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Interpretation of short term water level fluctuations in the Moscow Basin Latah County, Idaho

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INTERPRETATION OF SHORT TERM WATER LEVEL FLUCTUATIONS IN THE MOSCOW BASIN, LATAH COUNTY, IDAHO

by

Daniel Sokol

ABSTRACT

Moscow basin is underlain by a sequence of basalts and intercalated sediments along the eastern margin of the Columbia Plateau. The sequence includes at least 5 aquifers that are separated by rocks with such low permeability that hydraulic connection among aquifers is extremely poor. Not all aquifers are everywhere present throughout the basin.

Potentiometric surfaces of deeper aquifers are successively lower. Each aquifer has a distinctive pattern of seasonal water-level fluctuations. Water-level rises correlate with rainfall in the basin and with snow melt and relatively heavy surface runoff from adjacent mountainous areas. All aquifers, except the lowermost, show seasonal recharge indicating that each is part of an active hydrologic system. Information on the lowermost is insufficient to determine if it is now being recharged significantly.

Water levels in some wells responded to changes in barometric pressure, pumping in other wells, earthquakes, and wind, in addition to seasonal recharge. The largest fluctuation, caused by the Good Friday, 1964, earthquake in Alaska, was more than five feet. No permanent change in water level could be attributed to this or any other earthquake.

Seasonal fluctuation of one-half foot in one well was identified by two methods, although the record was obscured by barometric fluctuations of more than one and one-half feet.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

Aquifers below an altitude of 1900 feet (more than 700 feet below the land surface) have been developed as a source of water by the City of Moscow and the University since 1958. Prior to 1958, most wells in the Moscow basin produced from strata above an altitude of 2200 feet (about 400 feet) below the land surface. A deeper source of ground water was sought because of the poor quality of the water produced. In 1958, the City of Moscow Well No. 6 was deepened from 282 feet to 1300 feet and now (1965) produces 900 gpm (gallons per minute); in 1964, the University of Idaho Well No. 3 was completed at 1337 feet and can pump more than 2000 gpm; in 1965, the City of Moscow Well No. 8 was completed at 1453 feet and can pump more than 1200 gpm. Although the deep wells produce large quantities of water with a relative good quality, the engineering staffs of the city and the University are concerned about the future because the recharge of an aquifer has little relation to the initial capacity of well production in that aquifer.

The investigation on which this report is based was made in order to determine: (1) whether or not the deeper aquifers are being recharged, (2) the hydrologic regime of the aquifers, and (3) the hydraulic characteristics that can be ascertained from water-level measurements.

LOCATION AND EXTENT OF THE AREA

The Moscow basin (Fig. 1) includes about 60 square miles of western Latah County, Idaho. The northern, eastern, and southern margins of the basin are the drainage divide of the South Fork of the Palouse River. The western margin is considered to be the Idaho-Washington state line, which arbitrarily is used to separate the Moscow basin from the Pullman ground-water basin.

The wells discussed in this report are in or near the northwestern part of the City of Moscow, which is 2 miles east of the western margin of the basin. Moscow is at 117° west longitude and 46°44' north latitude. Moscow and the University of Idaho wells supply water for the use of about 12,000 persons.

PREVIOUS AND CURRENT INVESTIGATION

Because of water-supply problems at the City of Moscow, Idaho; the University of Idaho; the City of Pullman, Washington; and Washington State University; many geologic and hydrologic investigations have been made of the Moscow basin and adjacent areas. Ross (1965, Table I) listed 26 references that pertain to hydrologic conditions in the basin. These include published reports, private reports by geologic and engineering consultants, and unpublished results of research. The scope of these reports ranges from the description of a single aspect of the area to a regional reconnaissance.

The University of Idaho Water Resources Institute is currently sponsoring study of the detailed hydrology of Moscow basin. A preliminary report on the geohydrology (Ross, 1965) for the study has been prepared. The Geohydrologic Research Group of Washington State University is investigating recharge of ground water in the Moscow and Pullman basins, chiefly by use of isotope age-dating methods.

GEOLOGIC AND HYDROLOGIC SETTING

GEOLOGY

The Moscow basin consists of a rolling surface of low hills at the eastern margin of the Coumbia River Plateau and of mountains at the western margin of the Northern Rocky Mountains. The mountains rise 500 to 1700 feet above the rolling surface on the northern, eastern, and southern borders of Moscow basin. The base of Moscow Mountain (high point of the Palouse Range) is 3 miles northeast of the City of Moscow; the base of the highland to the east is 2 miles east of Moscow; and the base of Paradise Ridge is 2 miles south of Moscow.

These mountains are underlain by granitic and metamorphic rocks. The granitic rock is mainly granodiorite of the Thatuna batholith of Cretaceous (?) age (Tullis, 1944, p. 143-174); the metamorphic rock is mainly quartzite of the Belt Group of Precambrian age (Tullis, 1944, p. 139-140).

The basin is underlain by a sequence of basalt and interbedded sedimentary material as much as 1300 feet thick. The basalt is part of a thick sequence of Columbia River Basalt (Russell, 1901, p. 28), which covers much of eastern Washington and northeastern Oregon as well as large parts of northern Idaho. The basalt generally is a black, fine-grained rock with local zones of glassy, vesicular, or porphyritic texture. The interbedded sediments are mainly clays, silts, and fine-grained sands. The sequence of basalt and interbedded sedimentary rocks is overlain by reddish-brown loess (windblown silt).

Prior to Miocene time (about 25 million years ago) Moscow basin was part of a rugged mountain system with perhaps more than 4,000 feet of relief. The ancestral South Fork of the Palouse River, Paradise Creek, and Missouri Creek all flowed in steep, narrow valleys. During the Miocene Epoch, flows of basaltic lava invaded local drainage systems from the west and covered the lower parts of this mountainous area. Successively younger flows lapped farther eastward so that at the eastern margin of the basalt only one flow is present. Between flows, sedimentary material eroded from the mountains was deposited. The percentage of sedimentary material within the basalt sequence is greater in Moscow basin than it is to the west in the Pullman area because Moscow basin is closer to the source of the sediments and farther from the source of the basalt. The sediments become finer-grained, and thin or wedge out toward the west; some individual flow units of the basalt may not have contained enough lava to reach the eastern margin of the Columbia River Plateau. Many of the sedimentary beds are composed of fine-grained silts and clays that resemble sediments deposited in lakes. Ponded areas almost certainly were formed several times between periods of basalt crystallization when surface drainage was blocked by the basalt. Other sedimentary beds are typical of stream deposits. Many of the streams cut below the surface of older basalt flows, and subsequently sections of their channels and adjacent floodplains were filled with sedimentary materials.

The following sequence of events was wholly or partly repeated many times in the Moscow basin: Basaltic lava flowed into the basin from the west; the lava solidified into a basalt flow unit with a surface sloping down toward the east. Surface drainage was blocked by the basalt so that ponded areas were formed between the mountains east of the basin and the high basalt surface west of the basin. Clay and silt beds were deposited in the ponded areas before streams could cut new channels through the basalt dams to drain the ponded areas. Stream action dissected the lacustrine beds and the underlying basalt. Locally, streams deposited sand and gravel in channels and silt and clay on floodplains before the next invasion of lava. Thus individual basalt flows and sedimentary units have irregular surfaces of deposition.

At the lower part of the basin, wind-deposited, reworked fine-grained sediments formed a loess mantle, in which the present topography was developed by mass wasting and stream action.

HYDROLOGY

Hydrologic conditions in any given area can be expressed by the general hydrologic equation:

[Precipitation + surface inflow + ground-water inflow + imported water - surface outflow - ground-water outflow - exported water - evapotranspiration]

= [net increase in water in the snow pack + net increase in soil moisture storage + net increase in surface storage + net increase in ground-water storage.]

In the Moscow basin as used in this report surface inflow is zero because the northern, eastern, and southern boundaries are surface divides and streamflow is entirely westward along the western boundary. Ground-water inflow is negligible, assuming that subsurface flow nearly coincides with surface flow. No appreciable quantities of water are imported into the basin, exported from the basin, or held in surface storage at any one time. Thus the hydrologic equation for the Moscow basin can be reduced to:

[Precipitation - evapotranspiration - surface-water outflow - ground-water outflow]

= [net increase in snow pack + net increase in soil-moisture storage + net increase in ground-water storage.]

Soil-moisture storage and snow pack can be omitted in preparing a water budget for a water year, which ends on September 30, because in early autumn soil moisture storage and snow pack are negligible quantities. However, soil moisture and snow pack are important factors in the water budget during spans of short duration.

Ground-water elements of the budget are controlled in part by the other elements. Ground-water conditions in shallow aquifers in turn influence evapotranspiration and streamflow; ground-water conditions in deep aquifers do not. The quantitative relations between hydrologic elements in the Moscow basin are unknown.

Precipitation

All water in the hydrologic budget enters the basin as precipitation. The amount, form, distribution in space, and distribution with time of precipitation influence the amount of water (1) that is returned to the atmosphere by evapotranspiration, (2) that flows in the streams, or (3) that enters the ground-water aquifers. Annual precipitation at Moscow for the 30-year period, 1931-1960, averaged 22.20 inches. During this period, precipitation ranged from 14.13

inches in 1944 to 34.01 inches in 1948. Precipitation at most points in the basin is higher than at the gaging station at Moscow. More precipitation falls at higher altitudes; Bloomsburg (1959, Fig. 3) showed that precipitation on the Palouse Range above 4000 feet altitude is as much as twice the precipitation at Moscow. Because most of the basin is below 2800 feet altitude, the average precipitation on the basin probably approximates 1.25 times the precipitation at Moscow. The precipitation is not evenly distributed throughout the year (Table 1); about two-thirds falls in the six-month period October through March. Only part of the precipitation, particularly during the wetter half of the year, falls as rain, which immediately is returned to the atmosphere, infiltrates into the soil and aquifers, or enters the stream channels. Solid forms of precipitation, mostly snow, must melt before water can infiltrate or flow.

A large but unknown percentage of the precipitation during the winter falls as snow. The snow pack at lower altitudes melts several times each winter leaving bare ground; much of the snow pack at higher altitudes persists through the winter. Warm weather during the spring progressively melts snow at higher altitudes so that much snow at intermediate altitudes is melted when most snow at high altitudes remains on the ground.

Evapotranspiration

Most water that falls as precipitation is returned to the atmosphere by the processes of evaporation or transpiration. Evapotranspiration, the combination of these two processes, reduces the quantity of water that is available for stream runoff or for ground-water recharge. The quantity of water that can be returned to the atmosphere by evapotranspiration at any time is restricted by the energy available to change liquid water to water vapor or by the available water, whichever is less.

The volume of water per unit area that can be converted to water vapor using all available energy is termed potential evapotranspiration. Actual evapotranspiration is equal to potential evapotranspiration only when water is exposed to the atmosphere over the entire area considered; otherwise actual evapotranspiration is less than potential evapotranspiration. Although measurement of actual evapotranspiration is not feasible for an area as large as the Moscow basin, potential evapotranspiration can be estimated from meterologic parameters. Bloomsburg (1959) computed monthly potential evapotranspiration at Moscow for the period 1955 to 1958. The average monthly values obtained from Bloomsburg (written communication, May 1965) are shown on Table 1.

Potential evapotranspiration exceeds precipitation from May to September; thus during these months, almost all water that falls as rain is returned to the atmosphere within a few days. Precipitation exceeds potential evapotranspiration from October to April; thus during these months, excess precipitation of 12.51 inches (Table 1) not held in the snow pack, infiltrates into the ground or runs off in stream channels.

Infiltration

Water that infiltrates the soil is held as soil moisture until the soil-moisture storage capacity is reached. The soil-moisture storage capacity of the basin is unknown. Bloomsburg (1959, p. 38) assumed the storage capacity of Crumarine

TABLE 1 - Average monthly precipitation and potential evapotranspiration at Moscow, Idaho

	Average precipitation 1/ (inches)	Average potential evapotranspiration 2/ (inches)	Excess precipitation 3/ (inches)
Jan.	2.80	0.04	2.76
Feb.	2.13	0.20	1.93
Mar.	2.12	0.47	1.65
Apr.	1.70	1.57	0.13
May	1.63	3.31	______
June	1.73	4.00	______
July	0.51	5.08	______
Aug.	0.52	4.41	______
Sept.	1.24	3.01	______
Oct.	2.03	1.46	0.57
Nov.	2.64	0.16	2.48
Dec.	3.15	0.16	2.99
Total	22.20	23.87	12.51

1/ Average 1931-60 from U. S. Weather Bureau Records.

2/ Calculated by G. L. Bloomsburg for period January, 1955, to September, 1958, using the Thornthwaite method.

3/ Monthly excess of average precipitation over potential evapotranspiration.

and Gnat Creek basins is about nine inches. If this value is representative of the entire Moscow basin, the soil holds enough water in the spring to cover the basin to a depth of nine inches. Thus, 9 of the 12.5 inches of excess precipitation is evaporated or transpired during the relatively long summer.

The maximum rate at which water can enter the soil is the infiltration capacity. The infiltration capacity is greatest when soil moisture storage is low. During the early part of the wet season the soil has a high capacity to absorb and hold water. Thus, most rain during the fall enters the ground and is held in the soil until it is returned to the atmosphere. Rainfall exceeds the capacity of the soil to absorb water only during the most intense storms in the fall. During these rare and brief periods, water flows in the streams draining Moscow basin.

When the soil is saturated in the spring, water from snow melt and rainfall infiltrates the soil at lower rates. After the capacity of the soil to hold water is reached, water percolates downward to recharge ground water. As the soil moisture increases, the ability of the soil to absorb water decreases so that a larger percentage of the excess of precipitation over evapotranspiration flows into the streams.

Surface Water

The regimes of streams in the basin are poorly known. The South Fork of the Palouse River and Missouri Creek (also known as Missouri Flat Creek) at Pullman, Washington have been measured by the U. S. Geological Survey since 1934. The South Fork was not measured from 1942 to 1959; Missouri Creek was not measured from 1940 to 1959. Drainage areas of these creeks include 100 square miles in the Moscow basin. Two tributaries of the South Fork of the Palouse River, Gnat and Crumarine Creeks, were measured by Bloomsburg (1959) from 1955 to 1958. Gnat Creek, above the gaging station, drains 4.3 square miles that range from 2670 to 4100 feet above sea level; Crumarine Creek, above the gaging station, drains 2.4 square miles that range from 2800 to 4600 feet. The gaging station on Crumarine Creek has been maintained intermittently from 1958 to the present (1965).

The average annual flow at the four gaging stations ranges from 3 to 10 inches (Table 2). Flow in Crumarine Creek during the 3 years of records was equivalent to 9.9 inches of water over the drainage area. The drainage area of Crumarine Creek is almost entirely forested mountains underlain by granitic rocks. Flow in Gnat Creek during the same period was equivalent to 5.1 inches of water over the drainage area. About half of the drainage area of Gnat Creek is similar to the drainage area of Crumarine Creek; the other half is mantled with loess and is at a lower altitude than the drainage area of Crumarine Creek.

Flow in the South Fork of the Palouse River and Missouri Creek at Pullman for 11 and 9 year periods was equivalent to 3 inches over a drainage area that is mostly mantled by loess and is at a lower altitude than the drainage areas on Gnat and Crumarine Creeks.

Crumarine Creek is a perennial stream, but discharge is low through most of the year. Most of the runoff is during March, April, and May while snow on the mountains is melting. Gnat Creek is dry during the late summer and early fall. Peak flows coincide with periods of heavy rainfall in late winter and early spring. The South Fork of the Palouse River and Missouri Creek are perennial streams at Pullman. These streams peak following heavy rainfall during the late winter and spring; they also respond to snow melt in the mountains.

TABLE 2 - Average flow of streams in the Moscow basin, Idaho

Stream	Drainage area above gaging station (sq. mi.)	Water years	Average annual flow	
			Acre-feet	Inches
Crumarine Creek 1/ (1.5 miles above mouth)	2.4	1956-1958	1,290	9.9
Gnat Creek 1/ (0.5 mile above mouth)	4.3	1956-1958	1,170	5.1
South Fork of Palouse River 2/ (at Pullman, Wash.)	132	1934-1942 1960-1963	21,070	3.0
Missouri Creek 2/ (at Pullman, Wash.)	27.1	1935-1940 1960-1963	4,580	3.2

1/ Records from G. L. Bloomsburg (1958)

2/ Record published by U. S. Geological Survey

The surface water regimen in the Moscow basin, based on the above observations, can be summarized as follows: streams respond mainly to snow melt above an altitude of 2800 feet. At lower elevations, heavy rainfall is a more important source of stream flow. Where the streams flow on a granitic bedrock, they gain water through seepage from shallow ground water throughout the year. Where they flow over loess, the streams lose water through infiltration to ground water.

Ground water

The shallow aquifers are recharged by infiltration on the interfluvial areas as well as in stream channels. The water percolates slowly downward to deeper aquifers that have successively lower potentiometric surfaces. Natural discharge of all aquifers was westward into Washington before pumping of wells in Moscow permanently reversed the direction of flow in the uppermost confined aquifer in the western part of the basin (Ross, 1965, Fig. 5).

CITY OF MOSCOW WELL NO. 7

WELL DATA

City of Moscow Well No. 7 (State No. 39N-5W-7ba1) is about one mile northwest of the city center (Fig. 1). Altitude of the well is 2614 feet. The well was drilled to a depth of 666 feet in 1962. Drilling problems caused caving so that the well was abandoned at 632 feet. According to R. L. Tobin (oral communication, June 16, 1965), the well is perforated at 426 feet (altitude of 2188 feet). The geologic log is similar to that of City of Moscow Well No. 8 (Shown on Fig. 6).

RECORD ANALYZED

An automatic water-level recorder (Stevens Type F) was installed on the City of Moscow Well No. 7 on November 1, 1963 and maintained continuously to the present time, except for short periods during which no record was obtained. The record for the period November 1963 to May 1965 was analyzed for this report. The time scale used was 1.2 inches per day; the water-level record was reduced by use of 2:1 gears.

WATER-LEVEL FLUCTUATIONS

Daily water-level fluctuations of City of Moscow Well No. 7 are shown on Figure 2. Seasonal fluctuations in response to aquifer recharge and discharge are as much as 3 feet. Smaller fluctuations in response to changes in aquifer storage are masked by fluctuations caused by changes in barometric pressure. Change in barometric pressure affected water levels as much as 0.2 feet during a single day. Figure 3 shows the relation during one week between the water level in the well and barometric pressure.

Changes in atmospheric pressure affect the water levels in some confined aquifers because the rock material accepts only part of the load of the atmosphere while the water in the well is subjected to the full load (Ferris and others, 1962, p. 83). The barometric efficiency of the well is the change in observed water level caused by barometric pressure change divided by the corresponding change in atmospheric pressure, expressed in the same units (generally as feet of water).

The standard method of computing barometric efficiency (Taylor and Leggette, 1949, Fig. 14) is to plot the instantaneous water level of a well against the barometric pressure converted to height of a water column. The slope of the line that best fits the plotted points has the value of the barometric efficiency. The standard method was used to compute the barometric efficiency of City of Moscow Well No. 7 (Fig. 4); the average value for four plots is 32.4 per cent.

Daily maximum and minimum water levels in the well were then adjusted to an arbitrary barometric pressure of 30.00 inches of mercury by the following formula:

$$D_{30} = D_m - K\,b\,(B - 30.00)$$

in which

D_{30} = DEPTH TO WATER LEVEL IN FEET ADJUSTED TO A BAROMETER OF 30.00 INCHES OF MERCURY
D_m = DEPTH TO WATER LEVEL IN FEET, MEASURED
K = CONVERSION FROM INCHES OF MERCURY TO FEET OF WATER (1.129)
b = BAROMETRIC EFFICIENCY (0.324 FOR CITY OF MOSCOW WELL NO. 7)
B = BAROMETER READING IN INCHES OF MERCURY

The hydrograph, adjusted to a barometer of 30.00 inches of mercury, is shown on Figure 5. Many small fluctuations on the non-adjusted hydrograph (Fig. 2) are eliminated on the adjusted hydrograph (Fig. 5). Other fluctuations are reduced or reversed because of the imperfections in the adjustment. The adjustment is not perfect because correlation between barometric pressure and water level is not perfect (Fig. 4).

The adjusted hydrograph of City Well No. 7 shows distinct seasonal changes in water levels. The seasonal fluctuations do not correspond to either precipitation in Moscow basin or to runoff in Crumarine Creek, indicating that neither factor directly controls aquifer recharge. Patterns of the water-level fluctuations for the two winters differ as do the precipitation patterns, indicating that the difference in precipitation between the two winters caused a difference in regime as well as a difference in quantity of recharge.

The water level in City Well No. 7 declined 1.25 feet from November 8, 1963 to February 25, 1964. The decline, which indicates that aquifer discharge exceeded recharge, coincided with a period during which 13.4 inches of precipitation fell on Moscow. Most of the water from this precipitation probably was held in the snow pack or in soil moisture storage. The water level rose almost two feet from February 25 to March 16, 1964. The rise followed rain on February 15 and temperatures above 40°F at Moscow. The water-level rise preceeded relatively large runoff in upper Crumarine Creek, caused by snow melt at altitudes above 2800 feet. The rise probably coincided with runoff on creeks draining altitudes lower than the gaging station on Crumarine Creek.

The water level declined 3 feet from March to November 1964. Aquifer discharge exceeded recharge during this period. The water level rose 1.5 feet from November 1964 through May 1965. This rise consisted of two parts, separated by a period during which the water level remained constant while aquifer recharge was balanced by discharge. The rise from November through January probably was caused by infiltration of rainfall and melting snow at altitudes below 2800 feet; the rise during April and May was caused by melting snow at altitudes above 2800 feet. The larger quantity of snow that melted at a slower rate in 1965 than in 1964 caused a more attenuated rise to a lower peak. The attenuated rise portends (in June 1965) a higher water level in the winter of 1965 than in the winter of 1964 because parts of the aquifer distant from the recharge boundary were recharged simultaneously with points along the recharge boundary. Thus, discharge in the Moscow basin near the recharge boundary should be inhibited in 1965.

Differences in hydrograph shape between City of Moscow Well No. 7 (Figs. 2 and 5) and other wells penetrating aquifers about 2200 feet above sea level (Figs. 11 and 13) indicate that Well No. 7 penetrates a different aquifer than the aquifer penetrated by University of Idaho Well No. 2 or by the 24-inch casing of University of Idaho Well No. 3. Supporting evidence is that the water level in Well No. 7 is 75 to 90 feet lower than water levels in the other wells. Thus, some aquifers may not be everywhere present in the Moscow Basin. Discontinuities may be caused by buried structural features in the basalt and interbedded sediments. Such features as faults, bedrock ridges, cut-and fill structures, or lateral pinch-outs may be present.

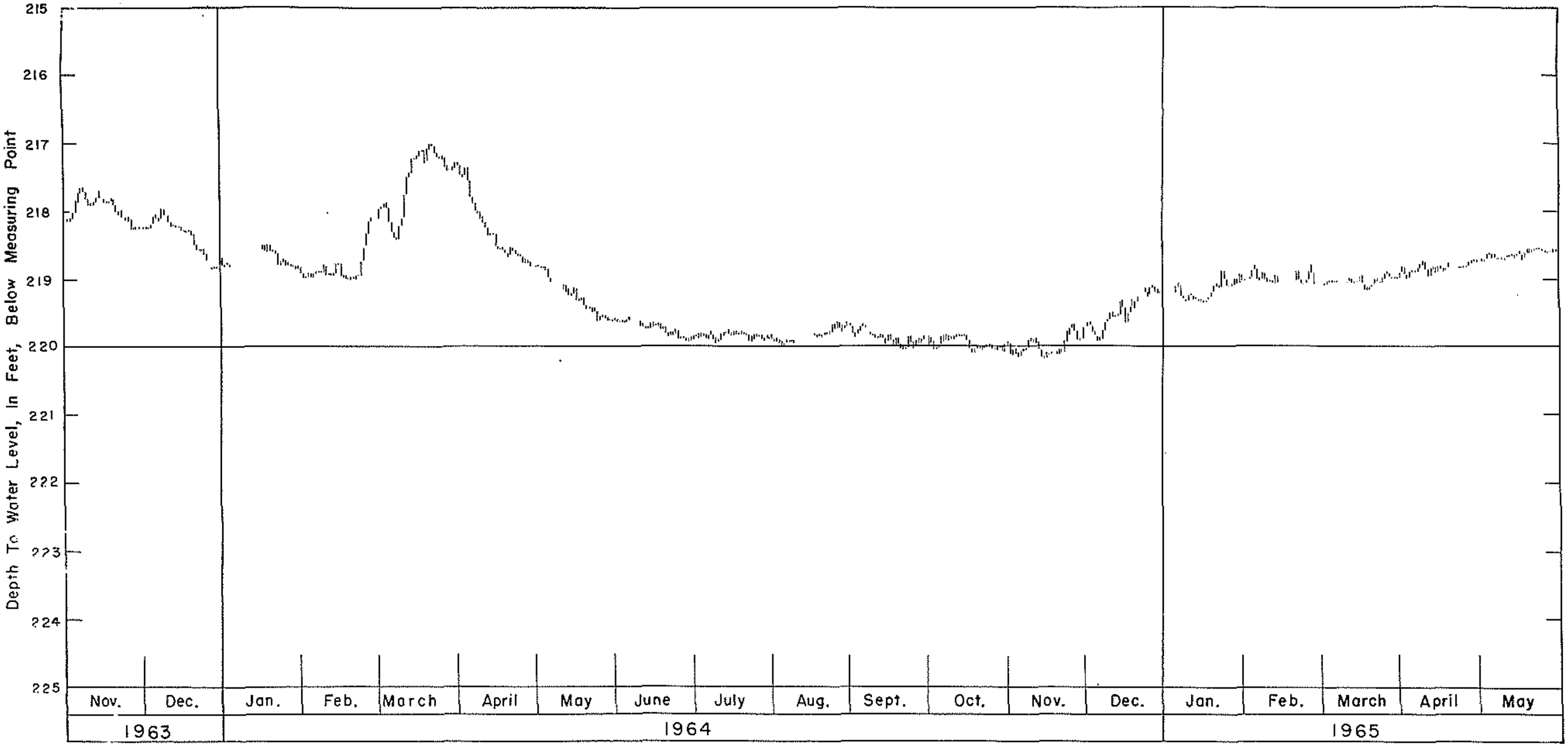

Figure 2. Hydrograph Of City Of Moscow Well No. 7, November, 1963 To May, 1965, Showing Daily Range Of Water Levels

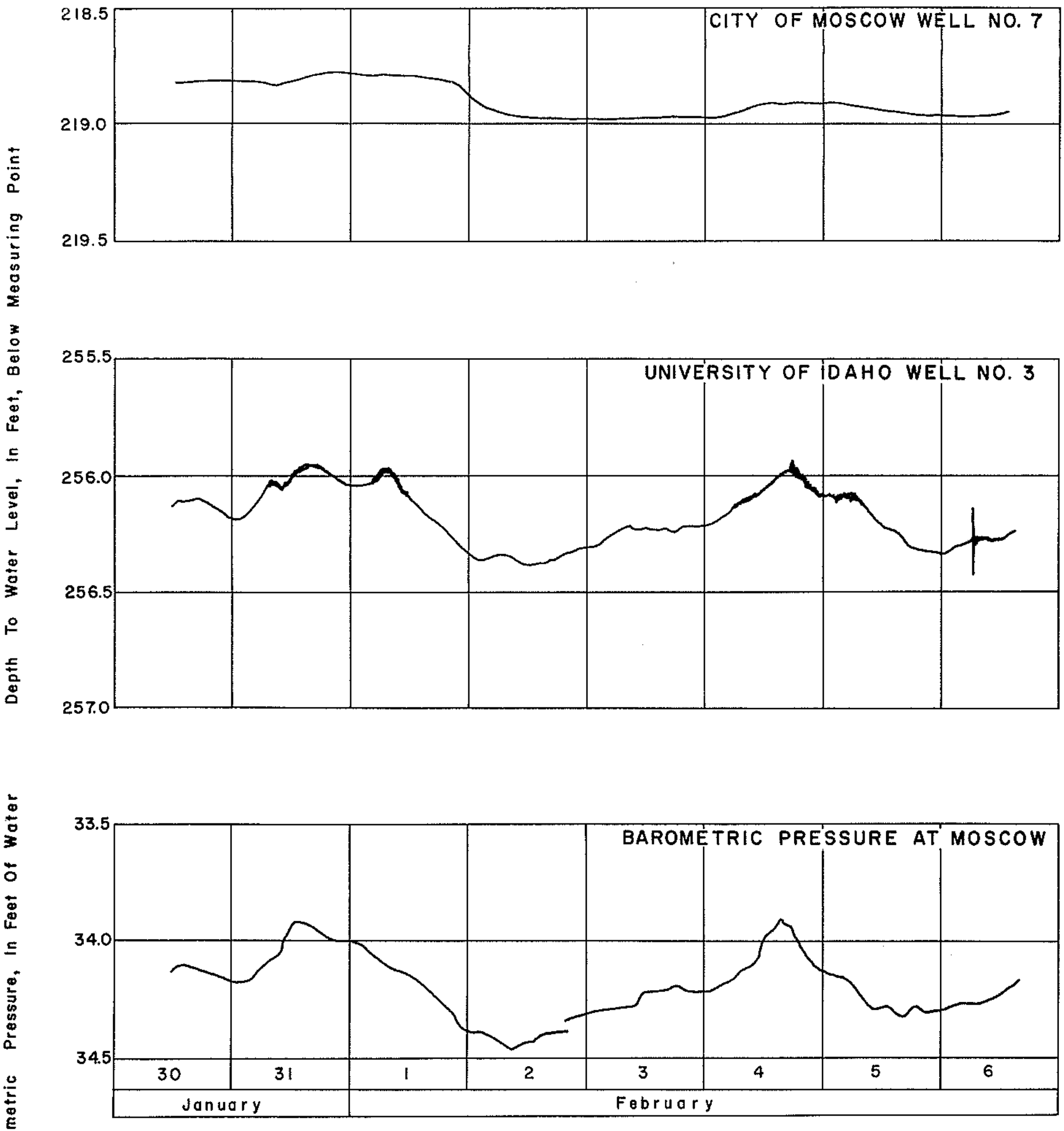

Figure 3. Comparison Of Hydographs Of City Of Moscow Well No. 7 And University Of Idaho Well No. 3 With Barometric Pressure At Moscow, January 30-February 6, 1964.

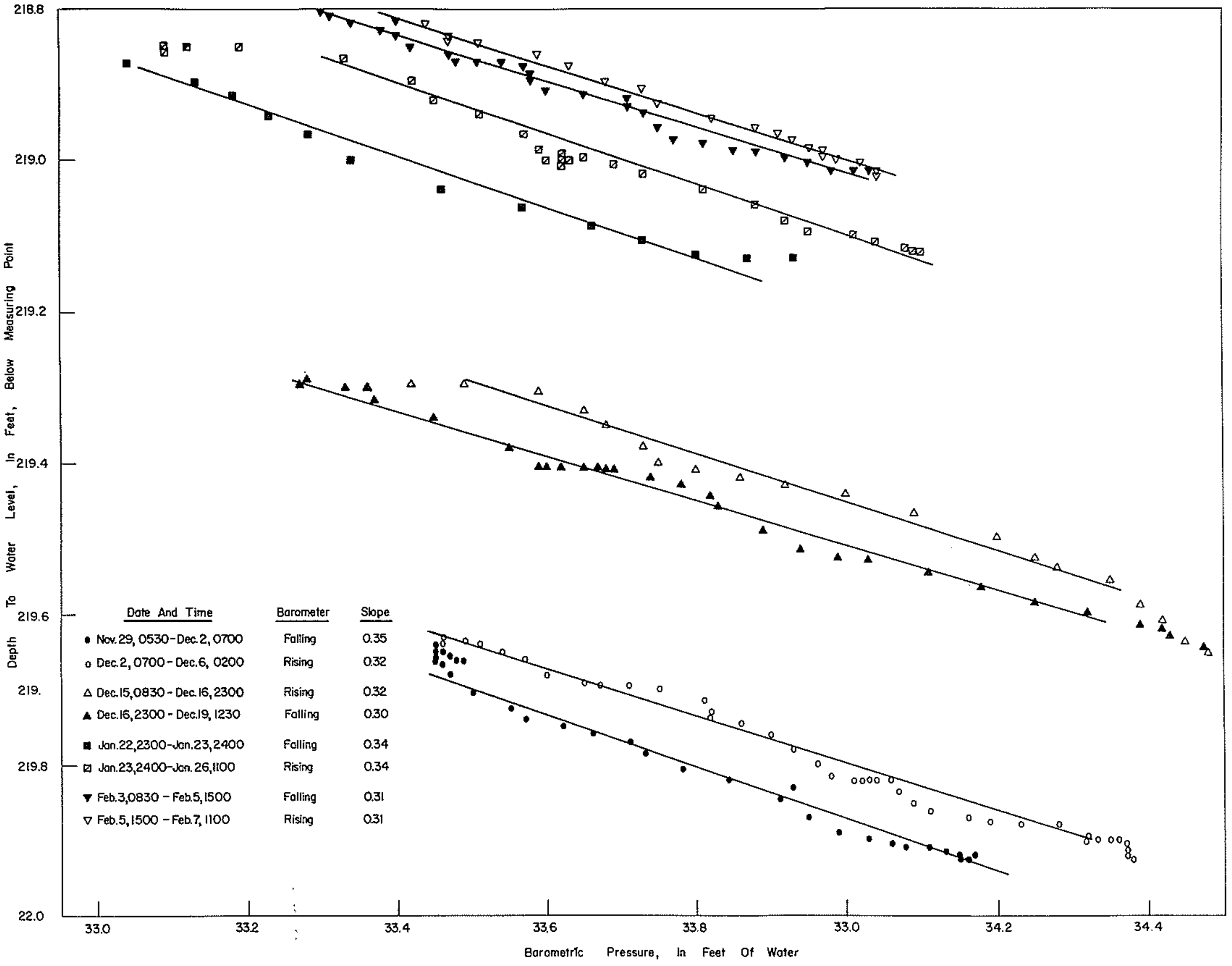

Figure 4. Correlation Between Water Level In City Of Moscow Well No. 7 And Barometric Pressure At Moscow During Selected Periods In Winter Of 1964-65

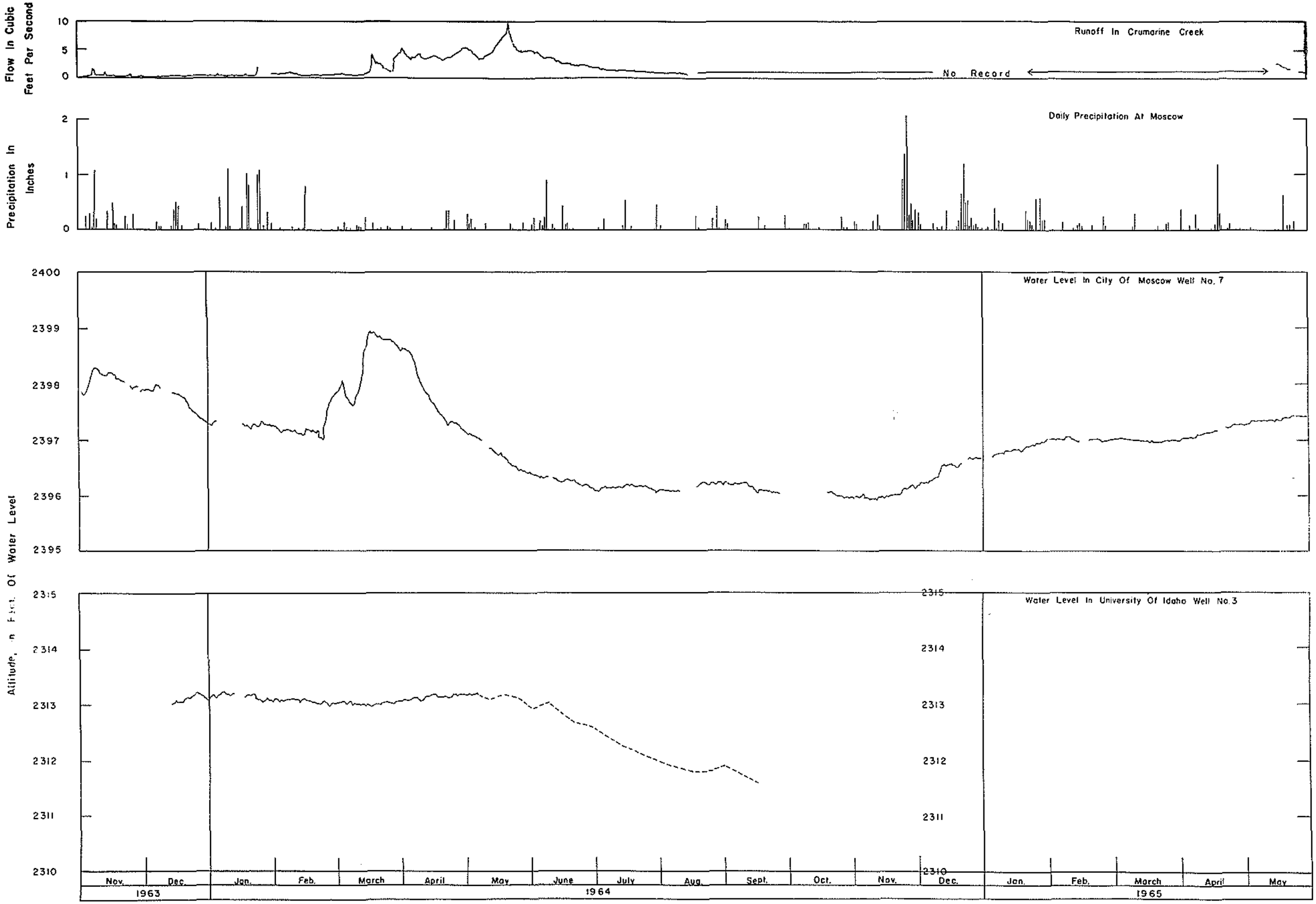

Figure 5. Hydrographs Of City Of Moscow Well No. 7 And University Of Idaho Well No. 3, 1963-1965, Water Levels Adjusted To 30.00 Inches On Barometer

UNIVERSITY OF IDAHO WELL NO. 3

WELL DATA

University of Idaho Well No. 3 (State No. 39N-5W-7bcl) is one mile west of the center of Moscow (Fig. 1). The well was drilled through the basalt and associated sediments into the granitic basement 1322 feet beneath the surface. A geologic log of the well is shown on Figure 6.

The well was drilled by cable tool from June 1962 to August 1963. The well was spudded in with a 30-inch hole at the top. Casing was reduced several times, ending with a 12-inch hole. After completion of drilling, the lowermost basalt was tested for possible water production on August 23, 1963, but a four-stage pump equipped with a 440-HP motor could not sustain flow. After casing was perforated from 661 to 776 feet and casing below 892 feet was pulled, a second test, on September 5 and 6, 1963, produced 2400 gpm with 7 feet of drawdown. A pump was installed in the well to produce from this upper zone during the spring of 1964.

The permanent measuring point of the well is the pump flange, which is 2567 feet above mean sea level. Measurements made between December 12, 1963 and May 7, 1964 were from the top of a temporary casing 1.98 feet above the permanent measuring point.

RECORD ANALYZED

An automatic water-level recorder (Stevens Type F) was maintained on the University of Idaho Well No. 3 from December 12, 1963 to May 7, 1964. The time scale used was 1.2 inches per day; the water-level record was reduced by use of 5:1 gears. After the water-level recorder was removed, weekly water-level measurements were made manually by steel tape until the well was put into production in September 1964. Since then, water levels have been measured by steel tape, electric sounder, or airline, as pumping conditions permit. The record from December 1963 to September 1964 is analyzed in this report.

Water levels in two outer casings were measured manually with a steel tape each week from February until June 1964, when the pump base was laid. The 30-inch casing reflected the water level in the depth zone between 14 and 98 feet; the 24-inch casing reflected the zone between 110 and 490 feet.

WATER-LEVEL FLUCTUATIONS IN THE 20-INCH CASING

The water level in University of Idaho Well No. 3 responded to seasonal changes in aquifer storage, barometric pressure, wind, and the effects of distant earthquakes from December 1963 to May 1964. Fluctuations caused by barometric pressure, wind and earthquakes can be observed readily from the recorder graphs (Figs. 3 and 7). Fluctuations caused by changes in aquifer storage are of such small magnitude that they are masked by the fluctuations caused by barometric pressure (Fig. 3).

In order to determine whether the water level in the 20-inch casing (which reflects the main pumping zone) responded to seasonal changes that were masked by barometric changes, the water levels were plotted for times when the barometer read selected values (Fig. 8). The selected values were 29.60, 29.80, 30.00, 30.20, and 30.40 inches of mercury corrected to sea level. A family of curves was constructed; one curve representing each value of barometric pressure. The curves were deliberately constructed parallel and equidistant because equidistant barometric pressures were selected. Each curve is the hydrograph of University Well No. 3 corrected to the barometric pressure represented by that curve. The interval between curves is the barometric efficiency multiplied by the chosen barometric interval (0.20 inches of mercury) expressed in feet of water (0.2258 ft).

The resultant hydrographs show a 0.25-foot rise in water level from mid-December 1963 and early January 1964, a 0.18-foot decline from early January to mid-March, and a 0.15-foot rise from mid-March into early May. The rising segments of the hydrograph represent periods during which recharge to the aquifer exceeds discharge; the falling segment represents a period during which discharge exceeds recharge. The rise during December and January is probably caused by autumn rainfall; the rise during March and April is probably caused by melting snow during the spring. Thus, the aquifer from which University of Idaho Well No. 3 pumps is in an active hydrologic system.

The interval between curves on Figure 8 indicates a barometric efficiency of 89 per cent.

The shape of the hydrograph and value for barometric efficiency were checked by using the same method used on City of Moscow Well No. 7. Barometric efficiency was computed from the fluctuations during four periods during which the barometer declined rapidly and then climbed (Fig. 9). The average of the four is 0.91 or 91 per cent. Daily fluctuations were corrected to a barometric pressure of 30.00 inches of mercury in the same manner as was done for the City of Moscow Well No. 7 but using a barometric efficiency of 91 per cent. The resulting hydrograph (Fig. 5) shows the same fluctuations as the hydrographs (Fig. 8) formed by constructing curves for each barometric pressure. Variations from a smooth curve on the hydrograph of Figure 5 are caused by errors inherent in the method of adjustment based on instantaneous barometric pressure without taking account of the prior history of the barometer. Nevertheless, the simple adjustment using corrections based on instantaneous barometric pressure apparently serves to delineate seasonal changes in water level as small as 0.15 foot although superimposed on barometric changes as much as 1.5 feet.

Minor water-level fluctuations caused by wind action were observed in the record of University of Idaho Well No. 3. The fluctuation is caused by a reduced air pressure over the well as wind velocity increases. Gusts, which are prevalent during periods of strong wind, cause a broad fuzzy line of the water level record (Figs. 3 and 10).

On several occasions when the well was visited during windy periods, the trace of the water level on the recorder chart could be seen to decline at an estimated rate of 0.005 to 0.01 feet per minute during strong gusts, and to rise at about the same rate during relative calms. Thus, the effect of wind is shown to be directed on the water and not on the instrument.

Fluctuations with a magnitude ranging from 0.01 to 0.04 feet were recorded 35 per cent of the time between December 12, 1963 and May 7, 1964. The distribution by clock time of wind effects during this period is shown on Table 3. Apparently, wind affects water levels in wells that have a good hydraulic connection to aquifers with a high transmissibility (the ability to transmit water easily) more readily than in wells that are poorly developed or are completed in aquifers with a low transmissibility. Water levels in wells such as University of Idaho Well No. 3 are affected easily because water can move freely through the well casing within the small time intervals between minute pressure changes.

The water level in University of Idaho Well No. 3 intercepted shock waves

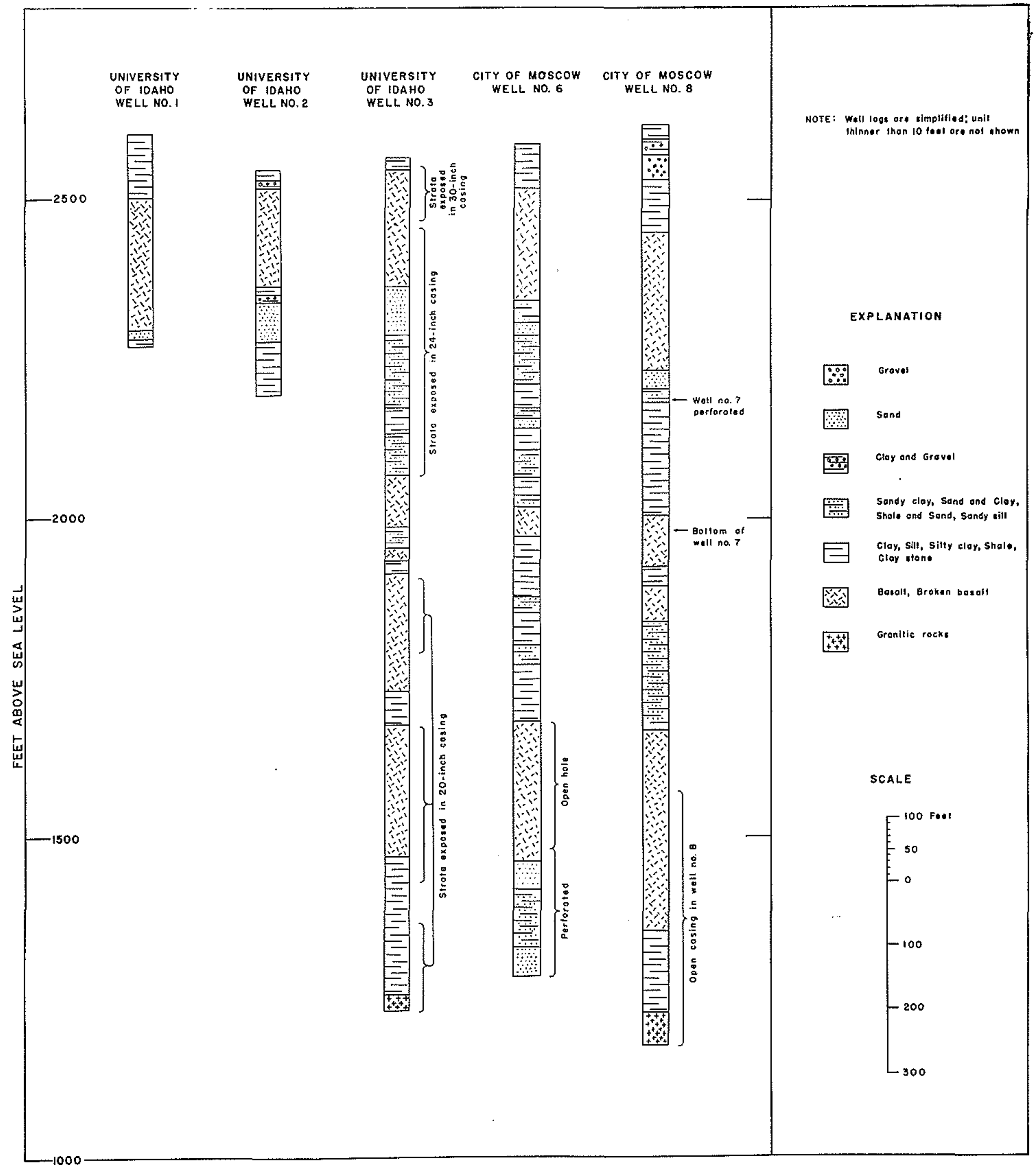

Figure 6. Selected Well Logs In The Moscow Basin, Latah County, Idaho

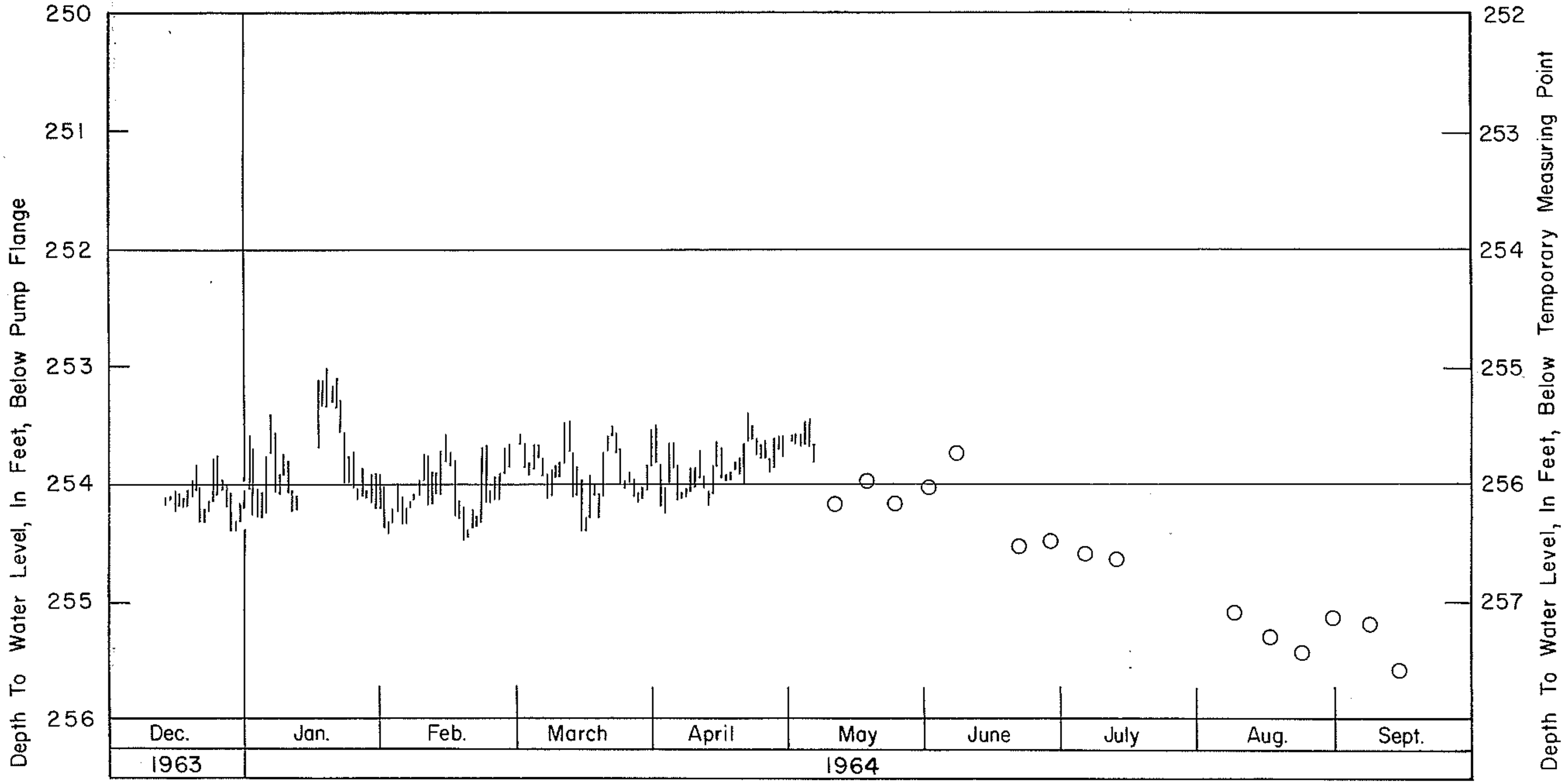

Figure 7. Hydrograph Of University Of Idaho Well No. 3, Showing Daily Range Of Water Levels, December 13, 1963 - May 6, 1964, And Weekly Measurements May 11, 1964 - September 15, 1964

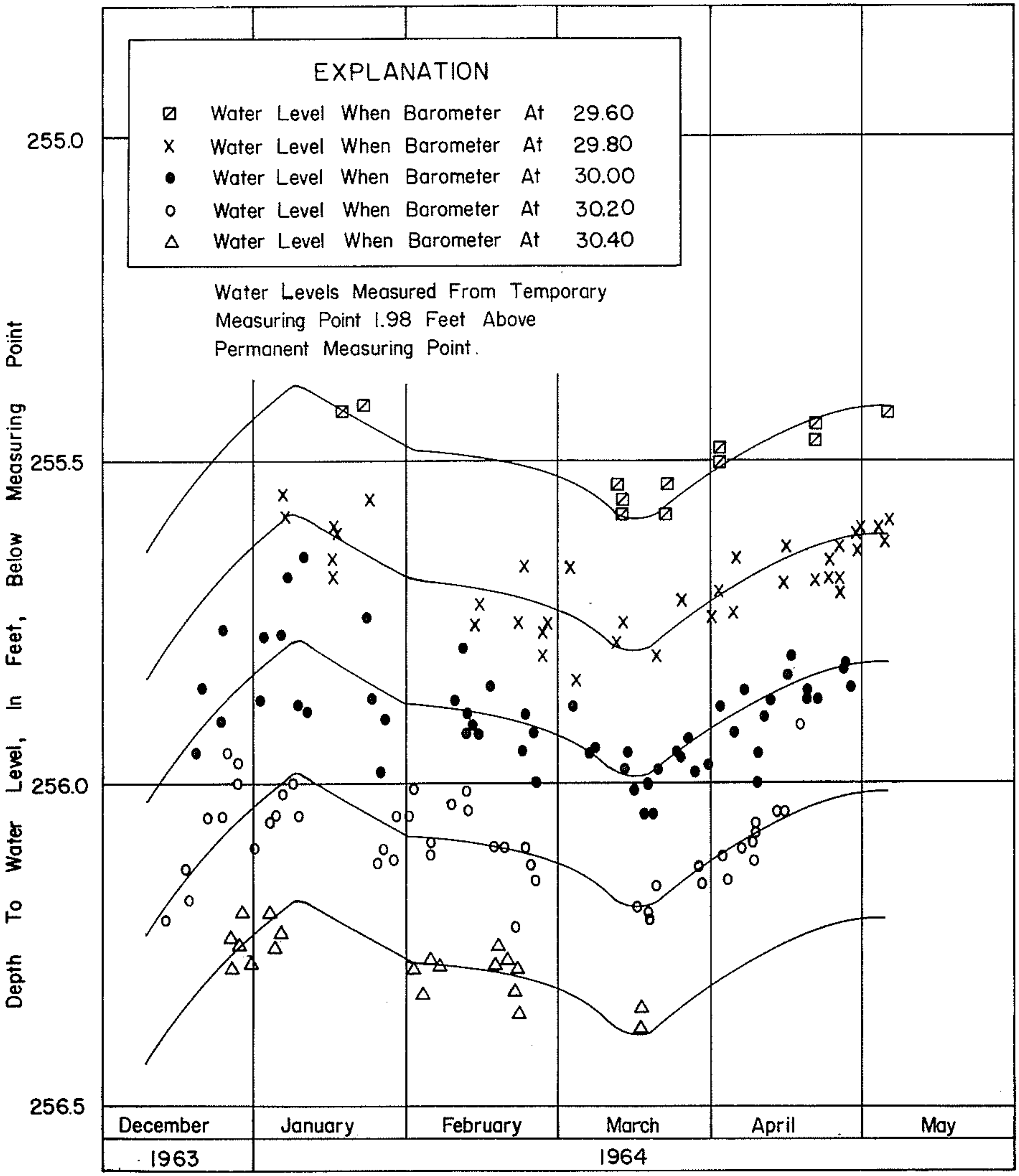

Figure 8. Water Level In University Of Idaho Well No. 3 Coincident With Selected Values Of Barometric Pressure

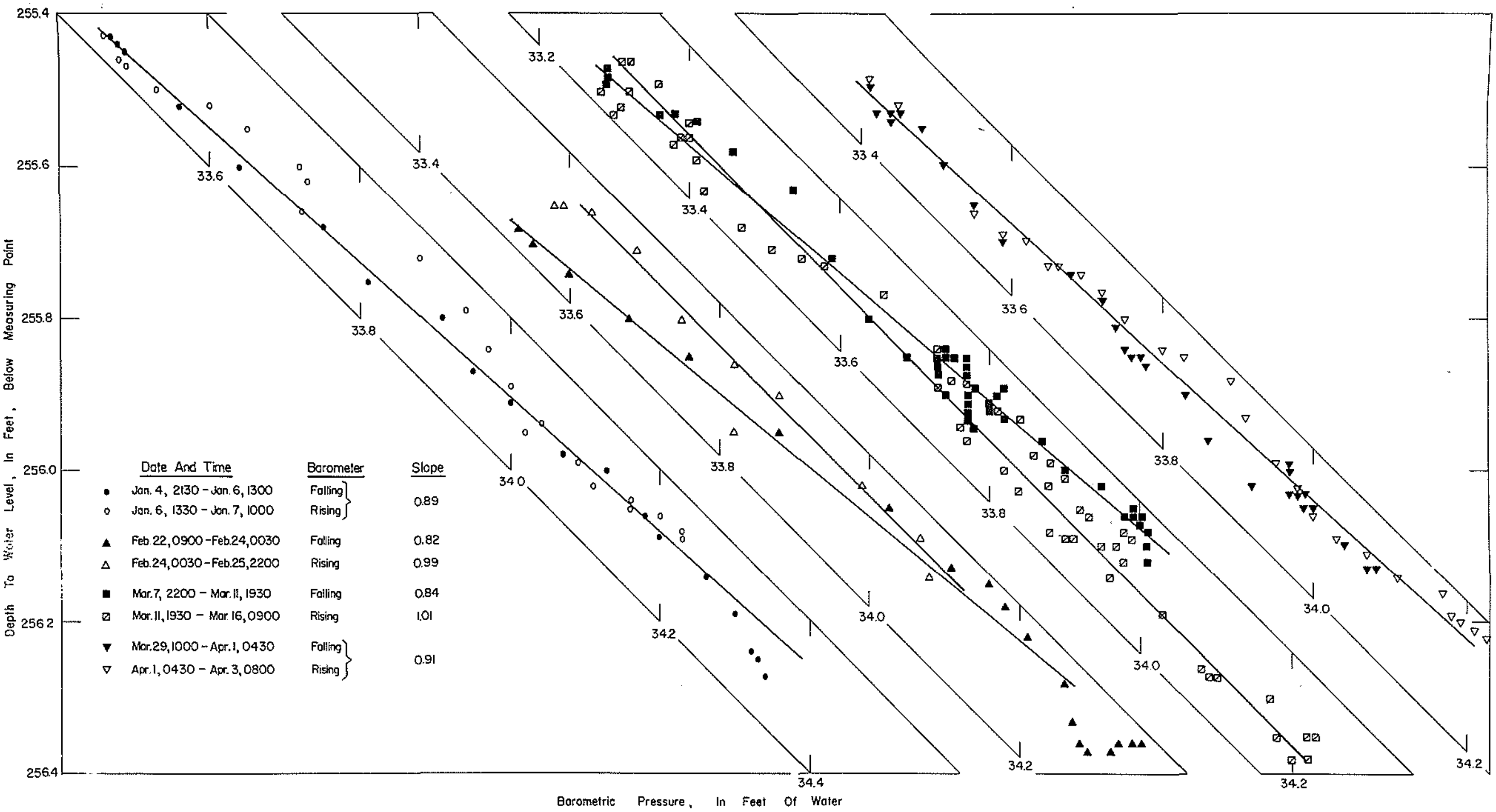

Figure 9. Correlation Between Water Level In University Of Idaho Well No. 3 And Barometric Pressure At Moscow During Selected Periods In 1964

TABLE 3. Percent of time wind-generated fluctuations were observed in University of Idaho Well No. 3, December 12, 1963 - May 7, 1964.

TIME	Percent of time wind-generated fluctuations exceeded given value.				
24-hour Clock	0.01 Ft.	0.02 Ft	0.03 Ft.	0.04 Ft.	0.05 Ft.
0200	28	11.2	3.4	0.7	0.0
0400	31	14.7	3.4	0.0	0.0
0600	32	14.7	2.1	0.7	0.0
0800	45	14.7	0.7	0.0	0.0
1000	46	19.0	2.8	0.7	0.0
1200	46	22	3.4	0.7	0.0
1400	48	19.5	2.8	0.0	0.0
1600	40	13.2	2.8	0.0	0.0
1800	30	11.1	1.4	0.0	0.0
2000	26	10.4	3.4	0.7	0.0
2200	26	10.4	3.4	1.4	0.0
2400	26	9.0	2.8	0.0	0.0

induced by several distant earthquakes while the water-level recorder was operated. Fluctuations of the type observed in this well are caused by the seismic waves being transmitted from the focus of the earthquake through the earth to the well. The seismic waves cause water to be forced alternately from the aquifer into the well and from the well into the aquifer. In an expanded time scale, as shown by Vorhis (1955, Fig. 2), individual flow pulses are distinct; on the time scale 1.2 inches per day used on University of Idaho Well No. 3, earthquake fluctuations appear as a single or multiple vertical lines on the hydrograph (Figs. 3 and 10). For fluctuations due to earthquake shock, the amplitude of the rise is equal or nearly equal to the amplitude of the decline; the water in the well commonly is at the same level before and after waves have passed.

The record of fluctuations that seem to be caused by earthquakes between December 12, 1963 and May 7, 1964 is presented on Table 4. Double amplitudes range from 0.02 feet to more than 5 feet. Fluctuations 5 feet or more within a few minutes are recorded as 5-foot fluctuations on the recorder used on this well.

The hydrograph from the week of March 26, 1964 (Fig. 10) shows the effect of the large earthquake off the Alaskan coast on March 27 and several of the aftershocks. Several other small aftershocks may be masked by fluctuations caused by wind during the week. Wind at Moscow was particularly strong on March 28 and April 1 so that fluctuations with a double amplitude less than 0.04 foot caused by earthquakes could not be distinguished. Conversely, several of the fluctuations that are identical to fluctuations caused by earthquakes and that are listed on Table 4 could not be correlated by reported earthquakes. These fluctuations were probably caused by disturbances near the well.

The University of Idaho Well No. 3 is a well that appears to be sensitive to seismic effects. The City of Moscow Well No. 7, which had the same type of recorder installed throughout the period earthquakes were recorded on the University of Idaho Well No. 3, and longer, has not responded to a single earthquake. The characteristics that cause some wells to be sensitive to seismic effects and other wells to be insensitive have not yet been defined (Vorhis, 1964). McConiga (1955) found a correlation between seismic effects and well depth, and he suggested that the length of the water column in a well affects the seismic sensitivity of wells because of the greater possibility of contact with several confined aquifers, improving the probability of detection.

The water column in the City of Moscow Well No. 7 (450 feet) is 630 feet less than in University of Idaho Well No. 3 (1080); this difference does not seem sufficient to explain why the water surface in the latter well fluctuated more than five feet while the water surface in the former well did not fluctuate. The difference is probably caused by one or more zones or horizons penetrated by University of Idaho Well No. 3 below the stratigraphic interval penetrated by the City of Moscow Well No. 7. The upper surface of the granitic rocks (penetrated by University of Idaho Well No. 3) may be a horizon along which surface seismic waves are transmitted to the well.

WATER-LEVEL FLUCTUATIONS IN THE 24-INCH CASING

The water level in the annular space between the 20- and 24-inch casings rose from 97.3 feet below the surface on February 6 to 80.6 feet on June 8, 1964 (Fig. 11). The shape of the hydrograph indicates that the 16.7 feet was only part of the full seasonal fluctuation during the 1963-64 winter. Nevertheless the fluctuation is larger than the fluctuation in any other well discussed in this report.

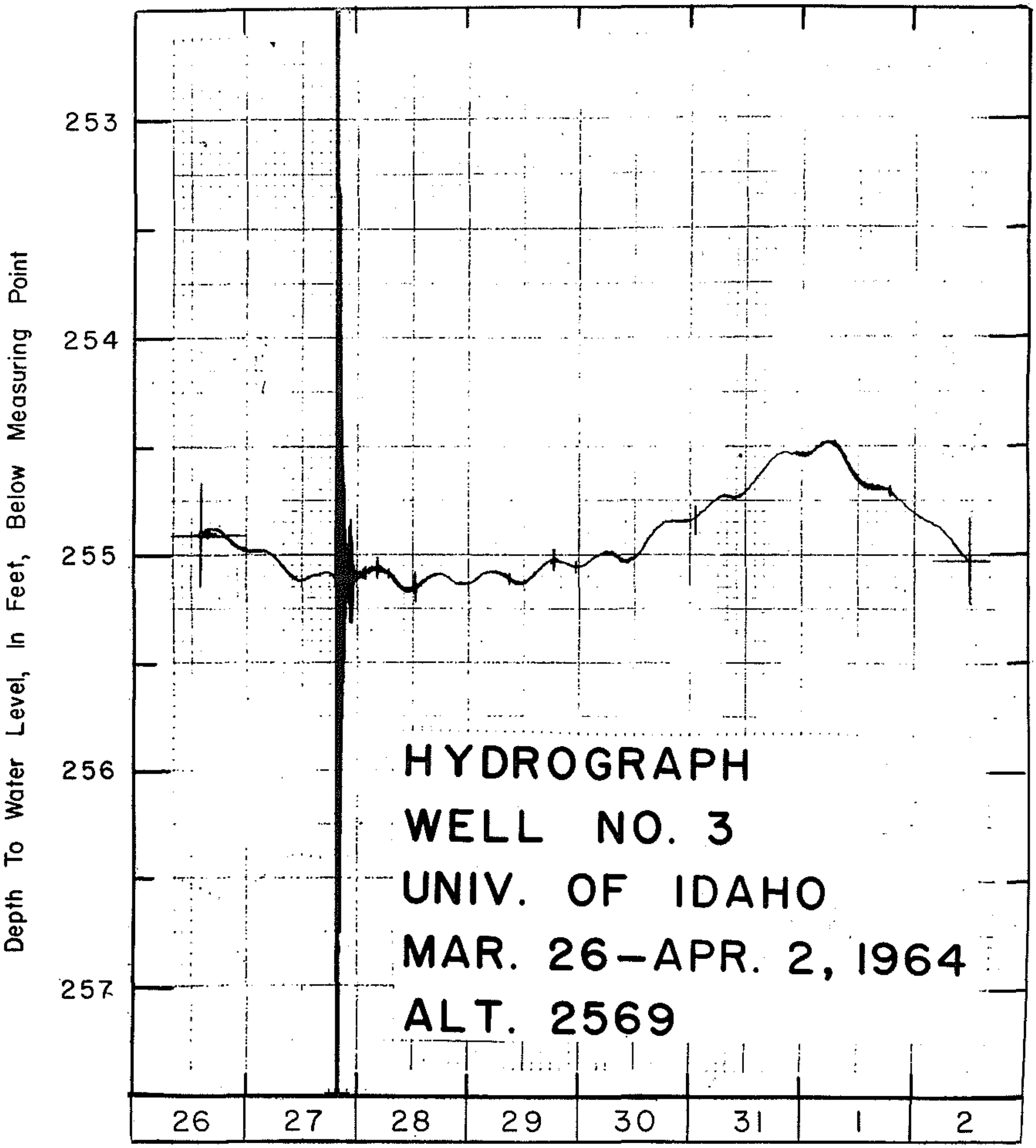

Figure 10. Hydrograph Of University Of Idaho Well No. 3, March 26-April 2, 1964, Showing Effects Of Alaska Earthquakes

TABLE 4- EARTHQUAKE AND EARTHQUAKE-LIKE FLUCTUATIONS IN UNIVERSITY OF IDAHO WELL NO. 3, DECEMBER 12, 1963 - May 7, 1964

Observed Deflection in Univ. of Idaho Well No. 3			Correlative Earthquake [1]		
DATE	TIME[2] G.C.T.	DOUBLE AMPLITUDE FT.	TIME G.C.T.	LOCATION	MAGNITUDE (Richter Scale)
Dec. 18, 1963	0045	0.08	----	----	---
Feb. 6, 1964	1315	.30	1314	Kodiak Island	5.4
Feb. 14	1645	0.65	1630	New Britain	6.0
Mar. 28	0330	>5	0336	Gulf of Alaska	8.5
"	0400	3.45	----	----	---
"	0415	1.40	----	----	---
"	0430	1.00	----	----	---
"	0445	0.81	0454	Gulf of Alaska	6.1
"	0500	0.45	----	----	---
"	0515	0.22	0536	Gulf of Alaska	5.7
"	0615	0.44	0608	"	5.6
"	0630	0.48	0632	"	5.5
"	0645	0.36	0636	"	5.1
"	0715	0.10	0710	"	6.2
"	0945	0.06	0953	"	5.5
"	1215	0.10	1221	"	6.1
"	1500	0.05	1449	"	5.8
"	2030	0.14	2029	"	5.8
Mar. 29	1700	0.05	1653	"	5.2
Mar. 30	0230	0.09	0218	"	5.8
"	0715	0.05	0710	"	5.6
Mar. 31	0845	0.13	0902	Vancouver Island	5.6
Apr. 2	0200	0.05	----	----	---
Apr. 3	2245	0.04	2233	Gulf of Alaska	5.7
Apr. 4	0500	0.02	0454	"	5.6
"	0900	0.02	0911	"	5.9
"	1800	0.06	1746	"	5.7
Apr. 11	2045	0.06	----	----	---
Apr. 12	0045	0.04	----	----	---
"	0145	0.03	0125	Gulf of Alaska	5.6
"	1300	0.02	1248	"	5.1
"	2330	0.05	----	----	---
Apr. 13	0145	0.06	----	----	---
Apr. 15	1530	0.02	1531	Gulf of Alaska	5.5
Apr. 16	1800	0.04	----	----	---
"	1945	0.04	1927	Gulf of Alaska	5.5
"	2115	0.03	----	----	---
Apr. 20	1145	0.07	1157	Gulf of Alaska	5.7
Apr. 23	0430	0.10	----	----	---
Apr. 24	0600	0.06	0556	New Guinea	6.3
Apr. 26	1830	0.04	----	----	---
May 7	0645	0.03	----	----	---
"	0830	0.03	----	----	---

1. Data from "Preliminary Determination of Epicenter" cards issued by U. S. Coast and Geodetic Survey.

2. Time accurate to 30 minutes.

The seasonal rise observed consists of two distinct segments. The first segment represents the period from February 6 to May 11; the second from May 11 to June 8. The average water-level rise during the first period was 0.06 foot per day; the average rise during the second period was 0.40 feet per day. The rise before May 11 was irregular: changes in water level within single weeks range from a two-foot drop to a three-foot rise; the rise after May 11 was regular: the ascent was initially sharp, gradually levelling to form a smooth curve.

The hydrograph of the water level in the 24-inch casing (Fig. 11) shows a fair correlation with Crumarine Creek flow (Fig. 5), which is an index of runoff from the higher altitudes in the Palouse Range. Both hydrographs show peaks about April 1 and May 1, and both show sharp ascents starting about May 11. These correlations, particularly the rise starting about May 11, suggests that runoff at high altitudes is related to recharge in the aquifer open to the 24-inch casing.

The source of recharge seems to be melting snow, not rainfall, because little precipitation fell during March, April and the first two weeks of May 1964 (Fig. 5). The water level in the 24-inch casing did rise during the weeks of February 6, 20, and 27, when no appreciable runoff was observed in Crumarine Creek. These rises may have been caused by rainfall during the last part of January and the middle part of February or by snowmelt at altitudes lower than the gaging station on Crumarine Creek while temperatures at altitudes above the gaging station were below freezing.

Thus, recharge of the aquifer between altitudes of 2070 and 2460 feet appears to be caused by hydrologic conditions above the eastern margin of the basalt but below the altitude of the Crumarine Creek gaging station. The source might be either infiltration from Paradise Creek or infiltration into loess that covers a large area between Missouri and Gnat Creeks.

Fluctuations due to causes other than changes in aquifer storage could not be defined in the 24-inch casing because of the magnitude of fluctuations caused by recharge and because of the relative infrequency of measurements.

WATER-LEVEL FLUCTUATIONS IN THE 30-INCH CASING

The water level in the annular space between the 24- and 30-inch casings during the first half of 1964 (Fig. 12) was at a different level and had a different pattern of fluctuation from the water level in the 24- or in the 20-inch casing. This difference indicates that the three parts of the aquifer system penetrated by the 20-, 24-, and 30-inch casings have little or no hydraulic connection.

The general pattern of the hydrograph (Fig. 12) is a rise in water level of about 0.08 feet per day during February and decreasing gradually to zero. The decline during the third week of June suggests that the seasonal peak was reached during the second week of June 1964. Deviations from the general pattern are shown on Figure 12. The hydrograph for February and the first three weeks of March can be made into a smooth curve by correcting for barometric effects, assuming a barometric efficiency of 40 percent. Larger irregularities from March 26 through June coincide with streamflow in Crumarine Creek and with rainfall at Moscow (Fig. 5). However, the most rapid rise in water level in the 30-inch casing is early in the winter and was probably caused by heavy rainfall during January.

The coincidence of the largest increase of aquifer storage with rainfall before much water flowed in the stream channels indicates that the uppermost basalt aquifer between the altitudes of 2470 and 2550 feet is recharged chiefly by infiltration of

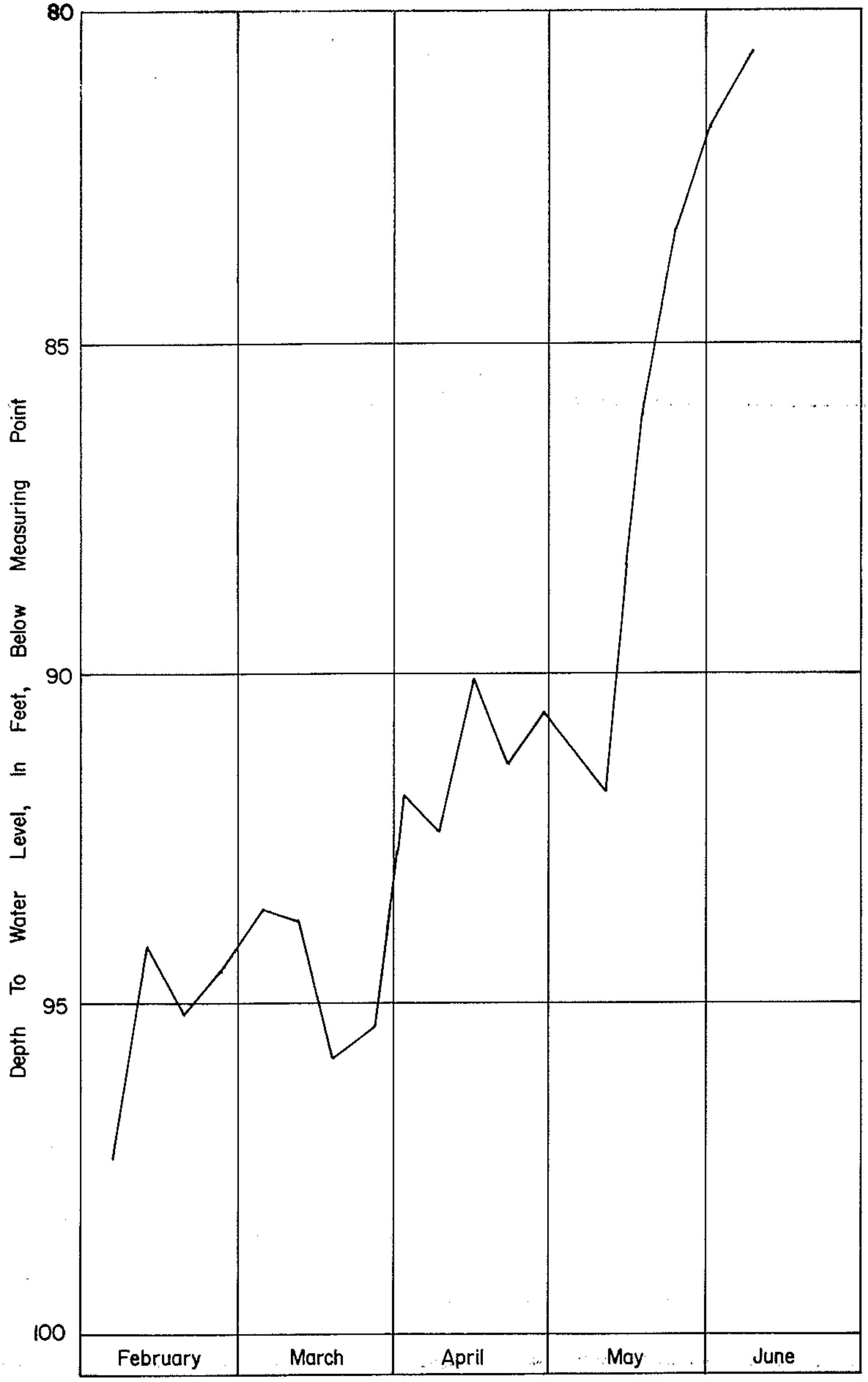

Figure II. Water Level In The 24-Inch casing Of University Of Idaho Well No. 3, February-June 1964

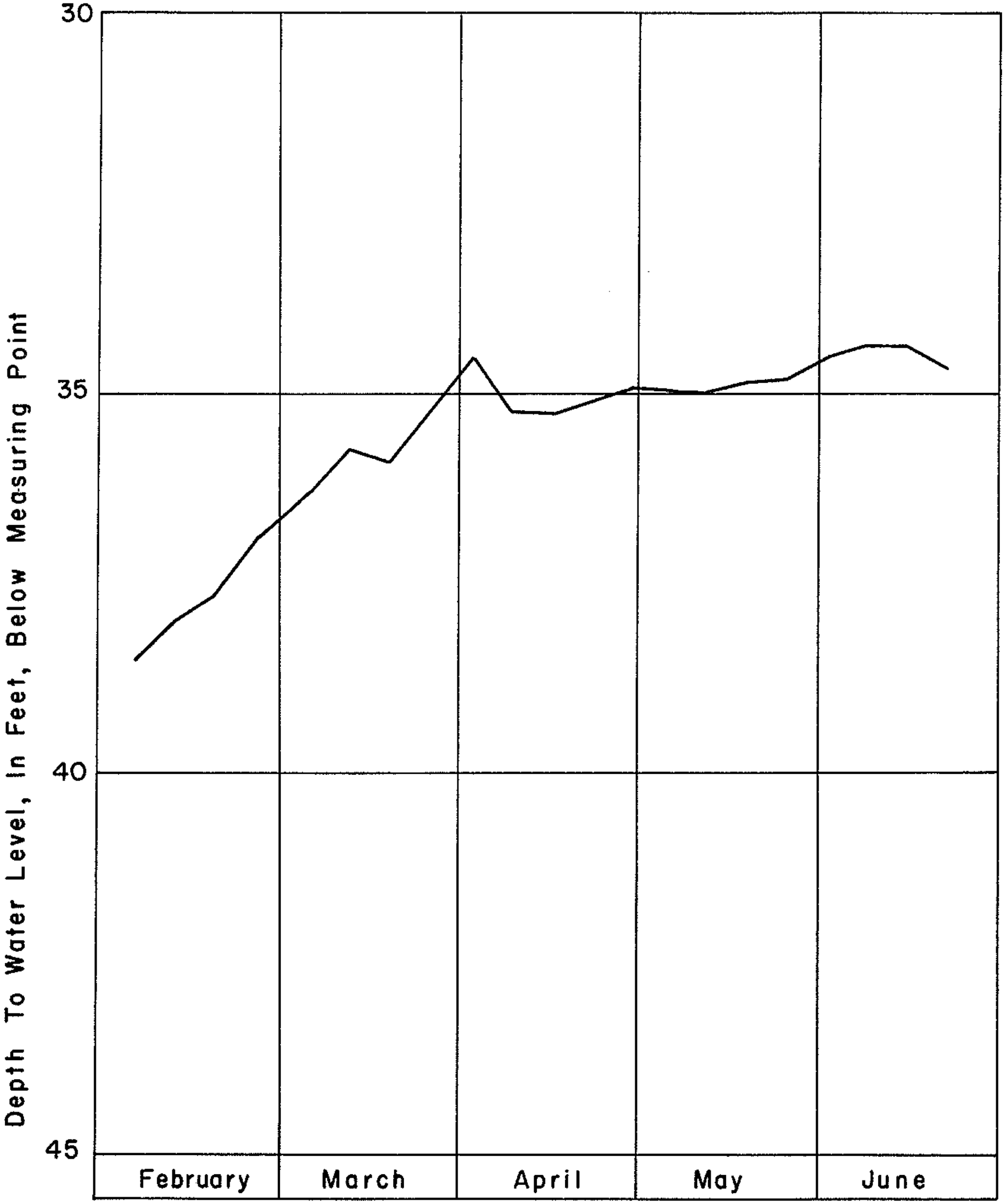

Figure 12. Water Level In The 30-Inch Casing of University Of Idaho Well No. 3, February-June 1964

rainfall and melted snow from interfluvial areas at the lower altitudes in the basin. Infiltration from stream channels may also recharge the uppermost basalt, but is relatively unimportant.

UNIVERSITY OF IDAHO WELL NO. 2

WELL DATA

University of Idaho Well No. 2 (State No. 39N-5W-7cdl) is about three-fourths of a mile west of the city center of Moscow, one-half mile south of University of Idaho Well No. 3 (Fig. 1). The well was drilled in 1951 to a depth of 355 feet and is cased with 20-inch iron casing. The altitude of the pump base is at 2548 feet; the altitude of the bottom of the well is at 2194 feet. The log of the well is shown on Figure 6.

University of Idaho Well No. 2 is considered to pump from the same zone as most of the public supply wells in the basin. Except for University of Idaho Well No. 3 and City of Moscow Wells Nos. 6, 7, and 8, public supply wells have been drilled only to an altitude of about 2300 feet. The water levels in these wells were about 2440 feet above sea level in 1965. The 24-inch casing of University of Idaho Well No. 3 is assumed to penetrate the same aquifer because the zone penetrated and water level are at about the same altitude as most of these public supply wells.

RECORD ANALYZED

An automatic water-level recorder (Stevens Type F) was maintained on University of Idaho Well No. 2 from June 25 to July 14, 1964, while the pump was being repaired. The time scale used was 1.2 inches per day excepting from July 6 to July 10 when a time scale of 9.6 inches per day was used. The water-level record was reduced by use of 2:1 gears.

WATER-LEVEL FLUCTUATIONS

The water level in University of Idaho Well No. 2 fluctuated through a range of 0.6 feet from June 25 to July 14, 1964 (Fig. 13A). The fluctuations were caused chiefly by changes in barometric pressure. Barometric efficiency of the well was computed to be 90.5 percent (Fig. 14). The water level was adjusted to a barometric pressure of 30.00 inches using the computed barometric pressure.

The adjusted hydrograph (Fig. 13B) shows that the water level rose at a rate of about 0.016 foot per day during the period of observation. This rise probably represents the last phase of seasonal recharge for the 1963-1964 winter. The water level in the 24-inch casing of University of Idaho Well No. 3, which is believed to penetrate the same aquifer as Well No. 2, was still rising during the first week in June (Fig. 11). A second possibility is that the rise may be due to recovery from continual pumping prior to removal of the pump for repairs.

Deviations from a smooth curve are reduced from a maximum of 0.3 foot on the unadjusted hydrograph (Fig, 13A) to a maximum of 0.12 foot on the adjusted hydrograph (Fig. 13B). Most of these minor fluctuations on the adjusted hydrograph coincide with fluctuations onthe unadjusted hydrograph. Some, in the same direction, indicate underadjustment; others, in the opposite direction, indicate overadjustment. Imperfections in adjustment are to be expected: points on the water level - barometric pressure diagram (Fig. 14) do not fall on a straight line, probably because water level response to barometric pressure is not instantaneous.

One fluctuation, a drop in water level of 0.11 foot about 11:30 P.M. on July 9 corresponds to pumping of University of Idaho Well No. 1, 2200 feet southwest of Well No. 2. The pumping record of Well No. 1, the closest well in the basin penetrating the same aquifer penetrated by Well No. 2, is shown on Figure 13C.

Well No. 1 was pumped at 19 other times during the 20 days of record; strangely, no perceptible response in Well No. 2 was recorded for these 19 other pumping cycles.

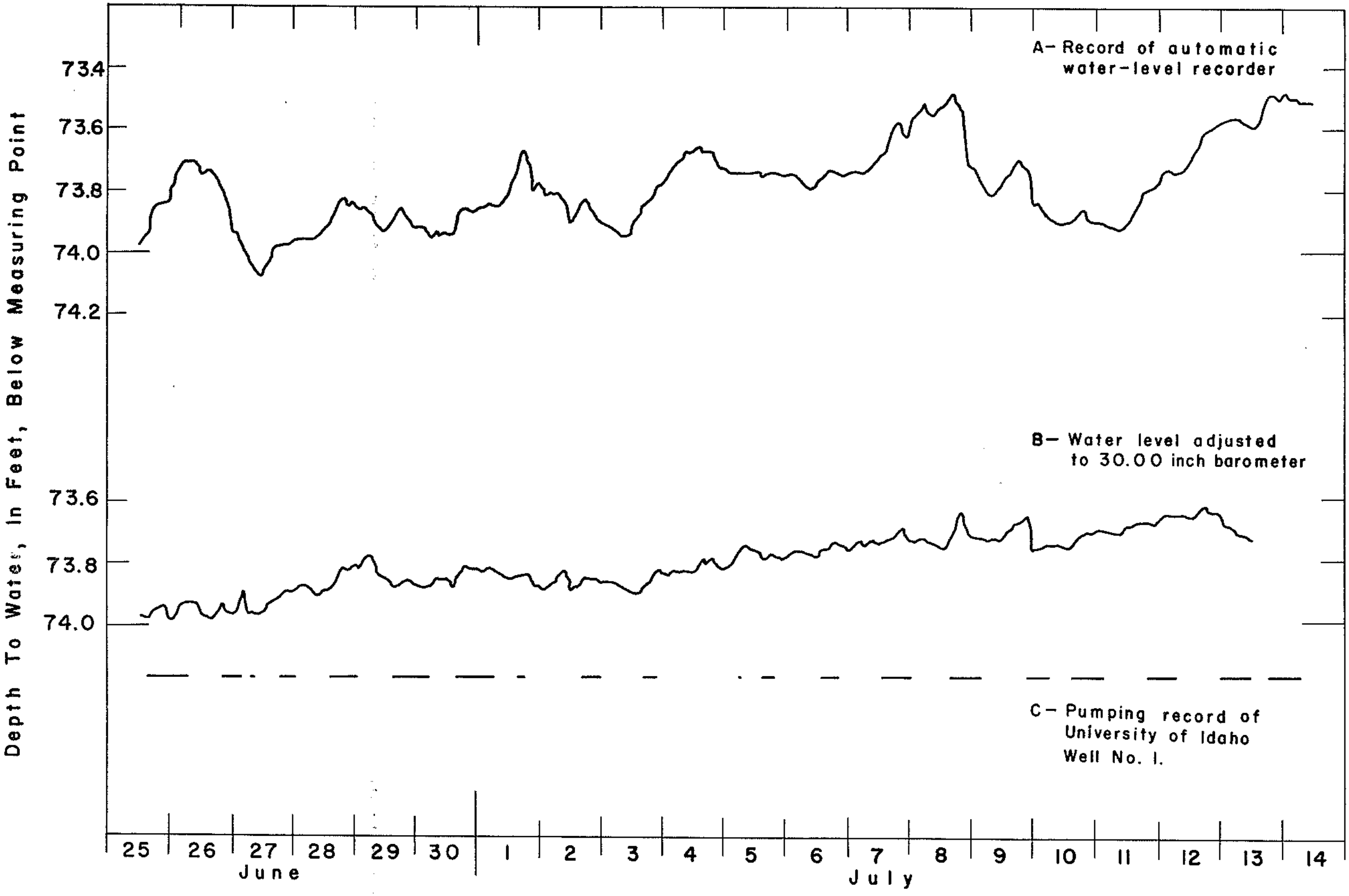

Figure 13. Hydrograph Of University Of Idaho Well No. 2, June 25–July 14, 1964

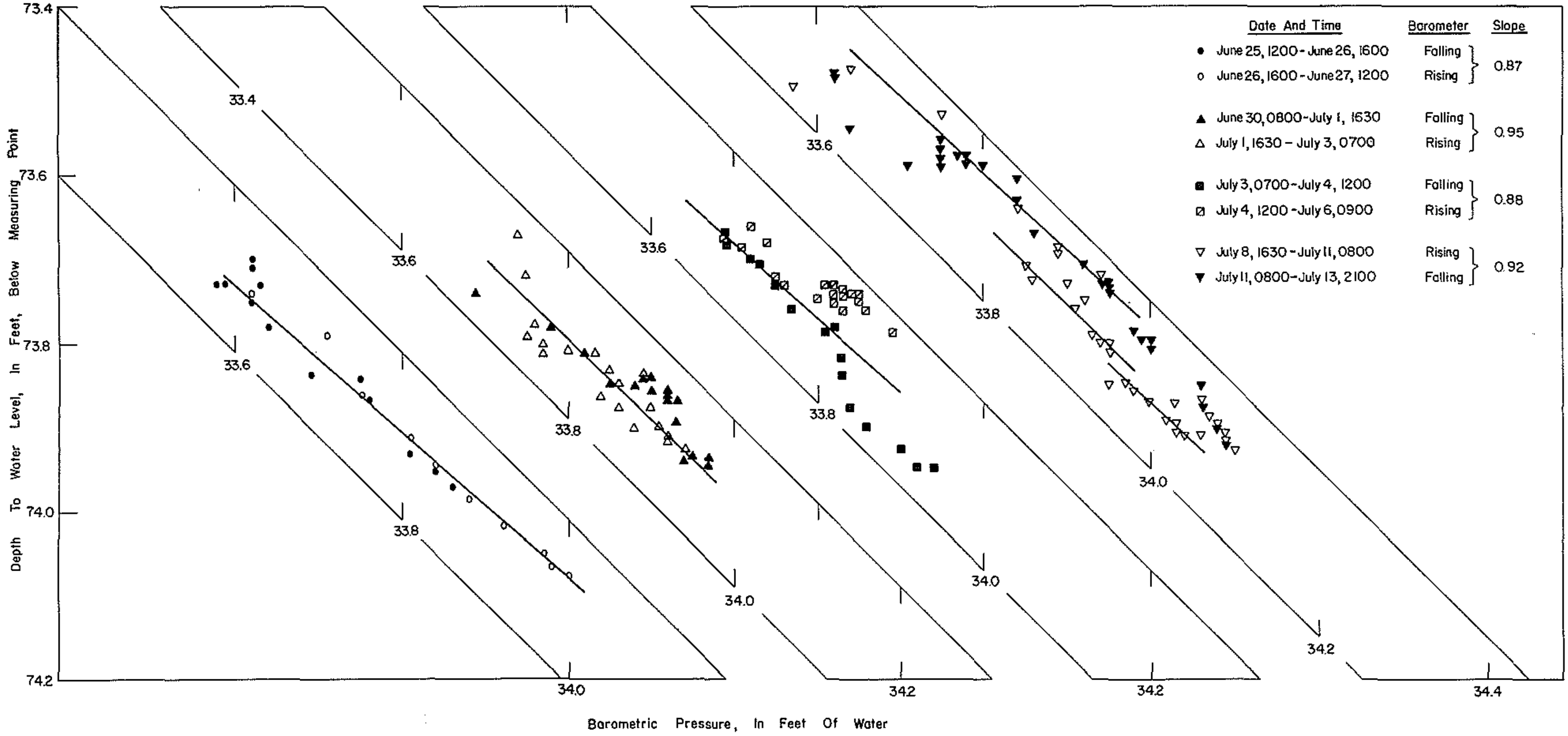

Figure 14. Correlation Between Water Level In University Of Idaho Well No. 2 And Barometric Pressure At Moscow During Selected Periods In 1964

CITY OF MOSCOW WELL NO. 8

WELL DATA

City of Moscow Well No. 8 (State No. 29N-5W-7ba2) is about one mile northwest of the city center of Moscow and 52 feet east of City of Moscow Well No. 7 (Fig. 1). The well was drilled 1453 feet deep into granitic rocks below the basalt and sedimentary rock sequence (Fig. 6). The altitude of the ground surface at the well is 2617 feet.

A pumping test performed on June 24, 1964, when the well was 1047 feet deep, with a four-stage pump powered with a 440 HP motor failed to produce water from the zone between 952 and 1047 feet below the surface. On December 11, 1964, after completion of the well, the zone 1047 to 1453 feet below the surface produced more than 1200 gallons of water per minute with 43 feet of drawdown. Presumably, the water is produced from the basalt 1047 to 1263 feet deep (1354 to 1570 feet above sea level).

RECORD ANALYZED

An automatic water-level recorder (Stevens Type F) was maintained on City of Moscow Well No. 8 from March 15 to April 19, 1965. The time scale used was 1.2 inches per day excepting from March 29 to April 1 when a time scale of 9.6 inches per day was used. The water-level record was reduced by use of 5:1 gears.

WATER-LEVEL FLUCTUATIONS

The water level in City of Moscow Well No. 8 fluctuated between 307.47 and 312.94 feet during the time the recorder was maintained on the well. Fluctuations can be correlated with pumping of City of Moscow Well No. 6, with changes in barometric pressure, and with earthquakes in the Aleutian Islands (Fig. 15). Any seasonal change in water level between March 15 and April 19, 1965 was obscured by pumping.

The most pronounced fluctuations were caused by pumping of City of Moscow Well No. 6, 4000 feet east of the well. The water level in Well No. 8 declined 4.67 feet while Well No. 6 was pumped almost continuously at an average rate of 909 gallons per minute for four hours on March 31, 1965. The rate of decline after four hours was 0.7 feet per hour. Continuous pumping of Well No. 6 at a rate of 900 gpm for 24 hours probably would effect a decline of more than 10 feet in Well No. 8. When pumping is discontinued the water level rises; after about 10 hours during which Well No. 6 had not been pumped, the water level in Well No. 8 stabilized with a water level about 308 feet below the surface in March and April 1965.

University of Idaho Well No. 3, 2100 feet southwest of City Well No. 8, was pumped regularly during March and April, 1965. The water level in City Well No. 8 did not respond to this pumping (Fig. 15). The lack of response in City Well No. 8 to pumping in University Well No. 3 indicates that hydraulic connection between the two wells is poor.

City Well No. 8 responds to changes in barometric pressure. Fluctuations caused by change in atmospheric pressure are masked most of the time by fluctuations caused by pumping, but wherever City Well No. 6 is off for six hours or more, barometric-pressure fluctuations become discernible (Fig. 15). The barometric efficiency is approximately 90 percent; the value cannot be calculated precisely because periods during which barometric effects can be measured are too few and too short.

Two earthquakes effected water-level fluctuations while the recorder was maintained on City of Moscow Well No. 8 (Fig. 15). Epicenters of the earthquakes were near the Rat Islands in the western Aleutians. Both earthquakes occurred when 9.6 inches-per-day gears were on the recorder. Therefore, several waves for each earthquake can be distinguished. The maximum double amplitude of the earthquake on March 29, 1827 hours (March 30, 1827 hours GCT) with a magnitude of about 7 on the Richter scale was 0.40 foot. The maximum double amplitude of the earthquake on March 31, 0246 hours PST (1046 hours GCT) with a magnitude of 5.6 was 0.07 foot. Both of the earthquakes show higher hydroseismic magnitudes than curves prepared by Vorhis (1965, Fig. 3) for a well in Dawson County, Georgia. He observed that the relation between earthquake magnitude was a function of the direction of the epicenter from the Dawson County well. Thus the orientation of the Moscow basin, which plunges westward in the direction of the earthquake epicenter, may be the cause of the high hydroseismic magnitudes.

The water level in City Well No. 7, 52 feet west of City Well No. 8, failed to respond to either earthquake. Because both wells penetrate the same sequence above 1947 feet, the difference is probably caused by a zone or horizon below an altitude of 1947 feet. The contact between granitic rocks and the sediments may well be a horizon that transmits earthquake waves with the westward plunge of the contact causing greater amplitudes of fluctuations due to earthquakes in southern Alaska and the Aleutian Island than for earthquakes of the same magnitude and distance in other directions.

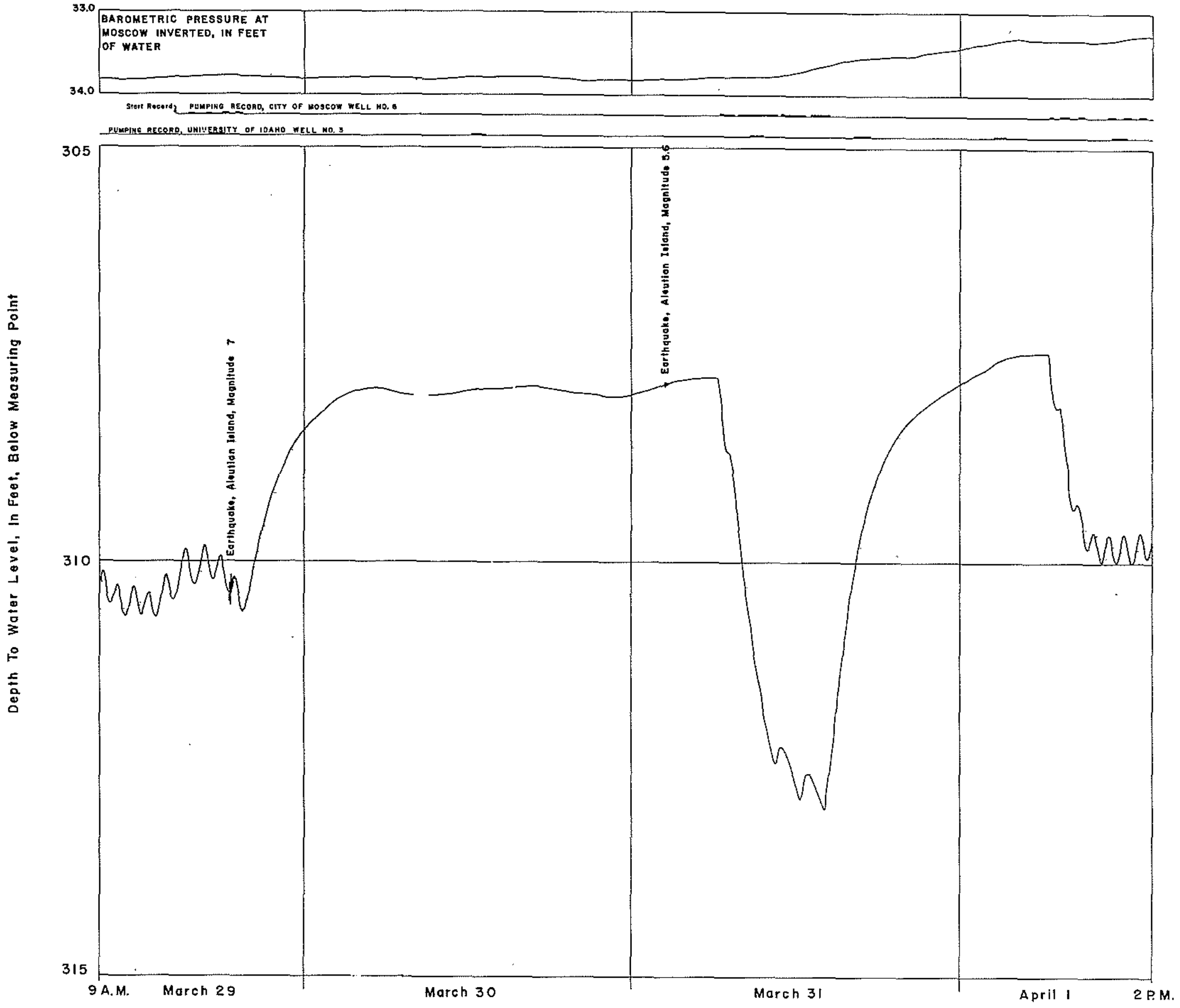

FIGURE 15. HYDROGRAPH OF CITY OF MOSCOW WELL NO. 8, MARCH 29- APRIL 1, 1965

SUMMARY OF CONCLUSIONS

At least 5 aquifers are present in the basalt and intercalated sedimentary sequence underlying the Moscow basin. Water levels in these aquifers are progressively lower in successively lower aquifers.

The uppermost aquifer is penetrated by the 30-inch casing of the University of Idaho Well No. 3 from 14 to 98 feet below the surface. The aquifer is about 2500 feet above sea level. Water level in the well rose from 38 feet in February to 34 feet below land surface in June, 1964. Most of the rise can be correlated with snow melt on interfluvial areas at low altitudes.

Two distinct aquifers are present at different locations at about 2200 feet above sea level. One of the aquifers is penetrated by University of Idaho Well No. 2 and by the 24-inch casing of University of Idaho Well No. 3. The water-levels in these wells were between 73 and 97 feet below the surface during early 1964. The water level in one well rose 16 feet from February to June as a result of recharge. Aquifer recharge can be correlated with snowmelt and, to smaller extent, rainfall above the eastern margin of the basalt below the altitude of the Crumarine Creek gaging station.

The other aquifer that is about 2200 feet above sea level is penetrated by City of Moscow Well No. 7 at a depth of 426 feet (2188 feet above sea level). The water level is about 50 feet lower than the water level in other wells perforated about 2200 feet above sea level. The water level in Well No. 7 apparently responds to rainfall and snow melt at altitudes below 2800 feet during late fall and early winter and responds to snow melt above 2800 feet during the spring.

An aquifer about 1800 feet above sea level is penetrated by the 20-inch casing of University of Idaho Well No. 3 between 661 and 776 feet below the ground surface. This aquifer, which supplies most of the water now used by the University of Idaho, appears to be recharged by autumn rainfall and by snow melt during the spring.

The lowest known aquifer in the basin is about 1500 feet above sea level. This aquifer is penetrated 1074 to 1263 feet below the surface by City of Moscow Well No. 8. The water level in this well responds to pumping in City of Moscow Well No. 6 but does not respond to pumping in University of Idaho Well No. 3. Thus, the aquifer from which University of Idaho Well No. 3 receives water has poor hydraulic connection with the aquifer penetrated by City of Moscow Wells Nos. 6 and 8.

All aquifers higher than 1500 feet above sea level responded to seasonal recharge during the period of study. The aquifer about 1500 feet above sea level was not monitored sufficiently long to determine seasonal recharge.

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