter gentilis</i>	Goshawk
<i>Accipiter striatus</i>	Sharp-shinned Hawk
<i>Accipiter cooperi</i>	Cooper's Hawk

GALLIFORMES—TETRAONIDAE	
<i>Dendragapus obscurus</i>	Blue Grouse
<i>Bonasa umbellus</i>	Ruffed Grouse
GALLIFORMES—PHASIANIDAE	
<i>Lophortyx californicus</i>	California Quail
<i>Phasianus colchicus</i>	Ring-necked Pheasant
<i>Alectoris graeca</i>	Chukar
STRIGIFORMES—STRIGIDAE	
<i>Otus flammeolus</i>	Flammulated Owl
<i>Bubo virginianus</i>	Great Horned Owl
<i>Asio otus</i>	Long-eared Owl
CORACIIFORMES—ALCEDINIDAE	
<i>Megaceryle alcyon</i>	Belted Kingfisher
PICIFORMES—PICIDAE	
<i>Colaptes cafer</i>	Red-shafter Flicker
<i>Sphyrapicus varius</i>	Yellow-bellied Sapsucker
<i>Dendrocopus villosus</i>	Hairy Woodpecker
<i>Dendrocopus pubescens</i>	Downy Woodpecker
PASSERIFORMES—CORVIDAE	
<i>Cyanocitta stelleri</i>	Steller's Jay
<i>Aphelocoma coerulescens</i>	Scrub Jay
<i>Pica pica</i>	Magpie
PASSERIFORMES—PARIDAE	
<i>Parus atricapillus</i>	Black-capped Chickadee
<i>Parus gambeli</i>	Mountain Chickadee
<i>Psaltriparus minimus</i>	Common Bushtit
PASSERIFORMES—SITTIDAE	
<i>Sitta canadensis</i>	Red-breasted Nuthatch
PASSERIFORMES—CERTHIIDAE	
<i>Certhia familiaris</i>	Brown Creeper
PASSERIFORMES—CINCLIDAE	
<i>Cinclus mexicanus</i>	Dipper
PASSERIFORMES—TURDIDAE	
<i>Myadestes townsendi</i>	Townsend's Solitaire
PASSERIFORMES—SYLVIIDAE	
<i>Regulus satrapa</i>	Golden-crowned Kinglet
PASSERIFORMES—STURNIDAE	
<i>Sturnus vulgaris</i>	Starling
PASSERIFORMES—ICTERIDAE	
<i>Sturnella neglecta</i>	Western Meadowlark
PASSERIFORMES—FRINGILLIDAE	
<i>Carpodacus mexicanus</i>	House Finch
<i>Spinus pinus</i>	Pine Siskin
<i>Junco oreganus</i>	Oregon Junco

In addition to the species that are permanent residents in Red Butte Canyon, the following list of summer residents represents species that probably also nest in the canyon:

ANSERIFORMES—ANATIDAE	
<i>Anas platyrhynchos</i>	Mallard Duck
FALCONIFORMES—AOCIPITRIDAE	
<i>Buteo jamaicensis</i>	Red-tailed Hawk
<i>Aquila chrysaetos</i>	Golden Eagle
FALCONIFORMES—FALCONIDAE	
<i>Falco sparverius</i>	Sparrow Hawk
CHARADRIIFORMES—SCOLOPACIDAE	
<i>Actitis macularia</i>	Spotted Sandpiper
COLUMBIFORMES—COLUMBIDAE	
<i>Zenaidura macroura</i>	Mourning Dove
APODIFORMES—TROCHILIDAE	
<i>Archilochus alexandri</i>	Black-chinned Hummingbird
<i>Selasphorus platycercus</i>	Broad-tailed Hummingbird
PASSERIFORMES—TYRANNIDAE	
<i>Empidonax oberholseri</i>	Dusky Flycatcher

<i>Empidonax difficilis</i>	Western Flycatcher
<i>Contopus sordidulus</i>	Western Wood Peewee
PASSERIFORMES—HIRUNDINIDAE	
<i>Tachycineta thalassina</i>	Violet-green Swallow
<i>Iridoprocne bicolor</i>	Tree Swallow
<i>Riparia riparia</i>	Bank Swallow
<i>Stelgidopteryx ruficollis</i>	Rough-winged Swallow
<i>Hirundo rustica</i>	Barn Swallow
<i>Petrochelidon pyrrhonota</i>	Cliff Swallow
PASSERIFORMES—TROGLODYTIDAE	
<i>Troglodytes aedon</i>	Honse Wren
<i>Salpinctes obsoletus</i>	Rock Wren
PASSERIFORMES—TURDIDAE	
<i>Turdus migratorius</i>	Robin
<i>Hylocichla guttata</i>	Hermit Thrush
<i>Hylocichla ustulata</i>	Swainson's Thrush
<i>Sialia currucoides</i>	Mountain Bluebird
PASSERIFORMES—SYLVIIDAE	
<i>Poliophtila caerulea</i>	Blue-gray Gnatcatcher
PASSERIFORMES—VIREONIDAE	
<i>Vireo gilvus</i>	Warbling Vireo
PASSERIFORMES—PARULIDAE	
<i>Vermivora celata</i>	Orange-crowned Warbler
<i>Vermivora virginiae</i>	Virginia's Warbler
<i>Dendroica petechia</i>	Yellow Warbler
<i>Dendroica auduboni</i>	Audubon's Warbler
<i>Oporornis tolmiei</i>	MacGillivray's Warbler
<i>Wilsonia pusilla</i>	Wilson's Warbler
PASSERIFORMES—ICTERIDAE	
<i>Icterus bullockii</i>	Bullock's Oriole
<i>Molothrus ater</i>	Brown-headed Cowbird
PASSERIFORMES—TIRRAUPIDAE	
<i>Piranga ludoviciana</i>	Western Tanager
PASSERIFORMES—FRINGILLIDAE	
<i>Pheucticus melanocephalus</i>	Black-headed Grosbeak
<i>Passerina amoena</i>	Lazuli Bunting
<i>Carpodacus cassinii</i>	Cassin's Finch
<i>Spinus tristis</i>	American Goldfinch
<i>Chonura chlorura</i>	Green-tailed Towhee
<i>Pipilo erythrophthalmus</i>	Rufous-sided Towhee
<i>Poocetes gramineus</i>	Vesper Sparrow
<i>Junco caniceps</i>	Gray-headed Junco
<i>Spizella passerina</i>	Chipping Sparrow
<i>Melospiza melodia</i>	Song Sparrow

ROLE OF RESEARCH NATURAL AREAS

Federal land-management agencies have been developing a national system of Research Natural Areas since 1927. More than 400 areas have received this designation nationally. Since inception of the RNA Program, there have been two primary purposes for Research Natural Areas:

1. to preserve a representative array of all significant natural ecosystems and their inherent processes as baseline areas; and
2. to obtain, through scientific education and research, information about natural system components, inherent processes, and comparisons with representative manipulated systems.

Research Natural Areas provide several specific advantages to the nation's scientific community, which are typically not otherwise available. These include potential use of an area that has had minimal human interference and has a reasonable assurance of long-term existence, and the potential association and interaction of scientists from different disciplines leading to discoveries unlikely to occur without such an association. Conducting research at common locations is key to developing these interactions. Research Natural Areas not only assist in the progress of basic science, but also provide federal and state agencies with information upon which to base management decisions. The melding of ecosystem preservation and research on basic ecological processes at Research Natural Areas provides numerous valuable options to society. The Red Butte Canyon RNA serves this purpose well. Although initially affected by human activities during the early settlement of the Salt Lake Valley, the canyon was soon set aside by the federal government and has now had nearly a century to recover (though the loss of beaver represents a significant impact to the ecology of the riparian ecosystem). Other canyons in the Wasatch Range have not received equivalent protection.

As we move into the twenty-first century, there will be increasing pressure to understand the dynamics of ecological systems and man's impact on ecological processes. Maintained as a protected watershed, the Red Butte Canyon RNA provides a unique opportunity for addressing these important issues to human society and to the preservation of our environment. Unprotected, it is an invaluable resource lost forever.

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APPENDIX

Nomenclatural Changes in the Flora, 1971-1990

The following is a list of nomenclatural and orthographic changes made since publication of the Vascular Flora of Red Butte Canyon, Salt Lake County, Utah (Arnold 1971). Family names of flowering plants are changed to accord with those used by Cronquist (1981). All other name changes are contained in Welsh et al. (1987) unless otherwise specified.

AMARANTHACEAE

Amaranthus graecizans of American authors, not L. = *A. blitoides* Wats.

AMARYLLIDACEAE = LILIACEAE

Brodiaea douglasii Wats. = *Triteleia grandiflora* Lindl.

ANACARDIACEAE

Rhus radicans L. = *Toxicodendron rydbergii* (Small) Greene

BERBERIDACEAE

Berberis repens Lindl. = *Mahonia repens* (Lindl.) G. Don

BORAGINACEAE

Cryptantha nana (Eastw.) Pays. = *Cryptantha humilis* (Gray) Pays.

Hackelia jessicae (McGregor) Brand = *H. micrantha* (Eastw.) J. L. Gentry

Lappula echinata Gilib. = *L. squarrosa* (Retz.) Dumort. (Weber 1987)

CACTACEAE

Opuntia aurea Baxter, misapplied to *O. macrorhiza* Engelm.

CARYOPHYLLACEAE

Cerastium vulgatum L. = *C. fontanum* Baumg.

Stellaria jamesiana Torr. = *Pseudostellaria jamesiana* (Torr.) Weber & Hartman (Weber and Hartman 1979)

CELASTRACEAE

Pachistima = *Paxistima*

CHENOPODIACEAE

Salsola kali L. = *Salsola iberica* Sennen & Pau

COMPOSITAE = ASTERACEAE

Aster chilensis Nees = *A. ascendens* Lindl.

Haplopappus rydbergii Blake = *H. watsonii* Gray

Lactuca pulchella (Pursh) DC. = *L. tatarica* (L.) C. A. Mey

Matricaria matricarioides (Less.) Porter = *Chamomilla suaveolens* (Pursh) Rydb.

Solidago nemoralis Ait. = *S. sparsiflora* A. Gray

S. occidentalis (Nutt.) T. & G. = *Euthamia occidentalis* Nutt. (Sieren 1981)

Taraxacum laevigatum (Willd.) DC. = *T. officinale* Wiggers (Weber 1987)

Viguiera multiflora (Nutt.) Blake = *Heliomeris multiflora* Nutt.

CORNACEAE

Cornus stolonifera Michx. = *Cornus sericea* L.

CRUCIFERAE = BRASSICACEAE

Arabis divaricarpa A. Nels. = *A. holboellii* Hornem.

Rorippa islandica (Oed.) Borb. = *R. palustris* (L.) Besser

R. truncata (Jeps.) Stuckey = *R. tenerrima* Greene

CUSCUTACEAE

Cuscuta campestris Yunck. = *C. pentagona* Engelm.

CYPERACEAE

Carex utriculata Boott = *C. rostrata* Stokes

GRAMINEAE = POACEAE (Arnou 1987)

Agropyron caninum (L.) Beauv. = *Elymus trachycaulus* (Link) Shinnars

A. dasystachyum (Hook.) Scribn. = *Elymus lanceolatus* (Scribn. & Sm.) Gould

A. intermedium (Host) Beauv. = *Elymus hispidus* (Opiz) Meld.

A. smithii Rydb. = *Elymus smithii* (Rydb.) Gould

A. spicatum (Pursh) Scribn. = *Elymus spicatus* (Pursh) Gould

Agrostis alba L. = *A. stolonifera* L.

A. semiverticillata (Forsk.) C. Christ. = *Polypogon semiverticillatus* (Forsk.) Nylander

Aristida longiseta Steud. = *A. purpurea* Nutt.

Bromus brizaeformis Fisch. & Mey. = *B. briziformis*

B. commutatus Schrad. = *B. japonicus* Thunb.

Glyceria elata (Nash) M. E. Jones = *G. striata* (Lam.) Hitchc.

Hesperochloa kingii (Wats.) Rydb. = *Leucopoa kingii* (Wats.) W. A. Weber

Koeleria cristata Pers. = *K. macrantha* (Ledeb.) Schult.

Oryzopsis hymenoides (R. & S.) Ricker = *Stipa hymenoides* R. & S.

Poa sandbergii Vasey = *P. secunda* Presl (Arnou 1981)

Sitanion jubatum J. G. Smith, misapplied to *Elymus elymoides* (Raf.) Swezey

Stipa occidentalis Thurb. = *S. nelsonii* Scribn.

JUNCACEAE

Juncus balticus Willd. = *J. arcticus* Willd.

J. tracyi Rydb. = *J. ensifolius* Wikst.

LABIATAE = LAMIACEAE

Moldavica parviflora (Nutt.) Britt. = *Dracocephalum parviflorum* Nutt.

LEGUMINOSAE = FABACEAE

MORACEAE = CANNABACEAE

Humulus lupulus L. = *H. americanus* Nutt.

ONAGRACEAE

Epilobium paniculatum T. & G. = *E. brachycarpum* Presl

E. watsonii Barbey = *E. ciliatum* Raf.

Oenothera hookeri T. & G. = *O. elata* H.B.K.

Zauchneria garrettii A. Nels. = *Z. latifolia* (Hook.) Greene

OROBANCHACEAE

Orobanche californica Cham. & Schlecht. = *O. corymbosa* (Rydb.) Ferris

POLEMONIACEAE

Ipomopsis aggregata (Pursh) V. Grant = *Gilia aggregata* (Pursh) Spreng.

POLYPODIACEAE, as it occurs in Red Butte Canyon, is now divided into the following families (Tryon and Tryon 1982):

DENNSTAEDTIACEAE, of which the genus *Pteridium* is a member

DRYOPTERIDACEAE, which includes the genera *Cystopteris* and *Woodsia*

Cystopteris fragilis (L.) Bernh. is now known to include two taxa (Lellinger 1985), of which only *C. tenuis* (Michx.) Desv. occurs in Red Butte Canyon.

RANUNCULACEAE

Ranunculus longirostris Godron = *R. aquatilis* L.

R. testiculatus Crantz = *Ceratocephalus orthocerus* DC. (Weber 1987)

SALICACEAE

Salix rigida Muhl. = *S. lutea* Nutt.

SAXIFRAGACEAE

Lithophragma bulbifera Rydb. = *L. glabra* Nutt.

SCROPHULARIACEAE

Castilleja leonardii Rydb. = *C. rhexifolia* Rydb.

TAMARICACEAE

Tamarix pentandra Pall. = *T. ramosissima* Ledeb.

UMBELLIFERAE = APIACEAE

Cicuta douglasii (DC.) Coult. & Rose = *C. maculata* L.

Lomatium nuttallii (Gray) Macbr. = *L. kingii* (Wats.) Cronq.