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GROUND-WATER SUPPLY FOR MOUNT RAINIER NATIONAL PARK HEADQUARTERS SITE NEAR ASHFORD, WASHINGTON

By

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ABSTRACT

A water well was drilled recently at the new headquarters site of Mount Rainier National Park, Washington. The headquarters site is in the narrow bedrock-walled, alluvium-floored valley of the Nisqually River. The well was drilled to a depth of 96 feet in a terraced outwash deposit which underlies the site. Two confined aquifers were penetrated but only the lower aquifer was screened and developed.

The well was test pumped at various rates, the highest being 235 gallons per minute. During the first of two pumping tests, the specific capacity decreased abruptly. The decrease may have resulted from increased resistance to water movement caused by shifting of the sand and gravel adjacent to the well screen. The specific capacity of the well probably can be increased by additional development; however, because the well is capable of meeting the production requirements of the National Park Service additional development is not essential.

Ground-water levels in the valley alluvium fluctuate at least 16 feet in response to seasonal variations in recharge.

A sample of water taken from the well after 24 hours of pumping was of excellent chemical quality and is classified as soft.

Future ground-water development probably will be most successful in the central and southeastern parts of the headquarters site where the valley alluvium is thickest.

INTRODUCTION

Purpose and Scope

The National Park Service plans to move its headquarters for Mount Rainier National Park from Longmire, Washington to a newly acquired site about 15 miles west, beyond the park boundary.

The new site will include 34 residences and several offices and shops. To provide enough water for domestic and irrigation use and for fire protection, the Park Service has estimated that a minimum well yield of 200 gpm (gallons per minute) will be required. A 100,000-gallon reservoir will be used to supplement the well yield during periods of peak demand.

In 1963, the Ground Water Branch of the U.S. Geological Survey was requested by the National Park Service to select a drilling site and to supervise the construction and testing of a well. This report presents a compilation and analysis of the data collected during the project.

The project was directly supervised by A. A. Garrett of the U.S. Geological Survey. Henry Anderson, also of the U.S. Geological Survey, collected the basic data.

Location

The new headquarters site of Mount Rainier National Park is on a forested terrace above the flood plain of the Nisqually River near Alder Reservoir in Pierce County, Washington (fig. 1). It is about a quarter of a mile north of State Highway 5, about 4.3 miles west of Ashford, and about 9.4 miles west of the entrance to Mount Rainier National Park.

Geologic Setting

The headquarters site is on the north side of a relatively narrow bedrock-walled valley leading away from the snow-capped cone of Mount Rainier. The valley floor ranges in width from about 3 miles near Ashford to about one mile in the vicinity of the site. It is underlain by unconsolidated alluvial and mudflow deposits which rest upon bedrock consisting mostly of volcanic breccias and flows. The terrace on which the headquarters site is situated is about 30 feet above the flood plain of the Nisqually River. Just west of the center of the site, the terrace is interrupted by a small scarp that borders a lower terrace. Both terrace surfaces are underlain by cobble to boulder gravel capped by 4 to 8 inches of sand-size volcanic ash. The full thickness of the gravel and the depth to bedrock are unknown.

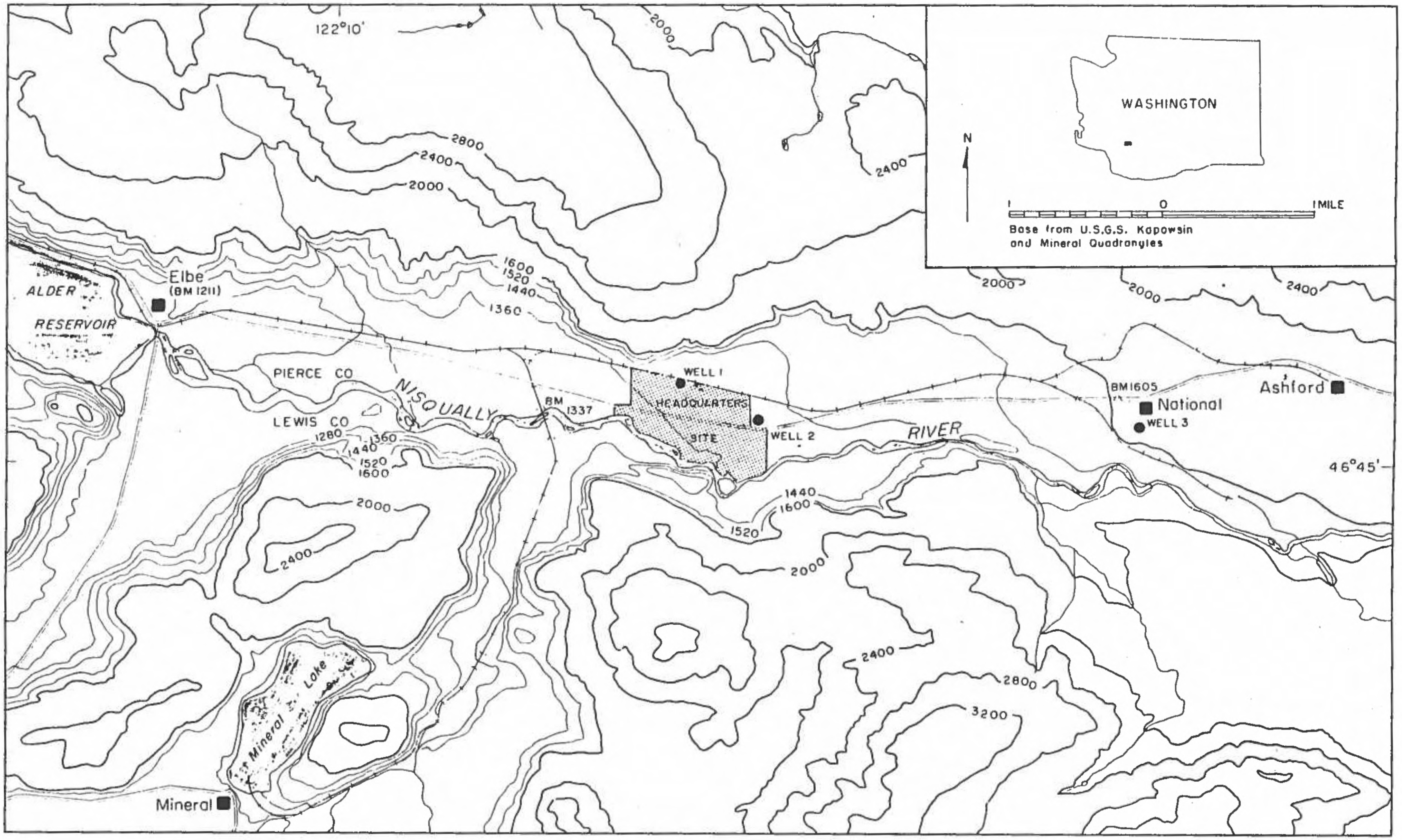

Figure 1.--Map of a segment of the Nisqually River valley showing the new headquarters site of Mount Rainier National Park.

According to D. R. Crandell of the U.S.Geological Survey (written communication), this segment of the Nisqually Valley was glaciated probably about 40,000 to 50,000 years ago (middle Wisconsin), at which time the valley was buried under at least 1,000 feet of ice. Deposits of this glacier may lie between the terrace gravel and bedrock. During the most recent glaciation, roughly 15,000 to 25,000 years ago, a valley glacier extended down the Nisqually Valley to the vicnity of National, about 2.5 miles east of the headquarters site. Meltwater from this glacier deposited the gravel that underlies the headquarters site. The proximity of the site to the ice front explains the relatively coarse texture of the gravel deposit. After retreat of the valley glacier, the Nisqually River cut into the glacial gravel, forming a terrace on the north side of the valley. Subsequently, much of the valley floor was repeatedly buried by flows of mud and boulders originating on Mount Rainier. About a mile west of the headquarters site, these flows have covered the entire valley floor, but the terrace at the headquarters site, because of its height, has remained above the crest of the mudflows.

Selection of Drilling Site

Reconnaissance of the proposed headquarters site and adjacent valley areas revealed several dug and drilled wells. The nearest of these for which information is available are two drilled wells located upstream from the proposed headquarters area at distances of half a mile and 3 miles (fig. 1, wells 2 and 3). These wells are, respectively, 91 and 157 feet deep, and have specific capacities of 13 and 30 gpm per foot of drawdown. Although both wells penetrated numerous water-bearing layers of bouldery gravel and sand, lithologic correlation between them was not apparent.

In addition to the existing well records, the geologic history of the valley indicated favorable conditions for obtaining a well yield of at least 200 gpm at the headquarters site.

CONSTRUCTION OF THE WELL

Drilling and Preliminary Testing

Drilling, by the cable-tool method, was started on October 7, and completed on October 18, 1963, by the Tacoma Pump and Drilling Co., Tacoma, Washington. Because the drilling site is on a bouldery terrace, the driller decided that a 12-inch casing should be used at the start to minimize difficulties that might be caused by the boulders. The 12-inch casing was set to a depth of 14.35 feet below the land surface.

Land-surface datum, as used in this report, is 1,392 feet above sea level and is estimated from U.S. Department of Interior Bench Mark 28, about 100 feet southwest of the drilling site. After setting the 12-inch casing, an 8-inch hole was drilled to a depth of 96 feet and cased to 94 feet. Samples of all the lithologic units were collected and are described on figure 2.

Two water-bearing sand and gravel zones were penetrated--an upper zone from 43 to 48 feet and a lower zone from 80 to 93 feet. The static water level in the upper zone was about 29 feet below land surface, and that in the lower zone was about 41 feet below land surface.

Bailing tests during drilling of both zones were made and, during each test, water entered the well through the open end of the casing. The upper aquifer (open from 45 to 46 feet) was bailed at 20 gpm for 10 minutes. The drawdown was about 5 feet. The lower aquifer (open from 88.5 to 89 feet) was bailed at 60 gpm for 2 minutes. The drawdown was not noticeable.

The lower aquifer was selected for development because it was thickest and appeared to have the best yield potential.

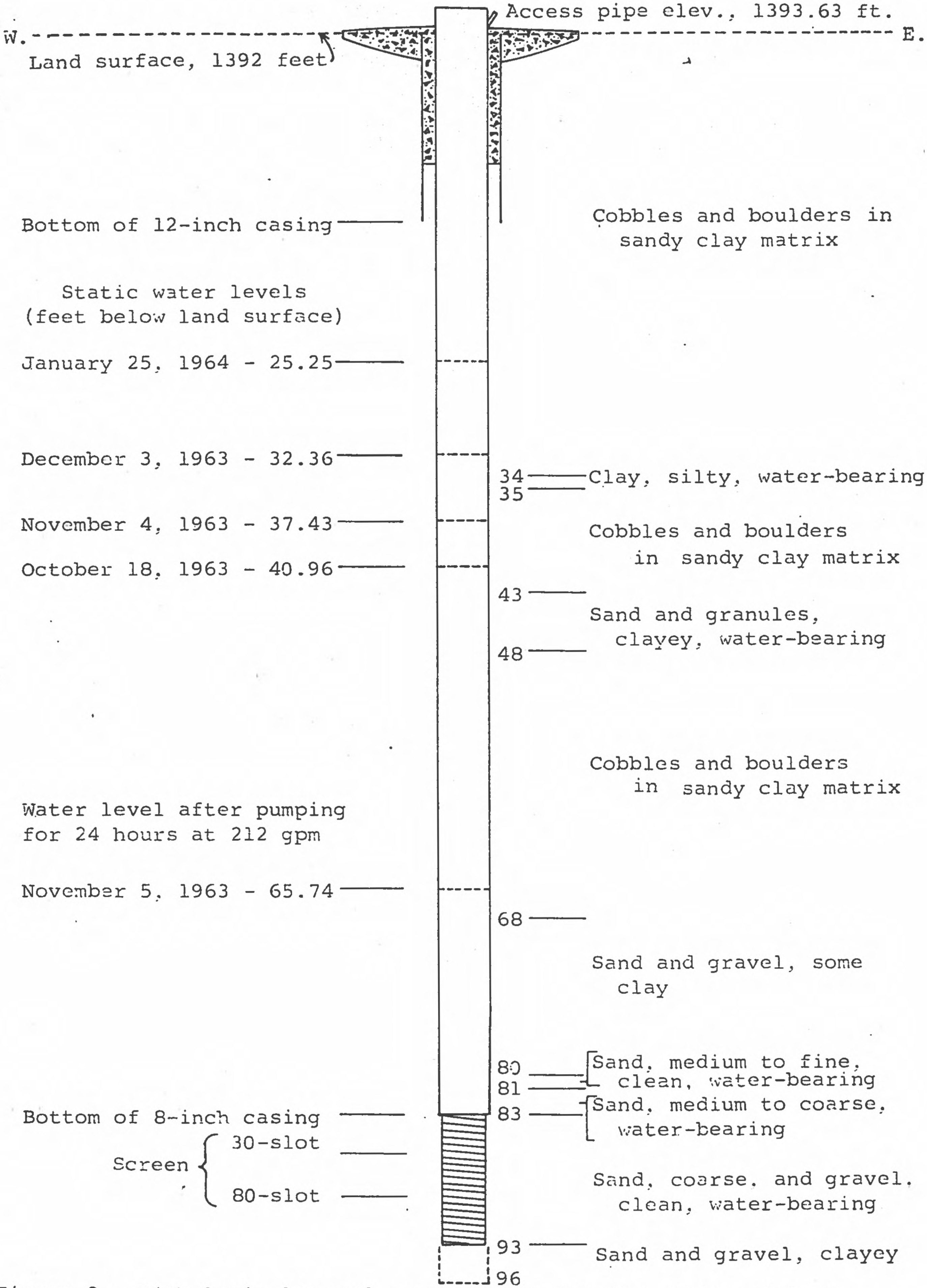

Figure 2.--Lithologic log and construction details, National Park well near Ashford, Washington

Selection of Screen Size

Numerous samples collected from the lower aquifer showed that the upper 3 feet contain fine sand and the remaining 10 feet contain coarse sand and gravel. For that reason, it was decided to develop only the section from 83 to 93 feet.

A sieve analysis of a composite sample taken from this lower section indicated that an 80-slot (0.80-inch openings) well screen should be installed. However, it was recognized that the overlying 3-foot section might slump during development and allow an excessive amount of fine material to pass through the relatively large openings of the 80-slot screen. To minimize this possibility, a 30-slot size (0.30-inch openings) was selected for the upper 3 feet of screen, (83 to 86 feet) and an 80-slot size for the interval from 86 to 93 feet (fig. 2).

Development

The well was developed by the surge-block method for a period of 18 hours, using a loose-fitting block operated at about 40 strokes per minute throughout the development period. Surging was begun just below the static water level and continued at successively lower depths as development progressed. About 5 cubic feet of sand was removed from the aquifer, most of which entered the screen during the first 9 hours of development.

PUMPING TESTS

Two pumping tests were performed; one was a step-drawdown test in which the well was pumped at successively higher rates and the other was a constant-rate test. A gasoline powered turbine pump. equipped with a foot valve, was used for both tests. The discharge rates were measured by an orifice and manometer attached to the discharge pipe of the pump. An electric tape was used to make the water-level measurements, and these were checked periodically with a steel tape.

Step-Drawdown Test

On October 31. a step-drawdown test was made at average pumping rates of 115, 143, 188, and 235 gpm. Data from this test are shown graphically in figures 3 and 4. Both figures represent different arrangements of the same data. Figure 3 has an expanded horizontal time scale that permits a better comparison of the drawdown curves and fluctuations in the pumping rates. Control of the pumping rate was most difficult during step 1 and, to prevent the motor from stopping, a rate increase was made to step 2 prematurely. Fluctuations in rate during the remaining steps were 9 gpm or less.

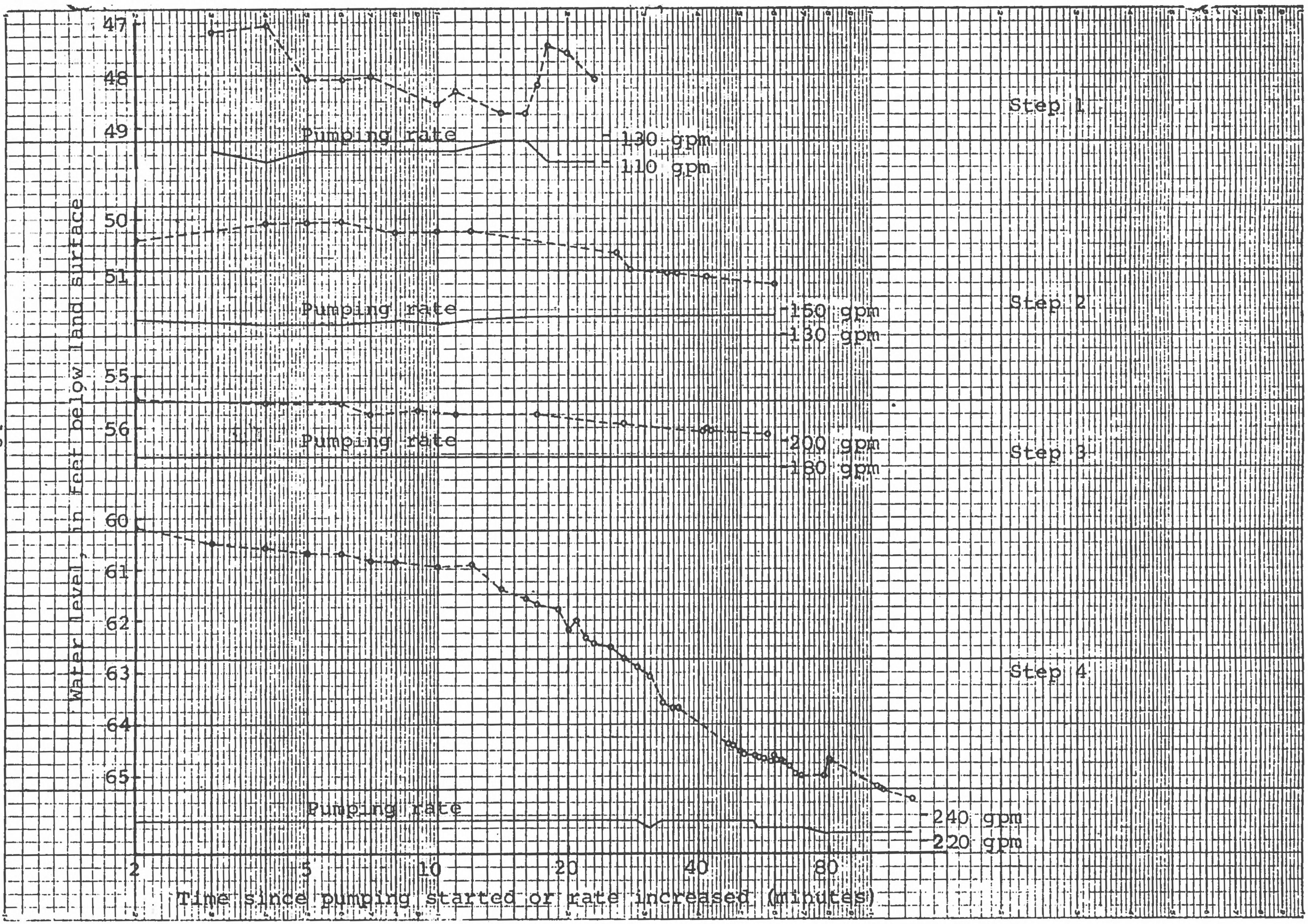

Figure 3.--Step-drawdown graphs, National Park well near Ashford, Washington

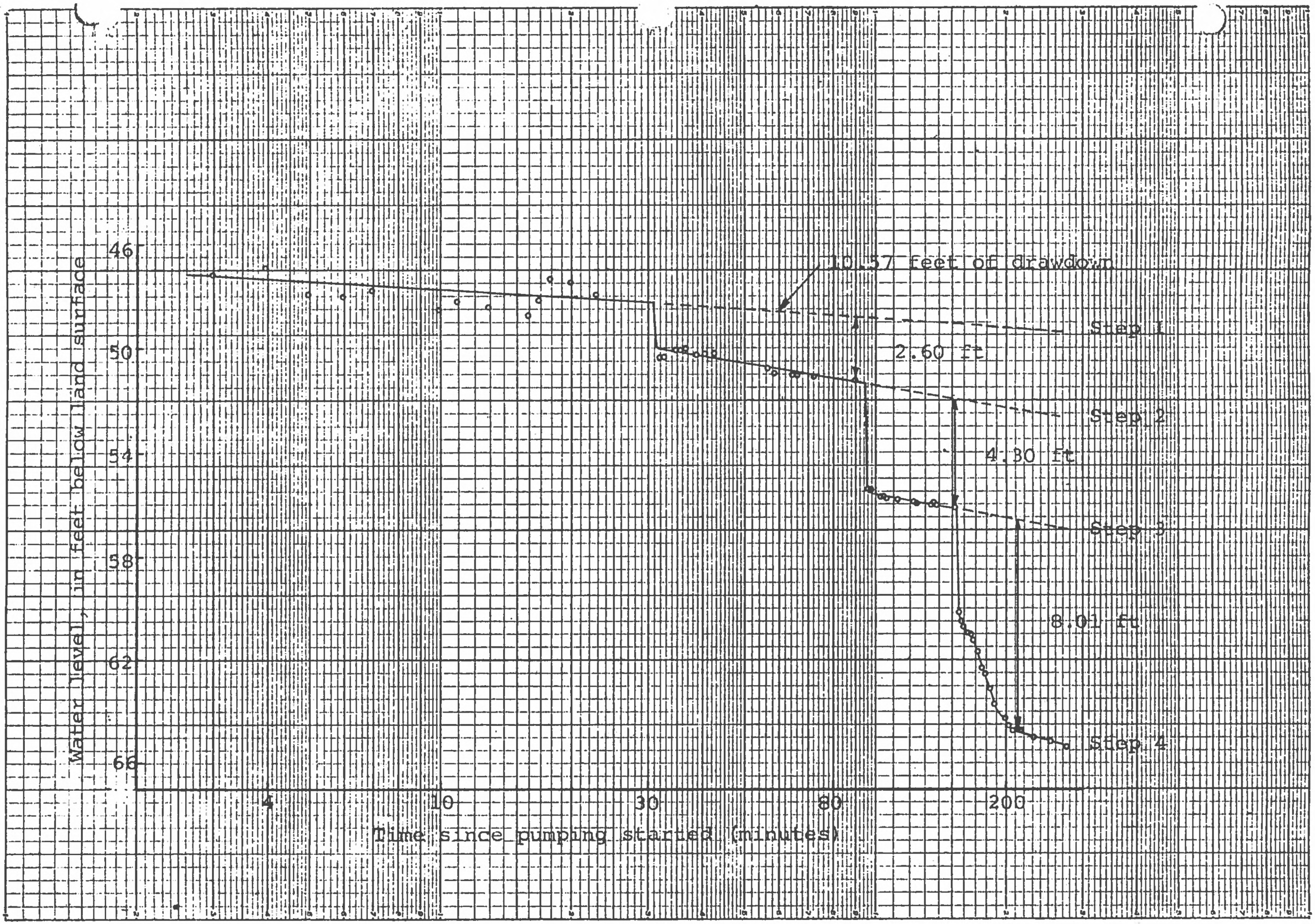

Figure 4.--Step-drawdown graph, National Park well near Ashford, Washington

The water level throughout each of the first 3 steps and the early part of the fourth step declined at about an equal rate. However, an abrupt increase in slope occurred in the fourth step 13 minutes after the pumping rate was increased (fig. 3). The water level declined at the greater rate for 41 minutes until a decrease in pumping rate (235 to 226 gpm) during the final 70 minutes caused a slight leveling off.

Data for calculating specific capacity (yield per foot of drawdown) were obtained by extrapolating water-level trends for each step (shown by the dashed lines in fig. 4). Increments of drawdown were measured graphically for pumping periods of 1 hour. The data for each step are included in the following table.

Pumping test	Average pumping rate (gpm)	Change in pumping rate (gpm)	Drawdown increment (feet)	Cumulative drawdown (feet)	Specific capacity (gpm per ft of drawdown)	
					Based on incremental drawdown	Based on cumulative drawdown
step 1	115	115	10.57	10.57	[a]10.9	10.9
step 2	143	28	2.60	13.17	[a]10.8	10.9
step 3	188	45	4.30	17.47	[a]10.5	10.8
step 4	235	47	8.01	25.48	[a] 5.9	9.2
Constant-rate test (after 1 hr)	212	..	24.07	..	8.8	..
Constant-rate test (after 24 hr)	212	..	..	28.37	..	7.5

a/ extrapolated drawdown for pumping periods of 1 hr

The specific capacity of the well decreased from an average of 10.7 gpm per foot of drawdown for the first three steps to 5.9 gpm per foot in the fourth step. The specific capacity of 5.9 applies only to the fourth step--the overall specific capacity of the well is appreciably greater. The abrupt loss in specific capacity in step 4 is unusual and was probably caused by settlement and rearrangement within the aquifer adjacent to the well screen. Some newly completed wells are unstable, and shifting of the sand and gravel outside the well screen will occur during high pumping rates.

Constant-Rate Test and Recovery

On November 4 and 5, a 24-hour constant-rate test was made at an average pumping rate of 212 gpm. At the end of the test, recovery measurements were taken for a period of 6.3 hours. Data obtained from the pumping test and during recovery are shown graphically in figures 5 and 6.

The slope of the time-drawdown curve in figure 5 is gentle and contains no major break. Small breaks occur but these are in response to fluctuations in the pumping rate.

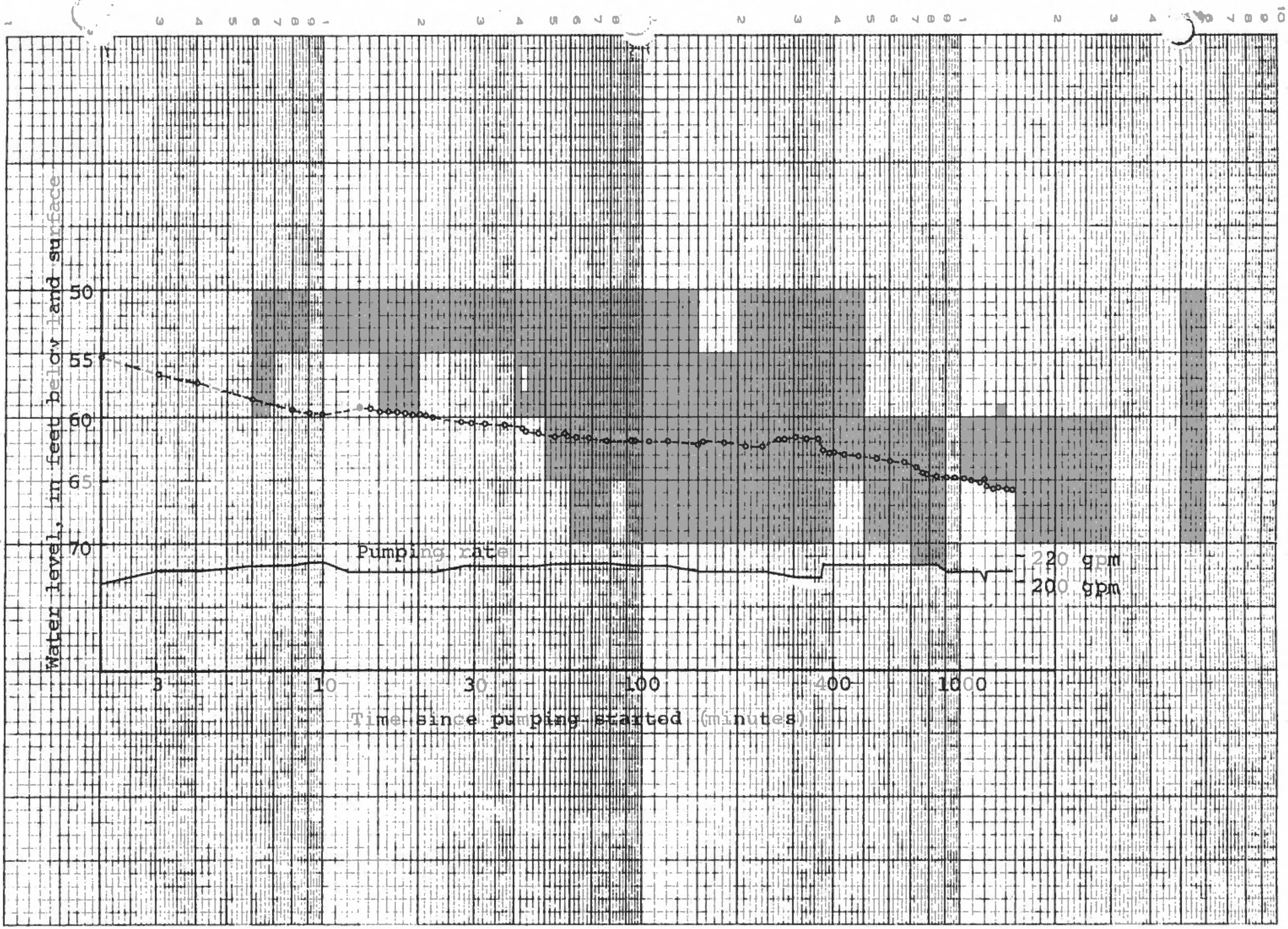

Figure 5.--Constant-rate drawdown graph, National Park well near Ashford, Washington

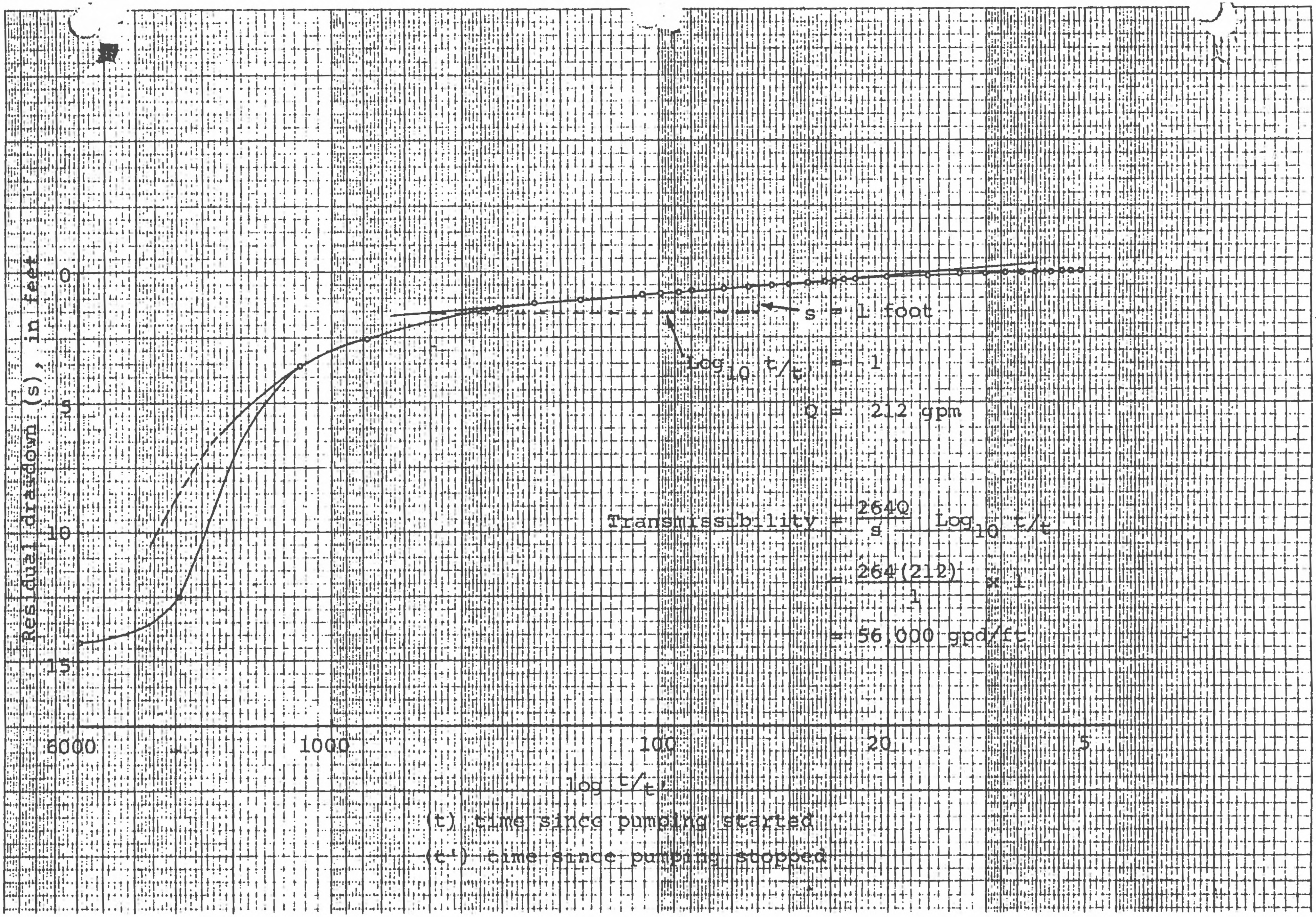

Figure 6.--Recovery curve, constant-rate test, National Park well near Ashford, Washington

The specific capacity at the end of the first hour was 8.8 gpm per foot of drawdown, as compared to an average value of 10.9 gpm per foot for the first three steps of the step-drawdown test and 9.2 gpm per foot in step 4. Thus, the specific capacity of the well was only slightly less than it was during the final step of the step-drawdown test.

A useful term, the coefficient of transmissibility, often has been used to describe the capacity of an aquifer to transmit water. This coefficient is defined as the rate of flow of water in gallons per day under a hydraulic gradient of 100 percent, through a saturated vertical strip of aquifer 1 foot wide. Transmissibilities shown in the following table were calculated from drawdown, recovery, and specific-capacity data.

Data used for calculating transmissibility		Transmissibility (gpd per foot)
[a]Recovery curve (fig. 6)		56,000
[b]Drawdown curve (fig. 5)		16,000
[c]Specific capacity		
steps 1, 2, 3 (avg.)	10.7	20,000
step 4	5.9	11,000
constant-rate test (after 1 hr)	8.8	15,000
constant-rate test (after 24 hr)	7.5	17,000

a/Theis recovery formula (Ferris and others, 1962, p. 100-102).

b/Modified nonequilibrium formula (Ferris and others, 1962, p. 98-100)

c/ Walton, 1962, p. 12-13

The specific capacities and the drawdown curve show a range in transmissibility considerably below the 56,000 gpd per foot computed from the slope of the recovery curve. Normally, the two methods should give transmissibilities which are in much closer agreement. The definite grouping of transmissibilities in the lower range indicates that 56,000 gpd per foot probably is too high. For all practical purposes, judging from the results of the constant-rate test, the well performs as though it were discharging from an aquifer that has a transmissibility of 15,000 to 20,000 gpd per foot.

RECHARGE

During the period October 18-January 25, the water level in the well gradually rose about 16 feet. Heavy precipitation in the Nisqually Valley area was the source of recharge to the aquifer. A U.S. Forest Service Weather Station at Mineral. about 4 miles southwest of the well site, recorded 45 inches of precipitation between October 20 and January 25, and only 5½ inches for the 100 days preceding this period. This heavy precipitation caused a slight rise in stage of the Nisqually River. However, the river probably contributes little recharge because the aquifer is confined.

It is apparent that the amount of ground water stored in the valley alluvium fluctuates in close response to precipitation. The pumping tests were made at the end of the dry season, at a time when the valley alluvium contained a minimum amount of ground water in storage and static water levels were low. During the wet season, static water levels are considerably higher and, accordingly, a greater amount of drawdown can be tolerated; thus permitting higher pumping rates.

EVALUATION OF THE COMPLETED WELL

Response to Prolonged Pumping

The length of time that the well can be pumped contin-usously will be controlled by: (1) the rate of decline of the pumping level and the lowest permissible pumping level; and (2) the position of the static water level. According to some well drillers, the water level should not be drawn down to the extent that the pumping level is opposite the screen. Thus, an arbitrary lower limit may be set at about 3 feet above the screen or about 80 feet below land surface. Since the well was drilled, the static water level has risen 16 feet (41 to 25 feet below land surface).

Of the two tests, the constant-rate test probably is the most reliable guideline to use in estimating the amount of time that the well can be pumped at 200 gpm. Although the test was made at a slightly higher rate than the planned production rate, data from the test can be used to make a conservative estimate of the response of the well to prolonged periods of pumping. This test (average rate 212 gpm) was started from a static level of about 37 feet, and after 24 hours the pumping level had declined to about 66 feet.

For pumping periods beyond 24 hours, the decline of the pumping level can be estimated by extrapolating the data obtained from the test. Assuming a transmissibility of 17,000 gallons per day per foot the decline per log cycle of time at a pumping rate of 200 gpm is about 3.1 feet. That is, the decline from one day to ten days is 3.1 feet and the decline from one day to a hundred days is 6.2 feet.

The table on page 18 shows that the specific capacity. at the end of one day, is 7.5 gpd per foot. Hence, at a pumping rate of 200 gpm, the drawdown would be 200/7.5 or about 27 feet. Extrapolating beyond 1 day, the drawdown at the end of 10 days would be about 30 feet and at the end of 100 days, 33 feet. If the static level were 41 feet, (p. 20) the pumping level would be 74 feet below land surface. Because the dry season is not much longer than 100 days (3 months) the well probably can be pumped continuously at 200 gpm without lowering the water level below the allowable limit of 80 feet below land surface.

Suggestions for Additional Well Development

Results of the pumping test and evaluation of related data indicate that the specific capacity of the well probably can be improved by additional development. The shifting of the sand and gravel that is thought to have occurred in the fourth step of the step-drawdown test apparently increased the head loss. More vigorous development probably would open the aquifer and decrease head loss. This would result in a higher specific capacity and less drawdown for a given pumping rate.

If additional development is decided upon, then additional pumping tests should be planned to check the results and predict new pumping performance. These tests could be conducted after the permanent production pump is installed.

Chemical Quality

A water sample was obtained during the constant-rate pumping test and analyzed by the U.S. Geological Survey. The chemical analysis and related data are listed in table 1.

The analysis shows that the water is of excellent chemical quality for the intended use. The water has a hardness of only 27 ppm (parts per million) and is therefore classified as soft (0-60 ppm). All the constituents for which determinations were made are present in concentrations well below the upper limits for drinking water as established by the Public Health Service (1962, p. 7).

FUTURE GROUND-WATER DEVELOPMENT

The headquarters site almost spans the width of the Nisqually River valley and is everywhere underlain by alluvial sand and gravel. The alluvium probably is thickest near the center and southeastern half of the headquarters site. Thin alluvial desposits underlain by bedrock are most likely to be encountered in the northwestern corner of the site.

This part of the site should not be considered for future ground-water development. All other locations probably have an equal chance of producing adequate supplies of ground water.

Certainly, the choice of additional well locations will depend more on economics that on other factors. However, consideration should be given to correct well spacing to minimize the possibility of mutual interference.

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Table 1.--Chemical analysis of water from the National Park Service well near Ashford, Washington

Analysis by U.S.Geological Survey
Collected Nov. 5, 1963
Discharge 212 gpm
Water temperature 44.5°F

Chemical data (parts per million)

Silica (SiO_2)	46
Iron (Fe), total	.07
Calcium (Ca)	8.0
Magnesium (Mg)	1.7
Sodium (Na)	5.0
Potassium (K)	1.9
Bicarbonate (HCO_3)	44
Carbonate (CO_3)	0
Sulfate (SO_4)	4.0
Chloride (Cl)	1.0
Fluoride (F)	.1
Nitrate (NO_3)	.9
Total solids	96
Hardness	27

Physical data

Specific conductance in micromhos at 25°C	86
pH	6.8
Color	none