UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GROUND-WATER RECONNAISSANCE STUDY OF SELECTED SITES IN ROCKY MOUNTAIN NATIONAL PARK AND SHADOW MOUNTAIN NATIONAL RECREATION AREA

By
Frank A. Welder

OPEN-FILE REPORT
71001

WATER
RESOURCES
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Colorado District
Denver, Colorado
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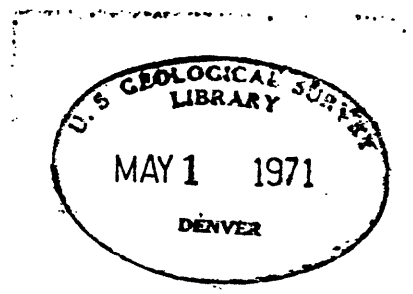

Prepared by the
U.S. Geological Survey
for the
National Park Service

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Ground-water reconnaissance study of selected sites in Rocky Mountain National Park and Shadow Mountain National Recreation Area

By FRANK A. WELDER

ABSTRACT

An evaluation of the ground-water supply potential at 30 sites within the Rocky Mountain National Park and Shadow Mountain National Recreation Area was made by the U.S. Geological Survey in 1967 and 1968. The work consisted of a geohydrologic reconnaissance, well inventory, and test drilling.

The study sites are underlain by Precambrian crystalline rocks, Tertiary sediments, or Quaternary glacial and alluvial deposits. The crystalline rocks are generally poor aquifers; however, some wells intercepting fractures may yield as much as 10 gallons per minute from wells 100 to 200 feet deep. Wells drilled in Tertiary sandstones to a depth of 50 to 500 feet may supply 1 to 50 gallons per minute. Wells drilled in unconsolidated glacial and alluvial deposits of Quaternary age yield the largest supplies of ground water in the Rocky Mountain National Park. These deposits commonly can supply 5 to 100 gallons per minute to wells.

INTRODUCTION

This report was prepared at the request of the National Park Service as part of a study of the water resources of Rocky Mountain National Park and Shadow Mountain National Recreation Area. The purpose of the study was to determine the prospects of obtaining ground-water supplies at 30 sites where new or expanded water supplies are needed. Most of the sites studied are campgrounds, picnic areas, sites for ranger stations, or living quarters for park personnel. Ground-water supplies are desired in preference to surface-water supplies at the sites because (1) ground-water supplies generally are easier to maintain and to protect from contamination, (2) ground-water supplies generally cost less because fewer structures (intakes, treatment facilities, and pipelines) are required, and (3) many of the sites are in use throughout the year and protection from freezing is required.

Field work for this study was done in 1967-68 and consisted of the following: a geologic and hydrologic reconnaissance to determine the general ground-water supply potential at each site; inventory of wells near each site; and test drilling to determine the character and saturated thickness of the underlying rocks. Twenty-nine test holes were drilled (a total footage of nearly 2,000 ft) using a truck-mounted power auger. The U.S. Geological Survey contracted for four test holes which were drilled by a cable tool drill. Observation wells consisting of 1¼-inch-diameter pipe and sand points were installed in 15 of the test holes so that water levels could be measured and water samples could be collected for chemical analysis.

This report also contains a summary of the prospects of obtaining ground-water supplies at six sites within the area which were studied previously.

Chemical analyses of water were made of samples obtained from two test wells in Moraine Park. No water-quality samples were obtained from the other sites; however, if a site is selected for a ground-water supply, a water sample should be analyzed to determine its chemical and biological character.

TOPOGRAPHY AND CLIMATE

The Rocky Mountain National Park and Shadow Mountain National Recreation Area, an area of 439 square miles, lie in north-central Colorado (fig. 1). The terrain ranges in altitude from 7,600 feet above sea level to 14,256 feet at the top of Longs Peak. There are about 84 peaks with altitudes above 11,000 feet. Areas of alpine tundra occur near the summits of the high mountains. At lower altitudes are stands of ponderosa and lodgepole pines, blue spruce, and narrow-leaf cottonwood. About two-thirds of the Park lies east of the Continental Divide.

At the town of Estes Park, located at the east entrance of the Rocky Mountain National Park (fig. 2), the average annual temperature is about 43°F and the average annual precipitation is about 16 inches. At the town of Grand Lake, located at the west entrance (fig. 2), the average annual temperature and precipitation are about 35°F and 19 inches, respectively. Annual precipitation at the higher altitudes within the Rocky Mountain National Park averages about 40 inches.

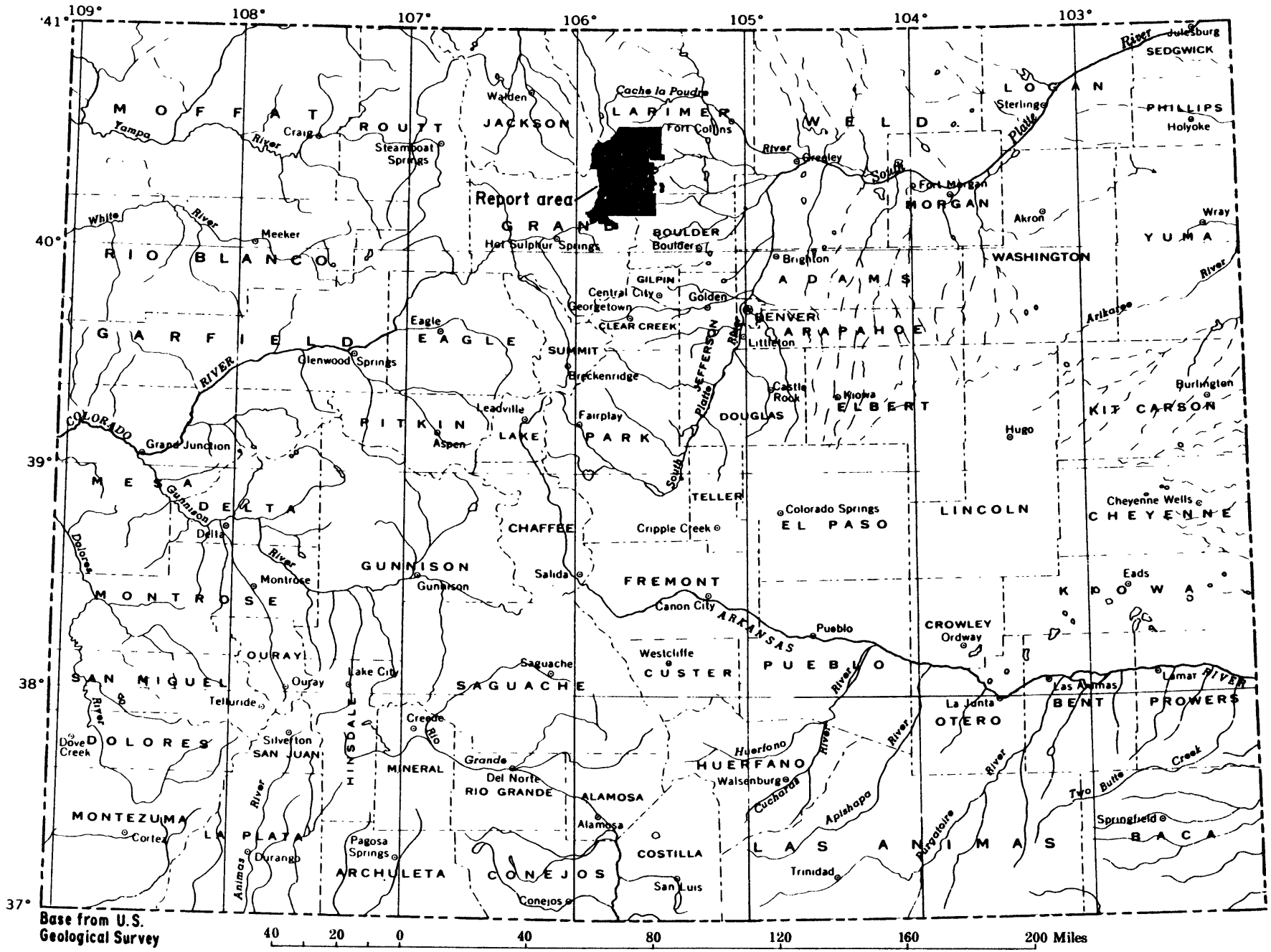


Figure 1.--Index map showing report area.

GEOHYDROLOGY

The sites in Rocky Mountain National Park and Shadow Mountain National Recreation Area are underlain by (1) Precambrian crystalline rocks, which may contain water in fractures; (2) Tertiary sediments, which may contain beds of water-bearing sandstone; or (3) Quaternary glacial and alluvial deposits, which may contain water in sand and gravel. The material underlying some of the sites could not be penetrated by the auger. It was not possible to auger at sites which are underlain by crystalline rocks and at some of the sites underlain by moraine material containing boulders.

About 95 percent of the area is underlain by Precambrian crystalline rocks (granite, gneiss, and schist). The crystalline rocks are relatively impermeable and are generally poor aquifers. Wells intercepting fractures and weathered zones in these rocks commonly yield 5 to 10 gpm (gallons per minute) from wells 100 to 200 feet deep. Greater yields may be possible in areas where several "fracture sets" intersect.

Areas along the south and west edges of Lake Granby and the west edge of Shadow Mountain Lake are underlain by as much as 500 feet of clay, silt, and sandstone of Tertiary age. These rocks are mainly lacustrine and alluvial in origin, and abrupt lateral changes in lithology are common. Wells tapping Tertiary deposits range from 50 to 500 feet in depth and yield 1 to 50 gpm.

The larger valleys in both Rocky Mountain National Park and Shadow Mountain National Recreation Area are underlain by glacier- and water-deposited rocks of Quaternary age. The deposits range from clay to boulders, and in general are poorly sorted. The deposits may be classified in two categories--moraines and outwash. The moraines generally form conspicuous ridges that border or terminate flat-lying meadows. Because the moraines generally contain large amounts of clay, they yield only small amounts of water to wells. The outwash deposits on the other hand, if thick enough, may supply large quantities of water.

The larger natural parks, such as Moraine and Horseshoe Parks, are underlain by glacial outwash and alluvial deposits consisting of sand and gravel. These deposits are the best aquifers in the Rocky Mountain National Park and should yield 100 gpm or more to wells. Alluvium, consisting of reworked glacial material, occurs in the valley of the North Fork Colorado River. Wells in these deposits, such as the one at Timber Creek Campground, might yield more than 100 gpm.

RESULTS OF SITE STUDIES

A summary of test drilling and an estimate of the potential for ground-water development at 20 sites are shown in table 1. Test hole augering was not possible at the remaining 10 sites because the sites were underlain by granite or large coarse boulders. A summary of the geohydrologic studies and an estimate of the potential for ground-water development at these 10 sites are given in table 2.

Table 1.--Summary of test drilling and estimate of ground-water potential at 20 sites (Rocky Mountain National Park and Shadow Mountain National Recreation Area)

Site	Test hole	Date drilled	Aquifer	Depth drilled (feet)	Depth to water below land surface (feet)	Thickness of saturated material (feet)	Thickness of saturated sand and gravel (feet)	Estimated yield (gallons per minute)	Remarks
Moraine Park----- (Site 1)	1	Oct. 1967	Alluvium and glacial deposits.	26	0.2	26	26	20	Observation well, screened from 13 to 15 feet. Drilling terminated because of dense sediments.
Do----------	2	---do-----	---do---------	75	2.7	72	59	200	Observation well, screened from 19 to 21 feet. Drilling terminated because aquifer was completely penetrated.
Do----------	3	---do-----	---do---------	97	2	95	55	200	Drilling terminated because aquifer was completely penetrated.
Do----------	4	---do-----	---do---------	97	2	95	59	200	Do.
Do----------	5	---do-----	---do---------	84	6	78	78	100	Drilling terminated because of cobbles.
Do----------	6	---do-----	---do---------	67	3.5	63	59	100	Observation well, screened from 18 to 20 feet. Drilling terminated because aquifer was completely penetrated.
Do----------	7	---do-----	---do---------	97	3.5	93	66	100	Do.
Do----------	8	---do-----	---do---------	87	2	85	57	100	Drilling terminated because aquifer was completely penetrated.
Do----------	9	---do-----	Glacial deposits.	15	6	9	9	1-5	Drilling terminated because of cobbles.

Table 1.--Summary of test drilling and estimate of ground-water potential at 20 sites (Rocky Mountain National Park and Shadow Mountain National Recreation Area)--Continued

Site	Test hole	Date drilled	Aquifer	Depth drilled (feet)	Depth to water below land surface (feet)	Thickness of saturated material (feet)	Thickness of saturated sand and gravel (feet)	Estimated yield (gallons per minute)	Remarks
Moraine Park----- (Site 1)	10	Sept. 1968	Alluvium and glacial deposits.	62	3.3	59	50	100	Observation well, screened from 9 to 11 feet. Drilling terminated because aquifer was completely penetrated.
Do----------	11	---do------	---do---------	55	3.6	51	48	100	Do.
Do----------	12	---do------	---do---------	47	3.4	44	41	100	Do.
Do----------	13	---do------	---do---------	67	3.1	64	64	100	Observation well, screened from 8.5 to 10.5 feet. Drilling terminated because of cobbles.
Beaver Meadows--- (Site 2)	14	July 1967	Alluvium and glacial deposits.	41	18.0	23	7	5-30	Observation well, screened from 19 to 21 feet. Drilled by cable tool. Granite at 39 feet. Drilling terminated because aquifer was completely penetrated.
Do----------	15	---do------	---do---------	43	12	31	22	5-30	Drilled by cable tool. Granite at 43 feet. Drilling terminated because aquifer was completely penetrated.
Buck Creek------- (Site 3)	16	Oct. 1967	None----------	15	----	0	0	0	Hole dry. Drilling terminated because of granite at 15 feet.
Mill Creek------- (Site 5)	17	Oct. 1968	Alluvium and glacial deposits.	44	9.4	35	35	10-50	Observation well, screened from 19 to 21 feet. Drilling terminated because of cobbles.
Glacier Basin Campground ---- (Site 6)	18	July 1967	---do---------	66	31.2	35	35	50	Observation well, screened from 40 to 42 feet. Drilled by cable tool. Drilling terminated because of cobbles.

Table 1.--Summary of test drilling and estimate of ground-water potential at 20 sites (Rocky Mountain National Park and Shadow Mountain National Recreation Area)--Continued

Site	Test hole	Date drilled	Aquifer	Depth drilled (feet)	Depth to water below land surface (feet)	Thickness of saturated material (feet)	Thickness of saturated sand and gravel (feet)	Estimated yield (gallons per minute)	Remarks
Glacier Basin Picnic Area--- (Site 7)	19	Oct. 1967	Alluvium and glacial deposits.	49	10	39	34	10-50	Drilling terminated because of dense clay.
Wild Basin, Deer Haven Lodge--- (Site 10)	20	July 1967	---do--------	38	21	17	17	25	Drilled by cable tool. Drilling terminated because of boulders.
Twin Owls-------- (Site 12)	21	Oct. 1968	Alluvium-----	38	7.9	30	27	2-15	Observation well, screened from 29 to 31 feet. Drilling terminated because of cobbles.
Horseshoe Park--- (Site 13)	22	Sept. 1968	Alluvium and glacial deposits.	67	5.5	61	51	100	Observation well, screened from 20 to 22 feet. Drilling terminated because aquifer was completely penetrated.
Endovalley Campground----- (Site 14)	23	Oct. 1968	---do---------	27	6.4	21	21	10	Observation well, screened from 13.5 to 15.5 feet. Drilling terminated because of cobbles.
East Inlet Trailhead------ (Site 18)	24	---do-----	---do---------	39	24	15	10	2	Drilling terminated because of cobbles.
Hilltop Ranger Station-------- (Site 19)	25	---do-----	---do---------	30	2	28	17	10	Drilling terminated because of dense clay.
Pine Beach Picnic Area--- (Site 20)	26	---do-----	---do---------	36	6	30	9	2	Do.
Recreation Area Headquarters -- (Site 21)	27	---do-----	None----------	18	1	17	0	0	Do.

Table 1.--Summary of test drilling and estimate of ground-water potential at 20 sites (Rocky Mountain National Park and Shadow Mountain National Recreation Area)--Continued

Site	Test hole	Date drilled	Aquifer	Depth drilled (feet)	Depth to water below land surface (feet)	Thickness of saturated material (feet)	Thickness of saturated sand and gravel (feet)	Estimated yield (gallons per minute)	Remarks
Granby Entrance--(Site 23)	28	Oct. 1968	None----------	36	28	8	0	0	Drilling terminated because of dense clay.
Sunset Point-----(Site 24)	29	---do-----	---do---------	16	7	9	0	0	Do.
Kamloop Cove-----(Site 25)	30	---do-----	---do---------	9	---	0	0	0	Drilling terminated because of granite at 9 feet.
Big Rock Campground-----(Site 27)	31	---do-----	Alluvium and glacial deposits.	36	9	27	12	5	Drilling terminated because of dense clay.
Moraine Campground-----(Site 28)	32	---do-----	---do---------	101	5	96	21	5	Do.
Roaring Fork Ranger Station--(Site 29)	33	---do-----	---do---------	24	11.6	12	12	5	Observation well, screened from 13 to 15 feet. Drilling terminated because of coarse gravel.

Table 2.--Summary of geohydrologic studies and estimate of ground-water potential at 10 sites (Rocky Mountain National Park and Shadow Mountain National Recreation Area)

Site	Date Studied	Potential aquifer	Estimated yield (gallons per minute)	Remarks
Tuxedo Park (Site 4)	1968	Granite	1-5	A well 100 to 200 feet deep intercepting fractures may supply estimated yield.
Bear Lake (Site 8)	--do--	Glacial deposits	5-10	A well 50 feet deep penetrating sand and gravel should supply estimated yield.
Longs Peak Ranger Station (Site 9)	--do--	Granite	5	Granite at surface fractured. A well 100 to 200 feet deep intercepting fractures may supply estimated yield. Present supply is Alpine Brook.
Wild Basin Ranger Station (Site 11)	--do--	Glacial deposits	1-5	A well 50 feet deep penetrating sand and gravel should supply estimated yield.
Rock Cabin Ranger Station (Site 15)	1967	Granite	1-5	A well 100 to 200 feet deep intercepting fractures may supply estimated yield. Springs 1/2 mile northwest of site yield 20 gpm.
Milner Pass Road Camp (Site 16)	--do--	Granite and glacial deposits	1-5	A well 100 to 200 feet deep intercepting fractures may supply estimated yield.

Table 2.--Summary of geohydrologic studies and estimate of ground-water potential at 10 sites (Rocky Mountain National Park and Shadow Mountain National Recreation Area)--Continued

Site	Date Studied	Potential aquifer	Estimated yield (gallons per minute)	Remarks
Phantom Valley Campground (Site 17)	1968	Alluvium	5	A well 50 feet deep penetrating sand and gravel should supply estimated yield.
Cutthroat Trout Bay Campground and Picnic Area (Site 22)	--do--	Glacial deposits and Tertiary sandstone	5-10	Site underlain by glacial material containing large boulders (see Coffin, 1962).
Inspiration Point (Site 26)	--do--	Granite	1-5	A well 100 to 200 feet deep intercepting fractures may supply estimated yield.
Harvey Island (Site 30)	--do--	Glacial deposits	5	A well 50 feet deep penetrating sand and gravel should supply estimated yield.

In addition, a detailed evaluation of the ground-water potential is given for Moraine Park, Beaver Meadows, Mill Creek, Twin Owls, and Horseshoe Park.

The locations of the 30 sites (1-30) included in this study and the six (31-36) sites studied previously are shown on figure 2. More detailed maps of the sites, showing the locations of test holes and observation wells are given in figures 3 through 16.

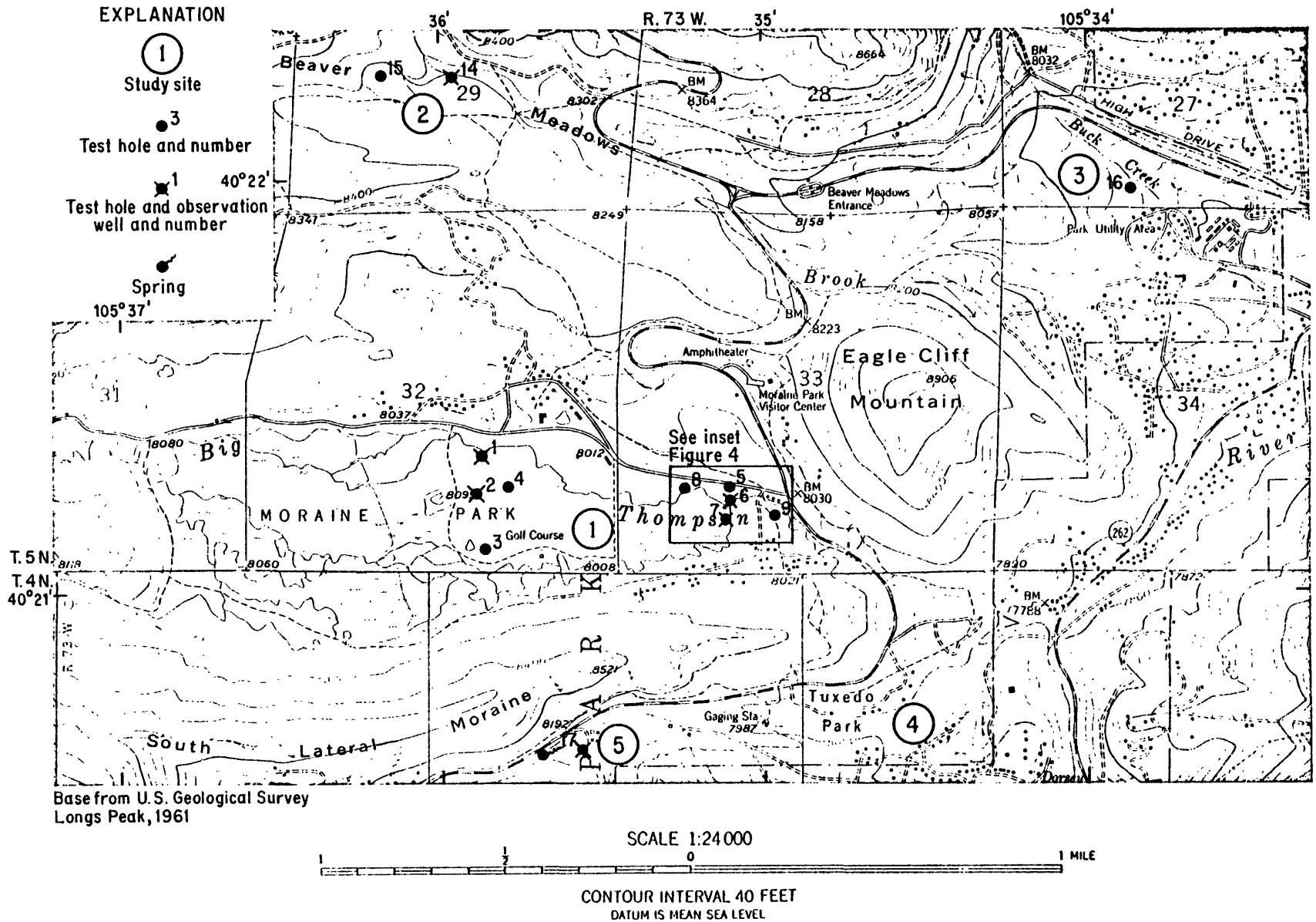


Figure 3.--Location of Moraine Park (Site 1), Beaver Meadows (Site 2), Buck Creek (Site 3), Tuxedo Park (Site 4), and Mill Creek (Site 5) study sites.

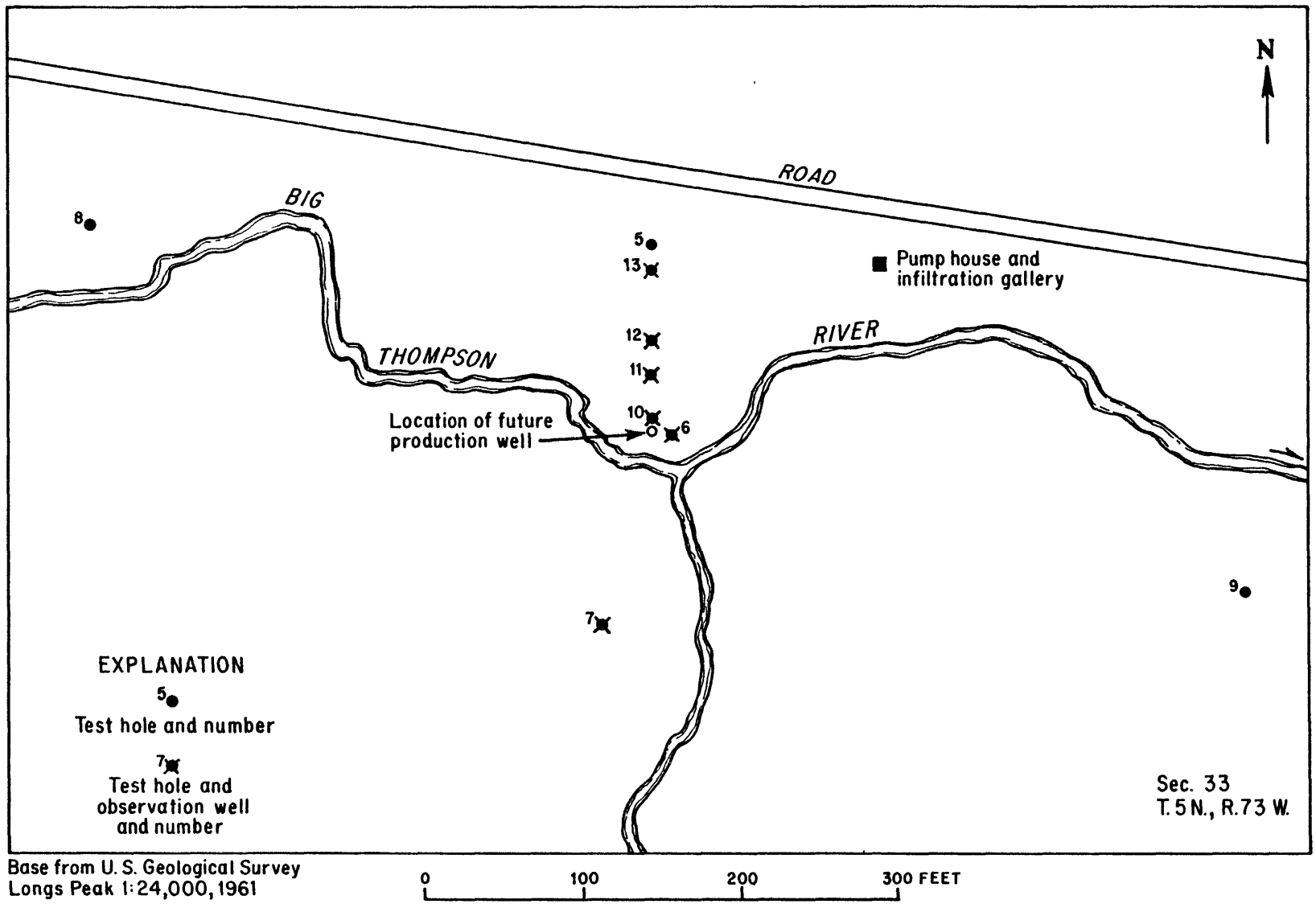


Figure 4. --Detailed map of Moraine Park (Site 1) showing proposed location of production well for Headquarters Area.

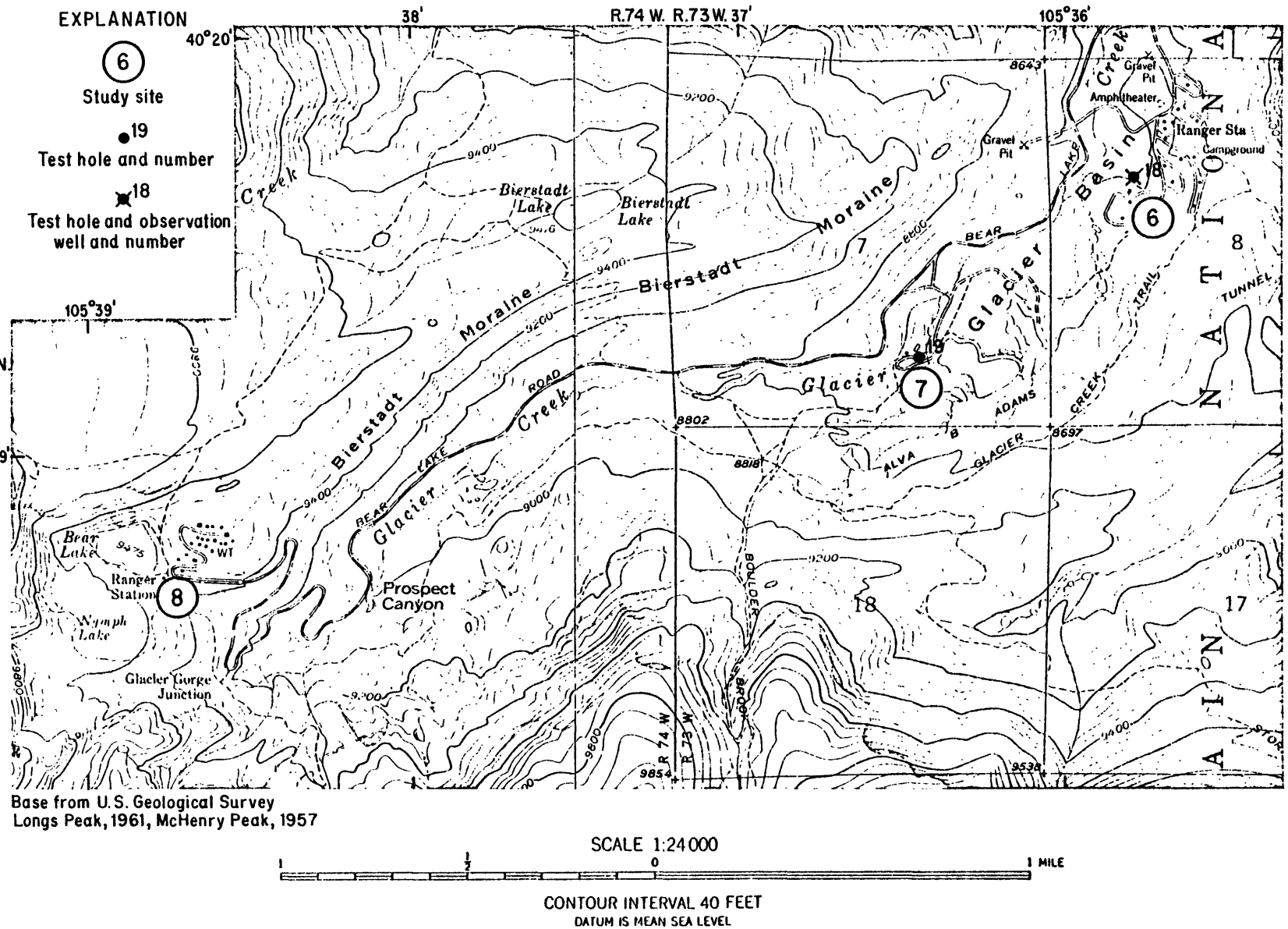


Figure 5.--Location of Glacier Basin Campground (Site 6), Glacier Basin Picnic Area (Site 7), and Bear Lake (Site 8) study sites.

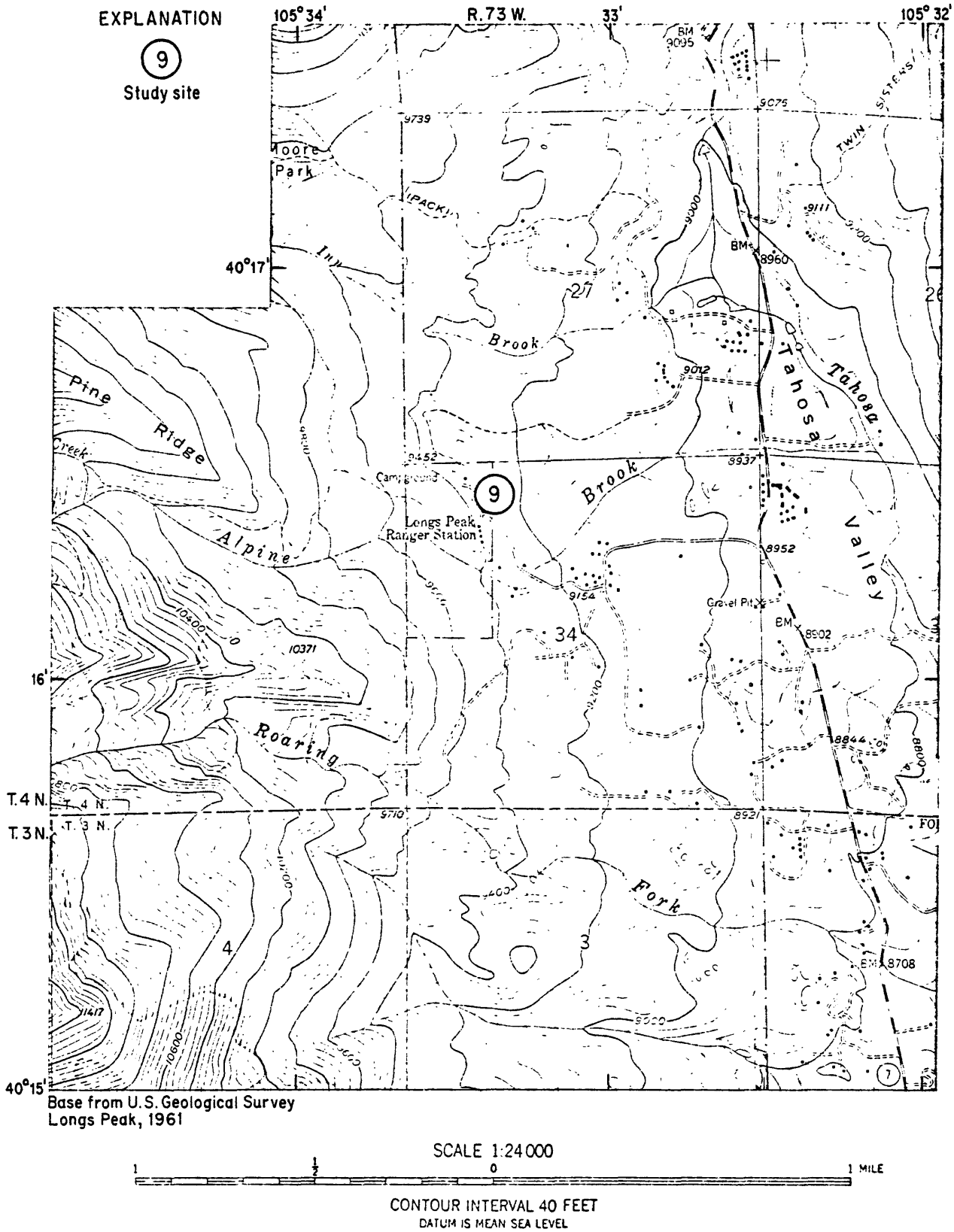


Figure 6.--Location of Longs Peak Ranger Station (Site 9) study site.

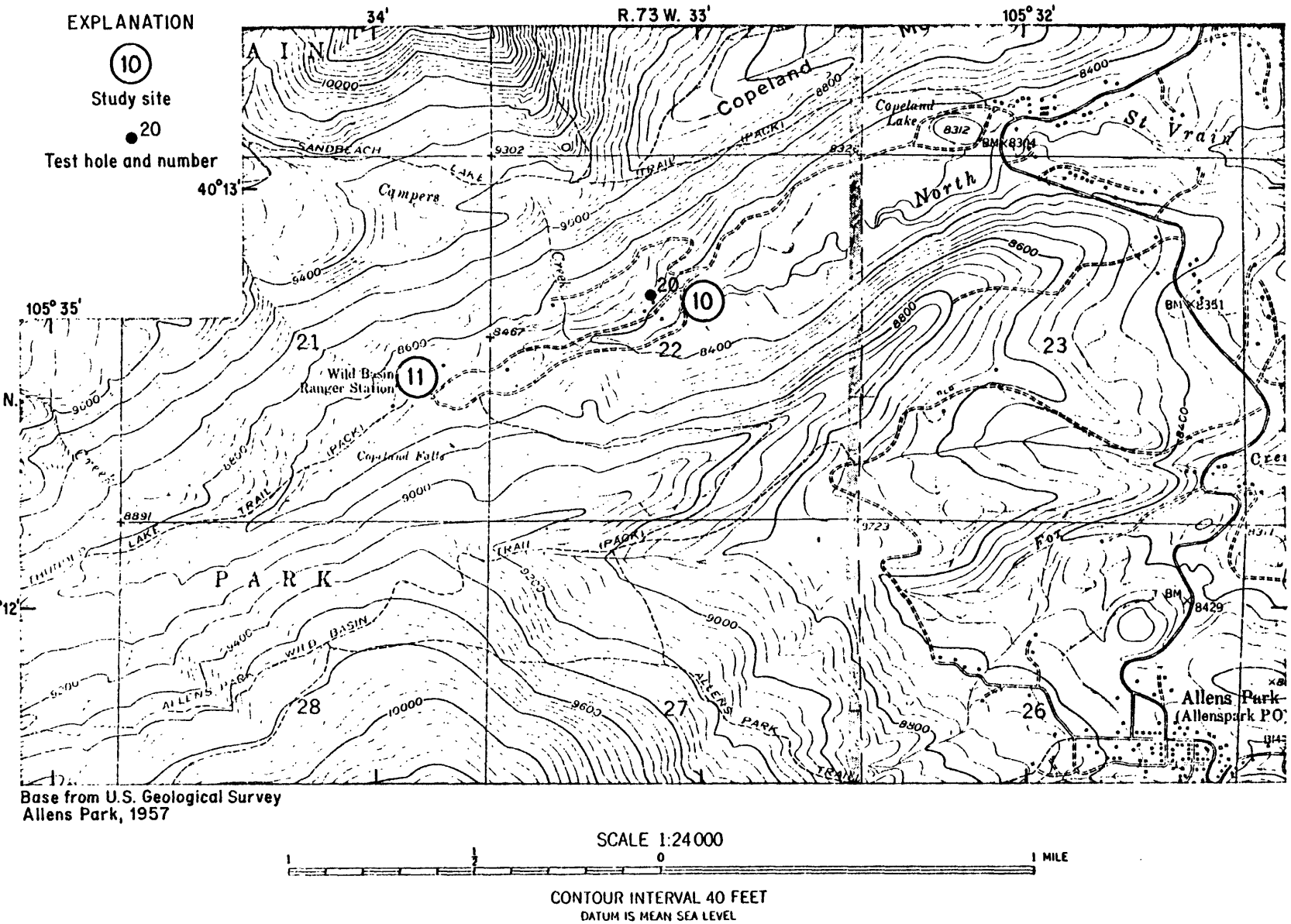


Figure 7.--Location of Deer Haven Lodge (Site 10) and Wild Basin Ranger Station (Site 11) study sites.

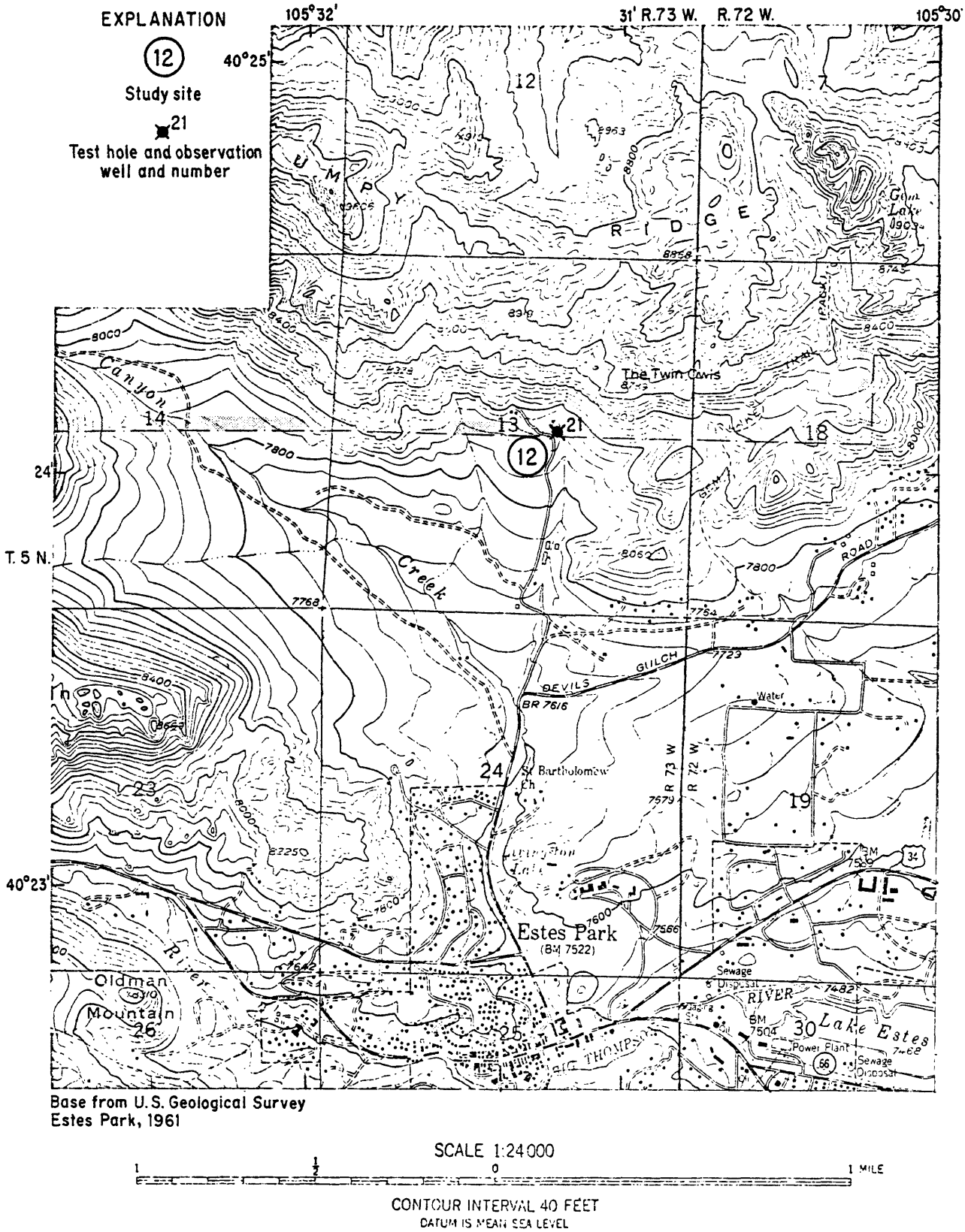


Figure 8.--Location of Twin Owls (Site 12) study site.

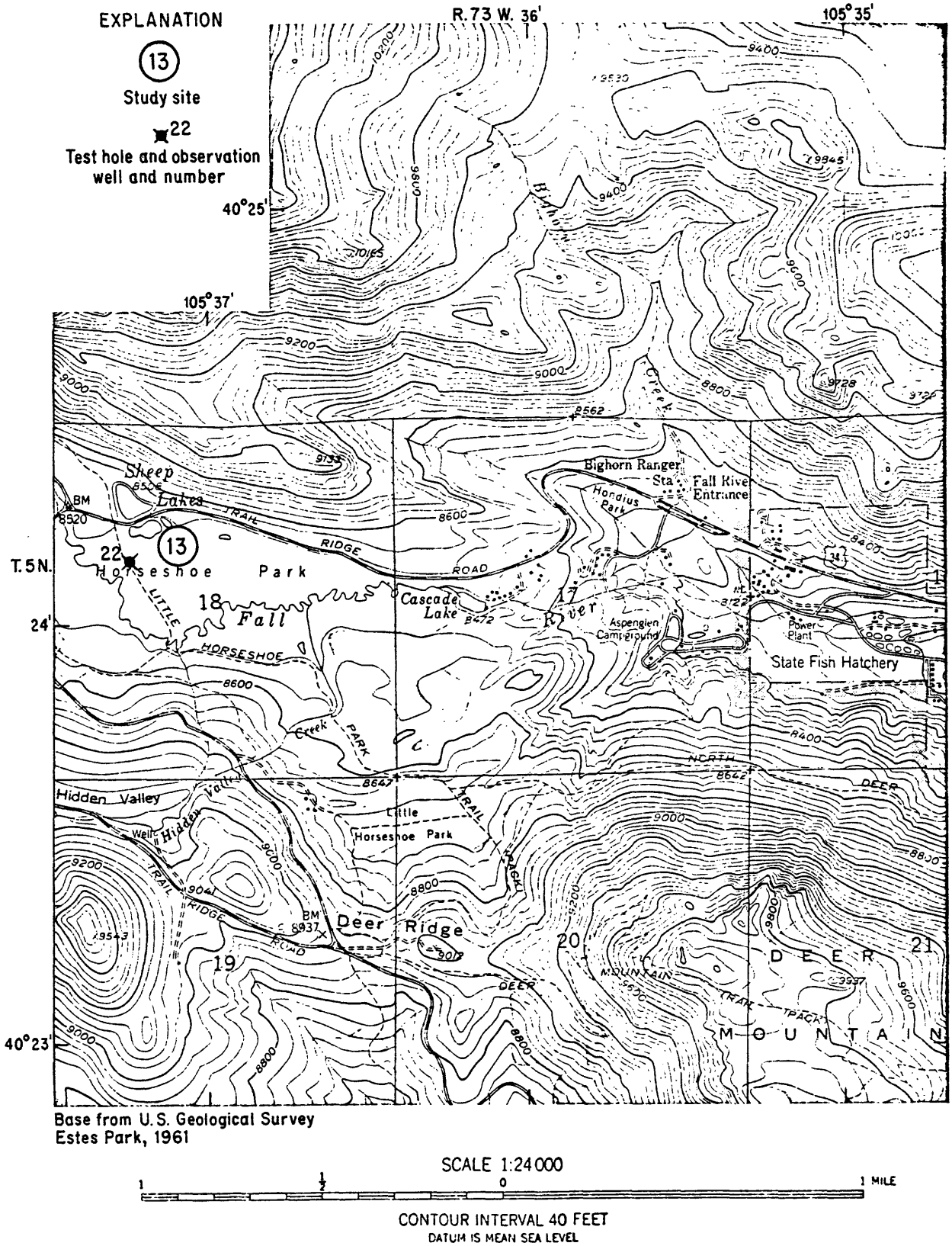


Figure 9.--Location of Horseshoe Park (Site 13) study site.

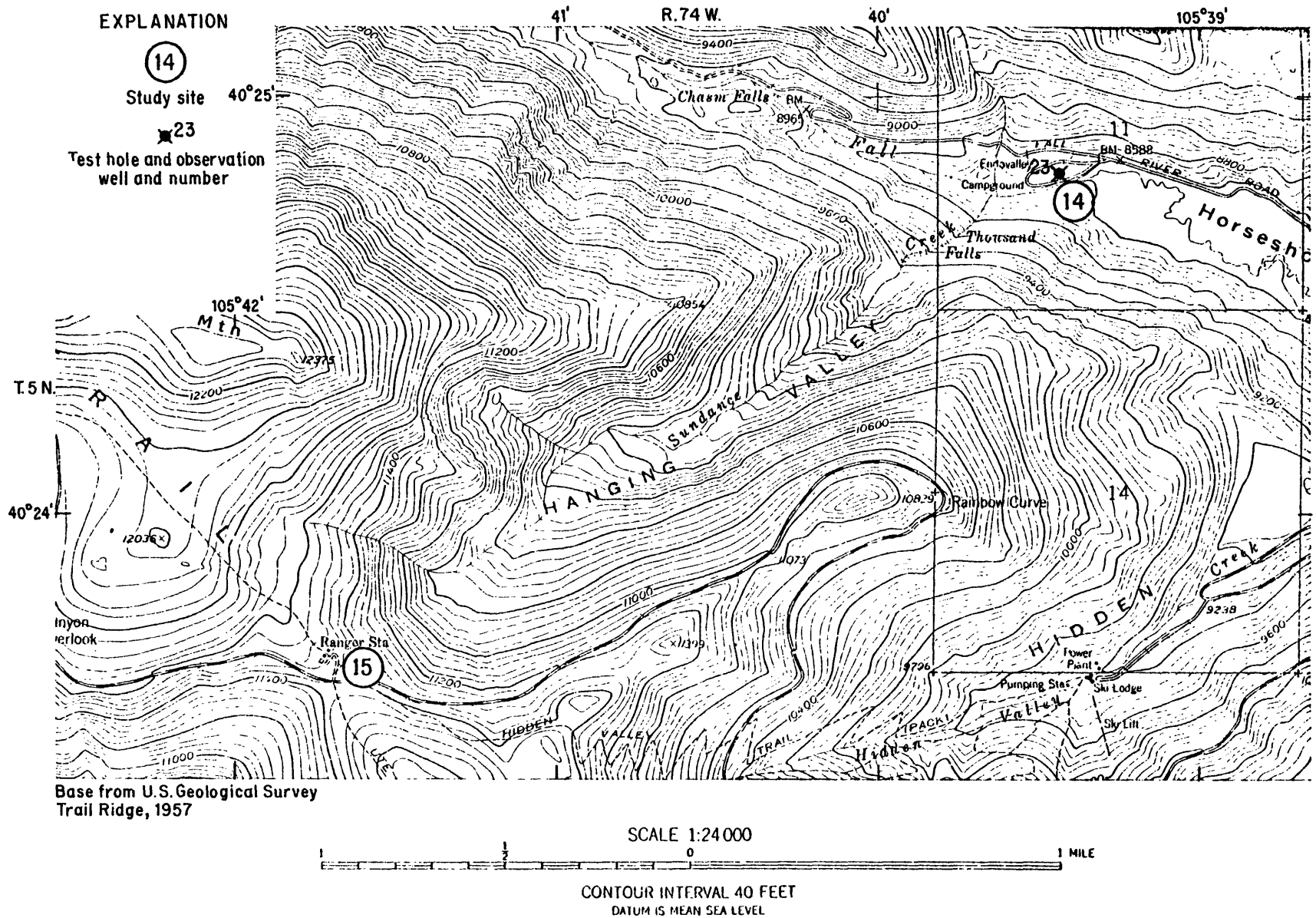


Figure 10.--Location of Endovalley Campground (Site 14) and Rock Cabin Ranger Station (Site 15) study sites.

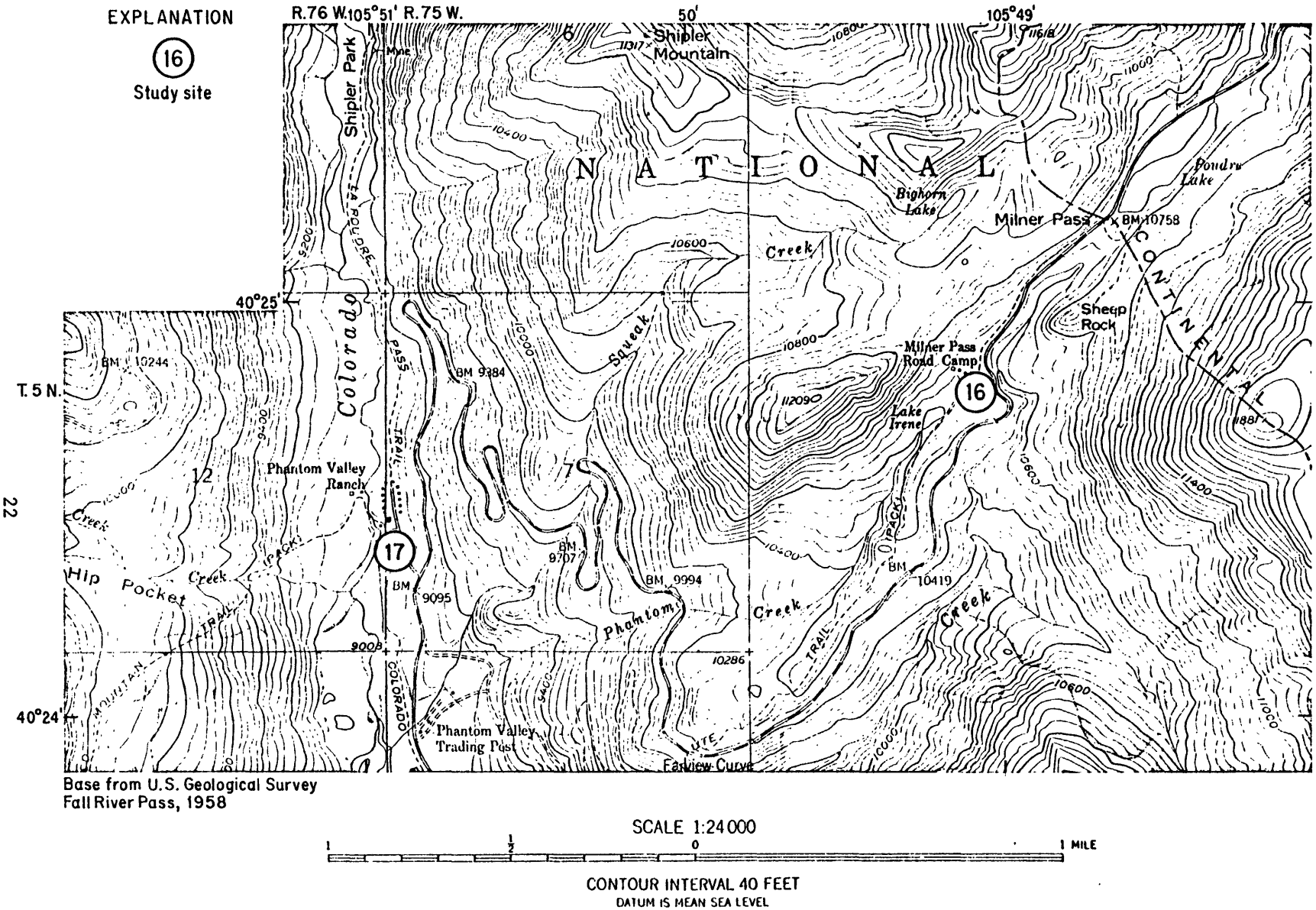


Figure 11.--Location of Milner Pass Road Camp (Site 16) and Phantom Valley Campground (Site 17) study sites.

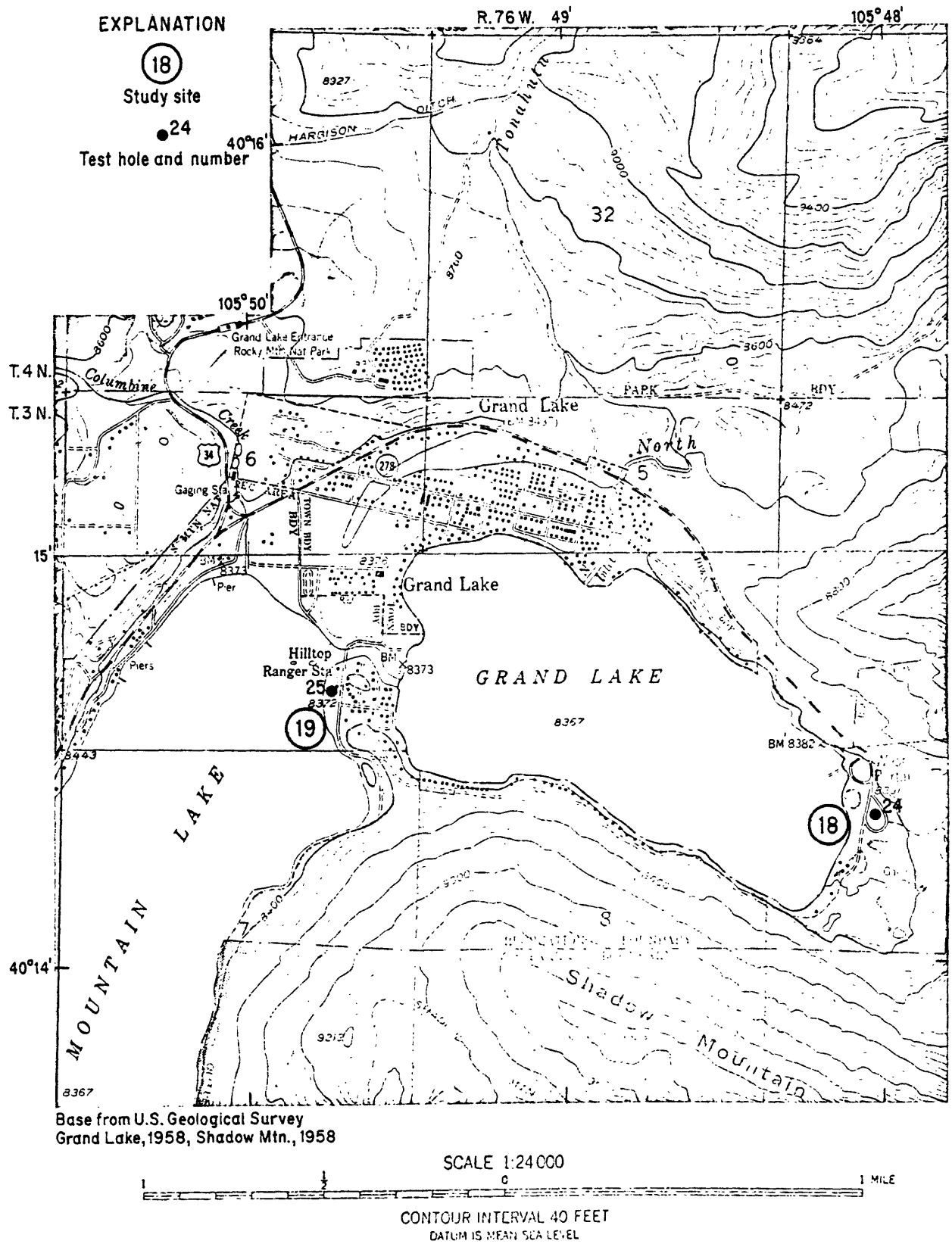


Figure 12.--Location of East Inlet Trailhead (Site 18) and Hilltop Ranger Station (Site 19) study sites.

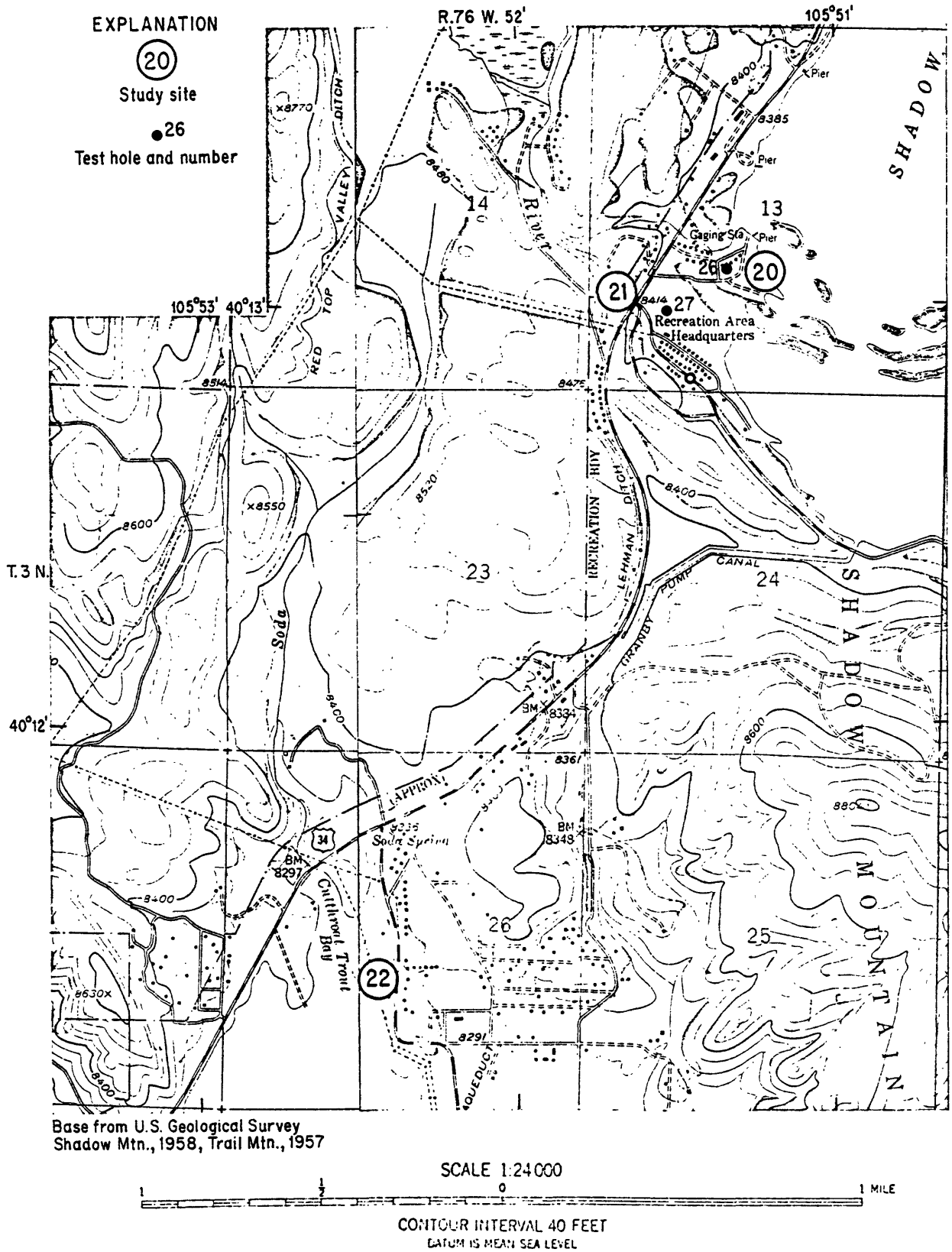
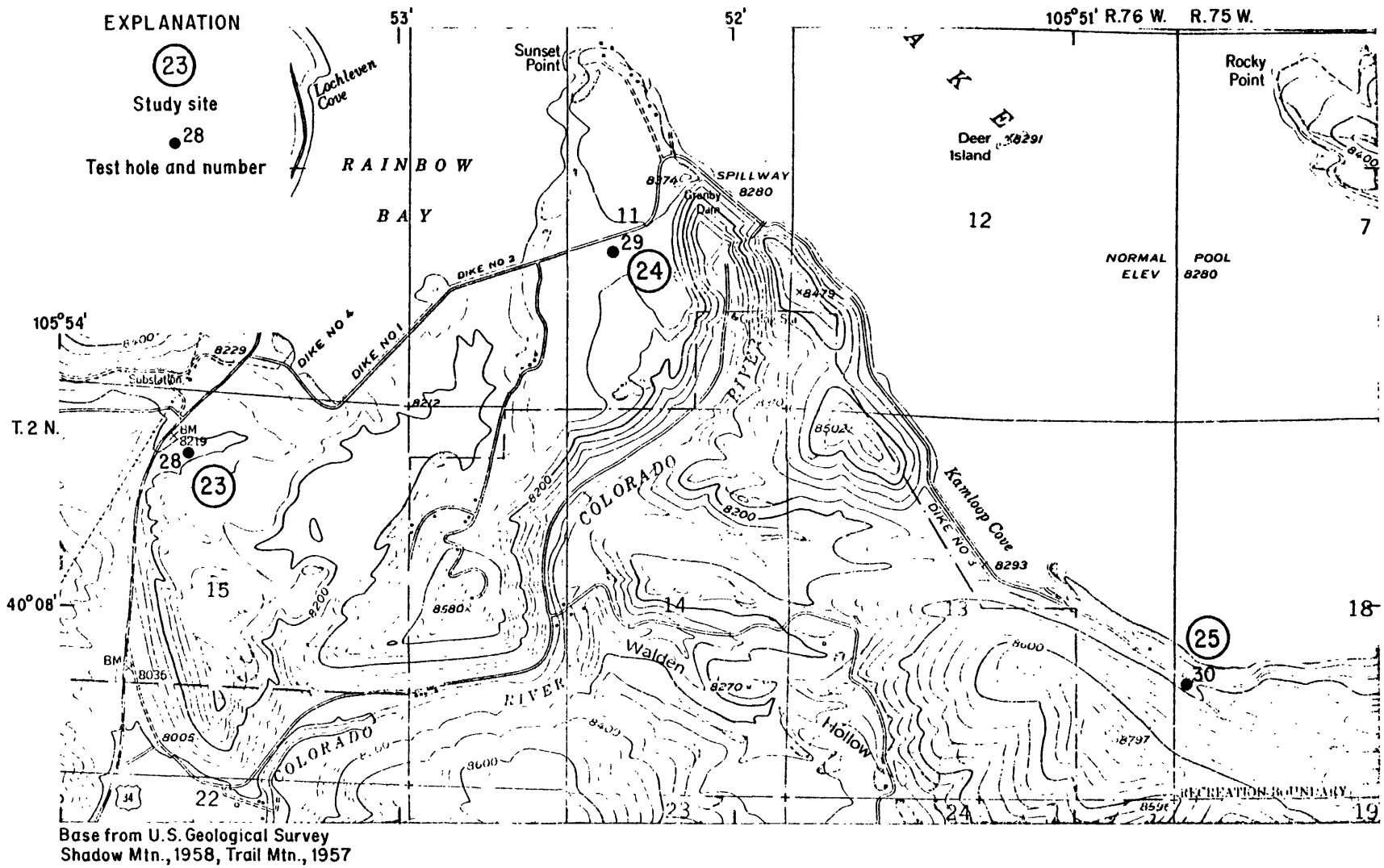


Figure 13.--Location of Pine Beach Picnic Area (Site 20), Recreation Area Headquarters (Site 21), and Cutthroat Trout Bay Campground and Picnic Area (Site 22) study sites.



Base from U.S. Geological Survey
Shadow Mtn., 1958, Trail Mtn., 1957

SCALE 1:24000

1 0 1 MILE

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

Figure 14.--Location of Granby Entrance (Site 23), Sunset Point (Site 24), and Kamloop Cove (Site 25) study sites.

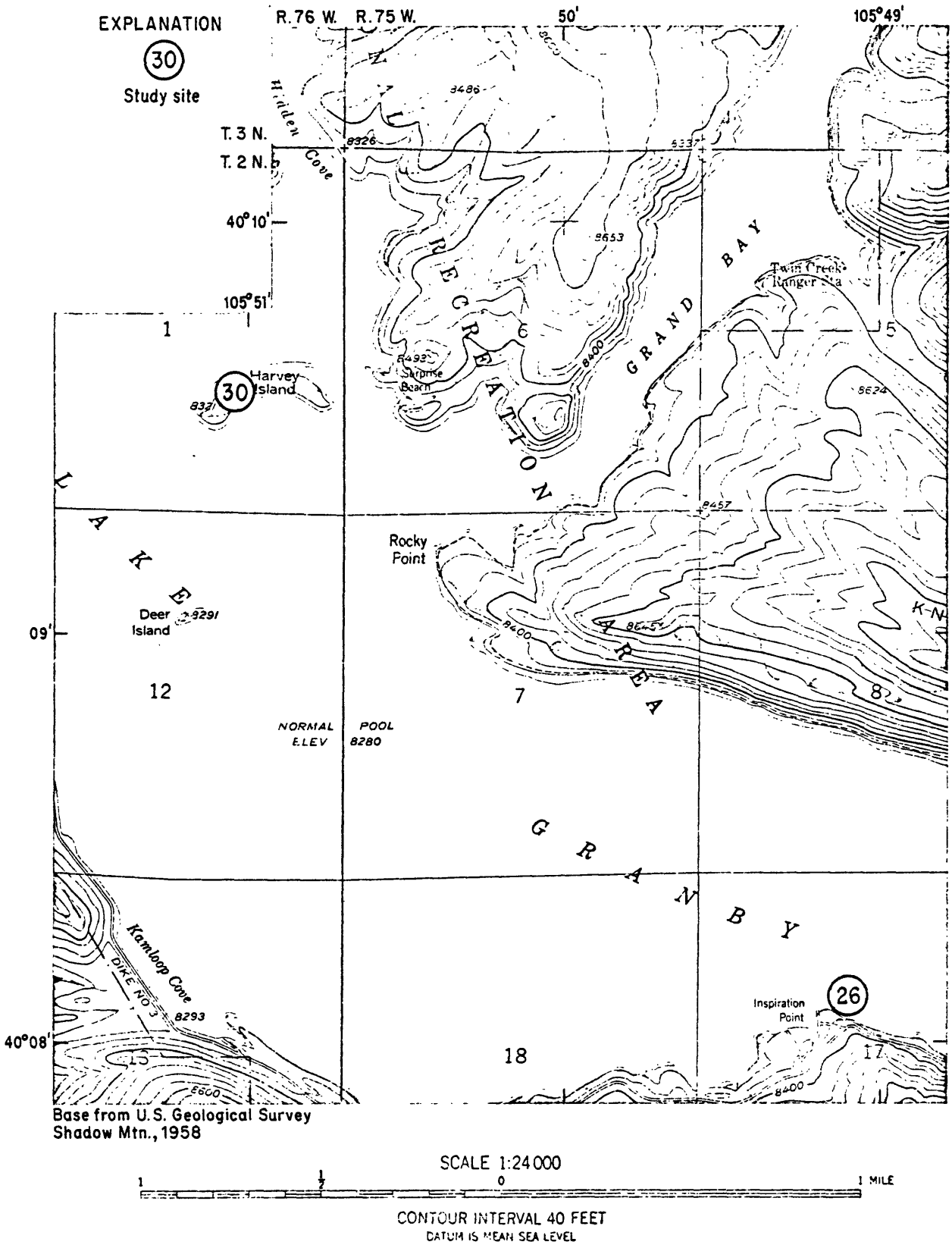


Figure 15.--Location of Inspiration Point (Site 26) and Harvey Island (Site 30) study sites.

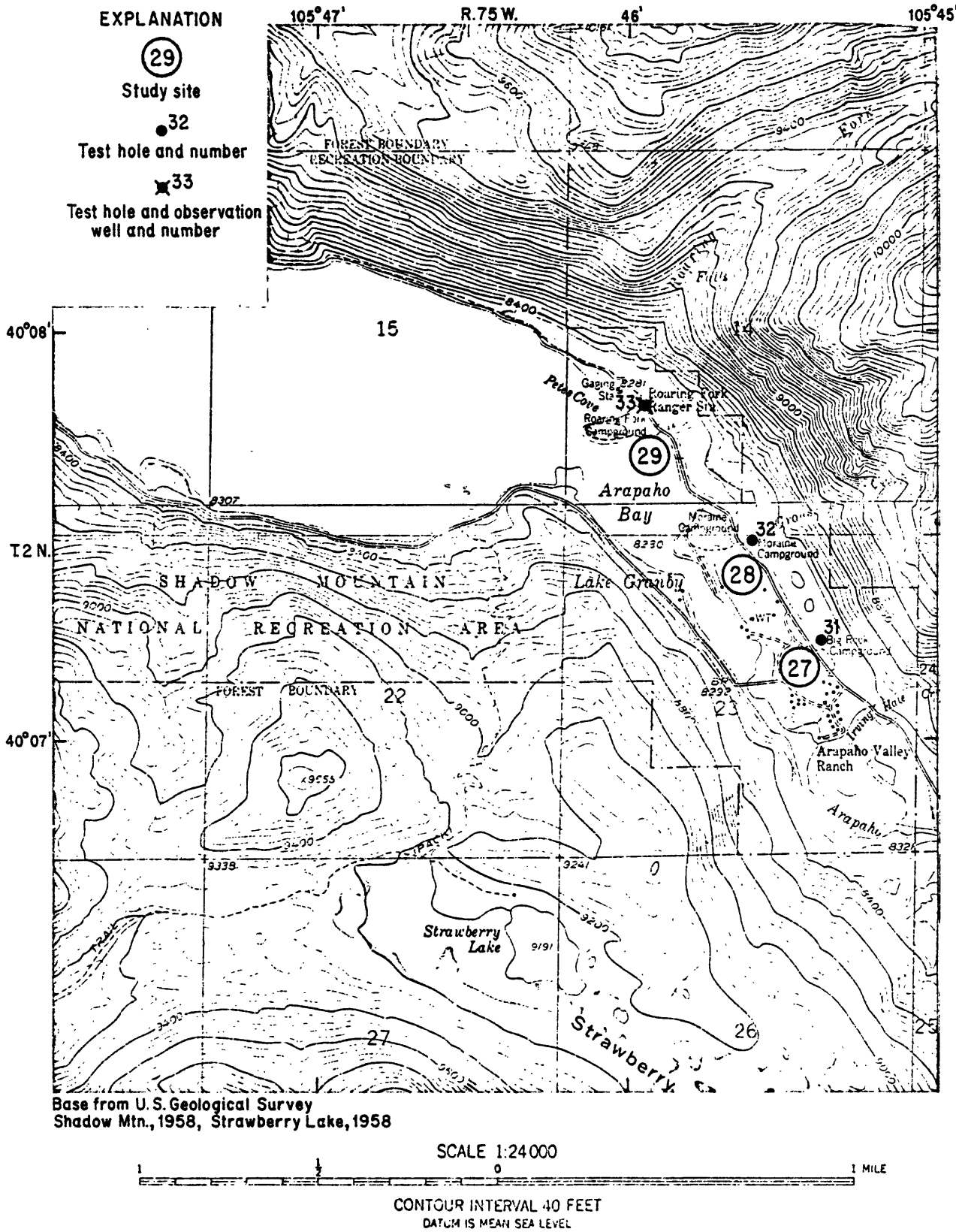


Figure 16. --Location of Big Rock Campground (Site 27), Moraine Campground (Site 28), and Roaring Fork Ranger Station (Site 29) study sites.

RESULTS OF DETAILED SITE STUDIES

Moraine Park (Site 1)

A substantial water supply for the Park Headquarters area could be obtained from wells tapping the alluvial and glacial deposits in Moraine Park. Wells drilled in these deposits would yield more than 100 gpm in many places.

Thirteen test holes were augered in Moraine Park to determine the thickness and water-bearing potential of the glacial outwash and alluvium in two areas. Nine test holes were augered near the pumphouse and four were augered about three-fourths of a mile west of the pumphouse (figs. 3, 4). The test holes drilled in October 1967 and September 1968 indicate sand, gravel, and clay with saturated thickness ranging from 9 to 95 feet. The greatest saturated thickness was near the center of the flood plain of the Big Thompson River. The holes near the east end of Moraine Park showed a much higher proportion of clay than those three-fourths of a mile to the west. Test holes 6 and 7 penetrated thick sand and gravel deposits and a production well at either test hole should yield at least 100 gpm.

Four test holes (10, 11, 12, 13) were drilled and observation pipes installed between test hole 6 and test hole 5 (fig. 4) in September 1968 to determine the suitability of the site and to provide observation wells for a future aquifer test. The additional test drilling confirmed that the site is suitable for construction of a production well.

The present water supply for the Rocky Mountain National Park Headquarters area is taken from the river at the east end of Moraine Park. The intake, an infiltration gallery located 20 feet south of the pumphouse, tends to clog frequently with very fine sediment. A production well near test hole 6, which is near the pumphouse and pipeline, should provide an adequate substitute for the present intake.

Two factors should be considered when preparing construction plans for a well in Moraine Park. The well pump should be installed high enough above ground level to prevent inundation by floods of the Big Thompson River. The upper 20 feet of the well should be cased and cemented to prevent the entry of very fine sediment into the well and to minimize chemical corrosion.

A water sample from test hole 10, which is screened in the upper part of the aquifer (9-11 feet), had a pH of 6.0 and water from this aquifer would be corrosive (table 3). The low pH is caused by humic acids from a marsh in this area. A water sample from test hole 6, which is screened in the lower part of the aquifer (18-20 feet), had a near-neutral pH of 7.3 (see table 3).

Chemical analyses of water from test holes 6 and 10 indicate that otherwise the water is of excellent quality and that the content of dissolved solids, sulfate, chloride, fluoride, and nitrate are well within the recommended limits set forth by the U.S. Public Health Service (1962). The results of these analyses and a comparison with Public Health standards are given in table 3.

Table 3.--Chemical analyses of water from test holes 6 and 10, Moraine Park

[Results in milligrams per liter. Analyses by U.S. Geol. Survey, ND: Concentration limits have not been established. Location: Test hole 6, SB5-73-33CDB2; Test hole 10, SB5-73-33CDB4. Date of collection: May 6, 1969.]

Constituent	Test hole 6 [1/]	Test hole 10 [2/]	Public Health Service drinking-water standards
Silica (SiO_2)	13	14	ND
Iron (Fe)	-----	-----	0.3
Manganese (Mn)	-----	-----	.05
Calcium (Ca)	9.1	8.4	ND
Magnesium (Mg)	4.0	3.6	ND
Sodium (Na)	6.2	4.0	ND
Potassium (K)	1.4	1.9	ND
Bicarbonate (HCO_3)	55	13	ND
Carbonate (CO_3)	0	0	ND
Sulfate (SO_4)	5.0	36	250
Chloride (Cl)	4.2	2.0	250
Fluoride (F)	0.7	0.3	3/
Nitrate (NO_3)	0.4	0.7	45
Phosphate (PO_4)	0.01	0.01	ND
Boron (B)	0.05	0.00	ND
Dissolved solids:			
Residue on evaporation at 180°C	67	86	500
Calculated	71	77	500
Hardness as $CaCO_3$:			
Total	39	36	ND
Non-carbonate	0	25	ND
Sodium-adsorption-ratio	0.4	0.3	ND
Specific conductance (micromhos per cm at 25°C)	97	93	ND
pH	7.3	6.0	ND

1/ Test hole 6, well screened 18 to 20 feet.
2/ Test hole 10, well screened 9 to 11 feet.
3/ Recommended control limits for fluoride concentration are based on the annual average of maximum daily air temperatures. For an annual average maximum daily air temperature from 53.8°F to 58.3°F, fluoride concentrations in milligrams per liter are: lower limit is 0.8, the optimum 1.1, and the upper 1.5.

Beaver Meadows (Site 2)

Test drilling indicated that wells in Beaver Meadows probably would yield 5 to 30 gpm. Beaver Meadows is a long, narrow valley (about 0.2 mile wide by 1.5 miles long) lying between parallel lateral moraines. Two test holes (fig. 3), drilled by the cable-tool method in July 1967, indicate that the meadow is underlain by about 40 feet of poorly sorted sand, gravel, and clay. The saturated thickness of the deposits is 31 feet, but the poor sorting and the high content of clay in the aquifer results in low permeability and thus in modest well yields.

Mill Creek (Site 5)

A well drilled in the valley of Mill Creek probably would yield from 10 to 50 gpm. The creek valley is about 200 feet wide. A test hole augered in October 1968 showed that the creek valley is underlain by at least 35 feet of saturated sand and gravel.

An observation well for water-level measurements was installed in the test hole. The well is screened from 19 to 21 feet and could be pumped for a temporary water supply until a production well is drilled.

A well located near Mill Creek might be damaged by flooding; therefore, a spring located about 1,400 feet southwest of the park residences should be considered as a potential source of water. The flow of the spring, measured in September 1967 and April, July, August, and September 1968, was 100 gpm or more.

Twin Owls (Site 12)

A well drilled at the Twin Owls site probably would yield 2 to 15 gpm. The site (fig. 8) is on an alluvial fan near the northern margin of the valley of Black Canyon Creek. Test drilling in October 1968 indicated that the site is underlain by at least 27 feet of saturated sand and gravel. The test hole was drilled to 38 feet but did not penetrate bedrock. The depth to water was 8 feet below land surface. An observation well installed in the test hole is screened from 29 to 31 feet and could be pumped for a temporary water supply until a production well is drilled. The present supply is from two springs which yield about 0.3 gpm.

Horseshoe Park (Site 13)

An excellent supply of ground water can be developed in Horseshoe Park (fig. 9). Test drilling in September 1968 indicated that a well drilled in Horseshoe Park probably would yield at least 100 gpm.

Horseshoe Park is a valley about 3 miles long and, at the test-drilling site, about half a mile wide. The valley is bounded on the north and south by prominent lateral moraines. The test hole shows that the site is underlain by silt, sand, gravel, and cobbles to a depth of 57 feet, and by silty clay from 57 to 67 feet. The depth to water was 5 feet below land surface.

RESULTS OF PREVIOUS SITE STUDIES

Studies of the possibilities of obtaining water supplies at seven sites within Rocky Mountain National Park and Shadow Mountain National Recreation Area were made by the Geological Survey prior to the studies made for this report. Results of these studies were released as administrative reports to the National Park Service in 1962, 1963, and 1966. Previous work on Cutthroat Trout Bay Campground and Picnic Area (Site 22) is summarized in table 2. A discussion of the other six sites follows.

Table Mountain (Site 31)

A study was made by D. L. Coffin (written commun., 1962) of the potential for developing a ground-water supply for domestic use at a ranger station near the base of Table Mountain (fig. 2). Geologic and hydrologic information contained in the report show that the site is underlain by 10 to 30 feet of unconsolidated sand, gravel, clay, and boulders, and as much as 350 feet of sandy clay, siltstone, and sandstone of Tertiary age. Several wells near the site obtain water of good quality from the Tertiary deposits at depths between 180 and 350 feet. A well 400 feet deep probably would supply enough water for the station.

Water could be pumped to the site from Lake Granby but because of the large water-level fluctuations of the lake, expensive intake facilities would be required, and the water would require treatment.

Harbison Meadow (Site 32)

A study of the Harbison Meadow site was made by D. L. Coffin (written commun., 1961). A well for the park administrative facilities near the south end of Harbison Meadow (fig. 2) was drilled in June 1961. The well was drilled to a depth of 75 feet (cased to 71 feet) through unconsolidated terrace deposits and glacial till consisting of sand, gravel, silt, clay, cobbles, and boulders. Test pumping indicates that the sustained yield at the well is 30 gpm and that the well will yield as much as 70 gpm during infrequent periods of maximum demand. At the higher rate, some sand may be pumped with the water; therefore, provision should be made to prevent suspended sediment from entering the distribution system.

Harbison Meadow Campground (Site 33)

The results of drilling and testing of a well to supply the proposed West Side, or Harbison Meadow Campground (fig. 2) is given in a report by Voegeli (1963b). The well which was drilled in 1962 penetrated 91 feet of terrace deposits and glacial(?) material consisting primarily of sand and gravel and the water level was 32 feet below land surface. Test pumping indicates that the well will yield 50 gpm for extended periods, and probably will yield 100 gpm during short, infrequent periods of maximum demand. At the higher yield some sand may be pumped with the water, requiring occasional cleaning of the well.

Timber Creek Campground (Site 34)

The results of drilling and testing a well to supply Timber Creek Campground (fig. 2) are presented in a report by P. A. Schneider, Jr. (written commun., 1966). The well was drilled in July 1966 approximately 100 feet north of the campground amphitheater. It penetrated 77 feet of unconsolidated terrace deposits consisting primarily of sand and gravel. Test pumping showed that the well would supply as much as 100 gpm for the campground. A pumping rate of 30 to 50 gpm would minimize the possibility of pumping appreciable quantities of sand with the water.

Fall River Entrance (Site 35)

The results of drilling and testing a well to supply additional water for the Bighorn Ranger Station and Aspenglen Campground near the Fall River Entrance (fig. 2) are presented in a report by Coffin and Jenkins (1966). The well, drilled in June 1965, penetrated 68 feet of glacial till consisting of clay, silt, sand, gravel, and boulders, and 35 feet of Precambrian crystalline rocks. Test pumping indicates that the well has a sustained yield of 30 gpm. The well may require occasional cleaning of sand and silt accumulated inside the casing.

Moraine Park Campground (Site 36)

The results of drilling and testing a well for the Moraine Park Campground (fig. 2) are presented in a report by Voegeli (1963a). The well penetrated 28.5 feet of glacial deposits consisting primarily of sand and gravel and 241.5 feet of granite underlying the glacial deposits. Pumping of the well indicated that the sustained yield is 2 to 2.5 gpm.

Other sources of water are the Big Thompson River, springs located in the NE¼SE¼ sec. 32, T. 5 N., R. 73 W., or the proposed well for the Park Headquarters Area discussed earlier in this report under the heading Moraine Park (Site 1). Obtaining water from any of these sources, however, would require laying from 2,000 to 7,000 feet of pipeline.

SELECTED REFERENCES

Coffin, D. L., 1966, Prospects for obtaining a water supply in the Fall River entrance area of Rocky Mountain National Park, Colorado, November 1964, and Addendum, October 1965, by E. D. Jenkins: U.S. Geol. Survey open-file report, 32 p.

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U.S. Public Health Service, 1962, Drinking water standards: U.S. Public Health Service Pub. 956, 61 p.

Voegeli, P. T., Sr., 1963a, Prospects for obtaining a water supply at the Moraine Park Campground site, Rocky Mountain National Park, Colorado: U.S. Geol. Survey open-file report, 16 p.

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LOGS OF TEST HOLES AND OBSERVATION WELLS
DRILLED BY THE U.S. GEOLOGICAL SURVEY (1967, 1968)

[Test hole location shown on figures 2 through 16. The well and test hole numbers are based on the U.S. Bureau of Land Management System]

	Thickness (feet)	Depth below land surface (feet)
SB5-73-32DBA		
Moraine Park (Site 1)		
Test hole 1 - Observation well		
Alluvium and glacial deposits:		
Clay, sandy, organic, black (water level at 0.2 feet)	1	1
Sand, coarse, and brown clay	7	8
Gravel, medium to coarse, rounded; contains coarse sand	5	13
Clay and fine sand	5	18
Sand, medium to coarse; contains medium to coarse gravel	7	25
Sand, fine to medium, clayey	1	26
SB5-73-32DCB		
Moraine Park (Site 1)		
Test hole 2 - Observation well		
Alluvium and glacial deposits:		
Sand, fine to coarse, and organic clay; contains gravel (water level at 2.7 feet)	3	3
Gravel, fine to coarse, and fine to coarse sand	3	6
Sand, fine; contains gravel	16	22
Gravel, fine to coarse; contains fine to coarse sand	30	52
Sand, fine to coarse; contains fine gravel	9	61
Gravel, fine to coarse; contains fine to coarse sand	1	62
Clay, black	13	75

	Thickness (feet)	Depth below land surface (feet)
SB5-73-32DCD		
Moraine Park (Site 1)		
Test hole 3		
Alluvium and glacial deposits:		
Silt, organic, black	1	1
Gravel, fine to coarse; contains fine to coarse sand and clay (water level estimated at 2 feet)	6	7
Gravel, medium to coarse	5	12
Gravel, fine to coarse, and fine to coarse sand	35	47
Sand, fine to very coarse; contains fine gravel	10	57
Clay, black	40	97
SB5-73-32DCA		
Moraine Park (Site 1)		
Test hole 4		
Alluvium and glacial deposits:		
Silt, organic, black (water level estimated at 2 feet)	3	3
Gravel, coarse	7	10
Gravel, fine to medium, and medium to coarse sand	22	32
Gravel, fine to medium, and fine to coarse sand	10	42
Sand, medium to coarse; contains some fine gravel	20	62
Clay, black	35	97
SB5-73-33CDB		
Moraine Park (Site 1)		
Test hole 5		
Alluvium and glacial deposits:		
Silt, organic, black	3	3
Sand, medium to coarse; contains clay	2	5
Gravel, medium to coarse; contains medium to coarse sand, clay, and boulders (water level estimated at 6 feet)	5	10
Sand, medium to coarse, clayey	12	22
Sand, fine to coarse, and clay	45	67
Sand, fine to coarse; contains cobbles and clay	17	84

	Thickness (feet)	Depth below land surface (feet)
SB5-73-33CDB2		
Moraine Park (Site 1)		
Test Hole 6 - Observation well		
Alluvium and glacial deposits:		
Silt, organic, black	3	3
Gravel, fine to coarse, and fine to coarse sand; contains clay (water level at 3.5 feet)	14	17
Gravel, fine to medium; contains fine to coarse sand	25	42
Gravel, fine to medium; contains fine to coarse sand and black clay	21	63
Clay, black	4	67
SB5-73-33CDB3		
Moraine Park (Site 1)		
Test Hole 7 - Observation well		
Alluvium and glacial deposits:		
Silt, organic, black	3	3
Sand, coarse, and medium to coarse gravel; contains cobbles (water level at 3.5 feet)	2	5
Gravel, medium to coarse	17	22
Sand, fine to coarse, and fine gravel	25	47
Sand, fine to medium	10	57
Sand, fine to medium; contains lenses of clay	5	62
Sand, fine to medium; contains coarse gravel	8	70
Clay, black	27	97
SB5-73-33CCA		
Moraine Park (Site 1)		
Test Hole 8		
Alluvium and glacial deposits:		
Silt, organic, black (water level estimated at 2 feet)	2	2
Clay, sandy, brown	1	3
Gravel, medium to coarse; contains clay and sand	7	10
Clay (no returns)	17	27
Sand (no returns)	50	77
Clay (no returns)	10	87

	Thick-ness (feet)	Depth below land surfac (feet)
SB5-73-33CDA		
Moraine Park (Site 1)		
Test Hole 9		
Glacial deposits:		
Silt; contains gravel	2	2
Gravel, fine to coarse; contains clay, sand, and cobbles (water level estimated at 6 feet)	13	15
SB5-73-33CDB4		
Moraine Park (Site 1)		
Test Hole 10 - Observation well		
Alluvium and glacial deposits:		
Sand, fine to coarse, and fine to coarse gravel	2	2
Sand, fine to coarse, and fine to coarse gravel; contains cobbles (water level at 3.3 feet)	33	35
Sand, fine to coarse, and fine to coarse gravel	18	53
Clay (no returns)	9	62
SB5-73-33CDB5		
Moraine Park (Site 1)		
Test Hole 11 - Observation well		
Alluvium and glacial deposits:		
Sand, fine to coarse, and fine to coarse gravel; contains cobbles (water level at 3.6 feet)	52	52
Clay	3	55
SB5-73-33CDB6		
Moraine Park (Site 1)		
Test Hole 12 - Observation well		
Alluvium and glacial deposits:		
Sand, fine to coarse, and fine to coarse gravel (water level at 3.4 feet)	12	12
Sand, medium	14	26
Sand and gravel	18	44
Clay	3	47

	Thickness (feet)	Depth below land surface (feet)
SB5-73-33CDB7		
Moraine Park (Site 1)		
Test Hole 13 - Observation well		
Alluvium and glacial deposits:		
Sand, fine to coarse, and fine to coarse gravel (water level at 3.1 feet)	12	12
Sand, fine to coarse; contains fine to coarse gravel and boulders	30	42
Sand, medium; contains fine gravel	25	67
SB5-73-29DBB		
Beaver Meadows (Site 2)		
Test Hole 14 - Observation well		
Alluvium and glacial deposits:		
Clay, sandy, organic, black (boulders at 12 feet)	12	12
Clay, sandy, black; contains streaks of gravel	4	16
Gravel, fine to medium; contains brown clay (water level at 18.0 feet)	2	18
Gravel, fine to medium; contains brown clay and cobbles.	2	20
Clay, brown, and fine to coarse sand	5	25
Clay, brown; contains fine to coarse sand and fine to coarse gravel	11	36
Sand, coarse, and medium gravel; contains clay	3	39
Bedrock:		
Granite	2	41
SB5-73-29CAC		
Beaver Meadows (Site 2)		
Test Hole 15		
Alluvium and glacial deposits:		
Clay, sandy, (boulder at 3 feet)	5	5
Sand, fine to coarse; contains clay and fine to coarse gravel (water level estimated at 12 feet)	16	21
Clay	1	22
Sand. fine to coarse, and fine to coarse gravel; contains brown clay (boulder at 36 feet)	18	40
Bedrock:		
Granite	3	43

	Thickness (feet)	Depth below land surface (feet)
SB5-73-27DCC		
Buck Creek (Site 3)		
Test Hole 16		
Alluvium:		
Silt	5	5
Gravel and cobbles	5	10
Sand, fine to coarse; contains clay and gravel	5	15
Bedrock:		
Granite at 15 feet		
SB4-73-5BAC		
Mill Creek (Site 5)		
Test Hole 17 - Observation well		
Alluvium and glacial deposits:		
Gravel and cobbles	4	4
Sand, fine to coarse; contains gravel and some cobbles (water level at 9.4 feet)	28	32
Gravel and cobbles	12	44
SB4-73-8BCA		
Glacier Basin Campground (Site 6)		
Test Hole 18 - Observation well		
Alluvium and glacial deposits:		
Sand, fine to coarse, and silt, gravel, and cobbles; contains clay	12	12
Sand, fine to coarse; and fine to coarse gravel; contains clay	3	15
Sand, fine to coarse; contains gravel	8	23
Sand, fine to coarse (water level at 31.2 feet)	24	47
Sand, fine to coarse	17	64
Gravel, cobbles, and sand	2	66

	Thickness (feet)	Depth below land surface (feet)
SB4-73-7DCA		
Glacier Basin Picnic Area (Site 7)		
Test Hole 19		
Alluvium and glacial deposits:		
Gravel, fine to medium; contains sand (water level estimated at 10 feet)	10	10
Sand, coarse; contains fine gravel	5	15
Gravel, coarse; contains sand	4	19
Clay and fine sand (no returns)	3	22
Gravel, fine; contains sand (cobbles at 31 feet)	10	32
Sand, fine to coarse	15	47
Clay and gravel (no returns)	2	49
SB3-73-22BDD		
Wild Basin, Deer Haven Lodge (Site 10)		
Test Hole 20		
Alluvium and glacial deposits:		
Boulders, gravel, sand, and clay (water level estimated at 21 feet)	21	21
Sand, fine to coarse; contains silt, gravel, and boulders	17	38
SB5-73-13ACC		
Twin Owls (Site 12)		
Test Hole 21 - Observation well		
Alluvium:		
Sand, fine to coarse, and black fine to medium gravel.	7	7
Gravel, fine to medium, and fine to coarse clayey sand (water level at 7.9 feet)	12	19
Clay	3	22
Gravel (cobbles at 38 feet)	16	38

	Thickness (feet)	Depth below land surface (feet)
SB5-73-18BDC		
Horseshoe Park (Site 13)		
Test Hole 22 - Observation well		
Alluvium and glacial deposits:		
Gravel, coarse; contains sand and silt	2	2
Gravel, fine to coarse; contains sand, silt, and cobbles (water level at 5.5 feet)	8	10
Gravel, fine	3	13
Sand, fine to coarse, and fine gravel	19	32
Sand, fine to coarse; contains gravel and clay	25	57
Clay, silty	10	67
SB5-74-11CAC		
Endovalley Campground (Site 14)		
Test Hole 23 - Observation well		
Alluvium and glacial deposits:		
Sand, fine to coarse, brown	2	2
Sand, fine to coarse, brown; contains gravel and cobbles (water level at 6.4 feet)	25	27
SB3-75-9BAC		
East Inlet Trailhead (Site 18)		
Test Hole 24		
Artificial fill	19	19
Alluvium and glacial deposits:		
Clay, sandy	4	23
Gravel and cobbles (water level estimated at 24 feet)	3	26
Sand and clay	5	31
Gravel and cobbles	8	39
SB3-75-6DDB		
Hilltop Ranger Station (Site 19)		
Test Hole 25		
Alluvium and glacial deposits:		
Gravel, coarse; contains sand (water level estimated at 2 feet)	12	12
Clay (no return)	6	18
Gravel	7	25
Clay, sandy	5	30

	Thickness (feet)	Depth below land surface (feet)
SB3-76-13BAC		
Pine Beach Picnic Area (Site 20)		
Test Hole 26		
Alluvium and glacial deposits:		
Sand, fine to coarse, and fine to coarse gravel (water level estimated at 6 feet)	10	10
Clay, sandy	8	18
Gravel, sand, and clay	5	23
Clay	13	36
SB3-76-13BBA		
Recreation Area Headquarters (Site 21)		
Test Hole 27		
Alluvium:		
Sand and gravel, poorly sorted; contains clay (water level estimated at 1 foot)	6	6
Clay, sandy, black	8	14
Undifferentiated Tertiary deposits:		
Clay, red	4	18
SB2-76-15BAD		
Granby Entrance (Site 23)		
Test Hole 28		
Undifferentiated Tertiary deposits:		
Clay, sandy, reddish-brown (water level estimated at 28 feet)	36	36
SB2-76-11DBB		
Sunset Point (Site 24)		
Test Hole 29		
Alluvium and glacial deposits:		
Sand, fine to coarse, gravel, and cobbles	4	4
Undifferentiated Tertiary deposits:		
Clay and sand, fine to coarse, gravelly (water level estimated at 7 feet)	12	16

	Thickness (feet)	Depth below land surface (feet)
SB2-75-18CBC		
Kamloop Cove (Site 25)		
Test Hole 30		
Alluvium:		
Sand, fine to medium, black	6	6
Sand, fine to medium, clayey, black	3	9
Bedrock:		
Granite at 9 feet		
SB2-75-23ACA		
Big Rock Campground (Site 27)		
Test Hole 31		
Alluvium and glacial deposits:		
Sand, fine to medium; contains gravel	3	3
Sand, fine to coarse; contains gravel	3	6
Sand, fine to coarse, clayey (water level estimated at 9 feet)	15	21
Clay, sandy, sticky, blue; contains gravel	15	36
SB2-75-23ABC		
Moraine Campground (Site 28)		
Test Hole 32		
Alluvium and glacial deposits:		
Sand, medium to coarse (water level estimated at 5 feet)	9	9
Clay, sandy, dark-blue	9	18
Sand, fine to coarse, and fine to coarse gravel	8	26
Sand, clay, gravel, and cobbles	5	31
Sand, gravel, and cobbles	4	35
Clay, silty, blue	66	101
SB2-75-14CBD		
Roaring Fork Ranger Station (Site 29)		
Test Hole 33 - Observation well		
Alluvium and glacial deposits:		
Sand, fine to coarse, and fine to coarse gravel; contains cobbles	7	7
Sand, fine to coarse, and fine to coarse gravel (water level at 11.6 feet)	17	24

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