Series 1936, No. 13 Issued March 1942

Soil Survey

The Virgin River Valley Area Utah-Arizona

By
F. O. YOUNGS, in Charge, and O. F. BARTHOLOMEW
United States Department of Agriculture
and
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Utah Agricultural Experiment Station

UNITED STATES DEPARTMENT OF AGRICULTURE
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SOIL SURVEY OF THE VIRGIN RIVER VALLEY AREA, UTAH-ARIZONA

By F. O. YOUNGS, in Charge, and O. F. BARTHOLOMEW, Division of Soil Survey,[1] Bureau of Plant Industry, United States Department of Agriculture, and D. S. JENNINGS, LeMOYNE WILSON, I D. ZOBELL, M. H. WALLACE, J. E. FLETCHER, and WILLIAM BAUGH, Utah Agricultural Experiment Station

Area Inspected by MACY H. LAPHAM, Inspector, District 5

United States Department of Agriculture in cooperation with the Utah Agricultural Experiment Station

CONTENTS

INTRODUCTION

The soil survey map and report of the Virgin River Valley area are intended to convey information concerning the soils, crops, and agriculture of the area to a wide variety of readers.

[1] The field work for this survey was done while the Division was a part of the Bureau of Chemistry and Soils.

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Farmers, landowners, and prospective purchasers and tenants ordinarily are interested in some particular locality, farm, or field. They need to know what the soil is like on a certain piece of land, what crops are adapted, what yields may be expected, and what fertilization and other management practices are needed for best results. Often they do not wish to read the whole soil survey report, and they need not do so to obtain much of the information essential to their purpose.

One interested in a particular piece of land should first locate it on the colored soil map attached to the report. Then, from the color and symbol, the soil may be identified in the legend on the margin of the map. Using the table of contents at the beginning of the report, the reader can find the description of the soil type or types. Under each soil type heading is specific information about that particular soil. There is a description of the landscape including the lay of the land, drainage, stoniness (if any), vegetation, and other external characteristics, and the internal or profile characteristics of the soil—its color, depth, texture, structure, and chemical or mineralogical composition. The description includes information about present land use, crops grown, and yields obtained, and statements concerning possible uses and present and recommended management.

By referring to the section on Productivity Ratings and Land Classification one may get an idea of how the soil types compare, one with another, as to productivity for the various crops and how well they are suited for the growing of crops or for other uses. Further ideas concerning land use and soil management can be obtained from the section dealing with those subjects. Irrigation, drainage, and the accumulation of salts ("alkali") are treated in a separate section.

For the person unfamiliar with the area or region, there is a general description of the area as a whole in the first part of the report. Geography, physiography, regional drainage, relief, vegetation, climate, population, transportation facilities, and markets are discussed. A brief summary at the end of the report gives a condensed description of the area and important facts concerning the soils and agriculture.

The agricultural economist and the general student of agriculture will be interested in the sections on Agricultural History and Statistics, Productivity Ratings and Land Classification, and Land Uses and Soil Management.

Soil specialists, agronomists, experiment station and agricultural extension workers, and students of soils and crops will be interested in the more general discussion of soils in the section on Soils and Crops, as well as in the soil type descriptions. They will also be interested in the productivity ratings and the section on Land Uses and Soil Management.

For the soil scientist, the section on Morphology and Genesis of Soils presents a brief technical discussion of the soils and of the soil-forming processes that have produced them.

AREA SURVEYED

The Virgin River Valley area is in the southern part of Washington County, Utah, and the northern part of Mohave County, Ariz. (fig. 1). St. George, Utah, the principal town and the county seat of Washington County, is about 27 miles from the southwest corner of the State, 8 miles north of the Arizona State line, and 265 miles, by air line, southwest of Salt Lake City. The area contains 320 square miles, or 204,800 acres, most of which is in Utah, although a small part is in Arizona.

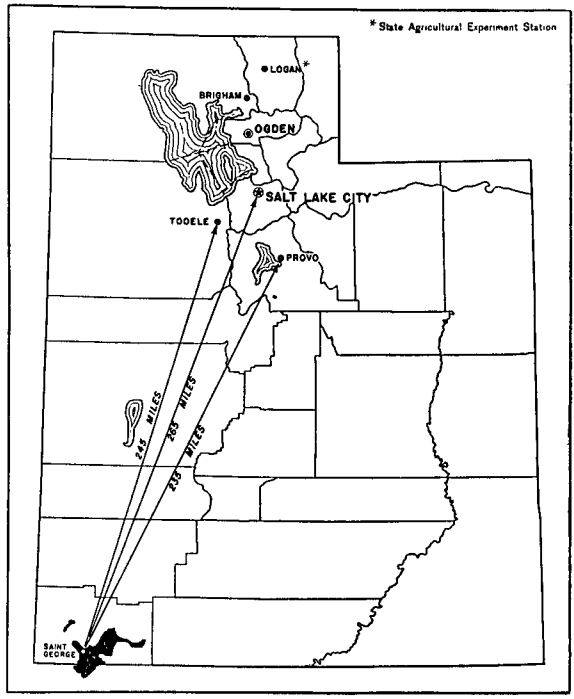


FIGURE 1.—Sketch map showing location of the Virgin River Valley area, Utah-Ariz.

PHYSIOGRAPHY, RELIEF, AND DRAINAGE

This area is a part of the Colorado River basin and lies in the Colorado Plateaus physiographic province. The general aspect of the area surveyed is that of a valley or basin having a very rough and uneven surface and surrounded by mountains and high plateaus. Extensive faulting and geologic erosion have given rise to numerous cliffs, sharp hogback ridges, more or less dissected mesas, canyons, and comparatively small areas of smooth valley lands. Lava flows, forming a more or less uneven surface, and volcanic cinder cones characterize parts of the area.

The Virgin River, the Santa Clara River, and a number of their tributaries have cut deep, narrow, vertical-walled canyons throughout much of their upper courses, but in places their troughs widen into narrow valleys with comparatively level floors. In the vicinities of Springdale, Rockville, Virgin, Bloomington, Santa Clara, and Gunlock and south of Washington and St. George these flats are of sufficient extent to be cultivated. Around Hurricane a valley lying at the foot of the Hurricane Fault cliff and surrounded on the north, west, and south by rough lava beds has been filled with alluvium to form a floorlike area of several square miles (pl. 1, *A* and *B*). In places, such as areas around St. George, Washington, Washington Fields, Ivins, Warner Valley, and in the Arizona Strip—that part of the area within Arizona—erosional or fault valleys have filled with

alluvial material to form flats and more or less gently sloping fan areas. In places the valley-filling materials have been severely eroded. Large areas of shales and sandstones are so extremely eroded and rough that they form a type of badlands. Around Veyo, in the northwestern part of the area, there is a high plateau with an undulating surface caused by an uneven lava flow. The area west of Hurricane, locally called Berry Springs Flat, represents a basaltic plain and has an uneven surface, as do the uplands around Toquerville. In places the sandier soils are blown into hummocks or dunes.

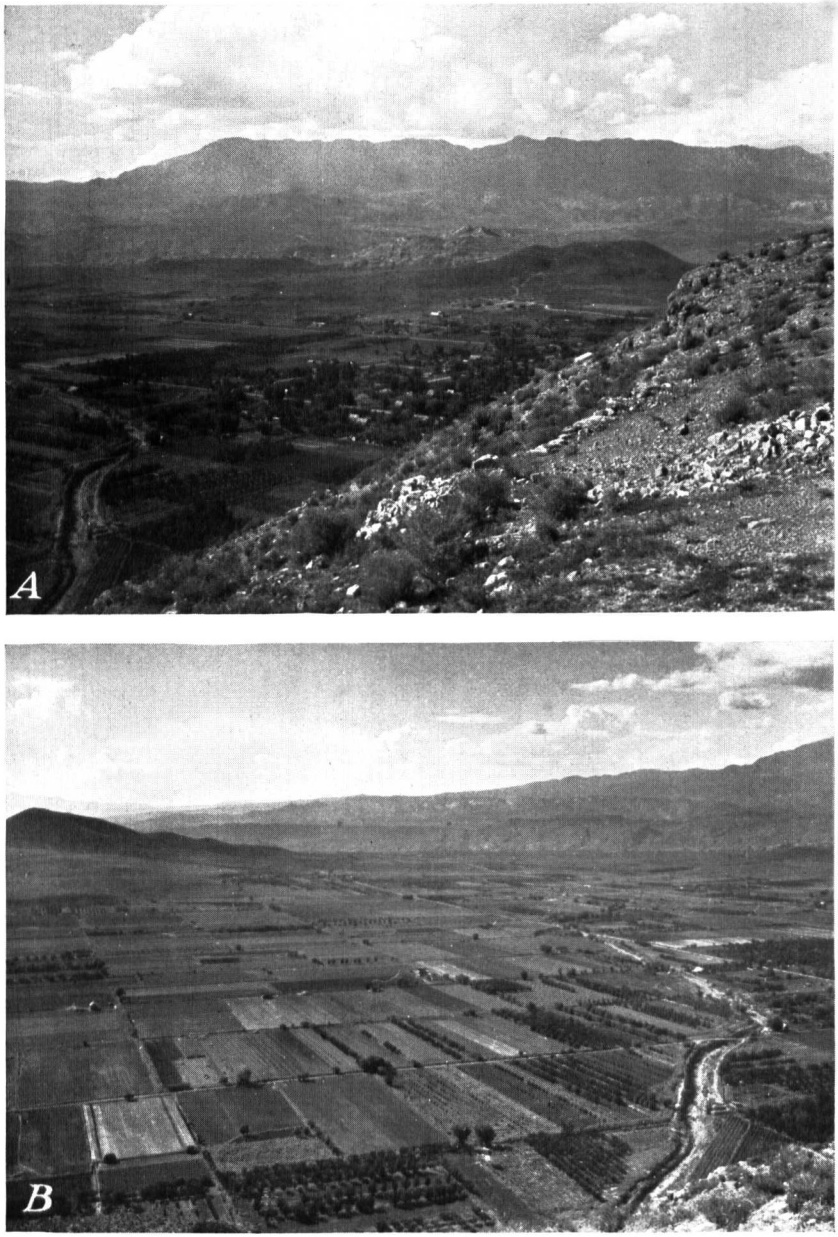
The area is drained by the Virgin River and its tributaries, chief among which are the Santa Clara River, Fort Pierce Wash, Ash Creek, and La Verkin Creek. The greater part of the area has a well-developed system of natural drainage courses, but there are a few exceptions. The southwestern part of the so-called Bench Lake Flat southwest of Hurricane has no drainage outlet, and during or after heavy rains a pond, called Bench Lake, is formed. Another such undrained depression is southeast of St. George in sec. 23, T. 43 S., R. 15 W. A few small areas on the upland benches south of the Arizona-Utah State line and in Warner Valley have no definite drainage outlets.

Although this area is in the lowest part of Utah, it is high above sea level. The lowest point is where the Virgin River leaves the southwestern part of the area. The elevation here is probably about 2,700 feet above sea level. The highest elevation is at the northeast end of the area, adjoining the Zion National Park. Here, the elevation in the canyon bottom is 3,930 feet,[2] and the cliffs rise to a much greater height. West Temple, a cliff just outside the boundary of the area, rises to a height of 7,798 feet.[2] At St. George the altitude is 2,880 feet,[3] at La Verkin about 3,270 feet,[4] and at Leeds 3,400 feet.[3] The range of elevation within the valley parts of the area is not sufficient to produce great differences in climate, although local variations in relief and elevation may vary the occurrence of killing frosts and consequently affect the adaptation of tender fruits and vegetables. The Veyo locality in the northwestern part of the area is at a comparatively high altitude, has a shorter frost-free season, and therefore is less well adapted than are other parts of the area to early vegetables and fruits, sugar-beet seed, sorgo, and a number of other crops.

VEGETATION

The native vegetation of the lower part of the area is of the desert brush type that characterizes much of the arid Southwest. In places coarse bunchgrass grows sparsely, and, after rains, short-lived annual grasses and weeds appear. Creosotebush, locally known as chaparral, is the prevailing species, and in places there is much squawbush, matchweed, shadscale, jointfir or Mormon-tea, and perennial brushy *Atriplex* species. Many of the eroded shale lands are nearly barren, but in places they support a scattered growth of shadscale. Species of cacti, particularly cholla and pricklypear,

[2] Information on elevations given by the National Park Service.
[3] Elevations given by the United States Weather Bureau.
[4] Elevation on State highway department survey stake.



Views looking northwest from the crest of the Hurricane Fault: *A*, Town of Hurricane, with Pine Valley Mountains in background. *B*, The intensively cultivated valley of Redfield soil south of Hurricane. Note the barren volcanic cinder cone and sandstone ridges in the background.

are rather common in this part of the area. Mesquite grows where moisture conditions are favorable, and arrowweed, screwbean, saltgrass, cottonwood, and willow are common on flats near perennial streams and around springs. Seepweed, saltgrass, and saltbush are common on salty areas.

At the higher elevations, where the rainfall is slightly higher and the temperature lower, sagebrush is common and there is a more or less scattered growth of juniper and piñon; and in places, especially near Anderson, there is a rather heavy growth of scrub evergreen oak, or live oak. Cottonwood, willow, ash, and boxelder grow near streams and springs.

Following is a list of common and scientific names of plant species native in this area:[5]

Scientific name	*Common name*
Acer negundo L.	Boxelder.
Artemisia filifolia Torr.	Sand sagebrush.
Artemisia tridentata Nutt.	Big sagebrush.
Atriplex sp.	Saltbush.
Atriplex confertifolia (Torr.) S. Wats.	Shadscale.
Chilopsis linearis (Cav.) Sweet	Desertwillow.
Covillea tridentata (DC.) Vail	Creosotebush.
Ephedra viridis Cov.	Jointfir, Mormon tea, or Brigham tea.
Fraxinus sp.	Ash.
Gutierrezia sp.	Snakeweed or matchweed.
Juniperus sp.	Juniper.
Lycium sp.	Wolfberry or squawbush.
Opuntia spp.	Cholla and pricklypear.
Pinus edulis Engelm.	Piñon.
Pluchea sericea (Nutt.) Cov.	Arrowweed.
Populus sp.	Cottonwood.
Prosopis chilensis (Mol.) Stuntz	Mesquite.
Prosopis pubescens Benth.	Screwbean.
Salix sp.	Willow.

SETTLEMENT AND POPULATION

This section of southern Utah, locally called Dixie, was first settled in the 1850's by Mormon pioneers. Washington County was established in 1852. The first settlement in the Virgin River Valley area was near the present site of Santa Clara in December 1854.[6] The towns of Washington and Gunlock were settled in 1857. Heberville (later abandoned) and Toquerville were established in 1858, Virgin in 1859, and St. George in 1861.

The present population of this section has sprung largely from the early Mormon settlers, with occasional additions from immigrant converts of northern European extraction and small additions from other communities of Latter Day Saints from time to time. The comparative isolation of the locality and the limited area of agricultural land have prevented a large influx of settlers or a great increase of population. The population of Washington County is only 3 persons to the square mile, yet there are available for each person only 1.9 acres of cropland, and even less in the area surveyed. Most of the people live in the small towns in the limited agricultural districts along the Virgin and Santa Clara Rivers. Much of the

[5] DAYTON, WILLIAM A. IMPORTANT WESTERN BROWSE PLANTS. U. S. Dept. Agr. Misc. Pub. 101, 214 pp., illus. 1931.

[6] HISTORY OF ST. GEORGE STAKE 1847–1873. [Typed manuscript on file in the Church Historian's Libr., Church of Jesus Christ of Latter Day Saints, Salt Lake City, Utah.]

area is uninhabited desert. The entire population of Washington County is classed by the census as rural. It has grown from 4,235 in 1880 to 7,420 in 1930. The small area in Arizona covered by this survey has no permanent inhabitants.

Most of the people are of northern European extraction, English, Scandinavians, Swiss, and Germans predominating. By far the larger number are American born. According to figures obtained by the economic survey [7] made in the winter of 1934–35, 96 percent of all the farmers of Washington County were American born, 89 percent were born in Utah, and 69 percent were born in Washington County.

St. George is the county seat and the principal town of Washington County. It had a population of 2,434 in 1930. It is the most important trading center of the area and enjoys a tourist trade of some importance. Hurricane, in the eastern part, also is an important trading point. Its population was 1,197 in 1930. Washington with 435 people, Toquerville with 288, Santa Clara with 249, La Verkin with 236, Rockville, Springdale, Leeds, Virgin, Gunlock, and Veyo are villages or community centers. Good schools are located in the towns. A centralized system is used, and busses carry children of the rural districts to and from school. Dixie Junior College is located at St. George. The Latter Day Saints (Mormon) Church has ward churches in the several towns and community centers and a temple at St. George. Telephones and electric lights are available in the towns and along the main highways.

TRANSPORTATION AND MARKETS

The Virgin River Valley area has no railroads. Cedar City, Utah, 53 miles from St. George, is the nearest railroad point. The area is traversed by United States Highway No. 91, commonly called the Arrowhead Trail—a hard-surfaced highway connecting Los Angeles and Salt Lake City. A large amount of trucking is done on this road. One State highway gives access to Zion National Park and the upper or eastern end of the area. Another, a graveled road, forms a short cut between St. George and Hurricane, and a third leads from St. George to Veyo, Enterprise, and Modena. The other roads are rather poor, although some of them are graded and occasionally dragged. A new graded road is under construction (1936) into the Arizona Strip south of St. George. Most of the outlying sections are reached by rough trails.

Much of the produce grown is consumed locally, as the population is rather large in proportion to the extent of cultivated land. A flour mill at Hurricane grinds wheat for local use. All dairy products are consumed locally. A large part of the early fruits and vegetables grown here are marketed at Salt Lake City and other northern points in Utah. Flour, sugar, canned goods, and produce are imported in considerable quantities.[8] Livestock, including cattle,

[7] CLAWSON, MARION, and THOMAS, W. PRESTON. ECONOMIC USE OF THE AGRICULTURAL RESOURCES OF WASHINGTON COUNTY, UTAH. *In* A Preliminary Report on the Agricultural Resources of Washington County, Utah. Utah Agr. Expt. Sta. 1935. [Typed.]

[8] See footnote 7, p. 6.

sheep, and goats, raised on the surrounding range lands, are fed at times on the ranches within the area. A small proportion of them are marketed locally, and many are sent to Pacific coast, northern Utah, or Eastern markets. Large numbers are shipped to the Imperial and Salt River Valleys to be fattened for market.

At present no important nonagricultural industry is carried on within the area. At one time several million dollars' worth of silver was taken from the Silver Reef mines near Leeds, but these mines are inactive. A number of wells have been drilled or are being drilled for oil, but up to April 1936 no flow of oil in commercial quantities had been obtained. The tourist trade has some importance, as the area lies on a much-traveled national highway and has many scenic attractions, including Zion National Park. The entire area is one of striking and colorful scenery. The mild, sunny winter climate attracts a number of winter visitors.

CLIMATE

This area has a continental or inland climate, with wide daily and annual variations in temperature. Records kept over a long period of years at St. George show an absolute maximum temperature of 116° F., and an absolute minimum of −1°. This area is a part of that climatic section sometimes referred to as the arid Southwest, which is characterized by scant rainfall, dry atmosphere, very little snow, short mild winters, and long hot summers. During the winter the days are for the most part sunny and fairly warm, but the nights are cold. Heavy frosts occur throughout December and January and are fairly common in November, February, and March. Earlier and later frosts occur occasionally, but the growing season is longer than in the higher parts of Utah to the north and east. The average frost-free season at St. George is 193 days and at Leeds 208 days. The comparatively long growing season has led to the production of special crops, such as early peaches, cherries, grapes, and apricots, and early vegetables, including onions, carrots, radishes, and many others. Almonds, figs, and English walnuts are grown to some extent.

The annual rainfall in this section is so low that it is of only slight direct benefit to agriculture. At St. George it averages 8.86 inches and at Leeds 13.15 inches. Its chief value is in providing a supply of water for irrigation. Crops seldom grow successfully without irrigation. The heat and dryness of the atmospheres are, without doubt, unfavorable for the growth of many crops during summer, regardless of the amount of irrigation water applied. Grains and grasses do not thrive so well here as in a cooler, moister climate.

Late frosts sometimes damage fruits and vegetables, and hail occasionally injures crops. Strong winds occur frequently in parts of the area, especially in spring. This is particularly true along the base of the Hurricane Fault, near Hurricane, La Verkin, and Toquerville. Much of the rest of the area is protected by encircling mountains.

Table 1 gives the more important climatic data as recorded at the United States Weather Bureau station at St. George, Washington County, Utah.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at St. George, Washington County, Utah*

[Elevation, 2,880 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1894)	Total amount for the wettest year (1907)	Snow, average depth
	°F.	°F.	°F.	Inches	Inches	Inches	Inches
December	38.0	71	0	0.75	1.90	0.17	1.3
January	37.9	71	−1	.98	.21	2.42	2.6
February	43.3	81	1	1.09	.40	.76	1.2
Winter	39.7	81	−1	2.82	2.51	3.35	5.1
March	50.2	89	12	.83	.18	.88	.4
April	58.0	98	18	.58	.01	.82	(1)
May	67.1	108	20	.43	.00	.44	.0
Spring	58.4	108	12	1.84	.19	2.14	.4
June	75.5	116	35	.25	.00	.05	.0
July	82.6	115	41	.91	.26	10.25	.0
August	80.9	113	43	1.02	.49	.50	.0
Summer	79.7	116	35	2.18	.75	10.80	.0
September	71.8	105	25	.66	.04	.33	.0
October	59.6	99	20	.80	.06	2.09	.0
November	47.5	86	4	.56	.00	.00	.5
Fall	59.6	105	4	2.02	.10	2.42	.5
Year	59.4	116	−1	8.86	3.55	18.71	6.0

[1] Trace.

AGRICULTURAL HISTORY AND STATISTICS

When the first Mormon pioneers and missionaries settled near the present site of Santa Clara in 1854, they found Indians farming in a crude way, growing wheat, corn, squashes, and melons. Other communities were established soon afterward. In each settlement the people immediately constructed dams and ditches, in order to irrigate small areas of land, on which they grew cotton, small grains, sorghum cane, corn, melons, and vegetables. Cotton was one of the more important crops at first, and, in 1863, 56,094 pounds of cotton was produced in this vicinity. The settlers began early to make use of the great areas of range land for grazing cattle, and after a time livestock raising became the principal source of income. Sheep and goats, introduced later, have become increasingly important. At present the production of livestock accounts for slightly more than one-half of the value of the agricultural production of Washington County. That part of the area lying in Arizona is entirely range land.

After years of effort, permanent irrigation dams were built to replace the temporary earth and brush structures that washed out at every flood, and larger ditches or canals were dug to irrigate the larger areas that were accessible and smooth enough to cultivate. The present Washington Dam was started in 1890, and the Washington Fields-St. George Ditch was completed in 1893. The Hurricane Ditch was completed in 1907. The limited acreage of

land capable of being irrigated and the limited supply of water have made extensive agricultural development impossible. For years, largely because of the isolation of the district and the small areas of irrigable land, farming was mainly of a subsistence type. The growing of vegetables and fruits for home use, wheat for flour, hay for farm animals, and cotton for spinning into cloth for local use were the principal agricultural occupations, except the grazing of livestock on the range. More recently the opening of good highways has encouraged the production of early fruits and vegetables for sale outside the area, mostly in Salt Lake City and other northern Utah cities. Sugar-beet seed has become a fairly important crop, as the demand is good and the crop may be grown in a single season here. Seed grown here replaces the expensive German-grown seed formerly used in northwestern beet-growing districts. Disease-resistant strains have been developed, and these are superior to the imported seed. Cotton is no longer grown, because of the high cost of production and marketing.

According to the United States census reports, land in farms in Washington County increased steadily from 1880, when it totaled 7,363 acres, to 1935, when it totaled 134,338 acres. Even in 1935, however, farm land represented only 8.5 percent of the area of the county. The area of improved land was 5,115 acres in 1880, 29,023 acres in 1920, 28,781 acres in 1930, and 24,586 acres in 1935. The cultivated acreage is still smaller, although it also has increased since 1880. It reached a maximum probably in 1920, decreased between 1920 and 1930, owing no doubt to unfavorable economic conditions and low prices of agricultural products, and increased again in 1935. The area of cropped land was 14,427 acres in 1930 and 15,135 acres in 1935. As the number of farms increased during this period, however, cropped land averaged 22 acres a farm in 1930 and only 19.8 acres in 1935.[9]

Alfalfa hay has been an important crop for many years, and in some years it occupies more than one-half of the entire cropped area. It is the principal hay crop, accounting for about 90 percent of the total acreage devoted to the production of hay. In 1880 the total acreage devoted to hay in Washington County was 775 acres. This rose to 8,782 acres in 1920, with 7,916 acres in alfalfa. The production of alfalfa hay in this year was 25,772 tons, or 3.3 tons an acre. In 1930 and 1935 the total hay-producing acreage was 6,497 and 5,281 acres, respectively, with 5,895 acres in alfalfa in 1930 and 4,648 acres in 1935. The yield of alfalfa was 14,632 tons, or 2.5 tons an acre, in 1930, and 10,482 tons, or 2.3 tons an acre, in 1935. Alfalfa is fed on the farms to the work animals or to livestock from the surrounding range lands.

Wheat has ranked second to alfalfa in acreage in all census reports of Washington County from 1880 to 1935. It was grown on 473 acres in 1879, 2,854 in 1919, 1,832 in 1929, and 1,932 in 1934. The average production was 16.8 bushels an acre in 1929 and 16.3 bushels in 1934.

[9] The figures quoted are for Washington County, of which the Virgin River Valley area comprises a small part. The greater part of the cultivated acreage, however, is in this area. The total acreage of cropped land in the area is probably somewhat more than 8,000 acres.

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Fruits, including principally peaches, grapes, and apples, are important. The land in fruit orchards, vineyards, and planted nut trees totaled 1,286 acres in 1934. The number of peach trees and vines and the total production have not changed materially since 1900. In 1929 and 1934, respectively, there were 30,622 and 47,128 peach trees, with a production of 20,710 and 65,261 bushels, and 143,386 and 110,494 vines, with a production of 976,370 and 563,670 pounds. The number of apple trees increased from 4,821 in 1899 to 10,418 in 1934, and the production increased from 5,502 bushels to 11,288 bushels. Pears, sweet cherries, plums, apricots, figs, almonds, and Persian (English) walnuts are of minor importance.

Barley and corn are crops of some importance, each occupying several hundred acres in most years.

Sugar-beet seed is a crop that has become important in the last few years. No figures are available, but the crop occupied several hundred acres during the 3 years 1934–36.

Market vegetables have become a rather important crop. In 1919 they were grown on 109 acres; in 1929 on 232 acres, with yields valued at $27,519; and in 1934 on 263 acres. Farm garden vegetables were valued at $22,329 in 1934. Minor crops are sorgo, grain sorghums, potatoes, sweetpotatoes, dry beans, and broomcorn.

The census figures for 1900 show 10 acres in cotton in 1899 with a total production of 5 bales. The crop is no longer grown in this section.

In 1934 a total of 89,889 acres was reported as pasture included in the farms of Washington County. Of this 4,438 acres were plowable pasture, 5,503 acres woodland pasture, and 80,038 acres other pasture. Most of the pasture land is dry unirrigated land, which produces only a sparse growth of brush and grasses. A few hundred acres of land along the Virgin River and in Washington Fields is wet or marshy, and on it saltgrass, sedges, and tules afford rather inferior pasturage. Alfalfa, grain, and beet fields are pastured after the crops are harvested.

Though the area surveyed comprises only a small part of Washington County, the following figures show the trend in the production of livestock here. In 1899 the estimated value of livestock products in the county was $83,598, including $68,515 for animals sold and slaughtered, $11,173 for dairy products sold, and $3,910 for poultry raised. In 1919 the value of livestock sold or slaughtered was not reported, but the value of dairy products sold was $30,560, the value of poultry and eggs produced was $49,196, the value of honey and wax produced was $6,267, and the value of wool shorn was $124,552. In 1929, $63,162 represented the value of dairy products sold, $89,970 the value of poultry and eggs, $2,219 the value of honey produced, $68,584 the value of wool shorn, and $33,381 the value of mohair and goat hair clipped. The value of dairy products was based on the production of 805,469 gallons of milk in 1929. In that year 26,391 chickens were raised and 110,125 dozen eggs produced; 244,943 pounds of wool was shorn and 85,592 pounds of mohair clipped. In 1934 the production of dairy and poultry products decreased, 640,092 gallons of milk was produced, 80,362 dozen eggs were produced, and 17,029 chickens were raised. Sheep and goats, however, contributed more to the

farmers' income; 289,090 pounds of wool was shorn, and 91,000 pounds of mohair was clipped.

Although the census did not report separately the value of livestock slaughtered in 1929, the importance of livestock and livestock products in the agriculture of Washington County is brought out in the following data: Of a total of $887,217, the value of all products sold, traded, or used by the farm operator's family, $197,101 represented the value of crops sold or traded, $284,127 the value of livestock sold or traded, $288,719 the value of livestock products sold or traded, $1,219 the value of forest products sold or traded, and $176,051 the value of all farm products used by the operator's family.

The numbers of horses and cattle on the farms of Washington County were 1,703 and 10,940, respectively, in 1935, about one-third of the number reported in the 1910 census. In 1935, 36,982 sheep and 16,370 goats were on farms. This represents an increase over the numbers reported in 1910, although there were fewer sheep and goats in 1935 than in 1930. Other livestock on farms in 1935 included 61 mules, 1,311 swine, and 14,292 chickens.

Analysis of these figures shows that a great expansion took place in livestock raising between 1900 and 1910, but that there was some recession in the enterprise, as a whole, thereafter. The value of dairy and poultry products, however, increased markedly.

Commercial fertilizers, although used to some extent, are not bought in large quantities. Fertilizer practices are described in the section on Land Uses and Soil Management.

Most of the labor is obtained locally, and many farmers exchange work among themselves. A small amount of transient labor is sometimes employed during fruit harvest.

Most of the farms are small, but the range in size is from 1 to several hundred acres. According to Clawson and Thomas,[10] the average acreage of irrigated cropland is 16 acres a farm. They give the average for different communities, among which are Springdale with 6 acres, Hurricane with 11 acres, and Veyo with 38 acres. The figures given by the census for the acreage of improved land do not seem to bear a very close relation to actual cropped land. In all instances they are much too high. Most of the unirrigated land on the farms hardly deserves the classification of improved land, as it is, for the most part, dry and unproductive. The census gives the average size of farms as 38 acres in 1880, 173.3 acres in 1920, 184.1 acres in 1930, and 175.6 acres in 1935.

The trend seems to be toward larger holdings, a larger number of farms, and a larger total acreage in farms, but the amount of cultivated land for each farm has changed very little. It is probable that the increase in size of farms shown by the census is due in part to the acquisition of land adjoining cultivated areas to use as privately owned pasture or range. A few thousand acres of dry-farmed land in the county outside the area surveyed was put into cultivation during the period covered by the census figures, but to offset that some holdings were divided among heirs and some areas of irrigated land were abandoned because of insufficient water supply, waterlogging, or unfavorable economic conditions.

[10] See footnote 7, p. 6.

By far the larger part of the farms are operated by owners. The census gives the figure as 91 percent in 1935. Land when rented is handled on either a share-crop or a cash basis.

One of the outstanding features of the findings of the economic survey was the very low average family income obtained by farmers in this area. Some of the lowest incomes were reported from districts having the most productive soils. This condition is apparently due to the very small size of farms, small amount of cultivated land for each farm, too few livestock, low prices obtained for farm products, and low acre yields compared with possible production. More efficient methods of farming and the growing of higher priced crops, such as fruits and truck crops, are advocated. In some communities the income from livestock grazed on the public range represented a large part of the total income, and in many instances most of the cash income was from outside work. The average cash balance from farming operations given for the farms of the county (yearly average for the period 1929–33) was $121, and the total family cash income averaged $460.

SOIL-SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field.

The soils are examined systematically in many locations. Test pits are dug, borings are made, and exposures, such as those in road or railroad cuts, are studied. Each excavation exposes a series of distinct soil layers, or horizons, called, collectively, the soil profile. Each horizon of the soil, as well as the parent material beneath the soil, is studied in detail, and the color, structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The reaction of the soil[11] and its content of lime and salts are determined by simple tests.[12] Drainage, both internal and external, and other external features, such as relief, or lay of the land, are taken into consideration, and the interrelation of soils and vegetation is studied.

The soils are classified according to their characteristics, both internal and external, special emphasis being given to those features influencing the adaptation of the land for the growing of crop plants, grasses, and trees. On the basis of these characteristics, soils are grouped into mapping units. The three principal ones are (1) series, (2) type, and (3) phase. Areas of land, such as coastal beach or bare rocky mountainsides, that have no true soil, are called (4) miscellaneous land types.

The most important group is the series, which includes soils having the same genetic horizons, similar in their important characteristics and arrangement in the soil profile, and developed from a particular type of parent material. Thus, the series includes soils having essentially the same color, structure, and other important internal characteristics and the same natural drainage conditions and range in

[11] The reaction of the soil is its degree of acidity or alkalinity expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality, higher values indicate alkalinity, and lower values indicate acidity.

[12] The total content of readily soluble salts is determined by the use of the electrolytic bridge. Phenolphthalein solution is used to detect a strong alkaline reaction.

relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The soil series are given names of places or geographic features near which they were first found. Thus, Redfield, Tobler, Harrisburg, and Shavano are names of important soil series in this area.

Within a soil series are one or more soil types, defined according to the texture of the upper part of the soil. Thus, the class name of the soil texture, such as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, and clay, is added to the series name to give the complete name of the soil type. For example, Redfield loam, Redfield fine sandy loam, and Redfield silty clay loam are soil types within the Redfield series. Except for the texture of the soil, these soil types have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is usually the soil unit to which agronomic data are definitely related.

A phase of a soil type is a variation within the type, which differs from the type in some minor soil characteristic that may have practical significance. Differences in relief, stoniness, and degree of accelerated erosion frequently are shown as phases. For example, within the normal range of relief for a soil type there may be areas adapted to the use of machinery and the growth of cultivated crops and others that are not. Even though there may be no important differences in the soil itself or in its capability for the growth of native vegetation throughout the range in relief, there may be important differences in respect to the growth of cultivated crops. In such an instance the more sloping parts of the soil type may be segregated on the map as a sloping or a hilly phase. Similarly, soils having differences in stoniness may be mapped as phases, even though these differences are not reflected in the character of the soil or in the growth of native plants.

The soil surveyor makes a map of the county or area, showing the location of each of the soil types, phases, and miscellaneous land types, in relation to roads, houses, streams, lakes, section and township lines, and other local cultural and natural features of the landscape.

SOILS AND CROPS

The soils of the Virgin River Valley area have certain general characteristics common to the soils of much of the arid Southwest. Most of them are red or have a decided red tinge; they are poor in organic matter and nitrogen but comparatively rich in the more soluble compounds of the alkali and alkaline-earth groups, including the salts of soda, potash, and lime. Both lime (calcium carbonate) and gypsum (calcium sulfate) are very common in these soils; in fact, the former is present nearly everywhere except in some of the extremely sandy soils. Some downward leaching and concentration of these soluble compounds has occurred, but only in a few places are they entirely removed from the soil. Phosphorus, although it may be present in fairly large quantities in many of the soils, apparently is largely in insoluble form and not available to plants. In some of the soils the total phosphorus con-

tent is rather small.[13] Large increases in yields of some crops, notably alfalfa hay and sugar-beet seed, follow the application of superphosphate.

A feature of the irrigated soils of this area is the presence on the surface of a layer of silt deposited by irrigation water. In places this layer of silt is as much as 3 feet thick, and on most of the older irrigated lands it extends below plow depth. In general, the silt is browner than the natural soil, is finer in texture, and probably is somewhat higher in content of organic matter. In most places it is heavy-textured—ranging from silty clay loam to clay—although in some places the texture may be loam or silt loam. Such silting is not noticeable on lands irrigated by waters from springs, but it is universal on lands irrigated from the larger streams.

Farming is carried on under irrigation, and the land not under irrigation furnishes meager grazing and browse. Alfalfa hay is the principal crop, and small grains, corn, sorghum cane, sugar-beet seed, and truck crops are grown in rotation with alfalfa. Fruit growing also is an important branch of farming. Alfalfa is grown among the trees in many of the orchards. Livestock are grazed on the surrounding public ranges and fed at times on the farms. Dairying is practiced to a limited extent.

The principal factors determining the use of the land are: (1) Availability of water, and (2) quality of the land, as determined by depth and character of soil, content of stone and gravel, slope or relief, drainage, and degree of freedom from concentration of soluble salts ("alkali"). Therefore, this area is divided roughly into the agricultural or arable lands, which have a water supply and good soils, and the nonarable range or grazing lands, which either do not have a supply of water or are not suitable for irrigation because of undesirable features of soil or topography. Only a small part of the area is farmed, and only a limited additional acreage is favorable for irrigation. Because farming under irrigation produces the greatest acre returns and because soil features are so important in determining the suitability of the land for cultivation, a grouping of soils has been made in an attempt to bring out the general relationships between the characteristics of the soils and their suitability for crop growing. The grouping that follows is essentially a natural grouping; that is, it is based on natural characteristics of the soils; but it also has a general relationship to their use capabilities.

The six natural groups are: (1) Deep soils of the bottom lands and alluvial fans; (2) soils with compact limy subsoils on uplands, fans, and terraces; (3) shallow soils of the uplands; (4) gravelly and stony soils of the alluvial fans; (5) loose sandy soils; and (6) miscellaneous nonarable soils and land types.

The soils of each group differ considerably in texture, stoniness, relief, and drainage, and therefore the use capabilities of the land do not follow the grouping consistently. It may be said, however, that the deep soils of the bottom lands and alluvial fans, where irrigated, are adapted to general farming and, in places, to fruit and vegetable growing; the soils with compact limy subsoils on uplands and alluvial fans are adapted to general farming and fruit growing; the shallow

[13] WIDTSOE, JOHN A., and STEWART, ROBERT. THE SOIL OF THE SOUTHERN UTAH EXPERIMENT STATION. Utah Agr. Expt. Sta. Bul. 121, pp. [241]–268, illus. 1913.

soils of the uplands and the gravelly and stony soils of the alluvial fans either are nonarable or are adapted in a limited way to the growing of grapes, tree fruits, and alfalfa; the loose sandy soils have little value except for browse; and the miscellaneous nonarable soils and land types have little value even for grazing. Poorly drained and salty areas occur in the deep soils of the bottom lands and alluvial fans and in the soils with compact limy subsoils. Such areas have resulted for the most part from seepage in the irrigated valleys. They are useful mainly for pasture, but if artificial drainage and special reclamation measures are practiced, they may be used for general farming.

In the following pages the soils are described in detail, and their agricultural relationships are discussed; their distribution is shown on the accompanying soil map; and table 2 gives their acreage and proportionate extent.

TABLE 2.—*Acreage and proportionate extent of the soils mapped in the Virgin River Valley area, Utah-Ariz.*

Soil type	Acres	Per-cent	Soil type	Acres	Per-cent
Redfield silty clay loam	1,344	0.7	Harrisburg loam, silted phase	384	0.2
Redfield silty clay loam, silted phase	1,344	.7	Harrisburg loam, rolling phase	832	.4
Redfield silt loam	1,664	.8	Harrisburg gravelly loam	5,696	2.8
Redfield loam	1,920	.9	Harrisburg stony loam	10,688	5.2
Redfield loam, silted phase	2,176	1.1	Harrisburg fine sand	1,472	.7
Redfield loam, shallow silted phase	704	.3	Harrisburg fine sand, hummocky phase	448	.2
Redfield loam, gypsiferous phase	4,288	2.1	Veyo stony clay loam	1,024	.5
Redfield loam, eroded phase	896	.4	Veyo clay loam	512	.3
Redfield fine sandy loam	2,112	1.0	Shavano clay loam	832	.4
Redfield fine sandy loam, gypsiferous phase	960	.5	Shavano stony clay loam	1,152	.6
Redfield clay	704	.3	Toquerville fine sandy loam	704	.3
Redfield clay, silted phase	320	.2	Toquerville fine sand	3,648	1.8
Tobler fine sandy loam	4,032	2.0	Toquerville fine sand, stony phase	1,664	.8
Tobler fine sandy loam, hummocky phase	512	.3	Tortugas stony loam	23,360	11.4
Tobler loam	576	.3	Purgatory loam	1,472	.7
Gila silty clay loam	1,472	.7	Moffat gravelly loam	832	.4
Gila loam	1,280	.6	Isom gravelly loam	3,200	1.6
Gila fine sandy loam	704	.3	Isom gravelly loam, silted phase	320	.2
Gila fine sand	1,216	.6	Isom stony loam	2,880	1.4
Fort Pierce silt loam	448	.2	Tobler fine sand, stony phase	448	.2
Junction coarse sandy loam	448	.2	Pintura fine sand	6,912	3.4
Leeds clay loam	640	.3	Pintura fine sand, dune phase	512	.3
Moffat fine sandy loam	3,456	1.7	Ivins fine sand, hummocky phase	192	.1
Moffat fine sandy loam, silted phase	896	.4	Tobler fine sand	1,728	.8
Moffat loam	2,368	1.1	Tobler fine sand, hummocky phase	2,240	1.1
Moffat fine sand	1,920	.9	Moffat fine sand, hummocky phase	1,152	.6
Bennett fine sandy loam	256	.1	St. George fine sand	128	.1
La Verkin loam	960	.5	Toquerville fine sand, deep phase	512	.3
La Verkin loam, silted phase	320	.2	Tobler fine sand, rough broken phase	448	.2
Ivins fine sand	832	.4	Rough stony land	39,104	19.1
Moenkopie loam	640	.3	Rough stony land (La Verkin soil material)	1,088	.5
Moenkopie clay loam	256	.1	Rough broken land (Harrisburg soil material)	4,608	2.2
Moenkopie fine sandy loam	128	.1	Scabland	6,336	3.1
St. George loam	576	.3	Badlands	24,512	12.0
St. George loam, overwash phase	192	.1	Riverwash	4,800	2.3
Bracken fine sandy loam	896	.4			
Bracken silty clay loam	192	.1			
Harrisburg loam	5,312	2.6	Total	204,800	100.0

DEEP SOILS OF THE BOTTOM LANDS AND ALLUVIAL FANS

The deep soils of the bottom lands and alluvial fans occupy comparatively smooth valley areas, in many places accessible to irrigation waters; and this fact, together with their depth, permeability, good moisture-holding capacity, and inherent fertility, makes them the most desirable and best adapted soils of the area for general

farming, under irrigation, and for the production of all the crops commonly grown in this section. Fruit growing is practiced on these soils in localities that are comparatively free from frost at blossom-time. These soils have been modified very little since deposition. They are mostly fine to medium in texture and reddish brown to red in color. Very little clay and lime has accumulated in the subsoil, although these soils are everywhere calcareous. Some small areas are too badly eroded to be used for farming, and other small areas are poorly drained, affected by excessive accumulation of salts, and inferior for the production of crops. This group includes all or most of the soils of the following series: Redfield, Tobler, Gila, Fort Pierce, and Junction. The Leeds soil, although it has some accumulation of clay and lime in the subsoil, is similar and for practical purposes may be considered in this group.

Redfield silty clay loam.—Redfield silty clay loam typifies the soils of the Redfield series, which are among the best agricultural soils of the area. It lies, for the most part, too high to be irrigated from present canals and therefore is not under cultivation. Most of the land of this type now irrigated has been modified by irrigation silting to such an extent that it is classified and mapped as a silted phase.

The surface soil is light reddish-brown or pale-red silty clay loam with fairly mellow consistence. In barren spots it has a rather hard, platy crust on the surface but otherwise has little distinct structure. The subsoil resembles the surface soil, but it is more or less stratified, predominantly rather heavy textured, and somewhat more compact, yet fairly mellow and pervious. Both surface soil and subsoil are highly calcareous and more or less flecked with white lime and gypsum, but there is no marked concentration of lime in any layer. Stratified alluvial materials extend to great depths beneath this soil. Small quantities of salts (alkali) are present, but the salt content in only a few places is high enough to be harmful to plants. A number of small areas, totaling about 160 acres, just south of St. George and in Washington Fields, have become waterlogged since irrigation was started in this section. In such places the salt content is high enough to affect vegetation.

This soil is most extensive on the large alluvial flat south and southwest of Hurricane. Drainage is good, except in the areas near St. George and in Washington Fields.

The native vegetation consists largely of shadscale and other species of *Atriplex*, with pricklypear and cholla prominent in places. Russian-thistle is common on lands where the native vegetation has been wholly or partly removed. The wet areas are covered largely by saltgrass.

If placed under irrigation, this soil doubtless would be well adapted to growing the common crops of the section, as its adaptation and productivity are very similar to those of Redfield silty clay loam, silted phase.

Gully erosion is fairly severe in a few places, as the soil erodes rather rapidly where a large head of water is concentrated in a narrow channel. The land lies fairly level, however, and reasonable care in the handling of irrigation water would prevent destructive erosion in most places. Most of this soil may be irrigated under proposed projects that would lift water high enough to cover it.

It is said by those who have had experience with this and similar soils that they settle from a few inches to as much as 3 feet after the first few heavy irrigations. It is thought that this may be due to the dissolving of the gypsum, which makes up a considerable proportion of the bulk of the soil material and of the deep deposits of alluvial material underlying the soil.

Both surface soil and subsoil are low in organic matter, and special attention should be given to building up the content of humus in order to maintain productivity. The use of barnyard manure, the application of nitrogen and phosphorus fertilizers, and the growing of alfalfa in rotation with other crops are recommended.

Redfield silty clay loam, silted phase.—The silted phase of Redfield silty clay loam is almost identical with the typical soil described above, except that it has a darker or browner surface soil—the product of artificial silting or sedimentation from muddy irrigation waters. The color of the surface layer ranges from reddish brown to medium brown or dark brown with a slight red tinge, and the thickness from a few inches to more than a foot. The silt, a mixture of fine materials—mostly silt and clay—probably contains somewhat more organic matter than does the unsilted soil. The subsoil commonly contains somewhat less gypsum than does that of virgin Redfield silty clay loam. The salt content is low, except in small areas south of St. George and in Washington Fields. Drainage is rather poor in these areas, owing to seepage from canals and irrigated fields; whereas most of this soil is well drained.

Most areas of this soil occupy the flat in and around Hurricane; and small areas are south of St. George, at La Verkin, and in Washington Fields. This is one of the best and most important agricultural soils in the Virgin River Valley area. Although not extensive, nearly all of the land is under irrigation and is producing good yields of a variety of crops.

Alfalfa, one of the more important crops, yields, according to farmers' estimates, from 2 to 7 tons an acre. The use of superphosphate is said to double the yield. The average yields are about 3 tons without superphosphate and 6 tons where it is used. Wheat, an important crop, yields from 20 to 50 bushels an acre, probably averaging slightly more than 30 bushels. Barley and oats, which occupy smaller acreages, give somewhat higher yields than wheat. Sugar-beet seed, a crop recently introduced, produces from 1,500 to 3,000 pounds of seed an acre, with an average of about 2,500 pounds. The price in 1936 was 9 cents a pound. Superphosphate and ammonium sulfate fertilizers are used in growing this crop. Grain sorghums, sorgo, corn, and vegetables are minor crops that are well adapted to this soil.

Some of the more frost-free areas around Hurricane and La Verkin are devoted to fruit growing. Peaches and pears are the most important fruits, and apricots, sweet cherries, and almonds are grown on a smaller scale. Where crops are not damaged by frost, average yields of 10 tons of peaches an acre are claimed, with old trees yielding as much as 17 tons an acre. Pears, which occupy a somewhat smaller acreage, are reported by one grower to average 20 tons an acre.

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Although apparently somewhat richer in organic matter than the unsilted virgin soils of the area, this soil probably is still rather poor in this constitutent, and care should be taken to maintain the organic content and the fertility of the soil. Suggestions for maintenance of fertility are made in the section on Land Uses and Soil Management.

Redfield silt loam.—Redfield silt loam is very similar to Redfield loam. It is, however, somewhat finer textured and contains more silt, is freer from gypsum, and is generally slightly lighter colored or less red than that soil. The parent material is alluvium derived largely from limestone. The surface soil is light reddish-brown or pink mellow silt loam or fine-textured loam. In many places the surface is crusted over with a very thin soft layer of very light brown or light pinkish-brown material. The subsoil is very much like the surface soil but is in places very slightly lighter in color and contains faint mottlings of lime and probably some gypsum. Both surface soil and subsoil are highly calcareous, soft, and friable. The salt content is comparatively low. This soil occupies smooth, well-drained, nearly level or gently sloping alluvial bottoms or fans. In places, erosion channels have been cut into the flats to a depth ranging from 4 to more than 6 feet.

This soil lies in Grassy Valley, on the flat south of Hurricane, in the Arizona Strip in the northwestern, central, and northeastern parts, and south of the Virgin River in T. 43 S., R. 16 W., secs. 25 and 36. Two small bodies, including approximately 50 acres, are one-half mile southeast of Veyo. The soil here is somewhat browner and of a coarser, grittier texture than the typical soil, but, because it is highly calcareous and occupies too small an area to warrant the establishment of a new soil type, it is classed as Redfield silt loam.

With the exception of the small bodies near Veyo, which are devoted to small grains, pasture, alfalfa, and apples, none of this soil is under cultivation. It is a good soil, and, under irrigation, would be well adapted to growing alfalfa, small grains, grain sorghums, sorgo, sugar-beet seed, truck crops, and, in the more frost-free locations, fruits, including peaches, pears, grapes, apricots, and early apples.

Redfield loam.—Redfield loam consists of light reddish-brown or pale-red deep mellow loam. There is little difference between the surface soil and the subsoil. The soil materials are more or less stratified and free from marked compaction or concentration of lime. Both surface soil and subsoil contain much lime and gypsum, which form small white flecks and faint mottlings. The soil normally contains traces of the more soluble salts, but only in a few very small areas southwest of Washington, in Washington Fields, and south of St. George are they present in definitely harmful quantities.

In places where the land has been irrigated for several years, more or less artificial silting has taken place and the surface soil is somewhat browner than typical.

This soil is most extensive in the vicinity of Hurricane and to the south and southwest of that town. Smaller areas are south of St. George, southwest and south of Washington, in Washington Fields, and along the Santa Clara River.

The surface typically is smooth and nearly flat or gently sloping. Both surface and internal drainage normally are good, although small areas south of St. George, in Washington Fields, and southwest of Washington have a high water table.

The soil material is derived from a wide variety of rocks, including limestones, shales, sandstones, and basalt. Much of it is transported from rather distant sources and is well mixed.

The native vegetation consists largely of a scant brushy cover, mostly of *Atriplex* species. Cholla and pricklypear are common, and Russian-thistle has appeared in many places where the land has been cleared and abandoned.

This is a very good soil for farming, although only about 300 acres are now under cultivation. Most of the rest is too high to irrigate from present ditches, but it may be irrigated under a proposed project in which water would be lifted to a higher level. The land under cultivation is producing alfalfa, small grains, peaches, pears, grapes, and other fruits, grain sorghums, sorgo, and vegetables. Crop adaptation and yields are very similar to those on Redfield silty clay loam, silted phase, previously described, but the loam is more easily worked.

Redfield loam, silted phase.—Redfield loam, silted phase, differs from typical Redfield loam chiefly in the surface soil, which is made up of or modified by a deposit of fine sediment from irrigation water. It is brown or reddish-brown, has a heavy texture ranging from heavy loam to clay, and is from a few inches to as much as 3 feet thick. The subsoil is medium textured, more or less stratified, friable, and open. Its color ranges from light reddish brown or pale red to red.

More or less gypsum is scattered through this soil in the form of crystals and small irregular fragments resembling sand. In some places the gypsum is much more plentiful than in others, but it is probably everywhere less abundant than in the virgin soil. It does not appear to have a significant effect on the growth of crops.

Most areas of this soil have a smooth, gently sloping surface. In most places drainage is reasonably good and the salt content is low. About 260 acres in Washington Fields has poor internal drainage, a high water table, and a slight, moderate, or strong salt concentration in the soil.

This soil is most extensive in Washington Fields, 1 to 3 miles south of Washington. Other bodies are in Little Valley, in Santa Clara and southeast of it, and near Rockville, Springdale, Gunlock, and Toquerville.

Nearly all of this soil is under cultivation. In agricultural adaptation and value it is somewhat similar to Redfield silty clay loam, silted phase, previously described, but the range of crops is somewhat narrower in some of the larger areas because of local drainage and frost conditions. Fruits, once important on this soil in Washington Fields, now are not grown to a great extent, as most of the land is more or less subject to frost at blossomtime. Another factor that discouraged fruit growing in this locality in the past was the presence of a high water table and concentration of salts. The water level, however, has been lowered in places by drainage ditches, the salt concentration has been reduced, and conditions are now more favorable. The important crops now grown are alfalfa, sugar-beet seed, small grains, and milo (a grain sorghum), all which yield well if the land is fertilized. Vegetables seem well adapted to this soil, and in a few places grapes and tree fruits do well.

Land of this type has been farmed for many years, and fertilization with phosphorus fertilizers seems essential to satisfactory production of some crops, especially alfalfa and sugar-beet seed. Where the land is not fertilized, alfalfa is said to yield not more than 3 tons an acre annually, whereas if fertilizer is used it commonly produces 5 tons or more. Sugar-beet seed yields 2,000 to 3,500 pounds or more an acre where properly handled, though crop failures have occurred, owing to damage from hail and the chinch bug. Ammonium sulfate, in addition to superphosphate, is used for this crop.

Redfield loam, shallow silted phase.—Redfield loam, shallow silted phase, is similar to Redfield loam, silted phase, but the degree of silting is less, the texture of the surface soil is lighter, and the soil is more easily worked. The surface soil to plow depth is light reddish-brown loam or clay loam, distinctly heavier and browner than the subsoil, which is pale-red or brownish-red loam or fine sandy loam. This soil lies on smooth, very gently sloping land, and in the greater part of its area it is well drained and free from harmful quantities of salts. About 220 acres in Washington Fields and south of St. George are poorly drained and moderately or strongly affected with salts.

This soil occupies a number of rather small bodies just south and west of Hurricane, south of St. George, in Washington Fields, and northeast of Springdale. All the land is under cultivation except parts of the poorly drained areas. This is a good all-round agricultural soil. Its value and adaptation to crops is much like that of the other Redfield soils described in the foregoing pages. It is more easily worked than some of the heavier and more deeply silted soils and probably is somewhat better adapted to the growing of alfalfa and truck crops. Much of it, especially around Hurricane, is favorably situated for fruit growing. The important crops are alfalfa, wheat, sugar-beet seed, peaches, pears, and milo. The poorly drained areas are not well suited for crop production, and many of them are used for pasture.

Redfield loam, gypsiferous phase.—Redfield loam, gypsiferous phase, is very similar to typical Redfield loam. The two soils are similar in color, depth, and structure, but the gypsiferous phase contains a larger quantity of gypsum scattered throughout the surface soil and subsoil in the form of fine flecks or sandy or gravelly lumps. The soil material is of more local origin and less weathered than that of most of the Redfield soils. It consists largely of outwash from sandstones and gypsiferous shales of many colors. The surface soil is reddish-brown or pale-red mellow granular loam containing some white or yellowish-white gypsum sand. The subsoil is slightly lighter colored or grayer than the surface soil and contains a large quantity of light-colored gypsum sand and gravel and fragments of shale. The content of soluble salts other than gypsum is not high in this soil.

Small areas, totaling about 70 acres, east of Washington Fields and near Leeds are somewhat heavier textured than typical. The texture in these places is clay loam. Other areas, totaling about 200 acres, about 1½ or 2 miles northeast of Santa Clara and north and northeast of Ivins, are decidedly red, especially in the surface

soil. Here, the soil material has come from red sandstones and shales and is much like that of the Tobler soils. The large areas in Purgatory Valley and some smaller areas elsewhere contain an exceptionally large quantity of gypsum sand, crystalline gypsum, and shale fragments.

This soil is most extensive south and southeast of Washington Fields, along the Utah-Arizona State line, especially in Arizona, and in Purgatory Valley. Smaller bodies are in the vicinities of Springdale, Rockville, Virgin, Bloomington, Leeds, Hurricane, and northeast of Santa Clara. The soil occurs on smooth, gently sloping alluvial fans or flats. It erodes easily and in places is cut by shallow gullies. Both drainage and the water-holding capacity are good.

This soil is well adapted for cultivation under irrigation; but as it lies mostly in situations where irrigation water is not now available, only a very small acreage, probably totaling less than 60 acres, is farmed. It seems well adapted to growing alfalfa, small grains, sorghums, vegetables, sugar-beet seed, and, in the more frost-free districts, tree fruits and grapes. Its agricultural value probably is slightly less than that of Redfield loam, as the high content of gypsum may make it somewhat less productive. Considerable trouble from settling of the soil would probably be experienced under irrigation, necessitating much work in leveling after the earlier irrigations.

The native vegetation consists largely of shadscale and creosotebush, with cacti in some places.

Redfield loam, eroded phase.—Redfield loam, eroded phase, is similar to Redfield loam, gypsiferous phase, except that it has been more or less severely eroded by gullies. This soil lies on sloping alluvial fans, and the run-off cuts into it easily, owing to the soft, incoherent character of the surface soil and the lack of protective vegetal cover. The color of the soil in most places is somewhat redder than that of Redfield loam or its gypsiferous phase; it is much like that of the Tobler soils.

This soil occurs chiefly along the northeast slope of Warner Valley. Areas are 1½ miles northeast of Santa Clara, southeast of Washington Fields, and near Bloomington. The relief ranges from rather steep, uneven, and ridgy to rather flat but badly gullied. Most of this soil is outside the areas now irrigated, and most of it would be poorly suited to irrigation farming. A few small areas of flatter land could be leveled and used for farming. Such an area is in sec. 1, T. 43 S., R. 15 W. It would probably be somewhat inferior in productivity to typical Redfield loam, even if leveled, as the raw gypsiferous subsoils would be exposed in leveling.

Redfield fine sandy loam.—Redfield fine sandy loam consists of pale-red or brownish-red deep mellow fine sandy loam. There is little difference between surface soil and subsoil. Both are low in content of organic matter and high in lime and gypsum, which form white flecks and very faint mottlings. Drainage is good, the moisture-holding capacity is fair to good, and the salt content is not excessively high. This soil occupies smooth alluvial bottoms and gently sloping fans.

Included with this soil as mapped is an area of about 30 acres, just west of Hurricane, of a silted soil, which originally was Redfield

sand. The surface layer to plow depth is reddish-brown sandy loam, gritty loam, or sandy clay loam, and below this is pale-red or light reddish-brown loose, porous, stratified, sandy material. This soil has a lower water-holding capacity and requires more frequent irrigation than the typical soil.

Probably somewhat more than 200 acres of this soil are under cultivation, mostly south and west of Hurricane and south of St. George, and small cultivated areas are near Gunlock and Virgin. This is a good soil for truck crops, peaches, grapes, and alfalfa. Small grains, milo, and sorgo do fairly well. The soil is easily tilled, warm, and productive. Organic matter should be added in the form of barnyard manure or green manure, or by growing alfalfa.

Redfield fine sandy loam, gypsiferous phase.—Redfield fine sandy loam, gypsiferous phase, is similar to typical Redfield fine sandy loam, but it contains more gypsum. The surface soil is light reddish-brown or pale-red granular fine or medium sandy loam or light-textured gritty loam. The subsoil is similar to the surface soil in texture and structure, but it is slightly lighter or grayer in color and contains a rather large quantity of gypsum in particles resembling sand and gravel. In a few small areas east of Washington Fields limestone gravel is scattered on the surface. Such areas are shown on the map by gravel symbols.

Little or none of this soil is under cultivation. It is widely scattered in small areas east of Washington Fields, in the Arizona Strip south of the Utah-Arizona State line, in Warner Valley, and around Bloomington. The land is well or excessively drained and free from harmful quantities of salts. Under irrigation, it probably would be a fairly good farming soil but somewhat less desirable than typical Redfield fine sandy loam and the less sandy Redfield soils. Alfalfa doubtless would be the best crop until the soil became silted by sediment from irrigation water. When silted, the land would be fairly well adapted not only to alfalfa but also to small grains, sorghums, and sugar-beet seed. It would require somewhat more frequent irrigation than Redfield loam.

Redfield clay.—Redfield clay is pale-red, dull-red, or brownish-red rather compact clay. The surface soil and subsoil are very similar, although the latter is somewhat tougher and more massive. Both are highly calcareous and contain more or less gypsum. Faint mottlings of lime occur in places in the subsoil, but there is no very marked concentration of lime. The greater part of the area of this soil is adequately drained at present, and in such places the content of salts is low or moderate. Some areas in Washington Fields have become affected by seepage or run-off from higher irrigated land and are waterlogged or marshy and more or less strongly affected by salts. Most of the land is rather flat, and the slow surface drainage and subdrainage, together with the low position, may give rise to further waterlogging and accumulation of salts if new areas are put under irrigation. This is particularly true of the areas southwest of Hurricane, close to Bench Lake. In such places drainage outlets should be provided at the time the land is put under irrigation.

More than one-half of this soil is on the flat southwest of Hurricane, east of Bench Lake. Areas are in Washington Fields, at Toquerville, and southeast of Ivins. Only that body on which Toquerville is located, comprising about 65 acres, is under cultivation. The land is well drained and is intensively cultivated in small tracts. It is producing vegetables, peaches, pears, apricots, apples, grapes, and alfalfa. The bodies in Washington Fields are poorly drained or wet and produce rather inferior pasturage of sedges, tules, saltgrass, and other grasses. It is believed that most of these areas could be successfully drained and the excess of salts washed out.

Although heavier and harder to work than the other Redfield soils, this soil should prove productive if properly managed, and it seems well adapted to the growing of small grains, grain sorghums, sorgo, and alfalfa. Sugar-beet seed and some kinds of vegetables probably would do well, and in a few of the areas having greater freedom from frost, some fruits could be grown. Areas of this soil lying southwest of Hurricane would come under the proposed Dixie project. According to one of the engineering plans, it might be flooded by the waters of a reservoir at Bench Lake.

Redfield clay, silted phase.—Redfield clay, silted phase, occupies several bodies in Washington Fields where the surface soil consists of medium-brown or dark reddish-brown clay that has been deposited by irrigation water. Otherwise, the soil is practically identical with typical Redfield clay.

This soil occupies low, nearly flat lands surrounding marshy areas. Subdrainage is restricted, a high water table exists, and the salt content of the soil ranges from moderate to high. The greater part of this soil is covered by a growth of saltgrass, foxtail, sedges, and other moisture-loving vegetation, and it provides pasture of rather low quality. Some of the higher and better drained parts are used for the production of small grains and sugar-beet seed. Crop stands are spotted and yields are probably somewhat more than half those on the adjoining better drained lands. Artificial drainage and leaching would improve the productivity of this soil.

Tobler fine sandy loam.—Tobler fine sandy loam is similar to Redfield fine sandy loam, but it is much redder. The soil material consists of outwash from red sandstones and shales. Both surface soil and subsoil are brick-red mellow fine sandy loam. The surface soil, to an average depth of about 8 inches, is slightly darker than the subsoil, and it is not calcareous or only slightly so. The subsoil is distinctly calcareous but in most places has very little visible concentration of lime. In places a rather large quantity of gypsum sand occurs in the subsoil; and in places, especially in the larger areas in Warner Valley, the subsoil is slightly more compact and contains rather faint white mottles or splotches of lime. Drainage is good, and the soil is free from harmful concentrations of salts.

This soil lies on smooth gently sloping alluvial fans. In a few places a veneer of wind-drifted fine sand forms hummocks as much as a foot high. The largest bodies are in and around Ivins and in Warner Valley. Smaller areas are southeast of Ivins, east and northeast of Santa Clara, in and around Washington, in the Arizona Strip,

south of St. George, in Little Valley, and at Virgin. About 200 acres, mostly in the vicinities of Ivins and Washington, are under cultivation. At Ivins the water supply is not sufficient for high production of crops. Grapes and tree fruits, principally peaches, do fairly well. Alfalfa does well when the land is sufficiently irrigated, and small grains and sorghums do fairly well. In Washington, where the water supply is plentiful, this soil is highly prized for growing early truck crops, including radishes, onions, carrots, melons, and home gardens that include many vegetables.

If provided with sufficient water for irrigation, this soil would be well suited to the production of vegetables, grapes, peaches, and alfalfa. Sugar-beet seed, small grains, grain sorghums, and sorgo also would be fairly well adapted. Somewhat more frequent irrigation is needed on this soil than on loams or soils of heavier texture, but each application of water need not be heavy. To maintain fertility, organic matter should be supplied to the soil in the form of barnyard manure or by plowing under alfalfa or other legumes. Superphosphate and ammonium sulfate fertilizers are used with good results.

In its virgin condition this soil supports creosotebush and matchweed, together with scattered coarse bunchgrasses. It has some slight value as range or grazing land.

Tobler fine sandy loam, hummocky phase.—Tobler fine sandy loam, hummocky phase, occupies areas in Warner Valley where the surface is covered by a veneer of loose, drifting fine sand. The thickness of this layer ranges from almost nothing to as much as 18 inches and gives rise to an uneven hummocky surface. The soil material, below this covering, is almost identical with typical Tobler fine sandy loam.

This soil lies on gently sloping alluvial fans. It is all virgin desert with a sparse brush covering accompanied by a small amount of coarse bunchgrass. If the land were brought under cultivation, difficulty probably would be experienced at first with blowing of the loose surface soil. Straw spread on the surface might check this, and if the land were seeded to alfalfa or pasture, blowing would be largely eliminated for a time. If silty irrigation water were available it would gradually improve the texture of the soil, minimize blowing, and make the land more productive. In time this soil might have a value equal to that of typical Tobler fine sandy loam.

Tobler loam.—Tobler loam, to an average depth of about 15 inches, is red or brownish-red friable loam resembling Redfield loam but much redder. It lies on gently sloping alluvial fans, generally at the bases of cliffs of red sandstone and shale. The subsoil is brick-red mellow loam or heavy fine sandy loam. Both surface soil and subsoil are distinctly calcareous but have little concentration of lime in any layer. In places faint white mottlings of lime or gypsum occur in the subsoil. This soil is mostly well drained and free from harmful quantities of salts, although small areas in St. George and southeast of Ivins in sec. 5, T. 42 S., R. 16 W. are wet and contain moderate to high salt concentrations in the surface soil.

Tobler loam occurs in rather small bodies in St. George, southeast of Ivins, east of Santa Clara, in Warner Valley, in Washington, and southwest of Grassy Valley. Less than 200 acres are under cultiva-

tion, in St. George, south of Ivins, and in Washington. The soil is used for home or truck gardens, home orchards, alfalfa, and small grains, all which do fairly well in most places. The small poorly drained salt-affected areas produce only a poor growth of grass and weeds. They probably could be reclaimed by drainage and flooding with irrigation water.

Gila silty clay loam.—Gila silty clay loam is a deep recent alluvial soil occupying stream-bottom lands or low terraces. It is somewhat similar to Redfield silty clay loam but is somewhat darker and browner. The surface soil, to a depth ranging from a few inches to a foot, is medium-brown or dark-brown rather friable granular or soft cloddy silty clay loam with a slight red or purple tinge. Probably it consists, at least in part, of irrigation silt in most places. The subsoil generally is slightly lighter colored and redder than the surface soil and is irregularly stratified. The texture of the materials ranges from sandy loam to clay, but the mass everywhere is pervious and has a good water-holding capacity. The content of organic matter appears to be somewhat higher than that of the Redfield and most other soils in the Virgin River Valley area. The soil is moderately or highly calcareous throughout, but there is no definite concentration of lime in the subsoil.

This soil occupies bottom lands along the Santa Clara and Virgin Rivers. Somewhat more than one-half of the total area is well drained and practically free from salts. The rest is wet or has a high water table and is more or less affected by accumulations of salts. The larger poorly drained areas are in Washington Fields, where poor drainage is due to seepage from irrigation canals and higher lying irrigated land. Practically all of the well-drained lands are cultivated and produce good yields of numerous crops, among which alfalfa hay is one of the most important. It produces about 5 tons an acre where the land is fertilized with superphosphate. Wheat yields 30 to 40 bushels an acre. Barley, grain sorghums, and sorgo are grown on small acreages and yield well. Sugar-beet seed also is grown on small acreages and returns yields of 2,000 to 3,000 pounds an acre. Near Santa Clara, peaches, grapes, apples, and other tree fruits grow and yield well in most years, but occasionally they are damaged by frost. Peaches are said to yield from 8 to 10 tons an acre. Vegetables are grown, mostly for home use. The more poorly drained areas are covered largely with saltgrass and other grasses and are used for pasture. The area near Santa Clara is in orchards, gardens, and general farm crops.

In places this soil is menaced by bank cutting by the larger streams, especially during periods of high water.

Gila loam.—The surface soil of Gila loam is medium-brown or dark-brown friable loam with a slight red or purple tinge. It appears dark brown when moist. Typically, the subsoil is mellow, pervious, and much stratified, the various layers ranging from sand to silty clay loam and from rather dark dull reddish brown to light pinkish brown. Drainage and moisture-holding capacity are normally good, and the salt content is low in most places. About 60 acres, occurring in small bodies near the Virgin River, are poorly drained and more or less affected by concentration of salts.

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This soil lies along the Santa Clara and Virgin Rivers and on the lower course of Ash Creek on low terraces and bottom lands. It is largely under cultivation. Alfalfa is the principal crop, and wheat, barley, milo, and sorgo are common crops in most places. In the vicinity of Santa Clara, the land is used for orchards, vineyards, and truck gardens. Peaches and pears yield well here in most years, although occasionally the crop is damaged by frost. Peaches on mature trees are said to yield 10 tons an acre. The soil seems well adapted to growing truck crops and sugar-beet seed, but the culture of these crops is not yet extensive. This soil is in places subject to bank cutting by streams, and undoubtedly much of it has been destroyed in this way.

Gila fine sandy loam.—Gila fine sandy loam occupies narrow strips paralleling the drainage channels of the Santa Clara and Virgin Rivers. The surface soil is medium-brown or light reddish-brown mellow fine sandy loam. The subsoil is much stratified, the material ranging in texture from sand to clay loam or clay and in color from light gray to light reddish brown or pale red. It is normally well drained, although a few small imperfectly drained salty areas occupy the low ground near the Virgin River.

Probably less than half the area of this soil is under cultivation, mostly to alfalfa, small grains, and pasture. Its position along stream channels makes it subject to destructive erosion, especially at flood periods. It is a fairly productive soil but requires rather frequent irrigation. It seems well adapted to growing early vegetables.

Gila fine sand.—Gila fine sand consists of pale reddish-brown loose fine sand. In places, the surface layer is grayish-brown medium sand containing many dark basaltic particles. The subsoil is similar to the surface soil but is much stratified and in places contains considerable medium sand and coarse sand. This soil lies along the channels of the Santa Clara and Virgin Rivers slightly higher than riverwash. Some areas, especially those along the Santa Clara River, are excessively drained; whereas most of the areas along the Virgin River are poorly drained or wet and in places crusted on the surface with salts. Such low-lying areas are subject to overflow and erosion during periods of high water.

This soil has very little value, present or potential, although small areas may possibly be irrigated and built up by the silt in the irrigation water.

Fort Pierce silt loam.—Fort Pierce silt loam consists of very light yellowish-brown, yellowish-gray, or cream-colored floury silt loam. In the field it appears nearly white in contrast to the red soils with which it is associated. The surface soil and subsoil are very similar. Both are soft, mellow, and have little definite structure, breaking up into soft easily powdered clods. The subsoil is typically very slightly lighter in color than the surface soil. The soil material is outwash from light-colored shales and is very rich in lime and probably in gypsum. The salt content is low or moderate. In a few places, shown on the map by gravel symbols, the soil contains rather large quantities of gravel and grit. In some other places red alluvial material occurs in the subsoil.

The largest bodies of this soil are from 5 to 6 miles south of St. George near the Utah-Arizona State line. Smaller bodies are southeast of Washington Fields and 2 miles northwest of La Verkin. It all lies within undeveloped desert areas but possibly may be put under irrigation at some future time. The surface is smooth and gently sloping, and the land probably is fairly well adapted to farming, although the soil material is rather raw (unweathered), is very low in humus, and probably is potentially less productive than the soils of the Redfield, Gila, and Tobler series. The native vegetation consists largely of a sparse growth of shadscale, and the land has only slight value for range or browse.

Junction coarse sandy loam.—The 12-inch surface soil of Junction coarse sandy loam is rusty-brown or reddish-brown coarse sandy loam or loam of coarse gritty texture. The upper part of the subsoil is reddish-brown friable gritty loam or coarse sandy loam, and, below a depth of about 2 feet, the material is similar but slightly lighter colored and not so red. The surface soil and the upper part of the subsoil are not calcareous, whereas the lower part of the subsoil is distinctly so. The subsoil is little if any more compact than the surface soil and shows little evidence of the higher lime content.

This soil occupies smooth gently sloping alluvial fans, and the parent soil material consists largely of outwash from granite or similar crystalline rocks. Drainage is good to excessive, and the water-holding capacity of the soil ranges from fair to good.

This soil occurs in comparatively small bodies around Anderson and Hurricane Junction. About 100 acres are under cultivation and devoted to alfalfa, small grains, peaches, and grapes. Crops do well where irrigated at sufficiently frequent intervals, although fruit crops occasionally fail on account of frost at blossomtime.

Around Hurricane Junction, the native vegetation consists largely of creosotebush and matchweed, whereas near Anderson matchweed predominates and there is a scattering of juniper. Annual grasses and herbs, such as "filaree" or alfileria, are common in the spring, when the land furnishes good pasture for sheep.

Leeds clay loam.—Leeds clay loam is dark reddish-brown friable clay loam to an average depth of about 7 inches. This is underlain by somewhat lighter reddish brown or brownish red clay loam that is slightly more compact than the surface soil. Neither of these upper layers is distinctly calcareous. At a depth of about 15 inches is somewhat compact reddish-brown heavy clay loam or clay, slightly mottled with lime. At a depth of about 32 inches and continuing to 72 or more inches is reddish-brown stratified material ranging from clay to coarse sand. This material is rather highly calcareous and contains many white mottles of lime.

This soil lies on alluvial fans with a smooth or slightly ridgy surface. It is well drained and free from harmful concentrations of salts.

Some small included areas have distinctly calcareous surface soils and little definite development of a profile, and in places both surface soil and subsoil are loam in texture.

This soil occupies rather small areas in and near Leeds and southwest of Harrisburg. About 250 acres around Leeds are under cultiva-

tion (pl. 2. *A*). A large proportion of the cultivated land is in peach orchards, and small areas are devoted to the production of alfalfa, small grains, and sugar-beet seed. All these crops yield well in normal years, but the peach crop sometimes is reduced by frost.

SOILS WITH COMPACT LIMY SUBSOILS ON UPLANDS, FANS, AND TERRACES

Soils with compact limy subsoils on uplands, fans, and terraces, but having no extremely cemented hardpan, are classed in the Moffat, La Verkin, Bennett, Moenkopie, Ivins, St. George, and Bracken series.

Most of these soils are on comparatively high well-drained alluvial fans, terraces, and mesas. The soils of the St. George and Bracken series, however, are on alluvial fans which have been subject to spring seepage and are in places still poorly drained and affected by high concentrations of soluble salts. The soils of the group range from rather coarse and sandy to medium textured or fine textured. The subsoils contain a very high concentration of lime in many places but probably in most places are not sufficiently tough or cemented to interfere greatly with the penetration of moisture and roots. The St. George and Bracken soils contain much gypsum as well as lime in the subsoils. The organic-matter or humus content is very low except in the St. George soils. The water-holding capacity of the soils and their natural fertility are somewhat lower than those of the fine-textured alluvial soils, but if furnished with sufficient irrigation water and properly managed they are fairly good agricultural soils. Fruits do well on those areas having good air drainage and comparative freedom from frost. Peaches and grapes are the most important fruit crops. Alfalfa is an important crop and gives good yields. Small grains, grain sorghums, sorgo, and sugar-beet seed are not so well adapted to these soils as they are to the fine-textured alluvial soils, although after these soils have been built up by deposition of silt from irrigation water, they become nearly as productive as those soils.

Moffat fine sandy loam.—Moffat fine sandy loam is light brownish-red or pale-red mellow fine sandy loam or loamy fine sand to an average depth of about a foot. It is distinctly calcareous. The upper part of the subsoil, to a depth ranging from 2 to 4 feet, is light-red or brownish-red soft and practically structureless fine sandy loam or loamy fine sand. Beneath this is a light-pink or mottled pink and white lime layer that is compact and more or less firmly cemented. In places it has the hardness of a true hardpan, but in other places it is much softer. It generally becomes somewhat softer when moist and probably would be pervious to roots in most places. In places this material grades, within 6 feet of the surface, into softer, less firmly cemented, and redder material. The moisture-holding capacity is fairly good, though it is lower than in the fine-textured alluvial soils.

An area of about 85 acres, 1½ miles southwest of Bloomington, is underlain by gravel beds at an average depth of about 3 feet. A heavy concentration of lime and soft cementation exists in the upper few inches of the gravel.

This soil is widely distributed throughout the area surveyed. It occurs on alluvial fans or high terraces, and the surface ranges from

A, Cultivated field on Leeds clay loam. Basaltic ridge of rough stony land in the background. *B*, Orchard on Moffat fine sandy loam, silted phase.

smooth and gently sloping to rather steep, uneven, and ridged. The land is naturally well drained, although a few of the lower lying areas might possibly be affected by seepage if the land were put under irrigation. Only a few acres west of Hurricane are under cultivation but several hundred acres of this soil, which have been modified by irrigation silting and are mapped as the silted phase of Moffat fine sandy loam, are cultivated. A fairly large area of this soil possibly may come under irrigation on the proposed Dixie project. The greater part of the land could be farmed if it were supplied with sufficient irrigation water. It seems fairly well adapted to the growing of alfalfa, grapes, and peaches. Small grains and sorghums may become fairly well adapted if the soil is modified by irrigation sediments. The organic-matter content of the soil is very low, and the growing of alfalfa and the application of barnyard manure are advisable in building up or maintaining productivity. Superphosphate fertilizer also is recommended, and ammonium sulfate would doubtless increase yields of some crops.

Moffat fine sandy loam, silted phase.—The silted phase of Moffat fine sandy loam is practically identical with typical Moffat fine sandy loam except that the surface soil is modified by silt deposited by irrigation waters. The surface soil, to plow depth, is reddish-brown heavy loam, clay loam, or clay, depending largely on the proportion of irrigation silt mixed with the original fine sandy loam material. The soil is well drained in most places, has fairly good moisture-holding capacity, and is productive where properly managed, but it has somewhat lower productivity than the finer textured, deeper alluvial soils, such as those of the Redfield series. The surface is smooth and gently sloping in most places.

An area including about 20 acres in the southwestern part of Washington Fields is wet and salty and is of use only as pasture land. The soil is most extensive west of Hurricane and south of St. George. Smaller areas are located at the southwest end of Washington Fields, in Little Valley, and near La Verkin. Practically all of this soil is cultivated and is producing alfalfa, small grains, and milo. Tree fruits (pl. 2, *B*), including peaches, and grapes are grown. Alfalfa yields from 2 to 5 tons an acre. The higher yields are obtained through the use of superphosphate fertilizer. Wheat yields 15 to 35 bushels an acre; milo as high as 70 bushels; and sugar-beet seed 1,500 to 2,500 pounds. Full-grown peach trees in the more frost-free locations yield from 5 to 10 tons an acre, with an average of about 7 tons.

Moffat loam.—The 12- to 18-inch surface soil of Moffat loam is light reddish- or pinkish-brown mellow loam of granular structure. It contains a small quantity of gravel and has a high content of lime. The subsoil, to a depth of about 40 inches, is pink or almost white compact or softly cemented fine-textured limy material. Beneath this, the parent soil material is light reddish-brown mellow loam, containing white flecks of lime. In places, the lower part of the subsoil contains much gypsum and has a mealy consistence. Gravel and boulders underlie the subsoil in places.

The soil lies almost entirely in the Arizona Strip south of the Utah-Arizona State line, with a few small areas just north of the line and 3 miles south of Berry Springs. It is all virgin desert

and supports a growth of creosotebush, squawbush, cholla, and Mormon-tea, with a scattered growth of bunchgrass in places, and, after rainy winter or summer seasons, a growth of small annual grasses and herbs. It has some value as range or pasture land.

This soil occupies undulating or gently undulating uplands consisting of old alluvial fans or terraces. Drainage is good, and the salt content of the soil is low. If water could be supplied for irrigation, the land doubtless would be adapted to growing the common crops of the area. Alfalfa would be well adapted, and, in the more frost-free areas, fruits, especially peaches and grapes, could be grown to good advantage. A part of this soil may be irrigated under the proposed Dixie project.

Moffat fine sand.—In most places Moffat fine sand has a layer of light-red or light reddish-brown loose fine sand a few inches thick on the surface. Light-red or reddish-brown soft structureless loamy fine sand extends to an average depth of about 3 feet, and this material is underlain by light-pink or almost white softly or partly cemented lime hardpan of more or less platy structure. The material below this is somewhat less cemented but is still compact.

This soil lies on old alluvial fans or high terraces and has a rather rolling, hummocky, or uneven surface. It is well drained, has a moderate or rather low moisture-holding capacity, and is free from harmful salt concentrations. It is rather widely distributed in small bodies throughout the area surveyed. The largest bodies are southwest of Hurricane, near Grassy Valley, and south of Berry Springs. Smaller areas are in the southwest end of Purgatory Valley, north and west of Washington, north and northeast of Santa Clara, south of Grapevine Spring, southwest of Bloomington, in Warner Valley, and near Fort Pierce Wash.

None of this soil is irrigated. In its present state it has value only as range land. There is a covering of creosotebush, matchweed, squawbush, scattered bunchgrass, and, after rainy seasons, a growth of small annual grasses and herbs. It is possible that some of this soil may be irrigated under the Dixie project or smaller developments. On account of its uneven surface and the coarse texture and loose porous character of the material in the upper part of the soil, it is doubtful that this would be a very desirable soil under irrigation. The water requirement would be high and frequent irrigation necessary. Alfalfa would be one of the best adapted crops, and grapes and peaches could be grown successfully in the more frost-free areas.

Bennett fine sandy loam.—Bennett fine sandy loam, to an average depth of 12 inches, has a surface soil of light brownish-red friable or rather loose loamy fine sand or fine sandy loam. The subsoil, which continues to a depth of 2 to 3 feet, is brownish-red loamy fine sand or fine sandy loam similar to the surface soil but slightly redder, soft, and without definite structure. Below this is a bed of gravel, cobbles, and boulders, with more or less cemented limy material in the interstices.

This soil occupies only a few small areas on high terraces along the Virgin River. None of the land is under irrigation, and it is not in positions where water is readily available. This soil is too sandy and too shallow to be desirable under irrigation, but, if

water were cheap and plentiful, it might be used for the production of fruit.

La Verkin loam.—La Verkin loam, to an average depth of about 12 inches, is light reddish-brown friable loam containing some gravel, which in places is concentrated on the surface. The upper part of the subsoil, to a depth of 2 feet or slightly more, is reddish-brown or dull-red tough or softly cemented clay loam containing a rather large quantity of gravel and white mottles or nodules of lime. Below this, the subsoil is dull-red or light-red gravelly clay loam mottled with white lime concentrations. It is tough and slightly cemented. Below a depth of 3½ or 4 feet there is, in most places, a bed of gravel or gravelly sand, with a brownish-red stain in the upper part. Drainage is good or excessive, and the soil is free from harmful salt concentrations.

This soil occurs on high terraces and alluvial fans of undulating to uneven and ridgy surface. The larger areas are in the Arizona Strip, and smaller ones are north of the Utah-Arizona State line south of St. George, near Bloomington, between La Verkin and Toquerville, near Virgin, and near Grafton.

Only a few acres of this soil are under cultivation, and these are devoted largely to tree fruits and alfalfa, to which the soil seems well adapted. The soil is somewhat similar to Moffat loam and has practically the same crop adaptations. Much of it lies in places where water is not readily available, but, if the land could be provided with water, much of it might be used for fruit growing. General farm crops could be grown, but in most instances the high cost of water would make their production impractical.

La Verkin loam, silted phase.—The silted phase of La Verkin loam is similar to typical La Verkin loam, but the surface soil, ranging from a few inches to more than a foot in thickness, is medium-brown or dark reddish-brown clay loam or silty clay loam, which has resulted from the deposition of silt by irrigation water. The original surface soil below the silted layer is light reddish-brown loam or clay loam, and the subsoil is rather compact clay loam or clay. Gravel beds lie within a depth of 6 feet. Drainage is good, and the soil is free from salt concentrations.

This soil lies on high smooth or undulating terraces near La Verkin and between La Verkin and Toquerville. It is not extensive but is all under cultivation. The principal crops are peaches and alfalfa hay. Other fruits, including sweet cherries, pears, apples, apricots, and grapes are grown, and there are some almond and English walnut trees. Air drainage favors fruit growing, and peaches generally are a safe and profitable crop. Yields average about 8 tons an acre. Alfalfa yields from 2 to 5 tons an acre. It is grown in many of the orchards. Small grains and sorghums are grown to some extent and give fairly satisfactory yields.

Ivins fine sand.—To a depth of about 12 inches, the surface soil of Ivins fine sand is soft and structureless red fine sand or loamy fine sand. Below this, and extending to a depth ranging from 2½ to 4½ feet, is red mellow loamy fine sand, which breaks up into soft easily crumbled clods. This sandy material rests on tough red clay of columnar structure. The columns are about 3½ inches in diameter and about 6 inches long, and they are capped with a thin layer of

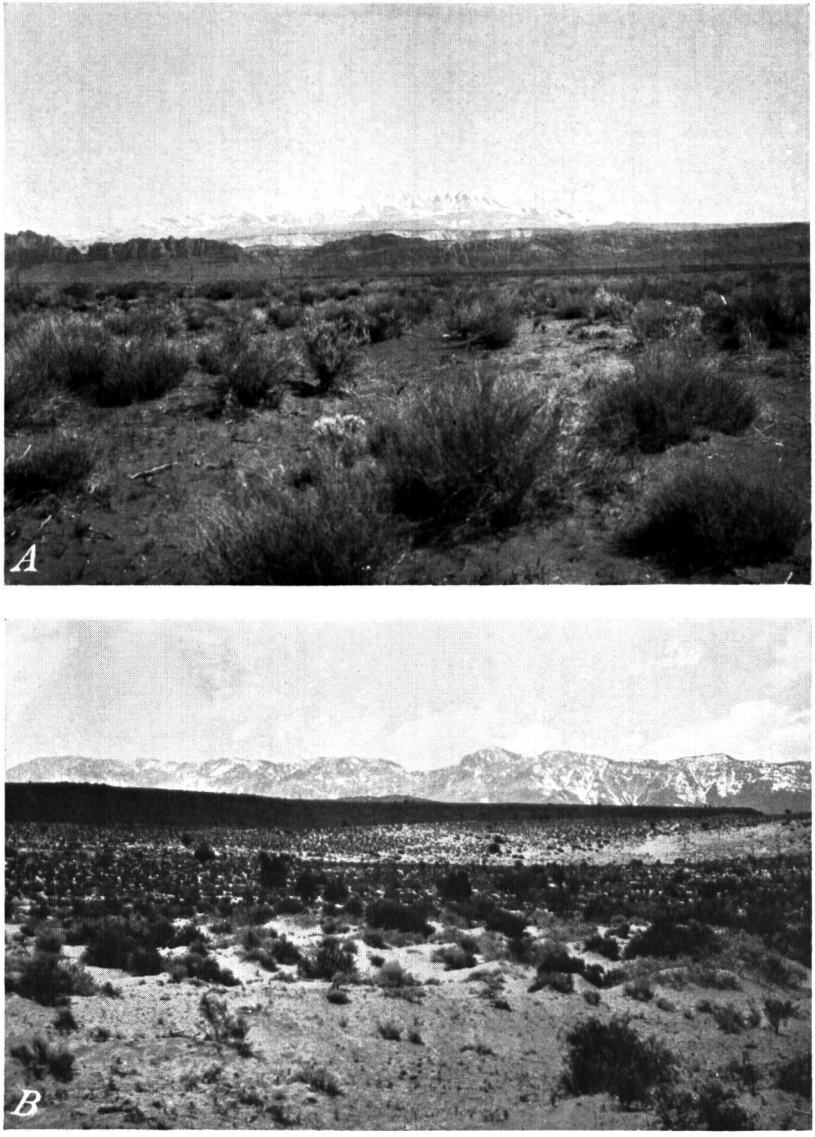
white siliceous material. Beneath the columnar layer is tough massive red clay with a heavy concentration of white lime in seams and mottlings. In places it is cemented into a hardpan. At a depth ranging from 4 to 6 feet below the surface, this grades into dark-red or purple shale.

This soil occurs largely in a single long irregular-shaped body extending from a point about 1 mile west of Ivins to a point about one-half mile east of Santa Clara. Smaller bodies are about 2 miles southwest of Anderson. The soil is situated on high plateaus or terraces having smooth or gently rolling surfaces. Surface drainage is good or excessive, and the soil is practically free from salts, although the shale substratum may contain rather large quantities. About 200 acres are under cultivation to alfalfa and small grains, but, as the water supply is limited and the soil does not hold much moisture, yields are light. If the soil were supplied with sufficient water, it would be fairly well adapted to the production of alfalfa hay, peaches, and grapes. It is possible that the water supply could be augmented by the building of a higher storage dam on the Santa Clara River. Frequent light applications of water are desirable. The unirrigated land supports a brushy vegetation (pl. 3, *A*) that has some value for grazing.

Moenkopie loam.—Moenkopie loam, to an average depth of about 9 inches, is light brownish-red or reddish-brown granular gritty loam. It is distinctly or highly calcareous. Below this, to an average depth of about 18 inches, is brownish-red or dull-red tough clay loam, with a rather indistinct or irregular prismatic structure. The prisms are 4 or 5 inches in diameter. There are a few white lime splotches in this layer. Below the prismatic layer and continuing to a depth of about 3 feet is light pinkish-brown or purplish-brown clay loam or clay, splotched and seamed with white lime. This is underlain by purple or purplish-red soft disintegrated shale seamed with white lime. At a depth of about 4 feet, the shale is less weathered and slightly harder, and it is mostly purple or purplish brown but contains some light greenish-gray material. Those areas near Ivins are redder in both the surface soil and subsoil than the typical soil described above, and the shale lies at somewhat greater depth.

This soil lies on smooth or gently rolling uplands. Surface drainage is normally good, but an area including about 20 acres south of Ivins lies on comparatively low ground, has a high water table, and has a slight concentration of salts. On account of the tough subsoil and underlying shale, natural subdrainage is restricted, and there is some possibility that the lower lying areas might become waterlogged and affected by a concentration of salts if irrigation were extended. The lower part of the subsoil and the shale substratum contain rather large quantities of salts in places.

The total extent of this soil is small. The greater part of it is south of Ivins and southeast of St. George in secs. 23, 24, and 25, T. 43 S., R. 15 W. A small area is about 1½ miles west of Toquerville. About 80 acres south of Ivins is under cultivation and is producing alfalfa and small grains, but, as the water supply is short, yields are not heavy. If sufficient water were available, this soil should be fairly well adapted to growing alfalfa, small grains, and grain



A, Ivins fine sand showing brushy vegetation. Red sandstone cliffs, from which parent soil material is derived, in middle distance, and Pine Valley Mountains in far distance. *B*, Wind-blown hummocky surface of Pintura fine sand. Basaltic ridge of scabland in middle distance and Pine Valley Mountains in far distance.

sorghums. Provisions for drainage would be essential on some of the lower areas. The land has some value for grazing.

Moenkopie clay loam.—Moenkopie clay loam is similar to Moenkopie loam, but both surface soil and subsoil are heavier textured. The surface soil ranges from gritty clay loam to clay, and the subsoil is clay. Shale underlies the subsoil within 3 feet of the surface. This soil lies for the most part in a large depression or basin in secs. 23, 24, 25, and 26, T. 43 S., R. 15 W. There is no surface drainage outlet, and, as the subsoil and shale substratum are comparatively impervious and contain soluble salts in rather large quantities, it is probable that unfavorable conditions of drainage and salt concentration would develop if the land were put under irrigation.

The total area of this soil is small, and it is not recommended for development. It is now mostly virgin desert and supports a growth of brush and scattered bunchgrass, which has some value for grazing.

An area including about 30 acres one-half mile west of Leeds occupies a gentle slope with good surface drainage. It seems fairly well adapted to growing alfalfa, small grains, and sorghums. It probably is not so well adapted to orcharding as are other soils in that locality.

Moenkopie fine sandy loam.—Moenkopie fine sandy loam is very similar to Moenkopie loam, but it is somewhat lighter or sandier, especially in the surface soil, which is fine sandy loam or loamy fine sand. The color of both surface soil and subsoil is red. The subsoil is tough and has a prismatic structure, and shale probably lies within 6 feet of the surface in most places.

This soil covers only a very small total area. The principal bodies are in Warner Valley. A small area is about 1½ miles southeast of Ivins. None of the land is under irrigation at present, as no water is available. If water were provided, the soil might be used for the production of alfalfa, small grains, and sorghums. Some trouble might be experienced from wind erosion or drifting of the surface soil, especially on the area of loose sandy soil mentioned above, although this difficulty might gradually be overcome by irrigation and by keeping the land seeded to alfalfa or in pasture.

St. George loam.—St. George loam occupies only a small total area. It occurs on gently sloping to nearly flat alluvial fans that are or have been affected by a natural high ground-water level or seepage from springs. It lies chiefly in the western and southwestern parts of St. George and just south of that town. Small bodies are southeast of St. George, southwest of Leeds, and in and near Middleton and Washington.

Typically, this soil has a dark-gray or dark grayish-brown loam or fine sandy loam surface soil, which appears nearly black when moist. The color, texture, and thickness of surface soil and subsoil layers are extremely variable, as the soil has been subject to alternating periods of deposition and soil formation. Generally, the upper part of the subsoil is gray or brownish-gray loam, but red layers occur in places. The lower part of the subsoil, below a depth ranging from 2 to 3 feet, in most places is gray or light-gray more or less marly loam or clay loam. The surface soil and subsoil are highly calcareous throughout. In places, there is some red material in the surface soil,

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but the larger areas in which this condition is present are mapped as the overwash phase of St. George loam. In an area in the southwest part of St. George and extending just south of that town, and in small areas in and near Washington, the surface soil is medium grayish-brown or dark grayish-brown silty clay loam that is granular and fairly mellow. The subsoil also is somewhat heavier than that of the more typical St. George loam.

This soil is poorly drained in most places and either is wet and marshy or has a water table within 3 feet of the surface. Some small areas, however, have been drained either naturally or artificially. The salt concentration ranges from slight to strong, depending largely on present drainage conditions and the extent to which leaching has occurred through irrigation.

Much of this soil occupies city lots and is used for lawns, gardens, and small pasture lots. In some of the better drained places tree fruits and grapes do fairly well. An area of about 35 acres just southeast of St. George is dry, but the soil contains much salt and is uncultivated. The high salt content and tough marly subsoil would make reclamation difficult. That part of the soil near Leeds is wet and is used for pasture. The area of heavier soil south of St. George is devoted mostly to pasture. Saltgrass grows naturally on much of it. Some of the better drained areas are producing good crops of small grains, sugar-beet seed, and alfalfa. Artificial drainage doubtless would improve conditions for crop growth on the wetter areas.

St. George loam, overwash phase.—The overwash phase of St. George loam occupies small areas on gently sloping alluvial fans in the northern and northeastern parts of St. George and in Washington.

This soil is similar to St. George loam but has a surface layer of red loam or fine sandy loam. There is little uniformity of profile, but dark-gray, dark grayish-brown, light-gray, and red layers occur in the subsoil. Marl and gypsum are prominent in the subsoil in many places but are of uneven or intermittent occurrence. Subdrainage is retarded in most places, and a high water table is common; but in few places is the surface soil permanently wet. In the northeast part of St. George the soil contains moderate quantities of salts. Rather strong salt concentrations exist in a few small spots. This soil is used for commercial truck growing in Washington. In St. George it is devoted to lawns, gardens, pasture lots, and alfalfa. Tree fruits and grapes do fairly well in some of the better drained and comparatively salt free locations.

Bracken fine sandy loam.—Bracken fine sandy loam lies on alluvial fans east and southeast of Middleton, west of Washington, and in and east of St. George.

This soil, to an average depth of about 12 inches, is light-brown or light reddish-brown mellow fine sandy loam. It is highly calcareous. Below this and continuing to a depth of about 2 feet is light-gray or light brownish-gray fairly mellow loam that is very rich in lime. This is underlain by light-gray, light yellowish-gray, or light greenish-gray very tough or softly cemented heavy loam or clay loam, containing a concentration of lime and gypsum. This subsoil varies considerably from place to place in consistence and degree of cementation. It is predominantly tough, although soft mealy gypsum layers exist in places and in many places the lower part of the sub-

soil, below a depth ranging from 3 to 4 feet, is cemented into a lime-gypsum hardpan. The surface soil is in most places free from salts, but the subsoil normally contains moderate or large quantities. In a few small areas, totaling about 35 acres, around Middleton the surface soil is fine sand that is more or less subject to wind drifting. Areas, totaling about 160 acres, in St. George and east of Middleton have a surface soil of light-red fine sandy loam or loam but otherwise are very similar to typical Bracken fine sandy loam. One small area in secs. 29 and 32, southeast of St. George, has a surface soil of brownish-red clay loam or silty clay loam, and a subsoil that is tough and full of lime, gypsum, and sodium salts.

Subdrainage is slow in this soil, but most of the land is dry, although doubtless it has been subject to high ground water at some time in the past.

The land is covered in most places by a shrub vegetation including creosotebush, saltbush, mesquite, matchweed, and cholla and other species of cacti. It affords limited grazing or browse.

Only a small area, probably not over 50 acres, is irrigated and is devoted to the production of alfalfa, pasture, vegetables, grapes, and tree fruits. All except the tree fruits do fairly well. It is probable that the tough, gypsiferous, saline subsoil is not conducive to a healthy growth of trees. If sufficient water were available, it is probable that the greater part of this soil near Middleton and Washington could be successfully used for the production of crops. Parts of the lower lying areas in this locality, as well as the greater part of the areas near St. George, might develop unfavorable conditions of drainage and salt concentration if irrigation were attempted.

The soil is very low in organic matter. Barnyard manure and superphosphate doubtless would be helpful.

Bracken silty clay loam.—Bracken silty clay loam occupies a few small areas southeast of St. George, in Washington, and west of that town.

The surface soil, to an average depth of 12 inches, is brown or reddish-brown clay loam or silty clay loam. The subsoil is light-gray or greenish-gray tough or marly clay loam containing much lime and gypsum. Subdrainage is slow, and the soil contains moderate or large quantities of salts in most places. The bodies of this soil in Washington and the cultivated area south of the St. George canal have a comparatively low salt content. The area near the center of Washington has a surface soil of loam. The land below the St. George canal has been modified to a depth of a few inches by the deposition of silt from irrigation water.

About 60 acres of this soil is under cultivation. Small grains, alfalfa, sugar-beet seed, and vegetables are grown and return fairly good yields. Most of the land not now under cultivation is too salty for the production of crops without washing or leaching, and this process would be difficult on account of the comparatively impervious subsoil. The uncultivated areas support a growth of saltbush, seepweed, and other salt-tolerant vegetation, which have some value for browse.

SHALLOW SOILS OF THE UPLANDS

The shallow soils of the uplands are underlain at slight depths by practically impervious substrata—either bedrock or massive cemented

hardpan of rocklike hardness. The rooting zone for plants is limited and the water-holding capacity is comparatively low.

The soils of the group either are not suitable for cultivation or may be used to a limited extent for certain crops under favorable conditions. Alfalfa, peaches, and grapes are grown on small acreages of the better soils, where water is plentiful and cheap. In places where the soil is extremely shallow or stony, cultivation is not practical, especially where there is better land on which to use the water.

This group contains most of the soils of the Harrisburg, Veyo, Toquerville, Shavano, Purgatory, and Tortugas series. The Tortugas, Shavano, Toquerville, and Purgatory soils are shallow so-called residual soils overlying bedrock, and the Harrisburg and Veyo soils are shallow lime-hardpan soils. Small areas of Harrisburg loam and its silted phase, and Veyo clay loam are under cultivation. Where silt-laden irrigation waters are available, the soils may gradually be improved and deepened by deposition of sediment. Frequent irrigation is essential, in order to maintain good moisture conditions on these soils, and fertilization is more essential than on the deeper soils.

Harrisburg loam.—Harrisburg loam lies on high terraces and alluvial fans that range from smooth to gently rolling. Surface drainage is good, and there is no accumulation of salts. This soil is widely distributed throughout the area. Large bodies are in the Arizona Strip south of St. George, on the Berry Springs flat south and southeast of Berry Springs, and on the bench south of Washington Fields. Smaller areas occur in the vicinities of Harrisburg, Leeds, and Anderson.

The 10-inch surface soil of Harrisburg loam is light reddish-brown or pale-red highly calcareous mellow gritty loam. There is, in many places, a concentration of mixed angular gravel on the surface. The upper part of the subsoil is dull-red or brownish-red somewhat compact and cloddy gravelly loam or gravelly clay loam, mottled with white lime. At an average depth of about 16 inches the soil material becomes much lighter colored—light reddish brown or pinkish brown, mottled with white—and softly cemented, and at a depth of about 2 feet it grades into hard or firmly cemented lime hardpan, or caliche, containing much embedded gravel. The hardpan is somewhat uneven or intermittent and ranges in thickness from a few inches to several feet. It is underlain by basalt or sandstone bedrock or by old, partly consolidated gravel. In places soft mealy gypsum occurs below the hardpan. In the areas near Harrisburg, Leeds, and Anderson, most of this soil is developed from granitic material, contains and is underlain by granitic boulders, is slightly darker and redder, and has, on the average, a somewhat thicker soil mantle.

Very little of this soil is under irrigation, but the small area mapped as a silted phase is farmed. Most of the land is outside the present irrigated districts and could be farmed only if water were provided by building new irrigation projects. Judging by results on areas of the silted phase, it seems probable that tree fruits, grapes, and alfalfa would do fairly well if water could be applied at frequent intervals. The soil, on account of its shallowness, has a low moisture-holding capacity and a limited zone for root development. It is low in humus, and this could be supplied by applications of barnyard manure or by

growing alfalfa. Much of the soil has the advantage of lying where air drainage is good, and the land is comparatively free from frosts in late spring. Small grains, corn, sorghums, or other general farm crops probably could be grown, but it is doubtful that they would yield heavily enough to make them profitable with the use of expensive irrigation water.

Harrisburg loam, silted phase.—The silted phase of Harrisburg loam is almost identical with typical Harrisburg loam, but, because the land has been under irrigation for several years, the surface soil is modified by an admixture of silt from irrigation waters. The texture of the surface soil ranges from heavy loam to clay loam, and the color is reddish brown. The depth of the layer of soil over the hardpan varies considerably. In the northern edge of Hurricane much of the soil is only about 18 inches thick, and bedrock outcrops in places. Several small areas of a shallow soil are south of Toquerville. On the flat 1 mile west of Hurricane the soil averages about 3 feet thick.

This soil occupies a limited acreage near Toquerville and Hurricane, and nearly all of it is under cultivation. The chief crops are peaches and other tree fruits, alfalfa hay, and grapes. These do fairly well where irrigated frequently, although yields are somewhat lower than those obtained on the Redfield and Moffat soils. In some of the orchards, water should be applied more frequently, but the quantity applied each time need not be large, as the soil has a low moisture-storage capacity. It is suggested that water be run across the slope rather than down the slope in order to save water, to prevent erosion, and to cause settling of silt on the land.

Harrisburg loam, rolling phase.—Areas of Harrisburg loam with an uneven or rolling surface that would render irrigation difficult are mapped as a rolling phase. The soil is much like typical Harrisburg loam, but it has a rather large content of stone in places, and the depth of the soil to the cemented layer is somewhat less in most places.

The total area of this soil is small. The largest bodies are in the Arizona Strip and south of Washington Fields. Smaller bodies are west of Washington and north of Bloomington. All the land is in its virgin condition, has little or no agricultural value, but has some value as grazing land.

Harrisburg gravelly loam.—Harrisburg gravelly loam is a fairly extensive soil widely distributed throughout the area surveyed. It lies mostly on high mesas and alluvial fans, and the surface ranges from smooth to undulating or gently rolling. Very little of this soil is under cultivation.

The soil is much like Harrisburg loam, but it is somewhat more gravelly and the mantle of soil material over the hardpan is thinner—less than 1½ feet thick in most places and averaging about 1 foot. The 6-inch surface soil is light-red or brownish-red fine sandy loam or loam, having a concentration of gravel on the surface. Below this the soil material is similar but contains a very large quantity of lime-hardpan fragments and lime-coated cobbles and gravel. This overlies the lime hardpan, or caliche, which is very hard and contains much embedded gravel and stone. In some places, as shown in exposures, the hardpan is several feet thick.

It is underlain in some places by basalt bedrock, in others by sandstone, and in others by beds of gravel or boulders. Rock outcrops are common in the areas underlain by basalt lava.

The thinness of this soil and its low moisture-holding capacity make it undesirable for agricultural development. The land is largely outside the irrigated districts, and it is very doubtful that it would be economically feasible to irrigate it with high-cost water.

Harrisburg stony loam.—Harrisburg stony loam is one of the more extensive soils in the Virgin River Valley area, but in most places it is of value only as grazing land. It lies on high mesas and alluvial fans throughout the area surveyed.

The soil is very similar to Harrisburg gravelly loam, but it contains a larger quantity of stones. The surface soil is light reddish-brown or pale-red gravelly loam or gravelly sandy loam, containing a large quantity of cobbles or boulders. At a depth ranging from 1 to 2 feet below the surface is the nearly white lime hardpan that contains much embedded gravel and stone.

Areas, totaling about 4 square miles, near Harrisburg, Leeds, and Anderson, consist largely of a mass of granite boulders, with gritty soil materials interspersed. It is very difficult to clear this land of stones and to penetrate the soil to an appreciable depth with tillage implements.

This soil as a whole is too stony and too shallow to be suitable for cultivation, but a few acres near Leeds have been cleared and planted to peach orchards. Peaches may be grown successfully in places where water is available, but owing to the great labor of clearing and the low moisture-holding capacity of the soil, it is not practical to expand the cultivated acreage greatly.

The land supports a cover of brush, with some juniper and scrub live oak near Anderson. Some bunchgrass grows in places, and after rainy seasons there is a growth of small annual grasses and herbs, including alfileria. The land has some grazing value.

Harrisburg fine sand.—Harrisburg fine sand is of no present agricultural importance, as it lies outside irrigated areas and would be of low value even if it were supplied with water for irrigation.

This soil lies on upland mesas or alluvial fans with smooth or uneven surfaces. The soil, to an average depth of about 1 foot, is loose or soft structureless pale-red or brownish-red fine sand. In places it contains some gravel composed largely of small lime hardpan fragments of rocklike hardness. Below this is a layer of hardpan fragments ranging in size from pebbles to cobbles, with mottled red and white loamy sand between the fragments. At an average depth of about 2 feet, this material is underlain by very hard massive lime hardpan, which is nearly white but streaked and stained with red. The depth of the soil mantle varies greatly. In places the hardpan outcrops, whereas in other places the sandy material is as much as 3 feet thick. In all places the soil has low water-holding capacity, low content of organic matter, and a tendency to blow easily. It has a native vegetal covering of matchweed, creosotebush, and squawbush, with bunchgrass scattered in some places. The only value of this land is in the limited amount of grazing it affords.

This soil occurs chiefly on the flat south of Berry Springs, near Grapevine Spring, and west of Toquerville. Several small bodies are near Washington and in secs. 24 and 25, T. 43 S., R. 15 W.

Harrisburg fine sand, hummocky phase.—The hummocky phase of Harrisburg fine sand lies on undulating or rolling uplands, associated with large areas of very sandy soils of other series. It is similar to typical Harrisburg fine sand, except that the surface is covered by very loose drifting red fine sand, which forms hummocks as much as 2 feet high in places. The total depth of the soil mantle ranges from a few inches to as much as 4 feet.

On account of its looseness and tendency to drift, as well as its very low moisture-holding capacity, this soil is practically worthless. It lies west of Toquerville, near Grapevine Spring, and southeast of Berry Springs.

Veyo stony clay loam.—Veyo stony clay loam occurs on the gently rolling basaltic plateau in and near Veyo.

This soil has developed from a thin mantle of soil material covering the uneven surface of the lava bedrock. Rock outcrops are common, and in most places the soil mantle is less than 2 feet thick. A heavy concentration of basalt stone and gravel occurs on the surface. The surface soil, to an average depth of about 6 inches, is highly calcareous brown mellow granular clay loam. The subsoil, to an average depth of about 14 inches, is brown clay loam or clay, which is somewhat more compact than the surface soil. It contains many lime-coated cobbles. Below this is a layer, a few inches thick, of nearly white lime hardpan resting on the basalt bedrock.

Practically all of this soil is in the virgin state. It supports a growth of sagebrush and a few junipers. Small annual grasses and herbs grow after the short rainy seasons. The land has some value for grazing. An area of about 270 acres, which has been cleared of loose stone and put under cultivation, is mapped as Veyo clay loam. Other areas might be cleared and farmed, but the soil is too stony and thin and has too low a moisture-holding capacity to be very desirable. Clearing is expensive, as the quantity of stone is very large.

Veyo clay loam.—Veyo clay loam lies on the high basaltic plateau in and near Veyo. It is similar to Veyo stony clay loam but is comparatively free from stone and averages somewhat deeper to bedrock. Probably about one-half of it was originally Veyo stony clay loam, but it has been cleared of most of its loose stone. The rest of its area consists of somewhat deeper soil practically free from stone.

The surface soil, to a depth of about 6 inches, is brown friable granular calcareous clay loam. The subsoil, to a depth of 1 to 2 feet, is brown or slightly reddish brown moderately compact clay loam or clay. The lower part of the subsoil is nearly white and more or less cemented with lime. The underlying basalt bedrock, which is very uneven or wavy, lies at a depth ranging from about 1½ to 4 feet below the surface in most places, but it may be somewhat shallower or deeper in others.

The greater part of this soil is under irrigation and produces mostly alfalfa, small grains, and pasture. A few acres are devoted

to orchards of apples, peaches, and pears which appear to be thriving fairly well. Alfalfa hay is the most important crop. It yields from 1½ to 4 tons an acre, depending on the depth of soil, management, and fertilization. The alfalfa is fed largely on the farms to livestock from the surrounding range. Yields of most crops are somewhat lower than on deeper soils, such as those of the Redfield, Gila, and Moffat series. The moisture-holding capacity is comparatively low, and rather frequent irrigation is essential, especially on the shallower areas.

Shavano clay loam.—Shavano clay loam is neither extensive nor is it an important agricultural soil. Not more than 40 acres are cultivated.

This is a shallow soil overlying beds of shale. The surface soil, ranging from a few inches to a foot or slightly more in thickness, is calcareous reddish-brown or dull-red heavy granular clay loam or clay. This layer rests directly on the soft disintegrating shale, which in most places has a red or purplish-red color, blotched or mottled with white lime. In some places the shale is harder and only slightly weathered within 3 feet of the surface. In places, gray or greenish-gray shales are mixed with the red. The small cultivated areas have been more or less modified by sediment (silt) from irrigation waters. These sediments consist of reddish-brown clay loam or clay. The soil is not heavily charged with salts, although the underlying shales may contain rather large quantities in some places.

The land ranges from smooth to sloping and is somewhat uneven or choppy. Underdrainage is very slow. Its shallowness, low water-holding capacity, and low productivity make this soil inferior for agricultural use. Unfavorable conditions of drainage and alkali might develop with extension of irrigation. The small irrigated areas are producing small grains, sorghums, alfalfa, and pasture, but stands are spotted and yields light. Frequent light irrigations are essential for best results. In its virgin condition it supports a growth of shadscale, matchweed, and creosotebush, accompanied by a little bunchgrass. It has slight value for grazing.

This soil occurs mostly in rather small bodies, in the southeastern part of Warner Valley, between St. George and the Utah-Arizona State line, and near Washington, Harrisburg, Leeds, and Virgin.

Shavano stony clay loam.—Shavano stony clay loam occupies virgin desert areas and has little present or potential value.

In most places the surface is covered by a heavy concentration of stone and gravel. The soil is shallow light reddish-brown granular clay loam or clay, containing much lime and gypsum. The shale lies at a depth ranging from a few inches to a foot or more, and in many places it contains a large quantity of gypsum. The surface ranges from smooth to uneven and choppy. The soil is raw, poor in organic matter, and doubtless would be very inferior for agricultural use. The vegetal covering is very sparse and consists largely of shadscale with some matchweed and creosotebush. The grazing value is low.

Most of this soil occurs in the Arizona Strip south of the Utah-Arizona State line. Small bodies are south of St. George and southeast of Washington.

Toquerville fine sandy loam.—Toquerville fine sandy loam is a shallow soil over shale or sandstone. It has a small total area, and none of it is cultivated.

The surface soil is red or reddish-brown fine sandy loam that ranges in thickness from a few inches to about a foot. In most places this material is underlain by a thin layer of red or brownish-red rather tough clay loam or clay, mottled or splotched with lime, and this material, in turn, lies on the soft disintegrating shale or sandstone. The surface ranges from flat to moderately sloping and uneven. The areas south of Berry Springs and southeast of Ivins are underlain by red sandstone, whereas most of the rest of the soil is underlain by red, purple, and greenish-gray shales. Bodies are north of Bloomington, 5 miles south of St. George, in Warner Valley, near Harrisburg and Leeds, and southwest of Toquerville.

This soil is not desirable for cultivation, owing to its shallowness and low water-holding capacity, but a few small areas could be used if irrigation water were available for use at frequent intervals.

Toquerville fine sand.—Toquerville fine sand occupies undulating desert uplands. It is a shallow soil over red sandstone or shale.

The surface layer, which ranges in thickness from a few inches to as much as 3 feet, is red loose fine sand that drifts easily in the wind and forms low hummocks in many places. Just above the bedrock there is, in most places, a thin layer of red loamy fine sand. To a depth of a foot or more, the bedrock is commonly soft and crumbly, but it is harder at greater depths. In many places the surface of the bedrock has a thin coating (one-fourth inch or less) of white lime. Typically, the underlying rock is red sandstone, but in a few areas it is red or purplish-red shale. Such bodies are 1 mile south of Ivins, southeast of Santa Clara, from 4 to 6 miles southeast of St. George, in Warner Valley, and in a single small body 2 miles south of Berry Springs. The typical soil over sandstone is developed most extensively south of Berry Springs and west of Toquerville, and a number of small bodies are near Washington, near Middleton, and in Warner Valley.

This soil is too coarse, loose, and shallow to be desirable for development under irrigation. It has a covering of brush, mostly creosotebush and matchweed. Its value as grazing land is low.

Toquerville fine sand, stony phase.—The stony phase of Toquerville fine sand lies on sandstone hills or ridges where frequent outcrops of bedrock occur. The soil is practically identical with typical Toquerville fine sand but averages somewhat thinner. There is a vegetal cover of creosotebush, matchweed, and other brush and, in places, some bunchgrass. The land affords a small amount of grazing.

This soil is most extensive west of Toquerville, in Warner Valley, and north of St. George. Small bodies are north and east of Washington and south of Berry Springs.

Tortugas stony loam.—Tortugas stony loam is extensive and is widely distributed throughout the area, on hills, mesas, and hogback ridges of limestone or buff or gray sandstone.

The soil is developed from a very thin mantle of weathered material over bedrock, and rock outcrops are common. In some places

more than one-half of the surface is bare rock. Loose stone or gravel is heavily concentrated on the surface. The surface soil is light yellowish-brown or light grayish-brown calcareous loam of soft cloddy structure a few inches thick. The upper part of the bedrock to a depth of several inches is broken into large chunks, and in the crevices is very light brown or grayish-brown loam containing white nodular limy material. About 200 acres in the south end of Warner Valley about 1 mile north of the Utah-Arizona State line are covered with red loose sand. The soils of some included areas developed over sandstone are not calcareous in the surface layer, but in most places they have a concentration of lime over the rock or in the crevices.

The vegetal growth consists of creosotebush, squawbush, and matchweed, with some pricklypear and bunchgrass in places. After winter or spring rains there is a growth of annual grasses and herbs including alfileria. The land has some grazing value but is worthless for cultivation.

Purgatory loam.—Purgatory loam is a nonarable shallow soil overlying beds of gypsum or gypsiferous shales.

The surface soil, which averages about 5 inches in thickness, is pale reddish-brown or pinkish-brown calcareous loam of floury or soft granular structure. It contains fragments of gypsum and shale. The surface soil is extremely thin in places and is absent in spots. It is underlain by soft spongy or mealy light-pink or mixed light reddish-brown and white material, which probably is largely gypsum with some admixture of soil material and small shale fragments. This gypsum layer is underlain in most places by soft dark-red shale that is mixed or streaked with soft white or cream-colored gypsum. The shale lies at depths ranging from 1½ to 3 feet or more below the surface. It is only slightly calcareous. In places gravel or stone is concentrated on the surface, and such areas are shown on the map by gravel or stone symbols. A few areas have a soil ranging from 2 to 3 feet in thickness over the gypsum layer. Such areas contain much gypsum scattered through the soil and sodium salts in both surface soil and subsoil.

As mapped, the soil occurs in dry desert areas, and its value for agricultural development is very low. The vegetal covering is very sparse, consisting mostly of shadscale with a small quantity of creosotebush, Mormon-tea, and other brush. It has some slight browse value.

This soil occurs in small bodies near the Utah-Arizona State line in both States, in Purgatory Valley, west, northwest, and east of St. George and in that city, and east and southwest of Washington.

GRAVELLY AND STONY SOILS OF THE ALLUVIAL FANS

The gravelly and stony soils of the alluvial fans include the stonier and more gravelly members of the Moffat, Isom, and Tobler series. These soils are very gravelly or stony, porous, and low in moisture-holding capacity. They are hard to work and therefore are best adapted to tree fruits, alfalfa, and other crops not requiring frequent

cultivation. For the most part, they are not very well adapted to farming, although some of the better areas, if properly managed, may give fairly good results.

Isom gravelly loam, silted phase, is the only one of these soils under cultivation. Irrigation with silt-laden water has improved and deepened this soil, and it is producing satisfactory crops of tree fruits, grapes, and alfalfa. Frequent irrigation is needed to maintain good moisture conditions on these soils.

Moffat gravelly loam.—Moffat gravelly loam occupies alluvial fans in uncultivated districts.

The surface is covered with a heavy concentration of gravel and stone. More than half the area is very stony. This condition is shown on the map by stone symbols. The surface soil is light reddish-brown gravelly loam or gravelly fine sandy loam, which ranges in thickness from a few inches to 1 foot or more. The subsoil is light pinkish-brown gravelly loam mottled with white and is rather compact and more or less cemented with lime. It contains many small hard white lumps or nodules of lime. The humus content of the soil and its moisture-holding capacity are low. Drainage ranges from good to excessive, and, for the most part, the soil is comparatively free from salts.

This soil has low potential agricultural value, but the less stony areas could be farmed if water were plentiful and cheap. The grazing value is low.

Many small bodies of this soil are widely scattered throughout the area. They are south of the Utah-Arizona State line, west and northwest of Hurricane, southeast of Washington Fields, 4 miles west of La Verkin, in Grassy Valley, and northwest of Virgin.

Isom gravelly loam.—Isom gravelly loam lies on rather gently sloping alluvial fans with smooth to somewhat uneven or dissected surfaces.

Much gravel and some stone are on the surface of this soil. To an average depth of 8 inches, the surface soil is light reddish-brown or pinkish-brown mellow gravelly loam. The subsoil is similar but very slightly lighter in color and is faintly mottled or veined with lime. Below a depth ranging from 2 to 3 feet in most places, gravel comprises the greater part of the soil material. Drainage is good to excessive, and the moisture-holding capacity of the soil is rather low.

In areas, totaling about 1½ square miles, lying near and on either side of the Utah-Arizona State line and near Bloomington, the subsoil contains large quantities of gypsum, mostly in the form of fragments ranging in size from sand to fine gravel. In places gypsum comprises a large part of the mass of the subsoil and imparts to it a soft mealy or spongy character.

This soil is too gravelly to be desirable for crops that require frequent cultivation, but it seems to be fairly well adapted to growing grapes, peaches and other tree fruits, and alfalfa. It needs frequent light irrigations for the best results. None of Isom gravelly loam is under cultivation, but its silted phase is farmed at La Verkin and Hurricane. The areas containing large quantities of gypsum in the subsoil are somewhat inferior to the typical soil.

This soil occurs, for the most part, in small areas in the Arizona Strip and north of the Utah-Arizona State line, south of St. George, near Bloomington, southwest of Washington Dam, along the east side of Grassy Valley, south of Hurricane, and north of La Verkin.

Isom gravelly loam, silted phase.—On the alluvial fans at the base of the Hurricane Fault cliff, in the east edge of La Verkin, and in Hurricane and to the south, Isom gravelly loam, silted phase, has been farmed under irrigation for many years. The soil, to plow depth, has been modified by the deposition of reddish-brown heavy-textured silt from irrigation waters. The surface soil is clay loam containing a small quantity of gravel, and it overlies gravelly loam like that described in connection with typical Isom gravelly loam.

This is not an extensive soil, but it is all under cultivation and is devoted largely to orchards, vineyards, and alfalfa. These crops are irrigated at frequent intervals and do well. The land is comparatively free from frosts at blossomtime, and peaches seldom are damaged by frost. Full-grown peach trees are said to yield about 6 tons an acre.

Isom stony loam.—Isom stony loam occupies moderately or steeply sloping stony alluvial fans of more or less uneven or dissected surface. It lies at the foot of the Hurricane Fault in Grassy Valley, south of Hurricane and east of La Verkin, and below the limestone and basalt cliffs in the southwestern part of the area in Arizona. Smaller areas are in Warner Valley, around Springdale, in the west edge of Rockville, and near Harrisburg.

The surface is covered with gravel, cobbles, and boulders, and the soil contains so much stone that it would be very difficult to cultivate. The soil material is derived mostly from limestone, but there is some admixture of shale in places. In one large body in the southwestern corner of the area the material is derived almost entirely from basalt. No definite compaction or cementation exists in the subsoil, which consists largely of a porous mass of gravel and stone. In some places the subsoil contains a large quantity of gypsum.

This soil is too stony to have any but very low potential value for agriculture. Little or none of it is under cultivation, and it is not recommended for development. There is a covering of creosotebush and other brush is most places, and the land has some slight value for grazing.

Tobler fine sand, stony phase.—Tobler fine sand, stony phase, lies on alluvial fans in undeveloped desert localities, west of Hurricane, west of La Verkin, and in Warner Valley.

The surface soil is pale-red loose medium sand or fine sand, containing a large quantity of gravel and stone. The subsoil is similar to the surface soil, but it is slightly lighter colored, or grayer. Some of the pebbles and cobbles are coated with white lime, but there is no very definite concentration of lime and no compaction or cementation of the subsoil material. The whole soil mass is loose and porous and has low moisture-holding capacity. It could be used successfully for farming only if water were plentiful and cheap and could be applied at very frequent intervals.

LOOSE SANDY SOILS

Loose sandy soils are widely distributed in the Virgin River Valley area. They are subject to drifting by wind, have low moisture-holding capacity, have little or no value for agricultural development, and their value for grazing is low.

Pintura fine sand.—Pintura fine sand is one of the more extensive soils of the area. Large bodies are around Grapevine Springs, south of Berry Springs, and in Warner Valley. Smaller ones are south of Ivins, near Washington, west of Hurricane, and west of Virgin. The land has little or no value for agriculture and little value for grazing.

This soil consists of loose porous red fine sand, in most places containing little or no lime. The material varies but little from the surface to a depth of 6 feet or more in most places, but in some places the subsoil is very slightly finer and firmer than the surface soil. In a few places, finer textured soils lie beneath the sand within 6 feet of the surface. The surface sand is subject to wind drifting, and in many places it forms hummocks several feet high (pl. 3, *B*). There is a sparse cover of brush in most places. Sand sagebrush is the most prominent species. Matchweed, cholla, yucca, and sour dock are common.

Pintura fine sand, dune phase.—The dune phase of Pintura fine sand covers areas in Warner Valley, south of Berry Springs, and near Grapevine Spring. It is similar to typical Pintura fine sand but is blown into larger ridges or dunes. It supports very little vegetation, has little or no value for grazing, and no value for cultivation.

Ivins fine sand, hummocky phase.—Areas of the hummocky phase of Ivins fine sand are covered by a loose layer of red fine sand that has been blown into hummocks ranging from a few inches to more than 3 feet in height. Otherwise the soil is practically identical with typical Ivins fine sand. This soil has a very low moisture-holding capacity, is subject to almost constant shifting by wind, and has little if any potential agricultural value. It has very little value as grazing or browse land. It occupies a few small bodies south of Ivins and several about 2½ miles southwest of Anderson.

Tobler fine sand.—Tobler fine sand consists of light-red or pale-red loose fine sand. In places the surface is covered by a veneer of wind-drifted sand. The surface soil and subsoil are more or less stratified, the soil materials ranging from fine sandy loam or gritty loam to sand or gravelly sand. These materials are for the most part loose and porous, but firm or slightly compact layers occur in places. In most places the surface soil is not distinctly calcareous, whereas the subsoil is distinctly so, although no concentration of lime is visible. The subsoil is slightly duller or less red than the surface soil. The land in general is excessively drained and free from salts.

Tobler fine sand occurs mostly in unirrigated areas, and its coarse texture and loose porous character are not favorable for economical use of water. Only a few acres are cultivated, and most of these are in vineyards. If water were very plentiful, the land probably could be used to grow grapes, peaches, and alfalfa.

This soil is widely distributed in rather small bodies on alluvial flats and fans in Warner Valley, along Fort Pierce Wash, near Ivins, around Washington, east of Washington Fields, and near Virgin and La Verkin.

Tobler fine sand, hummocky phase.—The hummocky phase of Tobler fine sand is characterized by a hummocky surface soil of red loose wind-drifted sand of fine or medium texture, overlying a subsurface layer or subsoil of very red stratified somewhat firmer and somewhat finer textured sandy material. The loose sandy covering ranges from almost nothing to as much as 3 feet.

This soil is most extensive in Warner Valley, southwest of Washington Dam, and near Ivins. Small areas are 2 miles northwest of Washington, 2½ miles south of St. George, along Fort Pierce Wash near the Utah-Arizona State line, and 2 miles south of Grapevine Spring. All the land lies in unirrigated desert localities inaccessible to any present supply of irrigation water, and, even though it might be furnished with water, it would be undesirable for farming. The looseness of this soil, its susceptibility to wind drifting, and its low water-holding capacity would make stands of crops exceedingly hard to obtain.

Moffat fine sand, hummocky phase.—The hummocky phase of Moffat fine sand is very similar to the typical Moffat fine sand previously described, except that the surface is covered by very loose drifting fine sand or medium sand, which forms hummocks ranging from a few inches to more than 2 feet in height. The subsoil, below an average depth of about 3½ feet, is light-pink or white fine-textured material more or less cemented by lime.

This soil occurs about 3 miles south of Berry Springs, in Warner Valley, and west of La Verkin and Toquerville. None of the land is cultivated, and it has little potential value for cultivation. The looseness of the soil would make it very difficult to irrigate the land or to obtain stands of crops.

St. George fine sand.—St. George fine sand occupies small areas on alluvial fans northwest of St. George and near Middleton.

The soil has very little uniformity of depth and arrangement of layers or horizons. It might be considered a complex rather than a soil type. The surface layer is light-red loose fine sand ranging from a few inches to more than 2 feet in thickness. It is underlain by dark-brown or dark-gray loamy fine sand, fine sandy loam, or loam, and this, in turn, is underlain by pale-red or pink sandy material or by blue-gray, light-gray, or yellow marly or gypsiferous material. In deep exposures as many as six dark organic layers may be seen, alternating with light-red and gray or yellow layers.

At present this soil is well drained, although in the past it has been subject to seepage from springs and a high water table. A deep gully now gives a drainage outlet to the area northwest of St. George. Moderate concentrations of salts occur in the subsoil in places.

Most of this soil still has its virgin cover of creosotebush, mesquite, and saltbush. It has some value for grazing or browse. The agricultural value is low, as the soil is too sandy, loose, and subject to wind drifting. The small supply of water available can be used more efficiently on finer textured soils in the locality.

Toquerville fine sand, deep phase.—Toquerville fine sand, deep phase, occupies gently sloping, undulating, or rolling uplands. The larger bodies are several miles south of Berry Springs and east of Washington Dam. Areas lie west and southwest of Toquerville. This soil consists of red loose porous shifting fine sand overlying red sandstone at a depth ranging from 3 to 6 feet. Because of wind drifting, the surface is uneven and hummocky. This soil is similar to typical Toquerville fine sand, but it has a deeper mantle of sandy material about the bedrock. It is also similar to Pintura fine sand, except that it overlies bedrock within a depth of 6 feet and possibly averages slightly finer, less porous, and more intensely red than that soil. In many places a layer a few inches thick just above the bedrock is somewhat loamy, and in a few places a thin shell of lime hardpan overlies the bedrock. The sandy mantle generally contains no lime.

This soil supports a sparse growth of brush, mostly creosotebush and matchweed. It has little or no potential value for farming and only very low value as range for livestock.

MISCELLANEOUS NONARABLE SOILS AND LAND TYPES

In addition to those lands that may readily be classified as soil types and phases are a number of miscellaneous nonarable soils and land types, in which the soil materials and profiles are varied and the land has little or no value for agricultural development and but small value for grazing. Under this heading are Tobler fine sand, rough broken phase; rough stony land; rough stony land (La Verkin soil material); rough broken land (Harrisburg soil material); scabland; badlands; and riverwash. These miscellaneous nonarable soils and land types comprise about one-third of the area surveyed.

Some of the striking scenic features of the region, such as the cliffs of Zion Canyon, the gorge of Virgin River, and the cliffs and badlands of Purgatory Valley, are included in these miscellaneous land types.

Tobler fine sand, rough broken phase.—The rough broken phase of Tobler fine sand lies on steep dissected alluvial fans below sandstone cliffs. The soil is red fine sand that is loose and subject to drifting by wind. Some small areas contain much stone. The land has no agricultural value as cropland, present or potential, and but little value for grazing. A scant cover of creosotebush and other brush and a scattered growth of coarse bunchgrass comprise the only vegetation.

This soil occurs mostly in Warner Valley.

Rough stony land.—Rough stony land is extensive and widely distributed. It occupies almost one-fifth of the Virgin River Valley area.

This type of land includes steep stony hillsides, mountainsides, cliffs, canyon walls, volcanic cinder cones, and very rough broken lava beds—all with little or no soil covering. It has no value for cultivation and furnishes little grazing, but it has many features of scenic interest.

Rough stony land (La Verkin soil material).—Rough stony land (La Verkin soil material) occurs on high uneven eroded terraces

along the Virgin River and Fort Pierce Wash. The soil ranges from fine sand to fine sandy loam, and in places it contains much stone. The color is light reddish brown or pale red.

Owing to the rough surface, coarse texture, and unfavorable position of this soil, it has little or no potential value for crops. Its value as grazing land is slight.

Rough broken land (Harrisburg soil material).—Rough broken land (Harrisburg soil material) is widely distributed throughout the area.

The surface ranges from choppy and uneven to very steep or strongly rolling. The soil material is somewhat similar to typical Harrisburg loam, but the profile is not very definite in most places. Outcrops of hardpan are common. In most places the soil contains much gravel and stone. West of Toquerville about 135 acres have a covering of loose wind-shifted red fine sand. The land has no value for cultivation and little or no value for grazing.

Scabland.—Scabland occurs in large areas northwest, west, and southwest of Hurricane, near Berry Springs, west of Grassy Valley, and south and southwest of Veyo. Smaller bodies are south of St. George, near Santa Clara and Ivins, and in the Arizona Strip.

This type of land consists of lava (basalt) beds or flows of very uneven or wavy surface and with comparatively little or no soil cover. Pockets of soil material occur between the ridges or outcrops of bedrock, but rock outcrops occupy so much of the surface that it would be very difficult to cultivate the soil, which is shallow, more or less stony, and in many places very sandy.

None of this type of land is under cultivation, and it is not recommended for development. It has some value for grazing or browse.

Badlands.—Badlands is another miscellaneous land type that covers large bodies throughout the area surveyed. It consists of rough eroded beds of shale with little or no soil covering in most places. The shales are varicolored, ranging from light gray or greenish gray to red and purple. Much gypsum is present in the form of plates, crystals, or soft mealy or spongy seams or layers.. Around Springdale and Rockville, many large boulders are scattered over the surface.

Much of the land is barren, although a scattered growth of shadscale occurs in some places. The land has no value for cultivated crops or grasses and very little for browse.

Riverwash.—Riverwash consists of the sandy or gravelly beds of the Virgin River, the Santa Clara River, Fort Pierce Wash, and numerous smaller tributaries or intermittent streams, which are submerged only at periods of high water.

This class of land has no value for crop growing and little or none for grazing. In places a scant growth of brush, weeds, and grass furnishes some grazing or browse.

PRODUCTIVITY RATINGS AND LAND CLASSIFICATION

In table 3 the soils of the Virgin River Valley area are listed in alphabetical order, and estimated average acre yields of the more important crops are given for each soil. Yield figures in parentheses indicate estimated expected yields for lands that now are not cultivated but may be brought under irrigation.

TABLE 3.—*Estimated average yields*[1] *per acre of the principal crops on each soil in the Virgin River Valley area, Utah-Ariz.*

Soil (soil types, phases, and land types)	Alfalfa hay[2]		Wheat	Barley	Corn	Grain sorghum	Sorgo	Sugar-beet seed[3]	Vegetables[4]	Peaches and other tree fruits[5]	Grapes	Pasture		General productivity grade[6]
	Unfertilized	Fertilized										Irrigated	Unirrigated	
	Tons	*Tons*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Gallons*	*Pounds*		*Tons*	*Tons*	*Cow-acre-days*[7]	*Cow-acre-days*[7]	
Badlands													1	10
Bennett fine sandy loam	(1½)	(2)	(10)	(15)	(18)	(20)	(100)		(Fair to poor)	(4)	(2½)		10	7
Bracken fine sandy loam[8]	2	4				(30)			Fair	(4)	3		10	5
Bracken silty clay loam[8]												100	15	7
Fort Pierce silt loam	(2)	(4)	(15)	(25)	(25)	(30)	(110)	(1, 500)	(Fair)				8	4
Gila fine sand	(1½)	(2)	(10)	(15)	(18)	(20)	(100)		(Fair to poor)	(4)	(2)		8	7
Gila fine sandy loam[8]	2	5	20	30	32	48	135	(1, 500)	Good to very good		4		12	3
Gila loam:[8]														
Well drained	3	5½	30	48	50	65	180	(2, 200)	Very good	10	5	160		1
Poorly drained													50	8
Gila silty clay loam:[8]														
Well drained	3	5	35	50	55	70	200	2, 500	Good	9	6	185		1
Poorly drained													50	8
Harrisburg fine sand													8	10
Harrisburg fine sand, hummocky phase													5	10
Harrisburg gravelly loam													10	10
Harrisburg loam	(1½)	(2)	(15)	(20)					Fair to poor	(3)	(2½)		10	6
Harrisburg loam, rolling phase													8	10
Harrisburg loam, silted phase	2	2½							Fair	4	3			6
Harrisburg stony loam														10
Isom gravelly loam	(2)	(3)								(5)	(3)		10	6
Isom gravelly loam, silted phase	2½	(4)							(Fair)	6	(4)			4
Isom stony loam													8	10
Ivins fine sand	2	(3)	15	25	(30)	(30)	(100)		(Fair)	(4)	(2½)		10	6
Ivins fine sand, hummocky phase													8	10
Junction coarse sandy loam	3	(4)	20	30	35	45	125		Fair to good	7	3½		15	3
La Verkin loam	2½	4	20	30	35	45	125	(1, 800)	Fair	7	3½	(120)	12	4
La Verkin loam, silted phase	2	4½	25	35	38	50	150	2, 000	do	7	3½	(140)		3
Leeds clay loam	3	5	30	45	(45)	65	170	2, 000	Good	8	4	170	15	1
Moenkopie clay loam:[8]														
Well drained	1½	(2½)	15	20		40	120						10	6
Poorly drained													12	10
Moenkopie fine sandy loam	2	(3)	(15)	(25)	(30)	(32)	(100)		(Fair)		(2½)		10	5
Moenkopie loam	(2)	(3)	20	30	35	(35)	(110)		(Fair)	(4)	(2½)		10	5
Moffat fine sand	(2)	(3)							(Fair to poor)	(4)	(3)		10	6
Moffat fine sand, hummocky phase													8	10
Moffat fine sandy loam	(2½)	(4)	(15)	(25)					(Fair)	(7)	(3½)		10	4
Moffat fine sandy loam, silted phase	2	4½	22	32	35	45	140	(2, 000)	Fair	7	3½	(140)		3

See footnotes at end of table.

TABLE 3.—*Estimated average yields* [1] *per acre of the principal crops on each soil in the Virgin River Valley area, Utah-Ariz.*—Continued

Soil (soil types, phases, and land types)	Alfalfa hay		Wheat	Barley	Corn	Grain sorghum	Sorgo	Sugar-beet seed	Vegetables	Peaches and other tree fruits	Grapes	Pasture		General productivity grade
	Unfertilized	Fertilized										Irrigated	Unirrigated	
	Tons	*Tons*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Gallons*	*Pounds*		*Tons*	*Tons*	*Cow-acre-days*	*Cow-acre-days*	
Moffat gravelly loam	(2)	(3)								(5)	(3)		10	6
Moffat loam	(3)	(4½)	(18)	(25)	(25)	(35)	(120)	(1, 500)	(Fair)	(7)	(3½)	(120)	10	4
Pintura fine sand													8	10
Pintura fine sand, dune phase													2	10
Purgatory loam	(1)	(2)				(20)							5	7
Redfield clay: [8]														
Well drained	2	4	20	(30)	(30)	(40)	(120)	(2, 000)	Fair	5	2½	(140)	5	4
Poorly drained												70	30	8
Redfield clay, silted phase, [8] poorly drained.	1½	4	16	27	(30)			1, 500	Fair to poor			100	40	5
Redfield fine sandy loam	2½	5	20	30	35	50	140	(1, 500)	Good to very good	8	4	125	10	2
Redfield fine sandy loam, gypsiferous phase.	(2)	(5)	(17)	(25)	(30)	(45)	(125)		(Good)	(6)	(3½)	(110)	10	3
Redfield loam: [8]														
Well drained	3	6	30	45	50	65	180	2, 200	Very good	10	5	150	10	1
Poorly drained												100	30	7
Redfield loam, gypsiferous phase [9]	(2½)	(4½)	(20)	(35)	(35)	(50)	(140)	(2, 000)	(Fair to good)	(6)	(4)	(130)	10	2
Redfield loam, shallow silted phase: [8]														
Well drained	3	6	30	48	50	65	200	2, 500	Good	10	5	170		1
Poorly drained												100	50	7
Redfield loam, silted phase: [8]														
Well drained	2½	5	25	40	40	60	(165)	2, 300	Fair	6		(150)		2
Poorly drained	1½	4	13	25				1, 500				75	30	4
Redfield loam, eroded phase: [10]														
Better area	(2)	(4)	(20)	(30)	(40)	(50)	(140)	(1, 500)	(Fair to good)	(8)	(4)	(100)	8	2
Poorer area													4	10
Redfield silt loam	(3)	(6)	(30)	(45)	(50)	(65)	(180)	(2, 200)	(Good)	(10)	(5)	(150)	10	1
Redfield silty clay loam: [8]														
Well drained	(3)	(5)	(30)	(45)	(45)	(65)	(170)	(2, 000)	do	(9)	(4)	(150)	10	1
Poorly drained												75	30	7
Redfield silty clay loam, silted phase: [8]														
Well drained	3	6	32	50	55	70	200	2, 500	Good	10	6	185		1
Poorly drained												100	50	7
Riverwash													2	10
Rough broken land (Harrisburg soil material).													5	10
Rough stony land													3	10

Rough stony land (La Verkin soil material).													5	10
Scabland													10	10
Shavano clay loam	1½	(2)	15	20		25		(Poor)					5	7
Shavano stony clay loam													5	10
St. George fine sand	(2)	(3)	(12)	(20)	(35)	(30)	(100)	(Fair)		(4)	(2½)		10	6
St. George loam. [8]														
Well drained	2	4	25	40	40		2,000	Fair		(4)	(2½)		15	4
Poorly drained												100	50	7
St. George loam, overwash phase: [8]														
Well drained	2	4	20	35	35		(1,800)	Fair to good		5	3		15	4
Poorly drained												100	40	7
Tobler fine sand	(1½)	(2½)	(10)	(15)	(18)	(20)	(100)	(Fair to poor)		(4)	(2½)		8	7
Tobler fine sand, hummocky phase													8	10
Tobler fine sand, rough broken phase													5	10
Tobler fine sand, stony phase													8	10
Tobler fine sandy loam	2	5	20	30	35	50	140	(1,800)	Good to very good	8	4	125	10	2
Tobler fine sandy loam, hummocky phase.	(2)	(4)	(15)	(20)	(25)	(40)	(120)		(Fair to good)	(6)	(3)		8	4
Tobler loam: [8]														
Well drained	2	5	30	45	(45)	(60)	(170)	(2,000)	Very good	(9)	4	(120)	10	1
Poorly drained												75	30	8
Toquerville fine sand													8	10
Toquerville fine sand, deep phase													8	10
Toquerville fine sand, stony phase													8	10
Toquerville fine sandy loam	(1½)	(2)	(12)	(17)	(20)	(20)			(Fair to poor)				10	7
Tortugas stony loam													10	10
Veyo clay loam [11]	2	3½	22	35	(35)	(40)	125		Fair	4	2	110	15	4
Veyo stony clay loam												100	15	7

[1] These are estimated average acre yields based on information gained from farmers and gained by observation during the progress of the soil survey. Figures and yield in parentheses indicate probable approximate yields to be expected if and when soil types now in the virgin condition are brought under irrigation.

[2] Alfalfa hay is commonly fertilized with superphosphate.

[3] Sugar-beet seed is fertilized with superphosphate and ammonium sulfate.

[4] Because of lack of data general descriptive terms are used here.

[5] Fruit yields are subject to occasional reduction by frost.

[6] The general productivity grade indicates the comparative general productivity of the soils under common practices of irrigation farming or range grazing. The most productive soils have a grade of 1 and the least productive a grade of 10.

[7] "Cow-acre-days" is a term used to express the carrying capacity of pasture land. As used here, it is the product of the number of animal units carried per acre multiplied by the number of days the animals are grazed without injury to the pasture. For example, a soil type able to support 1 animal unit per acre for 360 days of the year rates 360, whereas another soil type able to support 1 animal unit per 2 acres for 180 days of the year rates 90. Again, if 4 acres of pasture support 1 animal unit for 100 days, the rating is 25.

[8] These soils are more or less subject to concentration of salts. The yields given are for the least affected areas. The saltier areas, shown on the soil map, are less productive.

[9] This soil varies considerably in content of gypsum. Areas containing excessive quantities of gypsum are somewhat inferior. The rating is for the better areas.

[10] The degree of erosion varies considerably. The better areas may be leveled and farmed, but the more severely gullied ones are practically valueless

[11] This soil varies considerably in depth, water-holding capacity, and productivity.

This table gives a general idea of yields that may be expected on each soil type under the prevailing system of irrigation farming. It is based on information gained in interviews with farmers and on observations by the field party during the progress of the soil survey. Estimates of yields on soils not now cultivated were made after careful consideration of soil characteristics and comparison of these soils with others that are under cultivation.

Common farming practices in this area include a rather indefinite long rotation, including the growing of alfalfa. Commercial fertilizers are not commonly used on most crops, but barnyard manure is returned to the land. Superphosphate is used on alfalfa by some farmers and produces marked increases in yield. Superphosphate and ammonium sulfate are commonly used on land for sugar beets grown for seed.

The general productivity grade indicates the comparative general productivity of these soils under the common farming practices, or under range grazing if the soils are not suitable for cultivation. The most productive soils have a productivity grade of 1, whereas the least productive have a grade of 10. The general productivity grade is based on an approximate weighted average of crop productivity indexes.[14] These indexes are weighted roughly according to acreage and value of crops grown in the area. A productivity grade of 1 indicates a weighted average above 90; a grade of 2, an average between 80 and 90; a grade of 3, an average between 70 and 80; and so on.

Following are some of the acre yields used as standards of reference for crops grown in this area.

Crop:		
Alfalfa hay	tons	4
Peaches	do	10
Grapes	do	6
Sugar-beet seed	pounds	2,500
Wheat	bushels	25
Barley	do	40
Corn	do	50
Grain sorghum	do	40
Sorgo (sirup)	gallons	200
Pasture	cow-acre-days	100

In table 4 the soils are arranged in the approximate order of their productivity and suitability for growing the crops of the area; are characterized as to general productivity, workability, water-holding capacity, and erosion hazard; and are placed in a few groups as to their physical suitability for irrigation farming.

[14] A productivity index is the rating of a soil for a crop in terms of percentage of a standard yield. The standards for peaches, grapes, sugar-beet seed, and sorgo are local standards; the others are national.

TABLE 4.—*Classification of the soils of the Virgin River Valley area, Utah-Arizona, according to physical suitability for irrigation farming* [1]

Soils	General productivity [2]	Workability [3]	Water-holding capacity [4]	Erosion hazard [5]	Land classification
Gila silty clay loam [6]	High (90 percent+)	Fairly easy	High	Negligible in most places [7]	First-class soils (very well suited to irrigation.)
Redfield silty clay loam, silted phase [6]	do	do	do	do	
Gila loam [6]	do	Easy	do	do	
Redfield loam, shallow silted phase [6]	do	Fairly easy	do	do	
Redfield silt loam	do	Easy	do	do	
Redfield loam [6]	do	do	do	do	
Tobler loam [6]	do	do	do	do	
Redfield silty clay loam [6]	do	Fairly easy	do	do	
Leeds clay loam	do	do	do	do	
Redfield fine sandy loam	Fairly high (70–90 percent)	Easy	Fairly high	Negligible in most places [7]	Second-class soils (well suited to irrigation).
Redfield loam, silted phase [6]	do	Somewhat difficult	High	do	
Redfield loam, gypsiferous phase [8]	do	Easy	do	do	
Tobler fine sandy loam [6]	do	do	Fairly high	do	
La Verkin loam, silted phase	do	Fairly easy	do	do	
Moffat fine sandy loam, silted phase	do	do	do	do	
Gila fine sandy loam [6]	do	Easy	do	do	
Redfield fine sandy loam, gypsiferous phase	do	do	do	do	
Junction coarse sandy loam	do	do	Medium	do	
Moffat loam	Medium (50–70 percent)	Easy	Fairly high	Slight	Third-class soils (moderately well suited to irrigation).
La Verkin loam	do	do	do	do	
Moffat fine sandy loam	do	do	do	do	
Veyo clay loam [9]	do	Somewhat difficult	Medium	do	
Isom gravelly loam, silted phase	do	do	do	Negligible	
St. George loam, overwash phase [6]	do	Easy	High	do	
St. George loam [6]	do	do	do	do	
Fort Pierce silt loam	do	do	do	do	
Redfield clay [6]	do	Somewhat difficult	do	do	
Redfield clay, silted phase [6]	do	do	do	do	
Tobler fine sandy loam, hummocky phase	do	do	Medium	Rather great	
Bracken fine sandy loam [6]	do	Fairly easy	do	Moderate.	
Moenkopie loam	do	do	do	Negligible	
Moenkopie fine sandy loam	do	Easy	do	do	
Harrisburg loam, silted phase	do	Fairly easy	do	Slight	

See footnotes at end of table.

TABLE 4.—*Classification of the soils of the Virgin River Valley area, Utah-Ariz., according to physical suitability for irrigation farming*[1]—Continued

Soils	General productivity	Workability	Water-holding capacity	Erosion hazard	Land classification
Moffat fine sand	Rather low (30–50 percent)	Fairly easy	Rather low	Rather great	Fourth-class soils (poorly suited to irrigation).
St. George fine sand	do	Somewhat difficult	do	Great	
Isom gravelly loam	do	Difficult	do	Slight	
Moffat gravelly loam	do	do	do	do	
Ivins fine sand	do	Somewhat difficult	do	Great	
Harrisburg loam	do	Fairly easy	do	Slight	
Moenkopie clay loam	do	Somewhat difficult	Medium	Negligible	
Bennett fine sandy loam	do	Fairly easy	Rather low	do	
Redfield loam, erodedphase [10]	do	Difficult	Medium	Great	
Tobler fine sand	do	Somewhat difficult	Low	do	
Gila fine sand	do	do	do	do	
Toquerville fine sandy loam	do	Easy	Rather low	Negligible	
Shavano clay loam	do	Fairly easy	do	Rather great	
Bracken silty clay loam	do	Rather difficult	Medium	Moderate	
Purgatory loam	do	do	Rather low	do	
Harrisburg gravelly loam	Very low (0–30 percent)	Difficult	Low	Slight	Fifth-class soils (range land, unsuitable for irrigation).
Veyo stony clay loam	do	do	do	Negligible	
Moffat fine sand, hummocky phase	do	do	do	Great	
Tobler fine sand, hummocky phase	do	do	do	do	
Ivins fine sand, hummocky phase	do	do	do	do	
Toquerville fine sand, deep phase	do	do	do	do	
Harrisburg fine sand	do	do	do	do	
Harrisburg fine sand, hummocky phase	do	do	do	do	
Harrisburg stony loam	do	do	do	Negligible	
Shavano stony clay loam	do	do	do	do	
Isom stony loam	do	do	do	do	
Harrisburg loam, rolling phase	do	do	do	Rather great	
Tobler fine sand, stony phase	do	do	do	Great	
Toquerville fine sand	do	do	do	do	
Pintura fine sand	do	do	do	do	
Scabland	do	Practically impossible	do	Negligible	
Rough broken land (Harrisburg soil material)	do	do	do	Great	
Rough stony land (La Verkin soil material)	do	do	do	do	
Tobler fine sand, rough broken phase	do	do	do	do	
Toquerville fine sand, stony phase	do	do	do	do	
Tortugas stony loam	do	do	do	do	

Pintura fine sand, dune phase	Negligible (0–5 percent)	Practically impossible	Low	Great	Sixth-class soils (wasteland).
Riverwash	do	do	do	do	
Rough stony land	do	do	do	do	
Badlands	do	do	do	do	

[1] This classification deals merely with the capability of the soils for producing crops under common practices of irrigation farming. It does not consider economic factors or the location and pattern of distribution of soil types.

[2] General productivity refers to the ability to produce the common crops of the region under prevailing farming practices. Where the land is not farmed at present, its potential productivity is estimated. (See table 3.)

[3] The term workability as here used refers to the relative amount of labor required to till and irrigate the land and the relative feasibility of handling farm machinery and distributing irrigation water.

[4] The water-holding capacity of a soil is one of the factors determining the proper quantity and frequency of application of irrigation water. On soils of low water-holding capacity, much water is commonly wasted by too heavy applications; whereas on soils of high-water-holding capacity heavier applications are needed in order to obtain adequate penetration.

[5] Erosion hazard means the probable susceptibility of the soil to erosion if and when cultivated or heavily grazed. It refers both to wind drifting and to erosion by water.

[6] These soils as mapped include some areas where drainage is imperfect or poor, and soluble salts (alkali) have accumulated. The areas shown on the map as moderately affected with salts are lowered in value, and soils listed as First and Second class are thereby reduced to Third class. Areas strongly affected by salts are lowered to the Fourth or to the Fifth class, depending on feasibility of drainage and reclamation.

[7] In these soils the erosion hazard is very slight, except immediately adjoining stream channels, where bank cutting is a menace.

[8] This rating is for the better areas. Some areas containing excessive quantities of gypsum probably should be considered Third- or Fourth-class soils.

[9] This soil varies considerably in depth, productivity, and moisture-holding capacity.

[10] Redfield loam, eroded phase, varies considerably in the amount of erosion that has occurred. All this soil would require considerable work before it would be level enough to be irrigated.

In this classification geographic and economic factors, such as location and pattern of distribution of soil types, transportation and marketing facilities, and prices of agricultural products, are ignored. Consideration is given only to the ability of the soils to produce crops under the common farming practices of the region; to the ease or feasibility of handling farm machinery and distributing irrigation water; to the water-holding capacity of the soils, which determines quantities of water needed and when they shall be applied; and to the hazard of destructive erosion when the lands are cleared for cultivation or heavily grazed.

Because of limitations in the amount of detail that may be shown on a soil map and the unavoidable inclusion of considerable variations within areas of soil types as mapped, these ratings should not be considered as applying strictly to all areas of a soil type. Poor drainage conditions and concentration of salts, largely developed by seepage after the land is brought under irrigation, still further complicate the classification. The poorly drained or salty areas are less productive than the better drained areas. The salt concentrations are shown on the map by red boundaries and symbols. Areas with moderate salt concentrations are generally poorer than those which are comparatively salt free, whereas those having strong salt concentrations are unfit for cultivation unless reclaimed by special measures.

LAND USES AND SOIL MANAGEMENT

Most of the soils in the Virgin River Valley area and adjoining lands are of use only for grazing. Small areas are used in the production of a wide variety of crops under irrigation. A small amount of land in the higher part of the area has a growth of juniper and scrub live oak. The juniper is of such size that it is useful mainly for fence posts and firewood, but the oak is too brushy to be of much value. For range or grazing purposes the unirrigated land is of low value, but, as it has little or no value for other purposes and the acreage is large, it is used as range for sheep, cattle, and goats. In most places little grass grows, and the value of the range depends largely on browse provided by the prevailing brush cover and the growth of small annuals following rainy periods. In small wet areas along the streams or on low-lying areas affected by seepage, a fair growth of sedges, tules, saltgrass, and other grasses furnishes some inferior pasture. The only lands totally lacking in grazing or browse value are parts of the miscellaneous land types shown on the soil map as riverwash, rough stony land, badlands, and Pintura fine sand, dune phase.

The deep soils of the bottom lands and alluvial fans, described in detail in the preceding pages, are of value only for grazing when dry; but, when provided with sufficient water for irrigation, they are capable of rather high production of many crops. This is also true of the soils with compact limy subsoils. A few of the better areas of shallow, stony, and gravelly soils are fairly productive when properly managed, but the greater part of these and of the loose sandy soils are of very low value for farming.

Great differences in yields are obtained by farmers using different cultural methods and soil management. Average acre yields are rather

low compared with potential yields as demonstrated by some of the better farmers and by experiment stations on these and similar soils.

It is a common practice to leave land in alfalfa for a long period. This results in diminished yields and interferes with a system of rotation that is very desirable here. After alfalfa, other crops yield much better for 2 or 3 years than they do on land that has not been in alfalfa.

Fertilization with barnyard manure is desirable in order to maintain the fertility of the soil and build up the content of humus. In some instances the growing of green-manure crops may be advantageous. Fertilization with superphosphate and nitrogenous fertilizers also is desirable on these soils, and with some crops they notably increase the yields and profits obtained. Superphosphate gives large increases in yield of alfalfa hay and sugar-beet seed. Ammonium sulfate or other nitrogenous fertilizers give more vigorous growth and increased yields of sugar-beet seed and vegetable crops, according to field tests made by J. O. Culbertson, on the George Seegmiller farm, St. George, Utah, in 1933–34.

Deep plowing and thorough tillage are doubtless important on many of the heavier textured soils, such as the silted phases of the Redfield, Moffat, La Verkin, and Harrisburg soils, and on Gila silty clay loam, Bracken silty clay loam, and the heavier textured areas of St. George loam. These soils tend to bake and become very hard on drying, and, if not broken up and pulverized, they present a poor condition for the penetration of plant roots, moisture, and air and a generally unfavorable condition for plant growth. Some of the best and some of the poorest yields are obtained on these heavy soils, depending on whether or not they are kept in proper tilth and free from the hard, baked condition that follows flooding.

In fruit growing,[15] a better selection and standardization of varieties is desirable, that is, choosing those for which the popular demand is greatest. Some of the older peach trees should be replaced, as they lose their vigor and productivity with age. In many places, the use of smudge pots would save fruit from frost damage, where it is now common. In the shallower soils it is advisable when planting trees to dig the hole deep or to open up the subsoil or hardpan by blasting when the soil is dry.

Recommendations for irrigation and drainage are covered in a following section, but it seems well to emphasize here that too heavy irrigation, such as is practiced in many places, is both wasteful and detrimental. On the sandier and shallower soils frequent irrigation is necessary, but each application should be light. If new areas of the very loose sandy soils are put under irrigation, frequent light irrigations will reduce the tendency of the soil to blow. It is important to obtain a cover of vegetation as soon as possible on such soils, and the new seeding may be protected to some extent by spreading a thin layer of straw or manure over the surface. Comparatively permanent crops, such as alfalfa and pasture grasses, are desirable on such soils. Irrigation with silty waters soon puts a layer of heavy-textured material on the surface, overcomes the tendency to blow, and builds up the fertility of the soil.

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[15] BALLANTYNE, A. B. FRUIT VARIETY TESTS ON THE SOUTHERN UTAH EXPERIMENT FARM. Utah Agr. Expt. Sta. Bul. 124, pp. [59]–110, illus. 1913.

IRRIGATION, DRAINAGE, AND SALTS[16]

As previously stated, there is little possibility of successful crop growing in this area without irrigation. The rainfall serves as a supplement to irrigation but is not in itself sufficient to mature crops in normal years. Irrigation has been practiced on a limited scale since the arrival of the Mormon pioneers in the 1850's, and at present probably somewhat more than 8,000 acres of land are irrigated within the area surveyed. The present supply of water, obtained from the Virgin and Santa Clara Rivers, their tributaries, and springs, generally is sufficient for crop production, although occasional late summer droughts occur when the supply is restricted, and some damage to crops results. No provision has been made for storage, except some very small reservoirs fed by springs and a low dam built on the Santa Clara River for the primary purpose of flood control.

At times very large or excessive quantities of water are used on some of the lands, and water runs in many of the canals the year round. It is probable that, by providing reservoirs to store surplus water, holding the use of water to reasonable quantities, and not running it in the ditches in winter, not only would a plentiful supply be had for all areas now under irrigation, but water would be available for an additional acreage. Studies are being made (1936) by the Bureau of Reclamation, United States Department of the Interior, to determine the flow of the Virgin River, the quantity of water available for irrigating additional land, and the acreage of additional land suitable for irrigation. Storage dams may be built at some time on the Virgin River, the Santa Clara River, Mill Creek (a short spring-fed stream on the western edge of Washington), and other tributaries, to provide water for additional acreage or to supplement the present supply for irrigated lands. The area of land suitable for irrigation is limited. In the section on Productivity Ratings and Land Classification, the soils are classified in a general way according to their suitability for development under irrigation, if and when a supply of water is made available.

A rotation system of water distribution is used in most places, and water is delivered at intervals ranging from a few days to 2 weeks in different districts. A constant flow is had in some of the private water rights. Although in some instances lands may suffer a shortage of water, in many instances the total use of water is excessive, and damage is done to many areas by overirrigation. A total of 10 acre-feet or more of water has been used on some lands annually.[17] This leaches out the more soluble compounds, including those in the

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[16] In the western part of the United States the more soluble salts of the alkali and alkaline earth groups of elements are commonly called alkali or, in some localities, saleratus. Only in a few places in the arid Southwest is there a strongly alkaline or basic condition in the soil, with the presence of sodium carbonate and free hydroxyl ion (OH^-). In the Virgin River Valley area the more prevalent salts seem to be sodium sulfate and sodium chloride. The presence of a large quantity of gypsum (calcium sulfate) in most of the soils may account for the lack of a strongly alkaline condition. In order to avoid confusion, it should be understood that wherever the term "alkali" is used in this report it refers merely to the very soluble salts of the alkali and alkaline earth metals. The terms "salts" and "saline" are preferable to "alkali" and "alkaline," except in instances where the reaction of the soils or the salts is distinctly alkaline.

[17] CLYDE, GEORGE D. IRRIGATION. *In* A Preliminary Report on the Agricultural Resources of Washington County, Utah. Utah Agr. Expt. Sta. 1935. [Typed.]

fertilizers applied, and in some instances causes a rise in the ground water level in the land irrigated or in adjacent lower lying areas. This contributes to alkali conditions.

On the shallower and sandier soils in some districts more frequent irrigation is advisable than that now practiced, although in these places light applications are sufficient. In very loose sandy soils, the runs or furrows should be short, in order to prevent excessive loss by downward percolation. In the deeper and finer or heavier textured soils, which hold more moisture, fairly heavy irrigations may be given at times to good advantage, but these need not be so frequent as on the shallower and lighter soils. On clay soils that tend to bake and where water penetration is slow, an occasional heavy irrigation is advisable to obtain thorough penetration. This may be supplemented by rather frequent light irrigations to keep the surface soil soft and moist in the hotter and drier part of the year. Frequent heavy irrigations are not desirable anywhere except in places where it is desired to wash out large excesses of salt from the soils. Care should be taken not to allow water to form ponds or to flood the surface of land in clean-cultivated crops, especially on the heavier textured soils, as this causes baking of the soil and a very hard unfavorable condition for the growth of plants.

The flooding method of irrigation commonly is used for alfalfa and to some extent for small grains on the flatter lands. The corrugation or furrow method is used for row crops and, on the more steeply sloping or uneven lands, for alfalfa and small grains. This system has the advantages of more efficient water distribution and of keeping the surface in a softer more granular condition. Flooding is better in places where it is wished to wash excess salts from the soils.

Some low-lying areas along the Virgin River and around springs in the vicinity of St. George and Washington are naturally poorly drained. In addition to these, drainage problems have arisen in other places from excessive irrigation and seepage, combined with lack of sufficient drainage channels to carry off excess water.[18] An area, totaling probably between 1,400 and 1,500 acres, in the Washington Fields south of Washington has been damaged in this way, and similar areas totaling several hundred acres, are south of St. George and around Bloomington. Small areas thus affected are south of Ivins and west of La Verkin. It appears probable that drains, properly kept open, would carry off surface water from the marshy areas, and if they were 6 feet or more deep they would lower the water table in most places to such an extent that the lands could be cultivated. The effectiveness of such drains is demonstrated along the main east and west township line road through Washington Fields, where two parallel open drains have lowered the water table below 6 feet in an area of about 200 acres which formerly was waterlogged. An area in the southwestern part of Washington Fields in secs. 3 and 10, T. 43 S., R. 15 W., formerly called Dry Lake, is now a marsh, and, as the subsoil is heavy and comparatively impervious, drainage apparently is difficult. A drainage ditch from 3

[18] YODER, P. A., NORTHROP, R. S., and ATKIN, JOSEPH T. REPORT ON THE SOUTHERN UTAH EXPERIMENT STATION, 1906. Utah Agr. Expt. Sta. Bul. 97, 24 pp., illus. 1906.

to 6 feet deep leading from the lower end of the marsh has failed to relieve greatly the condition in this area. It seems probable that the best solution of the problem in such places is to cut off the water at its source. This may be accomplished by lining canals and using less water on higher lands, or by building intercepting drains. It has been suggested that water be shut out of the canals in the winter, keeping them full only during the irrigation season. This doubtless would relieve the condition to some extent but probably would not remedy it entirely. In parts of the Southwest, wells are used to provide both drainage and water for irrigation. They might be used here, but it is doubtful that the expense would be justified.

As a natural result of the rise of the ground water, salts have accumulated in the soil and, in most places, are concentrated at or near the surface. In general the concentration is not strong, and it seems probable that the high level of the ground water and not the salt content is the serious problem. There are some exceptions to this where a heavy surface concentration or so-called alkali crust inhibits the growth of vegetation. If the ground water were lowered to a depth of 6 feet or more, the excess of salts undoubtedly could be removed in most places and the land used for crop production.

In mapping alkali conditions in this area three grades of salt concentration, based on determinations of total soluble salts in the air-dry soil, are shown on the map.

Where the average salt content is comparatively low—less than 0.2 percent in the topmost 12 inches of soil or as an average to a depth of 6 feet—the land is classified as salt free and is shown on the map by the letter "F." It should be understood that but few of the soils of the area are in reality entirely free from salts. In the so-called salt-free soils, the content of salts is low enough that under ordinary conditions it produces little or no detrimental effect on vegetation.

Lands containing from 0.2 to 0.5 percent of salts, either concentrated in the topmost 12 inches or as an average to a depth of 6 feet, are mapped as slightly or moderately affected or slightly saline and are shown on the map by the letter "M." Such lands generally show some indication of the presence of salts by the poor condition of crops or spotted stands of crops on cultivated lands, or by the presence of salt-indicating vegetation on uncultivated lands. By providing adequate drainage and using sufficient water to leach out the excess of salts, most of such areas may be improved and may eventually become practically free from salts.

In the areas where 0.5 percent or more of salts is concentrated in the topmost 12 inches of soil or is present as an average to a depth of 6 feet the land is classified as strongly affected or strongly saline and is shown on the map by the letter "S." Such lands are too salty to be used for crop production in their present condition, but some areas may be improved by drainage and washing to lower the salt content of the soil.

In places strongly saline soils are bare of vegetation, whereas in others saltbush, seepweed, and saltgrass are common. Arrowweed, shadscale, and a number of species of *Atriplex* are common on soils of somewhat lower salt content, and mesquite and screwbean are decidedly salt tolerant. Creosotebush generally is an indicator of comparative freedom from salts, although salts may be present in the subsoil even where this shrub grows.

MORPHOLOGY AND GENESIS OF SOILS

Soil is the product of the forces of environment acting on the soil materials deposited or accumulated by geologic agencies. The characteristics of the soil at any given point are determined by (1) the physical and mineralogical composition of the parent soil material; (2) the climate under which the soil material has accumulated and existed since accumulation; (3) the relief, or lay of the land, which influences the local or internal climate of the soil, its drainage, moisture content, aeration, and susceptibility to erosion; (4) the biologic forces acting upon the soil material; that is, the plants and animals living upon and in it; and (5) the length of time the climatic and biologic forces have acted on the soil material.

The Virgin River Valley area lies in the arid Southwest in the region of Red Desert soils.[19] Most of the soils are either reddish brown or red. They have developed under a very dry climate similar to that in the region of grayer Desert soils farther north but under higher temperatures, which have tended to bring about more complete oxidation of the iron compounds. It also happens that red rocks furnish much of the parent materials from which these soils are developed. It is possible that the distribution of rainfall in the Southwest has an influence in bringing about the greater redness of these soils. The greatest rainfall occurs in the hot midsummer season. It does not penetrate deeply but probably promotes chemical activity and solution in the surface and subsurface layers, thus somewhat lowering the content of lime in the former and increasing the ratio of the iron oxides to calcium carbonate and silica.

The geologic forces of erosion and deposition are very active here and have a leading role in determining the character of many of the soils, whereas the soil-developing forces of climate and vegetation probably work rather weakly and slowly in changing the character of the deposits. The dryness of the climate results in a sparse vegetation—mostly desert shrubs with very little grass. For this reason, vegetation is not a potent factor in soil development, the soils contain little organic matter, and in most places the surface soil is not distinctly darker or browner than the material just below. The soils are not greatly leached, and many of them contain calcium carbonate, calcium sulfate, and, in some places, even sodium salts throughout. The older or more mature soils have had these soluble compounds partly leached from the upper horizons and heavily concentrated in the subsoils at or near the depth of penetration of the limited rainfall.

The parent materials of the soils in this area are unusually varied and, together with the differences of age and soil development, have given rise to a large number of distinct soils. The soil materials come from red, buff, yellow, and white sandstones; shales of many colors, including red, purple, white, gray, green, and buff; conglomerates; limestones; gypsum; black basalt; black or red volcanic cinders; gray granite; and old more or less consolidated valley-filling materials, in many places including lime hardpan, or caliche.

[19] U. S. BUREAU OF CHEMISTRY AND SOILS, SOIL SURVEY DIVISION. RED DESERT SOILS. Soils and Men, U. S. Dept. Agr. Yearbook 1938 : 1100–1101, illus. 1938.

There are some areas of so-called residual soils developed from the weathered underlying rock, but the larger areas are developed from outwash materials from the various formations listed above.

The following descriptions of the principal soil series are made in order of their degree of development, the most extremely developed soils being described first, then those of intermediate development, and finally the young, or unmodified soils.

The normal mature, or extremely developed, soil profile for this region is probably best shown in the Harrisburg soils. An examination was made of Harrisburg loam in an upland area, which comprises a remnant of an old gently sloping somewhat undulating or ridged alluvial fan. It is a virgin desert area with a sparse cover of creosotebush and squawbush. A description of the profile of Harrisburg loam in this location follows:

1. 0 to 1 inch, a softly crusted surface layer of light reddish-brown heavy sandy loam or loam, containing a rather large quantity of mixed angular gravel (mostly limestone and sandstone). The material is distinctly calcareous.
2. 1 to 10 inches, light reddish-brown friable loam or heavy fine sandy loam with little definite structure. This material contains only a small quantity of gravel and is highly calcareous.
3. 10 to 16 inches, somewhat compact and cloddy dull-red or brownish-red heavy loam or clay loam, mottled with white lime. It contains much gravel.
4. 16 to 22 inches, light-pink or white and brownish-red mottled or mixed, softly cemented loam containing a rather large quantity of gravel. This material is highly calcareous.
5. 22 to 30 inches+, hard or firmly cemented lime hardpan, or caliche, which contains much embedded gravel.

In most places the firmly cemented hardpan has a thickness of 1 to 2 feet and grades into a less cemented mass of gravel and boulders. In a few places a definite layer of mealy sugary-structured gypsum occurs beneath the lime hardpan. In some places the lime hardpan caps basalt, sandstone, or limestone bedrock.

This soil represents an extreme degree of calcification. It may be that calcium carbonate in the soil represents not only that present in the parent materials and freed from the more complex calcium compounds during chemical decomposition, but part of it may come from lime-charged waters running across or through the fans from higher lying lands. It seems probable that in places the present depth of soil represents only a part of the original depth of soil material and that parts of that material have been removed by geologic erosion.

In places the mantle of soil over the hardpan is less than 18 inches thick. This is especially true of Harrisburg gravelly loam and Harrisburg stony loam. The hardpan is commonly even harder and thicker than that in the profile described above. It has a rocklike hardness and may be several feet thick. It seems that the soil must have been subjected to thinning by geologic erosion on high exposed tablelands or on slopes from them, and that the lime accumulated from a much thicker soil layer than now exists. It may be that the land was at some time in the far distant past subject to high ground water, which deposited large quantities of calcium carbonate. In some places, as along the face of a slope or escarpment, the lateral movement of ground water has caused an extreme concentration of lime.

The Veyo soils are somewhat similar to the Harrisburg soils. They occur at higher elevations under somewhat greater rainfall and have

a distinctly darker or browner color. They have a white lime hardpan capping basalt rock at a slight depth. A description of a profile of Veyo stony clay loam follows:

1. 0 to 6 inches, brown friable and granular distinctly calcareous clay loam. A large quantity of basalt stone and gravel is scattered over the surface.
2. 6 to 14 inches, brown or slightly reddish brown rather compact clay loam or clay, containing many lime-coated basalt cobbles. This material is highly calcareous.
3. 14 to 20 inches, white lime hardpan containing basalt boulders and cobbles.
4. 20 inches +, basalt bedrock heavily coated with hard white lime.

This soil occupies a rolling upland plain covered with a basalt lava flow and, in its virgin state, supports a growth of sagebrush, with scattered juniper.

The soils of the Tortugas, Toquerville, and Shavano series represent shallow mantles of residual material over bedrock. They do not have sufficient depth to have very definite profiles, although in places a thin shell-like layer of lime hardpan caps the underlying rock. The Tortugas soils are in few places more than a foot deep. They are light-brown highly calcareous soils overlying limestone or calcareous sandstone. The Toquerville and Shavano soils are typically red, and they overlie red standstone or shale within a depth of 2 feet.

The Purgatory soils are very shallow soils over beds of gypsum or gypsiferous shales. The surface soils, which are very light brown or pinkish brown, are soft and friable. The upper part of the subsoil is a soft spongy mass of mealy gypsum, which becomes somewhat cemented with depth in places. It is underlain in most places by soft varicolored shales containing much gypsum.

The soils of the Moffat series are somewhat younger, or less extremely developed, than the Harrisburg soils, but their profiles are similar. The chief difference is in the degree of lime concentration and the hardness of the lime horizon. In the place where the sample was taken in Moffat loam, this horizon extends from a depth of 14 inches to a depth of 50 inches. It may be dug easily with a pick, can be crumbled, though with difficulty, in the hand, and softens quickly when moistened. It is underlain by softer and redder materials that contain, in places, a large quantity of granular sugary gypsum. In the lighter textured soils of the Moffat series—the fine sandy loam and the fine sand—the layer of heavy lime concentration lies much farther below the surface. In the fine sand type this layer lies between depths of about 40 and 72 inches. It is probable that the greater depth of these soils is due partly to deeper leaching in the sandier materials and partly to deposition of material on the surface. The sandy materials are distinctly red and probably have their origin in nearby areas of red sandstone. Deposition doubtless has been caused both by wind and by water.

The La Verkin soils present what is probably a somewhat younger or less mature profile. They have a much less marked concentration of lime in the subsoil than the Harrisburg and Moffat soils and the light or gray color, owing to the lime, is masked largely by the red color of iron oxides. The subsoil is distinctly heavier and tougher than the surface soil, owing to accumulation of clay and colloids; and the material in some places is softly cemented. Below a depth of about 40 inches it is coarse and porous.

The Leeds soils have developed under a higher rainfall than the soils in the lower parts of the area. The rainfall at Leeds has averaged 13.15 inches as compared with 8.86 inches at St. George. These soils are somewhat darker and contain less lime in the upper horizons than do most of the other soils of the area. They are typified by Leeds clay loam, a description of which follows:

1. 0 to 7 inches, dark-brown or dark reddish-brown friable granular clay loam or heavy loam. It does not contain sufficient lime to effervesce with hydrochloric acid.
2. 7 to 15 inches, reddish-brown or brownish-red fairly friable or soft cloddy clay loam, which shows no effervescence with hydrochloric acid.
3. 15 to 32 inches, reddish-brown rather compact and cloddy heavy clay loam or clay. The material contains a few lime mottlings, and the mass effervesces only where mottlings occur.
4. 32 to 45 inches, reddish-brown rather compact clay that is distinctly calcareous and contains many white mottlings of lime.
5. 45 to 72 inches, mottled reddish-brown and light-gray rather highly calcareous stratified materials ranging from clay to coarse sand. The grit is largely granitic.

This soil occupies undulating or ridged alluvial fans. The material is more or less mixed, as it is derived from granite, sandstones, and shales. It is probable that the heavy texture of the subsoil is due partly to deposition of heavy materials and partly to downward movement of clay from the surface soil.

The recent alluvial soils form a large group in the Virgin River Valley area. Five series of soils are differentiated, largely on the basis of color and derivation of the parent materials. These materials have been but little altered since deposition and inherit their characteristics from the weathered parent rocks. The Tobler soils have come largely from red sandstones and red shales. They are very red soils, friable, and rather uniform in surface soil and subsoil. The Redfield soils come from a wide variety of transported materials, including those from limestones, sandstones, and shales, and in places, from basalt. They are much less red than the Tobler soils. Their color is pale red, pink, or light reddish brown. In many places they contain flecks of gypsum. The gypsiferous phases of the Redfield soils come from parent material of somewhat more local origin than the typical Redfield soils. They consist mostly of materials washed from buff sandstone, red sandstone, and varicolored shales, containing a large quantity of gypsum, in which respect they differ chiefly from the typical Redfield soils. This gypsum is present, for the most part, as sandy or gravelly materials, stratified or interspersed with the other soil materials, though in places there is some concentration in the subsoil. The structure of these soils is for the most part open, granular, and mealy, or sugary. The Gila soils are developed from deposits of the Santa Clara River and the Virgin River. They consist of very much stratified materials of mixed composition. The color of the heavier materials is in most places medium brown or dark brown with a slight pinkish tinge, whereas the sandier materials are lighter in color, ranging from light red to gray. The Fort Pierce soils are light cream-colored soils that are very highly calcareous and consist of outwash from light-colored shales. The Junction soils are rusty-brown gritty soils consisting of granitic outwash. There is very little development of horizons, although apparently a very slight translocation of lime from the surface soil to the subsoil has taken place.

The surface soils to a depth of about 2 feet generally are not sufficiently calcareous to effervesce with hydrochloric acid, whereas the subsoils effervesce freely, although the lime is not visible.

The intrazonal soils include those of the St. George and Bracken series, which are or have been poorly drained, the Ivins and Moenkopie soils, which have a distinct Solonetz or solonetzlike profile over the underlying shale beds, and the wind-blown sands of the Pintura series.

The Bracken soils are light-brown, light grayish-brown, or light reddish-brown soils with heavy concentrations of gypsum and lime in the subsoils, which are tough and more or less cemented. In most places the surface soils or subsoils contain considerable quantities of soluble sodium salts. It seems probable that the lime, gypsum, and salts were deposited in the subsoils by seeping or ascending ground water at some former time. These soils now are well drained in most places. The St. George soils are, or have been rather recently, wet by natural seepage from springs. They have dark-gray surface layers having a large content of organic matter, and in many places marly layers are present in the subsoil. In some places these soils are buried by or stratified with red materials washed from sandstone.

The Moenkopie and Ivins soils might be considered deep phases of soils of the Shavano series, but they have distinct development of a profile, with more or less well-formed prismatic or columnar horizons in the subsoils, which are underlain by highly calcareous, lime-seamed, and more or less cemented horizons overlying the shales. The Moenkopie soils are purplish brown or reddish brown, and they overlie purple shales. The Ivins soils have red sandy surface soils consisting of transported materials that overlie red or purple shales. The shales carry sodium salts in readily detectable quantities, and it is possible that these salts have induced the formation of Solonetz as the materials were leached.

The Pintura soils consist of loose wind-shifted fine sands or medium sands. Little variation occurs from the surface downward, but the subsoils in places are very slightly finer textured and firmer than the surface soils. In most places the material is leached free of lime to a depth of 6 feet or more.

SUMMARY

The Virgin River Valley area lies largely in the southwestern corner of Utah. It includes a small adjoining area south of the State line in Arizona. The total area covered by the soil survey is 320 square miles, or 204,800 acres.

The general aspect of the country is rough and mountainous. The area surveyed lies in a valley or basin surrounded by mountains and high mesas, and it is broken by fault cliffs, canyons, hogbacked ridges, hills, and mesas, with comparatively small areas of smooth valley lands interspersed. A number of areas are covered by uneven or wavy lava beds, several volcanic cinder cones, and large expanses of eroded shale beds or badlands. The elevation ranges from about 2,700 to about 4,000 feet above sea level.

The climate is arid, with an average annual rainfall of 8.86 inches at St. George and 13.15 inches at Leeds. The summers are long and hot and the winters short and mild. The daily variation in temper-

ature is great. The growing season is longer than in other parts of Utah.

Moisture is the principal factor limiting crop growth in this area, and agriculture is carried on only with the aid of irrigation. The cultivated land in Washington County totals only about 11,000 acres. Of this, about 8,000 acres are within the area surveyed. This is only a very small part of the total area—about 4 percent. At present, the rest of the land has value only for grazing. It is possible that between 15,000 and 20,000 additional acres may be irrigated under proposed projects at some time in the future.

Raising livestock is the principal source of income. The animals, mainly sheep, cattle, and goats, are grazed on the surrounding desert and mountain ranges and fed at times on the irrigated farms.

The soils of this area are, for the most part, red or have a decided red tinge. They are poor in organic matter or humus and nitrogen and rich in lime, gypsum, and other salts of the alkali and alkaline earth elements. The total quantity of phosphorus ranges from plentiful to rather low in these soils, but the quantity of readily available phosphorus is low in many of them. Besides water, the factors limiting the growth of plants on most of the soils are nitrogen and phosphorus.

For purposes of discussion, the soils and land types are placed in six groups.

(1) Deep soils of the bottom lands and alluvial fans, which are the most desirable soils for farming. Except where poorly drained and excessively salty, they are well suited to farming under irrigation, and in places where air drainage is good they are well adapted to fruit growing. Redfield loam and its silted phases, the silted phase of Redfield silty clay loam, Redfield fine sandy loam, Gila silty clay loam, Gila loam, Gila fine sandy loam, Tobler fine sandy loam, Leeds clay loam, and Junction coarse sandy loam are all deep alluvial soils comprising a large proportion of the cultivated areas. They are naturally productive soils where moisture conditions are favorable.

(2) Soils with compact limy subsoils on uplands, fans, and terraces. They are fairly well adapted to general farming and fruit growing where supplied with sufficient irrigation water. Of these, the silted phases of Moffat fine sandy loam and La Verkin loam are cultivated and are fairly productive. They are well adapted to growing fruits and alfalfa.

(3) Shallow soils of the uplands, which overlie bedrock or hardpan. They have low water-holding capacity, limited rooting zones, and comparatively low productivity. They are either unsuited to agricultural development or may be used to a limited extent where water is plentiful and cheap. Harrisburg loam, silted phase, a member of this group, occupies small areas around Toquerville and Hurricane. It produces peaches and other tree fruits, alfalfa, and vegetables. It is a shallow soil, and only by frequent irrigation and fertilization is it possible to obtain good crops. Veyo clay loam is used largely for the production of alfalfa and small grains. Large areas of Harrisburg stony loam, Harrisburg gravelly loam, Harrisburg fine sand, the Tortugas, Toquerville, and Purgatory soils, and most of the Shavano soils probably will remain uncultivated, as the soils are shallow and more or less stony, gravelly, or excessively sandy.

(4) Gravelly and stony soils of the alluvial fans. These soils are porous, have low water-holding capacity, are hard to work, and, for the most part, are not desirable for cultivation, although small areas are irrigated and used for the production of tree fruits, grapes, and alfalfa. Isom gravelly loam, silted phase, is the only member of this group that is cultivated.

(5) Loose sandy soils that have very little value, either present or potential, although they afford a small amount of grazing or browse.

(6) Miscellaneous nonarable soils and land types, consisting mostly of very rough stony lands or riverwash. They are practically worthless, but in places they may have some value for grazing or browse.

Soils that may be irrigated in the future include virgin soils of the Redfield, Tobler, Gila, Junction, and Fort Pierce series, Moffat loam, Moffat fine sandy loam, Moffat fine sand, and Harrisburg loam.

In the section on Productivity Ratings and Land Classification, the soils are rated according to the estimated average production of the various crops under the prevailing system of irrigation farming. They are placed in a few groups on the basis of their relative suitability for farming under irrigation.

The average farm income in this area is low. The primary reasons for this seem to be as follows: (1) The small cultivated acreage per farm, (2) the lack of livestock on many farms, (3) low production compared with that possible under the best farming methods, (4) low prices obtained for agricultural products, and (5) high transportation and marketing costs.

The cultivated acreage per farm can be expanded only by an increase in the supply of irrigation water or by consolidation of small holdings. Proposed new irrigation projects may at some future time supply additional water, but the cost per acre will be high. The great distance to markets and high transportation costs contribute to the low price of products on the farm, and the most economical way to market such products as alfalfa hay and grains is to feed them to livestock on the farms. The growing of high-priced specialized crops, such as early fruits and vegetables and sugar-beet seed, helps to increase the farm income.

Average production could be increased in this area by a more systematic rotation of crops, growing alfalfa in the rotation but not leaving the land in this crop for too long periods, returning all manure produced to the land, using superphosphate fertilizer on alfalfa, sugar-beet seed, and vegetable crops, applying nitrogenous fertilizers (including ammonium sulfate) to high-priced crops, and more careful tillage and irrigation. Irrigation should be at sufficiently frequent intervals, especially on the shallower or sandier soils. The heavier and deeper soils do not need such frequent irrigation but can absorb more water at each irrigation. Excessive quantities of water are being applied on some land.

Artificial drainage is needed to carry off surface water and to lower the water table in some places, such as in the lower parts of Washington Fields and in the western part of St. George. Much of the land affected by salts can be reclaimed or improved by providing adequate drainage and by flushing it with irrigation water.

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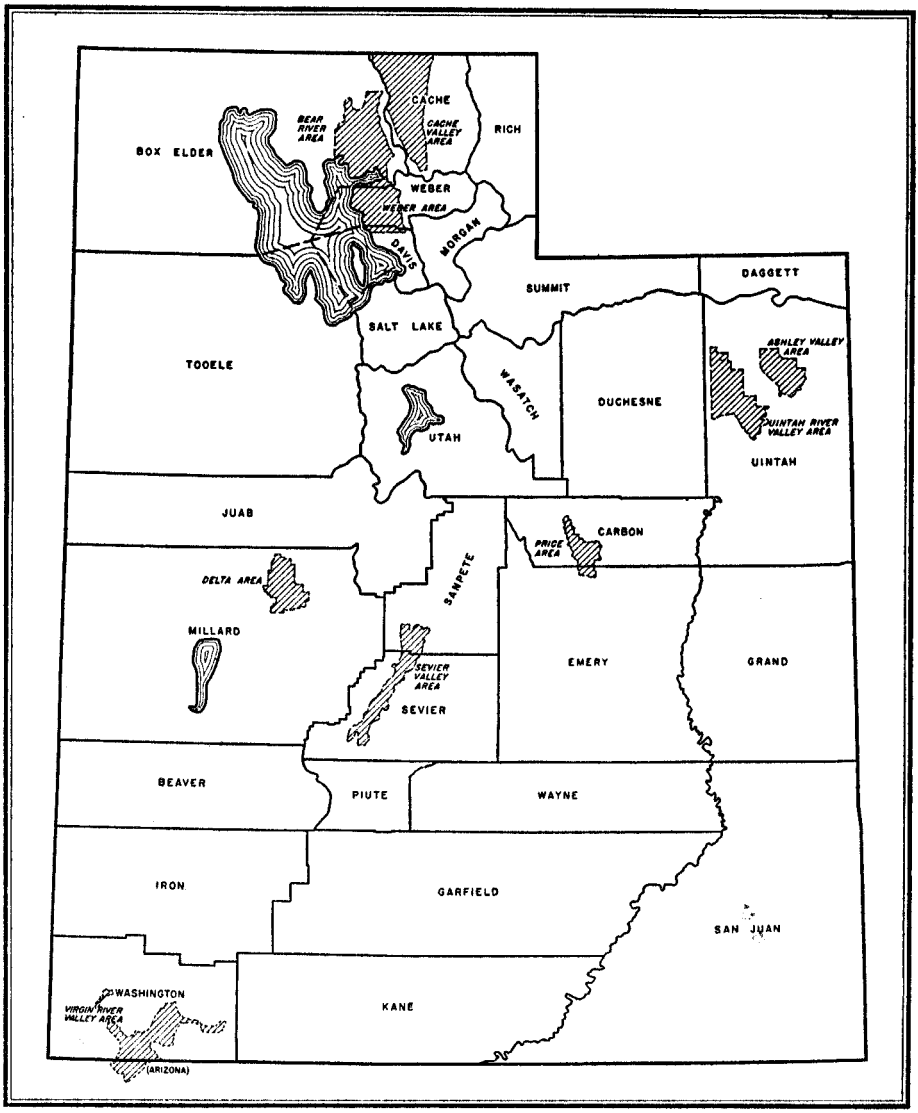

Areas surveyed in Utah, shown by shading.

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