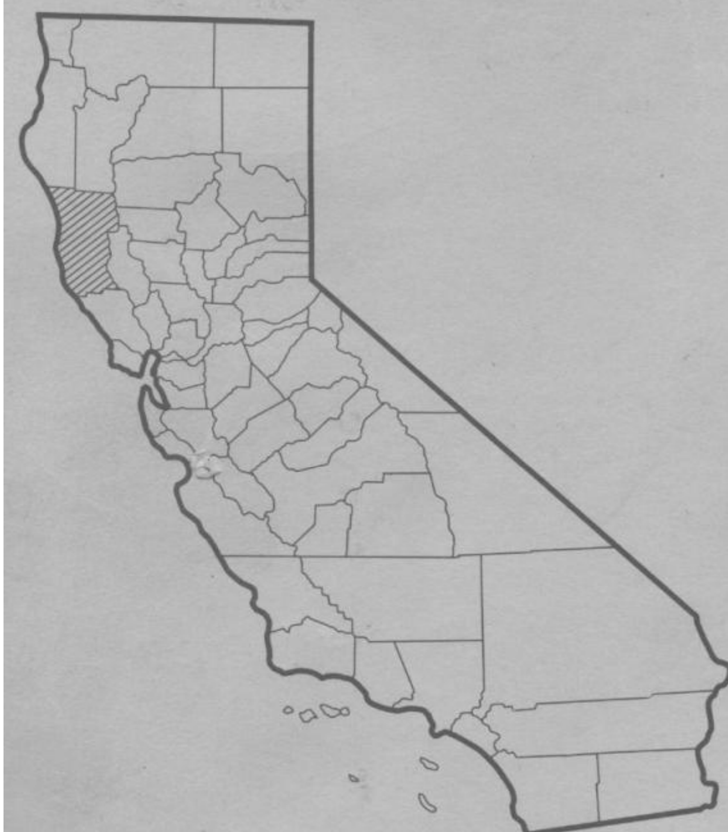
GROUND-WATER RESOURCES IN MENDOCINO COUNTY, CALIFORNIA



U.S. GEOLOGICAL SURVEY
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CALIFORNIA DEPARTMENT OF WATER RESOURCES
and
MENDOCINO COUNTY

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ABSTRACT

Mendocino County includes about 3,500 square miles of coastal northern California. Ground water is the main source for municipal and individual domestic water systems and contributes significantly to irrigation.

Consolidated rocks of the Franciscan Complex are exposed over most of the county. The consolidated rocks are commonly dry and generally supply less than 5 gallons per minute of water to wells.

Unconsolidated fill in the inland valleys consists of gravel, sand, silt, and clay. Low permeability in the fill caused by fine grain size and poor sorting limits well yields to less than 50 gallons per minute in most areas; where the fill is better sorted, yields of 1,000 gallons per minute can be obtained. Storage-capacity estimates for the three largest basins are Ukiah Valley, 90,000 acre-feet; Little Lake Valley, 35,000 acre-feet; and Laytonville Valley, 14,000 acre-feet.

Abundant rainfall (35 to 56 inches per year) generally recharges these basins to capacity. Seasonal water-level fluctuations since the 1950's have been nearly constant, except during the 1976-77 drought.

Chemical quality of water in basement rocks and valley fill is generally acceptable for most uses. Some areas along fault zones yield water with high boron concentrations (>2 milligrams per liter). Sodium chloride water with dissolved-solids concentrations exceeding 1,000 milligrams per liter is found in deeper parts of Little Lake Valley.

INTRODUCTION

In 1979 the U.S. Geological Survey, the California Department of Water Resources, and Mendocino County began a cooperative study to better understand the ground-water resources of Mendocino County.

Mendocino County is experiencing a rapid population growth as a result of the increasing trend of many Californians to change their lifestyle to reflect a rural perspective. The county's population increased by about 30 percent during 1970-80 and is expected to increase by about 18 percent during 1980-85. Estimates of water use in the county show an increase of 62 percent for urban use and 12 percent for irrigation during 1972-80. In order to meet the future demand for water, Mendocino County planners have expressed the view that quantification, utilization, and possible conservation of ground-water resources will be necessary.

The County General Plan has been prepared to provide guidelines for orderly development in the county while recognizing the importance of valuable resources. The plan will be updated as pertinent information becomes available. The planners recognize the present need for more complete information on ground-water supply, especially in Ukiah Valley, Little Lake Valley (Willits area), Laytonville Valley, and along the coast of the county (fig. 1).

Collection of ground-water data has been minimal in Mendocino County during 1960-79. Periodic water-level measurements have been made at a few observation wells in some of the ground-water basins, but no recent comprehensive data-collection effort has been made to define current conditions in the basins.

The cooperative agreement between the U.S. Geological Survey, the California Department of Water Resources, and Mendocino County resulted in a plan to study individually specific high-interest areas. The Department of Water Resources took responsibility for studying and publishing reports for the coastal section of the county and for Anderson Valley. The coastal part of the ground-water study has been completed, and a report describing the findings of the study was published (California Department of Water Resources, 1982). The Anderson Valley study is near completion, and a report covering this area will be published. The U.S. Geological Survey has been responsible for studying and reporting on Ukiah, Little Lake, and Laytonville Valleys and the Leggett area; the study of these areas is the subject of this report.

Mendocino County provided assistance in these studies by contributing data on water wells and the quality of water, furnishing reports and documents concerning water issues and problems, and suggesting which parts of the county had the greatest need for water-resources assessment. The county also provided personnel to make water-level measurements in wells along the coast.

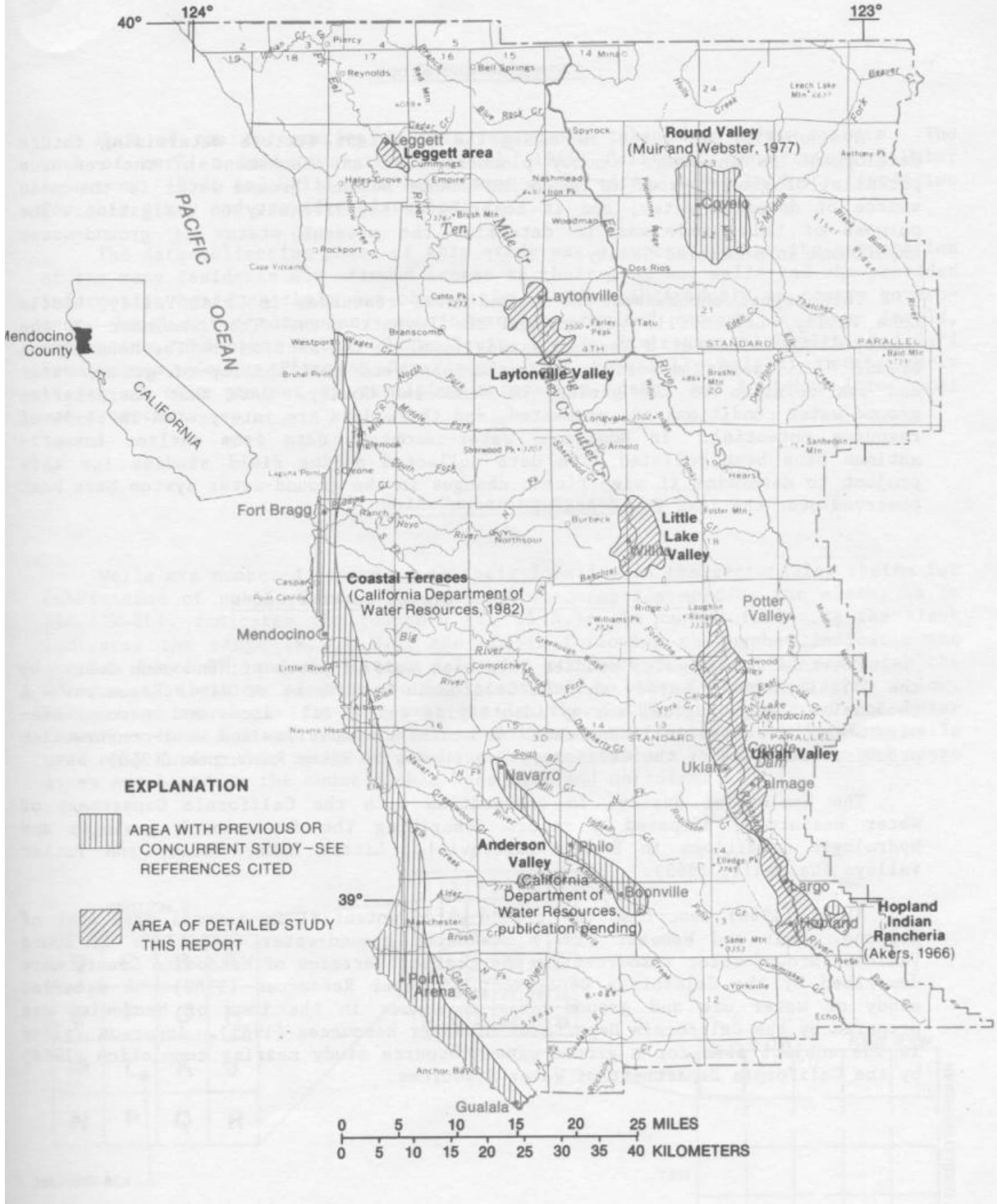


FIGURE 1. – Location of detailed study areas and location of areas previously studied.

Purpose and Scope

Availability of water is among the important factors determining future development in an area. County planners need an assessment of the resource potential of ground water in Mendocino County because ground water is the main source of domestic water, and it contributes significantly to irrigation. The purpose of this study was to determine the present status of ground-water conditions in Mendocino County.

This report emphasizes the ground-water resources in Ukiah Valley, Little Lake Valley, Laytonville Valley, and the Leggett area. The remainder of the county is discussed at a reconnaissance level in the section on "The Mountainous Areas." This report describes the occurrence and availability of ground water and its relation to the geology of Mendocino County. Data that characterize ground-water conditions are presented, and these data are interpreted in terms of resource potential. In addition, water-resources data from earlier investigations have been collated with data collected during field studies for this project to determine if significant changes in the ground-water system have been observed over the last few decades.

Previous and Concurrent Ground-Water Studies

Previous ground-water studies have been made of parts of Mendocino County by the U.S. Geological Survey and the California Department of Water Resources. A reconnaissance geological survey identifying valley-fill areas and a comprehensive survey of water wells to determine sanitary conditions and well-construction practices was made by the California Department of Water Resources (1958).

The Geological Survey, in cooperation with the California Department of Water Resources, prepared a report describing the fundamental geologic and hydrologic conditions in Round, Laytonville, Little Lake, Ukiah, and Potter Valleys (Cardwell, 1965).

Akers (1966) described the ground-water potential in a small area east of Hopland. Muir and Webster (1977) evaluated ground-water conditions in Round Valley. Ground-water resources in the coastal terraces of Mendocino County were described by the California Department of Water Resources (1982). A detailed study of water use and ground-water resources in the town of Mendocino was prepared by the California Department of Water Resources (1985). Anderson Valley is the subject area for a ground-water resource study nearing completion (1986) by the California Department of Water Resources.

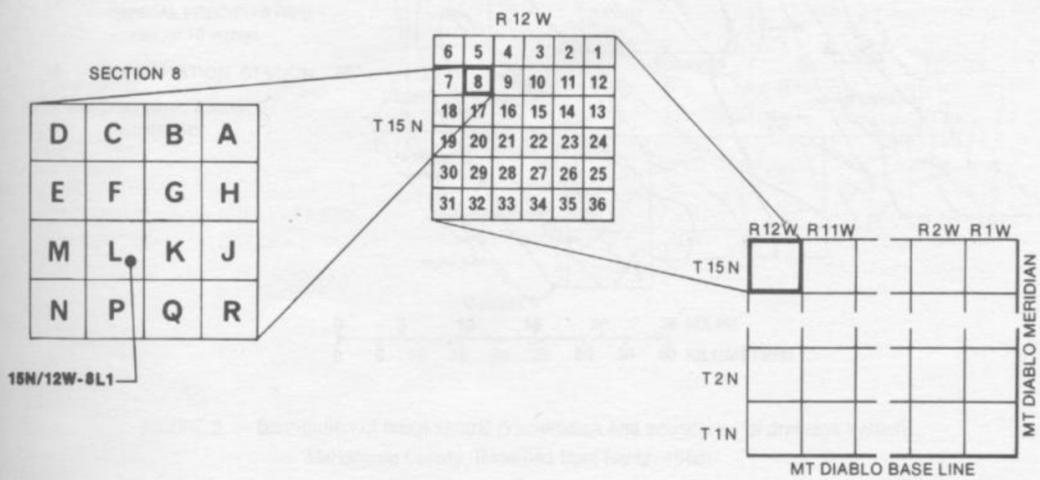
Acknowledgments

Much of the information in this report was taken from other sources. The work of earlier investigators (Cardwell, 1965; California Department of Water Resources, 1958; and California Department of Forestry, 1979) laid the foundation for this study and provided historical data.

The data-collection phase of this study was a success due to the cooperation of the many residents who allowed access to their land and wells and who provided information based on their own observations. Many individuals in county government, local water companies, and industries provided records of water levels, production, and other data. Jerry Davis, County Environmental Health, and Sari Sommarstrom, County Planning Department, were especially helpful in the early stages of this project by providing references, data, and insights into local water concerns.

Well-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. The part of the number preceding the slash, as in 15N/12W-8L1, indicates the township (T. 15 N.); the number following the slash indicates the range (R. 12 W.); the number following the hyphen indicates the section (sec. 8); and the letter following the section number (L) indicates the 40-acre subdivision of the section according to the lettered diagram below. Wells used routinely for observations by the California Department of Water Resources have a final sequence number following the lettered subdivision; wells used only during this study do not have sequence numbers. The township and range lines are based on the Mount Diablo base line and meridian.



Description of Area

Physical Setting

Mendocino County occupies approximately 3,500 mi^2 along the coast of northern California (fig. 1). The county extends south to north for approximately 80 miles from about 38°45' to 40°00' north latitude and ranges from about 35 to 60 miles in width. About 130 miles of the Pacific Ocean coastline forms the western boundary.

Flat-lying terraces, up to a few hundred feet in altitude, occupy a strip of land extending from the Pacific Ocean to 1 to 6 miles inland. The remainder of the county is mostly rugged mountainous terrain with a maximum altitude of 6,963 feet on Anthony Peak in the northeast part of the county. Within the mountainous terrain are isolated small valleys lying along major drainage systems. The valley floors range from about 500 to 2,000 feet in altitude and are bounded by mountains with 1,000 to 2,000 feet of local relief.

Three major surface-water drainage systems can be defined: the coastal, the Eel River, and the Russian River systems (fig. 2). The coastal drainage system consists of several relatively short streams flowing east to west that drain the western mountains and empty directly into the Pacific Ocean. The interior part of the county is drained by the two larger drainage systems--the Eel River and the Russian River systems; only parts of these drainage systems lie within the county. The headwaters of the South Fork Eel River and parts of the Middle Fork lie within the county; this system drains the northern interior. The headwaters of the Russian River lie near the middle of the county, and the Russian River drains the southern part of the county's interior.

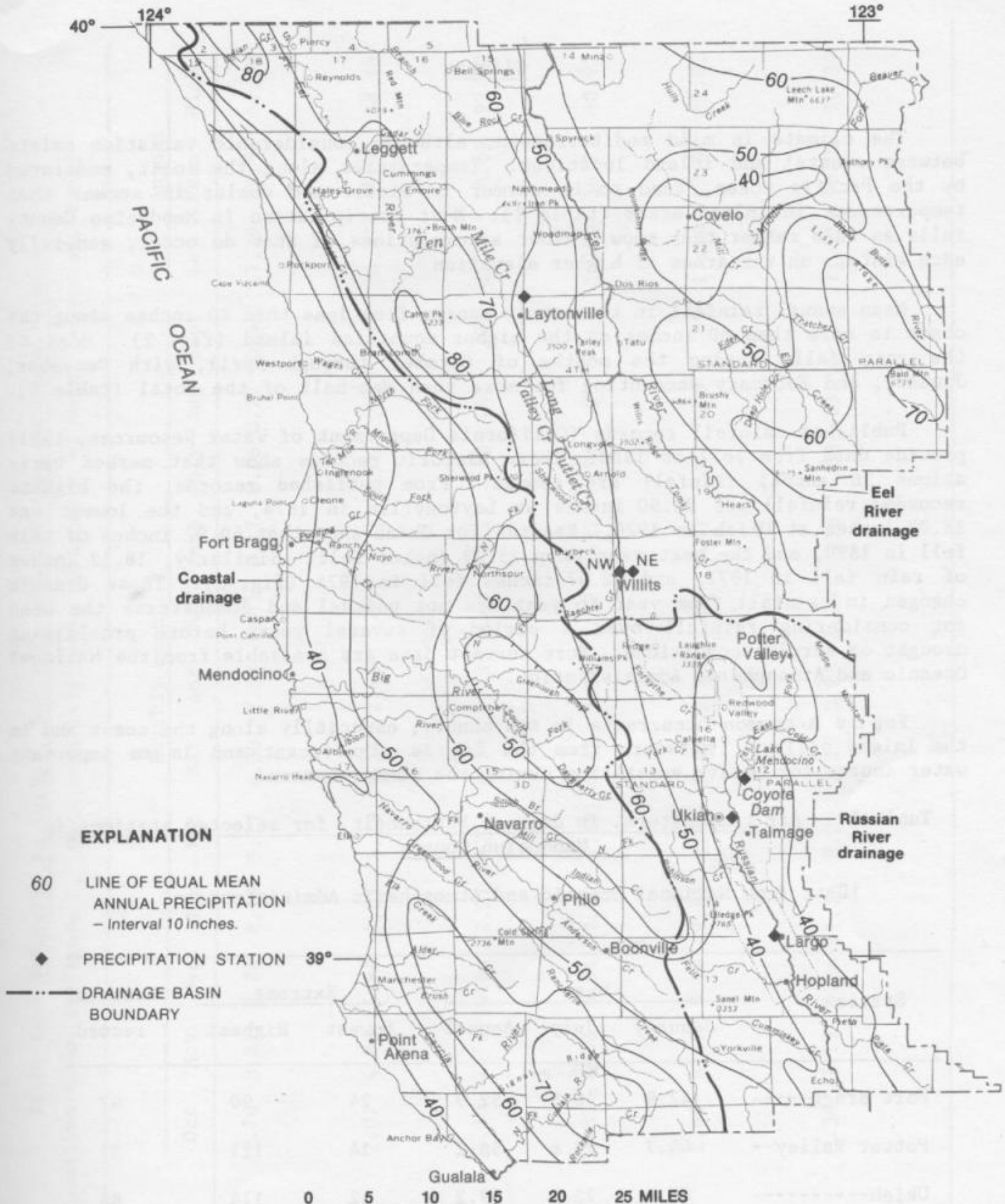


FIGURE 2. — Distribution of mean annual precipitation and boundaries of drainage systems, Mendocino County. (Modified from Rantz, 1968)

Climate

The climate is mild mediterranean, although considerable variation exists between coastal and inland locations. Temperatures along the coast, moderated by the Pacific Ocean, tend to be warmer in winter and cooler in summer than temperatures in inland areas (table 1). Most precipitation in Mendocino County falls as rain rather than snow. Minor accumulations of snow do occur, generally each winter, on the areas of higher elevation.

Mean annual rainfall in the county ranges from less than 40 inches along the coast to more than 80 inches on the higher mountains inland (fig. 2). Most of the rain falls during the months of October through April, with December, January, and February accounting for more than one-half of the total (table 2).

Published rainfall records (California Department of Water Resources, 1981) provide data from 1877 to 1980. These historic records show that marked variations in annual rainfall are common. From published records, the highest recorded rainfall was 92.90 inches at Laytonville in 1974, and the lowest was 13.09 inches at Ukiah in 1924. Records for Ukiah show that 60.97 inches of rain fell in 1890, and the next year only 25.29 inches fell. Similarly, 16.12 inches of rain fell in 1977, and 52.47 inches fell in 1978 (fig. 3). These drastic changes in rainfall from year to year are not unusual and demonstrate the need for considering rainfall over a period of several years before proclaiming drought or surplus conditions. More current data are available from the National Oceanic and Atmospheric Administration.

Fog is a common occurrence in the county, especially along the coast and in the inland valleys. Moisture from the fog is significant and is an important water source for native vegetation during the summer season.

Table 1.-- Air temperature, in degrees Fahrenheit, for selected stations in Mendocino County

[Data from National Oceanic and Atmospheric Administration]

Station	Mean			Extreme		Years of record
	January	July	Annual	Lowest	Highest	
Fort Bragg-----	47.9	56.5	52.9	24	90	47
Potter Valley--	44.7	73.6	58.2	14	111	39
Ukiah----------	46.0	73.7	59.2	12	114	88
Willits--------	45.0	70.5	54.2	--	--	21

Table 2.-- Rainfall, in inches, for selected stations, Mendocino County

[Locations shown in figure 2. Data from California Department of Water Resources, 1981]

Station and period of record	Monthly mean												Annual		
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Low	Mean	High
Coyote Dam 1964-80 altitude 720 feet.	1.70	5.21	7.28	8.10	5.27	4.30	2.38	0.45	0.17	0.08	0.27	0.44	17.39	35.56	51.09
Hopland-Largo 1948-69 altitude 550 feet.	2.07	4.83	6.86	8.01	5.79	4.21	2.45	.85	.37	.02	.13	.44	24.87	35.90	58.18
Laytonville 1941-78 altitude 1,640 feet.	3.75	7.73	10.64	12.21	8.22	6.79	3.48	1.43	.41	.10	.41	.78	25.00	56.02	92.90
Ukiah 1877-1980 altitude 623 feet.	1.83	4.38	6.94	7.97	6.17	4.62	2.38	1.03	.32	.04	.06	.46	13.09	36.27	60.97
Willits, NW (PAC RR) 1911-69 altitude 1,365 feet.	2.69	6.47	9.28	9.83	8.31	5.47	3.22	1.39	.41	.03	.09	.49	17.16	47.91	92.82
Willits, NE 1957-80 altitude 1,350 feet.	3.34	7.19	9.16	11.16	8.09	7.15	3.23	1.14	.16	.08	.31	.61	17.57	50.06	76.39

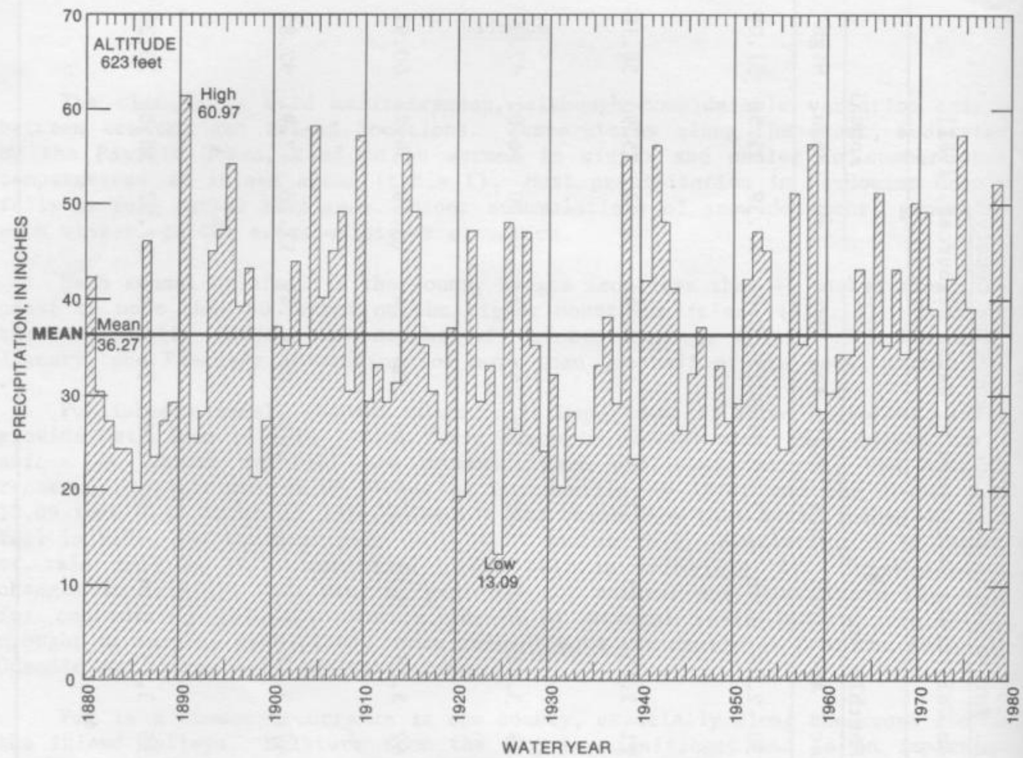


FIGURE 3. — Annual precipitation at Ukiah, water years 1880-1979. (Data from California Department of Water Resources, 1981; values rounded to nearest inch)

Cultural Development

The population of Mendocino County was shown as 66,738 in the 1980 census. About one-third of the population (21,487 people) lived in the four incorporated communities of Fort Bragg, Point Arena, Ukiah, and Willits. Most of the remainder of the population resided in small communities along the coast and in the unincorporated areas of the inland valleys; the mountainous areas were very sparsely settled.

Major economic activities in the area include forestry, fishing, agriculture, tourism, and manufacturing. Manufacturing, primarily related to lumber products, employs about 30 percent of the work force. Chief agricultural crops are wine grapes, fruits, and nuts.

GEOLOGY

Geologic Setting

Mendocino County lies within the Coast Ranges geomorphic province. The Coast Ranges comprise a group of mountain ranges extending 600 miles, from Santa Barbara County to the Oregon border, and ranging from a few to 70 miles in east-west dimension. The Coast Ranges lie between the Central Valley and the Pacific Coast and trend northwest, roughly paralleling the Sierra Nevada on the opposite side of the Central Valley. The northwest trend is seen in numerous elongate ranges and valleys and in the linear geologic structures of this complex province.

Mendocino County is mostly within that part of the Coast Ranges known as the Mendocino Range. This range is underlain almost entirely by rocks of the Franciscan Complex. The Franciscan Complex, the geomorphic features, and the geologic structures in the Coast Ranges are largely the result of global-scale crustal movements (plate tectonics) that involved the underthrusting and subduction of the Pacific oceanic plate beneath the continental margin of Western North America (Bailey and others, 1970). During Mesozoic time, an oceanic trench paralleling the coast marked the zone along which the overlapping of the plates occurred; this was the site of accumulation of the tectonically mixed sediments, which were later uplifted to form the mountainous terrain of the Franciscan Complex.

Geologic Units

The geologic units exposed at the surface can be divided into two major groups--basement rocks and valley fill. For this report, the term "basement rocks" includes all the rocks of pre-Pliocene age; "valley fill" refers to geologic units of Quaternary age or those that span Tertiary and Quaternary age. The geologic units discussed in this report include those that lie east of the coastal terraces and east of the San Andreas fault (fig. 4). Not including the thin mantle of soil locally concealing geologic units, about 95 percent of surface exposures consist of basement rocks. The valley fill is confined to small basins along major stream courses and thin alluvium in stream channels.

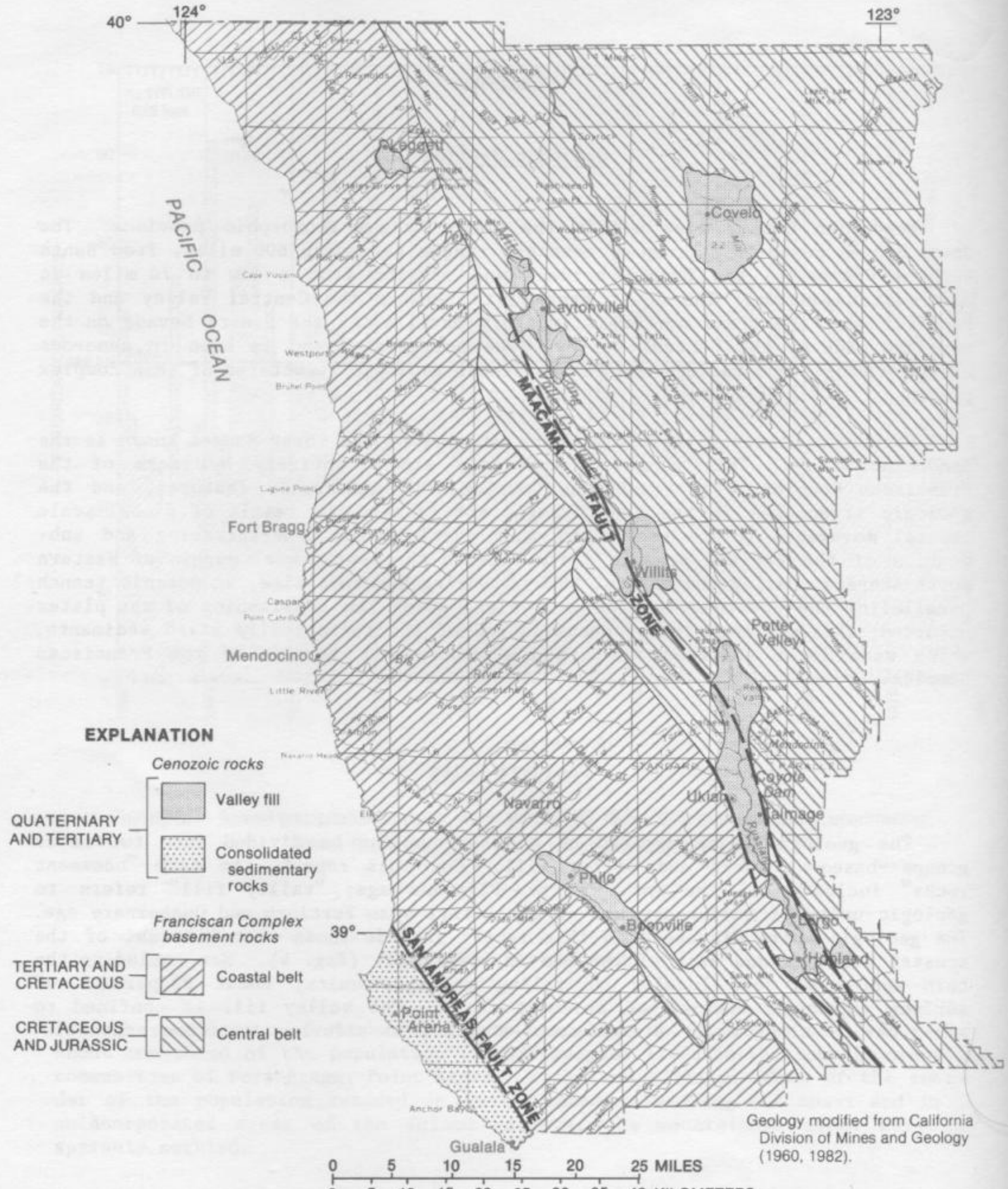


FIGURE 4. — Generalized geology of Mendocino County.

Basement Rocks

The basement rocks consist of rocks of the Franciscan Complex, a few small patches of rocks of the Great Valley sequence superimposed on the Franciscan, and outcrops of upper Tertiary sedimentary rocks. The incorporation of Great Valley rocks into the Franciscan terrane may have resulted from thrust faulting, gravity sliding, or original deposition (Maxwell, 1974). For this report, the two units are undifferentiated because of the minor presence of Great Valley rocks and their geohydrologic similarity to some of the lithologic units of the Franciscan. Upper Tertiary sedimentary rocks crop out in two areas, west of Piercy and southwest of Covelo. These rocks are present only in small areas and are not considered further in this report.

The basement rocks as defined above underlie the entire county, with the exception of the small sliver of land west of the San Andreas fault. The thickness of the basement rocks is unknown because of the complex structural relation with adjacent geologic units; however, it is estimated to be about 50,000 feet (Bailey and others, 1970).

The Franciscan Complex is a structural complex and a rock stratigraphic unit consisting of a structural aggregation of intact blocks of bedded sedimentary rocks in a faulted and sheared matrix of melange and broken formations. It has been subdivided into three major northwest-trending subparallel belts named, from west to east, the Coastal belt, Central belt and Yolla Bolly belt (Blake and Jones, 1981). In this report the Franciscan Complex is subdivided into Coastal-belt and Central-belt rocks. Rocks of the Yolla Bolly belt lie mostly east of the county; the few isolated outcrops within the Central belt are not differentiated.

Coastal-belt rocks of Cretaceous and Tertiary age lie mostly west of a line coinciding with U.S. Highway 101 and occupy about one-half of the county; Central-belt rocks cover the rest of the county. The Coastal-belt rocks consist of graywacke, mudstone, and minor conglomerate. These lithologic units contain abundant mica and potassium feldspar; low-grade metamorphism to the zeolite facies is found locally. Coastal-belt rocks are less deformed than Central-belt rocks. In places the Coastal belt includes undeformed blocks of graywacke in a highly sheared matrix of mudstone, but the Coastal belt is characterized generally by coherent rock units with a predominantly homoclinal structure striking northwest and dipping northeast under the Central-belt rocks.

The Central belt of Jurassic and Cretaceous age is a melange (Hsu, 1968; Fox, 1983a) consisting of a matrix of highly sheared graywacke and mudstone enclosing coherent blocks of graywacke, chert, greenstone, serpentine, blueschist, and limestone. Although the mudstone matrix is easily eroded, the coherent blocks are resistant to erosion. This results in a characteristic topography of resistant knobs, house-sized to boulder-sized, projecting through the hummocky hillsides. The grass-covered sheared mudstone units are unable to support dense stands of trees due to the unstable ground moving downslope by creep and debris flows.

Valley Fill

Valley fill refers to the unconsolidated to loosely cemented gravel, sand, silt, and clay deposited in the major valleys. The valley fill was deposited in topographically separated structural basins. As a consequence, the units are correlative from one basin to another but are not continuous between basins.

In this report the fill is subdivided into three distinct units--continental basin deposits, continental terrace deposits, and Holocene alluvium, based on the geologic age and origin of the units. The distinctive geologic attributes of each unit result in differences in water-bearing properties significant to this study.

The discussion of the valley-fill units presented here emphasizes the general lithologic characteristics of each and the geologic relations among the units. Not all units are present in each of the valleys studied. Specific discussion of units present in each valley and the water-bearing characteristics of each are presented later in this report under the heading "Ground-Water Conditions."

Continental basin deposits.--The oldest and stratigraphically lowest unit of the valley fill, this unit was deposited directly on the basement rocks in structural basins during late Pliocene and Pleistocene time. A schematic section of Ukiah Valley (fig. 5) shows stratigraphic relations. Lithologically, the continental basin deposits comprise a heterogeneous mixture of loosely cemented gravel, sand, silt, and clay. Bedding ranges from massive to thin. The lateral extent of individual beds is generally small for the coarse-grained material and larger for fine-grained materials. Beds of sand and gravel are typically lenticular and interfinger with beds above and below. From studies of structural basins 30 miles south of Ukiah by McLaughlin and Nilsen (1982), the origin of this unit may be inferred. The highly erodible Franciscan Complex provided material for landslides and debris flows, which built fans and talus slopes around the valley margins. Braided streams flowed across the fans and deposited sediments as they meandered out onto the valley floor. Each valley was partly occupied by a lake around which deltas were built by the inflowing streams. These sedimentary processes combined to produce and leave behind a highly complex distribution of gravel, sand, silt, and clay.

Deposition of the continental basin deposits began about 3 to 4 million years ago and continued until at least 0.45 million years ago (McLaughlin and Nilson, 1982). Since that time minor deformation of these beds has occurred, resulting from regional tectonics and movement along faults. In some outcrops at the margins of the valleys, beds are tilted as much as 10° from horizontal.

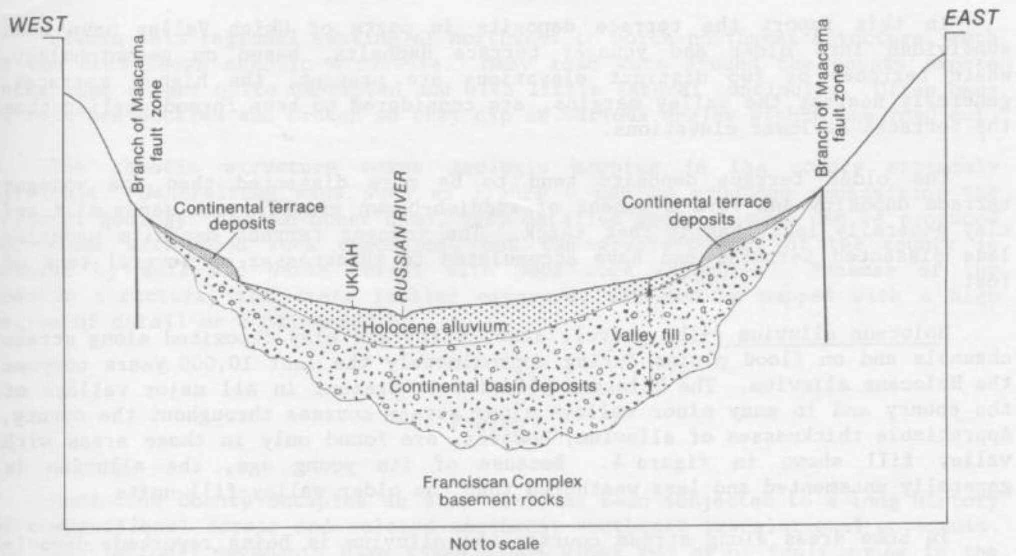


FIGURE 5. — Generalized geologic section of Ukiah Valley.

Continental terrace deposits.--The partially-to-loosely cemented beds of gravel, sand, silt, and clay underlying elevated terraces along the margins of Laytonville and Hopland-Ukiah Valleys compose the continental terrace deposits. Lithologically these deposits are similar to the underlying continental basin deposits (fig. 5); however, this unit generally contains less silt and clay. The terrace deposits are identified in part by their geomorphic expression--long, narrow, elevated, gently inclined surfaces formed by aggradation of eroded materials.

The continental terrace deposits comprise the materials deposited by streams draining the area during Pleistocene time. Downslope movement along the valley margins supplied Franciscan-derived sediment to streams that eroded and deposited material by processes similar to those active today along modern streams draining the valleys.

The fluvial origin resulted in lithologic heterogeneity of these deposits. Beds within the terrace deposits tend to be lens-shaped, laterally interfingering with neighboring beds. At depth, coarse- and fine-grained materials alternate as a result of changing hydraulic conditions at the time of deposition.

In this report the terrace deposits in parts of Ukiah Valley have been subdivided into older and younger terrace deposits, based on geomorphology. Where terraces of two distinct elevations are present, the higher terraces, generally nearest the valley margins, are considered to have formed earlier than the terraces at lower elevations.

The older terrace deposits tend to be more dissected than the younger terrace deposits and form a veneer of reddish-brown gravelly and sandy silt and clay generally less than 10 feet thick. The younger terrace deposits underlie less dissected terraces and have accumulated to thicknesses of several tens of feet.

Holocene alluvium.--The gravel, sand, silt, and clay deposited along stream channels and on flood plains during approximately the last 10,000 years compose the Holocene alluvium. The Holocene alluvium is present in all major valleys of the county and in many minor valleys along stream courses throughout the county. Appreciable thicknesses of alluvium, however, are found only in those areas with valley fill shown in figure 4. Because of its young age, the alluvium is generally uncemented and less weathered than the older valley-fill units.

In some areas along stream courses the alluvium is being reworked; deposition or erosion predominates depending on hydraulic and geologic conditions. Particle size of alluvium tends to be largest along the axis of a stream and becomes finer on the flood plain as distance from the stream axis increases. Because of the dynamic nature of stream channels, however, the alluvium in any location tends to be heterogeneous with depth due to the lateral shifting of main channels and flood plains.

In the major structural valleys the alluvium overlies either basement rocks or continental basin deposits. The alluvium is generally less than a few tens of feet thick but may exceed 100 feet in places. The material deposited is derived mostly from rocks of the Franciscan Complex, but both the continental terrace deposits and continental basin deposits contribute material as well.

Geologic Structures

Major geologic structures in Mendocino County have a predominant northwest to north-northwest trend. This trend is followed by topographic features and stream courses throughout much of coastal California from Santa Barbara northward and is related to geologic processes that affected the entire western continental margin of North America.

The courses of both the Eel and the Russian Rivers are controlled by the north-northwest trending structural grain. The main inland valleys (fig. 4) are also aligned along the north-northwest trending line. The long axis of Anderson Valley follows a northwest trend, approximately parallel with the San Andreas fault.

Within this regional setting of northwest to north-northwest structure, much of the area shows chaotic structure. Many road cuts around the county expose rocks that appear quite disrupted and with little lateral continuity. Often beds of rock are buckled and broken so they dip at various angles within one road cut.

The chaotic structure makes geologic mapping in the county extremely difficult. Generalized maps such as figure 4 can be produced emphasizing the regional geology. On the other hand, very detailed geologic maps can be produced for areas with good rock exposures, but the greatest part of the county is covered by soil and dense forest with poor rock exposures. Because of the chaotic structure, the areas lacking exposures can not be mapped with a high degree of detail or confidence.

Faults

Mendocino County occupies an area that has been subjected to a long history of compressional forces and related northwest-southeast translational movements. The translational movements have taken place along two major fault zones in the county (fig. 4). Numerous faults of lesser displacement or with more obscure surface manifestation exist throughout the county.

San Andreas fault.--The San Andreas fault is widely known due to the damaging earthquakes it has produced during historic time; its surface trace runs northwest across the extreme southwestern part of Mendocino County. The San Andreas fault is a major structural discontinuity along which the rocks on the southwest side have been displaced northwestward relative to rocks on the opposite side of the fault.

The San Andreas fault, shown as a single dashed line in figure 4, is actually a zone of en echelon faults. The individual fault-breaks trend parallel or subparallel to one another and respond to crustal stresses with similar displacement actions. Horizontal surface displacements of as much as 15 feet occurred near Point Arena in 1906 (Fox, 1983b). This segment of the fault is still considered active although there has been no measured displacement along it since 1906 (Brown and Wolfe, 1973).

Maacama fault.--The Maacama fault trends northwest through the central part of the county. Like the San Andreas, the Maacama fault is actually a zone of parallel or subparallel en echelon breaks with right-lateral displacement. As shown in figure 4, the Maacama fault can be seen to pass through or border the structural basins containing valley fill in the Ukiah, Willits, and Laytonville areas, and is related to their formation. The Maacama is an active fault zone--as attested by earthquakes centered near Willits during recent years (Simon and others, 1978).

Structural Basins

Ukiah, Little Lake, and Laytonville Valleys all are present along the trend of the Maacama fault zone. This relation is not merely coincidental; rather, the basins were created by oblique pull-apart extension between en echelon and minor branching faults of the Maacama fault zone (McLaughlin and Nilsen, 1982). The right-lateral strike-slip movement along parallel fault segments results in a wrenching apart and downdropping of the intervening crustal block. The grabens thus formed are bounded by faults on all sides. Sedimentation begins in-filling at the onset of basin formation and continues concurrent with the further downdropping of the graben. In this way a considerable thickness of valley fill may be deposited without changing the base level of erosion.

Studies of regional tectonics (Blake and others, 1978) have demonstrated that the development of pull-apart basins in the Coast Ranges has propagated northward over time. This suggests that within Mendocino County the Ukiah Valley basin began forming first and was followed by Little Lake Valley and then Laytonville Valley. The basins began developing less than 4 million years ago and may have been undergoing subsidence until less than 0.5 million years ago.

GROUND-WATER CONDITIONS

Ukiah Valley

Description of Area

Ukiah Valley, the largest of the interior valleys, is located in the southeastern part of the county. It occupies an area about 30 miles long and 4 to 6 miles wide along the course of the Russian River from near its headwaters to south of Hopland. The Hopland area, also known as Sanel Valley, lies at the southern end of Ukiah Valley. This area is separated from the main part of the valley by low hills, about 4 miles north of Hopland, through which the Russian River has cut a narrow gorge. Except for stream-gravel deposits this narrow gorge contains no valley fill. Hopland Valley is included as part of Ukiah Valley in this report because of the proximity of the valleys and because both areas contain similar geologic units.

Main population centers include the incorporated city of Ukiah in the central part of the valley and, from north to south, the smaller communities of Redwood Valley, Calpella, Talmage, Hopland, and Old Hopland. These communities are served by municipal and community water systems that obtain water from wells; surplus water from Lake Mendocino augments the water supply for Redwood Valley.

The report is continued on pg. 34 with the description of Little Lake Valley.

Little Lake Valley

Description of Area

Little Lake Valley, also known as Willits Valley, is located in the central part of the county about 25 miles north of Ukiah and lies immediately north of the drainage divide between the Eel and the Russian River basins (fig. 1). Several small streams, including Baechtel, Broaddus, Davis, Haehl, and Willits Creeks, flow through the valley and join in a marshy area near the north end (fig. 8). The marshy area is drained by Outlet Creek, a tributary of the main stem of the Eel River. The valley consists of an oblong-shaped flat floor measuring about 5 miles north to south and 2.5 miles west to east and an area of low hills encompassing an additional 5 mi^2 at the southern end of the valley. The average altitude of the the valley floor is approximately 1,350 feet above sea level.

Willits, the only town in the valley, had a population of 4,008 at the 1980 census. The community is served by a water system that obtains its supply from Morris Reservoir, which has a storage capacity of 835 acre-ft. The community has experienced water shortages during late summer during some years when the reservoir dropped to low levels. Ranches and residences outside the service area obtain water from individual wells and springs.

EXPLANATION FOR FIGURE 8

Qal	Alluvium	Holocene	Quaternary
QTc	Continental basin deposits	Pleistocene and Pliocene	Quaternary; Tertiary
	Unconformity		
TKJf	Franciscan Complex, undifferentiated		Tertiary, Cretaceous, and Jurassic

CONTACT – Dashed where approximately located

....? FAULT – Shows approximate location; dotted where concealed, queried where uncertain

A —— A′ LINE OF GEOLOGIC SECTION (See figure 9)

PETROLEUM EXPLORATION HOLE SITE

13B1 WELL AND NUMBER – Shows location of well used for geologic section, or mentioned specifically in section on "Water-Bearing Formations" in text

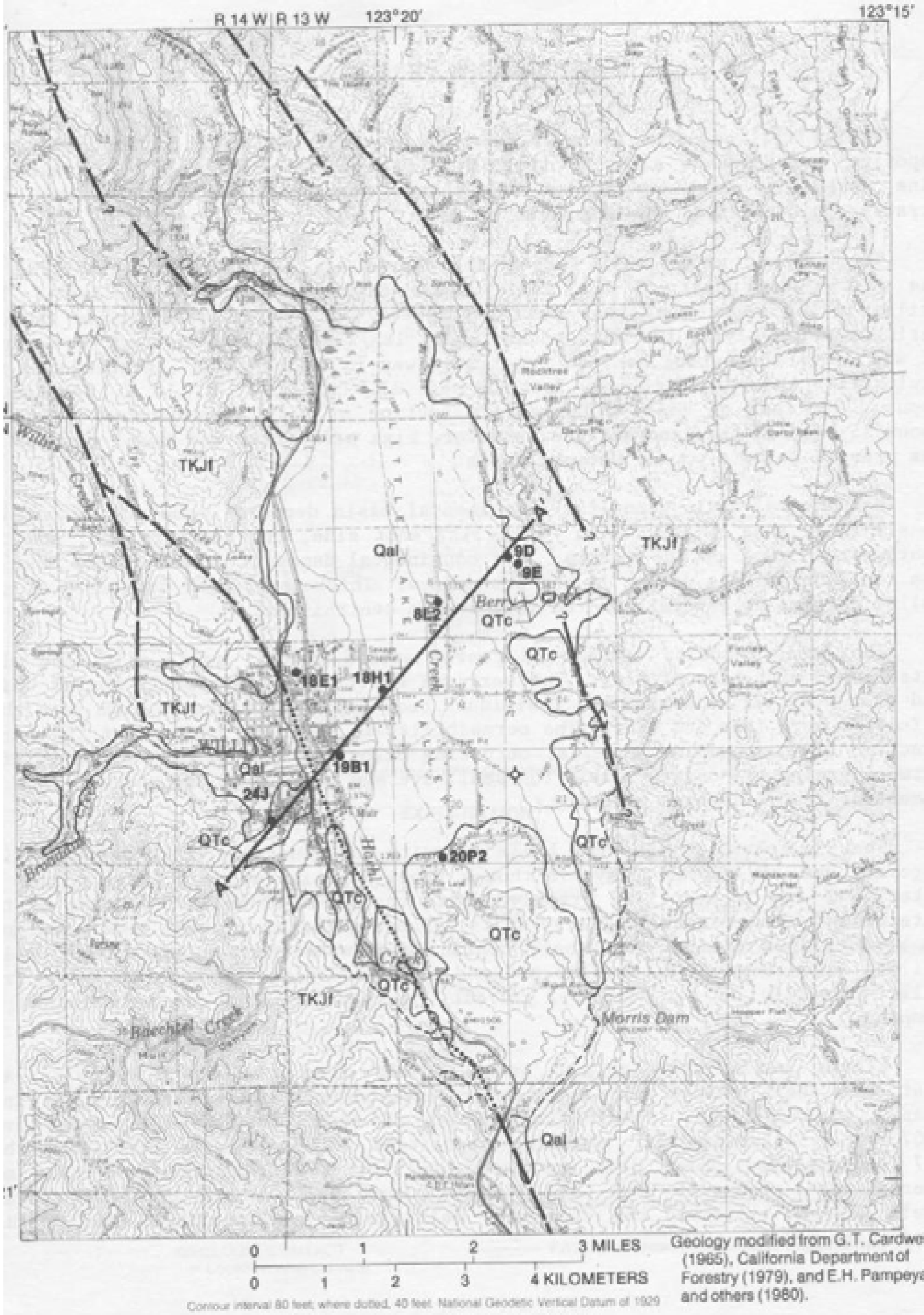


FIGURE 8. — Geology of Little Lake Valley.

Water-Bearing Formations

Valley fill occupies about 18 mi^2 and is subdivided into continental basin deposits and Holocene alluvium (fig. 8). A geologic section (fig. 9) along a line extending northeast across the central part of the valley shows the stratigraphic relation between units of fill.

The deepest water well for which records are available, 18N/13W-18E1 in the west-central part of the valley, has a total depth of 493 feet. The driller's log shows that this well penetrated 445 feet of fill before encountering the underlying basement rocks. Well 18N/13W-19B1 was drilled to a depth of 454 feet; the entire section penetrated was in valley fill. An abandoned gas exploration hole drilled 2,000 feet in sec. 21, T. 18 N., R. 13 W. penetrated about 1,000 feet of fill. This entire section of fill is saturated to within about 15 feet of the land surface; however, high salinities and small pockets of gas prevail below a poorly defined depth.

Continental basin deposits.--Continental basin deposits crop out discontinuously in an area of about 5 mi^2 along the east side, the southern end, and the southwestern part of the valley. The continental deposits extend across most of the remainder of the valley in the subsurface. Thickness ranges from zero at the valley margins to several hundred feet in the central part.

The basin deposits consist of poorly sorted gravel, sand, silt, and clay interbedded with beds of clay. The vertical distribution of poorly sorted units and clay beds varies markedly. Individual beds range in thickness from less than 1 foot to more than 100 feet. The permeability is very low because of the large fraction of fine-grained material occurring either as beds of clay or as filling between grains of coarser size. The small average grain size and general lack of cementing result in high porosity.

The widespread continental basin deposits are generally thick and have high porosity and low permeability. Although these deposits store a large volume of water, the low permeability greatly limits the yield of wells. Because of the interbedded, low-permeability clay units, ground water is present under confined or semiconfined conditions. Where confining pressures are great enough, wells drilled into these deposits flow at land surface. Although natural flows from wells generally do not exceed 2 gal/min, increased yields can be obtained by pumping.

Eleven wells that obtain water solely from the basin deposits and that have been tested for yield were inventoried. Yields range from less than 1 to 45 gal/min. Specific capacities of seven of the wells range from 0.07 to 2.5 (gal/min)/ft; specific capacities of five wells were less than 0.7 (gal/min)/ft. These data are based on short-term pumping tests that may overestimate potential long-term yields. Many well owners contacted during field surveys expressed the view that well yields have declined from initial production rates.

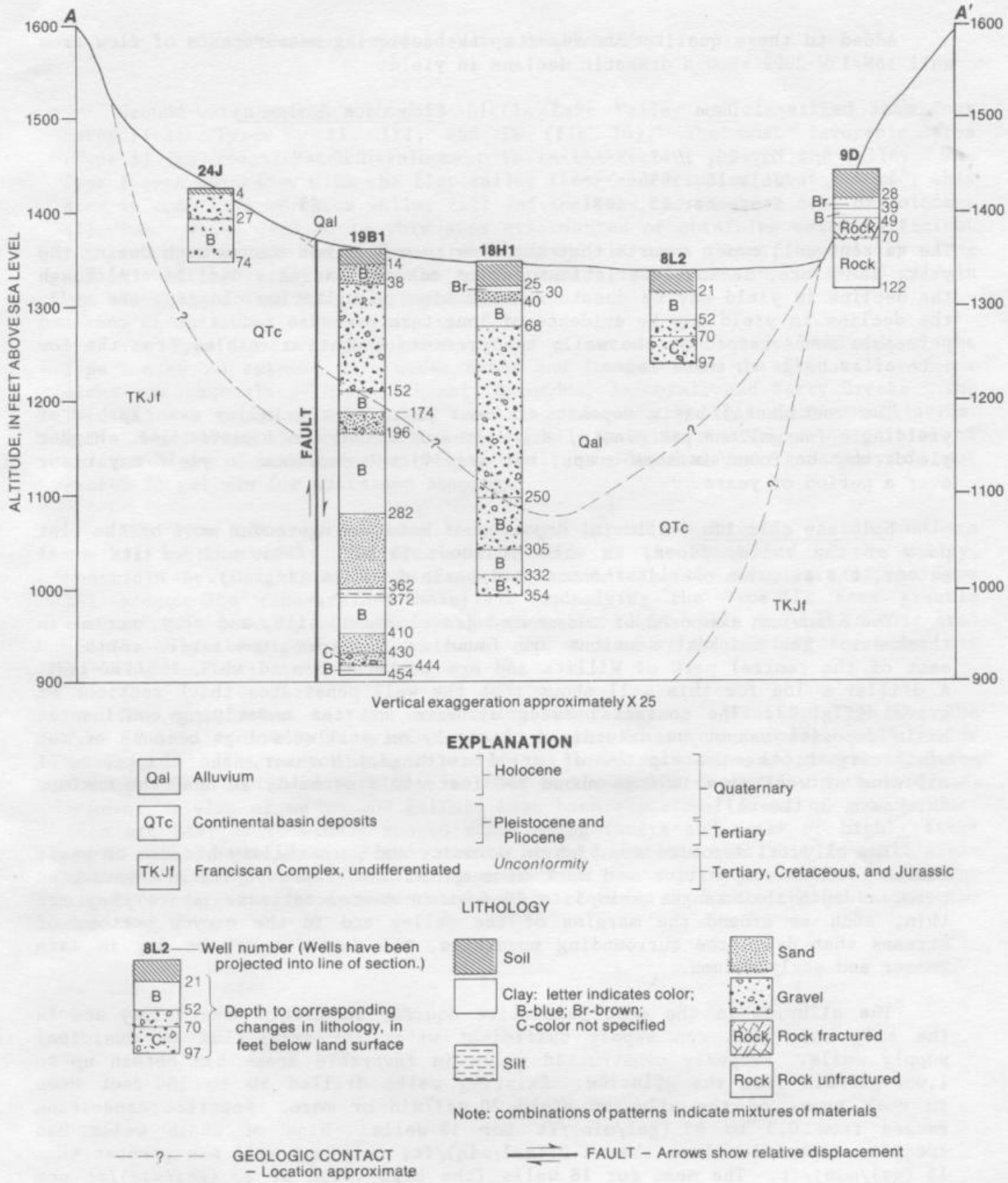


FIGURE 9. – Geologic section, Little Lake Valley. (Location shown in figure 8)

Added to these qualitative reports, the following measurements of flow from well 18N/13W-20P2 show a dramatic decline in yield:

Date	Flow rate (gal/min)
May 20, 1947---------	250
July 14, 1954--------	15
September 23, 1981---	.25

The current well owner reports that the flow rate does not change much during the year; therefore, seasonal variations do not account for this decline. Although the decline in yield may be due to encrustation or siltation clogging the well, the decline in yield may be evidence of long-term pressure reduction in confined permeable zones tapped by the well; the pressure reduction results from the low rate of recharge to these zones.

The continental basin deposits in most parts of the valley are capable of yielding a few gallons per minute, which is sufficient for domestic use. Higher yields may be found in some areas, but significant declines in yield may occur over a period of years.

Holocene alluvium.--Alluvial deposits of Holocene age cover most of the flat part of the valley floor, an area of about 13 mi^2. Over much of its areal extent, the alluvium overlies continental basin deposits (fig. 9).

The alluvium, composed of uncemented gravel, sand, silt, and clay, varies in thickness. The thickest sections are found in the area immediately south and east of the central part of Willits and are centered around well 18N/13W-18H1. A driller's log for this well shows that the well penetrates thick sections of gravel (fig. 9). The contact between alluvium and the underlying continental basin deposits cannot be determined precisely on driller's logs because of the similarity in the description of drill cuttings. However, the thickness of alluvium at well site 18H1 is about 250 feet; this probably is near the maximum thickness in the valley.

The alluvial deposits are high in porosity and permeability because of their coarse-grained composition and lack of cementation. The deposits are saturated below a depth that ranges from 5 to 20 feet in most locations. Where they are thin, such as around the margins of the valley and in the canyon bottoms of streams that drain the surrounding mountains, the deposits may be dry in late summer and early autumn.

The alluvium is the most productive aquifer in Little Lake Valley and is the only unit that can supply sufficient water for irrigation or municipal supply wells. Properly constructed wells in favorable areas can obtain up to 1,000 gal/min from the alluvium. Existing wells drilled 50 to 100 feet deep in most areas of the alluvium yield 20 gal/min or more. Specific capacities ranged from 0.3 to 83 (gal/min)/ft for 19 wells. Nine of these wells had specific capacities less than 1.0 (gal/min)/ft; only one well was greater than 11 (gal/min)/ft. The mean for 18 wells (the high value of 83 (gal/min)/ft not included) is 2.75 (gal/min)/ft.

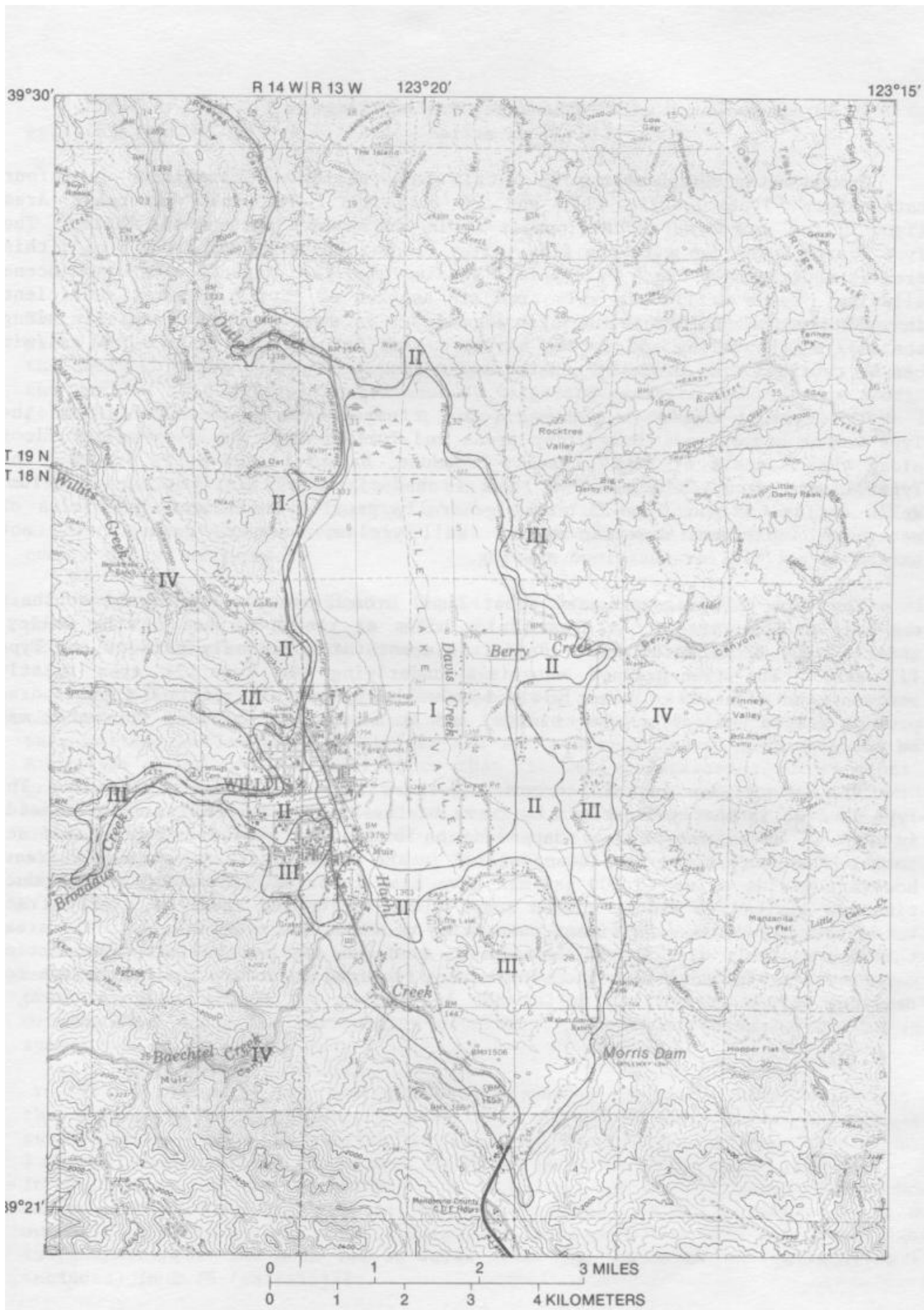
Ground-Water Availability

Ground-water availability in Little Lake Valley is classified into four categories: Types I, II, III, and IV (fig. 10). The most favorable area (Type I) for ground-water development is in the central part of the valley. The Type I area coincides with the flat valley floor and occupies about 7.5 mi^2; this area is underlain by thick valley fill and includes the thickest area of Holocene alluvium. Wells drilled in this area are assured of obtaining water sufficient in quantity for individual domestic supplies. In some places, especially along the axis of the valley and in the northern part, yields of 100 to 1,000 gal/min can be obtained from properly constructed wells.

The Type II area, in places, forms a narrow concentric band around the Type I area but extends into wider areas and further from the flat valley floor along the channels of Davis, Haehl, Broaddus, Baechtel, and Berry Creeks. The Type II area occupies about 3 mi^2 and is underlain by thin Holocene alluvium. Wells drilled in the Type II areas generally provide sufficient quantities of water for individual domestic wells. Well yields, however, generally do not exceed 10 gal/min for sustained pumping.

The Type III area occupies about 7 mi^2 around the margins of the southern one-half of the valley. An area of low hills at the south end of the valley, underlain by continental basin deposits, constitutes the main part of the Type III area. The fine-grained materials underlying the Type III area greatly restrict the quantity of water yielded to wells. Most wells drilled in this area provide only a few gallons per minute, and at some sites drilling for water may be unsuccessful.

The mountainous terrain surrounding the valley is classified Type IV. The Type IV area is mostly underlain by rocks of the Franciscan Complex. Well yields in Type IV areas vary widely depending on local rock type and degree of fracturing. Many dry holes have been drilled in the search for water in these areas; however, yields of up to 200 gal/min have been reported. Areas of good production are limited to widely spaced zones along faults and areas of highly fractured rock. Because significant quantities of water are available in small areas that are sparsely distributed among areas that are dry or of limited production capacity, careful site-specific studies are required to locate the best sites for drilling.



Contour interval 80 feet; where dotted, 40 feet. National Geodetic Vertical Datum of 1929

FIGURE 10. — Ground-water availability in Little Lake Valley.

EXPLANATION FOR FIGURE 10

MAP SYMBOL	GROUND WATER AVAILABILITY	WATER-BEARING UNITS
I	Ground water generally abundant. Production rate and supply sufficient for agricultural, industrial, municipal, and domestic uses.	All coarse-grained consolidated deposits of valley fill where thick and saturated. Any areas reported to have high-capacity wells.
II	Ground water generally available year-round at low production rates. Generally sufficient supply for domestic use; may provide adequate supply for irrigation or industrial use.	Margins of valley fill where partially saturated year-round, or areas where production is proven.
III	Ground water generally present, but production rates are extremely limited or ground water is only seasonally available; may provide sufficient supply for domestic use.	Areas where valley fill is thin, very fine grained, or cemented; or areas where water table seasonally drops below the fill. Includes some areas of shallow ground water, but very low permeability.
IV	Ground water generally not available in significant quantities. Where available, the occurrence is restricted to small areas lithologically or structurally favorable; may provide adequate supply for livestock or domestic use.	Franciscan Complex rocks comprising the mountainous terrain. Rocks are very fine grained or cemented.

Estimated Storage Capacity

The quantity of available ground water stored in the upper 100 feet of the most productive areas of valley fill (Type I) is estimated to be 35,000 acre-ft. This estimate was computed by determining the volume of saturated fill within 100 feet of the surface and multiplying the result by the estimated specific yield. The volume of saturated fill underlying the Type I area is about 430,000 acre-ft, based on an area of 7.5 mi^2 and a saturated thickness of 90 feet (water levels are about 10 feet below the land surface during the spring). This computed volume is probably within 10 percent of the actual value. The quantity of water that can be extracted from aquifer materials depends on the specific yield of the materials. The specific yield was estimated from lithologic observations at outcrops and from descriptions of materials on driller's reports. The average specific yield used for the storage-capacity computation was 8 percent. This estimated specific yield may be in error by about 25 percent. When the possible errors are considered, the storage capacity could range from 23,000 to 48,000 acre-ft.

Additional ground water is stored in aquifer materials underlying areas designated as Type II on the ground-water availability map. Estimated storage capacity in the upper 100 feet of Type II aquifer materials is 9,000 acre-ft, assuming an average specific yield of 5 percent.

No estimates were made of the storage capacity for Type III or IV areas because these areas have marginal capacities to yield water to wells.

The storage-capacity estimates for Type I and II areas include all available water regardless of quality. Chemical data for wells along the east side of the valley and in the north part indicate that some parts of the valley fill contain water with concentrations of chloride, boron, and dissolved solids that exceed the standards for some uses. Therefore, part of the quantity of water estimated in storage may not be usable for some purposes. Discussion of chemical quality in Little Lake Valley is covered in more detail in a later section of this report.

Water-Level Fluctuations

Water levels in wells in Little Lake Valley fluctuate principally in response to pumping and precipitation. Seasonal fluctuations result from seasonal variations in rainfall and pumping. Long-term changes may occur when the effects of pumping are not balanced by recharge from precipitation over a period of years.

Water-level records spanning 10 years or more are available for four wells in Little Lake Valley. Hydrographs for these wells show that the water level fluctuates about 10 to 15 feet seasonally (fig. 11). No significant long-term trends are evident from the records; water levels measured during the 1980's are nearly the same as levels measured during the 1950's. However, well 18E1 does show a slight water-level rise during 1959-73. The specific reason for this rise is not known, but it may relate to changes in local pumping. Because this is the deepest of these wells, it may respond more slowly than the shallow wells to seasonal variations in precipitation.

Variations in the quantity and distribution of precipitation cause some variability in the spring high water levels and autumn low water levels. Spring water levels measured during the drought of 1976 and 1977 (precipitation was 59 and 34 percent of normal, respectively) were lower than normal in the four hydrograph wells. Water levels rose to normal levels in three of the four wells by the end of the 1978 wet season (precipitation was 116 percent of normal during the 1978 rainfall season).

Comparison of precipitation records for stations in Little Lake Valley (California Department of Water Resources, 1981) with spring water-level measurements indicates that levels recover to normal if precipitation is at least 75 percent of normal during the preceding rainfall season. The available data for Little Lake Valley are not sufficient to ascertain if lesser amounts of precipitation would return water levels to normal; however, data from Ukiah Valley indicate that precipitation in excess of 60 percent of normal during the preceding season is enough to fully recharge the ground-water reservoir.

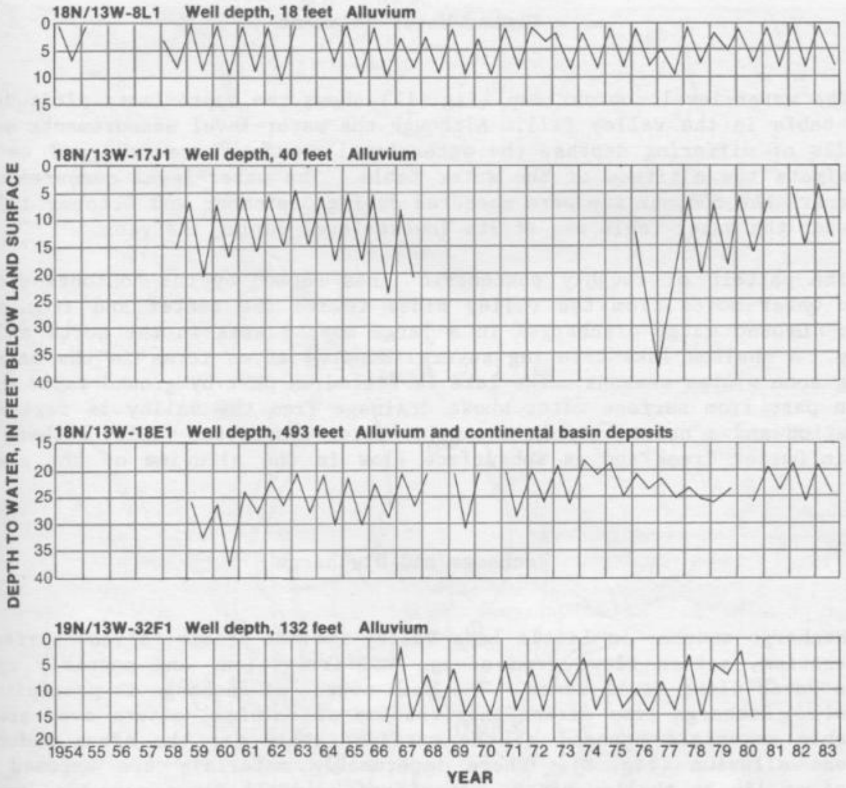


FIGURE 11. — Hydrographs for selected wells in Little Lake Valley.
(Locations shown in figure 12)

Ground-Water Movement

The water-level contour map (fig. 12) shows the approximate altitude of the water table in the valley fill. Although the water-level measurements were made in wells of differing depths, the water-level contours are believed to closely approximate the altitude of the water table. The water-level measurements used to prepare the contour map were measured during September and October 1981, at a time when the water table was at its lowest level during the year.

The pattern of roughly concentric lines formed by the contours shows that ground water moves from the valley sides toward the center and from south to north. Ground water discharges in a large marshy area in the north end of the valley. A shallow lake covering several hundred acres forms in the marshy area during some winter seasons. The lake is filled in part by ground-water discharge and in part from surface water whose drainage from the valley is restricted by vegetation and a narrow stream channel. Water leaves the valley both as surface flow in Outlet Creek and as subsurface flow in the alluvium of the creek bed.

Recharge and Discharge

Recharge sources in Little Lake Valley include precipitation, surface-water infiltration, return flows from sewage and irrigation, and possibly upflow of ground water along fault zones. The main source of recharge is precipitation as rainfall. Recharge from direct infiltration of rainfall occurs over areas with permeable materials exposed at the surface; these are the areas underlain by Holocene alluvium (fig. 8). Where impermeable materials are exposed at the surface or lie at shallow depth, water from rainfall flows over the impermeable materials to contacts with permeable materials. The contact zones between Holocene alluvium and continental basin deposits are important recharge areas (fig. 8).

EXPLANATION FOR FIGURE 12

— *1340* — — WATER-LEVEL CONTOUR – Shows altitude of water table or potentiometric surface. Contour interval is 20 feet. Dashed where approximately located.

← APPROXIMATE DIRECTION OF GROUND-WATER MOVEMENT

WELL AND NUMBER

32F1 ● Well with hydrograph shown in figure 11

19B1 ○ Well included in proposed ground-water-level monitoring network

18E1 ◉ Well included in proposed ground-water-level monitoring network with hydrograph shown in figure 11

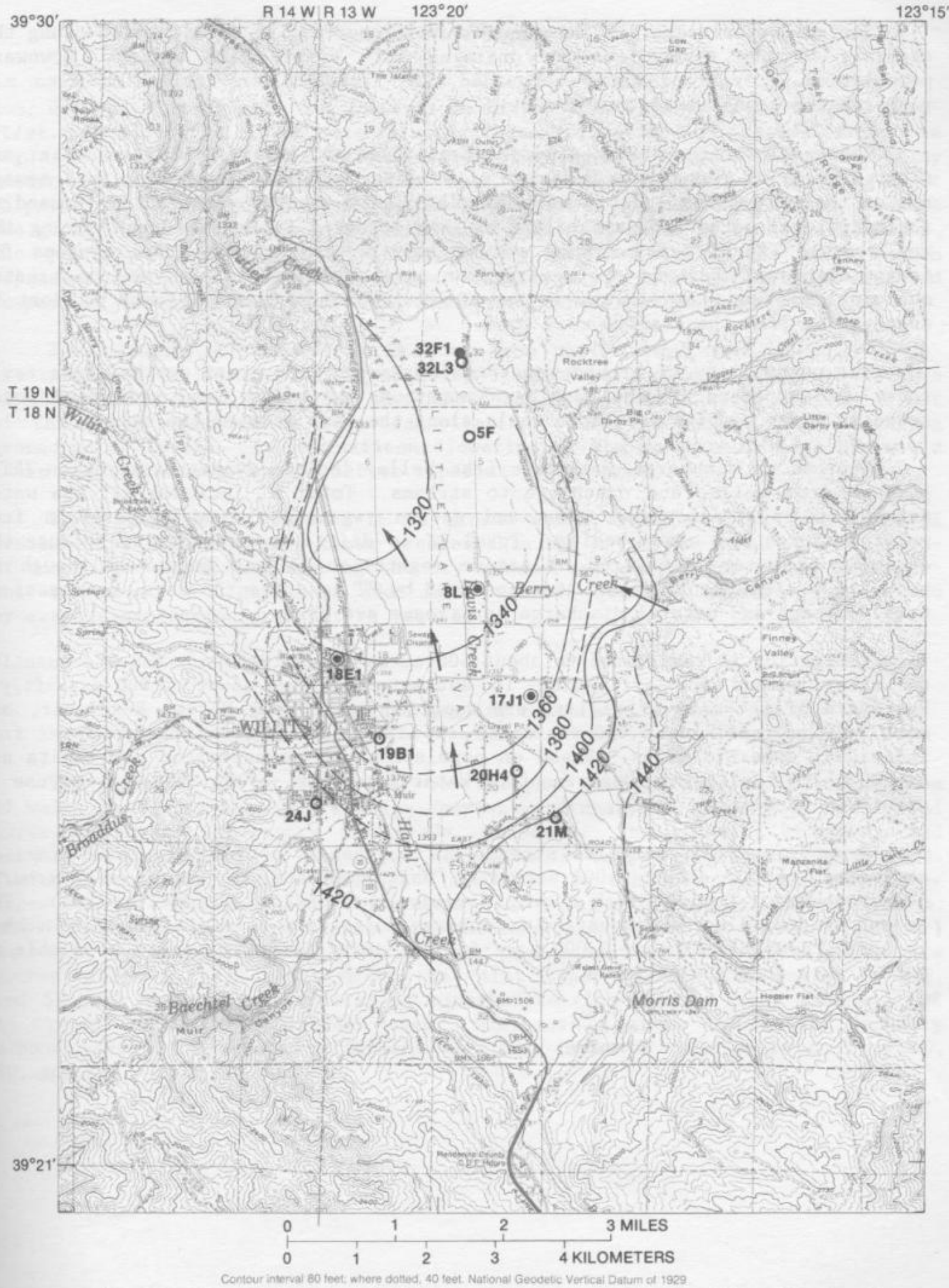


FIGURE 12. – Water-level contours in Little Lake Valley, September-October 1981, and location of wells for proposed ground-water-level monitoring network.

Surface water recharges the ground-water reservoir by infiltration along the channels of the several creeks draining into Little Lake Valley. Downward percolation of surface water impounded for livestock or irrigation also may recharge the ground-water reservoir.

Return flows from sewage-disposal facilities and excess irrigation water are minor sources of recharge. The city of Willits is served by a municipal sewage system that processes about 1 million gal/d. The treated waste water is used to irrigate local parks and pastureland or is discharged to Outlet Creek during the wet season. Rural areas of the valley rely on individual septic systems for sewage disposal. Part of the sewage from rural systems and part of the treated municipal sewage recharge the ground-water reservoir; part of each is lost by evaporation from the shallow soil zone.

The possibility of ground water moving upward from great depths along fault zones is supported by the high concentrations of sodium, chloride, and boron noted in water samples from some wells along the east side of the valley.

Sources of discharge in Little Lake Valley include evapotranspiration (ET), pumpage from wells, and discharge to streams. Total ET includes all the water transpired by plants (both crops and native vegetation) and evaporation from moist surfaces and water bodies. Total ET is difficult to quantify because the quantity of water transpired by native vegetation is not known. Although no estimate of the quantity of water consumed by ET is presented here, estimates of total pumpage and natural discharge to streams are given.

Irrigation is restricted to about 500 acres of pastureland, and the quantity of water pumped for irrigation is estimated to be about 1,000 acre-ft/yr. Residents of the city of Willits are supplied water from Morris Reservoir, and most of the remaining 4,000 residents in Little Lake Valley obtain water from individual domestic wells. Based on population and an estimated per capita use of 200 gal/d (California Department of Water Resources, 1983), total urban use is about 900 acre-ft/yr.

Ground-water discharge to streams during the dry period, May to October, is estimated to be about 2,000 acre-ft. This estimate is based on discharge measurements of Outlet Creek during periods of baseflow (Cardwell, 1965). The amount of ground water discharged to streams during the rainfall season, November to April, probably exceeds 2,000 acre-ft, but insufficient data are available to make a more accurate estimate.

Available Supply

Ground-water pumpage for all uses in Little Lake Valley is about 2,000 acre-ft/yr. An additional 2,000 acre-ft contributes to baseflow of streams during the dry season. The quantity of ground water discharged to streams during the rainy season is not known. During years when winter precipitation exceeds about 75 percent of normal, the ground-water reservoir is filled to capacity. Because the ground-water reservoir is refilled most years (as shown by water-level data), the quantity of ground water discharged as baseflow during the rainy season represents rejected potential recharge. This rejected recharge could be captured in part by lowering ground-water levels through increased pumpage.

The quantity of ground water lost from native vegetation through evapotranspiration is unknown. This quantity is probably quite significant because of the shallow water table and the considerable vegetation along streams. Part of the water consumed by evapotranspiration could be conserved by lowering ground-water levels. Any significant lowering of the water table probably would cause adverse effects on the native riparian vegetation.

The estimated 45,000 acre-ft of ground water available from Type I and II availability areas is many times greater than the estimated total of 4,000 acre-ft discharged to streams during the dry season and pumped for urban and agricultural uses. A significant additional unknown quantity of water is consumed by evapotranspiration from native vegetation.

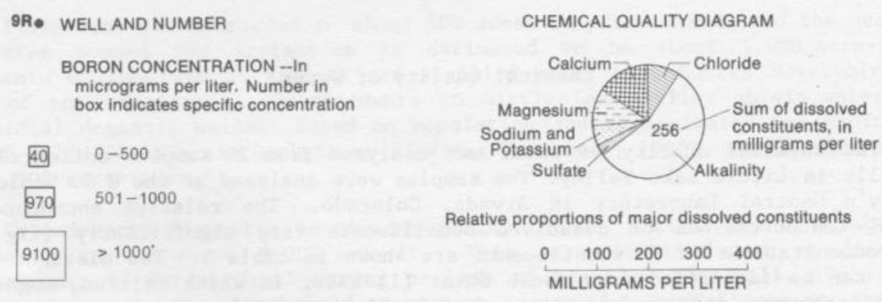
Chemical Quality of Water

The chemical quality of water was analyzed from 20 samples collected from 17 wells in Little Lake Valley. The samples were analyzed at the U.S. Geological Survey's Central Laboratory in Arvada, Colorado. The relative abundance and actual concentrations of dissolved constituents vary significantly (fig. 13). The concentrations of 23 constituents are shown in table 4. Two distinct water types can be identified from these data: (1) Water in which calcium, magnesium, and bicarbonate are predominant and chloride and sodium are minor, and (2) water in which sodium and chloride are predominant and the dissolved-solids concentration is high relative to the first type. Water from wells 7A, 31P, and 5F, for example, is typical of bicarbonate-rich water. Water from well 9E is typical of sodium chloride water. Mixtures of these two waters probably account for intermediate variations observed in water from wells such as 9D, 9R, and 31G.

The chemical quality of the bicarbonate water is generally acceptable for domestic, agricultural, or industrial uses. The dissolved solids in this water range from less than 100 to about 350 mg/L. Concentrations of iron and manganese generally exceed the secondary maximum contaminant levels for drinking water (U.S. Environmental Protection Agency, 1977). However, this standard was set on the basis of consideration of taste and cosmetic factors (staining of laundry and plumbing fixtures); the standard is not based on detrimental health effects. None of the other constituents tested exceed the U.S. Environmental Protection Agency (EPA) standards.

The chemical quality of the sodium chloride water may be unacceptable for some uses. A gas exploration hole in sec. 21 produced water with a sodium chloride concentration of 1,064 mg/L from a depth zone of 930 to 986 feet. Well 18N/13W-9E, located in the northeast part of the valley and drilled to a depth of 128 feet, produced water with sodium and chloride concentrations of 510 and 770 mg/L, respectively, which is greater than three times the chloride concentration permissible under EPA standards. This sample also contained 1,710 mg/L dissolved solids. Mixtures of sodium chloride water and bicarbonate water result in water with intermediate concentrations of dissolved solids and chloride.

EXPLANATION FOR FIGURE 13



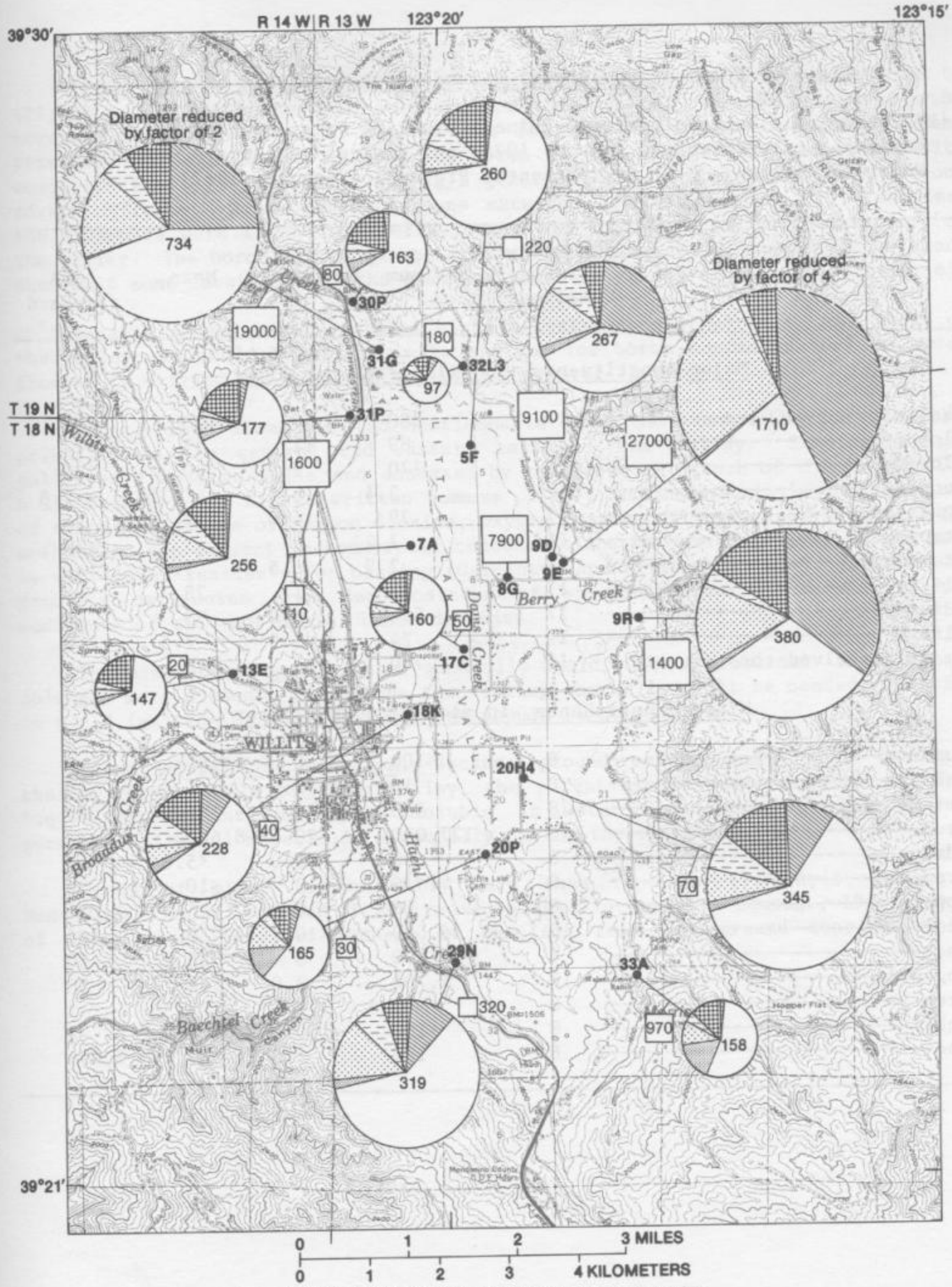


FIGURE 13. – Chemical quality of ground water, Little Lake Valley.

Table 4.-- Chemical quality of ground water in Little Lake Valley

[EPA standard: National Interim Primary Drinking Water Regulation, U.S. Environmental Protection Agency, 1975; and National Secondary Drinking Water Regulations, U.S. Environmental Protection Agency, 1977]

	Number of analyses	Maximum	Minimum	Mean	EPA standard
Major constituents, in milligrams per liter					
Alkalinity as $CaCO_3$	17	380	67	170	--
Calcium	17	89	11	37	--
Chloride	17	770	2.9	80	250
Fluoride	17	3.4	.1	.35	1.8
Magnesium	17	39	4.9	17	--
Nitrogen NO_2+NO_3 as N	17	7.2	0	.7	10
Potassium	17	2.9	.5	1.2	--
Silica	17	57	11	28	--
Sodium	17	510	6.0	58	--
Sulfate	17	24	5.0	7.5	250
Sum of dissolved constituents	16	1,710	97	340	--
Minor constituents, in micrograms per liter					
Aluminum	8	<100	<100	<100	--
Arsenic	8	16	1.0	4.1	50
Barium	8	500	40	185	1,000
Boron	20	127,000	20	8,600	--
Cadmium	8	<30	<1.0	<5.6	10
Chromium	8	<10	<10	<10	50
Copper	8	40	<10	<24	1,000
Iron	18	16,000	<10	<2,250	300
Lead	8	<100	0	<88	50
Manganese	17	1,700	3.0	528	50
Mercury	8	1.8	<.1	<.58	2
Nickel	8	<100	<100	<100	--
Zinc	8	150	5.0	37	5,000

Boron.--Boron was analyzed in 20 samples; concentrations ranged from 20 to 127,000 μg/L. EPA has set no standard for this element. Boron is known to be required by plants in small amounts but is toxic to plants at higher concentrations. The sensitivity of crops to boron varies considerably, but water with concentrations of less than 1,000 μg/L generally may be applied to crops without adverse effects. Boron concentrations exceeded 2,000 μg/L in 4 of 20 samples; the 4 samples were taken from wells located in the north and northeast parts of the valley. The boron may originate from water moving up from great depth along the fault zone located along the east and northeast sides of the valley (fig. 8).

Because ground water contains high concentrations of boron in some parts of the valley, it would be advisable to analyze for boron concentrations in water from newly drilled wells before applying the water to crops.

Gases.--Both flammable and nonflammable gases have been reported in wells, primarily in the central and eastern parts of the valley. Samples of gas collected from five wells and analyzed by the Research Branch of the Pacific Gas & Electric Co. (J. Kiely, written commun., 1979) indicate that the gas consists of varying mixtures of carbon dioxide, oxygen, argon, nitrogen, and methane. The methane is not present in commercial concentrations but has been used in the past by some local residents for heating (Carpenter and Millberry, 1914). The methane probably originates from decomposition of organic matter contained in the sediments of the continental basin deposits.

The presence of gas in water generally would pose no problems. If considerable gas were present, provisions for venting the wells might be needed. Caution to avoid ignition of the flammable gas should be considered.

Potential for contamination.--Because ground water generally is found at shallow depths in Little Lake Valley, the potential for contamination is high. Liquid contaminants or those soluble in water could pass quickly through permeable alluvial materials, especially during the rainy season.

Cases of minor contamination have been reported (J. Davis, Director, Mendocino County Division of Environmental Health, written commun., 1985). Most of these cases involved leakage of gasoline from underground storage tanks.